

*Final Report*

# Gabriola Island Fixed Link Feasibility Study



Prepared for  
**BC Ministry of Transportation and Infrastructure**

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# Executive Summary

Gabriola Island is located approximately 4.5 kilometres (km) east of downtown Nanaimo, with a resident population of 4,050. The British Columbia Ferry Services Inc. (BC Ferries) provides regular service between Descanso Bay on Gabriola Island and Nanaimo Harbour.

Consistent with the provincial government's goal of connecting coastal communities in a sustainable manner and finding innovative ways to reduce the upward pressure on coastal ferry fares, the BC Ministry of Transportation and Infrastructure commissioned CH2M HILL Canada Limited to provide a technical assessment of the feasibility of a Fixed Link, connecting Nanaimo and Gabriola Island.

The study objectives were to assess the technical feasibility of a potential Fixed Link crossing as a replacement for the ferry service, and evaluate feasible options against the existing ferry service, providing information to support informed debate.

The study area is under the authority of multiple jurisdictions, including the BC Ministry of Transportation and Infrastructure, the Island Trust, the City of Nanaimo, and the Regional District of Nanaimo. It encompasses four land reserves of the Snuneymuxw First Nation and the asserted traditional territory of the following First Nations: Snuneymuxw First Nation, Stz'uminus First Nation, Cowichan Tribes, Halalt First Nation, Lake Cowichan First Nation, Lyackson First Nation and Penelakut.

A variety of existing and proposed land uses within the study area were considered during the development of road and bridge options. Although archaeological and environmental factors require careful consideration, based on early assessments, none of them render the project technically unfeasible.

With continued ferry service, travel demands are expected to grow modestly between 2015 and 2044, increasing from 900 to 1,220 vehicle trips per day. With a Fixed Link, projections increase from 900 to 5,000 vehicle trips per day.

Of the Fixed Link options developed (see Figure ES-1), False Narrows East Crossing was determined to be technically unfeasible, as the navigational clearances could not be achieved without significantly compromising acceptable engineering standards for the approach grades to and from the structure.

The average cost for the technically feasible Fixed Link options is \$359 million (reported in 2015 Canadian dollars). The lowest cost option is \$258 million and the highest cost option is \$520 million.

As summarized in Table ES-1, a Fixed Link is estimated to have a Net Present Value of **-\$113.3 million**, based on the average capital cost. The negative Net Present Values indicates that the present value of this project exceeds the present value of the benefits. The benefit/cost ratio was calculated as 0.55, also based on average capital cost. Applying high and low value cost estimates produces a B/C range of 0.34 to 0.92.

FIGURE ES-1. SCHEMATIC OF ROAD AND BRIDGE OPTIONS



TABLE ES-1. NET PRESENT VALUE AND B/C CALCULATION (2015 \$MILLIONS)

Accounts	Base Case	Fixed Link	Incremental Change
<b>COSTS</b>			
Capital Cost (incl. Property)	\$33.7	\$359.0	\$325.3
O&M Costs (2020 - 2044)	\$109.3	\$5.4	(\$103.9)
Ferry Revenue	(\$98.1)	\$0.0	\$98.1
Salvage Value (20%)	(\$6.7)	(\$71.8)	(\$65.1)
<b>Total Incremental Cost (\$ Capital + O&amp;M + Property)</b>	<b>38.2</b>	<b>292.6</b>	<b>\$254.4</b>
<b>USER BENEFITS</b>			
Travel Time	\$173.2	\$98.5	\$74.7
Vehicle Operating Cost	\$7.8	\$33.5	(\$25.7)
Ferry Fare	\$98.1	\$0.0	\$98.1
Safety	\$2.6	\$8.6	(\$5.9)
<b>Total Incremental Benefit (\$ Travel time + Veh Ops + Safety)</b>	<b>281.7</b>	<b>140.6</b>	<b>\$141.1</b>
<b>Net Present Value</b>			<b>(\$113.3)</b>
<b>Benefit – Cost Ratio</b>			<b>0.55</b>

Should further investigation be done on a Fixed Link, it would be necessary to determine if the structure(s) would be tolled and, if so, in what amount. These decisions have a direct correlation with the forecasted traffic demand. This assumption of no toll results in the highest probable forecasted traffic use on the Fixed Link.

While a toll offsets the cost of a Fixed Link, it becomes a cost that is transferred to the users, therefore reducing their benefits.

A multiple accounts evaluation was completed to assess the non-financial aspects impacts of a Fixed Link. The findings of this MAE, displayed in Table ES-2, indicate there are pros and cons associated with the construction of a Fixed Link.

TABLE ES-2. MAE SUMMARY

Accounts		Base Case (Ferry Service)	Fixed Link
<b>CUSTOMER SERVICE</b> (non-monetized criteria)	Travel time reliability/flexibility	90%	100%
	Multimodal accessibility	●	●
	Emergency access	●	●
<b>SOCIAL/ COMMUNITY</b>	Alignment with plans and policies	●	○
	Island identity	●	○
	Property impact	●	○
	Visual impact	●	●
	Recreation	●	●
<b>ENVIRONMENT</b>	Greenhouse gas (GHG) emissions – travel-related	●	○
	Air pollution	●	○
	ALR impacts	●	●
	Terrestrial (flora/fauna) impacts	●	●
	Aquatic impacts	●	●
	Archaeological impacts	●	○
<b>ECONOMIC DEVELOPMENT</b>	Goods movement	●	●
	Growth/Development	●	●
	Impact on local businesses	●	●

## Legend:

○	Much Worse
●	Worse
●	Neutral
●	Better
●	Much Better

Based on the early level of conceptual engineering undertaken in this study, a Fixed Link from Vancouver Island to Gabriola Island appears to be technically feasible. However current costs of constructing a Fixed Link exceed that of the user benefits that have been measured. Understanding the impacts associated with the non-monetized accounts are of significant importance to local government and community members.

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# Acronyms and Abbreviations

AADT	average annual daily traffic
AIA	Archaeological Impact Assessment
ALR	Agricultural Land Reserve
B/C	Benefit/Cost
CAC	Criteria Air Contaminant
CAGR	Compounded Annual Growth Rate
CH2M	CH2M HILL Canada Limited
CO <sub>2</sub> e	carbon dioxide equivalent
DC	dangerous cargo
DFO	Department of Fisheries and Oceans Canada
ESA	Environmentally Sensitive Area
GDP	gross domestic product
GHG	greenhouse gas
IFRS	International Financial Reporting Standards
km	kilometre
km/h	kilometres per hour
m	metre
m <sup>2</sup>	square metre
MAE	Multiple Account Evaluation
MFLNRO	BC Ministry of Forests, Lands and Natural Resource Operations
ML-ARD	Metal Leaching and Acid Rock Drainage
NPV	Net Present Value
O&M	Operations and Maintenance
OCP	Official Community Plan
RAAD	Remote Access to Archaeological Data
RDN	Regional District of Nanaimo
RSL	relative sea-levels
StatCan	Statistics Canada
TAC	Transportation Association of Canada
VKT	vehicle kilometres travelled

# Introduction

## 1.1 Overview

Gabriola Island is located approximately 4.5 kilometres (km) east of downtown Nanaimo. Gabriola Island had a resident population of approximately 4,050<sup>1</sup>. In summer, the population almost doubles in size with the addition of tourists and visitors. Access to the island is by boat or ferry.

Mudge Island lies between Gabriola Island and Nanaimo. Access to Mudge Island is by private boat only. According to the 2007 Official Community Plan, the full time resident population is estimated at 65 people, with a summer population over 200.

The British Columbia Ferry Services Inc. (BC Ferries) provides regular service between Descanso Bay on Gabriola Island and Nanaimo Harbour. Residents of Gabriola Island rely on the ferry for commuter trips and access to a range of services and facilities in Nanaimo. The ferry service also provides access to Gabriola Island for tourists and visitors.

## 1.2 Project Scope

Consistent with the provincial government's goal of connecting coastal communities in a sustainable manner and finding innovative ways to reduce the upward pressure on coastal ferry fares, the BC Ministry of Transportation and Infrastructure (BC MoTI) commissioned CH2M HILL Canada Limited (CH2M HILL) to provide a technical assessment of the feasibility of road and bridge "Fixed Link" options between Nanaimo and Gabriola Island. This study is intended to assist discussion about how to connect coastal communities in an affordable, efficient, and sustainable manner.

The scope, as defined by the Terms of Reference, includes the following tasks:

1. Problem Definition Statement;
2. Prepare Forecast Demand Estimate;
3. Review Previous Studies;
4. Develop Crossing Alignment Alternatives;
5. Evaluation of Alternatives;
6. Preferred Corridor Identification; and,
7. Report and Recommendations.

This report is the outcome of Task 7 and incorporates the engineering review, analysis, and evaluations carried out in Tasks 1 through 6.

## 1.3 Project Objectives

The objectives of this feasibility study are as follows:

1. **Assess the technical feasibility of a potential Fixed Link crossing between Nanaimo and Gabriola Island as a replacement for the ferry service:** The study examines the facts regarding a Fixed Link crossing, considering alignment, road connections, construction costs, operation and maintenance costs, travel time, reliability, and flexibility for potential users. It includes a high-level assessment of the socio-economic and environmental impacts of such a connection.

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<sup>1</sup> Based on 2011 Census data from Statistics Canada

2. **Evaluate feasible options against the existing ferry service:** The study brings together quantitative and qualitative analysis in a structured Multiple Account Evaluation (MAE) framework, based on BC MoTI guidelines.
3. **Provide the information to support informed debate:** The study provides information about how bridges and roads would compare to the existing ferry services.

## 1.4 Previous Studies

Connecting Gabriola Island to Nanaimo has been discussed and under study a number of times over the last few decades.

A Fixed Link was examined in 1993, when BC MoTI and BC Ferries jointly commissioned a Mid-Island Transportation Strategy to review ferry and highway operations between Vancouver Island and the Mainland. The study reviewed alternate ferry terminal sites, including one at the south end of Gabriola Island. A further study, also 1993, assessed the technical feasibility of connecting the above proposed Gabriola ferry terminal to Nanaimo. The study concluded that the preferred route would consist of two bridges, one over Dodd Narrows and one over False Narrows, providing a link to Gabriola Island via Mudge Island. Direct connections between Nanaimo and Gabriola Island – spanning Northumberland Channel – were not believed viable given the excessive crossing distance and water depth.

## 1.5 Study Area

The study area includes downtown Nanaimo, Cedar area, Mudge Island, and Gabriola Island. The area overview is shown in Figure 1-1.

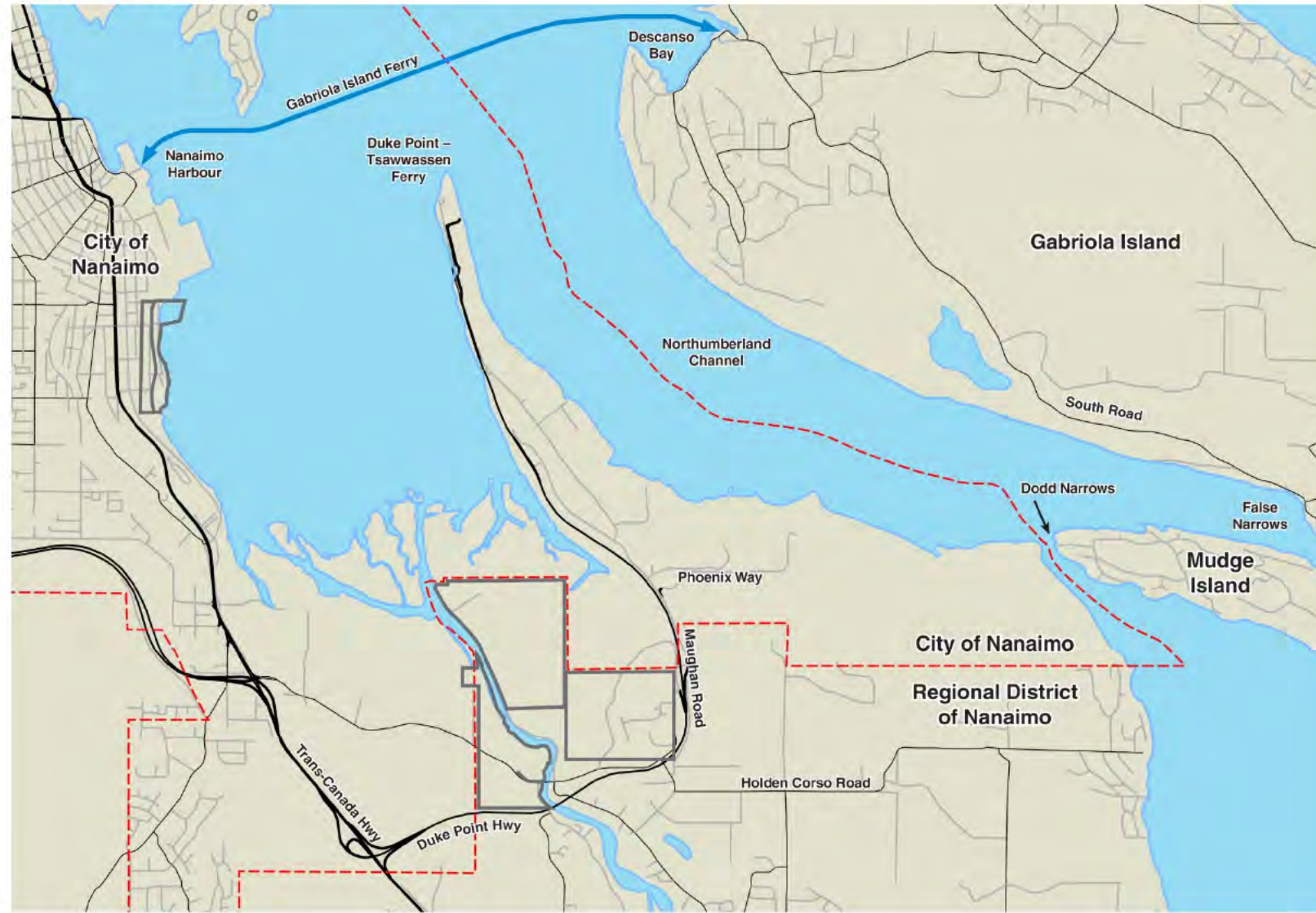
Northern crossing options, near the site of the existing ferry terminal, were not considered, as these routes require greater bridge lengths and pass through active ferry and marine shipping channels.

## 1.6 Local Government Authority

The study area includes lands within the City of Nanaimo (City), as well as lands within the Regional District of Nanaimo (RDN). While Mudge Island and Gabriola Island fall within the Regional District of Nanaimo Electoral Area B, it must be noted that land use planning decisions are under the jurisdiction of the Islands Trust. Notwithstanding both Islands, the RDN is responsible for regulating land use within the regional district boundaries. The regulation of land use is a City responsibility within municipal limits.

The BC MoTI is responsible for road and bridge maintenance within the RDN, including both Islands, while the City is responsible for road and bridge maintenance within municipal limits.

FIGURE 1-1. AREA OVERVIEW



**Legend**

- - - City of Nanaimo/Regional District of Nanaimo Boundary
- Snuneymuxw FN reserves

# Existing Conditions

## 2.1 Overview

This section describes the site context, archaeological and environmental conditions which require consideration in development of options for the Fixed Link. The existing conditions analysis is based on desktop assessments and data obtained from the following technical stakeholders: the Islands Trust, the Regional District of Nanaimo (RDN), the City of Nanaimo, Department of Fisheries and Oceans Canada (DFO), the Ministry of Forests, Lands and Natural Resource Operations, the Ministry of Environment, and the Council of Marine Carriers.

## 2.2 Site Context

This section describes land use, including: developments, facilities, and amenities within the study area.

### 2.2.1 Gabriola Island

Gabriola Island is slightly less than 58 square kilometres of land and is serviced by ~138 km of two-lane roads. Of these, ~100 km are paved and 38 km are gravel. While much of Gabriola Island is forested, some parts have been cleared for agriculture.

Residential homes and vacation properties are dispersed around the island. Other facilities and amenities include: local shopping, restaurants, a library, post office, an elementary school, and a museum.

### 2.2.2 Mudge Island

Mudge Island is approximately three (3) square kilometres with ~10 km of dirt and gravel roads. Residential development is low density and access to the island is via water only. The island has no shopping or schools and its residents travel to Gabriola Island or Vancouver Island for all amenities and services.

In 2006, BC Assessment indicated that Mudge Island had a total of 360 separate properties – 173 with single family dwelling units and 187 with vacant lands.

### 2.2.3 City of Nanaimo

The study area includes a portion of the City of Nanaimo and within that portion, a variety of land use exists. This section provides a broad outline of the various developments, facilities and amenities:

- Residential neighbourhoods: The semi-rural residential area has larger properties than in a more heavily urbanized environment. Generally, the residences are single family with few higher density developments;
- Areas of recreational value: Cable Bay Trail and other less formal trails exist within the study area. Further, Dodd Narrows and the adjacent shore lines are well used for water-based recreation by local residents and visitors;
- Industrial development: A variety of light industrial development exists along Duke Point;
- Schools: Cedar Community School is located within the study area;
- Farming activities: Hobby as well as commercial farming takes place in the area;
- Amenities, including: grocery stores, restaurants, gas stations, churches, retail outlets; and,
- Two large master plan communities: The proposed Ocean View development is a 500 acre site in the Cable Bay area and the Sandstone development is a 726-acre site adjacent to the Trans-Canada Highway and the Duke Point Highway.

## 2.2.4 First Nation Territory

The study area encompasses Snuneymuxw First Nation reserve land. The Snuneymuxw First Nation has a population of over 1,750 people with approximately 700 members living on 266 hectares of reserve land in four locations in the Nanaimo area, including: Nanaimo Harbour; Nanaimo River; and two reserves at Gabriola Sea.

In addition, the study area is within the asserted traditional territory of the following First Nations; Snuneymuxw First Nation, Stz'uminus First Nation, Cowichan Tribes, Halalt First Nation, Lake Cowichan First Nation, Lyackson First Nation and Penelakut.

## 2.3 Archaeological Conditions

A desktop assessment was undertaken to determine the occurrence of archaeological sites within the study area. It was conducted using a variety of mapping and database tools, including the BC Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) Archaeology Branch Remote Access to Archaeological Data (RAAD) website and available satellite imagery.

The review indicated that there would be high potential for encountering new archaeological sites anywhere within the study area, including intertidal and submarine environments.

Coastal and inland zones in the study area should be considered to be of high archaeological potential and of cultural importance to First Nations.

Research<sup>2</sup> indicates that the relative sea level in the vicinity of Nanaimo and Gabriola Island has varied by as much as 150 metres (m) relative to present sea level. A Fixed Link involving intertidal or submarine ground disturbance to an approximate depth of 25 m below current sea level may potentially affect archaeological deposits, possibly deeply buried beneath marine sediments. There is considered to be high potential for encountering new archaeological sites anywhere within the Fixed Link alignment option areas, including in intertidal and submarine environments.

## 2.4 Environmental Conditions

A desktop assessment was conducted to identify potential terrestrial, fresh water, and marine environmental sensitivities within the study area. This study included a review of species at risk, sensitive ecological communities, and critical habitats of various species.

The review indicated that the primary environmental concerns were the unidentified 'sensitive' species which are located throughout the study area. BC Conservation Data Centre database masks these species in order to protect them, and therefore, these species are likely to be more vulnerable to impacts and disturbances resulting from road and bridge construction.

Eight species at-risk were identified within the general study area. These include six plant species (Awned Cyperus; Banded Cord-Moss; Muhlenberg's Centaury; Nuttal's Quillwort; Slimileaf Onion; and White-top Aster); and one ecological community (Douglas-fir/Dull Oregon-grape). In addition, the blue-listed eulachon marine fish, an at-risk marine species, was found within the study area. This species has the potential to occur at the bridge crossing locations.

The review also highlighted potential spawning habitat for herring and ling cod, and the presence of oyster and clam beds along the coastal shorelines near the bridge crossings.

Treed habitats along Gabriola Island and Mudge Island provide nesting habitat for bald eagles.

<sup>2</sup> Shugar et al. (2014), James et al. (2009) and James et al. (2002).  
2-2

No at-risk fresh water aquatic species were identified, however fresh water drainages likely connecting to Northumberland Channel were identified which may contain potential rearing and spawning habitat for salmon, trout, and char species.

The Strait of Georgia, which encompasses the entire marine ecosystem within the study area, was also identified by DFO as an Ecologically and Biologically Important Area, meaning it is classified as containing significant or critical marine habitats.

No provincially designated parks, protected areas, or conservation areas were located within the project area; however Joan Point Park, a City of Nanaimo park is located within the study area.

Detailed environment findings can be referenced in Appendix D.

# Travel Demand Forecast

## 3.1 Overview

This section outlines how the changes to travel demand were estimated.

Annual travel demand forecasts were developed for the period between 2015 and horizon year 2044, assuming a 2020 fixed link opening and a 25-year study horizon from opening day. Demand forecasting was considered for two options:

- **Base Case** – travel demand with continued ferry service
- **Fixed Link** – travel demand with ferry service replaced by roads and bridges

The steps included examining current trends, patterns, and volumes. Next, the effects on these volumes were estimated. Finally, the total impacts were estimated to determine 2044 horizon year volumes.

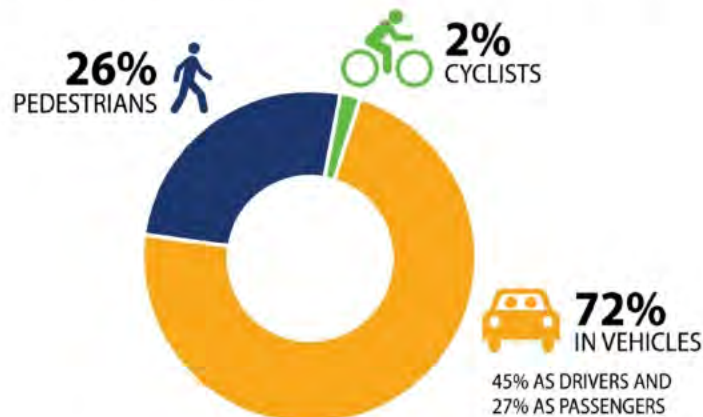
## 3.2 Base Case Travel Demand

Base Case demand assumes continuation of ferry services between Nanaimo and Gabriola Island. BC Ferries historic ridership data was used as the basis for estimating future demand for ferry services. It was assumed that the current trip rates (number of ferry trips per person between Gabriola Island and Nanaimo) would remain constant over the study period, and that changes in ferry ridership would occur as a result of population changes.



### 3.2.1 BC Ferries Ridership

In 2013, BC Ferries served approximately 348,000 motor vehicles and about 770,000 passengers between Gabriola Island (Descanso Bay) and Nanaimo Harbour. Data from BC Ferries for the year 2013 showed the breakdown of passenger trips was as follows:



Ridership data was examined for the past 3 years (2013 – 2015) and this proportion was confirmed to be broadly consistent.

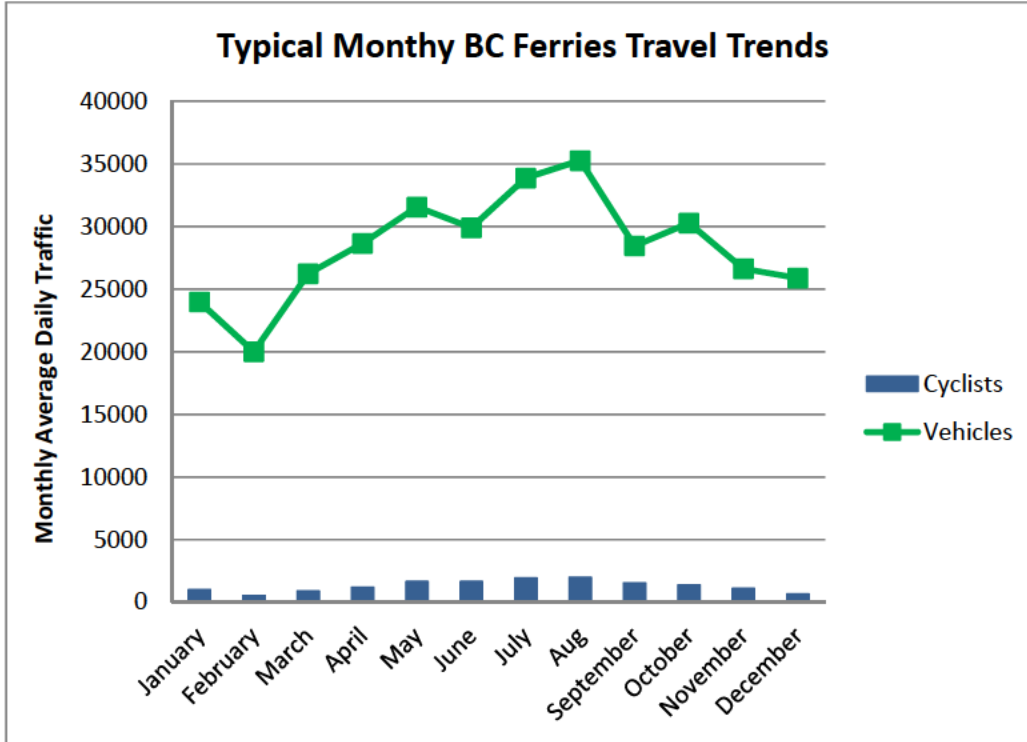
Walk-on traffic could be as a result of a variety of factors, including: convenience, cost savings, and a lifestyle desire for active transportation. The current ferry terminal location in downtown Nanaimo facilitates the connection from Gabriola to urban services. Presently, a shopping mall is located

approximately 200 m from the ferry terminal and offers a variety of services, restaurants, and transit connections.

A review of average daily traffic for all vehicles between 2004 and 2014 indicates that traffic volume is seasonal with the highest volumes observed in the summer months. Cycling traffic was analyzed for this same period and showed that it also peaked in July and August and dipped during the colder winter months.

Figure 3-1 shows the seasonal variation in vehicle and cycling traffic over the course of a year (2013/14).

FIGURE 3-1. SEASONAL FERRY VEHICLE AND CYCLIST TRAFFIC VARIATION



### 3.2.2 Base Case Population Growth Assumptions

Future ferry ridership growth was estimated by applying observed trip rates to assumed population growth. While census data indicate that the population of Gabriola Island grew from 2,625 in 1991 to 4,050 in 2006, the population of Gabriola Island has not grown since 2006. For forecasting purposes, it was assumed that Base Case population growth rates on Gabriola Island will mirror forecasts for the total Gulf Island population available from Statistics Canada (StatCan)<sup>3</sup>. StatCan data indicate that the population on the Gulf Islands is predicted to grow by 13% between 2015 and 2030, from approximately 15,400 to 17,500 people. This equates to a population growth rate of approximately 0.9% per annum. Using this annual growth rate and extending this to 2044, Gabriola Island population was calculated to grow as shown in Table 3-1.

TABLE 3-1. BASE CASE POPULATION GROWTH

Horizon Year	Base Case Population Growth
2015	4,050
2020 (year of fixed link opening)	4,150
2044	5,200

<sup>3</sup> This assumption was made as StatCan does not provided information specific to Gabriola Island.

### 3.2.3 Base Case Estimated Traffic Growth Forecasts

For the purposes of this report a trip is defined as a one way journey from Nanaimo to Gabriola or the reverse journey.

Ferry ridership was assumed to grow at the same rate as population growth. The current trip rate of 0.52 return trips per person per day on Gabriola Island was assumed to continue to 2044. It was assumed that the proportion of walk on passengers (28% pedestrians and cyclists) would remain constant and the occupancy rate of 1.6 people per vehicle unchanged. The total estimated ferry trips are shown in Table 3-2.

TABLE 3-2. 2015-2044 BASE CASE TRAFFIC GROWTH FORECASTS

Year	Forecast Daily Person Trips	Forecast Annual Average Daily Traffic
2015	2,100	950
2020	2,160	976
2044	2,700	1,220

## 3.3 Fixed Link Demand

Fixed Link travel demand was estimated assuming that the existing ferry service is replaced by roads and bridges. As with the Base Case, it is assumed that Fixed Link travel demand would be affected by the number of people living on Gabriola Island, the estimated travel time between Gabriola and Vancouver Island, and the 24-hour access provided by roads and bridges.

### 3.3.1 Fixed Link Population Growth Assumptions

Current population growth on Gabriola Island (and the rate for the Gulf Islands in general) is lower than that of the RDN population growth rate.

It is considered that a Fixed Link could result in an increase in population growth on Gabriola Island<sup>4</sup>, matching the forecasted RDN average growth rates of 2% per year<sup>5</sup>. Population growth projections were developed for Gabriola Island on this basis. An average annual growth rate of 2% was assumed after opening of the bridge in 2020 and projected forward to 2044. Based on this, the projected population of Gabriola Island in 2044 would be approximately 6,760 residents.

TABLE 3-3. PROJECTED POPULATION GROWTH ON GABRIOLA ISLAND (2011 – 2044)

Year	Forecast Population
2015	4,050
2020	4,200
2044	6,760

### 3.3.2 Travel Demand Assumptions

The City of Nanaimo's Travel Diary Survey undertaken in spring 2012<sup>6</sup> was used to derive vehicle trip rates for the fixed link.

<sup>4</sup> Note that this would require changes to Gabriola Island Official Community Plan policies.

<sup>5</sup> See: <http://www.rdn.bc.ca/cms/wpattachments/wplD440atID2097.pdf>.

<sup>6</sup> Surveys of Nanaimo households are undertaken every 4-5 years to determine residents' travel patterns, and represent travel patterns on a typical weekday. These surveys are used to forecast travel behavior in the RDN.

Based on data from the trip diary survey, one-way daily vehicle trip rates for Cedar and Cinnabar Valley residents travelling to the remaining sub-areas of Nanaimo were calculated. The data showed that each person living in Cedar or Cinnabar Valley generated more than three times the number of vehicle trips per day than each person living on Gabriola Island<sup>7</sup>.

Having a Fixed Link in place would encourage some, but not all, residents of Gabriola to make additional trips. The Fixed Link is expected to also result in additional tourist visitors.

Given the added distance between Gabriola Island and Nanaimo, as compared to Cedar and Cinnabar Valley, it was assumed that the trip rate would be lower than these areas. If a Fixed Link were constructed, it is estimated that travel to and from Gabriola Island would double, per capita.

FIGURE 3-2. FERRY AND FIXED LINK - ASSUMED TRIP ORIGIN/DESTINATION AND ROUTES

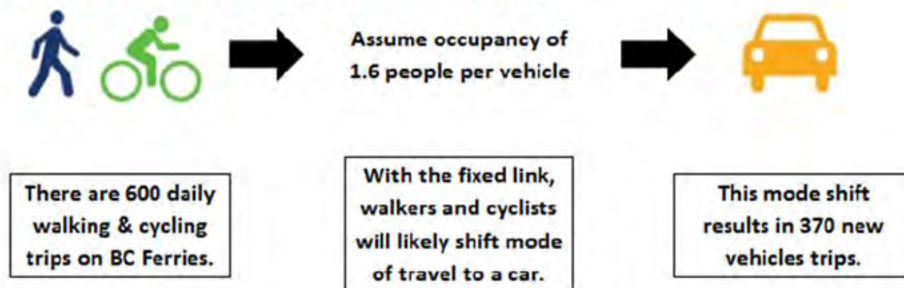


Source: Google Maps

Note: The Fixed Link route shown in Figure 4-2 is generalized and approximate, shown for illustrative purposes only.

In addition to the increased trips made by vehicle travelers, it is necessary to account for the 28%<sup>8</sup> of ferry users who are not using vehicles. Based on 2013 data 600 daily non-motorized trips were made by ferry. The Fixed Link would increase the total travel distance for these users to about 20 km which is a long trip, even for the most avid cyclist. It is assumed that these users would shift their mode of travel from walking/cycling to vehicle use. Using the vehicle occupancy rate from BC Ferries of 1.6 people/vehicle, these non-motorized users were converted into 370 (366 rounded) daily vehicle trips for 2015. This is shown in Figure 3-3.

FIGURE 3-3. MODE SHIFT AS A RESULT OF THE FIXED LINK



<sup>7</sup> Cedar/Cinnabar residents generate 0.38 one-way vehicle trips per day vs 0.11 trips for Gabriola residents.

<sup>8</sup> For assessment purposes, cyclists and pedestrians were combined as non-motorized ferry users.

It should be noted that currently there is no transit service to Gabriola Island, however should a future service be established, then some of these user trips may alter their mode of travel to transit, avoiding the use of a vehicle. The assumption of converting walking/cycling trips into vehicles was for the purposes of analysis only. Further discussion would be required with the RDN and BC Transit regarding a transit service from Nanaimo to Gabriola Island should a Fixed Link be explored further.<sup>9</sup>

The increase in new motorized users is shown in Table 3-4. This volume was grown at the same rate as the assumed population growth (see Section 3.3.1).

TABLE 3-4. INCREASE IN THE NUMBER OF MOTORIZED USERS AS A RESULT OF MODE SHIFT ASSOCIATED WITH THE FIXED LINK (2015 – 2044)

Year	New Motorized Users, Vehicles Per Day
2015	0
2020	370
2044	600

### 3.3.3 Fixed Link Estimated Traffic Growth Forecasts

To calculate the total estimated vehicle travel demand as a result of the Fixed Link, several sources of travel demand must be accounted for, including:

- vehicle trips currently using the ferry (calculated previously in Section 3.2);
- the additional demand created by shifting modes; and
- the additional trips made both by existing Gabriola Island residents, whose travel demand is estimated to double as a result of the improved reliability offered by a Fixed Link and reduced costs<sup>10</sup> as well as demand from new residents (included under Additional Trips in the table below).

The average occupancy for vehicles on the Gabriola Ferry is 1.6 people per vehicle. For travel on the fixed link that is expected to drop to 1.4 people per vehicle. The summary of these travel volumes are shown below in Table 3-5.

TABLE 3-5. SUMMARY OF FIXED LINK TRAVEL VOLUMES (2015 – 2044)

Year	Base Case Ferry Vehicle Trips (AADT)	New Motorized Users	Additional Trips	Total Trips per Day (rounded) AADT
2015	950	0	0	950
2020	976	370	1,770	3,200
2044	1,220	600	3,200	5,000

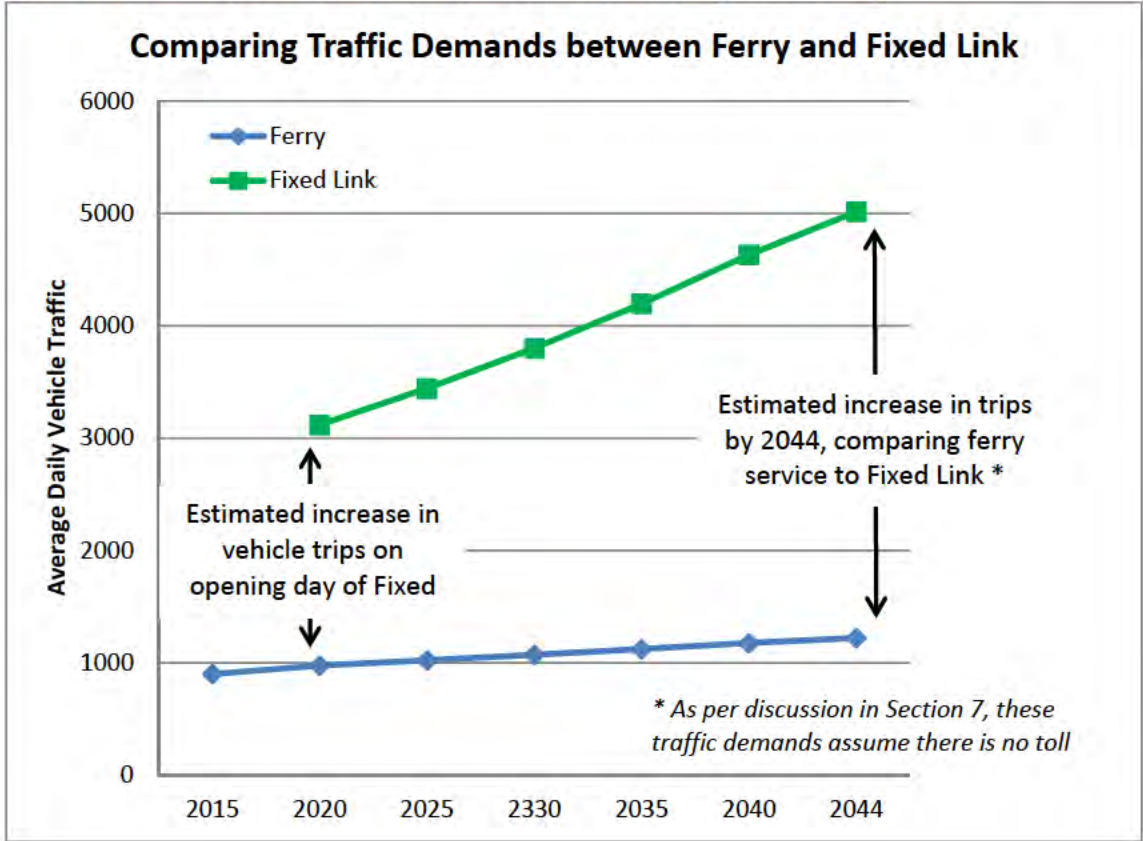
## 3.4 Travel Demand Summary

A graphic comparison between the demand forecast for the Base Case and Fixed Link is shown in Figure 3-4. The Fixed Link was estimated to create four times as many trips per day as the Base Case for the horizon year 2044.

<sup>9</sup> BC Transit undertook a Gabriola Transit Feasibility Study in 2010 - <http://www.rdn.bc.ca/cms/wpattachments/wpID2439atID4066.pdf>

<sup>10</sup> These users benefit from reduced costs as it is assumed that they are no longer subject to ferry fares (or equivalent tolls).

FIGURE 3-4. TRAFFIC VOLUME COMPARISON FERRY VERSUS FIXED LINK (2015 – 2044)



# Option Development (Roads & Bridges)

## 4.1 Overview

This section presents the road and bridge options that would make up a Fixed Link connection. It explains engineering design considerations, and develops options for main channel crossings, Dodd Narrows crossings and the roadway network.

## 4.2 Engineering Design Considerations

This section outlines the engineering design considerations for each component of the Fixed Link connection: bridge alignment, geotechnical research, navigational clearances, and road cross section design criteria.

### 4.2.1 Bridge Alignment Considerations

The location of a proposed crossing is constrained by many factors including but not limited to: land use, environmental issues, archaeological sites, and suitable foundation areas.

The horizontal alignment of a bridge is dependent on the approach roads and design speeds. A straight bridge is the least expensive to design and construct but is not always an option. The vertical alignment is a function of the elevation differences between the two land masses being connected and the required navigational clearances. For example in the case of connecting Vancouver Island and Mudge Island the height of land is very similar so a bridge is expected to have a very modest grade of 1-2%. Grades are an important consideration in ensuring driver safety and comfort.

### 4.2.2 Geotechnical Considerations

The findings from the geotechnical engineering assessment, prepared by Thurber Engineering Ltd., indicate that a Fixed Link is generally considered to be feasible from a geotechnical perspective. Geotechnical conditions are anticipated to be favourable, given the near-surface bedrock elevations. However, specific geotechnical expertise is required to develop the concept designs of the pier/abutment foundations, assess road pavement structure, and evaluate slope stability. It is anticipated that all technical issues identified can be addressed during any potential future design and construction stages.

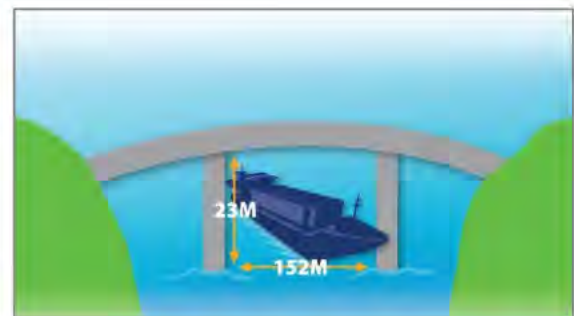
Detailed geotechnical findings can be referenced in Appendix B.

### 4.2.3 Navigational Clearances

The Council of Marine Carriers recommends:

- A minimum 23 m vertical clearance at high water in order to accommodate all sizes of barge traffic; and
- A minimum clear width in False Narrows of 152 m (500 feet) to accommodate log tows at high water.

A study of prevailing and potential future vessel traffic would be required to ascertain potential vessel dimensions which would be submitted to Transport Canada for review and approval.



## 4.2.4 Road Cross Section Design Criteria

The Fixed Link is projected to have traffic volumes of approximately 5,000 vehicles per day (2044 projection). This expected traffic volume is well within the capacity (15,000 to 20,000 vehicles per day) of a typical two lane road.

It is anticipated that the roadway would have a design speed of 50-70 km/h and would be utilized by cyclists and pedestrians for commuting and recreational purposes, as per Figure 4-1.

The assumed design criteria for the Fixed Link are based on the BC MoTI standards for a Rural Collector (BC Supplement to Transportation Association of Canada [TAC] Geometric Design Guide, 2007 – Figure 440.B).

FIGURE 4-1. ILLUSTRATIVE TWO LANE BRIDGE CROSS SECTION



## 4.3 Main Channel Crossing Options

Four different bridge crossing location options to Gabriola Island were developed:

- The Northumberland Crossing option provides a direct link from Vancouver Island to Gabriola Island across Northumberland Channel, avoiding Mudge Island. The maximum crossing depth<sup>11</sup> is 66 m.
- The False Narrows Crossing options link Mudge Island and Gabriola Island, spanning False Narrows at three possible locations. To enable any of these crossings, an additional bridge would be required spanning Dodd Narrows. The maximum crossing depth for False Narrows West is 37 m and, for False Narrows East and Central is 2 m.

Crossing locations are shown on Figure 4-2 and described in more detail in this section.

### 4.3.1 Northumberland Crossing

This option would require a bridge of over 1,500 m long on a gradient of 2.7%. Gradient is the slope of the approaches on or off a bridge. The Gabriola landing area is on a steep hillside and founding the abutment at this location could be challenging. On account of the differences in elevation at either end, the bridge height would be around 80 m above the sea level, meeting the recommended 23 m navigational clearance.

For this length of bridge, the most economical bridge is likely to be a cable stayed bridge (example of Port Mann cable-stayed bridge pictured on right). The piers would be in the channel with the main span being 800 m long and the approach spans of approximately 350 m each.



Cable-stayed structures are practical for main spans of up to about 1,100 m; however, it should be noted that there are only about 10 cable-stayed bridges in the world that are between 800-1,100 m.

<sup>11</sup> Depths are reduced to Chart Datum (lowest normal tide) which at Nanaimo is 3 m below Mean Water Level.

FIGURE 4-2. SCHEMATIC OF ROAD AND BRIDGE OPTIONS



### 4.3.2 False Narrows Crossing

Three options were developed for the False Narrows crossing, all of which have varying impacts as described below.

#### 4.3.2.1 False Narrows West Crossing Option

This option represents the longest span of all the crossings linking Mudge Island to Gabriola Island. This option would require a crossing of approximately 840 m (shore-to-shore distance), at a 5.6% grade<sup>12</sup>. This gradient is considered steep, causing driver discomfort and technical engineering challenges. The bridge landing area on Gabriola Island would be at a 70 m elevation on a steep hillside and founding the abutment at this location could be challenging.



Due to water depth, a cable-stayed bridge is recommended as it limits the number of deep water piers required. A main span of 700 m and backspans of approximately 250 m would allow for smoother transitions between the bridge and the connecting road network, and were assumed for cost estimating purposes. It was expected that the north pier would be founded on a deep water foundation, and the south pier would be built on shore.

#### 4.3.2.2 False Narrows Central Crossing Option

This crossing connects Weather Way on Mudge Island and South Road on Gabriola Island. This option could be accommodated with an 800 m long box girder structure, with a balanced cantilever main span to meet the recommended 23 m high and 152 m wide navigation envelope. Approach gradients on either side of the main span would be approximately 4.4%. The bridge landing would be in the vicinity of the South Road and Ferne Road intersection on Gabriola Island.

An example of a box girder bridge is shown in Figure 4-3.

FIGURE 4-3. EXAMPLE OF BOX GIRDER-TYPE STRUCTURE OVER THE TSABLE RIVER



#### 4.3.2.3 False Narrows East Crossing Option

This crossing connects Coho Boulevard on Mudge Island and South Road on Gabriola Island, and would require a 480 m long box girder structure. Due to the low elevations on either side of the False Narrows, it is not feasible to accommodate the recommended 23 m high and 152 m wide navigation envelope without excessive impacts to bridge approach grades (in excess of 10%). These considerations render this bridge option as 'not technically feasible'.

<sup>12</sup> Alternative alignments were explored to reduce the 5.6% grade; however, these were not pursued in detail since they created greater property impacts on Mudge Island.

## 4.4 Dodd Narrows Crossing Options

Two options were developed for the Dodd Narrows crossing, both of which have varying impacts as described below. The maximum crossing depth is 12 m.

### 4.4.1 Dodd Narrows Crossing Option 1

This option is the shorter potential crossing, and would require a bridge of 210 m, although this would likely impact Joan Point Park.

A concrete box girder structure was recommended as the appropriate structure type for this crossing. This bridge design could be built in sections and would not require towers or cables for support. A main span of 160 to 180 m could be achieved and would accommodate the navigational clearances required. Further study is required to determine how closely piers could be located to the edge of the channel.



This option requires significant fill (up to 20 m) at the west abutment on Vancouver Island. Building a fill of this height would be challenging; however technically feasible.

### 4.4.2 Dodd Narrows Crossing Option 2

An alternative alignment was developed crossing Dodd Narrows to avoid direct impacts to Joan Point Park. A concrete box girder bridge was recommended as the appropriate structure for this crossing, requiring a bridge of approximately 260 m.

This option appears feasible from a structural engineering and constructability perspective.

## 4.5 Road Network Options

Four different road alignment options (shown in Figure 4.2) were developed, providing a connection between the Duke Point Highway 19 on Vancouver Island and South Road on Gabriola Island.

The proposed road alignment options make use of existing roads on Vancouver Island, Mudge Island and Gabriola Island, however also require the construction of new roadways.

The extent of upgrades on Mudge Island and/or Gabriola Island are contingent on the location of the bridge crossings. This section focuses on describing the road network options on Vancouver Island.

All roadway options were determined to be technically feasible.

### 4.5.1 Phoenix Way

This route begins at the Maughan Road Interchange on Highway 19 (Duke Point Highway). It makes use of Maughan Road for 700 m to reach Phoenix Way.

This alignment makes use of Phoenix Way (pictured to the left) which is an existing private industrial road with limited access. This road which would require approximately 1,300 m of road and intersection improvements. It would also require construction of a 2,600 m extension of Phoenix Way to the start of the Fixed Link, near the main channel crossing.

This option intersects with the Cable Bay Trail and adjacent creek, requiring construction of a bridge or large multi-plate structure, due to significant elevation changes between the new road and existing trail grade.



All roadworks are within City of Nanaimo boundaries. Two options were explored, one of which avoids impacts to Joan Point Park.

### 4.5.2 Nicola Road



This option is also accessed from Highway 19, via the Maughan Road interchange, located approximately 1 km to the north of MacMillan Road. For the purposes of this study, no upgrades are proposed to provide direct access to Highway 19 at MacMillan Road.

This alignment makes use of existing rural public roads, with numerous driveway access points, in the Cedar area, including: MacMillan Road, Holden Corso Road (pictured to the left), Barnes Road and Nicola Road. All of these roads (~4 km) would require upgrades, including intersection improvements. Additionally, it requires ~1,500 m of new road construction from the end of Nicola Road to the start of the main channel crossing.

The roadworks are largely within the RDN, with a small portion falling in City limits.

### 4.5.3 Central Route

There were two options developed for the Central Route. Both alignments start using the existing Phoenix Way, for approximately 200 m, which would require upgrades, including intersection improvements. Access from Highway 19 is described above in the Phoenix Way option.

The roadway for both options is largely within the City, with a small portion falling within RDN boundaries.

#### 4.5.3.1 Option A

This alignment requires ~4,000 m of new road construction to the main channel crossing.

This option intersects with the Cable Bay Trail and adjacent creek, requiring construction of a bridge or large multi-plate structure, due to significant elevation changes between the new road and existing trail grade.

This option also requires the construction of a structure<sup>13</sup> to cross two existing Harmac pulp mill waterlines (pictured to the right).

#### 4.5.3.2 Option B

This option shares the same alignment as Central Route A, for approximately 1,700 m, before continuing east for another 2,300 m to the Dodds Narrows crossing.

This option also requires the construction of a structure to cross two existing pulp mill waterlines.

Alignment drawings for all of the road options can be found in Appendix A.



<sup>13</sup> For cost estimating purposes, it was assumed this crossing would be spanned using culverts

# Cost Estimates

## 5.1 Overview

Cost estimates for all Fixed Link road and bridge options are presented in this chapter.

### 5.1.1 Unit Rates

Typical unit rates, extracted from BC MoTI's cost estimating database, were used for the major construction items in order to arrive at the overall planning level cost estimate for the work.

For the purposes of this estimate, an all-inclusive unit rate for bridge construction was assumed.

- \$6,500/m<sup>2</sup> for concrete box girder bridges
- \$10,000/m<sup>2</sup> for cable stayed bridges

These rates reflect the complexity of the structures and account for total construction cost including mobilization and site preparation, temporary works, permanent works, and professional fees.

### 5.1.2 Property Impacts

Based on general property value ranges for various zonings and lot characteristics provided by BC MoTI, estimated property impact costs were determined and are included in the overall cost estimate. A contingency of 50% was added to property acquisition estimates, given the early stage of design, and the number of uncertainties.

### 5.1.3 Engineering and Supervision

As an estimate of the engineering and supervision, the following estimated rates were used, based on the total estimated construction cost:

- 10% of the construction cost was used to estimate construction supervision costs. This would cover activities such as site staff, administration, materials testing, monitoring, accommodation, and travel costs, etc.
- 10% of a select portion of construction cost was used to estimate Engineering Design services. This select portion included: grading, drainage, structures, paving, signing and pavement markings, and electrical works. Engineering Design services includes preliminary and detailed design, legal and topographic survey, geotechnical investigation, pavement analysis, and environmental impact assessment.

### 5.1.4 Contingencies

With the conceptual level of design completed under this study, a contingency allowance of 50% was included to account for items and conditions unknown at this level of design. Besides those items identified earlier, additional items could include sub-excavation in soft soils; additional haul for embankment materials or gravels; gravel pit development; environmental mitigation; and archaeological remediation.

### 5.1.5 Accuracy

BC MoTI published Project Cost Estimating Guidelines (2013) which provided guidance on the level of accuracy to be expected at various levels of planning and design. Applying these guidelines, the level of project development completed at the conceptual planning level is between 1% and 15%, and the associated level of accuracy to be expected for the cost estimates is  $\pm 35\%$ . However, it is considered

reasonable and advisable to apply an accuracy of ±50% at this stage of the study given that the level of completeness is within the 0%-2% range and owing to the following risk factors:

- Earthworks and paving quantities were developed with minimal geotechnical input;
- Bridge structures comprise a significant component of the costs;
- The likely need to barge in all construction materials; and,
- Limited, if any, obvious site establishment locations especially at the bridgeheads on Mudge Island.

## 5.2 Cost Estimate Summary

The costs for each of the technically feasible options are shown in Table 5-1.

TABLE 5-1. FIXED LINK OPTION COST ESTIMATES

Option	Road / Bridge Option	Road (\$ Millions)	Bridges (\$ Millions)	Total (\$ Millions)
<b>Phoenix Way Options</b>				
1	Phoenix Way / Northumberland Bridge (Cable Stay)	42	n/a	472
2	Phoenix Way / Dodds Bridge #1 / False Narrows West Bridge	42	47	279
3	Phoenix Way / Dodds Bridge #1 / False Narrows Central Bridge	42	47	185
4	Phoenix Way / Dodds Bridge #2 / False Narrows West Bridge	42	59	279
5	Phoenix Way / Dodds Bridge #2 / False Narrows Central Bridge	42	59	185
<b>Central Route B Options</b>				
6	Central Route B / Dodds Bridge #2 / False Narrows West Bridge	18	59	279
7	Central Route B / Dodds Bridge #2 / False Narrows Central Bridge	18	59	185
<b>Nicola Road Options</b>				
8	Nicola Road / Northumberland Bridge	15	n/a	472
9	Nicola Road / Dodds Bridge #2 / False Narrows West Bridge	15	59	279
10	Nicola Road / Dodds Bridge #2 / False Narrows Central Bridge	15	59	185
<b>Central Route A Options</b>				
11	Central Route A / Northumberland Bridge	48	n/a	472
12	Central Route A / Dodds Bridge #1 / False Narrows West	48	47	279
13	Central Route A / Dodds Bridge #1 / False Narrows Central	48	47	185
14	Central Route A / Dodds Bridge #2 / False Narrows West	48	59	279
15	Central Route A / Dodds Bridge #2 / False Narrows Central	48	59	185

Based on the information outlined in Table 5-1, capital costs for a fixed link are expected to range from \$258 million to \$520 million, with an average capital cost of \$359 million.

# Multiple Account Evaluation

## 6.1 Overview

A multiple account evaluation (MAE) is a multi-criteria information matrix designed to:

- Compare options;
- Provide a balanced view of all impacts;
- Present and understand compromises and trade-offs.
- The standardized BC MoTI methodology was used, which included five separate accounts. The financial accounts are described above in Table 6-1 and the non-financial measures are discussed in this section, comparing the Base Case impacts to those of a Fixed Link.
- The MAE compares the implications of continuing the ferry service over the next 25 years (known as the Base Case) to the implications of replacing the ferry with a Fixed Link.

FIGURE 6-1. MAE ACCOUNTS



## 6.2 Financial Account

The financial account assesses four factors: capital cost, operations and maintenance costs, salvage value and ferry revenue.

The underlying assumptions for this analysis were as follows:

- All costs reported in 2015 Canadian dollars;
- 25-year planning horizon;
- Continuation of existing ferry service until opening year of the Fixed Link in 2020;
- Inflation/Consumer Price Index adjustment of 2.1% per year based on Conference Board of Canada projections; and,
- Discount rate of 6% in accordance with BC MoTI guidelines.

Present Value = the current worth of a future sum of money or cash flow given a specified rate of return. It provides a common basis for comparing investment options.

## 6.2.1 Capital Costs

The cost estimate for the Fixed Link is described in Section 6. The cost estimate for the Base Case represents the expected costs to upgrade or replace the terminal facilities and the ferry currently in service, based on financial projections provided by BC Ferries.

## 6.2.2 Operations and Maintenance (O&M) Costs

Base Case costs for the period 2020 to 2044 were generated using BC Ferries financial projections. The Base Case costs account for direct operating expenses and indirect regional and corporate management costs. Direct operating expenses include such items as labour, fuel costs, marine insurance, and terminal O&M costs. However, they do not include corporate amortization and financing costs. The Fixed Link maintenance costs are based on BC MoTI's *"Default Values for Benefit Cost Analysis in British Columbia – 2012"*. The maintenance costs would begin in 2020 and continue through to 2044. The O&M costs associated with the Fixed Link include the net present value (NPV) of road maintenance including bridge maintenance and road resurfacing.

## 6.2.3 Salvage Value

Typically infrastructure such as roads, bridges, and ferry terminals last much longer than the planning analysis period. Twenty five years into the future, these assets will still be worth in the order of 70-90% of what they cost to build. The Salvage Value is the Present Value of this future worth. The average Salvage Value is calculated to be 20% of the capital costs.

## 6.2.4 Ferry Revenue

Ferry revenues were calculated based on BC Ferries fare, vehicle and passenger data provided for 2013. Ferry revenue was grown in line with vehicle and passenger growth forecasts. Fares were assumed to increase in line with an assumed Consumer Price Index of 2.1%.

# 6.3 Customer Service Account

## 6.3.1 Travel Times

The Fixed Link would be expected to reduce vehicle travel time between Nanaimo and Gabriola Island by approximately 20 minutes, taking into account drive time between the trip's origin and ferry terminal, ferry wait time, ferry crossing time, and drive time between ferry terminal and destination.

On average it has been observed and BC Ferries permits walk-on passengers and cyclists to arrive closer to sailing time than automobile drivers. This results in less travel time savings for these users. For the purposes of this analysis, it was assumed that these users would shift modes to use a vehicle. See Section 4 for this discussion.

## 6.3.2 Vehicle Operating Costs

The Fixed Link is expected to result in an increase in total vehicle kilometres travelled (VKT) over a 25-year period, based on the increase in forecasted travel demand as described in Section 3. The analysis assumes a vehicle operating cost of 17 cents per km. The increase to VKT results in a user dis-benefit for the Fixed Link.

## 6.3.3 Safety

BC MoTI's *"Default Values for Benefit Cost Analysis in British Columbia – 2012"* were used to determine the monetary values (2012 dollars) of crashes by severity as shown below:

- Property Damage Only:      \$11,367
- Injury:                              \$135,577
- Fatal:                                \$6,385,999

Based on observed Provincial Collision Rates (per VKT) for different road classes between 2006 and 2010<sup>14</sup> and using VKT forecasts, the Fixed Link is expected to result in approximately 130 additional crashes on the road network over the project's 25 year horizon. This increase in crashes results in a safety dis-benefit for the Fixed Link.

### 6.3.4 Ferry Fares

This report was not intended to assess the merits of tolling, therefore it was assumed there will be no toll in the Fixed Link. As users are currently paying a ferry fare, this assumption results in a significant user benefit for the Fixed Link.

### 6.3.5 Reliability and Flexibility

The ferry operates approximately 16 hours a day, averaging a headway of 70 minutes between trips. Analysis of historical ferry data, shows that approximately 2% of all vehicles experience a sailing wait on account of limited ferry vessel capacity.

A Fixed Link would establish a permanent link between Nanaimo and Gabriola Island, providing around the clock accessibility.

### 6.3.6 Multi Modal Accessibility

Section 3 shows that 28% of ferry users are walk-ons and cyclists, demonstrating the popularity of this form of travel as well as the convenience of the terminal location in downtown Nanaimo.

The Fixed Link would increase the estimated total travel distance for these users to more than 20 km which is a long trip, even for the most avid cyclist.

These users would primarily need to change their trip to a vehicle. Some users will have ready access to a vehicle, while others may not. If a Fixed Link were to be pursued, these user needs would need to be considered more closely to fully understand the impacts to individuals living on Gabriola Island.

### 6.3.7 Emergency Access

The closest hospital for Gabriola Island residents is the Nanaimo Regional General Hospital.

For non-urgent needs, residents use the scheduled ferry service to travel to the hospital. Where patients are in need of urgent/life threatening medical assistance, they are airlifted to the hospital.

Outside of ferry hours, the Nanaimo Harbour Patrol response vessel is available for emergencies with more urgent cases being air lifted.

With a Fixed Link the travel times to the hospital for non-emergencies would be reduced. Travel times by ambulance on a Fixed Link are expected to be similar to the time currently taken by the Harbour Patrol.

It is expected that a Fixed Link would result in a reduction in the use of helicopter air lifting.

## 6.4 Social/Community Account

### 6.4.1 Alignment with Plans and Policies

The Fixed Link is inconsistent with the objective in the Gabriola Island OCP (1997) to “oppose any Fixed Link or bridge to Vancouver Island”. Similarly, Policy 4 of the Mudge Island OCP (2007) states that “no island in the Plan Area shall be connected to any other island by a bridge”. A further social goal in the Gabriola Island OCP is to “encourage gradual and appropriate, rather than rapid, change and growth” while a community goal articulated in the Mudge Island OCP (2007) is “to keep the islands as a refuge from the pressures of urban life, as partially facilitated by the absence of ferry service and bridges between these and other

<sup>14</sup> [http://www.th.gov.bc.ca/publications/planning/Safety/Average\\_Provincial\\_Collision\\_Rates\\_2006-10\\_Collision\\_Data.xls](http://www.th.gov.bc.ca/publications/planning/Safety/Average_Provincial_Collision_Rates_2006-10_Collision_Data.xls)

islands.” Significant development of Gabriola and Mudge Islands would be inconsistent with policies in the currently approved OCPs.

### 6.4.2 Island Identity

The character, identity, and atmosphere of Gabriola Island and Mudge Island are defined precisely by the fact that they are separate from the Mainland and from Vancouver Island. It is considered that island identity is a quality worth preserving and is one of the reasons why people choose to live or vacation on Gabriola Island and/or Mudge Island. (The Mudge Island OCP states that Mudge Island residents and landowners favour low population density and “water access only”.) A fixed link is expected to result in significant population growth, more services and more tourism. Island identity is likely to be fundamentally altered by the provision of a Fixed Link.

### 6.4.3 Property Impacts

The Fixed Link will change traffic patterns in the study area. For those options that use existing roads, there will be a significant increase in through traffic. This will result in property impacts for residents, businesses and community facilities.

### 6.4.4 Visual Impacts

The height and location of the bridge structures for the Fixed Link would result in visual intrusion to properties on Gabriola Island, Mudge Island and Nanaimo.

### 6.4.5 Recreation

The Fixed Link may impact Joan Point Park to some extent if a Fixed Link were to be constructed. Impacts to the existing Cable Bay Trail could be mitigated by the possible inclusion of a bridge structure (versus earth embankment and culvert) over the trail and creek. While the Fixed Link would not impact designated parks on Gabriola Island or Mudge Island, it is anticipated that it would adversely impact beach settings (designated as “Water General” in the Gabriola and Mudge Island OCPs<sup>15</sup>), and could compromise public recreational enjoyment of the shoreline at the crossing locations. While a Fixed Link will arguably increase the number of people who are able to access the recreational amenities on Gabriola Island and Mudge Island, it may also compromise the enjoyment of these amenities.

## 6.5 Environmental Account

### 6.5.1 Green House Gas (GHG) Emissions - Travel Related

The ferry which serves Gabriola Island uses, on average, 190 litres<sup>16</sup> of fuel per round trip. Based on the current ferry schedule this equates to 908,960 litres of fuel per year (assuming 4,784 annual round trips based on the 2015 ferry timetable). Given this level of fuel consumption, it is estimated that the ferry service will produce 2,514 tonnes of carbon dioxide equivalent (CO<sub>2</sub>e) emissions per year, or 62,843 tonnes of CO<sub>2</sub>e emissions over the 25 year study period. In addition, automobile travel associated with ferry trips is estimated to produce 18,400 tons of CO<sub>2</sub>e over the study period, resulting in 80,883 tonnes of CO<sub>2</sub>e in total for the Base Case.

The GHG emissions associated with Fixed Link, over the 25 year period, are estimated at 225,264 tonnes. It is estimated that the Fixed Link will result in a net increase CO<sub>2</sub>e of 143,000.

<sup>15</sup> Permitted uses in the Gabriola OCP include boat moorage and boat launching facilities, public parks, and ecological reserves

<sup>16</sup> Island Futures “2008 GHG Emissions Gabriola Island” (February 8, 2010), available online at <http://www.nickdoe.ca/pdfs/Webp638.pdf>.

### 6.5.2 Air Pollution

Ferry Criteria Air Contaminant (CAC) emissions is complex and depends on a variety of considerations such as whether a ferry vessel is docked, maneuvering or underway and whether the vessel is fully loaded, engine size, and speed. In order to simplify the approach, generalized ferry emission factors were applied as shown below and apply only in the Base Case.

Ferry CAC Emissions (tonnes)	Base Case (tonnes)	Fixed Link (tonnes)
NO <sub>x</sub>	11,554	0
SO <sub>x</sub>	191	0

Automobile CAC emissions are dependent on speed, engine type and mode of operation. In order to enable a high level comparison, emissions factors<sup>17</sup> based on estimated fuel consumption have been applied. Estimates of total vehicle CAC emissions by type for the Fixed Link are shown below.

Vehicle CAC Emissions	Base Case(tonnes)	Fixed Link (tonnes)
CO	470	7,960
NO <sub>x</sub>	35	590
PM <sub>10</sub>	0.2	3.7
PM <sub>2.5</sub>	0.2	3.5

### 6.5.3 Agricultural Land Reserve (ALR) Impacts

The Fixed Link does not have any impact on ALR parcels.

### 6.5.4 Terrestrial (Flora/Fauna) Impacts

Potential impacts to plant and ‘sensitive’ species includes removal, disturbance, alteration, or loss of habitat as a result of construction of the roadway.

### 6.5.5 Fish and Aquatic Impacts

Impacts to marine species and/or their habitat may result from construction of permanent bridge piers in False Narrows, as well as temporary works to support construction access along the shoreline. Degradation of marine habitats may result from sedimentation or the introduction of other deleterious substances to the water.

The Strait of Georgia, which encompasses the entire marine ecosystem within the study area, was also identified by DFO as an Ecologically and Biologically Important Area, meaning it is classified as containing significant or critical marine habitats.

### 6.5.6 Archaeological Impacts

Existing archaeological sites have been identified, or are expected, along the entire alignment of the Fixed Link. It is considered that Fixed Link construction could potentially result in significant impacts to these resources.

<sup>17</sup> US EPA Emission Facts (2008) “ Average Annual Emissions and Fuel Consumption for Gasoline-Fueled Passenger Cars and Light Trucks” Office of Transportation and Air Quality EPA420-F-08-024 available online at <http://www.epa.gov/otaq/consumer/420f08024.pdf>

## 6.6 Economic Development Account

### 6.6.1 Goods Movement

Financial aspects of goods movement is captured in the B/C analysis.

A Fixed Link would reduce the cost of moving goods and building materials onto Gabriola Island (and potentially Mudge Island).

### 6.6.2 Growth/Development

As discussed in Section 3, a Fixed Link could result in population growth on Gabriola Island at a similar rate to that which is forecasted for the RDN. The realization of this growth potential would be dependent on community views and changes to local plans and policies, such as the Gabriola Island OCP.

### 6.6.3 Impacts on Local Businesses

The Fixed Link has the potential to bring people to Gabriola Island (due to improved accessibility), providing an increased customer base for local businesses, particularly those associated with tourism such as vacation accommodation, restaurants, galleries, and tourist retail. Many island businesses struggle in the off-season and improved access may contribute to their viability and sustainability.

However, this improved accessibility also opens up the off-island (Nanaimo and surrounding area) economic and retail opportunities for Gabriola Island residents.

Further investigation is required to assess the impacts on the local economy in greater detail.

## 6.7 MAE Summary

Table 6-1 provides a summary of the financial aspects of the Multiple Accounts Evaluation, whereas Table 6-2 provides a summary of the non-financial aspects of the Multiple Accounts Evaluation.

TABLE 6-1. MAE SUMMARY – FINANCIAL ACCOUNTS (2015 \$MILLIONS)

Accounts	Base Case	Fixed Link	Incremental Change
<b>COSTS</b>			
Capital Cost (incl. Property)	\$33.7	\$359.0	\$325.3
O&M Costs (2020 – 2044)	\$109.3	\$5.4	(\$103.9)
Ferry Revenue	(\$98.1)	\$0.0	\$98.1
Salvage Value (20%)	(\$6.7)	(\$71.8)	(\$65.1)
<b>Total Cost (S Capital + O&amp;M + Property)</b>	<b>38.2</b>	<b>292.6</b>	<b>\$254.4</b>
<b>USER BENEFITS</b>			
Travel Time	\$173.2	\$98.5	\$74.7
Vehicle Operating Cost	\$7.8	\$33.5	(\$25.7)
Ferry Fare	\$98.1	\$0.0	\$98.1
Safety	\$2.6	\$8.6	(\$5.9)
<b>Total Benefit (S Travel time + Veh Ops + Safety)</b>	<b>281.7</b>	<b>140.6</b>	<b>\$141.1</b>
<b>Net Present Value</b>			<b>(\$113.3)</b>
<b>Benefit – Cost Ratio</b>			<b>0.55</b>

Note: (brackets) indicates a negative incremental change

Table 6-1 assumes a Fixed Link cost of \$359 million, which was calculated as the average cost for all options which are considered to be technically feasible at this stage. As discussed in Section 5, estimated construction costs range between \$258 million and \$520 million. Using these high and low construction costs in the calculations produces a B/C range of 0.34-0.92.

While cost estimates have an impact on the B/C ratio, traffic demand forecasts (outlined in Section 3) also have a significant bearing on the accrued user benefits, and thereby the calculated B/C ratio.

As previously discussed, an assumption has been made that there will be no tolling fee associated with travel on the Fixed Link. Should further investigation be done on a Fixed Link, it would be necessary to determine if the structure(s) would be tolled and, if so, in what amount. These decisions have a direct correlation with the forecasted traffic demand. This assumption of no toll results in the highest probable forecasted traffic use on the Fixed Link.

While a toll offsets the cost of a Fixed Link, it becomes a cost that is transferred to the users, therefore reducing their benefits.

Net Present Value (NPV) represents the present value of capital cost estimates (less salvage value of the ferry/Fixed Link), periodic rehabilitation costs and annual operating/maintenance costs. The Net Present Value of the Fixed Link is estimated to be **(\$113.3 million)**. This negative number indicates that the costs of constructing a Fixed Link exceed that of the financial user benefits that have been measured.

TABLE 6-2. MAE SUMMARY – NON FINANCIAL ACCOUNTS

Accounts		Base Case (Ferry Service)	Fixed Link
CUSTOMER SERVICE (non-monetized criteria)	Travel time reliability/flexibility	90%	100%
	Multimodal accessibility	●	●
	Emergency access	●	●
SOCIAL/ COMMUNITY	Alignment with plans and policies	●	○
	Island identity	●	○
	Property impact	●	○
	Visual impact	●	●
	Recreation	●	●
ENVIRONMENT	Greenhouse gas (GHG) emissions – travel-related	●	○
	Air pollution	●	○
	ALR impacts	●	●
	Terrestrial (flora/fauna) impacts	●	●
	Aquatic impacts	●	●
	Archaeological impacts	●	○
ECONOMIC DEVELOPMENT	Goods movement	●	●
	Growth/Development	●	●
	Impact on local businesses	●	●

Legend:

○	Much Worse
◐	Worse
◑	Neutral
◒	Better
●	Much Better

# Conclusion

## 7.1 Overview

This section provides summary of this report and outlines considerations for future conversations related to the fixed link.

## 7.2 Summary

The objectives of this report were to:

- Assess the technical feasibility of a potential Fixed Link crossing as a replacement for the ferry service;
- Evaluate feasible options against the existing ferry service; and
- Provide the information to support informed debate.

Based on the early level of conceptual engineering undertaken in this study, a Fixed Link from Vancouver Island to Gabriola appears to be technically feasible.

There are a number of combinations of possible road and bridge options, ranging in costs from \$258 million to \$520 million.

A benefit cost ratio was calculated and determined to be in a the range from 0.34 to 0.92, with an average B/C ratio of 0.55 based on an average fixed link cost of \$359 million.

The Net Present Value of the Fixed Link is estimated to be **(\$113.3 million)**. This negative number indicates that the costs of constructing a Fixed Link exceed that of the financial user benefits that have been measured.

A multiple account evaluation was completed to assess the impacts of a Fixed Link on non-financial aspects. The findings of this MAE, displayed in Table ES-3, indicate there are pros and cons associated with the construction of a Fixed Link. Understanding the impacts associated with the non-monetized accounts are of significant importance to local government and community members.

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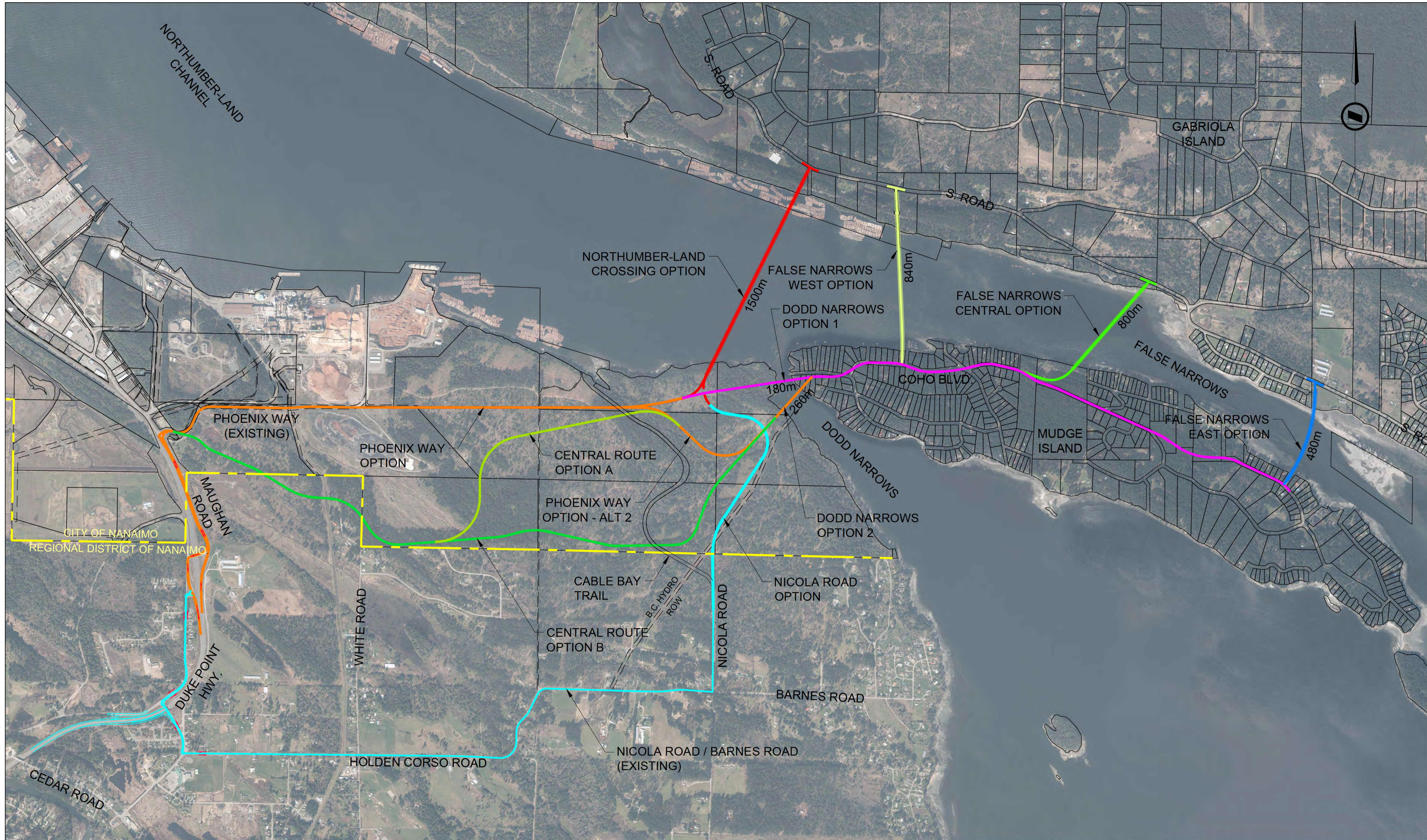
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APPENDIX A  
ALIGNMENT DRAWINGS



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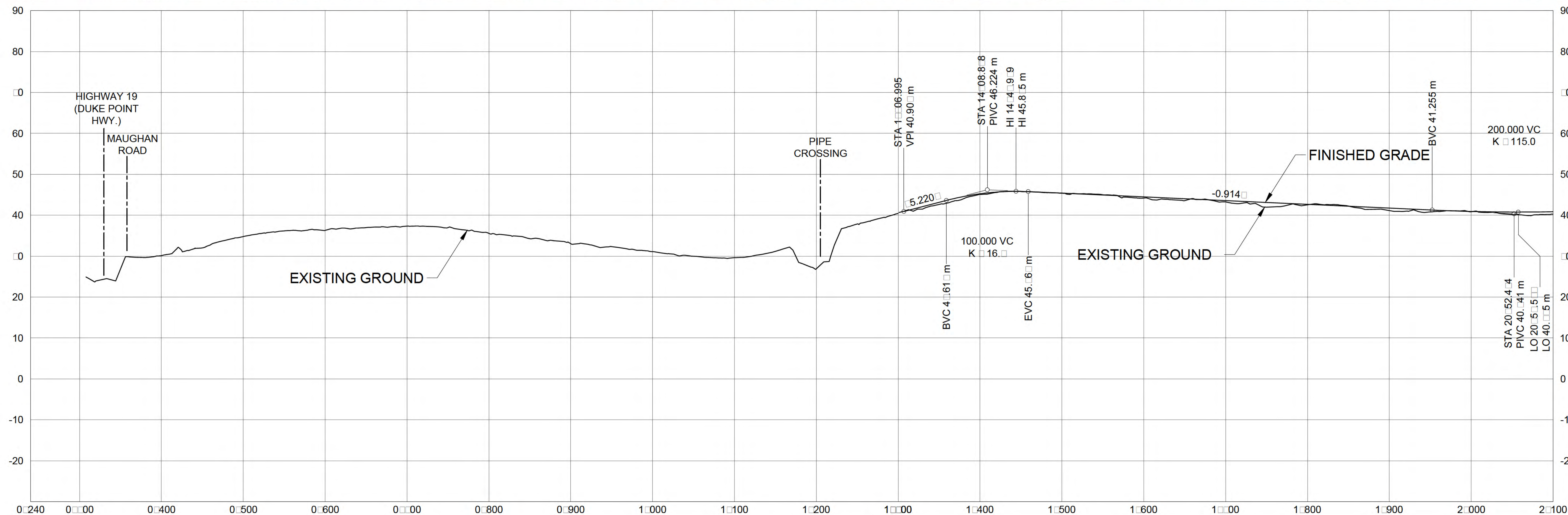
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**GENERAL LOCATION PLAN**  
GABRIOLA ISLAND STUDY  
FIXED LINK OPTIONS

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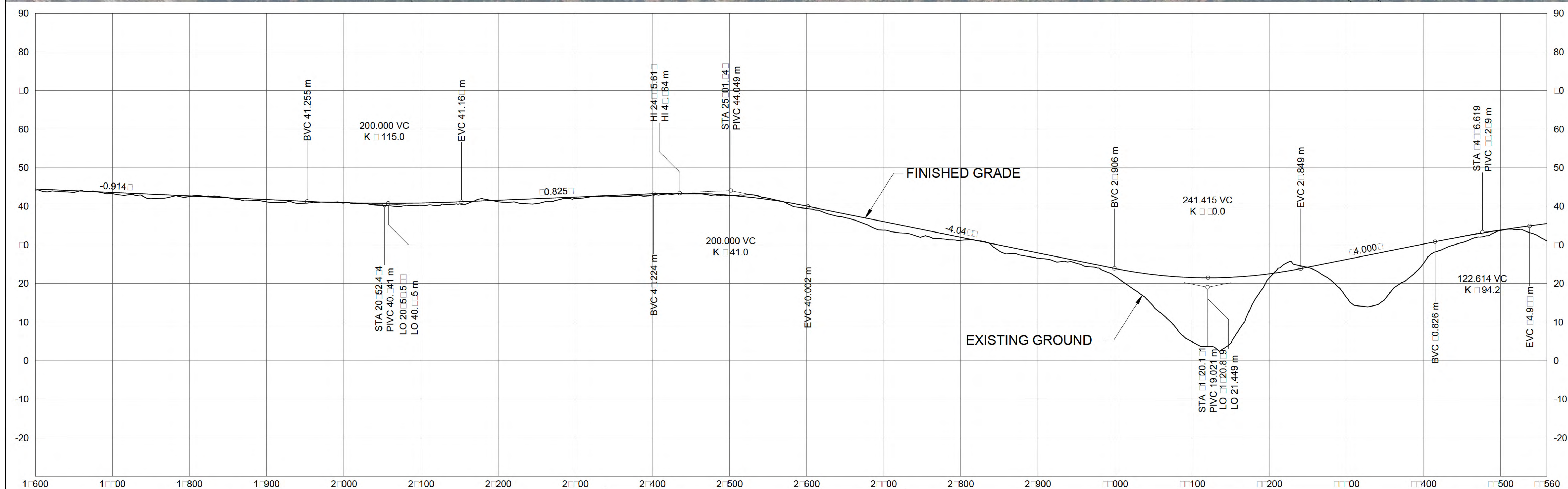
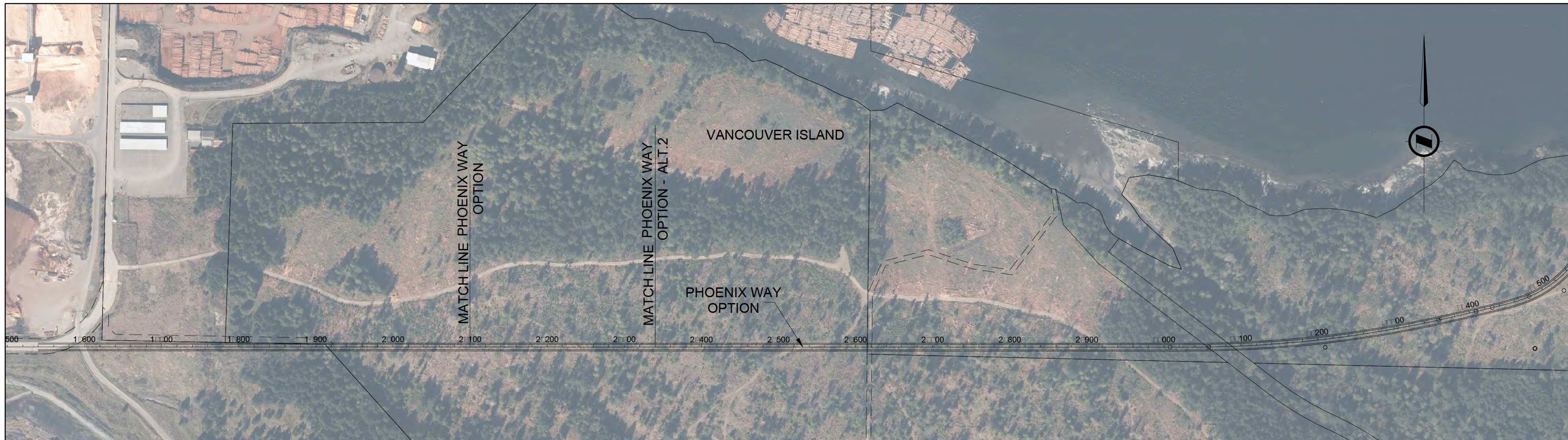
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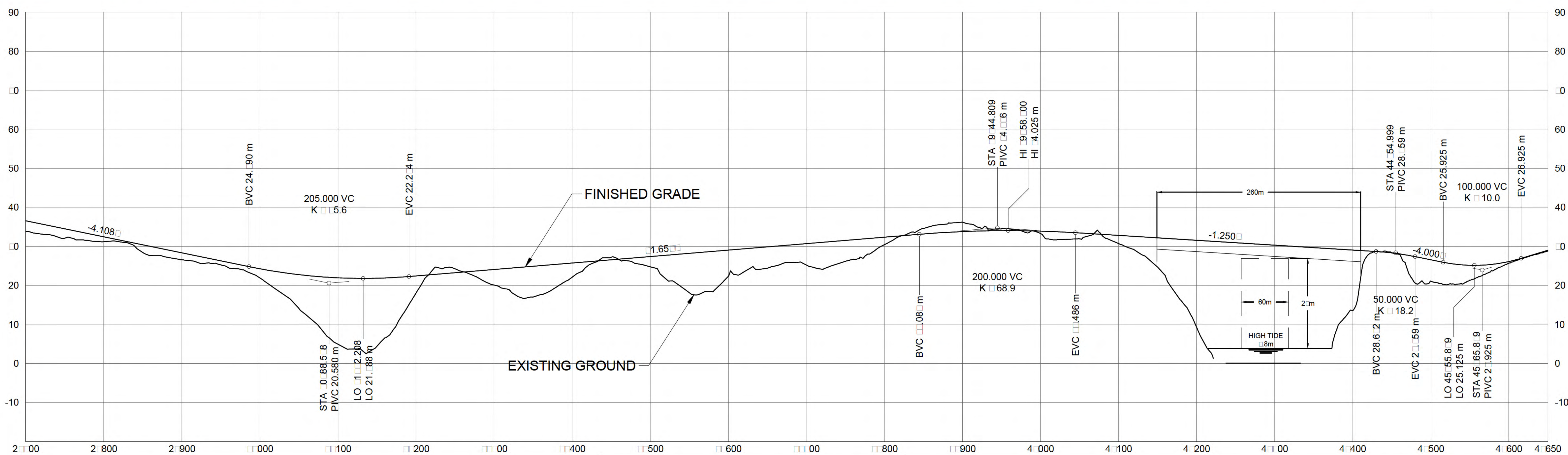
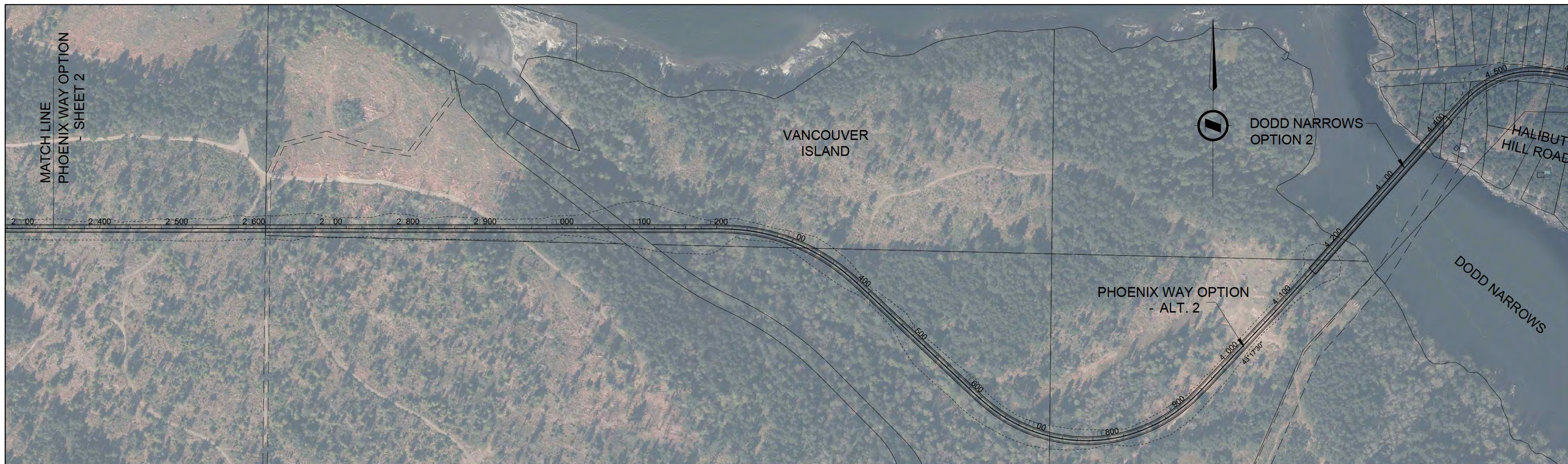
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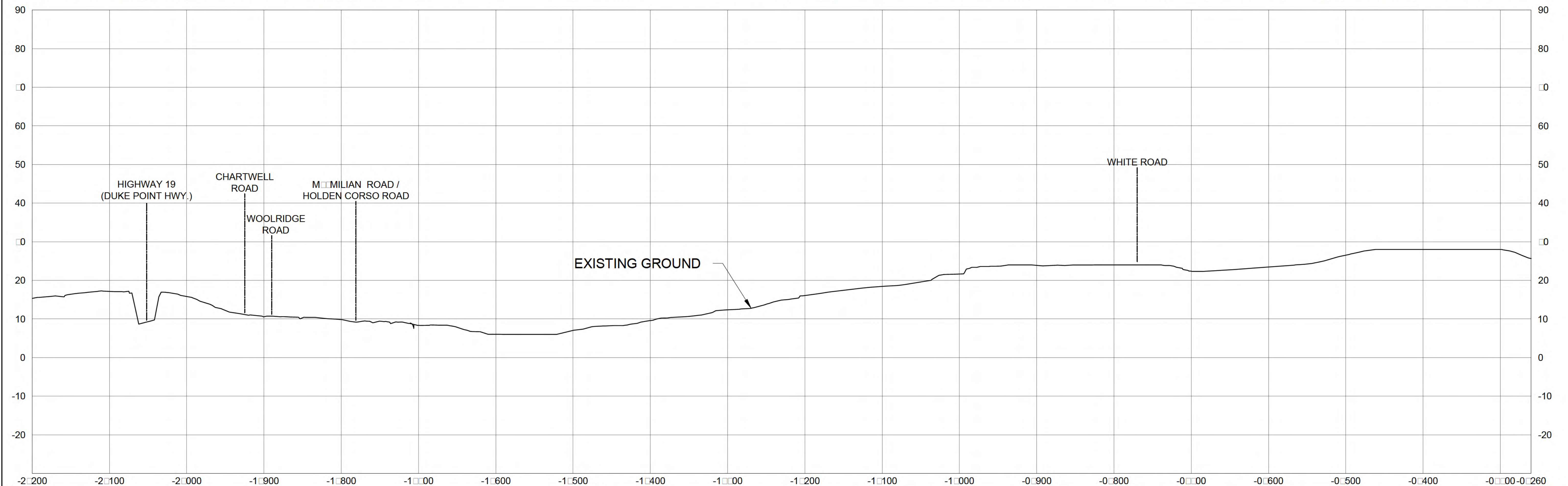
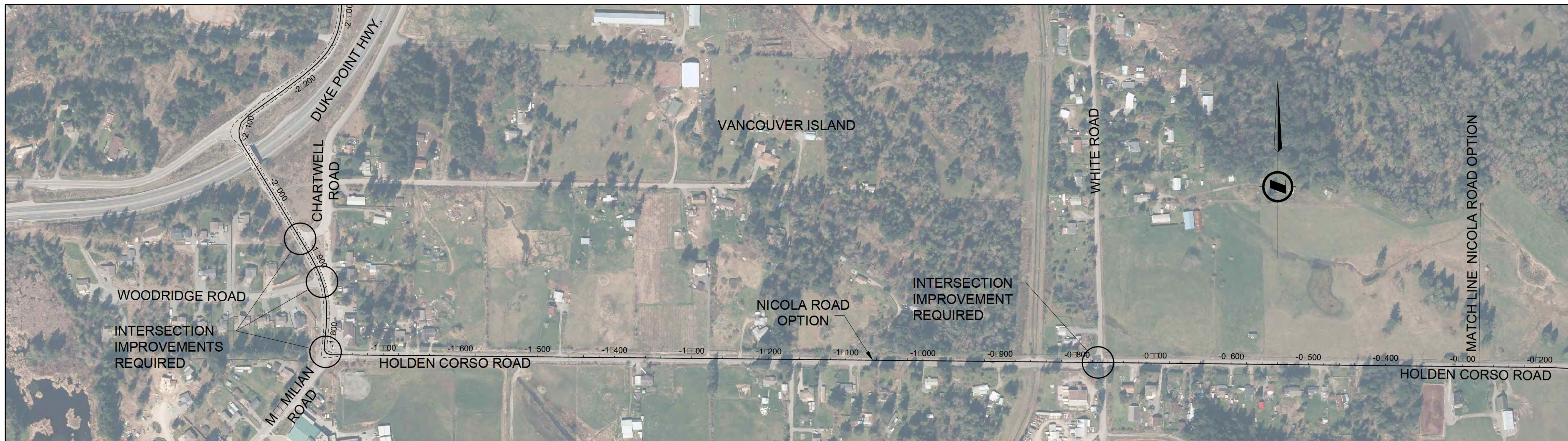
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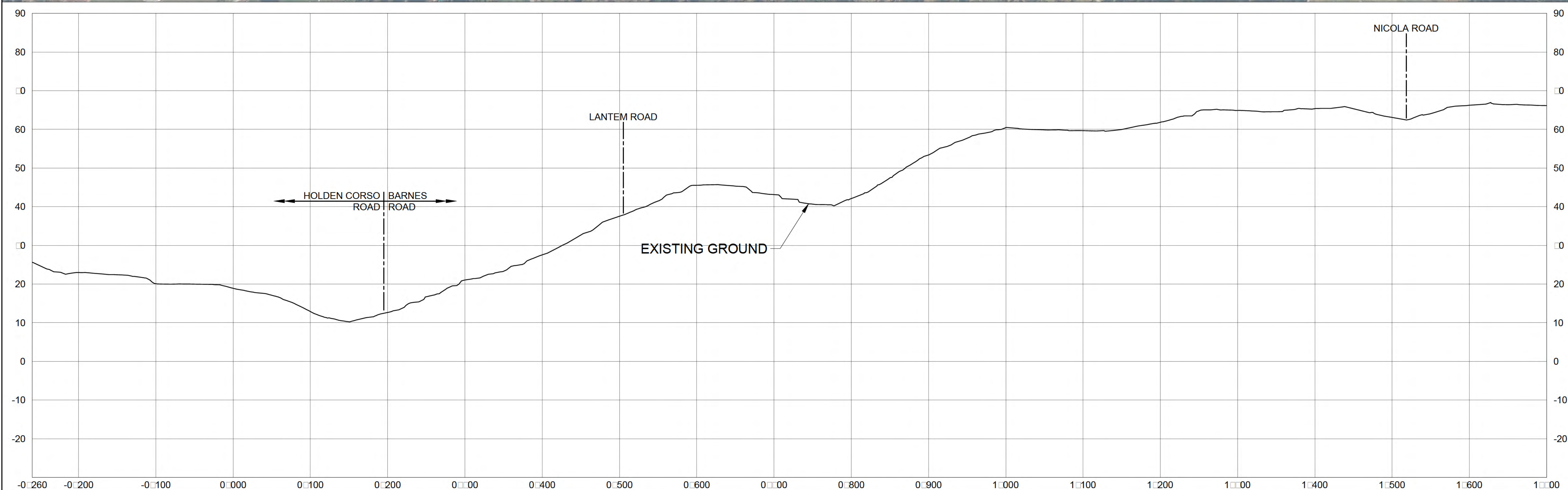
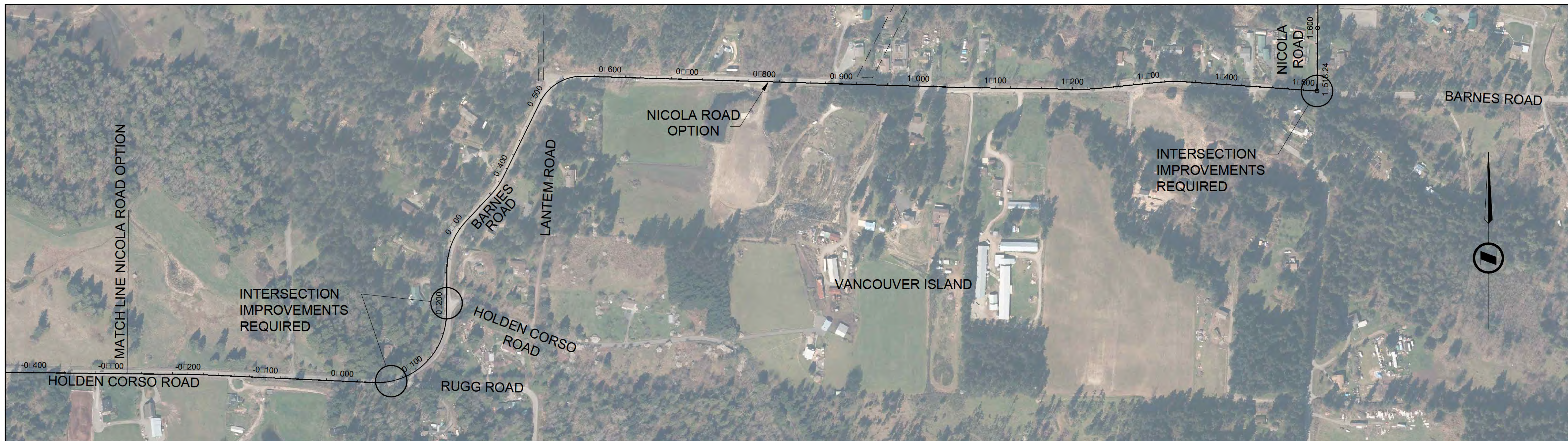


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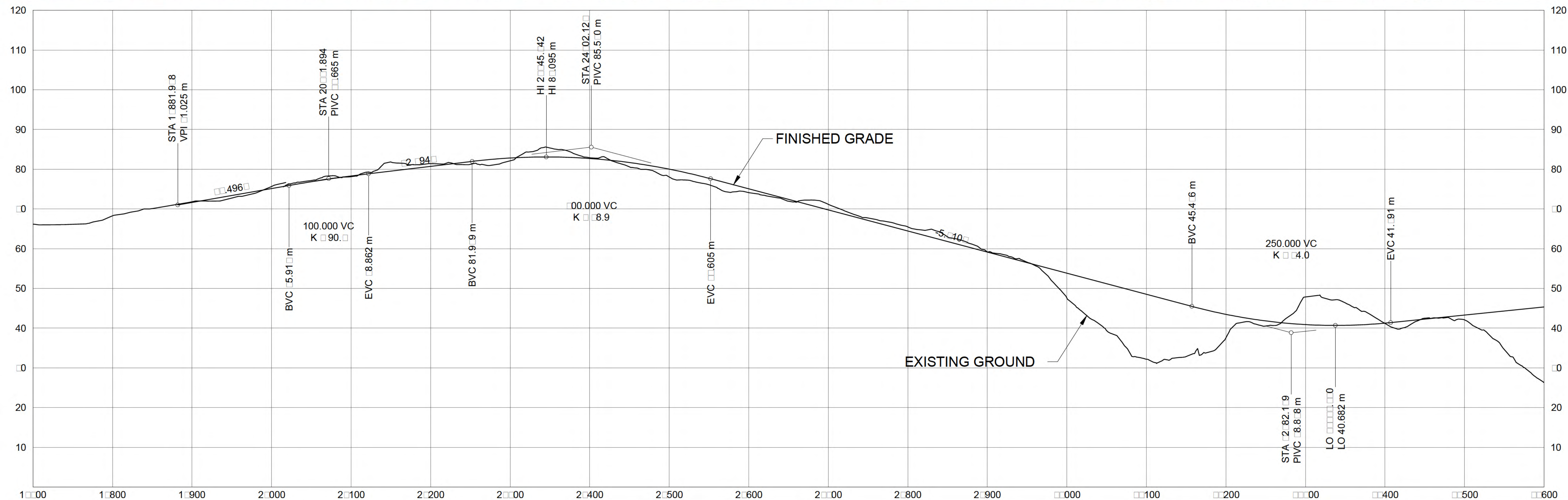
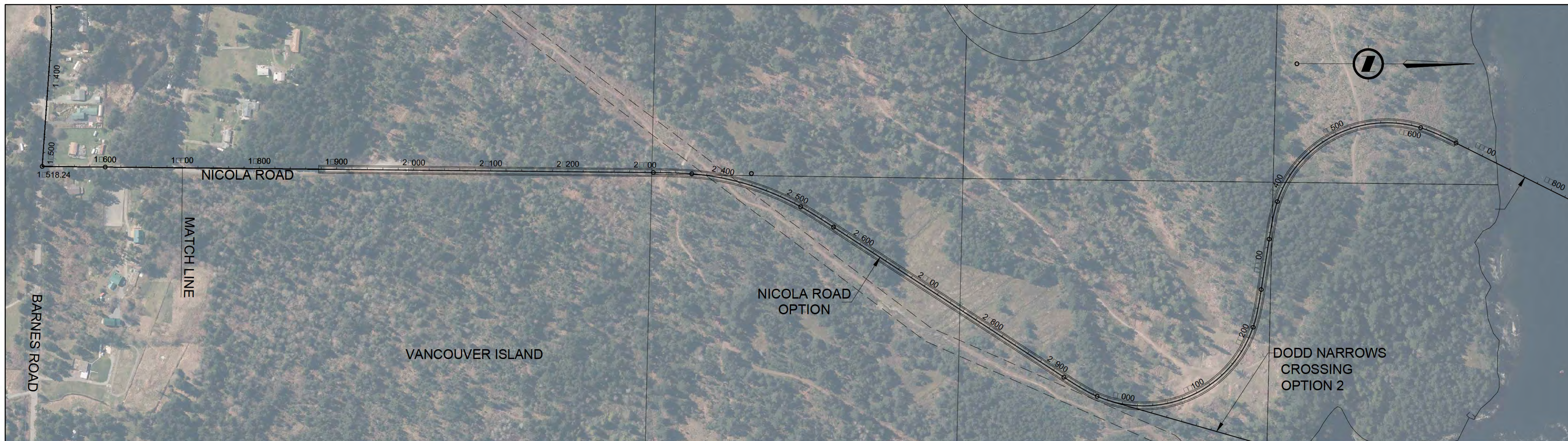
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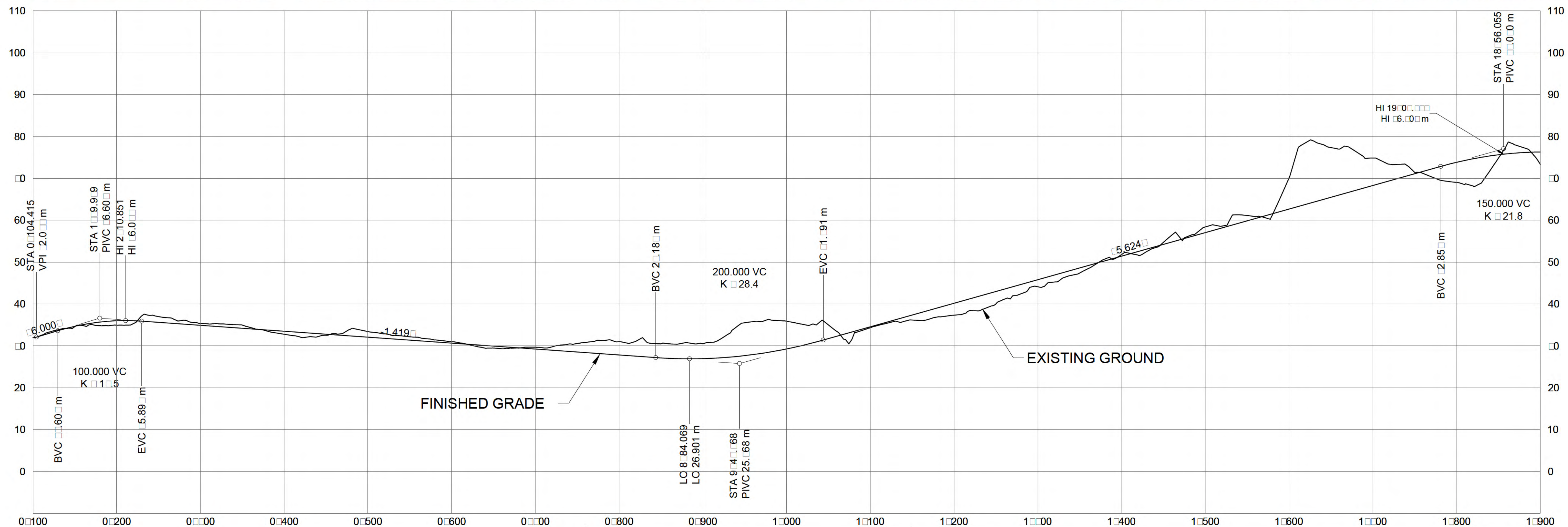
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**PLAN AND PROFILE**  
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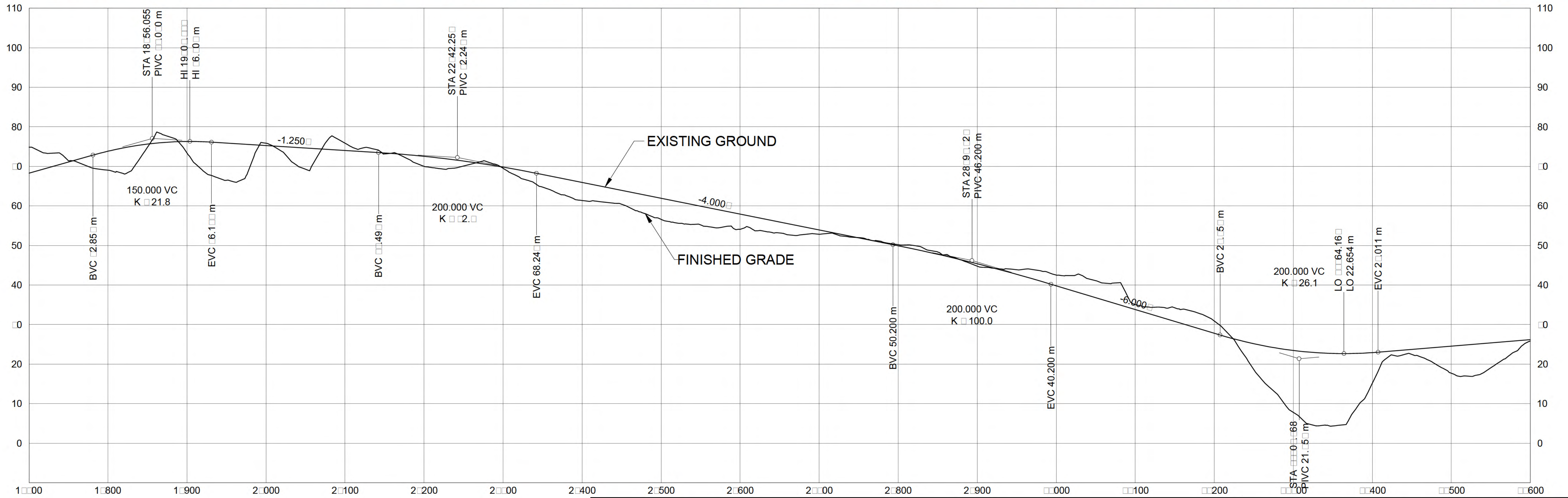
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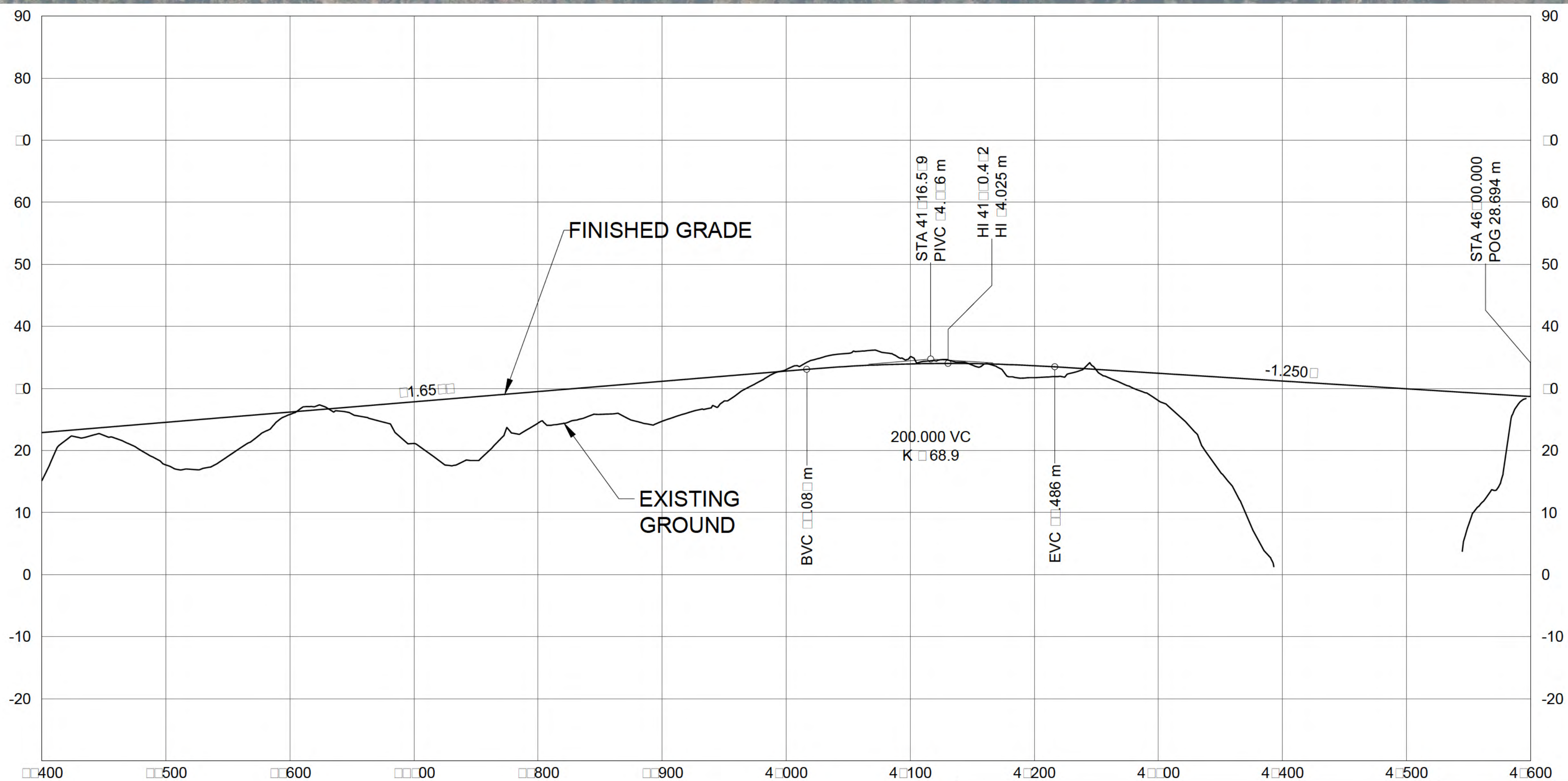
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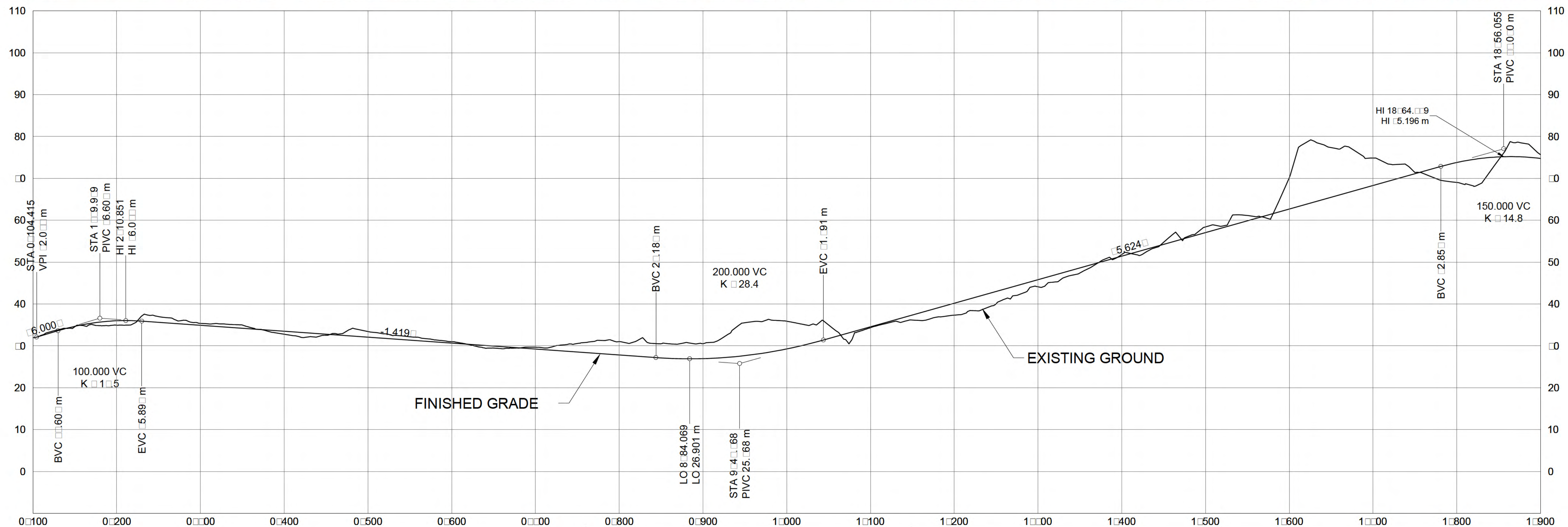
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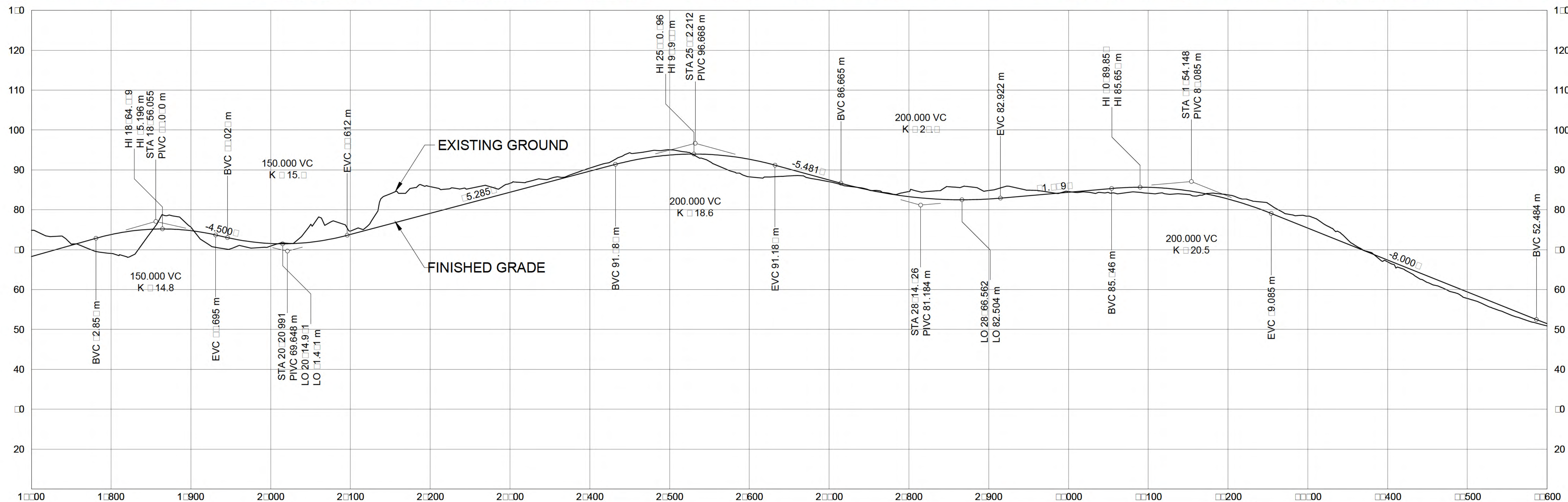
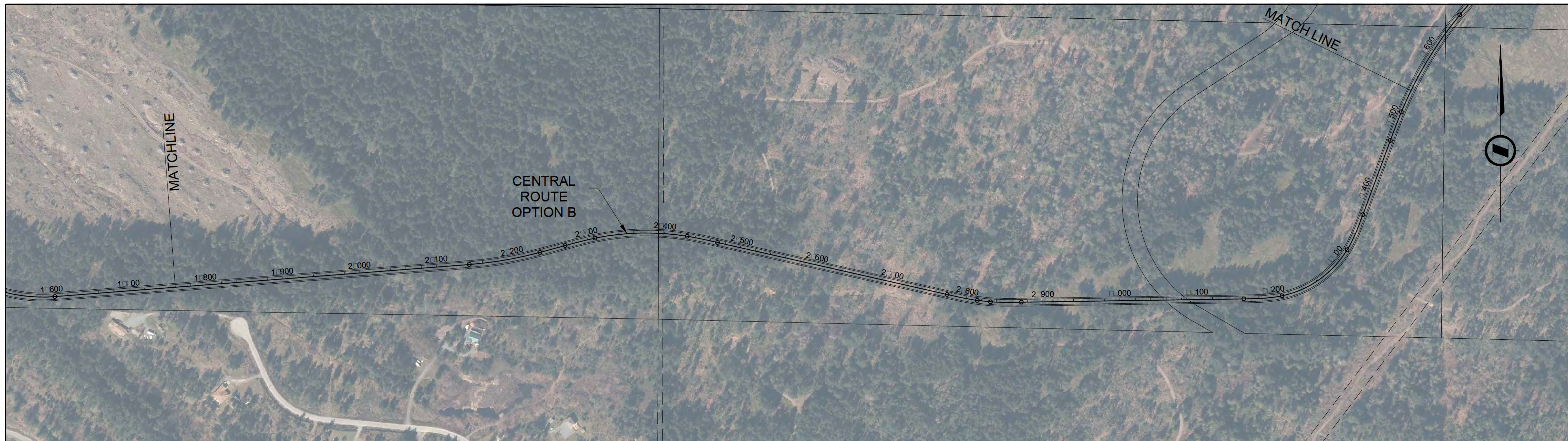
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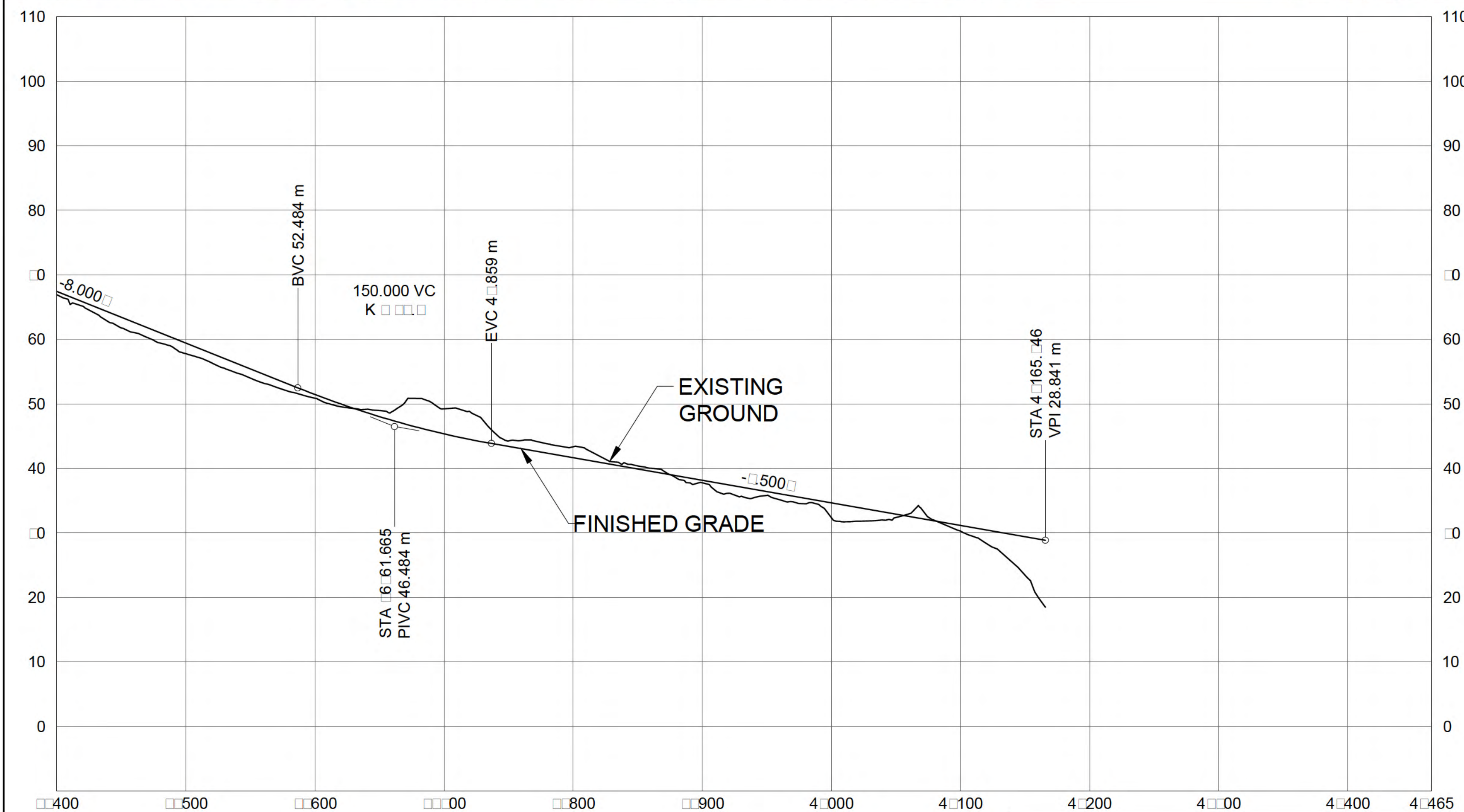
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GABRIOLA ISLAND STUDY

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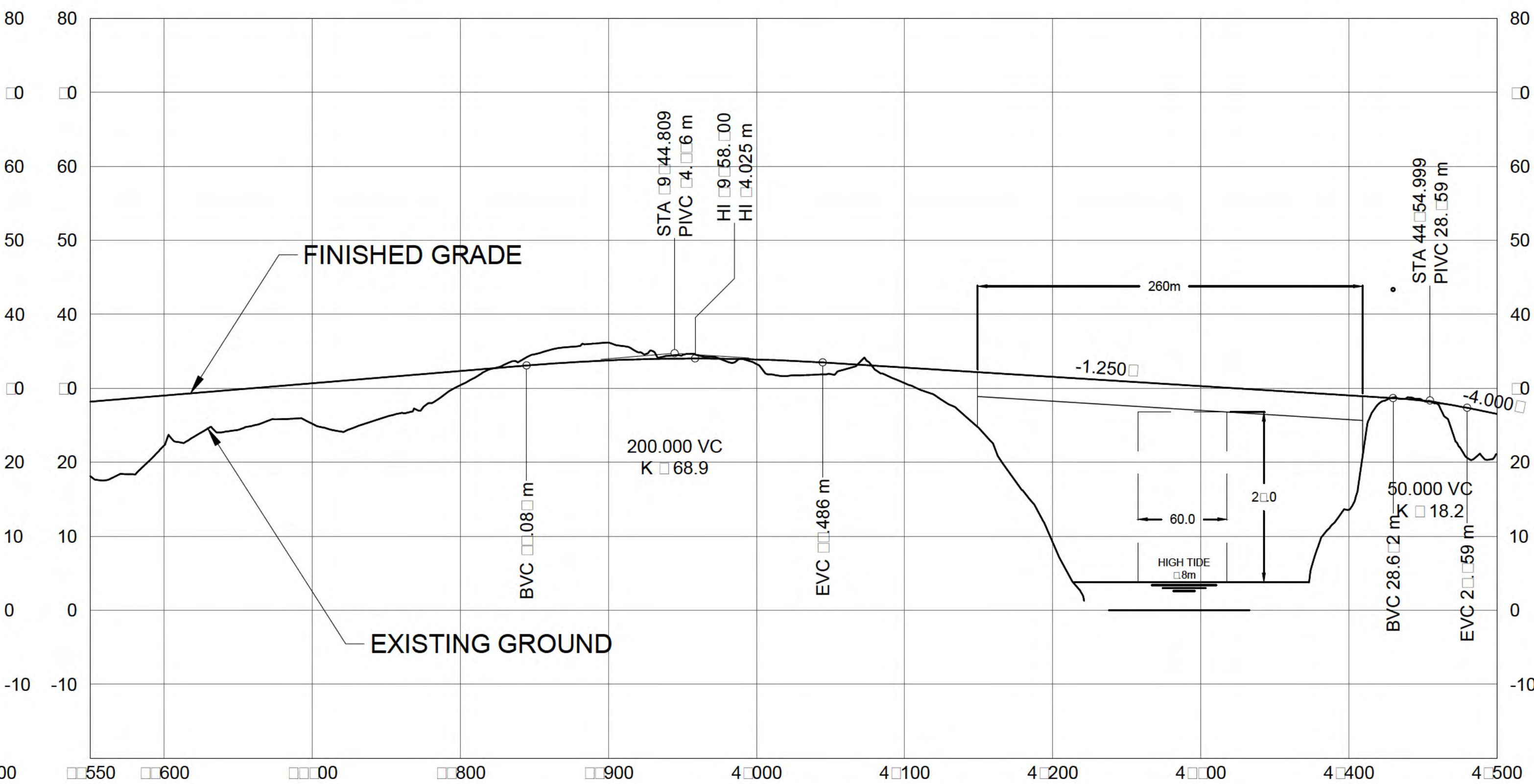
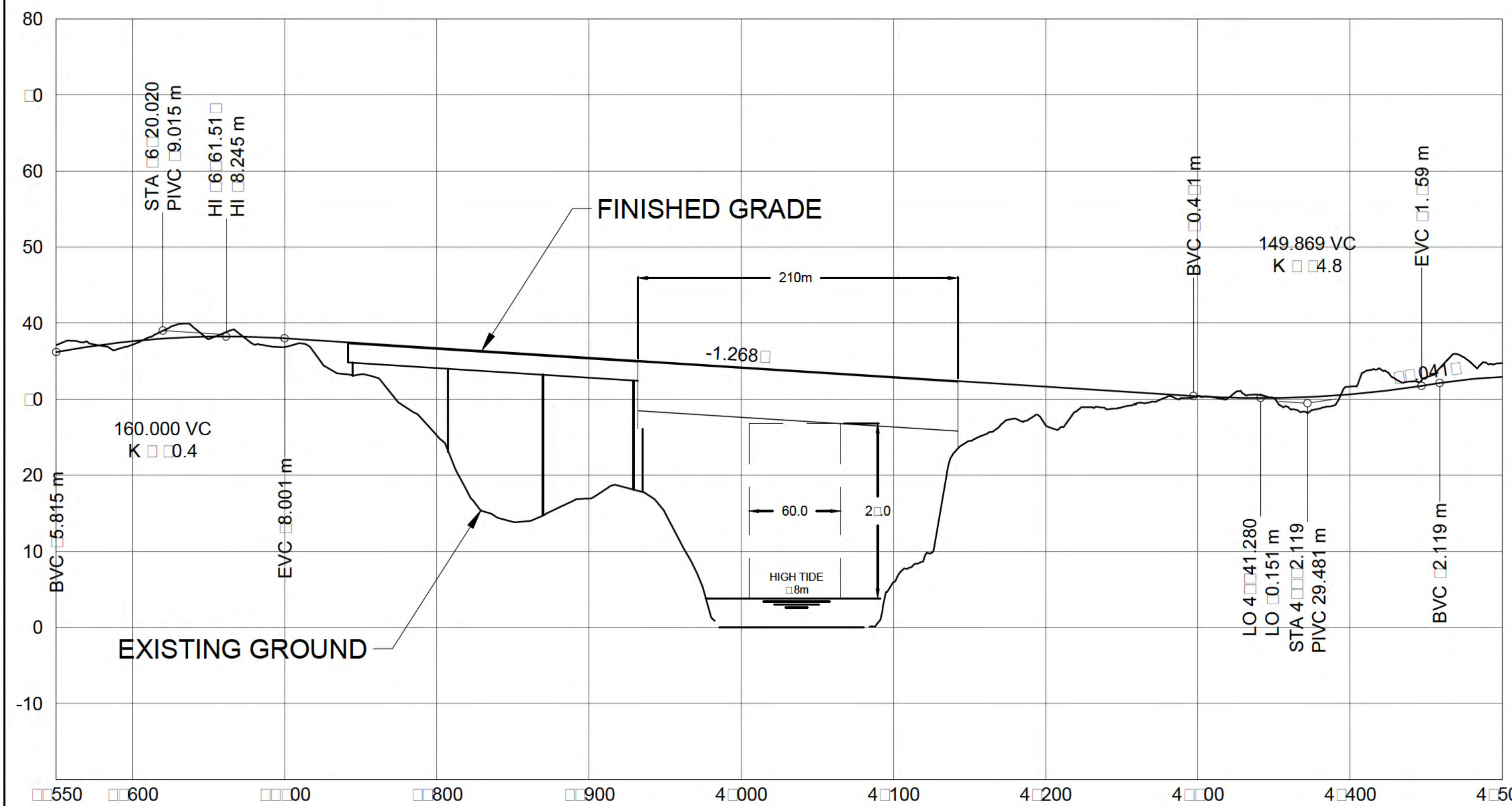
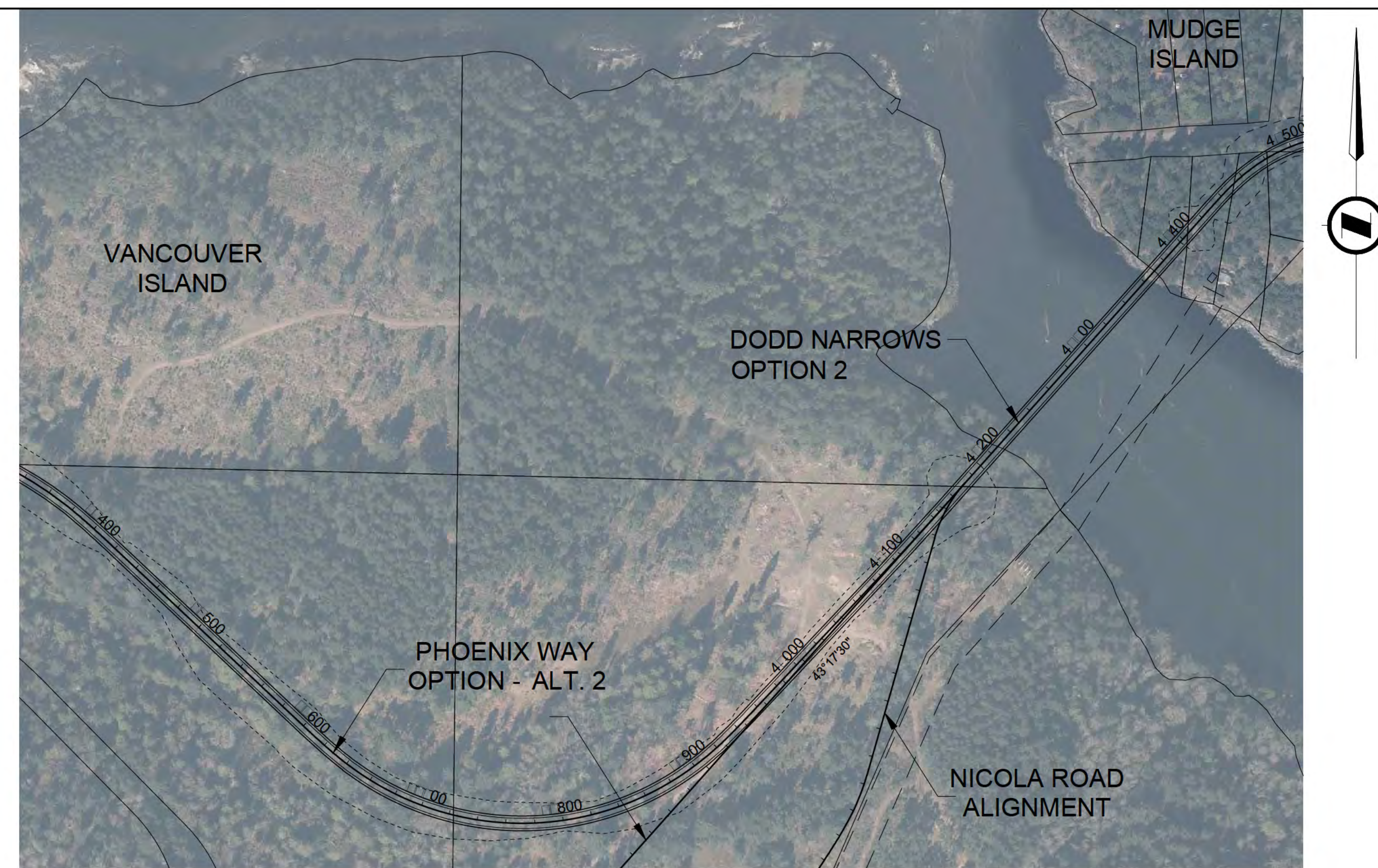
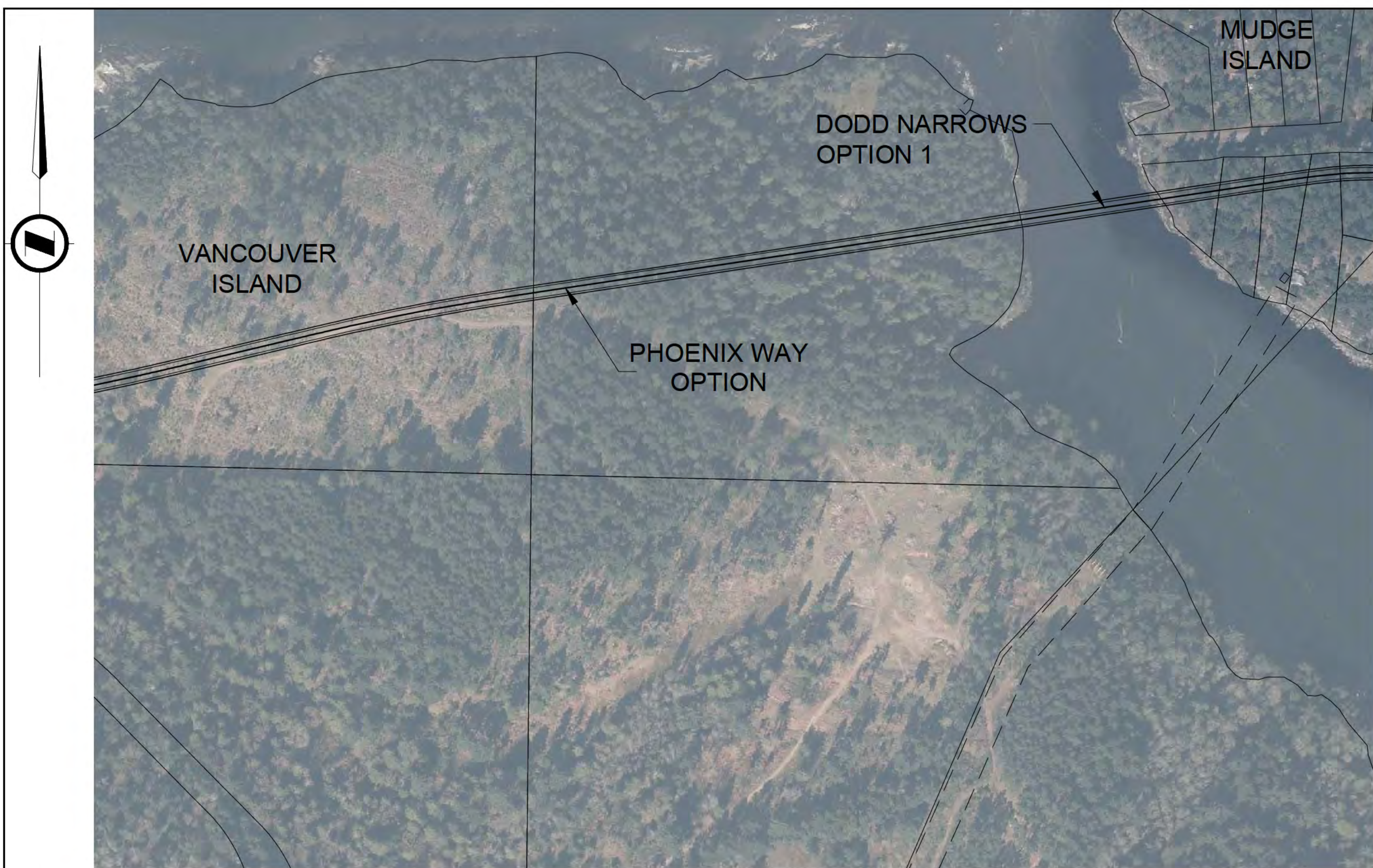
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**PLAN AND PROFILE**  
 GABRIOLA ISLAND STUDY

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
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DODD NARROWS CROSSING OPTION 1

DODD NARROWS CROSSING OPTION 2

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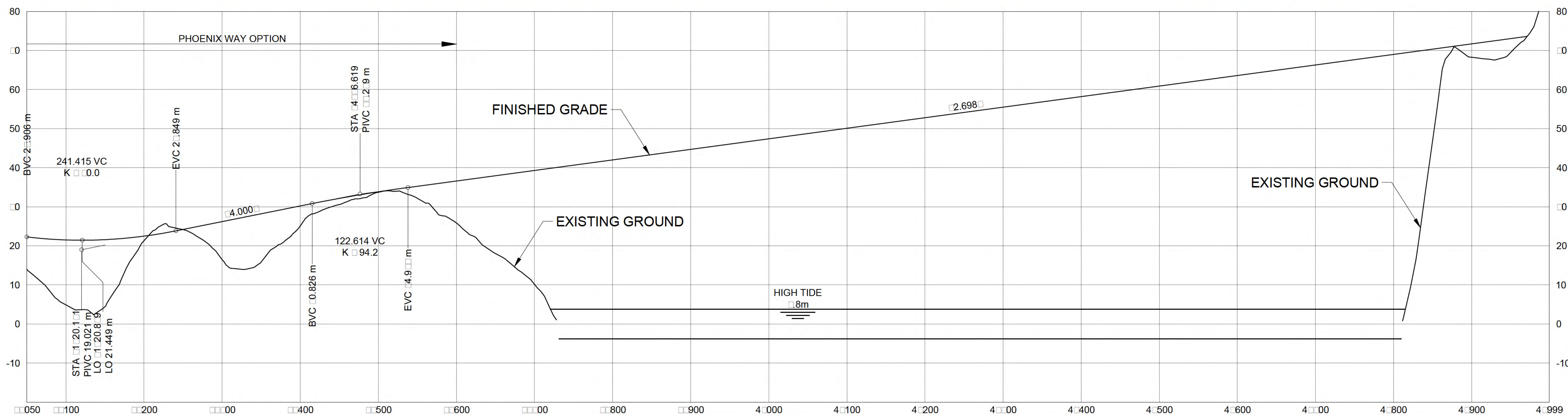
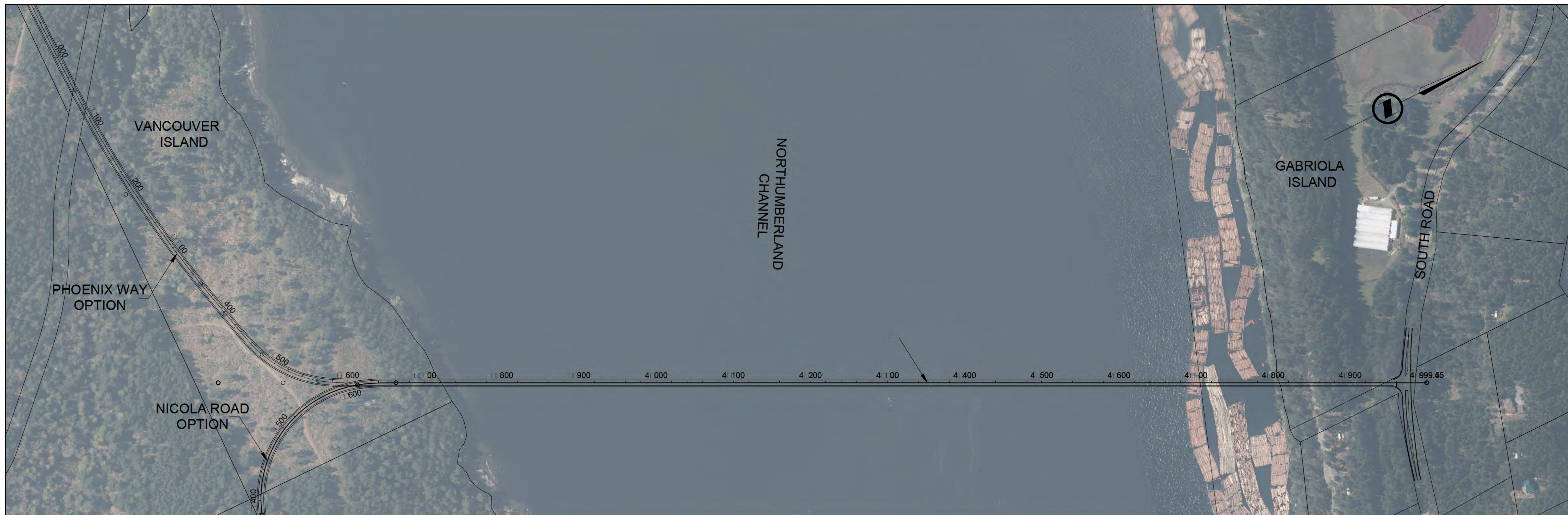
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**PLAN AND PROFILE**  
 GABRIOLA ISLAND STUDY  
 DODD NARROWS CROSSING OPTIONS

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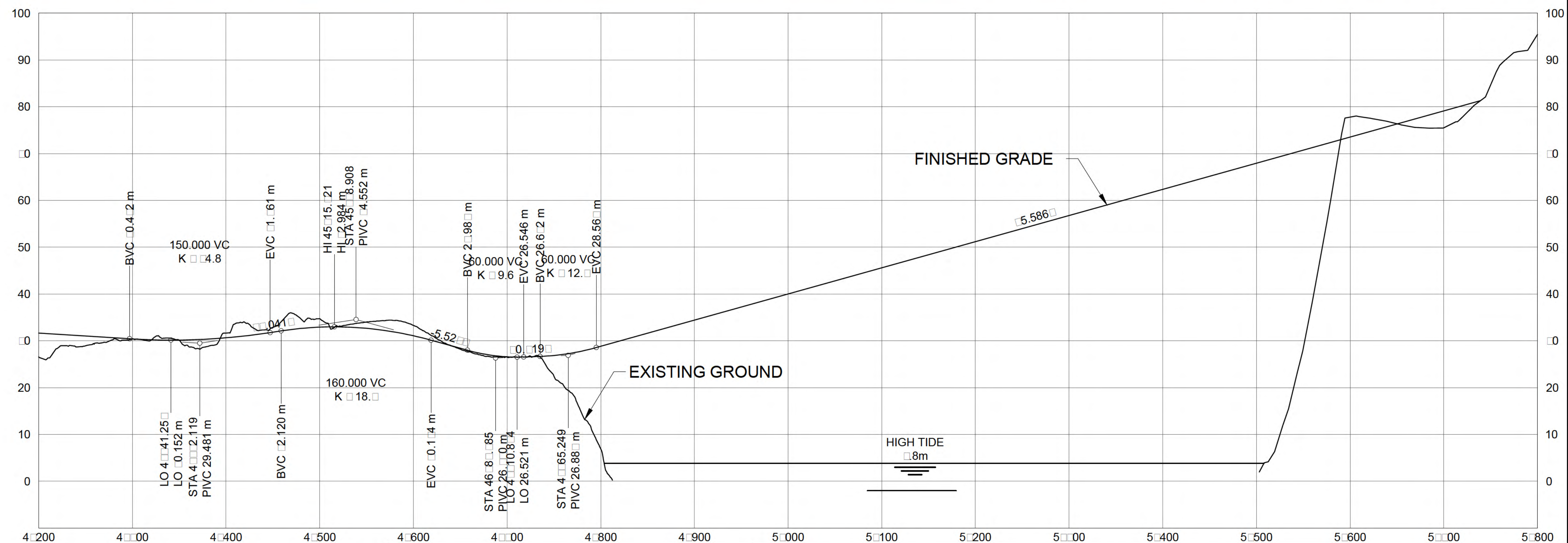
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 GABRIOLA ISLAND STUDY

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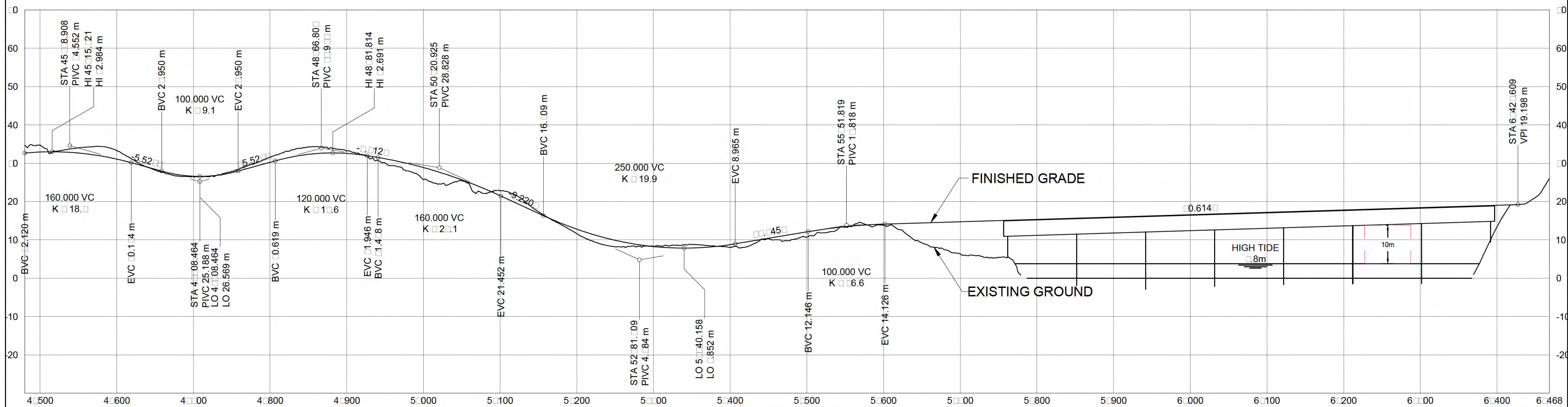
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**PLAN AND PROFILE**  
 GABRIOLA ISLAND STUDY

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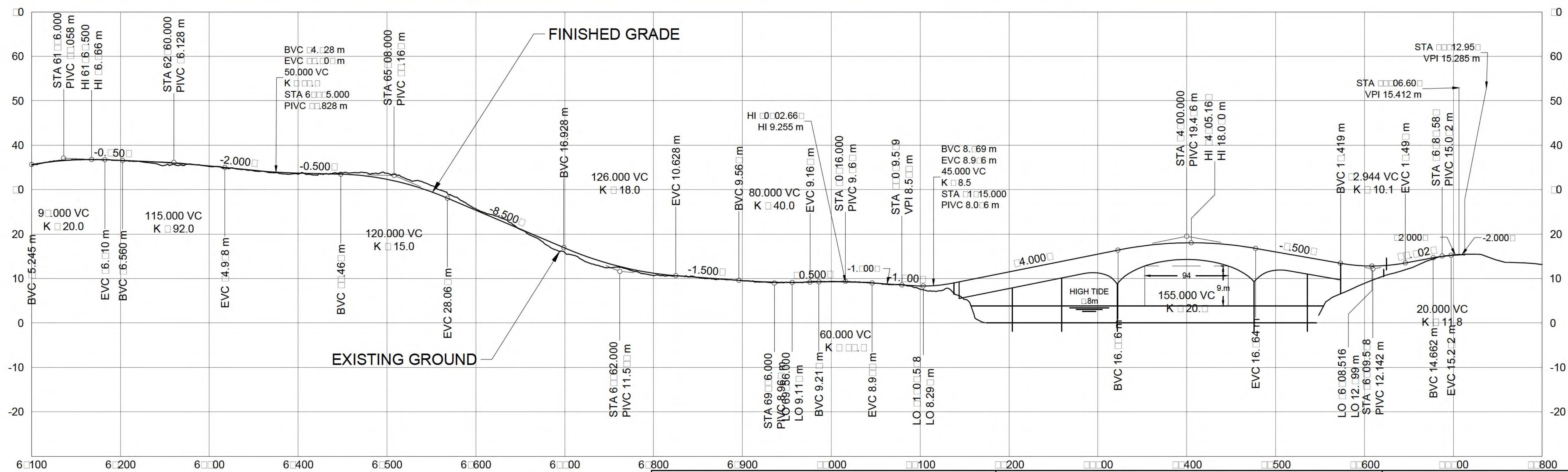
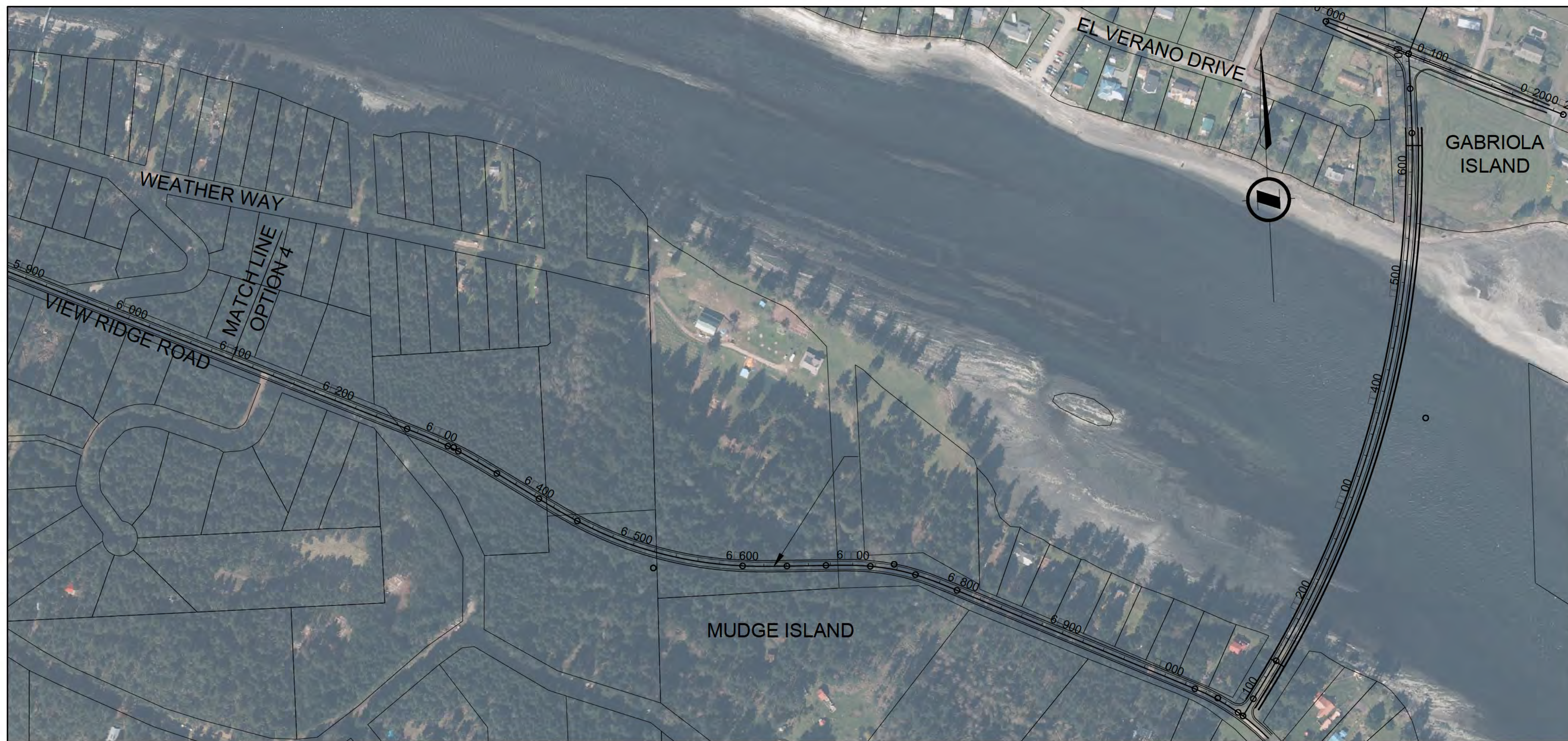
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**PLAN AND PROFILE**  
**GABRIOLA ISLAND STUDY**

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APPENDIX B  
GEOTECHNICAL ASSESSMENT



**THURBER ENGINEERING LTD.**

April 24, 2015

File: 17-834-185

CH2M HILL  
Metrotower II, Suite 2100, 4720 Kingsway  
Burnaby, BC V5H 4N2

Attention: Bernard Abelson, P.Eng.  
Project Engineer

### **GABRIOLA FIXED LINK FEASIBILITY STUDY GEOTECHNICAL INPUT**

Dear Bernard:

As requested, Thurber Engineering Ltd. (Thurber) has completed a site reconnaissance and desktop study for the Gabriola Fixed Link Feasibility Study. This letter summarizes the results of the site reconnaissance and desktop study, and provides preliminary geotechnical recommendations to aid the conceptual design. Recommendations in this report supercede those previously provided.

It is a condition of this letter that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions (SoLC). As noted in Item 4 of the SoLC, the report was prepared for the Client (CH2M Hill). Thurber also appoints the other members of the CH2M Hill design team and the Ministry of Transportation and Infrastructure (MoTI) as approved users of the report as described in Item 4 of the SoLC.

#### **1. INTRODUCTION**

We understand that MoTI requires an updated assessment of the technical feasibility of constructing a fixed link to Gabriola Island. The intent of the fixed link is to eliminate the requirement for a ferry connection to Vancouver Island. Previous studies, completed in 1972 and 1993 when new ferry terminals were being considered at the south end of Gabriola Island, contemplated bridges over Dodd Narrows and False Narrows to connect to the Island Highway and now to Duke Point Highway south of the former Harmac facility.

Four crossing alternatives (Options 1 to 4) are under consideration to connect South Road on Gabriola Island to Vancouver Island south of Nanaimo as shown on MoTI Dwgs. 1 to 17 and Thurber Dwgs. 17-834-185-1 to -4 (attached). Option 1 includes a single bridge crossing of Northumberland Channel from Vancouver to Gabriola Island whereas the remaining three options include a short bridge over Dodd Narrows to Mudge Island and with Option 2 crossing Northumberland Channel west of Percy Anchorage, Option 3 crossing Percy Anchorage and Option 4 crossing the east end of False Narrows.

The selected crossing would tie into one of three alignment alternatives (Options A to C) on Vancouver Island that would connect to Duke Point Highway. Alignment alternative Option A



would connect to Phoenix Way near Harmac, Option B to Nicola, Barnes and Holden Corso Roads and Option C would be a new alignment tying into the intersection of Phoenix Way and Duke Point Highway. Locally cuts and fills exceeding 10 m are anticipated.

Our scope of work in this phase of the project is to complete a desktop study and prepare a brief report summarizing the general geotechnical conditions along the contemplated alignments, identifying potential geotechnical-related risks for design and construction of the roadway, bridges and approaches, and to provide preliminary recommendations to mitigate such risks based on available existing geotechnical information.

## **2. BACKGROUND INFORMATION**

Available information is limited to surficial and bedrock geology. Information sources are summarized below.

1. Surficial geology, Map 27-1963, Sheet 92 G/4 and 92 F/1 East, Geological Survey of Canada.
2. Surficial geology and shaded seafloor relief, Naniamo, British Columbia, Geological Survey of Canada, Map 2118A.
3. BC Ministry of Energy and Mines Geological Survey Branch Open File 1998-07 Geology of the Naniamo Coal Field, British Columbia, NTS 92G/4.
4. Doe, N.A. 2000. Sandstone and Shale – Gabriola's origins, SHALE 1, pp. 26-35.
5. BC Ministry of Environment, Water Stewardship, Ground Water Resources of British Columbia, Chapter 9 — Ground Water Resources of the Basins, Lowlands and Plains, Section 9.1.2 Naniamo and Georgia Lowlands.
6. Salish Sea Pilot, A Cruiser's Guide to Anchorages & Marinas, 2014, 82 pages.

For discussion purposes, we refer to the document numbers listed above.

## **3. PROGRAM OF WORK**

Thurber conducted a site reconnaissance of the Vancouver Island portion of the alignment on November 27, 2014 and completed a desktop study in preparation of this report.

## **4. FINDINGS**

### **4.1 Site Reconnaissance**

The general area was visually assessed by automobile followed by a hike into Joan Point at Dodd Narrows via the Cable Bay Trail system accessed from Nicola Road. During the hike to Joan Point, generally undulating terrain with frequent bedrock exposures were observed. Depending on where the alignment crosses the creek that drains into Cable Bay, a small bridge may be required. Photo 1 shows the rock at Joan Point and Photo 2 shows the gently dipping rock at Purvis Point on Mudge Island.



Photo 1. Sandstone exposure at Joan Point.



Photo 2. Bedrock exposure at Purvis Point on Mudge Island. Note that an existing road ties into the mossy area in the photo.

## 4.2 Surficial Geology

As described in “The geology of Southern Vancouver Island, A field guide” by C.J. Yorath and H.W. Nasmith, 1995, “Southeastern Vancouver Island and the Gulf Islands are largely composed of sedimentary rocks deposited during the latter stages of the cretaceous period between eighty-five and sixty-five million years ago. These strata are included in the Nanaimo Group, which is divided into nine formations consisting of various combinations of conglomerate, sandstone, siltstone, shale and coal. In the Nanaimo area these strata are horizontal or very gently dipping; however, in the Gulf Islands they have been formed into a series of northwesterly trending folds and thrust faults.”

Dwgs. 17-834-185-1, -2, -3 and -4 show the various alignments superimposed on maps excerpted from Documents 1, 2, 3 and 4, respectively. As shown on Dwg. 17-834-185-1, the surficial



geology of the area generally consists of marine veneer over bedrock, with the exception of the thick fluvial deposits associated with the Nanaimo river delta. Information on the drawing suggests that foundation conditions along the alignments are anticipated to consist primarily of relatively thin overburden deposits overlying bedrock and that, in lowland areas, thicker deposits of soft, fine grained deposits may be present.

Only limited submarine geotechnical information is available for the crossings alignments as shown on Dwgs. 17-834-185-1, -2 and -3 and in Document 6. Dodd Narrows is a relatively deep, navigation channel and will likely require an elevated structure that completely spans the channel. However, Percy Anchorage is up to about 24 m deep and, as indicated in Document 6, is underlain by recent deposits comprised of gravel and mud. False Narrows is relatively shallow and may be underlain by recent soil deposits. We also infer that portions of Northumberland Channel are likely underlain by recent soil deposits.

## **5. ENGINEERING ASSESSMENT AND PRELIMINARY RECOMMENDATIONS**

### **5.1 General**

This section summarizes the results of our desktop study and site reconnaissance. For conceptual design purposes, we have assumed that the bridge crossings will be designed in general accordance with CAN/CSA S6-06, which contemplates a 1:475 year design earthquake, and that the proposed structures will be supported on pile foundations. Conceptual recommendations for design of rock cuts and embankment construction are based on our experience with similar site conditions.

### **5.2 Seismic Design**

#### **5.2.1 Site Response Spectrum**

Natural Resources Canada's seismic hazards calculation website was used to predict peak firm ground accelerations equal to 0.273g for the 1 in 475 year earthquake (10% probability of exceedance in 50 years). The 2010 National Building Code Seismic Hazard Calculation out for the site is attached. Based on the findings of our desktop study and site reconnaissance, the site condition for upland bridge foundations is classified as Soil Profile Type I following the CAN/CSA-S6-06 bridge code. The corresponding Site Coefficient (S) per Table 4.4 is 1.0. For marine foundations, it will be necessary to determine the nature and thickness of overburden present.

#### **5.2.2 Seismic Liquefaction**

Where present, recent deposits in Northumberland Channel, Percy Anchorage and False Narrows will likely be susceptible to seismic liquefaction. The nature and thickness of these deposits will have to be determined in the next phase of the work to assess the potential impacts to foundation



design. For conceptual design purposes, it should be assumed that all structural loads will be transferred to bedrock.

### **5.3 Bridge Foundations**

Bridge foundations for the various crossings will likely require rock socketed piles. Depending on seismic load requirements, pile embedment length may be controlled by lateral fixity requirements rather than vertical compression resistance requirements. Construction of rock socketed piles typically requires advancing steel casings by drilling techniques to the bedrock surface with a socket formed below. After clean out, reinforcing steel is placed and then the socket and pile casing filled with concrete. All load transfer is typically assumed to be from concrete to rock in shear along the socket length.

The design bond stress between the concrete and the walls of the socket will be a function of the concrete compressive strength, rock strength, and degree of fracturing. We expect that it will be difficult to advance the steel casing sufficiently far into the rock to effect a total cutoff of seepage into the hole. As such, we suggest that the design and construction anticipate water seepage into the socket. This will require maintaining water in the casing and placement of concrete using good tremie techniques.

Rock socket design should anticipate weathering, fracturing, sloping rock conditions and the usual challenges of cleaning from the base of the socket. Further, if it is apparent during installation that the rock slope is steep, that there is a considerable amount of muck that cannot be cleaned from the socket, or that the concrete will be contaminated for one reason or another, then the socket should be lengthened accordingly.

Very high loads are typically attainable with socketed caissons. Typically, the full structural resistance of a pile sections can be developed. The uplift resistance on socketed piles is governed by fracture in the rock mass and not simply by the bond length. Generally, the full uplift resistance can be developed, but the socket length is partially a factor of the proximity of other piles and must be reviewed during detailed design.

Inspection of the rock socket construction during drilling and after completion of the drilling is important to confirm that the rock conditions are as anticipated, that the sidewalls of the rock socket have been adequately cleaned, and that the required length of the socket has been obtained. The need to increase the socket length due to steeply sloping rock or inadequate cleaning of the base of the socket can only be made by an experienced inspector. For relatively shallow and dry installations, the visual inspection of the completed socket can be made using a lamp and or mirror. Deeper installations, or shallow installations where significant groundwater seepage is occurring, typically require inspection using an underwater colour camera.



## 5.4 Bedrock Cuts

### 5.4.1 Rock Cut Slope Angle

We have reviewed the regional bedrock geology mapping shown on Dwgs. 17-834-185-3 and -4 and information from our files for the Duke Point Ferry Access road to develop preliminary recommendations for the conceptual design. The following assessment is not based on any site specific observations and should be considered general only. We have not been provided with details such as rock cut heights, cut slope orientations or previous studies by others. A specific bedrock mapping program will be necessary to confirm our assumptions and finalize the rock cut geometry.

The Decourcy and Gabriola Sandstone units are anticipated to consist of medium grained, massive to blocky, medium strong to strong rock. Bedding is anticipated to be the predominant discontinuity set with orthogonal secondary and tertiary jointing. The bedding is typically relatively flat lying (<20° dip) and dips of about 75° to 90° are anticipated for the orthogonal joint sets.

The design rock cut slope angle geometry attempts to balance the excavation volume and construction footprint versus the potential for kinematic instability (due to wedges, daylighting planes and toppling) and the need for stabilization. We recommend using rock cut slope angles of 0.25H:1V for conceptual design. Flatter slopes may be required if the regional jointing in the sandstone is steeper than about 30° or in zones of weaker rock types such as shale, siltstone or coal (if encountered).

It should be assumed that higher cut slopes (i.e. greater than 10 m) will likely require scaling and some rock bolting to stabilize potential daylighting planar blocks and wedges. In addition, localized shotcrete and steel mesh may also be required in more fractured or weathered areas.

### 5.4.2 Rock Cut Slope Catchment Ditch Design

Typically, the minimum rockfall catchment ditch width design is based on the following documents:

- “MoTI Technical Bulletin GM02001 (Rock Slope Design)” dated September 17, 2002
- “Rockfall Containment for Rock Cuts Highway 99 – Horseshoe Bay to Whistler”, submitted to MoT by Wyllie & Norrish Rock Engineers in October 2002
- “Evaluation of Rockfall and Its Control.” by Ritchie in 1963, “Discussion on Rockfall Protection Measures” by P.G.D. Whiteside in 1986
- “Rockfall Catchment Design Guide” for Oregon Department of Transportation in 2001.

For conceptual planning purposes, the MoTI Technical Bulletin GM02001 provides a description of catchment ditch geometry and a table of preliminary catchment widths based on slope height. The recommended catchment widths in the MoTI document may require modification during detailed design based on the results of the investigation, analysis and construction geometry.



All rock slopes should be constructed in accordance with standard MoTI practice that includes smooth wall controlled blasting techniques (pre-shearing), rock scaling and spot rock bolting.

#### 5.4.3 Soil Cuts above Bedrock Cut Slopes

In locations where overburden will be encountered at the top of rock cut slopes, an assessment will be required to determine the appropriate slope angle. If topography limits the height of the slope, we expect that it will likely be feasible to cut the material to slopes of between 1.5H:1V to 2H:1V. The standard MoTI design section also requires a 3 m wide horizontal bench between the top of rock cut and the toe of the soil cut above.

Where thin overburden soils combined with steep slopes are encountered above the top of bedrock cuts, very high sliver cuts can be required in the overburden unless a retaining wall is constructed above the bedrock cut or an anchored mesh system such as Tecco Mesh is used to retain the soil.

#### 5.4.4 Coal Mines

The greater Nanaimo area is known for the presence of coal mines that were excavated in the 1800s and early 1900s. Our cursory review of the mine records database suggests that there are no recorded mines in the vicinity of this project. However, it should be noted that there is potential for undocumented mines to exist in this area and any future design should consider the possibility of coal mine existence.

#### 5.4.5 Metal Leaching and Acid Rock Drainage (ML-ARD)

Although we are not currently aware of any significant ML-ARD issues in the Nanaimo area, MoTI standard practice requires a screening level assessment is completed for all bedrock excavations that exceed 1000 m<sup>3</sup> of material in accordance with Technical Circular T04/13. As such, an assessment will be required in the preliminary design phase of this project. In general, sandstone (the primary anticipated rock type) would be anticipated to represent a low to moderate risk of ML-ARD generation. Shale and coal deposits (if encountered) would represent a moderate risk of ML-ARD generation.

### 5.5 Soil Cut Slopes

Soil cut slopes in granular or till-like soils should typically be cut at a slope angle of 1.5H:1V or flatter. If fine grained soils are encountered locally, they will have to be assessed on a case by case basis.

It is important that adequate measures be provided during construction to prevent erosion of cut slopes during periods of heavy rainfall, snow melt or runoff. Erosion control measures should be implemented in accordance with the BC MoT "Manual of Control of Erosion and Shallow Slope Movement (1997)".



Excavated slopes should be vegetated immediately following excavation. Seepage from overburden slopes may occur locally and can only be identified during excavation. Where such seepages are encountered, drainage measures should be installed. Seepage zones should be excavated to shallow depth and resloped with shotrock to match the adjacent cut slope. A geosynthetic should be placed over the overburden prior to placement of the rock fill.

## **5.6 Embankments**

General fill construction should be carried out in accordance with the Standard Specifications for Highway Construction, Sections 201.36 and 201.37. Embankments will generally be constructed of either blast rock fill or suitable earth backfill. Where encountered, we recommend that silt and clay material not be used in embankment construction.

Fills constructed on slopes steeper than 3H:1V should be constructed with rock fill and have their toes keyed into the slope. The keys should be constructed by excavating a horizontal bench at the toe of the fill such that the fill toe has a minimum horizontal width of 5 m. If solid bedrock is encountered before the 5 m horizontal width is reached, field assessment will be required. Benching should also be done on existing slopes to create horizontal terrace widths of at least 1.5 m.

Earth embankments should generally be constructed in accordance with SS201.37. For fill materials with less than 35% material passing the No. 200 (0.075 mm) sieve, the slopes can be constructed at 1.5H:1V to 2H:1V depending on the desired level of performance. Fill materials with greater than 35% material passing the No. 200 (0.075 mm) sieve will need to be constructed with 2H:1V or flatter slopes.

Blast rock embankments can typically be constructed at 1.5H:1V slopes. In some locations it may be preferable to use steeper slopes to fit the existing topography. These locations will have to be assessed on a case by case basis.

## **6. SUPPLEMENTARY WORK DURING PRELIMINARY DESIGN**

Once a preferred alignment has been selected, we recommend that a detailed marine investigation be undertaken. The investigation should include detailed bathymetry, seismic profiling and test hole drilling at select locations to determine the nature and thickness of overburden and sufficient information regarding the nature and quality of the bedrock for design of rock sockets.

## **7. CONCLUSIONS**

Based on the findings of our assessment, we consider the project to be technically feasible from a geotechnical perspective. Further, we believe that all technical issues identified in this report can be addressed during the design and construction stages of the fixed link project.



We trust that this information is sufficient for your needs. Should you require clarification of any item or additional information, please contact us at your convenience.

Yours truly,  
Thurber Engineering Ltd.  
David Regehr, P.Eng.  
Review Principal



David J. Tara, P.Eng.  
Project Engineer

Attachment: Statement of Limitations and Conditions  
Dwg. 17-834-185-1 Surficial Geology  
Dwg. 17-834-185-2 Sea Floor Geology  
Dwg. 17-834-185-3 Bedrock Geology  
Dwg. 17-834-185-4 Bedrock Geology  
2010 National Building Code Seismic Hazard Calculation



## STATEMENT OF LIMITATIONS AND CONDITIONS

### 1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

### 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 Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together 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. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

### 3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is 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 part of 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 THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

### 5. INTERPRETATION OF THE REPORT

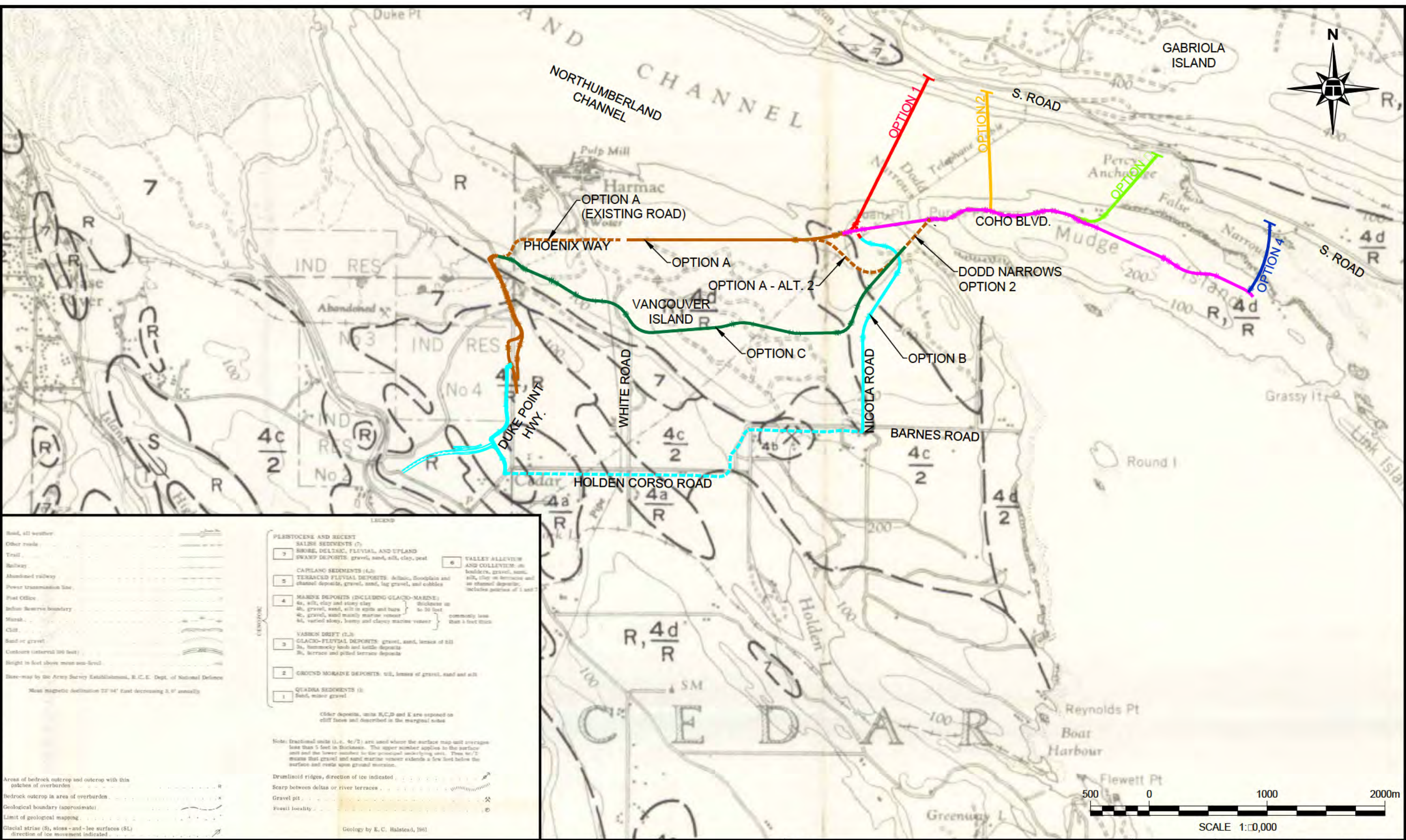
- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing 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 the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. 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. If 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 Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.
- c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.
- d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

### 6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

### 7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.



**NOTES:**

1. BASE PLAN TAKEN FROM GEOLOGICAL SURVEY OF CANADA'S MAP "2-196" SHEET 92 1/2 AND 92 1/4 EAST.



CLIENT: CH2M HILL CANADA LTD.

**SURFICIAL GEOLOGY**

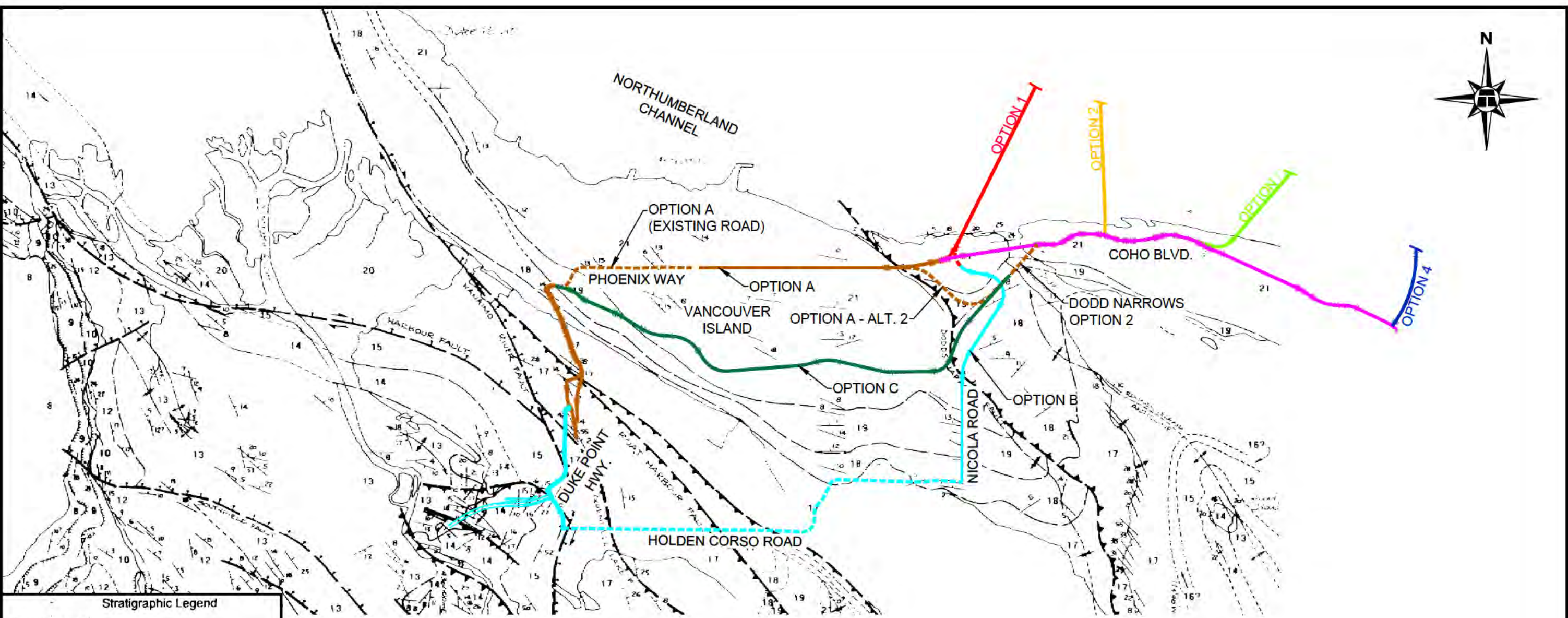
GABRIOLA ISLAND FIXED LINK FEASIBILITY STUDY

GABRIOLA ISLAND, BC

DESIGNED	DRAWN	APPROVED
-	NAK	DJT
DATE	SCALE	AS SHOWN
APRIL 21, 2015		
PROJECT NO.	DWG. NO.	REV.
1-8-185-1		-



PROJECT: APRIL 2015



**Stratigraphic Legend**

<b>Upper Cretaceous</b>	
Nanaimo Group	
Companion	
22	NORTHUMBERLAND FORMATION: shale, siltstone, minor sandstone
21	DE COURCY FORMATION: sandstone, minor conglomerate and siltstone
20	CEDAR DISTRICT FORMATION (undivided): shale, siltstone, minor sandstone
19	BOAT HARBOUR MEMBER: shale and siltstone, sandstone
18	WOODS ISLANDS MEMBER: sandstone, minor siltstone
17	HOLDEN CORSO MEMBER: shale and siltstone, sandstone dikes
16	OYSTER HARBOUR MEMBER: sandstone, minor siltstone
15	GRANBY MEMBER: shale
PROTECTION FORMATION	
14	McMILLAN MEMBER: sandstone, minor siltstone
13	RESERVE MEMBER: sandstone, siltstone, shale and coal
12	CASSIDY MEMBER: sandstone and gritstone, minor siltstone
PENDER FORMATION	
11	NEWCASTLE MEMBER (undivided): not mapped in this area
10	SOUTHFIELD BEDS: shale, minor sandstone, gritstone and conglomerate
9	DOUGLAS BEDS: conglomerate and gritstone, carbonaceous shale and coal (Douglas Seam at top, Newcastle Seam at base)
8	CRANBERRY MEMBER: shale and siltstone, conglomerate and sandstone
EXTENSION FORMATION	
7	MILLSTREAM MEMBER: conglomerate and gritstone, minor sandstone

*Note: Beds below Unit 7 do not outcrop within map-area*

**Symbols**

Bedding orientation	observed, approximate, inferred	
Geologic boundaries	observed, approximate, inferred	
Reverse fault	observed, approximate, inferred	
Normal fault	observed, approximate, inferred	
Anticline surface trace	observed, approximate, inferred	
Syncline surface trace	observed, approximate, inferred	
Coal seam trace	observed, approximate, inferred	



SCALE 1:10,000

**NOTES:**

1. BASE PLAN TAKEN FROM BC MINISTRY OF ENERGY AND MINES OPEN FILE "1998-01 GEOLOGY OF THE NANAIMO COALFIELD, BRITISH COLUMBIA NTS 92G/4".



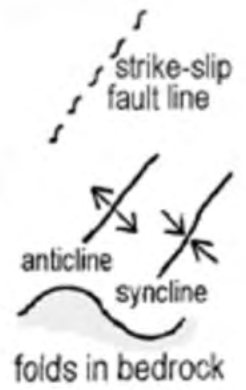
CLIENT	CH2M HILL CANADA LTD.
<b>BEDROCK GEOLOGY</b>	
GABRIOLA ISLAND FIXED LINK FEASIBILITY STUDY	GABRIOLA ISLAND, BC

DESIGNED	DRAWN	APPROVED
-	NAK	DJT
DATE	SCALE	AS SHOWN
APRIL 21, 2015	1:10,000	
PROJECT N°	DWG. N°	REV.
1-8-185		

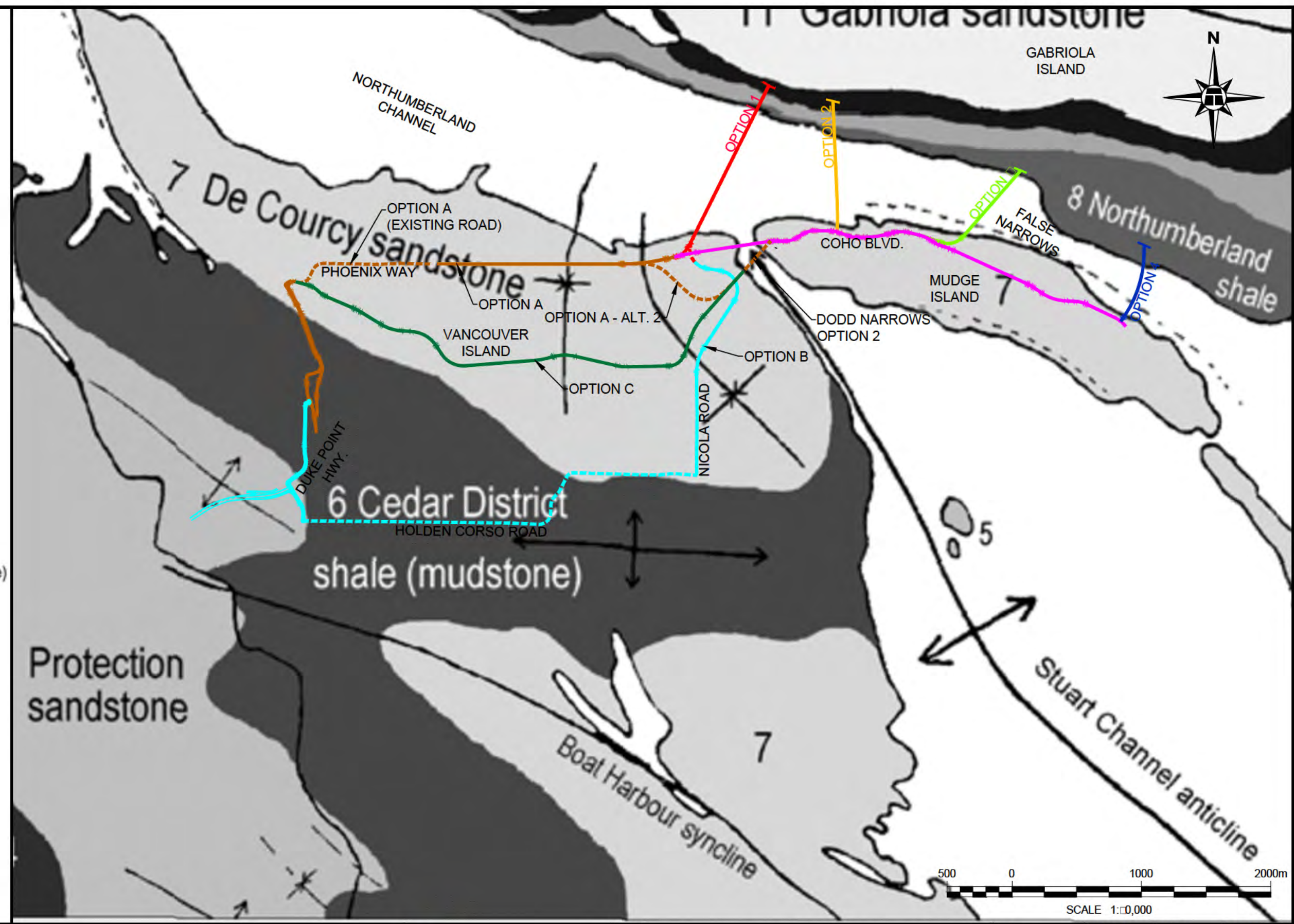
CANCEL PRINTS BEARING EARLIER LETTER

P:\000000\2015

### Nanaimo Group formations



- 11 Gabriola sandstone
- 10 Spray shale
- 9 Geoffrey sandstone
- 8 Northumberland shale
- 7 De Courcy sandstone
- 6 Cedar District shale (mudstone)
- 5 Protection sandstone
- 4 Pender shale (mudstone)



#### NOTES:

1. BASE PLAN TAKEN FROM "SANDSTONE & SHALE - GABRIOLA'S ORIGINS" BY NICK DOE (WWW.NICKDOE.CA/PASS/WEBP22.C.PDF.)



CLIENT	CH2M HILL CANADA LTD.
<b>BEDROCK GEOLOGY</b>	
GABRIOLA ISLAND FIXED LINK FEASIBILITY STUDY	GABRIOLA ISLAND, BC

DESIGNED	DRAWN	APPROVED
-	NAK	DJT
DATE	SCALE	
APRIL 21, 2015	AS SHOWN	
PROJECT N <sup>o</sup>	DWG. N <sup>o</sup>	REV.
1-8-4-185-4		-

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CANCEL PRINTS BEARING EARLIER LETTER

# 2010 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836  
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Requested by: David Tara, Thurber Engineering Ltd.

March 03, 2015

Site Coordinates: 49.136 North 123.81 West

User File Reference: Mudge Island

## National Building Code ground motions:

2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA (g)
1.028	0.700	0.354	0.179	0.507

**Notes.** Spectral and peak hazard values are determined for firm ground (NBCC 2010 soil class C - average shear wave velocity 360-750 m/s). Median (50th percentile) values are given in units of g. 5% damped spectral acceleration (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are tabulated. Only 2 significant figures are to be used. *These values have been interpolated from a 10 km spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the calculated values.* **Warning:** You are in a region which considers the hazard from a deterministic Cascadia subduction event for the National Building Code. Values determined for high probabilities (0.01 per annum) in this region do not consider the hazard from this type of earthquake.

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.2)	0.249	0.542	0.738
Sa(0.5)	0.166	0.363	0.496
Sa(1.0)	0.083	0.183	0.251
Sa(2.0)	0.041	0.090	0.124
PGA	0.128	0.273	0.367

## References

**National Building Code of Canada 2010 NRCC no. 53301;** sections 4.1.8, 9.20.1.2, 9.23.10.2, 9.31.6.2, and 6.2.1.3

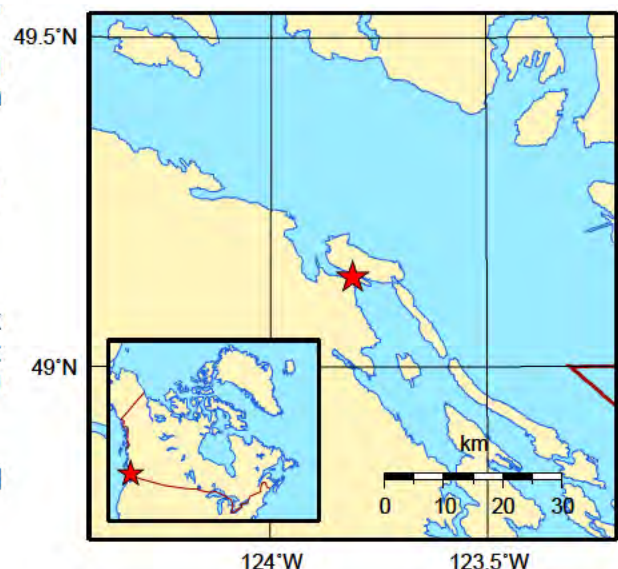
**Appendix C:** Climatic Information for Building Design in Canada - table in Appendix C starting on page C-11 of Division B, volume 2

**User's Guide - NBC 2010, Structural Commentaries NRCC no. 53543** (in preparation)  
**Commentary J:** Design for Seismic Effects

**Geological Survey of Canada Open File xxxx**  
Fourth generation seismic hazard maps of Canada: Maps and grid values to be used with the 2010 National Building Code of Canada (in preparation)

See the websites [www.EarthquakesCanada.ca](http://www.EarthquakesCanada.ca) and [www.nationalcodes.ca](http://www.nationalcodes.ca) for more information

Aussi disponible en français



APPENDIX C  
ROAD NETWORK OPTIONS DESCRIPTION

## Road Network Options

### Phoenix Way Option

This option assumes the extension of Phoenix Way from Maughan Road to Dodd Narrows. Drivers traveling to Gabriola Island would exit Hwy 19 onto Maughan Road, travel north on Maughan Road and turn right (east) onto Phoenix Way to access Gabriola Island. Drivers traveling from Gabriola would turn left from Phoenix Way onto Maughan Road, travel south, turn right onto the Maughan Road Bridge, then turn left onto Gordon Road and travel south to access Highway 19.

The horizontal alignment and vertical profile of Phoenix Way satisfies the design criteria, but sections will require upgrade to include paved shoulders and proper drainage. This option assumes upgrade of two existing intersections along Phoenix Way (Maughan Road and the eastern access to the Harmac site) as well as widening of the existing bridge on Phoenix Way for pedestrians and cyclists. The alignment will cross Cable Bay Trail and the adjacent creek. A bridge or large multiplate culvert structure is likely required to span over the trail and provide adequate clearance. A key aspect to be considered if this option is to be given further consideration is the health and safety concerns<sup>1</sup> associated with allowing public access via the Harmac Pulp Mill property as well as the need to acquire the Right of Way.

### Nicola Road Option

This option links Highway 19 and Dodd Narrows using the existing local road system. Drivers traveling to Gabriola Island would exit Hwy 19 onto Maughan Road, travel north on Maughan Road and turn left (west) across the Maughan Road Bridge. They would then turn left onto Gordon Road, travel south to MacMillan Road and continue south on MacMillan Road across the MacMillan Road Bridge to the MacMillan Road/Holden Corso Road Intersection. Drivers would then turn left onto Holden Corso Road and travel east, turning left onto Barnes Road and then travelling in an easterly direction to Nicola Road. They would turn left onto Nicola Road and travel north to connect to the new road section connecting to Gabriola Island.

A new on-ramp and off-ramp could be constructed in the vicinity of MacMillan Road to reduce travel distance. This facility would provide direct access to and from MacMillan Road to Highway 19 and eliminate the Maughan Road leg. (This new interchange has not been included as a required network upgrade, recognizing the generally low traffic volumes in the area<sup>2</sup>.)

Holden Corso Road, Barnes Road and Nicola Road would require upgrades to meet current design standards. Up to eight intersections will require upgrades under this option.

### Ocean View Road Option

This option follows a new local road alignment between Highway 19 and Dodd Narrows. Drivers traveling to Gabriola Island would exit Hwy 19 onto Maughan Road, then turn right to the new road. The alignment is located to the north of the ALR lands (that are subject to seasonal flooding) and crosses the two Harmac Pulp Mill pipelines via culverts. Following existing contours, the alignment then deviates due east, immediately north of the White Road and Kurtis Crescent. The road proceeds further east

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<sup>1</sup> Potential health and safety concerns include the plant's emissions, hazardous chemical production and storage facility.

<sup>2</sup> At the time of the Duke Point Highway construction, an agreement was reached with the local community that the highway would not impact the rural nature of the Cedar area. This explains why access to McMillan Road and other roads off the highway is circuitous and not standard diamond-type interchanges

where it generally follows the internal road network envisioned in the Oceanview Golf Resort and Spa Master Plan. A new intersection, where Maughan Road meets the new local road, will be required.

### **Mudge Island Section**

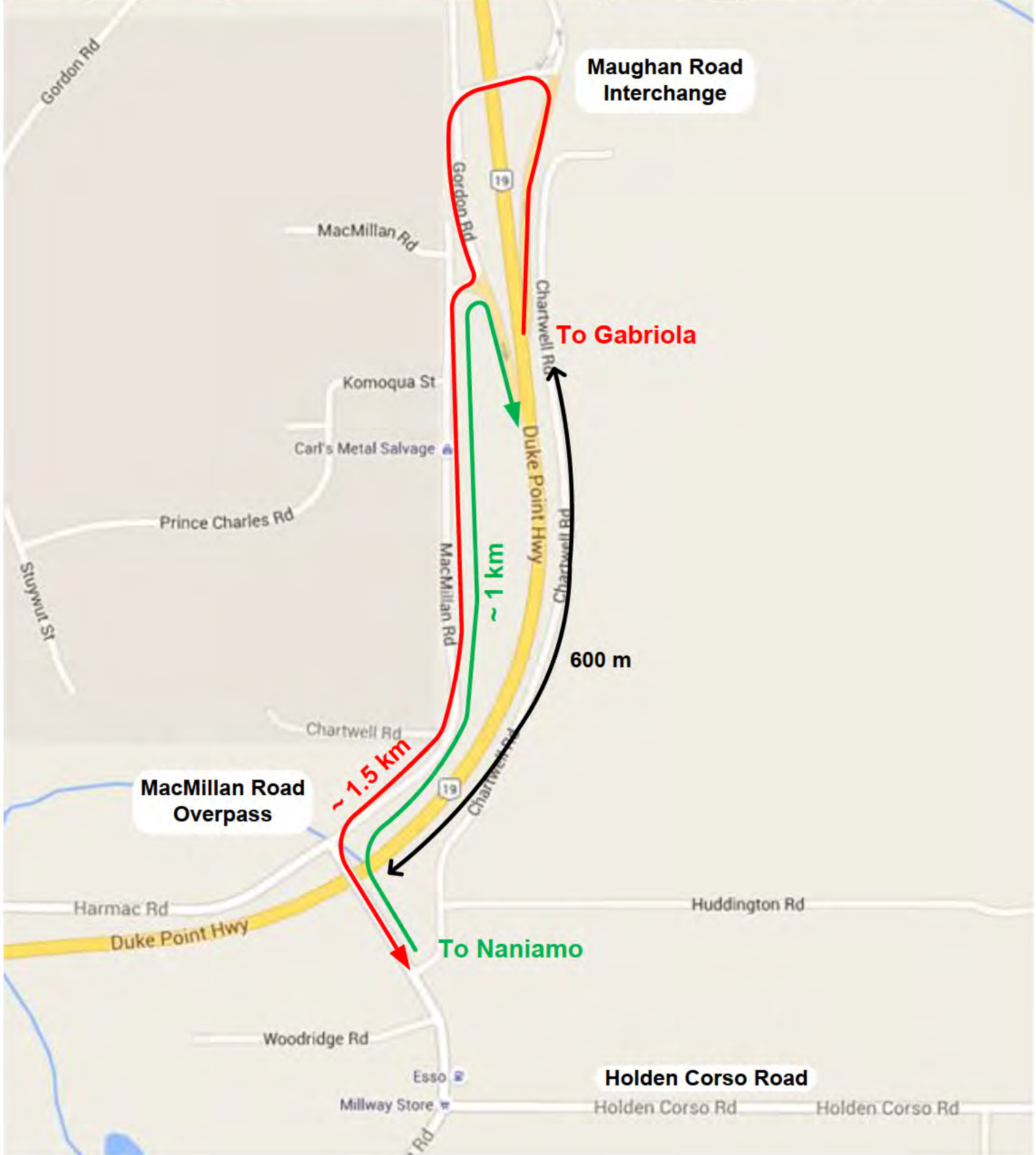
Fixed link options that have a connection between Dodd Narrows and the crossing to Gabriola Island will require the reconstruction of the existing roads on Mudge Island, including Ling Cod Lane, Coho Boulevard, Weather Way and View Ridge Road. These existing roads are low volume, gravel roads that will require extensive upgrading to meet the design criteria for horizontal and vertical alignment as well as road width. Two new road sections would also have to be constructed to access the proposed bridge crossing locations, (False Narrows Central Crossing option and the False Narrows East Crossing option).

A new road connecting to connect Coho Boulevard and Weather Way would be required to provide a link to the False Narrows Central Crossing option, while new road would have to be constructed between the east end of Weather Way and the easterly section of Coho Boulevard to provide access to the False Narrows East Crossing option. The upgrading of the existing roads and new road construction is likely to have significant impact on a number of private properties on Mudge Island. Potential Right of Way acquisitions of are likely to be required.

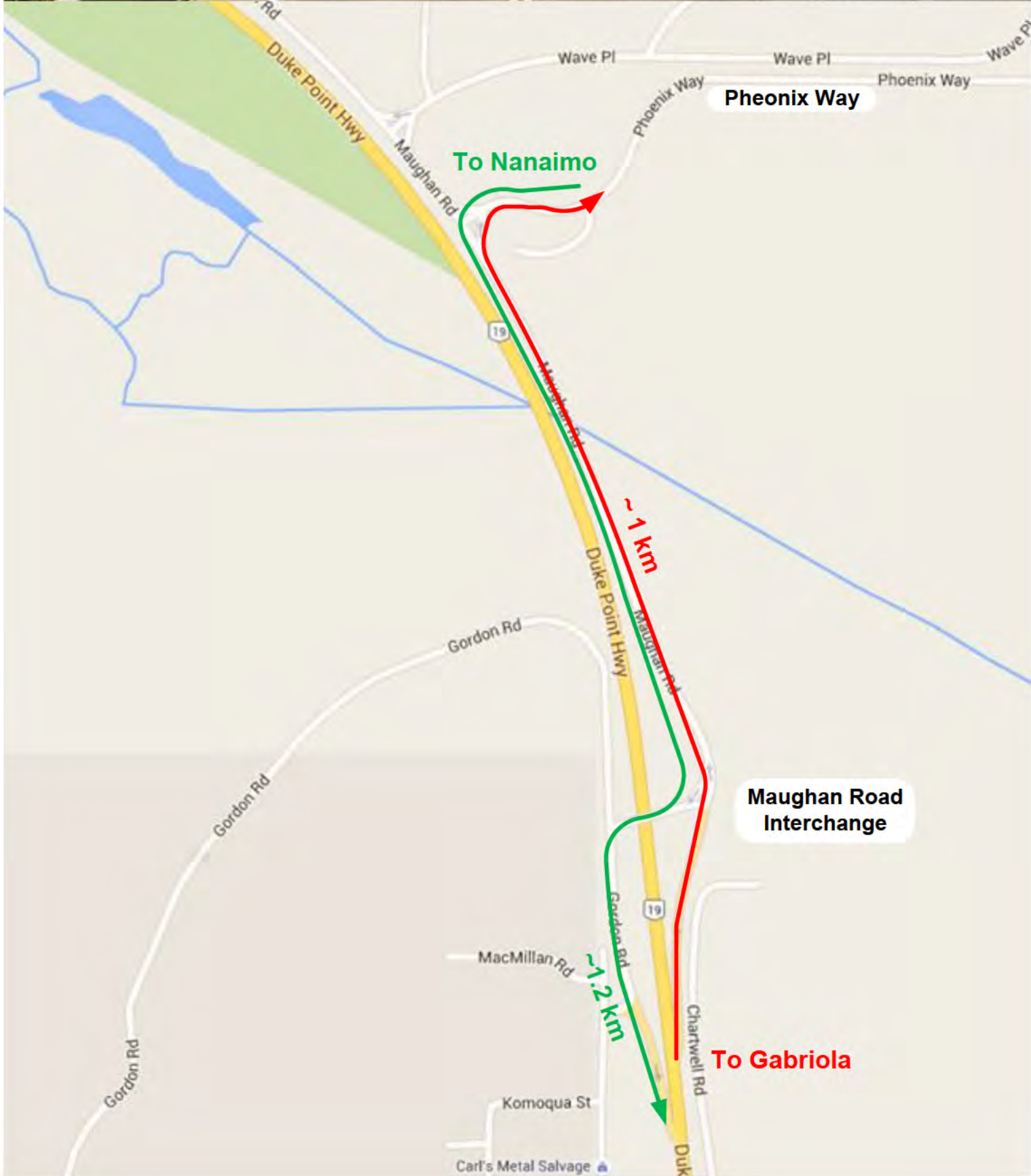
### **Gabriola Island Section**

It is proposed that all bridge crossings from Vancouver Island and Mudge Island would connect to South Road on Gabriola Island. For the purposes of this technical feasibility assessment, the roadworks on Gabriola Island will be limited to an intersection providing access to the bridge. However, as presented later in this section, substantial upgrading of South Road from the crossing location to the village centre will be required to meet the recommended design criteria.

Intersection of Highway 19 @ Maughan Road



Intersection of Maughan Road at Pheonix Way



APPENDIX D  
ENVIRONMENTAL REVIEW

# Environmental Conditions

## Existing Conditions

A desktop assessment was conducted to identify potential terrestrial, fresh water and marine environmental sensitivities within the Study Area. This desktop study included a review of species at risk, sensitive ecological communities<sup>1</sup>, and critical habitats of various species<sup>2</sup>. Several species at risk<sup>3</sup> were identified in the Study Area. A summary of the environmental sensitivities found during the desktop review are provided below.

TABLE F-1. AT RISK SPECIES FOUND WITHIN THE STUDY AREA\*

Common Name	Scientific Name	Species Type	British Columbia Listing	Provincial Status	COSEWIC Status	SARA Status
Awned cyperus	<i>Cyperus squarrosus</i>	Plant	Blue	S3	–	–
Banded cord-moss	<i>Entosthodon fascicularis</i>	Plant	Blue	S2S3	Special Concern	Threatened
Douglas-fir/Dull Oregon-grape	<i>Pseudotsuga menziesii/ Mahonia nervosa</i>	Ecological Community	Red	S2	–	–
Eulachon	<i>Thaleichthys pacificus</i>	Fish	Blue	S2S3	Endangered	–
Muhlenberg's centaury	<i>Zeltnera muehlenbergii</i>	Plant	Red	S1	Endangered	Endangered
Nuttall's quillwort	<i>Isoetes nuttallii</i>	Plant	Blue	S3	–	–
Slimleaf onion	<i>Allium amplexans</i>	Plant	Blue	S3	–	–
White-top aster	<i>Sericocarpus rigidus</i>	Plant	Red	S2	Special Concern	Special Concern

Source: BC Conservation Data Centre, 2012

### Terrestrial

Six at risk species were shown to be located in the proximity of the study area on Vancouver Island (Table F-1).

Treed habitats along Gabriola Island and Mudge Island likely provide nesting habitat for bald eagles, which would need to be considered during construction planning, should a fixed link be feasible.

<sup>1</sup> British Columbia's Conservation Data Center organizes species of concern into 'sensitive' and 'non-sensitive' categories. Due to the vulnerability of 'sensitive', location and species specific information is not provided in the database, rather an area polygon outlining the general area of where these species may be encountered is provided. For 'non-sensitive' species however, specific information is provided, including the location of observation, scientific name, and status ranking.

<sup>2</sup> The review was conducted using a variety of mapping and database tools, including the British Columbia Conservation Data Center and Fisheries and Oceans Canada online databases (BC Conservation Data Centre, 2012; Fisheries and Oceans Canada, 2009), BC iMAP, available satellite imagery, as well as data from previous studies.

<sup>3</sup> In British Columbia, **species at risk** are designated as red or blue-listed to indicate the potential need for designation and protection under the British Columbia Wildlife Act or to determine conservation priorities. Red-listed species include any 'ecological community, and indigenous species and subspecies that is *extirpated, endangered, or threatened* in British Columbia'. These species may become be legally designated under the Wildlife Act, if deemed necessary for their protection. Blue-listed species include any 'ecological community, and indigenous species and subspecies considered to be of *special concern* in British Columbia'. These species are known to be particularly sensitive to human activities and natural events (Government of British Columbia, 2015).

## **Fresh Water Aquatic**

No at-risk fresh water aquatic species were identified via the desk top study, however fresh water drainages likely connecting to Northumberland Channel were identified which may contain potential rearing and spawning habitat for salmon, trout, and char species. (McElhanney, 1993a; McElhanney, 1993b).

## **Marine**

The blue-listed eulachon marine fish is an at-risk marine species was found within the Study Area. This species has the potential to occur at the bridge crossing locations (BC Conservation Data Centre, 2012). Although not considered to be species at risk, the review highlighted potential spawning habitat for herring (BC Conservation Data Centre, 2012) and ling cod, and the presence of oyster and clam beds along the coastal shorelines near the bridge crossings (McElhanney, 1993a).

## **Environmentally Sensitive Areas**

The Douglas fir/dull Oregon grape ecological community, identified as a sensitive ecological community, is present in the Study Area. This ecological community is a Red listed environmentally sensitive area and is found throughout the terrestrial habitats, in particular on Mudge Island and in dispersed areas on Vancouver Island and Gabriola Island.

The Strait of Georgia, which encompasses the entire marine ecosystem within the Study Area, was also identified by DFO as an Ecologically and Biologically Important Area (Fisheries and Oceans Canada, 2009). These Ecologically and Biologically Important Areas are classified by DFO as containing significant or critical marine habitats and allows DFO to provide enhanced protection of these areas (Fisheries and Oceans Canada 2004). No provincially designated parks, protected areas, or conservation areas were located within the project area, however Joan Point Park, a City of Nanaimo park is located within the Study Area near Dodd Narrows.

## **Environmental Screening of Options**

### **Northumberland Crossing Option**

This option is the longest of the bridge crossing options and would require two deepwater pylons within the Northumberland Channel and two pylons on either shoreline.

Three BC listed species were identified along this alignment. The blue-listed eulachon may be impacted by instream work to build the deepwater pylons.

The alignment potentially impacts two unidentified 'sensitive' species (BC Conservation Data Centre, 2012). It is unknown if these species inhabit terrestrial or marine environments, therefore potential impacts to these species is unknown at this time, but may include loss of or alternation of habitat as a result of removal and clearing for construction of the pylons.

The Strait of Georgia has been identified as an Ecologically and Biologically Important Area by DFO (Fisheries and Oceans Canada, 2009). Potential impacts resulting from construction of the deepwater pylons may result in a direct loss of marine habitat or degradation of water quality and marine habitats due to sedimentation or the introduction of other deleterious substances.

Should a detailed environmental assessment be conducted for this project, additional information should be gathered on the unidentified BC listed species and DFO consulted to avoid or mitigate potential impacts to these marine ecosystems.

### **False Narrows West Crossing Option**

This is the longest of the crossing options between Mudge and Gabriola Islands. It is expected that the north pylon would be constructed instream, while the south pylon would be constructed on shore. Three BC listed species and one red-listed ecological community were identified along this alignment corridor.

The blue-listed eulachon may be impacted by instream work to build the deepwater pylon. The two unidentified 'sensitive' species are present within this crossing corridor (BC Conservation Data Centre, 2012). The red-listed Douglas fir/dull Oregon-grape Ecological Community is present throughout Mudge Island where the south pylon would be located. Potential impacts to the ecological community may include loss or alternation of habitat as a result of removal and clearing for construction of the pylons.

This bridge crossing is also located within the Strait of Georgia and identified as an Ecologically and Biologically Important Area by DFO (Fisheries and Oceans Canada, 2009). Potential impacts resulting from construction of the deepwater pylon may result in a direct loss of marine habitat or degradation of water quality and marine habitats due to sedimentation or the introduction of other deleterious substances.

Should a detailed environmental assessment be conducted for this project, additional information should be gathered on the unidentified species and DFO consulted to avoid or mitigate potential impacts to marine ecosystems.

### **False Narrows Central Crossing Option**

The proposed concrete box girder bridge includes six instream pier supports at the south end of Northumberland Channel and two supports along the shorelines of Mudge Island and Gabriola Island above the high tide. Three BC listed species and one red-listed ecological community were identified along this alignment corridor.

The blue-listed eulachon may be impacted by instream construction of the piers. It is unknown if this area is used by eulachon for critical life stages such as spawning. Marine areas, including False Narrows which is located to the east of this bridge crossing were identified as containing spawning habitat for herring (Fisheries and Oceans Canada, 2015). The presence of oyster and clam beds along the coastal shorelines in the vicinity of the bridge crossing were also reported (BC Conservation Data Centre, 2012; McElhanney, 1993a).

The two unidentified 'sensitive' species are present within this crossing corridor (BC Conservation Data Centre, 2012). It is unknown if these unidentified species inhabit terrestrial or marine environments. Potential impacts to these species may include loss or alteration of habitat due to clearing and removal for construction of the pylons on either shoreline. The red-listed Douglas fir/dull Oregon-grape Ecological Community is present throughout most of Mudge Island where the north bridge abutment will be located (BC Conservation Data Centre, 2012).

Should a detailed environmental assessment be conducted for this project, additional information should be gathered on the unidentified BC listed species and DFO be consulted to avoid or mitigate potential impacts to the marine ecosystems.

### **False Narrows East Crossing**

The proposed concrete box girder bridge will contain five instream pier supports, spaced at 60 metres through False Narrows, with an additional two supports along the north shoreline of Gabriola Island above the high tide. Three BC listed species were identified along this alignment option.

The blue-listed eulachon may be impacted by instream construction of the piers. It is unknown if this area is used by eulachon for critical life stages such as spawning. Marine areas, including False Narrows, were identified as containing spawning habitat for herring (Fisheries and Oceans Canada, 2015). The

presence of oyster and clam beds along the coastal shorelines in the vicinity of the bridge crossing were also reported (BC Conservation Data Centre, 2012; McElhanney, 1993a).

The two unidentified 'sensitive' species are present along this alignment option (BC Conservation Data Centre, 2012). It is unknown if these unidentified species inhabit terrestrial or marine environments and therefore impacts to these species as a result of the bridge cannot be adequately assessed, however potential impacts may include loss or alteration of habitat.

This bridge crossing is located within the Strait of Georgia and is identified as an Ecologically and Biologically Important Area by DFO (Fisheries and Oceans Canada, 2009). Construction of the instream piers may result in a loss of habitat for these marine species. Degradation of water quality may also result from sedimentation during construction of instream piers.

While the majority of Mudge Island contains the red-listed Douglas fir/dull Oregon-grape Ecological Community, this particular bridge location does not conflict with this ecological community as the bridge is located outside of the habitat polygon.

Should a detailed environmental assessment be conducted for this project, additional information should be gathered on the unidentified BC listed species and DFO consulted to avoid or mitigate potential impacts to marine species.

### **Dodd Narrows Crossings**

The bridge crossing options at Dodd Narrows will require construction of two support pylons on each shoreline above the high tide. This alignment option has the potential to impact three British Columbia (BC) listed species and one red-listed ecological community.

The blue-listed eulachon, a marine fish, was identified as occurring within the vicinity of Dodd Narrows. Marine areas including Dodd Narrows were identified as potential spawning habitat for herring (Fisheries and Oceans Canada, 2015) and ling cod (McElhanney, 1993a). The presence of oyster and clam beds along the coastal shorelines near the bridge crossing were also reported (McElhanney, 1993a).

The red-listed Douglas fir/dull Oregon-grape Ecological Community was located throughout much of Mudge Island including along the shores where vegetation removal may be required for construction of the bridge crossing. Two unidentified 'sensitive' species were also highlighted as potentially occurring in the vicinity of the crossing. It is unknown if these species inhabit terrestrial or marine environments, therefore potential impacts to these species is unknown at this time, but may include loss of or alternation of habitat as a result of removal and clearing for construction of the pylons. Should a detailed environmental assessment be conducted for this project, additional information on these unidentified species should be requested, in particular, location data with respect to the alignment options so impacts can be avoided or appropriately mitigated (BC Conservation Data Centre, 2012).

This bridge crossing is located within the Strait of Georgia which has been identified by DFO as an Ecologically and Biologically Important Area (Fisheries and Oceans Canada, 2009), based on uniqueness (rare or distinct habitats), aggregations (relative density of a species habitat use in one area), and fitness consequences (areas containing habitat for critical life stages). Impacts to marine species and/or their habitat, may result from construction of bridge pylons if works are conducted along the shoreline or extend instream. Degradation of marine habitats may result from sedimentation or the introduction of other deleterious substances to the water.

### **Phoenix Way Road Option**

Three unidentified 'sensitive' species could be impacted by this alignment option (BC Conservation Data Centre, 2012). It is unknown what type of environment these unidentified species inhabit, therefore impacts to these species as a result of the roadway cannot be adequately assessed without additional information. However, potential impacts may include loss of habitat.

A total of five BC listed plant species were also identified within 100 meters of the road way. These species included four blue-listed plants (awned cyperus, banded cord-moss, Nuttall's Quillwort, slimleaf onion) and one red-listed plant (white-top aster). Two red-listed plant species (Muhlenberg's centaury and white-top aster), were identified within 300 meters of the Alt 2 alignment. Potential impacts to these plant species include removal, disturbance, alteration, or loss of habitat for construction of any roadway.

Depressions identified along the roadway from a review of satellite imagery likely drain into the Northumberland Channel. While no known fish observations were identified along this route option (BC Ministry of Environment, 2011.), previous studies identified freshwater fish species (including chinook salmon, chum salmon, coho salmon, rainbow trout, cutthroat trout, and Dolly Varden) in the general project area. Previous studies also identified potential rearing and spawning habitat in unnamed watercourses located to the west of the alignment (McElhanney, 1993a; McElhanney, 1993b). It is therefore assumed that these depressions are fish bearing. Installation of culverts to facilitate drainage at these locations has been proposed. Potential impacts to the fresh water ecosystems resulting from the culvert installations may include alteration or loss of fish and aquatic habitat, loss of riparian habitat, sedimentation, or the introduction of other deleterious substances.

Should a detailed environmental assessment be conducted for this project, additional information should be gathered on the unidentified British Columbia listed species and DFO consulted to avoid or mitigate potential impacts to the fresh water ecosystems.

#### **Nicola Road Option**

Three unidentified 'sensitive' species were identified along this alignment (BC Conservation Data Centre, 2012). It is unknown what type of environment these unidentified species inhabit, therefore impacts to these species as a result of the bridge cannot be adequately assessed. However, impacts may include loss of habitat.

Two red-listed plant species (Muhlenberg's centaury and white-top aster), were identified within 100 meters of the roadway. Potential impacts to these plant species include removal, disturbance, alteration, or loss of habitat for construction of any roadway.

Should a detailed environmental assessment be conducted for this project, additional information should be gathered on the unidentified 'sensitive' species.

#### **Central Route A/B Options**

Three unidentified 'sensitive' species were identified along this alignment (BC Conservation Data Centre, 2012). It is unknown what type of environment these unidentified species inhabit, therefore impacts to these species as a result of the bridge cannot be adequately assessed. However, impacts may include loss of habitat.

One blue-listed plant species (Nuttall's Quillwort), was identified within 100 meters of the roadway. Potential impacts to this plant species includes removal, disturbance, alteration, or loss of habitat for construction of the roadway.

Two red-listed plant species (Muhlenberg's centaury and white-top aster), were identified within 300 meters of the roadway. Potential impacts to these plant species include removal, disturbance, alteration, or loss of habitat for construction of any roadway.

Should a detailed environmental assessment be conducted for this project, additional information should be gathered on the unidentified 'sensitive' species.

#### **Road Segments on Mudge Island**

Roadway segments on Mudge Island are required to connect the respective bridges from Mudge Island to Gabriola Island. Two unidentified 'sensitive' species were identified along these alignment options

(BC Conservation Data Centre, 2012). It is unknown what type of environment these unidentified species inhabit, therefore impacts to these species as a result of the road segments cannot be adequately assessed at this time, but may include loss of habitat.

The red-listed Douglas fir/dull Oregon-grape Ecological Community is present throughout most of Mudge Island and overlaps with all three road segments (BC Conservation Data Centre, 2012). Potential impacts to this ecological community includes removal, disturbance, alteration, and/or loss of habitat for construction of the roadway. Should a detailed environmental assessment be conducted for this project, additional information should be gathered on the unidentified 'sensitive' species.