Dallas Road Cliffs, Historic Foreshore Erosion Assessment

Report Context

The CRD has been planning wastewater treatment for the Core Area for over 30 years. During this time a significant number of reports have been prepared and/or reviewed to assess options and provide information to further planning.

In May 2016 a Project Board was established to define and implement wastewater treatment for the Core Area. The Project Board heard delegations and presentations from the public, industry professionals, and a CRD Director. The Project Board Chair and Vice Chair also met with staff from the CRD, all of the Core Area municipalities, and with Esquimalt and Songhees Nations representatives. The Project Board reviewed the previous technical work and extensive public commentary and developed a methodology to review and evaluate all options. This methodology included evaluation of a large number of options to identify a short list that best addressed the Project goals.

In September 2016 the Project Board presented its recommendation for wastewater treatment and on September 14, 2016 the CRD Board approved the Wastewater Treatment Project (the Project).

A significant number of the reports that have been prepared and/or reviewed still serve as useful background information, but not all of the reports are applicable to the Project. To respond to several recent public inquiries regarding topics of interest, the CRD has prepared a synopsis of reports along with a summary of the applicability of the report to the Project. The document summary is available here: https://www.crd.bc.ca/docs/default-source/wastewater-planning-2014/2017-05-30-summary-of-documents-related-to-topics-of-interest.pdf. The document summary does not provide a comprehensive list of reports completed as part of wastewater treatment planning for the Core Area, it is a compilation of a number of reports related to key topics of interest: odour; seabed pipeline; bluffs and shoreline; geotechnical; and noise.

Purpose of this Report

This report was prepared to assess preliminary forcemain alignment and geotechnical field investigation planning for the Clover Point to Ogden Point forcemain (the Clover Point Forcemain). The report had similar findings to the R.D. Gille, 1997 report with respect to cliff recession rates.

Applicability to Project

This report is applicable to the Project and will be used as an input into the development of the geotechnical field investigation requirements for the Clover Point to Ogden Point forcemain alignment. Further detailed slope stability analysis will be completed as part of the geotechnical analysis for the project.

Dallas Road Cliffs

Historic Foreshore Erosion
Assessment

Prepared for:
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c/o Wastewater Treatment
Project
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111700431

May 30, 2017

Revision	Description	Author	Quality Check
May 30, 2017	Historic Foreshore Erosion Assessment	S. Tsang	T. Rollerson

Sign-off Sheet

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Prepared by ______ 30 May 2017

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Stantec

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Executive Summary

The Capital Regional District's proposed McLoughlin Point wastewater treatment plant in Esquimalt, BC requires the construction of a new forcemain from the existing Clover Point pump station to the proposed wastewater treatment plant. The preliminary forcemain route parallels Dallas Road from Clover Point to Ogden Point. This assessment is part of the overall geotechnical planning for the project and will be used to inform the field test drilling program plan. The purpose of this report is to assess the rate of historic foreshore erosion and landslide activity along the sea cliffs between Clover Point and Ogden Point and to identify potential areas for forcemain exposure based on the preliminary forcemain route. This qualitative assessment of foreshore erosion is based on a desktop study using historical air photos, a preliminary review of the City of Victoria Archives including previous reports, and a site visit. As part of the geotechnical investigation for the project further analysis will be completed to support the design for the project.

Landslides and erosion historically occur throughout the study area. These conditions exist along many areas of the south coast of Vancouver Island. The sea cliffs between Clover Point and Finlayson Point have the highest concentration of historical landslides, dominated by shallow translational landslides, where the preliminary forcemain route is setback 15 to 200 m from the sea cliffs.

Site observations suggest that sea cliff recession is generally due to shallow, translational landslides, small rotational slumps, gullying and surface erosion. It was generally observed that areas with rip-rap berms or retaining walls seemed to be revegetating more quickly (less ongoing erosion) than the areas where the sea cliffs were still exposed to toe erosion by wave action.

Our findings generally support the lower average cliff recession rate of 1 cm/year as reported by Gillie 1997 rather than the approximate average of 10 cm/year reported by Thurber 1977 for estimated rate of regression.

Three areas have been identified where further geotechnical drilling will be completed along the preliminary forcemain route: (1) the slope below the intersection of Douglas Street and Dallas Road (suspected rock fill), (2) the slope below the Paddon Avenue seawall down to Fonyo Beach (suspected artificial fill), and (3) the James Bay seawall. These potential exposure locations will be assessed as part of the test geotechnical drilling program and can be mitigated by alignment adjustments or localized densification in these areas.

Stantec recommends a comprehensive focused geotechnical investigation be completed at these three areas with a slope monitoring program (install slope inclinometers) prior to the start of construction, during construction and post-construction activities along Dallas Road. To supplement the slope inclinometer data, it is also recommended that survey pins be installed along the alignment to enable monitoring of the slopes. This comprehensive geotechnical program is part of the work currently planned for the preliminary and detailed design of the forcemain.

Following the recommended geotechnical drilling, modifications to the preliminary forcemain route and mitigation may be required depending on the soil conditions encountered.

Abbreviations

asl	above sea level
cm	centimetres
CRD	Capital Regional District
m	metres
WWTP	wastewater treatment plant
ybp	years before present

1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) is supporting the Capital Regional District (CRD) with the preliminary engineering design of a new forcemain from the existing Clover Point pump station to the proposed McLoughlin Point wastewater treatment plant (WWTP) in Esquimalt, BC (Figure 1). The preliminary forcemain route parallels Dallas Road from Clover Point to Ogden Point and crosses the entrance to Victoria Harbour via a subsea horizontal direction drill to the McLoughlin Point WWTP. Underground utilities in this area have a long history of reliable service dating back to the early 1900s. The purpose of this report is to assess the rate of historic foreshore erosion and landslide activity along the sea cliffs between Clover Point and Ogden Point (study area) and to inform the planning of the detailed geotechnical investigation which will be completed as part of the preliminary and detailed design for the Clover forcemain.

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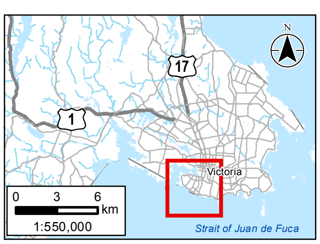

- Preliminary Forcemain Route
- Proposed Conveyance Pipe
- Proposed Harbour Crossing Conveyance Pipe
- Outfall
- Residual Solids Forcemain
- Arterial Road
- Local Street
- Proposed McLoughlin Point Wastewater Treatment Plant
- CRD Property
- Clover Point Pump Station Footprint
- Park/Sports field
- Residential Area
- Wooded Area

0 220 440 660 m

1:22,000 (at original document size of 8.5x11)

Stantec CRD Wastewater Treatment Project

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Base features: DataBC, Government of British Columbia (GovBC); GovBC; CanVec v12; Government of Canada (GC); Canadian Hydrographic Services; Environment Canada; Natural Resources Canada.
3. Orthoimagery © Capital Regional District

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Project Location
Capital Regional District

111700431
Prepared by D. Jozsa on 2017-05-17
Requested by S. Tsang on 2017-05-17
Reviewed by S. Parker

Client/Project
Capital Regional District
Dallas Road Cliffs
Historic Foreshore Erosion Assessment

Figure No.
1

Title
Location Map

2.0 METHODS

The historic foreshore erosion and landslide activity assessment was completed in stages comprising a desktop study, a site visit, and reporting.

2.1 DESKTOP STUDY

The desktop study involved a background review of relevant publications, a historical air photo review, and an archival studies review.

2.1.1 Background Review

Background publications and data on bedrock geology, soils, surficial geology, and glacial history were compiled and reviewed. The documents reviewed are listed in the Reference section.

2.1.2 Historical Air Photo Review

Historical air photos from 1932, 1946, 1948, 1956, 1964, 1968, 1972, 1976, 1980, 1986, 1992, 1997 and 2005 were borrowed from the University of British Columbia Geography Information Center's provincial air photo library and viewed stereoscopically to visually assess where significant historical change due to wave erosion and/or landslides have occurred along the sea cliffs. The air photos and imagery reviewed are tabulated in Appendix A. Air photo visible landslides were mapped only for the period 1948 - 2005 because the older air photos were of poor quality and stereo images were not available (Appendix B). Notes about visible landslides and erosion features (gullies) were compiled. The air photos were scanned at 600 dots per inch and the digital scans were georeferenced using select control points (e.g., street intersections, land marks) in ArcGIS 10.3 to facilitate the digital transfer of historical landslides onto maps and to detect changes along the foreshore over time. This first method proved a problematic exercise due to air photo distortion, size of the study area, and lack of a suitable digital elevation model to ortho-rectify the digitally scanned air photos. A second method involved the hand-eye transfer of air photo-visible landslides onto Google Earth (Appendix C). The landslide locations are approximate; however, both methods provide information on the presence and/or absence, frequency, and distribution of landslides over the 1948 - 2005 air photo period.

2.1.3 Archival Studies Review

The author visited the City of Victoria's archives on March 22, 2017 to locate resource information on foreshore erosion along the sea cliffs which included government records, reports, maps, photos, and news clippings (see Reference section). No City of Victoria engineering reports or geotechnical reports were provided by the CRD for this assessment.

2.2 SITE VISIT

Stantec's terrain specialists (Mr. Sidney Tsang, P.Geo. and Mr. Terry Rollerson, M.Sc., P.Geo.) carried out a site visit of the study area on March 23-24, 2017 to collect and record site observations relevant to the assessment of foreshore erosion. The site visit entailed foot traverses and visual inspection (non-invasive ground disturbance) of natural exposures of surficial materials and bedrock. The March 23rd traverse started at the west end of the study area near Ogden Point and progressed east along the James Bay seawall, down to the beach below Holland Park, up the footpath to Paddon Avenue. We then walked along the footpath above the sea cliffs to Douglas Street and back down the stairs to the beach, east along the shoreline, around Finlayson Point, and continued to Clover Point. We then returned westward along the footpath above the cliffs as far as Cook Street and then followed the preliminary forcemain route between Cook Street to Douglas Street. The March 24th traverse started at the east end of the James Street seawall. We walked east along the footpath to observe the top of the cliffs around Holland Park as far east as Holland Point. Site observations were recorded in field notebooks and summarized in Appendix E. Data collected include GPS locations, elevation, slope gradient, soil drainage, surficial material, material texture, evidence of seepage, signs of slope movement (e.g., landslides, scarps, tension cracks, leaning trees, landslide debris, etc.), landslide type, and landslide dimensions. Photos were taken at each site and along the traverse. The field site locations are presented on the maps in Appendix C.

Following the site visit, the site observations were compiled, reviewed, and compared to the historical landslide mapping.

3.0 FINDINGS

3.1 DESKTOP STUDY

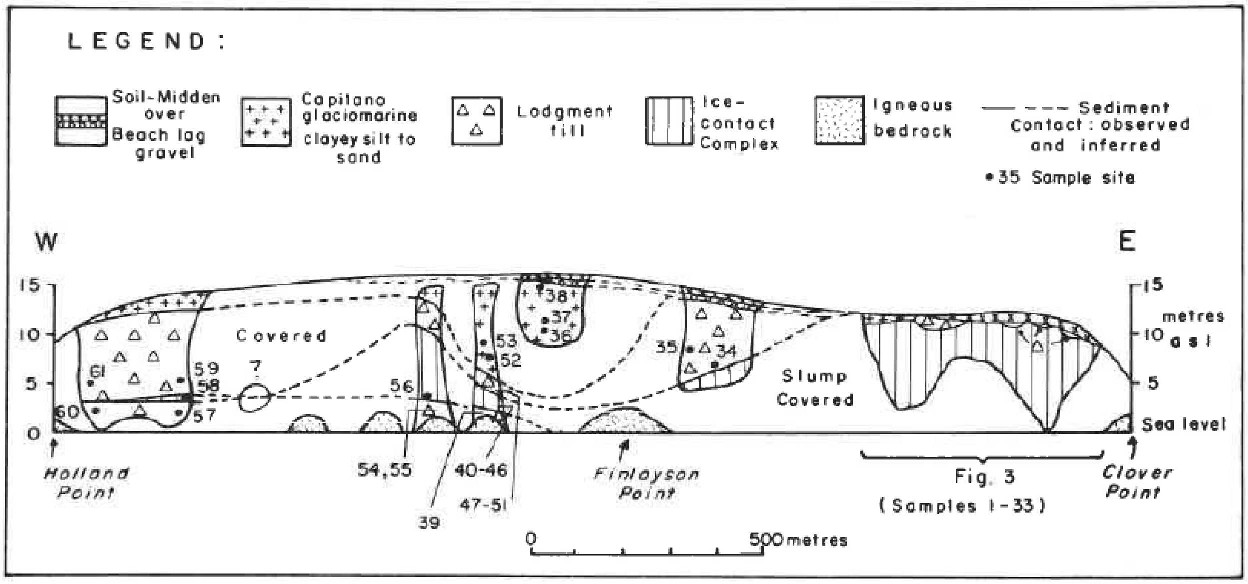
3.1.1 Background Review

The preliminary forcemain route is located within the Nanaimo Lowland physiographic subdivision, a strip of low-lying country, below 610 metres elevation, extending along the northeast, east and southwest coasts of Vancouver Island from Sayward to Jordan River, west of Victoria (Holland 1976). The bedrock underlying the preliminary forcemain route is Jurassic-age Westcoast Crystalline Complex comprising quartz diorite, tonalite, horneblende-plagioclase gneiss, quartz-feldspar gneiss, amphibolite, diorite, agmatite, gabbro, marble and metasediments, including the Wark-Colquitz Complex (Clapp 1913, Cui 2015). Bedrock outcrops along the shoreline between Finlayson Point to Holland Park. Fault-zone mylonites have been identified on the west side of Clover Point (Johnston et al. 2013).

During the last major glaciation (25,000-10,000 ybp) glaciers formed in the Vancouver Island Mountains and Coast Mountains and advanced down the Strait of Georgia to southeastern Vancouver Island after 19,000 ybp. During the glacial maximum (~15,000 ybp) southern Vancouver Island was completely covered by an ice sheet that flowed south-southwesterly across Juan de Fuca Strait and deposited Cordilleran till (Alley and Chatwin 1979). As the climate began to ameliorate, deglaciation was by downwasting and southern Vancouver Island was ice-free by 12,500 ybp (Clague 1981). During this period, the coastline was depressed due to glacio-isostatic effects such that marine waters invaded lowland areas below 75 metres elevation and glaciomarine sediments were deposited (Mathews et al. 1970). However, present sea level was attained as early as 11,700 ybp at Victoria (Clague 1981). A detailed study of the sediments overlying the bedrock along the sea cliff between Holland Point and Clover Point (Hicock et al. 1981) identified four general soil types (Figure 2):

1. ice-contact complex—submarine flow till, glacial outwash, and glaciomarine fine sediments bearing marine plankton,
2. lodgement till—material that accumulates at the base of a moving glacier and typically highly consolidated,
3. glaciomarine clayey silt and sand—deposited by glaciers in a marine environment in close proximity to glacier ice, and
4. soil-midden over beach lag gravels—organic soil mixed with shellfish remains left by indigenous people overlying a thin layer of cobbles and pebbles left behind as ocean waves washed-away the fine sediments.

Figure 2 Geological cross-section of the sea cliff between Holland Point and Clover Point (source: Hickock et al. 1981).



3.1.2 Historical Air Photo Review

The results of the historical air photo review of landslides and erosion features are shown on the historical landslide maps (Appendix B and Appendix C) and tabulated in Appendix D. At least 60 landslides and areas of sea cliff erosion were visible on the historical air photos and ortho-imagery from 1948 to 2015 between Clover Point to Ogden Point. For the historic foreshore erosion assessment, the study area is subdivided into four sections (listed from east to west):

Section 1 - Clover Point cliffs: encompasses the sea cliffs and beach between Finlayson Point to Clover Point. This section has the highest concentration of historical landslides (Appendix C1, Appendix F Sites ST17-017 to ST17-020). Most of the landslides are small, translational landslides (shallow debris avalanches). Laterally extensive, unvegetated to partially vegetated sea cliffs were mapped. We infer that ongoing surface erosion and occasional, small, shallow landslides are occurring where vegetation does not re-establish.

Section 2 - Finlayson Point to Fonyo Beach: encompasses sheltered bays with pocket beaches and headlands underlain by glacially smoothed bedrock (Appendix F - Sites ST17-012 to ST17-016). Many discrete, shallow translational and small, rotational landslides were mapped on the sea cliffs above the bays (Appendix C2). The largest historical landslide identified between the period of air photo record (1948 – 2005) occurred within this section, although this section had relatively fewer historical landslides mapped compared to the other sections. In December 1975, a rotational-translational slump (30 metres wide and 15 metres long) occurred on the east side of Horseshoe Bay, north of Finlayson Point (Appendix B6). In contrast, small, shallow translational landslides (debris avalanches) are more common in glacial sediments at the headlands where the underlying bedrock is generally exposed along the shoreline (Appendix F - Site ST17-014).

Section 3 - Fonyo Beach to James Bay seawall: encompasses sea cliffs and beaches from the east side of Fonyo Beach around Holland Point to the east side of the James Bay seawall. This section has the second highest concentration of historical landslides (Appendices C2 and C3, Appendix F - Sites ST17-004 to ST17-011). Laterally extensive, unvegetated to partially vegetated sea cliffs were mapped long the south slope of Holland Park. Here, it is inferred that ongoing surface erosion and small, shallow landslides are occurring where vegetation does not re-establish. A berm and footpath built along the toe slopes below the south slope of Holland Park is visible on the 1976 air photos. Shallow translational landslides (debris avalanches) and small, rotational slumps were mapped along the cliffs on the west half of Holland Park where outcrops of bedrock occur along the shoreline. Several small gullies are also visible along this section of cliff.

Section 4 - James Bay seawall to Ogden Point: encompasses the James Bay seawall, constructed circa 1911, and a short section of shoreline at the west end of the seawall (Appendix C3, Appendix F - Sites ST17-001 to ST17-003). A small, surface erosion exposure was mapped along the short section of shoreline near the Ogden Point jetty on the 1976 air photos (Appendix F - Sites ST17-002); however, this exposure may have existed as early as 1948.

Limitations

A review of the locally-georeferenced (method 1) air photos showed off-sets up to 50 metres due to insufficient control points, air photo distortion, topography, and lack of a digital elevation model to ortho-rectify the digitally scanned air photos. Therefore, this method is considered low accuracy for determining an average rate of sea cliff regression.

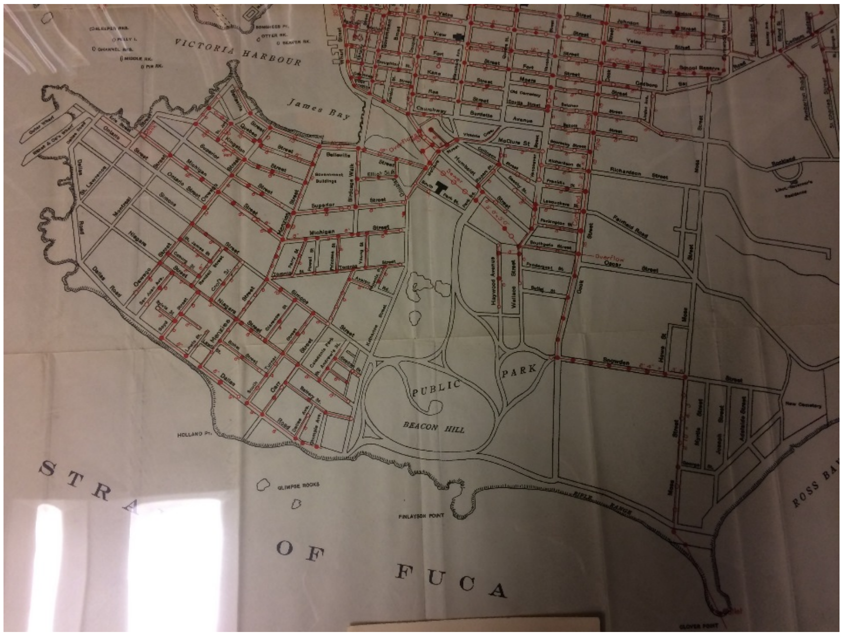
Other factors that limit the reliability of the historical landslide mapping on air photo include:

- air photo scale (some landform features are small and hard to identify on small scale air photos),
- quality of the air photos (sharpness, contrast, grey tones) can hinder air photo interpretation,
- vegetation cover – the degree to which vegetation obscures the ground surface has considerable influence on the reliability of mapping.

3.1.3 Archival Studies Review

A 1902 map of the City of Victoria's sewer system was located at the City Archives showing the extent of the system around the James Bay neighbourhood area (Figure 3). These documents and history of the sewer system in Victoria indicate a long period of reliable operation including pipes installed in Dallas Road.

Figure 3 Plan of the City of Victoria sewerage system dated December 1902 (source: City of Victoria Engineer's Office. 1902).



The archival studies review identified two documents relating to foreshore erosion along the cliffs: (1) a report by Thurber Consultants Ltd. in 1977, and (2) a report by R.D. Gillie in 1997 (see Reference). These reports are summarized below. The reader is referred to the original reports for further details.

3.1.3.1 Thurber Consultants Ltd. 1977

- Looked at the effects of shoreline erosion along Dallas Road between Holland Point to Clover Point.
- Used photogrammetric mapping of sea cliffs and beach, followed by field mapping of the geology of the area including landslides and groundwater seeps.
- Estimated rate of regression of part of the shoreline between Finlayson Point and Clover Point over the period 1900-1976 and was evaluated by comparing previous surveyed maps, and found an approximate average of 10 cm/year and maximum rate of erosion of about 23 cm/year.
- Identified Douglas Street (Figure 4) and Paddon Avenue (Figure 5) where fill may be blocking subsurface drainage and should be drilled and monitored for slope movement. Other suspected fill areas include above Horseshoe Bay and near Cook Street.
- Concluded shoreline regression in the area involved:
  - Sloughing and sliding caused by oversteepening due to wave erosion and periodic high groundwater levels,
  - Erosion by slope creep, surface runoff, frost action, wind, and human activity, and
  - Natural removal of sloughed material from toe of sea cliffs by wave action.

Figure 4 Suspected rocky fill below Douglas Street and Dallas Road intersection (source: Thurber Consultants Ltd. 1977).

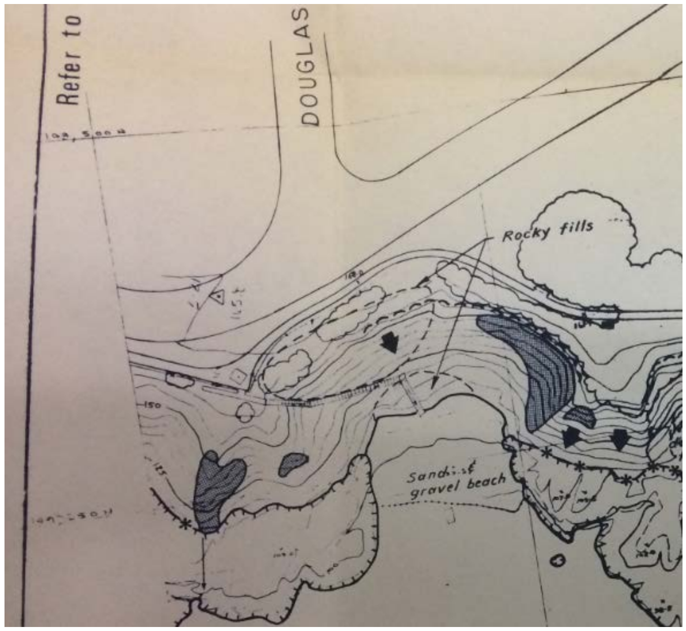
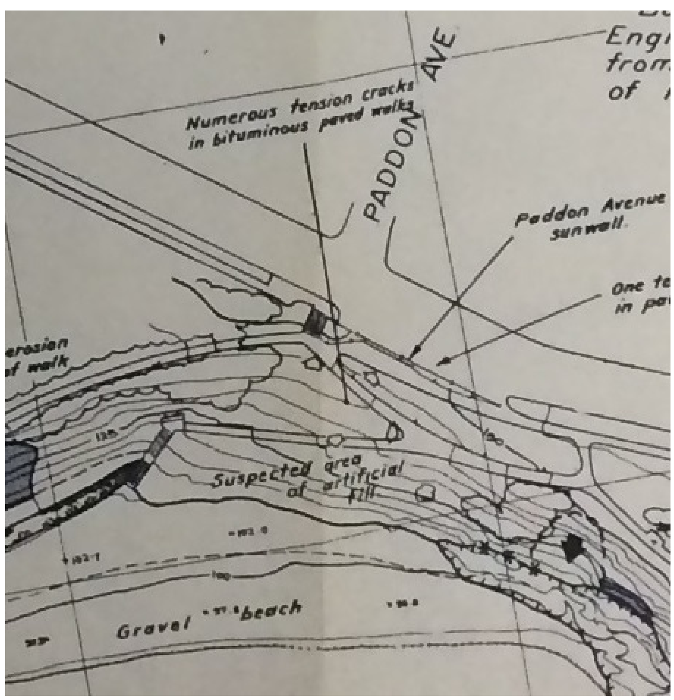


Figure 5 Suspected area of artificial fill below the Paddon Avenue seawall (source: Thurber Consultants Ltd. 1977).



3.1.3.2 R.D. Gillie 1997

- Refutes Thurber's 1977 rate of regression estimates noting the limitations and uncertainties of their sea cliff recession results.
- Used historical air photos from 1928, 1954, 1977 and 1992, and City Engineering department ground survey data for 1958 and 1991 including sea cliff crest and sea cliff toe positions for various shoreline segments between Paddon Ave to Clover Point.
- 33-year period of ground survey data shows an average sea cliff recession rate of 1 cm/year or an order of magnitude difference from the Thurber 1977 report.
- Estimated sea cliff toe recession of 4.5 m for 33-year period (7 cm/year) in fill below Douglas Street. The fill was assumed to have been placed between 1954 and 1958 to widen Dallas Road at this location. Fill reached the toe of the slope onto the beach and is currently eroding by wave action.
- Noted structural failure of a portion of the James Bay seawall between Pilot and Oswego Streets between 1910 to 1949 on engineering drawings.
- Concluded cliff recession is due primarily to mass movement processes such as:
  - shallow landslides,
  - small rotational slumps,
  - mudflows and gullying processes,
  - these processes are associated with seasonally high ground water levels and surface water flowing into and onto cliff sediments.
- Concluded in general, marine processes are not removing the supporting foundation of the sea cliffs and are not initiating sea cliff erosion.

Note: The City of Victoria's archives report copy was missing the plan maps.

3.2 SITE VISIT

Site observations are summarized in Appendix E and generally confirm the detailed surficial geology mapping by Hicock et al. 1981 between Clover Point and Holland Point. Also, site observations suggest that sea cliff recession is generally due to shallow, translational landslides, small rotational slumps, gullying and surface erosion, which generally supports the conclusions of the R.D. Gillie 1997 report. Seasonally high ground water levels and surface water flowing into and onto the sea cliffs are associated with these processes. It was generally observed that areas with rip-rap berms or retaining walls seemed to be revegetating more quickly (less ongoing erosion) than the areas where the sea cliffs were still exposed to toe erosion by wave action.

Limitations

The site visit relied on visual observations of the sea cliffs (no drilling or test pits were dug) and incidental hand-texturing of surficial material at natural exposures. Vegetation can obscure evidence of landslides in the field.

No attempt was made to assess the effects of foreshore erosion and landslide activity from the potential rise in sea level or seismic activity. However, sea level rise would likely be associated with increased toe erosion by wave action.

3.3 SUMMARY OF FINDINGS

A review and comparison of the historical air photos, archival studies and site observations indicate that in 1956 the top of sea cliff at the Dallas Road and Douglas Street intersection was closer to Dallas Road than the current location (Figures 4 and 6) as previously reported in Thurber 1977. It is suspected that fill was dumped over the cliff during the widening of Dallas Road between 1956 and 1958 based on the 1956 air photos and 1958 ground survey data by the City Engineering Department noted in Gillie 1997. The suspected fill appears to extend down to the beach where wave erosion has exposed the toe of the rocky fill material (Figure 7, Site ST17-013). The slope steepness of the suspect fill ranges from 70 to 85% along the upper 15 metres. The preliminary forcemain route appears to cross the top of the suspect fill slope; therefore, we consider the area around the Dallas Road and Douglas Street intersection to be a likely area for mitigation and recommend that a geotechnical investigation be carried out along this section of Dallas Road to validate the presence, extent, and character of the fill.

Previous studies (Thurber 1977, Gillie 1997) suspect the slope below the Paddon Avenue seawall contains artificial fill (Figures 5 and 8). The City of Victoria has constructed a lower seawall in the late 1970's at the toe slope to protect the shoreline from wave erosion (lower photo in Figure 8). Two possible old debris avalanche scars were mapped along this slope on the1948 air photos (Appendix C2 – Sites M and N) and newer landslides scars are visible on the 1980 air photos (Appendices B5 and C2). The preliminary forcemain route crosses upslope of the older (1948) debris avalanche scars near the Paddon Avenue seawall. Therefore, the area below the seawall is identified as a likely area for mitigation and it is recommended that a geotechnical investigation be carried out along this section of Dallas Road to validate the nature of the soils (either fill or native soil) on the north side of (behind) the Paddon Avenue seawall. It is recommended that a slope monitoring program be implemented prior to the start of construction, during construction and following construction activities between the edge of the sea cliffs and the potential trench excavation.

The James Bay seawall was constructed around 1911 to protect Dallas Road and the houses along the north side from foreshore erosion (Gillie 1997). It is unknown at this time whether fill or native soils underlie the seawall. Repairs to the concrete seawall surface were being completed during the site visit (Figure 9).

Figure 6 Comparison of 1956 air photo and 2015 orthophoto at Douglas Street and Dallas Road intersection. Red lines indicate the curb-to-curb extent of Dallas Road for reference.

Figure 7 Suspected fill material below Douglas Street stairwell exposed by wave erosion.

Figure 8 Paddon Avenue seawall circa 1930 and on March 23, 2017. (source: http://www.victoriaheritagefoundation.ca/Neighbourhoods/jamesbayhistory.html).

Dallas Road from below 642 Dallas at Paddon Av on the left, c.1930. All houses pictured were demolished in the late 1960s to make way for apartment buildings. Stairway to beach was removed from this location.
Photo attributed to Cecil Clark, collection Little Family.

Figure 9 Resurfacing the James Bay seawall face.

The preliminary forcemain route runs along the top of the seawall. The James Bay seawall is considered a likely area for mitigation along the preliminary forcemain route given the uncertainty of soils behind the sea wall and the historical foreshore erosion prompting the construction of the seawall over a century ago. Also, bedrock does outcrop approximately 15 metres offshore of the seawall; therefore, it is possible that bedrock may exist near the surface under the seawall. It is recommended that geotechnical drilling along the seawall should be carried out to determine whether fill or native soils underlies the preliminary forcemain route and to determine if bedrock will be encountered within the trench.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The purpose of this report is to assess the rate of historic foreshore erosion and landslide activity along the sea cliffs between Clover Point and Ogden Point (study area) and to identify potential areas requiring further investigation as part of the geotechnical investigation.

Landslides and erosion historically occur throughout the study area dating back to at least 1948 (based on the air photos) and most likely earlier. The sea cliffs between Clover Point and Finlayson Point have the highest concentration of historical landslides. The largest landslide since 1948 was a 30 metre-wide rotational slump that occurred in December 1975 on the east side of Horseshoe Bay, north of Finlayson Point.

Site observations generally confirm the detailed surficial geology mapping of the sea cliffs by Hicock et al. 1981 between Clover Point and Holland Point consisting of predominantly silty to sandy till, glaciomarine silt and clay, glacial outwash deposits and beach lag deposits.

Site observations identify sea cliff recession is generally due to shallow, translational landslides, small rotational slumps, gullying and surface erosion which confirms the conclusion of a previous study (Gillie 1997). It was generally observed that areas with rip-rap berms or retaining walls seemed to be revegetating more quickly (less ongoing erosion) than the areas where the sea cliffs were still exposed to toe erosion by wave action.

This qualitative assessment of foreshore erosion is based on a desktop study using historical air photos, a preliminary review of the City of Victoria Archives, and a site visit. Our findings generally support the lower average cliff recession rate of 1 cm/year as determined by Gillie 1997 rather than the order of magnitude higher approximate average of 10 cm/year as determined by Thurber 1977 for estimated rate of regression. A review of City of Victoria engineering reports and geotechnical reports that provide quantitative cliff erosion rates should be reviewed if they exist.

Based on the desktop study and the site visit, three likely areas for further investigation and mitigation along the preliminary forcemain route have been identified: the slope below the intersection of Douglas Street and Dallas Road (suspected rock fill), the slope below the Paddon Avenue seawall down to Fonyo Beach (suspected artificial fill), and the James Bay seawall.

Stantec recommends:

- a geotechnical borehole drilling program be completed around the Dallas Road - Douglas Street intersection and along the Paddon Avenue seawall, identified as potential areas for mitigation based on the preliminary forcemain route. At both areas, the preliminary forcemain route is adjacent to the sea cliffs. These two areas specifically would be considered higher risk due to the suspected fill that may underlie the preliminary forcemain route. Geotechnical investigation and preliminary design will assess the best method for mitigating risks.

- a geotechnical borehole drilling program be completed adjacent to the James Bay seawall, identified as a likely area for mitigation to determine whether fill or native soils underlies the preliminary forcemain route and to assess the potential to encounter near-surface bedrock. Geotechnical information should be obtained to determine the potential hazard associated with seawall undercutting due to wave erosion, which in turn could result in subsidence of the forcemain.

- implementing a slope monitoring program prior to the start of construction, during construction and post-construction activities along Dallas Road. Where possible, install slope inclinometers between the edge of the cliffs and potential trench excavation. Specifically, along the preliminary forcemain route at the Douglas Street and Dallas Road intersection. The slope inclinometers can be read multiple times prior to construction to establish baseline readings and while trenching activities are occurring. The instrumentation infrastructure will be left in the ground indefinitely which will allow for the CRD or City of Victoria to continue to monitor any potential slope movements well after the completion of the project. In addition to installing slope inclinometers, survey pins will be installed and monitoring of the points prior to, during and post construction will be completed. Survey pins should be installed in relative fixed objects such the curb, retaining walls or stair cases.

Following the recommended geotechnical drilling, modifications to the preliminary forcemain route or ground densification may be required depending on soil conditions (e.g., non-compacted fill) encountered.

5.0 REFERENCES

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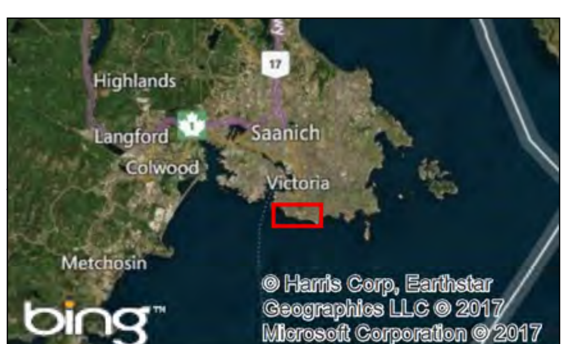
Appendix A HISTORICAL AIR PHOTOS AND IMAGERY

Date	Series	Numbers	Scale
1932	A4518	22, 24 (no stereopair)	unknown
1946	BC248	66 (no stereopair)	1:31,680
8-Jun-48	BC586	60-61, 66-65	unknown
1956	BC2042	92-95	1:15,840
15-May-64	BC5091	218-216, 248-249	1:15,840
17-May-68	BC5284	216-214, 249-250	unknown
2-Jul-72	BC7404	216-217	1:15,000
3-Jul-72	BC7404	221-220	1:15,000
20-Oct-76	BCC145	68-59	1:5,000
7-May-80	BC80005	150-149, 199-200, 202	1:10,000
27-May-86	BC86004	10-8	1:5,000?
27-May-86	BC86003	216-223	1:5,000?
1986	FF8606	60-61	unknown
14-Oct-92	BCB92141	176-178	1:10,000
15-Oct-92	BCB92139	95-94	1:10,000
14-Mar-97	BCB97004	43-44, 167-168	1:5,000
14-Mar-97	BCB97007	56-48	1:5,000
25-May-05	ME05440C	20-21	1:6,500
25-May-05	ME05439C	165-163, 219-221, 225-223	1:6,500
2015	Colour orthophoto	From CRD WMS server	unknown

Appendix B HISTORICAL LANDSLIDES AND AREAS OF CLIFF EROSION ON GEO-REFERENCED AIR PHOTOS (METHOD 1)



2005 Landslides

Preliminary Forcemain Alignment

0 230 460 metres

1:12,000 (At original document size of 11x17)

Stantec CRD Wastewater Treatment Project

Project Location

Dallas Road
Victoria, BC

111700431 REVA
Prepared by ER on 2017-05-16
Independent Review by ST on 2017-05-29

Client/Project

Capital Regional District
Dallas Road Cliffs Historic Foreshore
Erosion Assessment

Figure No.

Appendix B1

Title

Historical Landslides and Areas of Cliff Erosion (2005)

Notes
1. Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
2. Base features produced under license with the Ontario Ministry of Natural Resources © Queen's Printer for Ontario, 2013.
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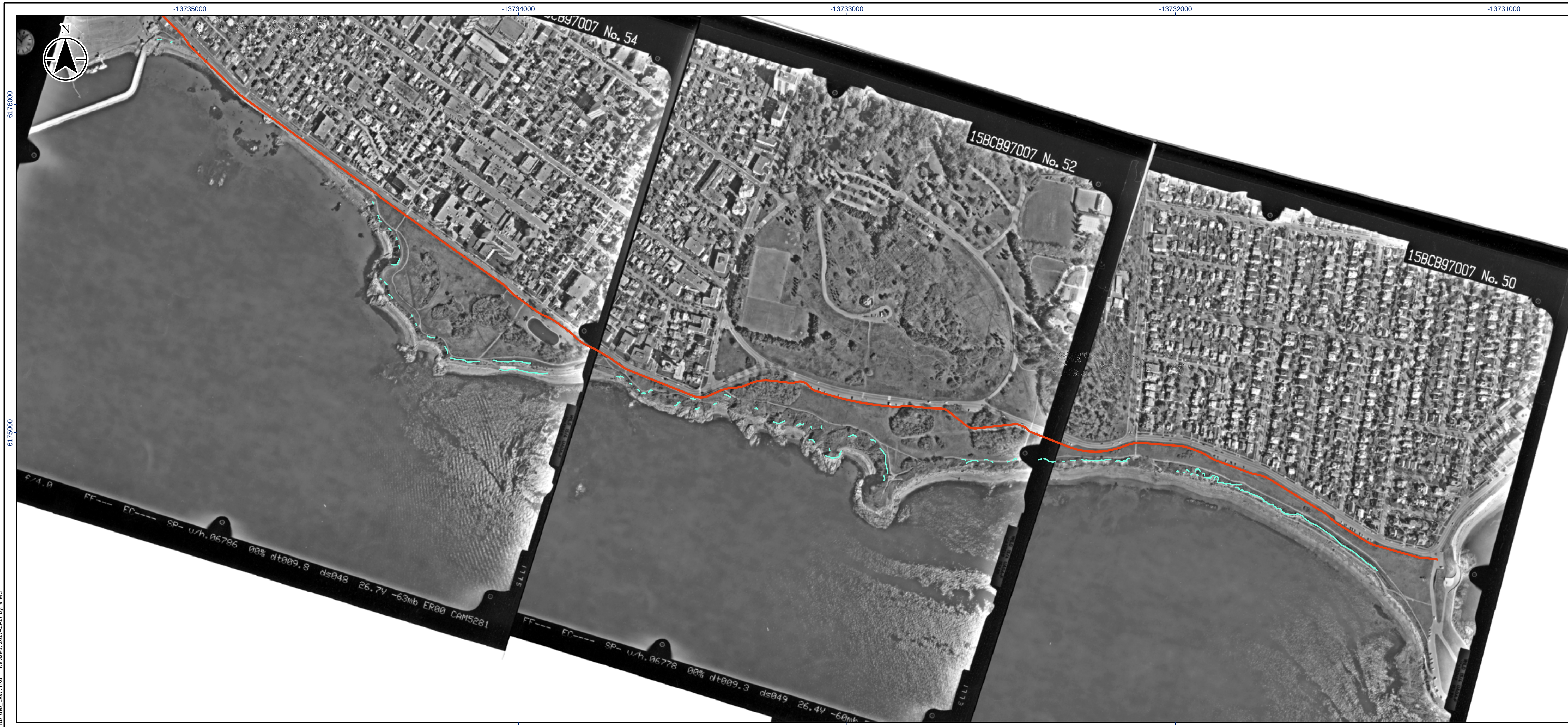

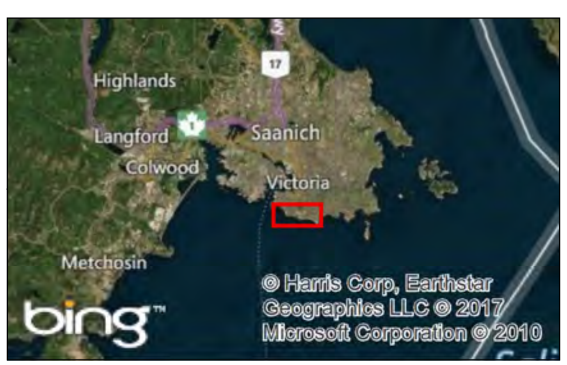

1997 Landslides

Preliminary Forcemain Alignment

0 230 460 metres

1:12,000 (At original document size of 11x17)

Notes
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Dallas Road Cliffs Historic Foreshore
Erosion Assessment

Figure No.
Appendix B2

Title
Historical Landslides and Areas of Cliff Erosion (1997)

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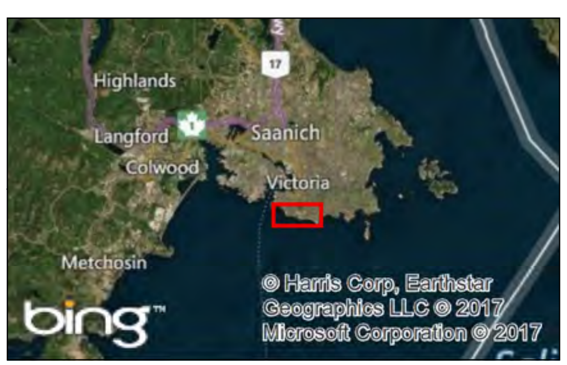

1992 Landslides

Preliminary Forcemain Alignment

0 230 460 metres

1:12,000 (At original document size of 11x17)

Stantec CRD Wastewater Treatment Project

Project Location
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Victoria, BC

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Figure No.
Appendix B3

Title
Historical Landslides and Areas of Cliff Erosion (1992)

Notes
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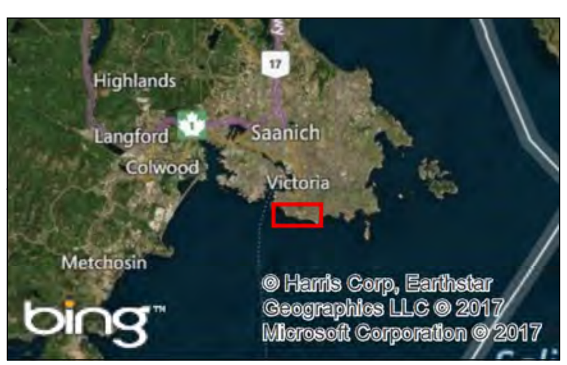

1986 Landslides

Preliminary Forcemain Alignment

0 230 460 metres

1:12,000 (At original document size of 11x17)

Project Location

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Erosion Assessment

Figure No.

Appendix B4

Title

Historical Landslides and Areas of Cliff Erosion (1986)

Notes
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1980

Preliminary Forcemain Alignment

0 230 460 metres

1:12,000 (At original document size of 11x17)

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CRD Wastewater Treatment Project

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Figure No.
Appendix B5

Title
Historical Landslides and Areas of Cliff Erosion (1980)

Notes
1. Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
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1976 Landslides

Preliminary Forcemain Alignment

0 230 460 metres

1:12,000 (At original document size of 11x17)

Project Location
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Independent Review by ST on 2017-05-29

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Erosion Assessment

Figure No.
Appendix B6

Title
Historical Landslides and Areas of Cliff Erosion (1976)

Notes
1. Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
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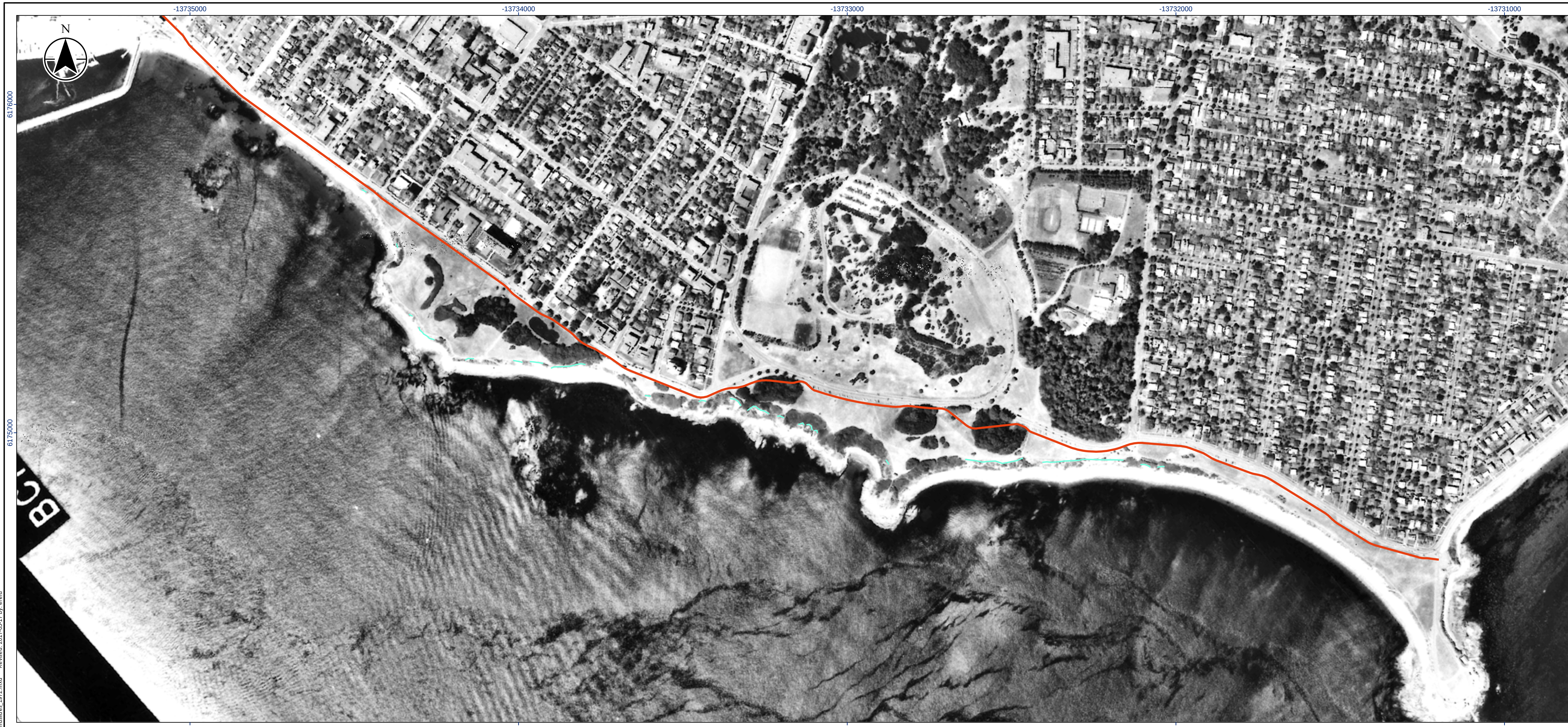

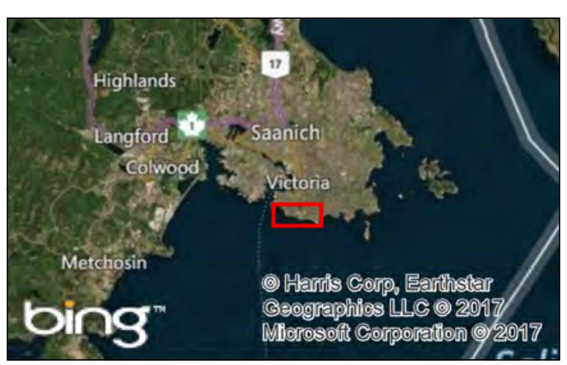

1972 Landslides

Preliminary Forcemain Alignment

0 230 460 metres

1:12,000 (At original document size of 11x17)

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Independent Review by ST on 2017-05-29

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Dallas Road Cliffs Historic Foreshore
Erosion Assessment

Figure No.
Appendix B7

Title
Historical Landslides and Areas of Cliff Erosion (1972)

Notes
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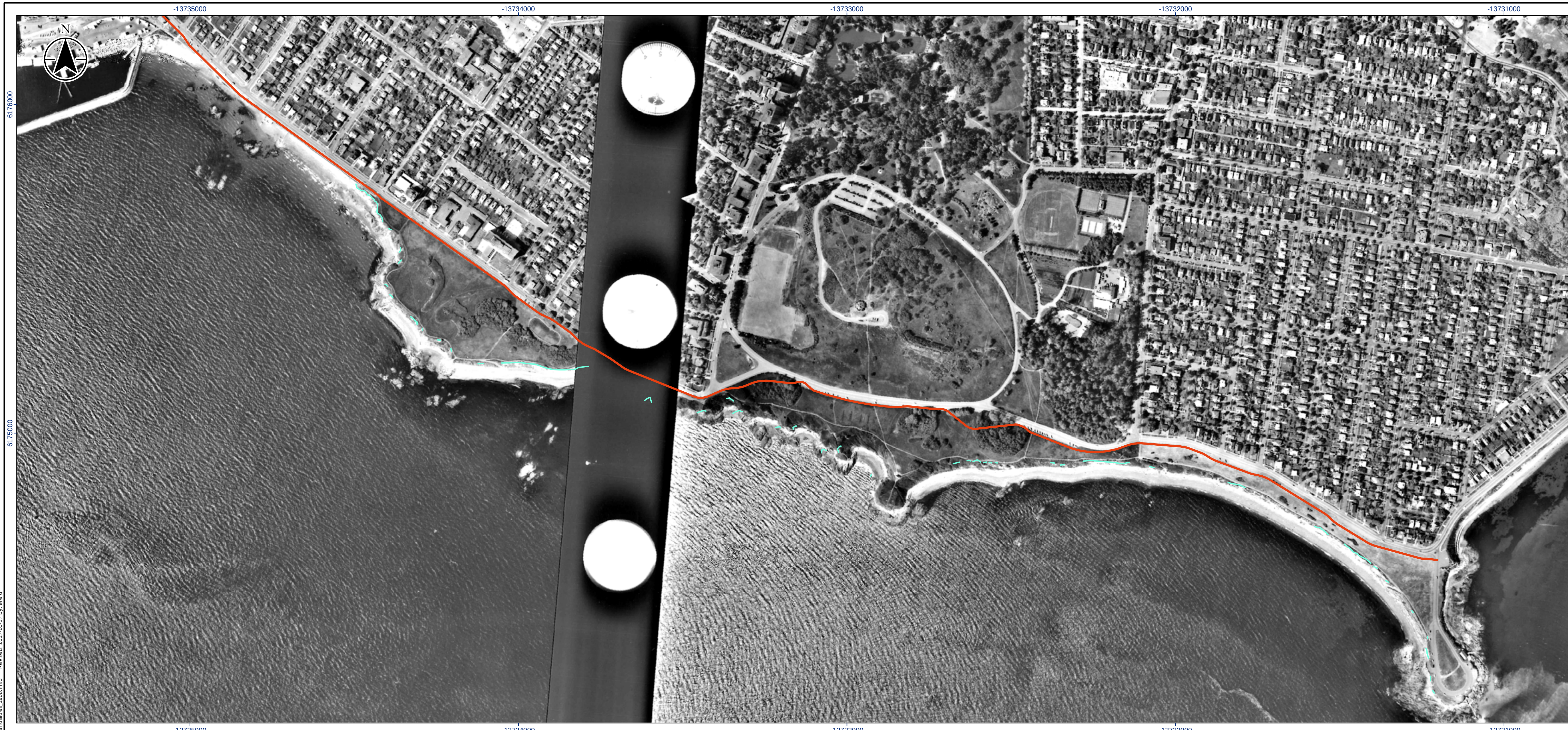

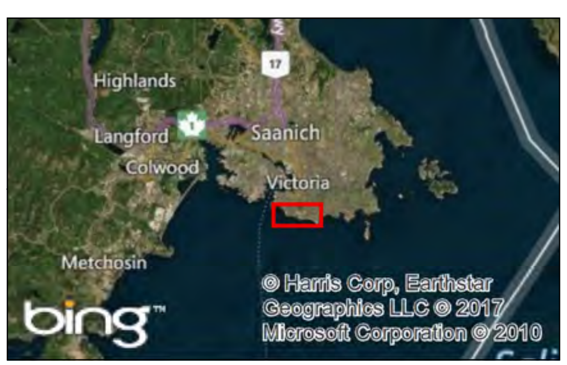

1968 Landslides

Preliminary Forcemain Alignment

0 230 460 metres

1:12,000 (At original document size of 11x17)

Project Location

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Client/Project

Capital Regional District
Dallas Road Cliffs Historic Foreshore Erosion Assessment

Figure No.

Appendix B8

Title

Historical Landslides and Areas of Cliff Erosion (1968)

Notes

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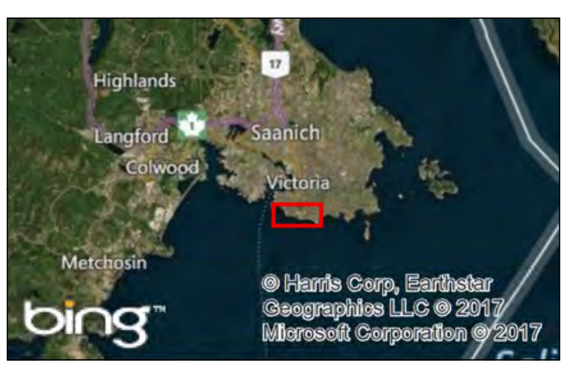

1964 Landslides

Preliminary Forcemain Alignment

0 230 460 metres

1:12,000 (At original document size of 11x17)

Notes
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Figure No.
Appendix B9

Title
Historical Landslides and Areas of Cliff Erosion (1964)

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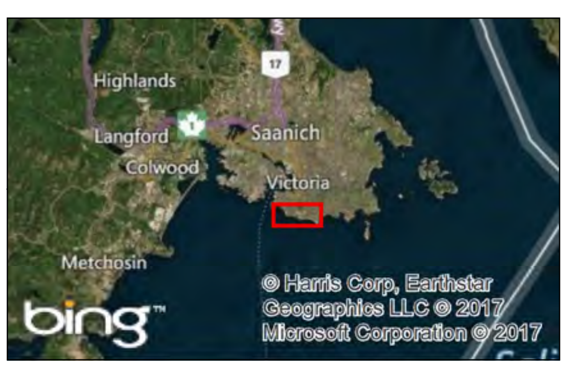

1956 Landslides

Preliminary Forcemain Alignment

0 230 460 metres

1:12,000 (At original document size of 11x17)

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Erosion Assessment

Figure No.
Appendix B10

Title
Historical Landslides and Areas of Cliff Erosion (1956)

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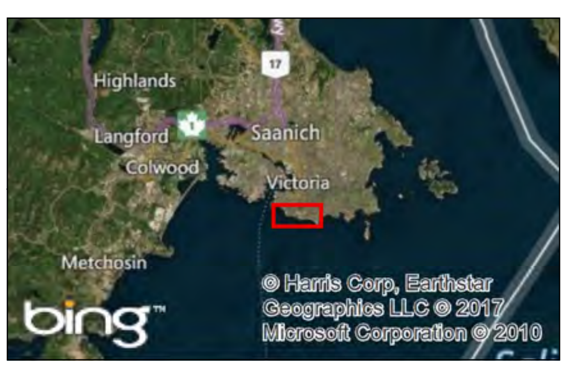

1948 Landslides

Preliminary Forcemain Alignment

0 230 460 metres

1:12,000 (At original document size of 11x17)

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CRD Wastewater Treatment Project

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Independent Review by ST on 2017-05-29

Client/Project
Capital Regional District
Dallas Road Cliffs Historic Foreshore
Erosion Assessment

Figure No.
Appendix B11

Title
Historical Landslides and Areas of Cliff Erosion (1948)

Notes
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Appendix C HISTORICAL LANDSLIDES AND AREAS OF CLIFF EROSION TRANSFERRED BY HAND (METHOD 2)

Preliminary Forcemain Alignment

Hand Transferred Landslides

Field Sites

0 90 180 metres

1:5,000 (At original document size of 11x17)

Notes
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Stantec | CRD Wastewater Treatment Project

Project Location
Dallas Road
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Client/Project
Capital Regional District
Dallas Road Cliffs
Historic Foreshore Erosion Assessment

Figure No.
Appendix C1

Title
Historical Landslides and Areas of Cliff Erosion

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Preliminary Forcemain Alignment

Hand Transferred Landslides

Field Sites

0 90 180 metres

1:5,000 (At original document size of 11x17)

Stantec

CRD Wastewater Treatment Project

Project Location
Dallas Road
Victoria, BC

111700431 REVA
Prepared by ER on 2017-05-16
Independent Review by ST on 2017-05-29

Client/Project
Capital Regional District
Dallas Road Cliffs
Historic Foreshore Erosion Assessment

Figure No.
Appendix C**2**

Title
Historical Landslides and Areas of Cliff Erosion

Notes
1. Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
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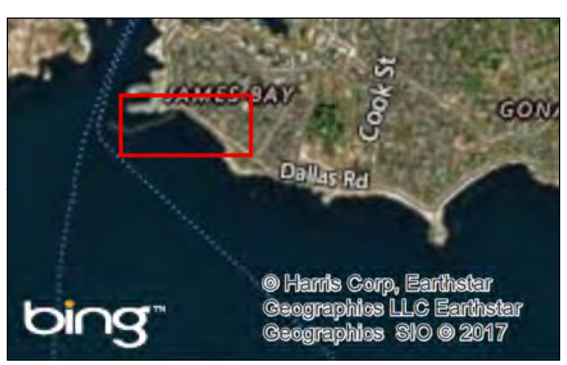

Preliminary Forcemain Alignment

Hand Transferred Landslides

Field Sites

0 90 180 metres

1:5,000 (At original document size of 11x17)

Stantec

CRD Wastewater Treatment Project

Project Location
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Client/Project
Capital Regional District
Dallas Road Cliffs
Historic Foreshore Erosion Assessment

Figure No.
Appendix C**3**

Title
Historical Landslides and Areas of Cliff Erosion

Notes
1. Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
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Appendix D SUMMARY OF HISTORICAL LANDSLIDE AND EROSION FEATURES

Feature Location Codes[1]	Air Photo Year	Comments/Changes
	1932	Insufficient detail for feature identification/classification. (no stereo)
	1946	Insufficient detail for feature identification/classification, sea cliffs visible, but it is not possible to distinguish discrete landslide or wave/surface erosion features. (no stereo)
A-Y	1948	Small to very small debris avalanche scars visible along the sea cliff at approximate locations A, D, E, F, H, I, J, K, L, P, Q, R (2 scars), S, T, U, V, X, Y and five scars between G and G'. A debris avalanche scar at J is partially vegetated as are possible old debris avalanche scars at M, N, and the slopes immediately NW and SE of location L. The exposed scarp slopes between D and D' are about 90 m long. An area of continuous toe slope erosion between locations B and B' and another short ~30 m-long section at C. There is a section of continuous debris avalanche scar between locations O and O', portions of which are partially vegetated. South of location A along the sea cliff to the point there are several very small debris avalanche scars.
B-B', C, D'-E, F-G, K-L, Z, 1-6	1956	The sea cliff erosion scar between B and B' is now continuous to C and extends about 50 m west of C. A small debris avalanche scar is present at Z. A partially vegetated erosional scarp is visible between D' and E and extending through F to location G. This partially vegetated scarp was not visible on the 1948 photos possibly due to a slightly smaller scale and lower resolution. Similarly, older revegetated to partially revegetated debris avalanche scars are visible on either side of location G marked as locations 1 and 2. Very small and small, fresh debris avalanche scars are visible at locations 3, 4, 5, 6. Location 6 may represent surface erosion resulting from foot traffic and runoff from the upslope trail. Between locations K and L are four or five vegetated concave features that may be old debris avalanche scars (red circles).
7-9	1964	Three small, fresh, debris avalanche scars are visible at locations 7, 8 and 9. New beach trail/path constructed below Paddon Avenue.
	1968	There are no obviously new landslides visible.

[1] Refer to historical landslide maps in Appendix C.

Feature Location Codes[1]	Air Photo Year	Comments/Changes
10	1972	There is one new landslide at location 10. There may be other recent small landslides, but the air photo scale is too small to detect others with certainty.
1, 10, 11-D', 12-17, O-O', U-V, 17-Y	1976	There is a concave, partially vegetated debris avalanche scar at location 10. This feature was likely present on previous air photos but was not visible due to scale and resolution. Similarly, there appear to be two older, almost completely vegetated, debris avalanche scars that form the sea cliff between locations 11 and D' (marked as red circles). Relatively fresh landslide scars are present at locations 12, 13, 14, 15, 16 and 17. Event 13 appears to have been a rotational slump rather than a debris avalanche. There is a visible deposition lobe on the beach at the toe of the slope. An older revegetated, concave, debris avalanche scar is present between locations 1 and 12 (red circle). Locations 14 and 15 indicate areas of recent movement on older vegetated landslide scars. Portions of the sea cliff between O and O' appear to have been recently or continuously active (they are non-vegetated), while other areas are partially vegetated. There are several non-vegetated, very small, narrow landslide scars or gullies visible between locations U and V. These may have been present for some time, but were difficult to identify with certainty on the earlier air photos due to scale and resolution issues. Construction (of lower seawall) is visible along the toe of the slope between locations 17, Y and about 20 m NW of Y. A relatively recent seawall and walkway is visible along the toe of the sea cliff between locations O and O'.
18, 15-16	1980	A small debris avalanche is present at location 18, otherwise there are no obvious new landslides. Many of the previously identified landslide scars are now vegetated or partially vegetated. A relatively new retaining wall is visible at the toe of the slope from a point midway between locations 15 and 16 to the end of the beach access pathway below location O.
13, 19, V-Y	1986	A small, fresh debris avalanche is visible at location 19, on the slope (fill slope?) below a walkway to the beach. The toe of the (1976) deposition lobe of the slump at location 13 that terminated on the beach has been partially removed, by wave action. Part of the toe scarp is still un-vegetated, but the rest of the landslide is vegetated. The reconstruction of the slope between location V and 20 m NW of Y has been completed, the slope is not vegetated.
7, 10	1992	There has been recent activity on the landslide scar at location 10 (or on the slope between locations J and 10), except for the base of the slope most of the scar is non-vegetated. This scar appears vegetated on the 1986 air photos. There appears to be fresh landslide activity at location 7.
A-B', D-D', O-O', 20, V-Y	1997	A rip-rap berm and footpath appears to have been placed along the base of the sea cliff between a point 70 m SSE of location A and a point 60 m SE of location B'. The slope between D and D' remains partially vegetated suggesting some ongoing erosion along the upper part of the slope.

Feature Location Codes[1]	Air Photo Year	Comments/Changes
		A section of the Holland Point seawall between locations O and O' appears to have been repaired in one location. There appears to be a slump developing in the slope at location 20. The fill slope between location V and 20 m NW of Y is partially vegetated, but there appears to be some gullying or small, narrow, shallow landslides occurring on the surface of the slope.
6, K, K-U, U, V, X-Y	2005	There appears to be recent landslide activity at locations 6, K, U, and V. Two small gullies or small narrow landslides midway between locations U and K appear to be enlarging as they are un-vegetated. The lower portions of the constructed slope between locations X and Y are still poorly vegetated and may be experiencing minor, ongoing debris avalanche activity (headscarp retrogression?).
6, L, K, K-U, U, J	Google Earth 2015	The landslides at 6, L, U and K are poorly vegetated as are the two small gullies between U and K. There is recent debris avalanche activity at location L and possibly J.

Appendix E SITE OBSERVATIONS

Site	UTM Zone 10 Northings (m)	UTM Zone 10 Eastings (m)	Elevation (m asl)	Slope (%)	Soil Drainage	Terrain Code[2]	Comments	Photo
ST17-001	536250	471604	0.00	0	n/a	n/a	Point of commencement at west end of James Bay seawall parking stall by Dock Street crosswalk.	-
ST17-002	536251	471543	3.50	40-90	Well	sMb	3 m high exposure of sandy till between glacially smoothed bedrock; < 5% coarse fragments; evidence of minor surface erosion.	P3230412
ST17-003	536222	471934	3.06	5	Rapid	sgWAp-W	Foot of southeast end of James Bay seawall and beach.	P3230429
ST17-004	536218	471976	0.00	80	Well	zsMb	2-3 m high exposure of sandy till over glacially smoothed bedrock.	P3230439
ST17-005	536211	472021	0.00	80	Well	zsMs-V	Active gully erosion exposing ~1 m of silty sandy till.	P3230449
ST17-006	536206	472033	0.00	85-90	Well	zcWGs[zsMs]-R^s	Active shallow debris avalanche on 8-10 m high scarp exposing glaciomarine silty clay overlying silty sandy till.	P3230452
ST17-007	536200	472017	0.00	60-90	Well	czCvb[czWGs or czMs] // yWs - R^sV	Active debris avalanche-rotational slump in silty till or glaciomarine sediments. Debris lobes along lower 6 m of toe slope. ~1.8 m high headscar.	-
ST17-008	536198	472030	4.00	40-90	Well	zcWGs . zcCvb - R^s	Active debris avalanche in glaciomarine silty clay. ~1 m high headscar.	P3230458
ST17-009	536194	472063	0.15	60-70	Well	zsMks-V	Outlet pipe exposed in small gully mid-slope on 5-6 m high cliffs in silty sandy till.	P3230460
ST17-010	536187	472136	0.00	40-120+	Well	zcsMs/zcsCh-R^s	Shallow rotational slump on 6 m high cliff in silty clayey sandy till. ~1.5-2.0 m	P3230466

[2] Refer to Terrain Classification System for British Columbia Version 2, 1997 for explanation of terrain codes.

Site	UTM Zone 10 Northings (m)	UTM Zone 10 Eastings (m)	Elevation (m asl)	Slope (%)	Soil Drainage	Terrain Code[2]	Comments	Photo
							deep, 12 m wide, 15 m long (downslope).	
ST17-011	536186	472176	0.00	75	Well	Ms-R^s	Small (10 m wide x 2.5 m high) slide in 6 m high cliff exposing till above sea wall.	P3230471
ST17-012	536182	472472	-0.47	90	Well	Ms?	Vegetated cliff above east end of lower seawall. Below Paddon Avenue.	P3230479
ST17-013	536177	472683	0.00	70-85	Well	xcsAs	Placed fill below Dallas Road and Douglas Street intersection by steps down to beach. Blocks up to 0.8 m diameter. Toe slopes exposed by wave erosion.	P3230503
ST17-014	536175	472645	0.00	70-100	Well to rapid	Ms	Till exposed along headland. Bedrock exposed along shoreline.	P3230504
ST17-015	536171	472884	-0.99	55	Well to moderately well	zcWGk // zcCh - R^sF^u	Active translation-rotational slide (8-10 m wide x 1.2-2.0 m deep x 16 m long). Contorted bedding in glaciomarine silty clay	P3230517
ST17-016	536165	473004	-3.98	52	Well	zcWGk . zcCh - R^s	Site of 1976 Horseshoe Bay landslide is grassed over. Rip-rap berm placed along toe slope.	P3230536
ST17-017	536163	473176	-8.78	80+	Well	sW[zcsM]	Exposed cliff with sandy marine(?) overlying sandy till.	P3230548
ST17-018	536164	473352	0.00	100+	Well	zsMs-R^s	Shallow, translation slide on 6-7 m high cliff exposing sandy till.	P3230552
ST17-019	536161	473679	0.00	100+	Well	Ms-R^s	~15 m high cliff exposes sandy till	P3230559
ST17-020	536158	473759	0.00	100+	Well to rapid	Flow till	~15 m high cliff; till likely described as flow till by Hicock et al. 1981.	P3230561
ST17-021	536143	474006	4.27	70-100	Well	sgWGvb[M]	~1 m of well-developed organic soil in glaciomarine sand and gravel overlying till exposed along top of cliff.	P3230568
ST17-022	536200	472022	4.90	50-80	Well	czCvb[czWGs or czMs] - R^sV	Site at top of translational-rotational slide in silty till or glaciomarine sediments which is grassed over. No tension cracks observed along the top. 3-4 small gullies observed. Upslope of ST17-007.	P3240589

Site	UTM Zone 10 Northings (m)	UTM Zone 10 Eastings (m)	Elevation (m asl)	Slope (%)	Soil Drainage	Terrain Code[2]	Comments	Photo
ST17-023	536198	472032	5.16	40-90	Well	zcWGs . zcCvb - R^s	Site at top of translational-rotational slide. 5-6 m high cliffs. ~1 m high exposed headscar. Lobate debris pile at toe slope. Same as ST17-008.	P3240591
ST17-024	536193	472074	5.21	80-140	Well	WGv[Ms]-R^s	Top of grassed over headscar. Veneer of glaciomarine sediments overlying till. ~5 m high cliff.	P3240593
ST17-025	536191	472100	5.12	60-120	Well	Ms-R^s	Site at top of translational-rotational slide. ~5 m high cliffs. ~1 m high exposed headscar in till. Minor surface erosion observed along headscar.	P3240596
ST17-026	536187	472142	0.00	40-120+	Well	zcsMs/zcsCh-R^s	Site at top of shallow rotational slump. 6 m high cliff in silty clayey sandy till. Same as ST17-010.	P3240597

Appendix F FIELD PHOTOS

Site ST17-002

Site ST17-003

Site ST17-004

Site ST17-005

Site ST17-006

Site ST17-008

Site ST17-009

Site ST17-010

Site ST17-011

Site ST17-012

Site ST17-013

Site ST17-014

Site ST17-015

Site ST17-016

Site ST17-017

Site ST17-018

Site ST17-019

Site ST17-020

Site ST17-021

Site ST17-022

Site ST17-023

Site ST17-024

Site ST17-025

Site ST17-026

Appendix G STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec's present understanding of the project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

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INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec at the time of the work at field observation locations (i.e., specific sites, areas, or traverses) and through interpretation of both hardcopy aerial photography and satellite imagery. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated behaviour of materials or geomorphic processes. Extrapolation of in situ conditions can only be made to some limited extent beyond the field observation locations. The extent depends on variability of the soil, surficial materials, bedrock, soil moisture and groundwater conditions as influenced by geological processes, construction activity, and land use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report, Stantec must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec will not be responsible to any party for damages incurred as a result of failing to notify Stantec that differing site or sub-surface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec, sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc.), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer or geoscientist; Stantec cannot be responsible for site work carried out without being present.