



THURBER ENGINEERING LTD.

July 20, 2012

File: 14-214-2

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Suite 1300 - Sun Tower, 128 Pender Street West
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Attention: Don Lidstone, Q.C.

**THE SHORES SUBDIVISION - PHASE 1
GEOTECHNICAL ASSESSMENT**

Dear Don:

As requested, Thurber Engineering Ltd. (TEL) has completed a review of the sinkhole formed on June 1, 2012 and previously reported sinkholes, slope instability, springs and erosion within The Shores subdivision. This letter documents our observations and provides our comments and recommendations.

This report is subject to the attached Statement of Limitations and Conditions.

1. INTRODUCTION

The site is a 28 lot residential development with a plan area of about 400 by 200 m, located on the west side of the neighbourhood of West Porpoise Bay, in Sechelt, BC. The site is on the south shore of Sechelt Inlet at Snake Bay and extends westward from the intersection of Gale Road North (L-100) and Crowston Road to Snake Bay Creek. The site was developed by Concordia Homes Ltd. (Concordia). Civil engineering for the development was provided by Web Engineering Ltd. (Web) and geotechnical engineering by GeoTacTics Engineering Ltd. (later incorporated as GeoTacTics Media Engineering (2007) Ltd.). For discussion purposes, we have used the name GeoTacTics to refer to both companies.

We understand that a spring developed on Lot 3 on May 26, 2012, and that significant quantities of sand and silt were observed discharging from the spring at that time. On June 1, 2012, a sinkhole collapse occurred on Seawatch Lane (L-200) adjacent to Lot 28 at about Sta. 5+80. Until the sinkhole collapse occurred, no surface manifestation of the sinkhole was reported. For public safety reasons, the District of Sechelt (DOS) has closed access to the lane and has backfilled the sinkhole with granular material. The DOS is conducting regular site inspections and is regularly topping up the sinkhole backfill as required.

Following the formation of the sinkhole, DOS retained TEL to provide geotechnical input on existing geotechnical issues and provide an assessment of the risk of similar issues occurring in the future. To aid our assessment and understanding of the site, DOS has provided us with available historical geotechnical information on the development, elevation contours from 2009 bare earth LiDAR mapping and miscellaneous documents, drawings and photos as background information for our review. The documents are summarized in Table 1.



2. SITE DESCRIPTION

2.1 Surface Conditions

The site physiography is described concisely in the GeoTacTics reports and is not repeated herein. In those reports, the overall development property is divided into 4 zones, namely the foreshore, the backshore marsh, the lower slope and the upper slope as shown on GeoTacTics' Dwg. No. 2 (attached) dated August 2004. Phase 1 of the development lies between the foreshore and the crest of the lower slope at about El. 50 m. GeoTacTics indicates that the overall slope of Phase 1 dips down at about 15° from the horizontal to the north east. Phase 2, which has not yet been developed, is proposed on the upper slope zone. Building lots are located both below the L-100 line (the extension of Gale Avenue North) and between the L-100 line and L-200 line (Seawatch Lane), which roughly follows the crest of the lower slope. There is a 15 m wide environmental setback along the shoreline which was intended to preclude development on much of the foreshore marsh zone. Most of the trees have been removed from this zone since commencement of construction.

2.2 Subsurface Conditions

Based on information provided by GeoTacTics, we understand that the typical soil profile in the development area comprises (from top down) an upper zone of very dense, cobbly, glacial till and marine silt layers underlain by a deposit of grey/brown, fine grained sand, underlain by firm to stiff marine silt with lenses of fine sand. Groundwater is believed to be perched on the surface of the lower marine silt layer and results in springs occurring in the fine sand layer exiting the slope near the base of the lower slope and on the backshore marsh. GeoTacTics' Figure 3, showing a schematic section of the site geology, is attached.

At the time of our 2008 site reconnaissance to assess the rock stack retaining walls on behalf of DOS, the grey/brown fine sand deposit was visible at the western end of the site and the lower marine silt was exposed in the foundation excavation for Lot 15. The near-vertical excavated faces in the sand were dry. Seepage was observed from above and from sand lenses within the marine silt layer. There were no exposures of the glacial till deposit at the time of the 2008 reconnaissance.

In 2012, the grey/brown fine sand deposit is still visible at the western end of the site above the L-200 alignment from the park dedication to south of about Lot 17.

2.3 Existing Geotechnical Issues

Review of GeoTacTics' reports indicates that wet zones and multiple springs formed on the cut slopes during site preparation, releasing significant volumes of water and soil. Following the formation of the springs, sinkholes began to be observed upslope of the springs. Additionally, there have been several instances of slope instability during and after construction. These issues were ongoing throughout construction and are documented in the available geotechnical



information. An active sinkhole and seepage feature were observed during our 2012 site reconnaissance and follow up site visits.

As described below, we believe that the springs and sinkholes are distinct manifestations of the same geotechnical issue. Accordingly, any geotechnical investigation program and remediation or mitigation measure must consider the whole system of which they are parts to be successful.

3. PROGRAM OF WORK AND REVIEW

Our program of work carried out in preparation of this letter report includes the following:

- 1) A site reconnaissance and follow up visits,
- 2) Soil sampling for laboratory testing
- 3) Geophysical survey with ground penetrating radar
- 4) A land survey of the sinkhole, spring and other indicators of springs and sinkholes
- 5) Airphoto interpretation
- 6) Review of available geotechnical information

Our geotechnical engineering assessment and recommendations are based on our interpretation of the above information.

3.1 Site Reconnaissance and Follow-up Site Visits

3.1.1 Sta. 5+80, L-200 Sinkhole and Lot 3 Spring

A site reconnaissance was conducted by David Tara, P.Eng. of TEL on June 2, 2012. Mr. Tara was accompanied by Mr. Phil Strain of DOS. The purpose of the reconnaissance was to visually assess the sinkhole and spring, provide interim guidance for management of the sinkhole and determine if there were any immediate life safety issues. Follow up visual inspections were conducted by Mr. Tara on June 5, 15 and July 1, 2012.

At the time of our initial site visit on June 2, the sinkhole area had been cordoned off with barriers. The hole in the asphalt was immediately adjacent to the south curb near Sta. 5+80 (L-200) and measured about 1.2 by 2.4 m in plan. Below the asphalt, the opening was visually estimated to be about 4.6 by 4.6 m as shown in Photo 1.

Based on discussions with several of the residents, we were informed that the spring had formed around midday on May 26. By mid-week, efforts were apparently made to contain the



flow and direct it through a series of stilling basins to reduce the amount of silt and sand running down the bank and into Snake Bay.

The spring on Lot 3 is shown on Photo 2 and the first of the stilling basins (nearest to the spring) in Photo 3. As seen in the photo, the water is silt laden and the volume of flow is significant.

On June 2, we also observed that the water flowing in the ditch on the west side of Crowston Road disappears into the ground well upstream of the storm water culvert inlet.

It was agreed that DOS would conduct regular visual inspections of the site until the sinkhole issue was resolved.

On June 4 the sinkhole was backfilled by DOS with granular material.

At the time of our June 5 site visit, DOS staff had returned to remove a section of the curb and complete backfilling operations. The zone around the spring on Lot 3 had been reworked and 19 mm crushed gravel placed around the opening. As a result, the exiting water was much more dispersed with a significant component draining down the slope and the remainder into the stilling basins.

By June 6, DOS reported that a 1.2 by 2.4 m zone of the sinkhole backfill had dropped about 0.5 m. Since that time, the backfill continues to disappear into the sinkhole and DOS continues to regularly top it up. We understand that, initially, DOS was topping up the backfill with the equivalent of about 1 load of a single axle gravel truck per day but that the volume has since decreased.

We were informed by Mr. Ron Davis of Concordia that the Crowston Road ditch has experienced significant downcutting since it was constructed.

3.1.2 Slopes and Retaining Walls

In general, rock stack walls have been constructed to the south of Lots 19 to 21 and to the north of Lots 22 to 28. The transition from south to north occurs between Lots 21 and 22. The rock stack walls range from single to multi-tier with minimum tier heights of about 2 m. Other than fencing on Lot 25, no safety rails or fences were observed.

The overall slope along the south side of Lots 19 to 21 dips down from Seawatch Lane at about 28° to 30° from the horizontal. The majority of the slope is supported by a system of rock stack walls. However, in the southeast corner of Lot 21, a scarp-like feature is present as shown in the oblique image (Photo 4) and 2009 airphoto (Photo 5) taken from Sunshine Coast Regional District (SCRD) Online Property Information System (OPIS).

The upper slope of Lot 18 dips down from the L-200 at about 38° to 40° from the horizontal.



At the southwest corner of the site, the existing cut slopes are benched. Several of the cut slopes are near vertical as shown in Photos 6, 7, 8 and 9. No seepage was observed on the soil exposures. No warning signs or hoarding are present.

The park dedication at the west end of the site appears to have been used as a spoil deposition area. Locally, slopes dip down towards Snake Bay Creek at about 55° to the horizontal.

3.2 Soil Sampling and Laboratory Testing

During our June 15 visit, six soil samples were collected. Two samples of the sand deposited downstream of the spring were collected (Sa-1 and Sa-2). Two samples of the sand exposure at the west end of the site were also collected near Sta. 2+40 of the L-200 alignment (Sa-3 and Sa-4) at about 1 and 2 m above the curb or about El. 45.5 and 46.5 m (Photos 6 and 7). A sand sample was also collected opposite Sta. 2+50 (Sa-5) about 2 to 3 m below the original ground surface as shown in Photos 7 and 8. Sa-6 was collected from the soil exposure south of Lot 17 (about Sta. 3+40, L-200) as shown in Photo 9.

All six samples were submitted for routine classification and moisture content testing. Gradation analyses were also conducted to evaluate the particle size distributions. The results are shown on Figures 1 to 6.

In general, material collected in the deposition zone below the outlet from the spring was finer overall than any of the 3 sand samples collected at the west end of the site. Figure 7 shows all 6 particle distributions and summarizes the pertinent gradation parameters. Based on the coefficient of uniformity (C_u), all of the samples have a relatively uniform particle size and are classified as poorly graded. The mean grain size (D_{50}) was about 0.18 mm in the deposition zone (Sa-1 and Sa-2) and ranged from about 0.25 to 0.41 mm in the undisturbed sand deposit at the west end of the site (Sa-3 to Sa-5).

3.3 Ground Penetrating Radar Survey

A geophysical survey using ground penetrating radar (GPR) was undertaken by Terraprobe Geoscience Corp. (Terraprobe) on June 5 and 6, 2012. The GPR survey was conducted along the Gale Avenue North (L-100) and Seawatch Lane (L-200) alignments, a limited portion of Crowston Road and on portions of Lots 27 and 28. The results are presented in Terraprobe's June 20, 2012 report (attached). In general, the GPR survey identified several anomalies as shown on Terraprobe's Figure 1 and our Dwg. 14-214-2-1.

3.4 Land Survey

DOS engaged John Theed Land Surveying Inc. (Theed) to conduct a survey of the locations of the sinkhole and spring, patches/repairs in the roadways, and where the water goes underground in the Crowston Road ditch. A copy of their survey drawing dated June 12, 2012 is attached for reference.



3.5 Airphoto Interpretation

We carried out airphoto interpretation of stereo pairs of photos borrowed from the University of British Columbia for the years 1947, 1976, 1980, 1998 and 2003. DOS provided us single image digital files for March 2009 and 2012. We have acquired stereo pairs of digital images from Integrated Mapping Technologies for March 27 (SRS 7264-59 and -60) and April 5, 2006 (SRS 7276-130 and -131) and have also reviewed images on Google Earth for November 1, 2004, June 23, 2006, September 11, 2009 and July 8, 2010.

The airphotos from 2003 and earlier were reviewed to assess the pre-development site conditions. In all the images, gullies are visible along (i) Snake Bay Creek at the west end of the site, (ii) near the centre of the development in line with Lots 10 and 19 and (iii) at the east end in line with Crowston Road. When comparing the airphotos, we note that the gullies generally appear to become more distinct with time suggesting some on-going erosional processes.

The 2004 Google Earth image shows the site prior to development in a state similar to the 2003 airphotos.

The 2006 images are of the development early in the construction phase. The centre gully is partially infilled and the L-100 and L-200 roads and some of the rock stack walls appear to be under construction. Several sinkhole-like features are also visible in the image as shown on Photo 10. A sedimentation basin is visible near the southeast corner of the site in the vicinity of the recent Sta. 5+80, L-200 sinkhole.

A portion of the March 2009 image provided by DOS is reproduced on Photo 11. The photo shows house foundations on Lots 13 to 15, largely completed houses on Lots 19 to 21, and completed houses on Lots 25 to 27. The scarp-like feature at the southeast corner of Lot 21 is clearly visible in the image. Scarp-like features and/or signs of recent instability are visible at the south end of Lot 18 and the north end of Lots 25 and 26. Numerous erosion features including rills (surficial erosion patterns), localized gullying and springs are visible at several locations including Lots 1 to 5/6, 9 to 12, 15, 16 to 18 and to the south of the Phase 1 development. Significant ground disturbance is visible south of the Sta. 5+80, L-200 sinkhole on the proposed Lot 29 (Phase 2) and behind Lots 23 to 26 as shown on the photo. A relatively small asphalt patch is visible adjacent to Lot 15.

The 2010 Google Earth image shows houses on Lots 19 to 21 and Lots 25 to 27 (Photo 12). House foundations are visible on Lots 13 to 15 and Lot 23. Springs or erosion features are visible near the toe of the fill on Lots 2 and 4. The asphalt patch adjacent to Lot 15 is visible as is the ground disturbance behind Lots 23 to 26. The scarp-like feature on Lot 21 is visible.

A portion of the March 2012 image provided by DOS is reproduced as Photo 13. The photo shows largely completed houses on Lots 7 and 8, the same house foundations on Lots 13 to 15 as seen on the 2009 image, completed houses on Lots 19 to 21 and Lots 23 to 27. The



scarp-like feature at the southeast corner of Lot 21 is still clearly visible in the image. While no signs of recent instability are visible and vegetation has taken hold on most of the undeveloped lots, erosion features including rills, localized gullying and springs are visible at several locations including the fill slope on Lots 1 to 6 and on Lots 9 to 12 as shown. Ground disturbance is visible south of Lot 18 and behind Lots 23 to 26 as shown. Also visible are the majority of the asphalt patches and repairs shown on Theed's drawing dated June 12, 2012. Of particular interest is the patch adjacent to Lot 15 which appears to have quadrupled in size since the 2009 image was taken.

3.6 Review of Available Geotechnical Information

In preparation of this letter, we were provided with the information listed in Table 1. For discussion purposes, we will refer to the various documents by the issuer and date. As described below, geotechnical recommendations for design and construction of the development were documented in GeoTacTics reports dated September 30, 2004 and April 28, 2006. GeoTacTics' addendum to the April 28, 2006 report was issued on May 9, 2006 to address the issue of sinkholes that had developed during site grading work.

On behalf of DOS, TEL completed a geotechnical review of the stability of rock stack retaining walls adjacent to Lots 19 to 25 as documented in our report dated December 15, 2008. Our 2008 review of the project relied on the above referenced reports to obtain an understanding of the site geology and construction history. No further geotechnical investigation was carried out as part of our 2008 review.

The documents described below include those that had information most relevant to developing our interpretation and recommendations.

3.6.1 Golder Associates Ltd. Study

May 1993 Report addressed to DOS

The May 1993 Golder study, completed as part of the Official Community Plan (OCP), classifies the site as Development Permit Area 5 (DPA 5), rocky beach front and upland slopes, Category b), natural hazard conditions. The report notes the following:

"The terrain within this Development Permit Area comprises predominantly steep rocky beach front and upland slopes with a discontinuous surficial blanket or veneer of fine grained or granular morainal soils or rubbly colluvium over bedrock. In the Snake Bay area, soils deposits are generally thicker and include a sand and gravel veneer of probable marine origin.

The soils are subject to potential shallow instability, small debris landslides and to minor storm wave erosion where they are exposed along the beach front. Creep and shallow instability in the surficial soils were observed."



The Golder report also notes that:

"Surficial runoff and seepage from perched groundwater tables have contributed to the formation of gullies within the thicker surficial soil deposits in these areas."

The Golder report indicates that, prior to the issuance of a development permit, the potential for slope instability and the impact of the development should be addressed by a registered professional with specific experience in geotechnical engineering and/or engineering geology. The Golder report also provides guidance with respect to geotechnical issues to be addressed including cut and fill stability, instability caused by groundwater seepage, erosion potential due to waves or drainage flows, setback zones, vegetation protection, etc.

3.6.2 Terra Engineering Ltd. Studies

Copies of a Terra Engineering Ltd. (Terra) letter dated October 24, 1988 for the Norbert Craft Subdivision which included the subject property, an appendix dated March 6, 1989 for the Sechelt/Snake Bay Retirement Development and a July 23, 1992 report for a proposed residential subdivision at the north end of Snake Bay Road were provided for our review. One of the most significant findings of the Terra documents was that several test pits encountered *"sands in a wet state which resulted in sloughing of"* the test pit walls. Terra also noted that *"these wet sands, if exposed, would be very unstable and subject to undermining if left open"* and that they are located *"in the area of Snake Bay Road down through the proposed Hotel area to the waters edge."* Terra generally noted that *"the majority of the site has good bearing for single family residential type structures"* and that *"ground slopes can generally be considered stable"*. Terra provided some preliminary recommendations with regards to cut and fill slopes and indicated that *"proper ground slope protection will be required to protect all newly created slopes from surface erosion and washouts"*.

3.6.3 Geotek Designs

Copies of a Geotek Designs (Geotek) letters dated October 31 and December 2, 1997 for the subject property were provided for our review. The letters were addressed to Sea Shores Development Corp. The two letters are generally very similar in content. One change regarding the waterfront lots relates to driveway grades wherein the maximum decreases from 20% to 15% from October to December. The other significant change is in the December version wherein Geotek added a *"conclusion"* section. In this section, Geotek concluded that *"the native soils and natural slopes of the proposed phase 4 development are presently in a highly stable configuration. There are no indications of any threat of landslide."* Geotek also states that *"the land can safely be used for the use intended."*



3.6.4 GeoTacTics Correspondence

September 30, 2004 Report addressed to Concordia

This report presents the results of a site reconnaissance and a preliminary geotechnical assessment for the subject site and provides geotechnical recommendations for site development. The report describes the site conditions in detail including the presence of the springs on the Lower Slope. GeoTacTics notes that the Lower Slope is experiencing on-going gradual erosion of the surficial soil and localized shallow sloughing of steeper pitches. The average rate of retreat of the existing slope is estimated to be less than 10 mm per year and it is noted that this rate would be expected to increase due to increases in rainfall and/or removal of vegetation cover. The report notes that *"slope retreat during a reasonable service life (60 to 80 years) of a residential structure would be unlikely to encroach more than 1 m into the setback zone."* The report also recommends no tree cutting or clearing in the shoreline environmental covenant areas.

The report recommends that site specific measures *"should be implemented to deal with the active spring areas on the Lower Slope"* and provides preliminary guidance regarding such measures. Finally, the report indicates that, provided the geotechnical recommendations are followed, *"the property can be subdivided and safely used for the intended purposes."*

July 27, 2005 Memorandum addressed to Concordia

The memorandum describes a July 22 site visit during which heavy seepage was observed exiting the slope along the L-200 (between Sta. 1+20 and 1+50) and associated slope instability on Lot 15. The memorandum also indicates that, west of about Lot 25 (Sta. 2+00), active seepage occurs along the L-100 alignment and that a number of drainage courses have developed that carry the seepage across the alignment.

July 31, 2005 Memorandum addressed to Concordia

The memorandum describes a July 27 site visit. The memorandum is silent on seepage and slope instability issues.

August 12, 2005 Memorandum addressed to Concordia

The memorandum describes July 31, August 7 and 11 site visits and several on-going issues including a sinkhole that developed at about Sta. 5+20 on the L-200. The sinkhole diameter was apparently about 20 feet (6 m) and was reported to have been excavated out to a depth of 18 feet (5.5 m). We believe that this is likely the sinkhole labelled "E" on GeoTacTics' Figure 2 (attached) of their April 2006 report.

August 27, 2005 Memorandum addressed to Concordia

This memorandum describes an August 25 site visit and the repairs of the sinkhole at Sta. 5+20 of the L-200 which included placement of a layer of mass concrete at the base and placement of compacted *"glacio-marine sediments"* above.



The memorandum describes on-going challenges and recommends placement of a 3 inch (75 mm) minus rock drainage blanket beneath the round-about area as per Sketch A25-2 (attached).

September 17, 2005 Memoranda addressed to Concordia

One of the two memoranda dated September 17 describes a September 8 site visit and notes that, as the recommended 3 inch minus rock for the drainage blanket was no longer available, 3/4 inch (19 mm) clear crush gravel could be substituted. It also notes that new areas of seepage have been encountered near Sta. 2+60 of the L-200.

The second memorandum describes the results of a September 15 site visit and a section of the slope above Sta. 2+60 of the L-100 that had slid. The slide was about 20 m in length. The spring at the toe of the slope was reported to have a flow of 100 to 150 gpm. The memorandum provides guidance for removal of the slide debris and recommendations for controlling the spring using filter fabric and clear crushed gravel.

September 26, 2005 Memorandum addressed to Concordia

The memorandum describes a September 25 site visit. The memorandum is silent on seepage and slope instability issues.

October 5, 2005 Memorandum addressed to Concordia

This memorandum describes a September 30 site visit conducted in the company of Mahmoud Mahmoud, P.Eng. of Global Earth Solutions Geotech Inc. (GES). Reference is made to a GES site reconnaissance report but no copy was provided for our review. The purpose of the visit was to assess tension cracks observed at Sta. 4+40 of the L-200 and about 40-50 m long on September 28 and provide recommendations to address the very large groundwater flows at the toe of the slope.

The memorandum also describes the large spring at Sta. 3+00 of the L-100 with an estimated flow of about 200 gpm and indicates that the volume of sand being washed out had increased substantially since formation to the equivalent of about 70 m³ per day.

This memorandum provides recommendations to address the spring and comprised extending a buttress and filter at least 10 m along the toe of the slope at this location and across the entire width of the road. The buttress and filter is described as a layer of geogrid placed on native soil, covered with layers of granular fill with nominal particle sizes ranging from 19 mm to 300 mm. Recommendations were provided to extend this buttress and filter to new areas as springs develop. The memo also provides recommendations for a drainage blanket to be constructed across the full width of the road so that the water can be collected and conveyed from the spring to the beach.



October 7, 2005 Memorandum addressed to Concordia

This memorandum describes October 4 and 7 site visits. The memorandum notes that the tension crack described in the previous memorandum had not significantly changed except that two sinkholes had developed along the tension crack at the L-200 level, one at the crest and the other just below. The location's were not specified by GeoTacTics and are therefore not shown on our drawing. It is inferred that these sinkholes were above the Sta. 3+00 spring on the L-100.

Two other sinkholes were reported. One was on the west site of the drainage course at the east end of the property and the other near Sta. 2+10 of the L-100. We believe that these two are shown on GeoTacTics' Figure 2.

October 10, 2005 Letter addressed to Concordia

This letter was prepared in response to an August 30, 2005 letter from DOS and includes the July 27 to October 7, 2005 memoranda.

April 28, 2006 Report (including April 30, 2006 Cover Letter) addressed to Concordia

This report includes test pits from a February 17, 2005 investigation report and provides an updated estimated average rate of recession of 6 to 12 inches per year. The report also describes the slope instability, springs and sinkholes and provides geotechnical recommendations for site development and a supplementary investigation. Figure 2 of the report shows the geology and approximate locations of 8 sinkholes.

The report indicates that further geotechnical investigation is contemplated and indicates that piezometers will be installed.

The report concludes that *"provided the site preparation, earthworks and foundation construction follow the general guidelines outlined above, the property can be safely used for the intended purposes."* The report also notes that "residences constructed in this subdivision are expected to be safe against reasonably conceivable geotechnical hazards, including slope instability, erosion and flooding" and that "the probability of occurrence of geotechnical hazards is estimated to be less than 10 percent in 50 years".

May 9, 2006 Letter addressed to Concordia

This letter was issued as an addendum to the April 28 report to address the issue of sinkholes. The letter indicates that the majority of the erosion cavities occur in the fine sand layer capped by glacial till and that the sinkholes have varied in diameter from 100 mm to greater than 6 m. GeoTacTics describes methods used to deal with sinkholes wherein the first involves excavation and removal of the entire sinkhole and the second involves cleaning the debris out of the sinkhole to expose the neck at the base followed by placement of mass concrete and then compacted fill. This method is referred to as *"plugging the neck"*. The letter indicates that both methods will continue to be used where sinkholes are encountered. From this we infer that both methods have been used on the site to remediate sinkholes.



June 1, 2007 Memorandum addressed to Concordia

This memorandum describes a June 1 site visit and the challenges faced with controlling a spring along the storm outfall corridor between Lots 9 and 10.

August 31, 2007 Letter addressed to Concordia

This letter describes site visits of July 5, 18, 23, August 2, 3, 16 and 24. In the July inspection summary section, the letter describes control of a significant spring on Lot 5 and a sinkhole that had developed in early June on Lot 29 of the future Phase 2 development. The letter notes that, on July 18, the sinkhole was 35 to 40 feet (11 to 12 m) in diameter and that it had subsided by 6 to 8 feet (1.8 to 2.4 m) at its centre. The letter indicates that, on July 23, GeoTacTics observed the excavation, plugging and filling of the sinkhole. The final extent of the excavated area was approximately 10.5 m deep and 12 m in diameter. The letter indicates that "the neck at the base of the sinkhole, approximately 1.5 m south of the edge of the L-200, was plugged by placing several large boulders to create a 'bridge' over the neck of the sinkhole and that the boulders were then capped with about 10 m³ of concrete and backfilled with native glacial till." The letter also notes that the sinkhole was backfilled to the same elevation as the curb.

In the August inspection summary section, the letter notes deficiencies in the construction of stacked rock retaining walls adjacent to the L-100 along Lots 24 through 27.

September 5, 2007 Fax addressed to Concordia

This fax describes an August 21 site visit for the Lot 26 garage foundations.

November 6, 2007 Faxes addressed to Concordia

These three faxes describe October 25 and November 6 site visits for the Lots 19, 20 and 21 foundation excavations.

January 17, 2009 Fax addressed to Concordia

This fax describes a January 14 site visit and several slides on Lot 25 and instability at the south end of Lot 18. Recommendations for mitigation measures were provided.

February 17, 2009 Letter addressed to DOS

This letter is written in response to Urban Systems' March 3, 2006 memorandum. The letter addresses geotechnical issues regarding site services. In particular, it notes that the drainage blanket has been placed on Lots 3 to 5 and Lots 9 to 12. The letter also describes the cause of instability of stockpiled fill on Lots 1 and 2.

February 28, 2009 Letter addressed to Concordia

This letter describes slope instability issues on Lots 1, 9 and 10.

March 7, 2009 addressed to Concordia

This letter provides recommendations for lot grading for Lots 1 to 12.



June 11, 2009 Fax addressed to Concordia

This fax describes a June 10 site visit and the progress of site grading on Lots 1 to 12.

June 17, 2009 Fax addressed to Concordia

This fax describes June 10, 12 and 16 site visits and the progress of site grading on Lots 1 to 12 and Lots 16 to 18. The fax also expresses concern regarding potential instability issues at Lots 18/19 and 21/22. Buttressing and flattening are recommended for Lots 18/19. The fax indicates that the stacked rock retaining wall was never completed in the southeast corner of Lot 21 and recommends, at a minimum, temporary buttressing and flattening of the unprotected area.

June 24, 2009 Fax addressed to Web

This fax describes June 16, 18 and 23 site visits and the progress of site grading on Lots 1 to 12. The fax notes that *"site grading has satisfactorily buttressed the slope on the northern side of the L-100, and there is no risk of catastrophic undermining of the road and the services buried beneath the road"* adjacent to Lots 3 to 12.

July 21, 2009 Fax addressed to Web

This fax describes July 16 and 21, 2009 site visits and the progress of site grading on Lots 1 to 12 and Lots 16 to 18. The fax notes that *"site grading has satisfactorily buttressed the slope on the northern side of the L-100, and there is no risk of catastrophic undermining of the road and the services buried beneath the road"* adjacent to Lots 1 to 12. The fax also notes that *"Lots 16 to 18 have been filled to the final lines and grades required to leave the lots in a maintenance-free condition until construction on the individual lots begins."*

December 18, 2009 Letter addressed to DOS

This letter describes the stacked rock retaining walls on Lots 19 to 24 and provides as-built sketches. In the first paragraph of the second page, the letter notes that Figures 3 to 8 *"show the proposed plan layouts of the stacked rock retaining walls on each of the respective locations and the as-built locations of the various tiers of stacked rock wall."* GeoTacTics' third, fourth and fifth paragraphs and Figures 5 and 6 suggest that the rock stack walls were actually completed on Lots 21 and 22. This does not seem to be consistent with our observations on site or review of airphotos (see our Figures 11, 12 and 13) and should be clarified with GeoTacTics.

February 2, 2010 Letter addressed to DOS

This letter confirms that temporary site grading of Lots 1 to 18 has been completed in general accordance with GeoTacTics' recommendations and notes that *"there is minimal risk of catastrophic undermining of the L-100 and L-200 roads and the services buried beneath the roads."*



September 27, 2011 Letter addressed to Concordia

This letter describes a September 15, 2011 site visit to review the temporary excavated slope at the southwest corner of the development. The letter notes that "*no deep-seated instability has occurred in the slope since the slope has been excavated*". The letter concludes that the "*overall stability of the excavated slope is satisfactory*" but that "*fragments of rock, gravel and sand will continue to fall and/or roll down*". For the temporary configuration, GeoTacTics recommends trimming the upper 0.6 m of the slope and vegetating other areas. For permanent slopes, GeoTacTics recommended flattening slopes to 2H:1V or flatter.

June 5, 2012 Fax addressed to DOS

This fax describes a sinkhole that appeared near the curb near Lot 9 (approximately Sta. 3+10).

3.6.5 Metro Testing Laboratories Inc.

Results of field density, concrete and gradation tests were provided. The August 15, 2007 field density report (attached) provides test results and a sketch for the Lot 29 remediation which suggests that the edge of the sinkhole was at least 10 m from the east property line of Lot 29.

A number of field density reports include a marked-up copy of a sediment control plan prepared by GeoTacTics. A copy of Metro's September 24, 2007 Field Density Report is attached. The plan shows a sedimentation basin near the intersection of Seawatch Lane and Crowston Road.

3.6.6 Sunco Civil Consulting Ltd.

Limited results of field density tests were provided.

3.6.7 Web Engineering Ltd.

Drawings, letters, faxes and memoranda were provided. Two memoranda dated June 8, 2007 addressed to N & B Contracting and Concordia make note of "*a sinkhole developing above L-200 road*". We infer that this is likely the Lot 29 sinkhole shown in Metro's field density report and described in GeoTacTic's August 31, 2007 letter.

4. ENGINEERING ASSESSMENT

4.1 General

The development has experienced many geotechnical challenges in the form of springs, erosion cavities and sinkholes, slope instability and surface erosion since commencement of construction. In particular, previous reports by others, as well as early reports by GeoTacTics, identified groundwater and the risk of problems where the sand is encountered below the groundwater table. Below we provide our assessment of the sinkholes and other geotechnical issues.



4.2 General Geological Processes

4.2.1 Geological Process

The sinkholes generally appear to be related to springs and subsurface erosion of the sand at this site. Springs, cavities and sinkholes are the result of the same geological process and may also lead to surface erosion and slope instability. Cavities and sinkholes can be formed either due to piping or internal erosion.

The piping process starts when water exits the ground with sufficient energy (hydraulic gradient) to erode the soil at the ground surface. This erosion of soil at the surface decreases the length of the seepage path thus increasing the hydraulic gradient. This results in a continuous retrogressive process of erosion at the exposed face. In some instances, the erosion can cause a distinct cavity or pipe. Once initiated, the cavity or pipe concentrates the flow and seepage which, in turn, causes the length of the cavity or pipe to increase with ever increasing flows. As described by Terzaghi, Peck and Mesri (1996), *"if a spring is powerful enough to start erosion in the first place, the erosion will almost certainly become more serious as time goes on, because the flow from a given spring increases with the length of the eroded tunnel."* The piping process only stops when the hydraulic gradient falls to a low enough level. Piping is evident where the discharge from springs contains silt and sand, and often may be turbid or muddy.

If the pipes are sufficiently shallow and large enough, a sinkhole or sinkholes may form at the ground surface when the pipe cavity collapses. This only fills the pipe cavity in the area of the collapse and the pipe remains open elsewhere. The open pipe may still be susceptible to collapse resulting in the formation of other sinkholes. The pipe also remains a preferential flow path and may be the parent of other pipes.

To prevent piping, properly engineered filters can be constructed to prevent soil erosion where the water is exiting, or has the potential to exit, the ground. Alternatively, the hydraulic gradients can be lowered by installing wells or other dewatering measures.

Conversely, sinkholes may also form as a result of internal erosion wherein only the smallest soil particles are eroded from the soil matrix. Internal erosion generally occurs in soil with a wide gradation or a gap gradation wherein the smallest particles of soil can be transported by water flow past larger particles. Internal erosion is typically a problem in man-made, manufactured soils and mechanically placed soils where segregation can occur. Uniform soils, such as typical beach sand, are not susceptible to internal erosion.

Springs will also contribute to surface erosion leading to slope instability resulting from high groundwater levels associated with the springs, and unstable ground due to the formation of underground cavities and sinkholes.



4.3 Specific Geotechnical Issues

4.3.1 Spring Locations

The approximate locations of several springs are shown on GeoTacTics' Figure 2 and our Dwg. 14-214-2-1. GeoTacTics reported significant springs on Lots 5 and Lots 9/10, at Sta. 2+60 and 3+100 of the L-100 alignment and between Sta. 1+20 and 1+50 of the L+200 alignment. Significant seepage was also noted west of about Lot 24 or Sta. 2+00 of the L-100 alignment.

4.3.2 Internal Erosion

We have assessed the potential for internal erosion (the potential for soil particles to move past one another) of the recently collected soil samples. Using the criteria described in Terzaghi et al. and Kenney and Lau (1985), all of the samples collected are not considered susceptible to internal erosion. Intuitively we feel that this is reasonable finding given the depositional nature of the deposits and that the materials are relatively uniform.

4.3.3 Erosion Potential of the Sand

The results of TEL's gradation testing indicate that the native sand is predominantly fine grained and is relatively uniform. Briaud (2011) classifies fine sand as very high erodibility and medium sand as high erodibility. Briaud shows that the critical velocity to initiate erosion is relatively low compared to other soil types. As such, relatively small exit seepage gradients are required to dislodge the sand particles and initiate the piping process. The risk of this behaviour was noted in the Terra reports for this site and Golder OCP study.

4.3.4 Sinkholes

Given the low potential for internal erosion of the soils present at the site, we believe the most likely cause of the sinkholes is collapse of piping cavities. Sinkholes have been identified at the locations shown on GeoTacTics' Figure 2 and, since April 2006, on Lot 29 and in the vicinity of Lots 19 to 21 as shown on Photo 10 and Dwg. 14-214-2-1. Sinkhole repairs have been described as complete removal and replacement or "plugging the neck" with concrete and placement of compacted fill above as was done on Lot 29 and at Sta. 5+20 of the L-200. The "plugging the neck" repair leaves an unfilled cavity downstream of the sinkhole which will still be vulnerable to future collapse. In this instance, we believe that the recent sinkhole at Sta. 5+80, L-200 may be related to the roof collapse of the unfilled cavity left over from the sinkhole repair on Lot 29.

Given that collapse of an existing cavity roof may be responsible for the Sta. 5+80, L-200 sinkhole, this suggests that cavities connected to other sinkholes repaired in the same manner may also be at risk of collapse. Only one other sinkhole has been clearly identified in the GeoTacTics correspondence as being repaired by "plugging the neck". This suggests that there is a risk of additional sinkholes occurring along the horizontal erosion cavities situated to the



north and possibly to the south of the Sta. 5+20 and 5+80/Lot 29 sinkholes and possibly elsewhere.

While we suspect that the Lot 3 spring and Sta. 5+80 sinkhole are connected, we can not be certain of this. They may in fact be related simply by changes in the groundwater regime. It is interesting to note that the large spring on Lot 5 and the Lot 29 sinkhole described in GeoTacTics' August 31, 2007 letter seem to have appeared at about the same time. We are concerned that significant groundwater flow carrying sand has continued to exit from the Lot 3 spring following the sinkhole formation and this suggests that the cavity may still be expanding in size.

All sinkhole repair records should be reviewed in detail to more accurately locate the sinkholes and to determine which repair option was employed at each location.

4.3.5 Filters and Drainage Blankets

Gradation analyses were conducted on several recently collected samples of native soil including material collected in the deposition zone below the spring on Lot 3. No samples of the filters used during construction are available for our assessment. Review of the GeoTacTics correspondence indicates that different materials were used for filter construction and suggests that construction of the filter/drainage blanket was difficult. In particular, controlling/containing a number of the springs was generally described as very challenging. Even if it can be shown that the filter design was adequate to control piping, challenges faced during construction may have rendered the filters inadequate or may have allowed erosion cavities to form below or behind the filter/drainage blanket.

GeoTacTics' September 15, 2005 memo recommending placement of a filter comprising filter fabric retained by clear crush gravel is likely adequate to prevent further erosion and piping of the sand. However, the filter and buttress system using geogrid and granular fill as described in GeoTacTics' October 5, 2005 memo is not considered an appropriate filter design to prevent erosion and piping of the fine sand.

We understand that drainage blankets were used throughout the site, and generally comprised 75 mm or 19 mm clear crush gravel rock fill placed on native soil, with finer site grading fill placed on top. We interpret that these drainage blankets are intended to convey water along the top of the native soil. It is unclear specifically if these drainage blankets are continuous, and on what types of native soil they were placed. If drainage blankets were placed on the fine sand layer, there still may be surficial erosion of the fine sand layer at the interface of the drainage blanket and native soil as the fine sand and clear crush are not gradationally compatible. Since the 19 mm clear crush is a relatively uniform product, it is not expected to be susceptible to internal erosion. However, the 75 mm minus rock fill will require testing to assess its susceptibility to internal erosion and its compatibility with the adjacent materials.



By inspection, the majority of the asphalt repairs shown on Theed's drawing and Dwg. 14-214-2-1 occur between Sta. 2+00, L-100 and Sta. 1+50, L-200 where drainage blankets/granular filters were reportedly used during construction. We believe that some of the movement observed at the road surface may be due to fine sand migrating beneath or through the drainage blankets/granular filters or possibly related to internal erosion of the drainage blanket/granular filter.

4.4 Crowston Road Ditch

Contour mapping and review of the airphotos suggests that the Crowston Road ditch alignment may have been altered during construction. Water in the Crowston Road ditch currently disappears into the ground before reaching the culvert inlet. We are uncertain if the water is flowing in the backfill of the former gully or if the water is flowing through a cavity within the native materials. If the water is flowing within the backfill, the likelihood of formation of a large cavity and sinkhole is relatively small. However, if the water is forming a cavity within the native materials, the risk of forming a large cavity, and ultimately a sinkhole, is significant.

4.5 Slope Stability

Issues of slope instability have been reported on Lots 1, 2, 9, 10, 15, 18, 19, 20, 21, 22 and 25. Some of the reported instabilities occurred during construction whereas some instances occurred on the completed slopes. Furthermore, it appears that spoil material has been placed in the park area at the west end of the site adjacent to the deeply incised Snake Bay Creek ravine. Also, either the slope at the southeast corner of Lot 21 has failed or construction was never completed. At a minimum, a more detailed slope stability assessment is warranted at this site to determine if the stockpiled material adjacent to Snake Bay Creek needs to be removed and remedial measures implemented for the south slope of Lot 21.

4.6 Stacked Rock Retaining Walls

We have not revisited the stacked rock retaining walls in detail at this time. However, in our December 15, 2008 report to DOS, we expressed concerns regarding the walls at the north end of Lots 22 through 25 and also the material used to backfill the rock walls. We believe that it would be prudent to revisit our assessment given the findings of our previous report and observations since that time.

TEL does not have expertise in safety engineering. However, we believe that fall hazards exist at many of the lots including Lots 19 through 28. The requirement for safety rails or fences should be assessed.

4.7 Shoreline Recession

GeoTacTics' September 2004 suggested that shoreline recession would likely be less than 1 m over a 60 to 80 year design life. In the April 2006 report, the yearly rate of recession increased



from 1 mm to about 150 to 300 mm (6 to 12 inches) per year which would be the equivalent of 9 to 24 m over a 60 to 80 year design life. If the 2006 estimate is correct, the whole development could be at risk in a relatively short period unless significant shoreline protection measures are undertaken. This should be reviewed in more detail.

5. RECOMMENDATIONS

5.1 General

As noted above, although the current focus of our work is on the sinkholes, the development has experienced many geotechnical challenges since commencement of the work. Below we provide our interpretation of the risk of other sinkholes forming, potential mitigation options and recommended supplementary investigation.

5.2 Risk of Sinkhole Reoccurrence

Given that the recent Sta. 5+80, L-200 sinkhole may be related to the previous repair of the sinkhole on Lot 29 and that at least one other erosion cavity is known to exist at Sta. 5+20 of the L-200, the formation of other sinkholes within the development should be anticipated. If other sinkholes were repaired in the same manner as the Lot 29 sinkhole by *"plugging the neck"*, the likelihood of the presence of erosion cavities and sinkholes is even greater. The timing of sinkhole collapse events is impossible to predict given the available information. However, we expect that they will occur.

5.3 Mitigation Options

Mitigation of the risk of sinkhole development related to existing erosion cavities would require that the existing erosion cavities be properly infilled. However, repair of the erosion cavities is expected to be challenging as the erosion cavities are expected to be relatively deep and difficult to detect. While the GPR survey identified a number of anomalies in the field that should be investigated in more detail, we are uncertain if these are related to erosion cavities or to other features. Several mitigation options are available to address the erosion cavities and the risk of sinkhole formation. All mitigation options will require additional geotechnical, hydrogeological and geophysical investigation for detailed assessment and all options carry different levels of risk.

Potential mitigation options for the Sta. 5+80 sinkhole and all sinkholes repaired using the *"plugging the neck"* approach include complete excavation of the sinkhole and associated erosion cavity and backfilling or possibly grouting. To facilitate this work, temporary dewatering of the sand layer using a series of wells or similar will be required.

Other erosion cavities may still exist or may be at risk of forming. We suspect that the granular filters and drainage blanket may not be functioning as intended given the performance of the on-site roads, particularly on Gale Avenue North between Lots 24 and 19 and on Seawatch



Lane adjacent to Lot 15. To mitigate the risk of development of erosion cavities, groundwater must be intercepted before it can exit through the granular filter. Alternatively, the granular filter should be reconstructed. The former option would require construction of a permanent dewatering system and the latter a temporary dewatering system while the existing filter materials are removed and replaced with properly designed granular filters. We expect that these approaches could be potentially quite disruptive and may require temporary support and possibly relocation of some of the existing services, and possibly homes, during construction of the remedial works. These options should be further assessed following completion of a supplementary investigation.

5.4 Slope Stability

As noted in Section 4.5, a more detailed slope stability assessment is warranted at this site to determine if the stockpile in the park area should be removed and to develop remedial measures for the south slope of Lot 21. In the interim, we recommend that a safety fence be installed at the south end of Lot 21 adjacent to the scarp. Also, we suggest that hoarding or fencing be installed in the southwest corner of the site adjacent to the near vertical cuts in the sand layer to keep the public away from the vertical slope hazard.

5.5 Stacked Rock Retaining Walls

As noted in Section 4.6, we have not revisited the stacked rock retaining walls in detail at this time. However, in our December 15, 2008 report to DOS, we expressed concerns regarding the walls at the north end of Lots 22 through 25 and also the material used to backfill the rock walls. Given that slope instability has occurred at the north end of Lots 25 and 26 and the former sinkholes at the south end of Lot 19, north end of Lot 24 and on Lot 21, we believe that it would be prudent to revisit our assessment of the stacked rock retaining walls in the near future.

To mitigate the potential fall hazard, the requirement for safety rails or fences should be assessed for all of the stacked rock retaining walls within the development.

5.6 Shoreline Recession

GeoTacTics predicts significant shoreline recession at this site. We recommend that this be assessed in more detail.

5.7 Supplementary Investigation

We recommend that additional geotechnical, hydrogeological and geophysical investigation be undertaken. A phased approach should be considered to build upon the findings of each of the phases. At a minimum, the investigation should be developed to determine the stratigraphy and hydrogeology of the site in sufficient detail to understand the groundwater flow and how to control it. The investigation should include collection of samples of the fine sand and the granular filter and drainage blanket materials used during construction control seepage. If



possible, at least one of the erosion cavities should be investigated to determine its size and its impact on the surrounding soil.

Additional geophysical testing could also be considered. Frontier Geosciences of North Vancouver suggest using a combination of streaming potential and ohmmapper resistivity imaging for detection and delineation of elevated seepage conditions in the soils.

5.8 On-going Inspections

In the interim, we recommend that DOS continue to regularly inspect the roads for signs of movement and the slope for springs and that TEL inspect the site intermittently with DOS personnel.

6. REFERENCES

Briaud, J.-L. (2011). Bridge scour and levee overtopping. ISSMGE 1st Webinar (<https://ceprofs.civil.tamu.edu/briaud/Webinar%20Lecture-23Aug2011.pdf>).

Kenney, T.C. and Lau, D. (1985). Internal stability of granular filters. Canadian Geotechnical Journal, 22(2): 215-225.

Terzaghi, K., Peck, R.B. and Mesri, G. (1996). Soil Mechanics in Engineering Practice, 3rd Edition, John Wiley & Sons, 549 pages.

7. CLOSURE

This report has been prepared by Thurber Engineering Ltd. for the exclusive use of the Lidstone and Company and the District of Sechelt. Any use of the report by third parties, or any reliance on decisions made based on it, are the responsibilities of such third parties. Thurber does not accept responsibility for damages suffered, if any, by any other party as a result of their use of this report



We trust that this information is sufficient for your needs. Should you require clarification of any item or additional information, please contact us at your convenience.

Yours truly,
Thurber Engineering Ltd.
David Hill, P.Eng.
Review Principal



David J. Tara, P.Eng.
Project Principal

Attachments:

- Statement of Limitations and Conditions (2 sheets)
- TEL Table 1 (1 sheet)
- TEL Photos 1 to 13 (13 sheets)
- TEL Figures 1 to 7 (7 sheets)
- TEL Dwg. 14-214-2-1 (1 sheet)
- Terraprobe Report dated June 15, 2012 (20 sheets)
- John Theed Land Surveying Inc. Site Plan dated June 12, 2012 (1 sheet)
- GeoTacTics Dwg. No. 2 dated August 2004 (1 sheet)
- GeoTacTics Sketch A25-2 (1 sheet)
- GeoTacTics Figure 2 dated April 30, 2006 (1 sheet)
- GeoTacTics Figure 3 dated April 30, 2006 (1 sheet)
- Metro Field Density Report dated August 15, 2007 (2 sheets)
- Metro Field Density Report dated September 24, 2007 (4 sheets)



STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This study and Report have been prepared in accordance with generally accepted engineering or environmental consulting practices in this area. No other warranty, expressed or implied, is made.

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 PROPERLY 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 REPORT

The Report has been prepared for the specific site, development, design objectives and purposes 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, subject to the limitations provided herein, are only valid to the extent that this Report expressly addresses proposed development, design objectives and purposes, and then only to the extent 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 or to consider such representations, information and instructions.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of 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 AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS WE MAY EXPRESSLY APPROVE. The contents of the Report remain our copyright property. The Client may not give, lend or, sell the Report, or otherwise make the Report, or any portion thereof, available to any person without our prior written permission. Any use which a third party makes of the Report, are the sole responsibility of such third parties. Unless expressly permitted by us, no person other than the Client is entitled to rely on this Report. We accept no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without our express written permission.

5. INTERPRETATION OF THE REPORT

- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities 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. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and this report is delivered on the express condition that such risk is accepted by the Client and such other persons. 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.
- b) 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 the Client or other persons providing information relied on by us. We are entitled to rely on such representations, information and instructions and are not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

(see over . . .)



INTERPRETATION OF THE REPORT *(continued . . .)*

- c) **Design Services:** The Report may form part of the design and construction documents for information purposes even though it may have been issued prior to the final design being completed. We should be retained to review the final design, project plans and documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the report recommendations and the final design detailed in the contract documents should be reported to us immediately so that we can address potential conflicts.
- d) **Construction Services:** During construction we must be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RISK LIMITATION

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause an accidental release of those substances. In consideration of the provision of the services by us, which are for the Client's benefit, the Client agrees to hold harmless and to indemnify and defend us and our directors, officers, servants, agents, employees, workmen and contractors (hereinafter referred to as the "Company") from and against any and all claims, losses, damages, demands, disputes, liability and legal investigative costs of defence, whether for personal injury including death, or any other loss whatsoever, regardless of any action or omission on the part of the Company, that result from an accidental release of pollutants or hazardous substances occurring as a result of carrying out this Project. This indemnification shall extend to all Claims brought or threatened against the Company under any federal or provincial statute as a result of conducting work on this Project. In addition to the above indemnification, the Client further agrees not to bring any claims against the Company in connection with any of the aforementioned causes.

7. SERVICES OF SUBCONSULTANTS AND CONTRACTORS

The conduct of engineering and environmental studies frequently requires hiring the services of individuals and companies with special expertise and/or services which we do not provide. We may arrange the hiring of these services as a convenience to our Clients. As these services are for the Client's benefit, the Client agrees to hold the Company harmless and to indemnify and defend us from and against all claims arising through such hirings to the extent that the Client would incur had he hired those services directly. This includes responsibility for payment for services rendered and pursuit of damages for errors, omissions or negligence by those parties in carrying out their work. In particular, these conditions apply to the use of drilling, excavation and laboratory testing services.

8. CONTROL OF WORK AND JOBSITE SAFETY

We are responsible only for the activities of our employees on the jobsite. The presence of our personnel on the site shall not be construed in any way to relieve the Client or any contractors on site from their responsibilities for site safety. The Client acknowledges that he, his representatives, contractors or others retain control of the site and that we never occupy a position of control of the site. The Client undertakes to inform us of all hazardous conditions, or other relevant conditions of which the Client is aware. The Client also recognizes that our activities may uncover previously unknown hazardous conditions or materials and that such a discovery may result in the necessity to undertake emergency procedures to protect our employees as well as the public at large and the environment in general. These procedures may well involve additional costs outside of any budgets previously agreed to. The Client agrees to pay us for any expenses incurred as the result of such discoveries and to compensate us through payment of additional fees and expenses for time spent by us to deal with the consequences of such discoveries. The Client also acknowledges that in some cases the discovery of hazardous conditions and materials will require that certain regulatory bodies be informed and the Client agrees that notification to such bodies by us will not be a cause of action or dispute.

9. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on our interpretation of conditions revealed through limited investigation conducted within a defined scope of services. We cannot accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

ABC =
ABC =
BC =
CC =
Consensus =
DFO =
DOS =
Glossary =
Golder =
Lash =
LVLS =
BCFD =
Sunco =
Telus =
Terra =
USL =
Wash =

ABC Paper Cleaning Services Ltd
Apteco & Associates
BC Hydro
Cable Cable
Consensus Marine
Department of Fisheries and Oceans
Division of Seafish
Geobak Design
Golder Associates Ltd
Anthony C. Lash & Associates
Van Vleet Landscape Builders
Suncoast Coast Regional District
Suncoast Civil Consulting Ltd
Terra
Terra Engineering Ltd
Urban Systems Ltd
West Environmental Ltd



Photo 1. Sinkhole enlarged below asphalt, fabric surround of interceptor drain (near right bottom corner) and broken sanitary sewer (near top centre).



Photo 2. Spring on Lot 2 prior to backfilling with crushed gravel.



Photo 3. First of the stilling basins on June 2.



Photo 4. Head of scarp-like feature at southeast corner of Lot 21 (left hand side of photo).



Photo 5. Rock stack walls at south end of Lots 19 to 21. Note scarp-like feature in southeast corner of Lot 21 (blue long dash line).
Extract from SCRD OPIS.

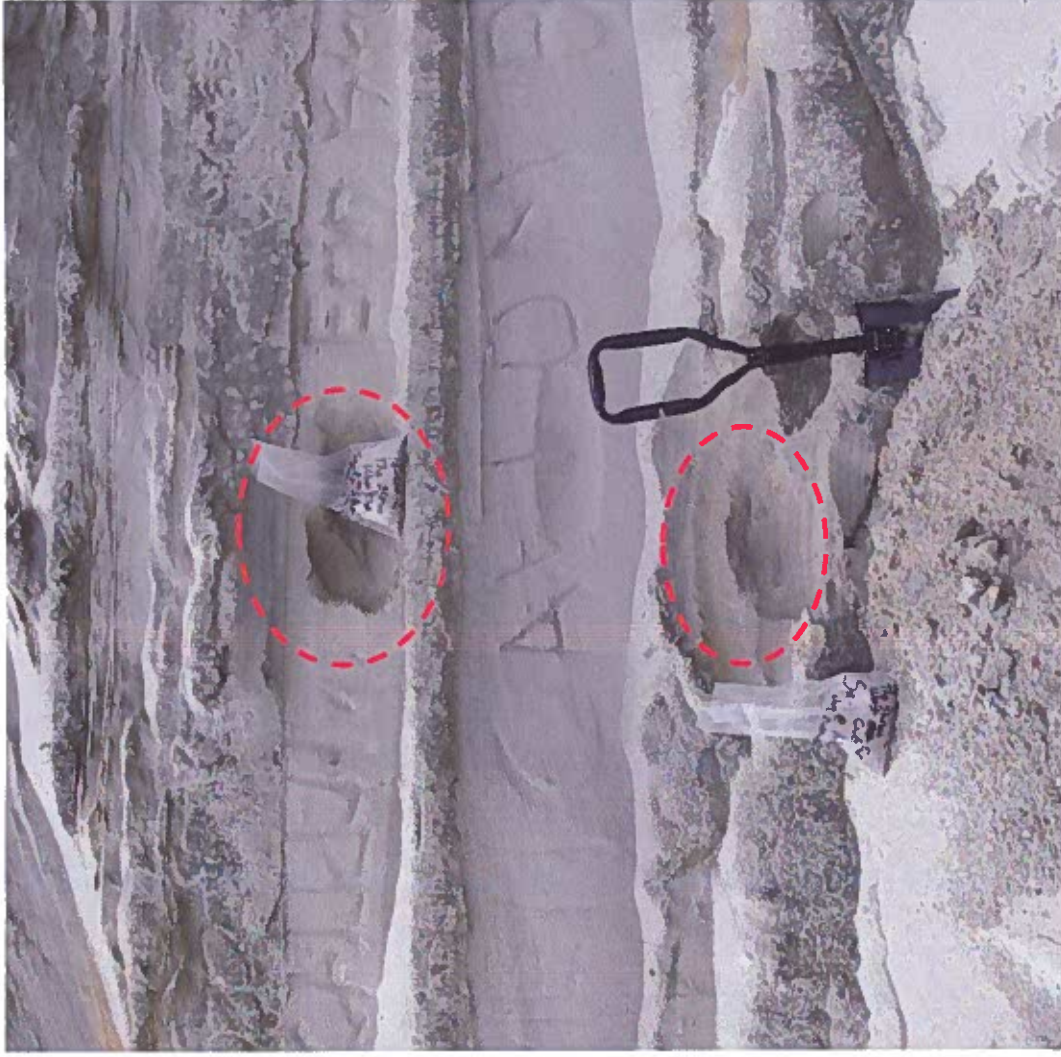


Photo 6. Sand exposure in cut slope at west end of site. Collection location of samples Sa-3 (bottom) and Sa-4 (top)



Photo 7. Cut slope at west end of site. Collection location of sample Sa-5 in upper left and Sa-3 and Sa-4 in lower left.



Photo 8. Sand exposure in cut slope opposite Sta. 2+50 (L-200) and sample Sa-5 collection location.



Photo 9. Soil exposure in cut slope opposite Lot 17 (Sta. 3+40, L-200) and sample Sa-6 collection location.

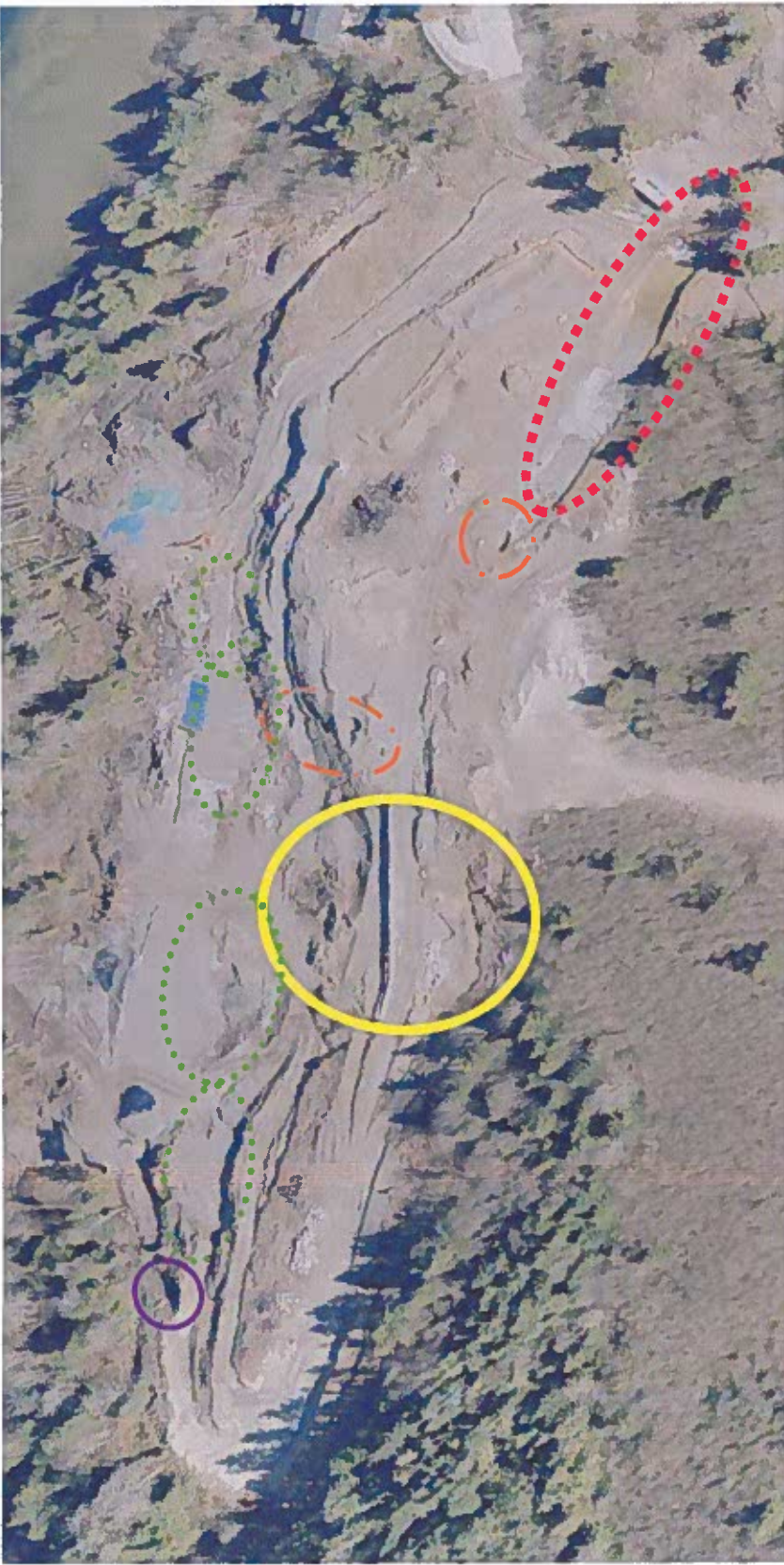


Photo 10. Infilled central gully (wide yellow line), multiple sinkhole-like features (orange dot-dash lines), recent instability (purple line), springs and/or erosion features (green dotted line) and sedimentation basin (dark red short dashed line). March 27, 2006 digital image (SRS 7264-59) provided by IMT.



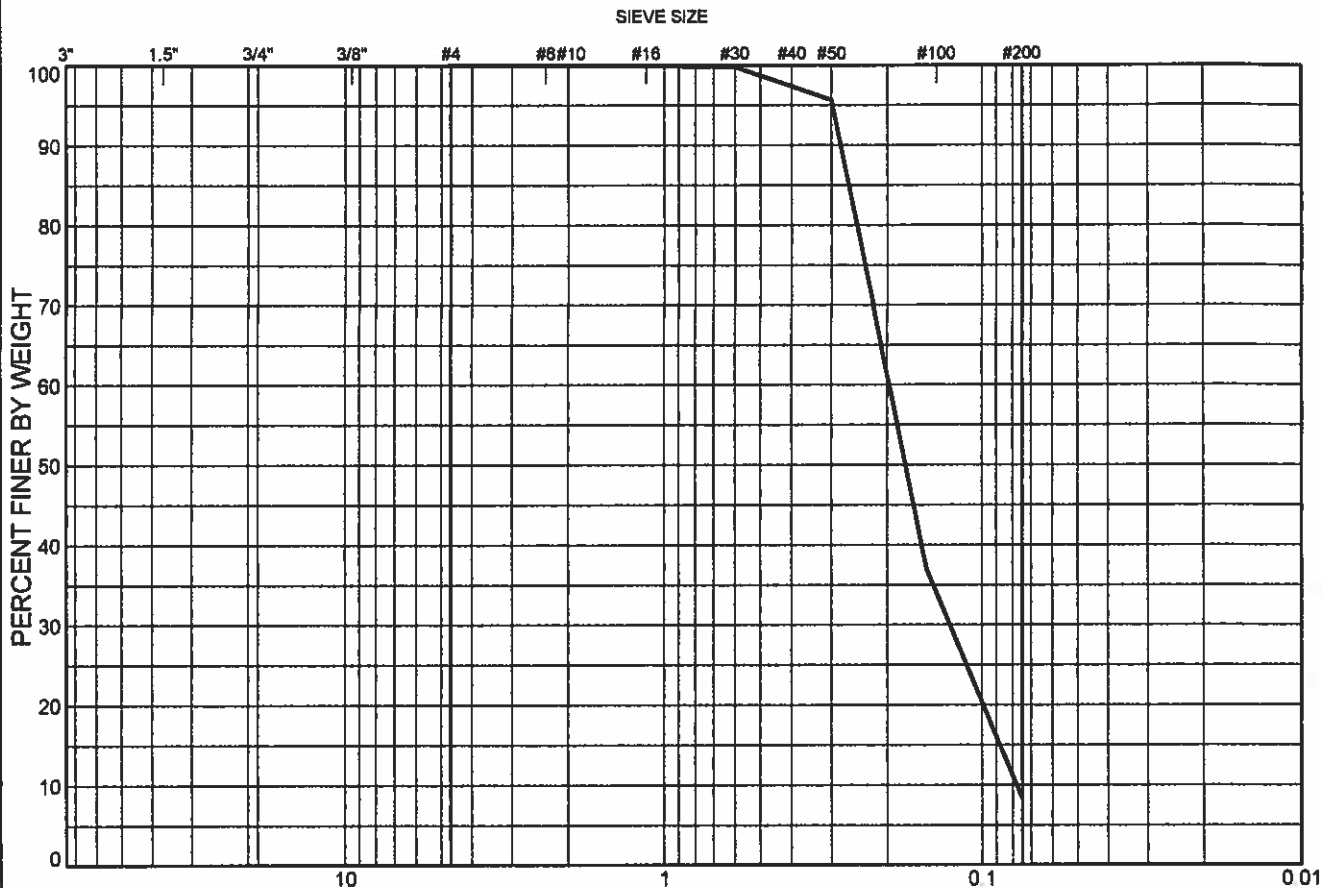
Photo 11. March 2009 image showing signs of recent instability (solid purple lines), springs and/or erosion features (green dotted lines) and significant ground disturbance (red dashed lines). Note that the scarp-like feature is visible at the southeast corner of Lot 21 (blue long dashed line). A small patch in the asphalt surfacing is visible adjacent to Lot 15. Image provided by DOS.



Photo 12. 2010 Google Earth image showing springs on Lots 2 and 4 (green dotted lines), ground disturbance (red dashed lines) and asphalt patch adjacent to Lot 15 (thin black line). Note that the scarp-like feature is visible at the southeast corner of Lot 21 (blue long dashed line).



Photo 13. March 2012 image showing springs and/or erosion features (green dotted lines) and significant ground disturbance (red dashed lines). Note that the scarp-like feature is visible at the southeast corner of Lot 21 (blue long dashed line). The asphalt patch adjacent to Lot 15 appears to have increased in size relative to the 2009 image and other patches visible (thin black line). Image provided by DOS.



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: See Dwg. 14-214-2-1

Sample: 1

Sample Depth: N/A

Date Sampled: June 15, 2012

Sampled By: DJT

Date Received: June 18, 2012

Date Tested: June 18-19, 2012

Tested By: JW

Test Method: ASTM C136 and C117

Specification: _____

Gravel	0.0%
Sand	91.5%
Fines	8.5%
Moisture Content	25.2%

D10	0.078
D30	0.127
D60	0.197
Cu	2.53
Cc	1.05

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	100.0
#8	2.36	100.0
#16	1.18	100.0
#30	0.6	99.8
#50	0.3	95.7
#100	0.15	36.9
#200	0.075	8.5

Description: Fine SAND, trace silt (SP-SM).

Comments: _____

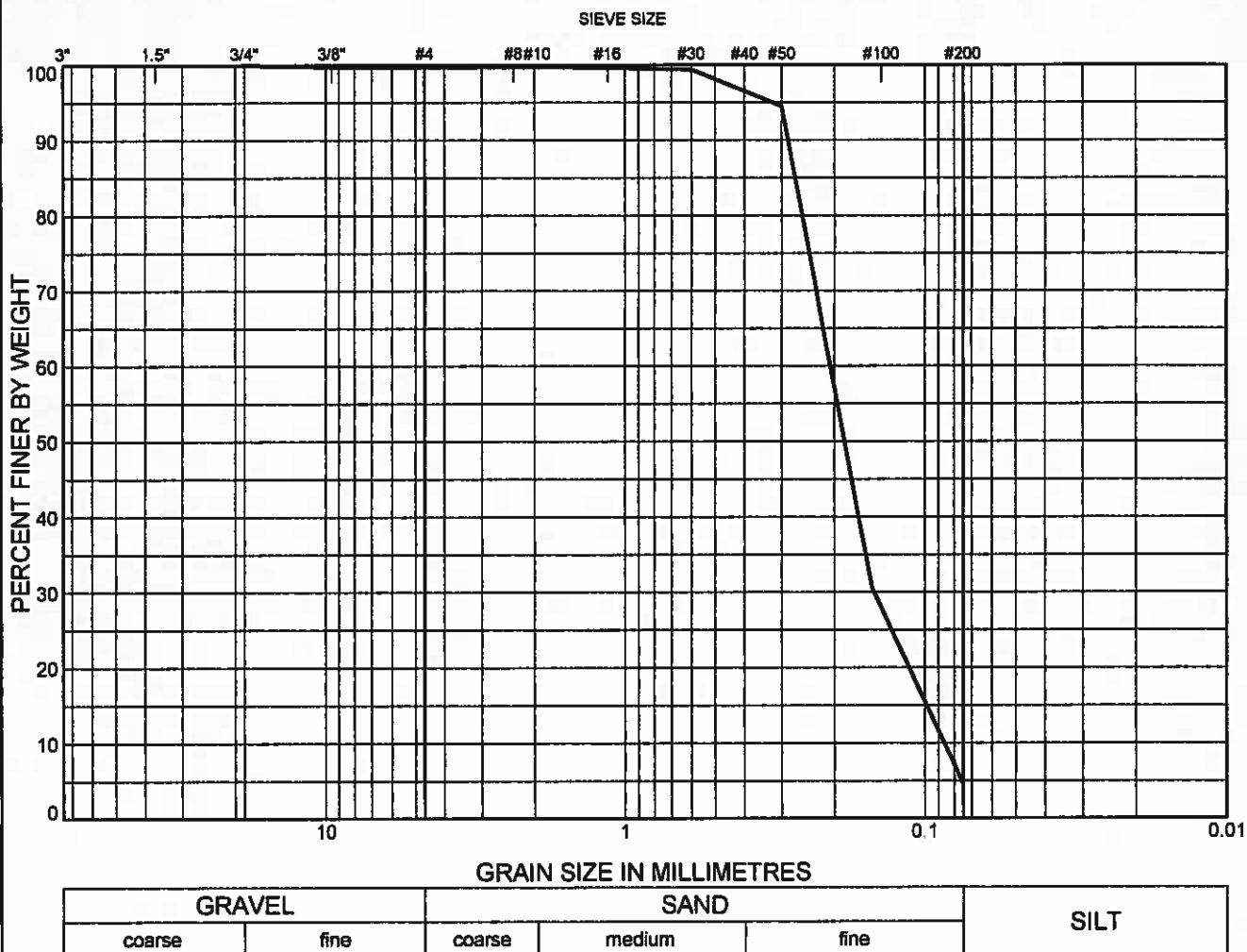
The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.



Thurber Engineering Ltd.
#900 - 1281 West Georgia Street
Vancouver, BC V6E 3J7
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: LIDSTONE AND COMPANY
PROJECT: THE SHORES SUBDIVISION
FILE NO.: 14-214-2
FIGURE NO. 1



Sample Location: See Dwg. 14-214-2-1

Sample: 2

Sample Depth: N/A

Date Sampled: June 15, 2012

Sampled By: DJT

Date Received: June 18, 2012

Date Tested: June 18-19, 2012

Tested By: JW

Test Method: ASTM C136 and C117

Specification: _____

Gravel	0.3%
Sand	95.0%
Fines	4.7%
Moisture Content	26.2%
D10	0.086
D30	0.148
D60	0.206
Cu	2.39
Cc	1.22

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	100.0
0.375	9.5	99.7
#4	4.75	99.7
#8	2.36	99.7
#16	1.18	99.7
#30	0.6	99.4
#50	0.3	94.5
#100	0.15	30.6
#200	0.075	4.7

Description: Fine SAND, trace silt (SP).

Comments: _____

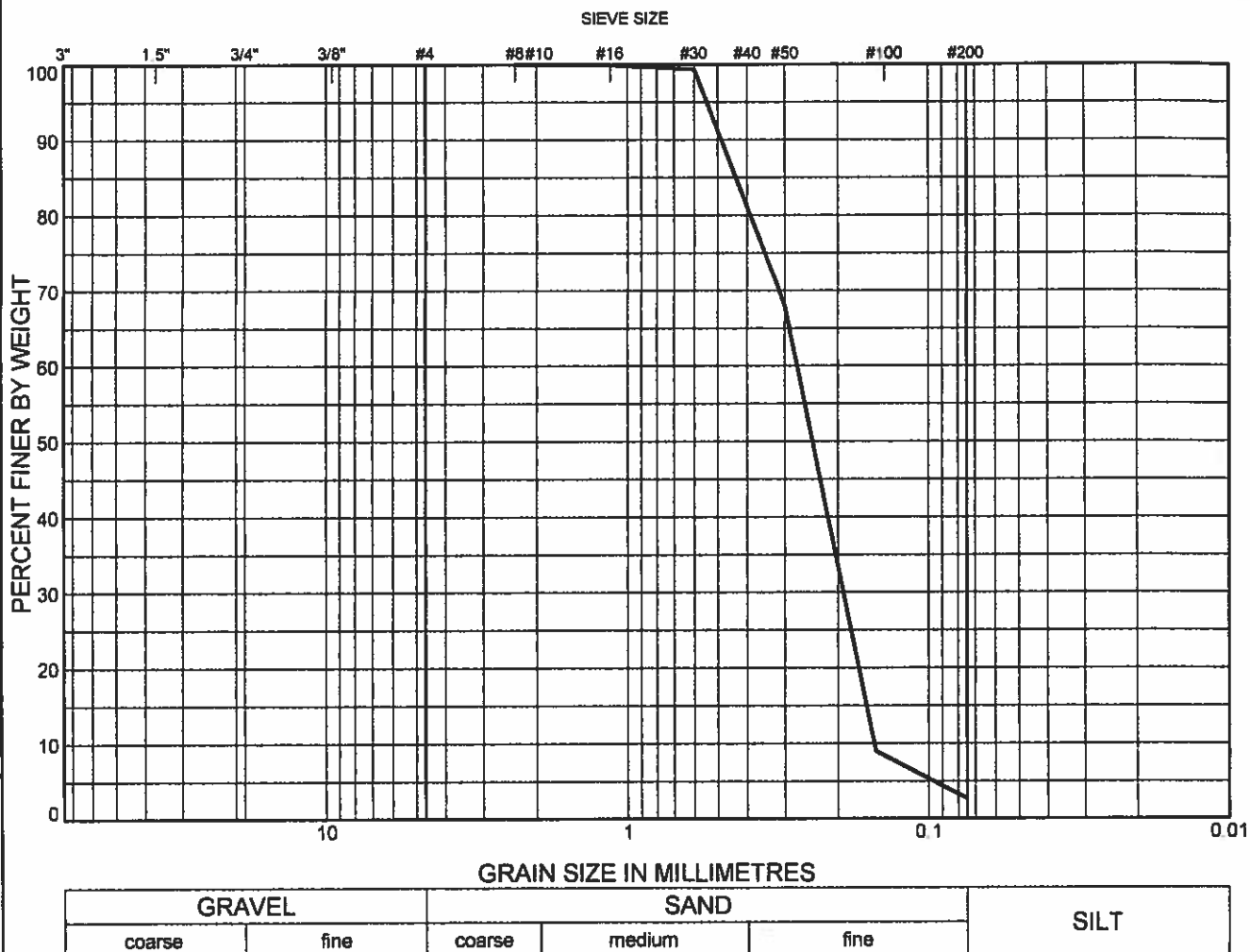
The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.



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GRAIN SIZE DISTRIBUTION

CLIENT: LIDSTONE AND COMPANY
PROJECT: THE SHORES SUBDIVISION
FILE NO.: 14-214-2
FIGURE NO. 2



Sample Location: See Dwg. 14-214-2-1

Sample: 3

Sample Depth: N/A

Date Sampled: June 15, 2012

Sampled By: DJT

Date Received: June 18, 2012

Date Tested: June 18-19, 2012

Tested By: JW

Test Method: ASTM C136 and C117

Specification: _____

Gravel	0.0%
Sand	97.3%
Fines	2.7%
Moisture Content	9.0%
D10	0.152
D30	0.192
D60	0.273
Cu	1.80
Cc	0.89

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	
#8	2.36	100.0
#16	1.18	100.0
#30	0.6	99.4
#50	0.3	68.0
#100	0.15	9.0
#200	0.075	2.7

Description: Fine SAND, trace silt (SP).

Comments: _____

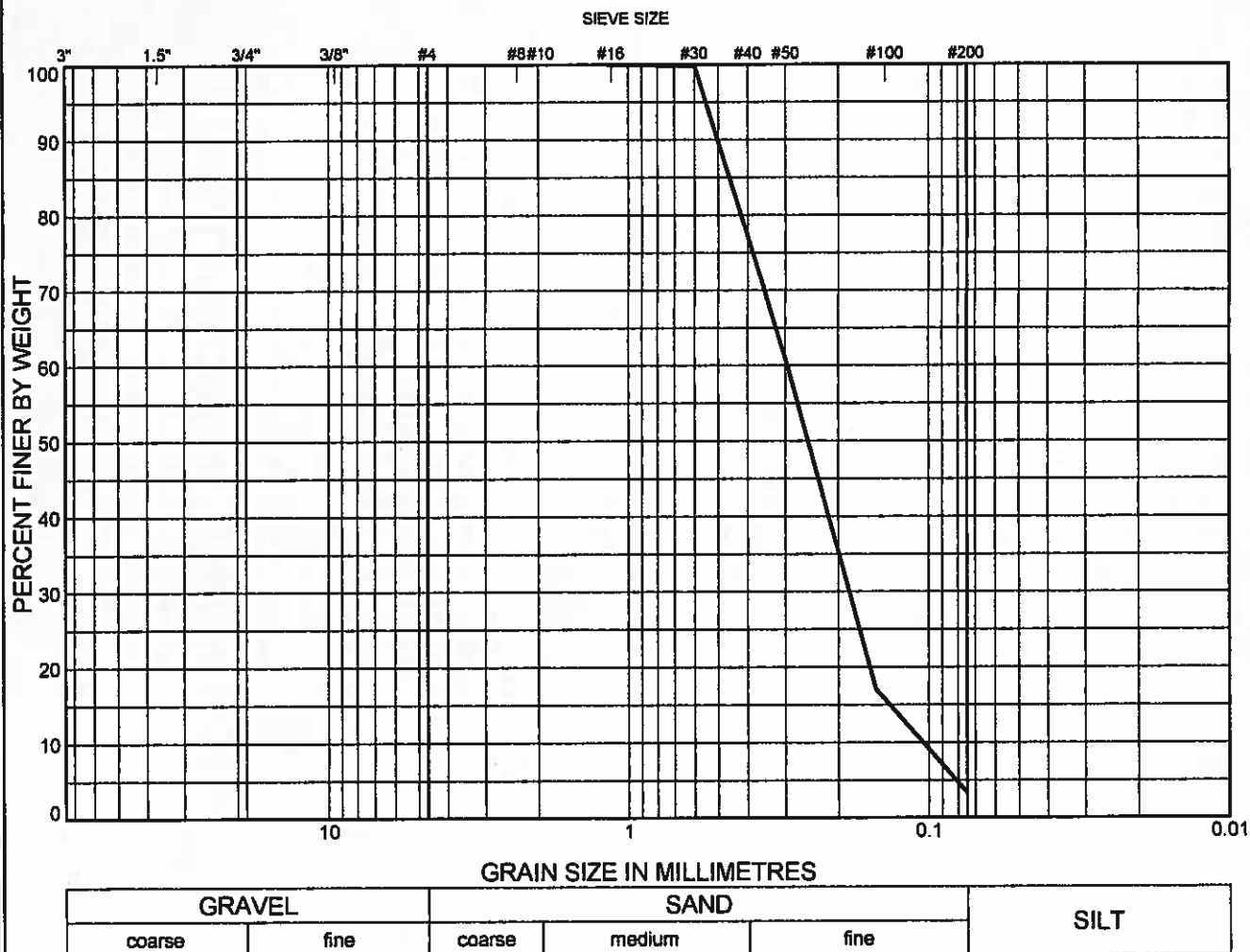
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CLIENT: LIDSTONE AND COMPANY
 PROJECT: THE SHORES SUBDIVISION
 FILE NO.: 14-214-2
 FIGURE NO. 3



Sample Location: **See Dwg. 14-214-2-1**

Sample: **4**

Sample Depth: **N/A**

Date Sampled: **June 15, 2012**

Sampled By: **DJT**

Date Received: **June 18, 2012**

Date Tested: **June 18-19, 2012**

Tested By: **JW**

Test Method: **ASTM C136 and C117**

Specification: _____

Gravel	0.0%
Sand	96.6%
Fines	3.4%
Moisture Content	4.8%
D10	0.105
D30	0.184
D60	0.295
Cu	2.82
Cc	1.09

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	
#4	4.75	
#8	2.36	
#16	1.18	100.0
#30	0.6	99.8
#50	0.3	61.0
#100	0.15	17.1
#200	0.075	3.4

Description: **Fine SAND, trace silt (SP).**

Comments: _____

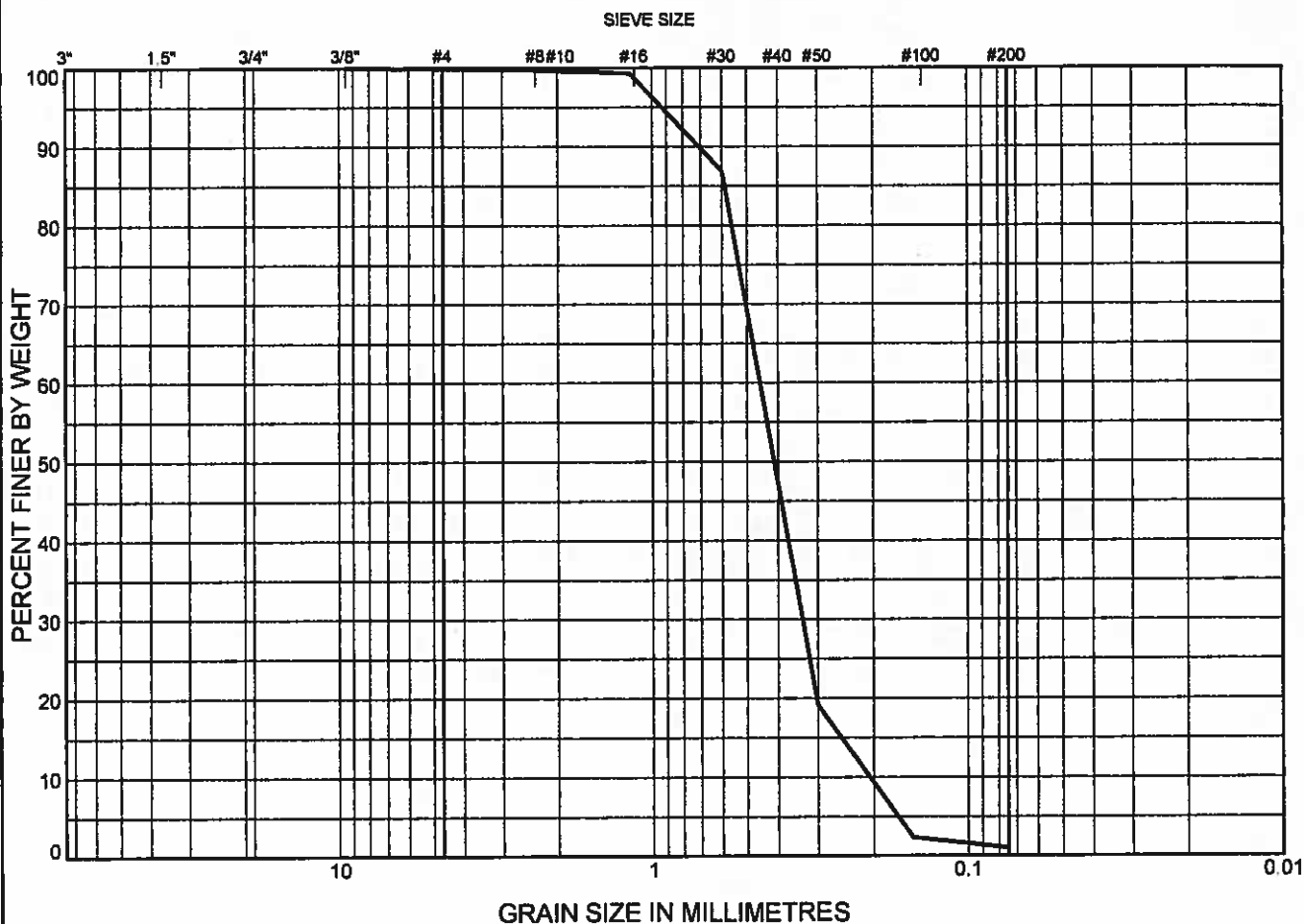
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PROJECT: **THE SHORES SUBDIVISION**
FILE NO.: **14-214-2**
FIGURE NO. **4**



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: See Dwg. 14-214-2-1

Sample: 5

Sample Depth: N/A

Date Sampled: June 15, 2012

Sampled By: DJT

Date Received: June 18, 2012

Date Tested: June 18-19, 2012

Tested By: JW

Test Method: ASTM C136 and C117

Specification: _____

Gravel	0.1%
Sand	98.8%
Fines	1.0%
Moisture Content	5.7%

D10	0.206
D30	0.335
D60	0.456
Cu	2.21
Cc	1.20

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	
0.375	9.5	100.0
#4	4.75	99.9
#8	2.36	99.7
#16	1.18	99.3
#30	0.6	86.9
#50	0.3	19.1
#100	0.15	2.3
#200	0.075	1.0

Description: Medium to fine SAND, trace silt (SP).

Comments: _____

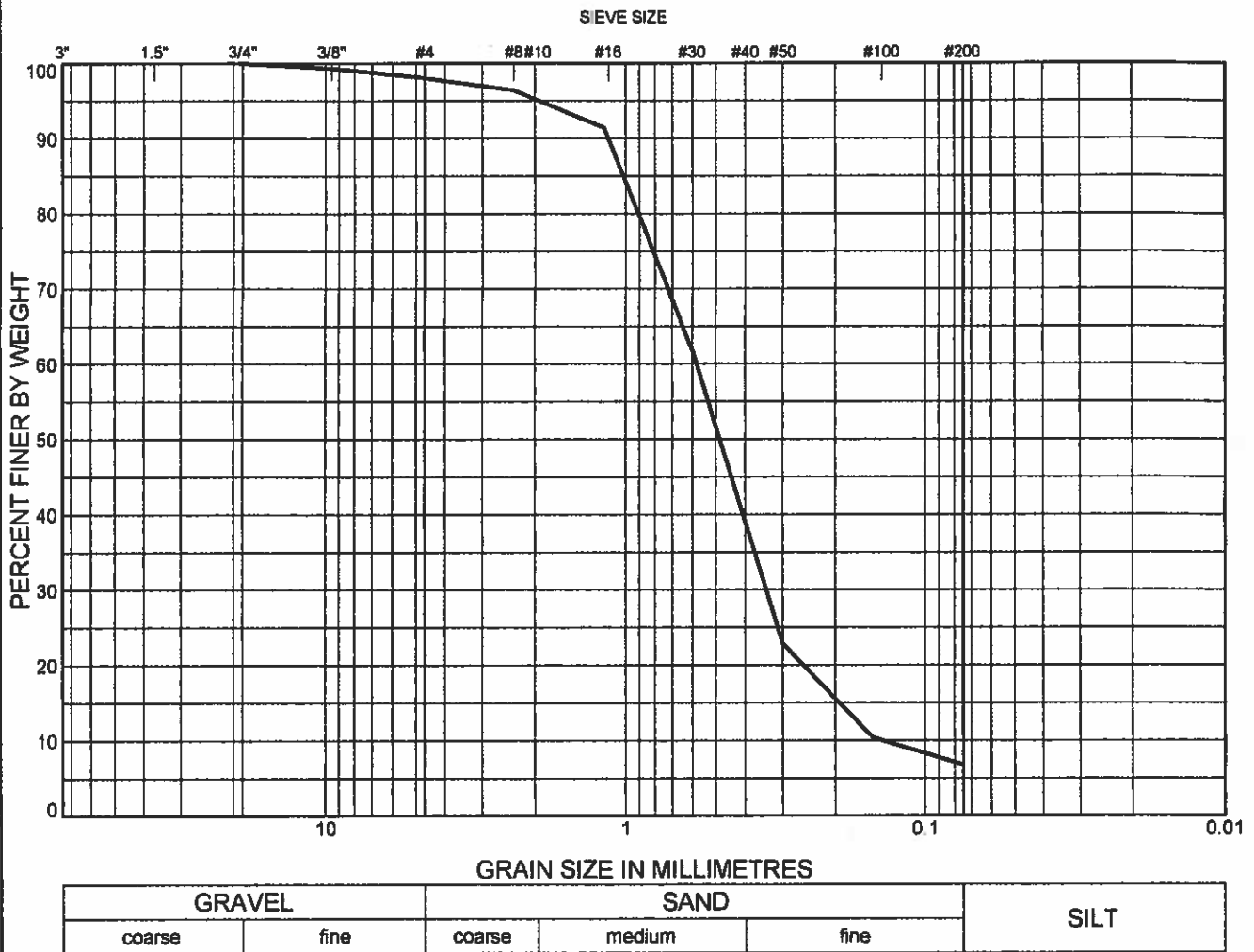
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PROJECT: THE SHORES SUBDIVISION
FILE NO.: 14-214-2
FIGURE NO. 5



Sample Location: **See Dwg. 14-214-2-1**

Sample: **6**

Sample Depth: **N/A**

Date Sampled: **June 15, 2012**

Sampled By: **DJT**

Date Received: **June 18, 2012**

Date Tested: **June 18-19, 2012**

Tested By: **JW**

Test Method: **ASTM C136 and C117**

Specification: _____

Gravel	1.9%
Sand	91.3%
Fines	6.8%
Moisture Content	12.1%
D10	0.14
D30	0.341
D60	0.581
Cu	4.16
Cc	1.43

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	
0.75	19	100.0
0.375	9.5	99.4
#4	4.75	98.1
#8	2.36	96.4
#16	1.18	91.4
#30	0.6	61.8
#50	0.3	22.8
#100	0.15	10.4
#200	0.075	6.8

Description: **Medium to fine SAND, traces of gravel and silt (SP-SM).**

Comments: _____

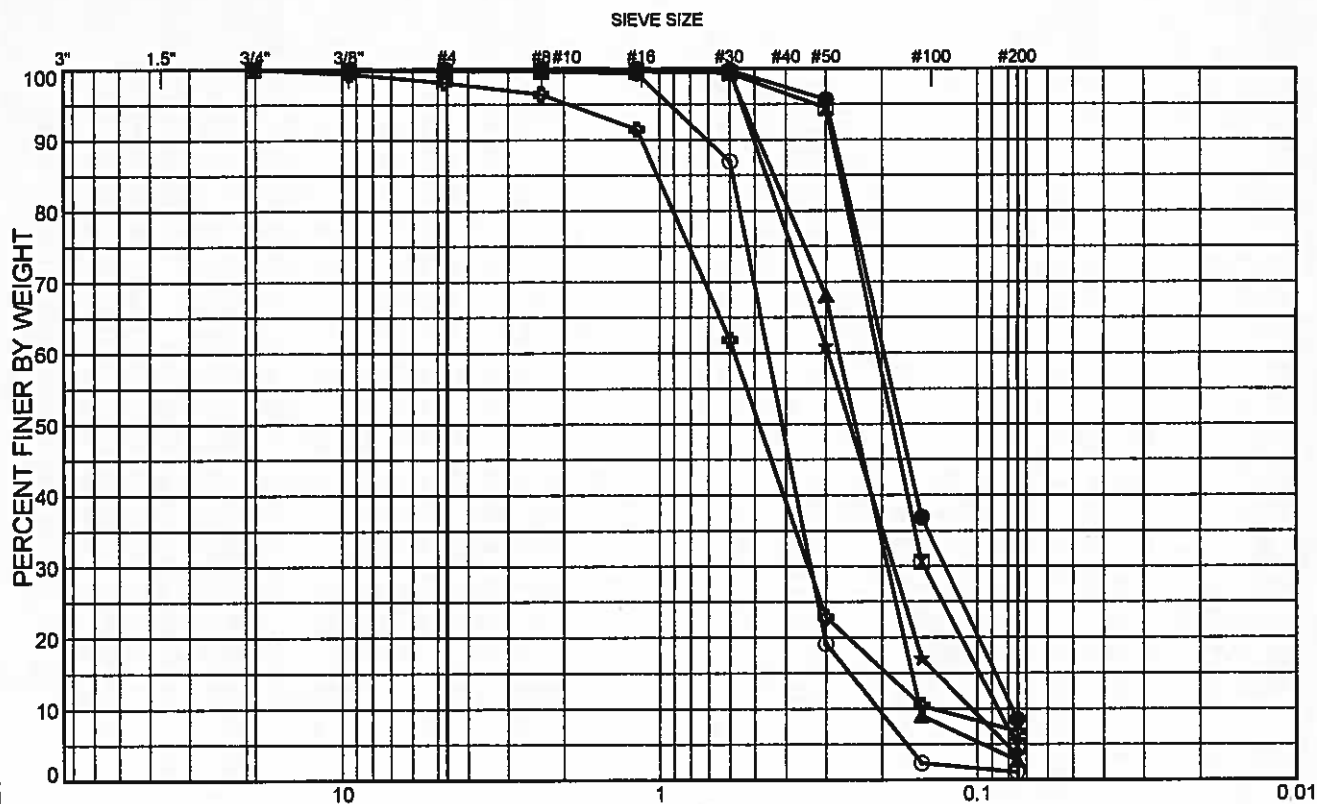
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GRAIN SIZE DISTRIBUTION

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 PROJECT: **THE SHORES SUBDIVISION**
 FILE NO.: **14-214-2**
 FIGURE NO. **6**



Specimen Identification	Gravel (%)	Sand (%)	Fines (%)	MC (%)
● 1, Sa. 1	N/A	91.5	8.5	25.2
■ 2, Sa. 2	N/A	95.0	4.7	26.2
▲ 3, Sa. 3	N/A	97.3	2.7	9.0
★ 4, Sa. 4	N/A	96.6	3.4	4.8
⊙ 5, Sa. 5	N/A	98.8	1.0	5.7
⊕ 6, Sa. 6	N/A	91.3	6.8	12.1

Specimen Identification	D100	D60	D50	D30	D10	Cc	Cu
● 1, Sa. 1	N/A	4.75	0.197	0.175	0.127	1.05	2.53
■ 2, Sa. 2	N/A	19	0.206	0.185	0.148	1.22	2.39
▲ 3, Sa. 3	N/A	2.36	0.273	0.243	0.192	0.89	1.80
★ 4, Sa. 4	N/A	1.18	0.295	0.252	0.184	1.09	2.82
⊙ 5, Sa. 5	N/A	9.5	0.456	0.411	0.335	1.20	2.21
⊕ 6, Sa. 6	N/A	19	0.581	0.486	0.341	1.43	4.16

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.



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PROJECT: THE SHORES SUBDIVISION
FILE NO.: 14-214-2
FIGURE NO. 7



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[illegible]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
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**Ground Penetrating Radar Survey
for
Thurber Engineering Ltd.
Concordia Homes, Sechelt, BC**

Terraprobe Geoscience Corp.

4650A Dawson St.
Burnaby, BC V5C 4C3

Tel: (604) 291-9391
Fax: (604) 648-8118

www.terraprobe.com

TGC446 – 20120605N

Project #: TGC 446 - 20120605N

June 15, 2012.

David J. Tara, M.Sc.A., P.Eng.
Principal | Geotechnical Engineer

Thurber Engineering Ltd.
Suite 900, 1281 West Georgia Street
Vancouver, B.C. V6E 3J7
T. 604 684 4384 ext. 118 | F. 604 684 5124

Attention: Mr. David J. Tara

Re: GPR Survey at Concordia Homes, Gale Ave North, Sechelt, BC

BACKGROUND

Terraprobe Geoscience Corp. (Terraprobe) was commissioned by Thurber Engineering Ltd. (Thurber) to undertake a Ground Penetrating Radar (GPR) survey at the Concordia Homes, Phase 1, in Gale Ave North, Sechelt, BC.

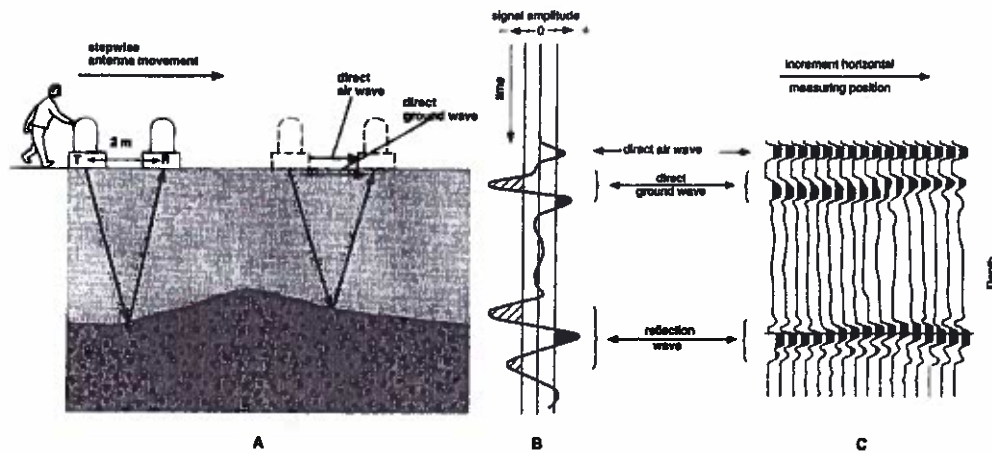
The objective of the survey was to determine the presence of any possible void or other anomaly beneath the surface of the road. An anomaly is an area in the subsurface where the electrical properties are different than its surroundings.

The field data collection was conducted on June 5 and June 6, 2012. This report summarizes the technology overview, the survey methodology and the results.

GPR TECHNIQUE

Ground penetrating radar is the general term applied to techniques that employ radio waves to profile structures and features in the subsurface. Although typically used for ground (soils) applications, GPR can be used to identify features beneath other surfaces. GPR method is based on emission, reflection and detection of electromagnetic waves. A short pulse of high frequency (10-2600 MHz) electromagnetic energy is produced and transmitted into the ground or other medium (i.e. concrete). The pulse spreads into the subsurface materials and is affected by the properties of the surrounding material. Some of the energy is reflected at the interface between materials of different dielectric constants. A receiver records the reflected energy at the surface. Processed radar data are plotted as surveyed horizontal distance (metres) versus two-way travel time in nanoseconds (2D mode). When GPR data are collected in a grid, 3D data processing and interpretation can be applied.

GPR can locate both metallic and non-metallic targets. Penetration depth and detectability of targets depend on antenna frequency, target orientation and the electrical properties of the host material.



GPR principle and reflection profiling. A: paths of the three main electromagnetic waves, B: corresponding single radar signal, C: resulting radar plot.

GPR FIELD SURVEY

A dual frequency (700MHz and 250MHz) GPR system by IDS was used for the survey. Due to the enormity of the survey area, the area was divided into 13 different segment. Their approximate size of each segment is shown in Table 1.

Longitudinal lines were collected along the actual road with 0.5 meters apart from each other. Transverse lines were collected every 5 meters perpendicular to the longitudinal lines. Please note, that Segment #10, #12 and #13 have different line spacing due to the site conditions.

Segment #	X max (m)	Y max (m)
1	46	5.5
2	55	5.5
3	25	5.5
4	110	5.5
5	100	5.5
6	100	8
7	55	8
8	130	8
9	120	8
10	175	8
11	110	8
12	20	17
13	20	10

Table 1: Approximate sizes of the surveyed segments. Refer to Figure 1 for location.

DATA PROCESSING AND INTERPRETATION

Data processing was done by the Terraprobe's proprietary RadArt processing and analysis software package. The following processing steps were carried out:

- Temporal and 2D spatial filters
- Gain recovery
- Amplitude analysis
- Time-Depth conversion

The interpretation was done manually by identifying the areas showing relatively high amplitude response. Please note that the anomalies can be caused by numerous reasons, including but not limited to: different electrical properties in the host material, (i.e. different water content, different minerals), void space, embedded human-made objects (tank, concrete, metal or plastic pipes etc).

GPR RESULTS

The dual frequency GPR system provided sufficient data quality, although the signal penetration depth was limited to approximately 3.0m probably due to the soil conditions. **Figure 1** shows the approximate location of the survey area as well as the approximate location of the GPR cross sections that are shown in **Figure 2** to **14**.

The results can be summarized as follows:

- There appear to be some significant anomalies of different sizes. The location of each anomaly is marked with a red oval on the GPR cross sections in **Figure 2** to **Figure 14**. The depth scale of the cross section is exaggerated. The depth of the anomalies is generally within the first 3 meters below the surface.
- In Segment #1 (**Figure 2**) the marked anomaly is located in the area where an existing sinkhole was discovered and filled back prior to the GPR survey.
- Segment #9 (**Figure 11**) was surveyed in the round about around the island. The start location is marked with pink arrow with the direction of the line both on the layout (**Figure 1**) and in **Figure 11** above the GPR cross section.
- The exact location of each anomaly can be marked off on site if adequate drawings are made available.

CONCLUSIONS AND RECOMMENDATIONS

The true nature of the marked anomalies cannot be verified based on the GPR data only. It is recommended to mark all the anomalies on site and correlate with the existing geological features and with the existing man made structures, i.e. manholes and pipes. Also it is recommended to excavate or drill the anomalies in order to verify their nature.

If required, a lower frequency GPR survey can be carried out in the area to extend the depth and the area of the investigation.

LIMITATIONS

The depth to subsurface features derived from ground penetrating radar surveys are generally accepted as accurate to within ten to twenty percent of the true depths to the boundaries. Since the depth scale was calculated using average velocities it could only be used as a guideline and not as accurate measurement. The results are interpretive in nature and are considered to be a reasonable accurate presentation of existing conditions within the limitations of the radar profiling method.

The information in this report is based upon radar measurements, the information provided to us and our interpretation of the data.

Thank you for choosing Terraprobe, if you have any questions regarding this report please feel free to contact us.

Best regards,

Peter Takacs
Project Geophysicist, Dipl. Geo.
Terraprobe Geoscience Corp.

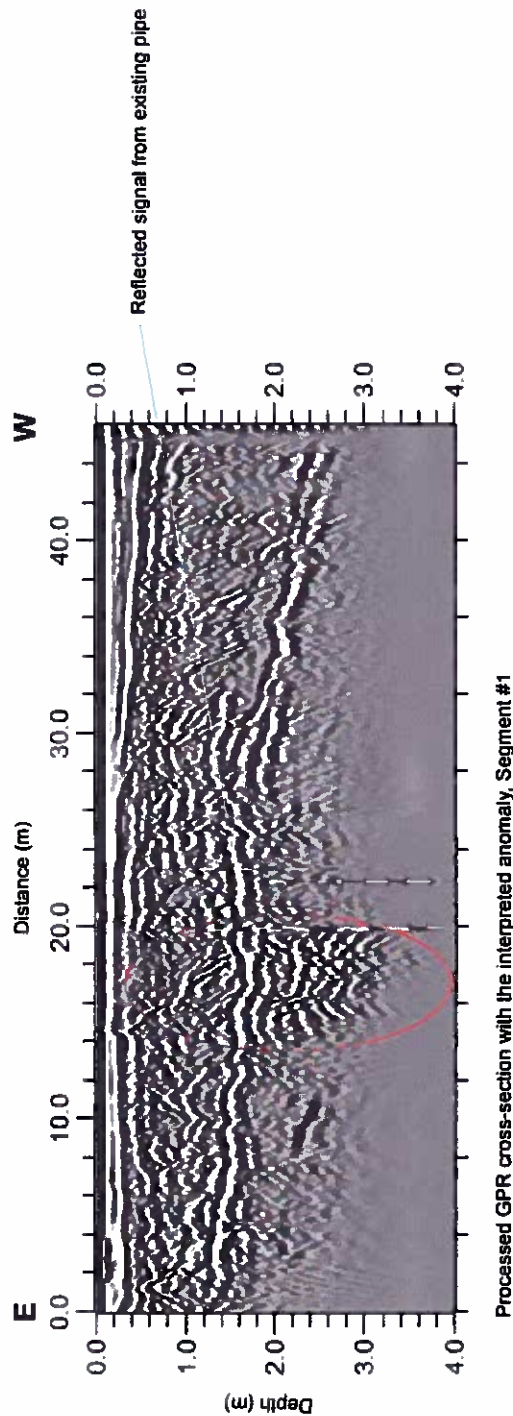
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Figure 1
GPR Survey Layout
and interpreted anomalies

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	Ground Penetrating Radar Survey 6633 Gale Ave North, Sechelt, BC			

Ground Penetrating Radar Survey, 6633 Gale Ave North, Sechelt, BC

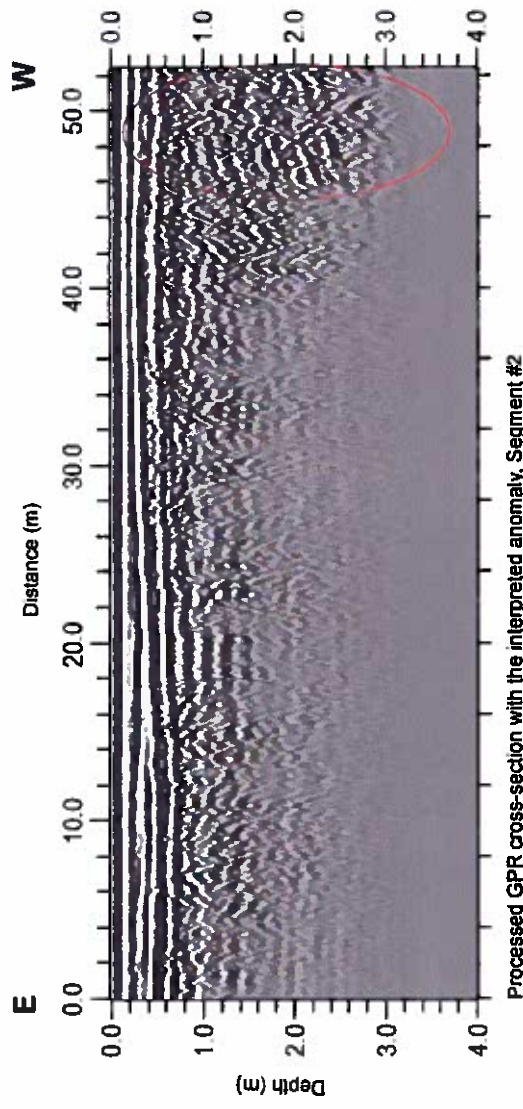


Note:
Not to scale. Units are in meter unless otherwise noted.
The size of the red ovals do not represent the actual size of the anomalies.

LEGEND GPR Anomaly		TERRAprobe The Leader in Geophysical Consulting Tel: 604 291 9301 Web: www.terraprobe.com	
Terraprobe Geoscience Corp.		Figure 2 Segment 1 GPR cross-section	
Peter Takacs	June 2012	446-PT	Thurber Engineering Ltd. Ground Penetrating Radar Survey 6633 Gale Ave North, Sechelt, BC

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LEGEND

GPR Anomaly

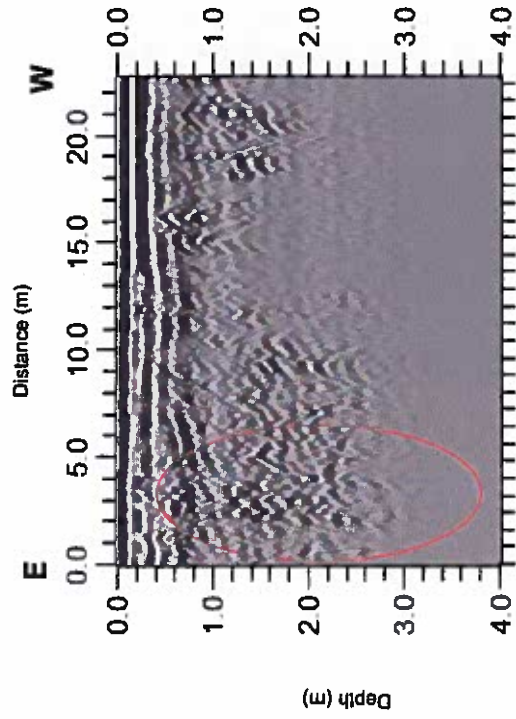
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Peer Takes	June, 2012	44L-PT	Ground Penetrating Radar Survey 6633 Gale Ave North, Sechart, BC

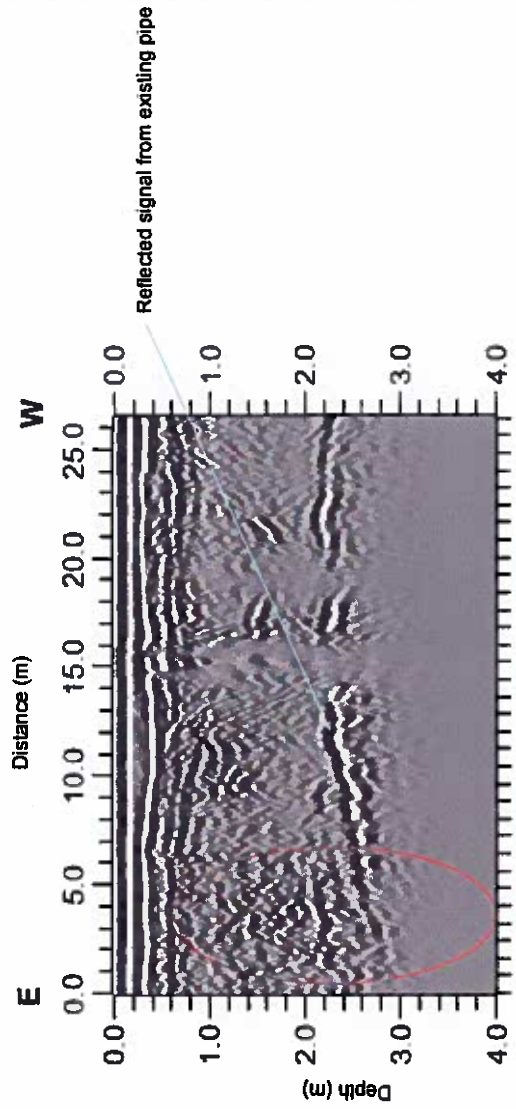
Figure 3
Segment 2
GPR cross-section

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Processed GPR cross-section with the interpreted anomaly Segment #3



Processed GPR cross-section with the interpreted anomaly Segment #3

LEGEND

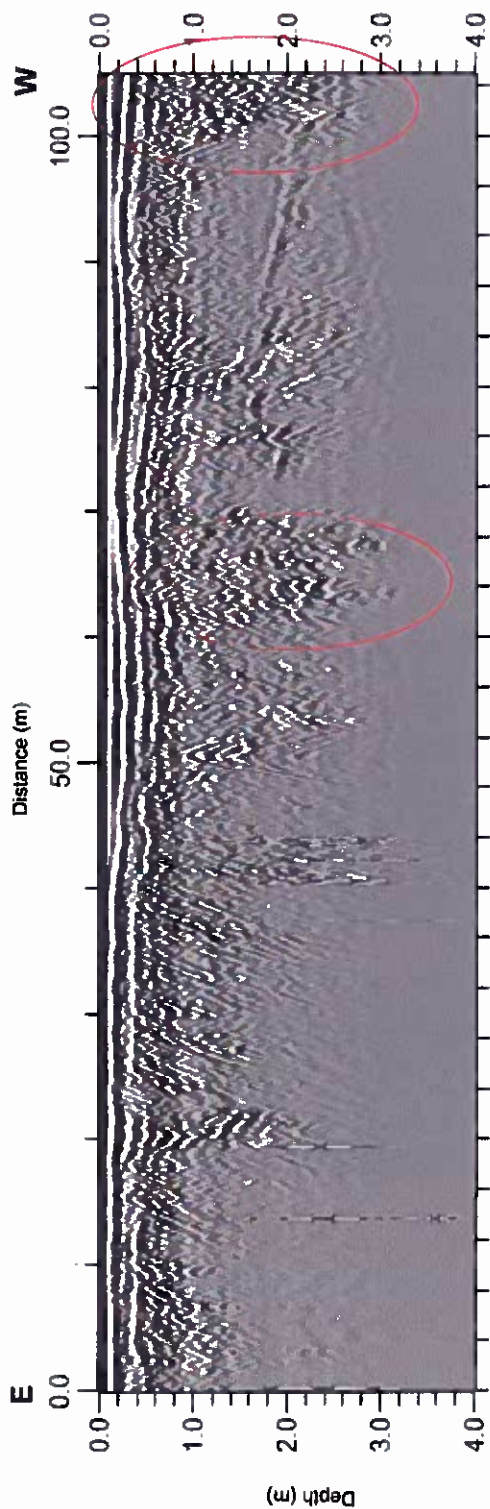


GPR Anomaly

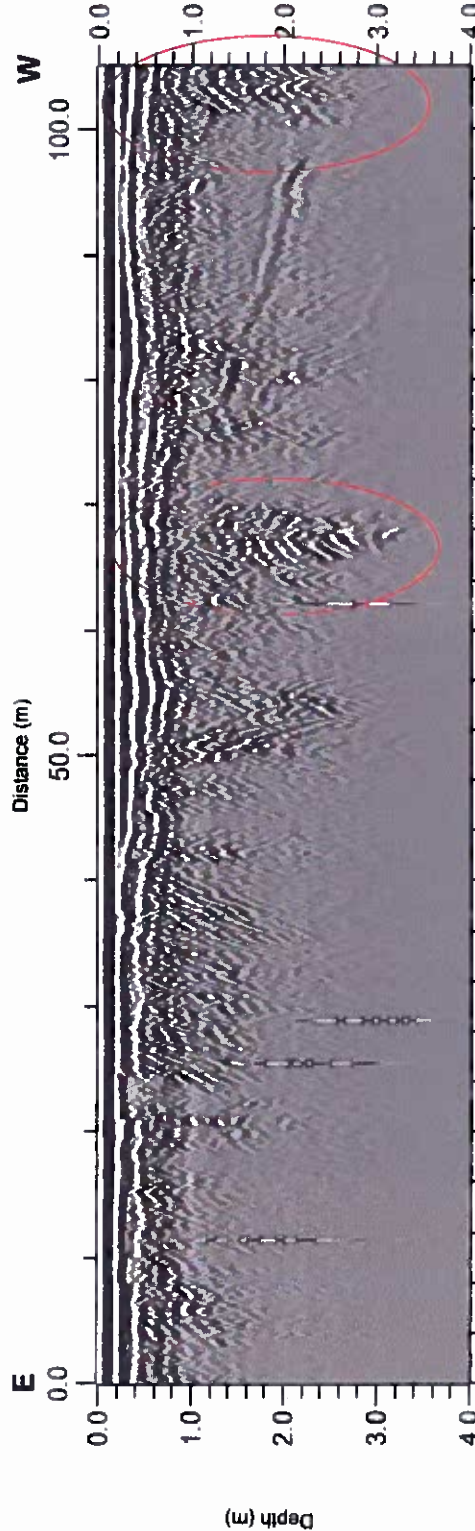
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Peter Takacs	June, 2012	441-PT	Ground Penetrating Radar Survey 6633 Gale Ave North, Sechelt, BC		

Ground Penetrating Radar Survey, 6633 Gale Ave North, Sechart, BC



Processed GPR cross-section with the interpreted anomaly, Segment #4



Processed GPR cross-section with the interpreted anomaly, Segment #4

LEGEND

GPR Anomaly



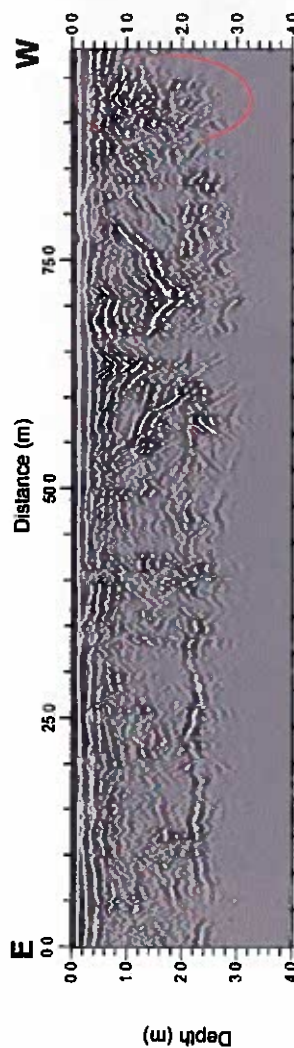
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Peter Tolkes	June, 2012	44E-PT	Ground Penetrating Radar Survey 6633 Gale Ave North, Sechart, BC

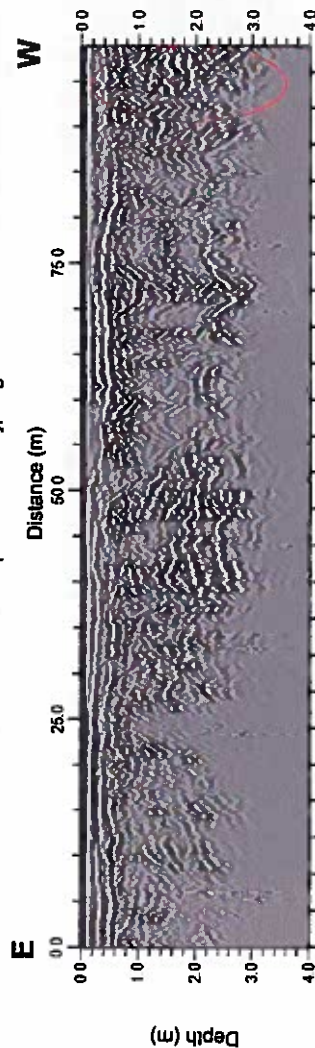
Figure 5
Segment 4
GPR cross-sections

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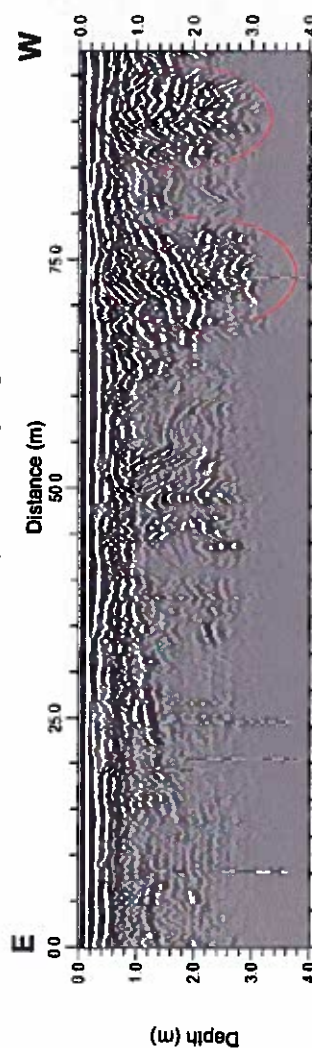
Ground Penetrating Radar Survey, 6633 Gale Ave North, Sechelt, BC



Processed GPR cross-section with the interpreted anomaly, Segment #5



Processed GPR cross-section with the interpreted anomaly, Segment #5



Processed GPR cross-section with the interpreted anomaly, Segment #5

LEGEND

GPR Anomaly



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Figure 6
Segment 5
GPR cross-sections

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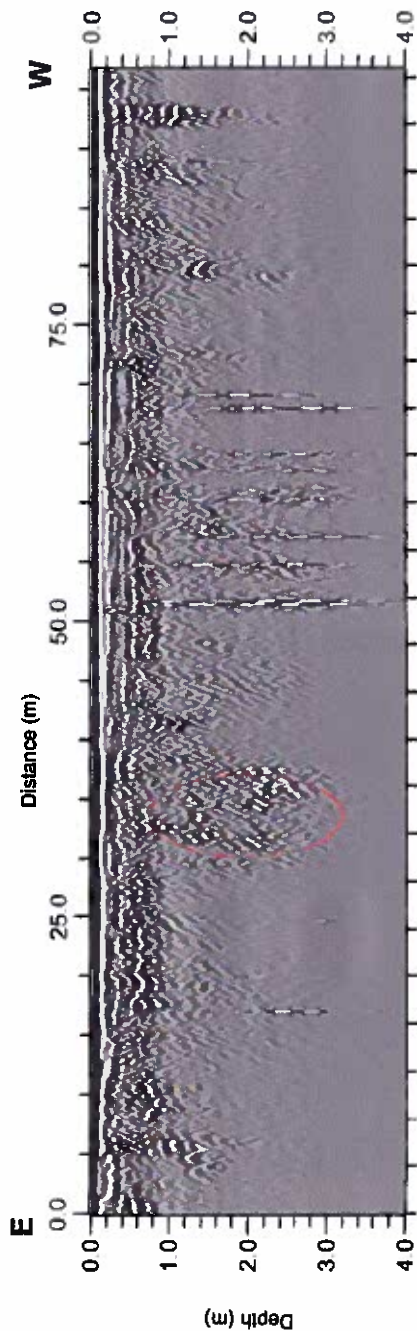
Thurber Engineering Ltd.
Ground Penetrating Radar Survey
6633 Gale Ave North, Sechelt, BC

Peter Talbot

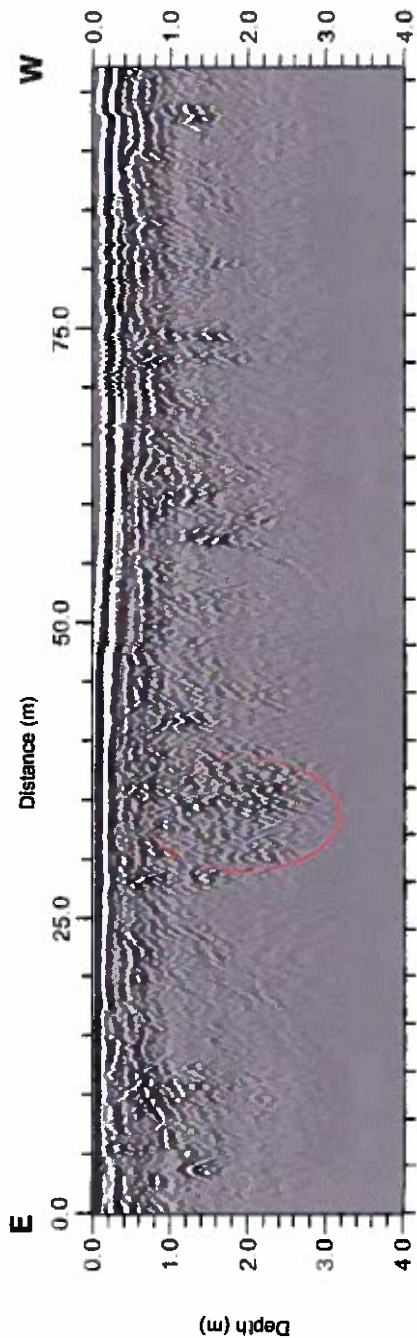
June 2012

44L-PT

Ground Penetrating Radar Survey, 6633 Gale Ave North, Sechart, BC



Processed GPR cross-section with the interpreted anomaly, Segment #8



Processed GPR cross-section with the interpreted anomaly, Segment #6

LEGEND



GPR Anomaly

The total aggregate liability of Terraprobe, arising from professional acts errors or omissions, shall not exceed the fees paid to Terraprobe. Terraprobe shall have no other liability obligation or responsibility of any kind for the expense or other damages (including without limitation special, indirect, incidental or consequential damages) relating to services or results provided by Terraprobe. All results provided by Terraprobe are strictly for the use of the Client, and Terraprobe shall not be responsible for any reliance on or any use or interpretation of such results by third parties. Terraprobe shall not be responsible for any loss, damage or liability arising from any use by the Client, its agents or staff or other consultants employed by the Client.

Terraprobe Geoscience Corp.

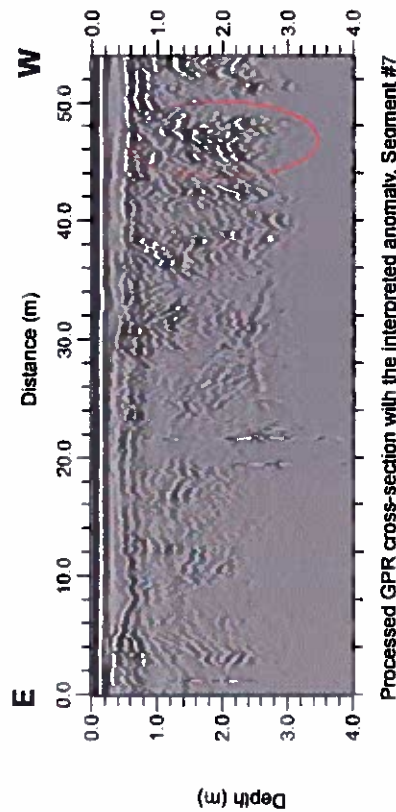
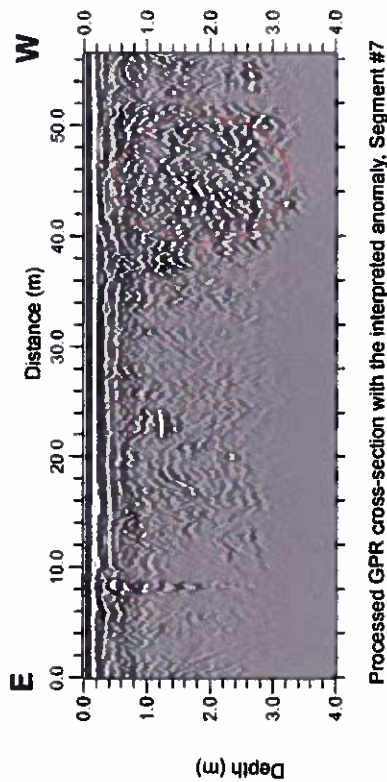
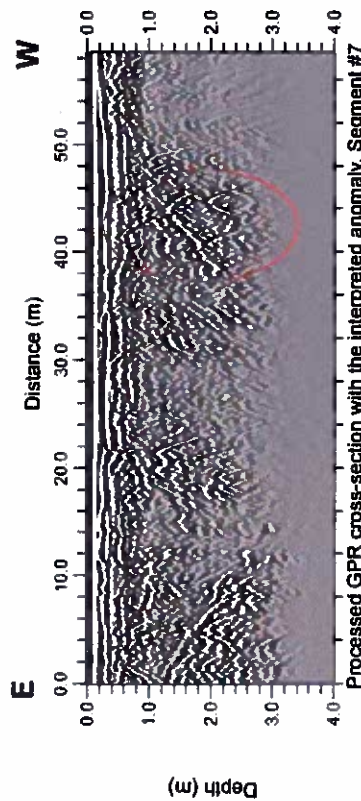
Figure 7
Segment 6
GPR cross-sections

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Web: www.terraprobe.com

Peter Talbot June 2012 44L-PT

Thurber Engineering Ltd.
Ground Penetrating Radar Survey
6633 Gale Ave North, Sechart, BC

Ground Penetrating Radar Survey, 6633 Gale Ave North, Sechart, BC



LEGEND

GPR Anomaly

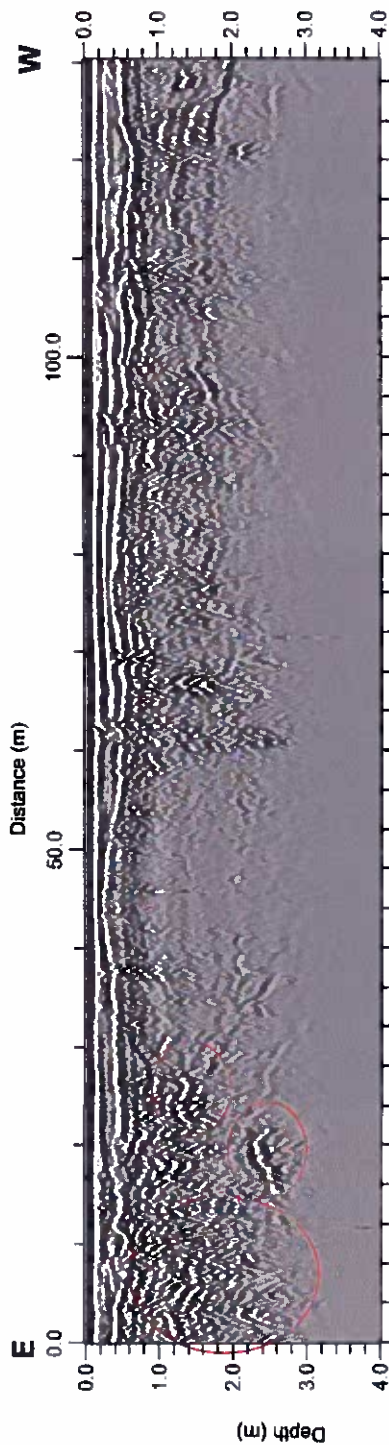
The total aggregate liability of Terraprobe arising from professional acts, errors or omissions shall not exceed the fee payable by the Client. The Client acknowledges that the results of this survey are for informational purposes only and shall have no other liability, obligation or responsibility of any kind for losses, costs, expenses or other damages (including without limitation special, indirect, incidental or consequential damages) relating to services or results provided by Terraprobe. All results provided by Terraprobe are strictly for the use of the Client, and Terraprobe shall not be responsible for any reliance on or any use or interpretation of such results by any third party. Terraprobe shall not be responsible for any loss, damage or liability arising from any acts by the Client, its agents or staff or other consultants employed by the Client.

Terraprobe Geoscience Corp.		Thurber Engineering Ltd.	
Peter Takacs	June 2012	Ground Penetrating Radar Survey 6633 Gale Ave North, Sechart, BC	
	44E-PT		

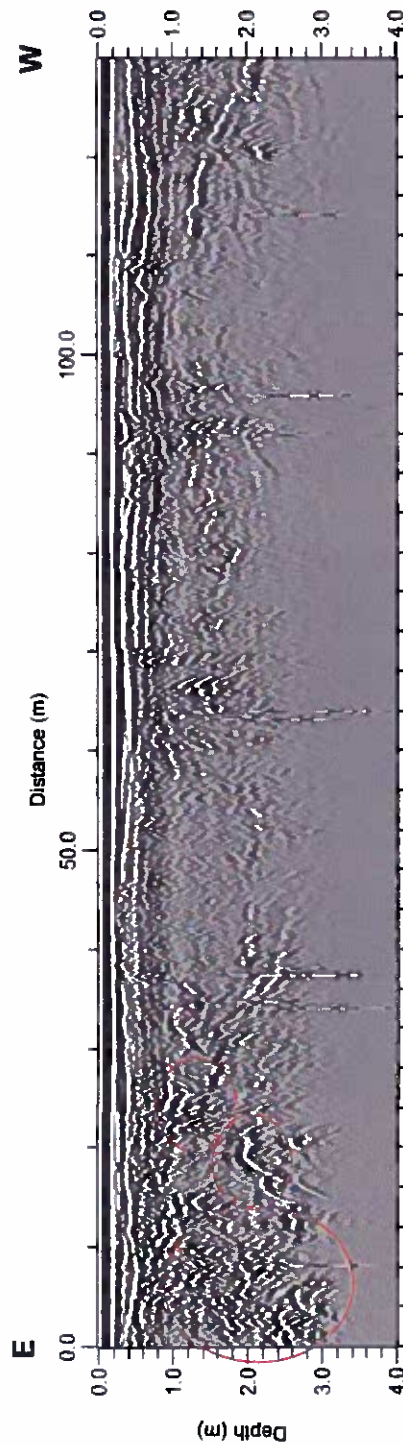
Figure 8
Segment 7
GPR cross-sections

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Ground Penetrating Radar Survey, 6633 Gale Ave North, Sechelt, BC



Processed GPR cross-section with the interpreted anomaly, Segment #8



Processed GPR cross-section with the interpreted anomaly, Segment #8

LEGEND

GPR Anomaly

The total aggregate liability of Terraprobe arising from professional acts, errors or omissions in the performance of its services shall not exceed the amount of the fees payable by the Client for the services performed. Terraprobe and its consultants shall have no other liability, obligation or responsibility of any kind for losses, costs, expenses or other damages (including without limitation special, indirect, incidental or consequential damages) relating to services or results provided by Terraprobe. All results provided by Terraprobe are strictly for the use of the Client, and Terraprobe shall not be responsible for any reliance on or any use or interpretation of such results by the Client. Terraprobe shall not be responsible for any loss, damage or liability arising from any acts by the Client, its agents or staff or other consultants employed by the Client.

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Ground Penetrating Radar Survey
6633 Gale Ave North, Sechelt, BC

Terraprobe Geoscience Corp.

444-PT

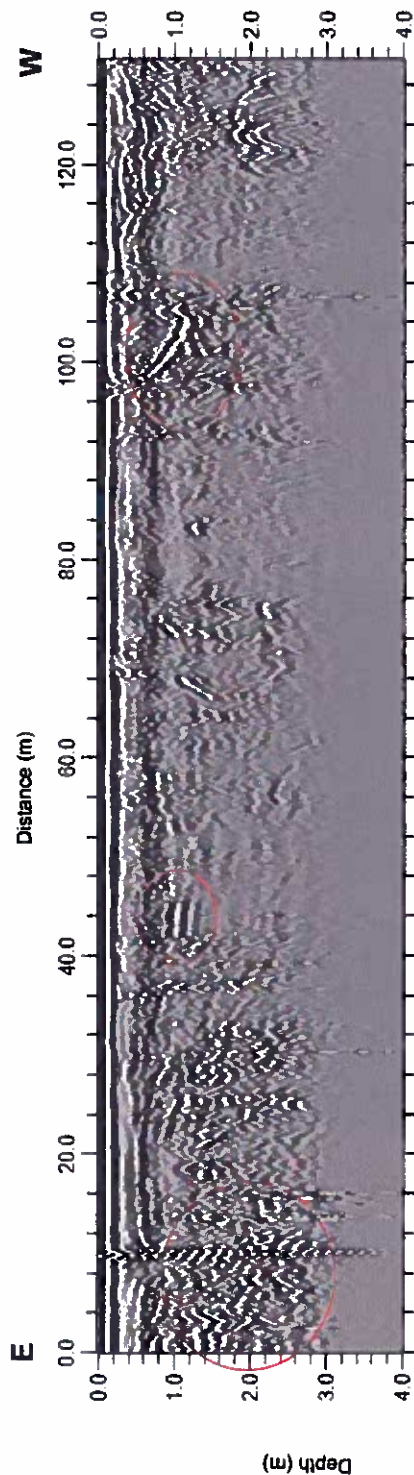
June, 2012

Peter Takacs

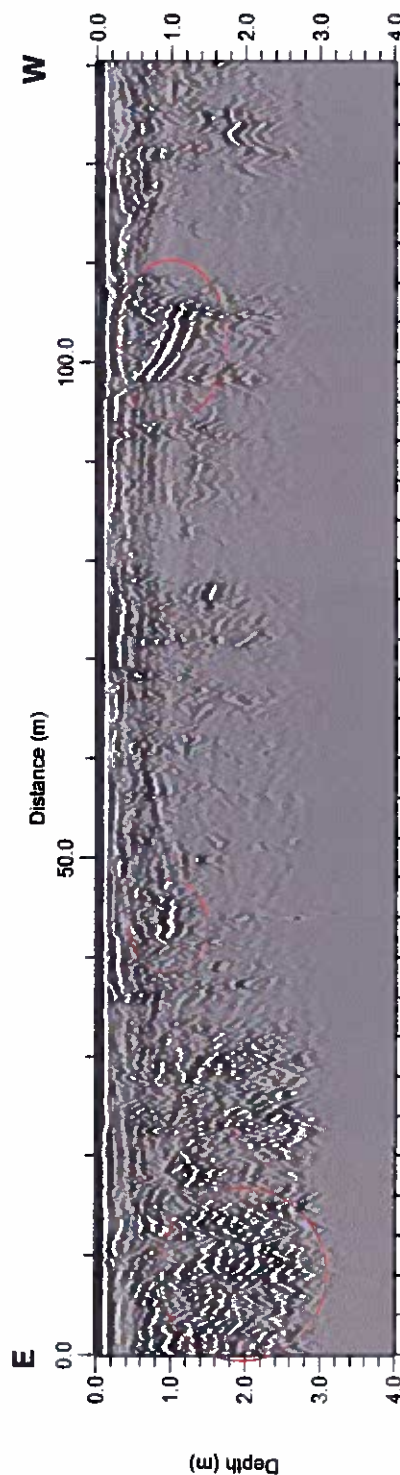
Figure 9

Segment 8
GPR cross-sections

Ground Penetrating Radar Survey, 5633 Gale Ave North, Sechelt, BC



Processed GPR cross-section with the interpreted anomaly, Segment #8



Processed GPR cross-section with the interpreted anomaly, Segment #8

LEGEND

GPR Anomaly

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Figure 10
Segment 8
GPR cross-sections

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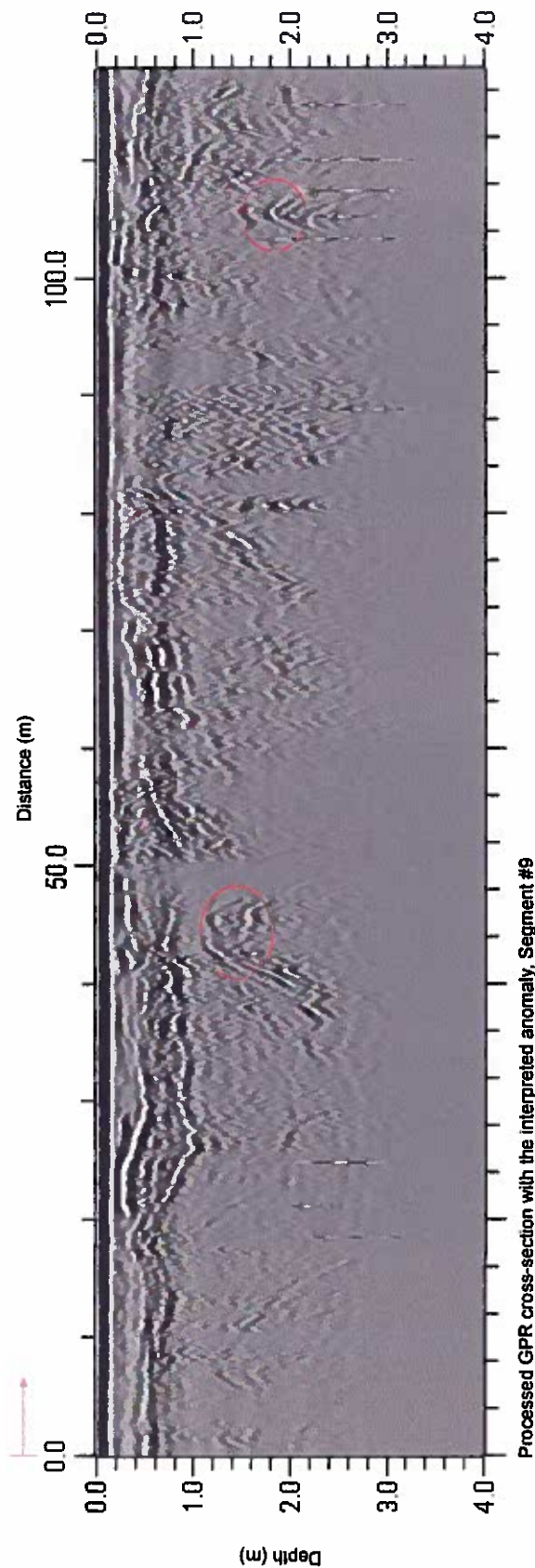
Thurber Engineering Ltd.
Ground Penetrating Radar Survey
5633 Gale Ave North, Sechelt, BC

44E-PT

June, 2012

Peter Takacs

Ground Penetrating Radar Survey, 6633 Gale Ave North, Sechelt, BC



Processed GPR cross-section with the interpreted anomaly, Segment #9

LEGEND



GPR Anomaly

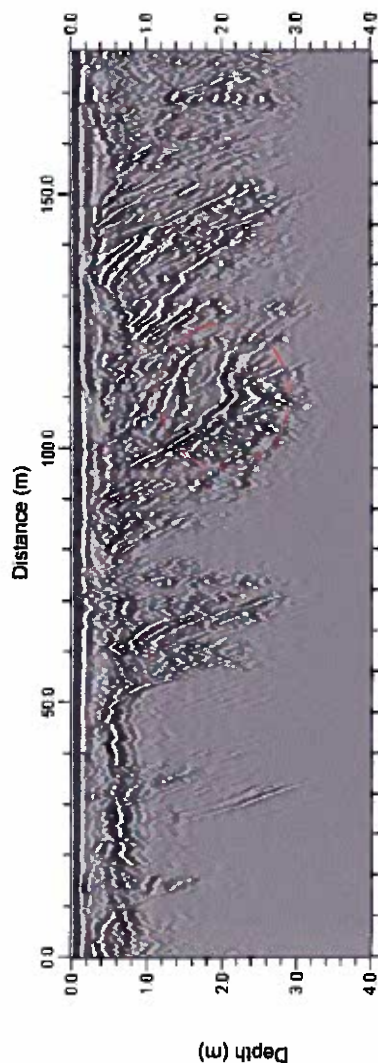
Note: Segment # 9 is a circumferential segment. The start and end location of the GPR cross section is approximately the same location. In Figure 1, a pink arrow represents the direction of the cross section.

The total aggregate liability of Terraprobe arising from professional acts, errors or omissions shall not exceed the total fees for the services rendered and Terraprobe shall have no other liability, obligation or responsibility of any kind for losses, costs, expenses or other damages (including without limitation special, indirect, incidental or consequential damages) relating to services or results provided by Terraprobe. All results provided by Terraprobe are strictly for the use of the Client, and Terraprobe shall not be responsible for any loss, damage or liability resulting from any acts by the Client, its agents or staff or other consultants employed by the Client.

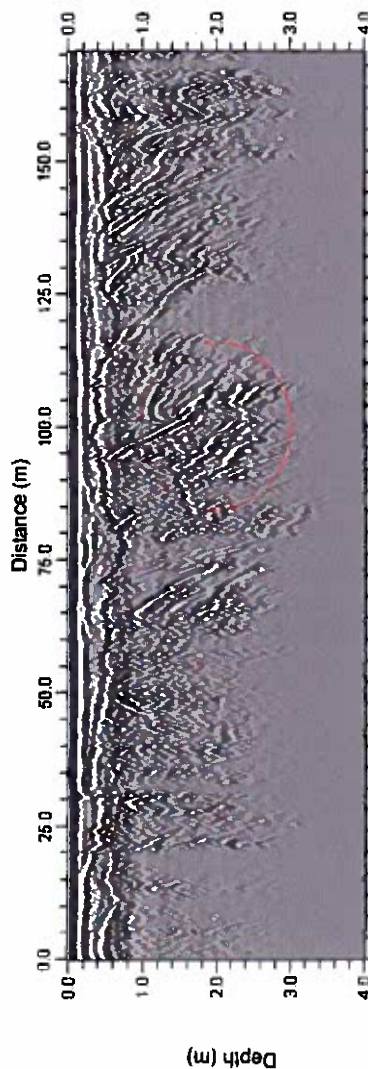
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Terraprobe Geoscience Corp.		Thurber Engineering Ltd.	
Peter Takacs	June, 2012	448-PT	Ground Penetrating Radar Survey 6633 Gale Ave North, Sechelt, BC

Ground Penetrating Radar Survey, 6633 Gale Ave North, Sechelt, BC



Processed GPR cross-section with the interpreted anomaly, Segment #10



Processed GPR cross-section with the interpreted anomaly, Segment #10

LEGEND

GPR Anomaly

Note: Segment # 10 was collected on a slope. Distance shown is linear distance on the surface of the road.

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Terraprobe Geosciences Corp. Thurber Engineering Ltd.

Ground Penetrating Radar Survey
6633 Gale Ave North, Sechelt, BC

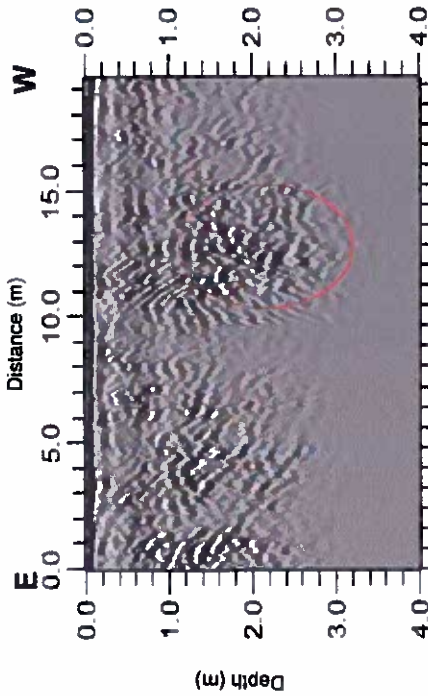
Peter Takesis June 2012 444-PT

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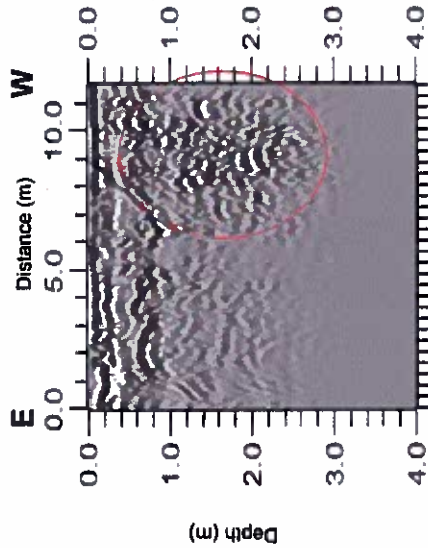
Tel: 604 291 9391
Web: www.terraprobe.com

Figure 12
Segment 10
GPR cross-section

Ground Penetrating Radar Survey, 6633 Gale Ave North, Sechart, BC



Processed GPR cross-section with the interpreted anomaly, Segment #12



Processed GPR cross-section with the interpreted anomaly, Segment #12

LEGEND

GPR Anomaly

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Figure 13
Segment12
GPR cross-sections

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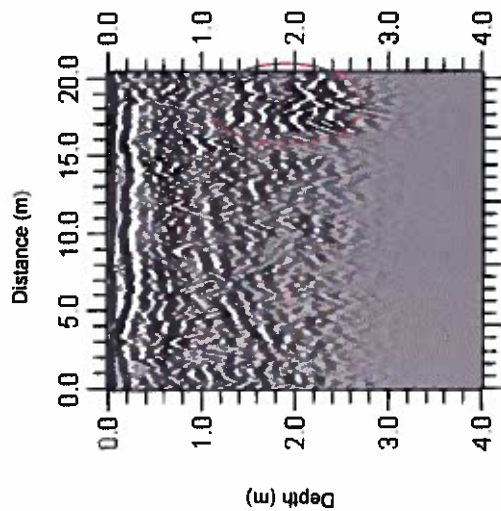
Peter Takacs

June, 2012

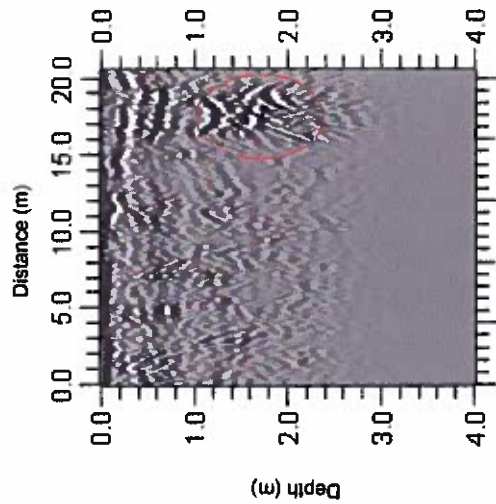
448-PT

Thurber Engineering Ltd.
Ground Penetrating Radar Survey
6633 Gale Ave North, Sechart, BC

Ground Penetrating Radar Survey, 6633 Gale Ave North, Sechelt, BC



Processed GPR cross-section with the interpreted anomaly, Segment #13



Processed GPR cross-section with the interpreted anomaly, Segment #13

LEGEND

GPR Anomaly



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Terraprobe Geoscience Corp.

Thurber Engineering Ltd.

Figure 14

Peter Tiskacs
June, 2012

444-PT

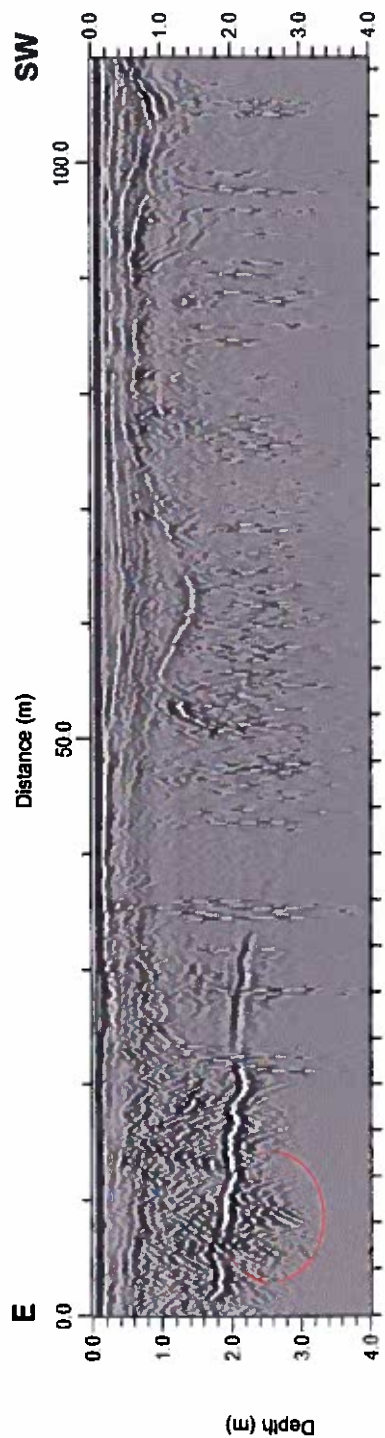
Ground Penetrating Radar Survey
6633 Gale Ave North, Sechelt, BC

Segment 13
GPR cross-section

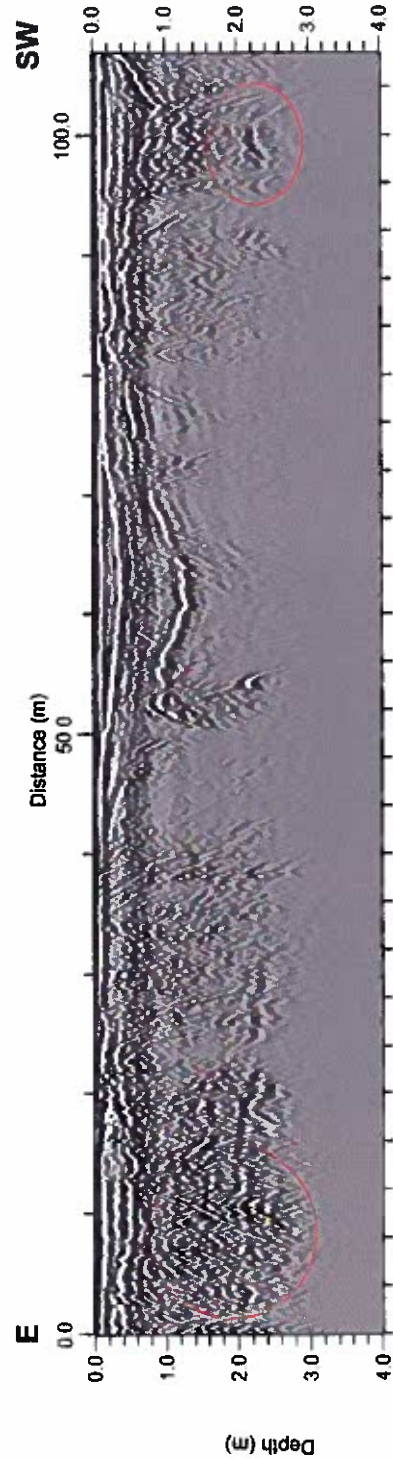
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Ground Penetrating Radar Survey, 6633 Gale Ave North, Sechart, BC



Processed GPR cross-section with the interpreted anomaly, Segment #11



Processed GPR cross-section with the interpreted anomaly, Segment #11

LEGEND

GPR Anomaly

TERRAprobe
The Ground Penetrating Radar Experts

Tel: 604 291 9391
Web: www.terraprobe.com

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TerraProbe Geoscience Corp.		Thurber Engineering Ltd.		Figure 11 Segment 11 GPR cross-sections	
Peter Talbot	June 2012	44L-PT	Ground Penetrating Radar Survey 6633 Gale Ave North, Sechart, BC		

SEACHELT BAND LANDS NO. 4
"DALTREY"
NOTICE
JUN 1970

SECRET

NORTH

PARK
DEDICATED BY
PLAN 80P24297

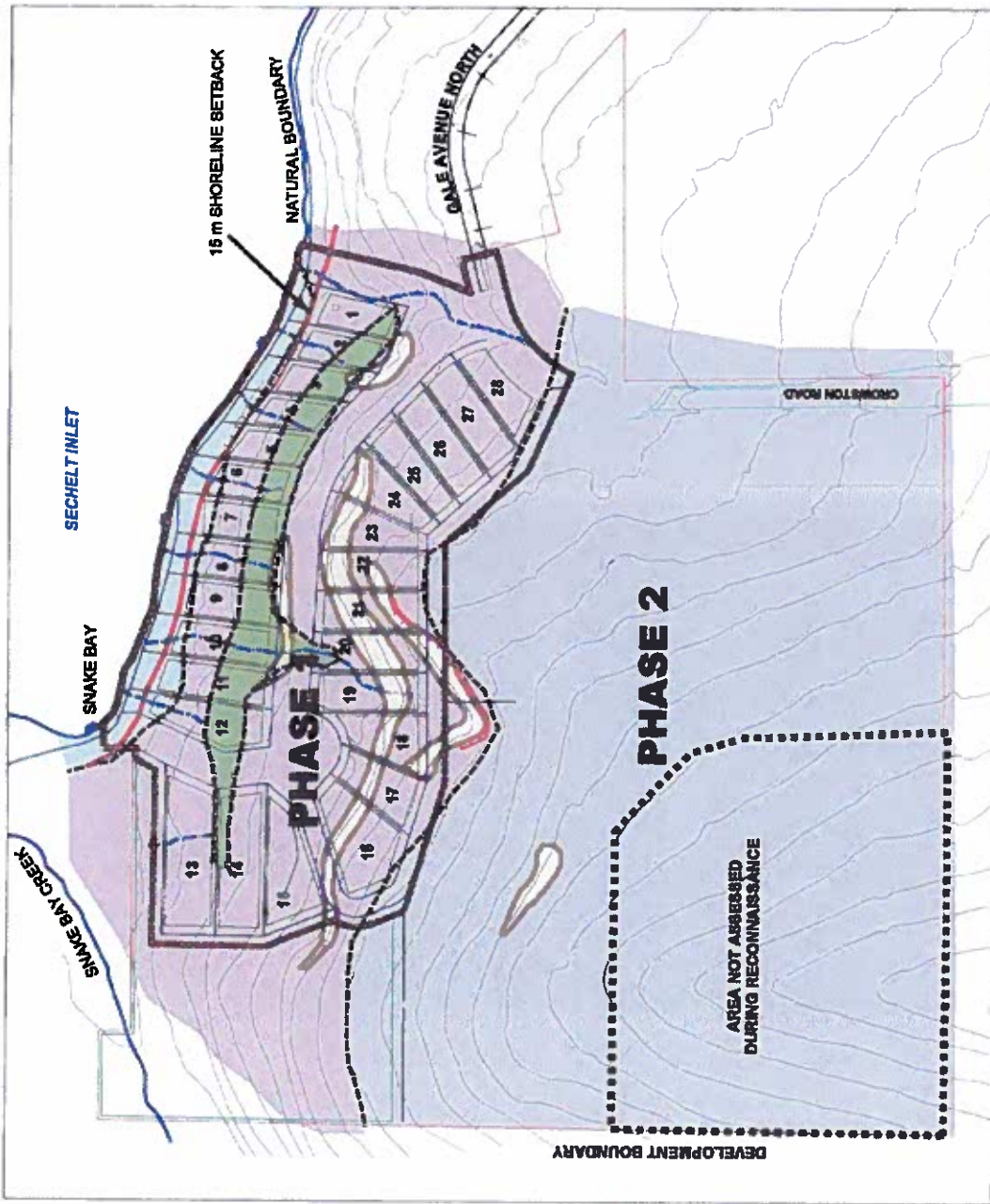
EXPLANATORY
PAGE 1588

EXPLANATORY
PLAN SHEET

21

[illegible]

QUESTIONS ARE IN ITALICS AND ARE ANSWERED FROM THE POINT OF VIEW OF STONE'S CURRENT ECONOMIC BELIEFS.



REF. DWG: WEB ENGINEERING LTD.,
PRELIMINARY UTILITY LAYOUT,
MAY 20, 2004

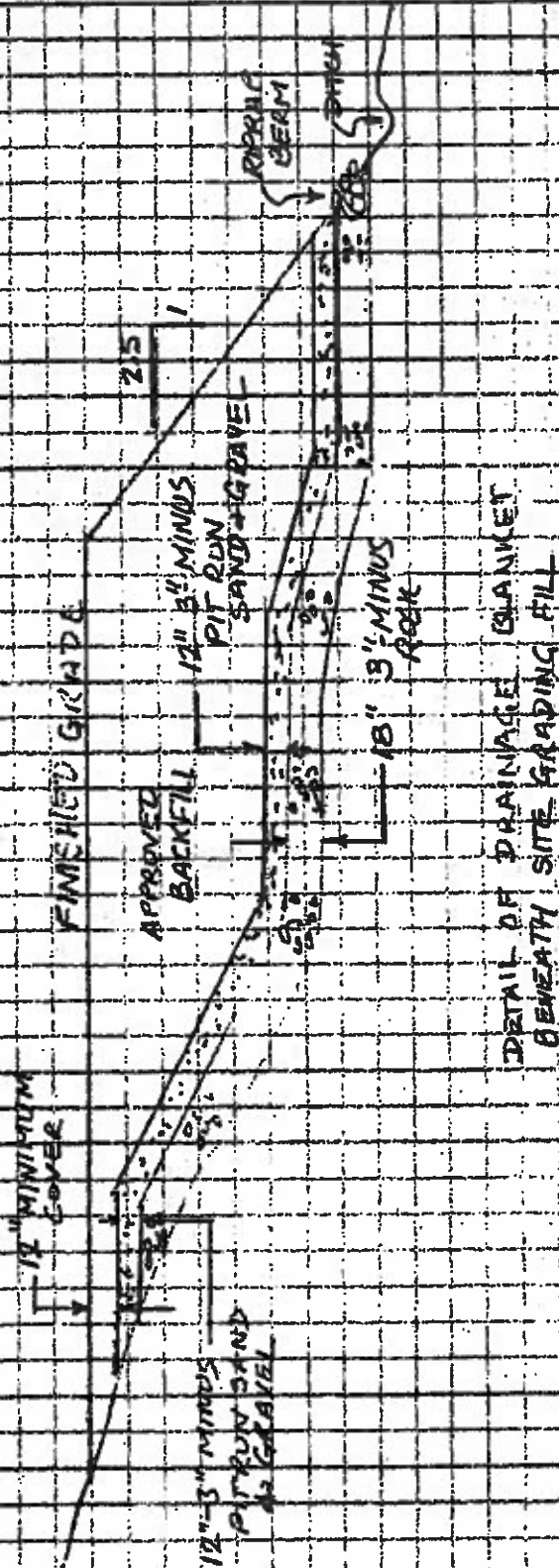
CONCORDIA HOMES LTD.		Project No.:	CO-03	Drawing No.:	2	ENGINEERING LTD.	
SITE PLAN		Date:	Aug. 2004	Drawn By:	Smart Map Services	Scale:	1:2500
WEST PORPOISE BAY, SECHELT, B.C.							



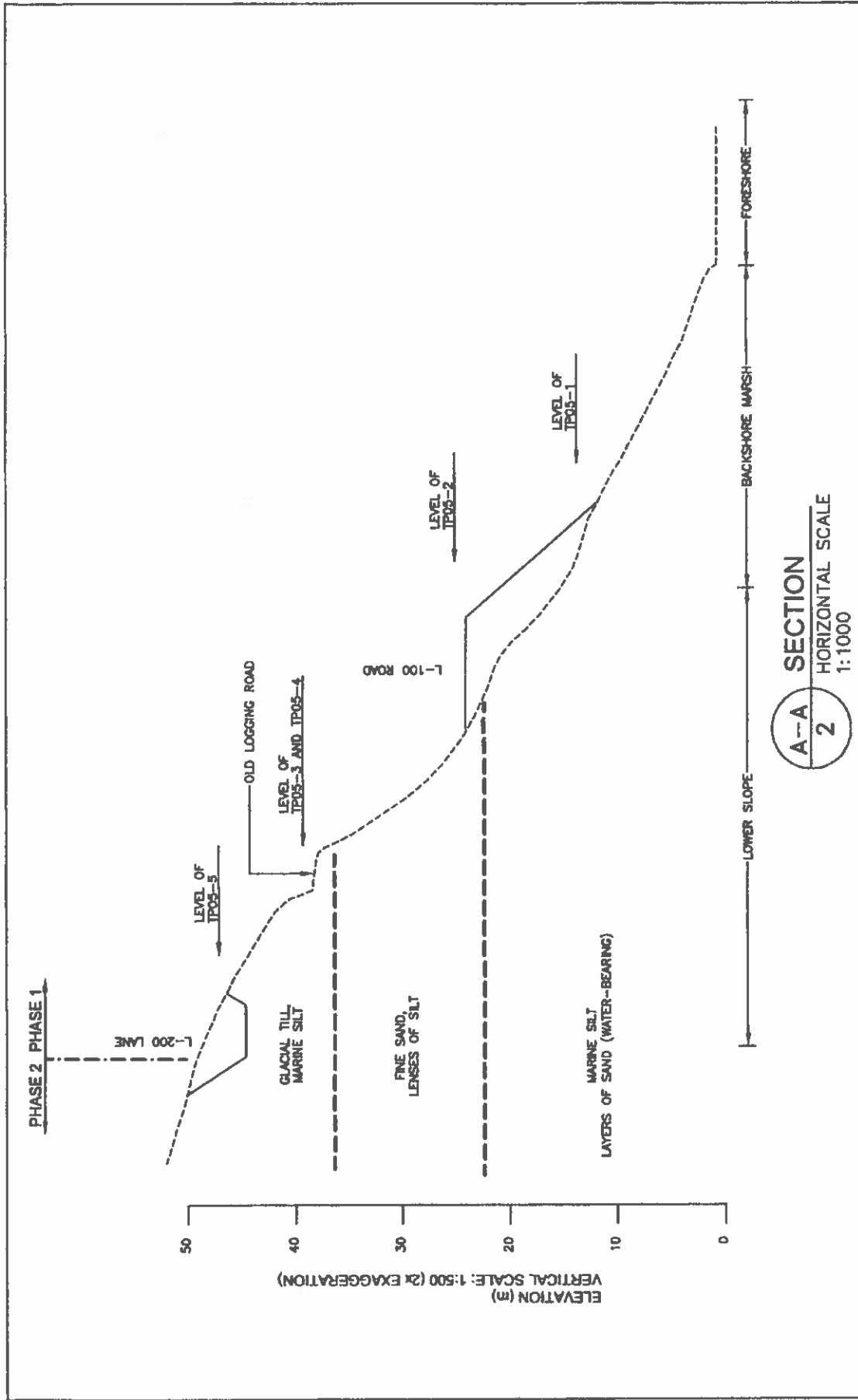
SRK - ROBINSON INC.
Consulting Engineers

Project # C0-03

Sheet _____ of _____ Data _____
Prepared by _____
Project/Client _____
Description _____



SKETCH A25-2



	ENGINEERING LTD.		PHASE 1 - THE SHORES SECHelt, BC	
	CLIENT CONCORDIA HOMES LTD.		TITLE SLOPE PROFILE A-A'	
DATE 2006 04 30	DWN. SG	CHKD. ME	FILE NO. CO-03	FIGURE 3


METRO TESTING LABORATORIES LTD.

6991 Curragh Avenue, Burnaby B.C., V5J 4V6

Tel: (604) 438-9111 Fax: (604) 438-9050

**FIELD DENSITY
REPORT**

 PROJECT NO. SC-18
 CLIENT CONCORDIA HOMES
 C.C.

 TO: CONCORDIA HOMES
 PO BOX 21027
 MAPLE RIDGE, BC
 V2X 1P7

ATTN: RON DAVIS

 PROJECT GALE AVE. NORTH 6600 "THE SHORES" PH. 1 GALE AVE. NORTH 6600
 SOILS/CONSULTING SECHLT

REPORT NO. 4 NO. OF DENSITIES 7 TESTED BY MY DATE TESTED 2007.Jul.23

 CONTRACTOR CONCORDIA HOMES LTD.
 AREA LOT 29 TIME TESTED 18:00
 CONSTRUCTION TYPE SINKHOLE REMEDIATION

DENSITY NUMBER	LOCATION	LAB REFERENCE AND MATERIAL TYPE	MOISTURE		OVER-SIZE MATERIAL %	DRY DENSITY		COMPACTION %
			FIELD %	OPTIMUM %		FIELD kg/m3	LAB kg/m3	
1	SEE ATTACHED SKETCH		8.2	8.0	0.0	2085	2110	99
2	SEE ATTACHED SKETCH		8.8	8.0	0.0	2060	2110	98
3	SEE ATTACHED SKETCH		7.6	8.0	0.0	2034	2110	96
4	SEE ATTACHED SKETCH		8.6	8.0	0.0	2017	2110	96
5	SEE ATTACHED SKETCH		8.2	8.0	0.0	2091	2110	99

 FIELD METHOD Nuclear ASTM D2922
 LABORATORY METHOD Standard Proctor ASTM D698
 ROCK CORRECTION METHOD None
 OVERSIZE SCREEN SIZE Passing 3/4" - 19mm

 SPECIFIED COMPACTION 95
 LOW DENSITIES INDICATED *

COMMENTS

 TEST LOCATION 6 TO BE RE-TESTED. FILL BEYOND SINKHOLE (SEE SKETCH) TO BE
 PLACED AND COMPACTED. EXISTING MATERIAL TO BE REMOVED.

Page 1 of 2 2007.Aug.15 METRO TESTING LABORATORIES LTD. PER

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GEOTACTICS MEDIA ENGINEERING LTD.
 Mailing Address: P.O. Box 624, Sechelt, B.C. V0N 3A0
 Laboratory: #4-1877 Field Road, Sechelt, B.C.
 Office: 604.740.0920 Fax: 604.740.0932

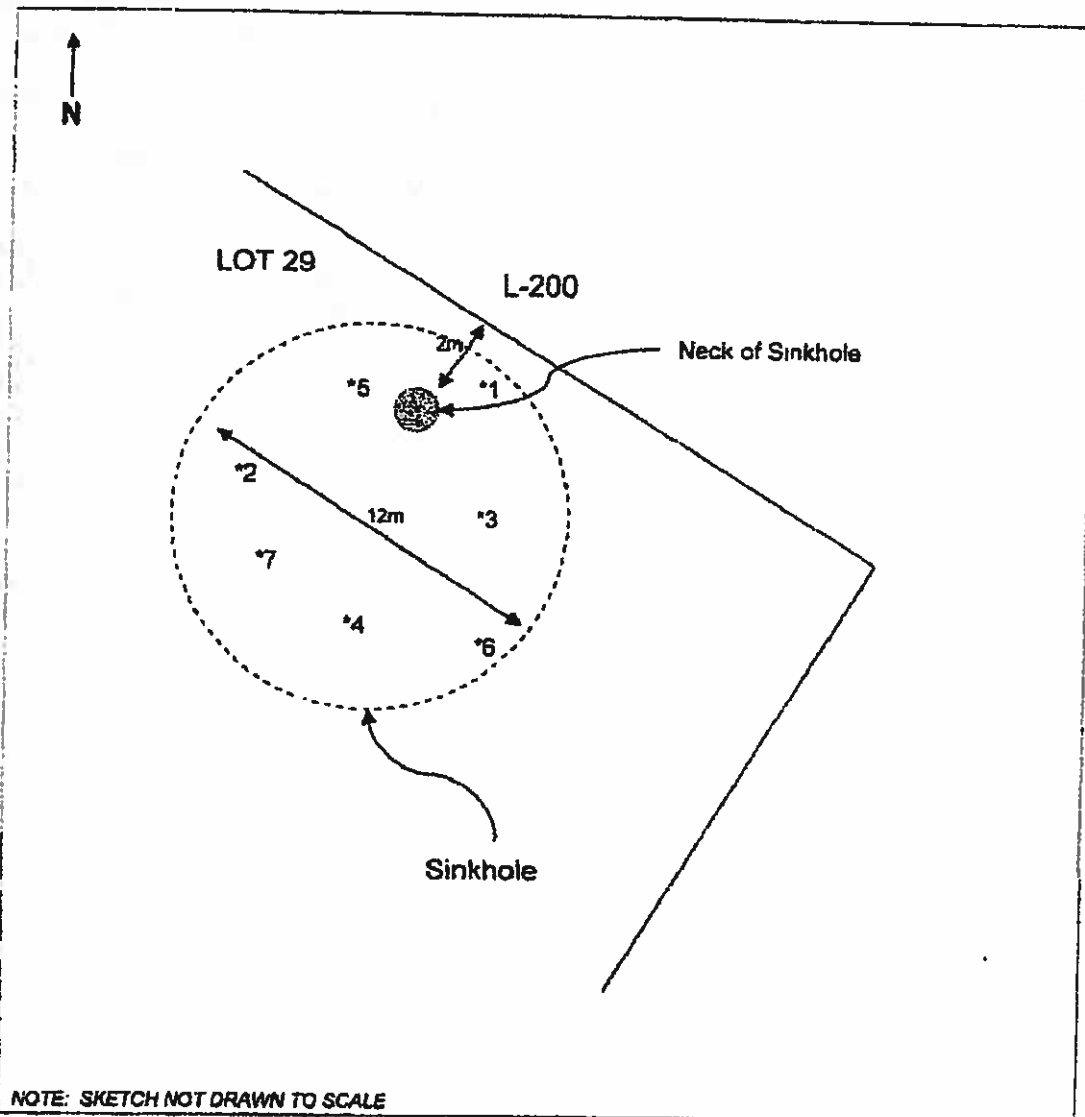
IN ASSOCIATION WITH
**METRO TESTING
 LABORATORIES LTD.**

FIELD DENSITY LOCATION SKETCH NO. 04

FIELD DENSITY REPORT NO.: 04
 DATE: AUGUST 1ST, 2007

OUR FILE NO.: SC-0018

PROJECT: THE SHORES DEVELOPMENT, 6400 N. GALE AVE.
 TEST LOCATION: LOT 29, PHASE 1



COMMENTS:

- Test Locations are approximate
- Tests were conducted on several different lifts. Compaction was monitored throughout placement of fill.


METRO TESTING LABORATORIES LTD.

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**FIELD DENSITY
REPORT**

 TO
 CONCORDIA HOMES
 PO BOX 21027
 MAPLE RIDGE, BC
 V2X 1P7

 PROJECT NO. SC-18
 CLIENT CONCORDIA HOMES
 C.C.

ATTN: RON DAVIS

 PROJECT GALE AVE. NORTH 6600 "THE SHORES" PH. 1 GALE AVE. NORTH 6600
 SOILS/CONSULTING SECHLT

REPORT NO. 15 NO. OF DENSITIES 11 TESTED BY MY DATE TESTED 2007.Sep.13

 CONTRACTOR BA BLACKTOP TIME TESTED 10:00
 AREA L100, LANE L100 TO L200
 CONSTRUCTION TYPE ROAD BASE

DENSITY NUMBER	LOCATION	LAB REFERENCE AND MATERIAL TYPE	MOISTURE		OVERSIZE MATERIAL %	DRY DENSITY		COMPACTION %
			FIELD %	OPTIMUM %		FIELD kg/m3	LAB kg/m3	
1	SEE ATTACHED SKETCH	Proctor 1 19MM GRAVEL	3.5	7.0	0.0	2079	2190	95
2	SEE ATTACHED SKETCH	Proctor 1 19MM GRAVEL	6.3	7.0	0.0	2084	2190	95
3	SEE ATTACHED SKETCH	Proctor 1 19MM GRAVEL	8.1	7.0	0.0	2089	2190	95
4	SEE ATTACHED SKETCH	Proctor 1 19MM GRAVEL	5.7	7.0	0.0	2093	2190	96
5	SEE ATTACHED SKETCH	Proctor 1 19MM GRAVEL	7.7	7.0	0.0	2109	2190	96

 FIELD METHOD Nuclear ASTM D2922
 LABORATORY METHOD Standard Proctor ASTM D698
 ROCK CORRECTION METHOD None
 OVERSIZE SCREEN SIZE Passing 3/4" - 19mm

 SPECIFIED COMPACTION 95
 LOW DENSITIES INDICATED *

 COMMENTS
 RETEST. COMPACTION APPROVED.

Page 1 of 3 2007.Sep.24 METRO TESTING LABORATORIES LTD. PER

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**FIELD DENSITY
REPORT**

 TO
 CONCORDIA HOMES
 PO BOX 21027
 MAPLE RIDGE, BC
 V2X 1P7

 PROJECT NO. SC-18
 CLIENT CONCORDIA HOMES
 C.C.

ATTN: RON DAVIS

 PROJECT GALE AVE. NORTH 6600 "THE SHORES" PH. 1 GALE AVE. NORTH 6600
 SOILS/CONSULTING SECHLT

REPORT NO. 15 NO. OF DENSITIES 11 TESTED BY MY DATE TESTED 2007.Sep.13

CONTRACTOR		BA BLACKTOP				TIME TESTED 10:00		
AREA		L100, LANE L100 TO L200						
CONSTRUCTION TYPE		ROAD BASE						

DENSITY NUMBER	LOCATION	LAB REFERENCE AND MATERIAL TYPE	MOISTURE		OVERSIZE MATERIAL %	DRY DENSITY		COMPACTION %
			FIELD %	OPTIMUM %		FIELD kg/m3	LAB kg/m3	
6	SEE ATTACHED SKETCH	Proctor 1 19MM GRAVEL	7.4	7.0	0.0	2117	2190	97
7	SEE ATTACHED SKETCH	Proctor 1 19MM GRAVEL	5.8	7.0	0.0	2119	2190	97
8	SEE ATTACHED SKETCH	Proctor 1 19MM GRAVEL	5.2	7.0	0.0	2131	2190	97
9	SEE ATTACHED SKETCH	Proctor 1 19MM GRAVEL	5.0	7.0	0.0	2158	2190	99
10	SEE ATTACHED SKETCH	Proctor 1 19MM GRAVEL	4.1	7.0	0.0	2117	2190	97

FIELD METHOD	Nuclear ASTM D2922	SPECIFIED COMPACTION	95
LABORATORY METHOD	Standard Proctor ASTM D698	LOW DENSITIES INDICATED	*
ROCK CORRECTION METHOD	None		
OVERSIZE SCREEN SIZE	Passing 3/4" - 19mm		
COMMENTS			
RETEST. COMPACTION APPROVED.			

Page 2 of 3

2007.Sep.24

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**FIELD DENSITY
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 PROJECT NO. SC-18
 CLIENT CONCORDIA HOMES
 C.C.

ATTN: RON DAVIS

 PROJECT GALE AVE. NORTH 6600 "THE SHORES" PH. 1 GALE AVE. NORTH 6600
 SOILS/CONSULTING SECHLT

REPORT NO. 15 NO. OF DENSITIES 11 TESTED BY MY DATE TESTED 2007.Sep.13

 CONTRACTOR BA BLACKTOP TIME TESTED 10:00
 AREA L100, LANE L100 TO L200
 CONSTRUCTION TYPE ROAD BASE

DENSITY NUMBER	LOCATION	LAB REFERENCE AND MATERIAL TYPE	MOISTURE		OVERSIZE MATERIAL %	DRY DENSITY		COMPACTION %
			FIELD %	OPTIMUM %		FIELD kg/m3	LAB kg/m3	
11	SEE ATTACHED SKETCH	Proctor 1 19MM GRAVEL	6.5	7.0	0.0	2136	2190	98

 FIELD METHOD Nuclear ASTM D2922
 LABORATORY METHOD Standard Proctor ASTM D698
 ROCK CORRECTION METHOD None
 OVERSIZE SCREEN SIZE Passing 3/4" - 19mm

 SPECIFIED COMPACTION 95
 LOW DENSITIES INDICATED *

 COMMENTS
 RETEST. COMPACTION APPROVED.

Page 3 of 3 2007.Sep.24 METRO TESTING LABORATORIES LTD. PER.

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P. 7

