GEOPACIFIC
VANCOUVER KAMLOOPS CALGARY

1779 West 75 Avenue
Vancouver, BC
V6P 6P2
604-439-0922

Tiyata Developments Inc.
1495 Marine Drive
West Vancouver, BC V7T 1B8

(*Revised February 13, 2018)* December 20, 2013
File: 11027

Attention: Bruce Van Mook

Re: Geotechnical Review of Flood Hazards and Construction Recommendations, Proposed Sub-Division, Portage Road, Pemberton, BC

1.0 INTRODUCTION

We understand that it is proposed to carry out a comprehensive subdivision on a portion of the property described as LOT 3 DISTRICT LOT 203 LILLOOET DISTRICT PLAN KAP77917 and THAT PART OF DISTRICT LOT 203 LILLOOET DISTRICT SHOWN ON PLAN A20 EXCEPT PLANS KAP63162, KAP64875, KAP77917, KAP78331 AND EPP1760 (referred to as the lands). The proposed subdivision has been referenced from the subdivision plan prepared by McElhanney Associates Land Surveying Ltd. dated August 7, 2016, which is included in Appendix A of this report, and from the sketch plan of the proposed phased bare land strata plan prepared by McElhanney Associates Land Surveying Ltd., which is included in Appendix B of this report. It is proposed to subdivide the lands into a bare land strata development consisting of 65 single family dwellings and one mixed-use lot (referred to as Lot B in the attached subdivision plan), with the balance of the property attributed to parks and roads.

In accordance with Section 86(1)(d)(i) of the Land Title Act, the Village of Pemberton has asked Tiyata Developments Inc. to "*provide the approving officer with a report certified by a professional engineer or geoscientist experienced in geotechnical engineering that the land may be used safely for the use intended*". This report has been prepared to satisfy this request.

The property is situated within a flood hazard area and falls within the area governed by the "*Village of Pemberton Bylaw No. 716, 2012*". The property is situated on the Pemberton Creek alluvial fan and therefore is outside of the Lillooet River floodplain and falls within the area defined as "Requires Geotech" as shown on Schedule C of the bylaw.

GeoPacific has been asked to provide geotechnical recommendations for the proposed development with respect to the potential for flood hazards to affect the site and to provide recommendations for hazard mitigation if necessary.

We have reviewed the comprehensive flood hazard study prepared for the Village of Pemberton entitled "*Pemberton Creek Fan Flood/Geohazard And Dike Study*" prepared by Northwest Hydraulic Consultants Ltd., dated December 20, 2001 (NHC 2001) in preparation of this report.

This report presents our review of the flood hazards and provides geotechnical recommendations to mitigate the effects of flooding as required to allow us to conclude that the land may be used safely for this use intended.

2.0 SITE DESCRIPTION

2.1 General Description

The proposed subdivision site is located south of Portage Road, south and west of Signal Hill Elementary School, east and north of Pemberton Creek and north of Highway 99 in Pemberton.

The site is situated on the lower extremities of the Pemberton Creek alluvial fan. The site elevation gradually increases from about 210 m geodetic elevation in the southeast extremity of the property to 214 m at the northwest. The ground elevation increases from south to north at a grade of about 1.3% and from the southeast to the northwest at a grade of about 1.8%.

The majority of the site is vegetated with medium sized deciduous trees and underbrush. There are two roughed in access roads near the alignments of the proposed subdivision roads.

2.2 Pemberton Creek Dike

There is a dike along the left downstream bank of Pemberton Creek which is situated within the property limits. We understand that dike improvements were carried out in September 2002 as described in the reports:

> "Pemberton Dike Upgrade, Summary of Proposed Work" prepared by NHC, dated June 26, 2002 (NHC 2002a) and
>
> "Pemberton Dike Upgrade, As-Built Report" prepared by NHC, dated December 18, 2002 (NHC 2002b).

Review of these reports indicates that the dike adjacent to the BCRP site was upgraded to Ministry of Water, Land and Air Protection (MWLAP) standards from the apex of the fan to approximately 100 m downstream of the rail bridge (NHC 2002b) to the southern property line of the proposed development site. We understand the following this work the dike was considered a "standard dike".

We understand that dike improvements were required by the Corporation of the Village of Pemberton in order for BCRP to be permitted to develop their land for housing (NHC 2002b).

We understand that further dike upgrades were carried out by the Pemberton Valley Dyking District (PVDD) in the summer of 2016 to address erosion issues along the dike and that the dike was further raised to meet provincial requirements.

We understand that a right-of-way is in place for maintenance.

GeoPacific has not been asked to carry out a geotechnical assessment of the dike.

3.0 SUBSURFACE CONDITIONS

GeoPacific previously carried out a geotechnical investigation for the lands which include those currently being considered for development. The investigation included 16 test pits excavated through the alluvial fan materials and into the underlying floodplain deposits. The results of this previous investigation and geotechnical recommendations for the subdivision are presented in our report dated January 9, 2013, entitled "Preliminary Geotechnical Report".

4.0 LILLOOET RIVER FLOOD HAZARD

The "*Village of Pemberton Bylaw No. 716, 2012"* provides flood construction levels (FCL's) for structures within the Lillooet River floodplain. The bylaw is based on the floodplain mapping carried out in 1985 and issued by Environment Canada in 1990 and considers a 1 in 200 year event. The proposed development site is outside of the Lillooet River floodplain defined on the map, although, the floodplain is located immediately east of the development site. The FCL on the adjacent lands to the east is interpreted to range from 209.6 m to 209.8 m elevation, increasing from the south to the north, based on linear interpolation of the isograms on the map. Based on the survey by R.B. Brown the minimum site elevation occurs at the southeast corner of the site and is about 210.0 m.

Although the development site is outside of the mapped floodplain it should be recognized that a hazard from flooding associated with the Lillooet River does exist although the likelihood of floodwaters reaching elevations above those of the development site is low with a probability of occurrence of less than 1 in 200 years.

There is no dike between the defined 200-year Lillooet River floodplain and the proposed development lands. Therefore, the lands could be subject to erosion should high water velocities or a shift in watercourse occur.

It should be appreciated that the 2012 Bylaw and our review are based on a review of the floodplain mapping carried out in 1985 and provided by Environment Canada in 1990. The geometry and channel capacity of the Lillooet River may have changed since the mapping was carried out which could affect the FCL. Further, the influence of any dikes, channel maintenance and new developments constructed since the mapping was done could affect the FCL. Therefore, there may be some uncertainty associated with the FCL based on the bylaw and reference materials available. The degree of uncertainty will persist until such time as a new comprehensive study of the floodplain is carried out and new FCL recommendations are available for reference.

5.0 PEMBERTON CREEK ALLUVIAL FAN

5.1 General Comments

The proposed development site is located within the Pemberton Creek alluvial fan deposition area which is located within the Lillooet River valley. The alluvial fan is a cone shaped deposit comprised of stream sediments and likely debris flow deposits which have been deposited as the stream has shifted position across the fan from its apex. The position of the apex of the fan is structurally controlled by bedrock. The fan has been deposited on top of (and likely within) the Lillooet River deposits as confirmed by our previous investigation and test hole logs.

5.2 Debris Flow Hazard

GeoPacific was previously requested to review and provide an opinion of the debris flow hazard posed by Pemberton Creek to the proposed development site. The details of our site reconnaissance and hazard review are presented in our report entitled "Geotechnical Review of Pemberton Creek Debris Flow Hazard" dated December 11, 2013.

Our review concluded that there is a low probability of a debris flow affecting the proposed development site corresponding to a range of annual probability of occurrence of 1/2500 to 1/500.

Based on the low probability of occurrence it was concluded that no special mitigation measures were

necessary to mitigate the effects of a debris flow at this site.

5.3 Pemberton Creek - Flood Hazard

The flood hazards associated with Pemberton Creek to the proposed development site include the following:

(1) Flooding associated with back-up of the creek due to restricted flow and/or blockage of the creek where it passes below Highway 99.
(2) Flooding associated with major slush events such as that which occurred in 2007.
(3) Flooding associated with constriction due to debris, logs, ice or snow blockages within the creek channel causing backup and overflow of the creek channel.

5.3.1 Flooding / Backup

We have reviewed the results of the flood modelling presented by NHC in their 2001. The hydraulic assessment considered the 200-year flood and complete blockage of the Highway 99 bridge and no blockage at the BC Rail bridge. The estimated FCL for the creek provided 1 m of freeboard which included a standard allowance of 0.6 m plus allowance for 0.4 m for sedimentation within the channel.

A 200-year maximum instantaneous flow of 104 m3/s was used by NHC in their 2001 flood model and is considered to be at the upper bound of end of the expected range (NHC 2001).

The longitudinal profile of the creek and cross-section stationing are included for ease of reference in Appendix C. The results of the NHC's 2001 hydraulic modelling are shown on their Table 5.4 which included in Appendix D for reference. The portion of the dike immediately adjacent to the proposed development site consists of the area from cross-sections 16 to 17 from the south end of the property to immediately south of the BC Rail bridge. Review of Table 5.4 indicates that there is sufficient freeboard (> 1 m) in the reach from cross-section 16 to 17 over the estimated 200-year flood level.

Review of the non-standard dike crest elevation to the south of the property indicates that it is below the estimated 200-year flood level.

The west bank of the creek consists of a "berm" (NHC 2001). We note that the berm is well below the estimated 200-year flood level and also below the elevation of the non-standard portion of the dike on the opposing side of the creek.

In our opinion, should a flood occur which approaches the estimated 200-year flood level, flood levels within the creek adjacent to the proposed development site are unlikely to exceed those estimated by NHC 2001 as the downstream berm and dike would overtop at much lower water levels and the topography is such that flows are unlikely to affect the BCRP land.

5.3.2 Outburst Flood and Slush Flood Events

There are historic reports of outburst flood events or wet avalanches occurring within the Pemberton Creek drainage dated back to the 1930's (NHC 2001). The events are thought to occur when the saturated snowpack slumps and temporarily blocks the creek until the eventual outburst sends a rush of slushy water downstream. NHC 2001 noted that Baumann (2000) concluded that the risks of outburst or slush floods related to snow avalanches is relatively minor.

A significant slush flood event occurred in December 2007 in which the Highway 99 Bridge became

blocked with snow and ice and flood waters overtopped the highway. We understand that this event was triggered when the snowpack on top of the creek collapsed into the creek causing blockage of the undersized passage beneath Highway 99. The blockage cause water levels to rise and an emergency response was needed to clear the snow and ice from the creek channel. We understand that a similar but lesser event occurred in 2010.

It is assumed that slush and/or outburst flood events would not produce water levels that exceeded the 200-year maximum instantaneous flow event (NHC 2001).

A study of how these events developed and the climactic factors which came together to cause the formation of slush and high water levels is beyond the scope of this report.

With respect to the proposed development lands we are of the opinion that construction of the proposed comprehensive development as planned would not contribute to an increase in likelihood of these events and due to the favorable grade of the development site would not likely be impacted by an outburst flood or slush flood event.

5.3.3 Channel Constriction Due to Debris /Log / Snow / Ice Jams

Flooding associated with other natural processes within the creek, such as debris, log, snow or ice jams, has the potential to cause the dike to be overtopped adjacent to the development site. Although these events are difficult to quantify we expect that they could occur at any point along the creek and could contribute to higher than expected flow conditions. To address the uncertainty of flooding related to these processes we are of the opinion that a flood mitigation strategy should be implemented as part of the proposed development.

6.0 HAZARD MITIGATION RECOMMENDATIONS

Following our review of the flood hazards which could impact the site, we recommend the following mitigation measures be implemented:

1. All structures should be constructed such that habitable space is located at least 1.0 m above surrounding finished grades. Finished grade is defined as the ground elevation directly adjacent to the foundation. Habitable space is as defined in the "*Village of Pemberton Bylaw No. 716, 2012"*.

2. The proposed finished grades should remain within 0.5 m of the existing site grade at any point on the property to help ensure the natural sloping topography is maintained. The existing site grades are shown on the Existing Grade Plan prepared by Webster Engineer Ltd. included in Appendix E.

3. All foundations should be buried a minimum of 1.0 m below final grades to help reduce the potential for undermining due to scour should overtopping of the dike occur. Due to the proximity to the creek foundations for Lots 54 to 59 should be buried a minimum of 1.5 m below finished grades.

4. All foundation walls below the main floor level should be constructed of reinforced concrete to an elevation of at least 1 m above finished site grades.

5. A 7.5 m setback should be maintained between the toe of the dike and any development on Lots 54 to 59. The area should be kept clear to allow for the passage of water, from the north to the

south, should overtopping of the dike occur.

6. A minimum of width of 1.8 m should be kept clear between the homes on Lots 54 to 59 to encourage water to flow down the natural gradient of the land should overtopping of the dike occur.

7. Overland flow would be expected to flow from the from high ground to lower ground (general from the northwest to the southeast). Any site grading should be such that the slope, and therefore surficial flow direction, is not changed or interrupted.

8. Flow velocities are expected to be relatively low; below 2 m per second. No significant earth fills are proposed. Additional erosion control measures are not considered necessary for these velocities. It is recommended that any exposed earth or small earth fills be sloped at less than 3H to 1V and be vegetated with grass and/or low lying brush to help reduce erosion potential.

9. All site preparation and earth fills should designed and reviewed by a Professional Geotechnical Engineer, in consideration of the proposed structural design and grading, for each of the individual lots at the time of construction.

10. A geotechnical engineer or otherwise Qualified Professional should be engaged by future property owners to confirm, in writing to the Village of Pemberton, that the Hazard Mitigation Recommendations described above have been implemented, prior to issuance of an occupancy permit.

7.0 ASSUMPTIONS

It is assumed that the adjacent dike currently in place on the property will be maintained in the future by the local Diking Authority to the a provincial "standard dike" condition.

It is further assumed that a sediment management strategy will be adopted by the local Diking Authority to manage sediment accumulation within Pemberton Creek to help ensure flows remain within the range estimated by NHC in their 2001 report.

8.0 CLOSURE

In accordance with Section 86(1)(d)(i) of the Land Title Act, and in consideration of the hazards described herein and assuming that the hazard mitigation strategies described in this report are implemented, we confirm that "the land may be used safely for the use intended". The phrase "used safely" is not defined in the act. In the context of this report "used safely" is interpreted to mean that the direct effects of the natural hazard itself are unlikely to cause structural damage so as to prevent egress from the buildings. GeoPacific is pleased to be of assistance to you on this project. We trust the foregoing is sufficient at this time.

For: **GeoPacific Consultants Ltd.**

February 16, 2018

Steven Fofonoff, M.Eng., P.Eng.
Principal

Reviewed by:

FEB 19 2018

Matt Kokan, M.A.Sc., P.Eng.
Principal

APPENDIX A

SUBDIVISION PLAN

SUBDIVISION PLAN OF: (1) PART OF THAT PART OF DL 203 LILLOOET DISTRICT SHOWN ON PLAN A20 EXCEPT PLANS KAP63162, KAP64875, KAP77917, KAP78331 AND EPP1760; (2) LOT 3 DL 203 LILLOOET DISTRICT PLAN KAP77917

PLAN EPP46258

BCGS 92J.036

0 50 100 150 m

ALL DISTANCES ARE IN METRES AND DECIMALS THEREOF

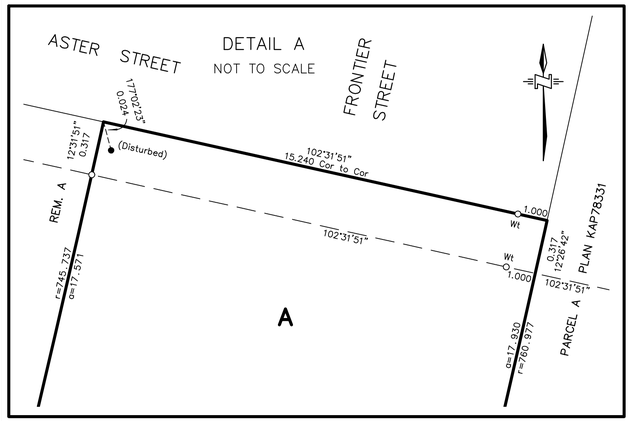
THE INTENDED PLOT SIZE OF THIS PLAN IS 864 mm IN WIDTH BY 560 mm IN HEIGHT (D-SIZE) WHEN PLOTTED AT A SCALE OF 1:1500

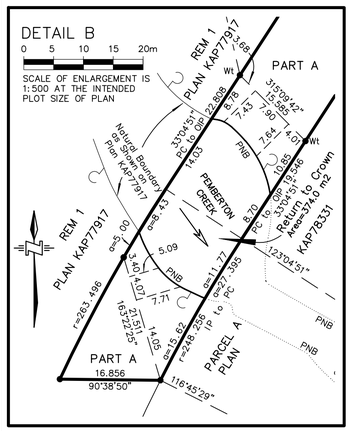
GRID BEARINGS ARE DERIVED FROM DIFFERENTIAL DUAL FREQUENCY GNSS OBSERVATIONS AND ARE REFERRED TO THE CENTRAL MERIDIAN OF UTM ZONE 10 (123° WEST LONGITUDE)

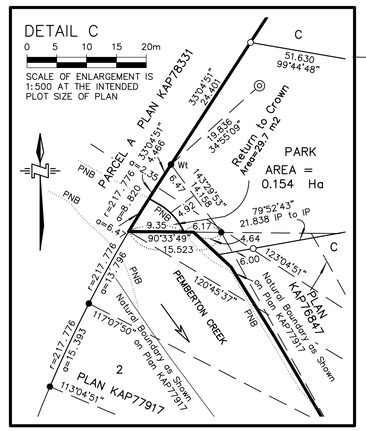
THE UTM COORDINATES AND ESTIMATED HORIZONTAL POSITIONAL ACCURACY ACHIEVED ARE DERIVED FROM DUAL FREQUENCY GNSS OBSERVATIONS TO CANADIAN ACTIVE CONTROL STATION WHISTLER (WSLR)

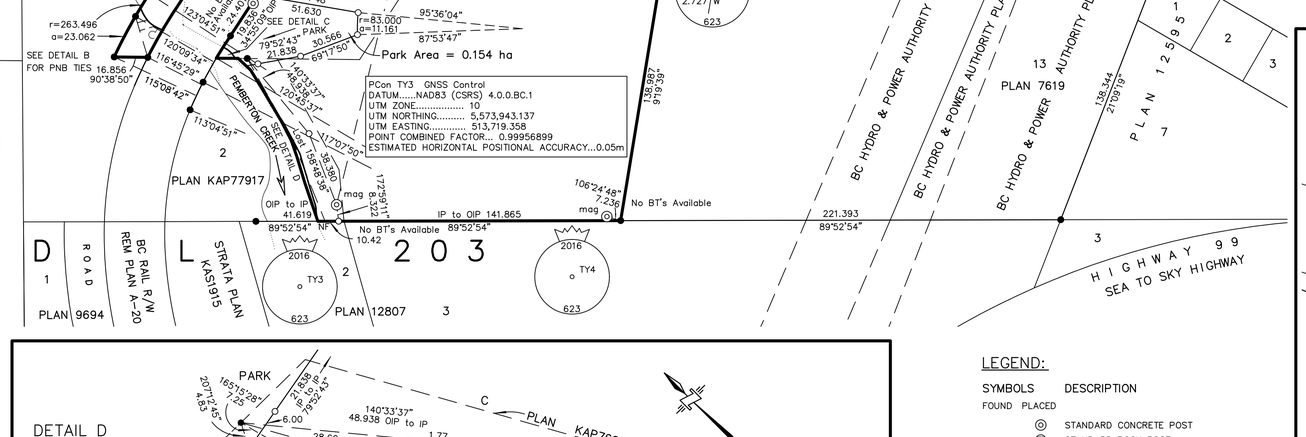
THIS PLAN SHOWS HORIZONTAL GROUND-LEVEL DISTANCES, UNLESS OTHERWISE SPECIFIED. TO COMPUTE GRID DISTANCES, MULTIPLY GROUND-LEVEL DISTANCES BY THE AVERAGE COMBINED FACTOR OF 0.99956924. THE AVERAGE COMBINED FACTOR HAS BEEN DETERMINED BASED ON AN ELLIPSOIDAL ELEVATION OF 197.44 METRES

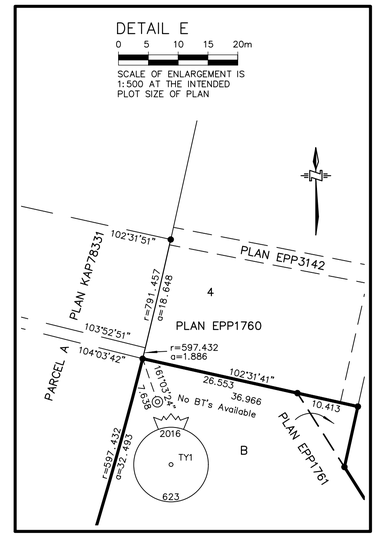
BOOK OF REFERENCE	
DESCRIPTION	AREA
LOT A – RETURN TO CROWN	374.0 m2
LOT C – RETURN TO CROWN PART	29.7 m2
LOT C – RETURN TO CROWN PART	69.5 m2
LOT C – RETURN TO CROWN TOTAL	99.2 m2

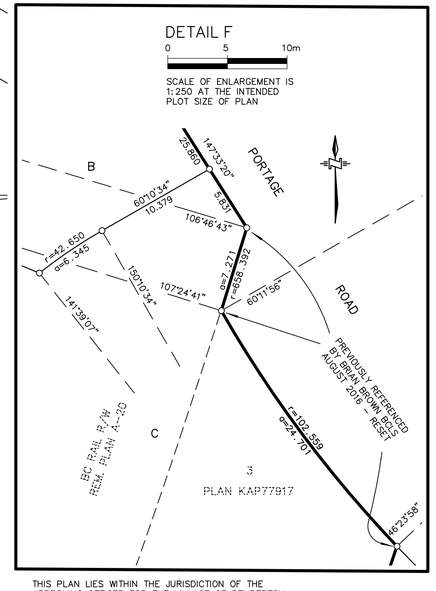


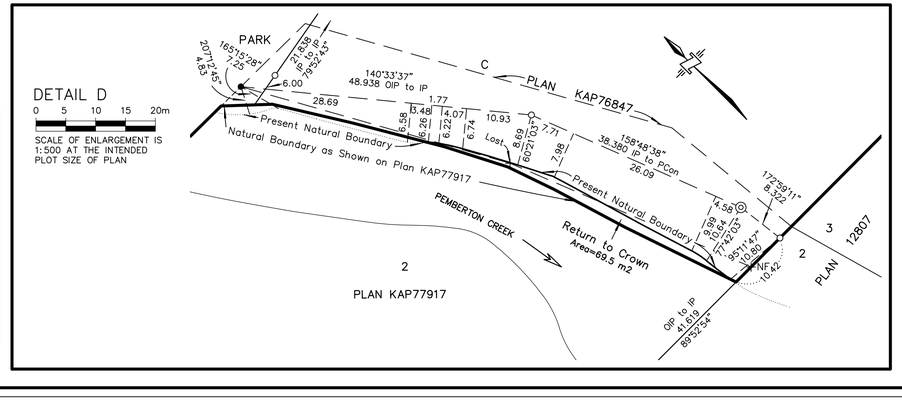


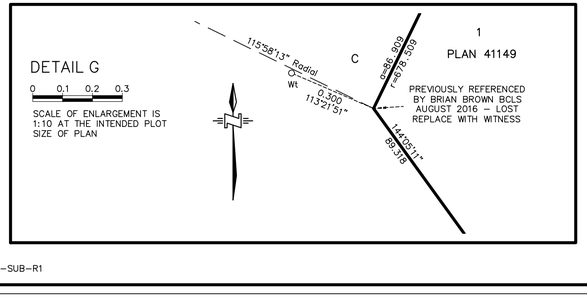












LEGEND:

SYMBOLS	DESCRIPTION
FOUND PLACED	
◎	STANDARD CONCRETE POST
⊡	STANDARD ROCK POST
⊙	STANDARD CAPPED POST
● ○	STANDARD IRON POST
m2	DENOTES SQUARE METRE(S)
REM	DENOTES REMAINDER
mag	DENOTES MAGNETIC PROPERTIES

NOTE:
THIS PLAN SHOWS ONE OR MORE WITNESS POSTS WHICH ARE NOT SET ON THE TRUE CORNER(S).

SOME POSTS ARE EXAGGERATED FOR CLARITY.

A COVENANT IN THE NAME OF THE VILLAGE OF PEMBERTON PURSUANT TO SECTION 219 OF THE LAND TITLE ACT IS A CONDITION OF APPROVAL FOR THIS SUBDIVISION

THIS PLAN NEED NOT COMPLY WITH SECTION 75 (1)(c) OF THE LAND TITLE ACT.

THIS PLAN LIES WITHIN THE JURISDICTION OF THE APPROVING OFFICER FOR THE VILLAGE OF PEMBERTON

THE FIELD SURVEY REPRESENTED BY THIS PLAN WAS COMPLETED ON THE 23rd DAY OF AUGUST, 2017
BRIAN O. BROWN, BCLS #623

THIS PLAN LIES WITHIN THE SQUAMISH-LILLOOET REGIONAL DISTRICT.

McElhanney
McELHANNEY ASSOCIATES LAND SURVEYING LTD.
Suite 205
1055 Millar Creek Road
Whistler BC
Canada V0N 1B1
Tel 604 932 5426

FILE NO. 2113-02926-00
DRAWING NO. 02926-00-W-0-SUB-R1

APPENDIX B

BARE LAND STRATA PLAN

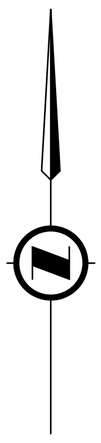
SKETCH PLAN TO ACCOMPANY FORM P FOR PHASED BARE LAND STRATA DEVELOPMENT OF LOT C DISTRICT LOT 203 LILLOOET DISTRICT PLAN EPP46258

SCALE 1 : 500

0 25 50 m

ALL DISTANCES ARE IN METRES AND DECIMALS THEREOF

THE INTENDED PLOT SIZE OF THIS PLAN IS 864 mm IN WIDTH BY 560 mm IN HEIGHT (D-SIZE) WHEN PLOTTED AT A SCALE OF 1:500



McElhanney
McELHANNEY ASSOCIATES LAND SURVEYING LTD.
Suite 205
1055 Millar Creek Road
Whistler BC
Canada V0N 1B1
Tel 604 932 5426

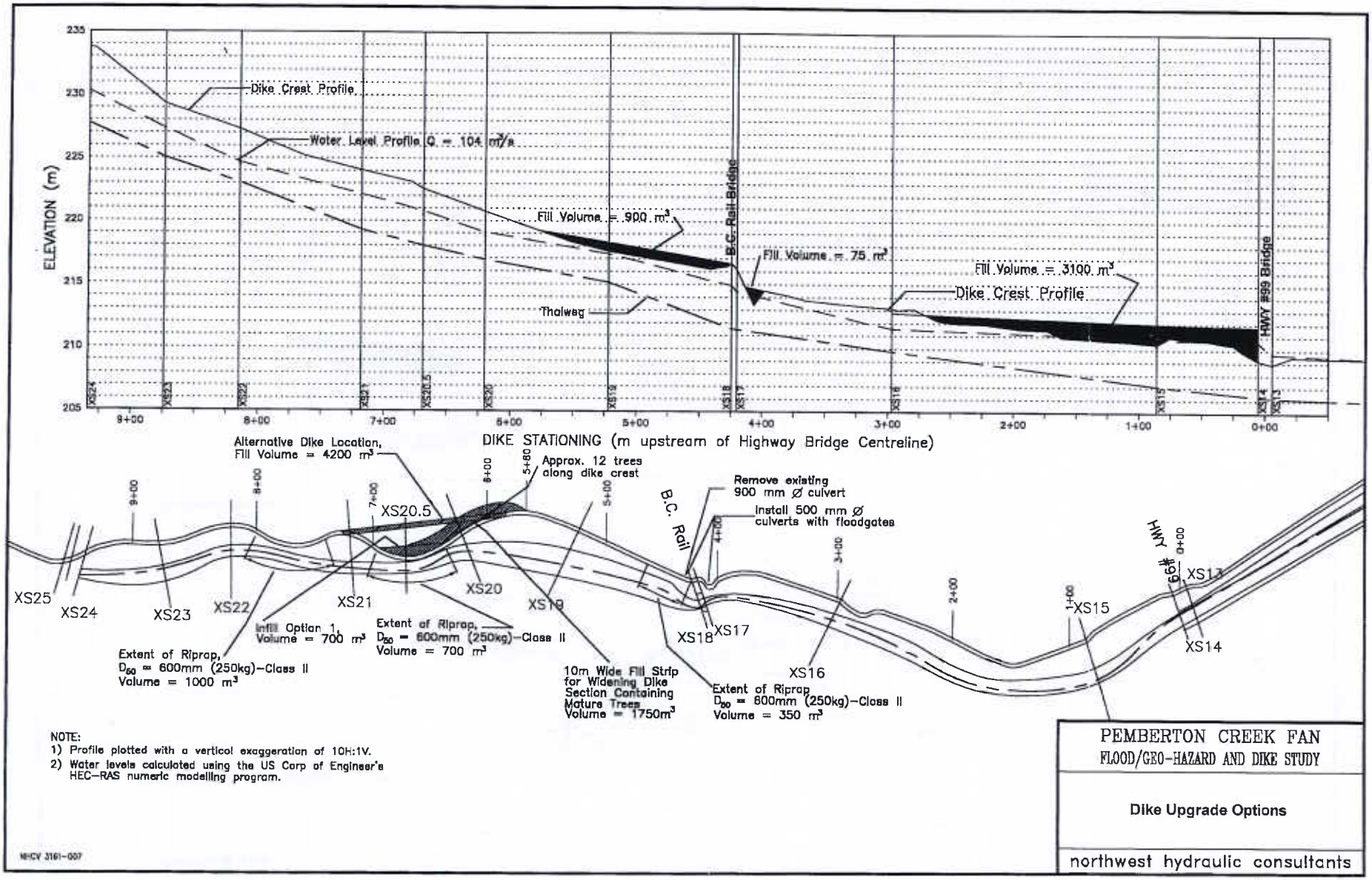
OUR FILE NO. 2113-02926-00
OUR DRAWING NO. 02926-00-W-0-FORM-P-R0.DWG

THIS PLAN LIES WITHIN THE SQUAMISH LILLOOET REGIONAL DISTRICT.

APPENDIX C

CREEK PROFILE

(from NHC 2001, Figure 6.1)



NOTE:
1) Profile plotted with a vertical exaggeration of 10H:1V.
2) Water levels calculated using the US Corp of Engineer's HEC–RAS numeric modelling program.

NHCV 3161–007

PEMBERTON CREEK FAN
FLOOD/GEO–HAZARD AND DIKE STUDY

Dike Upgrade Options

northwest hydraulic consultants

FIGURE 6.1

APPENDIX D

200-year Flood PROFILE

(from NHC 2001, Table 5.4)

Table 5.4

Adopted 20- and 200-Year Flood Profiles [1]

Cross-Section No.	Bridge Deck Elevations (m)	Left Dike Crest Elevation (m)	20-Year Flood Profile [2]		200-year Flood Profile [3]	
			Water Surf Elevation (m)	Available Freeboard [4] (m)	Water Surf Elevation (m)	Available Freeboard [4] (m)
11			205.8		207.0	
12			206.4		207.6	
13 (Hwy 99)		208.9	208.1	0.8	209.5	-0.6
14 (Hwy 99)	209.4	209.3	208.1	1.2	210.6	-1.3
15		210.4	208.7	1.7	210.8	-0.4
16		213.3	211.1	2.2	211.6	1.8
17 (BC Rail)		216.6	212.9	3.7	214.4	2.2
18 (BC Rail)	216.7	216.7	213.2	3.5	214.9	1.8
19		217.6	216.2	1.4	217.4	0.2
20		220.7	218.4	2.3	219.1	1.6
20.5		222.5	219.5	3.0	220.8	1.7
21		224.0	221.1	2.9	222.1	1.9
22		227.3	224.0	3.3	224.7	2.6
23		229.3	226.6	2.7	227.4	1.9
24		233.7	229.2	4.5	230.3	3.4
25		234.9	230.0	4.9	231.0	3.9

Notes

1. Profiles computed for 2001 channel geometry.
2. No bridge blockage for the 20-year instantaneous maximum flow.
3. Blockage of the Highway 99 Bridge, as described in Section 5.
4. Available freeboard is the elevation difference between the dike crest and the water surface elevation.

APPENDIX E

EXISTING GRADING PLAN

SERVICES LEGEND

DESCRIPTION	SYMBOLS PROPOSED	SYMBOLS EXISTING
PROPERTY LINE		
RIGHT-OF-WAY		
EDGE OF ASPHALT		
CURB		
STORM SEWER		EX. 250 STM
CULVERT		
CATCH BASIN		
LAWN DRAIN		
INFILTRATION TRENCH		
DITCH		
DETENTION/CLEANSING POND		
STREET LIGHT		
PHASING BOUNDARY		
CHAINLINK FENCE		

LEGAL DESCRIPTION

1. PART OF THAT PART OF DL 203 LILLOOET DISTRICH SHOWN ON PLAN A20 EXCEPT PLANS KAP63162, KAP64875, KAP77917, KAP78331 AND EPP1760;
2. LOT 3 DL 203 LILLOOET DISTRICT PLAN KAP77917.

BENCH MARK CONTROL

ELEVATIONS ARE ORTHOMETRIC AND ARE DERIVED FROM GPS OBSERVATIONS CONVERTED TO CGVD28 ELEVATIONS USING THE HT2.0 GEOID MODEL

no.	date	revision	chk'd	no.	date	revision	chk'd
0	JAN.29.18	ISSUED FOR INFORMATION	HKG				

client: TIYATA DEVELOPMENTS INC.

project: TIYATA VILLAGE
PEMBERTON, BRITISH COLUMBIA

PROFESSIONAL ENGINEERS — STEEP ROCKY TERRAIN SPECIALISTS — WEBSTER ENGINEERING LTD — LAND DEVELOPMENT CONSULTANTS
3745 DELBROOK AVENUE, NORTH VANCOUVER, B.C. V7N 3Z4 983-0458

approved:

designed by: H.K.G.
drawn by: M.J.F.
checked by: J.A.T.
date: JAN.26.18

title: EXISTING GRADE PLAN

scales: hor: 1:500 vert: -
file no.: 3439
page no.: 1
drawing no.: EGR-1
rev.: 0

F:\3400\3439-Tiyata Pemberton\DESIGN - DETAILED DESIGN\EXISTING GRADE PLAN.dwg, 1/30/2018 10:50:48 AM, PBB, PBB