Manitoba/Manitoba Hydro

Coordinated Aquatic Monitoring Pilot Program (CAMPP):

Three Year Summary Report (2008-2010) - Volume 1

Sections 1-4: Introduction and Background; CAMP Regional Descriptions; CAMP Waterbodies; Approach and Methods

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COORDINATED AQUATIC MONITORING PILOT PROGRAM (CAMPP)

MANITOBA/MANITOBA HYDRO COORDINATED AQUATIC MONITORING PILOT PROGRAM (CAMPP): THREE YEAR SUMMARY REPORT (2008-2010)

A Report Prepared for Manitoba/Manitoba Hydro MOU Working Group

by

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EXECUTIVE SUMMARY

Introduction

The Coordinated Aquatic Monitoring Program (CAMP) represents 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 in Manitoba.

CAMP integrates components of existing Manitoba Conservation and Water Stewardship (MCWS) and Manitoba Hydro long-term monitoring programs and was designed to document the environmental condition of waterways affected by Manitoba Hydro's hydraulic operating system and facilitate a better understanding over time, of the environmental effects of hydroelectric operations.

A three year Pilot Program – referred to as the Coordinated Aquatic Monitoring Pilot Program or CAMPP - was conducted from 2008/2009 through 2010/2011 to test methodologies and logistics for the long-term implementation of CAMP. This report presents the results of this Pilot Program, but also provides an overall description of the long-term CAMP.

Background

Over the last 35 years, numerous aquatic environmental studies and monitoring programs have been conducted by Manitoba, Manitoba Hydro, Fisheries and Oceans Canada (DFO), Environment Canada (EC), and several academic institutions on waterways affected by hydroelectric development in Manitoba, including several large-scale and/or long-term aquatic surveys. However, the majority of Manitoba Hydro's study and research to date has been focused in northern Manitoba and has been largely issue-driven and site-specific. As a result, historical studies have not been comprehensive or consistent across Manitoba Hydro's hydraulic system. Similarly, MCWS has conducted monitoring in some of the waterbodies along Manitoba Hydro's hydraulic system. These programs have spanned a large area and typically used consistent methods; however, these programs contained spatial or temporal gaps or variations in sampling intensity or collection methods. A comprehensive program that combined the valuable features of both entities was lacking.

With the need for a long-term coordinated aquatic monitoring program recognized, Manitoba determined that a Memorandum of Understanding (MoU) between Manitoba and Manitoba Hydro should be developed to identify and coordinate existing aquatic monitoring programs and to develop or expand monitoring programs as required to ensure that a consistent system-wide approach to aquatic environmental monitoring was implemented. The MoU was drafted by Manitoba and signed in 2006, and resulted in the development of CAMP. CAMP integrates components of existing MCWS and Manitoba Hydro long-term monitoring programs and addresses gaps that were identified in these existing programs. This integrated approach provides the basis for the largest coordinated monitoring program undertaken in Manitoba to date.

Why Do It?

The need for a coordinated approach to monitoring was identified during the environmental review process for the Wuskwatim Generation Project. Long-term and coordinated aquatic monitoring will strengthen the understanding of the effects of hydroelectric development on the aquatic ecosystem and support more informed decision making when it comes to water management.

What is CAMP?

CAMP represents a coordinated effort between Manitoba and Manitoba Hydro to implement a long-term, systematic and system-wide aquatic monitoring program across Manitoba Hydro's hydraulic operating system. The MoU established the following set of general objectives from which the program was developed (i.e., MOU Objectives):

- Assist in evaluating whether and to what extent the water regime in the areas of the system is or will be affected by the addition of additional hydro-electric facilities;
- Assist in identifying adverse effects and positive effects resulting from effects on the water regime; and,
- Assist in considering measures that may be undertaken to address any identified adverse effects.

From the MoU Objectives, a more refined set of objectives were established to help direct the program's development and implementation. These are referred to as CAMP Objectives and include the following:

- Coordinate standardized monitoring of aquatic ecosystem health by Manitoba and Manitoba Hydro via important physical, chemical and biological parameters from selected waterbodies within (on-system) and outside (off-system) of Manitoba Hydro's hydraulic system;
- Provide regular reporting on scientifically relevant indicators of aquatic ecosystem health;

- Provide the public and stakeholders with timely and accurate information on the state of waterbodies in Manitoba Hydro's system and seek feedback on the program;
- Annually review the program to ensure scientific rigor and evaluate applicability of new aquatic monitoring technologies, methodologies and protocols; and,
- Coordinate with researchers and regulators to identify research priorities to address needs or information gaps detected by the program.

Developing the Science (What Goes In)

CAMP has been designed to collect a range of environmental information with emphasis on components that are potentially affected by hydroelectric regulation. CAMP draft objectives and protocols were developed with representatives of federal and provincial agencies (e.g., DFO, EC, MCWS) and have been presented to Resource Management Boards, First Nations, and local communities for input and feedback to help guide their development.

Sampling protocols were developed by MCWS and Manitoba Hydro, with input from EC, DFO, and academics to provide a standardized approach to monitoring. Field sampling protocols were developed which included detailed descriptions of sampling methods and quality assurance/quality control measures for each CAMP component. Still, the science of CAMP is continually changing and evolving. Annual workshops are held following each year's open water monitoring season to discuss implementation of the previous year's field program and any changes required to the scientific protocols and/or program.

CAMP Components

CAMP incorporates an ecosystem-based approach to monitoring that includes sampling of key physical, chemical, and biological components of the aquatic environment. The major components monitored under CAMP are: hydrometrics; aquatic habitat; water quality; sediment quality; phytoplankton; benthic macroinvertebrates; fish communities; and fish mercury.

Scope of CAMP

CAMP is intended to identify long-term trends or changes in aquatic ecosystems and includes sampling of some waterbodies/areas annually, supplemented with monitoring in additional waterbodies on a three-year rotational basis. Additionally, CAMP includes the collection of physical aquatic habitat information on a one time basis only.

CAMP is conducted in eight regions that encompass Manitoba Hydro's hydraulic operating system. The regions span the province from southeastern Manitoba to the lower Churchill River in northern Manitoba and encompass five of the six ecozones in Manitoba and the majority of Manitoba's ecoregions. The eight regions included in CAMP are: Winnipeg River Region; Saskatchewan River Region; Lake Winnipeg Region; Upper Churchill River Region; Lower Churchill River Region; Churchill River Diversion Region; Upper Nelson River Region; and, Lower Nelson River Region.

Waterbodies monitored under CAMP include on-system and off-system locations. On-system waterbodies are those located on, and that are notably influenced by, Manitoba Hydro's hydraulic operating system (e.g., forebays and areas downstream of hydroelectric generating stations and control structures). Off-system waterbodies include lakes and areas of rivers where water levels and flows are either entirely or largely unaffected by Manitoba Hydro's hydraulic operating system. However, some waterbodies considered as off-system may still be subject to regulation of flows by other organizations (i.e., the Churchill, Saskatchewan and Winnipeg rivers).

Products (What Comes Out)

A significant amount of information has been, and will continue to be, generated through implementation of CAMP. A data management system for CAMP was identified and utilized from the initiation of the Pilot Program, to ensure data are stored in a manner that will facilitate long-term accessibility and use, and to ensure associated metadata are documented.

To meet Manitoba's and Manitoba Hydro's needs under the terms of the MoU, as well as to meet the needs of the public and the scientific community, three levels of reporting were defined in the reporting strategy for CAMP, and include: (1) an electronically prepared annual activity report submitted to MCWS and Manitoba Hydro; (2) a CAMP website (http://campmb.com/), which provides a detailed description of the program and presents a subset of data collected under CAMP; and, (3) a technical report prepared every three years. This report represents the first Three-Year Synthesis Report (technical report) produced for CAMPP. It is intended to provide a documentation of monitoring and the results of monitoring conducted during the Pilot Program which spanned a three year period from 2008/2009 through 2010/2011.

Contents of This Report

This report represents the first Three Year Synthesis Report produced under CAMP and provides the following:

- An introduction to CAMP and its key objectives;
- Information on Manitoba Hydro's generation system;

- Descriptions of the CAMP regions and waterbodies included in the program;
- Descriptions of CAMP site selection and methods employed under the Pilot Phase of the program (i.e., CAMPP);
- Summaries of recommendations generated from annual workshops; and,
- Results of the three-year Pilot Program (i.e., CAMPP) that was conducted from 2008/2009 through 2010/2011.

ACKNOWLEDGEMENTS

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MASTER TABLE OF CONTENTS

VOLUME 1

VOLUMES 2-8: RESULTS OF THE THREE YEAR PROGRAM

VOLUME 2

VOLUME 3

VOLUME 4

VOLUME 5

VOLUME 6

VOLUME 7

VOLUME 8

VOLUME 9

LIST OF APPENDICES

LIST OF ABBREVIATIONS

3PT	Threepoint Lake
AFS	American Fisheries Society
ANOVA	Analysis of variance
APU	Apussigamasi Lake
ASL	Above sea level
ASSN	Assean Lake
B	Biomass
BCMELP	British Columbia Ministry of Environment, Land, and Parks
BCMOE	British Columbia Ministry of the Environment
BIL	Billard Lake
BMI	Benthic macroinvertebrate(s)
BPUE	Biomass-per-unit-effort
BURNT	Burntwood River at Split Lake
CABIN	Canadian Aquatic Biomonitoring Network
CALA	Canadian Association for Laboratory Accreditation Inc.
CAMP	Coordinated Aquatic Monitoring Program
CAMPP	Coordinated Aquatic Monitoring Pilot Program
CCME	Canadian Council of Ministers of the Environment
CCREM	Canadian Council of Resource and Environment Ministers
CEDAR-SE	Cedar Lake-Southeast
CEDAR-W	Cedar Lake-West
CEO	Chief Executive Officer
CFIA	Canadian Food Inspection Agency
CFU	Colony forming units
CGVD	Canadian Government Vertical Datum
CHIRON	Chironomidae
CORM	Cormorant Lake

COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPUE	Catch-per-unit-effort
CRD	Churchill River Diversion
CRDR	Churchill River Diversion Region
CRM	Certified reference material
CROSS	Cross Lake
CS	Control structure(s)
DELT	Deformities, erosion, lesions and tumours
DFO	Fisheries and Oceans Canada (formerly known as Department of Fisheries and Oceans Canada)
DGPS	Differential global positioning system
DIN	Dissolved inorganic nitrogen
DL	Detection limit
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DP	Total dissolved phosphorus
d/s	Downstream
EAGLE	Eaglenest Lake
EC	Environment Canada
EEM	Environmental Effects Monitoring
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies)
EPT:C	Ratio of the combined abundances of Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies) to the abundance of Chironomidae (non-biting midges)
ESRI	Environmental Systems Research Institute
FEMP	Federal Ecological Monitoring Program
FID	Fidler Lake
FL	Fork length

FOOT	Footprint Lake
FSA	Fisheries Stock Assessment
FWIN	Fall Walleye index netting
GAU	Gauer Lake
GIS	Geographic Information System
GN	Standard gang index gillnet site
GPS	Global positioning system
GRV	Granville Lake
GS	Generating station(s)
GS of C	Geodetic Survey of Canada
HAYES	Hayes River
HPLC	High performance liquid chromatography
IBI	Index of biotic integrity
INCO	International Nickel Company of Canada
ITIS	Integrated Taxonomic Information System
K	Condition Factor; Brody growth coefficient
kW h	Kilowatt hours
L	Fork length (mm)
LCR-LiCR	Lower Churchill River at the Little Churchill River
LCRR	Lower Churchill River Region
LCR-RHR	Lower Churchill River at Red Head Rapids
LDB	Lac du Bonnet
LEFT	Leftrook Lake
LMFB	Limestone Forebay
LNR	Nelson River (downstream of the Limestone GS)
LNRR	Lower Nelson River Region
LPLAY	Little Playgreen Lake
LWCB	Lake of the Woods Control Board
LWCNRSB	Lake Winnipeg, Churchill and Nelson Rivers Study Board

LWR	Lake Winnipeg Regulation
LWRC	Lake Winnipeg Research Consortium
MANIG	Manigotagan Lake
Max	Maximum value
MCWS	Manitoba Conservation and Water Stewardship
MEMP	Manitoba Ecological Monitoring Program
MIEM	Manitoba Innovation, Energy and Mines
Min	Minimum value
MoU	Memorandum of Understanding
MQO	Measurement quality objective
MW	Megawatts
MWQSOGs	Manitoba Water Quality Standards, Objectives, and Guidelines
MWS	Manitoba Water Stewardship
MYN	West/Central Mynarski Lake
n	Sample size
N	Nitrogen
NHP	National Hydrometric Program
NIL	Northern Indian Lake
NMEA	National Marine Electronics Association
NSC	North/South Consultants Inc.
NTG	Notigi Lake
NTG-E	Notigi Lake-East
NTG-W	Notigi Lake-West
NTU	Nephelometric turbidity units
OC	Organic carbon
OECD	Organization for Economic Cooperation and Development
OLIGO	Oligochaeta
ON	Organic nitrogen
OPACH	Opachuanau Lake

ORP	Oxidation-reduction potential
P	Phosphorus
PAL	Protection of aquatic life
PBL	Partridge Breast Lake
PDB	Pointe du Bois Forebay
PFF	Pine Falls Forebay
PLAYG	Playgreen Lake
ppm	Parts per million
PRSD	Percent relative standard deviation
PSA	Particle size analysis
QA/QC	Quality assurance/quality control
QTC	Quester Tangent Corporation
R	Software program
RA	Relative abundance
RAT	Rat Lake
RPMD	Relative percent mean difference
SASK	Saskatchewan River
SD	Standard deviation
SE	Standard error of the mean
SET	Setting Lake
SIL	Southern Indian Lake
SIL-1	Southern Indian Lake-Area 1
SIL-4	Southern Indian Lake-Area 4
SIL-6	Southern Indian Lake-Area 6
SIP	Sipiwesk Lake
SMOOSE	South Moose Lake
SN	Small mesh index gillnet site
SPLIT	Split Lake
SRM	Standard reference materials

SRR	Saskatchewan River Region
STL-N	Stephens Lake-North
STL-S	Stephens Lake-South
TANCO	Tantalum Mining Corporation
TBD	To be determined
TCU	True colour units
TDS	Total dissolved solids
TIC	Total inorganic carbon
TKN	Total Kjeldahl nitrogen
TL	Total length
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
TPP	Total particulate phosphorus
TSS	Total suspended solids
UCRR	Upper Churchill River Region
UNR	Upper Nelson River upstream of Kelsey GS
UNRR	Upper Nelson River Region
u/s	Upstream
UTM	Universal Transverse Mercator
VBGM	Von Bertalanffy growth model
W	Weight
WLKR	Walker Lake
WPGOSIS	Lake Winnipegosis
WQI	Water quality index
WRR	Winnipeg River Region
YOY	Young-of-the-year

SECTION 1.0: INTRODUCTION

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION AND BACKGROUND

The Coordinated Aquatic Monitoring Program (CAMP) represents 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 in Manitoba. A three year Pilot Program – referred to as the Coordinated Aquatic Monitoring Pilot Program or CAMPP - was conducted from 2008/2009 through 2010/2011 to test methodologies and logistics for the long-term implementation of CAMP. This report presents the results of this Pilot Program, but also provides an overall description of the long-term CAMP.

Over the last 35 years, numerous aquatic environmental studies and monitoring programs have been conducted by Manitoba, Manitoba Hydro, Fisheries and Oceans Canada (DFO), Environment Canada (EC), and several academic institutions on waterways affected by hydroelectric development in Manitoba. These studies have included:

- Post-project environmental monitoring programs to determine the effects of existing facilities;
- Environmental assessment studies to determine the potential effects of future hydroelectric developments;
- Issue- and site-specific environmental studies to address community concerns and/or formal obligations;
- Monitoring of intensively used fish stocks on the system, such as commercial fisheries;
- Monitoring of water quality;
- The collection of hydrometric data;
- Monitoring associated with debris management programs; and
- Research in areas such as reservoir greenhouse gases, marine mammals, mercury, and lake sturgeon.

Examples of large-scale and/or long-term aquatic study or monitoring programs that have been conducted along Manitoba Hydro's hydraulic system include the following:

- The Lake Winnipeg, Churchill and Nelson Rivers Study Board (LWCNRSB) pre-Churchill River Diversion (CRD) and Lake Winnipeg Regulation (LWR) studies conducted from 1971 to 1975;
- The Federal Ecological Monitoring Program (FEMP) conducted from 1986 to 1992;

- The Canada – Manitoba Agreement on the Study and Monitoring of Mercury in the Churchill River Diversion conducted from 1982 to 1985;
- The Manitoba Ecological Monitoring Program (MEMP), conducted from 1985 through 1989, which complimented FEMP and transitioned from the 1982-1985 mercury monitoring program;
- Long-term monitoring of water quality by Manitoba Conservation and Water Stewardship (MCWS) and EC; and
- Long term mercury monitoring under various agreements from 1991-present.

The majority of Manitoba Hydro's study and research conducted to date has been focused on the northern part of Manitoba Hydro's hydraulic system. These studies have been effective at meeting regulatory requirements and assessing impacts caused by Manitoba Hydro's facilities. The studies, however, have been largely issue-driven and site-specific, which have reflected varying regulatory requirements at the time of approval of each of the facilities, and historically, greater emphasis has been placed on regions where communities are located. As a result, historical studies have not been conducted in a comprehensive or consistent manner across Manitoba Hydro's hydraulic system.

Concurrent with Manitoba Hydro's aquatic environment studies, MCWS has conducted monitoring in selected waterbodies along Manitoba Hydro's hydraulic system for resource management and environmental monitoring purposes. As these programs spanned a relatively large spatial scale, they have generally been conducted with consistent methods of data collection. However, these provincial monitoring programs also contained spatial and/or temporal gaps or variations in sampling intensity or collection methods.

With the need for a long-term coordinated aquatic monitoring program recognized, Manitoba determined that a Memorandum of Understanding (MoU) between Manitoba and Manitoba Hydro should be developed to identify and coordinate existing aquatic monitoring programs and to develop or expand monitoring programs as required to ensure that a consistent system-wide approach to aquatic environmental monitoring was implemented.

Accordingly, the MoU was drafted by Manitoba and signed in 2006, and resulted in the development of CAMP. CAMP integrates components of existing MCWS and Manitoba Hydro long-term monitoring programs and addresses gaps that were identified in these existing programs. This integrated approach provides the basis for the largest coordinated monitoring program undertaken in Manitoba to date.

CAMP was designed to document the environmental condition of waterways affected by Manitoba Hydro's hydraulic operating system and facilitate a better understanding over time, of the environmental effects of hydroelectric operations. The primary objectives of CAMP are:

- To monitor and document the physical, chemical, and biological conditions of Manitoba Hydro's existing hydraulic system, in accordance with established scientific protocols;
- To provide long-term information on key physical, chemical, and biological parameters that can be used to assess environmental conditions and track aquatic ecosystem health over time; and
- To provide information that can assist with: a) the licensing of future developments; b) the renewal of licenses at existing developments; and c) the assessment of the potential impacts of new hydroelectric developments on the existing hydraulic system[1].

CAMP has been designed to collect a range of environmental information with emphasis on components that are potentially affected by hydroelectric regulation. CAMP draft objectives and protocols were developed with representatives of federal and provincial agencies (e.g., Fisheries and Oceans Canada [DFO], EC, MCWS) and have been presented to Resource Management Boards, First Nations, and local communities for input and feedback to help guide their development.

Data collection under CAMP was initiated in spring 2008 and began with a three year Pilot Program (i.e., CAMPP). This report documents and describes the results of the three year Pilot Program conducted from 2008/2009 through 2010/2011, and includes a description of the program, methods and results.

The following section provides an overview of:

- Linkages between hydroelectric development and aquatic ecosystems;
- A description of CAMP, including monitoring components and spatial and temporal scope;
- Descriptions of CAMP monitoring regions;
- Development of scientific protocols;
- Database and data management; and
- Reporting framework.

[1] *Given the broad geographic scale of the program, information collected will by necessity lack the intensive sampling rigor required to prepare comprehensive Environmental Impact Statements for new facilities.*

Subsequent sections in this report provide the following:

- Section 2: CAMP Regional Descriptions;
- Section 3: CAMP Waterbodies;
- Section 4: Approach and Methods;
- Section 5: Results of Three Year Program; and
- Section 6: Summary of CAMPP Results.

1.1 LINKAGES BETWEEN HYDROELECTRIC DEVELOPMENT AND AQUATIC ECOSYSTEMS

Hydroelectric development modifies the aquatic ecosystem through various pathways or linkages of effect. The primary physical change related to the construction and operation of a hydroelectric generation station (GS) or control structure (CS) in relation to aquatic ecosystems is an increase in upstream water levels, resulting in the flooding of existing aquatic and terrestrial habitat, and downstream changes in water levels and flows. The extent of upstream flooding depends on the design of the GS (i.e., mode of operation), as well as the topography/morphology of the upstream terrestrial habitat. Generally, the upstream waterbody is expanded and deepened and water velocities are reduced as a result of impoundment. Aquatic habitat may also be directly lost due to the footprint of physical structures and in dewatered riverbeds immediately downstream of the structures.

Systems regulated for hydroelectric generation generally experience changes in water level/flow and ice regimes in accordance with the operating regime of the hydraulic operating system. The overall range of water level/flow variation may be reduced, but the frequency of water level/flow changes can occur more frequently, than in an un-regulated condition.

Water quality may be affected both upstream and downstream of GSs due to alterations in hydrology (water levels, depths, velocities), ice regimes, and flooding of terrestrial habitat. In addition, water diversion may affect water quality in cases where the water quality of the diverted flows differs from that of the aquatic system receiving the diverted flows.

Hydraulic effects (e.g., the creation of new habitat and alteration of existing habitat) and water quality effects may create cascading effects throughout the food web. The base of the food web is often affected (e.g., altering growing conditions for primary producers, including vascular plants and algae), causing subsequent changes at successive consumer levels (e.g. lower trophic organisms, fish). Consumers are also affected directly through habitat alterations. Examples of this include the loss of fish spawning habitat due to flooding and the blockage of upstream fish movements.

Humans are linked to the aquatic ecosystem in many ways, including the harvest and consumption of fish. Important hydroelectric-related effects may include adverse effects to the abundance and quality of species that are targeted in fisheries due to the provision of increased access to fish harvesting areas, as well as effects to the quality of fish that would affect their suitability for consumption.

The Coordinated Aquatic Monitoring Program (CAMP) has been designed to monitor the condition of the aquatic ecosystems along Manitoba Hydro's hydraulic system in consideration of these potential linkages of effect and includes monitoring of physical, chemical, and biological components of the aquatic environment.

1.2 DESCRIPTION OF CAMP

The Coordinated Aquatic Monitoring Program (CAMP) was established to monitor aquatic ecosystems throughout Manitoba Hydro's hydraulic operating system. The program was designed by Manitoba and Manitoba Hydro, with input from federal agencies (i.e., Department of Fisheries and Oceans [DFO], Environment Canada [EC] and external academic participants, to monitor key physical, chemical, and biological attributes of waterways affected by Manitoba Hydro's hydraulic generation system, including the Churchill River Diversion (CRD)/Lake Winnipeg Regulation (LWR), and hydroelectric development on the Winnipeg, Nelson, and Saskatchewan rivers in Manitoba. Sampling design and frequency were selected by Manitoba and Manitoba Hydro, with input from DFO and EC, to provide scientifically defensible monitoring information to meet scientific expectations and regulatory requirements within the limitations of what is technically feasible. As part of the MoU, a working group was established to oversee the development and delivery of CAMP and is responsible for submitting annual reports required under the MoU to the Minister of MCWS and the CEO of Manitoba Hydro. The program is intended to be adaptive if necessary and is reviewed regularly, including through an annual workshop attended by representatives of Manitoba, Manitoba Hydro, academic institutions, EC, and DFO, and is modified as warranted, in response to findings of the program and feedback received from workshop attendees.

CAMP was designed to provide a series of snapshots of the condition of the various aquatic ecosystems. Monitoring results will be compared to existing environmental health criteria (e.g., water quality guidelines) and to previous years' data and over time the information gathered will be used to identify changes in the environment and assess whether these changes are as a result of hydroelectric operations, other management activities (e.g. commercial fishing), or natural variation. For the foreseeable future, interpretation of changes identified during CAMP will use a weight of evidence approach. This approach integrates results of all components of CAMP to assess whether there is evidence of change occurring and, if so, in the long-term assess whether this change can be attributed to hydroelectric operations.

1.2.1 CAMP Components

The Coordinated Aquatic Monitoring Program (CAMP) was designed based on experience from existing monitoring programs in Manitoba, Canada, and globally. CAMP incorporates an ecosystem-based approach to monitoring that includes sampling of key physical, chemical, and biological components of the aquatic environment.

An ecosystem consists of the living and non-living components of the environment. Energy in the form of nutrients flows through a trophic structure/biological assemblage and transfers nutrients among living and non-living parts. An ecosystem-based approach recognizes that the effects of a stressor (e.g., hydroelectric development) are on both the larger aquatic ecosystem as well as its components parts.

The major components monitored under CAMP are:

- Hydrometrics;
- Aquatic habitat;
- Water quality;
- Sediment quality;
- Phytoplankton;
- Benthic macroinvertebrates (BMI);
- Fish communities; and
- Fish mercury.

1.2.1.1 Hydrometrics

Water levels and flows within a given system are the primary driver of aquatic ecosystem health and are a major consideration in water management decision making. Therefore a good understanding of past, present and forecasted water levels and flows within a given system are a necessity. Consequently, the collection of detailed hydrometric information is fundamental to making better water management and aquatic ecosystem health decisions.

Water Survey of Canada, Manitoba Conservation and Water Stewardship and Manitoba Hydro are the operating agencies for the Canada-Manitoba Hydrometric Program, the provincial component of the National Program. Hydrometric data used by Manitoba Hydro is collected, analyzed and published using processes and procedures referenced under these programs. A number of monitoring sites have been added to Manitoba Hydro's network of hydrometric stations to provide data for CAMP.

1.2.1.2 Aquatic Habitat

Aquatic habitat refers to the environment in which fish and other aquatic organisms live and include the physical, chemical, and biological constituents of the water, sediments, and terrestrial interface. However, as a component in the Coordinated Aquatic Monitoring Program (CAMP) aquatic habitat refers only to physical attributes of the aquatic environment including water depth, velocity, substratum and cover (e.g., aquatic vegetation, terrestrial debris, and riparian vegetation). Changes in the quantity or quality of aquatic habitat can affect fish or other aquatic biota either directly (e.g., impediment of fish movements) or indirectly (e.g., altering food supply).

Inventorying and cataloguing aquatic habitats within Manitoba Hydro's hydraulic operating system is being conducted under CAMP to provide information to support the interpretation of results of aquatic ecosystem monitoring and to establish a baseline against which the effects of future water flow manipulations on aquatic ecosystems can be assessed.

Results of aquatic habitat surveys are presented in the form of substrate and bathymetric maps. Substrate class area as well as depth, slope and volume statistics are calculated and tabulated for each waterbody surveyed. These and other physical habitat variables (e.g., velocity, aquatic and riparian vegetation) are ultimately expected to become key pieces of a broader habitat classification scheme that will be applied to all CAMP waterbodies as the program evolves.

1.2.1.3 Water Quality

Water quality is of fundamental importance to all aquatic biota in an ecosystem and is also important from a human perspective (e.g., drinking water, irrigation, recreation, aesthetics). Water quality may be defined as the chemical (e.g., nutrients), physical (e.g., water temperature), and biological (e.g., microbiological organisms) characteristics of water, typically in relation to its suitability for a particular purpose (e.g., support of aquatic life, recreational use). Some water quality variables are essential to aquatic life, such as nutrients or dissolved oxygen (DO), while others are non-essential (e.g., some metals such as cadmium). Water quality conditions suitable for the protection of aquatic biota depend on the species present in an ecosystem, the life stages present (e.g., fish eggs or embryos versus mature fish), and other factors that modify effects of a particular variable on aquatic life (e.g., hardness). Some water quality variables may be harmful to aquatic biota when above certain levels or thresholds – these levels are often functionally defined as water quality objectives or guidelines for the protection of aquatic life (PAL). Manitoba Water Stewardship (2011) developed Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs), last revised in November 2011, which include objectives and guidelines for various water uses including aquatic life, recreation, drinking water, aesthetics, and irrigation.

Water quality parameters monitored under CAMP include the key variables that may be affected by hydroelectric development and that are important from the perspective of the protection of aquatic life. Water quality parameters include 'routine' variables such as DO, pH, total suspended solids (TSS), turbidity, alkalinity, conductivity, hardness, nutrients (nitrogen and phosphorus), carbon, chloride, sulphate, and temperature, as well as metals (e.g., cadmium) and a bacterium (*Escherichia coli).* Additionally, chlorophyll *a* (a green pigment found in aquatic macrophytes and algae) is monitored at all locations as a general indicator of phytoplankton biomass, productivity, and trophic status.

Aquatic ecosystem health in relation to water quality is described by comparing water quality results to MWQSOGs for the protection of aquatic life. Water quality data are also analysed for temporal (between years) differences within a waterbody, spatial differences (comparisons between waterbodies within a region), and seasonal differences (comparisons between the four sampling periods within a waterbody).

1.2.1.4 Sediment Quality

Sediment quality is of significance to the health of aquatic biota that live in or on sediments, or that directly or indirectly associate with the sediments and/or benthic communities. Sediment quality monitoring was initiated under CAMP in 2011, following completion of the Pilot Program, and includes monitoring of metals, nutrients, and supporting variables in surficial sediments. Monitoring of sediment quality under CAMP will be conducted on a six year rotational basis at all annual waterbodies. As the initial round of monitoring was conducted following the pilot phase of CAMP, the results collected in 2011 will be presented in a future report.

1.2.1.5 Phytoplankton

Phytoplankton are small, aquatic plants (i.e., algae) that are most often found suspended in the water column and form the main base of the aquatic food web. As such, they are the foundation for higher trophic levels in an aquatic ecosystem. Phytoplankton biomass and production are key indicators of the productivity of an ecosystem and are commonly monitored in aquatic ecosystems to assess the degree of eutrophication.

Phytoplankton may be affected by changes in water quality and hydrology. Changes in phytoplankton abundance or composition can in turn affect invertebrate and fish populations. Although phytoplankton are a fundamental component of the aquatic ecosystem and food web, algal blooms can be problematic to aquatic biota and users of aquatic resources, since blooms may cause oxygen depletion (i.e., due to respiration at night and/or during die-off of algal blooms), fouling of commercial fishing nets, and can also be an aesthetic nuisance. The presence of blue-green algae (or cyanobacteria) can create additional issues since certain types of cyanobacteria may produce toxins, such as microcystin, that may adversely affect aquatic biota, wildlife, livestock, and humans.

Phytoplankton taxonomic composition and biomass (i.e., taxonomic biomass) are monitored under CAMP on a three year rotational basis, whereas chlorophyll *a* (an indicator of algal biomass) is measured annually at all sites. In addition, CAMP includes monitoring for a common algal toxin (microcystin). Monitoring of phytoplankton community composition on an annual basis was also initiated at four waterbodies beginning in Year 2 of the Pilot Program.

Chlorophyll *a* concentrations, total and relative biomass of the major groups of phytoplankton (e.g., cyanobacteria), and overall community metrics (e.g., diversity, species richness) are compared between sites and seasons to assess the health of the phytoplankton community within each ecosystem. Microcystin was also measured during algal blooms to determine whether blooms were associated with high concentrations of a common algal toxin.

1.2.1.6 Benthic Macroinvertebrates

BMI are small (can be seen with unaided eye, 500 microns (μm) or greater) animals without a backbone such as worms, snails, clams, crayfish, and aquatic stages of some insects (e.g., mayflies and caddisflies). BMI live on or in the sediments in the bottom of aquatic ecosystems (lakes and rivers) and provide an important link between primary producers (e.g., phytoplankton) and fish. BMI are an important food source for most fish species at some point in their life cycle, and are well established biological indicators of aquatic ecosystem health and/or various impacts on fresh waters.

BMI possess several features that make them useful as bioindicators. They are mainly sedentary and reflect site-specific impacts, they are ubiquitous, generally abundant, and easily collected, they are relatively long-lived (months to years) and integrate adverse effects over time, they are diverse and respond to a wide variety of stressors, and they are an ecologically important part of the food web.

Monitoring of BMI is one of the fundamental components of CAMP. Macroinvertebrates collected in the benthic sediments of lakes and rivers are collected and identified to major group (e.g., family) and to genus in the case of Ephemeroptera (mayflies). The results are expressed in terms of simple metrics that characterize the BMI communities. These metrics include measures of abundance and composition (e.g., total abundance, percent of major groups) and measures of community richness (e.g., total number of taxa, Simpson's Diversity and Evenness). BMI metric data are analysed for temporal (between years) differences within a waterbody and spatial differences (comparisons between waterbodies) within a region.

1.2.1.7 Fish Community

Fish represent most of the middle and upper trophic levels in aquatic ecosystems and many species are of direct interest to humans (i.e., harvested in subsistence, commercial, and/or recreational fisheries). The fish community is an effective integrator of effects to the aquatic ecosystem as a whole, since various fish species require different habitat types, are dependent on production from lower trophic levels, and are affected by changes to hydrology and/or water quality.

Monitoring of the fish community is a key component of CAMP. Monitoring targets both small-bodied fish species (i.e., forage fish) and large-bodied fish species (e.g., fish targeted in subsistence, commercial, and/or recreational fisheries) and includes measurements of parameters such as fish abundance, size, and condition. These data are used to generate key metrics describing the characteristics of the fish communities and populations (e.g., species composition, catch-per-unit-effort, size and age structure, condition factor, deformities, erosion, lesions, and tumours [DELTs], and Indices of Biotic Integrity [IBIs]).

1.2.1.8 Mercury Levels in Fish

Mercury is a naturally occurring metal that is present in abiotic media, including soils, rocks, and water, as well as biota. Mercury is introduced to aquatic ecosystems through natural and anthropogenic pathways including discharge of industrial effluents, atmospheric deposition, weathering of rock, and flooding of land. Inorganic mercury can be converted to the more toxic methylmercury (an organic form of mercury) through biotic (microbial) and abiotic processes. Typically, the majority of mercury found in surface waters is in inorganic form; generally, <10% of total mercury (which includes inorganic and organic forms) is present in the form of methylmercury (Canadian Council of Ministers of the Environment [CCME] 1999; updated to 2013). Methylmercury bioaccumulates and biomagnifies across food webs.

The concentration of mercury (a potent neurotoxin in vertebrates) in fish is of interest due to its importance in determining the suitability of fish for consumption by humans and wildlife. Creation of reservoirs, for hydroelectric development or other purposes, commonly causes increased mercury concentrations in fish as a result of the flooding of carbon-rich terrestrial soil and the subsequent methylation of mercury. Methylmercury enters the base of the food web and is biomagnified at each level such that large piscivorous fish (e.g., Walleye [*Sander vitreus*]) at the top of the aquatic food web typically contain the highest concentrations.

Monitoring of fish mercury concentrations under CAMP was fully initiated in 2010 (limited monitoring occurred in 2009) and represents the continuation of a long-term mercury monitoring program conducted by Manitoba Hydro and Fisheries and Oceans Canada. Mercury concentrations are measured in muscle tissue of commercially important fish species (i.e., Northern Pike [*Esox lucius*], Walleye, and Lake Whitefish [*Coregonus clupeaformis*]) and in 1-year old Yellow Perch (*Perca flavescens*), representing piscivorous fish of a young age that respond relatively quickly to changes in mercury exposure. Samples of fish muscle are collected during the conduct of the fish community monitoring.

1.2.2 Temporal Scope

As a broad (geographically and ecologically) monitoring program, the Coordinated Aquatic Monitoring Program (CAMP) is intended to identify long-term trends or changes in aquatic ecosystems. CAMP includes sampling of some waterbodies/areas annually and others sampled on a three-year rotational basis. In addition, CAMP includes the collection of physical aquatic habitat information on a one time basis only. Monitoring frequency varies according to each component as follows:

- Hydrometrics: hydrometric monitoring is conducted continuously at a range of sites in each of the CAMP regions;
- Aquatic Habitat: intensive aquatic habitat surveys are conducted at selected waterbodies on an opportunistic/as appropriate basis as inventory monitoring. Sampling is therefore conducted as a one-time event;
- Water Quality: water quality sampling (including sampling for chlorophyll a) is conducted four times per year (spring, summer, fall, and winter). Sampling occurs each year at annual sites and every three years at rotational sites;

- Sediment Quality: sediment quality monitoring was initiated in 2011/12 under CAMP and is sampled on a six year rotational basis at all annual waterbodies;
- Phytoplankton: phytoplankton community composition is monitored three times per year, on a three year rotational basis at most sites; the exceptions are four waterbodies where monitoring is conducted annually. Samples are collected in conjunction with water quality sampling;
- Benthic Macroinvertebrates: sampling is conducted once per year (summer/fall). Sampling occurs each year at annual sites and every three years at rotational sites;
- Fish Community: sampling occurs each year at annual sites and every three years at rotational sites. Within a given waterbody, sampling is conducted at approximately the same time of year during each year of monitoring; and
- Fish Mercury: sampling is conducted in conjunction with the fish community monitoring, generally on a three-year rotational basis; selected waterbodies are sampled annually.

1.2.3 Spatial Scope

The Coordinated Aquatic Monitoring Program (CAMP) is conducted in eight regions (Figure 1.2-1) that encompass Manitoba Hydro's hydraulic operating system as follows:

- Winnipeg River Region;
- Saskatchewan River Region;
- Lake Winnipeg Region;
- Upper Churchill River Region;
- Lower Churchill River Region;
- Churchill River Diversion (CRD) Region;
- Upper Nelson River Region; and
- Lower Nelson River Region.

These regions span the province from southeastern Manitoba to the lower Churchill River in northern Manitoba, a range in latitude of 7.5°. The regions encompass five of the six ecozones in Manitoba (Figure 1.2-2). Similarly, CAMP waterbodies span the majority of Manitoba's ecoregions (Figure 1.2-2).

Waterbodies or areas of waterbodies monitored under CAMP include on-system and off-system locations (Figure 1.2-3). On-system waterbodies are those located on, and that are notably influenced by, Manitoba Hydro’s hydraulic operating system (e.g., forebays and areas downstream of hydroelectric generating stations and control structures). Off-system waterbodies include lakes and areas of rivers where water levels and flows are either entirely or largely unaffected by Manitoba Hydro’s hydraulic operating system. However, some waterbodies considered as off-system may still be subject to regulation of flows by other organizations (i.e., upper reaches of the Churchill, Saskatchewan and Winnipeg rivers).

Sampling of on-system waterbodies addresses the primary objective of CAMP – to monitor aquatic ecosystem health along Manitoba Hydro’s hydraulic operating system. The off-system waterbodies were included in CAMP to provide regional information collected in a manner consistent with monitoring of on-system waterbodies that will assist in interpreting any observed environmental changes. Such comparisons are intended to help distinguish between hydroelectric-related effects and other external factors (e.g., climate change) in each CAMP region. For discussion regarding the selection of waterbodies/areas included in CAMP see Section 3.0.

Although the Lake Winnipeg Region is incorporated in CAMP, results of sampling from Lake Winnipeg and Lake Winnipegosis over the Pilot Program (i.e., CAMPP) have not been included in the current report. Pre-existing programming and program administration for Lake Winnipeg were such that not all parameters being sampled aligned with CAMP sampling protocols. Integration and synthesis of data collected for Lake Winnipeg under CAMP and Lake Winnipeg monitoring initiatives will be addressed in future reporting.

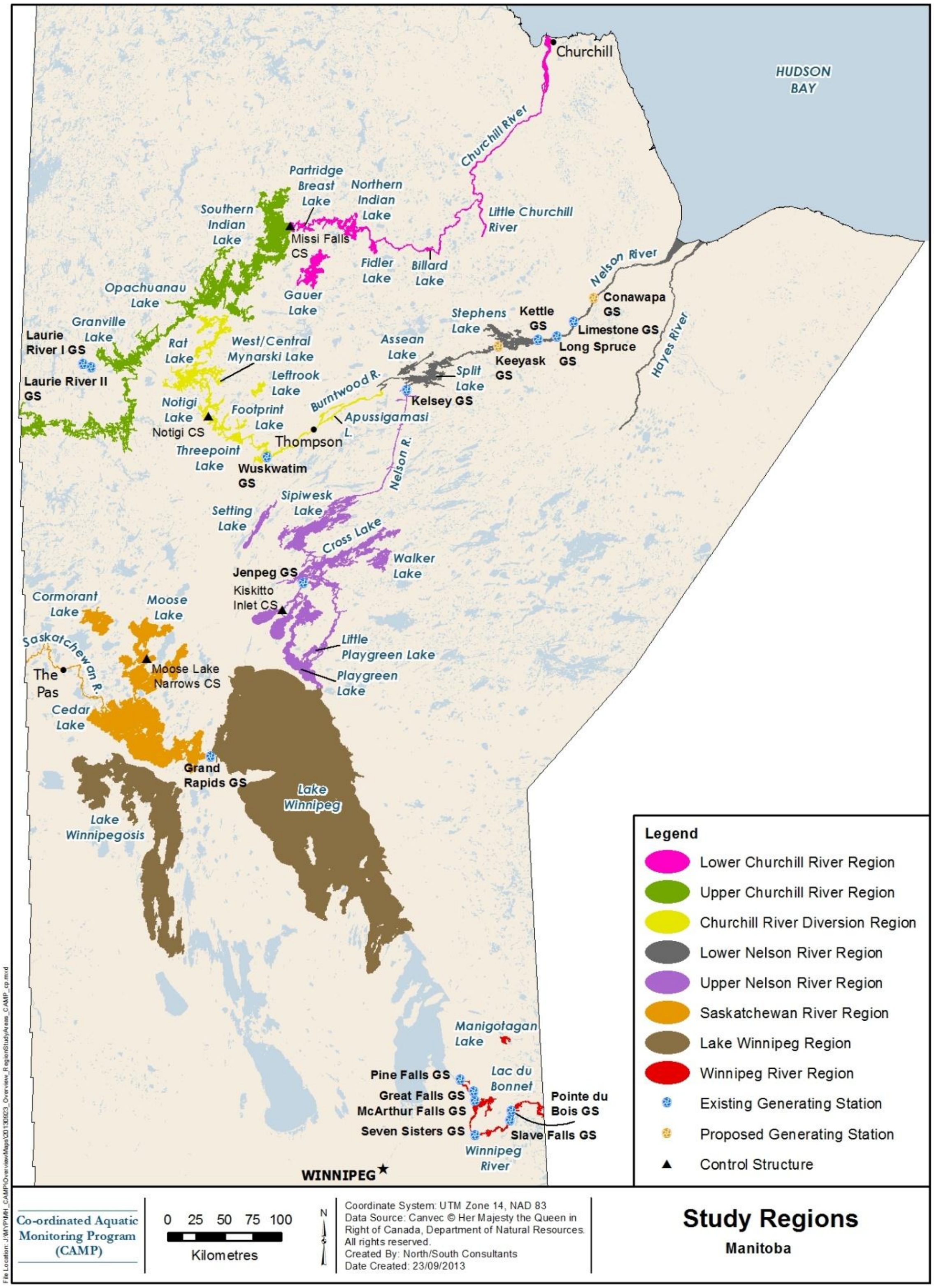

Figure 1.2-1. Study regions and waterbodies sampled under CAMP.

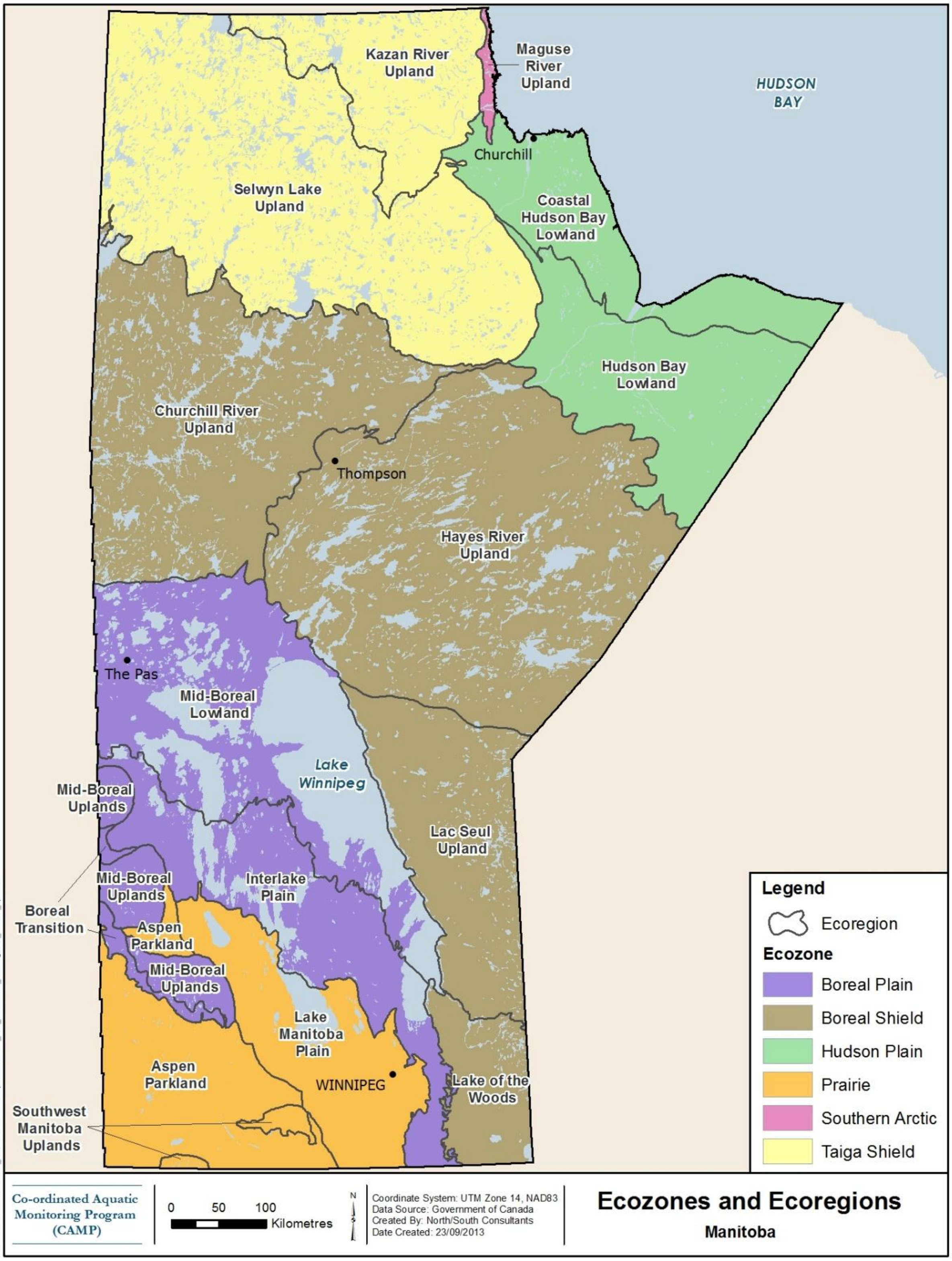

Figure 1.2-2. Manitoba ecozones and ecoregions.

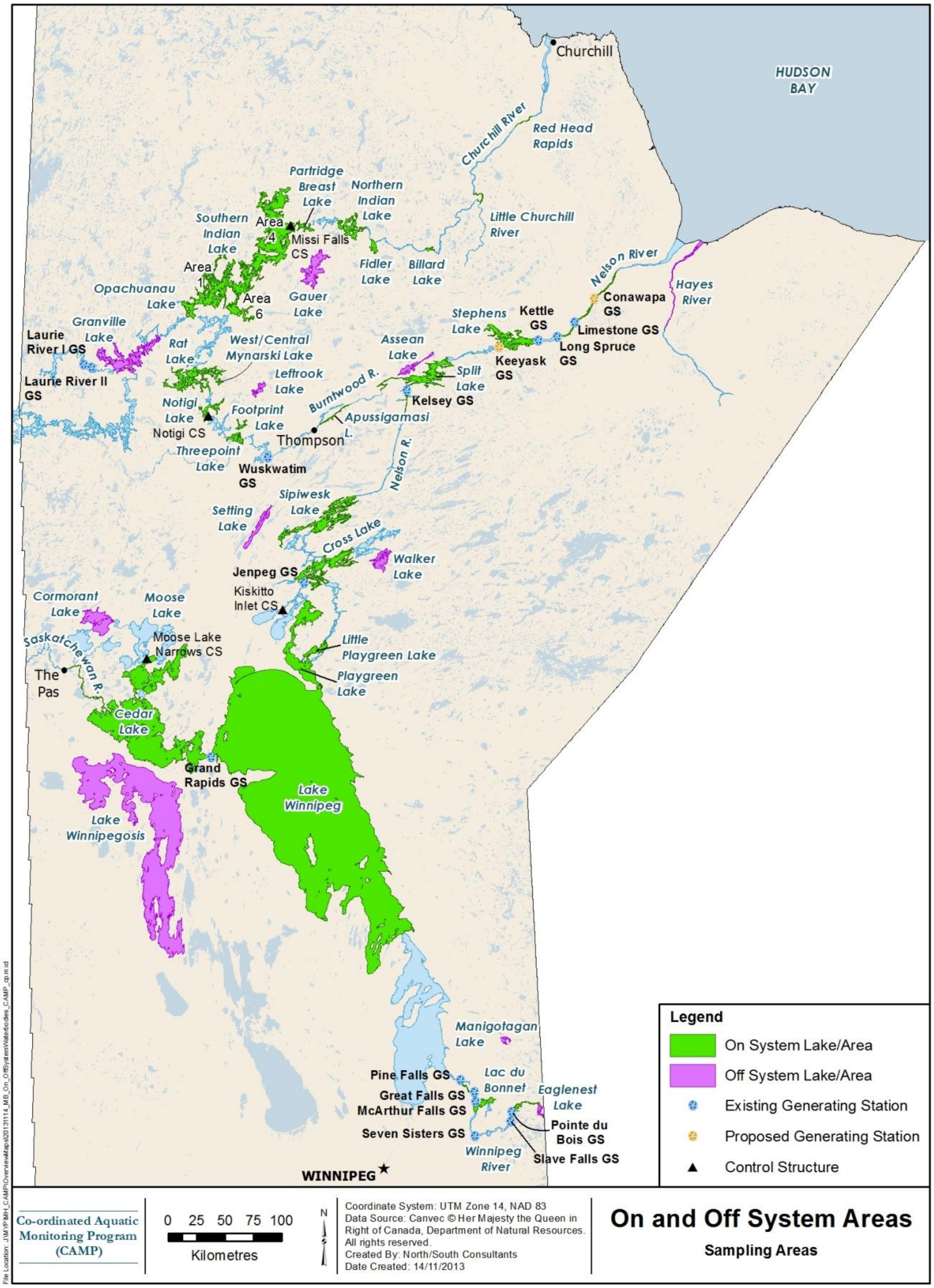

Figure 1.2-3. On-system and off-system waterbodies sampled under CAMP.

1.3 DEVELOPMENT OF SCIENTIFIC PROTOCOLS

Sampling protocols were developed by Manitoba Conservation and Water Stewardship (MCWS) and Manitoba Hydro, with input from Environment Canada (EC), Department of Fisheries and Oceans (DFO), and academics, for the chemical and biological components of the Coordinated Aquatic Monitoring Program (CAMP) to provide a standardized approach to monitoring. Field sampling protocols were developed which included detailed descriptions of sampling methods and quality assurance/quality control (QA/QC) measures for each CAMP component.

An initial workshop was held in 2007 to scope the overall approach and design, components, and methods for CAMP. Workshop participants included representatives from MCWS, DFO, EC, University of Manitoba, Manitoba Hydro and North/South Consultants Inc., as well as other external experts. Subsequent workshops were held annually (following completion of each year's open water monitoring season) to discuss implementation of the previous year's field program and any changes required to the scientific protocols.

1.4 DATABASE AND DATA MANAGEMENT

A significant amount of information has been, and will continue to be, collected as a result of the Coordinated Aquatic Monitoring Program (CAMP). A data management system for CAMP was identified and utilized from the initiation of the Pilot Program, to ensure data are stored in a manner that will facilitate long-term accessibility and use, and to ensure associated metadata are documented (e.g., site Universal Transverse Mercator Units [UTMs]). The data management system was designed to:

- simplify and improve access to large volumes of environmental data;
- facilitate the analysis of large data sets for monitoring and assessment purposes;
- facilitate the interpretation and synthesis of data;
- facilitate the preparation of technical reports and summary documents;
- assist in review of, and modifications to, CAMP; and
- organize and archive the environmental information in digital format for future use.

The information system was designed to be flexible and scalable. The database includes all the parameters listed in Section 1.2.1, with the exception of water levels and flows which are currently managed within a separate Manitoba Hydro database. To ensure the integrity and similarity of the data and written information, procedures have been developed for data handling, including quality assurance/quality control (QA/QC) measures.

1.5 REPORTING FRAMEWORK

To meet Manitoba's and Manitoba Hydro's needs under the terms of the Memorandum of Understanding (MoU), as well as to meet the needs of the public and the scientific community, the following three levels of reporting were defined in the reporting strategy for the Coordinated Aquatic Monitoring Program (CAMP):

- Annual Activity Report – an electronic report prepared annually and submitted to the Minister of Manitoba Conservation and Water Stewardship (MCWS) and the President/Chief Executive Officer (CEO) of Manitoba Hydro. The Annual Activity Report summarizes the previous year's sampling program and meets the requirements outlined in the MoU;
- Website Annual Reporting – the CAMP web-site was recently launched (MCWS 2012) which provides a detailed description of the program and presents a subset of data collected under CAMP. Annual reporting is published on the CAMP website (http://campmb.com/) which is updated as new information and/or data becomes available; and
- Three-Year Synthesis Reports – a hard copy, technical report prepared every three years. The Three-Year Technical Report includes analysis and interpretation of standard metrics in an integrated fashion for all ecosystem components for which data were collected. These reports will be posted on the CAMP website once they are completed.

This report represents the first Three-Year Synthesis Report produced for CAMP. It is intended to provide a documentation of monitoring and results of that monitoring conducted during the Pilot Program which spanned a three year period from 2008/2009 through 2010/2011.

SECTION 2.0: CAMP REGIONAL DESCRIPTIONS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

2.0 CAMP REGIONAL DESCRIPTIONS

The following provides background descriptions of the eight Coordinated Aquatic Monitoring Program (CAMP) monitoring regions, including descriptions of Manitoba Hydro's hydroelectric facilities. Information on drainage basins, ecozones, locations, and waterbody characteristics are presented in Table 2-1.

Table 2-1. CAMP waterbody and watershed characteristics.

Waterbody	Location	Sampling Frequency	Ecozone	Ecoregion	Drainage Basin (Total) (km^2)[1]	Dominant Land Cover (within total watershed)[2]	Latitude (DD)	Longitude (DD)	Altitude (mASL)[3]	Surface Area (km^2)[4]	Shoreline Length (km)[4]	Shoreline Development Ratio[5]	Max Depth (m)	Mean Depth (m)	Mean Depth Max. Depth Ratio	Lake Volume (million m^3)	Drainage Basin Area: Lake Surface Area
Winnipeg River Region					136871	Mixed Forest											
Eaglenest Lake	Off-system	Rotational	Boreal Shield	Lake of the Woods, Lac Seul Upland	125883	Mixed Forest	50.30679	-95.21338	299	31.3	130	6.6	32 [6]				4028
Pointe du Bois Forebay	On-system	Annual	Boreal Shield	Lake of the Woods, Lac Seul Upland	126179	Mixed Forest	50.34814	-95.48069	300	37.5	217	10.0	36.5 [7]	9.44 [7]	0.259	268 [7]	3367
Lac du Bonnet	On-system	Annual	Boreal Shield	Lake of the Woods, Lac Seul Upland	135350	Mixed Forest	50.37298	-95.91359	252	81.7	162	5.1	69 [6]				1656
Pine Falls Reservoir	On-system	Rotational	Boreal Shield	Lake of the Woods	136827	Mixed Forest	50.52595	-96.13456	228	7.3	32	3.4	42.5 [8]	12 [8]	0.282	8 [8]	18743
Manigotagan Lake	Off-system	Annual	Boreal Shield	Lac Seul Upland	1478	Coniferous Forest	50.85986	-95.61547	280	24.3	81.7	4.7	24.5 [9]				61
Saskatchewan River Region					411709	Cultivated Crops											
Saskatchewan River	On-system	Rotational	Boreal Plain	Mid-Boreal Lowland	405601	Cultivated Crops	53.79401	-101.06026	254								
South Moose Lake	On-system	Rotational	Boreal Plain	Mid-Boreal Lowland	9179	Coniferous Forest	53.768	-100.0285	254	735	682	7.1	12.0 [10]	4.8 [10]	0.400	1460 [10]	12.5
Cedar Lake - West Basin	On-system	Rotational	Boreal Plain	Mid-Boreal Lowland	408303	Cultivated Crops	53.42685	-100.3337	253	1216	1098	8.9					335.8
Cedar Lake	On-system	Annual	Boreal Plain	Mid-Boreal Lowland	411455	Cultivated Crops	53.13851	-99.91633	253	1246	851	6.8					330
Cormorant Lake	Off-system	Annual	Boreal Plain	Mid-Boreal Lowland	3162	Coniferous Forest	54.23665	-100.81528	254	333	269	4.2	27.5 [11]				9.50
Lake Winnipeg Region					1026845	Cultivated Crops											
North Basin of Lake Winnipeg	On-system	Annual	Boreal Plain, Boreal Shield	Mid-Boreal Lowland, Lac Seul Upland	1026845	Cultivated Crops	52.82412	-97.91339	216	19784	2424	4.9					51.9
Lake Winnipegosis	Off-system	Annual	Boreal Plain	Mid-Boreal Lowland, Interlake Plain	55061	Deciduous Forest	52.70757	-99.8627	251	5198	2482	9.7					10.6
Upper Churchill River Region					261443	Coniferous Forest											
Granville Lake	Off-system	Annual	Boreal Shield	Churchill River Upland	245069	Coniferous Forest	56.27949	-100.48200	259	412	1239	17.2					594
Southern Indian Lake (Area 1)	On-system	Rotational	Boreal Shield	Churchill River Upland	252895	Coniferous Forest	56.85841	-99.25742	258	354	817	12.3					715
Southern Indian Lake (Area 4)	On-system	Annual	Taiga Shield	Selwyn Lake Upland	261394	Coniferous Forest	57.30856	-98.37741	258	681	758	8.2					384
Southern Indian Lake (Area 6)	On-system	Rotational	Boreal Shield	Churchill River Upland	261394	Coniferous Forest	56.69493	-98.93234	257	132	361	8.9					1988
Opachuanau Lake	On-system	Rotational	Boreal Shield	Churchill River Upland	248663	Coniferous Forest	56.70840	-99.59440	258	84	228	7.0					2960
Lower Churchill River Region					299817	Coniferous Forest											
Partridge Breast Lake	On-system	Rotational	Taiga Shield	Selwyn Lake Upland	261870	Coniferous Forest	57.35300	-97.93028	242	22.3	98.2	5.9					11738
Northern Indian Lake	On-system	Annual	Taiga Shield	Selwyn Lake Upland	271193	Coniferous Forest	57.34695	-97.25575	234	100	388	10.9					2704
Fidler Lake	On-system	Rotational	Taiga Shield	Selwyn Lake Upland	271909	Coniferous Forest	57.19417	-96.94913	229	39.7	106	4.7					6849
Billard Lake	On-system	Rotational	Taiga Shield	Selwyn Lake Upland	273377	Coniferous Forest	57.14994	-96.13711	187	13.0	34.2	2.7	12.8 [10]	2.86 [10]	0.223		21078
Churchill River at Little Churchill River	On-system	Annual	Taiga Shield	Selwyn Lake Upland	284222	Coniferous Forest	57.52953	-95.32977	132								
Churchill River at Red Head Rapids	On-system	Rotational	Hudson Plain	Coastal Hudson Bay Lowland	293213	Coniferous Forest	58.12080	-94.62500	80								
Gauer Lake	Off-system	Annual	Boreal Shield	Churchill River Upland	4897	Coniferous Forest	57.00683	-97.81118	245	263	471	8.2	20.0 [12]				18.6

Table 2-1. continued.

Waterbody	Location	Sampling Frequency	Ecozone	Ecoregion	Drainage Basin (Total) (km^2)[1]	Dominant Land Cover (within total watershed)[2]	Latitude (DD)	Longitude (DD)	Altitude (mASL)[3]	Surface Area (km^2)[4]	Shoreline Length (km)[4]	Shoreline Development Ratio[5]	Max Depth (m)	Mean Depth (m)	Mean Depth Max. Depth Ratio	Lake Volume (million m^3)	Drainage Basin Area: Lake Surface Area
Churchill River Diversion Region					280754	Coniferous Forest											
Rat Lake	On-system	Rotational	Boreal Shield	Churchill River Upland	266363	Coniferous Forest	56.14204	-99.65726	257	168	646	14.1	20.0 [13]				1589
West/Central Mynarski Lake	On-system	Rotational	Boreal Shield	Churchill River Upland	276	Coniferous Forest	56.12786	-99.20156	257	15.8	72.9	5.2					17
Notigi Lake	On-system	Rotational	Boreal Shield	Churchill River Upland	267581	Coniferous Forest	55.94197	-99.31536	254	75.0	308	10.0					3568
Threepoint Lake	On-system	Annual	Boreal Shield	Churchill River Upland	276853	Coniferous Forest	55.69057	-98.95236	242	62.2	159	5.7	10.0 [14]				4450
Footprint Lake	On-system	Rotational	Boreal Shield	Churchill River Upland	1441	Coniferous Forest	55.79641	-98.87961	242	27.6	124	6.7					52.3
Apussigamasi Lake	On-system	Rotational	Boreal Shield	Hayes River Upland	280393	Coniferous Forest	55.84589	-97.61254	187	17.8	80.8	5.4	16.72 [10]	4.88 [10]	0.292	112 [10]	15744
Leftrook Lake	Off-system	Annual	Boreal Shield	Churchill River Upland	389	Coniferous Forest	56.06906	-98.62065	252	46.3	141	5.8					8.39
Upper Nelson River Region					1056135	Cultivated Crops											
Playgreen Lake	On-system	Rotational	Boreal Shield	Hayes River Upland, Mid Boreal Lowland	1028625	Cultivated Crops	53.99489	-98.26198	215	675	888	9.6	18.6 [15]				1525
Little Playgreen Lake	On-system	Rotational	Boreal Shield, Boreal Plain	Hayes River Upland	1032615	Cultivated Crops	54.00510	-97.87296	215	84.8	238	7.3	14.6 [15]				12176
Cross Lake (West Basin)	On-system	Annual	Boreal Shield	Hayes River Upland	1045983	Cultivated Crops	54.68237	-97.78479	207	365	1665	24.6					2867
Sipiwesk Lake	On-system	Rotational	Boreal Shield	Hayes River Upland	1051604	Cultivated Crops	55.05165	-97.71011	185	487	2014	25.8					2159
Walker Lake	Off-system	Rotational	Boreal Shield	Hayes River Upland	1183	Shrub	54.70547	-96.97272	205	133	636	15.5					8.87
Setting Lake	Off-system	Annual	Boreal Shield	Hayes River Upland	10952	Coniferous Forest	54.98334	-98.65392	222	126	269	6.8	24.5 [16]				87.0
Nelson River (d/s Sipiwesk to Kelsey GS)	On-system	Rotational	Boreal Shield	Hayes River Upland	1056135	Cultivated Crops	55.87261	-96.57375	184								
Lower Nelson River Region					1392453	Cultivated Crops											
Burntwood River (First Rapids to Split Lake)	On-system	Rotational	Boreal Shield	Churchill River Upland	290233	Coniferous Forest	56.1254	-96.8318	167								
Split Lake	On-system	Annual	Boreal Shield	Hayes River Upland	1374157	Cultivated Crops	56.1388	-96.2032	168	269	764	13.1	27 [17]				5109
Stephens Lake	On-system	Rotational	Boreal Shield	Hayes River Upland	1380009	Cultivated Crops	56.3850	-95.0464	138	307	658	10.6	35 [18]	7.63 [18]	0.218		4494
Limestone Forebay	On-system	Rotational	Hudson Plain	Hudson Bay Lowland	1380984	Cultivated Crops	56.4386	-94.1784	82	26.8	53.6	2.9	29 [19]				51587
Nelson River (d/s Limestone GS)	On-system	Annual	Hudson Plain	Hudson Bay Lowland, Coastal Hudson Bay Lowland	1392453	Cultivated Crops	56.7960	-93.5367	20				20.8 [19]				
Assean Lake	Off-system	Annual	Boreal Shield	Hayes River Upland, Churchill River Upland	542	Shrub	56.2241	-96.4684	176	76.3	196	6.3	19.8 [10]	2.97 [10]	0.15	224 [10]	7.11
Hayes River	Off-system	Annual	Hudson Plain	Hudson Bay Lowland, Coastal Hudson Bay Lowland	108960	Coniferous Forest	56.6026	-92.6684	13								

[1] PFRA 2008
[2] NRLC 2000
[3] USGS 2000
[4] NRC 2011
[5] Wetzel 1983
[6] DFO 2008
[7] Larter et al. 2010
[8] Murray and Gillespie 2011
[9] Manitoba Conservation 2007a
[10] Data collected by NSC between 2010 and 2011 as part of CAMP
[11] Manitoba Conservation 2006
[12] Manitoba Natural Resources 1990
[13] Manitoba Conservation 2007b
[14] Manitoba Conservation 2003a
[15] DFO 2009
[16] Manitoba Conservation 2007c
[17] Manitoba Conservation 2003b
[18] Cherepak 1990
[19] Manitoba Hydro Unpublished Data

2.1 WINNIPEG RIVER REGION

2.1.1 Regional Description

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 2.1-1). This region also includes Manigotagan Lake, an off-system waterbody on the Manigotagan River.

The Winnipeg River catchment drains 137,000 km^2 of northwestern Ontario, southeastern Manitoba, and northern Minnesota, flowing 260 km in a generally northwesterly direction before entering Lake Winnipeg at Traverse Bay (Rosenberg et al. 2005). Most of the drainage area is in northwestern Ontario (70%), while approximately 21% is in Minnesota, and 9% is in Manitoba (Jones and Armstrong 2001; Figure 2.1-2).

In Manitoba, the Winnipeg River runs through the Boreal Shield Ecozone which is in turn composed of the Lake of the Woods Ecoregion to the south and the Lac Seul Upland Ecoregion to the north (Figure 1.2-2). Most of the catchment area is underlain by igneous and metamorphic bedrock, over which lies a variety of surface features including lakes and wetlands, bare rock outcrops, tills, forest and peatland soil types, and clay plains.

Much of the basin is forested, with jack pine, white pine, red pine, white spruce, black spruce, balsam fir, northern white cedar, tamarack, white birch, and trembling aspen among the more common tree species. Peatlands with black spruce-sphagnum bogs and swamps are common in the basin. The contemporary boreal forest in northwestern Ontario is composed of 71 species of trees and shrubs, 11 grass species, 40 herbs, 18 mosses and lichens, and 16 ferns (Royal Ontario Museum 2005). The dominant land cover of the drainage basin is classified as mixed forest (Table 2-1).

Temperatures vary little across the basin, with mean annual values from 0.5ºC to 2.0ºC, mean summer values from 14.0ºC to 15.5ºC, and mean winter values from –12.5º to –14.5°C (Rosenberg et al. 2005). Annual precipitation is moderate, ranging from 50 to 70 cm, with most (80%) falling as rain (Rosenberg et al. 2005).

The Winnipeg River catchment area has an economy largely based on renewable energy, forestry, mining, and recreation. Forestry, trapping, hunting, and tourism are the dominant land uses, though a significant portion of the Rainy River system is used in mixed farming or grazing. Overall the area remains relatively undeveloped: 30% of the catchment is devoted to forestry activities, <5% is in agriculture, and <1% is urban; the remainder of the basin is natural. Twelve percent of the catchment has park designation or protected status.

The catchment area population is concentrated in a few small towns (Kenora, Dryden, Red Lake, Sioux Lookout, Atikokan, International Falls, Pinawa, Lac du Bonnet, and Pine Falls) devoted largely to forestry processing and tourism. In Manitoba, there is one First Nation community in the region near the Winnipeg River's confluence with Lake Winnipeg, Sagkeeng First Nation, which has an on-reserve population of approximately 2,100 (Chammartin 2008; Figure 2.1-1). The Winnipeg River basin has a low population density (0.6 people/km^2); however, the significant cottage development found on Lake of the Woods and along the Winnipeg River increases the population to >1 person/km^2 seasonally (Rosenberg et al. 2005).

The Winnipeg River has been regulated by several large dams to control water levels and provide storage to generate hydroelectric power. International and interprovincial regulatory boards oversee water-level and flow regulation, using 34 control structures that provide water for 11 power-generating facilities with a combined capacity of >900 megawatt (MW; Rosenberg et al. 2005). Alterations of stream water quantity, quality, and habitat have occurred with the intensification of logging and forestry, particularly in northwestern Ontario (Rosenberg et al. 2005). Three pulp mills (including Tembec at Pine Falls, Manitoba), nine lumber mills, and two panel-production facilities are currently operating or have recently ceased production in the Winnipeg River drainage basin. The Tantalum Mining Corporation of Canada Limited (TANCO) operates a tantalum, cesium, and spodumene mine at Bernic Lake, 60 km east of Lac du Bonnet, Manitoba (Manitoba Innovation, Energy and Mines [MIEM] and TANCO 2012).

Manigotagan Lake, an off-system waterbody, is located on the Manigotagan River system which flows directly into Lake Winnipeg near the community of Manigotagan (Figure 2.1-1). Manigotagan Lake receives inflows from both the upper Manigotagan and Moose rivers. The catchment area for the lake (1,500 km^2), part of which is located in Ontario, is two orders of magnitude smaller than the catchments for CAMP waterbodies located on the Winnipeg River (Figure 2.1-3). Like the Winnipeg River catchment, the Manigotagan Lake catchment lies entirely within the Boreal Shield ecozone. Conversely, while the Winnipeg River lies on the border of the Lake of the Woods and Lac Seul Upland ecoregions, the Manigotagan Lake drainage resides entirely in the latter. The dominant land cover is coniferous forest and there is presently little development (some cottages and a few outfitters) in the drainage basin. The drainage basin upstream of Manigotagan Lake is relatively undeveloped with a dominant land cover of coniferous forest. Historically, the Manigotagan Lake basin supported mines at Gem Lake (1932, 1934-1936), Long Lake (1927-1937, 1942, 1948-1951), and Beresford Lake (1933-1934, 1938-1940) (MIEM 2012). Construction of a dam in the Manigotagan River at the outlet of Quesnel Lake in the late 1930s raised water levels in Manigotagan Lake by about 3.0 to 3.5 m (McTavish 1953). The dam was built to facilitate boat and barge traffic associated with the mining industry, which was then able to easily pass between Manigotagan and Quesnel lakes (Fitzjohn 1985).

2.1.2 Hydroelectric Facilities

Prior to entering Manitoba, the Winnipeg River flows (comprised of inflows from the English and Rainy River systems) are regulated by the Lake of the Woods Control Board (LWCB) at Lake of the Woods and Lac Seul.

Within Manitoba, Manitoba Hydro operates six generating stations (GSs) on the Winnipeg River which together produce approximately 583 megawatts (MW) of hydroelectric power. The generating stations on the Winnipeg River include (beginning with the furthest upstream station) Pointe du Bois, Slave Falls, Seven Sisters, McArthur, Great Falls, and Pine Falls (Figure 2.1-1).

These hydroelectric GSs are designed and operated as run-of-the-river plants (i.e., water flowing to them from upstream is used immediately and not stored in a reservoir for later use). When river flows are greater than those needed to drive the turbines, water is spilled through the spillway and sluice gates.

2.1.2.1 Pointe du Bois GS

The Pointe du Bois GS is located approximately 160 km northeast of Winnipeg and approximately 45 km downstream of the Ontario/Manitoba border. The first of the station’s 16 turbine generators was placed in service in 1911, making it the oldest power plant still operating on the Winnipeg River. With an operating head of 14 m, the Pointe du Bois GS has a licensed capacity of 83 MW and can generate an average of 580 million kilowatt hours (kW h) of electricity per year. The Pointe du Bois GS Forebay area has a surface area of approximately 25.1 km^2 and a normal operating maximum forebay elevation of 299.1 m. To meet current dam safety requirements, Manitoba Hydro is in the process of constructing a new main dam and spillway at the Pointe du Bois facility, but the powerhouse is not being replaced. Construction and rehabilitation of the site are expected to be completed by the end of 2014.

2.1.2.2 Slave Falls GS

The Slave Falls GS is located approximately 10 km downstream of the Pointe du Bois GS. The first of the station’s eight turbine generators came into service in 1931. The Slave Falls GS has a licensed capacity of 72 MW at an operating head of 9.75 m and can generate an average of 499 million kW h of electricity per year. The Slave Falls Forebay has a surface area of 6.5 km^2 and a maximum operating forebay elevation of 284.6 m.

2.1.2.3 Seven Sisters GS

The Seven Sisters GS, located approximately 43 km downstream of the Slave Falls GS, has been in operation since 1931, when the first of six turbine generators was brought on line. The Seven Sisters GS has an operating head of 18.6 m, a licensed capacity of 167.8 MW and can generate an average of 990 million kW h of electricity per year. The Seven Sisters Forebay (Natalie Lake) has a surface area of 21 km^2 and a maximum operating forebay elevation of 274.2 m.

2.1.2.4 McArthur GS

The McArthur GS is located approximately 30 km downstream of the Seven Sisters GS and approximately 40 km upstream of Lake Winnipeg. The McArthur GS has eight turbine units and it first produced power in 1954. The McArthur GS has an operating head of 7 m, a licensed capacity of 59.7 MW, and can generate an average of 380 million kW h of electricity per year. The McArthur Forebay area (Lac du Bonnet) has a surface area of 115 km^2 and a normal water level of 254.8 m.

2.1.2.5 Great Falls GS

The Great Falls GS is located approximately 8 km downstream of the McArthur GS. The first of the station’s six turbine generators was brought into service in 1922. With an operating head of 17.7 m, the Great Falls GS has a licensed capacity of 136 MW and can generate an average of 750 million kW h of electricity per year. The Great Falls Forebay (the Winnipeg River) has a surface area of 10 km^2 and a normal operating forebay elevation of 247.5 m.

2.1.2.6 Pine Falls GS

The Pine Falls GS, the farthest downstream station on the Winnipeg River, is located approximately 13 km upstream of Lake Winnipeg, and 40 km north of the Town of Lac du Bonnet, and came into service in 1951. With an operating head of 11.3 m, the Pine Falls GS’s six turbine generators have a licensed capacity of 85 MW and can generate an average of 620 million kW h of electricity per year. The Pine Falls Forebay (the Winnipeg River) has a surface area of 9 km^2 and a maximum operating forebay elevation of 229.2 m.

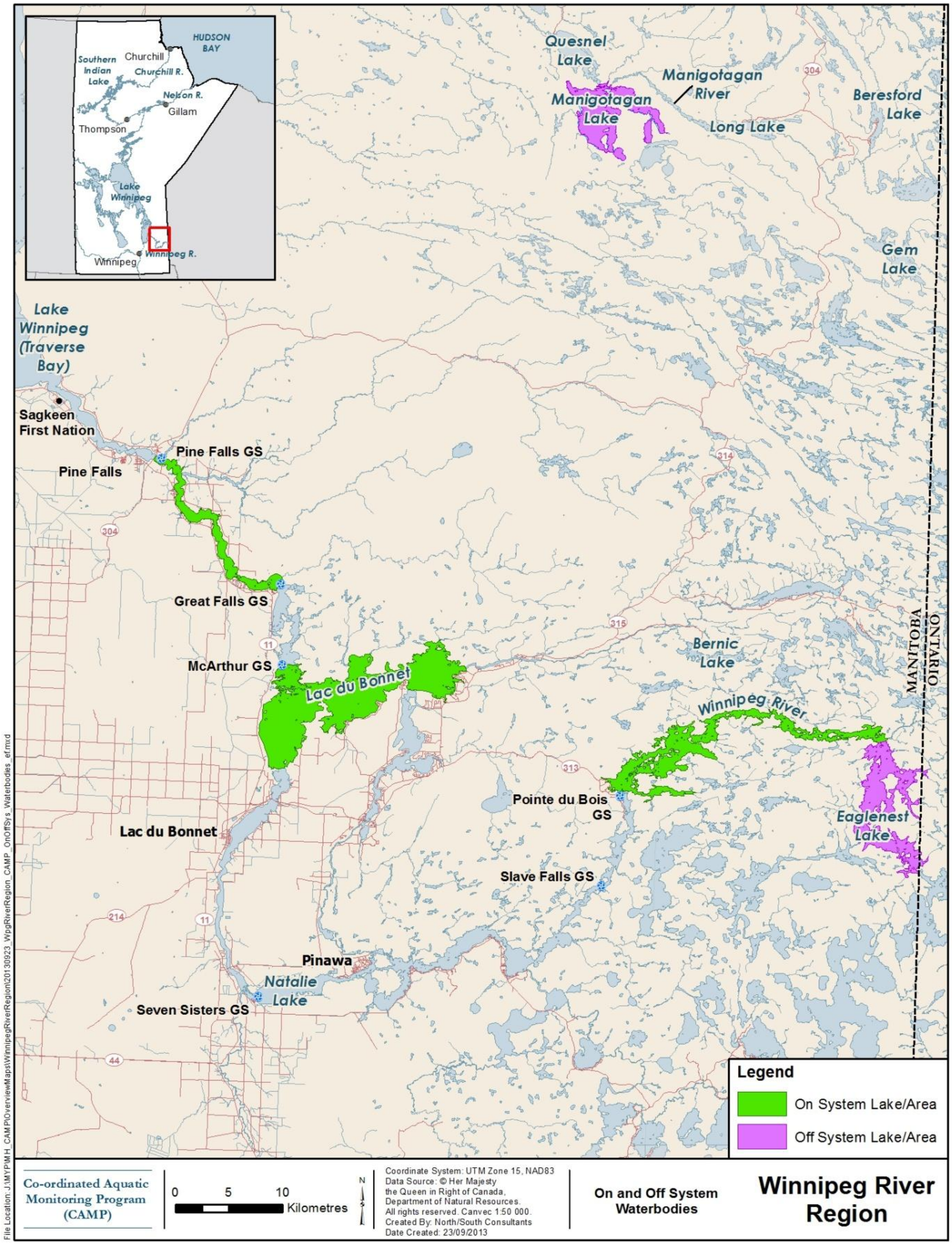

Figure 2.1-1. Winnipeg River Region.

Figure 2.1-2. Winnipeg River Region drainage basin.

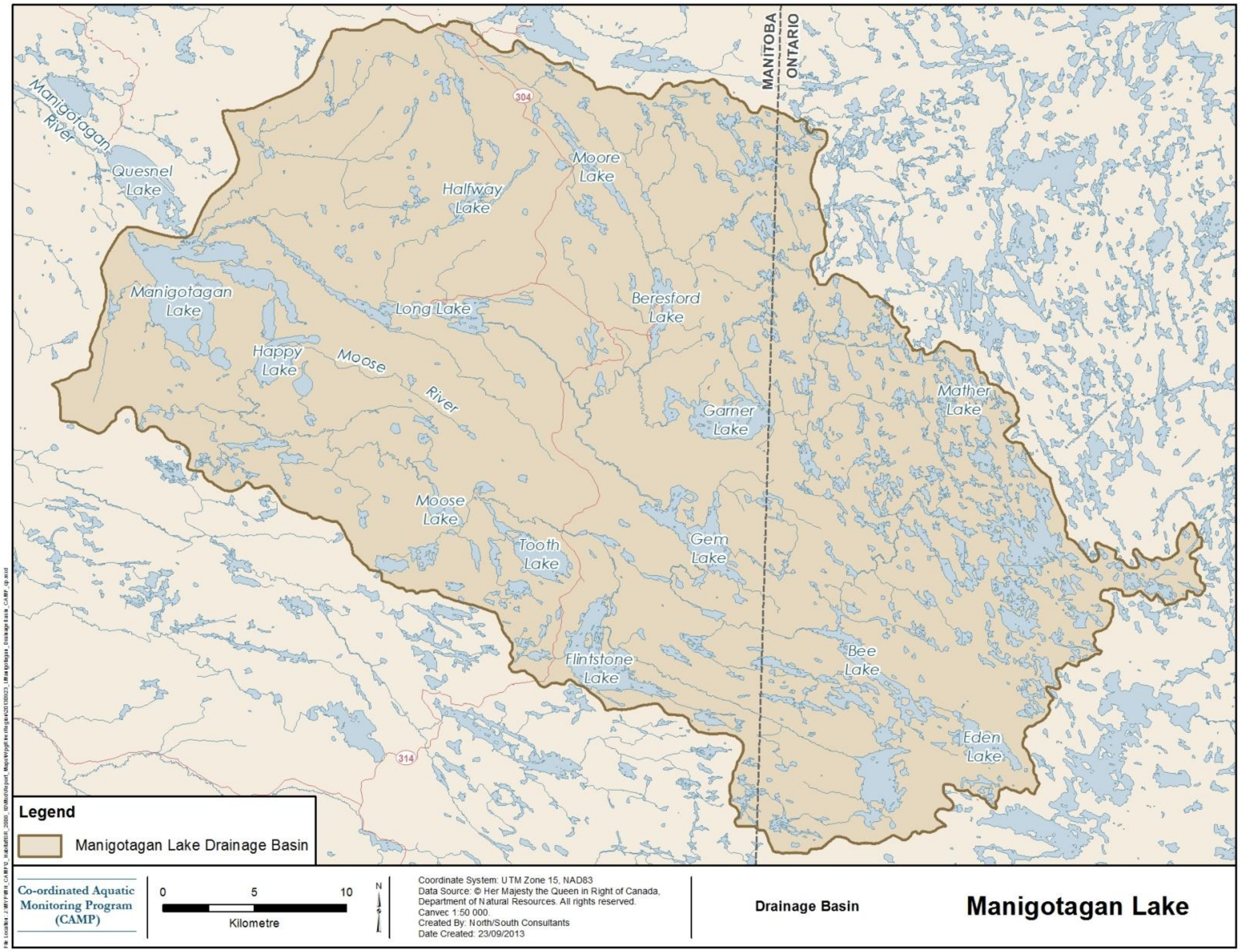

Figure 2.1-3. Manigotagan Lake drainage basin.

2.2 SASKATCHEWAN RIVER REGION

2.2.1 Regional Description

The Saskatchewan River Region includes the portion of the Saskatchewan River watershed from the Saskatchewan/Manitoba border to Lake Winnipeg and Cormorant Lake (Figure 2.2-1).

The Saskatchewan River system drains a large area of western Canada from the Rocky Mountains in Alberta eastward to Lake Winnipeg in Manitoba (Figure 2.2-2). The river drains a total area of approximately 416,000 km^2, most of which is in Alberta (220,000 km^2) and Saskatchewan (174,000 km^2) with approximately 5% of the basin lying in Manitoba (22,000 km^2; Jones and Armstrong 2001). The basin covers much of the Boreal Plains Ecozone and the western portion of the Prairies Ecozone of western Canada (Smith et al. 1998 *In* Jones and Armstrong 2001). Within Manitoba, the Saskatchewan River is located in the Boreal Plain Ecozone and the Mid-Boreal Lowlands Ecoregion (Figure 1.2-2). Soils are generally rich and natural vegetation communities are diverse and include marsh/wetland, grassland, aspen parkland, and boreal forest (Jones and Armstrong 2001). The dominant land cover of the watershed is classified as cultivated crops (Table 2-1).

The climate of the drainage basin is classified as continental, although mean annual air temperature varies considerably within the watershed (Rosenberg et al. 2005). In the southern portion of the drainage basin (e.g., Calgary, Medicine Hat) mean daily temperatures range from -10°C in January to 16°C in July, with mean annual temperatures ranging from 3°C to 5°C (Rosenberg et al. 2005). In the northern portion of the basin (e.g., Edmonton, Saskatoon, Prince Albert) mean annual temperatures are 0.5°C to 2°C and monthly means range from -20°C to 19°C (Rosenberg et al. 2005). Precipitation is low across the basin, ranging from 30 to 50 cm. Peak precipitation occurs during summer, although snowmelt accounts for a significant proportion of the runoff, particularly in the mountain headwaters (Rosenberg et al. 2005).

Land use within the drainage basin is largely agricultural, although forestry is common within the boreal forest portion of the drainage basin (Jones and Armstrong 2001). Agriculture varies from cultivation of specialty, cereal and forage crops, to range, pasture lands and livestock feedlots (Jones and Armstrong 2001). There are also several wastewater treatment lagoons and sewage treatment plants that discharge effluent directly to the Saskatchewan River mainstem or its tributaries (Jones and Armstrong 2001). One pulp and paper mill located at The Pas, Manitoba (Tolko Manitoba Kraft Papers) discharges effluent to the river.

The Saskatchewan River is a multi-use waterway, used extensively for agricultural irrigation and livestock watering, recreation, domestic and industrial consumption, and hydroelectric power generation (Jones and Armstrong 2001). Regulation of the Saskatchewan River basin began in the 1890s with the construction of irrigation projects and works to divert and deliver water to land in southern Alberta (Rosenberg et al. 2005). Diversion of water for irrigation projects was followed by regulation for hydroelectric power generation, first in the upper reaches of the Bow River (1911 to 1955) and then in the upper North Saskatchewan River (1965 to 1972) and Saskatchewan River (1963 to 1985) (Rosenberg et al. 2005). Presently there are eleven hydroelectric generating stations, six storage reservoirs (one on the mainstem and five on tributaries), and one regulating reservoir on the river (Rosenberg et al. 2005). Urban centres within the drainage basin include Banff, Calgary, Red Deer, Lethbridge, Medicine Hat, Edmonton, Saskatoon, Prince Albert, and The Pas.

The Cormorant Lake watershed (South Moose Lake watershed) is appreciably smaller (approximately 3,162 km^2; Table 2-1) than the Saskatchewan River watershed. The lake receives inflow from Clearwater Lake and several small tributaries and contains one outflow which drains via Frog Creek to North Moose Lake (Figure 2.2-3). Like the Saskatchewan River catchment, Cormorant Lake lies entirely within the Boreal Plain ecozone and the Mid-Boreal Lowlands ecoregion (Figure 1.2-2). The dominant land cover within the watershed is coniferous forest. The community of Cormorant is located on the east shore of the lake and there is one active fishing lodge nearby. Commercial fishing, trapping, forestry, and tourism are the primary industries in the area.

2.2.2 Hydroelectric Facilities

The Saskatchewan River is formed by the confluence of the North and South Saskatchewan rivers in east-central Saskatchewan. In total, it drains an area of approximately 335,900 km^2 including parts of Montana, Alberta, Saskatchewan and Manitoba. The Saskatchewan River is a multi-use waterway, being used extensively for agricultural irrigation and livestock watering, recreational purposes, domestic and industrial consumption, and hydroelectric power generation (Jones and Armstrong 2001). Regulation of the Saskatchewan River basin began in the 1890s with the construction of irrigation projects and works to divert and deliver water to land in southern Alberta (Rosenberg et al. 2005). Diversion of water for irrigation projects was followed by regulation for hydroelectric power generation, first in the upper reaches of the Bow River (1911 to 1955) and then in the upper North Saskatchewan River (1965 to 1972) and Saskatchewan River (1963 to 1985) (Rosenberg et al. 2005). Presently, there are eleven hydroelectric generating stations (GSs), six storage reservoirs (one on the mainstem and five on tributaries), and one regulating reservoir within the Saskatchewan River drainage basin (Rosenberg et al. 2005). The Grand Rapids GS is the only station on the Saskatchewan River in Manitoba (Figure 2.2-1). Manitoba Hydro also maintains the Moose Lake Narrows Control

Structure, a concrete spillway with a rock and earth fill dam, to isolate North Moose Lake from South Moose Lake, and the Red Earth Lake and One Man Lake control structures to enable management of the area north of Summerberry River separate from effects of the Grand Rapids GS (Figure 2.2.1).

2.2.2.1 Grand Rapids GS

The Grand Rapids GS is located approximately 200 km downstream of The Pas, Manitoba, and 4.4 km upstream of the outflow of the Saskatchewan River into Lake Winnipeg. Construction of the Grand Rapids GS was initiated in 1960, the first of the station's four turbine generators was in service in 1965, and the plant was fully operational by 1968. Regulation of the Saskatchewan River for hydroelectric power generation at Grand Rapids raised the water level of Cedar Lake by 3.5 m with a resulting reservoir of approximately 3,500 km^2. The Grand Rapids GS has an operating head of 36.6 m, can produce approximately 480 megawatts (MW) of power, and can generate an average of 1,540 kilowatt hours (kW h) of electricity per year. Maximum operating forebay elevation in Cedar Lake is 256.6 m. The Grand Rapids GS is a peaking plant, meaning one which operates based on changes in the demand for electricity.

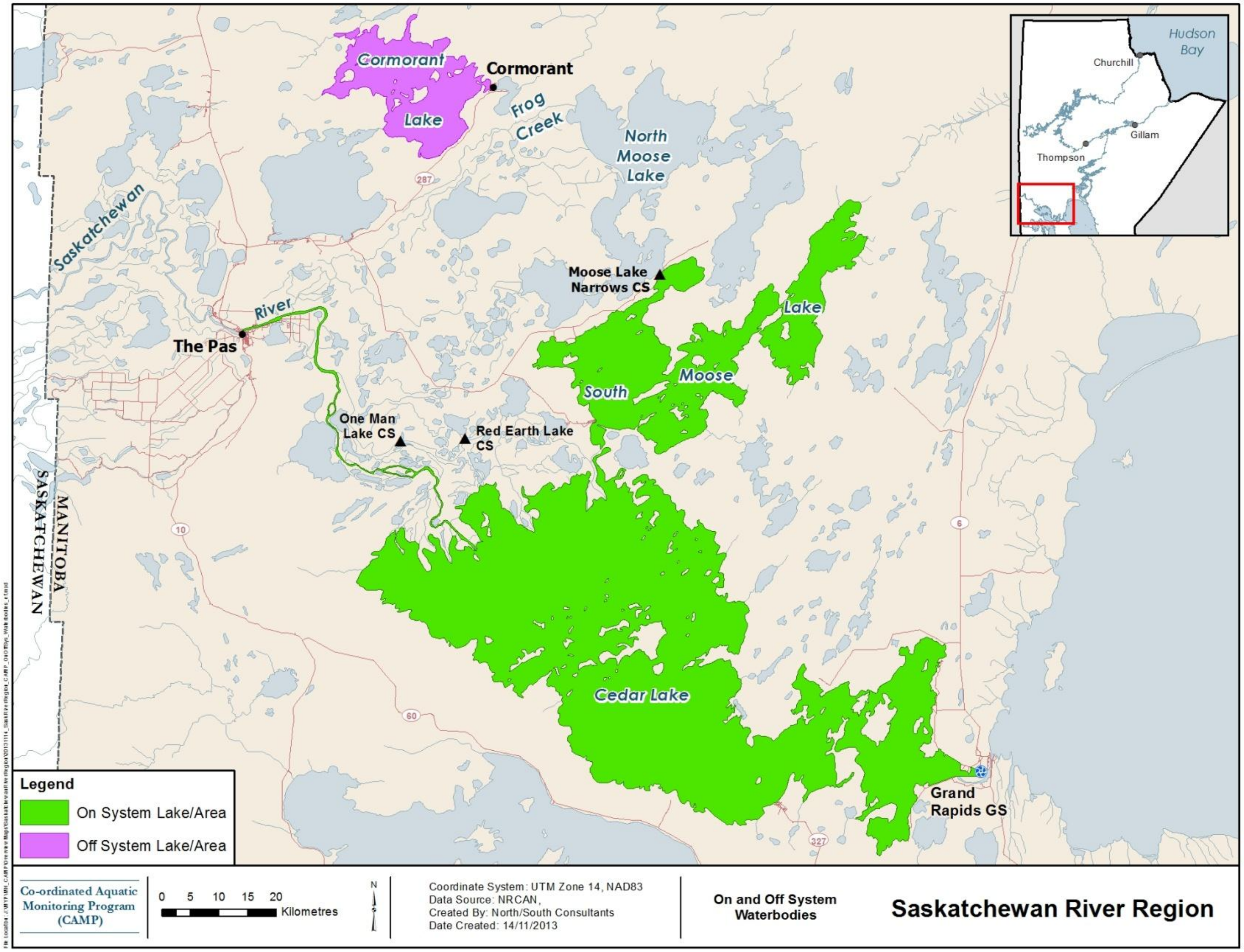

Figure 2.2-1. Saskatchewan River Region.

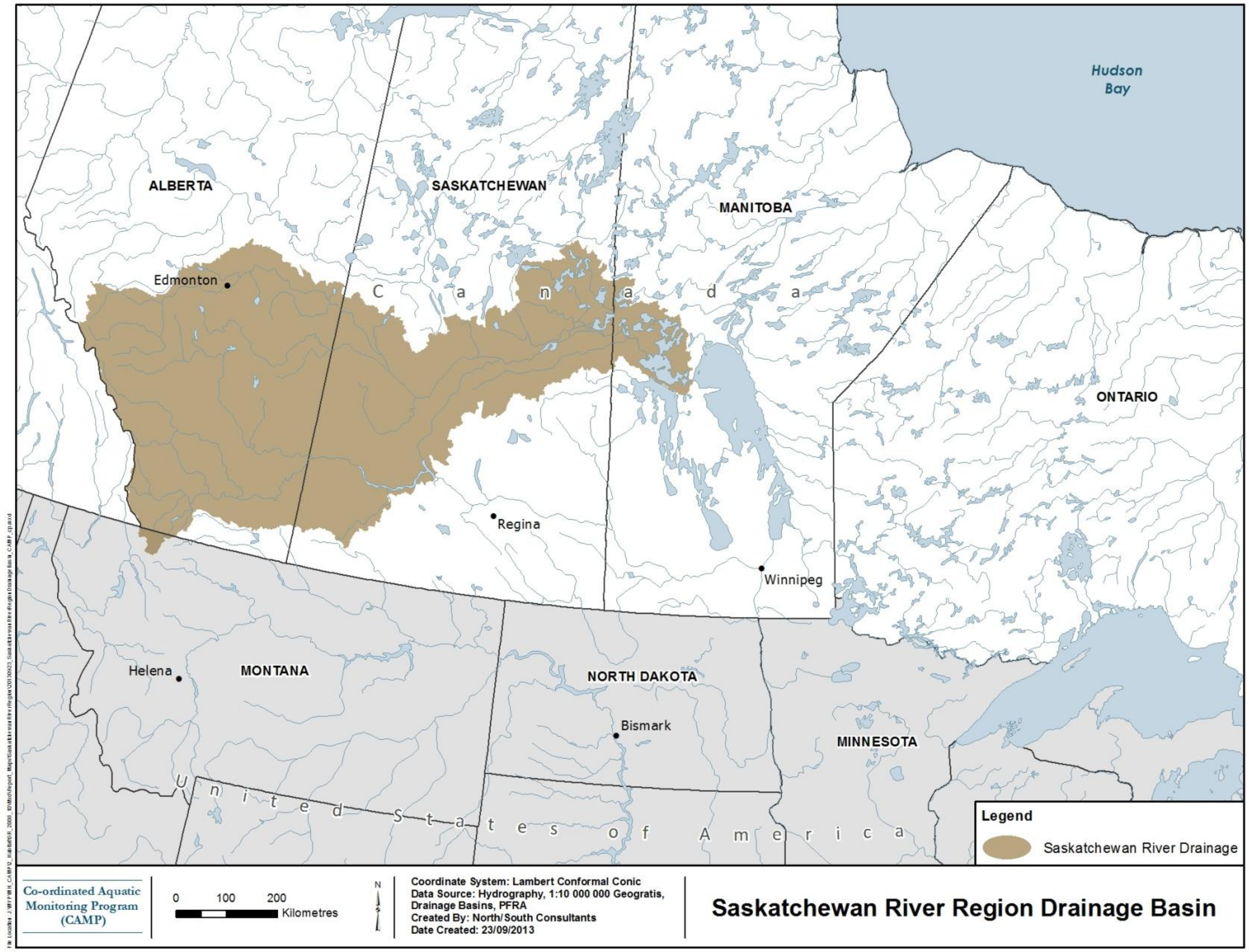

Figure 2.2-2. Saskatchewan River Region drainage basin.

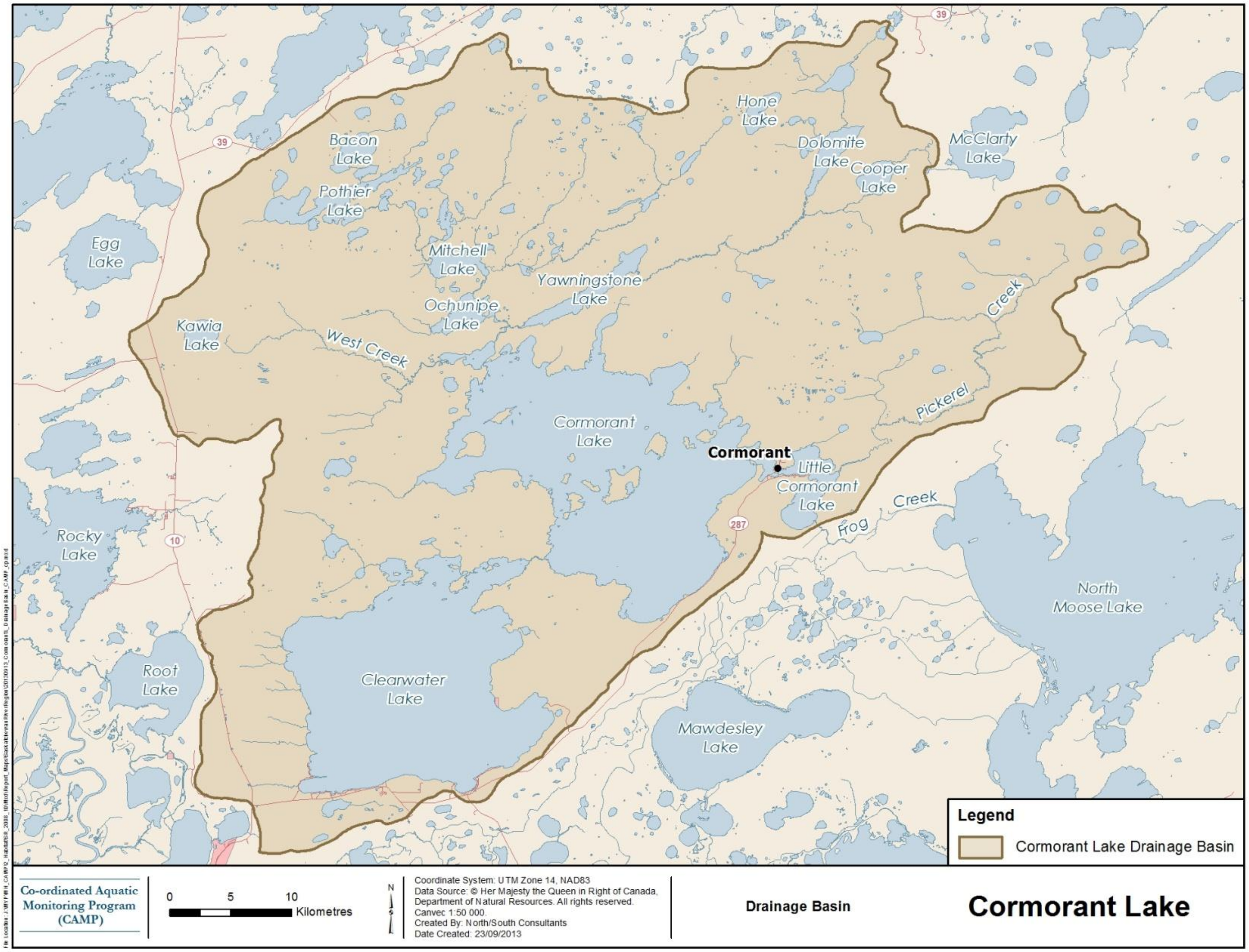

Figure 2.2-3. Cormorant Lake drainage basin.

2.3 LAKE WINNIPEG REGION

2.3.1 Regional Description

The Lake Winnipeg Region is composed of the north basin of Lake Winnipeg and Lake Winnipegosis (Figure 2.3-1). Lake Winnipeg, with a total surface area of approximately 23,750 km^2, is the largest lake in Manitoba and the tenth largest freshwater lake in the world (Brunskill et al. 1980; Environment Canada [EC] and Manitoba Water Stewardship [MWS] 2011). The lake's drainage basin, at nearly 1,000,000 km^2 in size, is the second largest watershed in Canada, encompassing parts of four Canadian provinces and four American states (EC and MWS 2011). The drainage basin includes parts of Alberta, Saskatchewan, Manitoba, Ontario, Montana, North Dakota, South Dakota, and Minnesota (Figure 2.3-2). The main tributaries to Lake Winnipeg, the Winnipeg and Saskatchewan rivers, account for 75% of Lake Winnipeg's inflow, while the waters of the Red/Assiniboine, Dauphin, Pigeon, and Berens rivers, plus other smaller tributaries, comprise the remaining 25% (EC and MWS 2011).

Lake Winnipeg lies within the Boreal Plain ecozone, although its entire eastern shoreline forms the boundary of the Boreal Shield ecozone (Figure 1.2-2). The majority of the lake falls within the Mid-Boreal Lowland ecoregion, with the southern portion of the South Basin falling within the Interlake Plain ecoregion. The southern portion of the eastern shore is situated in the Lake of the Woods ecoregion while the northern portion is situated in the Lac Seul Upland ecoregion.

The majority of the Lake Winnipeg watershed (primarily areas to the west and south of Lake Winnipeg) flows through sedimentary landscapes, with semi-arid and temperate prairies throughout (EC and MWS 2011). These sedimentary landscapes are characterized by croplands and grasslands. In the eastern portion of the watershed, sedimentary soils are replaced by shallow, bedrock-underlain soils of the Precambrian Shield (EC and MWS 2011). Bogs and other wetlands cover an extensive portion of these landscapes. Rivers flowing through these resistant shield landscapes to the east of Lake Winnipeg are clearer-flowing than those in sedimentary prairie landscapes, where the soils are more erodible (EC and MWS 2011). The dominant land cover in the basin is classified as cultivated crops (Table 2-1).

The climate of Lake Winnipeg varies from north to south, with cooler, drier conditions to the north and warmer, wetter conditions to the south (EC and MWS 2011). Mean annual air temperature from 1999 to 2007 was 0.8°C at The Pas in the north and 2.5°C at Gimli in the south. Over the same time period, total annual precipitation ranged from approximately 20 to 43 cm over the north basin.

Human alteration of portions of the Lake Winnipeg watershed began in the late 1800s. Since then, water control projects in Ontario, Manitoba, Saskatchewan, Alberta, Minnesota, and North Dakota have all affected natural inflows to the lake (Baird and Stantec 2000). Hydroelectric generating stations (GSs) were first constructed along the Winnipeg River in Manitoba over 100 years ago. Drainage from Lake Manitoba into the Dauphin River has been regulated by the Fairford Dam since the early 1960s. Construction of the Grand Rapids GS, which impounded a short section of the Saskatchewan River below Cedar Lake, was completed in 1968. Since the construction of the Jenpeg GS and Control Structure (CS) in 1976, Lake Winnipeg has become an important part of Manitoba Hydro's hydroelectric system.

Lake Winnipeg water levels undergo both short- and long-term changes (i.e., daily, monthly, seasonally, and annually) that result from variations in the amount of precipitation, evaporation, inflow to, and outflow from the lake, including the effects of regulation. Over the scale of centuries, isostatic rebound has been raising the outlet of the lake such that levels in the south basin are gradually increasing at an estimated rate of 20 cm/century (Baird and Stantec 2000; Nielsen 1998).

While there are few population centres on the north basin of Lake Winnipeg (e.g., Grand Rapids, Berens River), municipal and industrial wastewater discharges from large cities throughout the Lake Winnipeg basin contribute significant nutrient inputs to Lake Winnipeg as a whole and ultimately to the north basin. In Manitoba alone, Lake Winnipeg receives effluent from nearly 200 wastewater treatment facilities, as well as effluent from 10 large facilities, including municipal and industrial plants (Bourne et al. 2002).

Lake Winnipeg supports large commercial, subsistence, and recreational fisheries, recreational activities, cottage developments, and lakeshore communities (e.g., Gimli, First Nation communities). The basin is home to approximately six million people and 17 million livestock, and includes 55 million hectares of agricultural land (Lake Winnipeg Implementation Committee 2005). The contamination of Lake Winnipeg has been the subject of intermittent study over the past four decades. Although there have been issues related to other contaminants (e.g., the commercial fishery was closed one year in the early 1970s due to mercury levels), the primary focus has been related to eutrophication, as a result of organic loading in the 1960s and more recently, enrichment by nitrogen and phosphorus (North/South Consultants Inc. 2006).

Like Lake Winnipeg, Lake Winnipegosis lies within the Boreal Plain ecozone. The south portion (i.e., south of Birch Island) of Lake Winnipegosis is situated in the Interlake Plain ecoregion, while the north portion is situated in the Mid-boreal Lowland ecoregion (Figure 1.2-2). Although the Lake Winnipegosis watershed is considered large, Lake Winnipeg drains an area approximately 20 times larger than that of Lake Winnipegosis and the surface area of Lake Winnipeg is approximately four times larger than that of Lake Winnipegosis (Table 2-1). The Lake Winnipegosis watershed extends west to include the moderately high relief of the Manitoba Escarpment and the valleys and plains of eastern Saskatchewan (Figure 2.3-3). Major tributaries include the Mossy, Red Deer, and Shoal rivers, and the lake discharges into Lake Manitoba via the Waterhen River.

The shoreline of Lake Winnipegosis is scarcely populated, with the Village of Winnipegosis and a few First Nation communities being the only population centres. However, the drainage basin includes larger centres such as the Town of Dauphin and the Town of Swan River. The region's dominant land cover is deciduous forest (Table 2-1) and forestry is one of the primary industries of the region. A small portion of the land base, situated mainly in the southern portion of the region, is used for agriculture due to suitable soil composition, drainage, growing season length, and precipitation. This land base supports cereal and oil seed farming, as well as livestock production. The lake supports important subsistence, commercial, and recreational fisheries.

2.3.2 Hydroelectric Facilities

With a surface area of approximately 23,750 km^2, Lake Winnipeg is the seventh largest lake in North America (Brunskill et al. 1980). Although there are no structures related to hydroelectric generation in Lake Winnipeg proper (Figure 2.3-1), the lake is regulated as a natural reservoir by the Jenpeg GS located in the Upper Nelson River Region (Section 2.7.2). Under LWR, the natural annual water outflow pattern of Lake Winnipeg is modified (i.e., outflow into the Nelson River is decreased in the spring and early summer, and increased during the fall and winter. In flood years, LWR reduced the magnitude and duration of flood levels on Lake Winnipeg by increasing outflows by 40-50 percent.

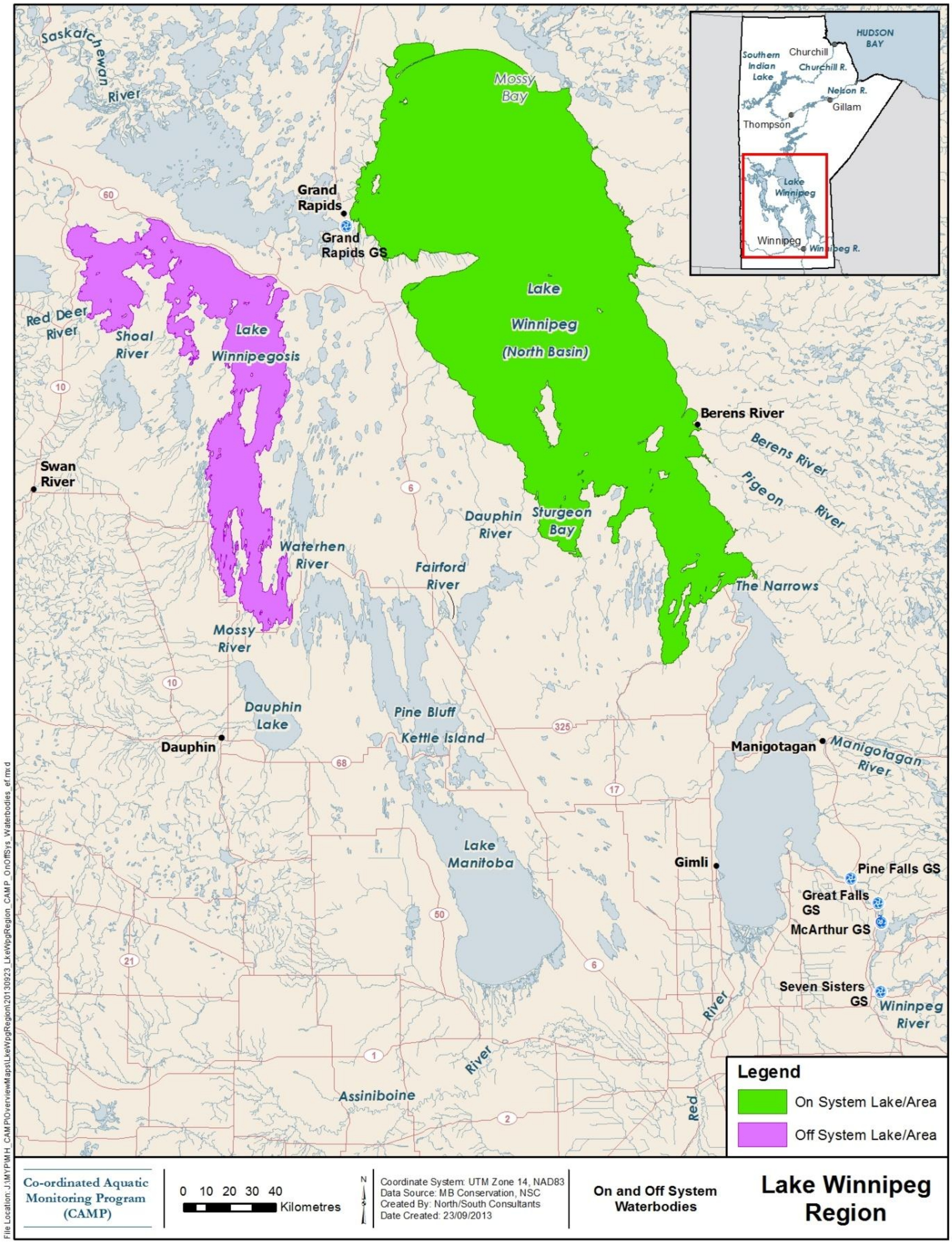

Figure 2.3-1. Lake Winnipeg Region.

Figure 2.3-2. Lake Winnipeg Region drainage basin.

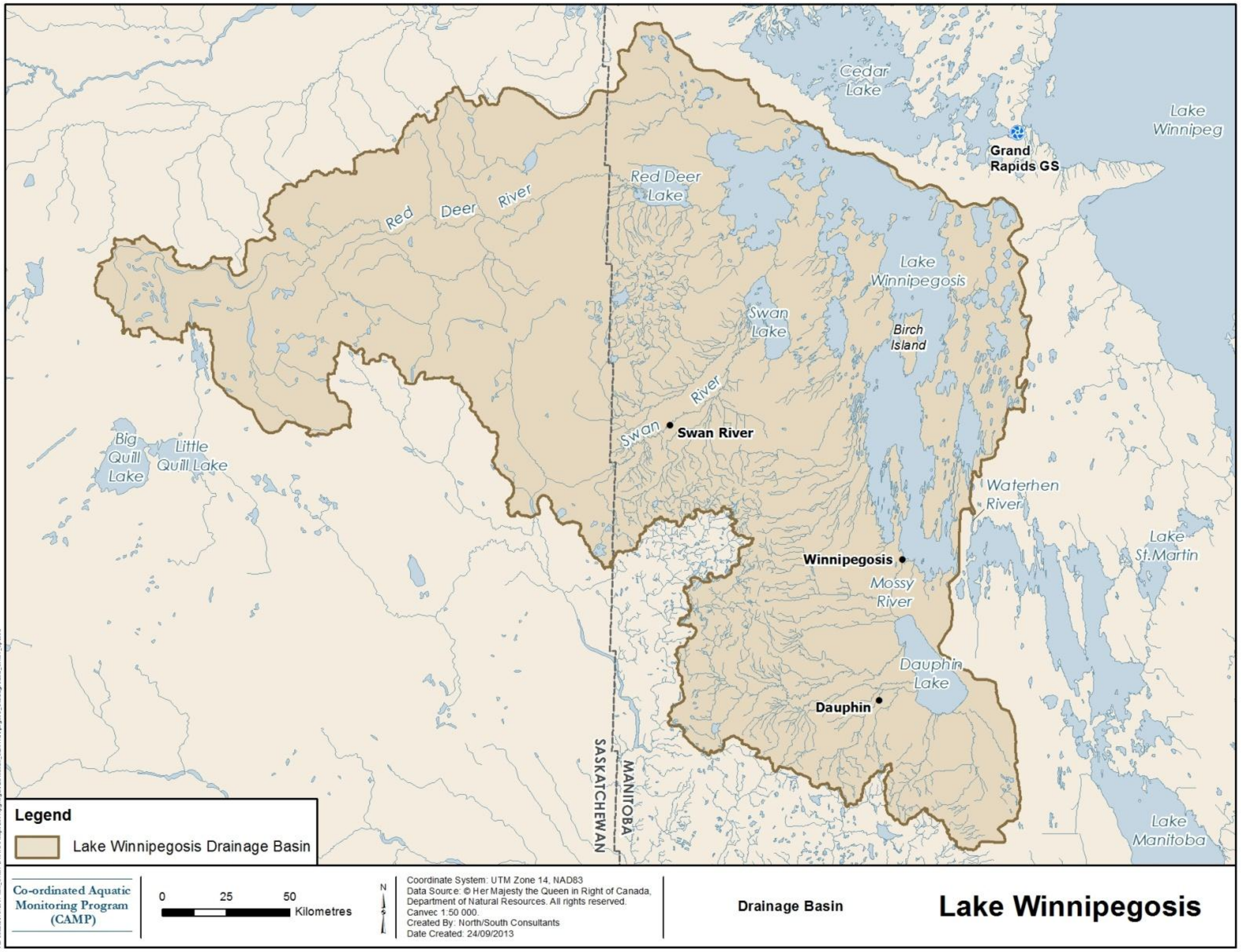

Figure 2.3-3. Lake Winnipegosis drainage basin.

2.4 UPPER CHURCHILL RIVER REGION

2.4.1 Regional Description

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 man-made outlet at South Bay (Figure 2.4-1).

The upper Churchill River watershed drains approximately 260,000 km^2 of northern Alberta, Saskatchewan, and Manitoba, eventually emptying into Southern Indian Lake, Manitoba (Figure 2.4-2). In 1976, the Churchill River was impounded at the outlet of Southern Indian Lake, and most of its flow was diverted by means of the Churchill River Diversion (CRD) into the Rat/Burntwood river system and eventually to hydroelectric generating stations (GSs) on the Nelson River.

The majority of the Upper Churchill River Region lies within the Churchill River Upland ecoregion of the Boreal Shield ecozone although the northern portion of Southern Indian Lake falls within the Selwyn Lake Upland ecoregion of the Taiga Shield ecozone (Figure 1.2-2).

The climate of the upper Churchill River drainage basin is variable due to the large size of the watershed. The coldest month of the year is typically January, with mean daily air temperatures generally ranging from –10ºC in the south to –27.5ºC in the north (Rosenberg et al. 2005). The warmest month of the year is typically July, with mean daily air temperatures generally ranging from 17.5°C in the south to 15ºC in the northern part of the basin (Rosenberg et al. 2005). The number of frost-free days range from approximately 120 in the south to 60 to 70 in the northern and western fringes of the portion of the watershed suitable for widespread agricultural activity (Rosenberg et al. 2005). The mean annual precipitation for the basin is approximately 40 cm (Rosenberg et al. 2005).

The dominant land cover within the upper Churchill River drainage basin is coniferous forest (Table 2-1) and these forests support a number of commercial forestry operations in central Saskatchewan (Rosenberg et al. 2005). Large portions of western central Saskatchewan lying within the upper Churchill River drainage basin are composed of grasslands underlain by brown, dark brown and black soils that support cultivated land or uncultivated land used for grazing (Rosenberg et al. 2005). There is also some non-renewable resource activity within the basin, including metal mining concentrated in northern Saskatchewan and Manitoba. Within Manitoba there are three mine properties in the Churchill River watershed (i.e., Lynn Lake mine, Ruttan Lake mine near Leaf Rapids, and the Farley Lake mine), all of which shut down in the early 2000s (Manitoba Innovation, Energy and Mines (2012). Hydroelectric development has altered the Southern Indian Lake portion of the upper Churchill River through the construction of CRD. Additionally, there are two hydroelectric GSs on the upper Churchill River system in Saskatchewan (Island Falls dam on the Churchill River and the Whitesand Dam on the Reindeer River) and two small hydroelectric GSs (Laurie River I and II) and several small Control Structures (CSs) on the Laurie River, a tributary to the Churchill River in Manitoba.

The upper Churchill River watershed supports extensive commercial and domestic fishing hunting and trapping, as well as commercial sport fishing and hunting operations. Additionally, recreational use of the Churchill River (particularly in Saskatchewan) is common.

The upper Churchill River basin is sparsely populated and all communities within the watershed in Saskatchewan and Manitoba are smaller than 5,000 people. Communities or First Nations found within the upper Churchill River basin in Manitoba include Pukatawagan, Granville Lake, Lynn Lake, Leaf Rapids, and South Indian Lake.

2.4.2 Hydroelectric Facilities

The Churchill River drainage basin, with an area of approximately 281,000 km^2, has its headwaters in northern Saskatchewan and Alberta. The upper Churchill River flows entering Manitoba have been regulated to some extent since 1928. MacKay (1992) reported that the Island Falls Generating Station (GS) on the upper Churchill River in Saskatchewan (constructed in 1928-1930) has had major impacts on water levels and flows along the Churchill River in Manitoba. As well, the Whitesand Dam (completed in 1942) on the Reindeer River in Saskatchewan continues to regulate the outflows from Reindeer Lake. Heilman-Ternier and Harms (1975) reported that the operating policy of the two dams is to minimize water level fluctuations at the Island Falls reservoir (Sokatisewin Lake) by increasing the flow from Reindeer Lake when the Churchill River flows are low, and by decreasing the flow from Reindeer Lake when the Churchill River flows are high. The authors reported that this policy had resulted in relatively constant levels on the Island Falls reservoir and a moderation of natural seasonal variation in flows to downstream areas. In 1981, a change in operating regime at Island Falls GS resulted in a shift from base load operations to those that maximized power generation. Following the change, EMA (1993) *In* Cooley and MacDonald (2008) reported that post-1980 winter monthly flows were 25-38% higher than natural conditions and summer flows were 15-25% lower than natural conditions.

The Churchill River flows northeast to Manitoba and, in its natural state, continued through Southern Indian Lake and a series of other smaller lakes before eventually emptying into Hudson Bay near the Town of Churchill. In 1976 a dam was constructed at Missi Falls (Missi Falls Control Structure [CS]) at the outlet of Southern Indian Lake which raised the level of the lake and diverted approximately 75% of the Churchill River flow southward into the Rat/Burntwood River system, eventually draining to the lower Nelson River at Split Lake.

The primary water regulation structure within the Upper Churchill River Region in Manitoba is the Missi Falls CS (Figure 2.4-1). Manitoba Hydro GSs located within the region consist of the Laurie River I and Laurie II GSs located on the Laurie River, a tributary to the Churchill River upstream of Granville Lake. Both Laurie I and Laurie II GSs were purchased by Manitoba Hydro in 1970 from Sherritt Gordon Mines Limited. Manitoba Hydro also maintains a number of CSs that were constructed by Sherritt Gordon Mines as part of the Laurie River project. These include the Loon River Diversion Control Structure, the Eager Lake Control Structure, the Russell Lake Control Structure, and the Kamuchawie Control Structure (Figure 2.4-1).

2.4.2.1 Laurie River I GS

The Laurie River I GS is located approximately 200 km northwest of Thompson and approximately 27 km west of the community of Granville Lake. The station was built to supply Sherritt Gordon's mining operations in the area and went into operation in 1952. With an operating head of 16.6 m, Laurie River I has two turbine units and a capacity of 5 megawatts (MW) of electricity. The Laurie River I Forebay has an area of 44 km^2 and the GS is operated as a run-of-the-river facility.

2.4.2.2 Laurie River II GS

The Laurie River II GS is located approximately 10 km upstream of the Laurie River I GS. Like the Laurie I GS, the Laurie II GS was built by Sherritt Gordon Mines and began operation in 1958 to supply local mining operations. With an operating head of 18.1 m, Laurie River II also has a capacity of 5 MW of electricity, but only one turbine unit. The Laurie River II Forebay has a surface area of 54 km^2 and the GS is a modified run-of-the-river operation.

2.4.2.3 Missi Falls Control Structure

The Missi Falls CS was constructed in 1976 at the natural outlet of Southern Indian Lake. It raised the water level of Southern Indian Lake by approximately 3 m and regulates both the water level in Southern Indian Lake and the amount of water allowed to pass downstream to the lower Churchill River. The Missi Falls CS consists of six spillway bays as well as earth dams and dykes. The Missi Falls CS forebay fluctuates between 256.9 m and 258.3 m. The minimum licensed outflow is 14.2 m^3/s during open-water conditions and 42.5 m^3/s under ice cover. The CS is capable of discharging 3,200 m^3/s at a forebay level of 258.3 m.

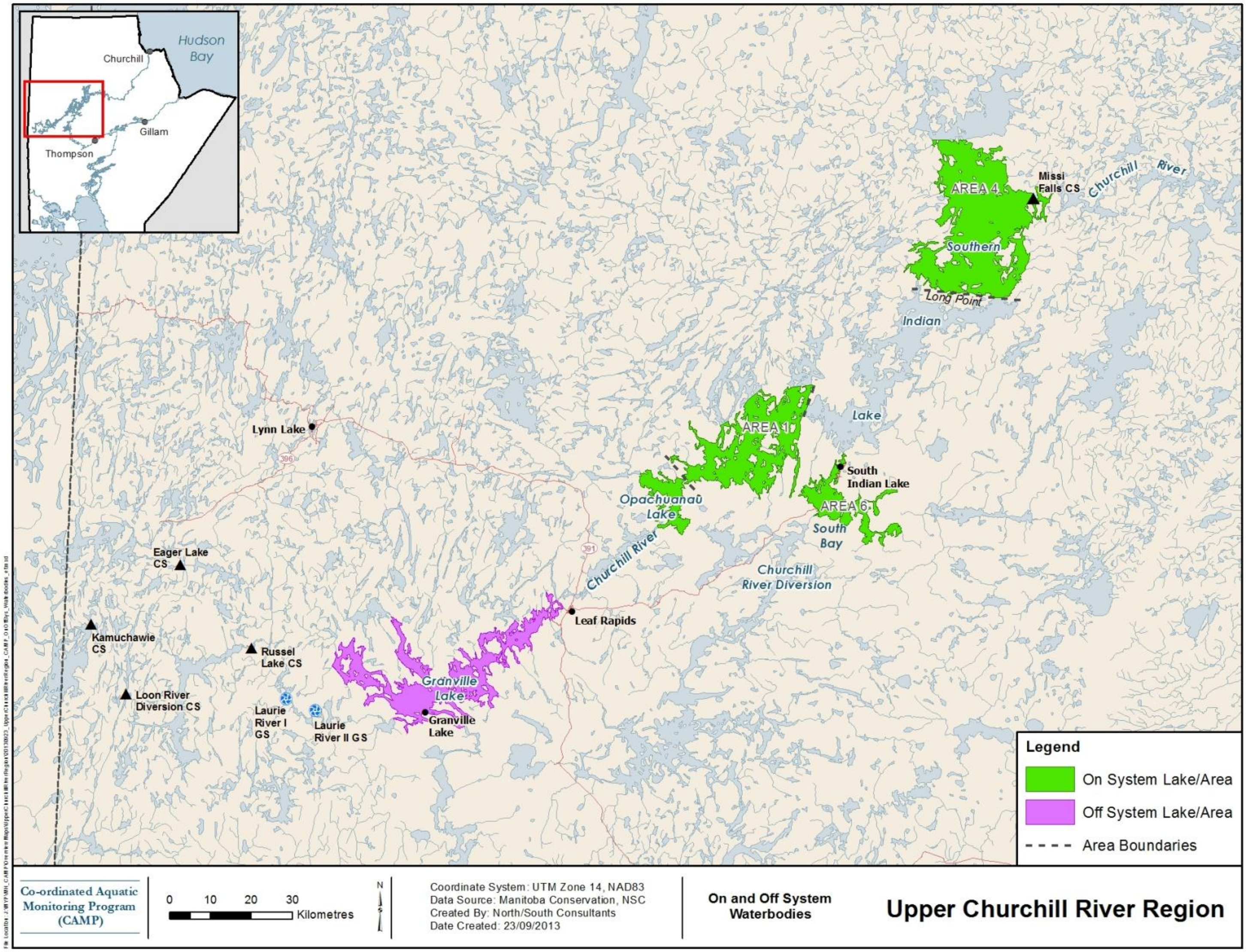

Figure 2.4-1. Upper Churchill River Region.

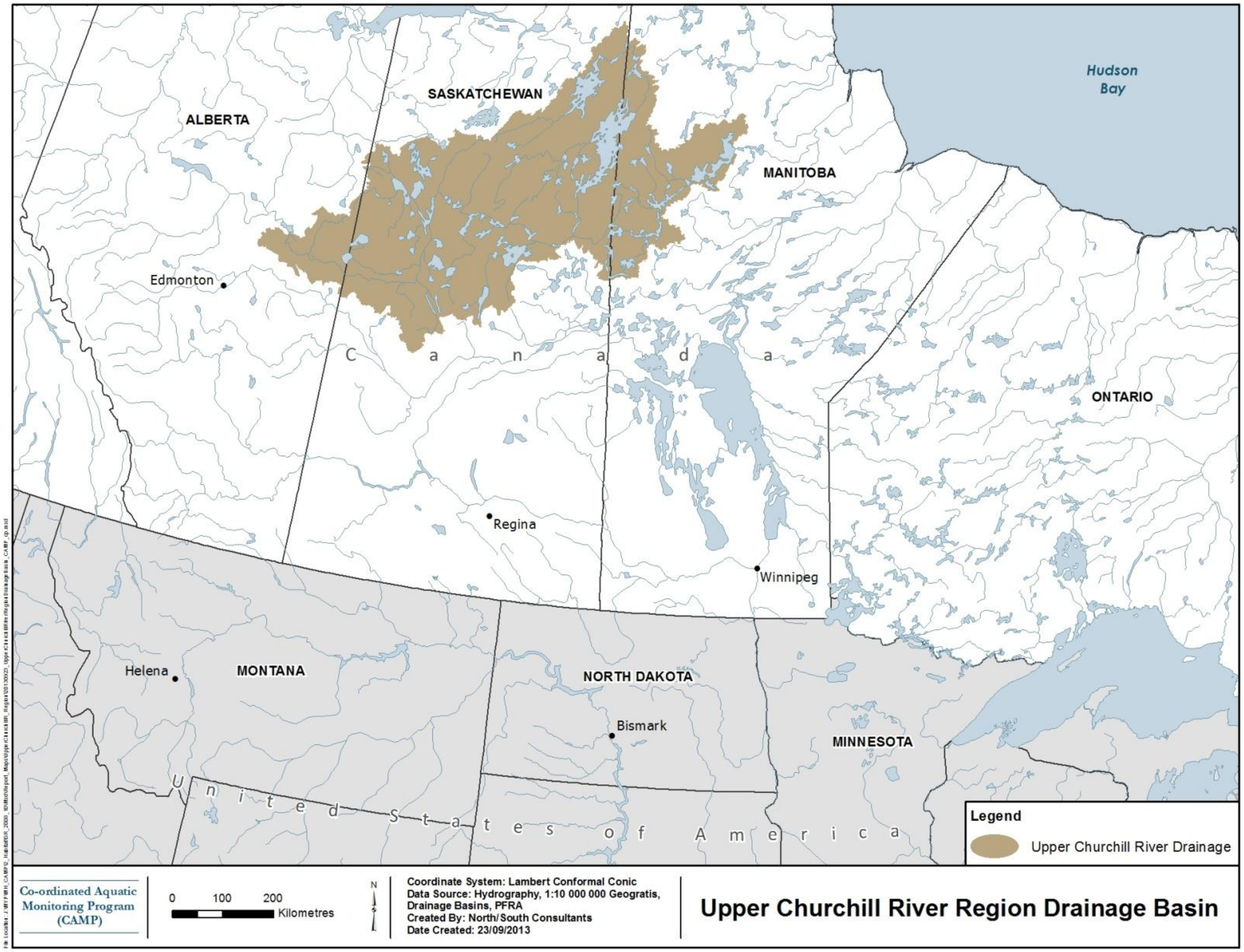

Figure 2.4-2. Upper Churchill River Region drainage basin.

2.5 LOWER CHURCHILL RIVER REGION

2.5.1 Regional Description

The Lower Churchill River Region is composed of the portion of the Churchill River extending from the Missi Falls Control Structure (CS) at the natural outlet of Southern Indian Lake to the mouth of the river at the Town of Churchill on Hudson Bay (Figure 2.5-1). The region also includes Gauer Lake, an off-system waterbody located south of the Churchill River.

Historically, the Churchill River at Southern Indian Lake drained approximately 260,000 km^2 of northern Alberta, Saskatchewan, and Manitoba (Figure 2.5-2). However, since the Churchill River was impounded at the outlet of Southern Indian Lake by the Missi Falls CS in 1976, a large portion of its flow was diverted by means of the Churchill River Diversion (CRD) to hydroelectric generating stations (GSs) on the lower Nelson River. Consequently, post-CRD discharge along the lower Churchill River has been considerably lower than historic rates.

The Lower Churchill River Region spans three ecozones (Boreal Shield, Taiga Shield, and Hudson Plain) and four ecoregions (Churchill River Upland, Selwyn Lake Upland, Hudson Bay Lowland, and Coastal Hudson Bay Lowland) (Figure 1.2-2). The shield ecozones are characterized by numerous lakes and wetlands and have a poorly organized drainage system (Rosenberg et al. 2005). The lower portion of the lower Churchill River flows through the Hudson Plain ecozone, an area characterized by flat muskeg plains, extensive permafrost, shallow lakes, and raised gravel beaches (Lane and Sykes 1982 *In* Rosenberg et al. 2005). The dominant land cover of the Lower Churchill River Region is classified as coniferous forest (Table 2-1).

The climate of the Lower Churchill River Region is characterized by long cold winters and short cool summers. The coldest month of the year is generally January with a mean daily air temperature near –27.5ºC recorded at Churchill (Rosenberg et al. 2005). The warmest month of the year is typically July, with mean daily air temperatures of around 11.5°C recorded at Churchill (Manitoba Hydro and the Town of Churchill 1997). The mean annual precipitation for the entire Churchill River basin (including both the Upper and Lower Churchill River regions) is approximately 40 cm (Rosenberg et al. 2005), which is similar to levels recorded at Churchill (Manitoba Hydro and the Town of Churchill 1997).

The Lower Churchill River Region is sparsely populated with only one community (i.e., Town of Churchill located along the shore of Hudson Bay) located within the region. Individuals from Churchill and several First Nation communities participate in domestic and commercial harvesting of fish and wildlife along the lower Churchill River. Additionally, recreational fishing and other recreational use of the lower Churchill River near Churchill are common. There are no forestry activities within the region and there are no historic or active mines in the Lower Churchill River Region.

Gauer Lake is located in the Boreal Shield ecozone and the Churchill River Upland ecoregion (Figure 1.2-2), approximately 125 km north of the City of Thompson (Figure 2.5-1). The surface area of the lake is 263 km^2, with a drainage basin of 4,897 km^2 (Table 2-1). Gauer Lake receives inflows from the upper portion of the Gauer River and a few smaller tributaries (Figure 2.5-3). The lower portion of the Gauer River forms the outflow from Gauer Lake and discharges into the lower Churchill River below Missi Falls (Figure 2.5-3). The dominant land cover of the watershed is shrub (Table 2-1). Gauer Lake supports a commercial fishery and likely supports some subsistence fishing, hunting, and trapping. There are no permanent residences in the watershed, although there are a couple of seasonal fishing camps on the shore of Gauer Lake. There is no forestry activity and no active mines in the watershed.

2.5.2 Hydroelectric Facilities

As discussed in Section 2.4.2, the Missi Falls Control Structure (CS) has minimum licensed open water and winter outflows and therefore controls the amount of water being released into the lower Churchill River. There are no hydroelectric generation facilities on the lower Churchill River. The Lower Churchill River Water Level Enhancement Weir Project was constructed in 1998 and 1999 to increase water levels along a 10 km long reach of the lower Churchill River, to enhance recreational opportunities in the area, and to increase the amount of aquatic habitat. The rock-fill weir and ancillary features were built 10 km south of the Town of Churchill, just upstream of Mosquito Point (Figure 2.5-1).

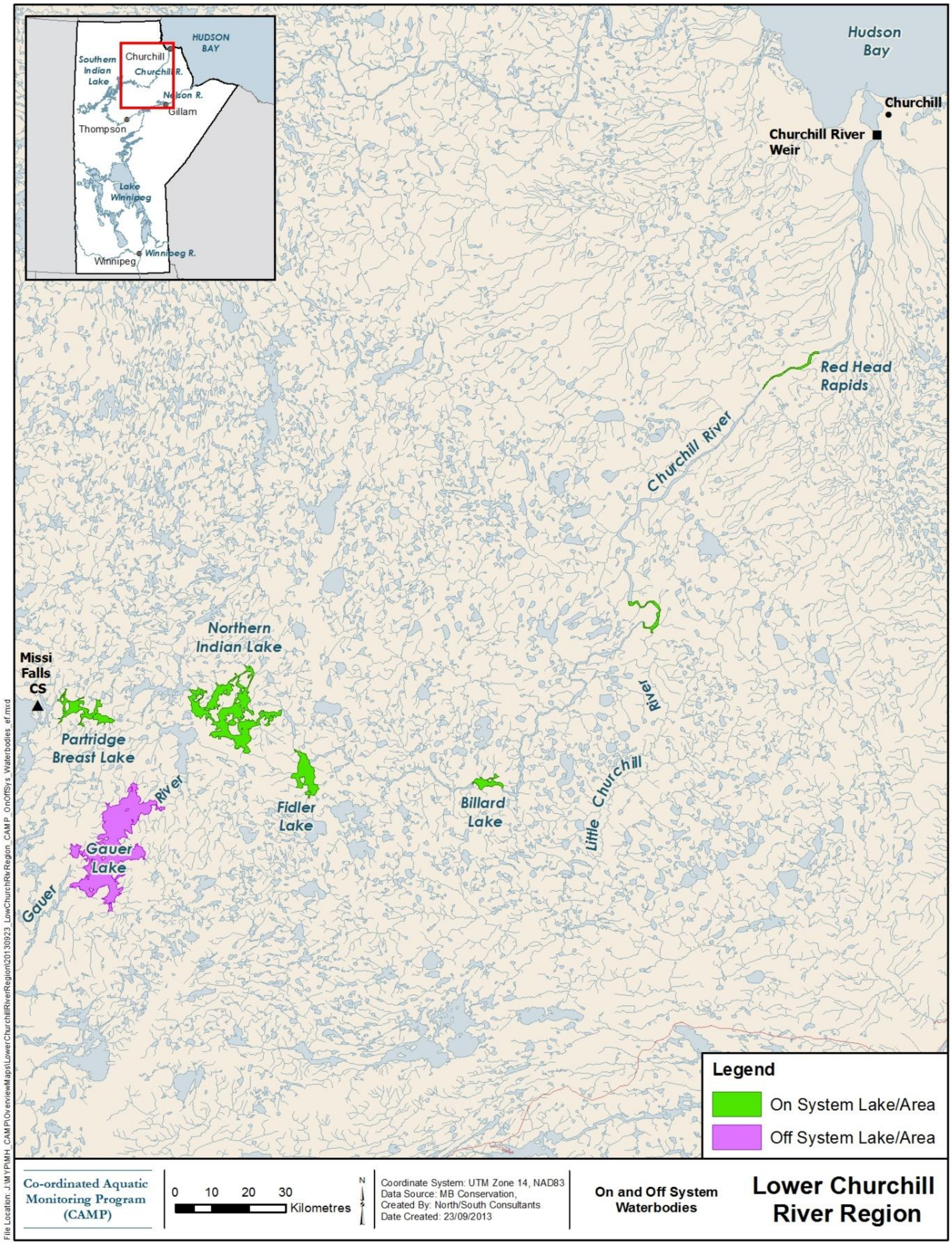

Figure 2.5-1. Lower Churchill River Region.

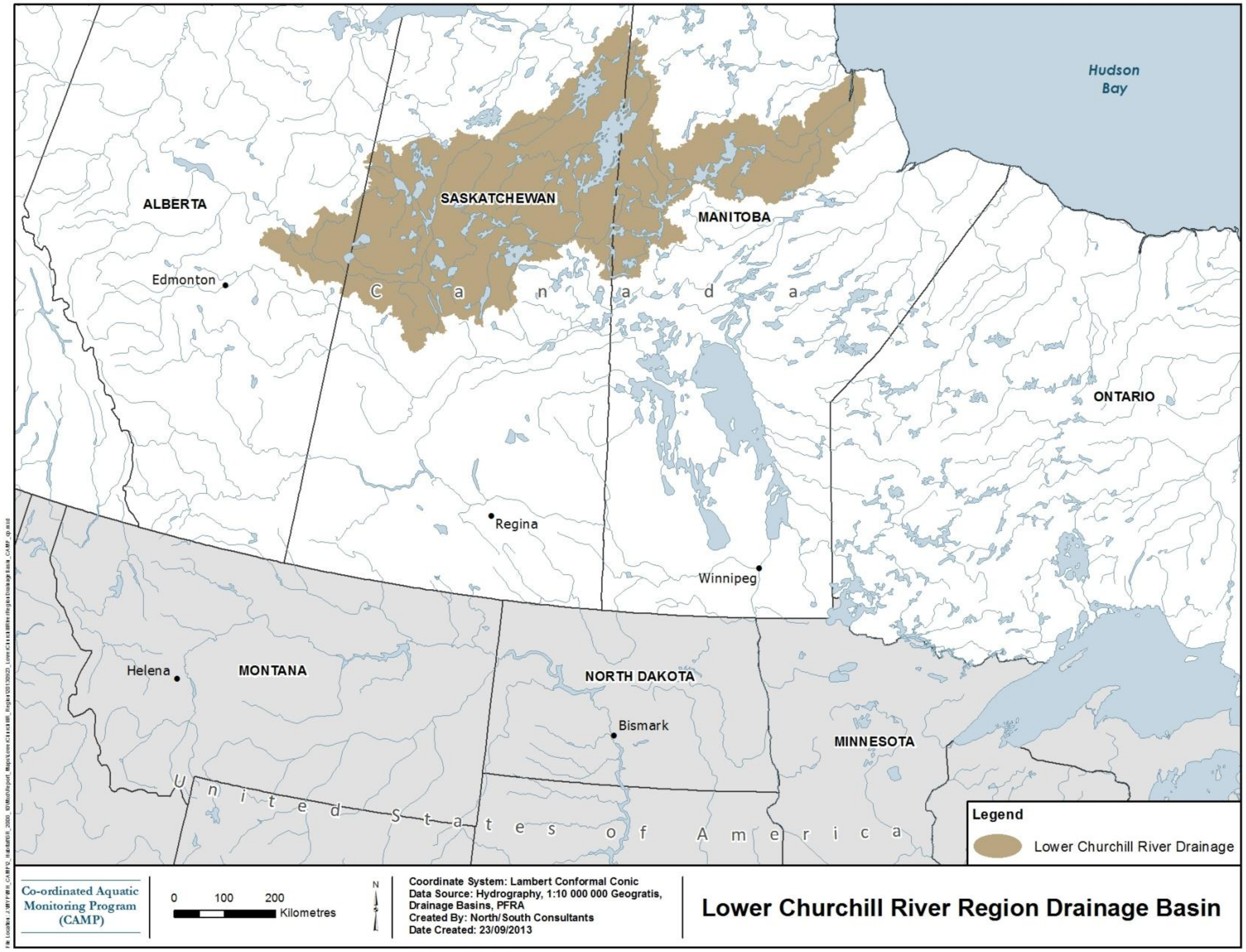

Figure 2.5-2. Lower Churchill River Region drainage basin.

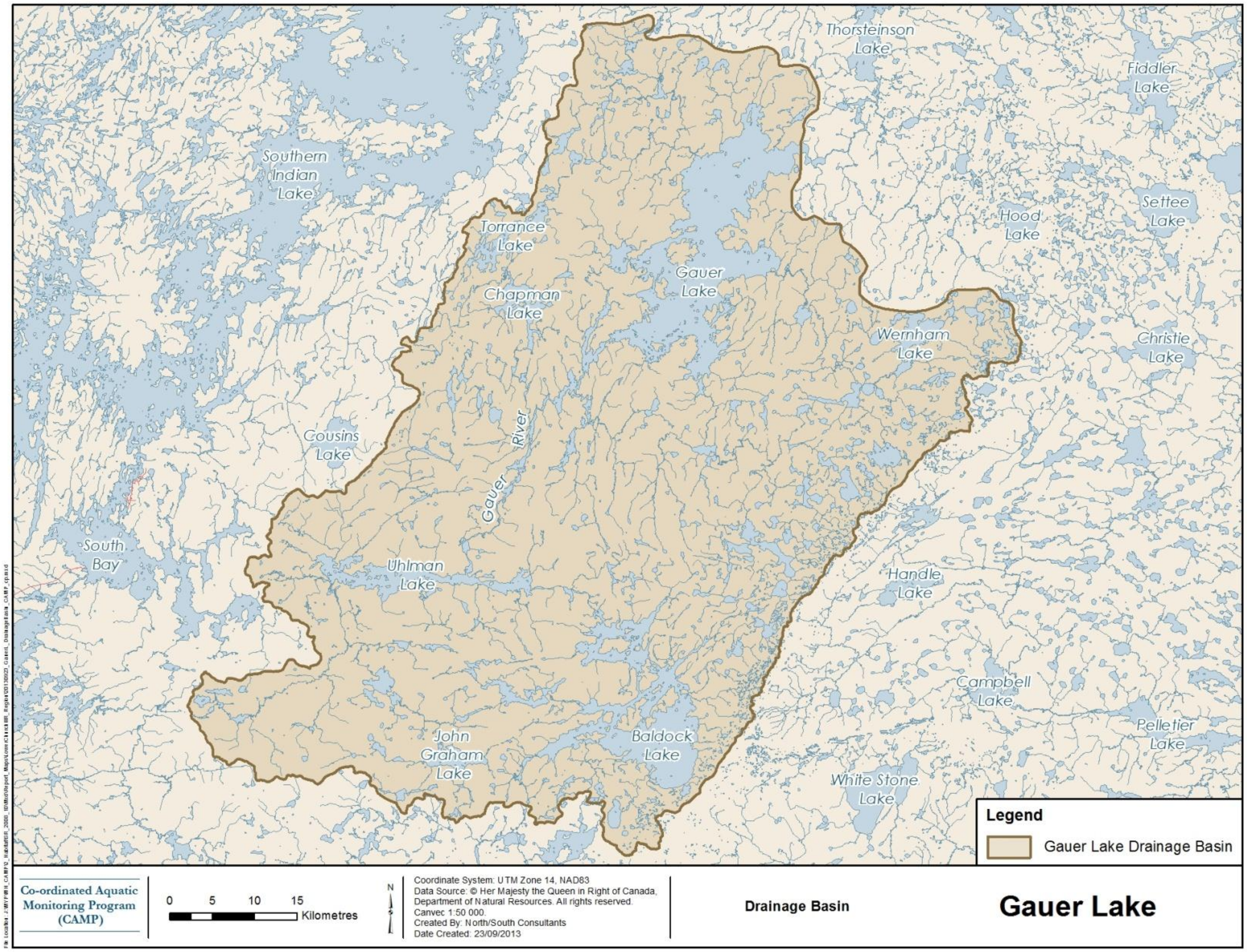

Figure 2.5-3. Gauer Lake drainage basin.

2.6 CHURCHILL RIVER DIVERSION REGION

2.6.1 Regional Description

The Churchill River Diversion (CRD) Region is composed of the portion of the CRD that extends from the man-made outlet of Southern Indian Lake at South Bay, through the Rat/Burntwood river system to First Rapids on the Burntwood River, approximately 20 km upstream of Split Lake (Figure 2.6-1). The region also includes Leftrook Lake, an off-system lake, located on the Footprint River system.

In 1976, the Churchill River was impounded at Southern Indian Lake and most of its flow was diverted by means of the CRD to hydroelectric generating stations (GSs) on the Nelson River. The CRD involved the construction of an artificial outlet at South Bay on Southern Indian Lake, construction of a channel linking Southern Indian Lake and the headwaters of the Rat River, impoundment of Southern Indian Lake by the Missi Falls Control Structure (CS), and impoundment of the upper Rat River by the Notigi CS. When commissioned, the CRD re-directed most of the natural flow of the Churchill River through the Rat River to its confluence with the Burntwood River at Threepoint Lake (Figure 2.6-2). The size of the effective drainage basin at Apussigamasi Lake (downstream of Threepoint Lake) after diversion is approximately 280,000 km^2 (Table 2-1).

The majority of the Churchill River Diversion Region lies within the Churchill River Uplands ecoregion of the Boreal Shield ecozone with a small proportion of the region falling within the Hayes River Upland ecoregion of the same ecozone (Figure 1.2-2). Precambrian Shield bedrock underlies the majority of this region (Smith et al. 1998 *In* Jones and Armstrong 2001). Outcroppings of granitic Precambrian bedrock are common throughout the region and, when not exposed at the surface, the bedrock is overlain by a variety of soil types including brunisols (derived from sand deposits), luvisols (derived from lacustrine clay deposits), and deep organic soils (derived from peat deposits) (Jones and Armstrong 2001). Some streams and lakes in the Rat/Burntwood River system are underlain by lacustrine clay deposits and are naturally turbid, a feature that is uncharacteristic of most waterbodies in the Boreal Shield ecozone (Jones and Armstrong 2001). The dominant land cover of the region is coniferous forest (Table 2-1). Black spruce and jackpine are the dominant tree species within forest cover; sphagnum moss, black spruce, and ericaceous shrubs and sedges and brown mosses dominate the bogs and fens, respectively (Jones and Armstrong 2001).

The climate of the Churchill River Diversion Region, based on data from Thompson for the period of record between 1971 and 2000, is characterized by mean monthly temperatures ranging from 15.8ºC in July to –24.9ºC in January (Manitoba Hydro and Nisichawasihk Cree Nation

2003). Rainfall accounts for about 67% of the approximately 50 cm of annual precipitation, with the majority occurring between June and September (Manitoba Hydro and Nisichawayasihk Cree Nation 2003).

Land use and industry within the Churchill River Diversion Region include forestry, mining, commercial fishing and trapping, subsistence fishing, hunting, and trapping, and recreation (including recreational fishing and sport hunting; Jones and Armstrong 2001). The region is sparsely populated, with the only major urban centre being the City of Thompson. The only other population centre within the region is at Nelson House located on Footprint Lake. The region is home to two nickel mines: the Vale Canada (Vale) INCO mining and smelting complex just south of Thompson; and the Birchtree Mine located at Birchtree Lake, approximately 10 km southwest of Thompson, both of which are currently active (Manitoba Innovation, Energy and Mines 2012). Both the City of Thompson and Vale discharge treated domestic and industrial effluent to the Burntwood River (Jones and Armstrong 2001).

Leftrook Lake is located in the Boreal Shield ecozone and the Churchill River Upland ecoregion (Figure 1.2-2), approximately 60 km northwest of the City of Thompson and 30 km north northeast of Nelson House near the head of the Footprint River system (Figure 2.6-1). The surface area of Leftrook Lake is 46 km^2, with a drainage basin of 389 km^2 (Table 2-1). The lake receives inflow from a few small tributaries and is drained by the Footprint River (Figure 2.6-3). The shorelines consist of exposed bedrock and bedrock overlain with lacustrine deposits of stratified silts and clays (Beke et al. 1973). The bedrock is primarily granitic with wide belts of gneissic and volcanic rock. The area surrounding the lake is characterized as one of moderate topographic relief with intermittent depressions and peat accumulations (Lake Winnipeg, Churchill and Nelson Rivers Study Board 1975). The dominant land cover of the watershed is Coniferous Forest (Table 2-1). Vegetation is dominated by black spruce forest with patches of mixed forest. Leftrook Lake supports subsistence fishing, hunting, and trapping. There are no permanent residences in the watershed although there are a few seasonal campsites on the shoreline of Leftrook Lake. There are no forestry activities or active mines in the watershed.

2.6.2 Hydroelectric Facilities

The Churchill River Diversion (CRD) directs much of the flow from the Churchill River into the Rat/Burntwood and Nelson rivers, to be used for added power generation at both existing and potential future generating stations (GSs) on the Burntwood and lower Nelson rivers. In addition to the Missi Falls Control Structure (CS), CRD consists of two major components and one ancillary component (Figure 2.6-1), as follows:

- an excavated channel (South Bay Diversion Channel) from South Bay in Southern Indian Lake to Issett Lake directs the Churchill River water to the Rat River (tributary to the Burntwood River) and ultimately into the Nelson River;
- a CS at Notigi Lake (Notigi CS) on the Rat River regulates the amount of water being diverted into the Burntwood/Nelson River system; and
- an ice CS at Manasan Falls reduces the risk of inundation to the City of Thompson as a result of ice jams in the Burntwood River. The project consists of an ice boom across the Burntwood River upstream of a groin/gap structure, a bypass channel with a concrete overflow weir and a flood channel protected by a dyke.

The region also contains the newly constructed Wuskwatim GS.

2.6.2.1 South Bay Diversion Channel

The South Bay Diversion Channel is a 9.3 km long, approximately 60 m wide excavated channel constructed from South Bay in Southern Indian Lake to Issett Lake at the headwaters of the Rat River system (a tributary to the Burntwood River). The channel diverts water from the Churchill River system to the Rat River and downstream to the Burntwood and Nelson rivers.

2.6.2.2 Notigi Control Structure

The Notigi CS was constructed between 1974 and 1975 and is located on the Rat River between Notigi and Wapisu lakes. It regulates the amount of water diverted to the Burntwood and Nelson rivers. The structure consists of three spillway bays, a main dam, and two saddle dams located on the Rat River at the outlet of Notigi Lake designed to regulate the amount of water released through the diversion route into the Burntwood and Nelson rivers. Under the Augmented Flow Program, Notigi CS has a maximum licensed average weekly outflow of 991 m^3/s during the open-water period and 963 m^3/s under ice cover. The Notigi CS Forebay fluctuates between 254.2 m (the minimum licensed level) and 258.3 m.

2.6.2.3 Wuskwatim GS

The Wuskwatim Power Limited Partnership, a partnership of Manitoba Hydro and Nisichawayasihk Cree Nation, recently completed construction of the Wuskwatim GS on the Burntwood River approximately 45 km southwest of Thompson. The 210 MW station was commissioned in 2012 and consists of three turbine generator units. The Wuskwatim GS is a low head, modified run-of-the river design that resulted in less than 0.4 km^2 of flooding.

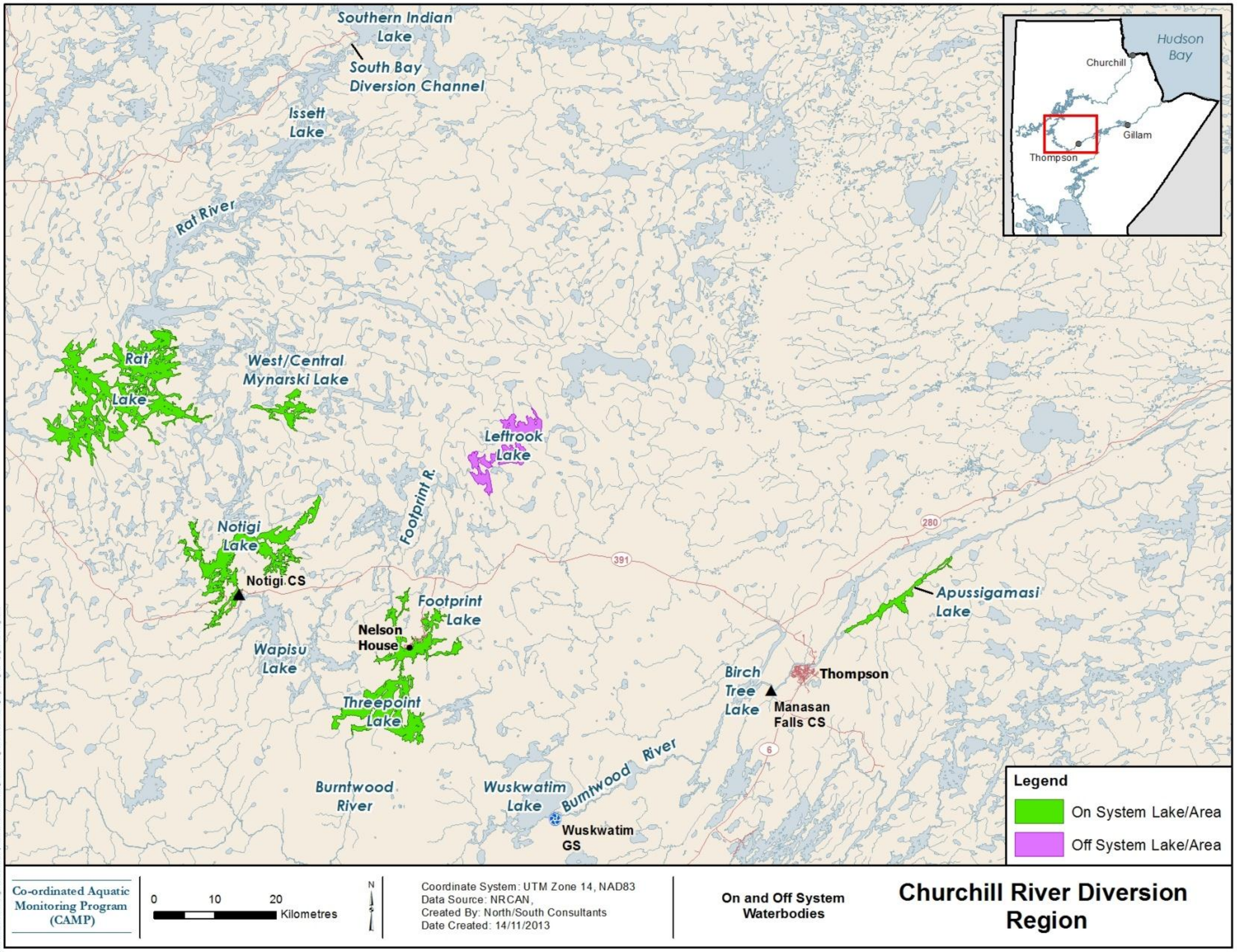

Figure 2.6-1. Churchill River Diversion Region.

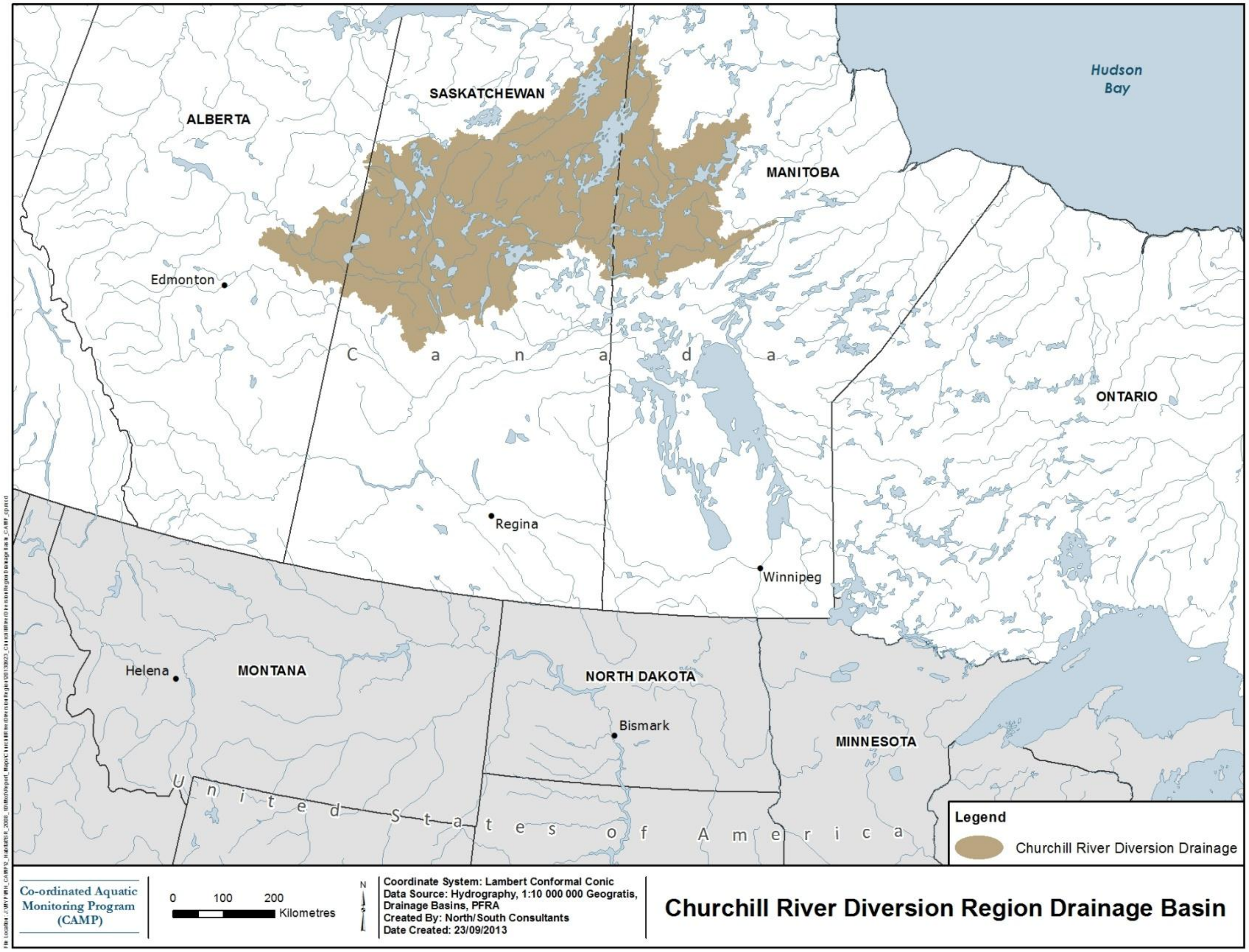

Figure 2.6-2. Churchill River Diversion Region drainage basin.

Figure 2.6-3. Leftrook Lake drainage basin.

2.7 UPPER NELSON RIVER REGION

2.7.1 Regional Description

The Upper Nelson River Region is composed of the Nelson River extending from the outlet of Lake Winnipeg to the Kelsey Generating Station (GS) near Split Lake (Figure 2.7-1). The region also includes Setting Lake, an off-system lake, located on the Grass River system.

In its headwaters near Lake Winnipeg, the upper Nelson River divides into two channels; the east channel conveys water past the community of Norway House and into Cross Lake, while the west channel directs water through a series of smaller lakes, past the Jenpeg Generating Station (GS) and into Cross Lake. At the outlet of Cross Lake, the Nelson River again forms one channel as it continues northward (Rosenberg et al. 2005).

Since the Nelson River is the only outflow from Lake Winnipeg, the watershed drains a total area of approximately 1,050,000 km^2, including the Saskatchewan, Winnipeg, and Red river basins (Figure 2.7-2). Cultivated crops are the dominant land cover within the entire Nelson River drainage basin (Table 2-1). Although the Nelson River watershed drains an area comprising several ecozones and ecoregions, the Upper Nelson River Region lies exclusively within the Boreal Shield ecozone and primarily within the Hayes River Upland ecoregion (Figure 1.2-2). However, because lacustrine clay materials underlie much of the drainage basin upstream of Lake Winnipeg, the Nelson River carries more dissolved solids and a higher sediment load than most other Canadian Shield rivers (Jones and Armstrong 2001). One hydroelectric GS is located at each of the upstream and downstream boundaries of the Upper Nelson River Region (Jenpeg GS at the upstream end and Kelsey GS at the downstream end).

In this region, the Nelson River generally flows as a series of short cascades through a complex series of bedrock-controlled lake basins (Rosenberg et al. 2005). The region was heavily glaciated and is covered by thin (< 2 m deep) glacial till overburden and poorly drained peat-based wetlands (Rosenberg et al. 2005). The vegetative community of the region is characterized by stunted black spruce, jack pine, aspen, and willows (Rosenberg et al. 2005).

The climate of the basin is continental and characterized by short, cool summers and long, cold winters. Mean daily air temperatures are highest in July and lowest in January, generally ranging from 17.5 to –22.5°C, respectively (Rosenberg et al. 2005). Annual precipitation is approximately 50 cm, with 67% of this total falling between May and October (Rosenberg et al. 2005).

The Upper Nelson River Region has a very low population density, with the Cree Nation communities of Norway House and Cross Lake being the only concentrated population centres along the river. Individuals from these communities, as well as individuals from the communities of Wabowden, Thicket Portage, and Pikwitonei, participate in domestic and commercial harvesting of fish and wildlife in the area (Rosenberg et al. 2005). The region also supports a limited number of sport fishing and hunting lodges. The region receives discharges from municipal wastewater treatment facilities at Norway House and Cross Lake. There are no active mines or pulp and paper mills in the Upper Nelson River Region.

Setting Lake, adjacent to the Town of Wabowden, is located in the same ecoregion (Hayes River Upland) and ecozone (Boreal Shield) as the other upper Nelson River waterbodies (Figures 1.2-2 and 2.7-1). The lake has a surface area of 126 km^2 and a drainage basin of 10,952 km^2 (Table 2-1). Setting Lake receives inflows from the upper portion of the Grass River and a few small creeks and discharges via the lower portion of the Grass River to the Nelson River (Figure 2.7-3). Surficial deposits are composed of lacustrine materials (silt and clay) and the soil is a grey-wooded podzol (Schlick 1968). The dominant land cover of the watershed is coniferous forest (Table 2-1) and the area around the lake is dominated by black spruce (Schlick 1968). With the exception of the Town of Snow Lake, the Setting Lake watershed has a low population density. In addition, although Wabowden is proximal to Setting Lake, the community lies within the drainage basin of a tributary that flows into the Grass River downstream of the outlet of Setting Lake. There are many historic mines and a few operating mines in the upper Grass River watershed (Manitoba Innovation, Energy and Mines 2012). Setting Lake supports a commercial fishery, a recreational fishery, and a cottage development.

Walker Lake is located in the Boreal Shield ecozone and the Hayes River Upland ecoregion (Figure 1.2-2). The lake has a surface area of 133 km^2 and a drainage basin of 1183 km^2 (Table 2-1). Walker Lake, located approximately 50 km east of the community of Cross Lake, flows into the east basin of Cross Lake via the Walker River. Walker Lake receives inflow from the Walker River and several smaller tributaries (Figure 2.7-4). The dominant land cover of the watershed is shrub (Table 2-1) and the area adjacent to the lake is poorly drained with black spruce forest in upland areas and spruce bogs, peatlands, and fens in low lying areas. There are no permanent residences in the Walker River watershed although there are a couple of seasonal camps on Walker Lake.

2.7.2 Hydroelectric Facilities

Manitoba Hydro’s development of the hydroelectric potential of the Nelson River includes the use of Lake Winnipeg as a natural reservoir. Prior to Lake Winnipeg Regulation, the flow of the Nelson River (Lake Winnipeg’s only outflow) depended upon the water level of the lake and the seasonal conveyance capacity which varied depending on vegetation in the summer and on the degree of obstruction of the river’s channels by ice during the winter. The LWR Project included a number of components built to substantially increase the outflow potential of Lake Winnipeg into the upper Nelson River, including construction of the Jenpeg Generating Station (GS) and a control structure (CS) at the outlet of Kiskitto Lake that prevents water from backing up into that lake (Figure 2.7-1). In addition, Two-Mile Channel (constructed between Lake Winnipeg and Playgreen Lake), Eight-Mile Channel (constructed between Playgreen Lake and the southern end of Kiskittogisu Lake), Ominawin Bypass Channel (constructed between the most northerly outlet of Kiskittogisu Lake and the west channel of the Nelson River), and a rock excavation in the Kisipachewuk Channel (the most southerly outlet of Kiskittogisu Lake) serve to bypass natural constrictions in these areas. LWR has increased the outflow capacity of Lake Winnipeg by 40-50% and has reduced the magnitude and frequency of flooding on Lake Winnipeg (Environment Canada and Manitoba Water Stewardship 2011). In an effort to mitigate effects of the LWR on Cross Lake, the Cross Lake Weir was constructed in 1991 to raise the water level of the lake by nearly 1.4 m and moderate season-to-season water level fluctuations. Manitoba Hydro operates two hydroelectric generating stations on the upper Nelson River (the Jenpeg and Kelsey GSs).

2.7.2.1 Jenpeg GS

The Jenpeg GS is located 525 km north of Winnipeg at the point where the west channel of the upper Nelson River flows into Cross Lake (Figure 2.7-1). The primary function of the Jenpeg GS is to regulate the outflow from Lake Winnipeg into the Nelson River. The secondary function is to utilize the hydraulic head at the site to produce electricity. Construction of the Jenpeg GS began in 1972 and all six generating units were operating by 1979. The Jenpeg GS has an operating head of 7.3 m, a licensed capacity of 164 MW, and can generate an average of 910 million kilowatt hours (kW h) of electricity per year. The Jenpeg reservoir includes the forebay immediately upstream of the station, the outlet lakes (Playgreen Lake, North Playgreen Lake, and Kiskittogisu Lake) and Lake Winnipeg. The immediate Forebay extends from the Kisipachewuk Channel north to the GS, and has a surface area of 0.47 km^2. The immediate forebay has a mean water level of 216.1 m and an operating range of 214.0 to 217.54 m.

2.7.2.2 Kiskitto Control Structure

High water levels, caused by construction of the Jenpeg GS, made it necessary to build a control structure at the outlet of Kiskitto Lake to prevent water from backing up into the lake (Figure 2.7-1). The Kiskitto Control Structure is about 600 m long and has a maximum height of 15 m. The lake is regulated within its natural range, and its water levels are controlled to provide maximum benefit for fish, wildlife, and recreational opportunities. A total of 14 km of dykes prevent flooding of the lake as a result of inflows from the west channel of the Nelson River. A gated culvert was installed to supply water from the west channel, while a small channel and control structure were built to regulate outflow.

2.7.2.3 Two-Mile Channel

Two-Mile Channel was constructed to augment the natural outlet of Lake Winnipeg, by cutting a channel across the narrowest point of land between the north end of Lake Winnipeg and Playgreen Lake about 10 km northwest of Warren Landing (Figure 2.7-1). The channel was cut to a depth of about 7.6 m and the bottom width of the channel averages about 112 m.

2.7.2.4 Eight-Mile Channel

Eight-Mile Channel was constructed to connect Playgreen Lake with the southernmost end of Kiskittogisu Lake to increase the outflow of water from Playgreen Lake (Figure 2.7-1). The channel was cut to a depth of about 7.6 m and the bottom width of the channel ranges from a minimum of about 130 m to a maximum of about 300 m.

2.7.2.5 Ominawin Bypass Channel

The Ominawin Bypass Channel was constructed to improve the outflow from Kiskittogisu Lake at its most northerly outlet into the west channel of the Nelson River (Figure 2.7-1). The excavation is 7.6 m deep and 2,300 m long with a center rock groin dividing the channel into two, each with a bottom width of 172 m.

2.7.2.6 Cross Lake Weir

Lake Winnipeg Regulation reversed the historic pattern of water levels and fluctuations at Cross Lake. In an effort to enhance water levels on Cross Lake, the Cross Lake Weir Project was constructed in 1991 (Figure 2.7-1). This included the construction of a rock weir and channel excavation at the outlet of Cross Lake. The weir raised the minimum water level on Cross Lake by nearly 1.4 m, increased the outflow capacity at high water levels and made season-to-season fluctuations more moderate and gradual.

2.7.2.7 Kelsey GS

The Kelsey GS is located approximately 680 km north of Winnipeg on the upper Nelson River where it enters Split Lake (Figure 2.7-1). The Kelsey GS was the first plant constructed on the Nelson River. The station, which came into service in 1961, has an operating head of 17.1 m, a licensed capacity of 288 MW and can generate an average of 1,800 million kW h of electricity per year. The Kelsey GS reservoir includes the forebay, the Nelson River, and Sipiwesk Lake upstream of the station. The immediate forebay has a surface area of 708 km^2 and a maximum operating forebay elevation of 184.4 m. The GS is generally operated as a base load station, which means all seven units operate at the maximum output all of the time.

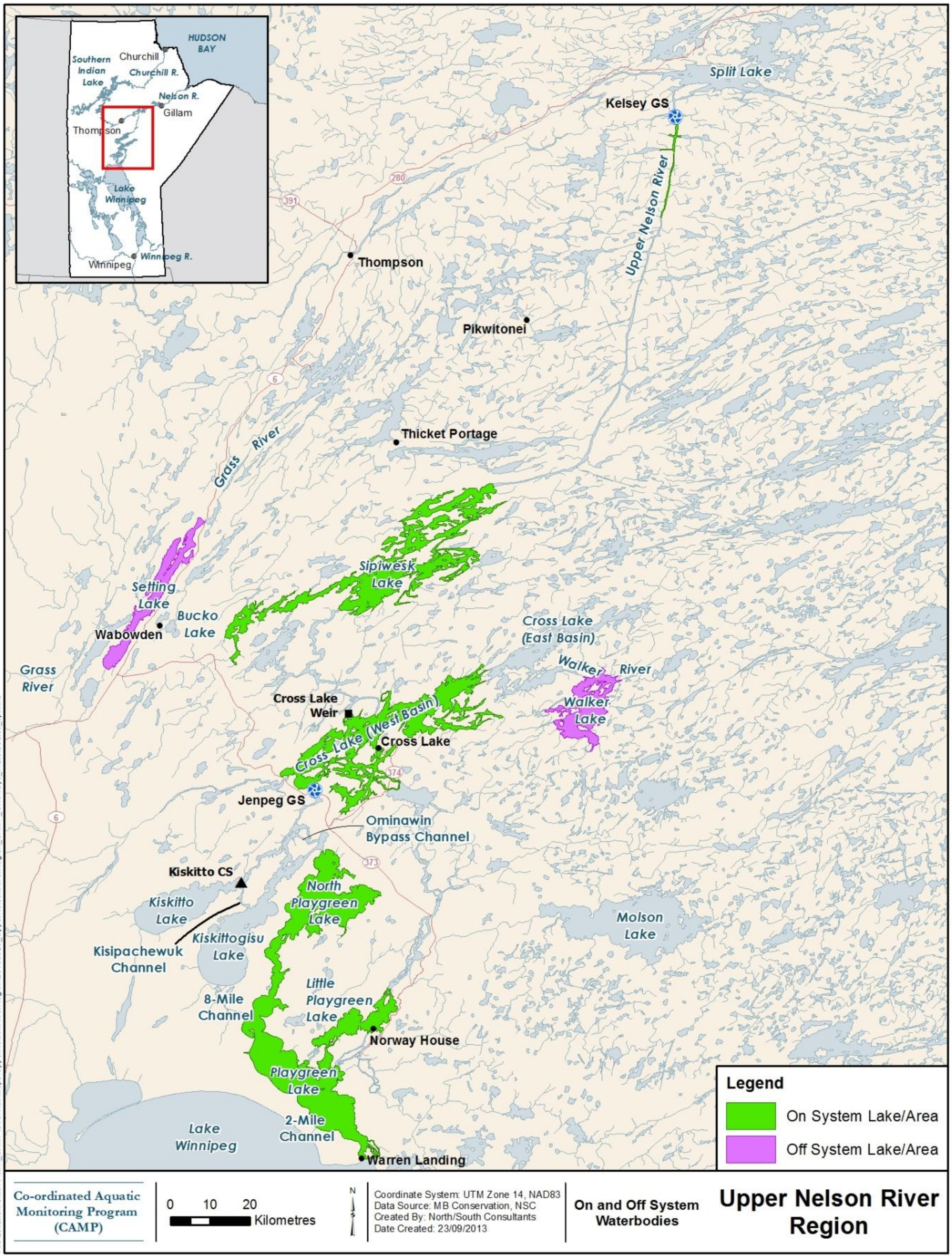

Figure 2.7-1. Upper Nelson River Region.

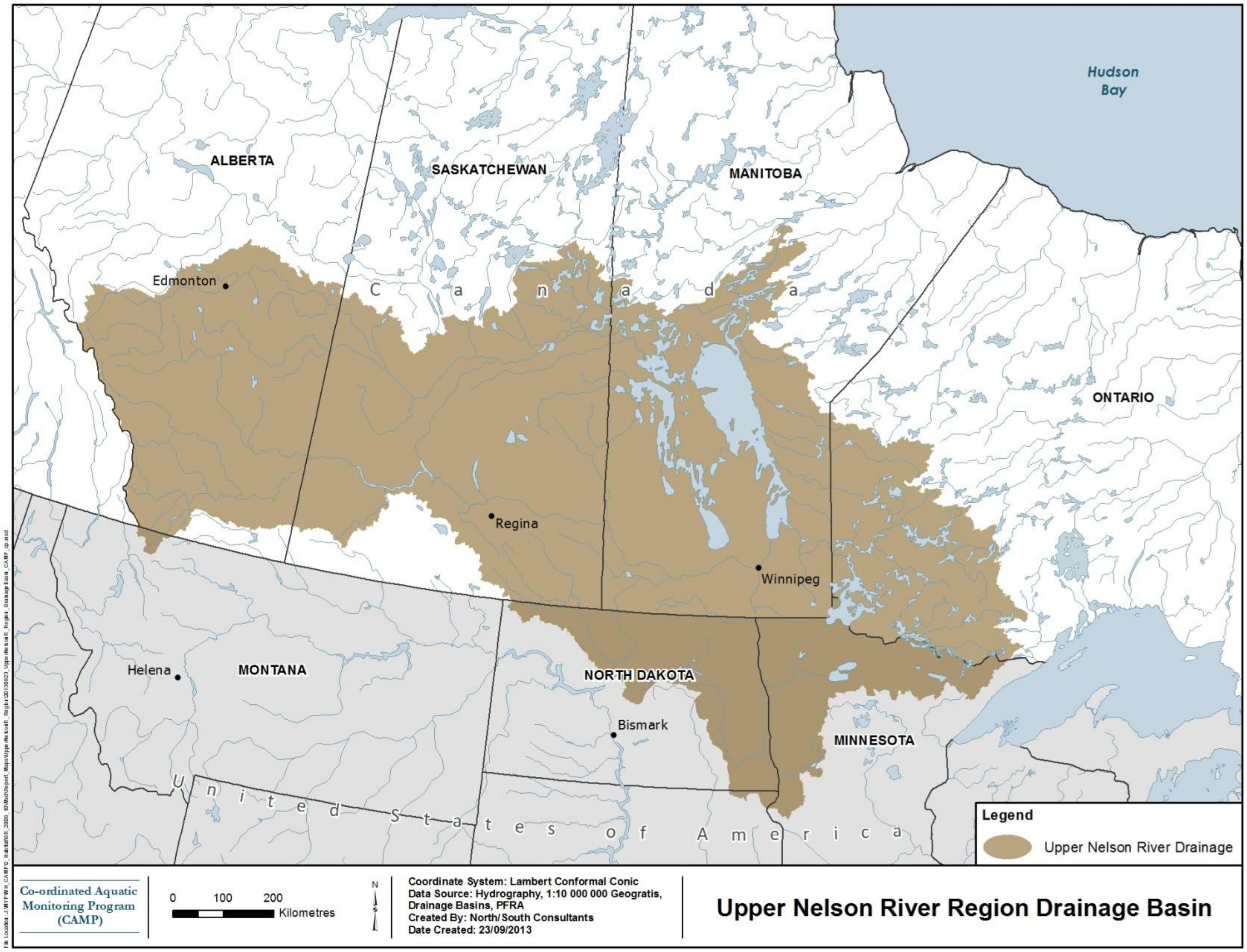

Figure 2.7-2. Upper Nelson River Region drainage basin.

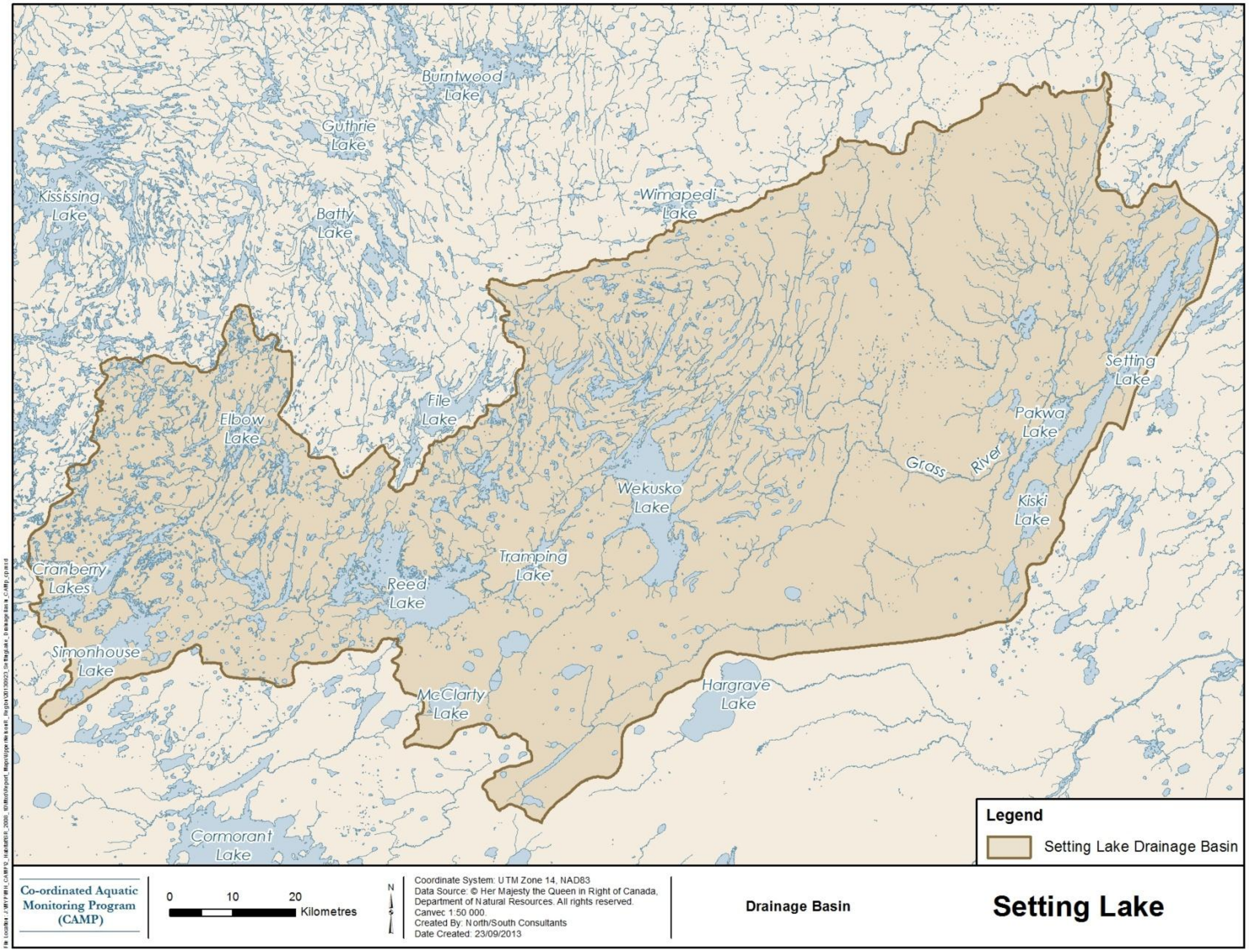

Figure 2.7-3. Setting Lake drainage basin.

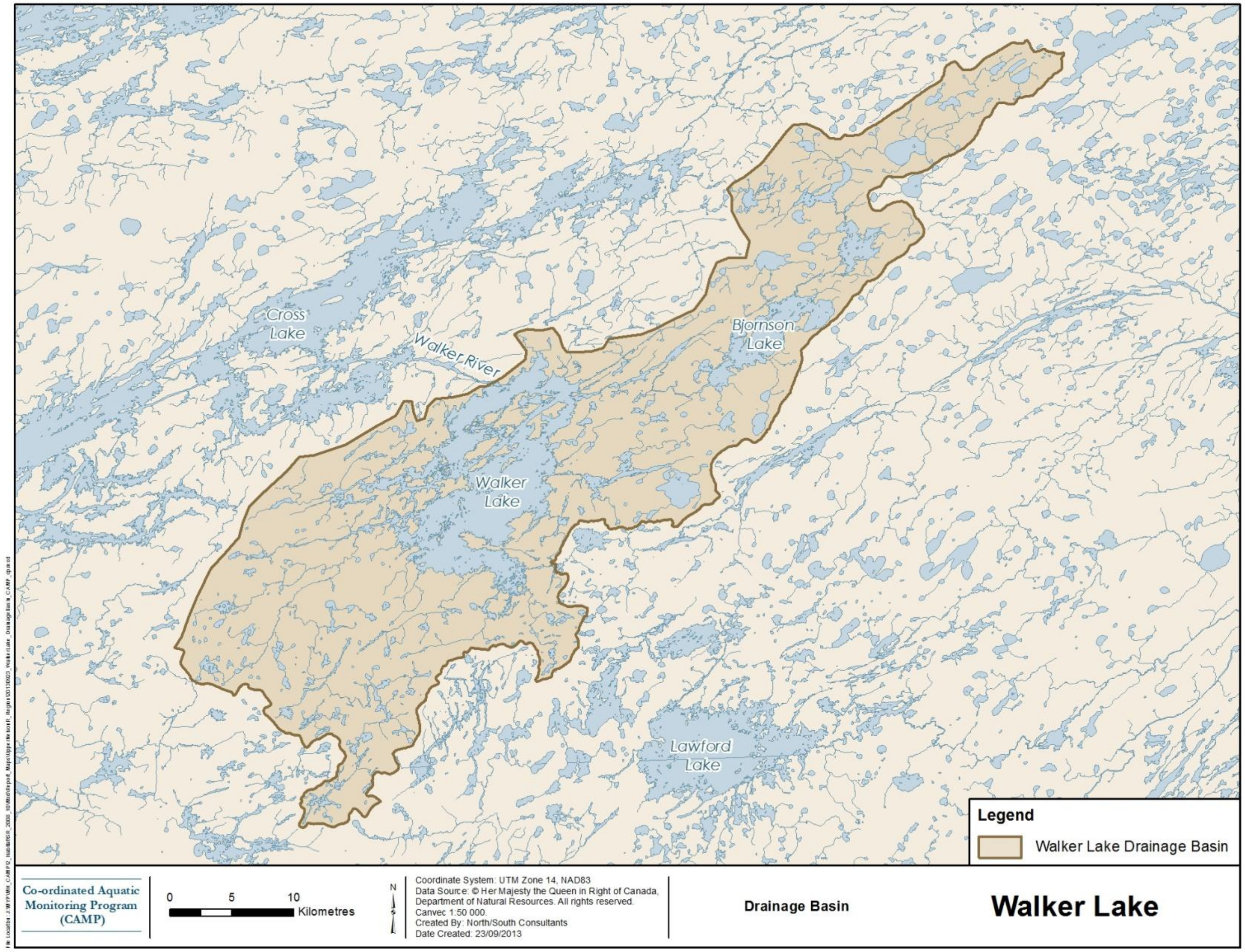

Figure 2.7-4. Walker Lake drainage basin.

2.8 LOWER NELSON RIVER REGION

2.8.1 Regional Description

The Lower Nelson River Region is composed of the reach of the Nelson River (including lakes and reservoirs) extending from the Kelsey Generating Station (GS) downstream to the river's outlet at Hudson Bay, the Burntwood River from First Rapids to Split Lake, an off-system river (Hayes River) and an off-system lake (Assean Lake; Figure 2.8-1).

The lower Nelson River flows in a relatively straight single channel from Split Lake to its mouth on Hudson Bay, interrupted by several lakes and reservoirs. Portions of this reach of the river have steep banks that gradually decrease in slope as they approach the estuary at Hudson Bay (Rosenberg et al. 2005). The most downstream 150 km of river is part of the marine intrusion zone that has emerged above sea level since the last glaciation (7,000 to 9,000 years ago; Rosenberg et al. 2005). Waterbodies along the lower Nelson River include Split, Clark, Gull, and Stephens lakes, and the Long Spruce and Limestone Generating Station (GS) forebays (Figure 2.8-1). Prior to dam construction and reservoir creation, Split Lake was the only substantial lacustrine waterbody along the lower Nelson River.

The Nelson River at its mouth drains an area of approximately 1,392,500 km^2 (Figure 2.8-2; Table 2-1). The lower Nelson River cuts through the Boreal Shield and Hudson Plain ecozones, but the watershed encompasses almost all other ecozones in Manitoba, including the Taiga Shield, the Boreal Plain and the Prairie (Figure 1.2-2). Although much of the lower Nelson River itself is situated on the Canadian Shield, because lacustrine clay materials underlie much of the drainage basin upstream of Lake Winnipeg, the lower Nelson River (as is the case with the upper Nelson River) carries more dissolved solids and a higher sediment load than most other Canadian Shield rivers (Jones and Armstrong 2001). The Lower Nelson River Region flows through the Hayes River Upland ecoregion of the Boreal Shield ecozone and the Hudson Bay Lowland and the Coastal Hudson Bay Lowland ecoregions of the Hudson Plain ecozone (Figure 1.2-2). The region was heavily glaciated and is covered by thin (<2 m) glacial till overburden and poorly drained peat-based wetlands (Rosenberg et al. 2005).

The dominant land cover within the watershed is cultivated crops (Table 2-1); however, the vegetative community of the region is characterized by stunted black spruce, aspen, and willows (Rosenberg et al. 2005). A major tributary of the lower Nelson River is the Grass River which flows into the Nelson River immediately downstream of the Kelsey GS. There are many historic mines and a few operating mines in the upper Grass River watershed (Manitoba Innovation, Energy and Mines [MIEM] 2012). In addition to the mines in the upper Grass River watershed, there is also an operating mine (the Bucko Lake mine) near Wabowden that falls within the drainage basin of the Grass River downstream of Setting Lake (Figure 2.7-1). There are no operating or historic mines in the Lower Nelson River Region apart from those in the Grass River system. There is some forestry activity in the upper Grass River system, but none in the rest of the Lower Nelson River Region. The region does support some tourism. The lower Nelson River is highly regulated for the purposes of hydroelectricity generation, with three existing, one proposed, and one potential hydroelectric GS located on this stretch of the river.

The climate of the basin is continental and characterized by short, cool summers and long, cold winters. Mean daily air temperatures are highest in July (≈17.5º) and lowest in January (≈ –22.5°C) (Rosenberg et al. 2005). Annual precipitation is approximately 50 cm, with 67% of this total falling as rain between May and October (Rosenberg et al. 2005).

The lower Nelson River watershed has a low population density, with the Cree Nation communities of Split Lake, York Landing, and Bird and the Town of Gillam being the only substantial population centres along the river. All have wastewater treatment facilities. Individuals from these communities, as well as individuals from the communities of Pikwitonei (Figure 2.7-1) and Ilford, participate in domestic, commercial, and recreational harvesting of fish and wildlife.

The Hayes River, a Canadian Heritage River, originates just upstream of Molson Lake in the Hayes River Upland ecoregion (Boreal Shield ecozone) and flows northeast through the Hudson Bay Lowland and Coastal Hudson Bay Lowland ecoregions (Hudson Plain ecozone) for a distance of approximately 650 km to Hudson Bay (Figure 2.8-3; Figure 1.2-2). The drainage basin of the Hayes River is 108,960 km^2 and the dominant land cover in the entire drainage basin is coniferous forest (Table 2-1). The major tributary is the Gods River, which originates in Ontario, but the Hayes River also receives inflows from the Fox and Pennycutaway rivers and numerous smaller tributaries (Figure 2.8-3). Historically, the Hayes River was a very important route of the fur trade and York Factory was the central link between Europe and inland Canada (Beck 1977). The area is much less travelled now, with a dozen or so First Nation communities scattered throughout the watershed. Present resource use (i.e., subsistence, commercial, and recreational fishing, hunting, and trapping) is centered around a small number of First Nation communities scattered throughout the watershed in both Ontario and Manitoba. There are also several commercial fishing lodges in the drainage basin. There are no active mines in the drainage basin; however, two gold mines in the Gods River watershed operated in the 1930s and 1940s (MIEM 2012).

Assean Lake is located in the Boreal Shield ecozone and straddles the border between the Hayes River Upland and Churchill River Upland ecoregions (Figure 1.2-2). The lake is located approximately 80 km northeast of the City of Thompson and 30 km west of the community of Split Lake (Figure 2.8-1) with a surface area of 76 km^2 and a drainage basin of 542 km^2 (Table 2-1). Assean Lake receives inflow from the Clay River and several smaller tributaries and either receives inflow from, or is drained by, the Assean River (Holm et al. 2003; Figure 2.8-4). Surficial deposits (up to 20 m thick) are composed of lacustrine materials (clay, silt, sand, and basal till) while the underlying bedrock is gneiss and schist (Christoffersen 2005). The dominant land cover of the watershed is shrub (Table 2-1) and the area adjacent to the lake is poorly drained with black spruce forest in upland areas and spruce bogs, peatlands, and fens in low lying areas. Stands of sporadically distributed trembling aspen are also present (Holm et al. 2003). Assean Lake supports subsistence and commercial fishing, hunting, and trapping and a recreational fishery. There are no permanent residences in the watershed although there are a couple of seasonal camps on the shoreline of Assean Lake. Although there has been considerable mineral exploration in the Assean Lake area (particularly during the decade between 2000 and 2010; Christoffersen 2005), there are no currently operating or historic mines in the Assean Lake watershed (MIEM 2012).

2.8.2 Hydroelectric Facilities

At Split Lake, the upper Nelson River is joined by the Burntwood (includes diverted flows from the Churchill River) and Grass rivers from the northwest to form the lower Nelson River. The lower Nelson River then flows northeastward for approximately 330 km to its mouth at Hudson Bay. Manitoba Hydro operates three hydroelectric Generating Stations (GSs) along this section of the Nelson River: the Kettle, Long Spruce, and Limestone GSs (Figure 2.8-1). The proposed Keeyask GS and the potential Conawapa GS are also located on the lower Nelson River (Figure 2.8-1).

2.8.2.1 Kettle GS

The Kettle GS came into service in 1970 and was the first plant built on the lower Nelson River. It is located approximately 5 km east of the Town of Gillam, and approximately 700 km north of Winnipeg. With an operating head of 30 m, Kettle has 12 turbine generators with a total capacity of 1,253 megawatts (MW) and can generate an average of 7,070 million kilowatt hours (kW h) of electricity per year. The Kettle GS Forebay (Stephens Lake) has a surface area of 337 km^2 and a maximum operating forebay elevation of 141.1 m.

2.8.2.2 Long Spruce GS

The Long Spruce GS was built between 1971 and 1979 and was Manitoba Hydro's second generating station constructed on the lower Nelson River. The station is located about 745 km northeast of Winnipeg, 27 km east of Gillam, and 16 km downstream from the Kettle GS. The first of the station's 10 turbine generators came on line in 1977, while the final turbine was put into service in 1979. With an operating head of 24.4 m, the Long Spruce GS has a capacity of 1,010 MW and can generate an average of 5,800 million kW h of electricity per year. The Long Spruce Forebay (the Nelson River) has a surface area of 36 km^2 and a maximum operating forebay elevation of 110.0 m under open-water conditions and 110.3 under ice cover. The Long Spruce GS is operated as a run-of-the-river system, with flows governed by releases from Stephens Lake at the Kettle Generating Station.

2.8.2.3 Limestone GS

The Limestone GS is Manitoba Hydro's newest and largest GS built on the Nelson River. It is located 750 km north of Winnipeg, 40 km northeast of Gillam, and 23 km downstream of the Long Spruce GS. The first of the station's 10 turbine generators came into service in 1990 and the last in 1992. With an operating head of 27.6 m, the Limestone GS has a capacity of 1,330 MW and can generate an average of 7,640 million kW h of electricity per year. The Limestone Forebay is almost entirely contained within the natural riverbanks of the Nelson River and has a surface area of 27.1 km^2 and a maximum operating forebay elevation of 85.3 m. As with other generating stations on the lower Nelson River, the Limestone GS is operated as a run-of-the-river operation.

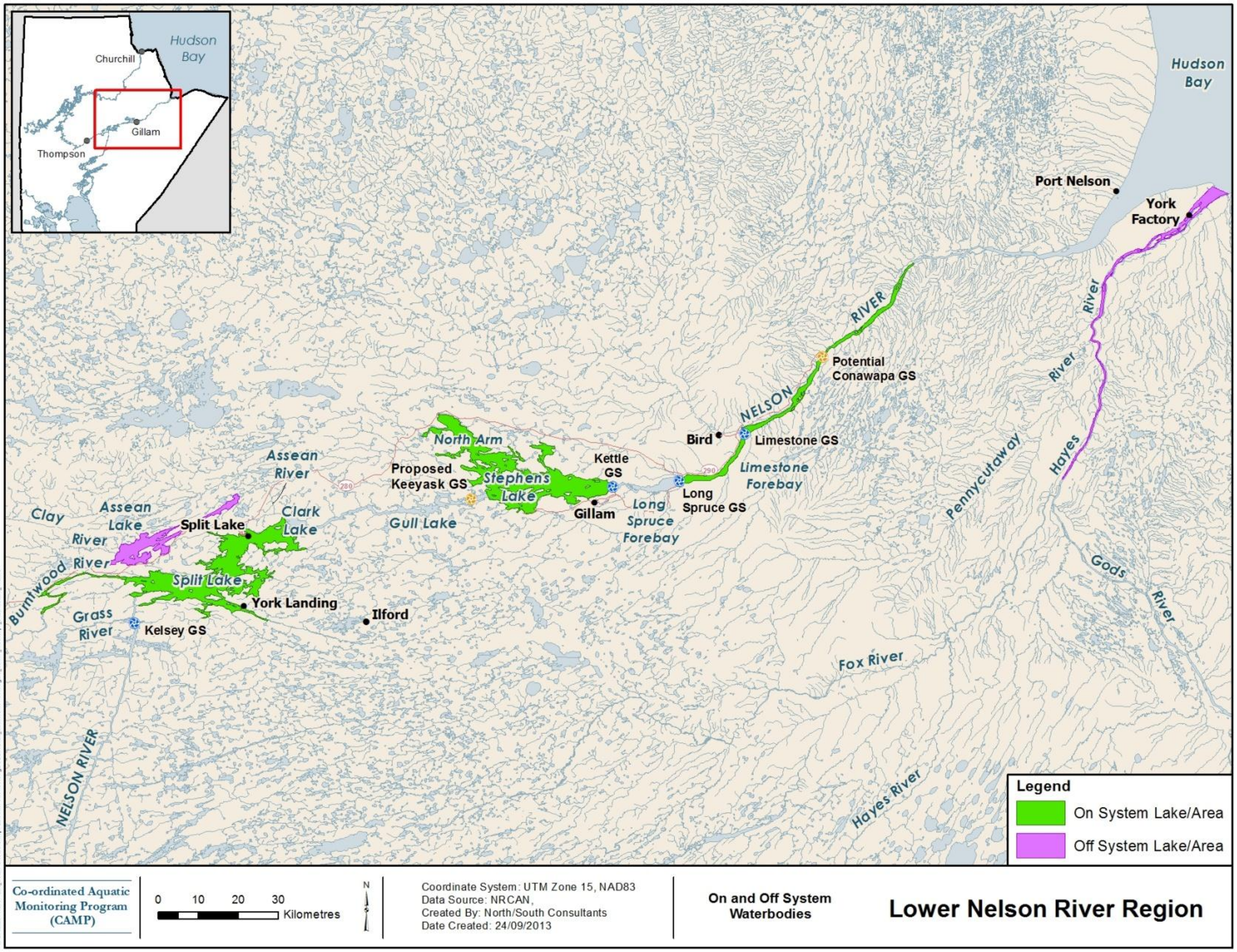

Figure 2.8-1. Lower Nelson River Region.

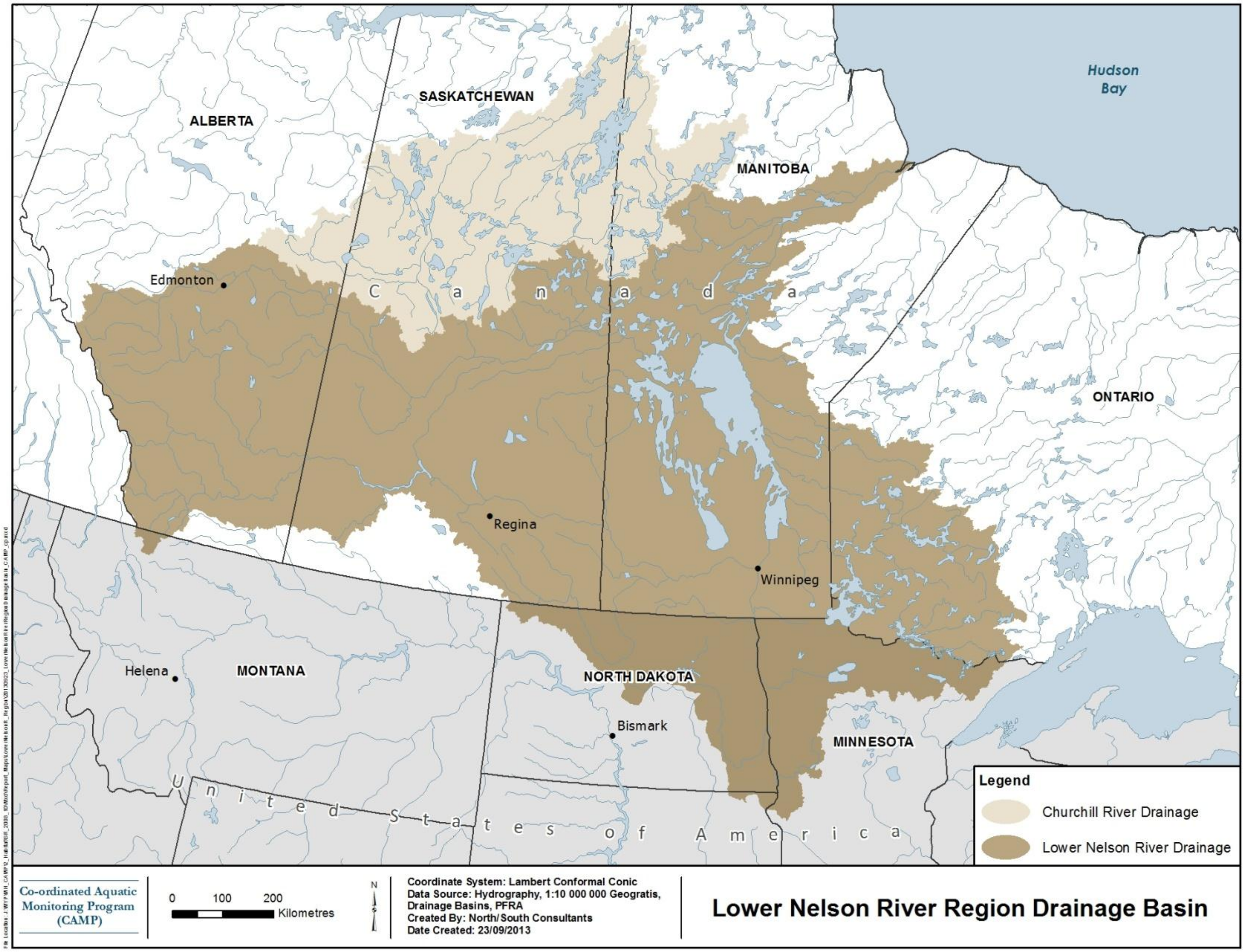

Figure 2.8-2. Lower Nelson River Region drainage basin.

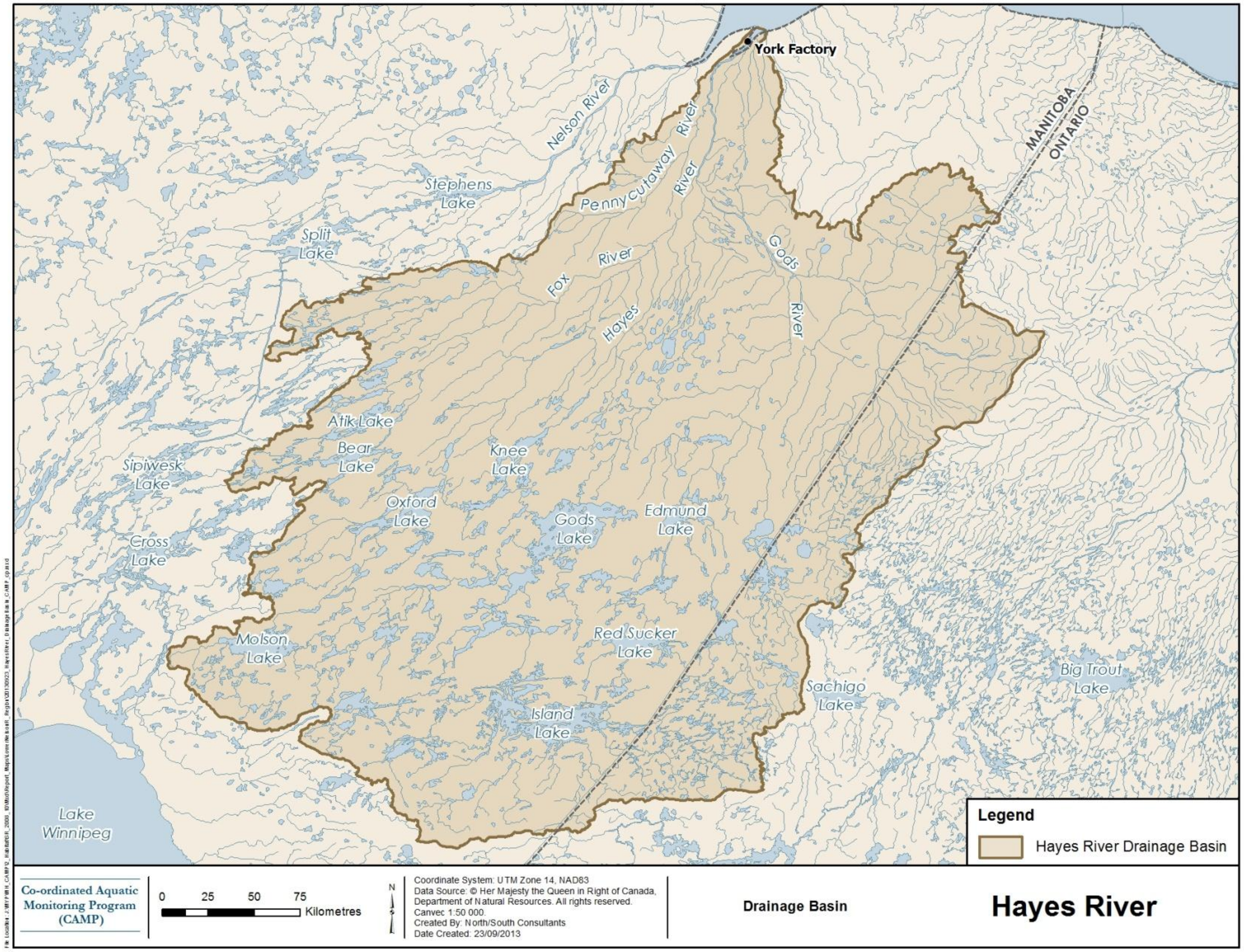

Figure 2.8-3. Hayes River drainage basin.

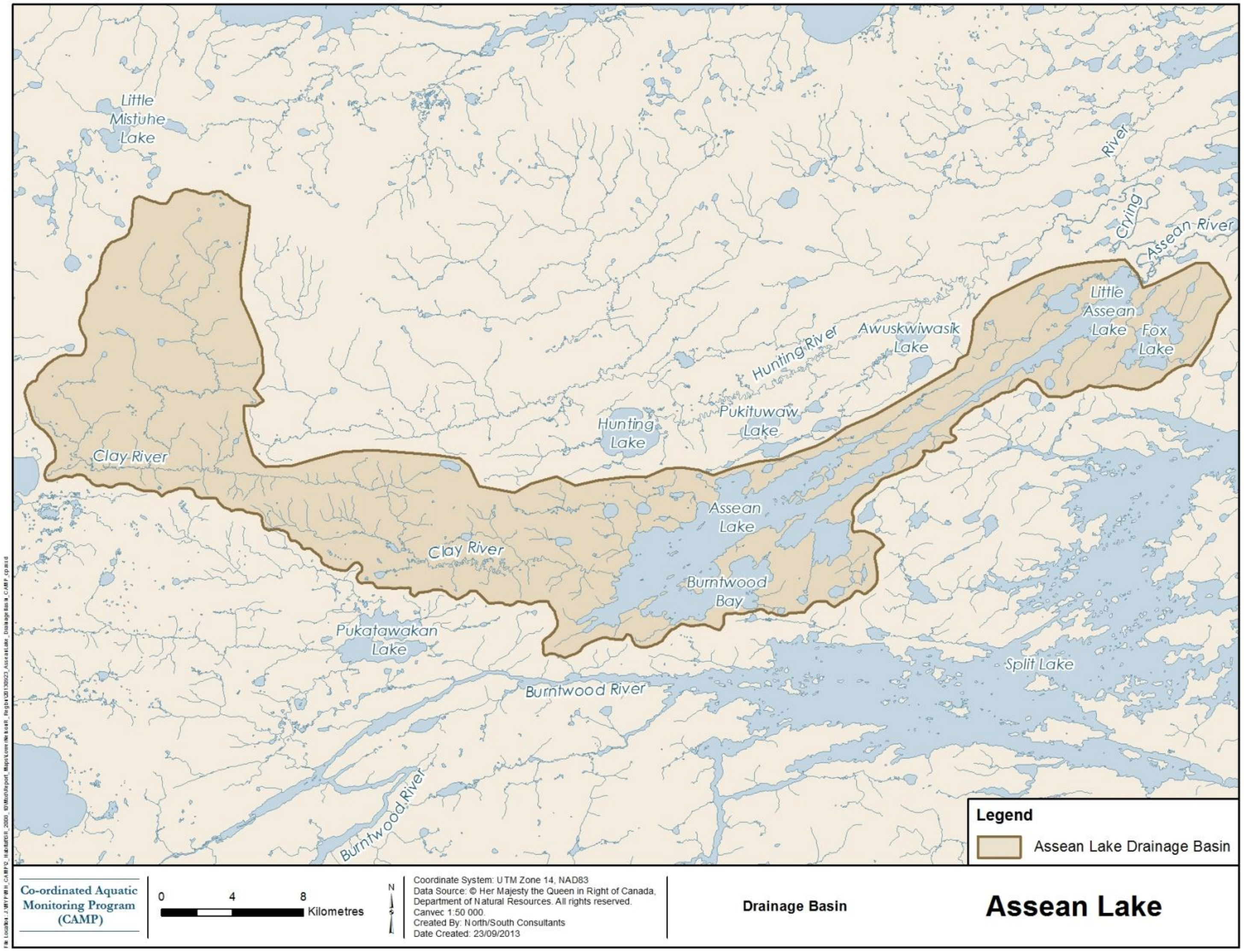

Figure 2.8-4. Assean Lake drainage basin.

SECTION 3.0: CAMP WATERBODIES

TABLE OF CONTENTS

Page 3-x

LIST OF TABLES

Page 3-x

3.0 CAMP WATERBODIES

The Coordinated Aquatic Monitoring Program (CAMP) incorporates monitoring of 43 waterbodies or reaches of river, spanning eight regions of Manitoba. The following provides a summary of background information on the waterbodies monitored under CAMP. As previously noted, some waterbodies monitored under CAMP were first sampled following completion of the Pilot Program (i.e., after 2010/2011). A complete list of CAMP waterbodies and the year of initiation of monitoring under CAMP is provided in Table 3-1.

3.1 SPATIAL AND TEMPORAL CONSIDERATIONS

3.1.1 On-System and Off-System Waterbodies

As previously described in Section 1.3, the Coordinated Aquatic Monitoring Program (CAMP) includes monitoring of on-system and off-system waterbodies. On-system waterbodies are those located on, and that are notably influenced by, Manitoba Hydro's hydraulic operating system (e.g., forebays and areas downstream of hydroelectric generating stations and control structures). Off-system waterbodies include lakes and areas of rivers where water levels and flows are either entirely or largely unaffected by Manitoba Hydro's hydraulic operating system. However, some waterbodies considered as off-system may still be subject to regulation of flows by other organizations (i.e., upper reaches of the Churchill, Saskatchewan and Winnipeg rivers).

Reference sites are typically used in monitoring programs to account for effects or changes in a given parameter or indicator that are not related to the impact/stressor under study. Therefore, choosing a reference area that is as similar as possible to the exposure area is essential in order to interpret differences between the areas (Environment Canada 2012a). Ideal reference waterbodies are similar in all attributes except for the development/activity/stressor of interest; however in practice, these conditions seldom, if ever, occur. Reference sites are ideally characterized by similar physical/chemical (e.g., drainage basin size, land use, soils/topography, hydrology, geology, lake morphometry, climate, aquatic habitat, etc.) and biological characteristics (community composition, population dynamics, food web structure, life history stages, etc.) as on-system sites.

Ideally, the off-system CAMP waterbodies would serve the role of reference waterbodies. However, since Manitoba Hydro's hydraulic operating system encompasses large rivers and lakes (including Lake Winnipeg), and large geographic areas and drainage basins, ideal reference waterbodies for comparison to most of these on-system waterbodies are not available. Off-system waterbodies are therefore not considered to be reference sites as used for an environmental impact assessment. Rather data collected from off-system waterbodies are intended to provide additional regional information for examining trends over time to assist in delineating the potential effects of Manitoba Hydro's hydraulic operating system from those of other stressors (e.g., climate change, presence of introduced species, management activities, etc.).

As this report represents the first analysis and discussion of the CAMP program, spatial comparisons between on- and off-system waterbodies were undertaken here to provide an initial description of differences for consideration in future reporting. These comparisons are intended to define how the systems now differ to assist with tracking change over the long-term. Differences are not intended to indicate relative status of ecosystem health among waterbodies as it is recognized that these waterbodies may fundamentally differ and would not be expected to exhibit similar chemical or biological characteristics.

3.1.2 Annual Waterbodies vs Rotational Waterbodies

The Coordinated Aquatic Monitoring Program (CAMP) includes monitoring conducted on an annual and semi-annual basis. Annual monitoring is conducted at selected on- and off-system waterbodies in each CAMP region (annual waterbodies). Less frequent monitoring is conducted at additional waterbodies or areas of waterbodies on a three-year rotational basis to provide additional spatial coverage within the CAMP regions. These waterbodies are referred to as rotational waterbodies.

The frequency of sampling of each CAMP component was previously discussed in Section 1.2 and is summarized here. Water levels and flows are monitored continuously at most waterbodies where CAMP monitoring occurs. Other key CAMP components, specifically water quality, benthic invertebrates, and fish community components, are monitored each year in which a waterbody is monitored. In addition, some CAMP components are monitored less frequently on a three year or six year rotational basis in each CAMP waterbody. In general, phytoplankton community composition and biomass and fish mercury are monitored on a three year rotational basis; however some waterbodies are monitored annually for these components to provide greater temporal resolution. Aquatic habitat surveys are conducted as inventory monitoring and are intended to be conducted as a one-time event.

Table 3-1. CAMP waterbodies and year of sampling initiation.

Region	Waterbody	Waterbody Abbreviation	Annual	Rotational	First Year of Sampling
Winnipeg River	Eaglenest Lake	EAGLE		x	2010/2011
	Pointe du Bois Forebay	PDB	x		2008/2009
	Lac du Bonnet	LDB	x		2008/2009
	Pine Falls Forebay	PFF		x	2011/2012
	Manigotagan Lake	MANIG	x		2008/2009
Saskatchewan River	Saskatchewan River	SASK		x	2010/2011
	Cedar Lake-Southeast	CEDAR-SE	x		2009/2010 [1]
	Cedar Lake-West	CEDAR-W		x	2011/2012
	South Moose Lake	SMOOSE		x	2009/2010
	Cormorant Lake	CORM	x		2008/2009
Lake Winnipeg	Lake Winnipeg (north basin)	TBD [2]	x		2008/2009
	Lake Winnipegosis	WPGOSIS		x	2008/2009
Upper Churchill River	Granville Lake	GRV	x		2008/2009
	Opachuanau Lake	OPACH		x	2011/2012
	Southern Indian Lake-Area 1	SIL-1		x	2009/2010
	Southern Indian Lake-Area 4	SIL-4	x		2008/2009
	Southern Indian Lake-Area 6	SIL-6		x	2010/2011
Lower Churchill River	Partridge Breast Lake	PBL		x	2009/2010
	Northern Indian Lake	NIL	x		2008/2009
	Fidler Lake	FID		x	2011/2012
	Billard Lake	BIL		x	2010/2011
	Lower Churchill River at the Little Churchill River	LCR-LiCR	x		2008/2009
	Lower Churchill River at Red Head Rapids	LCR-RHR		x	2011/2012
	Gauer Lake	GAU	x		2008/2009
Churchill River Diversion	Rat Lake	RAT		x	2010/2011
	West/Central Mynarski Lake	MYN		x	2011/2012
	Notigi Lake	NTG		x	2009/2010
	Threepoint Lake	3PT	x		2009/2010
	Footprint Lake	FOOT		x	2010/2011
	Apussigamasi Lake	APU		x	2009/2010
	Leftrook Lake	LEFT	x		2009/2010
Upper Nelson River	Little Playgreen Lake	LPLAY		x	2010/2011
	Playgreen Lake	PLAYG		x	2009/2010
	Cross Lake	CROSS	x		2008/2009
	Sipiwesk Lake	SIP		x	2011/2012
	Upper Nelson River upstream of Kelsey GS	UNR		x	2011/2012
	Walker Lake	WLKR		x	2010/2011
	Setting Lake	SET	x		2008/2009

Table 3-1. continued.

Region	Waterbody	Waterbody Abbreviation	Annual	Rotational	First Year of Sampling
Lower Nelson River	Burntwood River at Split Lake	BURNT		x [3]	2009/2010 (water quality); 2011/2012 (other components)
	Split Lake	SPLIT	x		2009/2010
	Stephens Lake-South	STL-S		x	2009/2010
	Stephens Lake-North	STL-N		x	2009/2010
	Limestone Forebay	LMFB		x	2010/2011
	Nelson River (d/s of the Limestone GS)	LNR	x		2008/2009
	Hayes River	HAYES	x		2008/2009
	Assean Lake	ASSN	x		2009/2010

[1] One water quality sampling event was conducted in 2008.
[2] An abbreviation for this waterbody has not yet been defined.
[3] Water quality is monitored annually at this site.

3.2 SELECTION AND DESCRIPTION OF WATERBODIES

Selection of on-system and off-system waterbodies monitored under the Coordinated Aquatic Monitoring Program (CAMP) was done through a collaborative approach between Manitoba Conservation and Water Stewardship (MCWS) and Manitoba Hydro for each of the eight CAMP regions. In general, on-system waterbodies were identified based on confirmation that the waterbody was being affected by Manitoba Hydro's operations, understanding that the waterbody was representative of conditions in the region, knowledge of local aquatic ecosystems (i.e., presence of existing data that could be compared with data collected under CAMP), importance of waterbodies from a stakeholder perspective, and locations of First Nation communities and resource management areas.

Off-system waterbodies were identified based on general proximity/location in relation to on-system waterbodies, size/morphology (e.g., surface area/depth of lakes and discharge of rivers), anthropogenic activities/land use in the drainage basin, accessibility, importance to local stakeholders (e.g., harvesting), and knowledge of the aquatic ecosystems (i.e., presence of existing data that could be compared with data collected under CAMP) in these waterbodies. As previously noted in Section 3.1.1, off-system waterbodies are not considered true reference sites due to inherent differences with on-system waterbodies, including but not limited to differences in drainage basin size, land use/topography/geology, and hydrology.

A total of 35 waterbodies were monitored under the Pilot Program in Years 1-3 (Table 3-1). An additional eight areas/waterbodies (Opachuanau Lake, West Mynarski Lake, Fidler Lake, Churchill River at Red Head Rapids, Pine Falls Forebay, Sipiwesk Lake, upper Nelson River downstream of Sipiwesk Lake, and the west basin of Cedar Lake), were incorporated into the current program (i.e., CAMP) beginning in Year 4 of the program. The following provides a brief description of the rationale for inclusion, as well as a general description, of each waterbody monitored under CAMP, for each of the eight regions. Characteristics of CAMP lakes and reservoirs are summarized in Table 2-1 and include drainage basin characteristics, locations, and general lake morphology and metrics. Regional maps showing the CAMP waterbodies are presented in Section 2.

3.2.1 Winnipeg River Region

The Winnipeg River Region includes the Winnipeg River from the Manitoba/Ontario border to Lake Winnipeg, a distance of approximately 120 km. This region also includes Manigotagan Lake, an off-system waterbody on the Manigotagan River. There are three waterbodies sampled annually in the Winnipeg River Region: the Pointe du Bois Forebay (on-system); Lac du Bonnet (on-system), and Manigotagan Lake (off-system). Two additional waterbodies are sampled on a three year rotational basis under the Coordinated Aquatic Monitoring Program (CAMP): Eaglenest Lake (off-system), which was first sampled under the Pilot Program (2010/2011); and the Pine Falls Forebay (on-system), which was first sampled in 2011/2012.

3.2.1.1 Eaglenest Lake

Eaglenest Lake, an off-system waterbody, is located directly upstream of the Pointe du Bois Generating Station (GS) on the Winnipeg River, and spans across the Manitoba/Ontario border. Water levels on Eaglenest Lake are not affected by the Pointe du Bois GS but are affected by regulation of the Winnipeg River in Ontario. Eaglenest Lake is home to a fishing/hunting lodge and is fished recreationally. Sampling is conducted every three years and was initiated in 2010/2011 (Year 3 of CAMPP).

3.2.1.2 Pointe du Bois Forebay

The forebay of the Pointe du Bois GS is one of two on-system waterbodies sampled annually in the Winnipeg River Region. Sampling was initiated in 2008/2009 (Year 1 of the Pilot Program). The operation of the Pointe du Bois GS and regulation of the Winnipeg River in Ontario affect water levels on the Pointe du Bois Forebay. The Pointe du Bois Forebay supports a cottage development and is fished recreationally. Aquatic environment studies have been conducted by Manitoba Hydro in the Pointe du Bois GS Forebay and downstream since 2006 in support of the Pointe du Bois Spillway Replacement Project. Water quality has been monitored at the Pointe du Bois GS by Environment Canada since 1972.

3.2.1.3 Lac du Bonnet

Lac du Bonnet, the reservoir for the McArthur GS, is one of two on-system waterbodies that is monitored annually (beginning in 2008/2009) under CAMP. The operation of the McArthur GS and regulation of the Winnipeg River in Ontario affect water levels on Lac du Bonnet. The Town of Lac du Bonnet is situated on Lac du Bonnet, and there are numerous cottage developments on the lake. Lac du Bonnet is fished recreationally. MCWS Fisheries Branch have conducted fish stock assessments on Lac du Bonnet since 1991.

3.2.1.4 Pine Falls Forebay

The forebay of Pine Falls GS is located on the Winnipeg River, just upstream of its confluence with Lake Winnipeg, and downstream of the Great Falls GS. Operation of the Pine Falls GS and the Great Falls GS affect water levels on Pine Falls Forebay. Like the upstream waterbodies on the Winnipeg River, the Pine Falls Forebay is also affected by water regulation in Ontario. The forebay is located immediately upstream of the Town of Powerview - Pine Falls, and is fished recreationally. Water quality has been monitored in the Pine Falls Forebay by MCWS since 2001. The Pine Falls Forebay is sampled every three years and was first sampled as part of CAMP in 2011/12.

3.2.1.5 Manigotagan Lake

Manigotagan Lake, located on the Manigotagan River system approximately 60 km northeast of Lac du Bonnet, is an off-system waterbody monitored annually, beginning in 2008/2009, under CAMP. The lake was flooded (water levels were increased by 3-3.5 m) approximately 80 years ago through construction of a dam in the Manigotagan River (McTavish 1953). Manigotagan Lake is fished recreationally by anglers, including guests of the nearby Quesnel Lake Lodge.

3.2.2 Saskatchewan River Region

The Saskatchewan River Region includes the Saskatchewan River from the Manitoba/Saskatchewan Border to the Grand Rapids Generating Station (GS) at the outlet to Lake Winnipeg. It also includes waterbodies situated in the Moose Lake watershed. Two waterbodies are sampled annually under the Coordinated Aquatic Monitoring Program (CAMP): Cedar Lake southeast basin (on-system), first sampled in 2009/2010; and Cormorant Lake (off-system), first sampled in 2008/2009. Two rotational waterbodies are also monitored in this region: the Saskatchewan River from the Town of The Pas to Cedar Lake (off-system), which was first sampled in 2010/2011; and South Moose Lake (on-system), which was first sampled in 2009/2010. Monitoring is also conducted in the west basin of Cedar Lake (on-system) on a three-year rotational basis, beginning in 2011/2012.

3.2.2.1 Saskatchewan River

The reach of the Saskatchewan River that is monitored under CAMP runs from the Town of The Pas downstream to its confluence at Cedar Lake. This reach of the Saskatchewan River is affected by Manitoba Hydro’s operations under some flow/water level conditions and is affected by upstream water regulation in Saskatchewan. The river supports subsistence, commercial and recreational fisheries. Environment Canada maintains a long-term water quality monitoring site upstream of The Pas. CAMP monitoring is conducted on a three year rotational basis and was first sampled in Year 3 of the Pilot Program.

3.2.2.2 South Moose Lake

Water levels on South Moose Lake are affected by the Grand Rapids GS and water level regulation in Saskatchewan. South Moose Lake is home to Mosakahiken First Nation and the Community of Moose Lake. The lake is fished for subsistence, and also supports commercial and recreational fisheries. Monitoring of the fish community and the commercial fishery has occurred periodically since the 1960s. CAMP monitoring is conducted on a three year rotational basis and was initiated in Year 2 of the Pilot Program.

3.2.2.3 Cedar Lake – West and Southeast Basins

Cedar Lake, the reservoir for the Grand Rapids GS, is an on-system waterbody sampled under CAMP. The operation of the Grand Rapids GS and water regulation in Saskatchewan both affect water levels on Cedar Lake. Cedar Lake is home to Chemawawin First Nation and the community of Easterville. The lake supports important subsistence, commercial, and recreational fisheries and has an extensive history of aquatic monitoring. Long term fish stock monitoring to support the management of the commercial fishery has been conducted by Manitoba Conservation and Water Stewardship (MCWS). Fish stocks have also been monitored since 1999 under an agreement between Manitoba Hydro and Chemawawin First Nation. Water quality has been monitored by MCWS at the Grand Rapids GS since 2001.

Two areas of Cedar Lake (west and southeast basins) are monitored under CAMP. The southeast basin is monitored annually and was first sampled in Year 2 of the Pilot Program. The west basin is monitored on a three year rotational basis and was first sampled in 2011/12.

3.2.2.4 Cormorant Lake

Cormorant Lake is an off-system waterbody that is monitored annually under CAMP in the Saskatchewan River Region. Cormorant Lake, located in the South Moose Lake watershed approximately 60 km northeast of The Pas, receives inflows from Clearwater Lake, and drains into North Moose Lake via Frog Creek. The Community of Cormorant is situated on the east shore of Cormorant Lake and there is one active fishing lodge situated on the lake. The lake supports subsistence, commercial and recreational fisheries. There is little history of aquatic environment monitoring in this waterbody. CAMP monitoring was initiated in Year 1 of the Pilot Program.

3.2.3 Lake Winnipeg Region

Two waterbodies are monitored annually under CAMP in the Lake Winnipeg Region. The on-system waterbody is the north basin of Lake Winnipeg and the off-system waterbody is Lake Winnipegosis. Although the Lake Winnipeg Region is incorporated in CAMP, results of sampling from Lake Winnipeg and Lake Winnipegosis over the Pilot Program (i.e., CAMPP) have not been included in the current report. Pre-existing programming and program administration for Lake Winnipeg were such that not all parameters being sampled aligned with

CAMP sampling protocols. Integration and synthesis of data collected for Lake Winnipeg under CAMP and Lake Winnipeg monitoring initiatives will be addressed in future reporting.

3.2.3.1 Lake Winnipeg

Lake Winnipeg, the tenth largest freshwater lake in the world (Environment Canada and Manitoba Water Stewardship 2011), is composed of a shallow, smaller, southern basin, and a deeper, larger, northern basin separated by a channel referred to as the narrows. The lake is affected by Manitoba Hydro’s hydraulic operating system as well as by water regulation in Alberta, Saskatchewan, and Ontario, and regulation for purposes other than hydroelectric power production in Manitoba. The lake supports important subsistence, commercial, and recreational fisheries and has an extensive history of aquatic monitoring. Numerous communities are located on the shores of Lake Winnipeg and it supports extensive cabin developments and recreational activities. Concerns over eutrophication of Lake Winnipeg have recently come to light which have spurned intensive and extensive scientific study, as well as management initiatives. Monitoring of Lake Winnipeg (north basin) under the Coordinated Aquatic Monitoring Program (CAMP) is largely fulfilled through monitoring programs that were already in existence at the time of initiation of the Pilot Program (i.e., 2008/2009).

3.2.3.2 Lake Winnipegosis

Lake Winnipegosis is a large off-system waterbody west of the north basin of Lake Winnipeg. It is not affected by water regulation for hydroelectric power production but is affected by regulation in some tributaries for other purposes, such as flood protection. The shoreline of Lake Winnipegosis is scarcely populated, with the Village of Winnipegosis and a few First Nation communities being the only population centres. However, the drainage basin includes larger centres such as the Town of Dauphin and the Town of Swan River. The lake supports important subsistence, commercial, and recreational fisheries and monitoring of the fish community has occurred annually since 1990. CAMP monitoring of this waterbody was initiated in Year 1 of the Pilot Program.

3.2.4 Upper Churchill River Region

The Upper Churchill River Region is composed of the Churchill River extending from the Saskatchewan/Manitoba border downstream to the natural outlet of Southern Indian Lake at Missi Falls and the man-made outlet at South Bay. Annual monitoring is conducted at Granville Lake (off-system) and Southern Indian Lake Area 4 (on-system) and was initiated in Year 1 of the Pilot Program in these waterbodies. Three additional areas (all on-system) are monitored under the Coordinated Aquatic Monitoring Program (CAMP) on a three-year rotational basis in this region: Opachuanau Lake, first monitored in 2011/2012; Southern Indian Lake Area 1, first monitored in Year 2 of the Pilot Program; and Southern Indian Lake Area 6, first monitored in Year 3 of the Pilot Program.

3.2.4.1 Granville Lake

Granville Lake, an off-system, annual waterbody, is located upstream of Southern Indian Lake along the Upper Churchill River. The majority of time, Granville Lake water levels are not affected by CRD. A measureable backwater effect occurs less than 10 percent of the time when low flows on the upper Churchill River (and consequently low Granville Lake levels) are combined with Southern Indian Lake being near its maximum operating limit. The water levels of Granville Lake are also affected by flow regulation upstream in the Saskatchewan portion of the watershed. Granville Lake is home to the Community of Granville Lake and the lake is fished for subsistence and commercially. Manitoba Conservation and Water Stewardship (MCWS) has maintained a long-term water quality sampling site on the lake since 1978 (site currently monitored under CAMP). Monitoring of Granville Lake under CAMP has been conducted annually since Year 1 of the Pilot Program.

3.2.4.2 Opachuanau Lake (Southern Indian Lake – Area 0)

Opachuanau Lake (also referred to as Southern Indian Lake – Area 0), is located upstream of Southern Indian Lake. The lake is affected by Manitoba Hydro’s hydraulic system and water regulation in Saskatchewan. Opachuanau Lake supports subsistence and commercial fishing and has been the subject of extensive historical aquatic monitoring. Opachuanau Lake is monitored under CAMP on a three-year rotational basis and was first sampled in 2011/12.

3.2.4.3 Southern Indian Lake – Areas 1, 4, and 6

Southern Indian Lake, an on-system lake, functions as a storage reservoir for the Churchill River Diversion (CRD) due to the operation of the Missi Falls and Notigi Control Structures (CSs). Like lakes upstream, Southern Indian Lake is also affected by water regulation in the Province of Saskatchewan. Southern Indian Lake is home to O-Pipon-Na-Piwin First Nation and the Community of South Indian Lake. There is a long history of aquatic monitoring in Southern Indian Lake, dating back to the pre-CRD period. It was investigated as part of the Lake Winnipeg, Churchill and Nelson Rivers Study Board studies, it was home to a DFO research station that operated in the 1970s and 1980s, was monitored under the 1986-1990 Federal Environmental Monitoring Program (FEMP), and is currently (2003-present) being studied by the South Indian Lake Environmental Steering Committee. Additionally, fish stocks have been monitored by Manitoba Fisheries Branch since the 1990s and water quality has been monitored at a site near the Community of South Indian Lake since 1972 by MCWS.

Historical studies of Southern Indian Lake divided the lake into seven areas (Areas 1-7) and three of these areas (1, 4, and 6) are monitored under CAMP. Areas 1, 4, and 6 support important subsistence fisheries and Areas 1 and 4 either presently support (Area 1) or have supported (Area 4) important commercial fisheries. The commercial fishery of Southern Indian Lake – Area 4 is currently closed.

Monitoring has been conducted annually since Year 1 of the Pilot Program in one area of the lake (Area 4, west of Missi Falls) under CAMP. Areas 1 (southwestern basin) and 6 (basin south of the Community of South Indian Lake) are sampled on a three year rotation and were first monitored under CAMP in 2009/2010 and 2010/2011, respectively.

3.2.5 Lower Churchill River Region

The Lower Churchill River Region includes the Churchill River from the Missi Falls Control Structure (CS) at the natural outlet of Southern Indian Lake to the mouth of the river at the Town of Churchill on Hudson Bay. The region also includes Gauer Lake, which is located south of the lower Churchill River. Three areas have been monitored annually under the Coordinate Aquatic Monitoring Program (CAMP) beginning in Year 1 of the Pilot Program: Northern Indian Lake (on-system); the lower Churchill River at the Little Churchill River (on-system); and Gauer Lake (off-system). Three additional lakes, all of which are on-system, are monitored on a three-year rotational basis in this region: Partridge Breast Lake, which was first sampled in Year 2 of the Pilot Program; Fidler Lake, which was first sampled in 2011/2012 under CAMP; and Billard Lake, which was first sampled in Year 3 of the Pilot Program. In addition, monitoring was conducted in 2011/2012 in the Churchill River at Red Head Rapids.

3.2.5.1 Partridge Breast Lake

Partridge Breast Lake, an on-system waterbody, is located on the lower Churchill River, immediately downstream of the Missi Falls CS and upstream of Northern Indian Lake. Its water levels are affected by the Churchill River Diversion (CRD). The lake supports a subsistence fishery and periodically supports a commercial fishery. There has been limited historical monitoring of the fish community and water quality in this waterbody. Benthic invertebrate sampling was conducted bi-annually on the lake from 1977 to 1983, and in 1973 and 1987. CAMP monitoring is conducted on a three-year rotational basis in Partridge Breast Lake and was first sampled in Year 2 of the Pilot Program.

3.2.5.2 Northern Indian Lake

Northern Indian Lake is an on-system waterbody located downstream of the Missi Falls CS and Partridge Breast Lake, and is affected by CRD. Although the lake supports subsistence and commercial fisheries, with the exception of limited data collected prior to CRD as part of the Lake Winnipeg, Churchill, and Nelson Rivers Study Board (LWCNRSB) studies, the fish community has received little study. There is comparatively more historical monitoring data for the benthic invertebrate community and water quality for Northern Indian Lake; benthic invertebrate sampling was conducted bi-annually on the lake from 1977 to 1983, and in 1973 and 1987, and water quality monitoring was conducted in most years over the period of 1978-2001 by Manitoba Conservation and Water Stewardship (MCWS). Northern Indian Lake has been monitored annually under CAMP beginning in Year 1 of the Pilot Program.

3.2.5.3 Fidler Lake

Fidler Lake, an on-system lake located on the lower Churchill River between Northern Indian Lake and Billard Lake, is also affected by CRD. Fidler Lake supported a commercial fishery in the past. Currently the lake is not commercially fished and is believed to support little subsistence or recreational fishing. In general, there is relatively limited historical monitoring information for Fidler Lake. Limited information on the fish community, commercial fishery, and water quality was collected prior to CRD as part of the LWCNRSB studies. In addition, benthic invertebrate sampling was conducted bi-annually on the lake from 1977 to 1983 and in 1973 and 1987. Fidler Lake is monitored on a three-year rotational basis under CAMP and was first sampled in 2011/12.

3.2.5.4 Billard Lake

Billard Lake is an on-system lake located on the lower Churchill River, downstream of Northern Indian Lake and upstream of the Churchill River at the Little Churchill River. Like lakes located upstream, it is affected by CRD. A fly-in hunting/fishing camp is located on the lake, suggesting that some recreational fishing occurs. Billard Lake supported a commercial fishery in the past; however, at present there is no commercial fishery and likely little subsistence fishing. With the exception of limited study of the commercial fishery done as part of the LWCNRSB studies prior to CRD, there has been limited aquatic monitoring in this lake. Billard Lake is monitored on a three-year rotational basis under CAMP and was first sampled in Year 3 of the Pilot Program.

3.2.5.5 Churchill River at the Little Churchill River

The second on-system waterbody sampled annually under CAMP is a reach of the lower Churchill River at its confluence with the Little Churchill River. Like upstream sites on this river, water levels and flows in this area are affected by CRD. The site is fished for subsistence. Prior to the initiation of CAMP, there had been very little aquatic environmental information collected at this location. Sampling has been conducted annually under CAMP beginning in Year 1 of the Pilot Program.

3.2.5.6 Churchill River at Red Head Rapids

This riverine sampling area is located on the lower Churchill River downstream of the Little Churchill River confluence and upstream of the Town of Churchill. Water levels and flows in this area are affected by CRD. The area supports a minimal amount of recreational fishing. No benthic invertebrate or fish community information had been collected from this site prior to the initiation of CAMP. However, water quality was monitored by Environment Canada from 1972 through 1996 at this location. This reach of the lower Churchill River, a rotational site, was first sampled in 2011/2012 under CAMP, at which time it was identified to pose significant safety/access and logistical challenges with respect to implementation of CAMP monitoring. An alternative site located downstream near the Town of Churchill is being considered to replace this location.

3.2.5.7 Gauer Lake

Gauer Lake is the off-system lacustrine site monitored annually under CAMP in the Lower Churchill River Region. Gauer Lake is situated on the Gauer River, which flows into the Churchill River downstream of the Missi Falls CS, and is not affected by water regulation. The lake is fished commercially and for subsistence. There is little history of aquatic monitoring on Gauer Lake. It was first sampled under CAMP in Year 1 of the Pilot Program.

3.2.6 Churchill River Diversion Region

The Churchill River Diversion (CRD) Region is composed of the portion of the CRD route that extends from the man-made outlet of Southern Indian Lake at South Bay, through the Rat/Burntwood river system (including the Notigi Control Structure [CS]) to First Rapids on the Burntwood River, approximately 20 km upstream of Split Lake. The region also includes Leftrook Lake, which is located on the Footprint River system. Two lakes have been monitored annually under the Coordinated Aquatic Monitoring Program (CAMP), beginning in Year 2 of the Pilot Program: Threepoint Lake (on-system); and Leftrook Lake (off-system). Five additional lakes, all of which are on-system, are monitored on a three-year rotational basis in this region:

Rat and Footprint lakes, which were first sampled in Year 3 of the Pilot Program; Notigi and Apussigamasi lakes, which were first sampled in Year 2 of the Pilot Program; and West/Central Mynarski Lake, which was first sampled in 2011/2012.

3.2.6.1 Rat Lake

Rat Lake is located on the Rat/Burntwood River system, upstream of Notigi Lake. Water levels on Rat Lake are regulated by CRD and it supports a commercial fishery. Information on Rat Lake was collected as part of the Lake Winnipeg, Churchill, and Nelson Rivers Study Board (LWCNRSB) studies conducted prior to CRD, and in a number of post-CRD studies conducted by the Department of Fisheries and Oceans (DFO), and under the Manitoba Ecological Monitoring Program (MEMP), the Federal Ecological Monitoring Program (FEMP), and the Wuskwatim Generation Project Environmental Impact Statement (EIS) baseline studies. Rat Lake is monitored on a three-year rotational basis under CAMP, beginning in Year 3 of the Pilot Program.

3.2.6.2 West/Central Mynarski Lake

Although West/Central Mynarski Lake is located off the Rat/Burntwood River system upstream of Rat Lake and Notigi Lake, its water levels are affected by CRD and it is considered an on-system waterbody. West/Central Mynarski Lake supports a commercial fishery. Aquatic environment information was collected from West/Central Mynarski Lake as part of the LWCNRSB studies conducted prior to CRD and in post-CRD studies. However, historical monitoring information for this lake is limited. West/Central Mynarski Lake is monitored under CAMP on a three-year rotational basis and was first sampled in 2011/12.

3.2.6.3 Notigi Lake

Notigi Lake is located on the Rat/Burntwood River system, downstream of Rat Lake and upstream of Threepoint Lake. It is the forebay of the Notigi CS, a primary component of CRD. The lake supports subsistence and commercial fisheries. Aquatic environment information was collected from Notigi Lake as part of the LWCNRSB studies conducted prior to CRD, and in post-CRD studies conducted by DFO, and under MEMP, and the Wuskwatim Generation Project EIS baseline studies. Notigi Lake is monitored under CAMP on a three-year rotational basis and was first sampled in Year 2 of the Pilot Program.

3.2.6.4 Threepoint Lake

Threepoint Lake is located on the mainstem of the CRD route (Rat/Burntwood River system), upstream of Wuskwatim Lake and downstream of Notigi Lake. The lake is affected by Manitoba

Hydro's hydraulic operating system. Threepoint Lake supports subsistence and commercial fisheries. Past aquatic studies include the LWCNRSB studies conducted prior to CRD, and post-CRD studies conducted under MEMP, FEMP, and the Wuskwatim GS aquatic baseline and monitoring programs. Threepoint Lake has been monitored annually under CAMP, beginning in Year 2 of the Pilot Program.

3.2.6.5 Footprint Lake

Footprint Lake is located downstream on the Footprint River system and is affected by backwater effects of CRD. Footprint Lake is home to Nisichawayasihk First Nation and the community of Nelson House. The lake supports a recreational fishery. Aquatic environment information was collected under the LWCNRSB studies conducted prior to CRD, and in post-CRD studies including the Wuskwatim Generation Project EIS baseline and monitoring studies. Manitoba Conservation and Water Stewardship (MCWS) has maintained a long-term water quality monitoring site on the lake since 1975 (site is currently monitored under CAMP). Footprint Lake is monitored under CAMP on a three-year rotational basis and was first sampled in Year 3 of the Pilot Program.

3.2.6.6 Apussigamasi Lake

Apussigamasi Lake is located on the Burntwood River, just downstream of the City of Thompson. The lake is affected by CRD and is fished recreationally. Fish population monitoring was conducted on the lake by Manitoba Fisheries Branch in 1984. Other historical monitoring has included the Wuskwatim Generation Project EIS baseline and monitoring studies and water quality monitoring conducted by MCWS. Apussigamasi Lake is monitored under CAMP on a three-year rotational basis and was first sampled in Year 2 of the Pilot Program.

3.2.6.7 Leftrook Lake

Leftrook Lake, an off-system waterbody, is a headwater lake on the Footprint River, located upstream of the effects of CRD. The lake supports subsistence and recreational fisheries. Aquatic environment data was collected from Leftrook Lake as part of the Wuskwatim Generation Project EIS studies and there is a long-term record of mercury in fish from Leftrook Lake. Leftrook Lake has been monitored annually under CAMP, beginning in Year 2 of the Pilot Program.

3.2.7 Upper Nelson River Region

The upper Nelson River area extends from the outlet of Lake Winnipeg near Warrens Landing to the Kelsey Generating Station (GS). The region also includes Setting Lake, which is located on the Grass River system. Two lakes have been monitored annually under the Coordinated Aquatic Monitoring Program (CAMP), beginning in Year 1 of the Pilot Program: Cross Lake (west basin; on-system); and Setting Lake (off-system). Four additional lakes and a reach of the upper Nelson River are monitored on a three-year rotational basis in this region: Playgreen Lake (on-system), which was first sampled in Year 2 of the Pilot Program; Little Playgreen (on-system) and Walker (off-system) lakes, which were first sampled in Year 3 of the Pilot Program; and Sipiwesk Lake and the upper Nelson River downstream of Sipiwesk Lake (both on-system), which were first sampled in 2011/2012.

3.2.7.1 Playgreen Lake

Playgreen Lake, one of the Lake Winnipeg outlet lakes, is the first lake downstream of Lake Winnipeg on the upper Nelson River. The majority of flow from Lake Winnipeg enters Playgreen Lake at Two Mile Channel, flowing out through Eight Mile Channel and the Ominiwan Bypass Channel; it is affected by Lake Winnipeg Regulation (LWR) and backwater effects from the Jenpeg GS. The lake supports an important commercial fishery and there is a long history of monitoring fish stocks under methods that differ from the CAMP protocol, as well as historical short-term studies conducted on the fish community. Water quality has also been monitored historically, though no long-term monitoring site exists for the lake. Playgreen Lake is monitored under CAMP on a three-year rotational basis and was first sampled in Year 2 of the Pilot Program.

3.2.7.2 Little Playgreen Lake

Little Playgreen Lake is home to Norway House Cree Nation and the Community of Norway House. The lake is affected by LWR and backwater effects from the Jenpeg GS and it supports an important subsistence fishery. There is a long history of monitoring water quality in the area but minimal monitoring of other components of the aquatic environment. Little Playgreen Lake is monitored under CAMP on a three-year rotational basis and was first sampled in Year 3 of the Pilot Program.

3.2.7.3 Cross Lake - West Basin

Cross Lake (west basin) is downstream of the Jenpeg GS. The operation of the Jenpeg GS and LWR impact water levels on Cross Lake and, until the construction of the Cross Lake outlet weir in 1992, which was constructed to partially mitigate the effects of LWR, these operations resulted in significant draw-downs during low flow conditions. Cross Lake is home to Cross Lake First Nation and the Community of Cross Lake and the west basin supports an important subsistence fishery. The adjoining east basin and Pipestone Lake also support important commercial fisheries. Cross Lake has a long history of aquatic environment monitoring and study. Historical studies have included a number of pre-LWR (e.g., Lake Winnipeg, Churchill and Nelson Rivers Study Board [LWCNRSB] studies) and post-LWR studies, such as the Manitoba Ecological Monitoring Program (MEMP) and Manitoba Hydro's Post Weir Monitoring Program, and routine fish stock monitoring since 1992. Water quality has also been monitored by Manitoba Conservation and Water Stewardship (MCWS) in the lake since 1973 (site is currently monitoring under CAMP). Historical monitoring programs have largely used methods that are similar to the CAMP protocol. Cross Lake (west basin) has been monitored annually under CAMP, beginning in Year 1 of the Pilot Program.

3.2.7.4 Sipiwesk Lake

Sipiwesk Lake is the most downstream lake on the upper Nelson River. Lake water levels were first affected by the Kelsey GS in 1960, and further altered by the operation of the Jenpeg GS and LWR in 1976. It supports an important commercial fishery operating out of Wabowden and is an important subsistence harvest area for both Wabowden and Cross Lake First Nation. Historical monitoring has included pre-LWR studies (e.g., LWCNRSB studies) and post-LWR studies (e.g., MEMP). MCWS has maintained a long-term water quality monitoring site on the lake since 1975. Sipiwesk Lake is monitored under CAMP on a three-year rotational basis and was first sampled in 2011/2012.

3.2.7.5 Upper Nelson River (Downstream of Sipiwesk Lake)

The upper Nelson River (downstream of Sipiwesk Lake) water levels were first affected by the Kelsey GS in 1960, and further altered by the operation of the Jenpeg GS and LWR in 1976. It supports an important commercial fishery, with an additional large scale fishery on the connected tributary, Cauchon Lake. There has been minimal aquatic monitoring in this area. This reach of the upper Nelson River is monitored under CAMP on a three-year rotational basis and was first sampled in 2011/12.

3.2.7.6 Walker Lake

Walker Lake drains into the east basin of Cross Lake via the Walker River and is an off-system waterbody for the Upper Nelson River Region. The lake is affected by a backwater effect when water levels exceed 207.6 m in Cross Lake; while this effect has always occurred naturally, LWR and construction of the Cross Lake Weir can affect the frequency, timing, and magnitude of backwater effects in Walker Lake. Walker Lake supports an important commercial fishery and is an important subsistence harvest area for Cross Lake First Nation and the Community of Cross Lake. There is relatively little historical monitoring information for Walker Lake and only a few limited studies of fish stocks using methods similar to the CAMP protocol. Walker Lake is monitored under CAMP on a three-year rotational basis and was first sampled in Year 3 of the Pilot Program.

3.2.7.7 Setting Lake

Setting Lake, an off-system waterbody, is on the Grass River system and both it and its tributaries are unregulated. Setting Lake is near the Town of Wabowden and also is home to a major cottage subdivision. The lake is fished for subsistence, commercially and recreationally. There is a long but sporadic history of monitoring of fish stocks and water quality using methods that are similar to the CAMP protocol. However, there is no previous record of water level monitoring. Setting Lake has been monitored annually under CAMP since Year 1 of the Pilot Program.

3.2.8 Lower Nelson River Region

The Lower Nelson River Region is composed of the reach of the Nelson River (including lakes and reservoirs) extending from the Kelsey Generating Station (GS) downstream to the river's outlet at Hudson Bay, the reach of the Burntwood River between First Rapids and Split Lake, and off-system lacustrine (Assean Lake) and riverine (Hayes River) waterbodies.

Four waterbodies/areas are monitored annually under the Coordinated Aquatic Monitoring Program (CAMP): Split Lake (on-system), which was first sampled in 2009/2010; the lower Nelson River downstream of the Limestone GS (on-system), which was first sampled in 2008/2009; Assean Lake (off-system), which was first sampled in 2009/2010; and the Hayes River (off-system), which was first sampled in 2008/2009. Four additional areas are monitored on a three-year rotational basis in this region: the Burntwood River below First Rapids (on-system), which was first sampled for all components in 2011/2012[1]; Stephens Lake north and south (both on-system), which were first sampled in Year 2 of the Pilot Program; and the Limestone Forebay (on-system), which was first sampled in Year 3 of the Pilot Program.

3.2.8.1 Burntwood River (Between First Rapids and Split Lake)

The reach of the Burntwood River between First Rapids and Split Lake is approximately 35 km long and is an on-system waterbody. It represents the second largest tributary to Split Lake and the lower Nelson River (the largest being the upper Nelson River). The hydrology of the Burntwood River, including this reach, has been affected by the Churchill River Diversion (CRD). The area supports subsistence and recreational fishing and Split Lake, located

[1] Water quality is monitored annually at this site and was first sampled under CAMP in 2009/2010.

downstream of the Burntwood River, also supports a commercial fishery. Past aquatic monitoring conducted in the area includes limited study prior to CRD (e.g., Lake Winnipeg, Churchill and Nelson Rivers Study Board [LWCNRSB] studies) and more extensive recent studies conducted as part of the Keeyask Generation Project environmental studies program. This reach of the Burntwood River is monitored annually for water quality (beginning in Year 2 of the Pilot Program) and on a three-year rotational basis for other components (beginning in 2011/2012).

3.2.8.2 Split Lake

Split Lake, an on-system lake, receives inflows from the upper Nelson and Burntwood rivers, and is therefore affected by both Lake Winnipeg Regulation (LWR) and CRD, as well as operation of the Kelsey GS. Split Lake is home to Tataskweyak Cree Nation, and the Community of Split Lake, and York Factory First Nation and the Community of York Landing. Split Lake supports an important subsistence fishery and is also fished commercially and recreationally. Aquatic environment studies have included pre-LWR/CRD studies conducted by the LWCNRSB, and post-LWR/CRD studies including the Manitoba Ecological Monitoring Program (MEMP), the Federal Ecological Monitoring Program (FEMP), the Split Lake Monitoring Program (1997-1998), and as part of the Keeyask Generation Project environmental studies program. Water quality has been monitored in the lake by Manitoba Water Stewardship (MCWS) since 1975 (site currently sampled under CAMP). Split Lake has been monitored annually under CAMP since Year 2 of the Pilot Program.

3.2.8.3 Stephens Lake – North and South

Stephens Lake, the forebay of the Kettle GS, is located on the lower Nelson River. The operation of the Kettle GS and other upstream Manitoba Hydro hydraulic operations impact water levels on Stephens Lake. The Town of Gillam is located along the shores of Stephens Lake. The lake can generally be described as consisting of a southern riverine portion through which the main flow of the Nelson River passes (i.e., Stephens Lake South), and a northern arm, which is relatively isolated from the Nelson River flow (i.e., Stephens Lake North). The North and South Moswakot rivers flow into the north arm of Stephens Lake, which was originally Moose Nose Lake.

The lake supports subsistence, commercial, and recreational fisheries. Aquatic environment studies have included pre-LWR/CRD studies conducted by the LWCNRSB, and post-LWR/CRD studies including MEMP, the Limestone GS Aquatic Environment Monitoring Program, and the Keeyask Generation Project environmental studies program. Stephens Lake North and South are monitored on a three-year rotational basis under CAMP, and were first sampled in Year 2 of the Pilot Program.

3.2.8.4 Limestone GS Forebay

The Limestone GS Forebay is located on the lower Nelson River downstream of Stephens Lake and is the furthest downstream GS on this river. The operation of the Limestone GS and upstream Manitoba Hydro hydraulic operations affect water levels on the Limestone GS Forebay. The forebay is fished for subsistence and recreation. There has been extensive pre-, during, and post-construction aquatic monitoring of the forebay area as part of Limestone GS Aquatic Environment Monitoring Program, and the Keeyask and Conawapa Generation Project environmental studies programs. The Limestone Forebay is monitored on a three-year rotational basis under CAMP, and was first sampled in Year 3 of the Pilot Program.

3.2.8.5 Lower Nelson River (Downstream of the Limestone GS)

The annual on-system riverine site in the region is the lower Nelson River mainstem just downstream of the location of the proposed Conawapa GS. The lower Nelson River is affected by LWR, CRD, and local GSs, notably operation of the Limestone GS which impacts water levels on the Nelson River mainstem. The lower Nelson River supports some subsistence and recreational fishing. Aquatic environment information has been collected from this general area as part of the Limestone GS Aquatic Environment Monitoring Program, and the Keeyask and Conawapa Generation Projects environmental studies programs. Annual sampling under CAMP was initiated in Year 1 of the Pilot Program.

3.2.8.6 Hayes River

The Hayes River, which flows to Hudson Bay, is a Canadian Heritage River and is one of the few large unregulated rivers in Canada; it serves as a riverine off-system waterbody for the Churchill and Nelson rivers under CAMP. The reach of the river monitored under CAMP is an approximately 20 km long stretch of the lower Hayes River, with the confluence of the Hayes and Pennycutaway rivers located near the mid-point of the reach. This portion of the river supports some subsistence fishing. Previous aquatic monitoring is relatively limited, though water quality was monitored by Environment Canada (EC) for approximately 20 years (1974 through 1996); water quality is currently monitored at this historical site under CAMP. Annual sampling under CAMP was initiated in Year 1 of the Pilot Program.

3.2.8.7 Assean Lake

Assean Lake, an off-system lake, discharges into the Nelson River at Clark Lake via the Assean River, and is unaffected by Manitoba Hydro’s hydraulic operating system. The lake supports a few cabins and is fished for subsistence, commercially and recreationally. Aquatic environment information has been collected from Assean Lake as part of the Keeyask Generation Project environmental studies program. Annual sampling under CAMP was initiated in Year 2 of the Pilot Program.

SECTION 4.0: APPROACH AND METHODS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

4.0 APPROACH AND METHODS

The following provides a description of the approach and methods applied over the three year Pilot Program (i.e., CAMPP) and descriptions of data analysis methods applied for production of this report. Also provided are summaries of comments generated from annual workshops held prior to and during the conduct of CAMPP (i.e., 2007-2010). Descriptions of the methods for site selection for the Coordinated Aquatic Monitoring Program (CAMP), which includes the Pilot Program, are also provided below.

4.1 CLIMATE

4.1.1 Site Selection

Environment Canada (EC) Meteorological Stations conforming to the United Nations' World Meteorological Organization standards are located in each of the CAMPP Regions. These stations are located at Pinawa (Winnipeg River Region), Grand Rapids (Saskatchewan River Region), The Pas (Saskatchewan River Region), Norway House (Upper Nelson River Region), Lynn Lake (Upper Churchill River Region), Churchill (Lower Churchill River Region), Thompson (Churchill River Diversion Region) and Gillam (Lower Nelson River Region). Sites are indicated in Figure 4.1.1-1.

4.1.2 Methods

Daily climate (temperature and precipitation) data were downloaded from EC's website: climate.weatheroffice.gc.ca. Monthly mean temperatures and precipitation values for each of 2008, 2009 and 2010 were calculated and compared to normal values for the period of 1971-2000. Climate data were considered in the interpretation of monitoring results for the various components since air temperature and precipitation may affect water quality conditions and the physical attributes of aquatic habitat.

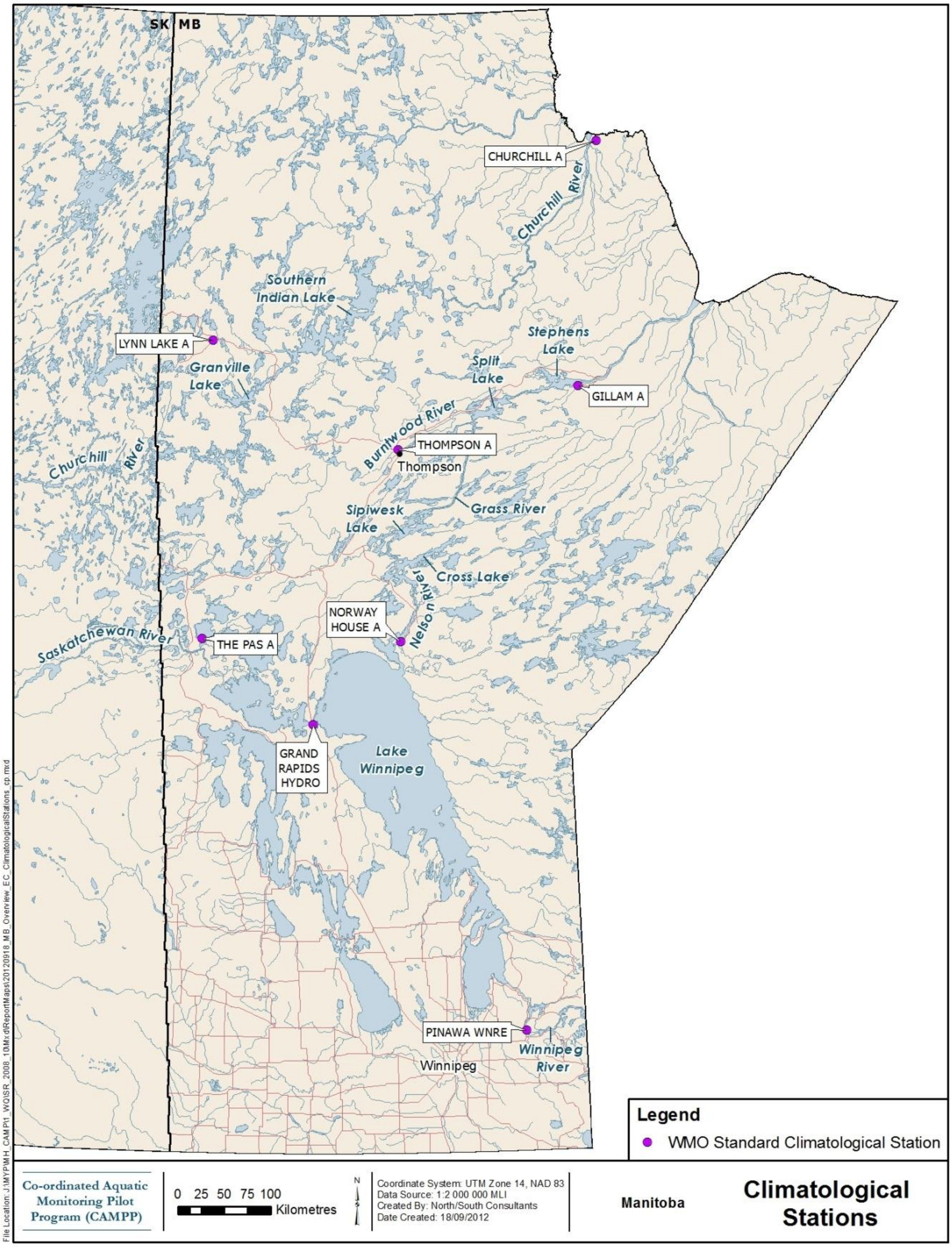

Figure 4.1.1-1. Environment Canada Meteorological Stations conforming to the United Nations' World Meteorological Organization standards summarized in the CAMPP report.

4.2 HYDROLOGY

The collection of hydrometric data is critical in understanding the availability, variability and distribution of water resources. It provides the basis for responsible decision making on the management of this resource. Historic hydrometric data provide an understanding of the potential extent and limitation of this resource and support activities such as ecosystem protection and scientific study, policy development, hydraulic analysis, infrastructure design, licence and contractual obligations and to document water and ice regimes for addressing impacts on waterways. Near real-time hydrometric data have become increasingly important to facilitate daily decisions in maximizing the requirements of this resource.

4.2.1 Site Selection

Hydrometric stations are generally constructed to serve a specific water management purpose at a specific site or are strategically located to document hydrological characteristics and processes required to understand the regional hydrology. Sites are carefully selected to ensure the efficient collection of accurate hydrometric data and depend on many factors such as:

- the purpose of the hydrometric station;
- the geographical features of the area;
- accessibility, availability of services; and
- the cost of site installation and operation.

There are hydrometric stations located in all eight of the monitoring regions associated with CAMPP. These locations include monitoring areas that are affected by Manitoba Hydro’s operations as well as off-system areas that are not. The hydrometric data collected at these stations are generally used as a physical parameter in monitoring and documenting the aquatic conditions of the system.

4.2.2 CAMPP Methods

Within CAMPP, hydrometric data refer to water levels and flows obtained from stations operated by either Water Survey of Canada or Manitoba Hydro. Both agencies are part of the National Hydrometric Program (NHP); a cooperative endeavor between the federal, provincial and territorial governments to provide accurate, timely and standardized data and information on the current and historic availability of surface water. Water Survey of Canada, Manitoba Conservation and Water Stewardship and Manitoba Hydro make up the provincial component of this program. The parties recognize the value of cooperative water monitoring activities for reasons including operational and cost efficiencies.

The NHP provides for the collection, interpretation, publication and distribution of surface water quantity data and information. Most important to the program is the commitment of the partners to maintain national standards under their respective Quality Management Systems, to develop hydrologic and hydrometric expertise, to implement efficient modern technology and to provide hydrometric data and information to those who need it. An annual audit of the above activities ensures that all agencies are consistent and maintain a high level of competency in hydrometric monitoring.

Hydrometric data were considered in the interpretation of monitoring results for the various components of CAMPP since water levels and flows may affect water quality conditions, the physical attributes of aquatic habitat, and aquatic biota.

4.2.2.1 Quality Assurance Management System

Vertical Control

Vertical control in the form of benchmarks has been established at all stations in order to effectively and accurately calibrate continuously recorded water levels. Water level information may or may not be based upon a Geodetic Survey of Canada (GS of C), Canadian Government Vertical Datum (CGVD). This information is available from the operating agency.

Note: All of Manitoba Hydro's stations are referenced to a GS of C datum. Which datum depends on the location of the hydrometric station.

Water Level Record

Water levels are recorded on a continuous basis using pressure transducers and data loggers; generally every five minutes in order to adequately capture surface water fluctuations. Hourly and daily values are calculated based on the five minute readings.

Field staff visit stations on a regular basis to maintain a high level of station performance. Direct water level measurements are taken during these visits and are compared to the level indicated by the water level sensor. The sensor is calibrated based on the water level measurement taking into account field conditions at the time of the visit.

Water Level / Discharge (Flow) Relationship

Discharges are calculated on a continuous basis; generally every five minutes since they are derived from the water level record. Hourly and daily values are calculated based on the five minute readings.

The water level record at a flow station is maintained and calibrated as mentioned above. In addition, discharge measurements (usually using an Acoustic Doppler Current Profiler) are also taken in order to develop and maintain a well-defined relationship (curve) between water level and flow throughout the entire range of water levels. Using the curve, flows can be calculated based on recorded water levels.

Record Interpretation and Computation

Raw data are transmitted via satellite in near real-time, retrieved and converted using a suite of software then ingested into the appropriate databases.

Data are processed by qualified technicians using national processes and procedures developed under the National Hydrometric Program. Using hydrological data management software, corrections are applied to the data based on field measurements and noted conditions. The data are compared to all available relevant data in the area to verify its accuracy and account for environmental influences.

Several levels of review ensure compliance with applicable standards and ensure that associated station information is up-to-date. Data are generally not estimated where values are missing.

4.3 AQUATIC HABITAT INVENTORY

Components of CAMPP, such as the benthic invertebrate and fish community monitoring, are habitat-based and therefore require an understanding of habitat types and distribution within the study lakes. Detailed and contemporary habitat information (i.e. depth, substrate types and aquatic plant communities) is currently lacking for a number of CAMPP lakes. As a result, CAMPP introduced an aquatic habitat inventory program in 2010. The program differs from the other study components of CAMPP in that habitat inventories are conducted on a one-time basis without additional monitoring in subsequent years. The objective is to obtain a contemporary snap-shot of the physical environment and overall aquatic habitats of the CAMPP waterbodies.

4.3.1 Waterbody Selection

A level of effort classification (Table 4.3.1-1) was produced in order to rank CAMPP waterbodies according to the degree of difficulty required to conduct habitat surveys. Physical characteristics that factored into the classification include surface area, shoreline development, and total shoreline length. The categorized list was used to aid in the selection of waterbodies for survey each study year. Apussigamasi Lake (Churchill River Diversion Region), Assean Lake (Lower Nelson River Region), Billard Lake (Lower Churchill River Region) and a portion of Northern Indian Lake (Lower Churchill River Region) were selected for survey in 2010/11.

4.3.2 CAMPP Methods

The following section outlines the general methods used for habitat data collection, analysis, classification, and mapping under CAMPP. Refer to Appendix 1 for a complete methodology for the 2010 habitat mapping program.

4.3.2.1 Sampling Methods

Boat-based hydroacoustic remote sensing combined with physical bottom validation sampling is the preferred method of large-scale bathymetric and bottom type data collection for the aquatic habitat inventory program. Typically the sampling period for these studies was targeted for early in the open-water season (late May through July) to avoid periods when aquatic plants are abundant in the shallow nearshore areas. Dense macrophyte beds limit the ability to survey in large shallow nearshore areas of the waterbodies.

Surveys consisted of three main activities: 1) boat-based global positioning system (GPS)-linked hydroacoustic depth and bottom-type surveys; 2) benthic validation sampling (substrate material size and composition); and 3) shoreline documentation (description, photos, GPS coordinates).

The hydroacoustic surveys were boat-based employing a Quester Tangent Corporation (QTC) scientific grade single beam echosounder coupled to a sub-metre grade Trimble real-time differential global positioning system (DGPS). The QTC system uses QTC VIEW hardware and software to log acoustic waveform data, along with National Marine Electronics Association (NMEA) positional data to an accompanying laptop. The QTC System contains an analogue-to-digital converter which obtains the amplitude envelope of the waveform echoed from the bottom of the waterbody. The signal shape of the echoed waveform is influenced by the physical properties of the surficial sediment and immediate subsurface. These physical properties include: sedimentary properties (grain size and condition of state); seabed roughness (sedimentary bedforms and bedrock outcropping features); and plant organisms found on the bottom. The signal shape is then described by 166 non-descriptive variables related to the grain size, hardness, and overall bottom roughness.

Typically the survey vessel was operated at 5-10 km/hr with the QTC system set to record data at 1 second intervals. Surveys consisted of parallel shoreline transects, and depending on the shape of the waterbody in question, a series of latitudinal or longitudinal grid lines spaced anywhere from 50 to 400 metres apart. Spacing was condensed in areas of significance, such as in the vicinity of CAMPP fish sampling areas.

Bottom validation of the water body was accomplished with a Ponar dredge sampler deployed at random locations along the hydroacoustic survey route in order to validate the acoustic data collection. At each selected validation site, GPS coordinates, substrate description (type and size according to a modified Wentworth (1922) scale, composition, and any additional comments), and digital photos of samples were recorded.

Shorelines were assessed for riparian condition, approximate slope, bank composition, and where required geo-linked photographs. These data along with the benthic sampling, were used to assist with final mapping of substrate classes.

Beginning in 2010/2011, habitat maps (i.e., substratum and depth) have been developed, by means of acoustic bottom typing and substrate validation, for waterbodies where there is either no existing information and/or where existing information is deemed inadequate.

4.3.2.2 Data Analysis Methods

Acoustic Bottom Typing Data Processing

Acoustic data collected in the field were imported into QTC Impact software. The software facilitates data processing, statistical analysis, and classification of the acoustic data. Where large data volumes were encountered, the data were merged, reviewed for errors, and imported to a third party statistical software package for statistical analysis and classification.

Records with anomalous depths and irregular waveform were rejected within QTC Impact prior to exporting to ASCII text format. The acoustic data were then imported into Microsoft Excel for further processing. Depths were corrected for transducer position below the surface of the water, which can range anywhere from 20 to 70 cm, depending on the waterbody.

Acoustic Data Analysis and Classification

Within QTC Impact, principal component analysis (PCA) was used to reduce the 166 acoustic elements or variables recorded in the field to three principal component variables (Q1, Q2, Q3) that contain greater than 90% of the acoustic variability found within the dataset. Using QTC Impact, an unsupervised cluster analysis was then used to group acoustic samples into classes with similar bottom type acoustic responses. This unsupervised classification approach requires user-supplied labelling of classes using validation data collected in the field after clustering.

4.3.2.3 Habitat Mapping Methods

Shoreline Mapping

Shoreline habitat mapping of CAMPP waterbodies required contemporary and relatively accurate georeferenced shoreline geometry data in order to produce the maps at a reasonable scale. CAMPP waterbody data were generally georeferenced to 1:50,000 federal topographic data (Centre for Topographic Information 2010), but when these vector data were not deemed sufficient, other data sources were sought. Examples of other shoreline data sources included but were not limited to: various resolutions of orthorectified satellite imagery; digital orthometric aerial imagery; or, other vector data products. Where possible, shorelines extracted from other sources were referenced to date of acquisition and mean water level of the target waterbody during acquisition.

Bathymetric Mapping

To develop a bathymetric surface (or grid) across each surveyed waterbody, spatial interpolation software was used to estimate depths for unsurveyed areas using depths measured at surveyed geographic locations. These interpolated depth surfaces were imported into a geographic information system (GIS). Environmental Systems Research Institute`s (ESRI) ArcGIS software was then used to symbolize the depth surfaces into a user-specified number of depth classes creating a continuous grid of depths. Vector contour lines were then produced and overlaid on the continuous depth surface interval map. Finally, background topographic data were used to provide additional context for the bathymetric depth data. ArcGIS was then used to summarize the interpolated depth data, and estimate such variables as mean and maximum depth, as well as volume for each waterbody.

Substrate Mapping

Acoustically classified bottom-type data were imported into ArcGIS software as a discrete point data layer and each point was then labelled according to its corresponding substrate class. Substrate classes were determined before importation into ArcGIS software using physical bottom-type samples collected with a ponar. The discrete acoustically classified point data were then interpolated to a continuous substrate surface that was classified and assigned a symbology that best reflects the substrate class they represented. Total area for each substrate class was calculated in the GIS and then exported into Microsoft Excel for formatting.

4.3.3 Workshop Recommendations

Annual workshops held from 2007 through 2010 provided the following recommendations and/or comments regarding the aquatic habitat component of CAMPP:

- Comment: Aquatic habitat types that are representative of both high impacted and low impacted sites should be identified across the whole system. High impacted sites include areas with high water fluctuations due to hydroelectric development. Low impacted sites include large lakes that have dampened regular water level fluctuations.

Response: CAMPP includes sampling of waterbodies across Manitoba Hydro's hydraulic system and captures environments with varying water level fluctuations.

- Comment: The aquatic habitat parameters needed to support the invertebrate and fish data should include: water depth, water velocity (lotic habitats), substrate type, presence/absence of macrophytes and presence/absence of flooded terrestrial vegetation.

  Response: Water velocity measurements were not incorporated in CAMPP and while presence/absence of macrophytes and flooded terrestrial vegetation are noted during the conduct of fish and benthic invertebrate field programs and during aquatic habitat surveys, detailed surveys of these habitat parameters were not undertaken under CAMPP. Aquatic habitat surveys were conducted in spring specifically to avoid dense macrophytes, as aquatic plants reduce the efficacy of the survey methods.

- Comment: Water level fluctuation is an essential parameter for understanding the potential effects of hydroelectric development on aquatic ecosystems.

  Response: Water levels and discharges continue to be monitored by Manitoba Hydro and other agencies across Manitoba.

- Comment: Bathymetric and aquatic habitat maps are considered valuable for all waterbodies being sampled.

  Response: Aquatic habitat surveys were initiated in 2010 under CAMPP to develop bathymetric and substrate maps of CAMPP waterbodies.

Table 4.3.1-1. Ranking of CAMPP waterbodies by relative level of effort required for habitat surveys.

Water Body	Water Body Metrics				Ranking					
	Area (km^2)	Shore (km)	SD	SL/A	Area Rank	Shore Rank	SD Rank	SL/A Rank	Total Rank	Relative Level of Effort
Billard Lake*	12.91	33.96	2.67	2.63	3	2	2	14	21	Low
Limestone Forebay	26.80	54.29	2.96	2.03	9	3	3	8	23	Low
Fidler Lake	1.31	6.43	1.59	4.92	1	1	1	33	36	Low
Apussigamasi Lake*	14.78	59.83	4.39	4.05	4	4	5	24	37	Low
Manigotagan Lake	24.27	81.65	4.67	3.36	7	5	6	22	40	Low
Threepoint Lake	45.04	124.22	5.22	2.76	14	9	8	17	48	Low
Lac du Bonnet	93.82	196.25	5.72	2.09	21	14	9	9	53	Low
Assean Lake*	76.20	198.60	6.42	2.61	17	15	11	13	56	Low
Leftrook Lake	46.34	140.77	5.83	3.04	15	12	10	20	57	Low
Cormorant Lake	332.00	276.92	4.29	0.83	32	21	4	4	61	Low
Eaglenest Lake	31.25	130.03	6.56	4.16	11	11	12	27	61	Low
Footprint Lake	27.75	124.22	6.65	4.48	10	10	13	29	62	Low-Moderate
Partridge Breast Lake	18.55	103.34	6.77	5.57	6	7	15	35	63	Low-Moderate
Burntwood River - First Rapids to Split L	12.12	89.72	7.27	7.40	2	6	18	38	64	Low-Moderate
Opachuanau Lake	82.16	219.20	6.82	2.67	18	17	16	15	66	Low-Moderate
Setting Lake	125.89	268.97	6.76	2.14	25	20	14	10	69	Low-Moderate
Pine Falls Reservoir	17.24	113.56	7.71	6.59	5	8	19	37	69	Low-Moderate
Little Playgreen Lake	84.96	236.24	7.23	2.78	19	18	17	18	72	Low-Moderate
Mynarski Lakes	35.42	170.59	8.09	4.82	12	13	20	32	77	Low-Moderate
Gauer Lake	262.71	468.73	8.16	1.78	29	25	21	7	82	Low-Moderate
Nelson River - DS Limestone GS	118.10	318.88	8.28	2.70	23	23	22	16	84	High-Moderate
Lake Winnipeg - North Basin	19774.21	2511.32	5.04	0.13	40	38	7	1	86	High-Moderate
Notigi Lake	74.53	309.18	10.10	4.15	16	22	26	26	90	High-Moderate
Upstream of Pointe du Bois	37.48	217.24	10.01	5.80	13	16	25	36	90	High-Moderate
Playgreen Lake	672.19	888.74	9.67	1.32	35	32	23	6	96	High-Moderate
North and South Moose Lake	1368.69	1272.93	9.71	0.93	36	34	24	5	99	High-Moderate
Stephens Lake	278.35	687.04	11.62	2.47	31	29	29	12	101	High-Moderate
Saskatchewan River – The Pas to Cedar Lake	26.0	277.00	15.32	10.65	8	21	34	40	103	High-Moderate

Table 4.3.1-1. continued.

Water Body	Water Body Metrics				Ranking					
	Area (km^2)	Shore (km)	SD	SL/A	Area Rank	Shore Rank	SD Rank	SL/A Rank	Total Rank	Relative Level of Effort
Northern Indian Lake*	122.60	507.75	12.94	4.14	24	26	30	25	105	High
Lake Winnipegosis	5210.17	2697.64	10.54	0.52	39	39	27	2	107	High
Split Lake	265.05	748.32	12.97	2.82	30	30	31	19	110	High
Rat Lake	165.56	637.79	13.98	3.85	27	28	33	23	111	High
Nelson River - Sipiwesk to Kelsey	85.79	466.97	14.22	5.44	20	24	34	34	112	High
Walker Lake	133.20	635.33	15.53	4.77	26	27	35	31	119	High
Granville Lake	430.77	1383.14	18.80	3.21	33	35	37	21	126	High
Cross Lake	196.13	902.94	18.19	4.60	28	33	36	30	127	High
Southern Indian Lake	2041.67	4396.29	27.45	2.15	37	40	40	11	128	High
Hayes River	105.96	840.52	23.03	7.93	22	31	38	39	130	High
Sipiwesk Lake	485.82	2055.62	26.31	4.23	34	37	39	28	138	High

*Proposed surveys for 2010/11

Italics = Water body has some form (digital or hardcopy) of bathymetric data

SD = Shore Line Development = SL ÷ 2·sqrt(π·Ao) (Hutchinson 1957)

SL/A = Shore Length/Area (Rawson, 1960)

4.4 WATER QUALITY

4.4.1 Site Selection

Water quality monitoring is conducted annually at a minimum of one off-system site and one site on Manitoba Hydro's hydraulic system (on-system site) within each monitoring region under CAMP. Beginning in 2009/2010, a larger group of water quality sites for each monitoring region have been sampled on a three year rotational basis (i.e., rotational sites).

CAMP water quality site selection considered the following:

- existing (i.e., current) or historical water quality sites monitored by Manitoba Conservation and Water Stewardship, Environment Canada (EC), Manitoba Hydro, or other agencies;
- bathymetry (where available);
- potential tributary influences;
- the locations/areas sampled for other CAMP components (i.e., fish and benthic invertebrates);
- site accessibility and safety; and
- where applicable, results of historical and/or current water quality monitoring in a waterbody that provided an indication of spatial variability in a waterbody.

Where no existing or historical water quality sites were identified for a waterbody, or where existing or historical sites were deemed to be unsuitable for the purposes of CAMP, sites were generally selected mid-basin in lakes (i.e., at or near the deepest part of the lake) or mid-stream in rivers and/or in consideration of site-specific conditions.

4.4.2 CAMPP Methods

The following provides an overview of sampling (i.e., field collection), laboratory analysis, and data analysis methods for CAMPP.

4.4.2.1 Sampling Methods

The following provides an overview of the field sampling methods employed in Years 1 through 3 of CAMPP. A detailed description of field sampling methods is provided in Appendix 1.

The water quality sampling program consisted of three sampling periods in the open-water season and one sampling period in late winter. Sampling consisted of measurement of *in situ* variables (temperature, dissolved oxygen [DO], turbidity, pH, specific conductance) across depth (where velocities are conducive), measurement of Secchi disk depths, and collection of samples of surface water for submission to an analytical laboratory accredited under Canadian Association for Laboratory Accreditation Inc. (CALA).

Samples for laboratory analysis were collected as near-surface grab samples, euphotic zone samples, and bottom samples (where sites are stratified at the time of sampling). Surface grab samples were collected at each site near the water surface (approximately 30 cm below the surface) for analysis of the full suite of variables including turbidity, total suspended solids (TSS), total dissolved solids (TDS), conductivity, alkalinity, pH, organic carbon, phosphorus (total, dissolved and particulate), nitrogen (ammonia, nitrate/nitrite and total Kjeldahl nitrogen [TKN]), true colour, hardness, *Escherichia coli*, and total metals (Table 4.4.2-1).

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. In addition, for the first two years of CAMPP, both surface grabs and euphotic zone samples for analysis of chlorophyll *a* were collected at lake sites to explore differences between these two sampling methods.

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. These bottom samples were analysed of all water quality variables except chlorophyll *a* and *E. coli*.

Standard quality assurance/quality control (QA/QC) measures were integrated into the water quality component of CAMPP, 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 interlaboratory comparison samples) and QA/QC of water quality data.

4.4.2.2 Laboratory Methods

All water quality samples for laboratory analysis were submitted to a CALA accredited analytical laboratory (ALS Laboratories, Winnipeg, MB). Inter-laboratory comparison samples for water quality were also submitted to a CALA laboratory (Maxxam Analytics, Winnipeg, MB).

4.4.2.3 Data Analysis Methods

Water quality data were subject to QA/QC review in two stages: (1) an initial review of laboratory results and *in situ* measurements; and (2) a secondary review of data during the reporting and data analysis stage. The initial QA/QC review included review of *in situ* data tables for transcription errors and/or anomalies as well as review of analytical laboratory results, including review of QA/QC sample results.

Percent relative standard deviation (PRSD) was calculated for triplicate samples and compared to the criterion of 18% precision, in accordance with the British Columbia Ministry of Environment, Lands, and Parks (BCMELP 1998) guidance. PRSD was calculated as:

PRSD = Standard deviation of the triplicate values/Mean of the triplicate values x 100.

Inter-laboratory comparison samples and laboratory vs. *in situ* measurements for pH, specific conductance, and DO were compared by calculating relative percent mean difference (RPMD) and compared to the criterion of 25%, in accordance with BCMELP (1998) guidance. RPMD was calculated as:

RPMD = (Value 1 – Value 2)/((Value 1 + Value 2)/2) x 100

Any laboratory results identified as potentially suspect were verified with the analytical laboratory and, when possible, analyses were re-run for confirmation.

During the reporting stage, all three years of water quality data were reviewed collectively to assist with identification of potential outliers or issues that required additional consideration for data analysis. Water quality variables measured both *in situ* and in the laboratory (turbidity, pH, and specific conductance) were subject to regression analysis to assist with identification of outliers or suspect data. Potential outliers were also identified through graphical methods, including box plots. In some instances, the field water quality meters were deemed to be improperly functioning and these *in situ* measurements were omitted from data analysis and reporting. However, in general, anomalous results identified through the reporting process were retained due to the relatively limited quantity of data available to date.

To assist with data interpretation and presentation, summary statistics including mean, median, minimum, maximum, standard deviation (SD), and standard error (SE) were calculated for water quality variables at each site. All data analyses treated censured values (i.e., values reported as below the analytical detection limit [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.

Statistical analyses were undertaken to evaluate seasonal, spatial, and interannual differences for the three years of CAMPP. Seasonality was only evaluated in waterbodies/areas sampled annually, as rotational waterbodies were only sampled during one year of CAMPP and data were inadequate for statistical analysis. Seasons were defined as spring, summer, fall, and winter. Spatial comparisons were made between annual waterbodies/areas in each of the regions and temporal comparisons were made between Years 1 through 3 for each annual waterbody/area.

All parameters detected in > 30% of samples for a given site were subjected to statistical analysis. Statistical methods varied in accordance with results of tests for normality of data. For parameters exhibiting a normal distribution, analyses were conducted using a t-test or analysis of variance (ANOVA) and a Tukey's test ($\alpha = 0.05$). For parameters not meeting the assumptions of a normal distribution (normality was tested on raw, untransformed data and log-transformed data), analyses were performed using the non-parametric Mann-Whitney test for two samples or with a Kruskal-Wallis test followed by the Dunn's multiple pairwise comparisons procedure (two-tailed; $\alpha = 0.05$).

4.4.2.4 Comparison to Manitoba Water Quality Objectives and Guidelines

Manitoba water quality objectives and guidelines have been developed for a number of water quality parameters for the purpose of protecting aquatic biota and wildlife, and various human usages including recreation, drinking, irrigation, and livestock watering (Manitoba Water Stewardship [MWS] 2011). As a primary objective of CAMPP is to document and monitor aquatic ecosystem health, CAMPP water quality monitoring results were compared to Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) for the protection of aquatic life (PAL). Data were summarized in terms of the frequency of exceedances of MWQSOGs for PAL for each waterbody.

For many water quality variables there is a single water quality objective or guideline for PAL specified in the MWQSOGs, but for some variables there are multiple objectives or guidelines, and for still others, objectives and guidelines are calculated based on site-specific conditions. A summary of MWQSOGs for PAL applied in this report is provided in Table 4.4.2-2; brief explanations for variables for which there are either multiple PAL objectives/guidelines, or for which site-specific objectives or guidelines are derived, are provided below.

Objectives for ammonia vary according to the presence of cool-water (e.g., Walleye) or cold-water (e.g., Lake Whitefish) aquatic life, the presence of early (e.g., fish eggs) or mature (e.g., adult fish) life history stages of biota, averaging duration (i.e., 1 hour, 4-day, or 30-day average), pH, and water temperature. Site-specific water quality objectives were calculated for ammonia based on the range of pH and water temperature measured at each site for both cool- and cold-water aquatic biota. In the interest of being conservative, the presence of early life history stages was assumed based on water temperatures (above or below 5^{o} C).

Site-specific PAL objectives were also calculated for cadmium, copper, chromium, lead, nickel, and zinc based on water hardness measured in the same water sample. To be conservative, monitoring results were compared to the long-term (4-day) objectives for PAL for these variables.

Like PAL objectives for ammonia, PAL objectives for DO vary according to the presence of cool- or cold-water aquatic life, the presence of mature or early life history stages of aquatic life, and exposure duration. As the presence of various life history stages at a particular water quality site sampled under CAMPP cannot always be determined, to be conservative, DO data were compared to the most stringent objectives associated with water temperatures/time of year. In addition, since CAMPP sampling frequency does not allow for determination of 7 day averages, minima, or 30-day averages of DO concentrations, the most stringent objectives in terms of exposure duration were applied.

In some instances, the laboratory analytical detection limits were higher than the MWQSOGs for PAL and comparisons to MWQSOGs could not be undertaken. The Manitoba PAL guideline for mercury was modified (revised from 0.0001 mg/L to 0.000026 mg/L) in 2011 (MWS 2011) and analytical detection limits employed for mercury under CAMPP were not always sufficiently low to facilitate comparison to the revised guideline. In addition, analytical detection limits for silver (0.0001 mg/L) and selenium (0.001 mg/) are equal to the Manitoba PAL guidelines. Therefore, where either variable was detected, the guidelines were exceeded. However, measurements that are at or near analytical detection limits are associated with relatively high uncertainty and there is low confidence that an actual exceedance of a PAL guideline has occurred when the guideline is at or near the DL.

In addition to the MWQSOGs, CAMPP water quality data were compared to the Canadian Council of Ministers of the Environment (CCME) PAL guidelines for chloride (CCME 1999; updated to 2013) and the British Columbia Ministry of the Environment (BCMOE) PAL guidelines for sulphate (Meays and Nordin 2013) as there are currently no PAL guidelines for Manitoba for these substances.

4.4.2.5 Categorization and Description of Waterbodies

Lakes, reservoirs and rivers sampled under CAMPP were compared to various published categorization schemes to describe trophic status, nutrient limitation, primary sources of organic carbon, and scales of water hardness, acid sensitivity, and water clarity.

Nitrogen to phosphorus (N:P) molar ratios were calculated to assist in estimating the limiting nutrient. Ratios less than 10 were considered indicative of nitrogen limitation and values greater than 20 were considered indicative of phosphorus limitation. Ratios between 10 and 20 were considered to indicate co-limitation. This approach is consistent with that applied by EC and MWS (2011) in the State of Lake Winnipeg Report.

Total organic carbon to organic nitrogen (TOC:ON) molar ratios were derived to provide an indication of the key source of carbon in each waterbody. Ratios greater than 50:1 were considered indicative of organic matter that is primarily allochthonous and ratios less than 12:1 were considered indicative of organic matter that is primarily autochthonous (Wetzel 1983).

Water hardness was compared to the Canadian Council of Resource and Environment Ministers (CCREM 1987) scale indicated in Table 4.4.2-3, and acid sensitivity was compared to the scheme reported in Saffran and Trew (1996), as summarized in Table 4.4.2-4. Water clarity was compared to the Swedish Environmental Protection Agency (EPA) scheme for lakes based on mean Secchi disk depth (Swedish EPA 2000), as summarized in Table 4.4.2-5.

Trophic status of CAMPP waterbodies (rivers, lakes, and reservoirs) was classified utilizing the CCME Canadian phosphorus guidance framework for the management of freshwater systems (CCME 1999; updated to 2013) and the trophic state categorization scheme based on total phosphorus (TP; Table 4.4.2-6). Lake and reservoir trophic states were also classified according to the Organization of Economic Cooperation and Development (OECD 1982) categorization scheme based on chlorophyll *a*, and the categorization scheme for total nitrogen (TN) presented by Nürnberg (1996). Comparison to the OECD trophic categorization scheme for lakes based on Secchi disk depth was also made in Section 6.2.

There are few trophic classification schemes available for streams and rivers and no nationally or internationally accepted schemes for these waterbodies. As noted above, the CCME trophic classification scheme for TP is intended to be applied to all freshwater ecosystems including rivers and as such this scheme was applied for CAMPP river sites. The trophic classification schemes based on TN and chlorophyll *a* for rivers presented in Dodds et al. (1998) were also applied to CAMPP sites (Table 4.4.2-6).

4.4.3 Workshop Recommendations

Annual workshops held from 2007 through 2010 provided the following recommendations and/or comments regarding the water quality component of CAMPP. Recommendations made at one or more of the annual workshops that have been adopted under CAMPP to date include:

- Comment: Monitoring sites/waterbodies should be selected to facilitate analysis of changes in water quality from upstream to downstream and between on- and off-system sites.

  Response: CAMPP incorporated sites/waterbodies at various locations upstream and downstream of Manitoba Hydro's hydroelectric generating stations (GSs) as well as at off-system waterbodies.

- Comment: CAMPP should utilize water quality monitoring data already being collected by other agencies (i.e., Manitoba Conservation and Water Stewardship and Environment Canada).

  Response: Selection of CAMPP water quality sites within each of the waterbodies considered the locations of active monitoring sites as well as historical monitoring locations. Where active and/or key historical sampling sites were deemed adequate to meet the objectives of CAMPP, these sites were retained to maximize opportunities for use of historical data. However, historical data have not been incorporated into CAMPP analysis and reporting to date.

- Comment: Annual monitoring at some sites would be preferred over monitoring all sites on a rotational basis. It was also generally agreed that annual monitoring would not be required at all sites.

  Response: CAMPP incorporates both annual monitoring and monitoring on a three year rotational basis.

- Comment: Measurement of super-saturation of oxygen and nitrogen at dams is a site-specific issue (and could form part of separate focused research effort or impact assessment study) but was not deemed a priority for CAMPP.

  Response: Gas supersaturation monitoring was not incorporated into CAMPP and has not been incorporated to date.

- Comment: Information on water quality parameters of particular interest to local communities (e.g., sediment load, turbidity, nutrients that contribute to algal blooms [phosphorus], and mercury) should be collected under CAMPP.

  Response: CAMPP incorporated measurement of water quality variables that are frequently raised as of concern by stakeholders.

Due to logistical and resource constraints and the intent to maintain consistency with pre-existing programs, not all recommendations were incorporated in CAMPP. Recommendations made at one or more of the annual workshops that have not been adopted under CAMPP include:

- Comment: Consideration of the use of water quality indices (WQIs) as a reporting mechanism for water quality was recommended. It was noted that WQIs provide a mechanism for the general classification of water quality data that can be used to direct future monitoring. However, it was also noted that there is no generally accepted standard for the derivation of WQIs (i.e., the number of parameters and the water quality thresholds applied in WQI derivations vary across jurisdictions).

  Response: WQIs have not been derived using data collected under CAMPP due to lack of a general standardization or consensus on what parameters and/or water quality guidelines should be included in the calculations. However, data collected under CAMPP are amenable to WQI derivation and can be generated, if desired in the future.

- Comment: Measurement of dissolved metals, rather than solely total forms of metals as measured under CAMPP, may be warranted if results indicate concentrations above PAL guidelines.

  Response: In general, the list of parameters recommended at the annual workshops has been included in CAMPP. However, as this report represents the first analysis of CAMPP data, this latter recommendation was not considered under CAMPP.

- Comment: Deployment of data loggers at selected sites to collect information at a higher sampling frequency.

  Response: CAMPP did not employ the use of data loggers for logistical reasons (i.e., due to the remoteness of the sites) and the large spatial scope of the program.

- Comment: Collection of additional water quality information during the spring freshet, to the degree possible (i.e., consistent with crew safety and ice conditions), and/or at a higher frequency at selected sites. During the first workshop (2007) it was generally agreed that sampling frequency for water quality should be at a minimum four times in the open-water season and once in the ice-cover season during each year of monitoring.

  Response: The frequency of sampling in the open-water season employed by Manitoba Conservation and Water Stewardship at northern water quality monitoring sites was adopted under CAMPP.

- Comment: Review water quality data collected during the pilot phase to determine whether more frequent sampling should be considered. If data collection periods were considered to be spaced too far apart to provide for appropriate analysis, a two-tiered sampling system, with provision for more frequent (e.g., biweekly) collection of water quality samples at a limited number of sites could be considered. More frequent sampling at some locations could provide an indication of what information may be missed with the sampling frequency of three times per open-water season.

Response: Analysis of key water quality parameters measured under CAMPP and at a small set of high frequency monitoring sites (Nelson River at the Jenpeg Generating Station, the Winnipeg River at Pine Falls, and the Winnipeg River at Pointe du Bois) concluded that the sampling frequency employed for CAMPP was adequate based on this qualitative exercise. However, statistical analysis of these data sets has not been undertaken.

Table 4.4.2-1. Water quality variables measured under CAMPP.

Variable	Unit	Variable	Unit
In situ Variables		**Metals**	
Dissolved oxygen	(mg/L)	Aluminum	(mg/L)
Turbidity	(NTU)	Antimony	(mg/L)
Temperature	(^{o}C)	Arsenic	(mg/L)
pH	-	Barium	(mg/L)
Specific conductance	(µS/cm)	Beryllium	(mg/L)
Secchi disk depth	(m)	Bismuth	(mg/L)
		Boron	(mg/L)
Laboratory Variables/		Cadmium	(mg/L)
Routine Variables		Calcium	(mg/L)
Total alkalinity (as $CaCO_3$)	(mg/L)	Cesium	(mg/L)
Bicarbonate alkalinity (as HCO_3)	(mg/L)	Chromium	(mg/L)
Carbonate alkalinity (as CO_3)	(mg/L)	Cobalt	(mg/L)
Hydroxide alkalinity (as OH)	(mg/L)	Copper	(mg/L)
Ammonia	(mg N/L)	Iron	(mg/L)
Nitrate/nitrite	(mg N/L)	Lead	(mg/L)
Total Kjeldahl nitrogen	(mg/L)	Magnesium	(mg/L)
Total dissolved phosphorus	(mg/L)	Manganese	(mg/L)
Total particulate phosphorus	(mg/L)	Mercury	(mg/L)
Total phosphorus	(mg/L)	Molybdenum	(mg/L)
Dissolved organic carbon	(mg/L)	Nickel	(mg/L)
Total organic carbon	(mg/L)	Potassium	(mg/L)
Total inorganic carbon	(mg/L)	Rubidium	(mg/L)
Total dissolved solids	(mg/L)	Selenium	(mg/L)
Conductivity	(µmhos/cm)	Silver	(mg/L)
Total suspended solids	(mg/L)	Sodium	(mg/L)
Turbidity	(NTU)	Strontium	(mg/L)
True colour	(TCU)	Tellurium	(mg/L)
pH	-	Thallium	(mg/L)
Hardness (as CaCO3)	(mg/L)	Tin	(mg/L)
Chloride	(mg/L)	Titanium	(mg/L)
Sulphate	(mg/L)	Tungsten	(mg/L)
		Uranium	(mg/L)
Biological Variables		Vanadium	(mg/L)
E. coli	(CFU/100 mL)	Zinc	(mg/L)
Chlorophyll *a*	(µg/L)	Zirconium	(mg/L)
Pheophytin *a*	(µg/L)		

Table 4.4.2-2. Summary of Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) for the protection of aquatic life (PAL; MWS 2011).

Parameter	Unit	MWQSOG	Objective or guideline	Comments
pH	-	6.5-9.0	Guideline	
Dissolved oxygen	(mg/L)	Open-water: 6.0 and 6.5 Ice-cover: 5.5 and 9.5	Objective	Most stringent objectives for cool- and cold-water aquatic life
Ammonia	(mg N/L)	Site-specific	Objective	Values calculated based on pH and water temperature
Nitrate	(mg N/L)	2.93	Guideline	
Total phosphorus	(mg/L)	Lakes, ponds, reservoirs: 0.025 Streams/rivers: 0.050	Narrative guideline	For protection of various water useages.
Metals				
Aluminum	(mg/L)	0.1	Guideline	
Arsenic	(mg/L)	0.15	Objective	
Boron	(mg/L)	1.5	Guideline	
Cadmium	(mg/L)	Site-specific	Objective	Values calculated based on water hardness
Chromium	(mg/L)	Site-specific	Objective	Values calculated based on water hardness
Copper	(mg/L)	Site-specific	Objective	Values calculated based on water hardness
Iron	(mg/L)	0.3	Guideline	
Lead	(mg/L)	Site-specific	Objective	Values calculated based on water hardness
Mercury	(mg/L)	0.000026	Guideline	Guideline for "inorganic mercury"
Molybdenum	(mg/L)	0.073	Guideline	
Nickel	(mg/L)	Site-specific	Objective	Values calculated based on water hardness
Selenium	(mg/L)	0.001	Guideline	
Silver	(mg/L)	0.0001	Guideline	
Thallium	(mg/L)	0.0008	Guideline	
Uranium	(mg/L)	0.015	Guideline	
Zinc	(mg/L)	Site-specific	Objective	Values calculated based on water hardness

Table 4.4.2-3. Hardness scale for aquatic ecosystems (CCREM 1987).

Hardness as calcium carbonate (mg/L)	Degree of Hardness
0-30	Very soft
31-60	Soft
61-120	Moderately soft (hard)
121-180	Hard
180+	Very Hard

Table 4.4.2-4. Saffran and Trew (1996) categorization of acid sensitivity of aquatic ecosystems.

Parameter	Units	Acid Sensitivity			
		High	Moderate	Low	Least
pH	-	<6.5	6.6-7.0	7.1-7.5	>7.5
Total Alkalinity	(mg/L $CaCO_3$)	0-10	10-20	21-40	>40
Calcium	(mg/L)	0-4	5-8	9-25	>25
Total dissolved solids	(mg/L)	0-50	51-200	201-500	>500

Table 4.4.2-5. Rankings for lake water clarity (Swedish EPA 2000).

Water clarity ranking	Secchi disk depth (m)
Very High	≥ 8
High	5 – 8
Moderate	2.5 – 5
Low	1 – 2.5
Very Low	< 1

Table 4.4.2-6. Trophic categorization schemes applied for CAMPP lakes and reservoirs.

Parameter/Metric		Trophic categories						Reference
		Ultra-oligotrophic	Oligotrophic	Mesotrophic	Meso-eutrophic	Eutrophic	Hypereutrophic	
Total phosphorus	(mg/L)	<0.004	0.004-0.010	0.010-0.020	0.020-0.035	0.035-0.100	> 0.100	CCME (1999; updated to 2013)
Chlorophyll *a*	(µg/L)	-	<2.5	2.5-8	-	8-25	>25	OECD (1982)
TN	(mg/L)	-	<0.350	0.350-0.650	-	0.651-1200	>1200	Nurnberg (1996)
Secchi disk depth	(m)	-	> 6	3-6	-	1.5-3	<1.5	OECD (1982)

Table 4.4.2-7. Trophic categorization schemes applied for CAMPP river sites.

Parameter/Metric		Trophic categories						Reference
		Ultra-oligotrophic	Oligotrophic	Mesotrophic	Meso-eutrophic	Eutrophic	Hypereutrophic	
TP	(mg/L)	<0.004	0.004-0.010	0.010-0.020	0.020-0.035	0.035-0.100	> 0.100	CCME (1999; updated to 2013)
Chlorophyll *a*	(µg/L)	-	<10	10-30	-	>30	-	Dodds et al. (1998)
TN	(mg/L)	-	<0.7	0.7-1.5	-	>1.5	-	Dodds et al. (1998)

4.5 PHYTOPLANKTON

4.5.1 Site Selection

The phytoplankton monitoring component of CAMP is conducted concurrent with the water quality sampling program and samples for analysis of chlorophyll *a*, phytoplankton community composition and biomass, and microcystin are collected at the same sites and times as water quality samples. See Section 4.4.1 for a discussion of site selection considerations.

4.5.2 CAMPP Methods

The following provides an overview of sampling (i.e., field collection), laboratory analysis, and data analysis methods employed for CAMPP.

4.5.2.1 General Methods

Phytoplankton monitoring included analysis of chlorophyll *a*, phytoplankton community composition and biomass, and microcystin-LR (an algal toxin). The phytoplankton sampling program consisted of three sub-components, all of which were conducted as part of the water quality sampling program:

- <u>Chlorophyll *a* Monitoring:</u> Phytoplankton biomass was determined using chlorophyll *a* concentrations as an indicator at all water quality sites. This component was conducted as part of the water quality sampling program and occurred during each sampling event (i.e., three times in the open-water season and once in the ice-cover season).
- <u>Phytoplankton Bloom Monitoring:</u> Where concentrations of chlorophyll *a* collected during the water quality sampling program exceeded 10 µg/L, samples were submitted for analysis of microcystin-LR and phytoplankton community composition. This sampling was intended to collect information under phytoplankton "bloom" conditions (which have been operationally defined as chlorophyll *a* concentrations at or exceeding 10 µg/L). The 10 µg/L trigger was based on triggers (Alert Level 1) employed by the New Zealand government under its alert levels framework for the management of cyanobacteria in drinking water supplies (i.e., Ministry of Health 2005).
- <u>Phytoplankton Community Composition Monitoring</u>: Phytoplankton community composition and biomass was measured on a three-year rotational basis, initiated in 2009 (Year 2) under CAMPP, at annual water quality sites (open-water season only); measurements were also made at rotational waterbodies during years in which sampling occurred. In addition, annual monitoring during the open-water season was initiated at four sites (Cross, Setting, Split and Assean lakes) in 2009 to provide a more robust data set for analysis.

4.5.2.2 Sampling Methods

As noted in Section 4.4.2.1, 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.

In addition, for the first two years of CAMPP, both surface grabs and euphotic zone samples were collected at lake sites to explore differences between these two sampling methods. Data collected using both methods were compared for the open-water seasons of 2008 and 2009 to determine which sampling method was most appropriate and the results indicated that chlorophyll *a* concentrations were similar in the surface grab and euphotic zone samples. Thereafter (i.e., beginning in 2010/2011), chlorophyll *a* analysis was restricted to euphotic zone samples collected in the open-water season, which is the sampling method applied for Lake Winnipeg monitoring.

Samples were also collected at all water quality sites from across the euphotic zone (open-water season) or near the surface (ice-cover season and high velocity sites), as described above, for phytoplankton bloom and community composition monitoring as well as microcystin-LR analysis. Samples for analysis of taxonomy and biomass were preserved with Lugol's solution and stored at 4^{o}C. Samples for potential analysis of microcystin-LR were stored at 4^{o}C and retained until the results of the chlorophyll *a* analyses were received (due to limited holding times, samples could not be archived); where chlorophyll *a* results were at or above 10 µg/L, samples were submitted for analysis of microcystin-LR.

Quality assurance/quality control (QA/QC) measures were integrated into the phytoplankton component of CAMPP, 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 data. Specifically, triplicate and blank QA/QC samples were analysed for chlorophyll *a* since initiation of CAMPP. Collection of triplicate phytoplankton samples at selected sites was initiated in Year 3 (2010). Laboratory QA/QC analyses are described in Section 4.5.2.3 below.

Additional details regarding the water quality and phytoplankton sampling methods are provided in Appendix 1.

4.5.2.3 Laboratory Analysis Methods

Samples for analysis of chlorophyll *a*, phytoplankton taxonomic composition and biomass, and microcystin-LR were submitted to an analytical laboratory accredited under the Canadian Association for Laboratory Accreditation Inc. (CALA; ALS Laboratories, Winnipeg, MB). As a CALA accredited laboratory, ALS Laboratories applies standard methods for analysis and internal QA/QC procedures.

Additional measures of laboratory QA/QC were implemented beginning in 2009 (Year 2), as follows:

- Method 1 – two different taxonomists analysed a separate aliquot taken from one sample.
- Method 2 – a single taxonomist analysed the same aliquot three separate times.
- Method 3 – a single taxonomist analysed three separate aliquots from one sample.
- Method 4 – two different taxonomists analysed the same aliquot.

4.5.2.4 Data Analysis Methods

All chlorophyll *a*, phytoplankton, and microcystin-LR data were evaluated qualitatively for potential outliers and transcription or analytical errors. Where anomalous values were encountered, data were verified against analytical laboratory reports for transcription errors and/or requests were made to the analytical laboratory to verify the values through sample re-analysis and/or verification of reporting accuracy. No phytoplankton data were removed from the reporting analysis due to the limited quantity of data and the inability to adequately define outliers at this stage of the program.

Percent relative standard deviation (PRSD) and relative percent mean difference (RPMD) were also calculated for field and laboratory QA/QC samples and compared to the criterion of 18% and 25% precision, respectively for chlorophyll *a* (BCMELP 1998). A criterion of 20% was applied for QA/QC analyses of phytoplankton taxonomy and biomass (Findlay and Kling undated). See Section 4.4.2.3 for a description of the derivation of these values.

All data analyses treated censured values (i.e., values reported as below the analytical detection limit [DL]) as equal to one half the DL. In cases where triplicate samples were collected or multiple QA/QC analyses were conducted, sample means were used for the determination of summary statistics and graphing. To assist with data interpretation and presentation, the biomass values of individual species were summed to determine the total biomass of the major groups of phytoplankton (e.g., blue-green algae, diatoms, etc.). Community metrics were also calculated to describe the diversity, heterogeneity, evenness, and effective richness of the phytoplankton community in each waterbody.

Statistical analyses of phytoplankton data were undertaken to evaluate seasonal, spatial, and interannual (i.e., temporal) differences for the three years of CAMPP. Seasonality of chlorophyll *a* was only evaluated in each annual waterbody/area, since rotational waterbodies and most phytoplankton taxonomy data were only collected during one year of CAMPP and were inadequate for statistical analysis. Seasons were defined as spring, summer, fall, and winter. Spatial and temporal comparisons of chlorophyll *a* were also made between annual waterbodies/areas within each of the regions, while comparisons of total phytoplankton biomass, community composition, and community metrics were only undertaken at the sites where sampling was conducted in multiple years (i.e., Assean, Cross, and Setting lakes) as the quantity of data were limited.

Statistical methods varied in accordance with results of the normality tests and with the number of comparisons. For parameters exhibiting a normal distribution, analyses were conducted using a t-test or analysis of variance (ANOVA) and a Tukey's test ($\alpha = 0.05$). For parameters that did not exhibit a normal distribution (normality was tested on raw, untransformed data and log-transformed data), analyses were performed using the non-parametric Mann-Whitney test for two samples or with a Kruskal-Wallis test followed by the Dunn's multiple pairwise comparisons procedure (two-tailed; $\alpha = 0.05$).

4.5.3 Workshop Recommendations

Annual workshops held prior to and over the course of CAMPP (2007-2010) generated a number of recommendations respecting the phytoplankton component of CAMPP. The following recommendations and comments were adopted in whole or in part in CAMPP:

- Comment: Microcystin should be analyzed on an "as required" basis (e.g., when an algal bloom occurred) and/or at selected locations (typically near communities).

  Response: Microcystin was analysed under CAMPP in samples where chlorophyll *a* exceeded 10 µg/L.

- Comment: Monitoring of chlorophyll *a* was considered of high priority for CAMPP because of its utility as an indicator of phytoplankton biomass, productivity, and trophic status.

  Response: Chlorophyll *a* was measured at all sampling sites and times under CAMPP.

- Comment: There was no overall consensus regarding the inclusion of phytoplankton community composition monitoring under CAMPP. It was recognized that while phytoplankton community and biomass samples are inexpensive to collect, laboratory analysis costs are relatively high. Some workshop participants felt inclusion of these analyses under CAMPP was important while others felt the value generated for the required resources was not warranted.

Response: CAMPP included analysis of phytoplankton taxonomy and biomass on a three year rotational basis, as well as in samples where chlorophyll *a* exceeded 10 µg/L.

- Comment: CAMPP should collect macroscopic photographs of algal blooms.

  Response: Photographs were collected during the conduct of the water quality and phytoplankton sampling programs, including aerial photographs of the sites.

Due to logistical and resource constraints and the intent to maintain consistency with pre-existing programs, not all recommendations were incorporated in CAMPP. Recommendations made at the annual workshops that were not incorporated into CAMPP include:

- Comment: Phytoplankton community data should be grouped at the genus or higher taxonomic level (i.e., not to species), so as to minimize the difference between taxonomists.

  Response: The phytoplankton program under CAMPP included a high level of taxonomic resolution (to genus or species). However, analysis of CAMPP phytoplankton data included analysis of higher taxonomic groups as well as metrics.

- Comment: It was suggested that phytoplankton could either be sampled at a subset of sites or that taxa could be identified to a low taxonomic classification.

  Response: CAMPP included analysis of phytoplankton taxonomy at all CAMPP waterbodies on a three year rotational basis and annually at four waterbodies.

- Comment: The use of High Performance Liquid Chromatography (HPLC) was suggested as a means of providing a broad measure of major phytoplankton taxa without the need to conduct species identification.

  Response: Standard methods for identification and enumeration of phytoplankton using a CALA accredited analytical laboratory were adopted for CAMPP. In addition, costs associated with taxonomic identification and measurements of biomass are similar to those required for HPLC analysis.

- Comment: The use of external taxonomists should be considered under CAMPP.

  Response: Inclusion of inter-agency/laboratory comparisons for phytoplankton samples was considered for CAMPP but was not adopted due to results of internal laboratory QA/QC assessments.

- Comment: The sampling frequency for phytoplankton should be greater than three times year.

  Response: Sampling frequency for phytoplankton followed the sampling frequency for water quality sampling (i.e., three times in the open-water season and once in the ice-cover season).

4.6 BENTHIC MACROINVERTEBRATES

Monitoring of benthic macroinvertebrates (BMI) was one of the fundamental components of CAMPP. The results were expressed in terms of simple metrics (abundance and composition) that characterized the BMI communities in nearshore and offshore habitats. The BMI metric data were used to assess general differences and similarities between on-and off-system waterbodies (spatially), and to assess general differences and similarities between years over time (temporally).The BMI component of CAMPP was refined prior to the 2010 field program in an attempt to minimize the inherent variability noted for 2008 and 2009 BMI data. Sampling areas (i.e., polygons) were stratified by water depth and constrained by other aquatic habitat attributes (e.g., substrate type, absence of aquatic plants, water velocity, etc.) such that sampling areas represented the predominant habitat type(s) within each waterbody and/or the habitat type(s) the may be most affected by water level fluctuation (natural and due to regulation). The refined study design gave consideration to Environment Canada (EC)'s Canadian Aquatic Biomonitoring Network (CABIN) and EC's Environmental Effects Monitoring (EEM) program guidance for metal mining and pulp and paper industries programs (EC 2010, 2012a, 2012b).

4.6.1 Site Selection

BMI monitoring is conducted annually at a minimum of one off-system waterbody and one on-system waterbody within each monitoring region under CAMP. Like other CAMP monitoring components, beginning in 2009, a larger group of waterbodies within each region was sampled for BMI and will be re-sampled on a three year rotational basis (i.e., rotational sites).

CAMP BMI site selection considered the following:

- existing (i.e., current) or historical benthic invertebrate sites monitored by Manitoba Hydro, or other agencies (e.g., Department of Fisheries Oceans);
- bathymetry (where available);
- potential tributary influences and other features that may cause localized effects (e.g., proximity to cottages, heavy boat traffic);
- the locations/areas sampled for other CAMP components (i.e., water quality and fish); and,
- site accessibility and safety.

Where no existing or historical sites were identified for a waterbody, or where existing or historical sites were deemed to be unsuitable for the purposes of CAMP, sites were generally selected with consideration of site-specific conditions and accessibility.

Based on a preliminary power analysis of the Year 1 BMI data, modifications to the lake/reservoir and riverine study design were made as discussed through a working group and implemented in the Year 3 field program in order to minimize the inherent variability within the BMI data. These changes were intended to increase the statistical power of the data without a major influence on sampling effort and analytical costs. Methods for site selection are described below for Years 1 and 2 and Year 3 of CAMPP.

4.6.1.1 Years 1 and 2

In lake and reservoir environments, BMI samples were randomly collected at pre-determined sampling sites within pre-determined polygons. Polygons were situated to represent the dominant habitat (e.g., substrate size) in each of the nearshore and offshore areas, and were defined as the area bounded by the lowest typical water elevation to depths defined by the lower extent of the littoral zone, and/or at a clear site-specific demarcation between near-shore and off-shore areas. In general, the water depth criterion for the nearshore habitat was between 3 and 5 m (predominantly-wetted); and greater than 5 m in the off-shore habitat (permanently-wetted).

Sampling sites were generated within polygons by the Random Point Generator extension for ArcGIS®. The program creates a geospatial set of random sites within the bounds of predetermined sampling polygons. Sampling sites were mapped on 1: 60,000 scale digital ortho-imagery. Field crews used a handheld Garmin global positioning system (GPS) unit to sample sites in consecutive order as provided by the Random Point Generator. If field crews are unable to sample a certain site (e.g., due to compaction of substrate), sampling was then attempted at the next site.

In northern riverine environments (lower Nelson River, lower Churchill River at the Little Churchill River, and the Hayes River), artificial substrate samplers (rockbaskets) were deployed to collect BMI. Rockbasket sites were determined by field crews and affected by limits imposed by site-specific characteristics (e.g., high river flows). Rockbaskets were randomly placed along a succession of water depths in order to capture both nearshore and offshore habitat types.

4.6.1.2 Year 3

In lake and riverine environments, nearshore and offshore polygons were established by field crews based on the dominant site-specific habitat attributes (e.g., substrate type, water velocity), spatially separated by at least 100 m x 100 m, and large enough to adequately accommodate five replicate stations (EC 2012b). Replicate stations are defined as a specific, fixed sampling location within each polygon that can be determined, recognized, and defined quantitatively (e.g., Universal Transverse Mercator [UTM] position and a written description), so to be re-sampled in subsequent years. The geographic extent of each replicate station was minimally 10 m x 10 m and separated from other replicate stations by at least 20 m (EC 2012b).

In the nearshore habitat (intermittently-wetted), water depths were selected to be ≤ 1 m (i.e., wadeable depth), with consistent water movement/velocity (low or medium velocity habitat), and areas containing aquatic macrophyte beds were avoided. In the offshore habitat (permanently-wetted), water depths were selected to be in the 5 to 10 m range with homogeneous substrate, and consistent water movement/velocity (low or medium velocity habitat).

4.6.2 CAMPP Methods

The following provides an overview of sampling (i.e., field collection), laboratory analysis, and data analysis methods employed for the BMI component of CAMPP.

4.6.2.1 Field Collection Methods

The following provides an overview of the BMI field sampling methods employed in Years 1 through 3 of CAMPP. A detailed description of field sampling methods is provided in Appendix 1.

The BMI sampling program consisted of one sampling period in late summer/fall. In Years 1 and 2, rockbaskets were deployed in the northern river sites in early summer and retrieved in late summer/fall.

Years 1 and 2

In lakes, fifteen BMI samples (i.e., replicates) were collected using an Ekman or Ponar grab sampler (0.023104 m^2) in each nearshore and offshore polygon for a total of 30 samples per waterbody.

In the northern rivers, 10 rockbaskets were deployed in Year 1 in each river site and 20 rockbaskets (0.03170 m^2) were deployed in Year 2 in each river site.

All BMI samples were retrieved to the surface, emptied into a 500 µm sieve bucket, and carefully sieved. Invertebrates retained by the screen were washed to labelled plastic jars and fixed with 10% formalin. Fixed samples were shipped to the North/South Consultants Inc. (NSC) laboratory (Winnipeg, MB) for processing and identification.

Sediments were also collected in association with the BMI sampling program for analysis of standard supporting variables. In Year 1, one sediment sample was collected in each habitat type; in Year 2, three sediment samples were collected in each habitat for a total of six sediment samples per waterbody. Sediments were collected using an Ekman or Ponar grab sampler, and contents were sub-sampled with a 5 cm diameter core tube (0.002 m^2 surface area) to provide a sample of approximately 100 mL of sediment. Sediment samples were kept in cool in the field, and then frozen until delivered to an analytical laboratory accredited under Canadian Association for Laboratory Accreditation Inc. (CALA; ALS Laboratories, Winnipeg, MB) for particle size (PSA: percent sand, silt, and/or clay), and total organic carbon (TOC) analyses.

Year 3

The new study design implemented in 2010 utilized a travelling-kick-sweep approach in the nearshore habitat; offshore habitat was sampled using the same methods as applied in Years 1 and 2 (i.e., using an Ekman or Ponar grab sampler). Within the each polygon habitat, each of the five replicate stations consisted of three randomly collected BMI sub-samples. The three sub-samples were combined to provide a single BMI composite sample for each replicate station for a total of ten samples per waterbody.

All BMI samples were emptied into a 500 µm sieve bucket, and carefully sieved. Invertebrates retained by the screen were washed to labelled plastic jars and fixed with 10% formalin. Fixed samples were shipped to the North/South Consultants Inc. laboratory (NSC; Winnipeg, MB) for processing and identification.

Five sediment grab samples were collected in each polygon (one from each replicate station) for a total of ten benthic sediment samples per waterbody. In the nearshore habitat, sediments were collected using a plastic soup ladle or by hand. In the offshore areas, sediments were collected using an Ekman or Ponar grab sampler. Sediment samples were sub-sampled with a 5 cm diameter core tube (0.002 m^2 surface area) to provide a sample of approximately 100 mL of sediment. Sediment samples were kept in cool in the field, and moved into refrigeration until delivered to ALS Laboratories for PSA and TOC analyses. In the nearshore habitat where sediment samples could not be collected because of predominantly hard substrate, (i.e., bedrock and/or cobble), a photographic and visual description was documented.

4.6.2.2 Laboratory Analysis Methods

The following provides an overview of the BMI laboratory methods employed in Years 1 through 3 of CAMPP. A detailed description of laboratory methods is provided in Appendix 1.

In the NSC laboratory, each BMI sample was rinsed through a 500 µm brass test sieve. The entire sample was examined visually to determine whether splitting (sub-sampling) was required as the target was 300 benthic invertebrates per sample. Samples containing fewer than 300 macroinvertebrates were sorted in their entirety. If splitting was required, the whole sample was scanned to remove any large and/or rare organisms. A Folsom Plankton Splitter (1.0 or 4.0 L, specific to sample volume) was used to divide the whole sample into aliquots that were sorted until at least 300 invertebrates were counted. When the 300 organism count was achieved part way through an aliquot, the remainder of that fraction was processed so that a known portion was sorted. The following taxa were not included in the 300 organism count: Ostracoda, Cladocera/Rotifera, Copepoda, Harpacticoida, Porifera, Nemata, Platyhelminthes, and non-aquatic taxa.

BMI were sorted from the sample matrix under a desktop magnifying lamp (3X magnification) and transferred to 70% ethanol prior to being identified to the appropriate taxonomic level. The approximate proportion of the organic and inorganic component (vegetation, detritus, and/or substrate) of each sample was recorded on the laboratory benchsheets. Samples were processed following the NSC quality assurance/quality control (QA/QC) sorting guidelines. All sorted samples were checked by a second laboratory technician; with the provision that a re-sort of the entire sample was required if sorting efficiency was less than 95%.

BMI were enumerated and identified using a Leica MZ12.5 stereomicroscope with maximum 100x magnification. Taxonomic analyses of BMI in lake/reservoir and riverine environments were identified to:

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

Taxonomic analysis was performed using reference texts: Clifford (1991), Merritt and Cummins (1996), Peckarsky et al. (1990), Smith (2001), Stewart and Stark (2002) and Wiggins (2004). Scientific names used followed the Integrated Taxonomic Information System classification (ITIS 2013). Taxonomic identifications were verified (i.e., subject to QA/QC) by submitting 10% of randomly selected samples from each waterbody to an external taxonomic specialist. The target accuracy for in-house identifications is 90%, identifications and/or enumeration discrepancies were corrected on the taxonomic benchsheet.

All sorted BMI samples are retained should further identification be required. A taxonomic reference collection of benthic invertebrates was assembled to ensure taxonomic consistency throughout the Program duration. An external taxonomic specialist was used to verify all of the identifications in the collection.

Sediment samples were submitted to a CALA accredited analytical laboratory (ALS Laboratories, Winnipeg, MB) for PSA and TOC analyses.

4.6.2.3 Data Summarization and Analysis

The following provides an overview of the BMI data analysis methods applied for Years 1 through 3 of CAMPP. A detailed description of data analysis methods is provided in Appendix 1. BMI communities in lake/reservoir and riverine environments were described based on variables related to composition, abundance, and richness. Metrics were:

- Total invertebrate abundance;
- Abundances and proportions of major groups (i.e., Non-Insecta, Oligochaeta, Amphipoda, Bivalvia, Gastropoda, Insecta, Chironomidae, Ephemeroptera, Plecoptera, and Trichoptera);
- Percent samples with only oligochaetes and/or chironomids;
- Percent of samples with no aquatic invertebrates;
- EPT (Ephemeroptera, Plecoptera, and Trichoptera) Index (as total abundance and proportion (%) of total invertebrates);
- EPT: Chironomidae (ratio of EPT to chironomid abundance);
- Taxonomic Richness (family-level);
- Simpson's Diversity (D) and Evenness (E_D) indices;
- Shannon's Diversity (H) and Evenness (E_H); and,
- Hill's Effective Richness ($E^{H'}$) and Evenness ($E^{H'}/S$).

During the reporting stage, BMI data were reviewed in consideration of the three years of CAMPP data collectively to assist with identification of potential outliers or issues that required consideration for data analysis. Potential outliers were identified through graphical methods, including box plots. However, in general, potential outliers identified through the reporting process were retained due to the relatively limited quantity of data available to date.

To assist with data interpretation and presentation, summary statistics including mean, median, minimum, maximum, standard deviation (SD), and standard error (SE) were calculated for invertebrate community variables at each site on an annual basis. Any suspect results were omitted from the analyses.

Statistical analyses were undertaken to evaluate spatial and temporal differences for the three years of CAMPP collectively. Spatial comparisons were made between waterbodies/areas in each of the regions and temporal comparisons were made between Years 1 through 3 for each waterbody/area. Due to study design change, nearshore data in Year 3 were not included in the spatial and temporal analyses.

Statistical methods varied in accordance with results of tests for normality of data. Normality was tested using Shapiro-Wilk test (α = 0.05) on raw, untransformed data, log-transformed (natural [ln] and base 10), and square-root-transformed data. For community variables exhibiting a normal distribution, analyses were conducted using an Analysis of Variance (ANOVA) and a Tukey's test (α = 0.05). For parameters not meeting the assumptions of a normal distribution, the non-parametric Kruskal-Wallis test followed by the Dunn's multiple pairwise comparisons procedure (two-tailed; α = 0.05) was applied.

4.6.3 Workshop Recommendations

Annual workshops held from 2007 through 2010 provided the following recommendations and comments regarding the CAMPP BMI component. Due to logistical and resource constraints and the intent to maintain consistency with pre-existing programs, not all recommendations were incorporated in CAMPP.

- Comment: There was discussion and acknowledgement that the CAMPP benthic invertebrate program methodology differs from that used in Lake Winnipeg, particularly with respect to spatial distribution of sampling locations and sieve mesh size. Benthic invertebrates are currently sampling in the north basin of Lake Winnipeg by Manitoba Conservation and Water Stewardship (MCWS) and the Lake Winnipeg Research Consortium (LWRC) under programs that are implemented independently of CAMPP. In order to make general comparisons between the north basin of Lake Winnipeg and Lake Winnipegosis (i.e., the off-system waterbody for the Lake Winnipeg Region), it was suggested to restrict comparisons to organisms that would be collected and retained using a 500 µm mesh sieve (i.e., the larger mesh size used of the various sampling programs). It was further suggested that comparing CAMPP results to MCWS results, which uses a 400 µm mesh, is better than comparing to LWRC results, which uses a 200 µm mesh. Concern was also expressed that comparing Lake Winnipegosis under the CAMPP study design to Lake Winnipeg under the MCWS design poses other issues since Lake Winnipegosis is not an appropriate reference waterbody due to differing hydrological and water quality influences.

  Response: Methods for benthic invertebrate sampling in Lake Winnipegosis were made consistent with other CAMPP sites for continuity purposes.

- Comment: The CAMPP benthic invertebrate study design may lead to interpretation issues and erroneous conclusions by using fixed sampling polygon locations dictated by water depths, since water levels fluctuate. It was suggested that to accurately describe the benthic community as water levels fluctuate, sampling along transects (from deep to shallow depths) would allow for detection of changes in the invertebrate community in accordance with the water level changes and shifts in thermocline locations. It was further suggested that a combination of intensive (transects) and less-intensive (polygons) approaches be undertaken in order to illustrate processes versus broad system perspectives, and that CAMPP should consider increasing the sampling effort at some sites.

Response: CAMPP did not incorporate the suggested method of sampling along transects. Most CAMPP waterbodies do not stratify and consideration of shifts in thermoclines is therefore not relevant for most sites.

- Comment: Sampling in rapids should be incorporated into the CAMPP riverine sampling design.

  Response: CAMPP did not incorporate sampling of rapids as they are generally inaccessible and pose a significant safety hazard for field crews.

- Comment: Benthic invertebrate samples should be described in terms of biomass in order to correlate the results with fish productivity. It was further suggested that CAMPP use a rough conversion factor as opposed to actual biomass measurements, since the latter would require destruction of invertebrate samples thereby eliminating future opportunity for reanalysis.

  Response: CAMPP does not incorporate measurements of biomass of invertebrates.

4.7 FISH COMMUNITIES

4.7.1 Site Selection

The CAMP fish community sampling sites were distributed between shallow and deep areas in lacustrine environments. Gillnetting sites were selected in such a way as to provide broad spatial representation and to avoid bias towards certain habitat types or fish species. In lakes in which previous sampling programs had been conducted, CAMP sampling sites were located to maintain consistency with these programs to the degree practicable. Once set locations were established, they were generally used consistently in subsequent years (i.e., revisited). Exceptions included instances in which previous set locations could not be sampled because of weather and/or site conditions, or new criteria (i.e., those that necessitated a change in location of certain individual set locations) were established as part of the pilot phase of the program.

For riverine sites, set locations were generally selected based on the practicality of setting in a given location. Set locations were chosen to encompass, to the degree possible and as flow conditions allowed, the full extent of the sample area and habitat types. As was the case for lacustrine sites, once set locations were established, they were generally used consistently in subsequent years.

4.7.2 CAMPP Methods

4.7.2.1 Sampling Methods

At each CAMPP sampling site, standard gang index gill nets comprised of five mesh sizes (each constructed as a separate panel) were set. Each panel was 22.9 m (25 yds) long, approximately 1.8 m (2 yds) deep and seamed on to #30 leadline and 1.0 cm (3/8”) floatline. All mesh was constructed of twisted nylon and coloured light green. Standard gangs were assembled by joining the nets from floatline to floatline and from leadline to leadline, and organized with the stretched meshes in sequence of size (51 mm [2”], 76 mm [3”], 95 mm [3.75”], 108 mm [4.25”], and 127 mm [5”]).

In addition, at approximately every third set location, the large mesh end of a small mesh index gillnet gang was attached to the small mesh end of the standard gang. If fewer than nine standard gang index gill nets were set in a given waterbody, a minimum of three small mesh index gillnet gangs were typically set. Small mesh index gillnet gangs were composed of three mesh sizes (16 mm, 20 mm and 25 mm bar measure), each constructed as a separate panel. Each panel was 10 m long, 1.8 m deep and constructed of clear monofilament. Small mesh gillnet gangs were assembled by joining the nets floatline to floatline and leadline to leadline with meshes in sequence of size.

Gill nets were set for an approximate 24 hour period and the following information was collected:

- date and time set/retrieved;
- type of net set (standard gang index gill net only or both standard gang index gill net and small mesh index gill net);
- global positioning system (GPS) coordinates;
- water temperature;
- weather conditions (e.g., air temperature, wind direction and wind velocity);
- water depth;
- Secchi disk depth;
- proximity and orientation to shore;
- shoreline conditions;
- water velocity (low, medium, high);
- aquatic vegetation present (low, medium, high);
- substrate conditions; and,
- quantity and type of debris present.

Upon standard gang index gill net retrieval, all fish captured were counted by mesh size and species at each site. For certain species of management interest (i.e., Northern Pike [*Esox lucius*], Lake Whitefish [*Coregonus clupeaformis*], Sauger [*Sander canadensis*], and Walleye [*Sander vitreus*]), individual metrics were collected from all fish captured in the standard index gill net gangs. Selected metrics were also collected from all Lake Sturgeon [*Acipenser fulvescens*] and some White Sucker [*Catostomus commersonii*]. No individual metrics were collected from fish captured in the small mesh index gill net gangs. Metrics collected from fish captured in the standard gill nets included:

- fork length (to nearest 2 mm);
- total length (to nearest 2 mm - Lake Sturgeon only);
- individual weight (to nearest 10 g for fish <4 kg, to nearest 25 g for fish > 4 kg) for species of management interest (i.e., Northern Pike, Lake Whitefish, Sauger and Walleye);
- internal examination of sex and state of gonad maturity for species of management interest;

- occurrence of deformities, erosions, lesions and tumours (DELTs) for Northern Pike, Lake Whitefish, Sauger, Walleye, Lake Sturgeon and White Sucker; and,
- collection of ageing structures (cleithra from Northern Pike and otoliths from Lake Whitefish, Sauger and Walleye).

The remaining species from the standard gang index gill net catch were counted and bulk weighed to the nearest 25 g by species and mesh size. Fish from the small mesh index gill nets were not separated by mesh size, but were separated on the basis of species, counted and bulk weighed to the nearest 25 g (large bodied species) or 1 g (small bodied species).

4.7.2.2 Laboratory Methods

Ageing of fish captured during CAMPP was conducted by two agencies: Manitoba Conservation and Water Stewardship – Fisheries Branch (MCWS); and North/South Consultants Inc. (NSC). Otoliths were used to age Lake Whitefish, Sauger, and Walleye, while cleithra were used to age Northern Pike. Although the general methodologies for ageing of otoliths and cleithra among the two agencies were similar, there were minor differences in methodology.

Most otoliths were cracked prior to toasting and viewing; however, otoliths that were particularly small and/or difficult to section or grind were toasted and viewed (read) whole. In the former case, the cracked plane of otoliths aged by MCWS were polished using a bench lathe. Cracked otoliths aged by either agency were placed cracked side up in plasticine with a drop of clearing medium (i.e., oil of wintergreen or water) applied to the cracked surface prior to reading. Whole otoliths, on the other hand, were placed in a shallow well (dish) and completely immersed in a clearing medium. In both cases, otoliths were then read under a dissecting microscope with reflected light against a dark background.

In preparation for reading, cleithra were boiled to remove any tissue or oil residue that was left on the structure after removal from the fish. Cleithra were then typically read ‘free hand’ (i.e., without a microscope) against a dark background; however, a dissecting microscope was utilized when required. MCWS used a magnifying light to read all cleithra.

NSC viewed all ageing structures two to three times before a final age was assigned while MCWS read the structure once and assigned an age and a confidence index score. In-house quality assurance and quality control (QA/QC) procedures conducted by both agencies included the re-ageing of a random sample of at least 10% of all structures by an ageing technician not involved in the initial age determination. After the in-house QA/QC was completed, each agency selected an additional 10% of the structures at random and they were sent to the other agency for ageing to assess accuracy and consistency between agencies. Please refer to Appendix 2 for additional detail on the fish ageing QA/QC procedures.

4.7.2.3 Data Analysis Methods

Relative Abundance and Biomass

For each waterbody, standard gang and small mesh index gill net catches were tabulated by total number of fish per species and total biomass per species. Using the numbers of fish caught, frequency of occurrence for each species was expressed as percent relative abundance (RA), calculated as

$$C_x / C_t \times 100$$

Where C_x is the number of fish caught of species *x* and C_t is the total number of fish caught.

Similarly for biomass, percent of total biomass was calculated for each fish species as

$$B_x / B_t \times 100$$

Where B_x is the bulk weight or biomass (g) of species *x* and B_t is the total biomass of all fish caught in the waterbody during that sampling year.

Catch-Per-Unit-Effort (CPUE) and Biomass-Per-Unit-Effort (BPUE)

For each site sampled with a standard gang index gillnet, site CPUE and BPUE were calculated for each fish species and all fish species combined (total) as the number or bulk weight of fish captured in 100 m of net/24 h, or:

$$C_x \text{ or } B_x \div E \times 24$$

Where C_x and B_x are catch - the total number of fish caught of species *x* and biomass – the bulk weight of species x, respectively at a given gillnet site, and *E* is effort – the duration (h) of the gill net set in the water at a given site.

For small mesh index gill nets, site CPUE and BPUE were calculated for each fish species and all fish species combined (total) as the number or bulk weight of fish captured in 30 m of net/24 h, or:

$$C_x \text{ or } B_x \div 1.143 \div E \times 24$$

Using these site values, CPUE and BPUE were then calculated for each waterbody in two separate ways. First, yearly CPUE and BPUE were calculated as the mean (±standard deviation [SD]) of all site values; and second, using these yearly CPUE and BPUE values, a simple moving (or running) average (±standard error [SE]) was then calculated (from herein referred to as overall CPUE or BPUE) for each waterbody.

Though infrequent, in some instances captured fish were counted and measured to fork length, but were not weighed. The majority of these cases were likely due to sampling error or equipment failure as the CAMPP sampling protocol specifies to obtain a weight from all fish that are measured. In such cases, and in order to allow direct comparison of CPUE and BPUE values, individual fish with no recorded weight were provided with an inferred weight based on the calculated weight-length relationship for the species and region of origin. For each region, a weight-length relationship was established for each species with a sample size ≥20 fish using least squares linear regression and fitting a straight line between $\log_{10}$ transformed weight and $\log_{10}$ transformed fork length. Using the resultant regression equation, fork length was used to predict weight for individuals that were not originally weighed in the field. BPUE was then calculated using both field measured and weight-length relationship derived weights. Predicted weight values were not used for any analysis other than for calculation of BPUE.

Length, Weight and Condition Factor

Mean (±SD) length, weight and condition factor (K) were calculated for fish species of management interest (i.e., Northern Pike, Lake Whitefish, Sauger, and Walleye) by waterbody. Condition factor was calculated (after Fulton 1911 *In* Ricker 1975) per fish as:

$$K = W \times 10^5 \div L^3$$

Where W = weight (g) and L = fork length (mm).

Mean fork length is also presented as a function of mesh size using the following groupings: small mesh (includes 16, 20 and 25 mm mesh collectively); 51 mm (2”); 76 mm (3”); 95 mm (3.75”); 108 mm (4.25”); and 127 mm (5”) mesh.

In many instances, fish were bulk weighed (rather than weighed individually). This action made quantifying a measure of variation (i.e., standard deviation) not possible, and as a result, in some cases only mean weight was calculable whereas SD was not.

Fork-length-frequency (%) distributions are presented at fork length intervals of 25 mm for Lake Whitefish, Sauger and Walleye, and at fork length intervals of 50 mm for Northern Pike.

Age and Growth

The results from ageing species of management interest were used to determine age- and year-class frequency distributions, and fork length- (mm), weight- (g), and condition factor-at-age. For each fish species, the number of fish aged were tabulated by age- and year-class, and used to calculate, for each age- and year-class, the percent of the total number of fish aged. For fork length, weight and condition factor, a mean (±SD) was calculated for each age- and year-class.

The Von Bertalanffy growth model (from herein referred to as VBGM) was chosen to analyze growth for species of management interest. The VBGM is calculated as follows (from von Bertalanffy 1934, 1938 *in* Ricker 1975):

$$l_t = L_\infty\left(1 - e^{-K(t-t_0}\right)$$

Where:

l_t is the expected or average length at age t, $L_\infty$is the asymptotic average length (the point where growth reaches an asymptote and slows), K is the Brody growth coefficient, and t_0 is a modeling artefact that represents the age when the average length was zero.

In an attempt to produce meaningful results and to further simplify analyses, age and length data collected in each of 2008, 2009 and 2010 were pooled. Using the compiled data set, modeling was then completed in two steps: (1) generating starting values for model parameters; and (2) fitting the model. Starting values were estimated for each parameter ($l_{t,}$ L_∞, K, and t_0) using Ford-Walford plots (Ford 1933; Walford 1946) and fitting second-degree polynomials to the length-at-age data. Once reasonable starting values were derived, models were then fit using non-linear least squares. Model assumptions were checked and diagnostics assessed to determine how well the model fit the data. All analyses were completed using the FSA (Ogle 2012a), NCStats (Ogle 2012b) and nlstools (Baty and Delignette-Muller 2011) packages for R Version 2.15.0 (R Development Core Team 2012).

Index of Biotic Integrity

Biotic integrity is the capacity of a habitat to support and maintain a balanced, integrated and adapted assemblage where the assemblage has a composition, diversity and functional organization comparable with that of a natural habitat of the same region (Karr et al. 1986). An Index of Biotic Integrity (IBI) is a multimetric approach using a defined group of metrics or measures that, when combined, reflect the overall biological condition of a waterbody (Barbour et al. 1995). Metrics comprising an IBI should reflect some aspects of the biological structure, function, or other measurable characteristic that change in a predictable manner with increased ecosystem stress (Fausch et al. 1990).

Various metrics have been proposed and used for IBI calculations; for CAMPP, eleven metrics from four categories were selected (Table 4.7.2-1). Niemela et al. (1999) provides a thorough description of the selected metrics. The species present within all waterbodies were classified into various categories based on previous studies and existing knowledge (Table 4.7.2-2). The species composition and richness category consisted of five metrics: total number of species; number of sensitive species; proportion of tolerant and invasive individuals; number of insectivore species; and, Hill's Effective Species Richness Index. Three metrics (percentage of insectivore biomass, omnivore biomass and piscivore biomass) were selected from the trophic composition category while one metric (the proportion of simple lithophilic spawners) was included from the reproductive composition category. Two metrics (standard index gillnet CPUE and the percentage of individuals with DELTs - the latter recorded only for certain species) were included for the abundance and condition category. Since DELTs were only recorded for certain species, the frequency of DELTs was only calculated for those species. This metric was also assigned a lower value or weight than the other ten metrics due to concerns about possible sampling bias and inconsistency with regard to field DELT observations.

Continuous variable, rather than discrete, scoring was performed for the selected metrics. Continuous scores allow a greater range of scores, avoid sequence gaps, and minimize bias (Fore et al. 1994). Each metric was standardized such that values ranged from 0 to 10, with the exception of percentage of individuals with DELTs which was scored from 0 to 5, using methodology outlined in Minns et al. (1994) as follows:

Ms = A + B x Mr

If Ms < Mmin, then Ms = 0

If Mr > Mmax, then Ms = 10

A standardized metric (Ms) was defined as a linear function of a raw metric (Mr). The minimum and maximum thresholds (Mmin = 0 and Mmax = 10) defined the upper and lower limits for the standardized metric. For metrics positively related to biotic integrity, the lower limit (Mmin) was set to zero and the upper limit (Mmax) was set at or near the 95th percentile of the cumulative frequency distribution of the raw metric values. For metrics negatively related to lake integrity, the lower limit was set close to the 95th cumulative percentile and the upper limit was set close to the 5th cumulative percentile. The relationship between the raw and standardized metric was assumed to be linear between the upper and lower bound.

4.7.3 Workshop Recommendations

Annual workshops held from 2007 through 2010 provided the following recommendations and/or comments regarding the fish community component of CAMPP. Recommendations made at one or more of the annual workshops that have been adopted under CAMPP include:

- Comment: At least one lake, one river system and one reference site in each region should be monitored annually to determine fish community composition and abundance; the remaining sites could be sampled on a three-year cycle. The results of index fishing can vary widely from year to year due to a number of factors including short-term or annual variation in weather. As a result, sampling only once every three years would not likely provide enough information to effectively interpret the data collected.

  Response: CAMPP incorporated annual monitoring of fish communities at a minimum of one on-system and one off-system waterbody in each region, as well as sampling of additional waterbodies on a three year rotational basis. Riverine waterbodies have been included as part of CAMPP sampling in some, but not all regions.

- Comment: Although fish populations, species composition, and relative abundance were often significantly affected by commercial and domestic fisheries (which may mask the effects of hydroelectric facilities) in the past, there is still a need to monitor these parameters due to their importance to local communities.

  Response: CAMPP includes regular, standardized monitoring of fish populations, species composition, and relative abundance in a wide range of waterbodies, many of which are important harvesting locations.

- Comment: Because two different agencies, along with multiple individuals within each agency, conduct fish ageing for CAMPP, a quality assurance/quality control (QA/QC) protocol was recommended.

  Response: A QA/QC fish ageing protocol was developed and implemented for CAMPP to address these concerns. Annual review of the results of the QA/QC has led to some modifications in ageing methodologies in an attempt to make methods more consistent among and within agencies.

- Comment: Following the first year of CAMPP data collection it was determined that there were differences in how staff from the two organizations conducting the field programs identified or designated and recorded deformities, erosions, lesions, and tumours (DELTs). Prior to CAMPP, DELTs were commonly incorporated into similar monitoring programs by one of the sampling agencies (North/South Consultants Inc.) but not the other sampling agency (Manitoba Fisheries Branch).

Response: A detailed protocol for identification of DELTs was developed and incorporated into the CAMPP Field Manual in 2010 to improve consistency within and between agencies..

- Comment: The inclusion of 1.5 inch mesh in standard index gangs was raised for consideration under CAMPP. Historical studies had included this mesh size.

  Response: Despite its inclusion in some previous studies, the decision was made not to include 1.5 inch mesh in the standard index gangs for CAMPP. However, some sampling programs continue to use 1.5 inch mesh to maintain consistency with previous sampling programs; any data collected from the 1.5 inch mesh under CAMPP has been omitted from analyses/reporting to maintain continuity across data sets for different waterbodies.

Due to logistical and resource constraints and the intent to maintain consistency with pre-existing programs, the following recommendations were not incorporated in CAMPP:

- Comment: It was acknowledged that non-lethal sampling would have to be conducted in waterbodies of high recreational value and potentially all waterbodies in the near future. Parallel sampling of standard gang gill nets and, for example, electrofishing, may have to be conducted in order to establish correlations that will allow comparisons to historical data based only on gillnet sampling. Standard gang index and small mesh index gill nets could be used for lake sampling and other gear types (e.g., seines) depending on the waterbody. For sampling rivers, gear type would also depend on the waterbody. It was noted that the choice of sampling gear should be flexible and that site selection and sampling frequency needed further discussion.

  Response: CAMPP employed sampling methods that were consistent with historical and active fish monitoring programs conducted by MCWS. This methodology included lethal sampling of fish. However, in at least one waterbody, sampling methods were adjusted to attempt to minimize fish mortality. Following the mortality of several young Lake Sturgeon at the confluence of the lower Churchill and Little Churchill rivers in 2010, it was decided to reduce gill net set times from 24 hours to 16 hours to reduce, and ideally eliminate mortality of Lake Sturgeon. To date, this modification has proven successful.

- Comment: It was suggested that CAMPP should integrate additional sampling methods (e.g., electrofishing, seining, baited minnow traps) with the use of Swedish gill nets for sampling the small-bodied fish community. It was suggested that a variety of methods might provide a more representative sample of the small-bodied fish community than use of gill nets alone.

  Response: This recommendation was not adopted in CAMPP.

- Comment: At the 2007 workshop there was discussion of using a monofilament standard gang (similar to Ontario's Fall Walleye Index Netting (FWIN) protocol or the American Fisheries Society (AFS) standard gang).
- Response: It was decided not to adopt this recommendation to facilitate usage of historical data (i.e., allow for comparisons to historical data), which were collected with multi-strand nylon nets.

Table 4.7.2-1. Index of Biotic Integrity metrics and scoring criteria used to evaluate the CAMPP waterbodies.

Category	Metric	Min Value	Max Value	Standardizing criteria
Richness and composition				
	Number of species	8	19	0.5 x number of species
	Number of sensitive species	1	8	1.2 x number of sensitive species
	Proportion of tolerant individuals	0.1	53.0	10 - 0.17 x % tolerant individuals
	Number of Insectivore species	3	12	0.75 x number of insectivore species
	Hill's Effective Species Richness Index	3.0	11.4	0.87 x Index value
Trophic composition				
	Insectivore biomass	2.4	50.0	0.18 x % of insectivores by biomass
	Omnivore biomass	3.1	80.1	10 - 0.15 x % of omnivores by biomass
	Piscivore biomass	16.1	91.0	0.1 x % of piscivores by biomass
Reproductive composition				
	Proportion simple lithophilic spawners	0.17	0.92	10 x proportion lithophilic spawners
Abundance and condition				
	CPUE	5.8	135.2	0.1 x CPUE
	% individuals with DELTS	0.0	6.1	5 - 0.5 x % individuals with DELTs

Table 4.7.2-2. Metric classifications for all species captured in CAMPP waterbodies from 2008 to 2010.

Species	Code	Tolerance	Feeding	Reproductive
Silver Lamprey	SLLM		PR	
Lake Sturgeon	LKST		IN	SL
Goldeye	GOLD	SN	IN	
Mooneye	MOON	SN	IN	
Lake Chub	LKCH		IN	
Common Carp	CMCR	TL	OM	
Common Shiner	CMSH		IN	
Northern Pearl Dace	NPDC		DT	
Emerald Shiner	EMSH		IN	
Spottail Shiner	SPSH		IN	
Fathead Minnow	FTMN	TL	OM	
Flathead chub	FLCH		OM	
Longnose Dace	LNDC		IN	
Quillback	QUIL	TL	OM	
Longnose Sucker	LNSC	TL	OM	SL
White Sucker	WHSC	TL	OM	SL
Silver Redhorse	SLRD	SN	IN	SL
Golden Redhorse	GLRD	SN	IN	SL
Shorthead Redhorse	SHRD	SN	IN	SL
Brown bullhead	BRBL		OM	
Channel Catfish	CHCT	TL	PI	
Northern Pike	NRPK		PI	
Rainbow Smelt	RNSM	TL	PI	
Cisco	CISC	SN	IN	SL
Lake Whitefish	LKWH	SN	IN	SL
Arctic grayling	ARGR	SN	IN	
Brook Trout	BRTR	SN	PI	
Troutperch	TRPR		IN	
Burbot	BURB		PI	SL
Mottled sculpin	MTSC	SN	IN	
Slimy Sculpin	SLSC		IN	
White Bass	WHBS	TL	PI	
Rock Bass	RCBS	SN	PI	
Smallmouth Bass	SMBS	SN	PI	
Black Crappie	BLCR		PI	
Yellow Perch	YLPR		IN	
Logperch	LGPR		IN	SL
Sauger	SAUG		PI	SL
Walleye	WALL		PI	SL
Freshwater drum	FRDR	TL	IN	

TL = tolerant species (includes invasive species), SN = sensitive species, PI = piscivore species, IN = insectivore species, OM = omnivore species, SL = simple lithophilic spawning species, PR = parasitic species.

4.8 FISH MERCURY

4.8.1 Site Selection

The waterbodies sampled for fish mercury represent a subset of the lakes and rivers included in CAMP, and as of 2010, represented waterbodies within all CAMP regions. Furthermore, there are historical data for 23 of the 25 locations sampled for fish mercury under CAMP (Table 4.8.1-1). The records for some of these waterbodies, notably on the Churchill River Diversion and the Nelson River, date back to the early 1970s (see Jansen and Strange 2007a for examples). As such, CAMP continues to be one of the longest running and most wide-ranging mercury in fish datasets ever created.

Southern Indian Lake was sampled for fish mercury within two of the three areas included in CAMP in order to evaluate whether local differences in fish mercury concentrations exist within a large lake (Table 4.8.1-1). Manigotagan Lake and the Little Churchill River were the only two waterbodies chosen without a pre-existing dataset on fish mercury (Table 4.8.1-1). Manigotagan Lake was included to provide information for an off-system lake for the Winnipeg River Region and the Little Churchill River was included to provide information for a riverine area within the Lower Churchill River Region.

In 2009 and 2010, fish mercury monitoring was conducted in 24 waterbodies, at a total of 25 locations. As samples were collected during the conduct of the fish community monitoring program, sampling sites were generally identical. However, because target numbers of fish for mercury analysis were often captured at the first few sampling sites during fish community monitoring, fish for mercury analysis typically represented only a subset of the sites sampled over the entire waterbody.

On several occasions the target sample size of fish for mercury analysis (see section 4.8.2.1 below) was not achieved during the fish community monitoring program, and some additional targeted sampling or sampling at additional sites was conducted in order to increase sample size.

4.8.2 CAMPP Methods

4.8.2.1 Sampling Methods

Three species of large-bodied fish (i.e., Lake Whitefish [*Coregonus clupeaformis*], Northern Pike [*Esox lucius*] and Walleye [*Sander vitreus*]) were sampled for mercury under CAMPP. These species were selected based on one or more of the following: (1) for historical reasons (i.e., species were commonly sampled in historical studies); (2) because of their economic importance; and/or, (3) in the case of Northern Pike and Walleye, because they are predators at the top of the aquatic food chain and therefore at the greatest risk for biomagnification of mercury. In addition to these large-bodied, long-lived fish, 1-year old (1+) Yellow Perch [*Perca flavescens*] were also sampled for mercury analysis. Yellow Perch are widespread and abundant prey fish for Pike and Walleye in the CAMPP waterbodies and, because they do not undertake extensive movements, are considered suitable indicators of “local” production and bioaccumulation of (methyl)mercury. The young Perch may also provide insights regarding annual changes in the supply of mercury to the ecosystem which is one reason that makes them a preferred biological indicator for the monitoring and evaluation of trends in methylmercury accumulation in freshwater systems (Wiener et al. 2007, Depew et al. 2013). Finally, as opposed to other species, age 1+ Yellow Perch can often be readily identified in the field based on the length distribution of the catch.

Initially, Lake Sturgeon [*Acipenser fulvescens*] was not a target species for the fish mercury monitoring component of CAMPP. However, because little information exists on mercury concentrations in this species from Manitoba waters and due to its status as endangered under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), muscle tissue for mercury analysis was collected from incidental mortalities of Sturgeon during the conduct of CAMPP sampling starting in 2010.

Sampling in 2009 and 2010 for fish mercury was conducted concurrently with the sampling of the fish community in June-September. Consistency of sampling time was maintained within individual waterbodies, but because of logistical constraints due to the south/north phenology gradient, sampling times differed between waterbodies.

To be consistent with the methodology of previous fish mercury monitoring programs in Manitoba (e.g., Jansen and Strange 2007a; Strange and Bodaly 1999) an effort was made to collect 36 fish each of Lake Whitefish, Northern Pike, and Walleye for analysis of mercury in skeletal muscle. 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 the large-bodied species, up to 25 young Yellow Perch were collected. These fish were retained for 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. Yellow Perch available for mercury analysis sometimes exceeded the upper limit of the target length range and subsequent ageing indicated that some individuals analysed for mercury were older than 1 year. Unless the mercury concentrations were considered outliers (see section 4.8.2.3 below), these data points were not removed prior to data analysis and are referred to as “1-yr old” Yellow Perch. A detailed account of field sampling and other analysis methods is provided in Appendix 1.

4.8.2.2 Laboratory Analysis Methods

Muscle samples of large-bodied fish and whole bodies of Yellow Perch were collected at each site. Whole Yellow Perch were processed for length, weight, and other biological data (see Appendix 1) and a sample consisting of the body midsection from (but excluding) the pectoral girdle to the caudal peduncle was prepared for submission for mercury analysis. All fish samples were weighed and to an analytical laboratory accredited under the Canadian Association for Laboratory Accreditation Inc. (CALA; ALS Laboratories, Winnipeg, MB). for analysis of total mercury.

Quality assurance/quality control (QA/QC) measures incorporated into the fish mercury program included development of a detailed field sampling protocol, which includes descriptions of measures to minimize sample contamination and maintenance of sample integrity, and the analysis of duplicate samples, standard reference materials (SRMs), and an inter-laboratory comparison (samples sent to Flett Research, Winnipeg, MB). For details of QA/QC laboratory procedures see Appendix 1.

4.8.2.3 Data Analysis Methods

Fish mercury data were subject to QA/QC review in three stages: (1) an initial review of field measurements and sample identification prior to submission for mercury analysis; (2) an initial review of laboratory results; and, (3) a secondary review of data during the data analysis and reporting stage. These QA/QC review stages included examination of the data for transcription errors and/or anomalies as well as review of analytical laboratory results, including review of QA/QC sample results. Potential outliers in mercury concentrations were mainly identified through graphical methods, such as species-specific scatter plots of concentration vs. fish length. Concentrations falling outside the 95% confidence limits of the sample distribution were considered outliers, unless fish length and/or age indicated that a concentration was biologically plausible. Two samples initially identified as outliers were reanalysed at the analytical laboratory; the results of the re-analysis were not outliers and no mercury concentrations were discarded prior to statistical analysis of all samples.

Percent deviation of duplicate samples and inter-laboratory comparison samples was calculated (Appendix 1) and values exceeding 20% were flagged. All data analyses treated censured values (i.e., values reported as below the analytical detection limit [DL]) as equal to two thirds of the DL. In cases where duplicate samples were collected, sample means were used for the determination of summary statistics.

The initial review of individual fish lengths and weights was facilitated by calculating a condition factor (K) and listing K values for each species in ascending order of magnitude. K was calculated for each fish as:

$K = (W / (L/10)^3) \times 100)$

Where W = round weight (g) and L = fork length (mm).

Based on the absolute level and the distribution of K values within each species, fish weights and lengths were flagged and removed from the data set prior to statistical analyses of summary parameters if no plausible explanation for an outlier value could be found (e.g., a switch of length and weight values, misplaced decimal point).

Comparisons of mean mercury concentrations must account for differences in mean fish size between years and lakes because fish accumulate mercury over their life time such that older, larger individuals usually have higher concentrations than younger, smaller fish (Green 1986; Evans et al. 2005). To reduce the effect of fish size on mean mercury concentrations and facilitate comparisons between lakes and years, mean concentrations were standardized for fish length. The standard lengths chosen for Lake Whitefish (350 mm fork length), Northern Pike (550 mm) and Walleye (400 mm) were those used in previous Manitoba fish monitoring programs (see summary in Jansen and Strange 2007a). Standard lengths of 100 mm and 1000 mm were used for 1-yr old Yellow Perch and Lake Sturgeon, respectively, largely based on lengths used in previous Manitoba studies.

Length-standardized mean mercury concentrations (referred to as standard concentrations in the following) were calculated from unique regression equations generated by species and waterbody from the relationship between logarithmic transformations of the muscle mercury concentrations (µg/g or parts per million [ppm]) and fork lengths (mm) of each individual. Subsequent to the regression analysis, the standard length of the respective species was entered into the equation and the standard concentration was calculated, having been generated from individuals captured in the waterbody of interest. On a few occasions (always associated with a small sample size), the relationship between fish length and mercury concentration was not significant and length standardization was not meaningful. In these instances arithmetic means were used for statistical comparisons. To present data in more familiar units, all standardized means and their measures of variance have been retransformed to arithmetic values.

In addition to means, the percentage of individual fish of each species with concentrations of mercury exceeding 0.2 ppm and 0.5 ppm was calculated. The value of 0.2 ppm represents the guideline originally instituted as a “safe consumption limit” for people eating “large quantities of fish" for subsistence purposes (Wheatley 1979) and has been used unofficially by Health Canada in the past. Currently, Health Canada may no longer recommend the value of 0.2 ppm but has not provided an alternative guideline for subsistence purposes. Nevertheless, no major international health agency has been identified which provides formal consumption restriction recommendations for subsistence use when fish mercury concentrations are less than 0.2 ppm (Ross Wilson, Wilson Scientific Consulting, pers. comm., September 2013). Thus, a concentration of 0.2 ppm mercury is included as a "guideline for human consumption" in this report. The 0.5 ppm value represents the Health Canada standard for commercial marketing of freshwater fish in Canada (Health Canada 2007a,b) and the Manitoba guideline for human consumers (Manitoba Water Stewardship [MWS] 2011). Fish mercury concentrations were also compared to the Canadian and Manitoba tissue residue guideline of 0.033 ppm for methylmercury for the protection of wildlife consumers of aquatic biota (Canadian Council of Ministers of the Environment [CCME] 1999; updated to 2013; MWS 2011). Although methylmercury in fish is not analyzed under CAMPP, it can be assumed that most of the total mercury is present as methylmercury. The proportion of methylmercury to total mercury has been reported as 68-83% in yearling Yellow Perch (Rodgers and Quadri 1982) and 78-92% in muscle of Lake Whitefish, Northern Pike, and Walleye (Jackson 1991).

Differences in mean length, weight, and age of fish species between lakes were ascertained employing a one-way analysis of variance (ANOVA). Comparisons of mean arithmetic mercury concentrations between fish species within a given waterbody were also performed using one-way ANOVA and Holm-Sidak's pairwise multiple comparison tests. If normality of data distribution or equality of variances could not be achieved by data transformation (usually logarithmic), Kruskal-Wallis one-way ANOVA on ranks was performed, applying Dunn's method for pairwise multiple comparisons. In all cases, significance was established at $p \leq 0.05$. Differences in standard concentrations between lakes or years were established if the 95% confidence limits of two means did not overlap. Statistical analyses were run using Sigma Stat V. 3.01 (SPSS Inc. 2003) and SAS for Windows V. 8.01 (SAS 1999) software.

4.8.3 Workshop Recommendations

Annual workshops held from 2007 through 2010 provided the following specific recommendations and/or comments regarding the CAMPP fish mercury component:

- Comment: The recently terminated, multi-partner (including Manitoba Hydro) Northern Manitoba mercury monitoring program should be continued and expanded under the auspices of CAMPP. Workshop attendees and First Nations representatives have independently recognized mercury in the food chain as a common concern in northern communities.

Response: CAMPP incorporates analysis of mercury in selected species of fish across the CAMPP regions.

- Comment: CAMPP should include a fish mercury component to ensure continuity and regularity of data collected using consistent methodology.

  Response: CAMPP incorporates analysis of mercury in selected species of fish and employs standardized methodologies.

- Comment: Attendees of the first CAMPP workshop recommended analysis of mercury in Walleye, Lake Whitefish, and Northern Pike, with forage species such as smelt to be considered but with a lower priority.

  Response: Walleye, Lake Whitefish, and Northern Pike were included in the CAMPP fish mercury program.

- Comment: Inclusion of 1-year old Yellow Perch under the CAMPP fish mercury program was discussed at the 2009 workshop.

  Response: One-year old Yellow Perch were included in the fish mercury program, beginning in 2009.

- Comment: Fish muscle samples collected under CAMPP for mercury analysis should be preserved and archived to allow future analysis of other components, such as stable isotopes.

  Response: The majority of Lake Whitefish, Northern Pike, and Walleye muscle samples collected under CAMPP in 2010 were donated to the Department of Fisheries and Oceans (DFO; Mike Patterson, Freshwater Institute) after the completion of mercury analysis. These samples are housed in DFO's long-term storage facility. Some samples of the large-bodied species and all Yellow Perch samples were destroyed as part of the mercury analysis process. No formal provisions exist for long-term storage of fish muscle samples within CAMPP.

- Comment: Consider analyzing mercury in fish muscle on a dry weight basis rather than a wet weight basis to reduce the variation in mercury concentration associated with variability in sample water content (i.e., due to differences in sample treatment and storage time).

  Response: Mercury is measured on a wet weight basis under CAMPP. This method is consistent with the majority of existing/historical data, is the most common method of analysis, and facilitates direct comparison to tissue residue guidelines (which are expressed on a wet weight basis). In addition, rigorous quality assurance/quality control {QA/QC) measures have been developed for CAMPP to ensure sample integrity, including minimization of moisture loss.

- Comment: There was a suggestion of adopting the non-lethal biopsy sampling method for obtaining tissue samples from fish for mercury analysis.

  Response: This method was not adopted as the fish sampled and analyzed for mercury under CAMPP are selected from fish that are lethally sampled to obtain ageing structures.

- Comment: For Lake Winnipeg, CAMPP may consider collecting fish muscle samples from the Transcona fish plant instead of conducting an independent sampling program.

  Response: This recommendation was not incorporated into CAMPP because of concerns with respect to the availability of target species within the desirable size range, QA/QC, and accuracy and availability of supporting data (e.g., fish sampling locations, fish lengths and weights).

Table 4.8.1-1. Waterbodies where fish mercury monitoring is conducted under CAMPP.

Region/Waterbody	On- or Off-System	Sampling Frequency	Year of first sampling under CAMPP	Comments and Rationale for Hg sampling
Winnipeg River				
Pointe du Bois Forebay	On-system	3 years	2010	Pre-existing dataset: samples for 2 years.
Manigotagan Lake	Off-system	3 years	2010	Off-system waterbody: no pre-existing dataset.
Saskatchewan River				
Saskatchewan River[1]	On-system	-[2]	2010	Pre-existing dataset: mainly small sample sizes for ~4 years.
Cedar Lake - Southeast	On-system	3 years	2010	Pre-existing dataset: samples for 17 years.
Cormorant Lake	Off-system	3 years	2010	Pre-existing dataset: mainly small sample sizes for ~7 years.
Lake Winnipeg				
Lake Winnipeg North Basin, Mossy Bay	On-system	3 years	2010	Pre-existing dataset: samples for 6 years from the North basin.
Upper Churchill River				
Granville Lake	Off-system	3 years	2010	Pre-existing dataset: samples for 14 years.
Southern Indian Lake-Area 4	On-system	3 years	2010	Pre-existing dataset: samples for 13 years starting in 1975.
Southern Indian Lake-Area 6	On-system	3 years	2010	Pre-existing dataset: samples for 18 years starting in 1975.
Lower Churchill River				
Northern Indian Lake	On-system	3 years	2010	Pre-existing dataset: small sample sizes for 5 years starting in 1978.
Lower Churchill River at Little Churchill River	On-system	3 years	2010	Riverine site.
Gauer Lake	Off-system	3 years	2010	Pre-existing dataset: samples for 7 years starting in 1978.
Churchill River Diversion				
Rat Lake	On-system	3 years	2010	Pre-existing dataset: samples for up to 16 years starting in 1978.
Threepoint Lake	On-system	Annually	2010	Pre-existing dataset: samples for 16 years.
Leftrook Lake	Off-system	Annually	2010	Pre-existing dataset: samples for 6-8 years.

Table 4.8.1-1. continued.

Region/Waterbody	On- or Off-System	Sampling Frequency	Year of first sample	Comments and Rationale for Hg sampling
Upper Nelson River				
Playgreen Lake	On-system	3 years	2010	Pre-existing dataset: samples for 5 years from 1978-1994.
Little Playgreen Lake	On-system	3 years	2010	Pre-existing dataset: samples for 2 years in1981 and 1994.
Cross Lake - West Basin	On-system	3 years	2010	Pre-existing dataset: samples for 9 years; for 5 years separately for East & West basins starting in 1971.
Setting Lake	Off-system	3 years	2010	Pre-existing dataset: small sample sizes for up to 9 years.
Lower Nelson River				
Split Lake	On-system	3 years	2010	Pre-existing dataset: samples for 25 years.
Stephens Lake – South	On-system	3 years	2009	Pre-existing dataset: samples for 16 years.
Limestone GS Forebay	On-system	3 years	2010	Pre-existing dataset: samples for 11 yrs.
Nelson River below Limestone GS	On-system	3 years	2010	Pre-existing dataset: samples for ~18 years starting in 1978.
Hayes River	Off-system	3 years	2010	Pre-existing dataset: samples for 2 years.
Assean Lake	Off-system	3 years	2010	Pre-existing dataset: samples for 16 years.

[1] Fish mercury samples were collected from the west basin of Cedar Lake rather than from fish captured in the Saskatchewan River proper.
[2] Sampled in 2010 only.