APPENDIX K
SURFACE WATER QUALITY

SPRINGBANK OFF-STREAM RESERVOIR PROJECT Environmental Impact Assessment

Volume 4: Appendices
Appendix K

Surface Water Quality Technical Data Report

Prepared for:
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Abbreviations

AA	atomic absorption spectroscopy
AB WQG	Alberta water quality guideline
AEP	Alberta Environment and Parks
$CaCO_3$	calcium carbonate
CCME	Canadian Council of Ministers of the Environment
COV	coefficient of variation
CWQG	Canadian water quality guideline
EIA	environmental impact assessment
ER WQO	Elbow River water quality objective
ESRD	Alberta Environment and Sustainable Resource Development (now AEP)
IC	ion chromatography
ICAPES	inductively coupled argon plasma emission spectrometry
ICP-MS	inductively coupled plasma mass spectrometry
ISQG	interim sediment quality guideline
LAA	local assessment area
LOWESS	locally weighted scatterplot smoothing
MCPP	Mecoprop
QC	quality control
RAA	regional assessment area
SVM	seasonal variability metric

TDR	technical data report
TDS	total dissolved sediment
the City	the City of Calgary
the Project	Springbank Off-stream Reservoir Project
TOC	total organic carbon
TP	total phosphorus
TSS	total suspended sediment
US	United States

1.0 INTRODUCTION

This appendix has information on surface water quality and sediment quality data that supports the environmental assessment for the Springbank Off-stream Reservoir Project (the Project). Surface water quality refers to the chemistry of water in watercourses, which are defined as rivers, creeks and streams, and waterbodies, such as lakes and ponds. This report focuses on the upper Elbow River (defined as a reach from the headwaters of Elbow River to Glenmore Reservoir), Elbow River tributaries and Glenmore Reservoir.

Water quality is closely associated with sediment (i.e., fine particle deposits) quality in watercourses and waterbodies. Because of this close relationship, sediment quality data are provided in this appendix. In addition, soil chemistry data for the off-stream reservoir are presented.

Specifically, this appendix:

- lists data sources (i.e., historical monitoring data and Project-specific field data)
- identifies data collection methods
- explains how data was analyzed
- presents results of data analysis

2.0 METHODS

2.1 STUDY AREAS

Study areas for surface water quality are consistent with the hydrology assessment and technical data report (TDR). The areas were selected at both regional and local scales to examine the potential cumulative changes to watercourses resulting from the Project and other development in the watershed. The local assessment area (LAA) is the low-level outlet channel (i.e., the unnamed creek that runs through the reservoir) and the Elbow River from the diversion structure to the inlet of the Glenmore Reservoir. The LAA encompasses the water quality modelling domain. The regional assessment area (RAA) is the upper Elbow River watershed, including Glenmore Reservoir. The upper Elbow River is defined as a reach from its headwaters to Glenmore Reservoir.

2.1.1 Selection of Measurement Endpoints

Baseline measurement endpoints (i.e., parameters) were selected based the Project Terms of Reference: "*describe the current baseline water quality of watercourses and waterbodies (unnamed creek, Elbow River, and the Glenmore Reservoir) and their seasonal variations, temporal and spatial trends. Include water quality for high flow events (1:20-year and 1:100-year) under current conditions. Consider appropriate water quality parameters (e.g., metals, nutrients, pesticides, temperature, BOD/TOC, bacteria, … , dissolved oxygen, etc.) Provide a summary of existing information available from literature review(s)*", see Table 2-1.

Table 2-1 Measurement Endpoints

Group	Measurement Endpoint
Physical parameters	Temperature pH and alkalinity Dissolved oxygen Total suspended sediment (TSS) Bacteria Particle size (for sediment)
Ions and ion balance	Sodium Chloride Potassium Fluoride Sulphate Sulphide Hardness Total dissolved sediment (TDS)

Table 2-1 Measurement Endpoints

Group	Measurement Endpoint
Nutrients and Carbon	Nitrite and nitrate Total Kjeldahl nitrogen (i.e. sum of ammonia and organic nitrogen) Ammonia Dissolved phosphorus Total phosphorus Total organic carbon (TOC)
Metals	Aluminum (Al) Antimony (Sb) Arsenic (As) Barium (Ba) Boron (B) Cadmium (Cd) Chromium (Cr) Copper (Cu) Iron (Fe) Lead (Pb) Lithium (Li) Manganese (Mn) Mercury (Hg) Molybdenum (Mo) Nickel (Ni) Selenium (Se) Silver (Ag) Strontium (Sr) Vanadium (V) Zinc (Zn)
Pesticides	Water quality data were available for 40 herbicides and 17 insecticides

2.2 DESKTOP DATA REVIEW

2.2.1 Water Quality

Relevant water quality data for the RAA were sourced from Alberta Environment and Parks (AEP) water quality database and the City of Calgary (the City) water quality database (Table 2-2, Figure 2-1). Additionally, a search for reports and journal articles related to water and sediment quality in the RAA was completed.

2.2.2 Sediment Quality

No sediment quality data were available for the RAA from AEP or the City, and no relevant reports were identified.

Table 2-2 Relevant Water Quality Data for the Regional Assessment Area

Site ID	Site Name	Source	Longitude	Latitude	First Year	Last Year
Elbow River Mainstem Sites						
N/A	Elbow River above Bragg Creek[a]	City of Calgary	-114.581043	50.943478	1998	2013
AB05BJ0115	Elbow River upstream of Bragg Creek RDB[a]	AEP	-114.343000	50.946390	1999	2002
N/A	Elbow River at Highway 22 Bridge[b]	City of Calgary	-114.466077	51.032861	1998	2013
ER H22	Elbow River at Highway 22 Bridge	Stantec	-114.466669	51.032943	2015	2016
AB05BJ0170	Elbow River at Highway 22[b]	AEP	-114.280500	51.031940	1979	2002
AB05BJ0290	Elbow River upstream of Twin Bridges at Highway 8[c]	AEP	-114.142500	51.016670	1979	2009
N/A	Elbow River at Twin Bridges[c]	City of Calgary	-114.237602	51.013748	1982	2013
AB05BJ0295	Elbow River downstream of Twin Bridges[c]	AEP	-114.141200	51.014030	1999	2008
N/A	Elbow River at Sarcee Bridge[d]	City of Calgary	-114.165348	50.995597	1981	2015
AB05BJ0300	Elbow River at Sarcee Bridge[d]	AEP	-114.095500	50.995000	1988	1999
AB05BJ0320	Elbow River at Weaselhead Bridge[e]	AEP	-114.085000	50.991670	1999	2002
N/A	Elbow River at Weaselhead Foot Bridge[e]	City of Calgary	-114.147664	50.992120	1991	2013
Elbow River Tributary Sites						
TR1	Outlet channel (unnamed tributary)	Stantec	-114.394953	51.046729	2016	2016
N/A	Lott Creek near mouth[f]	City of Calgary	-114.236598	51.008734	2002	2013
AB05BJ0020	Lott Creek at mouth[f]	AEP	-114.141100	51.008530	1986	2002
AB05BJ0200	Millburn Creek near the mouth	AEP	-114.230800	51.037170	1989	2002
AB05BJ0190	Pirmez Creek at the mouth	AEP	-114.235700	51.041530	1989	2002
AB05BJ0210	Springbank Creek near the mouth	AEP	-114.191400	51.035580	1989	2002

Table 2-2 Relevant Water Quality Data for the Regional Assessment Area

Site ID	Site Name	Source	Longitude	Latitude	First Year	Last Year
Glenmore Reservoir Sites						
N/A	Glenmore Reservoir - Raw Water Intake[g]	City of Calgary	-114.097400	51.000600	2000	2015

NOTES:

[a] Data for AEP site AB05BJ0115 Elbow River upstream of Bragg Creek RDB and the City site Elbow River above Bragg Creek were combined because the locations are close and water quality is assumed to be the same or very similar between the two sites.

[b] Data for AEP site AB05BJ0170 Elbow River at Highway 22, the City site Elbow River at Highway 22 Bridge, and Stantec data for the Elbow River at Highway 22 (ER H22) were combined because the locations are close and water quality is assumed to be the same or very similar between the three sites.

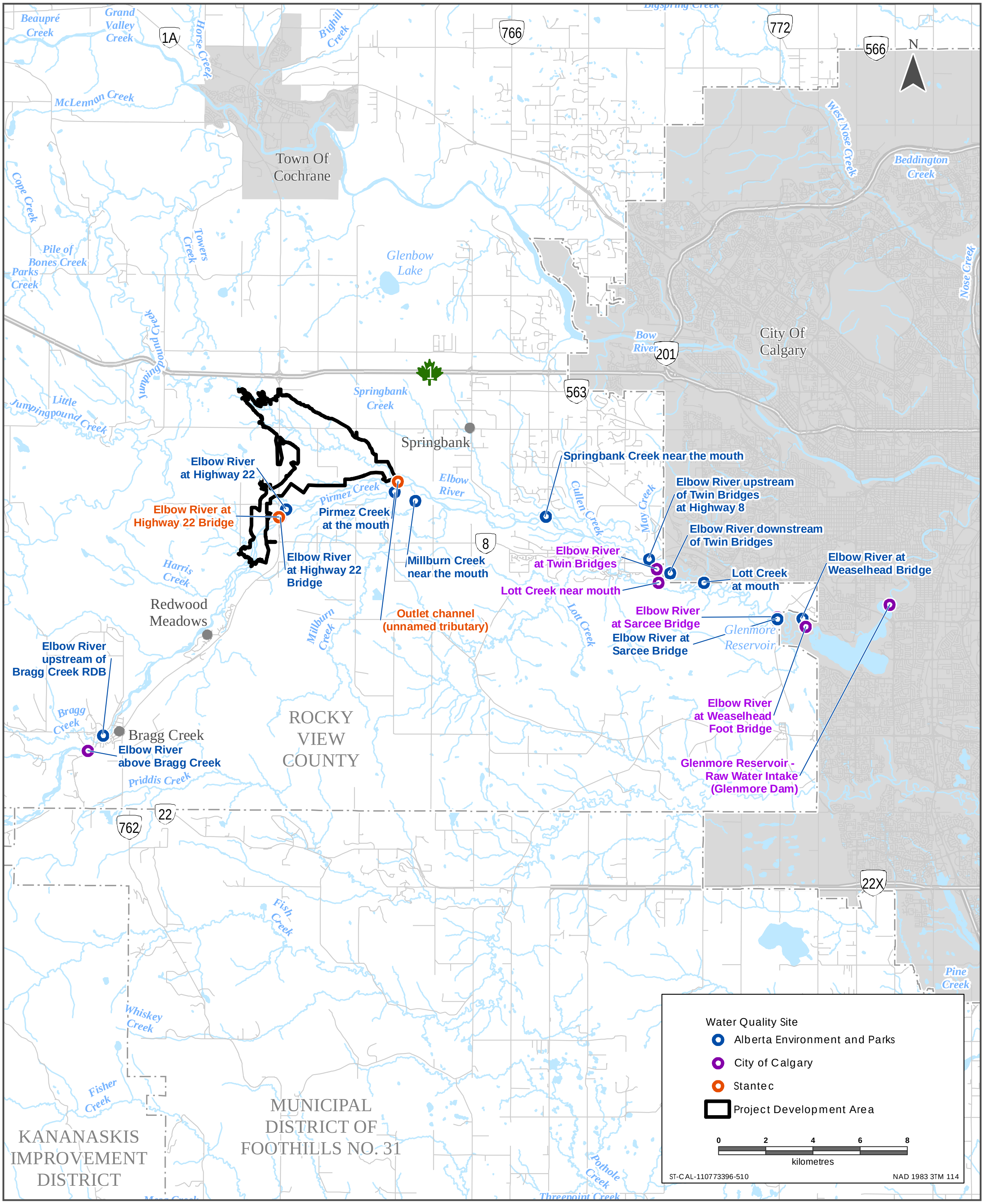
[c] Data for AEP site AB05BJ0290 Elbow River upstream of Twin Bridges at Highway 8, site AB05BJ0295 Elbow River downstream of Twin Bridges and the City site Elbow River at Twin Bridges were combined because the locations are close and water quality is assumed to be the same or very similar between the three sites.

[D] Data for AEP site AB05BJ0300 Elbow River at Sarcee Bridge and the City site Elbow River at Sarcee Bridge were combined because the locations are close and water quality is assumed to be the same or very similar between the two sites.

[E] Data for AEP site AB05BJ0320 Elbow River at Weaselhead Bridge and the City site Elbow River at Weaselhead Foot Bridge were combined because the locations are close and water quality is assumed to be the same or very similar between the two sites.

[F] Data for AEP site AB05BJ0020 Lott Creek at mouth and the City site Lott Creek near mouth were combined because the locations are close and water quality is assumed to be the same or very similar between the two sites.

[G] Data for the City sampling locations in the Glenmore Reservoir Water Treatment Plant at the raw water intake and dichlorination building were combined.



Sources: Base Data - ESRI, Natural Earth, Government of Alberta, Government of Canada
Thematic Data - ERBC, Government of Alberta, Stantec Ltd

Relevant Water Quality Sites in the Regional Assessment Area

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 2-1

2.2.3 Field Data Collection

2.2.3.1 Water Quality

Water quality data were collected by Stantec Consulting Ltd. in 2016 from the Elbow River at Highway 22 and in the low-level outlet channel, which is an unnamed tributary of the Elbow River that flows through the reservoir footprint (see Table 2-2, Figure 2-1).

Sampling procedures followed the *Protocols Manual for Water Quality Sampling in Canada* (CCME 2011) and *Aquatic Ecosystems Field Sampling Protocols* (AENV 2006). Field teams collected one grab sample per site per visit. Grab samples were submitted to ALS Canada Ltd. in Calgary for the laboratory analyses of general chemistry, nutrients, and hydrocarbons. Sampling dates were selected to represent as wide a range of flow conditions as possible. All laboratory parameters were analyzed for high and low flows, and additional samples were collected for total suspended sediment (TSS) and total phosphorus (TP) in between full parameter sampling events. For sampling dates and parameters, see Table 2-3, and or a full list of analytical parameters and analytical methods, see Table 2-4.

Table 2-3 Water Quality Sampling Dates and Parameters

Date	Site ID(s)	Parameters
20-May-16	ER H22	In situ, all lab parameters
26-May-16	ER H22	In situ, TSS, TP
30-May-16	ER H22	TSS, TP
3-Jun-16	ER H22	TSS, TP
3-Jun-16	TR1	In situ, all lab parameters
14-Jun-16	ER H22	In situ, TSS, TP
22-Jun-16	TR1	In situ, all lab parameters
23-Jun-16	ER H22	In situ, all lab parameters
18-Jul-16	TR1	In situ, all lab parameters
19-Jul-16	ER H22	In situ, all lab parameters
19-Jul-16	TR1	In situ, TSS, TP
3-Aug-16	TR1	In situ, all lab parameters
1-Sep-16	TR1, ER H22	In situ, TSS, TP
NOTES: TSS = total suspended sediment TP = total phosphorus		

Table 2-4 Water Quality Analytical Parameters and Methods

ALS Test Description	ALS Method
Colour (True) by Spectrometer	APHA 2120 Color
Hardness	APHA 2340B
Total Suspended sediment	APHA 2540 D-Gravimetric
Turbidity	APHA 2130 B-Nephelometer
Chloride in Water by IC	EPA 300.1 (mod)
Fluoride in Water by IC	EPA 300.1 (mod)
Ion Balance Calculation	APHA 1030E
Nitrate+Nitrite	CALCULATION
Ammonia-N	Grasshof NH3 1999
Nitrite in Water by IC	EPA 300.1 (mod)
Nitrate in Water by IC	EPA 300.1 (mod)
Phosphorus (P)-Total	APHA 4500-P PHOSPHORUS
Phosphorus (P)-Total Dissolved	APHA 4500-P PHOSPHORUS
pH, Conductivity and Total Alkalinity	APHA 4500H,2510,2320
Sulfate in Water by IC	EPA 300.1 (mod)
Sulphide	APHA 4500 -S E-Auto-Colorimetry
Total Kjeldahl Nitrogen by Fluorescence	APHA 4500-NORG (TKN)
Dissolved Organic Carbon	APHA 5310 B-Instrumental
Total Organic Carbon	APHA 5310 B-Instrumental
Total Mercury in Water by CVAAS	EPA 1631E (mod)
Total Metals in Water by HR-ICPMS	EPA 200.8
Total Metals in Water by ICPOES	EPA SW-846 3005A/6010B
Dissolved Mercury in Water by CVAAS	APHA 3030B/EPA 1631E (mod)
Diss. Metals in Water by HR-ICPMS	EPA 200.8
BTEX, Styrene and F1 (C6-C10)	EPA 8260C/5021A, and CWS PHC Tier 1
F2, F3, F4	EPA 3511/ CCME PHC CWS GC-FID

In situ water quality data for dissolved oxygen, temperature, specific conductivity, and pH were collected once per site per visit with a YSI Multi Probe Plus. At the sampling site, the YSI instrument probe was immersed directly in the watercourse or waterbody and the instrument provided instantaneous readings of dissolved oxygen, temperature, specific conductivity, and pH. At each location, a minimum of three turbidity measurements were collected with a LaMotte 2020we or Orbeco-Hellige TB200 meter. For the *in* situ turbidity measurement, a water sample was collected in a clear glass vial, placed in a turbidity meter, and the meter provided an instantaneous optical measurement of turbidity in the sample. All *in situ* water quality meters were calibrated prior to use per the manufacturer's instructions.

2.2.3.2 Sediment Quality

Sediment quality data were collected by Stantec Consulting Ltd. in 2016 for five sites in Elbow River and fives sites in Glenmore Reservoir. For sampling locations and dates, see Table 2-5 and Figure 2-2, and or a full list of analytical parameters and analytical methods, see Table 2-6.

Sediment samples were collected in Glenmore Reservoir using a Ponar sampler and in Elbow River using a plastic spoon/scoop. Sampling methods followed the *Protocols Manual for Water Quality Sampling in Canada* (CCME 2011) and *Aquatic Ecosystems Field Sampling Protocols* (AENV 2006). Field teams collected one sample per site per visit. Grab samples were submitted to ALS Canada Ltd. in Calgary for laboratory analyses.

In Elbow River, a composite sample was collected from an instream sediment deposition area at each sampling location using a plastic spoon. The sediment was stirred in a plastic bin and the homogenized sample was used to fill laboratory-provided glass jars and plastic bags. The plastic spoon and bin were carefully rinsed between sites.

In Glenmore Reservoir, at each sampling location, three Ponar lifts were collected and the sediment was stirred in a plastic bin with a plastic spoon. Laboratory-provided glass jars and plastic bags were filled from the. bin with three homogenized Ponar lifts. The exception was the methylmercury sample container, which was filled from the first Ponar lift from an undisturbed portion from the surface and bottom part of the sediment. Ponar sampler, plastic bin and plastic spoon were carefully rinsed between site visits.

Table 2-5 Sediment Quality Sampling Locations and Dates

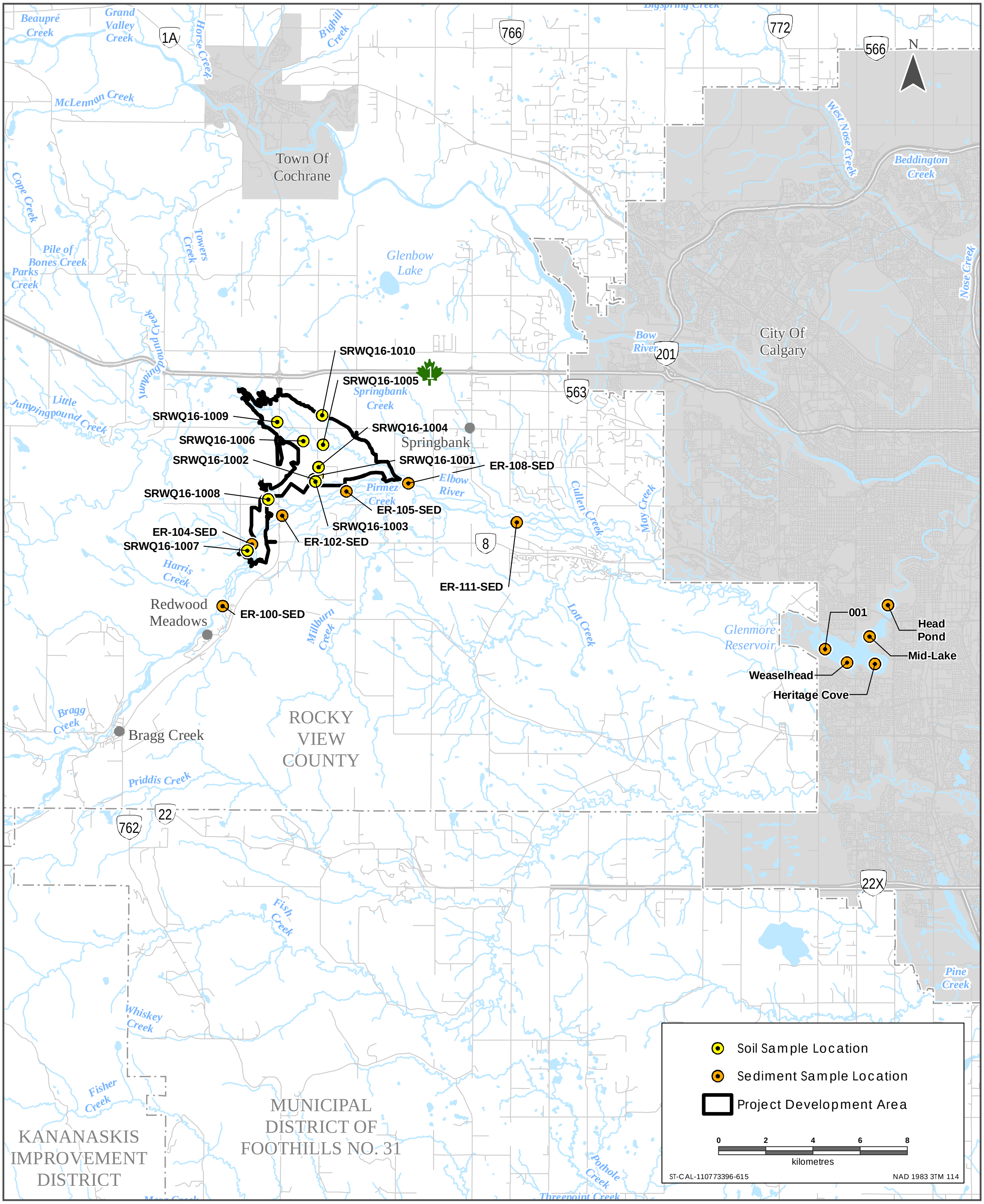
Site ID	Longitude	Latitude	Sampling Date
Elbow River Mainstem Sites			
ER-100-SED	-114.50032	50.99897	3-Nov-2016
ER-102-SED	-114.46492	51.03351	4-Nov-2016
ER-104-SED	-114.48285	51.02241	4-Nov-2016
ER-105-SED	-114.42595	51.04285	7-Nov-2016
ER-108-SED	-114.38852	51.04610	8-Nov-2016
Glenmore Reservoir			
Mouth	-114.13657	50.98343	28-Oct-2016
Weaselhead	-114.12319	50.97833	28-Oct-2016
Heritage Cove	-114.10620	50.97782	27-Oct-2016
Mid-Lake	-114.10961	50.98831	27-Oct-2016
Head Pond	-114.09850	51.00027	27-Oct-2016

Table 2-6 Sediment and Soil Quality Analytical Parameters and Methods

ALS Test Description	ALS Method
% Moisture	CWS for PHC in Soil - Tier 1
Redox Potential	APHA 2580
Particle size - Pipette removal OM & CO_3	Forestry Canada (1991) p. 46-53
Available Ammonium-N - Calculation	Soil Methods of Analysis (1993) CSSS
Total Kjeldahl Nitrogen	CSSS (2008) 22.2.3
Sulphide (as S)	APHA 4500S2D
Total Inorganic Carbon in Soil	CSSS (2008) P216-217
Total Organic Carbon Calculation	CSSS (2008) 21.2
Total Carbon by combustion method	SSSA (1996) P. 973-974
Carbon:Nitrogen Ratio - Calculation	Calculation
Inorganic Carbon as $CaCO_3$ Equivalent	Calculation
Nitrate, Nitrite & Nitrate+Nitrite-N KCL	CSSS (1993) p. 26-28
Available Ammonium-N	CSSS (1993) 4.2/COMM SOIL SCI 19(6)
Available Phosphate-P	Comm. Soil Sci. Plant Anal. 25 (5&6)
Boron in Saturated Paste	CSSS CH15/EPA 6010B
% Saturation	CSSS 18.2-Calculation

Table 2-6 Sediment and Soil Quality Analytical Parameters and Methods

ALS Test Description	ALS Method
Mercury in Soil by CVAAS	EPA 200.2/1631E (mod)
Metals in Soil by CRC ICPMS	EPA 200.2/6020A (mod)
Methyl Mercury in Soil by GCAFS	EPA 1630
CCME Gravimetric Heavy Hydrocarbons (SG)	CCME CWS-PHC, Pub #1310, Dec 2001
BTEX, Styrene and F1 (C6-C10)	EPA 8260C/5021A and CWS PHC Tier 1
CCME Total Hydrocarbons	CCME CWS-PHC, Pub #1310, Dec 2001
CCME F2-4 Hydrocarbons	CCME CWS-PHC, Pub #1310, Dec 2001



Sources: Base Data - ESRI, Natural Earth, Government of Alberta, Government of Canada
Thematic Data - ERBC, Government of Alberta, Stantec Ltd

Sediment and Soil Quality Sampling Sites

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 2-2

2.2.3.3 Soil Quality

Soil samples were collected by Stantec Consulting Ltd. in 2016 from ten locations within the reservoir footprint. For sampling locations and dates, see Table 2-7 and Figure 2-2, and or a full list of analytical parameters and analytical methods, see Table 2-6.

Ten soil quality sampling locations were chosen across soil types with different organic carbon content ranges. Composite soil samples of the top 20 cm of topsoil were taken from a minimum of three spot digs at each soil quality sampling location. Each composite soil sample was thoroughly mixed and distributed among three glass jars and two large ziploc bags and labelled accordingly with site name, date, and time of collection. The samples were kept in a cooler at 4 °C until the end of day, at which time they were taken to the lab accompanied with the corresponding Chain of Custody forms. Samples were analyzed at ALS Laboratory for carbon content, nutrients, metals, and hydrocarbons. Crew members each wore a new pair of nitrile gloves at each location, and all equipment was washed with deionized water between sampling locations.

Table 2-7 Soil Quality Sampling Locations and Dates

Site ID	Longitude	Latitude
SRWQ16-1001	-114.444	51.04882
SRWQ16-1002	-114.446	51.04748
SRWQ16-1003	-114.445	51.04655
SRWQ16-1004	-114.443	51.05215
SRWQ16-1005	-114.44	51.06073
SRWQ16-1006	-114.452	51.06196
SRWQ16-1007	-114.485	51.02015
SRWQ16-1008	-114.473	51.03968
SRWQ16-1009	-114.468	51.06914
SRWQ16-1010	-114.441	51.07185

2.2.3.4 Quality Management

In addition to the actual samples, the field team collected control (QC) samples to detect potential occurrences of grab sample contamination. The following types of QC samples were collected:

- field blanks—filled with laboratory-supplied distilled water at the sampling site and are handled as real samples. They are used to provide information on contamination from all phases of sampling and analysis. Any detected concentrations greater than five times the method detection limit are flagged and discussed in the results section (Mitchell 2006).
- trip blanks—samples filled at the laboratory with laboratory-supplied distilled water, then transported to and from the sampling sites and returned to the laboratory without being opened. They are used to check for contamination from the bottles, caps, and preservatives. Any detected concentrations greater than five times the method detection limit are flagged and discussed in the results section (Mitchell 2006).
- duplicates—collected by filling two sets of sample bottles at one sampling site directly from the waterbody in quick succession. Duplicate samples are used to evaluate the repeatability and accuracy of sampling efforts. Duplicate samples are compared using the Relative Percent Difference Method. Relative percent difference for duplicates greater than 25% are flagged and discussed in the results section (Mitchell 2006).

Before *in situ* water quality measurements were collected, the YSI Multi Probe Plus, and LaMotte 2020we or Orbeco-Hellige TB200 were calibrated. A Winkler titration test for dissolved oxygen was conducted in the field during each day to verify the dissolved oxygen readings from the YSI Multi Probe Plus (Mitchell 2006).

2.2.4 Data Analysis

Water chemistry patterns are the result of complex interactions between climatic forces and the landscapes on which they occur (e.g., Tong and Chen 2002; Interlani and Crockett 2003; Turner and Rabalais 2003). These interactions result in the spatial and temporal patterns exhibited in water quality data. The water quality patterns in the Elbow River are thought to be driven by flow and the sediment it transports (Volume 4, Appendix J (Hydrology TDR); Sosiak and Dixon 2004).

Comparisons between TSS, a measure of suspended sediment concentration, and other parameters such as nutrients and metals can provide insight into the processes that drive these parameters. Parameters that behave similarly to TSS are likely either directly associated with suspended sediment transport or related processes that contribute to high flows (e.g., overland flow during precipitation; Han et al. 2006). Parameters that behave in contrast to TSS are likely associated with processes unrelated to suspended sediment transport or the drivers that contribute to it (e.g., groundwater contribution to baseflow).

Spatial and temporal patterns of 59 water quality parameters were characterized (including TSS) in the mainstem of the Elbow River (several stations from Bragg Creek to Glenmore Reservoir) and the Glenmore Reservoir (raw water intake building dataset). Spatial and temporal patterns of each water quality parameter were compared to those of TSS. Based on these comparisons, parameters were classified as behaving similarly, in contrast, or in an intermediate fashion to TSS. Temperature and dissolved oxygen were analyzed separately because the processes that drive these physical parameters are primarily driven by season rather than by the climatic-landscape interactions that drive other parameters.

2.2.4.1 Data Management

Data was managed and visualized using ‘R’, which is an open source programming language used for statistical computation and graphics.

Raw water quality data was acquired from the City of Calgary, AEP, and from samples collected in the field in 2016 by Stantec. Each of these data sources were received in different spreadsheet formats, were the result of varying laboratory methods, sampling locations, and parameters were not necessarily measured using the same units. To combine the available data, several reference spreadsheets were created so that the data could be reliably manipulated and sorted using ‘R’. Metadata included information on:

- sampling locations and site name
- laboratory methods used to measure parameters
- units used to report parameter values
- comparability and any preferences of laboratory methods

Customized scripts then worked through the raw data and reference datasets to (1) standardize units between data sources, (2) compare and consolidate laboratory methods, and (3) consolidate sampling locations (Figure 2-3).

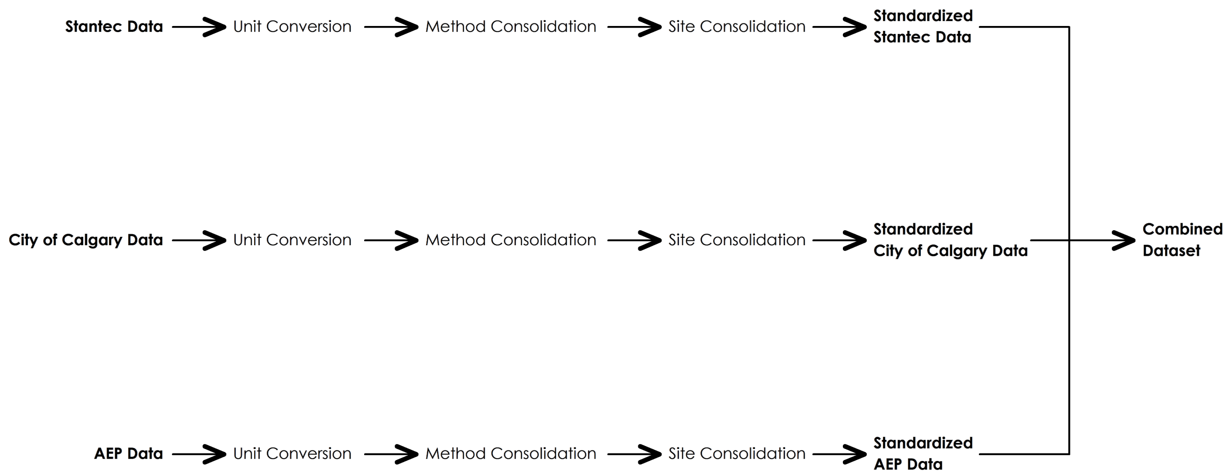


Figure 2-3 Data Management Process

Unit Conversion

Column headers in each of the data sources were crossed referenced with the appropriate reference data to determine if a given parameter was measured as a concentration and, if so, the units were used. Concentration parameters were then converted to µg/L so that equivalent parameters in each data source could be directly compared. Parameters that were not measured as a concentration (e.g., pH, conductivity, temperature) were cross referenced with the reference data to confirm that corresponding parameters from other data sources were measured using the same unit.

Method Consolidation

ALS Canada Ltd. was consulted to determine which laboratory methods were comparable. From these consultations, a laboratory methods reference dataset was created. This reference data was used to consolidate results from different laboratory methods into specific parameters which would be used for analysis and visualization.

The dissolved, extractable, and total components of metal (and some non-metal) parameters were not comparable, no matter the method used to estimate concentration. Within each of these components, all methods were comparable and included:

- atomic absorption spectroscopy (AA)
- inductively coupled plasma mass spectrometry (ICP-MS)
- inductively coupled argon plasma emission spectrometry (ICAPES)

Ion concentrations were estimated using ion chromatography (IC), and so no method consolidation was required. When calculated concentrations, field or other lab measurements were available, they were used as in addition to any other values for a given parameter.

In cases where a parameter was associated with comparable observations that used more than one method, each observation was compared to the median observation. Observations that differed from the median by more than 50% were removed. The median of the remaining observations was then used as the parameter value.

2.2.4.2 Treatment of Censored Data

The laboratory methods used to estimate concentrations of surface water quality variables have detection limits. A detection limit is a concentration below which the laboratory methods are unable to accurately distinguish between true and false positive signals. Many water quality parameters are associated with a high number of observations that are greater than or equal to zero, but less than the detection limit. Such data are referred to as censored data.

Censored data can be problematic because they represent small values between zero and the detection limit. Substituting these values with zeros, with the detection limit, or excluding them from analysis all together can result in biased estimates of means, medians, and other statistical estimates.

Where summary statistics and graphs were required, a combination of the approaches described above was used. When the number of censored observations was greater than 70%, summary statistics were not calculated. If more than ten uncensored observations were available, an imputation method was used, following Fleming and Harrington (1984) to estimate the mean. Otherwise, the substitution approach was followed, and the mean of the resulting values was used (Mitchell 2006).

2.2.4.3 Graphs

Data visualizations were designed to illustrate temporal and spatial variation. Box and whisker plots (i.e. box plots) are a type of data visualization that is used to compare the distribution of a continuous variable between categories of data (Figure 2-4). Box plots were used to visualize temporal and spatial variability because:

- temporal and spatial categories could be easily defined (i.e., sampling location, season, or month of sample collection)
- box plots illustrate the median, variability, and skew of data

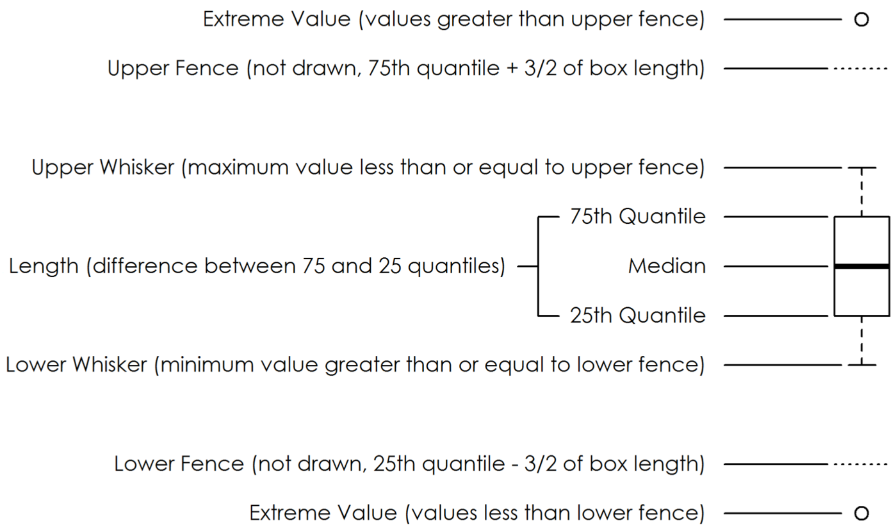


Figure 2-4 Box and Whisker Plot Explanation

2.2.4.4 Identification of Spatial and Temporal Patterns

Spatial patterns were examined for water quality changes along the upper Elbow River mainstem from upstream (Bragg Creek) to downstream (Weaselhead Bridges) and seasonal patterns in water quality data within each mainstem sampling location.

A statistical trend analysis of long-term water quality patterns was not completed because the data available was not appropriate for this type of analysis. Water quality data is highly variable, because it is the result of complex and fast moving processes. Continuous sampling is often required to characterize such variability (e.g., Robson et al. 1993; Jarvie et al. 2001; Tetzlaff et al. 2007). Irregularly sampled datasets (such as the data analyzed) are 'snapshots' of this variability and, with small sample sizes, are poorly suited to evaluate long-term trends.

Spatial Patterns

Visualizations of data were designed to characterize spatial patterns from upstream to downstream locations on the Elbow River.

Sampling sites were categorized into more general analysis locations along the upper Elbow River mainstem (Table 2-2). This increases the sample size for each analysis location and increases confidence in the resulting distribution. Glenmore Reservoir (station located at the Glenmore Dam) was also included as one of the analysis locations so that the effect of the Glenmore Reservoir on water quality could be evaluated. Comparisons of each parameter were made graphically by season, from upstream to downstream, for the Elbow River mainstem.

The spatial patterns of parameters were classified, based on the change between parameter values from the upper Elbow River mainstem upstream (Bragg Creek) to downstream (Weaselhead Bridge) sampling locations. When parameter values were greater at downstream locations than at upstream locations, the spatial patterns were classified as positive. When values were greater at upstream locations than at downstream locations, the spatial patterns were classified as a negative. Parameters that did not vary from upstream to downstream were not associated with a spatial pattern (i.e., no apparent pattern).

Seasonal Patterns

Due to the seasonality of many water quality parameters, visualizations of data were designed to characterize seasonal patterns in the upper Elbow River. A seasonal variability metric (SVM) was developed and applied to the data to identify parameter variability patterns across seasons.

Observations were classified into four seasons: spring, summer, fall, and winter. These seasons were defined by the month of data collection (as per Hatfield Consultants et al. 2016):

- March to May (spring)
- June to August (summer)
- September to November (fall)
- December to February (winter)

Seasonal comparisons of each parameter were made visually. Seasonal variability for each parameter was characterized by calculating the coefficient of variation (COV, Equation 1) for each Elbow River mainstem location and calendar month combination. COV is a measurement of a distribution's variability that is standardized against the distribution's mean (Sokal and Rohlf 1979). COVs measure variability of water quality parameters because water quality data is often highly variable, and COV effectively measures the volatility of a sample. COVs can therefore be used to reduce the effect of means on the variation measured in water quality data and make simple comparisons between site and month combinations.

COVs were calculated to:

- confirm that the season definitions used were meaningful
- quantitatively characterize seasonal variability using a COV-based SVM

Due to data availability constraints, data analysis on tributary data was limited to spatial characterization, and no seasonal pattern characterization was attempted.

Seasonal Variability Metric

To characterize seasonal variability quantitatively in addition to visual evaluation, the following method was used to calculate a SVM. The COV for each parameter were normalized for consistency, so that the distributions were preserved, but ranged from 0 to 1, using Equation 2. The normalized COV were then plotted in order from March to February. A locally weighted scatterplot smoothing (LOWESS) curve (Cleveland 1979) was then fit to the normalized COV, and the 95% confidence intervals of the curve were calculated. A LOWESS curve is a mathematical function made up of a series of simple curves fit to localized subsets of data. A LOWESS curve was used to fit to the normalized COV values across months because these relationships had the potential to be complex and were not necessarily well suited to conventional functions. The difference between the area of the confidence interval above and below the median normalized COV was divided by the total area of the confidence interval for the period (season) of interest. The resulting value is hereafter referred to as the SVM (see Figure 2-5 for graphical overview). SVMs were only calculated for parameters that had 20 or more COVs available, to avoid spurious results because of low sample sizes.

Equation 1: Coefficient of variation equation

$$\boldsymbol{C_V = \frac{\sigma}{\mu}}$$

$$C_V = Coefficient\ of\ Variation$$

$$\sigma = Standard\ Deviation$$

$$\mu = Mean$$

Equation 2: Normalization equation

$$\boldsymbol{X_i' = \frac{X_i - X_{min}}{X_{max} - X_{min}}}$$

$$X_i = ith\ Value\ of\ X$$

$$X_i' = ith\ Normalized\ Value\ of\ X$$

$$X_{min} = Minimum\ Value\ of\ X$$

$$X_{max} = Maximum\ Value\ of\ X$$

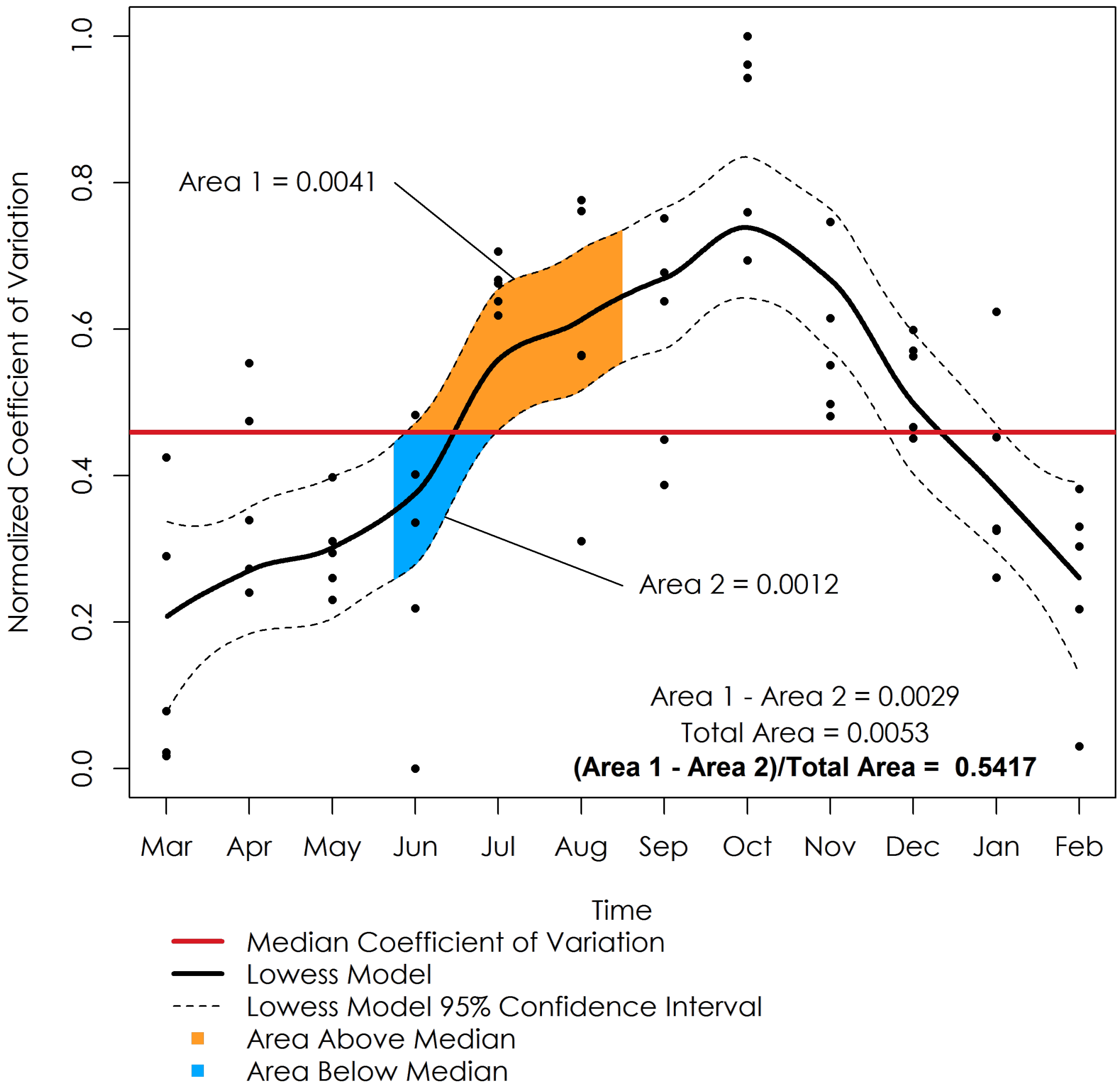


Figure 2-5 Seasonal Variability Metric Example

The SVM ranges from -1 to 1. Positive SVM are indicative of relatively high COV, whereas negative values are indicative of relatively low COV during the season of interest. The greater the absolute value of the SVM, the more pronounced the variability of the parameter during the season of interest.

The water quality patterns in the upper Elbow River are thought to be driven by flows and sediment transport (Sosiak and Dixon 2004). SVMs were used to classify parameters as those that behaved like TSS, and those that did not. SVMs for each parameter were compared to the SVM pattern of TSS by calculating the Euclidean distance between the seasonal SVMs of TSS with that of each parameter (Equation 3). Jenks natural breaks classification method was used to classify the distances into three categories of distances from the TSS SVMs:

- 'immediate' for parameters with variation patterns that are very similar to variation patterns of TSS
- 'moderate' for parameters with variation patterns that are similar to TSS in some respects, but different in others.
- 'distant' for parameters with variation patters that are distinct from those of TSS variation patterns

Jenks natural breaks classification method clusters observations into a predefined number of groups. This is done by minimizing the difference between observations and their group's mean.

Equation 3: Euclidean distance equation

$$\boldsymbol{d = \sqrt{(t_{spring} - p_{spring})^2 + (t_{summer} - p_{summer})^2 + (t_{fall} - p_{fall})^2 + (t_{winter} - p_{winter})^2}}$$

$$t_{season} = TVM\ of\ TSS\ for\ a\ Given\ Season$$

$$p_{season} = TVM\ of\ a\ Parameter\ for\ a\ Given\ Season$$

$$d = Euclidean\ Distance$$

2.2.4.5 Guidelines and Objectives

Environmental quality guidelines "*are science-based recommendations that protect water uses and form a cornerstone of aquatic ecosystem management and protection*" (ESRD 2014). Water quality guidelines are not legally binding, unless they are used to develop "*legally binding effluent limits under the Environmental Protection and Enhancement Act*" (ESRD 2014).

In this report, baseline water and sediment quality guideline exceedances are identified when an applicable and appropriate long-term guideline is available. Water quality guidelines are developed to protect aquatic ecosystems in large geographic regions. Local lithology and other local conditions can cause exceedances in ambient water quality. For context, a discussion of observed guideline deviations is provided.

Table 2-8 and Table 2-9 list guideline taken from:

- environmental quality guidelines for Alberta surface waters (referred to as Alberta water quality guidelines or AB WQGs, ESRD 2014)
- Canadian water quality guidelines (CWQGs, CCME 2016)
- interim sediment quality guidelines (ISQGs, CCME 2016)

In addition to generic water quality guidelines, watershed management water quality objectives developed by the Elbow River Watershed Partnership for the upper and central reaches of the Elbow River (BRBC 2012, ERWP 2009) are considered. Elbow River Water Quality Objectives (ER WQOs) for the central reach (includes the portion of the watershed in the Municipal District of Rocky View, and the Calgary municipal boundary upstream of Glenmore Dam) are relevant for this assessment (Table 2-8). These water quality objectives are not included in the South Saskatchewan Region Surface Water Quality Management Framework (Government of Alberta 2014) and are, therefore, not implemented. However, they are included in the assessment for completeness.

While pesticides are identified as a relevant measurement endpoint, only two pesticides have been detected in the watershed: 2,4-D and MCPP. These are the only pesticides included in the guideline table.

Table 2-8 CCME and Alberta Water Quality Guidelines for the Protection of Aquatic Life and Elbow River Water Quality Objectives

Parameter	Unit	CWQG acute	CWQG chronic	AB WQG short-term	AB WQG long-term	ER WQO central reach
Physical parameters						
Temperature	˚C	-	Narrative	Narrative	Narrative	18
pH	S.U.	-	6.5-9.0	-	6.5-9.0	-
Alkalinity (as $CaCO_3$)	mg/L	-	-	-	Minimum 20	-
Dissolved oxygen (cold water biota)	mg/L	-	Minimum 6.5	Minimum 5	Minimum 6.5	Minimum 6.5
Total suspended sediment	mg/L	-	Narrative	Narrative	Narrative	Narrative
Total coliforms (irrigation guideline)	CFU/100 mL	-	1,000	-	-	20,000
Fecal coliforms (irrigation guideline)	CFU/100 mL	-	100	-	100	100
Ions and ion balance						
Chloride	mg/L	640	120	640	120	-
Fluoride	mg/L	-	0.12	-	-	-
Sulphate	mg/L	-	-	-	Varies[a]	-
Sulphide	mg/L	-	-	-	0.0019	-
Nutrients and carbon						
Nitrate (as N)	mg/L	124	3.0	124	3.0	-
Nitrite (as N)	mg/L	-	0.06	Varies[a]	Varies[a]	-
Nitrate+nitrite (as N)	mg/L	-	-	-	-	0.267
Nitrogen (total)	mg/L	-	Narrative	-	-	Narrative
Ammonia (total as N)	mg/L	-	Equation[b]	-	Equation[b]	0.04

Table 2-8 CCME and Alberta Water Quality Guidelines for the Protection of Aquatic Life and Elbow River Water Quality Objectives

Parameter	Unit	CWQG acute	CWQG chronic	AB WQG short-term	AB WQG long-term	ER WQO central reach
Total dissolved phosphorus	mg/L	-	-	-	-	0.009
Phosphorus (total)	mg/L	-	-	-	Narrative	-
Total organic carbon	mg/L	-	-		-	5.0
Metals (dissolved)				6.5		
Aluminium	mg/L	-	-	0.1 or equation[b] when pH <6.5	0.05 or equation[b] when pH <6.5	-
Iron	mg/L	-	-	-	0.3	-
Metals (total)						
Aluminum	mg/L	-	0.005 at pH≤6.5; 0.1 at pH≥6.5	-	-	-
Arsenic	mg/L	-	0.005	-	0.005	-
Boron	mg/L	29	1.5	29	1.5	-
Cadmium	mg/L	Equation[b]	Equation[b]	Equation[b]	Equation[b]	-
Chromium (trivalent)	mg/L	-	0.0089	-	0.0089	-
Chromium (hexavalent)	mg/L	-	0.001	-	0.001	-
Cobalt	mg/L	-	-	-	0.0025	-
Copper	mg/L	-	Equation[b]	Equation[b]	0.007	-
Iron	mg/L	-	0.3	-	-	-

Table 2-8 CCME and Alberta Water Quality Guidelines for the Protection of Aquatic Life and Elbow River Water Quality Objectives

Parameter	Unit	CWQG acute	CWQG chronic	AB WQG short-term	AB WQG long-term	ER WQO central reach
Lead	mg/L	-	Equation[b]	-	Equation[b]	-
Mercury	mg/L	-	0.000026	0.000013	0.000005	-
Methylmercury	mg/L	-	0.000004	0.000002	0.000001	-
Molybdenum	mg/L	-	0.073	-	0.073	-
Nickel	mg/L	-	Equation[b]	Equation[b]	Equation[b]	-
Selenium	mg/L	-	0.001	-	0.001	-
Silver	mg/L	-	0.00025	-	0.0001	-
Thallium	mg/L	-	0.0008	-	0.0008	-
Uranium	mg/L	0.033	0.015	0.033	0.015	-
Zinc	mg/L	-	0.03	-	0.03	-
Pesticides						
2,4-D	mg/L	-	0.004	-	-	Should not exceed lower of <1/10 of federal drinking water guidelines or < CCME guidelines for aquatic life
Mecoprop (MCPP)	mg/L	-	-	10	0.013	

Table 2-8 CCME and Alberta Water Quality Guidelines for the Protection of Aquatic Life and Elbow River Water Quality Objectives

NOTES:

CWQG = Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life by Canadian Council of Ministers of the Environment (CCME 2016).

AB WQG = Environmental Quality Guidelines for Alberta Surface Waters (ESRD 2014).

ER WQO central reach = water quality objectives developed by the Elbow River Watershed Partnership for the central reach of the Elbow River (ERWP 2009)

- = no guideline

[a] Guidelines that vary based on other parameters were determined as per ESRD (2014) and CCME (2016):

- Sulphate guideline varies based on hardness from 128 mg/L to 429 mg/L
- Nitrite-N ABWQG varies based on chloride concentrations from 0.02 mg/L to 0.20 mg/L

[b] Equations were used to calculate hardness, pH, and temperature-dependent guidelines as per ESRD (2014) and CCME (2016).

- Ammonia CWQG and AB WQG: guideline for total ammonia is based on temperature and pH, see table for values in CCME (2016).
- Dissolved aluminum AB WQG (µg/L) = $\{e^{(1.6-3.327(pH)+0.402(pH)^2)}\}$
- Total cadmium chronic/long-term CWQG and AB WQG: At hardness ≥ 17 mg/L and ≤ 280 mg/L (µg/L) = $10^{\{0.83[\log10(hardness)-2.46]\}}$
- Total cadmium acute/short-term CWQG and AB WQG: At hardness <5.3 mg/L, the guideline is 0.00011 mg/L. At hardness ≥ 5.3 mg/L and ≤ 360 mg/L (µg/L) = $10^{\{1.016[\log10(hardness)-1.71]\}}$. At hardness >360 mg/L, the guideline is 0.0077 mg/L.
- Total copper chronic CWQG: When the water hardness is 0 to < 82 mg/L, the CWQG is 0.002 mg/L. At hardness ≥82 to ≤180 mg/L the CWQG is calculated as CWQG (µg/L) = 0.2 * $e^{\{0.8545[\ln(hardness)]-1.465\}}$. At hardness >180 mg/L, the CWQG is 0.004 mg/L. If the hardness is unknown, the CWQG is 0.002 mg/L.
- Total copper short-term AB WQG (µg/L) = $(e^{\{0.979123[\ln(hardness)]-8.64497\}})*1000$
- Total lead CWQG and AB WQG: When the hardness is 0 to ≤ 60 mg/L, the guideline is 0.001 mg/L. At hardness >60 to ≤ 180 mg/L the guideline is calculated as (µg/L)= $e^{\{1.273[\ln(hardness)]-4.705\}}$. At hardness >180 mg/L, the guideline is 0.007 mg/L. If the hardness is unknown, the guideline is 0.001 mg/L.
- Total nickel CWQG: When the water hardness is 0 to ≤ 60 mg/L, the CWQG is 0.025 mg/L. At hardness > 60 to ≤ 180 mg/L the CWQG is calculated as CWQG (µg/L) = $e^{\{0.76[\ln(hardness)]+1.06\}}$
- Total nickel long-term AB WQG (µg/L) = $e^{\{0.846[\ln(hardness)]+0.0584\}}$
- Total nickel short-term AB WQG (µg/L) = $e^{\{0.846[\ln(hardness)]+2.255\}}$

Table 2-9 Federal Sediment Quality Guidelines

Parameter	Unit dry weight	ISQG
Metals (total)		
Arsenic	mg/kg	5.9
Cadmium	mg/kg	0.6
Chromium (total)	mg/kg	37.3
Copper	mg/kg	35.7
Lead	mg/kg	35.0
Mercury	mg/kg	0.17
Zinc	mg/kg	123.0

NOTE:
ISQG = Interim Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life by Canadian Council of Ministers of the Environment (CCME 2016).

2.2.4.6 Introduction to Water Quality Parameters

This section provides a brief introduction to common water and sediment quality parameters:

- pH is a measure of the concentration of hydrogen ions in a solution. It influences chemical forms of substances and affects, for example, ammonia and metal toxicity. pH is often measured both in situ in the field and at a laboratory from grab samples. Field and laboratory measurements often vary because of differences in instrument sensitivity and accuracy.
- Alkalinity is an indicator of the acid-neutralizing capacity of water and it is expressed as an equivalent of calcium carbonate in water.
- Suspended sediment concentrations are an important factor in driving the concentration of particle-associated water quality constituents, such as total phosphorus and some metals, such as aluminum and iron.
- Dissolved oxygen is essential to aquatic organisms' respiration. Dissolved oxygen levels additionally affect the solubility and availability of nutrients, and therefore the productivity of aquatic ecosystems. Low levels of dissolved oxygen facilitate the release of nutrients from sediments.
- Conductivity reflects the concentration of ions in a solution and hardness reflects the sum of calcium and magnesium ion concentrations.

- The main nutrients in most surface waters include nitrogen and phosphorus; both are required for plant growth in very small amounts. Out of the nitrogen species, nitrite and nitrate are available for plant uptake, while ammonia and organic nitrogen (a sum of which is referred to as Kjeldahl nitrogen) need oxidation before they can be used for plant and algae growth. Phosphorus is often measured as total and dissolved fractions, with the total phosphorus reflecting both particle-associated and dissolved forms of phosphorus. Dissolved phosphorus includes orthophosphates, which can be used by plant and algae. The productivity or trophic status of an aquatic ecosystem can be defined based on total phosphorus concentrations as follows (CCME 2016):
  - ultra-oligotrophic: < 0.004 mg/L
  - oligotrophic: 0.004-0.010 mg/L
  - mesotrophic: 0.010-0.020 mg/L
  - meso-eutrophic: 0.020-0.035 mg/L
  - eutrophic: 0.035-0.100 mg/L
  - hyper-eutrophic: >0.100 mg/L
- Many metals and metalloids (i.e., elements that have electrical and chemical properties of both metals and non-metals) are present in surface waters in concentrations that vary by season.
- The non-metals arsenic and selenium, which are commonly considered together with metals and metalloids are referred to as 'metals' in this TDR. Metals in surface waters originate from both natural and anthropogenic sources, including atmospheric deposition, surface runoff, wastewater, and groundwater.
- Metals can be present in dissolved, colloidal, or particulate forms. Total metal analysis measures both all forms of an individual element in a sample, whereas dissolved metals are in solution and not associated with particles or colloids.
- Some metals such as cobalt, copper, iron, manganese, molybdenum, vanadium, strontium, and zinc are required in trace amounts by living organisms (Weiner 2008). However, these metals can be toxic to biota in higher concentrations. Non-essential metals that can be of particular concern because of toxicity include cadmium, chromium, mercury, lead, arsenic, and antimony (Weiner 2008).

3.0 DATA ANALYSIS RESULTS

The main effect of the Project on water quality is related to suspended sediment. The Project is intended to reduce Elbow River flood water flow into the Glenmore Reservoir by retention of water temporarily in an off-stream reservoir. This means that, by design, the project affects flows in the Elbow River and flow is the driving force behind suspended sediment concentration. The processes that effect suspended sediment patterns can also effect other water quality parameters (e.g., Foster and Charlesworth 1996), and so parameters associated with suspended sediment could be directly linked to the main Project effect on water quality. Therefore, the results discussion focuses on identifying data patterns in suspended sediment and sediment associated parameters. The similarity between suspended sediment and other water quality parameters were characterized using coefficients of variance (COVs) and seasonal variability metrics (SVMs).

In addition to evaluating suspended sediment and other water quality parameter data patterns in the upper Elbow River, existing conditions data are presented for soil and sediment chemistry in the PDA and Elbow River; and water quality in the low-level outlet channel, which is compared to other Elbow River tributary data for context.

3.1 INTRODUCTION

Water quality of the upper Elbow River is a result of lithology and geochemistry in the watershed and its relation to major sources of nutrients and suspended sediment from the City of Calgary limits (Sosiak and Dixon 2004) and other activity along Elbow River watershed.

Water quality in the upper Elbow River is good in relation to aquatic ecosystem and human uses of water from the river (Sosiak and Dixon 2004). However, concentrations of some parameters increased between 1979 and 1997 in the Elbow River upstream of Glenmore Reservoir within the City limits at Highway 8, including dissolved phosphorus, turbidity, and bacteria (Sosiak 1999). These changes are potentially related to runoff from livestock wintering areas and seepage from septic fields (Sosiak 1999). In general, two major sources affecting water quality in the watershed are (Sosiak and Dixon 2004):

- non-point source runoff from agriculture, recreation, and residential development upstream of the City of Calgary. There are no approved wastewater discharges to Elbow River upstream of Glenmore Reservoir.
- urban runoff from Calgary that is conveyed to Elbow River and Glenmore Reservoir

3.2 UPPER ELBOW RIVER MAINSTEM AND GLENMORE RESERVOIR WATER QUALITY

Water quality data for the upper Elbow River mainstem and Glenmore Reservoir were analyzed to identify seasonal and spatial patterns. Because the main Project effect on water quality is anticipated to be related to the settling of suspended sediment, the results discussion focuses on identifying data patterns in suspended sediment and sediment-associated parameters.

The silt and clay fractions of suspended sediment comprise clay minerals, iron hydroxides, manganese oxides and organic matter (Foster and Charlesworth 1996). Ion exchange processes occur between positively charged matter (such as metals and nutrients) and negatively charged particle surfaces, binding positively charged matter to particle surfaces. The majority (over 70%) of aluminum, arsenic, barium, chromium, copper, iron, manganese, nickel, zinc, and phosphorus have been found to be associated with suspended sediment particles in major United States (US) rivers (Horowitz 2004). In contrast, strontium was generally found in the dissolved phase, whereas lithium as divided equally between both phases (Horowitz 2004). In urban runoff, 70-80% of phosphorus and 50-80% of nitrogen have been reported to be particle-bound, with higher adherence to smaller particles (Vaze and Chiew 2004).

3.2.1 Total Suspended Sediment Data Patterns

Between 1979 and 2016, TSS concentrations in the upper Elbow River mainstem were greatest during the summer season, lowest during the fall and winter, and intermediate during the spring (Figure 3-1). Concentrations of TSS increased from upstream to downstream in the upper Elbow River between Bragg Creek and Weaselhead Bridge. This pattern could be associated with increase in land modification and, therefore, sediment mobilization as the Elbow River traverses an increasingly populated landscape towards the Glenmore Reservoir. The increase in concentration from upstream to downstream was particularly distinct during the spring and summer. During fall and winter this spatial pattern was less pronounced, but it still increased from upstream to downstream.

TSS concentrations were lower at the Glenmore Dam than at the upper Elbow River mainstem sites, indicating that suspended sediment settles when it reaches, or prior to reaching, Glenmore Dam. Despite the settling, the seasonal pattern, although less pronounced, was still apparent at Glenmore Dam. The highest measured concentration of TSS observed in the Elbow River was 3,570 mg/L at the Highway 22 bridge on June 16, 2002.

For additional information on the upper Elbow River sediment processes, see Volume 4, Appendix J Hydrology TDR.

Examining the data variation pattern of TSS showed that the COVs were greatest during the summer, lowest in the winter and fall, and intermediate during the spring (Figure 3-2), similar to the absolute concentrations of TSS. Highly variable data indicates high concentrations, where winter and fall concentrations are consistently low, whereas spring and summer concentrations vary between low and high.

Seasonal variation metrics (SVMs) were calculated to quantitatively compare data variation patterns of TSS to other parameters. TSS SVM patterns are similar to TSS COV patterns, greatest during the spring and summer, intermediate during the fall, and lowest during the winter (Figure 3-3). The calculated SMVs for TSS are compared to other parameters and discussed in the following sections.

In the upper Elbow River, TSS peaked during the spring and summer during high flows. Higher flows likely mobilize sediment in the upper Elbow River by accessing deposited sediment in the floodplain and suspending that sediment from the channel (for additional information on sediment mobilization (Volume 4, Appendix J, Hydrology TDR). Additional suspended sediment is probably introduced into the water column by the corresponding runoff, and tributary flows from precipitation (Volume 4, Appendix J, Hydrology TDR). High flows in the Elbow River are often the direct result of precipitation (Hudson 1983), and so precipitation and high flows generally occur during the spring and summer.

The variability of TSS, like the absolute concentrations, are greatest during the spring and summer. This variability is likely primarily due to short-term precipitation and changes in erosion/deposition patterns that correspond with more variable (than fall and winter) spring and summer flows.

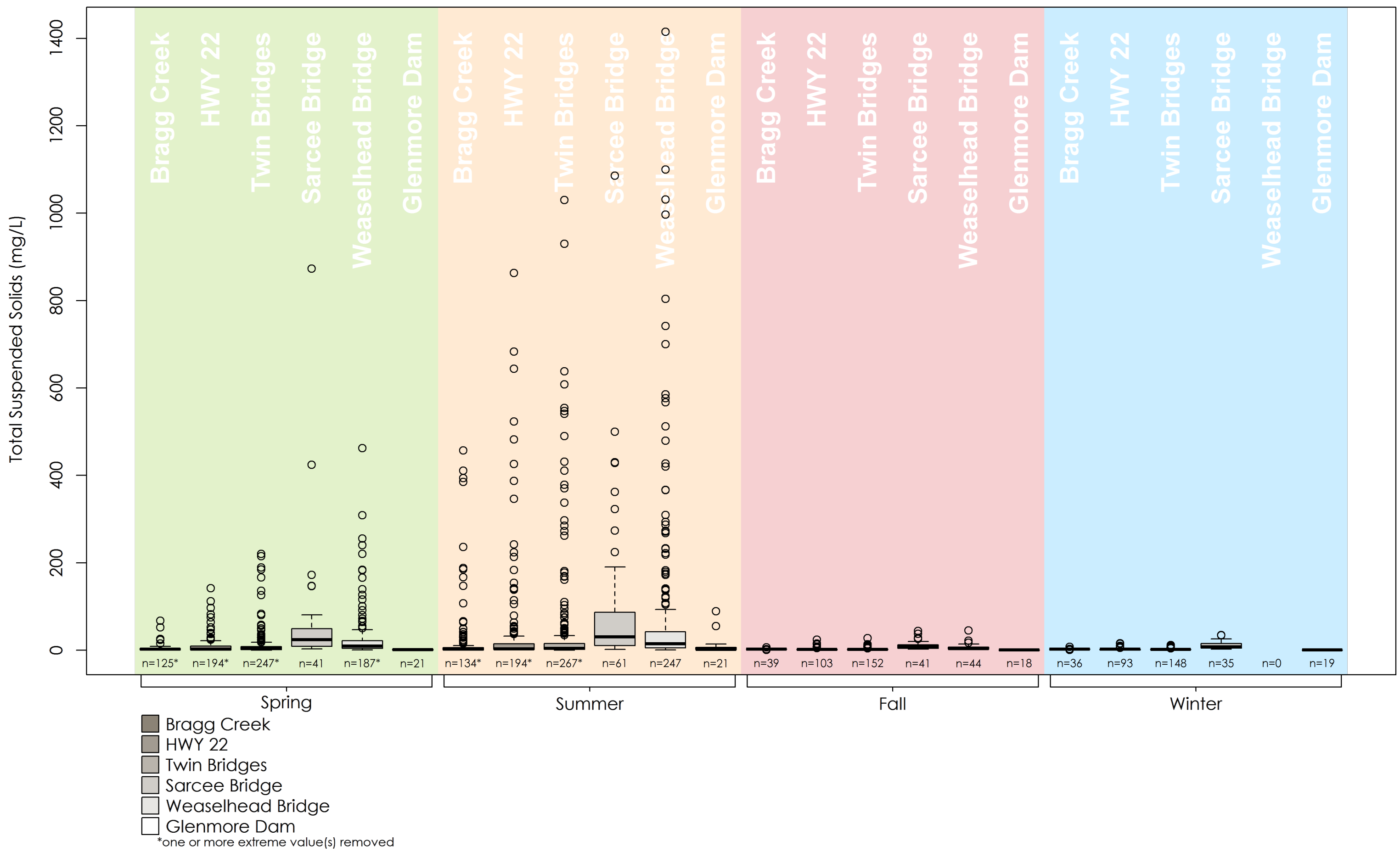


Figure 3-1 Total Suspended Sediment in the Elbow River Mainstem Sites and at the Glenmore Dam from 1979 to 2016

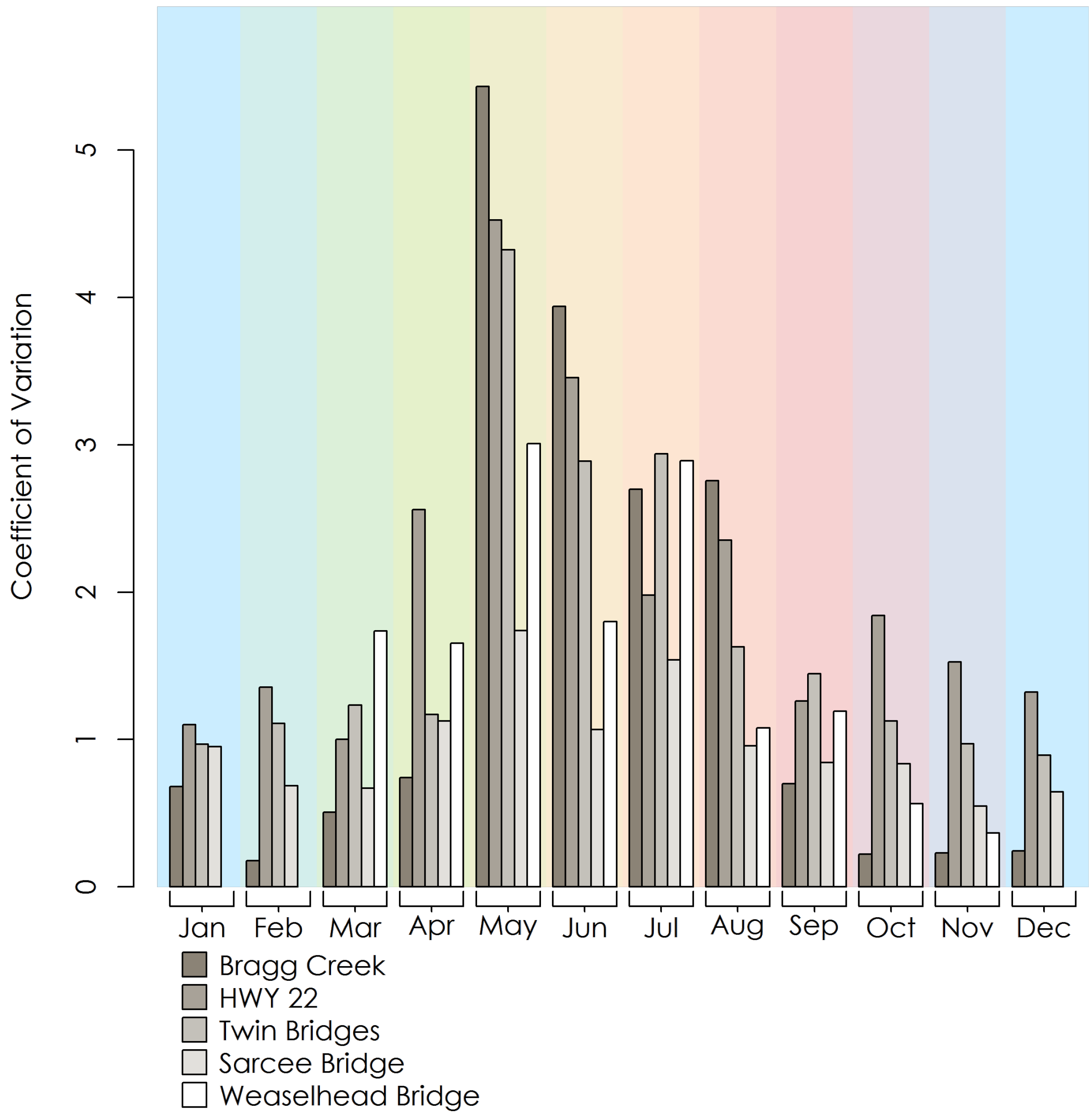


Figure 3-2 Seasonal Variation Metrics of Total Suspended Sediment in the Elbow River Mainstem and at the Glenmore Reservoir from 1979 to 2016

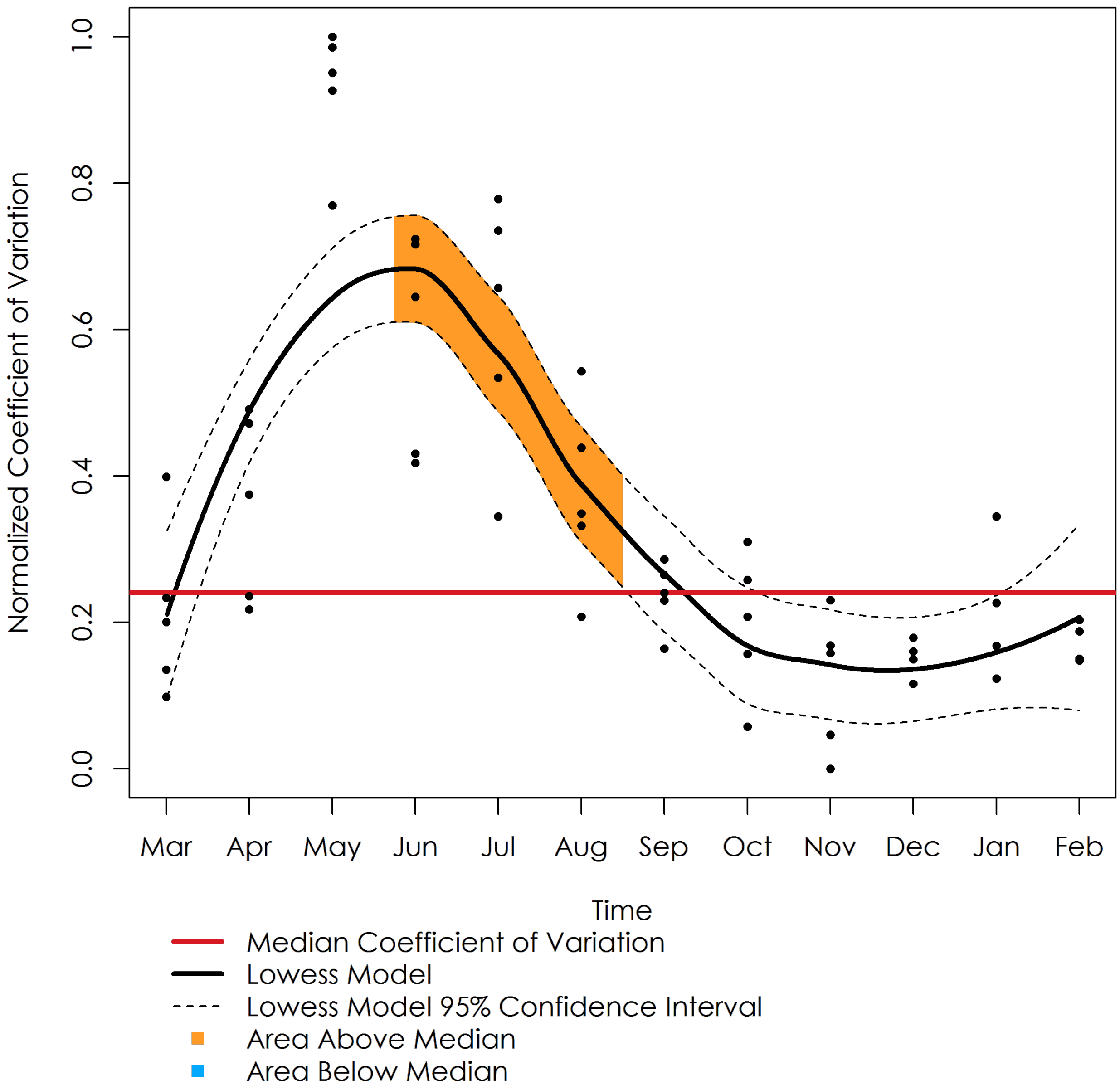


Figure 3-3 Total Suspended Sediment Seasonal Variability Metric for the Summer Season from 1979 to 2016

3.2.2 Comparison of Total Suspended Sediment Data Patterns with Other Parameter Data Patterns

The similarity between suspended sediment and other water quality parameters were characterize using coefficients of variance (COVs) and seasonal variability metrics (SVMs). A total of 31 parameters (including TSS) had sufficient site and month data to calculate SVMs, and could be used to measure the Euclidean distance to the TSS SVMs. Jenks natural breaks classification method divided the distances into three categories. The immediate, moderate, and distant categories ranged from 0.195 to 0.600, 0.600 to 1.616, and 1.616 to 2.768 respectively. Of the 30 parameters 8 parameters were in the immediate category, 14 were in the moderate category, and 8 were in the distant category (Table 3-1). This comparison and categorization provided a quantitative way to classify water quality parameters to be either similar or dissimilar to TSS. Parameters that had similar data patterns to TSS were interpreted to likely behave in a similar way as TSS during a flood.

Overall, the results of this comparison found that parameters that peak during the spring and summer, often had low SVM distances from TSS (i.e., variability was similar to TSS), and similar spatial patterns to TSS. 26 parameters have values that peak during the spring and/or summer, 11 of these parameters have sufficient data to calculate SVMs, 10 of which were either in the immediate or moderate SVM distance category. 20 of the 26 parameters that peak during the spring and summer, like TSS, had a positive spatial pattern. These results indicated that many parameters behaved similarly to TSS through space and time, and the assessment of potential effects on water and sediment quality during a flood focused on these parameters.

The following sections discuss parameters that behaved similarly to TSS and ones that did not.

Table 3-1 Seasonal Variation Metric and Distance from TSS SVM Results

Parameter	Variation Pattern (SVM Distance from TSS)	Variation Pattern Category	Seasonal Pattern	Spatial Pattern (from upstream to downstream)	Comments
Parameters Behaving Similarly to Total Suspended Sediment					
Total suspended sediment	0.00	-	spring and summer	positive	-
Turbidity	0.19	immediate	spring and summer	positive	-
Total phosphorus	0.59	immediate	spring and summer	positive	-
Total coliforms	0.37	immediate	spring and summer	positive	-
Total dissolved phosphorus	0.39	immediate	spring and summer	positive	-
Dissolved phosphorus	0.39	immediate	spring and summer	none	-
Total organic carbon	0.54	immediate	spring and summer	-	-
Fecal coliforms	0.68	moderate	spring and summer	positive	-
Conductivity	1.34	moderate	summer	positive	Values lowest during the summer. Positive downstream effect.
Kjeldahl nitrogen	1.37	moderate	spring and summer	positive	-
Total potassium	1.44	moderate	spring	positive	-
Dissolved arsenic	-	-	spring and summer	-	Low sample size and number of sampling sites.
Dissolved boron	-	-	spring and summer	positive	-
Dissolved organic carbon	-	-	summer	na	Low sample size, and number of sampling sites.
Nitrite	-	-	spring	none	Site differences, no apparent direction.

Table 3-1 Seasonal Variation Metric and Distance from TSS SVM Results

Parameter	Variation Pattern (SVM Distance from TSS)	Variation Pattern Category	Seasonal Pattern	Spatial Pattern (from upstream to downstream)	Comments
Total aluminum	-	-	spring and summer	positive	-
Total arsenic	-	-	spring and summer	positive	Low sample sizes. Little data in fall and winter.
Total boron	-	-	spring and summer	positive	-
Total chromium	-	-	spring and summer	positive	-
Total cobalt	-	-	spring and summer	positive	Low sample sizes. Lacking data during fall, and only one datum in winter.
Total inorganic carbon	-	-	spring and summer	none	-
Total iron	-	-	spring and summer	positive	-
Total manganese	-	-	spring and summer	positive	-
Total nickel	-	-	spring and summer	positive	-
Total titanium	-	-	spring and summer	positive	-
Total vanadium	-	-	spring and summer	positive	-
Total zinc	-	-	summer	positive	-
Temperature and Dissolved Oxygen					
Dissolved oxygen	dissolved oxygen	dissolved oxygen	dissolved oxygen	dissolved oxygen	dissolved oxygen
Temperature	temperature	temperature	temperature	temperature	temperature
Parameters Behaving in Contrast to TSS					
Dissolved sulphate	1.00	moderate	winter	positive	Data only available for two sites.
Alkalinity	1.15	moderate	none	positive	-

Table 3-1 Seasonal Variation Metric and Distance from TSS SVM Results

Parameter	Variation Pattern (SVM Distance from TSS)	Variation Pattern Category	Seasonal Pattern	Spatial Pattern (from upstream to downstream)	Comments
Total fluoride	1.22	moderate	none	negative	-
Nitrate and nitrite	1.22	moderate	spring and winter	none	Data only available for two sites.
Nitrate	1.30	moderate	spring and winter	none	Site differences, no apparent direction.
Total nitrogen	1.36	moderate	spring and winter	positive	-
pH	1.41	moderate	spring and winter	none	Site differences, no apparent direction.
Dissolved fluoride	1.51	moderate	none	none	-
Dissolved magnesium	1.53	moderate	none	positive	-
Dissolved calcium	1.57	moderate	none	positive	-
Dissolved potassium	1.62	distant	none	positive	Data only available for two sites.
Dissolved oxygen saturation	1.90	distant	none	none	-
Dissolved chloride	1.91	distant	none	positive	-
Total sodium	1.96	distant	spring and winter	positive	-
Dissolved sodium	1.97	distant	none	none	Data only available for two sites.
Total chloride	2.03	distant	spring and winter	positive	Low number of sites.
Dissolved ortho phosphorus	2.16	distant	none	none	Data only available for two sites.
Total barium	-	-	none	positive	-
Total copper	-	-	none	none	-
Total lithium	-	-	none	positive	-

Table 3-1 Seasonal Variation Metric and Distance from TSS SVM Results

Parameter	Variation Pattern (SVM Distance from TSS)	Variation Pattern Category	Seasonal Pattern	Spatial Pattern (from upstream to downstream)	Comments
Total molybdenum	-	-	none	none	-
Total selenium	-	-	none	none	-
Total strontium	-	-	spring, fall, and winter	negative	Negative spatial pattern is only apparent during the spring, fall, and winter.
Total uranium	-	-	none	none	Low sample sizes.
Intermediate Patterns					
Hardness	0.48	immediate	spring and winter	positive	-
Total calcium	0.55	immediate	fall and winter	positive	-
Total sulphate	0.59	immediate	spring and winter	none	-
Total magnesium	0.25	immediate	none	positive	-
Total ammonia	0.46	immediate	none	none	-

3.2.2.1 Parameters Behaving Similarly to Total Suspended Sediment

Several nutrient parameters, total coliforms, and several metals had similar seasonal patterns as TSS in the upper Elbow River mainstem. Similar seasonal pattern indicated that these parameters are particle-associated or increase as a response to similar conditions as suspended sediment. These parameter concentrations are greatest during the spring and summer, and they are most variable during this period. Like TSS absolute concentrations, spatial pattern of the absolute concentrations of these parameters increase in the upper Elbow River from Bragg Creek to Weaselhead Bridge.

Parameters that are the most similar to TSS in the upper Elbow River mainstem:

- are in the immediate distance category from TSS SVMs (i.e., had a similar seasonal data pattern as TSS)
- are highest in the spring and summer
- have a positive spatial pattern (i.e., increased from upstream to downstream)

These parameters included turbidity (an optical measure of TSS), total coliforms (Figure 3-4), dissolved phosphorus (Figure 3-5), total organic carbon (Figure 3-6), and total phosphorus (Figure 3-7). Of these parameters, total organic carbon is the only parameter not associated with a positive spatial pattern, but is otherwise similar to TSS.

Parameters that have a moderately similar seasonal variation pattern to TSS (i.e., that are in the moderate distance category from TSS SVMs) and similar seasonal and spatial pattern are fecal coliforms, conductivity, Kjeldahl nitrogen (Figure 3-8), and total potassium.

Other parameters lacked the data to calculate SVMs. Despite this, visual assessment of seasonal patterns could still be conducted. Metals include total aluminum (Figure 3-9), arsenic (Figure 3-10), boron (Figure 3-11), chromium (Figure 3-12), cobalt (Figure 3-13), iron (Figure 3-14), manganese (Figure 3-15), total nickel (Figure 3-16), titanium (Figure 3-17), and vanadium (Figure 3-18). These have similar seasonal patterns as TSS. Dissolved boron (Figure 3-19) and arsenic (Figure 3-20) concentrations are also greatest during the spring and summer. Total zinc concentrations are greatest only during summer and not during the spring as many other metals (Figure 3-21). Nitrite (Figure 3-22) and dissolved organic carbon (Figure 3-23) are greatest only during the spring and summer, respectively.

Several nutrients that were associated with TSS spatial and temporal patterns, including phosphorus, nitrogen, and organic carbon are primarily derived from terrestrial systems and enter the aquatic environment by overland flow (Wetzel 1975). Phosphorus and nitrogen species can also enter aquatic systems by groundwater, bank/channel erosion and rainfall. Rainfall and groundwater are thought to be relatively minor contributions of phosphorus and nitrogen relative to overland flow, and bank/channel erosion. This assumption is made based on a general understanding of watershed dynamics and professional judgment. Organic carbon enters aquatic systems through aquatic photosynthesizing organisms, or by overland leaching from terrestrial plants. The upper Elbow River mainstem is not reported to have substantial macrophyte (aquatic plant) growth in literature, and so the source of organic carbon is likely from terrestrial runoff. The sources of the nutrients associated with TSS are likely primarily the result of overland flow during spring and summer precipitation.

Total and fecal coliforms are associated with TSS spatial and temporal patterns. Fecal coliforms are found in the intestinal tract of mammals; other coliforms are found in terrestrial substrates. Like the nutrients discussed, coliforms are primarily transported from terrestrial to aquatic systems by overland flow (e.g., Crane et al. 1983; Tyrrel and Quinton 2003). The spatial and temporal patterns of total and fecal coliforms likely take place during the spring and summer precipitation because overland flow probably primarily drives them.

Metals are often associated with TSS, which generally have a negative charge, whereas most metals have a positive charge (Foster and Charlesworth 1996). As a result, metals tend to associate closely with TSS particles and can, therefore, enter the water column by the same processes as TSS. This close relationship is likely why the spatial and temporal patterns of metals corresponded well to those of TSS. The mechanisms for metal uptake into the water column are similar to those of TSS.

The parameters that corresponded with TSS spatial and temporal patterns appear to be driven by at least of the subset of the processes that control TSS patterns. Nutrients and total coliforms are likely primarily the result of overland flow resulting from precipitation that occurs during the spring and summer. Some phosphorus and nitrogen can also be contributed directly to the upper Elbow River directly by precipitation.

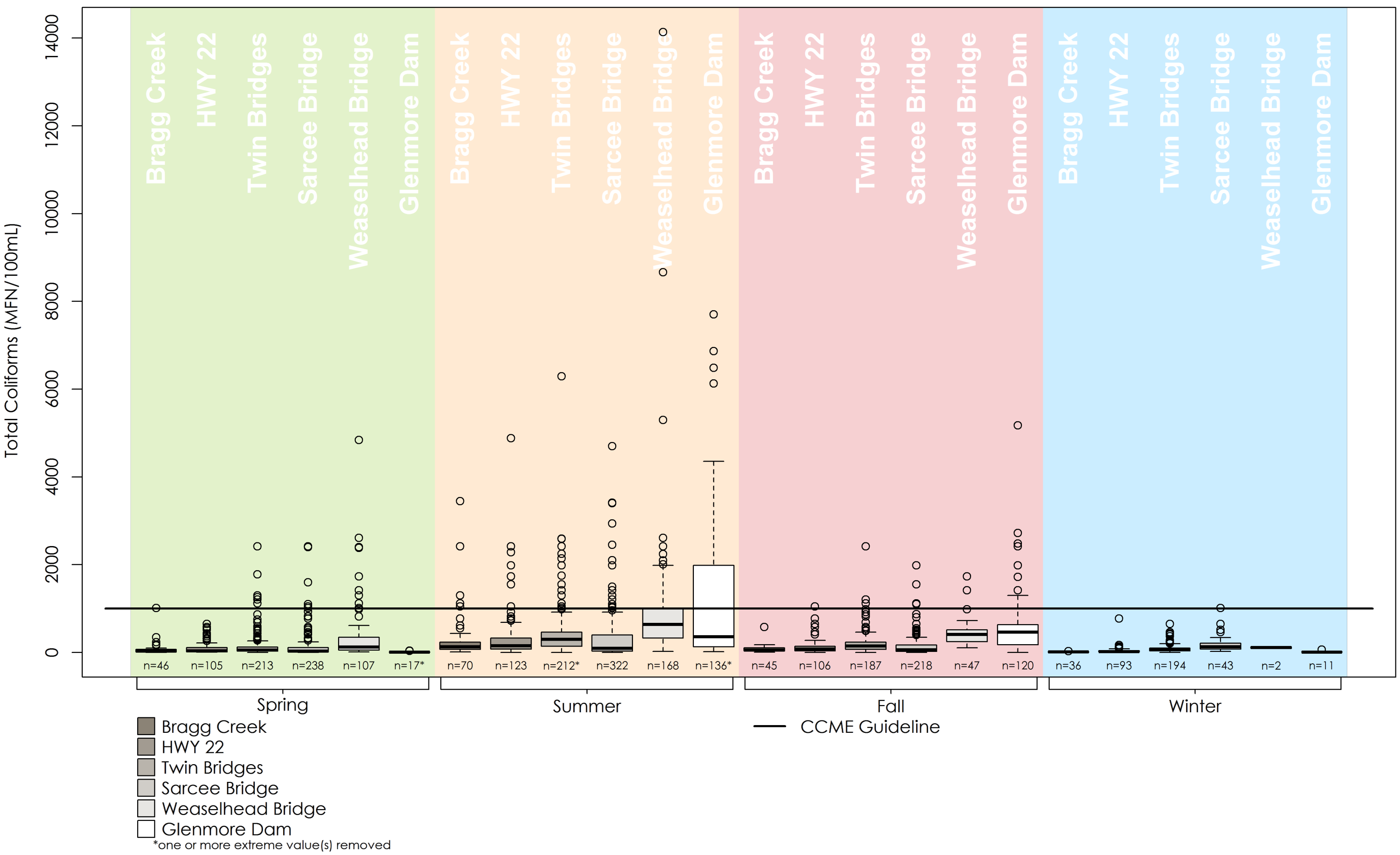


Figure 3-4 Total Coliform Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1979 to 2016

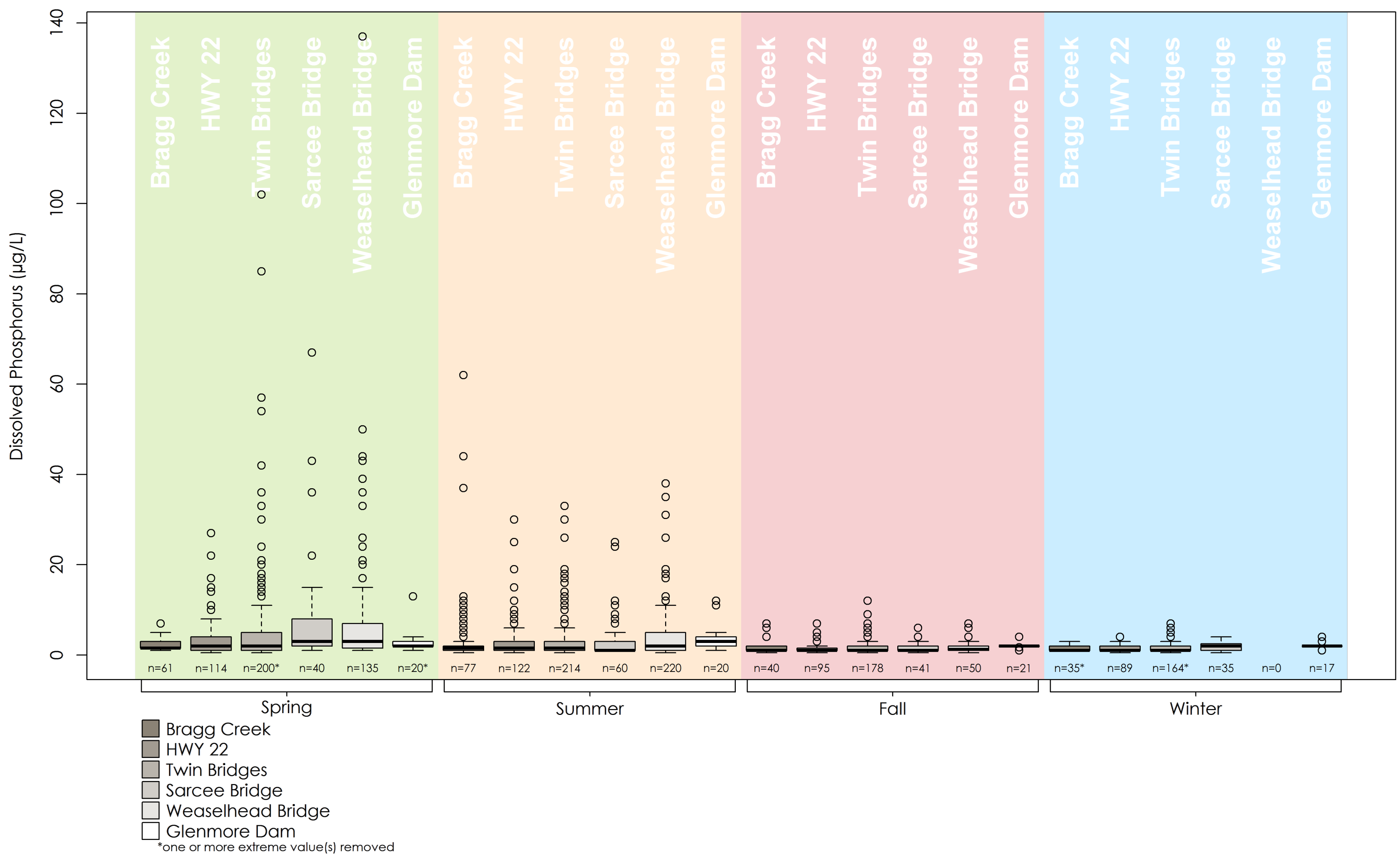


Figure 3-5 Dissolved Phosphorus Concentration in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1988 to 2015

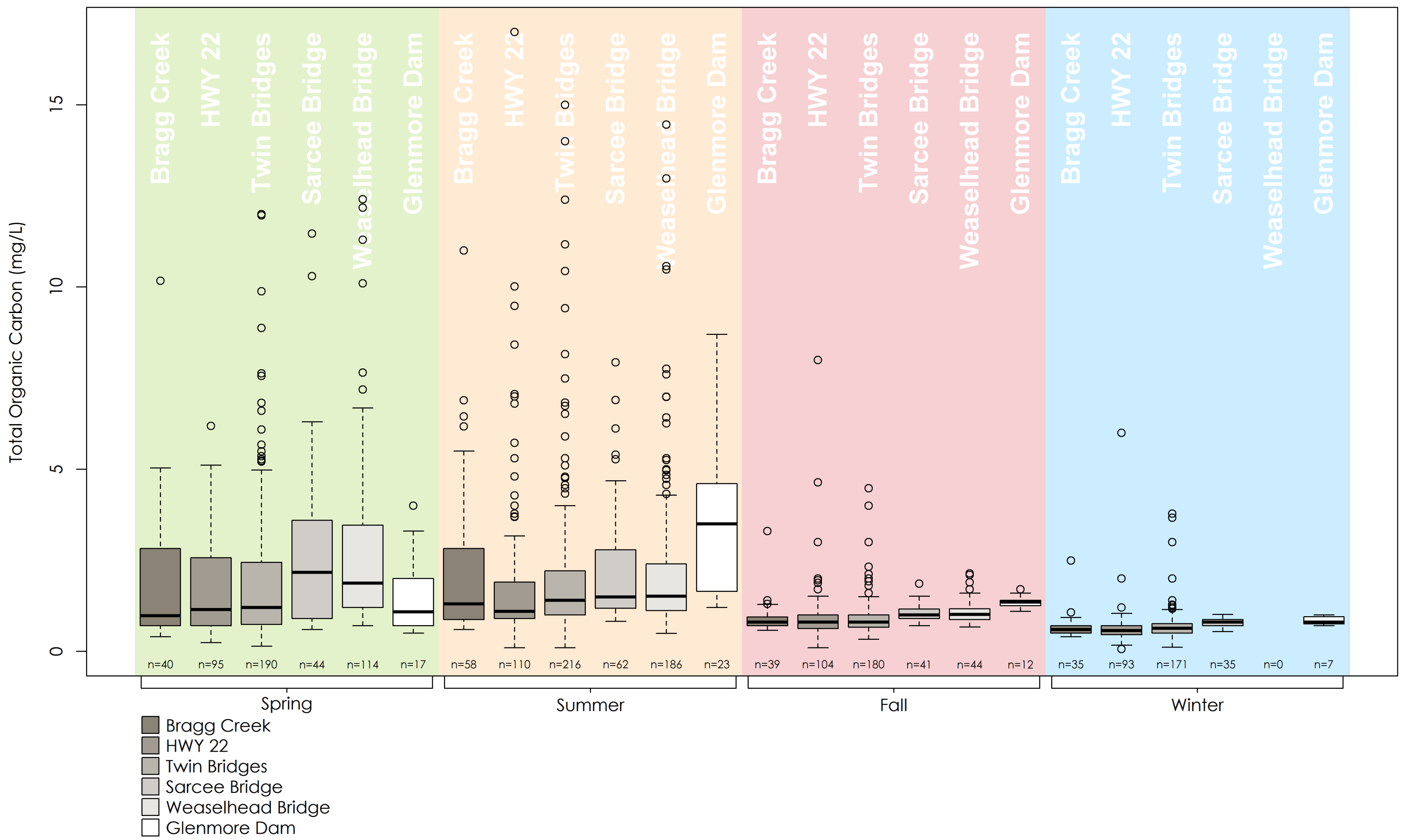


Figure 3-6 Total Organic Carbon Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1979 to 2016

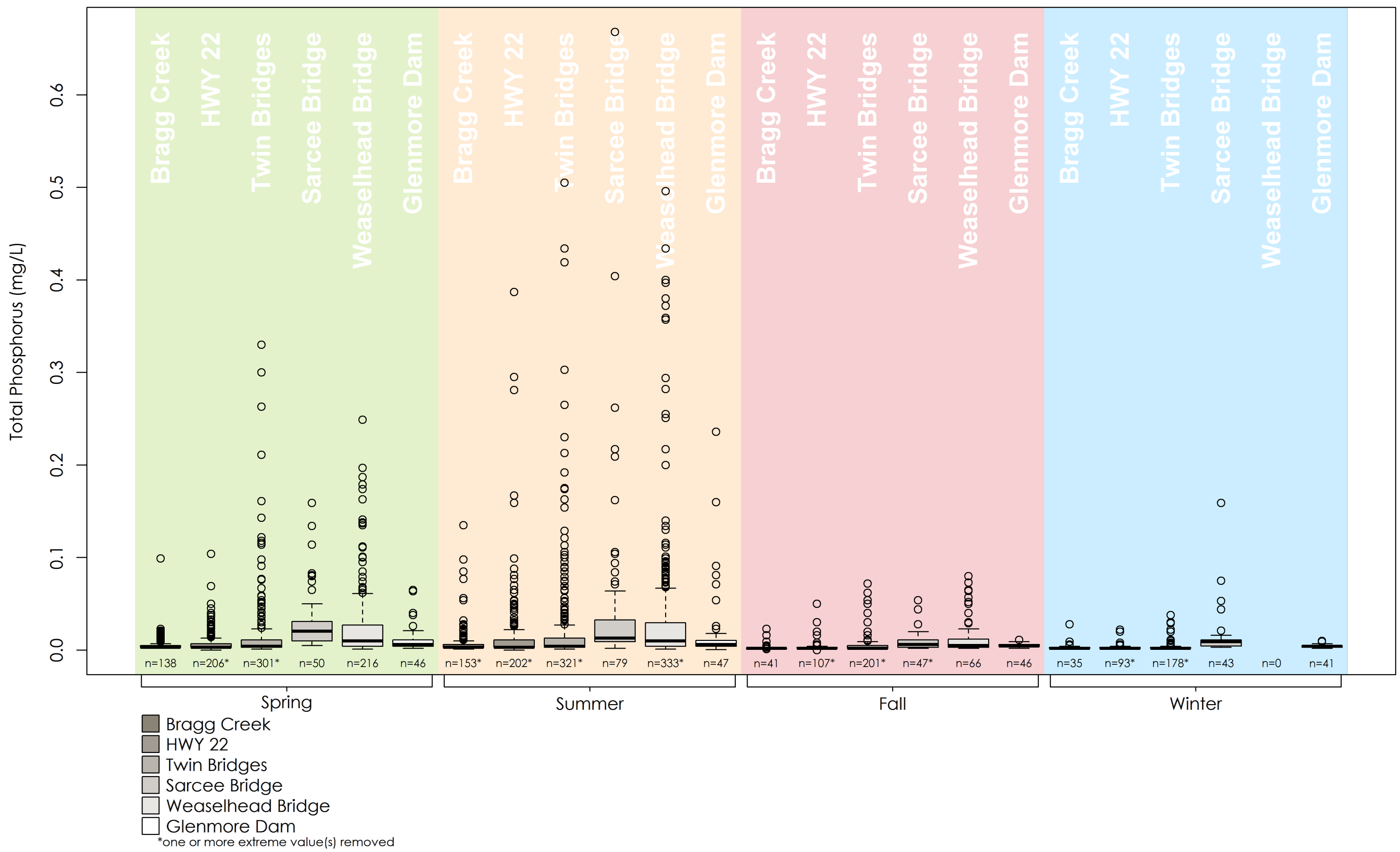


Figure 3-7 Total Phosphorus Concentration in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1979 to 2016

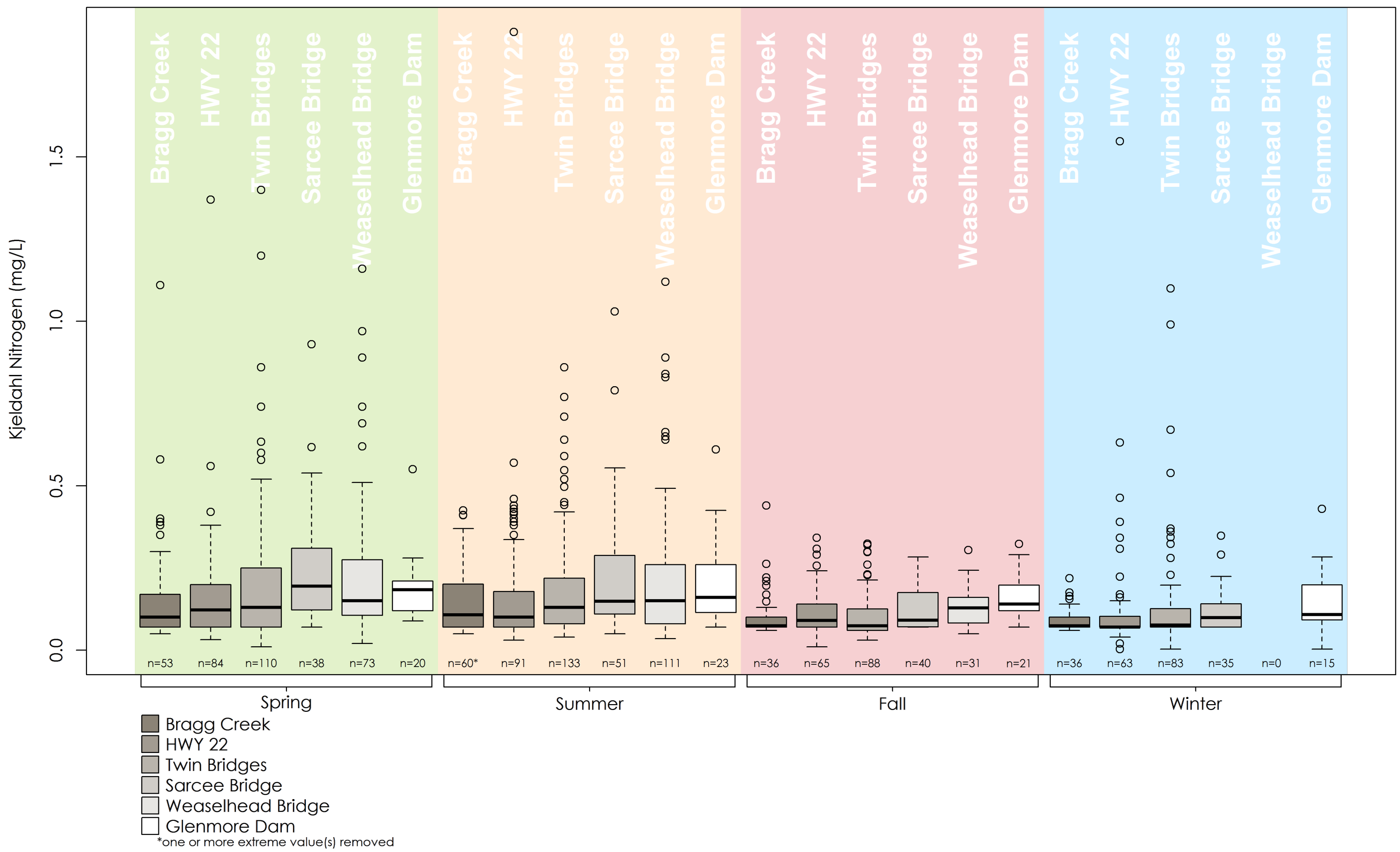


Figure 3-8 Kjeldahl Nitrogen Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1979 to 2016

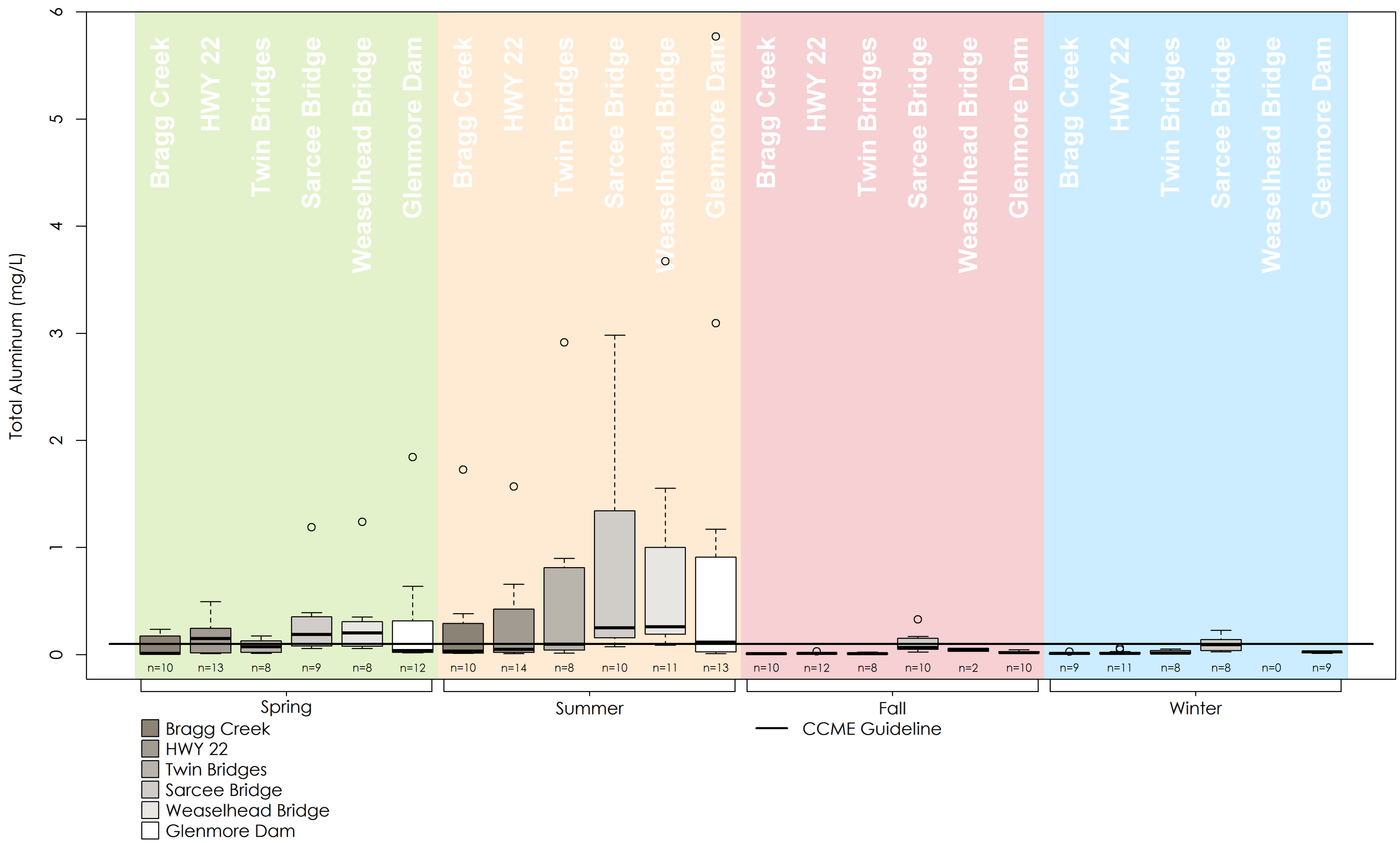


Figure 3-9 Total Aluminum Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 2006 to 2016

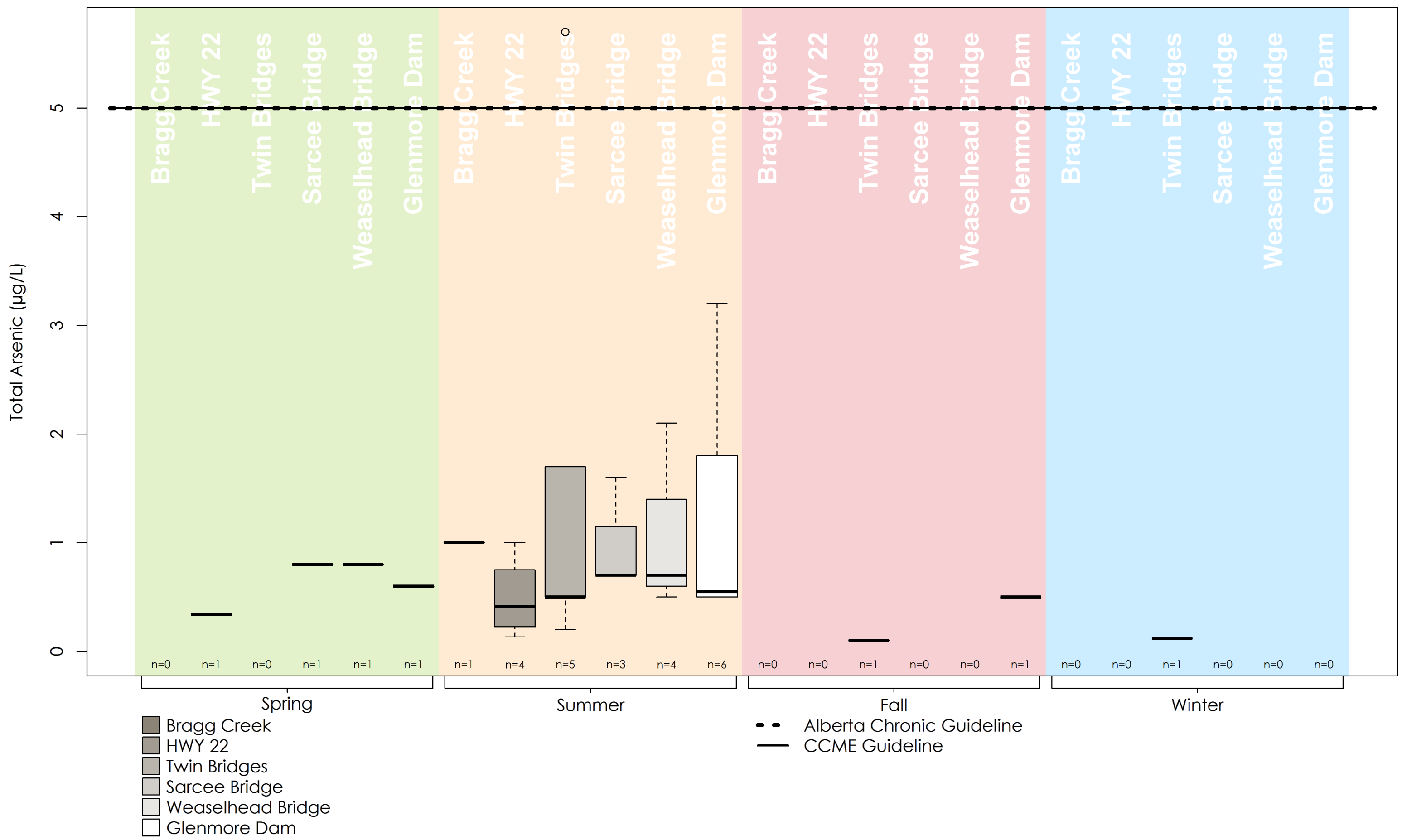


Figure 3-10 Total Arsenic Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1994 to 2016

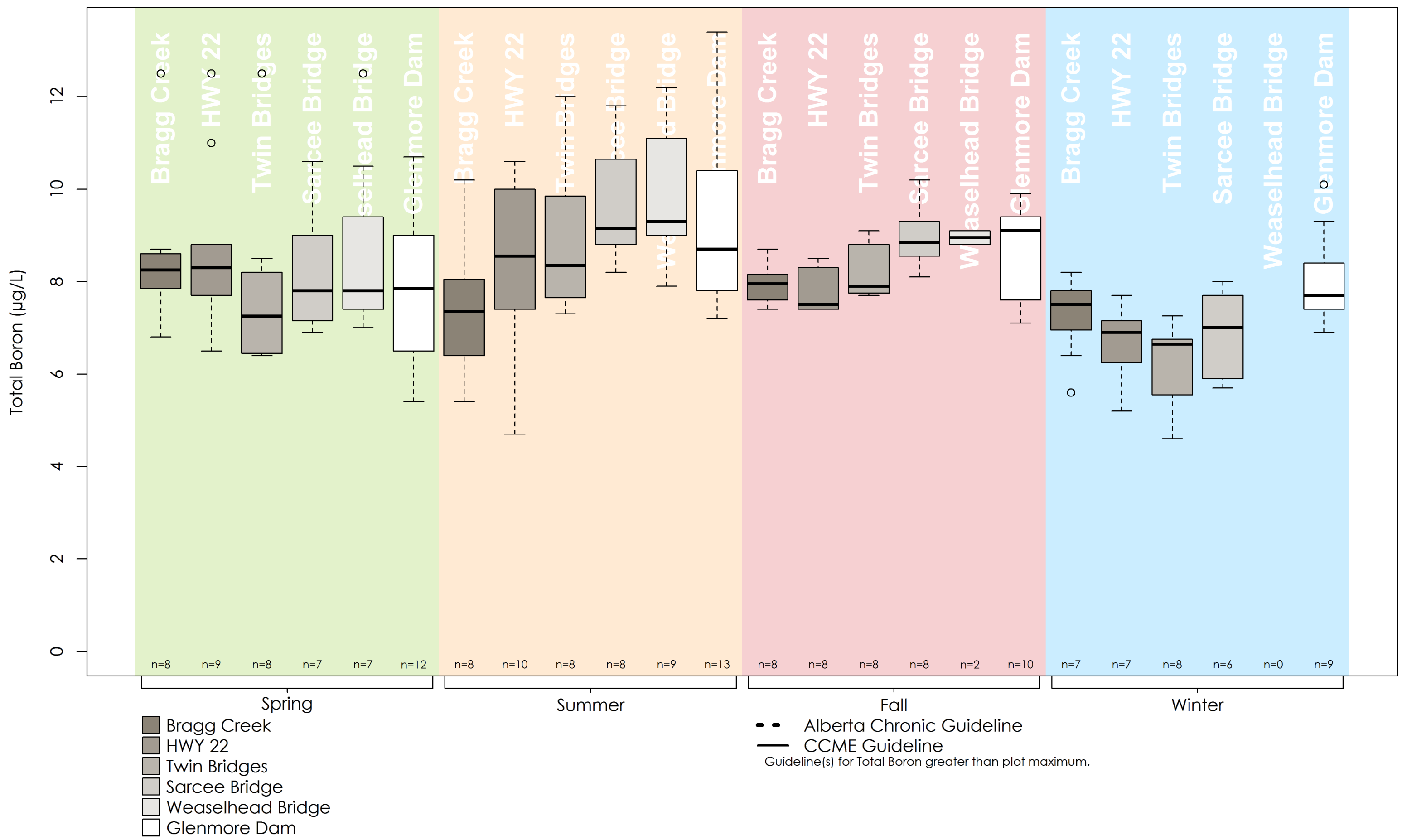


Figure 3-11 Total Boron Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 2006 to 2016

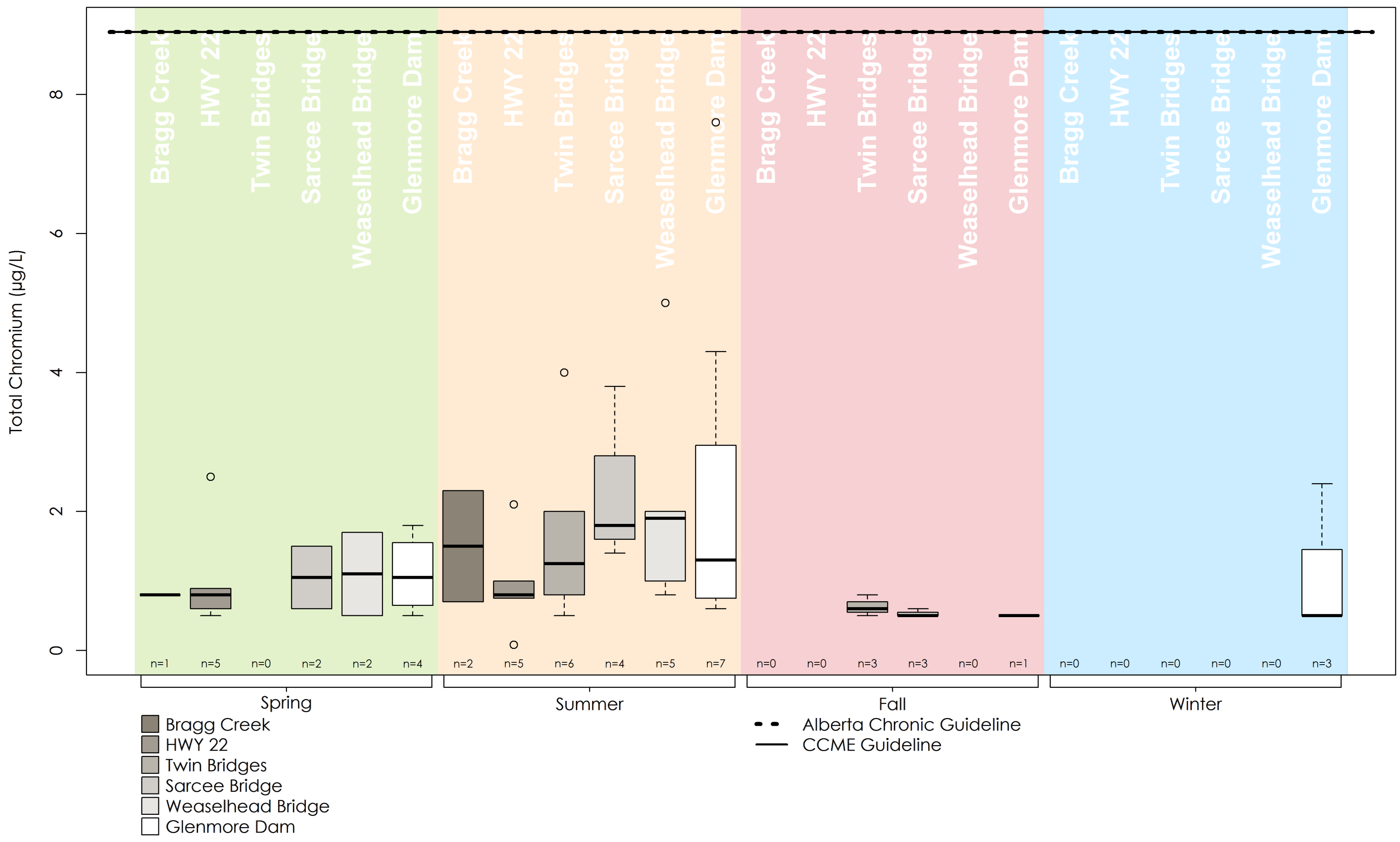


Figure 3-12 Total Chromium Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1994 to 2016

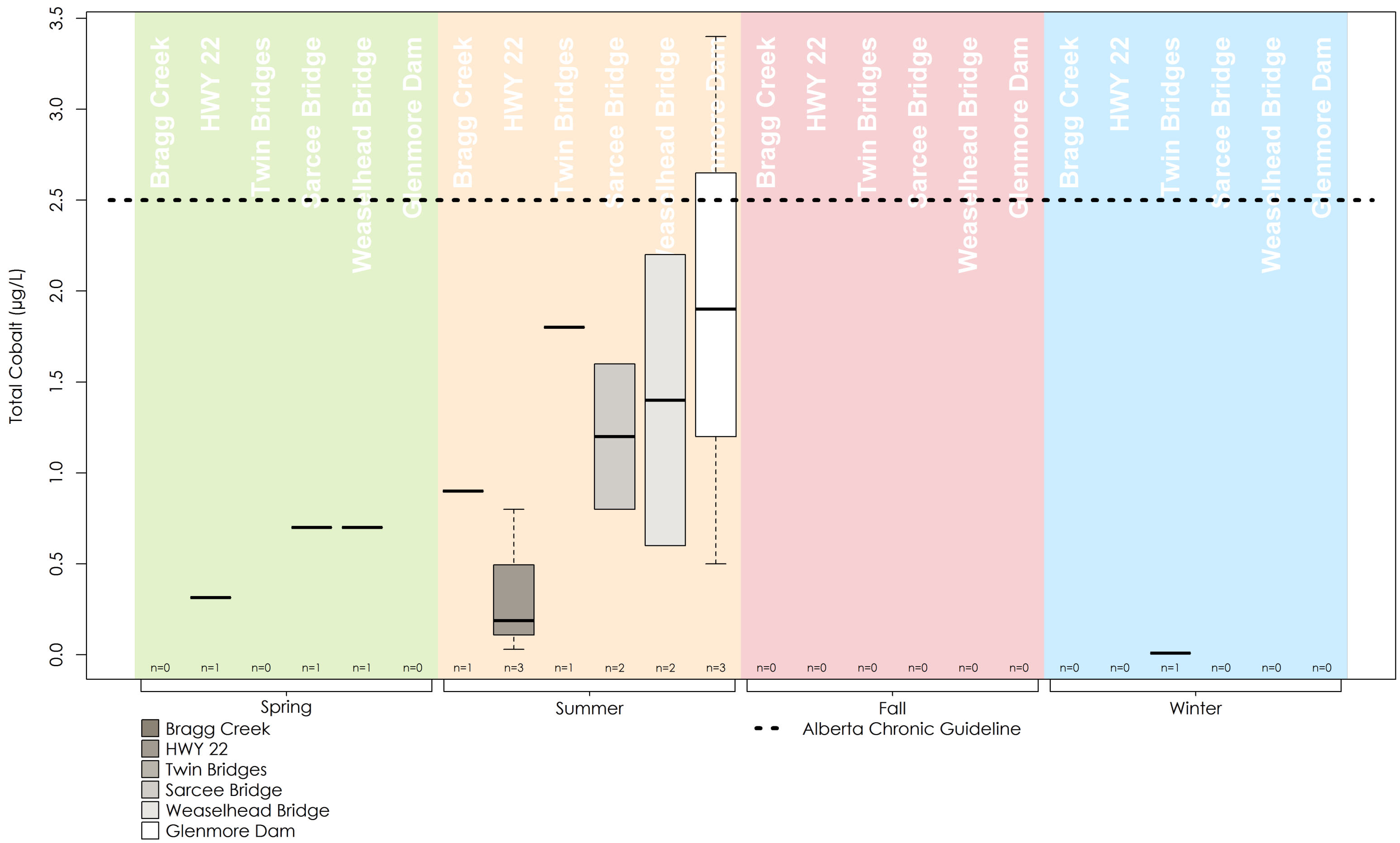


Figure 3-13 Total Cobalt Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 2007 to 2016

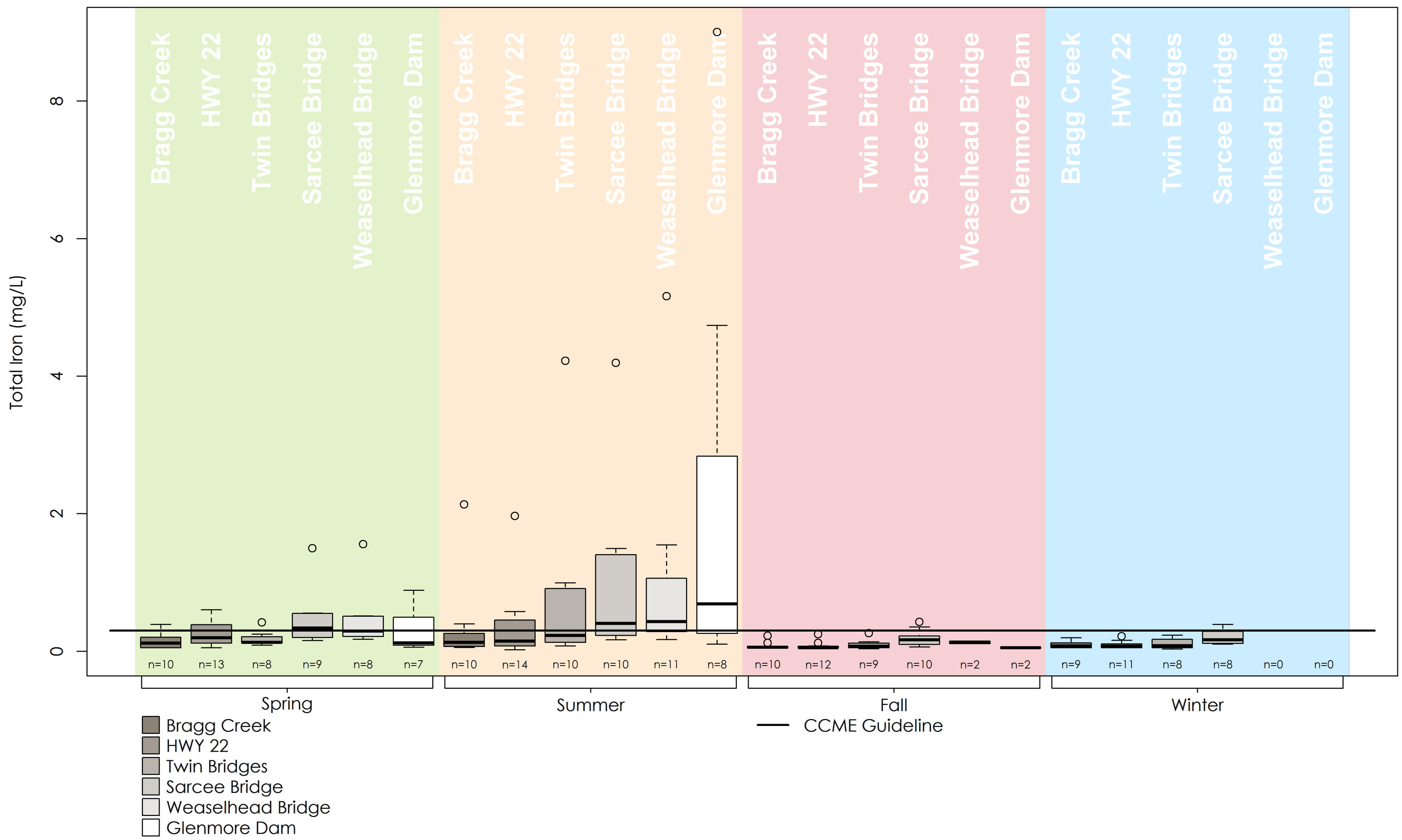


Figure 3-14 Total Iron Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1994 to 2016

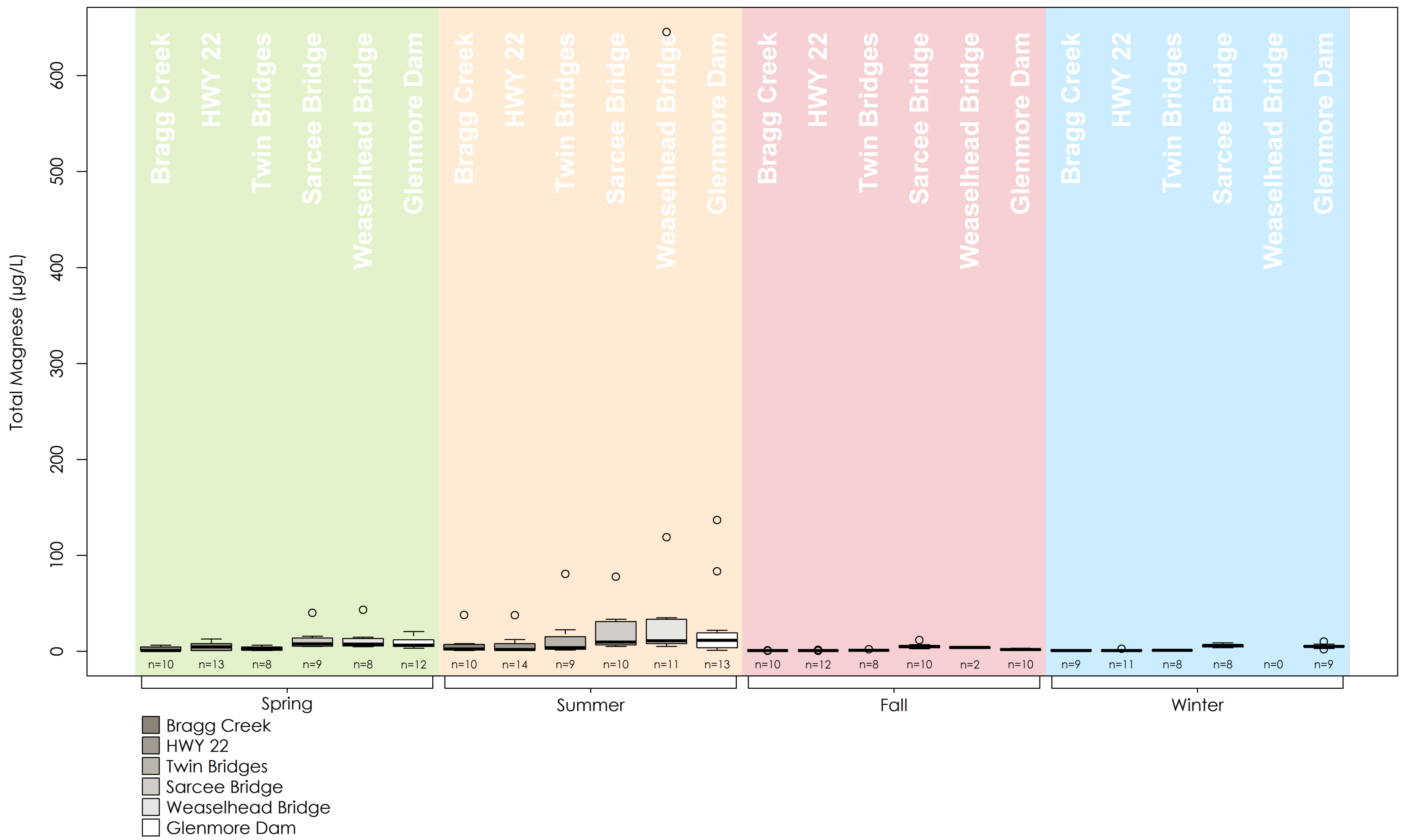


Figure 3-15 Total Manganese Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1994 to 2016

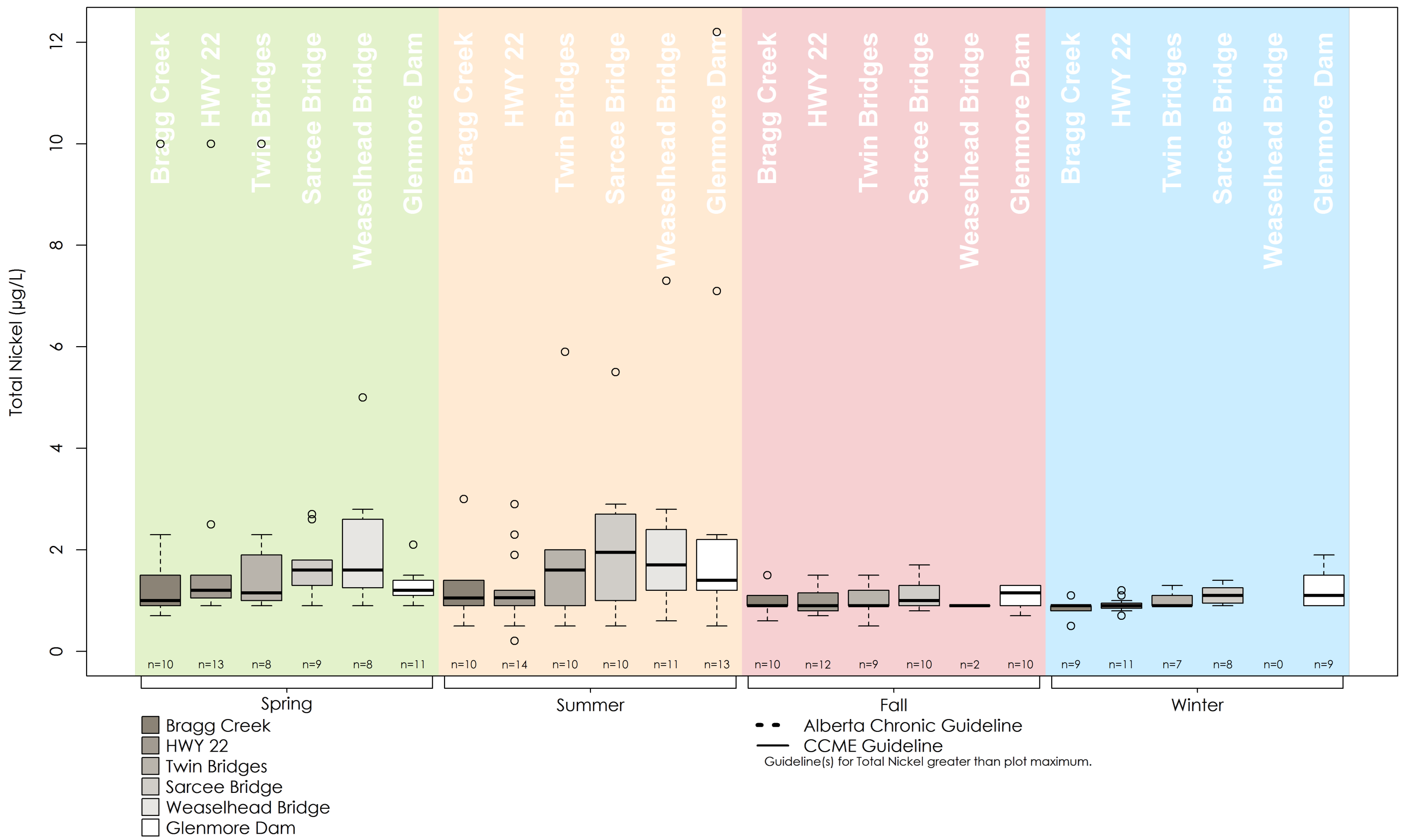


Figure 3-16 Total Nickel Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1994 to 2016

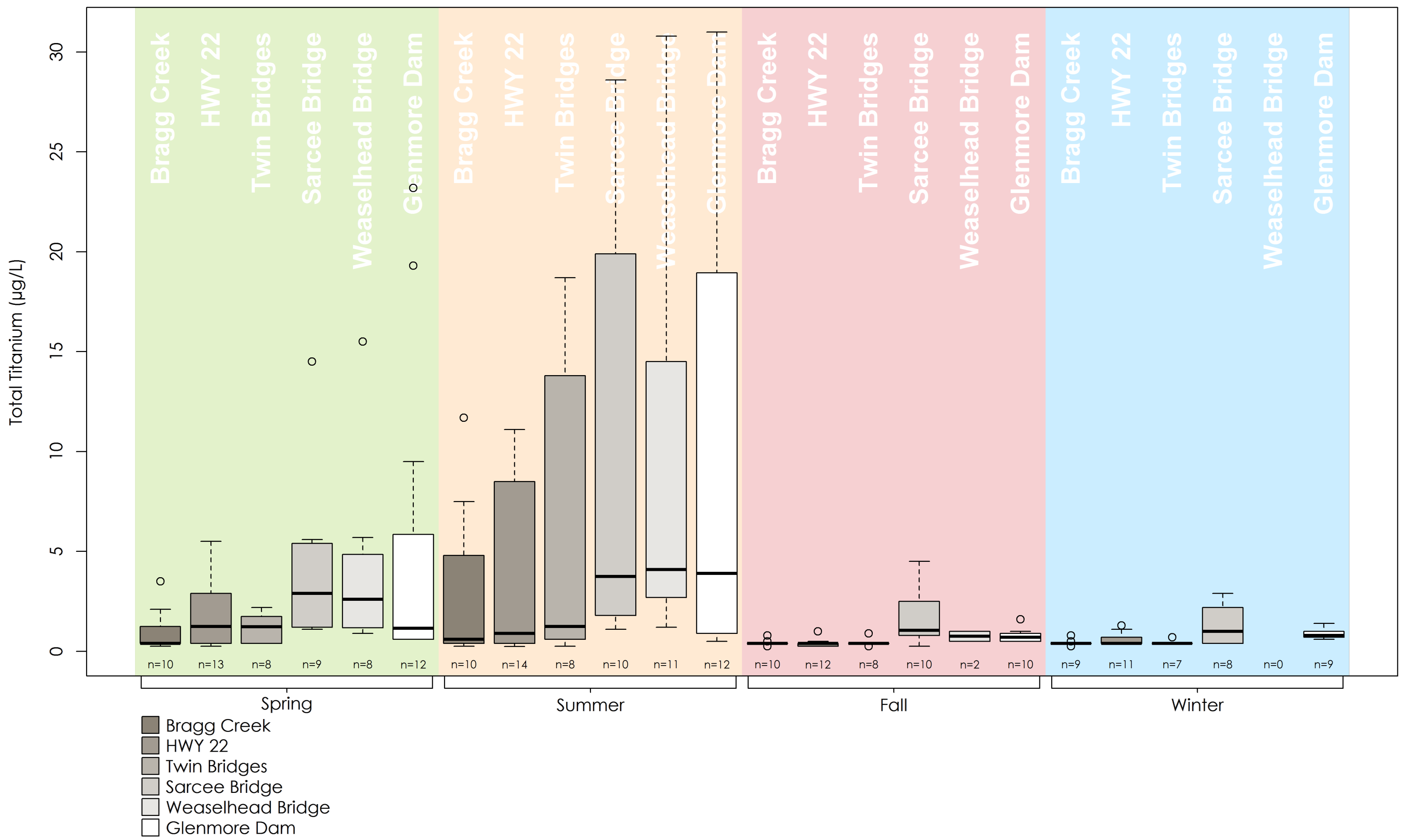


Figure 3-17 Total Titanium Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 2006 to 2016

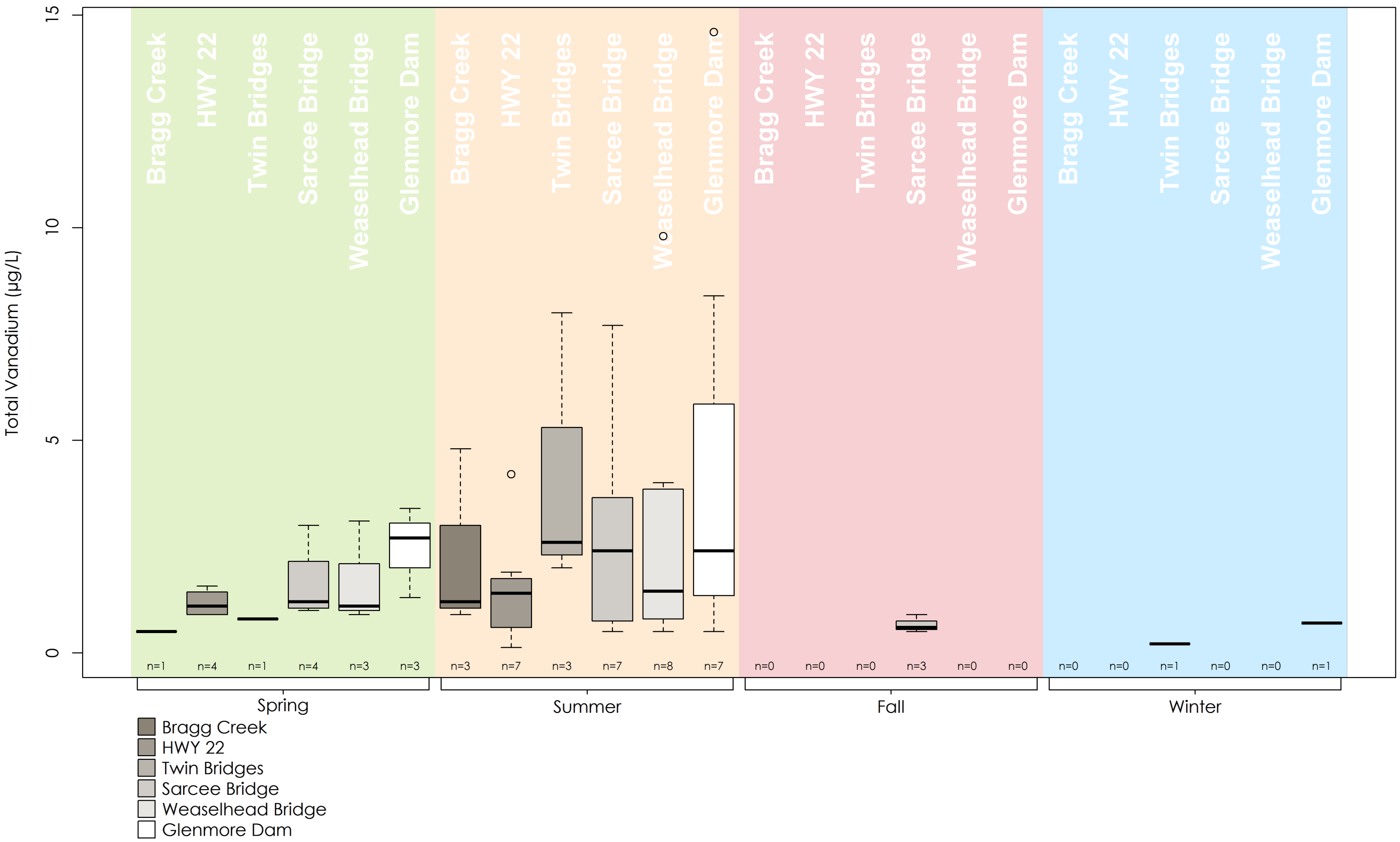


Figure 3-18 Total Vanadium Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 2006 to 2016

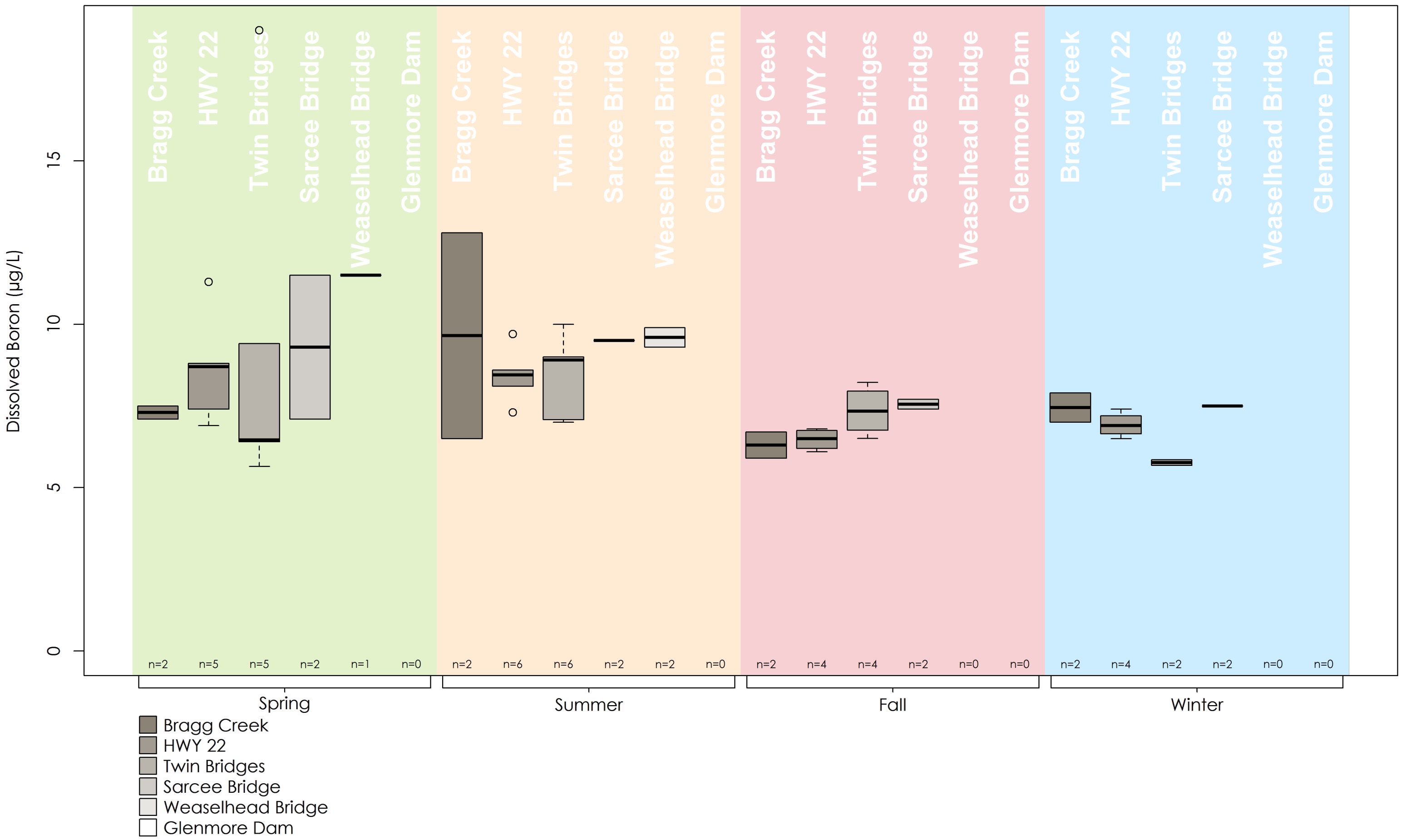


Figure 3-19 Dissolved Boron Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1994 to 2016

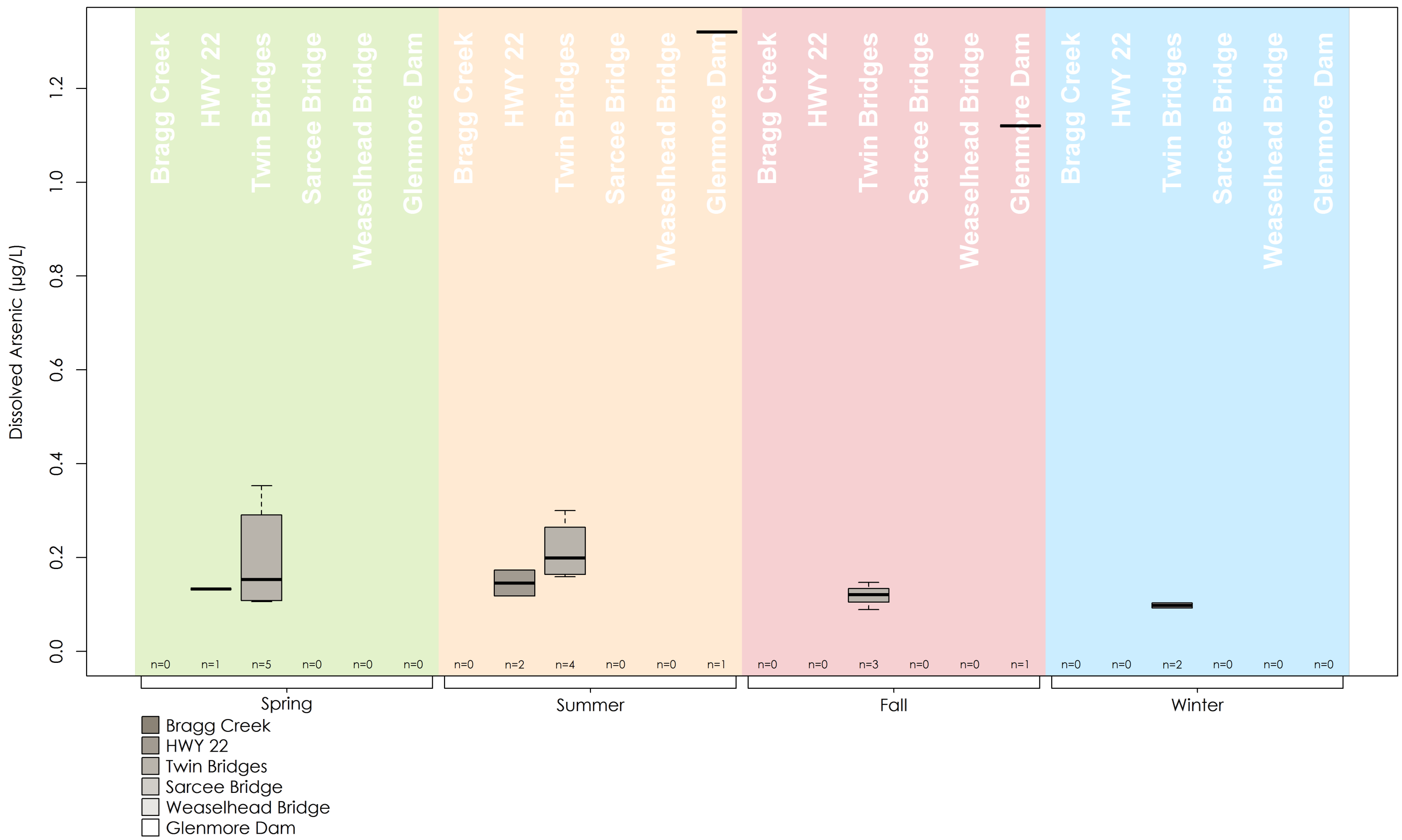


Figure 3-20 Dissolved Arsenic Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1998 to 2016

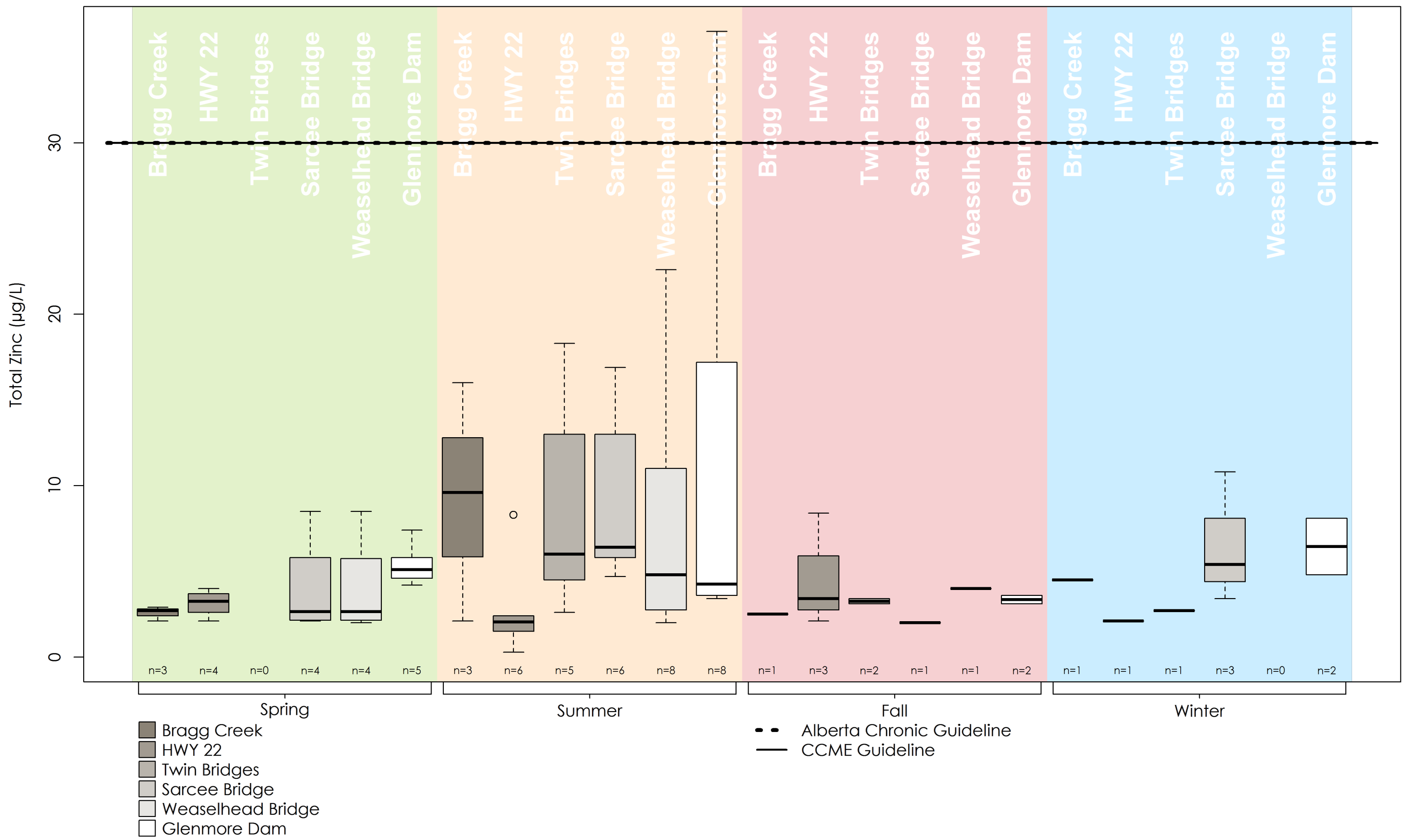


Figure 3-21 Total Zinc Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1994 to 2016

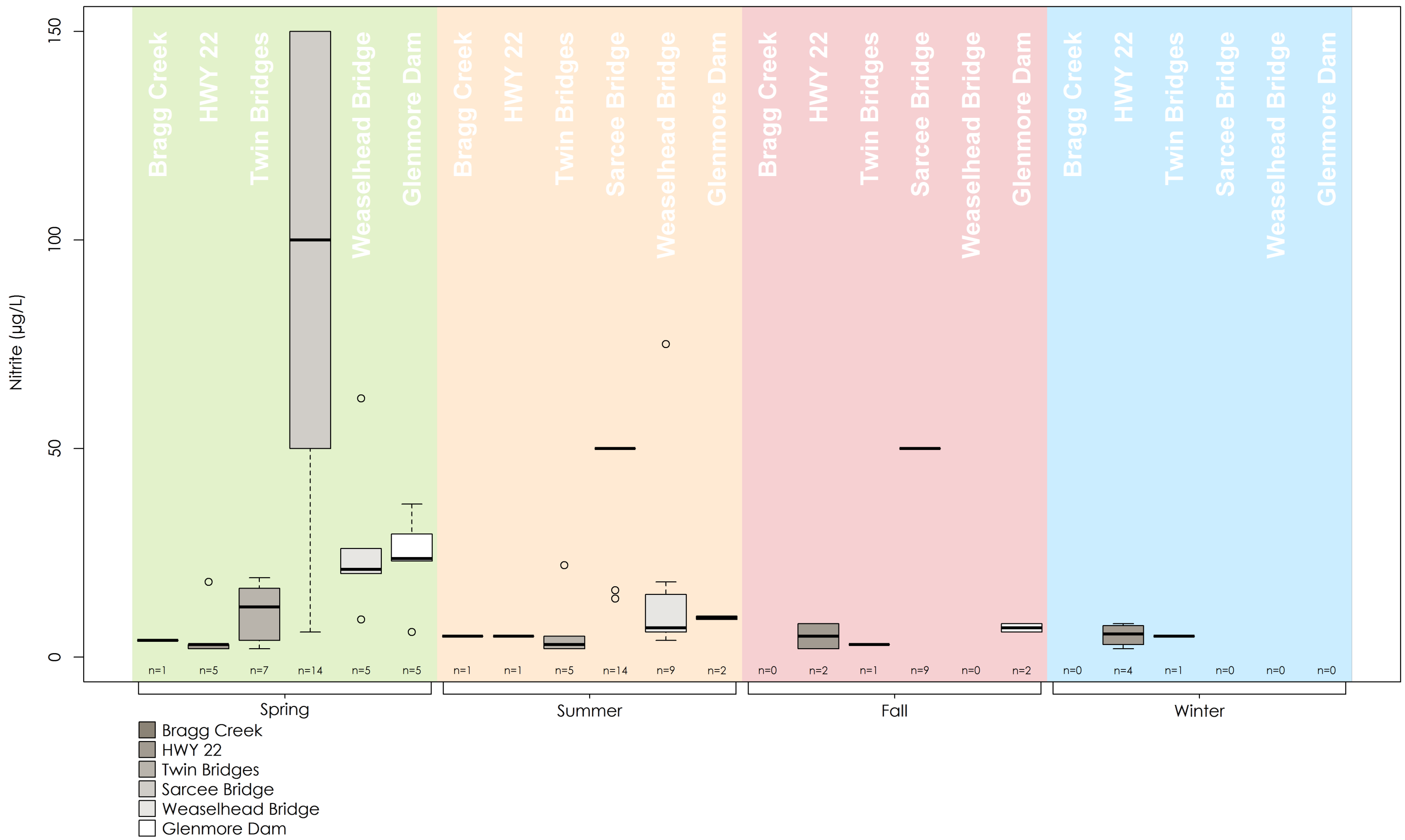


Figure 3-22 Nitrite Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1979 to 2015

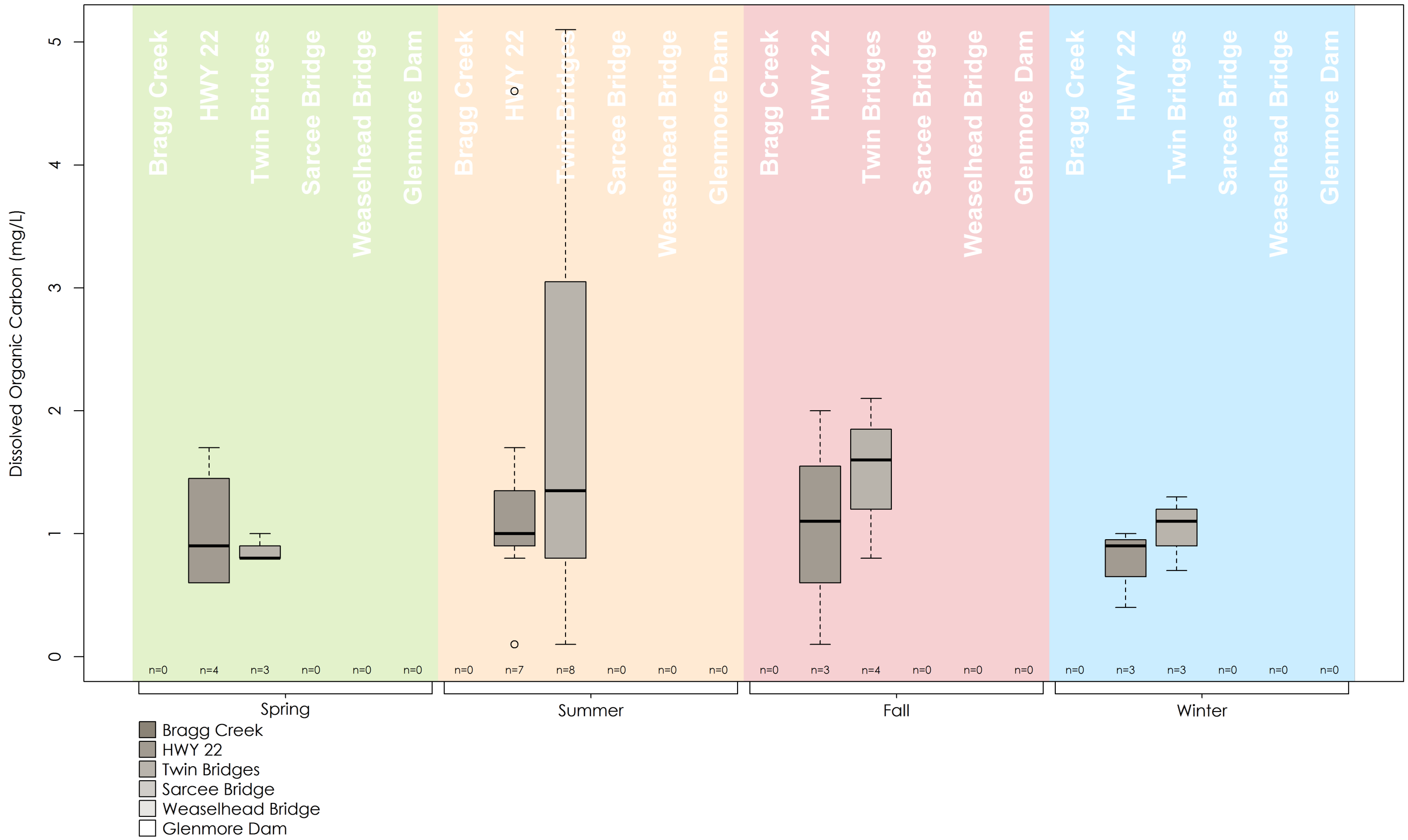


Figure 3-23 Dissolved Organic Carbon Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1988 to 2016

3.2.2.2 Temperature and Dissolved Oxygen

Water temperature and dissolved oxygen conditions change similarly in response to the diversion of flood water and retention in the reservoir prior to release back into Elbow River.

Temperature varied both seasonally and spatially (Figure 3-24). Temperatures generally increased in the upper Elbow River from upstream (Bragg Creek) to downstream (Weaselhead Bridge) during all seasons.

Temperature COVs were generally greatest during the winter months and lowest during the summer months. This indicates that temperatures are most variable during the winter and least variable during the summer. Spring COVs are generally greater than fall COVs, and both are intermediate to the summer and winter COVs. This indicates that temperature variability is greatest in the winter, second during the spring, third during the fall, and lowest during the summer. A chinook is a warm, westerly wind that blows down from the Rocky Mountains and causes unseasonably warm weather during the winter and spring. The temperature variability observed in the Elbow River may be the result of chinook events that increase water temperatures when they are the coldest, creating variability not observed during the summer and fall.

Dissolved oxygen concentrations varies seasonally, but are not associated with any apparent spatial pattern (Figure 3-25). Dissolved oxygen concentrations are greatest during the winter, lowest during the summer, and intermediate during the spring and fall. Dissolved oxygen concentrations are greater during the spring relative to the fall.

Dissolved oxygen COVs are greatest during the fall and lowest during the winter. This indicates that dissolved oxygen variability is greatest during the fall and lowest during the winter. Dissolved oxygen SVM distance metrics was in the ‘moderate’ category relative to TSS SVMs (Table 3-1). Indicating that the variation pattern is somewhat similar to TSS variation patterns.

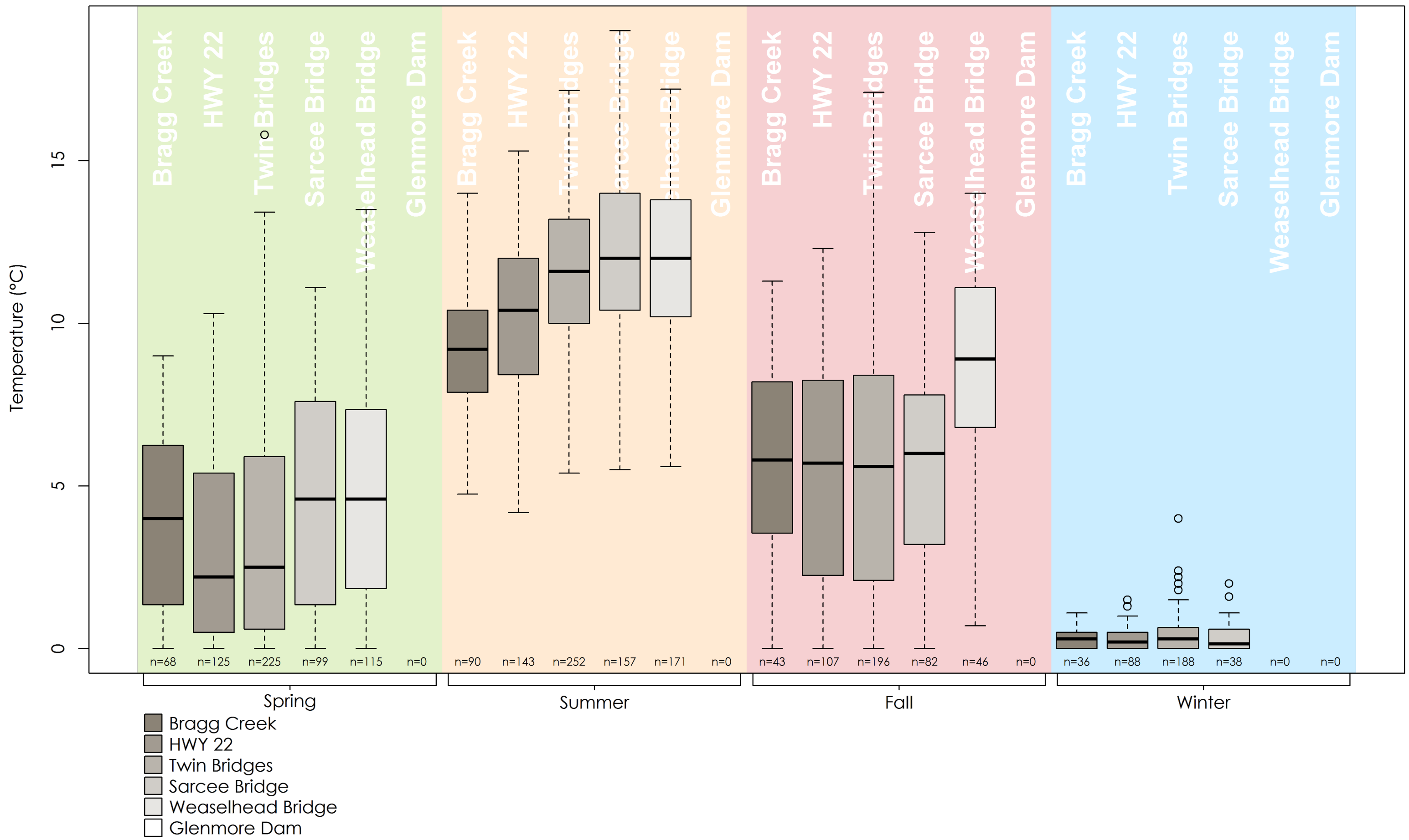


Figure 3-24 Temperature in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1979 to 2016

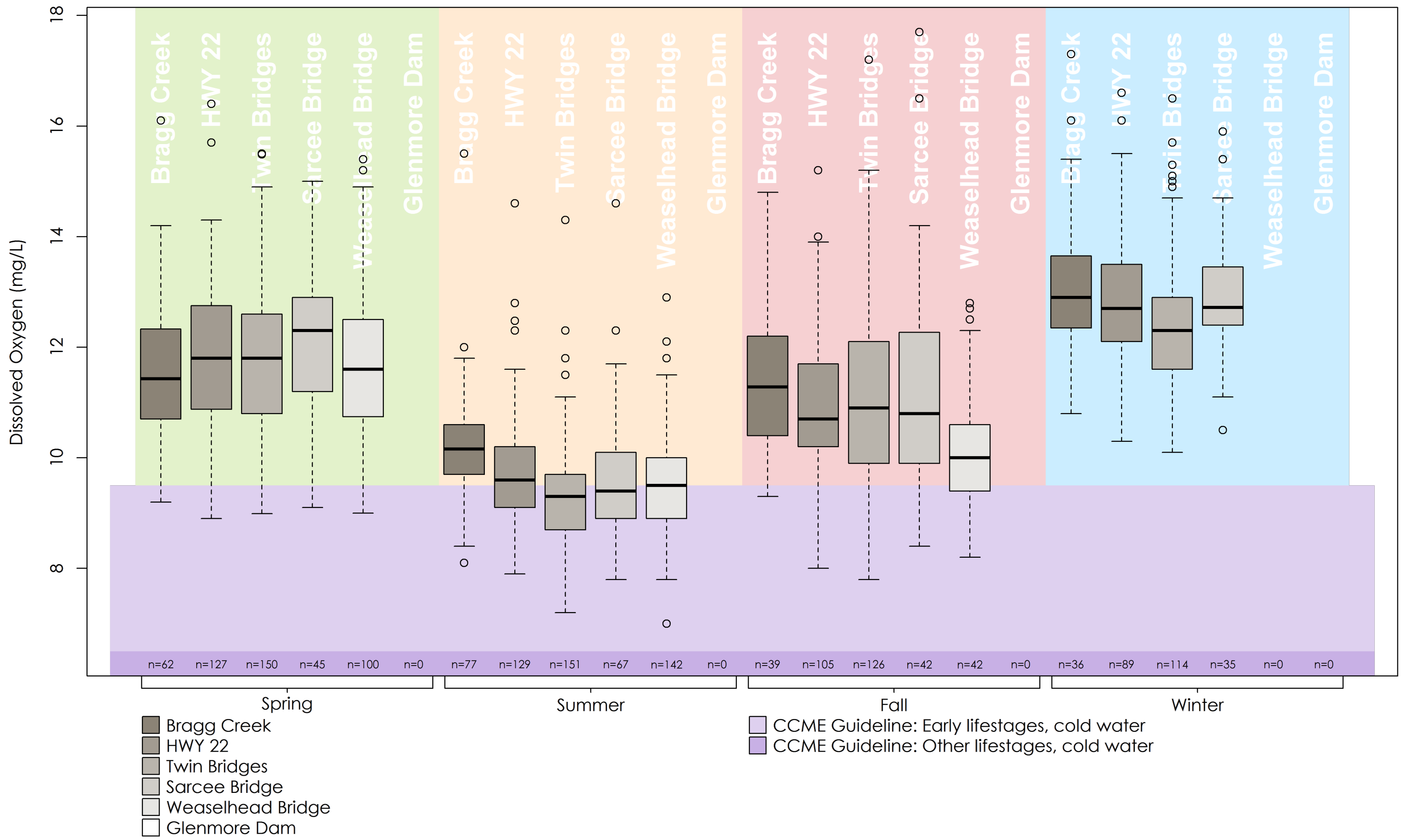


Figure 3-25 Dissolved Oxygen Concentration in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1979 to 2016

3.2.2.3 Parameters Behaving in Contrast to TSS

Ions and some nutrient parameter patterns generally differed from TSS seasonal and spatial patterns (Table 3-1). These parameters either lack seasonality or are at their highest values in winter and spring (with some exceptions). Parameters that behave distinctly from TSS are either not associated a spatial pattern or associated with a negative spatial pattern (i.e., decreased in concentration from upstream to downstream). These parameters are not anticipated to behave like TSS during a flood, and will likely be more diluted during a flood compared to lower flow conditions.

Dissolved chloride, total chloride, dissolved ortho phosphorus, dissolved oxygen saturation, dissolved potassium, dissolved sodium, and total sodium are in the distant TSS SVM category (Table 3-1). This indicates that the variability patterns of these parameters are among the most different from TSS of all parameters in the dataset. Dissolved chloride, dissolved ortho phosphorus, dissolved oxygen saturation, dissolved potassium, and dissolved sodium concentrations have no apparent seasonal pattern, whereas the remaining parameters in the distant SVM category peak during spring and winter. The variability patterns of these parameters are, therefore, amongst the most different from TSS, and their concentrations are greatest during spring and winter. Parameters in the distant SVM category tended to have positive spatial patterns; however, dissolved oxygen saturation, dissolved sodium, and dissolved ortho phosphorus had no apparent spatial pattern.

Ten parameters lacked seasonal patterns that are similar to TSS and are in the moderate TSS SVM category (Table 3-1). These parameter concentrations do not peak during spring and summer, and the variability of these parameters are neither particularly similar or dissimilar from TSS. The seasonal patterns of parameters in the moderate TSS SVM category are variable. Most of these parameters either have peak values during spring and winter or lack an apparent seasonal pattern. Dissolved sulphate is the only parameter to peak only in the winter. Parameters that peak during spring and winter included nitrate, nitrate and nitrite, total nitrogen, and pH. Parameters that lack a seasonal pattern are alkalinity, total fluoride, dissolved fluoride, dissolved magnesium, and dissolved calcium. The spatial patterns of parameters in the moderate TSS SVM category are also variable. Most of these parameters lack either apparent spatial pattern, or have a positive spatial pattern. Parameters that have a positive spatial pattern (concentrations are greatest at downstream locations) include dissolved sulphate, alkalinity, and total nitrogen. Parameters lacking a spatial pattern included nitrate, nitrate and nitrite, pH, and dissolved fluoride. Total fluoride has a negative spatial pattern, indicating that concentrations are greater at upstream locations.

Six parameters lacked the data to calculate SVMs, and did not have seasonal concentration patterns that were similar to TSS. These parameters are total barium, copper lithium molybdenum selenium, and uranium. Total strontium also lacked the data to calculate SVMs; however, concentrations are lowest during summer and are consistently higher through the other seasons.

Discharge in upper Elbow River is low during the winter because water sources such as precipitation and snow melt are generally not active during winter. Groundwater inputs continue during the winter and maintain a baseflow (see further discussion in Volume 4, Appendix J, Hydrology TDR). Parameters that are concentrated in groundwater are greatest during the winter, when other inputs that dilute groundwater concentrations are inactive (e.g., Grasby et al. 1999). Parameters such as dissolved sulphate, total sulphate, nitrate, nitrite and nitrate, total nitrogen, pH, total sodium, and total chloride that peak during winter are likely associated with groundwater inputs.

The variability observed in the data is likely the result of a many factors. For example, groundwater from different depths have been shown to exhibit different water quality patterns (e.g., Hill and Neal 1997; Grasby et al. 1999). Aquifers that are the source of groundwater for rivers also have variable characteristics such as thickness, hydraulic conductivity, porosity, velocity, and configuration, and they can cause yet more variability in surface water patterns (Gelhar et al. 1992). Parameters that are prevalent in groundwater may also occur in surface runoff patterns, making the role of groundwater in the patterns of surface water difficult to discern.

Despite this, some of the surface water parameters that are driven by groundwater inputs have been associated with groundwater inputs in literature. For example, most nutrients in upper Elbow River are associated with TSS; however, nitrate, nitrate, and nitrite, and orthophosphorus do not behave similarly to TSS. Nitrates and orthophosphorus, as this data shows, have been shown to particularly be prevalent in groundwater across North America (Tesoriero et al. 2009).

Dissolved oxygen saturation is an exception because groundwater oxygen concentrations are typically low (e.g., Malard and Hervant 1999) and oxygen saturations in the upper Elbow River mainstem peaked during the winter. Dissolved oxygen saturation values that correspond to a given dissolved oxygen concentration is dependent on temperature, where the capacity of water to dissolve oxygen is negatively associated with temperature (i.e., as temperature increases the capacity of water to dissolve oxygen decreases (Wetzel 1975)).

3.2.2.4 Intermediate Patterns

Some analyzed parameters were comparable with TSS in either seasonal mean or variation patterns, but were not comparable with both. Hardness, total calcium, total sulphate, total magnesium, and total ammonia are in immediate variation pattern category; however, concentrations are not greatest in the spring and/or summer. Total magnesium and total ammonia are not associated with any seasonal patterns. Total calcium concentrations are greatest during fall and winter. Hardness and total sulphate are greatest during spring and winter. These patterns in upper Elbow River are likely the result of a combination of surface runoff and complex groundwater dynamics.

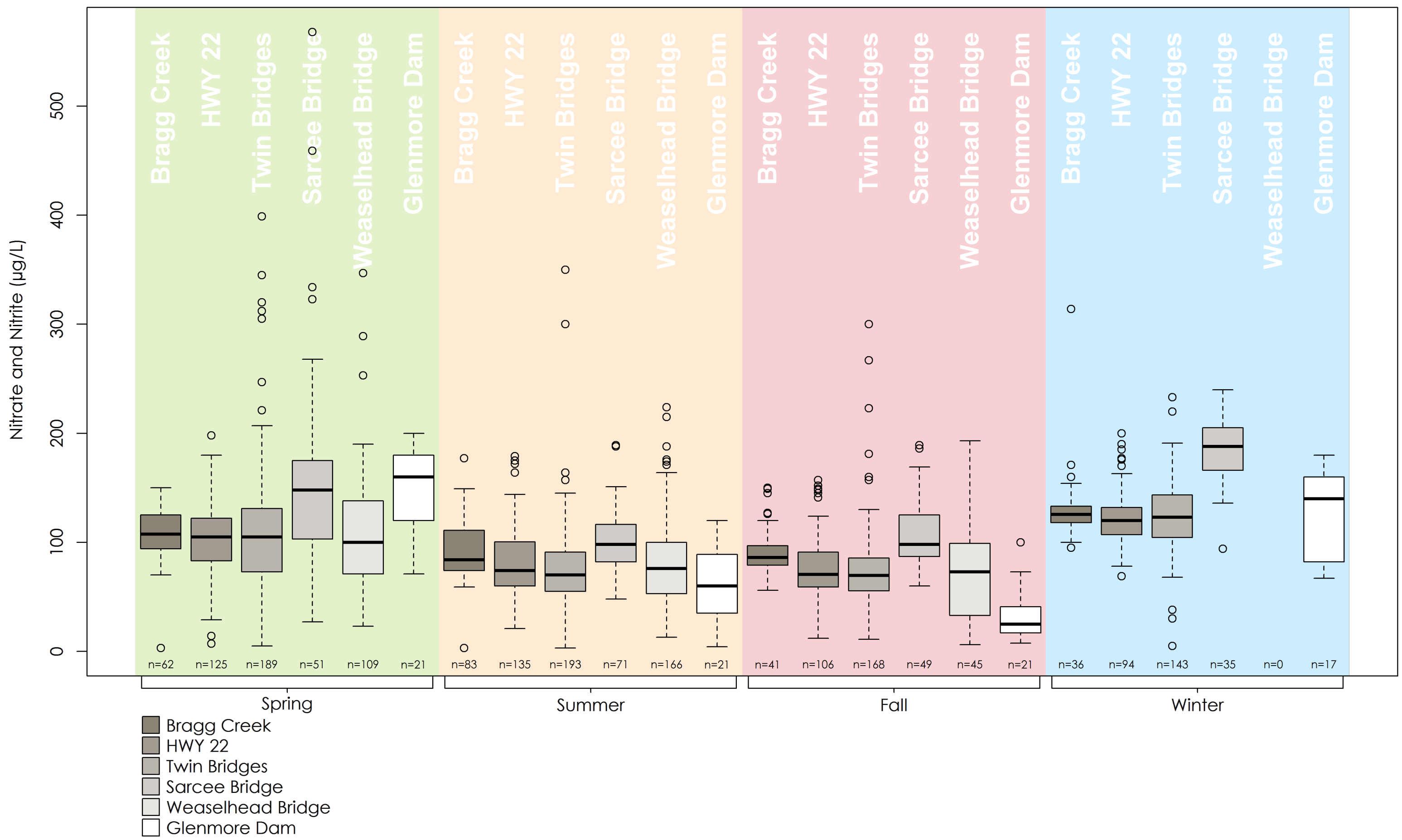


Figure 3-26 Total Nitrate and Nitrite Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1979 to 2016

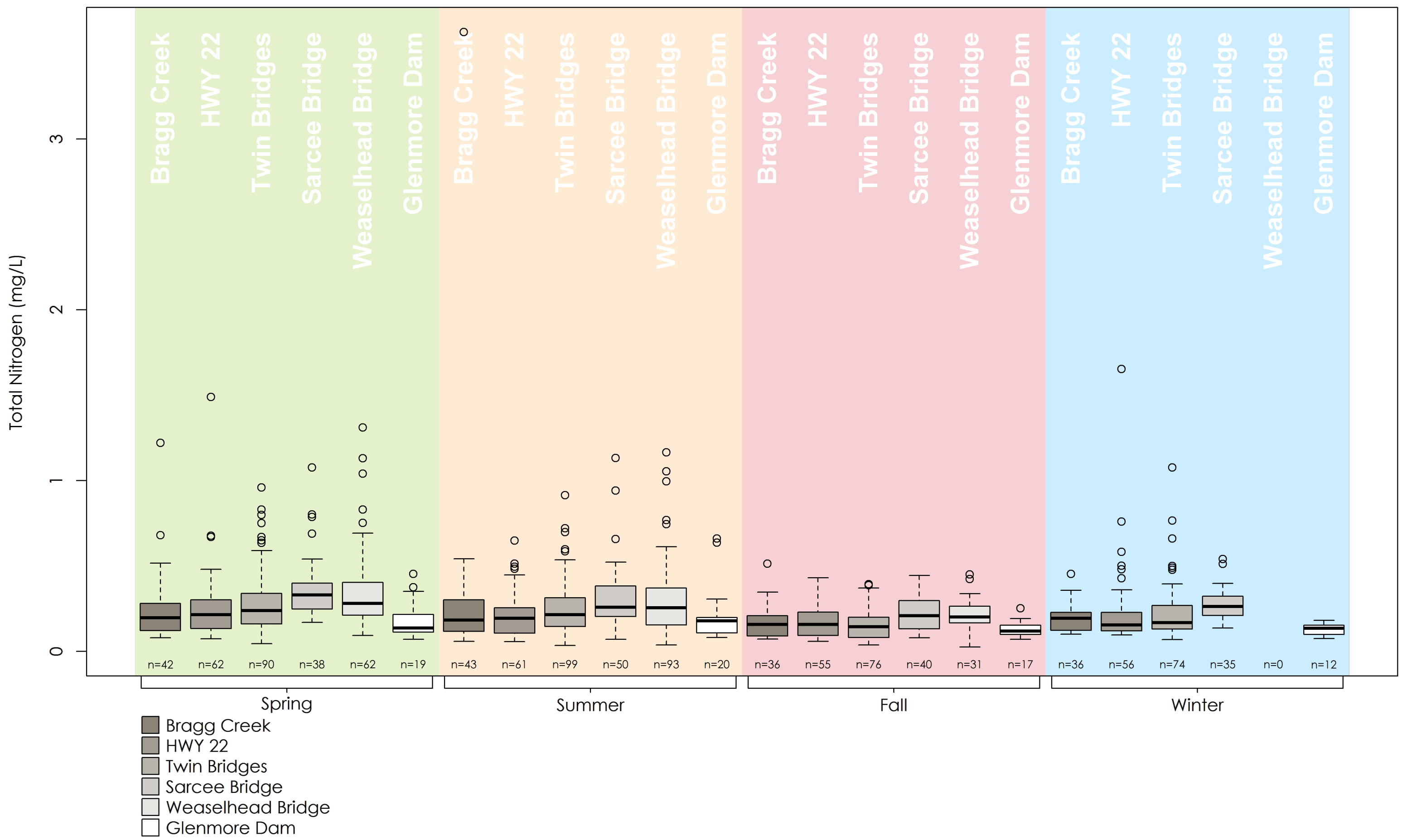


Figure 3-27 Total Nitrogen Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam from 1982 to 2015

3.2.3 Guidelines

Of the 39 parameters analyzed that are associated with either AB WQGs or CWQGs, 15 had observations outside of their respective guidelines (Table 3-2).

The percentage of observations outside of guidelines increases in the upper Elbow River mainstem from upstream (Bragg Creek) to downstream sites (Weaselhead Bridge) for dissolved oxygen, total aluminum, and total iron.

These guideline exceedance patterns correspond with the positive spatial data patterns of total aluminum and iron concentrations (i.e., increase in concentrations from upstream to downstream). Total iron guideline deviations are lower at the Glenmore Reservoir relative to Weaselhead Bridge; however, the difference is relatively small compared to total aluminum and dissolved oxygen. The percentage of observations deviating from guidelines for total aluminum, and dissolved oxygen is substantially lower at Glenmore Reservoir (at Glenmore Dam) relative to the Weaselhead Bridge.

Aluminum and iron are also associated with TSS and have greatest concentrations during high flow periods. Exceedances should, therefore, occur only during high flow and high sediment concentration conditions. Aluminum and iron commonly exceed guidelines in Alberta, suggesting that the observed exceedances can be the result the geologic context in which upper Elbow River is situated.

Dissolved oxygen is not associated with any spatial data pattern; however, exceedances appear to be more common at downstream than upstream sites. This pattern may be related to temperature, which during the summer months (when oxygen concentrations are smallest), is greatest at downstream locations. The water's ability to dissolve oxygen declines as temperature increases. Because dissolved oxygen concentrations below guidelines are more prevalent at downstream locations, the guideline deviations may be the result of temperature variability during the summer months.

Dissolved fluoride and total copper are associated with guideline deviations at most sites, but do not vary spatially. Nearly all (between 99% and 100%) of dissolved fluoride observations are above fluoride guidelines, whereas 4-10% of total copper observations are above guidelines. Beers and Sosiak (1993) collected very similar fluoride concentrations from Elbow River and concluded that these concentrations are likely result from groundwater inputs. Beers and Sosiak (1993) also compared these concentrations with other systems and concluded that fluoride concentrations in Elbow River are generally higher than in other rivers in the area. Copper concentrations do not vary spatially or temporally, making the source of copper exceedances in the Elbow River difficult to discern.

Guideline deviations of sulphide at Glenmore Reservoir and total mercury at Highway 22 are associated with guideline deviation values greater than 10%; however, these sample sizes are relatively small (10 and 4, respectively). No guideline deviations are observed for either parameter at any other site, however, data for each parameter was only available for one other site, where sample sizes were also small.

Although guideline deviations are observed in alkalinity, dissolved aluminum, nitrite, sulphide, total arsenic, total cobalt, total copper, total lead, total mercury, total silver, and total zinc, the deviations made up less than 5% of observations at one or two sites.

Table 3-2 Summary of Water Quality Data and Provincial and Federal Water Quality Guidelines

Parameter	Bragg Creek				Highway 22				Twin Bridges				Sarcee Bridge				Weaselhead Bridge				Glenmore Dam			
	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%
Physical Parameter																								
Temperature	237	0	0	0.0	463	0	0	0.0	861	0	0	0.0	376	0	0	0.0	332	0	0	0.0	99	0	0	0.0
pH	206	0	0	0.0	454	0	0	0.0	1046	0	0	0.0	511	0	0	0.0	348	0	0	0.0	287	0	0	0.0
Alkalinity (as CaCO3)	142	0	0	0.0	260	0	1	0.4	579	0	0	0.0	403	0	0	0.0	155	0	0	0.0	0	0	0	0.0
Dissolved oxygen (cold water biota)	214	0	16	7.5	450	0	74	16.4	541	0	129	23.8	189	0	50	26.5	284	0	90	31.7	0	0	0	0.0
Total suspended sediment	178	156	0	0.0	431	152	0	0.0	683	131	0	0.0	172	6	0	0.0	448	30	0	0.0	16	87	0	0.0
Total coliforms (irrigation guideline)	197	0	6	3.0	422	5	8	1.9	797	9	30	3.7	814	7	41	5.0	324	0	53	16.4	284	1	54	18.9
Fecal coliforms (irrigation guideline)	38	5	0	0.0	79	8	3	3.4	306	31	10	3.0	662	34	48	6.9	88	4	11	12.0	0	0	0	0.0
Ions and ion balance																								
Chloride	0	0	0	0.0	18	19	0	0.0	37	18	0	0.0	0	0	0	0.0	0	0	0	0.0	196	0	0	0.0
Fluoride	142	0	141	99.3	261	0	259	99.2	401	0	401	100.0	324	0	324	100.0	172	0	171	99.4	1	0	1	100.0
Sulphate	0	0	0	0.0	38	0	0	0.0	42	0	0	0.0	0	0	0	0.0	0	0	0	0.0	196	0	0	0.0
Sulphide	0	0	0	0.0	1	2	0	0.0	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0	2	1	2	66.7
Nutrients and carbon																								
Nitrate (as N)	179	0	0	0.0	379	0	0	0.0	448	1	0	0.0	306	30	0	0.0	250	0	0	0.0	189	7	0	0.0
Nitrite (as N)	2	177	0	0.0	12	391	0	0.0	14	462	0	0.0	37	171	9	4.3	14	236	2	0.8	9	187	0	0.0
Nitrate+nitrite (as N)	220	2	0	0.0	460	0	0	0.0	672	21	0	0.0	206	0	0	0.0	320	0	0	0.0	80	0	0	0.0
Nitrogen (total)	157	0	0	0.0	234	0	0	0.0	338	1	0	0.0	163	0	0	0.0	186	0	0	0.0	68	7	0	0.0
Ammonia (total as N)	7	79	0	0.0	12	114	0	0.0	103	112	0	0.0	1	83	0	0.0	24	62	0	0.0	3	44	0	0.0
Phosphorus (dissolved)	102	111	0	0	181	242	0	0	301	455	0	0	239	166	0	0	114	62	0	0	102	111	0	0
Phosphorus (total)	183	184	0	0.0	322	286	0	0.0	616	385	0	0.0	195	24	0	0.0	536	79	0	0.0	180	11	0	0.0
Total organic carbon	172	0	0	0.0	386	16	0	0.0	739	18	0	0.0	182	0	0	0.0	344	0	0	0.0	59	0	0	0.0
Metals (dissolved)																								
Aluminium	0	0	0	0.0	2	1	0	0.0	11	2	0	0.0	0	0	0	0.0	0	0	0	0.0	18	0	1	5.6
Iron	0	0	0	0.0	0	2	0	0.0	3	12	0	0.0	0	0	0	0.0	0	0	0	0.0	1	15	0	0.0

Table 3-2 Summary of Water Quality Data and Provincial and Federal Water Quality Guidelines

Parameter	Bragg Creek				Highway 22				Twin Bridges				Sarcee Bridge				Weaselhead Bridge				Glenmore Dam			
	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%
Metals (total)																								
Aluminum	37	2	5	12.8	49	1	12	24.0	31	1	6	18.8	37	0	21	56.8	20	1	15	71.4	44	0	10	22.7
Arsenic	1	38	0	0.0	5	45	0	0.0	7	29	1	2.8	4	33	0	0.0	5	16	0	0.0	8	36	0	0.0
Boron	30	1	0	0.0	33	1	0	0.0	31	1	0	0.0	29	0	0	0.0	17	1	0	0.0	44	0	0	0.0
Cadmium	0	39	0	0.0	2	48	0	0.0	0	34	0	0.0	0	37	0	0.0	0	21	0	0.0	0	44	0	0.0
Chromium (trivalent)	3	36	0	0.0	10	40	0	0.0	7	27	0	0.0	9	28	0	0.0	7	14	0	0.0	15	29	0	0.0
Chromium (hexavalent)	0	0	0	0.0	0	3	0	0.0	0	5	0	0.0	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0
Cobalt	1	38	0	0.0	4	46	0	0.0	2	31	0	0.0	3	34	0	0.0	3	18	0	0.0	3	41	1	2.3
Copper	16	23	1	2.6	21	29	0	0.0	19	15	2	5.9	24	13	1	2.7	18	3	1	4.8	44	0	4	9.1
Iron	26	13	3	7.7	34	16	8	16.0	30	5	5	14.3	37	0	15	40.5	21	0	12	57.1	17	26	9	20.9
Lead	1	38	0	0.0	6	50	0	0.0	4	38	1	2.4	4	33	0	0.0	4	17	0	0.0	4	40	0	0.0
Mercury	0	0	0	0.0	1	8	1	11.1	0	10	0	0.0	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0
Molybdenum	14	25	0	0.0	25	25	0	0.0	7	25	0	0.0	14	23	0	0.0	8	13	0	0.0	44	0	0	0.0
Nickel	24	15	0	0.0	39	11	0	0.0	23	12	0	0.0	30	7	0	0.0	18	3	0	0.0	43	1	0	0.0
Selenium	26	13	0	0.0	33	17	0	0.0	24	11	0	0.0	27	10	0	0.0	15	6	0	0.0	37	7	0	0.0
Silver	1	38	1	2.6	2	48	0	0.0	0	31	0	0.0	0	37	0	0.0	0	21	0	0.0	0	44	0	0.0
Thallium	0	39	0	0.0	3	47	0	0.0	1	31	0	0.0	0	37	0	0.0	0	21	0	0.0	0	44	0	0.0
Uranium	5	34	0	0.0	18	32	0	0.0	5	27	0	0.0	14	23	0	0.0	8	13	0	0.0	44	0	0	0.0
Zinc	8	31	0	0.0	13	37	0	0.0	8	25	0	0.0	14	23	0	0.0	13	8	0	0.0	17	27	1	2.3

NOTES:
n = Number of observations within detection limits.
DL = Number of observations outside of detection limits
GL = Number of observations outside of most conservative guideline
% = Percentage of observations outside of guidelines

3.2.3.1 Elbow River Water Quality Objectives

Deviations in the upper Elbow River from ERWQOs are uncommon and range at each site and parameter combination from 0 to12.3% of observations (Attachment A). Sample sizes for all site-parameter combinations are large, suggesting that these percentages are an accurate representation of deviations from ERWQOs. Deviations from ERWQO are most common in upper Elbow River at downstream sites (i.e., Twin Bridges and downstream) and are associated with fecal coliforms and dissolved phosphorus. Since dissolved phosphorus outside of these site-parameter combinations, the percentage of deviations from ERWQOs are low and never exceeded 4.2% of observations.

Table 3-3 Summary of Water Quality Data Compared to Elbow River Water Quality Objectives

Parameter	Bragg Creek				Highway 22				Twin Bridges				Sarcee Bridge				Weaselhead Bridge			
	n	<DL	>EG	%	n	<DL	>EG	%	n	<DL	>EG	%	n	<DL	>EG	%	n	<DL	>EG	%
Physical Parameters																				
Temperature	237	0	0	0.0	463	0	0	0.0	861	0	0	0.0	376	0	4	1.1	332	0	0	0.0
Dissolved oxygen (cold water biota)	214	0	0	0.0	450	0	0	0.0	541	0	0	0.0	189	0	0	0.0	284	0	0	0.0
Total coliforms (irrigation guideline)	197	0	0	0.0	422	5	0	0.0	797	9	0	0.0	814	7	0	0.0	324	0	0	0.0
Fecal coliforms (irrigation guideline)	38	5	0	0.0	79	8	3	3.4	306	31	10	3.0	662	34	48	6.9	88	4	11	12.0
Nutrients and Carbon																				
Nitrate+nitrite (as N)	220	2	1	0.5	460	0	0	0.0	672	21	9	1.3	206	0	5	2.4	320	0	2	0.6
Ammonia (total as N)	7	79	0	0.0	12	114	0	0.0	103	112	0	0.0	1	83	0	0.0	24	62	0	0.0
Dissolved phosphorus	102	111	9	4.2	183	240	17	4.0	301	455	47	6.2	114	62	17	9.7	239	166	50	12.3
Total organic carbon	172	0	0	0.0	386	16	0	0.0	739	18	0	0.0	182	0	0	0.0	344	0	0	0.0

NOTES:
n = Number of observations within detection limits.
DL = Number of observations outside of detection limits
EG = Number of observations outside of Elbow River Objectives
% = Percentage of observations outside of Elbow River Objectives

3.3 ELBOW RIVER TRIBUTARY WATER QUALITY

3.3.1 General Patterns

The existing water quality in the low-level outlet channel is expected to remain the same after Project construction and during Project dry operations. During flood operation, water quality of the outlet channel is anticipated to change during the reservoir discharge, and these changes are evaluated in the EIA. The following provides a comparison between the outlet channel and other Elbow River tributary water quality data for context.

Comparisons between the low-level outlet and other tributaries to the Elbow River are limited because only 28 of the 101 parameters that are associated with the tributaries include data for both the low-level outlet channel and at least one other tributary. Furthermore, when comparisons could be made, sample sizes were often low and samples from different tributaries were collected during different seasons. Low-level outlet samples were collected primarily during summer and occasionally during the fall. Despite these shortcomings of the tributary data, some generalizations could be made.

Most parameters are greater in the low-level outlet than in the other tributaries. Some of these parameters, mainly ions and some nutrients, are also considerably more variable in the low-level outlet channel than in other tributaries. These parameters are alkalinity, bicarbonate, total chloride, conductivity (Figure 3-28), hardness, Kjeldahl nitrogen (Figure 3-29), dissolved magnesium, total magnesium, dissolved organic carbon, total organic carbon, dissolved potassium, total potassium, dissolved sodium, total sodium, and dissolved phosphorus (Figure 3-30). Data availability allowed comparisons only between the low-level outlet channel and Lott Creek. The same general trends persisted when data from other tributaries (Pirmez and Springbank Creek) were available: conductivity, Kjeldahl nitrogen, and dissolved phosphorus. Spring temperatures are greater in the low-level outlet compared to other tributaries during the summer, with similar variability around the median (Figure 3-31).

Total fluoride, nitrate, and dissolved oxygen (Figure 3-32) concentrations are generally greater in Lott Creek than in the low-level outlet. TSS, and several nutrients were lower and were less variable in the low-outlet than in other tributaries. These parameters include nitrate and nitrite (Figure 3-33), total phosphorus, and TSS.

Dissolved and total calcium are more variable, but had similar medians in the low-level outlet than for other tributaries during spring. Low-level outlet channel pH (Figure 3-34) and turbidity values are generally comparable to the other tributaries.

Compared to the other tributaries, the low-level outlet is associated with low dissolved oxygen values, high temperatures, high conductivity, and high nutrient concentrations. Low oxygen concentrations (e.g., Malard and Hevant 1999), and high conductivity (e.g., Cheung et al. 2010) can be typical of groundwater inputs. Despite this, nutrient loads of phosphorus and nitrogen species are less typical of groundwater (Wetzel 1975). These results suggest that the main source for these parameters in the low-level outlet could be groundwater, and the channel itself is subject to nutrient loading from the surrounding landscape, which is primarily agricultural.

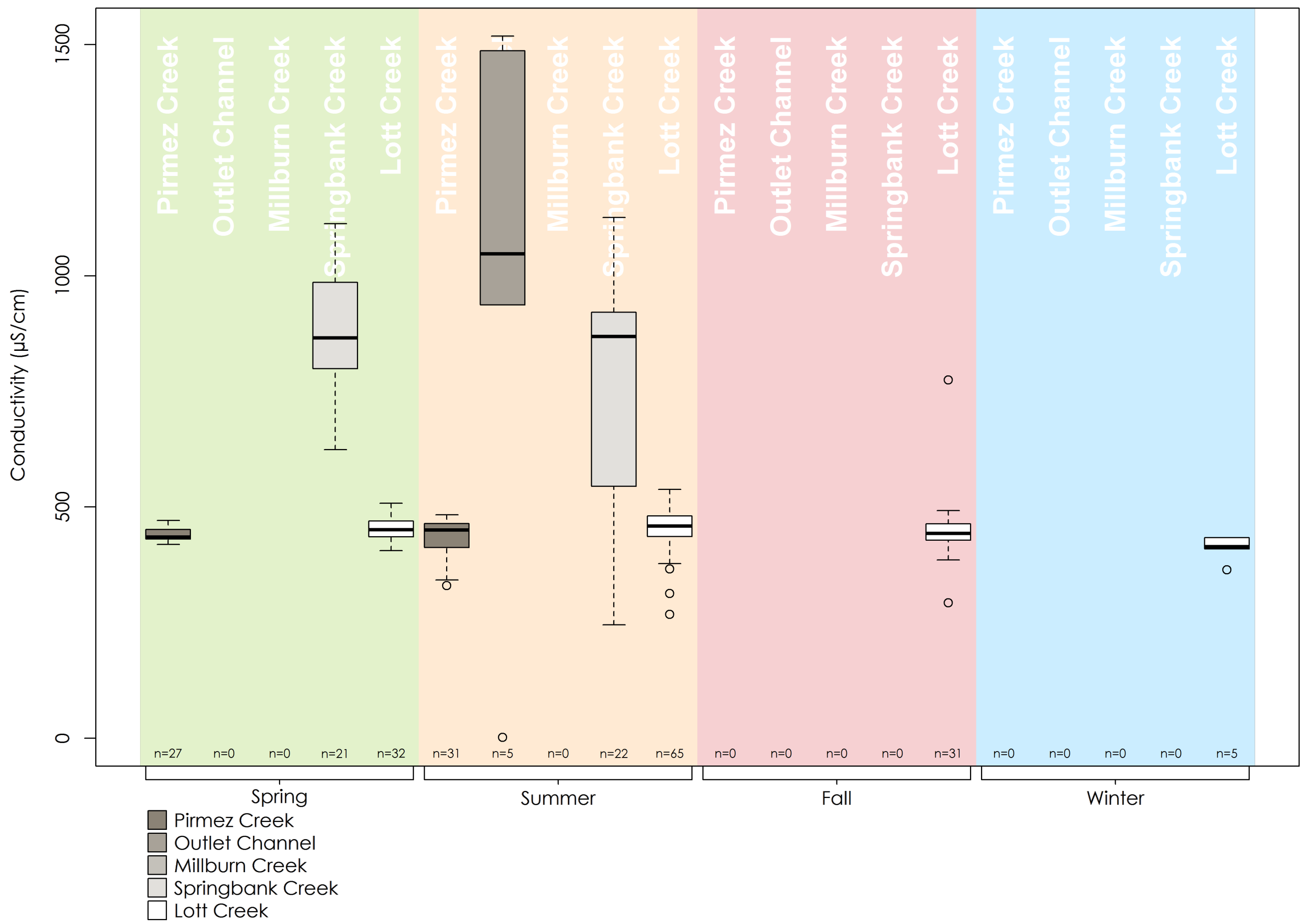


Figure 3-28 Conductivity in Elbow River Tributaries from 1986 to 2016

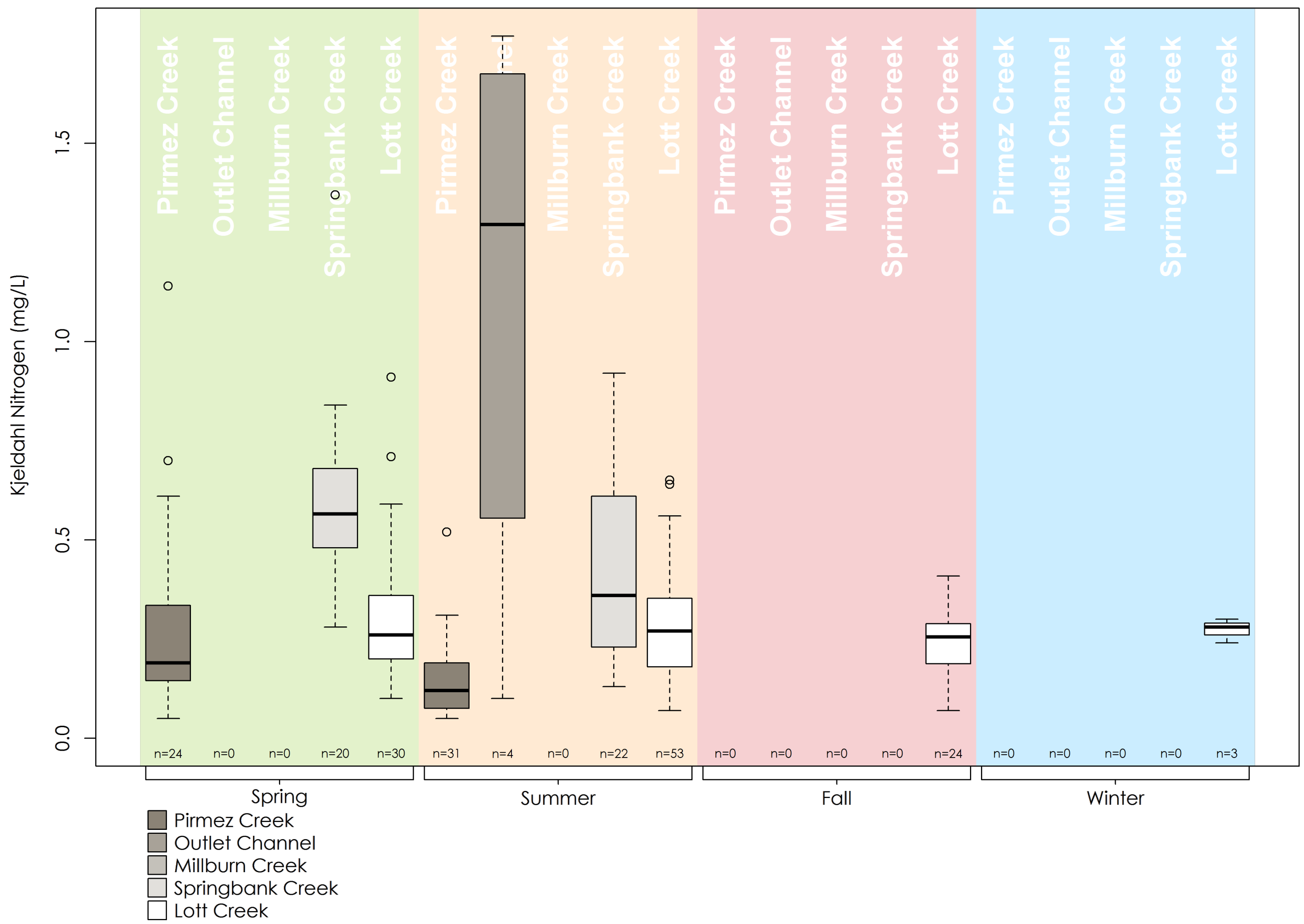


Figure 3-29 Kjeldahl Nitrogen Concentrations in Elbow River Tributaries from 1988 to 2016

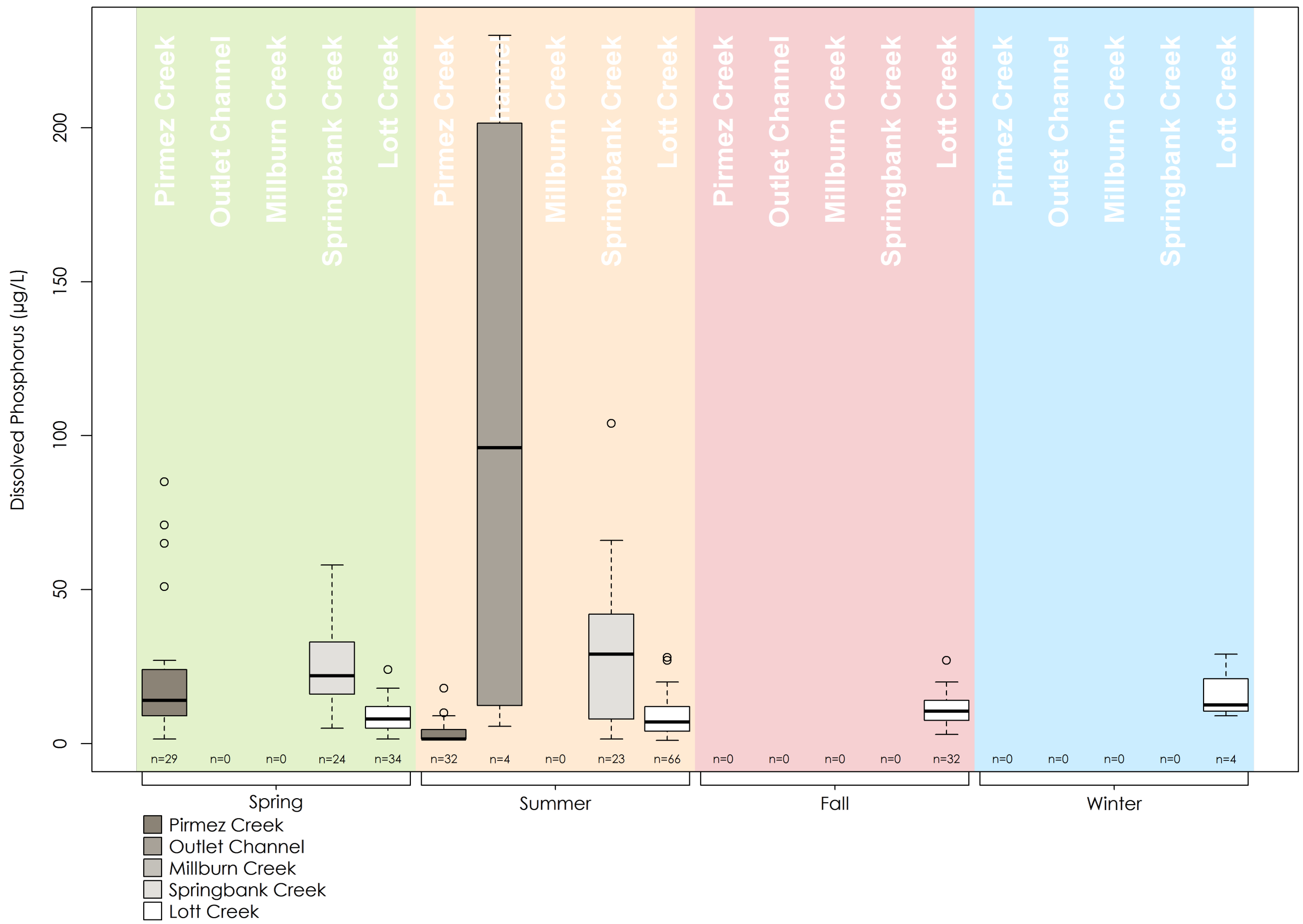


Figure 3-30 Dissolved Phosphorus Concentrations in Elbow River Tributaries from 1988 to 2016

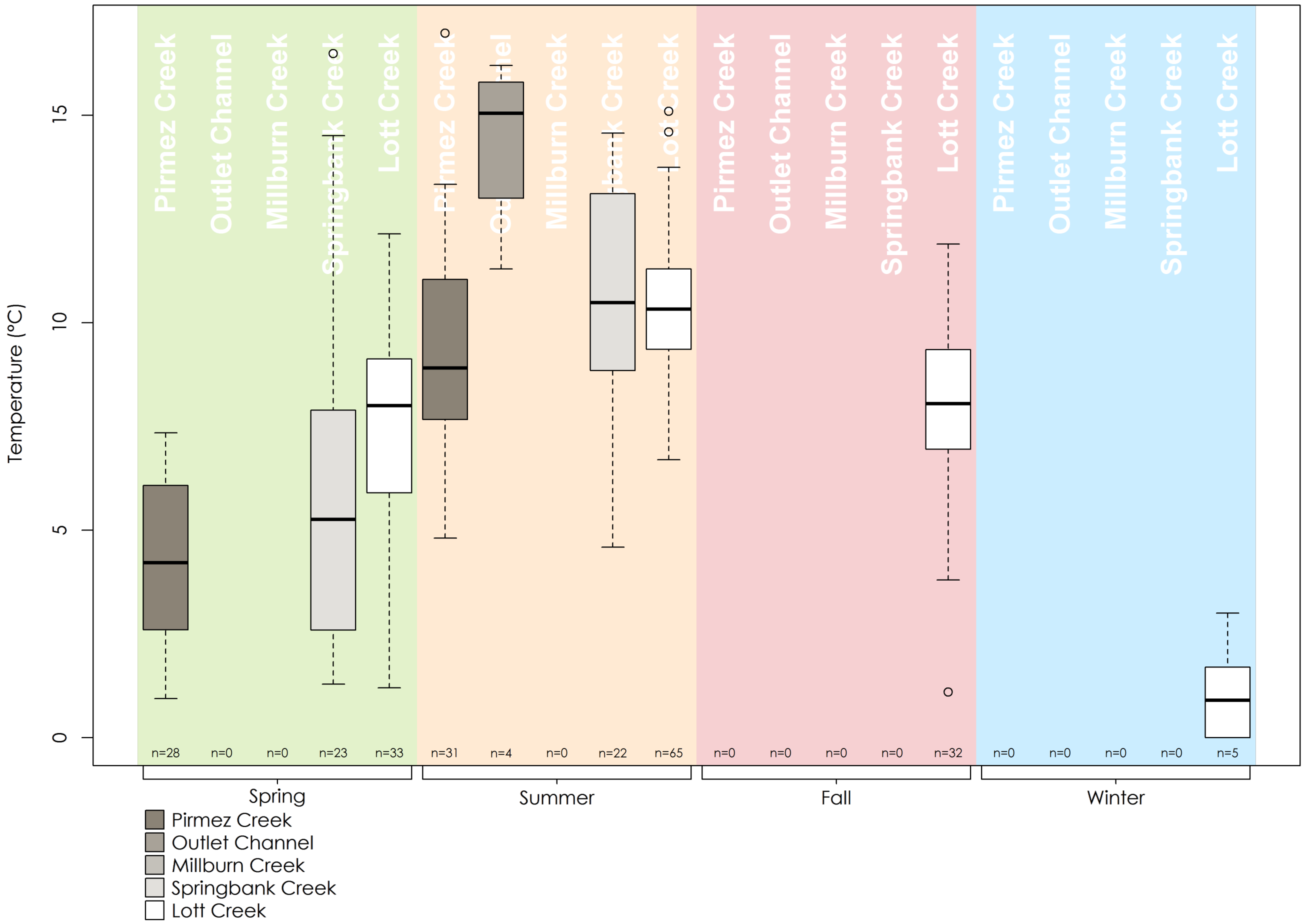


Figure 3-31 Temperature in Elbow River Tributaries from 1986 to 2016

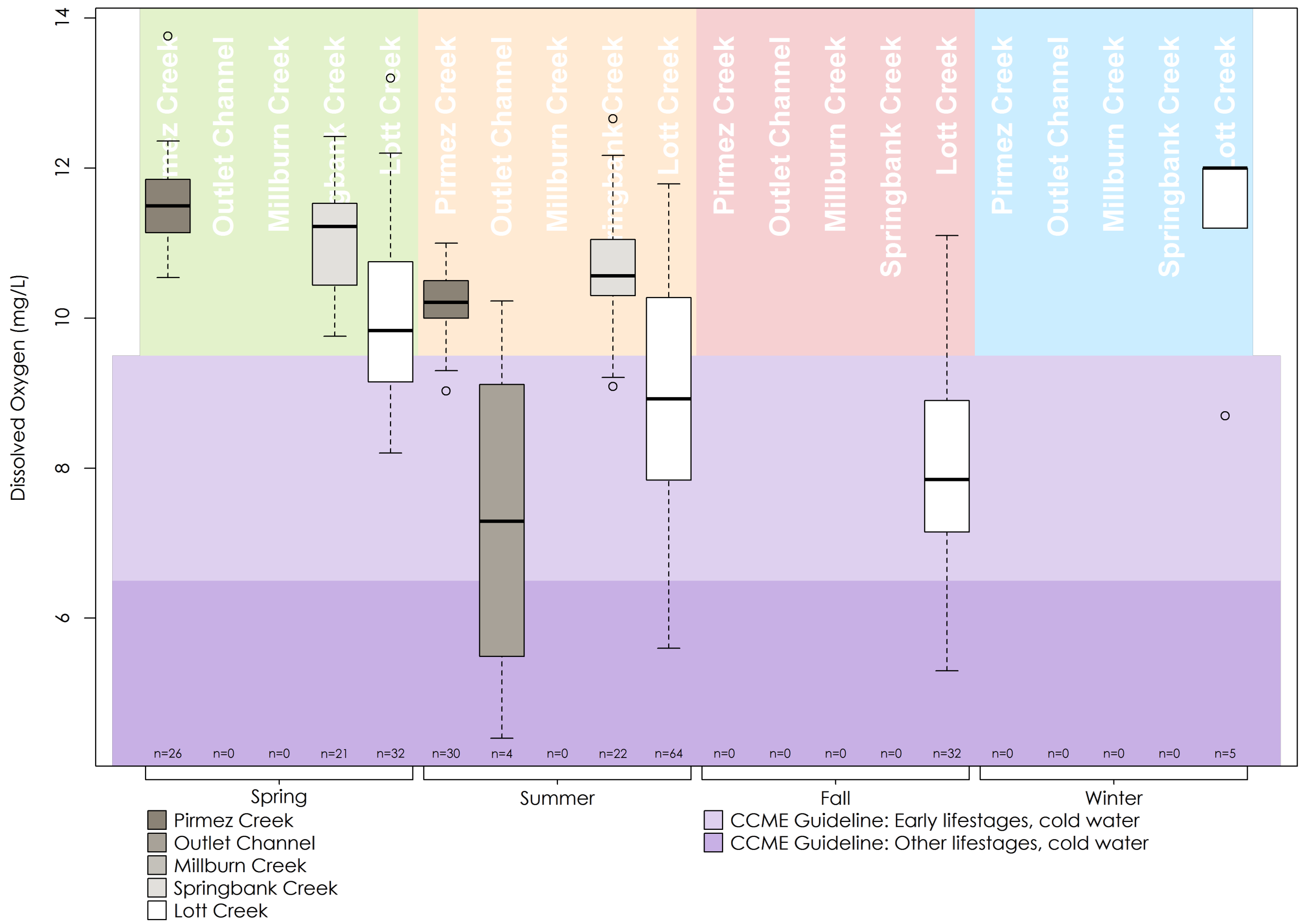


Figure 3-32 Dissolved Oxygen Concentrations in Elbow River Tributaries from 1986 to 2016

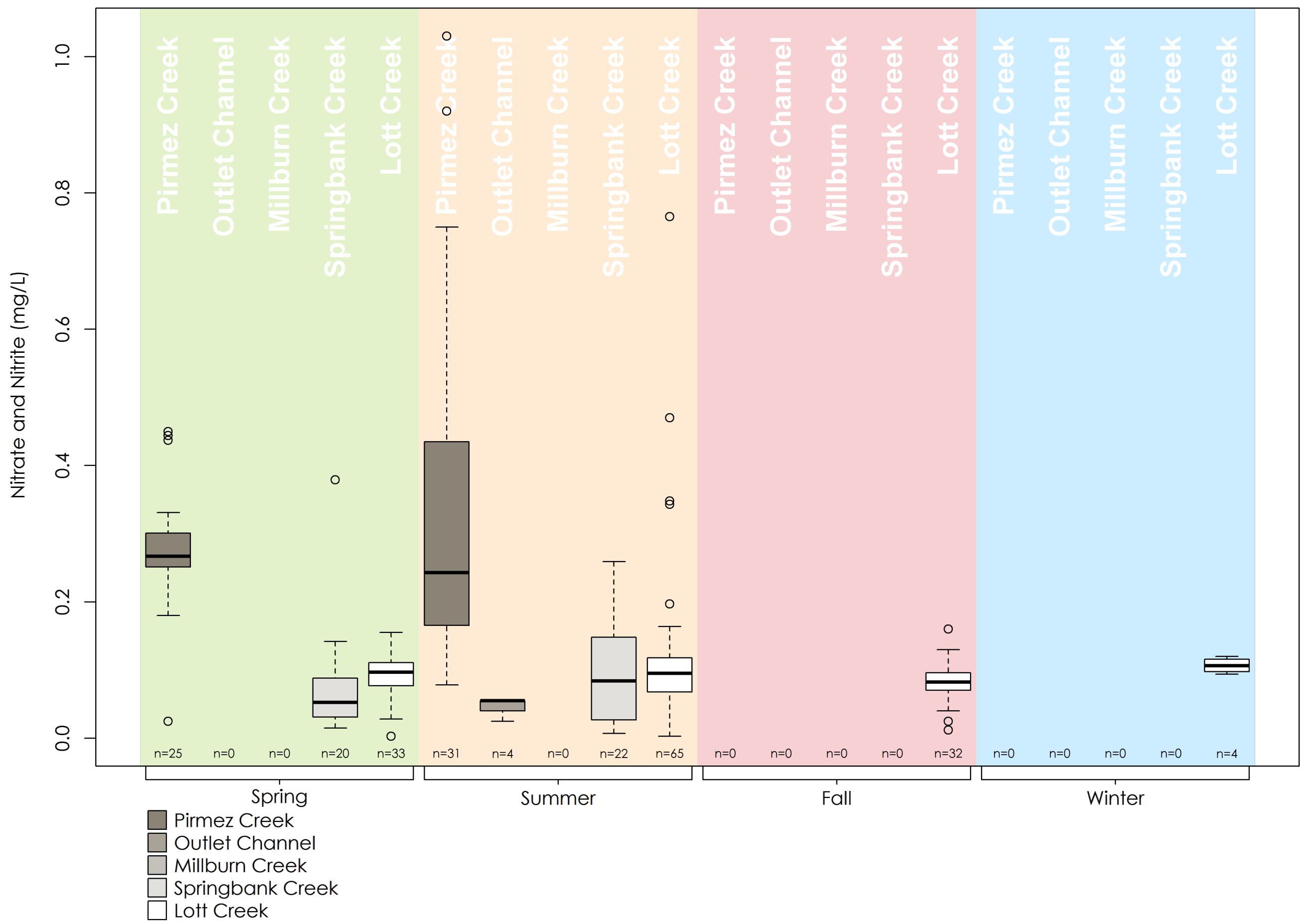


Figure 3-33 Nitrate and Nitrite Concentrations in Elbow River Tributaries from 1988 to 2016

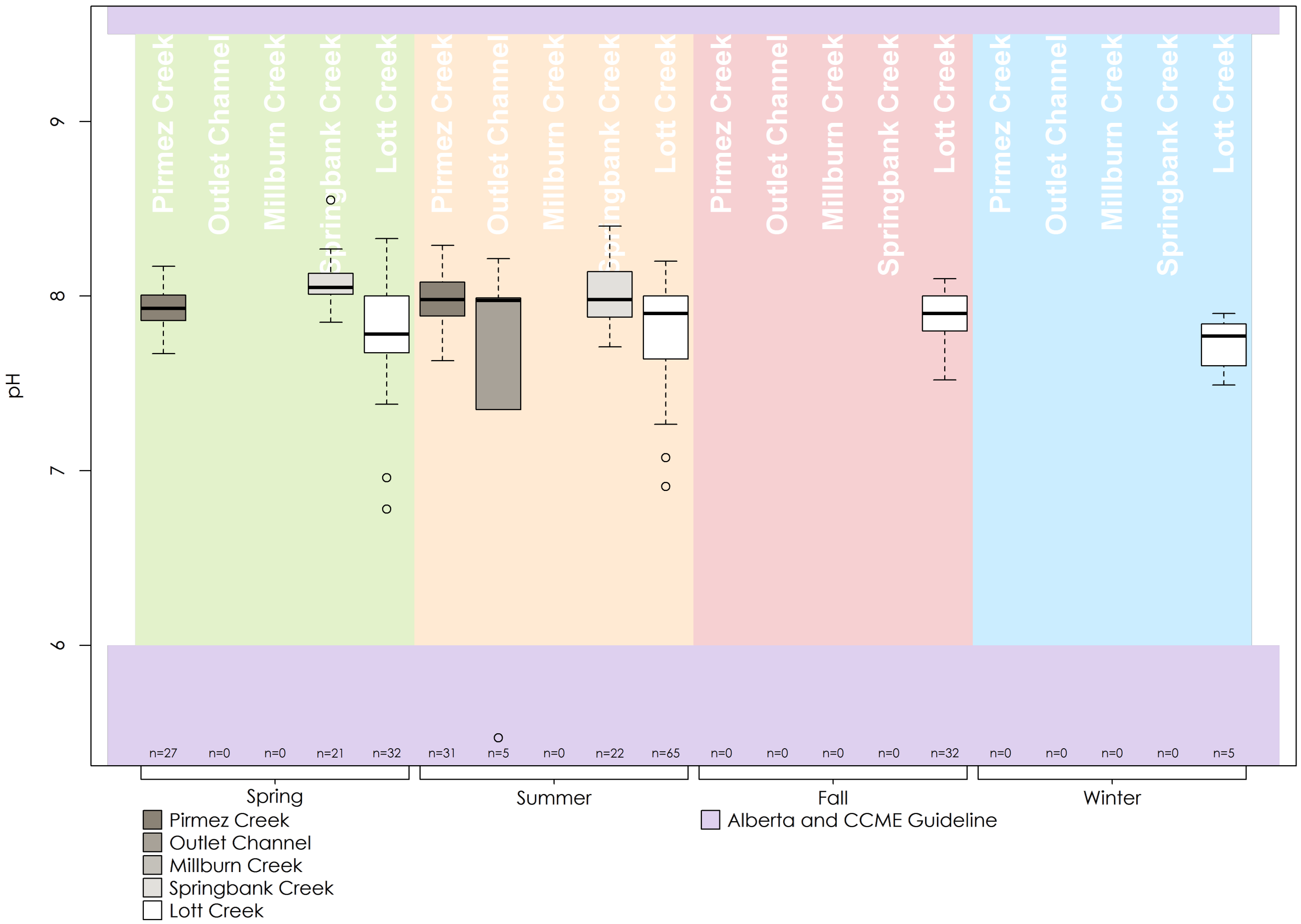


Figure 3-34 pH in Elbow River Tributaries from 1986 to 2016

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3.3.2 Guidelines

Of the 39 parameters analyzed that were associated with either CWQGs or AB WQGs, five have observations outside their respective guidelines (Table 3-4). Many site-parameter combinations have either no data or small sample sizes. Only one (hexavalent chromium) of the analyzed parameters have no data in the tributaries, whereas 10 have data for the low-level outlet and at least one other tributary. Twenty parameters only have data for the low-level outlet; the remaining seven parameters only have data associated with tributaries other than the low-level outlet.

Of the parameters that have data for both the low-level outlet and at least one other tributary, only dissolved oxygen is associated with observations that deviate from guidelines. The percent of deviations is most pronounced in the low-level outlet (75%), but guideline deviations are also common in the tributaries (4.4-60.2%).

Of the parameters where data is available only for the low-level outlet, two parameters have guideline deviations. Three of the four sulphide observations are above guidelines, and one of the four total aluminum observations are above guidelines.

Of the remaining parameters that lacked data in the low-level outlet but have data in at least one other tributary, four parameters have guideline deviations. The most pronounced of these parameters was fecal coliforms, where the percentage of guideline deviations range from 11% to 48.2% in all four tributaries. The remaining three parameters (total coliforms, fluoride, and nitrite) containing guideline deviations were all collected in Lott Creek and lacked data for other tributaries. For Lott Creek, 19.3% of total coliform, 100% of fluoride, and 1.3% of nitrite observations deviated from guidelines.

Table 3-4 Summary of Tributary Water Quality Data and CCME and Environmental Quality Guidelines for Alberta Surface Waters

Parameter	Pirmez Creek				Outlet Channel				Millburn Creek				Springbank Creek				Lott Creek			
	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%
Physical Parameters																				
Temperature	59	0	0	0.0	4	0	0	0.0	38	0	0	0.0	45	0	0	0.0	135	0	0	0.0
pH	58	0	0	0.0	5	0	0	0.0	39	0	0	0.0	43	0	0	0.0	134	0	0	0.0
Alkalinity (as CaCO3)	0	0	0	-	3	1	0	0.0	0	0	0	-	0	0	0	-	68	0	0	0.0
Dissolved oxygen (cold water biota)	56	0	5	8.9	4	0	3	75.0	38	0	11	28.9	43	0	2	4.7	133	0	80	60.2
Total suspended sediment	50	7	0	0.0	1	5	0	0.0	31	10	0	0.0	32	10	0	0.0	96	38	0	0.0
Total coliforms (irrigation guideline)	0	0	0	-	0	0	0	-	0	0	0	-	0	0	0	-	82	1	16	19.3
Fecal coliforms (irrigation guideline)	56	0	27	48.2	0	0	0	-	38	1	17	43.6	38	4	12	28.6	54	9	7	11.1
Nutrients and carbon																				
Chloride	0	0	0	-	0	0	0	-	0	0	0	-	0	0	0	-	14	0	0	0.0
Fluoride	0	0	0	-	0	0	0	-	0	0	0	-	0	0	0	-	82	0	82	100.0
Sulphate	0	0	0	-	0	0	0	-	0	0	0	-	0	0	0	-	14	0	0	0.0
Sulphide	0	0	0	-	3	1	3	75.0	0	0	0	-	0	0	0	-	0	0	0	-

Table 3-4 Summary of Tributary Water Quality Data and CCME and Environmental Quality Guidelines for Alberta Surface Waters

Parameter	Pirmez Creek				Outlet Channel				Millburn Creek				Springbank Creek				Lott Creek			
	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%
Nitrate (as N)	0	0	0	-	0	4	0	0.0	0	0	0	-	0	0	0	-	78	0	0	0.0
Nitrite (as N)	0	0	0	-	0	4	0	0.0	0	0	0	-	0	0	0	-	7	71	1	1.3
Nitrate+nitrite (as N)	56	0	0	0.0	0	4	0	0.0	16	24	0	0.0	42	0	0	0.0	132	2	0	0.0
Nitrogen (total)	15	0	0	0.0	0	0	0	-	12	1	0	0.0	16	0	0	-	69	0	0	-
Ammonia (total as N)	21	34	0	0.0	0	4	0	0.0	28	11	0	0.0	32	10	0	0.0	53	11	0	0.0
Total dissolved phosphorus	39	22	0	0.0	4	0	0	0.0	39	3	0	0.0	44	3	0	0.0	128	8	0	0.0
Phosphorus (total)	48	13	0	0.0	6	0	0	0.0	42	0	0	0.0	46	1	0	0.0	135	1	0	0.0
Total organic carbon	0	0	0	-	3	1	0	0.0	0	0	0	-	0	0	0	-	89	0	0	-
Metals (dissolved)																				
Aluminium	0	0	0	-	2	2	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Iron	0	0	0	-	2	2	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Metals (total)																				
Aluminum	0	0	0	-	3	1	1	25.0	0	0	0	-	0	0	0	-	0	0	0	-
Arsenic	0	0	0	-	3	1	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Boron	0	0	0	-	3	1	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-

Table 3-4 Summary of Tributary Water Quality Data and CCME and Environmental Quality Guidelines for Alberta Surface Waters

Parameter	Pirmez Creek				Outlet Channel				Millburn Creek				Springbank Creek				Lott Creek			
	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%	n	<DL	>GL	%
Cadmium	0	0	0	-	3	1	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Chromium (trivalent)	0	0	0	-	1	3	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Chromium (hexavalent)	0	0	0	-	0	0	0	-	0	0	0	-	0	0	0	-	0	0	0	-
Cobalt	0	0	0	0.0	3	1	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Copper	0	0	0	-	3	1	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Iron	0	0	0	-	2	2	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Lead	0	0	0	-	2	2	0	0.0	0	0	0	-	0	0	0	-	1	5	0	-
Mercury	0	0	0	-	0	4	0	0.0	0	0	0	-	0	0	0	-	0	6	0	-
Molybdenum	0	0	0	-	3	1	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Nickel	0	0	0	-	3	1	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Selenium	0	0	0	-	3	1	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Silver	0	0	0	-	0	4	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Thallium	0	0	0	-	2	2	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Uranium	0	0	0	-	3	1	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-
Zinc	0	0	0	-	2	2	0	0.0	0	0	0	-	0	0	0	-	0	0	0	-

3.4 PESTICIDE DATA IN THE ELBOW RIVER WATERSHED

Pesticide is a general term used for chemical compounds that are used to kill weeds (herbicides), fungi (fungicides), insects (insecticides), and other pests. Excess pesticides and their metabolites and degradation products can occur in watercourses and waterbodies. In the Elbow River watershed, within the RAA, 63 pesticides have been measured at the mainstem sites (Bragg Creek, Highway 22, Twin Bridges, and Weaselhead Bridge) during 18 discrete sampling events between 2005 and 2010. All analytical results were below the laboratory detection limit, apart from two pesticides: 2,4-D and MCPP (see Table 3-5). No pesticide data were available for Elbow River tributaries or the Glenmore Reservoir.

2,4-D (chemical formula 2,4-dichlorophenoxyacetic acid) is a herbicide used for the control of broadleaf weeds, weedy trees, and brush in Canada (Health Canada 2008). According to Health Canada, 2,4-D "*use is permitted on fine turf, forests, and woodlots (conifer release and forest site preparation), terrestrial feed and feed crops, and industrial non-food sites (non-cropland)*" (Health Canada 2008). This herbicide has been detected four times in the Elbow River between 2005 and 2010 (see Figure 3-35).

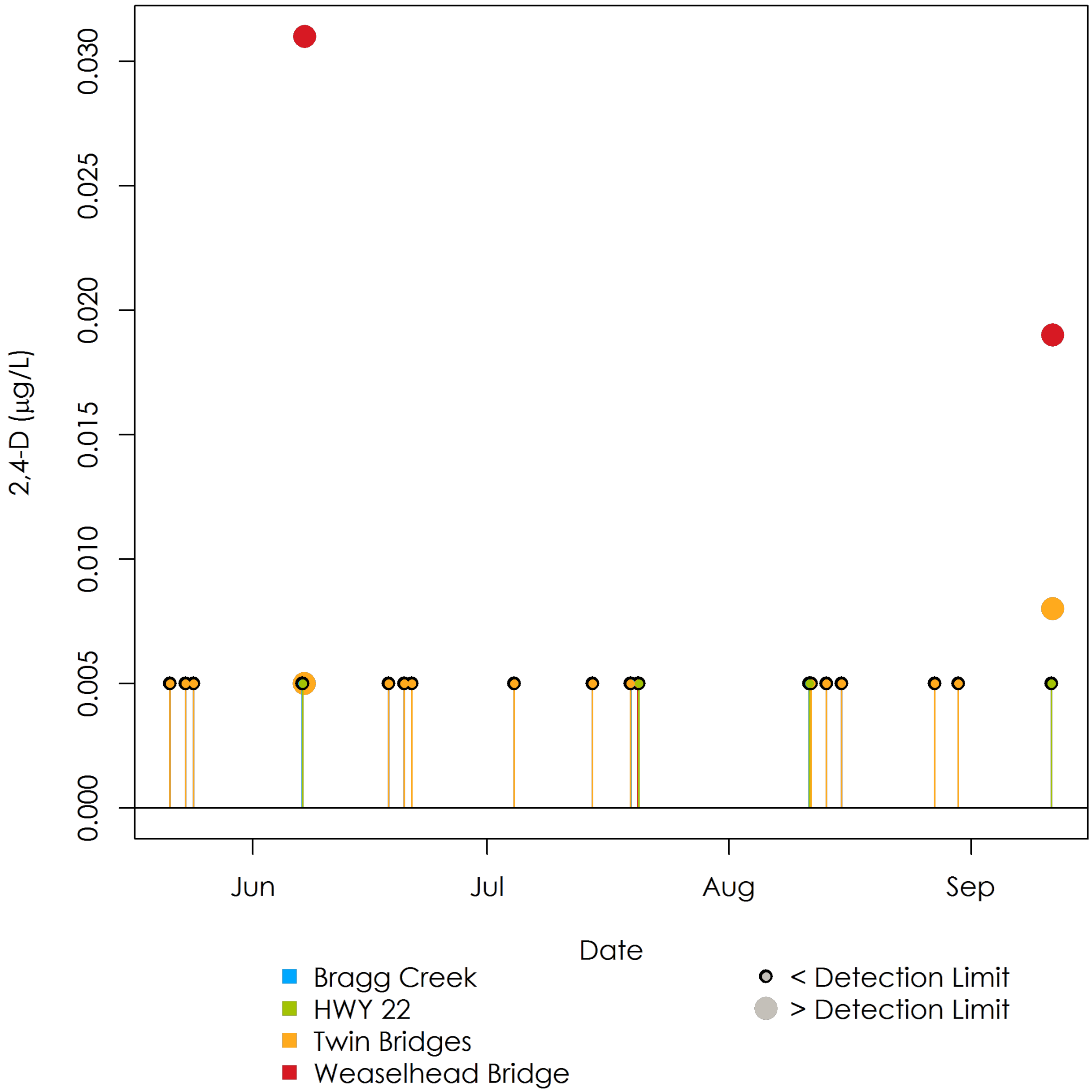

Figure 3-35 2,4-D Concentrations in Elbow River

MCPP (chemical formula 2-methyl-4-chlorophenoxyacetic acid) is a herbicide used to control a suite of broadleaf weeds in agricultural and non-cropland applications (CCME 1999). This herbicide has been detected twice in the Elbow River between 2005 and 2010 (see Figure 3-36).

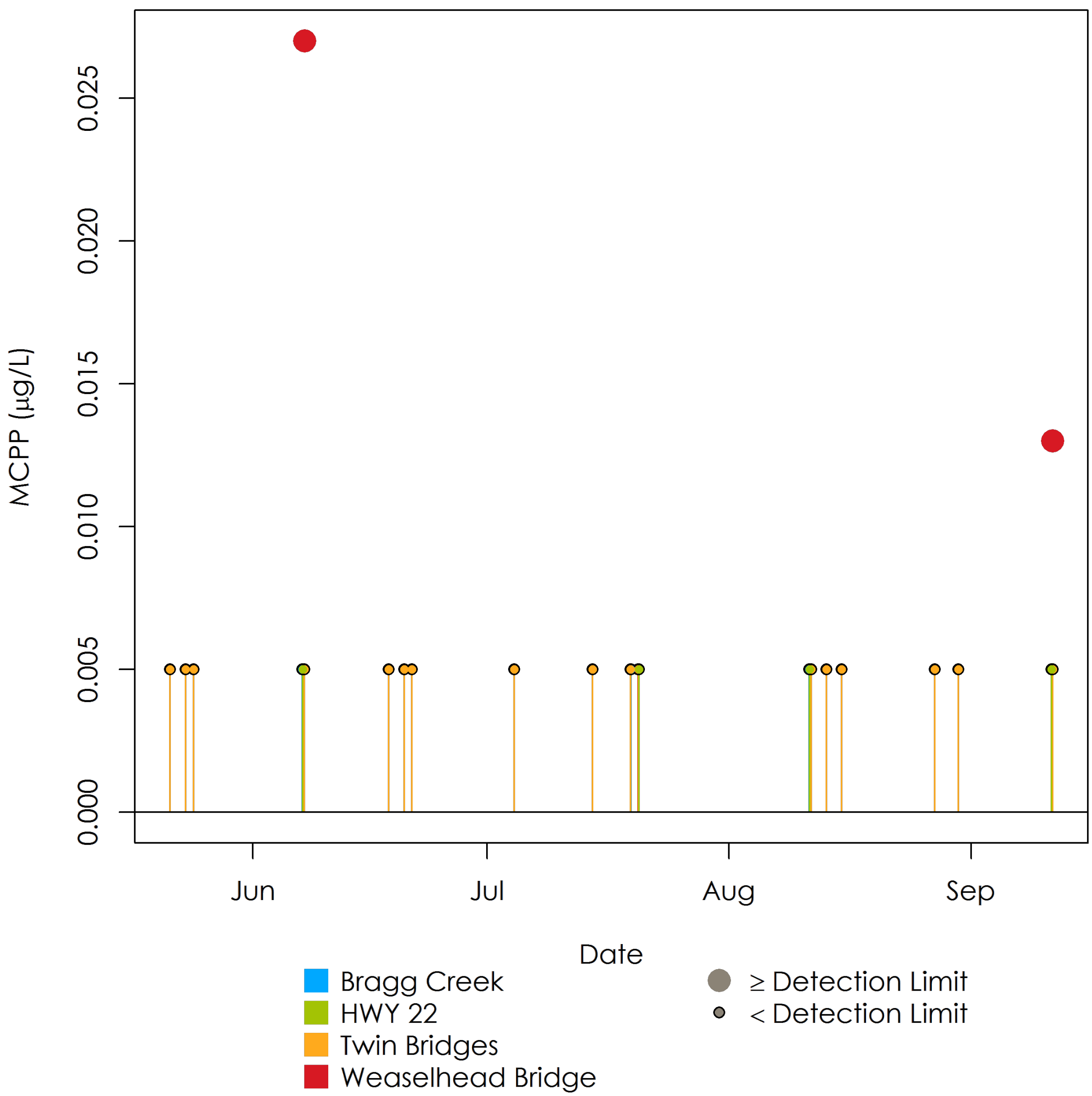

Figure 3-36 MCPP Concentrations in Elbow River

Table 3-5 Available Pesticide Data in the RAA (2005 – 2010)

Parameter	n	<DL	>DL
Herbicides and Fungicides			
2,4-D	29	25	4
2,4-DB	29	29	0
Atrazine	25	25	0
Bentazon	13	13	0
Bromacil	29	29	0
Bromoxynil	29	29	0
Carbathiin (carboxin)	29	29	0
Chlorothalonil	13	13	0
Clodinafop-propargyl	13	13	0
Clopyralid (lontrel)	29	29	0
Cyanazine	29	29	0
Dicamba (banvel)	29	29	0
Dichlorprop (2,4-dp)	29	29	0
Diclofop-methyl (hoegrass)	29	29	0
Diuron	29	29	0
Ethalfluralin (edge)	29	29	0
Ethofumesate	13	13	0
Fenoxaprop-p-ethyl	29	29	0
Fluazifop	13	13	0
Fluroxypyr	13	13	0
Hexaconazole	13	13	0
Imazamethabenz-methyl	29	29	0
Imazamox	29	29	0
Imazethapyr	29	29	0
Iprodione	13	13	0
Linuron	13	13	0
MCPA	29	29	0
MCPB	29	29	0
MCPP (mecoprop)	29	27	2
Metalaxyl-m	13	13	0
Metolachlor	13	13	0

Table 3-5 Available Pesticide Data in the RAA (2005 – 2010)

Parameter	n	<DL	>DL
Metribuzin	13	13	0
Napropamide	29	29	0
Propiconazole	13	13	0
Quizalofop	13	13	0
Simazine	29	29	0
Triallate (avadex bw)	29	29	0
Triclopyr	29	29	0
Trifluralin (treflan)	29	29	0
Vinclozolin	29	29	0
Insecticides			
Aldicarb	29	29	0
Aldrin	29	29	0
Alpha-endosulfan	29	29	0
Chlorpyrifos-ethyl (dursban)	29	29	0
Diazinon	29	29	0
Dieldrin	29	29	0
Dimethoate (cygon)	29	29	0
Disulfoton (di-syston)	29	29	0
Ethion	29	29	0
Gamma-benzenehexachloride (lindane) (gamma-bhc)	29	29	0
Guthion (azinphos methyl) (azinphos ethyl)	29	29	0
Malathion	29	29	0
Methomyl	29	29	0
Methoxychlor (p,p'-methoxychlor)	29	29	0
Parathion	13	13	0
Thiamethoxam	13	13	0
Terbufos	29	29	0
Other (i.e., degradates, metabolites and manufacturing byproducts)			
2,4-Dichlorophenol	29	29	0
4-Chloro-2-methylphenol	29	29	0
Alpha-benzenehexachloride (bhc)	29	29	0

Table 3-5 Available Pesticide Data in the RAA (2005 – 2010)

Parameter	n	<DL	>DL
Clodinafop acid metabolite	13	13	0
Desethyl atrazine	29	29	0
Desisopropyl atrazine	29	29	0

NOTES:
n = total count of samples in the RAA
<DL = value below laboratory detection limit
>DL = detected value

3.5 SEDIMENT QUALITY FOR ELBOW RIVER AND GLENMORE RESERVOIR; OFF-STREAM RESERVOIR SOIL QUALITY

The concentrations of organic carbon, methylmercury and mercury were considered in the assessment of methylmercury release from the off-stream reservoir.

Data was available for 53 soil and sediment quality parameters from the sampling conducted in 2016 (Table 3-6). Eleven of these parameters had no observations greater than detection limits. Seven parameters were associated with guidelines, which applied only to sediment quality data and not applicable to the off-stream reservoir soil samples. Of parameters that had guidelines, only two had exceedances from guidelines: arsenic (Figure 3-37) and cadmium (Figure 3-38). Arsenic guideline exceedances were observed in the sediment of both the Elbow River (33.3% of observations) and Glenmore Reservoir (60% of observations). Whereas, cadmium guideline exceedances were only observed in the Glenmore Reservoir (40% of observations).

Concentrations of analyzed parameters in Elbow River sediment, Glenmore Reservoir sediment, and off-stream reservoir soil are generally greatest in either the off-stream reservoir soil or Glenmore Reservoir sediment samples. This pattern is likely created by erosional forces. The off-stream reservoir soil is only subject to overland flow, providing limited opportunity for parameter removal. Similarly, Glenmore Reservoir sediment is predominantly the result of deposition and is a source for particles that have been mobilized from around the watershed. In contrast, Elbow River sediment samples are in moving water and are subject to constant erosional force. This environment provides many opportunities for parameters to be leached from the substrate and, thereby, reducing observed values in the substrate.

Although this occurs for most parameters, several parameters differed. These are arsenic, available ammonium, inorganic carbon, mercury, methyl mercury, redox potential, and sulphide. In these cases, values of the off-stream reservoir soil were comparable, or less than, Elbow River sediment parameters.

Ammonium is generally a waste product of aquatic organisms (Wright 1995). Aquatic organisms are not found in the off-stream reservoir soils and are both found in and around the Elbow River and Glenmore Reservoir. As for ammonium, methylmercury is generally formed in aquatic environments during decomposition. Some sulphides are also associated with decomposition; however, they are not primarily associated with aquatic environments.

Table 3-6 Available Soil and Sediment Data and Sediment Quality Guideline Exceedances (2016)

Parameter	Elbow River Sediment				Glenmore Reservoir Sediment				Off-Stream Reservoir Soil	
	n	DL	GL	%	n	DL	GL	%	n	<DL
Antimony	6	0	-	-	5	0	-	-	10	5
Arsenic	6	0	2	33.3	5	0	3	60.0	15	0
Available ammonium	6	0	-	-	5	0	-	-	15	0
Available phosphate	0	6	-	-	0	5	-	-	14	1
Barium	6	0	-	-	5	0	-	-	15	0
Benzene	0	6	-	-	0	5	-	-	0	15
Beryllium	6	0	-	-	5	0	-	-	15	0
Boron	0	6	-	-	0	5	-	-	0	15
Cadmium	6	0	0	0.0	5	0	2	40.0	15	0
Chromium	6	0	0	0.0	5	0	0	0.0	15	0
Clay	6	0	-	-	5	0	-	-	15	0
Cobalt	6	0	-	-	5	0	-	-	15	0
Copper	6	0	0	0.0	5	0	0	0.0	15	0
Ethylbenzene	0	6	-	-	0	5	-	-	0	15
F1 BTEX	0	6	-	-	0	5	-	-	0	15
F1 C6 C10	0	6	-	-	0	5	-	-	0	15
F2 C10 C16	0	6	-	-	0	5	-	-	1	14
F3 C16 C34	0	6	-	-	1	4	-	-	8	7
F4 C34 C50	0	6	-	-	0	5	-	-	5	10
F4G SG	0	6	-	-	1	4	-	-	5	10
Inorganic carbon	6	0	-	-	5	0	-	-	15	0
Inorganic carbon as calcium carbonate	6	0	-	-	5	0	-	-	15	0
Kjeldahl nitrogen	6	0	-	-	5	0	-	-	15	0
Lead	6	0	0	0.0	5	0	0	0.0	15	0
Mercury	6	0	0	0.0	5	0	0	0.0	15	0
Methylmercury	6	0	-	-	5	0	-	-	11	4
Moisture	6	0	-	-	5	0	-	-	15	0

Table 3-6 Available Soil and Sediment Data and Sediment Quality Guideline Exceedances (2016)

Parameter	Elbow River Sediment				Glenmore Reservoir Sediment				Off-Stream Reservoir Soil	
	n	DL	GL	%	n	DL	GL	%	n	<DL
Molybdenum	6	0	-	-	5	0	-	-	14	1
mpXylene	0	6	-	-	0	5	-	-	0	15
Nickel	6	0	-	-	5	0	-	-	15	0
Nitrate	0	6	-	-	0	5	-	-	5	10
Nitrate and nitrite	0	6	-	-	0	5	-	-	5	10
Nitrite	0	6	-	-	0	5	-	-	3	12
oXylene	0	6	-	-	0	5	-	-	0	15
Redox potential	6	0	-	-	5	0	-	-	15	0
Sand	6	0	-	-	2	3	-	-	14	1
Saturation	6	0	-	-	5	0	-	-	15	0
Selenium	6	0	-	-	5	0	-	-	10	5
Silt	6	0	-	-	5	0	-	-	15	0
Silver	0	6	-	-	5	0	-	-	8	7
Styrene	0	6	-	-	0	5	-	-	0	15
Sulphide	5	1	-	-	5	0	-	-	4	11
Thallium	6	0	-	-	5	0	-	-	9	6
Tin	0	6	-	-	0	5	-	-	0	15
Toluene	0	6	-	-	0	5	-	-	0	15
Total available nitrogen	5	1	-	-	5	0	-	-	14	1
Total carbon by combustion	6	0	-	-	5	0	-	-	15	0
Total hydrocarbons	0	6	-	-	1	4	-	-	8	7
Total organic carbon	6	0	-	-	5	0	-	-	15	0
Uranium	6	0	-	-	5	0	-	-	15	0
Vanadium	6	0	-	-	5	0	-	-	15	0
Xylenes	0	6	-	-	0	5	-	-	0	15
Zinc	6	0	0	0.0	5	0	0	0.0	15	0

NOTES:
n = Number of observations within detection limits.
DL = Number of observations outside of detection limits
GL = Number of observations outside of most conservative guideline
% = Percentage of observations outside of guidelines

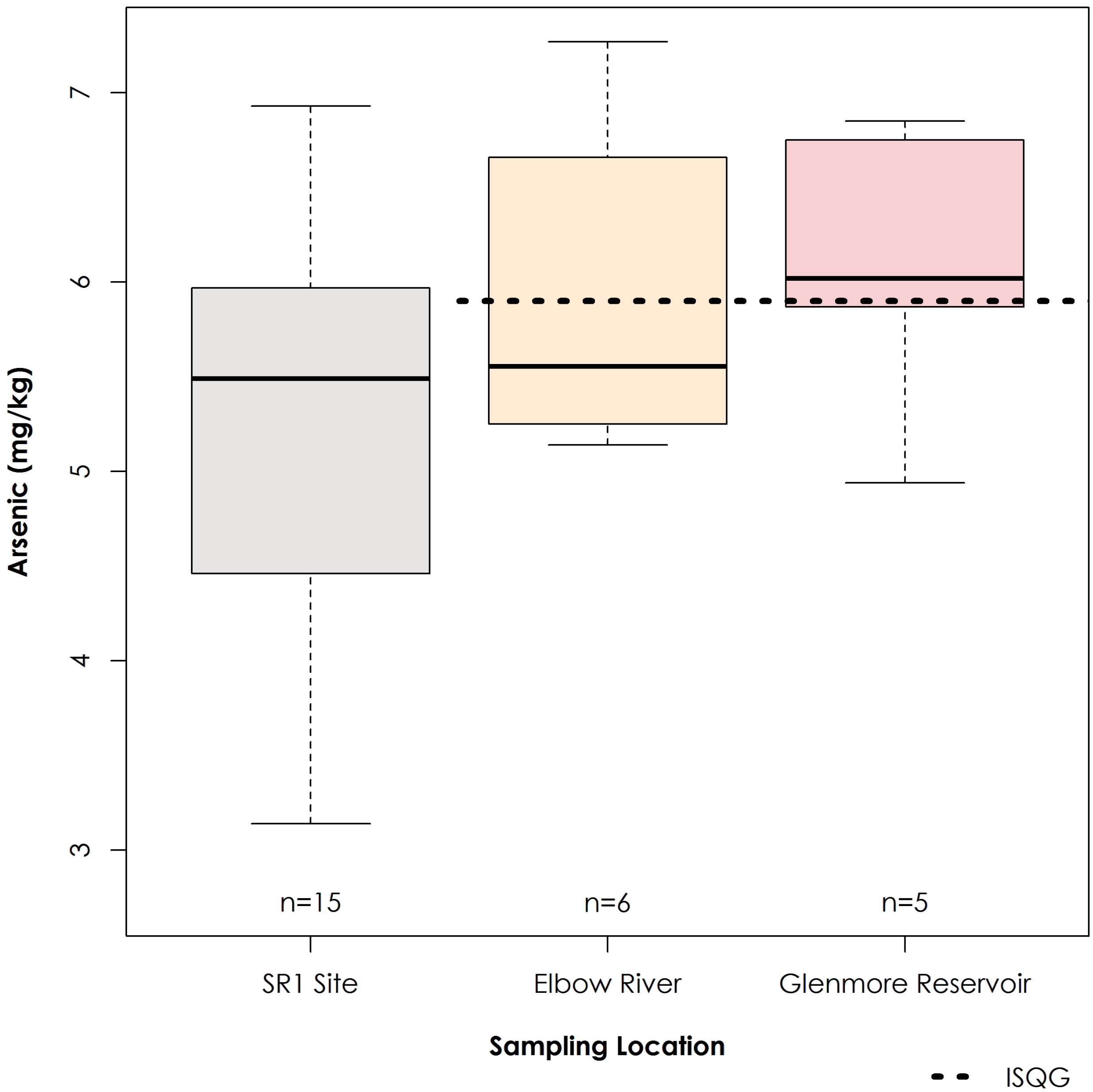

Figure 3-37 Arsenic Concentrations in Sediment from Elbow River, Glenmore Reservoir, and in the Off-stream Reservoir Soil

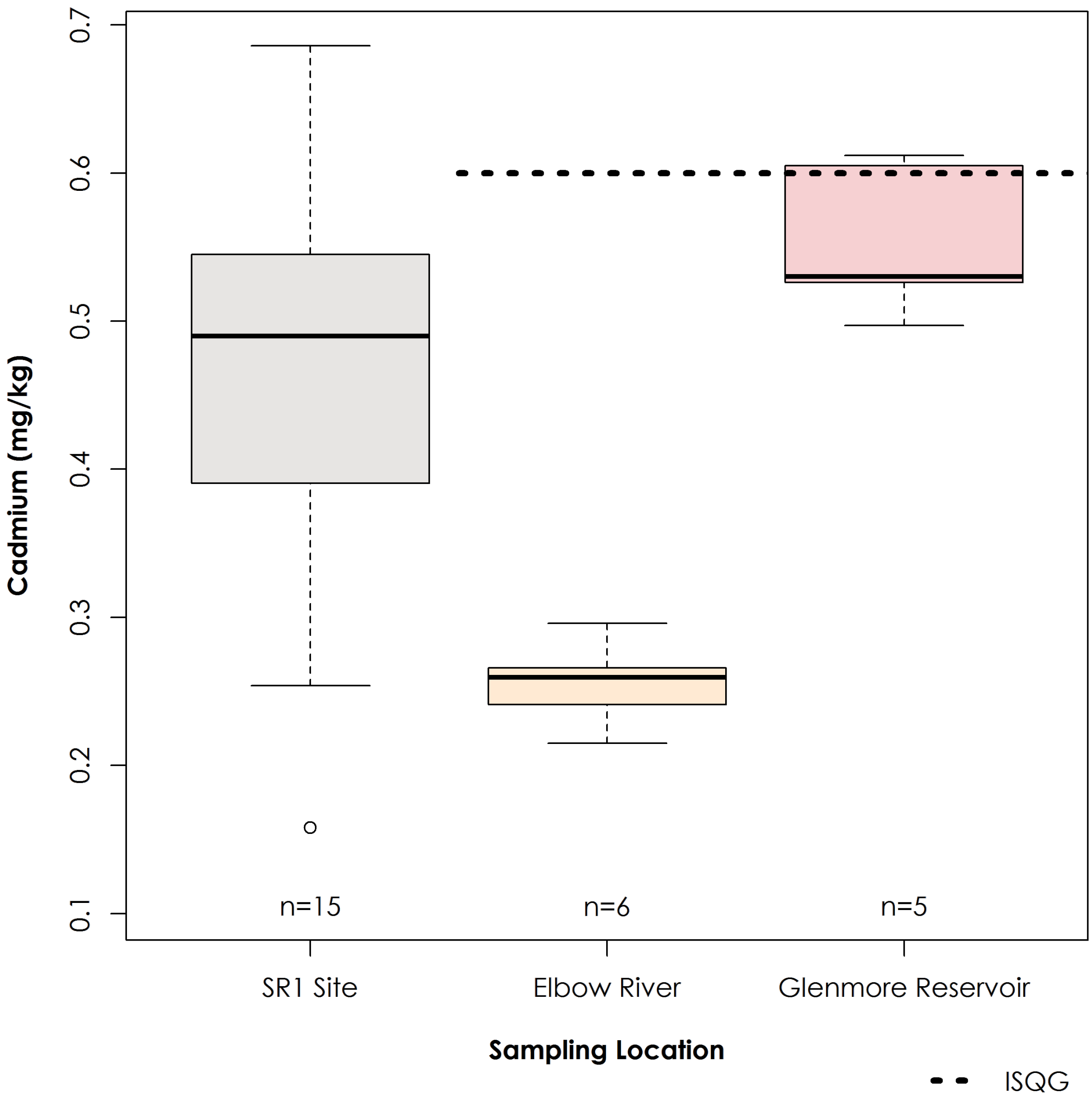

Figure 3-38 Cadmium Concentrations in Sediment from the Elbow River, Glenmore Reservoir, and in the Off-stream Reservoir Soil

3.6 QUALITY CONTROL

This section presents the results of quality control samples collected for water and sediment as part of the Project-specific data collection.

Three water duplicate samples were collected:

- May 20, 2016 at Elbow River at Highway 22
- July 18, 2018 at Outlet Channel
- July 19, 2018 at Elbow River at Highway 22

Duplicate results were within 25% for the duplicates and above five times the detection limit for all parameters, except for total titanium on June 3 (27% difference) and July 19 (39% difference), total uranium on July 18 (32% difference), and total zirconium on July 18 (33% difference) and July 19 (65% difference). These differences are more likely reflecting the low detection limits for these metals than a sample precision issue. Overall, sampling precision was acceptable.

One field blank sample was collected on June 3, 2017. All parameters were analyzed and were below detection limit or within five times the detection limit, except for dissolved strontium (result 0.000434 mg/L, which is several orders of magnitude lower than ambient concentrations. Overall sampling accuracy was acceptable.

Two sediment duplicate samples were collected to confirm sampling method precision: at ER-108 on November 8, 2016 and at Glenmore Reservoir Heritage Cove site on October 27, 2016. In the case of both duplicate samples, relative percent difference was less than 25% for all parameters, which indicates acceptable sampling precision (Mitchell 2006).

3.7 CONCLUSIONS

The main effect on water quality is anticipated to be related to the settling of suspended sediment. The processes that affect suspended sediment patterns can also effect other water quality parameters (e.g., Foster and Charlesworth 1996), and so parameters associated with suspended sediment could be directly linked to the main Project effect on water quality. Several nutrient parameters, total coliforms, and several metals had similar seasonal patterns as suspended sediment in the upper Elbow River mainstem. Similar seasonal patterns indicated that these parameters are particle-associated or vary as a response to similar conditions as suspended sediment.

Water temperature and dissolved oxygen conditions change similarly in response to the diversion of flood water and retention in the reservoir prior to release back into Elbow River. Temperatures were greatest during the summer, were lowest during the winter, and generally increased from upstream to downstream locations during all seasons. Water temperatures were higher during all seasons at Glenmore Dam compared to the upper Elbow River mainstem sites upstream of the Glenmore Reservoir. The upper Elbow River dissolved oxygen concentrations varied seasonally, but were not associated with any apparent spatial pattern. Dissolved oxygen concentrations were greatest during the winter, lowest during the summer, and intermediate during the spring and fall. This seasonal pattern likely reflects the water saturation of dissolved oxygen, which decreases with increasing temperature.

Water quality in the low-level outlet channel is expected to remain the same after Project construction and during Project dry operations.

During flood operation, water quality of the outlet channel is anticipated to change during the reservoir discharge, and these changes are evaluated in the EIA.

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Attachment A ADDITIONAL INFORMATION

Results of Project-specific water, sediment and soil sampling are provided in the following tables.

Table A-1 Elbow River and Low-Level Outlet Water Chemistry Sampling Results

Parameter	Units	Client Sample ID	ER H22	TR1	TR1	ER H22	TR1	ER H22	TR1
		Date Sampled	20-May-2016	3-Jun-2016	22-Jun-2016	23-Jun-2016	18-Jul-2016	19-Jul-2016	3-Aug-2016
		Time Sampled	12:15	13:00	8:08	14:00	11:00	19:00	9:30
		ALS Sample ID	L1772207-1	L1778469-1	L1788108-1	L1788285-1	L1799739-1	L1801019-1	L1807510-1
		Detection Limit							
Physical Tests (Water)									
Colour, true	CU	5.0 to 10.0	<5.0	23.8	17	<5.0	187	16.1	145
Hardness (as CaCO3)	mg/L	0.5	209	690	628		360	189	435
Total suspended sediment	mg/L	3	21.7	<3.0	8.3	<3.0	<3.0	39.0	<3.0
Turbidity	NTU		13.9	0.33	8.23	0.43	4.88	28.3	2.11
Anions and Nutrients (Water)									
Alkalinity, total (as CaCO3)	mg/L	5	131	396	379	144	251	125	332
Ammonia, total (as N)	mg/L	0.005	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Bicarbonate (HCO3)	mg/L	5	160	483	462	168	299	152	380
Carbonate (CO3)	mg/L	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	12.7
Chloride (Cl)	mg/L	0.5 to 2.5	1.00	166	113	0.82	69.5	1.11	96.8
Conductivity (EC)	µS/cm	2	390	1540	1430	387	962	331	1120
Fluoride (F)	mg/L	0.020 to 1.0	0.235	0.11	<1.0	0.234	0.10	0.206	0.12
Hardness (as CaCO3)	mg/L		209	644		233	352	155	419
Hydroxide (OH)	mg/L	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Ion balance	%		101	101		115	108	91.9	96.3
Nitrate and nitrite (as N)	mg/L	0.050 to 0.11	0.198	<0.11	<0.11	0.115	<0.11	0.141	<0.11
Nitrate (as N)	mg/L	0.020 to 0.10	0.198	<0.10	<0.10	0.115	<0.10	0.141	<0.10
Nitrite (as N)	mg/L	0.010 to 0.050	<0.010	<0.050	<0.050	<0.010	<0.050	<0.010	<0.050
Total kjeldahl nitrogen	mg/L	0.2	<0.20	1.01	0.74	<0.20	1.77	0.39	1.58
pH	pH	0.1	8.24	8.42	7.77	8.31	8.30	8.22	8.40
Phosphorus (P)-total dissolved	mg/L	0.0020 to 0.025	0.0039	0.0191	0.0299	0.0024	0.230	0.0044	0.173
Phosphorus (P)-total	mg/L	0.0020 to 0.010	0.0137	0.0212	0.0278	0.0024	0.246	0.0324	0.186
TDS (calculated)	mg/L		231	1040		239	579	179	701
Sulfate (SO_4)	mg/L	0.30 to 1.5	73.9	289	232	65.1	154	45.1	175
Sulphide (as S)	mg/L	0.0015	<0.0015	0.0021	0.0106	<0.0015	0.0077	0.0018	0.0110

Table A-1 Elbow River and Low-Level Outlet Water Chemistry Sampling Results

		Client Sample ID	**ER H22**	**TR1**	**TR1**	**ER H22**	**TR1**	**ER H22**	**TR1**
		Date Sampled	**20-May-2016**	**3-Jun-2016**	**22-Jun-2016**	**23-Jun-2016**	**18-Jul-2016**	**19-Jul-2016**	**3-Aug-2016**
		Time Sampled	**12:15**	**13:00**	**8:08**	**14:00**	**11:00**	**19:00**	**9:30**
		ALS Sample ID	**L1772207-1**	**L1778469-1**	**L1788108-1**	**L1788285-1**	**L1799739-1**	**L1801019-1**	**L1807510-1**
Parameter	**Units**	**Detection Limit**							
Organic / Inorganic Carbon (Water)									
Dissolved organic carbon	mg/L	1	1.7	11.6	7.7	<1.0	31.1	4.6	20.4
Total organic carbon	mg/L		1.6	11.0	7.8	<1.0	31.4	4.8	21.1
Total Metals (Water)									
Aluminum (Al)-total	mg/L	0.00020 to 0.0030	0.494	0.0052	0.255	0.0120	0.176	0.594	0.0393
Antimony (Sb)-total	mg/L	0.0000050 to 0.000030	0.000070	0.000209	0.000183	0.0000552	0.000188	0.000079	0.000197
Arsenic (As)-total	mg/L	0.000020 to 0.000050	0.000340	0.000886	0.00103	0.000132	0.00191	0.000321	0.00239
Barium (Ba)-total	mg/L	0.000020 to 0.00010	0.0710	0.0914	0.0819	0.0636	0.0766	0.0626	0.0868
Beryllium (Be)-total	mg/L	0.0000020 to 0.0000050	0.0000359	<0.0000050	0.0000150	<0.0000020	0.0000151	0.0000265	0.0000186
Bismuth (Bi)-total	mg/L	0.0000010 to 0.000050	<0.000050	<0.000050	<0.000050	<0.0000010	<0.000050	<0.000050	<0.000050
Boron (B)-total	mg/L	0.0050 to 0.010	0.011	0.028	0.034	0.0096	0.033	0.010	0.035
Cadmium (Cd)-total	mg/L	0.000005	0.0000157	0.0000156	0.0000159	<0.0000050	0.0000244	0.0000113	0.0000131
Calcium (Ca)-total	mg/L	0.030 to 0.050	59.2	126	120	61.1	65.6	52.9	77.9
Cesium (Cs)-total	mg/L	0.000005	0.000104	<0.0000050	0.0000373	<0.0000050	0.0000166	0.000112	<0.0000050
Chromium (Cr)-total	mg/L	0.000050 to 0.00050	0.00089	0.00092	<0.00050	0.000080	<0.00050	0.00075	<0.00050
Cobalt (Co)-total	mg/L	0.0000050 to 0.000050	0.000314	0.000132	0.000296	0.0000297	0.000338	0.000187	0.000315
Copper (Cu)-total	mg/L	0.000050 to 0.00050	0.00115	0.00155	0.00126	0.000223	0.00268	0.00100	0.00202
Gallium (Ga)-total	mg/L	0.00005	0.000143	<0.000050	0.000084	<0.000050	<0.000050	0.000160	<0.000050
Iron (Fe)-total	mg/L	0.0010 to 0.030	0.605	<0.030	0.361	0.0210	0.267	0.495	0.157
Lead (Pb)-total	mg/L	0.0000050 to 0.000050	0.000404	<0.000050	0.000225	0.0000203	0.000201	0.000278	0.000073
Lithium (Li)-total	mg/L	0.00020 to 0.00040	0.00393	0.0194	0.0189	0.00403	0.0139	0.00371	0.0157
Magnesium (Mg)-total	mg/L	0.030 to 0.10	15.9	82.2	71.0	16.1	47.6	13.8	58.5
Manganese (Mn)-total	mg/L	0.0000050 to 0.00020	0.0120	0.00631	0.0959	0.00108	0.0166	0.00804	0.0129
Mercury (Hg)-total	mg/L	0.0000050 to 0.000025	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.000025	<0.0000050	<0.000025
Molybdenum (Mo)-total	mg/L	0.000010 to 0.000050	0.000656	0.00149	0.00152	0.000681	0.00143	0.000706	0.00107
Nickel (Ni)-total	mg/L	0.000050 to 0.00020	0.00105	0.00340	0.00254	0.000209	0.00234	0.00101	0.00240
Phosphorus (P)-total	mg/L	0.050 to 0.30	<0.30	<0.30	<0.30	<0.050	<0.30	<0.30	<0.30
Potassium (K)-total	mg/L	2	<2.0	12.0	9.9		13.4	<2.0	10.7

Table A-1 Elbow River and Low-Level Outlet Water Chemistry Sampling Results

Parameter	Units	Client Sample ID	ER H22	TR1	TR1	ER H22	TR1	ER H22	TR1
		Date Sampled	20-May-2016	3-Jun-2016	22-Jun-2016	23-Jun-2016	18-Jul-2016	19-Jul-2016	3-Aug-2016
		Time Sampled	12:15	13:00	8:08	14:00	11:00	19:00	9:30
		ALS Sample ID	L1772207-1	L1778469-1	L1788108-1	L1788285-1	L1799739-1	L1801019-1	L1807510-1
		Detection Limit							
Rhenium (Re)-total	mg/L	0.000005	<0.0000050	0.0000230	0.0000238	0.0000057	0.0000376	0.0000051	0.0000316
Rubidium (Rb)-total	mg/L	0.0000050 to 0.000020	0.00129	0.000984	0.00127	0.000334	0.00145	0.00136	0.000875
Selenium (Se)-total	mg/L	0.000040 to 0.00020	0.00052	0.00038	<0.00020	0.000656	0.00043	0.00054	0.00029
Silicon (Si)-total	mg/L	0.050 to 0.050	2.88	4.59	3.69	2.08	13.1	3.79	11.5
Silver (Ag)-total	mg/L	0.000005	0.0000066	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.0000067	<0.0000050
Sodium (Na)-total	mg/L	0.20 to 2.0	2.2	133	101	1.86	82.5	2.3	90.6
Strontium (Sr)-total	mg/L	0.000020 to 0.00020	0.369	0.774	0.705	0.389	0.463	0.314	0.547
Tellurium (Te)-total	mg/L	0.00001	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-total	mg/L	0.0000010 to 0.000005	0.0000135	0.0000088	0.0000079	0.0000027	0.0000062	0.0000135	<0.0000050
Thorium (Th)-total	mg/L	0.000005	0.0000825	<0.0000050	0.0000417	<0.0000050	0.0000314	0.0000670	0.0000088
Tin (Sn)-total	mg/L	0.000010 to 0.00020	<0.00020	<0.00020	<0.00020	<0.000010	<0.00020	<0.00020	<0.00020
Titanium (Ti)-total	mg/L	0.000050 to 0.00020	0.00450	<0.00020	0.00358	0.000247	0.00439	0.00932	0.00102
Tungsten (W)-total	mg/L	0.00001	<0.000010	0.000015	<0.000010	<0.000010	0.000101	<0.000010	0.000065
Uranium (U)-total	mg/L	0.0000010 to 0.0000020	0.000498	0.00506	0.00508	0.000488	0.00274	0.000454	0.00296
Vanadium (V)-total	mg/L	0.000010 to 0.000050	0.00157	0.000647	0.00113	0.000124	0.00151	0.00159	0.00119
Yttrium (Y)-total	mg/L	0.000005	0.000323	0.0000425	0.000214	0.0000290	0.000214	0.000261	0.000116
Zinc (Zn)-total	mg/L	0.00010 to 0.0030	0.0031	<0.0030	<0.0030	0.00028	0.0064	<0.0030	0.0040
Zirconium (Zr)-total	mg/L	0.000010 to 0.000050	0.000079	0.000264	0.000289	0.000012	0.000785	0.000447	0.000305
Dissolved Metals (Water)									
Aluminum (Al)-dissolved	mg/L	0.001	0.0012	<0.0010	<0.0010	<0.0010	0.0103	0.0096	0.0055
Antimony (Sb)-dissolved	mg/L	0.00001	0.000050	0.000191	0.000204	0.000051	0.000179	0.000061	0.000198
Arsenic (As)-dissolved	mg/L	0.00005	0.000133	0.000874	0.000849	0.000118	0.00192	0.000173	0.00255
Barium (Ba)-dissolved	mg/L	0.0001	0.0596	0.0902	0.0775	0.0640	0.0719	0.0608	0.0905
Beryllium (Be)-dissolved	mg/L	0.000005	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.0000079	<0.0000050	0.0000078
Bismuth (Bi)-dissolved	mg/L	0.00005	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron (B)-dissolved	mg/L	0.005	0.0113	0.0273	0.0358	0.0097	0.0329	0.0085	0.0366
Cadmium (Cd)-dissolved	mg/L	0.000005	<0.0000050	0.0000185	<0.0000050	<0.0000050	0.0000185	<0.0000050	0.0000107
Cesium (Cs)-dissolved	mg/L	0.050 to 0.10	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050

Table A-1 Elbow River and Low-Level Outlet Water Chemistry Sampling Results

Parameter	Units	Client Sample ID	ER H22	TR1	TR1	ER H22	TR1	ER H22	TR1
		Date Sampled	20-May-2016	3-Jun-2016	22-Jun-2016	23-Jun-2016	18-Jul-2016	19-Jul-2016	3-Aug-2016
		Time Sampled	12:15	13:00	8:08	14:00	11:00	19:00	9:30
		ALS Sample ID	L1772207-1	L1778469-1	L1788108-1	L1788285-1	L1799739-1	L1801019-1	L1807510-1
		Detection Limit							
Calcium (Ca)-dissolved	mg/L	0.000005	-	125	121	65.9	-	-	-
Chromium (Cr)-dissolved	mg/L	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Cobalt (Co)-dissolved	mg/L	0.00005	<0.000050	0.000097	0.000065	<0.000050	0.000250	<0.000050	0.000325
Copper (Cu)-dissolved	mg/L	0.0002	0.00027	0.00137	0.00086	0.00025	0.00235	0.00049	0.00139
Gallium (Ga)-dissolved	mg/L	0.00005	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Iron (Fe)-dissolved	mg/L	0.010 to 0.030	<0.010	<0.030	<0.010	<0.030	0.101	<0.030	0.115
Lead (Pb)-dissolved	mg/L	0.00005	0.000081	<0.000050	<0.000050	<0.000050	0.000080	<0.000050	<0.000050
Lithium (Li)-dissolved	mg/L	0.0002	0.00353	0.0194	0.0200	0.00396	0.0130	0.00307	0.0164
Magnesium (Mg)-dissolved	mg/L	0.1	-	80.5	79.2	16.7	-	-	-
Manganese (Mn)-dissolved	mg/L	0.0002	<0.00020	0.00027	0.00042	0.00027	0.00272	0.00159	0.00653
Mercury (Hg)-dissolved	mg/L	0.000005	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.000025	<0.0000050	<0.000025
Molybdenum (Mo)-dissolved	mg/L	0.00005	0.000678	0.00142	0.00161	0.000721	0.00130	0.000587	0.00100
Nickel (Ni)-dissolved	mg/L	0.0002	0.00032	0.00295	0.00227	0.00028	0.00203	0.00045	0.00256
Potassium (K)-dissolved	mg/L	0.30 to 0.50	-	11.3	11.0	0.72	-	-	-
Rhenium (Re)-dissolved	mg/L	0.000005	<0.0000050	0.0000213	0.0000249	<0.0000050	0.0000368	<0.0000050	0.0000331
Rubidium (Rb)-dissolved	mg/L	0.00002	0.000275	0.000928	0.000988	0.000308	0.00131	0.000253	0.000864
Selenium (Se)-dissolved	mg/L	0.0002	0.00056	0.00037	<0.00020	0.00069	0.00037	0.00059	0.00025
Silicon (Si)-dissolved	mg/L	0.05	-	4.49	-	2.02	12.5	2.27	11.8
Silver (Ag)-dissolved	mg/L	0.000005	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Strontium (Sr)-dissolved	mg/L	0.00005	0.381	0.763	0.739	0.395	0.406	0.303	0.538
Sodium (Na)-dissolved	mg/L	1.0 to 2.0	-	129	116	2.4	-	-	-
Tellurium (Te)-dissolved	mg/L	0.00001	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-dissolved	mg/L	0.000002	0.0000029	0.0000076	0.0000045	0.0000022	0.0000042	0.0000040	0.0000034
Thorium (Th)-dissolved	mg/L	0.000005	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.0000194	<0.0000050	0.0000110
Tin (Sn)-dissolved	mg/L	0.0002	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Titanium (Ti)-dissolved	mg/L	0.0002	<0.00020	<0.00020	<0.00020	<0.00020	0.00192	0.00070	0.00101
Tungsten (W)-dissolved	mg/L	0.00001	<0.000010	0.000012	<0.000010	<0.000010	0.000092	<0.000010	0.000064
Uranium (U)-dissolved	mg/L	0.000002	0.000490	0.00495	0.00497	0.000476	0.00261	0.000429	0.00319

Table A-1 Elbow River and Low-Level Outlet Water Chemistry Sampling Results

Parameter	Units	Client Sample ID	ER H22	TR1	TR1	ER H22	TR1	ER H22	TR1
		Date Sampled	20-May-2016	3-Jun-2016	22-Jun-2016	23-Jun-2016	18-Jul-2016	19-Jul-2016	3-Aug-2016
		Time Sampled	12:15	13:00	8:08	14:00	11:00	19:00	9:30
		ALS Sample ID	L1772207-1	L1778469-1	L1788108-1	L1788285-1	L1799739-1	L1801019-1	L1807510-1
		Detection Limit							
Vanadium (V)-dissolved	mg/L	0.00005	0.000076	0.000614	0.000528	0.000079	0.00115	0.000115	0.00120
Yttrium (Y)-dissolved	mg/L	0.000005	0.0000125	0.0000345	0.0000243	0.0000104	0.000131	0.0000475	0.000100
Zinc (Zn)-dissolved	mg/L	0.001	0.0038	<0.0010	<0.0010	<0.0010	0.0032	<0.0010	0.0017
Zirconium (Zr)-dissolved	mg/L	0.00005	<0.000050	0.000259	0.000154	<0.000050	0.000651	0.000085	0.000498
Volatile Organic Compounds (Water)									
Benzene	mg/L	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Ethylbenzene	mg/L	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Styrene	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Toluene	mg/L	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
o-Xylene	mg/L	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
m+p-Xylene	mg/L	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Xylenes	mg/L	0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071
F1(C6-C10)	mg/L	0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
F1-BTEX	mg/L	0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Hydrocarbons (Water)									
F2 (C10-C16)	mg/L	0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
F3 (C16-C34)	mg/L	0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
F4 (C34-C50)	mg/L	0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25

Table A-2 Elbow River and Outlet Channel Additional Total Suspended Sediment and Total Phosphorus Sampling Results

Parameter	Units	Client Sample ID	ER H22	ER H22	ER H22	ER H22	ER H22	ER H22	ER H22	ER H22	ER H22	ER H22	TR1	ERH22	TR1
		Date Sampled	26-May-2016	26-May-2016	26-May-2016	30-May-2016	30-May-2016	30-May-2016	30-May-2016	14-Jun-2016	14-Jun-2016	14-Jun-2016	19-Jul-2016	1-Sep-2016	1-Sep-2016
		Time Sampled	13:15	16:30	19:39	13:30	15:30	13:30	15:30	14:00	14:45	15:30	11:00	9:55	12:00
		ALS Sample ID	L1774915-1	L1774915-2	L1774915-3	L1778467-1	L1778467-2	L1778467-1	L1778467-2	L1783427-1	L1783427-2	L1783427-3	L1801019-2	L1822752-1	L1822752-2
		Detection Limit													
Total Suspended sediment	mg/L	3	37.0	52.3	63.7	10.3	11.0	10.3	11.0	<3.0	<3.0	<3.0	3.0	<3.0	<3.0
Phosphorus (P)-total	mg/L	0.0020 to 0.010	0.0247	0.0243	0.0369	0.0041	0.0058	0.0041	0.0058	0.0041	0.0038	0.0052	0.0794	0.0021	0.0132

Table A-3 Elbow River and Glenmore Reservoir Sediment Chemistry Sampling Results

Parameter	Units	Client Sample ID	ER-100	ER-102	ER-104	ER-105	ER-108A	ER-111	GR-HEAD POND	GR-MID LAKE	GR-HERITAGE COVE	GR-WEASELHEAD	GR-MOUTH
		Date Sampled	3-Nov-2016	4-Nov-2016	4-Nov-2016	7-Nov-2016	8-Nov-2016	15-Nov-2016	27-Oct-2016	27-Oct-2016	27-Oct-2016	28-Oct-2016	28-Oct-2016
		ALS Sample ID	L1854114-1	L1854114-2	L1854114-3	L1855224-1	L1855224-2	L1858082-1	L1850139-1	L1850139-2	L1850139-3	L1850763-1	L1850763-2
		Detection Limit											
Physical Tests (Soil)													
Moisture	%	0.10 to 0.25	29.2	30.0	34.2	37.7	36.1	36.9	53.3	42.9	46.4	64.6	44.4
Redox potential	mV	-1000	178	186	191	166	156	294	77	114	114	120	132
Particle Size (Soil)													
% Sand (2.0mm - 0.05mm)	%	1.0	69.9	66.2	76.7	56.6	61.1	65.6	<1.0	4.0	<1.0	<1.0	5.4
% Silt (0.05mm - 2um)	%	1.0	22.2	25.9	18.5	38.0	32.6	29.8	55.8	72.0	67.4	70.9	73.2
% Clay (<2um)	%	1.0	7.9	7.9	4.8	5.4	6.3	4.7	43.6	24.0	32.4	29.0	21.4
Texture	-		Sandy loam	Sandy loam	Loamy sand	Sandy loam	Sandy loam	Sandy loam	Silty clay	Silt loam	Silty clay loam	Silty clay loam	Silt loam
Leachable Anions & Nutrients (Soil)													
Total kjeldahl nitrogen	%	0.020 to 0.320	0.060	0.062	0.063	0.083	0.076	0.100	0.125	0.106	0.134	0.156	0.109
Total available nitrogen	mg/kg	2.2 to 6.4	2.3	<2.2	2.6	5.9	4.5	2.8	18	18.7	24.6	11.5	24.7
Sulphide (as S)	mg/kg	0.20 to 200.0	1.27	<0.20	2.58	11.3	5.5	17.6	96	27.4	23.5	1330	48.1
Organic / Inorganic Carbon (Soil)													
Inorganic carbon	%	0.05	1.98	2.06	3.08	1.42	1.77	2.44	2.46	2.54	2.91	3.08	2.22
Inorganic carbon (as CaCO3 equivalent)	%	0.4	16.5	17.2	25.7	11.8	14.8	20.3	20.5	21.2	24.2	25.7	18.5
C:N ratio	-		63.1:1	80.9:1	100.7:1	62.6:1	67:01:00	59:01:00	39.4:1	53.9:1	45.7:1	40.6:1	50.6:1
Total carbon by combustion	%	0.05	3.80	5.00	6.32	5.23	5.10	5.93	4.92	5.69	6.11	6.31	5.49

Table A-3 Elbow River and Glenmore Reservoir Sediment Chemistry Sampling Results

		Client Sample ID	ER-100	ER-102	ER-104	ER-105	ER-108A	ER-111	GR-HEAD POND	GR-MID LAKE	GR-HERITAGE COVE	GR-WEASELHEAD	GR-MOUTH
		Date Sampled	3-Nov-2016	4-Nov-2016	4-Nov-2016	7-Nov-2016	8-Nov-2016	15-Nov-2016	27-Oct-2016	27-Oct-2016	27-Oct-2016	28-Oct-2016	28-Oct-2016
		ALS Sample ID	L1854114-1	L1854114-2	L1854114-3	L1855224-1	L1855224-2	L1858082-1	L1850139-1	L1850139-2	L1850139-3	L1850763-1	L1850763-2
Parameter	**Units**	**Detection Limit**											
Total organic carbon	%	0.050 to 1.3	1.82	2.9	3.2	3.81	3.3	3.5	2.46	3.2	3.2	3.2	3.3
Plant Available Nutrients (Soil)													
Available ammonium-N	mg/kg	1.0 to 4.0	2.3	2.2	2.6	5.9	4.5	2.8	18.0	18.7	24.6	11.5	24.7
Nitrate+nitrite-N	mg/kg	2.0 to 5.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Nitrate-N	mg/kg	2.0 to 5.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Nitrite-N	mg/kg	1.0 to 2.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Available phosphate-P	mg/kg	2.0 to 10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Saturated Paste Extractables (Soil)													
Boron (B), sat. paste ext.	mg/L	0.5	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
% Saturation	%	1	39.2	41.7	43.5	53.1	46.8	49.6	82.7	67.6	81.1	77.9	65.8
Metals (Soil)													
Antimony (Sb)	mg/kg	0.10 to 0.50	0.37	0.34	0.26	0.30	0.32	0.34	0.46	0.43	0.48	0.41	0.37
Arsenic (As)	mg/kg	0.10 to 0.50	7.27	6.66	5.25	5.14	5.48	5.63	5.87	6.85	6.75	6.02	4.94
Barium (Ba)	mg/kg	0.50 to 2.5	278	220	162	290	255	197	241	258	236	235	230
Beryllium (Be)	mg/kg	0.10 to 0.50	0.52	0.41	0.38	0.46	0.47	0.40	0.74	0.61	0.70	0.54	0.43
Cadmium (Cd)	mg/kg	0.020 to 0.10	0.261	0.215	0.241	0.258	0.296	0.266	0.605	0.497	0.612	0.526	0.530
Chromium (Cr)	mg/kg	0.50 to 2.5	14.7	11.5	10.9	12.4	13.1	11.5	23.1	19.1	20.7	17.4	14.2
Cobalt (Co)	mg/kg	0.10 to 0.50	7.61	5.60	4.51	5.71	5.81	5.47	7.60	7.33	7.53	6.57	5.36
Copper (Cu)	mg/kg	0.50 to 2.5	16.2	11.2	9.73	12.6	12.5	11.5	18.6	17.6	17.9	17.0	14.3
Lead (Pb)	mg/kg	0.50 to 2.5	8.14	7.63	5.34	7.50	6.97	6.93	13.4	9.65	10.6	8.90	7.53
Mercury (Hg)	mg/kg	0.005	0.0414	0.0283	0.0204	0.0308	0.0289	0.0300	0.0401	0.0349	0.0389	0.0343	0.0236
Molybdenum (Mo)	mg/kg	0.1 to 0.50	0.71	0.66	0.64	0.64	0.64	0.65	0.83	1.04	1.49	0.95	0.66
Nickel (Ni)	mg/kg	0.50 to 2.5	22.7	17.1	14.8	16.8	18.3	17.1	24.4	24.3	26.0	22.2	17.5
Selenium (Se)	mg/kg	0.20 to 1.0	0.43	0.32	0.34	0.46	0.44	0.47	0.73	0.61	0.68	0.67	0.49
Silver (Ag)	mg/kg	0.10 to 0.50	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.14	0.13	0.15	0.13	0.11
Thallium (Tl)	mg/kg	0.050 to 0.25	0.123	0.107	0.075	0.126	0.115	0.103	0.207	0.210	0.289	0.176	0.136
Tin (Sn)	mg/kg	2.0 to 10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Uranium (U)	mg/kg	0.050 to 0.25	0.568	0.512	0.470	0.623	0.612	0.578	0.728	0.692	0.705	0.668	0.607

Table A-3 Elbow River and Glenmore Reservoir Sediment Chemistry Sampling Results

Parameter	Units	Client Sample ID	ER-100	ER-102	ER-104	ER-105	ER-108A	ER-111	GR-HEAD POND	GR-MID LAKE	GR-HERITAGE COVE	GR-WEASELHEAD	GR-MOUTH
		Date Sampled	**3-Nov-2016**	**4-Nov-2016**	**4-Nov-2016**	**7-Nov-2016**	**8-Nov-2016**	**15-Nov-2016**	**27-Oct-2016**	**27-Oct-2016**	**27-Oct-2016**	**28-Oct-2016**	**28-Oct-2016**
		ALS Sample ID	**L1854114-1**	**L1854114-2**	**L1854114-3**	**L1855224-1**	**L1855224-2**	**L1858082-1**	**L1850139-1**	**L1850139-2**	**L1850139-3**	**L1850763-1**	**L1850763-2**
		Detection Limit											
Vanadium (V)	mg/kg	0.20 to 1.0	24.7	21.0	20.5	22.4	24.5	21.2	37.7	34.6	38.7	31.4	24.7
Zinc (Zn)	mg/kg	2.0 to 10	63.3	49.6	48.7	54.3	54.8	54.3	87.9	77.5	83.8	70.4	61.2
Speciated metals (Soil)													
Methylmercury (as MeHg)	mg/kg	0.00005	0.000255	0.000276	0.000482	0.00148	0.00107	0.00202	0.000197	0.000647	0.000898	0.00164	0.00206
Volatile Organic Compounds (Soil)													
Benzene	mg/kg	0.0050 to 0.030	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.010	<0.010	<0.010	<0.015	<0.010
Ethylbenzene	mg/kg	0.015 to 0.10	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.035	<0.035	<0.035	<0.050	<0.035
Styrene	mg/kg	0.050 to 0.30	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.10	<0.10	<0.10	<0.15	<0.10
Toluene	mg/kg	0.050 to 0.30	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.10	<0.10	<0.10	<0.15	<0.10
o-Xylene	mg/kg	0.050 to 0.30	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.10	<0.10	<0.10	<0.15	<0.10
m+p-Xylene	mg/kg	0.050 to 0.30	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.10	<0.10	<0.10	<0.15	<0.10
Xylenes	mg/kg	0.10 to 0.50	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.25	<0.20	<0.20	<0.30	<0.20
Hydrocarbons (Soil)													
F1 (C6-C10)	mg/kg	10 to 50	<10	<10	<10	<10	<10	<10	<25	<20	<20	<30	<20
F1-BTEX	mg/kg	10 to 50	<10	<10	<10	<10	<10	<10	<25	<20	<20	<30	<20
F2 (C10-C16)	mg/kg	25 to 40	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
F3 (C16-C34)	mg/kg	50 to 75	<50	<50	<50	<50	<50	<50	<50	<50	<50	56	<50
F4 (C34-C50)	mg/kg	50 to 75	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
F4G-SG (GHH-Silica)	mg/kg	500 to 500	<500	<500	<500	<500	<500	<500	<500	<500	<500	560	<500
Total hydrocarbons (C6-C50)	mg/kg	50 to 75	<50	<50	<50	<50	<50	<50	<50	<50	<50	56	<50

Table A-4 Off-stream Reservoir Soil Chemistry Sampling Results

Parameter	Units	Client Sample ID	SRWQ1601	SRWQ1602	SRWQ1603	SRWQ1604	SRWQ1605	SRWQ16-1001	SRWQ16-1002	SRWQ16-1003	SRWQ16-1004	SRWQ16-1005	SRWQ16-1006	SRWQ16-1007	SRWQ16-1008	SRWQ16-1009	SRWQ16-1010
		Date Sampled	23-Sep-2016	24-Sep-2016	25-Sep-2016	27-Sep-2016	28-Sep-2016	8-Nov-2016	8-Nov-2016	8-Nov-2016	8-Nov-2016	8-Nov-2016	8-Nov-2016	9-Nov-2016	9-Nov-2016	9-Nov-2016	9-Nov-2016
		ALS Sample ID	L1836880-1	L1836880-2	L1836880-3	L1836880-4	L1836880-5	L1856651-1	L1856651-2	L1856651-3	L1856651-4	L1856651-5	L1856651-6	L1856631-1	L1856631-2	L1856631-3	L1856631-4
		Detection Limit															
Physical Tests (Soil)																	
Moisture	%	0.10 to 0.25	35.1	41.6	28.9	22.9	27.7	22.9	31.8	74.5	29.7	37.4	16.8	18.5	27.9	28.9	16.6
Redox potential	mV	-1000	220	227	233	239	250	187	187	217	211	210	189	179	188	180	186
Particle Size (Soil)																	
% Sand (2.0mm - 0.05mm)	%	1.0	2.1	2.2	24.6	5.1	4.1	41.3	4.8	<1.0	5.8	4.7	3.6	46.3	4.9	3.9	17.5
% Silt (0.05mm - 2um)	%	1.0	38.8	59.8	56.7	58.8	64.4	49.0	34.0	64.0	40.4	43.7	78.1	49.0	41.7	81.5	63.8
% Clay (<2um)	%	1.0	59.1	38.0	18.8	36.1	31.5	9.7	61.2	35.1	53.8	51.6	18.3	4.7	53.4	14.5	18.7
Texture	-		Clay	Silty clay loam	Silt loam	Silty clay loam	Silty clay loam	Silt loam / Loam	Clay	Silty clay loam	Silty clay	Silty clay	Silt loam	Silt loam / Sandy loam	Silty clay	Silt loam	Silt loam
Leachable Anions & Nutrients (Soil)																	
Total kjeldahl nitrogen	%	0.020 to 0.320	0.494	0.64	0.83	0.815	0.691	0.44	0.72	1.68	0.51	0.548	0.173	0.088	0.67	0.486	0.206
Total available nitrogen	mg/kg	2.2 to 6.4	4	5.9	6.1	6	10.5	5.4	7.4	7.9	38.3	5.5	7.4	<2.2	10.8	5.9	24.8
Sulphide (as S)	mg/kg	0.20 to 200.0	<0.20	<0.20	<0.20	<0.20	<0.20	0.23	<0.20	0.24	<0.20	<0.20	<0.20	2.07	<0.20	<0.20	0.25
Organic / Inorganic Carbon (Soil)																	
Inorganic carbon	%	0.05	0.272	0.253	0.256	0.251	0.164	1.61	0.264	3.21	0.171	0.153	2.82	1.27	0.286	2.37	1.46
Inorganic carbon (as CaCO3 equivalent)	%	0.4	2.27	2.11	2.14	2.09	1.37	13.4	2.2	26.7	1.43	1.27	23.5	10.6	2.39	19.7	12.1
C:N ratio	-		13:01	14.8:1	12.5:1	11.5:1	11.9:1	14.6:1	13.2:1	17.7:1	12.5:1	13.7:1	35.9:1	73.8:1	12.4:1	19.2:1	21.3:1
Total carbon by combustion	%	0.05	6.43	9.57	10.4	9.34	8.24	6.47	9.51	29.8	6.42	7.50	6.21	6.53	8.33	9.33	4.40
Total organic carbon	%	0.050 to 1.3	6.16	9.32	10.1	9.09	8.08	4.86	9.25	26.6	6.25	7.35	3.4	5.26	8.04	6.96	2.94
Plant Available Nutrients (Soil)																	
Available ammonium-N	mg/kg	1.0 to 4.0	4.0	5.9	6.1	6.0	8.3	5.4	7.4	7.9	4.8	5.5	2.7	1.6	7.1	5.9	3.5
Nitrate+nitrite-N	mg/kg	2.0 to 5.0	<2.0	<2.0	<2.0	<2.0	2.1	<2.0	<2.0	<5.0	33.5	<2.0	4.7	<2.0	3.8	<2.0	21.4
Nitrate-N	mg/kg	2.0 to 5.0	<2.0	<2.0	<2.0	<2.0	2.1	<2.0	<2.0	<5.0	33.5	<2.0	3.6	<2.0	3.8	<2.0	21.4
Nitrite-N	mg/kg	1.0 to 2.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0	<2.0	<1.0	<1.0	1.1	<1.0	<1.0	1.1	<1.0
Available phosphate-P	mg/kg	2.0 to 10	2.8	2.9	2.6	158	2.2	3.9	6.1	4.1	42.4	4.9	3.2	<2.0	5.8	4.8	4.2
Saturated Paste Extractables (Soil)																	
Boron (B), sat. paste ext.	mg/L	0.5	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
% Saturation	%	1	93.4	99.4	101	85.6	93.9	74.9	103	410	78.6	75.4	55.0	40.6	94.3	83.0	54.1

Table A-4 Off-stream Reservoir Soil Chemistry Sampling Results

Parameter	Units	Client Sample ID	SRWQ1601	SRWQ1602	SRWQ1603	SRWQ1604	SRWQ1605	SRWQ16-1001	SRWQ16-1002	SRWQ16-1003	SRWQ16-1004	SRWQ16-1005	SRWQ16-1006	SRWQ16-1007	SRWQ16-1008	SRWQ16-1009	SRWQ16-1010
		Date Sampled	23-Sep-2016	24-Sep-2016	25-Sep-2016	27-Sep-2016	28-Sep-2016	8-Nov-2016	8-Nov-2016	8-Nov-2016	8-Nov-2016	8-Nov-2016	8-Nov-2016	9-Nov-2016	9-Nov-2016	9-Nov-2016	9-Nov-2016
		ALS Sample ID	L1836880-1	L1836880-2	L1836880-3	L1836880-4	L1836880-5	L1856651-1	L1856651-2	L1856651-3	L1856651-4	L1856651-5	L1856651-6	L1856631-1	L1856631-2	L1856631-3	L1856631-4
		Detection Limit															
Metals (Soil)																	
Antimony (Sb)	mg/kg	0.10 to 0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.40	0.28	0.12	0.31	0.11	0.40	0.35	0.33	0.34	0.49
Arsenic (As)	mg/kg	0.10 to 0.50	3.14	4.26	6.93	5.49	5.44	6.12	4.49	3.33	5.97	4.43	5.11	5.77	6.82	5.84	5.97
Barium (Ba)	mg/kg	0.50 to 2.5	229	231	219	225	286	385	203	128	254	187	204	259	301	205	282
Beryllium (Be)	mg/kg	0.10 to 0.50	1.03	0.83	0.61	0.94	0.96	0.45	0.87	0.15	0.94	0.68	0.66	0.44	1.09	0.64	0.67
Cadmium (Cd)	mg/kg	0.020 to 0.10	0.55	0.46	0.50	0.49	0.60	0.380	0.686	0.158	0.540	0.304	0.401	0.254	0.665	0.517	0.460
Chromium (Cr)	mg/kg	0.50 to 2.5	23.6	21.1	19.5	26.1	24.5	14.7	21.8	3.37	27.5	20.0	20.1	13.4	31.4	22.0	19.6
Cobalt (Co)	mg/kg	0.10 to 0.50	7.63	8.71	5.59	8.06	8.93	5.25	8.59	1.50	9.60	8.59	6.86	5.43	10.7	7.29	6.66
Copper (Cu)	mg/kg	0.50 to 2.5	20.8	18.2	14.9	22.1	21.6	11.5	23.1	4.63	22.8	16.3	16.9	11.7	25.8	18.4	16.7
Lead (Pb)	mg/kg	0.50 to 2.5	11.4	11.5	10.4	11.8	13.1	8.28	11.8	3.20	13.7	10.2	8.78	7.01	14.6	9.34	9.08
Mercury (Hg)	mg/kg	0.005	0.0156	0.0234	0.0301	0.0274	0.0201	0.0315	0.0371	0.0301	0.0310	0.0229	0.0242	0.0282	0.0285	0.0256	0.0372
Molybdenum (Mo)	mg/kg	0.1 to 0.50	<0.50	0.68	0.83	0.77	1.10	0.59	0.34	0.59	0.64	0.40	0.65	0.98	0.77	0.75	0.61
Nickel (Ni)	mg/kg	0.50 to 2.5	22.2	20.8	17.3	24.0	24.5	15.3	22.0	3.93	25.0	18.4	21.8	17.7	28.0	22.9	21.6
Selenium (Se)	mg/kg	0.20 to 1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.24	0.54	0.35	0.71	0.35	0.27	0.35	0.57	0.42	0.34
Silver (Ag)	mg/kg	0.10 to 0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.10	0.16	<0.10	0.13	0.11	0.12	<0.10	0.16	0.13	0.14
Thallium (Tl)	mg/kg	0.050 to 0.25	<0.25	<0.25	<0.25	<0.25	<0.25	0.138	0.184	<0.050	0.221	0.188	0.163	0.137	0.249	0.180	0.189
Tin (Sn)	mg/kg	2.0 to 10	<10	<10	<10	<10	<10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Uranium (U)	mg/kg	0.050 to 0.25	3.07	0.64	0.49	0.66	0.89	0.505	2.61	0.689	0.793	0.817	0.568	0.609	1.17	0.461	0.722
Vanadium (V)	mg/kg	0.20 to 1.0	35.1	36.7	29.2	42.3	42.2	25.8	37.5	5.90	50.2	33.3	34.3	24.6	59.4	38.5	35.1
Zinc (Zn)	mg/kg	2.0 to 10	124	99	86	107	111	53.9	115	22.7	104	76.3	59.5	54.7	116	73.5	64.9
Speciated Metals (Soil)																	
Methylmercury (as MeHg)	mg/kg	0.00005	no data	no data	no data	no data	no data	0.000308	<0.000050	<0.000050	0.000058	0.000160	<0.000050	0.000153	0.000060	<0.000050	0.000089
Volatile Organic Compounds (Soil)																	
Benzene	mg/kg	0.0050 to 0.030	<0.0050	<0.010	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.030	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Ethylbenzene	mg/kg	0.015 to 0.10	<0.015	<0.030	<0.015	<0.015	<0.015	<0.015	<0.015	<0.10	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Styrene	mg/kg	0.050 to 0.30	<0.050	<0.10	<0.050	<0.050	<0.050	<0.050	<0.050	<0.30	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Toluene	mg/kg	0.050 to 0.30	<0.050	<0.10	<0.050	<0.050	<0.050	<0.050	<0.050	<0.30	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
o-Xylene	mg/kg	0.050 to 0.30	<0.050	<0.10	<0.050	<0.050	<0.050	<0.050	<0.050	<0.30	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
m+p-Xylene	mg/kg	0.050 to 0.30	<0.050	<0.10	<0.050	<0.050	<0.050	<0.050	<0.050	<0.30	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Xylenes	mg/kg	0.10 to 0.50	<0.10	<0.20	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10

Table A-4 Off-stream Reservoir Soil Chemistry Sampling Results

Parameter	Units	Client Sample ID	SRWQ1601	SRWQ1602	SRWQ1603	SRWQ1604	SRWQ1605	SRWQ16-1001	SRWQ16-1002	SRWQ16-1003	SRWQ16-1004	SRWQ16-1005	SRWQ16-1006	SRWQ16-1007	SRWQ16-1008	SRWQ16-1009	SRWQ16-1010
		Date Sampled	23-Sep-2016	24-Sep-2016	25-Sep-2016	27-Sep-2016	28-Sep-2016	8-Nov-2016	8-Nov-2016	8-Nov-2016	8-Nov-2016	8-Nov-2016	8-Nov-2016	9-Nov-2016	9-Nov-2016	9-Nov-2016	9-Nov-2016
		ALS Sample ID	L1836880-1	L1836880-2	L1836880-3	L1836880-4	L1836880-5	L1856651-1	L1856651-2	L1856651-3	L1856651-4	L1856651-5	L1856651-6	L1856631-1	L1856631-2	L1856631-3	L1856631-4
		Detection Limit															
Hydrocarbons (Soil)																	
F1 (C6-C10)	mg/kg	10 to 50	<10	<20	<10	<10	<10	<10	<10	<50	<10	<10	<10	<10	<10	<10	<10
F1-BTEX	mg/kg	10 to 50	<10	<20	<10	<10	<10	<10	<10	<50	<10	<10	<10	<10	<10	<10	<10
F2 (C10-C16)	mg/kg	25 to 40	<25	29	<25	<25	<25	<25	<25	<40	<25	<25	<25	<25	<25	<25	<25
F3 (C16-C34)	mg/kg	50 to 75	113	70	84	78	57	<50	58	319	<50	<50	<50	<50	90	<50	<50
F4 (C34-C50)	mg/kg	50 to 75	108	57	51	54	<50	<50	<50	168	<50	<50	<50	<50	<50	<50	<50
F4G-SG (GHH-Silica)	mg/kg	500 to 500	520	700	750	790	640	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500
Total hydrocarbons (C6-C50)	mg/kg	50 to 75	221	156	135	132	57	<50	58	487	<50	<50	<50	<50	90	<50	<50