RYZUK GEOTECHNICAL
Engineering & Materials Testing

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February 28, 2020
File No: 9774-1

1117943 BC Ltd.
#38 – 3205 Gibbins Road
Duncan, BC
V9L 1G7

Attn: Mandeep Sindhi (By E-mail: mandeepsindhi1@gmail.com)

Re: Proposed 5 Story Residential Development
454, 446 Ypres St. & 455 Festubert St. – Duncan, BC

As requested, we have completed a geotechnical investigation of the above referenced site proposed for development. Our associated observations, comments and recommendations are contained herein. Our work has been carried out in accordance with, and is subject to, the previously sent Terms of Engagement.

PROPOSED DEVELOPMENT

Although there are currently no architectural plans, we understand that the concept for development would consist of a four or five story building constructed on 454 and 446 Ypres Street, with surface parking provided on neighboring 455 Festubert Street to the east. We understand that the building would be constructed at-grade, with no basement or underground parking, and would be wood framed construction. At this stage, we expect the building will be designed with a natural period of less than 0.5 seconds.

The site is bounded by Ypres Street to the west, multi-family buildings to the north and south, and Festubert Street to the east. There are currently two single family homes on the 454 and 446 Ypres Street lots, with associated driveway areas, which would be demolished to allow for the proposed development. Other than the houses, these lots are vegetated with a few small to medium sized trees, hedges, and lawn areas. The 455 Festubert Street lot is currently vacant and undeveloped. Topography of the site is relatively flat, gently sloping from west to east.

INVESTIGATION PROCEDURE

Our geotechnical investigation comprised an office-based desktop study, followed by an on-site subsurface investigation. The desktop study consisted of a review of geological maps, our file information from previous projects in the area, topographical maps, and flood hazard mapping.

The eight SPT samples from TH20-01 were analyzed to assess the % fines content of the noted soils. These percentages varied from 13% in the sandy gravels to >50% in the sandy silts and silt layers. These values were inferred to represent the site, and were used in the liquefaction assessments.

In each test hole the groundwater table elevation was observed to be 2.2 m below the surface. Long term groundwater monitoring was undertaken near to the site by Thurber Engineering in 2012 and 2013 for the City of Duncan. Test hole TH12-4 was installed by Thurber at the intersection of Queens Road and Ypres Street, just southwest of the site, and groundwater levels were monitored from October 2012 to October 2013. The data from the monitoring indicated that groundwater elevations fluctuated between 2.5 m (in December 2012) and 4.0 m (in September 2013) below the surface over the period. As such, we expect that the groundwater level will continue to fluctuate seasonally between 2.0 m and 4.0 m below the surface, with temporarily higher levels possible during periods of heavy and/or sustained rainfall.

Based on our review of the Lower Cowichan/Koksilah Integrated Flood Mapping and Management Plan – Flood Hazard Map, prepared by Northwest Hydraulic Consultants and dated September 2009, the site is located outside of the Floodway Zone. This zone delineates areas within the 200-year return period flood plain (which includes 0.6 m of freeboard) deep and fast flowing water are expected, which could lead to possible erosion and scouring, as well as flood water damage. The proposed development site is located within the Flood Fringe Zone of the 200-year return period flood plain, with an expected flood elevation of 11.0 m to 11.5 m. This zone is characterized by low velocity flowing water and ponding, which could result in flood water damage.

LIQUEFACTION CONSIDERATIONS

It is generally understood that loose to compact granular soils below the water table are susceptible to liquefaction during a large scale seismic event. Liquefaction can cause a significant decrease in bearing capacity, which can result in large differential settlements, lateral spreading, and earthflow. Based on the soil conditions noted above, we consider this site to be susceptible to seismically induced liquefaction.

For buildings constructed on liquefiable soils, a Seismic Site Classification of 'F – Other soils' is required under the current BC Building Code, for buildings with natural periods of greater than 0.5 seconds. For buildings with a period of less than 0.5 seconds, such as the proposed building at this site, the code allows for Seismic Site Classification and spectral accelerations to be determined without considering liquefaction. This avoids the need for a site-specific seismic analysis, but induced settlements and potential earthflows resulting from liquefaction will still need to be mitigated.

Table 1. Summary of PGA and Spectral Acceleration Values (NBC 2015)

Period (sec)	0.2	0.5	PGA (g)
Response (g) Site Class 'C'	1.169	1.086	0.511
Response (g) Site Class 'E'	**1.270**	**1.270**	**0.378**

Liquefaction Assessment, Induced Settlement and Lateral Displacements

To determine the potential for seismically induced liquefactions of the subsurface soils at the site, an assessment was carried out using the conventional cyclical stress ratio to cyclical resistance ratio (CSR/CRR) approach. These values were estimated through correlations based on the obtained SPT data in TH20-01 and assumed to be representative of the building site.

To assess liquefaction potential the Seed (1983), NCEER (1997), and Idriss & Boulanger (2004) methods were applied, while settlements were estimated based on Ishihara & Yoshimine (1992), Tokimatsu & Seed (1984), Shamamato (1998), Wu (2003) and Cetin (2009). Industry standard within the southern portion of BC is to base results on Idriss & Boulanger and Tokimatsu & Seed for liquefaction potential and settlements respectively.

Based on our analyses, the observed soils are anticipated to liquefy to depths of approximately 15 m below grade, however, this liquefaction is only expected to result in significant settlements to a depth of approximately 12 m. Based on these results, we anticipate total settlements to range from 100 mm to 200 mm. Lateral spread was neglected because no noticeable slope was observed on the site or within the surrounding terrain.

Foundation Considerations and Soil Remediation Options

Because of the expected settlements due to liquefaction within the site, measures will be required to ensure the proposed building can withstand the associated differential and total settlements. While there are several methods to address this, we expect that the most economical and practical for the proposed development will be the installation of deep foundations, or reinforced shallow foundations supported by a rock mat. Ultimately, the option chosen will depend on post-earthquake requirements of the proposed building.

Deep foundations generally consist of either driven piles or drilled cast-in-place concrete caissons, and these elements transfer the building loads from the surface to a denser strata below the liquefaction elevation. Of these, driven piles are generally more suited to this development. Because of the anticipated liquefaction, significant loads will be induced by the settlement (down-drag) on any potential piles. This will mean that the piles will need to be designed to accommodate loads that are substantially higher than the structural loads from the building. As well, given the depth to suitable bearing strata, and the size of the proposed building, this option

Engineered Fill

Engineered fill may be required to raise grades back to design grade after removal of topsoil/fill material, or for constructing a rock mat for foundations. Engineered fill is to consist of approved well-graded select granular material placed in maximum 0.3 m lifts and compacted to a minimum of 95% of Standard Proctor Maximum Dry Density (SPMDD) or judged equivalent. We recommend in-situ density testing or fill placement monitoring to ensure compaction in the engineered fill. The engineered fill must have a footprint that extends horizontally beyond the footings a distance equal 0.3 m plus the thickness of the engineered fill, to provide adequate splay for foundation loads. In perimeter areas, it is inadvisable to have the engineered fill/foundation load splay extend beyond property lines.

Grade Supported Floor Slab

We expect that use of a grade supported lower floor slab is feasible for lower floor area. A minimum 150 mm layer of medium to coarse sand or 19 mm minus gravel is recommended beneath the slab, as well as a subslab moisture barrier, to avoid capillary rise of moisture into the slab. All subslab fill should be compacted to at least 95% of SPMDD.

Foundation Drainage

Conventional perimeter foundation drainage consisting of perforated drain pipe surrounded by free draining granular material containing low fines, tied into the recommended free draining backfill material, is recommended. To prevent the migration of fine-grained soil particles into the drainage system, a layer of medium weight, non-woven geotextile should be placed between the clean drain rock around the perforated pipe and the granular backfill material. The geotextile should encompass the entire drain rock / drain pipe system.

Pavement / Road Structure Considerations

Generally for parking and light traffic areas, a pavement structure consisting of 50 mm of asphalt surfacing overlying at least 100 mm of 19 mm minus crushed base course and a minimum of 200 mm of 75 mm minus subbase is recommended over compact to dense native soils, or engineered fills over compact to dense native soils. For heavier traffic areas, the thickness of the asphalt surfacing should be increased to minimum 75 mm, and the base course thickened to 150 mm. Base and subbase layers should be compacted to 100% of SPMDD. The above noted pavement structures may need to be revised based on actual subgrade conditions within the proposed parking area, and could included thickening of the base and subbase and/or the addition of a geotextile layer beneath the road structure. This could be determined with an additional test-pit investigation as discussed below, or at the time of construction.

Notes:

1. Base imagery and property features taken from Google Maps
2. Sonic test holes advanced on February 4, 2020 with drill rig supplied by Drillwell Enterprises Ltd.
3. Tromino surveys completed on February 4 & 6, 2020
4. Test hole locations based relative to site features; actual locations may vary by +/- 2 m.

1117943 BC Ltd.

TEST HOLE LOCATION PLAN

Proposed 5 Storey Residential Development

454, 446 Ypres St. & 455 Festubert St. Duncan, B.C.

RYZUK GEOTECHNICAL Engineering & Materials Testing

DRAWN	ZTH
DATE	February, 2020
APPROVED	GY
SCALE	NTS
DRAWING No.	9774-1-1

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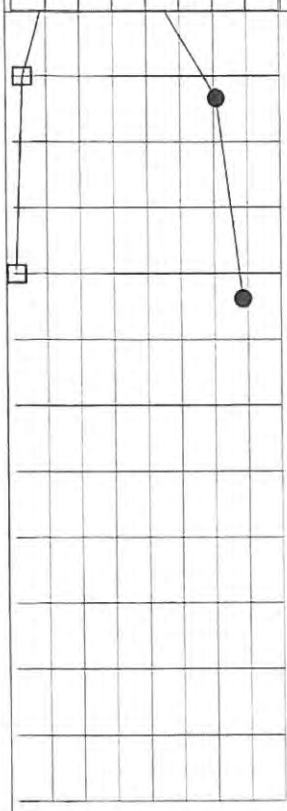
TEST HOLE LOG

TH20-01

Project: Proposed 5 Storey Residential Development
UTM: 448360 m E; 5403196 m N
Client: 1117943 BC Ltd. Job #: 9774-1
Location: 454, 446 Ypres St & 455 Festubert St Method: Sonic/SPT
Duncan, BC Driller: Drillwell
Drill Date: February 4, 2020 Inspector: ZTH



SPT Field 'N' Value (Blows / 150 mm)	Recovery %	Sample	Stratigraphy	Stratigraphic Description	Depth (m)
				SAND - loose, silty, fine grained, blue-grey, moist to wet	
1-2-1-1	65	⊠			
		■		SILT - firm, clayey, blue-grey, moist to wet	11.0
0-0-1-0	100	⊠			12.0
					13.0
		■		In-situ shear vane test at 13.5 m: Su= 44 kPa	
					14.0
		■		SAND - dense to very dense, till like, silty, grey, slightly moist to dry	
				BEDROCK	
				End of test hole at 15.0 m - desired depth	15.0
					16.0

LEGEND
⊠ Split Spoon ● Fines Content
□ 'N' Value
▲ Moisture Content ■ Grab Sample

COMMENTS:
Test hole backfilled with cuttings and bentonite seal

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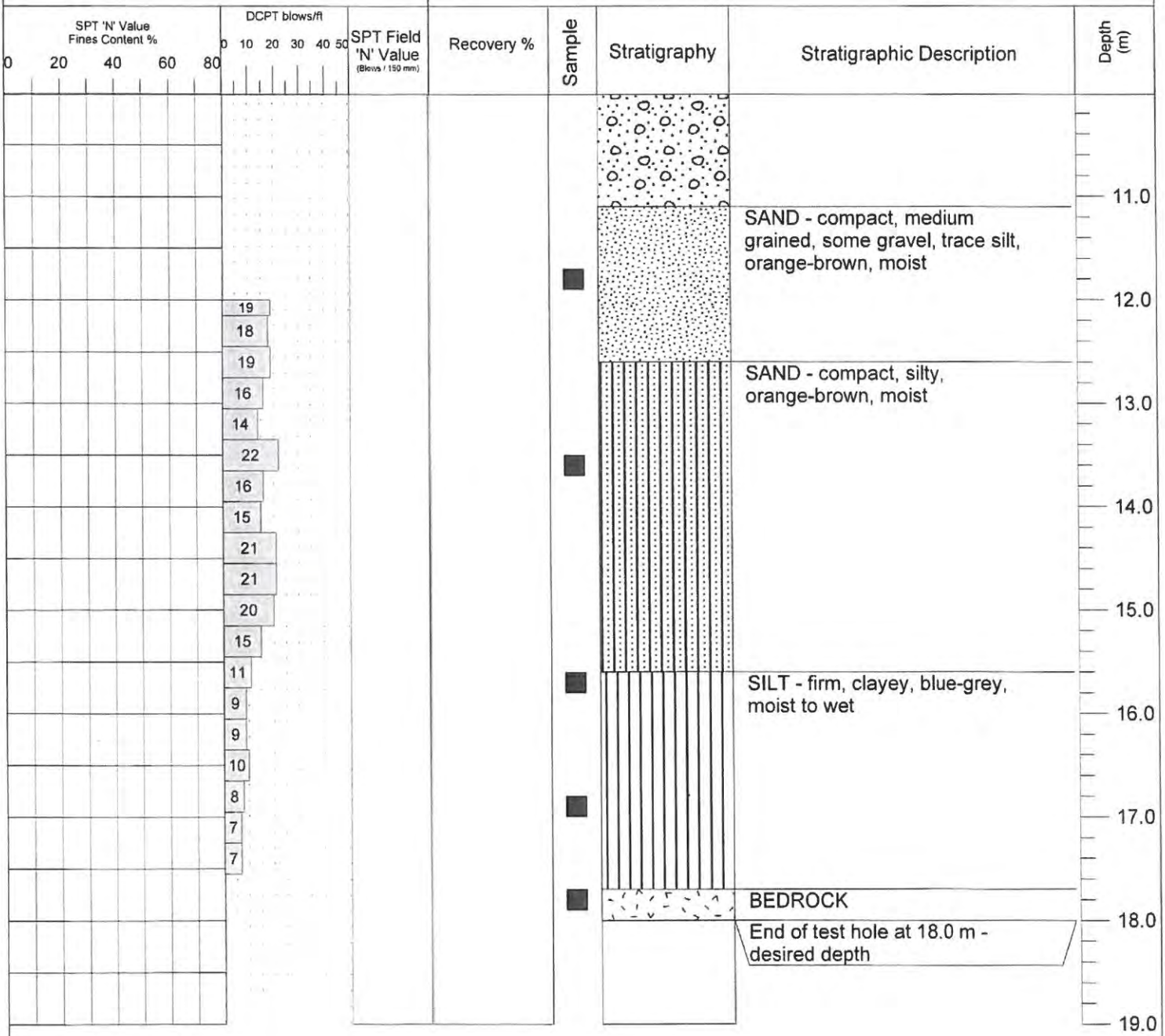
TEST HOLE LOG

TH20-02

Project: Proposed 5 Storey Residential Development
UTM: 448360 m E; 5403196 m N
Client: 1117943 BC Ltd. Job #: 9774-1
Location: 454, 446 Ypres St & 455 Festubert St Method: Sonic/SPT
Duncan, BC Driller: Drillwell
Drill Date: February 4, 2020 Inspector: ZTH

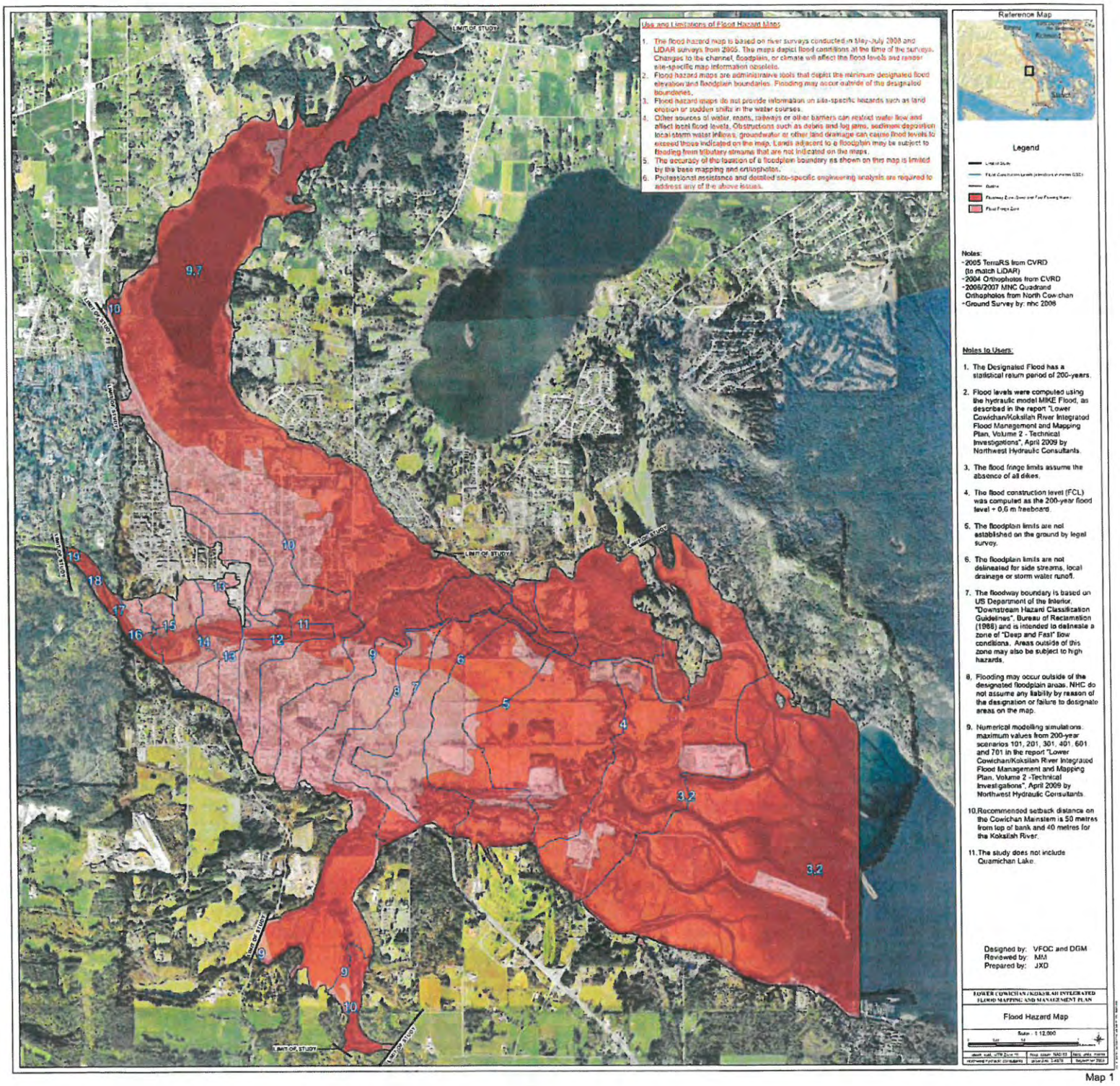


LEGEND

- ☒ Split Spoon
- ● Fines Content
- □ 'N' Value
- ▲ Moisture Content
- ■ Grab Sample

COMMENTS:

Test hole backfilled with cuttings and bentonite seal


Use and Limitations of Flood Hazard Maps
1. The flood hazard map is based on river surveys conducted in May-July 2008 and LiDAR surveys from 2005. The maps depict flood conditions at the time of the surveys. Changes to the channel, floodplain, or climate will affect the flood levels and render site-specific map information obsolete.
2. Flood hazard maps are administrative tools that depict the minimum designated flood elevation and floodplain boundaries. Flooding may occur outside of the designated boundaries.
3. Flood hazard maps do not provide information on site-specific hazards such as land erosion or sudden shifts in the water courses.
4. Other sources of water, roads, railways or other barriers can restrict water flow and affect local flood levels. Obstructions such as debris and log jams, sediment deposition, local storm water inflows, groundwater or other land drainage can cause flood levels to exceed those indicated on the map. Lands adjacent to a floodplain may be subject to flooding from tributary streams that are not indicated on the maps.
5. The accuracy of the location of a floodplain boundary as shown on this map is limited by the base mapping and orthophotos.
6. Professional assistance and detailed site-specific engineering analysis are required to address any of the above issues.
LIMIT OF STUDY
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Reference Map
Legend
Notes:
-2005 TerraRS from CVRD (to match LiDAR)
-2004 Orthophotos from CVRD
-2006/2007 MNC Quadrand Orthophotos from North Cowichan
-Ground Survey by: nhc 2008
Notes to Users:
1. The Designated Flood has a statistical return period of 200-years.
2. Flood levels were computed using the hydraulic model MIKE Flood, as described in the report "Lower Cowichan/Koksilah River Integrated Flood Management and Mapping Plan, Volume 2 - Technical Investigations", April 2009 by Northwest Hydraulic Consultants.
3. The flood fringe limits assume the absence of all dikes.
4. The flood construction level (FCL) was computed as the 200-year flood level + 0.6 m freeboard.
5. The floodplain limits are not established on the ground by legal survey.
6. The floodplain limits are not delineated for side streams, local drainage or storm water runoff.
7. The floodway boundary is based on US Department of the Interior, "Downstream Hazard Classification Guidelines", Bureau of Reclamation (1988) and is intended to delineate a zone of "Deep and Fast" flow conditions. Areas outside of this zone may also be subject to high hazards.
8. Flooding may occur outside of the designated floodplain areas. NHC do not assume any liability by reason of the designation or failure to designate areas on the map.
9. Numerical modelling simulations: maximum values from 200-year scenarios 101, 201, 301, 401, 601 and 701 in the report "Lower Cowichan/Koksilah River Integrated Flood Management and Mapping Plan, Volume 2 -Technical Investigations", April 2009 by Northwest Hydraulic Consultants.
10. Recommended setback distance on the Cowichan Mainstem is 50 metres from top of bank and 40 metres for the Koksilah River.
11. The study does not include Quamichan Lake.
Designed by: VFOC and DGM
Reviewed by: MM
Prepared by: JXD
LOWER COWICHAN/KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN
Flood Hazard Map
Scale: 1:12,500

Map 1