5.0 ENVIRONMENTAL SETTING

5.1 PHYSICAL ENVIRONMENT

5.1.1 *CLIMATE*

Climate data for the regional study area were obtained from Environment Canada (EC) meteorological stations located in Pinawa and Bissett, Manitoba. Pinawa is located approximately 50 km southwest of the Project Site and Bissett is approximately 60 km to the north (Figure 1.1). These stations were chosen because of their proximity to the Project Site and the long periods of record at each location. Climate normals between 1971 and 2000 were calculated for each station (Environment Canada 2013). At the Pinawa station, the mean daily temperature was 2.3°C with maximum and minimum mean daily temperatures occurring in July (24.8°C) and January (-23.5°C) respectively. The mean annual total precipitation was 565.3 mm. The mean annual rainfall was 445.5 mm and mean annual snowfall was 119.8 mm. At the Bissett station, the mean daily temperature was 1.4°C with the maximum mean daily temperature occurring in July (24.9°C) and the minimum mean daily temperature occurring in January (-25.1°C). The mean annual total precipitation was 557.2 mm. The annual rainfall and snowfall means were 430 mm and 134 mm, respectively.

5.1.2 *NOISE*

Noise levels are regularly monitored inside the operating facilities as required by the Manitoba Workplace Safety and Health Act and Regulations. Monitoring results are posted on bulletin boards throughout the minesite. The areas where noise exceeds the regulatory limit of 80 dBA are identified with signs indicating that hearing protection is required. All employees are provided with a selection of hearing protectors (e.g., ear muffs, plugs). A noise survey was conducted on the ventilation raises on June 16, 2011. The Jack Nutt shaft ventilation raise and East End ventilation raise have noise levels exceeding 80 dB at the source (95.5 and 93.0 dBA, respectively), butare < 80 dB at distances of > 20 m away. All employees have an annual audiogram, with unusual results being flagged for follow up. The results are submitted to the Manitoba Workplace Safety and Health Division. The aggregated results are reviewed by the site Workplace Safety and Health Committee.

5.1.3 *TOPOGRAPHY & SOILS*

Bernic Lake is located on the Precambrian drift plain of the Canadian Shield (Davies et al. 1962). This ice-scoured upland region ranges from rolling to hilly. Relief is generally low, typically less than 15 m, and is provided by granite outcrops and numerous eskers. Considerable glacial drift overlies the region. Approximately 40 to 60% of the area is comprised of lakes and bogs, reflecting the poor and disorganized drainage. Surface

deposits consist of glacial drift predominated by granitic materials. Acid soils prevail on uplands, including podzol, brown podzolic, andgrey-wooded types. Organic soils prevail in bogs.

5.1.4 HYDROGEOLOGY

The Precambrian bedrock in eastern Manitoba is overlain in most areas by Quaternary deposits consisting of glacial tills, glaciolacustrine clays, silts and sands, emerged marine deposits, and/or organics (Manitoba Mineral Resources Division 1981) of variable thickness. The native stratigraphy found beneath the East Tailings Management Area (TMA) is consistent with glaciolacustrine clays, silts and sands (Wardrop 2010b). Therefore, it is reasonable to assume that this glaciolacustrine depositional setting is representative of the local study area. Random and frequent bedrock outcrops in the local area indicate variable overburden thickness as a result of the undulating bedrock surface.

Groundwater is present in this depositional setting as perched water that receives direct recharge from rain or snow melt, or as part of a larger overburden aquifer that flows according to the direction of bedrock dip. The previous on-site investigations suggest that most of the groundwater is present in sandy gravel and/or sandy clay formations immediately above the bedrock. Due to the variable topography, this perched groundwater may interact with the various wetlands, streams and small lakes in the immediate vicinity.

An average sandy clay formation would have a hydraulic conductivity of around 10-7 m/s (± one order of magnitude), which corresponds to published ranges for sandy clay aquifers (Freeze and Cherry 1979). In areas of reduced clay content, published hydraulic conductivity for clean sand and gravel formations range from 10-5 to 10-1 m/s (Freeze and Cherry 1979).

Groundwater is also present in the fractures in the Precambrian bedrock, with the distribution of this water being dependent on the frequency, extent and interconnectivity of the fractures. Recharge to these fractures may occur through infiltration from overlying water bearing overburden, or as direct infiltration of precipitation in areas of exposed bedrock.

5.1.5 TAILINGS PILE HYDROGEOLOGY

5.1.5.1 EAST TAILINGS MANAGEMENT AREA

A hydrogeological study of the East TMA was conducted in 2001 and described the tailings as a 7 to 11 m thick unconfined aquifer with saturation at depths between 0.5 and 3.0 m below the surface of the tailings (UMA 2001). Aquifer gradients were calculated between 0.001 and 0.012. Groundwater divides were located near the north end of the East TMA with aquifer flow toward the East, West, and Main Dams.

Average linear groundwater velocities were calculated from gradients, slug test estimates of hydraulic conductivity and porosity estimates, and determined to be between 1.4 and 2.9 m/y (Wardrop 2009b). Based on aquifer properties, estimated annual seepage from the TMA was estimated to be in the range of 3,200 m^3/year to 6,700 m^3/year primarily through four key discharge locations (North Dam, East Dam, West Dam, and Main Dam) (Figure 2.3).

The tailings groundwater system is expected to be distinct and separate from any underlying groundwater system in the native overburden or bedrock. Flow in the tailings groundwater system appears to be lateral, with very limited vertical flow downward.

The documented hydrogeologic conditions formed the basis for the CPF residue dry stack placement plan in the East TMA. The dry stack was strategically located on groundwater divides in the northern part of the TMA to maximize the travel time to points of discharge to surface waters as well as to maximize the dilution of residue leachate. Subsequent assessment of the migration of CPF residue through the East TMA indicates that this is primarily through overland flow of precipitation runoff, with minimal subsurface migration through the tailings groundwater system.

5.1.5.2 *West Tailings Management Area*

The groundwater system in the West TMA has not been studied but is expected to function in the same manner as the extensively studied East TMA groundwater system. The tailings in the West TMA are the same as in the East TMA, with respect to ore source, grind, and mill process. Groundwater flow can be expected to be in the direction of topographic relief, which in the West TMA results in all flows being directed to the main dam, through the polishing pond, and out the West Discharge.

On the basis of extensive study in the East TMA, the tailings hydraulic conductivity is expected to be 10.6 m/s (± one order of magnitude), which corresponds to published ranges for silty to fine-grained sand formations (Freeze and Cherry 1979). As an active TMA, the static groundwater elevation in the West TMA tailings will fluctuate with the water level maintained in the main pond. This influence is absent from the inactive east TMA.

5.2 Terrestrial Environmental

5.2.1 *Vegetation*

The site is located in the Lac Seul Upland Ecoregion of the Boreal Shield Ecozone. This ecoregion is classified as having a sub-humid, mid-boreal ecoclimate. The dominant land cover is coniferous forest with some limited areas of mixed forest. Characteristic vegetation includes white spruce (*Picea glauca*), balsam fir (*Abies balsamea*), and black spruce (*P. mariana*) with some trembling aspen

(*Populus tremuloides*) and balsam poplar (*P. balsamifera*), although jack pine (*Pinus banksiana*) and black spruce are more common on moderately well to imperfectly drained sites. Poorly drained areas are covered by fens and bogs and are dominated by black spruce. Wetlands cover over 25% of the ecoregion.

A significant wetland complex is found in the area surrounding Bernic Lake. Wetlands are found in the floodplain of Bernic Creek, which is a low-gradient stream that runs north from Bernic Lake, and in depressional areas that are not directly connected to Bernic Creek. In addition to the floodplain wetlands, wetland areas considered in this report are found in a horseshoe-shaped area west and north of the outlet of Bernic Lake. The wetlands in the Bernic Creek floodplain are shown in Figure 5.1 as the "Bernic Wetland", and the other wetlands that have been identified to the west and north are shown as "Horseshoe Wetlands). Collectively, these wetland areas are referred to in this report as the "Bernic Creek wetland complex". Based on aerial photograph interpretation and topographic maps, these wetlands appear to drain by various sources to the Bird River, which lies to the north of them.

Although these wetlands are functionally distinct from each other, topographic data indicates that they may be hydrologically connected by surface channels for much of the year. Hydrologic conditions in these wetlands are supported by flow from Bernic Creek, by groundwater, and by surface runoff associated with melting snow and rainfall. Although existing data does not reveal the amount of water that passes through them as either overland flow or by percolating into underlying sediments, it appears that they are flooded or have a very high water table for most of the growing season, which is assumed to run from mid-May through mid-September. Some parts of the wetland complex appear to be open water with a fringe of wetland vegetation.

Based on review of topographic figures, aerial and ground-level photographs, and data recorded during reconnaissance-level site surveys, most of these wetlands appear to be marshes, according to the Canadian Wetland Classification System (CWCS) (Warner and Rubec 1997). Marshes are characterized by "periodic or persistent slow-moving surface water which is circumneutral to alkaline and generally nutrient-rich. Vegetation is dominated by graminoids, shrubs, forbs, or emergent plants" (Warner and Rubec 1997). The subclasses of marsh that appear to present in these wetland areas include riparian stream marsh, riparian floodplain marsh, and linked basin marsh. Vegetation in swamps is hydrophytic, meaning that it is adapted to long periods of saturation or inundation. Vegetation in the riparian stream and floodplain wetlands appears to be primarily sedges *(Carex* spp.*)* and rushes *(Juncus* spp.*),* with limited amounts of small willows *(Salix* spp.*),* Labrador tea *(Ledum groenlandicum),* and an underlayer of sphagnum moss *(Sphagnum* spp.). In the linked basin areas, similar vegetation is found, although a greater concentration of shrubs may occur. Most areas are fringed by black spruce and white spruce.

Soils in the riparian floodplain and riparian stream marshes appear to be highly organic and likely have a high concentration of peat. Soils in the linked basins likely have a greater mineral content than those in proximity to the stream, but still have a high

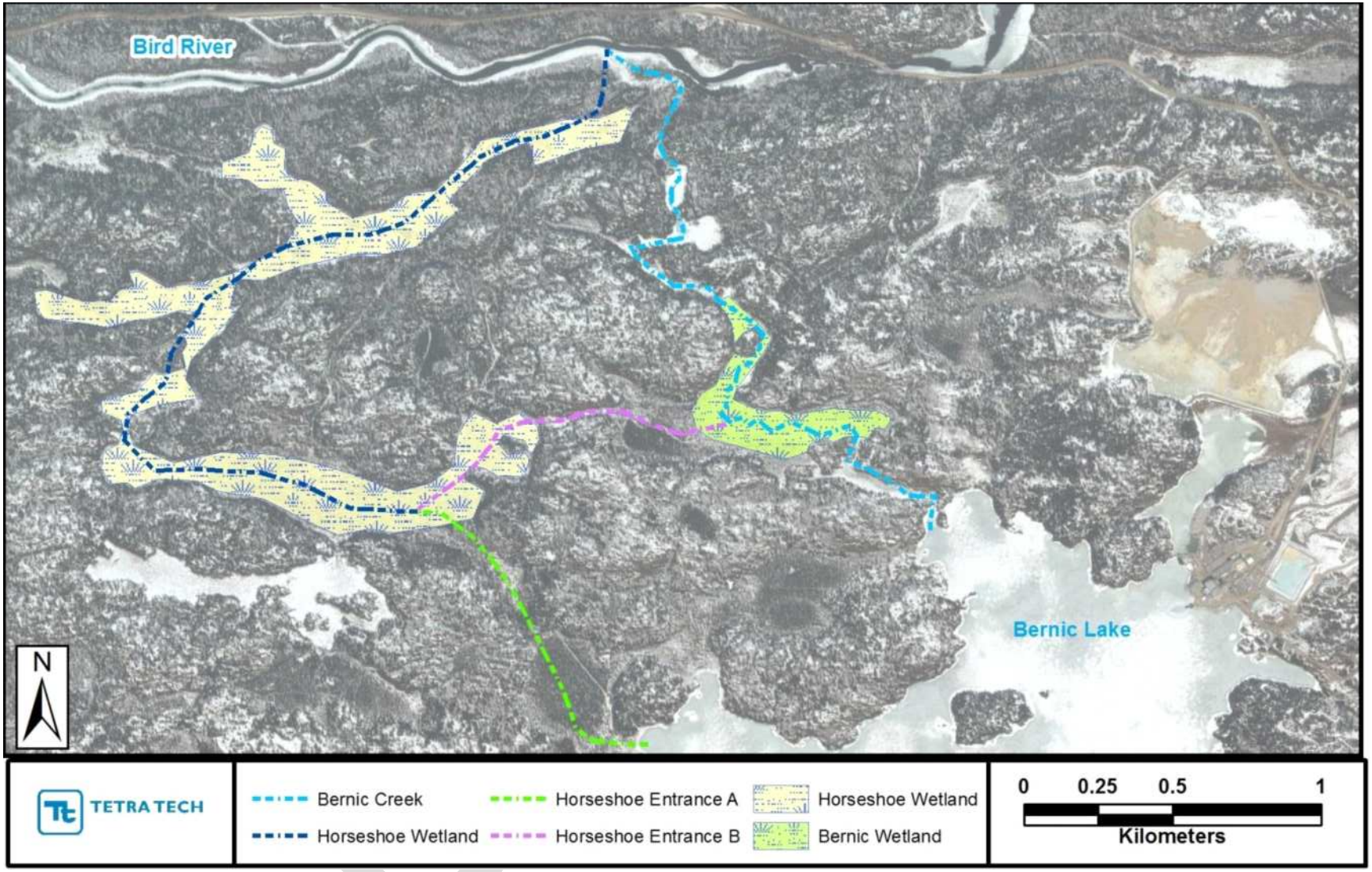

Figure 5. 1 Hydrographic Features Associated with Bernic Lake Dewatering

organic content. Highly organic soils have the greatest capacity to store water and nutrients, and are most efficient at facilitating uptake of nutrients including phosphorus and nitrogen.

5.2.2 *WILDLIFE*

Characteristic regional wildlife includes mammals such as moose (*Alces alces*), black bear (*Ursus americanus*), lynx (*Lynx canadensis*), and snowshoe hare (*Lepus americanus*). Birds in the region include ruffed grouse (*Bona saumbellus*), pileated woodpecker (*Dryocopus pileatus*), bald eagle (*Haliaeetus leucocephalus*), as well as many waterfowl and songbird species (Smith *et al* 1998). Several wildlife species are frequently observed within the minesite itself including white-tailed deer (*Odocoileus virginianus*) and red fox (*Vulpes vulpes*).

The local study area is approximately 20 km south of the current (2000-2010) range of the Owl-Flintstone caribou herd which is made up of approximately 60 to 70 individuals (Figure 5.2). The range is considered of high conservation concern in Manitoba's draft Action Plans for Boreal Woodland Caribou Ranges in Manitoba (Manitoba Conservation 2011). The woodland caribou is listed under the Manitoba *Endangered Species Act* (ESA) and is recognized as Threatened by COSEWIC and under the *Species at Risk Act (*SARA*)*. Caribou sightings have not been reported within the local study area, but could potentially occur in the area (MBCDC 2013). TANCO mine staff have not reported caribou on the site or along the mine road.

5.2.3 *SPECIES AT RISK AND CRITICAL HABITAT*

The Manitoba Conservation Data Centre (MBCDC) tracks plant and animal species of conservation concern within the province. The MBCDC assigns each species a conservation status rank from S5 (abundant) to S1 (very rare) and then collects detailed information on their locations. The ranking takes into account species listed under Manitoba's *Endangered Species Act* and those which have been assigned a special designation by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

The MBCDC was contacted to determine if any rare, threatened or endangered flora or fauna have been reported in the local study area. According to MBCDC, common nighthawk (*Chordeiles minor*), Canada warbler (*Wilsonia canadensis*) and common snapping turtle (*Chelydra serpentine serpentina*) have been reported within the study area. Common nighthawk is listed as threatened under the Manitoba ESA, COSEWIC and SARA. The Canada warbler is listed as endangered according to the Manitoba ESA and threatened under COSEWIC and SARA. The common snapping turtle is listed as a species of special concern under COSEWIC and SARA. Barred owl (*Strix varia;* provincial rank of S4), and northern parula (*Parula Americana;* provincial rank of S3), were also reported within the study area. Plantain-leaved pussytoe (*Antennaria plantaginifolia; p*rovincial rank of S1S2) could potentially occur in the area.

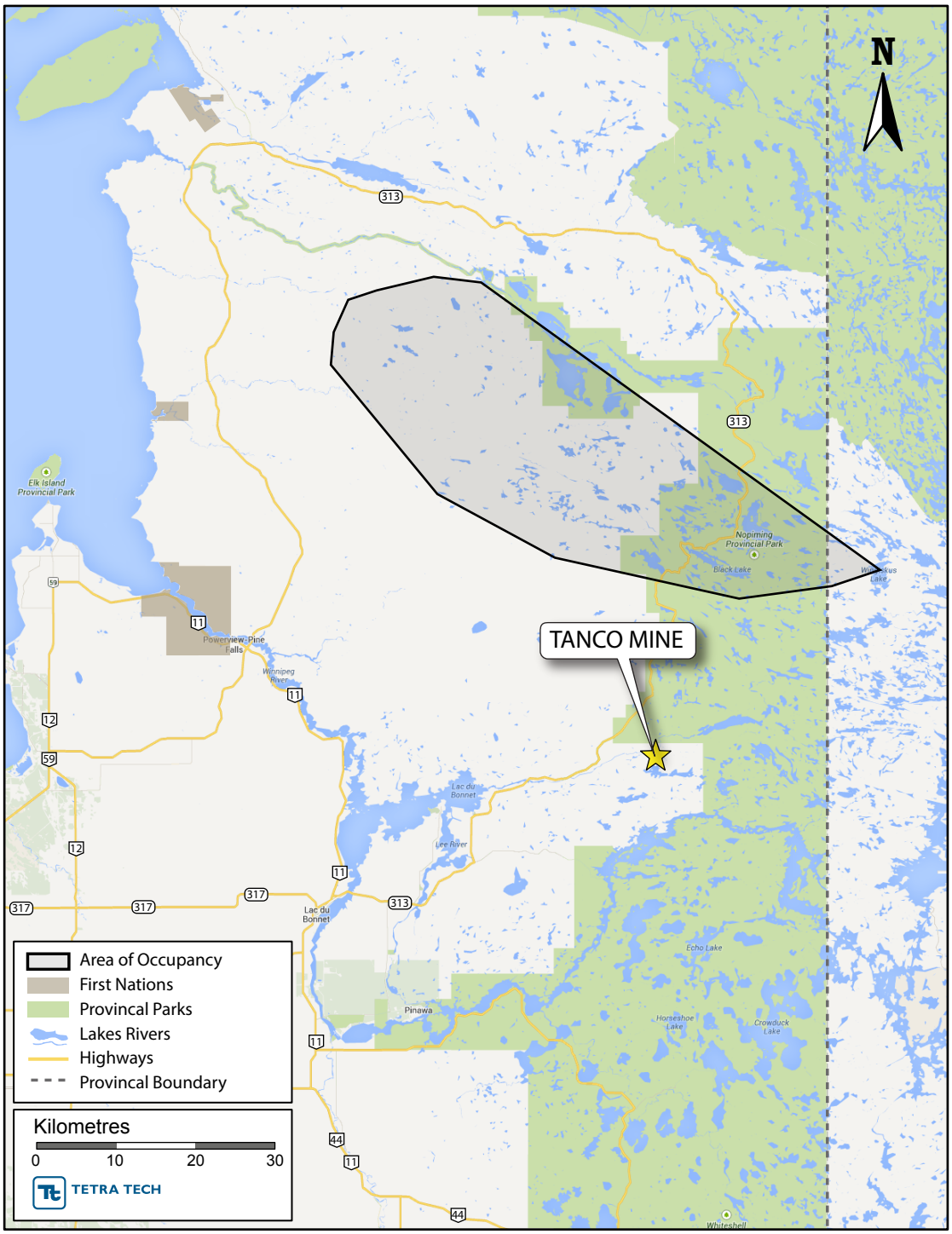

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FIGURE 5.2
RANGE OF THE OWL-FLINTSTONE CARIBOU HERD IN MANITOBA

5.3 AQUATIC ENVIRONMENT

The aquatic environment within the local study area is primarily represented by Bernic Lake and its inflowing and outflowing tributaries. Previous monitoring of aquatic environmental conditions within the local study area has been focused on Bernic Lake, as this is the primary receiving waterbody for effluent from the TANCO Mine. Environmental effects monitoring has also extended to the Bird River at the confluence of Bernic Creek. Data from these studies has been summarized in the following sections to characterize the existing aquatic environment.

5.3.1 *SURFACE HYDROLOGY*

5.3.1.1 *BERNIC LAKE*

Bernic Lake, located adjacent to the TANCO mine, is a small, second-order lake receiving inflow from five headwater streams to the eastern and central parts of the lake as well as surface flow directly from the watershed. The lake discharges into the Bird River via Bernic Creek (Figure 5.3). All of the inflow streams are small, approximately 2 m in width where they discharge to the lake, and typically flow through low-lying bogs (Wardrop 2009).

The lake is comprised of two basins of approximately equal size joined by a narrows (Figure 5.3). Both basins are characterised by relatively steep margins and wide flat bottoms. Bathymetric mapping of the west basin was conducted in 2013. Physical dimensions of Bernic Lake and its watershed are summarized in Table 5.1.

Table 5. 1 Physical characteristics of Bernic Lake and its watershed

Parameter	Estimate
Drainage Basin Area	3,297 ha
Lake Surface Area	400 ha
Shoreline Length	28.9 km
Mean Depth	4.59 m
Maximum Depth	9.17 m
Lake Residence Time	2.33 years

A single lake outlet, drains the western basin via Bernic Creek, a short stream to Bird River. A waterfall on the outlet stream presents a barrier to fish movements upstream from Bird River. Bird River flows into Lac du Bonnet, which is a widening of the Winnipeg River created by the McArthur Falls hydroelectric generating station.

The Bernic Lake outlet is not gauged. Limited observations indicate the outlet stream may typically flow during the spring freshet but other than during extreme wet periods, the stream is dry along some sections between Bernic Lake and the Bird River.

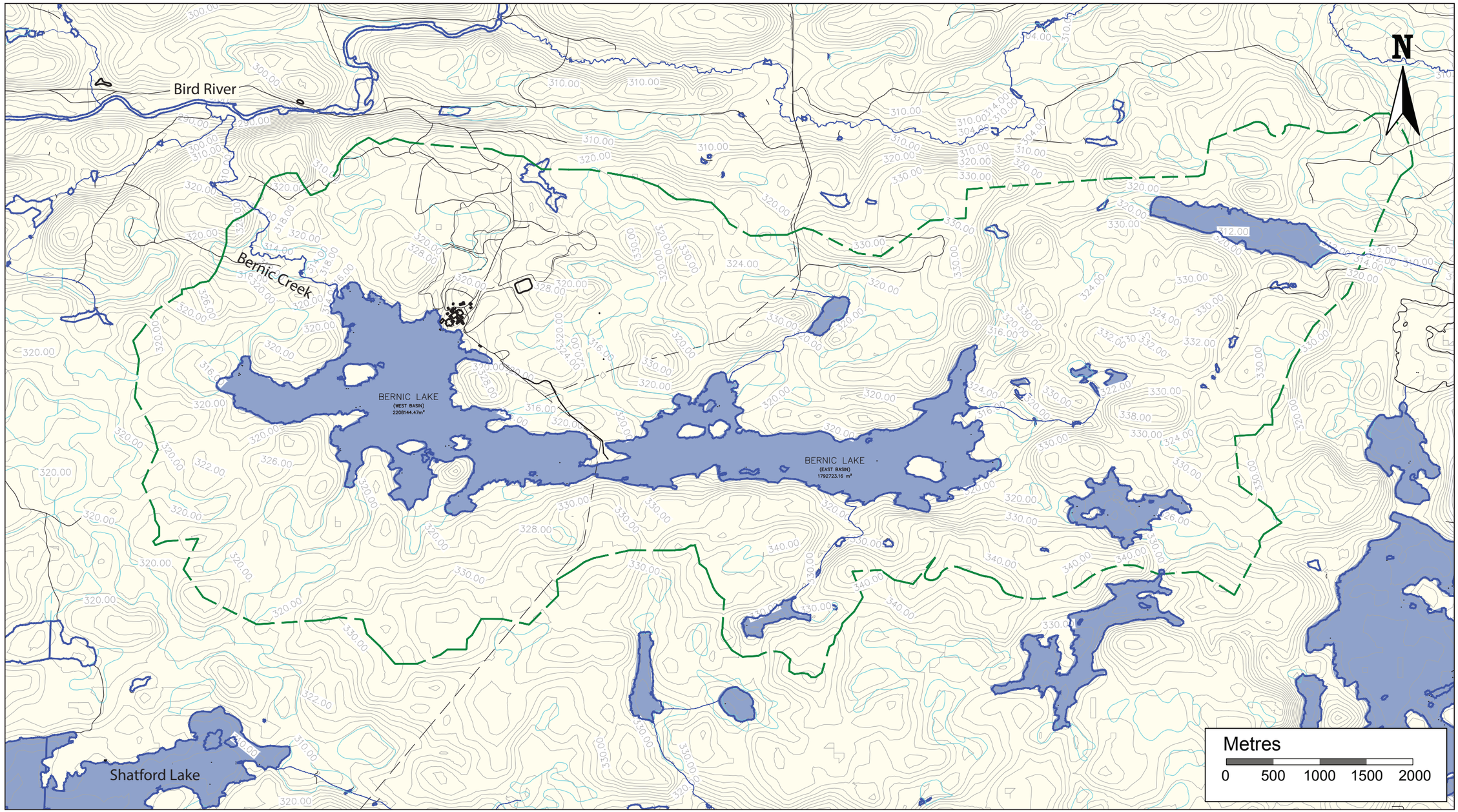

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Figure 5.3
WATERSHED OF
BERNIC LAKE AND THE
BERNIC LAKE TRIBUTARIES

5.3.1.2 *BERNIC CREEK*

The outflow from the lake to Bernic Creek is limited by the hydraulic control at the northwest end of the lake. During snowmelt in the spring, runoff into Bernic Lake raises the water-surface elevation to produce outflow into Bernic Creek; once the water surface elevation in Bernic Lake drops below the elevation of the hydraulic control, no further surface flow occurs.

Bernic Creek is a low-order stream, with a width on the order of 5 meters. It appears to flow for a distance of approximately 3 km between Bernic Lake and the Bird River (Figure 5.3). About 60 m downstream from the hydraulic control at the outlet of Bernic Lake, Bernic Creek enters Bernic Wetland. Outflow from Bernic Wetland (approximately 2.5 km downstream of Bernic Lake) appears to enter a cascading channel (approximately 8 percent gradient, 0.08m/m) that flows northward to the Bird River. Based on available aerial imagery and topographic mapping, the surface area of Bernic Wetland is approximately 10.4 ha.

Bernic Creek between Bernic Lake and the Bird River is ungaged, so the flow regime cannot be directly quantified. However, local knowledge of the creek's hydrology indicates that flow is ephemeral; runoff is conveyed in the creek only during the spring freshet.

5.3.1.3 *BIRD RIVER*

The Bird River begins northeast of the TANCO Mine at the west end of Bird Lake (Tulabi Lake drains into Bird Lake from the east in the Nopiming Provincial Park, and flows west-southwest, discharging approximately 18 km downstream into Lac du Bonnet on the Winnipeg River. The Winnipeg River eventually discharges into Lake Winnipeg at Fort Alexander/Pine Falls.

Bird River watershed has an estimated gross drainage area of 1039 km^2 (Environment Canada 2009). Bird River flows have been monitored since 1960 by Environment Canada at locations between the outlet of Bird Lake and the TANCO site (Environment Canada stream flow gauge station 05PJ001; 50°27'46" N, 95°35'0" W).

Stream flow follows a distinct seasonal pattern. Bird River flow was lowest in March. Flows increase in April as the spring melt and runoff starts and maximum flow typically occurs in May. River flow then declines through June, July, and August and then gradually diminishes through to the annual minimum in March (Table 5.2).

Table 5. 2 Bird River monthly flow statistics (m^3/s). Data from Environment Canada (2009).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	3.21	2.94	2.38	6.03	14.1	13	7	4.21	4.88	4.54	4.17	3.75
Max	5.74	4.79	5.02	15.1	47.5	52	12	11.4	14.3	13.6	11.8	8.46
Min	0.11	0.2	0.32	0.59	1.59	1.4	1.8	0.92	0.62	0.140	0.04	0.1

The shoreline in the Bird River study area varies from the north and south banks. The north bank is covered gravel and sand, quickly transitioning to gravel and silt substrate down to the river bottom. In the north east portion of the study area, bedrock outcrops transition into boulders under the river. Conversely, the south bank is primarily marsh, covered in loose silt with a slower transition into soft silt, woody debris and detritus and clay substrates down towards the river bottom.

5.3.2 *Physical Limnology of Bernic Lake*

The occurrence of open water season thermal stratification has been investigated in Bernic Lake several times over the past 35 years. These surveys (Crowe 1969; Crowe 1972a; Crowe 1972b; Crowe 1976) have clearly demonstrated the occurrence of thermal stratification in late spring and summer, followed by a period of autumnal mixing. It is not known if the lake also undergoes a period of mixing in the spring after ice-out, as sampling has not yet been undertaken sufficiently early in the open water season to capture the onset of stratification. By late June, stratification is well developed, with a uniform epilimnion (surficial mixed layer) temperature to about 4 m depth and a thermocline evident at about 5 m depth. In 2008, lake temperature had become uniform by early October, indicating the period of fall mixing was occurring.

There is some potential for a minor east-west flow in the lake during spring runoff when the outlet is flowing. Otherwise, any water currents in Bernic Lake during the open water season will be wind-driven.

5.3.3 *Bernic Lake Water Quality*

5.3.3.1 *Bernic Lake*

In its natural state Bernic Lake was considered to be a “typical” example of a soft water Shield lake (Crowe 1976), with low hardness (total hardness 10 to 37.6 mg/L), weakly buffered (total alkalinity 6 to 14 mg/L), low to moderate concentrations of TDS (36 to 60 mg/L); slightly acidic pH (6.1 to 7.01), and, transparent (Secchi visibility 1.5 to 1.9 m) but somewhat coloured waters (Table 5.3; Figure 5.4). By 1975, increases in major ion concentrations, alkalinity (total alkalinity 28 mg/L), hardness (total hardness 35.3 mg/L), and TDS (70 mg/L); were evident. These increases were attributed to the mine discharge, but the connection could not be confirmed because mine discharge quality monitoring did not include these parameters at that time (Crowe 1976). More comprehensive effluent sampling was initiated in 1997 in anticipation of the implementation of the Metal Mining Effluent Regulations (MMER), which eventually came into effect in December 2002.

Negligible increases in alkalinity and hardness have occurred since 1975, as indicated by the ranges of the most recent measurements overlapping the 1975 measurements. Elevated Total Disolved Solids (TDS) concentrations were evident in 1970, shortly after the mine went into operation through 2008. A decrease in TDS was observed between 2009 and 2012 (Table 5.3).

TSS concentrations in the mine discharge are managed in accordance with MMER effluent quality regulations. No changes in suspended solids concentrations or turbidity appear to have occurred since the pre-development baseline studies; however a decrease in Secchi disk visibility, a measure of water transparency, was consistently observbed from 1968 to 2010 (Table 5.3). This decrease has occurred in the absence of a significant source of inorganic turbidity to the lake and no areas of shoreline erosion have developed since the baseline studies.

N

"Bernic Creek"

Outlet Stream

S2

WEST DISCHARGE

WD

EXPOSURE AREA

FORMER EAST DISCHARGE

ED

S1

West Discharge Bay Near Field

S3

Bernic Lake (west basin)

S4

S5

DEPTH 9.8M

East Reference Bay

REF

S6

Far-Field

Inlet Stream

Inlet Stream

S7

DEPTH 8.7M

Bernic Lake (east basin)

S8

Inlet Stream

S9

Inlet Stream

Inlet Stream

Metres

0 400 800 1200

TETRA TECH

Figure 5.4
HISTORIC (1969-1975) AND CURRENT (2002-2012) WATER QUALITY SAMPLING STATIONS

The reduced water transparency appears to be attributable to increased algal standing crops. Seasonal mean chlorophyll a concentrations in Bernic Lake have ranged between 0.009 mg/L and 0.032 mg/L from 2002 through 2012, with a mean concentration of 0.016 mg/L over this period (Table 5.3) which can be attributed to phosphorus levels in the lake.

The primary nutrient limiting algal growth in Bernic Lake is phosphorus, as is typically the case in lakes of the Canadian Shield (Schindler 1977). The relative importance of phosphorus (P) and nitrogen (N) in regulating algal growth is evaluated on the basis of the ratio of the total N and total P concentrations in the lake. Sakamoto (1966) and Forsberg et al. (1978) found that P is the limiting nutrient at N:P>17, that N is limiting at N:P<10, and that N and P are jointly limiting at 10≤N:P≥17. Between 2005 and 2012, the only period for which detailed nutrient analyses have been completed in Bernic Lake, the open water seasonal mean N:P ratio in the exposure zone ranged from a low of 14.3:1 in 2009 to a high of 34.3:1 in 2006 (Table 5.3) indicating P-limited conditions throughout the period of consideration.

In the absence of an extensive characterization of pre-development water quality in Bernic Lake, as would be undertaken if baseline studies were being initiated today, it is necessary to infer the baseline concentrations of many parameters through consideration of water quality in an appropriate reference lake. Tulabi Lake, located on the Bird River upstream of Bird Lake, approximately 15 km northeast of Bernic Lake is the reference lake used for MMER compliance monitoring (Figure 5.5). Tulabi Lake was selected after extensive consideration of many lakes in Nopiming Park and in agreement with Manitoba Water Stewardship and Environment Canada. The occurrence of a parameter value in Bernic Lake that differs from the value in Tulabi Lake by a factor of 2 or more is interpreted as a significant difference under the MMER approach in the absence of pre-development baseline data that suggests otherwise. Tables 5.3 through 5.8 contain all water quality data for both Bernic Lake and Tulabi Lakes through 2012 and sample stations are shown in Figures 5.4 and 5.5.

Phosphorus concentrations were not measured in Bernic Lake as part of the pre-mining baseline studies; however, lake data indicates that phosphorus concentrations have increased (Table 5.3). Total phosphorus concentrations in Bernic Lake exceeded the Tier III MWQSOG for the prevention of excessive growth of aquatic macrophytes and algae in water bodies where the primary limiting nutrient for algal growth is phosphorus. Seasonal mean concentrations from 2005 to 2012 ranged from 0.0345 to 0.049 mg/L guideline for lakes. In comparison, seasonal mean total phosphorus concentration in Tulabi Lake has ranged from a low of 0.007 mg/L in 2010 to a high of 0.022 mg/L in 2005 (Table 5.4) and conditions have not changed in comparison to the 0.02 mg/L measured by Hagenson and O'Connor (1978) in 1976. Total iron also exceeded the Tier III MWQSOG in Bernic Lake in 2004 and 2006 (Table 5.7).

In consultation with Environment Canada, TANCO has implemented a number of operational modifications since 2011 including aeration of the settling and polishing

ponds in order to improve effluent quality. Operational modifications are discussed in Section 2.3.12.

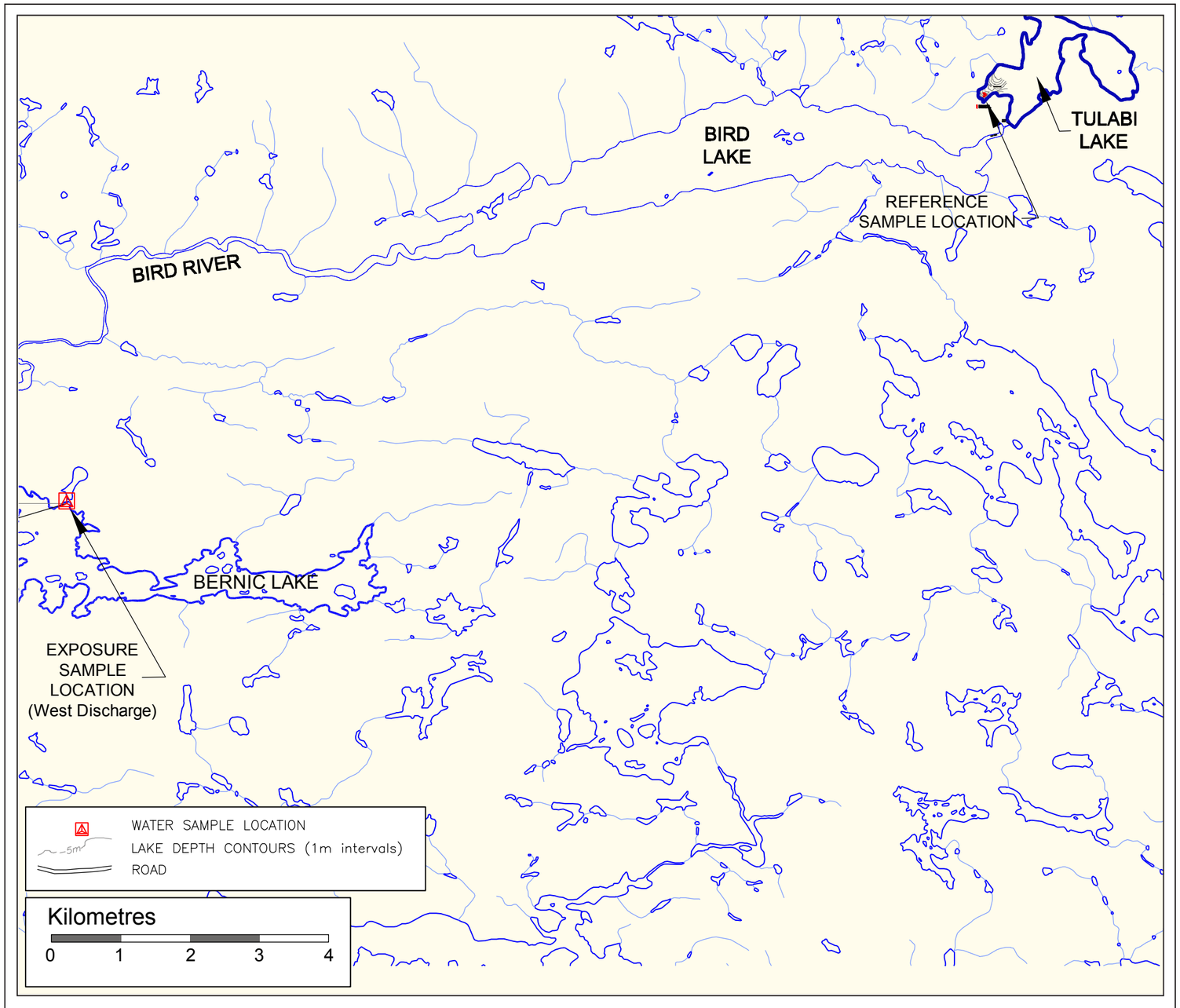

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FIGURE 5.5
TULABI LAKE WATER QUALITY SAMPLE LOCATIONS

Table 5. 3 Water quality in Bernic Lake; 1968 to 1975 and 2002 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figure 5.4 for sampling locations Units are mg/L except as noted.

Sampling Date	Jun 1968[a] (n = 9; S1 - S9)			May 1969[b] (n = 9; S1 - S9)			May 1970[c] (n = 9; S1 - S9)			Dec 1975[d] (n = 1)	October 2002 (n = 3, summary of S2, S5 & S7)				
Parameter	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**		**Mean**	**SD**	**Max**	**Min**	**MWQSOG**
Physicochemical															
pH (pH units)	6.85	7.01	6.71	6.5	6.72	6.1	7	7.4	6.7	7.4	7.67	0.08	7.75	7.6	6.5 - 9.0
Hydroxide (OH^-)	--	--	--	--	--	--	--	--	--	--	<5	<5	<5	<5	
Specific Conductance (µS/cm@25°C)	45	48	40	52	80	42	52	70	44	58	132	6	137	126	
Total Dissolved Solids	42	44	36	52	60	42	75	101	55	70	71	5	75	66	
Hardness, dissolved	--	--	--	--	--	--	--	--	--	--	33.9	1.1	35.1	32.9	
Hardness, total	18	19	18	21.8	37.6	10	25	44	20	35.3					
Alkalinity (PP as $CaCO_3$)	--	--	--	--	--	--	--	--	--	--	<5	<5	<5	<5	
Alkalinity (Total as $CaCO_3$)	13	14	12	10	14	6	16	24	12	28	46	4	51	43	
Bicarbonate	15.9	17.1	14.6	12.2	15	7.3	20	29.3	14.6	34	56	5	62	52	
Carbonate	0	--	--	0	--	--	0	--	--	0	<6	<6	<6	<6	
Total Suspended Solids	9	16	4	13	30	2	7	24	1	<5	16	1	16	15	
Turbidity (NTU)	5	15	2	7	25	1	7	10	4	3	--	--	--	--	
True Colour (Col. Units)	36	38	33	61	65	55	65	70	60	5	--	--	--	--	
Secchi depth (m)	1.91	2.45	1.5	1.53	2.15	1.4	--	--	--	--	1.05	0.15	1.15	0.85	
Major Ions															
Potassium, dissolved (K+)	--	--	--	--	--	--	--	--	--	--	3.8	0.4	4.3	3.5	
Sodium, dissolved (Na^+)	1.6	1.9	1.3	2.2	2.8	1.5	1.44	1	2	<10.0	10.4	0.3	10.8	10.2	
Calcium, dissolved (Ca^{2+})	5.7	6.4	5.6	6.8	12.8	5	7.8	12	4.8	7.5	9.7	0.4	10.1	9.4	
Magnesium, dissolved (Mg^{2+})	0.88	1.2	0.48	1.3	2	0.63	1.84	2.44	1.46	4	2.3	0.1	2.4	2.3	
Chloride, dissolved (Cl^-)	0.7	0.9	0.6	1.3	1.5	1.2	0.88	1	0.5	4	6.1	0.8	6.8	5.2	
Fluoride, dissolved (F^-)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Sulphate, dissolved (SO_4^-)	--	--	--	--	--	--	--	--	--	<5.0	11.0	0.7	11.7	10.3	
Nutrients															
Organic Carbon, dissolved	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Organic Carbon, total	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Nitrite	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.06
Nitrate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Nitrate_Nitrite	--	--	--	--	--	--	--	--	--	--	<0.006	<0.006	<0.006	<0.006	
Ammonia	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Total Kjeldahl Nitrogen	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Total Nitrogen	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Phosphorus, dissolved	--	--	--	--	--	--	--	--	--	--	<0.05	<0.05	<0.05	<0.05	
Phosphorus, total	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.025
Biological															
Chlorophyll a	--	--	--	--	--	--	--	--	--	--	0.032	0.000	0.032	0.032	
Radiochemical															
Radium-226 (Bq/L)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	

Table 5.3 Cont'd. Water quality in Bernic Lake; 1968 to 1975 and 2002 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figure 5.4 for sampling locations. Units are mg/L except as noted.

Sampling Date	June to September 2003 (n = 6; S2, S5, S7)				March to September 2004 (n = 5; S2, S5, S7, W)				March to October 2005 (n = 6)				June to September 2006 (n = 4)				MWQSOG
Parameter	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	
Physicochemical																	
pH (pH units)	8.54	0.84	9.35	7.72	7.74	0.38	8.38	7.39	6.8	0.2	7.1	6.7	7.9	0.3	8.3	7.5	6.5 - 9.0
Hydroxide (OH^-)	<5	<5	<5	<5	--	--	--	--	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Specific Conductance (µS/cm@25°C)	166	27	221	148	--	--	--	--	152	23	196	135	171	22	203	151	
Total Dissolved Solids	83	3	88	78	--	--	--	--	133	30	182	90	106	12	120	92	
Hardness, dissolved	38.4	0.9	39.9	37.1	--	--	--	--	39	5	48	35	--	--	--	--	
Hardness, total	--	--	--	--	39.5	2.4	43.2	36.9	--	--	--	--	46	5	53	41	
Alkalinity (PP as $CaCO_3$)	--	--	--	--	--	--	--	--	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Alkalinity (Total as $CaCO_3$)	50	4	55	45	49	7	55	38	34.5	1.7	36.8	31.5	38.3	3.1	41.4	34.9	
Bicarbonate	53	13	67	40	--	--	--	--	42.1	2.1	44.8	38.4	46.7	3.8	50.5	42.6	
Carbonate	5	3	8	<5	--	--	--	--	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Total Suspended Solids	6	5	12	2	7	3	11	4	8	2	10	4	8	2	11	6	
Turbidity (NTU)	5.8	1.6	8.3	4.4	--	--	--	--	10	3	13	7	10.9	2.4	14.0	8.2	
True Colour (Col. Units)	21	3	24	18	--	--	--	--	33	11	40	15	24	8	30	15	
Secchi depth (m)	1.00	0.10	1.15	0.85	--	--	--	--	0.68	0.03	0.70	0.65	0.89	0.09	0.97	0.76	
Major Ions																	
Potassium, dissolved (K+)	3.8	0.3	4.2	3.4	--	--	--	--	--	--	--	--	--	--	--	--	
Sodium, dissolved (Na^+)	10.9	0.4	11.4	10.2	--	--	--	--	10.1	1.4	12.7	8.7	11.55	1.45	13.60	10.20	
Calcium, dissolved (Ca^{2+})	11.4	0.3	11.9	10.9	--	--	--	--	12.2	1.7	15.3	10.8	14.33	1.89	17.10	12.90	
Magnesium, dissolved (Mg^{2+})	2.45	0.04	2.50	2.39	--	--	--	--	2.15	0.18	2.48	1.96	2.37	0.15	2.56	2.24	
Chloride, dissolved (Cl^-)	6.4	0.2	6.7	6.1	--	--	--	--	5.5	0.7	6.8	5.0	6.0	0.7	6.5	4.9	
Fluoride, dissolved (F^-)	0.31	0.03	0.34	0.27	--	--	--	--	0.3	0.0	0.4	0.3	0.41	0.12	0.58	0.31	
Sulphate, dissolved (SO_4^-)	18.3	1.5	19.6	15.7	--	--	--	--	25.5	6.6	37.9	19.6	30.3	9.2	44.0	24.3	
Nutrients																	
Organic Carbon, dissolved	15.1	0.5	15.8	14.6	--	--	--	--	17	1	17	16	13.1	0.9	13.9	12.2	
Organic Carbon, total	15.6	1.0	17.1	14.3	--	--	--	--	15	0	15	15	12.8	0.8	13.6	12.0	
Nitrite	--	--	--	--	--	--	--	--	<0.005	<0.005	0.011	<0.005	0.005	0.005	0.013	<0.005	0.06
Nitrate	--	--	--	--	0.15	0.15	0.38	<0.05	0.2	0.3	0.7	<0.02	0.09	0.05	0.13	<0.02	
Nitrate_Nitrite	<0.05	<0.05	0.06	<0.05	--	--	--	--	0.2	0.3	0.7	<0.02	0.09	0.05	0.13	<0.02	
Ammonia	0.16	0.15	0.30	<0.05	0.22	0.16	0.37	<0.05	0.09	0.18	0.46	0.01	0.010	0.009	0.020	<0.005	
Total Kjeldahl Nitrogen	--	--	--	--	--	--	--	--	1.2	0.1	1.3	1.0	1.09	0.49	1.80	0.70	
Total Nitrogen	--	--	--	--	--	--	--	--	1.3	0.4	2.0	1.1	1.18	0.53	1.93	0.70	
Phosphorus, dissolved	<0.05	<0.05	0.06	<0.05	--	--	--	--	<0.005	<0.005	0.009	<0.005	0.01275	0.014	0.033	0.004	
Phosphorus, total	<0.05	<0.05	0.10	<0.05	--	--	--	--	0.044	0.013	0.059	0.023	0.0345	0.006	0.041	0.027	0.025
Biological																	
Chlorophyll a	0.017	0.006	0.025	0.011	--	--	--	--	0.009	0.005	0.015	0.004	0.02705	0.0154	0.0489	0.0133	
Radiochemical																	
Radium-226 (Bq/L)	--	--	--	--	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	

Table 5.3 Cont'd. Water quality in Bernic Lake; 1968 to 1975 and 2002 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figure 5.4 for sampling locations. Units are mg/L except as noted.

Sampling Date	June to October 2007 (n = 4)				June to October 2008 (n = 4)				May to October 2009 (n = 4)				June to October 2010 (n = 4)				
Parameter	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**MWQSOG**
Physicochemical																	
pH (pH units)	7.7	0.1	7.8	7.6	7.5	0.05	7.6	7.5	7.6	0.1	7.7	7.5	7.7	0.1	7.8	7.6	6.5 - 9.0
Hydroxide (OH^-)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Specific Conductance (µS/cm@25°C)	147	7	152	136	170	18	190	150	144	9	150	131	121	9	131	111	
Total Dissolved Solids	113	19	136	94	123	17	140	100	114	19	140	94	90	8	96	82	
Hardness, dissolved	39.8	1.3	40.9	38.6	42.9	2.6	46.3	40.6	39.0	2.1	40.2	35.9	33.9	0.8	34.6	32.9	
Hardness, total	40.0	2.1	41.3	36.8	43.8	2.4	46.1	41.2	37.9	3.0	41.5	34.7	35.7	2.2	38.8	33.6	
Alkalinity (PP as $CaCO_3$)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Alkalinity (Total as $CaCO_3$)	32.7	2.3	35.6	30.1	28.0	2.2	31.0	26.0	33	2	35	30	37	3	39	32	
Bicarbonate	39.9	2.9	43.5	36.8	34.3	2.6	38.0	32.0	40	3	43	36	45	4	48	39	
Carbonate	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Total Suspended Solids	7	2	10	5	8	1	10	7	11	1	12	9	13	2	15	10	
Turbidity (NTU)	9.2	3.2	12.0	6.0	11.3	1.6	12.7	9.0	17.6	2.2	19.5	14.4	16.4	3.0	19.1	12.2	
True Colour (Col. Units)	33	5	40	30	33	5	40	30	40	8	50	30	48	5	50	40	
Secchi depth (m)	0.73	0.29	1.10	0.40	0.60	0.28	0.90	0.25	0.52	0.28	0.93	0.25	0.30	0.01	0.35	0.3	
Major Ions																	
Potassium, dissolved (K+)	3.36	0.25	3.61	3.12	3.69	0.29	3.95	3.36	2.99	0.20	3.22	2.75	2.55	0.06	2.60	2.50	
Sodium, dissolved (Na^+)	9.6	0.7	10.4	8.9	9.32	0.84	10.40	8.40	8.00	0.64	8.56	7.44	6.82	0.37	7.29	6.40	
Calcium, dissolved (Ca^{2+})	12.4	0.4	12.8	12.0	13.48	0.90	14.60	12.70	12.1	0.7	12.5	11.0	10.3	0.4	10.7	9.9	
Magnesium, dissolved (Mg^{2+})	2.16	0.06	2.25	2.10	2.25	0.10	2.37	2.12	2.15	0.07	2.20	2.05	2.02	0.09	2.10	1.90	
Chloride, dissolved (Cl^-)	5.1	0.2	5.3	5.0	4.9	0.5	5.4	4.3	4.2	0.3	4.5	3.9	3.3	0.5	3.9	2.6	
Fluoride, dissolved (F^-)	0.33	0.04	0.38	0.29	0.35	0.04	0.39	0.31	0.29	0.02	0.31	0.27	0.23	0.03	0.25	0.19	
Sulphate, dissolved (SO_4^-)	27.1	3.9	32.0	22.9	38.5	6.0	45.0	32.0	29	7	37	20	17	3	21	14	
Nutrients																	
Organic Carbon, dissolved	12.7	1.4	14.3	11.3	7.8	5.0	10.5	<0.5	11.9	1.1	12.9	10.7	12.1	1.6	14.3	10.7	
Organic Carbon, total	13.3	1.4	14.4	11.4	11.8	0.4	12.3	11.5	12.3	1.4	13.6	10.3	12.7	1.6	14.6	11.3	
Nitrite	<0.002	<0.002	0.002	<0.002	0.006	0.005	0.011	<0.002	<0.002	<0.002	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	0.06
Nitrate	0.012	0.012	0.023	<0.002	0.131	0.169	0.368	0.005	0.046	0.088	0.177	<0.002	0.003	0.003	0.007	<0.002	
Nitrate_Nitrite	0.013	0.014	0.025	<0.002	0.137	0.173	0.379	0.005	0.047	0.090	0.182	<0.002	0.003	0.003	0.007	<0.002	
Ammonia	<0.005	<0.005	0.007	<0.005	0.28	0.52	1.06	<0.01	0.01	0.01	0.03	<0.005	0.02	0.02	0.02	0.005	
Total Kjeldahl Nitrogen	1.08	0.22	1.35	0.86	0.78	0.57	1.28	0.01	0.78	0.43	1.22	0.38	0.83	0.30	1.22	0.51	
Total Nitrogen	1.09	0.22	1.35	0.88	1.17	0.40	1.66	0.68	0.82	0.38	1.23	0.44	0.81	0.36	1.22	0.52	
Phosphorus, dissolved	0.032	0.020	0.053	0.005	0.011	0.003	0.014	<0.005	0.025	0.025	0.058	0.006	0.017	0.018	0.044	0.004	
Phosphorus, total	0.042	0.016	0.058	0.021	0.039	0.013	0.050	0.020	0.040	0.025	0.062	0.008	0.040	0.042	0.096	0.007	0.025
Biological																	
Chlorophyll a	0.0165	0.0085	0.0278	0.0071	0.0161	0.0064	0.0226	0.0082	0.0174	0.0064	0.0240	0.0088	0.00973	0.00476	0.0166	0.0062	
Radiochemical																	
Radium-226 (Bq/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	

Table 5.3 Cont'd. Water quality in Bernic Lake; 1968 to 1975 and 2002 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG;Williamson 2011). See Figure 5.4 for sampling locations. Units are mg/L except as noted.

Sampling Date	May to October 2011 (n = 4)				June to October 2012 (n = 4)				
Parameter	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**MWQSOG**
Physicochemical									
pH (pH units)	7.6	0.2	7.8	7.4	8.1	0.8	8.9	7.2	6.5 - 9.0
Hydroxide (OH^-)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Specific Conductance (µS/cm@25°C)	114	3	118	110	118	6	127	114	
Total Dissolved Solids	90	14	110	78	88	7	96	80	
Hardness, dissolved	32.2	1.6	34.2	30.3	33.8	1.1	35.1	32.7	
Hardness, total	33.4	2.0	35.7	31.4	33.5	1.5	35.6	32.2	
Alkalinity (PP as $CaCO_3$)	<0.5	<0.5	<0.5	<0.5	0.8	0.8	2.0	<0.5	
Alkalinity (Total as $CaCO_3$)	34	3	36	30	33	1	34	33	
Bicarbonate	42	3	44	37	39	3	42	35	
Carbonate	<0.5	<0.5	<0.5	<0.5	0.8	1.1	2.4	<0.5	
Total Suspended Solids	9	2	12	7	8	1	9	7	
Turbidity (NTU)	14.1	2.4	16.8	11.0	8.6	2.6	12.0	5.7	
True Colour (Col. Units)	43	13	60	30	19	3	22	16	
Secchi depth (m)	0.39	0.10	0.50	0.30	0.48	0.37	1.75	0.40	
Major Ions									
Potassium, dissolved (K+)	2.30	0.08	2.40	2.21	2.47	0.16	2.62	2.28	
Sodium, dissolved (Na^+)	5.72	0.61	6.40	5.00	6.86	0.59	7.66	6.27	
Calcium, dissolved (Ca^{2+})	9.7	0.5	10.4	9.1	10.1	0.4	10.7	9.8	
Magnesium, dissolved (Mg^{2+})	1.91	0.11	2.00	1.80	2.04	0.09	2.18	1.99	
Chloride, dissolved (Cl^-)	3.5	0.5	4.1	2.8	3.7	0.2	3.9	3.4	
Fluoride, dissolved (F^-)	0.20	0.02	0.22	0.19	0.21	0.01	0.22	0.20	
Sulphate, dissolved (SO_4^-)	15.5	4.4	21.0	11.0	14.1	1.9	16.0	11.9	
Nutrients									
Organic Carbon, dissolved	12.3	1.2	13.8	11.1	11.3	0.6	12.0	10.7	
Organic Carbon, total	13.0	1.3	14.7	11.6	12.0	1.5	14.0	10.6	
Nitrite	<0.002	<0.002	<0.002	<0.002	0.003	0.002	0.006	<0.002	0.06
Nitrate	0.002	0.001	0.003	<0.002	0.005	0.004	0.010	<0.002	13.000
Nitrate_Nitrite	0.002	0.001	0.003	<0.002	0.006	0.004	0.010	<0.002	
Ammonia	0.05	0.05	0.13	<0.005	0.02	0.01	0.04	0.0082	
Total Kjeldahl Nitrogen	0.53	0.06	0.61	0.47	0.96	0.16	1.17	0.83	
Total Nitrogen	0.53	0.06	0.61	0.47	0.97	0.16	1.18	0.83	
Phosphorus, dissolved	0.007	0.002	0.010	0.005	0.009	0.001	0.010	0.008	
Phosphorus, total	0.037	0.025	0.068	0.009	0.049	0.006	0.055	0.043	0.025
Biological									
Chlorophyll a	0.013075	0.007507	0.0194	0.0042	0.0143	0.0105	0.0236	0.0048	
Radiochemical									
Radium-226 (Bq/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	

[a]Crowe (1969); [b]Crowe (1972a); [c]Crowe (1972b); [d]Crowe (1976)

Table 5. 4 Water quality in Tulabi Lake; 2005 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figure 5.5 for sampling locations. Units are mg/L except as noted.

Sampling Date	March to October 2005 (n = 6)				June to September 2006 (n = 4)				June to October 2007 (n = 4)				
Parameter	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**MWQSOG**
Physico-chemical													
pH (pH units)	6.7	0.3	7.1	6.4	7.4	0.2	7.6	7.1	7.2	0.1	7.2	7.1	6.5 - 9.0
Hydroxide (OH^-)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Specific Conductance (µS/cm@25°C)	79	49	131	34	37	1	38	36	32	2	34	30	
Total Dissolved Solids	68	47	115	20	32	6	38	24	45	8	54	38	
Hardness, dissolved	25	11	35	14	--	--	--	--	14	1	15	14	
Hardness, total	--	--	--	--	15.8	0.5	16.0	15.0	13.9	1.0	15.2	13.0	
Alkalinity (PP as $CaCO_3$)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Alkalinity (Total as $CaCO_3$)	22.7	11.2	35.7	11.6	12.2	0.2	12.4	11.9	9.6	0.5	10.1	9.1	
Bicarbonate	27.6	13.6	43.5	14.2	14.8	0.3	15.1	14.5	11.8	0.6	12.4	11.1	
Carbonate	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Total Suspended Solids	3	2	6	<1	2	1	3	1	2	1	3	2	
Turbidity (NTU)	4.5	2.9	7.8	1.8	1.4	0.4	1.7	1.0	2.2	0.7	3.1	1.4	
True Colour (Col. Units)	44	5	50	40	33	5	40	30	43	5	50	40	
Secchi depth (m)	1.92	0.09	2.00	1.80	2.87	0.41	3.44	2.56	1.38	0.15	1.50	1.20	
Major Ions													
Potassium, dissolved (K^+)	--	--	--	--	--	--	--	--	0.65	0.05	0.70	0.60	
Sodium, dissolved (Na^+)	4.89	4.25	9.39	1.02	1.09	0.05	1.14	1.02	0.94	0.06	0.99	0.88	
Calcium, dissolved (Ca^{2+})	6.93	3.76	10.50	3.46	3.90	0.16	4.12	3.75	3.53	0.11	3.63	3.42	
Magnesium, dissolved (Mg^{2+})	1.74	0.38	2.17	1.39	1.47	0.06	1.55	1.43	1.34	0.06	1.40	1.28	
Chloride, dissolved (Cl^-)	2.6	2.0	5.2	0.8	0.5	0.4	1.1	<0.5	1.0	0.9	2.2	<0.5	
Fluoride, dissolved (F^-)	0.14	0.10	0.25	0.04	0.06	0.01	0.07	0.04	0.05	0.01	0.06	0.03	
Sulphate, dissolved (SO_4^-)	9.4	8.4	17.8	1.7	0.7	0.6	1.6	<0.5	0.7	0.3	0.9	<0.5	
Nutrients													
Organic Carbon, dissolved	13.9	3.5	19.0	10.7	10.5	0.4	11.0	10.1	11.1	0.3	11.4	10.8	
Organic Carbon, total	13.0	3.5	18.0	9.8	10.2	0.5	10.8	9.6	11.8	1.1	13.0	10.3	
Nitrite	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.002	0.0005	0.002	<0.002	0.06
Nitrate	0.0483	0.0564	0.1600	0.0100	0.0425	0.0395	0.0900	<0.020	0.0095	0.0070	0.0180	<0.002	
Nitrate_Nitrite	0.0483	0.0564	0.1600	0.0100	0.0425	0.0395	0.0900	<0.020	0.0110	0.0079	0.0200	<0.002	
Ammonia	0.068	0.109	0.290	0.015	0.013	0.012	0.024	<0.005	0.008	0.008	0.019	<0.005	
Total Kjeldahl Nitrogen	0.76	0.37	1.30	0.43	0.33	0.20	0.49	0.05	0.51	0.06	0.58	0.44	
Total Nitrogen	0.82	0.41	1.35	0.46	0.37	0.18	0.55	0.14	0.52	0.05	0.59	0.46	
Phosphorus, total dissolved	0.011	0.005	0.017	0.005	0.009	0.006	0.016	0.003	0.019	0.012	0.032	0.005	
Phosphorus, total	0.022	0.009	0.039	0.015	0.021	0.002	0.023	0.018	0.022	0.009	0.034	0.012	0.025
Biological													
Chlorophyll a	0.0060	0.0027	0.0091	0.0039	0.0029	0.0009	0.0040	0.0018	0.0047	0.0005	0.0054	0.0042	
Radiochemical													
Radium 226 (Bq/L)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.005	<0.005	<0.005	<0.005	

Figure 5.4 Cont'd. Water quality in Tulabi Lake; 2005 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figure 5.5 for sampling locations. Units are mg/L except as noted.

Sampling Date	June to October 2008 (n = 4)				May to September 2009 (n = 4)				May to September 2010 (n = 4)				
Parameter	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**MWQSOG**
Physico-chemical													
pH (pH units)	7.0	0.2	7.3	6.8	7.1	0.1	7.2	7.0	7.07	0.10	7.20	6.98	6.5 - 9.0
Hydroxide (OH^-)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Specific Conductance (µS/cm@25°C)	32	1	33	30	31	2	33	29	31	2	33	28	
Total Dissolved Solids	38	16	62	28	33	8	42	24	21	4	26	16	
Hardness, dissolved	14	1	15	13	14	1	15	14	14.0	1.2	15.6	12.8	
Hardness, total	14.5	0.4	14.9	14.0	13.7	0.8	14.8	12.9	14.3	1.3	16.3	13.4	
Alkalinity (PP as $CaCO_3$)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Alkalinity (Total as $CaCO_3$)	7.0	2.3	10.0	4.9	10.1	0.7	11.0	9.5	11.4	1.5	13.0	9.6	
Bicarbonate	8.6	2.7	12.0	6.0	12.3	0.5	13.0	12.0	14.0	1.8	16.0	12.0	
Carbonate	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Total Suspended Solids	2	1	2	1	3	1	4	2	2	1	3	1	
Turbidity (NTU)	3.1	3.3	7.9	0.9	2.7	1.1	4.2	1.6	2.1	0.8	3.1	1.2	
True Colour (Col. Units)	43	5	50	40	55	6	60	50	48	5	50	40	
Secchi depth (m)	1.75	0.12	1.90	1.50	1.48	0.26	1.85	1.10					
Major Ions													
Potassium, dissolved (K^+)	0.58	0.05	0.62	0.51	0.57	0.04	0.61	0.53	0.6	0.0	0.6	0.5	
Sodium, dissolved (Na^+)	0.88	0.04	0.92	0.83	0.84	0.07	0.94	0.78	0.8	0.0	0.9	0.8	
Calcium, dissolved (Ca^{2+})	3.45	0.17	3.69	3.32	3.46	0.17	3.70	3.32	3.4	0.3	3.8	3.1	
Magnesium, dissolved (Mg^{2+})	1.29	0.10	1.43	1.20	1.34	0.11	1.50	1.27	1.4	0.1	1.5	1.2	
Chloride, dissolved (Cl^-)	0.8	0.2	1.1	0.6	1.0	0.1	1.2	0.9	<0.5	0.5	0.7	<0.5	
Fluoride, dissolved (F^-)	0.13	0.18	0.39	0.03	0.04	0.01	0.05	0.04	0.05	0.02	0.07	0.04	
Sulphate, dissolved (SO_4^-)	1.4	1.6	3.8	<0.5	1.0	0.4	1.3	0.5	<0.5	0.2	0.7	<0.5	
Nutrients													
Organic Carbon, dissolved	10.9	1.3	11.9	9.1	11.5	1.7	13.8	10.0	10.4	0.5	11.1	10.0	
Organic Carbon, total	10.9	0.9	11.7	9.8	11.4	1.8	13.4	9.0	10.8	0.1	10.9	10.6	
Nitrite	0.0025	0.001732051	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	<0.002	0.06
Nitrate	0.0040	0.0041	0.0100	<0.002	0.0183	0.0154	0.0400	0.0060	0.011	0.006	0.017	0.007	
Nitrate_Nitrite	0.0063	0.0048	0.0120	<0.002	0.0183	0.0154	0.0400	0.0060	0.009	0.007	0.017	<0.002	
Ammonia	0.105	0.124	0.290	<0.01	0.038	0.055	0.120	0.008	0.033	0.026	0.058	<0.005	
Total Kjeldahl Nitrogen	0.25	0.16	0.36	0.01	0.34	0.06	0.40	0.27	0.44	0.09	0.54	0.38	
Total Nitrogen	0.32	0.04	0.36	0.28	0.36	0.06	0.42	0.31	0.48	0.10	0.60	0.39	
Phosphorus, total dissolved	0.008	0.006	0.014	<0.005	0.016	0.012	0.031	0.006	0.004	0.003	0.008	<0.002	
Phosphorus, total	0.021	0.010	0.035	0.013	0.019	0.010	0.033	0.010	0.007	0.004	0.012	0.002	0.025
Biological													
Chlorophyll a	0.0033	0.0011	0.0042	0.0017	3.3500	0.8185	4.2000	2.6000	2.5	0.5	3.2	2.0	
Radiochemical													
Radium 226 (Bq/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	

Figure 5.4 Cont'd. Water quality in Tulabi Lake; 2005 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figure 5.5 for sampling locations.

Sampling Date	May to September 2011 (n = 4)				May to September 2012 (n = 4)				
Parameter	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**MWQSOG**
Physico-chemical									
pH (pH units)	7.1	0.1	7.2	7.0	6.9	0.2	7.2	6.7	6.5 - 9.0
Hydroxide (OH^-)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Specific Conductance (µS/cm@25°C)	31	2	33	29	33	1	34	32	
Total Dissolved Solids	29	3	32	24	30	2	32	28	
Hardness, dissolved	13.8	0.6	14.7	13.4	14.2	0.3	14.4	13.8	
Hardness, total	13.8	1.0	15.0	12.8	14.5	0.4	14.8	13.9	
Alkalinity (PP as $CaCO_3$)	<0.5	<0.5	<0.5	<0.5	<1	<1	<1	<0.50	
Alkalinity (Total as $CaCO_3$)	12	1	12	11	11	1	12	10	
Bicarbonate	14	1	14	13	13	1	15	12	
Carbonate	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Total Suspended Solids	2	1	3	1	2	1	3	1	
Turbidity (NTU)	2.0	0.7	2.7	1.4	1.1	0.2	1.4	0.9	
True Colour (Col. Units)	38	5	40	30	41	9	50	30	
Secchi depth (m)	1.53	0.23	1.75	1.25	1.72	0.18	2.00	1.50	
Major Ions									
Potassium, dissolved (K^+)	0.53	0.02	0.55	0.50	0.57	0.03	0.60	0.54	
Sodium, dissolved (Na^+)	0.79	0.05	0.85	0.75	0.86	0.03	0.88	0.81	
Calcium, dissolved (Ca^{2+})	3.4	0.1	3.5	3.3	3.5	0.1	3.6	3.4	
Magnesium, dissolved (Mg^{2+})	1.30	0.08	1.41	1.24	1.33	0.05	1.38	1.27	
Chloride, dissolved (Cl^-)	1.0	0.4	1.6	0.7	1.0	0.1	1.2	0.9	
Fluoride, dissolved (F^-)	0.04	0.01	0.05	0.04	0.04	0.00	0.04	0.04	
Sulphate, dissolved (SO_4^-)	<0.5	0.3	0.8	<0.5	0.6	0.4	1.0	<0.5	
Nutrients									
Organic Carbon, dissolved	10.7	0.6	11.2	9.9	9.8	0.8	10.3	8.6	
Organic Carbon, total	11.2	0.6	11.6	10.4	9.9	1.5	10.9	7.7	
Nitrite	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	0.06
Nitrate	0.009	0.009	0.017	<0.002	0.007	0.005	0.013	<0.002	13.000
Nitrate_Nitrite	0.009	0.009	0.017	<0.002	0.007	0.005	0.013	<0.002	
Ammonia	0.03	0.01	0.05	0.02	0.03	0.02	0.05	0.0097	
Total Kjeldahl Nitrogen	0.33	0.05	0.41	0.29	0.45	0.01	0.46	0.44	
Total Nitrogen	0.34	0.06	0.42	0.29	0.46	0.01	0.46	0.45	
Phosphorus, total dissolved	0.005	0.003	0.009	<0.002	0.007	0.001	0.008	0.005	
Phosphorus, total	0.011	0.003	0.015	0.008	0.015	0.003	0.018	0.013	0.025
Biological									
Chlorophyll a	0.0036	0.001407125	0.0056	0.0023	0.0038	0.0003	0.0041	0.0034	
Radiochemical									
Radium 226 (Bq/L)	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	0.005	<0.005	

Units are mg/L except as noted.

Table 5. 5 Dissolved metal concentrations (mg/L) in Bernic Lake; 2002 to 2012. (no data available for 1968 to 1975). Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figures 5.4 for sampling locations.

Sampling Date	October 2002 (n = 3, summary of S2, S5 & S7)				June to September 2003 (n = 6; S2, S5, S7)				March to September 2004 (n = 5; S2, S5, S7, W)				
	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Dissolved Metals													
Aluminum (Al)	<0.005	<0.005	<0.005	<0.005	--	--	--	--	--	--	--	--	
Antimony (Sb)	0.0010	0.0002	0.0011	0.0008	--	--	--	--	--	--	--	--	
Arsenic (As)	0.0019	0.0005	0.0023	0.0013	--	--	--	--	--	--	--	--	0.15
Barium (Ba)	0.017	0.010	0.029	0.011	--	--	--	--	--	--	--	--	
Beryllium (Be)	<0.0001	<0.0001	<0.0001	<0.0001	--	--	--	--	--	--	--	--	
Bismuth (Bi)	<0.0005	<0.0005	<0.0005	<0.0005	--	--	--	--	--	--	--	--	
Boron (B)	0.038	0.003	0.042	0.036	--	--	--	--	--	--	--	--	
Cadmium (Cd)	<0.00001	<0.00001	<0.00001	<0.00001	--	--	--	--	--	--	--	--	0.000728 [a]
Cesium (Cs)	--	--	--	--	--	--	--	--	--	--	--	--	
Chromium (Cr)	0.0008	0.0004	0.0012	0.0005	--	--	--	--	--	--	--	--	0.2423 [a]
Cobalt (Co)	<0.0001	<0.0001	<0.0001	<0.0001	--	--	--	--	--	--	--	--	
Copper (Cu)	<0.001	<0.001	0.001	<0.001	--	--	--	--	--	--	--	--	0.0050 [a]
Iron (Fe)	<0.01	<0.01	<0.01	<0.01	<0.02	<0.02	0.02	<0.02	--	--	--	--	
Lead (Pb)	<0.0001	<0.0001	<0.0001	<0.0001	--	--	--	--	--	--	--	--	0.0204 [a]
Lithium (Li)	1.48	0.08	1.56	1.40	--	--	--	--	--	--	--	--	
Manganese	<0.005	<0.005	<0.005	<0.005	0.013	0.012	0.032	<0.007	--	--	--	--	
Mercury (Hg)	<0.0001	<0.0001	<0.0001	<0.0001	--	--	--	--	--	--	--	--	
Molybdenum (Mo)	0.003	0.001	0.004	0.003	--	--	--	--	--	--	--	--	
Nickel (Ni)	<0.0005	<0.0005	<0.0005	<0.0005	--	--	--	--	--	--	--	--	0.1936 [a]
Rubidium (Rb)	--	--	--	--	--	--	--	--	--	--	--	--	
Selenium (Se)	<0.0002	<0.0002	<0.0002	<0.0002	--	--	--	--	--	--	--	--	
Silicon (Si)	0.84	0.13	0.99	0.75	--	--	--	--	--	--	--	--	
Silver (Ag)	<0.0001	<0.0001	<0.0001	<0.0001	--	--	--	--	--	--	--	--	
Strontium (Sr)	0.042	0.004	0.047	0.039	--	--	--	--	--	--	--	--	
Sulphur (S)	3.67	0.24	3.89	3.42	--	--	--	--	--	--	--	--	
Tantalum (Ta)	--	--	--	--	--	--	--	--	--	--	--	--	
Thallium (Tl)	<0.00005	<0.00005	<0.00005	<0.00005	--	--	--	--	--	--	--	--	
Tin (Sn)	--	--	--	--	--	--	--	--	--	--	--	--	
Titanium (Ti)	<0.0005	<0.0005	<0.0005	<0.0005	--	--	--	--	--	--	--	--	
Uranium (U)	--	--	--	--	--	--	--	--	--	--	--	--	
Vanadium (V)	0.0001	0.0000	0.0001	0.0001	--	--	--	--	--	--	--	--	
Zinc (Zn)	<0.001	<0.001	<0.001	<0.001	--	--	--	--	--	--	--	--	0.0484 [a]
Zirconium (Zr)	--	--	--	--	--	--	--	--	--	--	--	--	

Table 5.5 Cont'd. Dissolved metal concentrations (mg/L) in Bernic Lake; 2002 to 2012. (no data available for 1968 to 1975). Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figures 5.4 for sampling locations.

Sampling Date	March to October 2005 (n = 6)				June to September 2006 (n = 4)				June to October 2007 (n = 4)				
	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Dissolved Metals													
Aluminum (Al)	0.014	0.009	0.028	0.006	0.0073	0.0034	0.0110	0.0028	0.0100	0.0041	0.0157	0.0061	
Antimony (Sb)	0.0006	0.0002	0.0009	0.0004	0.00065	0.00021	0.00094	0.00048	0.00048	0.00007	0.00056	0.00041	
Arsenic (As)	0.001	0.000	0.002	0.001	0.0019	0.0004	0.0024	0.0016	0.0013	0.0001	0.0013	0.0012	0.15
Barium (Ba)	0.0093	0.0012	0.0112	0.0079	0.00885	0.00356	0.01240	0.00397	0.01007	0.00094	0.01080	0.00883	
Beryllium (Be)	<0.00005	<0.00005	0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Bismuth (Bi)	<0.00005	<0.00005	0.00008	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Boron (B)	0.037	0.007	0.045	0.029	0.040	0.007	0.048	0.032	0.036	0.004	0.040	0.032	
Cadmium (Cd)	<0.00001	<0.00001	0.00002	<0.00001	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	0.00001	<0.00001	0.000728 [a]
Cesium (Cs)	0.00071	0.00097	0.00244	0.00024	0.34925	0.05613	0.42700	0.29300	0.330	0.017	0.352	0.312	
Chromium (Cr)	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	0.0003	<0.0002	0.2423 [a]
Cobalt (Co)	0.00006	0.00006	0.00019	0.00003	0.00003	0.00001	0.00004	0.00002	0.00004	0.00001	0.00004	0.00003	
Copper (Cu)	0.0006	0.0002	0.0009	0.0003	0.0003	0.0003	0.0006	<0.0001	0.0003	0.0001	0.0004	0.0002	0.0050 [a]
Iron (Fe)	0.05	0.06	0.15	0.01	<0.005	<0.005	<0.005	<0.005	0.010	0.005	0.014	<0.005	
Lead (Pb)	<0.00002	<0.00002	0.00003	<0.00002	0.00003	<0.00002	0.00004	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	0.0204 [a]
Lithium (Li)	1.36	0.31	1.74	1.05	1.8800	0.7580	2.8300	1.0500	1.30	0.19	1.47	1.06	
Manganese	0.108	0.224	0.562	0.002	0.00271	0.00163	0.00482	0.00094	0.00067	0.00027	0.00092	0.00030	
Mercury (Hg)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Molybdenum (Mo)	0.00329	0.00087	0.00446	0.00236	0.00398	0.00086	0.00493	0.00288	0.00295	0.00047	0.00357	0.00253	
Nickel (Ni)	0.0013	0.0015	0.0043	<0.0005	<0.0005	<0.0005	0.0012	<0.0005	<0.0005	<0.0005	0.0007	<0.0005	0.1936 [a]
Rubidium (Rb)	0.0004	0.0003	0.0008	0.0002	0.34675	0.08021	0.46000	0.27100	0.273	0.036	0.325	0.246	
Selenium (Se)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	
Silicon (Si)	--	--	--	--	--	--	--	--	3.01	0.12	3.19	2.93	
Silver (Ag)	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	0.00001	0.00003	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
Strontium (Sr)	0.0451	0.0074	0.0594	0.0384	0.0538	0.0069	0.0638	0.0480	0.046	0.002	0.049	0.045	
Sulphur (S)	--	--	--	--	--	--	--	--	9.4	1.1	10.8	8.3	
Tantalum (Ta)	--	--	--	--	--	--	--	--	--	--	--	--	
Thallium (Tl)	<0.00005	<0.00005	0.00015	<0.00005	<0.00005	<0.00005	0.00008	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Tin (Sn)	0.00047	0.00050	0.00106	<0.00005	<0.00005	<0.00005	0.00005	<0.00005	<0.00005	<0.00005	0.00006	<0.00005	
Titanium (Ti)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	
Uranium (U)	0.00016	0.00004	0.00021	0.00011	0.00023	0.00010	0.00035	0.00011	0.00011	0.00001	0.00012	0.00010	
Vanadium (V)	0.00005	<0.00005	0.00010	<0.00005	0.00015	0.00002	0.00017	0.00013	0.00013	0.00003	0.00017	0.00010	
Zinc (Zn)	0.001	0.0007	0.002	<0.0005	0.0018	0.0021	0.0049	<0.0005	0.0010	0.0009	0.0022	<0.0005	0.0484 [a]
Zirconium (Zr)	<0.005	<0.005	0.01	<0.005	<0.009	<0.009	<0.009	<0.009	<0.005	<0.005	<0.005	<0.005	

Table 5.5 Cont'd. Dissolved metal concentrations (mg/L) in Bernic Lake; 2002 to 2012. (no data available for 1968 to 1975). Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figures 5.4 for sampling locations.

Sampling Date	June to October 2008 (n = 4)				May to October 2009 (n = 4)				June to October 2010 (n = 4)				
	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Dissolved Metals													
Aluminum (Al)	0.0114	0.0017	0.0136	0.0099	0.012	0.006	0.018	0.006	0.013	0.003	0.018	0.010	
Antimony (Sb)	0.00057	0.00014	0.00074	0.00040	0.0004	0.0001	0.0005	0.0003	0.00034	0.00005	0.00040	0.00030	
Arsenic (As)	0.00122	0.00025	0.00145	0.00097	0.0013	0.0003	0.0016	0.0009	0.00151	0.00040	0.00203	0.00120	0.15
Barium (Ba)	0.00853	0.00229	0.01190	0.00691	0.0081	0.0014	0.0101	0.0072	0.00721	0.00319	0.01180	0.00464	
Beryllium (Be)	0.00002	0.00001	0.00002	0.00001	<0.00005	<0.00005	<0.00005	<0.00005	0.00003	0.00002	0.00005	0.00001	
Bismuth (Bi)	<0.000005	<0.000005	<0.000005	<0.000005	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.000005	
Boron (B)	<0.05	<0.05	<0.05	<0.05	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.05	
Cadmium (Cd)	<0.000005	<0.000005	<0.000005	<0.000005	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.000005	0.000728 [a]
Cesium (Cs)	0.3490	0.0374	0.3860	0.2970	0.70	0.22	0.90	0.41	0.8305	0.0766	0.9140	0.7340	
Chromium (Cr)	<0.0001	<0.0001	0.0001	<0.0001	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0001	0.2423 [a]
Cobalt (Co)	0.00005	0.00001	0.00007	0.00003	0.00004	0.00001	0.00005	0.00003	0.00003	0.00001	0.00004	0.00003	
Copper (Cu)	0.00041	0.00010	0.00054	0.00029	0.0006	0.0003	0.0010	0.0004	0.0003	0.0002	0.0005	<0.0003	0.0050 [a]
Iron (Fe)	0.010	0.003	0.013	0.007	0.027	0.011	0.036	0.011	0.014	0.013	0.033	<0.005	
Lead (Pb)	0.000016	0.000011	0.000030	<0.000005	<0.00003	<0.00003	0.00006	<0.00003	<0.00003	<0.00003	<0.00003	<0.000005	0.0204 [a]
Lithium (Li)	1.6100	0.1598	1.8000	1.4500	1.20	0.14	1.35	1.02	0.963	0.096	1.080	0.870	
Manganese	0.00424	0.00462	0.00978	0.00040	0.0015	0.0016	0.0037	<0.0003	0.0007	0.0005	0.0013	0.0003	
Mercury (Hg)	<0.00001	<0.00001	<0.00001	<0.00001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00001	
Molybdenum (Mo)	0.00340	0.00093	0.00431	0.00251	0.0025	0.0005	0.0030	0.0019	0.0020	0.0002	0.0022	0.0018	
Nickel (Ni)	0.00101	0.00057	0.00163	0.00049	0.0008	0.0007	0.0017	0.0002	0.0006	0.0005	0.0013	0.0002	0.1936 [a]
Rubidium (Rb)	0.2938	0.0190	0.3150	0.2740	0.25	0.02	0.28	0.23	0.2180	0.0187	0.2340	0.1960	
Selenium (Se)	0.00005	<0.00004	0.00008	<0.00004	<0.0002	<0.0002	<0.0002	<0.0002	0.00009	0.00002	<0.0002	0.0001	
Silicon (Si)	3.5	0.1	3.6	3.3	3.6	0.1	3.6	3.5	3.4	0.2	3.6	3.3	
Silver (Ag)	<0.000005	<0.000005	<0.000005	<0.000005	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.000005	
Strontium (Sr)	0.05893	0.00697	0.06650	0.05020	0.0498	0.0032	0.0539	0.0462	0.0426	0.0025	0.0460	0.0403	
Sulphur (S)	14	2	16	11	10	3	13	6	<50	<50	<50	<10	
Tantalum (Ta)	<0.000001	<0.000001	<0.000001	<0.000001	--	--	--	--	--	--	--	--	
Thallium (Tl)	0.000044	0.000021	0.000065	0.000020	0.00002	0.00001	0.00003	<0.00001	0.00001	0.00000	0.00002	0.00001	
Tin (Sn)	0.00001	0.00001	0.00002	<0.00001	<0.00005	<0.00005	0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00001	
Titanium (Ti)	<0.0005	<0.0005	0.0006	<0.0005	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0005	
Uranium (U)	0.000133	0.000029	0.000155	0.000090	0.00017	0.00005	0.00023	0.00013	0.00016	0.00006	0.00022	0.00008	
Vanadium (V)	<0.0002	<0.0002	0.0002	<0.0002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0002	
Zinc (Zn)	0.0009	0.0006	0.0015	<0.0001	<0.0005	<0.0005	0.0007	<0.0005	0.0007	0.0005	0.0014	0.0002	0.0484 [a]
Zirconium (Zr)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0001	

Table 5.5 Cont'd. Dissolved metal concentrations (mg/L) in Bernic Lake; 2002 to 2012. (no data available for 1968 to 1975). Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figures 5.4 for sampling locations.

Sampling Date	June to October 2011 (n = 4)				May to October 2012 (n = 4)				
	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Dissolved Metals									
Aluminum (Al)	0.012	0.006	0.017	0.006	0.012	0.007	0.023	0.006	
Antimony (Sb)	0.00032	0.00010	0.00040	0.00020	0.00035	0.00016	0.00058	0.00021	
Arsenic (As)	0.00172	0.00049	0.00220	0.00110	0.00156	0.00047	0.00209	0.00097	0.15
Barium (Ba)	0.00892	0.00110	0.01010	0.00760	0.00884	0.00268	0.01140	0.00522	
Beryllium (Be)	<0.00005	<0.00005	<0.00005	<0.00001	<0.00005	<0.00005	<0.00005	<0.00005	
Bismuth (Bi)	<0.00003	<0.00003	<0.00003	<0.000005	<0.000025	<0.000025	<0.000025	<0.000025	
Boron (B)	<0.3	<0.3	<0.3	<0.05	<0.25	<0.25	<0.25	<0.25	
Cadmium (Cd)	<0.00003	4.94975E-06	0.000022	<0.00003	<0.000025	<0.000025	<0.000025	<0.000025	0.000728 [a]
Cesium (Cs)	1.1350	0.1827	1.3800	0.9500	1.1800	0.1219	1.3600	1.0900	
Chromium (Cr)	<0.0005	<0.0005	<0.0005	<0.0001	<0.00050	<0.00050	<0.00050	<0.00050	0.2423 [a]
Cobalt (Co)	0.00003	0.00001	0.00004	<0.00003	0.00003	0.00000	0.00003	0.000026	
Copper (Cu)	0.0004	0.0002	0.0006	<0.0003	0.0004	0.0000	0.0004	0.00033	0.0050 [a]
Iron (Fe)	0.035	0.010	0.044	<0.005	0.005	0.002	0.007	<0.005	
Lead (Pb)	<0.00003	<0.00003	<0.00003	0.000012	0.000062	0.0000811	0.000182	<0.000025	0.0204 [a]
Lithium (Li)	0.881	0.061	0.957	0.818	0.850	0.079	0.958	0.769	
Manganese	0.0764	0.1504	0.3020	0.0006	0.0011	0.0010	0.0025	0.0003	
Mercury (Hg)	<0.00005	<0.00005	<0.00005	<0.00001	<0.00005	<0.00005	<0.00005	<0.00005	
Molybdenum (Mo)	0.0018	0.0009	0.0030	0.0009	0.0019	0.0004	0.0025	0.0015	
Nickel (Ni)	0.0002	0.0001	0.0004	<0.0001	0.0003	0.0001	0.0004	0.0002	0.1936 [a]
Rubidium (Rb)	0.1983	0.0121	0.2160	0.1890	0.2178	0.0267	0.2530	0.1910	
Selenium (Se)	0.00014	0.00011	0.0003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Silicon (Si)	3.5	0.2	3.7	3.3	3.7	0.2	3.9	3.5	
Silver (Ag)	<0.00003	<0.00003	<0.00003	<0.000005	<0.000025	<0.000025	<0.000025	<0.000025	
Strontium (Sr)	0.0397	0.0033	0.0435	0.0357	0.0390	0.0018	0.0408	0.0366	
Sulphur (S)	<50	<50	<50	<10	<50	<50	<50	<50	
Tantalum (Ta)	--	--	--	--	--	--	--	--	
Thallium (Tl)	0.00001	0.00001	0.00002	<0.00001	0.00002	0.00001	0.00003	0.00001	
Tin (Sn)	0.00004	3.34166E-05	0.00009	0.00002	<0.001	<0.001	<0.001	<0.001	
Titanium (Ti)	<0.003	<0.003	<0.003	<0.0005	<0.0025	<0.0025	<0.0025	<0.0025	
Uranium (U)	0.00020	0.00014	0.00040	0.00010	0.00034	0.00043	0.00096	0.00005	
Vanadium (V)	0.000575	0.000298608	0.001	0.0003	0.001525	0.001617354	0.0039	<0.0010	
Zinc (Zn)	0.0023	0.0014	0.0039	0.0008	0.0012	0.0004	0.0015	0.0009	0.0484 [a]
Zirconium (Zr)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	

a Calculated range based on average dissolved water hardness (35.2 mg/L).

All samples are surface measurements.

Table 5. 6 Dissolved metal concentrations (mg/L) in Tulabi Lake; 2005 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figure 5.5 for sampling locations.

Sampling Date	March to October 2005 (n = 6)				June to September 2006 (n = 4)				June to October 2007 (n = 4)				
Parameter	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**	**MWQSOG**
Dissolved Metals													
Aluminum (Al)	0.0271	0.0048	0.0310	0.0194	0.0232	0.0064	0.0324	0.0177	0.0407	0.0147	0.0600	0.0276	
Antimony (Sb)	0.00020	0.00019	0.00038	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Arsenic (As)	0.0007	0.0002	0.0009	0.0005	0.0006	0.0001	0.0007	0.0005	0.0005	0.0001	0.0006	0.0004	0.15
Barium (Ba)	0.00887	0.00232	0.01250	0.00708	0.00729	0.00070	0.00828	0.00672	0.00742	0.00025	0.00773	0.00720	
Beryllium (Be)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.000045	0.00002	0.00007	<0.00005	
Bismuth (Bi)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Boron (B)	0.019	0.013	0.031	<0.008	0.006	0.004	0.012	<0.008	<0.008	0.003	0.009	<0.008	
Cadmium (Cd)	0.00001	0.00001	0.00002	<0.00001	0.00002	0.00002	0.00004	<0.00001	<0.00001	0.00000	0.00001	<0.00001	0.00031 [a]
Cesium (Cs)	0.00006	0.00008	0.00018	<0.00001	0.00011	0.00014	0.00031	<0.00003	0.00020	0.00020	0.00048	<0.00003	
Chromium (Cr)	0.0003	0.0002	0.0004	<0.0002	0.0003	0.0003	0.0007	<0.0002	0.0003	0.0002	0.0006	<0.0002	0.1192 [a]
Cobalt (Co)	0.00004	0.00001	0.00005	0.00003	<0.00002	<0.00002	<0.00002	<0.00002	0.00003	0.00002	0.00006	<0.00002	
Copper (Cu)	0.0008	0.0002	0.0010	0.0006	0.0007	0.0001	0.0007	0.0006	0.0009	0.0003	0.0013	0.0007	0.0022 [a]
Iron (Fe)	0.111	0.058	0.207	0.035	0.061	0.010	0.072	0.052	0.097	0.025	0.134	0.080	
Lead (Pb)	0.00003	0.00002	0.00007	<0.00002	0.00004	0.00002	0.00006	0.00002	0.00003	0.00001	0.00004	0.00003	0.0077 [a]
Lithium (Li)	0.6205	0.6923	1.4700	0.0008	0.0011	0.0003	0.0014	0.0008	0.0014	0.0008	0.0025	0.0009	
Manganese (Mn)	0.00230	0.00123	0.00473	0.00148	0.00127	0.00040	0.00170	0.00088	0.00117	0.00048	0.00187	0.00083	
Mercury (Hg)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Molybdenum (Mo)	0.00093	0.00098	0.00207	0.00004	0.00006	0.00001	0.00007	0.00005	0.00005	0.00001	0.00007	0.00004	
Nickel (Ni)	0.00068	0.00023	0.00090	0.00025	0.00075	0.00006	0.00080	0.00070	0.00098	0.00019	0.00110	0.00070	0.0930 [a]
Rubidium (Rb)	0.0001	0.0001	0.0002	<0.0001	0.0018	0.0002	0.0020	0.0016	0.0021	0.0004	0.0028	0.0018	
Selenium (Se)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	
Silicon (Si)	--	--	--	--	--	--	--	--	0.65	0.07	0.72	0.59	
Silver (Ag)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	
Strontium (Sr)	0.0250	0.0111	0.0364	0.0145	0.0170	0.0016	0.0194	0.0161	0.0145	0.0008	0.0153	0.0134	
Sulphur (S)	--	--	--	--	--	--	--	--	0.7	0.0	0.8	0.7	
Tantalum (Ta)	--	--	--	--	--	--	--	--	--	--	--	--	
Thallium (Tl)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Tin (Sn)	0.00055	0.00064	0.00150	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00008	0.00007	0.00018	<0.00005	
Titanium (Ti)	<0.0005	0.0002	0.0007	<0.0005	0.0005	0.0002	0.0007	<0.0005	0.0005	0.0002	0.0007	<0.0005	
Uranium (U)	0.00009	0.00001	0.00010	0.00008	0.00008	0.00001	0.00009	0.00006	0.00008	0.00001	0.00009	0.00007	
Vanadium (V)	0.00014	0.00009	0.00024	<0.00005	0.00016	0.00001	0.00017	0.00014	0.00019	0.00003	0.00022	0.00015	
Zinc (Zn)	0.0010	0.0005	0.0015	<0.0005	0.0075	0.0059	0.0134	0.0013	0.0012	0.0004	0.0017	0.0007	0.0232 [a]
Zirconium (Zr)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.006	<0.005	<0.005	<0.005	<0.005	<0.005	

Table 5.6 Cont'd. Dissolved metal concentrations (mg/L) in Tulabi Lake; 2005 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figure 5.5 for sampling locations.

Sampling Date	June to October 2008 (n = 4)				May to September 2009 (n = 4)				May to September 2010 (n = 4)				
Parameter	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Dissolved Metals													
Aluminum (Al)	0.0426	0.0058	0.0501	0.0361	0.0638	0.0134	0.0836	0.0543	0.0507	0.0087	0.0561	0.0376	
Antimony (Sb)	0.00004	0.00000	0.00004	0.00004	0.00004	0.00001	0.00005	0.00003	0.00004	0.00000	0.00004	0.00004	
Arsenic (As)	0.0005	0.0000	0.0005	0.0004	0.0005	0.0000	0.0005	0.0004	0.00043	0.00005	0.00049	0.00038	0.15
Barium (Ba)	0.00749	0.00017	0.00765	0.00728	0.00769	0.00049	0.00835	0.00721	0.00735	0.00025	0.00758	0.00699	
Beryllium (Be)	<0.00001	0.000005	0.00001	<0.00001	0.00001	0.00001	0.00002	<0.00001	0.00001	0.00001	0.00002	<0.00001	
Bismuth (Bi)	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	
Boron (B)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.05	<0.05	<0.05	<0.05	
Cadmium (Cd)	0.00000	0.00000	0.00001	<0.000005	0.00001	0.00001	0.00001	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	0.00031 [a]
Cesium (Cs)	0.00084	0.00158	0.00320	<0.0001	0.00024	0.00038	0.00080	<0.0001	0.0003	0.0005	0.0010	<0.0001	
Chromium (Cr)	0.0003	0.0001	0.0003	0.0002	0.0002	0.0001	0.0003	0.0001	0.0003	0.0001	0.0004	0.0001	0.1192 [a]
Cobalt (Co)	0.00002	0.00000	0.00003	0.00002	0.00003	0.00001	0.00004	0.00002	0.000022	0.000003	0.000024	0.000018	
Copper (Cu)	0.0007	0.0001	0.0008	0.0007	0.0010	0.0003	0.0014	0.0007	0.00107	0.00074	0.00218	0.00063	0.0022 [a]
Iron (Fe)	0.090	0.025	0.123	0.064	0.112	0.021	0.134	0.092	0.071	0.006	0.080	0.065	
Lead (Pb)	0.00003	0.00001	0.00004	0.00002	0.00004	0.00001	0.00005	0.00003	0.00003	0.00001	0.00003	0.00002	0.0077 [a]
Lithium (Li)	0.0013	0.0009	0.0026	0.0009	0.0010	0.0001	0.0012	0.0009	0.0008	0.0002	0.0009	0.0005	
Manganese (Mn)	0.00186	0.00135	0.00356	0.00064	0.00558	0.00747	0.01670	0.00095	0.00100	0.00067	0.00200	0.00058	
Mercury (Hg)	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	0.00001	0.00003	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
Molybdenum (Mo)	0.00006	0.00004	0.00011	<0.00005	<0.00005	0.00003	0.00009	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Nickel (Ni)	0.00100	0.00020	0.00125	0.00077	0.00106	0.00004	0.00112	0.00102	0.00099	0.00009	0.00110	0.00087	0.0930 [a]
Rubidium (Rb)	0.0025	0.0017	0.0051	0.0016	0.0017	0.0006	0.0022	0.0008	0.0017	0.0002	0.0019	0.0015	
Selenium (Se)	0.00007	0.00002	0.00009	0.00005	0.00009	0.00001	0.00009	0.00008	0.00009	0.00001	0.0001	0.0001	
Silicon (Si)	0.80	0.08	0.90	0.70	1.10	0.08	1.20	1.00	1.1	0.1	1.2	0.9	
Silver (Ag)	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	
Strontium (Sr)	0.0147	0.0003	0.0150	0.0143	0.0143	0.0006	0.0147	0.0135	0.0143	0.0005	0.0147	0.0136	
Sulphur (S)	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<10	<10	<10	<10	
Tantalum (Ta)	<0.000001	<0.000001	<0.000001	<0.000001	--	--	--	--	--	--	--	--	
Thallium (Tl)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	3.0E-06	0.000003	0.000001	0.000004	0.000002	
Tin (Sn)	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	0.00001	0.00002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
Titanium (Ti)	0.0009	0.0003	0.0013	0.0006	0.0009	0.0001	0.0010	0.0007	0.0008	0.0005	0.0013	0.0005	
Uranium (U)	0.00010	0.00001	0.00012	0.00009	0.00011	0.00004	0.00017	0.00009	0.000101	0.000037	0.000149	0.000071	
Vanadium (V)	0.00025	0.00006	0.00030	0.00020	0.00025	0.00013	0.00040	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Zinc (Zn)	0.0012	0.0004	0.0014	0.0006	0.0013	0.0005	0.0020	0.0008	0.0012	0.0006	0.0021	0.0008	0.0232 [a]
Zirconium (Zr)	0.00015	0.00006	0.0002	0.0001	0.0002	0	0.0002	0.0002	0.0002	0.0001	0.0002	0.0001	

Table 5.6 Cont'd. Dissolved metal concentrations (mg/L) in Tulabi Lake; 2005 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figure 5.5 for sampling locations.

Sampling Date	May to October 2011 (n = 4)				May to October 2012 (n = 4)				
	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Dissolved Metals									
Aluminum (Al)	0.047	0.015	0.062	0.030	0.0320	0.0052	0.0374	0.0272	
Antimony (Sb)	0.00004	0.00001	0.00005	0.00004	0.00004	0.00000	0.00004	0.00004	
Arsenic (As)	0.00048	0.00006	0.00054	0.00040	0.00047	0.00008	0.00054	0.00036	0.15
Barium (Ba)	0.00740	0.00106	0.00895	0.00666	0.00661	0.00033	0.00700	0.00620	
Beryllium (Be)	<0.00001	<0.00001	0.00001	<0.00001	<0.000010	<0.000010	0.00001	<0.000010	
Bismuth (Bi)	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	
Boron (B)	<0.05	<0.05	<0.05	<0.05	<0.050	<0.050	<0.050	<0.050	
Cadmium (Cd)	0.00001	0.00001	0.00002	<0.000005	<0.000005	0.00000275	0.000008	<0.000005	0.00031 [a]
Cesium (Cs)	<0.0001	<0.0001	0.0003	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	
Chromium (Cr)	0.0003	0.0001	0.0003	0.0002	0.0002	0.0001	0.0003	0.0001	0.1192 [a]
Cobalt (Co)	0.000023	0.000004	0.000027	0.000018	0.000022	0.000003	0.000026	0.000019	
Copper (Cu)	0.00100	0.00023	0.00132	0.00081	0.00115	0.00034	0.00158	0.00078	0.0022 [a]
Iron (Fe)	0.118	0.029	0.160	0.095	0.084	0.019	0.110	0.0674	
Lead (Pb)	0.00005	0.00001	0.00006	0.00004	0.00002	0.00001	0.00004	0.00001	0.0077 [a]
Lithium (Li)	0.0009	0.0001	0.0010	0.0007	0.0008	0.0001	0.0009	0.0007	
Manganese	0.00315	0.00246	0.00675	0.00121	0.00200	0.00213	0.00518	0.00080	
Mercury (Hg)	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
Molybdenum (Mo)	0.00005	0.00001	0.00006	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Nickel (Ni)	0.00090	0.00003	0.00094	0.00086	0.00082	0.00012	0.00093	0.00071	0.0930 [a]
Rubidium (Rb)	0.0016	0.0001	0.0017	0.0014	0.0019	0.0003	0.0022	0.0016	
Selenium (Se)	0.00009	0.00001	0.00009	0.0001	0.00009	0.00002	0.000116	0.0001	
Silicon (Si)	1.0	0.2	1.2	0.8	0.7	0.2	0.9	0.5	
Silver (Ag)	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	
Strontium (Sr)	0.0145	0.0008	0.0152	0.0135	0.0133	0.0007	0.0141	0.0124	
Sulphur (S)	<10	<10	<10	<10	<10	<10	<10	<10	
Tantalum (Ta)	--	--	--	--	--	--	--	--	
Thallium (Tl)	0.000003	0.000001	0.000004	0.000003	0.000004	0.000001	0.000004	0.000003	
Tin (Sn)	0.00003	0.00001	0.00003	<0.00001	<0.0002	<0.0002	<0.0002	<0.0002	
Titanium (Ti)	0.0008	0.0000	0.0008	0.0008	<0.0005	0.0002	0.0007	<0.0005	
Uranium (U)	0.000102	0.000010	0.000111	0.000092	0.000075	0.000013	0.000091	0.000061	
Vanadium (V)	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Zinc (Zn)	0.0018	0.0013	0.0030	0.0005	0.0011	0.0004	0.0016	0.0005	0.0232 [a]
Zirconium (Zr)	0.0001	0.0001	0.0002	<0.0001	0.0001	0.0000	0.0001	0.0001	

[a] Calculated based on average dissolved hardness (14.8 mg/L).

Table 5. 7 Total metal concentrations (mg/L) in Bernic Lake; 1975 and 2002 to 2012 (no data available for 1968 to 1970). Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figures 5.4 for sampling locations.

Sampling Date	Dec 1975[a] (n = 1; S1)	October 2002 (n = 3, summary of S2, S5 & S7)				June to September 2003 (n = 6; S2, S5, S7)				March to September 2004 (n = 5; S2, S5, S7, W)				
		Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Total Metals														
Aluminum (Al)	--	0.061	0.005	0.065	0.055	0.01	0.01	0.03	<0.01	0.017	0.006	0.025	0.011	0.100 [b]
Antimony (Sb)	--	0.0007	0.0001	0.0007	0.0006	0.0011	0.0006	0.0022	0.0007	--	--	--	--	
Arsenic (As)	--	0.0023	0.0004	0.0026	0.0018	0.002	0.0004	0.0025	0.0015	0.0015	0.0003	0.0019	0.0010	
Barium (Ba)	--	0.013	0.001	0.014	0.013	0.013	0.003	0.016	0.01	--	--	--	--	
Beryllium (Be)	--	<0.0001	<0.0001	<0.0001	<0.0001	<0.0002	<0.0002	<0.0002	<0.0002	--	--	--	--	
Bismuth (Bi)	--	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	--	--	--	--	
Boron (B)	--	0.035	0.001	0.035	0.034	0.045	0.003	0.048	0.041	--	--	--	--	
Cadmium (Cd)	0.005	0.00009	0.00004	0.00014	0.00006	<0.00002	<0.00002	0.00004	<0.00002	0.00004	0.00001	<0.0001	0.00003	
Calcium (Ca)	--	10.1	0.9	11	9.2	11.4	0.7	12.4	10.4	--	--	--	--	
Cesium (Cs)	--	0.248	0.015	0.26	0.232	--	--	--	--	--	--	--	--	
Chromium (Cr)	--	0.0024	0.0005	0.0028	0.0019	<0.001	<0.001	<0.001	<0.001	--	--	--	--	
Cobalt (Co)	--	0.0001	<0.0001	0.0002	<0.0001	<0.0002	<0.0002	<0.0002	<0.0002	--	--	--	--	
Copper (Cu)	0.076	0.001	0	0.001	0.001	<0.002	<0.002	<0.002	<0.002	<0.001	0.001	<0.01	<0.001	
Iron (Fe)	--	0.7	0.3	1	0.4	<0.2	<0.2	<0.2	<0.2	0.1	0.1	0.1	<0.1	0.3
Lead (Pb)	0.01	0.0004	0.0001	0.0005	0.0003	0.0005	0.0003	0.0007	<0.0001	0.0004	0.0002	0.0006	0.0002	
Lithium (Li)	--	1.79	0.09	1.86	1.69	1.61	0.09	1.73	1.5	--	--	--	--	
Magnesium (Mg)	--	2.6	0.2	2.7	2.4	2.3	0.2	2.5	2.1	--	--	--	--	
Manganese (Mn)	--	0.191	0.229	0.456	0.054	0.082	0.05	0.158	0.021	--	--	--	--	
Mercury (Hg)	--	--	--	--	--	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.00003	0.0001
Molybdenum (Mo)	--	0.003	0.001	0.004	0.003	0.004	0	0.004	0.003	0.004	0.001	0.004	0.003	0.073
Nickel (Ni)	0.01	0.0014	0.0002	0.0016	0.0013	<0.001	<0.001	<0.001	<0.001	0.0011	0.0008	0.0025	0.0006	
Potassium (K)	--	3.1	0.1	3.2	3	4	0.2	4.2	3.7	--	--	--	--	
Rubidium (Rb)	--	0.209	0.009	0.217	0.199	--	--	--	--	--	--	--	--	
Selenium (Se)	--	<0.0002	<0.0002	0.0002	<0.0002	<0.0004	<0.0004	<0.0004	<0.0004	--	--	--	--	0.001
Silicon (Si)	--	0.87	0.09	0.98	0.81	0.93	0.11	1.07	0.81	--	--	--	--	
Silver (Ag)	--	<0.0001	<0.0001	<0.0001	<0.0001	<0.0002	<0.0002	<0.0002	<0.0002	--	--	--	--	0.0001
Sodium (Na)	--	10.4	0.6	10.8	9.7	11.6	0.3	12	11.1	--	--	--	--	
Strontium (Sr)	--	0.044	0.001	0.045	0.043	0.05	0.002	0.053	0.047	--	--	--	--	
Sulphur (S)	--	4.82	0.22	5.03	4.59	5.67	0.54	6.16	4.69	--	--	--	--	
Tantalum (Ta)	--	--	--	--	--	--	--	--	--	--	--	--	--	
Thallium (Tl)	--	<0.00005	<0.00005	<0.00005	<0.00005	<0.0001	<0.0001	<0.0001	<0.0001	--	--	--	--	0.0008
Tin (Sn)	--	--	--	--	--	<0.002	<0.002	0.003	<0.002	--	--	--	--	
Titanium (Ti)	--	0.0018	0.001	0.0029	0.001	<0.001	<0.001	<0.001	<0.001	--	--	--	--	
Uranium (U)	--	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	--	--	--	--	
Vanadium (V)	--	0.0002	0	0.0002	0.0002	0.0003	0.0001	0.0004	0.0002	--	--	--	--	
Zinc (Zn)	0.01	0	0	0.004	0.002	0.006	0.005	0.016	0.001	0.005	0.003	0.008	0.001	
Zirconium (Zr)	--	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	<0.002	<0.002	--	--	--	--	

Table 5.7 Cont'd Total metal concentrations (mg/L) in Bernic Lake; 1975 and 2002 to 2012 (no data available for 1968 to 1970). Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figures 5.4 for sampling locations.

Sampling Date	March to October 2005 (n = 6)				June to September 2006 (n = 4)				June to October 2007 (n = 4)				
	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Total Metals													
Aluminum (Al)	0.0293	0.02	0.0657	0.0111	0.0221	0.004	0.0261	0.0166	0.0228	0.0059	0.0309	0.0171	0.100 [b]
Antimony (Sb)	0.0007	0.0002	0.001	0.0004	0.00065	0.00023	0.00097	0.00047	0.00048	0.00006	0.00053	0.00042	
Arsenic (As)	0.002	0	0.002	0.001	0.002	0.0002	0.0022	0.0017	0.0014	0.0002	0.0016	0.0012	
Barium (Ba)	0.0125	0.001	0.0135	0.0107	0.01072	0.00335	0.0147	0.0068	0.0121	0.0018	0.0146	0.0105	
Beryllium (Be)	<0.00005	<0.00005	0.00014	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Bismuth (Bi)	<0.00005	<0.00005	0.00007	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Boron (B)	0.038	0.005	0.044	0.032	0.045	0.007	0.054	0.04	0.038	0.002	0.04	0.035	
Cadmium (Cd)	0.00001	0.00001	0.00003	<0.00001	0.00001	<0.00001	0.00002	<0.00001	<0.00001	<0.00001	0.00001	<0.00001	
Calcium (Ca)	12	2	15	11	14.85	1.58	17.1	13.5	12.4	0.7	12.8	11.4	
Cesium (Cs)	0.00029	0.00004	0.00035	0.00025	0.37125	0.06749	0.469	0.315	0.356	0.008	0.365	0.345	
Chromium (Cr)	0.0004	0.0004	0.001	<0.0002	0.0005	0.0003	0.0007	<0.0002	0.0003	0.0002	0.0005	<0.0002	
Cobalt (Co)	0.0001	0.0001	0.0003	0.0001	0.00006	0.00003	0.00009	0.00003	0.00007	0.00002	0.00009	0.00006	
Copper (Cu)	0.0007	0.0003	0.001	0.0004	0.0005	0.0004	0.001	0.0001	0.0004	0.0001	0.0006	0.0003	
Iron (Fe)	0.46		0.46	0.46	0.054	0.027	0.081	0.021	0.059	0.015	0.073	0.037	0.3
Lead (Pb)	0.00006	0.00003	0.00011	0.00002	0.00038	0.0006	0.00128	0.00007	0.00006	0.00002	0.00009	0.00004	
Lithium (Li)	1.4	0.5	2.4	1	2.04	0.3226	2.48	1.77	1.4	0.19	1.62	1.17	
Magnesium (Mg)	2.13	0.11	2.34	2.04	2.44	0.12	2.58	2.3	2.16	0.1	2.25	2.01	
Manganese (Mn)	0.192	0.233	0.653	0.052	0.09475	0.03969	0.124	0.037	0.0775	0.0224	0.0955	0.0447	
Mercury (Hg)	0.00005	<0.00005	0.00008	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.0001
Molybdenum (Mo)	0.00383	0.00107	0.00509	0.00259	0.00437	0.00101	0.00519	0.003	0.00309	0.00049	0.0037	0.00264	0.073
Nickel (Ni)	0.0018	0.0015	0.0046	0.0007	0.001	0.0005	0.0017	0.0006	0.0008	0.0002	0.001	0.0006	
Potassium (K)	4	1	4	3	4.01	0.36	4.52	3.72	3.42	0.4	3.83	2.98	
Rubidium (Rb)	0.0003	0	0.0003	0.0003	0.38625	0.11325	0.55	0.291	0.292	0.033	0.332	0.259	
Selenium (Se)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.001	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.001
Silicon (Si)	3.04	0.23	3.29	2.74	3.17	0.32	3.64	2.95	3.04	0.19	3.3	2.83	
Silver (Ag)	<0.00001	<0.00001	<0.00001	<0.00001	0.00002	0.00002	0.00004	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.0001
Sodium (Na)	10	1	11	9	11.78	1.18	13.2	10.4	9.37	0.73	10.1	8.36	
Strontium (Sr)	0.047	0.006	0.058	0.041	0.0529	0.0072	0.0636	0.0485	0.0485	0.0029	0.0528	0.0468	
Sulphur (S)	9.1	2.7	12.8	6.9	10.7	2.9	15	8.6	9.4	1.4	11.1	7.9	
Tantalum (Ta)	--	--	--	--	--	--	--	--	--	--	--	--	
Thallium (Tl)	0.00006	0.00006	0.00017	<0.00005	<0.00005	<0.00005	0.00009	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.0008
Tin (Sn)	0.00055	0.00058	0.00132	<0.00005	0.00009	0.00006	0.00017	<0.00005	0.00007	0.00002	0.00009	0.00005	
Titanium (Ti)	<0.0005	<0.0005	0.0006	<0.0005	<0.0005	<0.0005	0.0007	<0.0005	<0.0005	<0.0005	0.0008	<0.0005	
Uranium (U)	0.0002	0.00006	0.00027	0.00013	0.00027	0.00009	0.00037	0.00016	0.00013	0.00001	0.00014	0.00011	
Vanadium (V)	0.00011	0.00007	0.00019	<0.00005	0.0002	0.00005	0.00026	0.00016	0.00017	0.00003	0.00021	0.00014	
Zinc (Zn)	0.0013	0.0006	0.0022	0.0005	0.00395	0.0036	0.0087	0.001	0.0027	0.001	0.0037	0.0017	
Zirconium (Zr)	--	--	--	--	--	--	--	--	<0.005	<0.005	<0.005	<0.005	

Table 5.7 Cont'd. Total metal concentrations (mg/L) in Bernic Lake; 1975 and 2002 to 2012 (no data available for 1968 to 1970). Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figures 5.4 for sampling locations.

Sampling Date	June to October 2008 (n = 4)				May to October 2009 (n = 4)				June to October 2010 (n = 4)				
	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Total Metals													
Aluminum (Al)	0.021	0.0022	0.0231	0.0187	0.023	0.012	0.038	0.009	0.019	0.005	0.025	0.012	0.100 [b]
Antimony (Sb)	0.00058	0.00014	0.00074	0.00041	0.0004	0.0001	0.0006	0.0003	0.00035	0.00010	0.00040	0.00020	
Arsenic (As)	0.00134	0.00024	0.0016	0.00113	0.0014	0.0003	0.0017	0.001	0.00175	0.00044	0.00239	0.00140	
Barium (Ba)	0.01255	0.00254	0.0156	0.0098	0.0136	0.001	0.0144	0.0122	0.0130	0.0029	0.0171	0.0107	
Beryllium (Be)	0.00002	0.00001	0.00003	0.00001	<0.00005	<0.00005	<0.00005	<0.00005	0.00002	0.00000	<0.00005	0.00002	
Bismuth (Bi)	0.000005	0.000005	0.000013	<0.000005	<0.00003	<0.00003	<0.00003	<0.00003	<0.000005	<0.000005	<0.000005	<0.00003	
Boron (B)	<0.05	<0.05	<0.05	<0.05	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.05	
Cadmium (Cd)	0.000006	<0.000005	0.00001	<0.000005	0.00001	0.00002	0.00004	<0.000005	<0.00003	<0.00003	<0.00003	<0.000005	
Calcium (Ca)	13.68	0.93	14.5	12.6	12	1	13	11	10.8	0.7	11.7	10.1	
Cesium (Cs)	0.3808	0.0243	0.413	0.355	0.741	0.222	0.952	0.433	0.8790	0.0439	0.9160	0.8180	
Chromium (Cr)	<0.0001	<0.0001	0.0001	<0.0001	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0001	
Cobalt (Co)	0.000057	0.000018	0.00008	0.000043	0.00005	0.00001	0.00007	0.00004	0.00004	0.00002	0.00005	<0.00003	
Copper (Cu)	0.00049	0.00012	0.00063	0.00039	0.0006	0.0004	0.0011	0.0002	0.00050	0.00036	0.00100	<0.0003	
Iron (Fe)	0.058	0.023	0.088	0.031	0.105	0.048	0.154	0.041	0.065	0.023079572	0.098	0.045	0.3
Lead (Pb)	0.000045	0.000019	0.000066	0.00002	0.00005	0.00003	0.00009	0.00001	0.00004	0.00002	0.00006	<0.00003	
Lithium (Li)	1.645	0.1678	1.8	1.49	1.2	0.1	1.3	1.1	0.9630	0.0650	1.0200	0.8810	
Magnesium (Mg)	2.35	0.04	2.39	2.29	2.09	0.11	2.22	1.96	2.16	0.12	2.30	2.02	
Manganese (Mn)	0.1315	0.0839	0.21	0.0473	0.165	0.059	0.229	0.088	0.0706	0.0145	0.0820	0.0493	
Mercury (Hg)	<0.00001	<0.00001	<0.00001	<0.00001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00001	0.0001
Molybdenum (Mo)	0.00331	0.00087	0.00419	0.00247	0.0024	0.0005	0.0029	0.002	0.0021	0.0004	0.0025	0.0016	0.073
Nickel (Ni)	0.00118	0.0007	0.00205	0.00058	0.0009	0.0006	0.0017	0.0003	0.0006	0.0005	0.0013	0.0003	
Potassium (K)	3.71	0.24	3.94	3.45	2.91	0.14	3.02	2.71	2.73	0.14	2.90	2.60	
Rubidium (Rb)	0.3223	0.0118	0.332	0.307	0.269	0.021	0.296	0.246	0.2463	0.0244	0.2650	0.2130	
Selenium (Se)	0.00007	0.00001	0.00008	0.00005	<0.0002	<0.0002	<0.0002	<0.0002	0.00009	0.00002	<0.0002	0.00007	0.001
Silicon (Si)	3.6	0.2	3.8	3.4	3.7	0.2	3.9	3.5	3.5	0.2	3.7	3.2	
Silver (Ag)	<0.000005	<0.000005	0.000005	<0.000005	<0.00003	<0.00003	<0.00003	<0.00003	0.00002	0.00002	0.00004	<0.000005	0.0001
Sodium (Na)	9.62	0.9	10.4	8.8	7.7	0.56	8.24	7.08	7.31	0.49	8.00	6.90	
Strontium (Sr)	0.05908	0.00696	0.065	0.0504	0.048	0.0042	0.0524	0.0425	0.0436	0.0020	0.0465	0.0419	
Sulphur (S)	15	2	16	13	12	4	17	9	<50	<10	<50	<10	
Tantalum (Ta)	0.000002	0	0.000002	0.000002	--	--	--	--	--	--	--	--	
Thallium (Tl)	0.000047	0.000025	0.000075	0.000022	0.00002	0.00001	0.00003	0.00001	0.000016	0.000005	0.000020	0.000010	0.0008
Tin (Sn)	0.00002	0.00001	0.00003	<0.00001	<0.00005	<0.00005	0.00006	<0.00005	<0.00005	<0.00005	<0.00005	0.00001	
Titanium (Ti)	<0.0005	<0.0005	0.0005	<0.0005	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0005	
Uranium (U)	0.000137	0.000038	0.00018	0.000088	0.00017	0.00005	0.00024	0.00013	0.000134	0.000061	0.000200	0.000067	
Vanadium (V)	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0002	
Zinc (Zn)	0.0022	0.001	0.0037	0.0015	0.002	0.001	0.002	0.001	0.00170	0.00121	0.00340	0.00070	
Zirconium (Zr)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0001	

Table 5.7 Cont'd. Total metal concentrations (mg/L) in Bernic Lake; 1975 and 2002 to 2012 (no data available for 1968 to 1970). Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figure 5.4 for sampling locations.

Sampling Date	June to October 2011 (n = 4)				June to October 2012 (n = 4)				
	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Total Metals									
Aluminum (Al)	0.019	0.007	0.027	0.011	0.011	0.005	0.018	0.006	0.100 [b]
Antimony (Sb)	0.00033	0.00010	0.00040	0.00020	0.00035	0.00013	0.00054	0.00024	
Arsenic (As)	0.00220	0.00059	0.00280	0.00140	0.00173	0.00051	0.00229	0.00106	
Barium (Ba)	0.0141	0.0012	0.0156	0.0127	0.0117	0.0014	0.0134	0.0099	
Beryllium (Be)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Bismuth (Bi)	<0.00003	<0.00003	<0.00003	<0.00003	<0.000025	<0.000025	<0.000025	<0.000025	
Boron (B)	<0.3	<0.3	<0.3	<0.3	<0.25	<0.25	<0.25	<0.25	1.5
Cadmium (Cd)	0.00002	0.00002	<0.00003	0.00002	<0.000025	<0.000025	<0.000025	<0.000025	
Calcium (Ca)	10.1	0.7	10.9	9.3	10.0	0.5	10.7	9.5	
Cesium (Cs)	1.1775	0.1919	1.4600	1.0400	1.2250	0.1234	1.4100	1.1600	
Chromium (Cr)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	
Cobalt (Co)	0.00005	0.00001	0.00006	0.00003	0.00004	0.00001	0.00005	0.00003	
Copper (Cu)	0.0005	0.0003	0.0009	<0.0003	0.00055	0.00035	0.00103	0.00027	
Iron (Fe)	0.131	0.045	0.195	0.097	0.0558	0.012812754	0.0726	0.0414	0.3
Lead (Pb)	0.00008	0.00006	0.00016	<0.00003	0.00015	0.00006	0.00023	0.00011	
Lithium (Li)	0.8948	0.0482	0.9490	0.8330	0.8555	0.1259	1.0200	0.7160	
Magnesium (Mg)	2.00	0.08	2.10	1.90	2.05	0.07	2.15	2.01	
Manganese (Mn)	0.2271	0.2418	0.5860	0.0633	0.0684	0.0287	0.1080	0.0398	
Mercury (Hg)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00001	0.0001
Molybdenum (Mo)	0.0020	0.0006	0.0029	0.0016	0.0018	0.0006	0.0026	0.0010	0.073
Nickel (Ni)	0.0006	0.0006	0.0014	0.0001	0.0003	0.0001	0.0004	0.0002	
Potassium (K)	2.43	0.10	2.50	2.30	2.51	0.18	2.77	2.38	
Rubidium (Rb)	0.2085	0.0182	0.2340	0.1910	0.2303	0.0267	0.2670	0.2060	
Selenium (Se)	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.001
Silicon (Si)	3.7	0.1	3.8	3.6	3.5	0.3	3.7	3.1	
Silver (Ag)	<0.00003	<0.00003	<0.00003	<0.00003	<0.000025	<0.000025	<0.000025	<0.000025	0.0001
Sodium (Na)	6.13	0.33	6.50	5.80	6.82	0.79	8.01	6.39	
Strontium (Sr)	0.0408	0.0019	0.0430	0.0386	0.0389	0.0018	0.0411	0.0368	
Sulphur (S)	<50	<50	<50	<50	<50	<50	<50	<50	
Tantalum (Ta)	--	--	--	--	--	--	--	--	
Thallium (Tl)	0.00001	0.00001	0.00002	<0.00001	0.000014	0.000008	0.000023	<0.00001	0.0008
Tin (Sn)	<0.00005	<0.00005	0.00006	<0.00005	<0.001	<0.001	<0.001	<0.001	
Titanium (Ti)	<0.003	<0.003	<0.003	<0.003	<0.0025	<0.0025	<0.0025	<0.0025	
Uranium (U)	0.000190	0.000119	0.000360	0.000090	0.000331	0.000419	0.000945	0.000054	
Vanadium (V)	<0.001	0.001	0.002	<0.001	<0.001	0.0003	0.0011	<0.001	
Zinc (Zn)	0.00483	0.00262	0.00850	0.00230	0.00232	0.00129	0.00339	0.00073	
Zirconium (Zr)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	

[a] Crowe (1976).

[b] Guideline based on pH ≥ 6.5.

All samples are surface measurements

Table 5. 8 Total metal concentrations (mg/L) in Tulabi Lake; 2005 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figures 5.5 for sampling locations.

Sampling Date	March to October 2005 (n = 6)				June to September 2006 (n = 4)				June to October 2007 (n = 4)				
Parameter	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Total Metals													
Aluminum (Al)	0.0550	0.0187	0.0736	0.0335	0.0536	0.0117	0.0694	0.0431	0.0824	0.0117	0.0931	0.0658	0.100 [a]
Antimony (Sb)	0.00021	0.00020	0.00043	<0.00005	0.00005	0.00002	0.00007	<0.00005	<0.00005	0.00002	0.00006	<0.00005	
Arsenic (As)	0.0010	0.0005	0.0017	0.0005	0.0006	0.0001	0.0007	0.0005	0.0005	0.0000	0.0005	0.0005	
Barium (Ba)	0.01040	0.00292	0.01410	0.00772	0.00742	0.00023	0.00774	0.00719	0.00798	0.00039	0.00830	0.00742	
Beryllium (Be)	<0.00005	0.00002	0.00006	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Bismuth (Bi)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	
Boron (B)	0.022	0.011	0.034	0.011	0.008	0.004	0.012	<0.008	<0.008	0.005	0.015	<0.008	
Cadmium (Cd)	0.00001	0.00001	0.00004	<0.00001	0.00002	0.00003	0.00006	<0.00001	<0.00001	0.00001	0.00001	<0.00001	
Calcium (Ca)	6.95	3.70	10.60	3.55	4.01	0.20	4.23	3.83	3.44	0.23	3.74	3.21	
Cesium (Cs)	0.00018	0.00000	0.00018	0.00018	0.00007	0.00006	0.00013	<0.00003	0.00021	0.00025	0.00058	< 0.00010	
Chromium (Cr)	0.0007	0.0003	0.0010	0.0002	0.0007	0.0002	0.0009	0.0005	0.0006	0.0002	0.0008	0.0004	
Cobalt (Co)	0.00007	0.00001	0.00008	0.00006	0.00006	0.00004	0.00012	0.00003	0.00007	0.00001	0.00009	0.00006	
Copper (Cu)	0.00088	0.00015	0.00100	0.00060	0.00103	0.00019	0.00130	0.00090	0.00103	0.00017	0.00120	0.00080	
Iron (Fe)	0.101	0.000	0.101	0.101	0.155	0.051	0.227	0.117	0.192	0.036	0.245	0.170	0.3
Lead (Pb)	0.00025	0.00040	0.00107	0.00005	0.00049	0.00080	0.00169	0.00007	0.00014	0.00008	0.00025	0.00008	
Lithium (Li)	0.6044	0.6892	1.4100	0.0008	0.0011	0.0002	0.0013	0.0009	0.0015	0.0011	0.0031	0.0009	
Magnesium (Mg)	1.70	0.33	2.07	1.40	1.50	0.10	1.65	1.43	1.29	0.10	1.42	1.20	
Manganese (Mn)	0.03148	0.03607	0.09940	0.00890	0.01431	0.00997	0.02690	0.00582	0.01510	0.00438	0.02020	0.01070	
Mercury (Hg)	0.00005	0.00003	0.00008	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.0001
Molybdenum (Mo)	0.00108	0.00113	0.00238	0.00005	0.00008	0.00001	0.00008	0.00007	0.00006	0.00001	0.00007	0.00005	0.073
Nickel (Ni)	0.00102	0.00021	0.00120	0.00070	0.00093	0.00019	0.00120	0.00080	0.00105	0.00017	0.00120	0.00090	
Potassium (K)	1.750	1.369	3.000	<1.000	0.663	0.030	0.692	0.621	0.715	0.069	0.810	0.660	
Rubidium (Rb)	0.0002	0	0.0002	0.0002	0.0019375	0.000147733	0.00207	0.00175	0.002065	0.000179722	0.00229	0.00186	
Selenium (Se)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.001
Silicon (Si)	1.24	0.68	2.26	0.90	0.68	0.17	0.91	0.54	0.74	0.10	0.83	0.65	
Silver (Ag)	<0.000010	<0.000010	<0.000010	<0.000010	0.000039	0.000037	0.000090	<0.000010	0.000011	0.000013	0.000030	<0.000010	0.0001
Sodium (Na)	4.63	3.94	8.35	1.03	1.11	0.07	1.19	1.03	0.92	0.06	0.97	0.84	
Strontium (Sr)	0.0263	0.0122	0.0385	0.0148	0.0164	0.0010	0.0177	0.0156	0.0147	0.0009	0.0158	0.0138	
Sulphur (S)	2.0	2.7	6.0	0.7	0.8	0.1	0.9	0.7	0.8	0.2	1.0	0.7	
Tantalum (Ta)	--	--	--	--	--	--	--	--	--	--	--	--	
Thallium (Tl)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.0008
Tin (Sn)	0.00062	0.00071	0.00168	<0.00005	0.00008	0.00006	0.00016	<0.00005	0.00009	0.00005	0.00015	<0.00005	
Titanium (Ti)	0.0012	0.0007	0.0020	<0.0005	0.0013	0.0002	0.0015	0.0010	0.0016	0.0002	0.0018	0.0014	
Uranium (U)	0.00010	0.00001	0.00011	0.00009	0.00009	0.00001	0.00011	0.00008	0.00008	0.00001	0.00009	0.00007	
Vanadium (V)	0.00022	0.00014	0.00035	<0.00005	0.00024	0.00004	0.00030	0.00020	0.00023	0.00004	0.00027	0.00017	
Zinc (Zn)	0.0015	0.0007	0.0028	0.0007	0.0082	0.0062	0.0154	0.0015	0.0028	0.0008	0.0039	0.0021	
Zirconium (Zr)	--	--	--	--	--	--	--	--	<0.005	<0.005	<0.005	<0.005	

Table 5.8 Cont'd. Total metal concentrations (mg/L) in Tulabi Lake; 2005 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figure 5.5 for sampling locations.

Sampling Date	June to October 2008 (n = 4)				May to September 2009 (n = 4)				May to September 2010 (n = 4)				
Parameter	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Total Metals													
Aluminum (Al)	0.0594	0.0049	0.0649	0.0552	0.0907	0.0245	0.1220	0.0624	0.0845	0.0173	0.0987	0.0603	0.100 [a]
Antimony (Sb)	0.00004	0.00000	0.00004	0.00004	0.00006	0.00004	0.00011	0.00003	0.00004	0.00001	0.00005	0.00003	
Arsenic (As)	0.0005	0.0000	0.0005	0.0004	0.0005	0.0001	0.0005	0.0004	0.00045	0.00002	0.00047	0.00043	
Barium (Ba)	0.00797	0.00049	0.00847	0.00737	0.00822	0.00076	0.00907	0.00756	0.00792	0.00039	0.00828	0.00742	
Beryllium (Be)	0.00001	0.00000	0.00001	0.00001	0.00001	0.00001	0.00002	0.00001	0.00001	0.00001	0.00002	0.00001	
Bismuth (Bi)	<0.000005	<0.000005	<0.000005	<0.000005	0.000005	0.000004	0.000010	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	
Boron (B)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
Cadmium (Cd)	0.00001	0.00000	0.00001	0.00001	0.00001	0.00001	0.00002	<0.000005	0.000006	0.000003	0.000009	<0.000005	
Calcium (Ca)	3.53	0.09	3.63	3.42	3.33	0.22	3.62	3.10	3.43	0.31	3.88	<0.0001	
Cesium (Cs)	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00073	0.00087	0.00200	0.00010	0.0552	0.1099	0.2200	0.0001	
Chromium (Cr)	0.0003	0.0001	0.0004	0.0002	0.0002	0.0001	0.0003	0.0001	0.0003	0.0001	0.0004	0.0003	
Cobalt (Co)	0.00005	0.00002	0.00008	0.00004	0.00007	0.00001	0.00008	0.00007	0.000057	0.000015	0.000077	0.000045	
Copper (Cu)	0.00098	0.00034	0.00147	0.00072	0.00105	0.00036	0.00137	0.00067	0.00135	0.00100	0.00284	0.00083	
Iron (Fe)	0.143	0.050	0.216	0.109	0.178	0.029	0.215	0.145	0.143	0.014	0.155	0.123	0.3
Lead (Pb)	0.00009	0.00003	0.00011	0.00005	0.00010	0.00004	0.00016	0.00006	0.000078	0.000010	0.000088	0.000065	
Lithium (Li)	0.0013	0.0007	0.0023	0.0009	0.0009	0.0001	0.0010	0.0007	0.0009	0.0001	0.0010	0.0008	
Magnesium (Mg)	1.36	0.05	1.42	1.31	1.31	0.07	1.40	1.24	1.40	0.14	1.61	1.29	
Manganese (Mn)	0.01157	0.00648	0.02100	0.00665	0.01460	0.00752	0.02550	0.00901	0.00979	0.00152	0.01150	0.00780	
Mercury (Hg)	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.0001
Molybdenum (Mo)	0.00006	0.00004	0.00010	<0.00005	0.00006	0.00004	0.00011	<0.00005	0.00008	0.00003	0.00010	0.00006	0.073
Nickel (Ni)	0.00129	0.00043	0.00172	0.00084	0.00113	0.00018	0.00138	0.00097	0.00107	0.00015	0.0012	0.0009	
Potassium (K)	0.595	0.039	0.630	0.540	0.555	0.037	0.600	0.520	0.56	0.06	0.65	0.52	
Rubidium (Rb)	0.0018	0.000141421	0.0019	0.0016	0.001975	0.000340343	0.0023	0.0015	0.0115	0.0194	0.0405	0.0016	
Selenium (Se)	0.0001	0.0000	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.00009	0.00000	0.00009	0.00009	0.001
Silicon (Si)	0.88	0.10	1.00	0.80	1.13	0.13	1.30	1.00	1.1	0.2	1.3	0.8	
Silver (Ag)	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	0.0001
Sodium (Na)	0.92	0.05	0.98	0.86	0.84	0.05	0.91	0.80	0.85	0.04	0.89	0.80	
Strontium (Sr)	0.0148	0.0005	0.0152	0.0141	0.0143	0.0009	0.0153	0.0134	0.0144	0.0005	0.0149	0.0137	
Sulphur (S)	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<10	<10	<10	<10	
Tantalum (Ta)	0.000001	0.000000	0.000001	0.000001	--	--	--	--	--	--	--	--	
Thallium (Tl)	0.000003	0.000001	0.000004	0.000002	0.000004	0.000001	0.000004	0.000003	0.000004	0.000001	0.000004	0.000003	0.0008
Tin (Sn)	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	0.00001	0.00003	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
Titanium (Ti)	0.0012	0.0004	0.0017	0.0007	0.0022	0.0016	0.0039	<0.0005	0.0017	0.0008	0.0026	0.0012	
Uranium (U)	0.00011	0.00001	0.00012	0.00010	0.00012	0.00004	0.00017	0.00009	0.000112	0.000036	0.000163	0.000082	
Vanadium (V)	0.00020	0.00012	0.00030	<0.0002	0.00038	0.00038	0.00090	<0.0002	0.0002	0.0001	0.0003	<0.0002	
Zinc (Zn)	0.0025	0.0010	0.0034	0.0012	0.0017	0.0008	0.0026	0.0007	0.0018	0.0006	0.0026	0.0012	
Zirconium (Zr)	0.00015	5.7735E-05	0.0002	0.0001	0.000225	0.00005	0.0003	0.0002	0.0002	0.0000	0.0002	0.0002	

Table 5.8 Cont'd Total metal concentrations (mg/L) in Tulabi Lake; 2005 to 2012. Shaded values exceed the Manitoba Water Quality Standards, Objectives and Guidelines for the Protection of Aquatic Life (MWQSOG; Williamson 2011). See Figure 5.5 for sampling locations.

Sampling Date	May to October 2011 (n = 4)				June to October 2012 (n = 4)				
	Mean	SD	Max	Min	Mean	SD	Max	Min	MWQSOG
Total Metals									
Aluminum (Al)	0.0740	0.0178	0.0923	0.0567	0.0624	0.0134	0.0811	0.0502	0.100 [a]
Antimony (Sb)	0.00004	0.00001	0.00005	0.00003	0.00004	0.00000	0.00004	0.00004	
Arsenic (As)	0.00051	0.00009	0.00060	0.00043	0.00046	0.00007	0.00054	0.00038	
Barium (Ba)	0.00794	0.00096	0.00934	0.00722	0.00730	0.00030	0.00774	0.00710	
Beryllium (Be)	0.00001	0.00000	0.00001	0.00001	0.00001	0.00000	0.00001	<0.00001	
Bismuth (Bi)	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	
Boron (B)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1.5
Cadmium (Cd)	0.000011	0.000005	0.000017	0.000006	0.000005	0.000003	0.000008	<0.000005	
Calcium (Ca)	3.37	0.22	3.61	3.13	3.54	0.09	3.60	3.41	
Cesium (Cs)	0.0005	0.0002	0.0008	<0.0001	<0.0001	0.0000	0.0001	<0.0001	
Chromium (Cr)	0.0003	0.0001	0.0004	0.0003	0.0003	0.0001	0.0004	0.0002	
Cobalt (Co)	0.000051	0.000007	0.000059	0.000043	0.000046	0.000009	0.000052	0.000033	
Copper (Cu)	0.00107	0.00022	0.00136	0.00084	0.00135	0.00040	0.00183	0.00092	
Iron (Fe)	0.176	0.051	0.250	0.141	0.149	0.040	0.197	0.106	0.3
Lead (Pb)	0.000088	0.000014	0.000107	0.000075	0.000173	0.000144	0.000388	0.000089	
Lithium (Li)	0.0009	0.0001	0.0010	0.0008	0.0009	0.0001	0.0010	0.0009	
Magnesium (Mg)	1.32	0.11	1.46	1.22	1.38	0.06	1.44	1.31	
Manganese (Mn)	0.01290	0.00684	0.02300	0.00789	0.01015	0.00380	0.01490	0.00624	
Mercury (Hg)	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.0001
Molybdenum (Mo)	0.00005	0.00003	0.00007	<0.00005	<0.00005	0.00001	0.00005	<0.00005	0.073
Nickel (Ni)	0.00094	0.00007	0.00102	0.0008	0.00096	0.00019	0.00119	0.0008	
Potassium (K)	0.53	0.04	0.59	0.49	0.60	0.03	0.64	0.57	
Rubidium (Rb)	0.0018	0.0001	0.0019	0.0017	0.0020	0.0001	0.0020	0.0019	
Selenium (Se)	0.00009	0.00002	0.00011	0.00007	0.00011	0.00001	0.00013	0.00010	0.001
Silicon (Si)	1.1	0.2	1.3	0.9	0.8	0.2	1.0	0.6	
Silver (Ag)	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	0.0001
Sodium (Na)	0.80	0.06	0.87	0.75	0.90	0.04	0.95	0.84	
Strontium (Sr)	0.0149	0.0008	0.0160	0.0141	0.0142	0.0006	0.0149	0.0134	
Sulphur (S)	<10	<10	<10	<10	<10	<10	<10	<10	
Tantalum (Ta)					--	--	--	--	
Thallium (Tl)	0.000004	0.000001	0.000004	0.000003	0.000004	0.000001	0.000005	0.000003	0.0008
Tin (Sn)	0.00002	0.00002	0.00005	<0.00001	<0.0002	<0.0002	<0.0002	<0.0002	
Titanium (Ti)	0.0016	0.0003	0.0019	0.0013	0.0015	0.0006	0.0023	0.0009	
Uranium (U)	0.000103	0.000018	0.000122	0.000087	0.000082	0.000013	0.000100	0.000069	0.033
Vanadium (V)	0.0003	0.0001	0.0004	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Zinc (Zn)	0.0027	0.0015	0.0045	0.0011	0.0022	0.0008	0.0034	0.0016	
Zirconium (Zr)	0.0002	0.0001	0.0002	0.0001	0.0001	0.0000	0.0002	0.0001	

[a] Guideline for water with pH > 6.5.

5.3.4 *Bernic Creek*

There are no published data for water quality in Bernic Creek.

5.3.4.1 *Bird River Water Quality*

The Bird River is a well-oxygenated, soft water body with low conductance, moderate concentrations of total dissolved solids, a low buffering capacity and has a circum-neutral pH (Table 5.9). Water quality samples were collected in 2008 as part of a periodic biological study upstream and downstream of the confluence of Bernic Creek and the Bird River (Figure 5.6). Concentrations of all metals were below the Manitoba Water Quality Standard, Objectives and Guidelines (MWQSOG; Williamson 2011). There were no observable differences in water quality between upstream and downstream, or surface and near bottom samples.

5.3.5 *Sediment Quality*

5.3.5.1 *Sediment Quality of Bernic Lake*

Sediment in Bernic Lake was not sampled as part of the pre-development baseline studies conducted in 1968 and 1969 (Crowe 1969 and 1972). Sediment has been sampled since 2005 as part of the periodic biological studies conducted in compliance with the EEM requirement of the MMER (Wardrop 2006 and 2009). These studies have examined sediment quality at sampling locations at increasing distance from the mine discharge within Bernic Lake (far-field and near-field sites) and compared sediment quality in Bernic Lake with reference sediment samples from nearby Tulabi Lake (Figure 5.4 and 5.5).

Sediment parameters measured in each sample included:

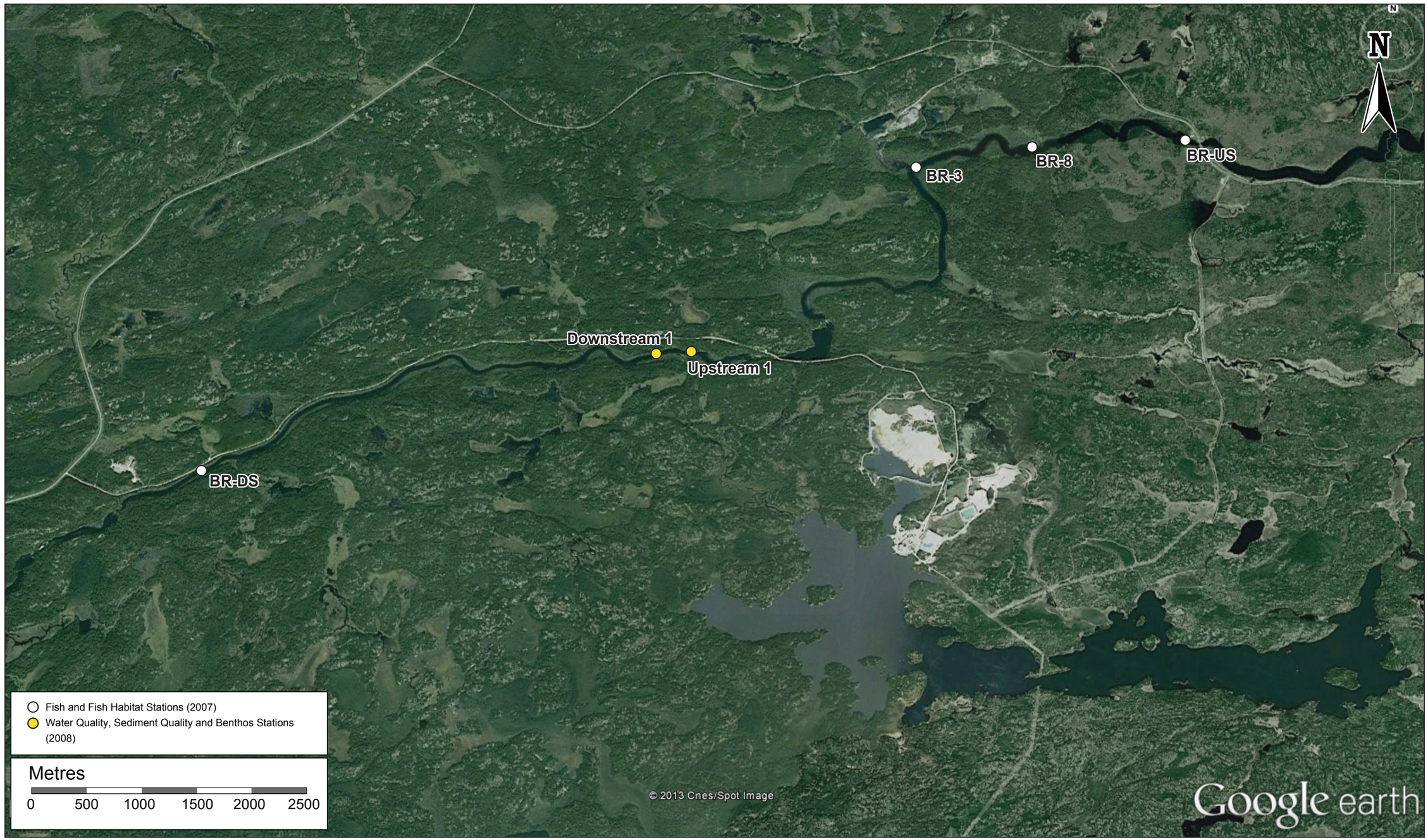
- Total Organic Carbon (TOC);
- Moisture content;
- Fine particle sediment size;
- pH; and,
- Total metals.

Table 5. 9 Water quality in the Bird River at two stations upstream and downstream of the Bernic Creek Inflow; October 2008. Units are mg/L. MWQSOG = Manitoba Water Quality Standards, Objectives and Guidelines.

Parameter	Upstream-1 surface	Upstream-1 bottom	Downstream-1 surface	Downstream-1 bottom	MWQSOG[1]
Physicochemical					
pH (pH units)	7.4	7.3	7.4	7.4	**6.5-9.0**
Hydroxide (OH^-)	<0.5	<0.5	<0.5	<0.5	
Specific Conductance (µS/cm@25°C)	42	43	43	43	
Total Dissolved Solids	54	42	70	54	
Hardness, dissolved	20.2	20.3	19.9	19.7	
Hardness, total	20.7	20.3	19.5	20.5	
Alkalinity (PP as $CaCO_3$)	<0.5	<0.5	<0.5	<0.5	
Alkalinity (Total as $CaCO_3$)	16	15	16	15	
Bicarbonate (HCO_3)	19	19	19	18	
Carbonate (CO_3)	<0.5	<0.5	<0.5	<0.5	
Total Suspended Solids	2	2	2	2	
Turbidity (NTU)	2.2	1.7	3.8	1.6	
True Colour (Col. Units)	40	50	50	50	
Major Ions					
Potassium, dissolved (K+)	0.66	0.65	0.65	0.63	
Sodium, dissolved (Na^+)	1.03	1.00	1.01	1.00	
Calcium, dissolved (Ca^{2+})	4.64	4.62	4.58	4.54	
Magnesium, dissolved (Mg^{2+})	2.09	2.12	2.07	2.04	
Chloride, dissolved (Cl^-)	1.2	5.3	1.0	1.0	
Fluoride, dissolved (F^-)	0.05	0.04	0.04	0.04	
Sulphate, dissolved (SO_4^-)	2.5	1.9	1.9	2.1	
Nutrients					
Organic Carbon, dissolved	10.3	10.4	10.8	10.6	
Organic Carbon, total	9.9	10.0	10.5	10.8	
Nitrite	<0.002	0.002	<0.002	<0.002	**0.06**
Nitrate	0.010	0.006	0.005	0.004	
Nitrate_Nitrite	0.010	0.008	0.005	0.004	
Ammonia	0.022	0.011	0.006	0.025	**>6.46**
Total Kjeldahl Nitrogen	0.25	0.26	0.28	0.29	
Total Nitrogen	0.26	0.27	0.29	0.29	
Phosphorus, total dissolved	0.008	0.008	0.008	0.009	
Phosphorus, total	0.009	0.010	0.009	0.009	**0.05**
Biological					
Chlorophyll a	0.0039	0.0040	0.0041	0.0039	
Radiochemical					
Radium-226 (Bq/L)	<0.005	<0.005	<0.005	<0.005	

Table 5.9 Cont'd. Water quality in the Bird River at two stations, upstream and downstream of the Bernic Creek inflow; October 2008. Units are mg/L. MWQSOG- Manitoba Water Quality Standard, Objectives and Guidelines.

Parameter	Upstream-1 surface	Upstream-1 bottom	Downstream-1 surface	Downstream-1 bottom	MWQSOG[1]
Dissolved Metals					
Aluminum (Al)	0.0335	0.0335	0.0351	0.0320	
Antimony (Sb)	0.00004	0.00004	0.00005	0.00004	
Arsenic (As)	0.00058	0.00058	0.00059	0.00058	
Barium (Ba)	0.00805	0.00814	0.00809	0.00828	
Beryllium (Be)	0.00001	<0.00001	0.00001	<0.00001	
Bismuth (Bi)	<0.000005	<0.000005	<0.000005	<0.000005	
Boron (B)	<0.05	<0.05	<0.05	<0.05	
Cadmium (Cd)	<0.000005	<0.000005	<0.000005	<0.000005	**0.00067**
Cesium (Cs)	0.0030	0.0028	0.0025	0.0026	
Chromium (Cr)	0.0002	0.0002	0.0002	0.0003	
Cobalt (Co)	0.000025	0.000026	0.000031	0.000026	
Copper (Cu)	0.00075	0.00076	0.00081	0.00124	**0.0022**
Iron (Fe)	0.127	0.127	0.147	0.132	
Lead (Pb)	0.000060	0.000066	0.000095	0.000113	**0.000410**
Lithium (Li)	0.0048	0.0048	0.0045	0.0046	
Manganese (Mn)	0.00210	0.00212	0.00227	0.00215	
Mercury (Hg)	<0.00001	<0.00001	<0.00001	<0.00001	
Molybdenum (Mo)	<0.00005	<0.00005	<0.00005	<0.00005	
Nickel (Ni)	0.00109	0.00111	0.00111	0.00108	**0.05201**
Rubidium (Rb)	0.0021	0.0020	0.0020	0.0021	
Selenium (Se)	0.00009	0.00010	0.00011	0.00010	
Silicon (Si)	1.1	1.0	1.2	1.1	
Silver (Ag)	<0.000005	<0.000005	<0.000005	<0.000005	
Strontium (Sr)	0.0166	0.0165	0.0163	0.0165	
Sulphur (S)	<3	<3	<3	<3	
Tantalum (Ta)	<0.000001	<0.000001	<0.000001	<0.000001	
Thallium (Tl)	0.000004	0.000004	0.000003	0.000003	
Tin (Sn)	<0.00001	<0.00001	<0.00001	<0.00001	
Titanium (Ti)	0.0013	0.0012	0.0011	0.0013	
Uranium (U)	0.000119	0.000122	0.000119	0.000117	
Vanadium (V)	0.0004	0.0005	0.0004	0.0004	
Zinc (Zn)	0.0005	0.0005	0.0007	0.0005	**0.0293**
Zirconium (Zr)	0.0001	0.0001	0.0001	0.0001	



TETRA TECH

Figure 5.6
SampleLocations in the Bird River

Studies of the environmental effects of the mine discharge on Bernic Lake have sampled sediment quality in Bernic Lake both adjacent (within 300 m) to the mine discharge (near-field) and at some distance (approximately 2 km) from the discharge (far-field) (Figure 5.4). The near-field zone was located substantially within the effluent discharge plume (i.e., the area defined by the 1% dilution boundary) in 2002, 2005, and 2008. The far-field zone was located in a bay in the east basin of Bernic Lake in similar water depths and bottom substrate to the exposure zone, with samples collected in 2002 and 2008. The reference area in Tulabi Lake (Figure 5.5) also is located in a bay with similar water depths and bottom substrate to the exposure zone, with sediment samples collected in 2005 and 2008. Complete documentation of the studies and methods may be found in SEACOR (2002) and Wardrop (2006 and 2009a).

Sediment quality in the near-field and far field zones of Bernic Lake is distinguished from the Tulabi Lake reference zone by higher concentrations of total organic carbon (TOC) and various metals (Tables 5.10 and 5.11). In this case a significant difference is defined as a concentration in the receiving water body that differs from the concentration in the reference water body by a factor of two or more. The metals for which the mean concentrations at the near-field and far-field sites exceeded the mean concentrations in the reference area by a factor of two or more included: antimony, arsenic, beryllium, bismuth, cesium, lithium, manganese, molybdenum, rubidium, sodium, tantalum, thallium, and tin. Concentrations of cesium, rubidium, and tantalum are much higher in the near-field zone than in the far-field zone (i.e., 7 to 26 times higher). Similarly, beryllium, bismuth and tin all notably occur in sediment at concentrations two to six times higher in the near-field zone relative to the far-field (Tables 5.10 and 5.11; Wardrop 2009a).

Table 5. 10 Sediment Quality For Bernic Lake Near-Field Sampling Stations October 2005 (n=10) and October 2008 (n=10). Values are mg/kg unless otherwise noted. Shaded and bolded values exceed the Canadian Council of Ministers for the Environment (CCME) interim sediment quality guideline (ISQG) and the probable effect level PEL), respectively. See Figure 5.4 for sampling locations.

	Near-field (2005)				Near-field (2008)				Far-field (2008)				CCME	
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	ISQG[1]	PEL[1]
Sand (%)	29	22	1	76	46	8	33	60	46	7	35	58		
Silt (%)	59	24	6	92	44	8	30	62	43	5	35	53		
Clay (%)	12	5	4	19	10	3	5	15	11	3	8	16		
Total organic carbon	96,600	19,884	48,000	120,000	109,600	32,776	37,000	170,000	164,000	6,992	160,000	180,000		
Total organic carbon (%)	9.7	2.0	4.8	12.0	11.0	3.3	3.7	17.0	16.4	0.7	16.0	18.0		
Moisture (%)	87.9	2.9	81.2	91.5	89.3	5.4	75.0	94.0	93.6	1.1	92.0	96.0		
Total Metals														
Aluminum (Al)	11,139	1,874	8,820	14,000	11,329	2,379	6,850	13,600	15,020	656	13,900	15,900		
Antimony (Sb)	3.2	0.6	2.4	4.4	3.8	1.1	1.0	4.7	3.3	0.3	2.9	3.8		
Arsenic (As)	13.9	1.8	10.9	15.9	14.0	1.3	11.9	16.3	14.2	0.9	13.1	16.4	5.900	**17.000**
Barium (Ba)	85.8	13.0	72.8	99.1	93.7	14.2	58.1	105.0	123.3	4.9	115.0	131.0		
Beryllium (Be)	3.4	0.8	2.5	4.6	3.8	1.0	2.6	5.4	0.9	0.1	0.8	1.1		
Bismuth (Bi)	3.1	0.8	1.8	4.7	3.1	1.1	0.6	4.9	0.5	0.0	0.4	0.5		
Cadmium (Cd)	0.63	0.09	0.52	0.75	0.79	0.18	0.42	0.99	0.80	0.04	0.73	0.86	0.600	**3.500**
Calcium (Ca)	-	-	-	-	7,772	1,650	4,170	9,960	9,993	818	8,830	11,300		
Cesium (Cs)	-	-	-	-	2,047.50	1,229.54	480.00	4,600.00	295.00	51.91	170.00	350.00		
Chromium (Cr)	23	3	19	27	26	9	15	45	31	3	28	36	37.300	**90.000**
Cobalt (Co)	9.2	1.5	7.2	11.7	9.8	1.7	6.3	11.5	13.2	0.4	12.2	13.9		
Copper (Cu)	30.4	3.4	24.3	33.9	33.2	3.5	24.5	35.8	34.5	1.4	32.0	36.7	35.700	**197.000**
Iron (Fe)	17,400	2,615	13,500	20,900	17,490	2,071	12,900	20,600	27,960	1,951	25,600	30,800		
Lead (Pb)	20.9	3.8	14.2	26.3	22.7	6.8	5.9	27.8	27.2	1.4	24.6	29.0	35.000	**91.300**
Lithium (Li)	-	-	-	-	211	57	66	259	131	14	117	155		
Magnesium (Mg)	-	-	-	-	2,937	492	1,870	3,590	4,450	283	4,040	5,040		
Manganese (Mn)	1,053.0	219.0	682.0	1,300.0	1,375.5	905.6	721.0	3,820.0	1,221.9	200.1	999.0	1,680.0		
Mercury (Hg)	0.10	0.02	0.07	0.12	0.12	0.02	0.08	0.14	0.17	0.01	0.16	0.18	0.170	**0.486**
Molybdenum (Mo)	4.4	0.9	3.4	5.8	6.9	1.6	3.6	8.9	7.2	1.2	5.4	9.4		
Nickel (Ni)	28.7	5.6	21.1	39.3	33.1	7.1	19.0	44.4	38.1	2.5	33.6	42.2		
Phosphorus (P)	1,593	250	1,310	1,940	1,809	336	969	2,110	1,428	104	1,200	1,550		
Potassium (K)	1,463	234	1,100	1,740	1,638	358	892	2,030	2,216	87	2,080	2,360		
Rubidium (Rb)	-	-	-	-	1,990.000	902.504	320.000	3,100.000	201.000	38.715	110.000	240.000		
Selenium (Se)	1.6	0.4	0.9	2.2	1.4	0.3	0.9	2.0	1.7	0.3	1.3	2.3		
Silver (Ag)	0.20	0.02	0.17	0.22	0.25	0.11	0.09	0.50	0.13	0.01	0.12	0.15		
Sodium (Na)	-	-	-	-	526	66	422	615	363	50	309	450		
Strontium (Sr)	32.6	4.3	27.6	37.7	38.8	5.8	24.3	44.1	43.3	3.1	39.5	49.7		
Tantalum (Ta)	-	-	-	-	128.25	55.75	22.00	200.00	4.91	0.92	2.80	6.30		
Thallium (Tl)	1.75	0.35	1.23	2.37	2.00	0.55	0.57	2.62	0.75	0.08	0.62	0.86		
Tin (Sn)	2.6	0.5	2.3	3.3	2.6	0.8	0.6	3.4	1.0	0.1	0.9	1.1		
Titanium (Ti)	204	33	173	291	175	38	144	277	240	11	222	261		
Uranium (U)	-	-	-	-	7.17	2.00	3.30	10.30	3.37	0.39	2.85	4.06		
Vanadium (V)	23	3	18	28	25	4	16	28	37	2	34	41		
Zinc (Zn)	82	10	66	94	89	11	69	103	100	5	92	107	123.000	**315.000**
Zirconium (Zr)	3.6	1.1	2.4	6.4	1.5	0.8	0.6	3.6	2.2	0.3	1.9	2.8		

[1] Values are the same as Manitoba Water Quality Standards, Objectives, Guidelines (MWQSOG; Williamson 2011).

Table 5. 11 Sediment Quality For Tulabi Lake Sample Stations. October 2005 (n=10) and October 2008 (n=10). Values are mg/kg unless otherwise noted. Shaded and bolded values exceed the Canadian Council of Ministers for the Environment (CCME) interim sediment quality guideline (ISQG) And the probable effect level PEL), respectively. See Figure 5.5 for sampling locations.

	2005				2008				CCME	
	Mean	SD	Min	Max	Mean	SD	Min	Max	ISQG[1]	PEL[1]
Sand (%)	--	--	--	--	18	9	3	34		
Silt (%)	--	--	--	--	40	11	27	61		
Clay (%)	--	--	--	--	43	6	31	52		
Total Organic Carbon	55,900	11,571	37,000	70,000	58,000	9297.55	41,000	67,000		
Total Organic Carbon (%)	5.59	11.57	3.7	7	5.8	0.93	4.1	6.7		
Moisture (%)	82.0	4.3	74.7	85.3	81.3	3.4	76.0	85.0		
Total Metals										
Aluminum (Al)	18,910	2,117	15,400	21,600	19,040	2,712	14,400	22,500		
Antimony (Sb)	0.4	0.05	0.3	0.4	0.3	0.1	0.2	0.4		
Arsenic (As)	3.7	0.65	2.7	4.7	3.1	0.6	2.0	4.3	5.9	**17.0**
Barium (Ba)	154	15.15	127	171	179	78	128	397		
Beryllium (Be)	0.7	0.07	0.5	0.7	0.8	0.1	0.6	0.8		
Bismuth (Bi)	0.3	0.04	0.2	0.3	0.3	0.1	0.2	0.3		
Boron (B)	8	0.55	7	8	--	--	--	--		
Cadmium (Cd)	0.54	0.05	0.45	0.64	0.53	0.06	0.42	0.61	0.60	**3.50**
Calcium (Ca)	--	--	--	--	4,825	713	3,720	5,960		
Cesium (Cs)	--	--	--	--	5.4	0.9	3.8	6.9		
Chromium (Cr)	40.1	4.2	32.0	45.0	49.1	6.2	39.0	59.0	37.3	**90.0**
Cobalt (Co)	13.3	0.60	12.7	14.1	12.54	0.67	11.9	14.1		
Copper (Cu)	25.1	3.2	19.5	28.4	22.5	2.9	17.4	25.5	35.7	**197.0**
Iron (Fe)	25,680	1,729	23,200	28,400	23,750	1,022	22,200	25,300		
Lead (Pb)	21.4	3.36	16.2	27.3	19.51	3.16	14.6	23.9	35.0	**91.3**
Lithium (Li)	--	--	--	--	19	2	15	21		
Magnesium (Mg)	--	--	--	--	5,020	554.30	3,930	5,790		
Manganese (Mn)	715	144.68	547	1,020	605.20	86.76	529	778		
Mercury (Hg)	0.12	0.02	0.09	0.14	0.11	0.01	0.09	0.13	0.17	**0.49**
Molybdenum (Mo)	0.5	0.1	0.3	0.6	1.1	0.2	0.7	1.5		
Nickel (Ni)	32.5	2.8	26.5	35.8	33.1	3.5	26.0	36.5		
Phosphorus (P)	1,057	82.94	911	1,170	962.10	79.74	806	1,080		
Potassium (K)	2,159	263.88	1,670	2,590	2,007	267.75	1,440	2,270		
Rubidium (Rb)	--	--	--	--	86	5	74	93		
Selenium (Se)	1.0	0.2	0.8	1.3	1.0	0.3	0.5	1.5		
Silver (Ag)	0.14	0.02	0.12	0.16	0.17	0.02	0.14	0.22		
Sodium (Na)	--	--	--	--	134	33	111	227		
Strontium (Sr)	31.4	3.3	25.2	34.8	31.2	4.1	24.3	38.0		
Tantalum (Ta)	--	--	--	--	0.9	0.1	0.8	1.1		
Thallium (Tl)	0.29	0.02	0.26	0.31	0.29	0.02	0.25	0.32		
Tin (Sn)	0.9	0.1	0.7	1.1	0.8	0.1	0.7	1.0		
Titanium (Ti)	276	22	239	310	275	33	195	308		
Uranium (U)	--	--	--	--	5.8	2.5	3.9	11.7		
Vanadium (V)	44	4	36	50	47	5	37	52		
Zinc (Zn)	97	8	82	107	89	10	71	99	123.000	**315.000**
Zirconium (Zr)	3.9	1.2	2.4	5.8	1.5	0.5	1.0	2.2		

[1] Values are the same as Manitoba Water Quality Standards, Objectives, Guidelines (MWQSOG; Williamson 2011).

Higher concentrations of aluminum, barium, chromium, and iron were found at the reference site compared to the exposure site in 2005 (Wardrop 2006). These metals also occurred in higher concentrations at the reference site in 2008 but the differences were all less than a factor of 2 in 2008 (Tables 5.10 and 5.11).

Several parameters exceeded the Canadian Council of Ministers of the Environment (CCME) interim sediment quality guidelines (ISQG) in both 2005 and 2008, but there were no exceedances of the CCME probable effect level (PEL) at any of the sites (Table 5.10).

5.3.5.2 *Bernic Creek*

There are no published sediment quality data for Bernic Creek.

5.3.5.3 *Sediment Quality of Bird River*

Sediments collected in Bird River immediately upstream and downstream of the Bernic Creek confluence showed no observable differences in parameter concentrations (Table 5.12; Figure 5.6). All samples consisted of primarily sand then silt. All metal concentrations were less than the MWQSOG although it is notable that arsenic, chromium, copper and zinc concentrations represented one third to one half of the interim sediment quality guidelines (Wardrop 2009a; Williamson 2011).

5.3.6 *Benthic Invertebrates*

5.3.6.1 *Bernic Lake*

Effects on the benthic community in the mine effluent exposure zone were examined during the three EEM studies conducted in 2002, 2005 and 2008. An effect on the benthic community in the mine effluent exposure zone (i.e., near-field site) was evident as characterized by three metrics: benthic invertebrate density was consistently higher at the near-field site in all three years; community dissimilarity (as measured by Bray-Curtis Distance) was consistently higher at the near-field site in all three years; and, in 2008, Simpson's Diversity index differed significantly across all three sites, with the lowest diversity at the near-field site (Table 5.13 Tetra Tech 2011).

The differences in benthic communities observed among the near-field, far-field, and reference sampling locations are most likely the indirect result of nutrient enrichment from the mine discharge. Nutrient enrichment enhances primary productivity which, in turn, has the primary indirect effect of increasing chironomid density and dominance within communities. The increase in algal biomass resulting from nutrient enrichment can also lead to a decrease in dissolved oxygen due to increased decomposition activity. The tolerance of chironomids (and chaoborids and naidids) of low oxygen environments may have provided an advantage over other taxa in competition for food, thus augmenting their density and community dominance (Tetra Tech 2011).

It is unlikely that metal toxicity is a primary factor influencing the benthic invertebrate communities in Bernic Lake. The main piece of evidence supporting this conclusion it

that concentrations of all metals were below reported acute toxicity levels of the focal taxa. A secondary piece of evidence is that candonids were present at the far-field but not the near-field site, despite similar metal concentrations in water and sediment at the two locations.

Table 5. 12 Sediment chemistry in the Bird River at two stations, upstream and downstream of the Bernic Creek inflow; October 2008. Units are mg/kg unless otherwise noted. (Manitoba Water Quality Standard, Objectives & Guidelines ISQG-interim sediment quality guideline, PEL-probable effect level).

Parameter	Upstream-1	Upstream-1 dup	Downstream-1	Downstream-1 dup	ISQG[1]	PEL[1]
Sand (%)	55	64	48	52		
Silt (%)	33	28	33	32		
Clay (%)	12	8	19	16		
Texture	SANDY LOAM	SANDY LOAM	LOAM	LOAM		
Soluble (2:1) pH	6.37	6.45	6.93	7.23		
Tot. organic carbon (g/kg)	26	24.0	21.0	27.0		
Boron, HWS (mg/kg)	0.2	<0.1	<0.1	<0.1		
Moisture (%)	58	75	54	57		
Total Metals						
Aluminum (Al)	7410	7160	7810	7190		
Antimony (Sb)	0.2	0.1	0.2	0.2		
Arsenic (As)	3.8	3.4	2.6	2.9	5.9	**17**
Barium (Ba)	74.3	63.9	72.0	65.6		
Beryllium (Be)	0.5	0.4	0.3	0.4		
Bismuth (Bi)	0.1	0.1	0.2	0.1		
Cadmium (Cd)	0.36	0.21	0.26	0.24	0.6	**3.5**
Calcium (Ca)	3550	4140	5060	5070		
Cesium (Cs)	– –	– –	– –	– –		
Chromium (Cr)	19	17	19	18	37.3	**90**
Cobalt (Co)	7.5	7.4	7.4	7.3		
Copper (Cu)	15.5	12.3	13.7	11.3	35.7	**197**
Iron (Fe)	11800	12300	12900	12300		
Lead (Pb)	8.4	6.3	8.0	7.0	35	**91.3**
Lithium (Li)	11	12	12	12		
Magnesium (Mg)	3340	3270	3630	3120		
Manganese (Mn)	594	555	373.0	420		
Mercury (Hg)	<0.05	<0.05	<0.05	<0.05	0.170	**0.486**
Molybdenum (Mo)	0.3	0.2	0.3	0.3		
Nickel (Ni)	18.1	16.2	19.1	17.9		
Phosphorus (P)	550	543	528	505		
Potassium (K)	1010	986	1210	988		
Rubidium (Rb)	– –	– –	– –	– –		
Selenium (Se)	<0.5	0.7	0.8	0.7		
Silver (Ag)	0.06	0.06	0.07	0.06		
Sodium (Na)	<100	<100	<100	<100		
Strontium (Sr)	16.1	14.1	16.1	19.3		
Tantalum (Ta)	6.60	5.4	2.80	4.00		
Thallium (Tl)	0.19	0.17	0.19	0.16		
Tin (Sn)	0.3	0.3	0.3	0.3		
Titanium (Ti)	253	240	258	245		
Uranium (U)	1.71	1.23	1.47	1.31		
Vanadium (V)	22	19	22	21		
Zinc (Zn)	49	42	50	45	123	**315**
Zirconium (Zr)	1.5	0.8	2.0	1.9		

Table 5. 13 Summary of benthos statistics for the far-field and near-field (exposure) gradients sampled in Bernic Lake, October 2002, 2005 and 2008.

				Bernic Lake Near-Field (2002) [a]							Bernic Lake Near-Field (2005) [c]						
Phylum	**Class**	**Order**	**Family**	**Mean**	**SD**	**SE**	**% of population**	**Max.**	**Min.**	**Median**	**Mean**	**SD**	**SE**	**% of population**	**Max.**	**Min.**	**Median**
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae														
		Haplotaxida	Naididae								47	32	10	6.8	101	13	37
			Tubificidae								21	21	7	3.0	60	2	12
Arthropoda	Arachnida	Hydrachnellae	Hydrachnidae	0.1	0.4	0.1	0.7	1	0	0							
		Acari	Pionidae								0	0	0	0.0	1	0	0
			Unionicolidae								2	2	1	0.3	8	0	1
		Hydracarina	Oxidae								0	0	0	0.0	1	0	0
			Limnesiidae								1	1	0	0.1	2	0	0
		Araneae									0	0	0	0.0	1	0	0
Arthropoda	Malacostraca	Amphipoda	Hyalellidae														
	Ostracoda			0.3	1	0.2	1.5	3	0	0	67	99	31	9.8	300	2	19
		Podocopida	Candonidae														
	Insecta	Diptera	Ceratopogonidae	3	4	1	18.5	10	0	1	69	34	11	10.2	130	38	64
			Chaoboridae	6	5	1	31.0	21	0	4	172	121	38	25.2	377	29	117
			Chironomidae	7	4	1	36.5	17	0	6	276	116	37	40.5	554	128	254
		Ephemeroptera	Caenidae														
		Odonata	Macromiidae														
		Trichoptera	Leptoceridae								1	1	0	0.1	2	0	0
			Phryganeidae														
Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae														
		Pulmonata	Physidae								0	0	0	0.0	1	0	0
		Basommatophora	Planorbidae	0.1	0.3	0.1	0.4	1	0	0	0	0	0	0.0	1	0	0
		Heterostropha	Valvatidae								0	0	0	0.0	1	0	0
Nematoda				2	6	1	11.4	22	0	0	27	49	16	4.0	163	2	9
			Total Number of organisms	**18**	10	3		39	3	16	**682**	218	69		1,142	428	628
			Total Density (ind./m^2)	**786**	453	117		1696	130	696	**4,237**	1,352	427		7,093	2,658	3,898
			Taxon No. (richness)	**3**	1	0.3		5	1	3	**9**	2	1		11	7	10
			Simpson's Index of Diversity	**0.585** [b]	0.197	0.051		0.780	0.000	0.650	**0.761** [b]	0.047	0.015		0.816	0.674	0.776
			Evenness	**0.662** [b]	0.202	0.052		1.000	0.220	0.640	**0.388** [b]	0.088	0.028		0.599	0.295	0.388

Table 5.13 Cont'd. Summary of benthos statistics for the far-field and near-field (exposure) gradients sampled in Bernic Lake, October 2002, 2005 and 2008.

				Bernic Lake Far-Field (2008) [d]							Bernic Lake Near-Field (2008) [d]						
Phylum	Class	Order	Family	Mean	SD	SE	% of population	Max.	Min.	Median	Mean	SD	SE	% of population	Max.	Min.	Median
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae								1			<0.1	1	1	1
		Haplotaxida	Naididae	30	40	13	6.6	110	1	11	136	129	53	4.9	346	7	116
			Tubificidae	3	1	1	0.2	4	1	3	5			<0.1	5	5	5
Arthropoda	Arachnida	Hydrachnellae	Hydrachnidae														
		Acari	Pionidae								1			<0.1	1	1	1
			Unionicolidae	1			<0.1	1	1	1							
		Hydracarina	Oxidae														
			Limnesiidae														
		Araneae															
Arthropoda	Malacostraca	Amphipoda	Hyalellidae	1			<0.1	1	1	1	4			<0.1	4	4	4
	Ostracoda																
		Podocopida	Candonidae	29	14	4	6.4	49	7	30	2	1	0	0.1	3	1	2
	Insecta	Diptera	Ceratopogonidae	6	2	1	1.4	10	2	6	10	8	3	0.4	24	3	8
			Chaoboridae	43	32	10	9.4	95	6	41	96	73	24	5.2	199	2	73
			Chironomidae	346	93	29	76	500	249	310	1478	595	188	89.3	2288	716	1506
		Ephemeroptera	Caenidae	1			<0.1	1	1	1	1			<0.1	1	1	1
		Odonata	Macromiidae								1			<0.1	1	1	1
		Trichoptera	Leptoceridae														
			Phryganeidae								1			<0.1	1	1	1
Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae								2			<0.1	2	2	2
		Pulmonata	Physidae														
		Basommatophora	Planorbidae								6			<0.1	6	6	6
		Heterostropha	Valvatidae	1			<0.1	1	1	1	5	5	4	0.1	8	1	5
Nematoda				1			<0.1	1	1	1	1			<0.1	1	1	1
			Total Number of organisms	**456**	82			575	352	463	**1,655**	582			2,428	806	1,822
			Total Density (ind./m^2)	**3,963**	714			5,000	3,061	4,022	**14,394**	5,060			21,113	7,009	15,843
			Taxon No. (richness)	**6**	1			7	5	6	**5**	3			11	2	5
			Simpson's Index of Diversity	**0.374**	0.189			0.653	0.095	0.350	**0.202**	0.134			0.409	0.029	0.178
			Evenness	**0.302**	0.113			0.484	0.182	0.282	**0.355**	0.175			0.602	0.094	0.338

[a] Method of collection included 15 stations, 1 replicate per station.

[b] Calculated values included non-benthic species (Cladocera, Hydracarina and Copepoda).

[c] Method of collection included 10 stations, 7 replicates per station.

[d] Method of collection included 10 stations, 5 replicates per station.

An additional explanation for the observed benthic community patterns, specifically for those taxa common at one sampling location but absent from another (e.g., Sphaeriidae), is that these taxa were absent from the sampling area prior to the disturbance. This absence could be related to historical patterns of lake colonization or to habitat (i.e., substrate) preferences (Tetra Tech 2011).

5.3.6.2 *BERNIC CREEK*

There are no published data for benthic invertebrates in Bernic Creek.

5.3.6.3 *BIRD RIVER*

A total of 98 taxa were identified in the samples from the Bird River in 2008 (Tetra Tech 2009a). The most abundant taxa at all sites included the Sphaeriidae (primarily Musculium lacustre and Sphaerium simile), oligochaetes (primarily Aulodrilus americanus and immature tubificids without hairs (Limnodrilus types)), various chironomids, the amphipod Hyallela azteca, and mayflies (Caenis youngi and Hexagenia rigida), although in low numbers. Overall community composition were consistent across sampling stations.

Community abundance at the upstream sites was characterized by the importance of a single family, the Sphaeriidae. Chironomidae and Tanypodinae were sub-dominant families, representing between 5 and 10% of community density. In contrast to the upstream sites, the benthic invertebrate community downstream was more evenly distributed among a number of families. Dominant families included the Hyalellidae, Tubificidae, Sphaeriidae, Chironomidae, and Tanypodinae. The differences in community dominance between the sites may reflect the differences in substrate composition. The south side downstream is a depositional zone, with the substrate comprised largely of woody debris and organic detritus. The upstream sites were predominately fine-grained sediments.

Zoobenthos density along the upstream gradient ranged from 11,043 to 18,536 individuals/m2 and densities along the downstream gradients ranged from 7,043 to 20,072 individuals/m2. Zoobenthos community densities were not significantly different between the upstream and downstream sites.

Taxon richness was similar across all sites ranging from 27 to 47 taxa/station. Richness was not significantly different between upstream and downstream sites. Evenness was generally low across all sites, ranging from 0.073 to 0.178, indicating a strong dominance of the community by a few taxa. There was no significant difference in evenness between the upstream and downstream sites.

Benthic community diversity, measured by Simpson's diversity index, was similar across all three sites ranging from 0.647 to 0.838, indicating all sites had a generally high level of diversity. There was a difference between diversity in one of the upstream stations and the downstream station.

Although the results indicate some differences in benthic invertebrate community statistics among the sites on the Bird River, there is no evidence that these differences are related to the TANCO Mine effluent discharge to Bernic Lake. The significant differences between the Site D community on the south side of Bird River, downstream of Bernic Creek and the two other sites clearly appear related to substrate differences. Further, there are no significant differences in sediment chemistry among the sites that can be related to the mine discharge.

5.3.7 *Fish and Fish Habitat*

5.3.7.1 *Bernic Lake*

Bernic Lake is a small (360 ha), typical Precambrian Shield lake. It is an upper watershed lake with a proportionally small watershed that discharges into the lake either directly or through several small, intermittent single-order streams (Figure 5.3). There is no indication of previous fishing activities at the lake (Crowe 1969). There is no public access to Bernic Lake as the TANCO road has remained gated and restricted to mine personnel and contractors since road construction.

Limited fish community surveys have been conducted by in 1969, 1975, and 1993 (Crowe 1972; Crowe 1976; and TetrES 1998). Although ten species of large- and small-body fish species were recorded through the combined survey results it is likely only six of the species can be reasonably considered present in the lake (Table 5.14). TetrES (1998) recorded a single small Lake Whitefish. Given the lack of Lake Whitefish in previous surveys of Bernic Lake and the Bird River and the migration barriers on the river and Bernic Creek it is more likely this record was either a misidentification of a Cisco or the result of sample equipment contamination. Similarly, the Slimy Sculpin, Western Blacknose Dace, and Pumpkinseed records are questionable as recent, more intensive surveys conducted by DFO specifically to sample small-body species in the Bird River did not record any of these species (Watkinson unpubl. data). Furthermore, the Western Blacknose Dace and Pumpkinseed records are outside the known Manitoba distribution for these species (Table 5.14 Stewart and Watkinson 2007). It is more likely these records are the result of misidentification or gear contamination rather than some unusual migration event. As a result, only six species have been reliably recorded in Bernic Lake: Cisco, Northern Pike, White Sucker, Emerald Shiner, Spottail Shiner, and Yellow Perch (Table 5.14).

It is important to note that Walleye (*Sander vitreus*) have not been observed or captured in Bernic Lake. Walleye are ubiquitous in the region and readily observed when present (Stewart and Watkinson 2007). No Walleye were captured by Crowe (1972) in 1969 which indicates Walleye have never been present in the lake. There are no readily apparent habitat or fish community limitations that would prevent Walleye from establishing in Bernic Lake, therefore it is likely the low population densities in the adjacent Bird River and the presence of a migration barrier on Bernic Creek have likely prevented colonization the colonization of the lake.

Table 5. 14 Fish species known to occur in the Bird River Watershed and the TANCO project area.

Species	Scientific Name	Expected to Occur in Bird River Watershed	Captured in Adjacent Bird River	Captured in Bernic Lake	Source
Cisco	*Coregonus artedi*	1		1	1,3,4,7,8
Lake Whitefish	*Coregonus clupeaformis*	1		1*	8
Northern Pike	*Esox lucius*	1	1	1	1,3,4,5,6,7,8
Central Mudminnow	*Umbra limi*	1	1		1,3,5,6
Burbot	*Lota lota*	1	1		1,5,6
Trout Perch	*Percopsis omyscomaycus*	**1**			1,5
White Sucker	*Catostomus commersoni*	1	1	1	1,3,4,5,6,7,8
Silver Redhorse	*Moxostoma anisurum*	1			1,5
Shorthead Redhorse	*Moxostoma macrolepidotum*	1			1,5
Common Shiner	*Luxilus cornutus*	1			1,5
Golden Shiner	*Notemigonus crysoleucas*	1			1,5
Emerald Shiner	*Notropis atherinoides*	1	1	1	1,5,6,7
Blacknose Shiner	*Notropis heterolepis*	1	1		1,5,6
Spottail Shiner	*Notropis hudsonius*	1		1	1,5,7,8
Carmine Shiner	*Notropis percobromus*	1			1,5
Weed Shiner	*Notropis texanus*	1			1,5
Mimic Shiner	*Notropis volucellus*	1	1		1,5,6
Northern Redbelly Dace	*Phoxinus eos*	1	1		1,3,5,6
Finescale Dace	*Phoxinus neogaeus*	1	1		1,3,6
Bluntnose Minnow	*Pimephales notatus*	1			1,5
Fathead Minnow	*Pimephales promelas*	1	1		1,3,5,6
Western Blacknose Dace	*Rhynichthes obtusus*			1*	8
Longnose Dace	*Rhynichthes cataractae*	1	1		1,5
Tadpole Madtom	*Noturus gyrinus*	1			1,2
Brook Stickleback	*Culea inconstans*	1	1		1,3,6
Slimy Sculpin	*Cottus cognatus*	1		1*	8
Rock Bass	*Ambloplites rupestris*	1			1,5
Pumpkinseed	*Lepomis gibbosus*			1*	8
Smallmouth Bass	*Micropterus dolomieu*	1			1,4,5
Iowa Darter	*Ethiostoma exile*	1			1,5

Table 5. 14 Cont'd. Fish species know to occur in the Bird River Watershed and the TANCO project area.

Species	Scientific Name	Expected to Occur in Bird River Watershed	Captured in Adjacent Bird River	Captured in Bernic Lake	Source
Johnny Darter	*Ethiostoma nigrum*	1	1		1,5
Yellow Perch	*Perca flavescens*	1	1	1	1,3,4,5,6,7,8
Logperch	*Percina caprodes*	1			1,5
River Darter	*Percina shumardi*	1			1,5
Sauger	*Sander canadensis*	1			1,5
Walleye	*Sander vitreus*	1	1		1,3,4,5,6
Total		**34**	**15**	**10**	

1 - Stewart and Watkinson (2004); 2 - Leroux (pers. comm.); 3 - Canmine (unpubl. data); 4 - Fisheries Branch (unpubl. data); 5 - Watkinson (unpubl. data); 6 - Mustang (unpubl. data); 7 - Crowe (1976); 8 - TetrES (1997)

* - Likely the result of misidentification or contaminated sampling gear

5.3.7.2 *BERNIC CREEK*

Bernic Creek is a small, sinuous watercourse that discharges Bernic Lake into the Bird River (Figure 5.3). Most of the 2.7 km length discharges through wetlands and is susceptible throughout to impoundment by beaver dams. The creek originates at the west end of Bernic Lake as a low gradient (< 1%) channel through 1.8 km of wetlands. Below this, the creek gradient increases to 3% over 600 m and includes rapids that are likely a barrier to fish migration due to the acute gradient and low flow. The channel gradient decreases to <1% as the creek once again discharges through the final 300 m into the Bird River. No fish community surveys have been conducted in Bernic Creek, but it is assumed the upper reach fish community is comprised of the species observed in Bernic Lake while the middle and lower reaches are more likely comprised of species observed in the Bird River (Table 5.15).

5.3.7.3 *BIRD RIVER*

The Bird River between Bird Lake and Lac du Bonnet is a moderate-size watercourse composed mostly of run and pool habitat segments separated by rapids and cascades. The Bird River system has been subject to a number of fish community surveys by several different agencies in recent years. Fish community surveys have been conducted by Canmine Resources Corporation (1998), Manitoba Conservation and Water Stewardship, Fisheries Branch (2003), Fisheries and Oceans Canada (2003 to 2006), and Mustang Minerals Corp. (2007). The collected results provide a description of the large-and small-body fish communities in the Bird River system.

The Bird River adjacent to the study area supports a community of five large-body species and six small-body species (Table 5.15). All large-body species captured were species that do not require access to a lake in order to sustain the populations (Scott and Crossman 1973). There was a gradient in fish density, as measured by (CPUE), along the Bird River. Fish density was highest at site BR-US, immediately downstream of the PR 315 crossing, moderate to low in the reach immediately upstream of the TANCO road crossing, and lowest at BR-US (Table 5.15; Figure 5.6). The high CPUE at BR-US was likely due to a higher degree of habitat heterogeneity than in other surveyed reaches of the Bird River (Matthews 1998). In the 250 m reach immediately downstream of the fifth set of rapids, the river flows turbulently between slowly circulating back eddies formed within embayments on either side of the channel. Also within this reach, there were several scour holes, ranging in depth from 4 to 10 m. Downstream of this reach, the river channel was relatively uniform in width, had a narrow range in water depth (2.5 to 3.5 m), and had a low degree in channel sinuosity. Together, these characteristics result in a continuous run (an area of uniform flow and little to no surface disturbance) which is typically characterized by lower habitat heterogeneity and therefore lower fish community diversity (Matthews 1998).

The small-body fish community was comprised of a mixture of river, fast-water, and headwater species (Table 5.15). Emerald Shiner, Blacknose Shiner, and Mimic Shiner are typically associated with areas of lower current velocities in rivers (Stewart and Watkinson 2007). Longnose Dace and Johnny Darter were captured in areas of Bird River with higher current velocities. Longnose Dace were captured at the PR 315 crossing within the rapids at the bridge which is consistent with known habitat preferences (Stewart and Watkinson 2007). Johnny Darter were captured downstream of the fourth set of rapids which is also consistent with known Johnny Darter habitat preferences (Stewart and Watkinson 2007).

Table 5. 15 Catch per unit effort for fishes captured in the Bird River, October 1998 and August 2007.

SITE	Effort	Species									
		NRPK[1]		WALL[2]		WHSC[3]		YLPR		Total	
ID	(hrs)	n	CPUE	n	CPUE	n	CPUE	n	CPUE	n	CPUE
BR-US	5.25	11	2.10	6	1.14	2	0.38	37	7.05	56	10.67
BR-3	4.13	6	1.45	2	0.48	4	0.97			12	2.91
BR-8	4.08	4	0.98	1	0.25	7	1.72			12	2.94
BR-DS	29.92	3	0.10	1	0.03	2	0.07	12	0.40	18	0.60

[1] Northern Pike *(Esox Lucius);* [2] Walleye *(Sander vitreus)*; [3] White Sucker *(Catostomus commersoni)*
[4] Yellow Perch *(Perca flavescens)*

5.3.8 *Species at Risk*

No aquatic species listed under the *Species at Risk Act* are known to occur in the TANCO project study area. The Carmine Shiner (*Notropispercobromus*) is known to occur in the region but the nearest location is 15 km downstream of the TANCO road crossing at the first set of rapids on the Bird River (COSEWIC 2006). A recent, intensive fish community survey along the Bird River conducted by DFO was unable to extend the distribution upstream in the Bird River (Watkinson unpubl. data).

5.4 Human Environment

5.4.1 *Regional Area of Interest*

The regional area of interest for the TANCO Mine is defined by a number of factors, including communities that derive economic benefits from the project and where the mine employees reside. At peak operating capacity, TANCO employs up to 150 people at its TANCO Mine/Mill operation. Most of these employees live in the Rural Municipality (RM) of Lac du Bonnet, the Town ofLac du Bonnet and the Local Government District (LGD) of Pinawa (Cabot Corporation 2001). The Bird River area north of the TANCO Mine is also of interest as many recreational and permanent residents use the river and are located along this watercourse.

5.4.1.1 *MUNICIPALITIES*

Municipalities in the regional study area closest to the minesite include:

- RM of Lac du Bonnet;
- Town of Lac du Bonnet;
- LGD of Pinawa;
- RM of Alexander;
- Town of Powerview-Pine Falls; and
- Pointe du Bois.

The **RM of Lac du Bonnet** has a population of 2,671 (Statistics Canada 2011). The population increases considerably during the summer months as there are a number of cottage developments within the municipality. The local economy is based on agriculture including small grains and oil seeds (Manitoba Community Profiles). Hydroelectric generation, mining, forestry and tourism sectors are also major employers in the area.

The **Town of Lac du Bonnet**, with a population of 1,328, is a retail and service centre for local residents and tourists in the area (Statistics Canada 2011).

The **LGD of Pinawa** has a population of 1,444 (Statistics Canada 2011). The decommissioning of Atomic Energy of Canada's Whiteshell Laboratories provides local employment, along with knowledge-based companies, health care, education services, mining, Manitoba Conservation, Manitoba Hydro, and tourism (Manitoba Community Profiles).

The **RM of Alexander** has a population of 2,983 (Statistics Canada 2011). With a number of cottage developments in the municipality, the population increases significantly during the summer months. Summer and permanent residents inhabit the subdivisions along the Bird River adjacent to Provincial Highway 315 southwest of Nopiming Park. Major economic activities in the RM include forestry, hydro, agriculture and tourism (Manitoba Community Profiles). The RM's largest community is Powerview-Pine Falls and other significant communities include Great Falls, St. Georges and Stead.

The **Town of Powerview-Pine Falls** has a population of 1,314 (Statistics Canada 2011 It was formed by the amalgamation of the two sister towns of Powerview and Pine Falls in 2005 (www.powerview-pinefalls.com). Historically, the largest employers in the town are the paper and hydro industry and the town also has a strong service industry.

Pointe du Bois is a small community on the Winnipeg River with a 78 Megawatt hydro generating station. Manitoba Hydro is currently designing a new powerhouse and spillway to replace the current one.

Municipalities in the regional study area located at a greater distance from the mine are described in Table 5.16.

5.4.1.2 *First Nations*

First Nations in the vicinity of the mine include:

- Fort Alexander (Sagkeeng First Nation);
- Black River First Nation;
- Brokenhead First Nation; and
- Hollow Water First Nation.

The **Sagkeeng First Nation (Fort Alexander)** has a total registered population of 7,455 with 3,301 residing on-reserve (AANDC 2013). The Sagkeeng First Nation advanced a claim of unextinguished aboriginal title with the Manitoba Court of Queen's Bench covering an extensive area from Fort Alexander east to the Ontario border in 2007.

The **Black River First Nation**, also referred to as the Little Black River First Nation, has a total registered population of 1,219 with 884 residing on-reserve (AANDC 2013).

The **Brokenhead First Nation** is an Ojibway Nation with a total registered population of 1,905 with 630 residing on-reserve (AANDC 2013). They are composed of the Birch Landing, Brokenhead 4 and Na-Sha-Ke-Penais reserves.

The **Hollow Water First Nation** has a total registered population of 1,824 with 985 residingon-reserve (AANDC 2013).

5.4.2 *Regional Economy*

The regional area was developed through mining, forestry, and hydro-electric projects and much of the early settlement in the area southwest of TANCO was due to the presence of fertile agriculture lands. By the early twentieth century, mining claims had been staked at Rice Lake, the first hydro-electric plant on the Winnipeg River had been built at Pinawa, and logging operations had begun in the region. The construction of the CPR rail line in 1901 helped stimulate the developing economy.

Historically, some of the larger mining projects that have operated in the area include: gold production at Central Manitoba Mines from 1927-1937; the San Antonio Gold Mines at Bissett from 1932-1968; the Dumbarton Ni-Cu Deposit 1969-1974; the Maskwa

Ni-Cu open pit from 1974-1976; and the Bissett Mine from 1998-2001. Transportation systems in the area expanded alongside the development of mining.

Today, the diversified regional economy includes agriculture, mining, forestry, technology, tourism, and hydro-electric production. The nearby provincial parks bring many vacationers and cottagers to the area, especially during the summer months. Six hydroelectric power generating stations operate along the Winnipeg River: Pointe du Bois, Great Falls, Seven Sisters, Slave Falls, Pine Falls and McArthur Falls.
San Gold Corporation has been operating the Rice Lake Mine at Bissett since 2006 and employs approximately 220 people.

5.4.3 *Regional Labour Force*

The municipalities that are closest to the mine and are of key interest with respect to the mine labour requirements are: the RM of Lac du Bonnet, the Town of Lac du Bonnet, the LGD of Pinawa, the RM of Alexander, and the Town of Powerview-Pine Falls; currently the majority of the mine employees live in nearby Lac du Bonnet or Pinawa. The labour distribution by industry from the 2006 federal census, for the above-mentioned municipalities, is presented in Table 5.17.

Table 5. 16 Municipalites in the regional study area.

Municipality	Population[a]	Economy[b]
RM of Whitemouth	1,548	Serves as a supply centre to many vacationers in the provincial parks. Local residents are also employed by the logging industry and cattle and grain farming.
RM of Reynolds	1,285	Population is comprised of small hamlets including Richer East, Ste Rita, Molson, Rennie, Hadashville, Prawda, McMunn and East Braintree (RM of Reynolds Website). Tourism is one of the main economic activities and others include forest product related businesses and farming. TANCO ships its ore concentrate out of Molson.
RM of Victoria Beach	374	A resort community located on the SE shores of Lake Winnipeg with a population that explodes during the summer months. It has a small economic base that provides necessary goods and supplies to local residents and a strong service industry.
RM of St. Clements	10,505	Tourism is one of the strongest economic activities, and the RM is home one of the world's most famous freshwater beaches (Grand Beach). Other communities include Libau and Thalbe.
RM of Brokenhead	4,635	Includes the Town of Beausejour and the unincorporated Village of Tyndall. In 2003 the Village of Garson amalgamated with and is now part of the RM of Brokenhead. Most residents are employed in the agricultural business and services.
Town of Beausejour	3,126	Its economy is based on agriculture and tourism, with grain production being the foundation of agricultural activities (TownofBeausejour website). It is also a major retail, service and shopping centre for much of eastern Manitoba.
RM of Springfield	14,069	Its economy is largely based on aggregate resources (sand and gravel pits and stone quarries) and agriculture. It includes the towns of Oakbank and Dugald.
Bissett	130	The community originally acted as a service centre to the San Antonio Gold Mine. San Gold Corporation's Rice Lake Mine is currently the community's largest employer. Mining, forestry, trapping and wild rice harvesting are the major contributors to the local economy, however, tourism and local services also provide income to the community. [c]
Manigotagan	213	Manigotagan and Seymourville are part of a group of four communities (also including Hollow Water Reserve and Aghaming). Economic activity includes forestry, commercial fishing, trapping, hunting, wild rice harvesting and tourism; there is also a large deposit of silica sand in the area that has yet to be developed.[c]
Seymourville	118	

[a]Populations are from Statistics Canada 2011

[b]Descriptions of economy are from Manitoba Community Profiles unless otherwise noted

[c]Descriptions of economy are from Manitoba Aboriginal and Northern Affairs Community Profiles (2003; 2011)

Table 5. 17 Labour force distribution by industry for municipalities in the regional study area (Statistics Canada 2006).

Industry	RM of Lac du Bonnet	Town of Lac du Bonnet	LGD of Pinawa	RM of Alexander	Town of Powerview-Pine Falls	Fort Alexander	Brokenhead First Nation	Hollow Water First Nation	Black River First Nation
Total experienced labour force 15 years and over	1,475	455	565	1,350	705	605	185	170	105
Agriculture and other resource-based industries	370	70	40	215	20	65	15	30	10
Construction	135	15	10	55	10	40	10	20	15
Manufacturing	55	0	25	110	205	10	10	0	0
Wholesale trade	25	0	10	20	15	0	0	0	0
Retail trade	150	55	65	125	35	40	0	0	0
Finance and real estate	30	30	0	40	35	10	10	0	0
Health care and social services	170	70	115	135	140	155	30	30	20
Educational services	90	40	45	100	90	95	15	20	20
Business services	150	30	130	105	25	50	20	15	10
Other services	300	145	120	440	130	145	70	45	20

5.4.4 LAND USE

5.4.4.1 PROVINCIAL PARKS

The TANCO Mine is located approximately 1 km south of the southern boundary of Nopiming Provincial Park and approximately 10 km north of Whiteshell Provincial Park.

Nopiming Provincial Park

Nopiming Provincial Park is a multiple-use park established in 1976 and classified as a Natural Park. The purpose of this park is to preserve areas that are representative of the Lac Seul Upland portion of the Precambrian Boreal Forest Natural Region, and to accommodate a diversity of recreational opportunities and resource uses (Manitoba Conservation 2010).

There are six cottage developments, four campgrounds and three lodges within the park. Four of the cottage developments and two of the campgrounds (Bird Lake Campground and Tulabi Falls Campground) are located near the southern edge of the park and are accessed via Provincial Road 315. There are two lodges in Nopiming Provincial Park; Nopiming Lodge and Windsock Lodge. Nopiming Lodge is located in the southern portion of the park and open year round for fishing, hunting, snowmobiling, water-skiing, hiking, and vacations.

The park includes four main canoe routes with designated backcountry camping areas. The Bird River canoe route from Tulabi Falls to McGregor Lake is one of the most travelled routes. Bird River is also an important recreational waterway used by fishers and hunters.

Other activities in the park include wild rice harvesting and snowmobiling. Wild rice lakes are located north of Bird Lake and farther north in the Cat Lake/Euclid Lake area. Snowmobiling is a popular winter activity in the park and the Wolf Trail is a popular trail near the southern edge of the park.

Whiteshell Provincial Park

Whiteshell Provincial Park was established in 1961 and is classified as a Natural Park. The purpose of the park is to preserve areas that are representative of the Lake of the Woods portion of the Manitoba Lowlands Natural Region and to provide a diversity of recreational opportunities and resource uses (Manitoba Conservation 2010).

The park has 13 main freshwater lakes used for boating, watersports and angling. The park includes numerous hiking trails, mountain biking trails, ski trails, over 325 km of canoe routes, and over 200 km of snowmobile trails. The park has 20 resorts/lodges, 10 campgrounds and numerous cottage developments.

5.4.4.3 *RECREATIONAL USE*

Bernic Lake is not accessible by the general public. The only access road to the lake is gated and only authorized personnel are allowed access. The only boating on the lake is conducted by TANCO contractors who carry out periodic environmental monitoring surveys. These surveys will not be required once the west basin has been dewatered. Until the risk of crown pillar failure has been mitigated, the instability remains a risk to any boating traffic on the lake surface.

The upper reaches of Bernic Creek are accessibly by canoe. The lower reaches are accessible by canoe depending on the seasonal water level. Beaver dams and waterfalls along the creek require several portages, therefore it is very uncommon for recreational activities to occur on Bernic Creek.

Bird River downstream of the confluence of Bernic Creek is used for recreation. A number of cottages are located on the river.

5.4.4.4 *RESOURCE USE*

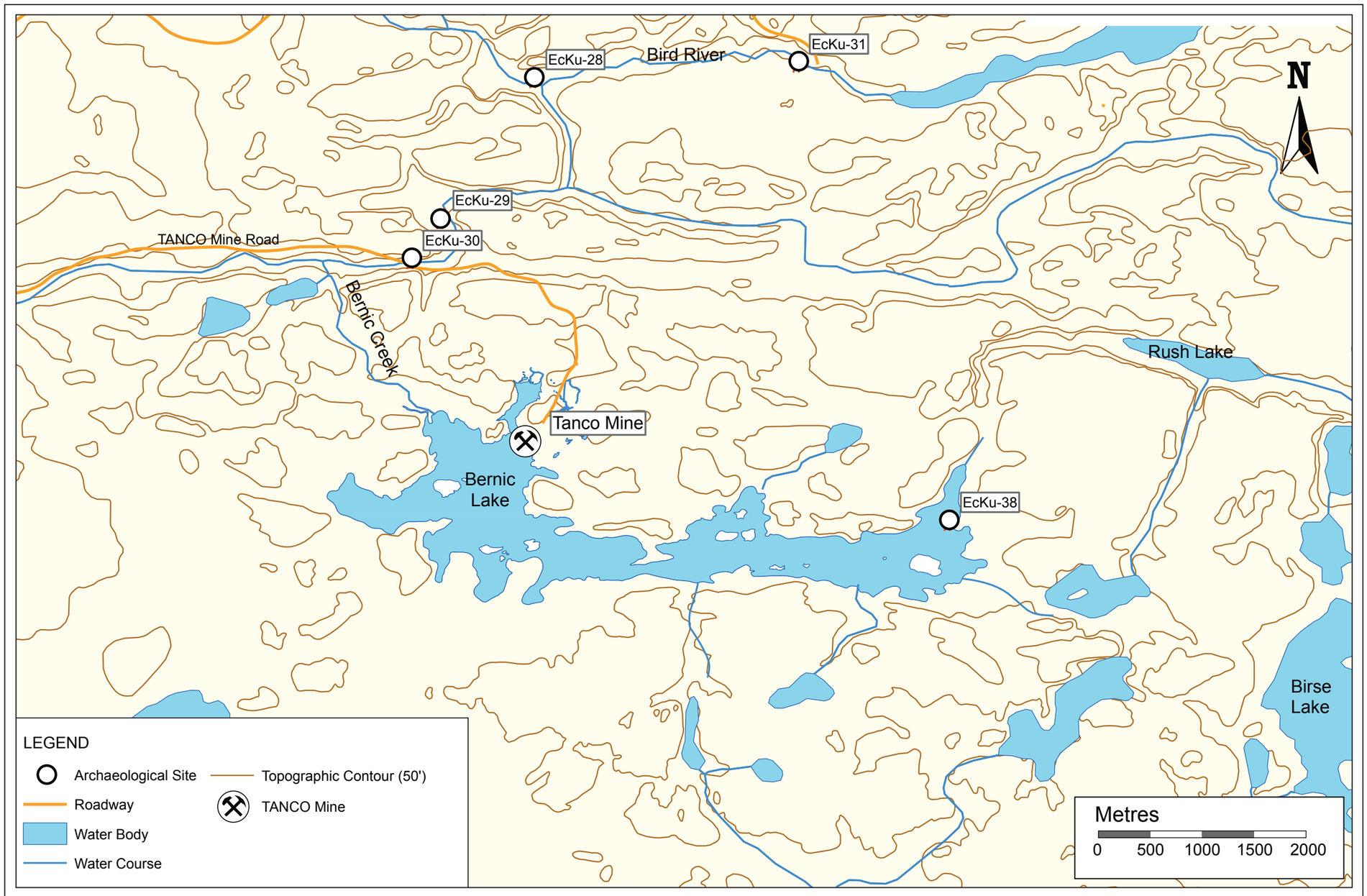
Resource use in the regional study area includes forestry, mining, wild rice harvesting, hunting, fishing and trapping. Forestry occurs north of the Winnipeg River in Forest Management Licence (FML) 1. The FML, held by Tembec Inc., covers approximately 9,000 km^2 of land bordered by Lake Winnipeg to the west, the Manitoba/Ontario border to the east, the Winnipeg River to the south and Atikaki Wilderness Park to the north. Wild rice planting and harvesting occur in lakes and rivers in and around the regional study area. Recreational hunting and fishing are common in the regional study area. Hunting opportunities include waterfowl, geese, grouse, and white tailed deer; black bear and moose are hunted in specific parts of the region (Eastern Manitoba Tourism 2010). Trapping in the regional study area is largely confined to registered trap lines in the Hole River and Lac du Bonnet Registered Trap Line Zones (Manitoba Aboriginal and Northern Affairs 2003).

5.4.4.5 *TRADITIONAL USE*

Hunting, fishing, and gathering by First Nations are common across the regional study area. The local study area, including Bernic Lake, has not been a site of traditional resource harvest during the period of mine operation.

5.4.5 *ARCHAEOLOGICAL RESOURCES*

The local study area is in the EcKu Borden block for archaeological site designation. There are five archaeological sites within/adjacent to the local study area: Ecku-28, 29, 30, 31 and 38 (Table 5.18; Figure 5.7; MB Historical Resources Branch 2010).



TETRA TECH

FIGURE 5.7
DOCUMENTED ARCHAEOLOGICAL SITES
NEAR THE TANCO MINE

Table 5. 18 Five archaeological sites in the study area; UTM coordinates are in NAD83

Borden No.	UTM Easting	UTM Northing	Common Name
EcKu-28	751656	5595767	Waneka Site
EcKu-29	750906	5594424	Paywistic Site
EcKu-30	750627	5593900	n/a
EcKu-31	754238	5596185	Forest Ranger Cabin Site
EcKu-38	755964	5591825	Bernic Lake Site

5.4.6 *Local Traffic*

Manitoba Infrastructure and Transportation (MIT) and the University of Manitoba Transport Information Group (UMTIG) compiled daily traffic data for the province of Manitoba for 2009 (MIT and UMTIG 2010). The following traffic volume data for the network of roads that run from Lac du Bonnet to the TANCO Mine (PR 313 east of the Winnipeg River and PR 315; Table 5.19) were compiled from MIT and UMTIG (2010).

Local residents, cottagers, park users, and employees of TANCO and other rural business are the usual travelers on these roads. Speed limits are 100 km/hr on PR 313 and 100 km/hr on paved sections and 90 km/hr on gravel sections of PR 315. The speed limit is further reduced when crossing narrow bridges.

At peak operation, the mine employs approximately 150 people, many of whom commute to work from Lac du Bonnet, Pinawa, and Winnipeg. Traffic volumes for the TANCO Mine Road are estimated at 40 to 50 cars and 5 to 6 trucks per day when the mine is at full production. Mine employees typically travel by carpool, which reduces the traffic load. Peak travel times occur around the mine shift changes (7:00 to 8:00, 16:00 to 16:30, and 19:00 to 20:00). Detailed truck volume data are available for 2007 to 2009. When operating at full capacity, there is an average of 5.5 trucks per day.

Table 5. 19 Average annual and peak traffic volumes for PR 313 and 315 (MIT and UMTIG 2009).

Highway	Average Annual Daily Traffic (AADT; (No. Vehicles)[a]	Average Summer Daily Traffic (ASDT; No. Vehicles)[b]	Average Daily TANCO Traffic at full capacity (No. Vehicles)[c]
PR 313[d]	1510	2205	101
PR 315 [e]	900	1314	101
PR 315 [f]	150	219	101

[a]The AADT is defined as the number of vehicles passing a point on an average day of the year. The reported combined AADT is based on the sum of the two directions.
[b]The average summer daily traffic is the number of vehicles passing a point on an average day during the period May 1 through September 30.
[c]Sum of the two directions for 2008.
[d]From Lee River to the junction of PR 315.
[e] From the junction of PR 313 to the Bird River bridge.
[f]From the Bird River bridge to the PR 314 junction.