4.1 River Hydraulics and River Morphology Assessment Highlights:

- The proposed bridge will have a clear-span over the Fraser River South Arm, which eliminates potential changes to river hydraulics or river morphology resulting from the new structure.
- The Fraser River South Arm is dynamic with scour in the order of several meters during freshet and migrating sand dunes with heights of up to four metres.
- Removal of the Tunnel is not expected to result in changes in water level or affect flow splits between the main channel and nearby channels.
- Suspended sediment load in the Fraser River is naturally high and the temporary increase in suspended sediments anticipated during Tunnel removal is expected to be relatively minor.
- Tunnel removal is expected to result in temporary bed lowering between the Tunnel and the Lulu Island–Delta watermain; however, with monitoring and mitigation, no permanent effect on the watermain is expected.
- No Project-related long-term residual effects or cumulative effects on river hydraulics or river morphology are expected.

4.1 River Hydraulics and River Morphology

This section describes the existing conditions related to water levels, velocities, and flow patterns (river hydraulics), and their influence on sedimentation and erosion (morphology) within the Fraser River, as well as anticipated Project-related changes in such conditions. River hydraulics and river morphology is studied as an intermediate component (IC), and information on predicted Project-related change in river hydraulics and river morphology is used to support the assessment of effects of the Project on fish and fish habitat (**Section 4.4 Fish and Fish Habitat**), marine mammals (**Section 4.6 Marine Mammals**), and marine use (**Section 5.2 Marine Use**).

A technical volume, **River Hydraulics and River Morphology Study***,* containing further detail on existing conditions and methodology used in predicting Project-related effects is included in **Section 16.2**.

4.1.1 Context and Boundaries

This section describes the context for assessment of Project-related effects on river hydraulics and river morphology in terms of Project setting, and defines the assessment boundaries. Rationale for selecting the assessment boundaries as defined is also provided.

4.1.1.1 Assessment Context

Although no permanent instream works are required in the Fraser River, temporary impacts to river hydraulics and river morphology as a result of Tunnel removal have been examined because of their potential to affect fish and fish habitat, marine mammals, and marine use. Input received through consultation with government agencies, Aboriginal Groups, and the general public also informed the decision to undertake a river hydraulics and river morphology assessment. During pre-Application consultation on the Project, Metro Vancouver expressed an interest in the potential effect of Tunnel decommissioning on Metro Vancouver Water Services infrastructure (i.e. River Road West Main and Lulu Island-Delta Main). No other feedback or information, including Traditional Knowledge, that would be of specific relevance to the assessment of river hydraulics or morphology was received during pre-Application consultation.

Additional information on the selection of VCs, and the link between river hydraulics and river morphology, and receptor VCs is provided in **Section 3.1 Issues Scoping and Selection of Valued Components**.

4.1.1.2 Methodology

The assessment of river hydraulics and river morphology follows the general methodology described in **Section 3.0 Assessment Methodology**. In early 2014, the Ministry initiated studies to meet the following key objectives:

- Understand the morphological evolution of the lower Fraser River and estuary and describe existing conditions.
- Assess potential changes in water levels, velocities, and flow patterns related to the Project.
- Assess potential Project-related changes in sediment deposition and erosion patterns.
- Assess potential adjustment of the riverbed profile following Tunnel removal.

4.1.1.3 Assessment Boundaries

Assessment boundaries for river hydraulics and river morphology are defined below.

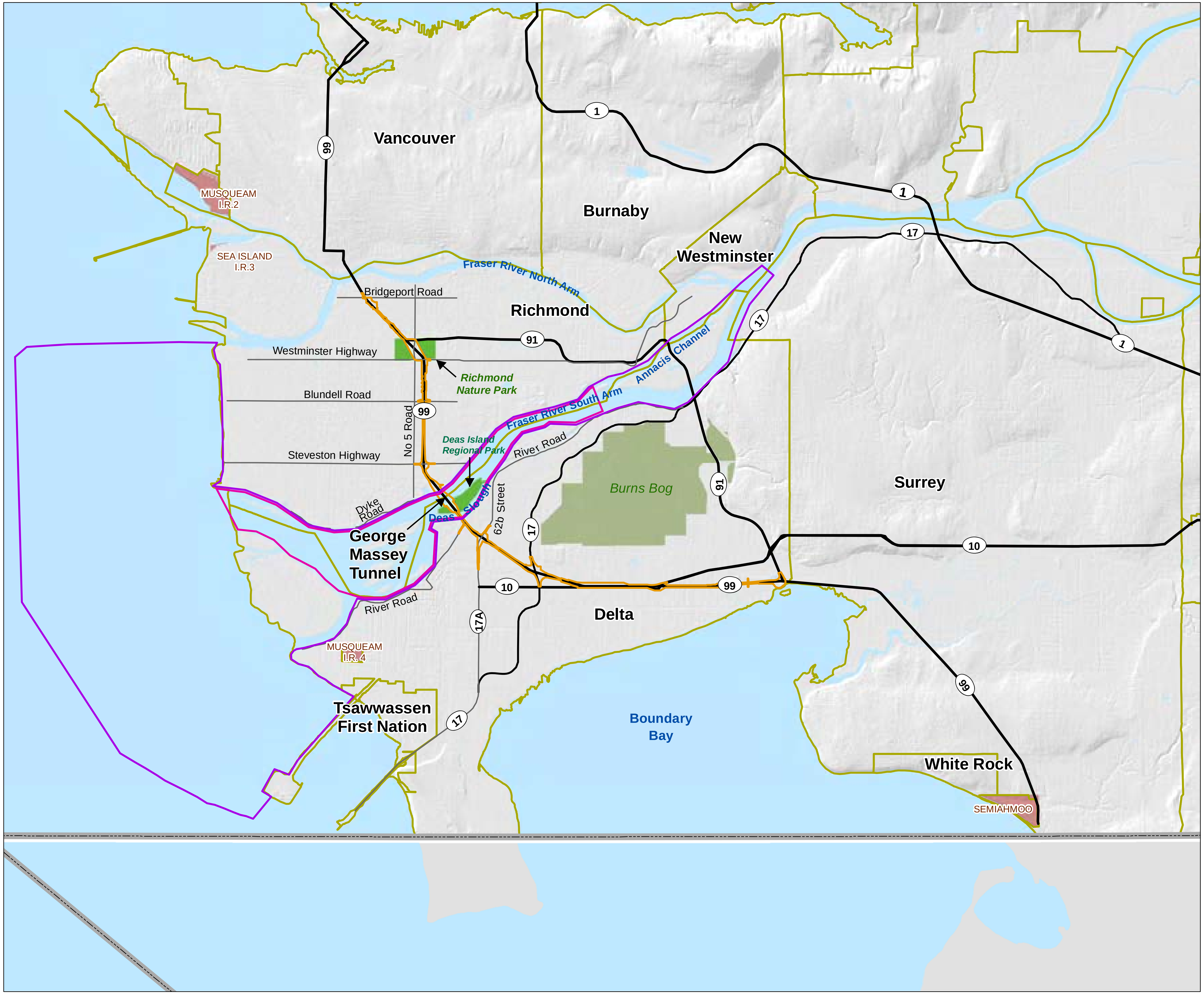
Spatial Boundaries

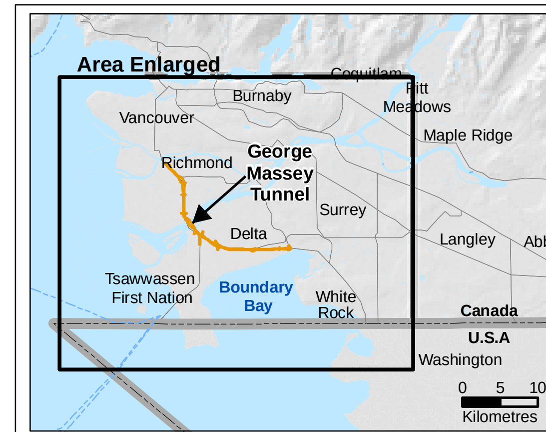
The local assessment area (LAA) includes the area where Project-related changes are likely to occur, and is defined as the Fraser River South Arm from just upstream of Tilbury Island to the mouth of the River, as shown on **Figure 4.1-1**.

The regional assessment area (RAA) is defined as the Fraser River South Arm, extending from just upstream of Annacis Island to the Fraser River estuary, including Sturgeon and Roberts Banks (**Figure 4.1-1**). While Project-related changes are not expected beyond the mouth of the Fraser River, the RAA incorporates the adjacent coastal waters to support tidal simulations and establish the boundary conditions for the numerical modelling used to predict Project-related effects.

Table 4.1-1 Spatial Boundaries for River hydraulics and river morphology Assessment

Spatial Boundary	Description of Assessment Area
Local Assessment Area (LAA)	Fraser River South Arm from just upstream of Tilbury Island to the mouth of the River
Regional Assessment Area (RAA)	Fraser River South Arm, extending from just upstream of Annacis Island to the Fraser River estuary, including Sturgeon and Roberts Banks





Legend

- River Hydraulics and Morphology Local Assessment Area
- River Hydraulics and Morphology Regional Assessment Area
- Project Alignment
- First Nation Reserve
- Municipal Boundaries
- Burns Bog Ecological Conservancy Area
- Waterbody
- Canada - U.S. Border
- Highway
- Arterial/Collector Road

SOURCES

Parks and Protected Lands, First Nations Reserves from GeoBC, United States basemap data courtesy of USGS. Burns Bog courtesy of The Corporation of Delta and based on the Metro Vancouver Burns Bog Ecological Conservancy Area Management Plan - May 2007, all other data courtesy of Canvec - GeoGratis.

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Kilometres

GEORGE MASSEY TUNNEL REPLACEMENT PROJECT

RIVER HYDRAULICS AND MORPHOLOGY LOCAL AND REGIONAL ASSESSMENT AREAS

Figure 4.1-1 | 13/05/2016

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Temporal Boundaries

Temporal boundaries for the assessment of Project-related effects on river hydraulics and river morphology were established based on the potential for each phase of the Project to interact with and have an effect on river processes. As discussed in **Section 3.1 Issues Scoping and Selection of Valued Components**, both the construction and operational phases of the Project include components and activities that could interact with and affect river processes within the Fraser River South Arm; therefore, the following temporal boundaries were defined for assessment of river hydraulics and river morphology:

- Existing conditions.
- Construction phase (including decommissioning of the Tunnel).
- Operations phase (new bridge and highway in operation).

Temporal characteristics of the Project phases are discussed in **Section 1.1 Description of Proposed Project**. Specific temporal considerations for the assessment of river hydraulics and river morphology and its sub-components are discussed in the context of Project interactions and potential effects in **Section 4.1.3 Potential Effects**.

Administrative Boundaries

No administrative boundaries have been identified that could impose limitations on the assessment of potential Project-related effects on river hydraulics and river morphology.

Technical Boundaries

Technical boundaries for predicting changes to river hydraulics and river morphology exist due to the interpretive nature of geomorphic studies and the limitations of the numerical methods used to model river hydraulics and river morphology. This uncertainty has been mitigated to some extent by using accurate data collection methods and by relying on data that were collected reliably by others.

The numerical modelling approach is consistent with standard practices and state of the science. Details of model validation are given in the technical volume, ***River Hydraulics and River Morphology Study*** included in **Section 16.2**.

4.1.2 Existing Conditions

This section provides an overview of the methodology used for collecting baseline data, and describes the existing conditions pertaining to current distributions, water levels and sedimentation patterns in the assessment areas. An overview of the regulatory context for management of surface water as relevant to the Project is also provided.

4.1.2.1 Baseline Data Collection

An interpretive geomorphology approach that involved the following tasks was used to collect baseline data and to understand the morphological evolution of the lower Fraser River and estuary:

- Literature review – Previous field, model, and theoretical studies were reviewed to understand the environment and driving forces at work near the Tunnel and interpret the results of the numerical modelling in this light.
- Aerial photograph interpretation – Aerial photographs of the LAA spanning the years 1938 to 2009 were analyzed. These provide insight into the planform changes that have taken place on the lower Fraser River since 1938 and the role of natural or man-made factors in driving these changes.
- Bathymetric surveys – Watermain crossings on the Fraser River have been surveyed regularly by the Greater Vancouver Water District since 1962. Data were also obtained from bathymetric surveys of the lower Fraser River conducted in 1988/89, 2000/01, 2008/09 and 2014 by Public Works and Government Services of Canada (PWGSC).

4.1.2.2 Regulatory Context

Two pieces of legislation are relevant to the Project in the context of river hydraulics and river morphology: the B.C. *Water Sustainability Act* S.B.C. 2014, c. 15, and the federal *Fisheries Act*, R.S.C. 1985, c. F-14.

In B.C., the ownership of water is vested in the Crown as stated in Section 5 of the *Water Sustainability Act*, the primary provincial statute regulating water resources. Since the Project involves works in or about the Fraser River, Sections 11 and 12 of the *Water Sustainability Act* and associated *Water Sustainability Regulation* B.C. Reg. 36/2016 would apply to such activities. Section 46 of the *Water Sustainability Act* regulates the introduction of foreign matter into streams. The *Water Sustainability Regulation* addresses the requirements to allocate surface water (e.g., application requirements) and identifies the requirements for using water or making changes to a stream in accordance with the regulation.

Fisheries Act

Section 35 (1) of the *Fisheries Act* regulates “any work, undertaking or activity that results in serious harm to fish that are part of a commercial, recreational or Aboriginal fishery, or to fish that support such a fishery.” Section 36 (3) regulates depositing or permitting the deposition of “a deleterious substance of any type in water frequented by fish”. A deleterious substance may include excess concentrations of suspended sediment.

4.1.2.3 Existing Conditions

George Massey Tunnel

The Tunnel is located on the Fraser River South Arm between km 18 and km 19 from Sand Heads (**Figure 4.1-2**). It is 629 m long and consists of six concrete segments (105 m long each). Tunnel width and height are 23.8 m and 7.3 m, respectively. The Tunnel configuration is shown in **Figure 4.1-3**.

The Tunnel is protected from scour by a rock apron and a flexible concrete mattress (**Figure 4.1-4**). The top of this scour protection layer was constructed to be flush with the riverbed in the centre channel. The elevation of the top of the Tunnel’s scour protection relative to the river bottom is shown in the as-built surveyed Tunnel cross sections provided in **Figure 4.1-5** and river bathymetry is shown in **Figure 4.1-6**.

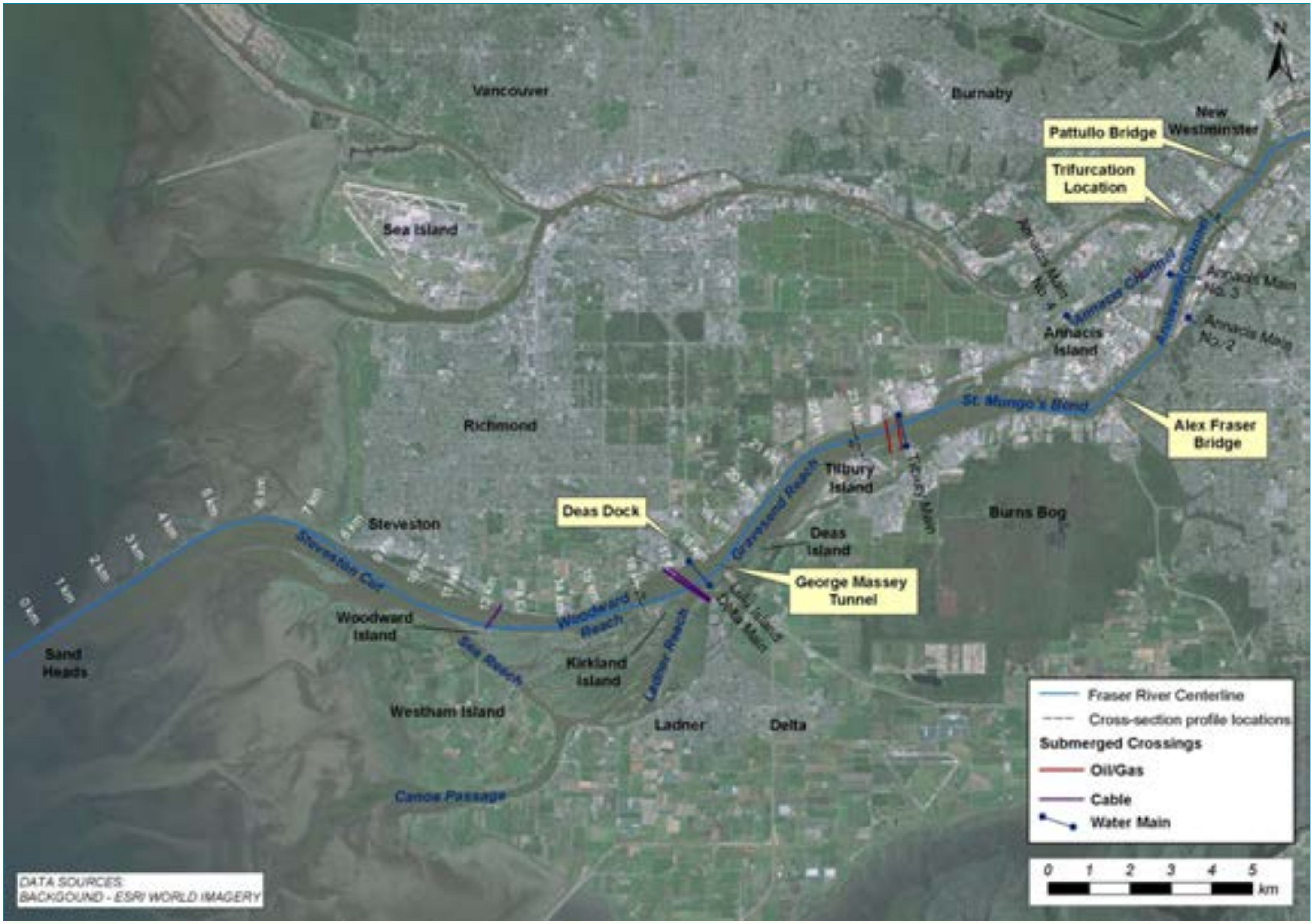

Figure 4.1-2 **Overview Map Showing Locations of Interest near the Local Assessment Area**

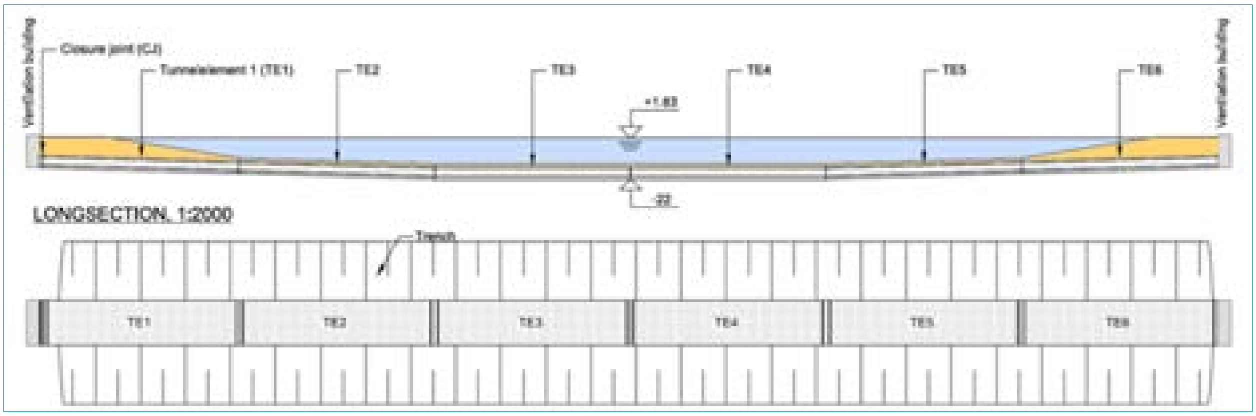

Figure 4.1-3 Longitudinal Section of the Tunnel (not to Scale)

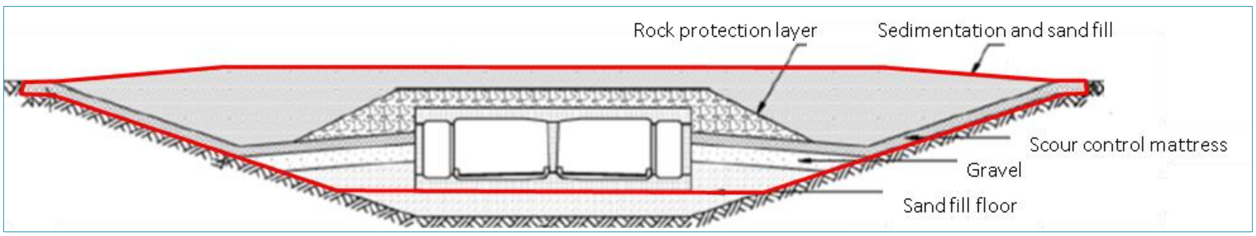

Figure 4.1-4 Cross-section of the Tunnel (not to Scale). Red Polygon Indicates Assumed Extent of Excavation.

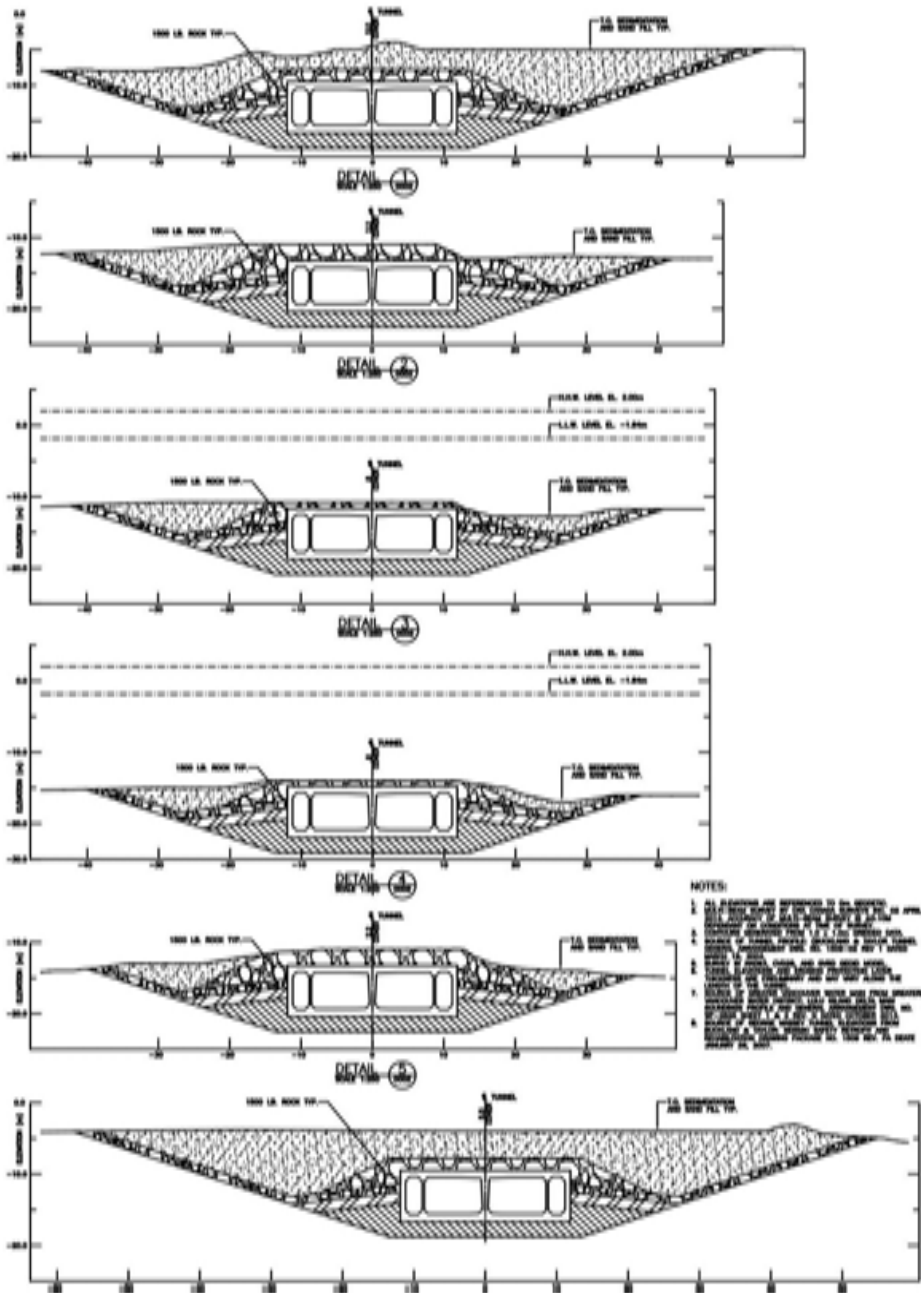

Figure 4.1-5 Surveyed Cross Sections of Tunnel

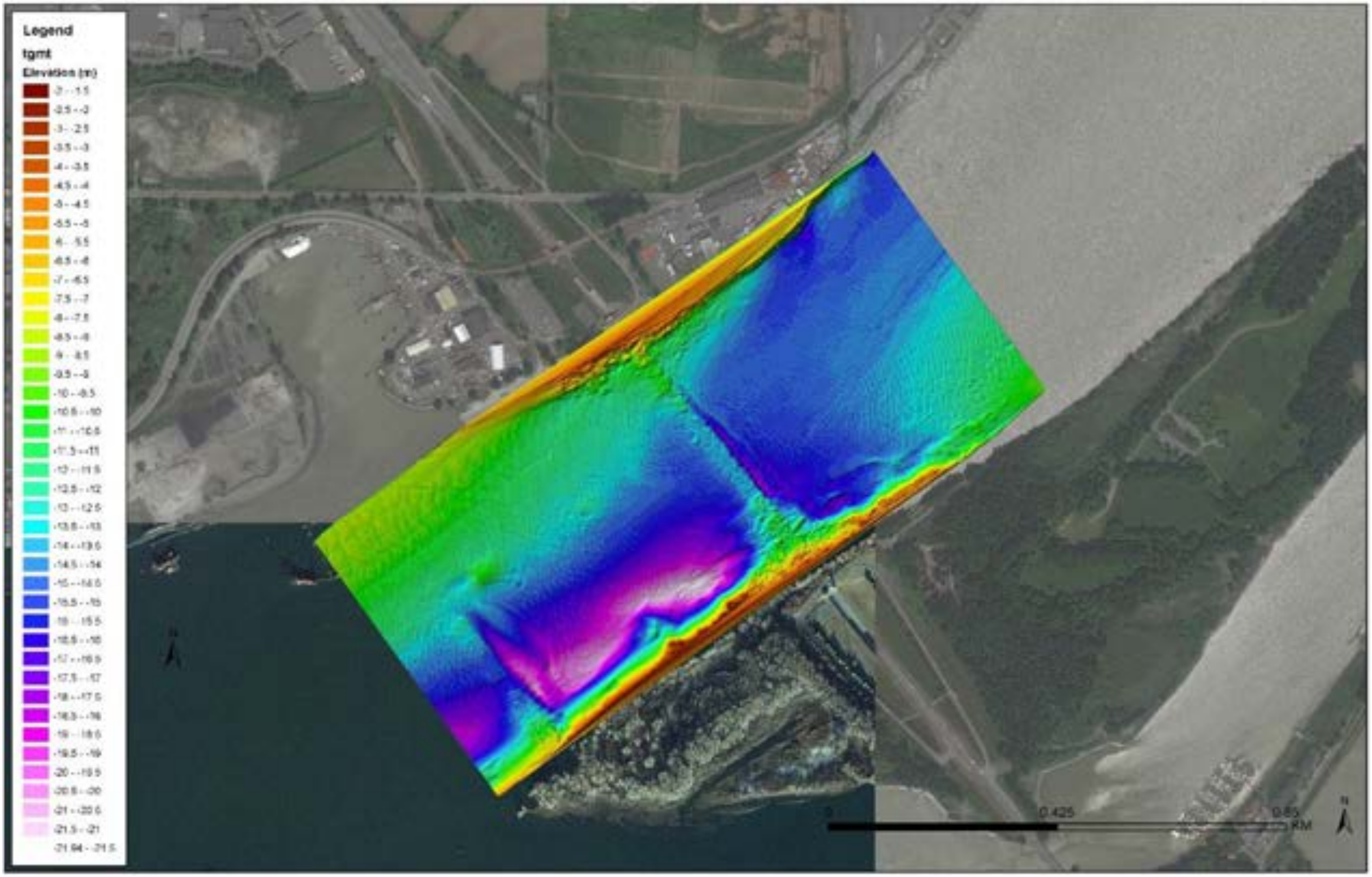

Figure 4.1-6 Riverbed Elevations from Bathymetric Survey Data Collected on April 2, 2014.

Fraser River Flows and Sediment Loads

The Fraser River South Arm is a single, meandering, sand-bed channel. Fraser River flows are dominated by snowmelt, with discharge typically rising in April, peaking between May and July during freshet, and receding during autumn and winter. Average peak flow of the Fraser River at Hope is about 7,000 m^3/s in June and average low flow is approximately 850 m^3/s in March (NHC 2002).

Sediment loads on the lower Fraser River range from 12.3 to 31.0 million tonnes/year (average 16.5 million tonnes/year) (1965-1986 data; McLean et al. 1999, NHC 2002). Fine sediments (i.e., washload) generally remain in suspension and have little effect on sedimentation patterns. In contrast, bed-material load (i.e., bedload or sediment load that gets deposited in the river) influences river morphology. In the lower Fraser River, bedload ranges from 1.2 million to 8.9 million tonnes/year (average 2.9 million tonnes/year; NHC 2002).

Dunes, characteristic features of a sand-bed channel, occur on the riverbed within a 1.2 km stretch centered over the Tunnel. Large dunes have also been observed from the Port Mann Bridge to the mouth of the river (NHC 2009). Dune height varies from 0.5 m to 2.0 m in approximately 12 m depth, although individual dunes can be considerably larger (Church and McLean 1994). As bedload sediments are transported downstream, dunes generate periodic scour and fill, and can increase total scour depths, damaging scour protection aprons and rock protection.

Flow in the lower Fraser River is influenced by a salt water wedge. The location of the salt wedge moves throughout the day in response to tide height variations, and seasonally in response to river discharge variations. The maximum upstream extent of salt water intrusion is about 30 km from the mouth during winter low flows and less than 15 km during freshet (Ward 1976). The salt wedge influences patterns of sediment entrainment and deposition, with rapid deposition occurring as the salt wedge migrates upstream, and re-entrainment as the salt wedge recedes (Kostaschuk and Luternauer 1989).

Water Levels

The river is tidally influenced. Tides in the Strait of Georgia are generally characterized by two highs and two lows of unequal height every lunar day (i.e., every 24 hours and 50 minutes). Greatest tidal amplitudes exceed 3.5 m from April to July and from October to January. At Deas Island, tides are moderated by Fraser River flows, and normal water levels range between minus 1.8 m (Canadian Hydrographic Service chart datum) and 2 m (Canadian Hydrographic Service high water datum). Extreme water levels in the Fraser River estuary are governed by high tides and storm surge in the winter, rather than high discharges during freshet. Annual minimum water levels in the lower Fraser River have exhibited a downward trend between 1969 and the late 1980s, likely due to lowering of the riverbed.

In-River Utilities and Infrastructure

Utilities, including pipelines, that currently cross the Fraser River downstream of New Westminster include: six watermains, four natural gas pipelines, and one oil pipeline (**Figure 4.1-2**). Scour protection aprons at a number of these crossings create grade controls that affect riverbed elevations. The Lulu Island–Delta watermain, the pipeline nearest to the Tunnel, is located approximately 600 m downstream. It has a scour protection apron over its southern half, which imparts a variable cross-channel elevation. Bathymetric surveys show considerable scour and bed degradation up and downstream of the Lulu Island-Delta main crossing.

Bridge crossings in the reach include the Pattullo Bridge, opened in 1937; the Port Mann Bridge, originally opened in 1964 and replaced in 2012; and the Alex Fraser Bridge, opened in 1986 (**Figure 4.1-2**). The Skybridge just downstream of the Pattullo Bridge was constructed between 1987 and 1989.

Extensive river training and bank protection works, undertaken since 1910, along the Fraser River South Arm have led to narrowing and deepening (McLean et al. 2007), as well as lengthening of the river channel by approximately nine kilometres in a seaward direction.

Banks of the lower Fraser River have been hardened over the years by extensive riprap protection. The banks of Woodward Island were riprap-armoured on the main channel side between 1927 and 1941. By 1953, most of the right[1] bank of the Fraser River from Steveston to upstream of the Tunnel was protected with riprap (Pretious and Thorne 1953). The bank of Deas Island on the main channel side has also been protected with riprap, although the time of construction is not known.

1 In hydrology, left bank and right bank are relative to an observer looking downstream.

Dredging

Annual dredging, conducted by Vancouver Fraser Port Authority, in the Fraser River South Arm has been extensive since 1960 and concentrated mostly downstream of New Westminster. Dredging volumes were greatest between 1976 and 1990, then declined through the following decade. During the height of dredging activity, about 15% of the total annual sediment removal on the Fraser River was from Gravesend Reach, upstream, and Woodward Reach, downstream, of the Tunnel (**Figure 4.1-2**). At Gravesend Reach, large-scale navigation and borrow dredging had a noticeable effect on bed levels. Bed lowering along Gravesend Reach occurred at a rate of about 25 cm/year, when dredging volume reached 700,000 m^3/year during the 1980s, and remained relatively constant when dredging volume was in the order of 200,000 m^3/year (NHC 2002). Although total removals have rebounded since 2001, less than one per cent of total dredging has been extracted from Gravesend Reach annually.

Dredging for maintenance of the navigation channel occurs annually at the mouth of the Fraser River, especially in Steveston Cut (**Figure 4.1-2**). Infrequent dredging of secondary channels occurs in Ladner Reach and Sea Reach to improve navigation for small vessels (FREMP 2006). Since 2004, the maximum vessel draft in the reaches downstream of Deas Island (Woodward Reach, Ladner Reach, Sea Reach, Canoe Passage, Steveston Cut, and Sand Heads Reach) has been increased from 10.7 m (in place since 1976) to 11.5 m (FREMP 2006).

Long-Term Changes in River Channel Configuration

Historically, the Fraser River estuary has been very active morphologically. The river transports large volumes of sand to the reach, where patterns of deposition, mobilization, and transport are heavily influenced by the tides. As a result, the configuration of channels at the river mouth is complex and in the absence of human intervention would be in constant flux. As late as 1898, Ladner Reach was considerably larger than its current size. Around 1827, the main channel occupied Ladner Reach and continued along Sea Reach to the mouth. Prior to this, the main flow path may have been along Canoe Passage via Ladner Reach. The Ladner Reach entrance was observed to have widened, and the deepest portion of the channel migrated from right to left bank at Deas Island in the years prior to Tunnel construction (Pretious and Thorne 1953).

Historic aerial photographs of the lower Fraser River, from 1938 to 2009, reflect increasing anthropogenic development over time along the river and on its floodplain. There has been no major shifting in the banklines over the 60-year period, due in large part to bank hardening (i.e., riprap) and river training works. Minor distinguishable changes are attributed to dredging of Deas Dock and some expansion of industrial water lots in the Steveston area.

Banklines of mid-channel islands, particularly of the Woodward Island complex, are largely unprotected, and therefore more likely to change over time. Mid-channel islands have expanded since 1949. In particular, expansion of Little Hart Island between 1949 and 1974 occurred due to dredge spoil dumping and transport by currents (Hay & Company Consultants Inc. 2010). This expansion appears to have forced the flow at the elbow of Ladner Reach north into Barber Island. The main channel of the reach has since shifted north of Little Hart and Big Hart islands, while the south channel has become constricted. Downstream in Sea Reach, the width of the southern portion of the channel has not changed appreciably, but the reach downstream of the confluence with Woodward Slough appears to have widened between 1949 and 2009.

A sand bar located approximately 1.5 km upstream of the Tunnel, at the downstream end of Tilbury Island, was first observed in the 1954 aerial photograph. Favourable tides allowed observation of it again in the 1984 photoset, by which time the bar/island had started to become colonized by vegetation, presumably due to vertical sediment accumulation. The bar/island is still present today, with roughly three-quarters colonized by marsh vegetation.

Between 1898 and 1953, the upstream end of Kirkland Island was subject to considerable erosion (Pretious and Thorne 1953). The bankline at the downstream end of Deas Island also receded mostly between 1948 and 1953. Since 1953, banklines upstream of Kirkland Island and Deas Marsh have largely stabilized.

Aboriginal Groups have noted that the Fraser River channel is shifting and causeway changes could have substantial effects, especially on saltwater marshes.

Long-Term Changes in River Profile

Changes in the profile of the riverbed within the LAA over time were assessed using historical PWGSC bathymetry survey data collected for the years 1988/89[2], 2000/01, 2008/09, and 2014[3]. In general, there has been a trend towards bed lowering. Riverbed profiles between the river mouth and Port Mann Bridge, and within one kilometre upstream and downstream of the Tunnel, show an average annual rate of lowering of around 10 cm/year (overall bed lowering by 1.5 m to 3.5 m) between 1988/89 and 2014. At the Lulu Island–Delta watermain crossing downstream of the Tunnel, the bed lowered by as much as 2.5 m between 1981 and 1997.

[2] Data are missing for the upstream portion of Ladner Reach and a section between Annacis Island and Tilbury Island.

[3] Survey data from Ladner Reach were not available at the time of analysis.

Scour protection was added to the Tunnel in 2000, resulting in the profile appearing to have risen between 1997 and 2011. Degradation of 0.5 m to 1.0 m occurred again between 2011 and 2013. At the Tilbury watermain crossing upstream of the Tunnel, the bed scoured by 2.5 m to 3.0 m between 1990 and 1997. As a result of scour protection added in 2001/2002, the profile was higher in 2008 than in 1997. From 2002 to 2008, only about 0.5 m of scour was observed at this crossing.

The trend toward bed lowering is consistent with previous findings of long-term riverbed degradation downstream of New Westminster. Between 1951 and 1988, average bed levels in the channel lowered by two to three metres (NHC 2002), with the greatest bed lowering occurring in the 1980s. This is consistent with the period when the rate of sediment removal routinely exceeded the incoming bed material load. Since the mid-1990s the rate of bed lowering has slowed considerably, or actually reversed in some years at a few locations due to the reduced dredging effort (McLean et al. 2006). Since 2004, sediment removal volumes have increased in the lower reaches resulting in a 0.8 m decrease in bed level

A detailed description of changes in riverbed elevations over time within the assessment area is provided in **Section 5.2** of the technical volume, ***River Hydraulics and River Morphology Study***, included under **Section 16.2** of the Application. Historical river profiles and cross-sections used to identify trends in river profile, as discussed above, are shown on **Figures 5-2** to **5-5** of this technical volume.

4.1.3 Potential Effects

This section discusses anticipated interactions of Project components and activities with river hydraulics and river morphology, and potential effects of such interactions. Information on mitigation of potential effects, including Project design measures to avoid adverse effects, is provided in **Section 4.1.4**. Potential for residual effects (i.e., effects remaining following the implementation of mitigation measures) is described in **Section 4.1.5**. A discussion of the potential for cumulative effects on river hydraulics and river morphology is presented in **Section 4.1.6**.

4.1.3.1 Project Interactions

An overview of potential interactions between Project activities and river processes during the construction and operation of the Project is provided in **Appendix A**. A preliminary evaluation of the potential effects of Project interactions on river hydraulics and river morphology, intended to focus the assessment on those interactions of greatest importance, is presented below. Interactions rated as having no effect are not considered further in the assessment.

Construction: The new bridge will be a clear-span and as such there will be no impact to river hydraulics and river morphology from the new bridge.

Upgrading of the existing shoreline riprap protection may be required at completion of bridge construction. These upgrades would be limited to placement of clean rock on the existing armoured slope (i.e. no instream excavation and no river training works) and would have little or no effect on river hydraulics or river morphology.

On the Richmond side of the river the existing provincial dike will be reconstructed and upgraded to current standards where it is impacted by the Project. This work will be carried out on shore and as such there will be no impact to river hydraulics and river morphology from this activity.

Green Slough will be realigned to a configuration closer to its pre-Highway 99 alignment. Currently, the slough turns sharply north at the highway embankment, before connecting with Deas Slough south of the crossing. The realigned slough will continue east beneath the bridge and connect with Deas Slough east of the highway, similar to pre-highway conditions. Realignment of Green Slough is not expected to have any effects on hydraulics or morphology in Deas Slough or the South Arm of the Fraser River. Proposed enhancements to estuarine and riparian habitat would provide a net benefit compared with existing conditions.

Tunnel removal and associated activities are expected to involve temporary riverbed disturbance and consequent re-suspension of sediments in the Fraser River South Arm as well as potential local scour. Removal of the Tunnel from the river bed and infilling of the trench left behind could also influence current velocities, water levels, movement of salt water, and flow splits in the Fraser River South Arm. This is discussed further in **Section 4.1.3.2**.

Operation: Given that the new bridge will have a clear span across the Fraser River South Arm, activities associated with Project operation, including routine maintenance, have no interaction with river hydraulics and river morphology.

Removal of Tunnel segments would have a temporary influence on river processes for approximately 210 days during the operational phase of the Project, while the trench left by the Tunnel gets filled in by sediments carried naturally in the river. This is discussed further below.

4.1.3.2 Potential Effects

Potential effects of the Project on river hydraulics and river morphology in the lower Fraser River were investigated using the TELEMAC-MASCARET (TELEMAC) modelling system.

The accuracy and results of the hydraulic modelling needs to be viewed in the context of the very dynamic morphology of the Fraser River, interpretive nature of geomorphic studies and the limitations of the numerical methods used to model river hydraulics and river morphology. The dynamic nature of the river morphology is illustrated by the fact that records at the Tunnel show that temporary scour during freshet can be in the order of several meters and migrating sand dunes with heights of up to 4 m are not uncommon.

With numerical modelling, there is uncertainty with respect to predictions of river currents and sediment transport. In this context, results presented on projected bed-level evolution should be interpreted as one of the reasonably possible outcomes.

The TELEMAC system, made up of a suite of finite element computer programs developed by the Laboratoire National d'Hydraulique et Environnement (LNHE), is an internationally-recognized modelling tool, with more than 4,000 registered users including BC Hydro, Hydro-Québec, and Canadian Coast Guard, as well as universities, engineering schools, and research centres.

The TELEMAC programs utilized for this study include the following:

- TELEMAC3D – A three-dimensional hydrodynamic model that solves the time-dependent Navier-Stokes equations with an evolving free surface, under the assumption of hydrostatic or non-hydrostatic pressure distribution using the finite element method.
- SISYPHE – A sediment transport and morphodynamic model that computes bed-load and suspended load separately, and the resulting bed changes using the Exner equation.

The hydrodynamic program TELEMAC-3D was used to compute hydraulic conditions in the lower Fraser River. Scour and deposition around the Tunnel were computed by coupling the sediment transport and morphodynamic model SISYPHE to TELEMAC-3D. The new bed elevation computed by SISYPHE was then fed back into TELEMAC-3D to re-compute the flow hydrodynamics, as illustrated in **Figure 4.1-7**. The resulting model serves as a tool for understanding potential changes to river hydraulics and river morphology due to Tunnel removal.

Future changes in physical inputs, such as sea level rise, changes to hydrograph timing and shape, sediment supply, and alterations to the river channel, will influence future hydraulics and morphology in ways that cannot be predicted by the model. Rather, the model captures the most important physical processes in the lower Fraser River and assists in predicting the consequences of a specific change to the system, and model results are interpreted in the context of known river behaviour, using professional judgement.

Figure 4.1-7 TELEMAC Model Coupling Flow Diagram

Model analyses were conducted to examine the following two scenarios:

1. Trench infilling – Short-term channel response to the removal of the Tunnel, particularly trench migration and infilling including review of potential effects on nearby infrastructure and habitat.
2. Post-trench infilling – Potential long term effects of Tunnel removal on river hydraulics and sedimentation patterns after the trench has infilled by deposition of river sediments.

The results of these analyses are presented below. Details on modelling methodology, including model geometries, boundary conditions, and calibration and validation, as well as detailed results of model simulation are presented in the technical volume, ***River Hydraulics and River Morphology Study***, included under **Section 16.2**.

Sediment Generation and Deposition

Tunnel removal will require removing the rock apron and concrete mattress, excavating the fill that was placed adjacent to the Tunnel segments when it was built, floating the pre-cast concrete Tunnel segments to the surface and towing the segments off site for recycling. It is expected that several months will be required to remove the four middle sections of the Tunnel.

The minor changes in current velocities during Tunnel removal are not expected to result in bank erosion, barriers to fish migration or impediments to marine traffic. Depositional changes resulting from re-suspension of sediments during Tunnel removal are expected to be minimal.

These activities will generate suspended sediment. The effect of sediment generation will depend on the ambient suspended sediment concentrations at the time of removal. It is assumed Tunnel removal will commence in mid-summer, after it is anticipated that freshet flows have receded, and will continue into the winter low-flow period.

Based on the volume and expected nature of the sediment and sand fill overlying the Tunnel, the temporary increase in suspended sediment volume due to the Tunnel removal activities is estimated to range from one per cent to nine per cent over ambient volumes between August and December. In the context of the natural seasonal and annual variability of suspended sediment, this expected increase in suspended sediment volume is considered low. Further detail on predicted increase in suspended sediment as a result of Tunnel removal is provided in Section 8.1.2.2 of the technical volume, ***River Hydraulics and River Morphology Study***, included as **Section 16.2** of this Application.

Suspended fine sediments generated during Tunnel removal would be transported to the Strait of Georgia before deposition could occur. Since the incremental volume of suspended sediment generated during Tunnel removal is expected to be small in comparison with the ambient load, and washload is mostly transported beyond the tidal flats at the river mouth, no noticeable effects on deposition in the Strait of Georgia are expected.

Local scour and deposition are expected during Tunnel removal due to flow acceleration around exposed edges of Tunnel segments. The segments are expected to be removed in sequence. Flow will accelerate around the exposed ends and entrain sediment, which would then be deposited downstream. The degree of sediment transport associated with local flow accelerations during construction will depend on time of year and associated current velocities. These effects are expected to be temporary and small in scale compared with overall bed material transport.

With the implementation of standard best management practices, such as the use of washed rock with no fines or debris, upgrades to the existing riprap bank protection along the shorelines are not expected to generate noticeable amounts of suspended sediment.

Current Velocities

Tunnel removal is predicted to result in a minor reduction of surface water velocity of between 0.3 m/s and 0.5 m/s. The corresponding reduction in near-bed velocities (Elevation -12 m GSC) is expected to be between 0.1 m/s and 0.4 m/s. The region that will experience this reduction extends from the Tunnel to about 50 m downstream.

Further detail on modelled current velocity distributions following Tunnel removal is provided in **Section 7.4.1.1** of the technical volume, ***River Hydraulics and River Morphology Study*** included in **Section 16.2**.

Water Levels

Based on hourly water levels modelled at several stations upstream and downstream of the Tunnel, post-infilling water levels are indistinguishable from the natural variability of the river system.

Details on the modelling results for water levels are provided in **Section 7.4.1.2** of the technical volume, ***River Hydraulics and River Morphology Study*** included in **Section 16.2**.

Flow Splits

The Fraser River South Arm divides just below Deas Island (18 km upstream from the Strait of Georgia) into Ladner Reach, and then again into Canoe Passage. The flow split between Woodward Reach and Ladner Reach was calculated from the results of flow modelling. Results of these calculations indicate that the predicted change in the flow splits were within the range of natural variability and as such removal of the Tunnel is not expected to have an effect on the flow split between Woodward Reach and Ladner Reach. This suggests that Tunnel removal is not likely to result in the expansion of Ladner Reach through erosion of Deas Island or the nose of Kirkland Island.

Details on flow split calculations are provided in **Section 7.4.1.3** of the technical volume, ***River Hydraulics and River Morphology Study*** included in **Section 16.2**.

Trench Infilling and Migration

Hydraulic modelling indicates that there will be a decrease in river flow velocity and consequent sediment deposition over the deeper trench region when the Tunnel segments are removed. Modelling shows that the trench would be almost completely infilled in approximately 210 days.

Model results indicate that the trench will migrate downstream as it infills. **Figure 4.1-8** shows a time-series of the bed profile along the centreline of the navigation channel over a trench-infilling simulation period of 210 days. **Figure 4.1-9** shows the change in riverbed elevation 210 days after Tunnel removal as compared with existing conditions. At the end of 210 days the trench is mostly filled in, but the riverbed between the Tunnel and the Lulu Island–Delta watermain has lowered by one to two metres. This lowering is expected to be temporary. It is most likely caused by sediment being “trapped” by the trench, resulting in less sediment available to replenish the downstream bed.

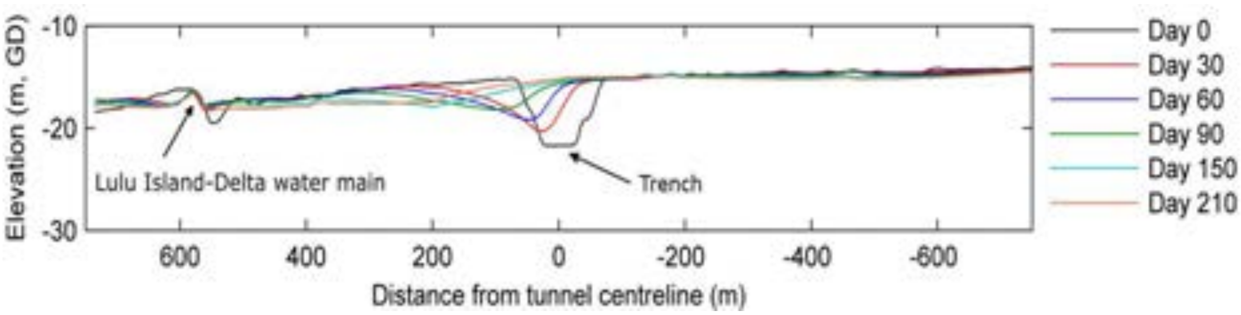

Figure 4.1-8 **Riverbed profile along the centreline of the navigation channel after tunnel removal.**

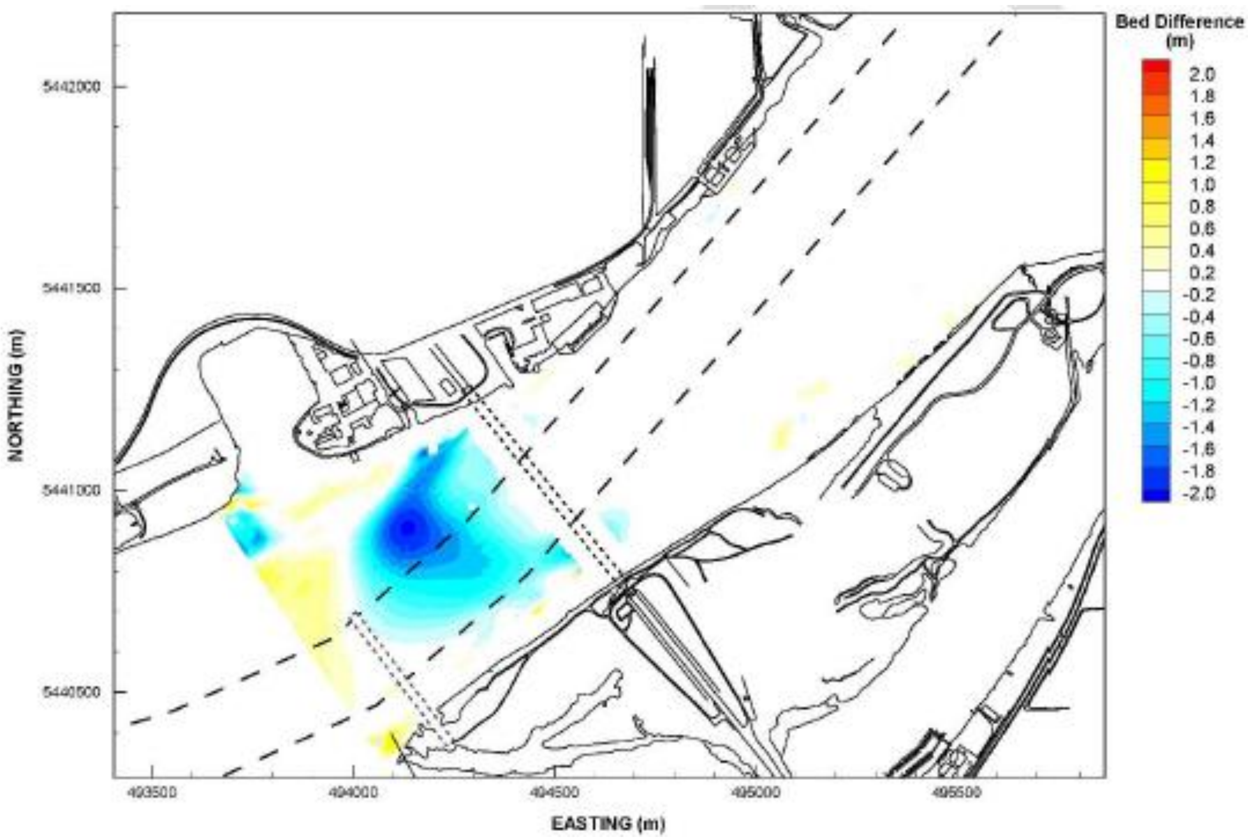

Figure 4.1-9 Change in riverbed elevation 210 days after Tunnel removal as compared with existing conditions

Expected changes in riverbed profile beyond the trench footprint are in the same order as normal variation in bed levels in the lower Fraser River.

Details on model simulations of riverbed elevations during trench infilling are provided in **Section 7.3.2** of the technical volume, ***River Hydraulics and River Morphology Study*** included in **Section 16.2**.

Post-Trench Infilling Morphological Changes

As noted under "Technical Boundaries" in **Section 4.1.1.3** there is uncertainty with respect to predictions of river currents and sediment transport given the limitations of numerical modelling, and the highly complex and dynamic nature of the Fraser River morphology at the Project site. In this context, results presented on projected bed-level evolution should be interpreted as one of several possible outcomes.

Near-field (fine resolution) modelling results indicated bed lowering 150 m upstream and downstream of the Tunnel for existing and post-trench infilling scenarios. However the magnitude of lowering was about 0.5 m to 1.0 m less for the post-trench infilling case. In other words, bed levels are expected to increase on average by 0.5 m to 1.0 m in this region (**Figure 4.1-10**). This change will likely result in less sediment available to be deposited in the channel downstream between the Tunnel and Lulu Island–Delta watermain, contributing to bed lowering in that segment.

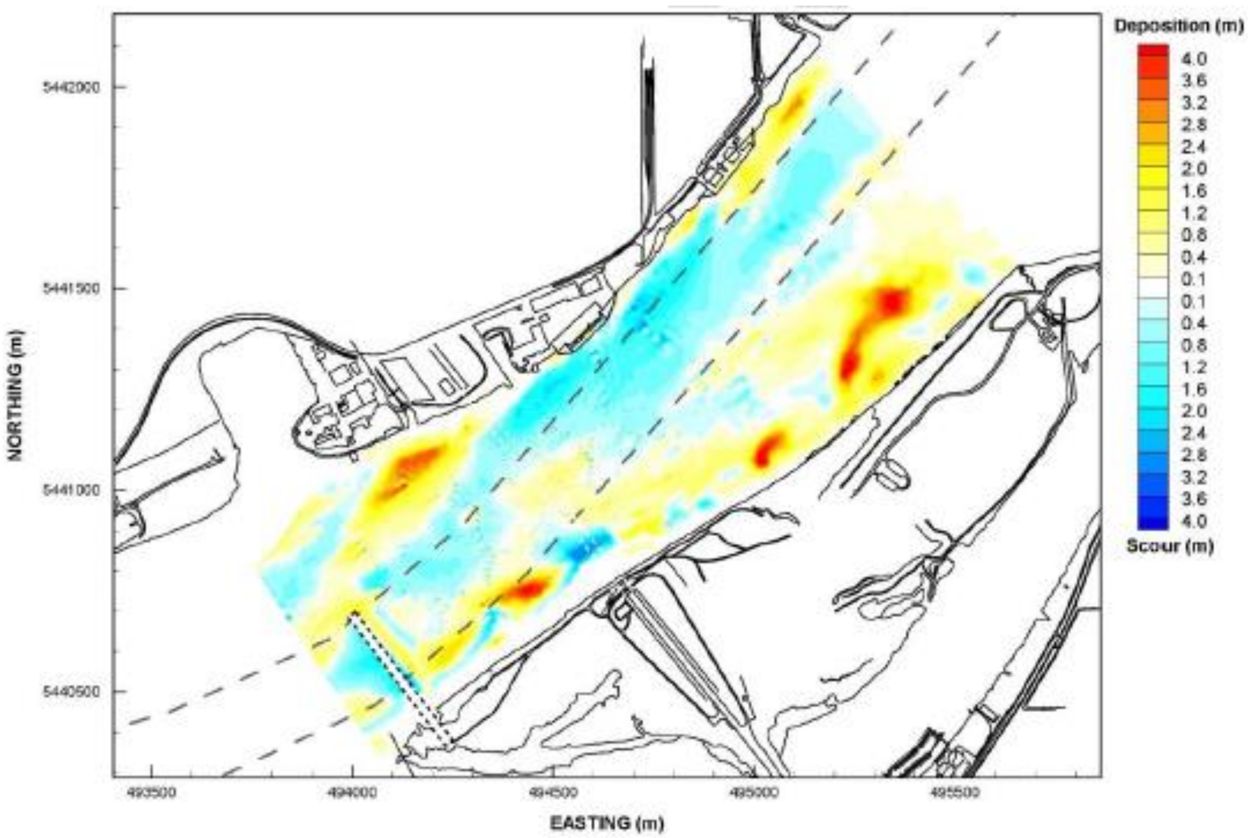

Figure 4.1-10 Change in river bed elevation during freshet after Tunnel removal as compared with existing conditions

Far-field modelling suggests river bed elevation changes as a result of Tunnel removal are limited to 500 m upstream and 1,500 m downstream of the Tunnel. In this region, deposition of about 0.5 m in the middle of the channel and scour of 0.5 m to 1 m at the margins could be expected. Negligible changes (less than ±0.05 m) are predicted to occur to the bed levels adjacent to Tilbury Island.

The majority of suspended fine sediments generated during Tunnel removal would be transported to the Strait of Georgia before deposition could occur. Minor deposition could occur in slower moving areas such as channel margins and sloughs. Since the incremental volume of suspended sediment generated during Tunnel removal is small in comparison with the ambient load, and washload is mostly transported beyond the tidal flats at the river mouth, no noticeable effects on deposition in the Strait of Georgia are expected.

4.1.4 Mitigation Measures

Potential Project-related changes that require mitigation consideration are: anticipated minor increase in volume of suspended sediment during Tunnel decommissioning activities, and riverbed lowering between the Tunnel alignment and the Lulu Island-Delta watermain for one to two years after Tunnel removal. As discussed in **Section 4.1.3.1**, other potential Project-related changes in river flow and sedimentation patterns are negligible or minor.

Mitigation measures to address potential effects associated with increases in volume of suspended sediments are discussed in **Section 4.4 Fish and Fish Habitat**. Mitigation measures to address potential effects associated with temporary Project-related changes in river bed elevations are presented below.

Temporary changes to downstream river bed elevations after Tunnel removal have the potential to affect the Lulu Island-Delta watermain. The following measures are proposed to mitigate these effects:

- Early engagement and coordination, during planning of the proposed decommissioning works, with Metro Vancouver (owner of the watermain). Engagement would continue through the construction and post-construction periods until confirmation that potential effects on the existing watermain have not occurred or have been appropriately mitigated.
- Development of a mitigation plan in conjunction with Metro Vancouver, which is anticipated to include the following:
    - Monitoring of riverbed within 100 m upstream and downstream of the watermain. Regular monitoring at appropriate intervals will begin during Tunnel removal. Monitoring frequency may be revised following Tunnel removal, based on a review and evaluation of monitoring results by a qualified registered professional (QRP). If a lowering of the edges of the scour protection apron is noticed, the scour protection aprons will be upgraded under the direction of a QRP.
    - Stockpiling of appropriately-sized rock near the Project site, for priority scour protection repairs at the watermain crossing.

- Establishment of on-call contracts with a QRP and a qualified marine contractor prior to Tunnel removal, to ensure that scour protection repairs can be designed and implemented on short notice if required. The on-call QRP and contractor will have relevant experience in scour protection for water crossings.

The mitigation measures described above involve commonly applied methods that have proven to be effective in protecting the existing infrastructure against scour, and are expected to have a high degree of success in ensuring potential effects on the Lulu Island/Delta watermain are avoided.

4.1.5 Residual Effects

Residual effects are those that remain following implementation of mitigation measures. Potential residual effects on river hydraulics and river morphology considered further in this assessment are:

- Suspended sediment generation during Tunnel removal: Tunnel removal activities are expected to result in a temporary increase in the volume of suspended sediment in the Fraser River South Arm.
- Temporary bed lowering between the Tunnel alignment and the Lulu Island-Delta watermain: Based on results of modelling, temporary changes to the river bed elevation, which could persist for one or two freshets, are expected between the Tunnel and the Lulu Island–Delta watermain after Tunnel removal.

The above effects are characterized in terms of the direction, magnitude, extent, duration, frequency, reversibility, and likelihood of each anticipated residual effect. Definitions for ratings applied to residual effects criteria, developed with specific reference to river hydraulics and river morphology are presented in **Table 4.1-2**. A summary of criteria ratings for the potential residual effects is provided in **Table 4.1-3** and **Table 4.1-4**.

Context: Context for the characterization of residual effects, i.e. sensitivity/resilience of hydraulics and morphology of the river to potential Project-related effects, based on existing conditions, has been taken into account in characterizing the residual effects. This includes the typically high volumes of sediment load transported by the Fraser River South Arm, wide variation in suspended sediment concentrations on a seasonal and annual timescale, and seasonal changes and the passage of dunes on the riverbed, which regularly induce changes in elevation greater than 2 m.

Table 4.1-2 Criteria Used to Characterize Residual Effects on River Hydraulics and River Morphology.

Criteria	Description	Definition of Rating	
Direction	Overall nature of the residual effect	Adverse	Negative effect as a result of the Project.
		Positive	Beneficial effect as a result of the Project.
		Neutral	Neutral effect as a result of the Project.
Magnitude	Intensity of the effect relative to natural or baseline conditions	Negligible	No measurable change to river hydraulics or morphology
		Low	A measurable change within the range of natural variability, but not affecting aquatic habitat, navigability, or infrastructure.
		Moderate	A measurable change within or outside the range of natural variability, and may pose a moderate risk to aquatic habitat, navigability, or infrastructure.
		High	A measurable change outside the range of natural variability and may affect long-term viability of aquatic habitat, navigability, or infrastructure.
Extent	Geographic extent / distribution of the residual effect	Site	Effect is restricted to the immediate Project alignment.
		Local	Effect is restricted to the LAA.
		Regional	Effect is restricted to the RAA.

Criteria	Description	Definition of Rating	
Duration	Length of time over which the residual effect is expected to persist	Transient term	Effect occurs once during Project construction or operation.
		Short term	Effect occurs during a limited period of days to weeks during Project construction.
		Moderate term	Effect persists over a period of weeks to months.
		Long term	Effect persists over several years. OR Change is permanent.
Frequency	Nature of the occurrence of the residual effect (e.g., how often the stressor affects the IC)	Rare	Effect occurs once during Project construction or operation.
		Uncommon	Effect occurs intermittently during Project construction or operation.
		Frequent	Effect occurs frequently during Project construction or operation.
		Continuous	Effect occurs continuously during Project construction or operation.
Reversibility	Potential for the effect to be reversed or naturally return to baseline level after the disturbance has ceased (or after a period of time after the disturbance has ceased)	Reversible	Baseline conditions will be naturally restored after disturbance has ceased.
		Irreversible	Baseline conditions will not be naturally restored after disturbance has ceased.
		Change	Effect may fluctuate between positive and adverse for the duration of the disturbance.
Likelihood	Likelihood that the residual effect may occur	Low	Likelihood of residual effect is less than 25%.
		Moderate	Likelihood of residual effect is between 25% and 75%.
		High	Likelihood of residual effect is greater than 75%.

Residual Effect #1: Suspended sediment generation during Tunnel removal

Activities associated with Tunnel decommissioning, including removal of Tunnel segments and overlying sediment, will be undertaken under active flow conditions, which could limit the effective use of isolation or sediment control structures such as silt curtains in the area immediately down river from the works. Bed sediments that are re-suspended during Tunnel removal, therefore, could add incrementally to suspended sediment loads in the river. An overview of the criteria ratings for this residual effect is provided in **Table 4.1-3**.

Table 4.1-3 Criteria Ratings: Suspended Sediment Generation during Tunnel Removal.

Criteria	Criteria Rating	Rationale for Criteria Rating
Direction	Adverse	Suspended sediment concentrations in the river will be higher than background levels.
Magnitude	Low	Change will be within the range of natural variability and is not expected to adversely affect viability of receptor VCs.
Extent	Local	Spatial extent is expected to be restricted to the LAA.
Duration	Transient term	Effect will occur only during Tunnel removal.
Frequency	Rare	Effect will occur only in association with Tunnel removal.
Reversibility	Reversible	Suspended sediment concentrations are expected to return to baseline conditions following removal of each Tunnel segment.
Likelihood	High	The likelihood of increased suspended sediment during Tunnel removal is greater than 75%.

Removal of the Tunnel and overlying material from the river bed will generate suspended sediment. Increased suspended sediment concentrations are considered an adverse effect since it has the potential to cause fish to avoid the area, or in severe cases, result in injury to fish. The magnitude of the effect will depend on the ambient suspended sediment concentrations at the time of removal, river discharge, tidal amplitude, and details of Tunnel removal methods. The study has assumed Tunnel removal will commence in mid-August, after freshet flows have receded, and continue into the winter low flow period (December). Suspended sediment concentrations in the low-flow period are typically low, so increases beyond background concentrations are considered likely.

The magnitude of the suspended sediment effect is considered low. The estimated volume of suspended sediment that could be generated by the Tunnel removal was compared to the typical ambient volumes of suspended sediment transported during the anticipated Tunnel removal period. Each Tunnel segment is overlain by approximately 28,000 m^3 of sediment or sand fill material (**Figure 3-2**). Assuming this material has the same size gradation as the bed material in the lower Fraser River, approximately 10% (2,800 m^3) of the overlying material would be smaller than 0.177 mm in diameter, and could therefore remain suspended in the water column (NHC 2002b). Assuming that removal of one Tunnel segment takes two weeks, the natural or ambient volume of suspended sediment transported through the study area during removal of one segment ranges from a maximum of 3x105 m^3 in August to a minimum of 3x104 m^3 in December. These estimates are based on analyses of seasonal flows and measured suspended sediment concentrations in the lower Fraser River (Milliman 1980, Kostaschuk, Luternauer, et al. 1989, Attard and Venditti 2014). Based on the above estimates, the increase in suspended sediment volume due to the Tunnel removal ranges from one per cent to nine per cent over ambient volumes. Considering the wide variation in suspended sediment concentrations in the Fraser River South Arm on a seasonal and annual timescale, the magnitude of the effect can be characterized as low.

Spatial extend of the suspended sediment increases is expected to be limited to within the LAA. After removal of each Tunnel segment, suspended sediment concentrations are expected to return to normal, so the effect is reversible. The generation of suspended sediment will occur only during Tunnel removal, and will return to normal after removal, so the frequency of the effect is rare and the duration is transient.

Depositional changes resulting from suspended sediment generation are expected to be minimal. Suspended fine sediments generated during Tunnel removal would be transported to the Strait of Georgia before deposition could occur in the main channel. Since the incremental volume of suspended sediment generated during Tunnel removal is expected to be small in comparison with the ambient load, and the depositional area at Sand Heads is large, no noticeable changes to deposition in the Strait of Georgia are expected. It is possible that some of the suspended sediment generated from removal of the southern Tunnel segments could deposit in low velocity environments such as Ladner slough or the margins of Ladner Reach, Canoe Passage or other side channels. If such deposition occurs, it is expected to be minor.

Residual Effect #2: Temporary bed lowering between the Tunnel alignment and the Lulu Island-Delta watermain

Removal of the Tunnel segments will leave a trench in the river bottom, and sediments transported from upstream will tend to be trapped in the trench as it fills and migrates downstream. During this time there will be less sediment available to replenish the river bed downstream of the Tunnel alignment. Model results suggest the river bed between the Tunnel and Lulu-Delta watermain will be temporarily lowered by 1 to 2 m compared with baseline conditions. Bed lowering is not expected to propagate upstream of the Tunnel or downstream of the watermain, and levels between the Tunnel and watermain are expected to return to normal after the trench has filled in (within one to two freshets). An overview of the criteria ratings for this residual effect is presented in **Table 4.1-4**.

Table 4.1-4 Criteria Ratings: Temporary Bed Lowering between the Tunnel Alignment and the Lulu Island-Delta Watermain

Criteria	Criteria Rating	Rationale for Criteria Rating
Direction	Adverse	Bed lowering could affect Metro Vancouver's Lulu-Delta watermain.
Magnitude	Moderate	Change will be within the range of natural variability but may have a moderate effect on in-river infrastructure.
Extent	Local	Spatial extent is expected to be restricted to within 600 m downstream of the Tunnel alignment.
Duration	Short term	Effect expected to persist only until one or two freshets following Tunnel removal.
Frequency	Continuous	Effect will occur continuously during Tunnel removal and for the following 1-2 years.
Reversibility	Reversible	River bed levels between the Tunnel and Lulu-Delta watermain are expected to return to normal after the trench has filled in.
Likelihood	High	The likelihood of lower river bed levels between the Tunnel and Lulu-Delta watermain is greater than 75%.

The lower bed levels are not expected to negatively impact fish habitat or navigability, but has the potential to dislodge rock at the edges of the existing scour protection apron at Lulu Island-Delta watermain, about 600 m downstream of the Tunnel. These types of rock aprons are designed to fall, or launch, into developing scour holes to prevent or delay further scour. However once this has occurred their ability to protect against further scour is compromised. The 1-2 m of bed lowering would not expose the watermain directly, but could diminish the future effectiveness of the scour protection.

The predicted 1-2 m of bed lowering is within the range of natural variability on the Fraser River. Seasonal changes and the passage of dunes on the riverbed regularly induce changes in elevation greater than 2 m; however given the potential for this bed lowering to affect the watermain, the magnitude of the effect is considered moderate.

4.1.6 Cumulative Effects

The combination of Project-related changes and changes from other certain and reasonably foreseeable projects and activities, as listed in **Section 3.10.1 Identifying Past, Present or Reasonably Foreseeable Projects and/or Activities**, comprise the total cumulative changes in river hydraulics and river morphology. The only other project or activity that has the potential to have effects that could interact with those of the Project is the routine maintenance dredging of the Fraser River South Arm by the Vancouver Fraser Port Authority (VFPA), which overlaps spatially with the Project. It is anticipated that Tunnel decommissioning will be scheduled in consultation with VFPA such that there is no temporal overlap of potential effects of the two activities on river hydraulics and river morphology, and no construction-related cumulative effects are expected.

4.1.7 Follow-up Strategy

Frequent monitoring of riverbed within 100 m upstream and downstream of the Lulu Island-Delta watermain is proposed during and after Tunnel removal to ensure resultant temporary change in river bed profile does not impact the watermain. Regular monitoring at appropriate intervals will begin during Tunnel removal. Monitoring frequency may be revised following Tunnel removal, based on a review and evaluation of monitoring results by a qualified registered professional (QRP). If a lowering of the edges of the water main’s scour protection apron is noticed, the apron will be upgraded under the direction of the QRP.

4.1.8 References

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APPENDIX A

Overview of Potential Project Interactions with River Hydraulics and River Morphology

Table 1 Overview of Potential Project Interactions with River Hydraulics and River Morphology

Project Phase/ Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Pre-Construction / Site Preparation			
Pre-Construction / Site Preparation	No interaction	• Surveying • Clearing and grubbing of vegetation within the existing Highway 99 ROW • Installing temporary roads, laydown areas, and site offices. • Relocating utilities • Preloading for embankment and highway construction • Acquiring property for the Project	**Nature of interaction:** No interaction anticipated. **Rationale:** All activities to be land-based.
	No effect	• Conducting additional site investigations (i.e., a geotechnical drilling program) • Restoration of Green Slough to its historic alignment • Installing temporary drainage structures and diversions • Installing temporary bridges and barging facilities	**Nature of interaction:** Works and activities within or along the shores of the Fraser River South Arm, Deas Slough, and Green Slough. **Rationale:** Activities not expected to have an effect on river hydraulics and river morphology.
	Potential Effect	• N/A	N/A

Project Phase/ Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Construction			
New bridge including approaches and ramp connections	No interaction	• Installing upland piers, including pile installation • Installing drainage structures/settling ponds • Constructing approach spans (concrete deck slab on steel or concrete girder) • Constructing bridge towers and installing support cables using land-based equipment • Installing retaining walls	**Nature of interaction:** No interaction anticipated. **Rationale:** All activities to be land-based.
	No effect	• Ground improvements associated with new bridge piers. • Installing piers adjacent to Deas Slough and Green Slough, including pile installation. • Hoisting pre-assembled deck segments from barges in the river or land-based transport system.	**Nature of interaction:** Activities with the potential to interact with river hydraulics and river morphology. **Rationale:** Activities not expected to have an effect on river hydraulics and river morphology.
	Potential Effect	• N/A	N/A

Project Phase/ Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Highway 99 improvements, including interchange upgrades	No interaction	• Replacement of interchanges at Westminster Highway, Steveston Highway and Highway 17A • Replacement of over/underpasses at Cambie Road, Shell Road, Highway 91 Westbound Ramp, Blundell Road, Ladner Trunk Road and 112th Street • Highway widening from Bridgeport in Richmond to Highway 91 in Delta including construction of embankments, placing and compacting fill for road base, establishing improved drainage and paving	**Nature of interaction:** No interaction anticipated. **Rationale:** All activities to be land-based.
	No effect	• N/A	N/A
	Potential Effect	• N/A	N/A

Project Phase/ Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Tunnel decommissioning	No interaction	• N/A	N/A
	No effect	• Transporting Tunnel elements for offsite disposal, and operating support vessels for that activity	N/A
	Potential Effect	• Removing electrical/mechanical/utilities equipment from the Tunnel • Removing of Tunnel segments and associated scour protection • Backfilling of onshore portions of Tunnel approaches	**Nature of interaction:** Potential for the removal of the Tunnel to result in temporary change in river hydraulics and river morphology. **Potential Project-related effects include:** • Temporary minor increase in suspended sediments. • Temporary change in riverbed elevations.
Decommissioning of Deas Slough Bridge	No interaction	• Removal of Deas Slough Bridge including substructures.	**Nature of interaction:** No interaction anticipated
	No effect	• N/A	N/A
	Potential Effect	• N/A	N/A

Project Phase/ Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Operation and Maintenance			
Highway 99 and interchanges	No interaction	• Operating reconfigured Highway 99 and interchanges. • Highway 99 and interchange maintenance (drainage maintenance, winter maintenance, emergency maintenance, road cleaning, etc.).	**Nature of interaction:** No interaction anticipated. **Rationale:** Proposed activities will be land-based.
	No effect	• N/A	N/A
	Potential Effect	• N/A	N/A
New bridge	No interaction	• N/A	N/A
	No effect	• Operating the new bridge • Bridge maintenance (winter maintenance, emergency maintenance, structure maintenance, etc.)	**Nature of interaction:** Activities with the potential to interact with river hydraulics and river morphology. **Rationale:** As the new bridge will have a clear span across the Fraser River South Arm, it is not expected to have any effect on river hydraulics and river morphology. Normally, protection of banks with riprap could have a cumulative effect on both hydraulics and morphology, however, the banks within the Project Area are already protected, and any minor upgrading of the existing riprap required for the Project is not anticipated to alter existing conditions.
	Potential Effect	• N/A	N/A

"N/A" indicates that no Project works and/or activities are applicable to the category