Note to the Reader

This report was finalized before the Pattullo Bridge Replacement Project was transferred from TransLink (South Coast British Columbia Transportation Authority) to the BC Ministry of Transportation and Infrastructure (MoTI).

References to TransLink should be read as MoTI unless referring specifically to TransLink policies or other TransLink-related aspects.

Pattullo Bridge Replacement Project: Sediment and Surface Water Quality Study

February 2018

Prepared for:

South Coast British Columbia Transportation Authority (TransLink)
New Westminster, British Columbia

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PATTULLO BRIDGE REPLACEMENT PROJECT: SEDIMENT AND SURFACE WATER QUALITY STUDY

Prepared for:

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FEBRUARY 2018

TRANS7593-NV

VERSION 4.0

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LIST OF ACRONYMS

CCME	Canadian Council of Ministers of the Environment
DO	Dissolved oxygen
ECCC	Environment and Climate Change Canada
EMS	Environmental Monitoring System
LFRO	Lower Fraser River water quality objectives (Swain et al., 1998)
LSA	Local study area
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyl
RSA	Regional study area
SQG	Sediment quality guidelines
TSS	Total suspended solids
WQG	Water quality guidelines
WSC	Water Survey of Canada

EXECUTIVE SUMMARY

The purpose of this document is to characterize sediment (loads, concentrations, particle size, and quality) and surface water quality conditions in the Lower Fraser River and tributaries near the Pattullo Bridge Replacement Project (PBRep, also referred to as the Project).

Mean annual suspended sediment load in the Lower Fraser River near the Project is about 1.8 x 10^7 tonnes. Of this, 82% is transported in May, June, and July. Only 9% is transported from September to March. Monthly average sediment concentration peaks in June at 276 mg/L (112 mg/L standard deviation). Average sediment concentration is lowest in December (26 mg/L), when discharge fed by snowmelt in the watershed headwaters is minimal. Peaks in suspended sediment concentrations in spring precede the freshet peak when abundant fine-grained sediment is available for transport; sediment is relatively exhausted in fall after readily transportable fine-grained sediment has been moved during freshet.

Bed material in the Project area is typically sand-sized. Transport of bed load is about 3 x 10^6 tonnes per year. Influx of bed material roughly equals outflows, meaning large-scale net erosion and deposition does not occur.

Sediment samples obtained near the Project in July and November 2017 did not exceed sediment quality guidelines. Guideline exceedances were also not found upstream of the Project, near Barnston Island in 2003. Analyses downstream near the George Massey Tunnel in 2014 showed exceedances for PAHs, arsenic, chromium, copper, and organic contaminants. Particle size at this downstream site is typically finer grained than near the Project. Trace element concentrations are typically higher in finer grained sediments.

Water quality exceedances have recently and historically occurred in the Lower Fraser River. In November 2017, concentrations of dissolved aluminum, dissolved iron, and total zinc exceeded guidelines in three samples. Longer-term Lower Fraser River water quality was also assessed using datasets from monitoring sites: one 12 km to 13 km upstream at Barnston Island, one immediately upstream of the Project, and one at a downstream buoy. Results were screened against Lower Fraser River water quality objectives (Swain et al. 1998) and provincial water quality guidelines (BC MOE 2017a). Maximum concentrations have historically exceeded objectives and guidelines at all locations for several analytes. Exceedances are much rarer for mean, median, and median plus one standard deviation. Exceedance for these statistics include microbiological parameters (*Enterococcus*, Fecal Coliform, and *Pseudomoas*), dissolved aluminum, and total metals (aluminum, cadmium, chromium, cobalt, copper, iron, lead, nickel, silver, thallium, and zinc). Concentrations of metals in water at levels that exceed applicable standards or guidelines are most common in spring, and least common in fall and winter.

Water quality in nearby upstream and downstream tributaries was also assessed. These include Manson Canal, Pattullo Channel, and Brunette Creek. Samples obtained in November 2017 in Manson Canal and Pattullo Channel had exceedances for dissolved and total iron, total copper, and total zinc. Water quality results from Burnette Creek are dated. However, in 2001 Canadian and/or provincial WQG were being exceeded for dioxins/furans, benzo(a)pyrene, DDT, PCBs, trace metals, pH, total coliforms, and *E. coli*. Data since 2001 are sparse, but samples analyzed in 2012 showed that *E. Coli* continued to exceed water quality guidelines. Based on its discharge and water quality, it was concluded in 2001 that Brunette Creek was a significant source of contaminants to the Lower Fraser River (GVRD 2001).

1.0 INTRODUCTION

The South Coast British Columbia (BC) Transportation Authority (TransLink) is proposing to replace the existing four-lane Pattullo Bridge connecting the Cities of Surrey and New Westminster with a new four-lane bridge spanning the Fraser River in the same general location. The existing Pattullo Bridge is 1.22 km long and was opened in 1937. The Pattullo Bridge Replacement Project (PBRep; also referred to as the Project) will tie into the existing municipal and provincial road networks. Major components of the Project will include infrastructure upgrades, construction of a new bridge and approaches, and decommissioning and removal of the existing bridge.

This report summarizes existing sediment and water quality conditions in the Project area. The study was completed to support the environmental effects assessment for the Project Environmental Assessment Certificate Application. Sediment and water quality are an Intermediate Component to an effect pathway that can affect a Valued Component (e.g., fish and fish habitat).

2.0 STUDY AREA

The Fraser River upstream of the proposed Project is about 1,325 km long and its catchment covers about 232,000 km^2 (about 25% of British Columbia). The Fraser River begins near Valemount in the Rocky Mountains, then passes near Prince George, Quesnel and Williams Lake, Lillooet, and Hope, before entering the Lower Mainland at Agassiz. Downstream of the Project, the river continues for approximately another 30 km before flowing into the Pacific Ocean at Roberts Bank and Westham Island.

The Pattullo Bridge is located about 30 km upstream of the mouth of the Fraser River (Figure 1). LSA and RSA boundaries are presented in Figure 1 and Figure 2. The selection of boundaries is described in the Valued Components Selection and Rationale document (Translink 2016).

The LSA includes the section of the Fraser River extending about 1 km upstream and downstream of the existing Pattullo Bridge. The upstream boundary on the Fraser River corresponds to the southwestern end of Sapperton Bar. The downstream boundary on the Fraser River corresponds to Tannery Road on the Surrey side and Church Street on the New Westminster side. These boundaries encompass the Fish and Fish Habitat and Hydraulics and River Morphology LSA boundaries (Sections 4.1 and 4.3). Downstream boundaries are consistent with modelled predictions of bed elevation changes caused by the Reference Concept, relative to existing conditions. In upland areas, the LSA encompasses tributary portions of surface water courses that discharge into the Fraser River near the Reference Concept. Larger tributaries in the LSA include Pattullo Channel, Manson Drainage Canal, and Glenbrook Creek. Overall, the LSA encompasses the Reference Concept, extends well above the High Water Level (HHWL), and includes tributaries near the Project area and upland areas near these tributaries. These boundaries were selected so that any Project-related effects on land are encompassed by the LSA.

The RSA extends from 6 km upstream to 5.5 km downstream of the existing Pattullo Bridge for the mainstem Annacis Channel and Fraser River North Arm, and 8 km downstream for the Fraser River South Arm. Upstream of Pattullo Bridge, the RSA extends to downstream of the Port Mann Bridge. Downstream of Pattullo Bridge, the RSA extends to about 0.5 km upstream of the Annacis Channel Bridge in the North Arm, and to about 1.5 km downstream of the Alex Fraser Bridge in the South Arm. The RSA extends upland to the High Water Line (HHWL) along the shoreline.

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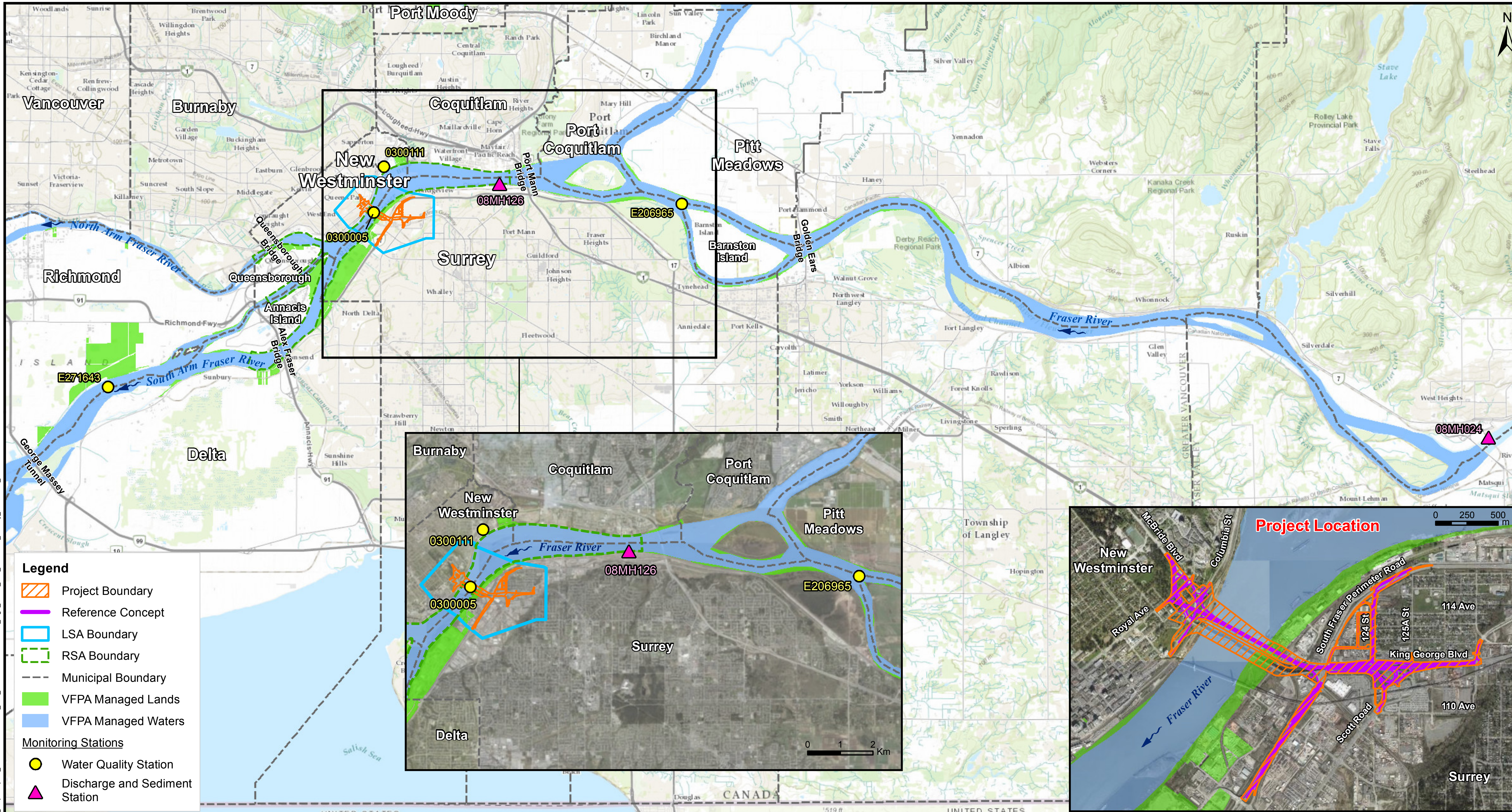

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APPROVAL		

REFERENCE DRAWING

NO.	DESCRIPTION
1	Reference Concept, Parsons 2018.
2	Water Quality Monitoring Stations, BC MOE, 2017.
3	Discharge and Sediment Quality Monitoring Stations, Environment Canada and Climate Change, 2017.

BRITISH COLUMBIA — Ministry of Transportation and Infrastructure

Hatfield CONSULTANTS

Proposed Pattullo Bridge Replacement Project

Surface Water and Sediment Quality Assessment - Key Monitoring Stations

Contract No. 0906-14/SC001110CA

SCALE	FIGURE NO.	REV NO.
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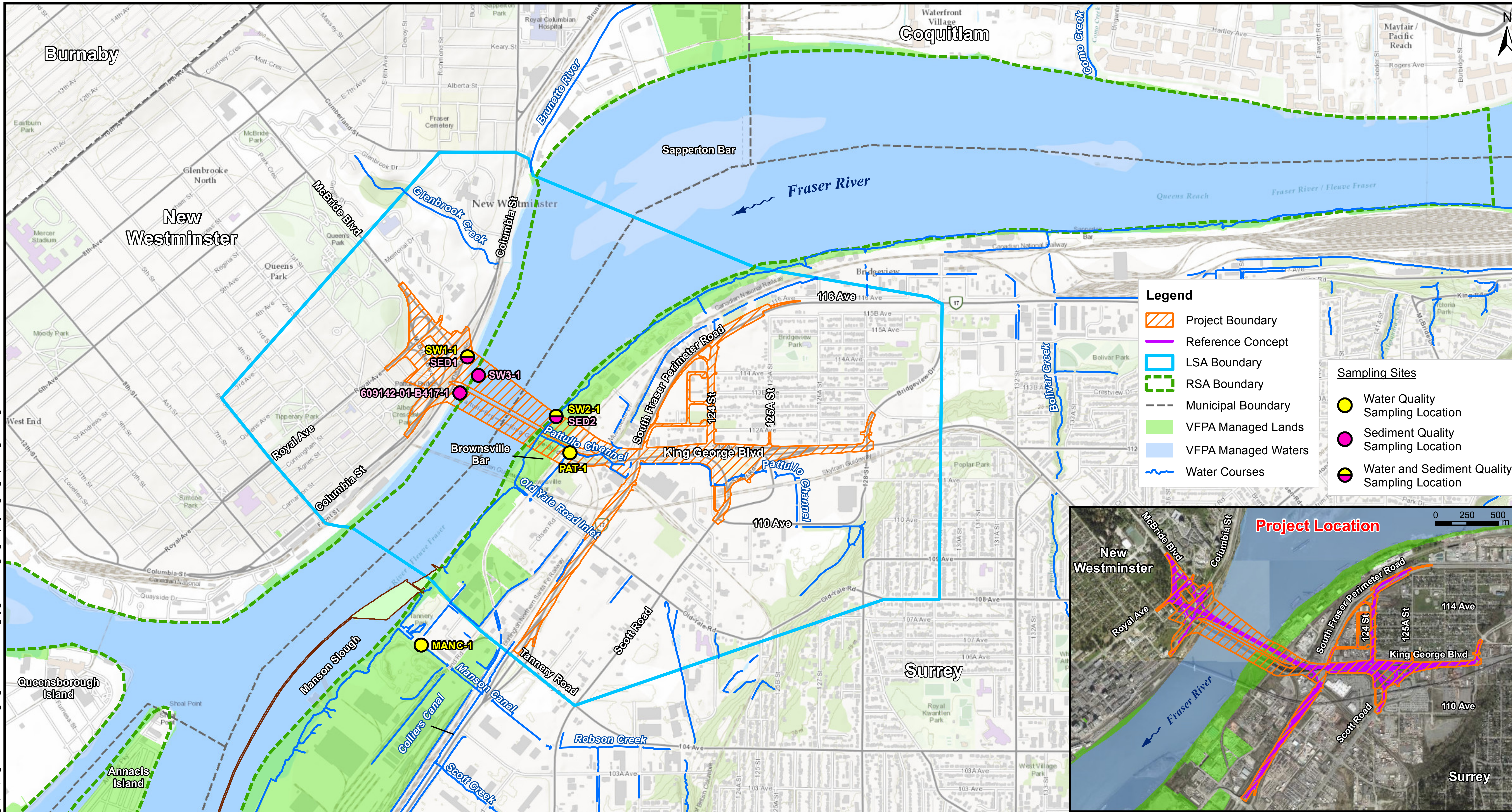

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REFERENCE DRAWING

NO.	DESCRIPTION
1	Reference Concept, Parsons 2018.
2	Watercourse, City of Surrey 2010.
3	Glenbrook Creek, Brunette River, and Como Creek watercourses are delineated based on visual interpretation of the orthophoto. Hatfield 2017.
4	Water and Sediment Sampling Sites Established for the PBRep Project, 2017.

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Proposed Pattullo Bridge Replacement Project

Water Courses and Sampling Sites Near the Project Area

Contract No. 0906-14/SC001110CA

SCALE 1:20,000 (0 250 500 m)

FIGURE NO. 2

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3.0 METHODOLOGY

Data were acquired and assessed using (1) water and sediment samples obtained in 2017 in the Project Area as part of the PBRep project, (2) pre-existing water quantity, sediment, and water quality data sources, and (3) reports prepared by Aboriginal Groups. Federal, provincial, and regional guidelines were used to assess water and sediment quality (Swain and Holms 1988; Province of British Columbia 1997; CCME 1999; BC MOE 2017a). Data sources and methodologies are described below.

Water and Sediment Samples Obtained in 2017

Water quality and sediment samples were obtained near Pattullo Bridge in 2017. Analyses were conducted by ALS Laboratories in Burnaby. Sampling locations are summarized in Table 1 in mapped on Figure 2. Sampling results relative to water quality and sediment guidelines are provided in Attachment 18.3-A.

Pre-existing Data Sources

Readily available data for pre-existing water quantity, sediment, and water quality data sources were compiled for sites both within and outside the LSA and RSA. Fraser River monitoring stations outside the RSA were also considered, as they contain a relatively large dataset and represent conditions both upstream and downstream of the Project. As such, they could be used to infer potential baseline conditions within the LSA/RSA and broader regional context within the Fraser River. Data sources include:

- Federal and provincial databases containing river discharge, sediment loads, and water quality. These include HYDAT and British Columbia's Environmental Monitoring System (BC MOE 2017a; Environment and Climate Change Canada 2017). These databases include water quality, water quantity, sediment quality, and sediment loads and concentrations. Site locations and available datasets are summarized in Table 2 and Figure 1;
- Water quality and sediment data from recent environmental assessments and reports on the Lower Fraser River. These include the George Massey Tunnel Replacement Project, Golden Ears Connector, Port Mann/Highway 1, South Fraser Perimeter Road, and assessments of dredging (nhc 2002; Greater Vancouver Transportation Authority 2003; TRAN 2006; EAO 2008); and
- Scientific literature – examples are referenced in the text.

Reports Prepared by Aboriginal Groups

The following reports prepared by Aboriginal Groups relating to the Project were reviewed for information regarding water use and water quality conditions:

- Cowichan Nation Alliance Strength of Claim Report – Pattullo Bridge Replacement Project – October 16, 2017
- Kwantlen Land Use and Occupation in the Vicinity of Pattullo Bridge – April 2017

- Kwikwetlem First Nation Traditional Knowledge and Cultural Heritage Interests Relating to the Pattullo Bridge Rehabilitation Project – July 2017
- Lyackson First Nation Traditional Land Use and Mapping Study for The South Coast British Columbia Transportation Authority's Pattullo Bridge Replacement Project – October 19, 2017
- Musqueam Indian Band Knowledge and Use Study – TransLink's Pattullo Bridge Replacement Project – July 11, 2017
- Tsawwassen First Nation – Pattullo Bridge Replacement: Project Impact Study – August 16, 2017
- Tsleil-Waututh Nation Traditional Use Study in Relation to the Pattullo Bridge Replacement Project – October 14, 2016

Table 1 Water and sediment sampling in 2017 near Pattullo Bridge.

Station Name	Water Course	Number of Samples		Sampling Date	Sediment Sampling Depth (m)	Easting	Northing	Location Description
		Sediment Quality	Water Quality					
609142-01-B417-1	Fraser River	1	0	Jul 31, 2017	0 m	507,491	5,450,686	right bank
SED1/SW1-1	Fraser River	1	1	Nov 28, 2017	0 to 0.2 m	507,529	5,450,840	right bank, about 130 m upstream of railway bridge.
SED2/SW2-1	Fraser River	2	1	Nov 28, 2017	0 to 0.2 m (SED2-1), and 0.5 to 0.75 m (SED2-2)	508,003	5,450,561	left bank, about 110 m upstream of railway bridge.
SW3-1	Fraser River	0	1	Nov 28, 2017	n/a	507,588	5,450,780	right bank, about 100 m offshore right bank and about 110 m upstream of railway bridge
PAT-1	Pattullo Channel	0	1	Nov 3, 2017	n/a	508,077	5,450,367	Pattullo Channel Pump Station, near Fraser River
MANC-1	Manson Channel	0	1	Nov 3, 2017	n/a	507,282	5,449,339	Manson Cannal Pump Station, near Fraser River

Table 2 Summary of long-term monitoring datasets used in this assessment.

Location Name	Station ID	Station Type	Data Type	Station Description	Upstream(u/s) or Downstream (d/s), and Distance from Pattullo Br. (km)	UTM Easting*	UTM Northing*	Data Begin	Data End
Fraser River Water Quality Buoy	E271643	Water quality	Discrete	Federal-provincial automated monitoring. Near Tilbury.	13.3 d/s	497,448	5,443,823	Aug-08	Nov-16
New Westminster Bridge	0300005	Water quality	Discrete	EMS Site. Under railway bridge near the Project in mid channel	0.1 u/s	507,730	5,450,593	Aug-88	Mar-03
Brunette River at Spruce St	0300111	Water quality	Discrete	EMS Site on Brunette River, near its mouth	n/a	508,103	5,452,361	Apr-85	Dec-12
Fraser River at Port Mann Pumping Station	08MH126	Water quantity	Continuous	WSC discharge	5.2 u/s	512,603	5,451,680	Apr-65**	Jan-93**
		Sediment load	Discrete	WSC suspended sediment				May-65	Dec-72
Fraser River at Barnston Island	E206965	Water quality	Discrete	EMS Site. Downstream of Barnston Island	12.4 u/s	519,665	5,450,925	Jan-87	Mar-11
Fraser River at Mission	08MH024	Water quantity	Continuous	WSC discharge	43 u/s	550,907	5,441,864	May-65***	Dec-1992***
		Sediment load	Discrete	WSC suspended sediment				May-65	Dec-92

Notes

* UTM Zone 10 U

** With a gap between December 1972 and December 1982

*** With additional summer-only data from April 2000 to November 2014

4.0 RESULTS

4.1 SUSPENDED SEDIMENT

Sediment is sourced from glacial deposits in valleys incised by river channels, rather than from upland areas that have been denuded since glaciation (McLean et al. 1999). Between Agassiz and Mission, the Fraser River is relatively steep, has a "wandering" morphology, and bed material is dominated by gravel. Downstream of Mission, the river profile flattens and the grain size of bed material is reduced to sand-size.

Daily suspended sediment loads were monitored at the "Fraser River at Port Mann Pumping Station" (station id = 08MH126) by the Water Survey of Canada from 1965 to 1972 (Environment and Climate Change Canada 2017) (Figure 1, Figure 3). This station is about 5 km upstream of the Project and about 1 km downstream of the Port Mann Bridge. The reported drainage area at the site is 232,000 km^2 (the Fraser River watershed at its mouth is about 250,000 km^2).

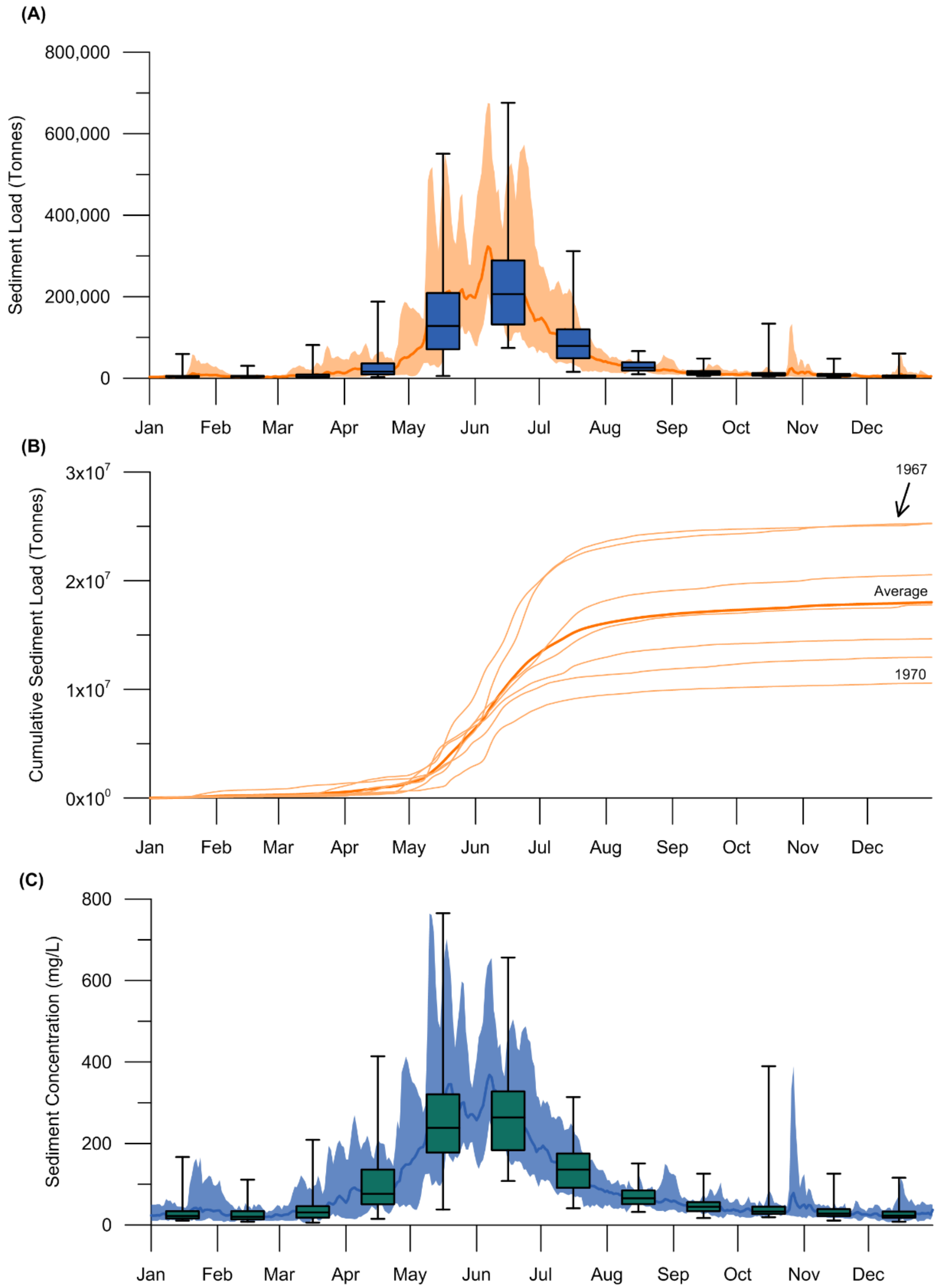
4.1.1 Suspended Sediment Load

Suspended load in the Lower Fraser River near the Project consists of particles finer than 0.177 mm (fine sand); coarser particles are transported as bedload (Section 4.2) (nhc 2002). Sediment loads are only available for seven complete years, from 1966 to 1972, at Fraser River at Port Mann Pumping Station. It is possible that this time period is not representative of longer-term normal, or that sediment loads changed after the monitoring was discontinued. However, total annual volumetric outflow (the volume of water moving past a gauging station in a year) varies linearly with total annual sediment load (R^2=0.78) over the period of record. This presents the opportunity to place the relatively short sediment load record into a longer-term context using longer records of volumetric outflow.

Between 1966 and 1972, total annual suspended sediment loads at the Port Mann pumping station varied from 1.1×10^7 to 2.5×10^7 tonnes, with an average of 1.8×10^7 tonnes (Figure 3). May to July is the most significant period for sediment transport, with 82% of the annual total occurring in these three months (Table 3). Relatively little sediment is transported in fall and winter; only 9% of the total annual load is transported in the seven months from September to March.

Sixteen complete years of volumetric outflow data exist from the Fraser River at Port Mann Pumping Station (08MH126, Figure 1), which is relatively close to the Project. However, a 27-year record is available about 43 km upstream at Fraser River at Mission (08MH024, Figure 1). The watershed area at station 08MH024 is 228,000 km^2, or 98% of the total Fraser River catchment. Exceedance probabilities were calculated for volumetric outflow at these two stations, and years where sediment records exist were flagged (Figure 4). Results from both sites show that the period of record for sediment (1966-1972) spans nearly the full range of recorded flows. However, the sediment record is biased towards years with above normal flow (P>0.5). Therefore, the average annual sediment load presented in Figure 3A is likely an overestimate relative to long-term flow conditions.

Figure 3 Suspended sediment loads from "Fraser River at Port Mann Pumping Station" (1966-1972, station id = 08MH126).



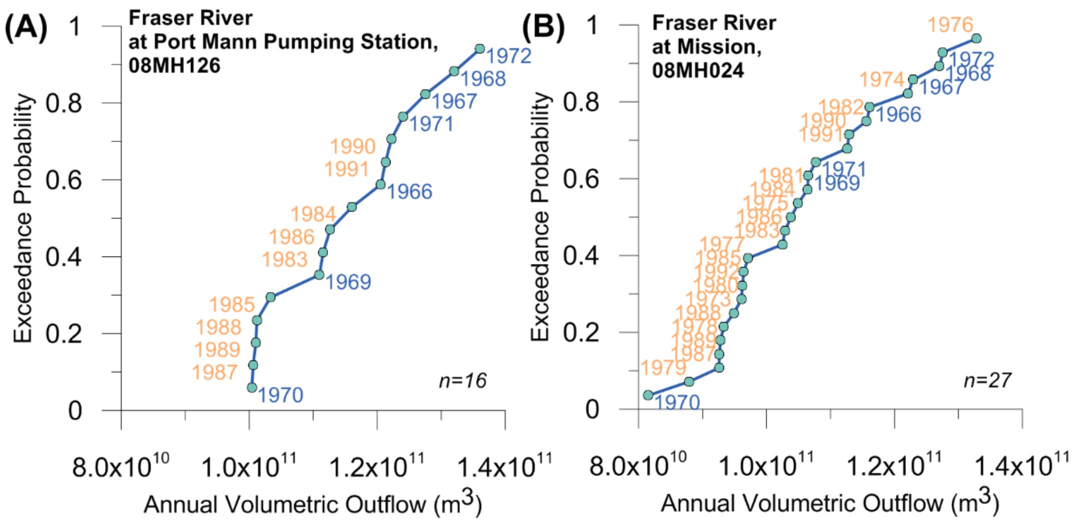
Notes: Box plots summarize maximum, minimum, median, and 25th and 75th in each month. In panel "A," the plot in the background is daily average load (heavy orange line), and the shaded envelope represents the range between daily maxima and minima. Lines in panel "B" are cumulative daily loads for each year of record, and the heavy orange line is the average cumulative load. In panel "C," the heavy blue line represents average daily sediment concentration, and the shaded envelope encompasses maxima and minima on each day.

Table 3 Summary statistics for sediment loads (tonnes) at "Fraser River at Port Mann Pumping Station," 1966 to 1972.

Statistic	January	February	March	April	May	June	July	August	September	October	November	December	Annual Sum
Minimum	749	827	648	1,830	4,500	73,300	14,600	8,760	3,900	3,480	1,640	759	114,993
10th Percentile	1,536	1,224	1,646	3,979	35,080	103,700	32,060	14,050	6,044	4,547	3,360	1,680	208,906
25th Percentile	2,090	1,915	2,280	8,373	70,000	130,500	47,975	17,675	7,448	5,620	3,875	2,460	300,210
Median	3,230	2,890	3,230	15,350	127,000	205,500	78,100	24,850	12,050	7,795	5,605	3,840	489,440
75th Percentile	4,540	4,720	8,120	34,950	208,000	285,000	118,250	38,025	16,225	11,700	9,243	5,590	744,363
90th Percentile	7,930	7,213	23,240	53,140	309,400	449,100	195,600	44,750	20,500	15,660	14,020	8,900	1,149,453
Maximum	58,400	29,400	80,300	187,000	550,000	675,000	311,000	65,400	47,400	133,000	47,000	59,600	2,243,500
Average	5,492	3,942	8,455	24,792	155,561	234,375	93,588	27,903	12,945	10,554	7,892	5,159	590,657
Percent of average annual	1	1	1	4	26	40	16	5	2	2	1	1	100
Standard Deviation	8,715	3,783	12,894	25,998	114,920	130,478	62,165	12,344	7,136	12,673	6,684	5,730	403,519

Note: Data in units of tonnes.

Figure 4 Volumetric outflow exceedance probabilities at “Fraser River at Port Mann Pumping Station,” 1966 to 1991.



Note: Labels in blue are years where suspended sediment data are available. Labels in orange are years where suspended sediment data are not available.

4.1.2 Suspended Sediment Concentration

Daily sediment concentrations were derived from published loads and discharge calculations; the data are summarized in Figure 3C (ECCC 2017). Concentrations are highest in May and June—as high as 650-750 mg/L—with average sediment concentrations of about 270 mg/L in these months (Table 4). Lowest concentrations are from November to January, when flow is lowest. However, the relationship between concentration and discharge is not linear, and is explored in following Section 4.1.3.

Table 4 Summary statistics for sediment concentrations (mg/L) at station at "Fraser River at Port Mann Pumping Station," 1966 to 1972.

Statistic	January	February	March	April	May	June	July	August	September	October	November	December	Annual Average
Minimum	10	7	5	14	37	107	40	31	16	18	10	7	25
10th Percentile	12	10	13	27	113	155	72	43	28	22	18	12	44
25th Percentile	15	13	17	50	177	182	90	50	33	26	21	17	58
Median	21	19	30	75	237	263	135	65	44	32	27	22	81
75th Percentile	33	33	45	134	320	324	172	84	55	44	38	32	109
90th Percentile	50	43	91	186	441	446	226	96	64	54	49	47	149
Maximum	166	110	208	413	764	656	313	150	125	389	125	115	294
Average	30	24	41	96	263	276	139	68	46	40	32	26	90
Standard Deviation	27	16	38	68	138	112	61	22	18	35	16	15	47

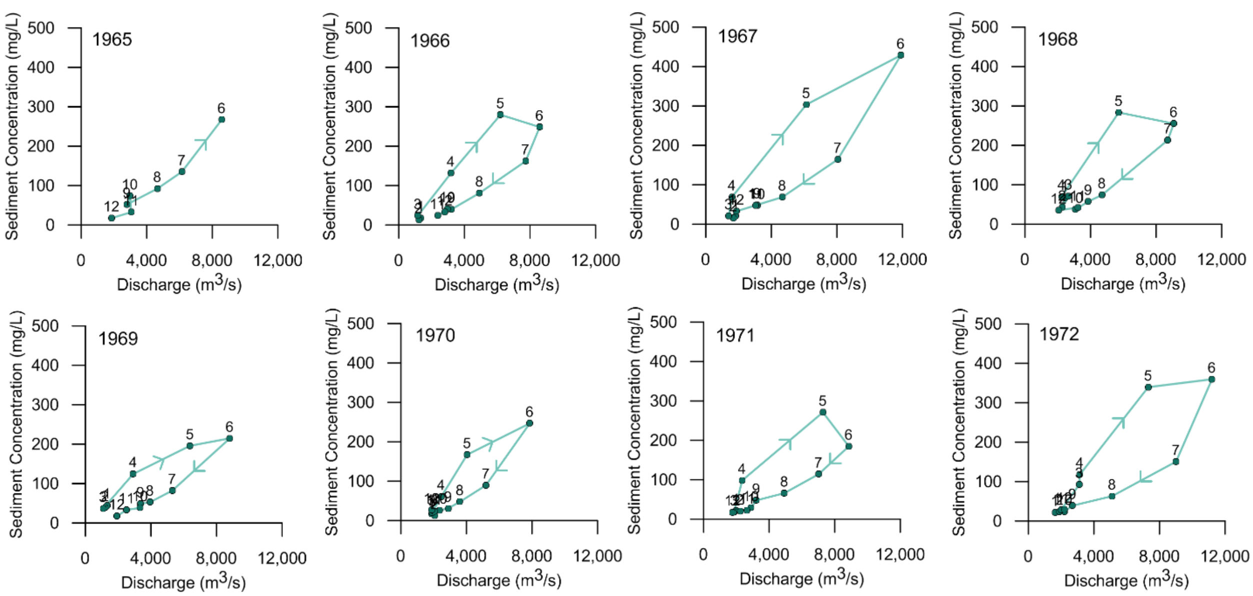
Note: Data are units of milligrams per litre.

Limited data are available for synchronously obtained pairs of suspended sediment concentrations for stations upstream and downstream of the Pattullo Bridge. However, one set of results from 2003 suggests there was no significant difference between concentrations measured at Barnston Island (about 12 km upstream of the Project) and Annacis Island (about 7 km downstream of the Project) (BC MWLAP 2004) (Figure 1). This suggests that the suspended sediment results above are representative of conditions in the LSA and RSA.

4.1.3 Relationships Between Discharge and Sediment Concentrations

Monitored monthly discharge and sediment concentration exhibit clockwise hysteresis (loops that progress in a clockwise direction with time; Figure 5). For a given discharge, sediment concentration is higher prior to freshet on the hydrograph rising limb, compared to the falling limb. This is important from a sediment and water quality perspective, since contaminant concentrations in the Fraser River also exhibit hysteresis (predominantly clockwise, but sometimes counterclockwise or indistinct) (Whitfield and Schreier 1981; Regnier and Shaw 1998).

Figure 5 Relationships between discharge and sediment concentration at "Fraser River at Port Mann Pumping Station," 1965-1972.



Note: Data points represent monthly average, and data labels represent the numeric month.

4.2 BED MATERIAL

4.2.1 Particle Size

Bed material near Pattullo Bridge is typically dominated by sand-sized or coarser particle sizes. The July 2017 sample was composed of 43% gravel, 57% sand, and <1.3% silts and clays. Samples obtained in November 2017 were >98% sand (Table 1).

In a review of the Lower Fraser River sediment budget, median particle size (d_{50}) near the Project area was 0.3 mm to 0.4 mm (medium sand), and d_{10} was about 0.2 mm (fine sand) (nhc 2002). Fine grained sediments tend to be deposited in the lee of obstructions and on banks during floods, and are transported when flow velocity and stage are sufficiently high.

4.2.2 Bed Material Transport

Overall, the Lower Fraser River from the Project to about 6.5 km upstream of the bridge appears to be roughly in equilibrium with respect to bed material transport (nhc 2002). Farther upstream (upstream of Douglas Island), the river is slightly erosional, and bed lowering has occurred. Downstream of Pattullo Bridge, net deposition has resulted in higher dredging volumes over time.

Near Pattullo Bridge, net sediment inflows equal outflows over long time periods. However, temporary storage and re-entrainment of bed material takes place within and between years. Scour conditions at the Pattullo Bridge are potentially the most severe in the lower Fraser River. Tide conditions combined with high river flows cause local bed levels to fluctuate by up to 7 m over a 24 hour period on both sides of the upstream rail bridge (Figure 2) (nhc 2017).

Annual bed material transport near Pattullo Bridge is about 3×10^6 tonnes (and ranges between about 1.2 and 8.9×10^6 tonnes/year) (nhc 2002; nhc 2017). Almost all this material is transported in intermittent suspension and saltation near the bed. Bed dredging in the Lower Fraser River is significant. For example, about 60% of the incoming bed load between 1998 and 2001 was dredged, mostly downstream of Pattullo Bridge. In the reach between Pattullo Bridge and Douglas Island (about 8 km upstream), no dredging was reported between 1998 and 2001; no data were found after 2001.

Measurement of bed load flux is difficult, prone to error, and sensitive to measurement methodology. Also, the historical dataset is not large. It is possible that the sediment budget and erosional/depositional state could change, for example, in response to changing flow conditions and anthropogenic changes.

Many factors control whether particles are transported or deposited in the lower Fraser River, including particle size, discharge, tides, river slope, and river morphology. The location of the salt wedge in the Lower Fraser River is also an important control on deposition/transport; however, it does not influence conditions as far upriver as the Project (BC MWLAP 2004).

4.2.3 Sediment Quality

4.2.3.1 Factors Affecting Sediment Quality near Project Area

Sediment quality is affected by inputs from local and distant upstream inflows, particle size, salinity, and sediment redistribution by currents and tides. Point source pollution can be transported and accumulate hundreds of kilometres downstream (Kummling 1999). Contaminants preferentially adsorb onto finer grained sediments. Particle size generally decreases downstream in the lower Fraser River, and is dominated by sand near Pattullo Bridge. Salinity intrusions and re-suspension also affect the accumulation and distribution of contaminants in sediment (BC MWLAP 2004).

4.2.3.2 Sediment Quality near Pattullo Bridge

Four near-surface sediment samples were collected in July and November 2017 near the Pattullo Bridge (Figure 2, Table 1, Attachment 18.3-A). Results were assessed relative to BC Contaminated Sites Regulations Schedule 9 for Sediment Criteria ("sensitive" and "typical"), and the Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (Province of British Columbia 1997; CCME 1999). No exceedances above standards and guidelines were found.

4.2.3.3 Upstream Sediment Quality

In the Fraser River Mainstem, the Fraser River Action Plan noted that guideline exceedances for dioxins and furans, PAHs, PCBs, and pesticides were common before 1997 (Brewer et al. 1997). Lower Fraser River sediment quality was reviewed by BC MWLAP (2004) for the period between 1987 and 2003. At Barnston Island and the Fraser River Mainstem, where particle size is typically fine sand and silt, dioxin and furan concentrations consistently decreased between 1987 and 2003. Objectives have been consistently met for chlorophenols, PCBs, and PAHs over this period, but not for chromium. The BC Environmental Monitoring System does not contain any sediment quality results since 2003 for the Barnston Island monitoring site (BC MOE 2017b); therefore, additional analyses are not undertaken here.

4.2.3.4 Downstream Sediment Quality

Downstream of Pattullo Bridge, a series of near-surface grab samples and deeper vibracores were obtained near Deas Slough in 2014 for the George Massey Tunnel environmental assessment (Figure 1) (TRAN 2015). Particle size was dominated by silts. Canadian sediment quality guideline (SQG) and interim guideline exceedances were found for PAHs, arsenic, chromium, copper, and organic contaminants. Concentrations of arsenic, chromium, and copper positively correlated with percent fines.

4.3 WATER QUALITY

4.3.1 Water Quality in the Lower Fraser River

Water Quality in the Lower Fraser River near Pattullo Bridge

Three water samples were collected from the Fraser River upstream of Pattullo Bridge in November 2017 (Figure 2, Table 1). Water quality results are presented and summarized in Attachment 18.3-B. Swain et al. (1998) was used to screen a relatively limited set of analytes based on local objectives, and BC MOE (2017b) was used to screen a larger suite of analytes. Concentrations of dissolved aluminum, dissolved iron, and total zinc exceeded in all three samples, while total copper and total iron exceeded in sample SW2-1.

Water Quality in the Lower Fraser River Upstream and Downstream of Pattullo Bridge

Long-term water quality data were obtained from the Environment Monitoring System (EMS) (BC MOE 2017b). Three monitoring stations on the Lower Fraser River near the Pattullo Bridge were selected (Figure 1, Table 2). Two sites are upstream of the Pattullo Bridge and one is downstream. Together, these stations span a 26 km reach of the Lower Fraser River, and were chosen to provide baseline and reference indicators of water quality. The selected water quality monitoring stations are as follows:

- A downstream buoy (station ID=E271643; 13.3 km downstream), where automated sampling has been carried out since August 2008, sampling has been relatively frequent (max observations/analyte = 149), and many variables have been analyzed (130 analytes). Data for this station were retrieved from EMS and ECCC (BC MOE 2017b; ECCC 2018).
- A proximal upstream monitoring site at the New Westminster railway bridge (station ID=0300005; 0.1 km upstream), where monitoring was conducted between August 1988 and March 2003. While the monitoring location is close to the Project site, the dataset is dated, and the suite of analyzed analytes is relatively small. Total metals were analyzed here, but not dissolved metals.
- A second upstream station (station ID=E206965) at the downstream end of Barnston Island, about 1.4 km upstream of the Port Mann Bridge and 12.4 km upstream of Pattullo Bridge. This dataset has a long period of record (January 1987 to March 2011) and a large suite of water quality analytes (n=87). However, compared to the downstream automated buoy, sampling was relatively infrequent (max observations/analyte = 34).

Water quality results were screened against Lower Fraser River water quality objectives (LFRO) (Swain et al. 1998) and the *British Columbia Freshwater Aquatic Life Long Term Average Guidelines* (BC WQG) (BC MOE 2017a). Analytical results with identified guideline exceedances are summarized in Attachment 18.3-C.

Concentrations of several parameters exceeded corresponding guideline values at all three sites. However, these exceedances generally correspond to the *maximum* (or *minimum for pH)* observed concentrations (e.g., these may correspond to extreme historic values, or seasonal maximum/minimum values within a year), rather than the mean or median conditions or values.

More regular exceedances were found for the following variables (i.e., for mean, median, or median plus one standard deviation concentrations):

- **At the farfield upstream Barnston Island site**, BC MOE exceedances were found for dissolved chromium and for total chromium, copper, iron, lead, and manganese.
- **At the proximal upstream New Westminster Bridge site**, BC MOE exceedances were found for total aluminum, cadmium, chromium, cobalt, copper, lead, nickel, silver, and zinc. LFRO exceedances were found for total copper and lead, *Enterococcus*, and fecal coliform. Dissolved metals were not tested at this site.
- **At the downstream Fraser River buoy site**, BC MOE exceedances were found for alkalinity, dissolved aluminum, and total cadmium, chromium, cobalt, copper, selenium, silver, and iron. LFRO exceedances were found for *E. Coli* and *Enterococcus*.

Upstream-downstream Trends

Upstream to downstream trends were investigated by calculating the difference between downstream and upstream median concentrations. The downstream site is the buoy, and the chosen upstream site is the Barnston Island site. The New Westminster site was not used because most data are very old, and dissolved metals were not measured.

A total of 91 analytes were measured at both sites. Of these, 37 (about 40%) have higher median concentrations downstream. Six analytes had much higher[1] upstream concentrations compared to downstream. These include specific conductance, dissolved oxygen, turbidity, alkalinity, *Enterococcus*, and total aluminum. Of these, only alkalinity and *Enterococcus* exceed analyzed WQG at the buoy (Attachment 18.3-C).

Based on the available data, there is no overall upstream-downstream difference in water quality between the two sites. Note that the time periods covered by both sites are different. Potential temporal trends in the data are explored in the next section.

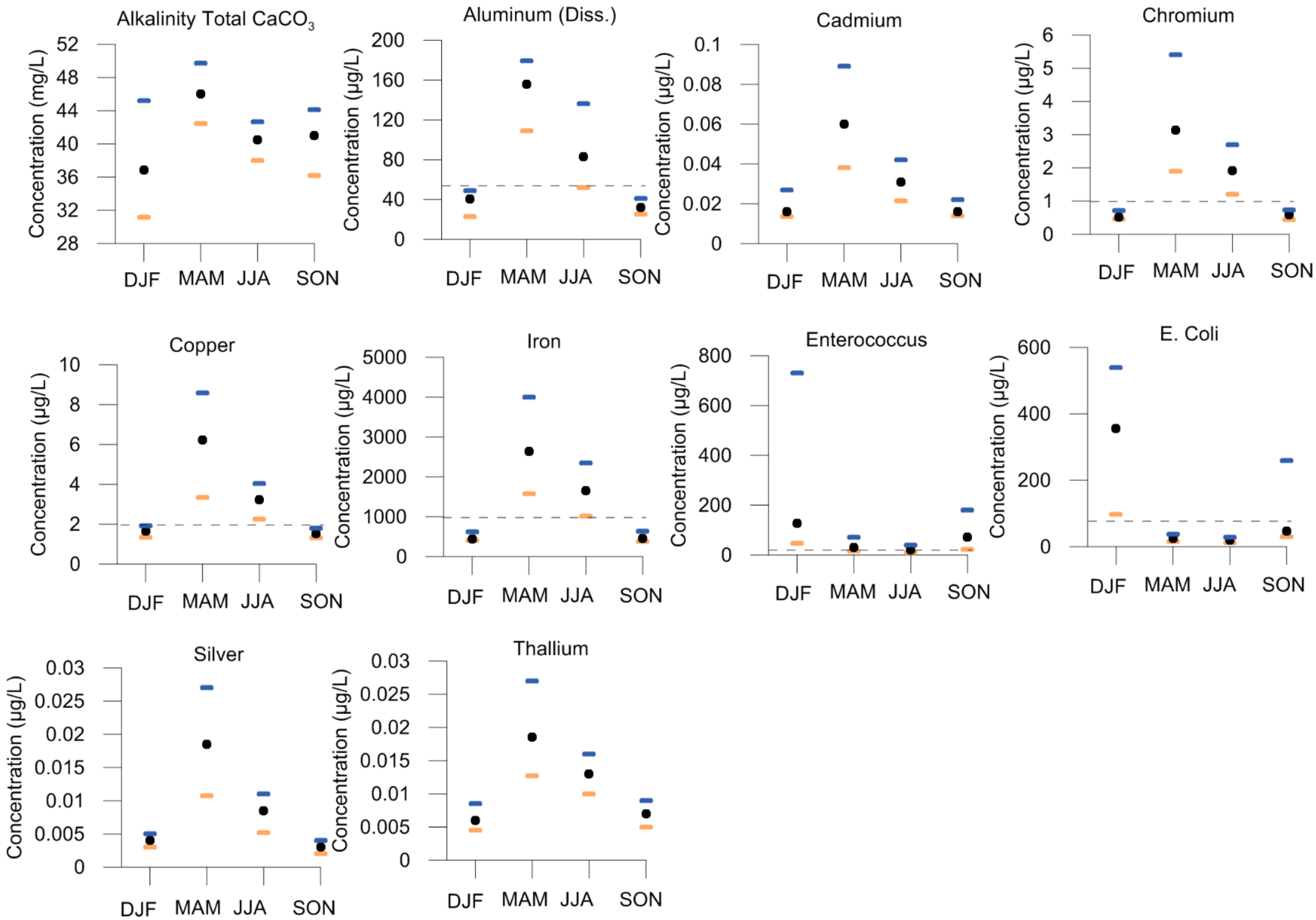
Temporal Trends

Water quality data from the Fraser River buoy were used for analysis of seasonal trends, since a relatively large dataset exists. The dataset size varies by analyte, but on average, data from 11 sampling events are available in winter, 24 in spring, 36 in summer, and 37 in fall. While the sampling frequency is relatively high, the record is relatively short (<10 years), making long-term trends difficult to assess.

Seasonal changes in water quality for analytes that exceed WQG are presented in Figure 6. A total of ten analytes were found to exceed WQG relatively frequently at the buoy. These include alkalinity, dissolved aluminum, total cadmium, chromium, copper, iron, silver, thallium, *E. Coli*, and *Enterococcus*. Concentrations for most of these are highest in spring, the period encompassing discharge, sediment load, and sediment concentration rising limbs (Figure 3). *Enterococcus* and *E. Coli* parameters are exceptions, and peak in fall and winter when discharge and dilution are lowest. Seasonal differences in concentration are especially large for cadmium, copper, *Enterococcus*, *E. Coli*, and thallium. Median concentrations for these elements are more than five times higher in spring than in fall and winter.

[1] Analyte variability was assessed by adding one standard deviation (S) to the median ('median + 1S'). A difference was considered large if the difference between downstream median concentration and upstream median +1S concentration was positive.

Figure 6 Seasonal variability in water quality at "Fraser River Water Quality Buoy" (Station ID= E271643).



Notes: Results are for total concentrations, unless noted. Dashed lines represent WQG thresholds. If a guideline is not shown, it is above or below axes limits. Black dots represent median concentration, and orange and blue horizontal lines represent lower and upper quartiles, respectively.

Figure 6 presents WQG thresholds in relation to the 25th, 50th, and 75th percentile of analytical results. WQG exceedances are sensitive to seasonality for dissolved aluminum, chromium, copper, iron, and microbiological parameters. If a WQG guideline threshold is not shown in Figure 6, then the threshold is beyond y-axes limits.

Additional Lower Fraser River Water Quality Assessments

In a review of 1973 to 2003 Lower Fraser water quality data in the Fraser Mainstem (from Hope to the New Westminster trifurcation), water quality objectives (LFRO) were generally met (BC MWLAP 2004). Exceedances of fecal coliform, *Enterococci*, and copper were found, but these were predominantly from the 1980s. Improvements in fecal coliform, minimum DO, suspended solids, copper, manganese, and zinc were noted. Ammonia, nitrite, and pH remained stable and within objectives. Water samples were also tested against the Canadian Council of Ministers of the Environment (CCME) water quality index, and water quality was rated as “excellent.”

For the upstream New Fraser River Crossing Project (Golden Ears Bridge) environmental assessment, pre-existing water quality data obtained in the fall, winter, and spring of 2002–2003 were reviewed (GVTA 2003). Fecal coliform frequently exceeded maximum objectives for drinking water and occasionally for irrigation/recreational use. Other analyte concentrations were typically low and met objectives.

Water quality was evaluated in 2004 and historic water quality data were reviewed as part of the upstream Port Mann/Highway 1 environmental assessment (EAO 2008). CCME WQG for the protection of aquatic life were used. Parameters that did not meet guidelines included pH, TSS, nitrite, fecal coliforms, some total metals (Al, Fe, Cu, Zn, and Pb), and some polycyclic aromatic hydrocarbons (PAH). Other PAHs, fluoride, and chloride consistently met criteria.

For the downstream George Massey Tunnel (GMT) replacement project, water samples were obtained in September 2014 at five locations upstream and downstream of the tunnel, and assessed against CCME WQG for the protection of aquatic life (TRAN 2015). Results indicate that water quality was good and met guidelines. These results differ from the assessment of water quality at the Lower Fraser River buoy, where several exceedances were recorded. Note that the GMT sampling was done in fall, when contaminant concentrations are typically close to annual minimums. Also, federal WQG were used, rather than the provincial and Fraser River WQG presented here.

These data suggest that water quality in the lower Fraser River exhibits some temporal and spatial variability. Seasonally, it could be expected that concentrations of selected parameters (e.g., metals) could exceed corresponding guideline values. Localized exceedances could also be observed.

Traditional Knowledge of Fraser River Water Quality

Review of Project-specific reports prepared by Aboriginal groups provided information regarding Fraser River water use and water quality. Several Aboriginal groups who have used the area historically and to the present accessed resources in the area, such as hunting grounds, berry patches, habitation and fishing sites, have noted a degradation of water quality over time. Members of the Musqueam Indian Band (2017) have observed a change in water quality within their lifetimes. They recall the Fraser River once being a source of potable drinking water, approximately 50 years ago. Today this is no longer possible due to several point and non-point sources of pollution associated with the various industries in the area.

4.3.2 Water Quality in Tributaries near Pattullo Bridge

Water samples and analytical water quality results were obtained from tributaries that flow into the Fraser River near their mouths (Attachment 18.3-B). Sampling sites are located within about 1.2 km upstream and downstream of Pattullo Bridge. Water quality samples were obtained from Manson Canal and Pattullo Channel in November 2017, both of which are downstream of Pattullo Bridge (Table 1, Figure 2). Water quality was also assessed in upstream Brunette Creek using archived datasets (Table 2, Figure 1). Results are summarized below.

Manson Canal and Pattullo Channel

Water quality results from Manson Canal and Pattullo Channel were screened against the British Columbia Freshwater Aquatic Life Long Term Average Guidelines (BC WQG) (BC MOE 2017a). Dissolved and total iron, total copper, and total zinc concentrations exceeded guidelines in both samples, and total lead exceeded in Manson Canal (Attachment 18.3-B).

Brunette Creek

Brunette Creek enters the Fraser River about 1.2 km upstream of the current Pattullo Bridge, on the right bank. Brunette Creek drains Still, Eagle, and Stoney creeks. At its mouth, Brunette Creek drains an area of 73 km^2 and is about 80% urbanized and 20% vegetated (Greater Vancouver Regional District 2001).

The creek was monitored about 4 km from its mouth by the Water Survey of Canada between 1934 and 1971. Monitored average annual flow was 2.7 m^3/s, with peak flows in winter (mean January flow 5.9 m^3/s; average annual peak flow 36 m^3/s). Salmon disappeared from the Brunette and Still creeks in the 1950s and 1960s, but had returned in small numbers by 2001 (Greater Vancouver Regional District 2001); since then increasing numbers of coho and chum salmon have been returning.

Water quality has been recorded and assessed at the mouth of Brunette River (Macdonald et al. 1997; GVRD 2001). As of 1997, Canadian and/or provincial WQG were being exceeded for dioxins/furans, benzo(a)pyrene, DDT, PCBs, trace metals, pH, total coliforms, and *E. coli*. Concentrations of lead, copper, zinc, nitrogen, and phosphorous were flagged as contaminants of concern (GVRD 2001). High flows during storm events are responsible for the majority of fluxes of contaminants in Brunette Creek. It was also determined that "*based on loading calculations, the Brunette watershed is a significant source of contaminants to the Fraser River receiving environment*" (GVRD 2001).

Results described above were supplemented with more recent data from the Environmental Monitoring System (Site ID = 0300111; Figure 1, Table 2). The only additional data available are from the fall and early winter of 2012. Of the parameters listed above, sufficient recent data were only available for *E. Coli* and nitrogen (nitrate and nitrite). *E. Coli* reached 1,800 to 1,900 CFU/ 100 mL in the fall and winter, which exceeds federal drinking water guidelines (CCME 2016) and Lower Fraser River objectives (Swain et al. 1998). Nitrate and nitrite did not exceed provincial WQG.

Other Tributaries

Water quality samples were obtained and analysed as part of the South Fraser River Perimeter Road environmental assessment (TRAN 2006). About 15 samples from tributaries on the south shore (left bank) of the Lower Fraser River were obtained in March 2004. Results were screened against CCME WQG. Exceedances of DO, pH, total aluminum, iron, and occasionally silver, zinc, pyrenes, and benz(a)anthracene were noted.

Traditional Knowledge of Tributary Water Quality

Water quality in Como Creek, Brunette Creek, Bon Accord Creek and the "old stream" on the south side under the Pattullo Bridge was noted as being particularly concerning (Kwikwetlem First Nation 2017). Profound 20th Century impacts to waterways have been noted, and point-source pollution in tributaries has been noted (Musqueam Indian Band 2017).

5.0 CONCLUSIONS

The following conclusions can be drawn about water quality and bed sediment near the Project:

- *Suspended sediment load*
  - Annual average suspended sediment load is about 1.8×10^7 tonnes based on historic monitoring. Monitoring appears to have sampled years within the full "typical" range of Lower Fraser River flows, with a bias towards years with high discharge and hence high sediment flux.
  - Most sediment flux occurs in May and June (66% on average), with relatively little from September through March.
- *Suspended sediment concentrations*
  - Annual average suspended sediment concentration is about 90 mg/L, but, concentrations are variable throughout the year. Peak concentrations occur in May and June (263 mg/L and 276 mg/L), respectively, and minimum concentrations occur from December through to February.
- *Bed load, bed material, and bed load flux*
  - Median particle size near Pattullo Bridge is fine sand. Bed material particle size distributions contain few silts and clays (<10%); however, fines accumulate in the lee of obstacles and near banks.
  - About 3.0×10^6 tonnes of bed material is transported annually. Roughly the same volume of sediment enters the reach as exits it.
- *Sediment quality*
  - No exceedances were found in four recent sediment samples obtained near Pattullo Bridge.
  - Historically, elevated concentrations of several metal and organic parameters have been noted in the Fraser River upstream and downstream of the Project area. Analytical data for an upstream station were only available up to 2003; however, an improvement in sediment quality was noted from 1987 to 2003.

- Elevated PAHs and elevated concentration for some metals were noted downstream of Pattullo Bridge near the George Massey Tunnel in 2014.
- These results suggest that while sediment concentrations near the Pattullo Bridge may not locally exceed corresponding guideline values, there is potential for regional exceedances.

- *Water quality in the Lower Fraser River*
  - Water samples obtained near Pattullo Bridge in 2017 had exceedances of dissolved aluminum, dissolved iron, and total zinc.
  - At long-term monitoring sites, water quality guidelines and objectives have been exceeded for microbiological parameters, physical parameters (pH and dissolved oxygen), and total and dissolved metals, both upstream and downstream of Pattullo Bridge.
  - Several studies have noted improvements to water quality in the Fraser River, and Lower Fraser River water quality has been rated as "excellent" overall (BC MWLAP 2004).
  - The most recent and most frequent water quality data are from downstream of Pattullo Bridge at the buoy (ID E271643; Table 2, Attachment 18.3-C). Results include:
    - WQG exceedances are most common for alkalinity, dissolved aluminum, total cadmium, chromium, copper, iron, silver, thallium, *E. Coli*, and *Enterococcus*.
    - WQG exceedances are most frequent, and higher parameter concentrations are most common in spring and typically least frequent and lowest in fall and winter.
  - Based on available data, there is no clear evidence for upstream-downstream trends in water quality, and time series are too short to assess long-term trends.

- *Water quality in nearby inflows*
  - Downstream of Pattullo Bridge, In Manson Canal and Pattullo Channel, water quality guidelines were exceeded for dissolved and total iron, total copper, and total zinc in November 2017.
  - In small creeks downstream of Pattullo Bridge on the Fraser River south shore, WQG exceedances have also been noted. Exceedances of DO, pH, total aluminum, chromium, iron, and occasionally silver, zinc, pyrenes, and benz(a)anthracene were found (TRAN 2006).
  - Upstream of Pattullo Bridge, water quality in the Brunette River has historically been low. Based on flow volumes and water quality, this river has the potential to be a significant source of contaminants. Until 1997, Canadian and/or provincial WQG were being exceeded in the Brunette River for dioxins/furans, benzo(a)pyrene, DDT, PCBs, trace metals, pH, total coliforms, and *E. coli*. Concentrations of lead, copper, zinc, nitrogen, and phosphorous were flagged as contaminants of concern. The dataset is of insufficient length to assess seasonality of exceedances. Insufficient data exist to evaluate water quality in Brunette River since 1997, except for *E. Coli* and nitrogen. *E. Coli* counts remained above WQG as of 2012.

6.0 LITERATURE CITED

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ATTACHMENTS

Attachment 18.3-A

Sediment Quality Summary

Table 18.3-A-1 Sediment quality in the Fraser River near the Pattullo Bridge in November 2017, and comparison to standards and guidelines.

Parameter	Lowest Detection Limit	Units	BC Sensitive Freshwater Sediment Standard	BC Typical Freshwater Sediment Standard	Interim Sediment Quality Guidelines for Canada (Fresh water)	SED1-1	SED2-1	SED2-2	Detection Limit	609142-01-B417-1
Sampling Date	-	-	-	-	-	28-Nov-17	28-Nov-17	28-Nov-17	-	31-Jul-17
Physical Tests										
pH	0.1	pH	-	-	-	7.69	8.26	7.92	0.1	8.54
Metal										
Arsenic (As)	100	µg/kg	11,000	20,000	5,900	3,340	3,610	4,870	100	3,480
Cadmium (Cd)	20	µg/kg	2,200	4,200	600	124	98	183	50	121
Chromium (Cr)	500	µg/kg	56,000	110,000	37,300	17,100	31,000	30,800	500	14,800
Copper (Cu)	500	µg/kg	--	--	35,700	13,100	15,200	24,300	500	14,200
Lead (Pb)	500	µg/kg	120,000	240,000	35,000	2,580	2,780	4,670	500	2,050
Mercury (Hg)	50	µg/kg	57,000	580	170	<50	<50	<50	50	<50
Zinc (Zn)	2000	µg/kg	200,000	380,000	123,000	39,800	40,200	54,300	2,000	37,100
Polycyclic Aromatic Hydrocarbons										
Acenaphthene	5	µg/kg	55	110	6.7	<5	<5	<5	50	<50
Acenaphthylene	5	µg/kg	80	150	5.9	<5	<5	<5	50	<50
Anthracene	4	µg/kg	150	290	46.9	<4	<4	<4	50	<50
Benz(a)anthracene	10	µg/kg	240	460	31.7	<10	<10	<10	50	<50
Benzo(a)pyrene	10	µg/kg	480	940	31.9	<10	<10	<10	50	<50
Chrysene	10	µg/kg	530	1,000	57.1	<10	<10	<10	50	<50
Dibenz(a,h)anthracene	5	µg/kg	84	160	6.2	<5	<5	<5	50	<50
Fluoranthene	10	µg/kg	1,500	2,800	111	<10	<10	<10	50	<50
Fluorene	10	µg/kg	89	170	21.2	<10	<10	<10	50	<50
Naphthalene	10	µg/kg	240	470	34.6	<10	<10	10	50	<50
Phenanthrene	10	µg/kg	320	620	41.9	<10	<10	<10	50	<50
Pyrene	10	µg/kg	540	101,000	53	<10	<10	<10	50	<50

Note: Data are 'dry weight' concentrations.

Attachment 18.3-B

Water Quality Summary

Table 18.3-B-1 Summary of Fraser River water quality guideline exceedances near Pattullo Bridge, November 2017.

Parameter	Unit	Lowest Detection Limit	BC MOE (2017)	Swain (1988)	SW1-1	SW2-1	SW3-1
Conventional							
pH	pH	0.1	6.5-9	6.5-8.5	7.68	7.77	7.71
Total Hardness (as	mg/L	0.5	-	-	25.5	33.1	26.9
Dissolved metals							
Aluminum	mg/L	0.001	0.05	-	**0.058**	**0.067**	**0.058**
Iron	mg/L	0.01	0.35	-	**0.047**	**0.062**	**0.048**
Total metals							
Copper	mg/L	0.0005	0.00004-0.002[a]	[b]	0.00176	**0.00218**	0.00174
Iron	mg/L	0.01	1	-	0.8	**1.11**	0.8
Zinc	mg/L	0.003	[c]	≤0.14	**0.0145**	**0.012**	**0.01**

Bolded data represent exceedances of "BC Approved Water Quality Guideline – Freshwater Aquatic Life – Long Term Average" (BC MOE, 2017) and/or Swain's Lower Fraser water quality guidelines (Swain 1998).

a: Hardness-dependent. Guideline = 0.00004 mg/L at CaCO3 >50 mg/L; guideline = 0.002 mg/L at CaCO3 <50mg/L.

b: Hardness-dependent. Guideline = 0.002 mg/L at hardness <50 mg/L; Guideline = [0.04(mean hardness)]/1000 mg/L at hardness >50 mg/L.

c: Hardness-dependent. Guideline = 0.0075 mg/L at hardness ≤90 mg/L; Guideline = (7.5 + 0.75 x (hardness -90))/1000 at hardness >90 mg/L

Table 18.3-B-2 Summary of water quality guideline exceedances from Manson Drainage Canal and Pattullo Channel, November 2017

Parameter	Units	Relative Detection Limit	BC water quality guidelines	MANC-1	PAT-1
Conventional Variables					
Total Hardness (as Ca	mg/L	0.5	-	95.2	82.5
Dissolved metals					
Iron	mg/L	0.005	0.35	0.7	0.43
Total metals					
Copper	mg/L	0.0005	0.00004-0.002[a]	**0.016**	**0.005**
Iron	mg/L	0.01	1	**3.2**	**2.4**
Lead	mg/L	0.0002	[c]	**0.0092**	0.0012
Zinc	mg/L	0.005	[b]	**0.051**	**0.031**

Bolded data represent exceedances of "BC Approved Water Quality Guideline – Freshwater Aquatic Life – Long Term Average" (BC MOE, 2017)

a: Hardness-dependent. Guideline = 0.00004 mg/L at CaCO3 >50 mg/L; guideline = 0.002 mg/L at CaCO3 <50mg/L.

b: Hardness-dependent. Guideline = (7.5 + 0.75 x (hardness -90))/1000

c: Hardness dependent. Guideline = (3.31+ e(1.273 ln(average hardness)-4.705))/1000

Attachment 18.3-C

Regional Water Quality Summary

Table 18.3-C-1 Summary of 1987 - 2011 water quality guideline exceedances for farfield upstream water quality results from "Fraser River at Barnston Island" (Station ID= E206965).

Parameter	Units	Maximum	Minimum	Mean	Median	Standard Deviation (S)	Median +1S	Latest Date	Total Obs.	Used Obs.
Dissolved metals										
Chromium	mg/L	**0.0012**	< 0.0001	0.00033	0.0002	0.00036	0.00069	7/3/2011	32	16
Total metals										
Antimony	mg/L	**0.06**	0.00002	0.00005	0.00005	0.00001	0.00006	7/3/2011	34	32
Arsenic	mg/L	**0.06**	0.0004	0.00047	0.00048	0.00008	0.00055	7/3/2011	34	32
Chromium	mg/L	**0.013**	0.0001	**0.0013**	0.0002	0.00295	0.00425	7/3/2011	34	26
Cobalt	mg/L	**0.014**	0.00003	0.0006	0.00011	0.00242	0.00302	7/3/2011	34	33
Copper	mg/L	**0.008**	0.00069	0.0015	0.00097	0.00151	**0.00301**	7/3/2011	35	34
Iron	mg/L	**6.42**	0.106	0.81	0.216	1.63678	**2.447**	7/3/2011	27	27
Lead	mg/L	**0.07**	0.00003	0.00228	0.0001	0.01197	**0.01425**	7/3/2011	35	34
Manganese	mg/L	**0.0813**	0.00808	0.01855	0.0149	0.01531	**0.03386**	7/3/2011	34	34
Selenium	mg/L	**0.06**	< 0.00004	0.00014	0.0002	0.00005	0.00019	7/3/2011	34	15
Silver	mg/L	**0.01**	< -	-	0.00002	-	-	7/3/2011	34	1
Zinc	mg/L	**0.013**	0.0005	0.00196	0.00115	0.00258	0.00454	7/3/2011	34	33

Notes:

Underlined data represent exceedances of Lower Fraser River water quality objectives (Swain et al. 1998)

Bolded data represent exceedances of “BC Approved Water Quality Guideline – Freshwater Aquatic Life – Long Term Average” (BC MOE 2017)

* Short-term life guideline

WQG thresholds that depend on hardness or pH were calculated using max/min/mean/median values, or typical ranges where appropriate.

If “Used Obs.” is <10, then only median statistics are shown.

Table 18.3-C-2 Summary of 1988 - 2003 water quality guideline exceedances for upstream water quality results from "Fraser River, New Westminster Bridge" (Station ID= 0300005).

Parameter	Units	Maximum	Minimum		Mean	Median	Standard Deviation (S)	Median +1 S	Latest Date	Total Obs.	Used Obs.
Total metals											
Aluminum	mg/L	-	-	-	-	**0.0662**	-	-	3/13/2003	5	5
Cadmium	mg/L	-	-	-	-	**0.01**	-	-	3/13/2003	15	4
Chromium	mg/L	-	-	-	-	**0.01**	-	-	3/13/2003	15	0
Cobalt	mg/L	-	-	-	-	**0.1**	-	-	3/13/2003	15	4
Copper	mg/L	**<u>0.05</u>**	<	0.001	**<u>0.007</u>**	**<u>0.003</u>**	0.014	**<u>0.017</u>**	3/13/2003	15	13
Lead	mg/L	**<u>0.1</u>**	-	0	0.001	**<u>0.1</u>**	0.001	**<u>0.101</u>**	3/13/2003	15	11
Nickel	mg/L	-	-	-	-	**0.05**	-	-	3/13/2003	15	6
Silver	mg/L	**-**	-	**-**	-	**0.00002**	-	-	3/13/2003	5	0
Zinc	mg/L	-	-	-	-	**0.01**	-	-	3/13/2003	14	8
Physical tests											
pH	pH	**<u>9.6</u>**	-	**<u>6.4</u>**	7.84	7.8	1.01	8.81	3/13/2003	19	19
Oxygen Dissolved	mg/L	13.8	-	<u>8.3</u>	11.26	11.3	2.26	13.56	3/27/1991	10	10
Microbiological Parameters											
Enterococcus	CFU/100mL	110	-	9	<u>36</u>	26	30	<u>56</u>	5/3/2003	13	13
Coliform - Fecal	CFU/100mL	3220	-	10	<u>277</u>	73	575	<u>648</u>	5/3/2003	38	38
Psudomonas	CFU/100mL	-	-	-	-	<u>2</u>	-	-	5/3/2003	7	3

Notes:

<u>Underlined</u> data represent exceedances of Lower Fraser River water quality objectives (Swain et al. 1998)

Bolded data represent exceedances of “BC Approved Water Quality Guideline – Freshwater Aquatic Life – Long Term Average” (BC MOE 2017)

*Short-term life guideline

WQG thresholds that depend on hardness or pH were calculated using max/min/mean/median values, or typical ranges where appropriate.

If “Used Obs.” is <10, then only median statistics are shown.

Table 18.3-C-3 Summary of 2008 - 2016 water quality guideline exceedances for downstream water quality results from "Fraser River Water Quality Buoy" (Station ID= E271643).

Parameter	Units	Maximum		Minimum	Mean	Median	Standard Deviation (S)	Median +1 S	Latest Date	Total Obs.	Used Obs.
Anions and Nutrients											
Alkalinity Total	mg/L	**130**		0.53	**42.39**	**42.45**	10.4	**52.78**	4/11/2016	114	114
Dissolved metals											
Aluminum	mg/L	**0.281**		0.0043	**0.08276**	0.0464	0.06635	**0.1128**	12/22/2015	87	87
Chromium	mg/L	0.001		0.00007	0.0002	0.00012	0.00014	0.0003	12/22/2015	87	74
Copper	mg/L	**0.00265**		0.0006	0.00111	0.00091	0.00048	0.0014	12/22/2015	87	87
Iron*	mg/L	**0.372**		0.018	0.09853	0.0594	0.08382	0.1432	12/22/2015	87	87
Total metals											
Antimony	mg/L	**0.023**		0.00002	0.00031	0.00006	0.00218	0.0022	12/22/2015	113	113
Arsenic	mg/L	**0.0275**		0.00037	0.00096	0.00055	0.00259	0.0031	12/22/2015	113	113
Cadmium	mg/L	**0.0237**		0.00001	**0.00026**	0.00002	0.00223	**0.0023**	12/22/2015	113	113
Chromium	mg/L	**0.0245**		0.00031	**0.0021**	**0.001**	0.00287	**0.0039**	12/22/2015	113	113
Cobalt	mg/L	**0.0286**		0.00015	0.00118	0.00054	0.00277	0.0033	12/22/2015	113	113
Copper	mg/L	**0.0276**		0.0003	**0.00352**	**0.00215**	0.00347	**0.0056**	12/22/2015	113	113
Iron*	mg/L	**7.82**		0.02	**1.5**	0.9	1.52	**2.42**	12/22/2015	113	113
Lead	mg/L	**0.0285**		0.00001	0.00099	0.00045	0.00272	0.0032	12/22/2015	113	113
Manganese	mg/L	0.235		0.0066	0.05067	0.0314	0.04691	0.0783	12/22/2015	113	113
Nickel	mg/L	**0.0287**		0.00069	0.00375	0.00199	0.00422	0.0062	12/22/2015	113	113
Selenium	mg/L	**0.0298**	<	0.00005	0.0004	0.00008	0.00284	0.0029	12/22/2015	113	112
Silver	mg/L	**0.0206**		0	0.00023	0.00001	0.00197	**0.002**	12/22/2015	113	113
Thallium	mg/L	**0.0305**		0	0.00032	0.00001	0.00289	**0.0029**	12/22/2015	113	113
Uranium	mg/L	**0.0279**		0.00005	0.00052	0.00022	0.00265	0.0029	12/22/2015	113	113
Zinc	mg/L	**0.0495**		0.00029	0.00541	0.003	0.00646	0.0095	12/22/2015	113	113
Physical tests											
pH	pH	8.4		5.6	7.71	7.74	0.28	8.02	4/11/2016	143	143
Microbiological Parameters											
E. Coli	CFU/100mL	1100	<	1	88	28	166	194	4/11/2016	109	108
Enterococcus	CFU/100mL	2000	<	1	108	38	245	283	4/11/2016	109	105

Notes:

Underlined data represent exceedances of Lower Fraser River water quality objectives (Swain et al. 1998)

Bolded data represent exceedances of “BC Approved Water Quality Guideline – Freshwater Aquatic Life – Long Term Average” (BC MOE 2017)

*Short-term life guideline

WQG thresholds that depend on hardness or pH were calculated using max/min/mean/median values, or typical ranges where appropriate.