INDUSTRIAL WASTEWATER TREATMENT FACILITY EXPANSION:

WATER QUALITY ASSESSMENT

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1.0 INTRODUCTION

In March 2003, the City of Brandon submitted an application to Manitoba Conservation to expand its Industrial Wastewater Treatment Facility (IWWTF), which is being constructed primarily to serve the second production shift of the Maple Leaf Foods pork processing facility. The proposed wastewater treatment method combines the existing biological system with an expanded biological and innovative membrane system that is capable of removing a larger percentage of nutrients. A description of the proposed expansion and information related to the potential impacts of the facility is provided in the "Manitoba Environment Act Form and Supporting Documentation for an Operating Licence for the City of Brandon's Expanded Industrial Wastewater Treatment Facility for Maple Leaf Pork's Second Shift, Brandon, Manitoba." In that report, the need to further assess impacts to water quality was identified with respect to:

- ammonia;
- dissolved oxygen; and,
- nutrient loading (nitrogen and phosphorus-containing compounds) and subsequent effects to algal growth.

Information with respect to these issues has been gathered during the Assiniboine River Monitoring Study, a multi-year study conducted by Earth Tech (Canada) Inc. and North/South Consultants Inc. on behalf of the City of Brandon. The purpose of the study was to monitor the effects of wastewater discharge from the IWWTF, in conjunction with other discharges in the vicinity of Brandon (i.e., the Brandon Municipal Wastewater Treatment Facility [WWTF] and the Simplot Canada Ltd. fertilizer plant), on water quality in the reach of the Assiniboine River between the cities of Brandon and Portage la Prairie. Water quality models, using QUAL2E (USEPA), were developed to assist in the interpretation of observed results and to predict water quality with respect to ammonia, dissolved oxygen, and nutrients and subsequent effects to algal (specifically phytoplankton growth) under a variety of conditions.

This report contains the following sections:

Section 2.0: Overview of ammonia, dissolved oxygen, and nutrient and algal dynamics
Section 3.0: Methods
Section 3.0: Existing environment
Section 4.0: Impact assessment
Section 5.0: Residual effects

2.0 OVERVIEW OF AMMONIA, DISSOLVED OXYGEN, AND NUTRIENT AND ALGAL DYNAMICS

2.1 AMMONIA

Considerable attention has been directed towards studying the effects of ammonia on aquatic biota because, at high concentrations, ammonia may be toxic to aquatic life. In aqueous solutions, ammonia exists in equilibrium between the ammonium ion (NH_4^+) and un-ionized ammonia (NH_3). The toxicity of ammonia to aquatic biota is related primarily to the concentration of un-ionized ammonia. The relative concentrations of ammonium ion and un-ionized ammonia are largely dependent on pH and water temperature, with the fraction of un-ionized ammonia changing as a function of pH and temperature. Additionally, the acute toxicity of un-ionized ammonia may be affected by several factors, including pH, temperature, dissolved oxygen concentration, carbon dioxide concentration, fluctuating or intermittent exposure regimes, salinity, and the presence of other toxic substances (USEPA 1998).

2.1.1 AMMONIA DYNAMICS

Ammonia nitrogen is an intermediate between the conversion of organic nitrogen to nitrates (via nitrites). The main sources of ammonia to surface waters are the decay of organic nitrogen, excretion from aquatic organisms, and inputs from point and non-point sources (e.g., effluents, runoff from agricultural land). In the aquatic environment, ammonia is taken up by plants and algae and is broken down (in a process known as nitrification) to nitrites and nitrates by nitrifying bacteria. Studies have demonstrated that nitrification occurs in the water and sediments, and that nitrifying bacteria are very sensitive to environmental conditions (Bowie et al. 1985). For example, scouring of sediments caused by flooding can significantly reduce nitrification until the bacterial flora becomes re-established (Bowie et al. 1985). The importance of processes related to the sediments varies with the size of the water body - in large rivers and lakes processes in the water column are relatively more important, while in small rivers, sediment processes may have a large influence on water quality (Ambrose et al. 1991). Aquatic plants can use nitrogen in the form of either nitrates or ammonia, although the latter is preferentially accumulated (Bowie et al. 1985).

During the winter, ammonia levels may approach a mass-balance relationship, as nitrification proceeds at slow rates at cold temperatures, while uptake by algae and plants is negligible. As temperatures warm, ammonia may be rapidly taken up by both bacteria and plants/algae, resulting in rapid fluxes in the aquatic environment.

2.1.2 REGULATION OF AMMONIA LEVELS

Water quality objectives for ammonia, for the protection of aquatic life, are provided in the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) final draft document (Williamson 2002). This document is currently undergoing review, and is an update of the previous 1988 Manitoba Surface Water Quality Objectives (MSWQO) (Williamson 1988). The 1988 ammonia objectives were based on un-ionized ammonia concentrations, whereas the revised objectives are based on total ammonia nitrogen. Objectives are also applicable to differenct design flows, including: Objectives are also applicable to different flow design scenarios, including: (1) 1Q10 (the lowest 1-day flow expected within a 10 year period); (2) 7Q10 (the lowest 7-day average flow with a return frequency of 10 years); and, (3) 30Q10 (the lowest 30-day average flow within a 10 year period).

There are short-term (i.e., 'acute') and long-term objectives (i.e., 'chronic') MWQSOGs for ammonia. 'Acute' criteria (which are objectives applicable to a one hour averaging duration and 1Q10 flows) apply within the mixing zone, as it is specified that the mixing zone should not be acutely lethal to aquatic life. 'Chronic' criteria (which are applicable to a 30-day averaging duration and a design flow of 30Q10 and a 4-day averaging duration and a design flow of 7Q10) apply downstream of the mixing zone.

The objective for ammonia is both temperature- and pH-dependent. In general, ammonia toxicity increases with pH and temperature; thus, the objectives for ammonia are most restrictive in alkaline, warm environments. Ammonia objectives calculated for the Assiniboine River near Brandon, using 10-year median temperatures and pH, were most restrictive during the summer/fall months (Table 1). The current operating licences for the City of Brandon Municipal WWTF (Environment Act Licence # 2351 S2R) and IWWTF (Environment Act Licence #2367 S2R) do not specify limits for ammonia discharges. Rather, the licences specify that the combined effluents should not cause, or contribute to, the unionized ammonia concentration[1] in the Assiniboine River, at the nearest downstream model-predicted fully-mixed river monitoring station, to rise above the MWQSOG when river discharge is greater than 7Q10 levels[2]. The operating licence for Simplot Canada Ltd. specifies effluents may be released from September 15 to May 15, with varying discharge limits between months (Table 2).

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[1] The licences were developed when Manitoba Water Quality Objectives (Williamson 1988) still referred to unionized ammonia. Current MWQSOGs refer to total ammonia (Williamson 2002).

[2] The licences were developed when Manitoba Water Quality Objectives (Williamson 1988) referred to 7Q10 flows only. Current MWQSOGs apply to 1Q10, 7Q10, and 30Q10 flow scenarios (Williamson 2002).

2.2 DISSOLVED OXYGEN

Dissolved oxygen (DO) is essential for the survival of most aquatic life and is one of the basic parameters used to assess aquatic ecosystem integrity. The amount of oxygen that can be dissolved in water varies with temperature such that colder water holds more oxygen than warmer water. Therefore, oxygen values may be reported as absolute concentrations (i.e., mg oxygen/L of water), or as percent saturation (the concentration of oxygen in the water relative to the concentration at equilibrium with air at that temperature).

The following are important in considering the oxygen balance in northern rivers:

- Water temperature - the amount of oxygen that water can carry is inversely related to the temperature; therefore, at low temperatures, percent saturation may be lower than at high temperatures, due to a greater capacity for oxygen in solution.

- Oxygen input by re-aeration - re-aeration is the process whereby water with oxygen concentrations below saturation can become re-saturated with oxygen. Re-aeration rates are affected by characteristics of the river channel such as velocity and depth. Water turbulence, such as that produced by rapids or as water passes over weirs, increases the rate of re-aeration.

- Effect of ice cover on re-aeration - ice cover determines the amount of area over which re-aeration can occur and is a critical parameter during the winter months. Ice generally forms later, and is thinner, in areas with high water velocity and turbulence (such as rapids) and where springs are present. These areas also rapidly open up when thawing conditions (i.e., warm sunny periods) occur during the winter, increasing the amount of re-aeration.

- Oxygen input by surface flow - tributary streams and other inputs (including effluents) may bring a significant load of oxygen into the river, depending on the rate of flow and oxygen concentration in the influent stream. Conversely, low dissolved oxygen concentrations in tributaries and other inputs (e.g., groundwater) may dilute dissolved oxygen in a stream.

- Groundwater inputs - depending on conditions within the aquifer, groundwater may contain little or no oxygen and significant inputs of groundwater may dilute the oxygen content of a stream. However, groundwater may also increase the oxygen content of a river if springs arise above the river surface and groundwater has the opportunity to become oxygenated prior to entering the river.

- Plants and algae (both in the water column and attached periphyton) produce oxygen during photosynthesis. The rate of photosynthesis depends on light (including photo period), nutrients, temperature, and other environmental factors. Conversely, plants and algae consume DO at night (i.e., in the absence of light) in a process called respiration. Therefore, DO may fluctuate significantly over a 24-hour period. Development of algal blooms or dense growth of periphyton may lead to wide diurnal DO fluctuations. The relative balance between photosynthesis and respiration determines the net effect of algae on DO (i.e., if respiration is greater than photosynthesis, algae would create an oxygen deficit). It should be noted that oxygen generation by photosynthetic organisms is usually negligible during the winter due to low temperatures and limited light.

- Oxygen use by non-photosynthetic organisms in the water column – the primary use of oxygen in the water column is by bacteria decomposing organic matter (measured as carbonaceous biochemical oxygen demand or CBOD). This organic matter may originate from natural sources or from the discharge of effluents. The rate of bacterial decomposition and oxygen consumption is greater at higher temperatures. Oxygen demand exerted by large organisms such as invertebrates and fish is generally insignificant in flowing rivers.

- Oxygen use by organisms in the sediments - organisms in the sediments, in particular bacteria that decompose organic matter, can use a significant amount of oxygen, resulting in a flux of oxygen from the water column to the sediments. Use of oxygen by organisms in the sediments is expressed as sediment oxygen demand, or SOD. As in the water column, the rate of oxygen consumption is temperature dependent.

- Oxygen use by nitrifying bacteria and in the conversion of nitrite to nitrate - the breakdown of ammonia by nitrifying bacteria requires oxygen (termed nitrogenous biochemical oxygen demand [NBOD]). The initial product is nitrite, which is then rapidly converted to nitrate.

- Settling and decay of phytoplankton and other aquatic plants can create a sediment oxygen demand (Thomann and Mueller 1987).

- River discharge may be critical to meeting minimum DO requirements for the protection of aquatic life. The inter-relationship between river discharge and DO is complex and relates to the relative effect of SOD under varying river travel times and volumes of water, as well as to re-aeration.

2.2.1 Regulation of Oxygen Levels

Because of its importance to aquatic life, suitable levels of oxygen are specified in guidelines and objectives for the aquatic environment. Although the 1988 Manitoba water quality objectives provided criteria based on DO saturation and concentration, the revised MWQSOGs refer to concentration only (Williamson 2002). Several criteria have been incorporated, based on averaging duration, temperature, and the presence of mature or early life stages of fish. Specific objectives have been proposed for waters containing cool-water fish (such as walleye and pike) *vs.* cold-water species (such as whitefish and trout). With the exception of burbot, which is typically considered a cold-water species[3], the Assiniboine River is inhabited by cool-water species. Compliance of measured dissolved oxygen concentrations in the Assiniboine River was gauged against the objectives for cool-water species.

Objectives for DO are dependent on the presence of mature or early life stages of fish, defined in terms of water temperature (Williamson 2002). In the open-water season, water temperature is in excess of 5 °C and early life stages of cool-water fish species are present; therefore, objectives are more restrictive to protect sensitive life stages. The following objectives apply:

- Chronic Objective – 6.0 mg/L: 7-day averaging duration, may not be exceeded more than once every 3 years (on average), under a design flow of 7-day, 3-year, or 7Q10; and,
- Acute Objective – 5.0 mg/L: instantaneous minimum, may not be exceeded more than once every 3 years (on average), under a design flow of 1-day, 3-year, or 1Q10.

Under ice-cover, temperatures are below 5 °C and objectives designed to protect mature life stages of cool water species apply. The following three objectives apply:

- Chronic Objective – 5.5 mg/L (30-day): 30-day averaging duration, may not be exceeded more than once every 3 years (on average), under a design flow of 30-day, 3-year, or 30Q10; and,
- Chronic Objective – 4.0 mg/L (4-day): 7-day minimum, may not be exceeded more than once every 3 years (on average), under a design flow of 7-day, 3-year, or 7Q10; and,
- Acute Objective – 3.0 mg/L (instantaneous): instantaneous minimum, may not be exceeded more than once every 3 years (on average), under a design flow of 1-day, 3-year, or 1Q10.

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[3] Cold-water objectives are not considered here because the system is a 'cool-water' system. However, it should be noted that burbot have been identified in this system and burbot is typically considered a cold-water species.

It is noted that Gurney (1991) recommended application of a DO concentration of 5.0 mg/L as a site-specific water quality objective for the Red and Assiniboine rivers; this document is the basis for several existing environmental licences for discharges to the Assiniboine River.

The potential oxygen demand of effluents discharged to surface waters is also regulated through specification of allowable inputs of biochemical oxygen demand (BOD). The 5-day BOD in the effluents discharged by the Municipal WWTF and the IWWTF are each limited to 30 mg/L. The current licences also stipulate that effluents should not cause, or contribute to, the reduction of DO concentration in the water column of the Assiniboine River, at the nearest downstream model-predicted location of lowest DO, to less than 5.0 mg/L. The operating licence for Simplot Canada Ltd. does not specify restrictions for the release of BOD or effects of effluent discharge on DO concentrations in the river.

2.3 NUTRIENTS AND ALGAL GROWTH

Inputs of nitrogen (N) and phosphorus (P) can stimulate the growth of algae and other primary producers. Excessive growth of algae and aquatic plants can compromise the aesthetic quality of surface waters, and/or the suitability of surface waters for recreation or as sources of raw water for potable water supplies. In addition, they may cause or exacerbate conditions of low DO, through respiration by plants and algae at night, and through decay when plants and algae die. Although P is typically the limiting nutrient in lakes, N has been identified as the limiting nutrient in many streams, particularly in those receiving municipal wastewater and in watersheds with a rich geological source of phosphorus and/or dominated by agriculture (Scrimgeour and Chambers 2000). Manitoba Conservation has indicated that phosphorus is often abundant in southern Manitoba streams, and is often not limiting (Williamson 2002).

Aquatic primary production is, in general, carried out by three groups of organisms: phytoplankton, periphyton, and aquatic macrophytes. Phytoplankton are microscopic algae entrained in the water column of rivers, lakes, and other aquatic habitats. Phytoplankton in riverine systems may consist of algae originating in upstream lakes or backwater areas, algae that have become detached from upstream substrata, and algae entrained and reproducing in the river current. As in lakes, there is a seasonal succession of dominant algal taxa as conditions for growth change. Periphyton, or attached/benthic algae, grow in association with various types of substrata, including rocks, sand, aquatic vegetation and mud. Periphyton are characterized by a distinct growth habit that follows a succession from initial adnate forms (small diatoms and bacteria) to larger diatom species, followed by stalked diatoms and filamentous green algae. Filamentous periphyton can form extensive growths that are macroscopic. As growth conditions decline, they die and the periphyton mat is sloughed off. In rivers, this sloughed periphyton may contribute to loading of nutrients downstream, as can senescence of phytoplankton that are carried downstream. Aquatic macrophytes are large plants that grow either completely under water (submersed macrophytes) or partially under water (emergent macrophytes). Submersed macrophytes generally are restricted to areas where sufficient light penetrates to the sediments to allow seed germination; in rivers, they are also limited by water velocity. Although not directly quantified in the Assiniboine River Monitoring Study, aquatic plants were observed within the mixing zone.

2.3.1 Factors Influencing Primary Production

The growth of photosynthetic organisms in riverine environments is determined by the interaction of many factors, including:

- Light availability - light is required for photosynthesis, the process whereby algae use carbon dioxide to form organic compounds required for growth and division. Light requirements vary among groups of algae and with growing conditions, as cells can adapt to prolonged low light levels. Light availability in rivers depends on water depth, turbidity, total hours of sunlight per day, and intensity of radiation. Periphyton is restricted to areas where sufficient light reaches the substratum.

- Water temperature - as with light, optimum temperatures for growth vary among groups of algae. Growth rate generally increases with warmer temperatures up to a point where heat disrupts enzyme-based processes.

- Flow/discharge - as the growth of algae is a time-dependent process, low flows or long residence times create the potential for greater accumulation of phytoplankton biomass in the water column under conditions where net growth occurs. Conversely, where net growth does not occur, phytoplankton biomass decreases further downstream of sources such as lakes and backwater areas. However, low velocities may enhance settling of phytoplankton.

- Water velocity also influences the biomass of benthic algae. Biomass may be greatest at intermediate water velocities, as biomass is lost due to scouring at high velocities, and nutrient depletion within the layer of water immediately adjacent to the benthic algae may limit growth at low velocities.

- Substratum type - the growth of benthic algae is closely related to substratum type, with various groups being adapted to different substrata. Dense mats of algae in riverine environments generally form only on rocky substrata.

- Nutrient availability - algae and plants require specific inorganic nutrients for growth. In fresh water, overall algal biomass is usually limited by N and/or P. Certain types of bluegreen algae can obtain nitrogen by fixing atmospheric nitrogen; therefore, phosphorus may ultimately be the limiting nutrient. Diatoms may be limited by silica, required for formation of their cell wall, or frustule. Nutrients may become limiting (or co-limiting) only if other growing conditions are suitable.

2.3.2 Regulation of Nutrient/Algal Levels

Although algal growth is influenced by many factors, nutrients have been linked to excessive algal growth in many systems. In Manitoba there are narrative guidelines for nutrients to prevent the nuisance growth of algae and aquatic plants (Williamson 2002). Although the P guideline was established at 0.05 mg/L in order to limit excessive primary production in Manitoba streams, it was recognized that many streams in southern Manitoba already exceed this guideline due to the presence of rich prairie soils. A guideline of 0.025 mg/L is applicable to lakes, reservoirs, ponds, and tributaries at the point of entry to these bodies of water.

Other jurisdictions have established water quality objectives specific to nutrients, phytoplankton, and/or periphyton. The Province of Alberta developed chronic guidelines for N (1.0 mg/L) and P (0.05 mg/L) “for the protection of aquatic life” (AB Environment 1999). Concentrations of chlorophyll *a* in excess of 15 µg/L have been deemed to exceed the ‘nuisance phytoplankton growth goal’ by some jurisdictions (e.g., State of Oregon, Rounds and Wood 2001). With respect to periphyton, the B.C. Ministry of the Environment has adopted a maximum criterion of 100 mg chlorophyll *a*/m^2 for the protection of aquatic life in streams and a criterion of 50 mg/m^2 for preservation of recreational use of streams (BC Ministry of Environment, Lands, and Parks 2001).

3.0 METHODS

3.1 MANITOBA CONSERVATION DATA

Water samples are routinely collected by Manitoba Conservation (Water Quality Management Section) along numerous waterways throughout the Province. Within the study area, water sampling is conducted at the 18th St. Bridge in Brandon (upstream of any inputs at Brandon), at Treesbank, and downstream of the dam at the Portage Water Reservoir. Water quality data for the period 1992 to 2002 were summarized, and were used to obtain estimates of background water quality for this assessment. Summary statistics for these sites, based on all available data for this time period, are provided in Tables 3-5. Detailed summaries of statistics for the various months for the Assiniboine River at Brandon are provided in Appendix 1.

3.2 ASSINIBOINE RIVER MONITORING STUDY

The Assiniboine River Monitoring Study was a multi-year study initiated in the late 1990s. The study considered the effect of discharge from the IWWTF in conjunction with other discharges in the vicinity of Brandon (i.e., the Brandon Municipal WWTF and the Simplot Canada Ltd. fertilizer plant) on water quality in the reach of the Assiniboine River between Brandon and Portage la Prairie. As part of the study, water quality models were developed to simulate water quality in the study reach under a variety of conditions.

The water quality portion of the monitoring study began in February 1999. Sampling continued with a spring (May 1999) and summer/fall (June, July, August, and September 1999) open-water program. These studies documented the condition of the river prior to the operation of the IWWTF. The facility began operating in September 1999; however, discharges during the September 1999 study were minimal. Production and corresponding effluent discharge at the Maple Leaf plant increased after commissioning in September 1999, reaching near one-shift capacity by early 2000. Post-project water quality in the Assiniboine River was examined through intensive monitoring in September 1999 (during commissioning), November 1999 at the time of ice formation, and in February, May, and June 2000. Intensive monitoring originally scheduled for summer and fall 2000 was deferred due to high river discharge; however, monitoring at limited sites continued through September 2000. Low river discharge in spring and summer 2002 provided an opportunity to continue monitoring under low-flow conditions, in fulfillment of the program deferred in 2000 due to high flows. The last intensive water quality monitoring took place in June, July, and August/September 2002. Intensive monitoring data were supplemented by weekly or bi-weekly sampling at select sites in the open-water season.

Samples were collected from 14 sites located on the approximately 300 km reach of the Assiniboine River between Brandon and Portage la Prairie (Figure 1). The timing of sample collection was staggered to permit sampling of approximately the same parcel of river water as it moved downstream of Brandon; samples were collected from the left, right, and/or middle of the river channel facing upstream and immediately submitted to the laboratory for water quality analysis. Major tributaries and point source inputs of nutrients to the river were sampled during the monitoring periods at times that corresponded to river travel times. Tributaries and point sources sampled included effluent from the Brandon Municipal WWTF and the Maple Leaf IWWTF, the municipal drainage ditch that receives discharge from the Simplot Canada Ltd. fertilizer plant and the Manitoba Hydro ash lagoon, and the Souris River. Additional tributaries were sampled during the conduct of monitoring activities in June, July, and August/September 2002, where discharge exceeded 0.1 m^3/s, in response to information needs identified through earlier studies. These included Willow Creek, the Little Souris River, Five Mile Creek, Epinette Creek, and the Cypress River. Two drains, one located upstream of site 8 and the other located upstream of site 13, have also been observed to discharge to the Assiniboine River during some periods in the open-water season. All tributaries and drains were sampled when flow was significant (i.e., < 0.1 m^3/s).

Vertically integrated water samples were collected from each site for the analysis of ammonia, nitrate/nitrite, total and dissolved Kjeldahl nitrogen, orthophosphate, total and dissolved phosphorus, dissolved reactive silica, chlorophyll *a* (open-water season only), faecal coliform bacteria, and carbonaceous 5-day biochemical oxygen demand. Enumeration and identification of phytoplankton was also conducted at selected sites during the open-water season in order to provide information regarding algal biomass and species composition. Dissolved oxygen, pH, turbidity, conductivity, temperature, and total ammonia were measured *in situ*. In 2002, 24-hour monitoring of oxygen levels was conducted at selected sites to assess the magnitude of diurnal changes in oxygen levels.

Periphyton, or attached algae, were identified as a major component of the Assiniboine River flora early in the study. Data collected during intensive monitoring periods and results of modeling activities, indicated that periphyton may play an important role in nutrient dynamics in the effluent mixing zone. Monitoring of periphyton abundance (i.e., chlorophyll *a* and ash-free dry weight) was undertaken in the growing seasons of 2000 and 2002. Qualitative assessment of periphyton was also undertaken in 1999. A periphyton survey was also conducted in August 2002 at reaches of the Assiniboine River, downstream of the mixing zone that are not normally accessed during the monitoring study. Additional analyses conducted during the study include measurements of light (i.e., light extinction), nitrification, and sediment oxygen demand (SOD).

3.2.1 Model Development

Development of a water quality model for the Assiniboine River was undertaken using the Enhanced Stream Water Quality Model (QUAL2E) version 3.0, supported and distributed by the USEPA. QUAL2E (or earlier versions of the modeling program) has been extensively used for simulating water quality conditions in streams, for predictive purposes, and as a management tool. A number of North American and European stream systems have been modelled using QUAL2E (or earlier versions), including the Red River of the North in North Dakota (Wesolowski 1994, 1996).

The water quality models were configured according to a recently revised hydraulic model; previous models are reported by Earth Tech (Reid Crowther & Partners Ltd. 1999, Earth Tech Canada 2001). The hydraulic model was used to generate: (i) river travel times for each intensive monitoring period; (2) coefficients and constants required for internal calculation within QUAL2E; and, (3) derivation of incremental flows.

Major water quality parameters identified for evaluation via modeling included ammonia nitrogen, DO, nitrogen and phosphorus compounds, and algae (i.e., phytoplankton). Because QUAL2E models each of these constituents as a function of loads, dilutions, and biological processes, separate water quality models were produced for the open-water and ice-cover seasons. Note that QUAL2E does not incorporate a periphyton component and therefore, periphyton was not modeled.

Winter water quality sampling occurred in February 1999 and 2000; river discharge, weather, and effluent inputs at Brandon are described in detail in Schneider-Vieira et al. (1999) and Toews et al. (2000). A water quality model (using QUAL2E) for ammonia and dissolved oxygen in the ice-cover season was calibrated using monitoring data collected primarily in February 2000 (Cooley et al. 2001a). Using the calibrated model, predictive simulations for ammonia and dissolved oxygen were generated under a range of river discharges and background water quality conditions (Cooley et al. 2001a).

Data collected during the summers of 1999, 2000 and 2002 are reported in Toews and Schneider-Vieira (1999, 2000); Toews et al. (1999, 2001), and Toews (2002). Interpretation and modeling results are provided in Cooley et al. (2001b) and Cooley et al. (2003).

4.0 EXISTING ENVIRONMENT

4.1 MANITOBA CONSERVATION DATA

Selected water quality parameters, pertinent to this assessment, measured by Manitoba Conservation at the three sampling locations are provided in Tables 3 to 5. Detailed monthly summaries of water quality for the period of 1992-2002 are provided in Appendix 1. This information was used to identify background conditions for the assessment (Section 5). The following section is a brief summary of water quality recorded over this 10-year period in the Assiniboine River at Brandon.

4.1.1 Temperature, conductivity and pH

Median monthly water temperature in the Assiniboine River at Brandon ranged from 0.5 ^{o}C to 21.0 ^{o}C in the open-water season (April to November, 1991 - 2001). Water temperatures are greatest in June (median 19.0 ^{o}C), July (median 19.8 ^{o}C), and August (21.0 ^{o}C) and have been consistently 0 ^{o}C in the ice-cover season (December through March). The maximum temperature recorded at Brandon by MB Conservation was 24.0 ^{o}C in August. Water temperatures observed during the intensive monitoring period in July 2002 in the Assiniboine River ranged up to approximately 26 ^{o}C (Toews 2002).

Conductivity in the Assiniboine River at Brandon tends to be higher and more consistent in the winter months with monthly median values ranging from 1075 µS/cm to 1120 µS/cm (Appendix 1). There is typically a decrease in conductivity in spring (median of 760 µS/cm in April and 755 µS/cm in May), likely attributable to the spring freshet. Levels in summer are intermediate between spring and winter months. When all measurements for the monitoring station over the 10-year period are pooled, 43% of samples are found to have exceeded 1000 µS/cm. In terms of spatial variabilities, median conductivities for Brandon (977 µS/cm), Treesbank (975 µS/cm), and Portage la Prairie (939 µS/cm) were quite similar.

The pH (*in situ* measurements) range in the Assiniboine River at Brandon (7.70 to 8.80), Treesbank (7.70 to 9.55), and Portage la Prairie (7.65 to 8.80) indicates alkaline conditions (Tables 3-5).

4.1.2 Nitrogen

Median total nitrogen (TN) concentrations were similar at the three Assiniboine River monitoring stations: 1.16 mg/L at Brandon; 1.42 mg/L at Treesbank; and, 1.33 mg/L at Portage la Prairie[4]. The range of observed TN is also quite large for the Assiniboine River, ranging from 0.41 mg/L to 8.86 mg/L. Monthly variability in the median concentration observed at Brandon is not large, although the highest median (1.6 mg/L), mean (1.9 mg/L), and maximum concentration (4.4 mg/L) occurred in April.

Measured nitrite/nitrate concentrations at Brandon ranged from 0.005 to 1.5 mg/L, with a median concentration of 0.150 mg/L (Table 3). Slightly higher values were recorded at Treesbank and Portage la Prairie, with median concentrations of 0.320 mg/L (Table 4) and 0.210 mg/L (Table 5), respectively. Maximum observed concentrations were also higher at Treesbank (2.14 mg/L) and Portage la Prairie (3.20 mg/L) than observed at Brandon. On a monthly basis, concentrations tend to be higher in the Assiniboine River at Brandon in January through April (Appendix 1).

Ammonia concentrations in the Assiniboine River ranged from 0.003 to 0.310 mg/L (median = 0.040 mg/L) over the 10 year period evaluated in the Assiniboine River at Brandon (Table 3); For comparison median concentrations for this period were 0.062 mg/L at Treesbank, 0.050 mg/L at Portage. Monthly median concentrations were highest for the months of January, February, and April and the lowest monthly median concentrations occurred for the months of September through November (Appendix 1). Ammonia objectives (Williamson 2002) were calculated using both the median and maximum monthly temperature and pH data; objectives were met on all occasions for the period of consideration.

4.1.3 Phosphorus

Total phosphorus (TP) concentrations measured along the Assiniboine River exceeded the narrative guideline of 0.05 mg/l established in the MWQSOGs in the majority of samples.

Total phosphorus levels at Brandon ranged from 0.045 to 0.649 mg/L, with a median concentration of 0.126 mg/L. Median and maximum concentrations were higher at Treesbank (median = 0.163 mg/L, maximum 0.683 mg/L) and Portage la Prairie (median = 0.170 mg/L, maximum = 3.01 mg/L). As observed for total nitrogen, the highest mean (0.26 mg/L), median (0.23 mgL), and maximum (0.65 mg/L) concentrations at Brandon occurred in April.

4.1.4 Dissolved Oxygen

Oxygen concentrations in the Assiniboine River at Brandon are have ranged between 4.4 mg/L to 14.90 mg/L during the ten-year period of record 1992 - 2002 (Tables 3-5). Median DO concentrations at Treesbank were similar to Brandon, although the minimum observed DO

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[4] TN was estimated as the sum of total kjeldahl nitrogen and nitrate/nitrite nitrogen.

concentration was lower (2.3 mg/L). The median DO was higher for the Portage la Prairie monitoring site (9.20 mg/L). The MWQSOGs set several criteria for oxygen, depending on water temperature, fish species, and life stages present. Some measurements fell below acute and chronic water quality objectives for dissolved oxygen for the protection of aquatic life (see Section 2.2.1 for description of objectives).

4.1.5 Total Suspended Solids

The amount of suspended solids in the Assiniboine River was highly variable, ranging from 2 to 1100 mg/L (Tables 3-5). Monthly median concentrations were highest in May (58.0 mg/L) and July (148.5 mg/L), and August (70.5 mg/L) at Brandon. Lower levels were typically observed in the winter months (Appendix 1).

4.2 ASSINIBOINE RIVER STUDY

As discussed in Section 2, factors affecting the levels of ammonia, dissolved oxygen, and nutrients/algae are very different under ice cover and during the growing season. Therefore, these two periods are described separately below.

4.2.1 Ice-cover Season

During data collection in February 1999 and February 2000, discharge in the Assiniboine River was near median levels (i.e., median February discharge near Brandon is 13.9 m^3/s). However, discharge in the Souris River was above median levels in both years, and near four times the median value (i.e., 0.78 m^3/s) in February 1999 (i.e., 3.0 m^3/s).

Data collected in February 1999 and 2000 reflected considerably different conditions with respect to the quality of effluent entering the river. The Municipal WWTF underwent an hydraulic upgrade during the winter of 1998/1999 and, during this period, effluent was discharged directly from the lagoon into the river. Effluent quality was much poorer and more variable than under normal operating conditions and sampling did not coincide with the same parcel of water (i.e., river travel times were overestimated), therefore, these data were of limited use for calibration of the model. Effluent loads from the City of Brandon Municipal WWTF were substantially lower and more consistent in 2000, and were used for model calibration and predictive simulations.

4.2.1.1 Ammonia

The major sources of ammonia in the reach of the Assiniboine River between the City of Brandon and the Portage la Prairie Reservoir are the Municipal WWTF, the municipal drainage ditch that receives discharge from the Simplot Canada fertilizer plant and Manitoba Hydro's Brandon Thermal Generating Station ash lagoon, and the IWWTF. Ammonia concentrations within the IWWTF effluent for the period November 1999-March 2000 were generally low, with the exception of a short-term process interruption in November 1999.

During the February 2000 study, combined ammonia inputs at Brandon increased ammonia levels in the river, tripling background levels at the downstream end of the mixing zone (i.e., 0.35 mg/L at site 8 vs. 0.13 mg/L at site 1; Figure 2). The fully mixed ammonia concentration, however, was well below the chronic MWQSOGs (Williamson 2002). Ammonia concentrations then gradually declined, reaching levels approximately 1.6 times values measured upstream of Brandon by the lower end of the study reach (i.e. 0.22 mg/L at site 14). This decline appeared to be the result of dilution by groundwater, as well as breakdown of ammonia by nitrifying bacteria (nitrification).

Model simulations indicated that IWWTF effluent had a minimal effect on ammonia concentrations during the February 2000 study as simulated ammonia nitrogen concentrations at the Portage Reservoir with and without IWWTF effluent discharges were equal (0.23 mg/L at the Portage Reservoir; Figure 3, Cooley et al. 2001a).

4.2.1.2 Oxygen

Major sources of oxygen demand (i.e., CBOD and ammonia) entering the river during winter between the City of Brandon and the Portage Reservoir are the Municipal WWTF, the municipal drainage ditch that receives discharge from both the Simplot Canada fertilizer plant and Manitoba Hydro's Brandon Thermal Generating Station ash lagoon, and the IWWTF. Background CBOD loads in the Assiniboine River upstream of effluent inputs near Brandon may be large; for example, during the February 2000 study the CBOD load in the river was 10-20 times larger than the load in the effluents. Consistent with CBOD loading, background concentrations of oxygen in the Assiniboine River entering Brandon may be well below saturation and show evidence of considerable oxygen uptake upstream. For example, in February 2000, upstream DO levels were 7.5 mg/L or 53% saturation (Figure 4).

Effluents discharged from the IWWTF in February 2000 are estimated to have had a negligible effect on DO, as a result of the balance between increased DO (due to the DO load within the effluent and the ice-free area in the river created by the thermal effluent) and the consumption of DO as a result of the breakdown of ammonia and CBOD. Simulations of the QUAL2E model for February 2000 indicated that the final DO concentration at the Portage Reservoir would be 0.06 mg/L lower if IWWTF effluents were not released (Figure 5, Cooley et al. 2001a). Simulations conducted under various flow and background water quality conditions indicated that, under “worst case” conditions, oxygen levels in the Assiniboine River could decline to well below guideline levels; however, projections with and without the IWWTF effluents showed little change in the ultimate predicted DO levels under median and 7Q10 flows (Cooley et al. 2001a).

Factors identified as affecting DO in the Assiniboine River in winter are as follows:

- Open water and re-aeration play a critical role in determining the DO concentration and profile in the river. The extent of open water is expected to vary widely both between and within years, as it is closely related to air temperature, as well as hydraulics (i.e, water velocity, discharge, and depth). Open-water areas are also created due to discharge of thermal effluents and groundwater springs that discharge above the ice surface.

- Incoming groundwater entering below the ice surface may dilute DO in the Assiniboine River. The effect of this dilution would be greater under low river discharge, when groundwater comprises a greater fraction of overall river discharge.

- Rates of oxygen-consuming processes affect both the final absolute concentration of DO as well as the DO profile in the river (e.g., location of the DO sag, or minimum). Under low river discharge, SOD and other oxygen-consuming processes exert a greater effect on DO depletion than under ‘average’ flows. This is due to low river velocities (i.e., there is more time for rate-dependent processes to consume oxygen in a given distance), high sediment surface area to surface water volume ratios, and effluents comprising a greater relative fraction of river discharge (i.e., less dilution).

- The Souris River may supply DO to or dilute DO in the Assiniboine River. This occurrence, however, will depend upon water quality and discharge of the Souris River, as well as conditions in the Assiniboine River itself.

4.2.2 Open-water Season

Flows in the Assiniboine and Souris rivers were atypically high (i.e., well above median levels) during data collection in the spring and summer of 1999 (Cooley et al. 2001b). In contrast, discharge in May and June of 2000 was well below median levels. Flows during data collection in 2002 for June to early September were also less than median levels throughout the sampling period and approached 7Q10 flows in early spring (Toews 2002).

4.2.2.1 Ammonia

In general, the load of ammonia discharged from the IWWTF during monitoring (September and November 1999, May through September 2000, and June through August 2002) was low (less than 1 kg/day). For comparison, during sampling periods, the load of ammonia discharged from the Municipal WWTF ranged from 16 - 465 kg/day, and the ammonia load of the municipal drainage ditch that receives discharge from the Simplot Canada Ltd. fertilizer plant and the Manitoba Hydro ash lagoon ranged from 24 - 198 kg/day. Background ammonia loads within the Assiniboine River upstream of the effluent discharges, measured at Site 1, were approximately 5 - 20 kg/day. Some tributary streams and drains also contributed significant loads of ammonia at certain times in the open-water season 2002 (e.g., the Cypress River contributed 11.5 kg/day of ammonia in June 2002). These loads were often higher than those originating from the IWWTF.

Background ammonia concentrations measured at Sites 1 and 2 in the Assiniboine River were low during all monitoring periods (i.e., < 0.002 to 0.070 mg/L). Ammonia inputs at Brandon caused ammonia concentrations in the Assiniboine River to increase downstream of effluent outfalls (e.g., Figure 6); however, ammonia was reduced to near-background concentrations by the end of the mixing zone (Site 8, approximately 35 km downstream).

The large declines in ammonia concentrations within the mixing zone observed in the open-water season of 2002, and May and June 2000 may be due to biological activity (e.g., uptake by algae and plants, nitrification by bacteria). As the relative contributions of algae (i.e., phytoplankton and periphyton) and bacteria (i.e., nitrification) to the observed reduction in ammonia in the river were not determined, it is not known at this time the extent to which ammonia dynamics would be affected by conditions not favourable for algal growth (e.g., low light).

Ammonia objectives were calculated based on ambient pH and temperature for all sites and sampling dates and are presented for Site 8 (Treesbank) for reference (Table 6). The most restrictive objectives at Site 8 occurred with high pH and temperature in July and August 2002, when chronic (30-day) objectives were less than 0.4 mg/L. All ammonia concentrations measured in the Assiniboine River, including detailed measurements collected within the effluent plume, met the applicable acute and chronic MWQSOGs.

4.2.2.2 Oxygen

As in winter, BOD and ammonia in effluents discharged by the Municipal WWTF and the IWWTF contribute the overall oxygen demand in the river. However, during the summer months, indirect effects of effluent inputs on the growth of algae may have a greater relative effect on oxygen levels.

Dissolved oxygen concentrations measured during intensive monitoring periods (daytime sampling) in 1999, 2000, and 2002 were generally high and usually met the chronic MWQSOG (6.0 mg/L) at all sites between Brandon and Portage la Prairie (e.g., Figure 7). In June and July 2002, lower DO concentrations were observed in the mixing zone around sites 6 and 7, and concentrations in July were below the acute (and chronic) water quality objective (Figure 8). These low concentrations were believed to reflect high water temperatures, low upstream DO concentrations, and effects of effluents. DO concentrations were also below the chronic water quality objective at sites 1 and 2, upstream of the effluent outfalls in July 2002.

Continuous dissolved oxygen monitoring took place at several sites in 2002 to determine the spatial and temporal extent of diurnal oxygen fluctuations in the study area. Declines in DO were observed overnight at all sites examined, including sites 5, 6, 8, 9, 12, and 14. Wide diurnal fluctuations in DO were observed in the mixing zone (e.g., decline of approximately 8 mg/L overnight at site 6 in August) and these declines at times caused DO levels to drop below the acute MWQSOG (5.0 mg/L) (e.g., DO declined to below 5 mg/L for up to 8.5 hours at night in early July at a site near Treesbank).

High densities of periphyton may be associated with extreme fluctuations in oxygen concentrations, and the occurrence of critically low levels overnight, in the growing season. Sloughing and die-off of periphyton in fall would also contribute to oxygen depletion through decay. In addition, accumulation of organic matter arising from dead algae within the mixing zone would increase SOD and potentially affect oxygen levels during the winter. This latter effect would be limited by the occurrence of periodic high flows that would scour accumulated organic matter.

4.2.2.3 Nutrients and Algae

High river discharge in 1999 resulted in large background concentrations and loads of both nitrogen and phosphorus in the Assiniboine River relative to historically observed concentrations and effluent loads (Toews et al. 1999). As such, Municipal WWTF nutrient loads were greatly exceeded by background nutrient loads throughout 1999. The IWWTF began discharging to the Assiniboine River in September 1999, and also contributed an insignificant nutrient load relative to background conditions at this time.

Brandon-area effluent discharges contributed large nutrient loads to the Assiniboine River during intensive monitoring in 2000 and 2002, resulting in increased nitrogen and phosphorus (total and dissolved forms) within the mixing zone (Figures 9 and 22). In May and June 2000, the Municipal WWTF and the IWWTF contributed between 9% and 17%, respectively, of background loads of total nitrogen in the river (i.e., expressed as a percentage of the load measured upstream at site2) and approximately 23% to 85%, respectively, of the background total phosphorus load in the river (Cooley et al. 2001b). During intensive monitoring in June, July, and August/September 2002, the relative contribution of total phosphorus from the Municipal WWTF and IWWTF was greater, ranging from approximately 36% to 84% of background loads in the river (Cooley et al. 2003). At these same times, contributions of total nitrogen from these sources ranged from 35% to 55% of background loads in the river. At times, the municipal drainage ditch receiving discharge from the Simplot Canada fertilizer plant and the Manitoba Hydro ash lagoon also contributed a significant nitrogen load. In 2002, tributary streams, most notably the Cypress and Souris rivers, were also major sources of total nitrogen and phosphorus to the Assiniboine River, with the relative contributions varying somewhat over the sampling periods.

In both 2000 and 20002, nitrogen and phosphorus declined markedly in the mixing zone (Figures 9 and 10). Comparisons between mass-balance model simulations and observed loads of nitrogen and phosphorus indicated a substantive loss of nutrients was occurring in the study area, notably in the mixing zone (Cooley et al. 2001b, 2003). Possible sinks for nutrients include accumulation by phytoplankton, periphyton, and macrophytes, settling, denitrification, and accumulation in higher trophic levels. Because periphyton are abundant in the mixing zone, they may play a significant role in the removal (i.e., reduction) of nutrients from the water column.

Data and modelling exercises indicate that there may be an unidentified source of nutrients, algae, and TSS beyond site 9 or 10. Loads of these substances notably increased at sites 11, 12, and 13 in June and August 2002 in the river (TSS also increased at these sites in July), although modelling predictions indicated that in-stream loads/concentrations should have remained quite consistent.

Figures 17-22 indicate the estimated loads of total and dissolved nitrogen and phosphorus in the study area for June, July and August 2002, respectively. These figures provide an estimate of the relative changes and inputs/losses of nutrients occurring in the study area. Since loads are calculated as the product of discharge and concentration, errors in the discharge estimates will result in inaccurate load estimates. As discussed in Cooley et al. (2003), sampling at times was conducted under changing flow conditions (e.g., July 2002), making accurate estimation of discharge difficult. In addition, comparison of relative loads at various sites to indicate input/uptake is contingent on accurate travel time estimates, as these were used to determine the time of sample collection.

In most instances, effluent inputs at Brandon caused a large increase in the load of dissolved inorganic nitrogen (the form of nitrogen directly used by algae and bacteria), which was rapidly removed from the water column (usually by Treesbank). Dissolved phosphorus (primarily orthophosphate) was likewise removed, but generally at a lower rate and not as completely as inorganic nitrogen. Levels of organic nitrogen generally remained constant, while inputs of organic phosphorus appeared to occur at sites 11, 12 and 13.

4.2.2.4 Phytoplankton

Chlorophyll a

Phytoplankton chlorophyll *a* measured in the Assiniboine River Monitoring Study was generally low at all sites throughout 1999, 2000, and 2002 (<15 µg/L). There was no evidence that phytoplankton abundance notably or consistently increased in the parcel of water as it moved downstream from Brandon to Portage la Prairie; this was attributed to limiting light conditions and rapid river travel times in 1999 (Cooley et al. 2001b). Low flows and improved light conditions (i.e., lower light extinction coefficients) in the river in 2000 and 2002 suggested the potential for phytoplankton to increase as the parcel of water traveled downstream; however, as in 1999, phytoplankton chlorophyll *a* did not increase markedly within the study reach during most monitoring periods, with the exception of June 2002 (Cooley et al. 2001b, 2003).

Chlorophyll concentrations in June 2002 were greater than observed in previous years and throughout the remainder of 2002, ranging from 11 µg/L to over 46 µg/L (Figure 23). Chlorophyll concentrations immediately downstream of wastewater inputs, at sites 4 and 5 (28 to 40 µg/L), were higher than upstream values (i.e., 15 - 20 µg/L at sites 1, 2, and 3). This increase in chlorophyll likely did not originate entirely within the river current, as river travel time between sites 3 and 5 was less than 24 hours. Algal growth rates are variable depending on species and/or environmental conditions, ranging from several hours to several days (Reynolds 1984); however, doubling times are thought to average out at approximately one day. It is more likely that the increased chlorophyll *a* concentration at sites 4 and 5 was due to sloughed-off periphyton that had accrued in the upstream reach of the study area and inputs from the Brandon Municipal WWTF and the Maple Leaf IWWTF. Chlorophyll *a* concentrations in the Brandon Municipal WWTF effluent ranged from 120 to 270 µg/L from June 03 to 06, equivalent to an average load of 2.6 kg/day, or approximately 17% of background chlorophyll loading. Due to differences in environmental tolerances, algal cells originating in the treatment lagoon were not likely reproducing phytoplankton populations, resulting in high mortality rates as they moved downstream of site 5. Beyond the mixing zone, phytoplankton chlorophyll *a* increased as the parcel of water moved downstream, from approximately 10 µg/L at site 9 to 40 µg/L at site 13; however, this may be an artefact of rainfall at the latter end of the June monitoring period (i.e., washout of existing phytoplankton from ponds, lagoons and tributaries along the downstream end of the study reach).

Chlorophyll *a* concentrations in the Assiniboine River were similar to those reported for turbid rivers in Alberta (e.g., South Saskatchewan River, Carr and Chambers 1998). In comparison, historical annual mean concentrations recorded for the Elbow River, Alberta, a system with low turbidity (mean turbidity of 4.2 NTU), ranged from 100 to 200 µg/L (Carr and Chambers 1998). Concentrations of chlorophyll *a* in excess of 15 µg/L have been deemed the ‘nuisance phytoplankton growth goal’ by some jurisdictions (e.g., State of Oregon, Rounds and Wood 2001). Other studies have demonstrated seasonal shifts in phytoplankton abundance, with a spring phytoplankton peak followed by summer minima (e.g., the River Nene, England exhibits spring peaks of >100 µg/L and summer concentrations of 1 – 15 µg/L; Balbi 2000).

Species composition

Phytoplankton communities typically change over the growing season, as a result of changing dominance among major groups. Phytoplankton biomass and relative species composition were measured at select sites in 1999, 2000, and 2002. Raw data have been presented previously and interpreted in Cooley et al. (2003, 2001b).

The seasonal succession of dominant algal groups followed patterns observed in many north temperate aquatic systems (Wetzel 1983). The algal community in early summer consisted of diatoms and green algae (chlorophytes) with variable amounts of other groups. The relative abundance of bluegreen algae tended to increase in late August and September, including some groups capable of fixing nitrogen. Diatoms in the phytoplankton consisted of both planktonic species and forms generally associated with a substratum, indicating that periphyton were becoming detached and entering river currents. In general, the diatom community within the mixing zone contained attached taxa, while planktonic forms were predominant at site 13 (the upstream end of the Portage reservoir). Heterocysts of the nitrogen-fixing blue-green algal species were observed in large numbers in late summer, suggesting that available N:P ratios had shifted in favour of nitrogen fixers.

4.2.2.5 Periphyton and Aquatic Macrophytes

High densities of periphyton were measured at several sites in the Assiniboine River in 2000 and 2002. In addition, the macrophyte *Potamogeton pectinatus* grew prolifically in the riffle areas within the mixing zone downstream of Brandon in September 2000 and summer 2002.

Periphyton densities measured upstream and downstream of Brandon in 2000 and 2002 were consistent with productive, nutrient-rich waters, ranging from approximately 400 to 1500 mg/m^2. These levels were consistently and notably above numeric criteria (50 mg/m^2 or 100 mg/m^2) proposed by other jurisdictions for the protection of aquatic life (Carr and Chambers 1998).

Observed chlorophyll *a* concentrations (a measure of phytoplankton) and nutrient concentrations in conjunction with model simulations indicate that the observed decline in nutrients in the mixing zone was not solely due to phytoplankton growth (Cooley et al. 2003). Removal of nutrients by periphyton likely plays a role in this decline. Periphyton may be very significant in reducing nutrients in small streams, partly due to its fixed position, which facilitates effective removal of dissolved nutrients that continually flow by (Thomann and Mueller 1987). Mesocosm studies have reported that removal of nutrients by periphyton can result in measurable declines in the concentrations of dissolved inorganic nitrogen (DIN) and soluble reactive phosphorus in water (Perrin and Richardson 1997).

The proportion of the biomass of periphyton in the mixing zone which can be attributed to nutrient input from the Maple Leaf IWWTF and the Municipal WWTF has not been determined. The flux of nutrients from the water column indicates that these substances may be taken up by the attached algae in this area.

4.2.2.6 Factors affecting algal growth

Discharge and its related physical variables (velocity, time of travel, turbidity) have an overriding impact on riverine phytoplankton. High and low discharges can inhibit phytoplankton through reduced light and insufficient turbulence to maintain cells in suspension, respectively (Balbi 2000); in addition, the extent and timing of phytoplankton growth is influenced by hydrology (Marker and Collett 1997). In general, turbid river systems are considered to exhibit some degree of light limitation, depending upon water depth. As the Assiniboine River is characterized as a turbid system, it was expected that phytoplankton and periphyton growth would be limited to some degree by light. Although poor underwater light penetration and rapid river travel times were thought to limit phytoplankton growth in 1999, a reversal of these conditions in 2002 did not result in increased phytoplankton abundance for most sampling times.

Examination of nutrient concentrations and ratios indicated that, in instances where other factors do not limit growth, nitrogen was the nutrient which would limit algal production in much of the Assiniboine River under low flow conditions. It should be noted that a few species of bluegreen algae are able to fix atmospheric nitrogen; these groups may become relatively more abundant and form large blooms in nitrogen-limited water if other factors (e.g., temperature) are favourable. Weekly monitoring in 2002 indicated that blooms of cyanophytes had developed on September 11, 2002 at the end of the mixing zone (site 8) and the sampling location situated upstream of the Portage Reservoir (site 13).

Typically, nitrogen limitation typically occurs at sites 1 and 2, upstream of effluent sources, and downstream of the mixing zone. In July 2002, upstream concentrations were high and nitrogen limitation did not occur in this area. During May and June 2000, and June, July, and August 2002, effluent inputs at Brandon resulted in the suppression of nitrogen-limitation (i.e., neither nitrogen nor phosphorus limiting) until approximately Treesbank/Stockton, after which levels of dissolved inorganic nitrogen were such that growth could again be nitrogen-limited.

5.0 IMPACT ASSESSMENT

The following section assesses the effect of effluent from the expansion of the IWWTF on water quality in the Assiniboine River, focusing on ammonia, dissolved oxygen and nutrients (nitrogen and phosphorus) in terms of their effects on the growth of attached and planktonic algae. As prescribed in the “Advice Document for the Preparation of an Environment Act Proposal and Environmental Assessment for an Alteration to the City of Brandon’s Industrial Wastewater Treatment Facility”, the assessment considered both the incremental effect of the expansion to the IWWTF, as well as the total cumulative effect of operation of the IWWTF.

Fecal coliform bacteria and protozoan parasites were addressed in the document “Manitoba Environment Act Proposal Form and Supporting Documentation for the Operating Licence for the City of Brandon’s Expanded Industrial Wastewater Treatment Facility for Maple Leaf Pork’s Second Shift Brandon, Manitoba”. Fecal coliform loading from the IWWTF is not expected to exceed the limit of 200 FCU/100 mL (MWQSOG for recreation) due to the continued use of a UV disinfection system. Measured inputs of protozoan parasites in the effluent from the existing IWWTF have been generally low, and it is not expected that this would increase substantially following expansion of the Maple Leaf pork processing facility.

The assessment incorporates the cumulative effect of planned future inputs at Brandon, i.e., the projected effluent quality for the City of Brandon’s municipal WWTF and the licenced discharge limits for the Simplot Canada fertilizer facility. Nutrient loading within the watershed may in the future be affected by initiatives arising from the Province of Manitoba’s *Nutrient Management Strategy*; at a minimum it was expected that loading would not increase. The Province is also developing minimum in-stream flow criteria for the Assiniboine River. This work is currently underway and, at a minimum, it is assumed that future low flow conditions (e.g., due to water withdrawals and diversions) will not be more extreme than observed at present.

5.1 EFFLUENT QUALITY

The predicted loading of key parameters related to effluent discharged from the expanded (second shift) IWWTF is provided in Table 7. Several projections are provided: the expected or “typical” effluent, as well as maximum or “extreme” projections reflecting poorer effluent quality that normally would be quite sporadic. The maximum projections are provided in terms of daily estimates but, as indicated in Table 7, apply to daily, weekly or monthly periods. Table 7 also provides the effluent loading that occurred for the period December 2002 to February 2003 when the Maple Leaf processing facility was operating at 1-shift capacity. Water quality sampling for the Assiniboine River Monitoring Study has occurred periodically at all effluent outfalls since the commissioning of the IWWTF; loading from the IWWTF during these periods (February, May, and June 2000, and June to August 2002) is also provided in Table 7 for context. Effluent quality measured during monitoring periods was consistent with that provided by the City of Brandon (Table 8).

The typical effluent quality projected for the expanded IWWTF represents a substantial decrease in nitrogen loading vs. that recorded in late 2002 / early 2003 (i.e., 160 *vs.* > 390 kg/day). The projected total nitrogen load is also approximately 54 to 60% lower than observed during the intensive monitoring periods in summer of 2002, but approximately three times higher than observed during monitoring in February 2000. Most of the nitrogen has been in the form of nitrate during all monitoring periods and will continue to be for projected effluent loading scenarios. The projected nitrogen loading (160 kg/day) would represent approximately 18 – 44% percent of the total combined loading of all discharges in Brandon, based on loads observed from the Brandon Municipal WWTF and the municipal drainage ditch during intensive monitoring periods in summer 2002 (Tables 9 - 11). Projected typical ammonia loads are very low (<2.5 kg/day), although somewhat higher than loads observed to date from the IWWTF and comprise approximately 0.5 to 2.5 percent of the total ammonia loading observed during the summer of 2002, when the combined ammonia inputs from the municipal WWTF, IWWTF, and the municipal drainage ditch ranged from 99 to 462 kg/day (Tables 9 - 11). Projected “typical” phosphorus loading (44.2 kg/day) ranges from approximately 12% to 27% less than loads discharged from the IWWTF during monitoring in summer 2002 and May 2000 but is approximately twice as high as observed during monitoring in June 2000 (25.4 kg/day) and February 2000 (20.8 kg/day). Relative to other sources in the Brandon area, the projected typical TP load for the expanded IWWTF would constitute approximately 25% to 57% of total combined loading from all sources in Brandon, based on loading discharged by the municipal drainage ditch and the Municipal WWTF during the intensive monitoring in the summer 2002 (Tables 9 - 11). Projected typical BOD loading (35 kg/day) is also greater than that recorded to date (e.g., loads ranged from 1.88 to 7.47 kg/day during the 2002 monitoring periods), but is still generally low compared to loadings from other sources (e.g, loads ranged from 36.24 to 371.03 kg/day from the Municipal WWTF during intensive monitoring in 2002).

For the purposes of this assessment, future effluent quality from the City of Brandon's municipal WWTF was based on projections provided by Mr. I. Christiansen[5] (City of Brandon) (Table 12) and projected loading from the municipal drainage ditch were based on licence limits for the Simplot Canada facility (Table 2). Based on these future projections, the typical effluent from

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[5] It should be noted that the location of the outfall for the Municipal WWTF may be moved in the future; the assessment of effects of existing and projected future IWWTF effluent quality on the receiving environment (including model simulations) was based on the existing location of the outfall.

the IWWTF would account for approximately 10 to 25 percent of the combined nitrogen loading (predictions vary with time period under consideration) and 13 – 21 percent of the phosphorus loading. Extreme IWWTF effluent quality is projected to account for 17 – 27 percent of combined nitrogen loading and 18 – 22 percent of combined phosphorus loading (Table 13).

5.2 ICE-COVER SEASON

5.2.1 Ammonia

As discussed in Section 5.1, ammonia levels in effluent from expansion of the IWWTF generally comprise only a small fraction of the total ammonia inputs at Brandon. During winter, when rates of ammonia uptake through biological processes proceed at low rates due to low temperature and light, ammonia levels can be approximated by a mass balance. The assimilative capacity of the river for ammonia has been defined as the amount of ammonia required to raise concentrations in the river to levels corresponding to site-specific ammonia objectives, assuming median concentrations of background ammonia, and median levels of pH and temperature for a given month. The assimilative capacity was calculated for three different flows: 1Q10 (the lowest 1 day flow expected within a 10 year period); 7Q10 (the lowest 7 day flow within a 10 year period); and 30Q10 (the lowest 30 day flow within a 10 year period). Each of these flows is associated with a different MWQSOG (Williamson 2002).

Table 14 presents the assimilative capacity of the river upstream of any inputs at Brandon. After incorporation of projected effluent quality for the Municipal WWTF and licence limits for the Simplot Canada fertilizer plant, it is apparent that projected ammonia loads from the IWWTF will fall well within 75% of the assimilative capacity of the river.

Results of model simulations suggest that ammonia levels during winter would actually be slightly less than calculated in Table 14, due to gradual dilution by groundwater and surface water inputs, and gradual breakdown by nitrification (Appendix 2).

5.2.2 Dissolved Oxygen

Dissolved oxygen was simulated under ice-cover, based on the three river discharge scenarios (1Q10, 7Q10, and, 30Q10) for the month of March, which is the winter month with the lowest flow (i.e., lowest Q10 flows). For each flow, a model simulation was run for the following effluent discharge scenarios: (1) existing Simplot Licence Limits, proposed future effluent quality for the Brandon Municipal WWTF, and the 'typical' effluent quality for the expansion of the IWWTF (i.e., scenario termed 'typical 2-shift'); (2) the same as (1), except the 'extreme' effluent quality for the expansion of the IWWTF was used (i.e., scenario termed 'extreme 2-shift'); and, (3) only Simplot and Municipal WWTF discharges were included (i.e., no IWWTF effluent).

Model settings were consistent with those used for predictive model simulations reported in Cooley et al. (2001a) and incorporated only minimal amounts of open-water in the study area (within the effluent plumes) and median historical concentrations of water quality parameters for the upstream conditions.

As illustrated in Figure 24 and Appendix 2, the expansion of the IWWTF effluent has a minimal effect on dissolved oxygen. Model simulations indicate that oxygen levels may decline to extremely low levels under low flow conditions; however, as discussed in Cooley et al. (2001a), this "worst case" scenario arises in large part due to the absence of open water downstream of ice-free areas created by thermal effluent plumes. The frequency with which the entire river is covered by ice during the winter months is not known – for most of the sampling periods, open water was observed at least in fast-flowing areas and where groundwater springs enter above the ice surface.

It should be noted that, in addition to the direct effect of effluent quality (i.e., BOD) on oxygen consumption, operation of the IWWTF over the longer term may affect SOD in the mixing zone due to the settling of BOD from the effluent, as well as the accumulation of dead organic matter as a result of plant and algal growth. The latter effect is related to nutrient inputs from the IWWTF stimulating the growth of plants and algae, and is considered in the following section.

5.3 OPEN-WATER SEASON

5.3.1 Ammonia

As for the winter, projected ammonia loadings from the expansion of the IWWTF will stay well within the assimilative capacity when the projected future effluent quality of the municipal WWTF and licence limits for the Simplot facility are considered (Table 14). Given that upgrades to the Municipal WWTF are planned to occur over a 20-year period, effluent quality from the Municipal WWTF may be more similar to current conditions than planned future conditions during the initial operation of the expanded IWWTF. However, as ammonia inputs from the IWWTF comprise only a small fraction of the total ammonia loading to the river during the open-water season, and as field observations indicated that ammonia levels rapidly decreased in the water column (Section 4.2.2.1), ammonia inputs from the IWWTF are not expected to have an adverse effect on water quality.

5.3.2 Dissolved Oxygen

During the open-water season, effluent discharged from the IWWTF would affect DO levels both directly, through the input of BOD, and indirectly, through effects to the stimulation of algal growth. As discussed in Section 5.1, the loading of BOD is expected to increase; however the projected load is small compared with other inputs at Brandon and of itself is not expected to have a significant adverse effect on DO levels.

Effluent from the IWWTF would also affect DO levels indirectly through the stimulation of algal growth. These effects are discussed below.

5.3.3 Nutrients and Algae

In general, the Assiniboine River can be characterized as a nutrient-rich environment, with concentrations of nutrients, growths of periphyton, and diurnal fluctuations in oxygen levels typical of eutrophic rivers.

As discussed in Section 4.2.2.3, during high flow conditions (e.g., open-water season 1999), high background concentrations and loads of nitrogen and phosphorus generally mask the effects of nutrient inputs at Brandon. In addition, growth of algae under high flow conditions is limited by factors such as turbidity. The following discussion, therefore, is limited to the relationship between nutrient enrichment and algal growth under lower flow conditions.

Under low flow conditions in May and June of 2000, and June to August 2002, effluent inputs at Brandon resulted in a substantial increase in levels of orthophosphate and inorganic nitrogen (in particular nitrate) within the mixing zone. The concentration of these substances, in particular dissolved inorganic nitrogen, then declined, in the case of dissolved inorganic nitrogen reaching levels comparable to background conditions just downstream of the mixing zone (between site 8 and 9). The total load of nitrogen and phosphorus was also increased by the effluent inputs and, based on both nutrient ratios and absolute concentrations of inorganic nutrients, the river was generally altered from a condition of nitrogen limitation, to a lack of nutrient limitation for approximately 50 to 80 kilometres (to site 8 at Treesbank or site 9 at Stockton) (Cooley et al 2001a, 2003a). After this point, the decline in the level of dissolved inorganic nitrogen resulted in the re-establishment of nitrogen limitation.

Effluent inputs at Brandon appeared to increase the concentration of phytoplankton (as indicated by chlorophyll *a*) within the mixing zone, as well as attached algae within the same area. However, phytoplankton peaks in the mixing zone (just downstream of the effluent outfalls) were thought to be partially comprised of non-reproducing phytoplankton discharged from the sewage lagoon and benthic algae that had become detached from substrates. The extent to which periphyton growth is directly attributable to nutrient inputs at Brandon is difficult to determine. The large nutrient flux suggests uptake by the periphyton is occurring, however, a survey in early August 2002 under extremely low flow conditions found periphyton growing abundantly throughout the river, even well downstream of the mixing zone at Brandon (Cooley et al. 2003). It should be noted that growing conditions during the August 2002 survey were atypical due to extremely low flows and had been preceded by a period of extremely high background nutrient concentrations (i.e., July 2002) when nitrogen may not have been limiting in the river.

The abundant growth of algae within the mixing zone also appeared to result in considerable diurnal fluctuations in DO, which under certain conditions resulted in overnight declines to below the MWQSOGs.

In general, it can be expected that a reduction in the input of a key limiting nutrient at Brandon (i.e., dissolved inorganic nitrogen) would tend to reduce the spatial extent and/or density of the area affected by heavy periphyton growth within the mixing zone. This in turn would tend to reduce adverse effects associated with excessive algal growth, such as the spatial extent of the area affected by major overnight declines in oxygen levels.

Although effects in the mixing zone can be attributed to nutrient inputs at Brandon, it is difficult to determine the relative effect further downstream, due to the complex interaction of nutrient losses (e.g., due to settling, uptake by periphyton), inputs of additional nutrients from non-point sources, and nutrient spiraling (i.e., accumulation of nutrients in algae and subsequent decay of the algae transported downstream). As illustrated on Figures 11-22, nutrient loads are highly dynamic and substantial inputs occur downstream of Brandon under certain conditions.

To assist in evaluating the potential magnitude of effects related to the input of nutrients from the IWWTF, simulations were conducted using a water quality model developed based on data collected during June 2002 (Cooley et al 2003). A water quality model for the open-water season could not be fully calibrated for all sampling periods, apparently due in part to a sink for nutrients (in particular dissolved phosphorus and dissolved inorganic nitrogen) within the mixing zone (Cooley et al 2003). Although other factors may also have contributed to the difficulty in calibrating the model (Cooley et al 2003), it appears that the abundant growth of periphyton within the mixing zone may be acting as a sink for these nutrients during the growing season and, as the current version of QUAL2E does not support a periphyton component, a fully calibrated model cannot be developed. However, the model was able to reasonably approximate nutrient loads and chlorophyll *a* concentrations in the water column in June 2002 (exceptions at certain sites could be attributed to external sources of nutrients not measured in the sampling program). Therefore, this model was used to conduct an analysis of the relative potential effect of the projected IWWTF effluents on levels of chlorophyll *a* and N and P in the river. It should be noted that this model was only fully appropriate for one set of conditions and has not been verified with other data collected in 2002. These projections assume background conditions and loadings from the Municipal WWTF and other sources as observed in June 2002.

The projected effluent from the expansion of the IWWTF is predicted to produce peak P levels similar to those observed in June 2002, and levels would decline through the study area. At the lower end of the study area, the net incremental increase in TP caused by the IWWTF is 0.02 mg/L, as a mass balance (i.e, 0.11 mg/L with the June 2002 IWWTF effluent and the projected typical 2-shift IWWTF vs. 0.09 mg/L without the IWWTF) (Figure 25). Inclusion of phytoplankton and settling of organic phosphorus in model simulations reduces this difference to 0.01 mg/L by the end of the study area (i.e., 0.09 mg/L with the June 2002 IWWTF effluent and the projected typical 2-shift IWWTF vs. 0.08 mg/L without the IWWTF) (Figure 26); the difference is due to settling of organic phosphorus and decay of phytoplankton.

The expansion of the IWWTF is predicted to result in a substantial decline in N concentrations compared to conditions observed in June 2002. Mass balance model simulations predicted peak total nitrogen concentrations as: (1) 1.27 for typical 2-shift IWWTF effluent; (2) 1.50 mg/L for the June 2002 IWWTF effluent (i.e., approximate 1-shift); and, (3) 1.09 mg/L in the absence of IWWTF discharge (Figure 27). By the end of the study area, these differences between effluent discharge scenarios become smaller; by site 14, predicted total nitrogen concentrations are: (1) 0.82 mg/L for the expanded IWWTF; (2) 0.92 mg/L under the June 2002 IWWTF loads; and, (3) 0.75 mg/L in the absence of IWWTF effluent. Model simulations that incorporate phytoplankton and nutrient processes (i.e., settling) reduce the differences in predicted total nitrogen concentrations between these three scenarios, most notably by the end of the study area (Figure 28). By site 14, predicted TN concentrations are: (1) 0.75 mg/L for typical 2-shift IWWTF effluent; (2) 0.79 mg/L for June 2002 IWWTF loads; and, (3) 0.69 mg/L with no discharge from the IWWTF. Overall, model simulations indicate a substantive decline in total nitrogen concentrations would be achieved by the end of the study area under the proposed expansion, relative to conditions that occurred in June 2002.

Model simulations indicated that the higher nutrient concentrations observed in June 2002 relative to the projected effluent quality for the IWWTF expansion had no effect on predicted chlorophyll *a* levels within the mixing zone (Figure 29). However, model simulations predict that chlorophyll *a* would be approximately 5 µg/L lower by the end of the study area under effluent discharged by the 2-shift IWWTF, relative to effects of loads observed in June 2002 (which approximate 1-shift effluent). Relative to predictions under an absence of discharge from the IWWTF, chlorophyll *a* is predicted to be approximately 4 µg/L and 8 µg/L higher under the projected 2-shift IWWTF and effluent discharged in June 2002 from the IWWTF, respectively.

Based on these results, it appears that the expansion of the IWWTF will reduce the amount of chlorophyll *a* that could occur in the lower part of the study area relative to current one-shift operation.

6.0 RESIDUAL EFFECTS AND SUMMARY

6.1 ICE-COVER CONDITIONS

Predicted effects of effluent from the expansion of the IWWTF on oxygen and ammonia concentrations during the winter months are expected to be negligible to small, even under low flow conditions. This assessment applies to both the incremental effect of the expansion of the IWWTF as well as the total cumulative effect of effluent from the IWWTF.

As indicated in the preceding section, there may be a long term negative effect to oxygen levels if effluent inputs result in an increase in the SOD within the mixing zone or downstream; however, the extent to which long term accumulation of organic matter will occur is highly uncertain given that this area is often subject to high velocity flows, in particular during the spring freshet. Therefore, any such effect would be considered reversible.

6.2 OPEN-WATER CONDITIONS

As for the winter months, effects of effluents from the expansion of the IWWTF on ammonia concentrations during the open-water season are expected to be negligible.

During the open-water season, inputs of N and P from the IWWTF are expected to contribute to the growth of both phytoplankton and periphyton, and potentially exacerbate overnight declines in DO related to algal growth. The net effect of the expansion of the IWWTF will be a decrease in N and P loading, compared to both the one-shift production levels observed in late 2002/early 2003 and the loading that occurred during the low flow conditions of the summer of 2002. However, the net effect of effluents from the IWWTF will remain negative. The magnitude of the impact will vary from low to moderate, depending on conditions in the river. The duration will be long term (i.e,. as long as effluents are discharged to the river) but would be considered reversible with respect to conditions in the river. Impacts occur during the growing season and would be greater during lower flow (i.e, median and below) conditions. Most effects are confined to within or immediately downstream of the mixing zone (ie., to approximately Treesbank) but some small effects may extend to the Portage Reservoir.

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TABLES AND FIGURES

Table 1. Water quality objectives (cool water aquatic life) for total ammonia under 10-year median pH and water temperature for the Assiniboine River at Brandon's 18th St. Bridge. Water quality objectives calculated from formulae provided in Williamson (2002). Equations 1-3 apply to water temperatures < 5 °C or when early life stages are absent; equations 4-6 apply to water temperatures ≥ 5 °C or when early life stages are present. Allowable exceedence frequency of occurrence for all objectives is not more than once each 3 years, on average.

				Water quality objectives for total ammonia (mg/L)		
Month	pH	Temp (^{o}C)	Applicable Equations	Chronic: 30 days averaging duration (Equations 1,4)	Chronic: 4 days averaging duration (Equations 2,5)	Acute: 1 hour averaging duration (Equations 3,6)
January	8.0	0.0	4-6	3.95	9.88	8.41
February	7.93	0.0	1-3	2.70	6.76	9.67
			4-6	4.39	10.98	9.67
March	7.93	0.0	1-3	2.70	6.76	9.67
			4-6	4.39	10.98	9.67
April	8.00	0.5	1-3	2.43	6.08	8.41
			4-6	3.95	9.88	8.41
May	8.20	10.8	1-3	1.79	4.48	5.73
June	8.30	19.0	1-3	1.14	2.85	4.72
July	8.25	19.8	1-3	1.18	2.95	5.20
August	8.30	21.0	1-3	1.00	2.51	4.72
September	8.45	17.8	1-3	0.96	2.40	3.53
October	8.45	10.0	1-3	1.19	2.96	3.53
November	8.40	2.3	4-6	2.09	5.24	3.88
December	8.15	0.0	4-6	3.15	7.88	6.31

Table 2. Simplot Canada Ltd. licence limits for ammonia, total nitrogen, total phosphorus.

Month [1]	Loads		
	Ammonia kg/day	Total Nitrogen kg/day	Total Phosphorus kg/day
January	120	204	20
February	120	204	20
March	120	204	20
April	90	204	20
May	80	204	20
September	38	204	20
October	40	204	20
November	50	204	20
December	130	204	20

[1] The Licence stipulates discharge occurs from September 15 to May 15.

Table 3. Summary statistics for major water quality parameters measured in the Assiniboine River at the Brandon 18th Street Bridge from January 1992 to July 2002. Data provided by Manitoba Conservation (MB Conservation 2002).

	Units	Mean	Median	n	SE	Minimum	Maximum
Temperature	°C	8.6	7.3	112	0.8	0.0	24.0
pH (lab)		8.22	8.26	130	0.02	7.76	8.71
pH (*in situ*)		8.20	8.20	85	0.03	7.70	8.80
Dissolved oxygen	mg/L	8.64	8.35	128	0.18	4.40	14.90
BOD	mg/L	2	2	43	0	1	9
Fecal coliforms	CFU/100 mL	20	5	124	4	5	240
Chlorophyll *a*[1]	mg/L	7	4	43	1	1	27
Nitrogen Measurements							
Ammonia [2]	mg/L	0.050	0.040	130	0.004	0.003	0.310
Nitrate/Nitrite[3]	mg/L	0.196	0.150	130	0.020	0.005	1.500
Total Kjeldhal nitrogen	mg/L	1.0	1.0	130	0.1	0.1	6.3
Total nitrogen [4]	mg/L	1.238	1.155	130	0.058	0.420	6.570
Dissolved inorganic nitrogen [5]	mg/L	0.246	0.201	130	0.023	0.010	1.810
Organic nitrogen[6]	mg/L	0.991	0.937	130	0.048	0.066	6.080
Phosphorus Measurements							
Total phosphorus	mg/L	0.155	0.126	130	0.007	0.045	0.649
Particulate phosphorus	mg/L	0.065	0.048	130	0.005	0.001	0.421
Dissolved phosphorus[7]	mg/L	0.091	0.078	130	0.004	0.019	0.393
Total organic carbon	mg/L	11	11	130	0	3	20
Total suspended solids	mg/L	52	29	130	5	2	340
Turbidity	NTU	32	19	130	3	3	190
True color	TCU	22	20	130	1	3	100
Total alkalinity	mg/L CaCO$_3$	258	267	130	4	128	376
Conductivity	µS/cm	969	977	130	16	403	1430

[1] Data only available for 1999 – 2002.

[2] Reported as soluble, dissolved, or total forms. Statistics based on all forms.

[3] Reported as soluble or dissolved. Statistics based on both forms.

[4] Estimated as sum of Kjeldahl nitrogen and nitrate/nitrite.

[5] Estimated as the sum of ammonia and nitrate/nitrite.

[6] Estimated as the difference between TKN and ammonia.

[7] Reported as orthophosphorus or dissolved phosphorus. Statistics based on both forms.

Table 4. Summary statistics for major water quality parameters measured in the Assiniboine River at PR 340 upstream of Treesbank from January 1992 to July 2002. Data provided by Manitoba Conservation (MB Conservation 2002).

	Units	Mean	Median	n	SE	Minimum	Maximum
Temperature	°C	7.63	3.00	113	0.78	0.00	24.00
pH (lab)		8.21	8.24	130	0.02	7.75	8.76
pH (*in situ*)		8.19	8.20	112	0.03	7.70	9.10
Dissolved oxygen	mg/L	8.85	8.70	127	0.22	2.30	15.60
BOD	mg/L	2	2	42	0	1	7
Fecal coliforms	CFU/100 mL	105	20	124	43	5	4520
Chlorophyll *a*[1]	mg/L	8	4	43	2	1	53
Nitrogen Measurements							
Ammonia [2]	mg/L	0.143	0.062	130	0.020	0.003	2.010
Nitrate/Nitrite[3]	mg/L	0.363	0.320	130	0.031	0.005	2.140
Total Kjeldhal nitrogen	mg/L	1.2	1.1	130	0.1	0.2	8.0
Total nitrogen [4]	mg/L	1.560	1.415	130	0.086	0.580	8.860
Dissolved inorganic nitrogen [5]	mg/L	0.506	0.405	130	0.043	0.015	2.52
Organic nitrogen[6]	mg/L	1.063	0.963	130	0.066	0.080	7.65
Phosphorus Measurements							
Total phosphorus	mg/L	0.185	0.163	130	0.008	0.043	0.683
Particulate phosphorus	mg/L	0.070	0.049	130	0.005	0.011	0.329
Dissolved phosphorus[7]	mg/L	0.115	0.103	130	0.006	0.005	0.403
Total organic carbon	mg/L	12	11	130	0	3	21
Total suspended solids	mg/L	52	25	130	6	3	450
Turbidity	NTU	32	16	130	4	2	280
True color	TCU	25	20	130	1	5	100
Total alkalinity	mg/L $CaCO_3$	254	262	130	4	130	349
Conductivity	µS/cm	953	975	130	17	406	1480

[1] Data only available for 1999 – 2002.

[2] Reported as soluble, dissolved, or total forms. Statistics based on all forms.

[3] Reported as soluble or dissolved. Statistics based on both forms.

[4] Estimated as sum of Kjeldahl nitrogen and nitrate/nitrite.

[5] Estimated as the sum of ammonia and nitrate/nitrite.

[6] Estimated as the difference between TKN and ammonia.

[7] Reported as orthophosphorus or dissolved phosphorus. Statistics based on both forms.

Table 5. Summary statistics for major water quality parameters measured at the Portage la Prairie Reservoir from January 1992 to July 2002. Data provided by Manitoba Conservation (MB Conservation 2002).

	Units	Mean	Median	n	SE	Minimum	Maximum
Temperature	°C	8.83	7.00	113	0.84	0.00	25.00
pH (lab)		8.22	8.30	129	0.03	7.66	8.70
pH (*in situ*)		8.19	8.25	112	0.03	7.65	8.80
Dissolved oxygen	mg/L	9.57	9.20	125	0.18	4.00	14.80
BOD	mg/L	2	2	43	0	1	8
Fecal coliforms	CFU/100 mL	32	10	122	5	5	370
Chlorophyll *a*[1]	mg/L	13	6	43	3	1	98
Nitrogen Measurements							
Ammonia [2]	mg/L	0.096	0.050	129	0.012	0.003	0.920
Nitrate/Nitrite[3]	mg/L	0.295	0.210	129	0.036	0.005	3.200
Total Kjeldhal nitrogen	mg/L	1.1	1.1	129	0.0	0.1	4.3
Total nitrogen [4]	mg/L	1.447	1.325	122	0.062	0.405	5.000
Dissolved inorganic nitrogen [5]	mg/L	0.388	0.236	122	0.045	0.008	3.620
Organic nitrogen[6]	mg/L	1.059	1.007	122	0.045	0.060	4.290
Phosphorus Measurements							
Total phosphorus	mg/L	0.218	0.170	129	0.025	0.044	3.010
Particulate phosphorus	mg/L	0.133	0.081	128	0.025	0.020	2.992
Dissolved phosphorus[7]	mg/L	0.085	0.075	128	0.005	0.005	0.380
Total organic carbon	mg/L	11	11	129	0	3	22
Total suspended solids	mg/L	98	44	129	15	3	1100
Turbidity	NTU	54	27	129	7	6	480
True color	TCU	26	20	129	1	3	100
Total alkalinity	mg/L $CaCO_3$	267	275	129	4	126	372
Conductivity	µS/cm	923	939	129	16	417	1390

[1] Data only available for 1999 – 2002.

[2] Reported as soluble, dissolved, or total forms. Statistics based on all forms.

[3] Reported as soluble or dissolved. Statistics based on both forms.

[4] Estimated as sum of Kjeldahl nitrogen and nitrate/nitrite.

[5] Estimated as the sum of ammonia and nitrate/nitrite.

[6] Estimated as the difference between TKN and ammonia.

[7] Reported as orthophosphorus or dissolved phosphorus. Statistics based on both forms.

Table 6. Water quality objectives (cool water aquatic life, water temperature ≥ 5 ^{o}C) for total ammonia under pH and water temperature measured at site 8 during monitoring periods in the open water season 1999, 2000, and 2002. Water quality objectives calculated from formulae provided in Williamson (2002). Allowable exceedence frequency of occurrence for all objectives is not more than once each 3 years, on average.

Monitoring Period	Site 8		Water quality objectives for total ammonia (mg/L)		
	pH	Temperature ^{o}C	Chronic: 30 days averaging duration - water temperature ≥ 5 ^{o}C (Equation 4)	Chronic: 4 days averaging duration - water temperature ≥ 5 ^{o}C (Equation 5)	Acute: 1 hour averaging duration - all periods (Equation 6)
May 1999	8.41	13.7	1.26	3.15	3.78
June 1999	8.40	19.8	0.92	2.29	3.88
July 1999	8.23	24.7	0.89	2.23	5.44
August 1999	8.32	19.8	1.04	2.61	4.51
September 1999	8.32	13.8	1.48	3.71	4.56
May 2000	8.62	19.2	0.66	1.66	2.58
June 2000	8.73	23.7	0.41	2.58	2.11
June 2002	8.07	17.6	1.80	4.50	7.36
July 2002	8.72	25.6	0.37	0.92	2.13
August 2002	8.86	21.1	0.39	0.98	1.66

Table 7. Comparison of Maple Leaf IWWTF effluent during periods of the Assiniboine River Monitoring Study (2000 and 2002), full one-shift operation, and projected two-shift (both typical and extreme).

		2000 [1]			2002 [1]			One-Shift [2]			Two-Shift [3]	Two-Shift		
Parameter	Unit	February	May	June	June	July	August	Daily	Weekly	Monthly	"Typical"	"Extreme"		
												Daily	Weekly	Monthly
Flow	m3/day							4190	3930	3654	6918	6918	6918	6918
Nitrogen														
Total	kg/day	59.1	104.0	202.0	353.5	348.7	396.1	-	471.6	392.1	160.0	291.0	218.4	174.7
Ammonia	kg/day	0.6	0.6	0.4	0.2	0.3	0.3	1.0	0.9	-	2.5	17.0	2.4	-
Nitrate/Nitrite	kg/day	-	98.4	199.0	347.0	343.0	388.7	-	466.4	-	151.9	-	212.0	138.0
Organic Nitrogen	kg/day	-	5.1	3.3	6.5	5.4	7.2	-	-	-	5.6	4.4	4.4	4.4
Phosphorus														
Total	kg/day	20.8	50.2	25.4	57.1	51.6	60.5	-	88.9	78.9	44.2	82.0	55.3	47.0
Dissolved Orthophosphate	kg/day	-	48.7 [4]	25.4 [4]	58.1	54.7	61.3	-	-	-	-	-	-	-
Dissolved phosphorus	kg/day	-	-	-	56.4	52.2	59.8	-	-	-	42.2	79.6	52.9	44.6
Particulate phosphorus [5]	kg/day	-	1.4 [6]	0.0 [6]	0	0	0.75	-	-	-	-	-	-	-
Organic phosphorus[7]	kg/day	-	-	-	-	-	-	1.3	-	-	2.0	2.4	2.4	2.4
Other														
BOD5	kg/day	13.0	5.7	7.4	6.5	5.7	7.5	34.0	31.4	25.6	35.0	107.0	68.7	44.1

[1] Data collected by North/South Consultants Inc. during monitoring.

[2] One-shift data provided by Maple Leaf Foods Inc.(based on effluent quality in December 2002 - February 2003).

[3] Two-shift effluent predictions provided by Maple Leaf Foods Inc.

[4] Measured as soluble reactive phosphorus

[5] Estimated as the difference between total and dissolved phosphorus

[6] Estimated as the difference between total phosphorus and soluble reactive phosphorus

[7] Data provided by Maple Leaf Foods Inc. specified organic phosphorus

Table 8. Comparison of loads of ammonia, total nitrogen, and total phosphorus in the Maple Leaf IWWTF and the Municipal WWTF in the weeks around intensive monitoring in the open-water seasons of 2000 and 2002. Data provided by the City of Brandon, with the exception of intensive monitoring (collected by North/South Consultants Inc.).

	Ammonia		Total Nitrogen		Total Phosphorus	
	Maple Leaf	Municipal	Maple Leaf	Municipal	Maple Leaf	Municipal
Date	kg/day		kg/day		kg/day	
2000						
Apr-04	1.4	68	32	204	58	23
Apr-11	1.5	46	37	224	69	26
Apr-18	0.8	22	84	203	47	22
Apr-25	0.4	24	190	42	59	22
May-02	1.3	20	102	138	48	16
May Monitoring	0.6	16	104	132	50	19
May-09	0.5	29	122	116	45	21
May-16	0.4	55	112	122	27	21
May-23	0.5	82	165	185	25	48
May-30	0.3	123	185	205	44	54
Jun-06	0.7	127	258	210	35	56
June Monitoring	0.4	148	202	222	25	56
Jun-13	1.5	173	218	203	48	41
Jun-20	1.8	115	172	177	35	36
Jun-27	44.4	112	150	158	51	47
2002						
May-01	0.3	128	216	217	36	18
May-08	0.4	91	380	207	43	17
May-15	0.7	38	276	136	52	13
May-22	0.5	-	215	-	29	-
May-29	0.6	-	320	-	59	-
Jun-05	0.5	73	318	172	53	41
June Monitoring	0.2	75	353	150	57	40
Jun-12	0.2	149	313	207	34	49
Jun-19	0.4	129	313	176	33	36
Jun-26	0.3	148	326	174	48	37
Jul-03	0.5	264	286	324	29	68
Jul-10	13.2	351	375	462	65	110
Jul-17	0.4	143	319	156	60	44
July Monitoring	0.3	465	348	581	51	131
Jul-24	0.5	153	371	233	60	58
Jul-31	0.4	117	356	204	48	53
Aug-07	1.3	141	333	204	45	59
Aug-14	0.3	174	297	260	40	68
Aug-21	0.5	180	377	294	61	51
August Monitoring	0.5	168	398	173	70	43
Aug-28	0.3	85	388	106	71	21
Sep-04	1.4	108	295	180	44	26

Table 9. Summary of total nitrogen, ammonia, and phosphorus loads measured in discharges from the Brandon Municipal WWTF, Maple Leaf IWWTF, and the Municipal Drainage Ditch that receives discharge from the Simplot Fertilizer Facility and the Brandon Thermal Generating Station ash lagoon during the June 2002 monitoring period.

Source	**Date**	**Calculated Load (kg/day)**		
		Total Nitrogen	**Ammonia**	**Total Phosphorus**
Simplot/Ash Lagoon Drainage Ditch	3-Jun-02	200.5	44.3	0.09
Brandon Municipal WWTF	3-Jun-03	127.1	63.8	33.11
Maple Leaf IWWTF	3-Jun-03	308.3	0.2	31.41
Sub-Total	**3-Jun-03**	**635.9**	**108.3**	**64.61**
Simplot/Ash Lagoon Drainage Ditch	4-Jun-02	119.5	35.0	0.06
Brandon Municipal WWTF	4-Jun-02	157.7	75.6	40.87
Maple Leaf IWWTF	4-Jun-02	355.6	0.2	49.47
Sub-Total	**4-Jun-02**	**632.8**	**110.8**	**90.4**
Simplot/Ash Lagoon Drainage Ditch	5-Jun-02	92.9	23.7	0.05
Brandon Municipal WWTF	5-Jun-02	150.5	75.5	39.66
Maple Leaf IWWTF	5-Jun-02	353.5	0.2	57.08
Sub-Total	**5-Jun-02**	**596.9**	**99.4**	**96.79**
Simplot/Ash Lagoon Drainage Ditch	6-Jun-02	601.7	197.8	0.80
Brandon Municipal WWTF	6-Jun-02	123.2	77.2	39.42
Maple Leaf IWWTF	6-Jun-02	346.8	0.2	55.36
Sub-Total	**6-Jun-02**	**1071.7**	**275.2**	**95.58**

Table 10. Summary of total nitrogen, ammonia, and phosphorus loads measured in discharges from the Brandon Municipal WWTF, Maple Leaf IWWTF, and the Municipal Drainage Ditch that receives discharge from the Simplot Fertilizer Facility and the Brandon Thermal Generating Station ash lagoon during the July 2002 monitoring period.

Source	**Date**	**Calculated Load (kg/day)**		
		Total Nitrogen	**Ammonia**	**Total Phosphorus**
Simplot/Ash Lagoon Drainage Ditch	15-Jul-02	39.06	3.03	0.79
Brandon Municipal WWTF	15-Jul-02	521.93	426.81	126.93
Maple Leaf IWWTF	15-Jul-02	398.72	0.67	57.84
Sub-Total	**15-Jul-02**	**959.71**	**430.51**	**185.56**
Simplot/Ash Lagoon Drainage Ditch	16-Jul-02	35.81	1.53	0.93
Brandon Municipal WWTF	16-Jul-02	581.67	465.22	131
Maple Leaf IWWTF	16-Jul-02	348.17	0.28	51.6
Sub-Total	**16-Jul-02**	**965.65**	**461.51**	**183.53**
Simplot/Ash Lagoon Drainage Ditch	17-Jul-02	22.11	1.62	0.67
Brandon Municipal WWTF	17-Jul-02	178.68	150.51	42.01
Maple Leaf IWWTF	17-Jul-02	334.17	0.27	56.34
Sub-Total	**17-Jul-02**	**534.96**	**152.40**	**99.02**

Table 11. Summary of total nitrogen, ammonia, and phosphorus loads measured in discharges from the Brandon Municipal WWTF, Maple Leaf IWWTF, and the Municipal Drainage Ditch that receives discharge from the Simplot Fertilizer Facility and the Brandon Thermal Generating Station ash lagoon during the August 2002 monitoring period.

Source	**Date**	**Calculated Load (kg/day)**		
		Total Nitrogen	**Ammonia**	**Total Phosphorus**
Simplot/Ash Lagoon Drainage Ditch	20-Aug-02	25.64	4.99	0.06
Brandon Municipal WWTF	20-Aug-02	277.18	235.87	65.7
Maple Leaf IWWTF	20-Aug-02	380.32	0.18	38.03
Sub-Total	**20-Aug-02**	**683.14**	**241.05**	**103.79**
Simplot/Ash Lagoon Drainage Ditch	21-Aug-02	120.28	29.92	0.14
Brandon Municipal WWTF	21-Aug-02	223.21	184.05	51.02
Maple Leaf IWWTF	21-Aug-02	396.12	0.30	60.54
Sub-Total	**21-Aug-02**	**739.61**	**214.27**	**111.70**
Simplot/Ash Lagoon Drainage Ditch	22-Aug-02	60.72	14.71	0.07
Brandon Municipal WWTF	22-Aug-02	173.33	167.62	43.04
Maple Leaf IWWTF	22-Aug-02	398.34	0.45	70.27
Sub-Total	**22-Aug-02**	**632.39**	**182.79**	**113.38**

Table 12. Projected future loading rates for the City of Brandon Municipal WWTF. Loading rates calculated from data provided by the City of Brandon.

	Effluent Discharge Rate m^3/s	BOD$_5$ kg/day	Nitrogen					Phosphorus		
			Organic N kg/day	Ammonia kg/day	Nitrate kg/day	TKN kg/day	TN kg/day	Organic P kg/day	Dissolved P kg/day	TP kg/day
Daily Simulations (1QQ10 flows)										
Winter (March)	0.417	1080	108	396	1152	504	1656	28.8	259.2	288
Spring (May)	0.417	1080	108	396	1152	504	1656	28.8	259.2	288
Summer (August)	0.417	1080	108	180	1152	288	1440	28.8	259.2	288
Fall (September)	0.417	1080	108	180	1152	288	1440	28.8	259.2	288
Weekly Simulations (7QQ10 flows)										
Winter (March)	0.260	337.5	45	135	360	180	540	15.75	141.75	157.5
Spring (May)	0.417	540	72	216	504	288	792	25.2	226.8	252
Summer (July/August)	0.417	540	72	72	720	144	864	25.2	226.8	252
Fall (September)	0.289	375	50	50	550	100	650	17.5	157.5	175
Monthly Simulations (30Q10 flows)										
Winter (March)	0.243	315	42	63	252	105	357	12.6	113.4	126
Spring (May)	0.255	330	44	66	264	110	374	13.2	118.8	132
Summer (July/August)	0.324	420	56	28	392	84	476	16.8	151.2	168
Fall (September)	0.278	360	48	24	384	72	456	14.4	129.6	144

Table 13. Projected future loading rates of total nitrogen and total phosphorus from effluent sources near Brandon. Seasonal municipal WWTF loading rates were provided by the City of Brandon for 1Q10, 7Q10, and 30Q10 periods (Table 12); "typical" and "extreme" Maple Leaf IWWTF loading rates were provided by Maple Leaf Foods Inc., and Simplot loading rates were obtained from monthly licence limits.

Source	Units	Typical - Summer			Typical - Fall			Extreme - Summer		
		1Q10	7Q10	30Q10	1Q10	7Q10	30Q10	1Q10	7Q10	30Q10
Total Nitrogen										
Simplot/Ash Lagoon Drainage Ditch	kg/day	-	-	-	204	204	204	-	-	-
Brandon Municipal WWTF	kg/day	1440	864	476	1440	650	456	1440	864	476
Maple Leaf IWWTF	kg/day	160	160	160	160	160	160	291	218	174
Sub-Total		**1600**	**1024**	**636**	**1804**	**1014**	**820**	**1731**	**1082**	**650**
Total Phosphorus										
Simplot/Ash Lagoon Drainage Ditch	kg/day	-	-	-	20	20	20	-	-	-
Brandon Municipal WWTF	kg/day	288	252	168	288	175	144	288	252	168
Maple Leaf IWWTF	kg/day	44	44	44	44	44	44	82	55	47
Sub-Total		**332**	**296**	**212**	**352**	**239**	**208**	**370**	**307**	**215**

Table 14. Ammonia assimilative capacity calculated for the Assiniboine River.

			Discharge					Ammonia				
	Ammonia Objective Equation[1]	River Discharge	Assiniboine River Q10[2] (m^3/s)	Brandon Withdrawal (m^3/s)	Simplot Discharge (m^3/s)	Brandon WWTF Discharge (m^3/s)	Brandon WWTF Corrected Discharge (m^3/s)	Objectives[3] (kg/day)	Background[4] (kg/day)	Simplot Licence[5] (kg/day)	City of Brandon[6] (kg/day)	Maple Leaf Capacity[7] (kg/day)
January												
	4	30Q10	6.44	0.23	0.01802	0.243	6.48	2212	43.8	120	63	1489
	5	7Q10	6.14	0.23	0.01802	0.260	6.20	5290	41.7	120	135	3745
	6	1Q10	6.03	0.23	0.01802	0.417	6.24	4536	40.9	120	396	2984
February												
	1	30Q10	5.60	0.23	0.01815	0.243	5.63	1316	34.1	120	63	824
	2	7Q10	6.18	0.23	0.01815	0.260	6.23	3640	37.8	120	135	2511
	3	1Q10	6.11	0.23	0.01815	0.417	6.32	5281	37.4	120	396	3545
	4	30Q10	5.60	0.23	0.01815	0.243	5.63	2137	34.1	120	63	1440
	5	7Q10	6.18	0.23	0.01815	0.260	6.23	5911	37.8	120	135	4213
	6	1Q10	6.11	0.23	0.01815	0.417	6.32	5281	37.4	120	396	3545
March												
	1	30Q10	5.74	0.24	0.01838	0.243	5.77	1347	23.8	120	63	855
	2	7Q10	3.11	0.24	0.01838	0.260	3.16	1845	12.4	120	135	1183
	3	1Q10	2.83	0.24	0.01838	0.417	3.03	2534	11.2	120	396	1505
	4	30Q10	5.74	0.24	0.01838	0.243	5.77	2188	23.8	120	63	1486
	5	7Q10	3.11	0.24	0.01838	0.260	3.16	2996	12.4	120	135	2046
	6	1Q10	2.83	0.24	0.01838	0.417	3.03	2534	11.2	120	396	1505
April												
	1	30Q10	9.65	0.23	0.01825	0.255	9.70	2039	53.3	90	66	1372
	2	7Q10	6.04	0.23	0.01825	0.417	6.25	3286	32.9	90	216	2210
	3	1Q10	3.96	0.23	0.01825	0.417	4.17	3031	21.1	90	396	1893

Table 14. - continued -

			Discharge					Ammonia				
	Ammonia Objective Equation[1]	River Discharge	Assiniboine River Q10[2]	Brandon Withdrawal	Simplot Discharge	Brandon WWTF Discharge	Brandon WWTF Corrected Discharge	Objectives[3]	Background[4]	Simplot Licence[5]	City of Brandon[6]	Maple Leaf Capacity[7]
			(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)
	4	30Q10	9.65	0.23	0.01825	0.255	9.70	3310	53.3	90	66	2326
	5	7Q10	6.04	0.23	0.01825	0.417	6.25	5335	32.9	90	216	3747
	6	1Q10	3.96	0.23	0.01825	0.417	4.17	3031	21.1	90	396	1893
May												
May 1-15	1	30Q10	6.55	0.23	0.02019	0.255	6.59	1022	15.0	80	66	646
	2	7Q10	5.78	0.23	0.02019	0.417	5.98	2318	13.2	80	216	1506
	3	1Q10	5.27	0.23	0.02019	0.417	5.47	2707	12.0	80	396	1664
May 16-31												
	1	30Q10	6.55	0.23	0.00	0.255	6.57	1019	15.0	-	66	703
	2	7Q10	5.78	0.23	0.00	0.417	5.96	2310	13.2	-	216	1561
	3	1Q10	5.27	0.23	0.00	0.417	5.45	2697	12.0	-	396	1717
June												
	1	30Q10	5.78	0.25	0.00	0.324	5.85	577	18.4	-	28	398
	2	7Q10	4.92	0.25	0.00	0.417	5.09	1255	15.5	-	72	876
	3	1Q10	4.51	0.25	0.00	0.417	4.67	1904	14.2	-	180	1283
July												
	1	30Q10	5.56	0.29	0.00	0.324	5.59	570	22.9	-	28	390
	2	7Q10	4.43	0.29	0.00	0.417	4.56	1163	18.1	-	72	805
	3	1Q10	4.02	0.29	0.00	0.417	4.15	1864	16.3	-	180	1251
August												
	1	30Q10	3.79	0.28	0.00	0.324	3.83	332	8.0	-	28	222
	2	7Q10	3.92	0.28	0.00	0.417	4.06	880	8.3	-	72	599

Table 14. - continued -

			Discharge					Ammonia				
	Ammonia Objective Equation[1]	River Discharge	Assiniboine River Q10[2] (m^3/s)	Brandon Withdrawal (m^3/s)	Simplot Discharge (m^3/s)	Brandon WWTF Discharge (m^3/s)	Brandon WWTF Corrected Discharge (m^3/s)	Objectives[3] (kg/day)	Background[4] (kg/day)	Simplot Licence[5] (kg/day)	City of Brandon[6] (kg/day)	Maple Leaf Capacity[7] (kg/day)
	3	1Q10	3.83	0.28	0.00	0.417	3.96	1614	8.1	-	180	1069
September												
Sept 1-14	1	30Q10	3.34	0.25	0.00	0.278	3.37	280	6.3	-	24	187
	2	7Q10	3.00	0.25	0.00	0.289	3.04	631	5.6	-	50	432
	3	1Q10	2.83	0.25	0.00	0.417	3.00	915	5.3	-	180	547
Sept 15-30												
	1	30Q10	3.34	0.25	0.01552	0.278	3.39	281	6.3	38	24	159
	2	7Q10	3.00	0.25	0.01552	0.289	3.06	634	5.6	38	50	405
	3	1Q10	2.83	0.25	0.01552	0.417	3.02	919	5.3	38	180	522
October												
	1	30Q10	4.32	0.24	0.01521	0.278	4.37	448	5.3	40	24	284
	2	7Q10	3.00	0.24	0.01521	0.289	3.07	786	3.6	40	50	519
	3	1Q10	2.83	0.24	0.01521	0.417	3.03	922	3.4	40	180	524
November												
	4	30Q10	5.77	0.24	0.01527	0.243	5.78	1047	9.8	50	63	693
	5	7Q10	4.60	0.24	0.01527	0.260	4.64	2099	7.7	50	135	1430
	6	1Q10	3.65	0.24	0.01527	0.417	3.85	1290	6.0	50	396	629
December												
	4	30Q10	6.27	0.22	0.01746	0.243	6.31	1717	21.2	130	63	1127

Table 14. - continued -

		Discharge					Ammonia				
Ammonia Objective Equation[1]	River Discharge	Assiniboine River Q10[2] (m³/s)	Brandon Withdrawal (m³/s)	Simplot Discharge (m³/s)	Brandon WWTF Discharge (m³/s)	Brandon WWTF Corrected Discharge (m³/s)	Objectives[3] (kg/day)	Background[4] (kg/day)	Simplot Licence[5] (kg/day)	City of Brandon[6] (kg/day)	Maple Leaf Capacity[7] (kg/day)
5	7Q10	5.60	0.22	0.01746	0.260	5.65	3847	18.8	130	135	2673
6	1Q10	5.29	0.22	0.01746	0.417	5.50	3000	17.7	130	396	1842

[1] Equations obtained from the Manitoba Water Quality Surface Objectives and Guidelines (2002).

[2] River discharges (Q10s) provided by Earth Tech.

[3] Ammonia objectives calculated with median field-measured pH and temperature, and with flow = (Q10 - withdrawal at Brandon + Simplot discharge).

[4] Background Ammonia Load calculated based on median concentration at the 18th St. Bridge (Brandon) and flow (Q10 - withdrawal at Brandon).

[5] Simplot licence limits for ammonia.

[6] Projected future ammonia loads, provided by the City of Brandon.

[7] Maple Leaf Capacity was calculated as 75% of the difference between Objectives - Background - Simplot - City of Brandon.

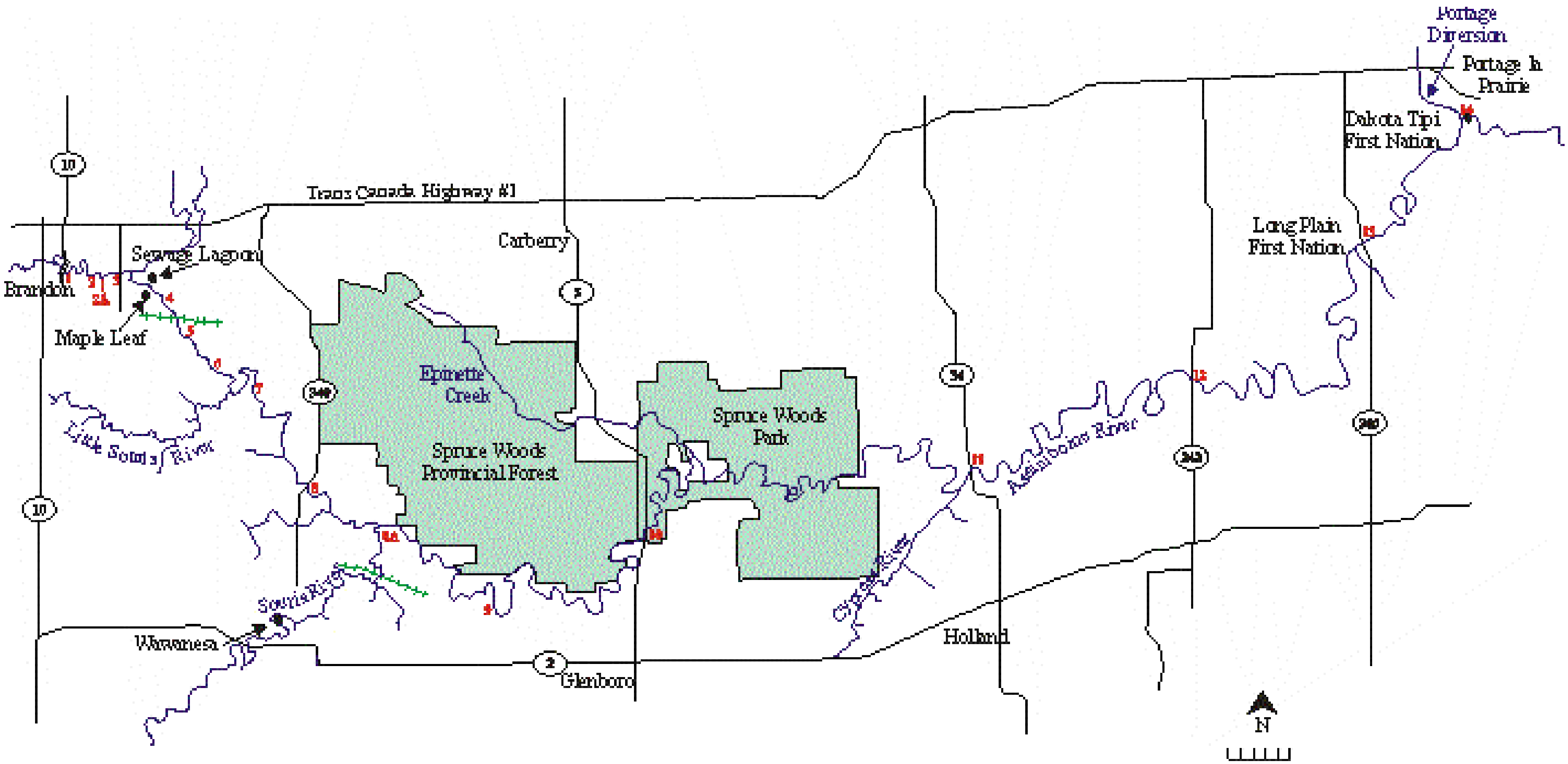

Figure 1. Study area of the Assiniboine River Monitoring Study (Brandon to Portage la Prairie), with sampling site locations.

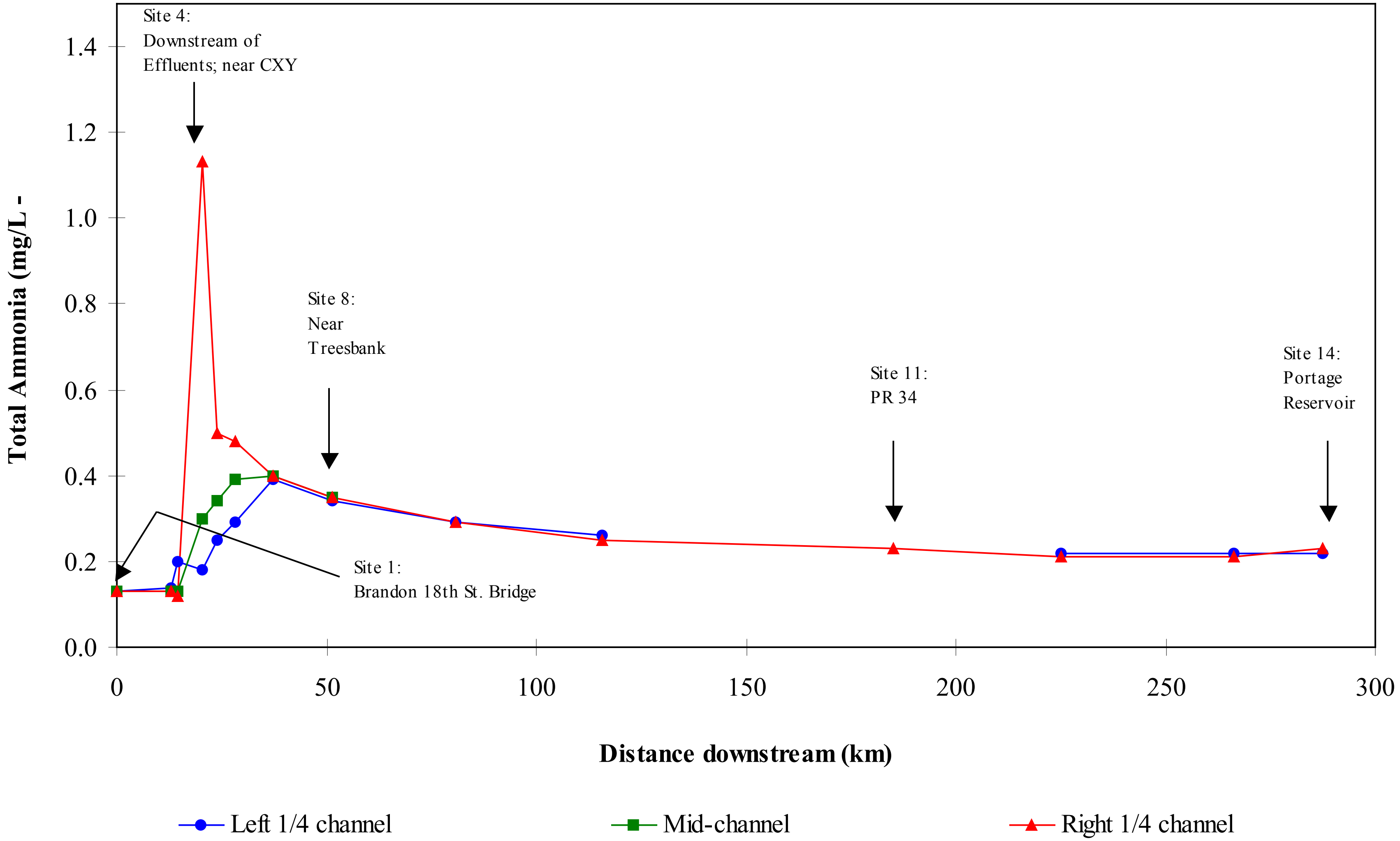

Figure 2. Ammonia nitrogen concentrations measured in samples collected from the Assiniboine River, 31 January - 7 February 2000.

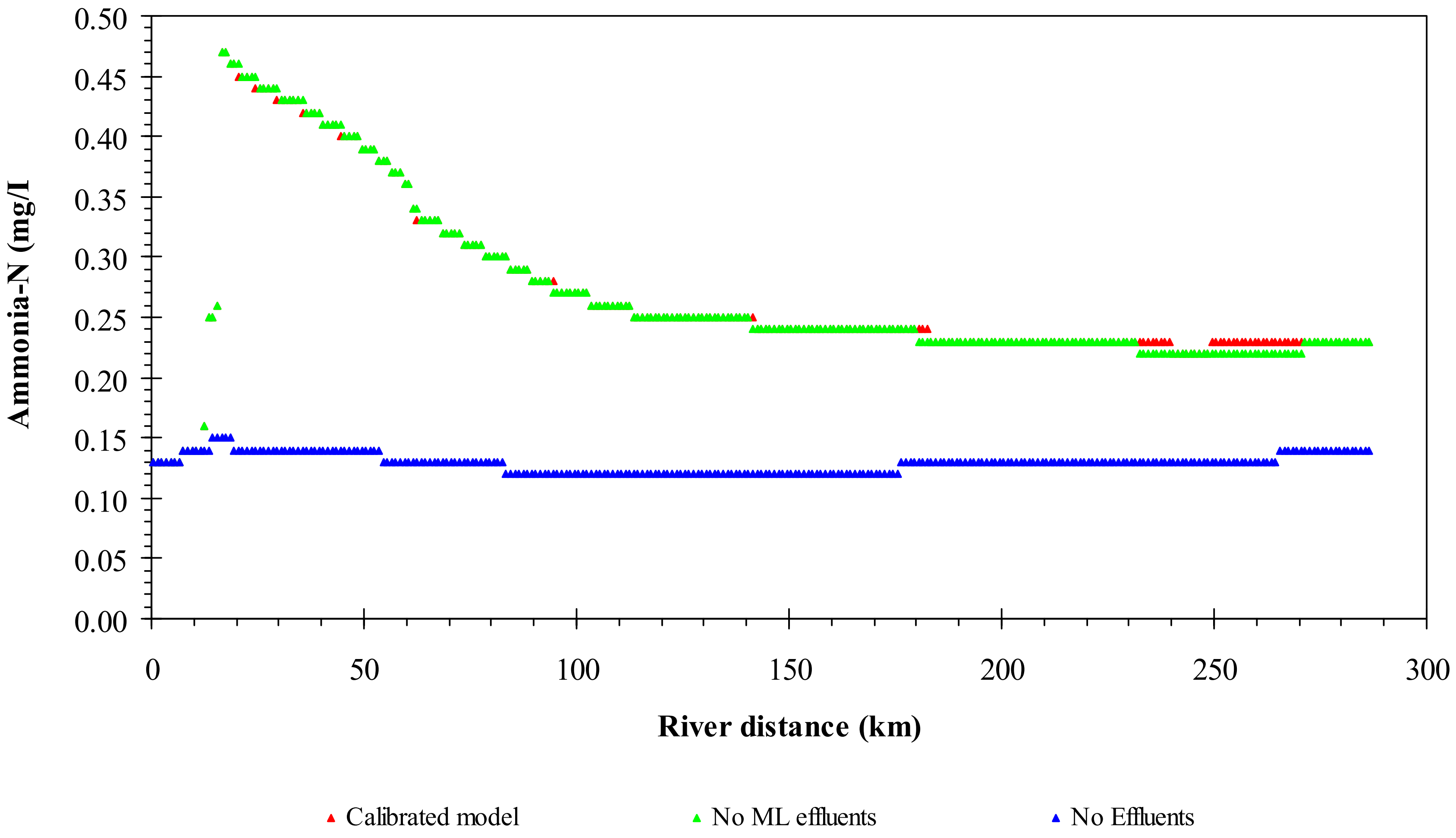

Figure 3. Effects of ML IWWTF effluent and all effluents on ammonia in the Assiniboine River, February 2000.

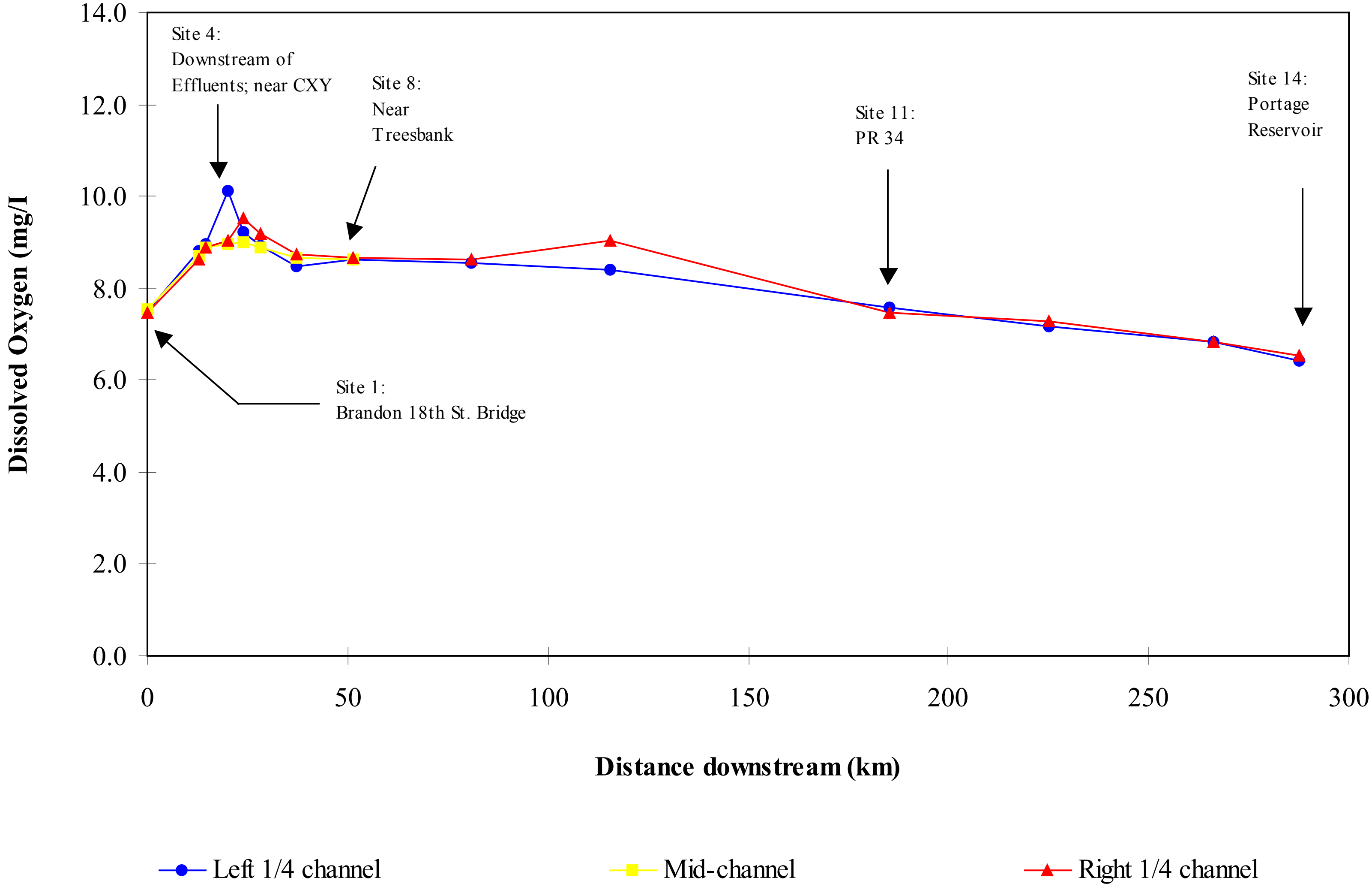

Figure 4. Dissolved oxygen concentrations measured in the Assiniboine River, 31 January - 7 February 2000.

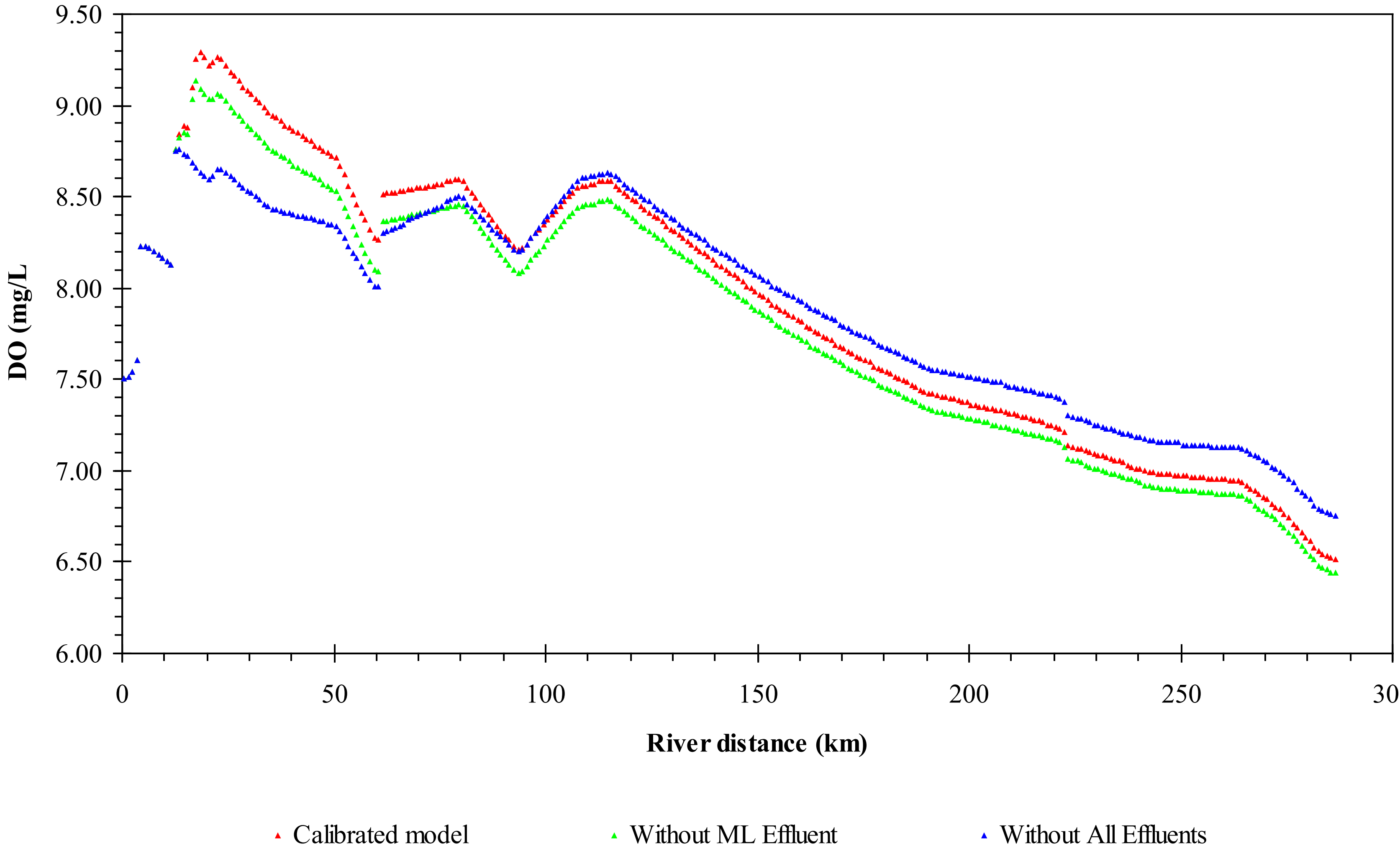

Figure 5. Effects of ML IWWTF effluent and all effluents on DO in the Assiniboine River, February 2000.

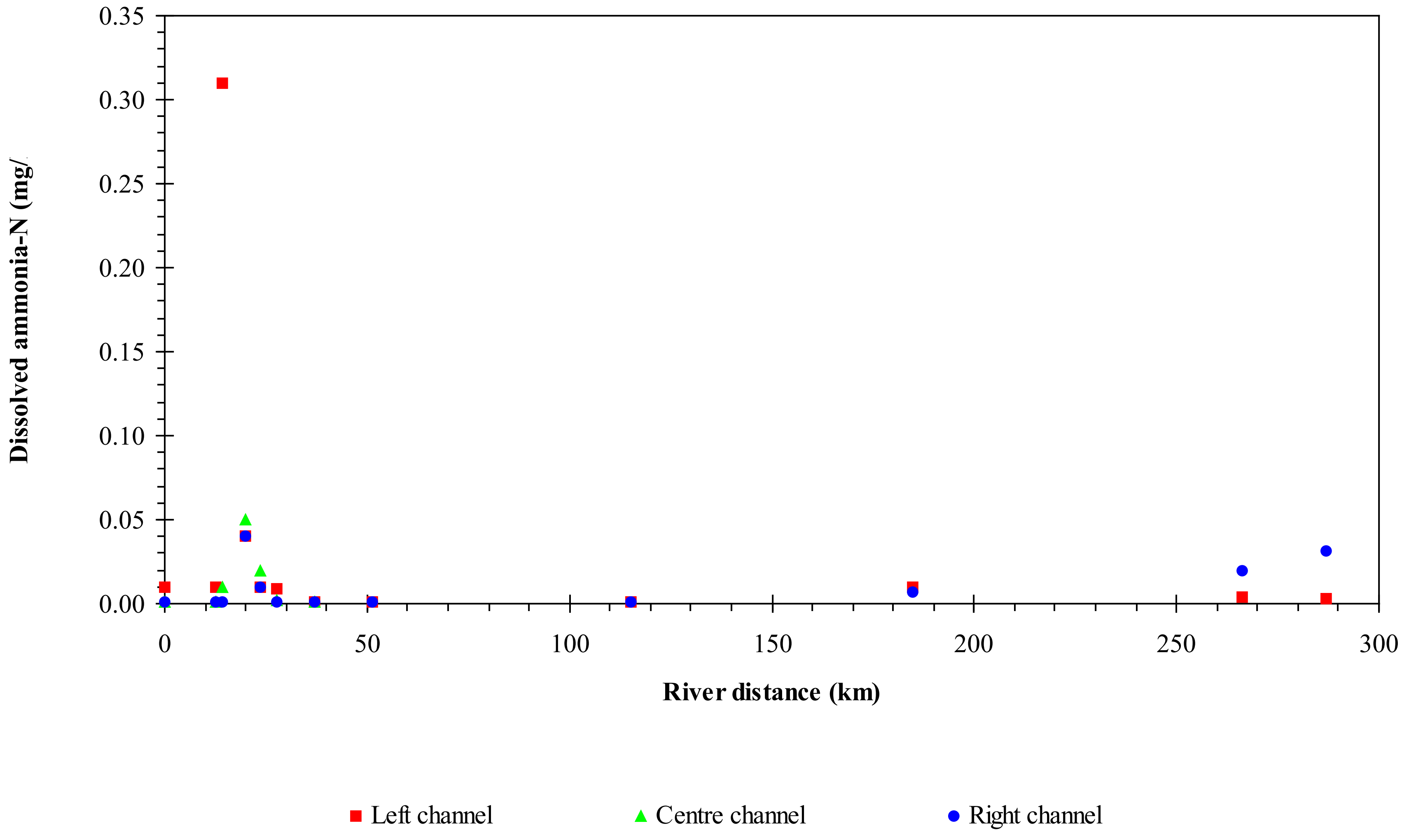

Figure 6. Concentrations of dissolved ammonia-N in the Assiniboine River measured during the May 2000 monitoring period.

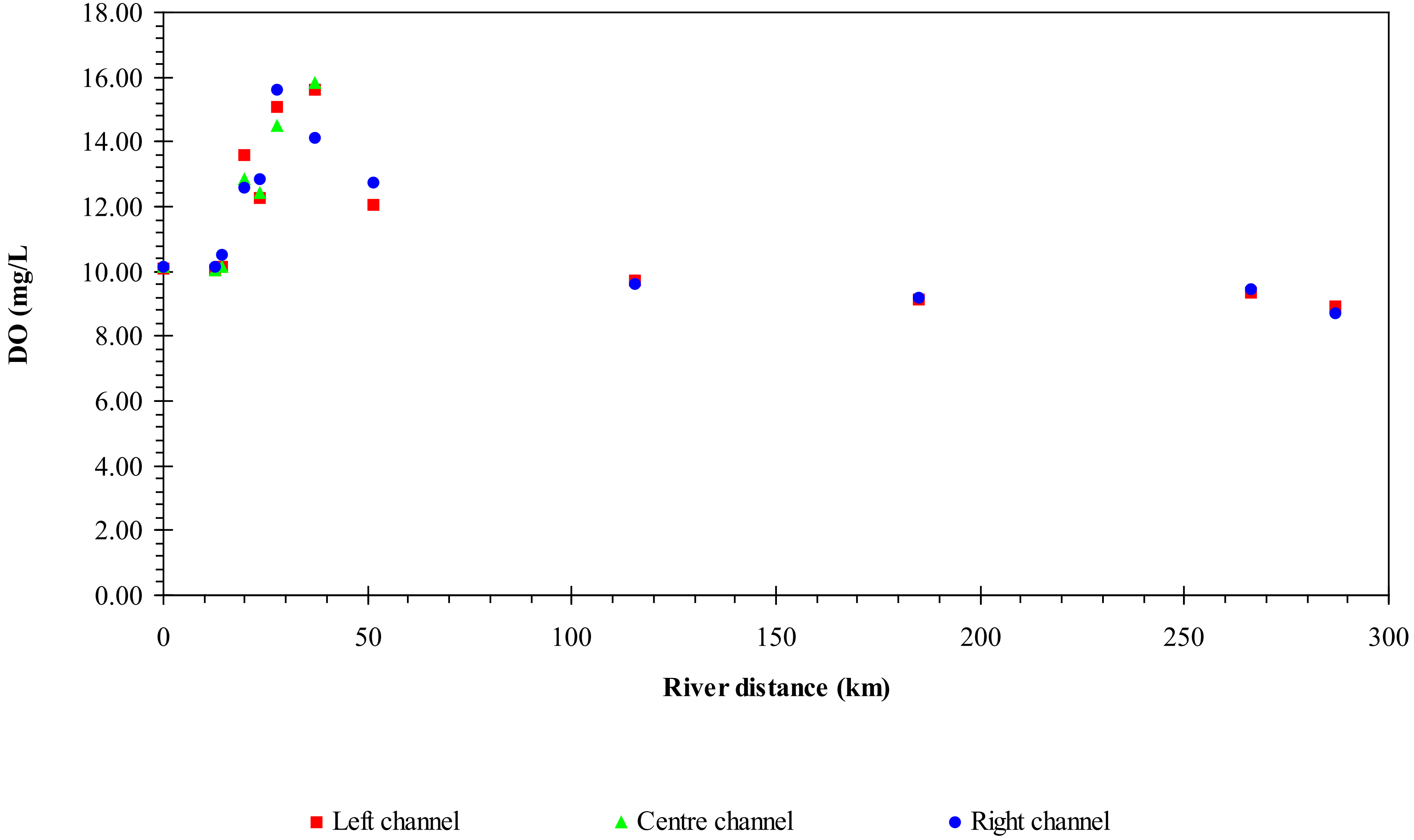

Figure 7. Concentrations of dissolved oxygen in the Assiniboine River measured during the May 2000 monitoring period.

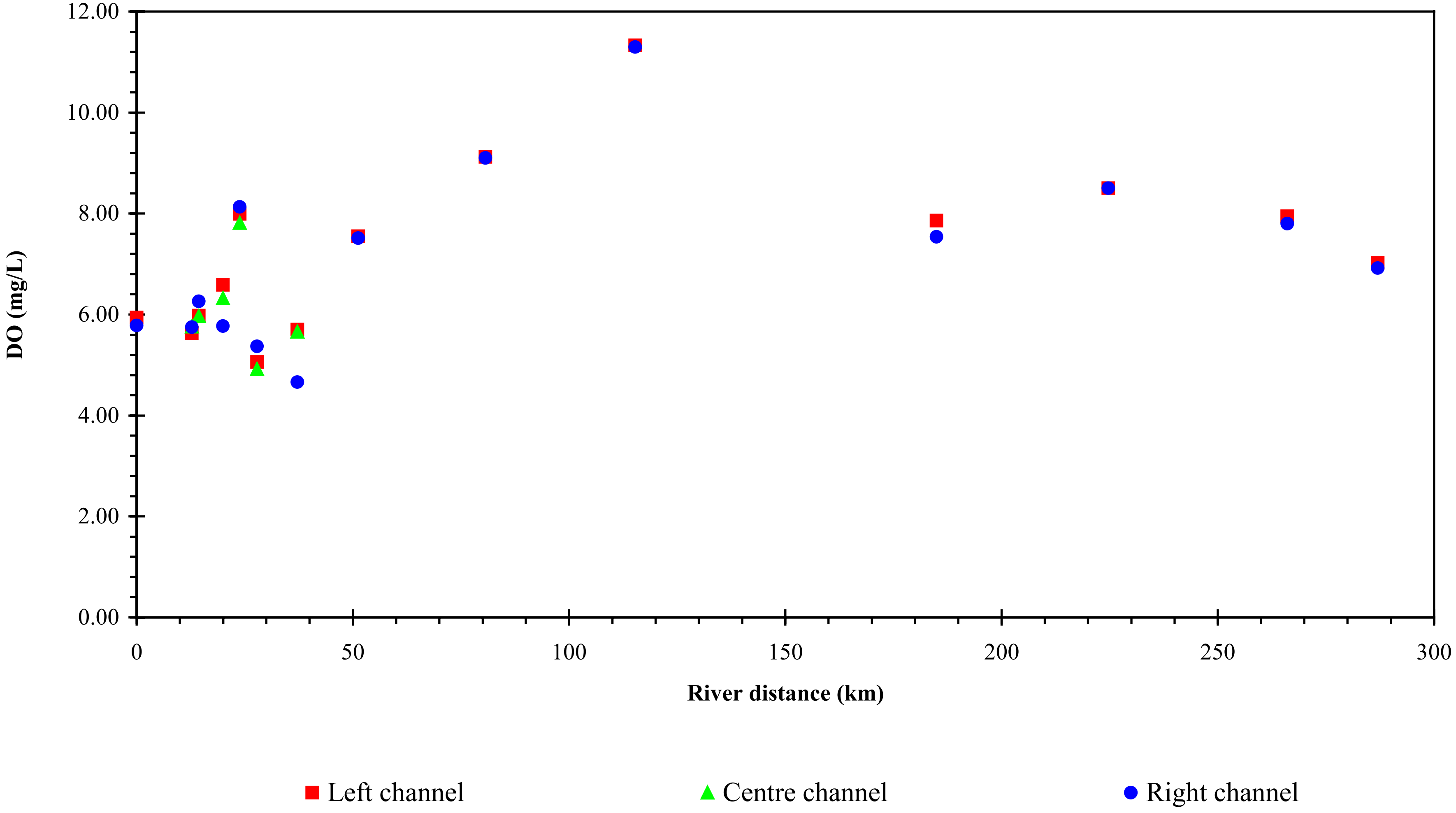

Figure 8. Dissolved oxygen (DO) concentrations measured in the Assiniboine River in July 2002. Site 1 (0 km) is the Brandon 18th St. Bridge; site 14 (287 km) is the Portage la Prairie Reservoir.

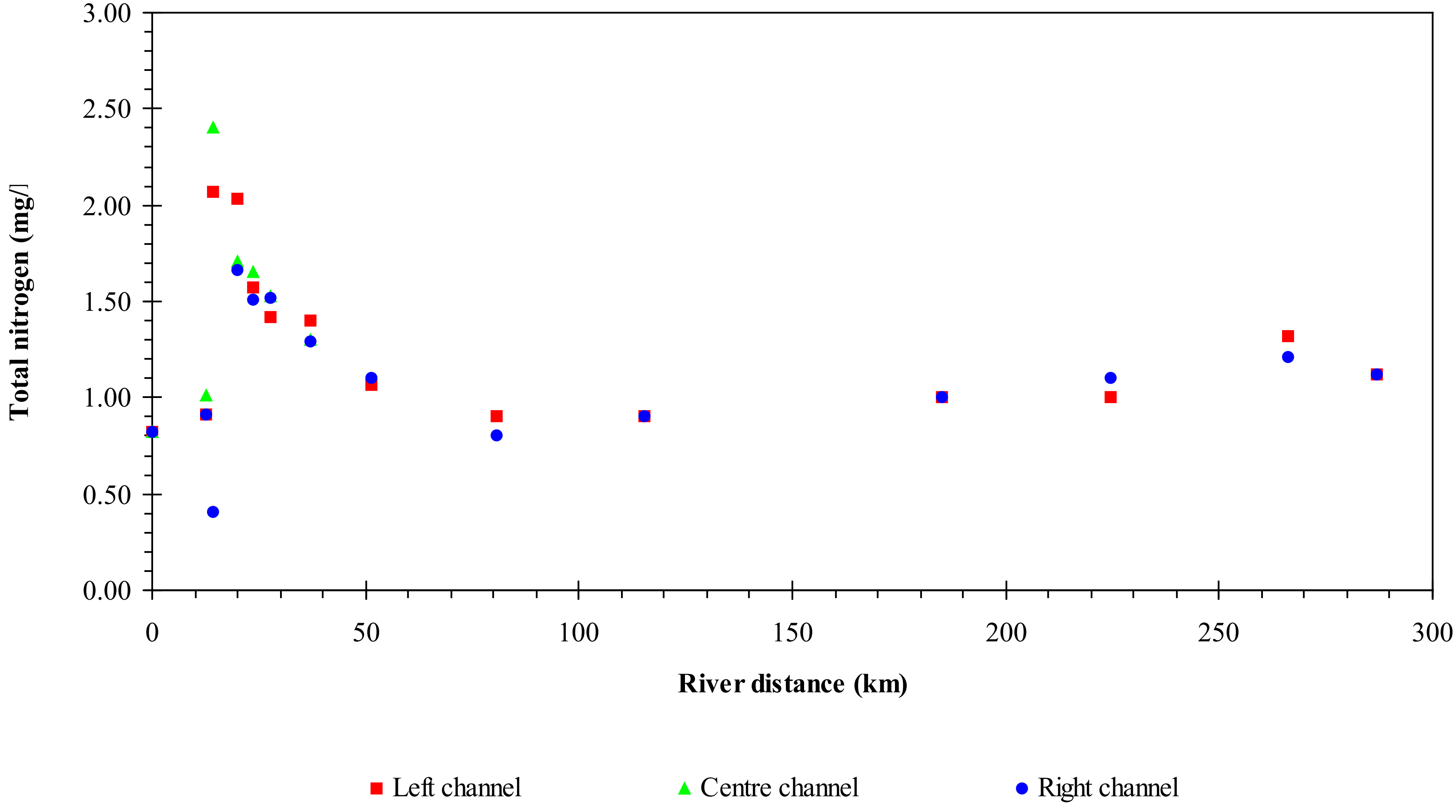

Figure 9. Concentrations of total nitrogen in the Assiniboine River measured during the June 2000 monitoring period.

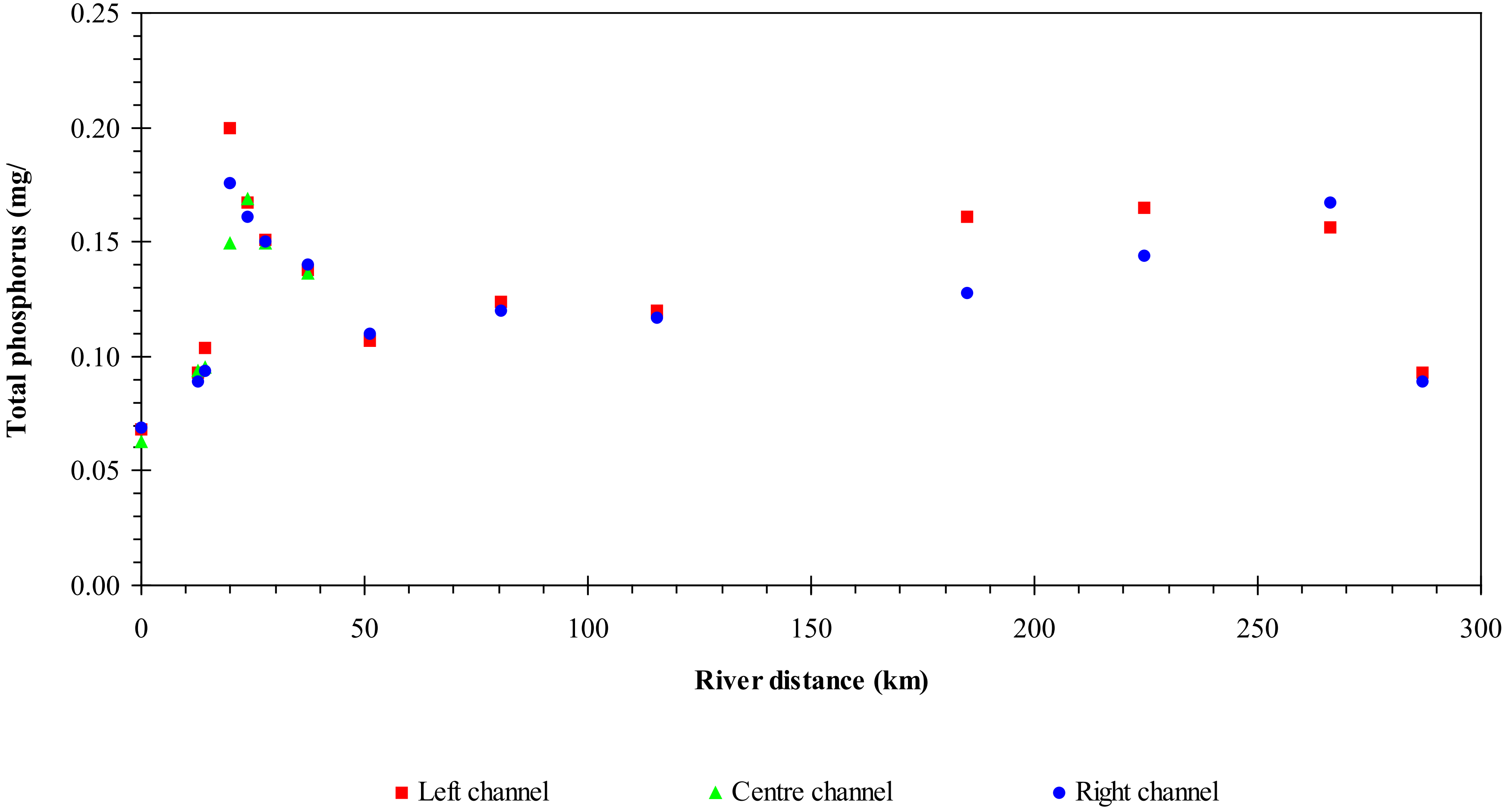

Figure 10. Concentrations of total phosphorus in the Assiniboine River measured during the June 2000 monitoring period.

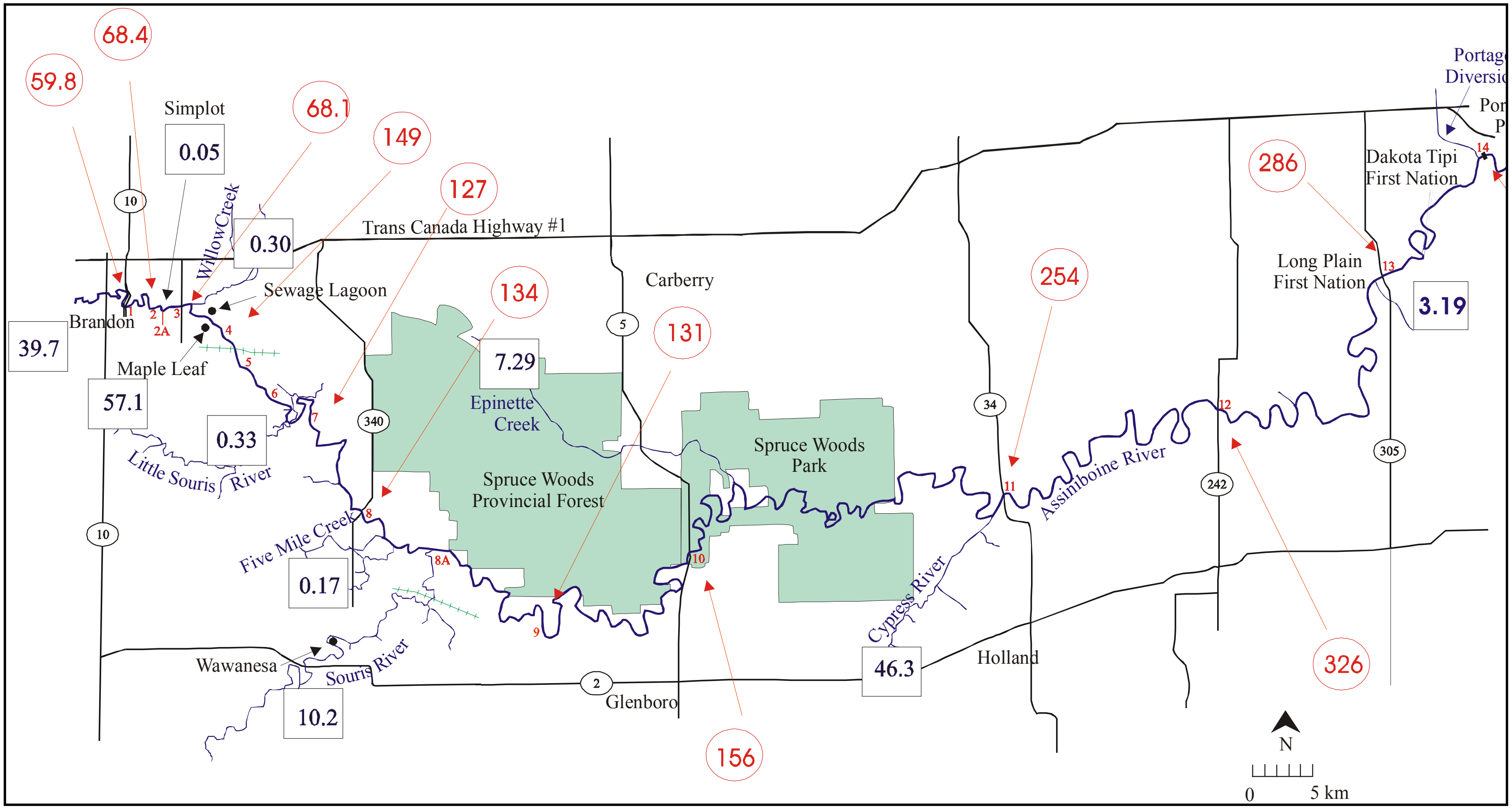

Figure 11. Total phosphorus loads (kg/day) in the Assiniboine River and various tributaries and effluent, June 2002. Numbers in red circles indicate calculated loads in the Assiniboine River and values in blue boxes indicate loads from tributaries and effluents.

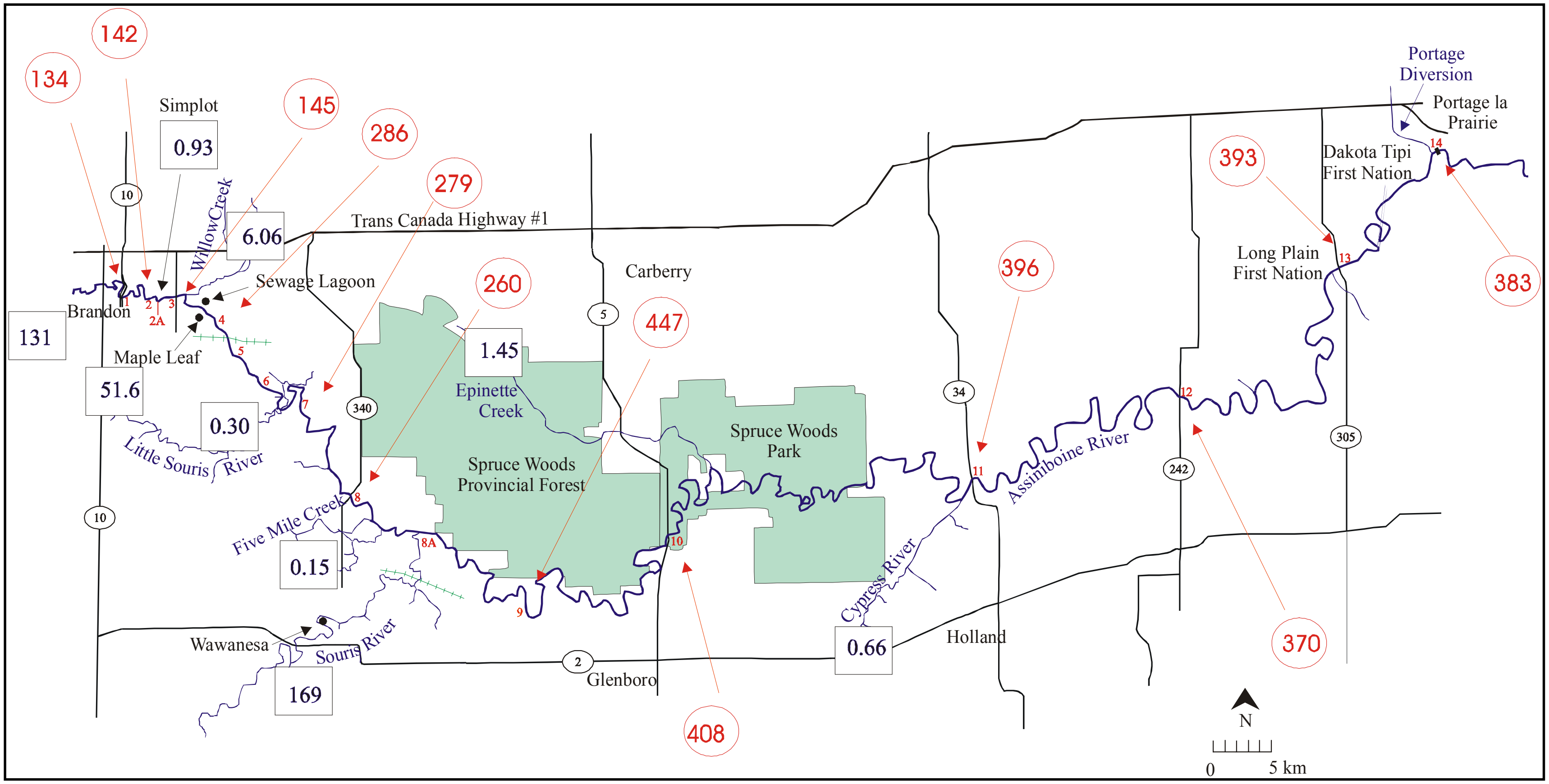

Figure 12. Total phosphorus loads (kg/day) in the Assiniboine River and various tributaries and effluent, July 2002. Numbers in red circles indicate calculated loads in the Assiniboine River and values in blue boxes indicate loads from tributaries and effluents.

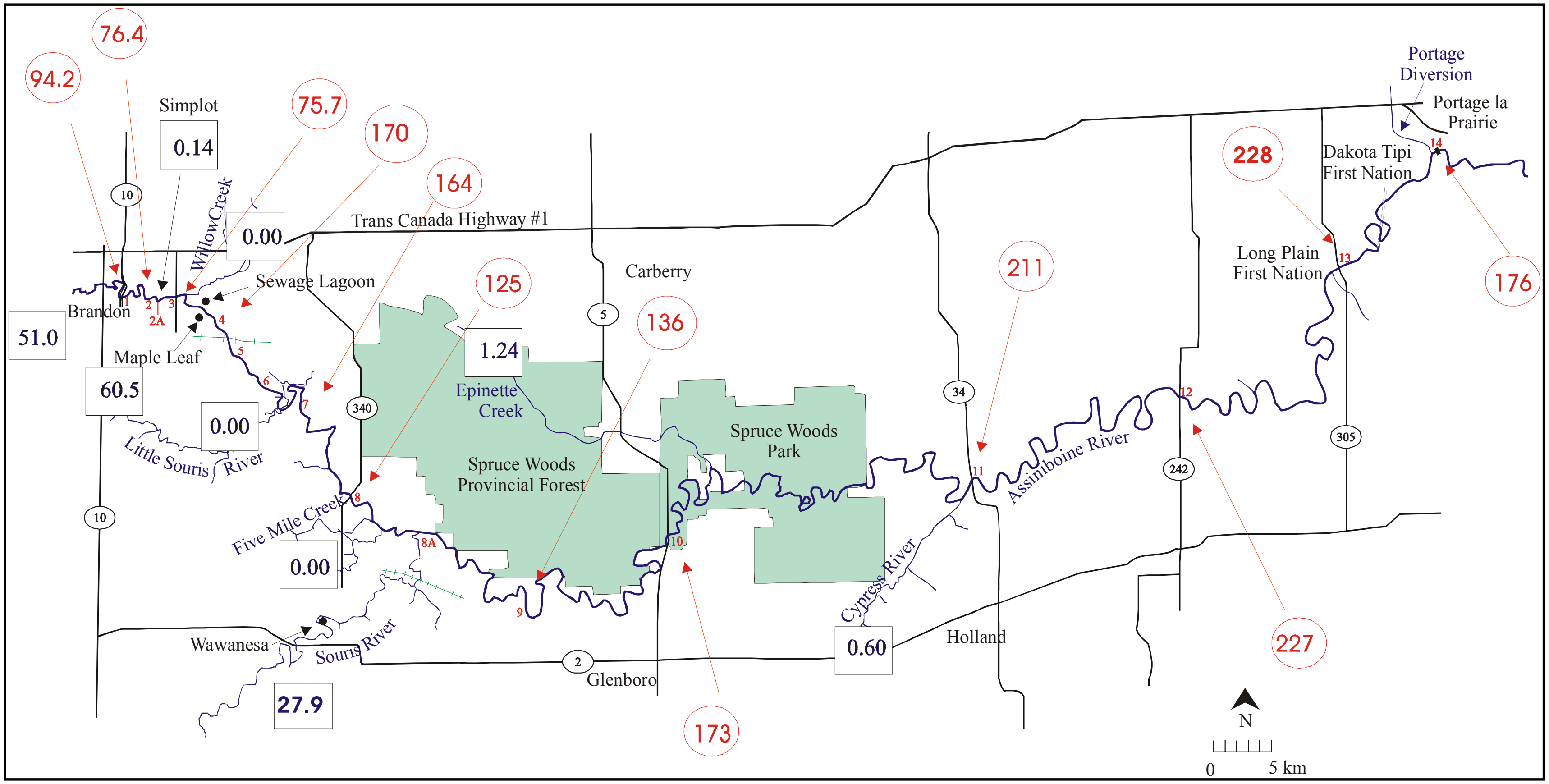

Figure 13. Total phosphorus loads (kg/day) in the Assiniboine River and various tributaries and effluent, August/September 2002. Numbers in red circles indicate calculated loads in the Assiniboine River and values in blue boxes indicate loads from tributaries and effluents.

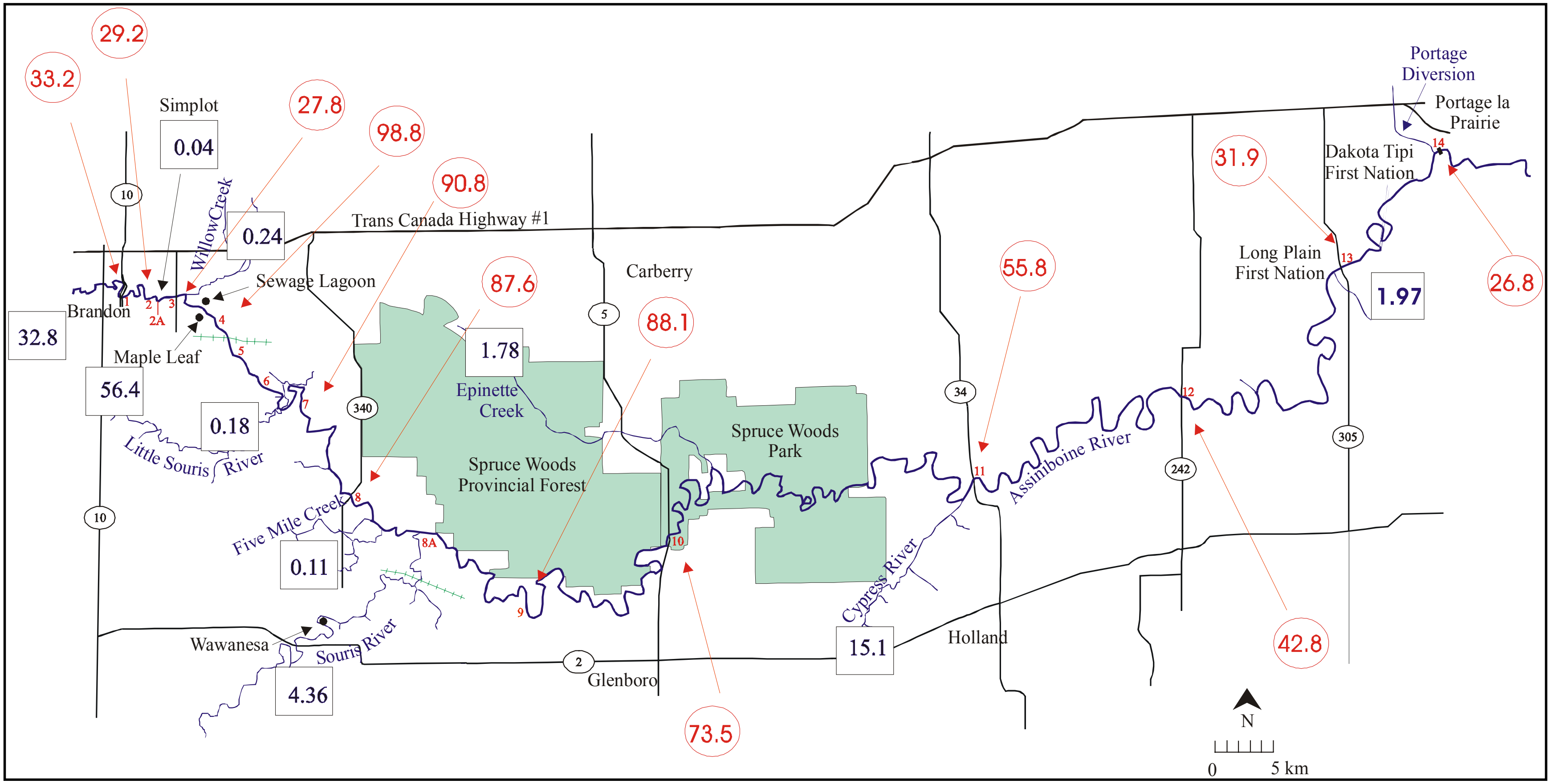

Figure 14. Dissolved phosphorus loads (kg/day) in the Assiniboine River and various tributaries and effluent, June 2002. Numbers in red circles indicate calculated loads in the Assiniboine River and values in blue boxes indicate loads from tributaries and effluents.

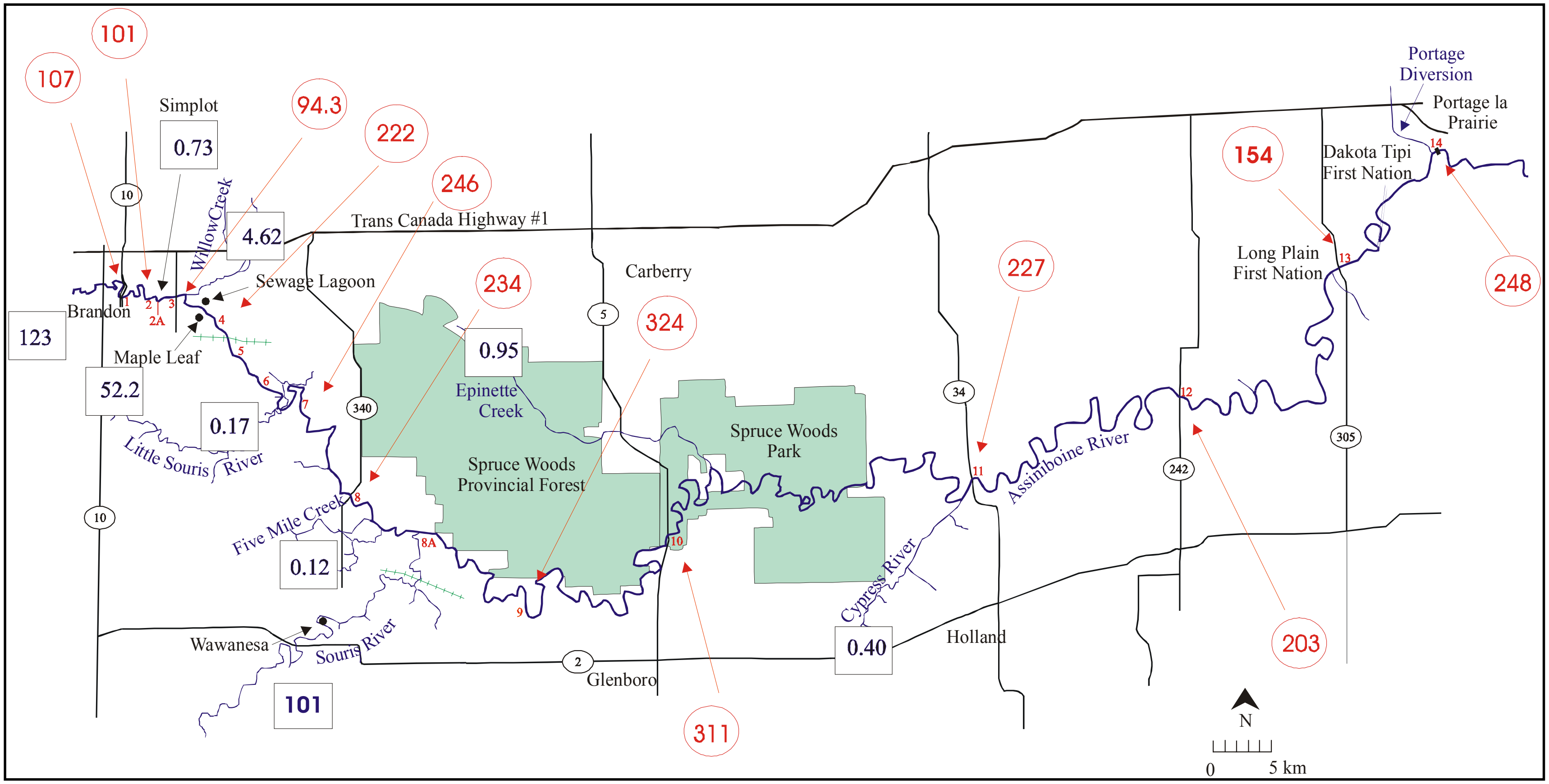

Figure 15. Dissolved phosphorus loads (kg/day) in the Assiniboine River and various tributaries and effluent, July 2002. Numbers in red circles indicate calculated loads in the Assiniboine River and values in blue boxes indicate loads from tributaries and effluents.

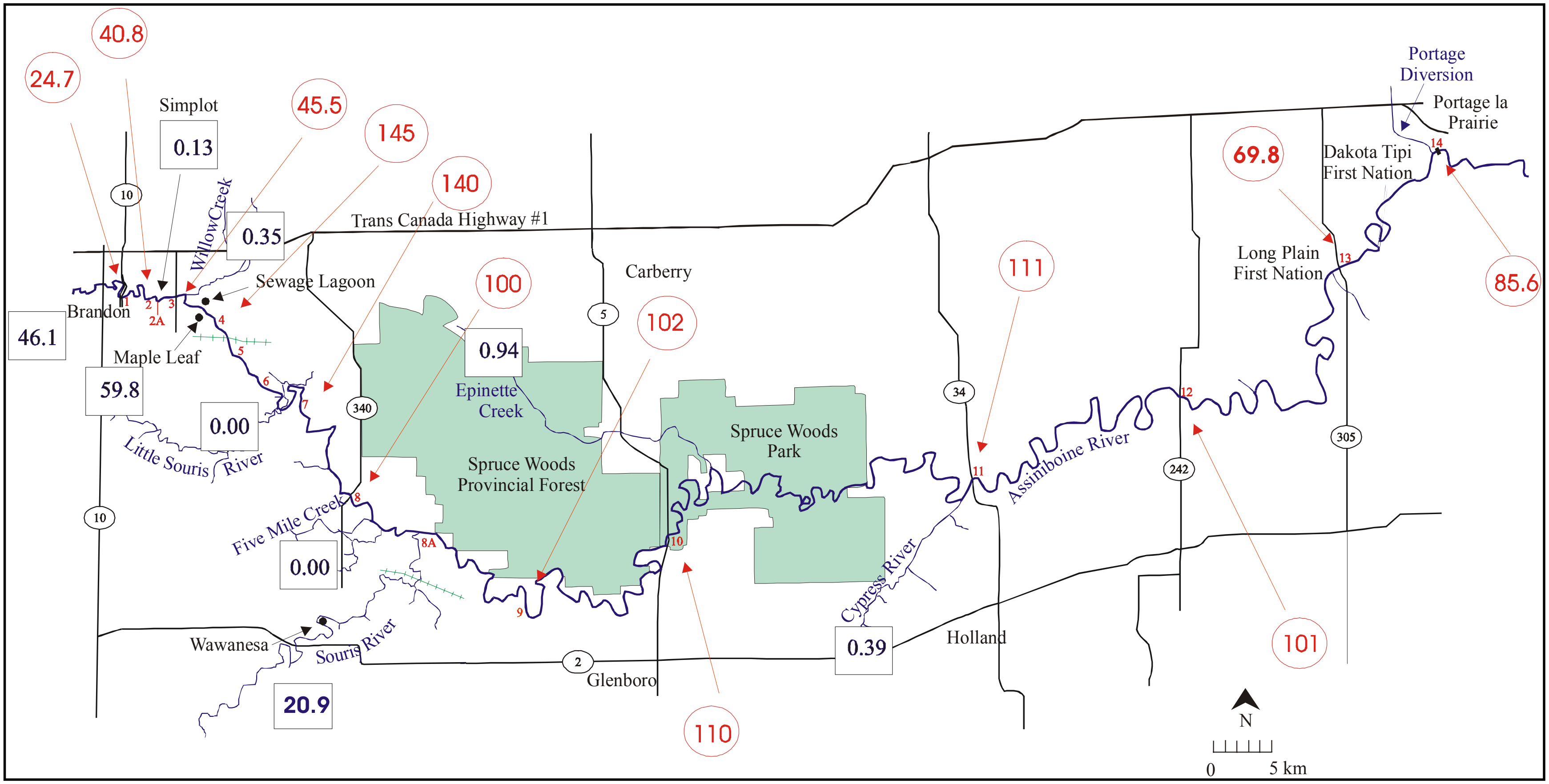

Figure 16. Dissolved phosphorus loads (kg/day) in the Assiniboine River and various tributaries and effluent, August/September 2002. Numbers in red circles indicate calculated loads in the Assiniboine River and values in blue boxes indicate loads from tributaries and effluents.

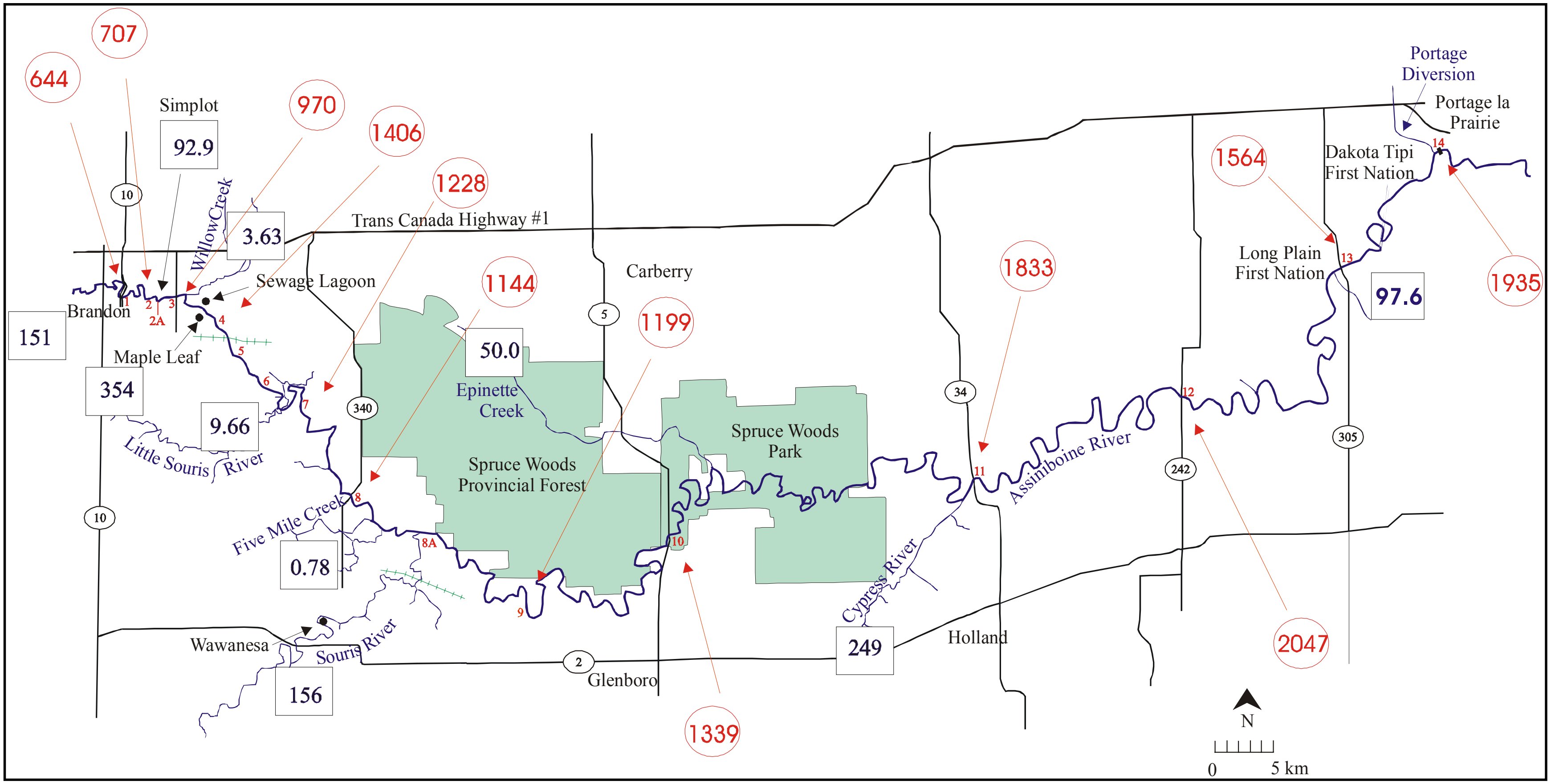

Figure 17. Total nitrogen loads (kg/day) in the Assiniboine River and various tributaries and effluent, June 2002. Numbers in red circles indicate calculated loads in the Assiniboine River and values in blue boxes indicate loads from tributaries and effluents.

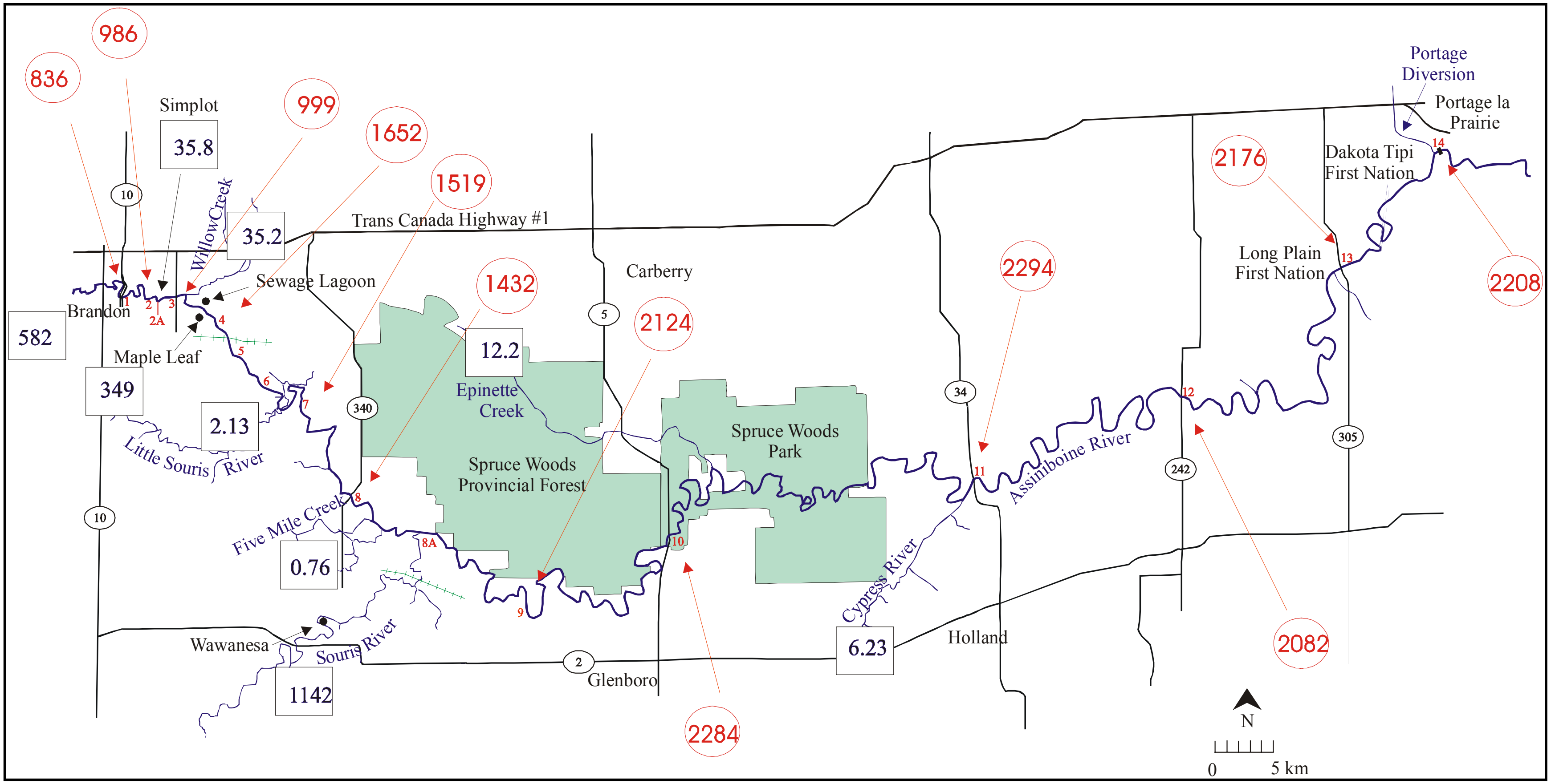

Figure 18. Total nitrogen loads (kg/day) in the Assiniboine River and various tributaries and effluent, July 2002. Numbers in red circles indicate calculated loads in the Assiniboine River and values in blue boxes indicate loads from tributaries and effluents.

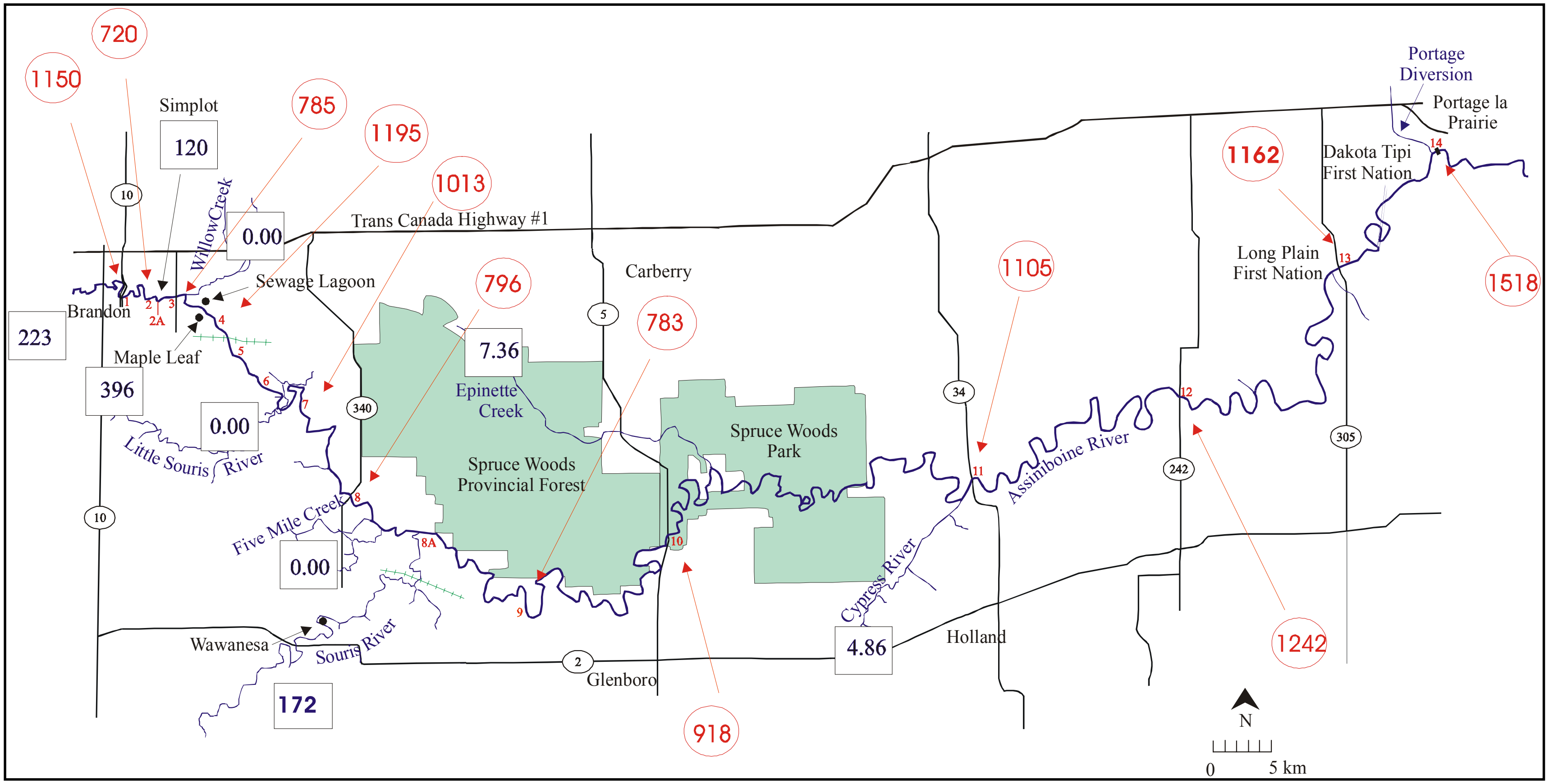

Figure 19. Total nitrogen loads (kg/day) in the Assiniboine River and various tributaries and effluent, August/September 2002. Numbers in red circles indicate calculated loads in the Assiniboine River and values in blue boxes indicate loads from tributaries and effluents.

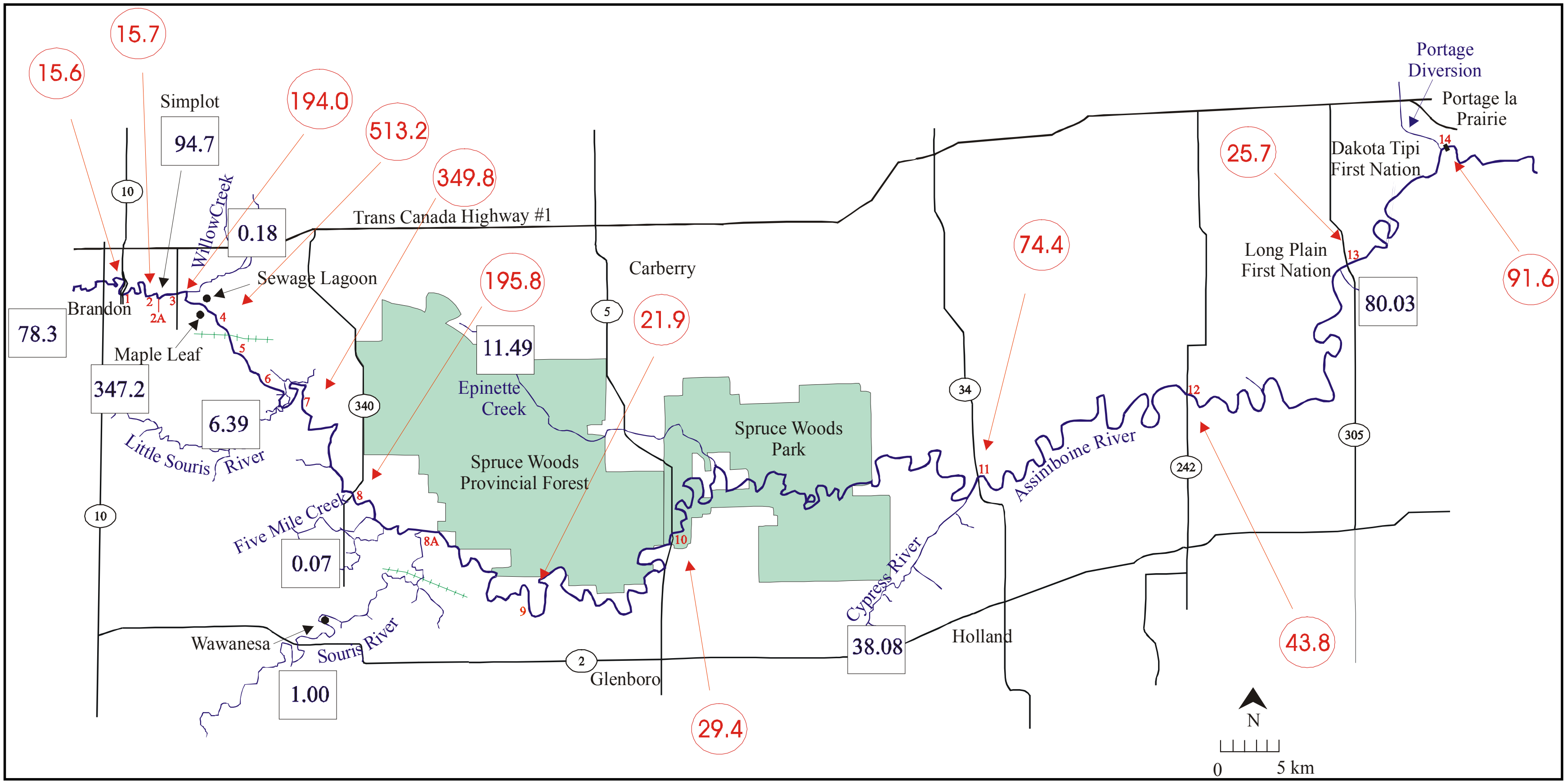

Figure 20. Preliminary dissolved inorganic nitrogen loads (kg/day) in the Assiniboine River and various tributaries and effluent, June 2002. Numbers in red circles indicate calculated loads in the Assiniboine River and values in blue boxes indicate loads from tributaries and effluents.

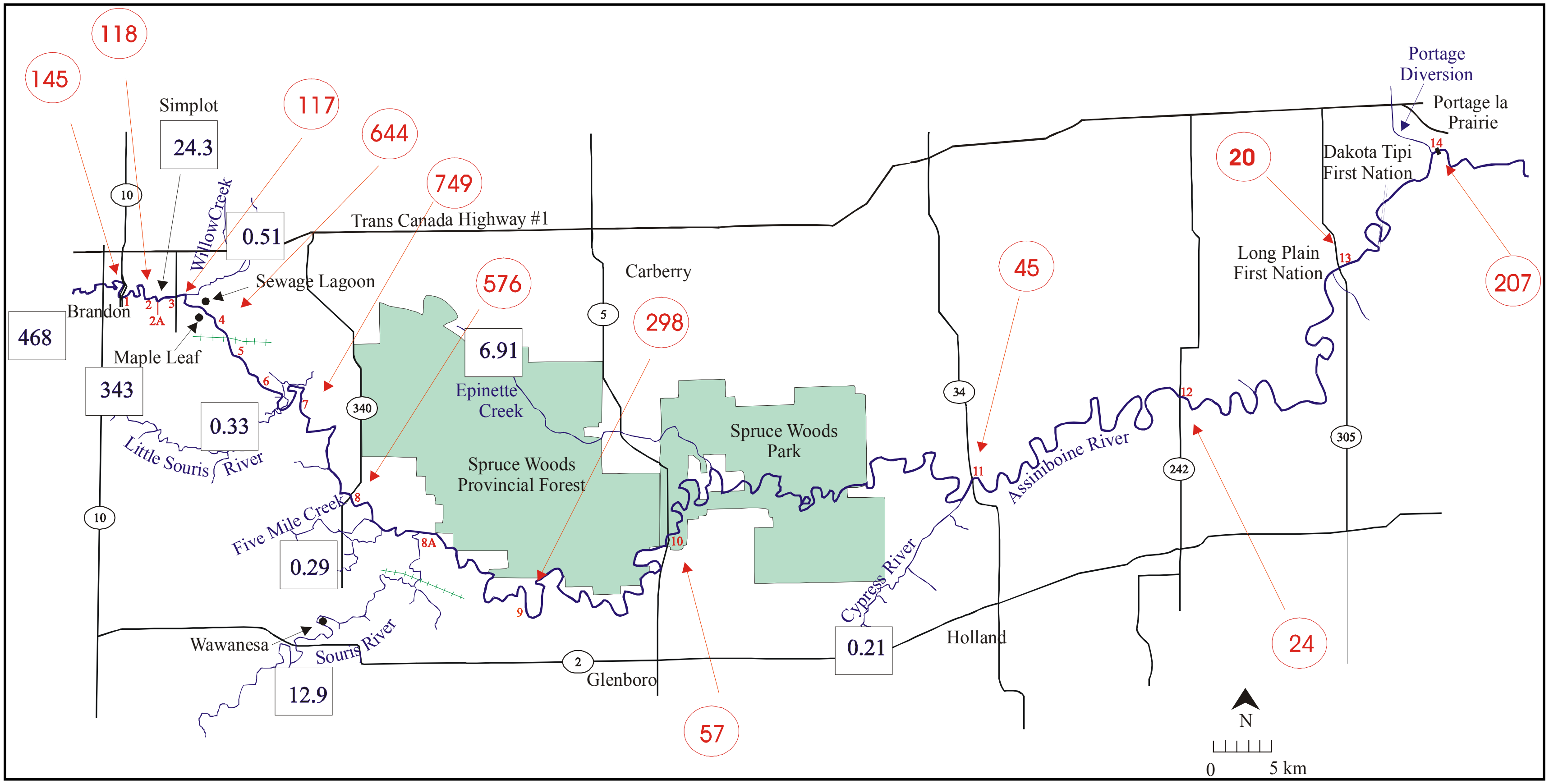

Figure 21. Dissolved organic nitrogen loads (kg/day) in the Assiniboine River and various tributaries and effluent, July 2002. Numbers in red circles indicate calculated loads in the Assiniboine River and values in blue boxes indicate loads from tributaries and effluents.

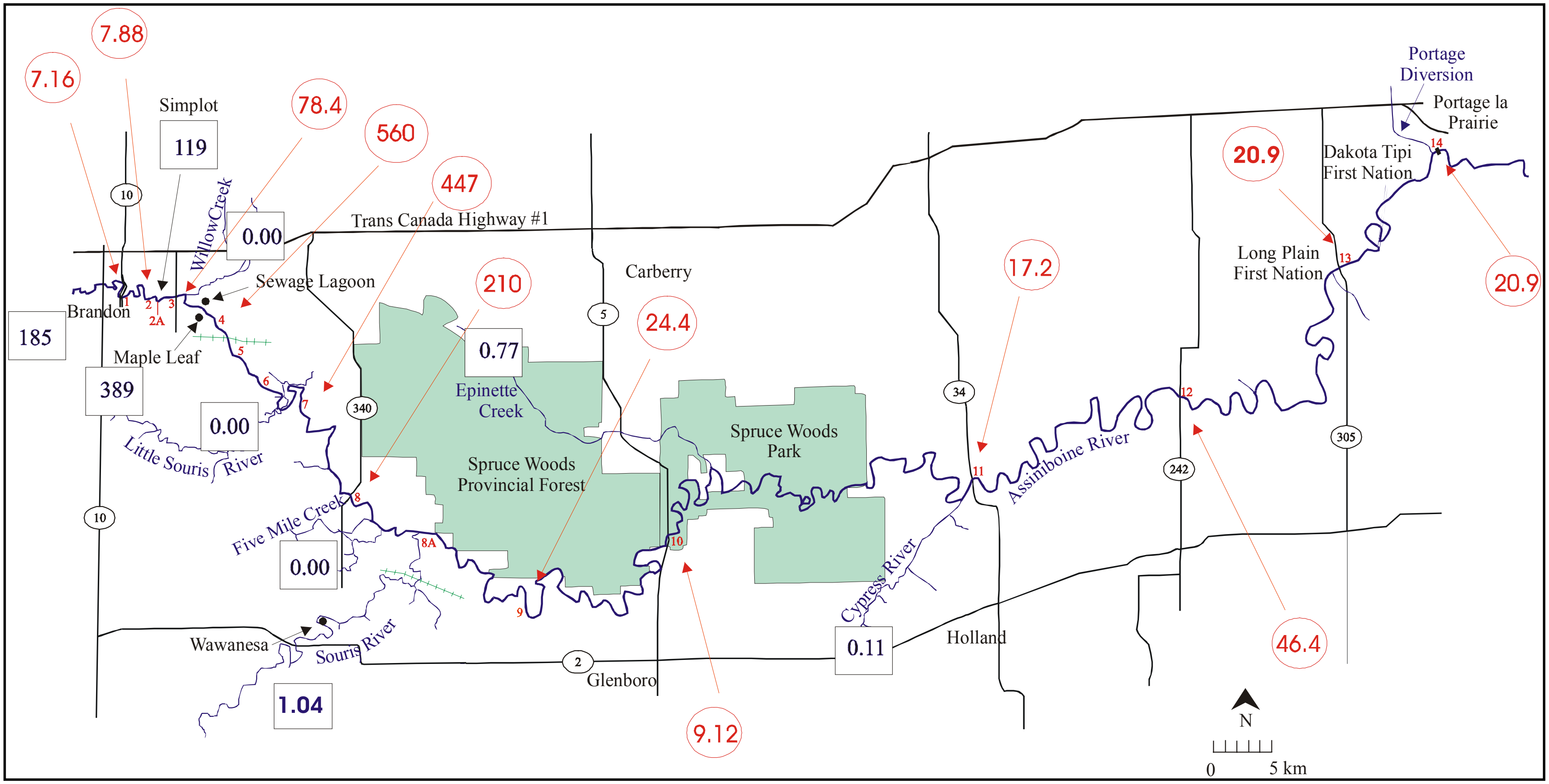

Figure 22. Dissolved inorganic nitrogen loads (kg/day) in the Assiniboine River and various tributaries and effluent, August/September 2002. Numbers in red circles indicate calculated loads in the Assiniboine River and values in blue boxes indicate loads from tributaries and effluents.

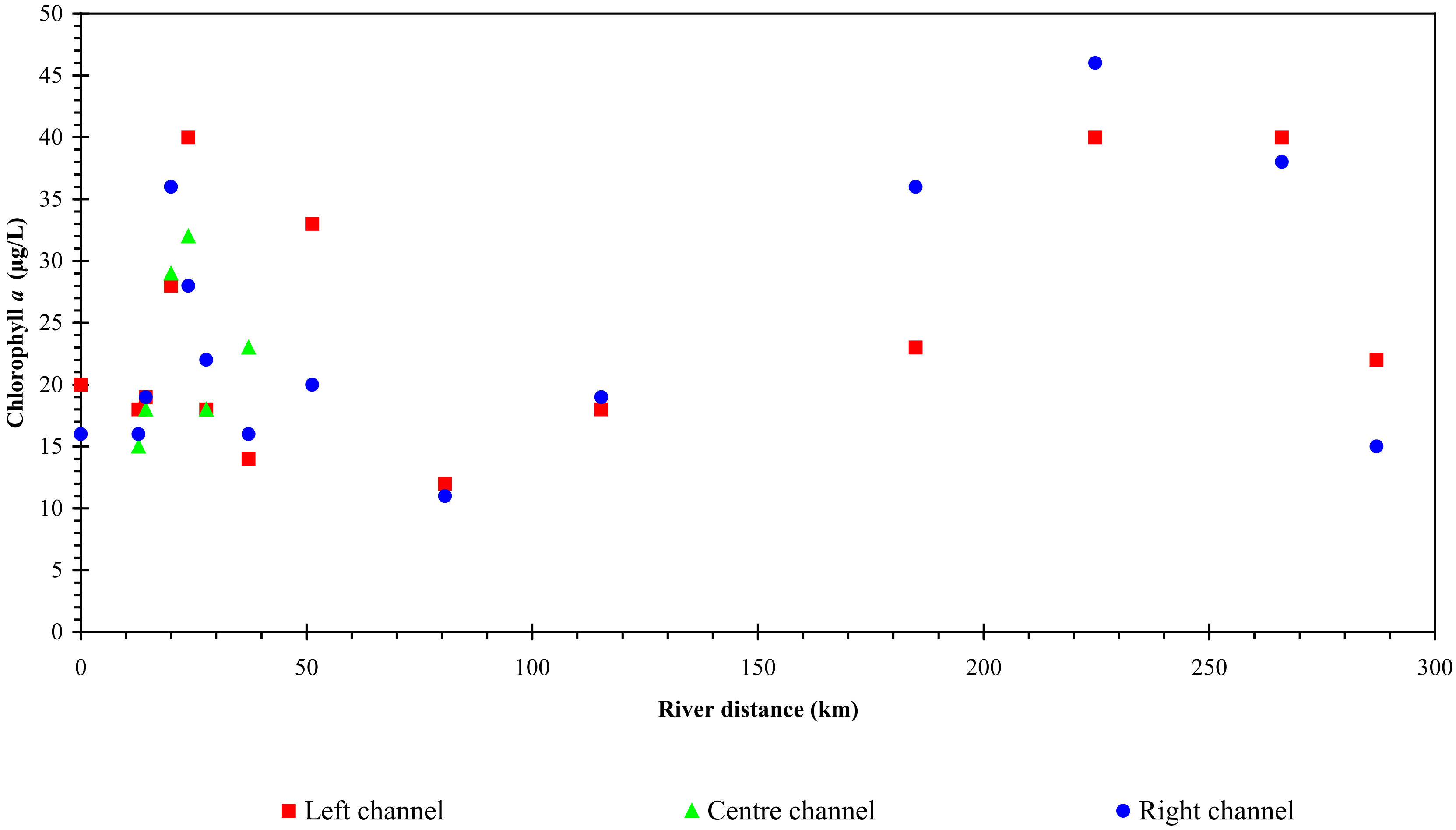

Figure 23. Chlorophyll *a* concentrations measured in the Assiniboine River in June 2002. Site 1 (0 km) is the Brandon 18th St. Bridge; site 14 (287 km) is the Portage la Prairie Reservoir.

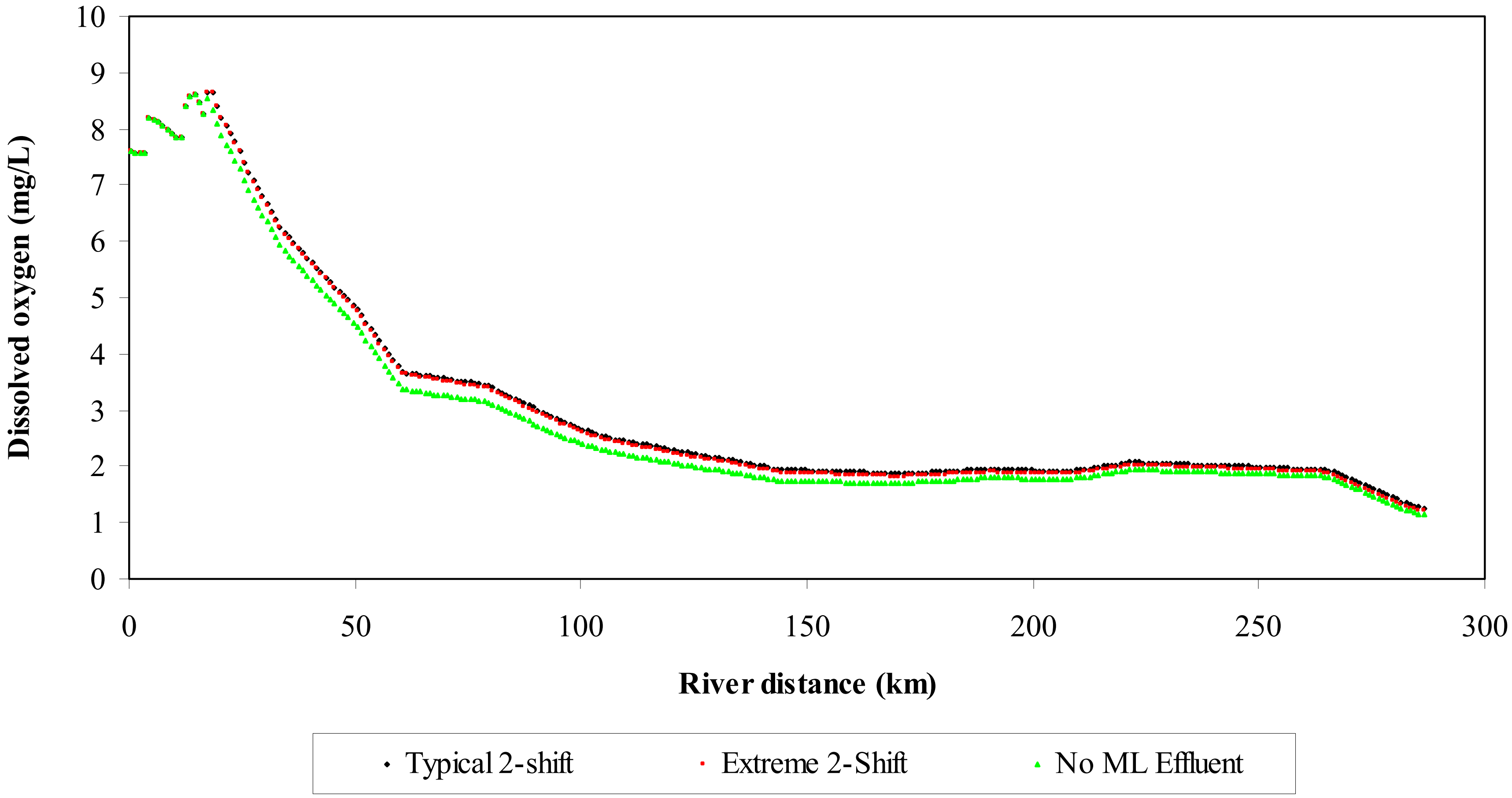

Figure 24. Simulated dissolved oxygen concentrations in the Assiniboine River for March, under 7Q10 flows, and 'typical 2-shift IWWTF effluent', 'extreme 2-shift IWWTF effluent', and in the absence of discharge from the IWWTF.

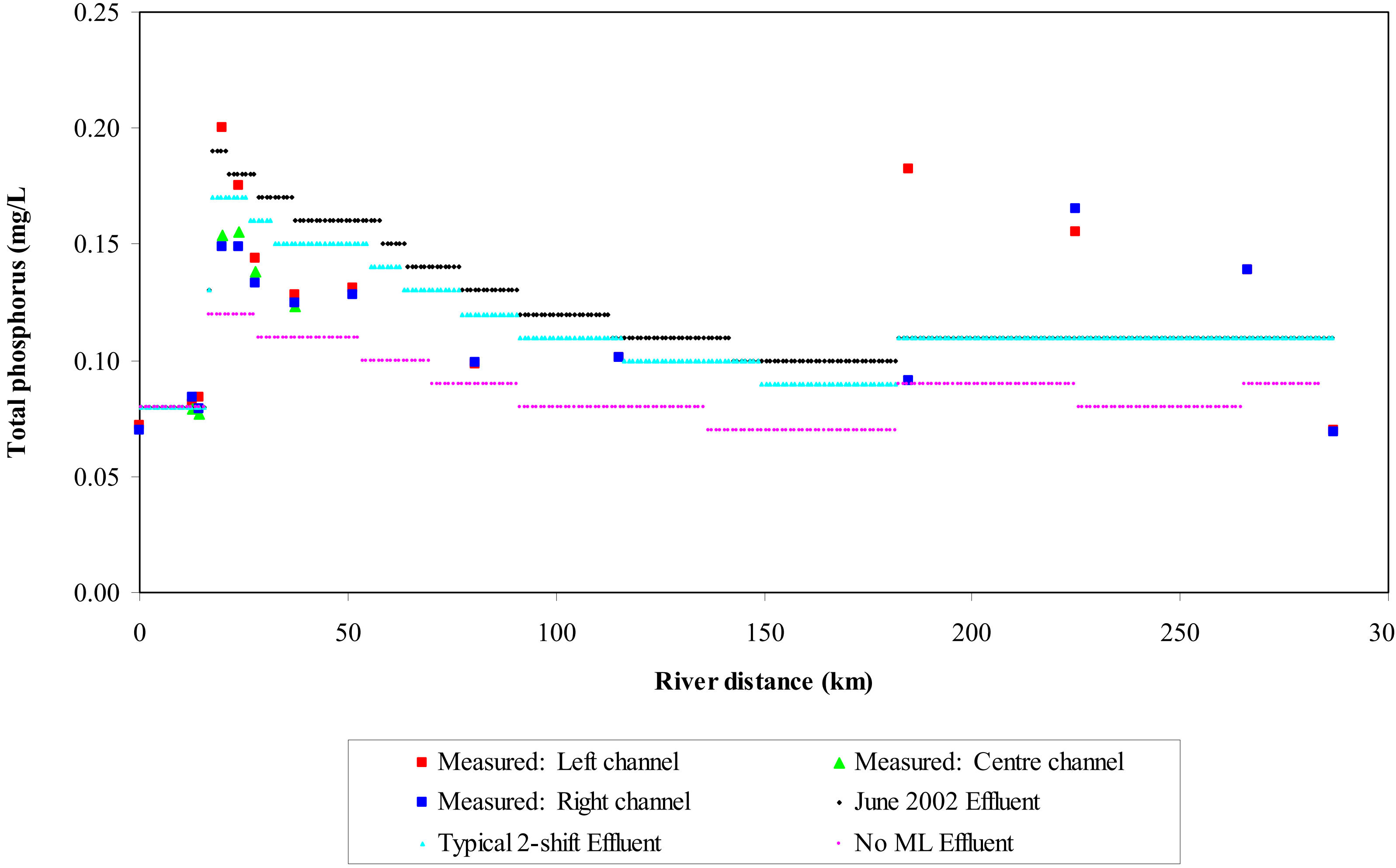

Figure 25. Simulated total phosphorus as a mass-balance using June 2002 ML IWWTF effluent, projected 2-shift IWWTF effluent, and with no discharge from ML IWWTF. Model settings, including other loads, are consistent with the June 2002 model (Cooley et al. 2003).

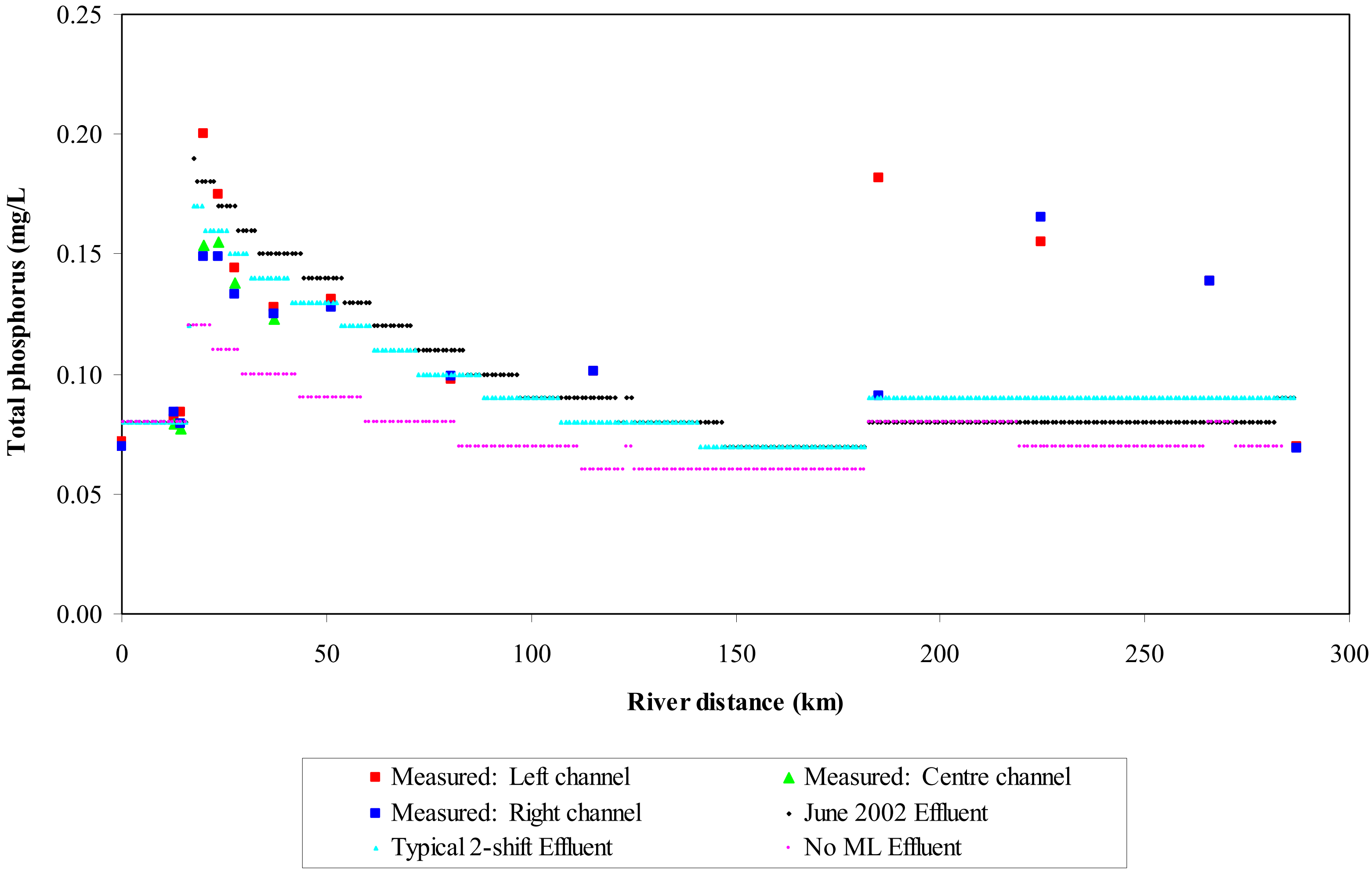

Figure 26. Simulated total phosphorus, with nutrients and algae simulated, using June 2002 ML IWWTF effluent, projected 2-shift IWWTF effluent, and with no discharge from ML IWWTF. Model settings, including other loads, are consistent with the June 2002 model (Cooley et al. 2003).

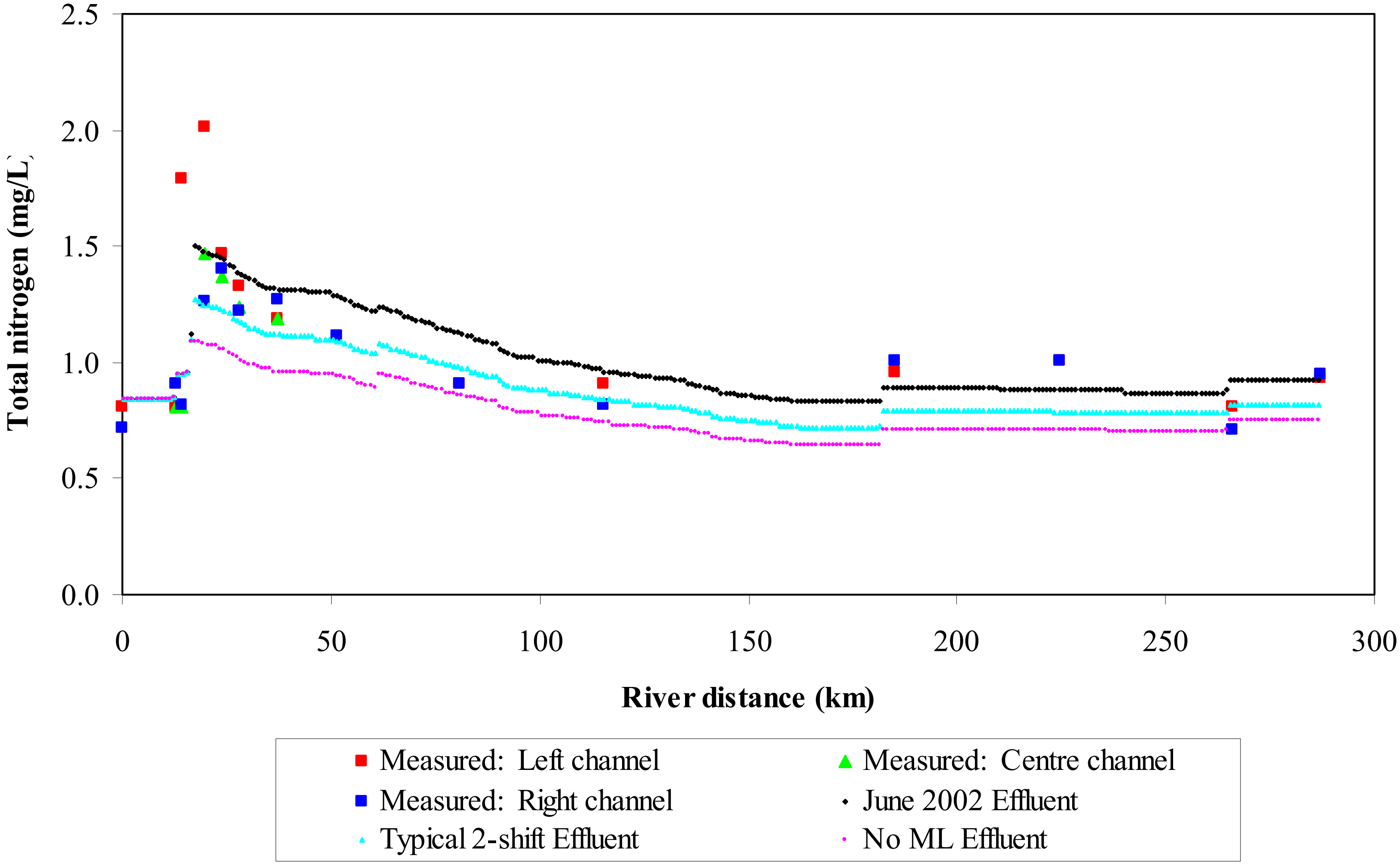

Figure 27. Simulated total nitrogen as a mass-balance using June 2002 ML IWWTF effluent, projected 2-shift IWWTF effluent, and with no discharge from ML IWWTF. Model settings, including other loads, are consistent with the June 2002 model (Cooley et al. 2003).

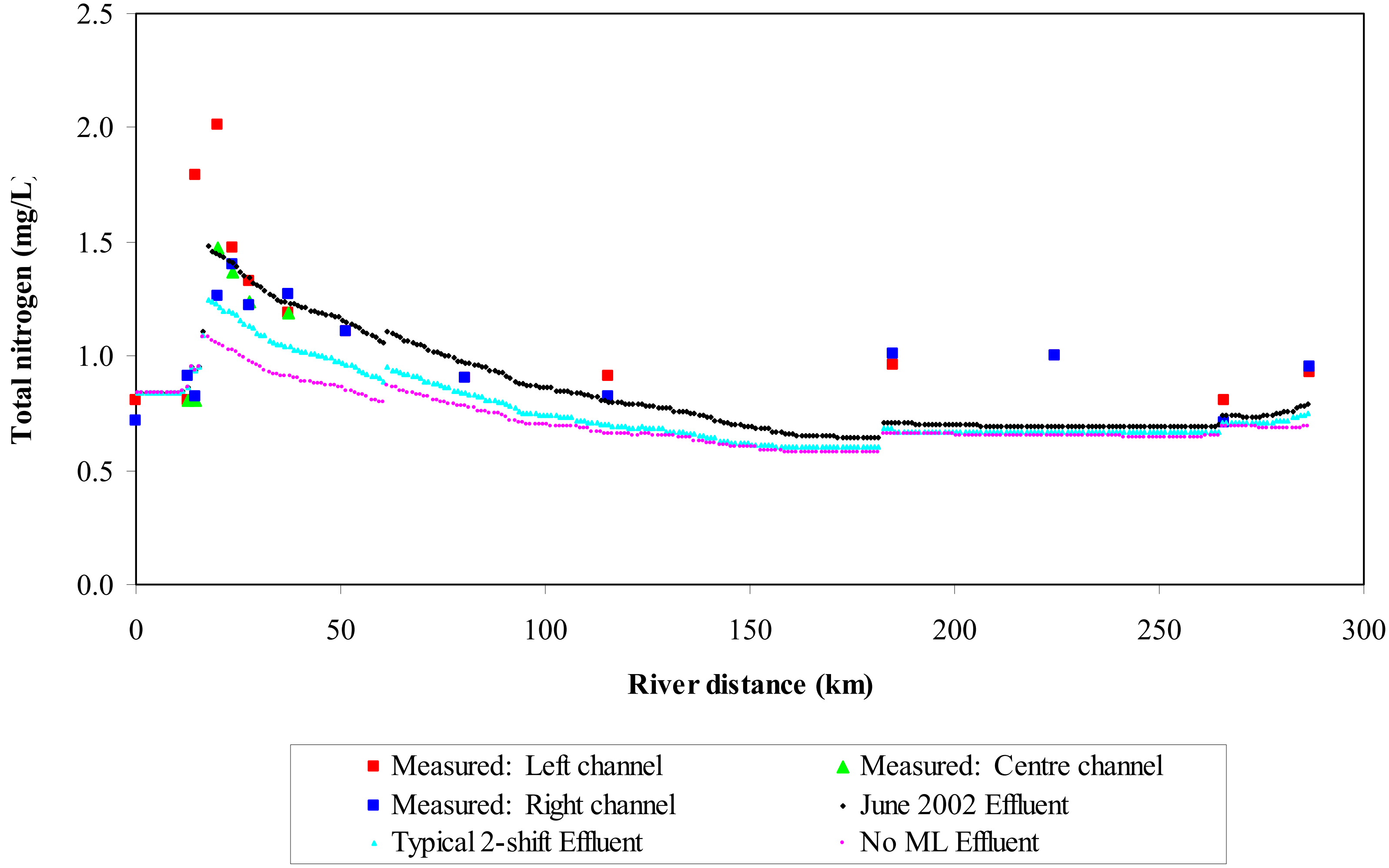

Figure 28. Simulated total nitrogen, with nutrients and algae simulated, using June 2002 ML IWWTF effluent, projected 2-shift IWWTF effluent, and with no discharge from ML IWWTF. Model settings, including other loads, are consistent with the June 2002 model (Cooley et al. 2003).

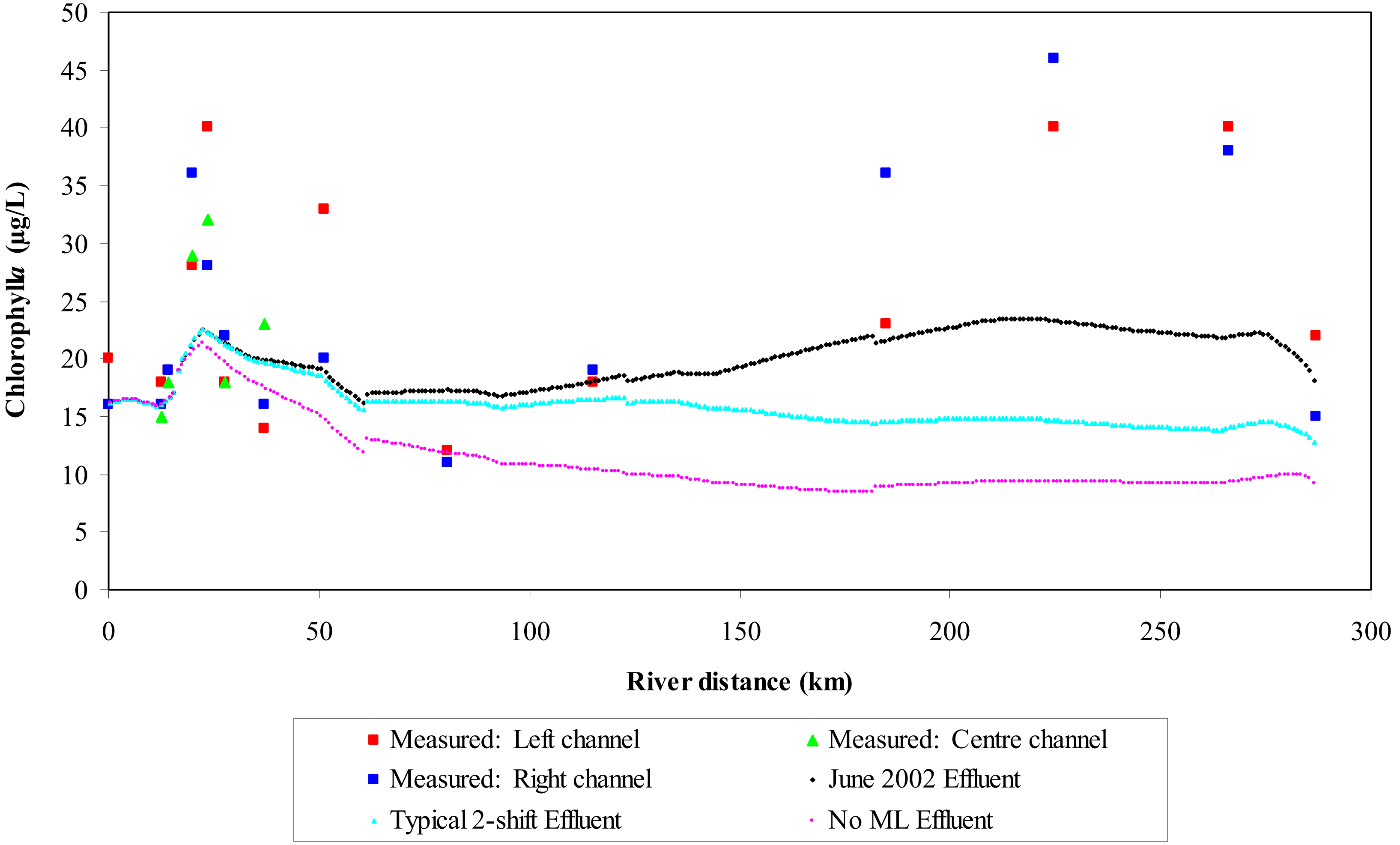

Figure 29. Simulated chlorophyll *a* using June 2002 ML IWWTF effluent, projected 2-shift IWWTF effluent, and with no discharge from ML IWWTF. Model settings, including other loads, are consistent with the June 2002 model (Cooley et al. 2003).

Appendix 1

Monthly statistical summaries for water chemistry data collected by MB Conservation in the Assiniboine River at the 18th Street Bridge, Brandon.

Table 1-1. Statistical monthly summaries of water temperature (°C) measured in the Assiniboine River at Brandon's 18th St. Bridge, using data collected April 1991 to March 2001. Data provided by Manitoba Conservation (MB Conservation 2002).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
mean:	0.0	0.0	0.0	1.1	10.8	18.9	19.9	21.5	17.3	10.2	2.0	0.0
SE:	0.00	0.00	0.00	0.49	0.86	0.87	0.48	0.41	0.63	0.60	0.67	0.00
median:	0.0	0.0	0.0	0.5	10.8	19.0	19.8	21.0	17.8	10.0	2.3	0.0
min:	0.0	0.0	0.0	0.0	6.0	15.0	18.0	20.0	13.7	8.0	0.0	0.0
max:	0.0	0.0	0.0	5.0	14.0	23.0	22.5	24.0	20.0	13.5	7.0	0.0
n[1]:	9	10	10	10	10	10	10	10	10	10	10	10

[1] Temperature was measured once per month except in January 2001 when no measurement was taken.

Table 1-2. Statistical monthly summaries of conductivity (µS/cm) measured in the Assiniboine River at Brandon's 18th St. Bridge, using data collected August 1992 to July 2002. Data provided by Manitoba Conservation (MB Conservation 2002).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
mean:	1114.0	1080.4	1073.0	752.7	781.6	966.7	893.8	886.1	938.7	941.0	1052.9	1127.4
SE:	44.18	29.27	26.91	53.95	63.72	59.07	53.17	40.84	39.69	32.14	40.76	41.70
median:	1105.0	1090.0	1075.0	760.0	755.0	954.0	910.0	872.0	921.5	896.5	996.5	1120.0
min:	926	953	967	461	403	603	675	703	775	831	910	964
max:	1420	1240	1239	1010	1090	1360	1240	1140	1110	1140	1340	1430
n[1]:	10	10	10	10	10	10	10	10	10	10	10	10

[1] Samples were collected once per month. Exceptions include 4 July 1994 when 3 samples were collected, and 5 November 2001 when 2 samples were collected. Averages for these dates were used in statistical calculations.

Table 1-3. Statistical monthly summaries of pH (*in situ*) measured in the Assiniboine River at Brandon's 18th St. Bridge, using data collected April 1991 to March 2001. Data provided by Manitoba Conservation (MB Conservation 2002).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
mean:	8.03	7.93	7.93	8.02	8.21	8.32	8.28	8.38	8.47	8.47	8.41	8.15
SE:	0.033	0.046	0.052	0.064	0.054	0.046	0.059	0.083	0.040	0.038	0.023	0.055
median:	8.00	7.93	7.93	8.00	8.20	8.30	8.25	8.30	8.45	8.45	8.40	8.15
min:	7.95	7.75	7.70	7.80	7.85	8.10	7.85	8.01	8.35	8.35	8.30	7.95
max:	8.20	8.20	8.25	8.50	8.45	8.50	8.50	8.80	8.70	8.70	8.55	8.45
n[1]:	9	10	10	10	10	9	10	10	10	10	10	10

[1] pH was measured once per month. Exceptions include January 2000 and June 1997 when no readings were taken.

Table 1-4. Statistical monthly summaries of total nitrogen (mg/L), estimated as the sum of total Kjeldahl nitrogen and nitrate/nitrite measured in the Assiniboine River at Brandon's 18th St. Bridge, using data collected August 1992 to July 2002. Data provided by Manitoba Conservation (MB Conservation 2002).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
mean:	1.7	1.2	1.4	1.9	1.2	1.1	1.0	1.3	1.2	1.2	1.0	1.1
SE:	0.54	0.07	0.16	0.34	0.11	0.11	0.11	0.07	0.09	0.09	0.05	0.09
median:	1.2	1.2	1.3	1.6	1.1	0.9	1.1	1.3	1.2	1.2	1.0	1.1
min:	1.0	0.8	0.9	0.6	0.6	0.7	0.4	0.9	0.8	0.8	0.8	0.5
max:	6.6	1.5	2.6	4.4	1.8	1.7	1.4	1.7	1.5	1.8	1.2	1.6
n[1]:	10	10	10	10	10	10	10	10	10	10	10	10

[1] Samples were collected once per month. Exceptions include 4 July 1994 when 3 samples were collected, and 5 November 2001 when 2 samples were collected. Averages for these dates were used in statistical calculations.

Table 1-5. Statistical monthly summaries of nitrate/nitrite (mg/L) measured in the Assiniboine River at Brandon's 18th St. Bridge, using data collected August 1992 to July 2002. Data provided by Manitoba Conservation (MB Conservation 2002).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
mean:	0.23	0.32	0.40	0.64	0.08	0.05	0.14	0.21	0.09	0.04	0.08	0.17
SE:	0.023	0.030	0.030	0.154	0.031	0.019	0.031	0.045	0.031	0.025	0.025	0.021
median:	0.22	0.32	0.39	0.55	0.03	0.03	0.16	0.19	0.04	0.01	0.04	0.18
min:	0.13	0.17	0.26	<0.01	<0.01	<0.01	0.01	0.03	<0.01	<0.01	<0.01	0.08
max:	0.34	0.45	0.58	1.50	0.27	0.20	0.30	0.45	0.30	0.26	0.18	0.28
n[1]:	10	10	10	10	10	10	10	10	10	10	10	10

[1] Samples were collected once per month. Exceptions include 4 July 1994 when 3 samples were collected, and 5 November 2001 when 2 samples were collected. Averages for these dates were used in statistical calculations.

Table 1-6. Statistical monthly summaries of ammonia (mg/L) measured in the Assiniboine River at Brandon's 18th St. Bridge, using data collected August 1992 to July 2002. Data provided by Manitoba Conservation (MB Conservation 2002).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
mean:	0.09	0.08	0.05	0.10	0.03	0.03	0.05	0.03	0.03	0.04	0.02	0.06
SE:	0.015	0.011	0.005	0.031	0.006	0.006	0.010	0.006	0.005	0.021	0.003	0.011
median:	0.08	0.07	0.05	0.07	0.03	0.04	0.05	0.03	0.02	0.02	0.02	0.04
min:	0.04	0.04	0.04	<0.01	<0.005	<0.01	0.02	<0.01	<0.02	<0.01	<0.02	0.01
max:	0.22	0.16	0.08	0.31	0.06	0.06	0.12	0.07	0.05	0.22	0.05	0.11
n[1]:	10	10	10	10	10	10	10	10	10	10	10	10

[1] Samples were collected once per month. Exceptions include 4 July 1994 when 3 samples were collected, and 5 November 2001 when 2 samples were collected. Averages for these dates were used in statistical calculations.

Table 1-7. Statistical monthly summaries of total phosphorus (mg/L) measured in the Assiniboine River at Brandon's 18th St. Bridge, using data collected August 1992 to July 2002. Data provided by Manitoba Conservation (MB Conservation 2002).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
mean:	0.11	0.10	0.11	0.26	0.17	0.15	0.22	0.18	0.17	0.15	0.13	0.11
SE:	0.009	0.007	0.017	0.058	0.028	0.020	0.023	0.016	0.023	0.016	0.009	0.012
median:	0.11	0.10	0.09	0.23	0.20	0.14	0.22	0.19	0.16	0.15	0.12	0.10
min:	0.08	0.07	0.07	0.07	0.05	0.09	0.11	0.10	0.08	0.11	0.09	0.08
max:	0.17	0.13	0.26	0.65	0.28	0.26	0.34	0.28	0.30	0.27	0.19	0.21
n[1]:	10	10	10	10	10	10	10	10	10	10	10	10

[1] Samples were collected once per month. Exceptions include 4 July 1994 when 3 samples were collected, and 5 November 2001 when 2 samples were collected. Averages for these dates were used in statistical calculations.

Table 1-7. Statistical monthly summaries of dissolved oxygen (mg/L) measured in the Assiniboine River at Brandon's 18th St. Bridge, using data collected August 1992 to July 2002. Data provided by Manitoba Conservation (MB Conservation 2002).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
mean:	8.6	7.1	7.5	9.0	9.1	7.6	7.2	6.6	8.1	9.3	12.1	11.2
SE:	0.38	0.64	0.43	0.55	0.31	0.29	0.32	0.18	0.27	0.61	0.30	0.52
median:	8.8	6.8	7.7	9.1	9.3	7.6	7.1	6.6	7.9	9.6	12.3	10.7
min:	6.2	4.4	4.9	6.0	7.4	5.9	5.5	5.8	7.2	4.5	10.3	9.0
max:	10.3	11.0	9.4	12.3	10.2	9.1	8.4	7.8	10.2	12.1	13.3	14.9
n[1]:	10	10	10	9	9	10	10	10	10	10	10	10

[1] Samples were collected once per month. Exceptions include 4 July 1994 when 3 samples were collected, and 5 November 2001 when 2 samples were collected. Averages for these dates were used in statistical calculations. Concentrations were not measured in samples collected April 2001 and May 1995.

Table 1-8. Statistical monthly summaries of total suspended solids (mg/L) measured in the Assiniboine River at Brandon's 18th St. Bridge, using data collected August 1992 to July 2002. Data provided by Manitoba Conservation (MB Conservation 2002).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
mean:	20.3	19.3	16.9	57.2	97.4	61.7	131.7	76.7	47.0	39.1	30.2	19.9
SE:	4.44	3.98	3.14	22.20	34.27	15.05	25.98	17.11	8.13	6.37	5.44	8.17
median:	16.0	16.0	18.5	27.0	58.0	40.0	148.5	70.5	41.0	40.0	31.5	13.0
min:	5	5	<5	<5	2	8	25	11	18	<5	<5	6
max:	46	41	35	220	340	130	280	160	85	75	59	93
n[1]:	10	10	10	10	10	10	10	10	10	10	10	10

[1] Samples were collected once per month. Exceptions include 4 July 1994 when 3 samples were collected, and 5 November 2001 when 2 samples were collected. Averages for these dates were used in statistical calculations.

Appendix 2

Predictive Water Quality Simulations: Ice-Cover

ICE-COVER SIMULATIONS

A water quality model of the Assiniboine River for the ice-cover season was developed using the Enhanced Stream Water Quality Model version 3 (QUAL2E), which is supported and distributed by the United States Environmental Protection Agency (USEPA) (Cooley et al 2001a). This report describes predictive water quality modeling for the ice-cover season conducted to assist in the assessment of potential effects of the expansion of the Maple Leaf IWWTF. Parameters of interest during the ice-cover season are ammonia and dissolved oxygen.

Model simulations were conducted using the previously developed model applied to flow conditions in March (the winter month with generally the lowest flows) and median background water quality conditions (Cooley et al 2001a). Flows, effluent quality and other parameters used in the simulations are listed below.

Water quality simulations were conducted using three scenarios:

- projected typical effluent from the expansion of the IWWTF for second shift operation and other effluents (i.e., Simplot Canada fertilizer plant and City of Brandon municipal WWTF);

- projected extreme (worst case) effluent from the expansion of the IWWTF for second shift operation with other effluents; and

- other effluents alone (i.e., no effluents from the IWWTF).

River Discharge

Each scenario was modeled under 1Q10, 7Q10, and 30Q10 flows (Table 2-1), to correspond with objectives in the MWQSOGs (Williamson 2002).

Under 1Q10 and 7Q10 discharge conditions, the Assiniboine River was the main headwater source in model simulations. The Souris River was included along with the Assiniboine River in the 30Q10 simulations, as river discharge was significant under these conditions.

Water Quality

The initial water quality conditions in the Assiniboine and Souris rivers were obtained from summary statistics generated for the month of March over a ten-year period of record (1993-2002, Manitoba Conservation data) (Table 2-2). Median values were used for background water quality in the simulations.

Effluent Quality and Discharge

Data for the predicted effluent quality and discharge for the expanded IWWTF were provided by W. Sneed (HDR Engineering Inc.), data for the municipal WWTF were provided by I. Christiansen (City of Brandon), and effluent quality for the Simplot Canada fertilizer plant was based on licence limits (Tables 2-3 to A2-6) Two effluent conditions are provided for the IWWTF: “typical” effluent and “extreme” effluent, the latter corresponding to poorer effluent quality that would normally occur quite sporadically. Values for some parameters for the “extreme” IWWTF and the municipal WWTF effluents varied with the river flows to correspond to various water quality objectives (i.e., 1-day, 7-day and 30-day averaging duration).

Where information for specific parameters was not available, loads were estimated from data collected during the February 2000 sampling period (Cooley et al. 2001a). .

Re-Aeration and Nitrification Coefficients

Segment re-aeration rates were entered into segments known to contain open water (i.e., segments 7, 10, and 11), and all other segments were assumed to be under full ice-cover (i.e., no re-aeration) (Table 2-7)

Nitrification rates (i.e. ammonia decay) are the major kinetic constant for the ammonia model. The final rates of 0.3 and 0.9/day (at 20 C), with a temperature correction factor of 1.08, are rates that were adopted by Cooley et al. (2001a) and used in this simulation (Table 2-8).

Results of Simulations

Results of simulations are presented in figures A2-1 – A2-3 (dissolved oxygen) and figures A2-4 – A2-6 (ammonia) and are discussed in the main body of this report. In these figures “typical 2-shift” refers to the normal effluent quality expected from the expanded IWWTF, “extreme 2-shift” refers to poorer effluent quality that would be expected to occur sporadically, and “no ML effluent” refers to the effects of the municipal and Simplot effluents alone (i.e., no effluent from the IWWTF).

Table A2-1. Discharge rates in the Assiniboine River at the Brandon 18th Street Bridge and in the Souris River at PR 530 near Treesbank. Data provided by Manitoba Conservation, Water Quality Management Section.[1]

	1Q10 m^3/s	7Q10 m^3/s	30Q10 m^3/s
Assiniboine River	2.41	2.85	5.357
Souris River	-	-	0.001

[1] Discharge for the Assiniboine River at the 18th Street Bridge in Brandon is a corrected flow, incorporating withdrawal by the Brandon water treatment plant.

Table 2-2. Median values for water quality in March for the period 1993-2002 used as initial headwater conditions for the upstream end of the Assiniboine River at the Brandon 18th Street Bridge and the Souris River at PR 530 near Treesbank. Data provided by Manitoba Conservation, Water Quality Management Section.

	Ammonia mg/L	Organic N mg/L	Nitrate mg/L	TKN mg/L	TN mg/L	Organic P [1] mg/L	Dissolved P mg/L	TP mg/L	DO mg/L	BOD mg/L
Assiniboine River	0.050	0.88	0.39	0.92	1.26	0.017	0.072	0.089	7.65	2.5
Souris River	0.16	1.72	0.89	1.95	2.94	0.13	0.21	0.34	7.55	-

[1] Organic P estimated as the difference between Total P and Dissolved P

Table 2-3. Effluent quality for typical effluent from the expanded Maple Leaf IWWTF at 1Q10, 7Q10, and 30Q10 flows.

	Flow cms	Ammonia mg/L	Organic N mg/L	Nitrate mg/L	TKN mg/L	TN mg/L	Organic P mg/L	Dissolved P [1] mg/L	TP mg/L	DO [2] mg/L	BOD mg/L
1Q10	0.0801	0.36	0.81	21.9	1.17	23.1	0.29	6.1	6.39	5	5.06
7Q10	0.0801	0.36	0.81	21.9	1.17	23.1	0.29	6.1	6.39	5	5.06
30Q10	0.0801	0.36	0.81	21.9	1.17	23.1	0.29	6.1	6.39	5	5.06

[1] Estimated as the difference between TP and organic P.

[2] DO value estimated from February 2000 sampling period

Table 2-4. Effluent quality for expanded IWWTF 'extreme case scenario' at 1Q10, 7Q10, and 30Q10 flows.

	Flow cms	Ammonia mg/L	Organic N mg/L	Nitrate mg/L	TKN mg/L	TN mg/L	Organic P mg/L	Dissolved P[1] mg/L	TP mg/L	DO[2] mg/L	BOD mg/L
1Q10	0.0801	5	0.63	31	-	42.1	0.4	11.6	11.9	5	15.5
7Q10	0.0801	0.36	0.63	31	-	31.6	0.4	7.7	8.0	5	9.9
30Q10	0.0801	0.36	0.63	31	-	25.3	0.4	6.5	6.8	5	6.4

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[1] Dissolved P calculated as the difference between TP and organic P.

[2] DO value estimated from February 2000 sampling period

Table 2-5. Effluent quality for projected Municipal WWTF operation at 1Q10, 7Q10, and 30Q10 flows.

	Flow Cms	Ammonia mg/L	Organic N mg/L	Nitrate mg/L	TKN mg/L	TN mg/L	Organic P [1] mg/L	Dissolved P [1] mg/L	TP mg/L	DO [2] mg/L	BOD mg/L
1Q10	0.417	11	3	32	14	46	0.8	7.2	8	1.5	30
7Q10	0.260	6	2	16	8	24	0.7	6.3	7	1.5	15
30Q10	0.243	3	2	12	5	17	0.6	5.4	6	1.5	15

[1] Organic P estimated as the difference between TP and Dissolved P; Dissolved P estimated as 90% of the TP concentrations provided by the City of Brandon (based on measured ratios for July and August, 2002)

[2] DO value estimated as an average based on concentrations provided by the City of Brandon

Table 2-6. Effluent quality (based on license limits) for Simplot Canada at 1Q10, 7Q10, and 30Q10 flows.

	Flow Cms	Ammonia mg/L	Organic N mg/L	Nitrate [1] mg/L	TKN mg/L	TN mg/L	Organic P mg/L	Dissolved P [4] mg/L	TP mg/L	DO [2] mg/L	BOD [2] mg/L
1Q10	0.13	10.68	-	7.48	-	18.16	-	-	1.78	10.96	3
7Q10	0.13	10.68	-	7.48	-	18.16	-	-	1.78	10.96	3
30Q10	0.13	10.68	-	7.48	-	18.16	-	-	1.78	10.96	3

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[1] Nitrates are estimated from the difference between total nitrogen and ammonia, assuming no organic nitrogen

[2] Values measured in February 2000; includes combined effluent from MB Hydro Ash Lagoon and Simplot Canada Ltd.

Table 2-7. Values for segment-specific re-aeration coefficients for predictive model simulations during the ice-cover season

River Reach	start km	end km	Number of computational elements	Re-aeration coefficient (day^{-1})	Sites of re-aeration
1	287	286	1	0.05	
2	286	282	4	0.05	
3	282	281	1	0.05	
4	281	277	4	0.05	
5	277	275	2	0.05	
6	275	274	1	0.05	
7	274	273	1	0.50	Plume downstream of ditch receiving MB Hydro Ash Lagoon/Simplot Canada effluents
8	273	272	1	0.05	
9	272	271	1	0.05	
10	271	270	1	2.00	Plume downstream of Brandon SBR Cell 5 outfall
11	270	269	1	1.00	Plume downstream of ML WWTF outfall
12	269	268	1	0.05	
13	268	267	1	0.05	
14	267	266	1	0.05	
15	266	265	1	0.05	
16	265	264	1	0.05	
17	264	263	1	0.05	
18	263	262	1	0.05	
19	262	260	2	0.05	
20	260	252	8	0.05	
21	252	236	16	0.05	
22	236	226	10	0.05	
23: Souris	3	0	3	0.05	
24	226	207	19	0.05	
25	207	197	10	0.05	
26	197	193	4	0.05	
27	193	179	14	0.05	
28	179	172	7	0.05	
29	172	152	20	0.05	
30	152	143	9	0.05	
31	143	124	19	0.05	
32	124	116	8	0.05	
33	116	96	20	0.05	
34	96	85	11	0.05	
35	85	78	7	0.05	
36	78	64	14	0.05	
37	64	63	1	0.05	
38	63	43	20	0.05	
39	43	23	20	0.05	
40	23	21	2	0.00	Model calibration
41	21	13	8	0.00	Model calibration
42	13	4	9	0.00	Model calibration
43	4	1	3	0.00	Model calibration
44	1	0	1	0.00	Model calibration

Table 2-8. Values for reach-specific biochemical oxygen demand (BOD) decay and nitrification rates used for predictive model simulations in the ice-cover season.

River Reach	start km	end km	Number of computational elements	Nitrification Rate (day^{-1}) at 20 °C	BOD decay rate at 20 °C
1	287	286	1	0.3	0.3
2	286	282	4	0.3	0.3
3	282	281	1	0.3	0.3
4	281	277	4	0.3	0.3
5	277	275	2	0.3	0.3
6	275	274	1	0.3	0.3
7	274	273	1	0.3	0.3
8	273	272	1	0.3	0.3
9	272	271	1	0.3	0.3
10	271	270	1	0.9	0.3
11	270	269	1	0.9	0.3
12	269	268	1	0.9	0.3
13	268	267	1	0.9	0.3
14	267	266	1	0.9	0.3
15	266	265	1	0.9	0.3
16	265	264	1	0.9	0.3
17	264	263	1	0.9	0.3
18	263	262	1	0.9	0.3
19	262	260	2	0.9	0.3
20	260	252	8	0.9	0.3
21	252	236	16	0.9	0.3
22	236	226	10	0.9	0.3
23: Souris River	3	0	3	0.9	0.3
24	226	207	19	0.9	0.3
25	207	197	10	0.9	0.3
26	197	193	4	0.9	0.3
27	193	179	14	0.9	0.3
28	179	172	7	0.9	0.3
29	172	152	20	0.3	0.3
30	152	143	9	0.3	0.3
31	143	124	19	0.3	0.3
32	124	116	8	0.3	0.3
33	116	96	20	0.3	0.3
34	96	85	11	0.3	0.3
35	85	78	7	0.3	0.3
36	78	64	14	0.3	0.3
37	64	63	1	0.3	0.3
38	63	43	20	0.3	0.3
39	43	23	20	0.3	0.3
40	23	21	2	0.3	0.3
41	21	13	8	0.3	0.3
42	13	4	9	0.3	0.3
43	4	1	3	0.3	0.3
44	1	0	1	0.3	0.3

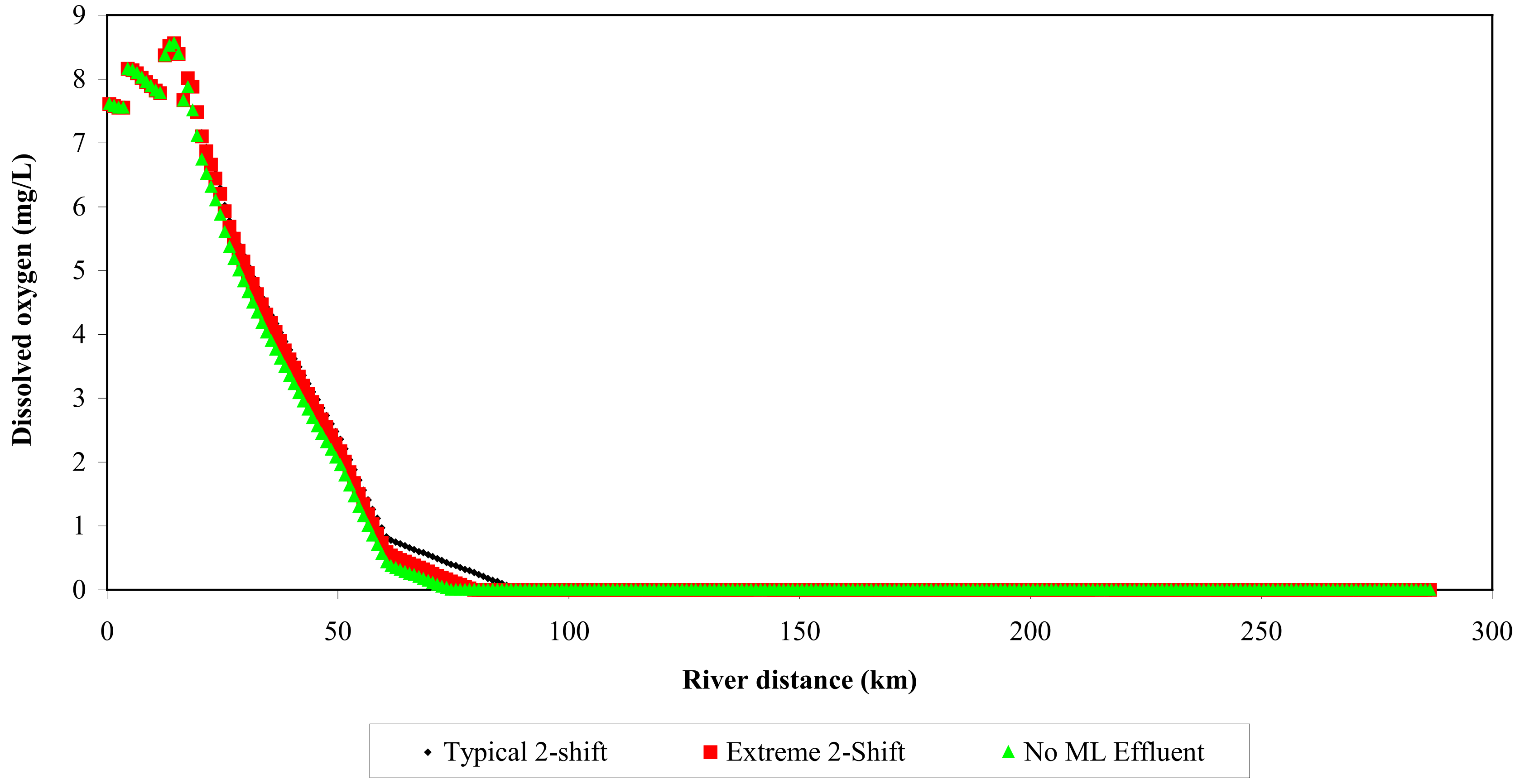

Figure 2.1 Simulated dissolved oxygen (DO) concentrations for March in the Assiniboine River under 1Q10 discharge, with all effluents, and without Maple Leaf 2nd shift effluents.

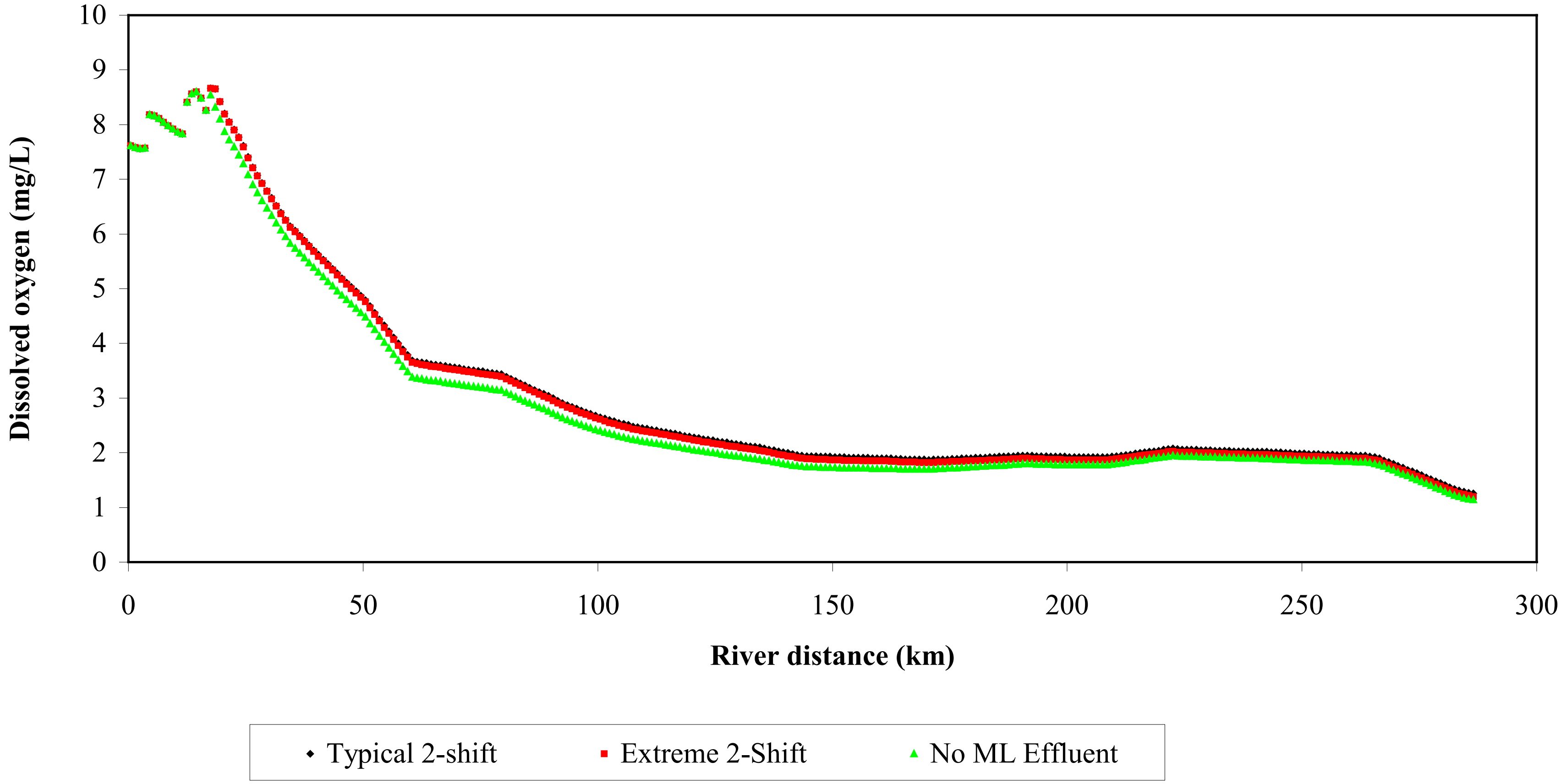

Figure 2.2 Simulated dissolved oxygen (DO) concentrations for March in the Assiniboine River under 7Q10 discharge, with all effluents, and without Maple Leaf 2nd shift effluents.

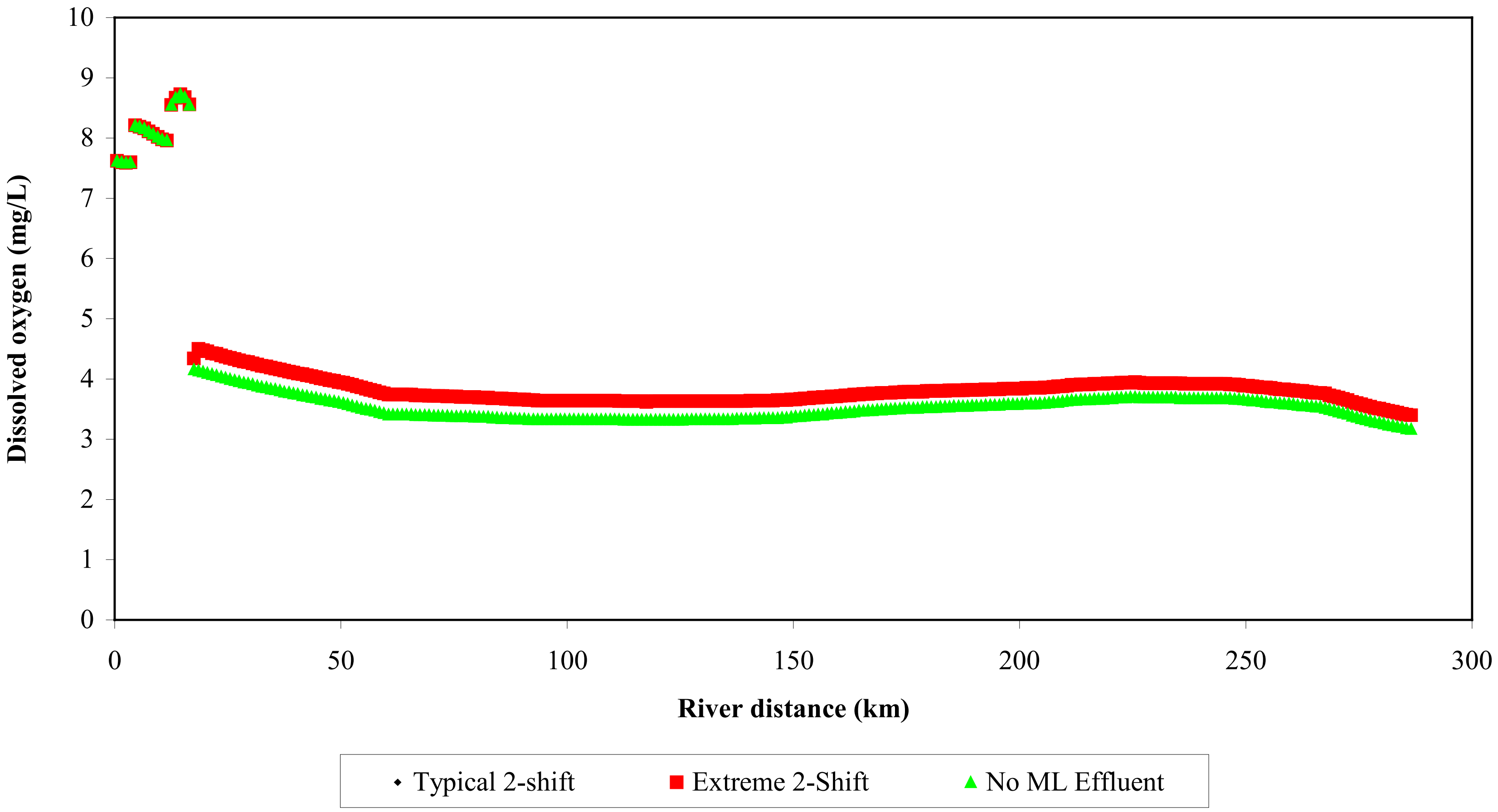

Figure 2.3 Simulated dissolved oxygen (DO) concentrations for March in the Assiniboine River under 30Q10 discharge, with all effluents, and without Maple Leaf 2nd shift effluents.

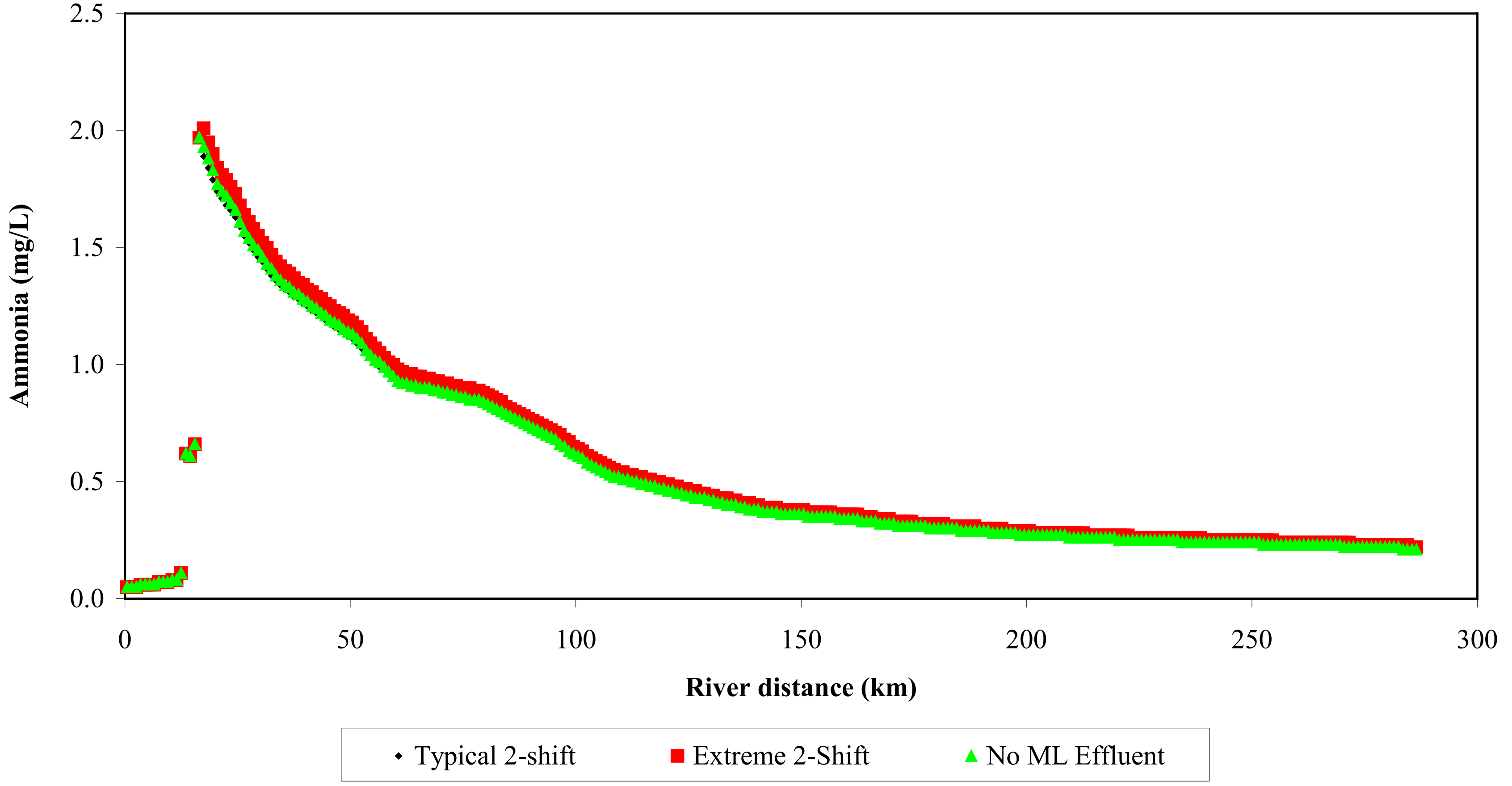

Figure 2.4 Simulated ammonia concentrations for March in the Assiniboine River under 1Q10 discharge, with all effluents, and without Maple Leaf 2nd shift effluents.

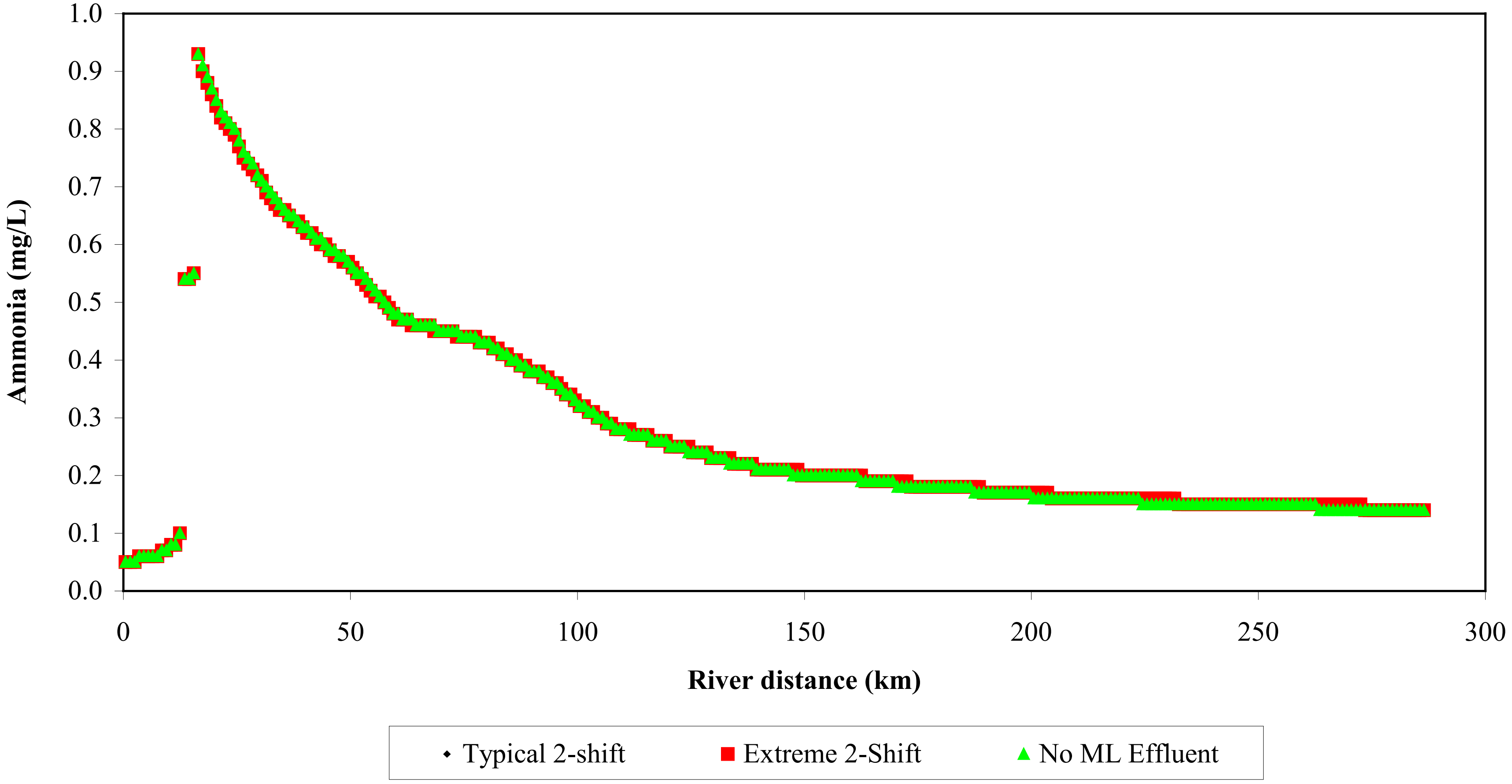

Figure 2.5 Simulated ammonia concentrations for March in the Assiniboine River under 7Q10 discharge, with all effluents, and without Maple Leaf 2nd shift effluents.

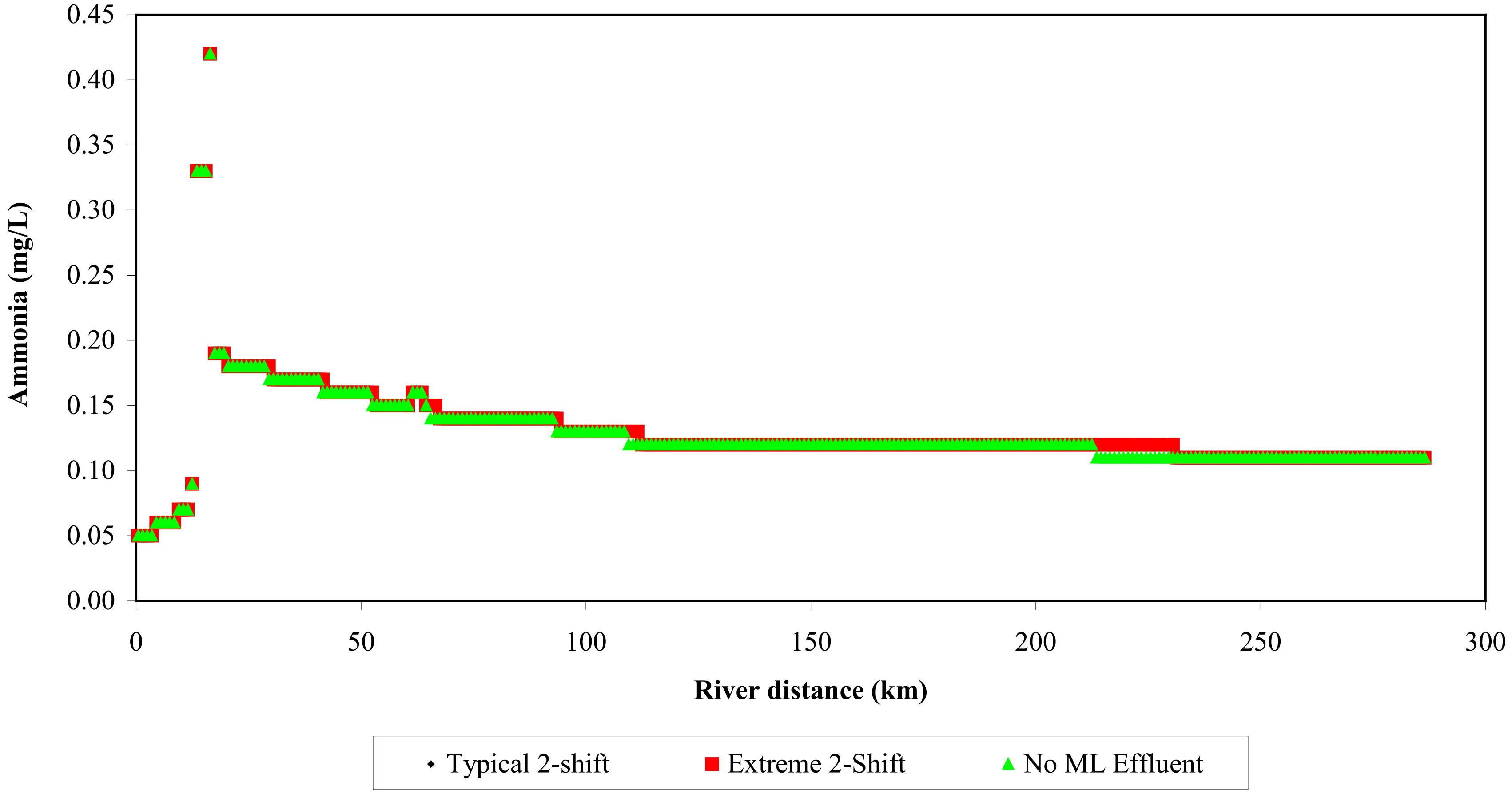

Figure 2.6 Simulated ammonia concentrations for March in the Assiniboine River under 30Q10 discharge, with all effluents, and without Maple Leaf 2nd shift effluents.