A five-year provincial water quality monitoring, evaluation and reporting plan for lotic systems

A program design series supporting Alberta's environmental science program

VOLUME 1.1

Alberta

A five-year provincial water quality monitoring, evaluation and reporting plan for lotic systems

Jason G. Kerr and Colin A. Cooke

This publication can be found at: open.alberta.ca/publications/9781460141366

Comments, questions, or suggestions regarding the content of this document may be directed to:
Ministry of Environment and Parks, Environmental Monitoring and Science Division
10th Floor, 9888 Jasper Avenue NW, Edmonton, Alberta, T5J 5C6
Email: EMSD-Info@gov.ab.ca
Media Inquiries: AEP.mediainquiries@gov.ab.ca
Website: environmentalmonitoring.alberta.ca

Recommended citation:
Kerr, J. G. and C. A. Cooke. 2019. A five-year provincial water quality monitoring, evaluation and reporting plan for lotic systems. Government of Alberta, Ministry of Environment and Parks. ISBN 978-1-4601-4136-6. Available at: open.alberta.ca/publications/9781460141366.

Date of publication: February 2019

ISBN 978-1-4601-4136-6

Alberta's Environmental Science Program

The Chief Scientist has a legislated responsibility for developing and implementing Alberta's environmental science program for monitoring, evaluation and reporting on the condition of the environment in Alberta. The program seeks to meet the environmental information needs of multiple users in order to inform policy and decision-making processes. Two independent advisory panels, the Science Advisory Panel and the Indigenous Wisdom Advisory Panel, periodically review the integrity of the program and provide strategic advice on the respectful braiding of Indigenous Knowledge with conventional scientific knowledge.

Alberta's environmental science program is grounded in the principles of:

- *Openness and Transparency.* Appropriate standards, procedures, and methodologies are employed and findings are reported in an open, honest and accountable manner.
- *Credibility.* Quality in the data and information are upheld through a comprehensive Quality Assurance and Quality Control program that invokes peer review processes when needed.
- *Scientific Integrity.* Standards, professional values, and practices of the scientific community are adopted to produce objective and reproducible investigations.
- *Accessible Monitoring Data and Science.* Scientifically-informed decision making is enabled through the public reporting of monitoring data and scientific findings in a timely, accessible, unaltered and unfettered manner.
- *Respect.* A multiple evidence-based approach is valued to generate an improved understanding of the condition of the environment, achieved through the braiding of multiple knowledge systems, including Indigenous Knowledge, together with science.

Learn more about the condition of Alberta's environment at: environmentalmonitoring.alberta.ca.

Acknowledgements

The authors would like to thank Dr. Craig Emmerton (Watershed Scientist, Alberta Environment and Parks) for providing the watershed maps used in this publication and Rachel Morse (Water Quality Technologist, Alberta Environment and Parks) for analysis of historic cyanide and hexavalent chromium data in support of parameter selection. We would also like to thank Dr. Paul Drevnick (Aquatic Scientist, Alberta Environment and Parks), Dr. Ron Zurawell (Aquatic Scientist, Alberta Environment and Parks), Dr. John Orwin (Acting Executive Director, Science Branch, Environmental Monitoring and Science Division, Alberta Environment and Parks), Dr. Craig Emmerton and Dr. Cynthia McClain (Hydrogeologist, Alberta Environment and Parks) for reviewing and providing comments on the Monitoring, Evaluation, and Reporting (MER) Plan. Furthermore, we would like to thank technical staff in the Monitoring and Observation branch who provided input into the logistical considerations of the MER plan including the selection of stations for the newly developed tributary monitoring network (TMN) and the implementation of the QA/QC program. In addition to this, we would like to thank all technical staff in the Monitoring and Observation branch and staff within Environmental Data Stewardship for the central role they play in data collection and storage in support of the Environmental Monitoring and Science Division's core lotic monitoring programs. We would also like to thank staff from AEP Operations, Policy and Environmental Data Stewardship who reviewed and provided comments on the draft five-year MER plan.

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

MER	Monitoring, evaluation and reporting
LTRN	Long term river network
TMN	Tributary monitoring network
QA/QC	Quality assurance/quality control
OSM	Oil sands monitoring
SOP	Standard Operating Procedure

1. Background and introduction

This document outlines the key scientific questions, approaches, and deliverables for a five-year provincial water quality monitoring, evaluation and reporting (MER) plan for lotic systems (rivers and streams) across Alberta. The goal of this plan is to provide a scientific foundation for understanding how various natural and anthropogenic stressors are potentially impacting water quality within Alberta's rivers and streams. To accomplish this goal, we outline a number of new MER activities, as well as changes to existing efforts (see Box 1 for a summary). Some of the most important changes include clearly identifying the key scientific questions that guide our monitoring efforts, rationalizing how data quality will be measured and evaluated for the province, implementing a new Quality Assurance / Quality Control (QA/QC) program to provide confidence in Alberta's water quality data, and adopting a Tributary Monitoring Network (TMN). Many of these changes will take time to implement and new resources will be required; however, this plan serves as a roadmap to guide these efforts over the next five years.

Box 1 – Key aspects of the five-year water quality MER plan

1. Question driven, with testable scientific hypotheses.
2. Harmonization of field and laboratory analytical methods across Alberta.
3. A new Quality Assurance / Quality Control program to provide confidence in Alberta's water quality data.
4. The adoption of a new Tributary Monitoring Network.

It is important to note that MER activities within the Athabasca oil sands region are now conducted under the auspices of the Oil Sands Monitoring (OSM) program. As such, this five-year monitoring plan does not include water quality monitoring within the lower Athabasca watershed. Nonetheless, every effort has been made to harmonize water quality monitoring within and outside of the Athabasca oil sands region.

During the development of this plan, we made every effort to understand the scope of current (and past) water quality MER activities. An important consideration was the maintenance of long-term water quality datasets. For example, monthly water quality data extend back years to even decades on many of Alberta's largest rivers. Maintaining a consistent monthly dataset at these stations can help to identify freshwater responses to both anthropogenic and natural drivers of environmental change. However, this does not mean that all monitoring activities conducted in the past will necessarily continue. Instead, similar to the approach used under the OSM program, we sought first and foremost to define key scientific questions that can be answered using the data collected. It is our hope that this plan represents a first step toward addressing the information needs for stakeholders across Alberta.

Answering questions about the rate, magnitude, and potential drivers of environmental change in Alberta's lotic systems requires that consistent data be collected among and within river systems. This means implementing standardized methods and protocols across space and time to eliminate potential bias and uncertainty that might otherwise complicate data interpretation. Therefore, a key focus of the MER plan is to review standard operating procedures (SOPs) to ensure that: a) SOPs are scientifically credible and appropriate to meet program objectives; b) SOPs are applied consistently among and within EMSD programs; and c) SOPs are clearly documented and made publically available.

Another important component of this plan is the adoption of a mass balance approach towards water quality monitoring (see Box 2). In practice, adopting a mass balance approach means co-locating discharge and concentration measurements to allow for calculation of mass fluxes and loadings. Many benefits stand to be realized by adopting a mass balance approach for monitored watersheds. For example, examining the relationship between discharge and the concentration of water quality parameters can help us reach a better understanding of hydrologic and biogeochemical processes governing water quality (Godsey et al., 2009; Stallard and Murphy, 2014), mass fluxes and loading, and, eventually, how changes in discharge may be linked to longer-term processes such as chemical weathering and carbon cycling (e.g., Ibarra et al., 2016; Maher and Chamberlain, 2014).

Box 2 – Fundamentals of a mass balance approach

Mass balance is based on the principle of conservation of mass within a defined system. By accounting for material entering and leaving a watershed, sources, sinks, and mass flows can be identified that otherwise might have been unknown or difficult to measure. Watershed budgets can also be derived to assess changes in the supply, export, and/or storage of water quality constituents. Mass fluxes, loads, and watershed yields are important tools for constructing a watershed budget, and are critical components in understanding the impact of diffuse sources on surface water quality. Mass flux (J) is defined as the product of discharge (Q) and concentration (C):

$$J = Q*C$$

While load, or mass (M), delivered over a given time period (t) is equivalent to:

$$M = Q*C*t$$

Watershed yield (Y) for a given substance can be calculated as load (M) divided by watershed area (A):

$$Y = M/A$$

2. Broad questions addressed in the proposed MER plan

This five-year MER plan was developed to answer four key scientific questions about lotic systems within Alberta. All proposed MER activities relate to one or more of these questions, which will guide MER activities during this period. These four questions define the scope of the proposed provincial monitoring program, and are used to establish clear goals upon which evaluation and reporting priorities are set. Collectively, we seek to understand the current condition of lotic systems across Alberta with respect to both water quality and water quantity, if this condition has changed through time, and, if so, to what degree and why.

2.1. Key science questions for the next five years

1. Do lotic waters in Alberta meet existing Provincial and Federal water quality guidelines, objectives and thresholds?
2. What impact have anthropogenic stressors had on water quality, hydrological dynamics and/or aquatic ecosystem health in surface waters across Alberta?
3. What impact(s) have hydro-climatic variability and/or climatic change had on water quality, hydrological dynamics and/or ecosystem health in surface waters in Alberta?
4. How will water quality, hydrological variability and aquatic ecosystem health change in the future under various land use, land cover, and climatic change scenarios?

Question 1 relates to the need to provide information on the quality of surface waters in the province relative to established thresholds for the protection of aquatic ecosystem health, human health, and other uses such as irrigation. In addition, this question addresses the need to assess surface water quality in the context of "trigger" values set out in regional Water Quality and Quantity Management Frameworks[1] or other water quality objectives linked to existing water management agreements.

Question 2 relates to the need to understand the link between major anthropogenic stressors in the province (Table 1) and the condition of Alberta's surface waters. The focus of this question is on identifying spatial and temporal cause and effect relationships operating at provincial, watershed or sub-watershed scales. Therefore, cause and effect relationships operating at relatively localized (e.g., reach) scales and monitoring in support of approvals or compliance activities are outside the scope of this question.

Question 3 relates to the need to understand how hydro-climatic and cryospheric processes affect the condition of regional surface waters and to what extent climate change has impacted surface water processes across the province. The scope of this question includes processes ranging in scale from individual storm events, to ice phenology, through to multi-year droughts and the effect of these processes on surface water condition at the sub-watershed to provincial scale. Answering this question will require understanding major sources of stream flow (e.g., snowmelt, runoff, groundwater) and how these sources vary seasonally, inter-annually, and spatially across the province.

Question 4 relates to the need to make predictions of surface water conditions based on future land use and/or land cover and climate change scenarios. Activities conducted to address this question will include the collection of data in support of model development and the use of watershed models

[1] For information on the Land Use Frameworks see: https://landuse.alberta.ca/REGIONALPLANS/Pages/default.aspx

to predict potential changes in water quality, hydrological dynamics and/or aquatic ecosystem health under various management and climate change scenarios.

All of the activities will be conducted to provide information needed to answer one or more of these four questions. A list of MER objectives for the next five years is provided in Table 2 and is discussed in further detail in Section 8. Monitoring activities conducted, which are described in further detail below, will be a combination of both routine water quality and quantity monitoring and focused studies.

At the end of this five-year plan, we hope to have answered some of these key science questions about the current state of rivers and streams within Alberta. Perhaps more importantly, we fully anticipate that the analysis of new and existing water quality data will lead to new questions. Thus, this plan represents the first step in rationalizing, documenting, and conducting MER activities across Alberta.

Table 1. Major anthropogenic stressors of lotic systems in the province.

Stressor
Urbanization
Agriculture
Legacy effects (e.g. abandoned coal mines, legacy pesticides)
Forestry
Transportation infrastructure
Industrial activities
Oil and gas
Water withdrawals
Recreational activities
Municipal and industrial effluent
Climate change

Table 2. Major provincial MER objectives for 2016–2021.

#	Objective description	Year(s)
1	Evaluate and report on historical data from the LTRN and other programs	1–5
2	Review the design of the existing LTRN program and implement changes where appropriate to address the following questions: a. Is the current spatial distribution of river water quality and quantity stations adequate to answer the core questions listed in Section 1? b. Is the current temporal frequency of sample collection adequate to quantify the mass loading of key nutrients and contaminants to rivers across the province? c. Are scientifically rigorous QA/QC protocols applied consistently across the province? d. Is the suite of parameters collected appropriate and are the labs employed the most appropriate and the best use of financial resources? e. Are current field and laboratory SOPs well documented and appropriate?	1–3
3	Develop and implement a provincial tributary monitoring network	1
4	Determine the need for, and where appropriate develop and implement focused studies which address issues at the sub-watershed to provincial scale which are not adequately covered under the LTRN and TMN programs including (for example): a. Emerging contaminants b. Pesticides c. Aquatic health (biomonitoring) d.. Urban watersheds e.. Headwaters	2–5
5	Develop the next five-year MER Plan based on information gained and needs identified in objectives 1–4.	4–5

3. Monitoring activities under the provincial surface water quality MER plan

Answering the questions identified above will require a mix of routine ambient environmental monitoring and focused studies (i.e., research). Here, we define routine ambient environmental monitoring as the regular collection of water quality data from fixed locations across Alberta. We define focused studies as short-term research projects designed to: (i) investigate and establish cause and effect; (ii) fill information gaps; (iii) develop or assess new monitoring methods and compare past methodologies; (iv) understand the drivers of variance (spatial and temporal) in data sets; and (v) optimize sampling designs. Thus, monitoring activities under the surface water quality MER plan are divided into two categories:

I. Core monitoring
II. Focused studies

4. Core water quality monitoring

Core water quality monitoring of lotic systems across Alberta will consist of three programs:

I. Long-Term River Monitoring Network (LTRN)
II. Tributary Monitoring Network (TMN)
III. Quality Assurance and Quality Control Program for lotic systems

The LTRN will build on the existing program maintained for years by AEP (and its predecessors); however, the LTRN program will be evaluated and modified as necessary to ensure the design is adequate to address the core questions identified above. Data from the LTRN will serve a variety of internal and external information needs about the status and trends of Alberta's major river systems.

The TMN is a new program aimed at augmenting data generated from the LTRN and will address the need to increase monitoring activities on tributaries to major river systems within Alberta. The TMN will be developed on a watershed-by-watershed basis starting with the Athabasca River and South Saskatchewan River basins. It is important to note here that tributaries within the lower Athabasca River watershed (i.e., areas downstream of the City of Fort McMurray) are already monitored under the OSM program.

To ensure the LTRN and TMN water quality monitoring programs generate consistent data quality, a new Quality Assurance and Quality Control (QA/QC) program is described below in Section 5. This new QA/QC program defines objectives for the QA/QC program, identifies what types of QA/QC samples will be collected at each monitoring station and is clear about what inferences can (and cannot) be made when making assessments of QA/QC sample results.

4.1. Long-term River Network (LTRN)

The LTRN is a collection of sites located in a number of Alberta's major rivers. Figure 1 is a map of all LTRN sites and details about each station are provided in Table A1. The LTRN, as implemented in Year 1 of this plan, will reflect an amalgamation of the existing LTRN and Medium-term River Network (MTRN) surface water quality programs. In the past, LTRN sites were monitored for a (relatively) consistent suite of water quality parameters at a monthly frequency (n=12 samples per year). The MTRN consisted of a collection of water quality monitoring sites that could be located on either large (mainstem) rivers or on smaller tributary rivers and streams. MTRN sites were not always measured at a consistent frequency and the parameter suite often differed between sites. Thus, one important change of this plan is the merger of MTRN sites into the LTRN program.

The LTRN program will consist of 37 water quality stations monitored at a monthly frequency (Figure 1 and Table A1). The exception to this is the furthest downstream stations on the Athabasca River. Here, two stations (Athabasca River at Old Fort – Right Bank and Athabasca River downstream of Devil's Elbow at Winter Road Crossing) were monitored historically during the open-water and ice-covered seasons, respectively. This was done because of difficulty accessing the Athabasca River at Old Fort – Right Bank station during the winter months. Data from these two stations was then merged to generate an annual (monthly) record of water quality near the mouth of the Athabasca River. The assumption has been that water quality does not change measurably between these two locations. Testing of this assumption (i.e., testing for a significant difference in water quality between these two stations) began in December 2013 with water quality samples collected at both locations December through March. Sampling at both of these stations will continue over the next five years in an effort to understand the potential implications for the historic water quality dataset.

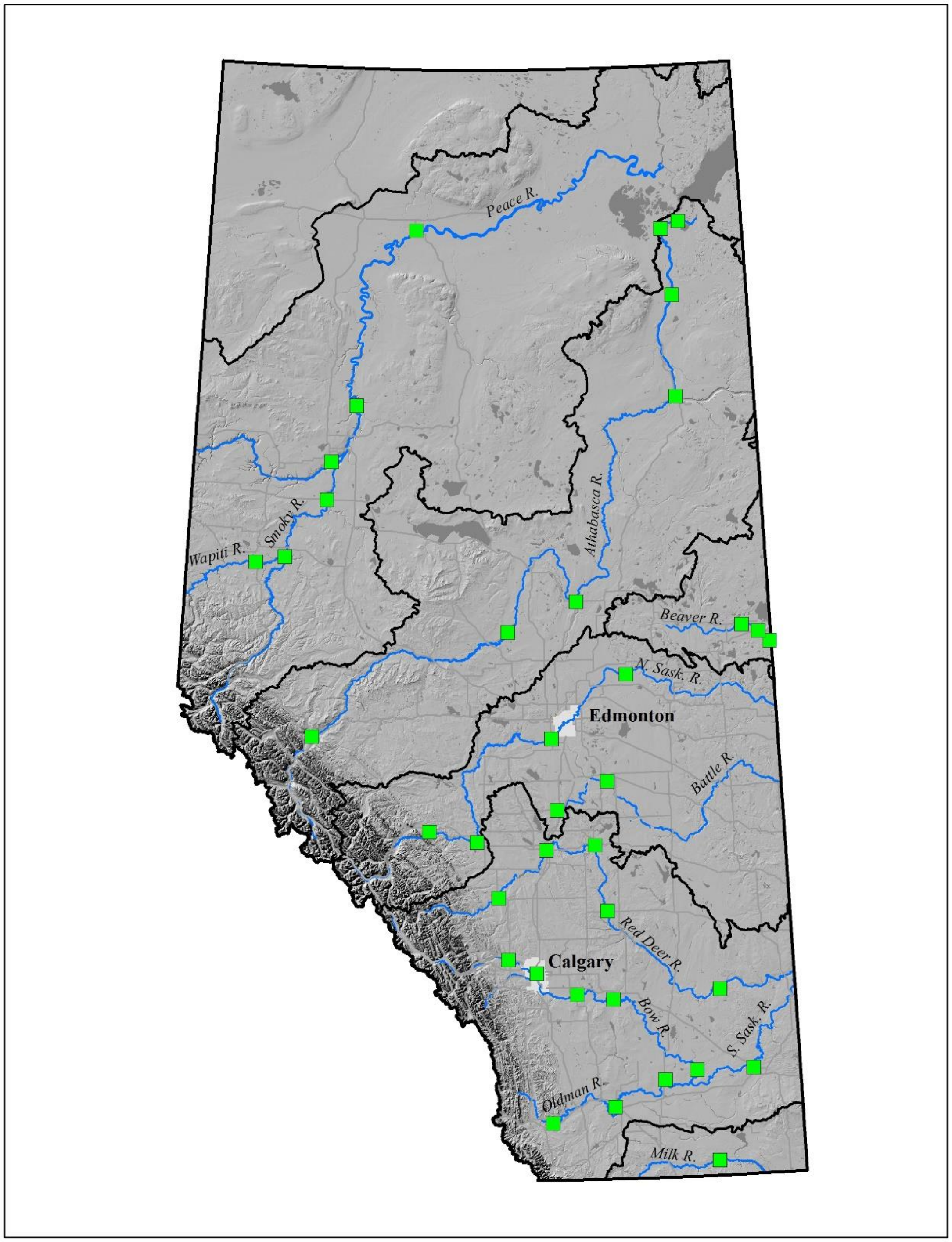

Figure 1. Map of long-term river network (LTRN) surface water quality monitoring stations.

4.1.1. Parameter suite for the LTRN

A full list of water quality parameters monitored for as part of the core LTRN program is included in Table A2. In addition to this core suite, it should be noted that pesticides are also measured at select stations for specific time periods. In terms of the core parameter suite, these parameters are generally consistent with parameters monitored historically. This reflects our intent to maintain existing long-term datasets that have yet to undergo evaluation; however, some changes have been made at some stations. Further refinement of the LTRN parameter suite will occur as evaluation and reporting activities progress.

Some changes to the core LTRN water quality parameter list have already been identified and initiated as part of the preparation of this five-year plan. These changes include cessation of sample collection for the parameters listed in Table 3. In general, these water quality parameters were dropped from the core LTRN program because: (i) it is not clear what concern or information need led to the parameter being measured; and/or (ii) preliminary analysis of historic data indicates that the method currently used has resulted in a large number of censored values (i.e., below analytical detection limit). For example, hexavalent chromium was added to the LTRN program 2004, and since then, has only been detected in 173 of 1040 river water samples analyzed (Table 3). Such a low detection rate indicates that, if the presence of hexavalent chromium is of concern, a different analytical method is required to routinely quantify its concentration. Monitoring of these four parameters has been suspended; however, they may be reintroduced at a later time if deemed necessary.

Table 3. Summary statistics for hexavalent chromium and cyanide, which are no longer included in core water quality monitoring.

Water Quality Parameter	# samples	# hits	# field blanks	# field blank hits
Hexavalent Chromium	1040	173	35	1
Cyanide	1043	62	35	2

4.2. Tributary Monitoring Network (TMN)

4.2.1 Design of the TMN

A comprehensive, province-wide tributary monitoring network (TMN) is an important new component of water quality monitoring within Alberta. Here we define tributaries as smaller (typically wadeable) streams and rivers not currently monitored under the LTRN program. A major driver for a TMN program is the need to better understand the relative contribution of point versus non-point sources for a range of water quality parameters. This need has been identified by both government and non-government scientists and by regional stakeholders. For example, the South Saskatchewan Regional Plan Water Quality Management Framework[2] identifies the need for information on non-point source inputs to the South Saskatchewan River. Some monitoring of tributaries has been conducted in the past by AEP and its predecessors; however, comprehensive information about the impact of both point and non-point sources on Alberta's smaller streams and rivers remains an important information gap across the province.

In designing the TMN we adopted a mass balance approach. This means the network was designed to quantify the input, storage, and output of material within each tributary system. This is necessary both to understand the fate of materials moving through each system, but also to understand the relative contribution of each tributary to Alberta's larger river systems. For this reason, every effort was made to co-locate water quality sampling stations with existing hydrometric stations. Hydrometric stations (typically) provide high temporal resolution measurements of water level and discharge at key nodes within each river network. By co-locating water quality at hydrometric stations, we aim to develop estimates of loading (i.e., mass flux) for monitored parameters. Co-location provides added logistical benefits as well. For example, monitoring staff can collect water quality samples as part of their routine visits to hydrometric stations (and vice-versa), and water quality probes can be co-located and supported by existing hydrometric infrastructure.

The TMN program will be implemented initially in five watersheds within the South Saskatchewan River Basin (Bow, Oldman, South Saskatchewan, Milk, and the Red Deer Rivers) and in the Athabasca River watershed (Figure 2). Full implementation of the TMN will depend upon the availability of sufficient resources. A phased approach will therefore be adopted, with implementation occurring as sufficient resources are available.

---

[2]South Saskatchewan Regional Plan Water Quality Management Framework available at: open.alberta.ca/publications/9781460118603

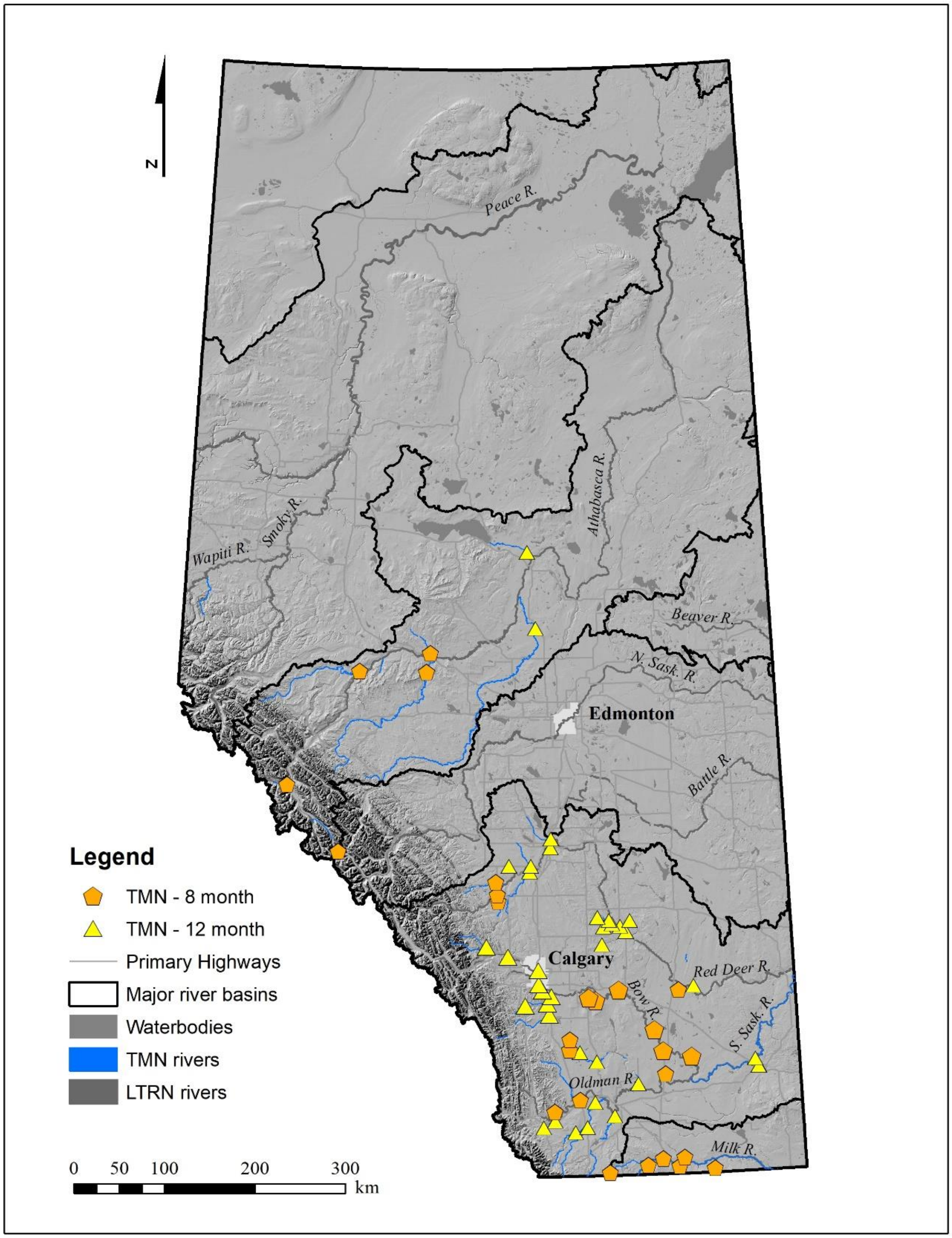

Figure 2. Map of tributary monitoring network (TMN) surface water quality monitoring stations. Note, yellow symbols indicate samples collected year round (Jan-Dec) while orange symbols indicate samples collected during open water season only (Mar-Oct)

4.2.2. Parameter Suite for the TMN

The core parameter list for the TMN program is shown in Table A2. These parameters align with those measured in the LTRN program. In addition to the core TMN parameters, specific parameters may be added to address watershed or site specific questions. For example, in the Red Deer River watershed, the core TMN parameter suite has been enhanced to include methylmercury (dissolved and total) in response to issues recently identified around the source, fate, and impacts of high metal concentrations (e.g., Hg, Pb, etc.) in the Red Deer River (Kerr and Cooke, 2017). For the Bow, Oldman, Milk and South Saskatchewan River watersheds, there are currently no additions to the core TMN parameter suite.

4.2.3. Station selection

A list of TMN stations is provided in Table A1. TMN stations were selected within each of the five major watersheds to meet the following objectives:

1. Quantify mass fluxes within major sub-watersheds;
2. Quantify major point and non-point inputs to each of the major rivers;
3. Characterize spatial and temporal patterns in pollutant concentrations within each watershed relative to established guidelines.

To meet these objectives, the following criteria were considered in site selection:

1. The volume of flow contributed to the mainstem;
2. Land-use and other anthropogenic stressors within the sub-watershed;
3. Co-location with existing flow gauging stations;
4. The extent to which a specific station was representative of the broader river reach;
5. Accessibility.

Particular emphasis was placed on obtaining adequate spatial resolution at sub-watersheds that are subject to the anthropogenic stressors listed in Table 1. An important component of the TMN is the co-location of water quality and water quantity stations. Where discharge stations exist, water quality sites have been co-located to enable estimation of mass fluxes; however, active flow stations are not available for every TMN water quality station. These sites have been flagged as a priority for the installation of new discharge gauging stations. Similarly, sites located near the confluence with major tributaries that currently do not have a flow gauging station are also considered a high priority.

4.2.4. Sampling regime

An accurate estimate of the mass or load of water-quality constituents transported by lotic systems is expressed as the total mass flowing through a stream location over a given time period. Load is quantified by summing the product of concentration and discharge (streamflow) compiled at smaller time steps (e.g., daily) over that time period. In Alberta, discharge is estimated using frequent (15 minute) stage measurements in combination with an up-to-date rating curve (calibration of the stage versus discharge relationship). However, concentration measurements are normally collected at a lower frequency. Initially, water quality samples will be collected once per month during either the open-water season (March–October) or year-round (January–December). This is consistent with the seasonal measurement of discharge in many of Alberta's wadeable streams and rivers. For example, many of Alberta's southern streams are characterized by low flow (<1 $m^3 s^{-1}$) during the winter months. In these types of systems, the Water Survey of Canada only measures discharge seasonally (i.e., between March–October). Thus, the sampling regime for each TMN station is coordinated with the frequency of discharge measurements.

We recognize that monthly water quality sampling does not always provide an accurate estimation of load (Lee et al., 2016). The information needed to make an informed decision regarding the most appropriate sampling frequency for both the LTRN and TMN programs will be determined through focused research examining the link between sampling regime and error in Alberta's major rivers (e.g., Kerr et a., 2018). As such, sampling regimes employed in the TMN and LTRN programs may change in the future in response to these findings. It is anticipated that in the future, the TMN will employ a number of different sampling regimes intended to meet the following criteria:

1. Maximize sampling frequency during periods of higher flow (open water *vs*. ice-covered seasons)[3]
2. Maximize sampling frequency in regions subject to relatively intensive anthropogenic pressures (e.g., headwater tributaries *vs*. urban/agricultural tributaries)
3. Account for seasonality of stressor inputs (e.g., irrigation return flows, road salt application)
4. Account for site specific hydrological regimes (e.g., total discharge, seasonality of discharge, and flashiness of discharge)

[3] The program will not target individual storm events. The issue of event driven constituent mass flux will be addressed in additional focused studies but not as part of the TMN program

5. Quality Assurance and Quality Control (QA/QC)

5.1. Background

In developing a QA/QC program for lotic waters we relied heavily on Mueller et al. (2015), which outlines the approach adopted by the United States Geological Survey (USGS) to ensure data quality for water-sampling projects. As per Mueller et al. (2015), we use the terms “bias” and “variability” to define the two types of errors in environmental data that are quantified by quality-control samples. Bias is defined as the systematic error inherent in a method or measurement system. Variability is the random error that occurs in independent measurements. Our focus is on effectively incorporating quality-control samples that will clearly identify potential areas of bias and/or variability within water quality data for lotic systems. Below we summarize the objectives and approach used to assess data quality as part of this five-year MER plan.

5.2. Objectives of the QA/QC program:

1. Quantify the overall accuracy and precision of core monitoring (LTRN and TMN) processes from field collection through to laboratory analysis for the purposes of:
    a. Auditing core monitoring processes for subsequent planning purposes (e.g., review of standard operating procedures [SOPs])
    b. Quantifying data uncertainty for a variety of internal and external reporting purposes (e.g., Water Quality Framework Reports, Technical Reports, etc.)
2. Quantify the performance of individual laboratories providing analytical services as part of the LTRN and TMN programs.

The broad approach used for the QA/QC program is similar to that used for the monitoring program as a whole. Like the monitoring program for lotic waters, we separate QA/QC work into “core” and “focused studies”. This program aims to address the above objectives and constitutes the “core” QA/QC program. In this program, we look to address fundamental questions relating to the overall performance of the LTRN and TMN programs. With the exception of QA/QC to address laboratory performance (Objective 2), the core QA/QC program is not intended to investigate and identify specific sources of error. If errors are identified as part of the core QA/QC program, focused QA/QC studies will be designed and implemented to specifically investigate and identify the source(s) of error.

5.3. Inferential space

Mueller et al. (2015) define inferential space as the location in time and space within which the results of the QC samples are representative of the uncertainty within a broader environmental data set. The QA/QC plan for the core monitoring networks (LTRN and TMN) defines two distinct study/spatial units (i.e., inferential spaces) within the program. These units are based on operational locations in Calgary and Edmonton, which differ in:

- Monitoring staff
- Field equipment
- Laboratories used for sample analyses

The QA/QC program is stratified into two operational units (Edmonton and Calgary) to provide individual quantitative measures of uncertainty within each operational unit in addition to collective measures of uncertainty across the entire provincial program. It is important to note that within each operational unit additional spatial and temporal sources of potential variability exist. For example, these include:

- Sample matrix (e.g., turbidity)
- Land use characteristics and potential sources of contamination
- Flow characteristics and seasonality
- Ambient constituent concentrations
- Individual staff and equipment

Although further stratification of the program into additional units – based on one or more of the above variables – has not been included, a number of these factors will be nested into the QA/QC design to ensure that QA/QC samples provide an adequate representation of variability within each operational unit. Furthermore, based on an assessment of variability of QA/QC data as a function of one or more nested variables, the creation of additional study units (i.e., inferential spaces) may be included in future QA/QC programs if required.

5.4. QA/QC sample types

The 2016-21 core monitoring program consists of three types of QA/QC sample:

1. Blanks (Equipment Blanks and Field Blanks)
2. Duplicate Samples
3. Certified Reference Waters

A total of five blanks and five sample duplicates will be collected monthly from stations within each of the two operational units (Edmonton and Calgary), with specific sampling sites rotating among water quality stations. In addition, four certified reference waters will be submitted monthly, one to each of the four analytical laboratories that routinely analyze samples collected as part of the core water quality monitoring program. All QA/QC samples will be submitted as “blind” samples (i.e., with any identifying sample names changed).

The following sections provide a detailed overview of how the results from each of these three types of QA/QC samples will be applied.

5.5. Blanks

The intention of using blanks is to assess positive bias as a result of sample contamination. A number of different types of blanks exist to serve specific purposes. However, only two types of blanks are included currently:

1. Equipment Blanks
2. Field Blanks

Equipment blanks are included to assess contamination specifically due to field equipment. Equipment blanks will be collected once per year prior to the beginning of a field season (i.e., April 1st) and analyzed for the complete suite of core parameters. The intention is to ensure that all field equipment is free from contamination, which might compromise subsequent environmental samples.

Field blanks are included to assess positive bias as a result of the entire process from sample collection and storage through to laboratory analysis. It is not the purpose of these blanks to determine the specific source of any error. Rather, the purpose of the field blanks is to quantify the overall performance of the core monitoring program within each operational unit as it pertains to sample contamination. Should a need for further investigation of contamination sources be identified through the analysis of field blanks, additional blanks will be incorporated into one or more focused QA/QC studies.

Field blanks will be rotated periodically across stations to provide a representation of positive bias due to contamination across the complete core monitoring data set within each operational unit. As such, field blanks are not intended to provide a direct measure of contamination within each individual sample set or trip. The total number of field blanks collected annually within each operational unit was determined based on guidance provided in Mueller et al. (2015). A statistical approach was applied to estimate the level of contamination across all environmental samples within acceptable limits of uncertainty and confidence. As described in Mueller et al. (2015), uncertainty is determined by the largest percentile of contamination that can be evaluated and was set to 95 % for the purpose of our program. The required confidence interval was also set to 95 %

so that the 95^{th} percentile of contamination could be estimated with 95 % confidence. Based on the equation provided in Mueller et al. (2015), the criteria could be met with a total of 60 field blanks per year within each of the two operational units. To ensure adequate seasonal representation across the program (e.g., open *vs*. ice season), the total number of field blanks collected per year is distributed evenly across months. As such, the 60 field blanks are comprised of five field blanks collected per month within each operational unit. In terms of the spatial distribution of field blanks, the selection of stations for collection and preparation of field blanks is designed to ensure adequate representation of the variability in conditions (e.g. land use and potential sources of contamination) that occur within each operational unit. As such, collection of field blanks will cycle among all water quality stations. When field blanks are included in a particular field trip, the blanks will be prepared on or near completion of the days sampling. Field blanks will be analyzed for the suite of core parameters listed in Table A2 with the exception of chlorophyll-a, *E Coli*, $\delta^{18}O$, and $\delta^{2}H$.

5.6. Duplicate Samples

Duplicate samples are included to assess the overall variability (precision) of the core monitoring program. Duplicate samples are intended to quantify variability in the data as a result of field and laboratory processes from sample collection and storage to laboratory analysis. Like field blanks, the program has not been designed to identify individual sources of variability (e.g., laboratory *vs*. sample collection). Duplicate samples are defined as two samples collected within the same, or very similar space and time. Duplicate samples measured in this program are collected concurrently (i.e., two samples collected side by side at the exact same time). We assume that spatial variability between duplicate samples is negligible and therefore any variability can be attributed to field and laboratory processes. The number of duplicate pairs collected within each of the operational units was determined based on a requirement that the standard deviation of the duplicate data was estimated within 15 % uncertainty of the true value with 95% confidence. Based on the equation provided in Mueller et al. (2015), the criteria could be met with 60 duplicate pairs per year within each of the operational units. To ensure adequate seasonal representation across the program, the collection of duplicate pairs is distributed evenly across months (i.e., 5 duplicate samples collected per month within each operational unit). In terms of the spatial distribution of duplicate samples, the location of duplicate sampling was designed to avoid having a large proportion of non-detects in the duplicate data set (see Mueller et al. 2015 for a discussion on the importance of avoiding non-detects). Therefore, in terms of station selection, a greater emphasis has been placed on collecting duplicates from stations that do not have a history of non-detects for one or more core parameters. Like field blanks, duplicate samples will be analyzed for the suite of core parameters listed in Table A2 with the exception of chlorophyll-a, *E Coli*, $\delta^{18}O$, and $\delta^{2}H$. As variance tends to increase with increasing concentrations (Mueller et al., 2015), the stations selected for duplicate sample collection will be modified to collect duplicate samples from sites with a wide range of concentrations as the program evolves.

5.7. Certified Reference Waters

Certified reference waters (CRWs) are included to assess the accuracy and precision of laboratories providing analytical services as part of the LTRN and TMN programs. While field blanks and duplicates will provide information on the overall performance of the program, there is a need to specifically determine the accuracy and precision of output from each laboratory over time. Because CRWs provide a sample with a known concentration that can be submitted directly to each laboratory, the accuracy and precision of laboratory results can be evaluated independently of field processes. The specific CRW (i.e., the specific surface water matrix) chosen for each parameter is determined based on the CRW that matches most closely the matrix of surface waters monitored as part of the LTRN and TMN. CRWs will be submitted monthly.

6. Focused studies

Together the LTRN and TMN programs will address all four of the core questions outlined above; however, we recognize that core long-term monitoring alone will not cover all information needs and answer all questions related to Alberta's lotic systems. In addition, ongoing data evaluation and reporting activities (discussed further below) may identify new questions requiring focused research (Figure 3). Where issues are identified that are not adequately addressed under the core LTRN and TMN programs, focused studies will be developed and implemented to address information gaps.

Focused studies are short-term research projects designed to answer a specific question or questions that cannot be answered through the analysis of data from the core monitoring programs. The specific objectives for focused studies will likely include: (i) investigations of cause; (ii) filling information gaps; (iii) development and assessment of new methods and methods comparisons; (iv) understanding drivers of variance (spatial and temporal) in data sets; and (v) optimizing sampling designs. While narrower in focus, the questions addressed by these studies relate directly to one or more of the four core questions. These studies, which must have clear and testable hypotheses supported by a robust study design, will be generated in response either to externally driven information needs or by questions that emerge from the results of the LTRN, TMN and QA/QC programs. Data from these focused studies will help to guide the continual improvement of core monitoring activities across the province, and will address information needs that may be temporally or spatially limited but of high importance.

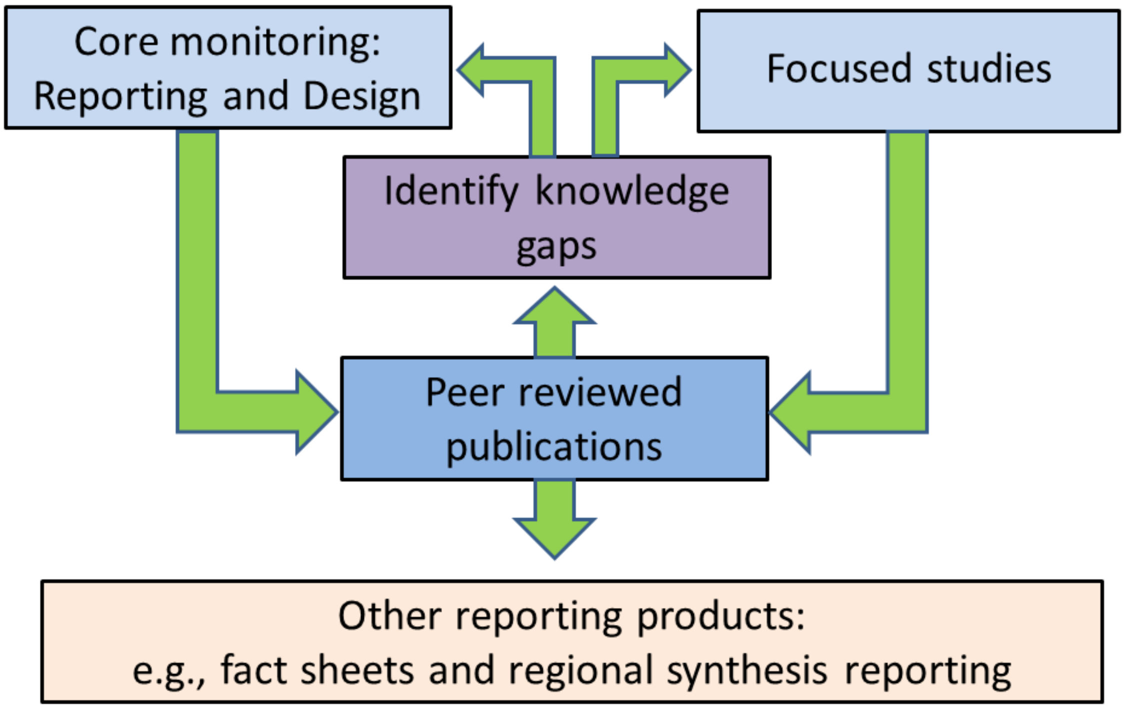

Figure 3. A conceptual model illustrating the linkages between the monitoring programs, the various types of reporting products and the identification of new knowledge gaps.

7. Provincial MER objectives and reporting products

Major objectives for surface water quality MER in lotic systems are listed in Table 2, while Figure 3 provides a conceptual model showing the linkages between the monitoring programs, the various types of reporting products and the identification of new knowledge gaps. Here we discuss first what the objectives of this program are, and second the various types of reporting products that will be generated as a result of working towards these objectives. By outlining both the objectives, and the framework for meeting these objectives, we hope to provide clarity around how the information generated from this program will be used and communicated.

7.1. Provincial MER objectives

Objectives 1 and 2 relate to the LTRN program run historically by AEP and its predecessors. In the past, AEP was criticized for inadequate evaluation and reporting of data collected under the LTRN program (AEMP, 2011; AEMWG, 2012). Decades of data from this program have yet to receive adequate attention in terms of evaluation and reporting. Therefore, a priority within this five-year MER plan is the mining of existing long-term data sets from the LTRN. This work is ongoing for data in the South Saskatchewan River Basin (SSRB) and has already yielded a number of important findings. For example, recent analysis has identified increasing trends in chloride (i.e., salinity) throughout the South Saskatchewan River Basin's that was previously unreported (Kerr, 2017).

Data mining of historic river water chemistry data will be an integral component of the decision-making process when addressing Objective 2 (Table 2). Objective 2 will address the need to ensure that the existing LTRN program is adequately designed to address the four core questions listed in Section 2.1. To meet this objective, we seek to answer a series of five questions (Objectives 2a–e) about the existing design of the LTRN. By answering these five questions, we hope to realize improvements to the LTRN design. Implementation of changes to the existing program will be phased in over the five-year period based on these results.

Objective 3 involves the development of the TMN, which will augment the existing LTRN program to better quantify inputs of key water quality parameters to Alberta's major river systems. While the TMN will eventually be provincial in scope, the specific suite of parameters included under the program will vary among watersheds to reflect the specific issues and stressors within each watershed. A key component of the program will be to couple measurements of concentration data with flow data to enable the estimation of constituent mass fluxes from major tributaries to each of Alberta's major rivers. Quantification of mass fluxes is crucial because different types of rivers, and different constituents, have varying concentration-discharge (C-Q) relationships that can give insight into large scale hydro-geochemical and physical processes operating within watersheds. The program will address all four core questions and more specifically will address the following data gaps and information needs:

1. Report on the condition of major tributaries in relation to established thresholds and guidelines (Question 1)
2. Enable the estimation of constituent mass fluxes and watershed mass balances for each of Alberta's major watersheds to:
    a. Quantify non-point source mass fluxes to major rivers (Question 2)
    b. Identify hot spots of constituent mass flux within watersheds that can be targeted for additional focused monitoring and/or management (Question 2)

c. Investigate causes of observed longitudinal patterns in surface water chemistry at LTRN sites (Questions 2 and 3)
d. Provide mass flux estimates for use in the calibration of watershed models (Question 4)

Specific issues which have been identified as potentially requiring the development of additional core programs or focused studies include, but are not limited to, those identified in Table 2 (Objectives 4a–e). This could include the addition of new parameters to the LTRN and/or TMN programs (e.g., emerging contaminants, pesticides, hydrocarbons, etc.), the development of biological indicators of aquatic ecosystem health (e.g., benthic macroinvertebrates), a network design for the deployment of near real-time *in situ* monitoring, or novel core monitoring programs focused on headwaters and/or urban inputs, just to name a few. It is anticipated that planning for these programs will begin in Year 1, with implementation of programs beginning in Year 2 if deemed appropriate.

The final objective in Table 2 (Objective 5) reflects the adaptive nature of this program and the need to revisit and revise the plan based upon information gained and needs identified over the next five years. It is anticipated that much will be learned and reported on as a direct result of conducting the activities outlined above. Ensuring lotic monitoring, evaluation and reporting continues to meet the information needs will require a commitment to begin developing the next five-year plan in years 4 and 5.

7.2. Reporting products

Achieving the provincial MER objectives outlined above will be accomplished through the generation of a number of evaluation and reporting products (Figure 3). Most important among these products will be peer-reviewed publications in the scientific literature. Peer review is the process of subjecting scientific findings or ideas to the scrutiny of experts in the same field. Focusing on peer-reviewed publications will ensure that our reporting products are held to the highest scientific standard, and that the information generated can be relied upon with confidence.

Peer-reviewed publications will result from both core monitoring and focused studies, and they are an important first step in ensuring the information presented is held to the highest scientific standard. It is fully anticipated that these peer-reviewed publications will also result in the identification of new knowledge gaps, which in turn may be used to realize improvements in Core Monitoring or in the initiation of new Focused Studies. This framework will help to ensure that our monitoring program remains adaptive and responsive response to new issues as they emerge.

Peer-reviewed publications will also serve as the foundation by which other reporting products will be produced. These other reporting products will include information briefings (e.g., Fact Sheets) and reports which synthesize information for a specific region and/or ecosystem type. The former will summarize key findings in a less technical format for policy makers, resource managers, and the public, while the latter will pull together information from a variety of sources, to build a more comprehensive, integrated, and holistic understanding of the environment. It is these latter two types of reporting products that are likely to be of the most interest to a variety of stakeholders. Importantly, while these products are intended for both technical and non-technical audiences, the process outlined in Figure 3 is meant to ensure that all information generated from the lotic program has been properly vetted through the peer review process. The purpose of this is to provide stakeholders with confidence that all reporting products are based on sound and credible science.

References

AEMP, A.E.M.P., 2011. A world class environmental monitoring, evaluation and reporting system for Alberta.

AEMWG, A.E.M.W.G., 2012. Implementing a world class environmental monitoring, evaluation and reporting system for Alberta.

Godsey, S.E., Kirchner, J.W. and Clow, D.W., 2009. Concentration–discharge relationships reflect chemostatic characteristics of US catchments. Hydrological Processes, 23(13): 1844-1864.

Ibarra, D.E., Caves, J.K., Moon, S., Thomas, D.L., Hartmann, J., Chamberlain, C.P. and Maher, K., 2016. Differential weathering of basaltic and granitic catchments from concentration–discharge relationships. Geochimica et Cosmochimica Acta, 190: 265-293.

Kerr, J.G., 2017. Multiple land use activities drive riverine salinization in a large, semi-arid river basin in western Canada. Limnology and Oceanography, 62(4): 1331-1345.

Kerr, J.G. and Cooke, C.A., 2017. Erosion of the Alberta badlands produces highly variable and elevated heavy metal concentrations in the Red Deer River, Alberta. Science of The Total Environment, 596–597: 427-436.

Kerr, J.G., Zettel, J.P., McClain, C.N., and Kruk, M.K., 2018. Monitoring heavy metal concentrations in turbid rivers: Can fixed frequency sampling regimes accurately determine criteria exceedance frequencies, distribution statistics and temporal trends?

Lee, C.J., Hirsch, R.M., Schwarz, G.E., Holtschlag, D.J., Preston, S.D., Crawford, C.G. and Vecchia, A.V., 2016. An evaluation of methods for estimating decadal stream loads. Journal of Hydrology.

Maher, K. and Chamberlain, C.P., 2014. Hydrologic regulation of chemical weathering and the geologic carbon cycle. Science, 343(6178): 1502-1504.

Mueller, D.K., Schertz, T.L., Martin, J.D. and W, S.M., 2015. Design, analysis, and interpretation of field quality-control data for water-sampling projects. U.S. Geological Survey Techniques and Methods

Stallard, R.F. and Murphy, S.F., 2014. A unified assessment of hydrologic and biogeochemical responses in research watersheds in Eastern Puerto Rico using runoff–concentration relations. Aquatic Geochemistry, 20(2): 115-139.

Appendix

Table A1. List of all stations currently included under the five-year water quality monitoring, evaluation and reporting plan for lotic systems.

Station Name and Description	Station Code	Station Latitude	Station Longitude	Samples per year	Project Name
Milk River at Hwy 880	AB11AA0070	49.144	-111.311	12	LTRN
Peace River at Fort Vermilion - Centre	AB07HF0010	58.404	-116.128	12	LTRN
Peace River 1.5 km Above Confluence Of Whitemud River - Centre	AB07HA0230	56.656	-117.147	12	LTRN
Wapiti River Above Confluence With Smoky River - Centre - km 0.5	AB07GJ0030	55.137	-118.308	12	LTRN
Smoky River at Watino	AB07GJ0010	55.716	-117.622	12	LTRN
Wapiti River at Hwy #40 Bridge - Centre - km 44	AB07GE0020	55.072	-118.805	12	LTRN
Peace River u/s Smoky River Near Shaftesbury Ferry Transect	AB07FD0135	56.093	-117.566	12	LTRN
Athabasca River d/s Of Devils Elbow at Winter Road Crossing	AB07DD0105	58.447	-111.186	12	LTRN
Athabasca River at Old Fort - Right Bank	AB07DD0010	58.383	-111.518	12	LTRN
Athabasca River Transect Above The Firebag River - Right Bank	AB07DA0980	57.724	-111.379	12	LTRN
Athabasca River u/s Fort McMurray, 100 M Above The Confluence With Horse River - Left Bank	AB07CC0030	56.720	-111.406	12	LTRN
Athabasca River at Town of Athabasca	AB07BE0010	54.722	-113.286	12	LTRN

Station Name and Description	Station Code	Station Latitude	Station Longitude	Samples per year	Project Name
Athabasca River at Vega Ferry (Klondyke) Centre Of River Arc km. 893.4	AB07BD0010	54.431	-114.461	12	LTRN
Athabasca River at Old Entrance Town Site - Left Bank	AB07AD0100	53.368	-117.723	12	LTRN
Beaver River at Gravel Pit Near AB/SK Border - Centre	AB06AD0130	54.251	-110.030	12	LTRN
Beaver River at Hwy #28 Bridge Near Beaver Crossing - Centre	AB06AD0060	54.355	-110.214	12	LTRN
Beaver River at Bridge On Highway 892 at Ardmore	AB06AC0100	54.430	-110.482	12	LTRN
Battle River at North End Of Driedmeat Lake	AB05FA0340	52.937	-112.849	12	LTRN
Battle River Approx 2 km d/s Hwy 53	AB05FA0060	52.659	-113.675	12	LTRN
North Saskatchewan River at Pakan Bridge	AB05EC0010	53.991	-112.476	12	LTRN
North Saskatchewan River at Devon	AB05DF0010	53.369	-113.751	12	LTRN
North Saskatchewan River 1 km u/s Clearwater River	AB05DC0050	52.348	-114.982	12	LTRN
North Saskatchewan River at Saunders Campground - Transect	AB05DC0025	52.454	-115.760	12	LTRN
Red Deer River d/s Dinosaur Prov Park at Hwy 884 Near Jenner-Right Bank	AB05CJ0070	50.839	-111.177	12	LTRN
Red Deer River at Morrin Bridge	AB05CE0009	51.653	-112.904	12	LTRN
Red Deer River at Nevis Bridge-Right Bank	AB05CD0250	52.306	-113.079	12	LTRN
Red Deer River 1 km u/s Hwy 2 Bridge	AB05CC0010	52.267	-113.864	12	LTRN

Station Name and Description	Station Code	Station Latitude	Station Longitude	Samples per year	Project Name
Red Deer River at Sundre	AB05CA0050	51.796	-114.635	12	LTRN
Bow River Near Ronalane Bridge	AB05BN0010	50.047	-111.591	12	LTRN
Bow River at Cluny	AB05BM0590	50.773	-112.846	12	LTRN
Bow River Below Carseland Dam	AB05BM0010	50.831	-113.417	12	LTRN
Elbow River at 9Th Ave Bridge	AB05BJ0450	51.045	-114.042	12	LTRN
Bow River at Cochrane	AB05BH0010	51.183	-114.487	12	LTRN
South Saskatchewan River Above Medicine Hat	AB05AK0020	50.043	-110.722	12	LTRN
Oldman River at Hwy 36 Bridge North Of Taber	AB05AG0010	49.961	-112.085	12	LTRN
Oldman River Above Lethbridge at Hwy 3	AB05AD0010	49.707	-112.863	12	LTRN
Oldman River Near Brocket-Left Bank	AB05AB0070	49.559	-113.822	12	LTRN
New West Coulee at Hwy 36 Crossing	AB05BN0130	50.217	-112.105	8	TMN-Bow
Twelve Mile Creek Near Cecil at Bridge Above Gauging Station	AB05BN0070	50.431	-112.228	8	TMN-Bow
Crowfoot Creek On Hwy 1	AB05BM0620	50.835	-112.763	8	TMN-Bow
East Arrowwood Creek Near The Mouth	AB05BM0585	50.735	-113.131	8	TMN-Bow
West Arrowwood Creek d/s Of Syphon	AB05BM0575	50.764	-113.236	8	TMN-Bow
Pine Creek Near The Mouth	AB05BM0145	50.845	-113.962	12	TMN-Bow
Sheep River Approximately 1.0 km d/s WSC Gauge	AB05BL1440	50.697	-114.235	12	TMN-Bow
Sheep River 1.6 km d/s Of Hwy 2	AB05BL0470	50.712	-113.883	12	TMN-Bow

Station Name and Description	Station Code	Station Latitude	Station Longitude	Samples per year	Project Name
Highwood River d/s Of High River at Bend In Back Road To High River	AB05BL0210	50.601	-113.858	12	TMN-Bow
Fish Creek #8 Near The Mouth NE 1/4-25-22-1-W5	AB05BK0070	50.907	-114.016	12	TMN-Bow
Highwood River at the Mouth	AB05BH0490	50.783	-113.821	12	TMN-Bow
Nose Creek Near The Mouth-Memorial Drive	AB05BH0370	51.047	-114.020	12	TMN-Bow
Jumpingpound Creek Near Mouth	AB05BH0040	51.184	-114.499	12	TMN-Bow
Waiparous Creek Above Confluence With Ghost River	AB05BG0100	51.283	-114.838	12	TMN-Bow
Ghost River Above Confluence With Waiparous Creek	AB05BG0090	51.282	-114.839	12	TMN-Bow
Coal Creek 1/2 Mile West Of Bow City	AB05AJ0060	50.149	-111.665	8	TMN-Bow
Miners Coulee site B	AB11AA0330	49.035	-111.388	8	TMN-Milk
Red Creek near the mouth	AB11AA0290	49.067	-111.922	8	TMN-Milk
Milk River near western boundary, at Hwy 501	AB11AA0280	49.090	-112.398	8	TMN-Milk
North Milk River near international boundary, upstream of Hwy 501	AB11AA0270	49.022	-112.973	8	TMN-Milk
Milk River u/s of town of Milk River	AB11AA0150	49.148	-112.167	8	TMN-Milk
Verdigris Coulee at Hwy 501	AB11AA0100	49.155	-111.837	8	TMN-Milk
South Saskatchewan River below Medicine Hat and above fertilizer plant	AB05AK0990	50.105	-110.691	12	TMN-SSR
Seven Persons Creek near the mouth	AB05AH0050	50.030	-110.646	12	TMN-SSR
Ross Creek near mouth	AB05AH0020	50.028	-110.638	12	TMN-SSR

Station Name and Description	Station Code	Station Latitude	Station Longitud e	Sample s per year	Project Name
Expanse Coulee Adjacent To Hwy 36 Bridge Crossing Oldman River	AB05AG0140	49.989	-112.082	8	TMN-OMR
St. Mary River Near Confluence With Oldman River	AB05AE0070	49.589	-112.881	12	TMN-OMR
Belly River Near Confluence With Oldman River	AB05AD0240	49.728	-113.178	12	TMN-OMR
Waterton River Adjacent To Sec Hwy 810 Bridge-Wr2	AB05AD0190	49.433	-113.485	12	TMN-OMR
Waterton River Adjacent To Sec Hwy 810 Bridge-Wr2	AB05AD0070	49.479	-113.302	12	TMN-OMR
Little Bow River Near The Mouth	AB05AC0320	49.902	-112.507	12	TMN-OMR
Little Bow River at Carmangay	AB05AC0190	50.132	-113.137	12	TMN-OMR
Little Bow River D/S Of Twin Valley Reservoir	AB05AC0175	50.225	-113.397	12	TMN-OMR
Mosquito Creek at Hwy 529 East Of Parkland	AB05AC0160	50.252	-113.554	8	TMN-OMR
Little Bow River at Hwy 533 East Of Nanton	AB05AC0100	50.353	-113.544	8	TMN-OMR
Willow Creek at Sec Hwy 811	AB05AB0260	49.753	-113.404	8	TMN-OMR
Beaver Creek West Of Peigan Indian Reserve	AB05AB0100	49.639	-113.795	8	TMN-OMR
Pincher Creek at Hwy 3 Near The Mouth	AB05AA0480	49.546	-113.795	12	TMN-OMR
Pincher Creek at Pincher Creek	AB05AA0440	49.484	-113.969	12	TMN-OMR
Matzhiwin Creek at Hwy 36	AB05CJ0030	50.821	-111.829	8	TMN-RDR
Berry Creek Near the Mouth	AB05CH0120	50.855	-111.591	12	TMN-RDR
Michichi Creek near the mouth	AB05CE0700	51.471	-112.717	12	TMN-RDR

Station Name and Description	Station Code	Station Latitude	Station Longitude	Samples per year	Project Name
Michichi Creek at RR 191	AB05CE0695	51.527	-112.557	12	TMN-RDR
Kneehills Ck near the mouth at HWY 575	AB05CE0690	51.497	-112.843	12	TMN-RDR
Kneehills Ck at RR 221	AB05CE0685	51.470	-112.978	12	TMN-RDR
Threehills Ck near the mouth at HWY 837	AB05CE0680	51.533	-112.889	12	TMN-RDR
Threehills Ck at HWY 836	AB05CE0660	51.565	-113.073	12	TMN-RDR
Rosebud River (mouth) at HWY 10	AB05CE0100	51.416	-112.629	12	TMN-RDR
Rosebud River (Redland) at HWY 840	AB05CE0090	51.294	-113.011	12	TMN-RDR
Blindman River near mouth at HWY 2A bridge south of Blackfalds	AB05CC0460	52.354	-113.795	12	TMN-RDR
Waskasoo Creek near the Mouth	AB05CC0225	52.269	-113.800	12	TMN-RDR
Medicine River (near mouth) at HWY 54	AB05CC0100	52.086	-114.123	12	TMN-RDR
Little Red Deer River west of Innisfail	AB05CB0270	52.028	-114.140	12	TMN-RDR
Raven River at Raven	AB05CB0070	52.089	-114.478	12	TMN-RDR
James River near James River Bridge	AB05CA0090	51.927	-114.686	8	TMN-RDR
Bearberry Creek Near Sundre	AB05CA0045	51.802	-114.663	8	TMN-RDR
Fallentimber Creek Near Mouth	AB05CA0015	51.737	-114.655	8	TMN-RDR
Lesser Slave River 9.5 km u/s Of Athabasca River Confluence	AB07BK0125	55.207	-114.123	12	TMN-UAR
Pembina River near Jarvie @ WSC Gauge	AB07BC0025	54.449	-113.992	12	TMN-UAR

Station Name and Description	Station Code	Station Latitude	Station Longitude	Samples per year	Project Name
Sakwatamau River Near Whitecourt @ WSC Gauge	AB07AH0005	54.201	-115.780	8	TMN-UAR
Mcleod River u/s Whitecourt @ WSC Gauge	AB07AG0345	54.013	-115.842	8	TMN-UAR
Berland River Near Mouth @ WSC Gauge	AB07AC0015	54.012	-116.967	8	TMN-UAR
Miette River Near Jasper @ WSC Gauge	AB07AA0007	52.864	-118.106	8	TMN-UAR
Sunwapta River at Athabasca Glacier @ WSC Gauge	AB07AA0005	52.217	-117.234	8	TMN-UAR

Table A2. List of core water quality parameters to be monitored at every LTRN station, the method code associated with measurement, the VMV code, the detection limit (DL), and the unit the result is reported in.

Parameter group	Analyte	Method code	VMV code	DL	Unit	Notes
Water Isotopes	$d^{18}O$		TBD	n/a	‰	
Water Isotopes	$d^{2}H$		TBD	n/a	‰	
Water E. Coli & Enterococcus	E. Coli & Total Coliforms					
Water Nutrients and Organic Carbon	Total Ammonia (N)	EPA 350.1 R2.0 m	2007	0.015	mg/L	
Water Nutrients and Organic Carbon	Total Dissolved Phosphorus	SM 22 4500-P A,B,F m	2010	0.003	mg/L	
Water Nutrients and Organic Carbon	Total Phosphorus	SM 22 4500-P A,B,F m	2013	0.003	mg/L	
Water Nutrients and Organic Carbon	Dissolved Reactive Phosphorus	SM 22 4500-P A,B,F m	2014	0.003	mg/L	
Water Nutrients and Organic Carbon	Dissolved Organic Carbon	MMCW 119 1996 m	6107	0.5	mg/L	
Water Nutrients and Organic Carbon	Total Nitrogen	Auto Calc	7602	0.055	mg/L	Calculated
Water Nutrients and Organic Carbon	Total Organic Carbon	MMCW 119 1996 m	22214	0.5	mg/L	
Water Nutrients and Organic Carbon	Dissolved Nitrate	SM 22 4110 B m	102647	0.003	mg/L	
Water Nutrients and Organic Carbon	Dissolved Nitrite	SM 22 4110 B m	102648	0.003	mg/L	
Water Nutrients and Organic Carbon	Nitrate + Nitrite	Auto Calc	102649	0.005	mg/L	Calculated
Water Nutrients and Organic Carbon	Dissolved Total Kjeldahl Nitrogen	Auto Calc	2008	0.05	mg/L	
Water Nutrients and Organic Carbon	Total Kjeldahl Nitrogen	EPA 351.1 R 1978 m	2009	0.05	mg/L	

Parameter group	Analyte	Method code	VMV code	DL	Unit	Notes
Water Routines, Major Anions and Cations	Bicarbonate	SM 22 2320 B m	1594	1	mg/L	
Water Routines, Major Anions and Cations	Carbonate	SM 22 2320 B m	1595	1	mg/L	
Water Routines, Major Anions and Cations	Dissolved Calcium	EPA 200.7 CFR 2012 m	20111	0.3	mg/L	
Water Routines, Major Anions and Cations	Dissolved Chloride	SM 22 4500-Cl G m	2003	1	mg/L	
Water Routines, Major Anions and Cations	Dissolved Iron	EPA 200.7 CFR 2012 m	102090	0.06	mg/L	
Water Routines, Major Anions and Cations	Dissolved Magnesium	EPA 200.7 CFR 2012 m	12111	0.2	mg/L	
Water Routines, Major Anions and Cations	Dissolved Manganese	EPA 200.7 CFR 2012 m	102089	0.004	mg/L	
Water Routines, Major Anions and Cations	Dissolved Potassium	EPA 200.7 CFR 2012 m	19111	0.3	mg/L	
Water Routines, Major Anions and Cations	Dissolved Sodium	EPA 200.7 CFR 2012 m	11111	0.5	mg/L	
Water Routines, Major Anions and Cations	Dissolved Sulphate	SM 22 4500-SO4 E m	1599	1	mg/L	
Water Routines, Major Anions and Cations	Hardness	Auto Calc	10602	0.5	mg/L	Calculated
Water Routines, Major Anions and Cations	Hydroxide (OH)	SM 22 2320 B m	1596	1	mg/L	
Water Routines, Major Anions and Cations	Ion Balance		107670	n/a	%	Calculated
Water Routines, Major Anions and Cations	Partial Alkalinity	SM 22 2320 B m	1593	1	mg/L	
Water Routines, Major Anions and Cations	pH	SM 22 4500 H+ B m	10301	n/a	pH	
Water Routines, Major Anions and Cations	Specific Conductance/Conductivity	SM 22 2510 B m	2041	2	uS/cm	

Parameter group	Analyte	Method code	VMV code	DL	Unit	Notes
Water Routines, Major Anions and Cations	Total Alkalinity	SM 22 2320 B m	1592	1	mg/L	
Water Routines, Major Anions and Cations	Total Dissolved Solids		201	10	mg/L	Calculated
Water Routines, Major Anions and Cations	Total Dissolved Solids	SM 22 2540 C m	2004	10	mg/L	
Water Routines, Major Anions and Cations	Total Suspended Solids	SM 22 2540 D m	2005	1	mg/L	
Water Routines, Major Anions and Cations	True Colour	SM 22 2120 C m	22213	2	PtCo units	
Water Routines, Major Anions and Cations	Turbidity	SM 22 2130 B m	2002	0.1	NTU	
Water Mercury	Mercury Dissolved	EPA Method 1631.E	109749	0.08	ng/L	
Water Mercury	Mercury Total	EPA Method 1631.E	109748	0.06	ng/L	
Water	Chlorophyll A	EPA 445.0	107995	0.0001	mg/L	
Water	Periphyton (3 Rocks Per Site)					Only at select LTRN stations
Water Trace Metals	Aluminum Dissolved	AC-038	103927	0.13	µg/L	
Water Trace Metals	Aluminum Total	AC-038	103999	2.0	µg/L	
Water Trace Metals	Antimony Dissolved	AC-038	103951	0.008	µg/L	
Water Trace Metals	Antimony Total	AC-038	80043	0.001	µg/L	
Water Trace Metals	Arsenic Dissolved	AC-038	103928	0.003	µg/L	
Water Trace Metals	Arsenic Total	AC-038	80020	0.004	µg/L	
Water Trace Metals	Barium Dissolved	AC-038	103930	0.05	µg/L	
Water Trace Metals	Barium Total	AC-038	80022	0.004	µg/L	

Parameter group	Analyte	Method code	VMV code	DL	Unit	Notes
Water Trace Metals	Beryllium Dissolved	AC-038	103931	0.009	µg/L	
Water Trace Metals	Beryllium Total	AC-038	80023	0.008	µg/L	
Water Trace Metals	Bismuth Dissolved	AC-038	103932	0.003	µg/L	
Water Trace Metals	Bismuth Total	AC-038	80024	0.001	µg/L	
Water Trace Metals	Boron Dissolved	AC-038	103929	0.13	µg/L	
Water Trace Metals	Boron Total	AC-038	80021	0.1	µg/L	
Water Trace Metals	Cadmium Dissolved	AC-038	103934	0.002	µg/L	
Water Trace Metals	Cadmium Total	AC-038	80026	0.002	µg/L	
Water Trace Metals	Calcium Dissolved	AC-038	103933	30.0	µg/L	
Water Trace Metals	Calcium Total	AC-038	80025	10.0	µg/L	
Water Trace Metals	Chlorine Dissolved	AC-038	103935	30.0	µg/L	
Water Trace Metals	Chlorine Total	AC-038	80027	40.0	µg/L	
Water Trace Metals	Chromium Dissolved	AC-038	103937	0.1	µg/L	
Water Trace Metals	Chromium Total	AC-038	80029	0.03	µg/L	
Water Trace Metals	Cobalt Dissolved	AC-038	103936	0.002	µg/L	
Water Trace Metals	Cobalt Total	AC-038	80028	0.002	µg/L	
Water Trace Metals	Copper Dissolved	AC-038	103938	0.08	µg/L	
Water Trace Metals	Copper Total	AC-038	80030	0.05	µg/L	
Water Trace Metals	Iron Dissolved	AC-038	103939	0.6	µg/L	
Water Trace Metals	Iron Total	AC-038	80031	0.7	µg/L	
Water Trace Metals	Lead Dissolved	AC-038	103949	0.004	µg/L	
Water Trace Metals	Lead Total	AC-038	80041	0.003	µg/L	
Water Trace Metals	Lithium Dissolved	AC-038	103942	0.02	µg/L	

Parameter group	Analyte	Method code	VMV code	DL	Unit	Notes
Water Trace Metals	Lithium Total	AC-038	80034	0.05	µg/L	
Water Trace Metals	Manganese Dissolved	AC-038	103944	0.01	µg/L	
Water Trace Metals	Manganese Total	AC-038	80036	0.005	µg/L	
Water Trace Metals	Molybdenum Dissolved	AC-038	103945	0.002	µg/L	
Water Trace Metals	Molybdenum Total	AC-038	80037	0.002	µg/L	
Water Trace Metals	Nickel Dissolved	AC-038	103947	0.006	µg/L	
Water Trace Metals	Nickel Total	AC-038	80039	0.008	µg/L	
Water Trace Metals	Selenium Dissolved	AC-038	103952	0.04	µg/L	
Water Trace Metals	Selenium Total	AC-038	80044	0.06	µg/L	
Water Trace Metals	Silver Dissolved	AC-038	103926	0.001	µg/L	
Water Trace Metals	Silver Total	AC-038	103998	0.002	µg/L	
Water Trace Metals	Strontium Dissolved	AC-038	103955	0.07	µg/L	
Water Trace Metals	Strontium Total	AC-038	80047	1.0	µg/L	
Water Trace Metals	Thallium Dissolved	AC-038	103958	0.0004	µg/L	
Water Trace Metals	Thallium Total	AC-038	80053	0.0009	µg/L	
Water Trace Metals	Thorium Dissolved	AC-038	103956	0.0008	µg/L	
Water Trace Metals	Thorium Total	AC-038	80048	0.0009	µg/L	
Water Trace Metals	Tin Dissolved	AC-038	103954	0.003	µg/L	
Water Trace Metals	Tin Total	AC-038	80046	0.003	µg/L	
Water Trace Metals	Titanium Dissolved	AC-038	103957	0.08	µg/L	
Water Trace Metals	Titanium Total	AC-038	80049	0.05	µg/L	
Water Trace Metals	Uranium Dissolved	AC-038	103959	0.002	µg/L	
Water Trace Metals	Uranium Total	AC-038	80054	0.003	µg/L	

Parameter group	Analyte	Method code	VMV code	DL	Unit	Notes
Water Trace Metals	Vanadium Dissolved	AC-038	103960	0.02	µg/L	
Water Trace Metals	Vanadium Total	AC-038	80055	0.01	µg/L	
Water Trace Metals	Zinc Dissolved	AC-038	103961	0.09	µg/L	
Water Trace Metals	Zinc Total	AC-038	80056	0.1	µg/L	