Coordinated Aquatic Monitoring Program

CAMP Twelve Year Data Report (2008-2019)

Technical Document 1:

Introduction and Methods

Prepared by

Manitoba Hydro

And

North/South Consultants Inc.

2024

Coordinated Aquatic Monitoring Program

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CAMP TWELVE YEAR DATA REPORT (2008-2019)

TECHNICAL DOCUMENT 1: INTRODUCTION AND METHODS

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CAMP

EXECUTIVE SUMMARY

The Coordinated Aquatic Monitoring Program (CAMP) is a coordinated effort between the Government of Manitoba (Manitoba) and Manitoba Hydro to implement a long-term, systematic, and system-wide aquatic monitoring program across Manitoba Hydro's hydraulic operating system. Monitoring began in 2008, with the first three years serving as a pilot program. Monitoring is conducted within a number of watersheds and includes the upper and lower Churchill rivers, the Rat/Burntwood River system, the upper and lower Nelson rivers, the Winnipeg and Saskatchewan rivers, and Lake Winnipeg.

The contents of this report represent 12 years of data collected for select metrics through CAMP from April 2008 to March 2020. The fiscal year, April to March, is used for all CAMP planning and data collection. In this report, when a single year of data is indicated, it follows a standardized naming convention, using the year at the start of the fiscal year (i.e., the first year of monitoring, 2008/09, may commonly be referred to as 2008 in the report).

CAMP monitors five components within the aquatic ecosystem: physical environment, benthic invertebrates, fish community, mercury in fish, and water quality. Each component is examined through indicators, which are measured by metrics. The focus of this report is the data collected under select metrics, which in turn informs the indicators, components, and overall state of the aquatic ecosystem. CAMP monitors additional metrics in waterbodies across the province beyond the program's reporting scope. More information can be found at campmb.ca.

The purpose of this report is to present data from select CAMP metrics to inform our understanding of indicators under each CAMP component. This will then enable future analysis of broad trends within aquatic ecosystems in Manitoba.

The 12 Year Data Report is comprised of eight technical documents as follows:

- Technical Document 1: Introduction and Methods
- Technical Document 2: Winnipeg River Region Results
- Technical Document 3: Saskatchewan River Region Results
- Technical Document 4: Upper Churchill River Region Results
- Technical Document 5: Lower Churchill River Region Results
- Technical Document 6: Churchill River Diversion Region Results
- Technical Document 7: Upper Nelson River Region Results

- Technical Document 8: Lower Nelson River Region Results

This document - Technical Document 1: Introduction and Methods - provides an overview of the indicators included in the report, the regions and waterbodies monitored through CAMP, and the field, laboratory, analysis, and reporting methods used.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS, ACRONYMS, AND UNITS

%	Percent
°C	Degrees Celsius
C	Catch
CALA	Canadian Association for Laboratory Accreditation Inc.
CAMP	Coordinated Aquatic Monitoring Program
CCME	Canadian Council of Ministers of the Environment
cms	Cubic metres per second
CPUE	Catch-per-unit-effort
CRD	Churchill River Diversion
CS	Control structure(s)
CVAAS	Cold Vapour Atomic Absorption Spectrophotometry
CVAF	Cold Vapour Atomic Fluorescence
DELTs	Deformities, Erosion, Lesions, and Tumours
DL(s)	Detection limit(s)
DO	Dissolved oxygen
E	Effort
ECCC	Environment and Climate Change Canada
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)
FL	Fork length
FLA	Fork length-at-age
FNU	Formazin nephelometric unit
g	Gram
GS(s)	Generating station(s)
h	hour
IQR	Interquartile range
ITIS	Integrated Taxonomic Information System
KF	Fulton's condition factor
L	Length
LWR	Lake Winnipeg Regulation
m	Metre
m^2	Square metre(s)
µg/L	Micrograms per litre
µm	Micron
µmhos/cm	Micromhos/centimetre
µS/cm	MicroSiemens /centimetre

mg/L	Milligrams per litre
mm	Millimetre
MPN/100 mL	Most Probable Number/100 millilitres
MWQSOGs	Manitoba Water Quality Standards, Objectives, and Guidelines
MW(s)	Megawatt(s)
MWS	Manitoba Water Stewardship
n	Sample size or number of samples
no.	Number
NTU	Nephelometric turbidity units
O+C	Oligochaeta and Chironomidae
OECD	Organization for Economic Cooperation and Development
PAL	Protection of aquatic life
ppm	Parts per million
QA/QC	Quality Assurance/Quality Control
RSA	Relative species abundance
RYCS	Relative year-class strength
SD	Standard deviation
SE	Standard error
T/day	Tonnes per day
TL	Total length
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
TSS	Total suspended solids
UTM	Universal Transverse Mercator
W	Round weight
Wr	Relative weight
Ws	Standard weight
WSC	Water Survey of Canada

1.0 INTRODUCTION

The Coordinated Aquatic Monitoring Program (CAMP) is a coordinated effort between the Government of Manitoba (Manitoba) and Manitoba Hydro to implement a long-term, systematic, and system-wide aquatic monitoring program across Manitoba Hydro's hydraulic operating system. Monitoring began in 2008, with the first three years serving as a pilot program. Monitoring is conducted within a number of watersheds and includes the upper and lower Churchill River, the Rat/Burntwood River system, the upper and lower Nelson River, the Winnipeg and Saskatchewan rivers, and Lake Winnipeg (Figure 1-1).

1.1 REPORT OUTLINE

The contents of this report represent 12 years of data collected for select metrics through CAMP from April 2008 to March 2020. The fiscal year, April to March, is used for all CAMP planning and data collection. In this report, when a single year of data is indicated, it follows a standardized naming convention, using the year at the start of the fiscal year (i.e., the first year of monitoring, 2008/09, may commonly be referred to as 2008 in the report).

CAMP monitors five components within the aquatic ecosystem: physical environment, benthic invertebrates, fish community, mercury in fish, and water quality. Each component is examined through indicators, which are measured by metrics. The focus of this report is the data collected under select metrics, which in turn informs the indicators, components, and overall state of the aquatic ecosystem. CAMP monitors additional metrics in waterbodies across the province beyond the program's reporting scope. More information can be found at campmb.ca.

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This document - Technical Document 1: Introduction and Methods - provides an overview of the indicators included in the report, the regions and waterbodies monitored through CAMP, and the field, laboratory, analysis, and reporting methods used.

Figure 1-1. Manitoba Hydro hydroelectric generating stations.

1.2 OVERVIEW OF MONITORING COMPONENTS

While CAMP collects a wide range of data across all components, for the purpose of reporting, only data under select indicators are presented. All CAMP data are publicly available. To submit a data request, visit campmb.ca.

This section describes the indicators and their associated metrics as presented in this report. Field and laboratory methods for each component can be found in Section 2.0, and reporting and analysis methods can be found in Section 3.0. More detailed descriptions of the indicators and their selection can be found in CAMP (2024).

1.2.1 PHYSICAL ENVIRONMENT

Under Physical Environment, indicators for which data are presented are Climate, Water Regime, and Sedimentation. While CAMP does not directly monitor climate, Environment and Climate Change Canada (ECCC) data are included in reporting to provide context for data collected under other indicators.

Table 1-1. Physical Environment indicators and metrics.

Indicator	Metric	Units
Climate[1]	• Temperature	°C
	• Precipitation	Millimetres (mm)
Water Regime	• Flow	Cubic meters per second (cms)
	• Water Level and Variability	Metres (m)
	• Water Temperature	Duration of temperature in 5-degree Celsius increments (#days/5 °C)
Sedimentation	• Continuous Turbidity	Formazin nephelometric unit (FNU)
	• Suspended Sediment Load	Tonnes/day (T/day)

Notes:

1. Climate is not monitored through CAMP; data are included for reporting purposes only.

1.2.2 WATER QUALITY

Under Water Quality, indicators are Dissolved Oxygen (DO), Water Clarity, and Nutrients and Trophic Status.

Table 1-2. Water quality indicators and metrics.

Indicator	Metric	Units
Dissolved Oxygen	• Dissolved oxygen (DO)	milligrams per litre (mg/L) and percent (%) saturation
	• Temperature/stratification [1]	°C
Water Clarity	• Secchi disk depth	m
	• Turbidity	Nephelometric turbidity units (NTU)
	• Total suspended solids (TSS)	mg/L
Nutrients and Trophic Status	• Total phosphorus (TP)	mg/L
	• Total nitrogen (TN)	mg/L
	• Chlorophyll *a*	micrograms per litre (µg/L)

Notes:
1. Supporting metric

1.2.3 BENTHIC INVERTEBRATES

Under Benthic Invertebrates, indicators are Abundance, Community Composition, Taxonomic Richness, and Diversity.

Table 1-3. Benthic invertebrate indicators and metrics for CAMP reporting.

Indicator	Metric	Units
Abundance	• Total Invertebrate Abundance	Number (no.) per sample
	• Total Invertebrate Density	no. per square metre (m^2)
Community Composition	• Relative Proportions of Major Invertebrate Groups	percent (%)
	• Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index	percent (%)
	• Oligochaeta and Chironomidae (O+C) Index	percent (%)
Taxonomic Richness	• Total Taxa Richness	no. of families
	• EPT Taxa Richness	no. of families
Diversity	• Hill's Effective Richness (Hill's Index)	value

1.2.4 FISH COMMUNITY

Under Fish Community, indicators are Abundance, Condition, Growth, Recruitment, and Diversity.

Table 1-4. Fish community indicators and metrics.

Indicator	Metric	Units
Abundance	• Catch-Per-Unit-Effort (CPUE)	# fish/30 m/24 hour (h) # fish/100 m/24 h
Condition	• Fulton's Condition Factor (KF)	-
	• Relative Weight (Wr)	-
Growth	• Fork Length-At-Age (FLA)	mm
Recruitment	• Relative Year-Class Strength (RYCS)	-
Diversity	• Hill's Effective Species Richness	species
	• Relative Species Abundance (RSA)[1]	%

Notes:
1. Supporting metric

1.2.5 FISH MERCURY

Under Fish Mercury, the indicator is Mercury in Fish.

Table 1-5. Mercury in fish indicators and metrics for CAMP reporting.

Indicator	Metric	Units
Mercury in Fish	• Arithmetic mean mercury concentration	Parts per million (ppm)
	• Length-standardized mean mercury concentration	ppm

1.3 OVERVIEW OF CAMP REGIONS AND WATERBODIES

For the 12 Year Data Report CAMP divides Manitoba Hydro's operating system into seven study regions across Manitoba as summarized below. Within the CAMP study regions, both on- and off-system waterbodies are monitored (Figure 1-2). On-system waterbodies are those located on, and that are notably influenced by, Manitoba Hydro's hydraulic operating system. Off-system waterbodies include lakes and river reaches where water levels and flows are either entirely or largely unaffected by Manitoba Hydro's hydraulic operating system. Off-system waterbodies are monitored with the intention of providing additional information for examining trends over time related to the potential effects of Manitoba Hydro's activities and other stressors such as climate change. Each region includes waterbodies sampled on an annual and three-year rotational basis.

The following sections provide brief descriptions of the seven monitoring regions. More detailed descriptions of regions can be found in the CAMP Six Year Summary Report (CAMP 2017).

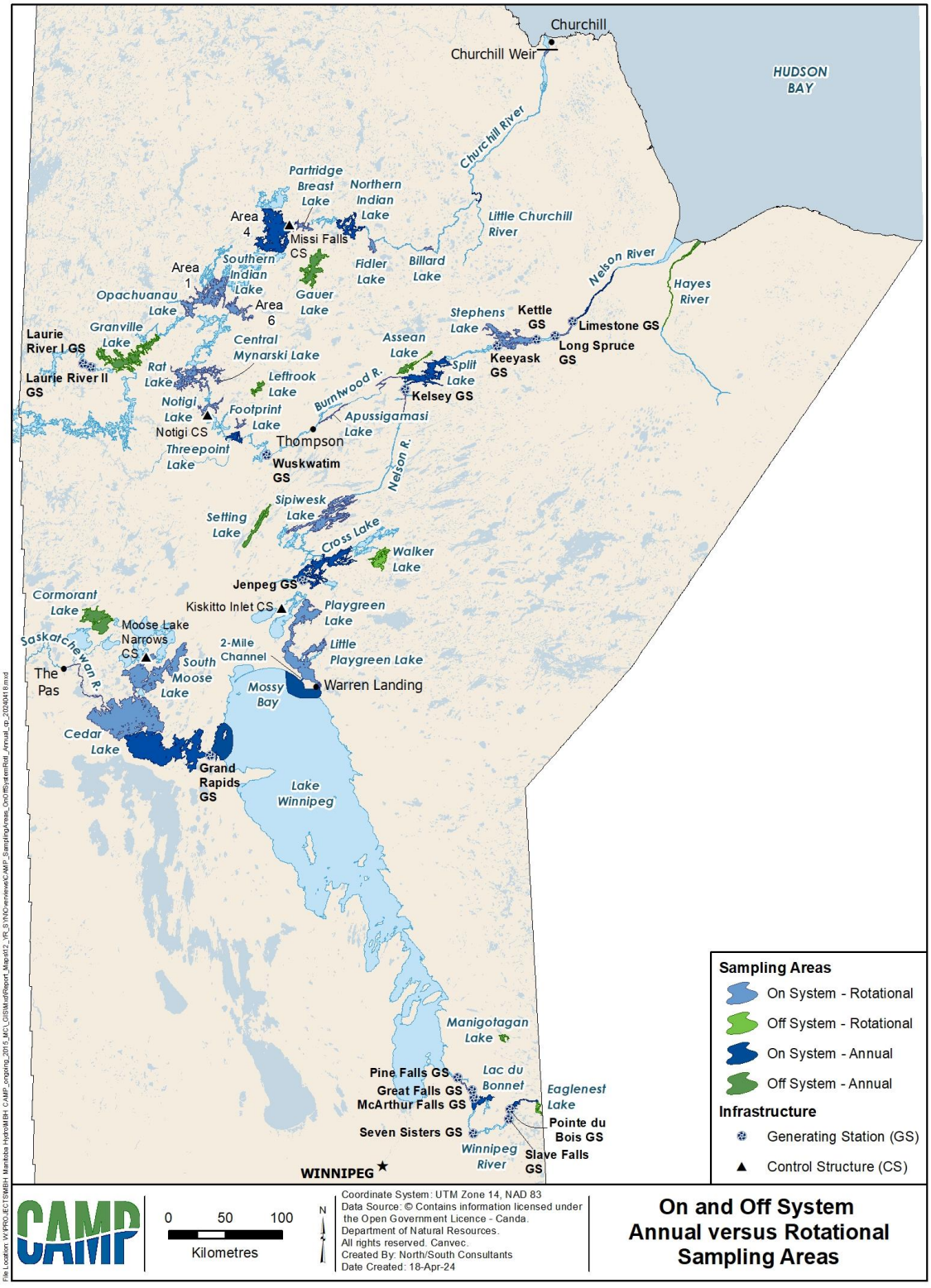

Figure 1-2. On-system and off-system waterbodies sampled under CAMP: 2008/2009-2019/2020.

1.3.1 WINNIPEG RIVER REGION

The Winnipeg River Region includes the portion of the Winnipeg River watershed from the Ontario/Manitoba border downstream to the mouth of the river at Traverse Bay on Lake Winnipeg (Figure 1-3). This region also includes Manigotagan Lake, an off-system waterbody on the Manigotagan River. This region runs through the Boreal Shield Ecozone, which is mostly underlain by bedrock. The dominant land cover is classified as mixed forest, however, peatlands with black spruce-sphagnum (moss) bogs are common. Manitoba Hydro operates six generating stations (GS) on the Winnipeg River which together produce approximately 583 megawatts (MW) of hydroelectric power. The Winnipeg River GSs include Pointe du Bois, Slave Falls, Seven Sisters, McArthur, Great Falls, and Pine Falls. The waterbodies monitored through CAMP in the Winnipeg River Region are as follows:

- On-system waterbodies:
  - Pointe du Bois Forebay (annual)
  - Lac du Bonnet (annual)
  - Pine Falls Forebay (rotational)
- Off-system waterbodies:
  - Manigotagan Lake (annual)
  - Eaglenest Lake (rotational)

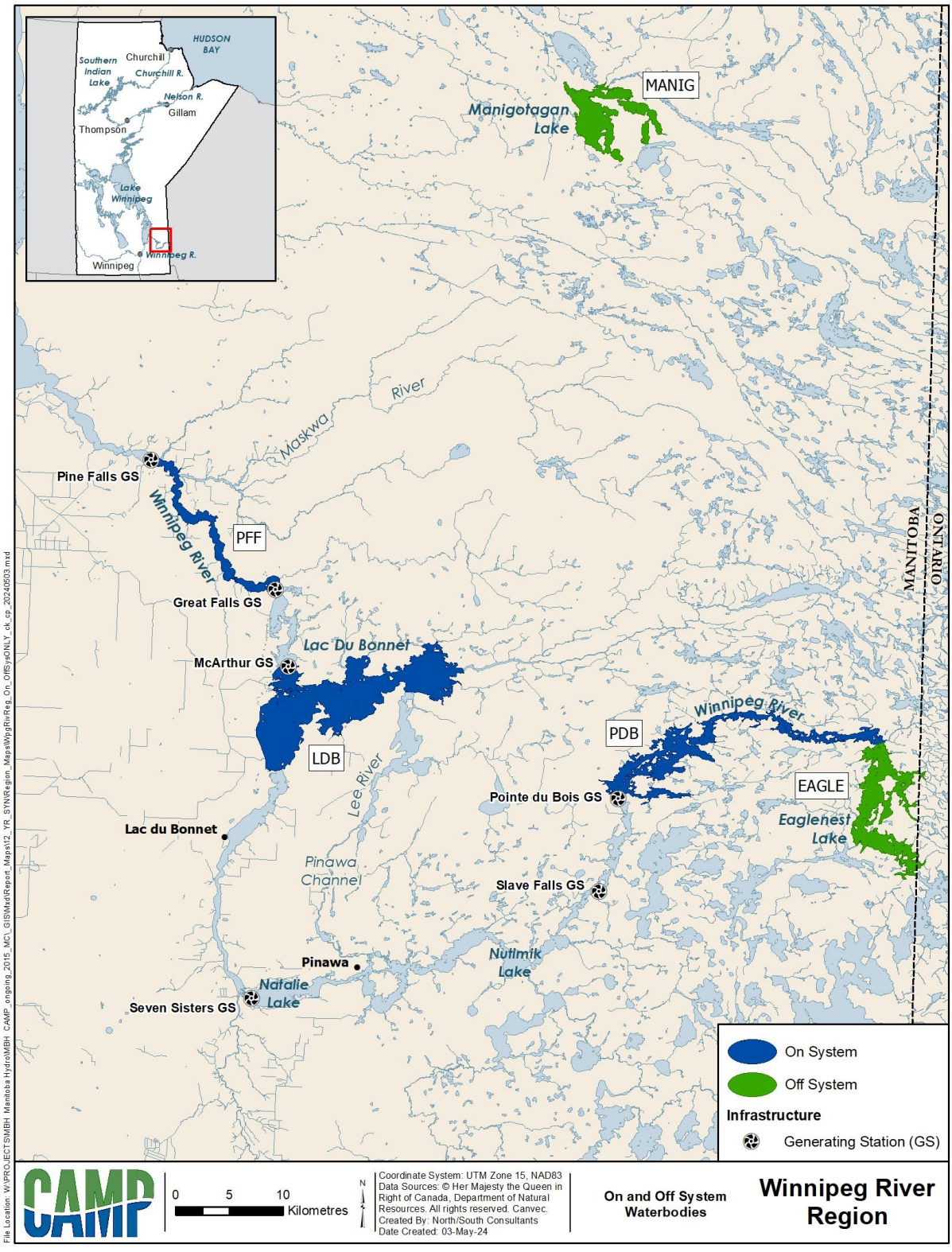

Figure 1-3. Waterbodies monitored under CAMP in the Winnipeg River Region.

1.3.2 SASKATCHEWAN RIVER REGION

The Saskatchewan River Region includes the portion of the Saskatchewan River watershed from the Saskatchewan/Manitoba border extending into Lake Winnipeg downstream of the Grand Rapids Generating Station (GS; Figure 1-4). The region also includes South Moose Lake and Cormorant Lake. The Saskatchewan River system runs through the Boreal Plains and the western portion of the Prairies Ecozones and the dominant land cover in this region is cultivated crops; these drainage basin characteristics are reflected as relatively high turbidity in the river. Manitoba Hydro operates the Grand Rapids GS, a load following facility located at the mouth of the Saskatchewan River where it flows into Lake Winnipeg. The Generating Station controls water levels on Cedar Lake, which also serves as its reservoir. The waterbodies monitored through CAMP in the Saskatchewan River Region are as follows:

- On-system waterbodies:
  - Cedar Lake - Southeast (annual)
  - Lake Winnipeg - Grand Rapids (annual)
  - Saskatchewan River (rotational)
  - South Moose Lake (rotational)
  - Cedar Lake - West (rotational)
- Off-system waterbodies:
  - Cormorant Lake (annual)

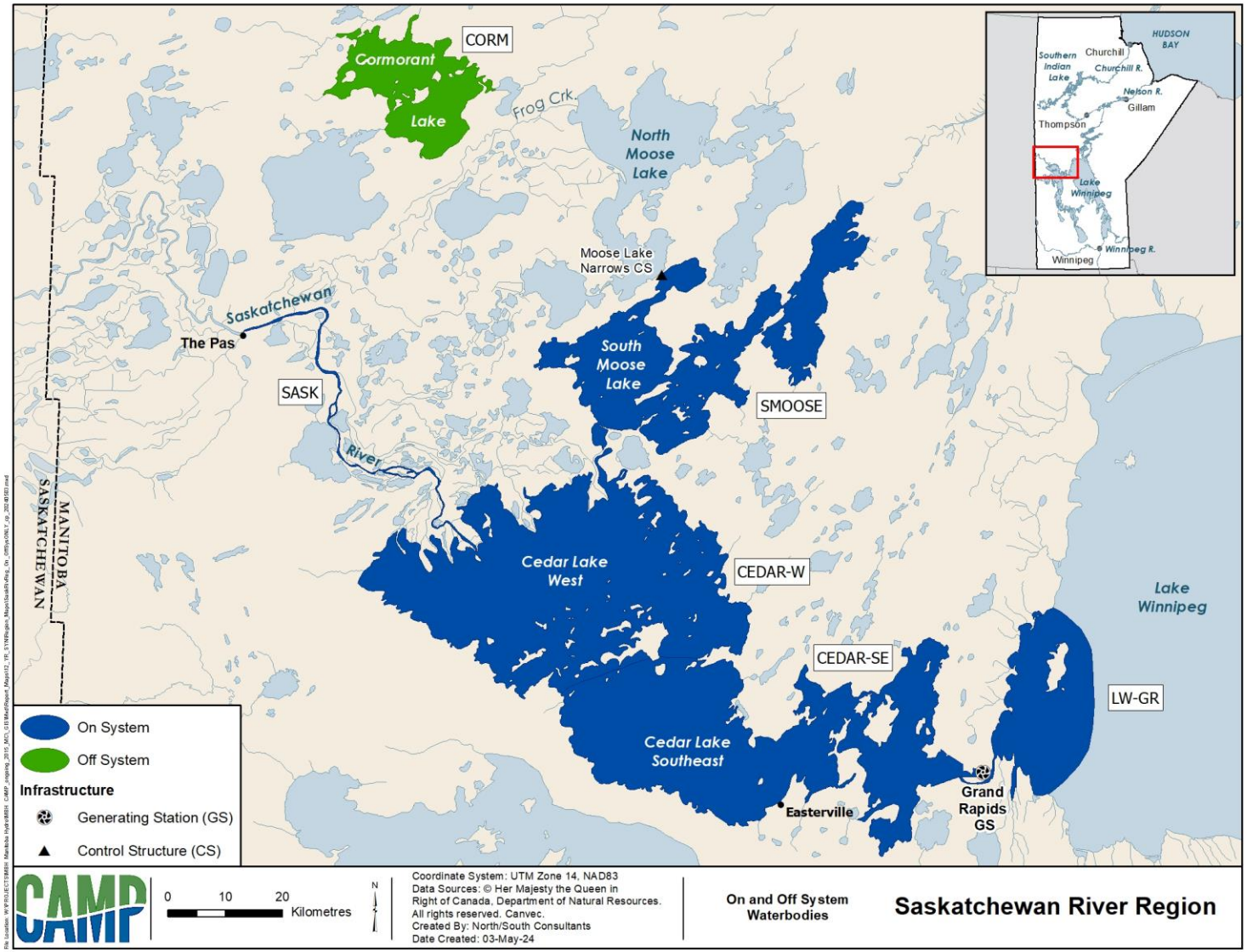

Figure 1-4. Waterbodies monitored under CAMP in the Saskatchewan River Region.

1.3.3 UPPER CHURCHILL RIVER REGION

The Upper Churchill River Region is composed of the Churchill River watershed extending from the Saskatchewan/Manitoba border downstream to the natural outlet of Southern Indian Lake at Missi Falls and the outlet of Notigi Lake (i.e., at the Notigi Control Structure [CS]), located on the Rat River system (Figure 1-5). This region is located primarily within the Churchill River Upland Ecoregion of the Boreal Shield Ecozone, though the northern portion of Southern Indian Lake falls within the Selwyn Lake Upland Ecoregion of the Taiga Shield Ecozone. The dominant land cover in the Upper Churchill River drainage basin is coniferous forest.

In 1976, the Churchill River was impounded at the natural outlet of Southern Indian Lake on the Churchill River by the Missi Falls CS and water was diverted via the Churchill River Diversion (CRD) into the Rat/Burntwood River system and ultimately the lower Nelson River at Split Lake. Water levels were raised on Southern Indian Lake for diversion to the Nelson River to supplement Lake Winnipeg Regulation (LWR) flows. The waterbodies monitored through CAMP in the Upper Churchill River Region are as follows:

- On-system waterbodies:
  - Southern Indian Lake - Area 4 (annual)
  - Opachuanau Lake (rotational)
  - Southern Indian Lake - Area 1 (rotational)
  - Southern Indian Lake - Area 6 (rotational)
  - Rat Lake (rotational)
  - Central Mynarski Lake (rotational)
  - Notigi Lake (rotational)
- Off-system waterbodies:
  - Granville Lake (annual)

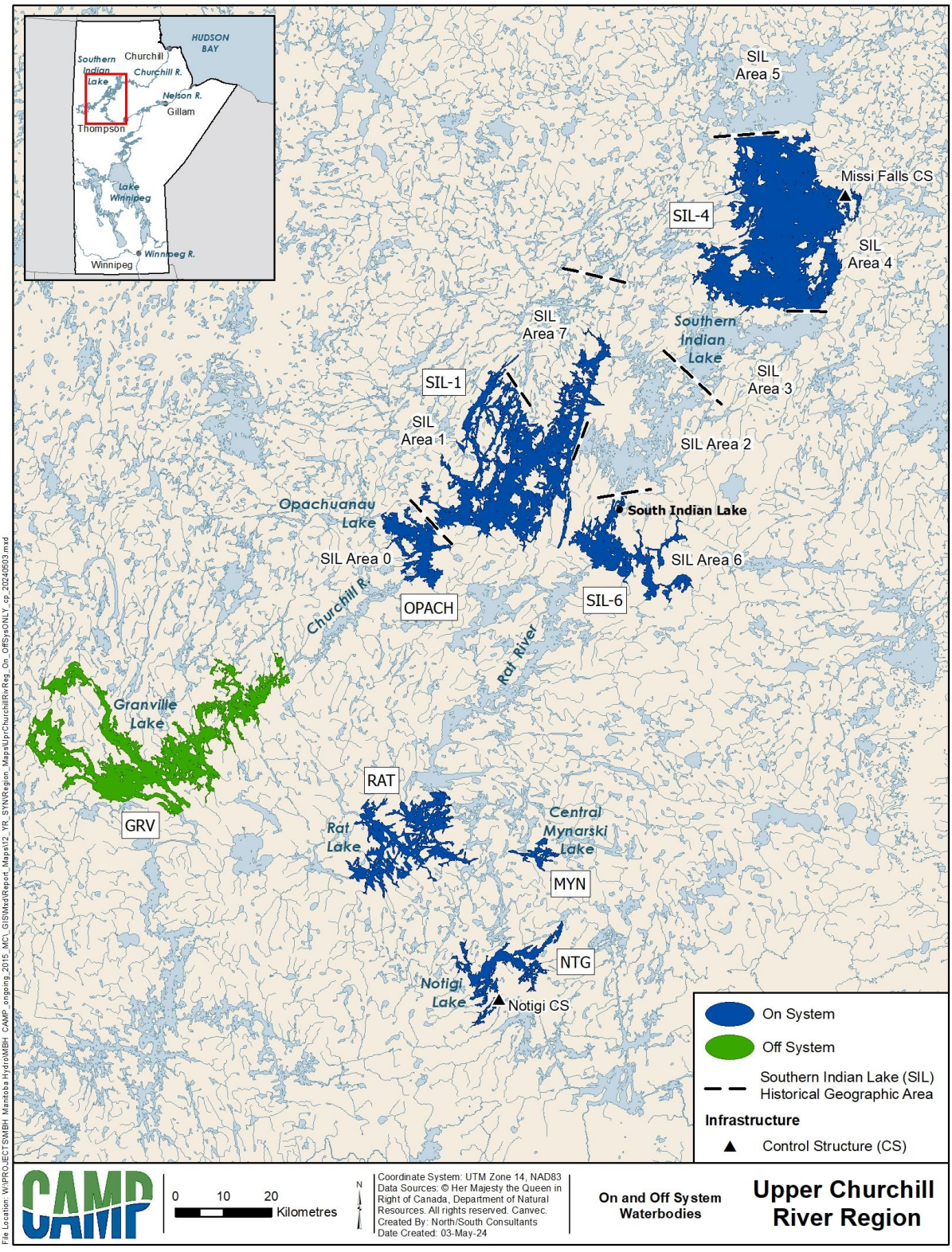

Figure 1-5. Waterbodies monitored under CAMP in the Upper Churchill River Region.

1.3.4 LOWER CHURCHILL RIVER REGION

The Lower Churchill River Region extends from the outlet of Southern Indian Lake downstream of Manitoba Hydro's Missi Falls CS to the Hudson Bay (Figure 1-6). This region spans across three ecozones: Boreal Shield; Taiga Shield; and, Hudson Plain. The dominant land cover of this region is sparse coniferous forest. The lower Churchill River currently serves as a release outlet for excess water from the northern portion of Manitoba Hydro's system, specifically when upper Churchill River flows are high and Southern Indian Lake is full, or when Nelson River flows are high, water is released down the lower Churchill River to Hudson Bay. The waterbodies monitored through CAMP in the Lower Churchill River Region are as follows:

- On-system waterbodies:
  - Northern Indian Lake (annual)
  - lower Churchill River at the Little Churchill River (annual)
  - Partridge Breast Lake (rotational)
  - Fidler Lake (rotational)
  - Billard Lake (rotational)
  - lower Churchill River at the Churchill Weir (rotational)
- Off-system waterbodies:
  - Gauer Lake (annual)

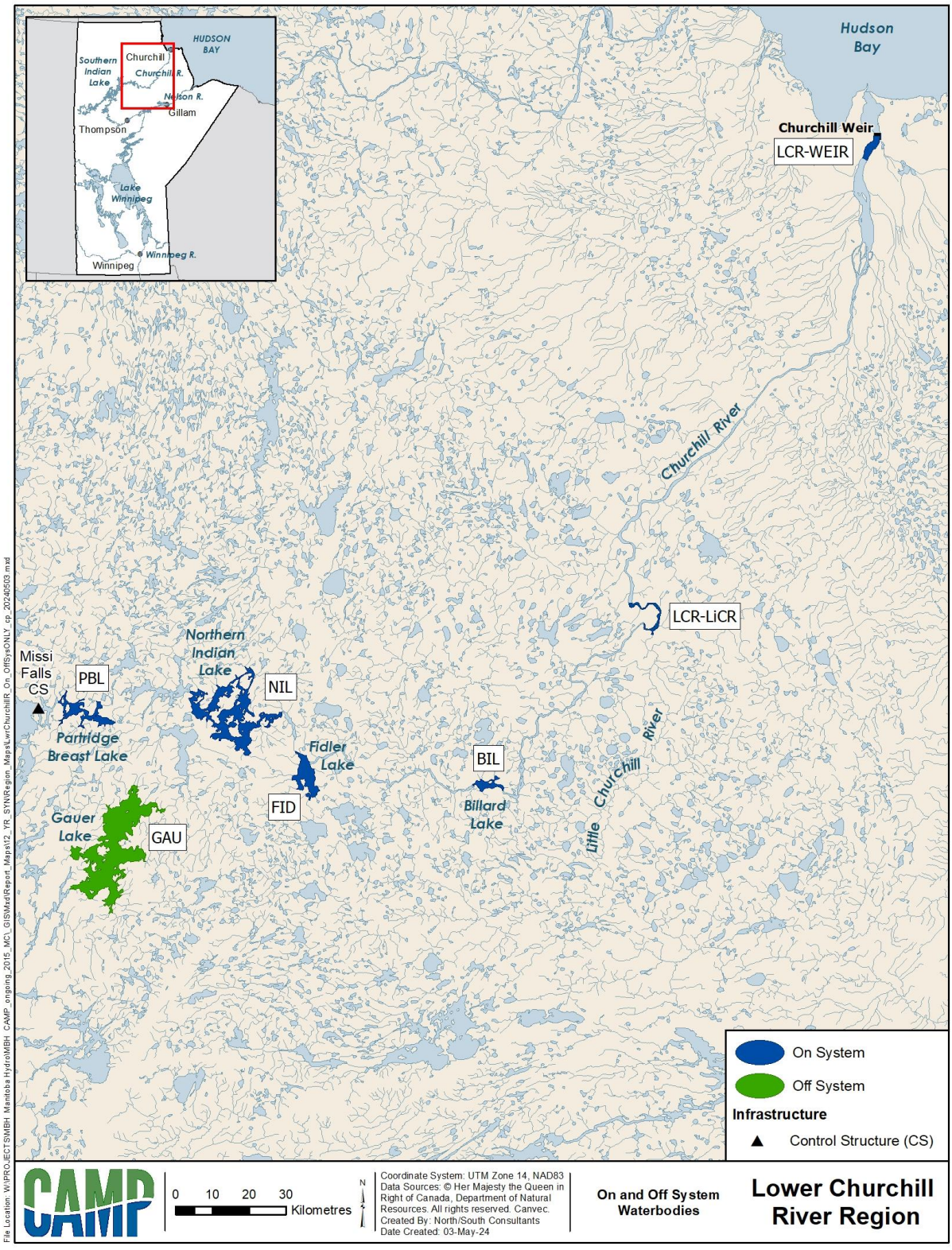

Figure 1-6. Waterbodies monitored under CAMP in the Lower Churchill River Region.

1.3.5 CHURCHILL RIVER DIVERSION REGION

The Churchill River Diversion Region extends from the Notigi CS, through the Rat/Burntwood river system to First Rapids, approximately 20 km upstream of Split Lake (Figure 1-7). Most of the Churchill River Diversion Region is in the Churchill River Upland Ecoregion of the Boreal Shield Ecozone. While waters in this region are not typically very turbid, some streams and lakes in the area are underlain by glacial clay deposits and are therefore naturally turbid. The three main components of this system are the Missi Falls CS, the Southern Indian Bay Diversion Channel, and the Notigi CS. The waterbodies monitored through CAMP in the Churchill River Diversion Region are as follows:

- On-system waterbodies:
  - Threepoint Lake (annual)
  - Footprint Lake (rotational)
  - Apussigamasi Lake (rotational)
- Off-system waterbodies:
  - Leftrook Lake (annual)

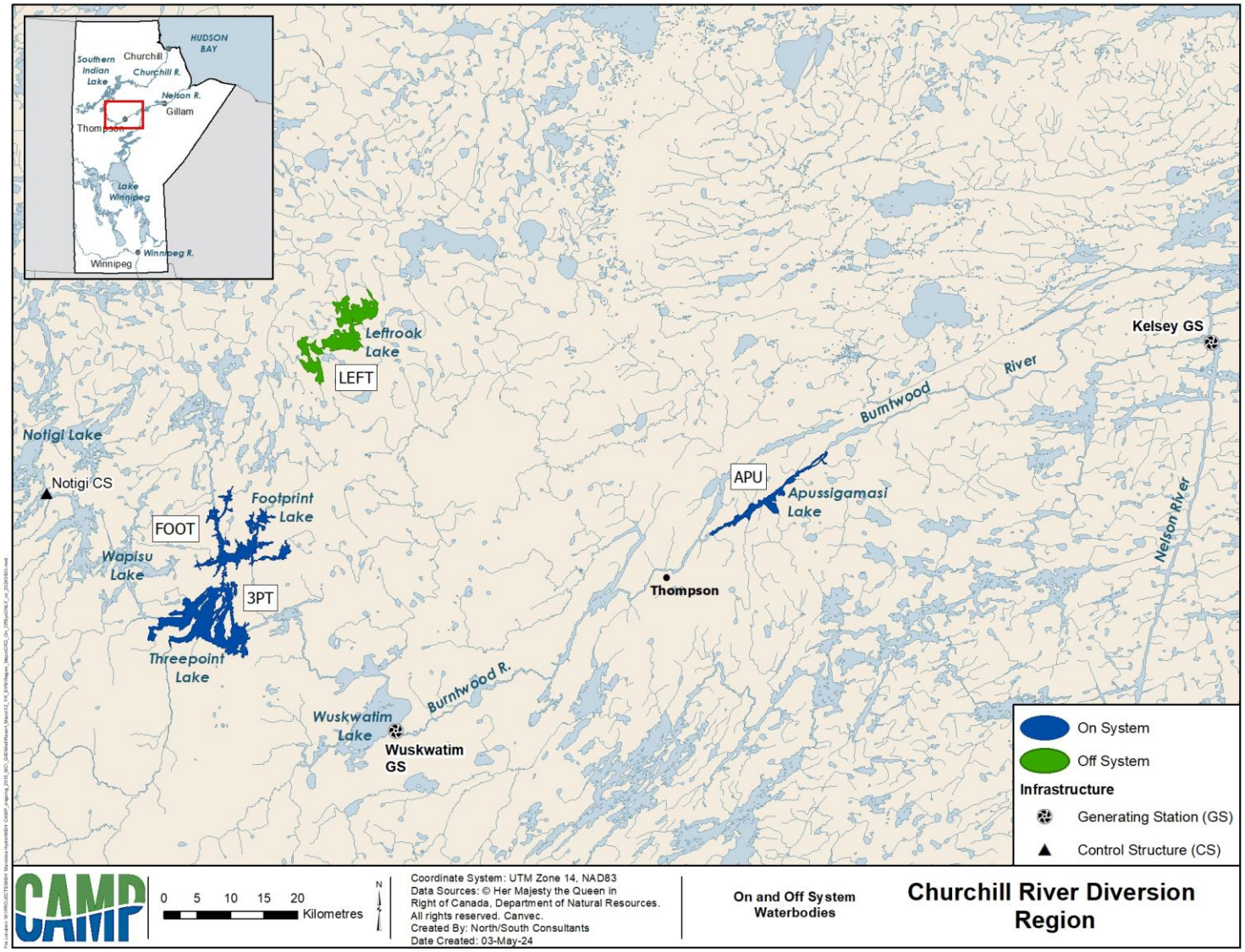

Figure 1-7. Waterbodies monitored under CAMP in the Churchill River Diversion Region.

1.3.6 UPPER NELSON RIVER REGION

The Upper Nelson River Region extends from the northern area of Lake Winnipeg (Mossy Bay) and the outlets of Lake Winnipeg (Two-Mile Channel and the Nelson River at Warren Landing) downstream to the Kelsey GS located upstream of Split Lake (Figure 1-8). This region lies exclusively in the Boreal Shield Ecozone and primarily within the Hayes River Upland Ecoregion. The Jenpeg GS controls 85% of the flows out of Lake Winnipeg into Cross Lake, while the remaining 15% of Nelson River flows pass unregulated through the East Channel into Cross Lake. At the downstream end of the upper Nelson River, the flow passes through the Kelsey GS and into Split Lake. The waterbodies monitored through CAMP in the Upper Nelson River Region are as follows:

- On-system waterbodies:
  - Lake Winnipeg – Mossy Bay (annual)
  - Two-Mile Channel (annual)
  - Nelson River at Warren Landing (annual)
  - Cross Lake (annual)
  - Playgreen Lake (rotational)
  - Little Playgreen Lake (rotational)
  - Sipiwesk Lake (rotational)
  - upper Nelson River upstream of the Kelsey GS (rotational)
- Off-system waterbodies:
  - Setting Lake (annual)
  - Walker Lake (rotational)

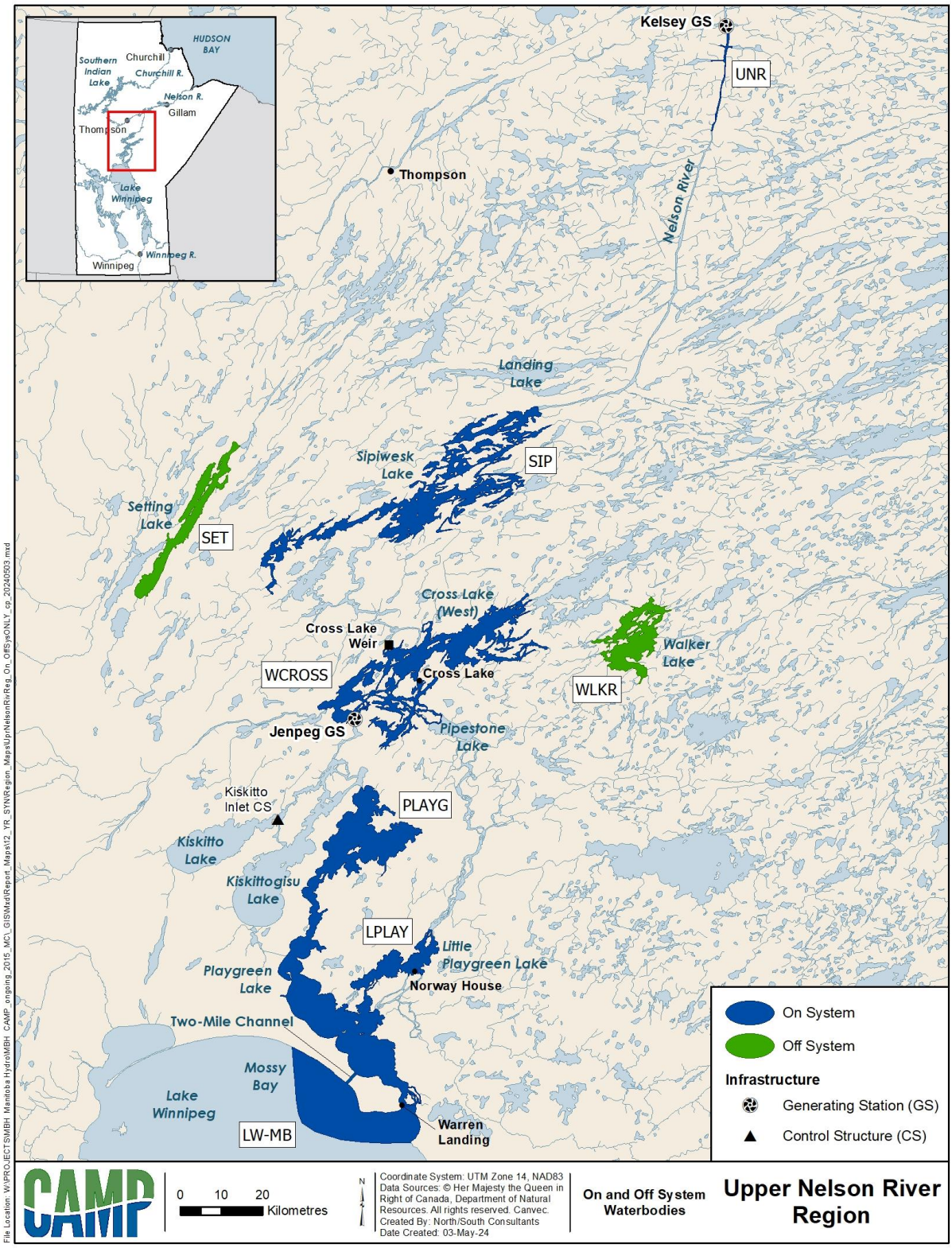

Figure 1-8. Waterbodies monitored under CAMP in the Upper Nelson River Region.

1.3.7 LOWER NELSON RIVER REGION

The Lower Nelson River Region extends from the Kelsey GS downstream to Hudson Bay and includes the Burntwood River from First Rapids to Split Lake (Figure 1-9). The lower Nelson River flows through a series of lakes and reservoirs from Split Lake to its estuary on Hudson Bay. This region is situated on the Canadian Shield, and within the Boreal Shield and Hudson Plain ecozones. The lower Nelson River is regulated for hydroelectricity generation through the Keeyask, Kettle, Long Spruce, and Limestone GSs. The waterbodies monitored though CAMP in the Lower Nelson River Region are as follows:

- On-system waterbodies:
  - Burntwood River (annual - water quality; rotational – benthic invertebrates and fish)
  - Split Lake (annual)
  - lower Nelson River downstream of the Limestone Generating Station (annual)
  - Stephens Lake - south (rotational)
  - Stephens Lake - north (rotational)
  - Limestone GS forebay (rotational)
- Off-system waterbodies:
  - Hayes River (annual)
  - Assean Lake (rotational)

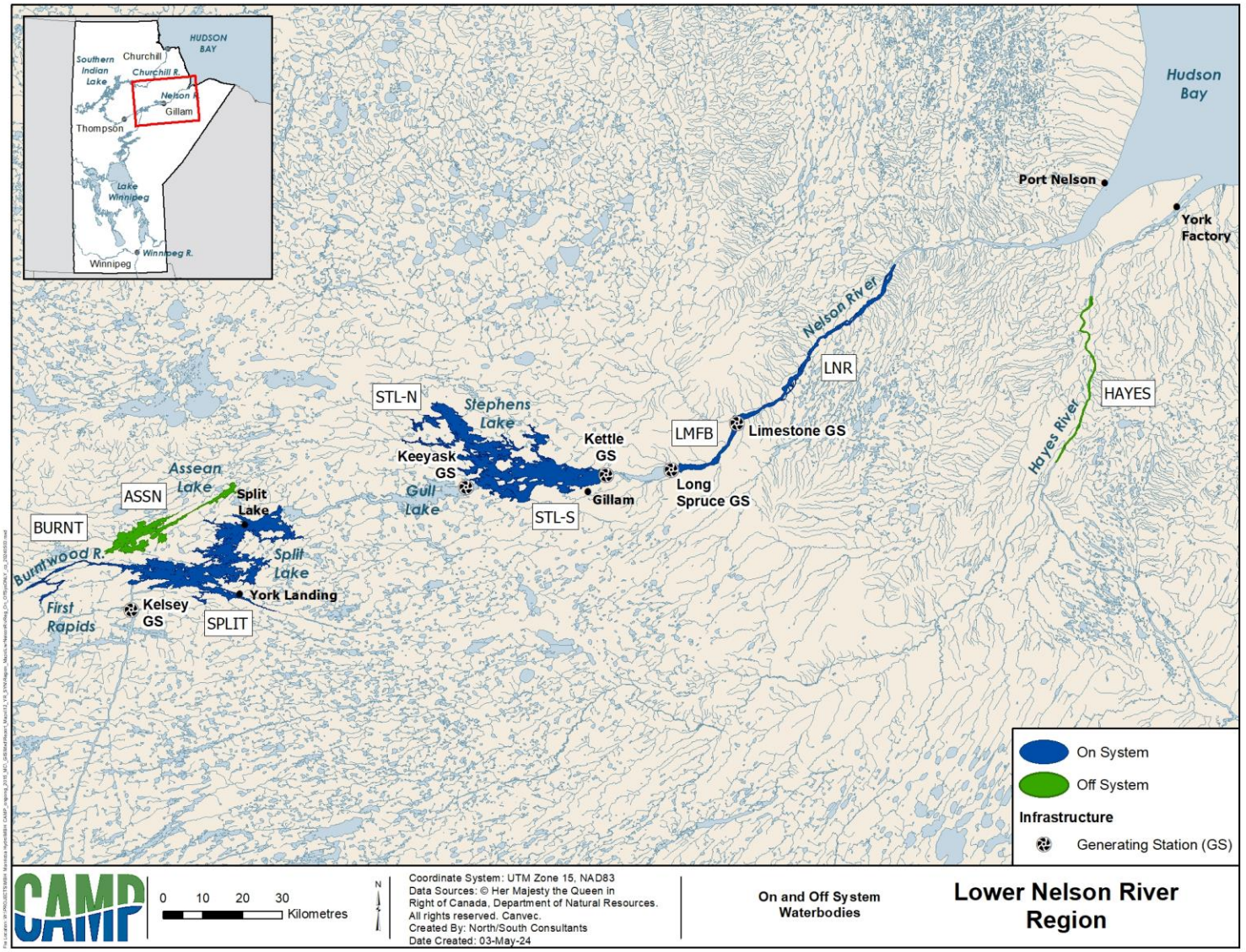

Figure 1-9. Waterbodies monitored under CAMP in the Lower Nelson River Region.

2.0 FIELD AND LABORATORY METHODS

The following provides a brief description of the field and laboratory methods for the water regime, sedimentation, water quality, benthic invertebrates, fish community, and fish mercury components of CAMP. Additional information on field methods is provided at http://www.campmb.ca/.

2.1 WATER REGIME

2.1.1 SAMPLING METHODS

2.1.1.1 FLOW AND WATER LEVEL

The forebay and tailrace water levels at a generating station were measured using water level gauges installed in stilling wells on the upstream and downstream sides of the structure, respectively. The collected data were transmitted in real-time and were used to calculate the available head. This, along with the power generated and unit performance curves established through performance testing, was used to calculate the powerhouse discharge. The spillway discharge was calculated using the forebay reading, alongside gate opening data and rating curves derived from numerical or physical model studies.

Manitoba Hydro's remote monitoring sites, often located near rivers or lakes, require access via helicopter, boat, or snowmobile. Each site is equipped with a shelter housing sensors connected to a data logger, powered by solar panels and batteries. Additionally, benchmarks were installed to calibrate water level sensors. Collected data were transmitted via satellite and underwent quality assurance and quality control (QA/QC) procedures based on Water Survey of Canada (WSC) protocols.

2.1.1.2 WATER TEMPERATURE

Water temperature monitoring was conducted using a continuous multi-parameter water quality sonde installed in generating stations and monthly visits to maintain the equipment. During monthly site visits a second multi-parameter water quality sonde was used to verify the readings and sensors were swapped out or calibrated if discrepancies were found. At permanent sites, measurements were also taken outside of the generating station in the reservoir to compare measurements with those taken inside the generating station.

2.2 SEDIMENTATION

2.2.1 SAMPLING METHODS

Sedimentation monitoring was conducted using continuous a multi-parameter water quality sonde and monthly visits to maintain the equipment and to collect water samples for laboratory analysis of total suspended solids (TSS). Permanent sites collect data year-round and are located within a generating station or control structure. Seasonal sites are installed during the open-water (summer) season within a waterbody.

The multi-parameter water quality sensors generally record turbidity, water temperature, DO, and conductivity measurements every five minutes and are stored in a central database. During monthly site visits a second multi-parameter water quality sonde was used to verify the readings and sensors were swapped out or calibrated if discrepancies were found. At permanent sites, measurements were also taken outside of the generating station in the reservoir to compare measurements with those taken inside the generating station.

Water samples were collected both inside and outside of the generating stations for laboratory analysis of TSS. All water samples were assigned barcodes for tracking purposes. Duplicate samples were collected as part of the QA/QC program.

2.2.2 LABORATORY METHODS

Grab samples for TSS analysis are collected inside the station from raw water pipes and outside the station and sent to an accredited analytical laboratory for analysis of TSS and particle size.

2.3 WATER QUALITY

2.3.1 SAMPLING METHODS

Water quality sampling was conducted four times (referred to as spring, summer, fall, and winter) per monitoring year (i.e., April-March) typically at a single location within each waterbody or area of a waterbody/river reach.

Sampling included measurement of *in situ* parameters (temperature, DO, turbidity, pH, specific conductance) across the water column (where velocities were conducive), measurement of Secchi disk depths (where velocities were conducive during the open-water season), and collection of samples of surface water for submission to an analytical laboratory accredited under Canadian

Association for Laboratory Accreditation Inc. (CALA) for analysis of conventional parameters (e.g., conductivity, pH, turbidity, and TSS), nutrients (including total and dissolved forms of phosphorus, nitrogen, and carbon), *Escherichia coli,* and total metals and major ions. See Table 2-1 for a complete list of water quality parameters measured by CAMP.

Samples for analysis of chlorophyll *a* were collected across the euphotic zone (estimated as two times the Secchi disk depth) during the open-water season at sites where velocities were conducive. At riverine sites with high velocities and at all sites in the ice-cover season, samples for analysis of chlorophyll *a* were collected as surface grabs.

At sites that were found to be thermally stratified at the time of sample collection, samples were also collected from approximately 1 m above the sediments (i.e., bottom sample) using a Kemmerer water sampler and analysed for all water quality parameters excepting chlorophyll *a* and *E. coli*.

Standard QA/QC measures were integrated into the water quality component of CAMP, including the preparation of detailed field sampling protocols, standard measures to avoid sample contamination during and following sample collection, inclusion of field QA/QC samples (triplicates, field and trip blanks, and inter-laboratory comparison samples) and QA/QC of water quality data.

2.3.2 LABORATORY METHODS

All water quality samples for laboratory analysis were submitted to a CALA accredited analytical laboratory. Inter-laboratory comparison samples for water quality were submitted to a second CALA accredited laboratory.

Table 2-1. Water quality variables measured under CAMP.

Parameter	Units	Parameter	Units
Laboratory Analyses		Total Copper (Cu)	mg/L
Conventional Parameters		Total Iron (Fe)	mg/L
Hardness (Total as $CaCO_3$)	mg/L	Total Lithium (Li)	mg/L
Total Dissolved Solids	mg/L	Total Magnesium (Mg)	mg/L
Turbidity	NTU	Total Manganese (Mn)	mg/L
Total Suspended Solids	mg/L	Total Mercury (Hg)	mg/L
True Color	True colour units	Total Molybdenum (Mo)	mg/L
pH	pH units	Total Nickel (Ni)	mg/L
Conductivity	micromhos/centimetre (µmhos/cm)	Total Potassium (K)	mg/L
Total Alkalinity ($CaCO_3$)	mg/L	Total Rubidium (Rb)	mg/L
Bicarbonate Alkalinity (HCO_3)	mg/L	Total Selenium (Se)	mg/L
Carbonate Alkalinity (CO_3)	mg/L	Total Silicon (Si)	mg/L
Hydroxide Alkalinity (OH)	mg/L	Total Silver (Ag)	mg/L
		Total Sodium (Na)	mg/L
Nutrients		Total Strontium (Sr)	mg/L
Nitrate and Nitrite	mg/L as N	Total Sulfur (S)	mg/L
Total Kjeldahl Nitrogen	mg/L as N	Total Tellurium (Te)	mg/L
Ammonia Nitrogen	mg/L as N	Total Thallium (Tl)	mg/L
Total Phosphorus	mg/L	Total Thorium (Th)	mg/L
Total Particulate Phosphorus	mg/L	Total Tin (Sn)	mg/L
Total Dissolved Phosphorus	mg/L	Total Titanium (Ti)	mg/L
Total Carbon	mg/L	Total Tungsten (W)	mg/L
Total Inorganic Carbon	mg/L	Total Uranium (U)	mg/L
Total Organic Carbon	mg/L	Total Vanadium (V)	mg/L
Total Dissolved Carbon	mg/L	Total Zinc (Zn)	mg/L
Dissolved Inorganic Carbon	mg/L	Total Zirconium (Zr)	mg/L
Dissolved Organic Carbon	mg/L	Dissolved Chloride (Cl)	mg/L
		Dissolved Sulphate (SO_4)	mg/L
Metals and Major Ions		Dissolved Fluoride (F)	mg/L
Total Aluminum (Al)	mg/L		
Total Antimony (Sb)	mg/L	**Biological Parameters**	
Total Arsenic (As)	mg/L	*Escherichia coli* (*E. coli*) [1]	Most Probable Number/100 millilitres (MPN/100 mL)
Total Barium (Ba)	mg/L	Chlorophyll *a*/pheophytin [1]	µg/L
Total Beryllium (Be)	mg/L		
Total Bismuth (Bi)	mg/L	***In situ* Measurements**	
Total Boron (B)	mg/L	Temperature	°C
Total Cadmium (Cd)	mg/L	Turbidity	NTU
Total Calcium (Ca)	mg/L	pH	pH units
Total Cesium (Cs)	mg/L	Dissolved Oxygen	mg/L
Total Chromium (Cr)	mg/L	Specific Conductance	microSiemens /centimetre (µS/cm)
Total Cobalt (Co)	mg/L	Secchi Disk Depth [2]	m

Notes:

1. Parameters are not measured in samples collected at depth (where depth samples are collected).
2. At lake sites and river sites with low velocity only. Not measured in winter.

2.4 BENTHIC INVERTEBRATES

2.4.1 SAMPLING METHODS

Benthic invertebrate community monitoring was conducted once per monitoring year in late summer or early fall. Ten invertebrate samples were collected from two sampling polygons (five nearshore samples and five offshore samples) at most sites.

The CAMP benthic invertebrate study design and sampling approach was refined prior to the 2010 field season to reduce the variability noted in the 2008 and 2009 datasets and to increase the statistical power of the data without a substantial change to effort and cost. A detailed description of field sampling methods employed in 2008 and 2009 is provided in CAMP (2014); a summary of the 2008 and 2009 methods are provided in CAMP (2017).

Five replicate stations were sampled in the nearshore (0-1 m water depth) and offshore (5-10 m water depth). A replicate station, comprised of three sub-samples, within the nearshore polygon was sampled by kicknet using a travelling-kick-sweep zig-zag pattern along three random transects that extended from the water line out to the maximum wadeable depth. Each transect was sampled for one minute to standardize the level of effort. In the nearshore habitat (intermittently exposed), water depths were ≤1 m, with consistent water movement/velocity (low or medium velocity habitat); areas containing aquatic macrophyte beds were avoided to minimize variability. The maximum water depth, water velocity, and a description of the substrate (adapted from Wentworth 1922) is recorded for each subsample.

A replicate station within the offshore polygon was sampled with a tall Ekman or a petite Ponar grab (depending on substrate composition and/or compaction). Three random benthic grab samples (subsamples) were collected and combined into one composite replicate sample. In the offshore habitat (permanently wetted), water depths were 5 to 10 m with homogeneous substrate, and consistent water movement/velocity (low or medium velocity habitat). The water depth, water velocity, and a description of the substrate is recorded for each subsample.

Benthic invertebrate samples were rinsed on-site through a 500 micron (µm) mesh sieve bucket, washed into labelled plastic jars, and fixed with a 10% formalin solution.

Samples of sediment were collected at each replicate station and analysed for total organic carbon (TOC) and particle size. Substrate samples from the nearshore polygon were collected using a plastic soup ladle or by hand; offshore substrate samples were collected using a benthic grab

sampler. Other supporting data recorded at replicate stations include location, riparian vegetation, canopy cover, algae, water colour, and water clarity; photographs of the shoreline, substrate, methods, and/or anomalies are taken to validate descriptions where necessary.

2.4.2 LABORATORY METHODS

Benthic invertebrate sample processing and taxonomic identification was conducted at the North/South Consultants Inc. laboratory. Samples were rinsed through a 500 µm brass test sieve and examined visually to determine whether splitting (sub-sampling) was required. Samples containing fewer than 300 invertebrates were sorted in their entirety. Samples containing more than 300 invertebrates were scanned to remove any large and/or rare organisms from the whole sample. A Folsom Plankton Splitter was used to divide the whole sample into equal portions and sorted until at least 300 invertebrates were counted. When the count was achieved part way through a sample fraction, the remainder was processed so that a known portion was sorted. The following taxa are not included in the 300-organism count: Ostracoda, Cladocera/Rotifera, Copepoda, Harpacticoida, Porifera, Nemata, Platyhelminthes, and non-aquatic taxa.

Benthic invertebrates were sorted from the sample matrix under a desktop magnifying lamp (3X magnification) and transferred to labelled sample vials containing 70% ethanol. The approximate proportion of the organic and inorganic component (vegetation, detritus, and/or substrate) of each sample was recorded on the laboratory data sheets. Sorted samples were checked by a second laboratory technician, to ensure that sorting efficiency was greater than 95%.

Benthic invertebrates were enumerated and identified using a Leica MZ12.5 stereomicroscope with maximum 100x magnification. The taxonomic resolution for CAMP benthic invertebrate samples is:

- family or lowest practical level for non-Insecta;
- family level for Insecta; and,
- genus level for Ephemeroptera.

Benthic invertebrate taxonomy was performed using reference texts: Clifford (1991), Merritt and Cummins (1996), Merritt et al (2019), Peckarsky et al. (1990), Smith (2001), Stewart and Stark (2002), and Wiggins (2004). Scientific names used followed the Integrated Taxonomic Information System classification (ITIS 2023). Taxonomic identifications were verified (i.e., subject to QA/QC) by a second taxonomic specialist for 10% of randomly selected samples. The target accuracy for

identifications was 90%; identifications and/or enumeration discrepancies were corrected on the taxonomic data sheet.

Sediment samples were submitted to a CALA accredited analytical laboratory for analysis of particle size and TOC.

2.5 FISH COMMUNITY

2.5.1 SAMPLING METHODS

Six to 24 fish community sites were typically established in each waterbody, primarily based on the size of the waterbody. Gillnetting sites were selected to provide a broad spatial representation and to avoid bias towards certain habitat types or fish species. Sites were selected based on the use of sites fished in existing monitoring programs, sites pre-selected based on habitat characteristics, and sites selected during the first (and sometimes subsequent) field visits based on either habitat characteristics or simply the ability to set a net at that site.

In lakes, sampling sites were distributed between shallow and deep areas, while in rivers, sampling sites were generally selected based on the practicality of setting a net in a given location and, to the degree possible, to encompass the full extent of the sampling area and habitat types. In a few waterbodies, some sites established under the pilot program were discontinued and were replaced with new sites. Typically, this was done to improve spatial coverage across the waterbody, to provide more equal representation of a variety of habitat types, or to eliminate a site where physical conditions did not allow the gill nets to be set properly.

In general, the fish community monitoring was conducted at approximately the same time of year within a given waterbody during each year monitoring was conducted. Sampling was undertaken using standard gang index gill nets, which consisted of five 22.9 m long by 1.8 m deep panels of 51 mm (2”), 76 mm (3”), 95 mm (3.75”), 108 mm (4.25”), and 127 mm (5”) green twisted nylon mesh (stretched). At approximately every third site, the smallest mesh end of the standard gang was attached to the largest mesh end of a small mesh index gillnet gang, which consisted of three - 10 m long by 1.8 m deep panels of 16 mm, 20 mm, and 25 mm clear monofilament mesh. Nets were set perpendicular to the nearest shore, except in riverine locations where current dictates that nets are set parallel to the flow. Standard gang sites were labeled as GN-# and small mesh sites were labeled as SN-#. All gillnet gangs were set for approximately 24 hours. Set times at the lower Churchill River at the Little Churchill River were reduced to approximately 16 hours to

minimize Lake Sturgeon mortality. Each time a site was sampled a number of details about the site were collected, including:

- Universal Transverse Mercator (UTM) coordinates at each end of the gang(s);
- Site photos;
- Which end of the net was closer and orientation (in degrees) to shore;
- Water depth at each end of the gang;
- Water temperature;
- Secchi disc depth;
- Air temperature;
- Wind direction and speed;
- Water velocity (e.g., none/standing, low, medium, high);
- Aquatic vegetation present (e.g., none, low, medium, high); and
- Debris type (e.g., aquatic vegetation, aquatic moss; silt/mud, sticks/logs, algae, terrestrial vegetation, or clams) and quantity (e.g., none, medium, high, very high, gang destroyed or gang).

All fish captured in standard gang and small mesh index gill nets at each site were counted by mesh size and species. Individual metrics were taken from all specimens of selected species (Walleye [*Sander vitreus*], Sauger [*Sander canadensis*; starting in 2017], Northern Pike [*Esox lucius*], White Sucker [*Catostomus commersonii*; starting in 2010], and Lake Whitefish [*Coregonus clupeaformis*]). The information collected from the selected species included:

- fork length (± 1 mm);
- weight (± 10 grams [g]);
- sex and state of maturity;
- occurrence of Deformities, Erosion, Lesions, and Tumours (DELTs); and
- ageing structures (otoliths from Walleye, Sauger, and Lake Whitefish and cleithra from Northern Pike).

In addition to the species listed above, Lake Sturgeon were weighed, measured for fork length and total length, and inspected for DELTs. Fins were collected for age analysis from any Lake Sturgeon (*Acipenser fulvescens*) mortality. All other fish species from each mesh in the standard gangs were separated by species, counted and bulk weighed (±10 g) and any remaining fish from small mesh gangs were not separated by mesh but were counted and bulk weighed (± 10 g for large-bodied species or ± 1 g for small-bodied species).

2.5.2 LABORATORY METHODS

Fish ageing analyses were conducted on otoliths (Lake Whitefish, Sauger, and Walleye) and cleithra (Northern Pike) by NSC and Manitoba – Fisheries Branch. Otoliths were aged using the "crack and toast" method where each otolith was first placed on a hard surface, seated on a piece of paper towel, and scored cross wise across the focus with a scalpel until the otolith snapped in half. The cracked plane of one half of the otolith was then lightly polished utilizing a Foredom® BL-1A Bench Lathe (Foredom Electric Company, Bethel, CT) customized with a coarse stone wheel and a secondary fine grit sandpaper attachment. After polishing, each otolith was "toasted" by slowly passing the cracked and polished plane of the otolith in and out of the tip of the flame of an alcohol-filled Bunsen Burner until it darkened. The cracked, polished, and toasted otolith was then inserted into plasticine with the cracked edge facing up, a drop of clearing medium (i.e., oil of wintergreen or water) was applied to the cracked surface, and finally the otolith was viewed under a dissecting microscope with reflected light.

Cleithra were boiled to remove any tissue or oil residue remaining on the structure following removal from the fish. Cleithra were typically read "free hand" (i.e., without magnification) at NSC; however, a dissecting microscope or magnified ring light was used when required. Manitoba – Fisheries Branch used a magnified ring light to read all cleithra.

At both agencies, all structures were viewed once by an experienced ageing technician and assigned an age and confidence index rating based on qualitative and quantitative characteristics of the structure. Internal QA/QC measures included ageing of 10% of the structures from each waterbody by an alternate experienced ageing technician not involved in the initial age determination. After the internal QA/QC was completed, 10% of the ageing structures collected in that sampling year were exchanged between NSC and Manitoba – Fisheries Branch and were aged to assess accuracy and consistency between agencies.

2.6 FISH MERCURY

2.6.1 SAMPLING METHODS

Fish mercury sampling was conducted annually at two waterbodies in the Churchill River Diversion Region (Leftrook and Threepoint lakes) and at all other waterbodies on a three-year rotation. Samples of fish skeletal muscle are collected during the conduct of the fish community monitoring from 36 individuals of three species of large-bodied fish (Lake Whitefish, Northern Pike, and

Walleye) under CAMP. The individuals chosen for mercury analysis of these three species were to represent a broad size range and, as much as possible, an equal representation of size classes.

In addition to these large-bodied, long-lived fish, up to 25 individual 1-year-old (1+) Yellow Perch were also sampled for mercury analysis. Yellow Perch were retained for mercury analysis based on their length; aged Yellow Perch from previous collections in Manitoba indicate that 1-year-old Yellow Perch nearing the end of their second summer measure between 60-100 mm fork length.

Large-bodied fish were measured for fork length and total weight, examined internally to determine sex and maturity, and bony structures were removed for age analysis (otoliths were dissected from Lake Whitefish and Walleye, and cleithra were collected from Northern Pike). A portion of axial muscle weighing approximately 10-100 g was removed from each fish anterior to the caudal (tail) fin for mercury analysis. The muscle with skin attached was covered with cling-wrap, placed in a Whirl-Pac bag with internal and external labeling, and stored on ice until it could be frozen. Whole Yellow Perch were placed individually or as a group into labeled Whirl-Pac bags and stored on ice until they could be transferred into a freezer. Frozen tissue samples and whole Yellow Perch were shipped to the NSC laboratory in Winnipeg for further processing.

2.6.2 LABORATORY METHODS

Partially thawed Yellow Perch were measured for length (fork and total) and weight in the laboratory and otoliths were removed for age determination. A "carcass" sample was processed for mercury analysis, which entailed the removal of all internal organs and severing the head (dorso-ventral oblique cut to anterior of the pelvic girdle) and the tail (at the caudal peduncle). The Yellow Perch samples were then weighed and wrapped in cling-wrap. Fish aging of both the Yellow Perch otoliths and structures collected from the large-bodied species in the field were aged as described in Section 2.5.2.

Frozen muscle samples and carcasses were submitted to a CALA accredited laboratory for mercury analysis. Mercury was analysed by cold vapour atomic fluorescence (CVAF) until 2017 and by cold vapour atomic absorption spectrophotometry (CVAAS) thereafter. The muscle samples from large-bodied fish were analyzed with the skin and scales removed.

Quality assurance/quality control measures included the analysis of duplicates at the primary laboratory and an inter-laboratory comparison of samples at a second laboratory. Duplicate samples for both intra- and inter-laboratory comparison were prepared by splitting the muscle samples and submitting for analysis.

3.0 ANALYSIS AND REPORTING METHODS

Data presented in this report are for the period of 2008/2009 through 2018/2019. Monitoring years presented and described in this report are for the period of April-March (e.g., April 2008 through March 2009).

Monitoring results are presented for the following CAMP components including:

- Climate[1]
- Water regime;
- Sedimentation;
- Water quality;
- Benthic invertebrates;
- Fish community; and
- Fish mercury.

Results for water quality, benthic invertebrates, fish community, and fish mercury are presented in tables and figures including for some metrics, boxplots. Information presented in boxplots include the mean, median, minimum, maximum, 25th percentile (lower quartile), 75th percentile (upper quartile), whiskers (which denote the limits beyond which data are considered outliers), and outliers; an example boxplot is provided in Figure 3-1.

Interquartile ranges (IQR) of water quality, benthic invertebrates, fish community, and fish mercury monitoring data over the 12-year period were calculated and presented in various figures; the IQR presents the range between the 25th and 75th percentile values for a given metric for all data from the 12-year period combined. Additional details regarding data analysis and presentation for each of the main components are provided below.

[1] Climate is not monitored under CAMP. However, climate data from Environment Climate Change Canada is included in reporting.

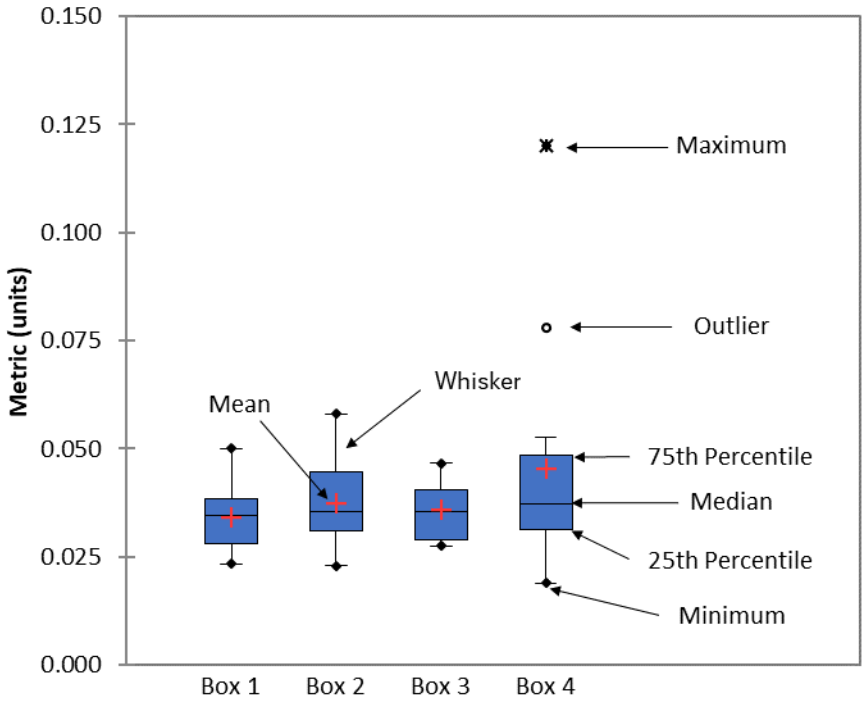

Figure 3-1. Example boxplot figure.

3.1 CLIMATE

Though climate is not monitored under CAMP, climatological data are included in CAMP reporting to provide context for data collected under monitored components. For each region, air temperature and precipitation data from a meteorological station are compared to ECCC climate normals to provide a summary of the conditions at that particular location. As recommended by the World Meteorological Organization, ECCC calculates climate normals using a 30-year period (e.g., 1981-2010).

Historical monthly average air temperature and total monthly precipitation during the monitoring period were calculated based on available daily data from ECCC at multiple stations. It is important to note that the use of multiple stations could introduce inhomogeneities in observations between various stations and the station used for climate normals (Climate ID: 5032162). For instances where datasets were missing more than 10% of the daily data in a month, monthly values were gap-filled using ERA5-Land data.

3.2 WATER REGIME

3.2.1 DATA ANALYSIS

3.2.1.1 DISCHARGE AND WATER LEVEL

All water level and discharge data undergo thorough verification processes before being deemed suitable for use. Station operators routinely calibrate the gauge by comparing manual and electronic measurements to ensure accuracy, while data from remote sites follow WSC protocols for approval. This process ensures the reliability of the data used to within this report.

3.2.2 DATA PRESENTATION

A record of daily mean discharge into and out of CAMP waterbodies has been included to describe the movement of water within each region, presented as a flow hydrograph. Similarly, the daily mean water level for each site is also provided as a water level hydrograph. These hydrographs allow for visual comparison of differences between years and illustrate peak and low flow events over the reporting period. Additionally, they demonstrate whether, and to what extent, the water level varies with flow.

The data are also presented as heat maps, with cells color-coded according to the classification criteria (included in heat plots), showcasing individual sites' monthly average discharge, monthly average water level, and monthly average water level variance. This facilitates straightforward comparisons across sites and highlights periods of wetter or drier conditions, and aids in identifying higher or lower water levels and corresponding variability.

3.2.2.1 WATER TEMPERATURE

All water temperature data were reviewed prior to analyzing the data for data outliers. The continuous data were compared to monthly discrete measurements taken to validate the data and corrections made. Where data were available, the number of days that water temperature was below 1°C and within 5 °C intervals was calculated.

3.3 SEDIMENTATION

3.3.1 DATA ANALYSIS

All sedimentation data were reviewed prior to analyzing the data for data outliers. The continuous data were compared to monthly discrete measurements taken to validate the data and corrections made. Hourly and monthly average turbidity was calculated from the 5-minute data after outliers and poor quality data had been removed.

To calculate the sediment load, a TSS/Turbidity ratio was calculated for each monthly discrete sampling event. For TSS values below 2 mg/L (analytical detection limit [DL]) a value of 1 mg/L was used. The following equation was used to calculate the average daily sediment load:

$$Qs = Q * Tu * (TSS/Tu\ ratio) * 0.0864$$

where:

Qs = sediment load in Tonnes/day

Q = average daily river discharge in cms

Tu = average daily turbidity; and

0.0864 = conversion factor

3.3.2 DATA PRESENTATION

Sedimentation data are presented for all sites that monitoring was completed during the reporting period. The sedimentation monitoring that includes continuous water quality monitoring was gradually added to the CAMP suite of monitoring and was not done in all regions during the current reporting period.

The average hourly data and monthly average data and box plots are shown for turbidity and calculated suspended sediment load.

3.4 WATER QUALITY

3.4.1 DATA ANALYSIS

All water quality data analyses treated values reported as below the analytical DL as equal to one half the DL. In cases where triplicate samples were collected, sample means were used for the determination of summary statistics and analyses. Total nitrogen (TN) was determined as the sum of total Kjeldahl nitrogen and nitrate/nitrite nitrogen.

Potential outliers were identified through data review and plotting. Few outliers were formally removed from the data analysis and reporting, with the exception of DO data for which issues were identified and a number of DO measurements were removed from the datasets for reporting purposes. Removal of other outliers from the datasets is documented within the presentation of results.

3.4.2 DATA PRESENTATION

Water quality data were summarized and are presented separately for the open-water and ice-cover seasons. Summary statistics presented for water quality metrics include mean, median, minimum, maximum, standard deviation (SD), standard error of the mean (SE), 25^{th} and 75^{th} percentiles (i.e., IQR), number of samples (n), and percent detections (i.e., the percentage of values reported as above the analytical DL). Summary statistics for the ice-cover season at rotational waterbodies do not include median or IQR due to the small sample size (i.e., $n<5$).

Where sufficient data were available (i.e., annual waterbodies with a minimum of five years of data), boxplots summarizing conditions observed during each sampling period (i.e., spring, summer, fall, and winter) over the 12-year period were also presented.

3.4.3 COMPARISON TO DISSOLVED OXYGEN OBJECTIVES FOR THE PROTECTION OF AQUATIC LIFE

DO concentrations were compared to the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) instantaneous minimum objectives for the protection of aquatic life (PAL; Manitoba Water Stewardship [MWS] 2011). As PAL objectives for DO vary according to the presence of mature or early life history stages of cool- or cold-water aquatic life, different objectives were applied to the open-water and ice-cover seasons. The following objectives were applied to CAMP waterbodies:

- open-water season:
  - the instantaneous minimum objective of 4 mg/L for mature life stages of cold-water aquatic life, and
  - the instantaneous minimum objective of 5 mg/L for early life stages of cool-water aquatic life; and
- ice-cover season:
  - the instantaneous minimum objective of 8 mg/L for early life stages of cold-water aquatic life, and
  - the instantaneous minimum objective of 3 mg/L for mature life stages of cool-water aquatic life.

3.4.4 TROPHIC STATUS CLASSIFICATION

Trophic status of all CAMP waterbodies (rivers, lakes, and reservoirs) was classified utilizing the Canadian Council of Ministers of the Environment (CCME) Canadian phosphorus guidance framework for the management of freshwater systems (CCME 1999; updated to 2024) and the trophic state categorization scheme based on total phosphorus (TP; Table 3.1-1). The CCME trophic classification scheme for TP is intended to be applied to all freshwater ecosystems including rivers.

Lake and reservoir trophic states were also classified according to the Organization for Economic Cooperation and Development (OECD 1982) categorization scheme based on chlorophyll *a*, and the categorization scheme for total nitrogen presented by Nürnberg (1996).

The trophic classification schemes based on total nitrogen and chlorophyll *a* for rivers presented in Dodds et al. (1998) were applied to CAMP riverine sites (Table 3.1-2). River sites were defined based on the Natural Resources Canada Canvec 1:50000 topographic database.

Table 3-1. Trophic categorization schemes applied for CAMP lakes and reservoirs.

Trophic Categories	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
Ultra-oligotrophic	<0.004	-	-
Oligotrophic	0.004-0.010	<0.350	<2.5
Mesotrophic	0.010-0.020	0.350-0.650	2.5-8
Meso-eutrophic	0.020-0.035	-	-
Eutrophic	0.035-0.100	0.651-1.20	8-25
Hypereutrophic	> 0.100	>1.20	>25
References	CCME (1999; updated to 2024)	Nürnberg (1996)	OECD (1982)

Notes:

1. CCME = Canadian Council of Ministers of the Environment.
2. OECD = Organization for Economic Cooperation and Development.

Table 3-2. Trophic categorization schemes applied for CAMP riverine sites.

Trophic Categories	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
Ultra-oligotrophic	<0.004	-	-
Oligotrophic	0.004-0.010	<0.7	<10
Mesotrophic	0.010-0.020	0.7-1.5	10-30
Meso-eutrophic	0.020-0.035	-	-
Eutrophic	0.035-0.100	>1.5	>30
Hypereutrophic	> 0.100	-	-
References	CCME (1999; updated to 2024)	Dodds et al. (1998)	Dodds et al. (1998)

Notes:

1. CCME = Canadian Council of Ministers of the Environment.

3.5 BENTHIC INVERTEBRATES

3.5.1 DATA INCLUDED IN REPORTING

This report includes the 2010 to 2019 invertebrate and supporting habitat datasets. The 2008 and 2009 benthic invertebrate datasets were excluded from the analysis because the study design and sampling approach were modified prior to the 2010 field program to reduce the variability noted in the first two years of the CAMP.

3.5.2 DATA ANALYSIS

In cases where invertebrate samples were sub-sampled, counts were multiplied by the split fraction to estimate the numbers in a whole sample. For example, if one quarter of the sample

was analyzed, invertebrate counts were multiplied by the split correction factor of four. Large and/or rare invertebrates (if present) were then added to the estimated count.

Substrate parameters (% sand, silt, clay, and % total organic carbon) identified as below the detection limit by the analytical laboratory were assigned a value of one half of the DL.

3.5.2.1 ABUNDANCE

Density (number of invertebrates per m^2) was derived by dividing the sample counts by the bottom area of the benthic grab sampler (0.023104 m^2) and then dividing by three (number of sub-samples). Kicknet sample counts are reported as number of invertebrates per sample and standardized according to sampling effort (a total of three minutes per sample) instead of sampler area.

Total invertebrate abundance (or total invertebrate density) was derived by summing all benthic invertebrates in a sample to report the value as total no. per kicknet sample (or total no. per m^2).

3.5.2.2 COMMUNITY COMPOSITION

Relative proportion (%) of the major benthic invertebrate groups was derived by dividing the abundance of each group by the total invertebrate abundance and multiplying by 100. The major benthic invertebrate groups are: Oligochaeta (aquatic worms), Amphipoda (amphipods or freshwater shrimps), Bivalvia (clams and mussels), Gastropoda (snails), Ceratopogonidae (biting midges), Chironomidae (non-biting midges), other Diptera (aquatic flies, other than biting and non-biting midges), Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies), Corixidae (water boatmen), Coleoptera (aquatic beetles), and all other taxa (all remaining aquatic invertebrates, such as leeches, alderflies, dragonflies, etc.).

The Ephemeroptera, Plecoptera, and Trichoptera (EPT) index was derived by dividing the summed abundances of the Ephemeroptera, Plecoptera, and Trichoptera by the total invertebrate abundance and multiplied by 100 to report the value in percent (%). The Oligochaeta and Chironomidae (O+C) index was calculated by dividing the summed abundances of the Oligochaeta and Chironomidae by the total invertebrate abundance and multiplied by 100 to report the value in percent (%).

3.5.2.3 TAXONOMIC RICHNESS

Total taxa richness was identified as the total number of distinct taxa at the family-level in each replicate sample. EPT taxa richness was identified as the total number of distinct taxa at the family-level within the groups Ephemeroptera, Plecoptera, and Trichoptera within each replicate sample.

3.5.2.4 DIVERSITY

Hill's effective species richness (Hill's index, H') is a measure of the number of taxa (i.e., richness) and the distribution of the different taxa (i.e., evenness) making up the community. Hill's index was derived by calculating the exponent of Shannon's heterogeneity index (H) value at the family-level:

$$H' = \exp(-\sum p_i * (\ln[p_i]))$$

where: p_i is the relative proportion of each taxon.

3.5.3 DATA PRESENTATION

Total invertebrate abundance (or density), EPT index, O+C index, richness, and diversity metric data were displayed by site and year in boxplots to show the summary statistic values (minimum, maximum, median, mean, 1st and 3rd quartiles) and outliers (all outliers were retained). The overall mean, overall median, and interquartile range for the reporting period (i.e., 2010-2019) were calculated and plotted on boxplots. Relative abundance of major groups was displayed by site and year within the following specified categories: 0%; <1 to 15%; >15% to 25%; >25% to 50%; and >50%. Sampling locations and supporting habitat data, organized by site and year, are presented in appendices.

3.6 FISH COMMUNITY

3.6.1 DATA INCLUDED IN REPORTING

Over the 12-year period there has been some variation in the number and location of gillnetting sites in some waterbodies. Reasons for this have included, but are not limited to, logistical issues preventing site access (e.g., equipment failures), modifications to the program (particularly after the pilot program), and unsafe conditions (i.e., high water velocities, debris). To make the data included in the 12-year analysis as consistent as possible, guidelines were established for the inclusion of data from sites as follows:

- Sites fished for 75% or more of the scheduled sampling years were included (i.e., minimum of 9 of 12 years for annual waterbodies, or 3 of 4 years for rotational waterbodies);
- Sites that were fished as an alternate/substitute for a target site (e.g., target site could not be fished due to high wind conditions, site set in close proximity to a target site prior to its establishment as a target) were included; and
- Sites set as "one-offs" (e.g., additional sites set in the pilot program, additional nets set for targeting additional fish, etc.) were excluded.

A description of the data included for each waterbody, including exceptions to the approach described above, is provided in appendices within each Regional Technical Document.

In some cases, biometric data (i.e., fish ages, fork lengths, and weights) were excluded from the analysis when they were identified as outliers in plots of log transformed length versus weight or age versus length. In addition, any biometric data collected for species prior to their inclusion as a target species in a region/waterbody (i.e., White Sucker, Sauger, Lake Whitefish) were excluded from the analysis.

3.6.2 DATA ANALYSIS

3.6.2.1 STANDARD INDEX CATCH-PER-UNIT-EFFORT

Catch-per-unit-effort (CPUE) was calculated by standardizing Lake Whitefish, Northern Pike, Sauger, Walleye, White Sucker, and the total catch of fish in the standard index gill nets to a 100-m long net over 24 h using the formula:

$$CPUE = C / E \times 24\ h / L \times 100\ m$$

where:

C = catch (number of individuals of a species or the total number of fish caught);

E = effort (hours); and

L = length of the gillnet gang.

CPUE was first calculated for each site and these values were then averaged to calculate a waterbody-specific value. Sites with net set durations greater than 36 hours were excluded from these CPUE analyses.

3.6.2.2 SMALL MESH INDEX CATCH-PER-UNIT-EFFORT

Catch-per-unit-effort was calculated by standardizing the total catch of fish in the small mesh index gill nets to a 30-m long net over 24 h using the formula:

$$CPUE = C / E \times 24\ h / L \times 30\ m$$

CPUE was first calculated for each site and these values were then averaged to calculate a waterbody-specific value. Sites with net set durations greater than 36 hours were excluded in these CPUE analyses.

3.6.2.3 FULTON'S CONDITION FACTOR

Fulton's condition factor (KF; Ricker 1975) was calculated for Lake Whitefish, Northern Pike, Sauger, Walleye, and White Sucker as:

$$KF = W \times 10^5 / FL^3$$

where:

W = round weight (g); and

FL = fork length (mm).

KF typically increases with fish length, limiting its application to fish of similar length (Blackwell et al. 2000; Murphy et al. 1991; Pope and Kruse 2007). To account for this limitation and to facilitate comparisons among years and waterbodies, species-specific fork length ranges were established, as follows:

- 200-349 mm FL for Sauger;
- 300-499 mm FL for Lake Whitefish, Walleye, and White Sucker; and
- 400-699 mm FL for Northern Pike.

3.6.2.4 RELATIVE WEIGHT

Lake Whitefish, Northern Pike, Sauger, Walleye and White Sucker relative weight (Wr) was calculated in a three-step process. The first step was to convert fish fork lengths collected under CAMP to the total lengths required to calculate relative weight using empirical length-length equations (Table 3-3). Once fork lengths were converted to estimated total lengths, species-specific, published, empirical standard weight equations were then used to calculate the log10

transformed standard weight of each fish in the sample using each fish's log10 transformed estimated total length (Table 3-4). Finally, the predicted log10 transformed standard weight calculated for each fish in step two was then back transformed to an untransformed standard weight, and divided by each fish's field measured weight to obtain relative weight, using the equation:

$$Wr = W/Ws \times 100$$

where:

Wr = a fish's relative weight;

W = a fish's actual observed, field measured round weight; and

Ws = a fish's standard weight calculated in step two.

Table 3-3. Length-length coefficients (α = intercept and β = slope of the regression line) used to estimate male and female fish total length (TL) from fork length (FL).

Species	Unknown Length (mm)	α[1]	β[1]	Known Length (mm)	Source
White Sucker	TL	1.4991	1.0782	FL	Province of Manitoba[2]
Northern Pike	TL	9.1108	1.0473	FL	Province of Manitoba[2]
Lake Whitefish	TL	6.8847	1.0953	FL	Rennie and Verdon (2008)
Sauger	TL	4.9607	1.0483	FL	Province of Manitoba[2]
Walleye	TL	7.0286	1.0436	FL	Province of Manitoba[2]

Notes:

1. When β is only present, fish fork length was multiplied by β, and when α and β were both present the formula α + β × FL was used.
2. D. Pisiak and G. Klein pers. comm.

Table 3-4. Summary of standard weight (Ws) equations and minimum total length (TL) used to calculate relative weight for CAMP target fish species.

Species	log Ws Equation	Minimum TL (mm)	Source
White Sucker	2.94×log10(TL)-4.76	100	Bister et al. (2000)
Northern Pike	3.10×log10(TL)-5.44	100	Willis (1989)
Lake Whitefish	3.22×log10(TL)-5.56	100-700	Rennie and Verdon (2008)
Sauger	3.16×log10(TL)-5.45	70	Guy et al. (1990)
Walleye	2.87×log10(TL)-4.80	30-149	Flammang and Olson (1999)
Walleye	3.18×log10(TL)-5.45	150	Murphy et al. (1990)

3.6.2.5 FORK LENGTH-AT-AGE

Growth was characterized by fork length-at-age (mm) and focused on the fork length distribution of fish of a given age selected for each species. The age selected was 3 years for Walleye and Sauger, 4 years for Northern Pike, and 4 years for Lake Whitefish. The age selected for each species was chosen to represent fish that are large enough to be recruited into the sampling gear, but are still young enough to be prior to, or at, the age of first maturity (immature fish are allocating energy to growth rather than reproduction). Another factor considered for the selection of the age-class was whether there were enough fish in the year-class for statistical analyses.

3.6.2.6 RELATIVE YEAR-CLASS STRENGTH

A relative year-class strength (RYCS) index value was calculated for Lake Whitefish, Northern Pike, Sauger, and Walleye based on the methodologies from Manitoba Hydro and the Province of Manitoba (2015), Mann (1973), Frear Cowx (2003), and Böhling et al. (1991). Because RYCS analysis requires a minimum of two or more surveys in consecutive years, RYCS could only be calculated for waterbodies that are monitored annually. An index value was calculated for each cohort following four steps:

1. The percentage of fish of each age in the catch was calculated for each of the sample years (e.g., the number of 5-year-old fish sampled in 2008).
2. The mean percentage of fish of each age for the whole sampling period was calculated (e.g., the total number of 5-year-old fish sampled from 2008–2016).
3. For each year class, the value from Step 1 was divided by the value from Step 2 and multiplied by 100 to generate the proportion of the age of that year class in each year, relative to the proportion for the whole sampling period (e.g., for the 2003 year class, the percent of 5-year-old fish in 2008 ÷ percent of 5-year-old fish in 2008–2016 × 100; the percent of 6-year-old fish in 2009 ÷ percent of 6-year-old fish in 2008–2016 × 100; etc.).
4. The index was then calculated by summing the values from Step 3 for a given year class and dividing the sum by the number of times that year class occurred within the sample period (e.g., the 2003 year class was sampled 9 times from 2008–2016, in 2008 as age 5, in 2009 as age 6, in 2010 as age 7, in 2011 as age 8, in 2012 as age 9, in 2013 as age 10, in 2014 as age 11, and in 2015 as age 12).

The range of ages included in the calculation was restricted to those that are reasonably well represented in the catch. For CAMP, the minimum age is typically between 3-5 years, which is when the target species are typically recruited into the standard gang index gill nets and the upper

age limit is restricted to ages reasonably well represented in the catch (i.e., the most common age-classes that are well represented in all years). These ranges may vary by waterbody and species. Fish captured in small mesh nets were excluded from the calculation of RYCS since this type of gill net is not set at all sites and not all fish captured in small mesh nets are aged.

Cohorts with index values >100 are considered stronger year classes compared to those <100 (Frear and Cowx 2003).

3.6.2.7 HILL'S EFFECTIVE SPECIES RICHNESS (HILL'S INDEX)

Hill's effective species richness is a measure of the number of species (i.e., richness) and the distribution of the different species (i.e., evenness) making up the community in an area. Hill's effective species richness (i.e., Hill's Index) was calculated for the combined small mesh and standard gang index gillnet catches using the formula:

$$H = \exp(-\Sigma Si(pi \times \ln pi))$$

where: pi = the proportion of each of i species.

3.6.2.8 RELATIVE SPECIES ABUNDANCE

Relative species abundance (RSA) is a measure of species diversity that is calculated as the proportion of the number of a particular species relative to the total catch. The metric was calculated separately for the small mesh and standard gang index gillnet catches using the formula:

$$RSA = Cx / Ct \times 100$$

where:

Cx = number of fish caught of species x; and

Ct = total number of fish caught.

3.6.3 DATA PRESENTATION

The catch-per-unit-effort of individual species and the total catch in the standard gangs, the catch-per-unit-effort of the total catch in the small mesh index gill nets, Fulton's condition factor, relative weight, and fork-length-at-age data were displayed by year in boxplots to show the summary statistic values (minimum, maximum, median, mean, 1st and 3rd quartiles) and outliers

(all outliers were retained). The overall mean, median, and interquartile range for the reporting period (i.e., 2008-2019) were calculated and plotted on boxplots.

Because of the difference in the number of samples (i.e., individual fish) with biometric measurements (i.e., age, fork length, and weight), the calculation of the overall statistics that included these measurements were weighted by the number of fish sampled.

Relative Year-Class Strength was plotted as a histogram and Hill's Effective Species Richness was plotted as a scatter plot (as only single values per year are generated for these metrics). The overall statistics (i.e., IQR, mean, median) could not be calculated for RYCS since the entire dataset is used in the analysis and the index does not result in annual values like the other metrics. Relative abundance of the fish species was displayed by site and year within the following specified categories: 0%; >0 to 5%; >5% to 10%; >10% to 25%; >25% to 50%, and >50%. Sampling locations and supporting set information, organized by site and year, are presented in appendices.

3.7 FISH MERCURY

Length-standardized mercury concentrations (also referred to as standard means) were derived for the large-bodied target species (Lake Whitefish, Walleye, and Northern Pike). The standard lengths used for derivation of length-standardized mercury concentrations (Lake Whitefish - 350 mm fork length, Northern Pike - 550 mm, and Walleye - 400 mm) were consistent with those used in previous Manitoba fish monitoring programs (see summary in Jansen and Strange 2007).

Length-standardized mean mercury concentrations were calculated from unique regression equations generated by species and waterbody from the relationship between logarithmic transformations of the muscle mercury concentrations (parts per million [ppm]) and fork lengths (mm) of each individual using the following formula:

$$\text{Log10 Hg} = a + b \times \text{Log10 L}$$

where:

Hg = muscle mercury concentration (ppm);

L = fork length (mm);

a = Y-intercept (constant); and

b = slope of the regression line (coefficient).

Data presented in this report for mercury in Yellow Perch were restricted to fish aged as 1-year-olds (1+) based on examination of otoliths. Data transformation was not undertaken for Yellow Perch as CAMP targets a specific age-class of this species and fish captured for this component are inherently of a limited size range.

All data analyses treated censured values (i.e., values reported as below the analytical DL) as equal to half of the DL.

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