4.2 Sediment and Water Quality Assessment Highlights:

- The new bridge will have a clear-span, which reduces potential Project-related effects on sediment and water quality in the Fraser River South Arm.
- Minor, temporary increases in turbidity in the Fraser River South Arm, as compared with baseline conditions, are expected during Tunnel decommissioning.
- No appreciable change in water quality, related to the re-suspension or re-distribution of sediments during Tunnel decommissioning, is anticipated.
- Applying mitigation, including timing windows for undertaking in-stream works, will avoid or minimize potential effects of Project-related changes in water quality on receptor components, including fish and fish habitat.
- Elements of the Project design, including the use of biofiltration ponds, will provide a benefit by improving the level of treatment of surface runoff from Highway 99.
- No Project-related post-construction residual effects or cumulative effects on sediment and water quality are expected.

4.2 Sediment and Water Quality

This section describes the existing conditions of sediment and water quality in waterbodies that could potentially be affected by the Project, and anticipated changes that may result from Project components and activities. Sediment and water quality comprises one of the 'steps' along the pathway of effects of the Project, with fish and fish habitat, marine mammals, vegetation, and at-risk amphibians being the ultimate receptors of Project-related effects. Sediment and water quality has therefore been studied as an intermediate component (IC), and information on predicted Project-related changes in sediment and water quality was used to support the assessment of Project-related effects on the following valued components (VCs): fish and fish habitat (**Section 4.4 Fish and Fish Habitat**), at-risk amphibians (**Section 4.5 At-risk Amphibians**), marine mammals (**Section 4.6 Marine Mammals**), and vegetation (**Section 4.7 Vegetation**).

This section focuses on the Fraser River South Arm, Deas Slough, and Green Slough, which are the major waterbodies that could be affected by the Project. Potential changes in sediment and water quality as a result of upland ditch construction and relocation to accommodate widening of Highway 99 are discussed in the assessment of Project-related effects on fish and fish habitat (**Section 4.4 Fish and Fish Habitat**).

The Project will include stormwater collection and treatment components (e.g. biofiltration ponds) to capture, detain, and treat stormwater runoff prior to discharging into water courses. These stormwater management components, and implementation of appropriate construction environmental management plans as described in **Section 12.0 Management Plans**, are

expected to avoid any potential effect due to stormwater runoff from the upgraded highway, including the new bridge. Proposed Project-related improvement in stormwater collection and management along the Highway 99 corridor is anticipated to result in an improvement in the quality of stormwater entering adjacent watercourses. As such, an assessment of Project-related change in water or sediment quality in upland ditches and streams was not undertaken as part of this assessment.

Standard best management practices such as development and implementation of a Fish and Fish Habitat Management Plan and compliance with the B.C. *Water Act*, are expected to prevent potential changes to sediment and water quality in upland ditches during Project construction and operation. These are discussed in more detail in **Section 4.4 Fish and Fish Habitat**, and are not considered further in this section.

4.2.1 Context and Boundaries

This section describes the context for assessment of Project-related effects on sediment and water quality in terms of Project setting and defines the spatial and temporal assessment boundaries. Rationale for selecting the assessment boundaries as defined is also provided.

4.2.1.1 Assessment Context

The Project alignment crosses the Fraser River South Arm, Deas Slough, and Green Slough, which support an important ecosystem. A clear span is proposed over the Fraser River and Deas Slough to minimize impacts to this ecosystem; however construction-related activities–specifically, installation of bridge foundations along the edge of Deas Slough, Tunnel removal, and decommissioning of the Deas Slough Bridge–have the potential to temporarily influence the quality of water and sediment in these water bodies through the introduction of turbidity and resuspension of bed sediments. Predicting the anticipated nature and magnitude of such changes is important for assessing Project-related effects on receptor VCs (fish and fish habitat, marine mammals, vegetation, and at-risk amphibians). Sediment and water quality has therefore been selected as an intermediate component in the assessment of Project-related effects on receptor VCs. Input received through consultation with government agencies, Aboriginal Groups, and the general public also informed the decision to undertake an assessment of sediment and water quality. During pre-Application consultation on the Project, water quality in the Fraser River was identified as an area of specific interest by Aboriginal Groups.

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

4.2.1.2 Methodology

Changes in riverbed sediment characteristics that have the potential to affect receptor VCs include changes in sediment composition and organic carbon content, and changes in sediment quality in terms of contaminant concentrations. Similarly, changes in the water column that have the potential to affect receptor VCs include changes in total suspended solids (TSS) and turbidity levels, or changes in ambient water chemistry. Therefore, Project-related study of water and sediment quality was designed to focus on these aspects.

A literature review, gap analysis, and field program, as outlined in **Table 4.2-1**, were undertaken to establish existing conditions, and sediment fate predictions described in **Section 4.1 River Hydraulics and River Morphology** were used to identify potential Project-related effects on water quality and sediment quality in the Fraser River South Arm, Deas Slough, and Green Slough.

Table 4.2-1 Sediment and Water Quality Studies to Support the Assessment

Study Name	Study Description
Literature Review/ Gap Analysis	Information from historic studies and data collected during previous field work in 2013 were reviewed to describe existing conditions of sediment and water quality and to identify information gaps.
Field Study	Project-specific sampling and analyses were conducted in September 2014 to describe sediment and water quality conditions in Fraser River South Arm in the vicinity of the Tunnel, and Deas Slough and Green Slough.

4.2.1.3 Assessment Boundaries

The assessment boundaries for sediment and water quality are defined below.

Spatial Boundaries

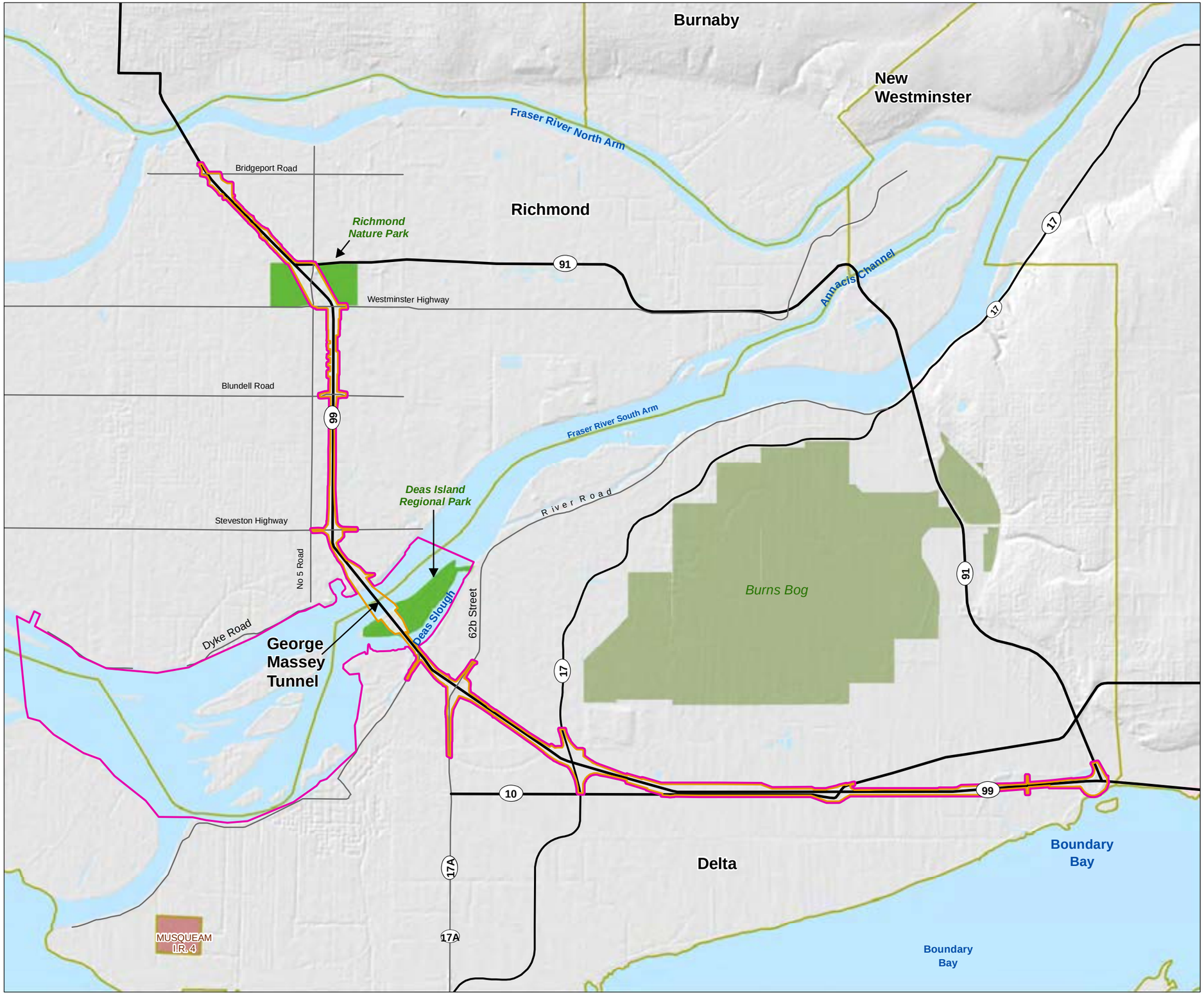
Changes in sediment and water quality in the Fraser River South Arm due to Project activities are expected to be most prominent within the Project alignment, immediately adjacent to instream or near-shore activities such as installation of bridge foundations along the edge of Deas Slough, Tunnel removal, and decommissioning of the Deas Slough Bridge. However, due to tidal influences and river hydrology, there could be Project-related effects to water quality, suspended sediment characteristics, or riverbed sediment characteristics some distance

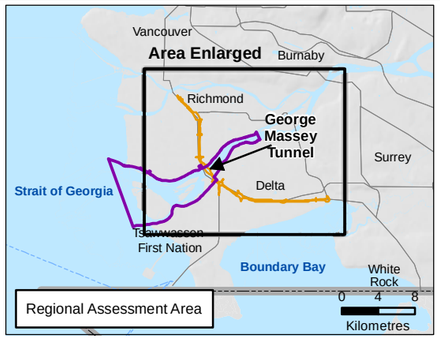
downstream and upstream of the Tunnel. A local assessment area as defined in **Table 4.2-2** and shown on **Figure 4.2-1** was selected, taking these factors into account. Spatial extent of the LAA was refined to include Ladner Reach and South Arm Marshes based on feedback received from Aboriginal Groups and regulatory agencies during pre-Application consultation.

A regional assessment area (RAA), which comprises the river reach extending approximately seven kilometres upstream from the Tunnel, and downstream from the Tunnel to the river mouth (**Figure 4.2-1**), has been defined to provide regional context.

Table 4.2-2 Spatial Boundaries for Sediment and Water Quality Assessment

Spatial Boundary	Description of Assessment Area
Local Assessment Area (LAA)	Fraser River South Arm extending approximately seven kilometres downstream from the Tunnel (including Ladner Reach and South Arm Marshes) and 1.5 km upstream of the Tunnel; Deas Slough and Green Slough; and upland water courses within the Project alignment plus 30 m buffer.
Regional Assessment Area (RAA)	Fraser River South Arm extending seven kilometres upstream from the Tunnel, and downstream from the Tunnel to the river mouth (past Westham Island).





Legend

- Sediment and Water Quality Local Assessment Area
- Sediment and Water Quality 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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GEORGE MASSEY TUNNEL REPLACEMENT PROJECT

SEDIMENT AND WATER QUALITY
LOCAL AND REGIONAL ASSESSMENT AREAS

Figure 4.2-1	13/05/2016

George Massey Tunnel Replacement Project | BC JOBS PLAN | B.C. on the Move

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Temporal Boundaries

Temporal boundaries for the assessment of Project-related effects were established based on the potential for each phase of the Project to interact with and have an effect on water and sediment quality. 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 the quality of water and sediments in the Fraser River South Arm, and Deas and Green Sloughs; therefore, the following temporal boundaries were defined for sediment and water quality assessment:

- Existing conditions
- Project construction, which includes Tunnel decommissioning
- Project operation, including maintenance

Temporal characteristics (timing) of the Project construction phase (including decommissioning of temporary construction-related facilities and the Tunnel), and operation phases are defined in **Section 1.1.3 Project Phases and Schedule**. Specific temporal considerations for the assessment of water and sediment quality are discussed in the context of Project interactions and potential effects in **Section 4.2.3**.

Administrative Boundaries

No political, economic, or social constraints that could impose limitations on the assessment of potential Project-related effects on water and sediment quality have been identified; therefore no administrative boundaries are defined.

Technical Boundaries

The technical boundaries for water and sediment quality assessment are associated primarily with the amount of location-specific data on sediment and water quality under existing conditions, including variations across space, depth in the water column or riverbed, and over time. The processes known to influence sediment and water quality within the LAA and RAA are well-understood, and the observations and interpretations that underpin this assessment are entirely consistent with expectations based on the greater theoretical understanding.

4.2.2 Existing Conditions

This section provides an overview of the methodology for collecting baseline data and describes the existing conditions of sediment and water quality within the assessment areas. An overview of the regulatory context for management of water and sediment quality as relevant to the Project is also provided.

4.2.2.1 Baseline Data Collection

In early 2014, the Ministry initiated desktop and field studies to support the environmental assessment of the proposed Project. The studies were designed to build on existing information and address known data gaps.

The information on existing sediment and water quality presented here is based on a review of multiple historical documents, previous sample data collected in 2013, and a field sampling program specific to the Project. The interpretation of existing conditions in relation to sediment and water quality is grounded in a contemporary theory regarding the relationships between river hydrology and sediment supply (as discussed in **Section 4.1 River Hydraulics and River Morphology**) and sediment fate, including contaminant hydrogeochemistry.

A Project-specific field program was conducted in September of 2014 to collect sediment and water quality data. While this limited field program does not capture temporal variations that are associated with river discharge stage or dry periods in comparison with extended periods of precipitation, fulsome historic data exists to address this gap. Seasonal variations in riverine conditions and in local runoff are expected to influence the characteristics of finer-grained sediments that are entrained in the river water, as well as the contaminants associated with them. Fine-grained sediments tend to be routinely transported through the Project Area without appreciable deposition (described as washload in **Section 4.1 River Hydraulics and River Morphology**), and therefore, are considered less relevant to an assessment of changes to sediment and water quality in the context of bed sediment re-suspension during Project construction activities. An exception to this is the accumulation of fine-grained sediments in Deas and Green Sloughs.

Literature Review

Background information was reviewed and data that pertain to the following were collected:

- Substances and conditions for which observed concentrations approach or exceed Canadian sediment quality guidelines (SQG) for the protection of aquatic life (CCME 2014*a*), the water quality guidelines (WQG) for the protection of aquatic life (CCME 2014*b*), or the B.C. WQGs (B.C. MOE 2006).

- Temporal trends in sediment and water quality parameters in the Fraser River South Arm, specifically within the LAA and RAA, where available.
- Causal relationships between environmental variables and water quality parameters (e.g., relationship between fine-grained sediment and chromium concentrations).

Field Studies

Field studies were undertaken within the LAA (**Figure 4.2-2**), to characterize surficial sediment and assess water quality. Sampling was conducted on September 11 and 12, 2014, during low-flow conditions in the Fraser River.

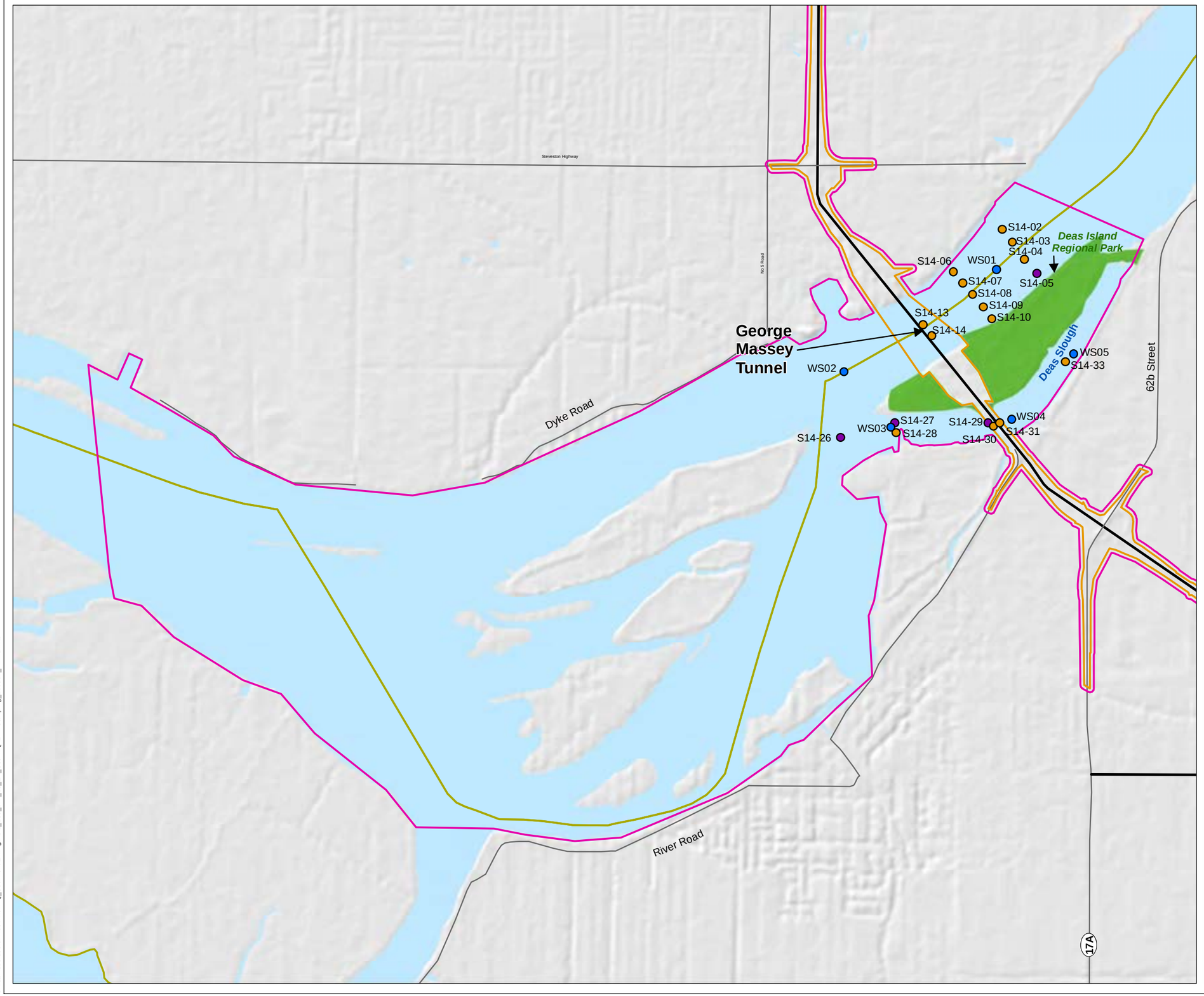
Sediment Characterization

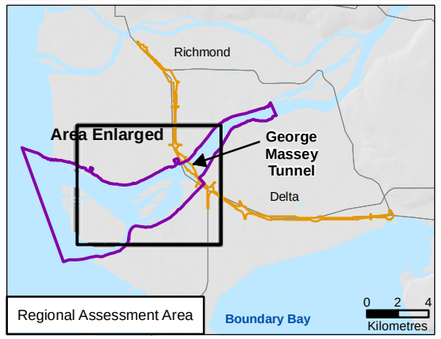
Sediment samples were collected using a combination of surface grabs from the top ~25 to 30 cm of the riverbed using a 0.1 m^2 stainless steel Van Veen grab and vibracoring to obtain information on vertical distribution of contaminants. The maximum sample depth achievable was approximately 2 m below the riverbed.

Information from historic studies and previous field work were reviewed to describe existing conditions of sediment and water quality. To supplement this existing data, samples were collected at representative locations in the Fraser River near the Tunnel and in Deas Slough. The samples were handled in accordance with the *B.C. Field Sampling Manual for Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples* (B.C. MWLAP 2003). Samples were stored in the appropriate non-contaminating containers provided by a commercial analytical laboratory (ALS Environmental Services). Samples were analyzed for particle size distribution, total organic carbon, trace elements, extractable petroleum hydrocarbons (EPH), polycyclic aromatic hydrocarbons (PAH), and polychlorinated biphenyls (PCB).

Water Quality Sampling and Analyses

Water samples were collected at five locations within the LAA (**Figure 4.2-2**): one mid-channel reference site upstream of the Tunnel, two mid-channel sites downstream of the Tunnel, and two sites in Deas Slough. Water samples were collected and analyzed in accordance with the *B.C. Field Sampling Manual for Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples* (B.C. MWLAP 2003).





Legend

Hemmera 2014 Sample(s)

- Van Veen Sample Location
- Vibracore Sample Location
- Water Sample Location
- Sediment and Water Quality Local Assessment Area
- Sediment and Water Quality 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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Metres

GEORGE MASSEY TUNNEL REPLACEMENT PROJECT

SEDIMENT AND WATER QUALITY SAMPLE LOCATIONS

Figure 4.2-2	13/05/2016

George Massey Tunnel Replacement Project | BC JOBS PLAN | B.C. on the Move

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4.2.2.2 Regulatory Context

Federal

In the context of sediment and water quality, the federal *Fisheries Act*, R.S.C. 1985, c. F-14 is relevant to the Project. Section 35 (1) of the *Fisheries Act* regulates any work, undertaking, or activity that results in serious harm to fish (defined as the death of fish or any permanent alteration or destruction of fish habitat) that are part of or support a commercial, recreational or Aboriginal fishery. Section 36 (3) regulates the deposition of a deleterious substance of any type in water frequented by fish. A deleterious substance may include excess concentrations of suspended sediment.

The Canadian Environmental Quality Guidelines (CEQG) of the Canadian Council of Ministers of the Environment (CCME) define numerical concentrations recommended as levels that should result in negligible risk to biota and fish habitat function. Specific CCME CEQG that apply to the Project include sediment quality guidelines for the protection of aquatic life (CCME 2014*a*) and the CCME water quality guidelines for the protection of aquatic life (CCME 2014*b*).

Provincial

The B.C. Ministry of Environment develops ambient WQGs to promote healthy ecosystems and protect human health. Water quality guidelines are science-based levels of physical, biological, and chemical parameters for the protection of water uses such as aquatic life, wildlife, agriculture, drinking water, and recreation. Approved WQGs are policy statements and applied generically province wide, providing the basis for water quality assessments and informing decision-making in the natural resource sector.

Section 9 of the B.C. *Water Act* R.S.B.C. 1996, c. 483 regulates changes in and about a stream. The Act defines “changes in and about a stream” as:

a) any modification to the nature of a stream including the land, vegetation, natural environment or flow of water within a stream

b) any activity or construction within the stream channel that has or may have an impact on a stream.

4.2.2.3 Existing Conditions

Sediment Texture

Sediments within the Fraser River South Arm comprise grain sizes dominated by sand ranging in diameter from 0.25 to 0.5 mm (Swain and Walton 1991, McLaren and Tuominen 1999, Phippen 2001). In contrast, sediments in and near Deas Slough shift to a more diverse and smaller particle size (McLaren and Tuominen 1999, Phippen 2001). In general, sloughs, side-channel areas, or nearshore eddies of the Fraser River South Arm tend to accumulate finer-textured clayey and silty sediments, while the higher current areas in the main river channel (and in the designated navigational channel) are characterized by sandy sediments with very limited fines. Grain size distribution from sediment core samples extracted from Deas Slough and the Fraser River South Arm during field studies conducted for the Project is illustrated in **Appendix A**, **Figure 1**. Grain size composition is consistent across all depths (**Appendix A**, **Figures 2** and **3**).

Sediment Quality

Bed sediments in some areas of the Fraser River South Arm contain trace elements, PAHs, and other organic contaminants at levels that may exceed Canadian SQGs. Historically, samples collected in the South Arm have routinely exceeded Canadian SQGs for arsenic, chromium, and copper (Swain and Walton 1991, 1993, Brewer et al. 1998). These trace elements occur at higher concentrations in the finer-textured (silt and clay) fractions of bed sediments (**Appendix A**, **Figure 4**). Fine-grained (<0.063 mm), organic-rich sediments, such as those occurring in Deas Slough and Green Slough, preferentially adsorb metals due to higher adsorption capacity and higher surface area compared with coarse-grained sediments (Ackermann 1980, Salomons and Förstner 1984, Horowitz et al. 1989, Tyson 1995). Arsenic, chromium, and copper concentrations that exceed Canadian interim SQGs were found in sediment samples collected from Deas Slough as part of the field studies completed for the Project in 2014 (**Appendix A**, **Figure 5**). There was no apparent variation in trace element concentrations within the sampling depth of two metres (**Appendix A**, **Figure 6**).

Sediment within the LAA that currently comprises the riverbed material directly adjacent to the Tunnel (except near the river banks) can be described as coarse-grained, with very low concentrations of chemical constituents. Annual dredging takes place in the Fraser River South Arm with associated disturbance to sediments and water in the LAA and RAA.

Water Quality

Data collected during Project-related field studies in 2014 indicate that water in the Fraser River South Arm is of good quality, with parameters such as pH, temperature, dissolved oxygen, and electrical conductivity falling within CCME WQGs for the protection of aquatic life (CCME 2014*b*).

Given that the river naturally carries large loads of suspended sediments, high turbidity/TSS concentrations are often observed during surface water sampling in the Fraser River South Arm. Turbidity levels can range widely, from 1.8 to 87.8 NTUs (nephelometric turbidity units), which reflects the influence of tides and freshwater outflow on silt loads and levels of sediment re-suspension. At the time of sampling for the Project (September 2014), TSS concentrations ranged between 8.8 mg/L and 28.4 mg/L, which reflects wind and tidal interaction rather than turbid freshwater outflow.

Instances of elevated concentrations of aluminum, chromium, and copper, whihc correlated with TSS concentrations at the same locations, were noted. Increased total levels of naturally occurring trace elements are typical in waters with increased TSS levels, with trace elements being more mobile and more bioavailable.

PAHs, EPH, oil, or grease were detected in any water sample. Concentrations of total and dissolved aluminum, chromium, and copper from grab samples collected during the 2014 field studies conducted for the Project are shown in **Appendix A**, **Figure 7**.

4.2.3 Potential Effects

This section provides a summary of potential changes to sediment and water quality related to the construction and operation of the Project, and describes the methodology used to assess potential project-related effects. An overview of potential interactions of Project components and activities with water and sediment within Fraser River South Arm, Deas Slough, and Green Slough is presented, and potential effects of such interactions on water and sediment quality are discussed. Information on mitigation of potential effects, including Project design measures to avoid adverse effects, is provided in **Section 4.2.4**. Potential residual effects (i.e., effects remaining following the implementation of mitigation measures) are described in **Section 4.2.5**. A discussion of the potential for cumulative effects on water and sediment quality is presented in **Section 4.2.6**.

4.2.3.1 Project Interactions

An overview of potential interactions between Project activities and water and sediment during the construction and operation of Project components is provided in **Appendix B**. A preliminary evaluation of the potential effects of Project interactions on sediment and water quality, 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: Potential interactions of Project-related construction activities with water and sediment include the following:

- Disturbance of river bed material during removal of sediment, rock apron, and concrete mattress in preparation for Tunnel removal, removal of Tunnel segments, installation of bridge piers along the edge of Deas Slough, and removal of the Deas Slough Bridge.
- Movement of construction vessels and equipment along the Fraser River during installation of bridge components, transportation of Tunnel elements for offsite disposal, and operating support vessels for that activity.

Operation: Potential interactions of Project-related operation activities with sediment and water include the following:

- Maintenance of stormwater management ponds and drainage facilities during operations.

4.2.3.2 Potential Effects

Construction

Localized disturbance of surficial sediments is expected to occur during installation of temporary barging facilities, and removal of Tunnel segments.

Potential effects of activities associated with Tunnel removal on sediment generation, or re-suspension, are discussed in **Section 4.1 River Hydraulics and River Morphology**. The impact of sediment generation will depend on ambient suspended sediment concentrations at the time of removal. It is assumed that Tunnel removal will commence in mid-summer, after freshet flows have receded, and extend into the winter low-flow period. Suspended sediment volume is predicted to temporarily increase between one per cent and nine per cent over ambient levels during the course of disturbance. The impact of this increase is considered low, given the natural variability of suspended sediment seasonally and annually in the river main channel. Fine sediments are anticipated to remain in suspension and be carried downstream to the Strait of Georgia (for details see **Section 4.1 River Hydraulics and River Morphology**).

During Tunnel decommissioning, water velocity is expected to decrease over the Tunnel trench as segments are removed in sequence, resulting in temporary, localized re-distribution of bed sediments through scouring and deposition, with entrained sediment deposited immediately downstream. Potential changes to sediment and water quality are therefore expected to be temporary and small in scale compared with overall bed material transport, as described in **Section 4.1 River Hydraulics and River Morphology**.

Project-related construction activities along the edge of Deas Slough and Green Slough that have the potential to induce turbidity include runoff, ground improvements, realignment of Green Slough to its historic location, and pile driving and construction of piers for the new bridge south approach. Temporary, localized disturbance of surficial sediments is also expected to occur during geotechnical investigations along the edges of Deas Slough and Green Slough and demolition of the Deas Slough Bridge.

Concentrations of metals (arsenic, chromium, copper) greater than those found in the sandy sediments of the Fraser River South Arm in the vicinity of the Project have been documented in the fine-grained sediments of Deas Slough historically, and were noted during field sampling conducted in September 2014 for the Project (see **Section 4.2.2**). This aligns with findings of historical reports, which show that fine-grained sediments preferentially adsorb organic particles and metals due to higher adsorption capacity and higher surface area compared with coarse-grained sediments. There is potential for temporary re-suspension of these materials into the water column in Deas Slough during Project construction.

The main channel of the Fraser River South Arm consists primarily of coarser-grained sediment, with metal concentrations not exceeding Canadian SQGs. Therefore no potential change in water quality due to re-suspended sediment contaminants is expected during construction-related activities in the Fraser River South Arm, including Tunnel decommissioning.

Accidental spills of toxic or hazardous materials (e.g., hydrocarbon fuels, lubricants, concrete), or potential failure of sediment containment measures could affect sediment and water quality during Project construction. The magnitude of such changes would vary as a function of the proximity of the disturbed areas to the river, its tributaries or stormwater collection points, or the extent and slope of exposed and erodible soils. Potential changes in surface water quality resulting from accidents or malfunctions during Project construction are assessed in **Section 8.0 Accidents and Malfunctions**.

Operation

Project-related widening of the highway and installation of the new bridge will result in an increase in impervious surface area and consequent increase in the rate of stormwater runoff that may enter the river and sloughs. An increase in peak flow rates has the potential to affect water quality in the receiving aquatic environment due to increased concentrations of nutrients, organics, metals, chlorides, bacteria, and hydrocarbons (Erickson et al. 2013), especially during first flush and peak storm events.

4.2.4 Mitigation Measures

This section describes the mitigation measures that will be implemented to avoid or reduce potential Project-related effects on sediment and water quality as discussed in **Section 4.2.3.2**.

4.2.4.1 Mitigation Selection Approach

Selection of mitigation measures has been informed by a review of standard industry and best management practices; consideration of mitigation measures and follow up programs undertaken for past developments by the Ministry; input from regulators, public, and Aboriginal Groups; and internal evaluation of technical and economic feasibility. Consideration was given to the following standards and guidelines:

- *2012 Standard Specifications for Highway Construction* (B.C. MOTI 2012)
- *Environmental Best Practices for Highway Maintenance Activities* (B.C. MOTI 2010)
- *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2013)
- *Land Development Guidelines for the Protection of Aquatic Habitat* (Chilibeck et al. 1993)
- *Environmental Management Strategy for Dredging in the Fraser River Estuary* (FREMP 2006)
- *Dredge Management Guidelines* (FREMP 2005)
- *Standards and Best Practices for Instream Works* (B.C. MWLAP 2004)
- *Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia* (B.C. MOE 2014)

Proposed mitigation considerations were informed by feedback received from Aboriginal Groups and stakeholders during pre-Application consultation, including interest expressed in use of bioengineering techniques on land (e.g. biofiltration areas) to prevent direct runoff into the Fraser River.

A hierarchical approach, based on avoidance of potential effects first followed by minimization or reduction of unavoidable effects, was used in identifying strategies to mitigate potential Project-related effects on water and sediment quality.

Measures to avoid potential effects have been/will be incorporated into project considerations such as site and route selection, scheduling, design, construction, and operation procedures and practices. Where potential effects cannot be avoided through project considerations, standard mitigation measures, Best Management Practices (BMPs), and construction and operation environmental management plans (EMPs) will be implemented to minimize potential Project-related effects or reduce them to acceptable levels. These measures are described in general terms below.

4.2.4.2 Avoidance

The bridge design will incorporate a stormwater collection and distribution system that conveys stormwater runoff to appropriate upland infrastructure for proper treatment (e.g., stormwater detentions ponds or biofiltration swales) before discharging to the Fraser River or adjacent streams, thereby avoiding potential impacts on the water and sediment quality. These enhanced stormwater management approaches are expected to result in an improvement in water and sediment quality in the Fraser River when compared to existing conditions

4.2.4.3 Minimization

Project Design

The new bridge will have a clear span over the Fraser River and over Deas Slough to minimize construction-related effects including effects on water quality and disturbance to the river bed.

Best Management Practices and Environmental Management

Specific environmental protection measures that will be implemented during Project construction and operation to prevent or minimize environmental effects will be identified in a CEMP, and subsequently in an Operation Environmental Management Plan (OEMP), as described in **Section 12.0 Management Plans**.

Control of Suspended Sediment during Tunnel Decommissioning

Construction methods that minimize levels of Project-induced turbidity in the Fraser River main channel will be employed where feasible and appropriate. To the extent technically feasible and viable, removal of fill materials adjacent to the Tunnel will be conducted in a manner that minimizes re-suspension of sediments–using hydraulic (hopper or cutter) suction for example.

Removed material is expected to be transported off-site using spoil barge(s) equipped with a sediment containment system (e.g., filter cloth, concrete lock blocks, straw bales).

Control of Suspended Sediment during Project Construction in and adjacent to Deas and Green Sloughs

Sediment control measures (e.g., turbidity curtains) will be used to control the dispersion of re-suspended sediments in Deas Slough generated by physical bed disturbance during ground improvements, pier construction activities on the edge of Deas Slough, and demolition of existing infrastructure. Measures to control suspended sediment during Project construction in Deas and Green Sloughs will be described in the Erosion and Sediment Control Plan within the CEMP. Erosion prevention and sediment control measures that will be implemented during construction may include, but be limited to:

- Development of temporary drainage systems to receive, filter, and direct stormwater and runoff during construction
- Installation of sediment control measures
- Development of sediment settlement ponds, if required
- Re-stabilization of vegetated areas that are cleared or disturbed during construction
- Careful storage of waste material and soil to prevent possible entry into the aquatic environment

Water Quality Monitoring during Construction

To assess the effects of Project-specific construction activities on sediment and water quality, and evaluate the effectiveness of mitigation measures, water quality monitoring will be conducted during Project-related construction activities that have the potential to induce turbidity (e.g., Tunnel removal, construction along the edges of Deas Slough and Green Slough). In general, water quality monitoring will include frequent collection of samples at established monitoring stations in the Fraser River main channel within proximity to the Tunnel crossing, as well as downstream of deployed sediment containment measures in Deas Slough, especially during higher risk construction activities. Water quality data will be evaluated in relation to the CCME (2002) and B.C. (B.C. MOE 2006) water quality guidelines (see **Section 4.2.2.2**).

Measures proposed to avoid or minimize Project-related effects on water and sediment quality as discussed above, including collection and treatment of stormwater runoff prior to discharge into streams, and sediment control during Project construction, were identified based on standard best practices and proven methodologies. Accordingly, there is a high level of confidence in the effectiveness of these measures and their ability to prevent Project-related effects on water and sediment quality.

4.2.5 Residual Effects

As discussed in **Section 4.2.4.2**, the Project has been designed with appropriate stormwater runoff collection and management features that prevent direct road runoff into the Fraser River. These enhanced stormwater management approaches are expected to result in an improvement in water and sediment quality in the Fraser River when compared to existing conditions, and no residual adverse effects on water or sediment quality are expected post construction.

Implementation of best practices and proven sediment and erosion control measures as discussed in **Section 4.2.4.3** are expected to avoid any potential effects on water and sediment quality during Project construction. Undertaking Project-related construction activities in Deas Slough within sediment containment structures or other measures will prevent any potential adverse effects to sediment and water quality in the slough due to re-suspension. The very limited extend of in-water or near-water activities are anticipated to be sufficiently small that introduction of suspended sediments into the larger water course can be avoided effectively through the isolation of works using multiple silt curtains or other sediment control measures. Therefore no residual effects on water and sediment quality related to construction within or adjacent to Deas Slough are expected.

Given the anticipated scale and nature of activities associated with Tunnel decommissioning, it is expected that standard best practices and mitigation measures, including use of equipment and methods that minimize sediment resuspension for removal of Tunnel segments and overlying material, will reduce, but not eliminate sediment resuspension. Sediment resuspension and entrainment in active Fraser River flows during Tunnel removal could, therefore, result in temporary increases in TSS and turbidity levels in the overlying water, especially near the river bed. This potential construction-related residual effect on water and sediment quality is characterized below in terms of the direction, magnitude, extent, duration, frequency, reversibility, and likelihood of the effect. Definitions for ratings applied to residual effects criteria, developed with specific reference to water and sediment quality, are presented in **Table 4.2-3**. A summary of criteria ratings for the potential residual effect is provided in **Table 4.2-4**. Context for the characterization of the residual effect, i.e. sensitivity/resilience of water and sediment quality to potential Project-related effects, based on existing conditions, is also provided.

Table 4.2-3 Criteria Used to Characterize Residual Effects on Sediment and Water Quality

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 in water or sediment quality
		Low	A measurable change within the range of natural variability, but not expected to directly impact receptor VCs (e.g. fish, including sensitive life stages or aquatic invertebrates).
		Moderate	A measurable change outside the range of natural variability, but not expected to result in substantive effects on receptor VCs.
		High	A measurable change outside the range of natural variability and potentially harmful to receptor VCs. Such changes could be driven either by measurable water quality changes or the associated changes in sediment characteristics following re-deposition.
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 extends beyond the LAA

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.
		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 beyond construction phase. 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 5%.
		Moderate	Likelihood of residual effect is between 5% and 25%.
		High	Likelihood of residual effect is greater than 25%.

Activities associated with Tunnel decommissioning, including removal of Tunnel segments and overlying material, 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. **Table 4.2-4** presents a summary of the criteria ratings for this residual effect.

Context: Bed sediments and suspended sediments potentially influenced by the Project comprise a minute fraction of the estimated 12 to 31 million tonnes/year of suspended sediment transported by the Fraser River, and the anticipated scale of disturbance to bed sediments is comparable to that associated with maintenance dredging routinely undertaken in the Fraser River South Arm. In addition, the physical and chemical characteristics of sediment likely to be suspended during Tunnel removal are consistent with sediments transported in the Fraser River in general, without any discernible influence of local contaminant source inputs. Sensitivity of water and sediment quality in the river to temporary changes resulting from activities associated with Tunnel removal is therefore considered to be low.

Table 4.2-4 Criteria Ratings: Change in Water Quality during Tunnel Decommissioning

Criteria	Criteria Rating	Rationale for Criteria Rating
Direction	Adverse	Tunnel decommissioning has the potential to result in a temporary increase in TSS and turbidity in the Fraser River South Arm.
Magnitude	Low	Change will be within the range of natural variability, given the high sediment loads transported by the Fraser River South Arm. It is likely that measurable increases in TSS/turbidity will be evident for short periods of time during Tunnel removal within the immediate vicinity of the works; however, influence of this localized change in water quality on fish would be limited, given avoidance behaviours. The re-suspended sediment will be of similar textural and chemical quality to the downriver sediments therefore, deposition of re-suspended sediments in downriver areas is not expected to measurably alter riverbed habitat quality or characteristics.
Extent	Site	Spatial extent will be restricted to the area of disturbance.
Duration	Short term	Effect will occur only during specific Tunnel removal activities that will unavoidably re-suspend sediments. It is anticipated that there will be periodic instances of sediment re-suspension over several weeks to several months during sequential removal of each of the four Tunnel sections.

Criteria	Criteria Rating	Rationale for Criteria Rating
Frequency	Frequent	Effect will occur only in association with Tunnel removal, which comprises a small portion of the overall construction and post-construction project window. Nonetheless, a number of different types of activities are anticipated during the overall Tunnel removal phase, including excavation of adjacent sediments, and various in-river works. As a result there might be relatively frequent bouts of sediment re-suspension that could affect TSS/turbidity levels in the immediate vicinity of the Tunnel.
Reversibility	Reversible	Water quality is expected to return to baseline conditions within a few hours, and generally less than one day, following cessation of activities that could result in re-suspension
Likelihood	High	There is provisionally estimated to be a greater than 25% probability that a measurable change in TSS or turbidity in the water immediately above and down river from the Tunnel removal work will occur.

When examining the characteristics of residual effects of Tunnel removal on water and sediment quality, it is important to appreciate that the characterization criteria as discussed above are applied to sediment and water quality as an intermediate component, and may not be relevant to the receptor VCs such as fish. The likelihood rating defines the likelihood of detecting a change in water quality (based on TSS) at a given point in space and time. The likelihood rating does not describe the associated probability of adverse effects to any VC. Characterization of residual adverse effects of construction-related sediment re-suspension on fish and fish habitat is provided in **Section 4.4 Fish and Fish Habitat**.

4.2.6 Cumulative Effects Assessment

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 sediment and water quality. 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 sediment and water quality effects of the two activities, and no construction-related cumulative effects are expected.

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4.2.7 Follow-up Strategy

Water quality monitoring will be undertaken during Project-related construction activities that have the potential to induce turbidity (e.g., Tunnel removal, construction within or along the edges of Deas Slough and Green Slough) to assess the influence of such activities on sediment and water quality, and evaluate the effectiveness of mitigation measures.

As no Project-related effects are predicted beyond the construction phase, no post-construction follow-up strategy is proposed.

4.2.8 References

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APPENDIX A

Results from Sediment and Water Quality Field Studies Conducted in September 2014 for the Project

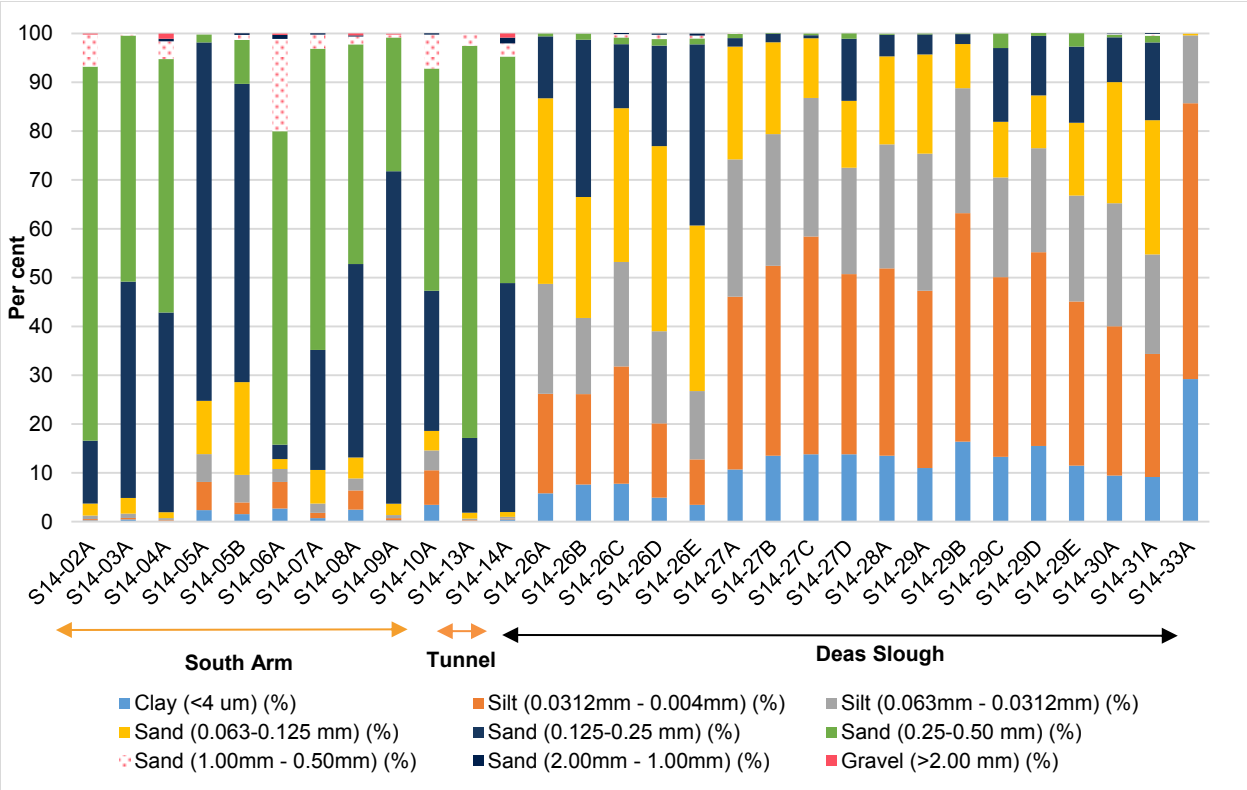

Figure 1 **Per Cent Grain Size in Sediment Core Samples from Deas Slough and the Fraser River South Arm, including the Tunnel**

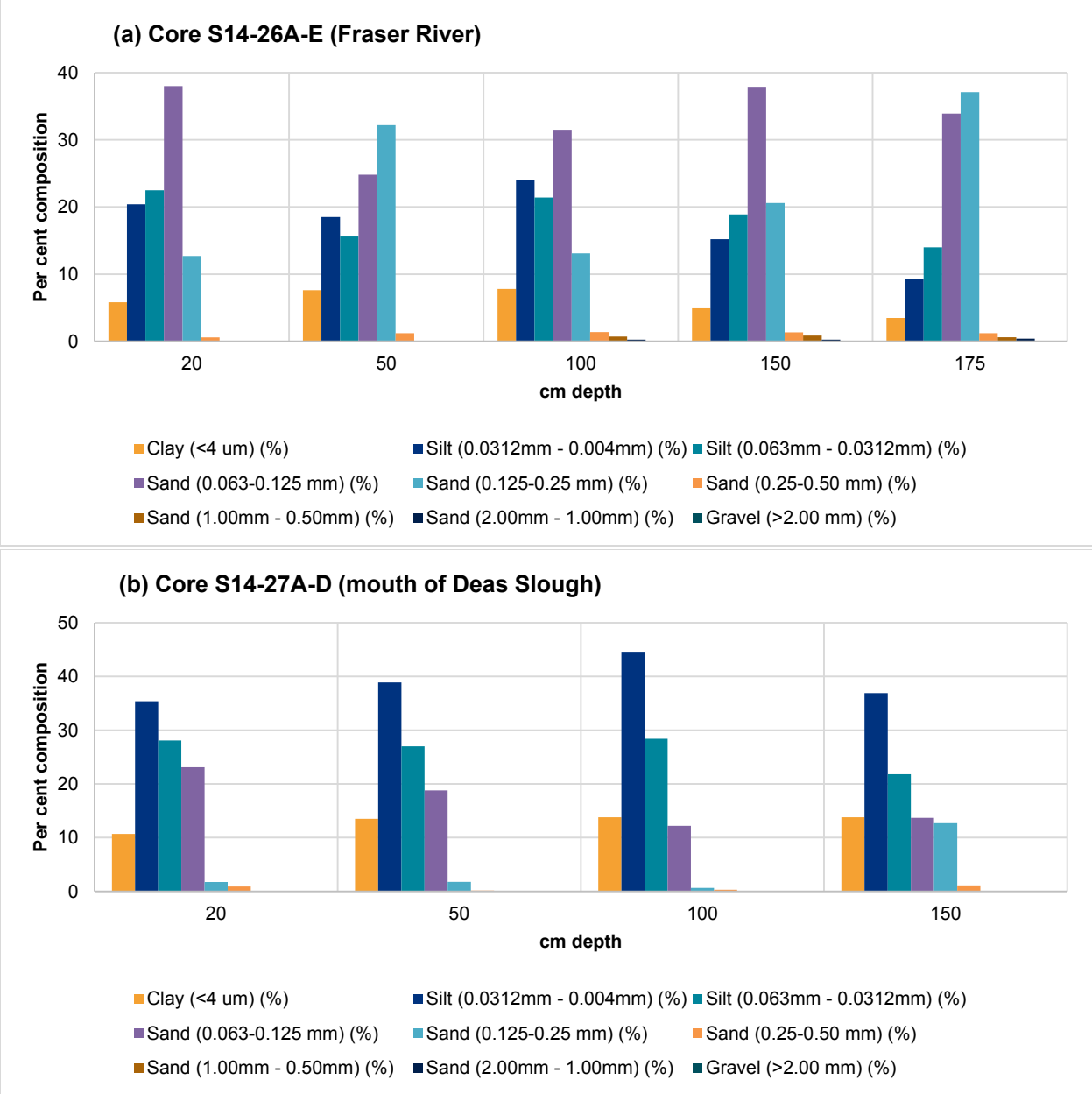

Figure 2 **Grain Size Distribution for Core Samples (a) S14-26A-E (Fraser River) and (b) S14-27A-D (Deas Slough)**

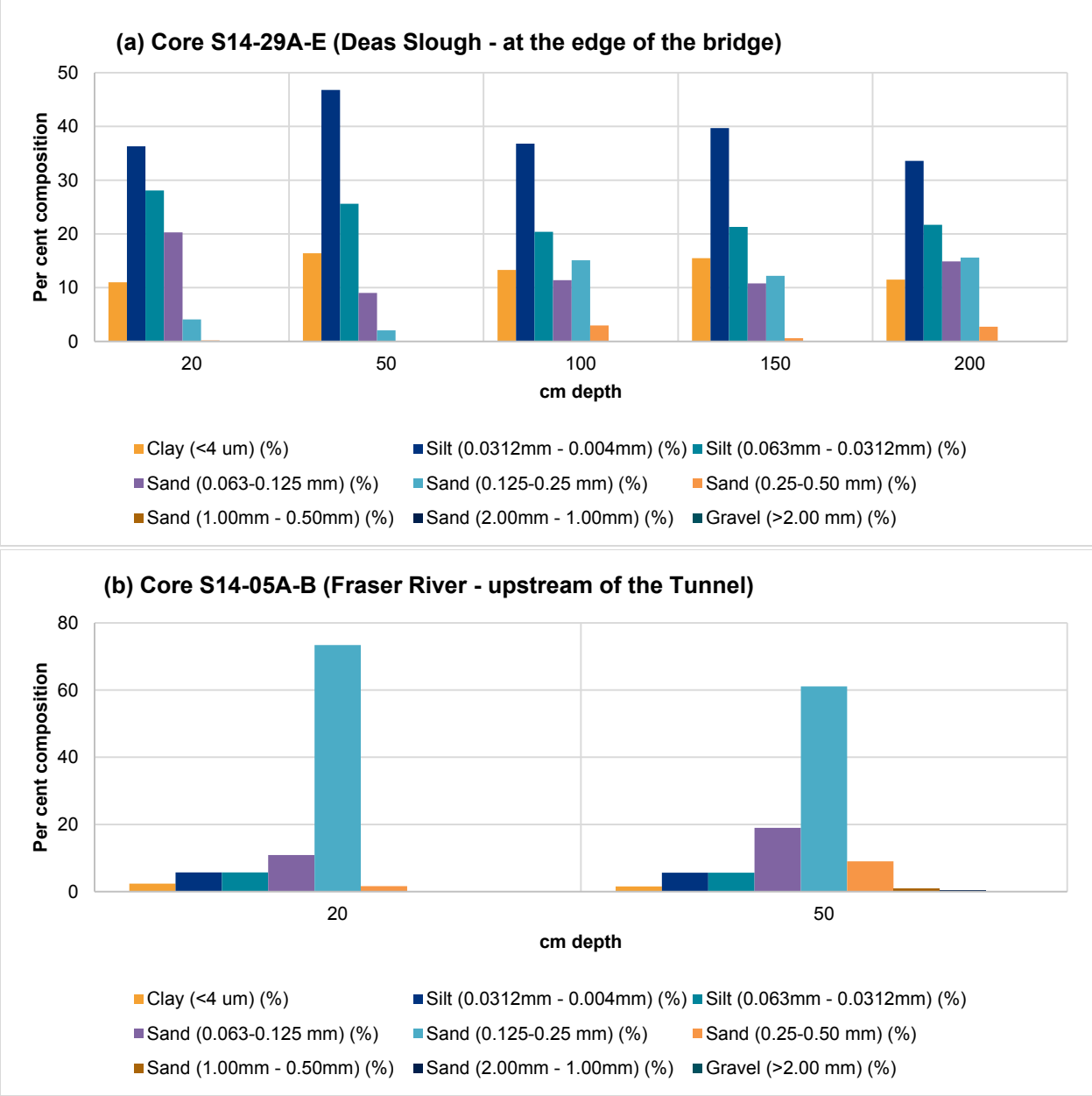

Figure 3 **Grain Size Distribution for Core Samples (a) S14-29A-E (Deas Slough) and (b) S14-05A-B (Fraser River)**

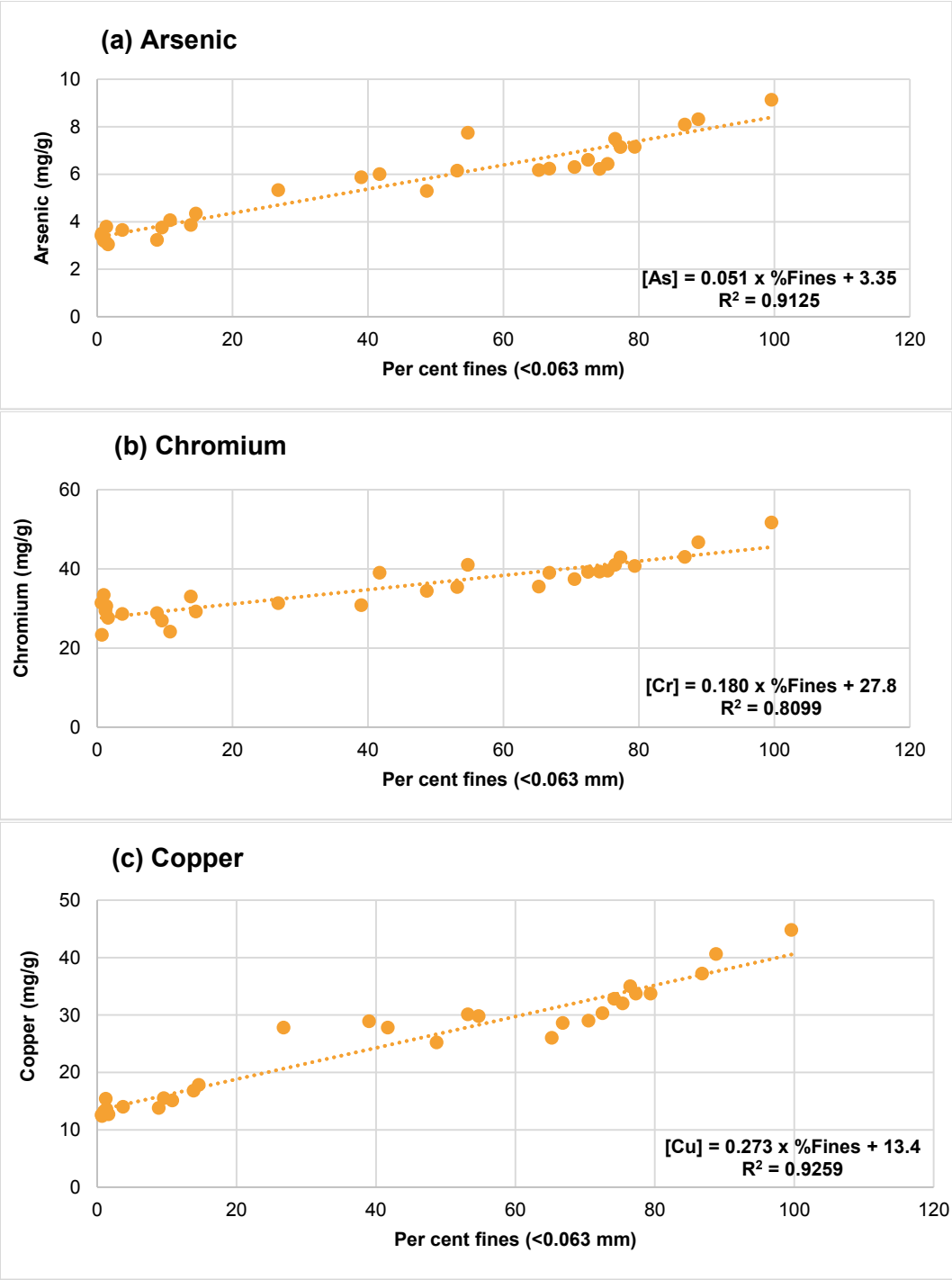

Figure 4 **Linear Regression Analysis between Per Cent Fines (<0.063 mm) and Concentrations of (a) Arsenic, (b) Chromium, and (c) Copper**

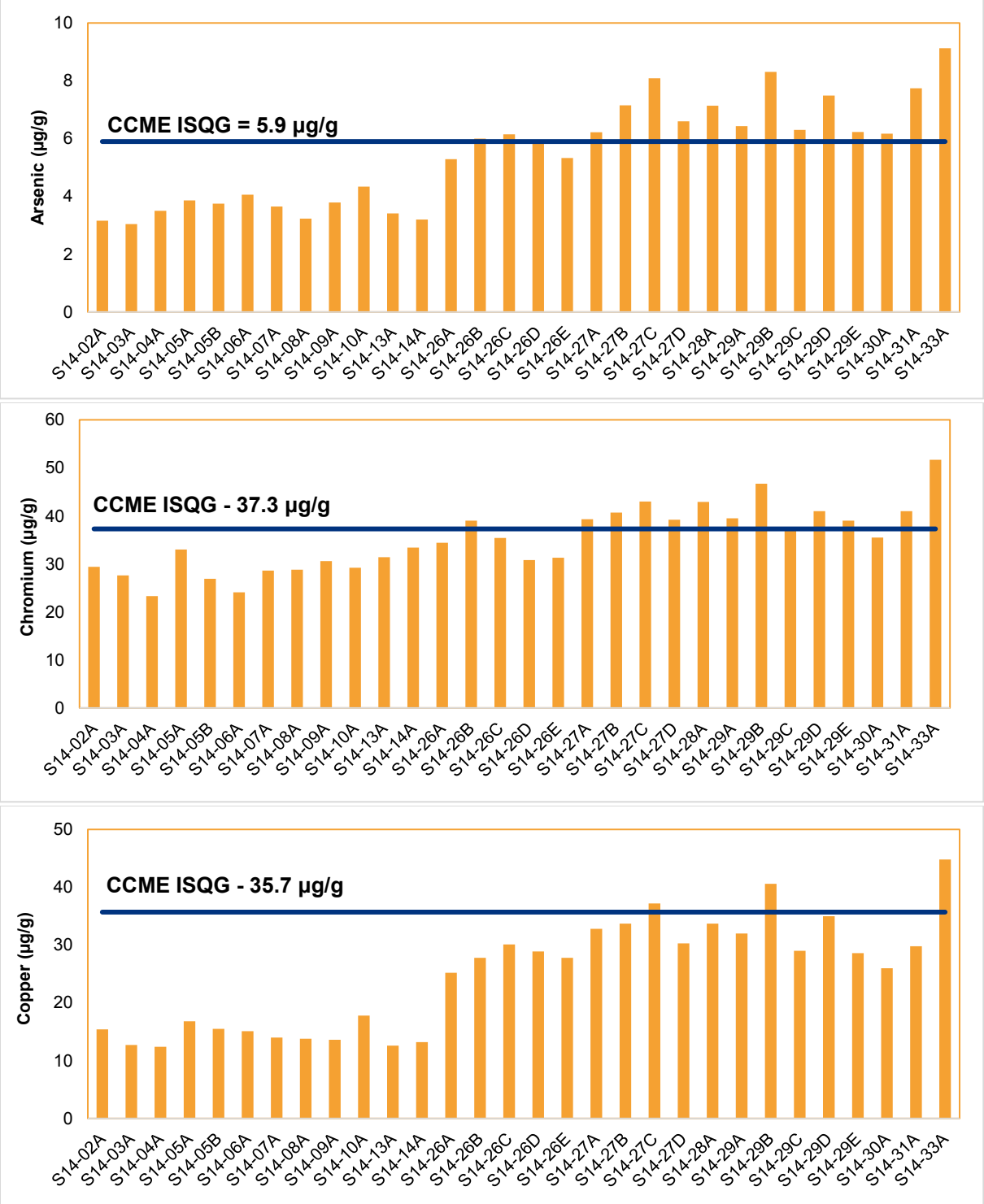

Figure 5 **Concentrations of Arsenic, Chromium, and Copper in September 2014 Sediment Samples**

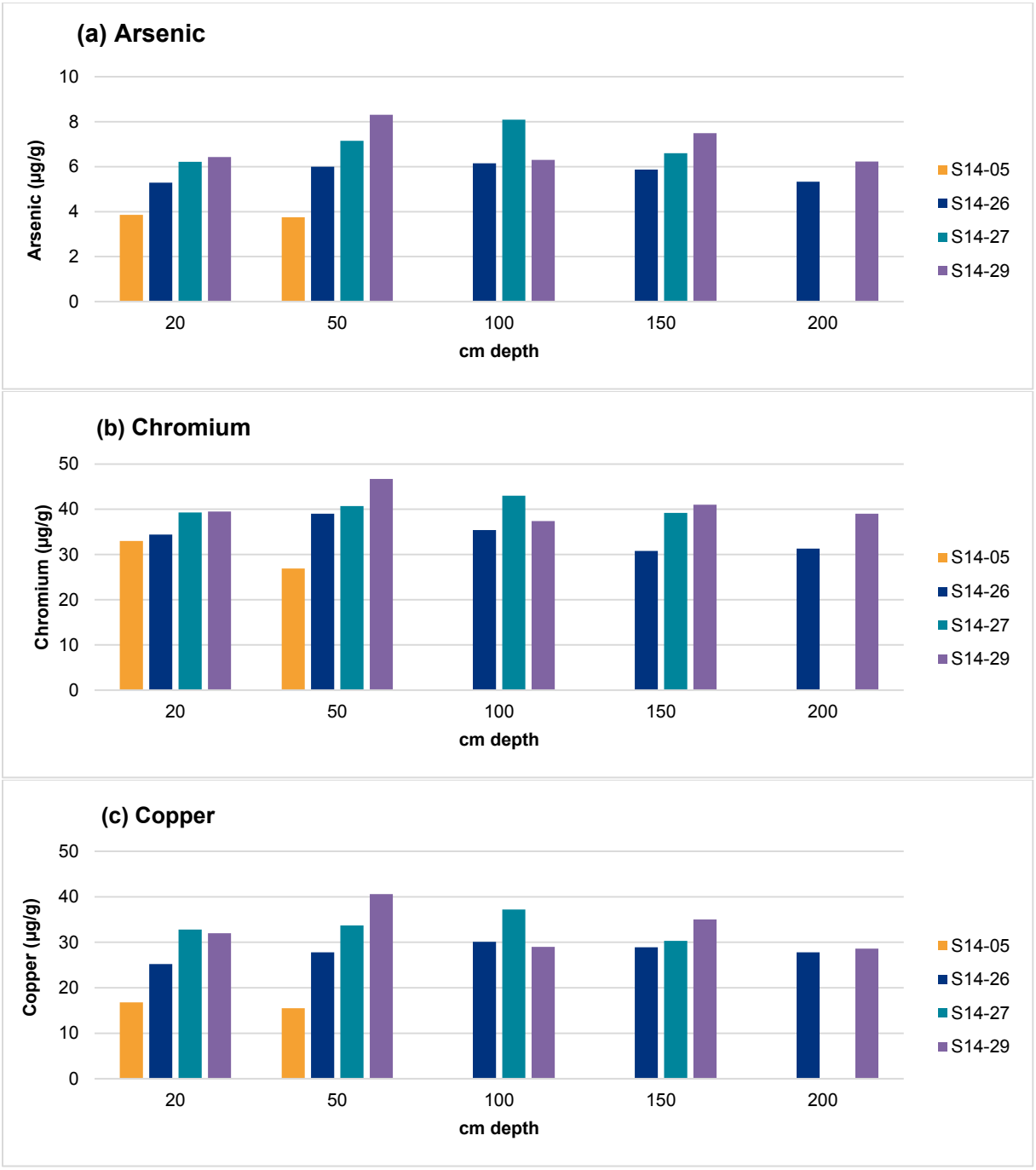

Figure 6 **Distribution of (a) Arsenic, (b) Chromium, and (c) Copper by Depth in Deas Slough Sediment Cores**

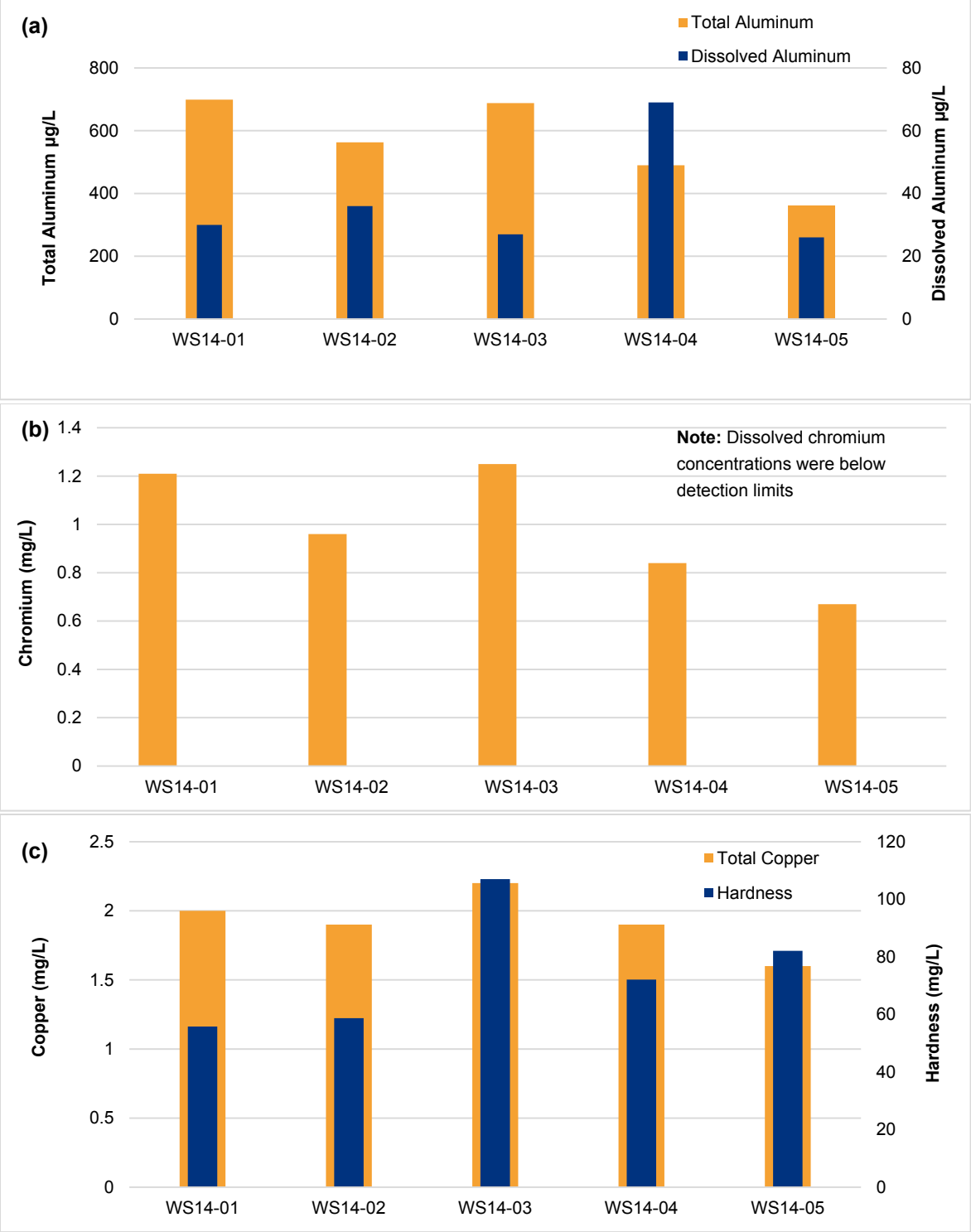

Figure 7 **Concentrations of (a) Total and Dissolved Aluminum, (b) Total Chromium, and (c) Total Copper and Hardness in September 2014 Water Samples**

APPENDIX B

Overview of Potential Project Interactions with Sediment and Water Quality

Table 1 Overview of Potential Project Interactions with Sediment and Water Quality

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 drainage structures and diversions • Relocating utilities • Preloading for embankment and highway construction • Acquiring land for the Project	**Nature of interaction:** No interaction anticipated. **Rationale:** All activities to be land-based.
	No effect	• Installing temporary roads, laydown areas, and site offices	**Nature of interaction:** Activities with the potential to interact with surface water and sediment quality. **Rationale: All activities to be land-based**
	Potential Effect	• Restoration of Green Slough to its historic alignment • Installing temporary bridges and barging facilities • Conducting additional site investigations (i.e., a geotechnical drilling program)	**Potential Project-related effects include:** • Increased turbidity within Green and Deas Sloughs. • Accidental spills of toxic or hazardous materials (e.g., hydrocarbon fuels, lubricants, concrete; see **Section 8.0 Accidents and Malfunctions**) • Temporary re-suspension of existing contaminants into the water column during Project construction.

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	• 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 surface water and sediment quality **Rationale:** Activities to be land-based, or will not have potential to impact sediment and water quality
	Potential Effect	• Ground improvements associated with new bridge piers • Installing piers on the edge of Deas Slough and Green Slough, including pile installation	**Potential Project-related effects include:** • Increased turbidity within Green and Deas Slough. • Temporary re-suspension of existing contaminants into the water column during Project construction.

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	• Removing electrical/mechanical/utilities equipment from the Tunnel • Backfilling of onshore portions of Tunnel approaches	**Nature of interaction:** No interaction anticipated. **Rationale:** All activities to be land-based.
	No effect	N/A	N/A
	Potential Effect	• Removing of four Tunnel segments and associated scour protection • Transporting Tunnel elements for offsite disposal, and operating support vessels for that activity	**Potential Project-related effects include:** • Re-distribution of bed sediments through scouring as a result of flow acceleration around exposed tunnel ends (as described in **Section 4.2 River Hydraulics and River Morphology)** • Accidental spills of toxic or hazardous materials (e.g., hydrocarbon fuels, lubricants, concrete; see **Section 8.0 Accidents and Malfunctions)**
Decommissioning of Deas Slough Bridge	No interaction	N/A	N/A
	No effect	• Removal of Deas Slough Bridge including substructures	**Nature of interaction:** Activities with the potential to interact with surface water and sediment quality **Rationale:** All activities to be land-based
	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:** All activities to 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	N/A	N/A
	Potential Effect	• Operating the new Bridge. • Bridge maintenance (winter maintenance, emergency maintenance, structure maintenance, etc.).	**Potential Project-related effects include:** • An increase of impervious surface area and stormwater runoff entering the river could increase concentrations of nutrients, organics, metals, chlorides, bacteria, and hydrocarbons (Erickson et al. 2013), if untreated.

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