PHASE 2 Technical Memorandum for Red and Assiniboine Ammonia Criteria Study

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To: City of Winnipeg Project Management Committee
Study Team Members

Subject: **Other Stressors; Physical Constraints Memorandum # OSPC 01**

Title: **OTHER STRESSORS; PHYSICAL CONSTRAINTS TO FISH POPULATIONS IN THE RED AND ASSINIBOINE RIVERS**

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EXECUTIVE SUMMARY

This report examines physical stressors such as habitat alteration, obstructions to fish passage, and direct causes of fish mortality within the Red and Assiniboine River Ammonia Criteria Study Area, that may influence the fish populations in the Red and Assiniboine rivers, or that may have historically reduced the capacity of the study area to support fish populations. A general understanding of these stressors is important to provide the context for the consideration of ammonia as a stressor on aquatic life.

This document represents a synthesis of information obtained from literature searches, original research conducted as part of the Ammonia Criteria Study, and key person interviews.

Physical stressors that may affect (or that may have affected in the past) fish populations in the Ammonia Criteria Study Area include:

- St. Andrews Lock and Dam: Impoundment of the Red River at Lockport decreases the diversity of aquatic habitat in the study area by reducing water velocities over riffle habitat, and by increasing the deposition of fine sediments over hard substrates. Elevated water levels during the summer prevents the growth of riparian vegetation along the banks of the Red River, eliminating shallow, vegetated habitat along the shorelines, and increasing bank erosion. Despite the presence of a fishway, the structure also appears to block fish migration, particularly under abnormally high or low flow conditions.

- Historical loss of tributary and headwater habitat: Drainage of land in the Red River Valley for agricultural and urban development has reduced the amount of tributary habitat available to the Red and Assiniboine rivers' fish community by eliminating headwater habitat, and by shortening the time period during which tributaries retain water. Impassible dams constructed on tributaries such as Sturgeon Creek and the La Salle River have also reduced tributary habitat in the study area.

- Rip-rap and bank stabilization: Stabilization of riverbanks with rip-rap can eliminate shallow, vegetated habitat along river shorelines. However, the shorelines of the Red River in the study area contain little riparian vegetation due to impoundment of the river during the summer by the St. Andrews Dam, and the rip-rap may increase habitat diversity in the study area by increasing the proportion of coarse substrate in the Red River.

- Bridges, docks, and boat launches: The footprints of structures such as docks and bridge pillars represent a small, direct loss of fish habitat. By providing cover for fish and altering water velocities, however, they may increase the diversity of habitat in the study area.

- Floodway control structure: The floodway control structure on the Red River near the south end of Winnipeg temporarily blocks fish passage during operation.

- Entrainment and impingement of fish in water intakes: Fish mortality can occur in water intakes through the entrainment of small fish in withdrawn water, and through the impingement of fish on intake screens. Forty five licensed water intakes exist within the study area, including that of the Manitoba Hydro Selkirk Thermal Generating Station, which withdraws 98% of the total withdrawn water (based on license allocations). In autumn 1999, a screen designed to prevent the impingement and entrainment of fish longer than 25 mm was installed on the water intake of the Selkirk Thermal Generating Station.

- Thermal effluents: Fish acclimated to warm water temperatures within plumes from thermal discharges can be subject to mortality from thermal shock if water temperatures suddenly decrease. Thermal discharges within the study area include those of the City of Winnipeg Water Pollution Control Centres (WPCCs), and that of the Selkirk Thermal Generating Station, which discharges heated Red River water into Cooks Creek. Manitoba Hydro prevents the occurrence of thermal shock in fish in Cooks Creek by installing a fish fence at the mouth of the creek each winter, and by conducting shutdown procedures that prevent rapid cooling of the creek.

- Physical damage to fish caused by boat traffic: Recreational boat traffic in the Red River and in the Assiniboine River near its mouth may result in direct injury to fish due to physical impacts from boats and boat propellers.

TABLE OF CONTENTS

1.0 INTRODUCTION 1

2.0 STUDY AREA AND METHODOLOGY 2

3.0 RESULTS AND DISCUSSION 3
3.1 HABITAT ALTERATION 3
3.1.1 St. Andrews Lock and Dam 3
3.1.2 Historical loss of tributary and headwater habitat 4
3.1.3 Rip-rap and bank stabilization 7
3.1.4 Bridges, docks, and boat launches 8
3.2 OBSTRUCTION TO FISH PASSAGE 8
3.2.1 St. Andrews Lock and Dam 9
3.2.2 Red River Floodway control structure 9
3.3 FISH INJURY AND MORTALITY 10
3.3.1 Entrainment and impingement of fish in water intakes 10
3.3.2 Thermal effluents 11
3.3.3 Injury to fish caused by boat traffic 11

4.0 OVERVIEW OF PHYSICAL STRESSORS WITHIN THE AMMONIA CRITERIA STUDY AREA 12

5.0 REFERENCES 14

LIST OF TABLES

Table 1a. Water rights licenses and applications on the Red River (St. Agathe to north of Selkirk) within the City of Winnipeg Ammonia Criteria Study . . 16

Table 1b. Water rights licenses and applications on the Assiniboine River (Headingley to the Forks) within the City of Winnipeg Ammonia Criteria Study 19

LIST OF FIGURES

Figure 1a. Water rights licenses and applications on the Red River (St. Agathe to north of Selkirk) within the City of Winnipeg Ammonia Criteria Study . . 20

Figure 1b. Water rights licenses and applications on the Assiniboine River (Headingley to the Forks) within the City of Winnipeg Ammonia Criteria Study 21

1.0 INTRODUCTION

As the Red and Assiniboine rivers flow through land developed for agricultural, urban, and industrial use, several anthropogenic stressors other than ammonia discharge from the City of Winnipeg's WPCCs exist within the Ammonia Criteria Study Area. These stressors include fish harvest, discharge of other chemical contaminants, and physical stressors that may impact fish populations either directly or through habitat alteration. Fish harvest (including fish mortality related to recreational fishing) and other chemical stressors are discussed in Tetr*ES* Consultants Inc. 2000a and Tetr*ES* Consultants Inc. 2000b, respectively. Physical stressors to the Red and Assiniboine river fish populations are the subject of this report.

Physical stressors to fish populations can include habitat loss and alteration, obstruction to fish passage, and fish injury and mortality. Since the overall condition of aquatic ecosystems is highly dependent on water quality, changes in water quality can result in physical stressors. For instance, the input of nutrients and organic matter to aquatic ecosystems can cause habitat alteration by inducing the growth of algae over fish spawning beds, and fish mortality through reductions in dissolved oxygen. In this report, only those stressors which cause or have caused direct physical disruption of fish or fish habitat are examined.

Fish populations within the Red River basin appear to be highly mobile (Clarke *et al.* 1980, Barth and Lawrence 2000) and, therefore, may be affected by stressors throughout the watershed. However, stressors to portions of the ecosystem outside of the study area are beyond the scope of this report.

2.0 STUDY AREA AND METHODOLOGY

The Ammonia Criteria Study Area includes the Red River, the Assiniboine River, and their tributaries within and near the City of Winnipeg, Manitoba. The portion of the Red River included in the study area extends from the town of St. Agathe downstream to just north of the City of Selkirk, and for terms of reference in the Ammonia Criteria Study, is divided into 86 segments. The portion of the Assiniboine River in the study area extends from Headingley (upstream of the West End WPCC) to its confluence with the Red River, and is divided into 30 segments.

The information contained in this report was obtained from published and unpublished literature, from the habitat and fish movement studies conducted as part of the City of Winnipeg Ammonia Criteria Study, and from key person interviews.

The physical habitat of the rivers and lower reaches of tributaries within the study area was described in a detailed, segment-by-segment fashion in Davies and MacDonell (2000). Habitat was characterized in terms of bottom substrate composition, water depth and velocity, shoreline features, riparian vegetation, and major anthropogenic features. Results of a study of fish movements within the study area are presented in Barth and Lawrence (2000).

Key person interviews were conducted to obtain specific information not available from published literature, to verify information obtained from unpublished sources, and to gain perspective on the relative significance of the numerous potential physical stressors to fish populations within the study area. Individuals contacted for key person interviews included:

- Ken W. Stewart, Ph.D. (Senior Scholar, Department of Zoology, University of Manitoba);
- Duncan Wain, M. Sc. (Contract Fisheries Biologist, Manitoba Wildlife Federation);
- Carl Wall (Angling Program Manager, Manitoba Conservation Fisheries Branch); and
- Joel Hunt (Fish Habitat Specialist, Manitoba Conservation Fisheries Branch).

3.0 RESULTS AND DISCUSSION

3.1 HABITAT ALTERATION

Fish at various stages of development have specific habitat requirements for life processes such as larval development, spawning, feeding, and overwintering. Alteration of habitat parameters such as water depth, water velocity, and bottom substrate composition can alter the suitability of available habitat for one or more processes in a fish's life cycle. For example, reduced water velocities can make riffle areas less suitable for spawning for species such as sauger (*Stizostedion canadense*) and walleye (*S. vitreum*).

Because most fish require a variety of habitat types to carry out various life processes, reductions in the diversity of available habitat can limit the ability of fish to inhabit an area. Decreased habitat diversity may also reduce the number of species that can successfully inhabit an area.

Shoreline development, water level management, and surrounding industries have altered fish habitat in the Red and Assiniboine rivers within the City of Winnipeg Ammonia Criteria Study Area. Although the physical aspects of aquatic habitat can be dependent on water chemistry, examples of direct physical alteration of aquatic habitat within the study area are the focus of this report. Eutrophication of habitat caused by the input of nutrients by point and non-point sources is beyond the scope of this report.

3.1.1 St. Andrews Lock and Dam

The St. Andrews Lock and Dam structure, in operation since 1910, was constructed to allow the passage of cargo ships between Winnipeg and Lake Winnipeg and to stabilize water levels in the Red River. The upstream limit of increased water depths in the Red River due to impoundment by the St. Andrews Dam each summer is near the town of St. Adolphe (Stewart 1990), towards the southern limit of the Ammonia Criteria Study Area.

Prior to impoundment by the St. Andrews Dam, the reach of the Red River within the study area offered fish habitat that varied widely in terms of water velocity, depth, and bottom substrate composition. Impoundment during summer has reduced the diversity of habitat in the study area. Water depth is elevated through most of the study area, but in particular over a series of riffles upstream of Lockport, previously known as Lister's Rapids.

Reduced water velocities have lead to the settling of suspended sediment in the river, and bottom features such as holes and rocky areas have become filled in. Cobble and gravel substrates have become blanketed by fine sediments, making them unsuitable for spawning by most species, and decreasing the variation in bottom substrate composition in the study area. Fine sediments dominated the bottom substrate composition in much of the study area in habitat surveys conducted in late autumn 1998 and June-July 1999 (Davies and MacDonell 2000).

In some areas within the impounded reach of the river, a seasonal shift in bottom substrate composition may occur due to the increased water velocities resulting from removal of the St. Andrews Dam structure each autumn. An increase in habitat diversity during winter, provided by the exposure of hard substrates, may not benefit fish to the extent that it would in summer, because in winter most fish remain relatively inactive in deep water with low velocity.

Impoundment and water level regulation during the summer growing season prevent the growth of riparian vegetation along the banks of the Red River. Flood-tolerant riparian vegetation, such as some willows and sedges, colonize the banks of unregulated rivers below the high water mark, and provide bank stabilization and protective cover for fish during periods of high flow. Increased erosion of the banks due to the lack of stabilizing riparian vegetation increases the transport of suspended sediment in the river, which may increase the deposition of sediment over coarse substrates.

Following the removal of the St. Andrew's Dam each October, the stage of the Red River in the study area drops approximately two metres, over a period of approximately three weeks (*pers. comm.* Grant Mohr, Tetr*ES* Consultants Inc., Winnipeg Manitoba, July 2000). Dewatering of the channel exposes habitat colonized by benthic invertebrates and displaces fish, but its effect on fish populations is not known. Fish species that spawn in autumn are not present in the Red River upstream of Lockport, so the drawdown does not cause spawning failure by exposing eggs.

3.1.2 Historical loss of tributary and headwater habitat

Prior to their drainage for agricultural purposes, large expanses of wetlands existed in the Red River Valley. The slow release of water from the wetlands maintained flow in tributaries to the Red and Assiniboine rivers after periods of surface runoff. For the purpose of agricultural development, drainage ditches have been excavated to quickly remove water from the land during periods of runoff. Small headwater streams have been incorporated into cultivated fields, and larger streams have been channelized to increase discharge rates. Streams in urban settings carry little, if any, water for the majority of the year, but undergo extreme spikes in discharge during periods of precipitation and snowmelt.

Headwater streams and wetland areas can play important roles in primary production and initial processing of organic matter in aquatic ecosystems, and can also provide rearing habitat for fish such as northern pike (*Esox lucius*), bullheads (*Ameiurus sp.*), and several cyprinid (minnow) species. Several species of fish, such as northern pike, carp (*Cyprinus carpio*), and yellow perch (*Perca flavescens*), require vegetated areas for spawning. Other species, such as walleye and sauger, spawn in riffle habitat within tributaries. The hatched larvae of these fish often remain in headwater or low velocity tributary areas during development prior to entering larger bodies of water.

Urbanization and land drainage in the Red River Valley has restricted the availability of aquatic habitat mainly to the mainstems of the large rivers. Nursery habitat for larval fish development provided by headwater and backwater areas has been lost. Due to the rapid drainage of surface runoff, most small tributaries to the Red and Assiniboine rivers do not retain water long enough to provide fish habitat through most of the year. Check dams constructed on many of the larger tributaries make them inaccessible to fish in the rivers.

All tributaries to the Red and Assiniboine rivers within the study area have undergone alterations which have diminished the quantity and/or quality of fish habitat that they once provided. Channelization, removal of riparian vegetation, installation of culverts, and discharge of urban runoff affect habitat suitability and water quality in small streams. However, habitat restoration and enhancement programs are being conducted on the lower reaches of several streams within and near Winnipeg. The following is a brief description of the fish habitat currently offered by the tributaries within and near the study area:

La Salle River

The lower La Salle River provides tributary habitat for Red River fish throughout the open-water season. A dam at La Barriere Park blocks fish passage, except possibly during periods of very high discharge. The upper reach of the river supports a variety of fish species, but is periodically subject to fish kills due to low oxygen levels, which are likely caused by high loads of organic matter and nutrients imparted by the agricultural land that it drains (*pers. comm.* Joel Hunt, Manitoba Conservation Fisheries Branch, July 2000).

Seine River

The lower Seine River provides tributary habitat throughout the open-water season for many species of fish found in the Red River. The river crosses the Red River Floodway via an underground tunnel. Recent repairs to the floodway crossing have helped to maintain a consistent supply of water to the lower Seine River, but the tunnel blocks fish passage to the upper reaches of the river (*pers. comm.* Joel Hunt, Manitoba Conservation Fisheries Branch, July 2000).

Bunns Creek

Bunns Creek provides nearly one kilometre of fish habitat except during periods of low flow. Riffle habitat has been added to the creek, and natural riffle habitat in the creek has been used for spawning by sucker (*Catostomid*) species and possibly by walleye and sauger. The amount of fish habitat provided by Bunns Creek is limited by its small drainage area and low discharge from a retention pond near its headwaters (*pers. comm.* Joel Hunt, Manitoba Conservation Fisheries Branch, July 2000).

Grassmere Drain

Grassmere Drain is heavily channelized and its discharge is characterized by brief periods of scouring flows, after which the channel retains little if any water. The straight channel and unstable banks resulting from the scouring flows make the drain unsuitable as fish habitat, even during periods of discharge.

Parks Creek

Parks Creek, similar to Grassmere Drain, has been heavily channelized and only discharges water during periods of surface runoff. Its banks are unstable, and its straight channel does not offer favourable fish habitat.

Cooks Creek

Cooks Creek, which enters the Red River just north of the study area, is one of two tributaries to the Red River between the St. Andrews Dam and Lake Winnipeg. Its lower reach provides approximately four kilometres of backwater habitat and several kilometres of natural riffle habitat. Its headwaters are channelized and drain agricultural areas. The creek receives warm water discharge from the Selkirk Thermal Generating Station, which may reduce the suitability of the creek as habitat for cool water fish species during periods when station operation coincides with warm water temperatures. To prevent the movement of fish into Cooks Creek during the winter, Manitoba Hydro installs a fish fence at the mouth of the creek each year just after freeze-up, and removes the fence prior to the spring freshet. The fence likely does not cause a loss of preferred fish habitat, as the creek contains little overwintering habitat.

Sturgeon Creek

The dam at Grant's Old Mill, situated on Sturgeon Creek approximately one kilometre upstream of its confluence with the Assiniboine River, is currently a complete barrier to fish passage except during very high flows. Downstream of the mill the creek has been the subject of habitat enhancement projects, including the installation of riffle habitat, and provides fish habitat throughout the open-water season. Upstream of the mill the creek provides approximately eight kilometres of rearing habitat for most fish found in the Assiniboine River, including northern pike, bullheads, suckers, carp, and several cyprinid species. The headwaters of the creek mainly consist of straightened, bermed channels,

but also include Grant's Lake Wildlife Management Area near Grosse Isle. The installation of a fishway over the Grant's Old Mill dam is planned for late in the year 2000, and habitat enhancement of the upper reaches of the creek may follow (*pers. comm.* D. Wain, Manitoba Wildlife Federation, July 2000).

Truro Creek

Truro Creek receives drainage from the Winnipeg International Airport and from an agricultural area within the City of Winnipeg. The creek has undergone habitat enhancement with the installation of riffle habitat and the excavation of a small retention pond just upstream of Portage Avenue. The creek may provide spawning habitat for spring spawning species such as walleye, northern pike, and white sucker (*Catostomus commersoni*), but does not support resident fish populations because the channel becomes dry during summer.

Omands Creek

The lowest reach of Omands Creek provides approximately one kilometre of fish rearing habitat and supports resident populations of fish including northern pike, suckers, and several forage species. The reach of the creek within Winnipeg provides rearing habitat when water levels permit. Sucker eggs have been collected from the creek, which suggests that other spring spawning species, such as walleye and sauger, may spawn in the creek as well (*pers. comm.* Joel Hunt, Manitoba Conservation Fisheries Branch, July 2000).

3.1.3 Rip-rap and bank stabilization

Backwater areas and shallow, vegetated margins along the banks of rivers provide habitat with reduced water velocities and vegetative cover for fish. In particular, these areas provide nursery habitat for developing fish larvae, which drift passively when entrained in stronger currents in the main channels of large rivers (Brown and Coon 1994, Rider and Margraf 1997).

The banks along much of the Red River within the Ammonia Criteria Study Area have been stabilized through the application of rip-rap. Of the 86 segments that comprise the Red River study area, 42 segments contain portions to which rip-rap has been applied to one bank, and 18 segments contain portions to which rip-rap has been applied to both banks (Davies and MacDonell 2000).

Long stretches of rip-rapped banks reduce habitat diversity in some rivers by eliminating the shallow, vegetated habitat that would otherwise exist along the banks. However, the Red River within the study area is dominated by fine substrates, and contains little vegetation along the banks, due to the effects of impoundment by the St. Andrews Dam.

At least a portion of the habitat diversity that is lost due to bank stabilization within the Ammonia Criteria Study Area may be offset by the increased proportion of coarse substrate provided by the rip-rap.

3.1.4 Bridges, docks, and boat launches

Some fish habitat in the Ammonia Criteria Study Area has been lost due to the construction of bridges, docks, and boat launches. However, the area occupied by the footprints of these structures is small in comparison to the total amount of fish habitat in the study area. In river systems that contain long stretches of uniform habitat, such as the portion of the Red River impounded by the St. Andrews Dam, the habitat loss resulting from the construction of structures such as bridge pillars can be more than compensated for by the increased habitat diversity that these structures create. For example, altered water velocities around bridge pillars can create fast water areas with exposed hard substrate, and back eddies that provide preferred feeding habitat for many fish species. The impact of structures such as bridges on fish populations within the study area is likely small, as the fish habitat lost through their construction is small in proportion to the habitat available, and because it may be compensated through the increased habitat diversity they provide.

3.2 OBSTRUCTION TO FISH PASSAGE

Although the life history characteristics of most fish species in the Red River and Lake Winnipeg are not well known, it has been confirmed that some species undergo migrations at various times of the year (Tyson 1994, Clarke *et al.* 1980, Barth and Lawrence 2000). Blockages of fish passage may impact fish populations by preventing access to preferred habitats for spawning, rearing, and overwintering.

Blockages to fish passage in the mainstems of the Red and Assiniboine rivers within the study area are the St. Andrews Dam, and, when in operation, the Red River Floodway control structure near the south end of the City of Winnipeg.

3.2.1 St. Andrews Lock and Dam

A fishway was constructed on the St. Andrews Dam in 1913 to facilitate the passage of fish over the structure. Nevertheless, congregations of fish occur downstream of the dam, indicating that the structure may slow the upstream migration of fish.

A study conducted from June to October 1994 monitored the passage of fish through the St. Andrews Dam fishway. The study revealed that fish of a variety of species utilized the fishway, including channel catfish (*Ictalurus punctatus*) up to 92 cm in length (Willis 1994). However, the fishway may not allow the passage of very long fish, such as lake sturgeon (*Acipenser fulvescens*) (*pers. comm.* K. Stewart, Department of Zoology, University of Manitoba, July 2000).

The 1994 study of the St. Andrews fishway revealed that its function was highly dependent on the water level at its downstream entrance, which, in turn, was determined by river discharge and the occurrence of north or south winds. Low water levels at its entrance reduced the ability of fish to ascend the fishway for a total of approximately 52 days (nearly 50% of the study period). Average discharge in the river during the study period was 299 m^3/s (Willis 1994), which is well above the historical median discharge. In years with less flow, utilization of the fishway may be prevented for a significant portion of the open-water season due to low flows through the fishway.

During periods of very high river discharge, it is necessary to dismantle the fishway. During the 1994 study period, the fishway was inoperative from 25 June to 4 July to accommodate high river flows.

Upgrades to the St. Andrews Dam and fishway have been completed recently, which may improve the efficiency of the fishway under various flow conditions.

3.2.2 Red River Floodway control structure

The floodway control structure just south of Winnipeg represents a temporary obstruction to fish passage when its gates are raised to divert water into the Red River Floodway.

The constriction in the river channel created by the floodway control structure provides habitat diversity within the study area. Increased water velocities together with channel protection placed just downstream of the structure provide riffle habitat which is otherwise rare in the reach of the Red River impounded by the St. Andrews Dam.

Diversion of flows from the Red River into the Red River Floodway has the potential to cause fish mortality by stranding fish in the floodway channel once it is dewatered. However, the floodway is well graded and does not contain pools that retain water upon dewatering of the channel, hence most fish retreat from the channel as water levels

decline. The Fisheries Branch of Manitoba Conservation has received no reports of fish kills caused by the stranding of fish in the floodway channel (*pers. comm.*, C. Wall, Manitoba Conservation Fisheries Branch, July 2000).

3.3 FISH INJURY AND MORTALITY

Anthropogenic sources of physical injury and mortality to fish within the Ammonia Criteria Study Area may include recreational fishing, entrainment and impingement of fish in water intakes, discharge of thermal effluents, and boat traffic. Injury and mortality related to recreational fishing, caused by hooks, lost lures, and handling of fish during catch-and-release, will be discussed in a separate technical memorandum on fish harvest (Tetr*ES* Consultants Inc. 2000a).

3.3.1 Entrainment and impingement of fish in water intakes

The withdrawal of water from fish bearing waters can lead to fish mortality through entrainment and impingement. Entrainment occurs when fish are drawn into a water intake and can not escape. Impingement occurs when fish are held against intake screens by the flow of withdrawn water and can not free themselves. The occurrence and degree of entrainment and impingement in water intakes are dependent upon the placement and design of the intakes and intake screens. The Department of Fisheries and Oceans has set out guidelines for the design of water intake screens to prevent the impingement and entrainment of fish (Canada Department of Fisheries and Oceans 1995).

Water is withdrawn from the Red and Assiniboine Rivers primarily for the purposes of irrigation, industry, and municipal water supply. Within the study area, a total of 45 licensed water intakes exist, with a total annual licensed withdrawal of 292 150.68 dam^3 (Table 1, Figure 1). The largest water withdrawal within the study area is that of the Manitoba Hydro Selkirk Thermal Generating Station, with an annual licensed withdrawal of 286 169 dam^3.

The Selkirk Thermal Generating Station operates intermittently, and withdraws water from the Red River for cooling of its condensers. Prior to autumn 1999, the cooling water was screened at the intake by 12.5 mm mesh screens. Small fish entrained in the cooling water passed through the condensers of the plant, and larger fish became impinged on the intake screens, resulting in mortality (Baker 1996, Baker and Horne 1994, Baker and Zrum 1997, Toews and Schneider-Vieira 1998). In autumn 1999, an intake screen, designed to eliminate the impingement and entrainment of fish greater than 25 mm in length, was installed.

3.3.2 Thermal effluents

During periods of cold water conditions, fish can be attracted to plumes of warm water created by the discharge of thermal effluents. Fish that become acclimated to warm water within the plumes can become subject to thermal shock if the water is allowed to suddenly cool. Thermal shock results from osmoregulatory failure, and effects can range from temporary disorientation to death of the fish.

Within the Ammonia Criteria Study Area, thermal effluents are discharged by the Manitoba Hydro Selkirk Thermal Generating Station and the City of Winnipeg Water Pollution Control Centres (WPCCs).

Heated cooling water from the Selkirk Thermal Generating Station is discharged into Cooks Creek. In the winter of 1987-1988, a fish kill occurred in Cooks Creek due to rapid cooling of the creek following a shutdown of the generating station (Macdonald 1988). A fence placed at the mouth of Cooks Creek currently prevents the migration of fish into the creek during winter operation of the station, and improved shutdown procedures prevent the occurrence of thermal shock in fish in the creek.

3.3.3 Injury to fish caused by boat traffic

Within the study area, the Red River and the Assiniboine River near its mouth are used by recreational boats. Physical injury to fish may occur through impacts with boat propellers, and the wakes created by boat traffic may displace small fish from sheltered habitat along the banks. The extent of fish mortality caused by boat traffic is unknown.

4.0 OVERVIEW OF PHYSICAL STRESSORS WITHIN THE AMMONIA CRITERIA STUDY AREA

The following is an overview of the anthropogenic features in the Ammonia Criteria Study Area that may influence fish populations in the Red and Assiniboine rivers in one or more ways:

- **St. Andrews Dam:** Impoundment of the Red River at Lockport decreases the diversity of aquatic habitat in the study area by reducing water velocities over riffle habitat, and by increasing the deposition of fine sediments over hard substrates. Elevated water levels during the summer prevents the growth of riparian vegetation along the banks of the Red River, eliminating shallow, vegetated habitat along the shorelines, and increasing bank erosion. Despite the presence of a fishway, the structure also appears to block fish migration under some flow conditions.

- **Historical loss of tributary and headwater habitat:** Drainage of land in the Red River Valley for agricultural and urban development has reduced the amount of tributary habitat available to the Red and Assiniboine rivers' fish community by eliminating headwater habitat, and by shortening the time period during which tributaries retain water. However, restoration of some habitat within the lowest reaches of tributaries has been accomplished through the initiation of habitat enhancement projects.

- **Selkirk Thermal Generating Station:** The Manitoba Hydro Selkirk Thermal Generating Station has the potential to impact fish populations in the Red River through the entrainment and impingement of fish in its water intake, and through the discharge of thermal effluent into Cooks Creek. The majority of the fish mortality caused by the Selkirk Thermal Generating Station has been eliminated through the installation in autumn 1999 of an intake screen designed to protect fish greater than 25 mm in length. The degree to which the generating station presently entrains fish smaller than 25 mm is currently being investigated (*pers. comm.* W.A. Brown, Manitoba Hydro, August 2000). Protection of fish from the occurrence of thermal shock is currently effected through the maintenance of a fish fence that prevents the migration of fish into the creek during the winter, and through the implementation of plant shutdown procedures that prevent rapid cooling of the creek.

- **Rip-rap and bank stabilization:** Stabilization of the riverbanks within the study area has been necessary to protect developed shorelines from erosion. The potential loss of vegetated shoreline habitat may be partially compensated for by the increased proportion of coarse river substrate provided by rip-rap.

- **Bridges, docks, and boat launches:** The area occupied by the footprints of structures such as boat launches and docks is small compared to the total amount of fish habitat within the study area. Additionally, structures such as docks and bridge pillars may diversify fish habitat.

- **Floodway Control Structure:** The floodway control structure temporarily blocks fish passage during the years in which it is operated. However, the structure increases fish habitat diversity by providing a short stretch of riffle habitat which is otherwise rare in the impounded reach of the Red River.

- **Injury to fish caused by boat traffic:** An unknown amount of injury to fish occurs due to impacts from boats and boat propellers.

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Table 1a.

Criteria Study (provided by Manitoba Conservation Water Resources Branch).

Date	Name	Location	License Number	Status	Purpose	Maximum Annual Alloc. (dam^3)
31-Mar-89	Gateway Industries Ltd.	17 River Lot, St. John	95-08	Approved License Issued	Industrial	166
26-Apr-91	Winnipeg, The City of	21 River Lot, Kildonan	93-54	Recommended Submitted	Irrigation	100
26-Apr-91	Winnipeg, The City of	19 River Lot, St. Vital	93-53	Recommended Submitted	Irrigation	56
11-Sep-91	Parisien, Paul	227 River Lot, St. Norbert	92-61	Approved License Issued	Irrigation	9
15-Aug-88	McLeod, Jerry Roy and Bonnie Barbara	617 River Lot, Ste Agathe	92-131	Approved License Issued	Irrigation	25
13-Dec-86	Petrie, Brian William	619 River Lot, Ste Agathe	90-35	Approved License Issued	Irrigation	7
11-Jan-89	Searle Greenhouses Ltd.	85 River Lot, St. Clements	90-21	Approved License Issued	Irrigation	49
27-Apr-89	Alty, J.S.R.	638 River Lot, Ste Agathe	89-086	Approved License Issued	Irrigation	16
7-Sep-88	McDonald, M. and C.	227 River Lot, St. Norbert	89-52	Approved License Issued	Irrigation	11
26-Feb-88	Southwood Golf and Country Club	7 River Lot, St. Vital	88-11	Approved License Issued	Irrigation	154
16-Jun-83	Manitoba Hydro	73 River Lot, St. Clements	88-06	Approved License Issued	Industrial	286,169
16-Jan-85	Schwabe, J.A.G. and D.E.	110 River Lot, St. Paul	87-12	Approved License Issued	Irrigation	6
17-Mar-82	Meyer, J.	R.L. 205, Parish of St.	85-04	Approved License Issued	Irrigation	12
18-Mar-82	Fox, C.J.	R.L. 189, Parish of St. Peter	84-32	Approved License Issued	Irrigation	15
20-Jun-75	Selkirk, Town of	E of Eveline St. at Rosser Ave., Selkirk	80-13	Approved License Issued	Municipal	4,194
17-Dec-79	Cybulsky, K.A.	R.L. 104, Parish of St. Clements	80-01	Approved License Issued	Irrigation	33
	Canada - Agriculture (Glenlea Research Station)	3 River Lot, St. Norbert	79-032	Approved License Issued	Irrigation	25
6-Apr-79	Winnipeg, The City of	108 River Lot, St. Norbert	79-21	Approved License Issued	Other	96
22-Apr-77	St. Boniface General Hospital	83 River Lot, St. Boniface	77-66	Approved License Issued	Irrigation	44
7-Jun-77	Middlechurch Home, etc.	18 River Lot, St. Paul	77-48	Approved License Issued	Irrigation	12

Table 1a. continued.

Date	Name	Location	License Number	Status	Purpose	Maximum Annual Alloc. (dam^3)
23-Aug-76	Mudry, N. and A.	R.L. 58, Parish of St. Norbert	76-48	Approved License Issued	Irrigation	2
23-Aug-76	Woytowwicz, P.	R.L. 63, Parish of St. Norbert	76-47	Approved License Issued	Irrigation	20
17-Feb-76	Loganberg, R.B. and A.J	R.L. 1, Parish of St. Pauls	76-07	Approved License Issued	Irrigation	15
20-Aug-75	Glen Eden Memorial Gardens	Lots 38-45, Parish of St. Pauls	75-33	Approved License Issued	Irrigation	12
30-Aug-74	Phippen, J.W.	169 River Lot, St. Norbert	75-06	Approved License Issued	Irrigation	7
14-Aug-74	Praznik, B.	70 River Lot, St. Andrews	74-30	Approved License Issued	Irrigation	19
2-Apr-73	Yablonski, J.T. and G.Y.	R.L. 248, Parish of St. Andrews	73-25	Approved License Issued	Irrigation	19
31-May-72	Shupena, E.S. and R.S.	585 River Lot, Ste Agathe	72-17	Approved License Issued	Irrigation	12
	Shale, H.J.	186 River Lot, St. Andrews	72-10	Approved License Issued	Irrigation	5
18-Sep-64	Pritchard, H.T. and M.	112 River Lot, St. Paul	65-05	Recommended Submitted	Irrigation	6
14-Sep-64	Soklolwski, V.	284 River Lot, St. Andrews	65-04	Recommended Submitted	Irrigation	27
8-Sep-64	Kaminski, W.	R.L. 277-279, Parish of St. Andrews	64-34	Approved License Issued	Irrigation	20
7-Mar-62	Praznik, B.J. and M.H.	R.L. 71, Parish of St.	63-33	Approved License Issued	Irrigation	16
16-Apr-62	Praznik, T. and R.	R.L. 78, Parish of St.	63-29	Approved License Issued	Irrigation	17
19-Nov-62	University of Manitoba (Glenlea Research Station)	6 River Lot, St. Norbert	63-017	Approved License Issued	Irrigation	296
17-May-62	Campeau, E.	193 River Lot, St. Norbert	62-38	Approved License Issued	Irrigation	25
22-Jan-62	Gibson, J. and C., E.J.	160 River Lot, St. Norbert	62-011	Approved License Issued	Irrigation	56
11-Jan-62	Connery, J. and D.	157 River Lot, St. Norbert	62-010	Approved License Issued	Irrigation	21
12-Jun-61	Scott, Gordon	69 River Lot, St. Paul	52	Approved License Issued	Irrigation	74
20-Apr-45	Winnipeg, The City of	Amy Street	6	Approved License Issued	Industrial	0
9-Jan-40	Manitoba Sugar Co.	21 River Lot, St. Vital	2	Approved License Issued	Industrial	0

Table 1a. continued.

Date	Name	Location	License Number	Status	Purpose	Maximum Annual Alloc. (dam^3)
18-Jun-40	Building Products Ltd.	20 River Lot, St. John	1	Approved License Issued	Industrial	0
30-Aug-84	Manitoba Rugby Union	148 River Lot, St. Norbert		Waiting for Assessment of Application	Irrigation	
18-Mar-97	Alty, J. and J.	35 River Lot, St. Norbert		Waiting for Assessment of Application	Irrigation	
23-Dec-92	Bullet Development Ltd.	46 River Lot, St. Norbert		Waiting for Assessment of Application	Irrigation	
15-Jun-88	Riese, P. or Larter's or R.M. of St. Andrews	9 River Lot, St. Andrews		Application Assessment Underway	Irrigation	

Table 1b. Water rights licenses and applications on the Assiniboine River (Headingley to the Forks) within the City of Winnipeg Ammonia Criteria Study (provided by Manitoba Conservation Water Resources Branch).

Date	Name	Location	License Number	Status	Purpose	Maximum Annual Alloc. (dam^3)
6-Jun-89	Winnipeg, The City of	Pt. R.L. 62. R.L. 63, Par. Of Headingly	89-095	Approved License Issued	Irrigation	185.00
6-May-88	Manchester Trading Company (1985) Ltd. (Elm Tree Nursery)	90 River Lot, St. Charles	89-094	Approved License Issued	Irrigation	43.00
16-Jun-59	Great West Life Assurance Co.	Near Osborne Street	11	Approved License Issued	Irrigation	30.00
20-Sep-95	The Forks North Portage Partnership	"The Forks", Par. Of St. John	1996-033	Approved License Issued	Irrigation	6.17
7-Jul-87	73778 Manitoba Ltd.	45 River Lot, Headingly		Waiting for Assesment of Application	Irrigation	
25-Feb-97	Domenco, R. & J.	10 River Lot, Headingly		Waiting for Assesment of Application	Irrigation	
23-Apr-97	Winnipeg, The City of	Bonnycastle Park	70-28	Renewal Application - Waiting for Assesment	Irrigation	12.34
23-Apr-97	Winnipeg, The City of	Assiniboine Park	68-12	Renewal Application - Waiting for Assesment	Irrigation	6.17
30-Mar-95	Breezy Bend Country Club	7 River Lot, Headingly		Waiting for Assesment of Application	Irrigation	
27-Feb-96	Western Golf Mgmt (Manitoba) Ltd.	Tuxedo Golf Course		Application Assessment Underway	Irrigation	

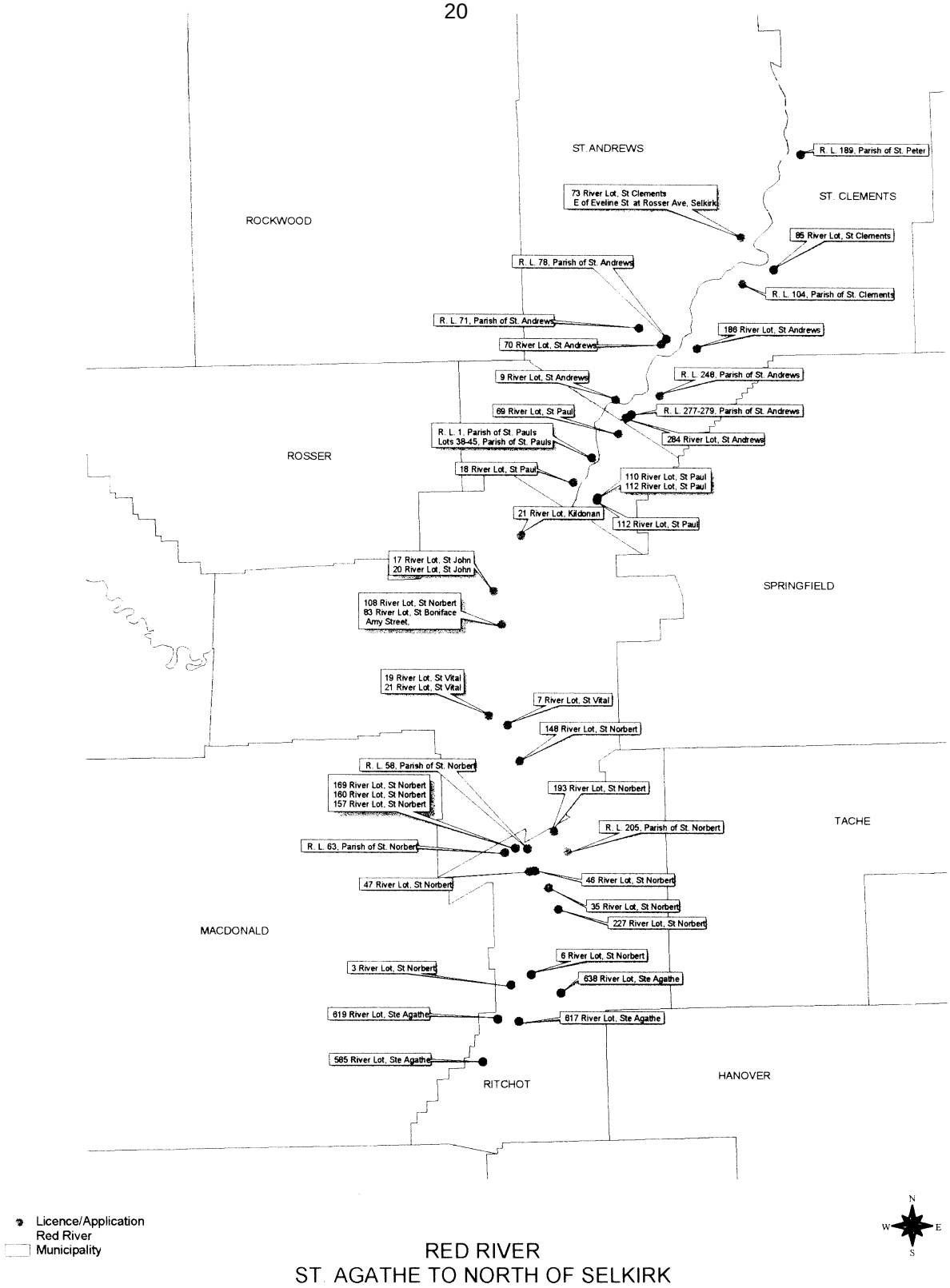

Figure 1a. Water rights licenses and applications on the Red River (St. Agathe to north of Selkirk) within the City of Winnipeg Ammonia Criteria Study (provided by Manitoba Conservation Water Resources Branch).

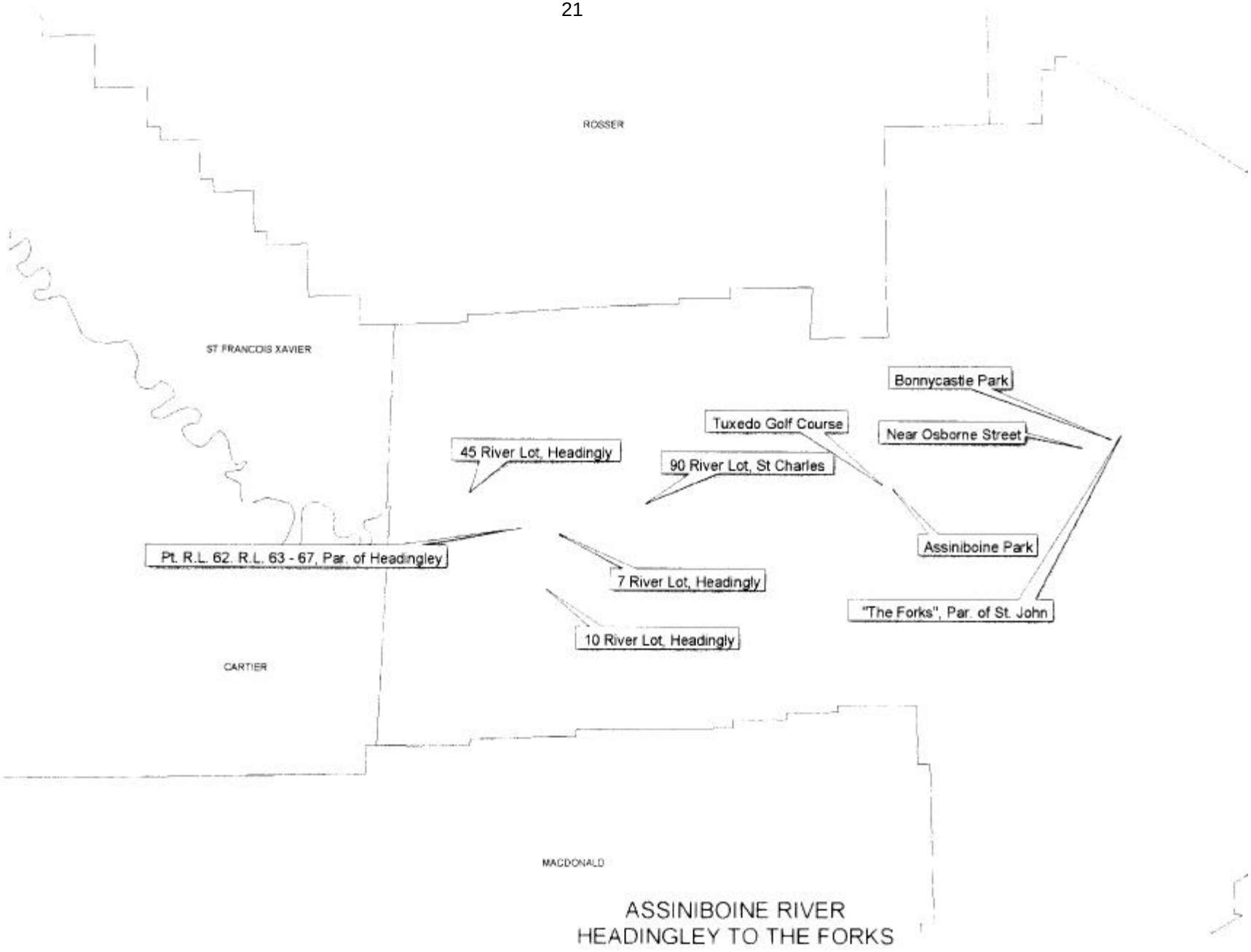

Figure 1b. Water rights licenses and application on the Assiniboine River (Headingley to the Forks) within the of City Winnipeg Ammonia Criteria Study (provided by Manitoba Conservation Water Resource Branch).