Longitudinal Water Quality Patterns in the Athabasca River: Winter Synoptic Survey (2015)

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EXECUTIVE SUMMARY

During the winter of 2015, Alberta Environment and Parks (AEP) conducted a synoptic survey on the Athabasca River to a) evaluate winter spatial patterns in water quality along the length of the Athabasca River, b) assess the cumulative effects of industrial and municipal point-source discharges on the Athabasca River during winter low flow, while considering contributions from major tributaries, and c) compare current water quality conditions in the Athabasca River to data collected in 1990-1993. A synoptic survey is a comprehensive spatial survey that aims to sample the same 'parcel' of water as it flows downstream in a river basin.

Beginning in Jasper National Park (upstream of Jasper), water samples were collected from 80 sites and included the mainstem (Athabasca River), major tributaries, and municipal and industrial wastewater along the entire length of the Athabasca River at the approximate rivers time of travel. Sampling was completed in the winter months (January and February) to capture critical low flow periods where dilution and assimilative capacity is at its lowest. A broad suite of water quality parameters were monitored including *in situ* measurements, inorganics, nutrients, total and dissolved metals, coliforms, and organics (resin and fatty acids, phenolic material, chlorinated phenolics, priority pollutants, total recoverable hydrocarbons, alkylated polycyclic hydrocarbons, naphthenic acids, and pesticides). Discharge was either measured or calculated at each sampling location on each sampling event, and was used to calculate in-stream loads.

Aspects of the water quality analysis included:

- A longitudinal assessment of water quality to evaluate spatial patterns along the Athabasca River;
- Mass loading calculations to determine the relative contribution of tributary and wastewater inputs to the Athabasca River;
- Comparison of water quality data to previous synoptic surveys conducted in the Athabasca River during the winters of 1990-1993; and
- A comparison of each parameter to existing surface water quality guidelines.

Results illustrated how spatial water quality patterns in the Athabasca River is influenced by natural transitions in the landscape, special landscape features, inputs from tributaries, and inputs from treated wastewater.

- The transition from the Rocky Mountains to the Boreal Forest resulted in a natural enrichment in colour, potassium, sodium, phosphorus, nitrogen, organic carbon, total metals (antimony, boron, barium, cadmium, mercury, lithium, strontium), and dissolved metals (antimony, arsenic, boron, barium, cadmium, cobalt, copper, iron, lithium, nickel, titanium, and vanadium).
- Data comparisons between the 2015 and 1990-1993 surveys indicated that most parameters had similar concentration ranges and spatial patterns. Exceptions to this generalization include potassium, total nitrogen, and total arsenic that had higher levels in 2015 within the Lower

Athabasca compared to previous surveys. Total aluminum concentrations in 2015 were also higher than the previous surveys along the length of the Athabasca River.

- Notable increases in major ions (calcium, magnesium, fluoride, and sulphate), dissolved solids, suspended solids, total phosphorous, and many total and dissolved metals occurred upstream of Hinton. This is likely due to the influence of Brule Lake and surrounding sand dunes, which creates a larger surface area that is in contact with finer river bottom sediments allowing for greater dissolution.
- Data collected during the survey also showed increased turbidity, suspended solids, and some nutrients and metals upstream of the Freeman River, near Fort Assiniboine.
- The Clearwater River had the largest influence on water quality in the Athabasca River and can cause an increase in concentrations of some variables (e.g., sodium, chloride, sulphate, total nitrogen, iron, and manganese), or have a diluting effect and lower the concentration of others (e.g., calcium, magnesium, potassium, bicarbonate, antimony, barium, cadmium, copper, molybdenum, strontium, and uranium).
- Greater impacts from treated wastewater were observed downstream of Hinton and Whitecourt, indicating that the headwater and upper reaches of the Athabasca River are more sensitive to treated wastewater and have lower assimilative capacity compared to reaches further downstream.
- During the 2015 survey, colour and total phosphorous were affected by pulp mill wastewater to the extent that they resulted in an exceedance of an Alberta or Canada SWQG directly downstream.
- Discharge from secondarily-treated pulp mill and municipal effluent are still causing localized issues of nutrient enrichment below wastewater outfalls in the Athabasca River.
- Tributary and wastewater inputs cumulatively contribute to a decline in dissolved oxygen during winter along the length of the Athabasca River. Dissolved oxygen concentrations in the Pembina and Muskeg rivers were below the short-term surface water quality guideline, and dissolved oxygen levels in the Firebag River were below the long-term surface water quality guideline.
- Treated wastewater resulted in increases in bacteria, major ions (bicarbonate, chloride, potassium, sodium, sulphate, sulphide, total dissolved solids), nutrients (ammonia, dissolved phosphorous, ortho-phosphate, total phosphorous, total nitrogen), adsorbable organic halides, colour, and temperature at one or more locations in the Athabasca River. These results were similar to observations made during the 1990-1993 surveys, indicating water quality has not changed significantly over the past 25 years.
- Metals (total and dissolved) displayed four general patterns in water quality: a) high association with suspended solids, b) an increase in concentrations from upstream to downstream, c) a decrease in concentrations from upstream to downstream, and d) a detectable increase downstream of treated wastewater.
- Inputs from treated wastewater at one or more locations along the Athabasca River resulted in a downstream increase in: dissolved aluminum, total barium, total and dissolved boron, total and dissolved cadmium, dissolved cobalt, dissolved manganese, dissolved tin, dissolved vanadium, and dissolved zinc.

- Although metal concentrations were below guideline levels in the ambient environment, metals in wastewater were high and at least one facility exceeded surface water quality guideline levels for dissolved aluminum, total cadmium, total chromium, total cobalt, total copper, dissolved iron, total lead, total mercury, total selenium, total silver, and total zinc.
- Total metal concentrations and hydrocarbons were high in municipal wastewater, especially Whitecourt STP.
- Low levels of organic compounds were detected in the Athabasca River, although there were detections of some priority pollutants in wastewater.
- The previous surveys recorded large effects from phenols, chlorinated phenols, resin acids, and trace organics that were not observed during the 2015 survey, indicating an improvement in water quality conditions owing to advancements in technology and wastewater treatment processes within the pulp and paper industry.

The results and conclusions in this report only reflect winter conditions and the influence of point-source contributions (wastewater and tributaries) to the Athabasca River. Additional surveys during the open-water season would be required to determine season longitudinal water quality patterns and the cumulative effects of both point-and non-point-source pollution.

ABBREVIATIONS

AEP	Alberta Environment and Parks
AER	Alberta Energy Regulator
ALPAC	Alberta-Pacific Forest Industries
ANC	Alberta Newsprint Company
AOX	Adsorbable organic halides
BOD	Biological oxygen demand
CCME	Canadian Council of Ministers of the Environment
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DTPA	Diethylene triamine penta acetic acid
EDTA	Ethylene diamine tetra acetic acide
HCE	Hinton combined effluent
LAR	Lower Athabasca Region
LTRN	Long-term river network
MAD	Mean annual discharge
MDL	Method detection limit
MTRN	Medium-term river network
NFR	Non-filterable residue
NRBS	Northern River Basin Study
NREI	Northern River Ecosystem Initiative
NTU	Nephelometric turbidity units
NWT	Northwest Territories
OSM	Oil sands monitoring
OSPW	Oil sands process water
PAD	Peace-Athabasca Delta
QA/QC	Quality assurance / quality control
RU	Relative units, for colour
SLP	Slave Lake Pulp Corporation
SOD	Sediment oxygen demand
STP	Sewage treatment plant
TDP	Total dissolved phosphorus
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
UAR	Upper Athabasca Region
UNESCO	United Nations Educational, Scientific, and Cultural Organization

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ACKNOWLEDGEMENTS

It is not an easy feat to chase a parcel of water down a river like the Athabasca, let alone in the middle of winter. AEP field staffs (John Willis, Brian Jackson, Chris Ware, Jessica Di Maria, Sarah Hustins, Trina Ball, Mike Bilyk, Monica Polutranko, Rick Pickering, Doug Rennie, Vien Lam, and Jon Goetz) are recognized for enthusiastically delivering a successful program, especially Shelley Manchur whom played a lead role in organizing monitoring logistics. Upper Athabasca Region compliance staffs (Nicole Pysh, Allan Undershultz, Maxwell Harrison, Tricia Coates, April Franks, Owen Butz, and Bruce Lange are appreciated for collecting industrial and municipal effluent samples. German Rojas calculated time of travel and provided hydrological and elevation data. Ahmad Asnaashari also provided hydrological data. Scott Neis provided GIS support and calculated distance downstream. Curtis Brock, Colin Cooke, and Nathan Ballard provided initial support with program design and field delivery. Review comments on a draft of this report were appreciated and provided by Richard Casey, Nathan Ballard, Claire Classen, Natalie Kromrey, and Alina Wolanski.

1. Introduction

The Athabasca River

The Athabasca River flows about 1,400 km from headwaters in Jasper National Park to its terminus at Lake Athabasca in north-eastern Alberta (Figure 1). The river gradient in the watershed changes dramatically from headwaters to Lake Athabasca, dropping approximately 1,200 m (Figure 2). Over 90 tributaries (Strahler stream order >4) drain into the Athabasca River, with main contributions of water from the Clearwater (mean annual discharge (MAD) = 120 m^3/s), Lesser Slave (MAD = 82 m^3/s), McLeod (MAD = 68 m^3/s), Pembina (MAD = 64 m^3/s), Berland (MAD = 49 m^3/s), Firebag (MAD = 34 m^3/s), and La Biche (MAD = 21 m^3/s) rivers.

The surface water quality and ecology of the Athabasca River is diverse as a result of the river's gradual traverse over three major natural regions: the Rocky Mountains, Foothills, and Boreal Forest. Headwaters are typical of a montane environment with high velocity, steep gradient (90 cm/km near Jasper), gravel/cobble substrate, and surface water that is cold, hard, alkaline, and low in organic content and nutrient (Noton & Saffran, 1995; Lyons & MacLock, 1996; Glozier, 2004). As the river travels northeast through the Foothills and Boreal Forest, river slope gradually decreases to approximately 40 cm/km at Athabasca and <20 cm/km near Fort McMurray (Figure 2). As a result of decreasing slope and velocity, the river bed becomes more dominated by sand and silt substrates. Water quality naturally increases in colour, organic carbon, iron, manganese, sodium, chloride, silica, and nutrients owing to landscape changes and tributary inputs (Noton & Saffran, 1995).

Changes in the physical environment (landscape, prevalence of forest and wetlands, geology, gradient, substrate, flow, water quality) along the length of the Athabasca River increases the variety of available habitat and therefore biodiversity as niche organisms respond to heterogeneity along the river. The Athabasca River located within Jasper National Park is designated as a Canadian Heritage River for its outstanding natural and cultural values and recreational opportunities (Parks Canada, 2008). Flow from the Athabasca River contributes to the globally significant Peace-Athabasca Delta (PAD). The PAD is one of the largest boreal deltas in the world and designated as a Wetland of International Significance (Ramsar Convention on Wetlands) and United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage Site for its ecological, historical, and cultural significance. Although the Athabasca River provides rich habitat, stressors within the basin have threatened populations of native Athabasca rainbow trout, bull trout, and Arctic grayling (Alberta Sustainable Resource Development, 2012; Alberta Athabasca Trout Recovery Team, 2014; Alberta Environment and Parks, In Preparation).

Water Quality Pressures

Supporting a diverse economy, the Athabasca River basin is under increasing pressure from industrial development, population growth, and climate change that influence water quantity, quality, and associated ecological integrity. The Athabasca River receives point-source of municipal and pulp mill treated wastewater (Figure 1), as well as non-point source pollution from landscape activities such as agriculture, timber harvesting, mining (aggregate, coal, oil sands, peat), oil and gas activities (conventional, *in situ* production, hydraulic fracturing), and recreation and tourism that cumulatively impact water quality.

Headwaters (Jasper to Hinton)

Attracting over 2 million visitors per year, tourism and recreation are the main economic drivers in the headwaters of the Athabasca River. Nutrient enrichment has been the primary concern for water quality, although upgrades to the Jasper Sewage Treatment Plant in 2003 substantially reduced nutrient loading and fecal contamination, improving the overall aquatic ecological integrity of the river (Parks Canada, 2011). The Athabasca River is in close proximity to the Yellowhead Highway and the use of road salts and spills of pollutants from motor vehicle accidents directly impact water quality (Parks Canada, 2011). State of the Park Reporting indicates that water quality is good and improving, although there is some evidence of recent deterioration owing to blooms of the invasive algae *Didymosphenia geminata* (Parks Canada, 2008).

Upper Athabasca (Hinton to Grand Rapids)

As the rivers leaves the park, the mountains give way to foothills that are underlain with rich coal deposits. Most metallurgical and thermal coal mining occurs in the McLeod sub-watershed near Hinton, except Obed Mine located in the Upper Athabasca sub-watershed. Coal production has remained relatively stable over the past five years, although some expansion projects (e.g. Rob Trend and Vista mine) have been approved for the region (Alberta Energy, 2014). Metallurgical coal mining has resulted in wide-spread selenium (Se) loading to surface waters in the upper McLeod watershed, resulting in high fish tissue concentrations and teratogenic deformities from the deposition of Se into fish eggs (Palace, et al., 2004; Casey, 2005; Holm, et al., 2005; Kuchapski & Rasmussen, 2015).

Continuing east, agricultural development increases and is concentrated in the middle reaches of the Athabasca River basin, primarily in the lower McLeod, Pembina, Lesser Slave, and La Biche sub-basins[1]. Diffuse sources of contamination from agriculture that can impact water quality of the Athabasca River include pesticides, herbicides, and nutrients. Although loading of non-point source pollution to the Athabasca River is not well documented, elevated nutrient levels in the Pembina (Noton, 1996), South Heart (HESL, 2015), and La Biche (Schindler, et al., 2008) rivers are likely associated with agricultural activity.

Forestry is the primary economic sector in the Upper Athabasca Region (UAR), with 12 Forest Management Areas (FMAs) that cover 49% of the region (Forcorp Solutions, 2012). Commercial timber harvesting began in 1955, rapidly expanded in the 1980's, and has been steadily increasing since then (Forcorp Solutions, 2012). Expansion of the forest industry in the 1980's fuelled the pulp and paper industry, leading to the addition of four pulp mills in the region: Millar Western (1988), Alberta Newsprint Company (1990), Slave Lake Pulp Corporation (1991), and Alberta-Pacific Forest Industries (1993). West Fraser Mills (Hinton) has been operating since 1957, and doubled its capacity in 1990 (Lyons & MacLock, 1996; MacLock & Thompson, 1996).

[1] See http://awcatlas.athabascau.ca/ for interactive map of the basin

Industrial growth of the forest sector prompted Alberta Environment to conduct intensive spatial water quality studies in the Athabasca River, collecting samples from Hinton to Lake Athabasca during the winters (low flow conditions) of 1990-1993 (Noton & Saffran, 1995). Results indicated that effluent discharge from pulp mills caused marked increases in colour, odour, phosphorus, and phenolic compounds. These early studies also revealed that pulp mill effluent caused increases in major ions, biological oxygen demand (BOD), dissolved organic carbon, tannins and lignins, adsorbable organic halides, chlorophenolics, and resin acids (Noton & Saffran, 1995).

Expansion of the pulp and paper industry and plans for increasing oil sands operations in the lower reaches raised concerns over the cumulative effects that developments within the basin (as well as the Peace and Slave rivers) would have on water quality. In response, the governments of Canada, Alberta, and Northwest Territories initiated the Northern River Basins Study (NRBS, 1992-1996). The NRBS comprised of over 150 research projects designed to address the ecological concern regarding pulp mill expansion, and to increase scientific knowledge of Alberta's northern rivers. The NRBS identified several issues of concern in the Athabasca River including low dissolved oxygen levels, nutrient enrichment, and contaminants which had potential human health implications via fish consumption and drinking water.

Research showed that dissolved oxygen in the Athabasca River displayed a gradual linear decline along the length of the river until Grand Rapids, which reaerates dissolved oxygen levels. The reach downstream of the town of Athabasca to upstream of Grand Rapids was identified as a concern due to the natural decline in dissolved oxygen levels that is exacerbated by high sediment oxygen demand and cumulative biological oxygen demand (BOD) loading from industrial and municipal treated wastewater (Chambers & Mill, 1996; Chambers, et al., 1997; Martin, et al., 2013). Many reaches along the Athabasca River were identified as having excessive levels of nutrients, particularly downstream of Jasper, Hinton, Whitecourt, Athabasca, and Fort McMurray (Chambers, 1996). The presence of contaminants such as dioxins, furans, polychlorinated biphenyls, chlorinated resin acids, chlorophenols, mercury, and polycyclic aromatic hydrocarbons in fish and sediment below Hinton, Whitecourt, and Fort McMurray also raised concern during the study.

Issues and concerns identified during the NRBS led to numerous recommendations that were addressed with the Northern Rivers Ecosystem Initiative (NREI, 1998 to 2003). The NREI found that dioxins and furans were no longer detectable in surface water owing to changes the pulp industry made in the bleaching process. Although trace amounts were found in fish and sediment downstream of Hinton, indicating there is a potential legacy of historic contamination. While the NREI contributed information to the issues of low dissolved oxygen and nutrient enrichment, they remain water quality issues in the upper Athabasca River basin (Chambers, et al., 2006).

Lower Athabasca (Grand Rapids to Lake Athabasca)

Alberta's oil sands have the third largest oil reserves in the world (166 billion barrels of bitumen),[2] most of which are located in the Lower Athabasca Region (LAR). The first oil sands operation began in 1967 with Suncor Energy, and Syncrude became the second major oil sands producer in 1978[3]. Since then the

[2] http://www.energy.alberta.ca/OilSands/791.asp
[3] www.iosi.ualberta.ca/en/OilSands.aspx

oil sands industry has grown rapidly, and as of 2014, total oil sands production reached about 2.3 million barrels per day[2]. As part of the extraction process, vast amounts of oil sands process water (OSPW) are produced and stored in large lakes and holding ponds. For the most part, oil sands operations are not authorized to discharge wastewater into the Athabasca River, except Suncor and Syncrude. Suncor discharges oil sands upgrading process wastewater and mine drainage after treatment, and Syncrude discharges treated sewage from its camp into the Athabasca River (Figure 1).

Oil sands process water contains several inorganic and organic constituents that are acutely toxic to aquatic life, including salinity, sulphate, ammonia, conductivity, and naphthenic acids (Allen, 2008). Naphthenic acids are thought to be a significant contributor to the toxicity of OSPW water (Rogers, et al., 2002; Clemente & Fedorak, 2005; Scarlett, et al., 2013), and while these waters are not directly released into the environment, seepage through tailings ponds impacts groundwater and surface water (Frank, et al., 2014). Additionally, oil sands operations contribute airborne particulates including polycyclic aromatic compounds and heavy metals that reach the river during spring snowmelt and storm events (Kelly, et al., 2009; Kelly, et al., 2010). Analysis of long-term monitoring data have revealed increases in dissolved sodium, chloride, sulphate, and dissolved nitrogen since oil sands development (Squires, et al., 2010; Dube & Wilson, 2012).

Urbanization and Population Growth

Densely populated urban areas can have a major influence on water quality through point-source releases of municipal wastewater and storm water, and changes in water run-off patterns that result from impervious surfaces. The Athabasca River basin supports more than 250,000 residents (estimated from Municipal Affairs, 2014), which has increased from a population estimate of 154,097 in 2001[4]. Fort McMurray experienced a growth rate of approximately 100% from 1999 to 2008, and Edson grew by 16% from 2000 to 2009 (Hatfield, 2011).

Numerous communities are situated within the basin and along the river. Major communities, including the municipalities of Jasper (population: 4,584) and Wood Buffalo (population: 116,407, including shadow population), and the towns of Hinton (population: 9,640), Whitecourt (population: 10,574), and Athabasca (population: 2,990), discharge municipal wastewater directly into the Athabasca River (Municipal Affairs, 2014). Municipal wastewater contains a variety of constituents such as suspended and dissolved substances that can exert a biochemical oxygen demand, nutrients, pathogens, metals, oil and grease, organic chemicals, and a wide range of emerging contaminants[5] (Chambers, et al., 1997).

Project Scope and Objectives

These increasing pressures on water quality coupled with climate change highlight the importance of assessing cumulative effects on large space and time scales. Such evaluations are necessary to determine if changes in water quality can be attributed to natural phenomena or anthropogenic activities, which is especially important for regulatory agencies that are mandated to manage human-induced stress to the aquatic environment (e.g., municipal and industrial treated wastewater and land

[4] http://albertawater.com/hydrological-modelling-of-alberta/water-availability/athabasca-river-basin

[5] http://www.ccme.ca/files/Resources/municipal_wastewater_efflent/mwwe_general_backgrounder_e.pdf

use activities). Alberta is committed to managing cumulative effects of land use activities on water quality through the development of surface water quality management frameworks (SWQMF) that contain legislated water quality triggers and limits to maintain and improve aquatic ecosystems.[6] Development of scientifically robust and defensible SWQMFs requires a comprehensive understanding of spatial and temporal water quality patterns within a large river system.

Current Alberta Environment and Parks (AEP) water quality monitoring programs within the Athabasca River basin include long-term and shorter term river monitoring stations where water quality samples are collected monthly or less frequently. Other water quality monitoring programs in the basin also include environmental effects monitoring at the pulp mills and more intensive monitoring in the lower Athabasca River as part of the Oilsands Monitoring Program (OSM). While these data are useful, they do not provide a detailed assessment of spatial water quality patterns or cumulative impacts associated with regulated point-source discharges. To address this data gap, AEP conducted a winter synoptic survey in 2015.

For some compounds, the potential impact of effluent discharge on water quality is greatest during winter owing to low flow conditions. Similar to previous synoptic surveys on the Athabasca River (Noton & Saffran, 1995), the 2015 project was conducted during critical low flow periods (January/February) where dilution and assimilative capacity are low. In addition, ice-cover eliminates the confounding influence of non-point source pollution and surface runoff.

The intent of this report is to:

- Evaluate winter spatial patterns in water quality along the length of the Athabasca River;
- Assess the cumulative effects of industrial and municipal point-source discharges on the Athabasca River during winter low flow, while considering contributions from major tributaries;
- Compare current water quality conditions in the Athabasca River to data collected during previous winter synoptic surveys; and
- Compare relevant parameters to existing water quality guidelines.

[6] https://landuse.alberta.ca/CumulativeEffects/EnvronmentalMgmtFrameworks/Pages/default.aspx

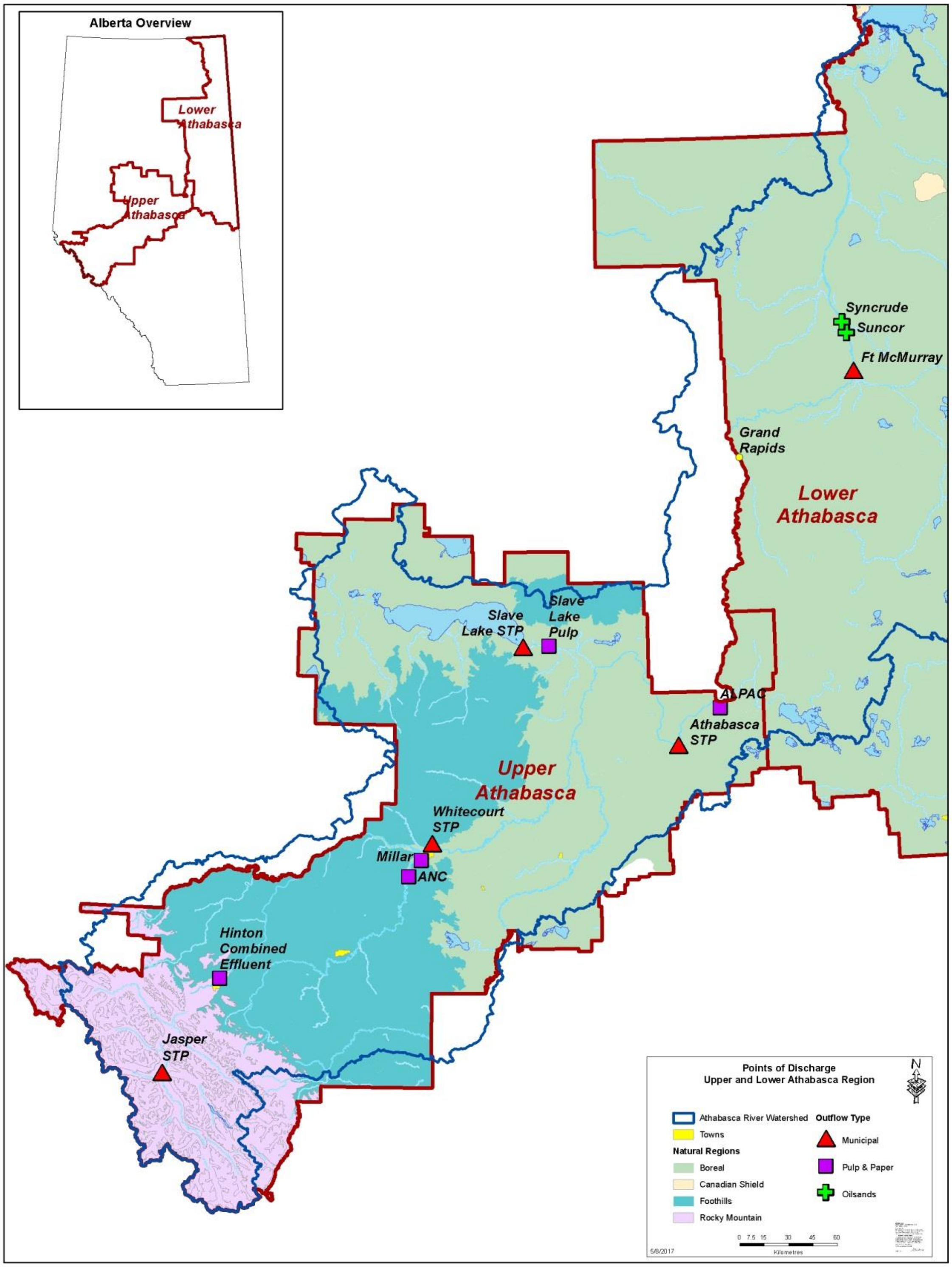


Figure 1. Map of the Athabasca River Basin, including municipal and industrial point-source effluent discharge locations.

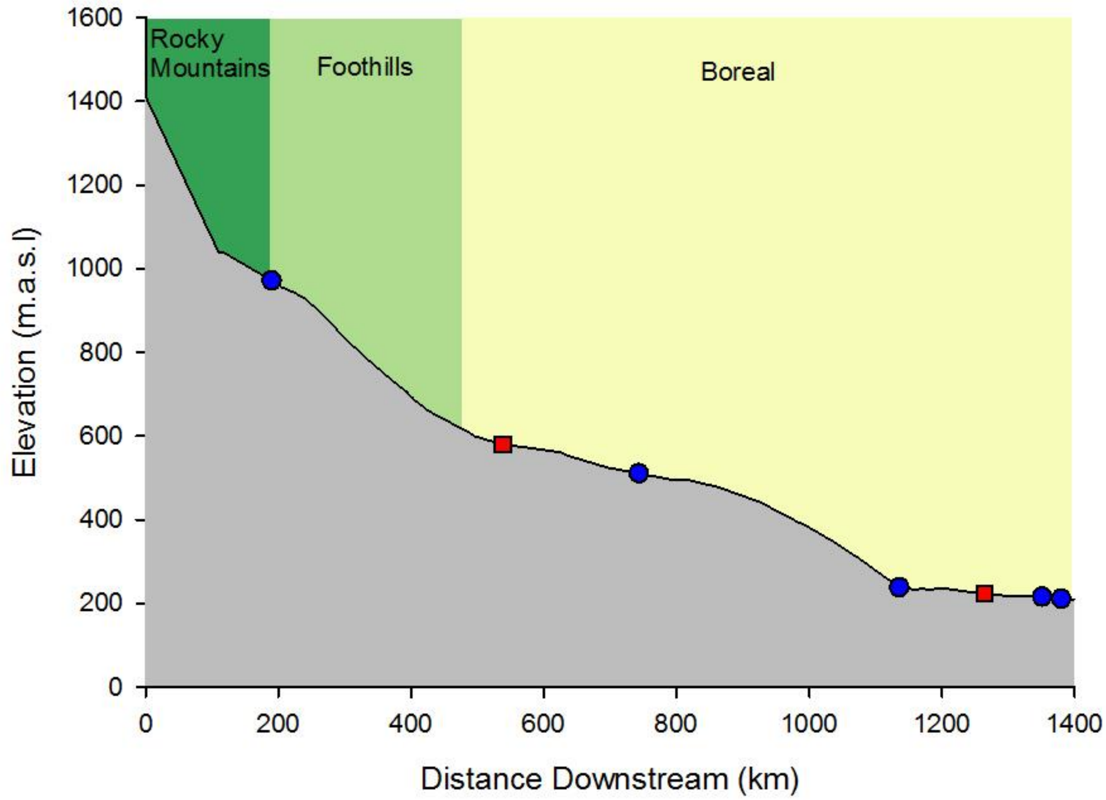


Figure 2. Elevation profile of the Athabasca River, with the general location of major natural regions. Blue circles represent location of long-term river network monitoring stations and red circles are medium-term river network monitoring stations. Data extracted from ArcGIS DEM by German Rojas.

2. Methods

A synoptic survey is a comprehensive spatial survey that aims to sample the same 'parcel' of water as it flows downstream in a river basin. This provides an understanding of the impact that individual and multiple point-sources of pollution and tributary inputs have on surface water quality in the river basin. During the 2015 synoptic survey, Alberta Environment and Parks (AEP) collected water quality samples along the Athabasca River from upstream of the town of Jasper and progressed downstream at approximately the river's time of travel to Lake Athabasca.

Study Design, Sites, and Sampling Schedule

AEP conducted four previous synoptic surveys on the Athabasca River during the winters of 1989-1993 (Noton & Saffran, 1995; Noton & Shaw, 1989). Each of these studies involved sampling sites from the mainstem, major tributaries, and effluent sources along the Athabasca River at the approximate time of travel, from upstream of Hinton to Lake Athabasca. The sample design of the 2015 synoptic survey was based on the previous surveys (i.e., Noton & Saffran, 1995).

The 2015 survey began upstream of the town of Jasper and included 43 mainstem sample sites in the Athabasca River, 25 tributaries, and 12 municipal and industrial effluent sources (Figure 3, see full list in Appendix A). The House, Tar, and Muskeg rivers were not sampled because of limited or no apparent flow at the time of the survey.

Field sampling began on January 22, 2015 and ended on February 13, 2015. The sampling schedule followed the estimated time-of-travel as close as possible as safety, weather, logistics, and other considerations allowed.

Sample locations, station codes, sample dates and times, and estimated river distance are provided in Appendix A.

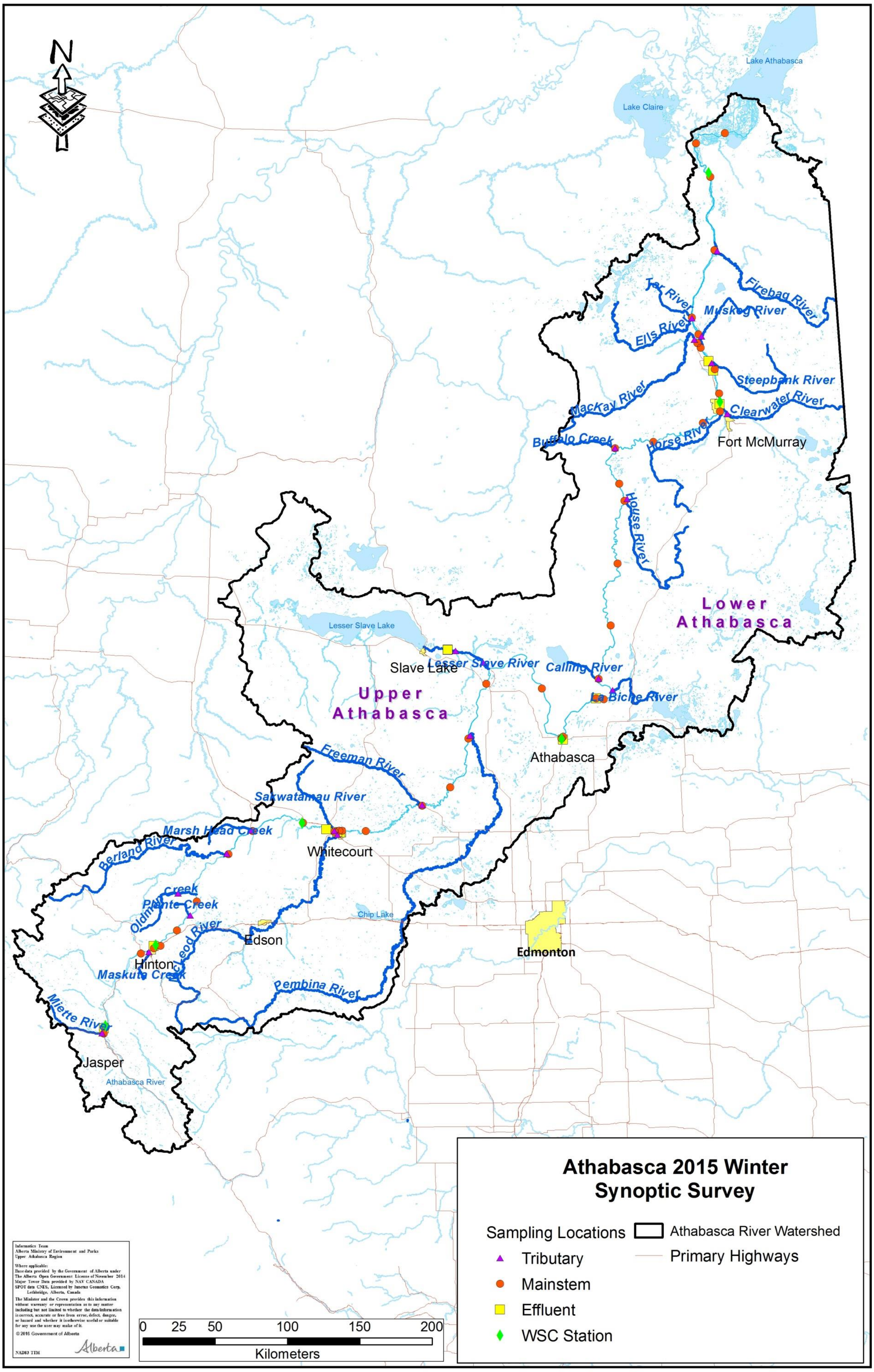


Figure 3. Sampling locations in the Athabasca River basin during the 2015 winter synoptic survey including the mainstem, tributaries, and treated wastewater sources.

River Network and Oil Sands Monitoring Sites

Where possible, monitoring sites were sampled in concert with current monitoring programs to enhance field efficiency, alleviate cost (both analytical and logistical), and improve overall datasets.

There are currently four long-term river network (LTRN) and two medium-term network sites (MTRN) on the Athabasca River that are operated by AEP (Table 1). The Oil Sands Monitoring (OSM) program monitors surface water quality to detect change and predict effects from Alberta's oil sands operations within the Lower Athabasca Region. Sites listed in Table 1 were sampled during the synoptic survey.

Table 1. Current long-term and medium-term monitoring networks and oilsands monitoring stations on the Athabasca River that were sampled during the 2015 winter synoptic survey.

Program	Station Code	Description	Sample Frequency	Data Availability
LTRN	AB07AD0100	Old Entrance town site	Monthly	2003
LTRN	AB07AD0110	Town of Athabasca	Monthly	1987*
LTRN	AB07CC0030	Upstream of Fort McMurray	Monthly	1985*
LTRN	AB07DD0010	Old Fort	Monthly summer	1987*
LTRN	AB07DD0105	Devil's Elbow	Monthly winter	1997
MTRN	AB07BD0010	Vega Ferry	Bi-monthly	2013
MTRN	AB07DA0980	Upstream of Firebag River	Bi-monthly	1989
MTRN	AB07BK0125	Lesser Slave River 9.5 km u/s confluence	Bi-monthly	1996**
OSM	AB07DA0065	6.5 km below WSC Gauge 07DA001	Monthly	2012
OSM	AB07DA0415	Above Muskeg River	Monthly	2012
OSM	AB07DA0650	Above MacKay River	Monthly	2012
OSM	AB07DA0690	Below MacKay River	Monthly	2012
OSM	AB07DA0800	Below Ells River	Monthly	2012
OSM	AB07DD0040	At Embarras Airport	Monthly	2012*

*Historic data collected by Environment Canada available
**Temporal gaps exist

Estimating River Travel Time in the Athabasca River under Ice Covered Conditions

Time of travel estimations were based on the dye study "Low Flow Winter Travel Time Characteristics of the Athabasca River, Hinton to Athabasca" (Andres, et al., 1989). This study used a hydraulic approach based on the Manning's equation which indicates that flow velocity (v) is a function of the channel roughness (n), flow cross section area (A), flow wetted perimeter (P) and bed slope (S), where R is the hydraulic radius (Equation 1).

$$v = \frac{1}{n}\left(\frac{A}{P}\right)^{\frac{2}{3}}(S)^{\frac{1}{2}} = \frac{1}{n}(R)^{\frac{2}{3}}(S)^{\frac{1}{2}} \qquad \text{(Equation 1)}$$

Discharge (Q) was calculated as the product of velocity (*v*) and area (A) in cross-section.

$$Q = A * v \qquad \text{(Equation 2)}$$

Equations 1 and 2 yield equation 3:

$$v = \left(\frac{Q}{2b}\right)^{0.4} \left(\frac{S^{0.5}}{n_o}\right)^{0.6} \qquad \text{(Equation 3)}$$

Andres et al. (1989) considered the roughness of the ice covered surface as part of a combined roughness coefficient (n_o) which also included walls and bed channel roughness.

Once velocity measurements and channel characteristics (*A, P* and *S*) were obtained, Equation 3 was used to estimate the combined roughness coefficient (n_o). For the 2015 synoptic study, Equation 3 was initially applied at Water Survey of Canada (WSC) station locations using the following data:

- mean flow for the last three weeks of January using historic data;
- channel width (b) and Slope (S) were estimated using ArcGIS; and
- the combined roughness coefficients (n_o) estimated in the 1989 study were also used.

Travel times for ungauged sites, located between any two given WSC stations, were estimated based on a continuous change in mean discharge and the distance along the river main channel. Channel characteristics for the reaches upstream of Hinton and downstream of Athabasca were estimated using nearby combined roughness coefficients (n_o).

Field Methods

Sample sites were accessed by vehicle, snowmobile, or helicopter. Since the river was frozen, an electric auger was used to drill holes through the ice and grab samples were generally collected in the channel centre following methods described in Alberta Environment (2006). In areas that were not completely frozen, samples were collected from open leads using proper safety protocol.

Temperature, pH, specific conductance, dissolved oxygen, and oxidation-reduction potential were measured *in situ* with field meters (HydroLab MS-5 Multiparameter Data Sonde). Water samples were collected for the analysis of major ions, nutrients, metals, bacteria, and various organic parameters (see Appendix A). Routine variables, including major ions and nutrients, were sent to Maxxam Analytics for analysis. Bacteria were analysed by the Provincial Laboratory for Public Health. Total and dissolved metals, chrlorophyll-*a*, and organic parameters including pesticides, hydrocarbons, alkylated polycyclic aromatic hydrocarbons, naphthenic acids, chlorate, and priority pollutants were analysed by Alberta Innovates Technology Futures Environmental Analytical Services. Chlorophenols and resin and fatty acids were analyzed by ALS Environmental. Mercury analysis was conducted by the University of Alberta Biogeochemical Analytical Service Laboratory.

Samples from industrial and municipal effluent were collected in an intermediate collecting vessel that was acid-washed prior to use, following standard procedures (Alberta Environment, 2006). Effluent sampling equipment was kept separate from river equipment. Discharge measurements were obtained from each facility as part of their monitoring requirements in their approval to operate.

Duplicates, field blanks, and trip blanks were collected periodically for quality assurance at a frequency of 1/10 (i.e., 1 QA/QC sample for every 10 samples), as recommended and described by Alberta Environment (2006).

At all tributary locations, velocity was measured using a Price-type current meter following standard methods (Water Survey of Canada, 1999). Depth and relative width were also recorded to determine cross-sectional area. For sites with a vertical depth less that one metre, measured from the bottom of the river ice, velocity measurements were recorded at 0.5 (half) of the river depth and multiplied by a 0.88 coefficient. For sites that had a depth greater than one metre, stream velocity measurements were measured at 0.2 and 0.8 depths and averaged (Water Survey of Canada, 1999). Where river width permitted, 20 measurements were collected.

Data Analysis

Data are organized from upstream to downstream. The figure below shows an example of how data are organized and provides a spatial legend for orientation (Figure 4). Effluent concentrations are often much greater than recorded in the ambient environment and are plotted on a second y-axis.

Measurements that were less than the laboratory analytical detection limit were replaced by one half of the detection limit before presenting in graphs. Surface water quality was evaluated by comparing it to the Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life (Alberta SWQG) and the Canadian Water Quality Guidelines for the Protection of Aquatic Life set by the Canadian Council of Ministers of the Environment (CCME).

Where data is available, comparisons are made between the 2015 and 1990-1993 surveys. In some cases, data were analyzed using different analytical techniques and the method detection limits are not always similar. This is particularly the case for metals that were analyzed by atomic absorption with solvent extraction in 1990-1993 and by inductively coupled plasma mass spectrometry in 2015. Comparisons of total metals show broad similarities and differences in spatial patterns, but often the method detection limit varies between the two datasets.

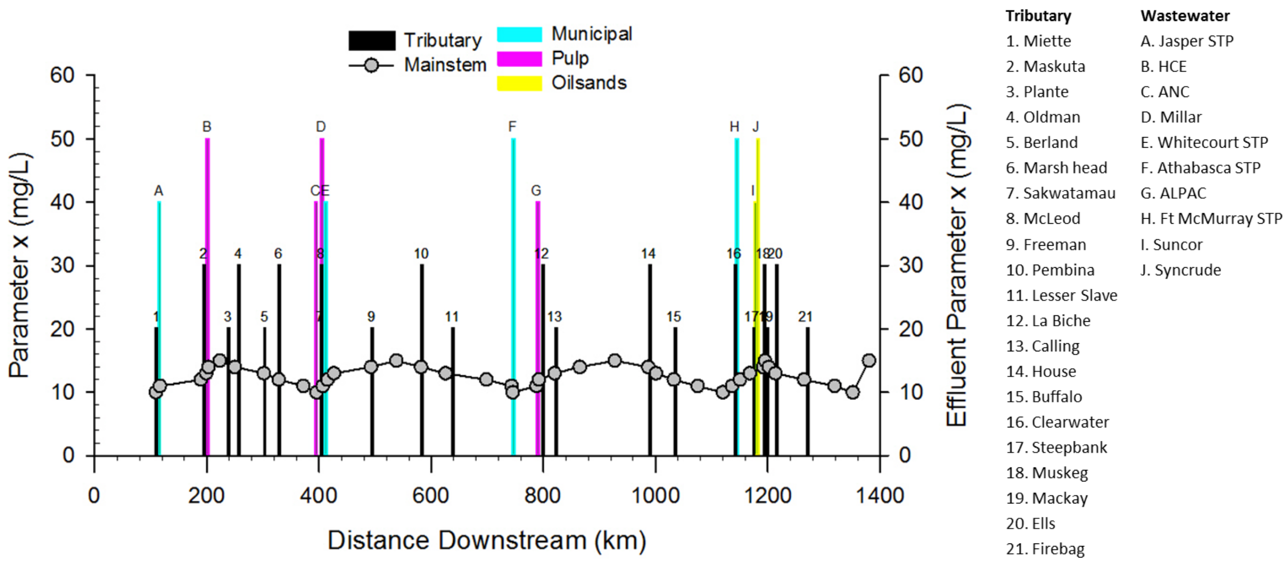


Figure 4. Relative location of sample sites with labels for the main tributaries and treated wastewater.

Load Calculations

Mass flux or load calculations were calculated as the product of instantaneous discharge and concentration and are expressed as kg/day or g/day, following the equations below. Calculations assume uniform concentrations across the channel and are only representative of conditions encountered during the survey (i.e., not average annual conditions). Loads were not calculated for values that were below the detection limit. Load calculation are presented in Appendix B.

$$Q\left(\frac{m^3}{day}\right) = Q\left(\frac{m^3}{s}\right) x\ 60\ \left(\frac{s}{\min}\right) x\ 60\left(\frac{min}{hr}\right) x\ 24\ (\frac{hr}{day})$$

$$Load\ \left(\frac{kg}{day}\right) = concentraion\left(\frac{mg}{L}\right)\ x\ \left(\frac{1g}{1000\text{mg}}\right) x\left(\frac{1kg}{1000g}\right) x\ \left(\frac{1000L}{m^3}\right) x\ Q\ (\frac{m^3}{day})$$

3. Hydrology

The Athabasca River is unregulated by dams and the average annual hydrograph reflects prevailing climatic conditions. Peak flows typically occur in the spring following winter snowmelt, and lowest flows occur during winter months (Figure 5). During the survey, much of the Athabasca River was ice-covered. Although, open-water leads were common in the upper half of the river owing to warmer air temperatures and groundwater recharge areas. Open-water leads occurred for several kilometers downstream of major treated wastewater locations.

Flow data measured during the survey in the Athabasca River and its tributaries are summarized in Table 2 and Table 3, respectively.

Table 2. Athabasca River flow measurements recorded at Water Survey of Canada (WSC) stations during the 2015 synoptic survey.

WSC Station	Station No.	Date Recorded	Flow (m^3/s)	Distance Downstream (km)
Jasper	07AA002	20-Jan-15	16.9	117
Hinton	07AD002	22-Jan-15	51.4	204
Windfall*	07AE001	27-Jan-15	63.3	332
Athabasca	07BE001	04-Feb-15	126.0	724
Fort McMurray	07DA001	09-Feb-15	157.0	1124
Embarras Airport	07DD001	12-Feb-15	191.2	1319
*field measurement				

Table 3. Tributary flow measurements recorded during the 2015 synoptic survey.

Date Recorded	Tributary	Flow (m^3/s)	Distance Downstream (km)
20-Jan	Miette River	1.4	110
22-Jan	Maskuta Creek	0.2	195
23-Jan	Plante Creek	0.3	238
23-Jan	Oldman Creek	1.4	256
25-Jan	Berland River	11.7	302
26-Jan	Marshhead Creek	0.4	328
27-Jan	Sakwatamau River	1.6	402
27-Jan	McLeod River	7.0	403
29-Jan	Freeman River	0.8	493
2-Feb	Pembina	4.7	582
2-Feb	Lesser Slave River	29.3	637
4-Feb	La Biche River	10.3	810
5-Feb	Calling River	1.4	820
8-Feb	House River	1.4	987
8-Feb	Buffalo Creek	0.03	1033
09-Feb	Horse River	0.0	1137
10-Feb	Clearwater River	48.2	1140
10-Feb	Steepbank River	1.3	1172
10-Feb	Muskeg River	0.4	1192
11-Feb	Mackay River	1.0	1196
11-Feb	Ells River	2.6	1213
11-Feb	Tar River	0.0	1215
12-Feb	Firebag River	16.3	1268

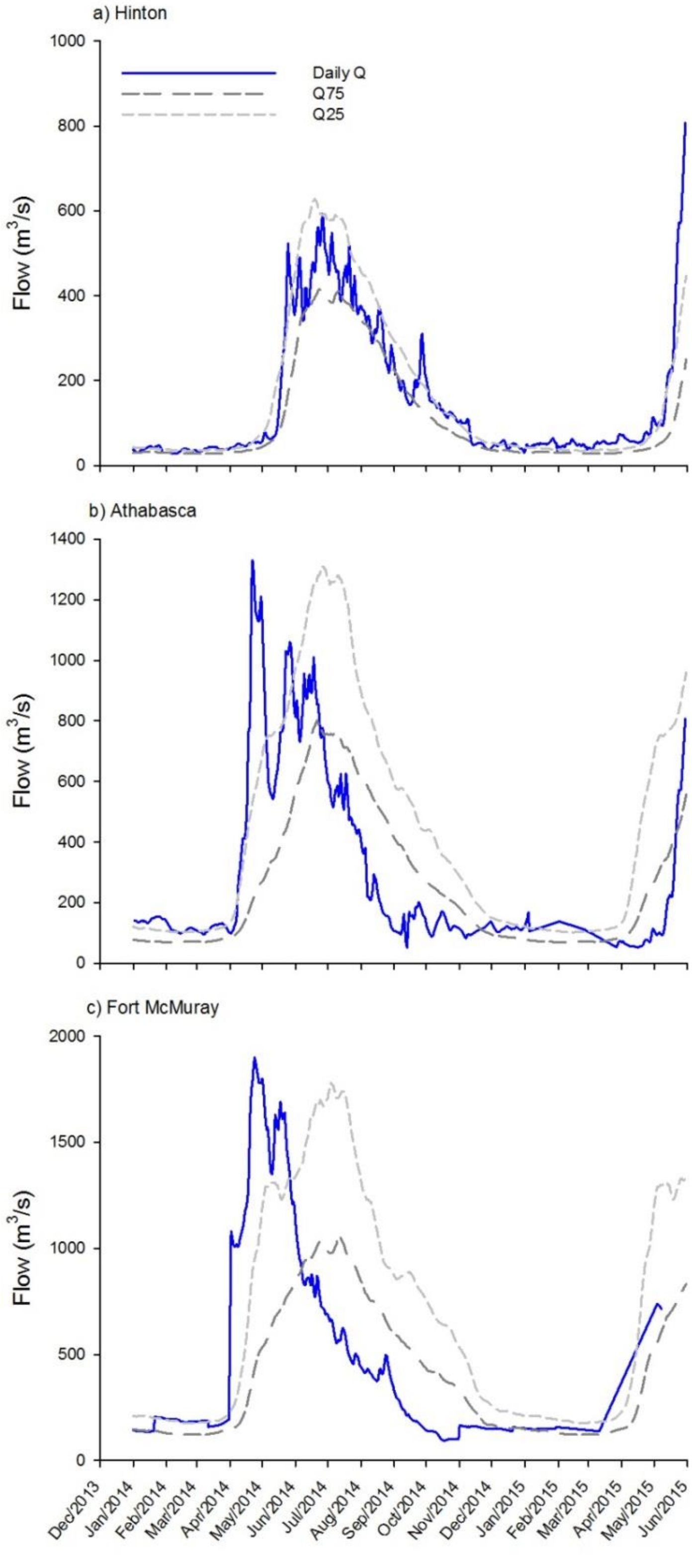


Figure 5. Mean daily discharge (Q; m^3/s) in the Athabasca River at a) Hinton, b) Athabasca, and c) below Fort McMurray for 2014-2015, and upper (Q25) and lower quartiles (Q75).

4. Wastewater Discharges

Both the Athabasca and Lesser Slave rivers receive treated wastewater from municipal and industrial sources, summarized in Table 4. Note that other tributaries in the basin receive municipal treated wastewater, but were outside the scope of this project and not sampled. The Athabasca River receives treated treated wastewater from four pulp mills, five municipalities, and two oilsands operations (Figure 1).The Lesser Slave River, a major tributary of the Athabasca River, receives treated treated wastewater from one pulp mill. Municipal discharge from the Town of Slave Lake reaches the Lesser Slave River via Sawridge Creek.

Table 4. Treated wastewater sources sampled in the 2015 survey.

Source	Acronym	Type	Treatment	Jan/Feb Discharge (m^3/day)	Distance Downstream (km)
Jasper	-	Municipal sewage	Tertiary - UV	3,798	115
Hinton Combined	HCE	Municipal sewage + bleached kraft pulp	Secondary	88,766	200
Alberta Newsprint Co.	ANC	Thermo-mechanical pulp	Secondary	15,969	393
Millar Western Pulp Ltd.	Millar	Bleached chemi-thermomechanical	Secondary	9,435	404
Town of Whitecourt	-	Municipal sewage	Secondary	3,694	407
Town of Athabasca	-	Municipal sewage	Secondary	598	745
Alberta Pacific Forest Ind.	ALPAC	Bleached kraft pulp	Secondary	79,562	788
Fort McMurray	-	Municipal sewage	Tertiary - biological	25,468	1142
Suncor Inc.	-	Oilsands upgrading process and wastewater	Secondary	165	1174
Syncrude Canada Ltd.	-	Domestic sewage from lower camp site	Secondary	626	1179
Town of Slave Lake	-	Municipal sewage	Secondary	2,586	-
Slave Lake Pulp Corp.	SLP	Bleached chemi-thermomechanical pulp	Secondary	10,523	-

5. Results and Discussion

Throughout the text, Alberta SWQG refers to Surface Water Quality Guidelines for the Protection of Aquatic Life outlined in the Environmental Quality Guidelines for Alberta Surface Waters (Alberta Environment & Sustainable Developement, 2014). Canada SWQG refers to Surface Water Quality Guidelines for the Protection of Aquatic Life as part of the Canadian Environmental Quality Guidelines set by the Canadian Council of Ministers of the Environment (CCME)[7].

Field Measurements

Water Temperature

Water temperature in the Athabasca River and its tributaries was generally near 0°C, ranging from -0.25 to 0.81°C during the survey (Figure 6). In general, surface water temperatures were warmer (above zero) in the Upper Athabasca and colder in the Lower Athabasca. Air temperatures were warm during the beginning of the survey (late January), and cooled as sampling progressed downstream (early February), which likely influenced surface water temperatures (Figure 7).

The heat content of rivers can be influenced by solar radiation, advection of heat from groundwater, inflowing tributaries, and effluent discharges. While the broad spatial pattern of surface water temperatures are governed by air temperatures (Figure 7), localized spikes and increases in water temperature are likely results of warmer wastewater and groundwater sources. Wastewater temperatures ranged from 0.18 to 30.8 °C. As a result of high heat inputs from treated wastewater, ice-free reaches were observed downstream of Hinton, ANC, Millar Western, Whitecourt STP, ALPAC, and SLP outfalls. Many open leads were observed in the Upper Athabasca during the survey as a result of treated wastewater and groundwater recharge zones, as well as warm temperatures.

Spatial patterns in surface water temperature during 2015 were similar to the 1990-1993 surveys (Figure 8), with the exception of an increase in temperature downstream of the Muskeg River during the 2015 survey. Data from all the synoptic surveys indicate that winter water temperature increases downstream of Hinton, Whitecourt, and Fort McMurray associated with open leads resulting from the discharge of treated wastewater.

Dissolved Oxygen (DO)

During the survey, dissolved oxygen (DO) concentrations in the Athabasca River ranged from 9.7 to 13.2 mg/L (Figure 9), and displayed a linear decline of 3.5 mg/L from headwaters (13.2 mg/L) to upstream of Grand Rapids (9.7 mg/L). Reaeration at Grand Rapids increased DO levels by approximately 3 mg/L, and DO levels gradually declined again reaching 10.5 mg/L at the end of the river. Dissolved oxygen levels were generally high in tributaries, except the Pembina (4.3 mg/L), Muskeg (1.3 mg/L), and Firebag (5.2 mg/L) rivers (Figure 9). Treated wastewater from pulp mill sources ranged from 1.8 mg/L (Millar) to 7.4 mg/L (HCE), municipal sources ranged from 6.0 mg/L (Jasper STP) to 10.6 mg/L (Athabasca STP), and treated wastewater from oilsands sources were greater than 10.0 mg/L (Figure 9).

[7] http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/

The spatial patterns of DO in 2015 were similar to 1990-1993 surveys (Figure 10). Data from all surveys indicate that the concentration of DO in the Athabasca River has a linear drop of about 0.5 mg/L every 100 km in winter conditions. Grand Rapids infuses the Athabasca River with DO, and this re-aeration increase dissolved oxygen levels between 3 to 4 mg/L. Dissolved oxygen levels decline more sharply after this reaeration point, with a linear drop of about 0.9 mg/L per 100 km. In 2015, DO levels were lower than previous years downstream of Grand Rapids to the end of the river.

The Alberta and Canada SWQG for DO is a minima of 6.5 mg/L for long-term and 5.0 mg/L for short-term. Dissolved oxygen levels in the Athabasca River were not below these guidelines during the 2015 survey. However, DO concentrations in the Pembina and Muskeg rivers were below the short-term guideline, and DO levels in the Firebag River were below the long-term guideline. Treated wastewater from ANC and ALPAC were slightly above the long-term guidelines (6.7 and 6.6 mg/L, respectively), Jasper STP, Whitecourt STP, and SLP were below the long-term guideline, and treated wastewater from Millar was below the short-term guideline (Figure 9).

pH

Measurements of pH during the survey indicate the Athabasca River is slightly basic, as pH ranged from 6.8 to 8.2 (Figure 11). The range of pH recorded in the tributaries and treated wastewater were similar to the Athabasca River: 7.0 to 8.4. Small changes in pH did not appear to be influenced by tributary or wastewater inputs, with the exception of a sharp decline in pH downstream of the Muskeg River, likely a result of more neutral inputs from tributaries and wastewater sources (Figure 11).

Spatial patterns in pH during the 2015 survey were more variable than the previous surveys, with several sites displaying a decline in pH that were not noted in the historical surveys (Figure 12). General spatial patterns of pH were similar in all surveys and displayed a small observational decline in pH from headwaters (average pH = 8.3) to the terminus of the river (average pH = 7.6).

The Alberta and Canada SWQG for pH is between 6.5 and 9.0. All of the samples collected during the 2015 survey (mainstem, tributaries, and wastewater) were within these guidelines.

Specific Conductivity

Specific conductivity in the Athabasca River was low in Jasper National Park, increased upstream of Hinton, and remained relatively constant along the length of the Athabasca River (range = 208 to 455 µS/cm), with the exception of drop in specific conductivity at the terminus of the river (Figure 13). There were small increases in specific conductivity downstream of HCE and Whitecourt. Specific conductivity measured in the tributaries were similar to the Athabasca River, with the exception of the Pembina (804 µS/cm), Steepbank (610 µS/cm), and Mackay (667 µS/cm) rivers (Figure 13). Treated wastewater had a high specific conductivity that ranged from 705 to 6536 µS/cm (Figure 13).

Specific conductivity measured during the 2015 survey was similar to historical surveys (Figure 14), although data from the 1990-1993 surveys did not show a drop in specific conductivity at the terminus of the river. Average specific conductivity measured at LTRN station Devil's Elbow from 2003-2014 was 385 µS/cm and ranged from 149 to 451 µS/cm, indicating the 2015 data point (225 µs/cm) is lower than average, but not out of range.

There are no provincial or federal SWQGs for specific conductivity.

Inorganic Constituents

Turbidity

Turbidity during the survey was relatively low in Jasper National Park and increased upstream of Hinton (Figure 15). Turbidity decreased through the Hinton-Berland reach, and increased in the vicinity of Whitecourt. A spike in turbidity occurred upstream of the Freeman River (493 km downstream), and then values remained between 1.6 and 3.7 NTU along the length of the river (Figure 15). Turbidity in the tributaries ranged from 0.3 to 16.0 NTU (Miette and House rivers, respectively; Figure 15). In general, turbidity was lower in tributaries located in the Upper Athabasca and higher in the Lower Athabasca tributaries. Turbidity in treated wastewater sources ranged from 0.6 NTU (Suncor) to 230 NTU (Whitecourt STP; Figure 15).

Spatial patterns in turbidity were similar to historical data (Figure 16). Data from 1991 and 1992 also showed high levels of turbidity upstream of Hinton, and data from 1990 displayed an increase in turbidity downstream of HCE. Data from all years showed an increase in turbidity near Whitecourt, likely associated with cumulative inputs from tributaries and treated wastewater. Increases in turbidity occurred at 625 km downstream (upstream of the Freeman near Ft Assiniboine) in all years, although this increase was highest in 2015. Increases in turbidity occurred upstream of Fort McMurray in 1990-1992, and small increases occurred downstream of Fort McMurray in 1993 and 2015.

Alberta and Canada SWQG for turbidity during clear water (low flow) conditions is a maximum increase of 8 NTU from background for any short-term exposure (e.g. 24-h period), and a maximum average increase of 2 NTU from background for longer-term exposures (greater than 24 hours). These guidelines were not exceeded as a result of anthropogenic discharge into the Athabasca River during the survey.

Total Suspended Solids

Spatial patterns of total suspended solids (TSS) during the survey were relatively constant along the length of the Athabasca River (range = <1 to 6 mg/L), with the exception of two major increases upstream of Hinton (86 mg/L) and upstream of the Freeman River (21 mg/L), similar to turbidity (Figure 17). Concentrations of TSS in tributaries were relatively low, except the La Biche River (20 mg/L). The highest concentrations of TSS in treated wastewater were found in Millar Western(270 mg/L) and Whitecourt STP (460 mg/L) effluents, while other treated wastewater sources ranged from 5.3 mg/L (ANC) to 85 mg/L (SLP; Figure 17).

Data from the 2015 survey are similar to previous surveys (Figure 18). Similar to turbidity, data from all years showed high concentrations of TSS in the immediate area near Hinton that quickly declined to upstream background conditions further downstream. Smaller increases in TSS occurred upstream of the Freeman River in all years, and upstream of Fort McMurray in 1991 (Figure 18). Data from 1990 and 1991 showed an increase in TSS at approximately 700 km downstream, although this was not observed in other years.

Alberta and Canada SWQG for TSS states that background levels should not be exceeded by 25 mg/L during any short-term exposure, and a maximum average increase of 5 mg/L from background for longer-term exposures. These guidelines were not exceeded as a result of anthropogenic discharge into the Athabasca River during the survey.

Total Dissolved Solids

During the survey, total dissolved solids (TDS; calculated) in the Athabasca River ranged from 120 to 280 mg/L (Figure 19). Concentrations of TDS were low in Jasper National Park, increased upstream of Hinton, and then remained relatively constant along the length of the river. Small observational increases in TDS were notable downstream of HCE and Whitecourt. In contrast, more notable declines in TDS occurred downstream of the Pembina River and downstream of Fort McMurray, the latter due to dilution of the Clearwater River. The concentration of TDS in tributaries ranged from 130 mg/L (Calling River) to 410 mg/L (Mackay River). Treated wastewater ranged from 380 mg/L (Jasper STP) to 4,800 mg/L (Millar Western). Mass loading from HCE (115.4 Mg/day) increased TDS downstream, while increases in TDS near Whitecourt are likely due to cumulative contributions from Millar (45.3 Mg/day) and the McLeod River (195.5 Mg/day; Appendix B).

Spatial patterns in TDS during 2015 were similar to previous surveys (1990-1993), which displayed a narrow range of TDS concentrations along the length of the river (Figure 20). Data from all surveys showed a small increase in TDS downstream of HCE and Whitecourt. Data from the 2015 survey showed a decline in TDS at 625 km downstream that is not consistent with data collected from the previous surveys, although notable declines in TDS occurred in 1990-1993 at approximately 700 km downstream (Figure 20).

There are no provincial or federal SWQGs for total dissolved solids.

True Colour

True colour is due to dissolved material and is measured after particulate matter has been removed by filtration, whereas, apparent colour is the combination of true colour (dissolved material) and particulate matter.

Figure 21 and Figure 22 show that true colour in the Athabasca River gradually increased from upstream to downstream (3 to 31 relative units (RU)). A 3-fold increase in true colour occurred in the Athabasca River downstream of HCE, which contributed a load of 25,742 kg/day of colour to the Athabasca River (Figure 21; Appendix B). True colour quickly decreased and remained low through the Hinton-Whitecourt stretch, yet values were higher than headwater concentrations. Increases in true colour occurred at 625 km, 1000 km, and 1150 km downstream, which could reflect contributions from the Pembina (11,651 kg/day), House (9,953 kg/day), and Clearwater (137,428 kg/day) rivers, respectively (Appendix B). In general, tributaries in the Upper Athabasca had lower concentrations of true colour than tributaries in the Lower Athabasca. True colour ranged from 5 RU (Oldman Creek) to 29 RU (Pembina River) in the Upper Athabasca, and from 14 RU (Calling River) to 140 RU (Buffalo Creek) in the Lower Athabasca (Figure 21).

Millar Western and SLP (note that SLP is not shown in Figure 21) had markedly high true colour concentrations, 1,800 and 2,700 RU, respectively. Both of these pulp mills have anaerobic pre-treatment systems ahead of their aerobic treatment systems that generate bioenergy used in mill operations (Bertoldo, et al., 2015; Jensen & Eckford, 2013). As a result, colour is much greater in these effluent discharges; however, samples collected during the survey did not exceed wastewater limits set in their approvals. Moreover, effluent discharge from these two mills did not appear to influence colour in the Athabasca River during the survey.

True colour over the years showed slightly differently longitudinal patterns along the length of the Athabasca River (Figure 22). Yet, in all years, true colour increased greatly immediately downstream of Hinton as a result of high true colour contributions from HCE into clear montane water. Four out of the five surveys showed an increase in true colour downstream of Fort McMurray, likely associated with the Clearwater River. Data from 1990 and 2015 displayed a similar increasing pattern along the length of the river, with increases occurring downstream of HCE and the Pembina River. Conversely, data from 1993 increased dramatically downstream of HCE and declined along the length of the Athabasca River. Differences in longitudinal patterns suggest that flow levels may have an influential role in the concentration of colour in the Athabasca River.

The Alberta SWQG states that colour should not exceed a 20% increase over natural (background) conditions. True colour downstream of HCE increased 30%, exceeding this water quality guideline.

Major Ions

Concentrations and mass loads of major cations (calcium, magnesium, potassium, and sodium) are shown in Figure 23 and Figure 24, respectively, and major anions (bicarbonate, chloride, fluoride, and sulphate) are shown in Figure 25 and Figure 26, respectively. The dominant cation and anion in the Athabasca River was calcium and bicarbonate, respectively, as it has been historically (Figure 27, Figure 28).

Calcium (range = 26 to 57 mg/L) and magnesium (range = 6 to 17mg/L) displayed similar spatial patterns along the length of the Athabasca River (Figure 23, Figure 24).These ions had low concentrations in Jasper National Park that increased upstream of Hinton and remained relatively constant along the length of the river, with the exception of notable declines that occurred 625km and 1150 km downstream, the latter decline related to dilution from the Clearwater River (Figure 23). Concentrations of calcium and magnesium in the tributaries ranged from 22 to 78 mg/L and 6 to 22 mg/L, respectively (Figure 23). Treated wastewater concentrations of calcium ranged from 46 to 150mg/L and concentrations of magnesium ranged from 13 to 33 mg/L. Mass loads of calcium and magnesium from treated wastewater inputs did not appear to influence water quality in the Athabasca River during the survey (Figure 24).

Data from 2015 are similar to previous surveys, which showed a general decline in calcium and magnesium concentrations along the length of the Athabasca River (Figure 27). Noton & Saffran (1995) attributed the decline in calcium to inflow of the Lesser Slave and Clearwater rivers, however, calcium concentrations in the Lesser Slave River were much higher in 2015 (60 mg/L) than the previous studies

(25 to 28 mg/L). The decline in calcium and magnesium at 625 km downstream noted in the 2015 survey did not occur in 1990-1993.

Concentrations of potassium increased along the length of the river, from 0.5 to 3.3 mg/L, with small increases occurring downstream of HCE and Millar Western, and a more pronounced increase downstream of the Pembina River (Figure 23). Potassium concentrations decreased downstream of the Clearwater River (Figure 23), owing to dilution. Tributary concentrations of potassium were much higher in the Lower Athabasca than the Upper Athabasca, which likely attributes to increasing concentrations along the length of the river. Treated wastewater concentrations ranged from 4 (Suncor) to 71 mg/L (SLP), and inputs from HCE (559 mg/day) and Millar Western (623 mg/day) resulted in slight increases directly downstream in the Athabasca River (Figure 24).

Spatial patterns of potassium observed during the 2015 survey were similar to historical surveys (Figure 27), and all years showed a general increasing pattern from upstream to downstream. The observed increase in potassium at 625 km downstream noted in the 2015 survey was not observed in the previous surveys. Potassium concentrations in the Lower Athabasca were much higher in 2015 compared to previous years (1990-1993; Figure 27).

Sodium concentrations displayed a general increasing pattern along the length of the Athabasca River, from 1.5 mg/L to 33 mg/L. Increases in sodium concentrations in the mainstem occurred downstream of HCE, Millar Western, and the Clearwater River (Figure 23, Figure 24), as a result of mass loads from HCE (32 tonne/day), Millar Western (15 tonne/day), McLeod River (21 tonne/day), and Clearwater River (162 tonne/day). Similar to potassium, concentrations of sodium were higher in tributaries in the Lower Athabasca River compared to the Upper Athabasca.

Sodium data collected from all synoptic surveys (1990-1993 and 2015) were similar and showed a general increasing pattern along the length of the Athabasca River with slight increases downstream of HCE, Millar Western, and Clearwater River (Figure 27). Concentrations of sodium measured during the 2015 survey were much higher in the Lower Athabasca compared to 1990-1992 data, but similar to levels measured in the 1993 survey (Figure 27).

Concentrations of bicarbonate ranged from 110 to 220 mg/L, and remained relatively stable along the length of the Athabasca River, with the exception of declines that occurred 625 km downstream and downstream of the Clearwater River (Figure 25), the latter owing to dilution of the Clearwater River. These patterns are very similar to alkalinity (Figure 29). Bicarbonate concentrations measured in 2015 were similar to previous surveys and all data showed an increase in bicarbonate from headwaters to approximately 410 km downstream that plateaued until approximately 1136 km downstream and then declined (Figure 28). Data from 1990-1993 displayed a slight increase in bicarbonate at 625 km downstream, while data from 2015 at this location showed a sharp decline (Figure 28).

Chloride concentrations in the Athabasca River were relatively low (from <1 to 38 mg/L), with increases occurring downstream of HCE, Whitecourt, and Fort McMurray (Figure 25). Tributaries within the basin also had relatively low concentrations of chloride, except the Clearwater and Mackay rivers. Treated wastewater had higher concentrations of chloride, ranging from 49 to 170 mg/L. Mass loads from HCE

(13 tonne/day) resulted in an increase in chloride directly downstream, and increases in chloride downstream of Whitecourt likely resulted from the cumulative inputs of treated wastewater (2.1 tonne/day) and the McLeod River (6.7 tonne/day; Figure 26). Although the Lesser Slave River and ALPAC contributed a high mass flux of chloride (12.4 and 12.7 tonne/day, respectively), they had little influence on the Athabasca River. By far, the largest mass load of chloride to the Athabasca River was from the Clearwater River (179 tonne/day), which caused a large increase in chloride concentrations downstream (Figure 25). Data from all surveys (1990-1993 and 2015) showed similar spatial patterns of chloride with a slight increases occurring downstream of HCE and Whitecourt, and a large increase downstream of the Clearwater River (Figure 28).

Fluoride concentrations were low in Jasper National Park, increased upstream of Hinton and remained relatively stable along the length of the Athabasca River (Figure 25). In general, tributaries in the Upper Athabasca had lower concentration of fluoride than tributaries in the Lower Athabasca. Wastewater also had low concentrations of fluoride, with the exception of Whitecourt STP. Fluoride concentrations during the 2015 survey were similar to previous surveys, although data in 2015 were lower in the Hinton area and displayed less variability than the previous surveys (Figure 28).

Sulphate displayed an overall decreasing pattern from upstream of Hinton to the terminus of the river (Figure 25), with concentrations ranging from 14 to 100 mg/L. Sulphate concentrations increased slightly downstream of HCE, likely a result of high inputs from HCE (47 tonne/day), yet declined downstream of Whitecourt despite high inputs from the McLeod River (18.7 tonne/day) and Millar Western (11.3 tonne/day; Figure 26). Minimum values of sulphate occurred at 625 km and 1150 km downstream, the latter a result of inputs from the more dilute Clearwater River (9.7 mg/L; Figure 25). Concentrations of sulphate measured in 2015 displayed a similar spatial pattern as previous years; although, the decline at 625 km downstream noted in 2015 was not observed in 1990-1993 (Figure 28).

Alberta SWQGs exist for a few ions such as chloride (short-term = 640 mg/L, long-term = 120 mg/L) and sulphate (varies with hardness). All mainstem and tributary concentrations of chloride and sulphate were below the guideline during the survey.

Sulphide

During the survey, sulphide concentrations in the Athabasca River and its tributaries ranged from <0.0019 to 0.0085 mg/L, whereas treated wastewater ranged from 0.011 to 0.27 mg/L (Figure 30). The majority of sulphide detections occurred between 200 and 400 km and 930 and 1200 km downstream (Figure 30). The large increase in sulphide concentrations downstream of HCE is likely associated with high inputs from HCE (24 kg/day, Appendix B). Noton and Saffran (1995) also reported that sulphide concentrations in the Athabasca River were often below the method detection limit (<0.001 mg/L) and that the highest concentration occurred immediately downstream of Hinton.

The Alberta SWQG for total sulphide is 0.0019 mg/L, thus all samples that were above the method detection limit exceeded the water quality guideline. The relative percent difference in some duplicate samples for sulphide were high, and on three occasions the sample recorded a value <MDL, yet the duplicate measured a detectable concentration. In general, precision decreases as concentrations

approach the detection limit (Ministry of Environment, Lands and Parks, 1998), thus there is reduced certainty in the extent of SWQG exceedances. As noted by Noton & Saffran (1995), it is assumed that most of the sulfide detected in the Athabasca River would be in a dissociated form, based on pH, and potentially not a toxic threat to aquatic life. However, peaks in sulphide in surface water could indicate potential issues of high hydrogen sulfide at the sediment-water interface where reducing conditions often exist.

Cyanide

All water samples collected from the Athabasca River and its tributaries for cyanide analysis were <0.002 mg/L. Treated wastewater concentrations of cyanide were also below, at, or very slightly above the method detection limit of 0.002 mg/L.

Biochemical Oxygen Demand (BOD)

All samples from the Athabasca River and its tributaries had BOD values that were below, at, or very slightly above the MDL of 2 mg/L. BOD values in treated wastewater were above the MDL (except Syncrude) and ranged from 2.8 to 140 mg/L. Previous synoptic surveys detected BOD levels in the Athabasca River between 0.2 and 2.75 mg/L, with a detection limit of 0.1 mg/L. Thus, owing to a high detection limit, data collected in 2015 likely missed potential influences of wastewater and tributary inputs to the Athabasca River. Noton & Saffran (1995) reported distinguishably higher BOD immediately downstream of HCE as a result of wastewater inputs, and that wastewater inputs near Whitecourt influenced BOD in the Athabasca River in 1992.

Nutrients

Total Phosphorus

Total Phosphorus (TP) concentrations ranged from 3 to 56 µg/L in the Athabasca River during the survey, with the maximum TP concentrations occurring downstream of Whitecourt STP (Figure 31a). TP levels were low in Jasper National Park and increased upstream of Hinton. This increase in TP values is likely associated with elevated levels of TSS at this sampling location (Figure 15). In general, TP loads increased longitudinally downstream, with a large increase occurring downstream of Whitecourt, and smaller increases occurring downstream of Calling, House and Clearwater rivers (Figure 31b).

Tributary concentrations of TP ranged from 3 µg/L (Berland River) to 110 µg/L (La Biche River). Tributaries within the Rocky Mountain and Foothills ecoregions (Figure 2) had low TP concentrations, typical of low nutrient systems (4-10 µg/L). Within the Boreal Forest ecoregion, TP values increased and the watershed reflected mesotrophic to eutrophic conditions (20-100 µg/L), based on trophic distinctions made by Kalff (2002) and CCME (1999b). The Lesser Slave River (25 kg/day), La Biche River (98 kg/day), Clearwater River (150 kg/day), and Firebag River (79 kg/day) contributed large mass loads of TP to the Athabasca River (Figure 31b).

Treated wastewater from Jasper STP, HCE, ANC, Fort McMurray STP, and Suncor had concentrations of TP <1.0 mg/L, while TP concentrations from Millar Western, Whitecourt STP, and Syncrude were ≥5.0 mg/L (Figure 31a). In terms of mass loading, ALPAC (103 kg/day), Millar Western (94 kg/day), and

HCE (78 kg/day) contributed the largest loads of TP to the Athabasca River during the survey (Figure 31b).

Total phosphorus concentrations measured during the 2015 survey were similar to historic surveys (Figure 32). In all surveys, total phosphorus concentrations were elevated downstream of HCE, increased in the Whitecourt area (in 1990 below Millar and in 1991-1993 downstream of ANC), and increased downstream of Fort McMurray.

Total Dissolved Phosphorus and Dissolved Orthophosphate

Concentrations of total dissolved phosphorus (TDP) and dissolved orthophosphate (ortho-p) were low in Jasper National Park, with notable increases occurring downstream of Hinton and Whitecourt. Concentrations of TDP in the Athabasca River ranged from 4 and 24 µg/L, and ortho-P ranged from <0.003 to 20 µg/L (Figure 33a; Figure 34a). Similar to TP, TDP and ortho-p loads increased longitudinally downstream, with a notable step increase occurring approximately 800 km downstream (Figure 33b; Figure 34b).

Tributary concentrations of TDP ranged from 4 to 91 µg/L and ortho-p ranged from <0.003 to 78 µg/L. Similar to TP, concentrations of the dissolved phases of phosphorus were lower in headwater tributaries and higher in tributaries within the lower reaches of the Athabasca River. The Lesser Slave River (23 and 13 kg/day), La Biche River (81 and 69 kg/day), Clearwater River (79 and 75 kg/day), and Firebag River (28 and 31 kg/day) contributed large loads of TDP and dissolved ortho-p, respectively, to the Athabasca River.

Treated wastewater from Millar Western (7.6 and 7.2 mg/L) and Syncrude (6.8 and 7.3 mg/L) had high concentrations of TDP and dissolved ortho-p, respectively. Although Whitecourt STP had high levels of TP in their wastewater, dissolved forms of phosphorus were low; indicating most of the phosphorus was in particulate form, either as biomass or attached to soil particles. The La Biche River (81 kg/day) and ALPAC (95 kg/day) contributed the highest load of dissolved phosphorus to the Athabasca River (Figure 33b), although there was no corresponding increase in loads directly downstream in the Athabasca River. Conversely, loads of TDP and ortho-p from HCE and Millar Western resulted in increased concentrations directly downstream in the Athabasca River (Figure 33; Figure 34).

Total dissolved phosphorus concentrations measured in 2015 were similar to 1990 and 1992-1993 and showed a general increasing spatial pattern along the length of the river with increases downstream of HCE and Whitecourt (Figure 35). Data from 1991 showed a decreasing spatial pattern from Hinton to Athabasca owing to very high concentrations detected downstream of HCE. Concentrations of TDP were much higher in 2015 compared to 1990 and 1992-1993 between 200 and 400 km downstream, but were within a similar range further downstream.

Phosphorus Surface Water Quality Guidelines

The interim Alberta SWQG for nutrients is qualitative and states that "for a major river total phosphorus concentrations should be maintained so as to prevent detrimental changes to algal and aquatic plant communities, aquatic biodiversity, oxygen levels, and recreational quality." This survey did not collect measures of algal and aquatic plant communities to adequately assess compliance with these guidelines.

The Canada SWQG for phosphorus follows a framework-based approach such that phosphorus should not exceed a predefined trigger range or increase more than 50% over baseline (reference) levels (CCME, 1999b). Total dissolved phosphorous and ortho-p increased more than 50% from upstream levels downstream of Hinton and total phosphorus increased more than 50% from upstream levels downstream of Whitecourt, suggesting that these areas are of concern for nutrient enrichment.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of organic nitrogen, ammonia (NH_3), and ammonium (NH_4^+). In most aquatic systems, the majority of nitrogen in TKN is organic.

Concentrations of TKN ranged from <0.05 to 0.65 mg/L in the Athabasca River during the survey. TKN vales were low in Jasper National Park and increased markedly downstream of HCE (Figure 36a). As the parcel of water continued to move downstream, TKN decreased but did not reach background levels, and values increased again downstream of Whitecourt, Pembina River, and Clearwater River (Figure 36a). After Whitecourt (~400 km), TKN loads displayed an almost linear increasing pattern along the length of the Athabasca River, with a notable peak downstream of the Pembina and Clearwater rivers (Figure 36b).

Concentrations of TKN in the tributaries were similar to the mainstem and ranged from <0.05 to 1.4 mg/L (Buffalo Creek). Tributaries in the Upper Athabasca had lower values of TKN than tributaries in the Lower Athabasca. The Clearwater River had the highest loading of TKN (1,749 kg/day) to the Athabasca River during the survey (Figure 36b), resulting in an increase in TKN values downstream.

Effluent concentrations of TKN were much higher than the mainstem and tributaries, and showed a high degree of variability, ranging from 0.65 mg/L (Suncor) to 74 mg/L (Syncrude). HCE contributed the highest load of TKN to the Athabasca River (675 kg/day), resulting in an increase in TKN values in the Athabasca River (Figure 36). The increase in TKN values downstream of Whitecourt is likely due to contributing TKN loads from Millar Western (226 kg/day) and Whitecourt STP (144 kg/day).

TKN values during the 2015 survey were similar to pervious years (Figure 37), and all years showed increases in TKN downstream of HCE, Whitecourt, the Pembina River, and the Clearwater River. Data from 1990-1992 also showed a small increase in TKN at Athabasca (~743 km downstream), although it is prior to the start-up of ALPAC.

Total Nitrogen

Total nitrogen (TN) is defined as the sum of TKN (organic nitrogen, ammonia, and ammonium) plus nitrite and nitrate (NO2 + NO3). TN concentrations ranged between 0.09 and 0.9 mg/L, with notable increases occurring downstream of HCE, Whitecourt, the Pembina River, and Fort McMurray (Figure 38a). Mass loads of TN increased linearly along the length of the Athabasca River (Figure 38b)

Concentrations of TN in tributaries ranged from 0.08 to 1.8 mg/L. Similar to TKN, concentrations of TN were higher in tributaries in the Lower Athabasca (Figure 38a), and the Lesser Slave (936 kg/day), La Biche (703 kg/day), Clearwater (2,626 kg/day) and Firebag (606 kg/day) rivers contributed the highest loads of TN to the Athabasca River (Figure 38b).

Treated wastewater concentrations of TN were highest at Syncrude (75 mg/L; Figure 38a); however, HCE (684 kg/day), Millar Western (226 kg/day), and Fort McMurray STP (433 kg/day) contributed the highest loads of TN to the Athabasca River (Figure 38b). TN loads from Whitecourt STP were also high (144 kg/day). Similar to TKN, treated wastewater from HCE, Millar Western, and Whitecourt STP influenced TN concentrations in the Athabasca River, as well as inputs from the Pembina and Clearwater rivers.

TN values during the 2015 survey were similar to pervious years (Figure 39), and all years showed an increasing pattern along the length of the Athabasca River with peaks occurring downstream of HCE, Whitecourt, Pembina River, and Fort McMurray (Clearwater River). Data from 1990-1992 also showed a small increase in TN at Athabasca (~743 km downstream), similar to TKN data.

Nitrite (NO_2) and Nitrate (NO_3)

During the survey, NO_2+NO_3 concentrations ranged from 0.07 to 0.53 mg/L and increased between 200 and 500 km downstream and then reached a plateau and remained relatively similar along the remaining length of the river (Figure 40a). However, mass loads of NO_2+NO_3 displayed a linear increase along the entire length of the Athabasca River, with the exception of a peak downstream of Whitecourt and a sharp decline downstream of the Pembina River (Figure 40b). For the most part, values of NO_2 were <0.003 mg/L at 83% of the mainstem sampling locations. Thus, most of the oxidized form of nitrogen in the Athabasca River was NO_3. This is typical since NO_2 readily oxidizes to NO_3 in aquatic environments rendering NO_2 to be relatively rare in natural surface waters. Detections of NO_2 in the Athabasca River occurred downstream of HCE, downstream of Whitecourt STP, near the Town of Smith, downstream of Fort McMurray, and downstream of Syncrude.

Tributaries in the Upper Athabasca had lower concentrations of NO_2+NO_3 than the Lower Athabasca, similar to patterns in TKN and TN. Most often, tributary concentrations of NO_2+NO_3 were less than the Athabasca River, with the exception of the Lesser Slave and Clearwater rivers. Similar to the mainstem, NO_2 was <MDL in 81% of the tributary samples.

Concentrations of NO_2+NO_3 in treated wastewater were relatively low, except Fort McMurray STP (14 mg/L), and consequently Fort McMurray STP contributed the highest load of NO_2+NO_3 to the Athabasca River (357 kg/day) during the survey (Figure 40). Loads of TKN were much smaller from the Fort McMurray STP, indicating that the largest contribution of nitrogen from this wastewater was NO_2+NO_3. All treated wastewater had small quantities of NO_2, except Millar Western and Suncor. Thus, most of the NO_2+NO_3 concentrations were NO_3.

Concentrations of NO_2+NO_3 during the 2015 survey were similar to values recorded during the 1990-1993 surveys (Figure 41). Concentrations of NO_2+NO_3 measured in 2015 were slightly higher than 1990-1993 values between 300 and 600 km downstream and at the lower portion of the mainstem.

Ammonia

Ammonia levels ranged between <0.05 and 0.12 mg/L in the Athabasca River. Concentrations of ammonia in the Athabasca River were <0.05 mg/L in Jasper National Park and increased downstream of HCE (0.11 mg/L; Figure 42a). Concentrations gradually decreased downstream and increased again downstream of Whitecourt. Between 492 and 743 km downstream ammonia values were ≤0.05 mg/L.

Ammonia levels were detected downstream of the Athabasca STP and decreased to below the MDL from 820 to 1136 km downstream. Downstream of Fort McMurray, ammonia concentrations were above the MDL (Figure 42a).

Tributary ammonia concentrations ranged from <0.05 to 0.38 mg/L (Muskeg River). Ammonia levels in most tributaries in the Upper Athabasca were <0.05 mg/L, except the McLeod, Pembina, La Biche, and Calling rivers. All tributaries within the Lower Athabasca had ammonia values above the MDL, with the exception of Ells River. The Clearwater River contributed the largest load of ammonia to the Athabasca River (412 kg/day), resulting in an increase immediately downstream.

Whitecourt STP (18 mg/L), Slave Lake STP (23 mg/L), Athabasca STP (28 mg/L), and Syncrude (71 mg/L) had high levels of ammonia in their wastewater. All other treated wastewater sources had concentrations <1.0 mg/L, except HCE (3.0 mg/L). Total ammonia in Syncrude's wastewater represented 95% of its total nitrogen, whereas total ammonia represented 46% of total nitrogen in Whitecourt STP and 82% in Athabasca STP. HCE contributed the highest load of total ammonia to the Athabasca River (266 kg/day) causing an increase in total ammonia levels in the ambient environment (Figure 40b). Loading from Whitecourt STP (66 kg/day) and Athabasca STP (17 kg/day) also appeared to have an impact on the water quality of the Athabasca River.

Method detection limits during the 2015 survey (0.05 mg/L) were not comparable to the previous surveys (0.01 mg/L) making the data challenging to compare. Broadly, ammonia data from all the surveys were within the same range and showed increases in ammonia immediately downstream of HCE, Whitecourt, and Fort McMurray.

Nitrogen Surface Water Quality Guidelines

The interim Alberta SWQG for total nitrogen is qualitative and that states "for a major river total nitrogen concentrations should be maintained so as to prevent detrimental changes to algal and aquatic plant communities, aquatic biodiversity, oxygen levels, and recreational quality." Similar to phosphorus, this survey did not collect measures of algal and aquatic plant communities to adequately assess compliance with these guidelines.

The long-term and short-term SWQG for nitrate in Alberta is 3 and 124 µg/L, respectively. This guideline was not exceeded in the Athabasca River and its tributaries during the survey. However, treated wastewater from Fort McMurray STP (14 mg/L) exceeded the long-term SWQG. The Alberta SWQG for nitrate values vary with chloride levels and were not exceeded in the mainstem, tributary, or treated wastewater samples.

The long-term Alberta SWQG for un-ionized ammonia is 0.016 mg/L and short-term guidelines for total ammonia vary with temperature and pH. For a temperature range of 0-1°C and pH range of 6.8-8.4, total ammonia guidelines vary from 30.1 to 0.710 mg/L. Total ammonia levels in the Athabasca River and its tributaries were well below the lower range of the ammonia guideline. Total ammonia values in treated wastewater from HCE, Millar Western, Whitecourt STP, Slave Lake STP, Athabasca STP, and Syncrude exceeded water quality guidelines. Despite the fact Millar Western had a relatively low concentration of total ammonia the temperature and pH of the treated wastewater were high, resulting in an increase in the un-ionized fraction of ammonia.

Total and Dissolved Metals

Spatial patterns for all total and dissolved metals measured in the Athabasca River during the survey are shown in Figure 43and Figure 44, respectively. Data in these figures highlight different longitudinal patterns between metals and their fractions (total and dissolved). Where data is available, comparisons of total metals are made between the 2015 and historic surveys. As noted in the methods section above, comparisons show broad similarities and differences in spatial patterns, but often the method of analysis and detection limits vary between the two datasets.

Aluminum

Concentrations of total aluminum along the extent of the Athabasca River ranged from 17 to 1890 µg/L. Levels of total aluminum were low within the headwaters area near Jasper and increased to a maximum value upstream of Hinton and quickly decreased to upstream concentrations downstream of HCE (Figure 45a). Values of total aluminum increased slightly downstream of Whitecourt and an abrupt increase was observed upstream of the Freeman River. This increase quickly returned to upstream background levels that remained relatively constant until the end of the river. Total aluminum measured in the Athabasca River showed a strong correlation with total suspended solids (r= 0.96). Major peaks in total aluminum did not occur in relation to locations of wastewater releases or tributaries, thus fluctuations in total aluminum are likely reflective of suspended material.

Total aluminum concentrations within the tributaries ranged from 44 (Berland River) to 861 µg/L (La Biche River). Treated wastewater had varying concentrations of total aluminum that ranged from 19 (ANC) to 21,500 µg/L (Whitecourt STP). Total mass loading from treated wastewater were much lower than tributary inputs (Figure 46a).

Total aluminum concentrations were higher in 2015 compared to data collected from 1990-1993 (Figure 47). Total aluminum concentrations in 1991 and 1992 were also high upstream of Hinton and were associated with high turbidity and suspended solids (Noton & Saffran, 1995).

Dissolved aluminum ranged from 1.7 to 13.2 µg/L, and displayed a different spatial pattern than total aluminum. Concentrations were low upstream of Hinton and increased markedly downstream of HCE. Dissolved aluminum concentrations decreased to upstream background levels by approximately 500 km downstream, where concentrations remained relatively low and consistent to the end of the river, with the exception of an increase downstream of House River (Figure 45b).

Tributaries had low concentrations of dissolved aluminum, with the exception of House River (18.7 µg/L), which likely resulted in an increase in dissolved aluminum concentrations in the Athabasca River immediately downstream. The sharp increase in dissolved aluminum downstream of Hinton is associated with treated wastewater from HCE. Concentrations of dissolved aluminum in HCE wastewater was 404 µg/L; a loading of 36 kg/day (Figure 46b).

Surface water quality guidelines for both total and dissolved aluminum are pH dependent. There are no Alberta SWQG for total aluminum, but the Canada guideline is 5 µg/L if pH is <6.5 and 100 µg/L if is pH ≥6.5. The pH of the Athabasca River during the survey was above 6.5 (Figure 6), thus the guideline of 100 µg/L is appropriate. This guideline was exceeded at 36 sampling sites (86%) along the Athabasca River, 12 tributaries, and 7 wastewater samples.

Alberta applies SWQG to the dissolved form of aluminum because this metal is strongly associated with suspended solids, which can be naturally high in Alberta rivers. Thus, applying the guideline to the dissolved form is more appropriate because the particulate fraction is largely natural and of limited bioavailability (Alberta Environment & Sustainable Developement, 2014). The Alberta SWQG for dissolved aluminum is also pH dependent. For water with a pH ≥6.5, the long-term guideline is 50 µg/L and the short-term guideline is 100 µg/L. Dissolved aluminum guidelines were not exceeded in the ambient environment; however, wastewater from HCE, ALPAC, and Fort McMurray STP exceeded the long-term and short-term guidelines.

Antimony

Total and dissolved antimony concentrations displayed similar spatial patterns along the length of the Athabasca River, ranging from 0.01 and 0.1 µg/L and 0.01 to 0.08 µg/L, respectively (Figure 48). Concentrations of antimony were low in Jasper National Park and exhibited a general increasing pattern downstream with maximums occurring upstream of Hinton, downstream of Whitecourt, downstream of the Lesser Slave River, and upstream of the House River (total antimony only). Total and dissolved antimony decreased downstream of the Clearwater River and quickly increased to upstream background levels to end of the river.

Concentrations of total and dissolved antimony in tributaries ranged from 0.01 to 0.1 µg/L and <0.008 to 0.01 µg/L, respectively. The increase in total antimony downstream of Whitecourt was due to cumulative loads from the Sakwatamau River (10.9 g/day), McLeod River (44.2 g/day), and Whitecourt STP (22 g/day). The Lesser Slave River contributed the highest load of total and dissolved antimony (243 g/day and 240 g/day, respectively) that likely contributed to a peak in antimony downstream of the Lesser Slave River (Appendix B).Lower concentrations of antimony in the Clearwater River diluted concentrations in the Athabasca River.

Municipal wastewater from Whitecourt STP had high levels total antimony (6 µg/L; 22 g/day), while all other treated wastewater were below 0.6 µg/L. Dissolved antimony concentrations in treated wastewater were low (<0. 7µg/L).

There are no Alberta and Canada SWQGs for total or dissolved antimony.

Arsenic

In general, concentrations of total arsenic in the Athabasca River increased from upstream to downstream, and ranged from 0.05 to 0.7 µg/L, with one peak value measuring 5.3 µg/L (Figure 49). Dissolved arsenic displayed a similar pattern with concentrations progressively increasing from upstream to downstream and also showed a step-change occurring approximately 700 km downstream (Figure 49). Total and dissolved arsenic concentrations in many of the tributaries were higher than the

Athabasca River and ranged from 0.06 to 1.9 µg/L and 0.06 to 1.6 µg/L, respectively (Figure 49). Tributaries in the Upper Athabasca also increased from upstream to downstream, and high levels of arsenic were measured in the Lesser Slave and La Biche rivers. Municipal and industrial wastewater concentrations of total and dissolved arsenic were comparable to levels measured in the tributaries, except total arsenic in Whitecourt STP wastewater (4.6 µg/L).

Increases in arsenic were not influenced by wastewater contributions, and largely reflect inputs from tributaries and groundwater. During winter conditions, groundwater can contribute to a majority of baseflow. Groundwater in Northern Alberta, particularly geological areas of the Smokey Group, Lea Park Formation, and La Biche Formation tend to have higher concentrations of arsenic (Alberta Health and Wellness, 2000). This corresponds to higher concentrations of arsenic in the Lesser Slave and La Biche rivers, and the step-increase observed in dissolved at ~700 km downstream.

Total arsenic measured during the 2015 and 1990-1993 surveys display an overall increasing pattern along the length of the Athabasca River (Figure 50). In some years, arsenic levels were high downstream of HCE and then declined through the Hinton-Whitecourt reach, increased downstream of Whitecourt and ~700 km downstream. Arsenic concentrations measured in the Lower Athabasca were notably higher than the previous surveys (Figure 50).

All samples collected in the mainstem, tributaries, and wastewaters were below the long-term Alberta SWQG for total arsenic (5 µg/L) during the survey. There are no SWQGs for dissolved arsenic.

Barium

During the survey, total barium levels ranged from 37 and 91 µg/L and dissolved barium ranged from 33 to 83 µg/L (Figure 51). Total and dissolved barium displayed similar spatial patterns with low concentrations near Hinton that increased downstream of Whitecourt and then remained relatively stable until concentrations decreased substantially downstream of the Clearwater River (1150 km downstream). The Clearwater River had relatively low concentrations of barium and a high contribution of flow to the Athabasca River resulting in a diluting effect. In general, barium concentrations in tributaries within the Upper Athabasca were higher than tributaries within the Lower Athabasca.

Whitecourt STP had a high concentration of total barium (1,310 µg/L) and all other facilities were <500 µg/L. Dissolved barium in Whitecourt STP wastwater was much lower (69.1 µg/L), indicating most of the barium was in suspended form. Conversly, a majority of barium was in the dissolved form in Millar Western (399 µg/L) and SLP (318 µg/L). Total loading of barium from wastewater near Whitecourt was 13.2 kg/day and total loading from tributary inputs was 90 kg/day, incidcating that the increase in barium near Whitecourt reflects natural inputs.

Total barium measured during the 2015 survey was similar to previous surveys conducted in 1990-1993 (Figure 52). Data from all the winter survyes showed an increase in total barium downstream of Whitecourt and a decrease downstream of the Clearwater River.

There are no Alberta or Canada SWQGs for total or dissolved barium.

Beryllium

Total beryllium concentrations were very low in the Athabasca River and 60% of samples in the mainstem were below the MDL (<0.008 µg/L). Detections of total beryllium occurred upstream of Hinton, downstream of Whitecourt, upstream of the Freeman River, and a few locations in the Lower Athabasca (Figure 53a). Detections of totally beryllium may have been associated with increases in sediment load as there was a high correlation with total suspended solids (r = 0.92).

All tributaries within the Upper Athabasca were ≤0.008 µg/L, while tributaries within the Lower Athabasca had concentrations of total beryllium above detection limits. Total beryllium concentrations in wastewater were also very low and often below the detection limit, with the exception of Whitecourt STP (0.4 µg/L). This high level of total beryllium could have resulted in a detection of total beryllium in the Athabasca River directly downstream of the Whitecourt STP.

All dissolved beryllium samples collected in the Athabasca River were <0.009 µg/L, with the exception of one sample collected downstream of the Whitecourt STP (0.011 µg/L; Figure 51b). Similary, most tributraries, except House River (0.01 µg/L) and Buffalo Creek (0.018 µg/L), were below the MDL. Dissolved beryllium concentrations in wastewater samples were also below the MDLs, with the exception of HCE (0.01 µg/L).

There are no Alberta or Canada SWQGs for total or dissolved beryllium for the protection of aquatic life.

Bismuth

Total bismuth concentrations ranged from <0.001 to 0.03 µg/L and 52% of samples collected from the Athabasca River were below the MDL (Figure 54a). Detections of total bismuth occurred upstream of Hinton, upstream of the Freeman River, near Athabasca, and a few locations in the Lower Athabasca. There was a moderate correlation between total bismuth and total suspended solids (r = 0.61), thus detections of total bismuth may be related to sediment. Tributaries within the headwater area, Miette to McLeod (100 to 400 km downstream), did not have detectable limits of total bismuth. The Freeman River and all tributaries downstream had detectable limits of total bismuth, although levels were very low.

The pattern of dissolved bismuth was very similar to total bismuth, with many values <0.003 µg/L and detections occurring upstream of Hinton, near Athabasca, and several locations in the Lower Athabasca. Similarly, concentrations of dissolved bismuth in the tributaries were often below the MDL, especially in the upper reaches (100 to 400 km; Figure 54b).

Wastewater concentrations of total and dissolved bismuth were relatively low and ranged from <0.001 to 3.7 µg/L and <0.003 to 0.9 µg/L, respectively. Levels of total barium were much higher in wastewater from Whitecourt STP compared to other wastewater sources, although dissolved barium concentrations were low and similar to other facilities (Figure 54). Treated wastewater did not have a measurable impact on water quality in the Athabasca River during the survey.

There are no Alberta or Canada SWQGs for bismuth.

Boron

Total and dissolved boron displayed a similar increasing pattern along the length of the Athabasca River, ranging from 2.4 to 44.7 µg/L and 1.8 to 34.4 µg/L, respectively (Figure 55). Most of the boron present in the Athabasca River and its tributaries was in the dissolved form. Increases in boron occurred downstream of Whitecourt and downstream of the House and Clearwater rivers. Concentrations of boron in the Lower Athabasca tributaries were higher than the mainstem and tributaries in the Upper Athabasca (Figure 55). Increases in boron downstream of House River and Clearwater River were likely a result of inputs from these tributaries.

Treated wastewater from ANC had very high concentrations of total (931 µg/L) and dissolved (881 µg/L) boron compared to other wastewater sources (Figure 55). The combined load of total and dissolved boron from ANC (14.9 and 14.1 kg/day, respectively) and the McLeod River (12.6 and 9.7 kg/day, respectively) likely resulted in the observed increase in total and dissolved boron downstream of Whitecourt.

The short-term and long-term Alberta SWQG for total boron is 29,000 and 1,500 µg/L, respectively. All samples collected (mainstem, tributaries, wastewater) were below these guidelines.

Cadmium

Total cadmium concentrations during the survey ranged from <0.006 to 0.06 µg/L (Figure 56a). Total cadmium concentrations were below the MDL in Jasper National Park and generally increased along the length of the Athabasca River. Notable increases in total cadmium concentrations occurred upstream of Hinton, in the Whitecourt area, downstream of Lesser Slave River, and upstream of House River. Concentrations decreased downstream of the Clearwater River owing to a diluting effect. Total cadmium concentrations in the tributaries were relatively low and ranged from <0.002 to 0.03 µg/L, with the exception of Lesser Slave River that had a higher concentration (0.063 µg/L).

Dissolved cadmium concentrations were <0.001 µg/L in Jasper National Park and displayed a general increasing pattern as water flowed downstream (Figure 56b). There was a small increase in dissolved cadmium downstream of HCE and a large increase downstream of ANC and Whitecourt STP. Similar to total cadmium, dissolved cadmium also increased downstream of the Lesser Slave River and remained higher and relatively constant until the end of the river, although there was a decrease in concentrations downstream of the Clearwater River. Similar to total cadmium, dissolved cadmium concentrations were low in most tributaries, except the Lesser Slave River (0.056 µg/L).

Treated wastewater of total and dissolved cadmium was relatively low, except for SLP (11.9 and 9.6 µg/L, respectively). The mass load of total and dissolved cadmium from SLP to the Lesser Slave River was 125 and 100 g/day, and the Lesser Slave River contributed 159 and 142 g/day to the Athabasca River, representing the highest inputs of cadmium (Appendix B).

Alberta short-term and long-term SWQG for total cadmium are related to water hardness (Government of Alberta, 2014). All samples collected from the Athabasca River and its tributaries were below the Alberta SWQG at their respective hardness. Total cadmium levels in SLP wastewater exceeded the short-term and long-term guidelines, and wastewater from Millar Western, Whitecourt STP, and ALPAC exceeded the long-term guideline.

Chromium

Concentrations of total chromium ranged from 0.1 to 1.9 µg/L in the Athabasca River and from 0.1 to 0.9 µg/L (La Biche River) in the tributaries (Figure 57a). Hexavalent chromium was also measured during the survey and all samples were <0.001 mg/L. Increases in total cadmium occurred upstream of Hinton and the Freeman River. These increases are likely a result of high levels of suspended solids occurring at these locations, as there is a strong positive correlation between TSS and total chromium measured in the Athabasca River (r = 0.96).

At most locations, dissolved chromium concentrations were ≤0.1 µg/L (Figure 57b). Eleven sites on the Athabasca River between Hinton and Athabasca were slightly above detection limits (0.2 µg/L), and all mainstem sites downstream of Calling River were ≤0.1 µg/L. Similarly, dissolved chromium concentrations of most tributaries were ≤0.1 µg/L, except the Pembina, Lesser Slave, and Muskeg rivers were slightly above the MDL.

Total chromium concentrations in wastewater measured during the survey were generally low (below 2.5 µg/L), with the exception of SLP (10.7 µg/L) and Whitecourt STP (13.9 µg/L). Dissolved chromium levels were also high in SLP (8.5 µg/L), but not in Whitecourt STP (0.4 µg/L). Hexavalent chromium was <0.001 mg/L in all wastewater samples.

The long-term Alberta and Canada SWQG for hexavalent chromium is 1 µg/L and for trivalent chromium is 8.9 µg/L. Samples collected from the Athabasca River and its tributaries did not exceed these guidelines during the survey. Concentrations of total cadmium in SLP and Whitecourt STP wastewater exceeded the trivalent chromium guideline value. Based on pH and redox potential and considering that only trivalent and hexavalent chromium are stable enough to occur in the environment, the aqueous form of chromium is likely to be mostly trivalent since hexavalent was below detection limits.

Cobalt

Total cobalt concentrations in the Athabasca River ranged from 0.008 and 0.65µg/L, with peak concentrations occurring upstream of Hinton and the Freeman and House rivers (Figure 58a). Total cobalt concentrations displayed a strong positive correlation with total suspended solids in the Athabasca River (r =0.93), thus increases in total cobalt are likely associated with suspended sediments. Total cobalt concentrations in the tributaries ranged between 0.01 (Berland River) and 0.7 µg/L (House River).

In general, dissolved cobalt concentrations increased along the length of the Athabasca River, with lower concentrations in Jasper National Park and higher concentration at the end of the river (range = <0.002 to 0.1 µg/L). Dissolved cobalt increased downstream of Jasper STP (0.003 to 0.012 µg/L), downstream of HCE (0.015 to 0.026 µg/L), downstream of Whitecourt STP (0.013 to 0.042 µg/L), downstream of the House River (0.045 to 0.109 µg/L), and downstream of Suncor and Syncrude (0.032 to 0.054 µg/L). Generally, tributaries had higher concentrations of dissolved cobalt than the Athabasca River, ranging from 0.01 to 0.56 µg/L (Figure 58b).

Concentrations of total and dissolved cobalt in treated wastewater ranged from <0.002 (Suncor) to 4.1 μg/L (Whitecourt STP) and <0.002 (Suncor) to 2.48 μg/L (SLP), respectively (Figure 58). The largest input of total cobalt to the Athabasca River was the Clearwater River (471 g/day) and the largest input of dissolved cobalt was the Lesser Slave River (185 g/day; Appendix B). Inputs from the Miette River, HCE, Millar Western, Whitecourt STP, Lesser Slave River, and House River appeared to influence water quality in the Athabasca River.

The long-term Alberta SWQG for total cobalt is 2.5 μg/L. All water quality samples collected during the survey were below this guideline, with the exception of wastewater from Whitecourt STP and SLP.

Copper

Total copper concentrations in the Athabasca River ranged between 0.2 to 4.2 μg/L (Figure 59a). Concentrations were low in Jasper National Park, increased upstream of Hinton and then quickly declined, although levels did not reach background upstream values. Total copper remained relatively constant along the remaining length of the Athabasca River, with increases occurring upstream of the Freeman River and House River and a decrease occurring downstream of the Clearwater River owing to its diluting effect. Noton & Saffran (1995) reported that total copper concentrations in the Athabasca River were associated with sediments; however, the 2015 data showed a weak correlation ($r = 0.27$) between TSS and total copper. Concentrations of total copper in the tributaries ranged from 0.2 (Oldman Creek) to 1.5 μg/L (Pembina River).

In general, dissolved copper increased from upstream to downstream, with the exception of a decrease in concentrations downstream of the Clearwater River (Figure 59b). Dissolved copper concentrations ranged between 0.2 and 0.9 μg/L in the Athabasca River and from 0.1 (Firebag River) to 1.2 μg/L (Pembina River) in the tributaries.

Wastewater concentrations of total and dissolved copper ranged from 0.9 (ANC) to 109 μg/L (Whitecourt STP) and 0.7 (ANC) to 31 μg/L (Athabasca STP), respectively. Inputs of total and dissolved copper from tributaries and wastewater did not appear to influence water quality in the Athabasca River during the survey.

Copper concentrations measured during the 2015 were much lower than previous surveys (Figure 60), but all data showed higher elevations of total copper upstream of Hinton, upstream of the Freeman River (~500 km downstream), and a decrease downstream of the Clearwater River (~1150 km downstream). The increase in total copper concentrations ~985 km downstream (upstream of House River) observed in 2015 were not detected in the previous surveys.

The short-term Alberta SWQG for total copper is 7 μg/L for water with a hardness ≥50 mg/L and the long-term guideline varies with hardness (Alberta Environment & Sustainable Developement, 2014). Total copper concentrations in the Athabasca River and its tributaries did not exceed Alberta SWQGs during the survey. Treated wastewater from Jasper STP, Millar Western, Whitecourt STP, Athabasca STP, SLP, and Slave Lake STP exceeded the short-term SWQG, and treated wastewater from Whitecourt STP and Athabasca STP exceeded long-term SWQG for total copper.

Iron

Total iron concentrations ranged between 28.5 and 1,990 µg/L (Figure 61a). Concentrations of total iron were low in Jasper National Park and increased upstream of Hinton, upstream of the Freeman River, and downstream of the House River. In each instance, total iron concentrations quickly returned to upstream background levels. An increase in total iron also occurred downstream of the Clearwater River and although levels declined downstream they did not reach upstream background levels. The increase in total iron upstream of Hinton and the Freeman River are likely associated with high levels of TSS ($r = 0.78$), while the increases downstream of the House River and Clearwater River are associated with tributary inputs.

Total iron concentrations in tributaries ranged from 104 to 3,860 µg/L. Total iron concentrations were higher in the Lower Athabasca tributaries compared to tributaries in the Upper Athabasca and the mainstem (Figure 61a). House River had the highest concentration of total iron and likely led to the subsequent increase in iron concentrations in the Athabasca River at 1000 km downstream. Similarly, the Clearwater River had a measurable impact on total iron concentrations in the Athabasca River, and contributed a load of 56 g/day to the Athabasca River, the highest load of any tributary (Appendix B).

Dissolved iron concentrations in the Athabasca River ranged between 3 and 243 µg/L, with small increases occurring downstream of the House and Clearwater rivers, likely associated with inputs from these tributaries (Figure 61b). Dissolved iron concentrations in tributaries ranged from 7 to 1,480 µg/L, and tributaries in the Lower Athabasca also had higher concentrations of dissolved iron than tributaries in the Upper Athabasca, especially House, Buffalo, and Mackay rivers.

Wastewater concentrations of total iron ranged between 16 and 18,200 µg/L. Whitecourt STP (18,200 µg/L) and Slave Lake STP (4,090 µg/L) had highest levels of total iron during the survey, whereas all other wastewater sources were ≤500 µg/L (Figure 61). Slave Lake STP (851 µg/L) and Whitecourt STP (515 µg/L) also had high concentrations of dissolved iron. No effects of treated wastewater were discernible on iron concentrations in the Athabasca River during the survey.

The spatial patterns of total iron displayed in 2015 were similar to historical surveys (Figure 62). Noton and Saffran (1995) also found high levels of iron upstream of Hinton and the Freeman River associated with TSS, although the increase in total iron approximately 500 km downstream is much more pronounced in the 2015 dataset. Total iron concentrations from 1990-1993 also showed an increase in total iron downstream of Fort McMurray associated with inputs from the Clearwater River, although the increase in iron approximately 1000 km downstream was not detected din the previous surveys (Figure 62).

The Canada SWQG for total aluminum is 300 µg/L. Similar to aluminum the Alberta SWQG is applied to the dissolved fraction of iron owing to the fact that total iron is naturally high in Alberta rivers (Alberta Environment & Sustainable Developement, 2014). The long-term Alberta SWQG for dissolved iron is 300 µg/L. Water in the Athabasca River did not exceed this guideline; however, the guideline was exceeded in the House River, Buffalo Creek, Clearwater River, and Mackay River. Wastewater from Whitecourt STP, Slave Lake STP, and SLP also exceeded this guideline during the survey.

Lead
Total lead concentrations in the Athabasca River were generally low with sharp increases occurring upstream of Hinton, near the Freeman River, and upstream of the House River (Figure 63a). Total lead concentrations in the Athabasca displayed a strong positive relationship with TSS (r =0.87), thus increases are associated with particulate matter. Total lead concentrations in the tributaries were relatively low, ranging from 0.01 (Berland River) to 0.3 µg/L (La Biche River).

Dissolved lead concentrations were more variable and increased downstream of Hinton, Whitecourt, and Athabasca, and several peaks occurred in the lower reaches of the river (Figure 63b). A notable peak in dissolved lead concentration occurred downstream of the Freeman River, and this peak does not appear to be related tributary contribution. Tributaries in the Lower Athabasca had much higher concentrations of dissolved lead compared to the Upper Athabasca.

Treated wastewater had relatively low concentrations of total lead, with the exception of Whitecourt STP (16 µg/L); although, the overall loads of total and dissolved lead did not appear to impact water quality in the Athabasca River during the survey.

Long-term Alberta SWQG for total lead is dependent on hardness (Alberta Environment & Sustainable Developement, 2014). For water with a hardness >180 mg/L, the long-term SWQG is 7.0 µg/L. Total lead concentrations in the Athabasca River and its tributaries did not exceed this guideline during the survey; however, water quality in Whitecourt STP wastewater did exceed this guideline.

Lithium
In general, total and dissolved lithium concentrations increased slightly from upstream to downstream in the Athabasca River, with values ranging from 1.5 to 11.7 µg/L and 1.5 to 10.8 µg/L, respectively (Figure 64). Concentrations of lithium were typically higher in tributaries within the Lower Athabasca than the Upper Athabasca, with the exception of the Sakwatamau River (Figure 64). Concentrations of treated wastewater were similar to the tributaries and were below 20 µg/L, expect Jasper STP which had high levels of both total (154 µg/L) and dissolved (128 µg/L) lithium.

There are no Alberta or Canada SWQGs for lithium.

Manganese
Total manganese concentrations in the Athabasca river were relatively low in Jasper National Park and increased upstream of Hinton (Figure 65a). This increase quickly returned to upstream background levels and slightly increased again downstream of Whitecourt and upstream of the Freeman River. Total manganese values remained low and constant downstream of the Freeman River to the Clearwater River, with the exception of an increase downstream of the House River. Concentrations increased downstream of the Clearwater River to the end of the river. Tributary concentrations were often higher than the Athabasca River, with elevated concentrations of total manganese occurring in the House (300 µg/L) and Muskeg (280 µg/L) rivers (Figure 65a).

Wastewater concentrations of total manganese ranged from 54 to 1,190µg/L. High concentrations were detected in wastewater from ANC (1,190 µg/L), Millar Western (1,010µg/L), Slave Lake STP (953 µg/L), and SLP (748 µg/L; Figure 65). High loading from wastewater (ANC = 19 kg/day, Millar Western = 9.5 kg/day) and tributary inputs resulted in an increase in total manganese in the vicinity of Whitecourt. Inputs from the House (37 kg/day) and Clearwater (134 kg/day) rivers resulted in increased total manganese directly downstream. The overall mass load of total manganese from HCE was 39 kg/day, which would likely influence water quality in the Athabasca River; however, elevated levels upstream masked any effect.

Total manganese concentrations measured during the 2015 survey were similar to historical surveys, with the exception of high total manganese measured approximately 1000 km downstream in 2015 (Figure 66). All data showed an increase in total manganese near Hinton, Whitecourt, upstream of the Freeman River (approximately 500 km downstream), and the Clearwater River. Noton & Saffran (1995) also reported that high total manganese upstream of Hinton in 1991 and 1992 made the influence of HCE discernible; however, data from 1990 and 1993 showed an increase in total manganese concentrations directly below HCE (Figure 66).

Dissolved manganese concentrations in the Athabasca River during the survey ranged from 0.1 to 25.0 µg/L (Figure 65b). Dissolved manganese increased downstream of Jasper, Hinton, Whitecourt, House River, and Clearwater River. Tributary concentrations of dissolved manganese were higher than the Athabasca River and ranged from 1 to 268 µg/L (Figure 65b). High concentrations of dissolved manganese were detected in the House River and Muskeg River. The House River (33 kg/day) and Clearwater River (53 kg/day) contributed the highest loads of dissolved manganese to the Athabasca River, which resulted in increased levels in Athabasca River downstream.

Wastewater concentrations of dissolved manganese ranged from 1 to 1,090 µg/L, with HCE (32 kg/day), ANC (19 kg/day), and Millar Western (9.5 kg/day) contributing large mass loads of dissolved manganese to the Athabasca River. These inputs resulted in increases in dissolved manganese downstream of HCE and Whitecourt.

There is no Alberta or Canada SWQGs for total manganese.

Mercury

Concentrations of total mercury ranged from 0.09 to 4.1 ng/L in the Athabasca River during the survey, and displayed a slight increase from upstream to downstream (Figure 67a). Tributaries had a similar concentration range of total mercury as the mainstem; 0.2 to 4.2 ng/L. Distinct peaks in total mercury occurred upstream of Hinton and upstream of the Freeman River. These are also locations of high TSS values, and total mercury had a moderately high association with TSS ($r = 0.64$). It is likely that the increases in total mercury are influenced by TSS; although, concentrations of total mercury in the Freeman River were high, indicating total mercury levels in this area of the watershed may be naturally high. Treated wastewater had relatively low concentrations of total mercury, with the exception of the Whitecourt STP (37.5 ng/L), although this did not have detectable impact on ambient total mercury levels in the Athabasca River.

Methyl mercury was <0.016 ng/L in Jasper National Park and increased to above detection limits upstream of Hinton. These values quickly decreased, were ≤ the MDL from approximately 220 to 500 km downstream, and were recorded at low levels to the end of the river (Figure 67b). Methyl mercury in tributaries ranged from <0.016 to 0.12 ng/L. Similar to total mercury, methyl mercury levels in treated wastewater were relatively low, except Whitecourt STP (0.45 ng/L).

Long-term and short-term Alberta SWQGs for total mercury are 0.005 and 0.013 µg/L, respectively. These guidelines were not exceeded in the Athabasca River or its tributaries during the survey. Total mercury levels in treated wastewater from the Whitecourt STP were above both the long-term and short-term guideline.

Molybdenum

Both total and dissolved molybdenum displayed similar spatial patterns (Figure 68). Total and dissolved molybdenum were low in Jasper National Park and increased markedly upstream of Hinton, remained high, and displayed a slight longitudinal decrease from upstream to downstream. A notable decrease in both total and dissolved molybdenum concentrations occurred downstream of the Clearwater River.

In general, tributary concentrations of total and dissolved molybdenum were lower than the mainstem, with the exception of the Berland and House rivers (Figure 68). The Clearwater River had a low concentration of molybdenum that resulted in a diluting effect on the Athabasca River water quality. Wastewater inputs also had low levels of total and dissolved molybdenum, with the exception of Syncrude (32 and 30 µg/L, respectively).

Total molybdenum concentrations measured during the 2015 survey were lower than the previous surveys (Figure 83); although, values measured during 1990-1993 were also low. This decrease is may be reflective of changes in analytical techniques.

The interim Alberta SWQG for total molybdenum is 73 µg/L. Molybdenum concentrations in the Athabasca River, its tributaries, and wastewater sources did not exceed this guideline.

Nickel

Total nickel concentrations were low during the first ~625 km stretch of the Athabasca River, with the exception of a few peaks upstream of Hinton and the Freeman River, and ranged from <0.008 to 1.3 µg/L (Figure 70a). Total nickel concentrations in the Lower Athabasca were higher and showed greater variability (range = 0.3 to 6.4 µg/L), with increases occurring upstream of the House River and downstream of the Clearwater, Muskeg, and Ells rivers. Most of tributaries within the Lower Athabasca had higher concentrations of total nickel than tributaries in the Upper Athabasca.

Total nickel concentrations measured during the 2015 survey were lower than previous surveys (Figure 71). Note that the method detection limit in the 2015 survey (0.008 ug/L) was much lower than the previous surveys (1 µg/L). Nonetheless, all surveys did not reveal any apparent longitudinal patterns in total nickel in the Athabasca River.

Dissolved nickel concentrations were <0.006 µg/L for the first ~625 km stretch of the Athabasca River and increased downstream of the Lesser Slave River and remained high to the end of the river, reaching a maximum of 0.9 µg/L (Figure 70b). High levels of dissolved nickel were detected in House River, which may be associated with an increase in concentrations in the mainstem. Dissolved nickel decreased slightly downstream of Fort McMurray, owing to the lower concentration of dissolved nickel in Clearwater River.

Municipal wastewater from Whitecourt STP had high levels of total nickel (13.7 µg/L), although wastewater did not appear to influence nickel concentrations in the Athabasca River (Figure 70). Levels of dissolved nickel in wastewater were higher than the Athabasca River, but comparable to concentrations in the House River.

Short- and long-term Alberta SWQGs for total nickel vary with hardness (Alberta Environment & Sustainable Developement, 2014). Neither the long-term nor short-term SWQG for total nickel was exceeded in any samples (mainstem, tributaries, or wastewater) collected during the survey.

Selenium

Concentrations of total and dissolved selenium displayed a similar pattern along the length of the Athabasca River (Figure 72). Selenium concentrations were low in Jasper National Park and increased markedly upstream of Hinton. Concentrations are variable down the length of the Athabasca River, but generally displayed a decreasing pattern from upstream to downstream (Figure 72). Levels of selenium (total and dissolved) in the tributaries were lower than the Athabasca River, with the exception of the McLeod River. The Berland River also had higher levels of selenium, relative to other tributaries in the basin.

Millar Western (0.8 and 0.5 µg/L) and Whitecourt STP (1.2 and 0.5 µg/L) had the highest levels of total and dissolved selenium in treated wastewater, respectively. Both Millar Western and the Town of Whitecourt draw water from the McLeod River, which had elevated levels of selenium. Thus, the higher concentration of selenium in these treated wastewater is likely a result of higher levels in source water.

The long-term Alberta SWQG for selenium is 1 µg/L, and all water samples collected from the Athabasca River and its tributaries during the survey were below this guideline. Treated wastewater were also below this guideline, with the exception of Millar Western (1.5 µg/L) and Whitecourt STP (1.2 µg/L).

Silver

Values for total silver were generally low in the Athabasca River and often not detected: 33% of samples in the Athabasca River and 43 % of samples in tributaries were <0.002µg/L during the survey (Figure 73a). High total silver values were detected upstream of Fort McMurray, and long-term data collected from this LTRN station suggest that this value is uncharacteristically high during winter. Elevated levels of total silver were detected in the Freeman River (1.6 µg/L). Total silver concentrations were also low in treated wastewater, with the exception of Whitecourt STP (0.8 µg/L) and Slave Lake STP (0.4 µg/L).

Dissolved silver concentrations were also very low in the Athabasca River and its tributaries with many sample sites <0.001 µg/L (60% and 57% of samples, respectively; Figure 73b). Similar to total silver, dissolved silver was lower in the Upper Athabasca compared to the Lower Athabasca (Figure 73b) Dissolved silver concentrations were high in treated wastewater from Slave Lake STP (0.12 µg/L), HCE (0.03 µg/L), and Fort McMurray STP (0.04 µg/L).

The long-term Alberta SWQG for total silver is 0.1 µg/L. This guideline was exceeded at one location in the Athabasca River (upstream of Fort McMurray) and the Freeman River. Treated wastewater from Whitecourt STP, Slave Lake STP, and Fort McMurray STP also exceeded the long-term Alberta SWQG.

Strontium

Total and dissolved strontium displayed a similar spatial pattern along the length of the Athabasca River, and the majority of strontium was in the dissolved form. Concentrations were low in Jasper National Park and increased upstream of Hinton and then continuously declined to the terminus of the river (Figure 74). Total and dissolved strontium values decreased downstream of the Clearwater River. Concentrations of total and dissolved strontium in treated wastewater were similar to ambient levels.

There are no Alberta or Canada SWQGs for total or dissolved strontium.

Thallium

Total thallium concentrations in the Athabasca River ranged between <0.0009 to 0.031 µg/L and were highly associated with TSS (r = 0.95; Figure 75a). Concentrations of total thallium in the tributaries were similar to the mainstem and ranged from <0.0009 to 0.013 µg/L. Wastewater concentrations of total thallium were also low, with the exception of Whitecourt STP (0.17 µg/L).

Dissolved thallium concentrations in the Athabasca River were relatively low and ranged from <0.0004 to 0.005 µg/L and displayed no longitudinal pattern. Dissolved thallium values were also relatively low in tributaries and often lower than the mainstem, except Lesser Slave and House rivers (Figure 75b). Treated wastewater also had low concentrations of dissolved thallium, although ANC had elevated levels compared to other wastewater sources (Figure 75b).

The long-term Canada and Alberta SWQG for total thallium is 0.8 µg/L. This guideline was not exceeded in the ambient environment or treated wastewater during the survey.

Thorium

Total thorium concentrations were relatively low in the Athabasca River and ranged between 0.006 to 0.8 µg/L (Figure 76a). Increases in total thorium occurred upstream of Hinton, upstream of the Freeman River, and ~700 km downstream at the Town of Athabasca. Total thorium was highly correlated with TSS during the survey (r = 0.95), which is likely the cause of these increases. Total thorium levels were low in the tributaries and treated wastewater, with the exception of Whitecourt STP (2.6 µg/L).

Concentrations of dissolved thorium were also low (range = 0.004 to 0.07 µg/L; Figure 76b), with increases occurring upstream of Hinton and near the town of Athabasca (~700 km downstream). These increases coincided with increases in total thorium (Figure 76a). Similar to total thorium, dissolved thorium values were low in tributaries and treated wastewater, although Whitecourt STP had elevated levels (0.4 µg/L).

There are no Alberta or Canada SWQGs for total or dissolved thorium.

Tin

Total tin concentrations in the Athabasca River ranged between 0.007 and 0.1 µ/L and showed no overall spatial pattern along the length of the Athabasca River (Figure 77a). Total tin concentrations were low in most tributaries, but elevated in Buffalo Creek (0.2 µg/L). Treated wastewater from HCE (1.4 µg/L), Millar Western (2.7 µg/L), and SLP (1.2 µg/L) had high concentrations of total tin.

Dissolved tin showed a high degree of variation, ranging from 0.006 to 0.6 µg/L. Values of dissolved tin were relatively low in Jasper National Park and increased markedly downstream of HCE. Levels of dissolved tin decreased along the length of the river but did not reach upstream background levels until the terminus of the river. Concentrations of dissolved tin in the tributaries were often lower than the mainstem and had no discernible influence on water quality. Treated wastewater from HCE (1.3 µg/L) and Millar Western (1.8 µg/L) were relatively high (Figure 77b). The large mass load of dissolved tin from HCE (112 g/day) resulted in an increase in dissolved tin in the Athabasca River.

There are no Alberta or Canada SWQGs for total or dissolved tin.

Titanium

Total titanium concentrations ranged from 1.0 to 15.8 µg/L, and increased slightly from upstream to downstream (Figure 78a). Notable increases in total titanium occurred upstream of Hinton and upstream of the Freeman River. These increases are likely a result of elevated TSS, as total titanium and TSS showed a high correlation (r = 0.70). Concentrations of total titanium in tributaries ranged from 0.7 to 10.1 µg/L (Figure 78a). Treated wastewater from Whitecourt STP had a notably high concentration of total titanium (42 µg/L); although, there was no concomitant increase in ambient water quality downstream of the facility during the survey.

Dissolved titanium ranged from 0.4 to 1.4 µg/L and increased slightly from upstream to downstream (Figure 78b). Dissolved titanium concentrations were lower in the Upper Athabasca tributaries compared to Lower Athabasca, suggesting that the increasing pattern in titanium may reflect natural changes in geography. High concentrations of dissolved titanium were present in Millar Western (31 µg/L) and Syncrude (26 µg/L) treated wastewater during the survey.

There are no Alberta or Canada SWQGs for total or dissolved titanium.

Uranium

Both total and dissolved uranium displayed similar spatial patterns along the length of the Athabasca River and decreased slightly from upstream to downstream (Figure 79). Most of the uranium was in the dissolved form. Concentrations were relatively high in Jasper National Park and increased slightly to 400 km downstream, and then decreased until the end of the river. Concentrations of uranium markedly decreased downstream of the Clearwater River, owing to the diluting effect (Figure 79).

Tributaries in the Upper Athabasca had higher concentrations of uranium compared to tributaries in the Lower Athabasca, likely reflecting differences in regional geology. Treated wastewater from Whitecourt STP (1.7 µg/L and 0.8 µg/L), SLP (3.7 µg/L and 2.9 µg/L), and Suncor (1.2 and 1.1 µg/L) had elevated levels of total and dissolved uranium, respectively, compared to the ambient environment.

The Alberta and Canada short-term and long-term SWQG for total uranium is 33 and 15 µg/L, respectively. These guidelines were not exceeded in any samples collected during the survey.

Vanadium

Concentrations of total vanadium ranged from 0.05 to 2.8 µg/L and increased slightly from upstream to downstream (Figure 80a). Increases in total vanadium occurred upstream of Hinton and the Freeman river, likely associated with high levels of TSS (r = 0.95). Tributaries in the Upper Athabasca had lower concentrations of total vanadium than tributaries in the Lower Athabasca (Figure 80a). The highest concentration of total vanadium occurred in the La Biche River (1.9 µg/L), which also had the highest concentration of TSS. Concentrations of total vanadium were relatively low in treated wastewater, except Whitecourt STP (15.9 µg/L).

Dissolved vanadium ranged from 0.01 to 0.2 µg/L and exhibited an increasing pattern from upstream to downstream (Figure 80b). Concentrations of dissolved vanadium in the tributaries ranged from <0.02µg/L (Miette River) to 0.3 µg/L (Buffalo Creek). Dissolved vanadium in treated wastewater from SLP was very high (9.5 µg/) compared to discharge from HCE (1.2 µg/L), ALPAC (1.3 µg/L), and Syncrude (1.4 µg/L). Inputs of dissolved vanadium from HCE (106 g/day) likely resulted in an increase in dissolved vanadium levels in the Athabasca River directly downstream.

There are currently no Alberta or Canada SWQGs for vanadium; however, a federal long-term guideline value of 120 µg/L has been proposed[8]. This proposed guideline was not exceeded in any samples collected during the survey.

Zinc

Concentrations of total zinc were relatively low and generally displayed a narrow range of variation, except notable increases that occurred upstream of Hinton, upstream of the Freeman River, upstream of the House River, and at the very end of the river (Figure 81a). Following each sharp increase, total zinc concentrations quickly returned to upstream background levels. Total zinc concentrations measured in 2015 were lower than previous surveys and less varying, but all data showed an increase in zinc upstream of Hinton and the Freeman River (Figure 82). Increases in total zinc at 987 km and 1380 km downstream were not detected in the previous surveys. These data points are above the 90th percentile for total zinc concentrations in February measured at the LTRN stations located upstream of Fort McMurray (1136 km downstream) and Devil's Elbow (1380 km downstream).

Overall zinc levels were poorly correlated with TSS (r = 0.07); however, removal of the two major increases in total zinc at 987 km and 1380 km downstream increased the association (r = 0.59). Thus, the first two increases in zinc levels are likely associated with TSS and the latter two a result of sample contamination. Noton & Saffran (1995) also suggested that total zinc concentrations were likely related to flow and suspended solids, and that occasional contamination complicated the dataset. Although, QAQC data from the 2015 survey did not show high levels of contamination in trip or field blanks, or large variation between duplicates.

[8] http://www.ec.gc.ca/ese-ees/default.asp?lang=En&n=48D3A655-1

Total zinc concentrations in tributaries were relatively low and similar the mainstem; ranging from 0.3 (Berland River) to 5.7 µg/L (Ells River). Both Millar Western and Whitecourt STP had high concentrations of total zinc in their treated wastewater (278 and 186 µg/L, respectively).

Dissolved zinc displayed greater variability and an overall increase from upstream to downstream, with noticeable increases occurring upstream of the Freeman River, downstream of ALPAC, and at the end of the river (Figure 81b). Similar to total zinc, the measure of dissolved zinc at 1380 km downstream (27.1 µg/L) is well above the 99th percentile and outside the range of historical data recorded at the Devil's Elbow LTRN station. Therefore, this data point likely represents an outlier and potential sample contamination.

Tributaries within the Lower Athabasca had higher concentrations of total zinc than in the Upper Athabasca, with the exception of the Lesser Slave River. Treated wastewater from Millar Western had a high concentration of dissolved zinc (117 µg/L), and may have caused an increase in dissolved zinc downstream (Figure 81b). SLP also had a high concentration of dissolved zinc (495 µg/L), which may explain the high levels of dissolved zinc in the Lesser Slave River.

Alberta and Canada long-term SWQGs for the protection of aquatic life for zinc is 30 µg/L. This guideline was exceeded in the Athabasca River at 1380 km downstream, although this data point appeared to be a spatial outlier (Figure 82) and was outside the range of natural variation at this location for the month of February. Wastewater samples collected from ANC (39.5 µg/L), Millar Western (278 µg/L), Whitecourt STP (186 µg/L), Athabasca STP (58.2 µg/L), ALPAC (47.14 µg/L), Fort McMurray STP (49.8 µg/L), Slave Lake STP (52.7 µg/L), and SLP (596 µg/L) were also above this guideline.

Organic Constituents

Organic Carbon

Total and dissolved organic carbon (TOC and DOC) displayed a similar longitudinal pattern along the Athabasca River, and most of the TOC was made up of DOC (Figure 83a and Figure 84a). Ranging from <0.5 to 13 mg/L, organic carbon values were low in Jasper National Park and increased along the length of the Athabasca River. Mass loads of organic carbon were relatively constant from 200 to 600 km downstream, and then increased linearly to the end of the river (Figure 83b and Figure 84b). Notable increases in organic carbon content occurred downstream of HCE and the Pembina River.

Tributary concentrations of TOC and DOC ranged from <0.5 to 39 mg/L and <0.5 34 mg/L, respectively. Tributaries in the Lower Athabasca had higher concentrations of TOC and DOC than the Upper Athabasca, likely associated with extensive peatlands that supply terrestrial inputs of carbon into rivers and streams in that area.

TOC and DOC in treated wastewater ranged from 5 to 280 mg/L and 5 to 220 mg/L, respectively. HCE contributed 6.3 tonne/day of TOC and 4.9 tonne/day of DOC to the Athabasca River (Figure 83b and Figure 84b), which had a notable impact on water quality in the ambient environment. The Pembina, Lesser Slave, La Biche, Clearwater, and Firebag rivers also contributed high loads of organic carbon to the Athabasca River (Appendix B).

Total and dissolved organic carbon measurements collected during the 2015 survey were similar to previous surveys (Figure 85 and Figure 86). All data showed an increase in organic carbon downstream of HCE and another increase in organic carbon downstream of the Lesser Slave River. The large increase in TOC and DOC at 625 km downstream in 2015 was not similar to previous years.

There are no Alberta or Canada SWQGs for organic carbon.

Resin and Fatty Acids

Resin and fatty acids are carboxylic acids with lipophilic characteristics that occur naturally in tree wood and bark and are transferred to process waters during pulp and paper activities (Taylor, et al., 1988). Fatty acids are open long chains and resin acids have a tricyclic diterpenoids structure (Morales, et al., 1992). There are eight resin acids commonly found in pulp and paper effluents: abietic, dehydroabietic, neoabietic, pimaric, isopimaric, sandaracopimaric, levopimaric, and palustric acids (Taylor, et al., 1988). Both resin and fatty acids are potentially toxic to fish (Ali & Sreekrishnan, 2001).

All resin acids were below the method detection limit (<0.01 mg/L) in the Athabasca River and its tributaries. All treated wastewater also had concentrations of resin acids that were <0.01 mg/L, except for HCE that had low levels of pimaric acid (0.013 mg/L).

Fatty acids were also below method detection limits (<0.1mg/L for stearic and palmitic acids, and <0.01 mg/L for all other fatty acids) in the Athabasca River and its tributaries, except for one sample ~250 km downstream where low levels of linoleic (0.107 mg/L), linolenic (0.024 mg/L), and oleic (0.03 mg/L) acid were detected. Several fatty acids were detected in treated wastewater sources, most in very low levels that were slightly above the method detection limit. Linoleic acid was most commonly detected, with values ranging from <0.01 mg/L to 0.79 mg/L. Whitecourt STP had that highest concentration of oleic (1.4 µg/L), palmitic (2 µg/L), and stearic (1.5 µg/L) acids. Palmitic and stearic acids are commonly found in cell membranes and the membranes of microorganisms, and could reflect bacterial cultures used for biodegradation.

Alberta has an interim SWQG for total resin acids and dehydroabietic acid (DHA), the most common and toxic resin acid (because it can form chlorinated derivatives). The water quality guideline varies with pH. For water with pH ranges between 7.0 and 8.2 (Figure 6), the guideline for DHA is 12 to 14 µg/L and total other resin acids is 25 to 60 µg/L. All samples collected during the survey (mainstem, tributary, and effluent) were below these guidelines. There are no SWQGs for fatty acids.

Phenolic Material

Phenols and phenolic substances are aromatic organic compounds with hydroxyl groups attached to an aromatic benzene ring and are either monohydric, dihydric, or polyhydric (CCME, 1999d). Pulp and paper activities are a major source of phenols, as well as other industrial activities, domestic sewage, and the natural breakdown of aquatic vegetation. Phenols are toxic to aquatic life and can also be responsible for flavour tainting in fish tissue.

Phenol concentrations in the Athabasca River were generally at or below the method detection limit (<2 µg/L; Figure 87). A few notable increases in phenol concentrations occurred downstream of Hinton, upstream of Fort McMurray, and the last sample point along the river. Phenol concentrations in tributaries were also <2 µg/L. Phenol concentrations in wastewater ranged between 3.8 µg/L and 55 µg/L, with Hinton (0.75 kg/day), Millar Western (0.49 kg/day), and ALPAC (0.57 kg/day) having the highest loading to the Athabasca River (Figure 87; Appendix B). Contributions of phenols from treated wastewater did not appear to impact water quality in the Athabasca River during the survey.

Concentrations of total phenolic compounds were much lower during the 2015 survey compared to the previous surveys conducted in 1990-1993 (Figure 88). All synoptic surveys showed an increase in total phenols downstream of HCE, Athabasca, and Fort McMurray. The previous surveys also reported higher concentrations of total phenols in the tributaries, especially the Lesser Slave River (Noton & Saffran, 1995); however, total phenol levels in the tributaries were below or slightly above the MDL in 2015.

The Alberta SWQG for phenols (mono- and dihydric) is 4 µg/L. Water samples collected from the Athabasca River and its tributaries during the survey were below this guideline, although, most wastewater samples were above the guideline value.

Chlorinated Phenolic Compounds

Chlorophenols are phenolic compounds that have one or more bonded chlorine atoms. Chlorinated phenolic compounds in pulp and paper effluent are produced from the reaction of bleaching chemicals with lignin (LaFleur, 1996), although improvements in pulp bleaching technology have reduced the concentrations of chlorinated organic compounds in wastewater (NRBS, 1996; Servos, 1996; Verta, et al., 1996). There are two bleached Kraft pulp mills in the Upper Athabasca that produce both hardwood and softwood pulp: Hinton and ALPAC. Chlorination of sewage and drinking water that contain phenols can also produce chlorinated phenolic compounds. Chlorophenolic compounds are of importance and of interest owing to their toxicity, general recalcitrant nature, potential for bioaccumulation, and potential to cause tainting of fish tissue and odour problems (Hatfield, 2014).

Chlorophenols were not detected above the method detection limit (<0.0001 mg/L) in the Athabasca River and its tributaries. Trace amounts of chlorovanillin was detected in wastewater from both Hinton and ALPAC, and trace amounts of chloroguaiacol and chlorosyringaldehyde were detected in Hinton and ALPAC wastewater, respectively.

An Alberta SWQG exists for each type of chlorophenol, based on the number of chlorines: mono = 7 µg/L; di: 0.2 µg/L; tri: 18 µg/L; tetra: 1 µg/L; and penta: 0.5 µg/L. All of the samples collected during the survey were below these guideline levels.

Adsorbable Organic Halides

Adsorbable organic halide (AOX) refers to the amount of organic compounds containing halogen atoms, principally chloride but also bromide, iodide, and fluoride (Noton, 1990). AOX is commonly used as a measure of total chlorinated organic material. The major component of AOX in bleach kraft mill effluent is chlorinated lignin, which is fairly non-toxic. Although other chlorinated components are toxic, persistent in the environment, and bioaccumulate (Noton & Saffran, 1995; Enell, 1996). Vera et al. (1996) report a high correlation between AOX and toxicity, although this may be due to its high intercorrelation with phenols and chemical oxygen demand. AOX can come from both natural and anthropogenic sources, including direct discharge, surface runoff, and atmospheric deposition (Enell, 1996).

AOX concentrations in the Athabasca River were <0.01 mg/L in Jasper National Park and increased downstream of HCE (Figure 89). AOX concentrations remained variable along the length of the Athabasca River, ranging from <0.01 mg/L to 0.07 mg/L, and displayed a longitudinally decreasing trend, with the exception of a peak in AOX upstream of the Firebag River. Noton & Saffran (1995) suggest AOX is correlated to DOC, yet a very low association was found during the survey (r = 0.13).

AOX concentrations in tributaries were slightly above the MDL and generally lower than the mainstem, with the exception of Steepbank River (0.7 µg/L; Figure 89). Concentrations of AOX in treated wastewater ranged from <0.01 mg/L (Fort McMurray STP) to 1.9 µg/L (HCE).

Concentrations of AOX measured in 2015 were much lower than previous surveys (Figure 90). All surveys showed an increase in AOX concentrations downstream of HCE; although, this increase was much lower in magnitude in 2015. The total mass load of AOX from HCE was much lower in 2015 compared to the previous surveys (Table 5).

Table 5. Mass load of AOX (kg/day) from HCE during all winter synoptic surveys (1990-1993, 2015)

Year	HCE AOX load
1990	230 kg/day
1991	1,188 kg/day
1992	1,367 kg/day
1993	1,334 kg/day
2015	166 kg/day

There are no Canada or Alberta SWQGs for AOX.

Priority Pollutants

A total of 112 other trace organic priority pollutants, including volatile and extractable groups, identified on *The Canadian Environmental Protection Act (CEPA)* published Priority Substance List were also analyzed. These organic chemicals are considered to be toxic to both aquatic and human life and constitute a danger to human health.

The majority of priority pollutants were not detected in the Athabasca River and its tributaries; the few that were are listed in Table 6. Di-n-butyl phthalate was detected at six sites in the Athabasca River and eight tributaries, although the concentrations detected were very close to the MDL (<0.1 to <0.4 µg/L). Chloroform was detected at one site, with a value slightly above the MDL (0.2 mg/L). Bis(2-ethylehexyl) phthalate (DEHP, also known as di[2-ethylhexyl] phthalate) was detected at many sites along the Athabasca River and its tributaries, at varying concentrations (Figure 91).

More priority pollutants were detected in wastewater than in the ambient environment. Wastewater from Whitecourt STP, Athabasca STP, and Slave Lake STP had more than five types of priority pollutants detected (18, 6, and 8, respectively). Most sample detections were slightly above the MDL with the exception of phenol (1.4 µg/L – Millar Western), naphthalene (1.1 µg/L – Whitecourt STP), tetrachloroethylene (3.3 µg/L – Slave Lake STP), toluene (5.6 µg/L – Whitecourt STP), and DEHP (see below).

Di-n-butyl phthalate (DBP) was measured above the MDL in one field blank and one trip blank, and duplicate samples show large divergence with concentrations occurring above and below the MDL. Chloroform was also detected in 7 out of 8 field blanks, but duplicate samples were similar. DEHP was detected in 5 out of 8 field blanks and one replicate sample showed high variance in values (sample = 0.5 µg/L, duplicate= 20.5 µg/L). Thus, detections of di-n-butyl phthalate and chloroform in the ambient environment are likely spurious, owing to the close proximity to the MDL and detections in QA/QC samples. The high variance of DEHP noted in QA/QC samples places less reliance on the high values detected in the basin (Figure 91). Furthermore, the Government of Canada (1994) found that phthalates frequently occur as contaminants in laboratory air, solvents, and as plasticizers in analytical equipment that may cause contamination of environmental samples and result in overestimated concentrations of phthalates.

The Alberta SWQG for the long-term exposure of DEHP is 16 µg/L. This guideline was exceeded in one sample in the Athabasca River (23.5 µg/L) and Calling River (47.1 µg/L). All sample detections of DPB were well below the Alberta SWQG of 19 µg/L. Similarly, the detection of chloroform in one sample was well below the Alberta SWQG of 1.8 µg/L.

Table 6. Detection of priority pollutants in the Athabasca River and its tributaries during the 2015 winter synoptic survey

Parameter	No. of Sampling Sites >MDL*	Concentration Range	Method Detection Limit	Detected in QA/QC samples
Butylbenzyl Phthalate	1[a]	1.2 µg/L	0.1 µg/L	No
Di-N-Butyl Phthalate (DBP)	6 (8)	0.2 – 0.5 µg/L	0.1 µg/L	Yes
Di-N-Octyl Phthalate (DOP)	1[a]	3 µg/L	0.1 µg/L	No
Bis(2-ethylhexyl) Phthalate (DEHP)	37 (20)	0.2 – 47.1 µg/L	0.1 µg/L	Yes
Chloroform	1[b]	0.2 µg/L	0.1 µg/L	Yes

[a]Atha R @ Vega Ferry
[b]Atha R downstream Whitecourt STP
*Values in brackets indicate number of tributaries that exceed the method detection limit.

Phthalates

Most priority pollutants detected in the basin were phthalates, a group of chemicals that are used to make plastics (e.g. polyvinyl chloride (PVC)) more flexible (USEPA, 2000; European Joint Research Commission, 2008; Hatfield, 2014). DEHP is the most important plasticizer used in Canada, and released into the environment from manufacture and industrial uses (Environment Canada, 1994; CCME, 1999c). DEHP has also been detected in Canadian municipal wastewater, textile mills, coal mines, coal preparation plants, coal storage transfer terminals, and landfill leachate (Environment Canada, 1994; CCME, 1999c; Sosiak & Hebben, 2005). According to the Nation Pollutant Release Inventory (NPRI), 0.374 tonnes of DEHP were released to the atmosphere in 2014, although no releases were recorded from industries located in Alberta.

Phthalates degrade in aerobic environments, but adsorb strongly to soil and sediments and are more persistent in anaerobic conditions (Environment Canada, 1994; European Joint Research Commission, 2008). Phthalates are endocrine disruptors, although more research is required to fully understand acute and chronic toxicity impacts on aquatic ecosystems, especially sediment dwelling organisms (Environment Canada, 1994; European Joint Research Commission, 2008).

DEHP concentrations in the Athabasca River were generally low (Figure 91). Three notable peaks in DEHP occur along the length of the Athabasca River, and DEHP appears to increase towards the Athabasca Delta, with the most downstream sample site detecting an elevated concentration of 23.5 µg/L (Figure 91). Concentrations of DEHP detected in the tributaries were low, ranging between 0.2 to 2.4 µg/L, except one sample from the Calling River that had a concentration of 47.1 µg/L. DEHP was also detected in most wastewater samples and ranged from <0.1 µg/L to 10.5 µg/L (Figure 91). Treated wastewater locations do not coincide with peaks in DEHP in the Athabasca River. As discussed above, these data are not reliable or accurate and should therefore be evaluated with caution.

Total Recoverable Hydrocarbons

Hydrocarbons are organic compounds consisting of carbon and hydrogen atoms, that can be in a straight-chain, branched-chain, or cyclical. There are hundreds of hydrocarbons that are sub-divided into fractions according to specific ranges of equivalent carbon number (CCME, 2008): F1 (C6 to C10); F2 (>C10 to C16); F3 (>C16 to C34); and F4 (C34+). Benzene, toluene, ethylbenzene, and xylene, given the acronym BTEX, are volatile organic compounds that are common hydrocarbon contaminants in soil and groundwater. F1 and F2 fractions are composed of lighter more volatile hydrocarbons that are often constituents of gasoline, diesel, kerosene, and jet fuel (CCME, 2008; Hatfield, 2014). F3 and F4 fractions are composed of heavier hydrocarbons that are less volatile often found in lubricants, heavy fuel oils, waxes, asphalt, and also occur naturally in organic matter (CCME, 2008; Hatfield, 2014).

BTEX and F1 and F2 hydrocarbons were not detected in the Athabasca River or its tributaries. Elevated levels of F3 hydrocarbons were detected at three sites in the Athabasca River and two tributaries (Figure 92). F4 hydrocarbons were detected at two sites in the Athabasca River, but not in the tributaries (Figure 92). These detections were not consistently downstream of treated wastewater locations and may reflect natural origins.

Benzene and F1 hydrocarbons were not detected in any wastewater samples. Toluene, ethylbenzene and xylene were detected in Whitecourt STP wastewater. All wastewater samples, except ALPAC, had elevated levels of F2, F3, or F4 hydrocarbons (Figure 93). Wastewater from Whitecourt STP had high concentrations of hydrocarbons, and both HCE and Whitecourt STP wastewater contributed high loads of F2, F3, and F4 hydrocarbons into the Athabasca River (Figure 93).

Long-term SWQG for benzene (40 µg/L), toluene (0.5 µg/L), ethylbenzene (90 µg/L), and xylene (30 µg/L) were not exceeded in the Athabasca River or its tributaries during the survey. Alberta SWQGs for F1 and F2 petroleum hydrocarbon fractions are 150 µg/L and 110 µg/L, respectively. These guidelines were also not exceeded in the Athabasca River or its tributaries; although, the F2 guideline was exceeded in wastewater from HCE, Whitecourt STP, and Slave Lake STP. SWQGs do not exist for F3 and F4 petroleum hydrocarbon fractions.

BTEX and F1-F4 hydrocarbons were not detected in trip or field blanks samples and duplicate QA/QC samples were similar.

Alkylated Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds that have fused aromatic carbon rings, and alkylated PAHs are PAHs with various alkyl groups attached. PAHs in the environment can be generated petrogenically (erosion of bituminous geologic formations), pyrogenically (combustion of fuel such as wood, grass, coal, diesel), and diagenically (microbial degradation) (Birks, et al., 2013; Hatfield, 2014). There are hundreds of PAHs in the environment, and they are currently one of the greatest concerns for chronic pollution associated with oil sand development in the Lower Athabasca (Schindler, 2013), owing to their potential for carcinogenic, mutagenic, and teratogenic effects (Birks, et al., 2013). Alkylated PAHs comprise the majority of PAHs associated with bitumen, and thus activities within the Lower Athabasca (Hatfield, 2014).

The majority of PAHs were not detected in the Athabasca River and its tributaries; the few that were are listed in Table 7. All PAHs detected in the Athabasca River were at very low levels, and all sample sites were located within the Upper Athabasca. Several PAHs were detected in Ells River, and one or two PAHs were detected in Maskuta Creek, Oldman Creek, Plante River, Lesser Slave River, and Calling River.

Table 7. Alkylated PAHs detected above the method detection limit in the Athabasca River and its tributaries during the 2015 winter synoptic survey.

Parameter	No. of Sampling Sites >MDL*	Concentration (µg/L)	Method Detection Limit (µg/L)
2-Methyl-n-phthalene	1	0.03	0.01
Anthracene	3	0.02	0.01
Benzo(B,J,K) fluoranthene	2 (2)	0.02	0.01
C3-naphthalene	1	0.02	0.01
Retene (7-isopropyl-1-methylphenanthrene)	2 (3)	0.006 – 0.045	0.002
C1-chrysene	(1)[a]	0.02	0.01
C1-fluorene	(1)	0.05	0.01
C2-chrysene	(1)[a]	0.02	0.01
C2-di-benzothiophene	(1)[a]	0.02	0.01
C2-fluoranthene/pyrene	(1)[a]	0.02	0.01
C3-chrysene	(1)[a]	0.02	0.01
C3-di-benzothiophene	(1)[a]	0.05	0.01
C3-fluoranthene/pyrene	(1)[a]	0.02	0.01
C3-phenanthrene/anthracene	(1)[a]	0.02	0.01
C4-phenanthrene/anthracene	(1)[a]	0.02	0.01

[a]Ells River
*Values in brackets indicate number of tributaries that exceed the method detection limit.

Similar to priority pollutants, far more PAHs were detected in industrial and municipal treated wastewater than the ambient environment. Over 40 alkylated PAHs were detected (equal to greater than the MDL) in Whitecourt STP and over 20 were detected in Millar Western's wastewater. Slave Lake STP wastewater had 19 different compounds of PAHs. Other treated wastewater had less than 10 PAHs detected, while wastewater from ANC, ALPAC, and Suncor had zero detection of PAHs. Concentrations of PAHs in wastewater were generally low, with the exception of Whitecourt STP that had high levels of some PAHs, especially naphthalene derivatives (e.g., C2-naphthalene = 8 µg/L and C3-naphthalene = 12 µg/L).

PAHs were not detected in field or trip blank samples, and duplicate samples did not show large deviations in values. Alberta SWQGs exist for a variety of PAHs, all of which were not exceeded except for anthracene. The long-term SWQG for anthracene (0.012 µg/L) was exceeded at three locations in the Athabasca River (203, 223, and 250 km downstream), although concentrations at these locations were slightly above the MDL (Table 7).

Naphthenic Acids and Oilsands Acid Extractable Organics

Naphthenic acids (NAs) are complex group of acids, chiefly monocarboxylic, derived from naphthenes that are a natural component of petroleum and common by-product of oil sands production frequently found in oil sands tailings (Clemente & Fedorak, 2005; Hatfield, 2014). NAs have traditionally been given the formula $C_nH_{2n+z}O_2$, however recent analysis has revealed the presence of other organic acids suggesting that the classification and analysis of NAs is much more complex (Grewer, et al., 2010). To address the issue regarding analysis of NAs, AEP has been measuring "oilsands acid extractable organics" (AEOs).

NAs and AEOs in the ambient environment were only measured at LTRN and MTRN stations in the Upper Athabasca, and at all sampling sites in the Lower Athabasca because these acids are of primary concern to oil sands operations in that region. Similarly, NAs and AEOs were only measured in wastewater samples within the Lower Athabasca. NAs measured in the Upper Athabasca were <0.02 mg/L and appear in the Athabasca River approximately 930 km downstream (Figure 94). Similarly, concentrations of AEOs were <0.1 mg/L upstream of Hinton, but were detected downstream of the Freeman River (~538 km downstream) and further downstream along the length of the Athabasca River. Concentrations of NAs and AEOs were much higher in tributaries than the mainstem. Oilsands wastewater had high concentrations of NAs and AEOs, and Fort McMurray STP had elevated concentrations of AEOs (Figure 94). These elevated levels of NAs and AEOs in wastewater may reflect high concentrations in the intake water.

There are no Alberta or Canada SWQGs for NAs or AEOs.

Pesticides

Pesticides were measured at the LTRN and MTRN sites (Table 1) and no pesticides were detected in the Athabasca River or the Lesser Slave River.

Biotic Variables

Pathogens

Patterns of coliforms (total, fecal, and *E. Coli*) were similar during the survey. Counts were low in the upper portion of the river, and high counts were detected downstream of Millar Western and Whitecourt STP, which gradually decreased and remained low along the length of the Athabasca River (Figure 95). Although total coliform counts decreased downstream of Whitecourt, the decline is much more gradual compared to fecal coliforms and *E. coli*, and levels of total coliforms remained slightly higher at the terminus of the river than in the headwaters.

Total coliforms were generally low in tributaries, except for the Pembina, Lesser Slave, La Biche, and Calling rivers, all of which had counts over 150/100 mL (Figure 95). Both fecal coliforms and *E. coli* were low and often at or below the limit of detection in all of the tributaries. Levels of bacteria were elevated in most treated wastewater, with the exception of Jasper STP, Fort McMurray STP, and Suncor. Millar Western and Whitecourt STP had excessive amounts of total and fecal coliforms and *E. coli* (all values for both wastewater sources were recorded as greater than 100,000/100mL). High levels of bacteria in these treated wastewaters likely led to an increase in bacteria counts in the Athabasca River within the Whitecourt area (Figure 95).

Values of total coliforms are somewhat difficult to interpret since many of the values were recorded as being "greater than" and "less than" the actual recorded value. Figure 96 below shows the counts of bacteria that were recorded as being "greater than" or "less than" the recorded value. The ability to enumerate consistent detection sizes of bacteria depend on the dilution series that were used to prepare the samples (personal communication, Cheryl Hilner, Alberta Health Services). Nonetheless, the data show that treated wastewater from Millar Western and Whitecourt STP may be having an impact on bacteria counts in the Athabasca River near Whitecourt.

There is no Alberta SWQG for the protection of aquatic life for coliforms. The Alberta SWQG for recreation and aesthetics for *E. coli* is 126/mL (note that this is a geometric mean and consecutive sampling on a daily or weekly basis is required). This guideline was exceeded downstream of Whitecourt from 406 to 425km downstream, and water quality returned to compliance by 492 km downstream. The Health Canada guideline for Canadian Recreational Water Quality, for primary contact, is ≥400 *E.coli*/100 mL in a single-sample, which was also exceeded 406 km downstream.

Chlorophyll-*a*

Chl-*a* values in the Athabasca River ranged from 0.05 to 1.2 mg/m^3, and displayed variability along the length of the Athabasca River (Figure 97). Chl-*a* values were lowest in Jasper Nation Park, as would be expected for low nutrient headwaters, and increased downstream of Hinton and Whitecourt. Chl-*a* values increased downstream of the Calling River and were relatively higher in the Lower Athabasca compared to the Upper Athabasca (Figure 97).

Chl-*a* in the tributaries were similar to the mainstem, ranging from 0.1 to 1.96 mg/m^3, with tributaries in the Upper Athabasca having lower values than tributaries in the Lower Athabasca. Concentrations of chl-*a* were slightly higher in treated wastewater (0.2 to 3.8 mg/m^3).

Values of chl-*a* measured during the 2015 were higher than previous surveys within the upper (~200 to 550 km downstream) and lower (~850 to 1400 km downstream) reaches, while data in the middle reaches (~550 to 850 km downstream) were more similar (Figure 98).

There are no Alberta or Canada SWQGs for chl-*a*.

6. Discussion and Summary

This report summarized the findings from the winter synoptic survey conducted in 2015 and incorporated data collected during previous surveys to compare current data to historical conditions. Results illustrate how spatial trends in water quality along the Athabasca River are influenced by natural transitions in the landscape, as well as inputs from wastewater and tributaries. The results and conclusions in this report only reflect winter conditions and the influence of point-source contributions (wastewater and tributaries) to the Athabasca River during the winter. Seasonally varying flows, climate, and ecosystem processes result in seasonally distributed water quality data. Additional surveys during the open-water season would be required to determine seasonal longitudinal water quality patterns and the cumulative effects of both point-and non-point-source pollution on the Athabasca River.

Longitudinal Water Quality Patterns

Natural longitudinal changes in water quality were anticipated and observed as the Athabasca River traversed across the landscape (Vannote, et al., 1980). In addition to this natural longitudinal enrichment of water quality parameters, special landscape features, inputs from anthropogenic wastewater, and inputs from tributaries resulted in localized increases in many parameters.

- The transition from the Rocky Mountains to the Boreal Forest resulted in a natural enrichment in colour, potassium, sodium, phosphorus, nitrogen, organic carbon, total metals (antimony, boron, barium, cadmium, mercury, lithium, strontium), and dissolved metals (antimony, arsenic, boron, barium, cadmium, cobalt, copper, iron, lithium, nickel, titanium, and vanadium).
- Notable increases in major ions (calcium, magnesium, fluoride, and sulphate), dissolved solids, suspended solids, total phosphorous, and many total and dissolved metals occurred upstream of Hinton. There are no point-source wastewater discharges between downstream of Jasper and upstream of Hinton. The Athabasca River widens immediately east of Jasper National Park to form Brule Lake. Brule Lake is surrounded by an abundance of natural sand dunes and is characterized by very shallow water and fine sediments. Historical data collected at the Old Entrance LTRN station shows that TSS levels are often elevated upstream of Hinton.
- Data collected during the survey also showed increased turbidity and suspended solids upstream of the Freeman River, near Fort Assiniboine. Metals and nutrients associated with suspended solids also exhibited elevated concentrations at this location, but notable increases in dissolved silver, tin, and zinc as well as a few metals not correlated with suspended solids (cadmium, copper, silver, and tin) also occurred. The Athabasca River widens downstream of the Freeman River and velocity in the river declines. Owing to this widening and reduction in flow, ice jams commonly occur in this is area. Bottom scour of ice could have increased levels of turbidity and suspended solids. Significant aggregate activities occur near the Fort Assiniboine/Freeman River area owing to rich sand and gravel deposits,[9] which could also influence suspended solid levels and potentially groundwater contributions to the Athabasca

[9] http://ags.aer.ca/document/MAP/MAP_505.PDF

River. Changes in water quality and the associated cause in this area require further investigation and understanding.

- Inputs from tributaries and wastewater (discussed below) influenced water quality along the length of the Athabasca River. The Clearwater River had the largest influence on water quality in the Athabasca River and can cause an increase in concentrations of some variables (e.g., sodium, chloride, sulphate, total nitrogen, iron, and manganese), or have a diluting effect and lower the concentration of others (e.g., calcium, magnesium, potassium, bicarbonate, antimony, barium, cadmium, copper, molybdenum, strontium, and uranium).
- Data comparisons between the 2015 and 1990-1993 surveys indicated that most parameters had similar concentration ranges and spatial patterns. Exceptions to this generalization include potassium, total nitrogen, and total arsenic that had higher levels in 2015 within the Lower Athabasca compared to previous surveys.
- Total aluminum concentrations in 2015 were higher than the previous surveys along the length of the Athabasca River. Hebben (2009) found a statistically significant increasing trend in total aluminum at Athabasca and Old Fort, although the trend at the Town of Athabasca was not significant when adjusted for flow. Nonetheless, trend analyses for ions, nutrients, and metals is warranted given the elevated levels in comparison to previous studies and increases reported in literature (Squires, et al., 2010; Alexander & Chambers, 2016).

Influence of Treated Wastewater on Water Quality over the Past 25 Years

The effects of treated wastewater on water quality are summarized and compared to the results of previous surveys (1990-93) in Table 8. Noton & Saffran (1995) classified a 'slight effect' as observed only once or very small effects seen more than once; a 'moderate effect' as measurable and consistent; and a 'large effect' as an input that resulted in an exceedance of a SWQG, the concentration more than doubled, or the effect was seen in more than one year. Since multiple years of new data are not available to apply these criteria, the 2015 survey data are listed as either having an effect (observed as an increase directly downstream), or no effect.

In general, most of the wastewater effects on bacteria, major ions, nutrients, AOX, dissolved oxygen, colour, and temperature observed during the 1990-1993 surveys were also observed in 2015 (Table 8), indicating water quality has not changed significantly over the past 25 years. During the 2015 survey, colour and total phosphorous were affected by pulp mill wastewater to the extent that they resulted in an exceedance of Alberta or Canada SWQGs directly downstream. Noton & Saffran (1995) indicated inputs of total manganese from pulp mill wastewater had a large effect on water quality; however, elevated levels upstream of Hinton masked any effect in 2015. Dissolved metals were measured during the 2015 survey and revealed that several dissolved metal parameters in the Athabasca River were affected by wastewater inputs. The previous surveys recorded large changes for phenols, chlorinated phenols, resin acids, and trace organics that were not observed during the 2015 survey, indicating an improvement in water quality conditions owing to advancements in technology and wastewater treatment processes within the pulp and paper industry.

Most of the impacts to water quality from treated wastewater occurred downstream of Hinton and Whitecourt, while little to no impact was observed downstream of Athabasca, ALPAC, Fort McMurray, and the oilsands discharges. Hinton and Whitecourt are located within more pristine river conditions (closer to headwaters) that have lower concentrations of most parameters. Large inputs from point-source discharge can have a greater impact because it introduces a sudden contrast to background conditions rather than a small or gradual change. Additionally, flow in the river at these locations is much lower comparted to reaches further downstream, offering less available dilution. It also important to note that the survey design made it challenging to asses impacts of Fort McMurray STP on the Athabasca River owing to the large influence of the Clearwater River, as the sampling location was downstream of the river and sewage treatment plant.

Table 8. Summary of the 2015 Athabasca River winter synoptic survey findings and comparison to 1990-1993 surveys.

Variable	Category	1990-1993	2015 *	Area
Fecal Coliforms	Bacteria	Moderate Effect	Effect	Whitecourt
Total Coliforms	Bacteria	Large Effect	Effect	Whitecourt
Alkalinity	Ions	Slight Effect	Uncertain	-
Bicarbonate	Ions	Slight Effect	Effect	Hinton, Whitecourt
Chloride	Ions	Large Effect	Effect	Hinton, Whitecourt, Fort McMurray
Potassium	Ions	Slight Effect	Effect	Hinton, Whitecourt
Sodium	Ions	Large Effect	Effect	Hinton, Whitecourt, Fort McMurray
Sulphate	Ions	Moderate Effect	Effect	Hinton
Sulphide	Ions	Large Effect	Effect	Hinton, Whitecourt
Total Dissolved Solids	Ions	Slight Effect	Effect	Hinton
(Total) Lead	Metals	Slight Effect	No Effect	-
(Total) Manganese	Metals	Large Effect	Uncertain	-
(Total) Zinc	Metals	Uncertain	No Effect	-
Dissolved Aluminum	Metals	-	Effect	Hinton
Dissolved Boron	Metals	-	Effect	Whitecourt
Dissolved Cadmium	Metals	-	Effect	Whitecourt, Lesser Slave
Dissolved Cobalt	Metals	-	Effect	Jasper, Hinton, Whitecourt
Dissolved Copper	Metals	-	Effect	Hinton, Whitecourt
Dissolved Lead	Metals	-	Effect	Hinton, Whitecourt
Dissolved Manganese	Metals	-	Effect	Hinton, Whitecourt
Dissolved Tin	Metals	-	Effect	Hinton
Dissolved Vanadium	Metals	-	Effect	Hinton, Athabasca (?), Syncrude
Dissolved Zinc	Metals	-	Effect	Hinton, Whitecourt, Athabasca

Ammonia	Nutrients	Large Effect	Effect	Hinton, Whitecourt, Athabasca
BOD	Nutrients	Large Effect	No Effect	BOD effects on DO
Nitrate	Nutrients	Slight Effect	No Effect	-
Nitrite	Nutrients	Slight Effect	No Effect	-
Ortho-phosphate	Nutrients	-	Effect	Hinton, Whitecourt
Phosphorous, Dissolved	Nutrients	-	Effect	Hinton, Whitecourt
Nitrogen, Total	Nutrients	Large Effect	Effect	Hinton, Whitecourt, Athabasca
Phosphorous, Total	Nutrients	Moderate Effect	Effect	Hinton (?), Whitecourt
AOX	Organics	Large Effect	Effect	Hinton
Chlorinated Phenolics	Organics	Large Effect	No Effect	-
Hydrocarbons	Organics	-	Uncertain	Whitecourt
Carbon, Organic	Organics	Large Effect	Effect	Hinton, Whitecourt
Phenols	Organics	Large Effect	No Effect	-
Resin Acids	Organics	Large Effect	No Effect	-
Tanin and Lignin	Organics	Large Effect	Not sampled	-
Trace Organics	Organics	Effect Uncertain	No Effect	-
Colour	Physical	Large Effect	Effect	Hinton
Dissolved Oxygen	Physical	Moderate Effect	Effect	-
Suspended solids	Physical	Slight Effect	No Effect	-
Temperature	Physical	Moderate effect	Effect	All
Turbidity	Physical	Slight Effect	No Effect	-

Winter Dissolved Oxygen

Data from the synoptic surveys revealed a linear decline in DO from headwaters to Grand Rapids, known as the "DO sag" (Noton & Allan, 1994; Noton & Saffran, 1995; Chambers & Mill, 1996). Low winter DO levels has been a long recognized water quality issue in the Athabasca River owing to ice cover that inhibits reaeration, inputs of oxygen-depleted groundwater, and oxidation of natural and anthropogenic organic material. Previous research in the Athabasca River has shown that effluent from pulp mills contributes to the linear decline in DO along the length of the river (Chambers, et al., 1997). The Athabasca River also has a linear decline in DO levels downstream of Grand Rapids, despite the fact that this reach does not receive industrial effluent. Thus, natural sources of organic material can also affect DO declines, and in some cases this affect can be greater than impacts from effluent sources (Chambers, et al., 1997).

Historically, low levels of winter DO occurred during the years 1989, 1993, 1994, 1995, 2002, 2003, 2004, and 2015 upstream of Grand Rapids (measured with data loggers deployed by AEP during the winter). In 2003, this linear drop was about 0.7 mg/L per 100 km (compared to 0.5 mg/L per 100 km in the synoptic surveys), resulting in low dissolved oxygen levels (5.4 mg/L) in the Athabasca River that were below the long-term SWQG (Martin, et al., 2013). These levels remained below guideline levels for a month and significantly impacted the abundance of benthic macroinvertebrate taxa (Chambers, et al., 2006). Considering the potential impact of low DO to fish and other aquatic organisms (lethal and sublethal physiological and behavioural effects), AEP and the pulp and paper industry developed a dissolved oxygen model for the Athabasca River to provide a management tool that can predict low DO events that can be mitigated through management actions (Martin, et al., 2013).

Nutrients

Nutrient levels showed a general increasing pattern from headwater to the delta, as anticipated owing to natural changes in the physical characteristics of the Athabasca River and the terrestrial landscape. Data from the surveys identified several localized zones of nutrient enrichment in the Athabasca River downstream of pulp and paper wastewater outfalls, notably Hinton and Whitecourt. These findings are similar to previous research (Chambers, et al., 2000; Chambers, et al., 2006; Dube, et al., 2006). Nutrient levels were also very high in the La Biche River, which led to a corresponding increase in nutrient levels in the Athabasca River downstream of this inflow. The Northern River Basin Study rated nutrient enrichment as being of high to moderate concern along the length of the Athabasca River, and data from the 2015 suggest that this issue persists.

Total and Dissolved Metals

Metals (total and dissolved) displayed four general patterns in water quality: a) high association with suspended solids, b) an increase in concentrations from upstream to downstream, c) a decrease in concentrations from upstream to downstream, and d) a detectable increase downstream of wastewater inputs. Total metals that were highly associated with suspended solids during the 2015 survey included: aluminum, mercury, beryllium, bismuth, cobalt, chromium, iron, manganese, lead, thorium, titanium, thallium, and vanadium. Many total metals, such as total aluminum, notoriously exhibit seasonal variation associated with suspended solids and flows levels in the Athabasca (North/South Consultants, 2007; Hebben, 2009; Fiera Biological Consulting, 2013). Inputs from treated wastewater at one or more locations along the Athabasca River resulted in a downstream increase in: dissolved aluminum, total barium, total and dissolved boron, total and dissolved cadmium, dissolved cobalt, dissolved manganese, dissolved tin, dissolved vanadium, and dissolved zinc. Inputs of treated wastewater into the Lesser Slave River likely contributed to high levels of dissolved cadmium and dissolved cobalt. Previous reports have found high levels of cadmium in the Lesser Slave River that exceeded water quality guidelines (Noton & Seneka, 2000; Worley Parsons Komex, 2006).

For the most part, metal concentrations in the Athabasca River and its tributaries were below Alberta and Canada SWQGs. Metals in wastewater were high and at least one facility exceeded guideline levels for dissolved aluminum, total cadmium, total chromium, total cobalt, total copper, dissolved iron, total lead, total mercury, total selenium, total silver, and total zinc. Total metal concentrations were especially high in Whitecourt STP wastewater.

Organic Compounds

Low levels of organic compounds were present in the Athabasca River and its tributaries during the winter. The survey indicated that most organic compounds (resin and fatty acids, chlorinated phenolic compounds, priority pollutants, and pesticides) in the Athabasca River were below detection limits, although there were detections of some priority pollutants in wastewater. Total hydrocarbons (F2-F4) were high in municipal wastewater, especially Whitecourt STP.

7. Results Figures

Field Measurements Figures

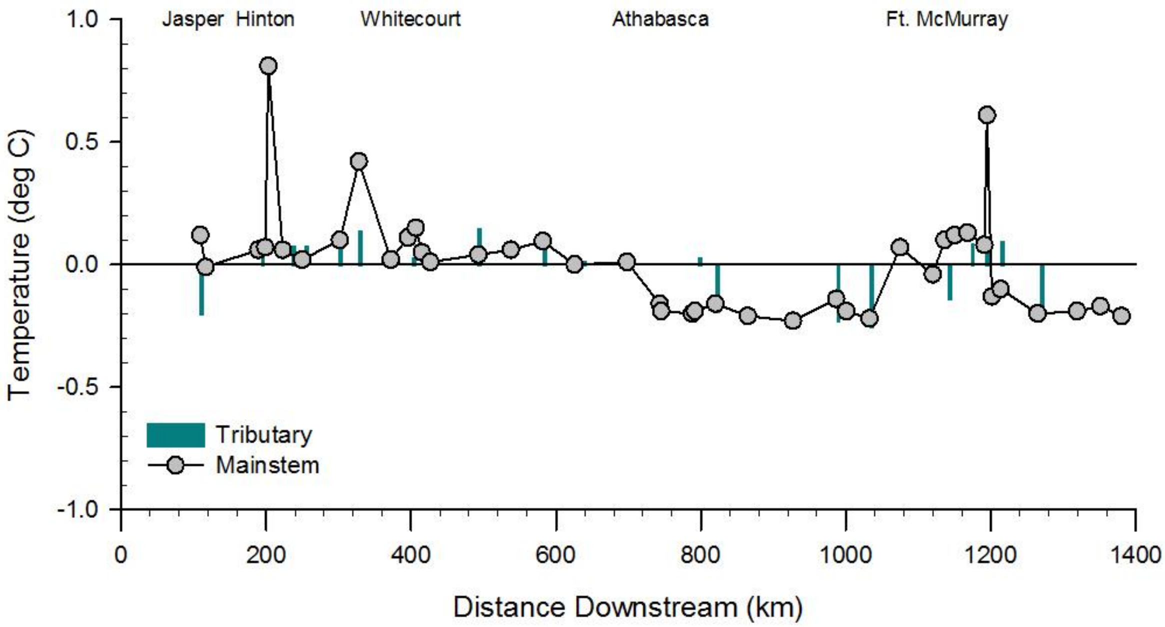


Figure 6. Field measurements of surface water temperature (°C) during the 2015 winter synoptic survey.

Figure 7. Air temperature (°C) during the survey recorded by Environment Canada at Hinton (Station ID: Jasper Warden, 3053536), Whitecourt (Station ID: Whitecourt A, 3067373), Athabasca (Station ID: Athabasca AGCM, 3060330), and Fort McMurray (Station ID: Fort McMurray A, 3062697).

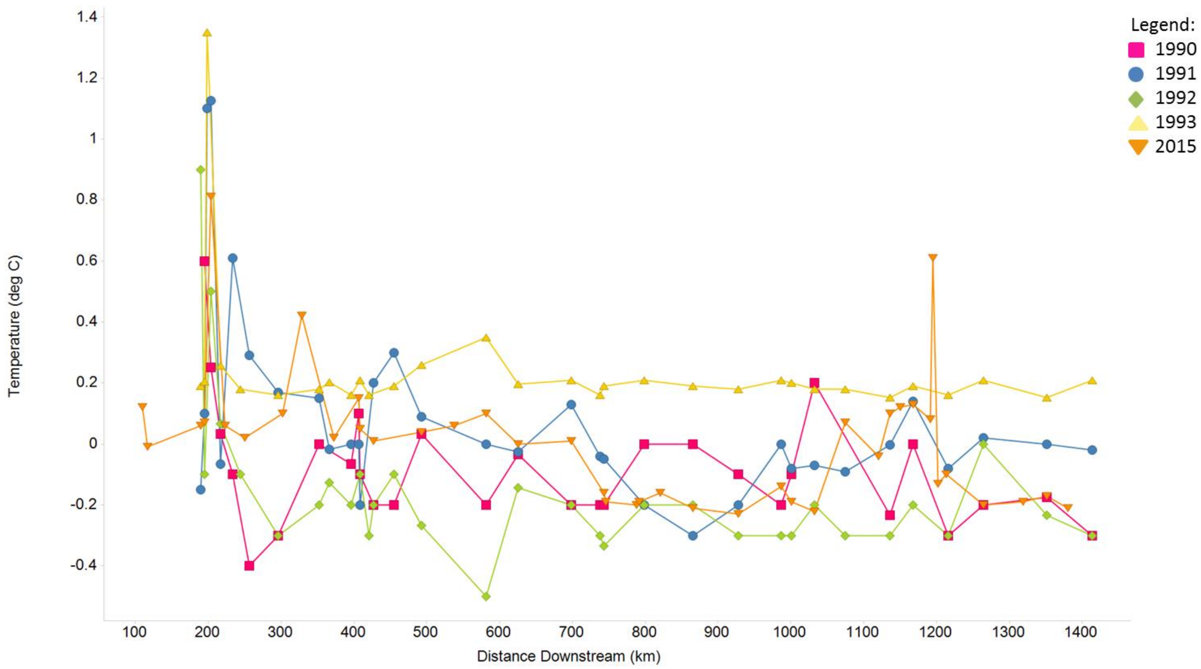


Figure 8. Comparison of surface water temperature measured during winter synoptic surveys in the Athabasca River (1990-1993 and 2015).

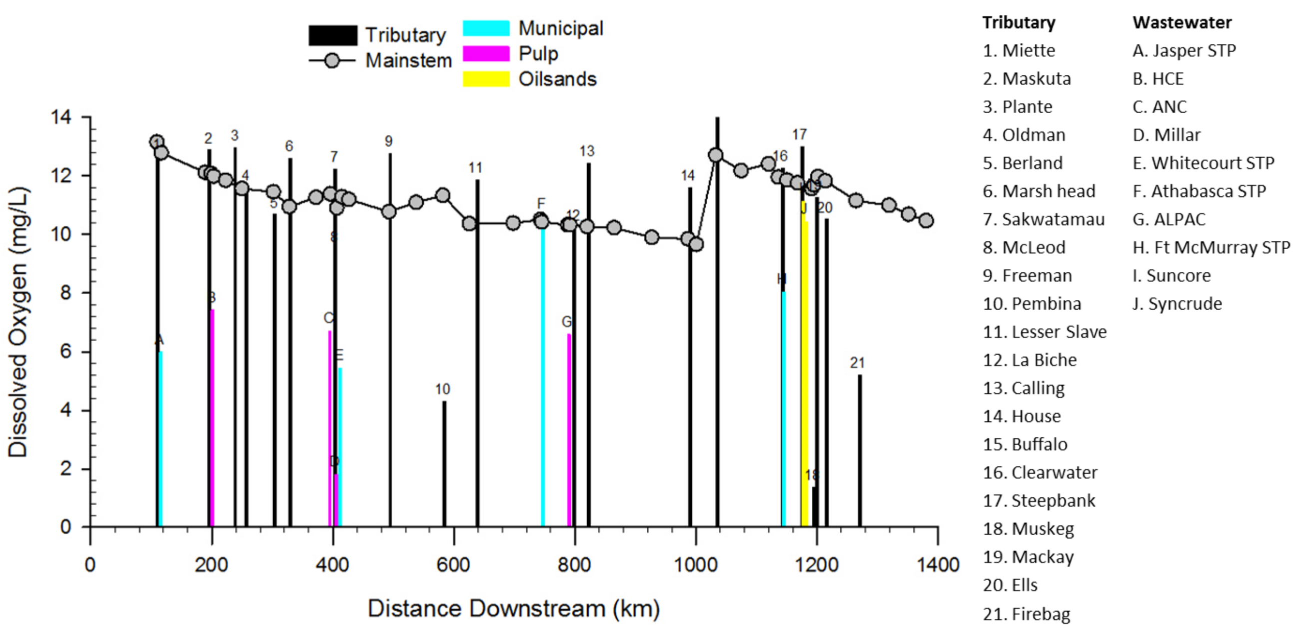


Figure 9. Dissolved oxygen (mg/L) in the Athabasca River and its tributaries during the 2015 winter synoptic survey.

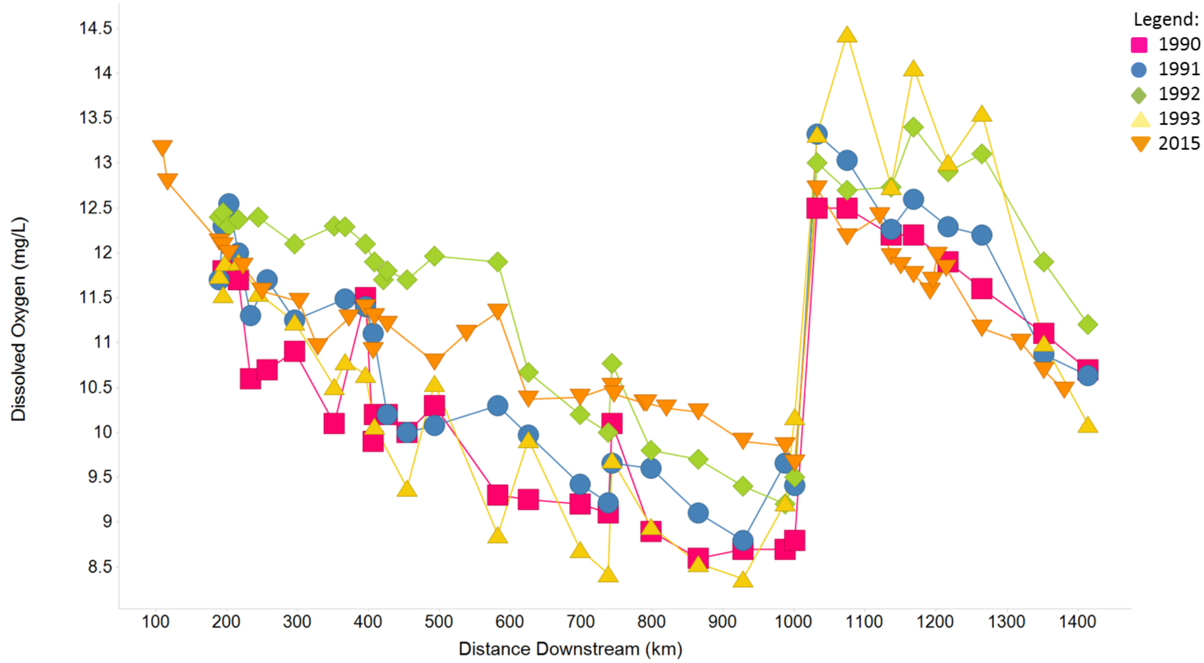


Figure 10. Comparison of winter dissolved oxygen (mg/L) measured during the 1990-1993 and 2015 synoptic surveys.

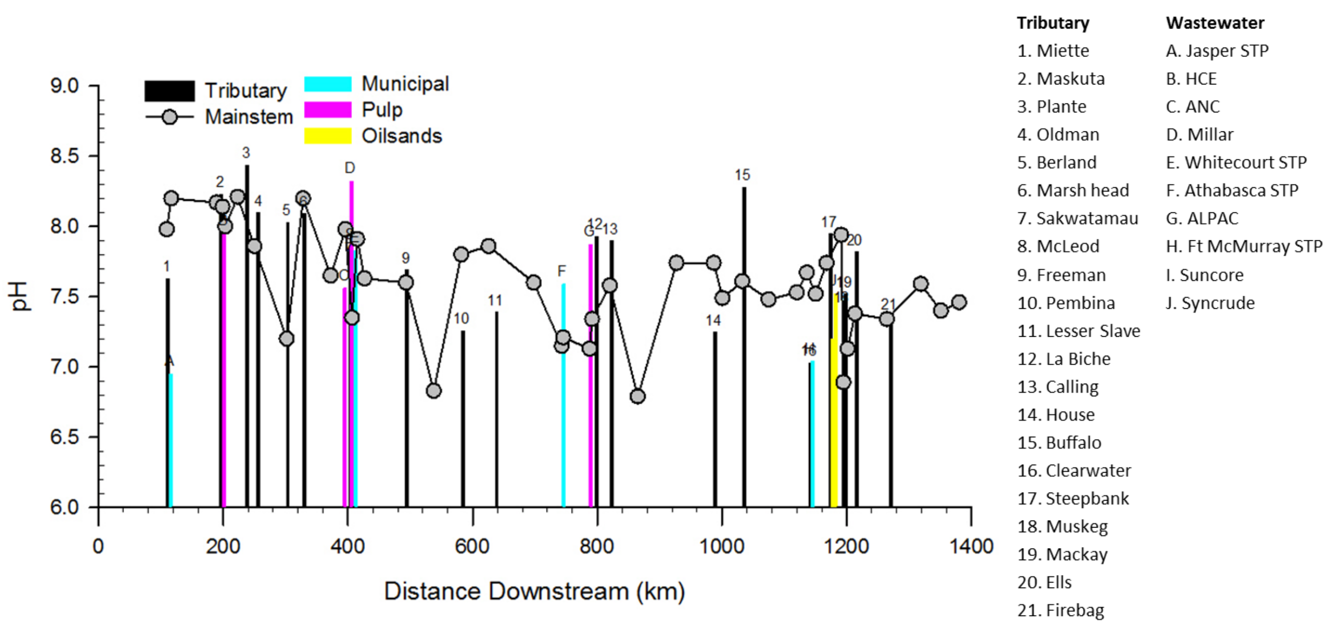


Figure 11. pH measured in the Athabasca River during the 2015 winter synoptic survey.

Figure 12. Comparison of pH measured in the Athabasca River during the winter synoptic surveys from 1990-1993 and 2015.

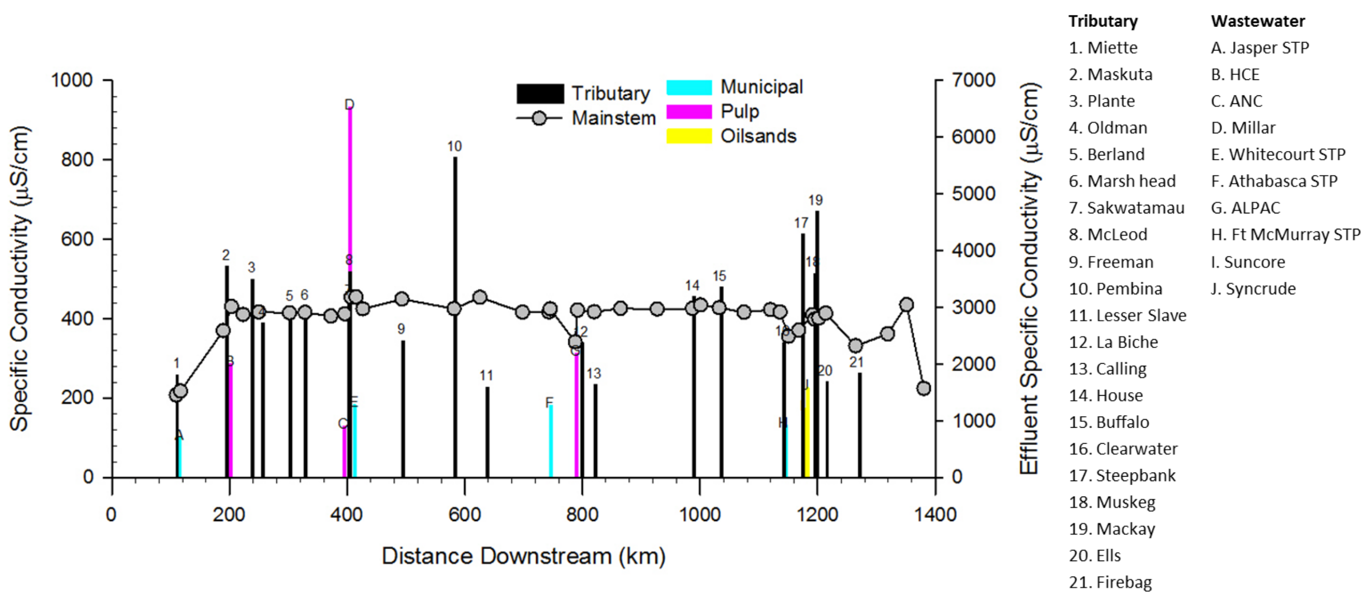


Figure 13. Specific conductivity (µS/cm) measured during the 2015 winter synoptic survey. Note that wastewater concentrations are shown as the second y-axis.

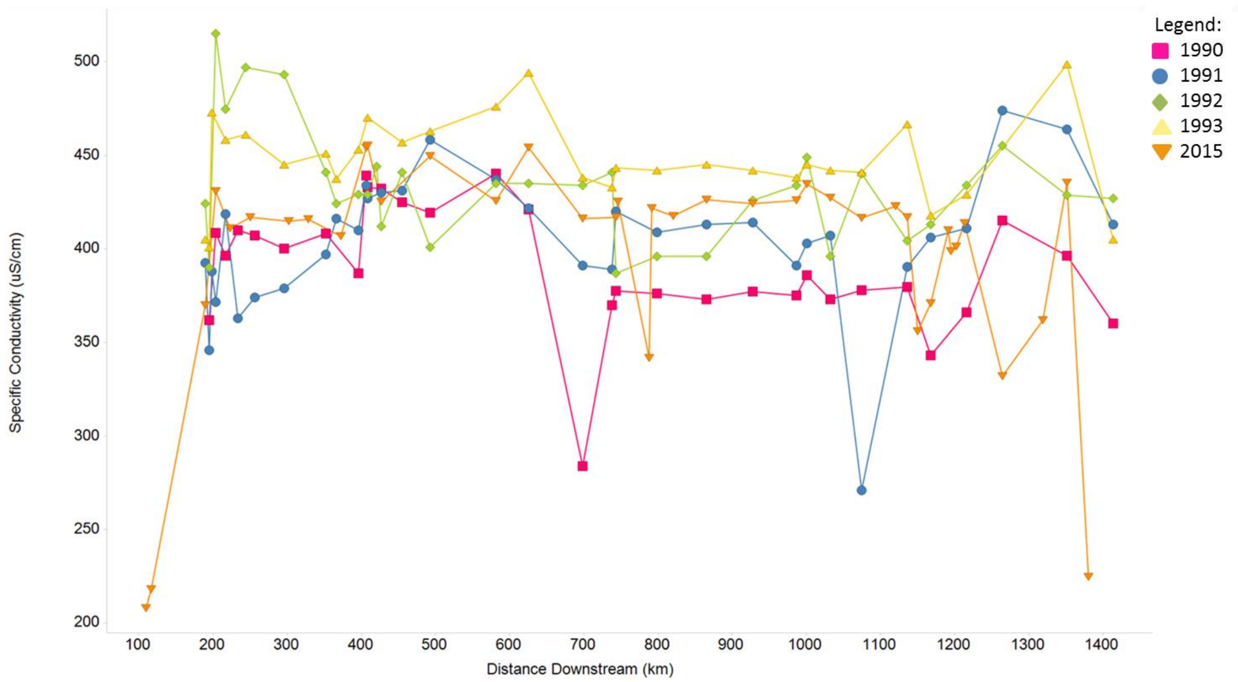


Figure 14. Comparison of specific conductivity (μS/cm) measured in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015.

Inorganic Constituents Figures

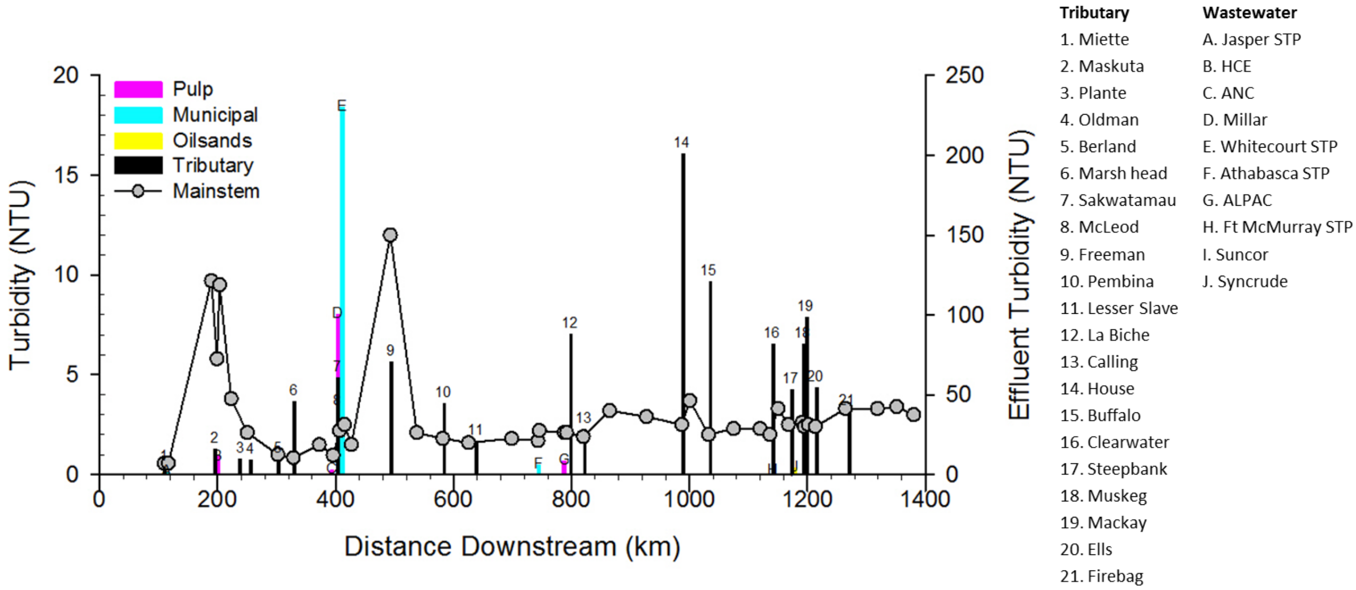


Figure 15. Turbidity (mg/L) measured during the 2015 survey in the Athabasca River (mainstem), tributaries, and wastewater effluent.

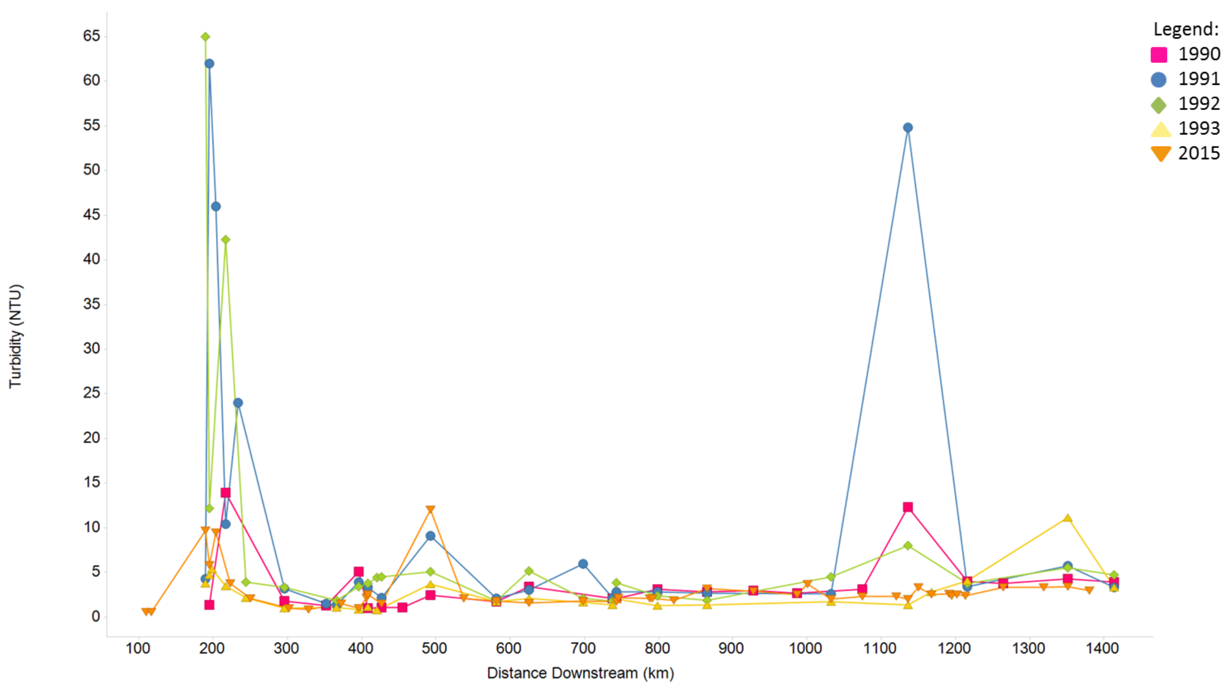


Figure 16. Comparison of turbidity (NTU) measured in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015.

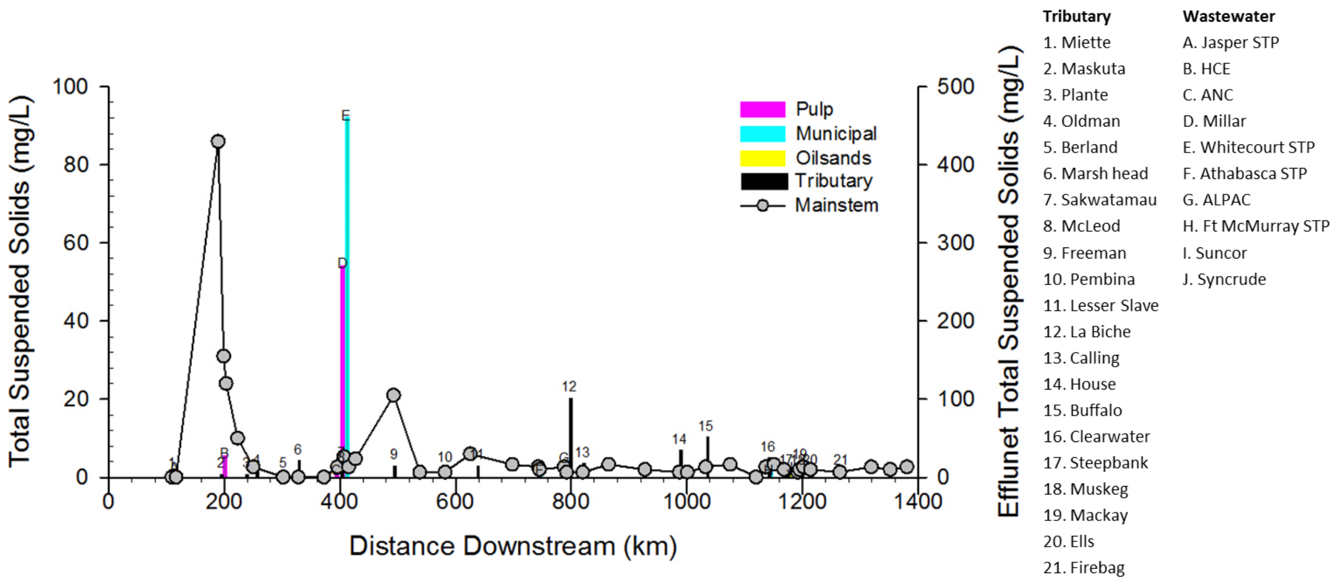


Figure 17. Total suspended solids (mg/L) measured during the 2015 winter synoptic survey in the Athabasca River (mainstem), tributaries, and wastewater effluent.

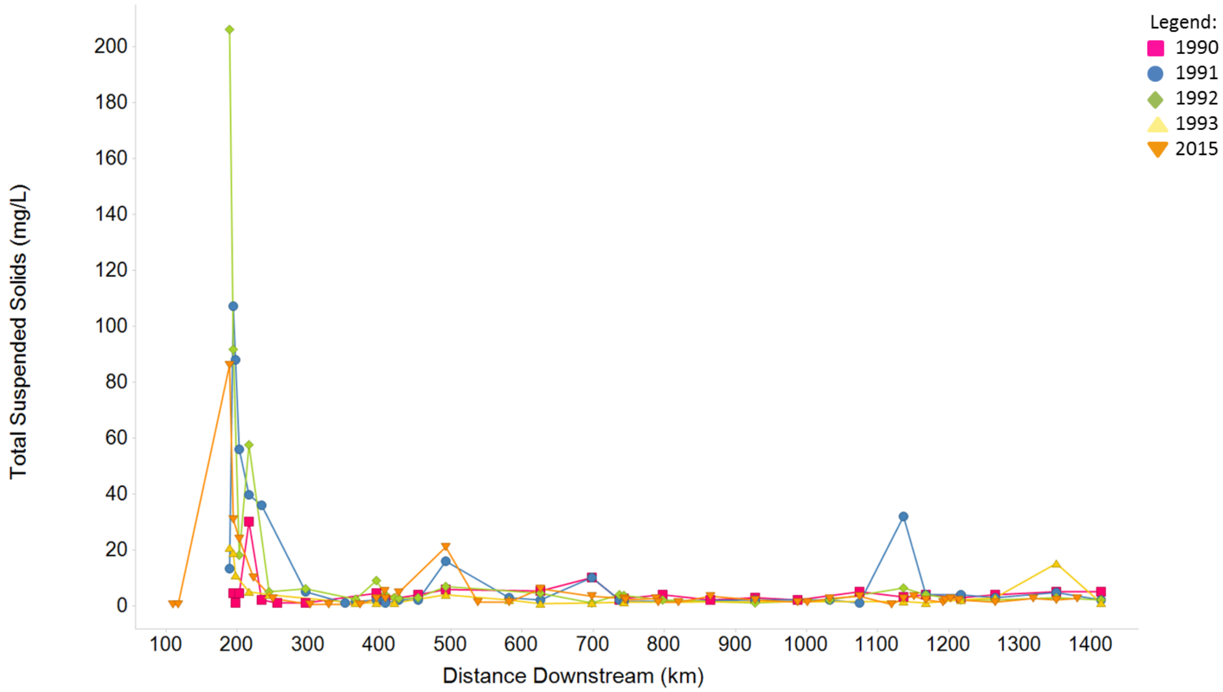


Figure 18. Comparison of total suspended solids (mg/L) measured in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015.

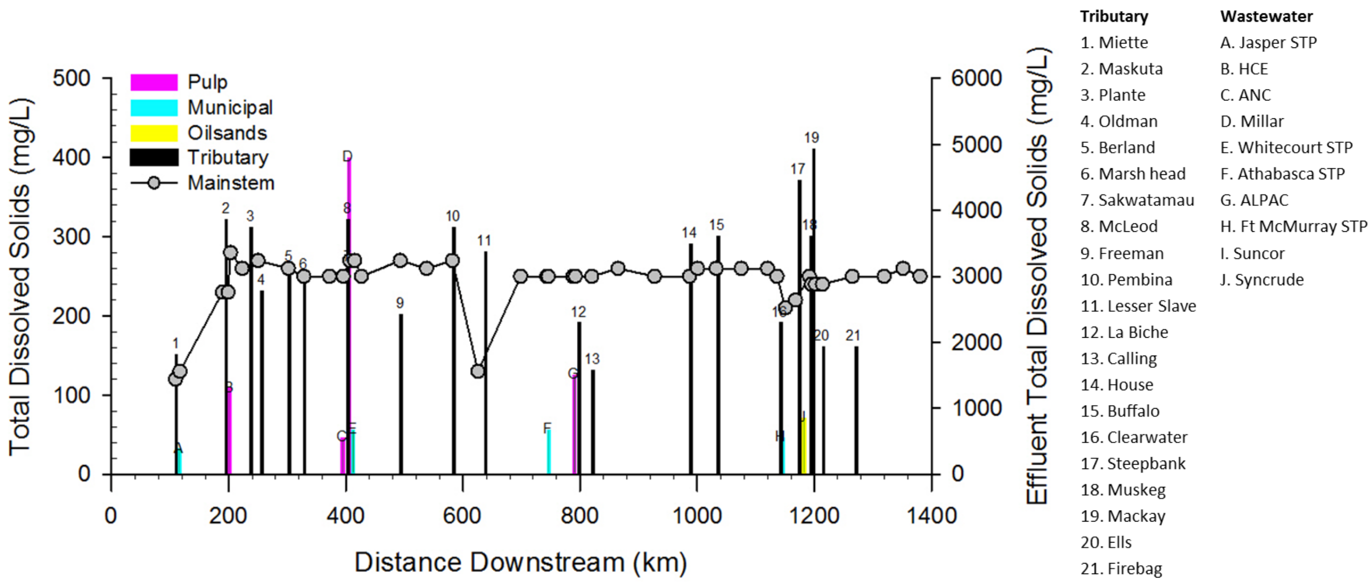


Figure 19. Calculated total dissolved solids (mg/L) in the Athabasca River, tributaries, and treated wastewater during the 2015 winter synoptic survey.

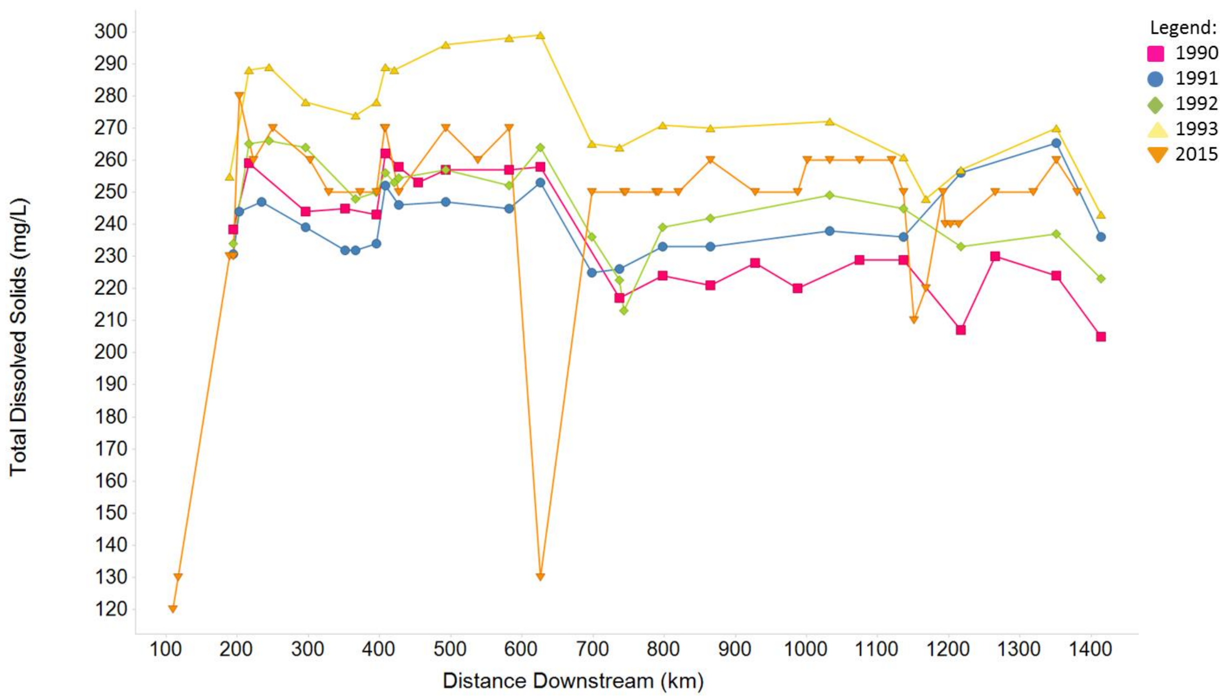


Figure 20. Comparison of calculated total dissolved solids (mg/L) measured in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015.

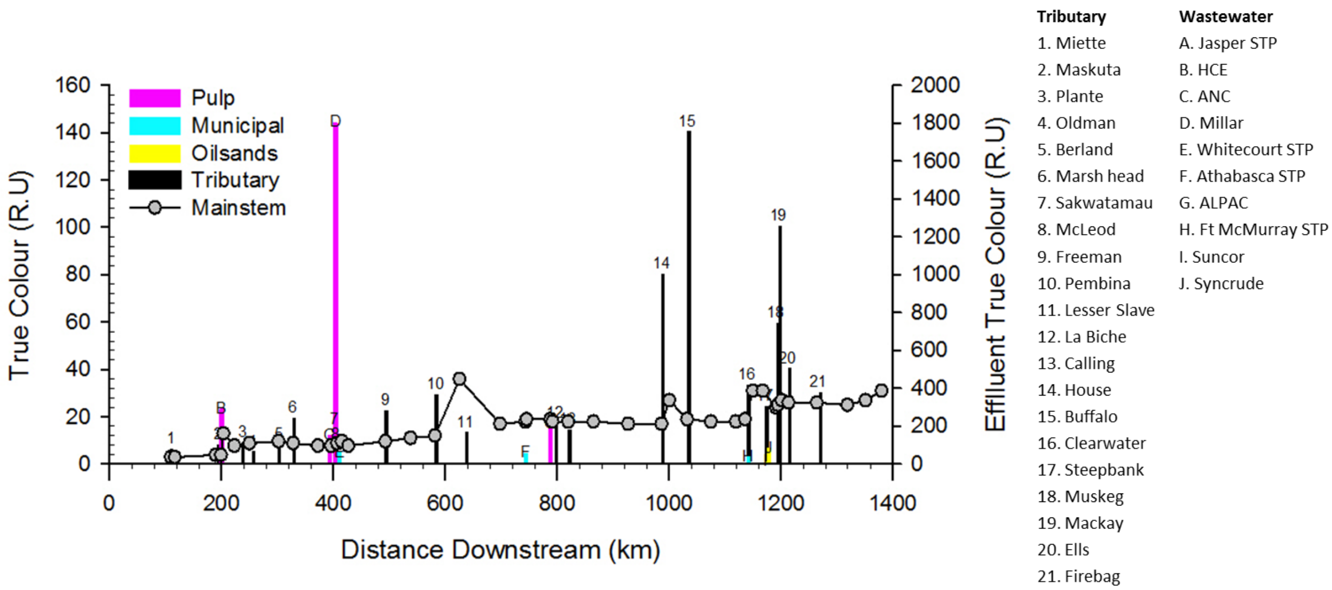


Figure 21. True colour (relative units) during the 2015 synoptic survey.

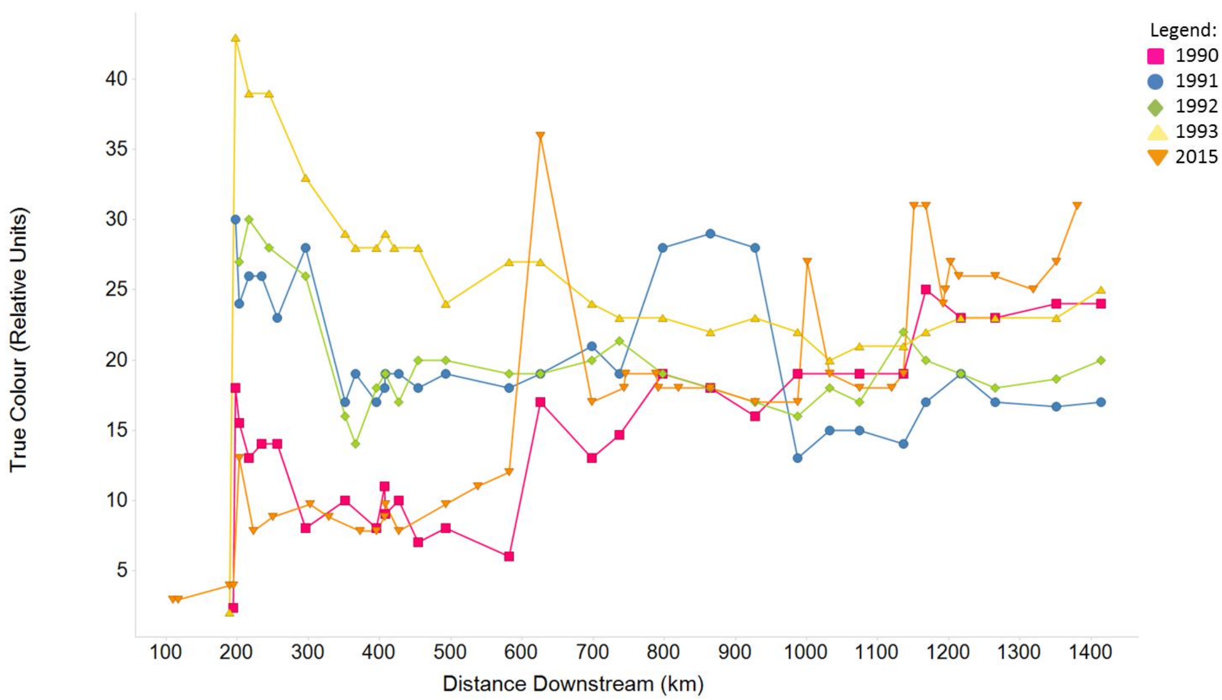
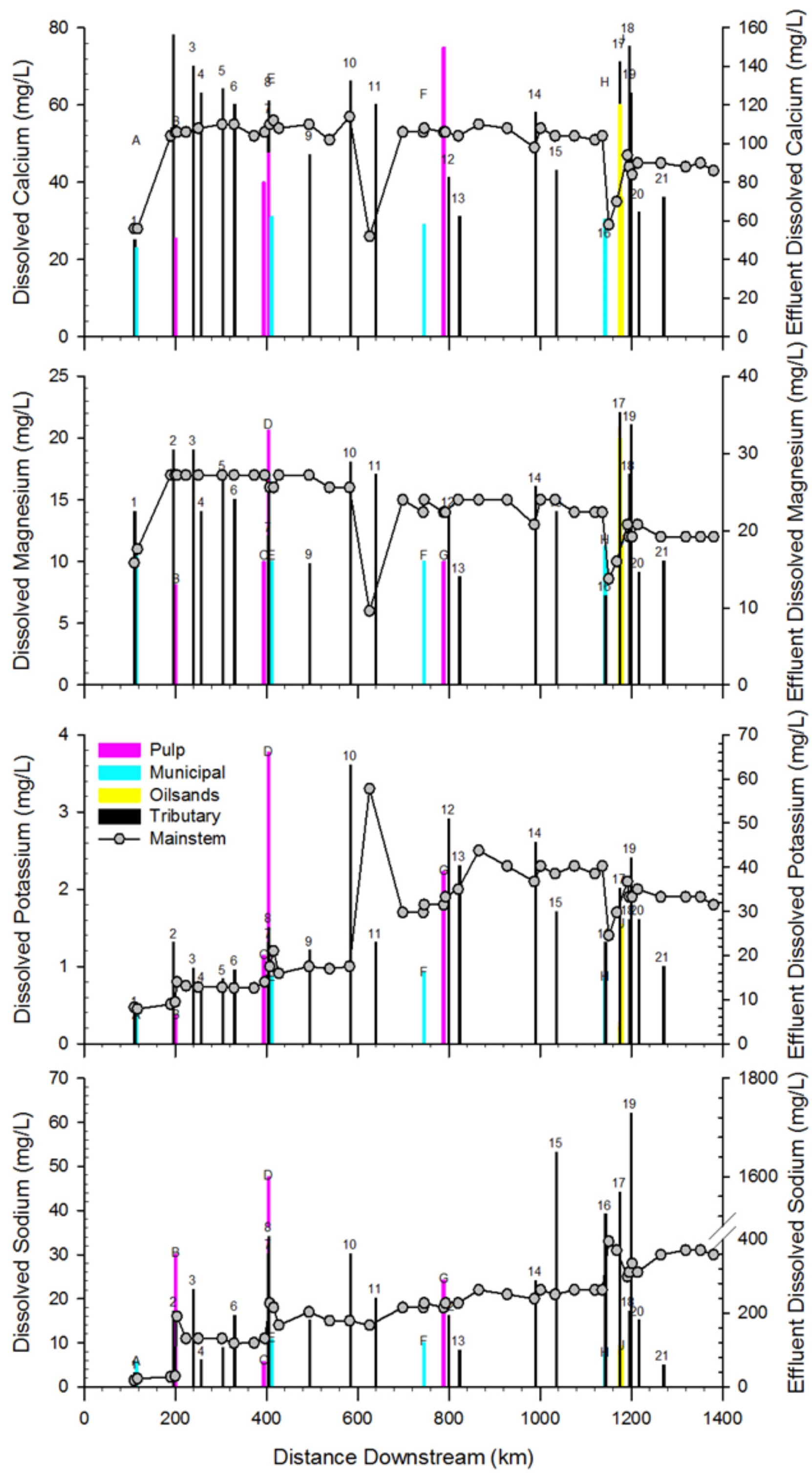


Figure 22. Comparison of true colour (relative units) measured in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015



Tributary	Wastewater
1. Miette	A. Jasper STP
2. Maskuta	B. HCE
3. Plante	C. ANC
4. Oldman	D. Millar
5. Berland	E. Whitecourt STP
6. Marsh head	F. Athabasca STP
7. Sakwatamau	G. ALPAC
8. McLeod	H. Ft McMurray STP
9. Freeman	I. Suncor
10. Pembina	J. Syncrude
11. Lesser Slave	
12. La Biche	
13. Calling	
14. House	
15. Buffalo	
16. Clearwater	
17. Steepbank	
18. Muskeg	
19. Mackay	
20. Ells	
21. Firebag	

Figure 23. Spatial pattern of cations a) dissolved calcium (mg/L), b) dissolved magnesium (mg/L), c) dissolved potassium (mg/L) and d) dissolved sodium (mg/L) in the Athabasca River, tributaries, and effluent discharge during the 2015 winter synoptic survey.

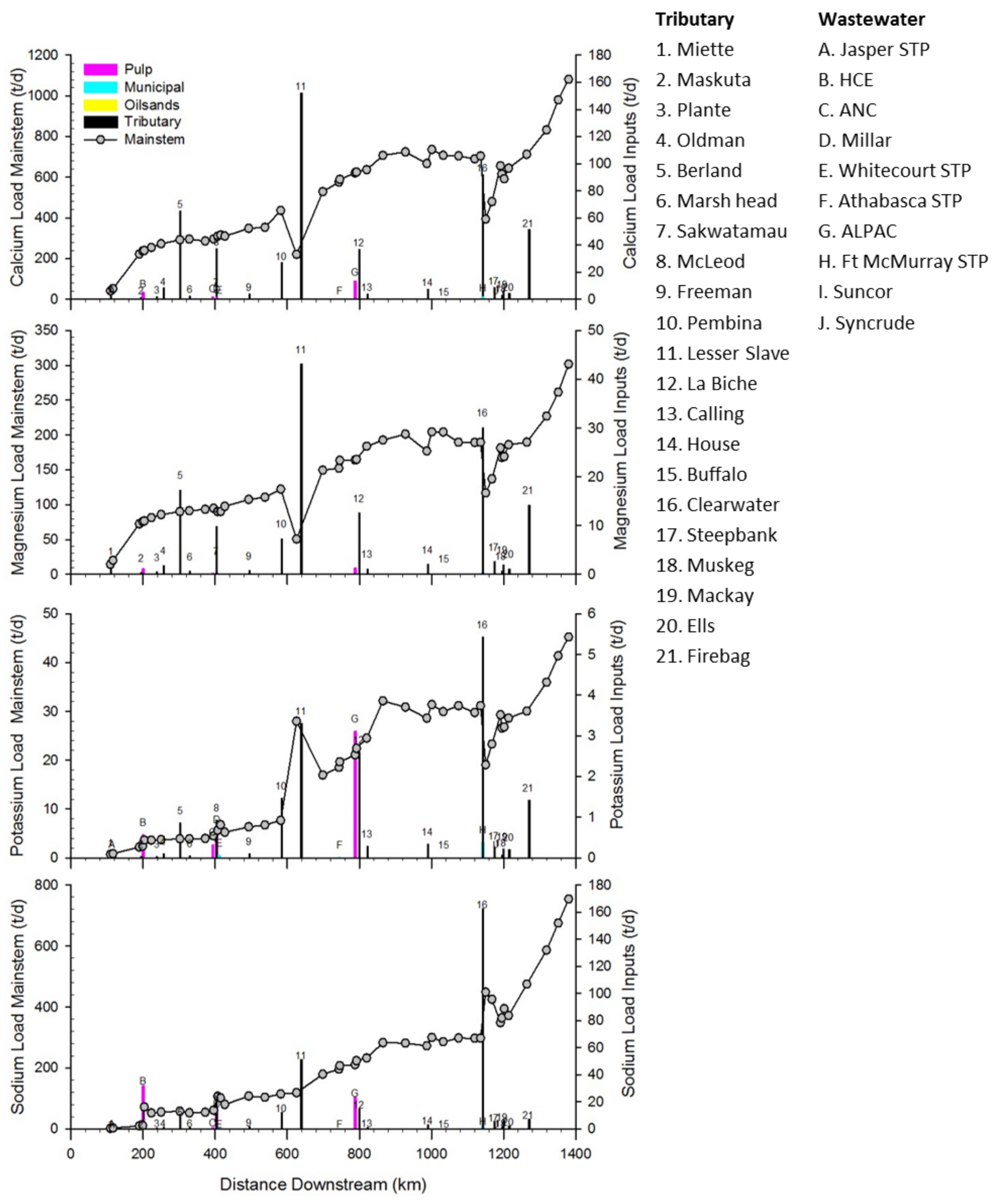
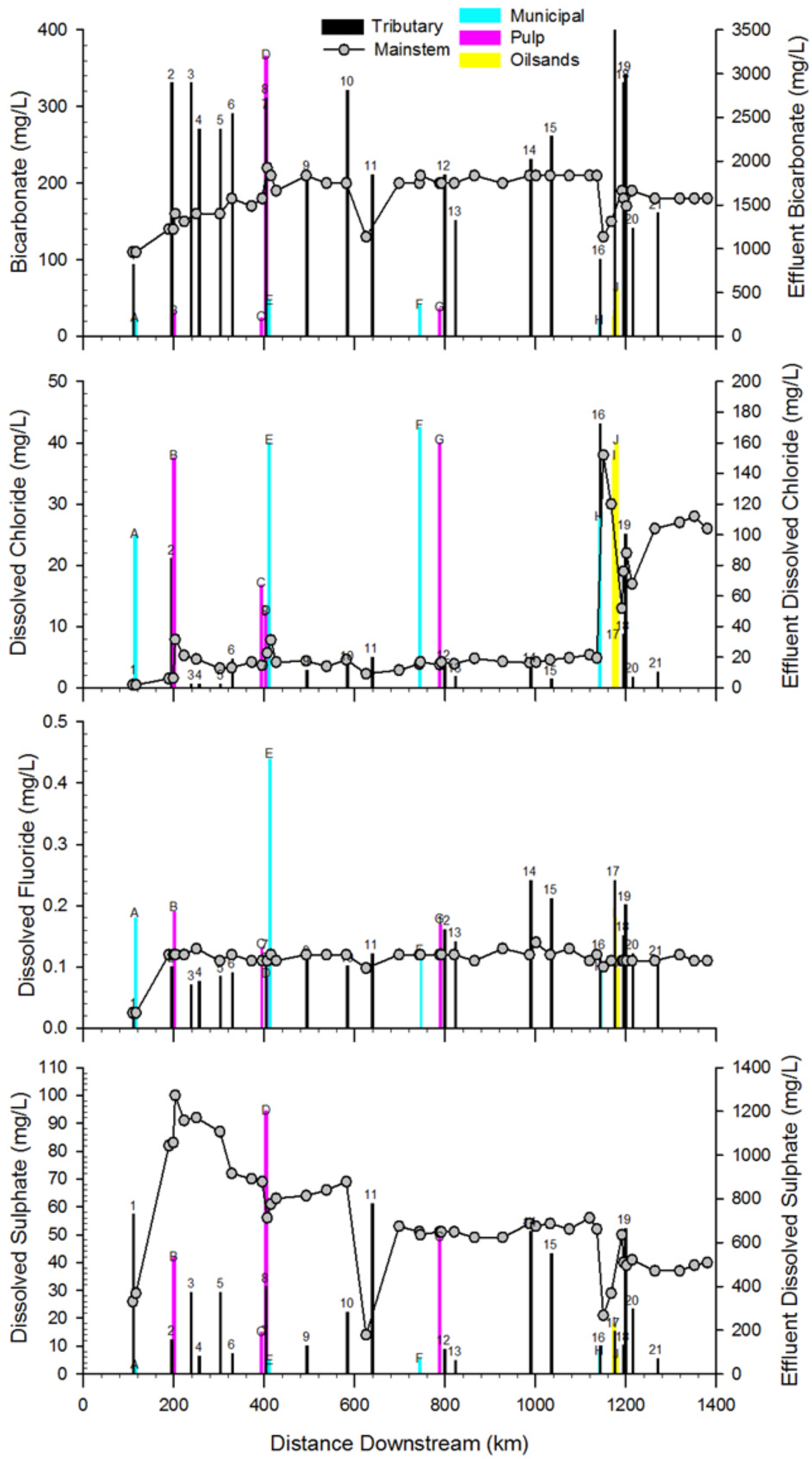


Figure 24. Mass loads of major cations a) dissolved calcium (t/d), b) dissolved magnesium (t/d), c) dissolved potassium (t/d) and d) dissolved sodium (t/d) in the Athabasca River, tributaries, and effluent discharge during the 2015 winter synoptic survey (t = tonne = mega kilogram).



Tributary	Wastewater
1. Miette	A. Jasper STP
2. Maskuta	B. HCE
3. Plante	C. ANC
4. Oldman	D. Millar
5. Berland	E. Whitecourt STP
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7. Sakwatamau	G. ALPAC
8. McLeod	H. Ft McMurray STP
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12. La Biche	
13. Calling	
14. House	
15. Buffalo	
16. Clearwater	
17. Steepbank	
18. Muskeg	
19. Mackay	
20. Ells	
21. Firebag	

Figure 25. Spatial pattern of anions a) bicarbonate (mg/L) b) dissolved chloride (mg/L), c) dissolved fluoride (mg/L), and d) dissolved sulphate (mg/L) in the Athabasca River, tributaries, and effluent discharge during the 2015 winter synoptic survey.

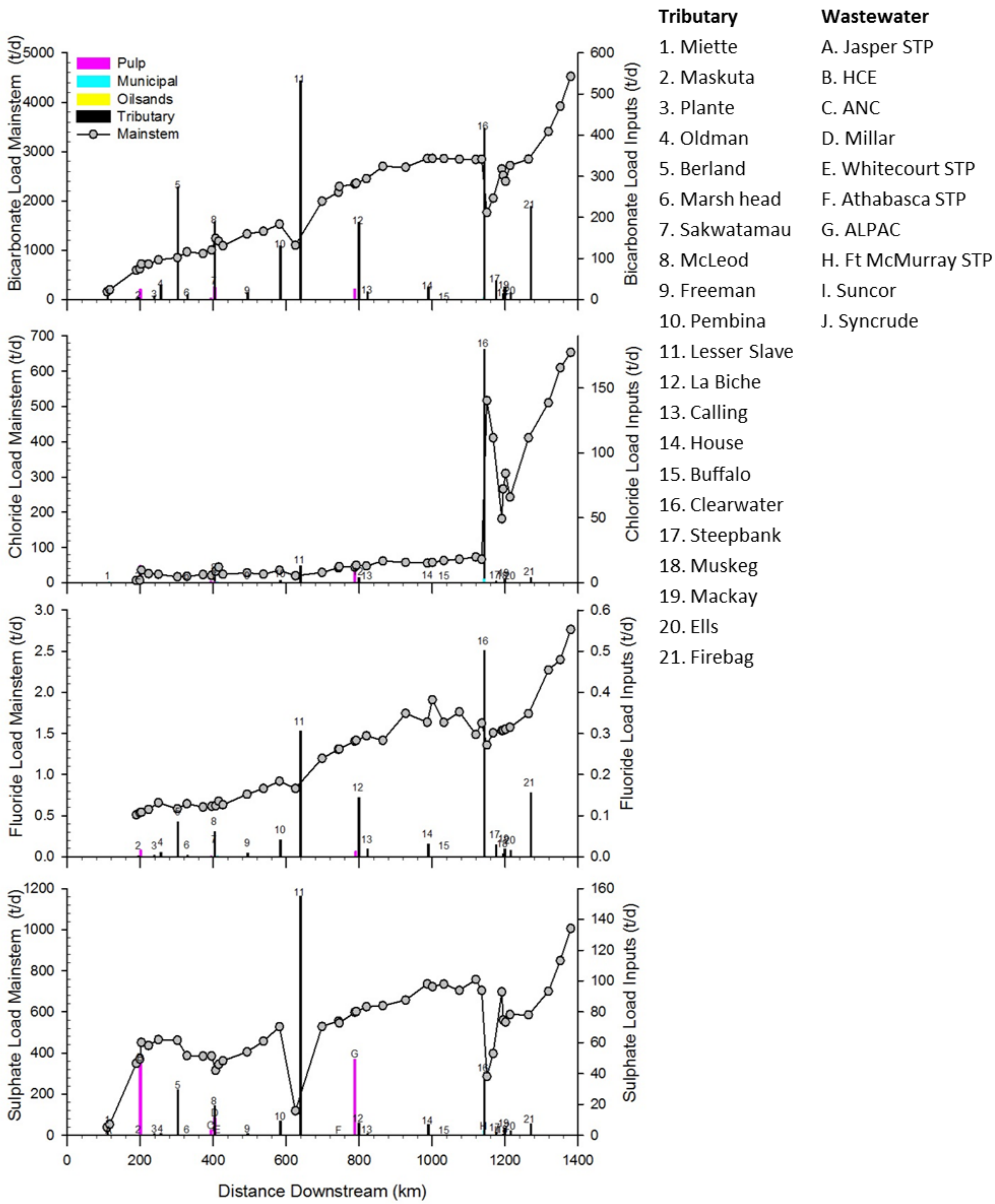


Figure 26. Mass loads of major anions a) dissolved bicarbonate (t/d), b) dissolved chloride (t/d), c) dissolved fluoride (t/d) and d) dissolved sulphate (t/d) in the Athabasca River, tributaries, and effluent discharge during the 2015 winter synoptic survey (t = tonne = mega kilogram).

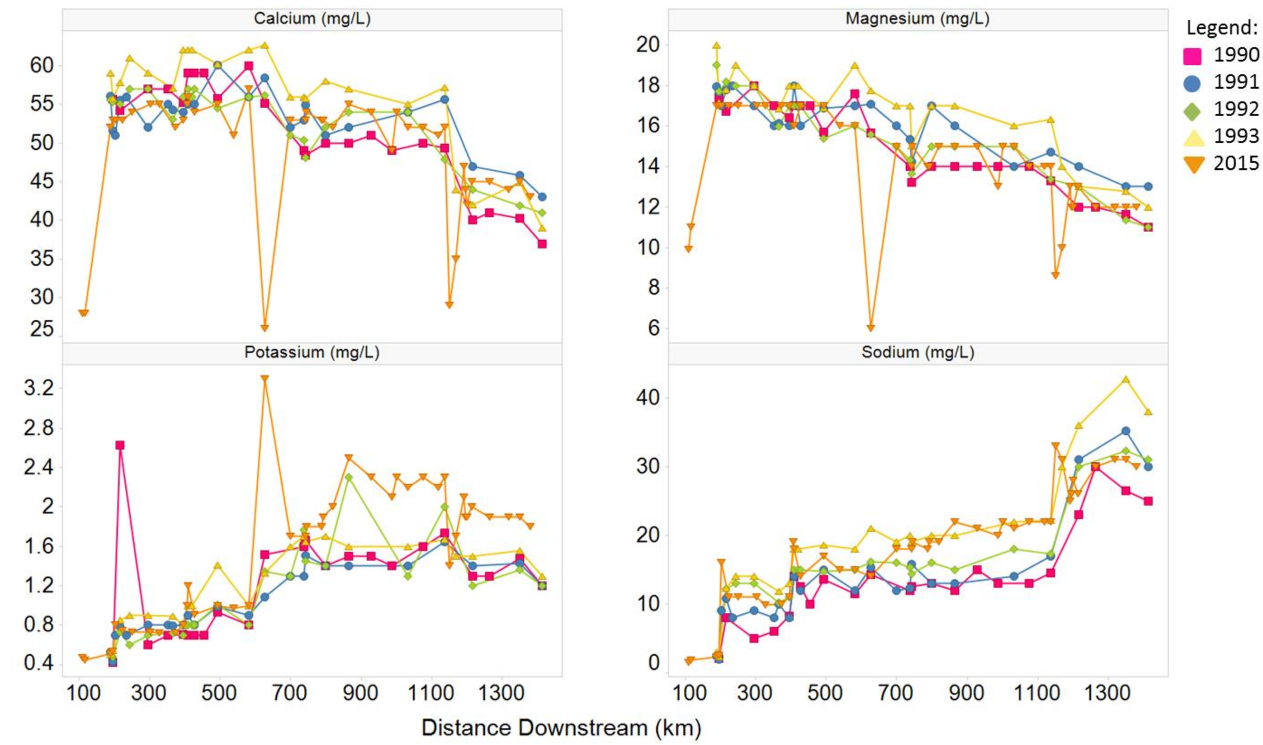


Figure 27. Comparison of cations a) dissolved calcium (mg/L), b) dissolved magnesium (mg/L), c) dissolved potassium (mg/L), and d) dissolved sodium (mg/L) in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015.

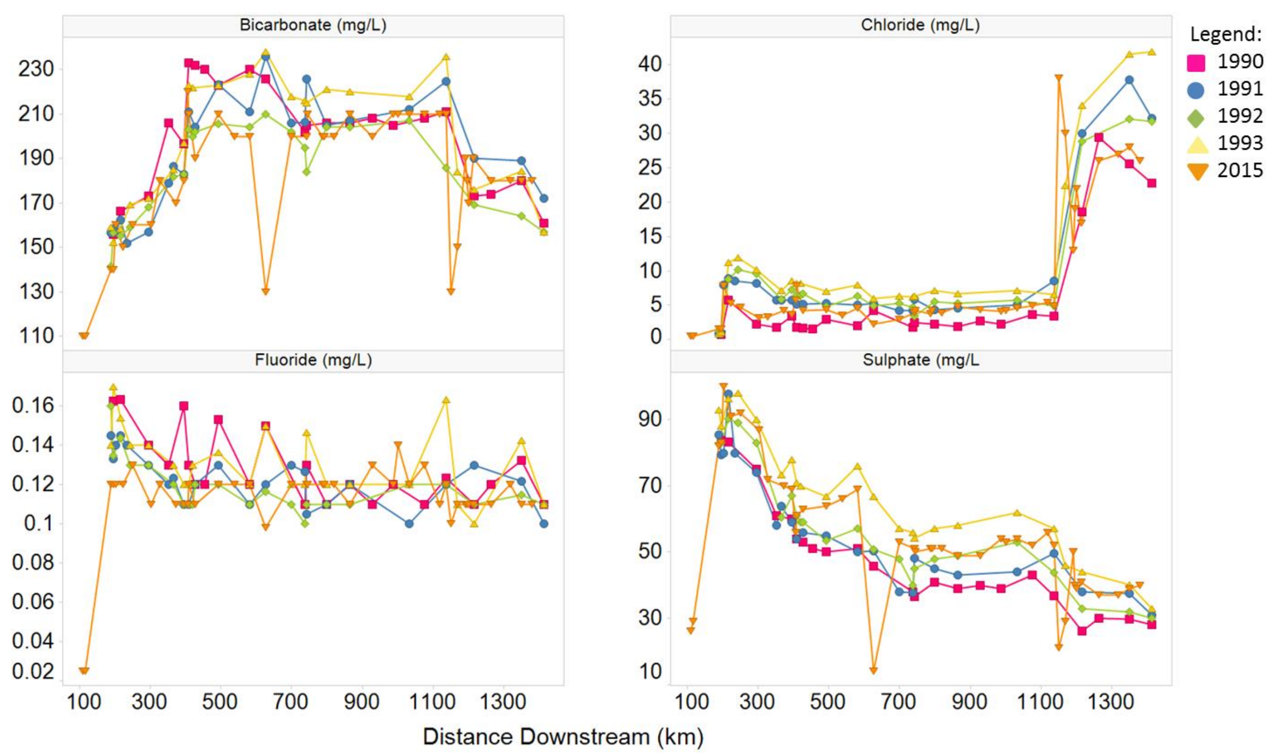


Figure 28. Comparison of anions a) bicarbonate (mg/L), b) dissolved chloride (mg/L), c) dissolved fluoride (mg/L), and d) dissolved sulphate (mg/L) in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015.

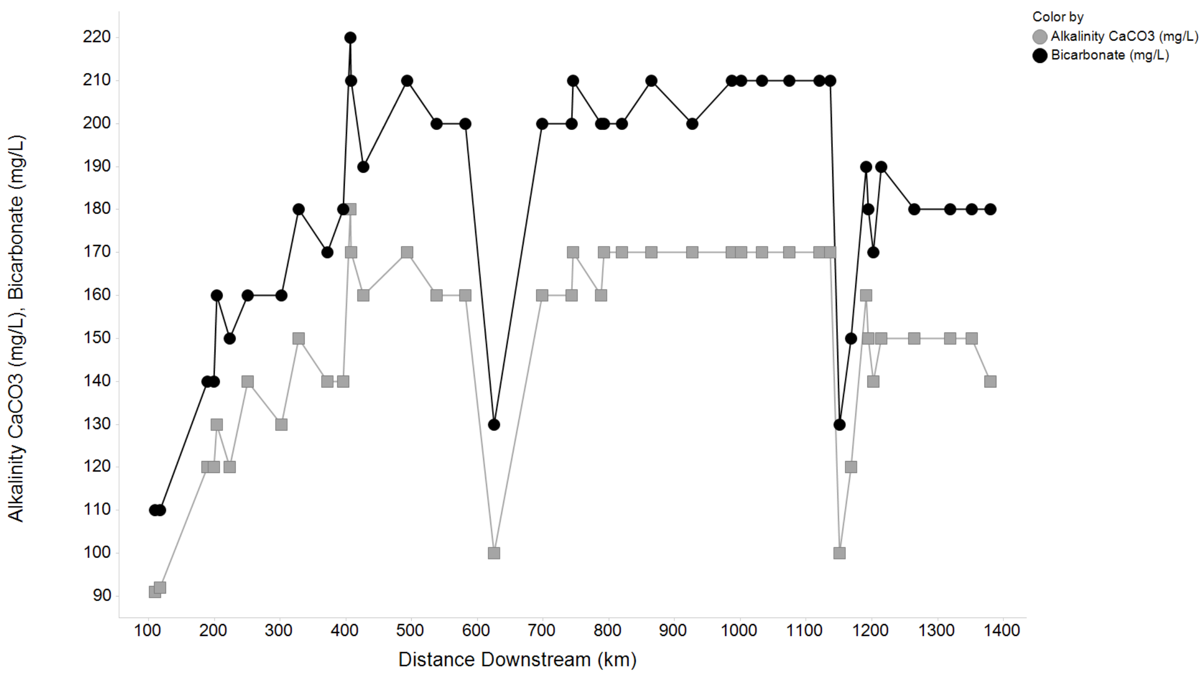


Figure 29. Alkalinity $CaCO_3$ (mg/L) and bicarbonate (calculated, mg/L) measured in the Athabasca River during the 2015 synoptic survey.

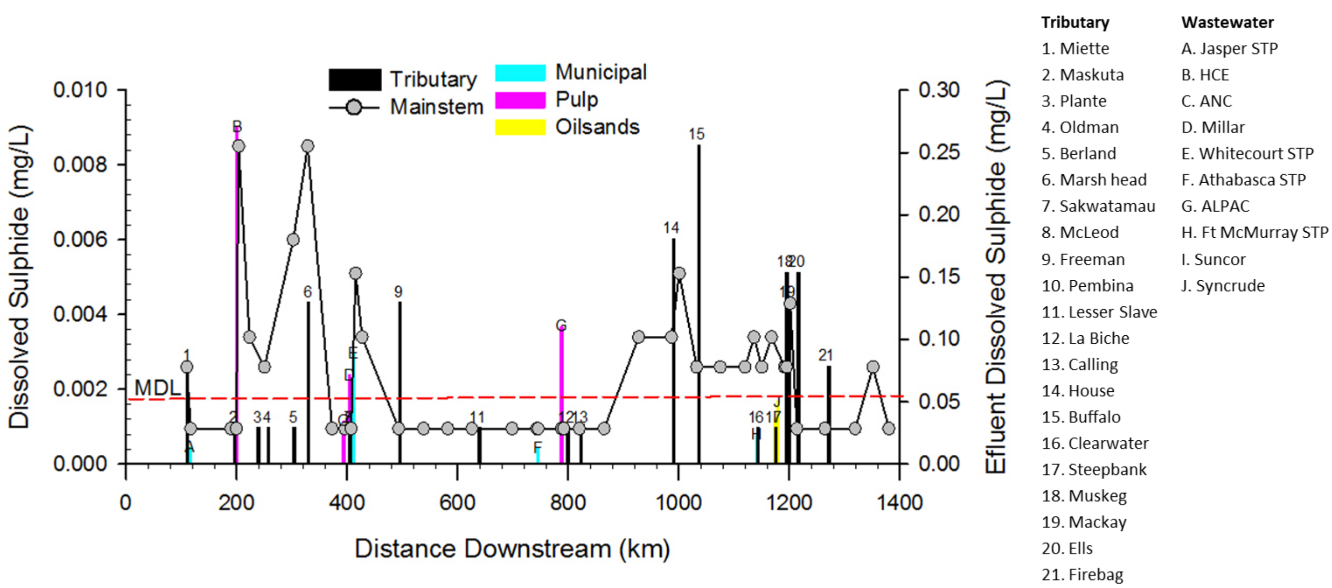
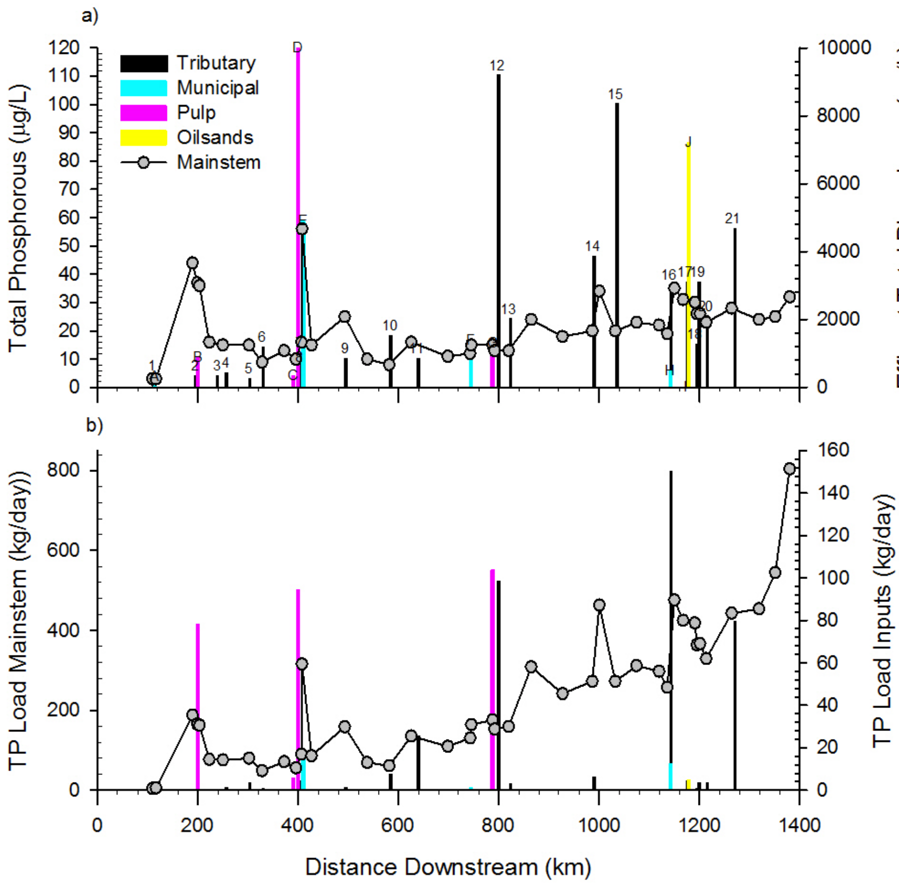


Figure 30. Dissolved sulphide (mg/L) in the Athabasca River during the 2015 winter synoptic survey. The red dashed line represents the method detection limit and applies to the left y-axis only.

Nutrient Figures



Tributary	Wastewater
1. Miette	A. Jasper STP
2. Maskuta	B. HCE
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8. McLeod	H. Ft McMurray STP
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11. Lesser Slave	
12. La Biche	
13. Calling	
14. House	
15. Buffalo	
16. Clearwater	
17. Steepbank	
18. Muskeg	
19. Mackay	
20. Ells	
21. Firebag	

Figure 31. (a) Total phosphorus (mg/L) in the Athabasca River during the 2015 winter synoptic survey. (b) total phosphorus loads (kg/day) calculated during the survey.

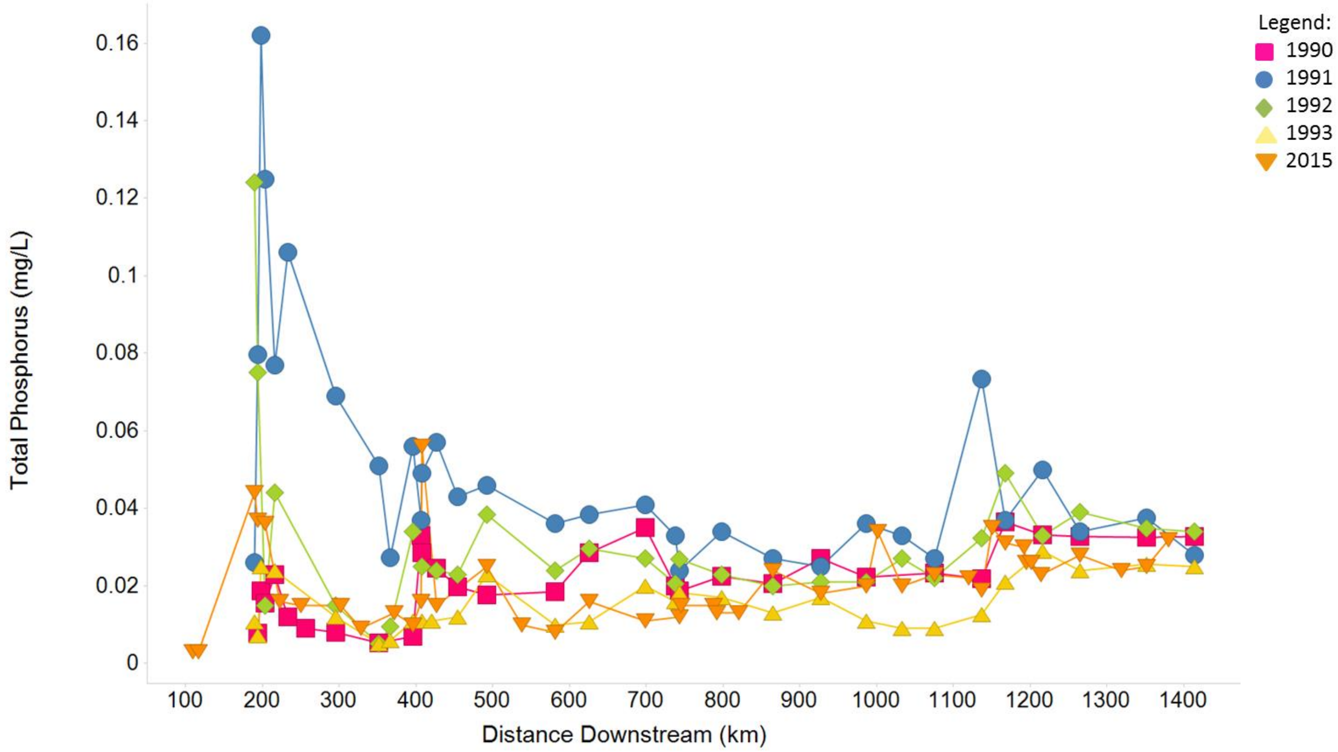

Figure 32. Comparison of total phosphorus (mg/L) measured in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015

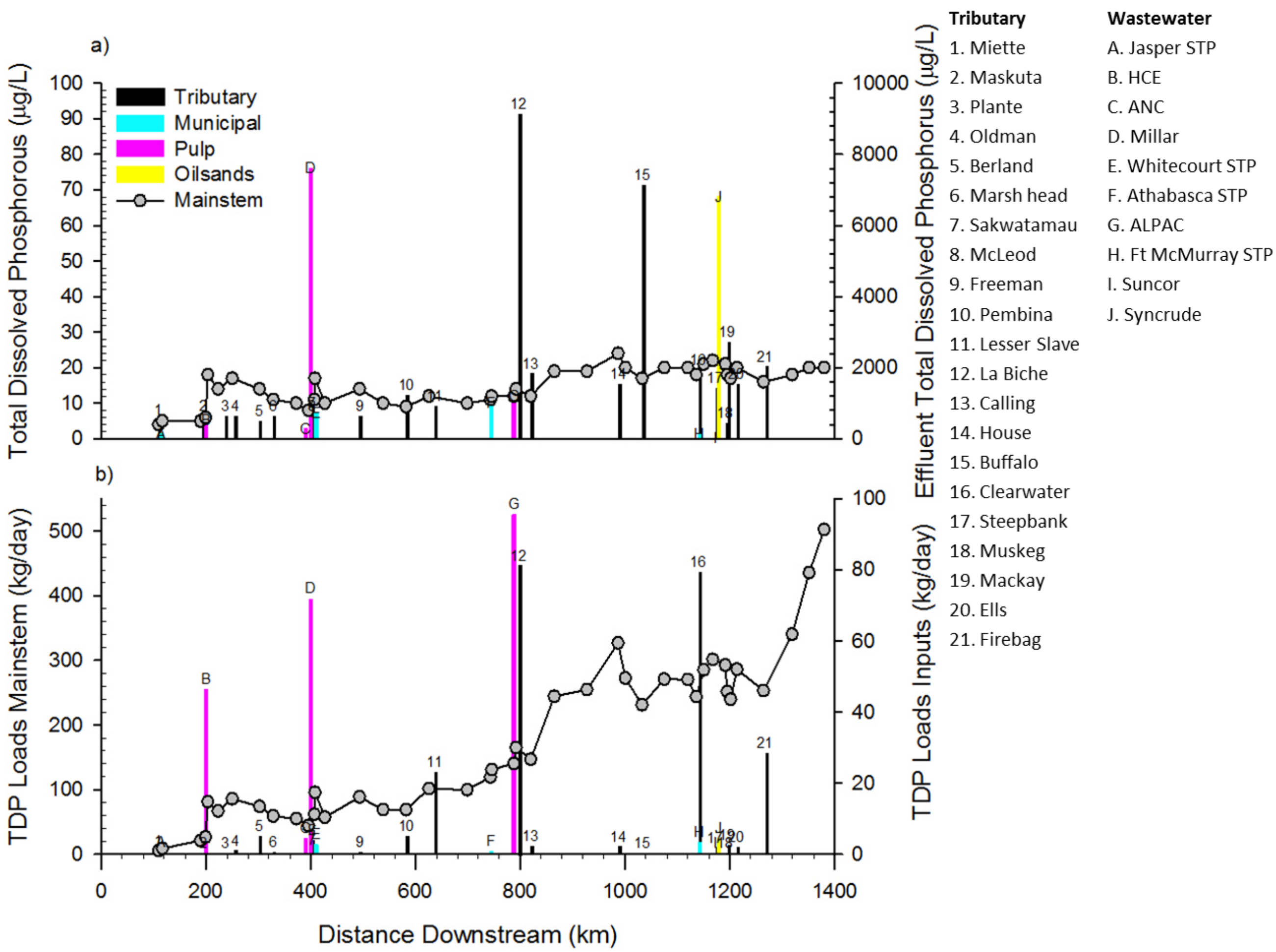

Figure 33. (a) total dissolved phosphorus (mg/L) in the Athabasca River during the 2015 winter synoptic survey. (b) total dissolved phosphorus loads (kg/day) calculated during the survey.

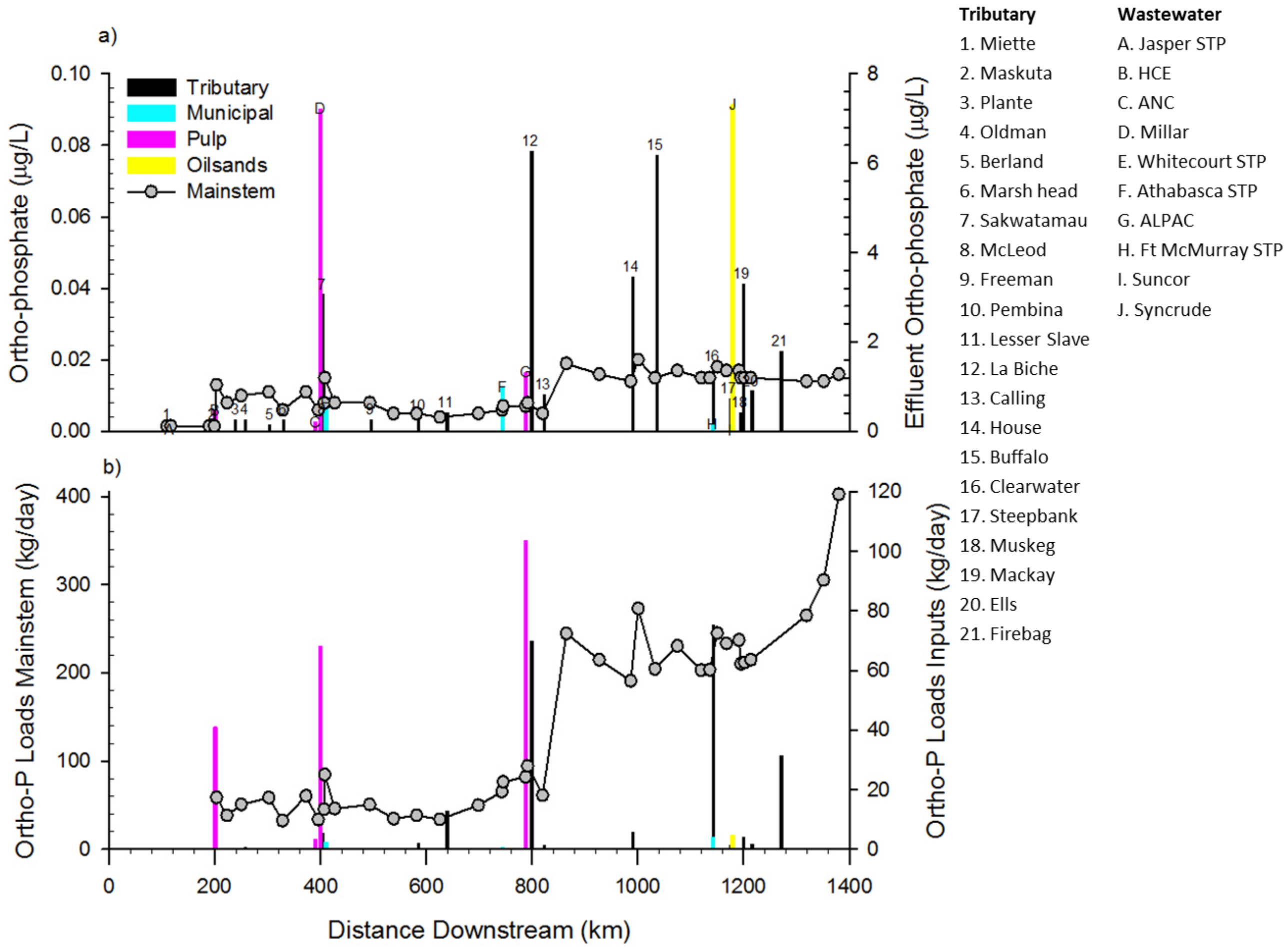

Figure 34. a) ortho-phosphate (mg/L) in the Athabasca River during the 2015 winter synoptic survey. (b) ortho-phosphate loads (kg/day) calculated during the survey. Note values below the detection limit do not have a calculated load.

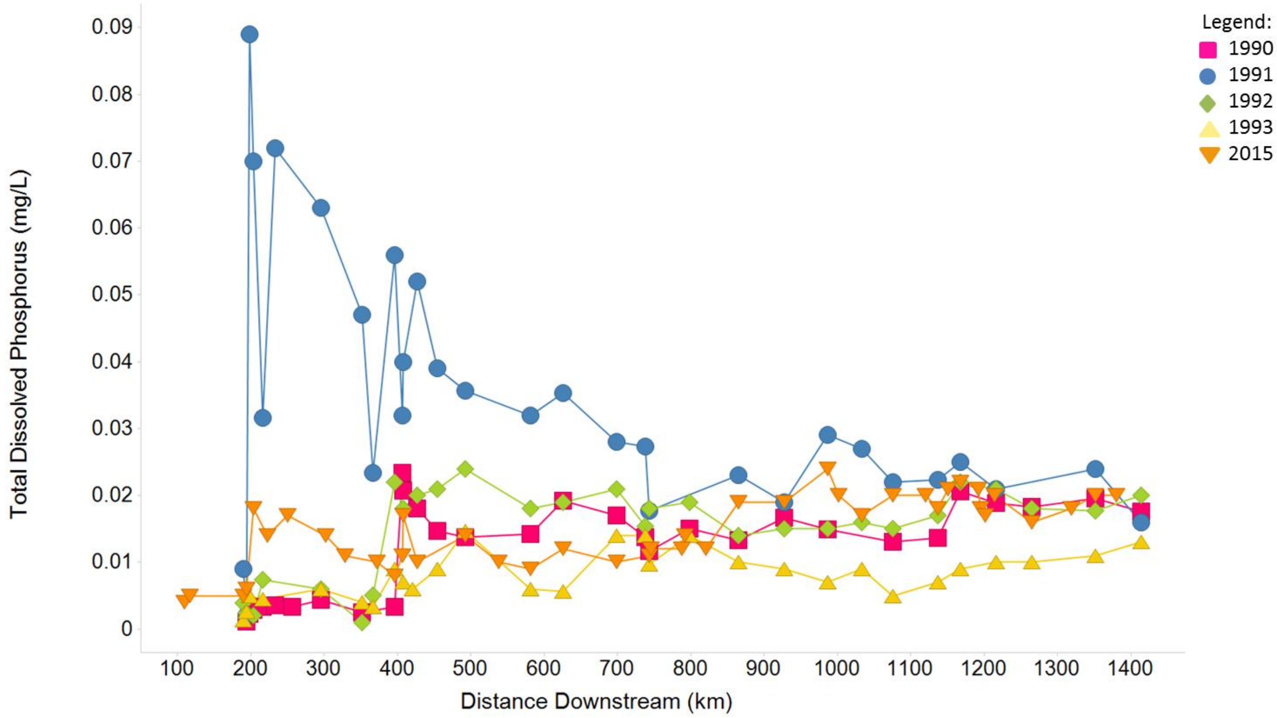

Figure 35. Comparison of total dissolved phosphorus (mg/L) measured in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015

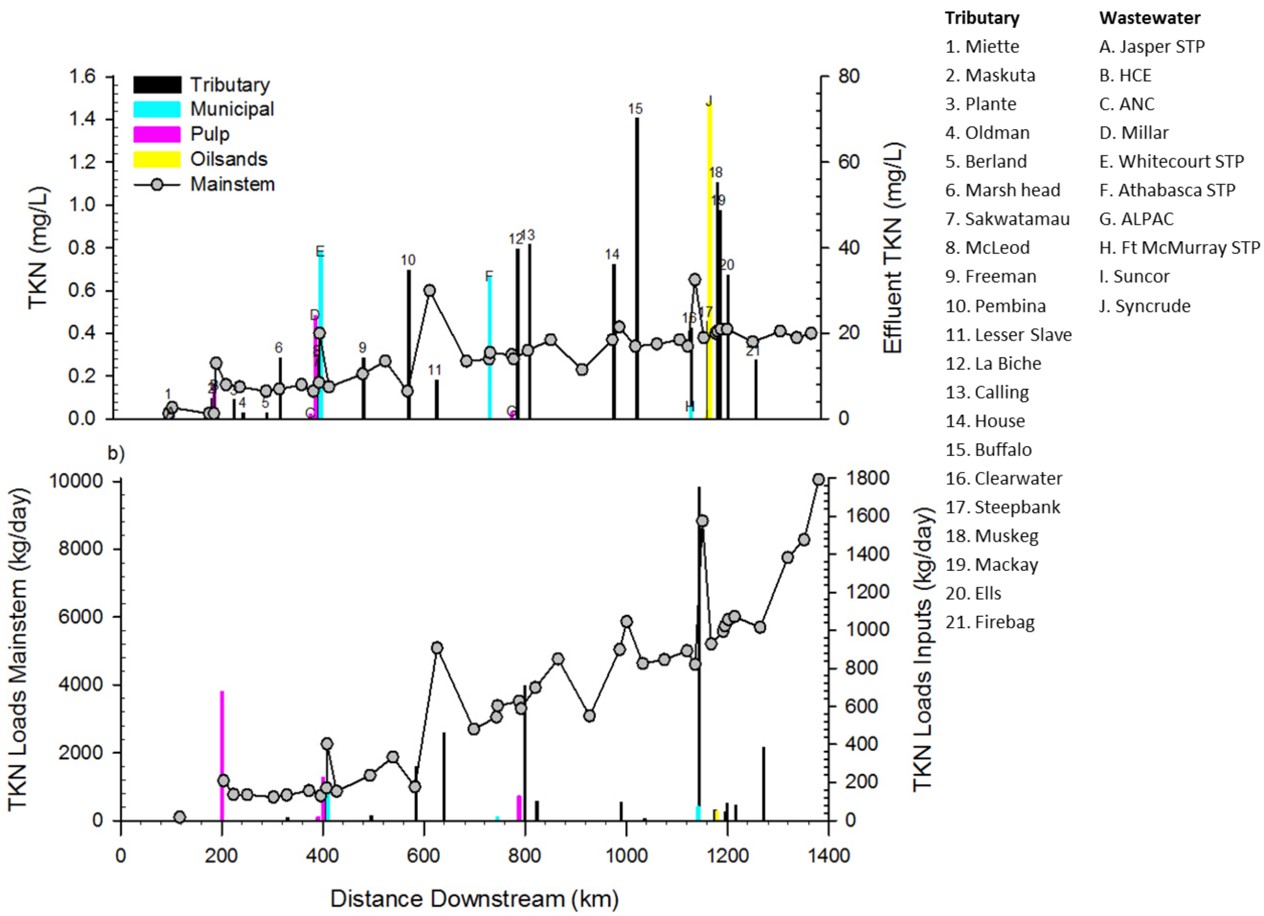

Figure 36. a) total kjeldahl nitrogen (TKN; mg/L) in the Athabasca River during the 2015 winter synoptic survey. (b) total kjeldahl nitrogen loads (TKN; kg/day) calculated during the survey. Note values below the detection limit do not have a calculated load.

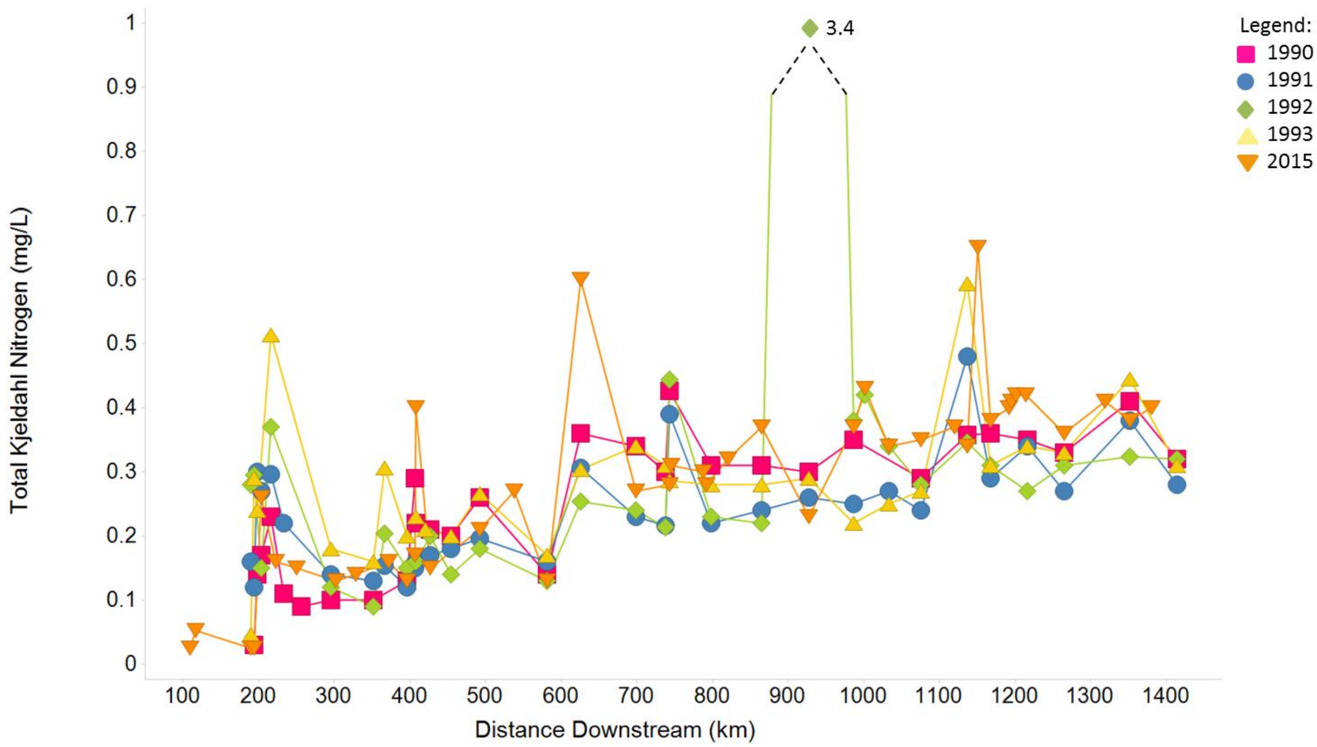

Figure 37. Comparison of total kjeldahl nitrogen (TKN; mg/L) measured in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015

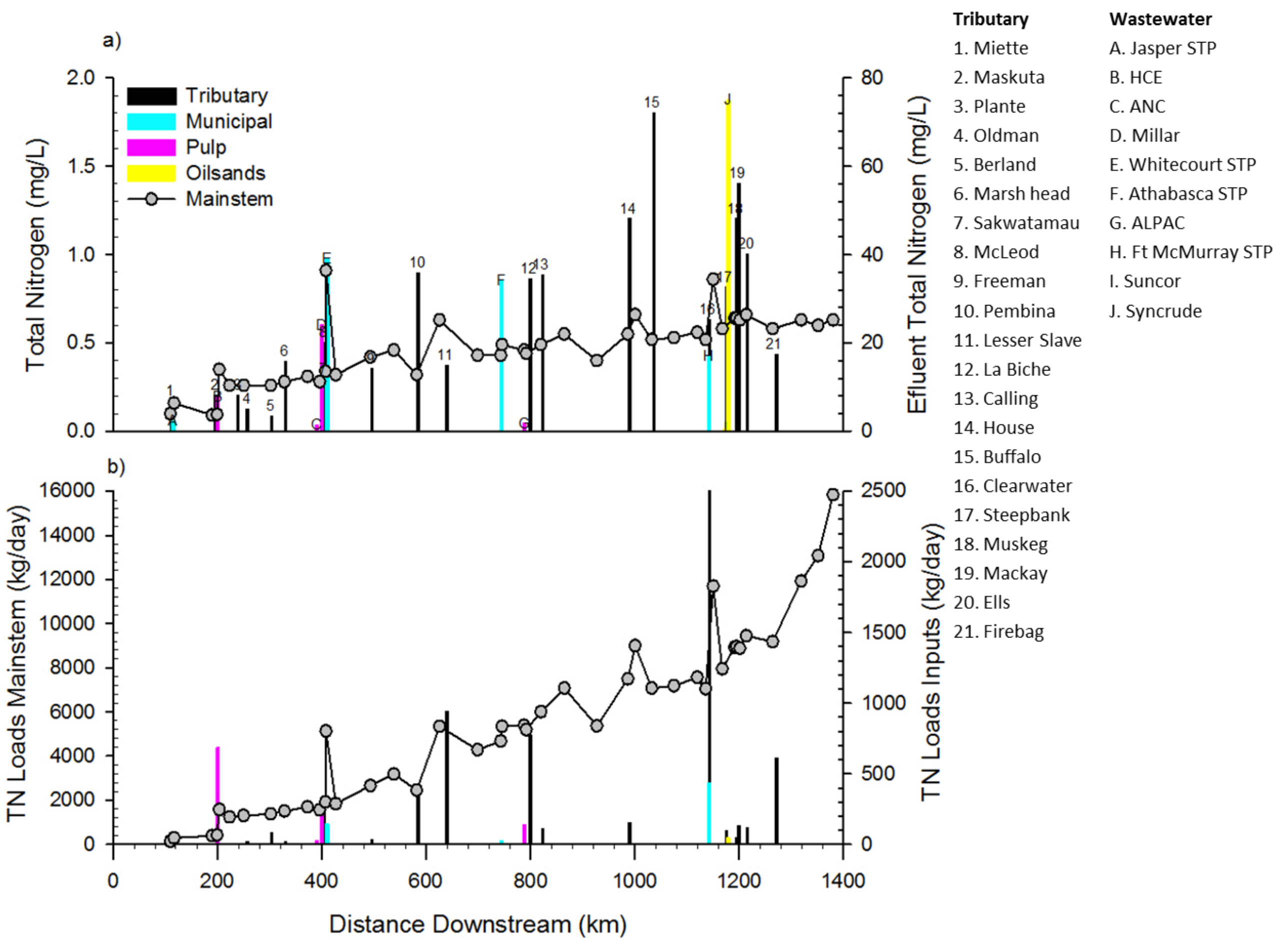

Figure 38. a) total nitrogen (TN; mg/L) in the Athabasca River during the 2015 winter synoptic survey. (b) total nitrogen loads (TN; kg/day) calculated during the survey.

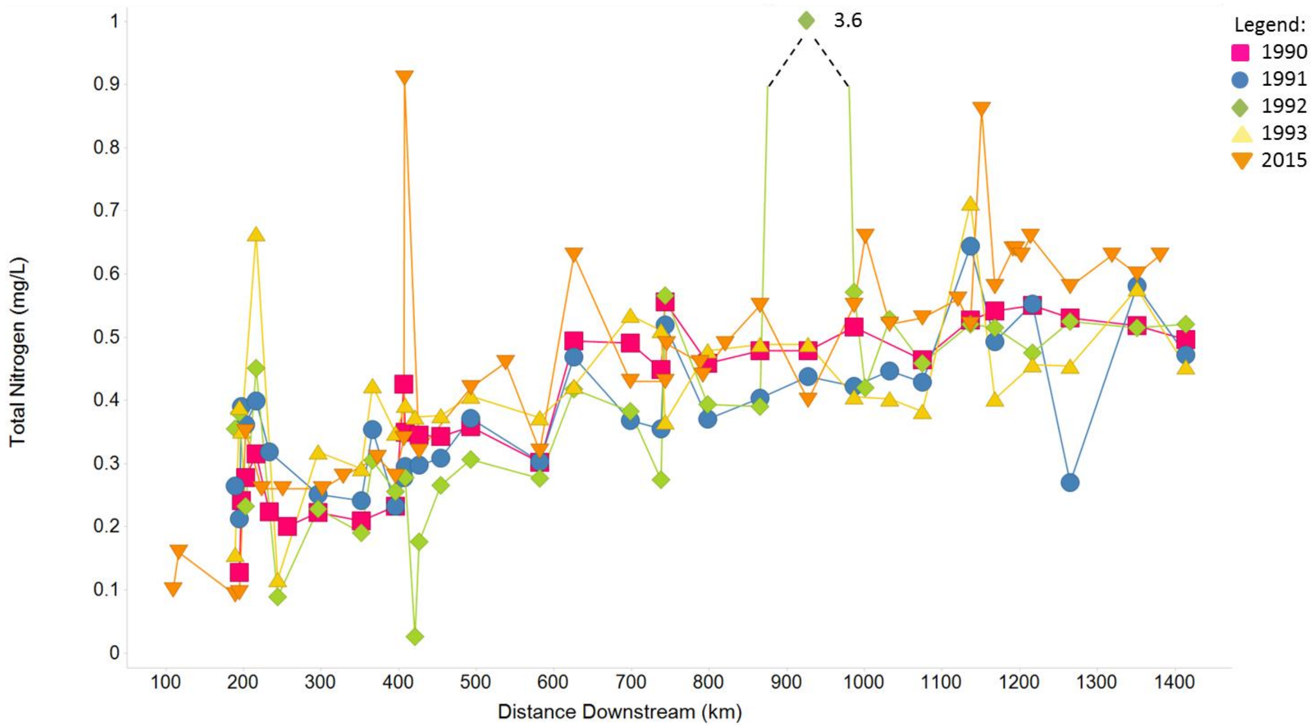

Figure 39. Comparison of total nitrogen (TN; mg/L) measured in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015

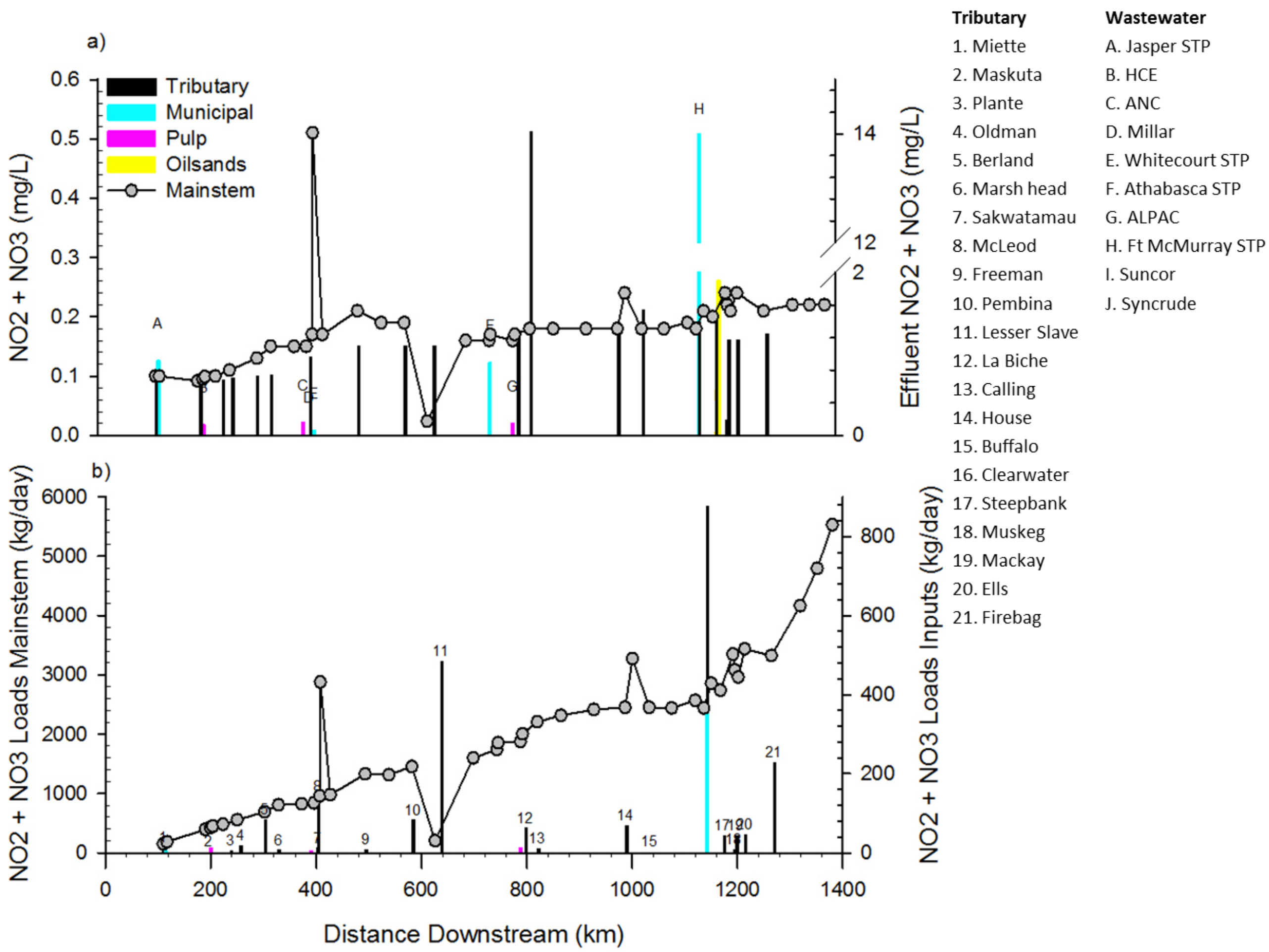

Figure 40. a) total nitrite + nitrate nitrogen ($NO_2 + NO_3$; mg/L) in the Athabasca River during the 2015 winter synoptic survey. (b) total nitrite + nitrate nitrogen loads (kg/day) calculated during the survey.

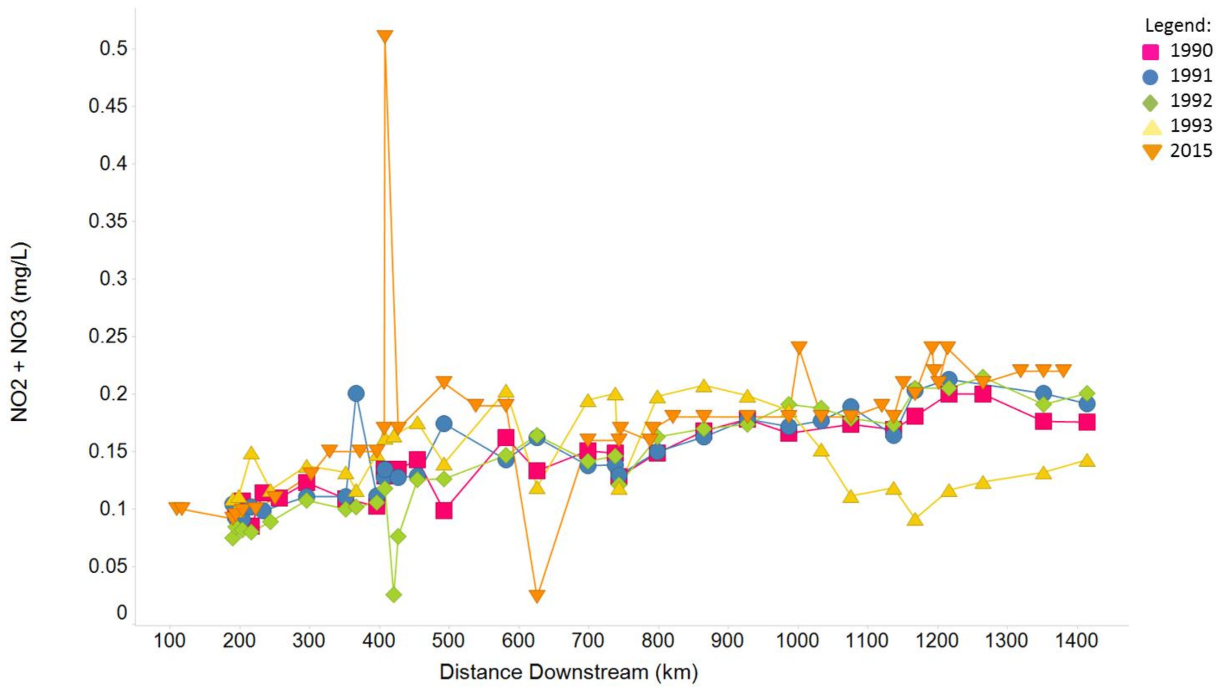

Figure 41. Comparison of total nitrite + nitrate nitrogen (TN; mg/L) measured in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015

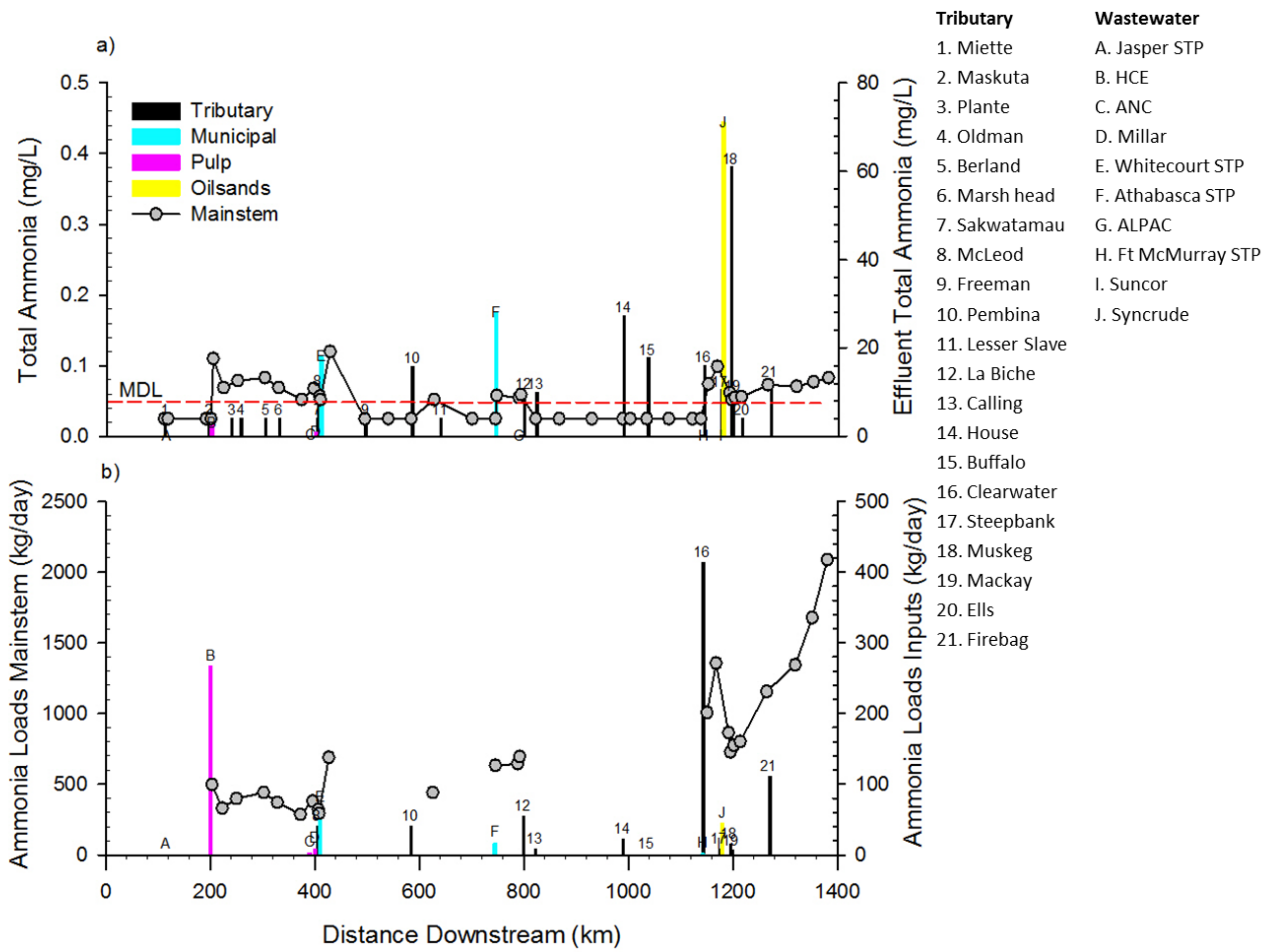

Figure 42. a) total ammonia (mg/L) in the Athabasca River during the 2015 winter synoptic survey. (b) total ammonia loads (kg/day) calculated during the survey.

Total and Dissolved Metals Figures

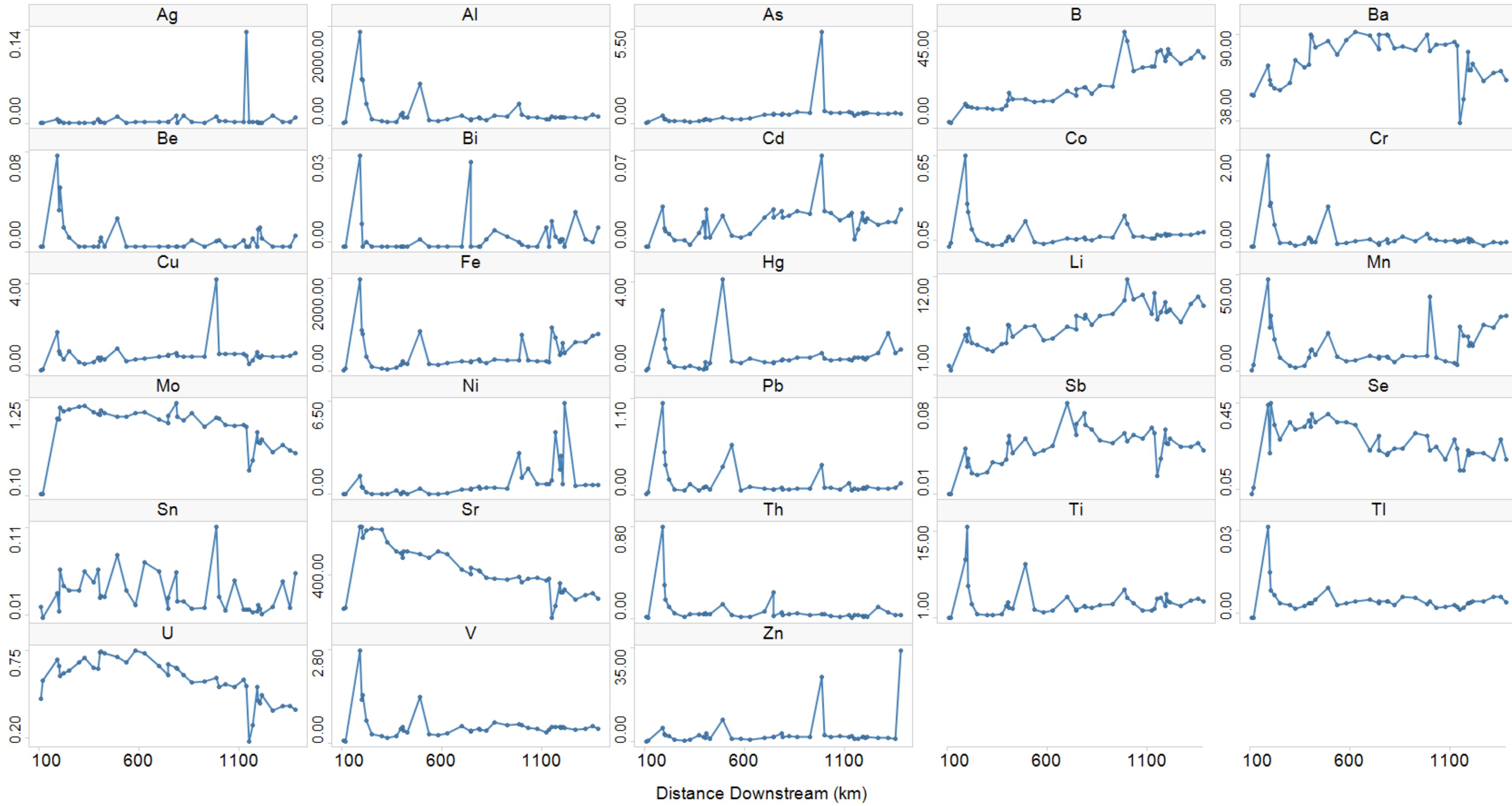

Figure 43. Total metal concentrations (µg/L) in the Athabasca River during the survey.

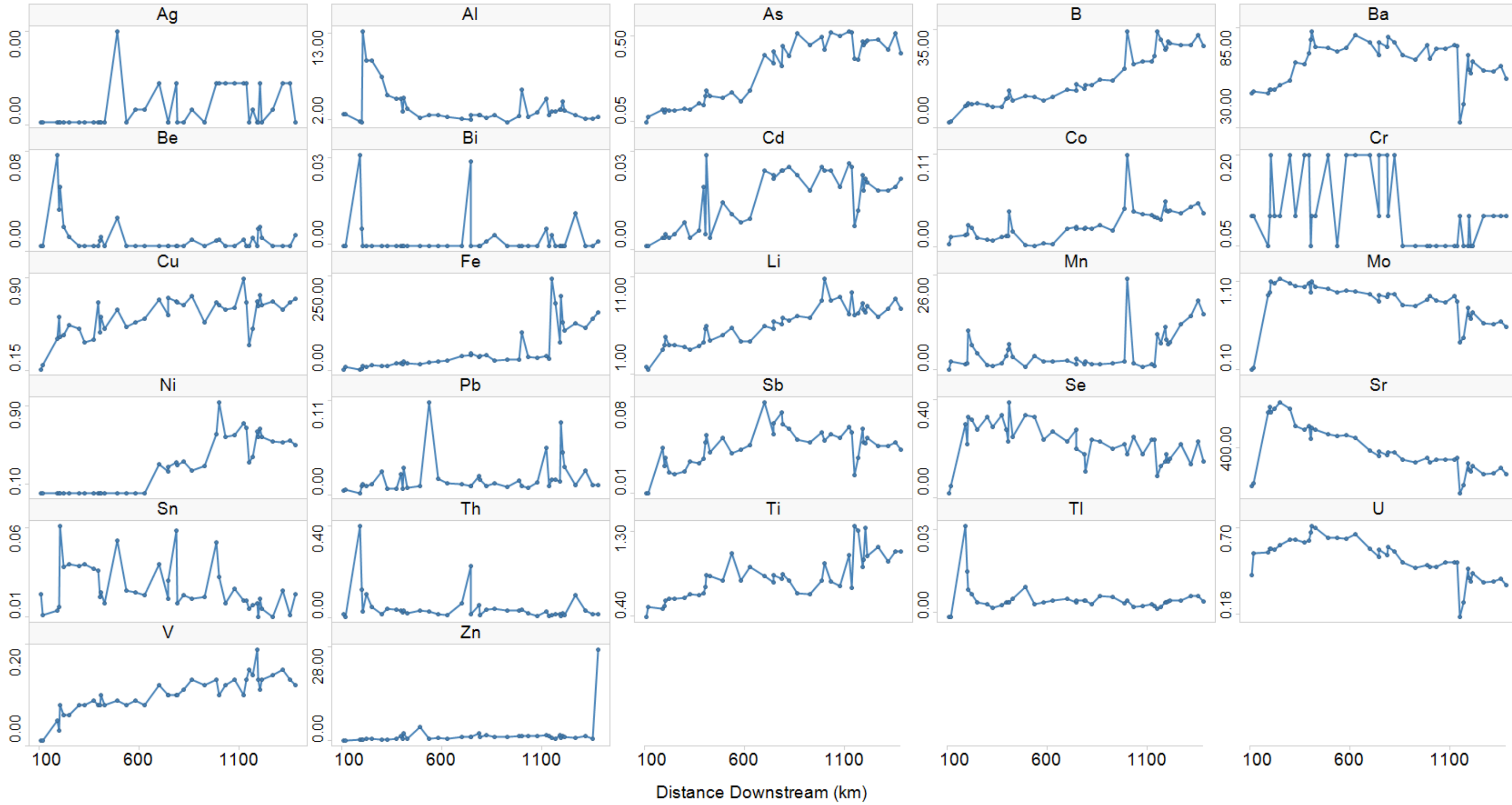

Figure 44. Dissolved metal concentrations (µg/L) in the Athabasca River during the survey.

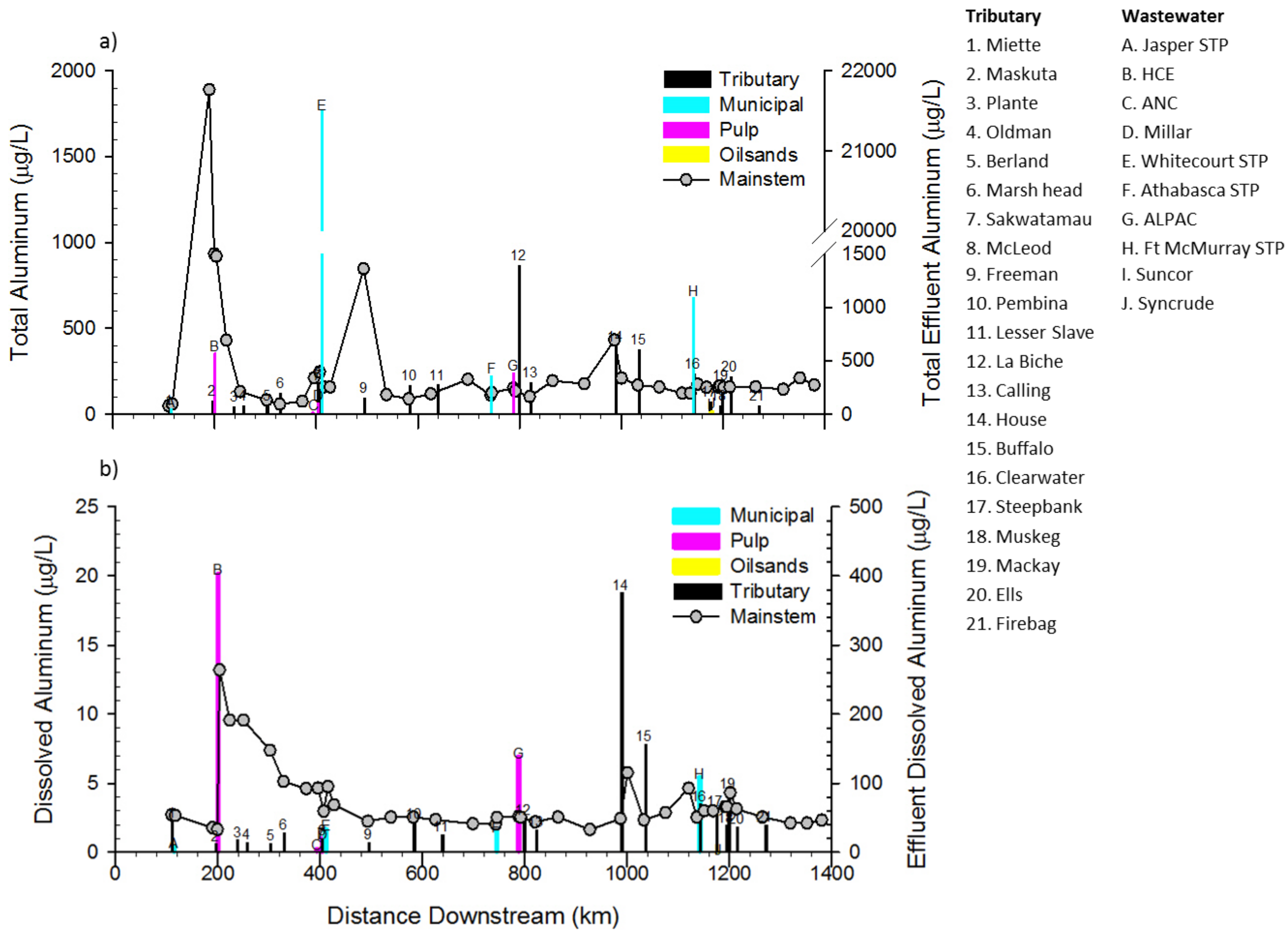

Figure 45. Concentrations of a) total aluminum (µg/L) and b) dissolved aluminum (µg/L) during the 2015 winter synoptic survey.

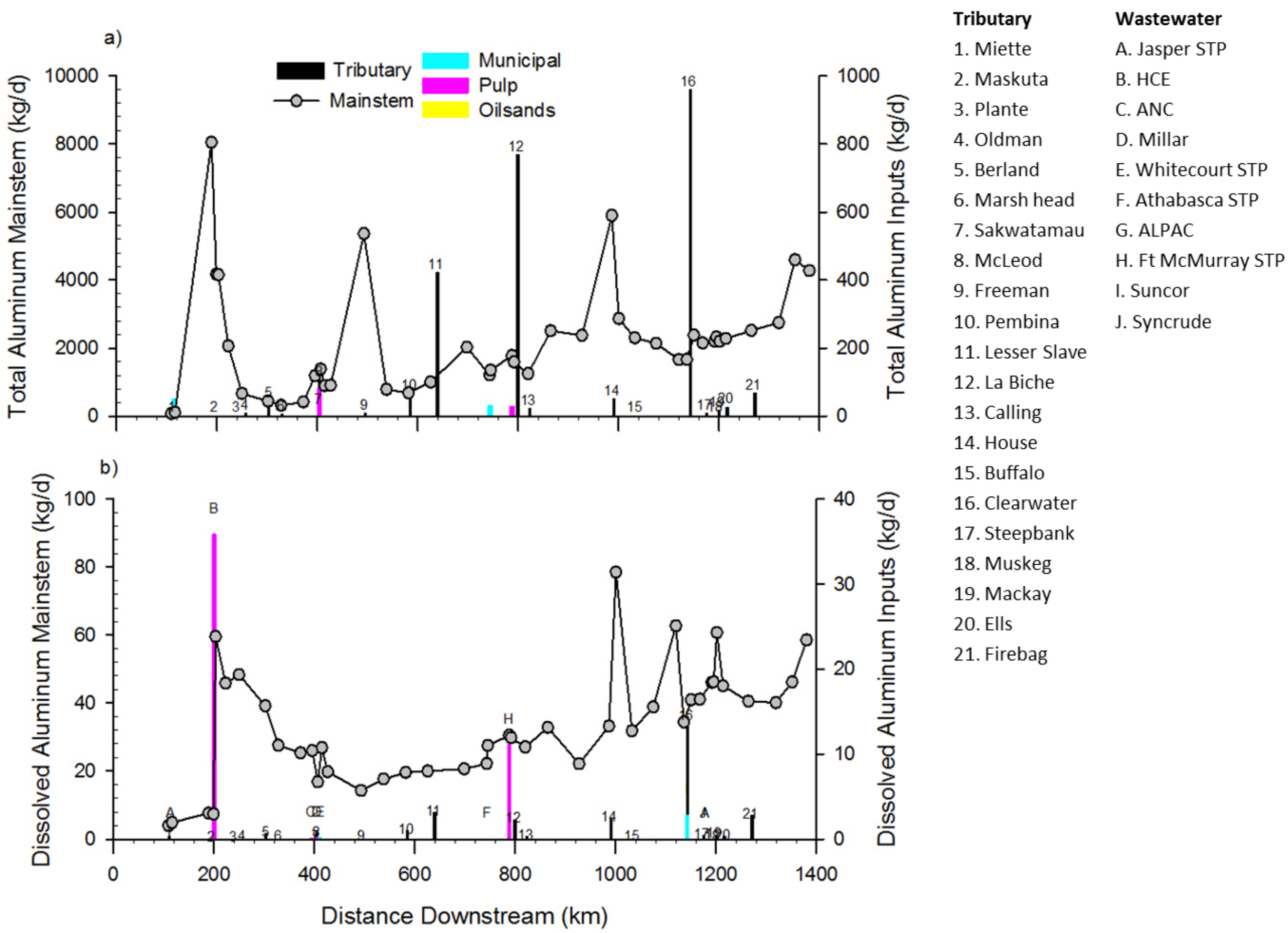

Figure 46. Calculated mass loads of a) total aluminum (kg/day) and b) dissolved aluminum (kg/day) during the 2015 winter synoptic survey.

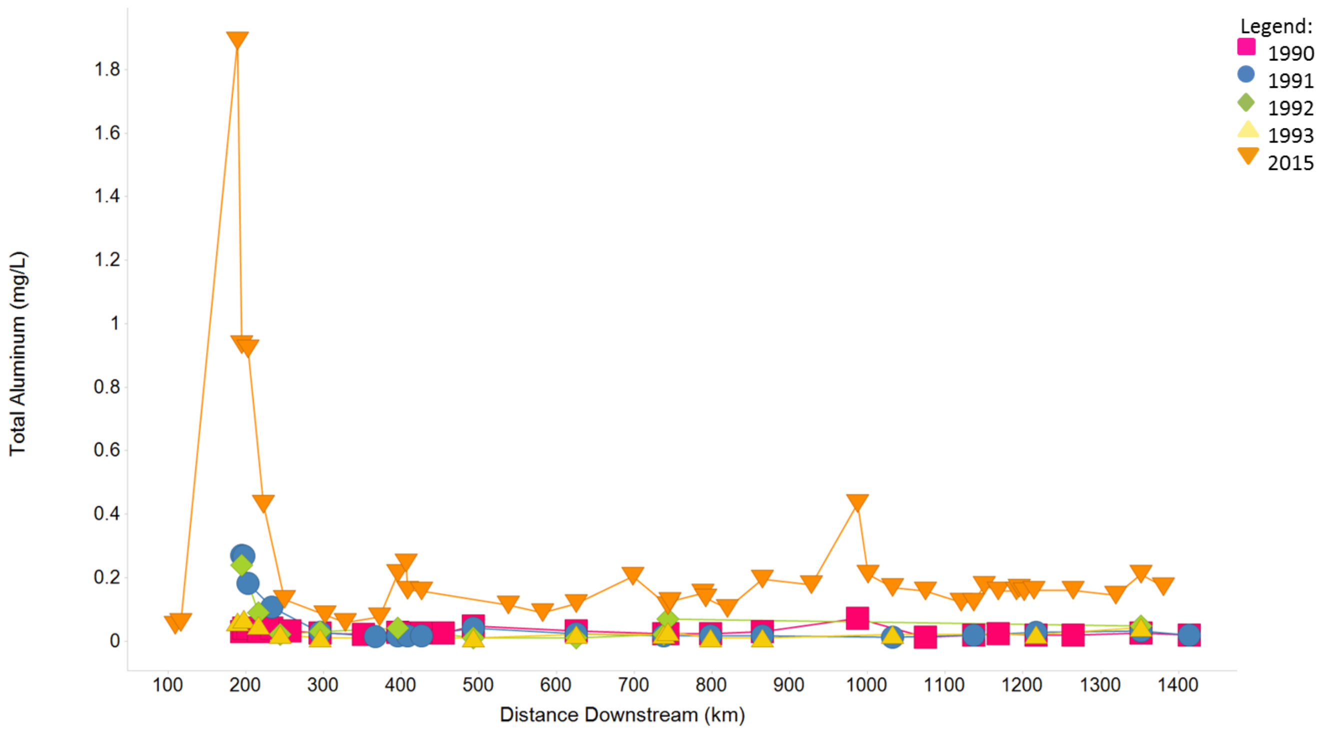

Figure 47. Comparison of total aluminum (mg/L) measured during the winter synoptic surveys from 1990-1993 and 2015.

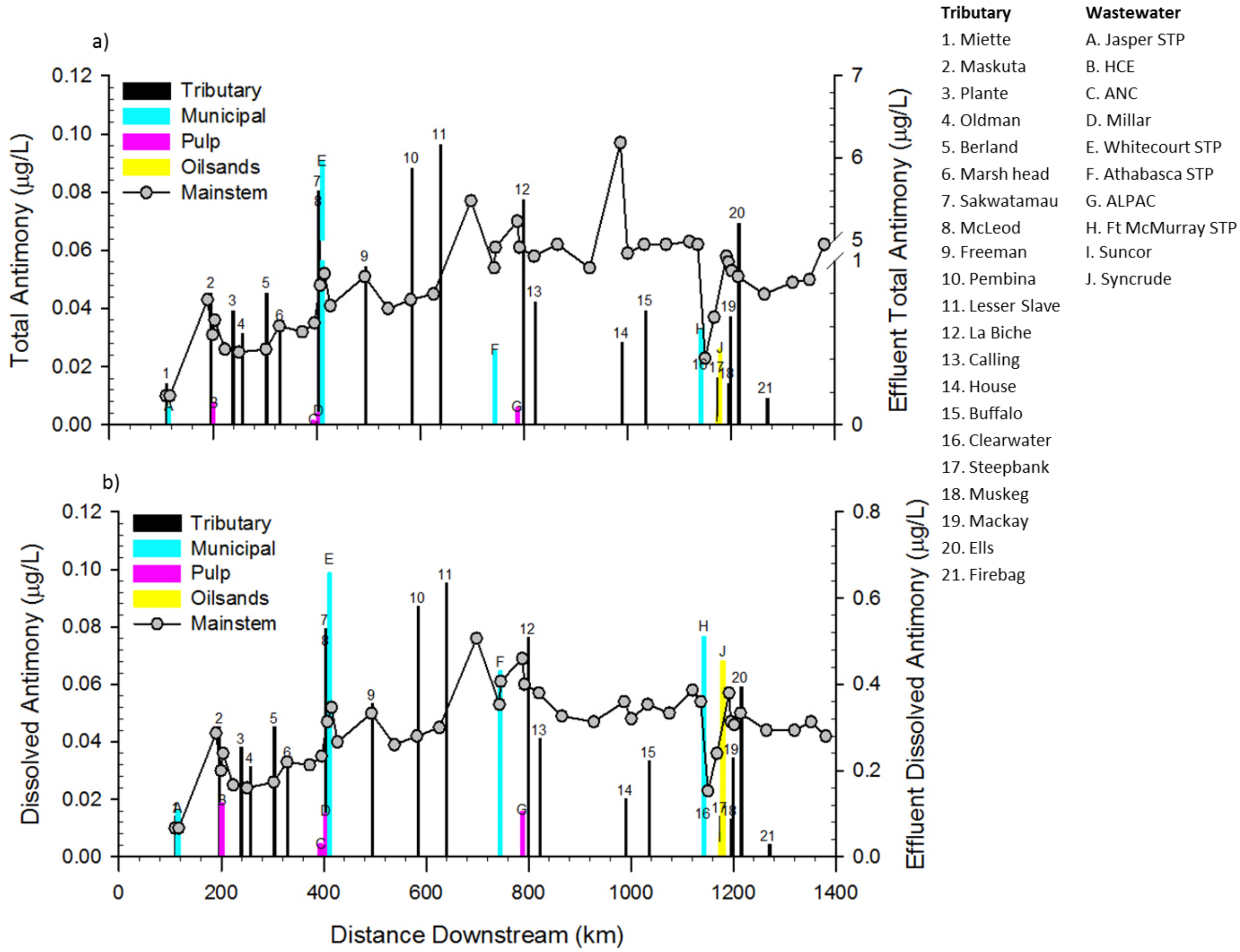

Figure 48. Concentrations of a) total antimony (µg/L) and b) dissolved antimony (µg/L) during the 2015 winter synoptic survey.

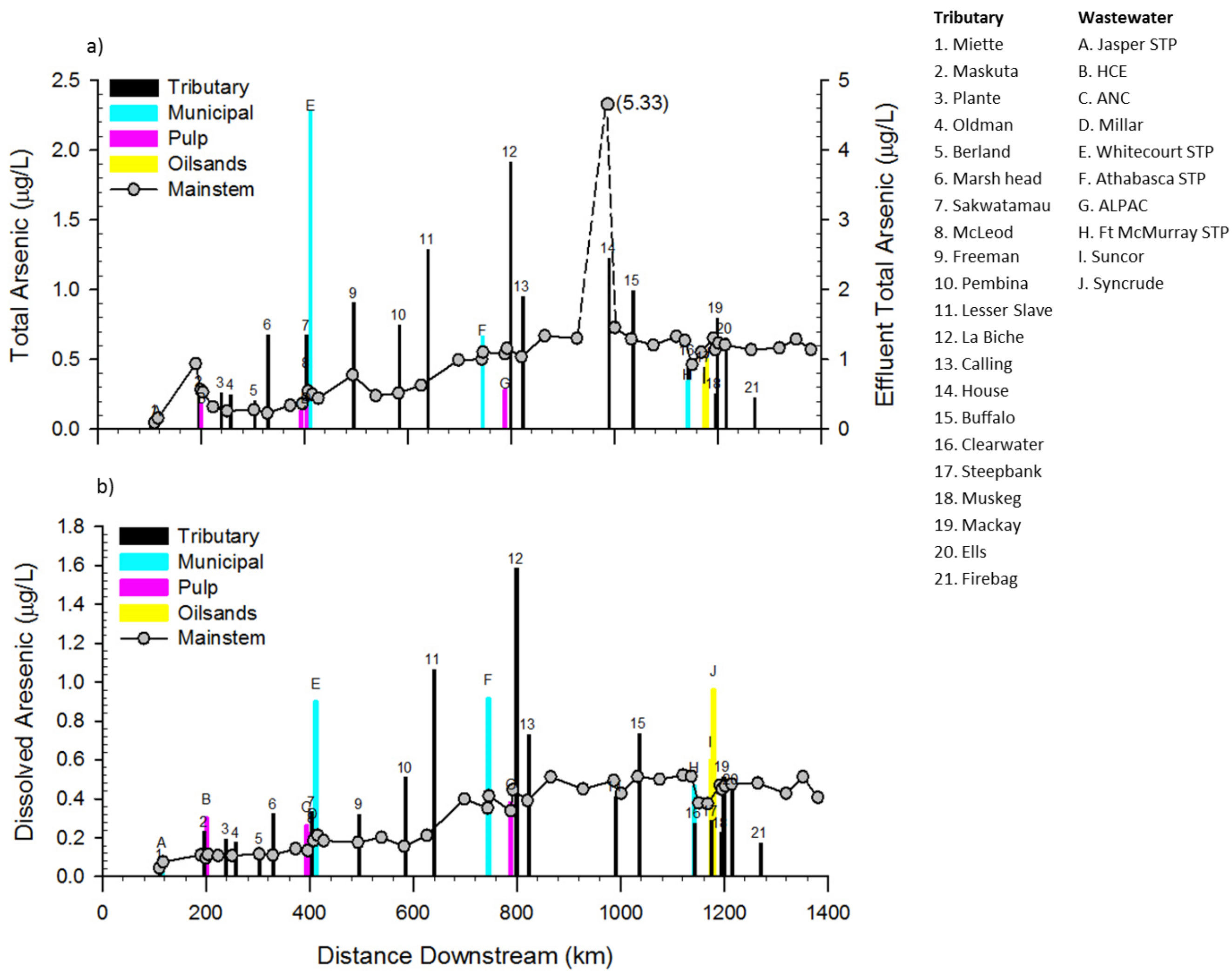

Figure 49. Concentrations of a) total arsenic (µg/L) and b) dissolved arsenic (µg/L) during the 2015 winter synoptic survey.

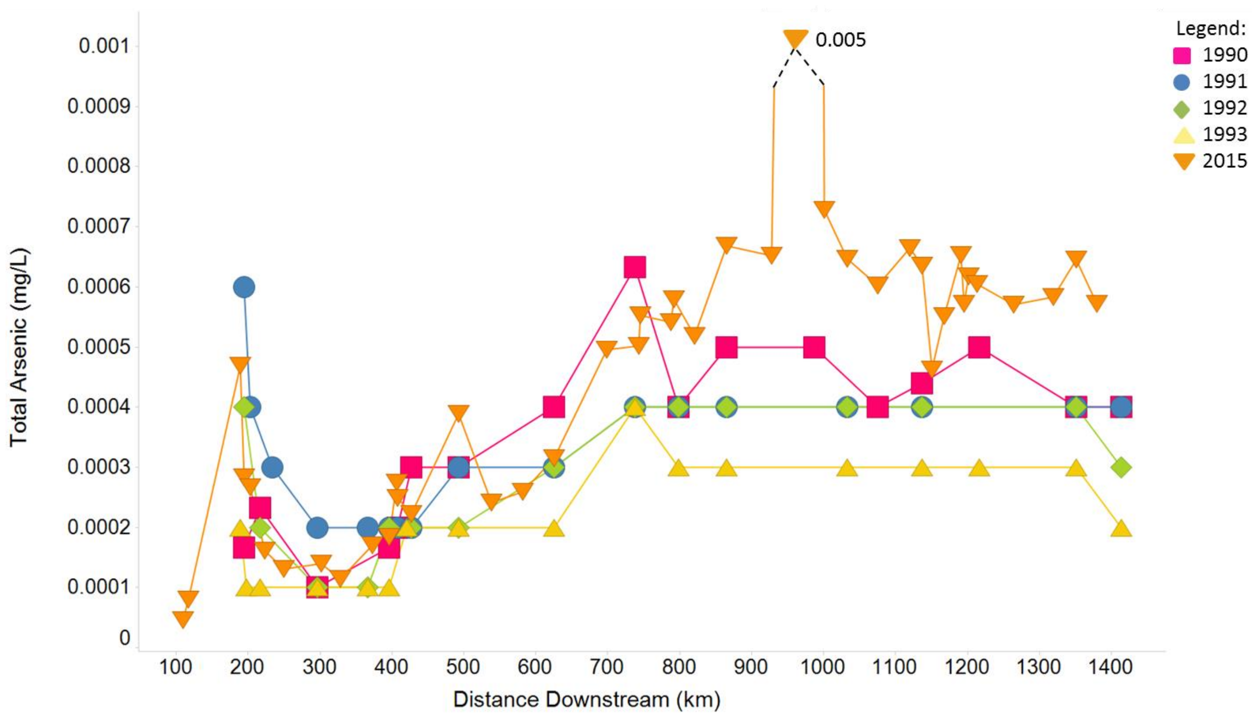

Figure 50. Comparison of total arsenic (mg/L) measured during the winter synoptic surveys from 1990-1993 and 2015

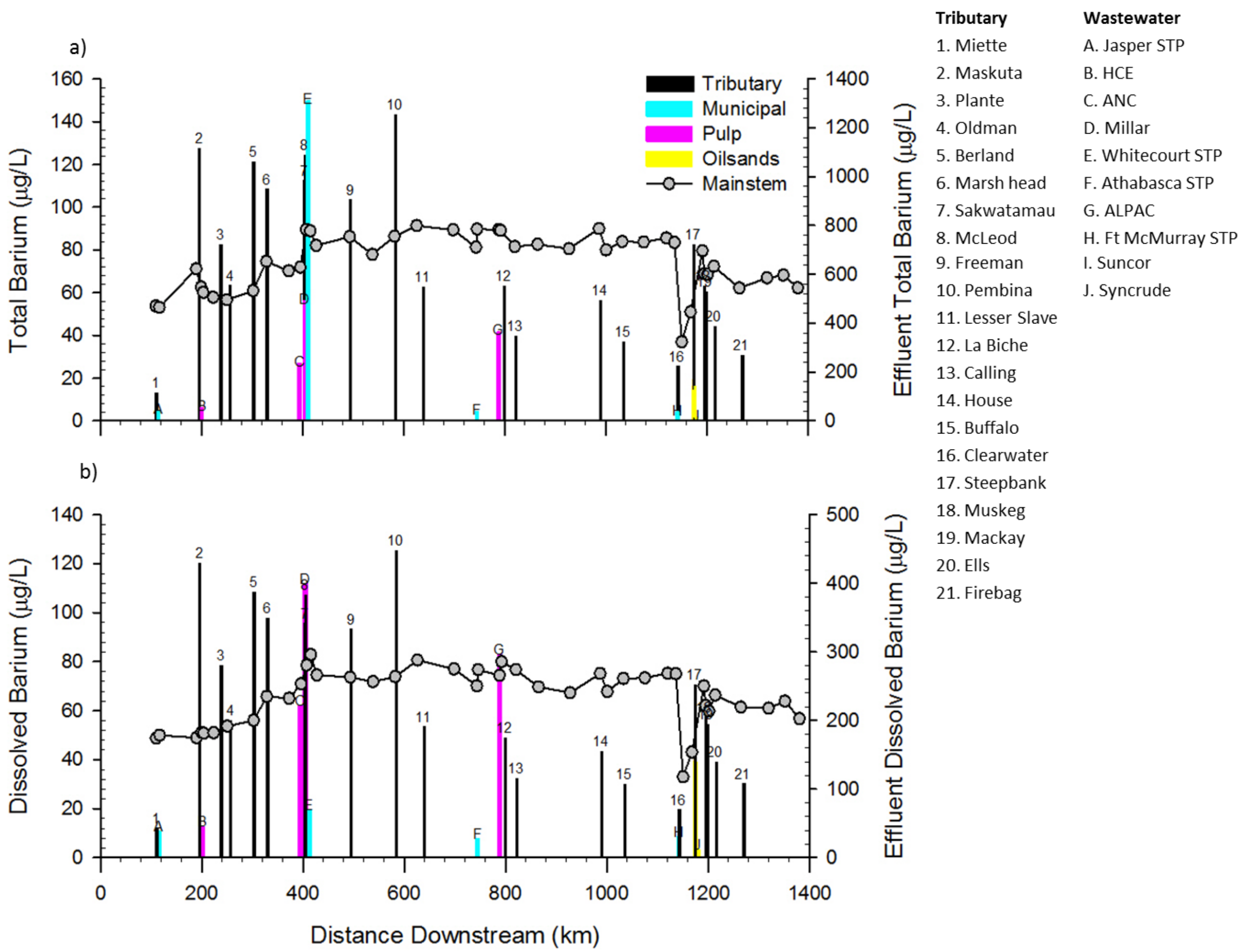

Figure 51. Concentrations of a) total barium (µg/L) and b) dissolved barium (µg/L) during the 2015 winter synoptic survey.

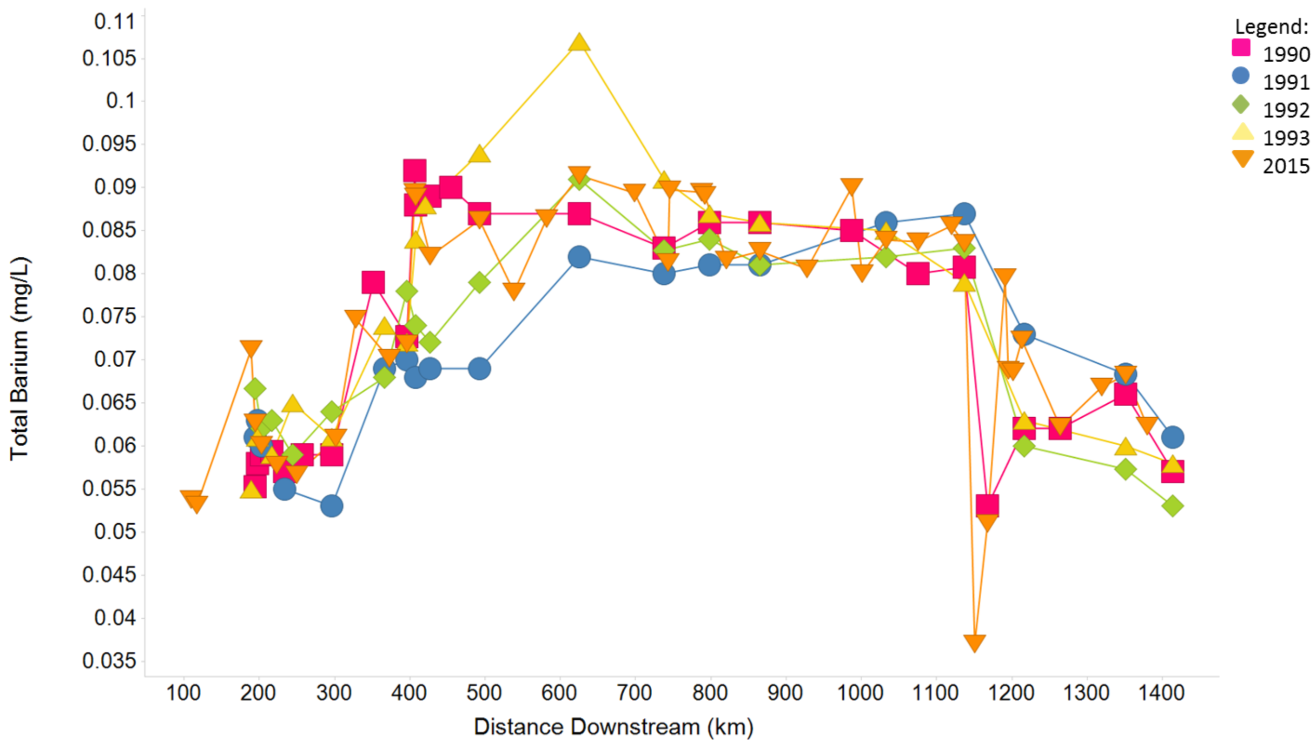

Figure 52. Comparison of total barium (mg/L) measured during the winter synoptic surveys from 1990-1993 and 2015

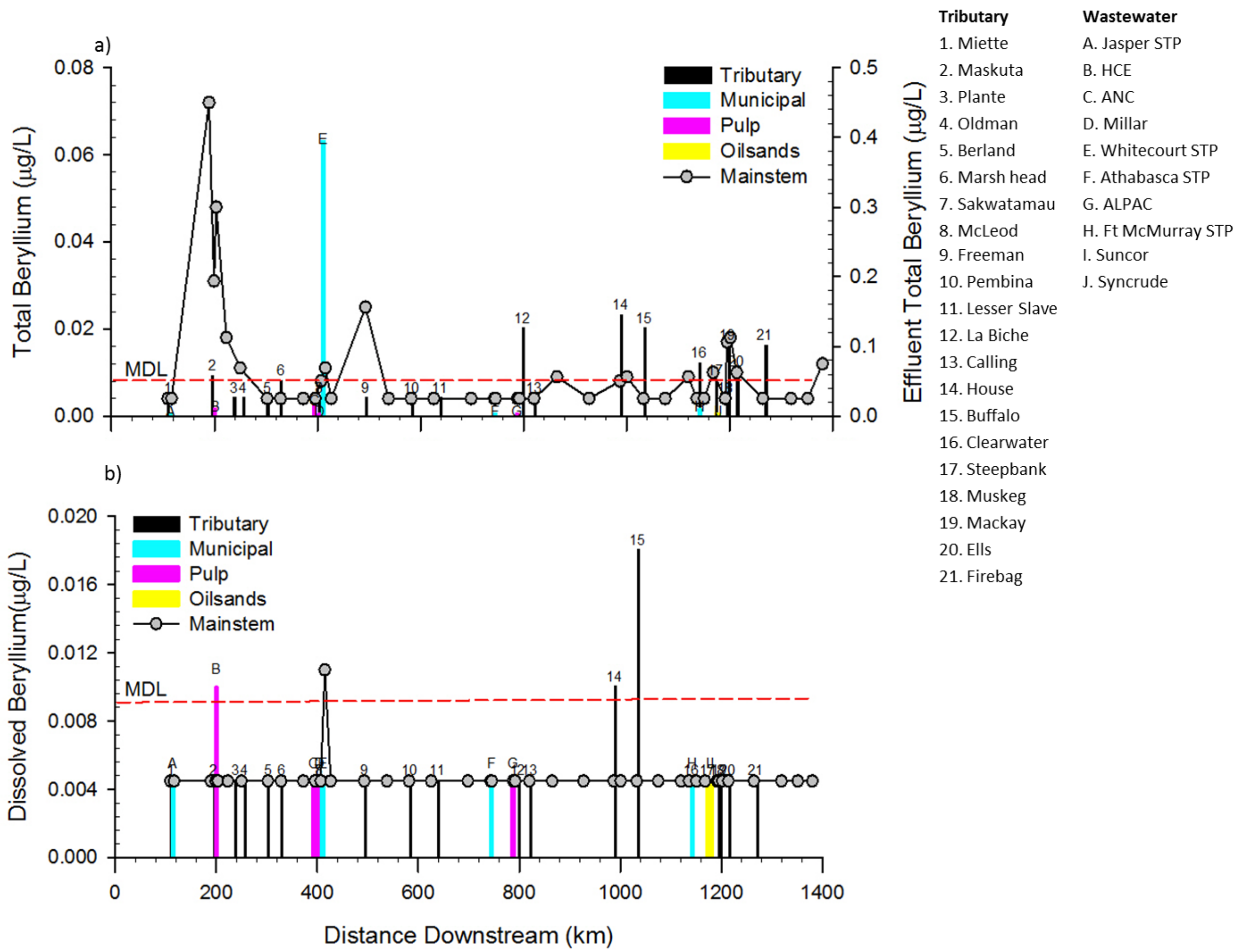

Figure 53. Concentrations of a) total beryllium (µg/L) and b) dissolved beryllium (µg/L) during the 2015 winter synoptic survey.

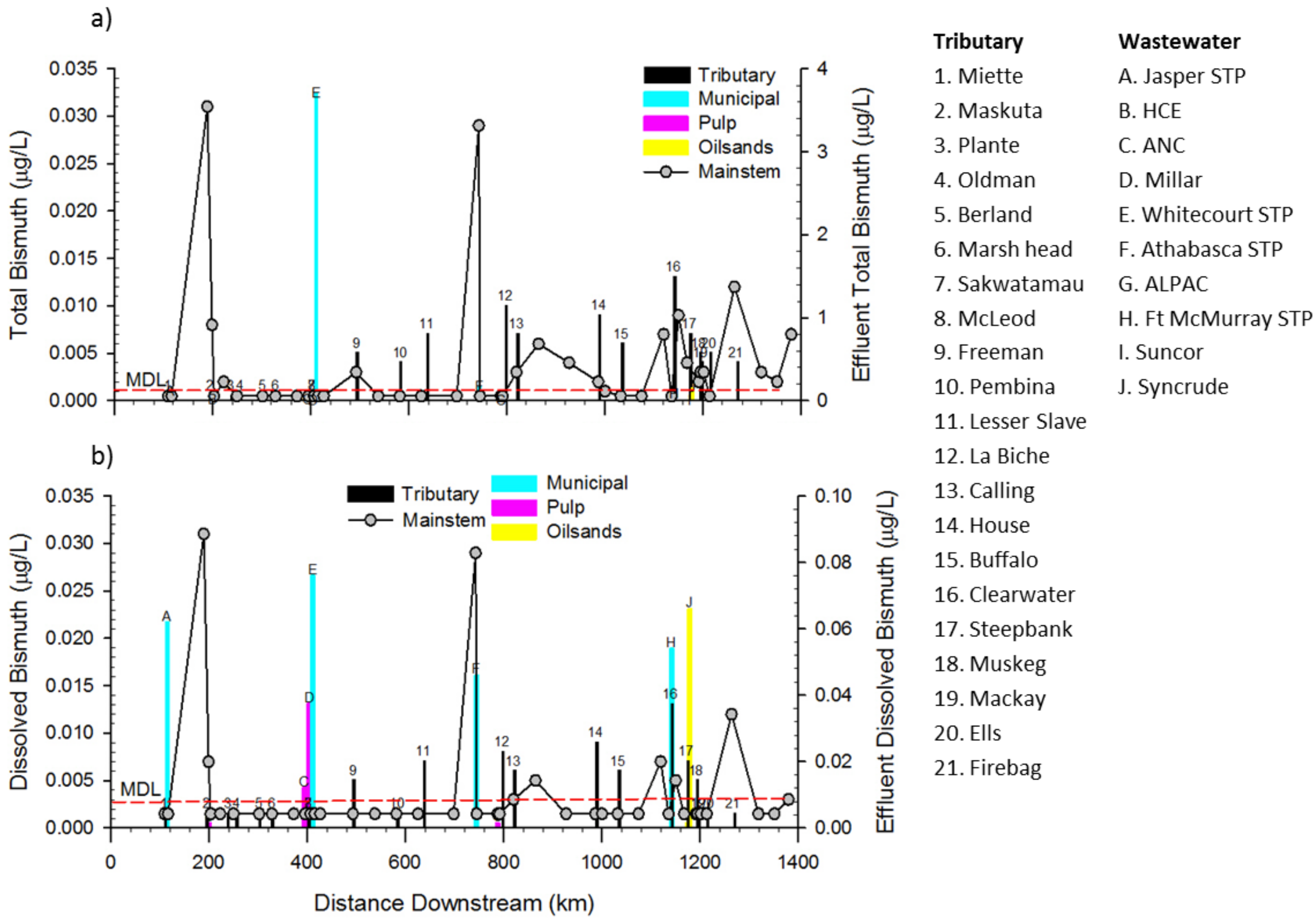

Figure 54. Concentrations of a) total bismuth (µg/L) and b) dissolved bismuth (µg/L) during the 2015 winter synoptic survey.

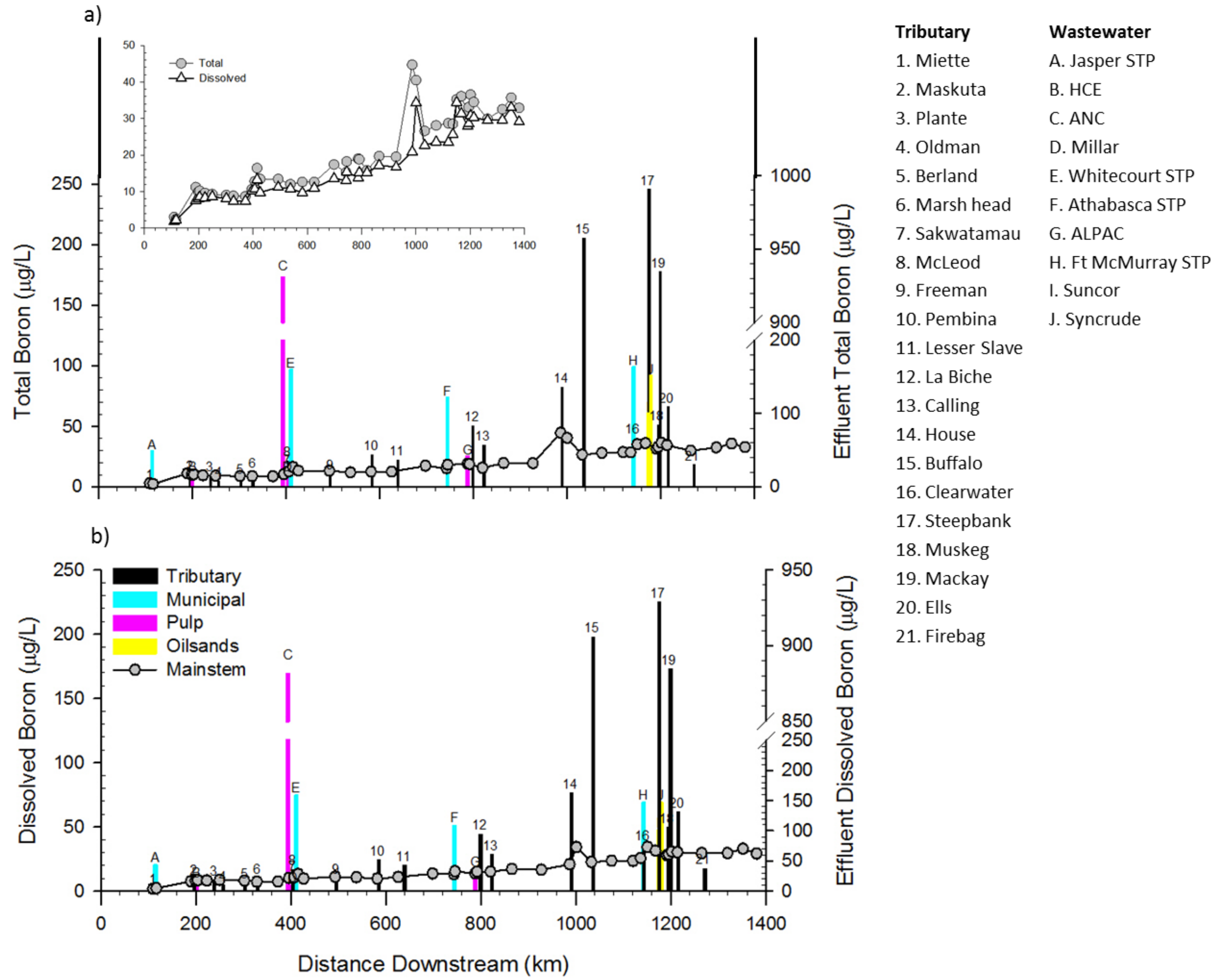

Figure 55. Concentrations of a) total boron (µg/L) and b) dissolved boron (µg/L) during the 2015 winter synoptic survey.

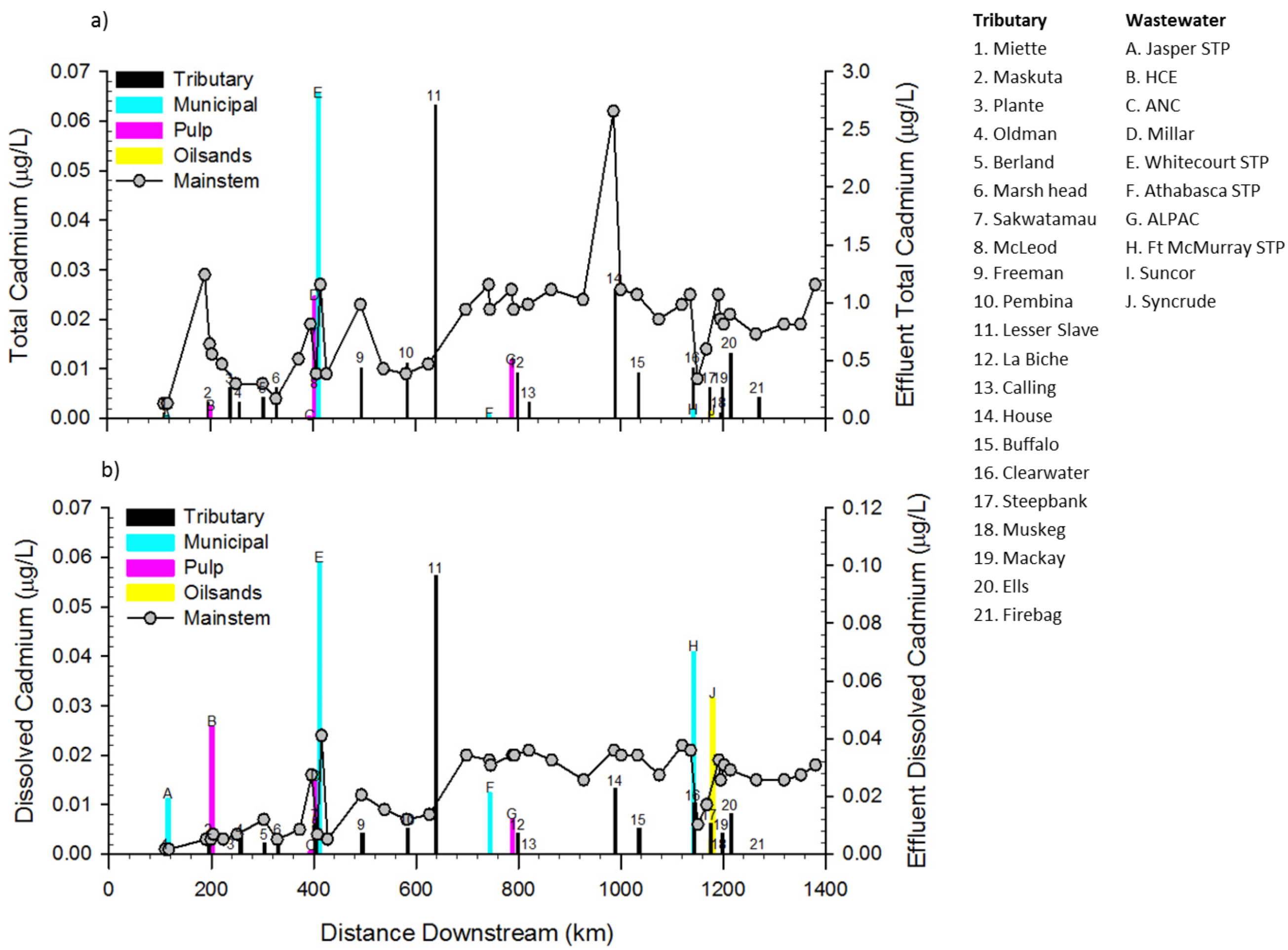

Figure 56. Concentrations of a) total cadmium (µg/L) and b) dissolved cadmium (µg/L) during the 2015 winter synoptic survey.

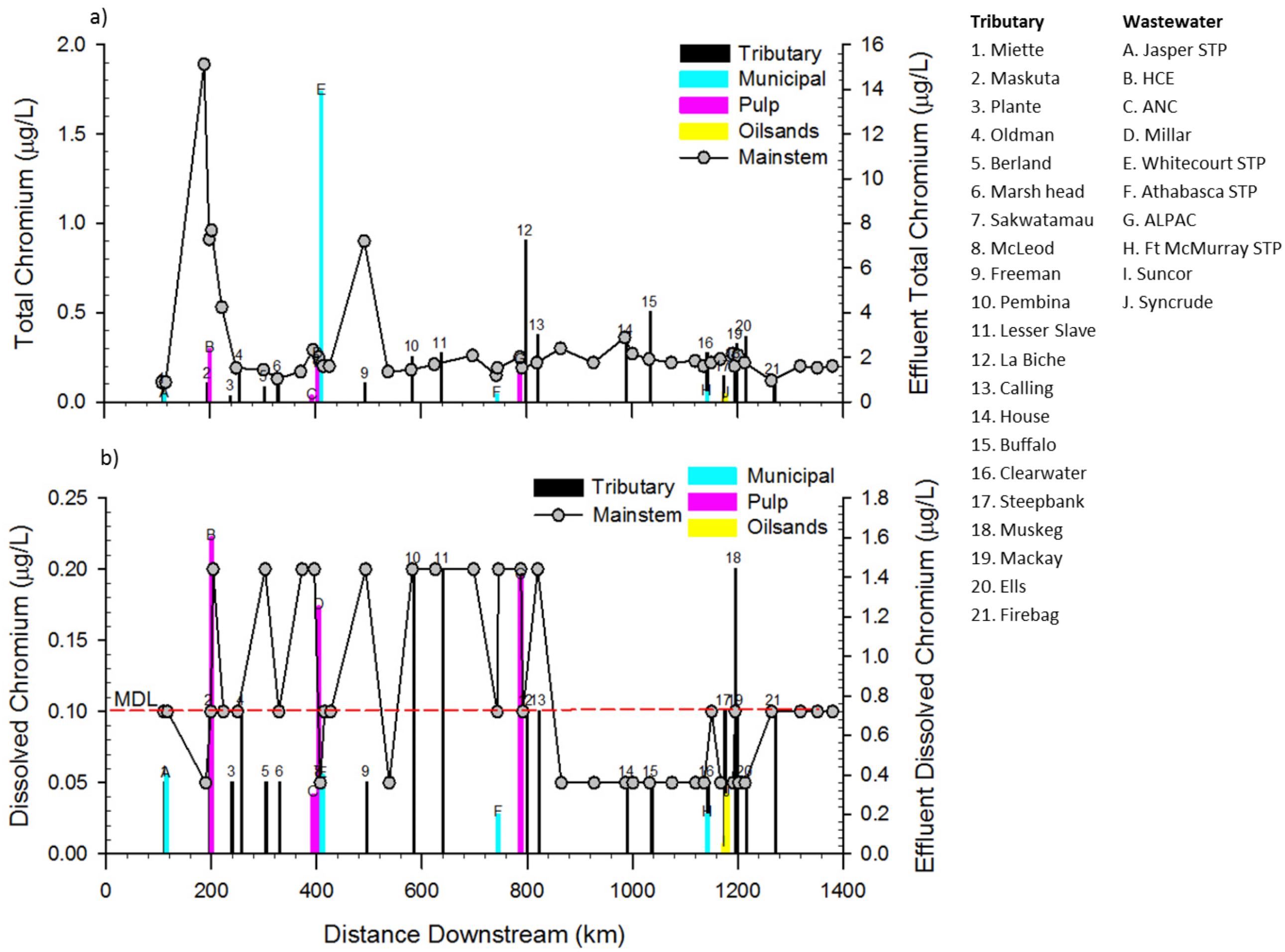

Figure 57. Concentrations of a) total chromium (µg/L) and b) dissolved chromium (µg/L) during the 2015 winter synoptic survey.

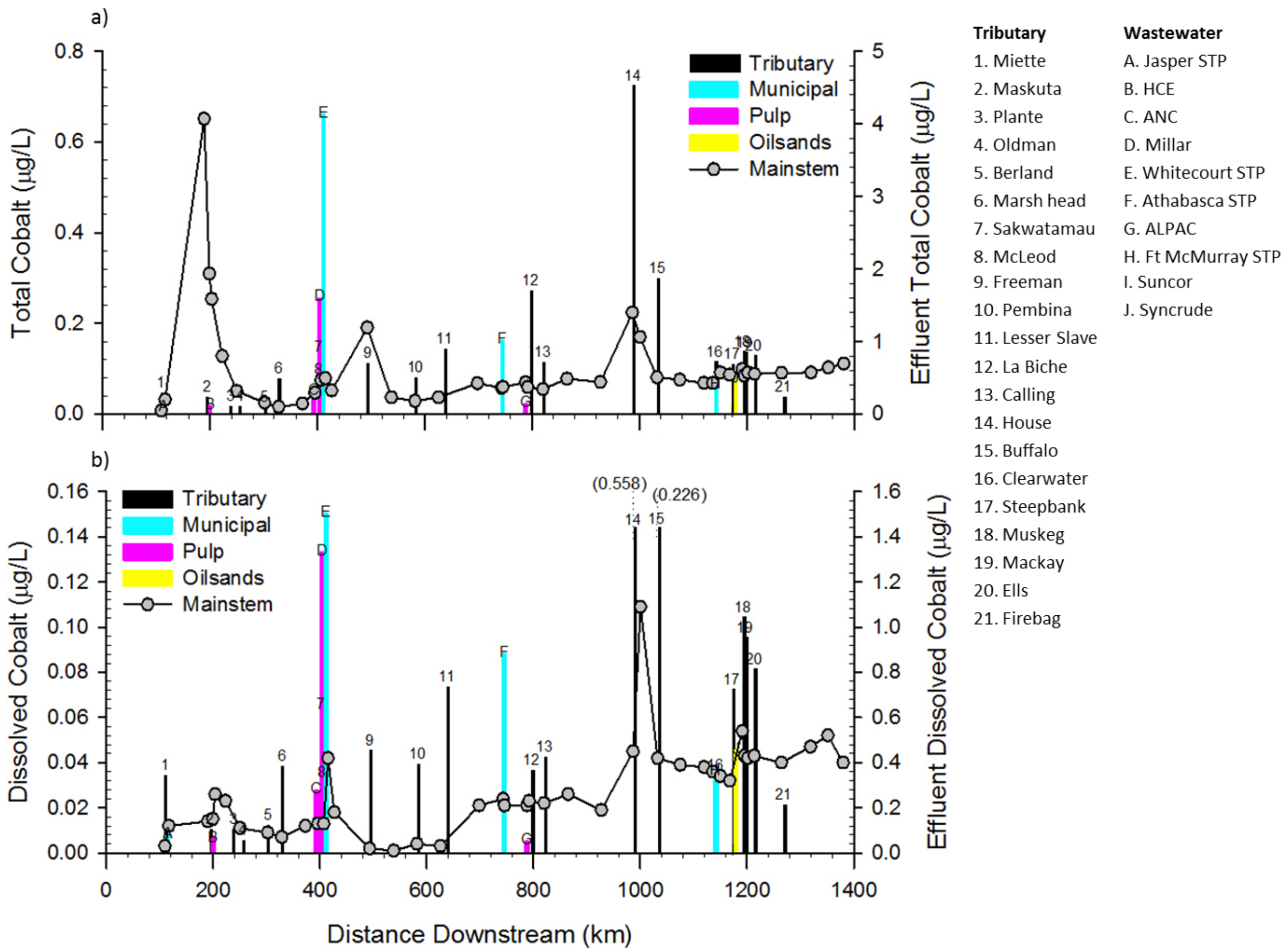

Figure 58. Concentrations of a) total cobalt (µg/L) and b) dissolved cobalt (µg/L) during the 2015 winter synoptic survey.

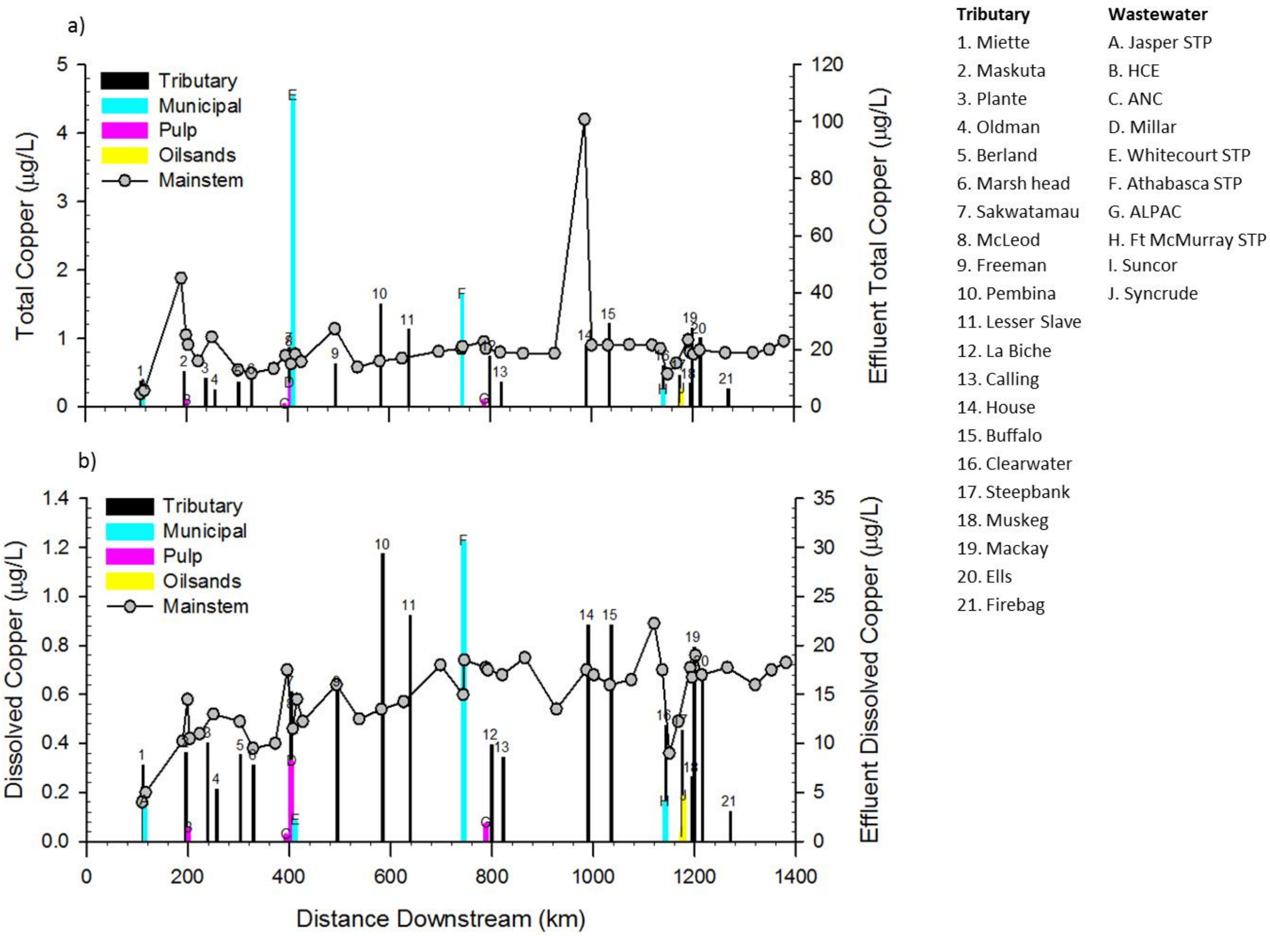

Figure 59. Concentrations of a) total copper (µg/L) and b) dissolved copper (µg/L) during the 2015 winter synoptic survey.

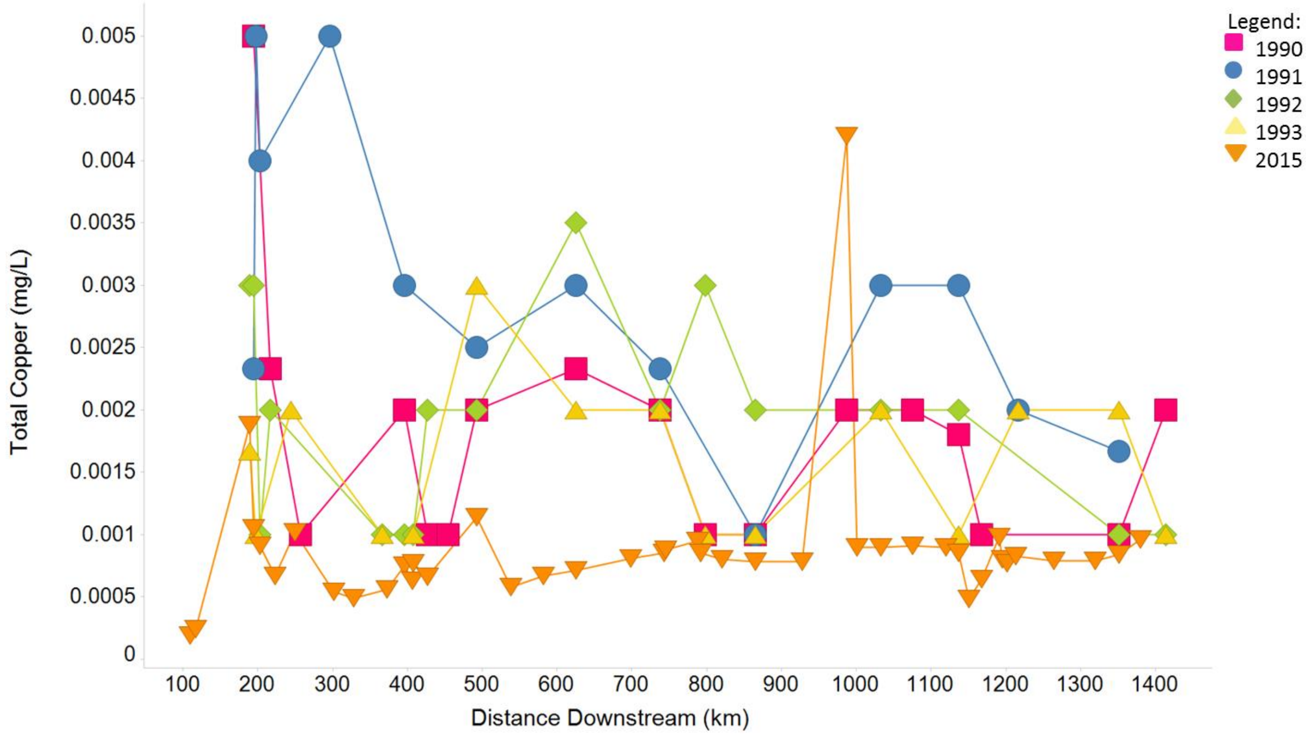

Figure 60. Comparison of total copper (mg/L) measured during the winter synoptic surveys from 1990-1993 and 2015.

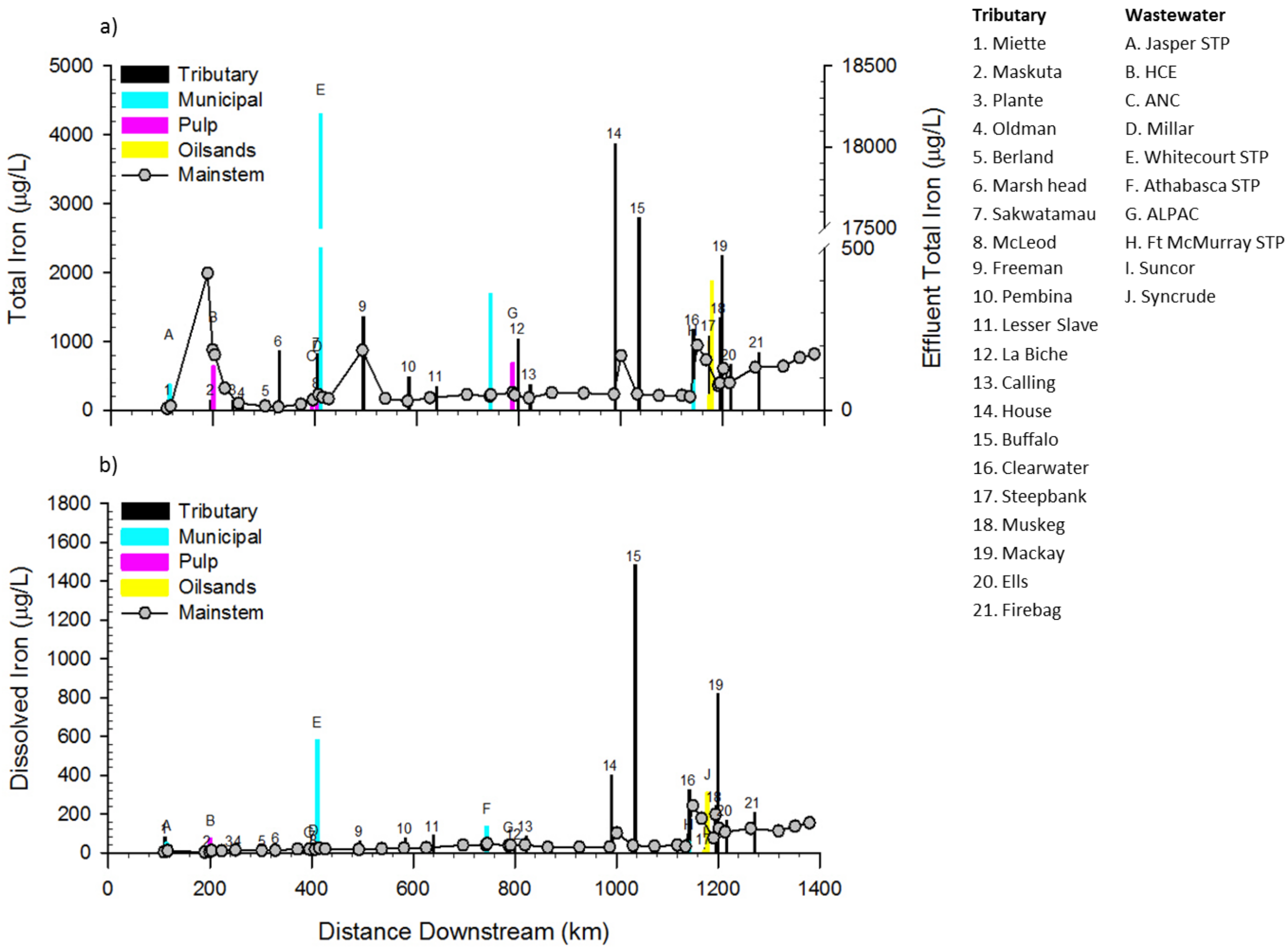

Figure 61. Concentrations of a) total iron (µg/L) and b) dissolved iron (µg/L) during the 2015 winter synoptic survey.

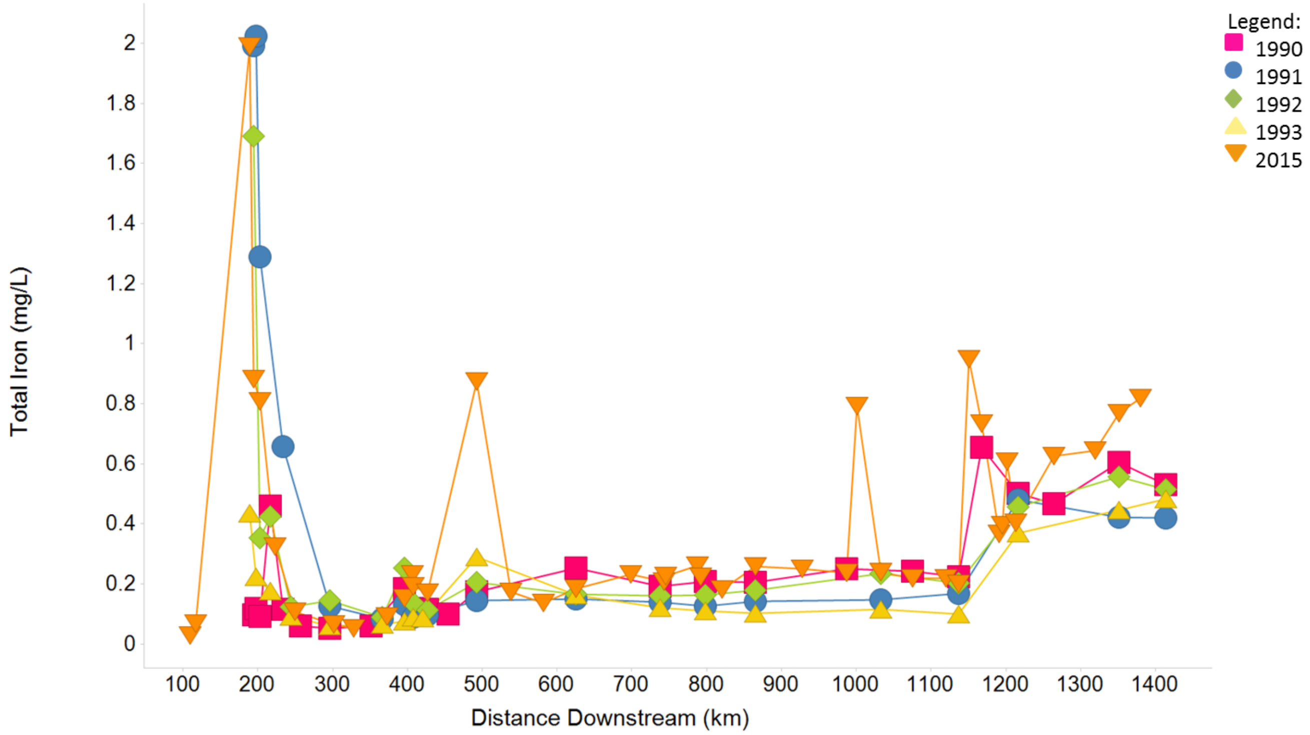

Figure 62. Comparison of total iron (mg/L) measured during the winter synoptic surveys from 1990-1993 and 2015

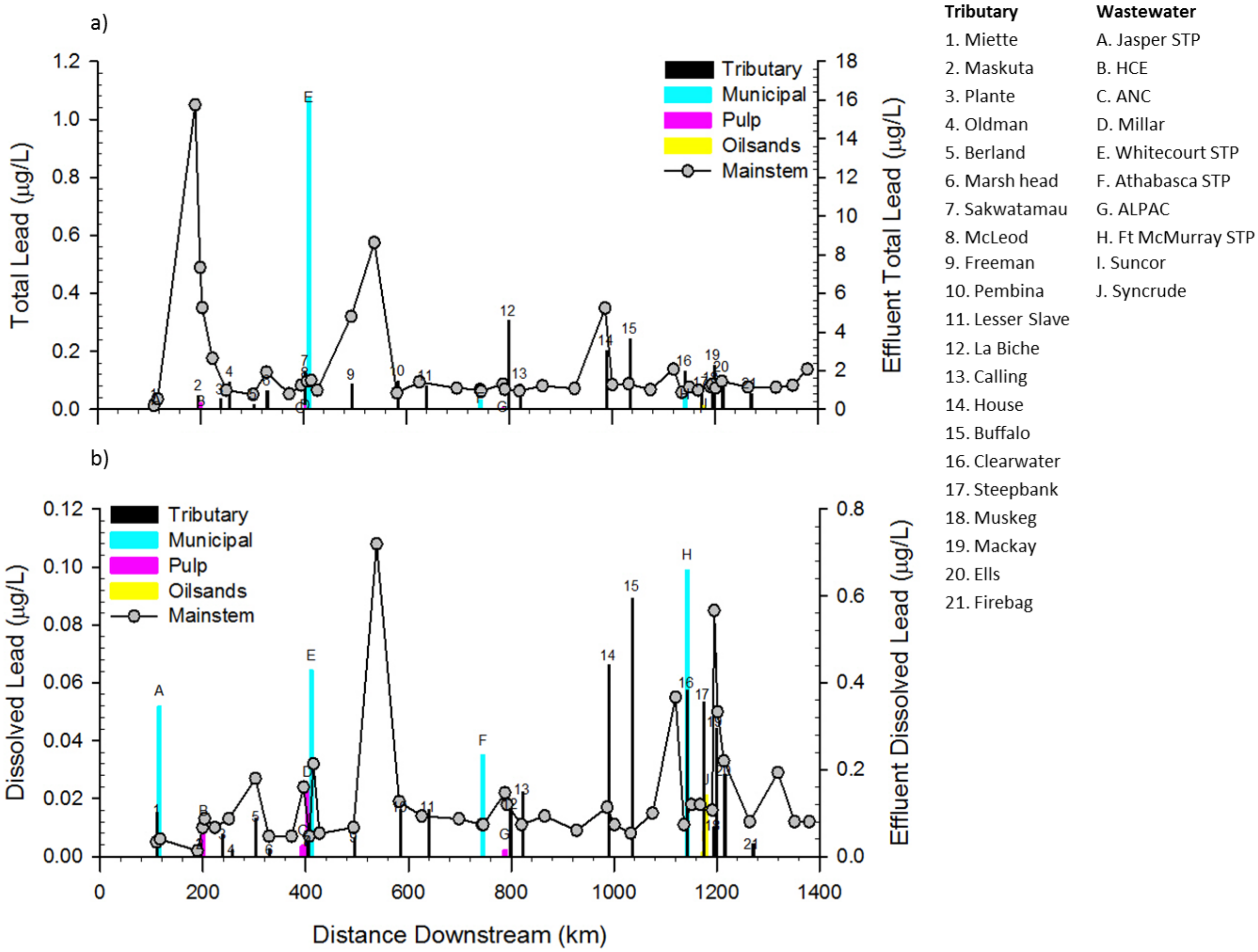

Figure 63. Concentrations of a) total lead (µg/L) and b) dissolved lead (µg/L) during the 2015 winter synoptic survey.

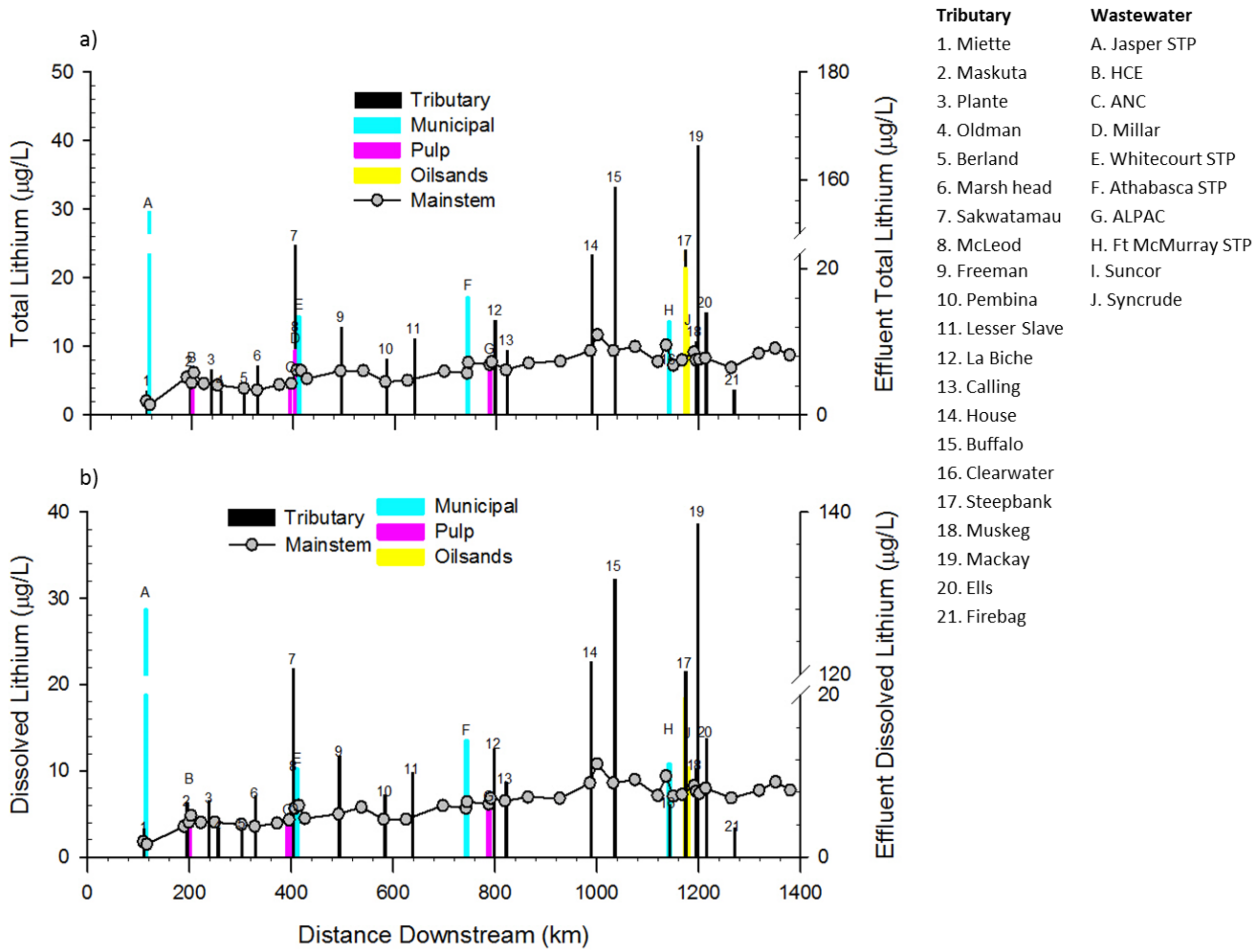

Figure 64. Concentrations of a) total lithium (µg/L) and b) dissolved lithium (µg/L) during the 2015 winter synoptic survey

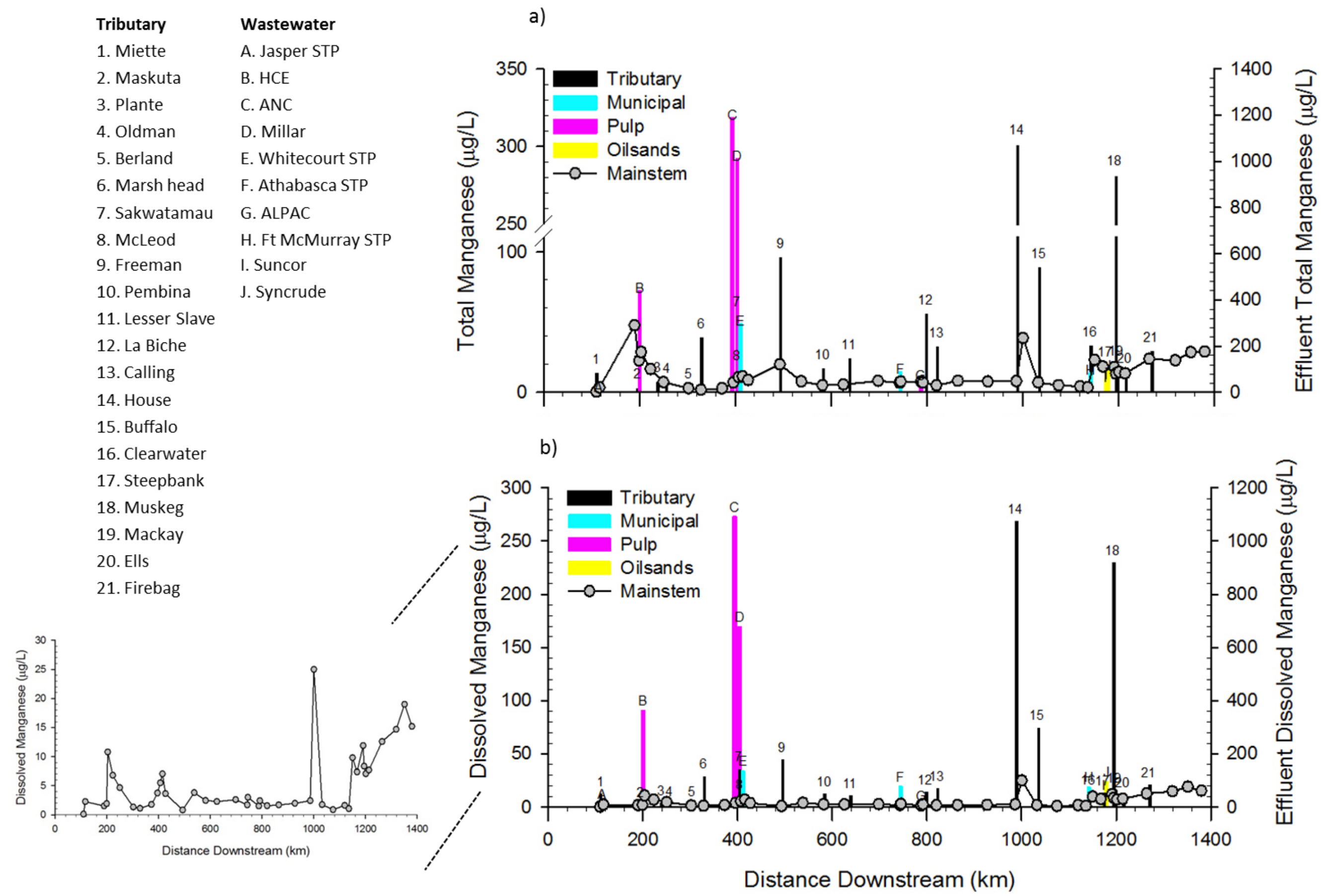

Figure 65. Concentrations of a) total manganese (µg/L) and b) dissolved manganese (µg/L) during the 2015 winter synoptic survey

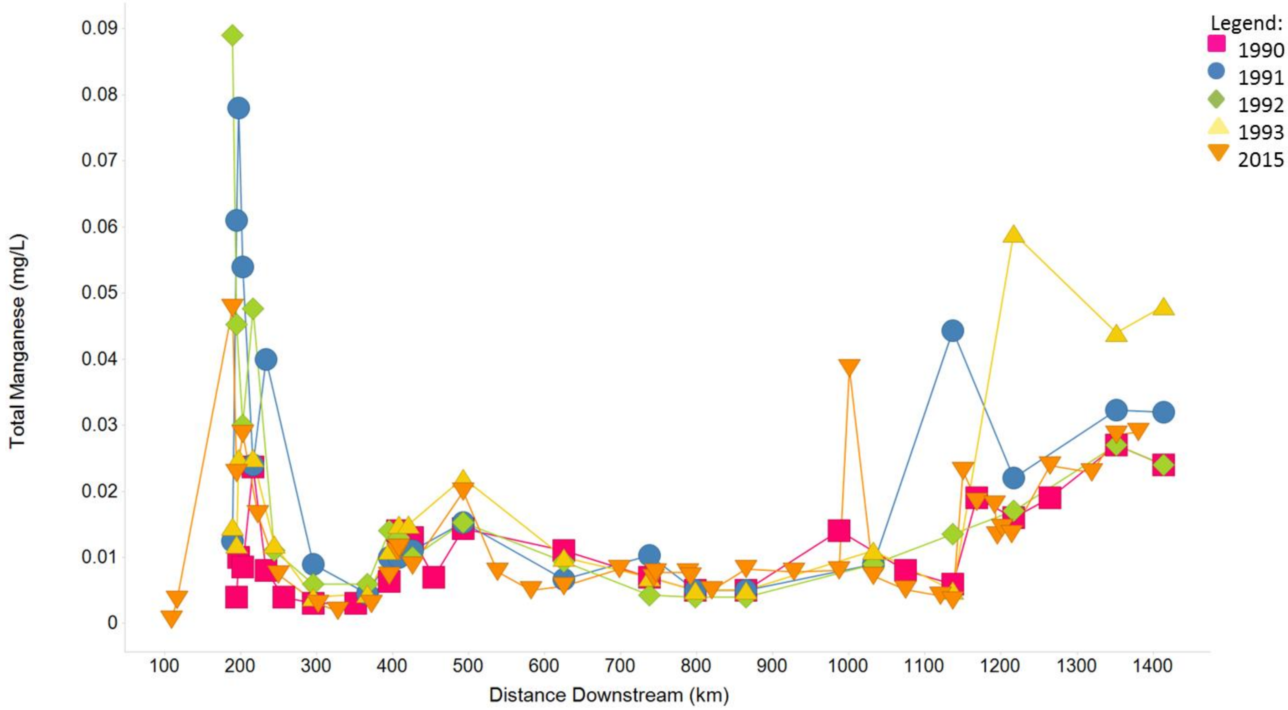

Figure 66. Comparison of total manganese (mg/L) measured during the winter synoptic surveys from 1990-1993 and 2015

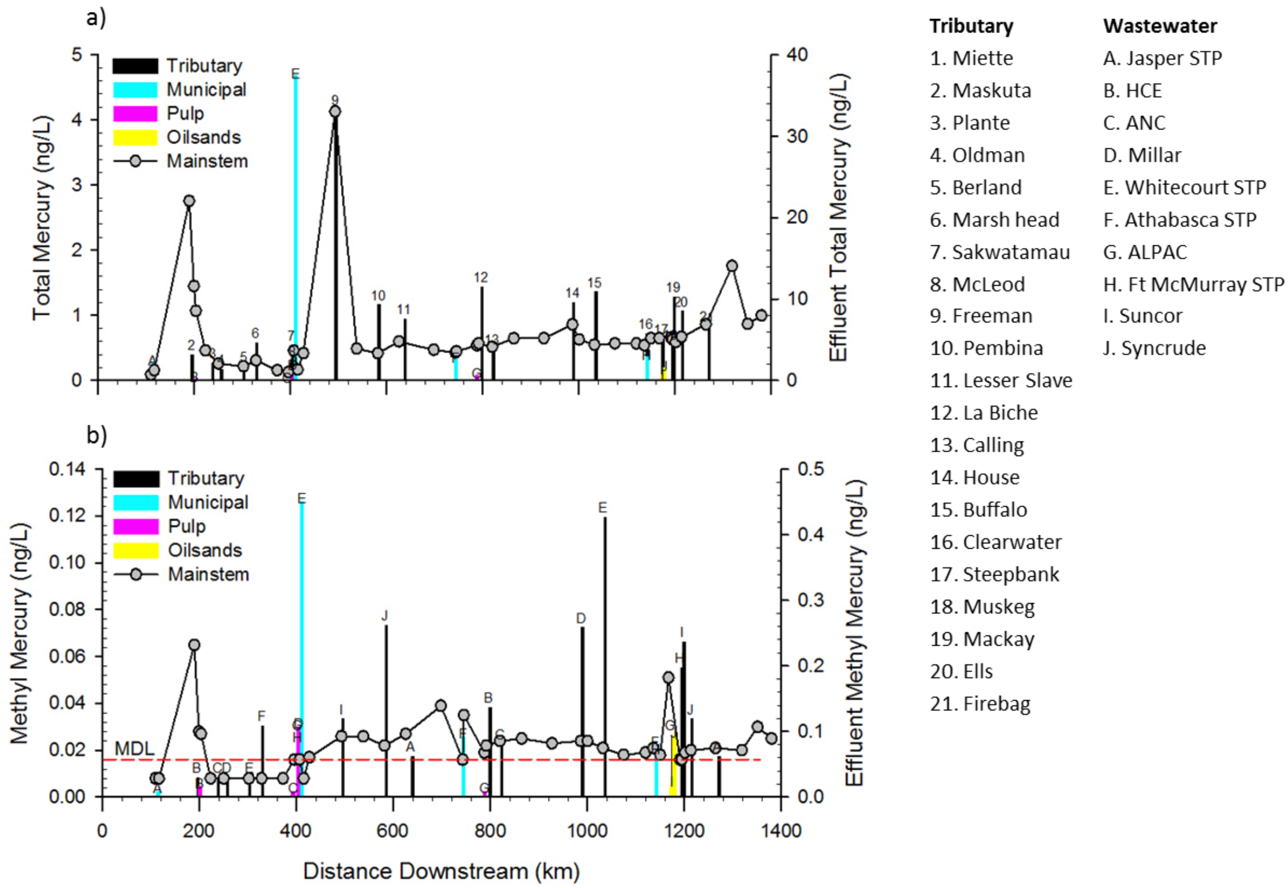

Figure 67. Concentrations of a) total mercury (ng/L) and b) methyl mercury (ng/L) during the 2015 winter synoptic survey

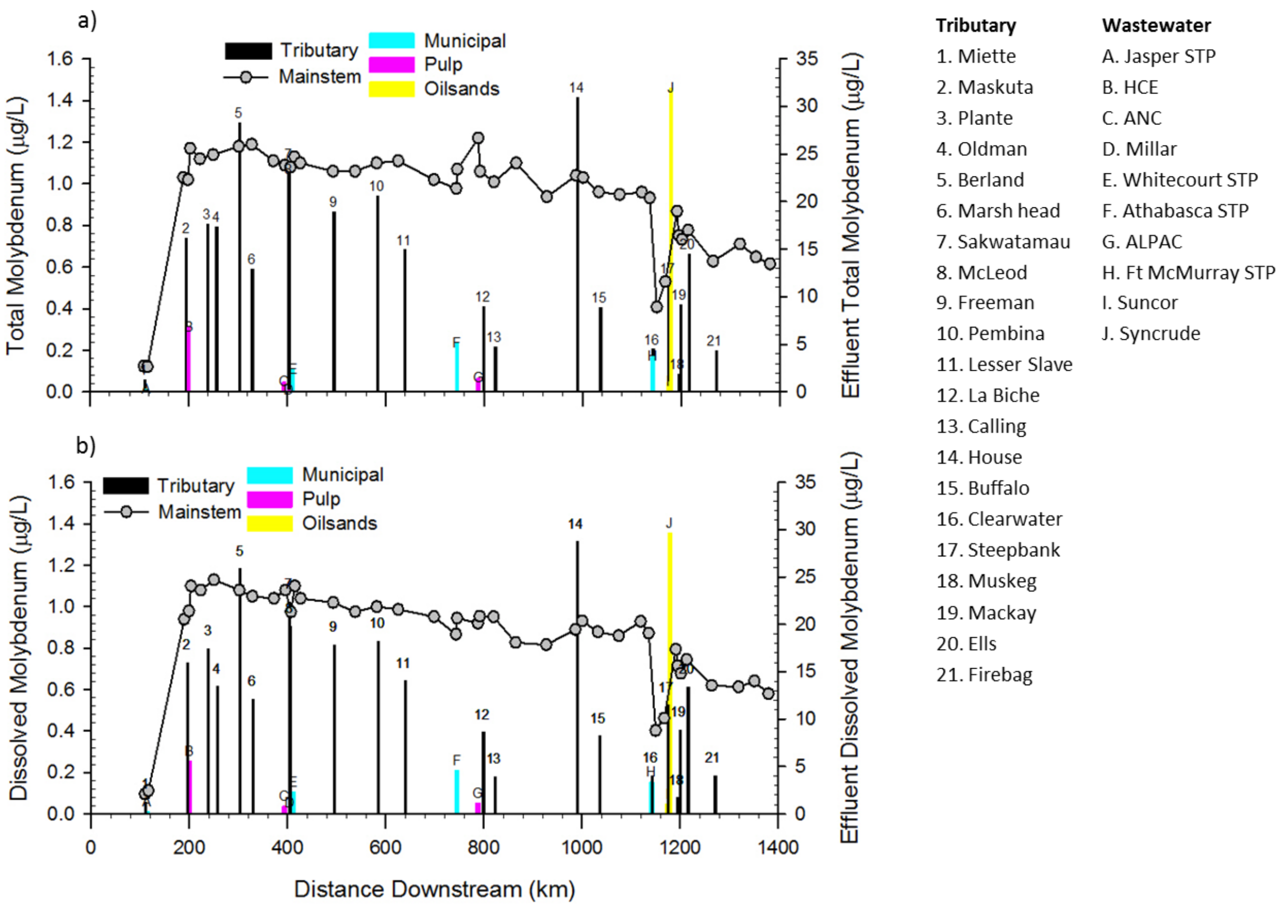

Figure 68. Concentrations of a) total molybdenum (µg/L) and b) dissolved molybdenum (µg/L) during the 2015 winter synoptic survey

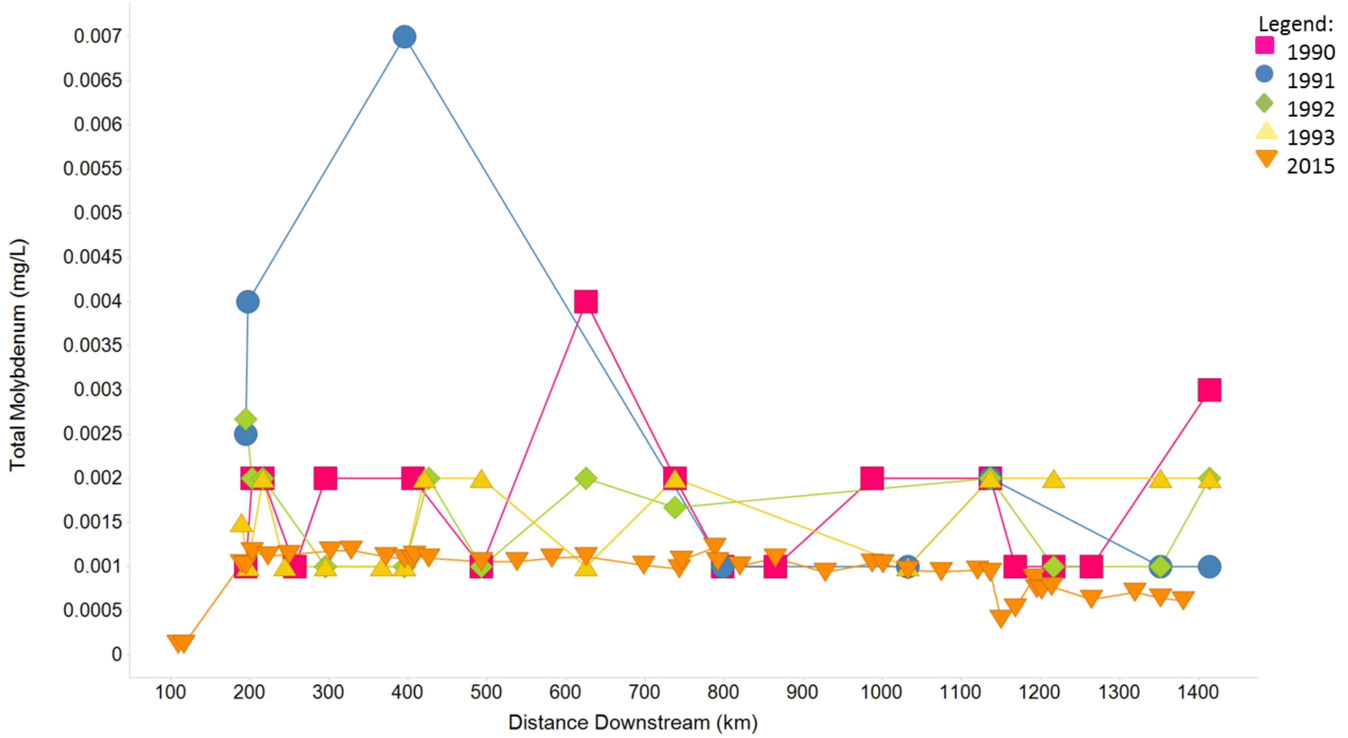

Figure 69. Comparison of total molybdenum (mg/L) measured during the winter synoptic surveys from 1990-1993 and 2015

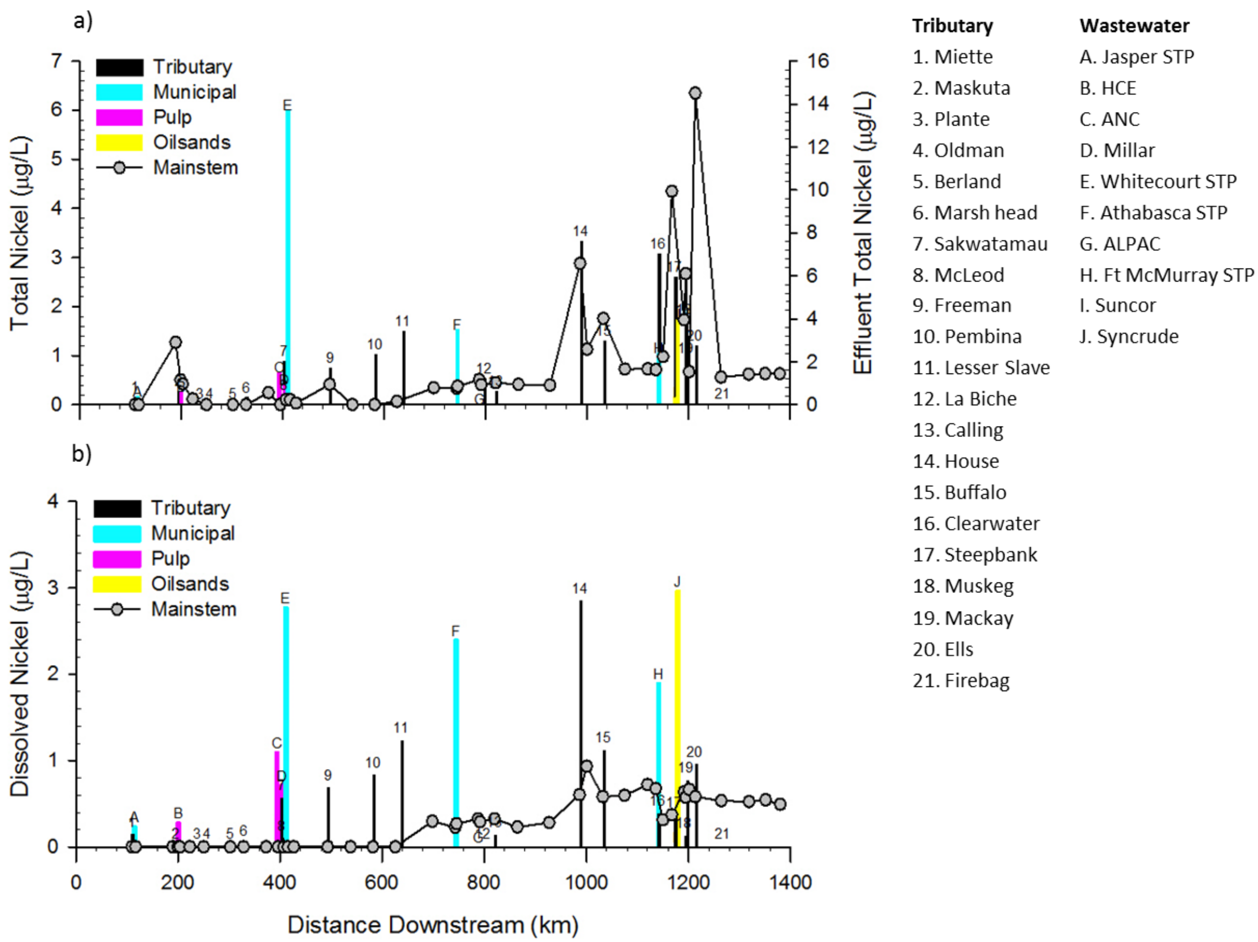

Figure 70. Concentrations of a) total nickel (µg/L) and b) dissolved nickel (µg/L) during the 2015 winter synoptic survey

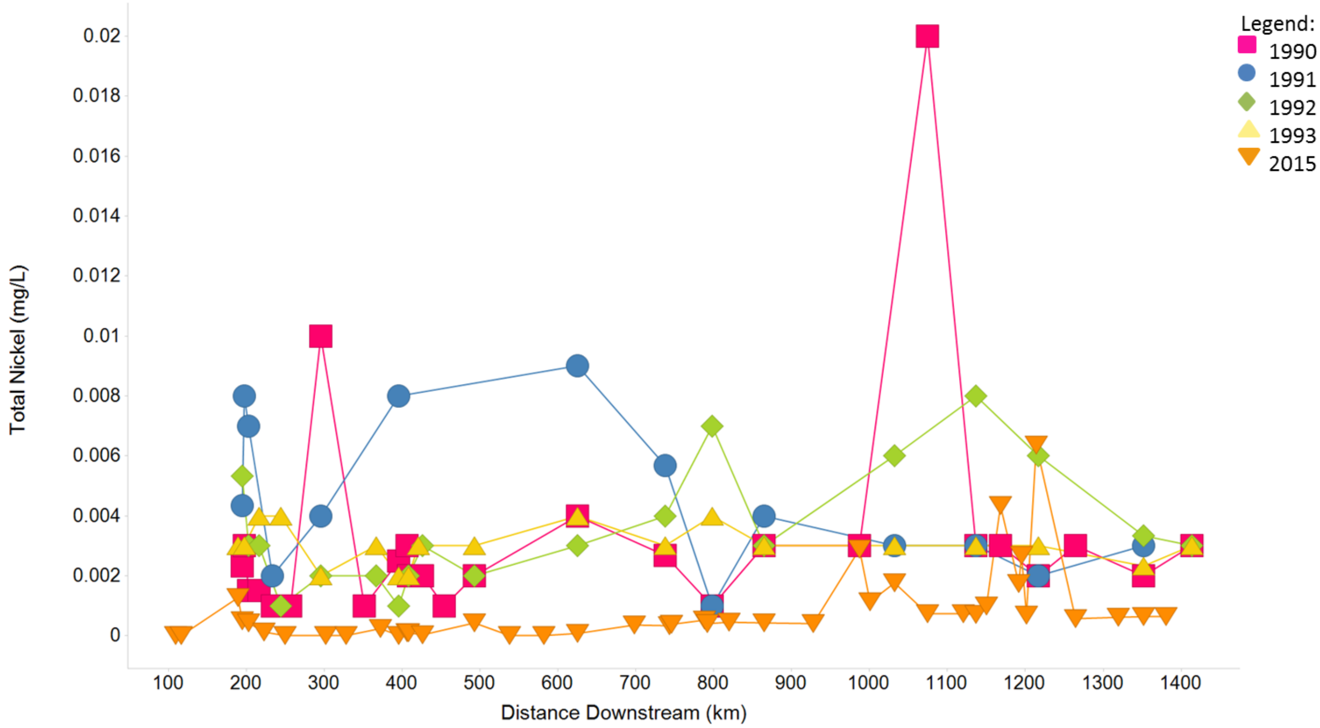

Figure 71. Comparison of total nickel (mg/L) measured during the winter synoptic surveys from 1990-1993 and 2015

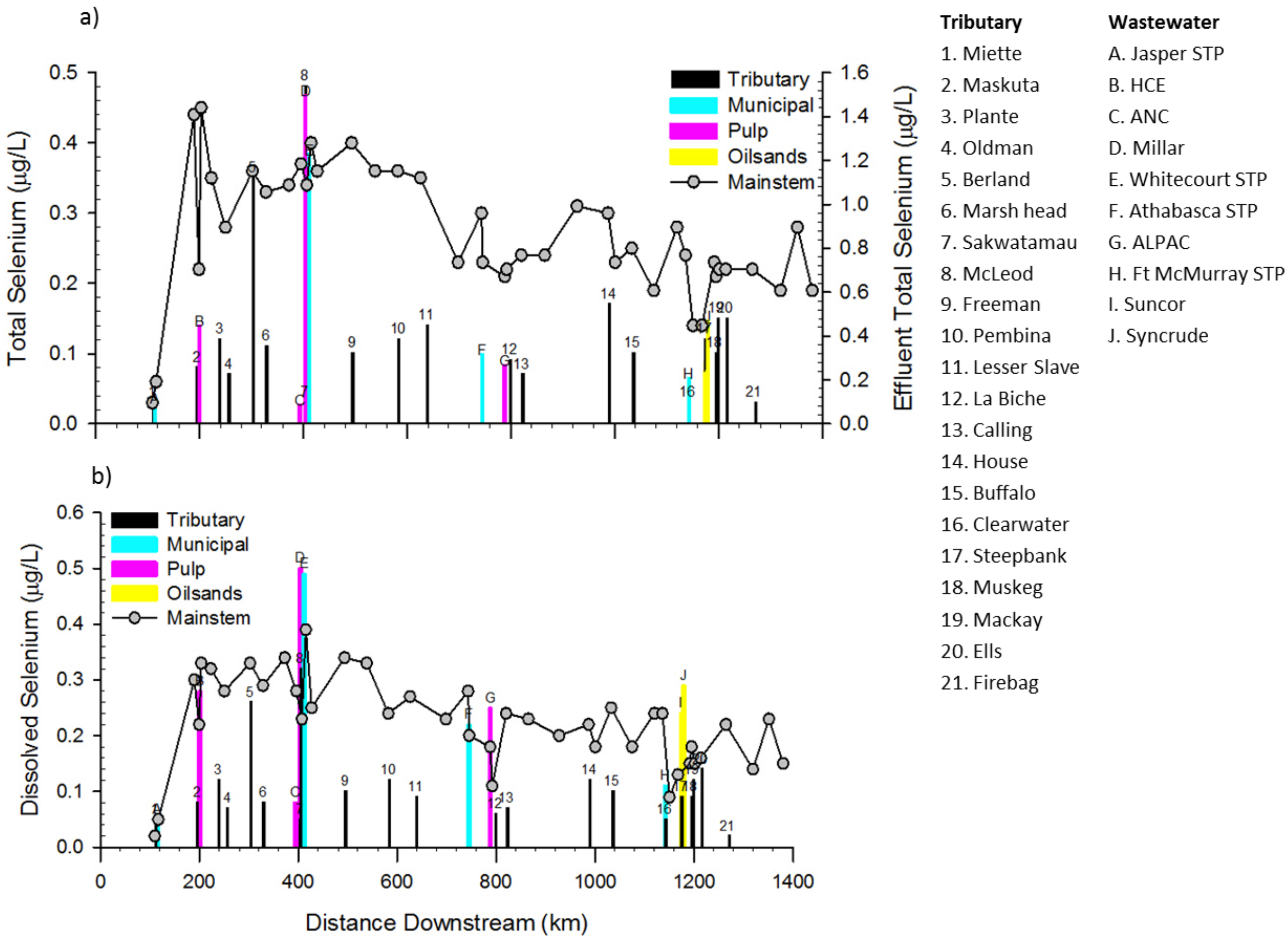

Figure 72. Concentrations of a) total selenium (µg/L) and b) dissolved selenium (µg/L) during the 2015 winter synoptic survey

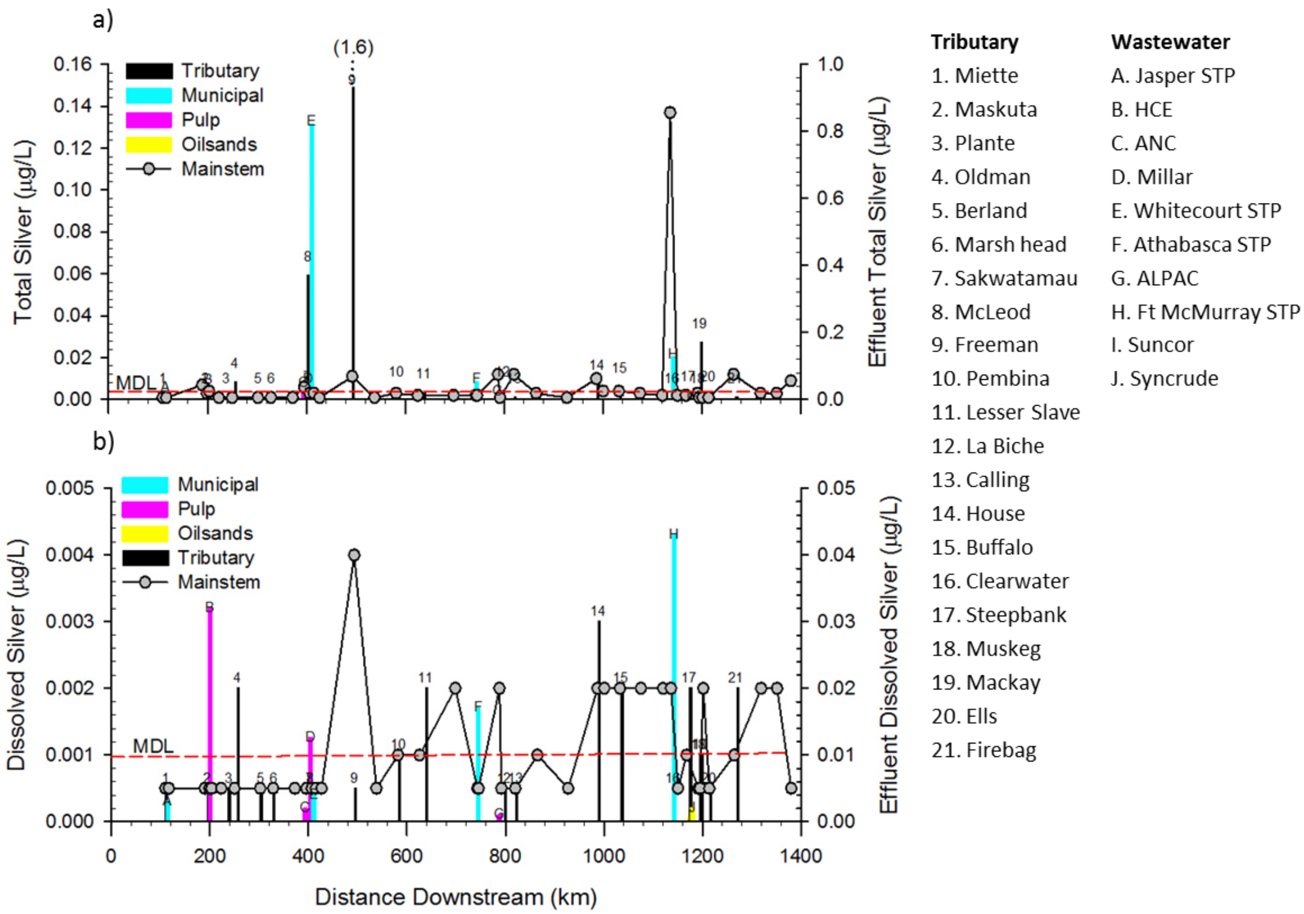

Figure 73. Concentrations of a) total silver (µg/L) and b) dissolved silver (µg/L) during the 2015 winter synoptic survey

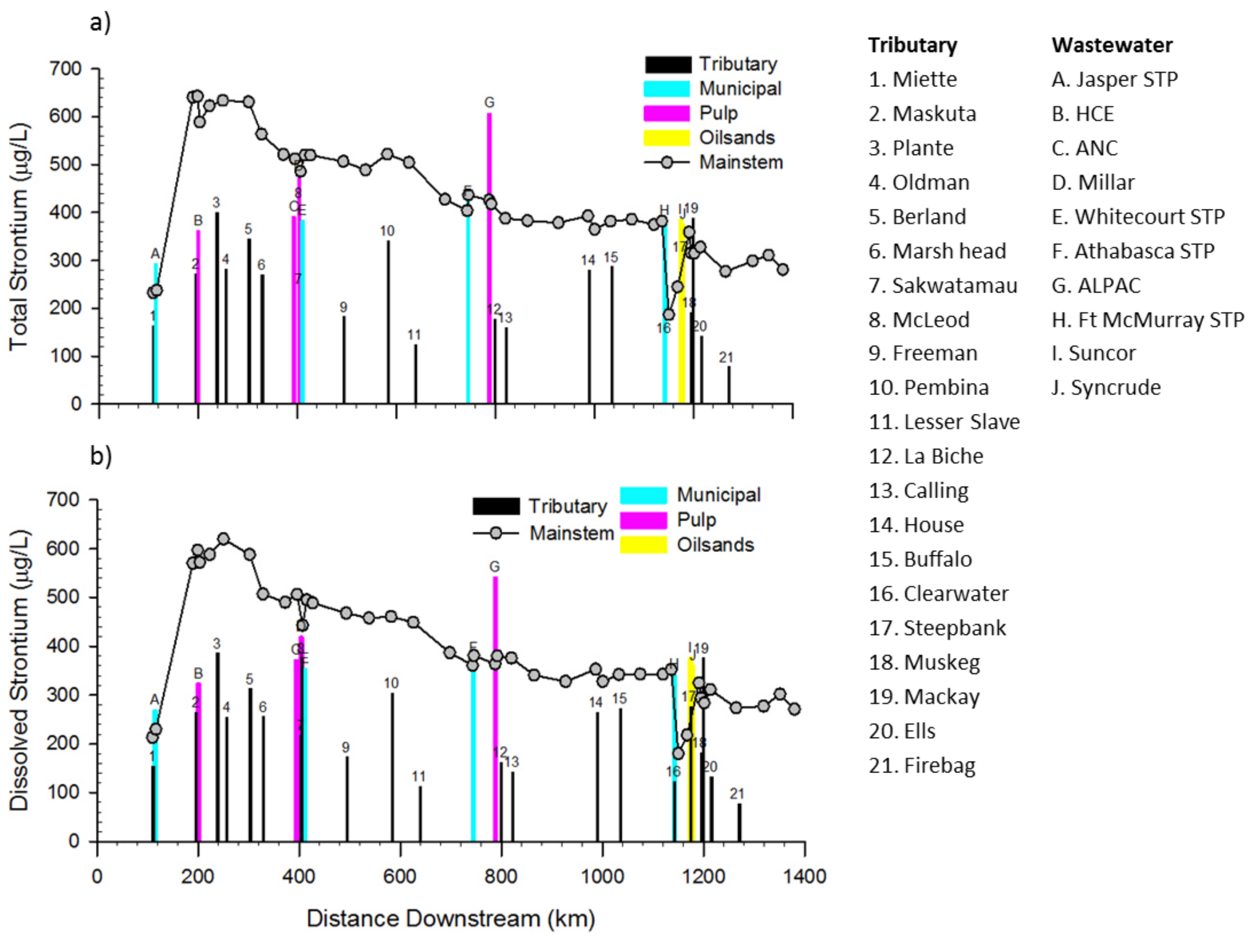

Figure 74. Concentrations of a) total strontium (µg/L) and b) dissolved strontium (µg/L) during the 2015 winter synoptic survey

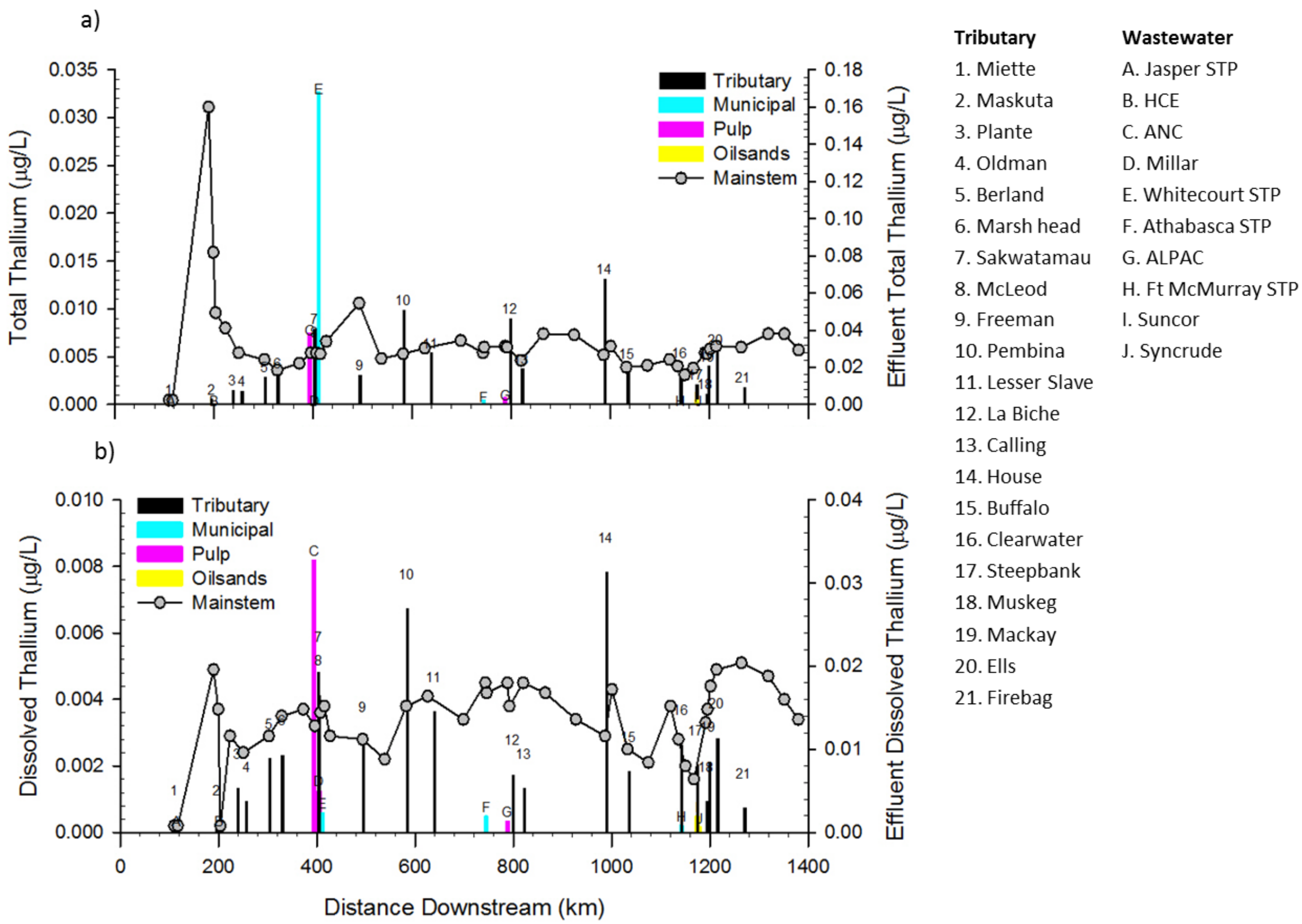

Figure 75. Concentrations of a) total thallium (µg/L) and b) dissolved thallium (µg/L) during the 2015 winter synoptic survey

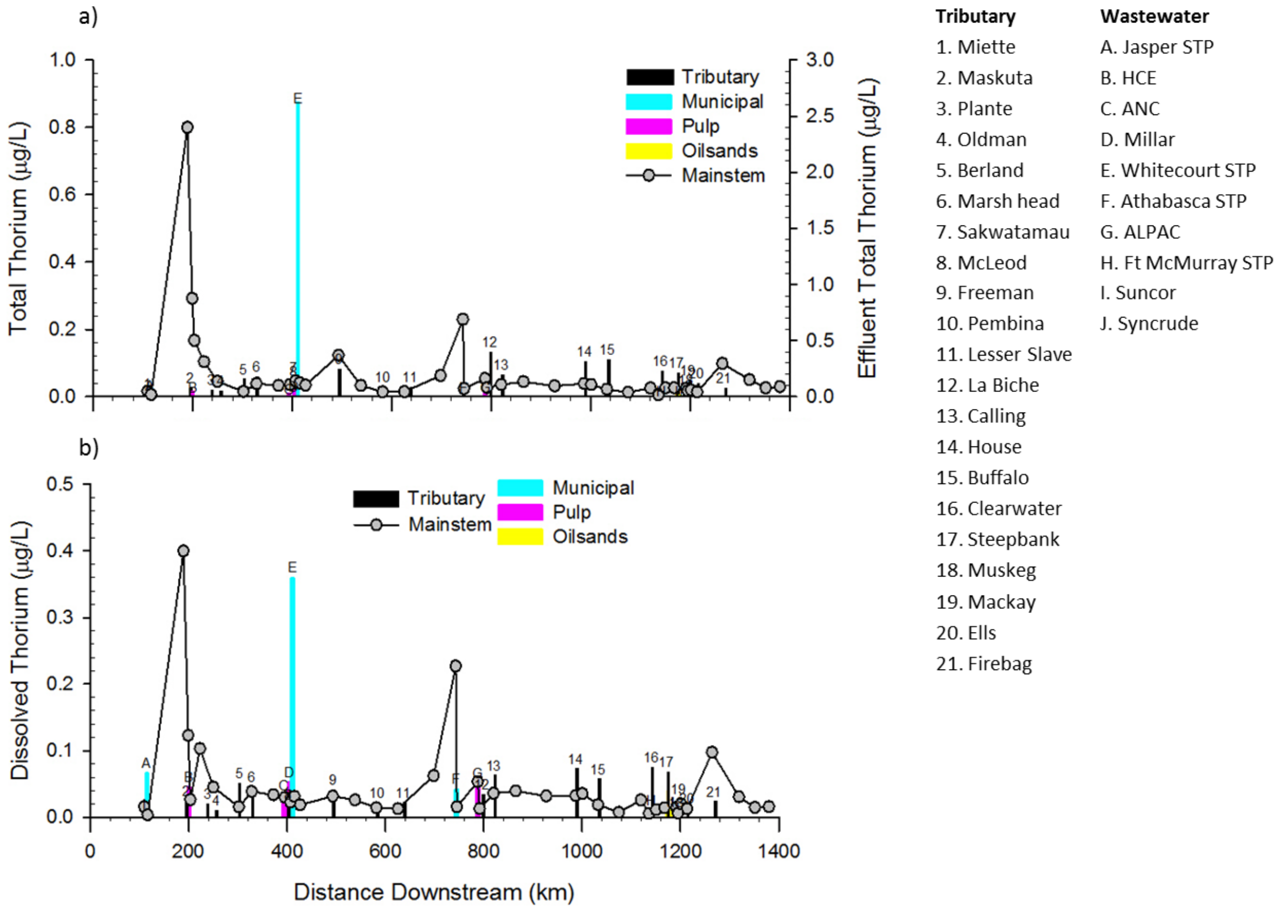

Figure 76. Concentrations of a) total thorium (µg/L) and b) dissolved thorium (µg/L) during the 2015 winter synoptic survey

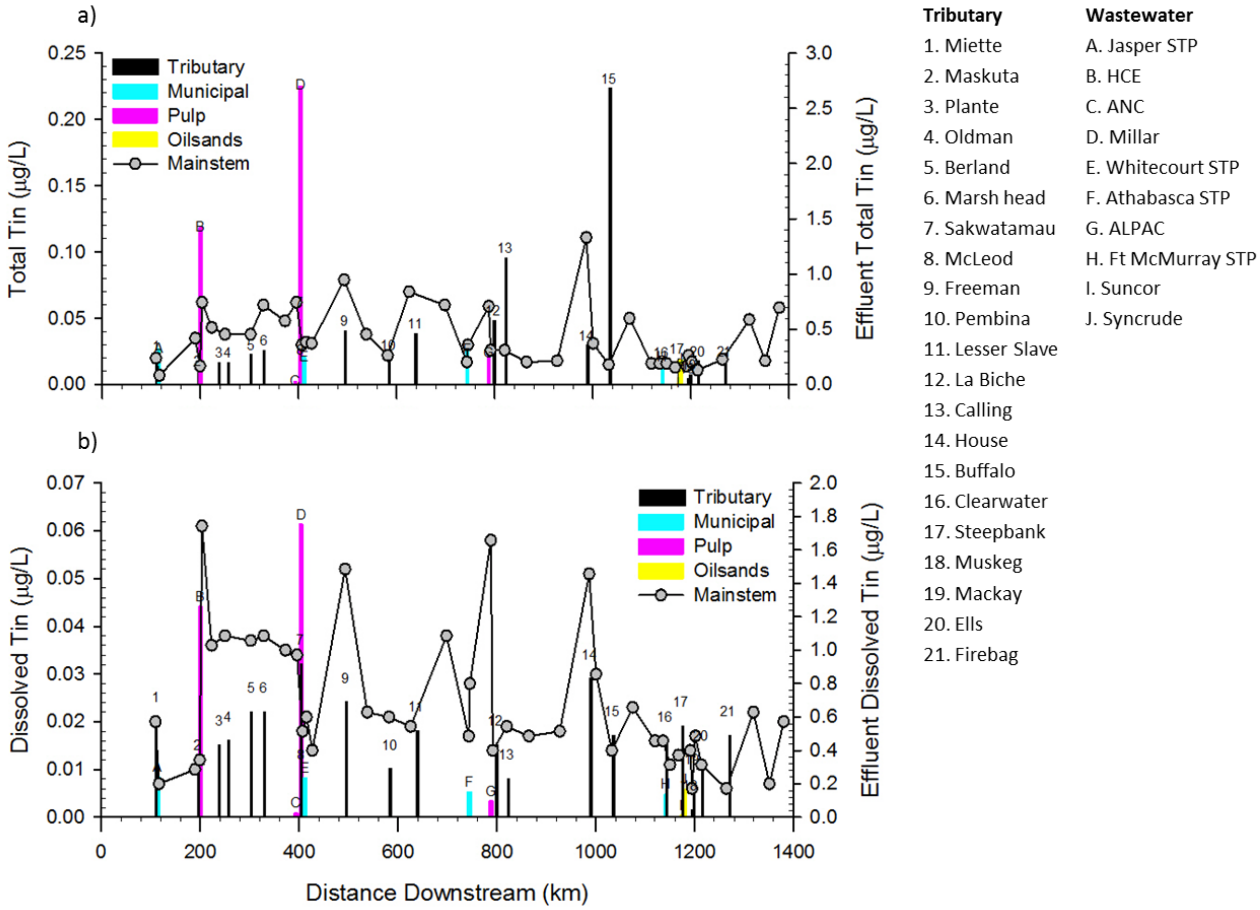

Figure 77. Concentrations of a) total tin (µg/L) and b) dissolved tin (µg/L) during the 2015 winter synoptic survey

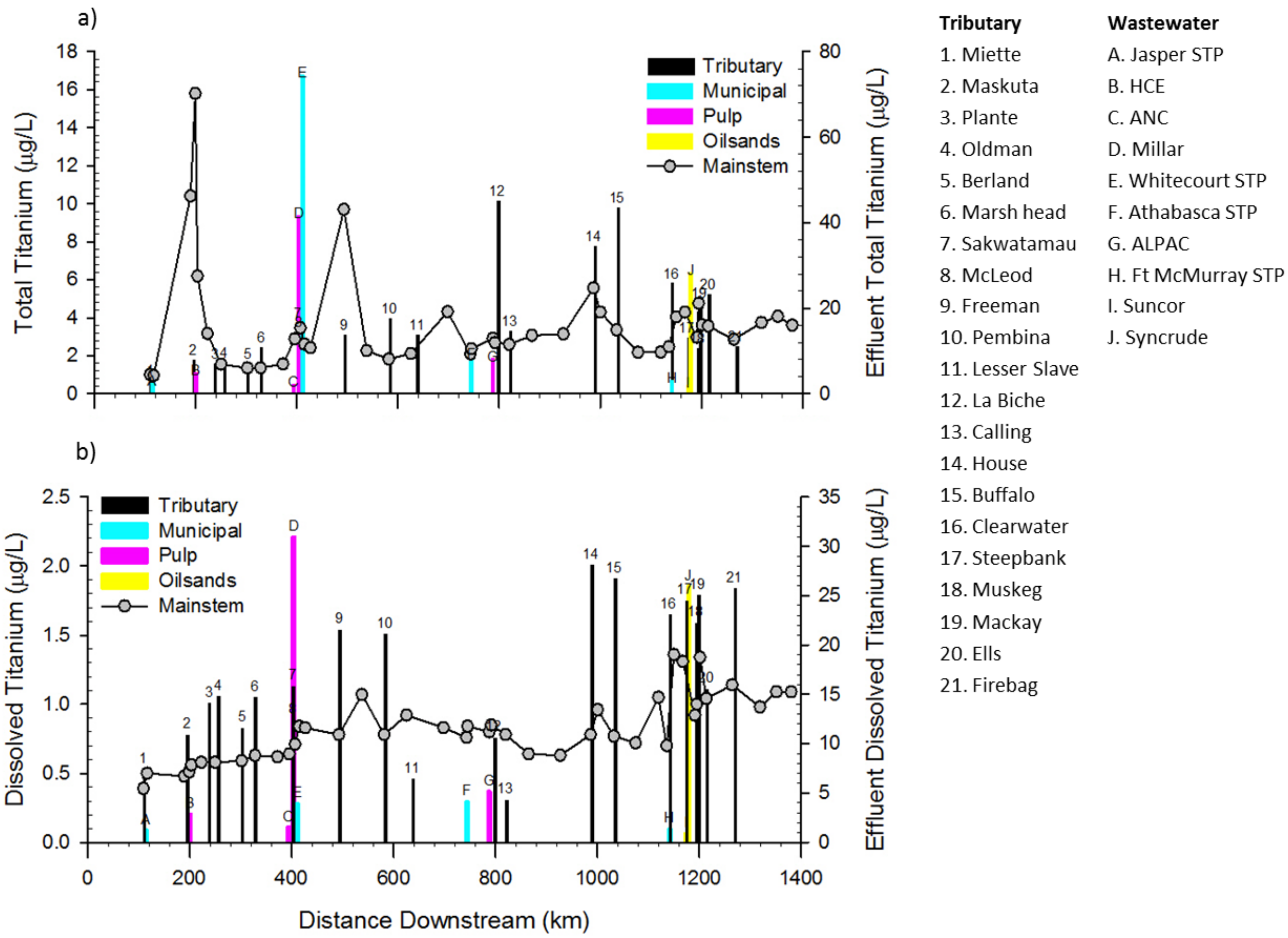

Figure 78. Concentrations of a) total titanium (µg/L) and b) dissolved titanium (µg/L) during the 2015 winter synoptic survey

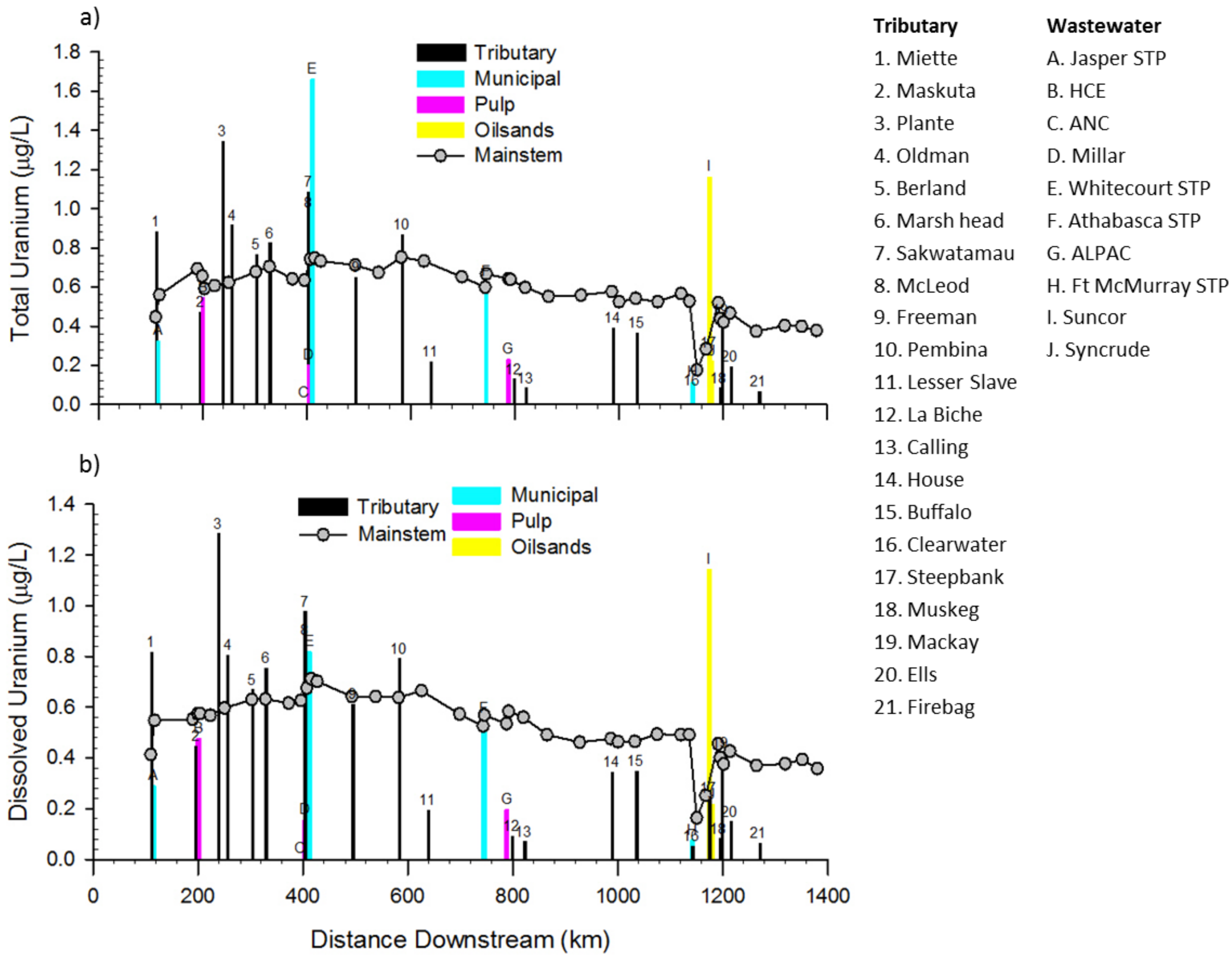

Figure 79. Concentrations of a) total uranium (µg/L) and b) dissolved uranium (µg/L) during the 2015 winter synoptic survey

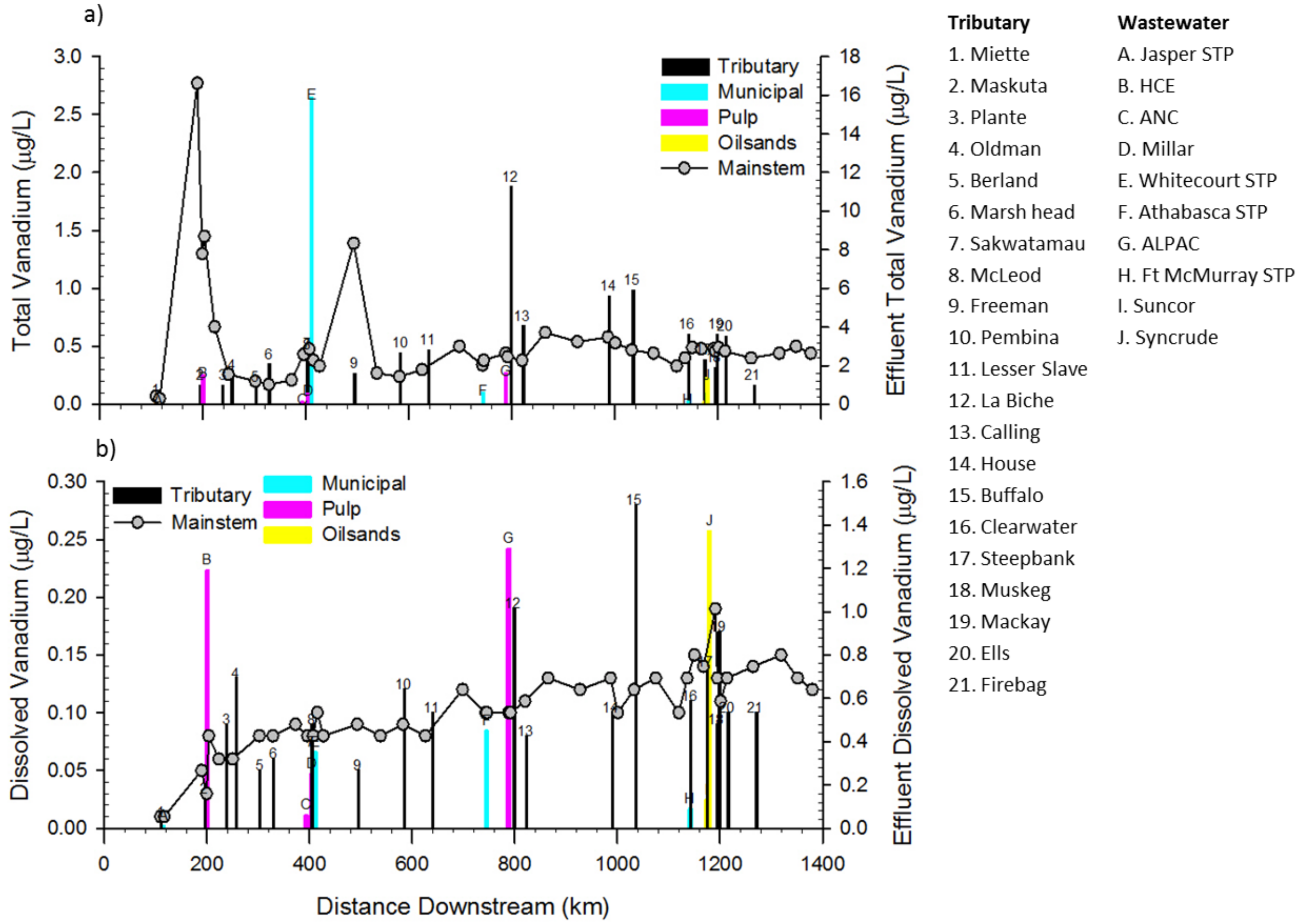

Figure 80. Concentrations of a) total vanadium (µg/L) and b) dissolved vanadium (µg/L) during the 2015 winter synoptic survey

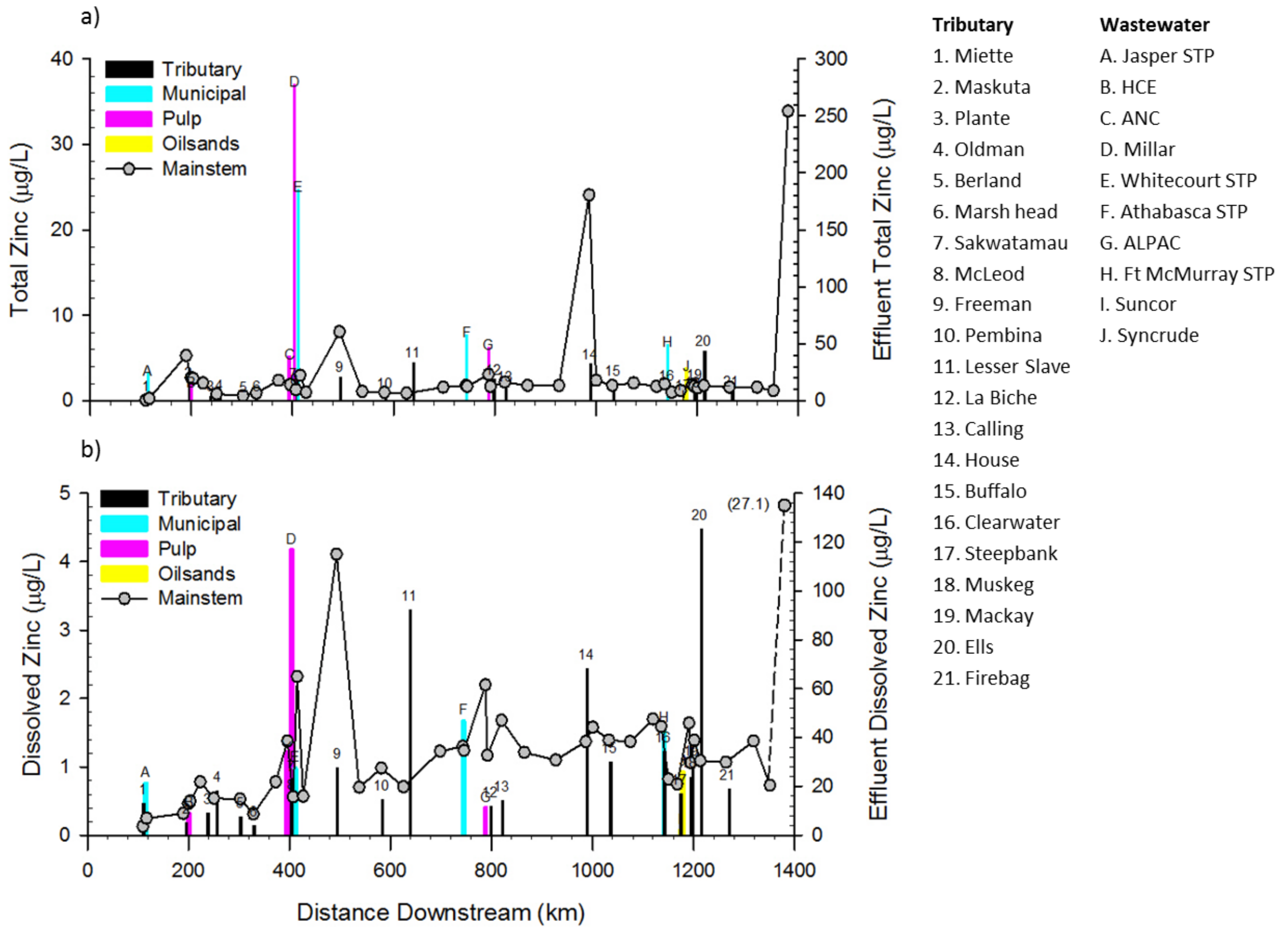

Figure 81. Concentrations of a) total zinc (µg/L) and b) dissolved zinc (µg/L) during the 2015 winter synoptic survey

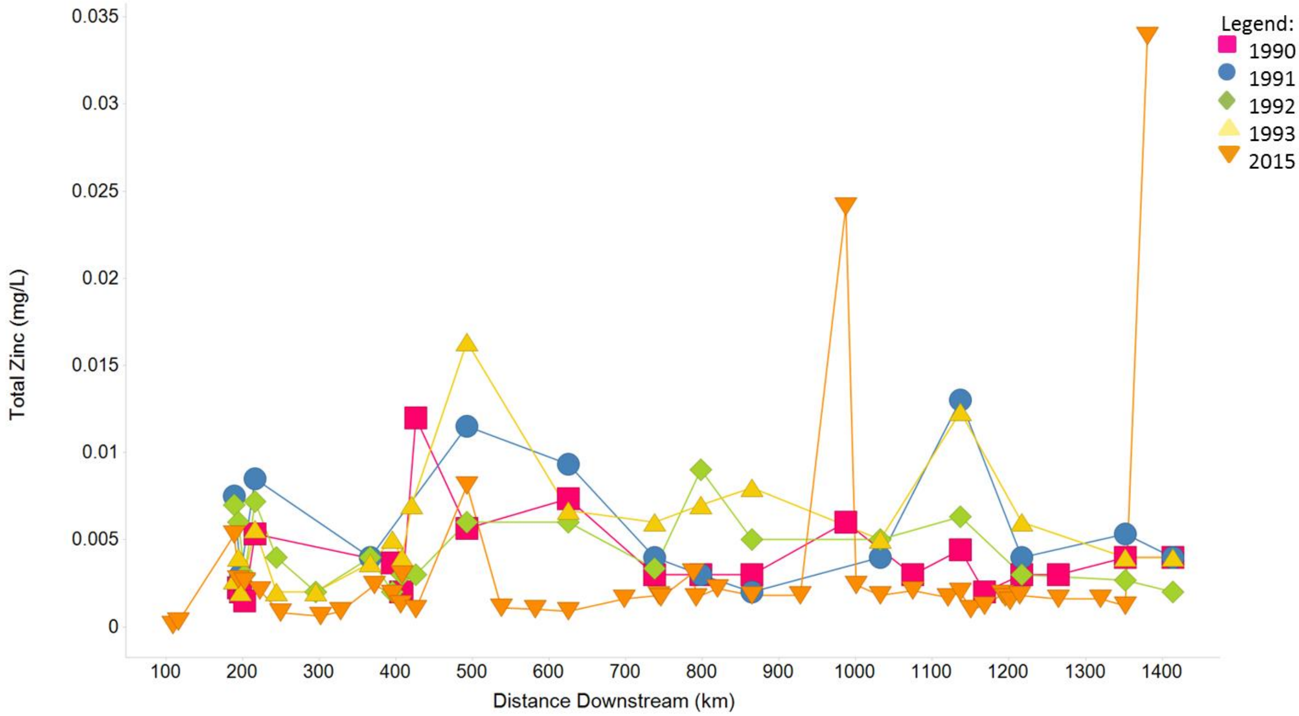

Figure 82. Comparison of total zinc (mg/L) measured during the winter synoptic surveys from 1990-1993 and 2015

Organic Constituents Figures

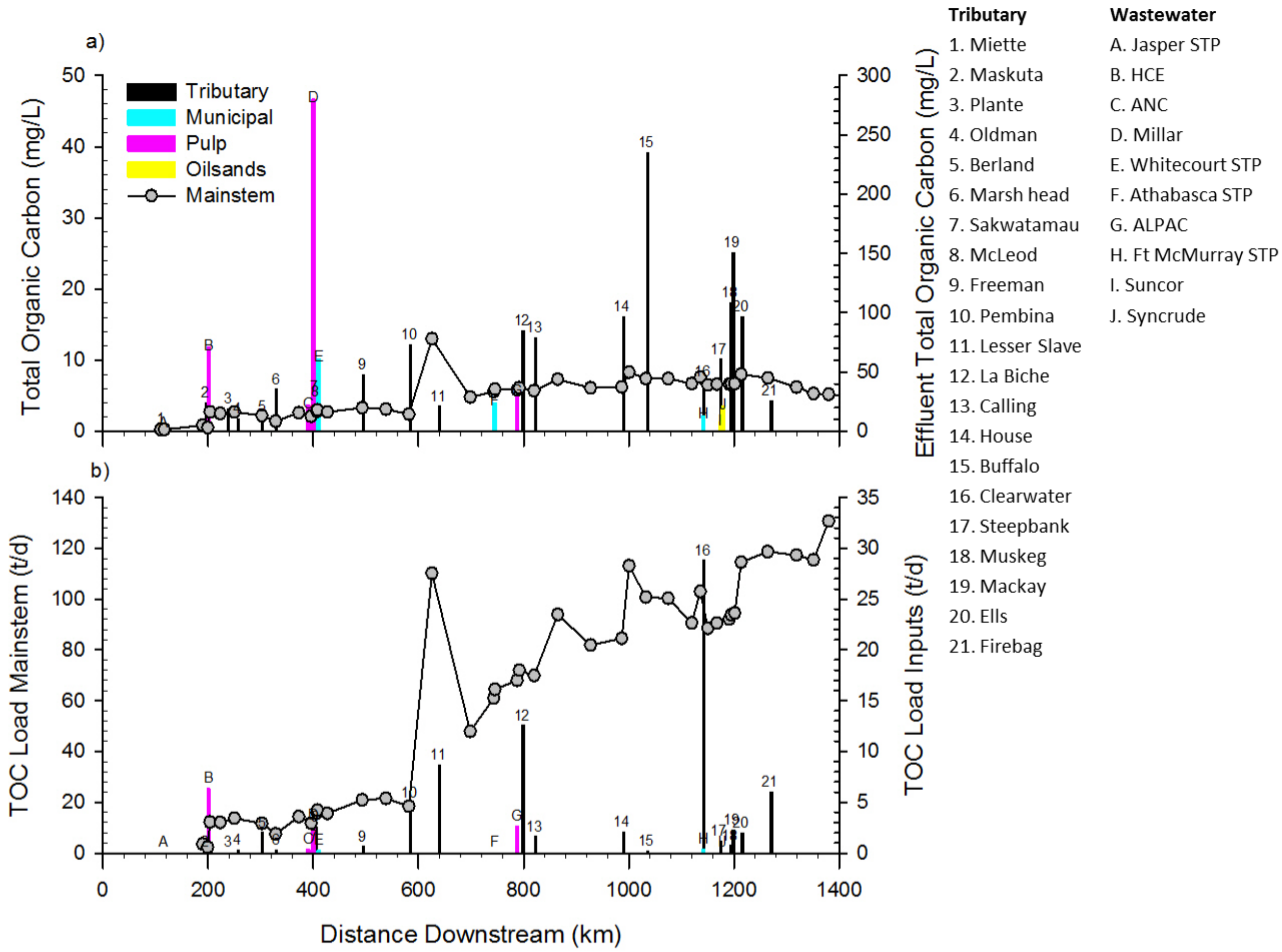

Figure 83. a) Concentrations of total organic carbon (mg/L) and b) total organic carbon (TOC) loads (tonne/day) calculated during the survey. Note values below the detection limit do not have a calculated load.

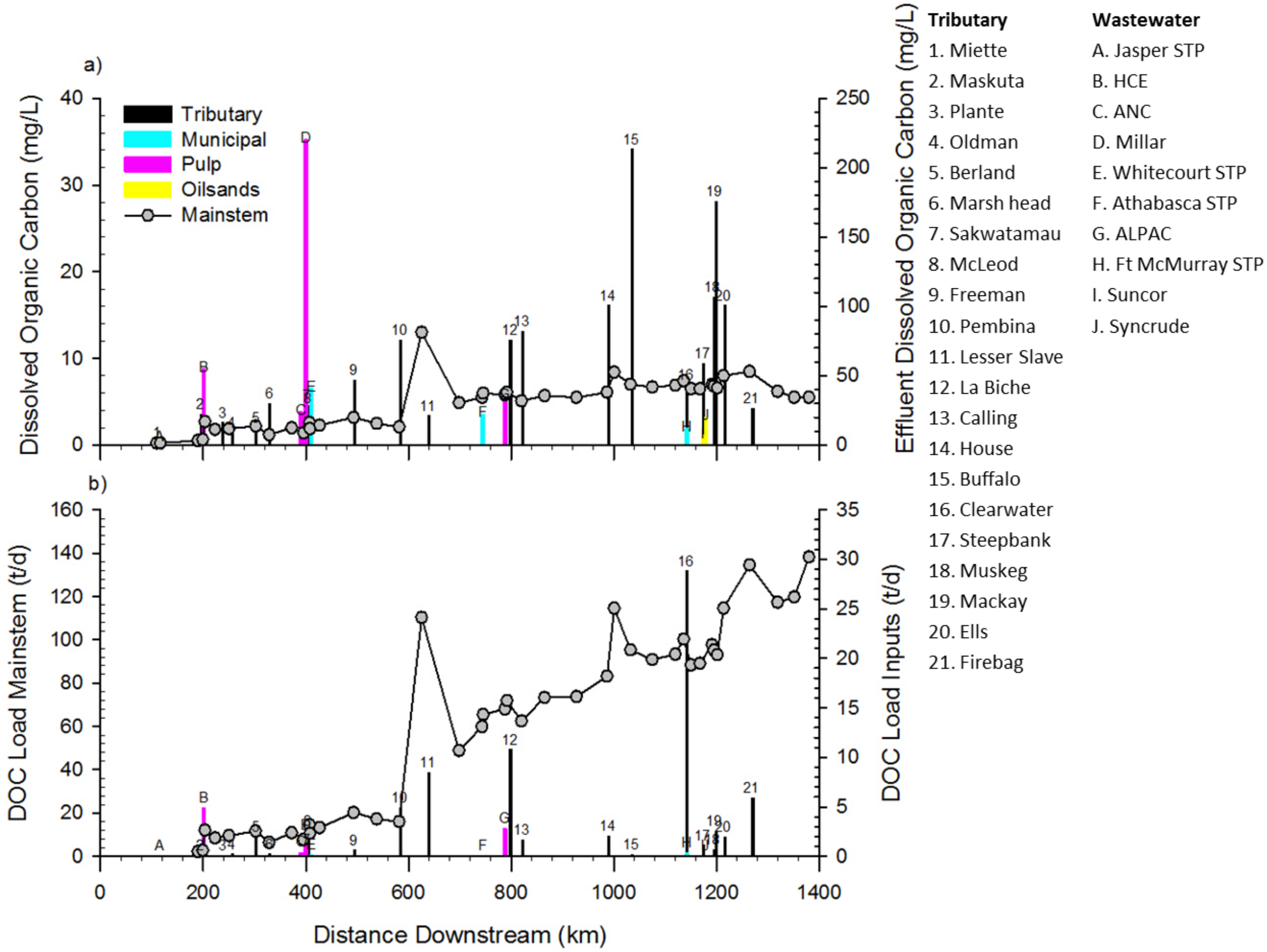

Figure 84. a) Concentrations of dissolved organic carbon (mg/L) and b) total dissolved carbon (DOC) loads (tonne/day) calculated during the survey. Note values below the detection limit do not have a calculated load.

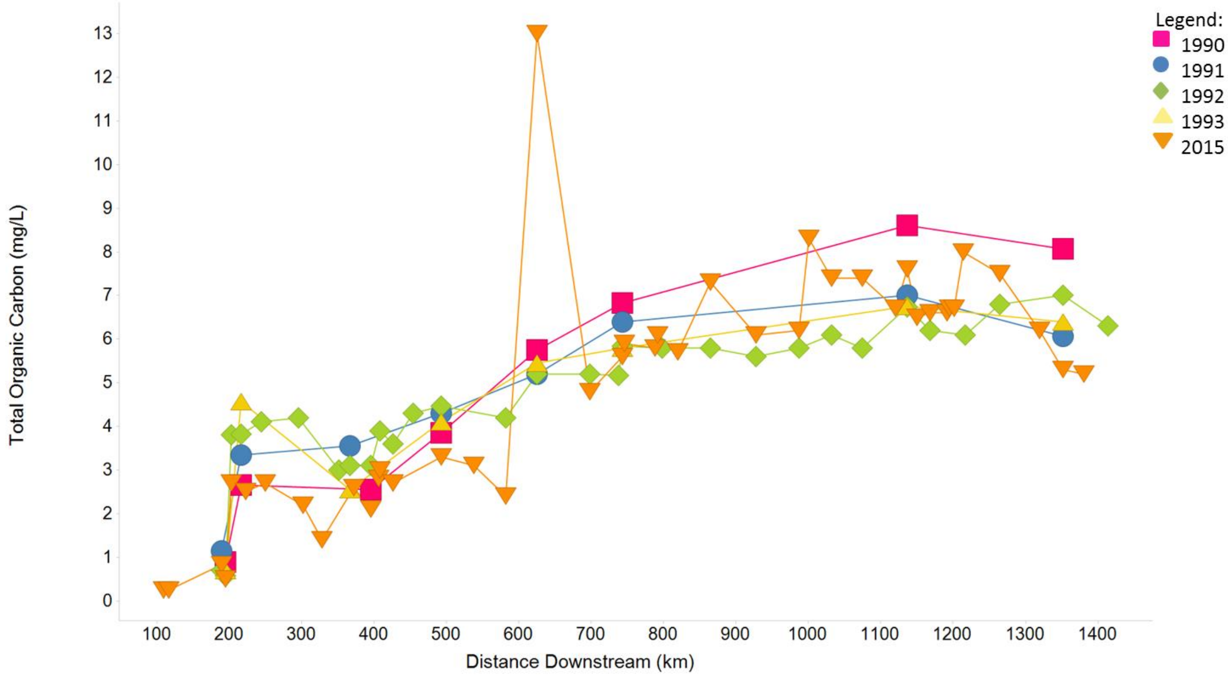

Figure 85. Comparison of total organic carbon (mg/L) measured during the winter synoptic surveys from 1990-1993 and 2015.

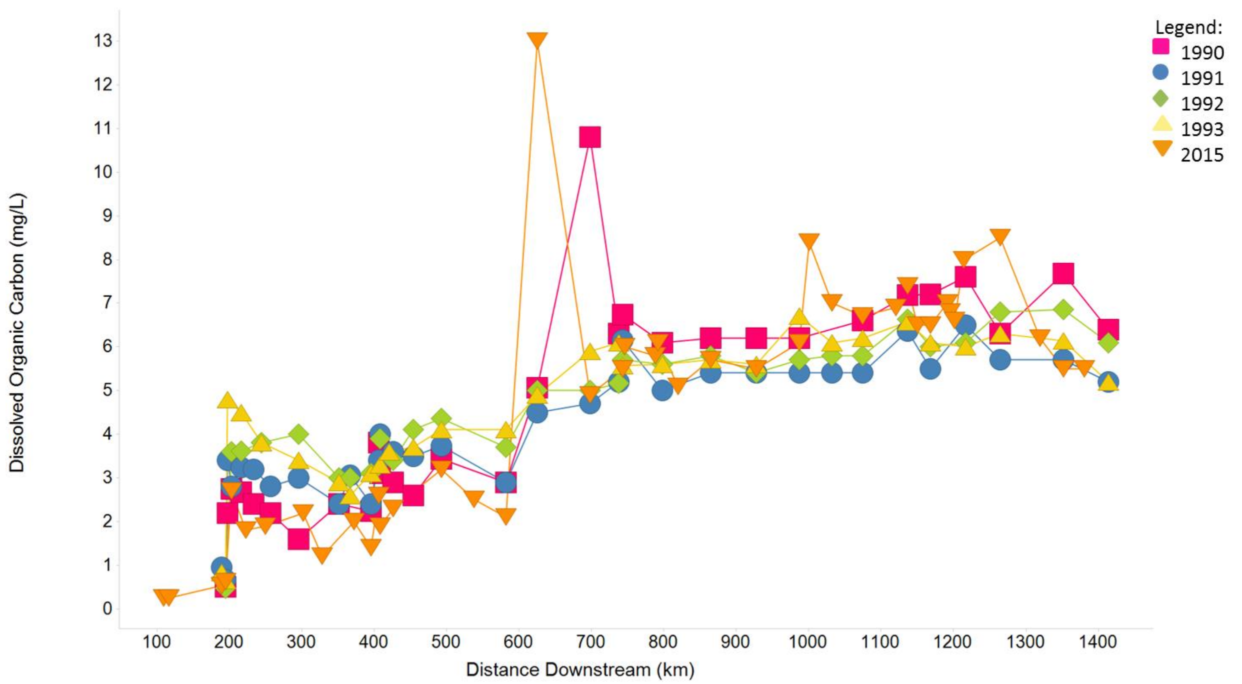

Figure 86. Comparison of dissolved organic carbon (mg/L) measured during the winter synoptic surveys from 1990-1993 and 2015.

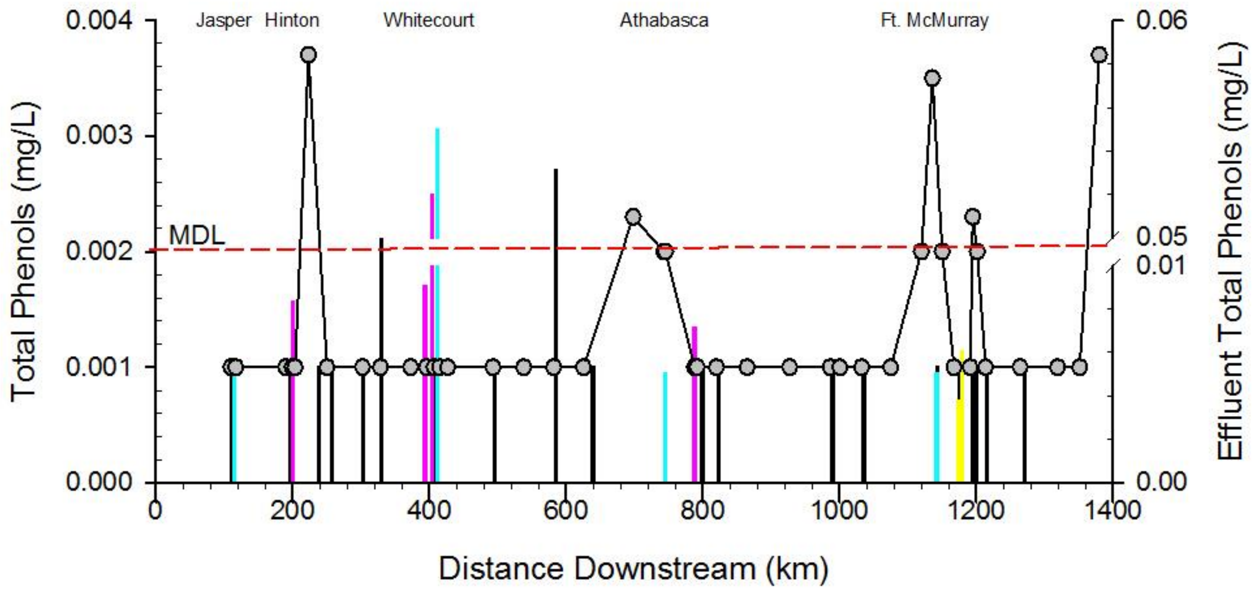

Figure 87. Concentrations of total phenols in the Athabasca River during the 2015 winter synoptic survey.

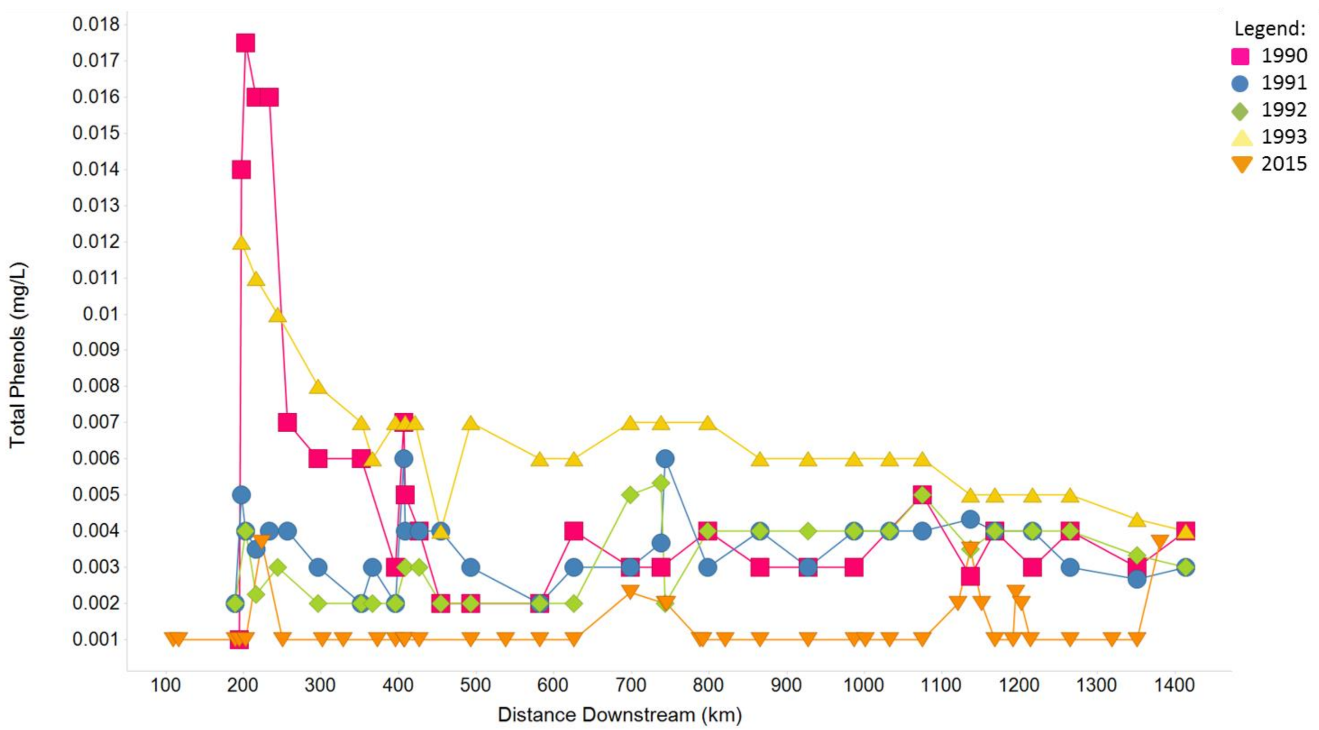

Figure 88. Comparison of total phenols (mg/L) measured in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015

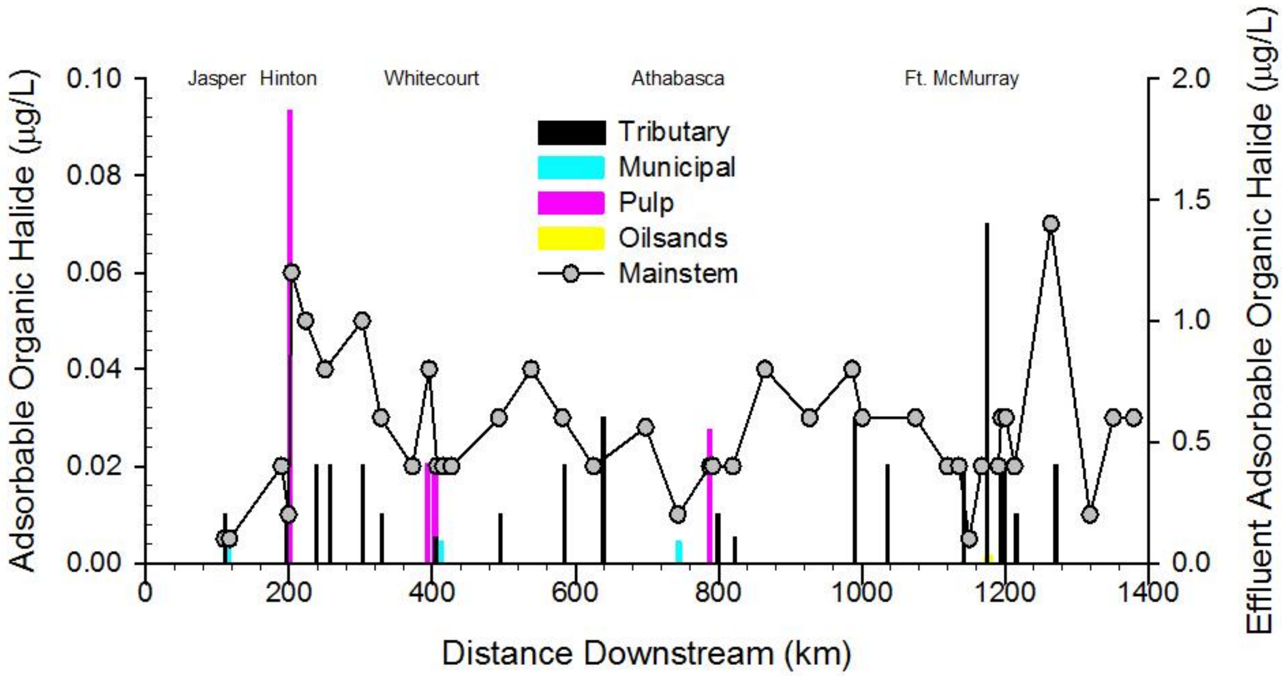

Figure 89. Concentrations of adsorbable organic halide (AOX; mg/L) in the Athabasca River during the 2015 winter synoptic survey.

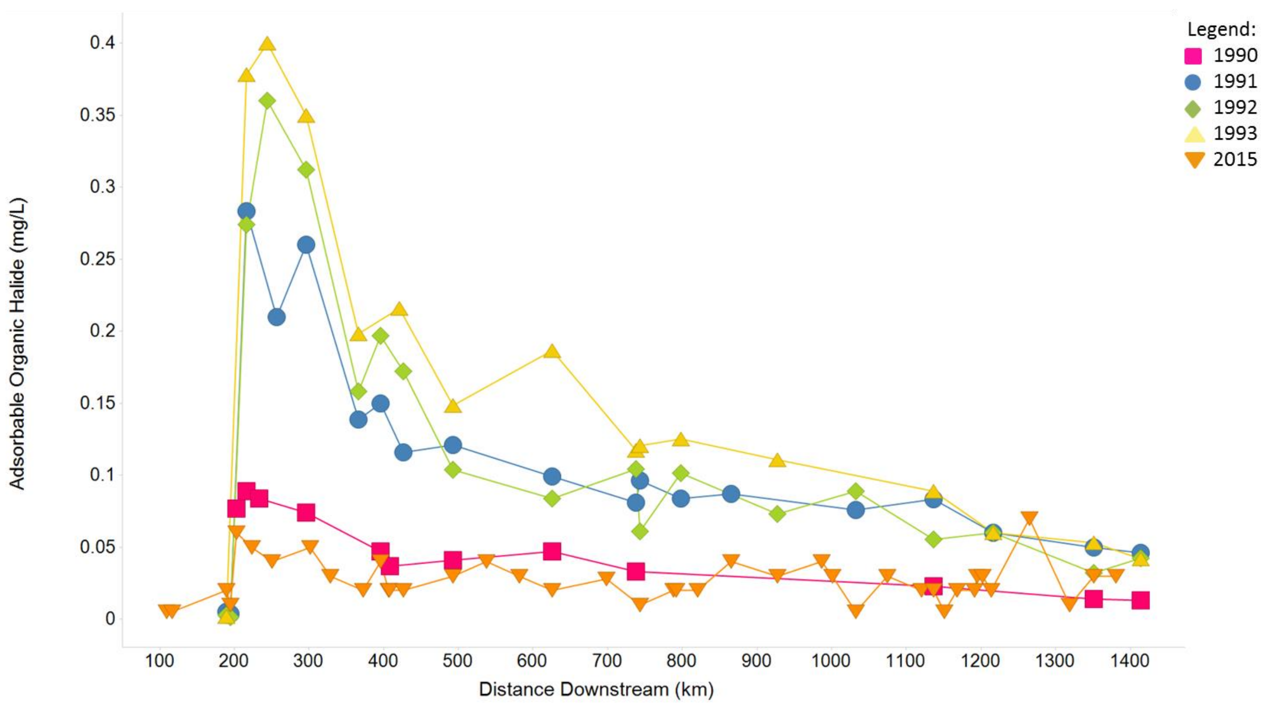

Figure 90. Comparison of adsorbable organic halide (AOX; mg/L) measured in the Athabasca River during winter synoptic surveys from 1990-1993 and 2015

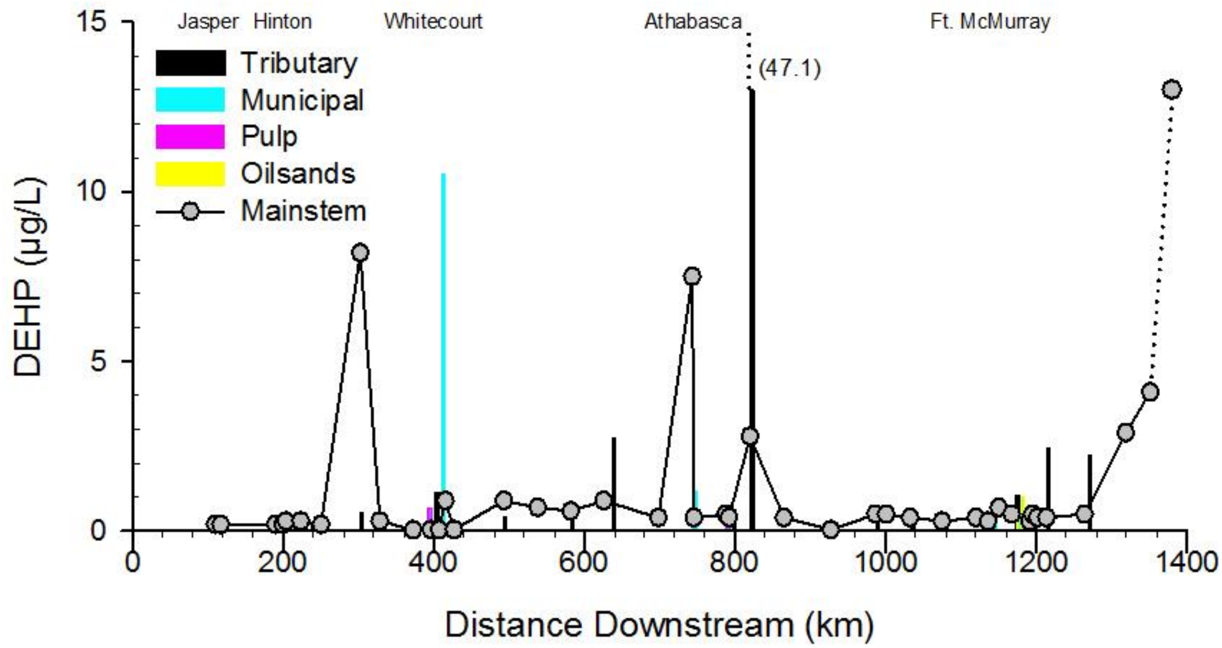

Figure 91. Concentrations of Bis(2-ethylhexyl) phthalate (DEHP; µg/L) in the Athabasca River during the 2015 synoptic survey.

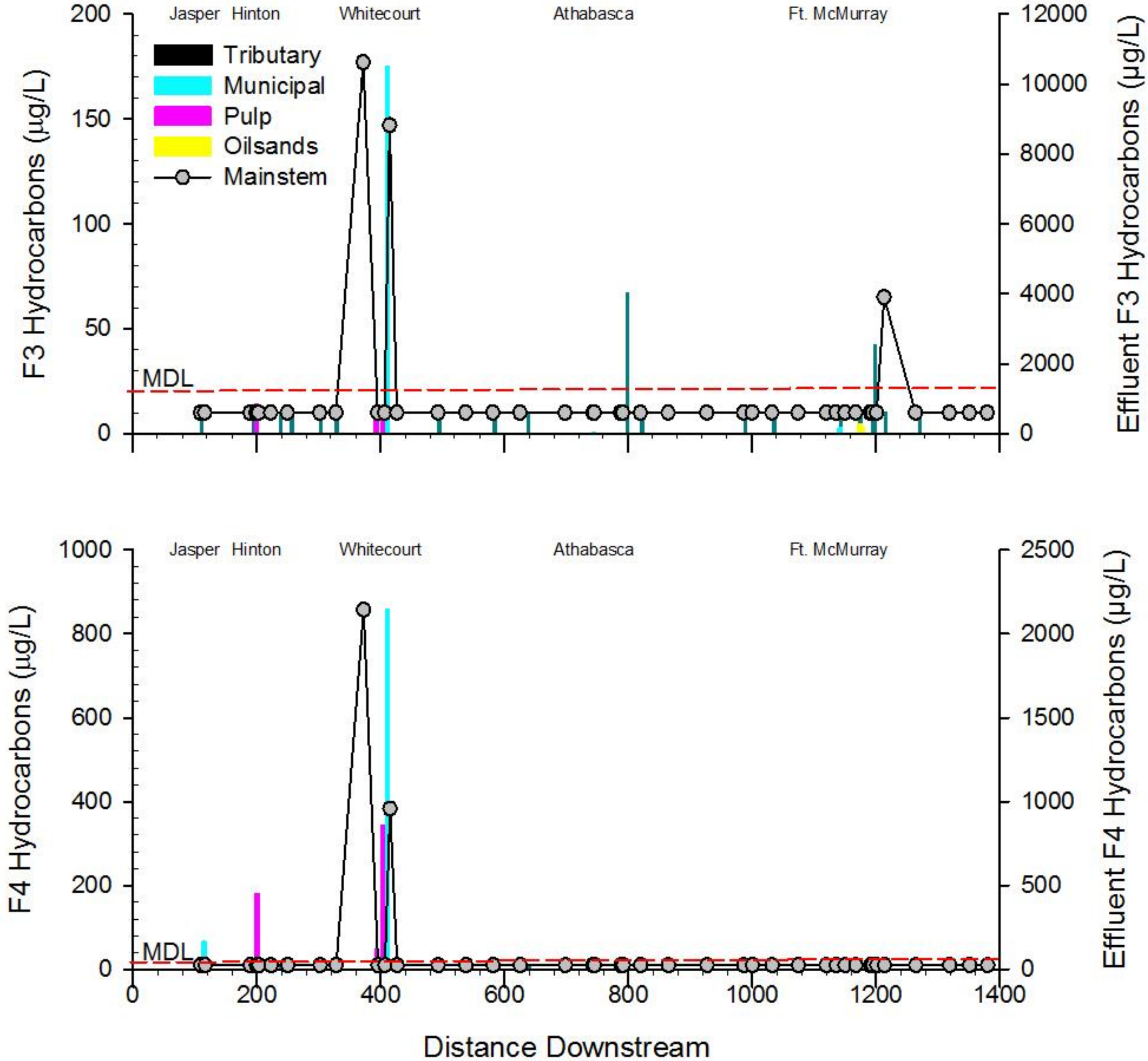

Figure 92. Concentrations of a) F3 and b) F4 hydrocarbons measured during the 2015 winter synoptic survey

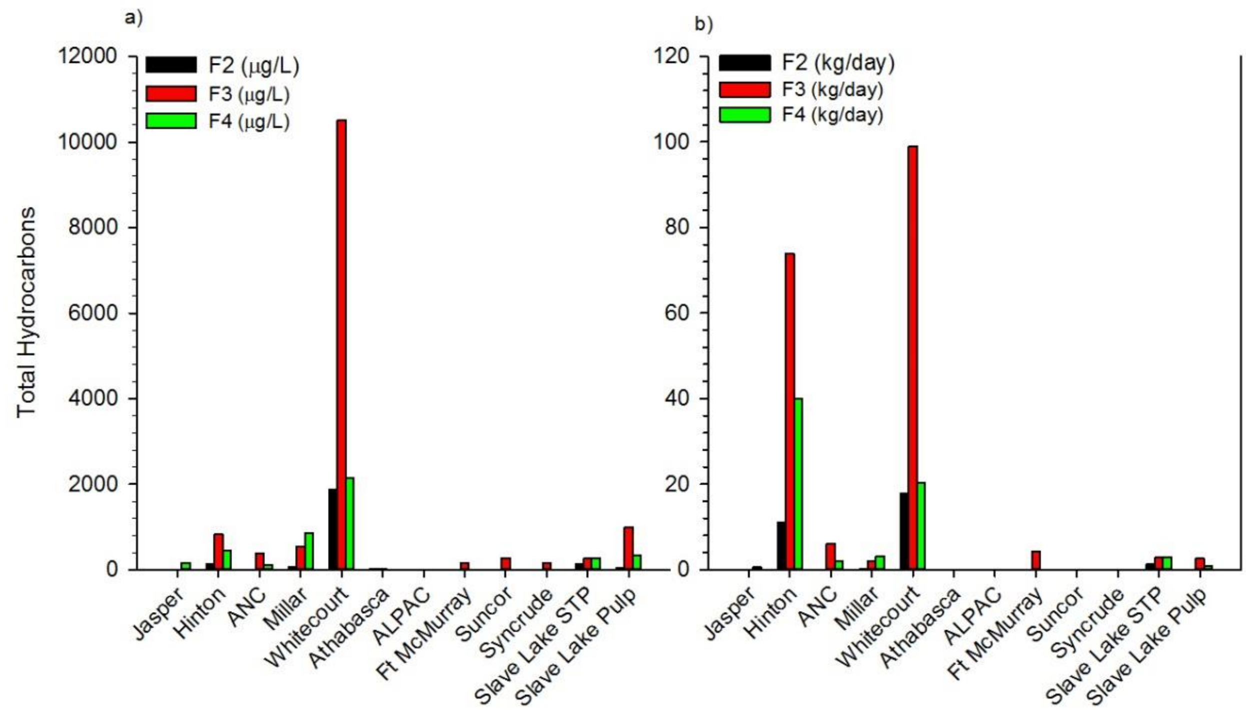

Figure 93. a) concentration (µg/L) and b) loading (kg/day) of total hydrocarbons in effluent samples during the 2015 winter synoptic survey.

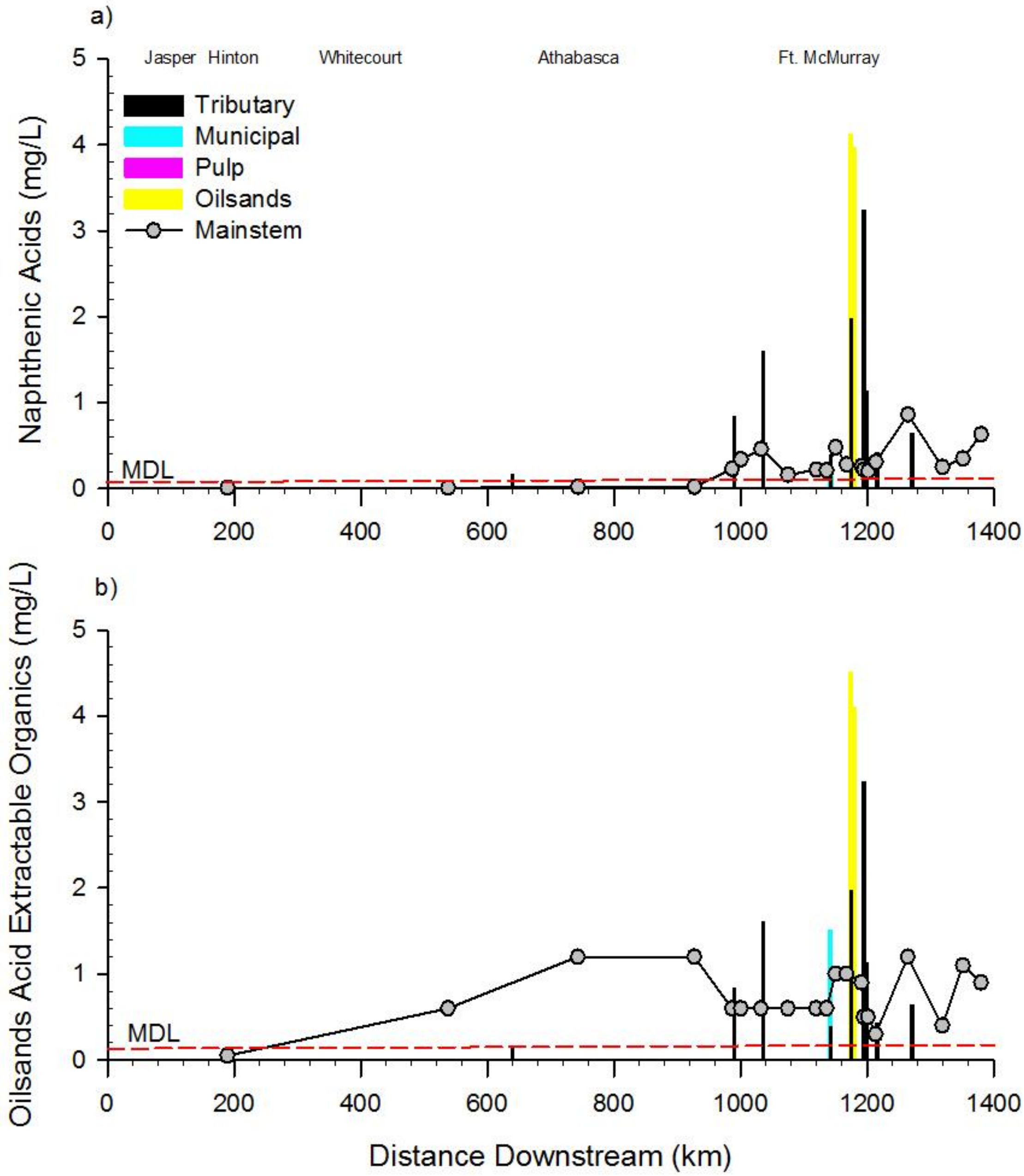

Figure 94. Concentrations of (a) naphthenic acids (mg/L) and b) oilsands acid extractable organics measured during the 2015 winter synoptic survey.

Biotic Variables Figures

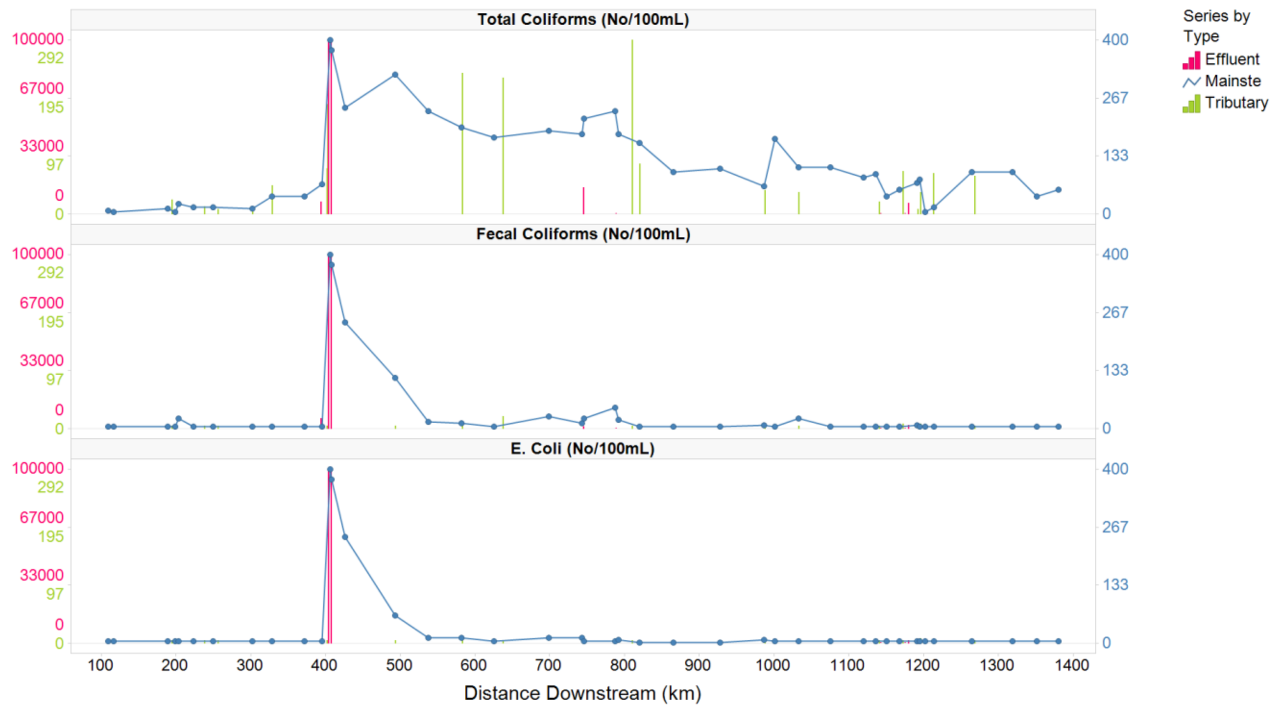

Figure 95. Counts of total coliforms, fecal coliforms, and *Escherichia coli* (*E. coli*) measured in the Athabasca basin during the winter synoptic survey.

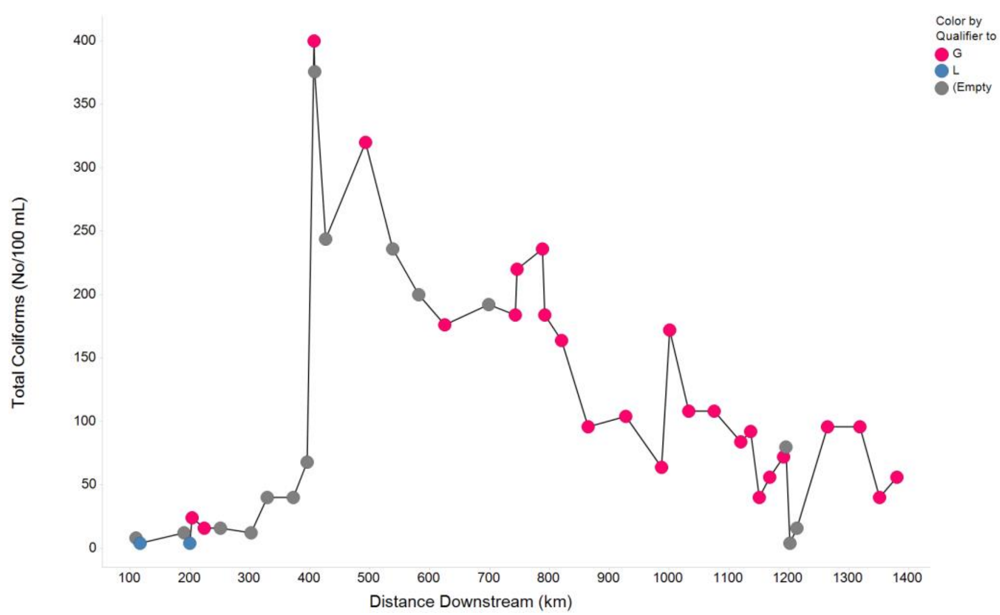

Figure 96. Counts of total coliforms, fecal coliforms, and *Escherichia coli* (*E. coli*) measured in the Athabasca River. Red circles denote values that were qualified with a "greater than" the recorded value blue circles were qualified as "less than" the recorded value, and grey circles were unqualified data received from the laboratory.

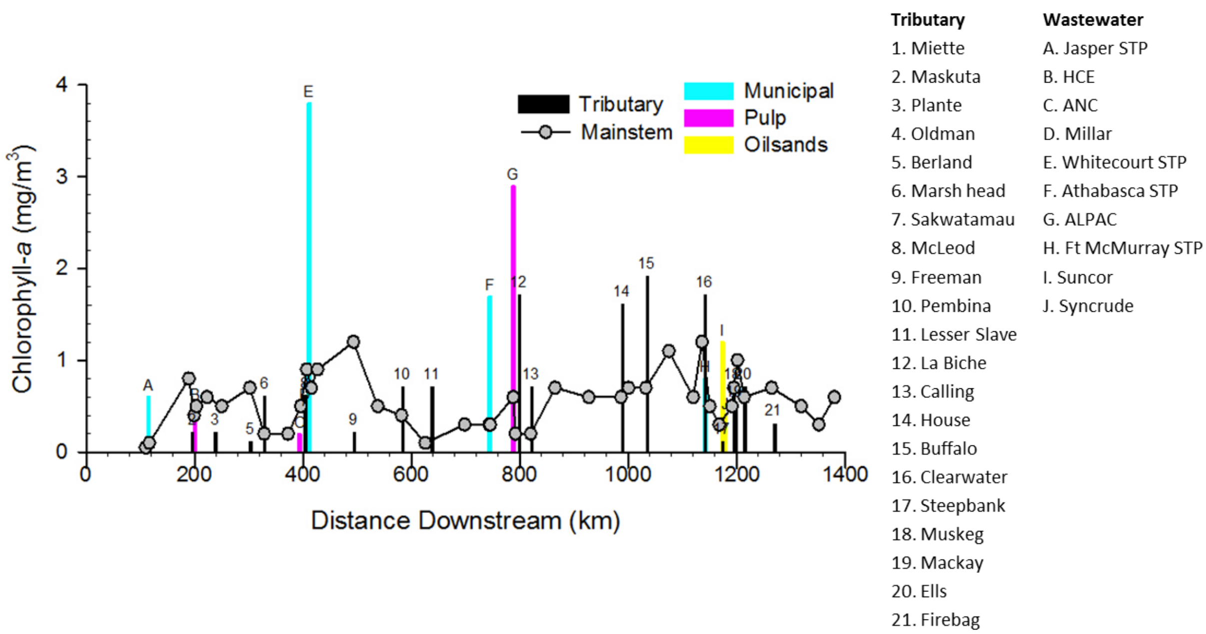

Figure 97. Concentrations of chlorophyll-*a* (mg/m³) measured during the 2015 survey in the Athabasca basin.

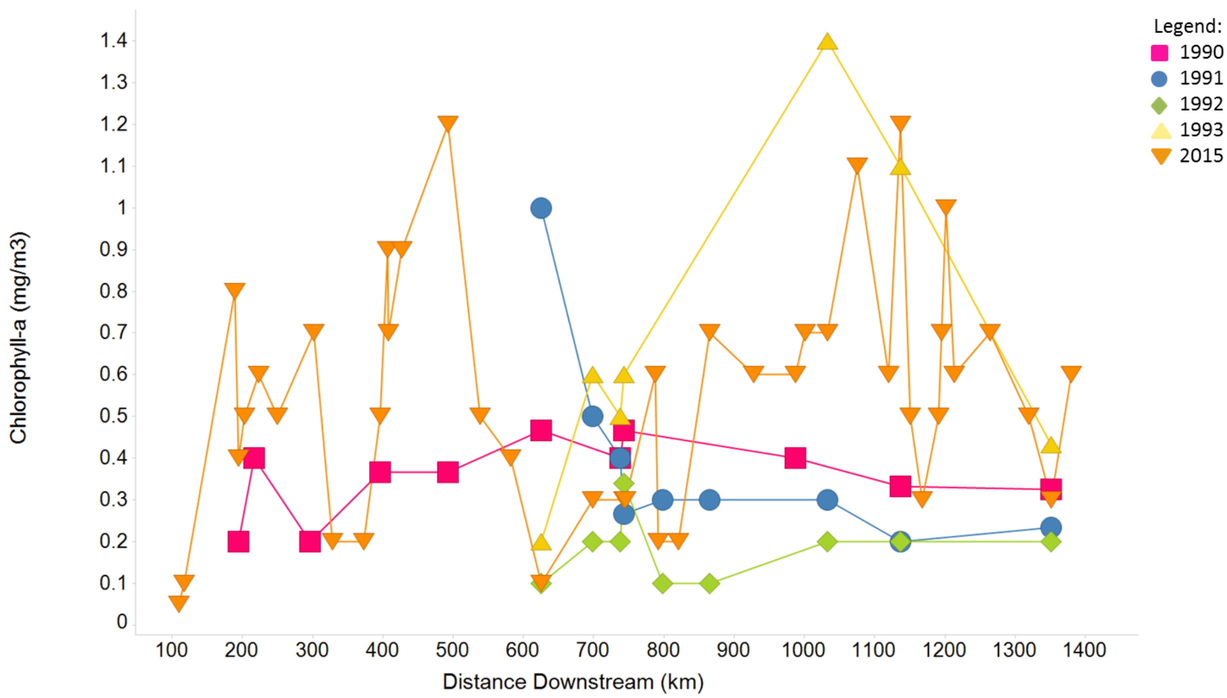

Figure 98. Comparison of chlorophyll-*a* (mg/m³) values measured during the 1990-1993 and 2015 winter synoptic surveys in the Athabasca River.

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9. Appendices

Appendix A1: Sampling Sites

Station Name	Station Number	Distance Downstream (km)	Sample Date	Type
U/S Miette River	AB07AD0002	109.4	1/20/15 9:00	Mainstem
Miette River		110	1/20/15 10:00	Tributary
Jasper STP	AB07AD0004	114.77	1/20/15 11:15	Effluent
D/S Maligne Rd	AB07AD0006	116.57	1/20/15 13:00	Mainstem
Old Entrance	AB07AD0100	189.30	1/22/15 8:45	Mainstem
Maskuta Ck	AB07AD0900	194.85	1/22/15 11:00	Tributary
Hinton Pump House	AB07AD0140	198.90	1/22/15 12:45	Mainstem
Hinton Pulp	AB07AD0610	200.40	1/22/15 13:45	Effluent
Weldwood Bridge	AB07AD0240	203.16	1/22/15 16:30	Mainstem
OBED Coal Bridge	AB07AD0340	223.03	1/23/15 8:50	Mainstem
Plante River	AB07AD0412	237.56	1/23/15 11:15	Tributary
Emerson Lakes Bridge	AB07AD0490	250.00	1/23/15 14:00	Mainstem
Oldman Ck	AB07AD0500	255.67	1/23/15 15:30	Tributary
U/S Berlund River	AB07AD0570	301.92	1/25/15 12:30	Mainstem
Berlund River	AB07AC0010	302.22	1/25/15 13:50	Tributary
U/S Marsh Head Ck	AB07AE0025	328.21	1/26/15 10:00	Mainstem
Marsh Head Ck	AB07AE0030	328.39	1/26/15 11:00	Tributary
Windfall Bridge	AB07AE0150	372.15	1/27/15 10:15	Mainstem
ANC Pulp	AB07AE0460	393.46	1/27/15 10:31	Effluent
D/S ANC	AB07AE0310	395.66	1/27/15 11:00	Mainstem
Sakwatamau River	AB07AH0010	402.20	1/27/15 12:15	Tributary
McLeod River	AB07AG0380	403.10	1/27/15 14:00	Tributary
Millar Western Pulp	AB07AH0530	404.01	1/27/15 14:30	Effluent
D/S McLeod	AB07AH0130	406.57	1/27/15 15:15	Mainstem
Whitecourt STP	AB07AH0610	407.14	1/27/15 15:30	Effluent
D/S Whitecourt STP	AB07AH0170	407.83	1/27/15 17:20	Mainstem
Blueridge Bridge	AB07AH0280	426.56	1/28/15 11:00	Mainstem
U/S Freeman River	AB07AH0360	492.82	1/29/15 11:45	Mainstem
Freeman River	AB07AH0430	493.27	1/29/15 12:20	Tributary
Vega Ferry MTRN	AB07BD0010	537.78	1/31/15 11:40	Mainstem
U/S Pembina River	AB07BD0020	581.67	2/2/15 12:15	Mainstem
Pembina	AB07BC0070	582.46	2/2/15 13:30	Tributary
Hwy 2 Bridge @ Smith	AB07BD0050	625.51	2/2/15 14:30	Mainstem
LSR MTRN	AB07BK0125	637.15	2/2/15 10:50	Tributary

45km U/S Athabasca	AB07BE0310	698.28	2/3/15 11:30	Mainstem
Athabasca LTRN	AB07BE0010	743.27	2/4/15 9:20	Mainstem
Athabasca STP	AB07CB0860	744.64	2/4/15 9:00	Effluent
Hwy 813 Bridge	AB07CB0080	745.44	2/4/15 10:40	Mainstem
U/S ALPAC	AB07CB0460	787.84	2/4/15 13:20	Mainstem
ALPAC Pulp	AB07CB0840	788.00	2/4/15 15:05	Effluent
D/S ALPAC	AB07CB0520	791.86	2/4/15 14:40	Mainstem
La Biche River	AB07CA0040	810.00	2/4/15 17:10	Tributary
U/S Calling River	AB07CB0645	820.10	2/5/15 11:15	Mainstem
Calling River	AB07CB0640	820.37	2/5/15 12:10	Tributary
West of McMillan Lak	AB07CB0700	864.90	2/7/15 15:30	Mainstem
U/S Pelican River	AB07CB0710	927.32	2/7/15 16:45	Mainstem
U/S House River	AB07CB0760	986.91	2/8/15 10:00	Mainstem
House River	AB07CB0770	987.25	2/8/15 10:45	Tributary
Grand Rapids	AB07CC0130	1000.81	2/8/15 12:50	Mainstem
U/S Buffalo Ck	AB07CC0150	1032.56	2/8/15 14:10	Mainstem
Buffalo Ck	AB07CC0160	1033.13	2/8/15 15:40	Tributary
U/S Boiler Rapids	AB07CC0170	1074.86	2/9/15 9:50	Mainstem
Mountain Rapids (M1)	AB07CC0100	1119.91	2/9/15 11:15	Mainstem
Ft McMurray LTRN (M2)	AB07CC0030	1136.26	2/9/15 15:00	Mainstem
Clearwater River	AB07CD0210	1140.04	2/10/15 9:15	Tributary
Ft McMurray STP	AB07DA2660	1142.40	2/10/15 11:45	Effluent
D/S Ft. McMurray STP (M3)	AB07DA0065	1150.41	2/10/15 9:15	Mainstem
U/S Suncor	AB07DA0170	1167.81	2/10/15 10:30	Mainstem
Steepbank River	AB07DA0260	1172.01	2/10/15 11:00	Tributary
Suncor	AB07DA2410	1174.49	2/10/15 14:30	Effluent
Syncrude	AB07DA2640	1179.24	2/10/15 16:15	Effluent
U/S Muskeg River (M4)	AB07DA0415	1191.32	2/10/15 12:15	Mainstem
Muskeg River	AB07DA0610	1191.96	2/10/15 13:00	Tributary
D/S McKay Bridge (M5)	AB07DA0650	1194.89	2/11/15 10:45	Mainstem
Mackay River	AB07DB0060	1195.99	2/11/15 11:30	Tributary
D/S Ft. McKay (M6)	AB07DA0690	1201.66	2/11/15 11:30	Mainstem
Ells River	AB07DA0750	1212.81	2/11/15 14:15	Tributary
D/S Ells River (M7)	AB07DA0800	1213.66	2/11/15 13:20	Mainstem
U/S Firebag (M8)	AB07DA0980	1264.58	2/12/15 10:00	Mainstem
Firebag River	AB07DC0110	1267.87	2/12/15 13:00	Tributary
Embarras Airport (M9)	AB07DD0040	1318.95	2/12/15 14:40	Mainstem
Old Fort LTRN	AB07DD0010	1351.38	4/1/15 13:38	Mainstem
Devils Elbow LTRN	AB07DD0105	1380.30	2/13/15 11:00	Mainstem
Slave Lake STP	AB07BK0360	-	2/2/15 8:30	Effluent

U/S Otauwau River (LSR)	AB07BK0070	-	2/2/15 9:45	Tributary
Slave Lake Pulp	AB07BK0330	-	2/2/15 14:15	Effluent

Appendix A2. Analytical Methods for Conventional Variables and Trace Organic Compunds

VMV Code	Parameter	Units	Lab	Parameter Grouping	Lab Analysis Method Title
Field Analysis					
100923	PH	pH units	Field Meter	Water Inorganics	Electronic meter with a glass pH reference electrode
100924	SPECIFIC CONDUCTANCE	uS/cm	Field Meter	Water Inorganics	Electronic meter with nickel cell
100925	TEMPERATURE WATER	deg C	Field Meter	Water Inorganics	Electronic meter with a thermistor
80558	OXYGEN DISSOLVED	mg/L	Field Meter	Water Inorganics	Electronic meter (luminescent)
2031	REDOX POTENTIAL	mV	Field Meter	Water Inorganics	Closed flow cell; platinum electrode
Laboratory Analysis					
103927	ALUMINUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
103999	ALUMINUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103951	ANTIMONY DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80043	ANTIMONY TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103928	ARSENIC DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80020	ARSENIC TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103930	BARIUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80022	BARIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103931	BERYLLIUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80023	BERYLLIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103932	BISMUTH DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80024	BISMUTH TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103929	BORON DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80021	BORON TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103934	CADMIUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80026	CADMIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103933	CALCIUM DISSOLVED	mg/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80025	CALCIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103935	CHLORINE DISSOLVED	mg/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80027	CHLORINE TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
99212	CHLOROPHYLL A	mg/m3	AITF	Water Inorganics	Fluorometry method: non-acidification
103937	CHROMIUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80029	CHROMIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103936	COBALT DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80028	COBALT TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103938	COPPER DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80030	COPPER TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103939	IRON DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80031	IRON TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.

VMV Code	Parameter	Units	Lab	Parameter Grouping	Lab Analysis Method Title
103949	LEAD DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80041	LEAD TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103942	LITHIUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80034	LITHIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103944	MANGANESE DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80036	MANGANESE TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
74475	MERCURY TOTAL	ng/L	AITF	Water Inorganics	Atomic fluorescence
103945	MOLYBDENUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80037	MOLYBDENUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103947	NICKEL DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80039	NICKEL TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
108477	OILSANDS ACID EXTRACTABLE ORGANICS	mg/L	AITF	Water Inorganics	Acidic extraction with hexane/dichloromethane, analysis by GC/iontrap
103952	SELENIUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80044	SELENIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103926	SILVER DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
103998	SILVER TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103955	STRONTIUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80047	STRONTIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103958	THALLIUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80053	THALLIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103956	THORIUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80048	THORIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103954	TIN DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80046	TIN TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103957	TITANIUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80049	TITANIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103959	URANIUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80054	URANIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103960	VANADIUM DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80055	VANADIUM TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
103961	ZINC DISSOLVED	ug/L	AITF	Water Inorganics	Dissolved Elements by ICP-MS: Samples filtered and then analysed
80056	ZINC TOTAL	ug/L	AITF	Water Inorganics	Elements, Total Recoverable by ICP-MS: Samples preserved and analysed.
108348	1-METHYLNAPHTHALENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108349	2-METHYLNAPHTHALENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108350	ACENAPHTHENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108351	ACENAPHTHYLENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108352	ANTHRACENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108353	BENZO(A)ANTHRACENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108354	BENZO(A)PYRENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry

VMV Code	Parameter	Units	Lab	Parameter Grouping	Lab Analysis Method Title
108355	BENZO(B,J,K)FLUORANTHENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
110104	BENZO(E)PYRENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108356	BENZO(G,H,I)PERYLENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108357	C1-CHRYSENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108358	C1-DIBENZOTHIOPHENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108359	C1-FLUORANTHENE/PYRENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108360	C1-FLUORENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108361	C1-PHENANTHRENE/ANTHRACENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108362	C2-CHRYSENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108363	C2-DIBENZOTHIOPHENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108364	C2-FLUORANTHENE/PYRENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108365	C2-FLUORENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108366	C2-NAPHTHALENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108367	C2-PHENANTHRENE/ANTHRACENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108368	C3-CHRYSENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108369	C3-DIBENZOTHIOPHENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108370	C3-FLUORANTHENE/PYRENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108371	C3-FLUORENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108372	C3-NAPHTHALENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108373	C3-PHENANTHRENE/ANTHRACENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108374	C4-CHRYSENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108375	C4-DIBENZOTHIOPHENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108376	C4-FLUORANTHENE/PYRENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108377	C4-FLUORENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108378	C4-NAPHTHALENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108379	C4-PHENANTHRENE/ANTHRACENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108380	CHRYSENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108381	DIBENZO(A,H)ANTHRACENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108383	FLUORANTHENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108384	FLUORENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108385	INDENO(1,2,3-C,D)PYRENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108386	NAPHTHALENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
110105	PERYLENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108387	PHENANTHRENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108388	PYRENE	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
110106	RETENE (7-ISOPROPYL-1-METHYLPHENANTHRENE)	ug/L	AITF	Water Organics - ALK PAH	Polycyclic hydrocarbons by gas chromatography/mass spectrometry
108338	NAPHTHENIC ACIDS	mg/L	AITF	Water Organics - Naphthenic Acids	Hexane/dichloromethane extraction, MTBSTFA derivatization GC/iontrap
106092	BENZENE	ug/L	AITF	Water Organics - Total Recoverable Hydrocarbons	Hydrocarbons in water, CCME derived, GC/MS
106094	ETHYL BENZENE	ug/L	AITF	Water Organics - Total Recoverable Hydrocarbons	Hydrocarbons in water, CCME derived, GC/MS

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106091	F1, HYDROCARBONS (C6-C10)- BTX	ug/L	AITF	Water Organics - Total Recoverable Hydrocarbons	Hydrocarbons in water, CCME derived, GC/MS
106097	F2, HYDROCARBONS (C10-C16)	ug/L	AITF	Water Organics - Total Recoverable Hydrocarbons	Hydrocarbons in water, CCME derived, GC/MS
106098	F3, HYDROCARBONS (C16-C34)	ug/L	AITF	Water Organics - Total Recoverable Hydrocarbons	Hydrocarbons in water, CCME derived, GC/MS
108342	F4, HYDROCARBONS (C34-C50)	ug/L	AITF	Water Organics - Total Recoverable Hydrocarbons	Hydrocarbons in water, CCME derived, GC/MS
106095	M- + P-XYLENE	ug/L	AITF	Water Organics - Total Recoverable Hydrocarbons	Hydrocarbons in water, CCME derived, GC/MS
106096	O-XYLENE	ug/L	AITF	Water Organics - Total Recoverable Hydrocarbons	Hydrocarbons in water, CCME derived, GC/MS
106093	TOLUENE	ug/L	AITF	Water Organics - Total Recoverable Hydrocarbons	Hydrocarbons in water, CCME derived, GC/MS
100651	1,1,1,2-TETRACHLOROETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95227	1,1,1-TRICHLOROETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95224	1,1,2,2-TETRACHLOROETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95228	1,1,2-TRICHLOROETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95214	1,1-DICHLOROETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95216	1,1-DICHLOROETHYLENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100645	1,1-DICHLOROPROPYLENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100652	1,2,3-TRICHLOROBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100655	1,2,3-TRICHLOROPROPANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100653	1,2,4-TRICHLOROBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100730	1,2,4-TRICHLOROBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100656	1,2,4-TRIMETHYLBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100640	1,2-DIBROMO-3-CHLOROPROPANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100641	1,2-DIBROMOETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95211	1,2-DICHLOROBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95215	1,2-DICHLOROETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95218	1,2-DICHLOROPROPANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100734	1,2-DIPHENYLHYDRAZINE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100657	1,3,5-TRIMETHYLBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95212	1,3-DICHLOROBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100644	1,3-DICHLOROPROPANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95213	1,4-DICHLOROBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100643	2,2-DICHLOROPROPANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
103632	2,3,4,6-TETRACHLOROPHENOL	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100708	2,4,6-TRICHLOROPHENOL	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100700	2,4-DICHLOROPHENOL	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100701	2,4-DIMETHYLPHENOL	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100703	2,4-DINITROPHENOL	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100732	2,4-DINITROTOLUENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100733	2,6-DINITROTOLUENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
95207	2-CHLOROETHYLVINYLETHER (2-CHLOROETHOXYETHYLENE)	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry

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100725	2-CHLORONAPHTHALENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100699	2-CHLOROPHENOL	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100638	2-CHLOROTOLUENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100702	2-METHYL-4,6-DINITROPHENOL	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100704	2-NITROPHENOL	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100738	4-BROMOPHENYL PHENYL ETHER	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100698	4-CHLORO-3-METHYLPHENOL	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100742	4-CHLOROPHENYL PHENYL ETHER	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100639	4-CHLOROTOLUENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100705	4-NITROPHENOL	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100709	ACENAPHTHENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100710	ACENAPHTHYLENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100711	ANTHRACENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
95200	BENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100731	BENZIDINE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100712	BENZO(A)ANTHRACENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100716	BENZO(A)PYRENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100713	BENZO(B)FLUORANTHENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100715	BENZO(G,H,I)PERYLENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100714	BENZO(K)FLUORANTHENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100739	BIS(2-CHLOROETHOXY) METHANE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100740	BIS(2-CHLOROETHYL) ETHER	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100741	BIS(2-CHLOROISOPROPYL) ETHER	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100748	BIS(2-ETHYLHEXYL) PHTHALATE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100634	BROMOBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95202	BROMOFORM	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95203	BROMOMETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100743	BUTYLBENZYL PHTHALATE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
95204	CARBON TETRACHLORIDE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95205	CHLOROBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95206	CHLOROETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95208	CHLOROFORM	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
106204	CHLOROMETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100717	CHRYSENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100642	CIS-1,2-DICHLOROETHENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95219	CIS-1,3-DICHLOROPROPENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100718	DIBENZO(A,H)ANTHRACENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
95209	DIBROMOCHLOROMETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95210	DIBROMOMETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry

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95201	DICHLOROBROMOMETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100745	DIETHYL PHTHALATE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100746	DIMETHYL PHTHALATE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100744	DI-N-BUTYL PHTHALATE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100747	DI-N-OCTYL PHTHALATE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
95221	ETHYL BENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100719	FLUORANTHENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100720	FLUORENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100726	HEXACHLOROBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100646	HEXACHLOROBUTADIENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100727	HEXACHLOROBUTADIENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100728	HEXACHLOROCYCLOPENTADIENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100729	HEXACHLOROETHANE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100721	INDENO(1,2,3-C,D)PYRENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100749	ISOPHORONE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100647	ISOPROPYLBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95234	M- + P-XYLENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95222	METHYLENE CHLORIDE (DICHLOROMETHANE)	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
102608	MTBE (METHYL TERTIARY BUTYL ETHER)	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100649	NAPHTHALENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100722	NAPHTHALENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100637	N-BUTYLBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100735	NITROBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100737	N-NITROSO-DI-N-PROPYLAMINE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100736	N-NITROSODIPHENYLAMINE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100650	N-PROPYLBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95233	O-XYLENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100706	PENTACHLOROPHENOL	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100723	PHENANTHRENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100707	PHENOL	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100648	P-ISOPROPYLTOLUENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100724	PYRENE	ug/L	AITF	Water Organics - VPP/EPP	Extractable priority pollutants in water: analysis by GC-MS
100635	SEC-BUTYLBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95223	STYRENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
100636	TERT-BUTYLBENZENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95225	TETRACHLOROETHYLENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95226	TOLUENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95217	TRANS-1,2-DICHLOROETHENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95220	TRANS-1,3-DICHLOROPROPENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry

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100654	TRICHLOROETHYLENE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95229	TRICHLOROFLUOROMETHANE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
95232	VINYL CHLORIDE	ug/L	AITF	Water Organics - VPP/EPP	Batch purge and trap/capillary column gas chromatography/mass spectrometry
97852	2,3,4,6-TETRACHLOROPHENOL	mg/L	ALS	Water Organics - Chlorophenols	Extractable priority pollutants in water: analysis by GC-MS
80173	2,4 & 2,5-DICHLOROPHENOL	mg/L	ALS	Water Organics - Chlorophenols	Extractable priority pollutants in water: analysis by GC-MS
80162	2,4,5-TRICHLOROPHENOL	mg/L	ALS	Water Organics - Chlorophenols	Extractable priority pollutants in water: analysis by GC-MS
97853	2,4,6-TRICHLOROPHENOL	mg/L	ALS	Water Organics - Chlorophenols	Extractable priority pollutants in water: analysis by GC-MS
97845	2,6-DICHLOROPHENOL	mg/L	ALS	Water Organics - Chlorophenols	Extractable priority pollutants in water: analysis by GC-MS
80212	2,6-DICHLOROSYRINGALDEHYDE	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
97841	2-CHLOROPHENOL	mg/L	ALS	Water Organics - Chlorophenols	Extractable priority pollutants in water: analysis by GC-MS
80213	2-CHLOROSYRINGALDEHYDE	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80214	3,4,5-TRICHLOROCATECOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80216	3,4,5-TRICHLOROCATECOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80215	3,4,5-TRICHLOROGUAIACOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80217	3,4,6-TRICHLOROCATECHOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80218	3,4,6-TRICHLOROGUAIACOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80219	3,4-DICHLOROCATECHOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80220	3,4-DICHLOROGUAIACOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80221	3,5-DICHLOROCATECHOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80222	3,6-DICHLOROCATECHOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80223	4,5,6-TRICHLOROGUAIACOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80176	4,5,6-TRICHLOROSYRINGOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80177	4,5-DICHLOROCATECHOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80178	4,5-DICHLOROGUAIACOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80179	4,5-DICHLOROVERATROLE	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80180	4,6-DICHLOROGUAIACOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80181	4-CHLOROCATECHOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80182	4-CHLOROGUAIACOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80183	4-CHLOROPHENOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80184	5,6-DICHLOROVANILLIN	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80185	5-CHLOROVANILLIN	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80186	6-CHLOROVANILLIN	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80187	PENTACHLOROPHENOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80188	TETRACHLOROCATECOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80189	TETRACHLOROGUAIACOL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80190	TETRACHLOROVERATROL	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
80191	TRICHLOROMETHOXYBENZENE (2,4,6-TRICHLOROANISOLE)	mg/L	ALS	Water Organics - Chlorophenols	CPS in ambient water: acetylation, extraction & analysis by SIM GC-MSD
74318	12,14-DICHLORODEHYDROABIETIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode

VMV Code	Parameter	Units	Lab	Parameter Grouping	Lab Analysis Method Title
74319	12-CHLORODEHYDROABIETIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74320	14-CHLORODEHYDROABIETIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74321	9,10-DICHLOROSTEARIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74322	ABIETIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74323	ARACHIDIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74324	DEHYDROABIETIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74326	ISOPIMARIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74327	LEVOPIMARIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74328	LINOLEIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74329	LINOLENIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74330	MYRISTIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74331	NEOABIETIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74332	OLEIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74333	PALMITIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74334	PALUSTRIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74335	PIMARIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74336	SANDARACOPIMARIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
74337	STEARIC ACID	mg/L	ALS	Water Organics - Resin and Fatty Acids	Resin and fatty acids by GC/MS in SIM mode
10151	ALKALINITY PHENOLPHTHALEIN CACO3	mg/L	Maxxam	Water Inorganics	Potentiometric titration
10111	ALKALINITY TOTAL CACO3	mg/L	Maxxam	Water Inorganics	Titro processor
7505	AMMONIA TOTAL	mg/L	Maxxam	Water Inorganics	Colorimetrically (Berthelot method)
6201	BICARBONATE (CALCD_)	mg/L	Maxxam	Water Inorganics	Calculated method
20111	CALCIUM DISSOLVED/FILTERED	mg/L	Maxxam	Water Inorganics	Inductively coupled argon plasma emission spectroscopy
6104	CARBON DISSOLVED ORGANIC	mg/L	Maxxam	Water Inorganics	Infrared analysis
6005	CARBON TOTAL ORGANIC	mg/L	Maxxam	Water Inorganics	Infrared analysis
8218	CARBONACEOUS OXYGEN DEMAND	mg/L	Maxxam	Water Inorganics	DO meter
6301	CARBONATE (CALCD_)	mg/L	Maxxam	Water Inorganics	Calculated method
100537	CHLORATE	mg/L	Maxxam	Water Inorganics	Suppressed ion chromatography
17206	CHLORIDE DISSOLVED	mg/L	Maxxam	Water Inorganics	Colourimetry on autoanalyzer with Fe(NO3)3 & HgSCN
24101	CHROMIUM HEXAVALENT	mg/L	Maxxam	Water Inorganics	Colorimetric with diphenylcarbazide
2021	COLOUR TRUE	rel units	Maxxam	Water Inorganics	Visual comparison
97806	CYANIDE TOTAL	mg/L	Maxxam	Water Inorganics	Carbon by chloramine-t, pyridine barbituric acid colorimetry
9105	FLUORIDE DISSOLVED	mg/L	Maxxam	Water Inorganics	Specific ion electrode
10602	HARDNESS TOTAL (CALCD) CACO3	mg/L	Maxxam	Water Inorganics	Calculated method
8501	HYDROXIDE (CALCD_)	mg/L	Maxxam	Water Inorganics	Calculated method
111	IONIC BALANCE (CALCD)	meq/L	Maxxam	Water Inorganics	Calculated method
102090	IRON DISSOLVED	mg/L	Maxxam	Water Inorganics	Filtered and preserved samples analyzed by ICP-AES
12111	MAGNESIUM DISSOLVED/FILTERED	mg/L	Maxxam	Water Inorganics	Inductively coupled argon plasma emission spectroscopy
102089	MANGANESE DISSOLVED	mg/L	Maxxam	Water Inorganics	Filtered and preserved samples analyzed by ICP-AES

VMV Code	Parameter	Units	Lab	Parameter Grouping	Lab Analysis Method Title
102648	NITROGEN NITRITE	mg/L	Maxxam	Water Inorganics	Ion chromatography
102649	NITROGEN NO3 & NO2	mg/L	Maxxam	Water Inorganics	Ion chromatography
7015	NITROGEN TOTAL	mg/L	Maxxam	Water Inorganics	Colorimetrically (Berthelot method)
7602	NITROGEN TOTAL	mg/L	Maxxam	Water Inorganics	Calculated method
102647	NITROGEN, NITRATE	mg/L	Maxxam	Water Inorganics	Ion chromatography
8202	OXYGEN BIOCHEMICAL DEMAND	mg/L	Maxxam	Water Inorganics	DO meter
10301	PH	pH units	Maxxam	Water Inorganics	Electrometric method
6537	PHENOLIC MATERIAL	mg/L	Maxxam	Water Inorganics	Automated 4-aminoantipyrine colorimetric method
15256	PHOSPHATE DISSOLVED ORTHO	mg/L	Maxxam	Water Inorganics	Colourimetry with ammonium molybdate; etc.
15406	PHOSPHORUS TOTAL	mg/L	Maxxam	Water Inorganics	Colourimetry with ammonium molybdate; etc.
15423	PHOSPHORUS TOTAL DISSOLVED	mg/L	Maxxam	Water Inorganics	Sulfuric acid-persulfate mixture digestion
19111	POTASSIUM DISSOLVED/FILTERED	mg/L	Maxxam	Water Inorganics	Inductively coupled argon plasma emission spectroscopy
10451	RESIDUE FILTERABLE	mg/L	Maxxam	Water Inorganics	Gravimetric method
10405	RESIDUE NONFILTERABLE	mg/L	Maxxam	Water Inorganics	Gravimetric method
14106	SILICA REACTIVE	mg/L	Maxxam	Water Inorganics	Colourimetry using heteropoly blue method (autoanalyzer)
11111	SODIUM DISSOLVED/FILTERED	mg/L	Maxxam	Water Inorganics	Inductively coupled argon plasma emission spectroscopy
2041	SPECIFIC CONDUCTANCE	uS/cm	Maxxam	Water Inorganics	Conductivity meter; platinum electrodes
106150	SULPHATE DISSOLVED	mg/L	Maxxam	Water Inorganics	BaSO4 suspension, automated photometric method
16101	SULPHIDE DISSOLVED	mg/L	Maxxam	Water Inorganics	Colourimetry on autoanalyzer with Fe(NO3)3 & HgSCN
201	TOTAL DISSOLVED SOLIDS	mg/L	Maxxam	Water Inorganics	Calculated method
2074	TURBIDITY	NTU	Maxxam	Water Inorganics	Nephelometric method using a hach turbidimeter; units ntu
102640	ADSORBABLE ORGANIC HALIDE - AOX	mg/L	Maxxam	Water Organics - AOX	Ag ion titration
100629	COLIFORMS FECAL	No/100 mL	Provincial Lab	Water Inorganics	Membrane filter procedure
100628	COLIFORMS TOTAL	No/100 mL	Provincial Lab	Water Inorganics	Membrane filter procedure
100632	ESCHERICHIA COLI	No/100 mL	Provincial Lab	Water Inorganics	Membrane filter procedure
109750	METHYL MERCURY	ng/L	U of A	Water Inorganics	Isotope dilution, purge and trap and ICP-MS

Appendix B: Calculated Mass Loads

Station Name	Distance Downstream	Type	Flow	True Colour	BOD	Alkalinity	TDS	TSS	Na	K	Mg	Ca	HCO3	Cl	F	SO4	Sulphide	Silica Reactive	Phenolic Material
	(km)		m3/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
MIETTE RIVER	110	Tributary	117,504	682	-	8,930	17,626	-	353	49	1,645	2,938	10,928	165	-	6,698	0.3	458	-
Jasper STP	115	Effluent	3,798	110	11	646	1,443	35	254	24	65	175	760	376	1	144	0.05	23	0.02
MASKUTA CREEK	195	Tributary	14,083	110	-	3,802	4,507	-	239	18	268	1,098	4,647	296	1	169	-	108	-
HCE	200	Effluent	88,766	25,742	1,331	20,416	115,396	2,397	31,956	559	1,154	4,527	24,855	13,315	17	47,046	24.0	479	0.7
PLANTE RIVER	238	Tributary	22,637	199	-	6,112	7,017	-	498	22	430	1,585	7,470	-	2	656	-	195	-
OLDMAN CREEK	256	Tributary	123,552	605	-	27,181	28,417	161	729	90	1,730	7,784	33,359	-	9	766	-	1,149	-
BERLAND RIVER	302	Tributary	1,010,880	7,885	-	222,394	262,829	-	8,795	839	17,185	64,696	272,938	-	84	29,316	-	7,076	-
MARSH HEAD CREEK	328	Tributary	36,115	686	-	8,306	9,029	144	578	34	542	2,167	10,473	166	3	253	0.2	350	0.1
ANC	393	Effluent	15,969	2,395	50	2,715	8,783	85	1,102	319	255	1,277	3,353	1,070	2	3,034	0.5	93	0.1
SAKWATAMAU RIVER	402	Tributary	136,512	1,911	-	32,763	35,493	450	4,095	177	1,638	7,372	39,588	273	16	1,638	-	1,365	-
MCLEOD RIVER	403	Tributary	604,800	4,717	-	151,200	193,536	1,210	20,563	907	9,677	36,893	187,488	6,653	60	18,749	-	5,504	-
Millar	404	Effluent	9,435	16,983	491	24,530	45,287	2,547	15,096	623	311	896	30,191	462	1	11,322	0.7	1,321	0.5
Whitecourt STP	407	Effluent	3,694	211	517	1,219	2,475	1,699	480	55	59	229	1,477	591	2	218	0.3	36	0.2
FREEMAN RIVER	493	Tributary	72,922	1,604	-	12,397	14,584	197	1,094	88	715	3,427	15,314	204	8	722	0.3	875	-
PEMBINA RIVER	582	Tributary	401,760	11,651	-	104,458	124,546	804	12,053	1,446	7,232	26,516	128,563	1,446	40	8,839	-	4,018	1.1
LESSER SLAVE RIVER	637	Tributary	2,531,520	32,910	-	455,674	708,826	6,835	50,630	3,291	43,036	151,891	531,619	12,404	304	154,423	-	16,708	-
Athabasca STP	745	Effluent	598	33	8	173	400	4	72	10	10	35	209	102	0.1	39	0.0	3	0.0
ALPAC	788	Effluent	79,562	16,708	286	20,686	119,343	1,671	23,073	3,103	1,273	11,934	25,460	12,730	14	49,328	8.8	668	0.6
LA BICHE RIVER	810	Tributary	889,920	15,129	-	151,286	169,085	17,798	14,239	2,581	12,459	36,487	186,883	3,382	142	7,564	-	1,780	-
CALLING RIVER	820	Tributary	119,232	1,669	-	14,308	15,500	393	978	274	1,037	3,696	17,885	203	17	537	-	143	-
HOUSE RIVER	987	Tributary	124,416	9,953	-	23,639	36,081	834	2,986	323	1,991	7,216	28,616	411	30	6,345	0.7	1,742	-
BUFFALO CREEK	1033	Tributary	2,765	387	-	608	829	28	147	5	39	119	719	4	1	119	0.02	24	-
CLEARWATER RIVER	1140	Tributary	4,164,480	137,428	-	358,145	791,251	19,573	162,415	5,414	29,984	91,619	416,448	179,073	500	40,395	-	49,974	-
Ft McMurray STP	1142	Effluent	25,468	866	102	3,566	14,007	135	2,318	382	458	1,554	4,330	2,801	2	2,547	0.6	163	0.1
STEEPBANK RIVER	1172	Tributary	113,184	2,716	-	37,351	41,878	147	4,980	226	2,490	8,036	45,274	804	27	1,698	-	1,358	-
Suncor	1174	Effluent	165	2	-	31	124	-	16	1	5	20	38	25	0.0	38	0.01	1	0.001
Syncrude	1179	Effluent	626	50	7	275	532	6	69	17	11	45	338	100	0.1	54	0.03	4	0.004
MUSKEG RIVER	1192	Tributary	36,029	2,126	-	9,728	10,809	47	612	58	612	2,702	11,890	310	5	360	0.2	468	-
MACKAY RIVER	1196	Tributary	88,128	8,813	-	24,676	36,132	238	5,464	212	1,851	5,552	29,964	2,203	18	4,583	0.4	881	-
ELLS RIVER	1213	Tributary	116,640	4,666	-	12,830	18,662	152	1,750	187	1,061	3,732	16,330	187	14	2,683	0.6	863	-
FIREBAG RIVER	1268	Tributary	1,410,048	42,301	2,820	183,306	225,608	1,833	6,768	1,396	14,100	50,762	225,608	3,525	155	7,191	3.7	22,561	-
SLP	-	Effluent	2,586	134	70	646	1,370	59	251	39	28	101	802	388	0.5	72	0.03	26	0.01
Slave Lake STP	-	Effluent	10,523	28,412	368	24,202	31,568	894	10,523	747	158	326	28,412	253	2	3,473	2.1	884	0.3

Station Name	Distance Downstream	Type	Flow	Total Organic Carbon	Dissolved Organic Carbon	Total Phosphorous	Total Dissolved Phosphorous	Dissolved Ortho-phosphate	Nitrate N	Nitrite N	Nitrate + Nitrite	Total Kjeldahl Nitrogen	Total Ammonia	Total Nitrogen
	(km)		m3/day	(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)
MIETTE RIVER	110	Tributary	117,504	-	-	0.5	0.6	-	11.8	-	11.8	7.9	-	20.0
Jasper STP	115	Effluent	3,798	21	19	1.2	0.5	0.1	3.0	0.5	3.5	5.3	0.4	8.7
MASKUTA CREEK	195	Tributary	14,083	55	49	0.1	0.1	-	1.4	-	1.4	1.3	-	2.8
HCE	200	Effluent	88,766	6,302	4,882	78.1	46.2	40.8	3.9	7.5	11.5	674.6	266.3	683.5
PLANTE RIVER	238	Tributary	22,637	68	57	0.1	0.1	0.1	2.5	-	2.5	1.9	-	4.5
OLDMAN CREEK	256	Tributary	123,552	198	161	0.6	0.7	0.4	14.8	-	14.8	-	-	14.8
BERLAND RIVER	302	Tributary	1,010,880	1,921	1,921	3.0	4.9	-	80.9	-	80.9	-	-	80.9
MARSH HEAD CREEK	328	Tributary	36,115	209	170	0.5	0.2	0.1	4.0	-	4.0	10.1	-	14.1
ANC	393	Effluent	15,969	351	383	5.4	4.3	3.0	2.4	0.2	2.6	19.2	2.7	22.4
SAKWATAMAU RIVER	402	Tributary	136,512	655	614	1.6	1.0	5.2	9.7	-	9.7	30.0	-	39.6
MCLEOD RIVER	403	Tributary	604,800	2,480	2,480	4.2	3.6	1.8	139.1	-	139.1	163.3	39.9	302.4
Millar	404	Effluent	9,435	2,642	2,076	94.3	71.7	67.9	-	-	-	226.4	8.4	226.4
Whitecourt STP	407	Effluent	3,694	225	151	18.1	2.7	2.3	-	0.2	0.2	144.0	66.5	144.0
FREEMAN RIVER	493	Tributary	72,922	569	540	0.7	0.4	0.2	5.6	-	5.6	20.4	-	25.5
PEMBINA RIVER	582	Tributary	401,760	4,821	4,821	7.2	4.8	1.6	76.3	1.4	80.4	277.2	39.4	357.6
LESSER SLAVE RIVER	637	Tributary	2,531,520	8,607	8,354	25.3	22.8	12.7	481.0	-	481.0	455.7	-	936.7
Athabasca STP	745	Effluent	598	14	13	0.8	0.6	0.6	0.5	0.0	0.5	19.7	16.7	20.3
ALPAC	788	Effluent	79,562	2,626	2,785	103.4	95.5	103.4	10.3	0.5	11.1	127.3	-	135.3
LA BICHE RIVER	810	Tributary	889,920	12,459	10,679	97.9	81.0	69.4	59.6	-	59.6	703.0	54.3	765.3
CALLING RIVER	820	Tributary	119,232	1,550	1,550	2.9	2.1	1.2	8.2	-	8.2	96.6	7.3	104.9
HOUSE RIVER	987	Tributary	124,416	1,991	1,991	5.7	1.9	5.3	64.7	0.5	65.9	89.6	21.2	149.3
BUFFALO CREEK	1033	Tributary	2,765	108	94	0.3	0.2	0.2	1.0	0.0	1.0	3.9	0.3	5.0
CLEARWATER RIVER	1140	Tributary	4,164,480	28,735	28,735	149.9	79.1	75.0	874.5	-	874.5	1,749.1	412.3	2,623.6
Ft McMurray STP	1142	Effluent	25,468	331	306	12.5	3.3	3.8	356.6	1.5	356.6	71.3	1.6	433.0
STEEPBANK RIVER	1172	Tributary	113,184	1,132	1,053	4.2	1.6	1.0	39.6	0.4	40.7	50.9	7.4	91.7
Suncor	1174	Effluent	165	1	1	0.0	0.0	0.0	0.0	-	0.0	0.1	0.0	0.1
Syncrude	1179	Effluent	626	13	13	4.5	4.3	4.6	1.1	0.0	1.2	46.3	44.4	47.0
MUSKEG RIVER	1192	Tributary	36,029	649	612	0.5	0.1	0.2	4.7	-	4.7	39.6	13.7	43.2
MACKAY RIVER	1196	Tributary	88,128	2,203	2,468	3.3	2.4	3.6	41.4	-	41.4	85.5	5.1	123.4
ELLS RIVER	1213	Tributary	116,640	1,866	1,866	2.9	1.7	1.3	44.3	-	44.3	78.1	-	116.6
FIREBAG RIVER	1268	Tributary	1,410,048	5,922	5,781	79.0	28.2	31.0	225.6	-	225.6	380.7	110.0	606.3
SLP	-	Effluent	2,586	72	52	3.1	0.8	0.8	0.2	0.0	0.3	80.2	59.5	80.2
Slave Lake STP	-	Effluent	10,523	2,525	2,420	11.6	2.8	1.7	-	-	-	168.4	-	168.4

Station Name	Distance Downstream	Type	Flow	Total Hg	Total Ag	Total Al	Total As	Total B	Total Ba	Total Be	Total Bi	Total Cd	Total Co	Total Cr	Total Cu	Total Fe	Total Li	Total Mn	Total Mo
	(km)		m3/day	ug/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day
MIETTE RIVER	110	Tributary	117,504	-	-	1962.32	7.17	258.51	1504.05	-	-	-	5.17	8.23	42.30	16,450.56	397.16	1,515.80	6.58
Jasper STP	115	Effluent	3,798	8.32	0.11	183.06	0.67	186.86	161.42	-	0.43	0.11	0.33	1.41	28.64	309.16	584.89	39.12	1.02
MASKUTA CREEK	195	Tributary	14,083	5.35	-	1009.77	3.75	130.97	1788.57	0.13	-	0.04	0.51	1.41	7.04	1,957.56	87.74	30.70	10.34
HCE	200	Effluent	88,766	18.64	4.44	50774.26	31.51	1739.82	4748.99	0.89	0.53	9.05	10.03	211.26	172.21	12,249.73	553.01	38,968.36	600.95
PLANTE RIVER	238	Tributary	22,637	5.89	-	891.89	5.73	201.47	1858.48	-	-	0.14	0.36	0.68	9.28	3,123.88	147.59	154.38	18.18
OLDMAN CREEK	256	Tributary	123,552	19.77	0.99	5522.77	29.53	531.27	7783.78	-	-	0.37	1.85	24.71	29.65	12,849.41	418.84	756.14	97.61
BERLAND RIVER	302	Tributary	1,010,880	202.18	-	43973.28	201.17	6873.98	122316.48	-	-	4.04	13.14	80.87	353.81	121,305.60	3,841.34	2,466.55	1,304.04
MARSH HEAD CREEK	328	Tributary	36,115	20.59	-	4297.71	24.16	429.77	3900.44	0.29	-	0.22	2.74	5.06	14.08	30,697.92	256.42	1,375.99	21.24
ANC	393	Effluent	15,969	-	0.67	305.00	4.36	14866.67	3768.57	0.30	0.19	0.29	4.93	4.47	14.21	250.71	80.32	19,002.52	16.61
SAKWATAMAU RIVER	402	Tributary	136,512	70.99	0.27	22114.94	91.05	2006.73	15289.34	-	-	2.05	16.79	21.84	116.04	110,984.26	3,358.20	7,289.74	148.80
MCLEOD RIVER	403	Tributary	604,800	169.34	35.68	105840.00	239.50	12640.32	74995.20	-	-	3.02	45.36	102.82	483.84	148,780.80	6,834.24	9,132.48	616.90
Millar	404	Effluent	9,435	15.57	0.50	1009.52	3.42	180.20	4641.92	-	-	10.00	15.10	20.00	77.84	426.45	83.50	9,529.15	1.32
Whitecourt STP	407	Effluent	3,694	138.51	3.04	79410.25	16.81	590.96	4838.49	1.46	13.70	10.38	15.25	51.34	402.59	67,221.70	49.86	1,104.36	8.42
FREEMAN RIVER	493	Tributary	72,922	302.62	116.67	6519.19	65.56	736.51	7510.92	-	0.36	0.73	8.02	7.29	45.21	98,444.16	926.10	6,927.55	62.93
PEMBINA RIVER	582	Tributary	401,760	462.02	1.61	66290.40	296.90	10526.11	57451.68	-	1.61	4.42	31.34	100.44	598.62	192,443.04	3,250.24	6,387.98	376.45
LESSER SLAVE RIVER	637	Tributary	2,531,520	2354.31	7.59	420232.32	3240.35	54933.98	157713.70	-	17.72	159.49	356.94	683.51	2,835.30	855,653.76	27,846.72	58,984.42	1,718.90
Athabasca STP	745	Effluent	598	1.55	0.03	217.56	0.79	72.92	22.71	-	0.10	0.02	0.61	0.21	23.43	215.76	9.62	53.01	3.01
ALPAC	788	Effluent	79,562	51.72	1.27	30790.48	45.11	3381.38	28960.55	-	-	40.02	11.54	144.80	201.29	11,775.17	596.71	4,932.84	112.18
LA BICHE RIVER	810	Tributary	889,920	1263.69	3.56	766221.12	1699.75	44318.02	55886.98	17.80	8.90	8.01	240.28	800.93	649.64	916,617.60	12,191.90	49,034.59	361.31
CALLING RIVER	820	Tributary	119,232	56.04	-	21342.53	112.79	4041.96	4685.82	-	0.83	0.36	13.35	44.12	41.73	43,758.14	1,105.28	3,779.65	25.28
HOUSE RIVER	987	Tributary	124,416	146.81	0.87	48646.66	151.79	10189.67	6954.85	2.86	1.12	3.23	89.83	42.30	110.73	480,245.76	2,886.45	37,324.80	175.43
BUFFALO CREEK	1033	Tributary	2,765	3.73	0.02	1020.21	2.72	566.78	100.64	0.06	0.02	0.02	0.82	1.38	3.32	7,686.14	91.51	243.58	1.11
CLEARWATER RIVER	1140	Tributary	4,164,480	2956.78	-	957830.40	2036.43	165746.30	104528.45	49.97	54.14	41.64	470.59	1,124.41	2,457.04	4,830,796.80	27,110.76	134,096.26	841.22
Ft McMurray STP	1142	Effluent	25,468	74.11	3.23	27760.05	17.88	4176.74	924.49	0.25	2.04	1.81	10.09	11.21	144.40	2,401.63	325.99	2,180.06	95.00
STEEPBANK RIVER	1172	Tributary	113,184	70.17	0.23	7402.23	49.35	27730.08	9281.09	0.91	0.79	0.68	12.22	15.85	50.93	121,106.88	2,705.10	2,014.68	61.23
Suncor	1174	Effluent	165	0.10	-	4.32	0.11	16.67	23.43	-	0.00	-	-	0.02	0.16	7.71	3.32	8.94	0.16
Syncrude	1179	Effluent	626	0.94	0.00	20.47	0.63	95.15	8.89	-	0.10	0.04	0.30	0.21	3.93	250.40	7.14	65.10	19.97
MUSKEG RIVER	1192	Tributary	36,029	19.46	-	1682.54	8.86	1826.66	2266.21	-	0.18	-	4.90	7.57	11.89	47,918.30	381.91	10,088.06	2.95
MACKAY RIVER	1196	Tributary	88,128	111.92	2.38	14364.86	69.36	15598.66	5287.68	1.41	0.35	0.53	11.81	28.20	100.47	196,525.44	3,445.80	1,656.81	36.66
ELLS RIVER	1213	Tributary	116,640	122.47	0.23	24727.68	75.35	7639.92	5120.50	1.17	0.58	1.52	14.81	41.99	115.47	76,049.28	1,726.27	1,562.98	76.87
FIREBAG RIVER	1268	Tributary	1,410,048	1156.24	-	64439.19	313.03	24816.84	42724.45	22.56	5.64	5.64	50.76	169.21	352.51	1,164,699.65	5,062.07	40,327.37	274.96
SLP	-	Effluent	2,586	13.24	1.06	535.20	5.95	336.12	139.62	-	0.49	0.22	4.27	1.71	18.98	10,574.70	39.30	2,463.98	9.33
Slave Lake STP	-	Effluent	10,523	4.31	-	448.27	9.43	345.15	4167.03	0.56	0.31	125.22	32.52	112.59	163.10	5,261.40	189.41	7,871.05	3.49

Station Name	Distance Downstream	Type	Flow	Total Ni	Total Pb	Total Sb	Total Se	Total Sn	Total Sr	Total Th	Total Ti	Total Tl	Total U	Total V	Total Zn
	(km)		m3/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day
MIETTE RIVER	110	Tributary	117,504	16.45	1.88	1.65	-	2.47	19,035.65	0.76	79.90	-	103.17	3.53	58.75
Jasper STP	115	Effluent	3,798	1.41	1.60	0.41	0.38	1.21	1,109.02	0.25	9.38	-	1.23	0.38	93.05
MASKUTA CREEK	195	Tributary	14,083	3.73	0.62	0.63	1.13	0.14	3,816.55	0.33	24.36	-	6.59	2.25	28.17
HCE	200	Effluent	88,766	52.99	31.07	11.27	39.94	126.05	32,133.36	4.04	437.62	-	48.47	135.81	1,295.99
PLANTE RIVER	238	Tributary	22,637	-	0.75	0.88	2.72	0.36	9,009.45	0.43	34.63	0.03	30.33	3.62	9.05
OLDMAN CREEK	256	Tributary	123,552	-	11.24	3.83	8.65	1.98	34,718.11	1.96	198.92	0.16	112.56	29.65	74.13
BERLAND RIVER	302	Tributary	1,010,880	-	14.15	45.49	353.81	22.24	346,731.84	50.95	1,526.43	2.83	770.29	141.52	303.26
MARSH HEAD CREEK	328	Tributary	36,115	4.77	2.20	1.23	3.97	0.90	9,714.99	2.08	87.04	0.12	29.61	12.28	18.06
ANC	393	Effluent	15,969	23.79	0.54	0.45	1.44	0.35	6,243.68	0.51	33.37	0.61	0.08	2.08	630.76
SAKWATAMAU RIVER	402	Tributary	136,512	117.95	17.75	10.92	-	7.37	32,762.88	7.49	503.73	1.06	147.43	58.70	259.37
MCLEOD RIVER	403	Tributary	604,800	106.44	54.43	44.15	290.30	10.89	253,411.20	26.61	1,935.36	3.87	589.68	254.02	725.76
Millar	404	Effluent	9,435	8.82	1.51	0.74	-	25.47	4,490.97	0.50	392.49	-	1.90	5.47	2,622.88
Whitecourt STP	407	Effluent	3,694	50.60	59.47	21.98	4.54	0.90	1,414.61	9.68	275.17	0.62	6.13	58.73	686.99
FREEMAN RIVER	493	Tributary	72,922	53.38	6.05	3.94	7.29	2.92	13,198.81	5.88	221.68	0.22	47.03	18.96	196.89
PEMBINA RIVER	582	Tributary	401,760	405.78	37.77	35.35	48.21	8.84	136,196.64	10.97	1,570.88	3.94	346.72	176.77	321.41
LESSER SLAVE RIVER	637	Tributary	2,531,520	3,746.65	197.46	243.03	354.41	96.20	308,845.44	66.58	7,721.14	13.42	544.28	1,164.50	11,138.69
Athabasca STP	745	Effluent	598	2.09	0.30	0.27	0.19	0.19	252.82	0.03	5.17	0.00	0.37	0.37	34.79
ALPAC	788	Effluent	79,562	-	5.41	8.35	21.48	21.80	48,294.11	4.03	646.04	0.29	18.30	128.89	3,747.37
LA BICHE RIVER	810	Tributary	889,920	455.64	269.65	68.52	80.09	42.72	156,625.92	116.58	8,988.19	7.92	111.24	1,664.15	2,135.81
CALLING RIVER	820	Tributary	119,232	30.52	10.13	5.01	8.35	11.33	18,838.66	7.44	386.31	0.43	9.42	79.89	190.77
HOUSE RIVER	987	Tributary	124,416	413.06	24.88	3.48	21.15	3.61	34,587.65	12.81	961.74	1.62	48.27	115.71	522.55
BUFFALO CREEK	1033	Tributary	2,765	3.54	0.67	0.11	0.28	0.62	787.97	0.30	26.93	0.01	1.00	2.71	6.08
CLEARWATER RIVER	1140	Tributary	4,164,480	12,743.31	541.38	70.80	-	66.63	566,369.28	310.25	24,029.05	17.91	274.86	2,498.69	7,079.62
Ft McMurray STP	1142	Effluent	25,468	61.12	18.13	14.72	5.35	6.11	9,779.69	0.23	76.40	-	2.85	3.57	1,268.30
STEEPBANK RIVER	1172	Tributary	113,184	292.01	6.11	1.81	13.58	2.15	34,634.30	7.69	328.23	0.23	29.43	43.01	67.91
Suncor	1174	Effluent	165	0.06	0.00	0.01	0.04	0.00	63.69	0.00	0.30	0.00	0.19	0.03	0.40
Syncrude	1179	Effluent	626	2.48	0.12	0.29	0.29	0.14	234.75	0.01	17.65	-	0.14	0.87	18.28
MUSKEG RIVER	1192	Tributary	36,029	61.97	2.59	0.50	3.60	0.14	6,845.47	0.61	83.59	0.04	2.88	11.17	32.43
MACKAY RIVER	1196	Tributary	88,128	82.14	13.13	3.26	13.22	0.62	34,105.54	4.10	415.08	0.34	37.72	52.88	158.63
ELLS RIVER	1213	Tributary	116,640	138.80	12.60	8.05	17.50	1.98	16,446.24	4.41	604.20	0.66	21.93	67.65	664.85
FIREBAG RIVER	1268	Tributary	1,410,048	-	71.91	12.69	-	23.97	107,445.66	33.28	3,468.72	2.40	87.42	225.61	1,410.05
SLP	-	Effluent	2,586	9.85	4.14	1.50	0.65	0.64	780.82	0.22	27.41	0.01	0.26	1.40	136.26
Slave Lake STP	-	Effluent	10,523	53.56	7.37	1.80	3.89	12.73	3,230.50	0.25	178.89	-	38.62	125.22	6,271.59

Station Name	Distance Downstream	Type	Flow	Diss MeHg	Diss Ag	Diss Al	Diss As	Diss B	Diss Ba	Diss Be	Diss Bi	Diss Cd	Diss Co	Diss Cr	Diss Cu	Diss Fe	Diss Li	Diss Mn	Diss Mo
	(km)		m3/day	ug/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day
MIETTE RIVER	110	Tributary	117,504	-	-	262.0	6.8	196.2	1,374.8	-	-	-	4.0	-	36.4	8,953.8	377.2	1,351.3	6.5
Jasper STP	115	Effluent	3,798	-	0.0	32.9	0.3	163.7	145.1	-	0.2	0.1	0.3	1.5	15.4	167.1	486.1	33.2	0.8
MASKUTA CREEK	195	Tributary	14,083	-	-	7.7	3.2	120.6	1,690.0	-	-	0.04	0.1	1.4	5.1	92.9	87.0	13.7	10.2
HCE	200	Effluent	88,766	1.4	2.8	35,861.5	26.9	1,500.1	4,021.1	0.9	-	3.9	5.5	142.0	119.8	5,698.8	476.7	32,044.6	487.3
PLANTE RIVER	238	Tributary	22,637	-	-	18.8	4.2	178.2	1,765.7	-	-	-	0.2	-	9.1	251.3	145.8	63.4	18.0
OLDMAN CREEK	256	Tributary	123,552	-	0.2	79.1	21.1	455.9	6,894.2	-	-	0.4	0.6	12.4	25.9	1,025.5	412.7	271.8	75.5
BERLAND RIVER	302	Tributary	1,010,880	-	-	576.2	138.5	5,812.6	109,175.0	-	-	2.0	12.1	-	353.8	9,704.4	3,730.1	1,597.2	1,192.8
MARSH HEAD CREEK	328	Tributary	36,115	1.1	-	48.4	11.4	343.8	3,521.2	-	-	0.1	1.4	-	11.2	874.0	253.2	1,004.0	19.9
ANC	393	Effluent	15,969	-	0.03	91.0	4.2	14,068.2	3,529.0	-	0.2	-	4.4	4.8	10.7	202.8	72.8	17,405.7	12.2
SAKWATAMAU RIVER	402	Tributary	136,512	3.5	-	98.3	44.5	1,569.9	13,009.6	-	-	0.8	8.3	-	83.3	4,341.1	2,976.0	4,723.3	139.2
MCLEOD RIVER	403	Tributary	604,800	12.7	-	556.4	148.8	9,737.3	64,713.6	-	-	2.4	18.7	-	314.5	7,560.0	6,029.9	5,316.2	546.1
Millar	404	Effluent	9,435	1.0	-	201.0	2.2	88.4	3,764.5	-	-	-	12.5	-	76.9	186.8	63.2	6,377.9	0.7
Whitecourt STP	407	Effluent	3,694	1.7	0.01	127.8	3.3	583.6	255.2	-	0.3	0.4	5.5	1.5	7.8	1,902.2	40.3	491.2	8.3
FREEMAN RIVER	493	Tributary	72,922	2.4	-	47.4	23.0	672.3	6,774.4	-	0.4	0.3	3.3	-	44.5	4,222.2	845.9	3,164.8	59.3
PEMBINA RIVER	582	Tributary	401,760	29.3	0.4	859.8	202.9	9,320.8	50,220.0	-	-	2.0	15.7	80.4	470.1	29,288.3	2,880.6	4,539.9	333.1
LESSER SLAVE RIVER	637	Tributary	2,531,520	43.0	5.1	3,063.1	2,683.4	48,352.0	134,423.7	-	17.7	141.8	184.8	506.3	2,329.0	217,963.9	24,505.1	23,821.6	1,617.6
Athabasca STP	745	Effluent	598	0.1	0.01	18.9	0.5	64.5	16.3	-	0.0	0.0	0.5	0.1	18.3	71.7	8.6	45.1	2.7
ALPAC	788	Effluent	79,562	-	0.1	11,059.1	30.4	2,744.9	23,550.3	-	-	1.0	4.0	111.4	140.0	2,649.4	498.1	110.6	87.5
LA BICHE RIVER	810	Tributary	889,920	33.8	-	2,162.5	1,406.1	38,622.5	43,161.1	-	7.1	3.6	32.0	89.0	347.1	39,334.5	11,035.0	11,569.0	347.1
CALLING RIVER	820	Tributary	119,232	2.6	-	190.8	86.4	3,278.9	3,803.5	-	0.7	-	5.0	11.9	40.5	10,015.5	1,029.0	1,943.5	21.1
HOUSE RIVER	987	Tributary	124,416	9.0	0.4	2,326.6	50.4	9,393.4	5,362.3	1.2	1.1	1.6	69.4	-	109.5	49,268.7	2,799.4	33,343.5	163.0
BUFFALO CREEK	1033	Tributary	2,765	0.3	0.01	21.5	2.0	544.7	82.1	0.05	0.0	0.0	0.6	-	2.4	4,091.9	88.8	203.5	1.0
CLEARWATER RIVER	1140	Tributary	4,164,480	79.1	-	14,284.2	1,116.1	147,422.6	79,958.0	-	54.1	41.6	141.6	-	1,957.3	1,336,798.1	24,820.3	53,305.3	757.9
Ft McMurray STP	1142	Effluent	25,468	1.7	1.1	2,801.5	11.9	3,718.3	751.3	-	1.4	1.8	9.1	5.1	101.9	1,227.6	292.9	1,866.8	84.8
STEEPBANK RIVER	1172	Tributary	113,184	2.9	0.2	342.9	31.7	25,353.2	7,945.5	-	0.8	0.7	8.1	11.3	50.9	2,150.5	2,422.1	1,392.2	58.9
Suncor	1174	Effluent	165	0.003	-	0.1	0.1	16.5	22.9	-	-	-	-	-	0.1	1.9	3.2	7.0	0.2
Syncrude	1179	Effluent	626	0.1	0.001	0.8	0.6	91.4	6.7	-	0.04	0.03	0.3	0.2	2.9	171.5	6.9	58.7	18.5
MUSKEG RIVER	1192	Tributary	36,029	2.0	0.04	68.1	8.0	1,751.0	2,053.6	-	0.2	-	3.7	7.2	9.4	8,574.9	363.9	8,250.6	2.7
MACKAY RIVER	1196	Tributary	88,128	5.8	0.1	379.0	44.8	15,158.0	4,776.5	-	-	0.4	8.4	8.8	69.6	71,824.3	3,392.9	1,295.5	35.3
ELLS RIVER	1213	Tributary	116,640	3.8	-	208.8	51.9	7,068.4	4,502.3	-	-	0.9	9.4	-	80.5	19,362.2	1,598.0	1,166.4	71.0
FIREBAG RIVER	1268	Tributary	1,410,048	24.0	2.8	2,693.2	235.5	23,688.8	42,019.4	-	-	-	29.6	141.0	169.2	289,059.8	4,709.6	27,636.9	255.2
SLP	-	Effluent	2,586	0.4	0.3	9.5	3.1	302.5	68.0	-	0.2	0.1	3.6	0.5	9.2	2,200.3	35.7	2,094.3	8.1
Slave Lake STP	-	Effluent	10,523	2.3	0.1	167.3	7.8	232.6	3,346.2	0.5	0.3	100.9	26.1	89.4	117.9	3,598.8	165.2	6,524.1	0.8

Station Name	Distance Downstream	Type	Flow	Diss Ni	Diss Pb	Diss Sb	Diss Se	Diss Sn	Diss Sr	Diss Th	Diss Ti	Diss Tl	Diss U	Diss V	Diss Zn
	(km)		m3/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day
MIETTE RIVER	110	Tributary	117,504.0	16.2	1.8	1.6	5.9	2.4	17,978.1	0.4	61.1	-	95.6	-	54.1
Jasper STP	115	Effluent	3,798.0	1.1	1.3	0.4	0.2	0.9	1,021.7	0.2	4.7	-	1.1	-	81.7
MASKUTA CREEK	195	Tributary	14,083.2	-	0.1	0.6	1.1	0.1	3,689.8	0.3	10.8	-	6.2	0.4	2.4
HCE	200	Effluent	88,766.2	32.0	6.1	11.1	24.9	111.8	28,671.5	4.0	258.3	-	42.2	105.6	817.5
PLANTE RIVER	238	Tributary	22,636.8	-	0.2	0.9	2.7	0.3	8,692.5	0.4	22.6	0.03	29.0	2.0	7.0
OLDMAN CREEK	256	Tributary	123,552.0	-	-	3.8	8.6	2.0	31,258.7	1.2	129.7	0.1	99.1	16.1	79.1
BERLAND RIVER	302	Tributary	1,010,880.0	-	13.1	45.5	262.8	22.2	314,383.7	50.3	828.9	2.2	672.2	50.5	252.7
MARSH HEAD CREEK	328	Tributary	36,115.2	1.0	-	1.2	2.9	0.8	9,173.3	1.6	37.6	0.1	27.1	2.2	4.7
ANC	393	Effluent	15,968.5	21.9	0.4	0.4	1.3	0.4	5,924.3	0.5	25.1	0.5	0.05	1.0	550.9
SAKWATAMAU RIVER	402	Tributary	136,512.0	75.9	0.7	10.8	6.8	4.4	29,350.1	2.4	152.9	0.7	132.8	9.6	107.8
MCLEOD RIVER	403	Tributary	604,800.0	54.4	3.0	43.5	193.5	4.8	226,195.2	10.2	532.2	2.5	519.5	54.4	314.5
Millar	404	Effluent	9,434.8	8.5	1.5	-	-	16.5	3,953.2	0.5	292.5	-	1.5	-	1,103.9
Whitecourt STP	407	Effluent	3,693.5	12.8	1.6	2.4	1.8	0.9	1,303.8	1.3	14.6	0.01	3.0	1.3	101.9
FREEMAN RIVER	493	Tributary	72,921.6	49.4	0.4	3.9	7.3	1.8	12,469.6	2.9	111.6	0.2	44.4	3.6	71.5
PEMBINA RIVER	582	Tributary	401,760.0	330.6	6.4	35.0	48.2	4.0	121,331.5	8.0	602.6	2.7	316.6	48.2	204.9
LESSER SLAVE RIVER	637	Tributary	2,531,520.0	3,088.5	40.5	240.5	227.8	45.6	280,998.7	52.4	1,139.2	9.1	481.0	253.2	8,303.4
Athabasca STP	745	Effluent	597.7	1.8	0.1	0.3	0.1	0.1	224.1	0.0	2.5	0.001	0.3	0.3	28.0
ALPAC	788	Effluent	79,562.0	-	1.1	8.3	19.9	7.4	43,043.0	4.0	413.7	0.1	15.4	102.6	907.0
LA BICHE RIVER	810	Tributary	889,920.0	-	15.1	67.6	53.4	13.3	143,277.1	29.1	667.4	1.5	77.4	169.1	364.9
CALLING RIVER	820	Tributary	119,232.0	15.6	2.6	4.9	8.3	1.0	16,692.5	7.4	35.8	0.2	8.0	9.5	58.4
HOUSE RIVER	987	Tributary	124,416.0	353.3	8.2	2.5	14.9	3.6	32,721.4	8.9	248.8	1.0	42.2	12.4	302.3
BUFFALO CREEK	1033	Tributary	2,764.8	3.1	0.2	0.1	0.3	0.05	749.3	0.2	5.3	0.005	0.9	0.8	2.9
CLEARWATER RIVER	1140	Tributary	4,164,480.0	1,574.2	237.4	50.0	208.2	66.6	503,902.1	306.5	6,829.7	10.8	208.2	458.1	5,039.0
Ft McMurray STP	1142	Effluent	25,467.9	60.4	16.8	13.0	2.8	3.4	8,684.6	0.2	36.2	0.02	1.9	2.3	1,123.1
STEEPBANK RIVER	1172	Tributary	113,184.0	40.4	6.0	1.6	10.2	2.2	31,012.4	7.6	196.9	0.2	26.9	15.8	67.9
Suncor	1174	Effluent	165.0	-	0.0	0.01	0.04	0.002	62.0	0.003	0.2	0.0003	0.2	0.02	0.3
Syncrude	1179	Effluent	626.0	2.3	0.1	0.3	0.2	0.1	224.7	0.004	16.3	0.0004	0.1	0.9	16.3
MUSKEG RIVER	1192	Tributary	36,028.8	4.4	0.4	0.5	3.2	-	6,485.2	0.2	56.9	0.03	2.8	3.2	30.3
MACKAY RIVER	1196	Tributary	88,128.0	67.1	3.9	3.0	10.6	0.6	32,959.9	2.3	156.9	0.2	36.6	15.0	89.0
ELLS RIVER	1213	Tributary	116,640.0	110.2	3.3	6.9	16.3	1.4	15,279.8	1.4	128.3	0.3	16.9	11.7	520.2
FIREBAG RIVER	1268	Tributary	1,410,048.0	-	5.6	-	-	24.0	106,176.6	31.6	2,580.4	1.0	86.0	141.0	944.7
SLP	-	Effluent	2,585.5	8.5	0.8	1.3	0.3	0.2	674.8	0.2	7.0	0.004	0.2	0.3	99.0
Slave Lake STP	-	Effluent	10,522.8	43.6	6.4	1.8	-	7.1	2,630.7	0.2	110.5	-	30.9	99.4	5,208.8