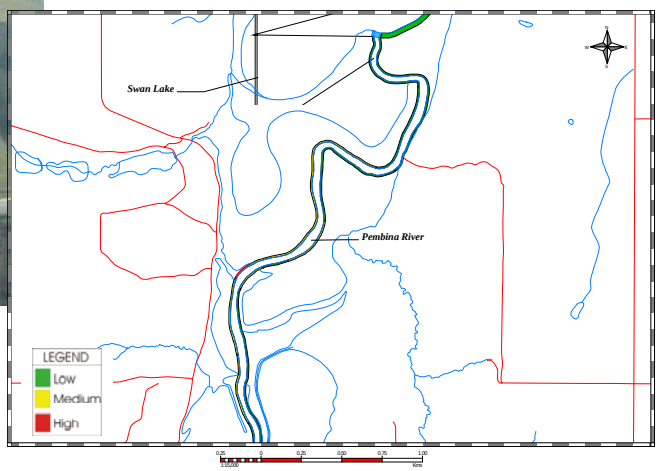
UPPER PEMBINA RIVER WATERSHED
FISHERIES AND RIPARIAN AREA SURVEY



Prepared By
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APPENDICES

Upper Pembina River Watershed Analysis

1.0 INTRODUCTION

The Pembina River is the major water course in south central Manitoba. The importance of the watershed has led to numerous initiatives and studies over the years in an effort to better manage this valuable resource. Recently, two groups, namely the Pembina River Basin Advisory Board and the TriLakes Group have begun major initiatives to implement improvements to the management and use of the Pembina River. With the intense interest in the watershed, it was decided some additional information was required for the purposes of identifying potential habitat for aquatic life and to examine any opportunities for water quality improvement measures.

The study was entitled the "Upper Pembina River Watershed Analysis" and was sponsored by a group of three stakeholders as follows:

- Tiger Hills Conservation District
- Turtle Mountain Conservation District
- Pembina Valley Conservation District

. Logistical support for the project was assumed by the Tiger Hills Conservation District (THCD) with the other Districts providing support in their geographical areas. The group issued tenders, and retained Aquatic and Environmental Consultants (AEC) under funding from the FEI to prepare the information required. The scope of the study included the main stem of the Upper Pembina River from the Tiger Hills to Swan Lake. The stakeholder group recognized the need to include not just the Upper Pembina River, but also major streams and creeks that fed into the Upper Pembina River including:

- Starke Creek,
- Little Pembina River,
- North Pembina River,
- Kelly's Ravine

- Badger Creek
- Long River
- Cypress Creek
- Crystal Creek
- Pilot Creek

The initial goal of the project was to assist in the assembly of a prioritized list of shore land or riparian rehabilitation projects. This approach has been successfully utilized in other areas, including the Little Saskatchewan River watershed, Upper Whitemud River and the Lower Pembina River watershed. These projects would be undertaken with the goal of improving water quality to benefit fish habitat, domestic use, and recreational opportunities. Selected projects were to be funded from a variety of sources, such as the Manitoba Natural Resources Fisheries Enhancement Initiative (FEI), the Green Banks Program, PFRA, Manitoba Agriculture, IMCD, and cooperating landowners.

The project consisted of three principal objectives as follows:

Objective 1: Compiling existing watershed data.

Objective 2: Survey the Upper Pembina River and the tributaries and assesses stream bank areas to determine agricultural, municipal, or natural occurrences that may be negatively affecting water quality, valuable fish and wildlife habitat, and recreational opportunities within the watershed. During the course of this work it was hoped to determine the approximate ranges and distribution of fish species within the watershed at various stages in their life cycles. A final undertaking was to examine the role of Pelican Lake and Rock Lake on the system

Objective 3: Produce a survey report

To this end, Objective 1 was completed prior to the advent of the field season. Several published reports were found that pertained directly to the watershed itself, ranging from the 1930s era to excellent recent and ongoing studies in the third millennium. Information was augmented with input from various government agencies, unpublished reports, and personal communications regarding physical data, resource inventory information, and economic considerations.

Objective 2 was completed with numerous field surveys for data collection during the period of July to October of 2004. It was decided to gather additional information pertaining to fish distribution in the spring period, and thus the field study was extended through June, 2005. Data were analyzed and evaluated on an ongoing basis from November 2004 to July 2005.

Objective 3, which is encompassed by this report, began in January 2005, following the partial completion of data analysis for field collections. This approach was consistent with the original schedule, but was slightly expanded in time as a result of the volume of data requiring more time than was initially anticipated, and an alteration to include a spring study in 2005.

As a result, this report will focus on three key elements as follows:

1. All information collected during objective 2 will be summarized and presented.

2. The tributaries of the Upper Pembina River watershed will be evaluated for physical and hydrological characteristics to provide a framework for future project work.

3. Selected projects will be listed and prioritized.

2.0 STUDY AREA

The study area (Figure 1) is located in south central Manitoba between latitudes 49°00"00' N at the southern boundary, and latitude 49°28"00' N at the northern boundary. East and west boundaries are located at approximately longitudes 99°05" and 100°30" respectively. The rivers and streams in the area were formed as part of a glacial spillway during the last ice age. There has been some intervention by man that has altered the flow regime and channel courses of the tributary streams and main river channel in the study area. The primary control structures within the study area are the Pembina River Diversion and Pelican Lake Control Structure located at the south end of Pelican Lake, and the Rock Lake Dam/Weir located on the downstream end of Rock Lake. Numerous low head dams and ford crossings are present in all of the tributaries and the main river channel. Beaver dams are prevalent, particularly in the headwaters of the Upper Pembina River, and the various tributaries.

The study area is located entirely within the province of Manitoba, although some consideration was given to North Dakota information that gave insight into various tributaries originating south of the border. The entire area forms a portion of the Red River drainage system. In addition to the main stem of the Pembina River and the tributaries listed above, the study area included Pelican Lake, Rock Lake, and Swan Lake.

The rationale for the geographic scope of the study area was based on the following factors:

- The lower Pembina River had received similar examination in 1997
- Ongoing activities were focused in this area
- Economic considerations

The following are brief descriptions of each component of the study area.

Pembina River Mainstem

The Pembina River begins its flow south-east from the hills that form the Turtle Mountains, from its highest point (elevation 2000 feet). From here, the river descends almost 500 feet to a point just north of Killarney Manitoba. After this point the river progresses in a deeply incised glacial valley through rolling hills and farm land until reaching Swan Lake at the eastern end of the study area, at an elevation of 1300 feet. The river flows into Pelican Lake, via a control diversion structure designed to augment lake levels. Rock lake uses a small earthen dam at the outlet end to control water levels on a passive basis. Several small "lakes" are formed along the run of the Pembina River as a result of the erosion of the shale/limestone faces forming the Pembina Valley, which create small "weirs" at deposition points.

Kellys Ravine

Kellys Ravine joins the Pembina River less than one kilometer west of Rock Lake, after flowing through rolling to flat agricultural land before dropping almost 100 vertical feet into the valley. The shallow ravine contains a small intermittent stream that is blocked by a small dam 4.5 miles north of the Pembina River. Past this small dam, the stream branches west to Williamson Marsh, and north as far as Baldur, Manitoba.

Starke Creek

Starke Creek is a small, sometimes intermittent stream that flows northeast towards the Little Pembina River after dropping nearly 300 feet from the Turtle Mountains. The creek crosses heavily utilized agricultural lands, and is highly sinuous in nature.

Little Pembina River

The Little Pembina River is really a south west branching of the mainstem of the Pembina River, with its origin in the Turtle Mountains. Several smaller creeks feed into

the Little Pembina River prior to it joining the Pembina River approximately 5 miles south east of Ninga, Manitoba. Land use in the area is entirely agricultural, with cattle operations being common.

North Pembina River

The North Pembina River is a north west branch of the Pembina River. It flows through heavily utilized agricultural lands prior to entering the Pembina River 2 miles due south of Ninga, Manitoba. The river is fed by numerous wetlands in the area, some of which are intermittent in nature. The river is highly sinuous, and has a fairly deep and steep walled valley associated with it.

Badger Creek

Badger Creek is a relatively large stream that originates in North Dakota, and flows north until joining the Pembina River near Neelin, Manitoba. The creek travels through a deeply incised valley starting just north of Cartwright, Manitoba, and drops 125 feet over 10 miles. During this run, the Creek is joined from the west by the Long River. The lower reaches of the creek are marshy in nature. Several low ford crossings and small structures were observed in the late fall period, but were mostly submerged during the spring runoff period.

Long River

The Long River originates in the hills of the Turtle Mountains and flows northeast before turning due east near Holmfield, Manitoba. From this point, the river enters a deeply incised valley and drops 150 feet over a four mile run. The River then joins with Badger Creek and flows north to the Pembina River.

Gimby Creek

Gimby Creek joins Badger Creek near the town of Cartwright, Manitoba. It flows across fairly flat farmland before dropping almost 50 feet to Badger Creek. Over the course of its flow, it passes through areas of heavy livestock utilization, and is the receiving channel for the sewage lagoons at Cartwright.

Cypress Creek

Cypress Creek originates in North Dakota and flows north westward over highly tilled plains to Clearwater, Manitoba. At this point, a small weir holds water back for recreation and domestic purposes. The creek then enters a deep valley and drops 175 feet to the Pembina River just east of Rock Lake.

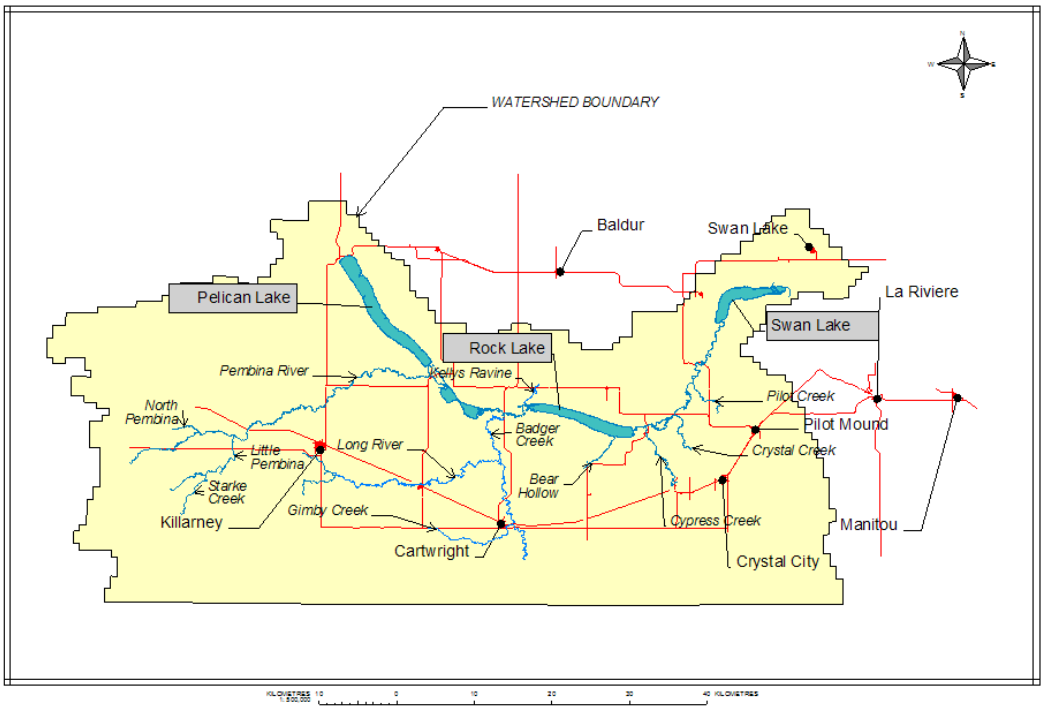
Crystal Creek

Crystal Creek is a small creek that originates in the sloughs and bogs in southern Manitoba. It flows northwest towards Crystal City, Manitoba, where a low head dam creates the Crystal City Reservoir. From here, the creek meanders in a generally north direction and joins the Pembina River in between Rock and Swan Lake.

Pilot Creek

Pilot Creek begins in the sloughs to the south east of Pilot Mound, Manitoba. It flows north west to just north of Pilot Mound, where a small dam forms the Pilot Mound Reservoir. From this point, the creek meanders in a northerly direction and drops 100 feet to join the Pembina River just west of Swan Lake.

Figure 1: Study Area



The climate within the study area is typical of northern temperate zones. Although weather is similar throughout the area, there are significant localized variations in precipitation and temperature. Extremes often occur as a result of elevation differences (Manitoba Economic Atlas, 1982). This is most apparent in the area of the Turtle Mountains, which experience the greatest elevation changes (up to 700 feet over less than 10 km) in the study area and is subject to a somewhat different micro climate.

Within the study area, mean monthly precipitation can range from 3.2 inches in June to 0.7 inches in February. Average January temperature is 1.4, and average July temperature is 66.5. The mean annual temperature ranges from 1.2 to 1.6 degrees Celsius. Effective growing degree days (above 5 degrees Celsius) range from an annual mean of 140 to 170 throughout the area.

Geologically, the area is part of the Drift Prairie Plateau. Soils consist of medium to coarse till, with mixed shale, limestone and granite, with alluvial and sedimentary deposits (PFRA, 1975).

Much of the area has been affected by agricultural practices, with natural vegetation becoming increasingly less common along the eastern portion of the watercourse. In the Turtle Mountain area, the vegetation is mixed, with poplar, spruce, birch, and elm providing most of the cover. There are still several areas along the Upper Pembina River that retain a gallery forest along the watercourse and are relatively undisturbed by man. Some sections of Long River and Badger Creek are untouched. This generally occurs in areas where the steep valley walls make access very difficult, if not impossible. However, most of the tributaries are highly impacted with virtually no undisturbed areas remaining along their length where access is available.

3.0 METHODOLOGY

3.1 Riparian Surveys, Classification, and Project Site Evaluation

Evaluating an area as extensive as the Upper Pembina River watershed is a formidable task. To this end, it was essential that the evaluation utilize a combination of aerial survey, ground survey, literature review, and personal communication.

Riparian Surveys

Aerial surveys were conducted along the riparian corridors of the river system to achieve three goals;

i) Riparian classification
ii) Identify potential project sites
iii) Identify land use practices affecting the river

Aerial surveys were completed in May, July and October. Each of these flights compiled video records of the river. Flights were conducted utilizing fixed wing aircraft equipped with a remote controlled Sony video camera equipped with shot stabilization. Location information was recorded using a Trimble Pathfinder GPS with synchronized read out to computer with the video record. Evaluation of the video tape was later accomplished utilizing a Red Hen Systems decoding setup, coupled to Sony computers equipped with fire wire video connections.

Photographic records of potential sites of interest identified from the evaluation of the video record were obtained using digital camera equipment, and used both still photo at 2 megapixel resolution, and video at 0.64 megapixel resolution.

The aerial video tape was continuously recorded at an altitude of 500 to 800 feet above ground level. All flights began at Morden, Manitoba, and followed the main stem of the Upper Pembina River to the headwaters in the Turtle Mountains. Tributary streams were filmed during separate flights. The October flight excluded the Long River portions of the study area, due to inclement weather.

Ground Truthing

Ground surveys were carried out to meet two criteria. The first was to evaluate river riparian corridors which were identified from the aerial survey as potential project sites requiring rehabilitation and/or protection. The second criteria was to provide data to fill information gaps which were identified during the course of the study including physical and hydrological data.

Riparian Classification

Once the aerial record had been reviewed and ground verification studies conducted, all information was transferred onto digital 1:50,000 topographical maps provided by the Manitoba Land Initiative System (MLIS). The classification used three categories as follows:

Level 1: Primary source of nutrient loading to watercourse (i.e. feedlots or livestock watering areas), or extensive bank erosion causing loss of valuable crop land or pasture land, or vegetative buffer zone on shorelines inadequate for protection. (**Severe impacts to Riparian Corridor**)

Level 2: Source for occasional nutrient loading (livestock grazing areas) which can range from extensive to limited, or damage to vegetative zone on shorelines caused by livestock grazing, or width of vegetative zone on shoreline less than adequate, with moderate to no bank erosion, which may cause loss of crop lands or pasture lands.(**Moderate Impacts to Riparian Corridor**).

Leve3: No significant nutrient loading or bank erosion problems occurring on immediate shoreline areas and widths of vegetative buffer zones adequate to protect the watercourse (**No impacts to Riparian Corridor**).

The vast area and numerous tributaries being studied required a modified riparian corridor evaluation. Rather than attempting to construct one contiguous buffer around the main stem of the Pembina River, it was decided to segment the evaluation as follows:

- **The Lakes Division** including Swan Lake, Rock Lake, and Pelican Lake
- **Upper Pembina West Division** including Starke Creek, Little Pembina River, North Pembina River, and the reach from the Turtle Mountains
- **Badger Creek Division** including Long River and Kellys Ravine

- **Upper Pembina East Division** including Cypress Creek, Crystal Creek and Pilot Creek

Lakes were evaluated for riparian zone health using a buffer of 30 meters, whereas the Pembina River was examined using a buffer zone of 10 meters on each side of the watercourse. The tributaries were also evaluated using a 10 meter per side buffer zone.

Where possible, tributaries were evaluated for a minimum of eight kilometers of their length, either from where they entered the Pembina River, or the next order of stream that entered the Pembina River.

Project Site Evaluation

A review of the complete aerial photo record, including video, slides and prints was undertaken with the goal of identifying sites suitable for rehabilitation work. The video was digitally viewed using stop motion computer frames, which included the GPS position information. Potential sites were then listed for ground truthing.

In total, more than 180 potential sites were identified through the air photo record. Initially, the focus was on those projects on the main stem of the Pembina River. All tributaries were evaluated for potential projects. Although it was attempted to remain within the 8 kilometer zone assigned to the riparian assessment, in some cases high priority projects were located past this zone. Ground truthing occurred throughout the summer of 2004 and spring/summer of 2005, and ranged from small areas of erosion to large cattle operations affecting the water courses. Subsequent to this, the total potential sites were reduced from 180 to 65. All areas were evaluated for extent of impact to the watercourses, and potential for rehabilitation. The following evaluation table was utilized to assign priorities for potential projects:

CRITERIA FOR EVALUATION	low 0		medium 2		high 4
Project Affects Water Quality					
Project Affects Fish Habitat					
Project Affects Fish Migration					
Potential for Rehabilitation					
Landowners Participation					

Projects were then assigned a priority as follows:

0 - 6 points	low priority
6 - 9 points	medium priority
10 or greater	high priority

In essence, the projects evaluated three physical characteristics which could potentially affect fisheries values, namely water quality, fish habitat, and migration, one assessment characteristic (i.e. potential for rehabilitation), and one social characteristic, (i.e. the willingness of the landowner to participate in the program). In instances where the landowners participation was not yet determined, the project was assigned a medium (2) value.

Most projects affected only one, or at most two of the physical characteristics that were evaluated. Thus, a project that highly affected any physical characteristic, and had a high potential for rehabilitation, but had an unknown landowner participation, would still rate as a high priority project. Likewise a project that had a medium effect on all three physical characteristics, a medium potential for rehabilitation, and an unknown landowner participation could also receive a high priority.

Sites that scored less than four points were dropped from the survey.

In addition to the in-stream projects identified by the above methodology, an effort was made to establish a list of studies required to fill information gaps. These studies were also assigned priorities based on discussions with stakeholders and Department of Conservation personnel.

3.2 Physical Characteristics and Hydrology

Examination of the physical characteristics of the watercourses was done to evaluate both the gross morphology and the stream characteristics and parameters. Tributaries and the main stem of the Upper Pembina River were included in the examination of the physical characteristics. Several cross sections were available from the Pembina Valley Conservation District and are included on the compact disk accompanying this report.

Digital topographic maps were provided by MLIS, and were utilized to acquire data on the valley profile, and the stream bed profile for the watercourses. Digital topographic information was only available at a 1:250,000 scale. Valleys were considered to run for two kilometers on either side of the stream bed. Profiles were calculated and plotted for these sections.

Based on slope characteristics, three study reaches were selected for further evaluation. These reaches were selected to provide a general overview of hydrological characteristics in the Upper Pembina River. Ideally, several reaches in each tributary watercourse would have been selected, one from each habitat type. However, time and budget constraints did not allow this. Instead, reaches were selected to illustrate areas that would benefit from rehabilitation efforts.

Measurements were obtained for various parameters. Three cross sections which were representative of the reach were surveyed using methods described by Newbury and

Gaboury (1993). Measurements were obtained using a Trimble GPS unit capable of sub meter post corrected accuracy, for both vertical and horizontal position. Longitudinal profiles and thalweg were measured over a minimum of 12 X the mean bankfull width. Average slope was determined by dividing the total fall by the reach length, and was expressed as a percentage. Random samples of bed paving materials were obtained, and median diameter obtained by calculating frequency curves. Channel velocities were not measured during the survey.

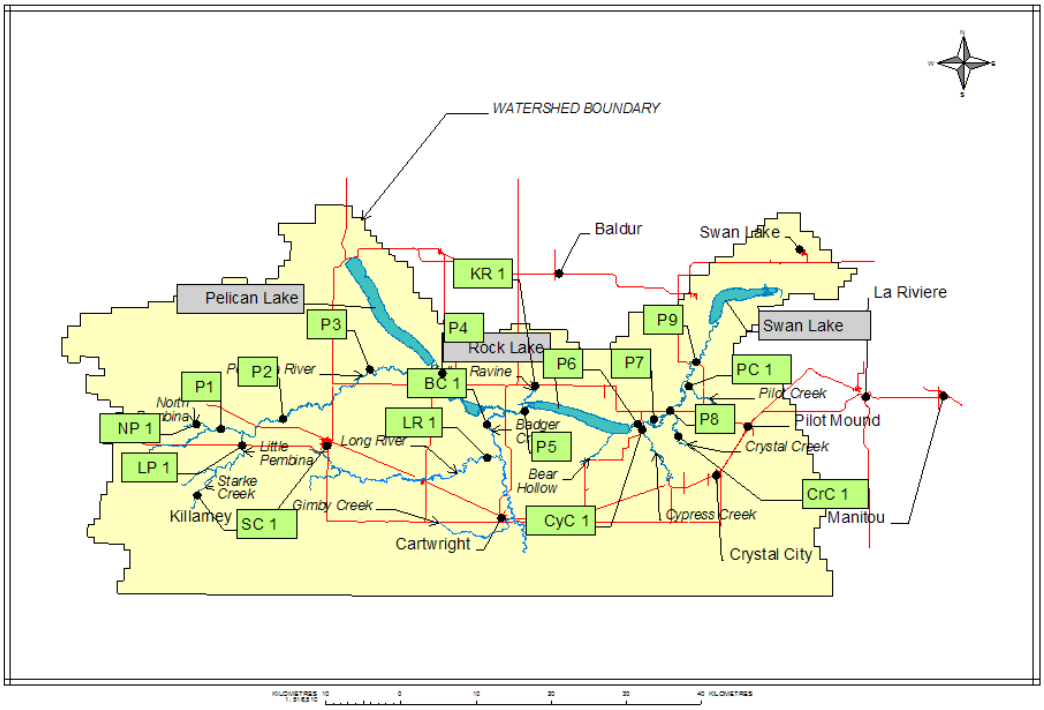
Bankfull velocity, bankfull discharge, Froude Number and tractive force were calculated as described in Newbury and Gaboury (1993). Discharge information for some of the watercourses was not available.

3.3 Water Chemistry

Water Chemistry was obtained using two methodologies. The first was through the WRAS program sampling results. This program obtained fairly complete water quality profiles at 11 stations on the Pembina River, Pembina River tributaries, and the major lakes.

Other Basic water chemistry was obtained at nine locations on Upper Pembina River and one location on each of the tributaries at the designated sample points (Figure 2). Data collected included pH, conductivity, and dissolved oxygen, using a Hach multi meter. A Hach field coliform incubator was used to gather total coliform count information twice at each location. Samples of algae were collected using a zooplankton tow in Pelican Lake, Rock Lake and Swan Lake, and sent to EnviroTest for analysis. All samples were single point in time data collections.

Figure 2: Sampling Locations (water chemistry, fish capture, and benthic sampling)



3.4 Fisheries Information

Small mesh minnow traps were set in 9 locations on the Pembina River, and 1 location on each of the tributaries (Figure 2) in June and mid August 2004, in an attempt to capture young of the year (Y.O.Y) fish species. The traps were all set at a depth ranging from 0.4 to 1.5 meters, and monitored on a daily basis for 3 contiguous days. All fish caught were identified.

Additional fish capture, including large bodied fish capture was accomplished with the use of a Smith Root electro shocker. Sweeps were conducted for 30 second intervals at all nine standard sampling locations on the Pembina River. The number of samples varied at each location, due to time constraints. Electroshocking sweeps were also conducted on the Badger Creek and Long River. The purpose of the large bodied fish collection was to determine presence or absence of fish during the summer of 2004. Additional work was conducted using electroshocking in the spring/early summer period of 2005 to augment fish distribution knowledge during this critical period. During this timeframe, the focus was on the 9 stations on the Pembina River, and all tributaries included in the study. Manitoba Conservation has conducted fairly complete species identification studies, and their information is also utilized in this report.

Fish distribution information was not attempted on the major lakes, as this information is readily available from Manitoba Conservation. While no attempt was made to conduct a formal creel survey on any of the watercourses, several anglers were interviewed as to the success they were having. Several local residents also volunteered information on the presence of fish species in their area.

3.5 Benthic Invertebrate Collection

Benthic samples were collected during September at nine locations on the Pembina River, and 1 location on each of tributaries (Figure 2). Samples were gathered using a six inch Eckman dredge and later sieved through 500 micron mesh screens. Samples were fixed, and shipped to Selko Aquatics in British Columbia for species identification.

4.0 RESULTS AND DISCUSSION

The review of the Upper Pembina River watershed for aquatic health and fisheries values utilized information which had been gathered during the course of this project, and existing data from a variety of sources. The following results and discussion include all information.

4.1 Riparian Survey, Classification, and Project Site Identification

Riparian areas are generally referred to as the transition zones along the banks of streams, rivers and lakes. These zones, sometimes called shorelands, are capable of holding saturation within the soil, resulting in the presence of lush vegetation. This vegetation in turn protects water quality by buffering run off to the water body. The vegetation also provides excellent habitat for a variety of wildlife and shore birds. Shore land vegetation also provides habitat and food sources for fish. Most importantly, the riparian zone allows rivers and streams to maintain a healthy channel profile, necessary to control water temperature, erosion, and depth.

Riparian zones can be highly altered by the activities of man. These include agricultural practices such as cattle grazing along river banks, or clearing of land for crops. Likewise, municipal activities such as road crossings, and lagoon operation can contribute to water quality degradation. Recreational activity, such as cottage subdivision activity, can remove valuable riparian area, and provide a source of nutrient loading from septic systems.

The riparian survey indicated land use practices around the Upper Pembina River area provide an opportunity for all of these alterations to potentially occur. The following summarizes the riparian survey by Division.

The Lakes Division

Pelican Lake

Pelican Lake is a highly utilized recreational water body that is undergoing continuous demands for more development opportunities. Where recreational development has taken place, the riparian zone ranges in condition from excellent to highly impacted depending on the individual cottage owners approach to lot management. Many areas were observed to be completely devoid of any riparian zone, particularly at the south and south west ends of the lake.

In general, the riparian zone is highly dependant on the level of the water within the lake. Shoreline vegetation tends to consist of sedges, willows and dogwoods, with poplar also common. Based on the information available at the time of the study, the riparian zone of 30 meters would encompass 121 hectares of land, and be composed of the following:

- Highly Impacted – 11 hectares (9.1%)
- Moderately Impacted – 44 hectares (36.3%)
- Low or Not Impacted – 66 hectares (54.5%)

Rock Lake

Rock Lake is also a highly utilized recreational water body that is undergoing continuous demands for more development opportunities. Where recreational development has taken place, the riparian zone ranges in condition from excellent to highly impacted depending on the individual cottage owners approach to lot management. Valley walls are steep, and the potential for increased shoreline erosion from a lack of riparian zone is high.

The steep banks and V-shaped nature of the basin make the riparian zone more sensitive to changes in water levels. Shoreline vegetation tends to consist of typical aspen parkland, with poplar and willow being common. Based on the information available at the time of the study, the riparian zone of 30 meters would encompass 104.4 hectares of land, and be composed of the following:

- Highly Impacted – 8.6 hectares (8.2%)
- Moderately Impacted – 31.0 hectares (29.7%)
- Low or Not Impacted – 64.8 hectares (62.1%)

An additional 16.8 hectares of buffer zone on Bear Hollow, which was included in the riparian analysis of Rock Lake, added 16.8 hectares (10 meter buffer zone) over the length examined as follows:

- Highly Impacted – 7.1 hectares (42.2%)
- Moderately Impacted – 5.5 hectares (32.7%)
- Low or Not Impacted – 4.6 hectares (27.4%)

Swan Lake

Swan Lake is a relatively undeveloped water body that is used primarily for occasional recreational use. The steep banks for much of the shoreline area make access difficult.

In general, the riparian zone is highly dependant on the level of the water within the lake. Shoreline vegetation tends to consist of sedges, willows and dogwoods, with poplar also common. Based on the information available at the time of the study, the riparian zone of 30 meters would encompass 90.6 hectares of land, and be composed of the following:

- Highly Impacted – 1.1 hectares (12.1%)
- Moderately Impacted – 14.0 hectares (15.5%)
- Low or Not Impacted – 75.5 hectares (83.3%)

<u>Upper Pembina West Division</u>

This division of the study area is the most geographically extensive portion, including Starke Creek, Little Pembina River, North Pembina River, and the reach from the Turtle Mountains to Rock Lake. The Pembina River meanders through primary agricultural land, with a relatively accessible clearly defined valley. Most of the riparian zone is subjected to some type of impact over the length of the river, with very occasional areas of non-impacted riparian zone. Most of the impacts were the result of cattle which in many locations were fenced in to riparian area pastures.

This same pattern was true for the three tributaries examined. Cattle were observed in the watercourses on many occasions in these streams during the summer of 2004. There were several areas where evidenced of past grazing could be found as well.

In spite of the extensive utilization of the riparian corridor for agricultural purposes, there is very little of the riparian zone that would be regarded as highly impacted. This is due to the steep drop to water level in most locations that limits access to a very few points. Where the impacts are severe, they tend to be very severe. Likewise, in the areas where valley walls prevented access the riparian zone appeared almost pristine in places.

The total run of these tributaries and the Pembina River would constitute a riparian buffer zone of 245.5 hectares at 10 meters in width. The riparian evaluation was as follows: In total, 8.91hectares were class 1,162.6 hectares class 2, and 74.02 hectares class 3 rating.

- Highly Impacted – 8.9 hectares (3.6%)
- Moderately Impacted – 162.6 hectares (66.2%)
- Low or Not Impacted – 74.0 hectares (30.1%)

Badger Creek Division

This division of the study area also includes the lower 8 kilometers of Long River and Kellys Ravine, Plus Badger Creek for 20 km from the Pembina River. These areas exhibited some of the most severe riparian zone impacts. This was especially true in the lower reaches of Badger Creek and Long River where the watercourses entered deeply incised valleys that had high erosion potential. Where cattle operations were present in these areas, the riparian zone tended to be highly impacted.

In addition to these impacts, there were several areas observed in the spring of 2005 where crop land was prepared to bare soil conditions virtually to the edge of the water courses. The high water levels and heavy rainfalls associated with the spring/early summer of 2005 illustrated the sediment loading that resulted from a lack of buffer zone in places. This type of impact tended to take place in the upper reaches of Badger Creek, and to a lesser extent along Kellys Ravine.

The total area of a 10 meter buffer zone for this division would be 87.8 hectares, with the following makeup:

- Highly Impacted – 30.2 hectares (34.4%)
- Moderately Impacted – 34.3 hectares (39.1%)
- Low or Not Impacted – 23.5 hectares (26.8%)

Upper Pembina East Division

This division of the river includes a 20 km run of the Pembina River from Rock Lake to Swan Lake, as well as the lower 8 kilometers of Cypress Creek, Crystal Creek and Pilot Creek.

The Pembina River snakes through a low marshy valley for much of its run in this area, and even though there are several agricultural operations in the area they tend to not

effect the riparian zone. This is in part due to the inability of land owners to make direct use of the shoreline, and in part to the resilience of the buffer zone along the river.

This is not the case when talking about the tributaries in this area. Several areas have highly impacted riparian zones resulting from agricultural operations. The banks of these tributaries tended to be highly erosion prone, and any type of near shoreline activity tended to cause slumping and collapse.

This was very evident in the spring/early summer period of 2005 when high water levels resulted in active erosion taking place along several stretches of the tributaries.

The total 10 meter wide buffer zone for the division encompassed 266.2 hectares, and was classed as follows:

- Highly Impacted – 28.8 hectares (10.8%)
- Moderately Impacted – 55.4 hectares (20.8%)
- Low or Not Impacted – 182.2 hectares (68.4%)

The high ratio of Low or Not Impacted was due to the Pembina River reach.

The associated buffer zones for all reaches included in the study area are found in Appendix 1.

Project Site Identification

The study was instructed to primarily include the Pembina River and its tributaries for consideration in the evaluation of projects and priorities. Lakes tended to receive more general assessment as they tended to reflect the results of increased nutrient loading or decreased water quality in feeder streams.

The study indicated several notable high priority projects along the Pembina River which if remediated could improve water quality and fish habitat. It was noted that the tributaries included in this study were contributing significantly to the deterioration of water quality in the Pembina River, and subsequently the lakes. Several high and medium projects were selected from these areas.

All of the watercourses within the study area were evaluated for potential project sites which would contribute to improving water quality, riparian zones or habitat. These projects included water quality deterioration due to municipal, residential, commercial and agricultural operations, spawning ground deterioration, and decreased recreational opportunities. In addition, barriers to fish migrations were evaluated.

Riparian and in-stream projects to protect water quality and improve environmental conditions have been on-going in the area, primarily as a result of efforts by the local Conservation Districts. The Manitoba Habitat Heritage Corporation, through its Green Banks Program, has also initiated many smaller scale projects. Manitoba Agriculture, through a variety of funds, has undertaken some extensive site rehabilitation projects to reduce nutrient loading resulting from run off through cattle operation areas. In spite of this, there is much work to be done, and a concentrated effort to protect the riparian zone remains.

Sixty-five projects were identified during the study which would meet the criteria for restoration or protection activities. Twenty-three projects were designated high priority, and another twenty as medium priority. These are summarized in Table 1, and locations are shown in Figure 3. Photographs of selected priority project sites are presented on the compact disk included with this report.

TABLE 1: PROJECT LIST

Project #	**Trace #**	Description	**Priority**
Pembina River			
PR-1	58	Cattle ranging along river, overland drainage from uplands unimpeded to river, some bank slumping	Low
PR-2	57	Cattle ranging along river	Low
PR-3	56	Road to river, low crossing, some erosion	Low
PR-4	59	Straight drain direct to river, need riffle	Low
PR-5	102	Cattle along river, yard to river, bank erosion	Medium
PR-6	54	Wetland being drained to river, sediment loading	Low
PR-7	53	Grazing to river, unimpeded access for cattle, some erosion	Medium-High
PR-8	52	Heavy grazing along river bank	Medium
PR-9	50	No riparian zone, direct drainage to river from crossing, cattle grazing	Medium
PR-10	45	Lawn to edge, nutrient loading issues	Low
PR-11	44	Unrestricted access to river, grazing, erosion, bank slumping	High
PR-12	43	Grazing to edge, bank slumping	High
PR-13	26	Low level crossing poorly constructed	High
PR-14	27	Grazing to edge, bank slumping	Low-Medium
PR-15	28	Cattle in river, trampling, erosion, poorly constructed crossing	High
PR-16	29	Field prepared to river edge, sediment loading	Low
PR-17	30	Grazing to edge of river, some slumping	Medium
PR-18	31	Heavy cattle use, severe trampling and erosion	High
PR-19	32	Heavy cattle use, erosion, poorly constructed crossing	High
PR-20	34	Cattle grazing to edge	Low
PR-21	35	Heavy cattle use, stream blockage (weir) stream bank erosion	High
PR-22	36	Unrestricted access, bank slumping	Medium
PR-23	37	Heavy cattle use, trampling, some slumping	Medium-High

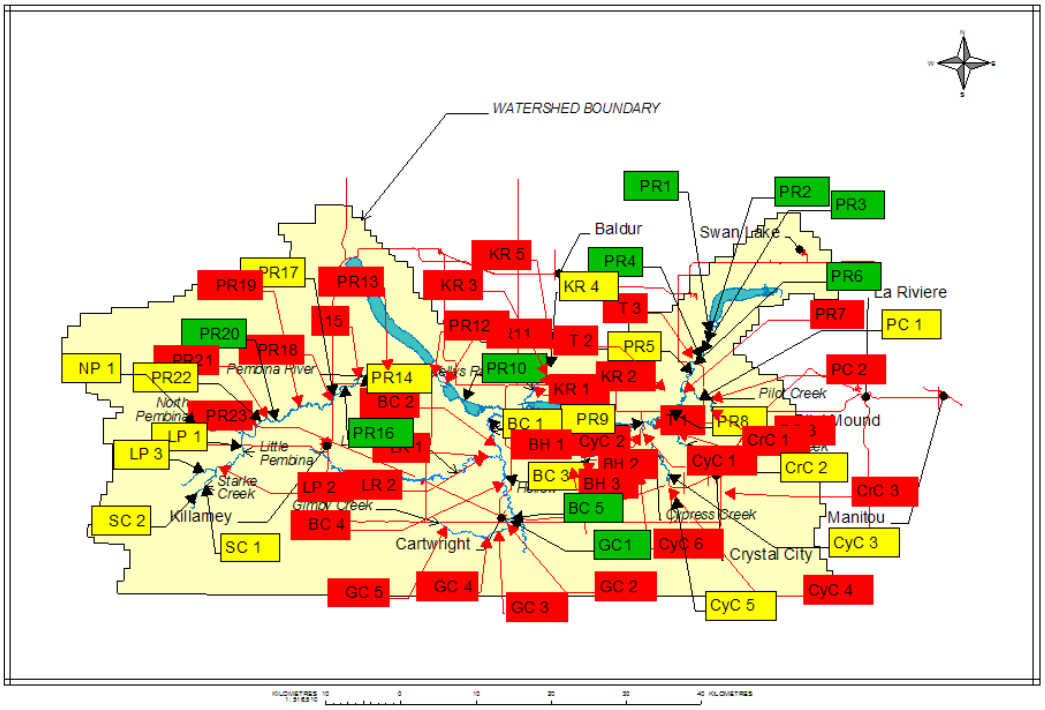
Badger Creek			
BC-1	9	Cattle grazing, some erosion	Low-Medium
BC-2	10	Heavy grazing, unrestricted access, heavy erosion	High
BC-3	11	Cattle grazing, some erosion	Medium
BC-4	12	Heavy grazing, erosion, need drainage plan for operation	High
BC-5	13	Cattle grazing to edge, some trampling	Low
Gimby Creek			
GC-1	14	Lagoons with short run to creek	Low
GC-2	15	Heavy use both sides, heavy erosion and trampling	High
GC-3	16	Heavy use, trampling, stream blockage, erosion	High
GC-4	17	Very heavy use, trampling, erosion, bank collapses, unrestricted access, improper crossing	High
GC-5	18-20	Very heavy cattle use, trampling erosion, bank collapse, several owners over 2 mile stretch	High
Kellys Ravine			
KR-1	2	Cattle in creek, heavy trampling	High
KR-2	4	Heavy cattle use, trampling, erosion, bank slumping, cattle in creek	High
KR-3	5	Heavy use by cattle, no riparian zone	High
KR-4	6	Cattle yarded along the edge of the river, need runoff management	Medium
KR-5	7	Heavy cattle usage, some trampling, erosion	High

Bear Hollow			
BH-1	96	Cattle with unrestricted access, bank slumping	High
BH-2	97	Heavy cattle use, cattle in creek, bank slumping	High
BH-3	98	Large cattle operation, unrestricted access, bank slumping, erosion, stream blockage	High
Cypress Creek			
CyC-1	77,78	Large cattle operation along river, unrestricted access, stream blockage	High
CyC-2	94	Heavy cattle use, bank slumping, erosion, poorly constructed crossing	High
CyC-3	79	Cattle along edge, some slumping	Medium
CyC-4	81	Large cattle operation, stream blockage, poorly constructed crossing, trampling, erosion	High
CyC-5	82	Cattle yard along creek, runoff plan needed	Medium
CyC-6	92	Tributary to Cypress Creek, large cattle yard, heavy grazing and erosion, need runoff management	High
Crystal Creek			
CrC-1	73	Heavy cattle use, trampling, unrestricted access to creek	High
CrC-2	72	Minor creek blockage, grazing, some bank slumping	Medium
CrC-3	69	Heavy cattle use, bank slumping, erosion, trampling	High
Pilot Creek			
PC-1	60	Grazing on river bank, some slumping	Medium
PC-2	62	Cattle in river, trampling, erosion occurring	High
PC-3	63	Cattle in river, poorly designed crossing, erosion, trampling	High
North Pembina			
NP-1	202	Cattle along river, trampling, yard management	Medium

Little Pembina			
LP-1	215	Cattle in river, erosion	Medium
LP-2	216	Grazing to edge, unrestricted access	Medium
LP-3	219	Cattle, trampling, partial stream blockage	Medium
Starke Creek			
SC-1	186	Grazing to edge, bank slumping	Medium
SC-2	188	Grazing to edge, bank slumping, some erosion	Medium
Unnamed Tributaries			
T-1	75	Heavy cattle use, trampling, bank slumping, north branch of Pembina River near Rock Lake	High
T-2	101	Unnamed tributary near Swan Lake, heavy cattle use, erosion, loss of riparian area	High
T-3	99	Cattle yard on small tributary near Pembina River at Swan Lake, trampling, runoff management	High

		LAKE PROJECTS	
Pelican Lake, Rock Lake, Swan Lake			
Lake-1		All grazing activities along lakeshore need to be curtailed. All lakes showed some evidence of this.	Medium
Lake-2		Numerous access roads have been built to the lakes. Most do not have any controls on runoff, and provide a direct conduit to the lake, bypassing the riparian zone. Proper berms and velocity controls are needed.	High
Lake-3		Pelican Lake and Rock Lake are extensively developed for cottages, with more development anticipated. Need continued public information sessions on riparian zone management to ensure lakeshore integrity and nutrient input.	High
Lake-4		Numerous large upland livestock operations may be nutrient loading lakes due to drainage system that often bypasses the riparian zone. Need runoff management study for the area.	Medium

Figure 3: Potential Project Locations



Agricultural Related Projects

The evaluation highlighted a need for riparian area projects related to cattle operations. Of the 47 medium to high priority projects identified, 38 related to this type of project. The rational for each project ranged from a need to reduce bank erosion and subsequent sediment loading caused by trampling, to protecting sensitive habitat for fish. In many locations, the tributaries to the Pembina River were far more sensitive to impacts to the riparian corridor and resulting nutrient loading in the lower reaches.

The issues were primarily related to livestock operations. While cattle operations were identified as a serious contributor to water quality issues, erosion and sediment loading were also serious issues.

Riffle construction projects were not a high priority in the Pembina River area. The primary reason is that the Upper Pembina River has extensive natural riffles throughout its reach. However, this may not be true of the tributaries, where steep runs down into the Pembina valley tend to increase tractive force and cause localized increases in erosion.

Municipal Related Projects

The Pembina River and its tributaries is crossed by numerous bridges for both rail and road traffic. The majority of the major crossings are well constructed and present little problem. However, several of the smaller crossings were identified throughout the area, which were subject to erosion and washout problems. In these areas, long relatively steep approaches allowed run off water to gather substantial velocity, eroding the ditches along the roadside, resulting in sedimentation in the river channel.

Flows in the Upper Pembina River were very high during the course of the field portion of this study. This prevented an evaluation of the impact of several of the crossings to fish migration. In the tributary reaches, several crossings are constructed as “ford” type of crossing. These overflow during high water periods, but during low to medium flows may not allow passage back downstream.

Access points to the lakes in the study area were more likely to be problematic. Most of the lakeshore, particularly on Pelican Lake and Rock Lake, are located on steep slopes. While these slopes were well buffered for the most part, and provided good riparian vegetation, access roads tended to provided upland drainage an unimpeded path to the lakes. This allowed nutrient loading to occur from drainage ditches located far back from the lake. As well, considerable erosion was noted on some of the access roads, further increasing sediment loading to the water course.

Potential Improvements to Fish Migration

Evaluation of the Upper Pembina River and associated watercourses indicated numerous barriers to fish migration throughout the area, which precluded the movement of fish under certain low flow conditions. These included several poorly constructed ford crossings for machine movement, poorly constructed temporary roadways for harvesting activities, and numerous small weirs that seem to have been constructed for water retention purposes. Beaver activity was very prevalent in the upper reaches of the Pembina River and in some of the tributaries, although activity could be found throughout the entire area. No consideration was given to beaver dams or their removal in this study.

The poorly constructed ford crossings were evaluated, and in several cases recommendations for improvements have been included in the project list.

Spawning Grounds

Spawning structure rehabilitation was not a major consideration in this study. The construction of spawning structure would not provide significant additional benefits and should not be considered. Any improvements to spawning would only be effective after issues pertaining to water quality; habitat destruction and creek bed disturbances by cattle are addressed.

Other Projects

Several projects were identified which potentially could benefit the area, but which were given a low priority due to several factors, such as high costs, staging of other higher priority projects, or the lack of a developed plan to address specific considerations. However, these projects could provide significant benefits as events change, and in the future may be given higher Priorities.

It was clear from discussions with interest groups, sportsmen, and landowners that further educational initiatives regarding practices around Pelican and Rock Lake would be beneficial in the area. The Conservation Districts have done an excellent job in presenting conservation information throughout the area, but further work would be beneficial. In addition, the Department of Conservation and Manitoba Habitat Heritage Corporation have put in significant effort in this regard, and have been successfully explaining their programs to the general public. A targeted educational effort that involved all disciplines involved with riparian and stream protection and management, along with available funding and incentive programs would further benefit the area. Any such further efforts would include the Department of Agriculture, game and fish groups, and the federal Department of Fisheries and Oceans.

In particular, the topic areas should include protection and restoration of riparian areas, alternatives to stream access for cattle, and construction and use of river fords by heavy machinery. While these messages have been widely broadcast, it is important that efforts continue.

Several initiatives are underway to improve the water quality in Rock Lake (increased water level via a raising of the east end dam) and Swan Lake (Pembina River Diversion and aeration). These activities will provide temporary improvements to the situations, but only by reducing the input of nutrient will the desired results be achieved on a long term basis.

Numerous information gaps exist which, if addressed could further enhance restoration and protection efforts in the Upper Pembina River Watershed. The most important of these is address the knowledge regarding water quality parameters on tributary streams to the Upper Pembina River. At this juncture, the Upper Pembina River has been monitored on a regular basis for several years. However, only very recent and incomplete information exists for the tributaries. Monitoring water quality parameters regularly would serve to establish a baseline which could be used to identity potential problems,

evaluate the effectiveness of mitigative and restoration efforts, and provide information to make informed decisions regarding future development in the area.

Finally, information regarding the use of the area by anglers and domestic harvesters is not available. A survey to establish use and fishing patterns would be implement management strategies for this area.

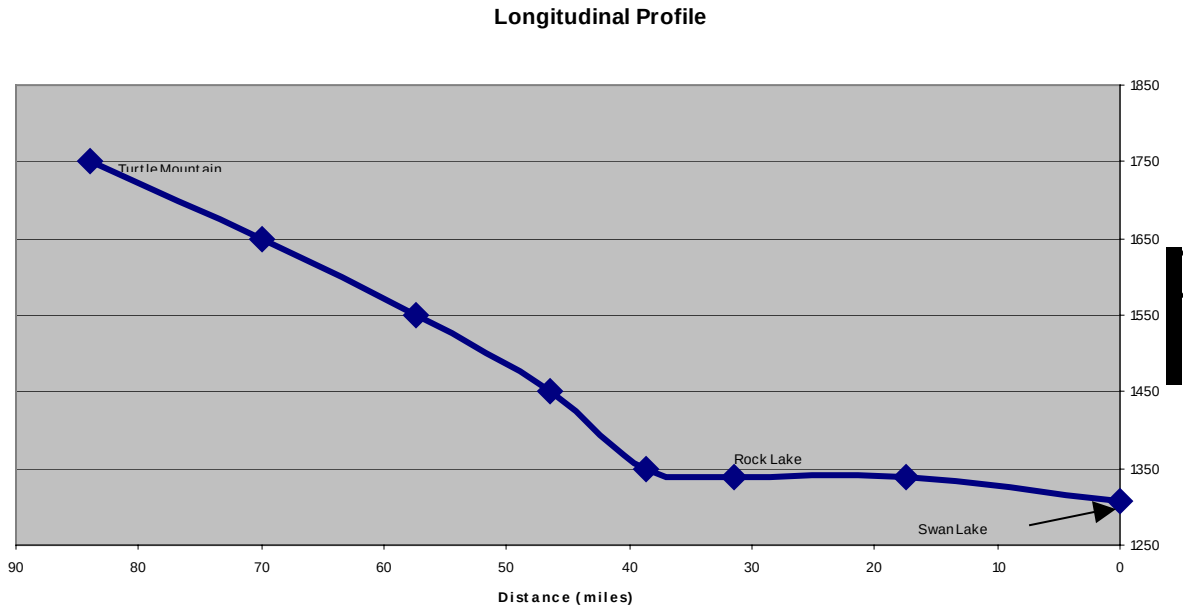
4.2 Physical Characteristics and Hydrology

Valley profiles and elevations for the Pembina River and the included tributaries in the study were reviewed as part of this study. The shape of the valley can have a large impact on the land uses and the subsequent impacts to the watercourse. For example, broad flat valleys such as those associated with the upper reaches of the Pembina River tend to incur agricultural activity, which includes crop production. In these sections, impacts can result from siltation associated with field preparation activities, loss of riparian area, and stream bank erosion. Steeper valleys, such as those found in the mid reaches of the Pembina River, and where tributaries approach the steep valley, make heavy equipment usage less likely, and often promote grazing activities in order for the landowner to get some use to what can amount to a significant portion of this land holding. In these sections, impacts are more likely to include erosion problems caused by drainage down the relatively steep valley walls, and bank erosion and streambed trampling caused by cattle left to graze in the valley.

The Pembina River is a low gradient watercourse ranging from a shallow gradient of 0.09% to 0.64%. The longitudinal profile is shown in Figure 4. This profile shows Upper Pembina River dropping some 700 feet over its run from the Turtle Mountains to Swan Lake. Unlike most rivers, the Upper Pembina River does not start out as a relatively narrow channel that increases in width as the slope decreases. Riffles, bank profiles and varying slopes throughout the run of the river lead to a series of alternating

wide and narrow sections of the river over the course of its run.

Figure 4: Longitudinal Profile



The slope of the river proceeds in a series of steps, with the steepest gradient at the headwaters. As the river comes off the Turtle Mountains, the slope decreases to just east of Killarney. A slight increase in the slope occurs from this point to about the highway 5 junction, where the river once again flattens out for the last reach before entering Rock Lake.

Straitening stream channels has the effect of increasing velocity, and the resulting tractive force of the water. The velocity of most streams is moderated by numerous meanders. The relation of meanders to the stream length is referred to as sinuosity. Stream meanders tend to complete a full sinusoidal wave form approximately every 12 times the bankfull width of the river (Newbury and Gaboury, 1993). The Pembina River has a sinuosity of greater then 2.1 to 1 (average) for its entire length. Shorter stretches can be as high as 3:1 in the middle/upper stretches, and as low as 1.9: 1 in the flatter section east of Rock Lake. Tributaries ranged from a high of 3.3:1 in the lower reaches of Starke

Creek, to a low of 1.4:1 in channelized sections of Kellys Ravine.

Increased velocity of the creeks provides a greater carrying capacity for suspended solids such as silt. It is expected that the channelization of some sections of the tributary streams has greatly increased the carrying capacity and erosion force in the water course.

In stream hydrological measurements were taken fro three reaches in the Upper Pembina River. Mean bankfull width and mean bankfull depth were 14.63 meters and 1.82 meters respectively for the upper reaches in the surveyed stretches, 24.8 and 1.9 meters in mid reaches, and 28.1 and 1.6 meters in the lower reaches. As previously mentioned, these values vary widely over the course of the river run, and should not be taken as indicative of the general characteristic of the river in any particular reach.

Bankfull discharges were not calculated for the entire river and all tributaries due to the need to survey several stretches of the watercourses to arrive at accurate figures. However, extensive profiles were compiled by the WRAS study, and are included on the compact disk that accompanies this report.

Flow records for mean flows for the Upper Pembina River are included on the compact disk accompanying this report. Three stations have provided records for more than 50 years regarding Upper Pembina River flows. Minimum flows of 0 m^3/s have occurred in all months except May, September and October.

4.3 Water Chemistry

Basic water chemistry was gathered for each component of the watercourse included as part of the study area scope. Additional information was gathered from the extensive WRAS data base for the Pembina River. Appendix 2 shows information regarding the nine sites where water chemistry information was gathered on the Upper Pembina River, and the one site on each of the tributaries. In general, the information was similar to

parameters reported by Manitoba Conservation (1999) for the watershed. Additional water chemistry results can be found on the compact disk that accompanies this report. The water quality at the time of the survey was fair/good in the streams when compared to similar prairie streams, and moderate in Badger Creek and Kellys Ravine. Water quality is affected by many criteria, and during the course of this study, was most affected by the unusually high water levels and flows. A consequence of this may be that the water quality appeared somewhat better than would be achieved under more normal flow conditions. This would only be captured during longer term monitoring.

The Lake Division was sampled for additional parameters relating to the inquiries voiced by local citizens. These included fecal coliform counts, total coliforms, and ammonia (NH,) levels. At the time of the observations, Pelican and Rock Lake were showing evidence of moderate algal blooms in backwater, and shallow shoreline areas where light penetration fostered such growth. There appeared to be two distinct types of algae present. The first type occurred in all the areas of the watercourse. Analysis of this sample showed that blue-green algae dominated this sample. The main species were Aphanizomenon flos-aquae and Gomphosphaerium spp. Also present in lesser numbers, and generally restricted to shallow areas were Microcystis viridis, Pzuedonanabaena consticta, Anabaena sp., and Lyngbya Limnetica.

Numerous diatoms were also present in the sample, including Stephanodiscus spp., Gomphonema spp., Nitzschia spp., and Navicula spp. These are all common to prairie water bodies.

Manitoba Surface Water Quality Objectives (MSWQO) suggest that extensive algae blooms or aquatic macrophyte (weed) production is promoted when concentration of phosphorus are higher than 0.025mg/1. Total phosphorus values of up to 1.1mg/1 were several orders of magnitude higher than the values suggested for healthy water courses.

The presence of Aphanizomenon is significant in that is usually an indicator of polluted water. It can also be an indicator of high pH, which was the case for the sample (pH 8.8).

When large masses of Aphanizomenon decompose, a foul septic or "pig-pen" odour can be present. This odour was not evident at the time of the sample. Dense blooms of the species found can be highly toxic to livestock and other animals.

Extremely high coliform counts (>1,000) have been reported for the Pembina River, but were not found during the course of the study. This was due to the limited scope of the sampling, and the high water levels.

4.4 Fisheries Information

Small mesh trap net sets were intended to provide information on the distribution of fish throughout the study area. As well, it was hoped that the study would provide some indication of spawning success for fish species in the Upper Pembina River. The sets were spread out in various areas, with a focus on those habitats that appeared to be suitable for game species, but also to get an overall idea of the species composition of the Upper Pembina River.

The most widely distributed fish were the fathead minnow and the brook stickleback, which seemed to occupy virtually all reaches of the Pembina River and the tributaries. In several of the tributaries, these were the only species caught.

Game species were restricted to Northern Pike, with samples caught throughout the Pembina River, and in the Starke Creek and Little Pembina River tributaries. Anecdotal information indicates that under certain conditions, pike distribute much more widely than was indicated by the results of the study. Indeed, although several of the barriers to fish passage appeared to block any kind of migration, high flows in the early summer of 2005 showed how easily passable these structures could become under the right conditions. When this happens, fish most likely become stranded if water levels recede. In the case of several of the smaller tributaries, this stranding would lead to fish kills, as little over wintering habitat is available off the main stem of the Pembina River.

The steep gradients associated with the Pembina Valley probably serve to discourage the spread of fish from the lakes and into the streams during the spawning season. Velocities are high at these times, and the duration of the flows is short. It is expected that the majority of game species spawn in the lakes, or where possible make short river runs.

All fish species captured and the distribution maps are shown in Appendix 3.

4.5 Benthic Invertebrates

Benthic invertebrate collection in the tributaries and the Pembina River showed a wide range of species, with Chironomid larvae, caddis fly larvae and small clams being common among the 30 plus species identified. The exception to this was Kellys Ravine, where the species composition showed that members of the family Oligochaete dominated the species makeup. Members of this family are generally associated with slightly polluted or stagnant waterways, such as those found below marshy areas.

Badger Creek had the lowest species diversity with 12 different species of benthic invertebrate noted. The study was designed strictly to be qualitative and not quantitative in nature.

Listings of benthic invertebrates are found in Appendix 4.

5.0 CONCLUSIONS

The Upper Pembina River and its tributaries comprise a diverse watershed, which provides important benefits to numerous users, as well as providing important habitat for aquatic life. Each watercourse evaluated had very different characteristics and as a result, an associated diverse set of issues.

The following summarize the observations from this study:

- The lakes associated with the Upper Pembina River watershed serve as settling basins for a vast quantity of nutrient loaded water
- High nutrient loading in the Upper Pembina River watershed is a direct result of land use practices that increase the potential for damage to the riparian zone
- The riparian zone for the main stem of the Pembina River is most effected in the western reaches, and less effected below Rock Lake
- All tributaries included in the study showed various and sometimes extensive degradation of the riparian zone, leading to high nutrient loading
- Agricultural operations, primarily cattle, were the source of the majority of the impacts detected during the course of the study.
- Although water quality was the major issue for the study, it should be noticed that no lethal levels to fish were encountered. It is known that there have been past fish kills in the lakes associated with the Upper Pembina River watershed
- 65 projects were identified which could over time lead to improvements in water quality for the Upper Pembina River watershed
- educational initiatives aimed at helping stakeholders understand the nature of the watercourse, and the impacts that practices can have, should be intensified
- blockages to fish migration were more likely to impact via stranding than lack of access, as was evidenced during the high waters in the spring/early summer of 2005

A concentrated effort at riparian zone management is likely to pay significant

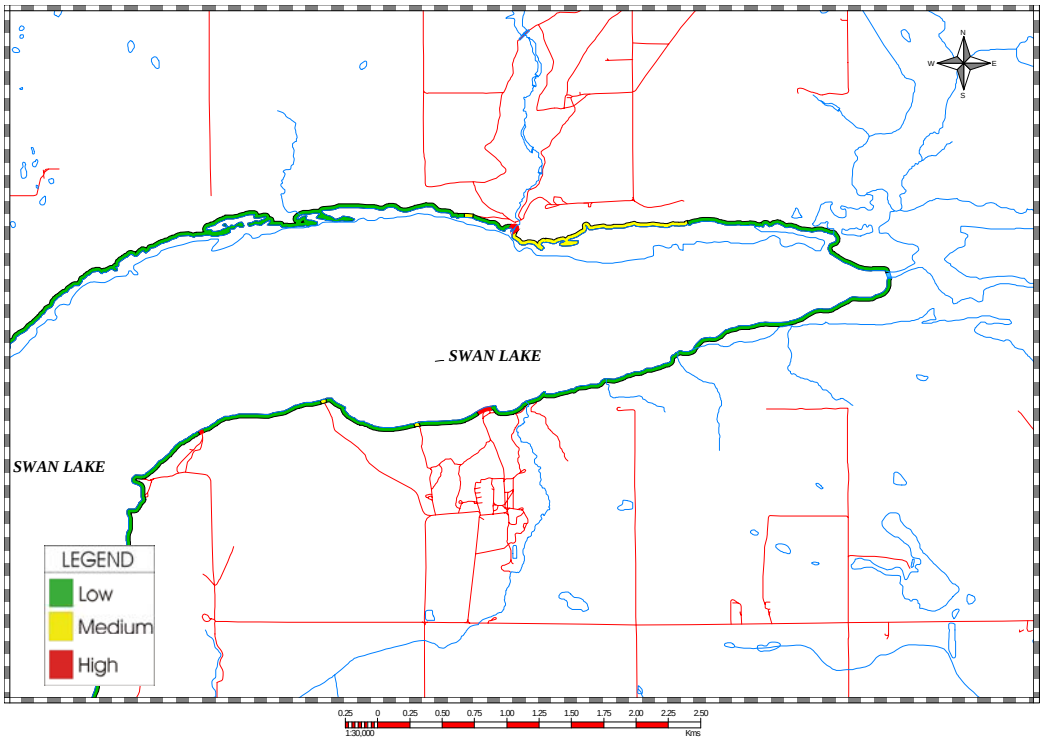
dividends in improving water quality in the Upper Pembina River watershed. In particular, it is felt that a concentrated effort must be made to address the issue of tributary restoration, as many of the impacts occur in what are often considered "less important" streams and creeks.

Appendix 1-Riparian zone classification

APPENDIX 1: BUFFER ZONES

Note: buffer zones begin at the eastern tip of Swan Lake and proceed west to include the study area. The only exceptions are:

- Badger Creek – when the view gets to Badger Creek it follows the creek south to Long River, and then returns to the Pembina River
- Pelican Lake – Pelican Lake is encompassed by the last four views.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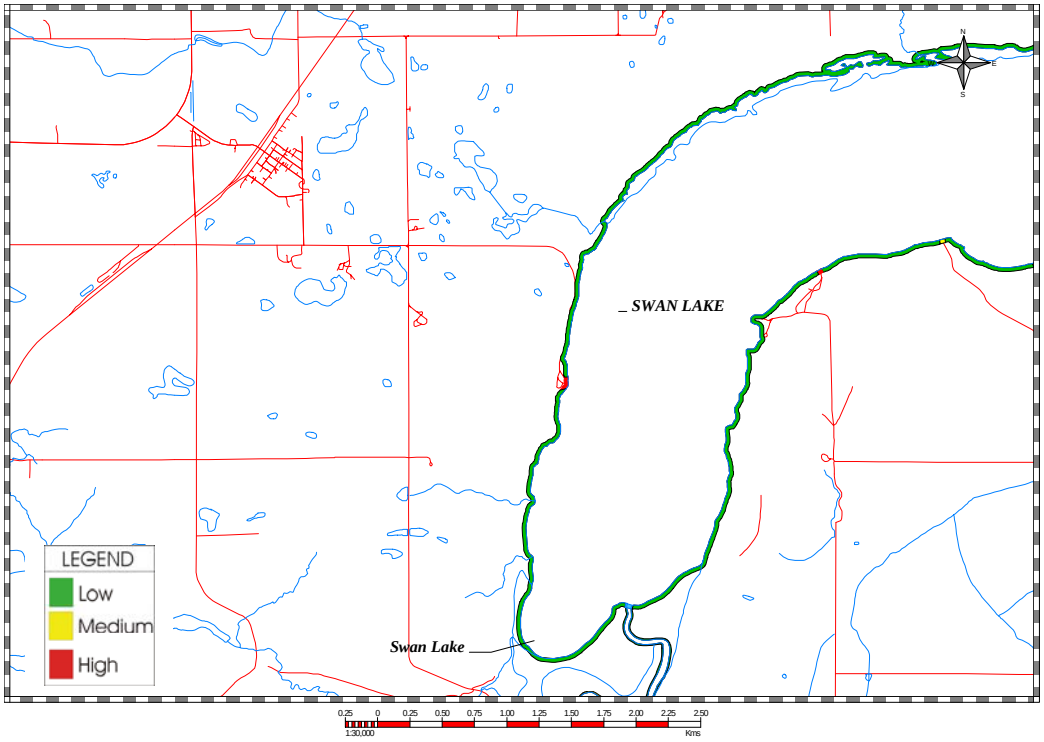
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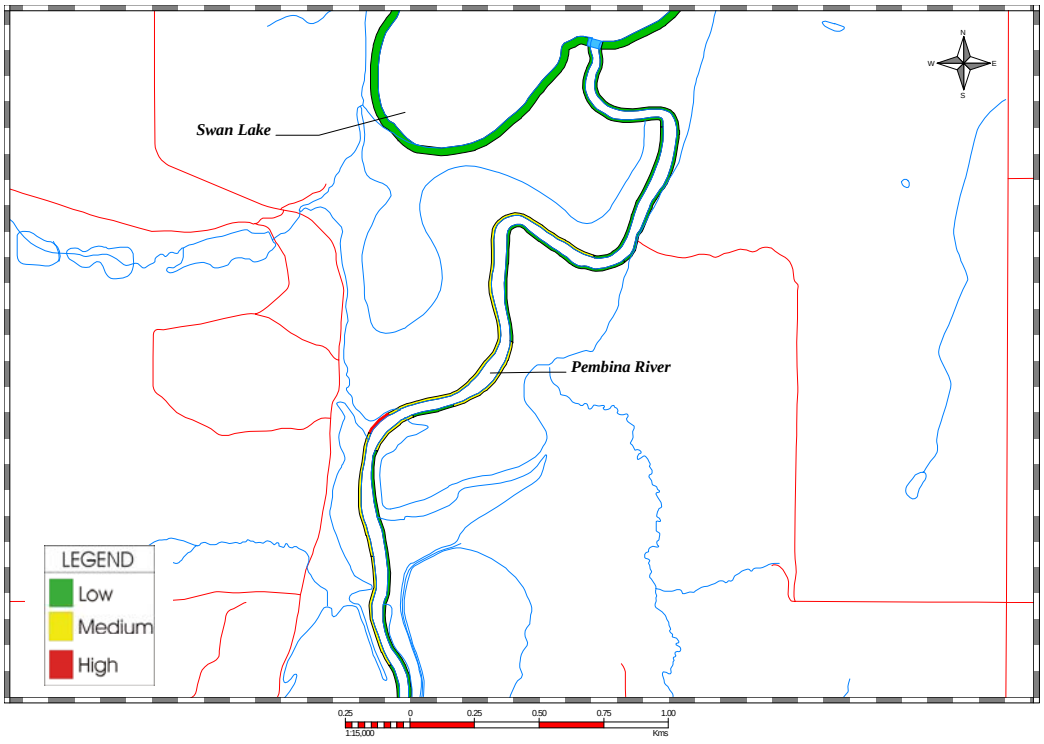
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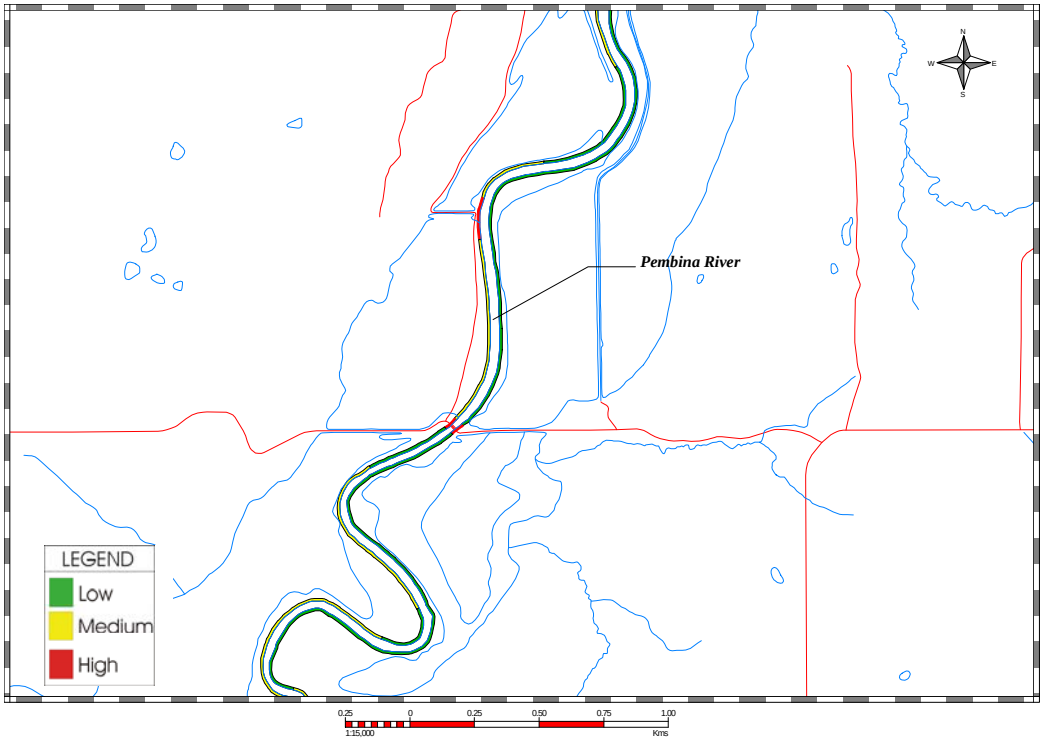
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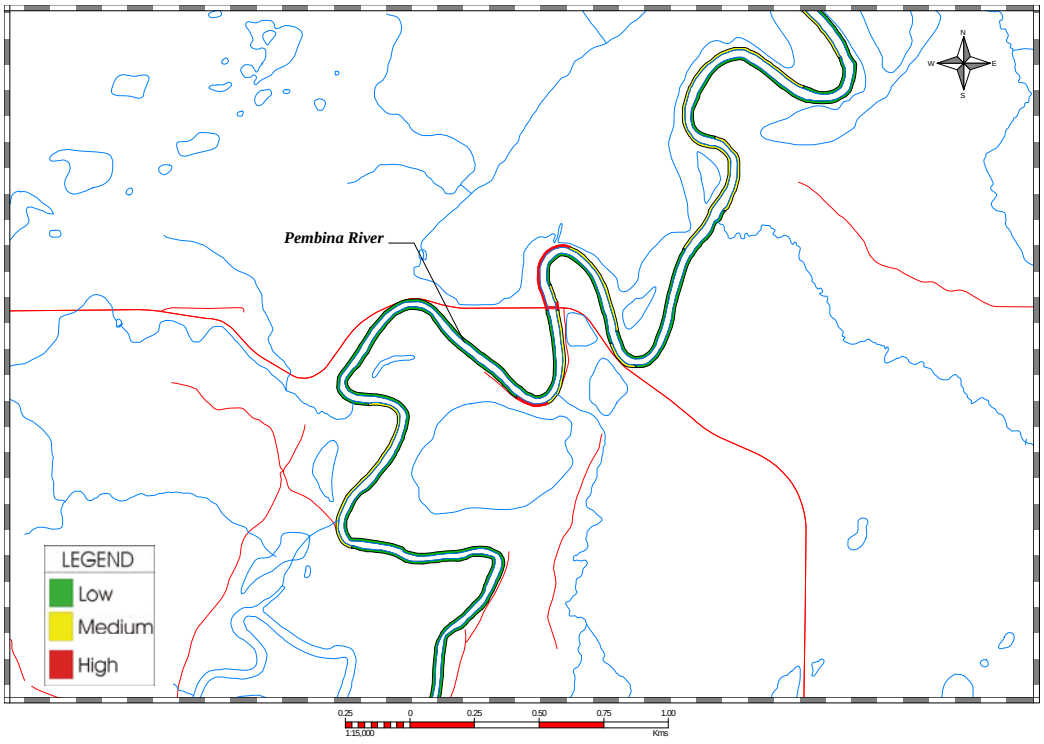
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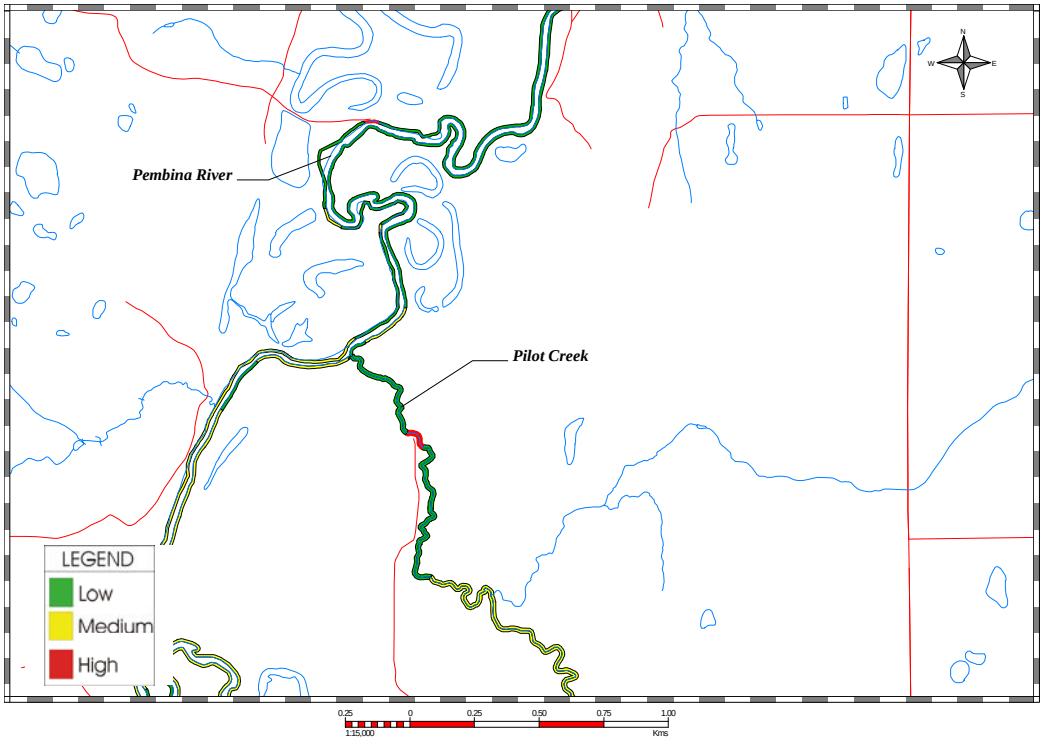
Pembina River
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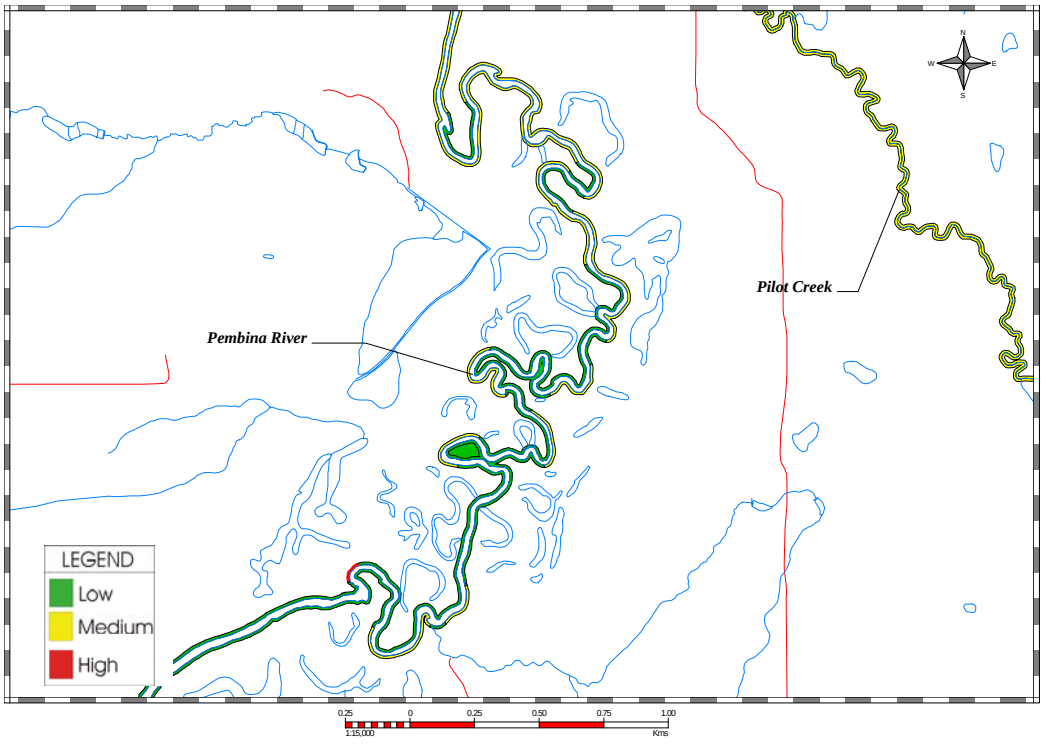
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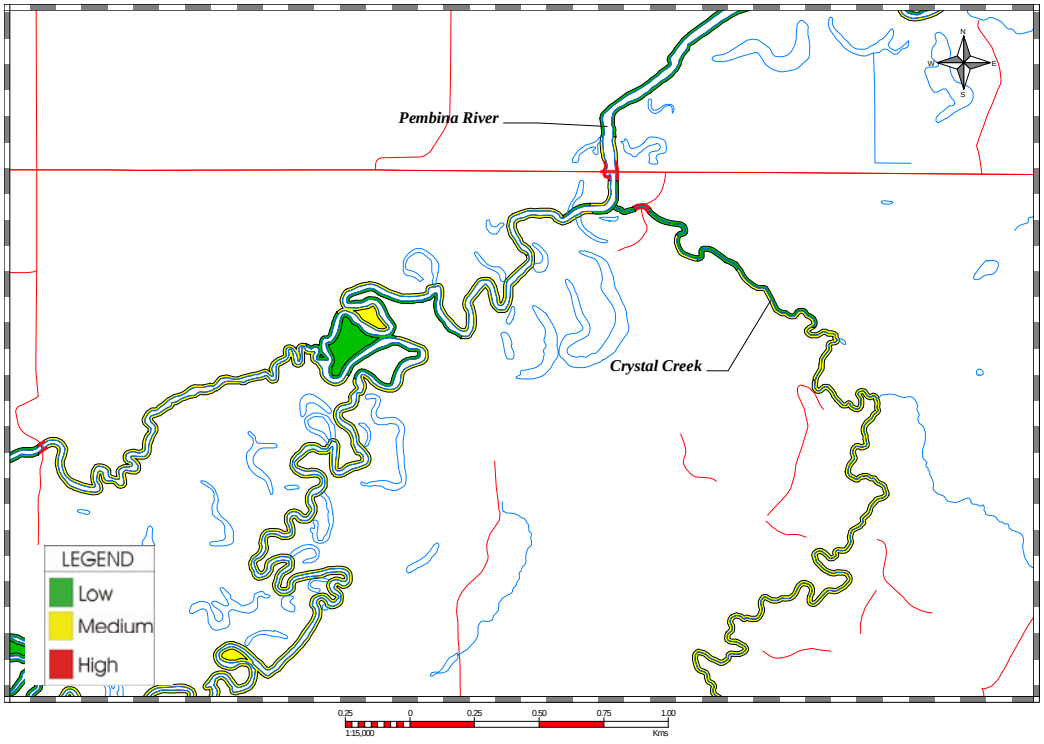
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Crystal Creek
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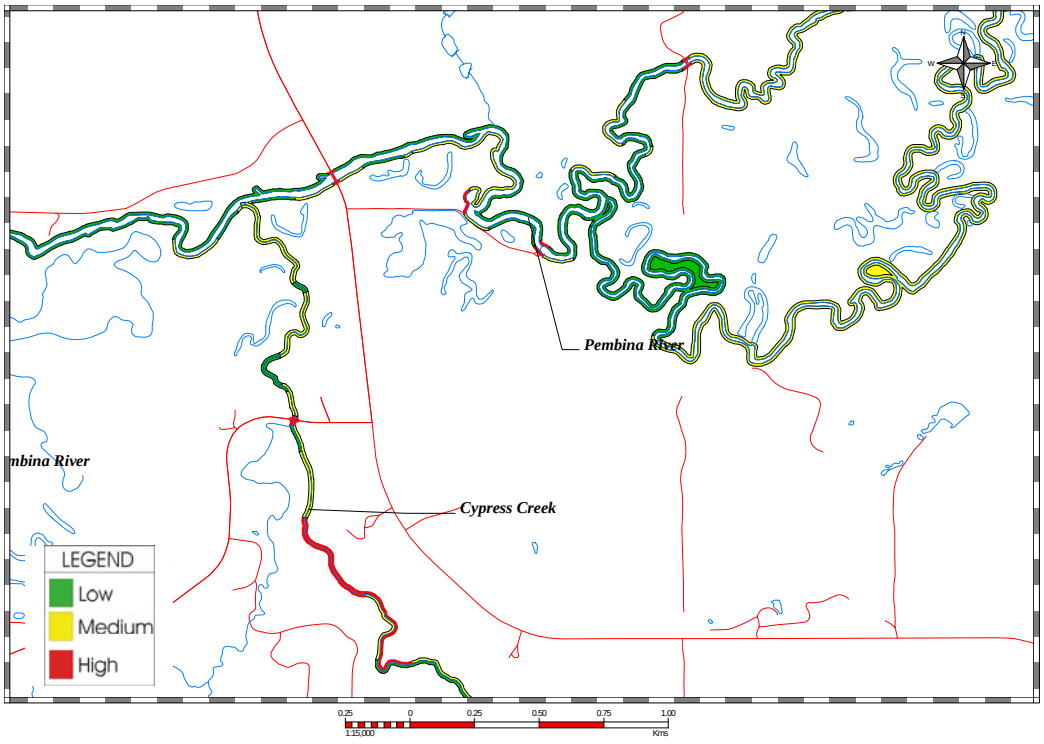
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Cypress Creek
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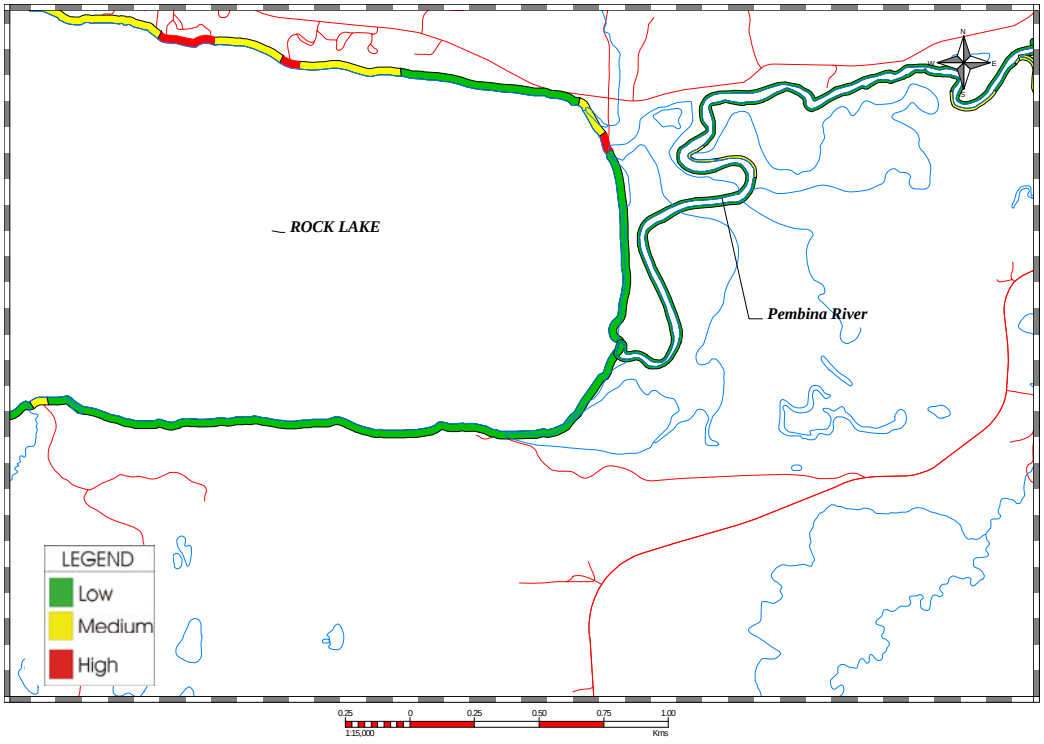
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Pembina River
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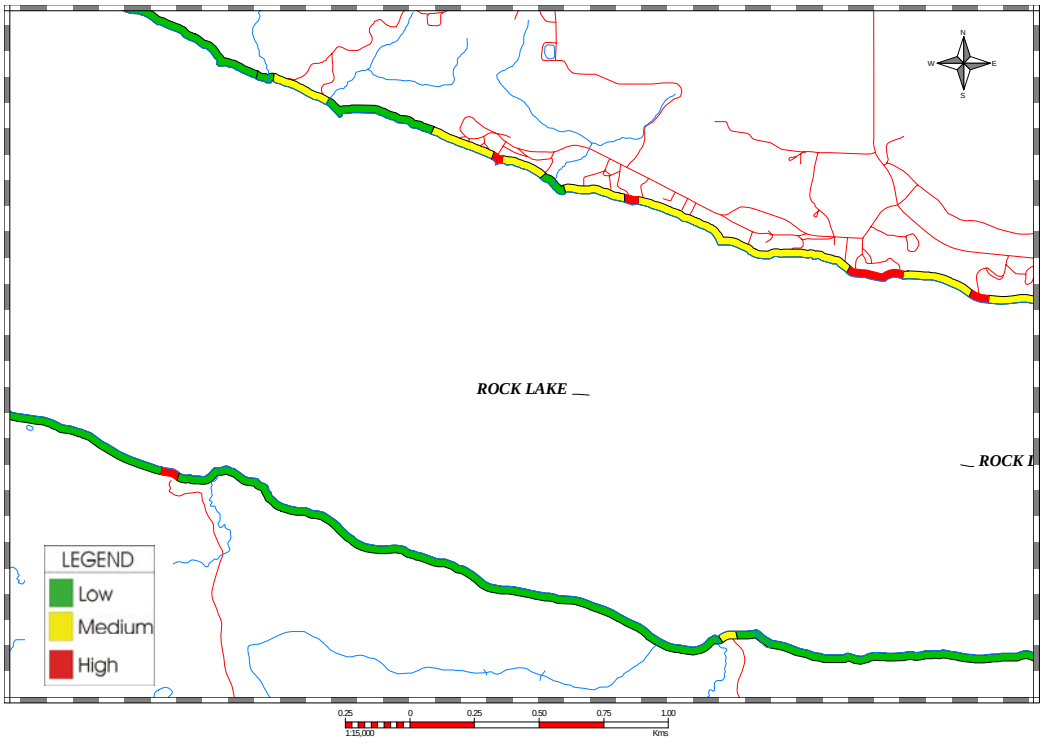
Kms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LEGEND
Low
Medium
High
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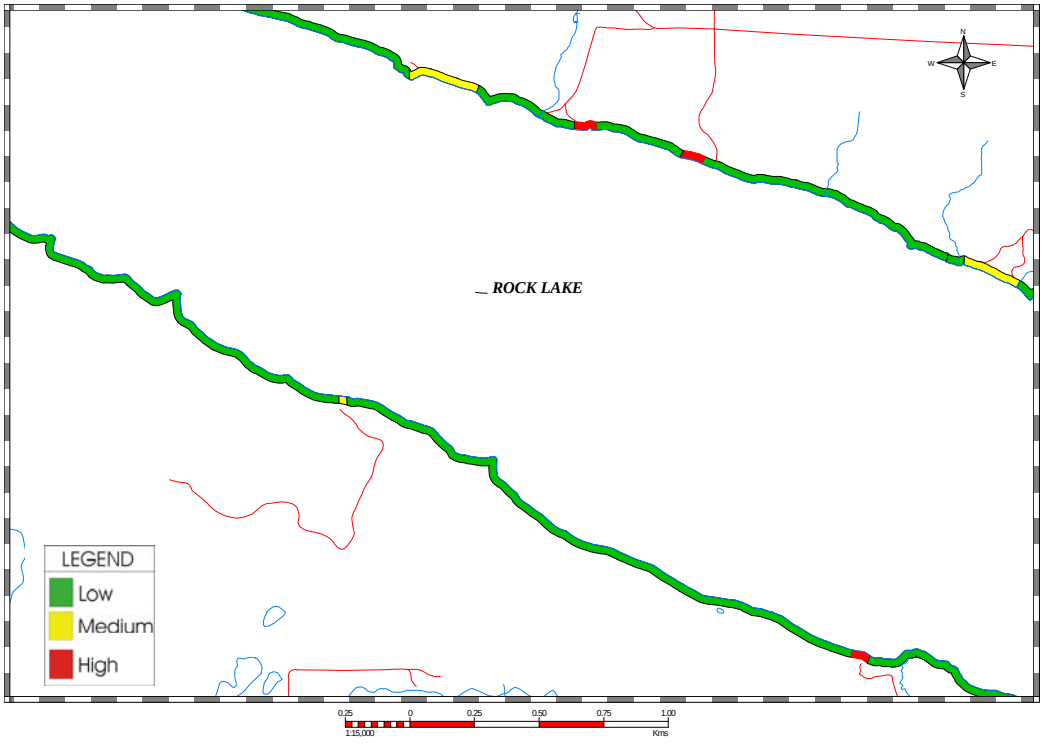
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LEGEND
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Medium
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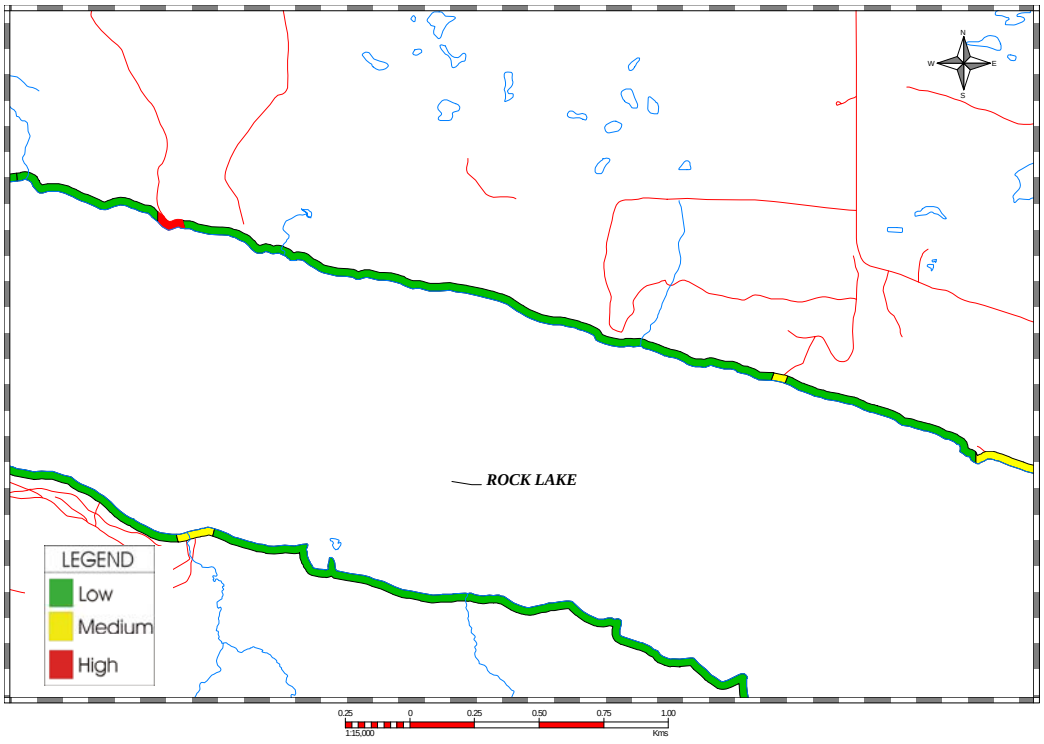
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LEGEND
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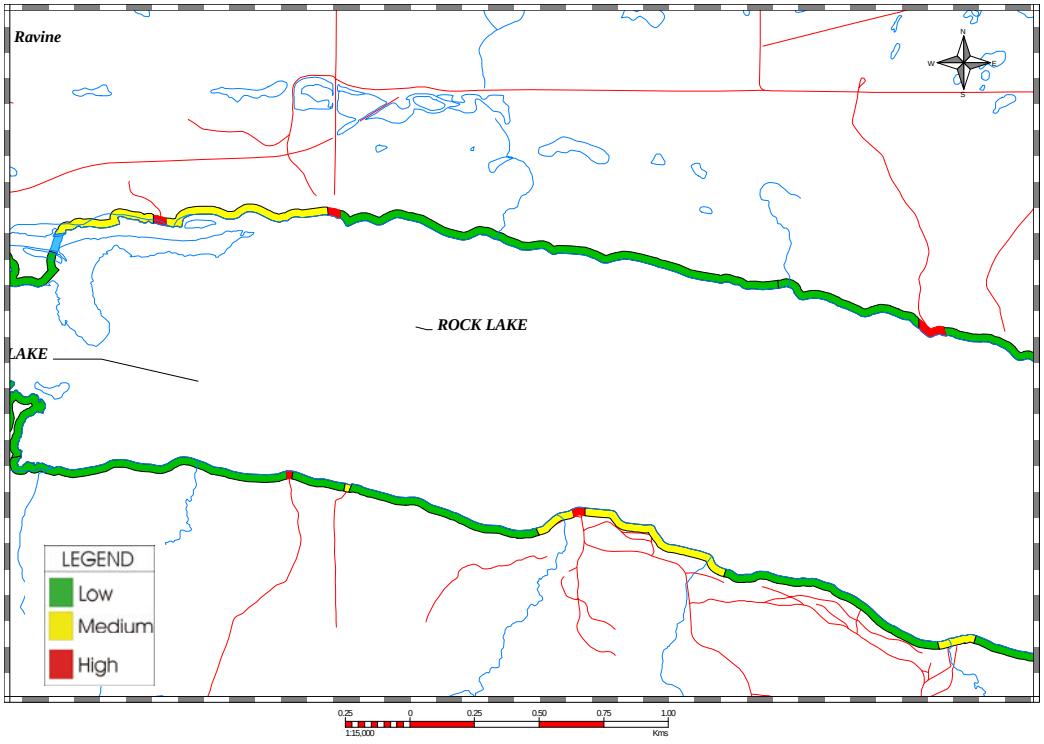
Ravine
ROCK LAKE
LAKE
LEGEND
Low
Medium
High
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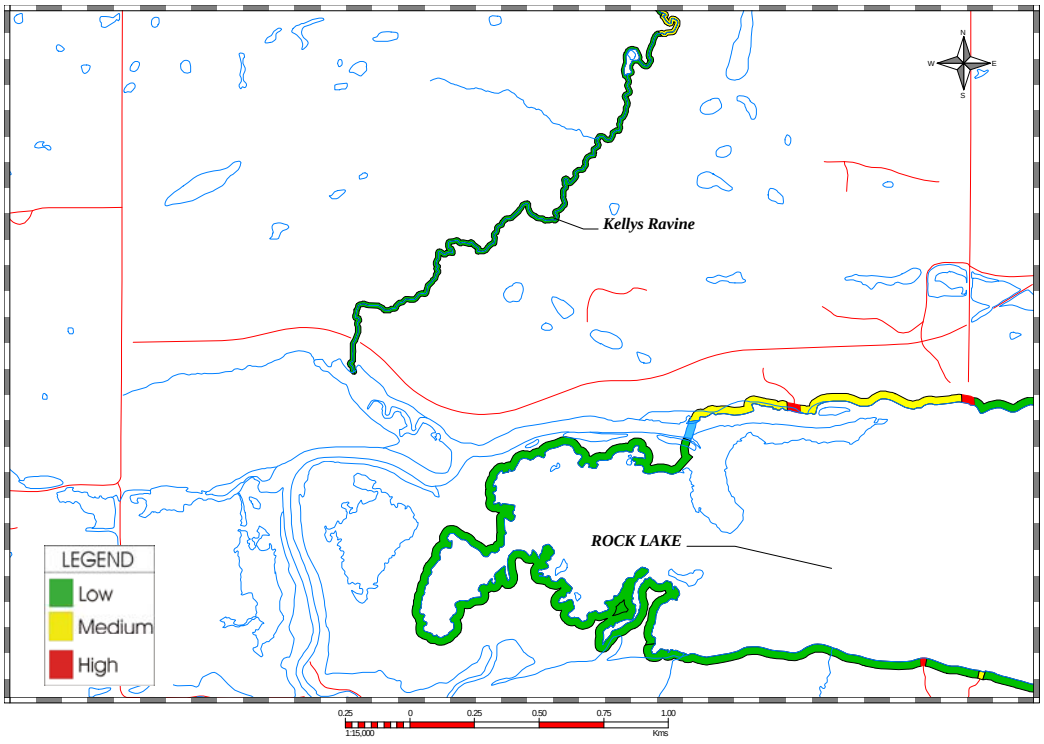
Kms


Kellys Ravine
ROCK LAKE
LEGEND
Low
Medium
High
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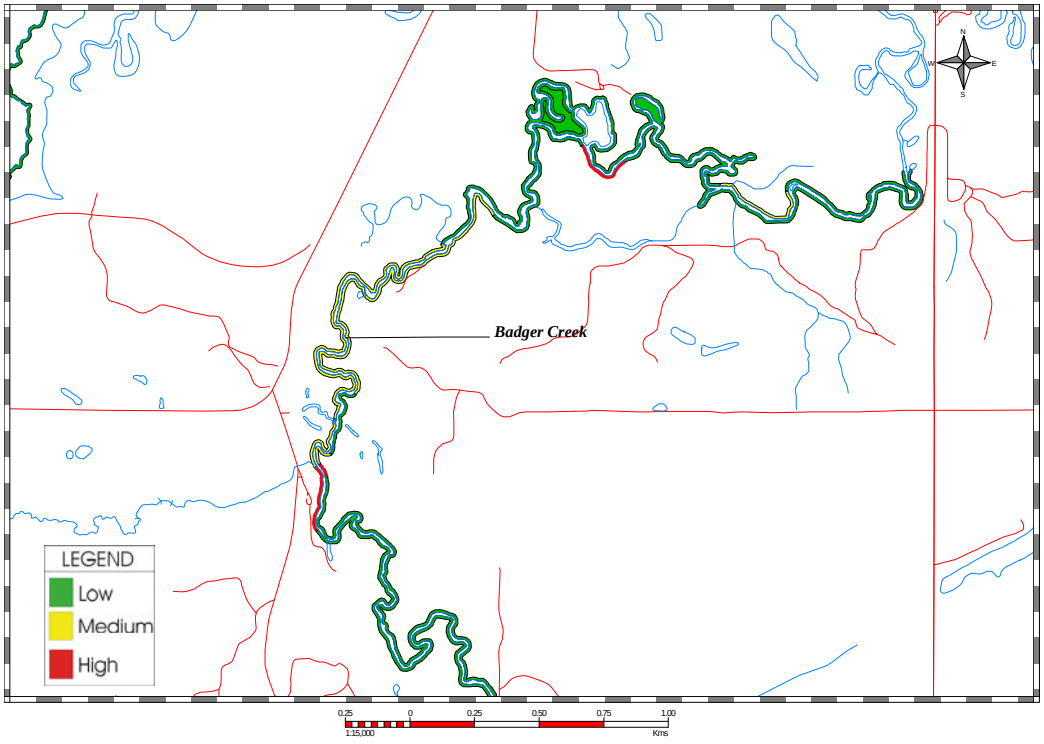
1:15,000
Kms


Badger Creek
LEGEND
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High
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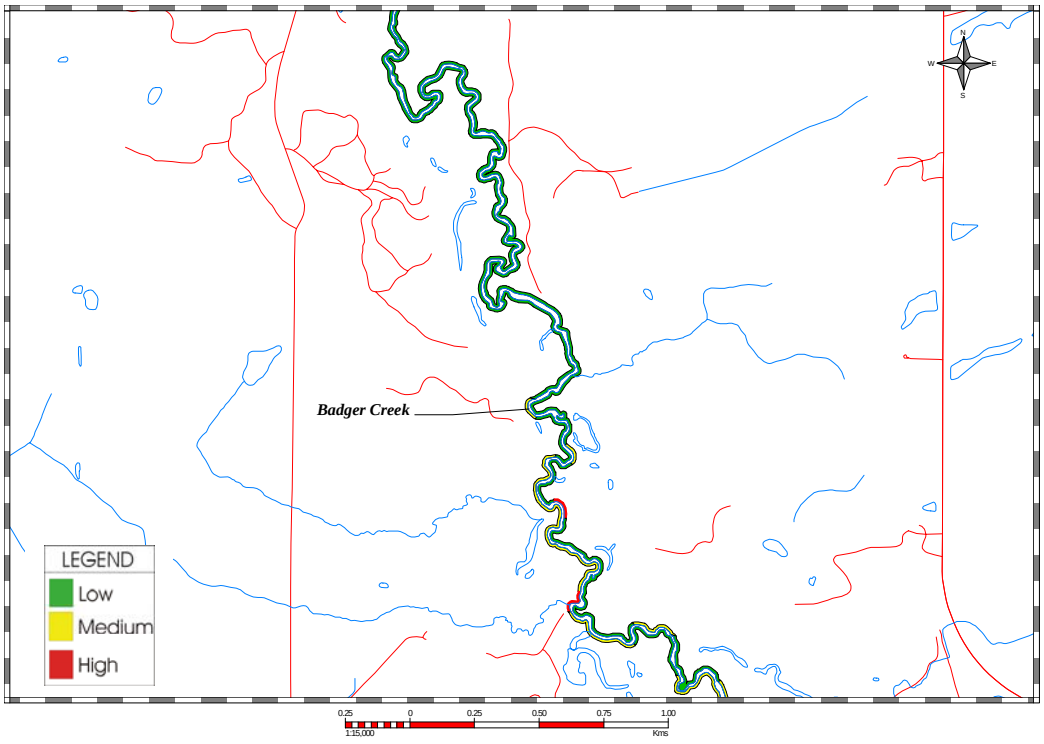
Kms


Badger Creek
LEGEND
Low
Medium
High
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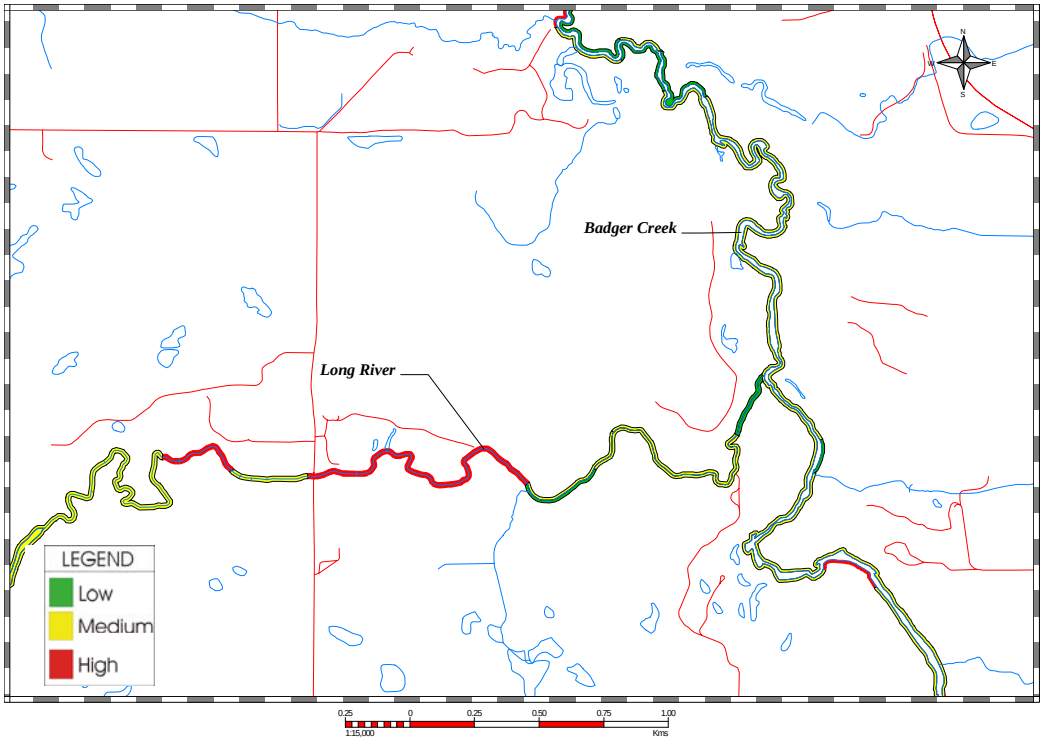
Kms


Badger Creek
Long River
LEGEND
Low
Medium
High
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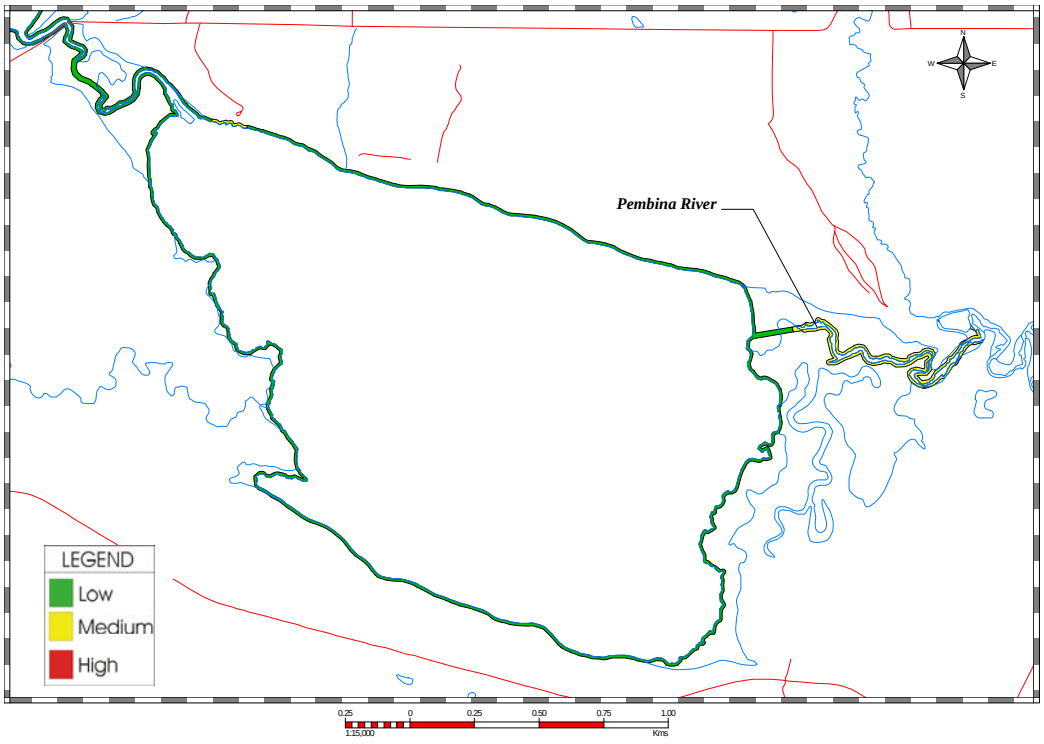
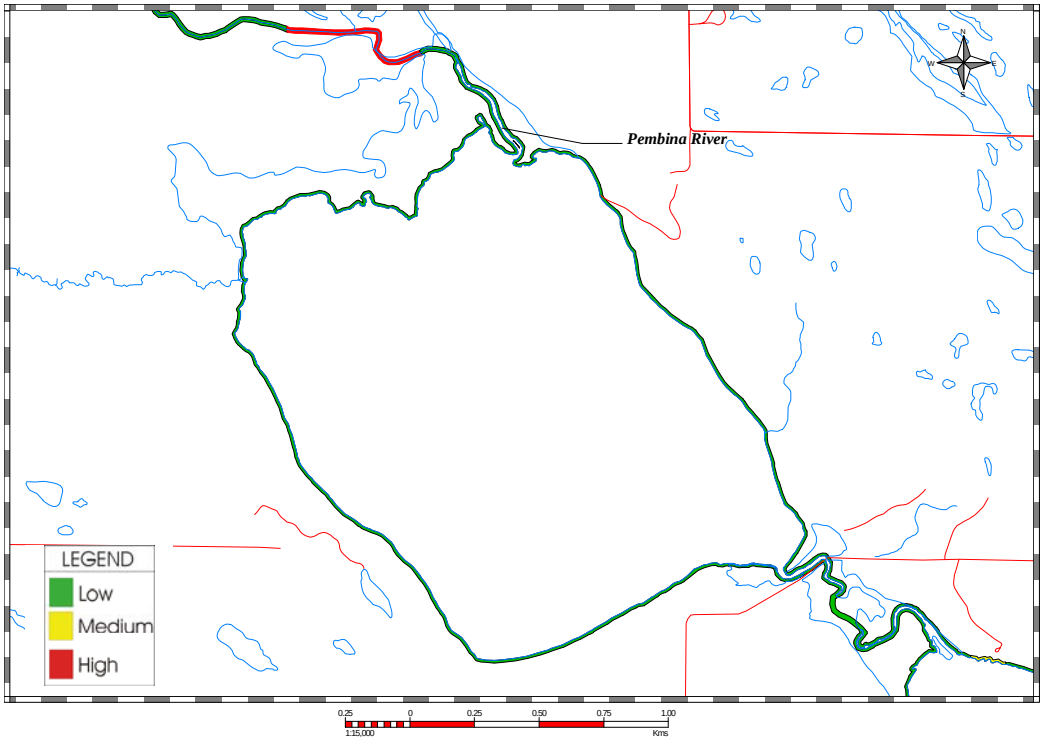
Kms


Pembina River
N
W
E
S
LEGEND
Low
Medium
High
0.25
0
0.25
0.50
0.75
1.00
1:15,000
Kms


Pembina River
N
W
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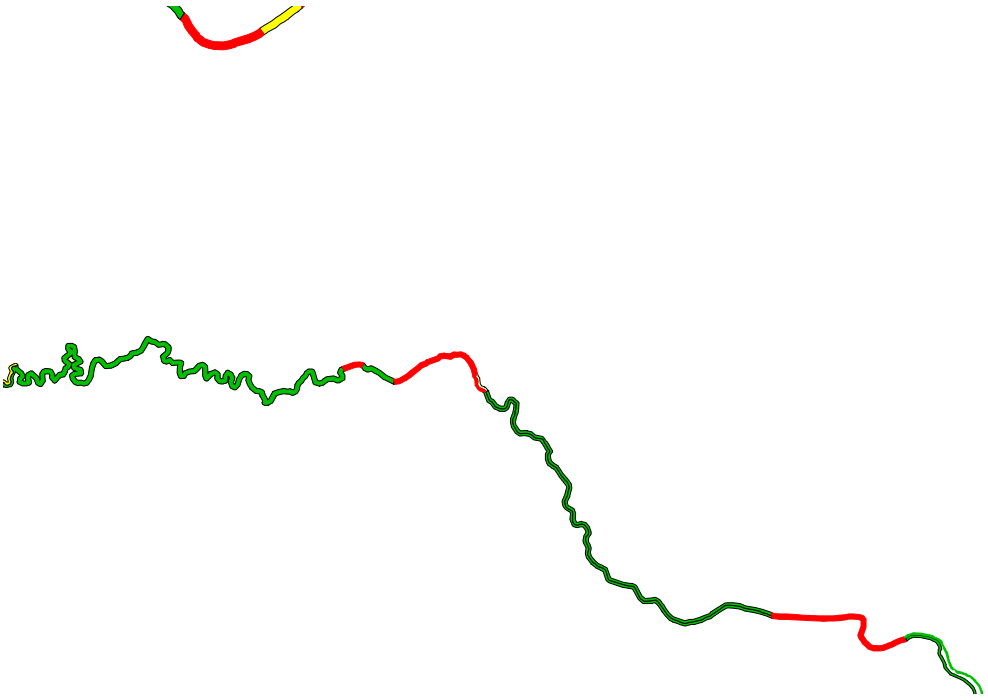
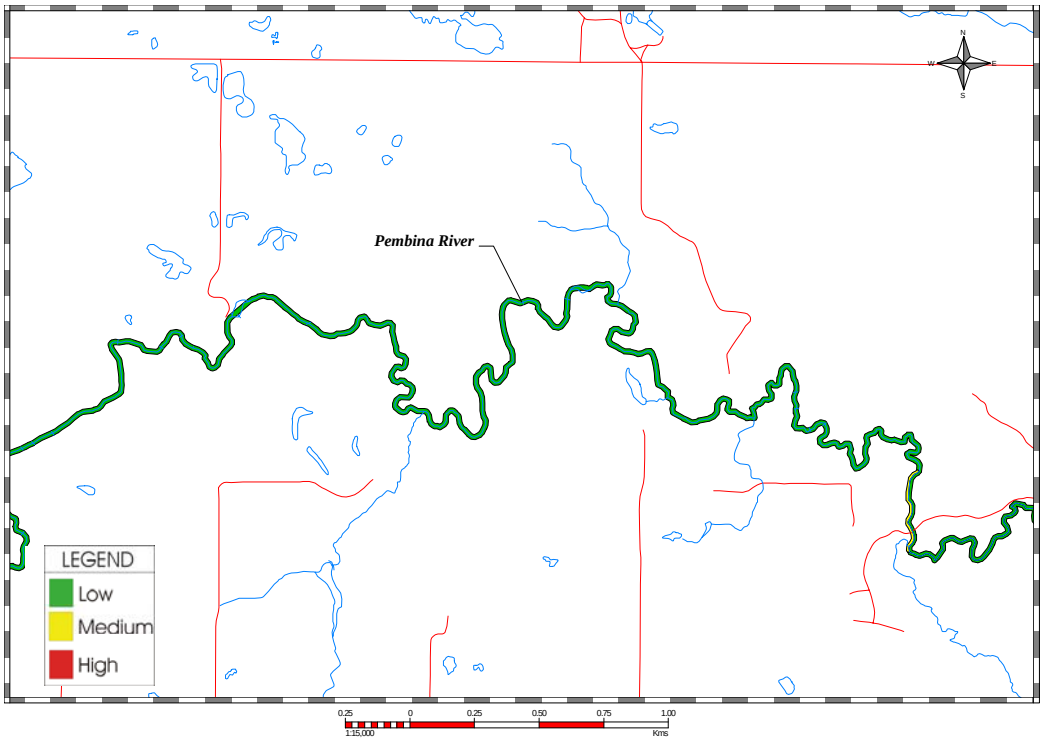
LEGEND
Low
Medium
High
0.25
0
0.25
0.50
0.75
1.00
1:15,000
Kms




Pembina River
LEGEND
Low
Medium
High
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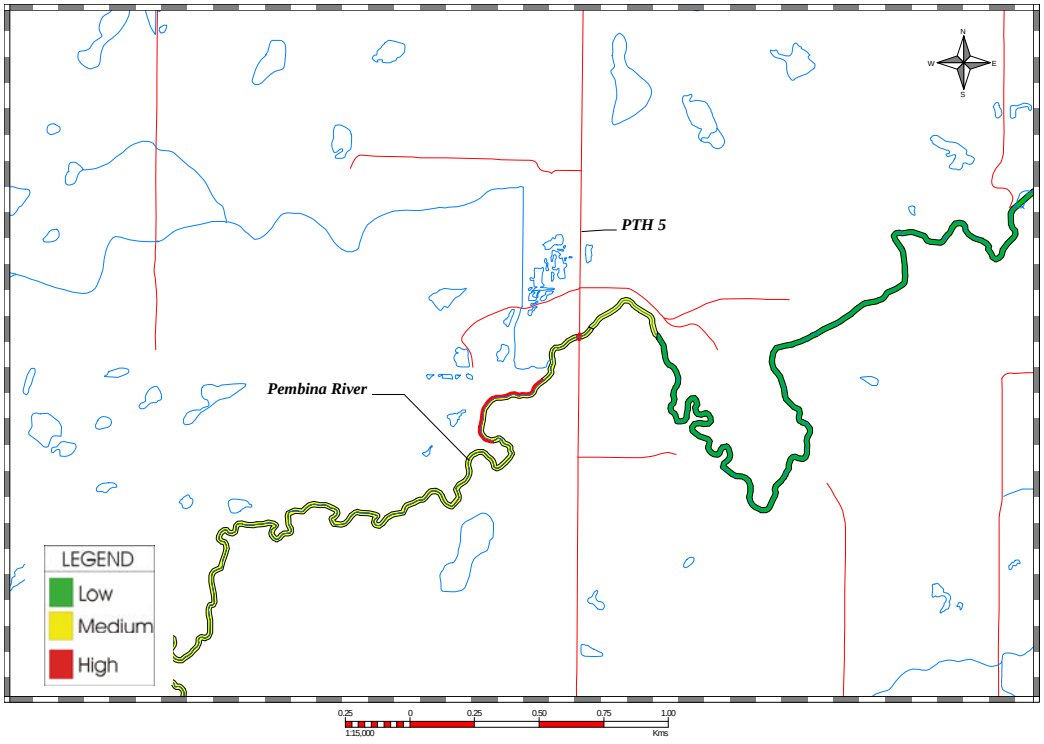
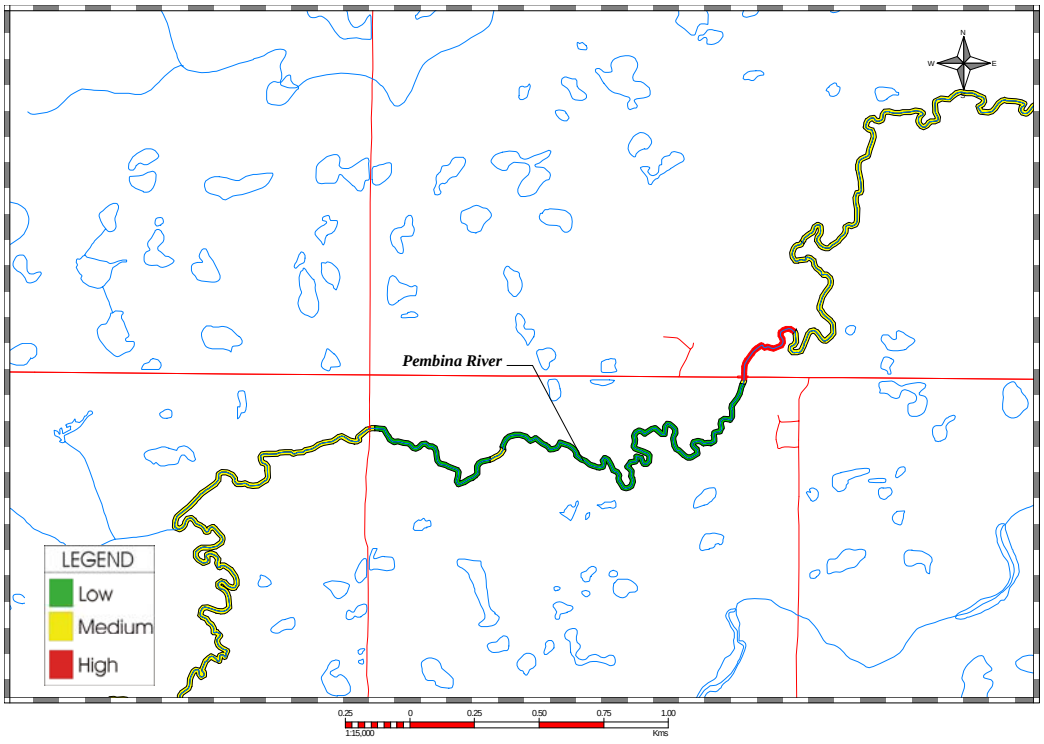
1:15,000
Kms


PTH 5
Pembina River
LEGEND
Low
Medium
High
0.25 0 0.25 0.50 0.75 1.00
1:15,000
Kms


Pembina River
LEGEND
Low
Medium
High
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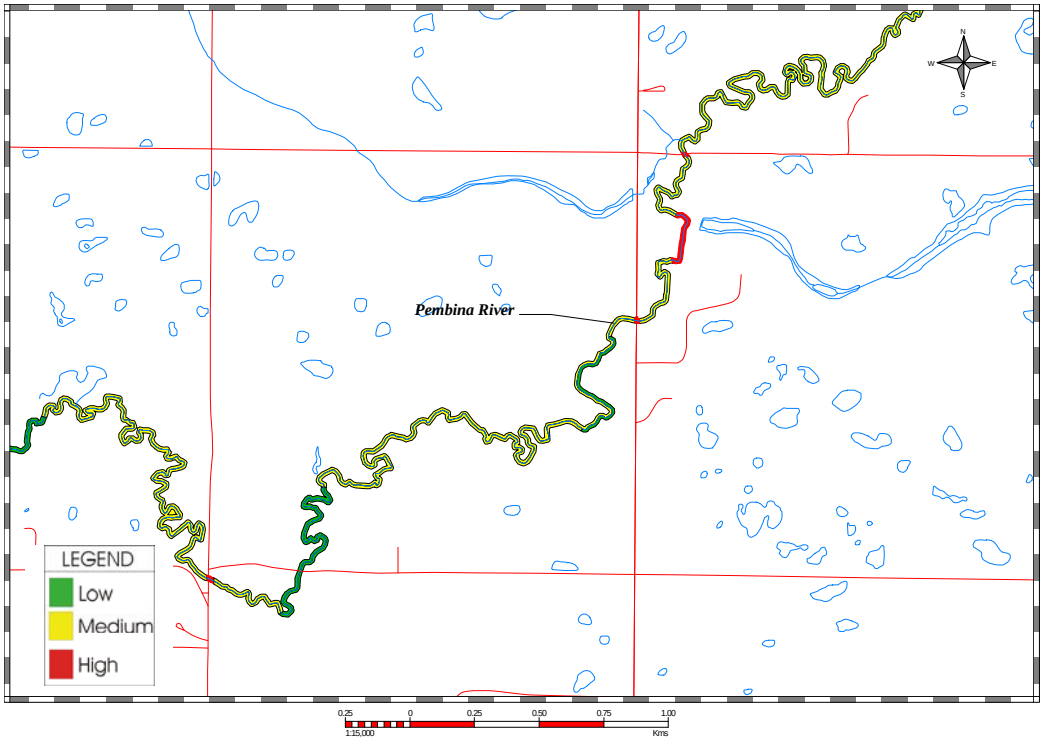
1:15,000
Kms


Pembina River
LEGEND
Low
Medium
High
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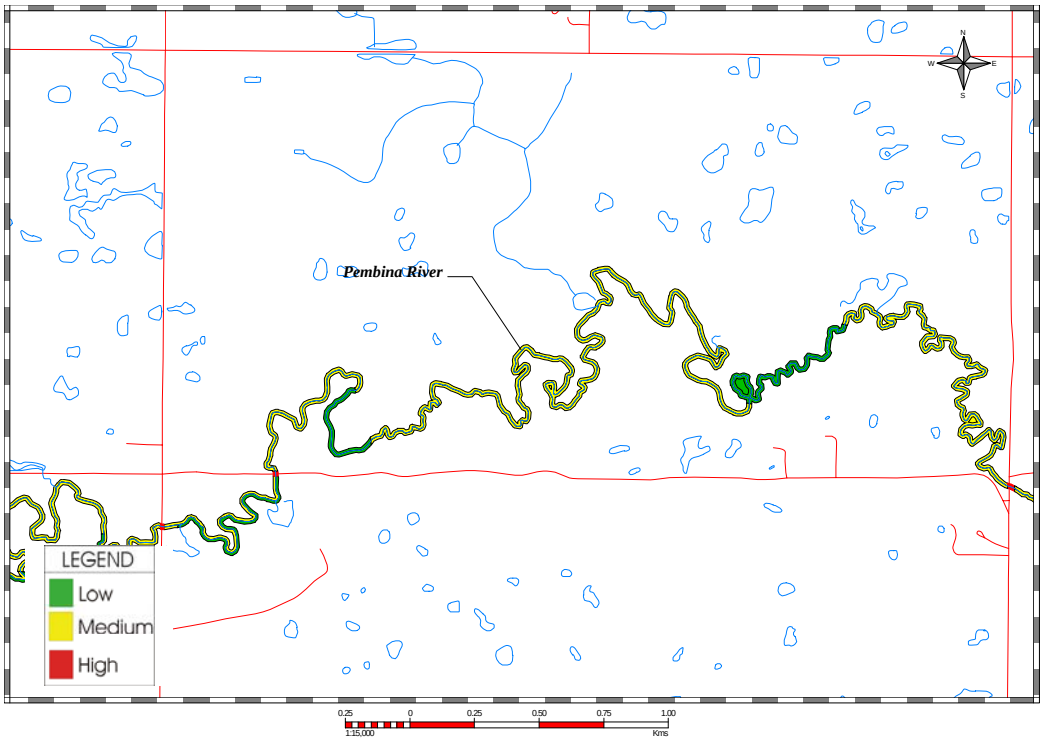
1:15,000
Kms


N
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Pembina River
LEGEND
Low
Medium
High
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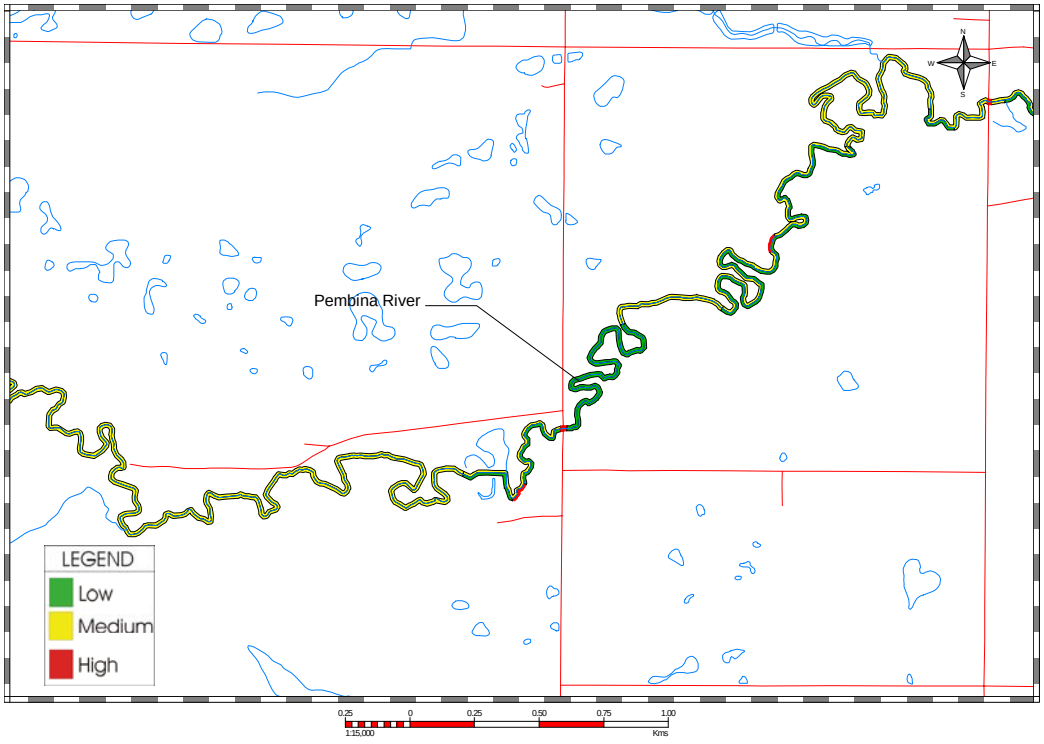
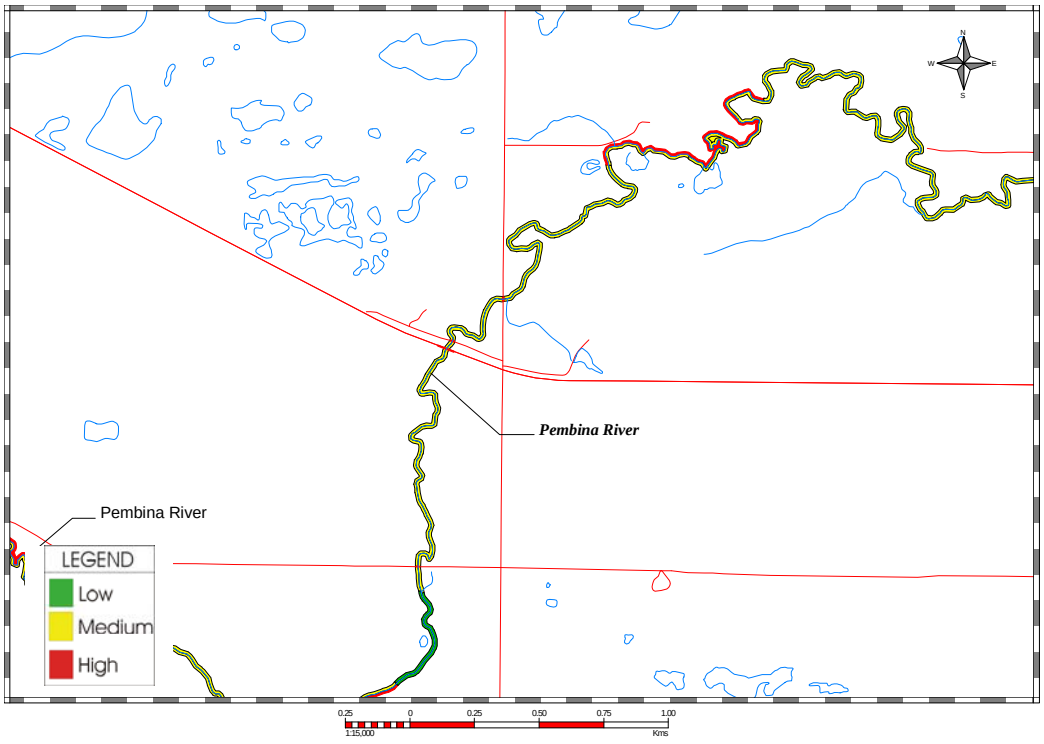
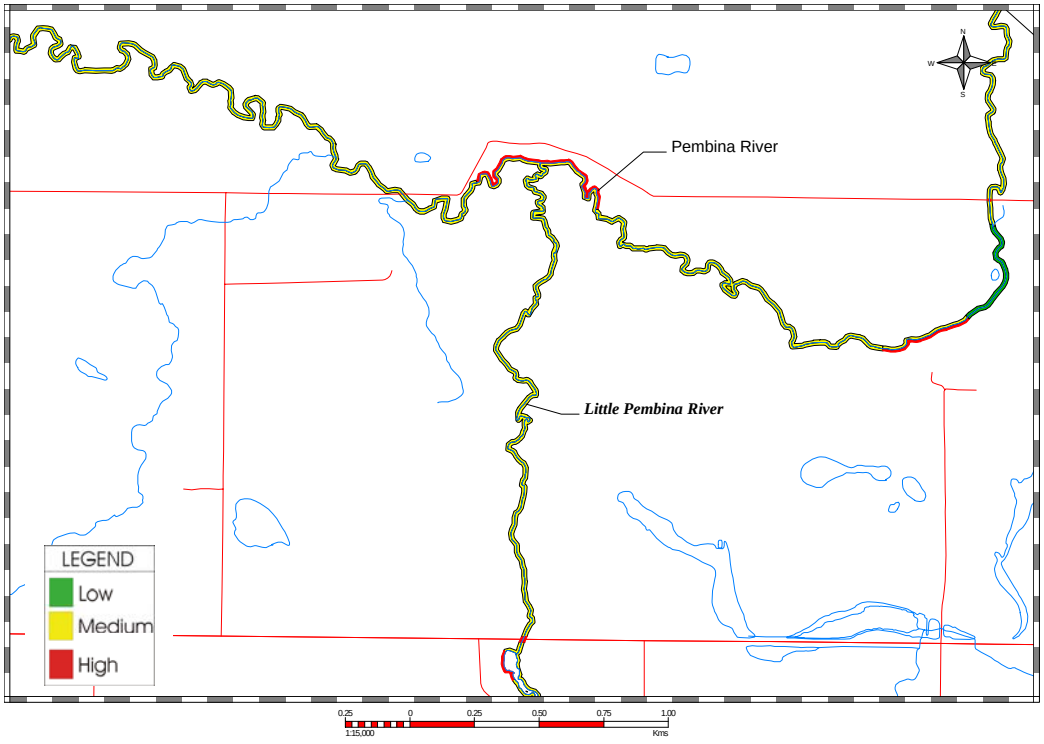
Kms


N
W
E
S
Pembina River
LEGEND
Low
Medium
High
0.25 0 0.25 0.50 0.75 1.00
1:15,000
Kms


Pembina River
Pembina River
LEGEND
Low
Medium
High
0.25 0 0.25 0.50 0.75 1.00
1:15,000
Kms


Pembina River
Little Pembina River
LEGEND
Low
Medium
High
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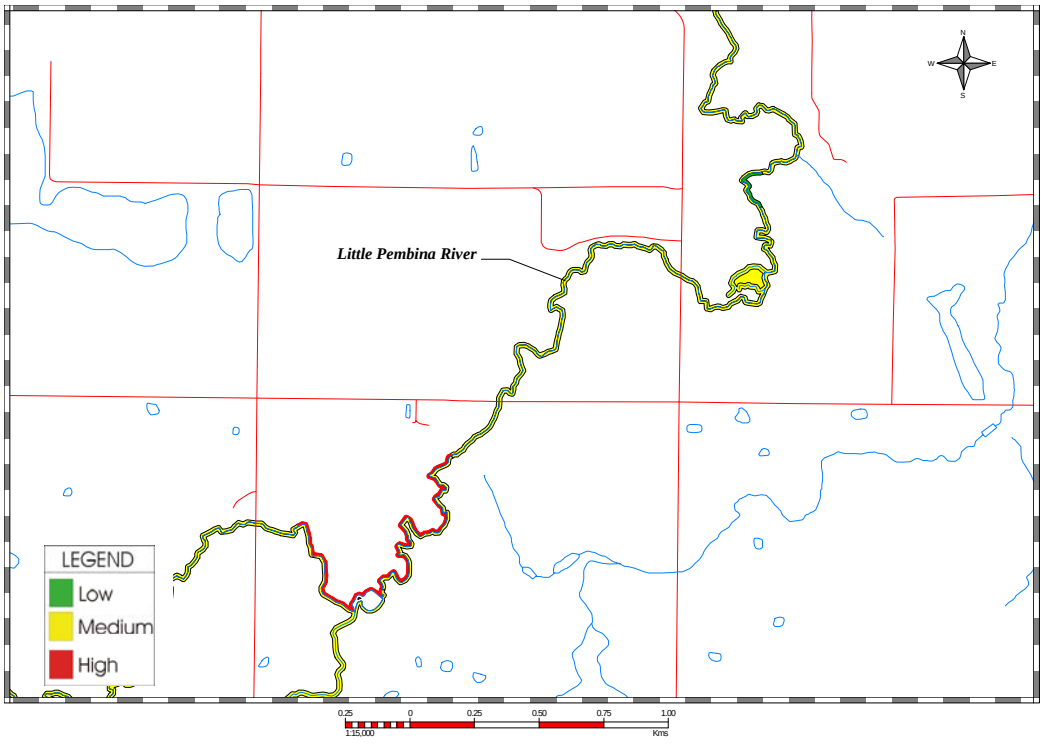
1:15,000
Kms


Little Pembina River
LEGEND
Low
Medium
High
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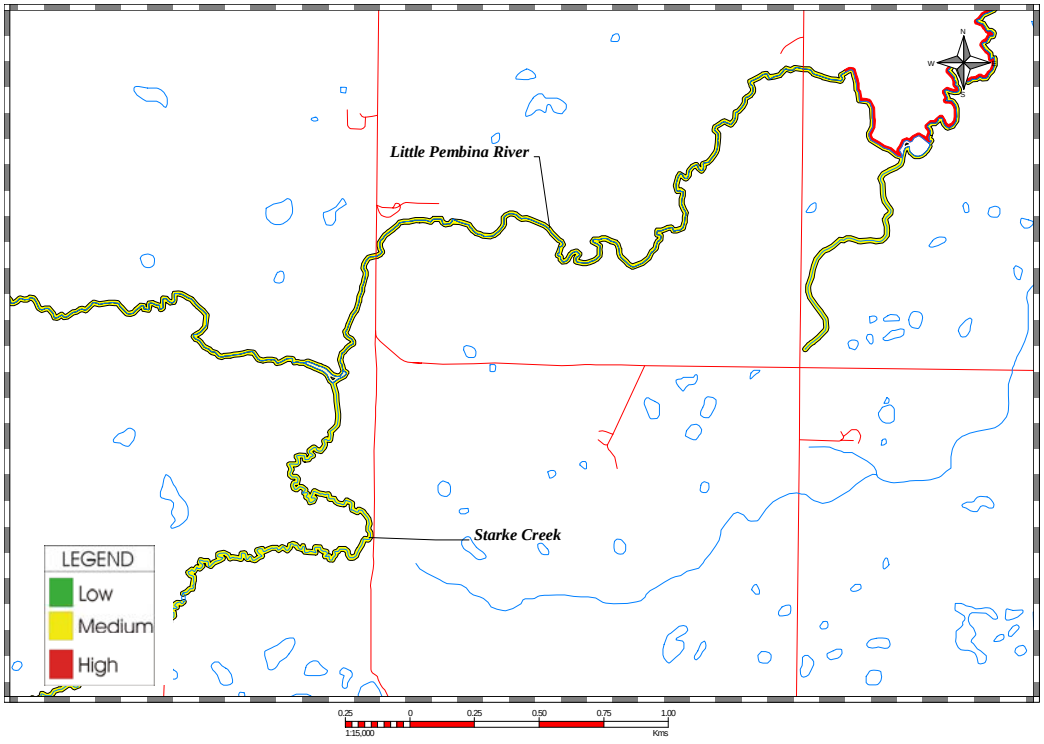
1:15,000
Kms


Little Pembina River
Starke Creek
LEGEND
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Medium
High
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1:15,000
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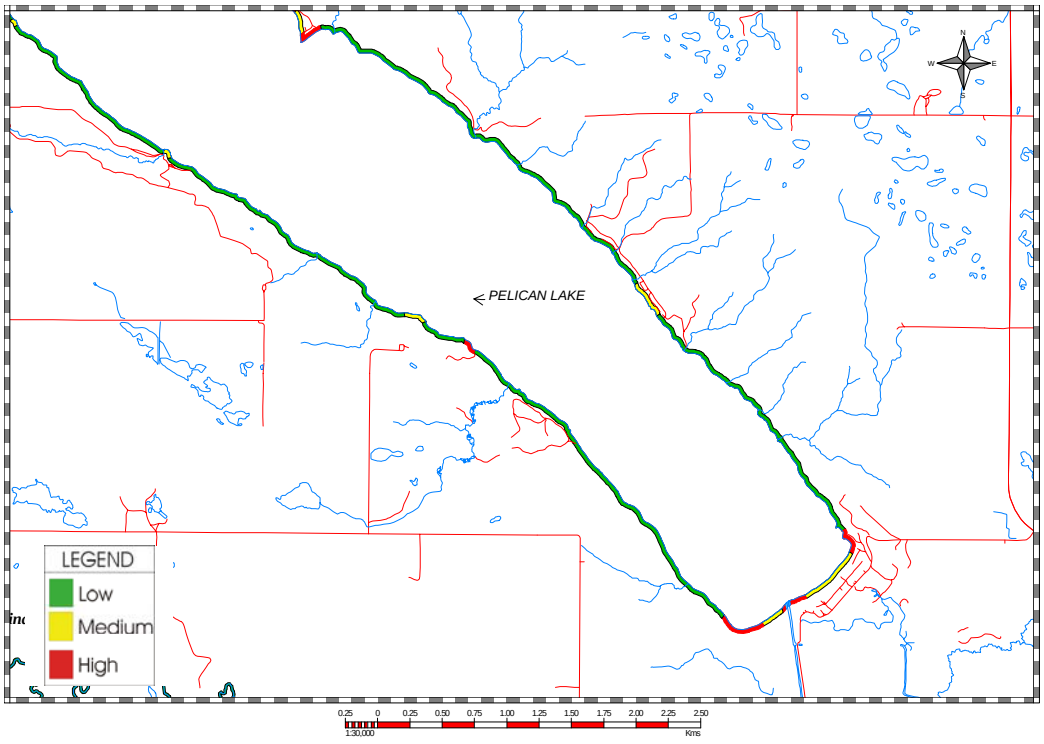
PELICAN LAKE
LEGEND
Low
Medium
High
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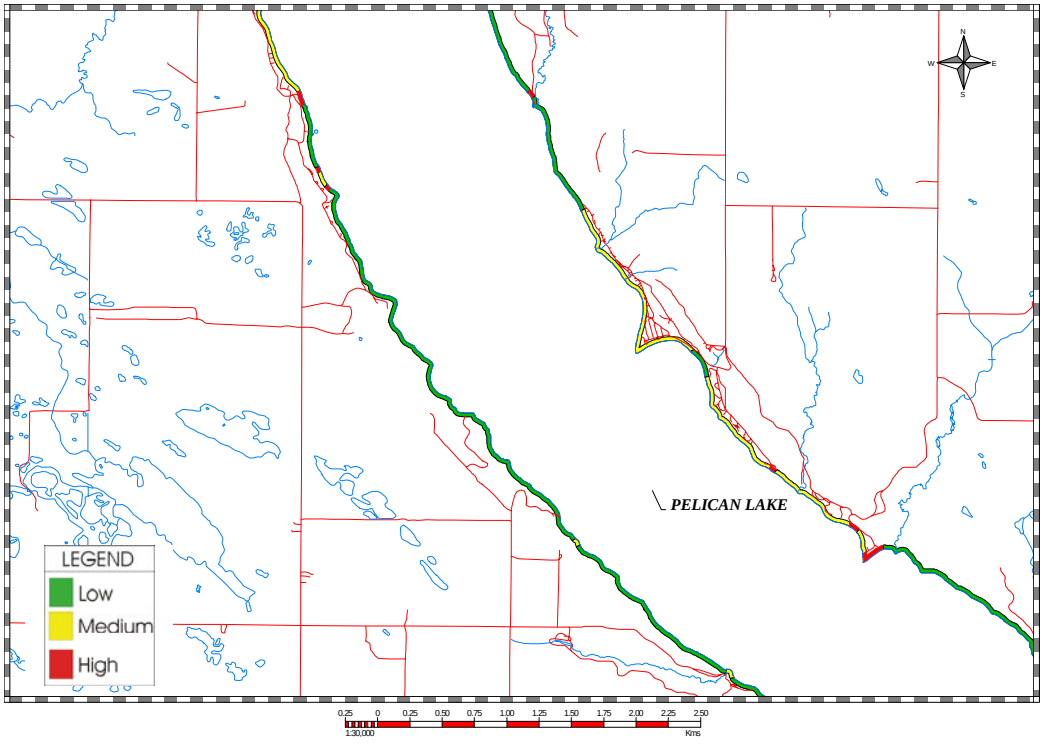
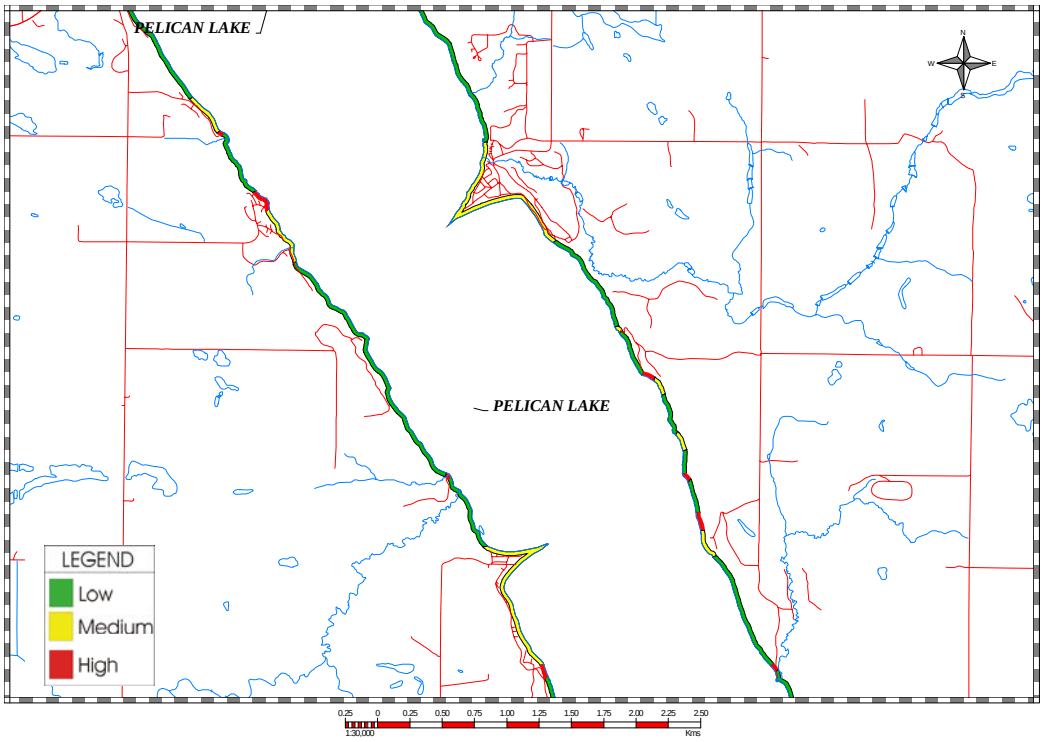
Kms


PELICAN LAKE
LEGEND
Low
Medium
High
0.25 0 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50
1:30,000
Kms


PELICAN LAKE
PELICAN LAKE
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LEGEND
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Medium
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0.25 0 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50
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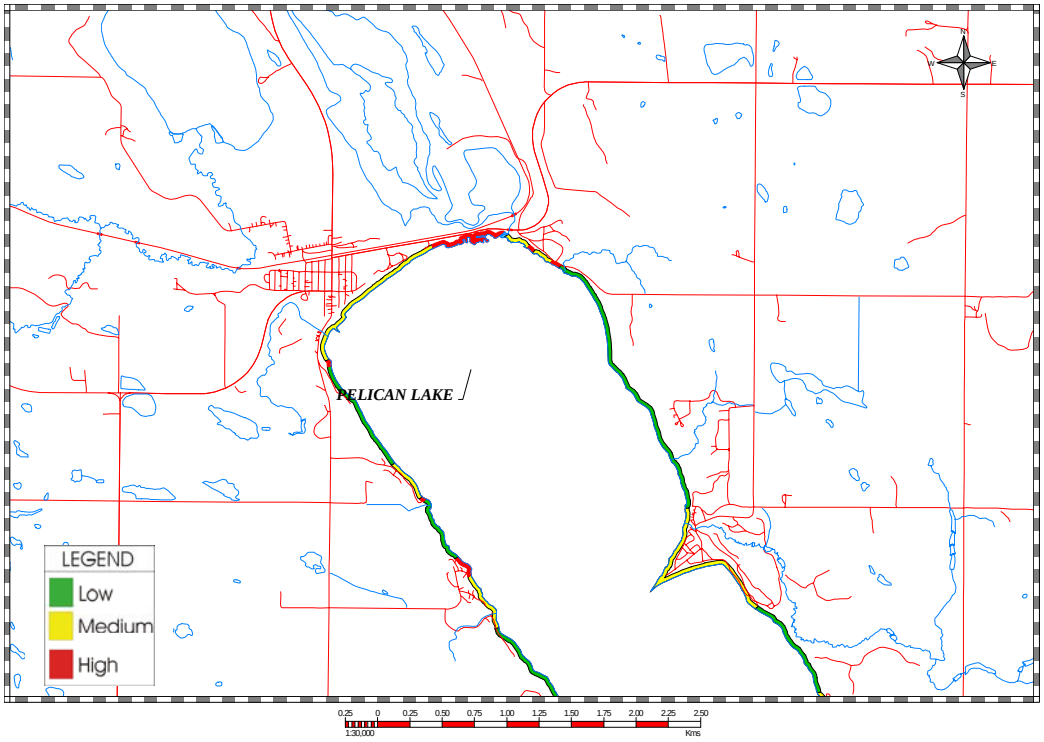
Kms


PELICAN LAKE
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LEGEND
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0.25 0 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50
1:30,000
Kms

Appendix 2-Field Water Chemistry Results

Water Chemistry Notes:

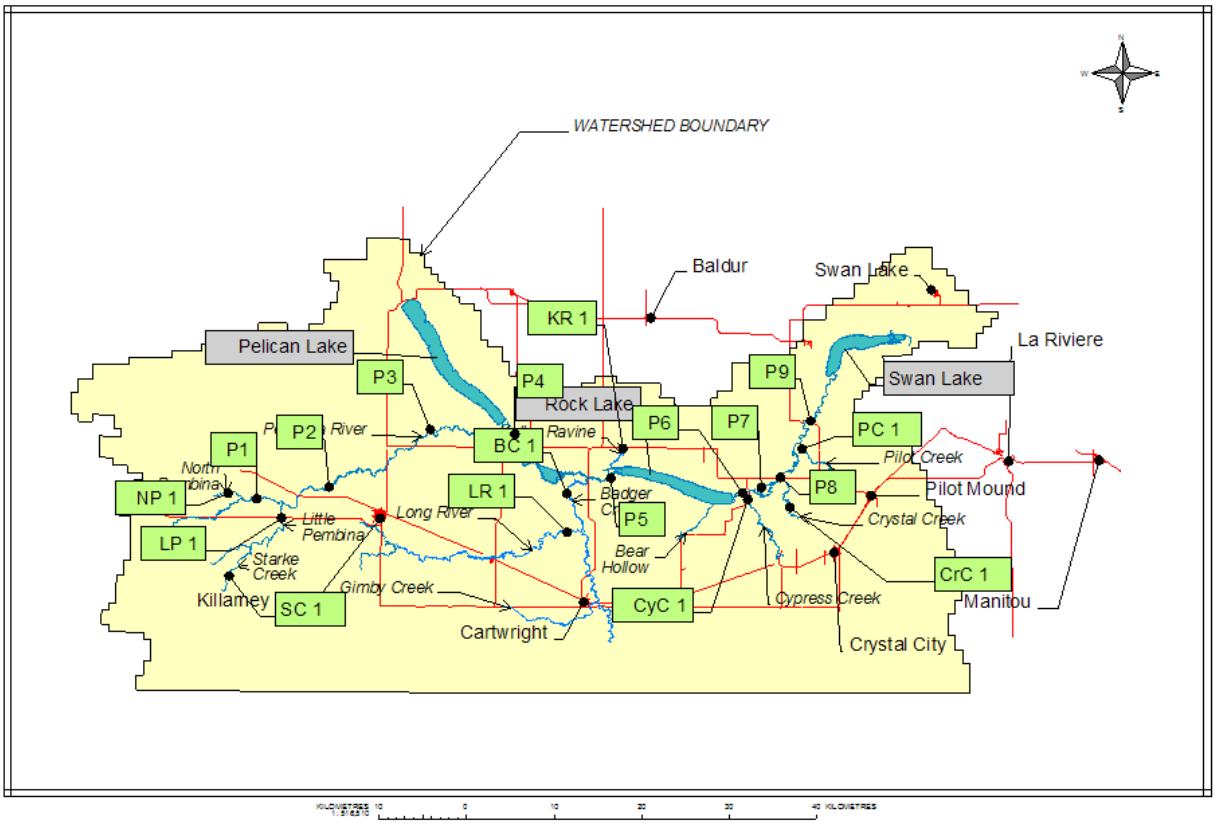
Basic water chemistry was gathered for each component of the watercourse included as part of the study area scope. Additional in-depth information was available from the extensive WRAS data base for the Pembina River. The following chart shows information regarding the nine sites where water chemistry information was gathered on the Upper Pembina River, and the one site on each of the tributaries.

Basic water chemistry was obtained at nine locations on Upper Pembina River and one location on each of the tributaries at the designated sample points. Data collected included pH, conductivity, and dissolved oxygen, using a Hach multi meter. A Hach field coliform incubator was used to gather total coliform count information twice at each location. Samples of algae were collected using a zooplankton tow in Pelican Lake, Rock Lake and Swan Lake, and sent to EnviroTest for analysis. All samples were single point in time data collections.

The following are the sample locations:

Pembina River main stem	-	P1 to P9
North Pembina River	-	NP 1
Little Pembina River	-	LP 1
Starke Creek	-	SC 1
Long River	-	LR 1
Badger Creek	-	BC 1
Kellys Ravine	-	KR 1
Cypress Creek	-	CyC 1
Crystal Creek	-	CrC 1
Pilot Creek	-	PC 1

Figure 5: Sample Locations



Location	PH	Conductivity	Dissolved Oxygen	Coliforms
P1	7.7	620	9	<10
P2	7.6	550	11	<10
P3	7.7	600	6	<100
P4	7.8	590	9	<10
P5	8.0	640	9	<10
P6	7.6	390	10	<10
P7	7.6	600	10	<10
P8	8.0	710	8	<100
P9	8.1	660	8	<100
NP1	8.1	720	8	<10
LP1	7.9	690	8	<10
SC1	7.5	380	9	<10
LR1	7.6	690	7	<100
BC1	7.6	500	9	<10
KR	8.2	720	9	<1000
CyC1	8.0	640	9	<10
CrC1	8.1	600	9	<10
PC1	8.4	740	8	<100

Appendix 3-Fish Capture Results and distribution

Fish Collection Notes:

All trap nets were set between June 15 and July 7, 2004. Electroshocking (Sweep 1) was conducted on the main stem of the Pembina River over the same period, with additional sweeps taking place on Badger Creek and Long River. Sweeps 2 and 3 of the electroshocking record occurred between April 28 and May 7, 2005, and was done on all tributaries included in this study, as well as the main stem of the Pembina River.

It should be noted that electroshocking, while partially effective, did not produce the best results. This was particularly true during the spring of 2005 collection. On several occasions, fish were able to recover and swim off before being netted for positive identification. This was a function of the conditions at the time, which included heavy flows and debris problems. Attempts were made to utilize gill nets, but were quickly abandoned as the current quickly rolled the nets, and heavy debris loads made them ineffective.

The list of species used for the chart is a compilation from Manitoba Conservation sources. Not all species listed were observed during the fish collection.

The following are the sample locations:

Pembina River main stem	-	P1 to P9
North Pembina River	-	NP 1
Little Pembina River	-	LP 1
Starke Creek	-	SC 1
Long River	-	LR 1
Badger Creek	-	BC 1
Kellys Ravine	-	KR 1
Cypress Creek	-	CyC 1
Crystal Creek	-	CrC 1
Pilot Creek	-	PC 1

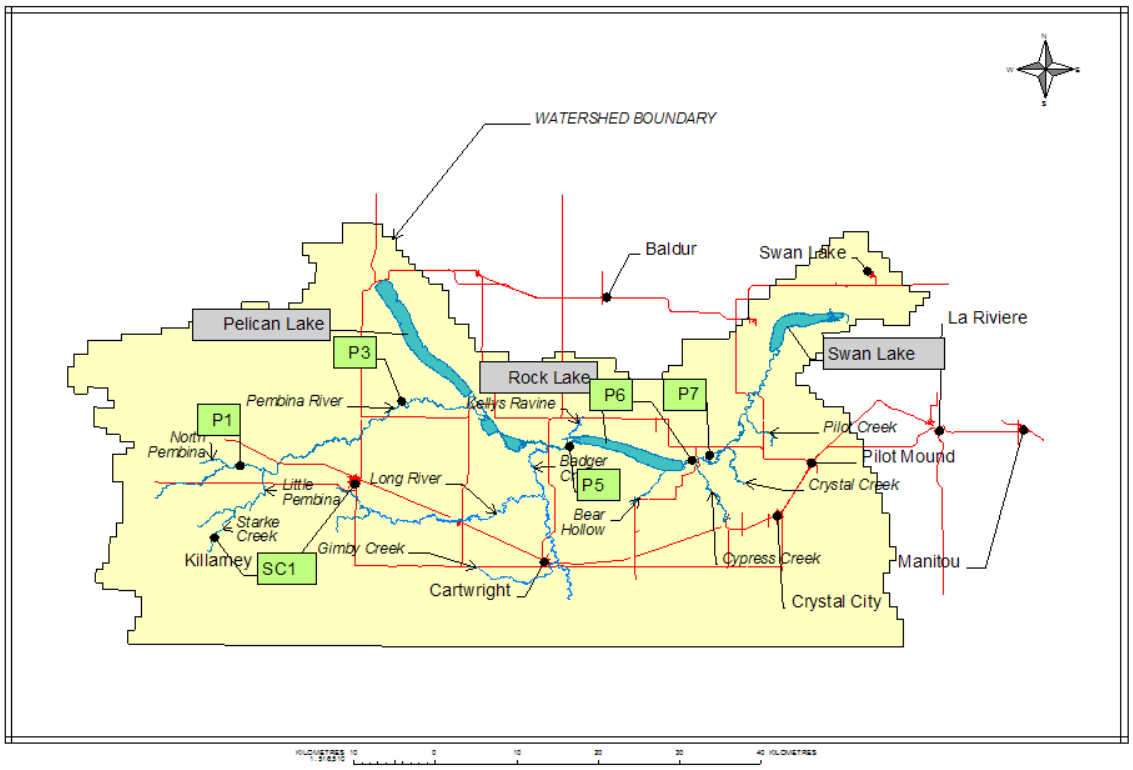


Figure 6: Northern Pike Distribution

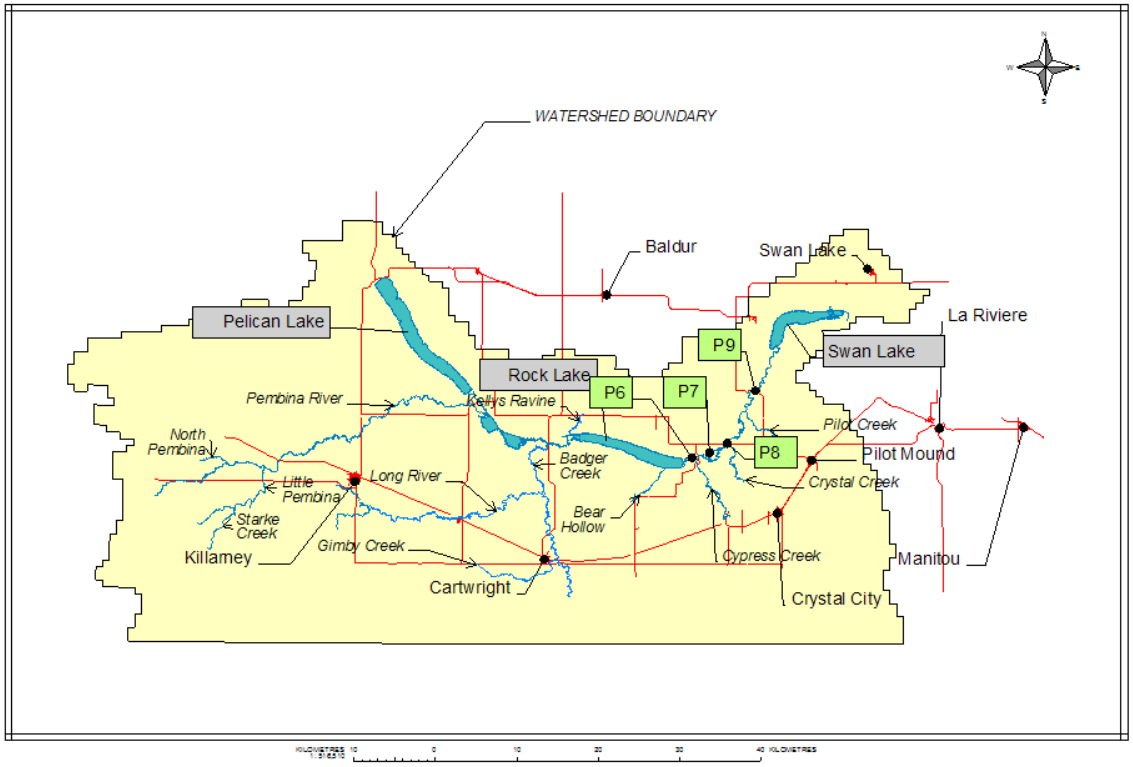


Figure 7: Black Bullhead Distribution

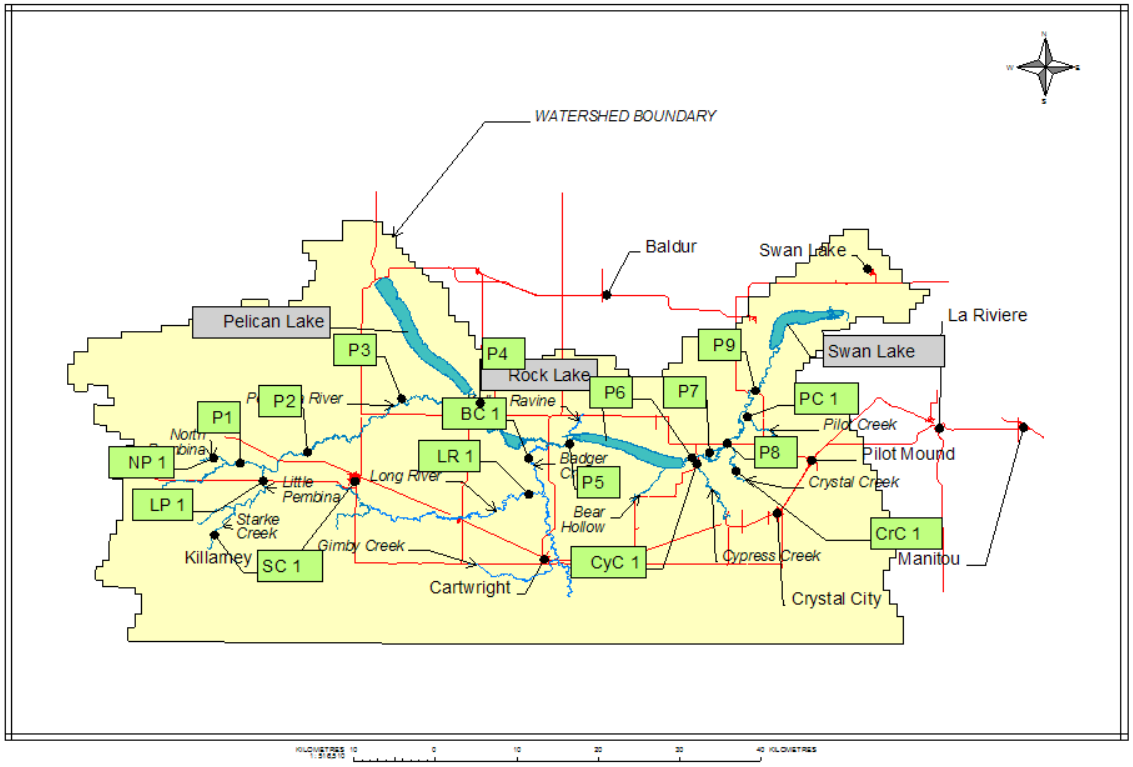


Figure 8: Fathead Minnow Distribution

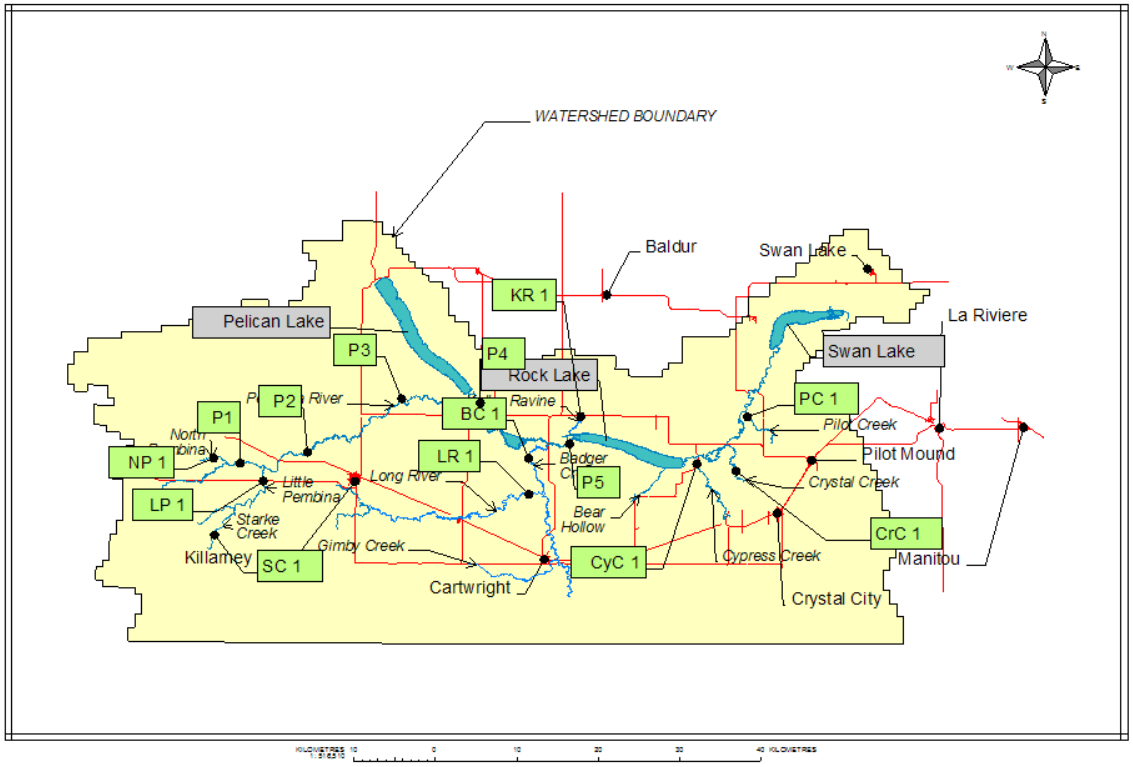


Figure 9: Brook Stickleback Distribution

P 1

Bottom Type: Silt margins, hardpan centre
Riffles and eddies: No riffles, slight backwater
Pools: Pool about 2.5 m
Emergent Vegetation: 30%
Submergent Vegetation: 15%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp	Freshwater Drum
	Set 1											8															
Trap Net	Set 2														4												
	Set 3														1												
Electro-	Sweep 1										1	1					6										
Shocker	Sweep 2											1		1			1										
	Sweep 3											12		1													

P 2

Bottom Type: Silt Margins, mainly hardpan centre
Riffles and eddies: No riffle
Pools: Small pool
Emergent Vegetation: 10%
Submergent Vegetation: 10%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp
	Set 1																									
Trap Net	Set 2																									
	Set 3											1														
Electro-	Sweep 1																									
Shocker	Sweep 2																									
	Sweep 3											6														

P 3

Bottom Type: Silt and sand Bottom
Riffles and eddies: No riffles, algae present, tributary
Pools: No pools
Emergent Vegetation: 60%
Submergent Vegetation: n/a

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp
	Set 1											1			1											
Trap Net	Set 2											1			2											
	Set 3											4			1											
Electro-	Sweep 1											2														
Shocker	Sweep 2											1					1									
	Sweep 3											1					1									

P 4

Bottom Type: Silt Bottom, centre hardpan, some gravel
Riffles and eddies: Small backwater on north side
Pools: No pools
Emergent Vegetation: 20%
Submergent Vegetation: 30%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp
	Set 1																									
Trap Net	Set 2																									
	Set 3							1				6														
Electro-	Sweep 1											1														
Shocker	Sweep 2											6														
	Sweep 3											6														

P 5

Bottom Type: Silt Bottom, some boulder
Riffles and eddies: No riffles
Pools: small pool
Emergent Vegetation: 40%
Submergent Vegetation: 30%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp
	Set 1											1			2											
Trap Net	Set 2																									
	Set 3														1											
Electro-	Sweep 1											2					1									
Shocker	Sweep 2											8					1									
	Sweep 3											2			4											

P 6

Bottom Type: Silt Bottom, some sand
Riffles and eddies: Riffle just upstream, good back eddy along north bank
Pools: Small pool
Emergent Vegetation: 20%
Submergent Vegetation: 30%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp
	Set 1										1															
Trap Net	Set 2											22														
	Set 3										1	4														
Electro-	Sweep 1																									
Shocker	Sweep 2		2									5					1									
	Sweep 3		2									4					1									

P 7

Bottom Type: Silt bottom, sand and gravel present
Riffles and eddies: Downstream riffle, eddies along both shores
Pools: Medium pool <2m
Emergent Vegetation: 30%
Submergent Vegetation: n/a

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp
	Set 1																									
Trap Net	Set 2																									
	Set 3											2														
Electro-	Sweep 1																									
Shocker	Sweep 2		1									5														
	Sweep 3		2									2					1									

P 8

Bottom Type: Silt and mud bottom over hardpan
Riffles and eddies: Small riffle downstream, well developed eddy on west side
Pools: Small pool < 2m deep
Emergent Vegetation: 40%
Submergent Vegetation: 40%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp
	Set 1							1				2														
Trap Net	Set 2											2														
	Set 3											11														
Electro-	Sweep 1																									
Shocker	Sweep 2		1																							
	Sweep 3		2																							

P 9

Bottom Type: Silt and sand bottom
Riffles and eddies: Slight riffle, close to bridge crossing, small eddy north side
Pools: Small deeper pool (2.5 m)
Emergent Vegetation: 60%
Submergent Vegetation: 30%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp
	Set 1																									
Trap Net	Set 2																									
	Set 3										4	14														
Electro-	Sweep 1																									
Shocker	Sweep 2		1																							
	Sweep 3		1									8														

NP 1

Bottom Type: Silt Bottom, cobble some larger boulders and gravel
Riffles and eddies: No riffles, back eddy along north side
Pools: No pools
Emergent Vegetation: 20%
Submergent Vegetation: 10%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp	Freshwater Drum
	Set 1																										
Trap Net	Set 2																										
	Set 3																										
Electro-	Sweep 1																										
Shocker	Sweep 2														2												
	Sweep 3											1			2												

LP 1

Bottom Type: Hardpan bottom, silt margins
Riffles and eddies: No riffles, slight eddy on north side
Pools: No pools
Emergent Vegetation: 20%
Submergent Vegetation: 10%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp	Freshwater Drum
	Set 1																										
Trap Net	Set 2																										
	Set 3																										
Electro-	Sweep 1																										
Shocker	Sweep 2											2															
	Sweep 3											4			1												

SC 1

Bottom Type: Silt/gravel Bottom
Riffles and eddies: Slight riffle, well trampled, algae present
Pools: No pools
Emergent Vegetation: 30%
Submergent Vegetation: 20%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp
	Set 1														2											
Trap Net	Set 2																									
	Set 3											1														
Electro-	Sweep 1																									
Shocker	Sweep 2														4		1									
	Sweep 3											16			1		1									

KR 1

Bottom Type: Silt Bottom, some large boulder
Riffles and eddies: No riffles
Pools: small pool
Emergent Vegetation: 40%
Submergent Vegetation: 30%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp
	Set 1																									
Trap Net	Set 2																									
	Set 3																									
Electro-	Sweep 1																									
Shocker	Sweep 2																									
	Sweep 3																									

BC 1

Bottom Type: Gravel bottom/some larger rock, silt
Riffles and eddies: Riffle downstream
Pools: small pool
Emergent Vegetation: 10%
Submergent Vegetation: n/a

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp
	Set 1											1			1											
Trap Net	Set 2											3														
	Set 3											5			1											
Electro-	Sweep 1										1	2			1											
Shocker	Sweep 2											6			1											
	Sweep 3											6			11											

LR 1

Bottom Type: Silt Bottom, highly eroded
Riffles and eddies: No riffles
Pools: no pool
Emergent Vegetation: 40%
Submergent Vegetation: n/a

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp
	Set 1																									
Trap Net	Set 2																									
	Set 3																									
Electro-	Sweep 1																									
Shocker	Sweep 2																									
	Sweep 3																									

CyC 1

Bottom Type: Silt Bottom, centre gravel/hardpan
Riffles and eddies: Slight riffle 20m downstream
Pools: Pool 1.5 m deep
Emergent Vegetation: 30%
Submergent Vegetation: 30%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp	Freshwater Drum
	Set 1																										
Trap Net	Set 2																										
	Set 3																										
Electro-	Sweep 1																										
Shocker	Sweep 2											1															
	Sweep 3											1			1												

PC 1

Bottom Type: Silt, centre hardpan, some gravel
Riffles and eddies: Slight riffle downstream
Pools: Pool 2 m deep
Emergent Vegetation: 30%
Submergent Vegetation: 30%

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp	Freshwater Drum
	Set 1																										
Trap Net	Set 2											2															
	Set 3																										
Electro-	Sweep 1																										
Shocker	Sweep 2											16			2												
	Sweep 3											1			1												

CrC 1

Bottom Type: Silt Bottom, some gravel
Riffles and eddies: Small riffle, eddy on north side/good backwater
Pools: Small pool 1.5m
Emergent Vegetation: 20%
Submergent Vegetation: n/a

	SET #/SPECIES		Black Bullhead	Brown Bullhead	Emerald Shiner	Spottail Shiner	Common Shiner	Longnose Dace	Pearl Dace	Blackside Darter	Johnny Darter	Fathead Minnow	Central Mudminnow	White Sucker	Brook Stickleback	Tadpole Madtom	Northern Pike	Walleye	Goldeye	Trout Perch	Shorthead Redhorse	Rock Bass	Goldfish	Black Crappie	Burbot	Carp	Freshwater Drum
	Set 1																										
Trap Net	Set 2																										
	Set 3																										
Electro-	Sweep 1																										
Shocker	Sweep 2													1													
	Sweep 3											2															

Appendix 4-Benthic Invertebrate Capture Records

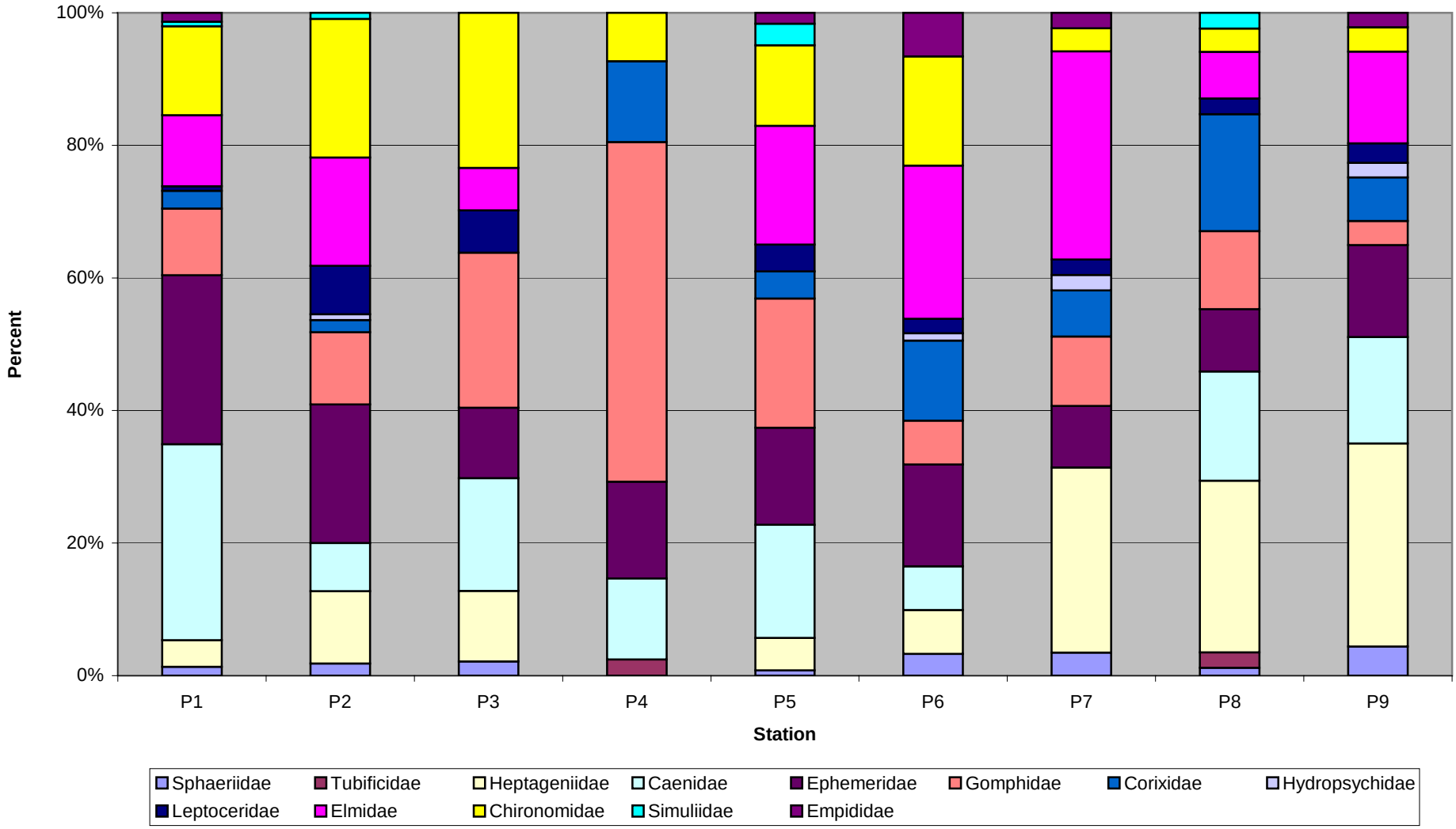
Invertebrate Collection Notes:

Replicate invertebrate samples were gathered for each component of the watercourse included as part of the study area scope. These results were significantly different from those provided by other sources studying the Pembina River (M. Hinzpinter) due to several reasons such as:

- Different collection methodology (kick net versus small Eckman Dredge)
- Different seasonality (spring versus early fall)
- Locations and habitat differences between the two studies
- Annual variations between invertebrate communities

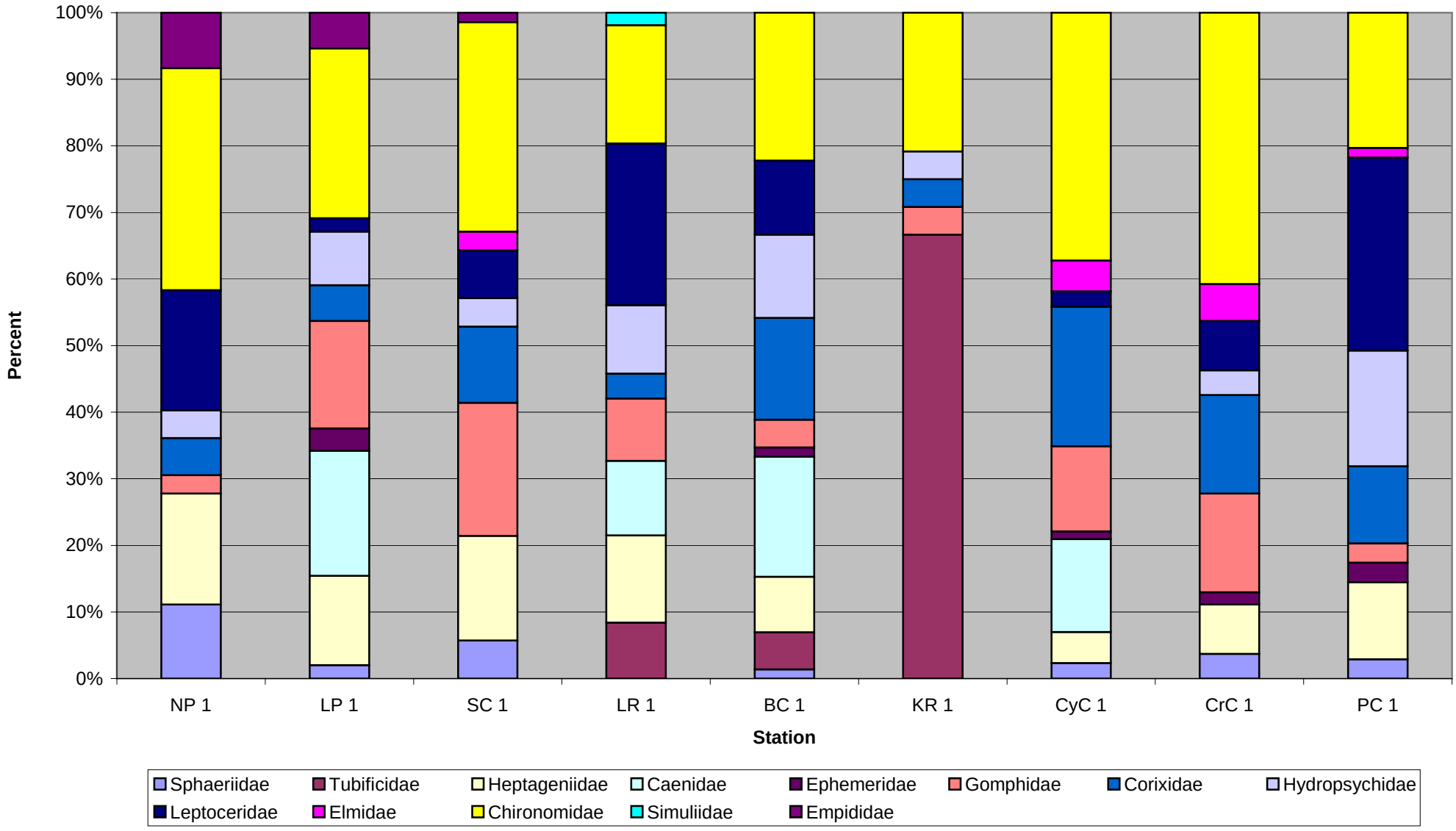
The following are the sample locations:

Pembina River main stem	-	P1 to P9
North Pembina River	-	NP 1
Little Pembina River	-	LP 1
Starke Creek	-	SC 1
Long River	-	LR 1
Badger Creek	-	BC 1
Kellys Ravine	-	KR 1
Cypress Creek	-	CyC 1
Crystal Creek	-	CrC 1
Pilot Creek	-	PC 1


100%
80%
60%
40%
20%
0%
Percent
P1
P2
P3
P4
P5
P6
P7
P8
P9
Station
Sphaeriidae
Tubificidae
Heptageniidae
Caenidae
Ephemeridae
Gomphidae
Corixidae
Hydropsychidae
Leptoceridae
Elmidae
Chironomidae
Simuliidae
Empididae

Common Name	*Class*	Order	*Family*	Sample Site P1	P2	P3	P4	P5	P6	P7	P8	P9
	BIVALVIA											
Freshwater Clam		**Heterodonta**	*Sphaeriidae*	2	2	1		1	3	3	1	6
	OLIGOCHAETA											
Round Worms		**Haplotaxida**	*Tubificidae*				1				2	
	INSECTA											
Mayflies		**Ephemereoptera**	*Heptageniidae*	6	12	5		6	6	24	22	42
			Caenidae	44	8	8	5	21	6		14	22
			Ephemeridae	38	23	5	6	18	14	8	8	19
Dragonflies and Damselflies		**Odonata**	*Gomphidae*	15	12	11	21	24	6	9	10	5
True bugs		**Hemiptera**	*Corixidae*	4	2		5	5	11	6	15	9
Caddisflies		**Tricoptera**	*Hydropsychidae*		1				1	2		3
			Leptoceridae	1	8	3		5	2	2	2	4
Beetles		**Coleoptera**	*Elmidae*	16	18	3		22	21	27	6	19

True flies		**Diptera**	*Chironomidae*	20	23	11	3	15	15	3	3	5
			Simuliidae	1	1			4			2	
			Empididae	2				2	6	2		3
	Total Taxa			149	110	47	38	123	91	86	82	132
	Taxa Richness			11	11	8	5	11	10	10	9	9


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
NP 1
LP 1
SC 1
LR 1
BC 1
KR 1
CyC 1
CrC 1
PC 1
Station
Sphaeriidae
Tubificidae
Heptageniidae
Caenidae
Ephemeridae
Gomphidae
Corixidae
Hydropsychidae
Leptoceridae
Elmidae
Chironomidae
Simuliidae
Empididae

Common Name	***Class***	**Order**	*Family*	Sample Site NP 1	LP 1	SC 1	LR 1	BC 1	KR 1	CyC 1	CrC 1
	BIVALVIA										
Freshwater Clam		**Heterodonta**	*Sphaeriidae*	8	3	4		1		2	2
	OLIGOCHAETA										
Round Worms		**Haplotaxida**	*Tubificidae*				9	4	16		
	INSECTA										
Mayflies		**Ephemereoptera**	*Heptageniidae*	12	20	11	14	6		4	4
			Caenidae		28		12	13		12	
			Ephemeridae		5			1		1	1
Dragonflies and Damselflies		**Odonata**	*Gomphidae*	2	24	14	10	3	1	11	8
True bugs		**Hemiptera**	*Corixidae*	4	8	8	4	11	1	18	8
Caddisflies		**Tricoptera**	*Hydropsychidae*	3	12	3	11	9	1		2
			Leptoceridae	13	3	5	26	8		2	4
Beetles		**Coleoptera**	*Elmidae*			2				4	3

True flies	**Diptera**	*Chironomidae*	24	38	22	19	16	5	32	22	
		Simuliidae				2					
		Empididae	6	8	1						
	Total		72	149	70	107	84	12	86	54	
	Taxa										
	Taxa Richness		8	10	9	10	10	5	9	9	