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January 9, 2012

VAN-09102075-01

BC Conservation Foundation
#3-1200 Princess Ave.
Nanaimo, BC, V9S 3Z7

Email: cwightman@bccf.com
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Attention: Mr. Craig Wightman

Re: Broadway Run, Cowichan River, BC
Supplemental Geotechnical Investigation for Slope Stability Review

Dear Mr. Wightman:

1.0 INTRODUCTION

Exp Services Inc. has completed a geotechnical assessment of apparent slope instabilities adjacent to the Cowichan River in an area known as Broadway Run. Our assessment generally conformed to the scope of work presented in our proposal dated March 22, 2010. The purpose of our study was to provide opinions related to the possible mechanism(s) of observed slope failures, indicate potential influences that future failures may have on the river and provide recommendations for monitoring of slope activity and mitigative action plans. This report is supplemental to our report titled "Slope Stability Review, Broadway Run, Cowichan River, BC", dated February 17, 2010.

Information used during the course of our study includes:

- Reports related to sediment loads in Cowichan River;
- Surficial geology plan map (Soils of South Vancouver Island, British Columbia, Soil Report No. 44, Sheet 1);
- Topographic plan maps;
- Aerial Photographs from 1968 to 2005;
- An aerial photograph mosaic of the river showing changes in channel alignment over the period 1968 to 20005;
- A LIDAR survey conducted over the lower portions of the slope in the summer of 2009;
- Site reconnaissance during both dry and wet times of the year with significant features located with a hand held GPS unit and photographed;
- Three solid stem auger holes drilled to depths ranging from about 12 to 18 m with a single Dynamic Cone Penetration Test completed to a depth of about 10.5 m;

Attached to this report are a Location Plan, Site Plans (Test Hole Location Plan and Recommended Monitoring Location Plan) and Schematic Slope Sections.

2.0 SITE DESCRIPTION

The study area under review is approximately 150 m in length and is located on the south side of the Cowichan River, flowing in a southeast to east direction, in a section known as Broadway Run. The river alignment in this area begins a gentle curve to the east with the study area being on the outside on the bend (see Drawing 091-02075-05). The south bank of the river is located at the toe of a mountain within the Seymour Range, which rises to an elevation of about 950 m geodetic. The study area is located approximately 15 km west of Duncan, BC where the Cowichan River outlets into the ocean.

Access to the study area is via an existing private forest road which ends near the site. From the private forest service road to the study area access is by foot via old logging roads. The old logging road was rehabilitated and additional access roads constructed to allow the drill rig to access the site for this report.

Vegetation within the study area generally consisted of a wide variety of trees and underbrush in the lower areas with the upper areas having been recently logged. Many of the trees, particularly within about 100 m of the river exhibited curved trunks. Underbrush in the lower areas of the slope frequently consisted of ferns, skunk cabbage and other wetland vegetation.

Site reconnaissance was conducted in the summer and fall of 2009 and the spring of 2011, primarily in the area from the river to about 200 m south (upslope) of the river. The south bank of the river consisted of a small, near vertical incised slope about 0.6 m in height. Soils exposed by river erosion appeared to consist of varved silty clay with trace to some sand. There appeared to be some small areas of active soil flows and recent deposits of sand and gravel in small fan features. These features along the river bank appear to have originated from seepage within slopes immediately adjacent to the river bank.

Above the river bank, ground topography rises steadily with an average inclination of approximately 20^{o}, although the area is hummocky with local slopes varying from flat lying to steeply inclined. Localized, hummocky areas with small soil scarps above were common, particularly within about 100 m of the river. In these hummocky areas, tree trunks were noticeably curved and numerous fallen trees were noted. About 50 m from the river an area of scarps approximately 50 m in length and up to about 8 m in height was noted. There was minimal vegetation covering the surface in this area and sloughed soils were observed at the toes of slopes in this area. During our site reconnaissance conducted in the fall, this area was noted to have undergone active erosion, in addition soil flows originating from the steep slopes were observed. The slopes had undergone significant changes between the summer and fall site reconnaissance. Exposed soils in this area were generally identified as dense sand and gravel with trace to some silt overlain by silt. Surficial silts were noted to become very soft when saturated, both in place and where sloughed silt had been recently deposited.

Approximately 200 m from the river, a long continuous, near vertical scarp about 2 to 3 m in height trending sub-parallel to the river was noted. Topography immediately above the crest of the scarp flattened with the ground surface below the scarp appearing hummocky. Soils exposed in this scarp generally consisted of very dense silty sand with some gravel, cobbles and small boulders (till-like). Vegetation in the area of the scarp generally consisted of ferns and deciduous trees with some stumps left from previous logging. The scarp appeared unchanged between the summer and fall reconnaissance.

A brief visual reconnaissance along an existing logging road above the study area noted slope cuts constructed for the road generally consisted of bedrock with localized areas of thin soil veneers overlying the bedrock.

3.0 SUBSURFACE CONDITIONS

Geotechnical exploration for this study included visual reconnaissance of the site in both dry and wet conditions, drilling of three solid stem auger holes completed to depths from about 1 m to 18 m, and a DCPT completed to a depth of about 10 m on June 8, 2011. A Site Plan with test hole locations (Figure 2) and test hole logs are attached to this report.

Subsurface soils encountered in the test holes generally consisted of silt, with trace to some sand and gravel. Layers of silty sand were encountered in TH 11-1 and TH 11-3. These silty sand layers would likely provide a path for groundwater during times of high precipitation, due to their high permeability relative to the surrounding silt layers. A section derived from the LIDAR survey show the test holes with generalized description of soils encountered in each hole attached to this report (Drawings 091-02075-05).

The DCPT indicated that subsurface soils are generally firm to very stiff with the exception of some of the soils within about the upper 1 m of the soil, which were loose. The results of the DCPT are shown on the attached log for TH 11-1.

In general, soils encountered in Test Holes and observed in scarps near the south river bank within the study area, were typical of glacio-lacustrine deposits. Exposed soils in the upper scarp, 200 m from the river, are typical of glacial till. The glacio-lacustrine soils were likely deposited adjacent to the till deposits following down-cutting into the till by glacial melt water. A subsequent damming or plugging of the watercourse may have resulted in observed lake deposits immediately adjacent to the river.

Groundwater was encountered in TH 11-2 and TH 11-3 at depths of 5.6 m and 6.1 m respectively. The presence of groundwater in TH 11-2 and TH 11-3, but not TH 11-1, indicates that the groundwater encountered was likely localized perched water tables, possible within thin sand layers not identified during drilling. It should be noted that groundwater levels typically fluctuate with changes of season, intensity and duration of precipitation, local land use and other factors.

4.0 SLOPE STABILITY

Curved tree trunks and hummocky terrain are indicative of ongoing soil movement. The lower portion of the slope, within approximately 50 m of the river's edge, appears to be the area where the most active marginally stable slopes are located; however, indications of slope movement were noted as far upslope as the old road. The slope failures in this area appear to be relatively shallow and localized with the most prominent failure being about 50 m across, located about 40 m from the river (see Drawing 091-02075-06). Significant changes to slopes in this area occurred between summer and fall reconnaissance indicating that slope instabilities in this area are likely sensitive to water infiltration.

A possible mechanism for the lower slope instabilities is surface water infiltrating the soils and flowing along the soil/ till contact until encountering a permeable layer of sand where it flows through the permeable layer back to surface. As the groundwater flows exit the permeable layer it removes some of the granular soil destabilizing the overlying silt layers. The presence of permeable layers, relative to the more prevalent silt layers in the test holes, supports this interpretation as a likely mechanism for small scale slope failures in the lower portions of the slope. In addition, the presence of groundwater in the confined aquifers is likely increasing pore pressure in the cohesive soils (silt) adjacent to the aquifer reducing the stability of the slopes resulting in some shallow depth rotational failures.

The presence of the upper scarp along with numerous smaller scarps and slide features closer to the river indicates existing slope stability within the study area has a Factor of Safety close to 1.0. The continuity of the upper scarp is indicative of a potential large scale deep seated slope failure; however this slope instability appears to be ancient and there was little evidence of continued movement along this scarp during our site reconnaissance. It is considered unlikely that this large scale slope failure extends into the till-like soils below the glacio-lacustrine deposits (a depth of about 11 m in TH 11-2 downslope of the scarp).

Erosion of the toe of the slope by the river appears to be ongoing; however the majority of the noted slope instabilities are located away from the river, the river is not considered to be a significant cause of the slope instabilities at this time. It should be noted that the study area is located on the outside of a river bend and as such future erosion of the bank may be anticipated. Should significant erosion of the river bank causing regression of the slope toe, large scale slope instabilities, such as the reactivation of the upper scarp, may occur. Based on the test hole information it appears that a very dense till-like soil layer, overlying bedrock, projects to the approximate elevation of the river bottom; hence, it is considered unlikely that the river will further erode the bottom of the channel at an appreciable rate and river movement will generally be in a lateral direction into the slope toe.

5.0 DISCUSSION AND RECOMMENDATIONS

It appears silt deposition into the river within the study area is originating from both erosion of the river bank and from small scale failures and soil flows in the slopes adjacent to the river. Erosion of the river banks in this area at this time generally consists of fans from small scale slope failures adjacent to the river which are being eroded, depositing silt into the river. It should be noted that it appears that erosion of the slope toes is not a major source of slope failure and slope failures upslope of the river are not likely a major contributor to silt deposition into the river at this time. However; as discussed above the small scale slope failures and soil flows are likely to influence the river over time as the failures and deposition areas increase in size. In addition, any future erosion of the slope toe by the river will likely activate significant small scale slope failures near the river and there is also potential for large scale slope failures to occur, including remobilization of the old slide delineated by the upper old scarp. Such large scale failures would likely severely influence the river including potential river blockages.

Recommended mitigation and monitoring programs with respect to slope stability and silt deposition into the river would address the three identified potential sources of silt deposition during our study. Recommended mitigative measures and monitoring programs and relative priority are provided below.

5.1 River Bank Erosion

As discussed above, silt deposition into the river bank due to erosion within the study area is primarily from fans created by slope instabilities near the river. Mitigation of river bank erosion would consist of placement of rip rap near the river bank. We recommend the rip rap berm be constructed within a trench offset from the existing river bank for constructability and environmental reasons. The rip rap should be suitably sized for the design flood velocities and founded with an invert level below scour elevation of the river.

Due to the potential consequences of river erosion undermining the existing marginally stable slope toe and mobilizing significant volumes of silt (from about 12 to 18 m thick) adjacent to the river the construction of a rip rap berm to mitigate such erosion is considered a high priority.

5.2 Small Scale Slope Failures

Small scale slope failures, generally within 100 m of the river banks, consist of silt layers undercut by groundwater moving through permeable layers within the subsurface and removing material. Additional surficial slope movement was also identified within the study area as indicated by scarps, undulating topography and curved tree trunks. The primary active slope failure is located about 40 m from the river bank (see Drawing 071-02075-04) and was noted to have experienced significant changes over the relatively short time period between the spring and fall reconnaissance. We recommend that this particular area be mitigated by placement of 75 mm minus well-graded pit run sand and gravel immediately against the slope, overlain with well-graded 300 mm minus shot rock. Both materials recommend above should have less than 5% fines passing the #200 (75 µm) sieve in order to provide drainage for groundwater. The shot rock layer should be at least 450 mm thick and be inclined between 1.5H: 1V to 2.0H: 1V. The fill material should be keyed into the subgrade at least 0.75 m with base preparations consisting of removal of all soft, loose or other unsuitable soils and placement of a layer of shot rock at least 300 mm thick to provide a level and firm foundation.

The purpose of these works is to allow the groundwater to exit the subsurface while retaining the sand particles preventing further undermining of the overlying silt layers. As noted above the area of the proposed mitigation is about 50 in length and 8 m in height. A sketch of the proposed mitigation is presented in Drawing 091-02075-07.

Other noted small scale slope failures should be monitored along with the monitoring for large scale slope monitoring (see below) to assist in prioritization of future mitigation in the study area, if required. The installation of a monitoring system is considered to be of medium priority. If the installation of the monitoring system not be possible in the short term continued visual monitoring of the area is recommended.

5.3 Large Scale Slope Failures

As discussed previously, there is potential for large scale slope failures to occur which would significantly influence the river by impeding flow and/or introducing additional silt load to the river. It is anticipated that such large scale slope failures would be progressive in nature and sudden significant movement is considered unlikely. To assess long term large scale patterns of progressive slope movement within the study area we recommend a monitoring program be established. Monitoring should extend from the river bank to an area above the old scarp, about 200 m from the river bank.

Monitoring should consist of permanent survey markers located in areas where they are unlikely to be disturbed over the long term. The survey markers should be easily located over a period of several years. At least two markers should be installed above the old scarp in areas, where it is considered that soil movement is unlikely, to serve as benchmarks against which other marker positions can be compared. Additional markers should be installed along the toe of the old scarps and in several locations within the lower unstable areas. Approximate recommended locations for survey markers are shown on the attached Drawings 091-02075-04; however final locations should be determined in the field. Data collection should include the horizontal and vertical positions of the survey markers. Measurement data should be collected every 6 months for the first three years, with frequency of data collection re-evaluated following analysis of the measurement data for this period.

If the survey data indicate the large scale slope movement is ongoing, remedial measures such as moving the river away form the slope may need to be considered. Due to the significant consequences of potential large scale slope movement the implementation of slope movement monitoring is considered to be a medium priority.

6.0 CLOSURE

Exp has completed our geotechnical assessment of slope stability based on our characterization of subsurface conditions within the study area. Our characterization of subsurface conditions was based on the geotechnical exploration program, site reconnaissance, topographic plan maps, surficial geology plans, aerial photographs, previous reports regarding other portions of the Cowichan River and our experience with similar sites throughout British Columbia.

This report was prepared for the exclusive use of our client, the BC Conservation Foundation, and their designated consultants and agents and may not be used by other parties without written consent of **exp** Services Inc. The attached "Interpretation & Use of Study and Report" forms an integral part of this report and must be included with any copies of this report.

Sincerely,

exp Services Inc.

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
E. G. SYKES
Jan 11/12

Evan Sykes, P.Eng.
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Reviewed by:

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Enclosure: Interpretation & Use of Study and Report
Location Plan (Drawing 091-02075-01)
Cross Sections (Drawings 091-02075-03 rev 1 & 04)
Site Plan – Test Hole Locations (Drawing 091-02075-05)
Site Plan – Approximate Monitoring Locations (Drawing 091-02075-06)
Schematic Small Scale Slope Instability Mitigation (Drawing 091-02075-07)
Test Hole Logs

LE 2012 01 09 Supplemental Investigation

INTERPRETATION & USE OF STUDY AND REPORT

1. STANDARD OF CARE

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

2. COMPLETE REPORT

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

IN ORDER TO 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 THE REPORT

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

4. USE OF THE REPORT

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

5. INTERPRETATION OF THE REPORT

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

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 persons providing information.

c. To avoid misunderstandings, **exp** Services Inc. (**exp**) should be retained to work with the other design professionals to explain relevant engineering findings and to review their plans, drawings, and specifications relative to engineering issues pertaining to consulting services provided by **exp**. Further, **exp** should be retained to provide field reviews during the construction, consistent with building codes guidelines and generally accepted practices. Where applicable, the field services recommended for the project are the minimum necessary to ascertain that the Contractor's work is being carried out in general conformity with **exp**'s recommendations. Any reduction from the level of services normally recommended will result in **exp** providing qualified opinions regarding adequacy of the work.

6.0 ALTERNATE REPORT FORMAT

When **exp** submits both electronic file and hard copies of reports, drawings and other documents and deliverables (**exp**'s instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by **exp** shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancy, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by **exp** shall be deemed to be the overall original for the Project.

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