Geotechnical Design Report HWY97 Skaha Hills Drive Intersection Improvement, Penticton, BC

Presented To: British Columbia Ministry of Transportation and Infrastructure

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PERMIT TO PRACTICE # 1001040
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Acronyms and Abbreviations

AADT	Annual Average Daily Traffic
ASTM	American Society for Testing and Materials
BC	British Columbia
BEF	Bridge End Fill
CBC	Crush Base Course
CPT	Cone Penetration Test
ESAL	Equivalent Single Axle Load
MoTI	Ministry of Transportation and Infrastructure
MPMDD	Modified Proctor Maximum Dry Density
ODEX	Overburden Drilling Eccentric
OPOH	Old Penticton – Oliver Highway
PVC	Poly Vinyl Chloride
SADT	Summer Average Daily Traffic
SGSB	Select Granular Subbase
SPMDD	Standard Proctor Maximum Dry Density
SPT	Standard Penetration Test
SS	BC MoTI Standard Specifications for Highway Construction
WGB	Well-Graded Base

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1. Introduction

1.1 General

The BC Ministry of Transportation and Infrastructure (MoTI) retained Ecora Engineering & Environmental Ltd. (Ecora) to carry out a geotechnical assessment in support of the detailed design of the Highway 97 Skaha Hills Drive Intersection Improvement Project immediately south of Penticton, BC.

Ecora understands that, in general, the scope of the project comprises the design of a signalized intersection improvement of Highway 97 at Skaha Hills Drive (relocated Old Penticton- Oliver Highway Intersection, OPOH) in Penticton, and access management for Highway 97. The project also included significant highway drainage improvements including a stormwater outfall into Skaha Lake.

MoTI requested that Ecora undertake a detailed geotechnical field investigation to gain an understanding of the soil properties, groundwater conditions and provide geotechnical recommendations for the proposed intersection development works that is to include pavement design considerations, design of infiltration basins and MoTI signal and light bases.

Geotechnical recommendations in support of the detailed design of the intersection improvement project are provided in this report. This geotechnical design report should be read in conjunction with the issued companion geotechnical investigation report.

1.2 Site Description

The project area is located within Penticton Indian Band Reserve Lands and is situated along the northern shore of Skaha Lake between Airport Road and Riva Ridge Drive (Figure 1.2). The proposed Skaha Hills Drive intersection will be located within a 237 m radius curve near the bottom of a 6% slope, where the highway transitions from a two-lane rural section to four-lane semi urban.

There are currently two commercial developments situated along this stretch of Highway 97 including Wrights Beach Campground to the south and Lakeside Villa Inn & Suites and Barefoot Beach Resort to the northeast of the project area.

The project area is generally characterized by gently sloping terrain. Existing slopes are fairly consistent within the project area with overall grades ranging between 4% and 6%.

2. Geotechnical Investigation Report

The companion Geotechnical Investigation Report presents the results of our intrusive geotechnical field investigation and laboratory testing work undertaken to date. The intrusive geotechnical field investigations comprised:

- The drilling of six hollow stem auger, one solid stem and five Overburden Drilling Eccentric (ODEX) (Downhole Air Hammer System) test holes;
- The advancement of one Cone Penetration Test (CPT);
- Conducting in-situ strength/consistency testing (i.e., Standard Penetration Testing (SPT);

- The installation of nine standpipe piezometers;
- The advancement of four test pits; and
- Undertaking infiltration testing using a double-ring infiltrometer apparatus.

In addition to the field investigation a laboratory testing program was undertaken on representative soil samples that included moisture content, grain size distribution analysis and Atterberg Limits Tests to gain an understanding of the physical characteristics of the encountered subsurface soils. Please see Ecora's "Geotechnical Investigation Report Skaha Hills Drive Intersection Improvement Report", Rev 3, dated July 16, 2024, for detailed test hole logs and lab testing results.

3. Earthworks & Site Grading

3.1 Site Stripping

The footprint of any proposed roadway or structure shall be thoroughly cleared of all rubbish, debris, vegetation, and uncontrolled fill. All stripped material shall be disposed of away from these areas to limit contamination of exposed subgrades and structural fill. If topsoil will be used for landscaping purposes, it shall be stripped from earthworks areas and stockpiled separately in an area clear of the earthworks.

3.2 Subgrade Preparation

Prior to the placement of any fill, the stripped subgrade shall be reviewed by a geotechnical engineer or ministry representative. The review should include a Proof-Roll by a truck having a 9 tonne single axle dual tire or 17 tonne tandem axle group with dual tires and a tire pressure of 600 kPa. Any areas where rutting or displacement occurs shall be excavated and replaced with suitable material as per the following sections.

Care should be taken during winter construction to ensure that fill materials are not placed in a frozen or excessively wet state. Also, fill soils shall not be placed on frozen or excessively wet subgrade.

3.3 Structural Fill, Granular Surfacing, Base and Subbases

Production, supply and construction of granular surfacing, granular base and select granular subbase (SGSB) shall follow the BC MoTI 2020 Standard Specifications for Highway Construction (SS) – Section 202.

Granular surface materials shall be placed in maximum compacted lift thicknesses of 150 mm, adequately moisture conditioned and compacted to 98% of the Standard Proctor Density (ASTM D698).

3.4 Re-Use of Native Soils

The MoTI Pavement Structure Design Guideline indicates that SGSB may not be required in exceptional circumstances where the existing subgrade soil consists of a clean granular deposit that satisfies MoTI SGSB gradation and meets the structural design criteria.

Gradation analysis completed on representative samples obtained from test holes and test pits advanced within the project site generally indicated the native alluvial granular soils were predominately well graded and free draining with an average fines content ranging from 3% to 13%. Selected samples were plotted to, and generally fall within, MoTI gradation curves for SGSB and Bridge End Fill (BEF). It is likely that during typical construction and grading processes the native subgrade soils will be mixed producing a material that may be used as structural fill for subgrade soils, SGSB for roadway construction and/or subbase soil for the construction of sign bases and ancillary structures.

If the existing subgrade soils along roadway surfaces are at an elevation that would allow them to be used as SGSB and also if approved by MoTI as a feasible option, the upper 300 mm of existing subgrade soils shall be scarified, adequately moisture conditioned and compacted to 100% Standard Proctor Maximum Dry Density (SPMDD) and proof-rolled prior to placing additional subbase and base materials in accordance with Section 201.37 of the SS

3.5 Temporary Excavations and Permanent Slopes

All work conducted in and around excavations should be carried out in accordance with requirements specified by the WorkSafe BC Occupational Health & Safety Regulations, Part 20.

Unsupported excavations greater than 1.2 m depth should be reviewed by a professional engineer in accordance with WorkSafe BC. Alternatively, service line trenches or excavations deeper than 1.2 m must be shored. To maintain the stability of the trench, all materials excavated from the trench shall be placed a minimum distance away from the excavation, equal to the depth of the excavation.

Temporary cut slopes/excavations in the native alluvial soils encountered onsite shall be graded no steeper than 1H:1V. Where a temporary cut slope of 1H:1V cannot be achieved, temporary shoring will be required.

Permanent cut and fill slopes formed in the natural alluvial soils or compacted granular fill soil shall be graded no steeper than 2H:1V. Permanent fill slopes shall be over-built and then trimmed back to the recommended inclination. Permanent cut and fill slopes shall be vegetated after construction.

4. Foundations

4.1 General

It is anticipated that the project will likely include the construction of minor structures such as signs, signals and illumination, or other ancillary structures constructed in general accordance with the following BC MoTI Standard Specifications for Highway Construction:

- Section 407 for Foundation Excavations; and
- Section 635 Electrical and Signing.

4.2 Shallow Foundation Design Parameters

Typically, the minor structures associated with signs, signals and illumination, etc. are relatively tall and lightweight, as such overturning due to wind loading generally govern the foundation design instead of settlement.

Section 635 in the BC MoTI 2020 Standard Specification has several standard shallow foundation designs for typical highway structures mentioned above. If the typical shallow foundation designs are not applicable for the structure, or a specific foundation design is required, the following geotechnical recommendations and parameters have been provided.

If a sign base, highway marker or ancillary structure with a shallow foundation cannot be designed or constructed in accordance with Drawings in Section 635, the foundation should be designed with the parameters given in Table 4.2.a below.

Geotechnical resistance factors for ultimate and serviceability limit states shall be in accordance with Table 6.2 of S6-19 Canadian Highway Bridge Design Code (CHBDC 2019).

Table 4.2.a Parameters for the Design of Shallow Foundations in Compression and Sliding

Anticipated Soil Type at Footing Subgrade	Unit Weight (kN/m^3)	ULS Ultimate Bearing Resistance (kPa)	Foundation/Soil Interface Angle of Friction[1] (degrees)
Alluvial Soils (Sand and Gravel) or Compacted Structural Fill	20	600	29

Note: [1] Interface friction angle from Table 24.4 Canadian Foundation Engineering Manual (CFEM)

It is anticipated that excavated on-site materials may be used as a foundation surcharge to resist uplift and overturning forces. Geotechnical design parameters for the re-use of on-site material in the design of shallow foundations in uplift are provided in Table 4.2.b below, assuming these materials are compacted to a minimum of 95% of SPMDD or greater.

Table 4.2.b Parameters for the Design of Shallow Foundations in Uplift

Surcharging Material	Unit Weight (kN/m^3)	Angle of Friction (degrees)	Passive Earth Pressure Coefficient
Alluvial Soils (Sand and Gravel) or Compacted Structural Fill	20	30°	3.0

A geotechnical engineer shall review the soil conditions at the foundation grade prior to the construction of foundation formwork, to confirm the actual soil conditions encountered at the foundation grade are suitable to support the footings.

A minimum footing width of 600 mm is recommended, and the underside of foundations should also be located below a 2H:1V line projected up from the base of adjacent foundations, underground services, etc. otherwise the bearing resistances provided above may need to be reduced.

4.3 Frost Penetration

Frost susceptibility of soils refers to the propensity of the soil to grow ice lenses and heave during freeze and thaw cycles. According to the National Research of Canada (Canada Building Digest 182) the frost penetration depth for the region where the proposed site is located is estimated (from normal freezing index) at 0.6 m below ground surface. Therefore, the underside of footings and utilities should be placed at least 0.6 m below the site grade to conform to the frost protection requirement.

5. Site Stormwater Disposal Systems

Site grading shall be designed in such a manner as to promote positive drainage and prevent ponding of surface water near any structure, foundation, or paved areas. Drainage considerations established during the design and construction should be maintained for the life of the development.

The native site soils are considered suitable for site stormwater disposal systems such as dry wells and infiltration galleries.

Soil infiltration rates obtained from in-situ Double Ring Infiltration Tests are summarized in Ecora's geotechnical investigation report. An average infiltration rate was calculated as 1.7×10^{-3} cm/sec. These results need to be converted to the "field saturated hydraulic conductivity" as follows:

$$K_{fs} = \frac{I}{i}$$

- K_{fs} is the field saturated hydraulic conductivity (cm/s);
- I is the infiltration rate (1.7×10^{-3} cm/s);
- i is the hydraulic gradient (obtained from test information); and
- The field saturated hydraulic conductivity corresponding to an average infiltration rate of 1.7×10^{-3} cm/sec is calculated as 5×10^{-4} cm/sec.

Grain size analysis tests completed on selected samples obtained from Ecora's field investigation were also used to estimate the saturated hydraulic conductivity throughout the project site. The United States Department of Agriculture (USDA) Soil Texture Triangle (Figure 5.0) provides estimated saturated hydraulic conductivity values based on textural properties. The soils encountered across the site typically have the following gradation: 19%-52% Gravel, 37%-53% Sand, and 7%-13% fines. Based on the gradation of native soils, a saturated hydraulic conductivity of 1×10^{-3} cm to 1×10^{-4} cm/sec has been estimated. This value is comparative to the saturated conductivity obtained from the Double Ring Infiltration results.

In summary, the saturated hydraulic conductivity across the project site is expected to range from 1×10^{-3} cm/sec to 1×10^{-4} cm/sec.

Under operating conditions, the stormwater system may see changes in infiltration capacity due to clogging with fine-grained sediment. Argue (2004) recommends hydraulic conductivity values be reduced by a factor of five for the design of stormwater management features.

6. Pavement Design

6.1 Relevant Standards

Ecora used the following design guidelines and relevant background information in pavement design:

- British Columbia Ministry of Transportation and Infrastructure. (Jan 26, 2015). "Pavement Structure Design Guidelines – Technical Circular T-01/15";
- American Association of State Highway and Transportation Officials, AASHTO (1993). "AASHTO Guidelines for Design of Pavements Structures";
- American Association of State Highway and Transportation Officials, AASHTO (2004). "Mechanistic-Empirical Pavement Design Guide"; and,
- U.S. Department of Transportation Federal Highway Administration (FHWA),13 Vehicle Classification System.

6.2 Existing Pavement Structure

Road structure was encountered at all test hole locations carried out within the existing roadway. The existing pavement structure generally extended to approximately 0.76 m below the road surface, except for test hole TH16-11, where the pavement structure/fill soil extended to a depth of approximately 1.8 m below the existing road surface. The additional fill at this location is likely due to the grade/elevation difference between the highway and adjacent ground elevation and therefore may not be part of the pavement structure.

Asphalt varied in thickness from 100 mm to 200 mm. The existing asphalt was observed to be in good condition with no evidence of major cracking, rutting or deterioration of the pavement surface noted during the field investigation in 2017. Due to the drilling method used (ODEX), it was difficult to determine the type and extent of each of the existing road structure material types (i.e. base, subbase).

The existing pavement subgrade generally consists of compact to dense granular (sand and gravel) soils. The subgrade soils were typically well graded and free draining with a fines content of less than 10%.

6.3 Available Traffic Data

Available traffic data for the Skaha Hills Drive Intersection Improvement project was obtained from the BC Traffic Data Program (https://www.th.gov.bc.ca/trafficData/). Traffic data was used from the following BC MoTI traffic count station: Station 26-010NS – Route 97, 1.4 km south of Penticton Airport Road, Penticton BC. The station provided the Annual Average Daily Traffic (AADT) and the Summer Average Daily Traffic (SADT). Table 6.3.a below summarizes the traffic data utilised in the pavement structure design.

Table 6.3.a Historical Traffic Data

Traffic Data	2013	2016	2019	2022
AADT	11,725	14,159	15,102	12,509
SADT	15,622	19,565	21,282	16,898

A count class distribution was completed from August 23 to August 28, 2005. The vehicles recorded were classified according to the Federal Highway Administration (FHWA) 13 vehicle classification system. The following is a summary of the distribution of vehicle types recorded in a 24-hour summary:

- Passenger Vehicles (FHWA classes 1-3) – 90%
- Single Unit Trucks (FHWA classes 4-7) – 8%
- Combo Unit Trucks (FHWA classes 8-13) – 2%

6.4 Minimum Required Pavement Design Structural Number

The required minimum pavement design Structural Number has been calculated based on the "AASHTO Guide for Design of Pavement Structures" (AASHTO, 1993) formula for flexible pavements using the recommended design parameters provided in Table 3 of the MoTI "Pavement Structure Design Guidelines" as summarized in Table 6.4.a.

A subgrade resilient modulus (M_r) of 80 MPa was assumed in the analysis based on the type of soil encountered during the site investigation. The soil index properties of the encountered pavement subgrade soils are summarized in Table 2 of Appendix CC-1 of the National Cooperative Highway Research Program (NCHRP) publication “Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures” (2004).

The obtained traffic data has been used to estimate the 20-year design Equivalent Single Axle Loads (ESAL’s). A growth factor of 2% per year has been used to calculate the ESAL’s.

A summary of the AASHTO (1993) design parameters and the minimum required pavement design structural number is provided in Table 6.4.a.

Table 6.4.a Minimum Required Pavement Design Structural Number (based on AASHTO, 1993)

Design Parameter	Design Lane
20-Year Design Lane Traffic (ESALs x 10^6)	13.0
Analysis Period (Years)	20
Reliability (R)	85%
Standard Deviation (S_0)	0.45
Initial Serviceability Index (pi)	4.2
Terminal Serviceability Index (pt)	2.5
Design Resilient Modulus (M_r)	80
Minimum Required Pavement Design Structural Number (S_N) mm	**110.0**

6.5 Pavement Structure Type

Of the four typical pavement structures provided in the MoTI Pavement Structure Design Guidelines (Type A, B, C, and D), the applicable pavement structure type, determined by traffic loading, subgrade type, drainage, local climate, etc. is considered to be Type B. The typical pavement types and their respective attributes are shown in Table 6.5.a below.

Table 6.5.a Pavement Structure Type

Pavement Structure Type	Roadway Designation	20 yr. Design ESAL Criteria	Typical Asphalt Concrete Pavement Thickness
A	High volume roads, truck lanes, specialty locations	> 20,000,000	≥ 150 mm
B	Medium to high volume roads	1000,000 to 20,000,000	75 to 150 mm
C	Low volume & subdivision roads	< 100,000	50 to 75 mm
D	Low volume sealcoat or gravel road	< 100,000	Graded aggregate sealcoat layer(s)

6.6 Pavement Design

Based on the encountered subgrade soils, and estimated ESAL’s, the required minimum Structural Number is 110.0 mm.

- For pavement types A and B with soil subgrade, MoTI design guidelines specify a minimum 300 mm of Crush Base Course (CBC) and 300 mm of Select Granular Subbase (SGSB).

- Based on the existing pavement performance, existing asphalt thicknesses, available traffic data/ESAL's, pavement structure type, etc., Ecora recommends the minimum pavement structure thicknesses outlined in Table 6.6.a. The following pavement structure exceeds the minimum required structural number.

Table 6.6.a Pavement Structure Design Thickness

Pavement Structure Type	Minimum Thickness
Hot Mix Asphalt	125 mm
Crushed Granular Base (25 mm Well-Graded Base -WGB)	300 mm
Select Granular Subbase (SGSB)	300 mm

All granular pavement materials (base and subbase materials etc.) must meet the MoTI standard specifications outlined in the current MoTI Standard Specifications for Highway Construction SS 202, unless approved by the MoTI.

6.7 Pavement Joints and Transitions

In areas of transition between existing and new pavement construction some areas of asphalt levelling course or overlay may be required to compensate for irregularities in the existing surface. In areas where asphalt levelling course or overlay is required it is recommended that this consists of Class 1 Medium 16 mm asphalt mix placed in lift thickness between 50 mm and 75 mm.

Where asphalt levelling course or overlay is not required at transitions between existing and new pavement construction the formation of a butt joint is recommended. The butt joint shall be milled within the existing pavement a minimum of 300 mm in width and approximately 50 mm deep and repaved inconjunct ion with the new asphalt placement. For longitudinal pavement and traverse pavement details, see Diagrams 7.1 and 7.2, respectively, below.

Where new pavement construction is to occur adjacent to lanes of existing pavement, care shall be taken that construction of the new pavement will not impede drainage of the existing pavement base and sub-base layers. In situations where an increase of the vertical alignment of the road profile results in an overlay of the existing pavement it may be necessary to increase the thickness of the sub-base layers of the new pavement structure to ensure adequate drainage.

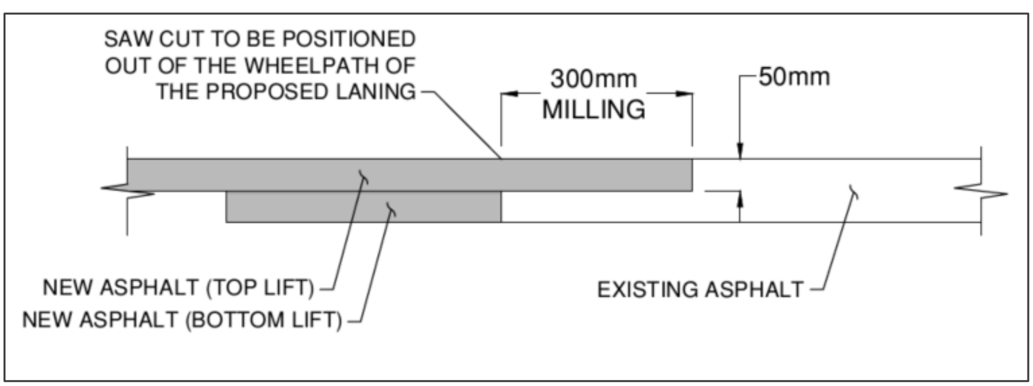

Diagram 6.1 Longitudinal Pavement Joint Detail

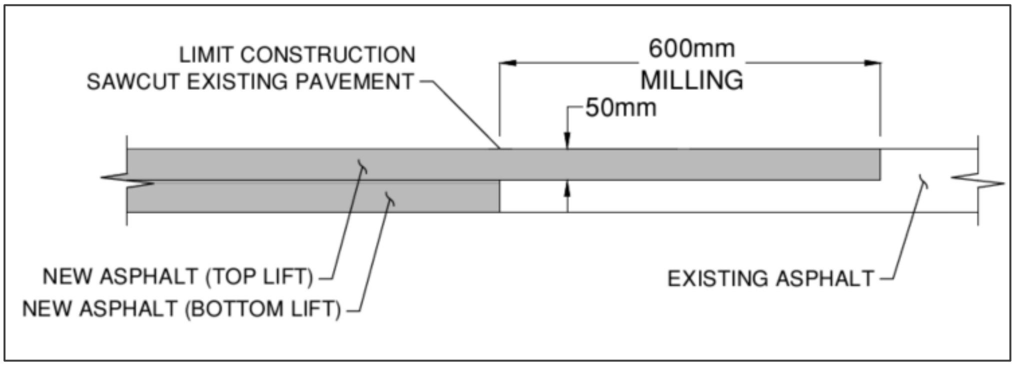

Diagram 6.2 Traverse Pavement Joint Detail

7. Closure

We trust this report meets your requirements. Do not hesitate to contact us if you have any questions or comments.

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Figures

Figure 1.2 Site Plan

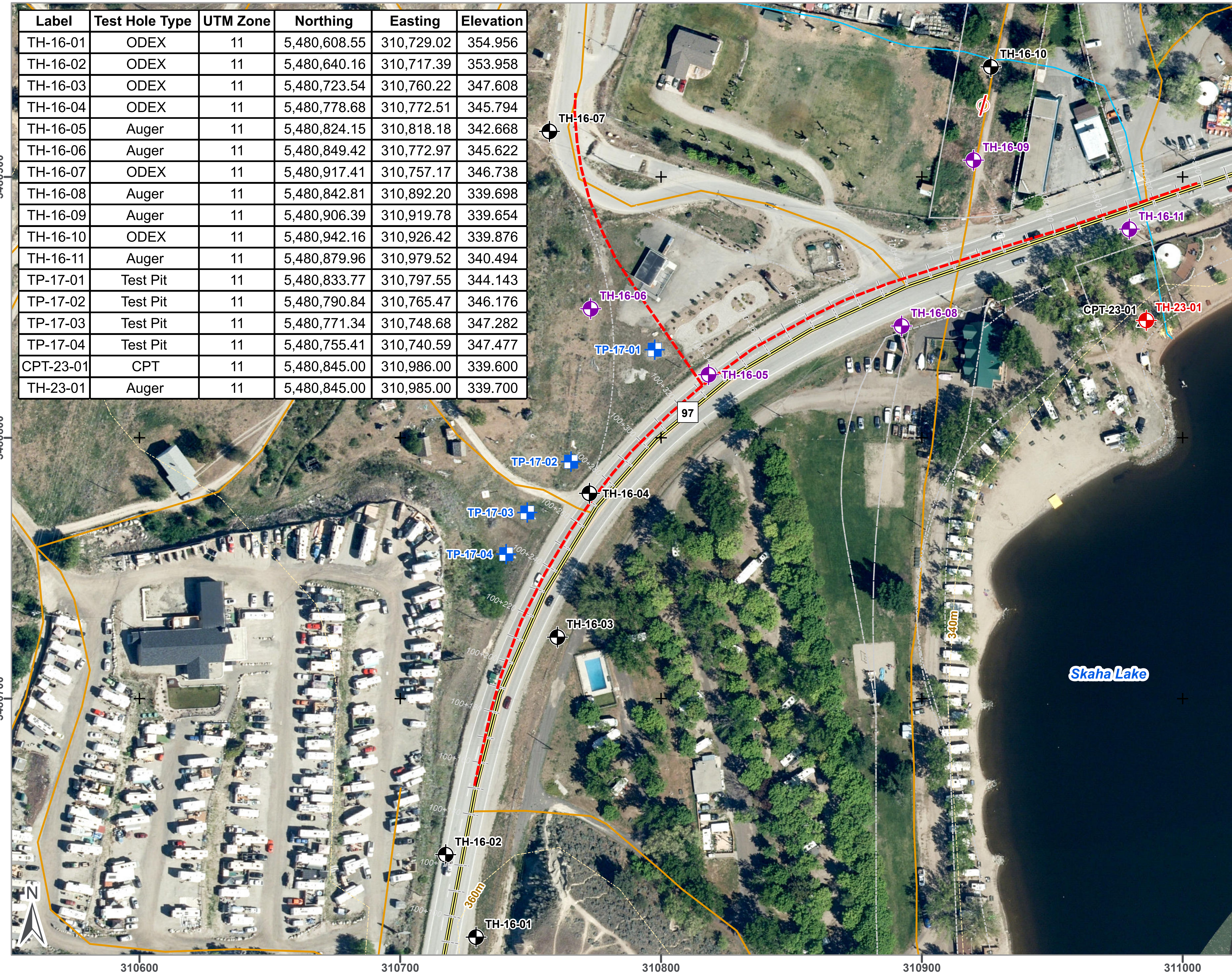
Figure 5.0 Saturated Hydraulic Conductivity Estimation Based on Gradation (Medium Bulk Density)

SITE PLAN

ecora

GEOTECHNICAL ASSESSMENT HWY97 SKAHA HILLS DRIVE INTERSECTION IMPROVEMENT PENTICTON, BC

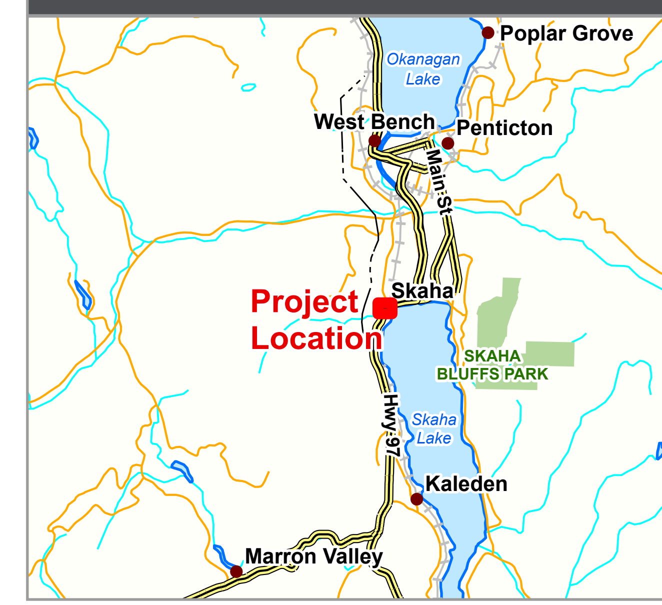
Label	Test Hole Type	UTM Zone	Northing	Easting	Elevation
TH-16-01	ODEX	11	5,480,608.55	310,729.02	354.956
TH-16-02	ODEX	11	5,480,640.16	310,717.39	353.958
TH-16-03	ODEX	11	5,480,723.54	310,760.22	347.608
TH-16-04	ODEX	11	5,480,778.68	310,772.51	345.794
TH-16-05	Auger	11	5,480,824.15	310,818.18	342.668
TH-16-06	Auger	11	5,480,849.42	310,772.97	345.622
TH-16-07	ODEX	11	5,480,917.41	310,757.17	346.738
TH-16-08	Auger	11	5,480,842.81	310,892.20	339.698
TH-16-09	Auger	11	5,480,906.39	310,919.78	339.654
TH-16-10	ODEX	11	5,480,942.16	310,926.42	339.876
TH-16-11	Auger	11	5,480,879.96	310,979.52	340.494
TP-17-01	Test Pit	11	5,480,833.77	310,797.55	344.143
TP-17-02	Test Pit	11	5,480,790.84	310,765.47	346.176
TP-17-03	Test Pit	11	5,480,771.34	310,748.68	347.282
TP-17-04	Test Pit	11	5,480,755.41	310,740.59	347.477
CPT-23-01	CPT	11	5,480,845.00	310,986.00	339.600
TH-23-01	Auger	11	5,480,845.00	310,985.00	339.700



Legend

- Cone Penetration Test Location
- Hollow Stem Auger Test Hole Locations
- Solid Stem Auger Test Hole Location
- ODEX Test Hole Locations
- Test Pit Locations
- Infiltration Test Location
- Proposed Alignment
- Road Stations
- 20m TRIM Contour Lines
- Highways
- Digital Road Atlas Roads
- Fresh Water Atlas Streams
- PMBC Legal Parcels

LOCATION MAP



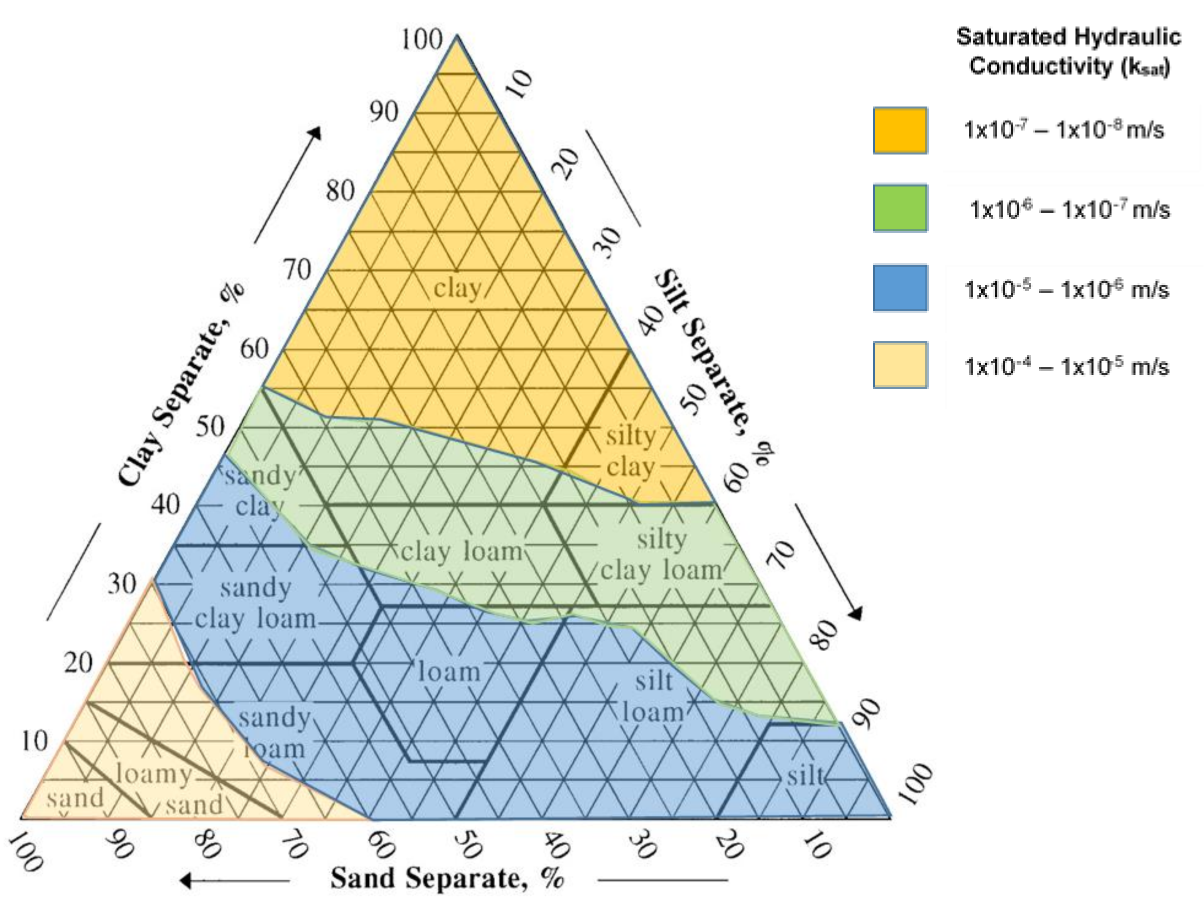
1:1,500

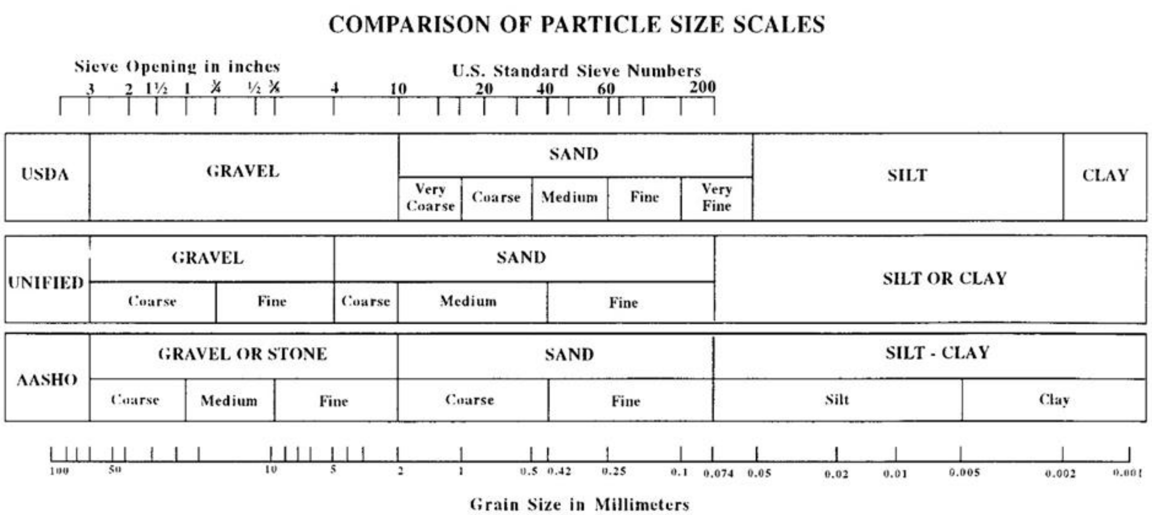
0 50 100 Meters

Project No.: 221266-26
Client: Ministry of Transportation & Infrastructure
NAD 1983 UTM Zone 11N

Date: 2023/06/22
Drawn: SC Check: MJL

Figure 1.2





Reference:

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Geotechnical Design Report HWY97 Skaha Hills Drive Intersection Improvement Penticton, BC

Saturated Hydraulic Conductivity Estimation Based on Gradation (Medium Bulk Density)

Project No. 221266-26
Client: BC Ministry of Transportation and Infrastructure
Office: Kelowna
Scale: NTS
Date: June 22, 2023
DWN: VF CHK: MJL

ecora

Figure 5.0