



Keeyask Generation Project Environmental Impact Statement

Supporting Volume Aquatic Environment



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APPENDICES



AQUATIC ENVIRONMENT
SECTION 2: WATER AND SEDIMENT QUALITY

APPENDIX 2A BACKGROUND INFORMATION ON SELECTED WATER QUALITY PARAMETERS



The following provides a brief description of key water quality variables that are considered in the main document.

2A.1 WATER TEMPERATURE AND STRATIFICATION

Water temperature is an important variable in aquatic systems not only for its direct relevance to the growth, condition, and survival of biota, but also because it affects the rates and occurrence of biological processes and influences water chemistry (*e.g.*, the amount of DO that water can hold is determined by its temperature). Changes to water temperature may affect water chemistry, growth and biological processes, toxicity of some substances, spawning times and locations, and productivity of aquatic organisms. Water temperature also affects important physical processes such as ice regimes.

Some waterbodies, notably lakes, may regularly or periodically stratify. Stratification is a function of changes in water's density with changes in temperature (*e.g.*, through surface warming or cooling) and the ability of the lake to mix upper and lower layers of water. It is commonly defined as a temperature change of 1°C or more in 1 m of water. Two distinct layers may form: an upper layer (epilimnion); and a lower layer (hypolimnion). Stratification may develop in summer when the epilimnion is warmed due to surface heating and the lake circulation is not strong enough to mix the less dense water at the surface with the cooler, denser hypolimnetic waters. In fall/winter, the epilimnion may cool and remain unmixed from the warmer and denser hypolimnion thus forming stratification. Numerous physical conditions affect the ability of stratification to develop in a lake including: lake morphometry; distance across which the wind blows (fetch); lake depth; lake volume; water residence time; air temperatures; wind speed; and solar radiation. Stratification is significant from a biological perspective as it affects temperature profiles in waterbodies and because it results in isolation of upper and lower layers of water, thus affecting exchange and flow of chemical constituents. In particular, stratified waterbodies may develop significant DO depletion in bottom waters.

A2.2 DISSOLVED OXYGEN

Dissolved oxygen is essential for the survival of most aquatic biota. It is consumed by aquatic organisms including animals, plants, algae, and bacteria in the water column and sediments. Sources of DO to aquatic systems are aeration (*i.e.*, input of oxygen from the atmosphere) and photosynthesis by plants and algae. The concentration of DO in surface waters is affected by water temperature; colder water can hold more DO than warmer water and saturation occurs at a higher concentration in winter. DO may decrease in north temperate ecosystems that experience long periods of ice cover due to the lack of an oxygen source from the atmosphere (*i.e.*, no or minimal reaeration due to ice). DO may also vary across depth in environments that stratify, typically being lowest at depth.

2A.3 WATER CLARITY: TOTAL SUSPENDED SOLIDS, TURBIDITY, SECCHI DISK DEPTH, AND COLOUR

Water clarity is often described using measures of TSS or turbidity, which are generally interrelated (and typically correlated) but represent different measures. TSS is a measure of the amount (by weight) of suspended solids such as sediments in water whereas turbidity is a measure of scattering of light by suspended particles in water and it reflects the transparency of water caused by dissolved and suspended substances (Caux *et al.* 1997). At very high concentrations, TSS can reduce fish growth rates, modify fish movements, affect fish egg and larval development, impair foraging and predation behaviour of fish, reduce abundance of fish diet items, affect reproduction of aquatic biota, reduce immunocompetency of aquatic biota, and harm benthic habitats. At lower concentrations, suspended sediment can influence aquatic ecosystems by reducing light penetration into the water column, thereby limiting the growth of plants and algae, and may affect behaviour of aquatic life (*e.g.*, predation success of fish). Turbidity and TSS are also relevant to the suitability of water used for drinking and recreation, and affect the aesthetic quality of aquatic ecosystems. Primary sources of TSS in surface waters include shoreline erosion, point sources (*e.g.*, municipal or industrial wastewaters), surface water runoff/land use, and sediment resuspension.

Secchi disk depth refers to the depth at which a black and white coloured disk lowered into the water is no longer visible. It is used as a general indicator of water clarity and can be used to estimate the depth of the euphotic zone (generally defined as the depth at which 1% surface radiation remains) in aquatic ecosystems. As Secchi disk depth is affected by all factors affecting visibility, including the presence of algae, it is often used as one of several indicators of trophic status in lakes.

Colour is the result of backscattering of light upward from a water body after it is selectively absorbed at various depths (CCME 1999; updated to 2012). Both the colour of light and turbidity determine the depth to which light penetrates a water body. The colour of water can be measured as apparent colour or true colour. True colour, which was measured in this study, depends on the dissolved fraction of substances in water, and also on the physical and chemical properties that affect the solubility and stability of the dissolved and particulate fractions of water such as pH and temperature (CCME 1999; updated to 2012). It is important in terms of aesthetics, drinking water quality (aesthetics), the toxicity of certain contaminants (*e.g.*, mercury toxicity increases with increasing water colour [Haines *et al.* 1995]), and is pertinent to the behaviour and presence of aquatic flora and fauna (*e.g.*, algal species composition; reviewed in CCME 1999; updated to 2012).

2A.4 NITROGEN AND PHOSPHORUS

Nitrogen and phosphorus are the major nutrients in surface waters that support the growth of aquatic plants, benthic algae (*i.e.*, periphyton), and algae in the water column (phytoplankton). Sources of nutrients in surface waters include the breakdown of organic matter, excretion by organisms, wastewater discharges, erosion and run-off from the watershed, sediment resuspension, and atmospheric deposition.

Nutrients are not toxic at the concentrations normally found in surface waters. However, nutrient enrichment can stimulate excessive growth of plants and algae (*i.e.*, eutrophication), which can subsequently lead to the degradation of aquatic habitat through physical changes (*e.g.*, excessive plant or algal growth over gravel substrate), and through changes to water quality (reduced dissolved oxygen at night, reduced water clarity due to phytoplankton, and possible production of toxins by some forms of phytoplankton). Stimulation of plant or algal growth by nutrient enrichment in individual water bodies also depends on several other factors that potentially limit plant or algal growth, such as water clarity, temperature, flushing rates, and turbulence.

Nitrogen is a major plant nutrient that may affect the productivity of fresh waters (Wetzel 1983). In water, nitrogen may be found in a number of forms: ON, ammonia-nitrogen, nitrate-nitrogen, and nitrite-nitrogen. Within surface waters, these various nitrogen pools may exist in particulate or dissolved forms. Organic nitrogen decays to produce ammonia via anaerobic bacterial decay processes. Ammonia in turn is converted to nitrite and ultimately to nitrate via the process of nitrification - an aerobic bacterial process. Algae (and other aquatic plants) readily take up dissolved inorganic nitrogen, which consists of ammonia and nitrate, with a typical preference for ammonia. Three forms of nitrogen were measured in this study: dissolved nitrate/nitrite-nitrogen; total Kjeldahl nitrogen (*i.e.*, the sum of ON and ammonia); and dissolved ammonia-nitrogen.

Phosphorus is the most common nutrient limiting the growth of phytoplankton in lentic fresh water systems and concentrations are often related to the productivity of aquatic systems (Wetzel 1983). Two types of phosphorus, TP and DP, were quantified in this study. Dissolved forms of phosphorus are those most readily used by phytoplankton for growth. The amount of DP in the water column may fluctuate over the growing season, as phosphorus is bound up in algal cells and plants in the spring and summer, and is released in the fall and winter with the death and decomposition of plankton and plant matter. Total phosphorus includes DP as well as the phosphorus contained in suspended matter such as plankton (small plants and animals that exist in the water column) or bound to mineral sediments.

2A.5 CARBON

In the aquatic environment, carbon exists in two primary forms: OC (such as the carbon contained in humic acids, sugars, and carbohydrates); and inorganic carbon (IC; such as the carbon contained in carbon dioxide, carbonate, and bicarbonate). Carbon is found in many different substances, some of which may be dissolved in water and others that may be bound to (or contained within) particles suspended in the water column.

Algae and rooted plants can use IC, in the form of carbon dioxide, and convert it to OC through photosynthesis. Bacteria and other microorganisms may consume dissolved and particulate OC, and in turn provide food for larger organisms such as invertebrates and fish. The amounts and types of carbon present in aquatic ecosystems are dependent on numerous variables, including the type of rock in the area (*i.e.*, geological conditions), climate, topography, vegetative cover, and size of the watershed (Horne and Goldman 1994). Dissolved organic carbon may also affect light attenuation in waterbodies; generally, as DOC, particularly the concentration of humic materials, increases, light attenuation also increases (Wetzel

1983). DOC may also form complexes with nutrients and metals, thus reducing their bioavailability (Faithfull *et al.* 2006; Gorniak *et al.* 1999; Jones *et al.* 1988).

2A.6 pH

The pH of water indicates the acidity of an aquatic system, and is influenced by nutrients, organic acids, metals, gases, algae (*i.e.*, photosynthesis), solar radiation (*i.e.*, temperature), and particulates (CCME 1999; updated to 2012). Changes in pH can influence the chemical state of important plant nutrients such as phosphate, ammonia, iron, and trace metals (Horne and Goldman 1994). pH may directly affect aquatic biota (*i.e.*, highly acidic or alkaline conditions can threaten aquatic life) or may be indirectly harmful to aquatic life (*e.g.*, increase bioavailability of metals). Reductions of pH may mobilize metals bound in sediments (*i.e.*, release metals to water) and may alter the physico-chemical form of metals in aquatic systems. Additionally, accumulation of methylmercury in fish is greater in low pH lakes (Spry and Wiener 1991). pH may be altered by flooding of soils, decomposition of organic matter, and photosynthesis. A fairly wide range of pH in surface water is suitable for aquatic life and wildlife.

2A.7 HARDNESS

Hardness, a measure of the concentration of calcium carbonate in water, affects the accumulation and toxicity of numerous metals to aquatic biota (*i.e.*, metals are less toxic to aquatic life in hard water). Hardness is a reflection of the type of soil minerals and bedrock in the local environment, as well as the hydrological characteristics of the area (*e.g.*, length of time water is in contact with bedrock). In general, soft water occurs in watersheds characterized by igneous rock, whereas hard water occurs in systems draining through carbonate rock (Williamson and Ralley 1993). The hardness of surface waters is generally categorized according to the ranges presented in Table 2-2 (CCREM 1987).

2A.8 ALKALINITY

Alkalinity is a measure of the water's acid-neutralizing capability, which is largely dependent upon the concentration of calcium carbonate (water hardness) in the water. It is generally a reflection of the local geology and bicarbonates being leached from the soil. High alkalinity may indicate high levels of primary production and nutrient inputs. Production and bioaccumulation of methylmercury in aquatic food webs is greater in low alkalinity/low pH lakes (Spry and Wiener 1991). Furthermore, lakes with low-buffering capacity may be more susceptible to acidification due to flooding or acidic precipitation. The sensitivity of lakes to acidification is often categorized on the basis of total alkalinity. A commonly applied categorization scheme is presented in Table 2-3 (Saffran and Trew 1996).

2A.9 TOTAL DISSOLVED SOLIDS AND CONDUCTIVITY

Total dissolved solids and conductivity are measures of the amount of minerals and organic matter dissolved in water, reflecting both natural conditions such as local geology, and anthropogenic activities

that increase these substances in water (*e.g.*, mining effluents). Total dissolved solids may affect the quality of water for human use (*i.e.*, taste, scaling, corrosion, and laxative effects).

Electrical conductivity is a measure of water's ability to conduct an electrical current and indicates the amount, but not the type, of dissolved solids present. As the amount of solute dissolved in water is temperature dependent, conductivity of a solution typically increases by approximately 2% with each 1°C increase in temperature (Wetzel 1983). To provide comparable data between locations and sampling times, conductivity is frequently expressed as specific conductance, which is conductivity standardized to a water temperature of 25°C.

2A.10 METALS AND METALLOIDS

Metals and metalloids (*i.e.*, mercury, selenium, and arsenic) are typically present in surface waters and sediments. At sufficient concentrations, certain metals/metalloids (such as arsenic, cadmium, and mercury) can be harmful to fish, wildlife, and humans. Conversely, many metals are biologically essential (*e.g.*, iron, calcium). Metals are introduced to surface waters through erosion and weathering of soils and rock and atmospheric deposition. Whereas high concentrations of metals occur naturally in some waterbodies, they may become elevated due to various anthropogenic activities, including acidification (*e.g.*, acid rain), agricultural activities, mining and smelting, combustion of fossil fuels, or the release of municipal and industrial effluents. In aquatic ecosystems, metals may bioaccumulate in aquatic biota through water and ingestion of food containing metals. Mercury also biomagnifies across the food web and is generally found at the highest concentrations in top predators. In freshwater aquatic ecosystems, the highest concentrations are generally observed in piscivorous fish, such as northern pike and walleye. Flooding may increase the accumulation and magnification of mercury in aquatic ecosystems, an effect that is commonly observed in newly created hydroelectric reservoirs.

2A.11 BACTERIA AND PARASITES

Fecal coliform bacteria (used as an indicator of the potential presence of pathogenic bacteria) and the protozoan parasites *Cryptosporidium* sp. and *Giardia* sp. can be spread through the release of untreated human and animal wastes into surface waters. These organisms may have human or animal (*i.e.*, livestock or wildlife) origin. *Giardia* causes giardiasis, known colloquially as 'beaver fever', and *Cryptosporidium* causes cryptosporidiosis in humans, both of which are intestinal disorders. Their presence affects the quality of water used for drinking and for recreation.

2A.12 REFERENCES

2A.12.1 LITERATURE CITED

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APPENDIX 2B

WATER AND SEDIMENT QUALITY

OBJECTIVES AND GUIDELINES



The following is a summary of water and sediment quality objectives and guidelines applied for evaluation of water quality data collected in the study area. Water and sediment quality objectives and guidelines discussed below refer to those presented in MWS (2011) and CCME (1999; updated to 2012) for PAL, drinking water, and recreation.

Many of MWQSOGs for water and sediment quality are identical to the CCME guidelines. Where differences exist, they are discussed in the following sections.

2B.1 WATER QUALITY OBJECTIVES AND GUIDELINES FOR THE PROTECTION OF AQUATIC LIFE

2B.1.1 AMMONIA

MWQSOGs for ammonia are dependent upon water temperature and pH and the presence of cool- or cold-water aquatic life (MWS 2011). A representative range of Manitoba water quality objectives for ammonia for the range of pH and temperature measured at across the study area (*i.e.*, site-specific objectives) during water quality sampling is presented in Table 2B-1.

The CCME PAL guidelines for ammonia (Table 2B-2) are similar to the MWQSOGs as they are also based upon water temperature and pH. Major differences relate to the data used for derivation of the guidelines and the application of multiple objectives for different life history stages of cool- and cold-water aquatic life in the MWQSOGs. Ranges of MWQSOGs are provided for comparison in Table 2B-2. Depending upon pH and temperature, and the specific applicable MB objective for that location/condition, MWQSOGs are lower than, similar to, or higher than the CCME guidelines (Table 2B-2).

2B.1.2 DISSOLVED OXYGEN

Manitoba water quality objectives for DO are dependent upon water temperature, life history stages, and the presence of cool-water fish (such as northern pike and walleye) or cold-water fish species (such as lake whitefish; MWS 2011). Objectives are generally more stringent in environments inhabited by cold-water fish species. Objectives, which are specific for early life stages and mature life stages and vary according to the averaging duration, are presented in Table 2B-3.

In winter, when water temperature is less than or equal to 5°C and early life stages of fall spawning cold-water fish species (*e.g.*, lake whitefish and cisco) may be present in the study area, the first two objectives apply (9.5 mg/L chronic objective and 8.0 mg/L instantaneous minimum objective) to ensure the protection of these early life stages. Less stringent objectives apply in winter for cool-water fish species that are spring spawners (3.0, 4.0, and 5.5 mg/L).

In the open water season, when water temperature is greater than 5°C and early life stages of cold-water fish species are not present, objectives are less stringent (objectives range from 4.0 to 6.5 mg/L). However, early life stages of spring spawning fish species (e.g., walleye) may be present in the study area at this time, thus requiring application of appropriate guidelines to ensure their protection (*i.e.*, early life stages of cool water species are present). Of the two, objectives for the protection of mature life stages of cold-water fish species and early life stages of cool-water fish species (*i.e.*, when water temperature is greater than 5°C) are similar, with one major exception. The instantaneous minimum for the protection of early life stages of cool-water fish species in the ice-free season (5.0 mg/L) is more stringent than the instantaneous minimum objective for the protection of mature life stages of cold-water fish species (4.0 mg/L); chronic objectives are similar for both (5.0 to 6.5 mg/L).

The CCME (1999; updated to 2012) has also adopted guidelines that vary according to the presence of early life history stages but differ by differentiating between warm-water and cold-water ecosystems rather than cool- and cold-water ecosystems (Table 2B-4). The study area does not contain warm-water species and only the cold-water guidelines would be applicable. The CCME also indicate a minimum DO concentration of 6.5 mg/L should be applied within redds to protect fish embryos. While there are fewer CCME guidelines for DO, the guidelines for cold-water ecosystems are identical to the most stringent Manitoba water quality objectives (*i.e.*, 6.5 and 9.5 mg/L).

2B.1.3 TOTAL SUSPENDED SOLIDS AND TURBIDITY

The MWQSOGs specify two objectives for TSS, depending upon the averaging duration, and vary according to the environment (*i.e.*, background TSS conditions). The short-term objective indicates an allowable increase of up to 25 mg/L above background, where background TSS concentrations are less than or equal to 250 mg/L or a 10% change from background where TSS is greater than 250 mg/L. The applicable averaging duration for this objective is one day.

The applicable long-term Manitoba PAL objective for the study area would generally be an allowable increase in TSS of 5 mg/L (applies to aquatic environments where 'background' TSS is less than or equal to 25 mg/L) for the protection of aquatic life (MWS 2011), as TSS is generally below 25 mg/L along the Nelson River. However, TSS has ranged above 25 mg/L; in such instances the chronic objective would be the equivalent of a 10% increase above background. The MWQSOGs also indicate that turbidity may be used as a surrogate for TSS, with guidelines reflecting an equivalent level of change as calculated from site-specific or regional-specific correlations between these variables.

The CCME (1999; updated to 2012) have adopted similar water quality guidelines for TSS as summarized in Table 2B-5.

2B.1.4 NITRATE

The Manitoba water quality guideline for nitrate for the protection of aquatic life is 2.93 mg N/L¹, which is consistent with the CCME PAL guideline.

2B.1.5 CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT PHOSPHORUS GUIDANCE FRAMEWORK

The CCME introduced a phosphorus guidance framework in 2004 (CCME 1999; updated to 2012). Once the background or reference condition has been defined, the trophic status of a waterbody is classified according to total phosphorus concentrations (Table 2B-6). The framework indicates two triggers to define increases from background (*i.e.*, reference conditions) that may indicate a potential problem or risk of an impact. The first trigger specifies that TP should remain within the defined trophic category (*i.e.*, the upper limit of a trophic category is considered the trigger). The second trigger specifies that TP should not increase by more than 50% from background, regardless of whether the first trigger is met or exceeded.

2B.1.6 MANITOBA NARRATIVE NUTRIENT GUIDELINE

MWS (2011) presents a narrative nutrient guideline, with a numerical guideline for phosphorus, for Manitoba surface waters, which is intended to protect various water usages. The guideline specifies: “Nitrogen, phosphorus, carbon, and contributing trace elements should be limited to the extent necessary to prevent the nuisance growth and reproduction of aquatic rooted, attached and floating plants, fungi, or bacteria, or to otherwise render the water unsuitable for other beneficial uses. For general guidance, unless it can be demonstrated that total phosphorus is not a limiting factor, considering the morphological, physical, chemical, or other characteristics of the water body, total phosphorus should not exceed 0.025 mg/L in any reservoir, lake, or pond, or in a tributary at the point where it enters such bodies of water. In other streams, total phosphorus should not exceed 0.05 mg/L. It should be noted that maintenance of such concentrations may not guarantee that eutrophication problems will not develop.”

¹ The Manitoba PAL guideline for nitrate indicated in MWS (2011) was incorrectly identified as 13 mg N/L. The PAL guideline should read 2.93 mg N/L (Armstrong *pers. comm.* 2012).

2B.1.7 pH

The Manitoba (MWS 2011) and the CCME (1999; updated to 2012) pH guideline for the protection of aquatic life is a range of 6.5–9.

2B.1.8 METALS

The majority of MWQSOGs for metals and major ions for the protection of aquatic life are identical to the CCME PAL guidelines (Table 2B-7). Exceptions include metals which are identified as Tier II objectives in the MWQSOGs. Although both the CCME and MWS specify that guidelines/objectives for cadmium, copper, and nickel should be derived based on site-specific hardness the absolute values differ; CCME guidelines for copper and cadmium are more stringent than MWQSOGs while the MWQSOG for nickel is more stringent than the CCME guideline. In addition, the CCME guidelines for chromium and zinc are lower than the MWQSOGs. It should be noted that the MWQSOGs incorporate water hardness in the calculation of site-specific objectives for both chromium and zinc whereas the CCME guidelines do not. The CCME guideline for arsenic is notably lower than the MWQSOG for PAL.

2B.1.9 CHLORIDE

The CCME has recently developed a guideline for chloride whereas there is currently no guideline identified in the MWQSOGs.

2B.2 DRINKING WATER QUALITY OBJECTIVES AND GUIDELINES

Drinking water quality guidelines are presented in Table 2B-8. MWQSOGs for variables presented in Table 2B-8 are identical to the CCME (1999; updated to 2012)/Health Canada (2010) drinking water quality guidelines.

2B.3 WATER QUALITY OBJECTIVES AND GUIDELINES FOR RECREATION

Manitoba water quality objectives and guidelines for recreation are largely identical to CCME/Health Canada guidelines (Table 2B-9). In addition to the numerical guidelines presented in Table 2B-9, both Manitoba and CCME/Health Canada also specify narrative guidelines for the protection of aesthetics (*e.g.*, odour, appearance), debris, and oil and grease. While Health Canada (Health and Welfare Canada 1992) suggest a guideline of 50 NTU for turbidity, MWS only identify a narrative guideline for this parameter. In addition, MWS do not identify a minimum Secchi disk depth for primary contact recreation waters.

2B.4 SEDIMENT QUALITY GUIDELINES

Manitoba adopted the CCME sediment quality guidelines in the MWQSOGs (MWS 2011) as indicated in Table 2B-10. Guidelines adopted by other agencies for additional substances are also presented in Table 2B-10 below. The British Columbia Ministry of the Environment (2009) guideline for selenium (2.0 µg/g d.w. based on a total organic carbon content of 5%) was also used for comparison to Keeyask environmental studies.

2B.5 REFERENCES

2B.5.1 LITERATURE CITED

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2B.5.2 PERSONAL COMMUNICATIONS

- Armstrong, Nicole. 2012. Manitoba Conservation and Water Stewardship, Water Stewardship Division, Water Science and Management Branch. Suite 160, 123 Main Street, Winnipeg MB, R3C 1A5. May 01, 2012.

Table 2B-1: Range of applicable Manitoba Water Quality Objectives for ammonia, for the protection of cool-water and cold-water aquatic life and wildlife. Values calculated from algorithms provided in Manitoba Water Stewardship (2011) and the range of pH (laboratory) and water temperature measured in the study area. The most stringent objective is indicated in red

pH	Temperature (°C)	Ammonia Objective (mg N/L)		
		Averaging Period		
		30-day	4-day	1-hour
Cool-water species: early life stages present				
6.70	0.0	6.44	16.1	44.6
	23.1	3.71	9.26	44.6
8.69	0.0	0.791	1.98	2.25
	23.1	0.455	1.14	2.25
Cool-water species: early life stages absent				
6.70	0.0	10.5	26.2	44.6
	23.1	3.71	9.26	44.6
8.69	0.0	1.29	2.25	2.25
	23.1	0.455	1.14	2.25
Cold-water species: early life stages present				
6.70	0.0	6.44	16.1	29.8
	23.1	3.71	9.26	29.8
8.69	0.0	0.791	1.50	1.50
	23.1	0.455	1.14	1.50
Cold-water species: early life stages absent				
6.70	0.0	10.5	26.2	29.8
	23.1	3.71	9.26	29.8
8.69	0.0	0.455	1.14	1.50
	23.1	0.455	1.14	1.50

Table 2B-2: Range of applicable Canadian Council of Ministers of the Environment (CCME) water quality guidelines for ammonia, for the protection of aquatic life, based on the range of pH (*in situ*) and water temperature measured in the study area. The ranges of Manitoba Water Quality Standards, Objectives and Guidelines (MWQSOGs) for the same temperature and pH are provided for comparison

pH	Temperature (°C)	CCME Total Ammonia	MWQSOGs Total Ammonia
		Guideline (mg N/L)	(mg N/L)
6.0	0	190	6.67–55.0
	25	27.6	3.39–55.0
6.5	0	60.0	6.67–48.8
	25	8.72	3.39–48.8
7.0	0	19.0	5.91–36.1
	25	2.77	3.01–36.1
7.5	0	6.02	4.36–19.9
	25	0.888	0.222–19.9
8.0	0	1.92	2.43–8.41
	25	0.291	1.24–8.41
8.5	0	0.616	1.09–3.20
	25	0.103	0.554–3.20
9.0	0	0.206	0.486–1.32
	25	0.044	0.247–1.32

Table 2B-3: Manitoba Water Quality Objectives for dissolved oxygen (Manitoba Water Stewardship 2011)

Conditions	Dissolved Oxygen Objective (mg/L)			
	Averaging Duration			
	Instantaneous Minimum	7 Day Min.	7 Days	30 Days
Cold-Water Aquatic Life and Wildlife				
When Water Temperature $\leq 5^{\circ}\text{C}$ and Early Life Stages Present	8.0	-	9.5	-
When Water Temperature $> 5^{\circ}\text{C}$ and Mature Life Stages Present	4.0	5.0	-	6.5
Cool-Water Aquatic Life and Wildlife				
When Water Temperature $\leq 5^{\circ}\text{C}$ and Mature Life Stages Present	3.0	4.0	-	5.5
When Water Temperature $> 5^{\circ}\text{C}$ and Early Life Stages Present	5.0	-	6.0	-

Table 2B-4: Canadian Council of Ministers of the Environment water quality guidelines for dissolved oxygen (CCME 1999; updated to 2012)

Ecosystem	Dissolved oxygen (mg/L)	
	Early Life Stages	Other Life Stages
Warm-water	6	5.5
Cold-water	9.5	6.5

Table 2B-5: Canadian Council of Ministers of the Environment total suspended solids guidelines for the protection of aquatic life

Conditions	Duration	Guideline
Clear Flow	Short-Term (<i>e.g.</i> , 24-hour period)	Maximum increase of 25 mg/L from background levels for any short-term exposure.
	Longer-Term (<i>e.g.</i> , inputs lasting between 24 h and 30 d).	Maximum average increase of 5 mg/L from background levels for longer-term exposures.
High Flow	All periods	Maximum increase of 25 mg/L from background levels at any time when background levels are between 25 and 250 mg/L. Should not increase more than 10% of background levels when background is >250 mg/L.

Table 2B-6: Canadian Council of Ministers of the Environment total phosphorus trigger ranges for Canadian lakes and rivers

Trophic Status/Category	Canadian Trigger Ranges for Total Phosphorus (µg/L)
Ultra-oligotrophic	<4
Oligotrophic	4–10
Mesotrophic	10–20
Meso-eutrophic	20–35
Eutrophic	35–100
Hyper-eutrophic	>100

Table 2B-7: Manitoba Water Quality Standards, Objectives and Guidelines (MWQSOGs; MWS 2011) and Canadian Council of Ministers of the Environment guidelines (CCME 1999; updated to 2012) for metals and major ions for the protection of aquatic life. The most stringent objectives/guidelines are indicated in red

Parameter	MWQSOGs		CCME Guidelines	
	Guidelines: Not dependent on water hardness (µg/L)	Objectives for Total Metals: Dependent on water hardness ¹ (µg/L)	Guidelines: Not dependent on water hardness (µg/L)	Guidelines for Total Metals: Dependent on water hardness ¹ (µg/L)
Aluminum	5 or 100 ²	-	5 or 100 ²	-
Arsenic	150 ^{3,4}	-	5	-
Boron	29,000 µg/L (short-term) and 1,500 µg/L (long-term)	-	29,000 µg/L (short-term) and 1,500 µg/L (long-term)	-
Cadmium	-	1.54–3.35	-	0.02–0.05
Chloride	-	-	640,000 µg/L (short-term) and 120,000 µg/L (long-term)	-
Chromium (III)	-	53–119 ⁴	8.9	-
Copper	-	5.58–13.0 ⁴	-	2–3.31
Iron	300	-	300	-
Lead	-	1.5–5.2 ⁴	-	1.5–5.2
Mercury (inorganic)	0.026	-	0.026	-
Methylmercury	0.004	-	0.004	-
Molybdenum	73	-	73	-
Nickel	-	31–73 ⁴	-	61–129
Selenium	1	-	1	-
Silver	0.1	-	0.1	-
Sodium	-	-	-	-
Thallium	0.8	-	0.8	-
Uranium	33 µg/L (short-term) and 15 µg/L (long-term)	-	33 µg/L (short-term) and 15 µg/L (long-term)	-
Zinc	-	72–167 ⁴	30	-

1. Based on range of water hardness in the study area.

2. Guideline is 5 µg/L where pH < 6.5 and 100 µg/L where pH ≥ 6.5. The latter is applicable to the study area.

3. Dissolved arsenic objective (MWS 2011).

4. Values represent the chronic (4-day averaging duration objective) objectives.

5. Short-term and long-term guidelines, respectively.

6. Total chromium (i.e., Cr (III) + Cr (VI)).

Table 2B-8: Selected Manitoba Water Quality Standards, Objectives and Guidelines (MWQSOGs) and Canadian Council of Ministers of the Environment (CCME) drinking water quality guidelines

Parameter	MWQSOGs		CCME/Health Canada Guidelines	
	Maximum Acceptable Concentration (µg/L)	Aesthetic Objective (µg/L)	Maximum Acceptable Concentration (µg/L)	Aesthetic Objective (µg/L)
Aluminum	-	-	¹	-
Antimony	6	-	6	-
Arsenic	10	-	10	-
Barium	1,000	-	1,000	-
Boron	5,000	-	5,000	-
Cadmium	5	-	5	-
Chloride	-	≤ 250,000	-	≤ 250,000
Chromium	50	-	50	-
Copper	-	≤ 1,000	-	≤ 1,000
Fluoride	1,500	-	1,500	-
Iron	-	≤ 300	-	≤ 300
Lead	10	-	10	-
Manganese	-	≤ 50	-	≤ 50
Mercury	1	-	1	-
Molybdenum	-	-	-	-
Nickel	-	-	-	-
Selenium	10	-	10	-
Silver	-	-	-	-
Sodium	-	≤ 200,000	-	≤ 200,000
Sulphate	-	≤ 500,000	-	≤ 500,000
Thallium	-	-	-	-
Uranium	20	-	20	-
Zinc	-	≤ 5,000	-	≤ 5,000
Fecal Coliform	0 CFU/100 mL	-	0 CFU/100 mL	-
Total Coliform	0 per 100 mL	-	0 per 100 mL	-
Total Dissolved Solids	-	≤ 500 mg/L	-	≤ 500
Colour	-	≤15 TCU	-	≤15 TCU
pH	-	6.5-8.5	-	6.5-8.5
Turbidity	0.3/1.0/0.1 NTU ²	≤ 5 NTU	0.3/1.0/0.1 NTU ²	-
Nitrate/nitrite	10 mg N/L	-	10 mg N/L	-

1. Health Canada applies an operation guidance value (0.1/0.2 mg/L) designed to apply only to drinking water treatment plants using aluminum-based coagulants.

2. "The treated water turbidity target is 0.1 NTU at all times. Where this is not achievable, the maximum treated water turbidity level depends on the method of treatment used. Based on chemically assisted filtration/slow sand or diatomaceous earth filtration/membrane filtration.

Table 2B-9: Select Manitoba Water Quality Standards, Objectives and Guidelines (MWQSOGs) and Canadian Council of Ministers of the Environment (CCME)/Health Canada water quality objectives and guidelines for recreation

Parameter	Objectives / Guidelines	
	MWQSOG	CCME/Health Canada
Fecal Coliform Bacteria/ <i>Escherichia coli</i>	200 CFU/100 mL	200 <i>E. coli</i> / 100 mL ¹
Turbidity	Narrative: Free from materials that produce colour, odour, taste, turbidity, or other conditions in such a degree as to be objectionable or to impair any beneficial use.	50 NTU
Secchi disk depth	-	1.2 m (minimum)
pH	5.0–9.0	6.5–8.5/5–9 ²

1. Guideline not to be exceeded as determined using the geometric mean of a minimum of five samples collected within a 30-day period.
2. Larger range in poorly buffered systems.

Table 2B-10: Manitoba (MWS 2011), Canadian Council of Ministers of the Environment (CCME 1999; updated to 2012), and Ontario (Persaud *et al.* 1993) sediment quality guidelines for metals for the Protection of Aquatic Life. Sediment quality guidelines used for the Keeyask Environmental Impact Statement are indicated in red

Substance	Manitoba/CCME Sediment quality guidelines (µg/g d.w.)		Ontario Sediment quality guidelines (µg/g d.w.)	
	SQG ¹	PEL ¹	LEL ¹	SEL ¹
Arsenic	5.9	17	6	33
Cadmium	0.6	3.5	0.6	10
Chromium	37.3	90	26	110
Copper	35.7	197	16	110
Iron	-	-	20,000	40,000
Lead	35	91.3	31	250
Manganese	-	-	460	1,100
Mercury	0.17	0.486	0.2	2
Nickel	-	-	16	75
Selenium	-	-	-	-
Zinc	123	315	120	820

1. SQG = sediment quality guideline; PEL = probable effect level; LEL = lowest effect level; and SEL = severe effect level.

APPENDIX 2C
DETAILED DESCRIPTION OF METHODS
FOR WATER AND SEDIMENT QUALITY
SAMPLING PROGRAMS AND DATA
ANALYSIS



2C.1 INTRODUCTION

The following provides a detailed description of sampling and data analysis methods for the water quality and sediment quality Keeyask environmental studies conducted from 1999–2006.

2C.2 WATER QUALITY SAMPLING PROGRAM

2C.2.1 SAMPLING SITES

Water quality sampling was conducted in the study area, ranging from the inflows to Split Lake, along the mainstem of the Nelson River to Gillam Island, and several off-system sites including tributary streams, Assean Lake, and the north arm of Stephens Lake over the period from 1999–2006. Sampling was conducted on one or more occasions at the following sites:

Tributaries to Split Lake

- Two sites (one site upstream and one site downstream of the Kelsey GS) on the Nelson River upstream of Split Lake (SPL2 and SPL9);
- One site at the mouth of the Burntwood River (SPL1); and
- One site in the Aiken River (AK1).

Nelson River Mainstem Sites

- Nine sites in Split Lake, including two sites near the community of York Landing (SPL3-SPL8, YL1);
- One site at the outlet of Clark Lake (CL1);
- Two sites on the Nelson River between Clark and Stephens lakes (NR1 and NR2);
- Two sites in Gull Lake (GL1 and GL2);
- Two sites near the south and north shores of the Nelson River just upstream of Stephens Lake (CAMP1 and CAMP2);
- Three sites in Stephens Lake, including two on the south end along the main flow of the Nelson River and one in the north arm (STL1-STL3);
- One site in Stephens Lake near the Town of Gillam's drinking water intake location (GT1);
- One site in each of the Longspruce and Limestone reservoirs (NR3 and NR4);
- Four additional sites on the lower Nelson River up to Gillam Island (NR5-NR8).

Large Tributaries to the Nelson River

- Two sites in Assean Lake (an off-system waterbody which flows to Clark Lake; AL1 and AL2); and

- One sample in each the Limestone, Angling, and Weir rivers (LR1, AL1, and WR1).

Small Tributaries to the Nelson River

- One site near the mouths of each of Two Goose (Trib1), Portage (Trib2), and Rabbit (Trib3) creeks that discharge to the Nelson River upstream of Gull Lake; and
- One site near the mouths of each of Beaver Creek (BC1), Swift Creek (SCK1), Tiny Creek (TC1), Goose Creek (GS1), and Creek #15 (15C1) that discharge to the lower Nelson River downstream of Stephens Lake.

A list of sampling sites is provided in Table 2C-1. Sites are illustrated in Map 2-3.

2C.2.2 SAMPLING PERIODS

Water quality studies were initiated at a limited number of sites in 1999. The majority of the sampling occurred from 2001 to 2004, with additional data collected in 2005 and 2006 to address data gaps. A summary of sites sampled by year is provided in Table 2C-1.

Sampling was conducted four times in the open water season from 2001–2004 to provide an indication of seasonal variability. Approximate sampling times were:

- June;
- July;
- Mid-August to early September; and
- Mid-September to early October.

Additionally, water quality was examined at a subset of sites in winter from 2001–2004; not all sites can be accessed in winter due to logistics and safety issues. A focused water quality study was also conducted near the community of York Landing in winter 2007.

Parameters measured included *in situ* variables and a suite of variables measured at an accredited analytical laboratory. A list of parameters measured in the study area is provided in Table 2C-2. Not all parameters were measured at all sites and times. Additional sampling was conducted in winter 2004, 2005 and 2006 to examine DO conditions in off-current areas under long periods of ice cover (Map 2C-1).

Water quality was also measured at a number of sites downstream of Stephens Lake in the open water seasons of 2002–2004 and in the ice-cover seasons of 2003, 2004, and 2006 at accessible sites. Sites included six locations on the mainstem of the Nelson River, major tributaries (Limestone, Angling, and Weir rivers), and smaller tributaries (Beaver, Swift, Tiny, and Goose creeks and Creek #15).

A water quality sampling program was also conducted in the open water season of 2009 to provide more current information for the study area. However, this information has not been summarized in the AE SV.

2C.2.3 SAMPLING METHODS

In the open water season, all mainstem sampling sites located upstream of the Long Spruce reservoir were accessed by and sampled from a boat. The three tributaries (Two Goose Creek, Rabbit Creek, and Portage Creek) entering the Nelson River between Clark Lake and Gull Lake were also accessed by boat, however, water samples were collected from shore at a point approximately 50 metres (m) upstream of where the tributary entered the mainstem. All sites on the lower Nelson River downstream of the Limestone River were accessed by helicopter and sampled from shore. Sample sites in the Long Spruce and Limestone reservoirs were accessed by road and sampled directly from the GS structure. The sampling site located in the Kelsey reservoir (SPL9) was accessed by boat then sampled directly from the GS structure. The Limestone River was also accessed by road and sampled from shore. Sites sampled in the winter were accessed by helicopter and/or snowmobile.

In the open water season, samples were collected directly into laboratory-supplied sample bottles from approximately 30 centimetres (cm) below the water surface. Sample sites in the Kelsey, Long Spruce, and Limestone reservoirs were sampled from the GS structure using a Kemmerer water sampler. In winter, water samples were collected with a Kemmerer sampler from holes drilled in the ice with a 10 inch gasoline-powered auger.

Samples for analysis of total metals were preserved in the field by the addition of 5 millilitres (mL) of 20% nitric acid to a 500 mL sample volume. Immediately after collection, samples were stored on ice in the dark until received by ALS Laboratories in Winnipeg (which generally occurred within 24 hours).

In situ temperature, specific conductance, DO, pH, and turbidity measurements were made using a Horiba® U-10 Water Quality Checker, a YSI Model 30 Handheld Salinity, Conductivity, and Temperature System, a YSI Model 55 or 95 Dissolved Oxygen Meter, an Analite Turbidimeter and/or a HACH 2100P Turbidimeter. *In situ* measurements were obtained near the water surface and at select sites, along depth profiles or near the bottom (or at a depth of 10 m, whichever was less); due to high velocities and depths, depth profiles could not be measured with *in situ* meters at all sites.

In September 2004, dissolved oxygen was measured at depth from the Limestone GS reservoir to determine if the water column stratifies and/or if there was significant depletion of DO at depth. The sampling method was consistent with the sampling protocol described by Clark (2003) for sampling DO at deep sites that are not accessible with standard hand-held water quality meters. Specifically, a Kemmerer water sampler was lowered to a depth just above the sediment-water interface (*i.e.*, 28 m), filled, retrieved, and the water was emptied into a sampling vessel by placing the hose near the bottom of the vessel and slowly releasing the water while minimizing aeration. This was repeated such that the vessel was overfilled three times and DO was measured from the vessel using the Horiba® U-10 Water Quality Checker.

Secchi disk depths were determined by averaging two readings: the depth at which a black and white disk was no longer visible when lowered into the water column; and the depth at which the disc returns to view upon being raised from the water column. Secchi disk depths could not be obtained at all sites due to high velocities.

2C.2.4 PARAMETERS

All laboratory analyses were conducted by ALS Laboratory Group in Winnipeg, MB, using standard methods. A list of the parameters measured in the baseline sampling program is provided in Table 2C-2 (not all parameters were analysed at each site).

Water samples were collected for the analysis of dissolved ammonia-N, dissolved nitrate/nitrite-N, total Kjeldahl nitrogen, total phosphorus, dissolved phosphorus, total organic carbon, and dissolved organic carbon, TSS, pH, turbidity, and chlorophyll *a* at all sampling locations for each sampling period. *In situ* measurements of DO, turbidity, temperature, specific conductance/conductivity, pH, and depth were also collected at the time of sampling. Secchi disk depth was also measured at some sites.

Water samples were also collected at select locations for the analysis of major ions and total and dissolved metals/metalloids, fecal coliform bacteria, the protozoan parasites *Cryptosporidium* sp. and *Giardia* sp., and additional water chemistry variables, including conductivity, true colour, hardness, alkalinity, total dissolved solids, and inorganic carbon. Dissolved silica was measured at sites on the lower Nelson River and its major tributaries.

2C.2.5 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance/quality control measures incorporated in the water quality sampling program included field blanks, trip blanks, and sample replicates (*i.e.*, triplicate samples).

Blanks

Field blanks are intended to provide information on sample contamination from atmospheric exposure and sample handling techniques (*i.e.*, cleanliness of sampling equipment, carry-over contamination from site to site) as well as potential laboratory contamination and/or error (British Columbia Ministry of Environment, Land, and Parks [BCMELP] 1998). Field blanks were prepared by filling sample bottles with deionized water (both provided by the analytical laboratory) in the field and transporting the blanks along with environmental samples.

Trip blanks are used for evaluating the potential for sample contamination that may occur from the container or preservatives through transport and storage of the sample, as well as laboratory precision (BCMELP 1998). Trip blanks were prepared in the laboratory by filling sample bottles with deionized water.

Field and trip blanks were treated in a manner consistent with field samples and submitted concurrently with field samples to the analytical laboratory.

Field and trip blank results were also evaluated for evidence of sample contamination. Values for any parameter that exceeded five times the analytical detection limit were considered to be indicative of sample contamination and/or laboratory error.

Sample Replicates

Triplicate samples were collected to provide a measure of variability of environmental conditions and the overall precision associated with field methods and laboratory analyses.

QA/QC samples were assessed according to standard criteria to evaluate precision and identify potential sample contamination issues (*i.e.*, BCMELP 1998). Percent relative standard deviation (PRSD) was calculated for triplicate samples as follows:

PRSD = standard deviation (SD) of the triplicate values / Mean of the triplicate values x 100.

Precision of replicate samples was evaluated using the “rule of thumb” criteria for precision of 18% for triplicate samples (BCMELP 1998). Where one or more of the replicate values were less than five times the DL, an analysis of precision was not undertaken, in accordance with guidance provided in BCMELP (1998).

Quality Assurance/Quality Control of Laboratory Results and Water Quality Data

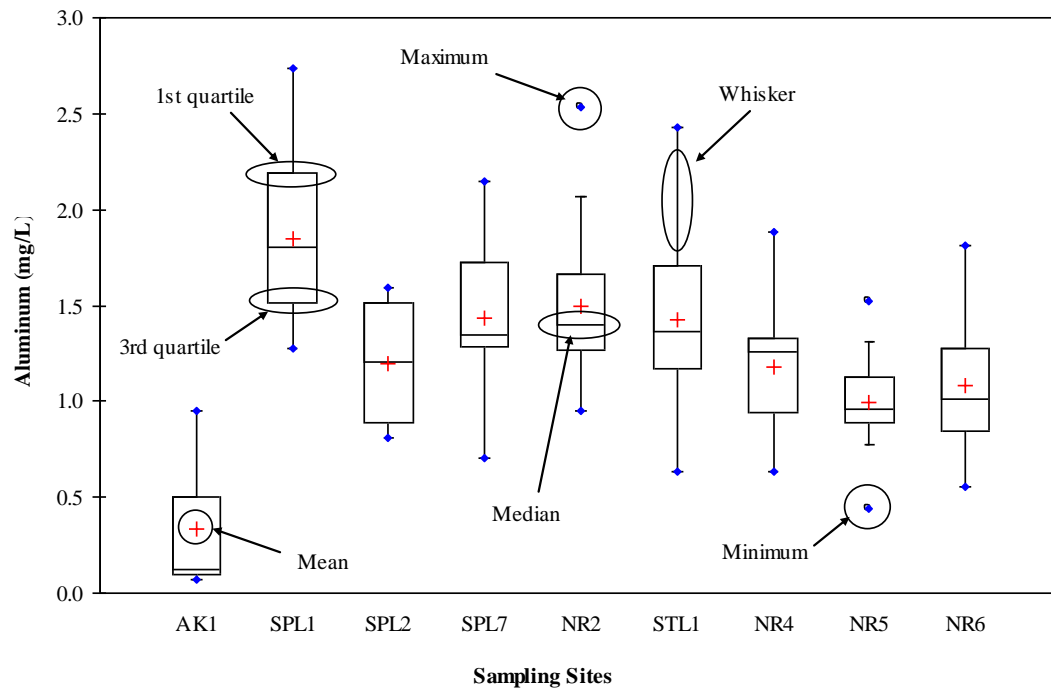
Additionally, all water quality data were evaluated qualitatively for potential outliers and/or transcription or analytical errors. Where values were encountered that departed considerably from results obtained at the same site during other sampling periods and/or where one replicate sample differed notably from the others, the measurement was flagged as suspect. In these instances, values were verified against analytical laboratory reports for transcription errors and/or requests were made to the analytical laboratory to verify the values through sample reanalysis and/or verification of reporting accuracy.

2C.2.6 DATA ANALYSIS

2C.2.6.1 Summary Statistics

To assist in data interpretation, summary statistics were calculated for water quality variables. For the purposes of generating summary statistics (e.g., calculating mean values), measurements reported below DL were assigned a value of one half the DL.

Data were presented graphically as box-and-whisker plots (or “box plots”) for selected variables. Box plots present information on means, medians, quartiles, outliers, and “whiskers”, which represent limits beyond which values are considered anomalous. An example of a box-and-whisker plot is provided below.



2C.3 SEDIMENT QUALITY

2C.3.1 SAMPLING SITES

Surficial sediments were collected at three sites in the study area, near water quality sampling sites:

- One site in Split Lake (SPL7);
- One site in Gull Lake (GL2); and
- One site in Stephens Lake (STL1).

2C.3.2 SAMPLING PERIODS

Sediment quality samples were collected from each site in July 2001 and August 2002.

2C.3.3 SAMPLING METHODS

Sediment samples for analysis of metals, organic matter, and particle size were collected in triplicate (spaced 50–200 m apart) at each site. Intact sediment samples containing sediment depths greater than 10 cm were retrieved using an Ekman dredge. A cellulose acetate core tube (inside diameter 4.8 cm) was used to extract the upper 5.0 cm from samples, with care being taken not to sample any of the sediment

that had touched the walls or bottom of the dredge. Five cores were extracted from one or two dredges to nearly fill a 500 mL glass jar (provided by ALS Laboratory Group, Winnipeg, MB). Two to three cores collected from the same dredges were placed in polyethylene sample bags for analysis of organic content and particle size.

Immediately upon collection, samples were placed on ice in coolers and in the dark. The samples for chemical analysis were shipped overnight to ALS Laboratory Group, Winnipeg, MB, and the samples for organic content and particle size analysis were frozen until analyzed.

2C.3.4 PARAMETERS

Sediments were analysed for organic matter, particle size (sand, silt, and clay), and total metals/metalloids at ALS Laboratory Group.

2C.3.5 QUALITY ASSURANCE/QUALITY CONTROL

Samples were collected in triplicate to provide a measure of variability at each sampling site. Sampling equipment was pre-cleaned and rinsed with site water prior to sampling.

2C.3.6 DATA ANALYSIS

To assist in data interpretation, summary statistics were calculated for sediment quality variables. For the purposes of calculating mean values, measurements reported below analytical DLs were assigned a value of one half the DL.

2C.4 REFERENCES

2C.4.1 LITERATURE CITED

BCMELP (British Columbia Ministry of Environment, Lands, and Parks). 1998. Guidelines for interpreting water quality data. Version 1, May 1998. Prepared for the Land Use Task Force Resources Inventory Committee.

Table 2C-1: Summary of core water quality sites sampled by year in the study area

Waterbody	Site Location	Site ID	Year ¹				
			2001	2002	2003	2004	2006
Major Rivers and Lakes							
Burntwood River	Mouth	SPL-1	OW/ICE	OW/ICE	OW	OW/ICE	-
Nelson River	Upstream of Kelsey GS	SPL-9	-	-	-	OW	-
	Downstream of Kelsey GS	SPL-2	OW	OW	OW	OW	-
Aiken River	Near Mouth	AK-1	-	OW	OW	-	-
Split Lake	Western end of Split Lake	SPL-3	OW/ICE	OW/ICE	OW	-	-
	Split Lake north of York Landing	SPL-4	OW/ICE	OW/ICE	OW	-	-
	Near community of York Landing	SPL-5	OW/ICE	OW/ICE	OW	ICE	-
	Eastern area of Split Lake	SPL-6	OW/ICE	OW/ICE	OW	-	-
	Upstream of Split Lake	SPL-7	OW/ICE	OW/ICE	OW	OW/ICE	-
	Outflow of Split Lake	SPL-8	OW/ICE	OW/ICE	OW	OW	-
	Near community of York Landing	YL-1	-	OW	OW	OW	-
Assean Lake	Southwestern basin	AL-1	OW/ICE	OW/ICE	OW	-	-
	Northeastern basin	AL-2	OW/ICE	OW/ICE	OW	-	-
Clark Lake	Outflow of Clark Lake	CL-1	OW	OW	OW	OW	-
Nelson River	Downstream of Birthday Rapids	NR-1	OW/ICE	OW	OW/ICE	OW	-
Gull Lake	Gull Lake	GL-1	OW	OW	OW/ICE	-	-
	Gull Lake	GL-2	OW	OW/ICE	OW/ICE	ICE	-
Nelson River	Nelson River downstream of Gull Lake	NR-2	OW	OW	OW/ICE	OW/ICE	-
	North shore of Nelson River	CAMP-1	-	-	OW	-	-
	South shore of Nelson River	CAMP-2	-	-	OW	-	-
Stephens Lake	Stephens Lake mainstem	STL-1	OW/ICE	OW/ICE	OW/ICE	OW/ICE	-
	Stephens Lake mainstem	STL-2	OW	OW/ICE	OW/ICE	OW	-
	North arm of Stephens Lake	STL-3	-	-	-	OW	-
	Near the Town of Gillam	GT-1	-	OW	OW/ICE	OW	-
Nelson River	Reservoir of Long Spruce GS	NR-3	-	OW	OW/ICE	OW/ICE	ICE
	Reservoir of Limestone GS	NR-4	-	OW	OW/ICE	OW/ICE	ICE
Limestone River	Near the Mouth	LR-1	-	OW	OW/ICE	OW	ICE
Nelson River	Upstream of the proposed Conawapa GS	NR-5	-	OW	OW	OW	-
	Downstream of the proposed Conawapa GS	NR-6	-	OW	OW	OW	-
Angling River	Near the Mouth	AR-1	-	OW	OW/ICE	OW	ICE

Table 2C-1: Summary of core water quality sites sampled by year in the study area

Waterbody	Site Location	Site ID	Year ¹				
			2001	2002	2003	2004	2006
Weir River	Near the Mouth	WR-1	-	OW	OW	OW	-
Nelson River	Downstream of the Weir River	NR-7	-	OW	OW	OW	-
	Gillam Island	NR-8	-	OW	OW	OW	ICE
Small Tributaries: Keeyask Area							
Two Goose Creek	Near the Mouth	TRIB-1	-	-	OW	OW	-
Portage Creek	Near the Mouth	TRIB-2	-	-	OW	OW	-
Rabbit Creek	Near the Mouth	TRIB-3	-	-	OW	OW	-
Small Tributaries: Downstream Area							
Beaver Creek	Near the Mouth	BC-1	-	-	-	OW	ICE
Swift Creek	Near the Mouth	SCK-1	-	-	-	OW	ICE
Tiny Creek	Near the Mouth	TC-1	-	-	-	OW	ICE
Goose Creek	Near the Mouth	GC-1	-	-	-	OW	ICE
#15 Creek	Near the Mouth	15C-1	-	-	-	OW	ICE

1. OW = open water season; ICE = ice-cover season.

Table 2C-2: List of water quality parameters measured during the Keeyask environmental studies in the study area. Not all parameters were measured at all sites or times

Parameter	Unit	Parameter	Unit
<i>In Situ</i> Variables		Total and Dissolved Metals	
Temperature	°C	Aluminum	mg/L
pH	-	Antimony	mg/L
Specific Conductance	µS/cm	Arsenic	mg/L
Turbidity	NTU	Barium	mg/L
Dissolved Oxygen	mg/L	Beryllium	mg/L
Secchi disk depth	mg/L	Boron	mg/L
		Cadmium	mg/L
Routine Laboratory Variables		Calcium	mg/L
Bicarbonate Alkalinity	mg/L	Chromium	mg/L
CaCO ₃ Alkalinity	mg/L	Cobalt	mg/L
Carbonate Alkalinity	mg/L	Copper	mg/L
Hydroxide Alkalinity	mg/L	Iron	mg/L
Dissolved Ammonia	mg N/L	Lead	mg/L
Dissolved Nitrate/ite	mg N/L	Magnesium	mg/L
Total Kjeldahl nitrogen	mg/L	Manganese	mg/L
Total dissolved phosphorus	mg/L	Mercury	mg/L
Total phosphorus	mg/L	Molybdenum	mg/L
Total organic carbon	mg/L	Nickel	mg/L
Dissolved organic carbon	mg/L	Potassium	mg/L
Total inorganic carbon	mg/L	Selenium	mg/L
Dissolved inorganic carbon	mg/L	Silver	mg/L
Total dissolved solids	mg/L	Sodium	mg/L
Conductivity	µmhos/cm	Thallium	mg/L
Total suspended solids	mg/L	Tin	mg/L
Turbidity	NTU	Uranium	mg/L
True Colour	TCU	Vanadium	mg/L
Hardness as CaCO ₃	mg/L	Zinc	mg/L
Biological Variables		Major Anions	
Chlorophyll <i>a</i>	µg/L	Chloride	mg/L
Pheophytin <i>a</i>	µg/L	Sulphate	mg/L
Fecal coliform bacteria	CFU/100 mL	Fluoride	mg/L
<i>Cryptosporidium</i>	Oocysts/10 L		
<i>Giardia</i>	Cysts/10 L		

APPENDIX 2D
TEMPORAL ANALYSIS OF WATER
QUALITY IN THE STUDY AREA: WATER
QUALITY DATA FOR SPLIT LAKE
1987–2006



2D.1 INTRODUCTION

An analysis was undertaken to evaluate potential recent temporal changes in water quality parameters in the study area. There is only one data set in which water quality conditions in the area have been documented in a relatively consistent manner over a period sufficiently long enough to facilitate analysis of changes over time. This data source, the MWS water quality monitoring site on Split Lake near the community of Split Lake, is the sole long-term water quality monitoring site in the study area. Other sources of water quality data collection have been conducted over a shorter period of time.

2D.2 METHODS

2D.2.1 DATA SOURCES AND DESCRIPTION

A statistical analysis of historical data from Split Lake was conducted to determine if the water quality has changed in the last twenty years. MWS data collected from Split Lake near the community of Split Lake (station MB05FS011; Map 2D-1) from 1987 to 2006 were provided by MWS (2006). The data were reviewed and a subset of the data was selected for statistical analysis. This subset included:

- Nutrients (TP, TKN, TIC, and TOC);
- Routine parameters (pH, total alkalinity, turbidity, TSS, true colour, specific conductivity, hardness); and
- Select ions and metals (see Table 2D-1 for a list).

Parameters were identified for this analysis based on:

- The period of record (*i.e.*, number of samples);
- Their significance from an ecological perspective;
- Parameters that have been identified to have been affected by the CRD/LWR; and
- Consideration of key parameters most likely to have undergone changes in recent years.

From 1987 to 2001, MWS measured water quality at this site up to six times per year. From 2001 through 2006, only three sampling events, all in the open water period typically in June, July, and August, were conducted at this location. As water quality parameters may vary seasonally, the dataset was standardized to the extent possible to incorporate the same number of sampling events and the same sampling times (*i.e.*, months) for each year. Thus, water quality data collected over the open water period, generally one sampling event in June, July, and August, were extracted from the dataset for further analysis. However, it should be noted that the frequency and timing of water quality sampling was not consistent across years. Exceptions to note are:

- From 1999–2001 the lake was only sampled twice during the open water period (June and August), which may have resulted in the conditions during this period being under-represented in the analysis;

- Sampling was conducted in July, August, and September in 2004;
- Sampling was conducted in June, July, and September in 2006; and
- Occasionally data for an individual parameter were not available for a particular sample.

Where replicate samples were collected, results for these dates were averaged and the mean was included in the dataset used in the analysis. All values that were reported below the DL were assigned a value equivalent to one half the DL for statistical evaluation. All statistical analyses described herein were performed with XLSTAT 2006 Version 2006.2 by Addinsoft.

2D.2.2 EVALUATION OF NELSON AND BURNTWOOD RIVER DISCHARGES

The Nelson and the Burntwood Rivers combine at Split Lake and water quality of the lake is therefore largely a reflection of the water quality of the two rivers. In order to determine to what extent each of the rivers was contributing to the historical water quality of Split Lake, discharge data from both the Nelson River and the Burntwood River from 1987–2006 were obtained. Flow data for the Nelson River were obtained from Manitoba Hydro for the Kelsey GS. The nearest available discharge data for the Burntwood River at Split Lake, are available from the Water Survey of Canada hydrometric station on the Burntwood River at Thompson (Station 05TG001 Q). However, because the Odei River enters the Burntwood River downstream of this station, but upstream of Split Lake, it was necessary to combine the discharge data for both the Thompson station and the hydrometric station on the Odei River near Thompson (Station 05RG003 Q) in order to get an accurate representation of the discharge of the Burntwood River at Split Lake. Daily mean discharge rates for both rivers from June to September were used here.

2D.2.3 COMPARISON OF TWO BLOCKS OF TIME

The objective of this analysis was to statistically compare water quality parameters collected in two blocks of time: 1987–1996 versus 1997–2006. These time frames were selected for several reasons. Firstly, the 1997–2006 time frame represents the period selected for describing the existing environment in the study area. A period of 10 years was identified to provide a reasonably long time frame in which varying environmental conditions might be captured as well as sufficient number of data points for analysis. Lastly, as the objective of this exercise was to determine if there have been relatively recent changes in water quality, the intent was to restrict the analysis to a relatively recent period and avoid earlier periods when the environment may have been in flux due to CRD/LWR.

Review of the data indicated that not all parameters, notably metals, could be analysed in this manner due to changes in analytical methods and the form of some water quality parameters measured over those two decades. As a result, two different approaches were applied for routine parameters (*e.g.*, turbidity and nutrients), for which data were more consistently analysed over the twenty year period, and metals, for

which data varied considerably over this period. The methods applied for analysing these two groups of variables are described below.

2D.2.4 ANALYSIS OF ROUTINE PARAMETERS

Data for routine parameters and nutrients were divided into two ten year time periods (1987–1996 and 1997–2006) and compared using an analysis of variance (ANOVA). Prior to analysis, each parameter was verified to ensure that the data met the assumptions of the model; if necessary, data were transformed (by methods appropriate to the parameter) in order to meet the assumption of normality. Parameters that could not meet or approximate the assumptions of an ANOVA were analysed using a Mann-Whitney U-test (a non-parametric method appropriate for determining if a difference exists between two groups of non-normally distributed data).

Prior to 2001, laboratory analysis of water quality samples was conducted at Enviro-Test Laboratories (ETL; Winnipeg, MB). Beginning in 2001, laboratory analysis was conducted by CANTEST Ltd. (Winnipeg, MB). As the use of different analytical laboratories may affect water quality data (*i.e.*, inter-laboratory variability), a second analysis was performed on any parameters for which a significant difference was observed to exist between the two time periods. In these instances, data from 1997–2006 were divided into two new groups: 1997–2000 (representing samples processed at ETL); and 2001–2006 (representing samples processed at CANTEST Ltd.). These data were then analysed with an ANOVA or a Mann-Whitney U-test. Additionally, a qualitative comparison was made between data collected under the Keeyask environmental studies (sites SPL7 and SPL8 in Split Lake; Map 2D-1) and MWS data for data collected at similar times (*i.e.*, open water seasons 2001–2004). This comparison was useful as samples collected under the Keeyask environmental studies were analysed at the same analytical laboratory used by MWS prior to 2001.

2D.2.5 LINEAR REGRESSION ANALYSIS

Routine parameters for which significant differences were observed between 1987–1996 and 1997–2006, and for which no evidence of an effect related to changing analytical laboratories could be found (See Section 2D.2.4), were also subject to a regression analysis. Linear regression analysis between water quality data and flows of the Nelson River, Burntwood River, and the combination of the two rivers (for those corresponding sample dates) was conducted to evaluate the potential influence of overall discharge on water quality, and to examine the potential relative influence of the Nelson or Burntwood rivers on water quality.

2D.2.6 ANALYSIS OF IONS AND METALS

As a result of changes in analytical methods and improvements with detection limits, a comparable dataset for ions and metals was only available for the six most recent years of data and long-term comparison of the data was not possible. To facilitate some temporal comparison, data collected from 2001–2006 were divided into two, three-year time periods (2001–2003 and 2004–2006) and compared

using an ANOVA. Each parameter was first evaluated to ensure that the data met the assumptions of the model; if necessary, data were log transformed in order to meet the assumption of normality. Parameters that could not meet or approximate the assumptions of an ANOVA were analysed using a Mann-Whitney U-test. Only metals for which all or the majority of measurements exceeded the analytical detection limit were analysed for temporal differences.

2D.2.7 COMPARISON TO MANITOBA WATER QUALITY OBJECTIVES AND GUIDELINES

For context, each parameter analysed was compared to the current Manitoba water quality objectives and guidelines (MWQSOGs; MWS 2011) for the protection of aquatic life (PAL) and for drinking water.

2D.3 RESULTS AND DISCUSSION

2D.3.1 ROUTINE PARAMETERS AND NUTRIENTS

2D.3.1.1 Comparison of 1987–1996 to 1997–2006

Statistically significant differences in phosphorous (TP; Figure 2D-1), pH (Figure 2D-2), total alkalinity (Figure 2D-3), turbidity (Figure 2D-4), TSS (Figure 2D-5), true colour (Figure 2D-6), specific conductance (Figure 2D-7) and hardness (Figure 2D-8) were found between the periods of 1987–1996 and 1997–2006 in Split Lake (Table 2D-2). Of all routine parameters analysed, only nitrogen (TKN) and carbon (TIC and TOC) did not differ significantly between the two time periods (Table 2D-2). The mean TP, alkalinity, specific conductance, and hardness increased by 58%, 10%, 18%, and 10%, respectively. Only pH was found to be lower in the latter period.

2D.3.1.2 Analysis of Analytical Laboratory Effects

The analysis undertaken to evaluate potential effects related to changes in analytical laboratories (*i.e.*, comparison of 1997–2000 and 2001–2006 time periods) indicated no significant differences for TP and pH (Table 2D-2). Consideration must therefore be given to the possibility that the observed statistical differences in TP and pH between the 1987–1996 and 1997–2006 time periods, may at least in part, reflect effects of the change in the analytical laboratory.

The role of varying analytical laboratories on observed changes in pH and TP in recent years is further supported by comparison of the MWS data collected in Split Lake, with data collected at similar locations during the conduct of the Keeyask environmental studies (2001–2004). As illustrated in Figure 2D-1, TP concentrations measured from 2001–2004 under the present study are very similar to concentrations collected at the MWS monitoring site prior to 2001 and both of these data sets were derived from the same analytical laboratory. Conversely, many of the TP concentrations measured by MWS from 2001–2004 are notably higher than those obtained in the present study and values obtained prior to 2001.

There is even considerable discrepancy for samples collected on the same dates. For example, on 27 August 2003, TP measured 0.048 mg/L in the sample collected at SPL7 in the Keeyask program and 0.077 mg/L at the MWS site on the same date.

Similarly, comparison of pH measurements (Figure 2D-2) indicates that data collected under the Keeyask Environmental Studies Program from 2001–2004 are very similar to data collected in Split Lake by MWS prior to 2001. These data also demonstrate a greater consistency over time (*i.e.*, the data are less variable). The data collected by MWS from 2001 onward indicate a lower pH than samples collected prior to 2001 and those collected under the Keeyask environmental studies. It is noteworthy that the analytical laboratory used for the Keeyask program (ALS Laboratory Group – formerly ETL) is the same as that used by MWS prior to 2001. Collectively, these analyses indicate that TP and pH have likely not changed notably from 1987–2006 in Split Lake.

Conversely, other parameters (total alkalinity, specific conductivity, hardness, TSS, turbidity and colour) do appear to have increased in the recent decade (*i.e.*, from 1987–1996 to 1997–2006) as there is no statistical indication that the change in analytical laboratories affected the water quality data. On average, total alkalinity, specific conductivity, hardness, TSS, turbidity and colour were all lower during the period of 1987–1996 than they were from 1997–2006.

2D.3.1.3 Effect of River Discharge on Split Lake Water Quality

As previously described (Section 2.4.2.3), the water quality of Split Lake is influenced by the relative inflows of its tributaries; the two largest being the Nelson River and the Burntwood River. As also described in Section 2.4.2.3, water quality conditions of the Nelson and Burntwood rivers vary for some parameters. Specifically, the Burntwood River is generally more turbid and coloured and the Nelson River generally has a higher specific conductance, hardness, and alkalinity.

Flow of the Nelson River relative to the Burntwood River was examined to determine whether the relative influence of the two rivers on Split Lake water quality may have changed over the two decades examined. The average daily flow (from June–September) of the Nelson River was higher over the period of 1997–2006 than the period of 1987–1996 (Table 2D-3; Figure 2D-9). Although the same can be said for the Burntwood River, as the latter decade represents a higher flow period in general, the magnitude of the increase in flow was much greater in the Nelson River than it was in the Burntwood River. As a result, the relative average contribution of the Nelson River was almost 10% greater from 1997–2006 (74.4%) than it was during the previous decade (1987–1996, 65.8%). It was hypothesized that the observed increase in alkalinity, specific conductivity and hardness in Split Lake from 1997–2006 relative to 1987–1996, could be a result of the greater influence of the Nelson River on the lake.

To examine this hypothesis further, a linear regression analysis was conducted between alkalinity, specific conductance, and hardness, and the discharge of the Nelson River, the Burntwood River, and the two rivers combined. The analyses indicated weak, but significant, correlations for alkalinity (Figure 2D-10) and specific conductance (Figure 2D-11) in relation to the Nelson River discharge. Linear regression could not be applied to hardness or true colour (raw or log-transformed) as the data did not meet the

assumption of normality. For illustrative purposes, hardness and true colour versus river discharge are presented in Figure 2D-12 and Figure 2D-13, respectively.

Conversely, the observed difference in TSS and turbidity from 1987–1996 to 1997–2006 in Split Lake cannot be explained by changes in the relative inflows of the Nelson and Burntwood rivers. The Burntwood River is generally more turbid than the Nelson River (see Section 2.4.2.3); therefore, the greater influence of the Nelson River during the most recent decade would be expected to dilute the water of Split Lake, resulting in lower turbidity and TSS. These parameters were however greater in Split Lake in the period of 1997–2006 than in the period of 1987–1996 (Table 2D-2). No relationship between turbidity and river discharge (Burntwood, Nelson, or Burntwood and Nelson discharges combined) was found by linear regression (Figure 2D-14). TSS data did not conform to the assumption of normality; therefore statistical analysis could not be reliably conducted. For illustrative purposes, plots are presented in Figure 2D-15. Data collected at similar times and locations (SPL7 and SPL8) in Split Lake under the Keeyask environmental studies from 2001–2004, were similar to data collected by MWS over that time frame. This provides further corroboration that the statistical analyses indicate actual increases and not artefacts of a change in analytical laboratories (Figure 2D-4 and Figure 2D-5).

Collectively, these results indicate that TSS and turbidity have been higher in Split Lake in recent years and there is no indication that this increase is related to river discharge. However, as described in the Physical Environment Supporting Volume, Section 7 (Appendix 7B), while TSS was weakly correlated to river discharge over the period of 2005–2007, the relationship is complicated by hysteresis.

The observed increases may reflect local processes of sediment transport and deposition and/or shoreline erosion within Split Lake. Conversely, alkalinity and specific conductance (and potentially hardness) although higher in recent years in Split Lake, may reflect a larger influence of the Nelson River over this timeframe. The analysis for true colour and hardness is inconclusive as linear regression could not be reliably applied to the data.

2D.3.2 IONS AND METALS

The mean concentrations of all ions and most metals measured in Split Lake in 2001–2003 were similar to those measured in 2004–2006 (Table 2D-1). No statistically significant differences between these time periods were found for chloride, sulphate, calcium, magnesium, sodium, potassium and most metals. However, significant differences in concentrations were found for antimony and silicon. The mean concentration of antimony was 67 % higher in 2004–2006 than it was in 2001–2003. Despite this increase, antimony remained present only in trace amounts in 2004–2006, and never exceeded the drinking water quality objective in either time period. Conversely, the mean silicon concentration decreased 65% from 2001–2003 to 2004–2006; there are no MWQSOGs for silicon.

2D.3.3 COMPARISONS TO MANITOBA WATER QUALITY STANDARDS, OBJECTIVES AND GUIDELINES

Most parameters fell within the MWQSOGs (MWS 2011) across the years examined (Table 2D-1 and Table 2D-2). There were, however, some exceptions:

- TP concentrations in Split Lake were typically above the Manitoba narrative water quality guideline (0.025 mg/L) from 1987–2006 (Figure 2D-1);
- Turbidity levels were always above the maximum acceptable concentration for drinking water from 1987–2006 (Figure 2D-4);
- True colour in Split Lake was generally above the aesthetic objective for drinking water (85% exceedance) from 1997–2006, whereas true colour only occasionally exceeded this guideline in the previous decade (23% exceedance; Figure 2D-6); and
- Iron concentrations were above both the aesthetic objective for drinking water and the PAL guideline from 1998–2006 (Figure 2D-16). Iron was measured in extractable form prior to 1998; and
- Aluminum concentrations were above the guideline for the protection of aquatic life from 1998–2006 (Figure 2D-17). Aluminum was measured in extractable form prior to 1998.

2D.4 SUMMARY AND CONCLUSIONS

Analysis of potential temporal changes in water quality in Split Lake indicated the following:

- Comparison of selected routine water quality parameters between the last two decades (1987–1996 and 1997–2006) revealed that several parameters were significantly higher in the latter decade (TP, TSS, turbidity, specific conductance, alkalinity, hardness, and true colour), while pH was significantly lower;
- Discharges of the two main tributaries to Split Lake were higher in the period of 1997–2006 than the previous decade and discharge of the Nelson River increased more than the Burntwood River over the last decade;
- The observed statistically significant increase in TP and decrease in pH in 1997–2006 may be an artefact of the use of a new analytical laboratory and not an actual change;
- The observed increase in specific conductance and alkalinity over the last decade may reflect higher river discharges, most notably, the greater proportional contribution of the Nelson River – which is characterized by a higher specific conductance and alkalinity than the Burntwood River. Linear regression analysis indicates a significant influence of the Nelson River discharge on the concentrations of these two parameters in Split Lake;

- Conversely, regression analysis did not demonstrate a significant correlation between turbidity and TSS and the flows of the Burntwood River, Nelson River, or the Burntwood and Nelson rivers combined. Additionally, there is good agreement between measurements of these parameters collected under the Keeyask baselines studies in Split Lake near the community (2001–2004) at similar times as the MWS water quality monitoring was conducted, suggesting that inter-laboratory variability was not an issue. However, as described in the Physical Environment Supporting Volume, Section 7 (Appendix 7B), while TSS was weakly correlated to river discharge over the period of 2005–2007, the relationship is complicated by hysteresis;
- The observed increases in true colour and hardness in the most recent decade may be related to changes in river flows. However, the analysis is not conclusive as linear regression analysis could not be reliably conducted on the data;
- Data for metals in Split Lake are inadequate to facilitate a comparison of concentrations over a 20-year time frame due to changes in analytical methods; as a result, a shorter time frame was analysed (2001–2003 versus 2004–2006). No statistically significant differences between these time periods were found for chloride, sulphate, calcium, magnesium, sodium, potassium and most metals including iron and aluminum. However, significant differences in concentrations were found for antimony and silicon. Antimony increased from 2001–2003 to 2004–2006; however, it was only present in trace amounts during both time periods. Silicon on the other hand was lower during the second time period; and
- From 1987–2006, most parameters fell within the MWQSOGs (MWS 2011); however, there were a few exceptions. Iron and aluminum were consistently, and TP was often in exceedance of the relevant guidelines for the protection of aquatic life from 1987–2006. Additionally, iron consistently exceeded the aesthetic objective for drinking water during this same time period. Lastly, true colour was typically above the aesthetic objective for drinking water from 1997–2006, whereas it only occasionally exceeded this objective in the previous decade.

2D.5 REFERENCES

2D.5.1 LITERATURE CITED

- MWS (Manitoba Water Stewardship). 2006. Water Quality Management Section, Water Science and Management Branch. 123 Main St., Suite 160, Winnipeg, MB, R3C 1A5.
- MWS. 2011. Manitoba Water Quality Standards, Objectives, and Guidelines. Water Science and Management Branch, MWS. MWS Report 2011-01, November 28, 2011. 67 pp.

Table 2D-1: Results of temporal statistical analysis on concentrations of ions and metals in Split Lake from 2001–2006. Manitoba Water Stewardship data collected in Split Lake near the community of Split Lake (station MB05FS011) were used. The data were analysed for differences between 2001–2003 (sample size = 8) and 2004–2006 (sample size = 9) with an analysis of variance (ANOVA) or by a Mann-Whitney U-test if the data did not meet or approximate the assumptions of ANOVA

Parameter	Mean (mg/L)		p-value		Were the periods significantly different?	MWQSOGs (mg/L) ¹	
	2001–2003	2004–2006	ANOVA	Mann-Whitney		Aquatic Life	Drinking Water
Anions							
Chloride (dissolved)	12.9	12.4	0.988	-	N	-	≤250 ²
Sulphate (dissolved)	20.5	25.4	-	0.408	N	-	≤500 ²
Cations							
Calcium (total)	28.0	25.6	-	0.558	N	-	-
Magnesium (total)	9.68	9.57	0.835	-	N	-	-
Sodium (total)	13	12	-	0.525	N	-	≤200 ²
Potassium (total)	2.32	2.28	0.891	-	N	-	-
Metals							
Aluminum (total)	0.85	0.66	0.735	-	N	0.100	-
Antimony (total)	0.0003	0.0005	-	0.010	Y	-	0.006
Arsenic (total)	0.0010	0.0010	0.532	-	N	(0.150 Dissolved ³)	0.010
Barium (total)	0.031	0.034	0.303	-	N	-	1.0
Boron (total)	0.028	0.029	-	0.452	N	1.5 ⁴	5.0
Chromium (total)	0.0013	0.0014	0.919	-	N	0.070-0.119 ⁵	0.05
Cobalt (total)	0.0004	0.0004	-	0.410	N	-	-
Copper (total)	0.0021	0.0021	0.797	-	N	0.007-0.013 ⁵	≤1.0 ²
Iron (total)	0.79	0.75	0.730	-	N	0.3	≤0.3 ²
Lead (total)	0.0005	0.0006	0.580	-	N	0.002-0.005 ⁵	0.01
Lithium (total)	0.009	0.008	0.353	-	N	-	-
Manganese (total)	0.019	0.020	0.716	-	N	-	≤0.05 ²
Molybdenum (total)	0.0005	0.0006	-	0.274	N	0.073	-

Table 2D-1: Results of temporal statistical analysis on concentrations of ions and metals in Split Lake from 2001–2006. Manitoba Water Stewardship data collected in Split Lake near the community of Split Lake (station MB05FS011) were used. The data were analysed for differences between 2001–2003 (sample size = 8) and 2004–2006 (sample size = 9) with an analysis of variance (ANOVA) or by a Mann-Whitney U-test if the data did not meet or approximate the assumptions of ANOVA

Parameter	Mean (mg/L)		p-value		Were the periods significantly different?	MWQSOGs (mg/L) ¹	
	2001–2003	2004–2006	ANOVA	Mann-Whitney		Aquatic Life	Drinking Water
Nickel (total)	0.002	0.002	-	0.840	N	0.04-0.07 ⁵	-
Rubidium (total)	0.003	0.003	0.835	-	N	-	-
Silicon (total)	5.1	1.8	-	0.006	Y	-	-
Strontium (total)	0.082	0.089	-	0.946	N	-	-
Titanium (total)	0.034	0.020	0.675	-	N	-	-
Uranium (total)	0.0005	0.0005	-	0.520	N	0.015 ⁴	0.02
Vanadium (total)	0.0018	0.0018	0.929	-	N	-	-
Zinc (total)	0.003	0.003	0.905	-	N	0.10-0.17 ⁵	≤5.0

1. Water quality objectives and guidelines for Manitoba (MWS 2011). Water quality means in red indicate values in exceedance of the current Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs).
2. Aesthetic objective.
3. The maximum average concentration for a 4-day exposure period.
4. Guideline for long-term exposure.
5. Calculated for the four-day exposure duration using the range of water hardness values for Split Lake.

Table 2D-2: Results of temporal statistical analysis on the water quality of Split Lake from 1987–2006. Manitoba Water Stewardship data collected in Split Lake near the community of Split Lake (station MB05FS011) were used. The data were analysed for differences in nutrients and routine parameters with an analysis of variance (ANOVA) or by a Mann-Whitney U-test if the data did not meet or approximate the assumptions of ANOVA

Parameter	Units	1987–1996 vs 1997–2006				Were the periods significantly different?	1997–2000 vs. 2001–2006				Were the periods significantly different?	MWQSOGs ¹		
		Mean (n)		p-value			Mean (n)		p-value			Aquatic Life	Drinking Water	Recreation
		1987–1996	1997–2006	ANOVA	Mann-Whitney		1997–2000	2001–2006	ANOVA	Mann-Whitney				
Nutrients														
Total phosphorus (TP)	mg/L	0.031 ² (30)	0.049 (27)	-	0.002	Y	0.028 ² (10)	0.062 (17)	-	<0.0001	Y	0.025 ³	-	-
Total Kjeldahl nitrogen (TKN)	mg/L	0.39 (30)	0.4 (27)	-	0.185	N	-	-	-	-	-	-	-	-
Total inorganic carbon (TIC)	mg/L	20 (26)	21.3 (27)	0.159	-	N	-	-	-	-	-	-	-	-
Total organic carbon (TOC)	mg/L	8.1 (29)	8.2 (27)	-	0.527	N	-	-	-	-	-	-	-	-
Routine														
pH	pH units	8.15 ⁴ (30)	7.91 (27)	0.0002	-	Y	8.16 ⁴ (10)	7.77 (17)	<0.0001	-	Y	6.5-9.0	6.5-8.5 ⁵	5.0-9.0
Total Alkalinity (CaCO ₃)	mg/L	84.2 (30)	92.8 (27)	-	0.001	Y	91 (10)	93.9 (17)	-	0.340	N	-	-	-
Turbidity	NTU	14 (30)	21 (27)	<0.0001	-	Y	18 (10)	20 (17)	0.319	-	N	-	0.3/1.0/0.1	-
Total suspended solids (TSS)	mg/L	9.4 (30)	13.9 (26)	-	0.002	Y	11.9 (10)	15.2 (16)	-	0.136	N	5 mg/L above background where TSS ≤25 mg/L; or 25 mg/L above background where TSS ≤250 mg/L	-	-

Table 2D-2: Results of temporal statistical analysis on the water quality of Split Lake from 1987–2006. Manitoba Water Stewardship data collected in Split Lake near the community of Split Lake (station MB05FS011) were used. The data were analysed for differences in nutrients and routine parameters with an analysis of variance (ANOVA) or by a Mann-Whitney U-test if the data did not meet or approximate the assumptions of ANOVA

Parameter	Units	1987–1996 vs 1997–2006				Were the periods significantly different?	1997–2000 vs. 2001–2006				Were the periods significantly different?	MWQSOGs ¹		
		Mean (n)		p-value			Mean (n)		p-value			Aquatic Life	Drinking Water	Recreation
		1987–1996	1997–2006	ANOVA	Mann-Whitney		1997–2000	2001–2006	ANOVA	Mann-Whitney				
True Colour	TCU	14 (30)	28 (27)	<0.0001	-	Y	25 (10)	30 (17)	0.213	-	N	-	≤15 ⁵	-
Specific conductance	µS/cm	223 (30)	264 (27)	<0.0001	-	Y	264 (10)	265 (17)	0.951	-	N	-	-	-
Hardness	mg/L	97.2 (30)	107.4 (27)	-	0.002	Y	108.8 (10)	106.5 (17)	-	0.684	N	-	-	-

1. Water quality objectives and guidelines for Manitoba (MWS 2011). Water quality means in red indicate values in exceedance of the current Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs).
2. The results of a Mann-Whitney U-test comparing TP in 1987–1996 with 1997–2000 yielded a p-value of 0.174 indicating that the two time periods were not significantly different from one another.
3. General narrative guideline for nutrients.
4. The results of an ANOVA comparing pH in 1987–1996 with 1997–2000 yielded a p-value of 1.0 indicating that the two time periods were not significantly different from one another.
5. Aesthetic objective.

Table 2D-3: Relative mean contribution (based on flow) of both the Nelson and Burntwood Rivers to the water of Split Lake from June to September during the last two decades: 1987–1996; and 1997–2006

Waterbody	Mean daily flow (m ³ /s)			Percent of combined flow		
	1987– 1996	1997– 2006	1987– 2006	1987– 1996	1997– 2006	1987– 2006
Nelson River	1585	2580	2082	65.8	74.4	70.9
Burntwood River	823	887	855	34.2	25.6	29.1
Combined (<i>i.e.</i> flow into Split Lake)	2408	3466	2937	100	100	100

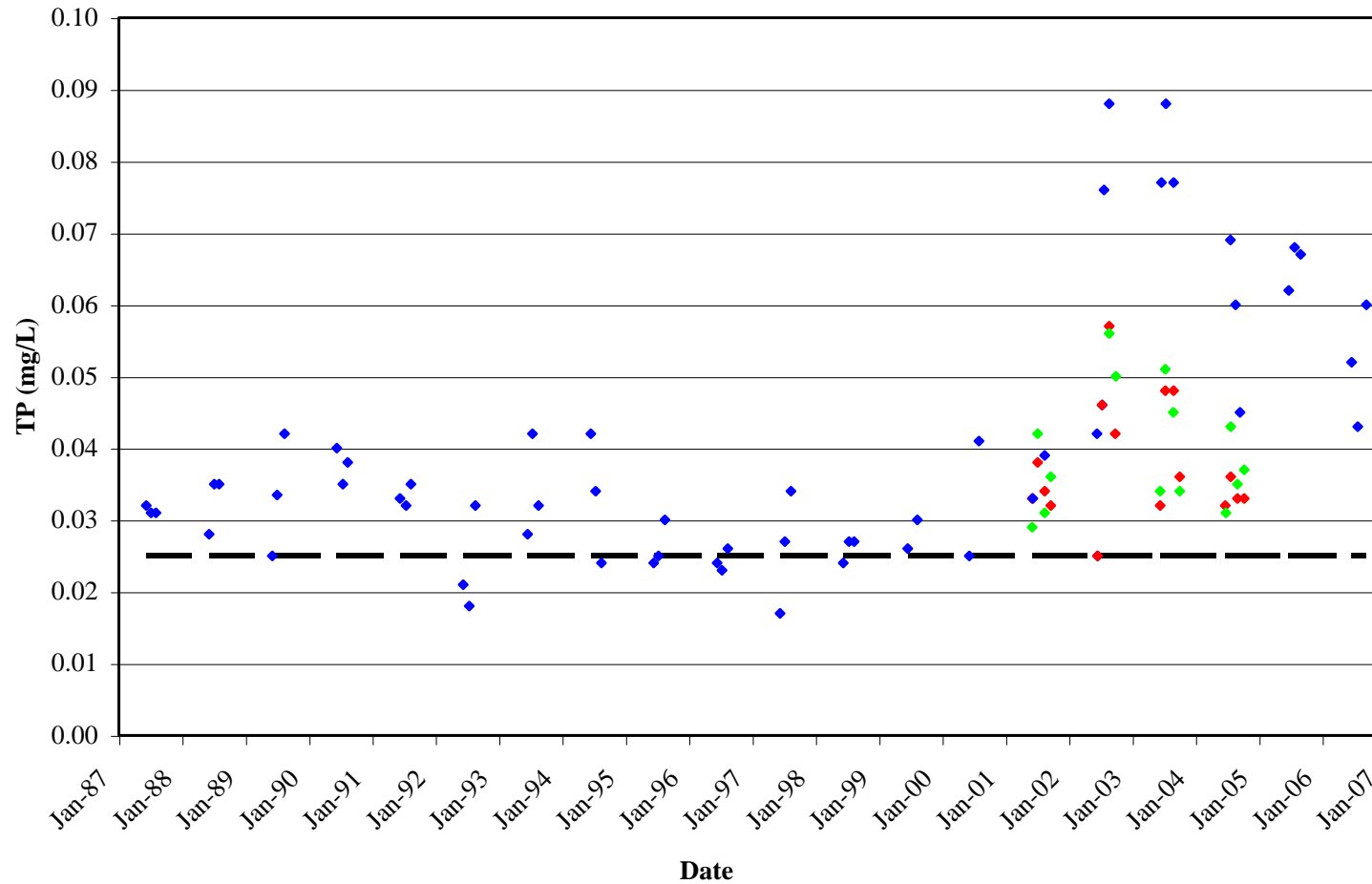


Figure 2D-1: Comparison of total phosphorus (TP) concentrations measured in Split Lake by Manitoba Water Stewardship (blue dots) and under the Keyyask environmental studies (red dots SPL7 and green dots SPL8) for the open water season. The dashed line indicates the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOG) for lakes, ponds, and reservoirs

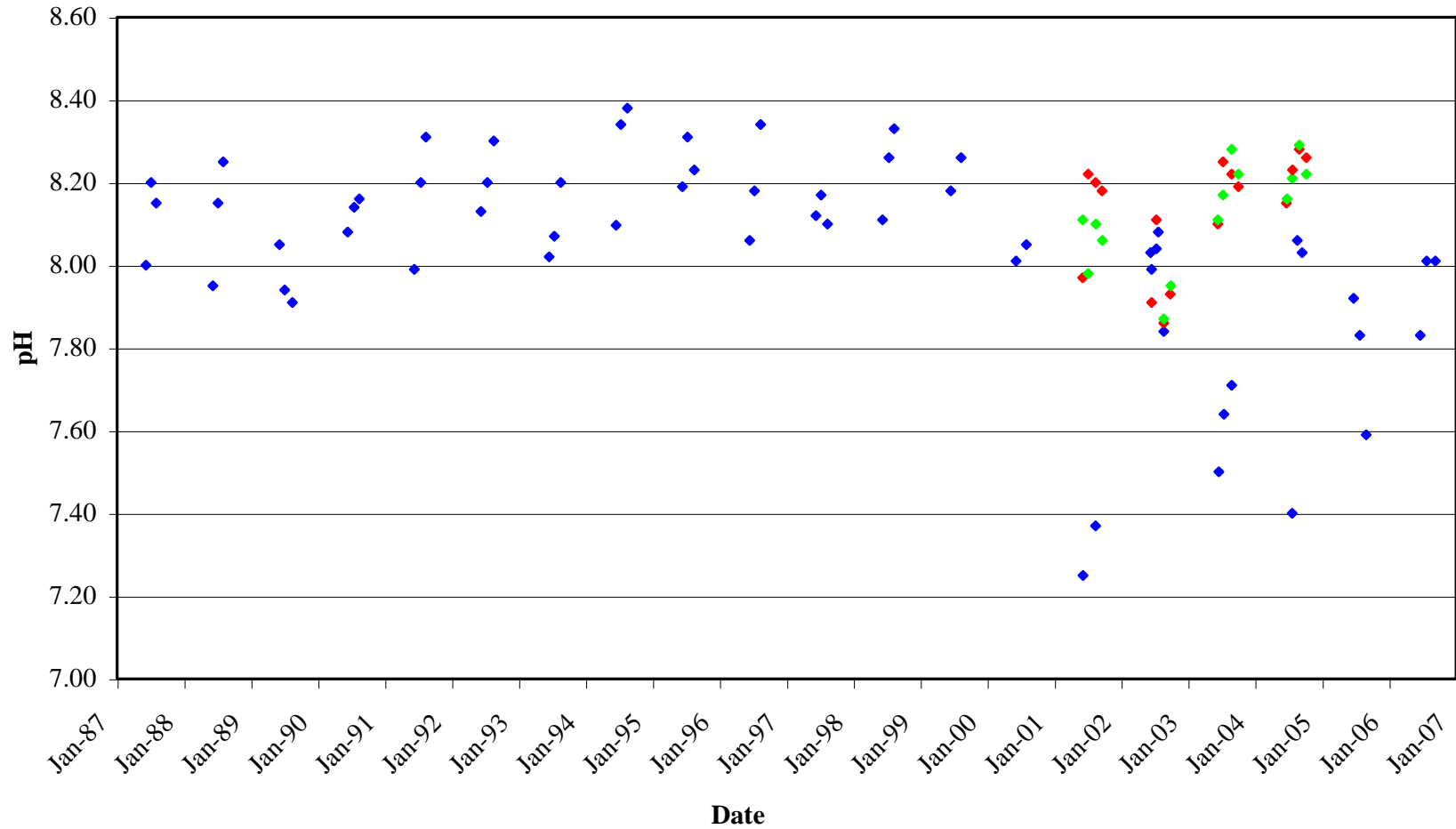


Figure 2D-2: Comparison of pH measured in Split Lake by Manitoba Water Stewardship (blue dots) and under the Keeyask environmental studies (red dots SPL7 and green dots SPL8) for the open water season

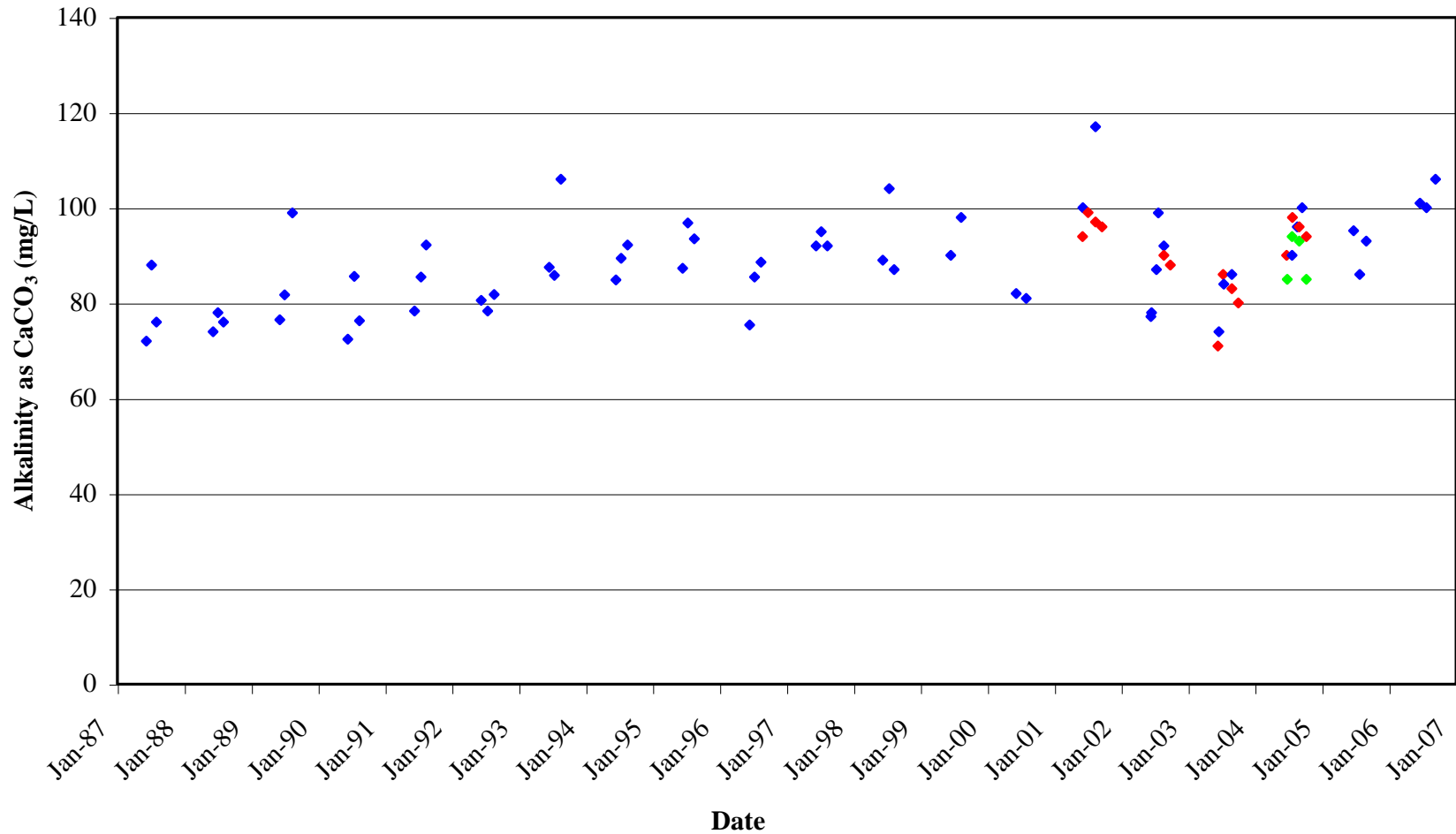


Figure 2D-3: Comparison of total alkalinity measured in Split Lake by Manitoba Water Stewardship (blue dots) and under the Keyeyask environmental studies (red dots SPL7 and green dots SPL8) for the open water season

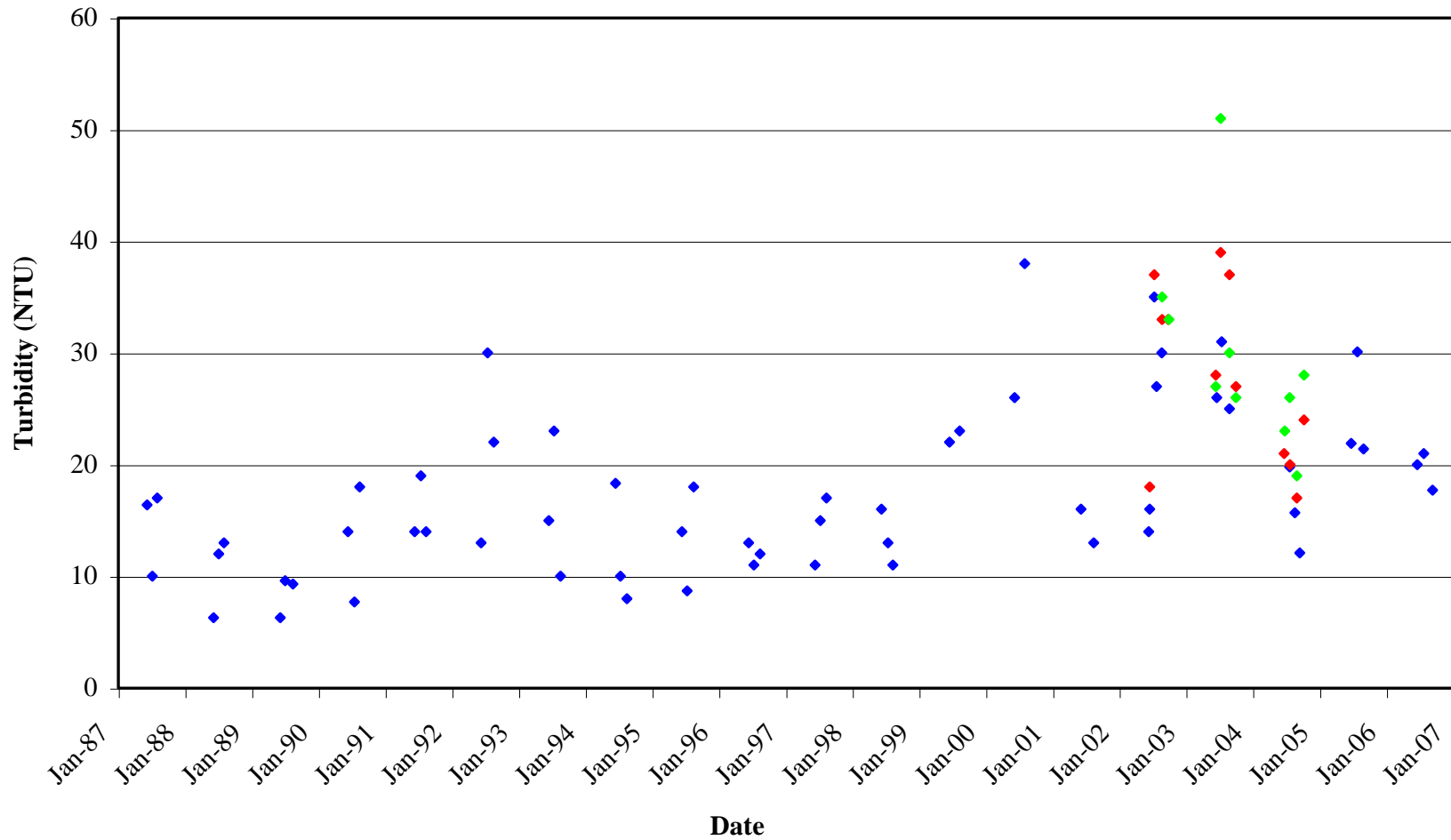


Figure 2D-4: Comparison of turbidity measured in Split Lake by Manitoba Water Stewardship (blue dots) and under the Keeyask environmental studies (red dots SPL7 and green dots SPL8) for the open water season

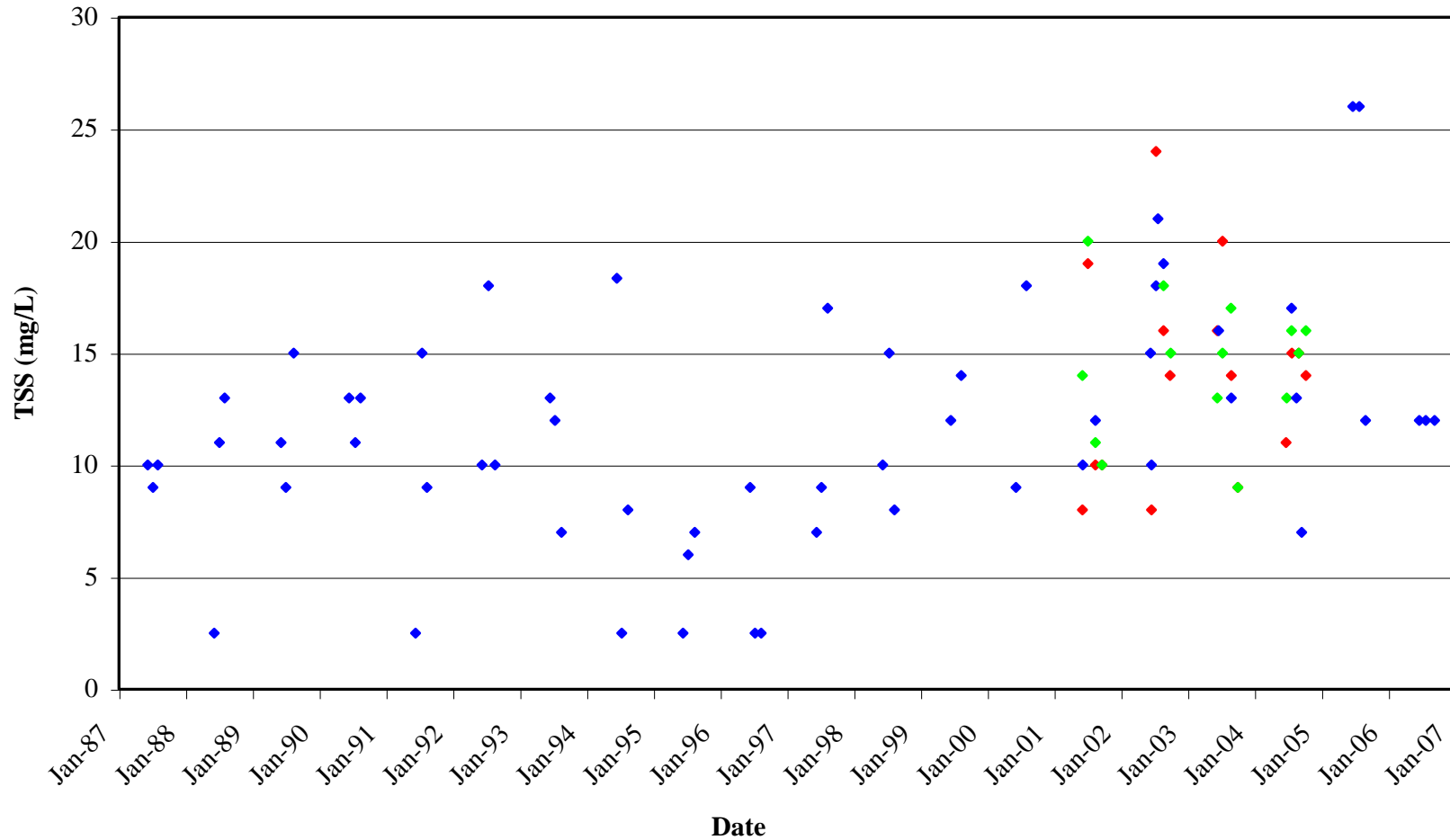


Figure 2D-5: Comparison of total suspended solids measured in Split Lake by Manitoba Water Stewardship (blue dots) and under the Keyeyask environmental studies (red dots SPL7 and green dots SPL8) for the open water season

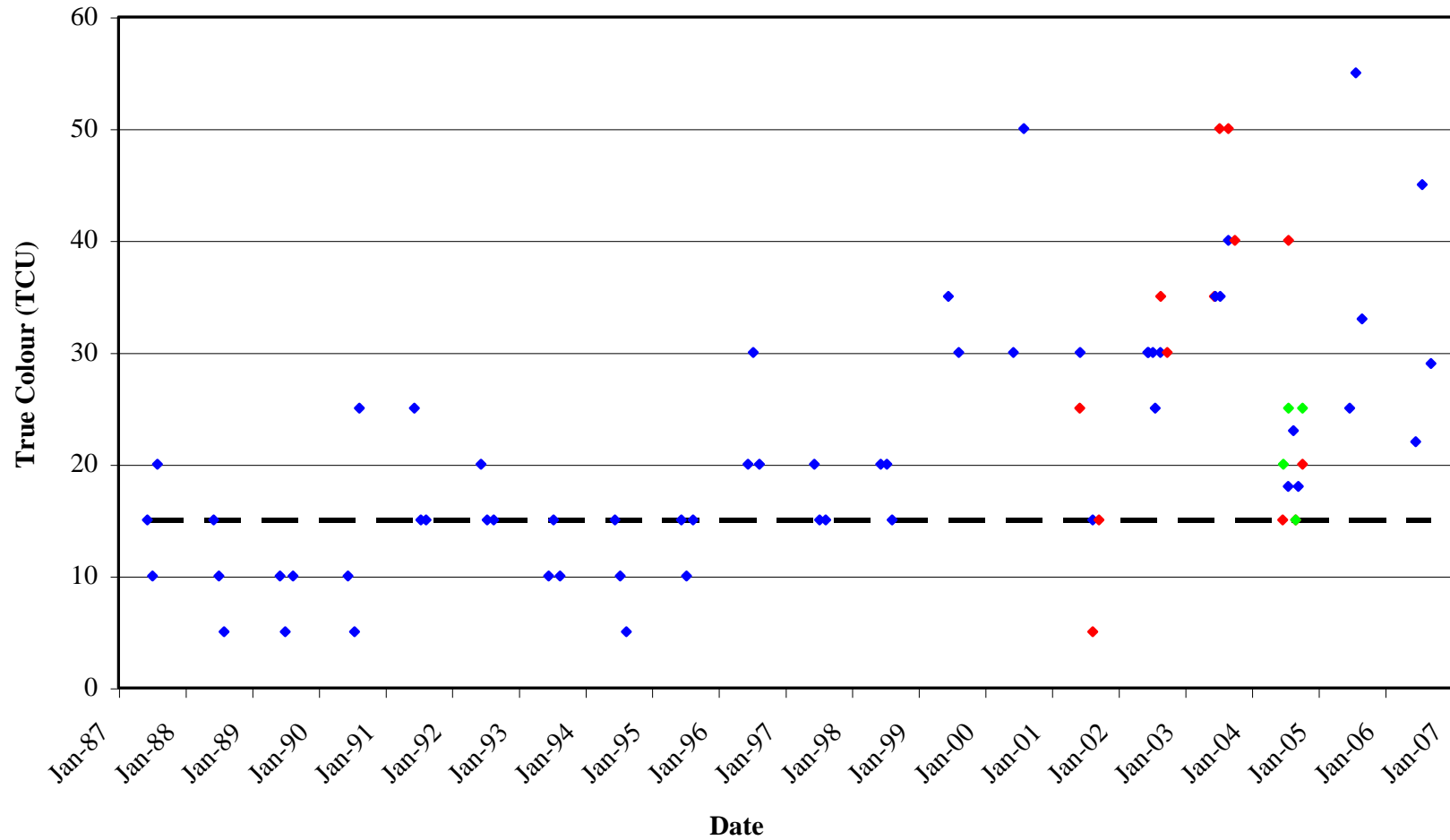


Figure 2D-6: Comparison of true colour measured in Split Lake by Manitoba Water Stewardship (blue dots) and under the Keyask environmental studies (red dots SPL7 and green dots SPL8) for the open water season. The dashed line indicates the Manitoba aesthetic drinking water quality guideline

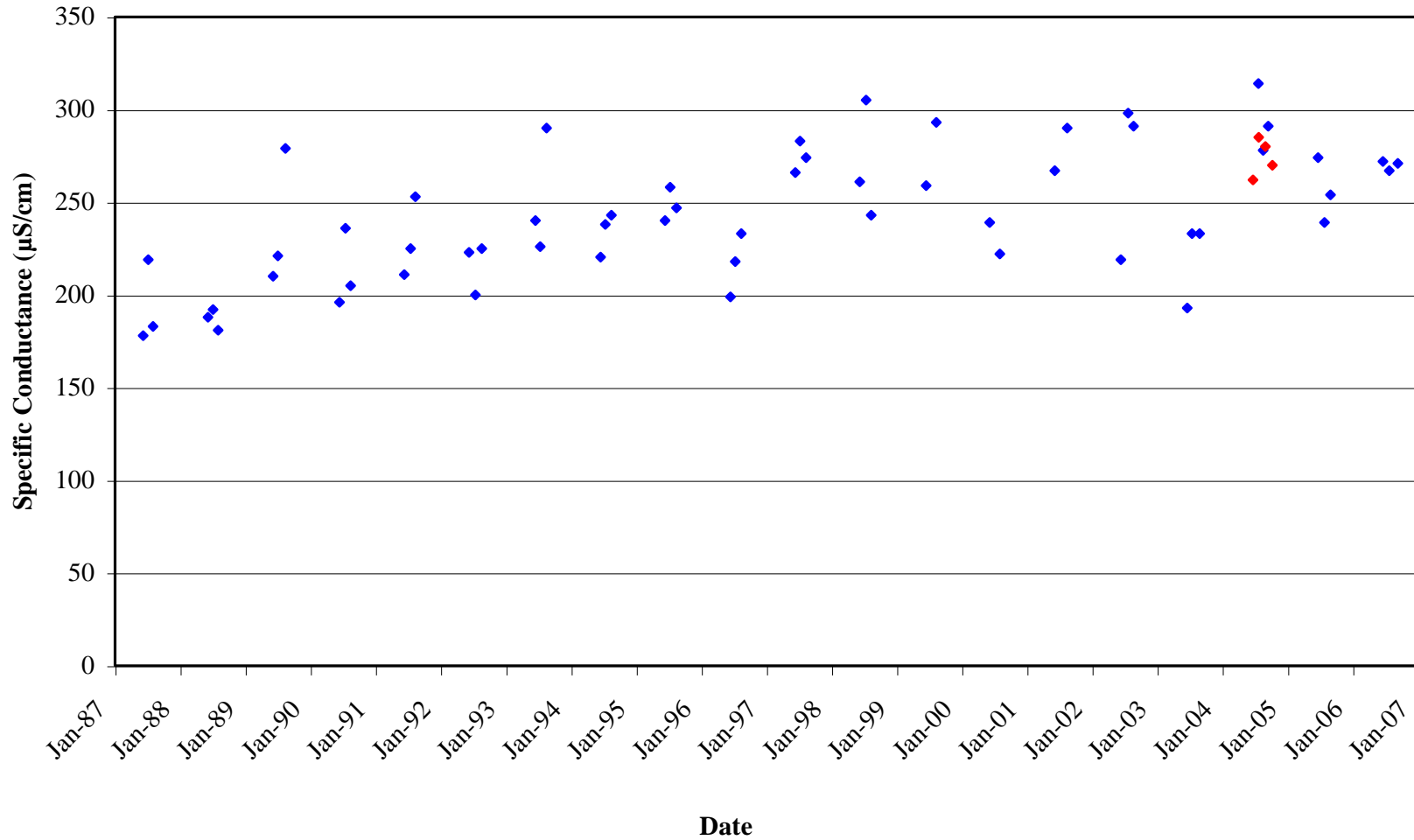


Figure 2D-7: Comparison of specific conductance (laboratory) measured in Split Lake by Manitoba Water Stewardship (blue dots) and under the Keyeyask environmental studies (red dots SPL7) for the open water season

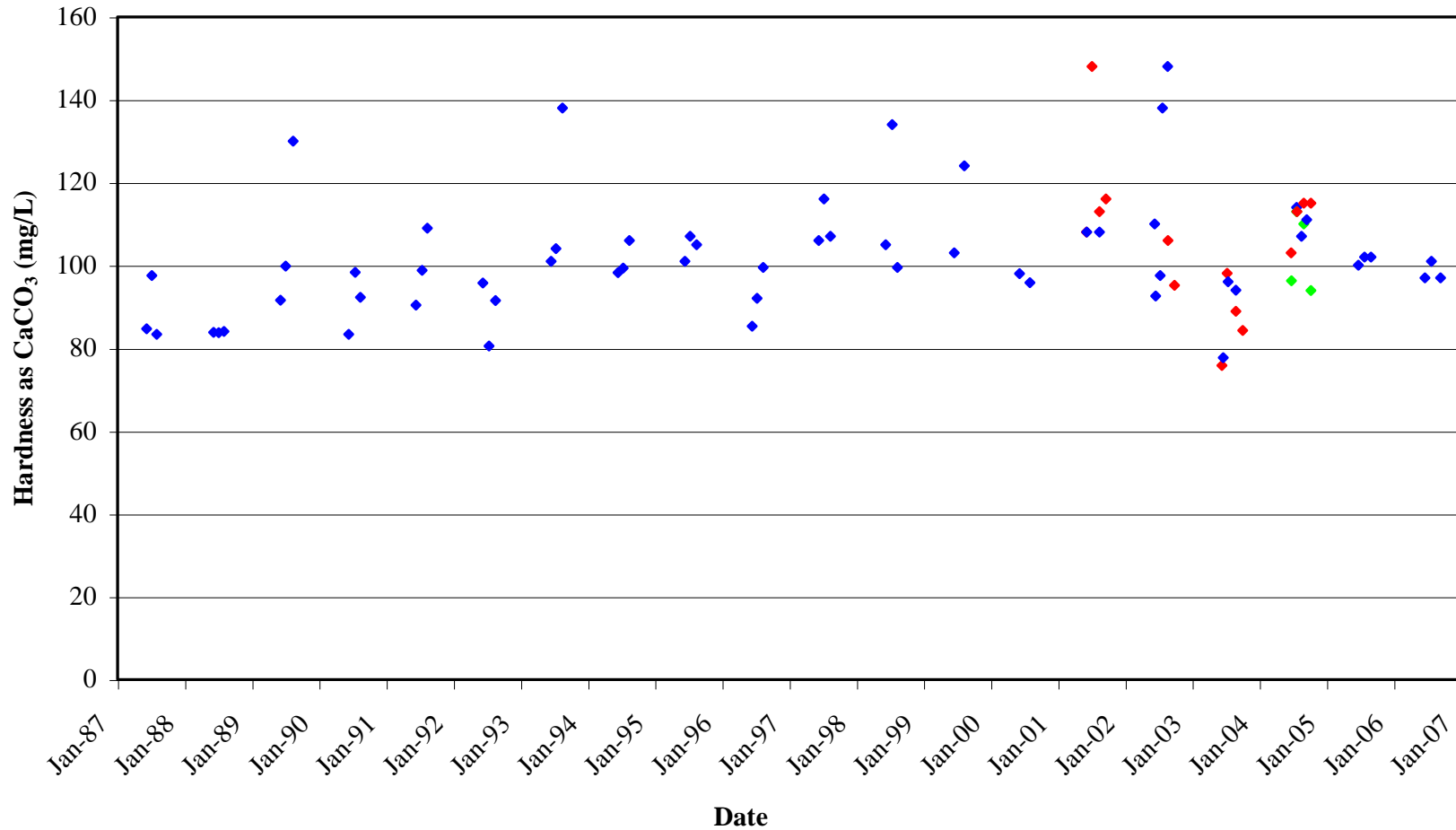


Figure 2D-8: Comparison of hardness measured in Split Lake by Manitoba Water Stewardship (blue dots) and under the Keyask environmental studies (red dots SPL7 and green dots SPL8) for the open water season

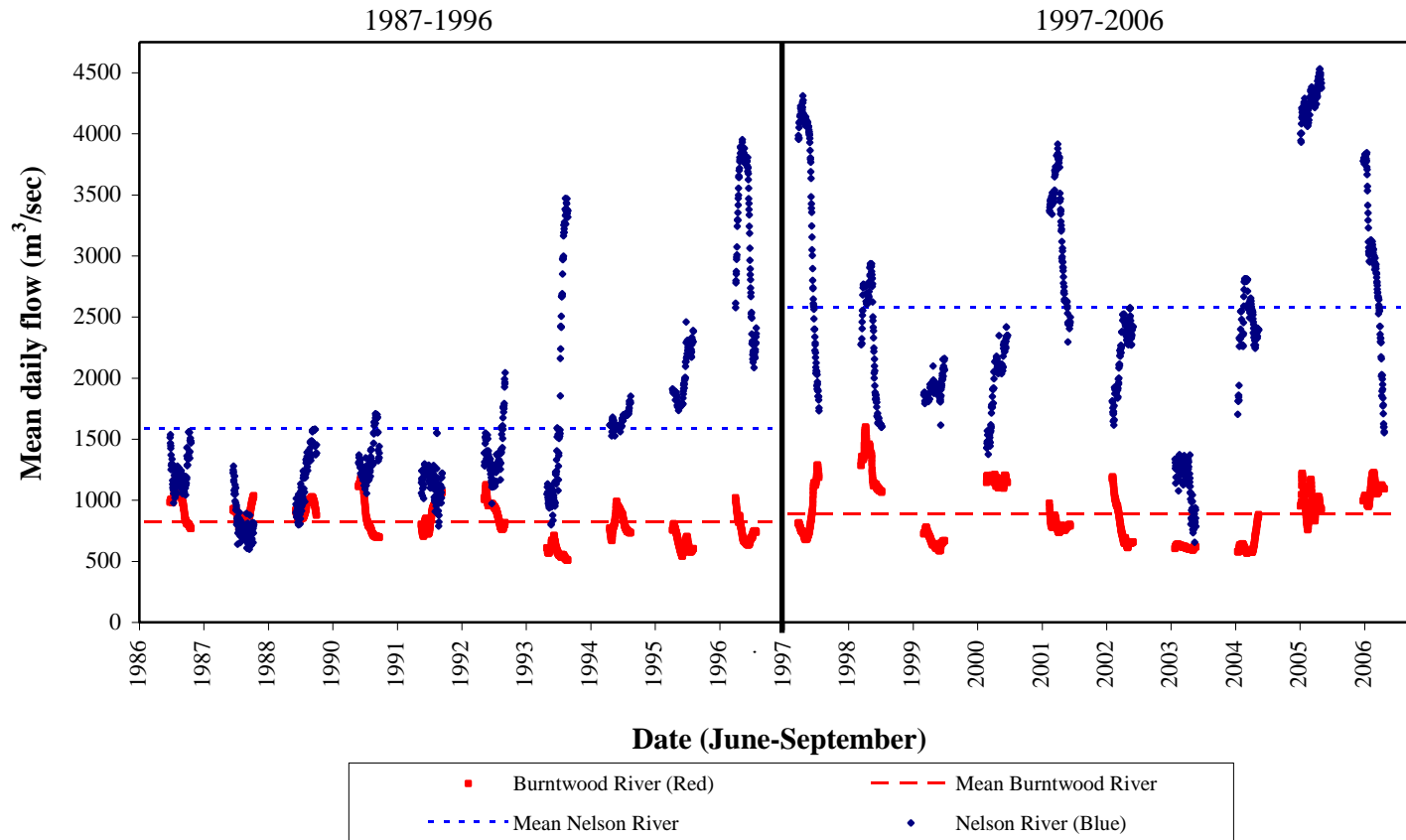


Figure 2D-9: Average daily discharge (m³/sec) of the Nelson and Burntwood rivers into Split Lake during June, July, August and September from 1987–2006. Dashed lines depict mean flows for those periods

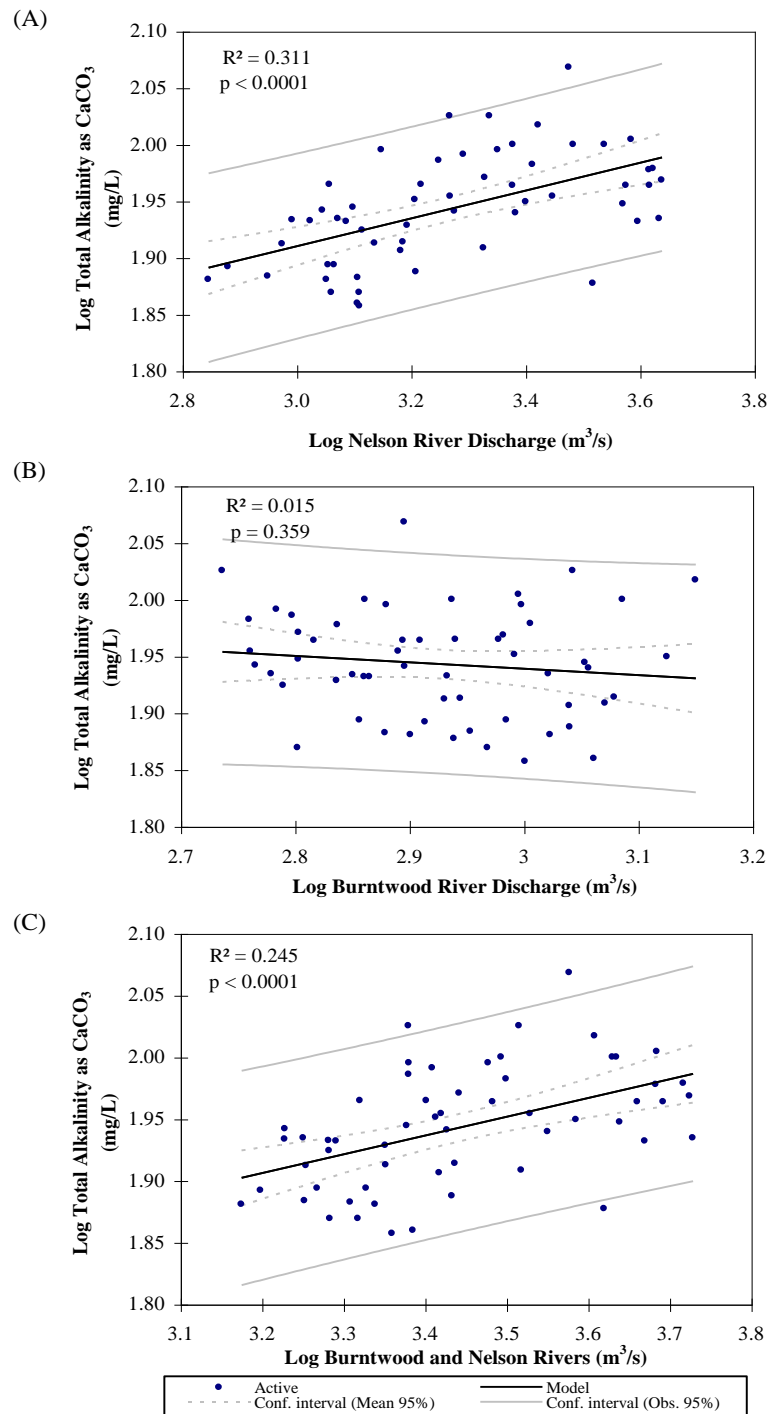


Figure 2D-10: Linear regression between total alkalinity (log) and (A) Nelson River discharge (log), (B) Burntwood River discharge, and (C) Burntwood and Nelson river discharge for the period of 1987–2006 (open water season only)

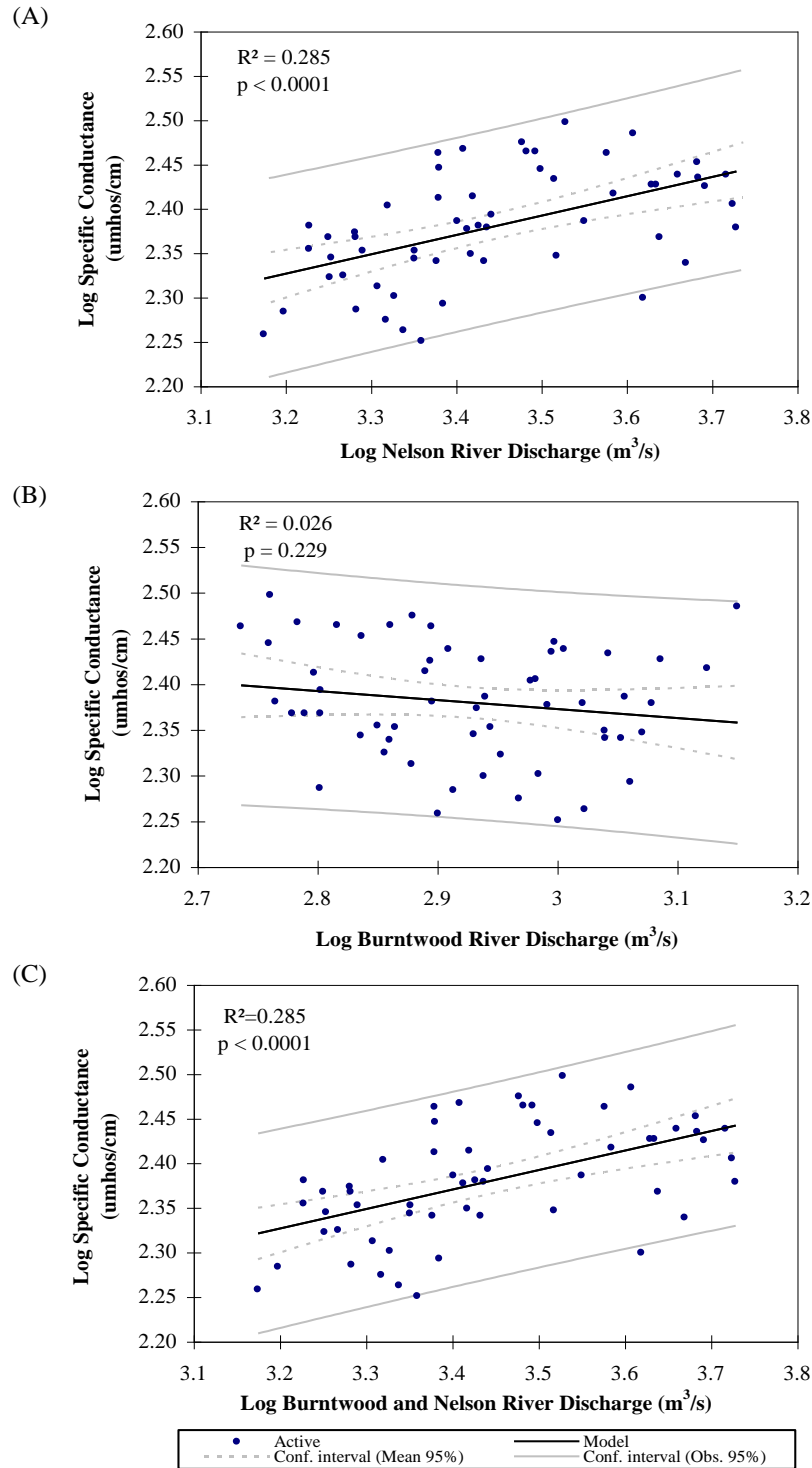


Figure 2D-11: Linear regression between specific conductance (log) and (A) Nelson River discharge (log), (B) Burntwood River discharge, and (C) Burntwood and Nelson river discharge for the period of 1987–2006 (open water season only)

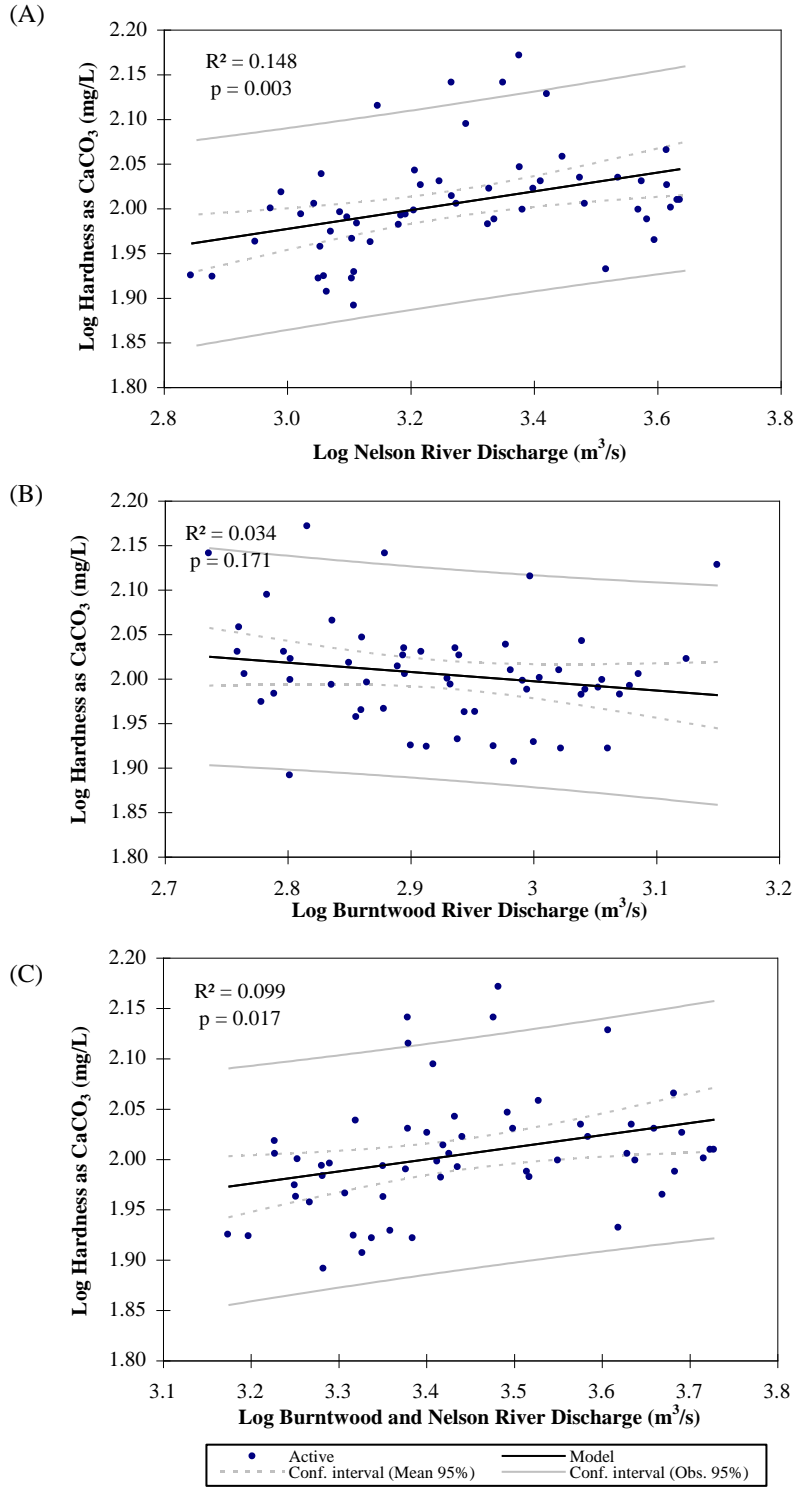


Figure 2D-12: Linear regressions between hardness (log) and (A) Nelson River discharge (log), (B) Burntwood River discharge, and (C) Burntwood and Nelson river discharge for the period of 1987-2006 (open water season only)

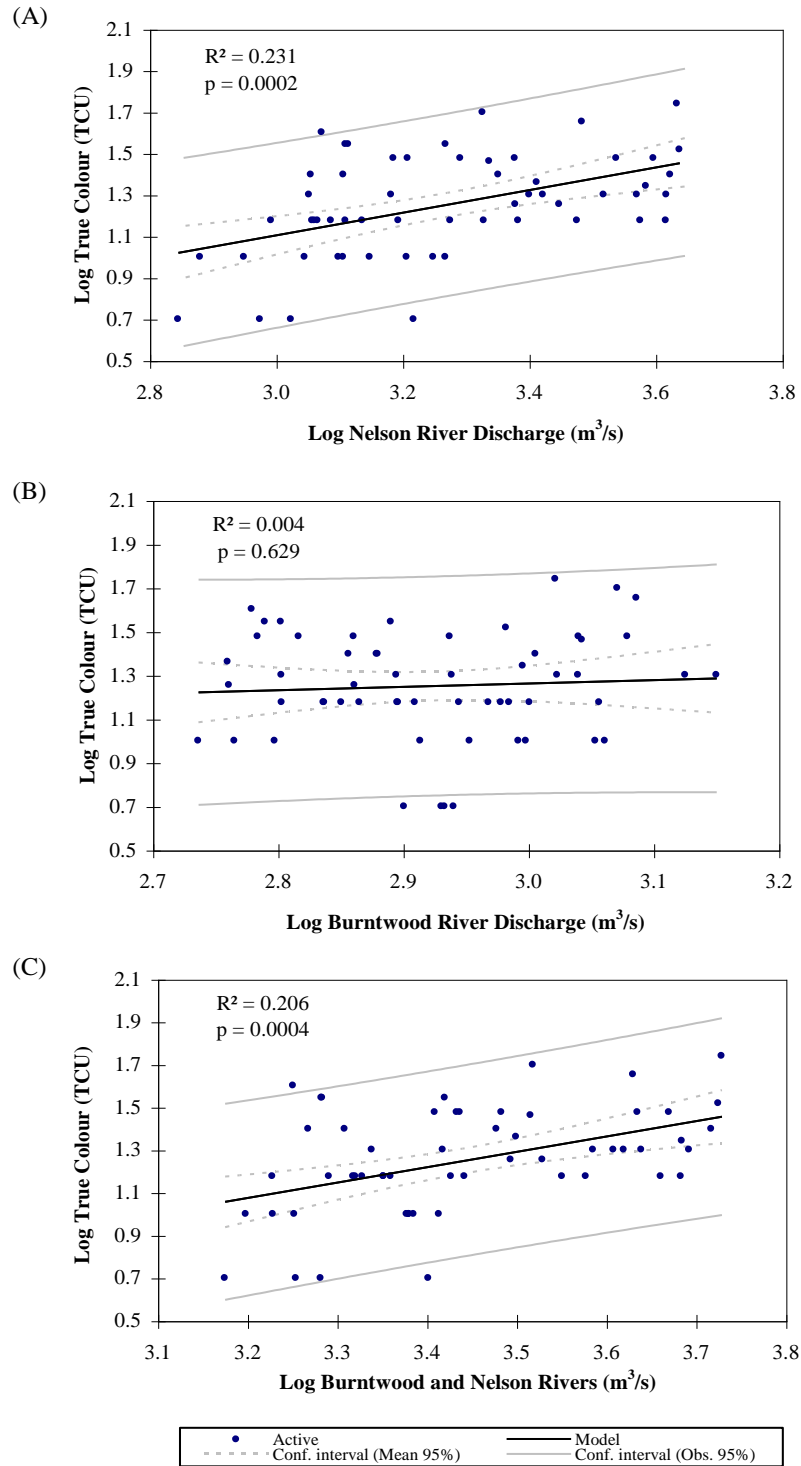


Figure 2D-13: Linear regressions between true colour (log) and (A) Nelson River discharge (log), (B) Burntwood River discharge, and (C) Burntwood and Nelson river discharge for the period of 1987–2006 (open water only)

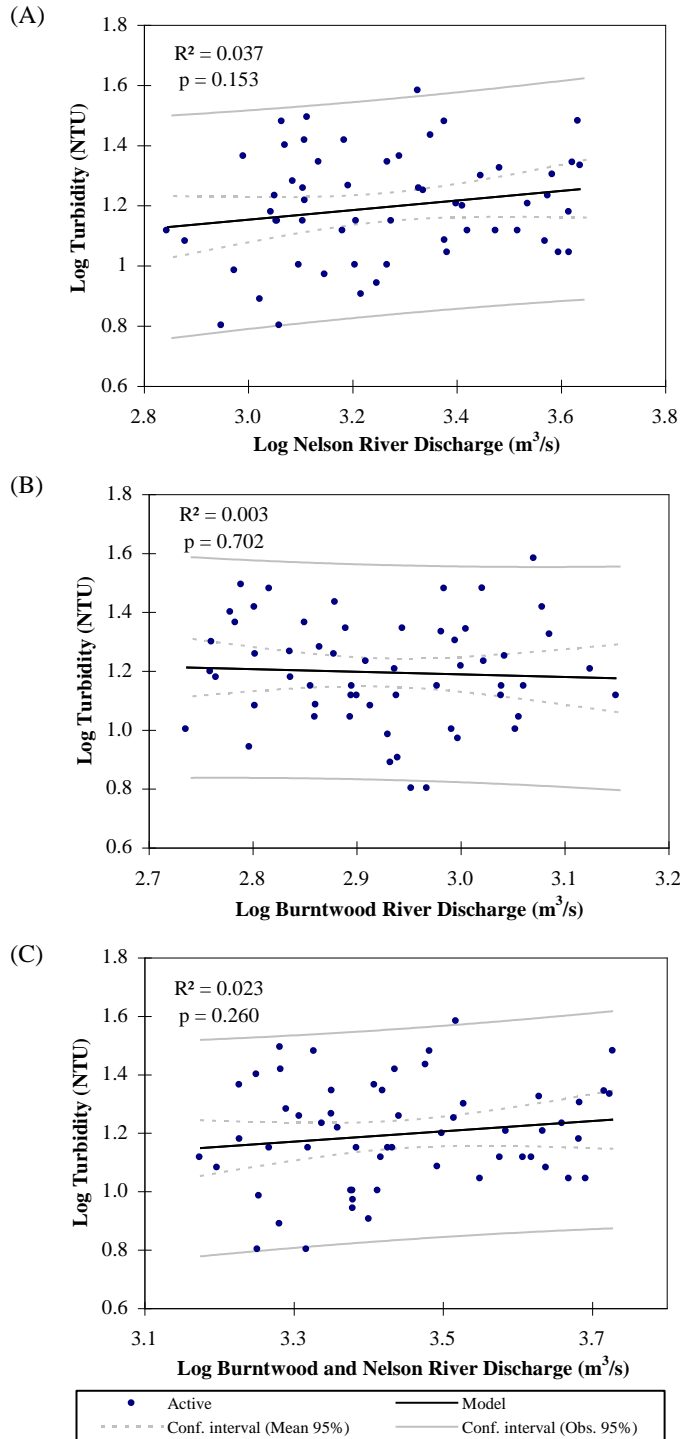


Figure 2D-14. Linear regressions between turbidity (log) and (A) Nelson River discharge (log), (B) Burntwood River discharge, and (C) Burntwood and Nelson river discharge for the period of 1987–2006 (open water season only)

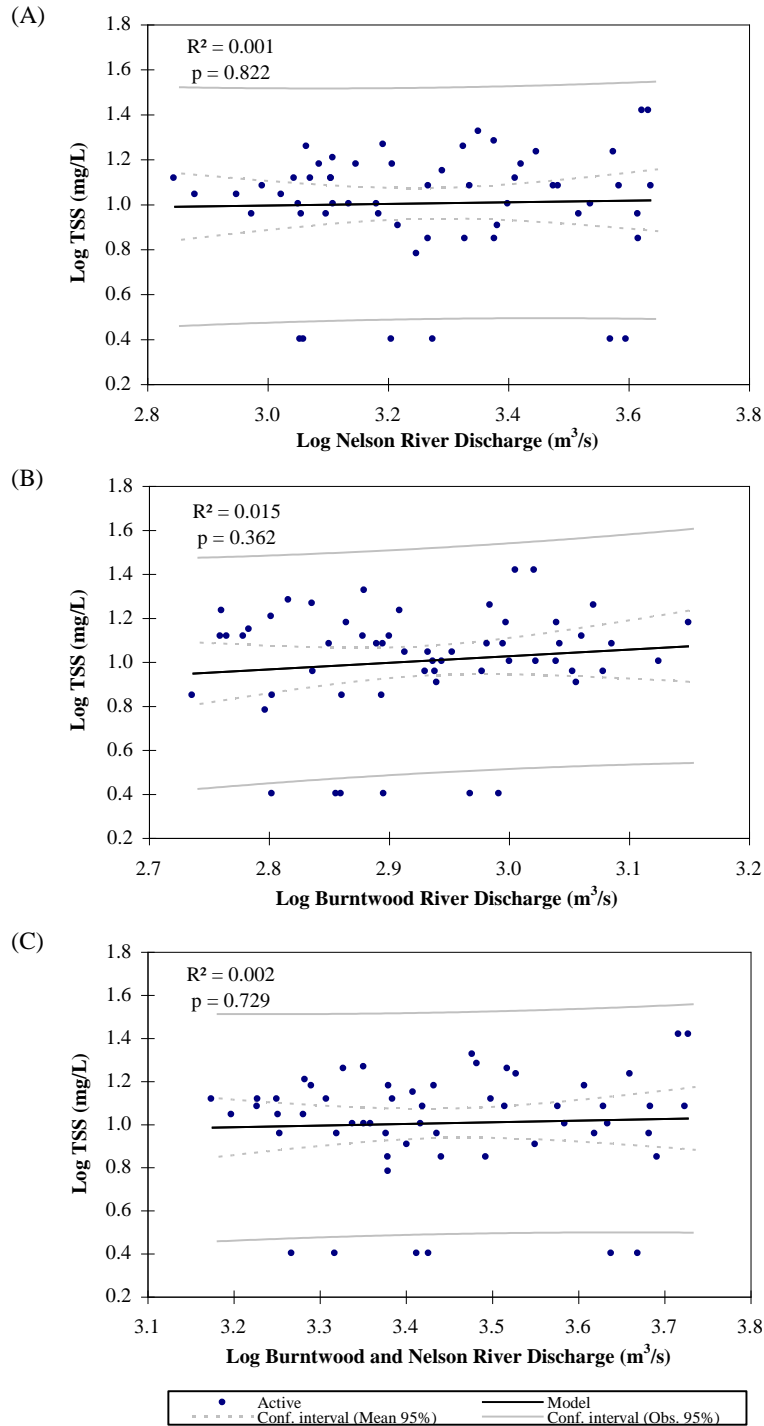


Figure 2D-15: Linear regressions between total suspended solids (TSS) (log) and (A) Nelson River discharge (log), (B) Burntwood River discharge, and (C) Burntwood and Nelson river discharge for the period of 1987–2006 (open water season only)

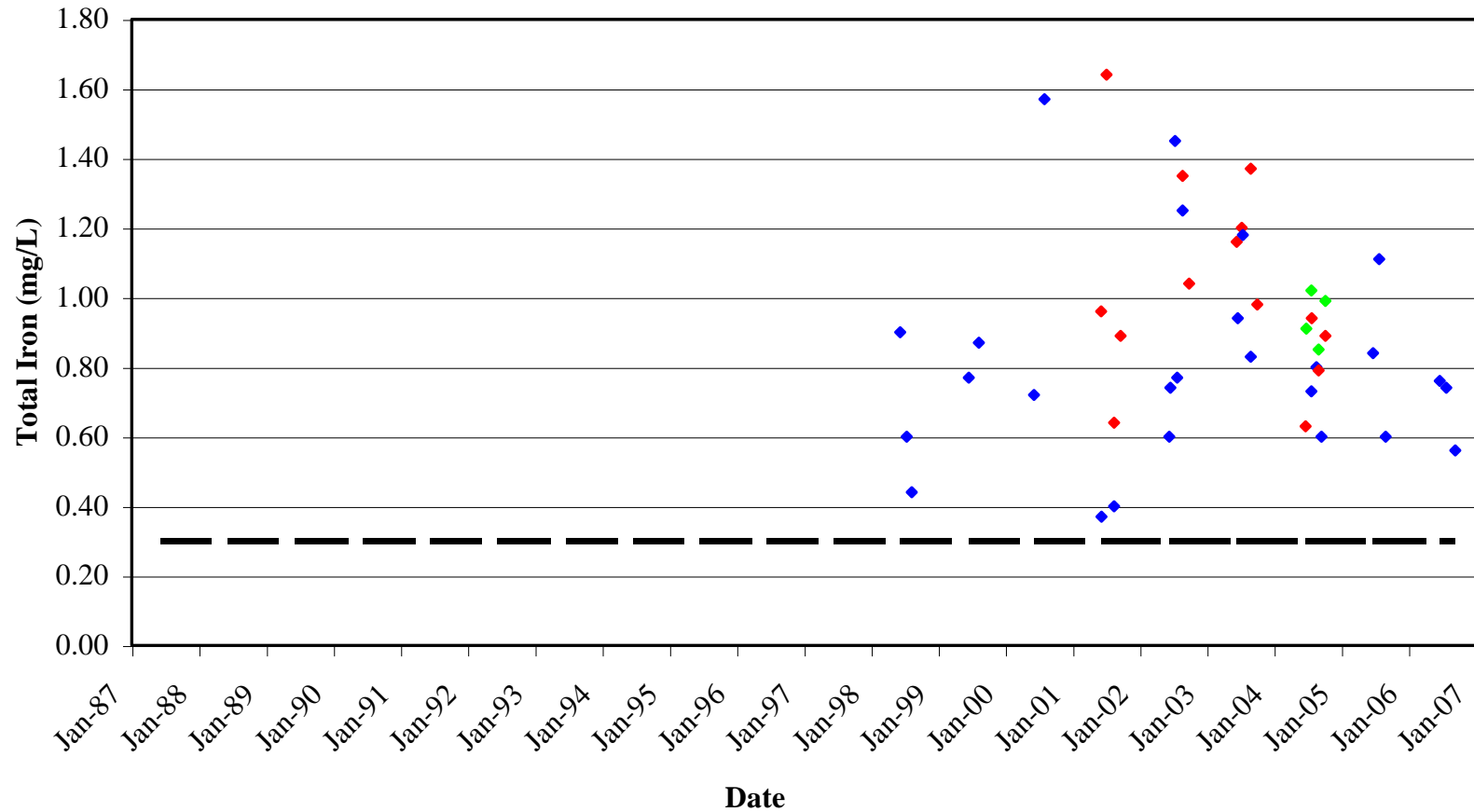


Figure 2D-16: Comparison of total iron concentrations measured in Split Lake by Manitoba Water Stewardship (blue dots) and under the Keyyask environmental studies (red dots SPL7 and green dots SPL8) for the open water season. The dashed line indicates the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOG) for the protection of aquatic life and the aesthetic drinking water quality objective

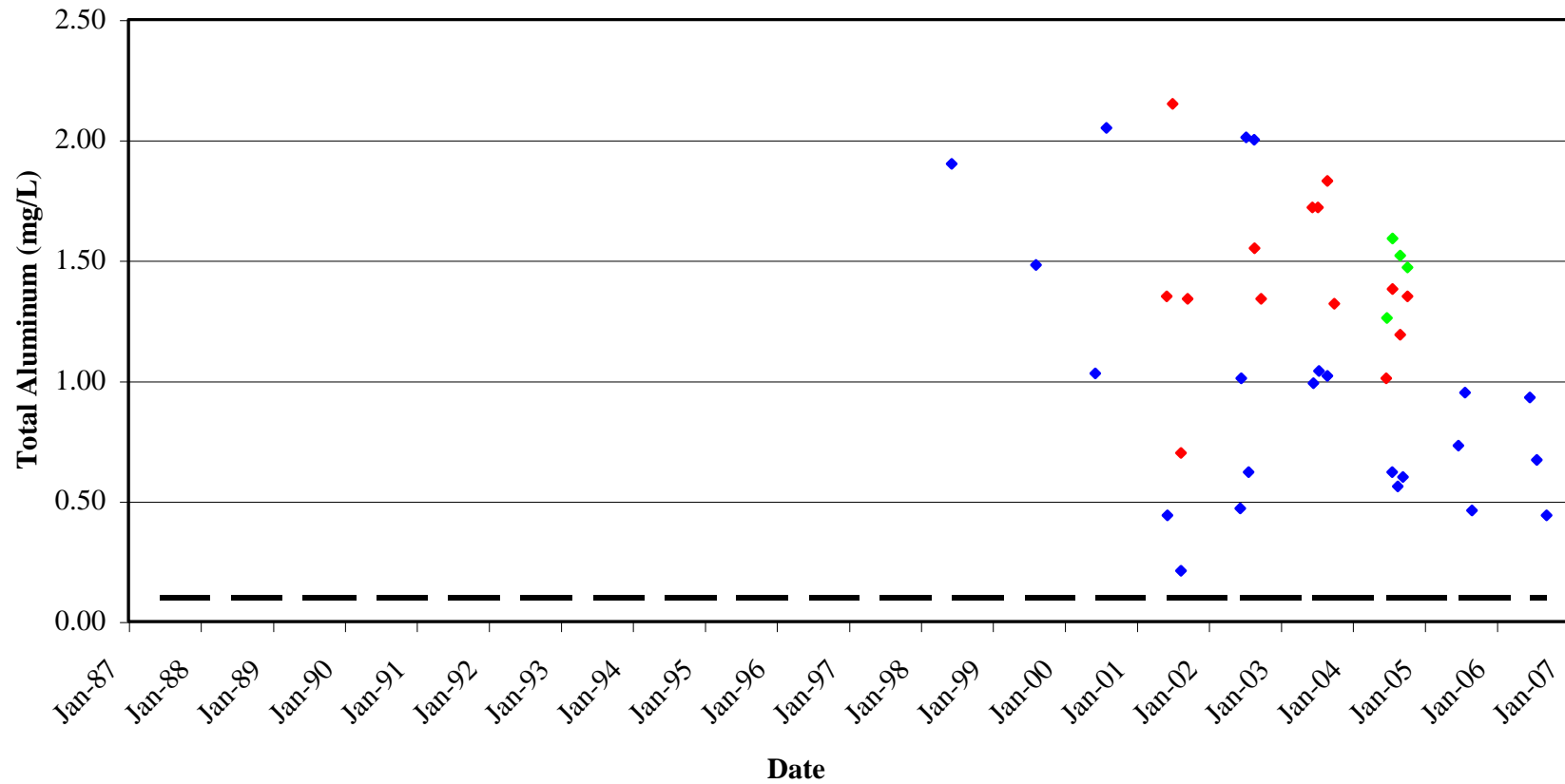
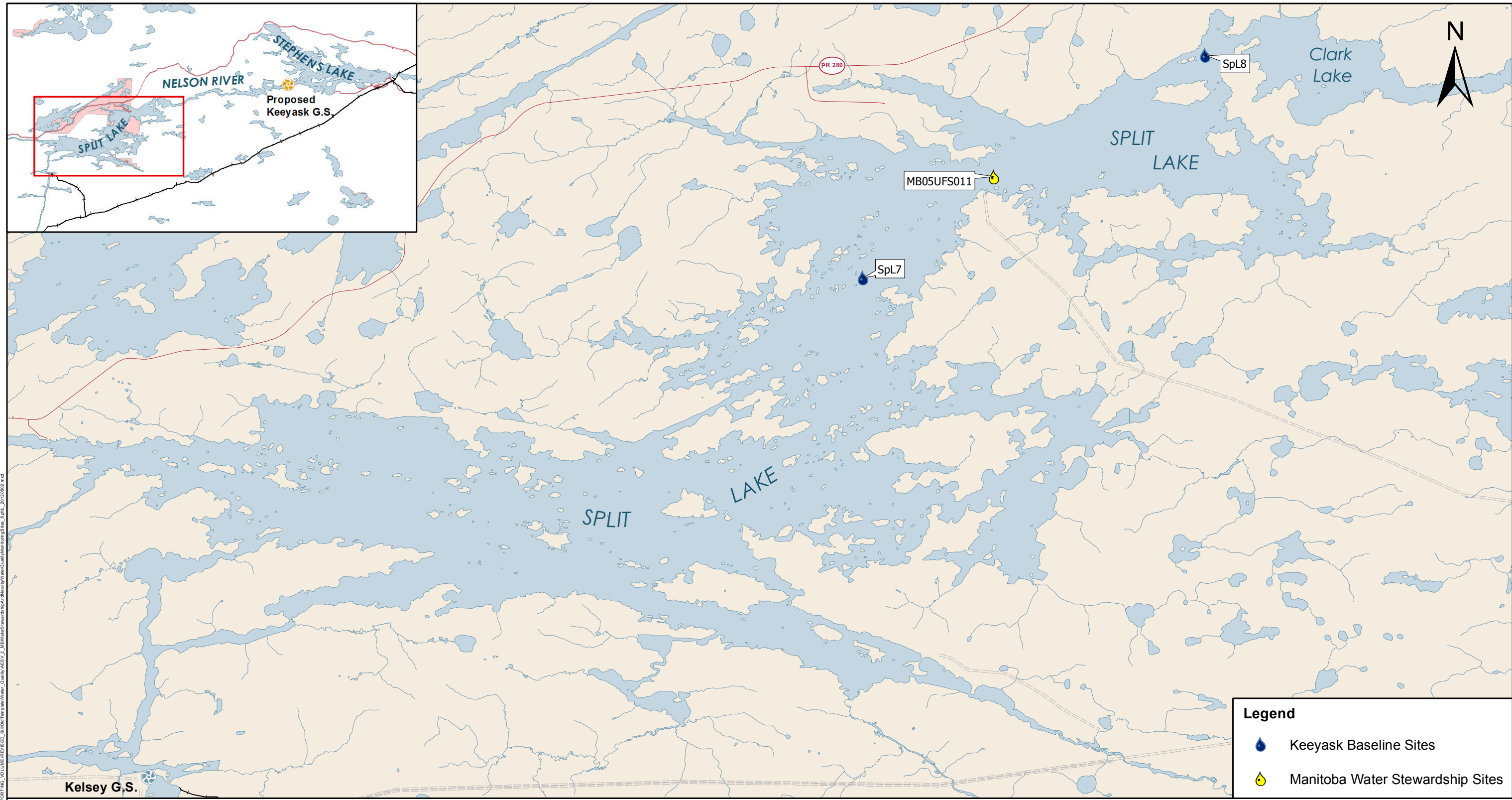




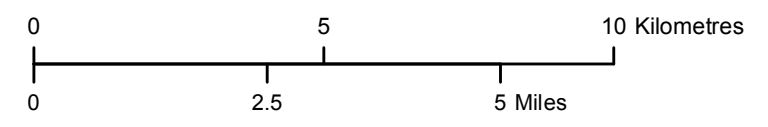
Figure 2D-17: Comparison of total aluminum concentrations measured in Split Lake by Manitoba Water Stewardship (blue dots) and under the Keeyask environmental studies (red dots SPL7 and green dots SPL8) for the open water season. The dashed line indicates the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOG) for the protection of aquatic life



Legend

-  Keeyask Baseline Sites
-  Manitoba Water Stewardship Sites

File Location: G:\EEB\Keeyask\Subst_Maps\SUPPORTING_VOLUMES\REVISED_SRS\DOTemplate\Water_Quality\MESV_2_MRW\mes2\stewardship\Water_Quality\Monitors\Site_SplL_20120802.mxd



Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000

Manitoba Water Stewardship and Nearby Water Quality Monitoring Sites

Split Lake