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Lac La Nonne 2023 State of the Watershed

Prepared for:

Lac La Nonne Enhancement and Protection Association (LEPA)

June 23, 2023

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May 31, 2023

Mr. Rod Kause
Lac La Nonne Enhancement and Protection Association
Site 1, Box 14, RR#1
Gunn, AB, T0E 1A0

Dear Mr. Kause,

RE: LEPA State of the Watershed Update

Aquality is pleased to present the Lac La Nonne Enhancement and Protection Association with the following 2023 update to the Lac La Nonne State of the Watershed Report. This current report is an update of information gathered since the original State of the Watershed Report was commissioned by the Lac La Nonne Watershed Stewardship Society in 2006.

If you have any questions or concerns, please feel free to contact me at (780) 757-5530 or via email at jay.white@aquality.ca.

Yours truly,

AQUALITY ENVIRONMENTAL CONSULTING LTD.

Per:_____

Jay S. White, M.Sc., P. Biol., Authenticating Professional

Principal

Lac La Nonne State of the Watershed Update

Signature Page

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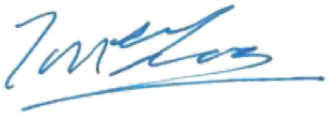

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Acknowledgements

This work would not have been possible without the tireless efforts of concerned citizens living and recreating in the Lac La Nonne watershed. The Lac La Nonne 2023 State of the Watershed Update is an update of information compiled in the original 2006 Lac La Nonne State of the Watershed Report, work that was commissioned by the Lac La Nonne Watershed Stewardship Society in 2005. Funding has generously been provided by the Lac La Nonne Enhancement and Protection Association for the 2023 updated report.

2 Executive Summary

The Lac La Nonne watershed includes Lac La Nonne, Nakamun and Majeau Lakes that straddle both Lac Ste. Anne County and the County of Barrhead in central Alberta. The lakes are popular recreational lakes that experience poor water quality including blue-green algal blooms and aquatic vegetation growth, both of which are of concern to local residents and lake users.

The purpose of this report is to update the 2006 State of the Watershed report that summarized environmental information for the Lac La Nonne watershed. This report is an update to that report that can be used for additional planning including the development of a Lac La Nonne Watershed Management Plan.

While many updates have been undertaken since 2006, there are still many information gaps that need to be filled, including environmental data on Nakamun and Majeau Lakes. These gaps need to be filled to develop the best and most comprehensive management plan for this watershed.

Based on the information gathered for this report, we conclude that overall the watershed health is good, with some obvious problem areas. Streams in the area are inputting excess nutrients into all three lakes and will continue to reduce lake water quality.

Recommendations for this watershed fall into the following four categories:

1. Planning – This is an ongoing, regulatory approach which will include the watershed management planning process, and the municipal process (intermunicipal development plans, bylaws, others)
2. Stewardship – This is ongoing and requires continued community involvement. Components of this step are education and awareness, use of cottage owner best management practices (BMPs) provided by organizations such as Respect Our Lakes and ALMS, better animal husbandry and agricultural land use practices, nutrient and manure management, and others.
3. Reclamation and restoration – These are the most invasive steps. This could involve activities such as fencing of riparian areas, off site watering, riparian restoration and revegetation, and others.
4. Data gaps – Significant data gaps will need to be filled to move forward with a Watershed Management Plan. These gaps include paleolimnology studies on the lake, an overall nutrient budget for each lake, and riparian health information.

Residents, landowners, watershed groups such as LEPA and municipal, provincial and federal governments must work together in order to improve the health and functionality of the Lac La Nonne watershed. Their efforts should include education and outreach, stewardship initiatives, planning, activities geared towards improvement of water quality in the lakes and tributaries, changes to the land use bylaws and continued improvement in sewage management practices.

3 Introduction

The purpose of this report is to summarize available current and historic information on the Lac La Nonne watershed, including Lac La Nonne, Nakamun and Majeau Lakes. The watershed includes these three lakes and straddles Lac Ste. Anne County and the County of Barrhead. This report is an update on information on the watershed, stream and lake water quality/quantity, land-use and the potential effects of resource and land-use practices. Lake and tributary water quality data has been used as an indicator of the overall health of the watershed.

This report addresses the indicators of watershed health as suggested by the *Guide to Reporting on Common Indicators Used in State of the Watershed Reports* produced by Alberta Environment and Sustainable Resource Development (Alberta Government, 2012). This includes surface water quality indicators, surface water quantity, groundwater quantity, landscape use and land cover, riparian health, and biotic integrity. In addition to the recommended indicators, a section on wetland health was added as wetlands serve a very important role in filtering runoff, recharging aquifers, and mitigating drought and flood events. Each section of this report is intended to summarize known social, physical and environmental information within the Lac La Nonne watershed that are available via a desktop assessment.

The report begins by summarizing historical public perceptions and concerns from lake residents and then considers the physical aspects of the entire watershed, first on a broad scale, then focusing on the specific land and water resources. The report also identifies the jurisdictions of the various Federal, Provincial and Municipal regulators to decipher roles and mandates.

The report then outlines how state of the basin reporting fits into the greater context of watershed management planning in Alberta under Alberta Environment and Protected Area's *Water Strategy: Water for Life* and identifies legislation and policies affecting watershed management in Alberta. A special emphasis has been placed upon the role of this document in future planning within the larger Athabasca River basin, and how this report can assist with local municipal planning and decision making. Since the previous report, considerable work under Water for Life has been completed by Alberta Environment and Protected Areas, the Alberta Water Council and the Athabasca Watershed Council.

This report will provide a benchmark against which the effectiveness of future stewardship activities and best management practices aimed at improving watershed health can be assessed. The information will provide landowners, stakeholders, municipalities and stewardship groups the information needed to make better management decisions and help implement beneficial management practices and develop solutions to protect and/or enhance land and water resources. This report prioritizes the issues to be addressed and makes recommendations toward the development of strategies to address those issues and opportunities.

4 Public Perception and Concerns

4.1 Lac La Nonne Area Structure Plan Review Survey (1999)

In 1999, a survey was sent to Lac La Nonne residents asking for their input into the area structure plan review. Questions centered on perceived problems with the lake itself, land ownership, planning and development, recreation and environmental concerns. Areas of the survey dealing primarily with the lake itself and the surrounding environment are summarized below.

4.1.1 According to the survey respondents, things that are considered unpleasant about the Lac La Nonne area include:

- Algae
- High speed boats
- Dirty lake
- Poor water quality
- Unclean shorelines, no beach areas
- Lack of respect for nature
- Limitations on fishing
- No fish
- Poor water levels
- Weeds
- Too many geese
- Smell from lake
- Number of seadoos
- Sewage

Water quality and algae were identified as a common problem with the lake.

4.1.2 Things that are considered positive about the Lac La Nonne area include:

- Birds
- Waterfowl
- Deep lake
- Little commercial development
- Public boat dock
- Recreation
- Relatively undeveloped
- Wildlife
- Good fishing
- Public beach
- Scenery
- Snowmobile trails
- Winter access
- Sparse population

4.1.3 Lake Concerns

- Problems with property – Many people had concerns and/or problems with wave erosion on their property.
- Aesthetic condition and water quality of the lake for recreational use – The majority of responses dealt with weed and algal problems, and many listed lake odours as an issue.
- Issues of most concern regarding lake levels – Most respondents were concerned with the effect of lake levels on fish populations. Lake water levels were of moderate concern.

4.1.4 Recreation

- Problem areas in the physical condition of the lake – Again, many residents are concerned about weeds and algal growth. Some feel that the lake water is dirty and polluted.
- Problems with property – Many listed a soft or mucky bottom in the lake, along with poor beach quality.
- Common recreational activities around the lake include swimming, fishing, snowmobiling, ice fishing, cross country skiing, and boating.
- Most respondents felt that the current level of lake use was within an acceptable range.

4.1.5 Environmental Concerns

- Generally, respondents felt that a poor job has been done to protect environmentally sensitive regions of the lake area.
- Suggested protection measures included protecting marshlands, restricting cottage development, and placing restrictions on livestock operations.
- Most respondents have noticed a change in the water quality over time. Generally, the changes seen include algal growth and weed problems.
- Most respondents were not in favour of commercial fisheries on the lake.
- Most people feel that the dumping of sewage into the lake and agricultural operations have negatively impacted the sport fish populations in the lake.
- Most feel that Crown land should be used for wildlife habitat, hunting, watershed protection and bird watching, rather than for activities such as hiking and cross-country skiing.

4.1.6 Zoning and Infrastructure

- Many respondents felt that weed control, water quality improvement, and protection of wildlife habitat were necessary measures for the management of the Lac La Nonne area.
- Sewage – Most common responses for the question regarding what residents used for sewage facilities included holding tanks and pumpouts. The majority used septic tanks or "other" for grey water disposal, but some responded, "poured on ground". The "other" methods were not specified in the survey summary.

The results listed above were from a preliminary report only; no statistics were provided as to how many people received the survey, how many completed it, or the response percentage for each question.

4.2 Water's Edge Resource Group Watershed Survey (2003)

A toxic blue-green algal bloom in Lac La Nonne in August 2002 prompted public concern over water quality and lake health. In response to these concerns, Alberta Environment and the Water's Edge Resource Group (WERG) conducted a watershed stewardship survey in March 2003. Surveys were sent to approximately 1,400 landowners, and 251 completed surveys were returned (Waters Edge Resource Group, 2004), the results of which are summarized below.

4.2.1 General Results

For a mail-out survey, the number of responses received back was very good. Out of the 251 respondents, over half were cottage owners, while others were acreage residents and agricultural producers. The vast majority of respondents supported the idea of establishing a multi-stakeholder watershed stewardship group in order to improve the quality of water within the Lac La Nonne watershed, and many were satisfied with the proposed committee structure that was provided for their review.

4.2.2 Public Perceptions of Water Quality

Overall, the survey respondents felt that the water quality in Lac La Nonne, Majeau Lake, Nakamun Lake and their associated tributaries had deteriorated over time, and rated lake water quality as poor (31%) to

very poor (56%) during the 2002 season. The majority of respondents felt that the quality of the water flowing into Lac La Nonne through creeks and tributaries was poor (25%) to very poor (43%).

The main concerns identified included:

- Lake water level
- Algae
- Concern for birds, fish, wildlife and pets
- Concern for continued recreation
- Shoreline/aquatic vegetation
- Odour
- Contaminants
- Overuse of lake

4.2.3 Perceived Concerns and Opportunities

Survey recipients were asked to identify conditions or activities perceived to impact watershed health. The conditions and activities are listed below, and are ranked in order of importance or impact:

1. Low water levels
2. Application of agricultural fertilizers and/or other chemicals
3. Livestock grazing and/or manure management practices
4. Cottage septic/wastewater systems
5. Application of lawn fertilizers and/or other chemicals
6. Upstream on-farm/private/municipal drainage
7. Annual agricultural cropping practices
8. Water allocations or withdrawals
9. Lakeshore cottage/beach development
10. Clearing of riparian (streamside) and/or shoreline areas
11. Removal of lakeshore and aquatic vegetation
12. Local oil and gas activity
13. Erosion/sedimentation/runoff
14. Recreational activities (boating, swimming, others)
15. Other (included road construction and oiling, obstructions on inflow/outflow streams, high volume of public traffic, others).

Sixty-eight percent of respondents also felt that the current quality of groundwater was a concern that should be addressed.

This section of the survey lists many stakeholder and resident concerns regarding the lake and what issues they feel should be addressed in a watershed management plan. This information should be consulted if terms of reference and a watershed management plan are written for the area.

4.2.4 Watershed Management Activities

When asked if they were aware of any water monitoring activities within the watershed, 74% stated they were not aware of any activities, and 86% stated they would be willing to make simple changes to their landscape and/or current land use practices to reduce nutrient inputs into the lake.

This survey was a valuable tool in soliciting many of the issues and concerns that watershed residents have. Overall, the comments provided by the respondents provide insight into their concerns regarding water quality, and may be a valuable resource in future watershed management planning.

4.3 Love Your Lake Public Engagement Survey (2019)

In early 2019, individuals from the County of Barrhead, LEPA, and Alberta Environment and Parks engaged in a tour of Lac La Nonne to discuss water quality issues (County of Barrhead, 2019). A survey using the Love Your Lake shoreline evaluation program, developed by the Canadian Wildlife federation and Watersheds Canada, was mailed to 179 residents and made available online (Love Your Lake, 2023). A total of 50 responses were received. The results are summarized below.

4.3.1 Top Issues

Survey recipients were asked to identify the top three issues that they were concerned with related to watershed health. The issues are shown below as they ranked in order of most importance to least importance for residents.

Issues (Select Top Three)	Number of Positive Responses	Percent Who Responded Positively
Water Quality	46	92
Water Levels	28	56
Faulty or Poorly Maintained Septics	26	52
Fish Populations	15	30
Shoreline Development	9	18
Misuse of Reserve Lands	8	16
Enforcement Issues	8	16
Noise Pollution	3	6
Boating	2	4
Light Pollution	1	2
Wildlife	0	0
Cottage Conversion to Permanent Homes	0	0
Other	4	10

Other responses included:

- Lack of weed control
- Overgrowth of aquatic vegetation
- Cyanobacteria (blue-green algae)
- Issues with fish populations
- Concerns with septic tanks and outhouses.

4.3.2 Lake Water Quality

Forty-one respondents (82%) rated the water quality in Lac La Nonne as poor, while 5 rated it as good, and 4 stated they don't know. Respondents were asked to indicate their level of concern regarding the following water quality parameters.

Water Quality Concerns	Number of Positive Responses	Percent Who Responded Positively

Algae/Aquatic Vegetation	48	96
Smell	39	78
Bacteria	32	64
Clarity	26	52
Chemical Contamination	17	34
Other	2	4
No Concerns	0	0

4.3.3 Recommended Actions

Actions (Select Top Three)	Number of Positive Responses	Percent Who Responded Positively
Increase sewage regulations and enforcement	30	60
Create lake management plan	29	58
Undertake more water quality testing	26	52
Create or enforce stricter rules for new development	20	40
Provide additional education materials to property owners	8	16
Create or enforce stricter rules for redevelopment	6	12
Engage more property owners in lake activities	5	10
Plant trees and shrubs along the shore	4	8
Nothing	4	8
Stop mowing grass by the shoreline	2	4
Limit boat wake near shore	2	4
Other	14	28

Other responses included several recommendations to remove aquatic vegetation from the lake. One respondent indicated that it is hard to get boats into the lake due to the amount of vegetation in the water.

4.3.4 General Comments and Suggestions

- The fish population should be managed with a fish stocking program for Walleye.
- No open septic field should be allowed near the lake.
- Outhouses without liners for pumping out should be removed.
- Lack of action regarding water quality initiatives by local, provincial, and federal governments.
- Algae and aquatic vegetation need to be harvested to improve access, smell, and visual appearance of the lake.
- Need better education and enforcement about shoreline alteration.
- Better management of agricultural runoff.
- Tax revenue should be allocated to lake sustainability initiatives.

5 Institutional and Regulatory Authorities

This section will provide a regulatory overview of the main legislation that impacts lakes and surface waterbodies in Alberta[1].

5.1 Federal Government

The Canadian Environmental Protection Act (CEPA), 1999, is the main federal law to protect the environment in Canada. With respect to water resources, CEPA empowers the federal government to create and enforce regulations regarding toxic substances, fuels, and nutrients. CEPA enables the federal government to undertake environmental research, develop guidelines and codes of practice, and conclude agreements with provinces and territories. Environment Canada administers CEPA but assesses and manages the risk of toxic substances jointly with Health Canada.

Fisheries and Oceans Canada has the federal authority to protect fish and fish habitat under the guidelines of the *Fisheries Act* and the *Species at Risk Act*. Fish habitat by definition includes spawning grounds and nurseries, rearing, food supply and migration areas on which fish depend to carry out their life processes (Fisheries Act, 1985). It is their mandate to preserve healthy marine and freshwater aquatic ecosystems in support of scientific, ecological, social and economic interests. The *Fisheries Act* was updated June 21, 2019 to prohibit any activity that results or could result in the harmful alteration, disruption or destruction of fish habitat. It also protects fish populations from pollution and recommends mitigation measures where loss of habitat is unavoidable. Work carried out near a fish-bearing watercourse must have the approval of Fisheries and Oceans Canada, and failure to comply with the Act may result in significant fines or imprisonment.

5.2 Provincial Government

The jurisdiction over water management in Alberta was given to the Province under *the Transfer of Natural Resources Act* of 1930. Since then, the province has focused on water quantity using the *Water Resources Act* (1943) and only recently has there been focus on water quality since introduction the modern *Water Act* (1999) which replaced the *Water Resources Act*.

The *Water Act* governs the allocation and use of water from both surface and groundwater sources. It protects the right to divert water for household purposes for all Albertans as the primary priority. Secondarily, it protects the right of agricultural operations to divert up to 6,250m^3 of water per year for the purposes of raising animals or applying pesticides. This agricultural exemption applies to people whose land directly borders a waterbody or watercourse or with groundwater underneath their land. Water diverted for household and traditional agricultural uses does not require a license.

The *Water Act* supports the conservation and management of water and allows for regional differences in water management to be reflected through the development of water management plans, as outlined in the *Framework for Water Management Planning*, released in 2001 (Alberta Environment, 2001). Interestingly, the Framework includes the *Strategy for the Protection of the Aquatic Environment*, that details the government's commitment to maintaining, restoring, or enhancing the condition of the aquatic environment.

[1] Note: This is general guidance of the regulations protecting the natural environment and is not comprehensive. Be sure to discuss your specific project with regulators and environmental professionals prior to any disturbance.

The updated *Guide to Watershed Management Planning in Alberta* (2015), provides advice on the steps to develop and implement a watershed management plan. The Government of Alberta relied on the work of the Alberta Water Council's Recommendations for a Watershed Management Planning Framework for Alberta as the foundation for this planning guide. The guide is based on the iterative process of adaptive management, from planning through to implementation and evaluation, and back to planning. The planning process should include the development of actions that support the protection, restoration, or maintenance of watersheds without compromising the water needs of the community. This guide is intended to assist Watershed Planning and Advisory Councils and Watershed Stewardship Groups in their planning processes and activities.

The *Environmental Protection and Enhancement Act* is intended to support and promote the protection, enhancement, and sustainable use of all aspects of the environment, from land to water. It covers conservation, reclamation, pesticide use, waste control and wastewater, and storm drainage.

The Government of Alberta is committed to sustainable development through an integrated resource management (IRM) approach to protect the environment and manage Alberta's resources (Alberta Environment, 2001). IRM requires a comprehensive, interdisciplinary approach to the management of water, timber, air, public land, fish, wildlife, range, oil, gas, and mineral resources. The Alberta Government released a province-wide comprehensive strategy called Water for Life: Alberta's Strategy for Sustainability in 2003 (Alberta Environment, 2003). Renewed in 2008, the purpose of the Strategy is to identify short, medium, and long-term plans to effectively manage the quantity and quality of the province's water systems and supply. The three main goals of the strategy are to ensure that Albertans have a safe and secure drinking water supply, healthy aquatic ecosystems and reliable, quality water supplies for a sustainable economy (Alberta Environment, 2008). The provincial government uses both the *Water Act* and the *Environmental Protection and Enhancement Act* (EPEA) to enforce regulations regarding the preservation of Alberta's water supplies.

Other provincial acts that can be utilized to protect Alberta's water resources include the *Agricultural Operations Practices Act (AOPA); Safety Codes Act (Municipal Affairs); Regional Health Authorities Act; Wildlife Act (AEPA); Public Lands Act (AEPA); Provincial Parks Act; Wilderness Areas, Ecological Reserve, Natural Areas and Heritage Rangelands Act; Alberta Fisheries Act*; and policies such as the *Wetlands Policy* (AEPA). Brief descriptions of these acts are provided in Table 1.

- AOPA provides guidelines and regulations regarding environmental management in livestock operations. It allows the province to be able to manage issues such as manure runoff, odour, noise, dust, smoke or other disturbances resulting from an agricultural operation, and provides clear manure management standards.
- The *Safety Codes Act* applies to the construction, installation and maintenance of septic systems. It ensures that septic systems follow minimum engineering standards for manufacture and installation, and that their integrity is preserved through regular maintenance. Leaking septic systems around lakes are a concern throughout the province. Private septic systems seen in lakeside properties and recreational sites can cause contamination of groundwater and surface water bodies.
- The *Regional Health Authorities Act* ensures the preservation of the health and safety of Albertans and can be used alongside the *Safety Codes Act* in ensuring water supplies are kept free of sewage contamination.
- Alberta Environment and Protected Areas (AEPA) is responsible for enforcing many acts which can be used in the protection of aquatic resources. These acts include the *Wildlife Act*, which governs the management of wildlife as a Crown resource, enables the hunting and trapping of wildlife, and addresses the conservation of species at risk (endangered, threatened). The *Public*

Lands Act deals with the selling and transferring of public land, riparian rights, access to bed and shores and environmental reserves, as well as the management of rangeland and activities permitted on designated land.

- The *Provincial Parks Act* and the *Wilderness Areas, Ecological Reserve, Natural Areas and Heritage Rangelands Act* ensure the preservation and conservation of natural areas as parks or reserves. These Acts prohibit development and limit access to protected areas in order to preserve their natural state and ecological integrity.
- Fisheries (Alberta) Regulation addresses licenses for fishing (recreational, commercial, subsistence), fish culture (specified fish held live for sale for human consumption), research, import of aquatic invasive species (AIS), fish stocking, salvage fishing and competitive fishing events.
- The *Wetlands Policy* (2013) strives to balance growth and economic development in the province while protecting, conserving, and restoring wetlands in Alberta which are essential to protect water quality and quantity in the province.

5.3 Municipal Governments

The following guiding documents are used by municipalities to protect and maintain watershed health and integrity:

- The *Municipal Government Act* (MGA) provides municipalities with authorities to regulate management of private land to control non-point sources. It also provides municipalities with the authority to enact bylaws and municipal land use to ensure that land use practices are compatible with the protection of aquatic environment.
- Land Use Bylaws divide the municipality into land use districts and establish procedures for processing and deciding upon development applications. It sets out rules that affect how each parcel of land can be used and developed and includes a zoning map.
- An Area Structure Plan or Land Use Plan is a plan adopted by Council pursuant to the *Municipal Government Act* that provides a framework for future subdivisions and development of an area.
- A Municipal Development Plan is a plan adopted by Council pursuant to the *Municipal Government Act* that provides a framework for how lands will be used and how future developments will be zoned.

Current and past land use plans, guiding documents and bylaws enacted for the Lac La Nonne watershed include:

- Nakamun Lake: Options for a Management Direction (1979)
- Lac La Nonne Background Information and Management Issues (1980)
- Lac La Nonne Management Study (1981)
- Nakamun Lake Area Structure Plan (1981)
- Lac La Nonne Area Structure Plan (1982)
- Lac La Nonne Intermunicipal Development Plan (2002)
- *Summer Village of Nakamun Park Land Use Bylaw* (2007) (Summer Village of Nakamun Park, August 2007)
- Lac La Nonne Municipal Development Plan (2014)
- Summer Village of Nakamun Park Municipal Development Plan (2020) (Summer Village of Nakamun Park, 2020)
- *Majeau Lake RV Park Area Structure Plan* (2020) (Lac Ste. Anne County, 2020)

Table 1 summarizes the applicable acts and legislation available to assist with watershed management planning initiatives.

Table 1. Legislation and policy involving water and watershed management.

Legislation/Policy	Description
Federal *Fisheries Act* - Department of Fisheries and Oceans Canada (DFO)	Regulates and enforces harmful alteration, disruption and destruction of fish habitat in Section 35.
Provincial *Water Act* – Alberta Environment (EPA)	Governs the diversion, allocation and use of water. Regulates and enforces actions that affect water and water use management, the aquatic environment, fish habitat protection practices and in-stream construction practices.
Provincial *Environmental Protection and Enhancement Act* (EPEA) – AEPA	Management of storm water, contaminated sites, storage tanks, landfill management practices, hazardous waste management practices and enforcement.
Provincial *Agricultural Operations Practices Act* (AOPA) – Natural Resources Conservation Board (NRCB)	Regulates and enforces on confined feedlot operation and environment standards for livestock operations.
Provincial *Municipal Government Act* (MGA) – Municipal Affairs	Provides municipalities with authorities to regulate water on municipal lands, management of private land to control non-point sources, and authority to ensure that land use practices are compatible with the protection of aquatic environment.
Provincial *Public Lands Act* - AEPA	Regulates and enforces on activities that affect Crown-owned beds and shores of water bodies and some Crown-owned uplands that may affect nearby water bodies.
Provincial *Safety Codes Act*- Municipal Affairs - AEPA	Regulates and enforces septic system management practices, including installation of septic field and other subsurface disposal systems.
Regional Health Authorities Act – Alberta Health Services (AHS)	RHA have the mandate to promote and protect the health of the population in the region and may respond to concerns that may adversely affect surface and groundwater.
Wildlife Act - AEPA	Regulates and enforces on protection of wetland-dependent and wetland-associated wildlife, and endangered species (including plants).
Provincial Parks Act & *Wilderness Areas, Ecological Reserve and Natural Areas Act* – AEPA	Both Acts can be used to minimize the harmful effects of land use activities on water quality and aquatic resources in and adjacent to parks and other protected areas.

and Community Development	
Alberta Wetlands Policy (2013)	This policy will be used to protect wetlands and mitigate losses.
Land Use Bylaws (Municipal)	The bylaw that divides the municipality into land use districts and establishes procedures for processing and deciding upon development applications. It sets out rules that affect how each parcel of land can be used and developed and includes a zoning map.
Area Structure Plans (Municipal)	Adopted by Council as a bylaw pursuant to the *Municipal Government Act* that provides a framework for future subdivisions, development, and other land use practices of an area, usually surrounding a lake.
Municipal Development Plans	The plan adopted by Council as a municipal development plan pursuant to the *Municipal Government Act*.

6 History

6.1 Lac La Nonne

The lake's name, which means "the nun" in French, has an uncertain origin dating back to the early 1800s. The Cree name for the lake, mi-ka-sioo, means "eagle". It is speculated that the lake may have been named for the white-winged scoter, a duck that is common on the lake and is similar to an English duck known as "the nun". The bird's colouring, which is black with white wing bars and a white spot on the head, suggests a black-robed nun (Mitchell & Prepas, 1990). Another suggestion is that the lake was named for the nuns at the nearby Lac Ste. Anne Mission, though that mission was not founded until 1878.

The Hudson's Bay Company established a trading post at Lac La Nonne in the early 1800s. The post was used to pasture the pack horses needed to portage goods from Edmonton House to Fort Assiniboine on the Athabasca River (ERPC, 1980). By the 1830s, there were considerable numbers of Métis living by the lake. Missionaries arrived in the 1870s, and in 1878, the Oblate Fathers established a mission on the southeast shore at the site of the present-day Catholic Church at Camp Encounter. When the fur trade declined, the Métis moved away and the trading post and mission were closed (Mitchell & Prepas, 1990). Six Hudson's Bay Company land reserves were set aside in 1873, totaling approximately 500 acres northeast of Lac La Nonne. By the 1890s, several white families had settled around the lakeshore, and by 1912, most of the available land had been home-steaded. Horse and cattle raising were important occupations, and sawmills operated periodically near the lake. The first summer cottages were built on the eastern shore in the early 1900s.

By the 1970s, cottage development had increased to the point that most of the shoreline was privately owned (ALMS, 2002). Due to concerns expressed over water quality in the lake, further development was halted in 1977 through the Lake Shoreland Development Operation Regulations put in place by Alberta Environment (Mitchell & Prepas, 1990). This allowed preparation of the Lac La Nonne Management Plan, which was completed in 1980 (ERPC, 1980); (ERPC, 1981). This plan determined the extent of future land developments, allocated land use and determined ways to minimize environmental impacts and conflicts

in uses of the lakeshore. It also recommended preferred lake uses and ways to minimize lake-user conflicts.

Subsequently, an area structure plan was adopted by the counties of Lac Ste. Anne and Barrhead in 1982 (Edmonton Metropolitan and Yellowhead Regional Planning Commissions, 1982).The area structure plan defines land-use and development policies for the area and classifies parcels of land for various uses. The area structure plan was updated in 2002 and is now the Lac La Nonne Intermunicipal Development Plan. This plan includes a brief biophysical analysis of the lake and its surroundings, as well as lake and land use policies, land use classification, development policies, and implementation and administration of the plan.

Today, Killdeer Beach Resort, Willowbend Resort, and Sunny Beach Campground (previously Elks Beach) are the three main commercial facilities at the lake. There are no provincial or municipal campgrounds at the lake.

6.2 Nakamun Lake

Nakamun is a Cree word for “song of praise” or “songbird” (Mitchell & Prepas, 1990). Settlers arrived in the area at the end of the nineteenth century and began clearing land for agriculture to the east and northeast of the lake. Most of the land around the lake is privately owned and the south shore is extensively developed. The first subdivision was established in 1960; it was incorporated as the summer village of Nakamun Park in 1966. Four Oakes subdivision was founded in 1962 about 400 m east of Nakamun Park, and Nakamun Court subdivision (also called Losie Glade) was built in 1975 adjacent to the west side of Four Oakes. The north shore remains mostly undeveloped except for a Bible camp and a few cottages.

6.3 Majeau Lake

Historical information regarding Majeau Lake is not well documented and no published information was found during the research stage of this report. The majority of the shoreline currently remains undeveloped aside from some agricultural operations and a seasonal RV Park and campground featuring a 9-hole golf course on the east side of the lake.

7 Watershed Characteristics

The watershed boundary used for this report is the same as used in the previous report, developed by PFRA, Alberta Environment, and Aquality Environmental Consulting Ltd. for the Lac La Nonne watershed and the subwatershed catchments of Lac La Nonne Lake, Nakamun Lake and Majeau Lake (Figure 1). Where possible, we try to use our improved watershed boundary areas to avoid reader confusion. However, some older data and maps used in this report may still reflect the old boundary areas.

7.1 Description of Lac La Nonne Watershed

The watershed is part of the Athabasca River Basin in the Counties of Barrhead and Lac Ste. Anne, and lies approximately 100 km northwest of Edmonton, Alberta, Canada. It has a drainage basin area of approximately 299.1 km^2 (PFRA, 2006) and includes the Majeau Lake and Nakamun Lake subwatersheds (Figure 1). The region is part of the Moist Mixedwood Subregion of the Boreal Mixedwood Ecoregion, which means the area is dominated by aspen (*Populus tremuloides*) and balsam poplar (*Populus*

balsamifera), with predominantly grey luvisol soils (Mitchell & Prepas, 1990). Some white spruce (*Picea glauca*) stands are present around the edge of depressional sites or wetland areas (Bentz & Wells, 1990).

7.1.1 Lac La Nonne Subwatershed

Lac La Nonne is a highly developed and popular recreational lake located approximately 90 km northwest of the City of Edmonton, in the counties of Barrhead and Lac Ste. Anne. Lac La Nonne has an area of 12.28 km^2 (Table 2), which is approximately 4% of its drainage basin area. Mean depth of Lac La Nonne is 7.8 m (Mitchell & Prepas, 1990), and the subwatershed area is approximately 129.906 km^2 (PFRA, 2006). The water residence time of Lac La Nonne is approximately 6.5 years, and the maximum depth of the lake is 20 m (Hamilton, 1980). This water residence time is relatively short for a prairie lake and may help the lake respond quickly to management activities. A detailed bathymetry map appears in Figure 2. The large drainage basin area to lake volume ratio would suggest that Lac La Nonne is eutrophic due to activities on the land that contribute nutrients (Alberta Environment, 1985a). The large subwatershed area of Lac La Nonne affords more opportunity for nutrients to runoff into the lake from point and non-point sources.

7.1.2 Nakamun Lake Subwatershed

Nakamun Lake is located 95 km northwest of Edmonton and 28 km south of Barrhead. It is a headwater lake, with no major inflows into it aside from nearby Kakina Lake. The outflow of Nakamun Lake flows infrequently into Lac La Nonne when water levels are high. Nakamun Lake has an area of 3.54 km^2, a mean depth of 4.5 m and maximum depth of 8 m (Table 2). A detailed bathymetry map appears in Figure 3. It has a length of 2.2 km and a maximum width of 0.8 km. The Nakamun Lake subwatershed includes Kakina Lake and has an area of 48.579 km^2 (PFRA, 2006) which is about 13 times the size of the lake and is large for a prairie lake. The majority of land around Nakamun Lake is privately owned, and the south shore is extensively developed.

7.1.3 Majeau Lake Subwatershed

Majeau Lake has an area of 12.14 km^2 (Table 3) with a maximum depth of 1.2 m (Rhude, 1979). The Majeau watershed has an area of 102.643 km^2 (PFRA, 2006). There is little other physical data available for Majeau Lake at this time and bathymetry has not been established. The major outflow from Majeau Lake is Majeau Creek, which flows into Lac La Nonne, and there are numerous other inflows and outflows around Majeau Lake, predominantly to the west.

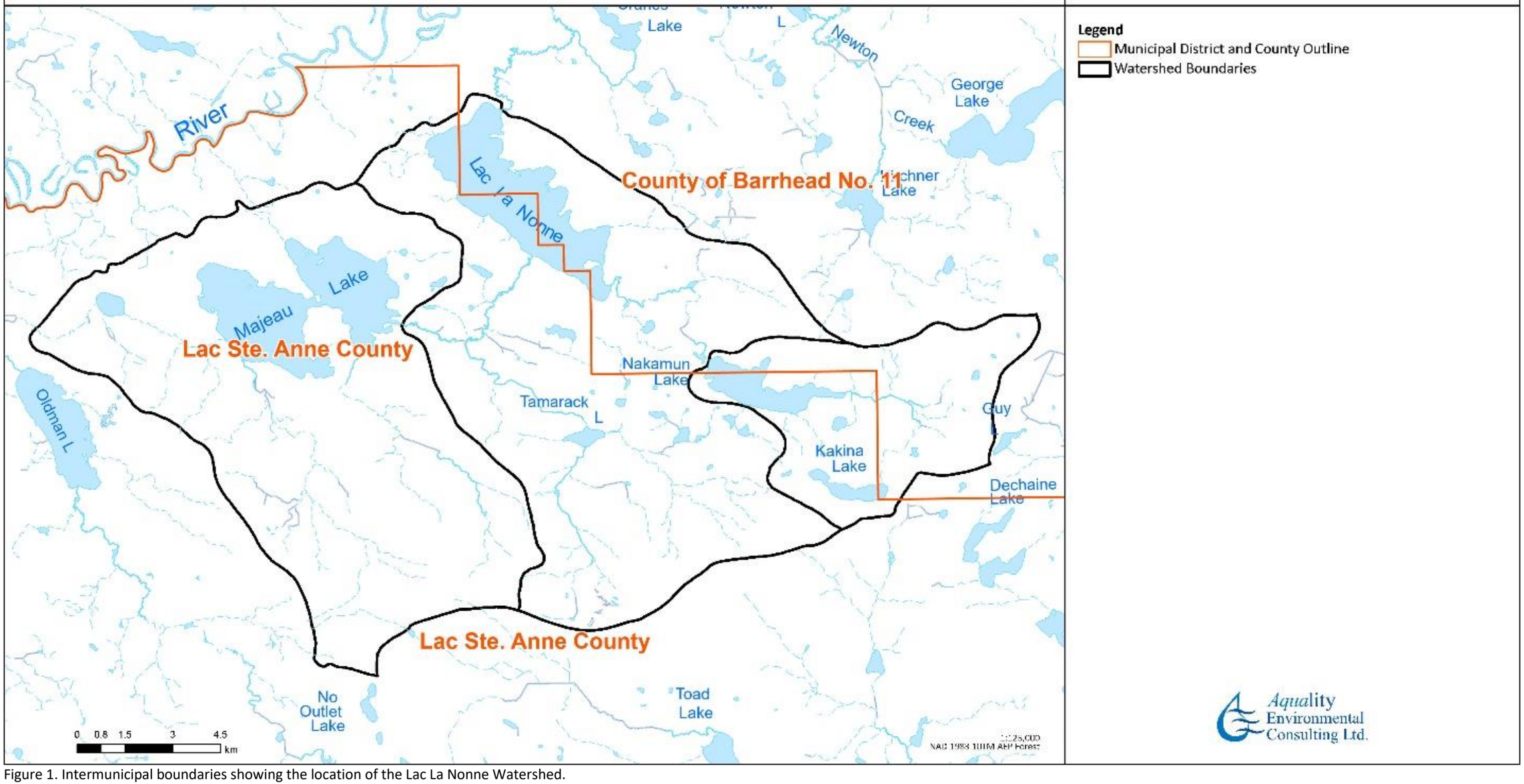

Figure 1. Intermunicipal boundaries showing the location of the Lac La Nonne Watershed.

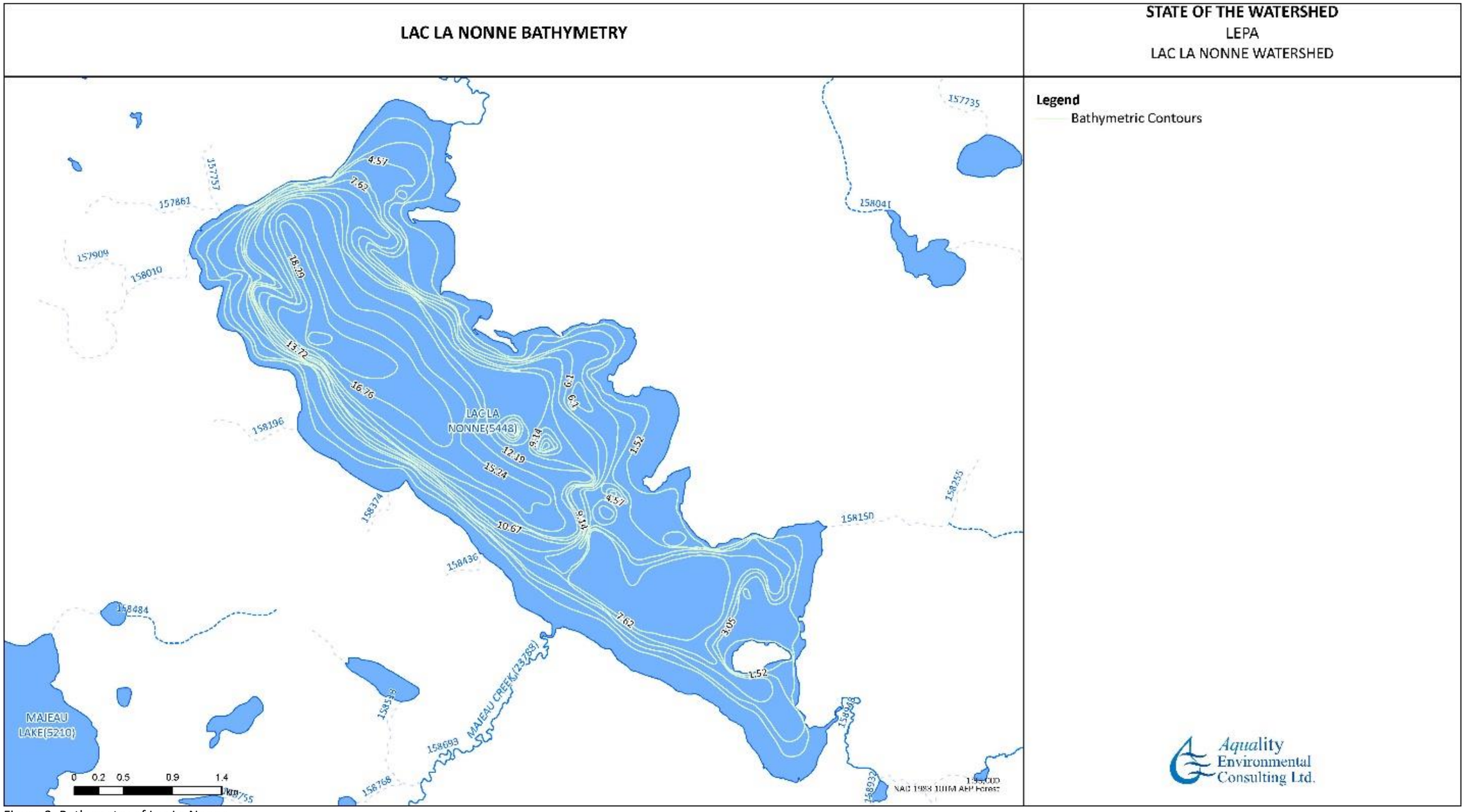

Figure 2. Bathymetry of Lac La Nonne.

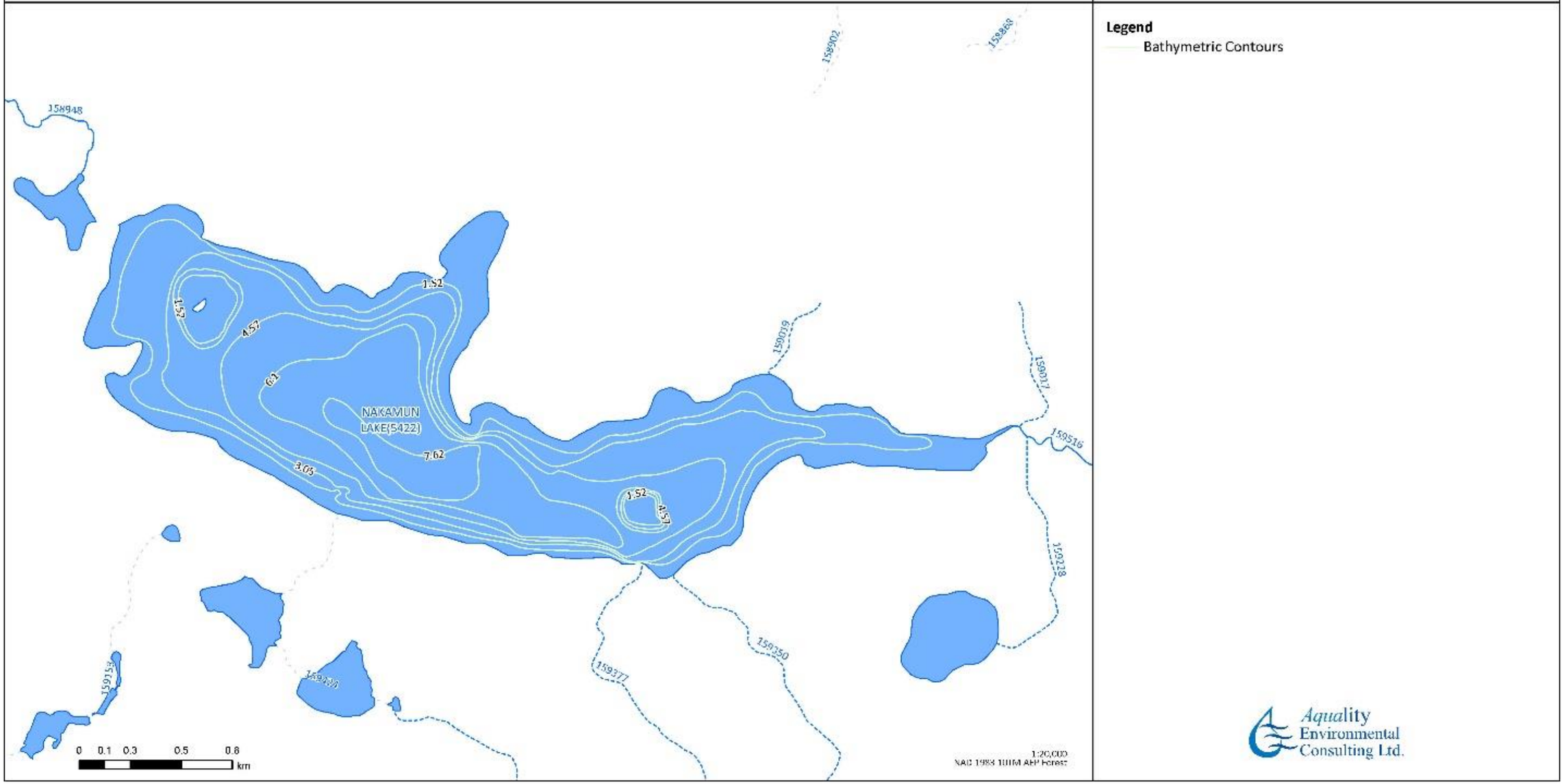

Figure 3. Bathymetry of Nakamun Lake.

Table 2. Physical parameters of Lac La Nonne, Nakamun, and Majeau Lakes.

Parameter	Lac La Nonne[1]	Nakamun Lake[2]	Majeau Lake
Drainage Basin Area	129.91 km^2	48.58 km^2	**102.64 km^2**
Lake Area	12.28 km^2	3.54 km^2	**12.14 km^2**
Drainage Basin/Lake Area	10.5	13.7	**8.45**
Volume	95,956 dam^3	15,800 dam^3	**N/A**
Maximum depth	20 m	8 m	**1.2m**
Mean annual inflow	14,241 dam^3	1,320 dam^3	**N/A**
Mean annual outflow	6,399 dam^3	N/A	**N/A**
Residence time	**6.5 years**	**21 years**	**N/A**

[1] Data from Alberta Environment (1980).
[2] Data from (Mitchell & Prepas, 1990)

7.2 Climate

According to the Barrhead Climate Station, from 1990 to 2022, the average minimum air temperature was -2.86°C and the average maximum air temperature was 9.09°C. In 2022, the lowest temperature reached was -41.40 °C and the highest temperature recorded was +32.21°C.

The amount of precipitation (rainfall and snowfall combined) varies from year to year with particularly wet years seen in 2004, 2011, 2016, and 2017 (Figure 4). Rainfall in the region is generally highest in June and July (Figure 5), and snowfall generally begins in October and can carry through until April (Government of Canada, 2023).

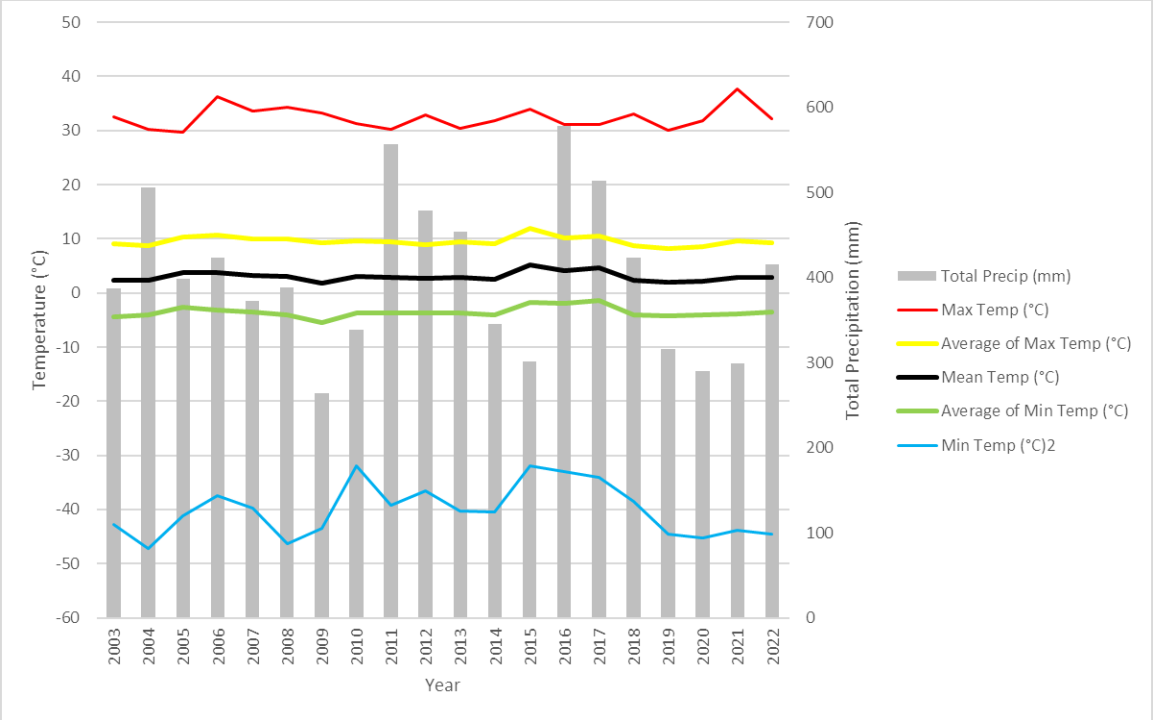

Figure 4. Annual climate trends from 2003 to 2022 for the region, based on data from the Barrhead Climate Station (Station ID 3060535) (Government of Canada, 2023).

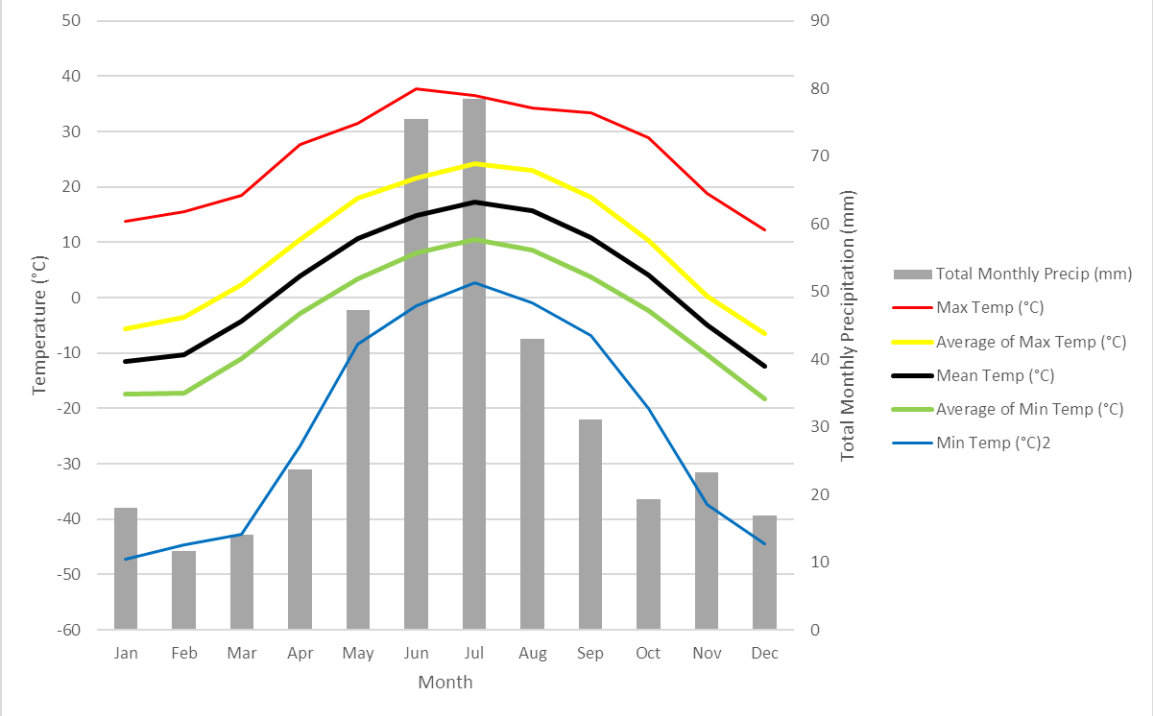

Figure 5. Monthly climate trends from 2003 to 2022 for the region, based on data from the Barrhead Climate Station (Station ID 3060535) (Government of Canada, 2023).

7.3 Geology, Topography, and Hydrology of the Watershed

7.3.1 General

Lac La Nonne watershed is underlain by the Edmonton Formation of the Late Cretaceous age, and is composed of bentonitic clays and sandstones, sandy shales and coal seams (Twardy, 1977). Soils that have developed from outcrops of this parent material are weak to moderately saline in nature. Site-specific sampling would be required to assess whether soils around the lakes are contributing a significant phosphorus loading.

Soil types in the Lac La Nonne watershed may help with indicating what land use activities may be suitable or unsuitable. For instance, poorly drained, sloped and depressional areas would not be suitable for agriculture or housing development. In particular, sloped areas should be avoided due to the potential for runoff of stormwater and agricultural fertilizers into the lake. Poorly drained areas may indicate an interaction with groundwater and may also be a source of runoff to the lakes.

7.3.2 Lac La Nonne Subwatershed

The topography around Lac La Nonne is variable, ranging from level lacustrine and till plains to undulating and moderate to strongly rolling glacial moraine areas (ERPC, 1980). Gently undulating to level topography occurs to the northeast of the lake, and strongly rolling topography occurs to the west and south of the lake (Twardy, 1977). Relief is approximately 50 meters, with the lowest elevations on the east side of the lake (670 m above sea level) and the highest elevations to the west and south (720 m above sea level) (Twardy, 1977) (Figure 6).

Soils have been mapped and described in general for the drainage basin and in detail for an area within 1.6 km of the shoreline (Twardy & Brocke, 1976); (Twardy, 1977)). Adjacent to the lake, the predominant soils are moderately well-drained to well-drained gray luvisols that developed on lacustrine material or glacial till. Regosolic soils are present on the beach sands near parts of the lakeshore and on the floodplains of creeks. Imperfectly to moderately well-drained solonetzic soils that developed on moderately fine-textured till, weathered bedrock material, and fine-textured lacustrine material are located northeast of the lake. Throughout the remainder of the drainage basin, orthic and solodic gray luvisols and solonetzic soils are common and organic deposits are significant. Organics are characterized by accumulations of moss or sedge peat in depressional and poorly drained areas.

7.3.3 Nakamun Lake Subwatershed

The topography of the Nakamun drainage basin is quite varied. To the south and west, the land is gently rolling to rolling, with slopes from 5 to 15%. Wetlands have formed in some depressions. To the northwest, the terrain is undulating to gently rolling, with slopes from 1 to 8%, and to the northeast the land is gently rolling to rolling, with some slopes greater than 15% (Mitchell & Prepas, 1990). The elevation of the land ranges from 732 m at the northeastern and southern edges of the drainage basin to 683 m at the lakeshore (Mitchell & Prepas, 1990).

Soils around the north and west side of the lake are well-drained to moderately well-drained orthic gray luvisols and moderately well-drained to imperfectly drained dark gray luvisols. Soils are overlain by moderately fine textured and medium textured glacial till. To the south, black and gray solodized solonetz are present on medium textured softrock and till (Alberta Agriculture and Forestry, 2023). Large areas of poorly drained mesisols are located around the watershed. These wet depressions contain peat, sedges and slough grass (Twardy & Brocke, 1976).

7.3.4 Majeau Lake Subwatershed

To the north and west, the landscape is hummocky with slopes of up to 6%. To the east and south, the land is undulating with high relief with a limiting slope of 4%.

To the north and west, soils are coarse textured orthic gray luvisols on top of medium textured till. To the east, soils are poorly drained with orthic gray luvisol and solonetzic gray luvisol on medium textured till. (Alberta Agriculture and Forestry, 2023). On the southeast side, orthic gray luvisols and poorly drained chernozemic soils are found on very fine textured water-laid sediments, the dominant soil type on the southwest end of the west bay is solonetzic dark gray chernozems, again on fine textured water-laid sediments.

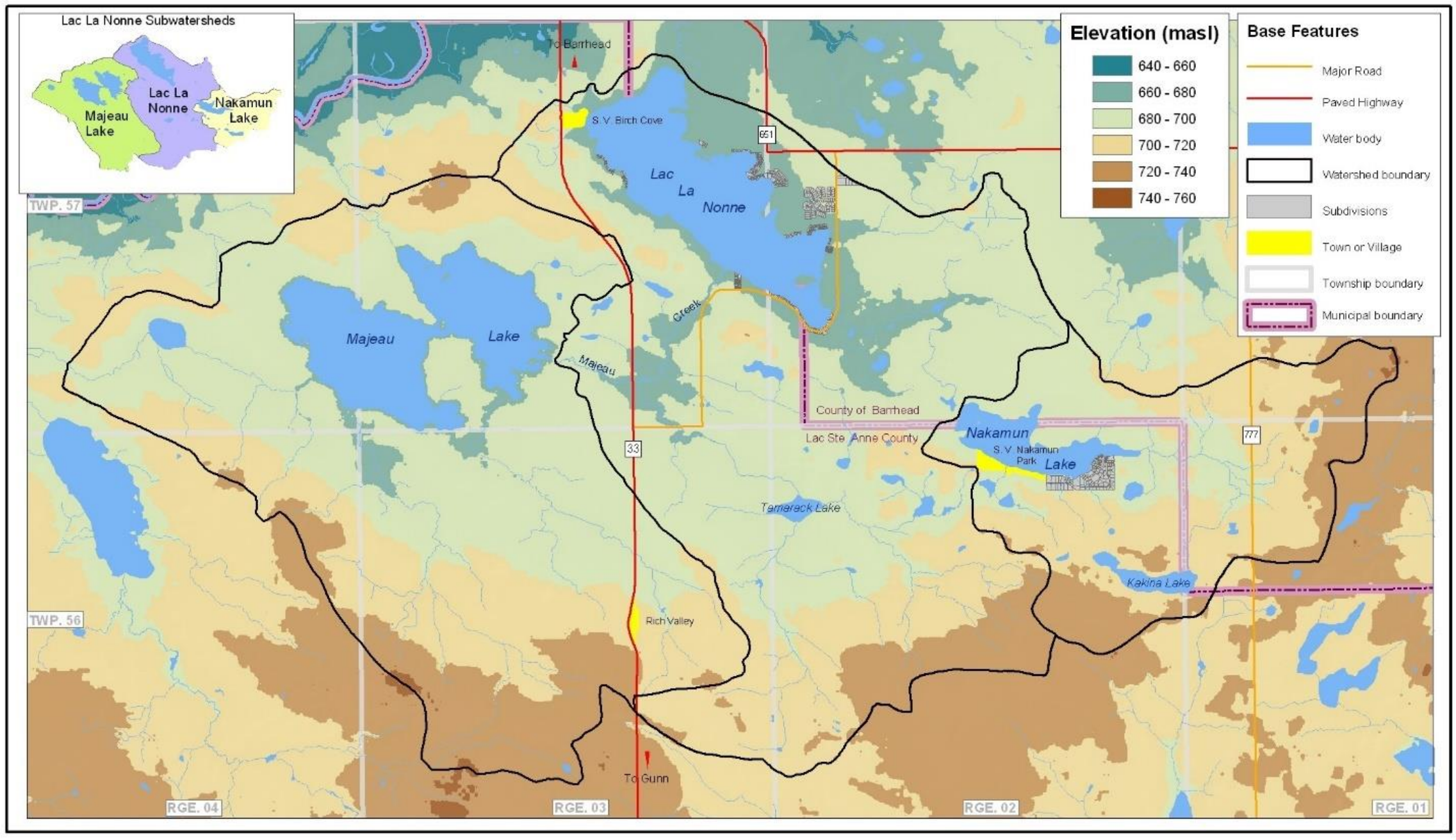

Figure 6. Overview of Lac la Nonne watershed topography, showing heights of land at the south and eastern portions of the watershed. Watershed boundaries delineated by PFRA, Alberta Environment, and Aquality (PFRA, 2006).

8 Land Cover and Land Use

8.1 Land Resources Overview

As previously reported, a large part of the watershed has been cleared of forest, with a comparison of data from 1992-1995 against data from 2001-2003 suggesting that much of this change has been recent. Over that time period, tree cover loss was 41% for the Lac La Nonne subwatershed, 52% for the Majeau subwatershed and 39% for the Nakamun subwatershed. Presumably, this loss has been due to the substantial increase in forage and cropland cover during the same time period, as Lac La Nonne cropland increased by 174%, Nakamun increased by 105% and Majeau increased by 65% (PFRA, 2006).

More recent changes in land cover were analyzed based on analyses conducted by the Alberta Biodiversity Monitoring Institute (Alberta Biodiversity Monitoring Institute, 2000); (Alberta Biodiversity Monitoring Institute, 2010) (Figure 7). The largest component of cover in the most recent data from 2010 was agriculture, at over 45 % of the watershed area. Forested lands (broadleaf, mixedwood, and coniferous) comprise approximately 28 % of the watershed. In contrast to the changes observed from 1990 to 2000, changes in land cover from 2000 to 2010 showed an increase of 8.6 % of developed lands (settlements, buildings, roads), coming predominantly at the expense of agricultural lands and broadleaf forest (Table 3).

Table 3. Land cover classification and changes in area from 2000 to 2010.

Land Cover Classification	Area, 2010	Area, % of basin	Area, 2000	Area, % change 2000-2010
Agriculture	137.5	45.7%	138.4	-0.6%
Broadleaf forest	81.7	27.1%	82.2	-0.6%
Coniferous forest	1.6	0.5%	1.6	-0.3%
Developed	20.6	6.9%	19.0	8.6%
Exposed Land - Mining	0.0	0.0%		-
Grassland	18.8	6.2%	19.1	-2.0%
Mixed forest	2.6	0.9%	2.6	0.0%
Shrubland	0.5	0.2%	0.5	-1.2%
Water	37.8	12.5%	37.8	0.0%

LAND COVER

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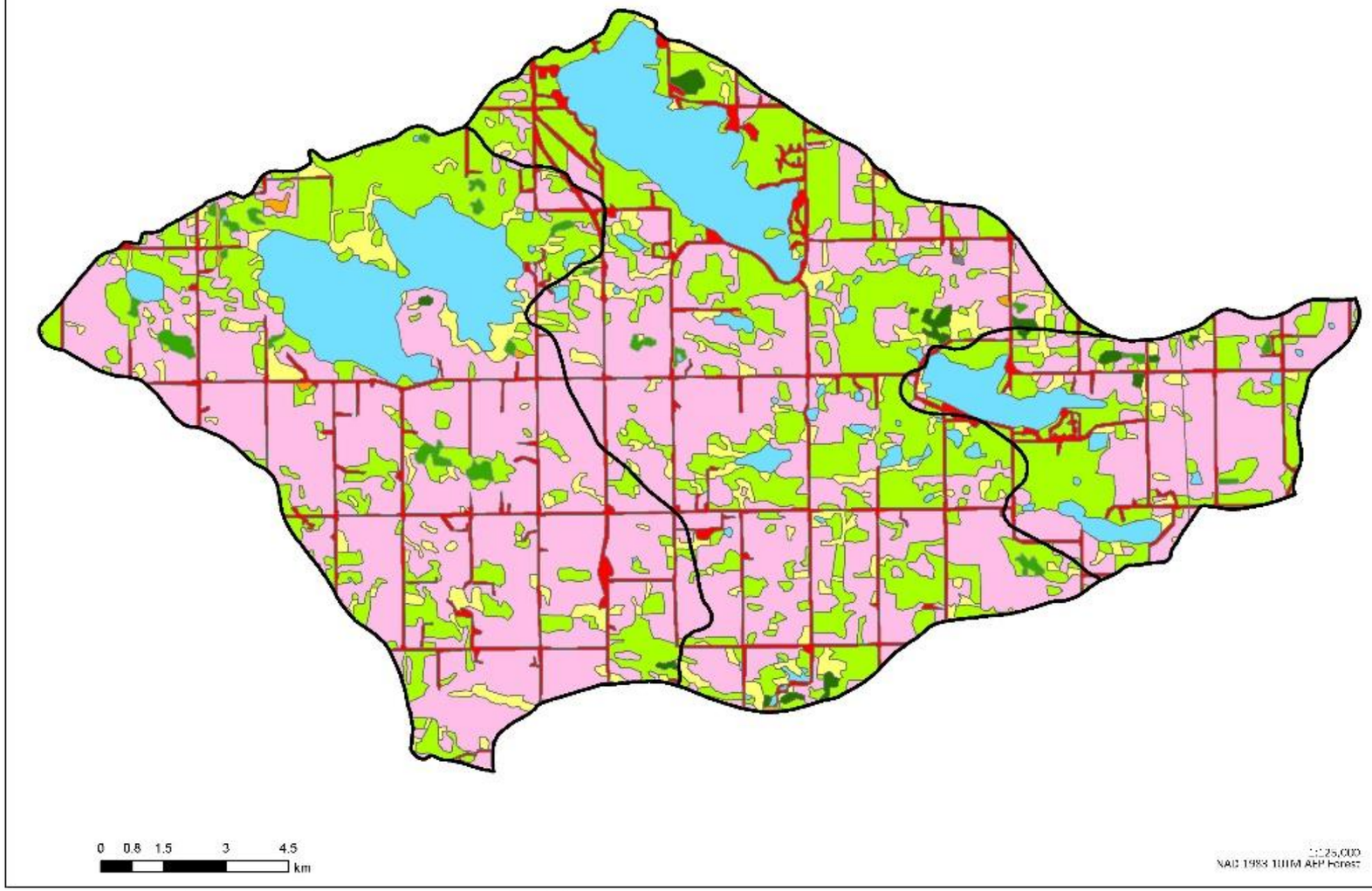
LAC LA NONNE WATERSHED



Legend
- Watershed Boundaries

Land Cover Classification
- Agriculture
- Grassland
- Shrubland
- Broadleaf forest
- Mixed forest
- Coniferous forest
- Exposed Land - Mining
- Developed
- Water

Aquality Environmental Consulting Ltd.

Figure 7. Land cover classification of the Lac La Nonne watershed (Alberta Biodiversity Monitoring Institute, 2010).

8.2 Agricultural Resources

Data from the Census of Agriculture are not available at scales appropriate for the analysis of small watersheds. The previous report analyzed data based on the aggregate data from Lac Ste. Anne County and Barrhead County in order to provide a regional analysis, but interpolating from these scales to the size of the Lac La Nonne watershed can introduce significant inaccuracies. However, recent data on human footprints from the Alberta Biodiversity Monitoring Institute (ABMI) include a breakdown of different agricultural uses and provide insight into the nature of agricultural operations within the watershed.

Overall, agricultural activity impacts approximately 52% of the watershed area (Figure 8). The majority of agricultural operations in the watershed are related to livestock production, with 86% of the land base under pasture, dominated by tame pasture (Table 4). Cropland contributes a further 20.7 km^2 of area (13% of the total agricultural footprint), while previously cleared/cultivated but now abandoned lands contribute 2% of the total footprint.

Table 4. Summary of agricultural footprints within the Lac La Nonne watershed as of 2019 (Alberta Biodiversity Monitoring Institute, 2022).

Agricultural Footprint	Area (km^2)	Area (% of total)
Cropland	20.7	13%
Tame Pasture	119.1	76%
Rough Pasture	15.2	10%
Abandoned Cultivation	2.5	2%

AGRICULTURAL FOOTPRINTS

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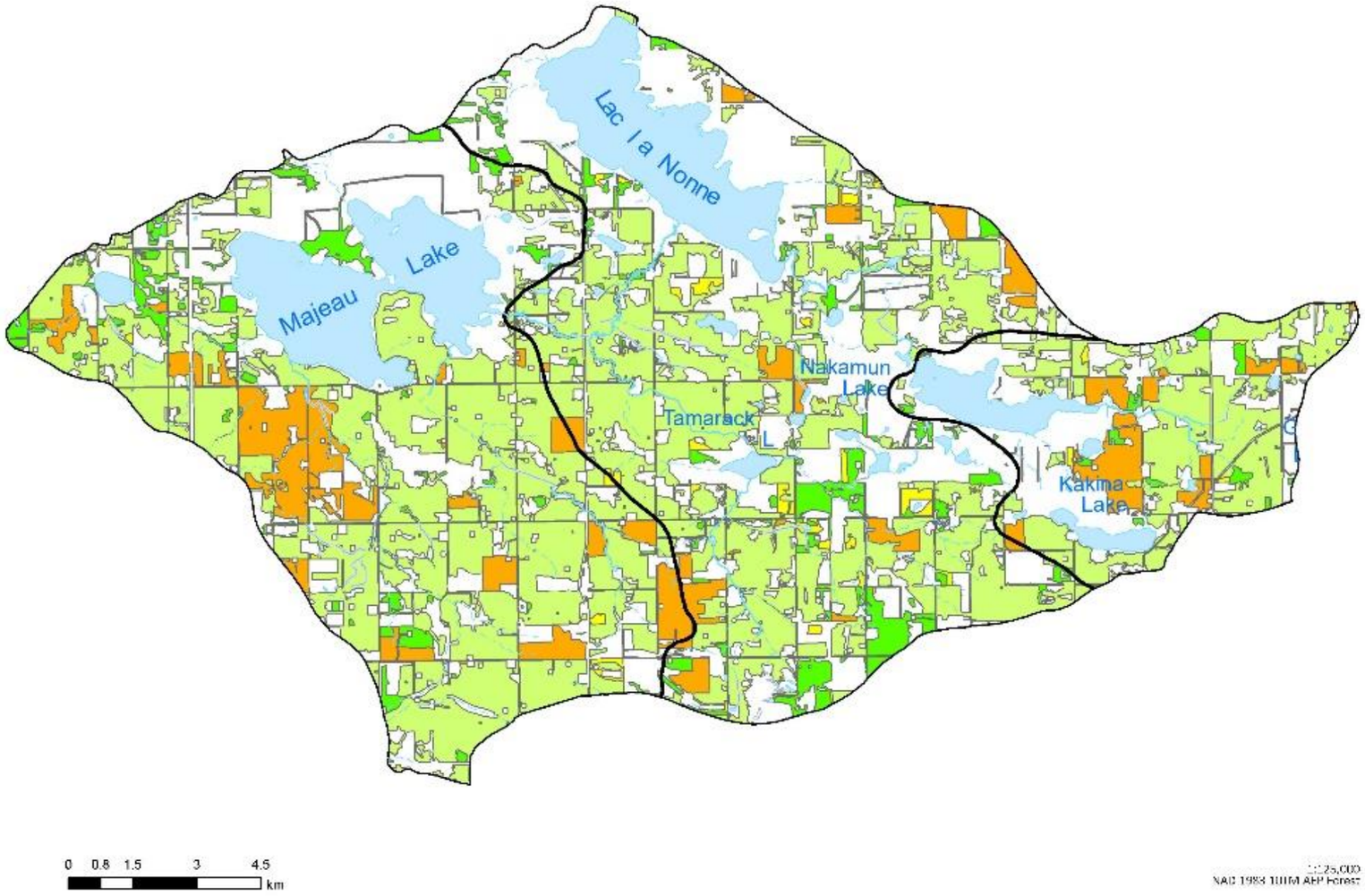


Legend
Watershed Boundaries
Agricultural Footprints
Cropland
Abandoned Cultivation
Rough Pasture
Tame Pasture

Aquality Environmental Consulting Ltd.

Figure 8. Distribution of agricultural footprints within the Lac La Nonne watershed (Alberta Biodiversity Monitoring Institute, 2022).

Although undesirable soil structure, adverse topography and, in some areas, excessive moisture, have limited agriculture in parts of the Nakamun subwatershed, more than half of the land has been cleared for agriculture. The predominant agricultural activity is beef production and most of the cleared land is used for either improved pasture or forage production (Twardy & Brocke, 1976); (ERPC, 1979).

Impacts to water quality are largely from certain agricultural practices including tillage practices, manure management and animal management. Zero-till practices are preferred to heavy cultivation, as are best management practices for manure. Off-site watering that restricts cattle access to shorelines or sensitive riparian areas is also preferred to prevent riparian damage and erosion.

8.3 Recreational Resources

Non-agricultural development, such as residential and commercial areas, can pose a problem to aquatic health due to the poor quality of stormwater runoff typically associated with such areas, as well as the large amount of clearing, grading and paving that is required. Stormwater runoff from paved areas can include heavy metals, pesticides, nutrients, and fecal matter from pets, which typically gets funneled into a central collection system and directed towards the nearest waterbody, where it is released untreated.

Clearing and grading of the land changes the natural topography of the area and removes valuable vegetation, consequently altering the pre-existing surface water runoff patterns and reducing groundwater recharge through percolation. There is extensive development throughout the Lac La Nonne and Nakamun subwatersheds, which could play a large role in the poor water quality seen in the area.

8.3.1 Lac La Nonne Subwatershed

Figure 9 demonstrates the land use types specified in the Intermunicipal Development Plan for Lac La Nonne. Some riparian areas around the perimeter of Lac La Nonne have been declared environmentally sensitive areas, and the land surrounding the lake has been parceled into agriculture conservation, residential recreation, rural conservation, institutional and commercial recreation uses. The vast majority has been assigned to residential recreation, agriculture conservation and rural conservation. Reserve land widths between developments and lakeshore have been set at 30.5 m, and at 55 m around creeks and watercourse slopes (County of Barrhead, 2003).

The first subdivision at Lac La Nonne of 23 lots was registered in 1947. In 1980, there were 13 resort subdivisions located on portions of 11 quarter sections, with 678 subdivided lots, 537 commercial recreation sites (i.e., lakeshore areas of high scenic value, meant for outdoor recreational activities) and 45 municipal reserves in 47 registered plans of subdivision (ERPC, 1981a). There are three commercial campgrounds or trailer parks: Sunny Beach Resort, Willowbend Resort and Killdeer Beach (ERPC, 1981a). Nine quarter sections of Crown Land are owned by the Province of Alberta, and three of these are grazing leases (ERPC, 1981a). The number of developments has not changed significantly since the 1980s.

Currently, there are many residential developments around the lake, including Whiterock Beach, Greendale, Idlehours Resort, Moonlight Bay Estates, Moonlight Bay, Winkleman Beach, Williams Beach, Mortenson Beach, Chrystyna Beach, Killdeer Beach, Bearland Condominiums, Murray's Beach and the Summer Village of Birch Cove (Figure 13). There are boat launches at Willow Bend Beach, Idlehours Resort and at the southern tip of the lake. Over one hundred of these are beachfront properties.

8.3.2 Nakamun Lake Subwatershed

The first subdivision at Nakamun Lake was registered in 1960 and became the Summer Village of Nakamun Park in 1966. This subdivision is on the southwest shore of the lake (Figure 14). Four Oakes subdivision was registered in 1962, and Nakamun Court (also called Losie Glade) followed in 1975, again on the south shores of the lake. There is a campground on the northern shore of the lake and the majority of the surrounding lands on the north side are either treed or grasslands, mixed with agricultural lands. Much of shoreland around the south end of the lake has been developed for seasonal and permanent residences. As of 1990, 23% of the shoreline was developed, predominantly on the south shore (Mitchell & Prepas, 1990).

Areas to the north of Nakamun Lake have been identified as agricultural land in the future land use plans, and lands to the south have been designated as Inter-Municipal Development Plan Country Residential, with restricted development (Figure 10).

8.3.3 Majeau Lake Subwatershed

There is very little development on the shores of Majeau Lake. The land to the north of the lake is treed and classified as a protected area (Figure 11). There is considerable forage land and grasslands to the south of the lake. Although the County of Lac Ste. Anne has not completed an individual development plan for Majeau Lake, it has restricted development around it and all lakes in the Lac La Nonne watershed by not permitting Confined Feeding Operations (CFOs) within approximately a kilometer of all lakeshores (PFRA, 2006).

8.4 Other Human/Industrial Influences

Oil and gas exploration has occurred throughout the Lac La Nonne watershed, with the majority occurring southwest of Lac La Nonne (Figure 15). There is limited sand and gravel extraction in the area, with approximately 65 ha of aggregate extraction development in the southern headwaters of the Lac La Nonne subwatershed (Alberta Biodiversity Monitoring Institute, 2022).

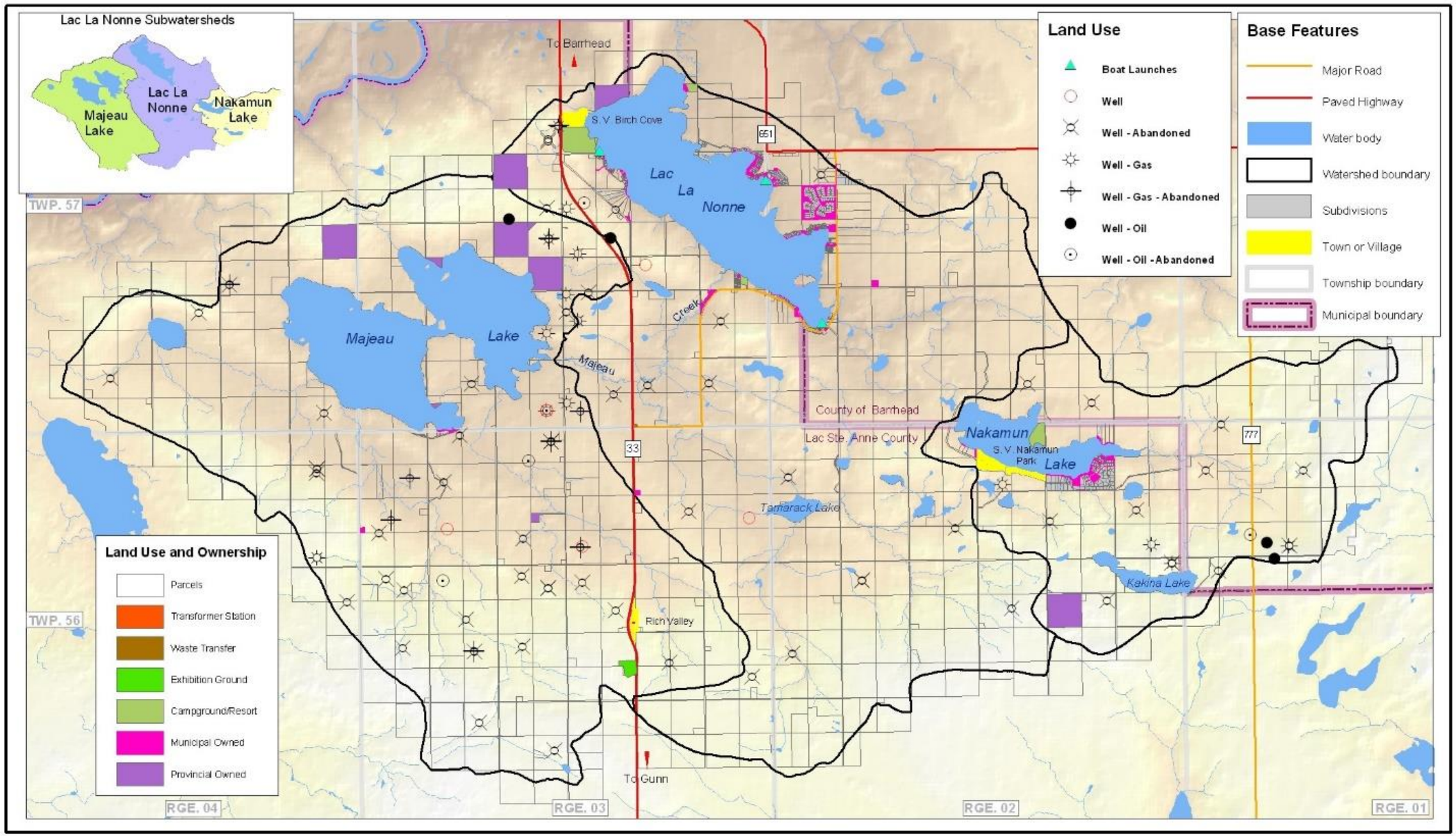


Figure 9. Lac La Nonne Watershed Land Use and Ownership Map. Features identified include oil and gas wells, municipal land, crown land, towns and subdivisions. Data from PFRA (2006).

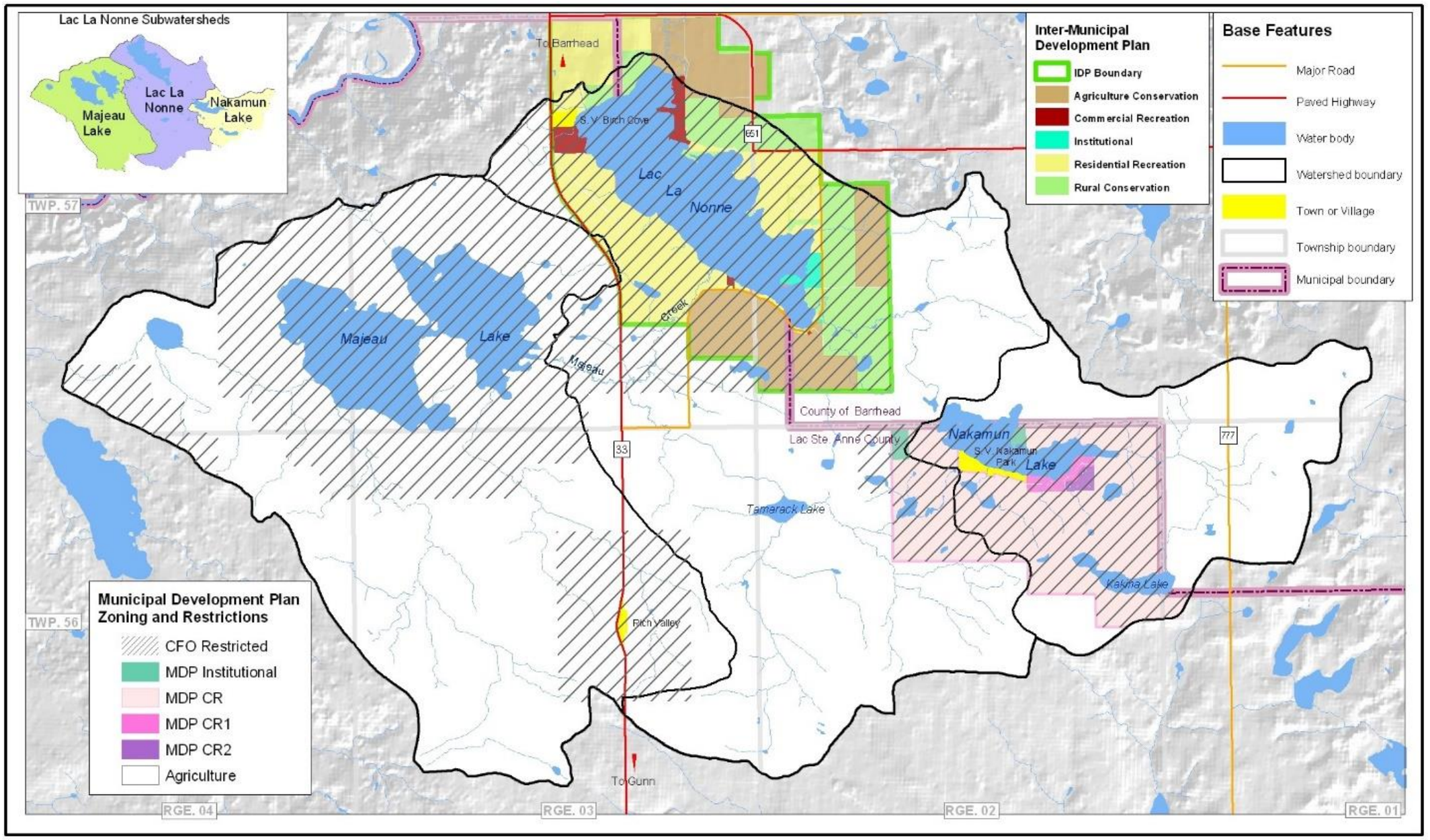


Figure 10. Lac La Nonne Intermunicipal Development Plan (IDP) – Land Use Planning. Key features identified include Confined Feeding Operation (CFO) restrictions, IDP for Lac La Nonne and Municipal Development Planning for both Counties. These include land zoning for environmentally sensitive areas, agriculture conservation, rural conservation, commercial recreation, country residential (CR1 and CR2) and residential recreation areas. Refer to the IDPs and County MDPs for more details. Data from (PFRA, 2006).

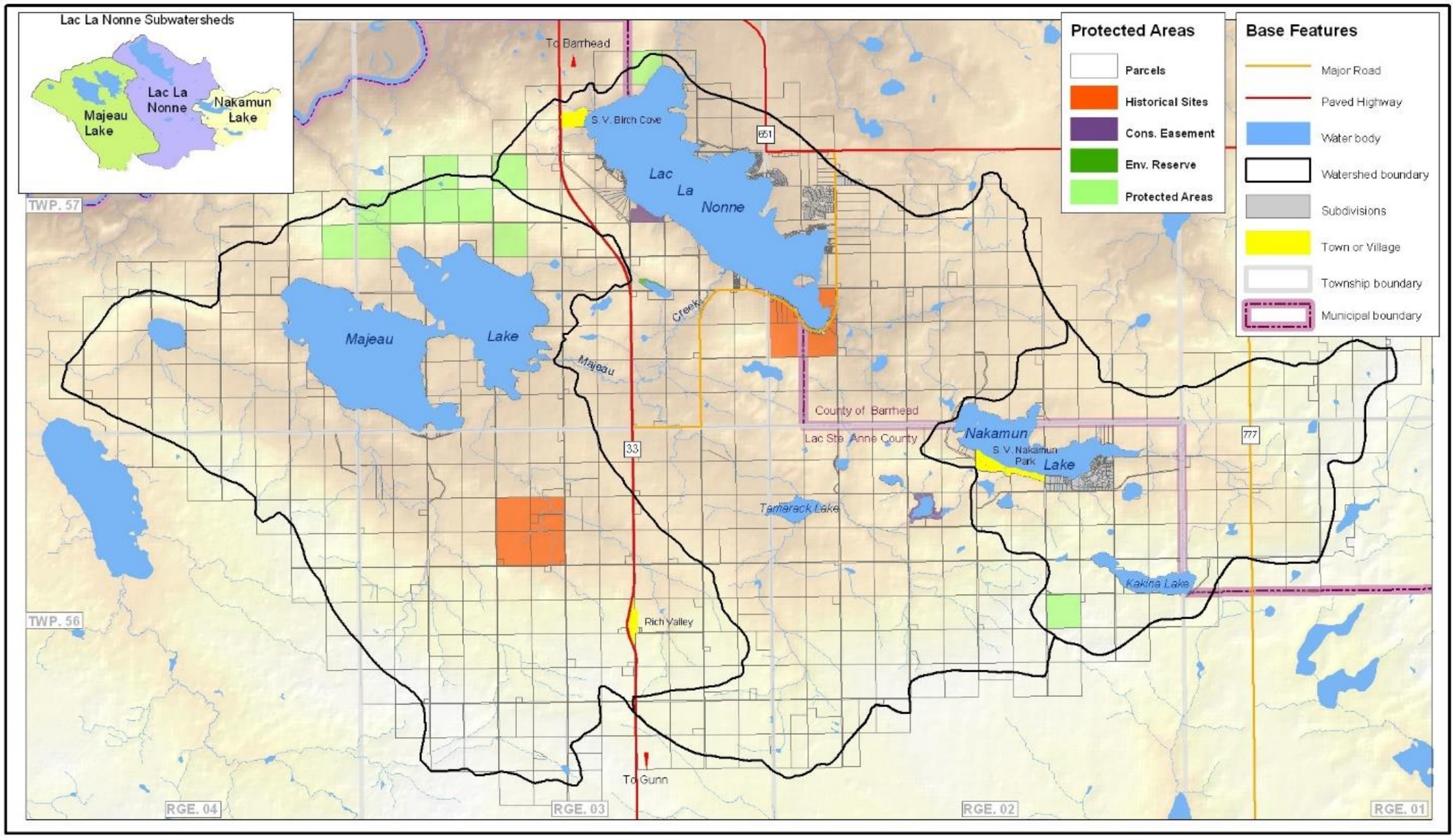


Figure 11. Lac La Nonne Watershed Protected Areas. Key features identified include conservation easements, environmental reserves, historical sites and protected areas. Data from PFRA (2006).

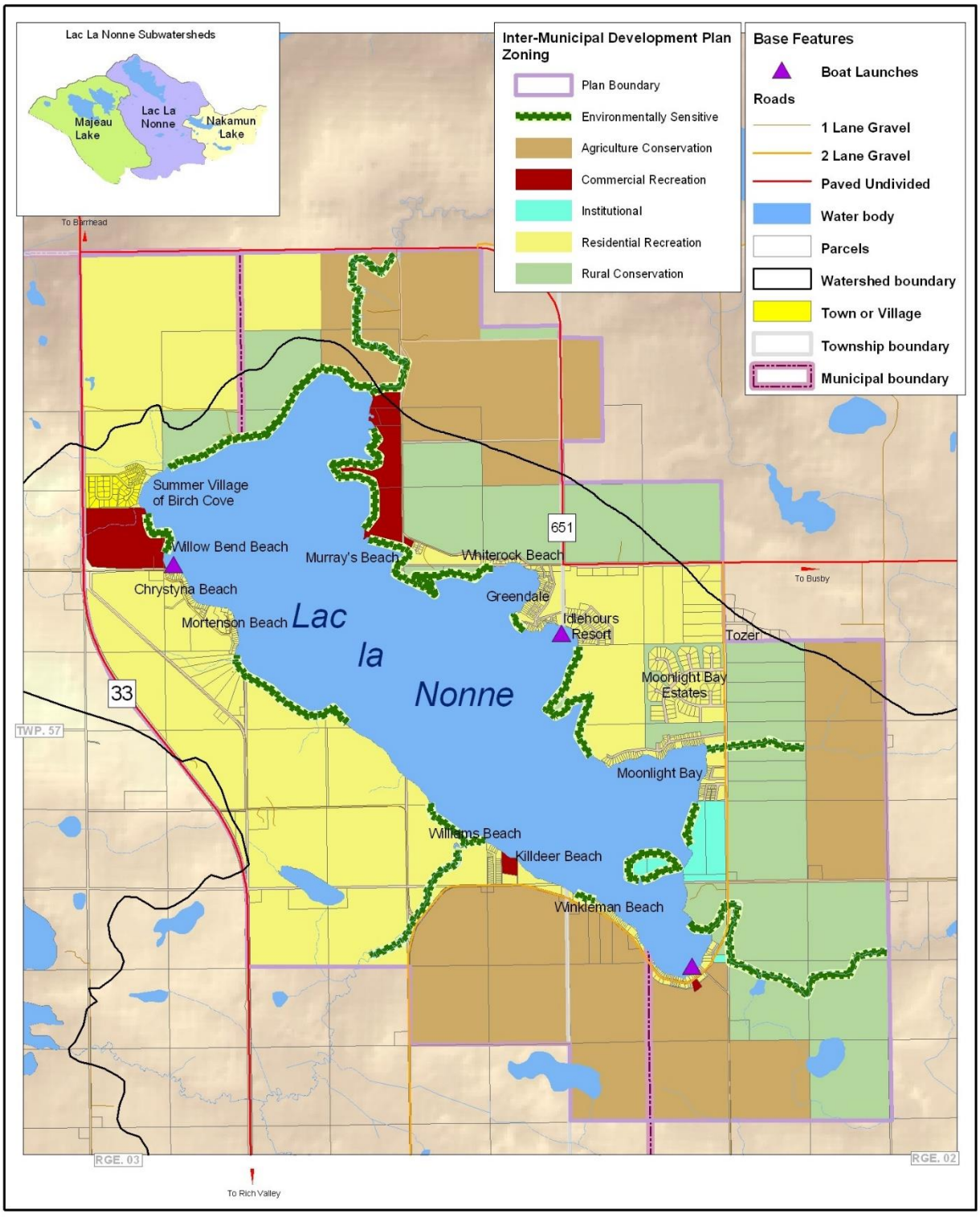


Figure 12. Intermunicipal Development Plan Zoning for Lac La Nonne. Data from PFRA (2006).

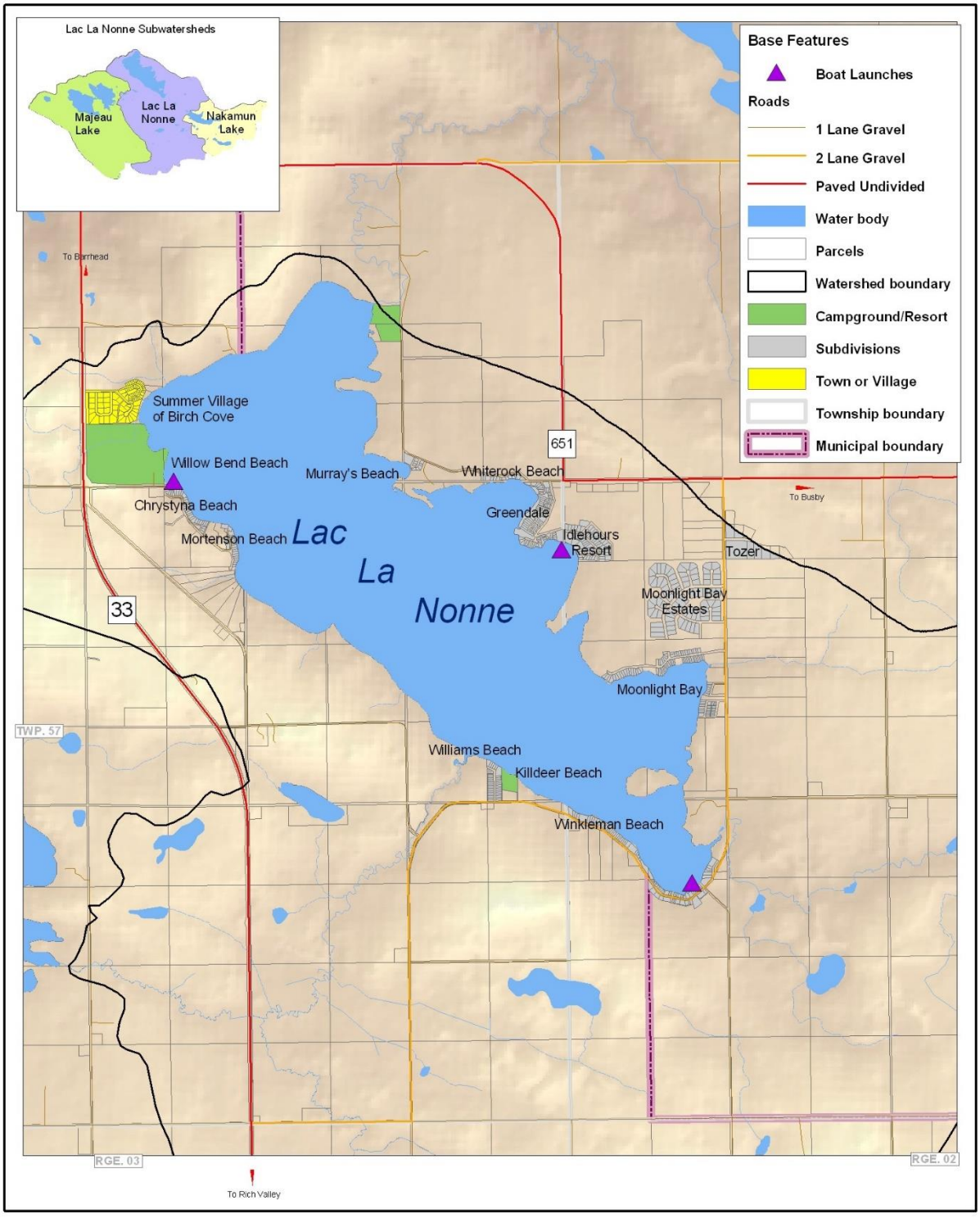


Figure 13. Lac La Nonne Lake Subdivisions. Several small subdivisions are scattered around the east, west and south portions of the lake. Data from PFRA (2006).

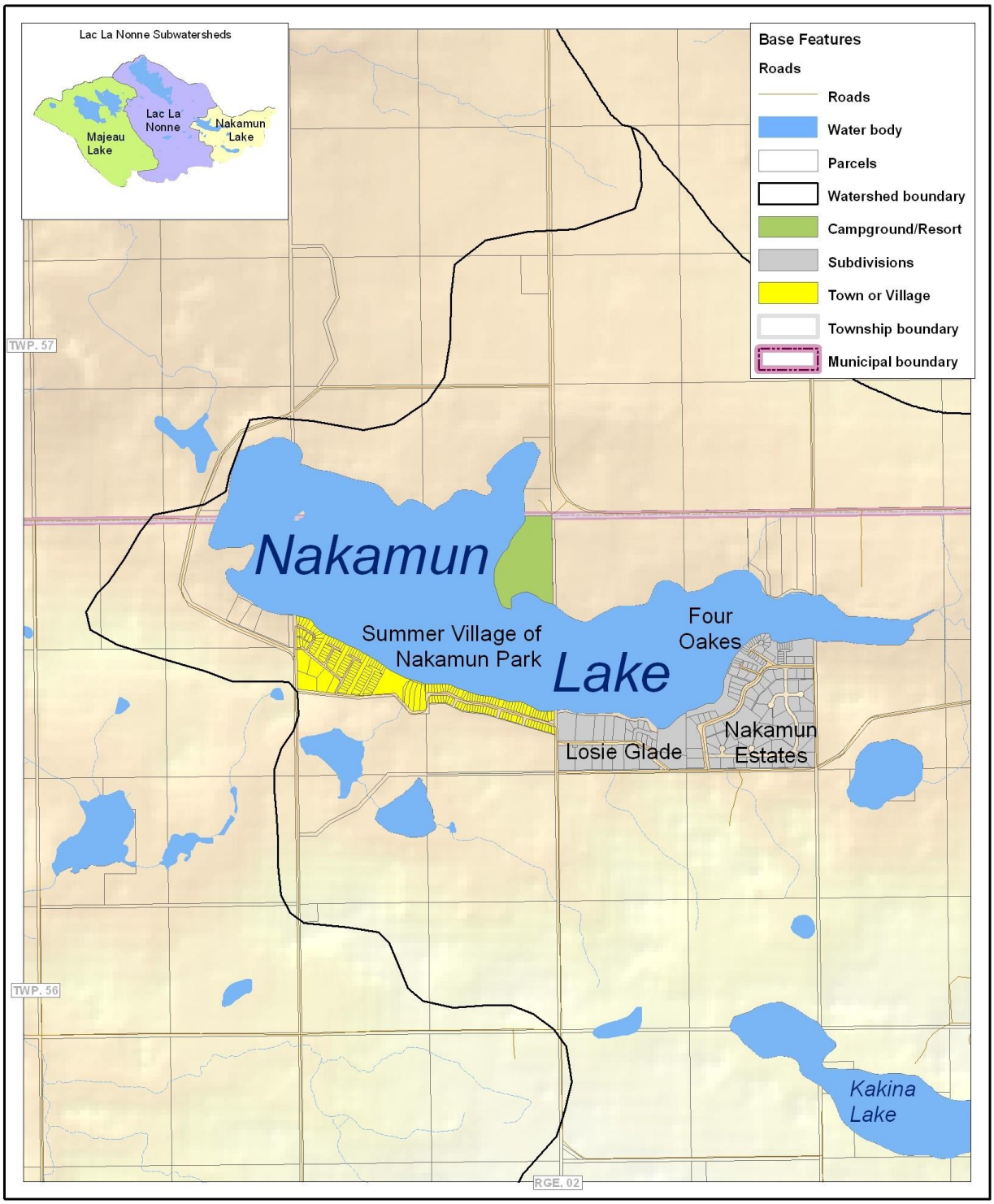
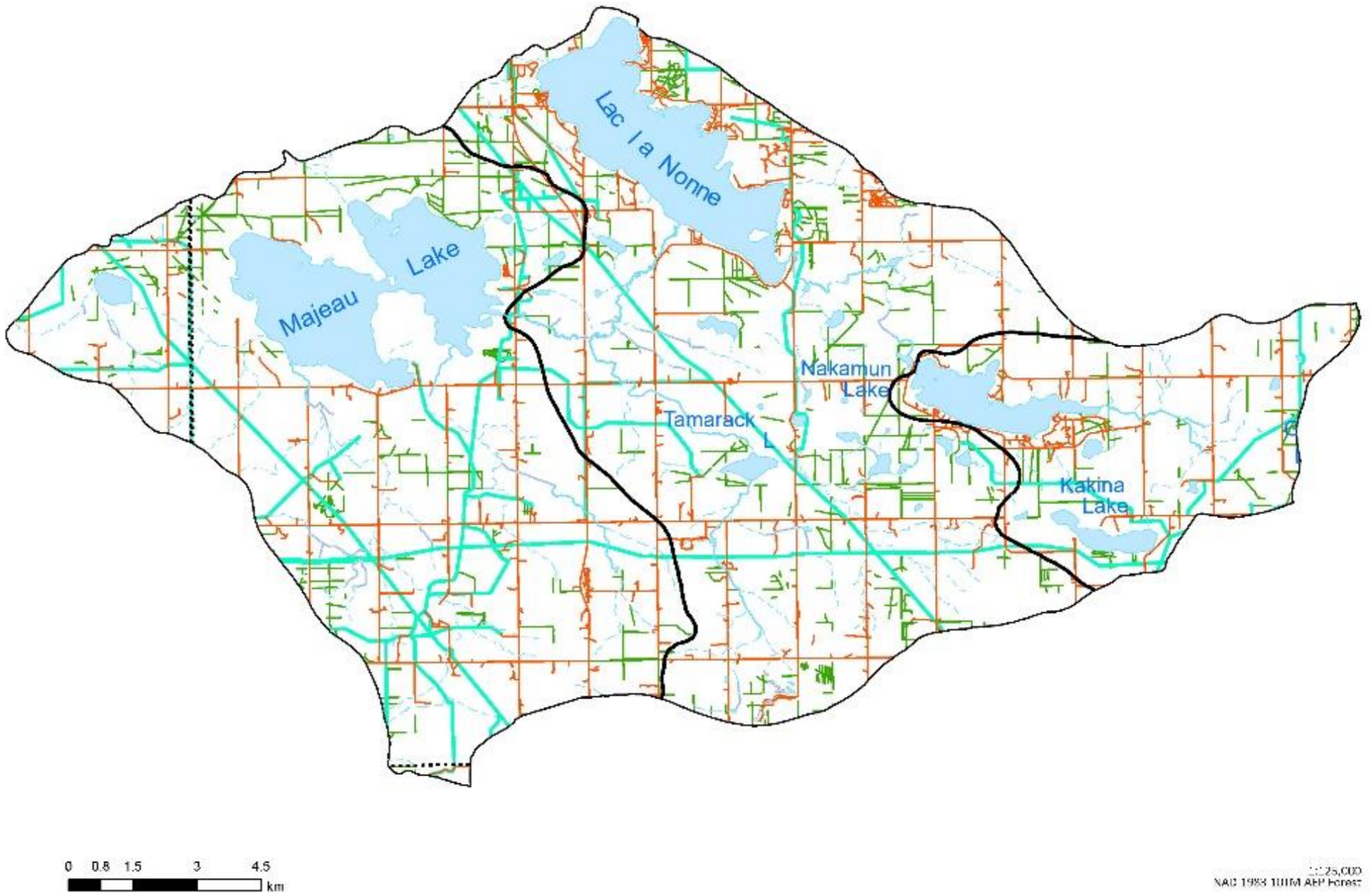


Figure 14. Nakamun Lake Subdivisions. Development of subdivisions has only occurred on the southern portion of the lake. Data from PFRA (2006).

LINEAR FEATURES



STATE OF THE WATERSHED
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LAC LA NONNE WATERSHED

Legend
- Watershed Boundaries

Linear Developments
- Seismic, Trails, and Cut Lines
- Pipelines
- Power Transmission Lines
- Roads

Aquality Environmental Consulting Ltd.

Figure 15. Lac La Nonne Watershed Linear Features. Key features identified include pipelines, powerlines, roads and cut trails. Data from PFRA (2006).

8.4.1 Sanitary Sewer

8.4.1.1 Lac La Nonne

According to the Lac Ste. Anne County Private Sewage System Standards, within any subdivision it is mandatory to install enhanced waste treatment systems or holding tanks. Effective January 1, 2005, soil tests are required for all installations of non-holding tank private sewage disposal systems. All installed sewage systems within multi-parcel subdivisions that are registered after January 5, 2004 must be inspected a minimum of once every 5 years. Any existing private sewage systems that were developed prior to the guideline implementation must be brought into compliance if they require replacement (Lac Ste. Anne County, 2018). This applies to residences around Majeau Lake and the west side of Lac La Nonne.

The County of Barrhead follows the Alberta Private Sewage Systems Standard of Practice 2021 for governing the use of septic tanks, privies, and septic fields for the east side of Lac La Nonne (Safety Codes Council, 2021). They have not had a program to conduct sewage system inspections like the County of Lac Ste. Anne has (Lac Ste. Anne County, 2018).

8.4.1.2 Nakamun Lake

According to the MDP for the Summer Village of Nakamun Lake, "Any remaining pit toilets must be removed and replaced with a sealed impermeable onsite sewage pump out tank. Sealed pump out tanks are required with any new residential development". All outhouses are to be located a minimum of 9.0m away from any body of water and 9.0m away from any groundwater wells (SV of Nakamun Park, 2007).

In Addition, "Existing septic fields should be phased out when replacement is required or be considered when redevelopment or replacement of the house occurs. It is noted that Nakamun Park has some large lots where septic fields can be accommodated" (SV of Nakamun Park, 2013).

8.4.1.3 Majeau Lake

According to the Lac Ste. Anne County Private Sewage System Standards, within any sub??division it is mandatory to install enhanced waste treatment systems or holding tanks. Effective January 1, 2005, soil tests are required for all installations of non-holding tank private sewage disposal systems. All installed sewage systems within multi-parcel subdivisions that are registered after January 5, 2004 must be inspected a minimum of once every 5 years. Any existing private sewage systems that were developed prior to the guideline implementation must be brought into compliance if they require replacement (Lac Ste. Anne County, 2018). This applies to Majeau Lake and the east side of Lac La Nonne.

8.5 Riparian Health

Riparian areas are the zone of land immediately surrounding a waterbody or watercourse that is characterized by water tolerant vegetation and waterlogged soils. By definition, these lands are wetlands, having waterlogged soils and water loving vegetation. Healthy riparian vegetation is important for catching soil particles, nutrients, and contaminants during runoff of precipitation from the surrounding landscape thereby protecting the quality of water. A healthy plant community in the riparian zone is characterized by vegetation that has deep, binding roots that protect the shoreline from erosion due to inclement weather and changes in water levels. Less than three percent of the lands in Alberta are riparian, and while they make up only a small portion of the landscape, riparian areas provide for diverse habitat that supports both aquatic and terrestrial organisms and support a significantly higher level of biodiversity than surrounding upland habitat (Cows and Fish, 2023).

Following the recommendations in the original Aquality (2006) report, the Lac La Nonne Watershed Stewardship Society (LWSS) partnered with Cows and Fish on a "Riparian Health Initiative". The purpose of this initiative was to complete a riparian health inventory for Nakamun Lake, Majeau Lake and Lac La Nonne. This was funded by the Alberta Conservation Association and other partners. Riparian health inventories provide comprehensive information about the diversity, structure and health of plant communities as well as the physical soil and hydrology within the project area. Detailed methods of the assessments can be found in the reports. These inventories establish an important baseline to compare to future work, to see if health is being maintained, improving or declining. This work was undertaken in August 2008 and the results are presented below.

8.5.1 Lac La Nonne

Riparian vegetation disturbances on Lac La Nonne have been recorded as far back as 1980. The ERPC (1981a) noted that shrubs, trees and ground cover had been removed in the vicinity of resort cottage areas, while shoreline vegetation "has often been removed completely". Cows and Fish has flown the watershed in 2000 and 2004 to gather an aerial photographic record of the riparian areas and surrounding landscape in the watershed. There are three riparian improvement demonstration sites, one on the west side of Lac La Nonne and two on the east side, and the health of these sites has been assessed to establish baseline data (K. O'Shaughnessy, pers. comm. 2006).

Lac La Nonne includes three municipalities: Barrhead County, Lac Ste. Anne County and the Summer Village of Birch Cove, with three commercial businesses (Willowbend Resort, Killdeer Beach, Elks Beach) and one youth camp (Camp Encounter). Agriculture is a common land use in the uplands of the watershed but no longer common along the shoreline. Approximately 50% of the shoreline is highly developed while other areas remain undeveloped.

Riparian health inventories for Lac La Nonne Lake were conducted in August 2009 (O'Shaughnessy, 2010). Fifteen sites totaling 4.55 kms of shoreline (18.5%) was assessed. Twenty percent of the sites assessed were "unhealthy". While there was good plant diversity seen in the assessed riparian areas, invasive species, reduced vegetative cover and human-caused alterations to vegetation were problems. The invasive weed species Canada thistle and smooth perennial sow-thistle were present and abundant at all sites assessed (O'Shaughnessy, 2010).

Future inventories will provide a better picture of whether current management (local and watershed level) is maintaining, improving or negatively impacting riparian health.

8.5.2 Nakamun Lake

Nakamun Lake includes three municipalities: Barrhead County, Lac Ste. Anne County and the Summer Village of Nakamun Park, with two country residential subdivisions (Four Oaks and Losie Glade) and one youth camp (Camp Nakamun). The south shore is highly developed and dominated by recreation and cottages while the north shore remains mostly undeveloped.

Riparian health inventories for Nakamun Lake were conducted in August 2008 (O'Shaughnessy, 2009). Six sites totaling 2.39 kms of shoreline (13.3%) was assessed. Half of the sites assessed were "unhealthy". While there was some plant diversity seen in the assessed riparian areas, invasive species and human-caused alterations to vegetation were problems. Recreational and residential properties on the south shore have problems with clearing of vegetation, hardening of the bank (with rock, concrete or wood), and maintaining illegal "beach" areas along the shoreline. Invasive weed species were present on all sites

assessed and were abundant with Perennial Sow Thistle, common tansy and Canada thistle on every site, in order of overall abundance (O'Shaughnessy, 2009).

Future inventories will provide a better picture of whether current management (local and watershed level) is maintaining, improving or negatively impacting riparian health.

8.5.3 Majeau Lake

Majeau Lake is entirely within Lac Ste. Anne County and there is only one commercial development (Rich Valley Golf Course) on the Lake. The south shore is primarily privately owned land while the north shore public lands are leased for grazing.

Riparian health inventories for Majeau Lake were conducted in August 2008 (O'Shaughnessy, 2009). Ten sites totaling 7.73 kms of shorelines approximately one-third of the lake's shoreline was assessed. Half of the sites assessed were "unhealthy". While there was an abundance of plant diversity in the assessed riparian areas, invasive species and human-caused alterations to vegetation were problems. In areas that had been disturbed and overgrazed, there was a resultant increase in the presence of invasive weed species with Canada thistle and Sow thistle being the most common and abundant invasive species present.

Future inventories will provide a better picture of whether current management (local and watershed level) is maintaining, improving or negatively impacting riparian health.

8.6 Wetlands

In Alberta, lakes are classified as waterbodies greater than 2 meters deep, while wetlands are 2 meters deep or less. Wetlands are essential to maintaining the health of a watershed. They mitigate both floods and droughts by capturing precipitation on the landscape thereby reducing soil erosion, storing water and releasing it slowly into the environment, and recharging groundwater aquifers. Healthy abundant riparian vegetation uptake excess nutrients and breakdown contaminants. In addition, wetlands support biodiversity by providing food, breeding habitat, cover, and movement corridors for wildlife.

The loss and degradation of wetlands across the landscape due to drainage, tilling, and infilling results in poorer water quality across the landscape as the remaining wetlands, lakes, and streams become high in nutrients and contaminants. Erosion due to runoff from precipitation events and loss of protective riparian vegetation increases the instability of banks and shorelines. The result is decreased water clarity and increased algal and cyanobacterial (blue-green algae) blooms, large amounts of decaying aquatic vegetation, and loss of biodiversity.

8.6.1 Wetland Inventory

Two wetland inventories have been produced for the province of Alberta, which include complete coverage of this watershed, the Alberta Merged Wetland Inventory (AMWI) by the Province of Alberta (Alberta Environment and Parks, 2017) and one by ABMI (Alberta Biodiversity Monitoring Institute, 2021). Each uses slightly different underlying data sources and methodologies and so discrepancies between the two datasets are expected, but both are essentially a statistical classification based on satellite imagery. Both approaches are limited in that they do not include water depth, and consequently classify the entire area of deeper lakes as shallow open water wetlands, while only waters less than 2 metres deep are

considered wetlands under the Alberta Wetland Classification System (Government of Alberta, 2015). Thus, both these inventories identify the full extent of lakes as shallow open water wetlands.

The ABMI wetland inventory identifies a total of 35.5 km^2 of wetland habitat (Figure 16), including 30 km^2 of open water wetlands which are dominated by the major lakes within the watershed (Table 5). The AMWI wetland inventory identifies 57 km^2 of wetland habitat (Figure 17), with a similar area of open water habitat. There is a much higher area of swamp and fen wetland habitat identified in the AMWI inventory compared to the ABMI inventory. In both, the total area of marsh habitat is approximately 3 km^2. Excluding the open water wetlands, wetlands make up between 1.8 and 8.4 % of the watershed area depending upon the inventory system used.

Table 5. Wetland areas within the watershed from the Alberta Merged Wetland Inventory and the Alberta Biodiversity Monitoring Institute wetland inventory.

Wetland Class	ABMI Wetland Area (km^2)	AMWI Wetland Area (km^2)
Bog	0.0114	0.6003
Fen	0.2722	2.9121
Marsh	3.0423	3.1282
Open water	30.0030	31.8032
Swamp	2.1338	18.6799
Grand Total	**35.4628**	**57.1238**

8.6.2 Wetland Restoration and Enhancement Opportunities

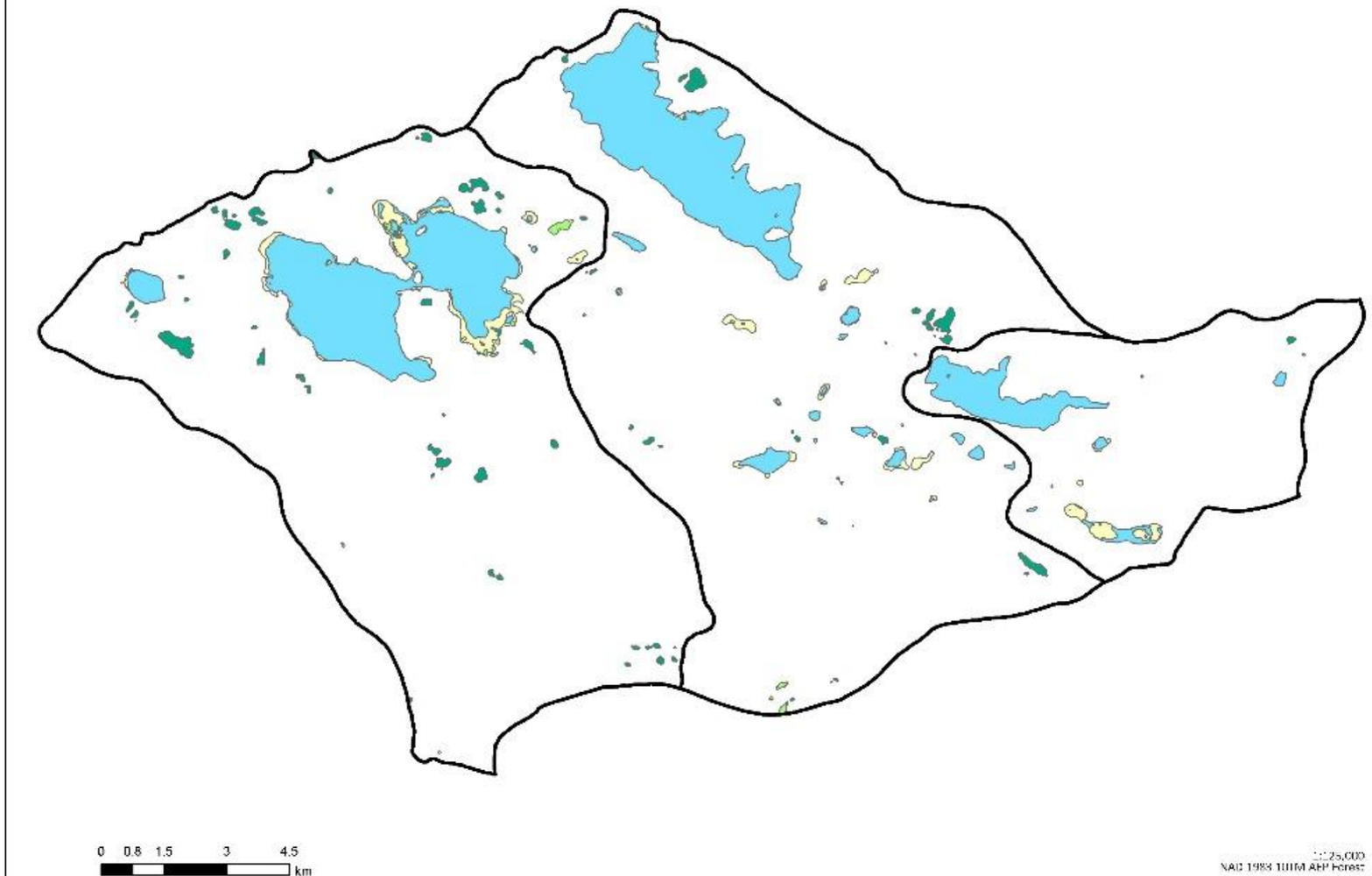
Ducks Unlimited Canada (DUC) does not have any current or historical wetland restoration projects in the Lac La Nonne Watershed (Olson, 2023) as it falls outside of DUC's target area of wetland habitat for waterfowl in the province of Alberta.

ALUS (Alternative Land Use Services) is a charitable organization that works with farming and ranching community members to make improvements to their land that enhance and restore ecosystem services. This includes programs such as wetland restoration and enhancement, restoring riparian buffers around lakes and wetlands, protecting forest growth, and planting shelterbelts.

Both the County of Lac Ste. Anne and the County of Barrhead have partnerships established with the ALUS program to support environmental stewardship activities. The Lac Ste Anne County partnership started in 2015 (Lac Ste. Anne County, 2023) and the County of Barrhead has a partnership with Westlock County and Athabasca County that started in 2022 (ALUS, 2022).

WETLANDS

STATE OF THE WATERSHED
LEPA
LAC LA NONNE WATERSHED



Legend
Watershed Boundaries
ABMI Wetlands
Marsh
Swamp
Fen
Bog
Open water

Aquality Environmental Consulting Ltd.

Figure 16. Distribution of wetlands identified within the ABMI wetland inventory (Alberta Biodiversity Monitoring Institute, 2021).

WETLANDS

STATE OF THE WATERSHED
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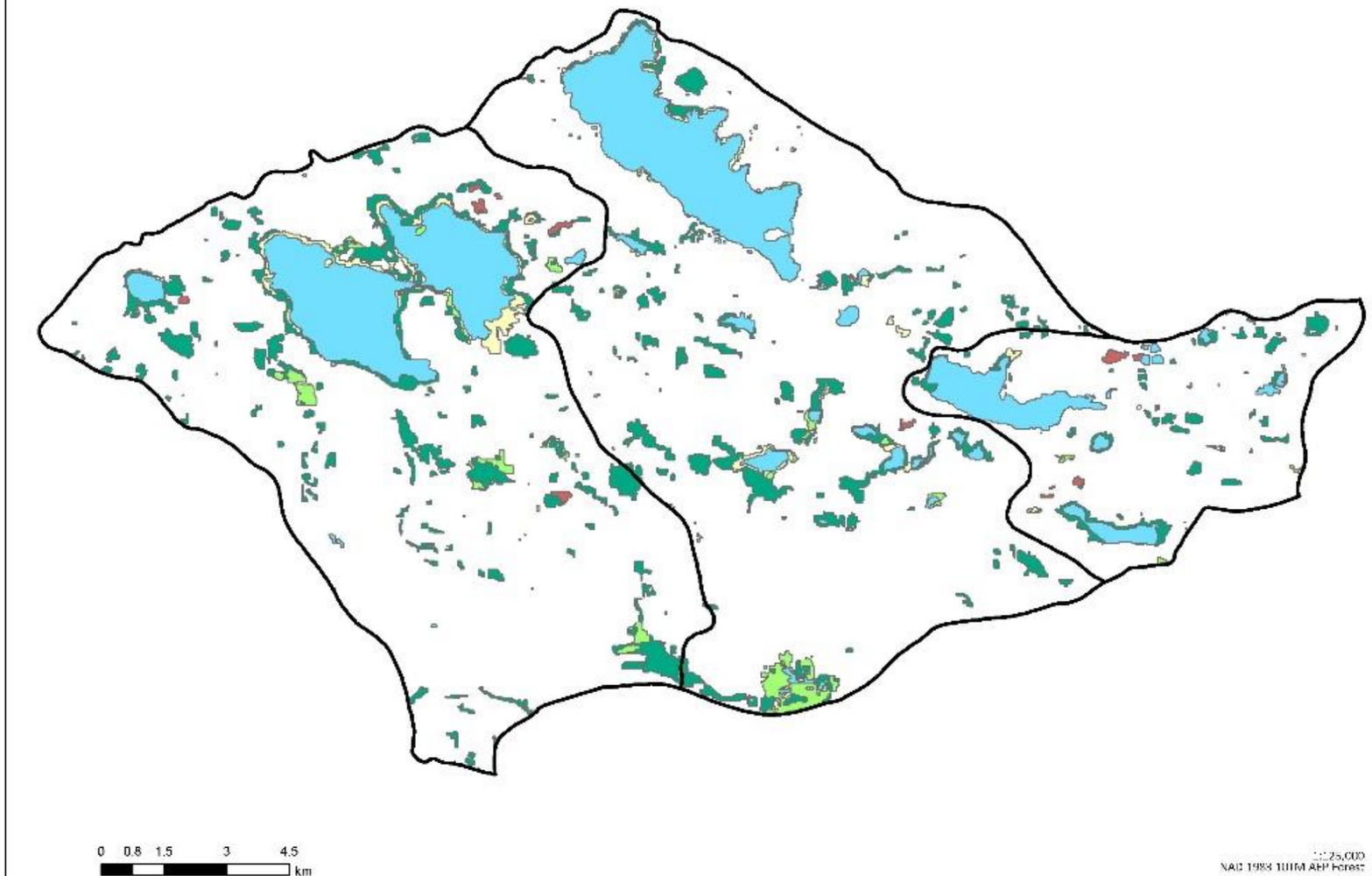
LAC LA NONNE WATERSHED



Legend
Watershed Boundaries
AMWI Wetlands
Marsh
Swamp
Fen
Bog
Open Water

Aquality Environmental Consulting Ltd.

Figure 17. Distribution of wetlands identified within the Alberta Merged Wetland Inventory (Alberta Environment and Parks, 2017).

9 Water Quantity

It is important to look at the volume of both surface water and groundwater to understand the health of the watershed. Surface water in the lakes, wetlands, and streams are a function of both the amount of precipitation that falls on the earth and the availability of water from ground sources. Many rivers are supplied at least in part by groundwater flows which is why we see rivers continuing to flow during dry and frozen conditions when surface water is not readily available.

Groundwater is stored in the spaces between the particles of soil, sand, and fractured rock. Surface water replenishes groundwater in areas of recharge in the landscape. These areas contain porous sand, gravel, fractured rock, and loosely packed materials that allow precipitation to easily infiltrate below the surface of the ground (Lake Simcoe Region Conservation Authority, 2023). These areas are essential to recharging the groundwater aquifers that we tap into via wells for household, agricultural, commercial, and industrial uses.

Knowing where groundwater recharge areas are located within a watershed is essential to protecting the quantity and quality of the groundwater available for use. Development and ground disturbance that disrupts the infiltration of surface precipitation should be limited to these areas. Groundwater recharge areas are susceptible to contamination by surface waters that have been subjected to applications of salts, chemicals, manure and sewage on the surface of the ground.

9.1 Surface Water Quantity in the Lac La Nonne Watershed

The main inflow into Lac La Nonne is Majeau Creek, which runs from Majeau Lake and drains the central and western portions of the watershed with a drainage area of 129.91 km2. There are also two other inflows on the southeast shore and a number of small intermittent inflow streams accounting for a drainage area of 111.84 km2 (Hamilton, 1980). These inflows account for approximately 81% of the drainage into Lac La Nonne. Only 38% of the watershed drains directly into the lake, while the remaining 62% flows into Nakamun or Majeau lakes. Inflows to Lac La Nonne from Nakamun Lake are rare and occur only during instances of high precipitation (Mitchell P. , 1991). The outflow is MacDonald Creek, which flows into the Pembina River about 3 km north of Lac La Nonne.

9.1.1 Lac La Nonne Water Levels

According to the County of Barrhead, the Provincial Government built a rock and timber weir on the outlet in 1939, in an effort to control water levels on Lac La Nonne. This was removed in 1965, but a temporary weir was reinstalled in 1966 and removed again in 1985. Someone placed an unauthorized rock structure in 1989 which currently remains in place (County of Barrhead, 2019).

Water levels have been recorded intermittently since 1968 with variations around 1.5 meters (Figure 18). As shown in Figure 18, water levels decreased steadily from 1997 to 2010 and then returned to average historical levels by 2018. Average levels as measured through May in 2023 were at 663.55 m, which is slightly higher than the average of 663.40 m over the available historical record. Low water levels can severely impact fish and wildlife populations as well as lake water quality.

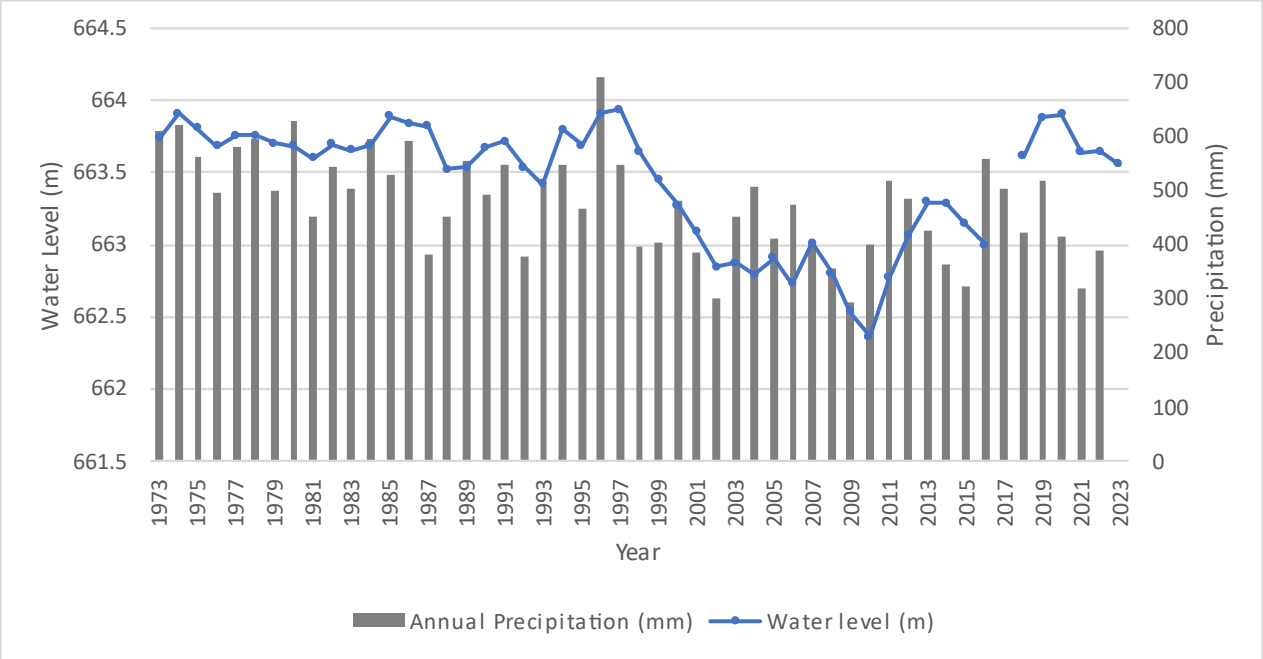


Figure 18. Annual average water levels and total annual precipitation levels for Lac La Nonne. Precipitation data derived from data interpolated to Township 057 and Range 03 W5M (Government of Alberta, 2023).

9.1.2 Nakamun Lake Water Levels

Water levels in Nakamun Lake have been monitored since June 1968. Historical water levels remained relatively stable from 1968 to 1997, with a noticeable decline starting in 1997 (Figure 19). In 2010, water levels were approximately 1.5 meters below the historical average. Water levels have risen again by 2018.

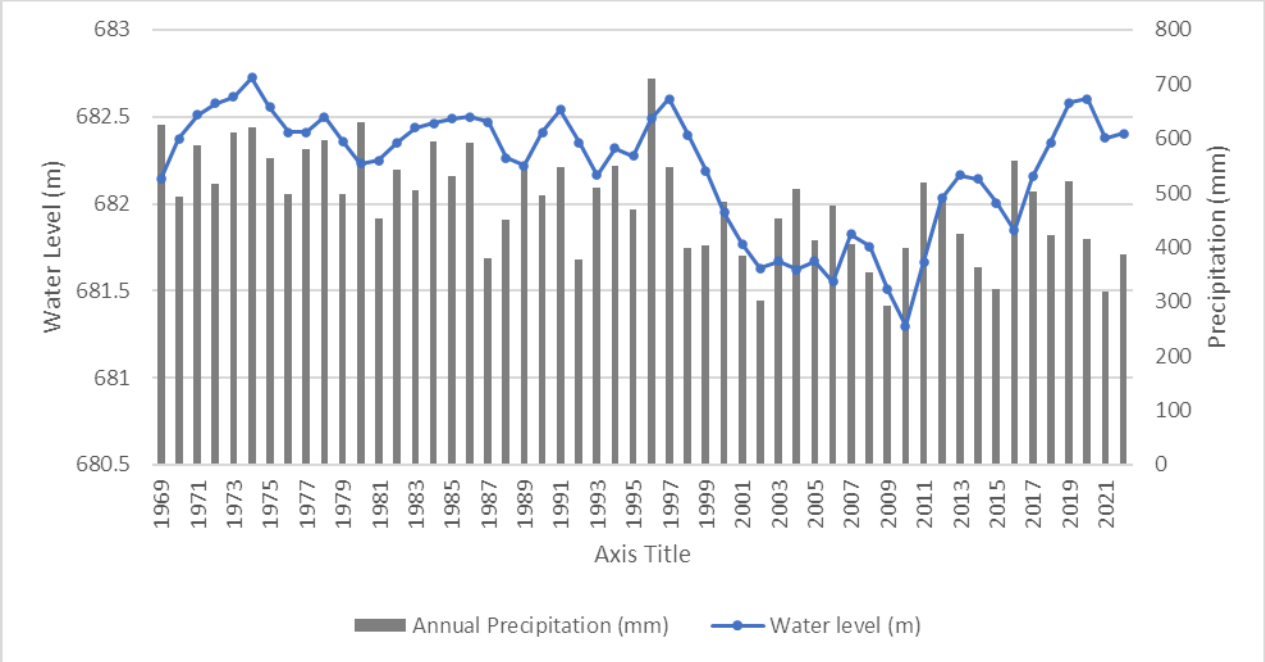


Figure 19. Annual average water levels and total annual precipitation levels for Nakamun Lake. Precipitation data derived from data interpolated to Township 057 and Range 03 W5M (Government of Alberta, 2023).

9.1.3 Majeau Lake Water Levels

Majeau Lake has experienced the same drops in lake elevation as seen in Nakamun and Lac La Nonne. Levels from 1969 to 1999 were relatively stable, while levels from 1999 to 2010 saw a large drop, in the order of 1.5 meters (Figure 20). Lake levels recovered some between 2010 and 2016.

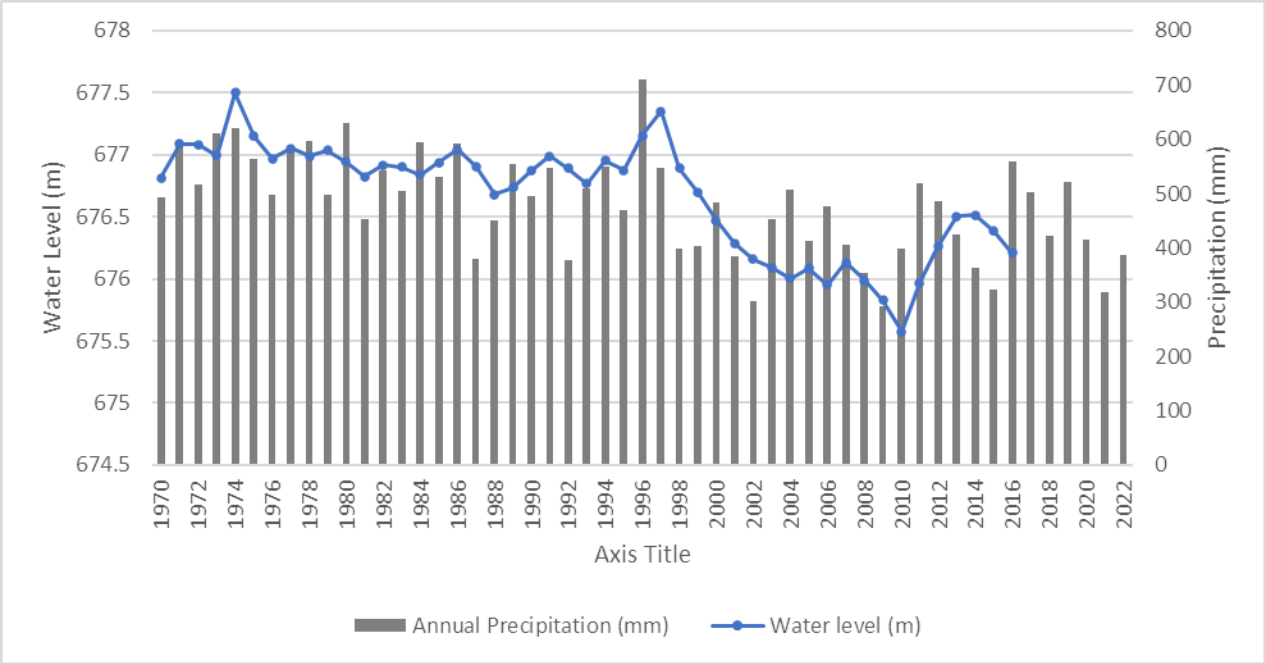


Figure 20. Annual average water levels and total annual precipitation levels for Majeau Lake. Precipitation data derived from data interpolated to Township 057 and Range 03 W5M (Government of Alberta, 2023).

9.2 Water Withdrawals and Consumption

According to the groundwater availability map provided by the Alberta Geological Survey, the availability of non-saline groundwater in the lac La Nonne watershed is comparable to the rest of north-central Alberta. It falls within the 0.11-10.0 (x 10^6 m^3/yr) category (Figure 21).

Groundwater well records indicate good yields from the bedrock of this area. The majority of the watershed shows good yields of 5-25 Imperial gallons per minute (igpm). Only a small area in the southwest had lower yields around 1-5 igpm (ERPC, 1981a). Groundwater is alkaline and high in total dissolved solids. Alkalinity increases with well depths, and in relation to variation in bedrock strata.

Figure 22 shows the groundwater recharge areas for upper bedrock aquifers in the watershed. Large groundwater recharge areas exist around Majeau Lake and Nakamun Lake, and the southern and northern shores of Lac La Nonne. Certain developments in these areas could pose a significant risk to groundwater contamination.

9.2.1 Unlicensed Withdrawals

It is estimated that approximately 20% or over 600,000 rural Albertans rely on groundwater for domestic water consumption (Government of Alberta, 2023). The Alberta *Water Act* stipulates that individual households may withdraw up to 1,250m^3 of groundwater per year for domestic or household use without obtaining a license. The Energy Resources Conservation Board (Lemay & Guha, 2009) has estimated the actual usage to be approximately 1,000 liters/day or 365m^3/household/year (assuming average of 3 people per household and that each well serves only 1 domestic family). That number goes up by an additional 5,000m^3 for watering livestock and the use of water for the application of pesticides.

There are 953 groundwater wells identified within the Lac La Nonne watershed in the Alberta Water Well Information database (Government of Alberta, 2023), with the highest concentration of these found in the vicinity of Lac La Nonne itself (Figure 23).

9.2.2 Licensed Withdrawals

At the time of the original SoW report in 2006, there were a total of 17 licensed water allocations and withdrawals on record for the Lac La Nonne watershed: 12 for withdrawals from Lac La Nonne, one for Nakamun Lake, and four for Majeau Lake. These licensed withdrawals were directly from the lakes themselves, and from the records obtained, only 3 out of 17 allocations were being used, all from Majeau Lake. The allocations used from Majeau Lake amount to approximately 30,600 L/yr, with no return volumes reported (Alberta Environment, 2006).

As of April 2023, there are a total of 6 licensed water allocations and withdrawals on record: two for withdrawals from tributaries to Lac La Nonne Lake and four for Majeau Lake (Alberta Government, 2023b). The allocations used from Majeau Lake remain the same at approximately 30,600 L/yr, again with no return volumes reported. The decrease in number is due to temporary diversion licenses that were not renewed.

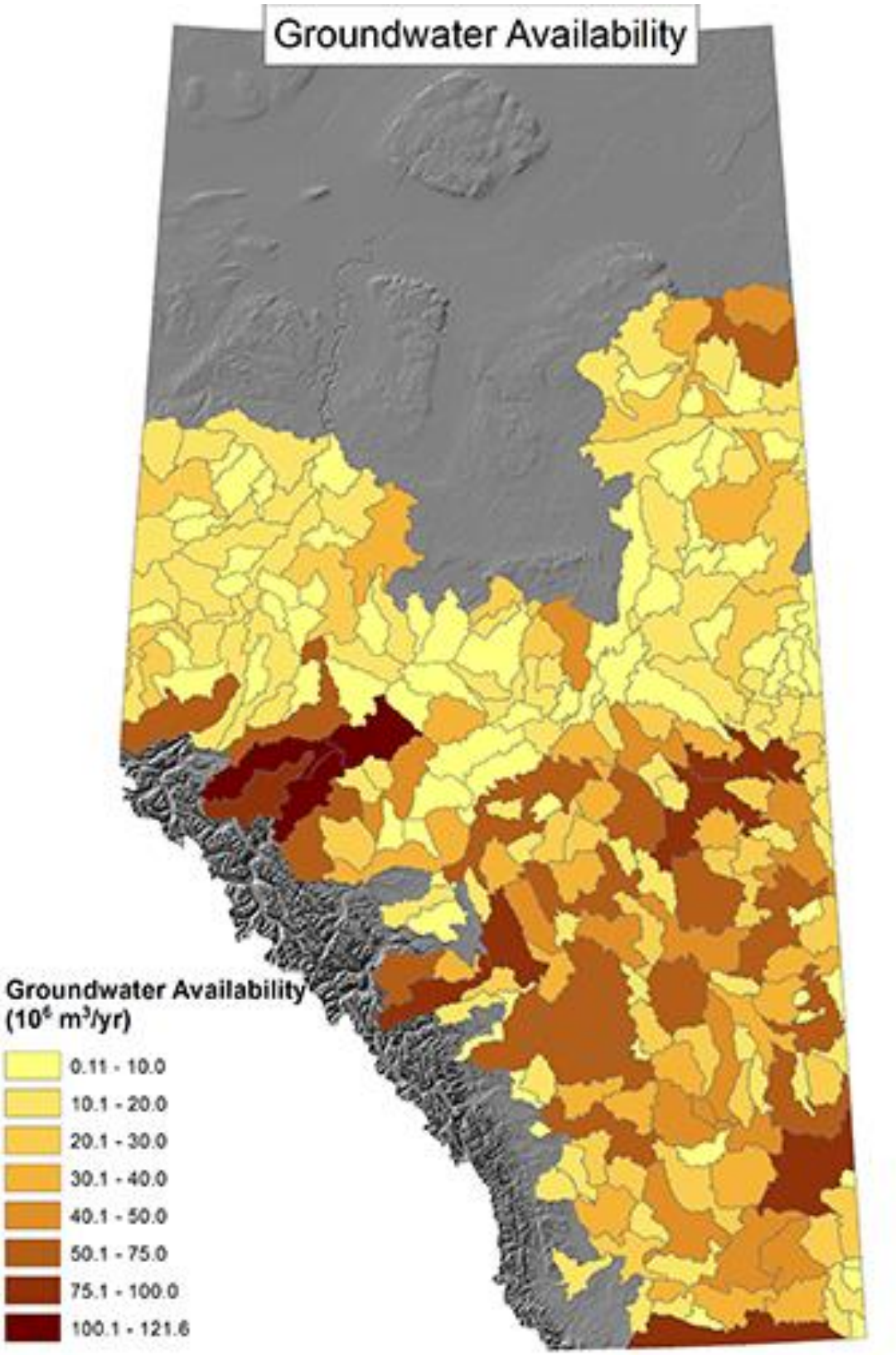


Figure 21. Groundwater availability presented at the watershed scale in Alberta (Alberta Geological Survey, 2023).

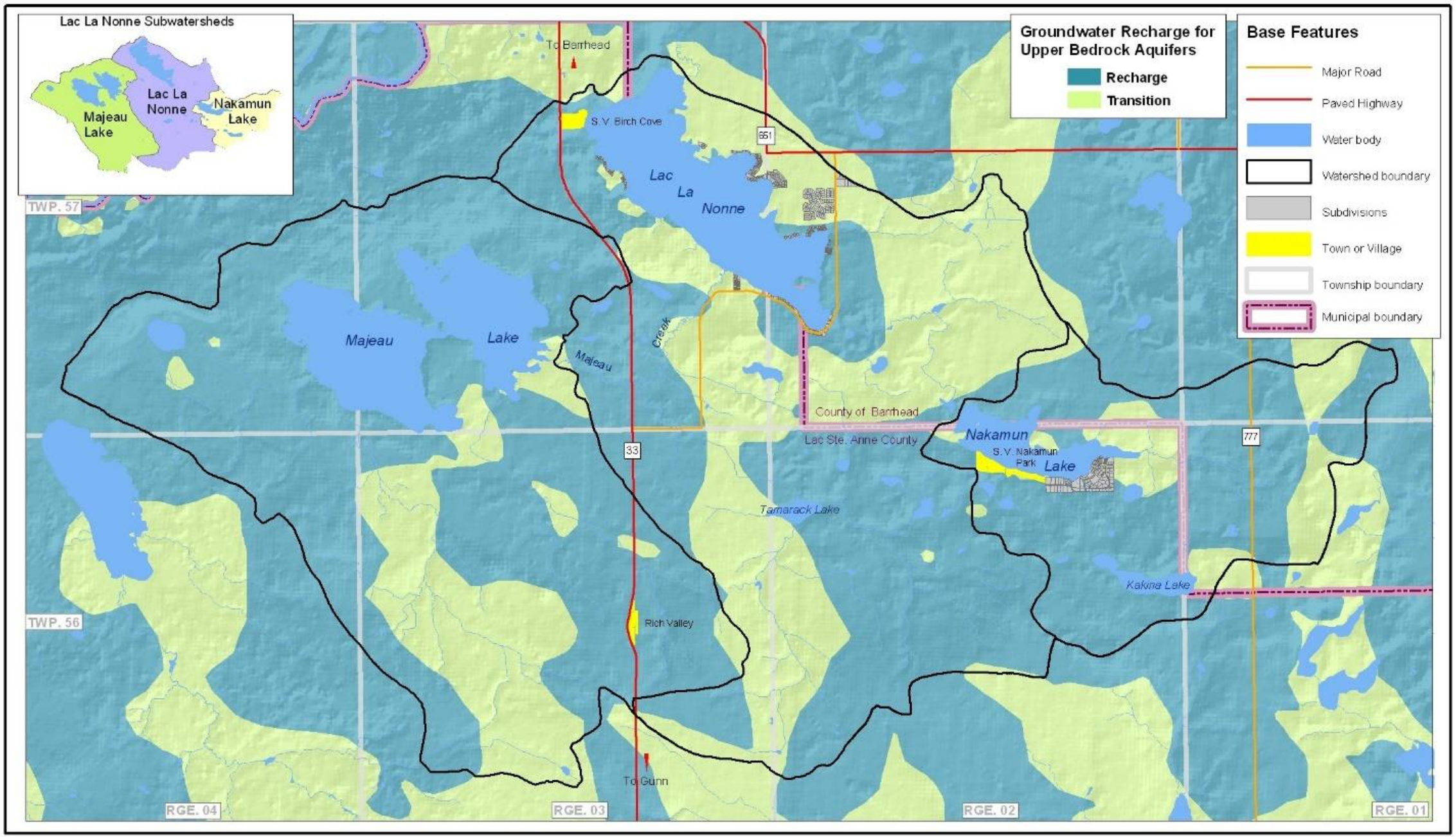


Figure 22. Lac La Nonne Watershed Groundwater Recharge Areas for Upper Bedrock Aquifers. Watershed boundaries delineated by PFRA, Alberta Environment and Aquality (PFRA, 2006).

GROUNDWATER WELLS

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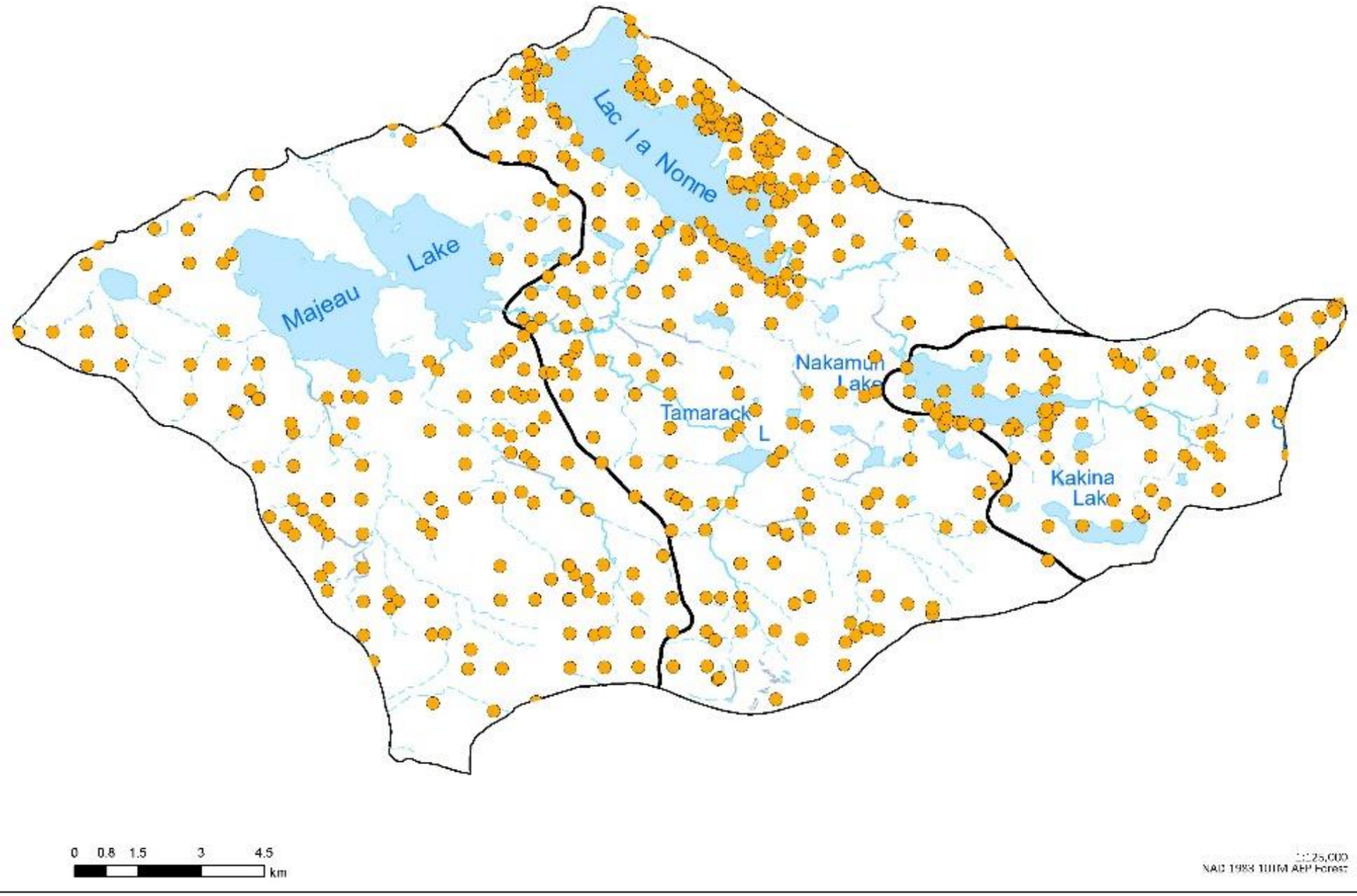

Legend
Watershed Boundaries
Alberta Water Well Information Database Wells

Figure 23. Domestic groundwater wells 2023.

9.3 Risk of Groundwater Contamination

Surface permeability data and presence of sand or gravel within one meter of the ground surface were combined from groundwater surveys for both Counties (Hydrogeological Consultants, 1998a); (Hydrogeological Consultants, 1998b) to establish a risk of groundwater contamination for the watershed, which was presented in the previous report. The Province of Alberta has conducted updated assessments of aquifer vulnerability and groundwater risk for the settled area of the province from 2002 to 2005 (Agriculture, Forestry and Rural Economic Development, 2002) (Agriculture, Forestry and Rural Economic Development, 2005).

Aquifer vulnerability refers to the potential for contamination, based on the thickness and permeability of the formations overlying the aquifer, and groundwater recharge through excess precipitation. Vulnerability is moderate in the Nakamun subwatershed and the lower portions of the Majeau and Lac La Nonne subwatersheds. Vulnerability is lower throughout the majority of the middle and upper Majeau subwatersheds, except for isolated areas at the southernmost extent where vulnerability is high (Figure 24).

Groundwater risk incorporates much of the same information as aquifer vulnerability, but also accounts for the land use practices that may impact groundwater quality including livestock, crop production and agrochemical use. Incorporating land use practices, groundwater risk is generally low throughout the majority of the watershed, except for relatively small areas with moderate risk found at the extreme northern, southern, and eastern margins of the watershed (Figure 25).

Future development in these areas should be closely monitored in order to prevent contamination of groundwater sources, especially by avoiding developments with high potential for groundwater contamination in the areas of highest vulnerability. Additional groundwater mapping and monitoring could be performed in the area in order to track changes and to implement protective measures as required.

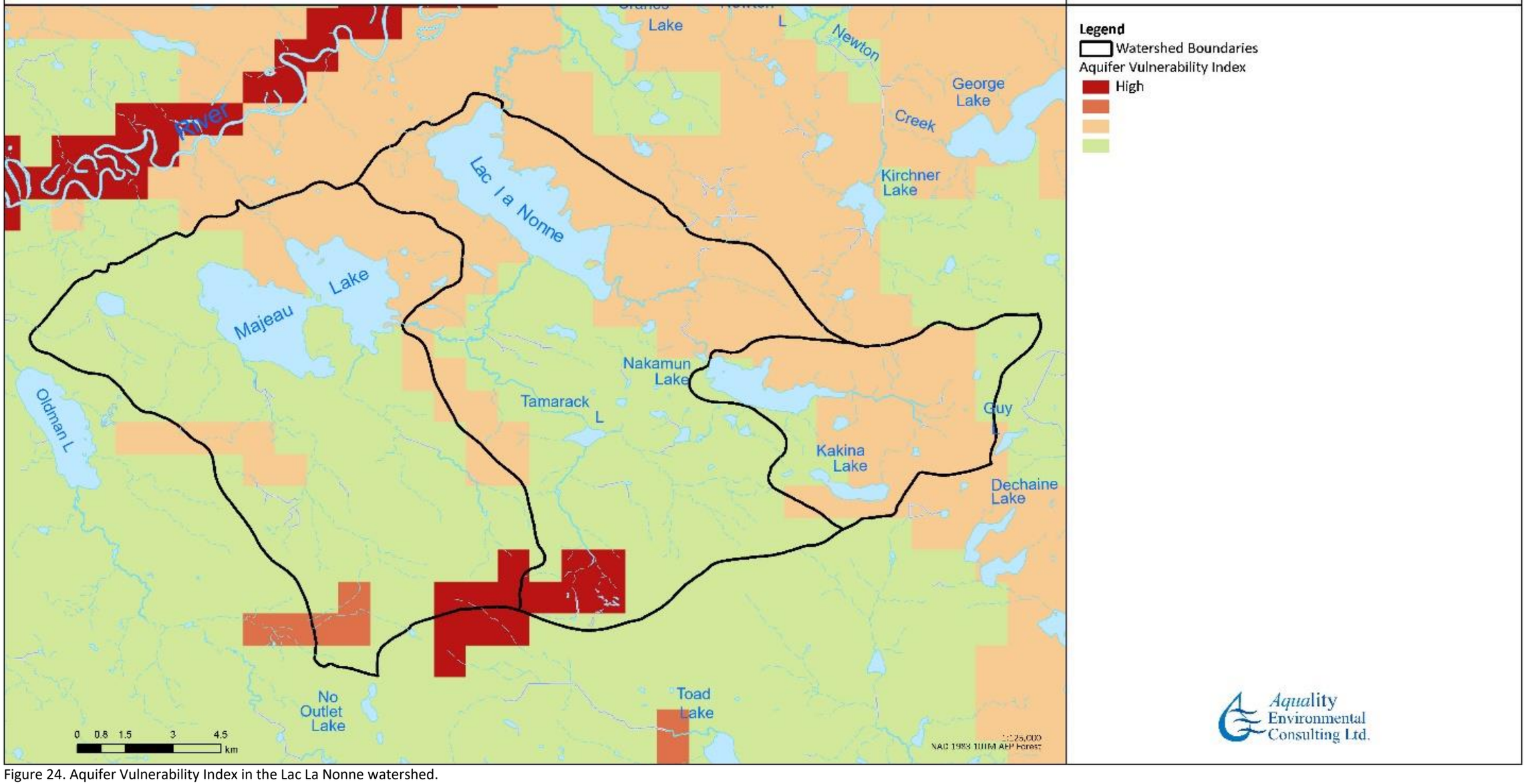

Figure 24. Aquifer Vulnerability Index in the Lac La Nonne watershed.

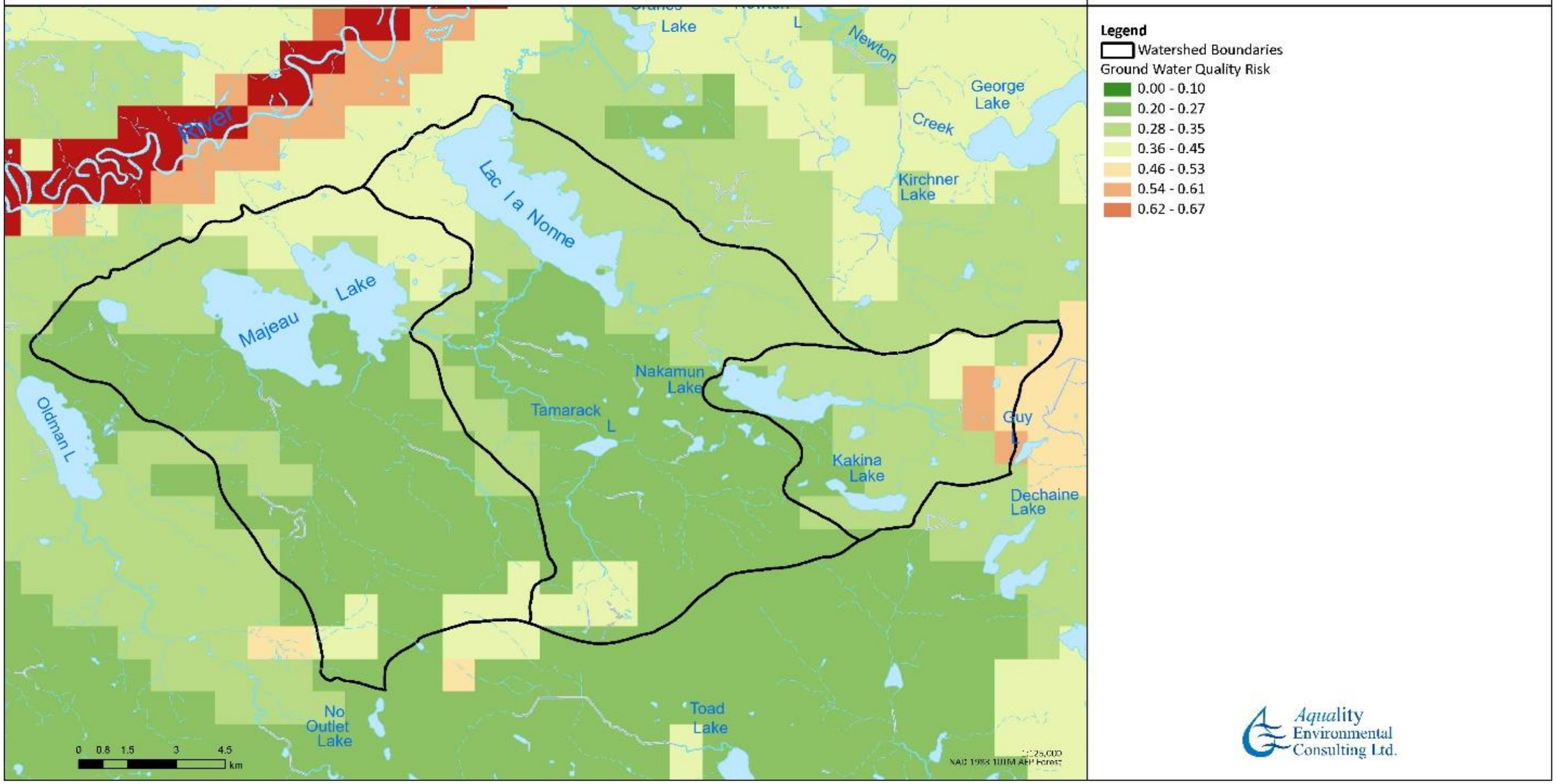

Figure 25. Groundwater contamination risk in the Lac La Nonne subwatershed.

10 Water Quality (Lake and Streams)

Water quality information on the various lakes in Alberta is collected and compiled by a variety of sources for various purposes including environmental consultants, educators, researchers, water stewardship groups, municipalities, industry, non-profit organizations, and the provincial government.

The Alberta Lake Management Society (ALMS) has been collecting water quality data from Alberta's lakes with the assistance of volunteer citizen scientists since 1992. One of their aims is to provide resources and expertise to assist interested parties in assessing the health of their watershed and educating the public about the effects of human activities on water quality. Their Summer LakeKeepers program utilizes willing community members who can volunteer their time and resources to assist with the collection of water samples on multiple occasions throughout the summer season. Their funding and staff capacity allows water quality sampling to occur at approximately 25 lakes each summer season. Lakes are selected each year based on the availability of volunteers, interest and concerns about the water quality, and historical information about the lakes. In 2019, ALMS initiated the Winter LakeKeepers program which has volunteers collect water quality information under ice during the winter months. ALMS also has a recent partnership with Alberta Health Services to assist beach operators with the collection of water samples for testing for cyanobacteria (blue-green algae) and fecal contamination as per the guidelines in the Alberta Safe Beach Protocol. This program serves to protect people and their pets from unsafe water conditions at recreational sites at Alberta lakes.

10.1 Nutrient Concentrations, Trophic Status

The natural baseline nutrient content of lakes and streams vary tremendously across the province of Alberta. In the mountainous areas of the western edge of the province, waterbodies are nutrient poor compared to the rest of the province where they are underlain by fertile soils and organic matter. Baseline nutrient levels are influenced and impacted by many factors including land use, soil, vegetation, hydrological factors, climatic influences, salinity, and pH (Government of Alberta, 2018).

Nutrient enrichment in Alberta lakes, streams, and rivers has a great impact on the quality of water in our watersheds. Though many nutrients are not directly toxic to humans, wildlife, and aquatic organisms, their effects on the environment can have great consequences. Excess nutrients in aquatic ecosystems result in algal blooms, excessive aquatic plant growth, proliferation of toxic cyanobacteria, changes in species assemblages and loss of biodiversity. Overgrowth of aquatic vegetation and cyanobacteria can lead to a reduction in dissolved oxygen levels which affects fish, amphibians, birds, and all the aquatic organisms that feed them. Death of aquatic organisms due to low oxygen levels leads to increased bacterial counts, release of toxins by cyanobacteria, and odours from decaying vegetation and organic matter.

Alberta's surface water quality guidelines for the protection of aquatic life no longer indicate a specific value of nutrient concentrations that should not be exceeded. Guidelines have been replaced with narrative statements about nutrient concentrations because there are many factors which affect the nutrient status which makes it impossible to assign one specific value for the entire province (Table 6).

Table 6. Government of Alberta Surface Water Quality Guidelines for Nutrients (Government of Alberta, 2018).

Water Body Type	Guideline
Lakes	No increase in nitrogen (total) or phosphorus over existing conditions. Where nitrogen and/or phosphorus have increased due to human activity, develop lake-specific nutrient objectives and management plans where warranted.
Major Rivers (Interim*)	For major rivers, nitrogen (total) and phosphorus concentrations should be maintained so as to prevent detrimental changes to algal and aquatic plant communities, aquatic biodiversity, oxygen levels, and recreational quality. Where priorities warrant, develop site-specific nutrient objectives and management plans.
Other Water Bodies	For surface waters not covered by specific guidelines, nitrogen (total) and phosphorus concentrations should be maintained so as to prevent detrimental changes to algal and aquatic plant communities, aquatic biodiversity, oxygen levels, and recreational quality. Where priorities warrant, develop site-specific nutrient objectives and management plans.

Trophic status refers to the level of biological activity within a lake because of the nutrient content. There are four classifications of trophic status as indicated in Table 7.

Table 7. Trophic Status Classifications (Government of Alberta, 2023).

Trophic Status Classification	Defining Characteristics
Oligotrophic	Lakes have low levels of phosphorus and limited biological activity in the forms of algae, cyanobacterial, and plankton (low levels of Chl-*a*). Water is clear and tends to have lot of oxygen throughout the year.
Mesotrophic	These lakes have moderate levels of phosphorus, and support greater levels of biological production (increasing levels of Chl-*a*). Water clarity is moderately reduced.
Eutrophic	Lakes have even greater concentrations of phosphorus (greater concentrations of Chl-*a*). They tend to experience greater aquatic plant and algae growth. Surface accumulations or 'blooms' of algae may occur during the warmest months. Water clarity is significantly reduced. Oxygen depletion in deep waters may occur throughout the year due to excessive microbial decomposition of plants and algae.
Hypereutrophic	Lakes have concentrations of phosphorus (high concentrations of Chl-*a)*. Algal blooms are common in these lakes and often intense and persistent throughout the summer and well into autumn. Oxygen depletion throughout the year may extend to the surface, resulting in fish kills.

Any inputs of excess nutrients caused by human activity will affect the trophic status of a lake over time. Phosphorus in particular builds up within lake systems, as it becomes trapped in the sediments and

continues to cycle year after year in a process called internal loading. Anthropogenic (human caused) sources of nutrients come from many sources.

- Increased stormwater runoff from developments with impermeable surface (building rooftops, driveways, roadways, patios, parking lots, compacted soils)
- Increased stormwater runoff from loss of wetland storage in the landscape.
- Increased erosion of soils due to clearing and removal of vegetation, short grasses due to mowing and grazing, and disturbing soil by tilling for gardens and agriculture
- Stormwater runoff carrying nitrogen and phosphorus rich fertilizers from yards and agricultural fields.
- Inputs of nitrogen rich fecal matter from human sewage, livestock, and pets.

10.1.1 Lac La Nonne

Lac La Nonne is the most researched lake in this particular watershed, with water quality studies dating back to 1978. EPA monitored the water quality in Lac La Nonne from the 1960's to 1990, and then again in 2000. The 2000 ALMS report stated that the phosphorus levels in the lake published by Alberta Environment were hypereutrophic and were likely due to cattle operations in the Majeau subwatershed that were exporting more than five times more phosphorus than cottages (ALMS, 2000); (Mitchell & Hamilton, 1982). Total phosphorus concentrations averaged 187 µg/L in 2000 and peaked in mid-summer (ALMS, 2000). The Alberta Lake Management Society (ALMS) sampled Lac La Nonne in 2002, 2003, 2008, 2011, 2014, 2015, and 2020 (Table 8). The trophic status of Lac La Nonne compared to other Alberta lakes is shown in Figure 25 as a comparison of Chlorophyll-*a* concentrations.

Table 8. Select water chemistry parameter means for Lac La Nonne from 2002 to 2020 (ALMS, 2020).

Mean Parameter[1]	2002	2003	2004	2008	2011	2014	2015	2020
TP (µg/L)	167	149	149	155	213	219	204	333
TDP (µg/L)	98	101	111	95	157	36	152	300
TKN (mg/L)	3.4	1.6	1.9	1.8	1.8	2.1	1.8	2.5
Nitrate + Nitrite (µg/L)	3	24	42	12	7	228	40	9
Chlorophyll-a (µg/L)	43.0	28.3	45.7	35.8	30.4	62.8	24.8	74.8
Secchi Depth (m)	0.70	2.10	2.42	1.80	1.98	1.35	2.84	1.87

10.1.2 Nakamun Lake

Nakamun Lake has a historical water quality database dating back to 1979. Both the University of Alberta and Alberta Environment have collected extensive water quality samples. The lake is hyper-eutrophic, and frequent algal blooms are of concern (Table 9).

Table 9. Mean Historical Water Quality Measurements for Nakamun Lake from 1979 to 2009.

Mean Parameter[1]	Nakamun Lake

Total Phosphorus (µg/L)	82
TDP (µg/L)	25
Total Nitrogen (mg/L)	1.9
Nitrate + Nitrite (µg /L)	14
Chlorophyll-a (µg/L)	41.4
Secchi Depth (m)	1.6

[1]Data from Casey (2011)

A detailed phosphorus budget, including internal loading estimates has been completed for Nakamun Lake. An estimated 779 kg/year of phosphorus enters the lake from external sources (precipitation, dust fall, runoff and sewage) and approximately 60% of this external load is from agriculture and cleared areas (Riley, 1983). Almost twice that number, 1,468 kg/year of phosphorus, was released from the sediments from May to November in studies (Riley, 1983); (Riley & Prepas, 1984). Approximately 80% of the annual loading of phosphorus in Nakamun lake originates from the sediments. Scientists call this phenomenon "internal loading", and little can be done to manage this nutrient source without treatment. Nakamun Lake was one of the lakes used to prove the significance of internal loading in shallow, productive Alberta lakes. The trophic status of Nakamun Lake compared to other Alberta lakes is shown in Figure 26.

10.1.3 Majeau Lake

Water quality data on Majeau Lake is limited. The majority of sampling in the Majeau subwatershed has been performed on Majeau Creek, and not the lake itself.

Mitchell and Hamilton completed an assessment of the phosphorus export from the Majeau Creek in 1981. Average phosphorus export in Majeau Lake streams was 0.904 mg/L, and they calculated an export coefficient of 0.51 kg/ha/yr (Mitchell & Hamilton, 1982). Majeau Lake itself retains approximately 53-93% of the phosphorus it receives from the surrounding watershed (Mitchell and Hamilton, 1982). There appeared to be an increase in phosphorus levels corresponding with increasing numbers of cattle in the watershed (Mitchell & Hamilton, 1982).

Table 10. Select water chemistry parameter means for Majeau Lake.

Mean Parameter[1]	Majeau Lake
Total Phosphorus (µg/L)	540 (hyper)[2]
TDP (µg/L)	396
Total Nitrogen (µg/L)	3875
Nitrate + Nitrite (µg/L)	76
Period of Record	Mar – Jun 81
# of Observations	125

[1]Data from Alberta Environment (2006).

[2] Hyper = hypereutrophic (see Table 7 for Alberta Lake trophic status definitions).

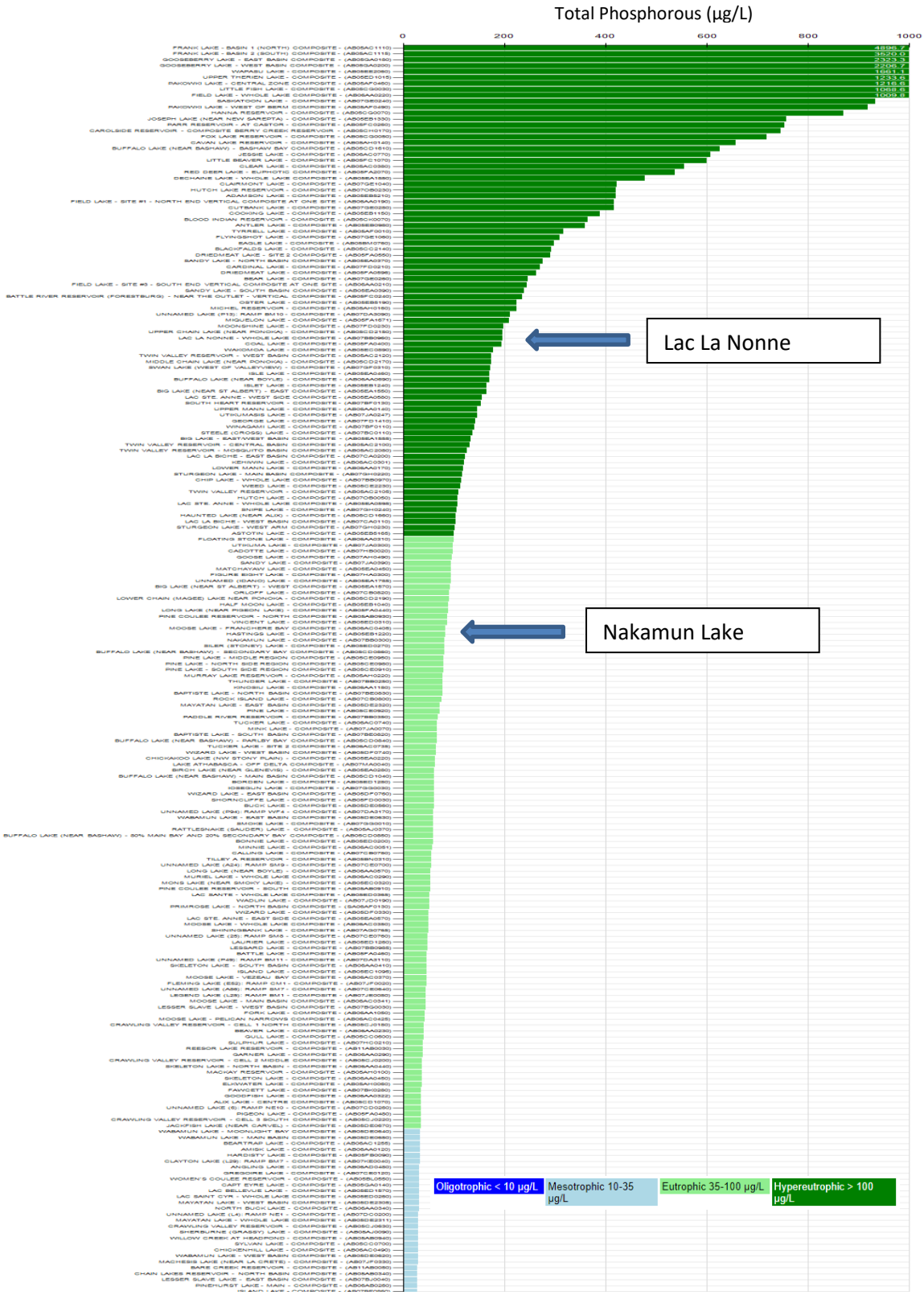

Figure 26. A comparison on trophic status of Alberta Lakes based on Average (May-October) Chlorophyll-a Concentrations (Alberta Environment and Parks, 2023).

10.1.4 Streams in the Lac La Nonne Watershed

Two major stream water quality studies have been performed in the Lac La Nonne watershed. In 1981, Hamilton and Mitchell sampled several streams in the watershed to gauge the impact of livestock density on water quality in streams. In 2004 and 2005, LEPA and Aquality sampled Lac La Nonne inflows, Nakamun Lake inflows and Majeau Creek, a total of eight streams (Table 11).

Two sites from the Hamilton and Mitchell (1982) and LEPA stream survey 2004 - 2005 were compared to determine if there had been any changes in nutrient input from Majeau Creek over the past 25 years (Table 12). These sites were Site 4: Majeau Creek at the culvert under Highway 33, and Site 6: Majeau Creek at the Lac La Nonne Road culvert. Almost all of the parameters sampled had increased significantly between 1981 to 2005. Phosphorus results for both sites were very high for agricultural streams.

Table 11. Select water chemistry parameter means for Lac La Nonne streams taken during the 2004-2005 LEPA sampling (Aquality, 2004); (Aquality, 2005)

Mean Parameter	Lac La Nonne Streams
Total Phosphorus (µg/L)	415
TDP (µg/L)	N/A
Total Nitrogen (µg/L)	3065
NO_2-N (Nitrite) (µg/L)	16
Period of Record	March-April

Table 12. Average total phosphorus and total dissolved phosphorus (µg/L) values for two sites in Majeau Creek. Site 4 is located at the culvert for Majeau Creek running under Highway 33, Site 6 is located just upstream of Lac La Nonne.

	Hamilton and Mitchell (1981)		**LEPA Stream Study 2004**		**LEPA Stream Study 2005**	
	Site 4	**Site 6**	**Site 4**	**Site 6**	**Site 4**	**Site 6**
TP (µg/L)	342	536	266	335	529	731
TDP (µg/L)	148	341	174	278	373	589

The 2004 sampling program was also designed to detect caffeine, an indicator of human sewage pollution. Samples were taken on major lake inflows on Lac La Nonne and Nakamun Lake. There was one positive hit for caffeine in Majeau Creek in May 2004, and none in September 2004. Negative hits could indicate that there is no sewage present, that dilution was too great for detection limits, or that the caffeine had already degraded in the environment. Positive hits indicate recent releases of human sewage into the receiving waterbody.

The 2005 sampling program was expanded to include nutrients and bacteria from 8 different streams within the watershed. Overall, nutrient levels were high in all streams, with many exceeding the Alberta Surface Water Quality Guidelines (ASWQG) for the Protection of Aquatic Life (PAL). Caffeine detections were negative in 2005; however, bacterial results showed two streams in the watershed with *E. coli* counts

exceeding the ASWQ Recreational Guideline (Table 13). This is a sign of fecal contamination, and future monitoring in the area should include methods such as microbial source tracking to help identify sources of contamination in the watershed.

The streams sampled were ranked according to the Alberta Agricultural Water Quality Index (AWQI). All streams sampled rated either poor or marginal in 2004 (Figure 27, Table 14) and 2005 (Figure 28, Table 15) (Aquality, 2004); (Aquality, 2005).

Table 13. Alberta and CCME Surface Water Quality Guidelines for Recreation and Aesthetics, Agricultural Uses and Protection of Freshwater Aquatic Life.

Parameter	Recreation and Aesthetics	Agricultural Uses	Protection of Aquatic Life
***E. coli* (#/100 mL)**	200	100	**N/A**
Total Phosphorus (µg/L)	N/A	N/A	**50**
Total Nitrogen (µg/L)	N/A	N/A	**1000**
Nitrate + Nitrite (µg/L)	N/A	100000	**N/A**
Nitrite (µg/L)	**N/A**	**10000**	**60**

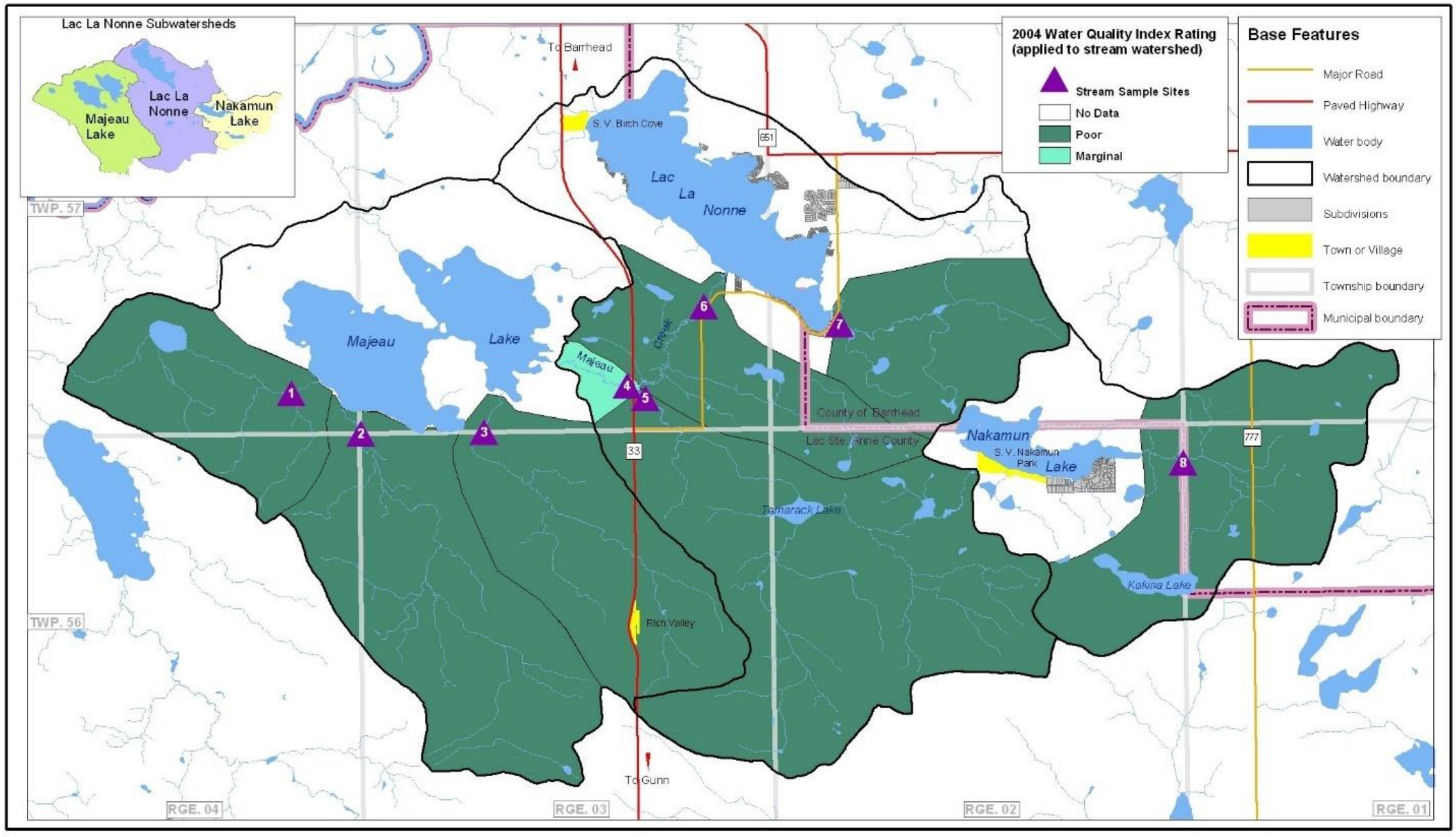

Figure 27. Lac La Nonne Watershed 2004 Water Quality Index Ratings. Data from PFRA (2006).

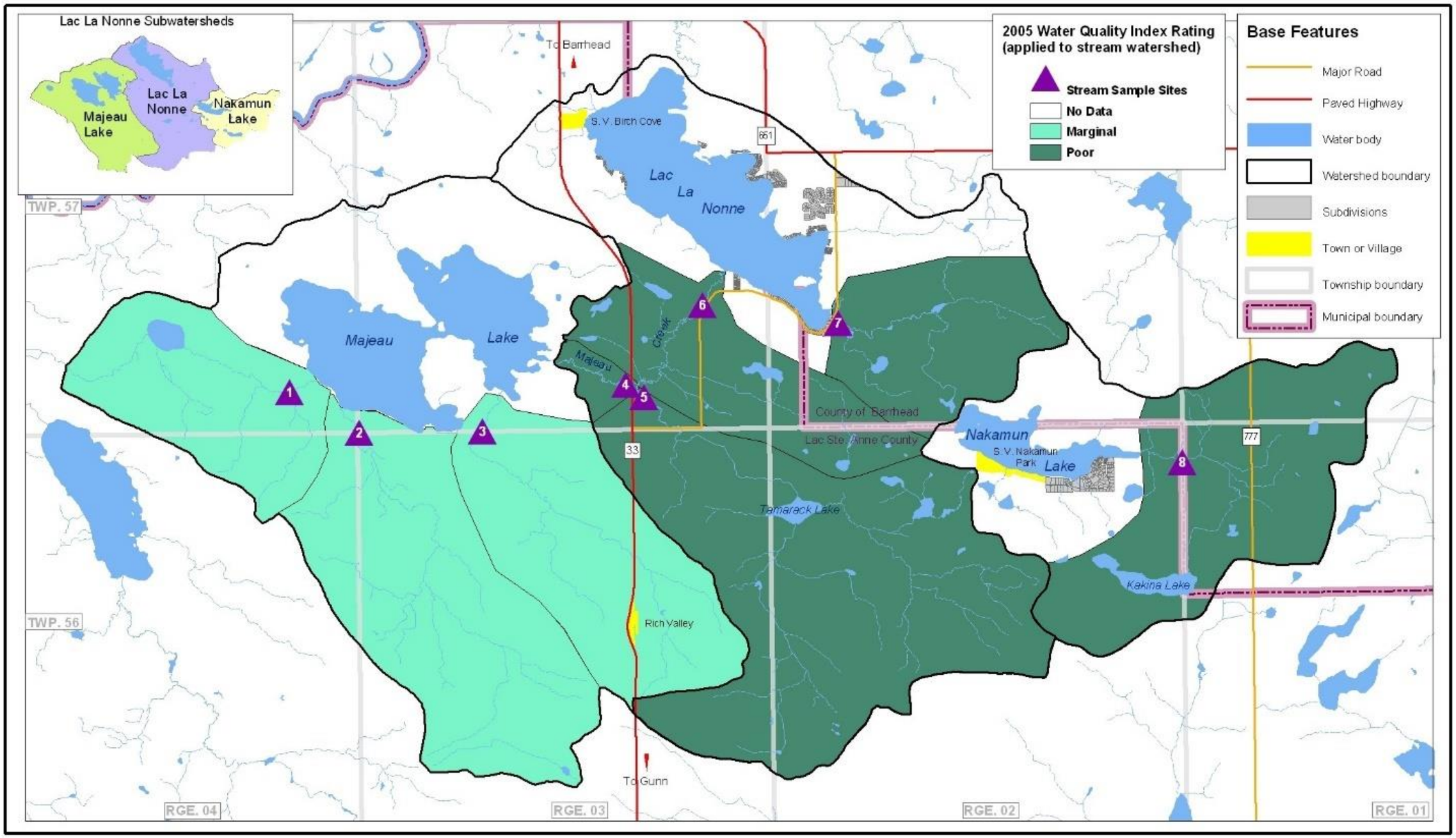

Figure 28. Lac La Nonne Watershed 2005 Water Quality Index Ratings. Data from PFRA (2006).

Table 14. Alberta Agricultural Water Quality Index scores for streams in the Lac La Nonne Stream Water Quality Survey 2004. Scores from 100-95 are Excellent, 94-80 Good, 65-79 Fair, 64-45 Marginal and 44-0 Poor. Data courtesy of Sarah Depoe, Alberta Agriculture Food and Rural Development (Depoe, 2005).

Site No.	AAWQI Nutrient Sub-Index Score	Ranking
1	24.5	Poor
2	17.0	Poor
3	13.3	Poor
4	53.3	Marginal
5	15.6	Poor
6	23.0	Poor
7	19.7	Poor
8	8.8	Poor

Table 15. Alberta Agriculture Water Quality Index scores for streams in the Lac La Nonne Stream Water Quality Survey 2005. Data courtesy of Sarah Depoe, Alberta Agriculture Food and Rural Development (Depoe, 2005).

Site No.	Score	Ranking
1	52.6	Marginal
2	45.5	Marginal
3	50.2	Marginal
4	34.2	Poor
5	39.3	Poor
6	39.4	Poor
7	41.6	Poor
8	39.8	Poor

10.2 Heavy Metals

In some locations in Alberta, various species of fish may be exposed to mercury and other contaminants that when consumed in high levels can impact human health. Methylmercury is the most toxic form of mercury and is formed through natural biological processes in the water and sediment from other forms of mercury found naturally in the environment. These contaminants can accumulate in the fatty tissues of fish, particularly large predatory fish. The Chief Medical Officer of Health in Alberta Health and Wellness is responsible for issuing food consumption advisories. Search “Fish Consumption Advisory” on My Wild Alberta (www.mywildalberta.ca) for more information or download the “Should I Eat This Fish” App on your mobile device (Alberta Government, 2023).

The Alberta Fishing Regulations directs anglers to the My Wild Alberta website and other resources for the most recent information on fish consumption advisories in Alberta lakes. Most recently, Alberta Health published a fish consumption guidance document specifically for mercury in fish (2019).

10.2.1 Lac La Nonne

In 2009 a study of walleye and pike in the Lac La Nonne and Lac Ste Anne was conducted to assess mercury concentrations in fish to determine safety for human consumption (Government of Alberta, 2009). In the end all the fish were found to be within the ranges of fish caught in rivers and other lakes in Alberta. Although it was recommended that young children and women of childbearing age avoid eating fish caught from the lake and everyone else limit their consumption to 400 grams of walleye or pike a week. As of 2019, there is still a recommended fish consumption limits for >2 lbs walleye from Lac La Nonne as a preventative health measure (My Wild Alberta, 2019).

10.2.2 Nakamun Lake

There are no guidelines regarding the safety or risk associated with the consumption of fish from Nakamun Lake, as no testing for mercury levels in fish from this lake has been conducted (My Wild Alberta, 2019).

10.2.3 Majeau Lake

There are no guidelines listed for the safety or risk associated with the consumption of fish from Majeau Lake, as no testing or mercury levels in fish from this lake has been conducted (My Wild Alberta, 2019).

Future studies on fish health monitoring at the above lakes could involve partners from the Metis Nation of Alberta who are monitoring fish from Alberta lakes for mercury and PAHs to ensure human health is protected to support traditional harvesting activities. Lakes are selected annually under the Askîy environmental monitoring program (https://albertametis.com/programs-services/environment-climate/environment-team/askiy-initiative/).

10.3 Oxygen Concentrations

Dissolved oxygen (DO) is the amount of oxygen that is present in water and is influenced by wind mixing and ice cover. Fish and other aquatic organisms require dissolved oxygen for respiration to survive. Most fish species require >6mg/L of DO to survive. Changes in both water temperature or dissolved oxygen can have important consequences for fish and other aquatic organisms. Warmer water holds less dissolved oxygen than cooler water as oxygen solubility decreases as temperature increases. In prairie lakes, warmer surface waters typically have less oxygen than cooler deeper waters. Limnologists call this state stratification with higher DO levels found in surface waters thermally stratified on top of cooler water with low DO levels. At the deepest levels, oxygen may be completely consumed (anoxia). Further, aquatic plants can impact oxygen levels throughout the day and night. Decaying plant material can consume oxygen from the water column and even turn water anoxic as bacteria break down the plants. A dissolved oxygen crash can follow prolific algal blooms and result in fish kills. Lac La Nonne Oxygen Concentrations

Summer oxygen levels in Lac La Nonne are typically uniform, but the lake does stratify in summer (ALMS, 2000; ALMS, 2002; ALMS, 2020). Despite its depth, Lac La Nonne is warm with typical summer surface temperatures of 21.0^{o} C and bottom temperatures of 11.7^{o} C (ALMS, 2020). The water column dissolved oxygen concentrations are typically highly oxygenated at the surface (> 10 mg/L) and declining with depth below the thermocline. Sampling was limited to 10 m, where oxygen concentrations remained above 4 mg/L through the summer. Previous AENV data suggests this is typical, with much of the bottom remaining

oxygenated until mid-July when anoxic conditions prevail below 15 m (Mitchell, 1991). The deepest areas of the lake thermally stratify in the summer months, resulting in oxygen depletion in the deeper waters of the lake, also known as the hypolimnion.

Winter oxygen conditions for Lac La Nonne are depleted below 10m yearly. Since the lake is fairly deep, the risk of winterkill is likely low (Alberta Environment, 1985a).

10.3.1 Nakamun Lake Oxygen Concentrations

Summer oxygen levels for Nakamun bottom waters are very low, despite mixing on windy days (Alberta Environment, 1985b). Nakamun is usually well-mixed due to its shallow depths, and too wind-blown to thermally stratify for the entire summer. Observations by the SRD in the 1980's supported the theory that Nakamun Lake goes almost completely anoxic during winter months. Dissolved oxygen profiles performed during the winters of 2003, 2004 and 2005 by Hildebrandt (2006), all recorded dissolved oxygen levels below the Alberta Surface Water Quality Guidelines for Protection of Aquatic Life (Short-term exposure 5.0 mg/L, long-term exposure 6.5 mg/L) (Government of Alberta, 2018).

More recently, in February 2019, The ALMS Winter LakeKeepers program had volunteers collect temperature and dissolved oxygen profiles for Nakamun Lake. The oxygen concentration was below 6 mg/L from the surface of the ice to the maximum depth of 8.5m at one location on the lake (ALMS, 2019) (Figure 29). Low dissolved oxygen conditions appear to persist during winter months, so is unlikely that Nakamun Lake will be capable of supporting a healthy sport fishing population.

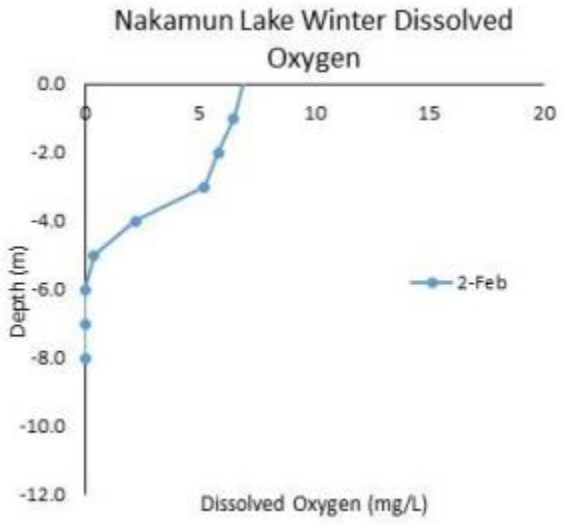

Figure 29. Dissolved oxygen (DO) profile for Nakamun Lake for Winter LakeKeepers Program 2019 (ALMS, 2019).

10.3.2 Majeau Lake Oxygen Concentrations

No summer or winter dissolved oxygen data were found for Majeau Lake from Alberta Environment or ALMS.

10.4 Bacteria Concentrations

Bacteria exist in every aspect of our environment and in balanced situations serve many essential roles. From a watershed perspective they are important for breaking down dead organic matter to release nutrients that support life. Humans and other living organisms have symbiotic relationships with bacteria that allow us to digest the food we eat. However, bacteria can also become a source of contamination in the environment that makes people and other organisms sick when exposed to them in large numbers. Sources of bacteria in our environment that typically affect humans, pets, and livestock include sewage, manure, cyanobacteria, and fish kills.

10.4.1 Lac Ste. Anne County Private Sewage Inspections 2004/2005

In 2004, 182 private sewage system inspections were carried out in Lac Ste. Anne County, and 181 sewage systems were inspected in 2005. Table 16 lists a summary of the results. 180 lots were selected for inspection in 2006, but the results were not available at the time of this report.

Table 16. Summary of sewage system inspections in 2004/2005 in Lac Ste. Anne County (Lac Ste. Anne, 2006).

Year	Number of systems inspected	% in compliance with Safety Codes Act	% Not in compliance with Safety Codes Act
2004	182	72	28
2005	181	91	9

Non-compliant owners were sent a letter in the spring of 2005 to address the issue, and 35% of the recipients did not respond to the letter. By the end of 2005, however, the County saw a compliance rate of 90% (Lac Ste. Anne, 2006). Non-compliant owners in 2005 would have been sent a letter in the spring of 2006 to address the issue.

Leakage of sewage from faulty private sewage systems could definitely pose a problem for lake water quality, introducing bioavailable nutrients, fecal bacteria and parasites to the water. We recommend that Lac Ste. Anne County proceed with their private sewage system inspection program, and that the County of Barrhead adopt a similar program.

There have been no more recent sewage inspections.

10.4.2 Recreational Beach Water Monitoring Program

Alberta Health Services (AHS) implemented the Recreational Beach Water Monitoring Program in 2009 to test for the presence of cyanobacteria (blue-green algae) and *Enterococcus* at beaches around the province. Due to the limited availability of resources, not all lakes are tested annually. Priority sites are selected in the province of Alberta based on a history of high usage, presence of recreational beach areas, poor water quality measurements and visual inspections. When a beach is designated as a priority site,

beach owners/operators are asked by Alberta Health to collect water samples weekly between the beginning of May to the end of August when cyanobacterial blooms are most likely to occur.

As outlined in the Alberta Safe Beach Protocol (Alberta Health, 2022), water samples for cyanobacteria are analyzed for total cyanobacterial cell count, speciation, and the microcystin LR-equivalent concentration. Microcystin is a toxin produced by certain species of cyanobacteria that can cause illness in humas, pets, and livestock. The guidelines for safe water quality measurements according to the Safe Beach Protocol decreased in 2022 to include a total cyanobacterial cell count of < 50,000 cells/mL (decreased from 100,000 cells/mL) and microcystin LR-equivalent concentration of < 10 µg/L (decreased from 20 µg/L). A public health inspector can also issue a public health advisory based on visual evidence of cyanobacteria at a recreational water site. Once an advisory is established for a site, it is only removed at the conclusion of the swimming season (i.e., in October each year).

Enterococcus is a fecal bacterium that has been found to be a better indicator of potential to cause gastrointestinal upset in humans than *E. coli*. The sources of *Enterococcus* that cause human symptoms are typically humans and ruminants, though certain avian sources can cause gastrointestinal distress in high enough concentrations. The guidelines for sample analysis state that a single Statistical Threshold Value (STV) of less than 1,280 CCE, is deemed as satisfactory water quality. If a sample result is between 1,280 CCE and 6,400 CCE, the sample is sent for microbial source tracking to determine if the *Enterococcus* is human or ruminant species. If human or ruminant species are present, then the water quality is deemed unsatisfactory. Any results above 6,400 CCE are deemed unsatisfactory water quality regardless to the source, whether it be human, ruminant, or avian (Alberta Health, 2022).

10.4.2.1 Lac La Nonne

Lac La Nonne has been on the priority list for routine water sample collection for cyanobacteria (blue-green algae) with water samples collected most years since 2009. Staff from the Alberta Lake Management Society (ALMS) assisted AHS and beach operators with sample collection at Lac La Nonne in 2021 and 2022. Images of cyanobacterial blooms from Lac La Nonne taken by staff at ALMS are included in Figure 30. Table 17 indicates the years where cyanobacteria counts have been above the safe water quality guidelines and/or an elevated *Mircocystin* LR equivalent concentrations. No water samples for *Enterococcus* have been collected on behalf of Alberta Health Services in the past 3 years, and no public health advisories for *Enterococcus* have been issued in the past 10 years (Legare, 2023).

Figure 30. Images of cyanobacterial bloom at Lac La Nonne in the summer of 2021 (left) and Summer of 2022 (right) (ALMS, 2022).

Table 17. Recreational Water Quality Measurements in Exceedance Between 2009-2022 at Lac La Nonne as per the Alberta Safe Beach Protocol (Alberta Health, 2022).

Date	Microcystin LR-equivalent concentration (µg/L)	Total Cyanobacterial Count (cells/mL)
Aug 24, 2010	28.59	-
Aug 17, 2012	36.08	-
Aug 12, 2013	24.56	3,494,874
Sept 17, 2015	98.24	1,110,405
Jul 17, 2017	150.47	246,992
July 16, 2018	38.52	317,256

10.4.2.2 Nakamun Lake

Nakamun Lake has not been on the priority list for recreational water quality sampling, but one sample was collected at Nakamun Lake in 2021 for which a public health advisory was issued. Years where microcystin levels or total cyanobacterial cell count have exceeded acceptable guidelines are represented in Table 18. No water samples for *Enterococcus* have been collected on behalf of Alberta Health Services in the past 3 years, and no public health advisories for *Enterococcus* have been issued in the past 10 years (Legare, 2023).

Table 18: Recreational Water Quality Measurements in Exceedance in 2021 at Nakamun Lake as per the Alberta Safe Beach Protocol.

Date	Microcystin LR-equivalent concentration (µg/L)	Total Cyanobacterial Count (cells/mL)
Aug 29, 2021	24.07	7,387

10.4.2.3 Majeau Lake

No water samples are recorded as being collected at Majeau Lake by Alberta Health Services as a part of the Alberta Safe Beach Protocol Monitoring Program for cyanobacteria or *Enterococcus.* There have not been any public health advisories issued by Alberta Health Services for Majeau Lake in the past 10 years (Legare, 2023).

10.5 Biotic Indicators

10.5.1 Fish Population Assessments

Fish populations are important indicators of watershed health because they reflect the cumulative influence of many factors that affect lake ecosystems. Healthy fish populations tend to indicate a healthier aquatic environment (National Park Service, 2023). Fish serve as "ecological indicators", "keystones", "umbrellas", "flagships" and "vulnerables" in the ecosystem (Tashla, et al., 2018). By monitoring changes in the behavior, physiology, or number of an indicator species, scientists can monitor the health of its whole environment (National Geographic Society, 2023). Conserving native fish is part of a larger movement to conserve biodiversity in Canada. More variety of species leads to better ecosystem services (National Park Service, 2023).

Alberta Fish and Wildlife staff manage fish populations and set sportfishing guidelines annually for Alberta lakes. They also work in partnership with the Alberta Conservation Association on fish stocking projects.

Two methods of assessing fish populations are Creel surveys and Fall Index Net (FIN) surveys. Creel surveys record the number, type and size of fish captured by anglers over a set period of time.

FIN surveys are conducted during late summer to early fall, most often mid-September when the water is between 10-15 degrees. Standard gill nets are set at random locations 2-15 meters deep and left for roughly 24 hours, then they are picked up and reset in a new random location. The fish caught are counted, identified and measured. The data is then compiled and used for a variety of purposes.

The Fish Sustainability Index (FSI) is a metric used to calculate the sustainability of a fish population. It is found by counting the mean number of mature fish per net pulled with every species having a different scale. Pike and walleye are included in the table below (Table 20).

Table 19: Fish Sustainability Index (FSI) Guidelines (Morgan, 2002)

Mature Walleyes / net	Mature Pike / net	Risk to Sustainability
>29.0	>21.8	Very Low
20.3-29.0	15.3-21.8	Low
14.5-20.2	10.9-15.2	Moderate
5.8-14.4	4.4-10.8	High
<5.8	<4.4	Very High

10.5.1.1 Lac La Nonne - Fish Populations

Lac La Nonne has a high capability (Class 2) for warm water sport fish such as northern pike (*Esox lucius*), walleye (*Stizostedion vitreum vitreum*), and yellow perch (*Perca flavescens*). Historically, there was a high density of Cisco (*Coregonus artedi*) that has decreased substantially (Spencer, 2006). Commercial fishing for whitefish occurred prior to 1975 on Lac La Nonne and was used for mink food. Controversy between sports and commercial fishermen over walleye resulted in the closure of the commercial fishery in February 1975 (ERPC, 1981a).

In 1996, the walleye population was considered vulnerable, and a 50 cm length catch limit was imposed. In 1997, creel surveys by Alberta Sustainable Resource Development staff captured 12 walleyes, 8 of which were smaller than the minimum length. Catch rates were recorded at 0.005 walleye per angler hour. Based on the criteria used to classify walleye stocks in Alberta, the walleye population in Lac La Nonne was identified as "collapsed" (Spencer, 2006). Catch and release policies were later implemented for the lake.

In 2001, creel surveys were again performed to assess walleye populations. During the summer, over 108 walleye were captured, ranging from 230 mm to 560 mm fork lengths. The most numerous sizes of fish were those with 320 mm fork lengths (11 caught) followed by 340 mm and 410 mm fork length fish. The population seems to be normally distributed and would appear to be healthy. Of all fish captured, four were older than four years, the typical age of fertility for walleye.

Creel surveys in 2001 also assessed northern pike populations (*Esox lucius*) in Lac La Nonne. During the survey period, a total of 109 northern pike were captured, ranging from 410 mm to 910 mm fork lengths. The most common size class for northern pike was 500 mm fork length. The population seems to be fairly normally distributed and would appear to be healthy. In total, 43 fish were aged older than 5 years, the typical age of reproduction in most northern populations of northern pike (Scott and Crossman, 1973).

In 2014, Fall Index Netting (FIN) was completed by Alberta Environment to survey pike and walleye populations in Lac La Nonne. Eight nets were set over the course of 3 days capturing 26 Lake Whitefish, 74 Northern Pike, 210 Walleye and 59 Yellow perch. The Walleye captured had a median size of about 480mm, few Walleyes had a size over 500mm or under 350mm. The 210 Walleyes were estimated to make up roughly 1% of their population and because there was a large amount of adult sized fish, their population was considered low risk. The median size of Northern pike was also about 480 mm but there were more individuals over 500mm and less under 450mm. The 74 pike were assumed to only make up 0.3% of their population within the lake and there was a small number of adults, making their population a high-risk population. A fish kill was report in Lac La Nonne in the winter of 2015 (Alberta Government, 2016).

In 2016, the FIN used 6 nets over the course of 3 days to capture 5 Lake Whitefish, 43 Northern Pike, 39 Walleye and 31 Yellow perch. The median size of walleye dropped to about 240mm, the drop in adult captured Walleyes from 2014 to 2016 has brought their population for low to very high risk. The size of the median Northern pike had gone up to about 530mm. Their population had seen a drop from 2014 to 2016 but not as drastic, they are still considered high risk.

In 2018, the FIN used 12 nets over the course of 2 days to capture 9 Lake Whitefish, 151 Northern Pike, 93 Walleye and 151 Yellow perch. The median size of a Walleye moved up to 350mm, although this was not adult sized fish to remove them from very high risk. The median size of the northern pike also increased to about 570mm. They also experienced a much higher catch rate, catching many more adults and this moved them from high to moderate risk.

Alberta Environment and Protected Areas have been relocating perch and pike from Lac La Nonne for introduction into nearby Thunder Lake. Ages and numbers of fish relocated annually vary based on the methods used to trap the fish and the age classes caught. Lac La Nonne is a good transfer lake for many reasons, mostly because the populations of perch and pike are found to be "in good shape" and the close proximity to Thunder Lake, which is less stressful for the fish (Kerton, 2021).

As of 2023, according to the Alberta Sportfishing regulations no walleye can be kept, 1 northern pike over 63cm, 15 yellow perch, 10 lake whitefish, and only 2 burbot can be kept (Alberta Government, 2023).

10.5.1.2 Nakamun Lake - Fish Populations

During the winter of 2002-2003, citizens of Nakamun Lake reported an extensive winterkill to Alberta Sustainable Resource Development (SRD). SRD staff performed test netting in the lake, and after setting the test nets for approximately 23 hours, no pike were captured. The SRD concluded that the 2002-2003 winterkill was extensive, if not complete, and that winter dissolved oxygen levels should be monitored in 2003/2004 to determine the likelihood of further fish kills before restocking was attempted (SRD memorandum, 2003). Subsequent monitoring has confirmed the lack of winter oxygen and halted any restocking efforts.

Alberta Lake Management Society's (ALMS) Winter LakeKeepers program conducted sampling measurements of dissolved oxygen levels under the ice in 2019 (ALMS, 2019). This assessment indicated that Nakamun Lake continues to experience poor oxygen levels under ice in the winter and therefore is not likely to support a healthy fish population.

10.5.1.3 Majeau Lake - Fish Populations

No fish data was found for Majeau Lake when researching this report.

10.5.2 Aquatic Invasive Species

Aquatic Invasive species (AIS) are any non-native species or disease that threatens the diversity of abundance of native species and the health of waters. AIS are a problem in Canada because they can cause great economic and environmental harm. They can change habitats in ways that are bad for native species, compete with native species for space, food, or other resources and prey upon native species in ways that they respond to. New species can spread new diseases or parasites, or act as a reservoir for native ones, making them a problem for other species. With no natural predators, invasive species can proliferate and cause a lot of ecological and economic damage where they have invaded.

The movement of watercraft in Alberta is the highest risk of infecting Alberta's waters. AIS of concern for the Lac La Nonne watershed include Quagga and Zebra Mussels, Eurasian Water Milfoil, purple loosestrife and flowering rush. Alberta currently does not have mussels or Eurasian Watermilfoil. In 2021, the Alberta Lake Management Society (ALMS) collected and submitted samples of Eurasian watermilfoil plants from Lac La Nonne and Nakamun Lake to the Alberta Plant Health Lab for genetic analysis using the rhPCR method. A sample was also submitted from Lac La Nonne in 2022. Tests confirmed that the water-milfoil samples submitted were the native species of Northern water-milfoil (*Myriophyllum sibiricum)* (ALMS, 2023). Continued monitoring and vigilance is recommended.

10.5.3 Whirling Disease

Whirling disease is a parasite that affects salmonid fish (trout, salmon and whitefish) which is present in Alberta, but not in the Lac La Nonne watershed. Containment and prevention are the best management options as there is no treatment for the disease. The Lac la Nonne Watershed is in the high to moderate risk (yellow) zone for Whirling Disease with no positive detections as of 2020 (Alberta Government, 2020). Whirling disease has been declared as present in 4 watersheds in central and southern Alberta including the following: Bow River, North Saskatchewan River, Oldman River, and the Red Deer River (Alberta Government, 2023).

11 Issues and Challenges

11.1 Validation of Issues

Based on current and historical water quality results completed in the Lac La Nonne watershed, public concerns over poor water quality in the lakes have been validated, and many issues still need to be addressed. Stewardship groups such as LEPA continue to provide grassroots actions around the watershed, but larger, coordinated planning programs need to be initiated with regional planners at the municipal level. Guidance could be sought from the Athabasca Watershed Alliance (https://awc-wpac.ca/) who are the WPAC this area. Smaller actions such as riparian demonstration sites with willing landowners, volunteer stream monitoring and lake water quality samplings for sewage testing have been undertaken with great success. Suspicion and mistrust between the local farming community and cottage community regarding their individual issues may undermine stewardship activities in the watershed. This will need to be overcome in future planning and stewardship initiatives, perhaps through the involvement of agricultural fieldmen and continued education and outreach initiatives for producers and cottage owners.

County involvement (County of Barrhead, Lac St. Anne County) will be critical for input, issue identification, development and implementation of plans, bylaw enforcement and fundraising. A lake watershed management plan should be struck immediately to address the concerns raised above. Considerable resources are now available to assist with watershed planning activities. Financial support for some watershed undertakings may only be available to watershed stewardship groups through their county partners, to ensure accountability. County-supported watershed projects around the province have been very successful at raising large grants for watershed management projects, such as Lac La Biche County (Lac la Biche), Northern Sunrise County (Heart River) and the M.D. of Bonnyville (Moose Lake). Federal and provincial dollars can be used to supplement funding for projects such as public outreach and education, water quality monitoring, and eventual completion of a watershed management plan. Ideas for grants include the Land Stewardship Centre's Watershed Stewardship Grant Program, or Alberta Environment and Protected Areas' Watershed Resiliency and Restoration Program Grants.

Education and awareness, behavioural change and enforcement are all tools that will need to be explored with the community to address concerns. All levels of government will need to support the planning efforts to have the political will to enforce environmental infractions to ultimately see changes. Enforcement of environmental regulations at the local level (i.e., the landowner) continues to be the most challenging of these tools. Staffing resources, cost and political will continue to undermine environmental enforcement actions, and this needs to be addressed by the agencies involved (see section 10.2).

11.2 Data and Data Gaps

Several data gaps have been identified in the compilation of this report. These gaps include, but are not limited to:

- Riparian Health – The shorelines of all three lakes should be flown annually with a drone to assess health and capture any changes year over year.
- Riparian Health – The inflowing creeks to each lake should be flown annually with a drone to assess health and capture changes year over year.
- **Agriculture census breakdown** – Could be used to provide data on land use around the lake and point out any areas of high agricultural intensity.

- **Drained wetland inventory** – A historical wetland loss tool that can highlight areas for restoration. This will improve watershed health and functionality and will provide a background level to help determine the rate of wetland loss.
- **Water quality monitoring in Majeau Lake** – This will provide a picture of the condition of the lake as well as offer a background for comparison for performance monitoring of watershed initiatives.
- **Long term water quality monitoring for Nakamun Lake and Lac La Nonne and tributaries** – This will provide a picture of the condition of the lake as well as offer a background for comparison for performance monitoring of watershed initiatives, as well as give an indication of the water quality entering through the streams. A nutrient budget for each lake would be ideal.
- **Groundwater mapping** – This will help identify recharge and discharge areas, and when used with the groundwater contamination risk areas map in this report will assist with preservation of groundwater quality and quantity.
- **Groundwater quality data –** This will provide a picture of the condition of the groundwater as well as offer a background for comparison for performance monitoring of watershed initiatives.
- **Historical information on the Majeau subwatershed –** This would provide some historical context for land use around Majeau Lake.
- **Paleolimnological assessments of Lac La Nonne, Majeau and Nakamun Lakes –** Paleolimnological assessments will provide a record of water quality changes in the lakes throughout the past 100 years or longer, which will allow a comparison of lake water quality change over time.

Many of these data gaps can be filled through establishing partnerships with groups such as Ducks Unlimited Canada, Cows and Fish, Alberta Agriculture, Alberta Environment and Protected Areas, the Alberta Conservation Association, and Universities. Fundraising opportunities should be considered on a project-by-project basis. The services of a professional fundraiser could be considered. Numerous federal (Federation of Canadian Municipalities, Department of Fisheries and Oceans) and Provincial (Alberta Lotteries, Alberta Stewardship Network, Alberta Conservation Association) funding opportunities exist for a variety of projects including habitat restoration.

12 Conclusions and Recommendations

12.1 Conclusions

Based on the information gathered for this report, we conclude that overall, the watershed health is good, with some continued problem areas. Streams in the area are inputting excess nutrients into all three lakes and will continue to impair lake water quality. Changing climate will continue to affect this watershed. Degraded water quality will lead to more frequent and prolific algal blooms, increased aquatic plant growths, low oxygen levels, fish kills and degraded aquatic habitat. Land use practices and excess development, if left unchecked, will only exacerbate the problem due to the clearing of vegetation, stormwater inputs and demands on local water supply. As seen in Figure 7, land cover has changed dramatically since the 1990's; continued alteration of the landscape will negatively affect both groundwater and surface water supplies. A watershed management plan needs to be undertaken for the whole watershed of Lac La Nonne to assess these and other watershed changes.

The following sections identify stewardship opportunities, make recommendations for improving the water quality within the watershed, and direct future strategies for watershed management planning in the Lac La Nonne watershed.

12.2 Stewardship Opportunities

This report should be used by landowners, stakeholders, municipalities and government as a baseline for future watershed management planning and for the implementation of BMPs. All regulatory agencies have a role to play in watershed management planning, and watershed groups must work closely with Alberta Environment and Protected Areas to ensure success. Financial and technical support will be required from project partners. Communication and outreach will continue to be an important role that the watershed stewardship groups play in educating local landowners and achieving local support and behavioural changes that benefit water quality.

Affected municipalities must be made aware of the importance of preserving watershed health, either through public consultation or advisement from LEPA. Important points to make would include the cost of infrastructure and/or restoration to improve water quality, the loss of tax revenues from individuals no longer interested in living next to a "polluted" lake, the public health risks associated with toxic algal blooms and the subsequent loss of recreational value of the lake, among others.

Municipalities have a significant role to play in the protection and preservation of watershed health in many ways, including:

- Enforcement of Land Use Bylaws
- Creation of environmentally conscious Area Structure Plans, Municipal Development plans and Intermunicipal Development Plans
- Harmonizing bylaws with other municipalities and ensuring the highest standards are used from each
- Regular review and revision of statutory plans and bylaws as required (IDP now over 20 years old)
- Support watershed management planning activities, including staffing resources, establishing/maintaining ratepayer buy-in, continued education and awareness programs, newsletters and newspaper articles, and establishing a progressive approach with developers and realtors
- Considering wider environmental reserves, municipal reserves, and minimum setbacks from water bodies
- Stormwater management and low impact development initiatives
- Control development in sloped areas due to the potential for stormwater runoff.
- Enrol in the ALUS program and pay residents for ecological goods and services
- Continue private sewage inspections (Lac Ste. Anne County)
- Begin private sewage inspections (County of Barrhead)
- Undertake updated riparian health assessments on lakes and other waterways

Another partner that Municipalities and producers can work with is ALUS Canada. The Alternative Land Use Services (ALUS) is a unique incentive program that recognizes the role that producers play in producing both food and a healthy environment. Specifically, ALUS helps farmers and ranchers preserve/restore wetland and upland habitat, reforest, plant windbreaks, install riparian buffers, manage sustainable drainage systems, create pollinator habitat and establish other ecologically beneficial projects on their properties by providing annual payments to ensure the ongoing stewardship of each project.

Cottage owners have many options available to them for helping to restore the health of the lake and watershed. Groups such as ALMS, Cows & Fish, the Land Stewardship Centre and the Alberta Conservation Association have many programs available for assisting cottage owners with improving their land use practices, from how to better manage vegetation to fertilizing practices and water management.

Associated with water quality improvement would be restoration and protection of wetlands and riparian areas, sewage and stormwater best management practices, nutrient management in residential areas, changes to the land use bylaws and update the IDP to further protect sensitive areas and limit development, and public education and outreach regarding watershed health and beneficial land use practices. A recommendation for future management initiatives would be to implement a long term, annual sampling program for Lac La Nonne in order to monitor lake water quality and as a performance measure for watershed restoration programs. Sources of fecal contamination should be identified and quantified with methods such as microbial source tracking or eDNA analysis.

12.3 Recommendations

Recommendations for this watershed fall into the following four categories:

1. Planning – This is an ongoing, regulatory approach which will include the watershed management planning process, and the municipal process (intermunicipal development plans, statutory bylaws, others) and involvement with the larger basin WPAC Athabasca Watershed Council. This would start with Municipal partners.
2. Stewardship – This is ongoing as well and requires community involvement. Considerable resources are available from many agencies. Components of this step are education and awareness, use of cottage owner BMP's provided by organizations such as Cows & Fish or ALMS, better animal husbandry and agricultural land use practices, nutrient and manure management, and others. Materials are freely available from dozens of agencies online.
3. Reclamation and restoration – This is the most invasive and costly of all of the steps. This would involve activities such as fencing of riparian areas, off-site watering, riparian restoration and planting, and others. ALUS could fund some of these projects.
4. Data gaps – Significant data gaps will need to be filled to move forward with a Watershed Management Plan. These gaps could include paleolimnology and other sediment studies on the lake, an overall nutrient budget for each lake, and riparian health information. The Alberta Conservation Association could fund some of these projects.

Planning is a slow process but will be the most effective method to help preserve the health of the Lac La Nonne watershed. The main areas of concern that have been noted are listed in Table 21, along with the corresponding parties responsible for addressing these priorities.

Table 20. Priority Areas of Concern and Responsibilities

Priority Areas (Highest to Lowest Concern)	Lead Role	Contributors
Water quality of the lakes and tributaries	Provincial and Federal Governments	LEPA/LWSS
Sewage inputs and concerns over lake recreational use	Municipal Government	Municipal Affairs, LWSS, Alberta Health
Education and Awareness	LWSS/LEPA	Municipal Government, Alberta Environment
Zoning and infrastructure, land use bylaws	Municipal Government	All Municipalities
Improving land use practices	Municipal Government, Producers and General Public	All Municipalities

12.4 Future Strategies

To move forward, LEPA and project partners should embark on the watershed management planning process to address some of the issues identified in this state of the watershed report. To start this process, a watershed advisory committee (WAC) should be formed, followed by technical advisory committees (TACs) as required. The WAC, once formed, will need to formalize their mandate, include all involved municipalities and stakeholders, and identify grants or other funding and in-kind assistance in order to complete the watershed management plan and associated activities. The watershed management plan for Lac La Nonne should be linked with the larger planning initiatives in the Athabasca River Basin in order to ensure consistency and harmony among plans. Alberta Environment and Protected Areas should be approached to lead this process and provide guidance on how to move this initiative forward.

Planning initiatives with the two Counties should be undertaken to harmonize legislation to protect watershed health. For example, the County of Lac Ste. Anne has outlawed septic pits, but Barrhead County has not. Outreach and education programs should focus on nutrient management beneficial management practices for the agricultural and recreational cottage communities. Several data gaps should be filled. The ALUS Project should be embraced by both Counties, and this will involve a commitment from county agricultural fieldmen.

13 References

Agriculture, Forestry and Rural Economic Development. (2002). *Aquifer Vulnerability Index.* Edmonton, AB: Government of Alberta.

Agriculture, Forestry and Rural Economic Development. (2005). *Ground Water Quality Risk.* Edmonton, AB: Government of Alberta.

Alberta Agriculture and Forestry. (2023, April 5). *Alberta Soil Information Viewer.* Retrieved from https://soil.agric.gov.ab.ca/agrasidviewer/

Alberta Biodiversity Monitoring Institute. (2000). ABMI Wall-to-Wall Land Cover, 2000. Edmonton, AB.

Alberta Biodiversity Monitoring Institute. (2010). ABMI Wall-to-Wall Land Cover, 2010 update. Edmonton, AB.

Alberta Biodiversity Monitoring Institute. (2021). *ABMI Wetland Inventory – Metadata.* Edmonton, AB.

Alberta Biodiversity Monitoring Institute. (2022). *Wall-to-Wall Human Footprint Inventory 2019.* Edmonton, AB: Alberta Biodiversity Monitoring Institute and Alberta Human Footprint Monitoring Program.

Alberta Environment. (1985a). *Lac La Nonne.* Brochure prepared by water quality control branch, pollution control division.

Alberta Environment. (1985b). *Nakamun Lake.* Brochure prepared by water quality Control Branch, pollution control division. Alberta Environment.

Alberta Environment. (2001). *Framework for Water Management Planning.* Edmonton, Alberta: Alberta Environment.

Alberta Environment. (2003). *Water for Life: Alberta's Strategy for Sustainability.* Edmonton, Alberta: Queens Printer.

Alberta Environment. (2006). Water License and Allocation Data. *Curtis Horning, Personal Communication*.

Alberta Environment. (2008). *Water for Life: A Renewal.* Edmonton, Alberta: Alberta Environment.

Alberta Environment and Parks. (2017). *Alberta Merged Wetland Inventory digital dataset*.

Alberta Environment and Parks. (2023, April 28). *Trophic Conditions of Alberta Lakes, All Years*. Retrieved from http://environment.alberta.ca/apps/EdwReportViewer/TrophicGraph.aspx

Alberta Geological Survey. (2023, April 26). *Groundwater Availability Based on Hydrologic Data*. Retrieved from https://ags.aer.ca/research-initiatives/groundwater-availability

Alberta Government. (2012). *Guide to Reporting on Common Indicators Used in State of the Watershed Reports.* Edmonton: Environment and Sustainable Resource Development. Retrieved from https://open.alberta.ca/publications/9781460102794#summary

Alberta Government. (2016). *Lac La Nonne FIN Summary, 2016.* Retrieved from https://open.alberta.ca/dataset/1144f2a5-bc04-46fa-a9cd-185c26b63ff2/resource/2ffe1b1e-afb8-4ea2-a905-ff94004398ae/download/laclanonne-fallindexnettingreport-2016.pdf

Alberta Government. (2020, August). Whirling Disease Decontamination Risk Zone Map. Retrieved from https://open.alberta.ca/publications/whirling-disease-decontamination-risk-zone-map

Alberta Government. (2023). *2023 Alberta Guide to Sportfishing Regulations*. Retrieved from https://albertaregulations.ca/fishingregs/index.html

Alberta Government. (2023). *2023 Alberta Guide to Sportfishing Regulations.* Retrieved from https://albertaregulations.ca/fishingregs/NB2-Lakes.pdf

Alberta Government. (2023). *Whirling Disease*. Retrieved from https://www.alberta.ca/whirling-disease.aspx

Alberta Government. (2023b, April 13). *Alberta Flow Etimation Tool for Ungauged Wtershedss (AFETUW)*. Retrieved from https://afetuw.alberta.ca/

Alberta Health. (2022, May 19). *Alberta Safe Beach Protocol.* Retrieved from https://open.alberta.ca/publications/9781460145395

ALMS. (2000). *Alberta Lake Management Society 2000 Lakewatch Report.* Edmonton, Alberta: Alberta Lake Management Society.

ALMS. (2002). *Lac La Nonne 2001: The Alberta Lake Managmenet Society Volunteer Lake Monitoring Report.* Edmonton, Alberta: Alberta Lake Managmeent Society.

ALMS. (2019). *Winter Lakekeepers 2019.* Alberta Lake Management Society. Retrieved from https://alms.ca/wp-content/uploads/2020/05/WinterLakeKeepers_2019-Final.pdf

ALMS. (2020). *Lac La Nonne 2020: The Alberta Lake Management Society Volunteer Lake Monitoring Report.* Edmonton, Alberta: Alberta Lake Management Society.

ALMS. (2022). Images of Cyanobateria Blooms. Alberta Lake Management Society.

ALMS. (2023, April 3). Personal communication regarding water-milfoil plant specimens. Edmonton.

ALUS. (2022, February 16). *Announcing a New ALUS Community in Alberta*. Retrieved from https://alus.ca/alus_news_and_events/alus-welcomes-three-new-municipalities-to-its-network-of-grassroots-environmental-stewards/

Aquality. (2004). *Lac La Nonne Water Quality Report 2004: Nutrients, Bacteria, and Caffeine.* Edmonton, Alberta: Report prepared for the Lac la Nonne Enhancement and Protection Association. Aquality Environmental Consulting Ltd.

Aquality. (2005). *Lac La Nonne Water Quality Report 2005: Nutrients, Bacteria, and Caffeine.* Edmonton, Alberta: Report prepared for the Lac La Nonne Enhancement and Protection Association.. Aquality Environmental Consulting Ltd.

Bentz, J. A., & Wells, R. (1990). *Biophysical analysis of the Lac La Nonne study area (recreation lease 860010).* Edmonton, Alberta: Alberta Forestry, Lands and Wildlife, Land Information Services Division, Resource Information Branch.

Casey, R. (2011). *Water Quality Conditions and Long-Term Trends in Alberta Lakes.* Edmonton, Alberta: Alberta Environment and Water.

Central New York's Near-Real-Time Surface Water Quality Network. (2006, August 29). *Data Interpretation and Temperature Information*. Retrieved from http://www.ourlake.org/html/temperature.html

County of Barrhead. (2003). *Lac La Nonne: Intermunicipal Development Plan.* Barrhead, Alberta: Adopted by the County of Barrhead No. 11 bylaw 7-2001 third and final reading August 19, 2003.

County of Barrhead. (2019). *2019 Frequently Asked Questions - Lac La nonne Water Levels.* Retrieved from https://www.countybarrhead.ab.ca/p/lac-la-nonne-public-engagement

County of Barrhead. (2019). *Love your Lake Survey.* County of Barrhead: Canadian Wildlife Federation and Watersheds Canada.

Cows and Fish. (2023).

Depoe, S. (2005). Information Provided for LEPA, Stream Water Quality Reports, 2004/2005.

Edmonton Metropolitan and Yellowhead Regional Planning Commissions. (1982). *Lac La Nonne Area Structure Plan.* Adopted by Bylaw No. 9-82 in the County of Barrhead and Bylaw no. 7-82 in Lac Ste. Anne County.

ERPC. (1979). *Nakamun Lake: Options for a Managmement Direction.* Edmonton, Alberta: Edmonton Regional Planning Commission.

ERPC. (1980). *Lac La Nonne: Background Information and Managmeent Issues.* Edmonton, AB: Edmonton Regional Planning Commission and Alberta Municipal Affairs.

ERPC. (1981). *Lac La nonne: Management Study.* Edmonton, Alberta: Edmonton Regional Planning Commission.

ERPC. (1981a). *Lac La Nonne: Management Pan Alternatives.* Edmonton, Alberta: Edmonton Regional Planning Commission.

Fisheries Act. (1985). *Fisheries Act.* Retrieved from C.F-14: https://www.dfo-mpo.gc.ca/campaign-campagne/fisheries-act-loi-sur-les-peches/introduction-eng.html

Government of Alberta. (2009). *Fish Consumption Limit Established for Lac La Nonne and Lac Ste. Anne - Public Health Advisory.*

Government of Alberta. (2015). *Alberta Wetland Classification System.* Edmonton AB: Alberta Environment and Sustainable Resource Development (ESRD), Water Policy Branch, Policy and Planning Division.

Government of Alberta. (2018). *Environmental Quality Guidelines for Alberta Surface Waters.* Edmonton, Alberta: Water Policy Branch, Alberta Environment and Parks.

Government of Alberta. (2018). *Environmental Quality Guidelines for Alberta Surface Waters.* Edmonton, Alberta: Water Policy Branch, Alberta Environment and Parks.

Government of Alberta. (2023). Alberta Water Well Information Database. Alberta, Canada.

Government of Alberta. (2023, April 10). *Groundwater - Information, resources and regulation and policy regarding groundwater*. Retrieved from https://www.alberta.ca/groundwater.aspx

Government of Alberta. (2023, April 10). *Interpolated Weather Data Since 1901 For Alberta Townships*. Retrieved from Alberta Climate Information Service: https://acis.alberta.ca/township-data-viewer.jsp

Government of Alberta. (2023, April 20). *Water Indicators - Lake Trophic Status*. Retrieved from https://www.alberta.ca/water-indicators-lake-trophic-status.aspx

Government of Canada. (2023). *Climate data*. Retrieved from http://climate.weather.gc.ca

Hamilton, H. R. (1980). *Lac La Nonne water quality report.* Alberta Department of Environment, Pollution Control Division, Water Quality Control Branch. Alberta Environment.

Hildebrandt, D. (2006, January 10). Majeau, Nakamun, and Lac la Nonne Watersheds.

Hydrogeological Consultants. (1998a). *Groundwater Potential Evaluation County of Barrhead No. 11.* Edmonton, Alberta: Prepared by Hydrogeological Consultants 97-103.

Hydrogeological Consultants. (1998b). *Groundwater Potential Evaluation Lac Ste. Anne County.* Edmonton, Alberta: Prepared by Hydrogeological Consultants 97-112.

Kerton, B. (2021). *Fish stocking effort at Thunder Lake.* Barrhead News.

Lac Ste. Anne County. (2018). *Private Sewage System Standards - Resolution # 619-18.* Lac Ste. Anne County.

Lac Ste. Anne County. (2020). *Majeau Lake RV Park Area Structure Plan - Bylaw 13-2020.*

Lac Ste. Anne County. (2023, April 28). *ALUS Lac Ste. Anne - Where Agriculture and Nature Meet*. Retrieved from https://alus.ca/alus_community/alus-lac-ste-anne/

Lake Simcoe Region Conservation Authority. (2023, April 26). *Lake Simcoe Science - Groundwater Recharge*. Retrieved from https://www.lsrca.on.ca/Pages/Groundwater-Recharge.aspx

Legare, J. (2023, April 4). Personal Communication.

Lemay, T. G., & Guha, S. (2009). *Compilation of Alberta Groundwater Information from Existing Maps and Data Sources.* Edmonton: Energy Resources Conservation Board - Alberta Geological Survey.

Love Your Lake. (2023). *Healthy Shorelines for Healthy Lakes*. Retrieved from Love Your Lake: https://loveyourlake.ca/

Mitchell, P. (1991). *Volunteer Citizens' Lake Monitoring Program (1990).* Environmental Quality Monitoring Branch, Environmental Assessment Division. Alberta Environment.

Mitchell, P., & Hamilton, H. (1982). *Assessment of phosphorous export from Majeau Creek watershed, Lac La Nonne.* Water Quality Control Branch, pollution control division. Alberta Environment.

Mitchell, P., & Prepas, E. (1990). *Atlas of Alberta Lakes.* Edmonton, AB: University of Alberta Press.

Morgan, G. E. (2002). *Manual of Instructions - Fall Walleye Index Netting.* Sudbury, Ontario: Laurentian University.

My Wild Alberta. (2019). *Fish Consumption Guidelines: Mercury in Fish.* Retrieved from https://mywildalberta.ca/fishing/advisories-corrections-closures/documents/FishConsumptionLimitsAlberta-Jun2019.pdf

National Geographic Society. (2023, April 26). *These Animals Offer Key Clues for Environmental Change*. Retrieved from https://www.nationalgeographic.com/animals/article/these-animals-offer-key-clues-for-environmental-change

National Park Service. (2023, April 26). *Benefits of Native Fish*. Retrieved from https://www.nps.gov/subjects/fishing/benefits-of-native-fish.htm

Olson, J. (2023, April 3). Personal Communication. Camrose, Alberta: Ducks Unlimited Canada.

O'Shaughnessy, K. (2009). *Riparian Health Summary Final Report, Majeau Lake.* Alberta Riparian Habitat Management Society (Cows and Fish).

O'Shaughnessy, K. (2009a). *Riparian Health Summary Final Report, Nakamun Lake.* Alberta Riparian Habitat Management Society (Cows and Fish).

O'Shaughnessy, K. (2010). *Riparian Health Summary Final Report, Lac La Nonne.* Alberta Riparian Habitat Management Society (Cows and Fish).

PFRA. (2006). Original GIS data assembled by Jason Vanrobaeys.

Rhude, L. A. (1979). *Characteristics of the lakes and ponds within the Edmonton area.* Edmonton, Alberta: Recreation, Parks, and Wildlife, Fish and Wildlife Division.

Riley, E. T. (1983). *Internal Phosphorous loading from the sedimentsand the phosphorous-chlorophyll model in shallow lakes.* Edmonton, Alberta: Department of Zoology M.Sc. Thesis, University of Alberta.

Riley, E. T., & Prepas, E. E. (1984). Role of Internal Phosphorous Loading in Two Shallow Production Lakes in Alberta. *Canadian Journal of Fisheries and Aquatic Sciences, 41*, 845-855.

Safety Codes Council. (2021). *Alberta Private Sewage Systems Standard of Practice 2021.* Edmonton, Alberta: Safety Codes Council. Retrieved from https://ebs.safetycodes.ab.ca/documents/webdocs/PI/PSS_SOP_2021-web6.pdf

Spencer, S. (2006). Personal Communication.

Summer Village of Nakamun Park. (2020). *Municipal Development Plan.*

Summer Village of Nakamun Park. (August 2007). *Land Use Bylaw No. 2007-03.*

SV of Nakamun Park. (2007). *Land Use Bylaw No. 2007-03.* Summer Village of Nakamun Park: Consolidated by SV Planning and Development Services.

SV of Nakamun Park. (2013). *Municipal Development Plan.* Summer Village of Nakamun Park.

Tashla, T., Zuza, M., Kenjves, T., Prodanovic, R., Solesa, D., Bursic, V., . . . Puvaca, N. (2018). Fish as an Important Bio-indicator of Environmentla Pollution With Persistent Organic Pollutants and Heavy Metals. *Journal ofAgronomy, Technology, and Engineering Management, 1*(1), 52-56.

Twardy, A. G. (1977). *Soil Survey and Land Suitability Evaluation of the Lac la Nonne Study Area.* Prepared by Pedology Consultants for Alberta Environment.

Twardy, A. G., & Brocke, L. K. (1976). *Soil Survey and Land Suitability Evaluation of the Sandy Lake-Wabamun Lake Study Area.* Prepared by Pedology Consultants for Alberta Environment.

Waters Edge Resource Group. (2004). *Results of the Lac La Nonne Watershed Stewardship Survey - Spring 2003.* Waters Edge Resource Group.