STATE OF THE WATERSHED ENVIRONMENTAL INVENTORY REPORT FOR MOOSE LAKE: SUMMARY OF CURRENT INFORMATION

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EXECUTIVE SUMMARY

Moose Lake is a popular recreational lake in M.D. of Bonnyville of central Alberta. Permanent residents, seasonal residents and daily users have long been concerned about the environmental quality of Moose Lake. Early documented concerns included algal blooms, weed growth, boating speeds, boating noise, polluted water, poor fishing, excessive crowds and excessive development. These concerns led to the development of a Municipal Area Structure Plan by 1980 that was updated in 1985. These plans focused primarily on residential land development but there was consideration for agricultural land development and the lake environment.

The purpose of this report is to summarize and document all of the current environmental information for Moose Lake and the watershed. This is an initial step required for the development of the Moose Lake Watershed Management Plan. The development of this plan is led by the Moose Lake *Water for Life* committee but is guided by the Alberta Environment document *Framework for Water Management Planning*.

There was a large resource of reports and experts consulted during the preparation of this report. There is currently a lot of information available about the environmental status of Moose Lake but there are substantial information gaps that need to be filled. These need to be filled in order to develop the best and most comprehensive watershed management plan.

Recommendations to address the data gaps are summarized:

- The total contribution of surface water and groundwater to the hydrological cycle of Moose Lake needs to be quantified.
- Baseline water quality needs to be quantified using palaeolimnological techniques.
- The amount of riparian and wetland area lost through disturbance needs to be quantified.
- A phosphorus nutrient budget, with total contributions from all sources, especially the sediments, needs to be developed.
- Human use of the lake and watershed needs to be determined.
- Accounting of all septic systems in use and confirmation that they are functioning properly is needed.
- During the development of the watershed management plan, the goals and objectives for fisheries and wildlife, as part of the functioning watershed, needs to be defined.
- A user's perception survey has been completed for one summer village but additional surveys should be considered for the remaining summer villages and campground users.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

Water is a resource that is managed for both quality and quantity. Conservation and management of water in Alberta is legislated under the provincial Water Act. Sustainable management of water and the development of water management plans is guided by Alberta Environment and The Framework for Water Management Planning (AENV, 1999). Earlier plans were focused on land development planning and sub-division of land. This new planning process takes an integrated resource approach. Planning is based on watershed boundaries and not on political or municipal boundaries. It also requires the inclusion of all stakeholders within the watershed boundaries, requires thorough consultation prior to implementation and requires clear objectives or strategic directions.

The purpose of this report is to review and document the current environmental information available for Moose Lake and its watershed. This report will serve as a starting point for the watershed management planning process.

Moose Lake is located in Northeastern Alberta in the Lakeland Region, 240km Northeast of Edmonton and 3.5km west of the Town of Bonnyville (Figure 1). Moose Lake is in the Boreal Mixedwood Subregion of Eastern Alberta (Alberta Community Development). Most of the shoreline has relatively easy access from Secondary road 660 to the North and Highways 28 and 28A to the South and East (ALMS, 2003).There is a large proportion of recreational shoreland in this region (Runge, 1977).

Moose Lake is a popular and scenic lake in the Lakeland Region of Alberta (Water for Life Committee, 2004). The sandy beaches and captivating landscapes were good draws from both local and regional sources of people seeking outdoor recreation (Mitchell and Prepas, 1990). Lakes, like other natural resources, need to be managed for long-term sustainability. In order to develop a long-term plan with those intrinsic values, the limiting factors within the landscape, the water environment, human environment and social environment must be considered (Runge, 1977). Land development and water quality issues are not new to Moose Lake. Through the process of developing earlier management plans for this lake, surveys were taken with the residents and users of this lake (Alberta Municipal Affairs, 1979). The primary concerns raised at that time were: 1) algal blooms and weed growth; 2) boating speeds and noise disturbances; 3) polluted water; 4) poor fishing; 5) crowding, especially on weekends; and 6) rapid and unrestricted development.

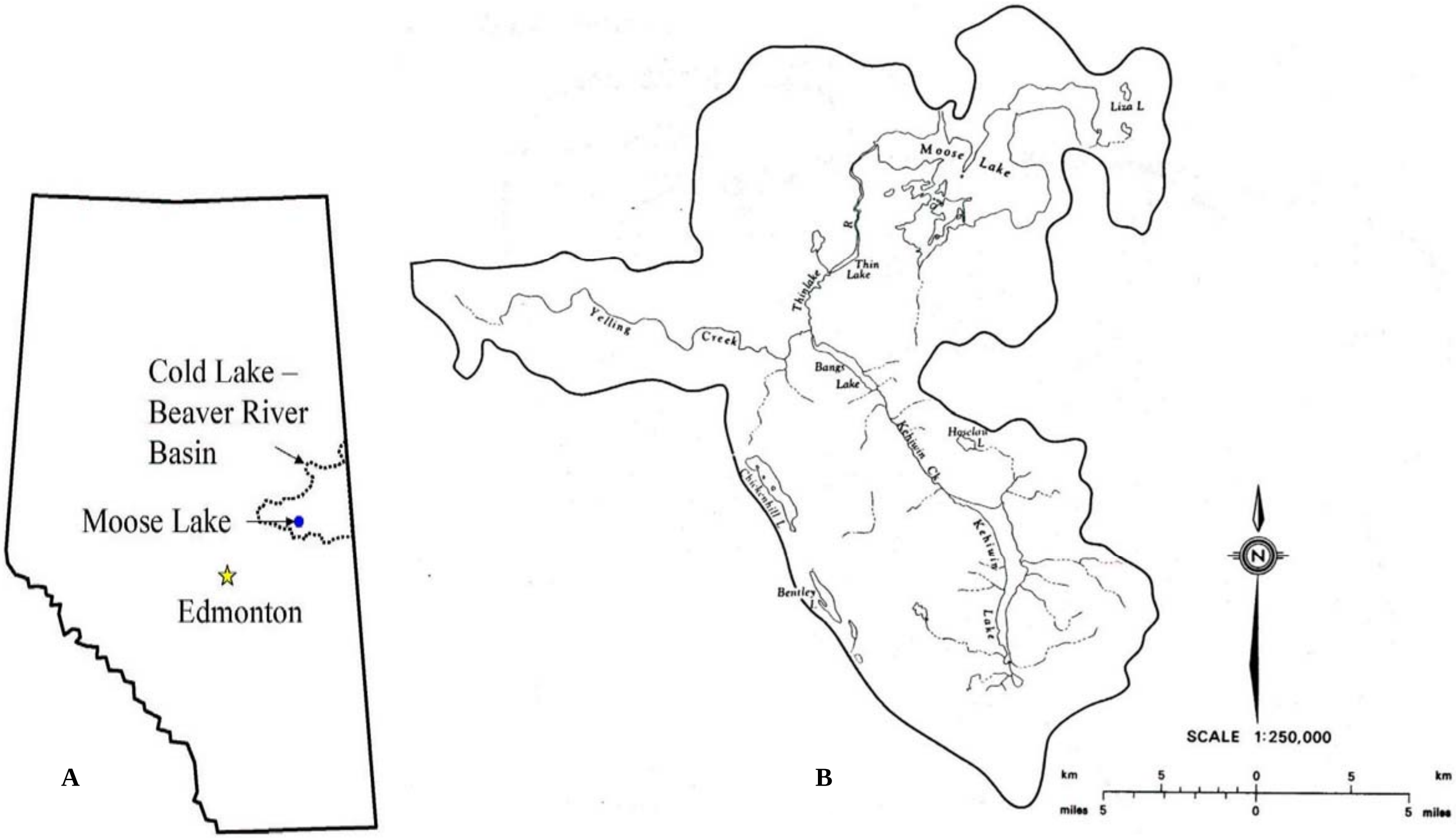

Figure 1. A) Map of Alberta and the Beaver River drainage basin. **B)** Moose Lake Watershed within the Beaver River drainage basin.

Concerns about the water quality of Moose Lake have not decreased. Members of the local community and recreational users of the lake have been more and more concerned about many years of low water levels, more frequent algal blooms, and increasing development around the lake shore. These concerns have lead to the formation of local committees with the goal of determining the causes of the decline in the environmental quality of the lake and watershed. One committee in particular, The Water for Life Committee, includes residents from the Summer Village of Pelican Narrows, Summer Village of Bonnyville Beach, Town of Bonnyville and The Municipal District of Bonnyville No. 87. This committee has been formed to develop a Watershed Management Plan for the Moose Lake watershed. The vision of the committee is to maintain a healthy and functioning watershed and ensure sustainable recreational and agricultural benefits by living within the capacity of the natural environment. A watershed management plan needs to be inclusive of all components that have or may potentially have an impact upon the environment. The first step is to develop a comprehensive Terms of Reference that detail the goals and objectives of the new plan (Water for Life, 2004). The next step is to review all current information about the Moose Lake Watershed and describe gaps in the information.

The objective of this State of the Watershed Report is to review current environmental information from Moose Lake and the surrounding watershed, identify deficiencies in the data/knowledge and identify areas of concern. Residents and users of Moose Lake are concerned about the quality of the lake. Through the development of the Terms of Reference, issues and concerns were identified. These issues and concerns include:

- Substantial algal growth in the lake;
- Quality of drinking water related to treatment requirements for public consumption;
- Quality of seasonal run-off water entering the lake;
- Proper functioning private sewage disposal systems;
- Lack of regulatory support for control and mitigation of contaminants entering the lake;
- Decline in fish stocks;
- The link between riparian area degradation and decline in fish stocks;
- Disturbance of the shoreline and upland;
- Total wetland area lost to development is unknown; to enhance source water protection in the watershed management plan, areas of lost wetlands need to be identified.

This report is structured to complement the current Terms of Reference for the Moose Lake Watershed Management Plan (Water for Life, 2004). Under the Terms of Reference for the Management Plan, technical sub-committees were formed to address the major issues of ***i***) water quality and land use and ***ii***) aquatic resources (fisheries, wildlife, riparian habitat, wetlands). These sub-committees were formed to conduct additional studies and gather information, coordinate with on-going regional studies, coordinate public consultation and provide recommendations and reports to the Moose Lake Watershed Management Committee. Finally, it is the intent of this document to address the issues and concerns outlined in the Terms of Reference document with the current environmental information and to further elaborate on information requirements also outlined in the Terms of Reference document.

2. SITE DESCRIPTION

2.1. Regional Climate

Warm summers and long, cold winters describe the general climate of the Moose Lake area. Environment Canada collects long-term climate data from permanent stations established across the country. Long-term average climate for this region was determined from the Canadian Daily Climate Data (CDCD) (Environment Canada, 2004). The station at the Town of Cold Lake is the closest long-term Environment Canada monitoring point to Moose Lake; climate data has been collected from this station since 1952. The long-term annual averages are given in Table 1. To put the climate for this station into perspective the long-term climate from a station in southern Alberta (Medicine Hat) and from a station in northern Alberta (Peace River) are given as a comparison of different average climates in Alberta.

Table 1. Climate averages for the Moose Lake Area (Environment Canada, 2004). The closest long-term monitoring station is at Cold Lake. Climate data for Medicine Hat (Southern Alberta) and Peace River (Northern Alberta) are given for comparison.

Parameter	Cold Lake 1952-2003	Year of extreme value	Medicine Hat 1883-2003	Year of extreme value	High Level 1970-2003	Year of extreme value
Mean annual Temperature (°C)	1.5	-	5.5	-	-1.2	-
Mean annual Maximum Temperature (°C)	7.1	1987	12.1	1987	5.1	1981
Mean annual Minimum Temperature (°C)	-4.1	1982	-1.2	1887	-7.5	1972
Rainfall (mm)	320.8	1960 (high) 501.5 1967 (low) 153.6	243.2	1927 (high) 528.4 2001 (low) 93.2	258.9	1973 (high) 434.7 1995 (low) 136.5
Snowfall (cm)	132.0	1955 (high) 234.7 2001 (low) 57.8	101.7	1973 (high) 223.1 1930 (low) 17.8	151.3	1972 (high) 257.4 2000 (low) 72.8
Precipitation (mm)	432.9	1960 (high) 628.6 2002 (low) 269.3	339.5	1927 (high) 643.0 2001 (low) 148.0	387.8	1973 (high) 597.9 2002 (low) 224.1
Evaporation (mm) 1954-2001	610.2	1981 (high) 697 1954 (low) 515	N/A		N/A	

Mean annual temperature measured at Cold Lake is 1.5°C, with January being the coldest month (mean daily temperature of -17.3°C) and July being the warmest month (mean daily temperature of 17.1°C). Precipitation occurs throughout the year in the region at a mean annual value of 432.9 mm. Of this, approximately 74% occurs as rainfall (320.8 mm mean annual). Cold Lake (and the Moose Lake region) has a climate that falls within the range of climate found in Medicine Hat (Prairie region) and High Level (Boreal Forest region). Overall, climate at Cold Lake is most similar to the northern station. There is some variation as to when the different stations received record low amounts of precipitation (either as rainfall, snowfall or total precipitation) but in all cases, at least two out of the three of the extreme low occurrences have occurred since the mid 1990's and all three stations had lowest recorded total precipitation this century.

2.2. Drainage Basin Characteristics

Moose Lake covers about 8,530 ha and drains a gross area of 84,581 ha (excluding the lake) (Figure 1). The surface area of the lake is less than 5% of the entire drainage basin. Most of the watershed has a gently undulating terrain (Mitchell & Prepas, 1990)and the slopes around the lake are generally less than 9% but there are some sections with steep banks (Runge, 1977). The main surface water inflow to Moose Lake is the Thin Lake River. This enters directly into Franchere Bay in the southwest corner of Moose Lake. The Thin Lake River is formed by the confluence of two lotic sources: Yelling Creek and Kehewin Creek. Yelling Creek flows through the western most portion of the watershed through predominantly agricultural land. Kehewin Creek forms a surface drainage path in a gradual southeast to northwest direction. Small surface tributaries drain into Kehewin Lake; this lake drains into Kehewin Creek and then into Bangs Lake. Bangs Lake drains via a short tributary that merges with Yelling Creek to form the Thin Lake River. Bently Lake and Chickenhill Lake form another surface drainage pattern in a southeast to northwest direction. However, in recent years the outflow of Chickenhill Lake has been dry and has not drained into Yelling Creek (pers. obs. T. Charette, AENV). In total, the Thin Lake River drains approximately 75% of the entire catchment (Runge, 1977). In addition, five intermittent streams drain the remaining 25% of the catchment and flow directly into Moose Lake on the south, southeast, northeast and northwest shores.

The outflow of Moose Lake is the Mooselake River. It leaves the lake from Franchere Bay, less than 3.5km from the predominant inflow. It has been estimated that the residence time (the time required to empty and refill a lake) of Moose Lake is 7.5 years (Mitchell & Prepas, 1990). However, since the major inflow and outflow of the lake are within the same bay, and the lake has many separate bays, the actual residence time in outreach portions of the lake is likely quite longer.

In addition to this surface water, which has yet to be quantified, there is extensive ground water through this region. Groundwater quality and quantity is being studied as part of the process to update the Cold Lake-Beaver River (CLBR) Water Management plan. Moose Lake is described as a groundwater discharge lake; there is a net input of groundwater to Moose Lake over the long-term but contributions on a month to month basis are relatively small (CLBR

Technical Team, 2004a). Groundwater quality is also being investigated in the larger CLBR watershed. Aquifer sensitivity maps were developed for the region based on concentrations of total dissolved solids, salts metals and contaminants in various geological formations (CLBR Technical Team, 2004b). Maps were not available for review at this time but should be consulted during the development of the watershed management plan.

Groundwater discharge and recharge sites (wetlands and some lakes) provide important links between surface and groundwater. There is the potential for exchange of nutrients, salts and other contamination between surface water, and shallow and deep aquifers. It is important that we know the quantity of water, quality of water and number of exchange sites in order to develop thorough environmental assessment programs and integrated watershed management programs.

Bedrock geology in this area is Lea Park Formation (Upper Cretaceous) comprised mainly of shale, silty shale, ironstone concretions and marine deposits (Alberta Geological Survey, 2004). More detail on the geology of the area is provided in the CLBR reports (CLBR Technical Team 2004b, Stantec, 2005). There are various combinations of organic, loamy, and sandy soils on the landscape surrounding Moose Lake and Runge (1977) interpreted most appropriate use of the land based on these soil types (Figure 2). Based on the types of soils and vegetation that they can support, most appropriate land uses were proposed (Runge, 1977). There are organic soils (i.e., wetlands) north of the provincial park, in the Thinlake river valley and on the West side of Island Bay. These poorly drained areas are not suitable to any type of development because they would require extensive modification of topsoil and subsoil but more importantly, these types of areas are required to maintain good aquatic/environmental health. During wet years these low lying areas provide additional area for water drainage. There are well-drained loamy soils that occupy approximately 40% of the total shoreland and can support vegetation for intensive recreational use. These soils are found predominantly along the north and east sides of the lake. Lastly, there are rapidly drained loamy sands that occupy approximately 50% of the shoreline. These soils are on the northwest and southwest shorelines and would be best suited for low intensity recreational use such as cottages. However, at the present there is very little development in that area. Intensive recreational use (i.e., campgrounds) would be best suited for the eastern portion of the lake (9km shoreline, 14% shoreline), moderate to low density cottages would be best around Franchere Bay and the south shore of the lake (11km, 17%), shoreline with organic soils are unsuitable for any development (10km, 15%) and the remaining shoreline (at the time of the 1977 report) should be left in its state of natural tree cover (Runge, 1977). Development patterns did not agree with basic resource potential.

The Moose Lake Watershed is within the Boreal Transition Ecoregion and is part of the Boreal Plain Ecozone of western Canada (Environment Canada, 1996). This is a broad ecological land classification that considers soil, geology, vegetation and climate. The natural forest of this area is mixedwood dominated by species of trembling aspen, balsam poplar, white birch, white spruce and balsam fir (Mitchell & Prepas, 1990). There is agricultural development throughout the watershed but primarily in the Western portion near Yelling Creek and to the South and East of the lake. Agriculture is typically mixed farming (Runge, 1977). There is a large area of Crown land on the north and west shores of the lake. Within these Crown lands, there is a provincial park on the north shore. Additional lands on the west side of the lake have been identified for "future parks consideration" for conservation purposes.

Shoreline and land within the drainage basin is private and Crown land (Runge, 1977). Disturbance within the watershed is predominantly agriculture, urban development and other land disturbance. Most of the agricultural land is not directly adjacent to the lakeshore. One of the most important sources of impacts on the lake is from urban and cottage development. Cottage development constitutes the principal use of land adjacent to the lake. The principal area with cottage development is along the Eastern shore of the lake. The first subdivision of lots dates back to 1945 and significant subdivision development did not occur until the 1960's. In 1972 it was estimated there were 481 lots (Provincial Planning, 1972) and by 1979 there were 700 lots (Alberta Municipal Affairs, 1979). Current information on the total number of seasonal and permanent cottages around this lake is not available. However, the most current population statistics indicate that in the M.D. of Bonnyville, there are 8,399 people, in the summer village of Pelican Narrows there are 112 people (in 35 units on 32 hectares) and in the summer village of Bonnyville Beach there are 74 people (in 24 units on 13 hectares) (Alberta Municipal Affairs, 2004).

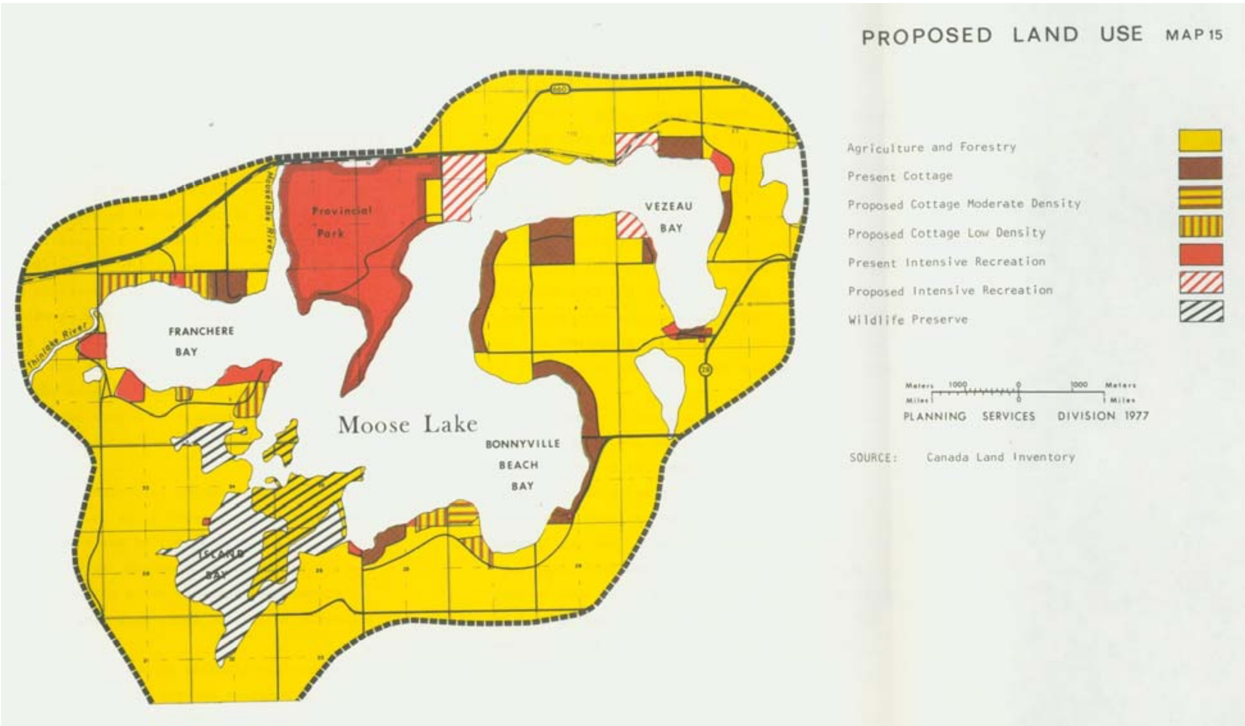

Figure 2. Proposed land use around the shoreline of Moose Lake. Adapted from Runge (1977).

There are five camping areas around the lake operating as either private or public campgrounds. Moose Lake Provincial Park, on the north shore, contains a campground for overnight camping and day use (59 individual sites plus 2 group use areas). In 2003, there were 1026 occupied campsite nights between May to September (A.Nicol, pers. comm., Community Development). Franchere Bay Provincial Recreational Area, on the west shore near the Thinlake

River; provides overnight camping (200 sites) plus day use areas. In 2003, there were 2201 occupied campsite nights between May to September (A.Nicol, pers. comm., Community Development). These are provincially operated campgrounds managed by Alberta Community Development. Pelican Point M.D. Park is on the southeast shore of Franchere Bay and has 80 overnight sites. Vezeau Beach RV Park is located on the east shore at the southern tip of Vezeau Bay. It has 24 full serviced camping sites. There is also the Bonnyville Beach Day Use Area, on the east shore, in the Summer Village of Bonnyville Beach. The former Eastbourne Provincial Recreational Area, on the south shore, has been decommissioned and reclaimed (A.Nicol, pers. comm., Community Development).

Depth and elevation of water level in Moose Lake has been recorded since 1950 (Figure 3). In the past, the lake was, on average, 5.7m deep with the deepest points located in Vezeau Bay (Runge, 1977). Following years of low water levels, a weir on the lake outflow, Moose Lake River on the north side, was installed in 1951 (Mitchell & Prepas, 1990; Figure 4). Lake water levels began to rise after the installation of the weir to a high of 534.1m in 1966. The purpose of installing the weir was to protect fish and waterfowl habitat, establish suitable water levels for recreational purposes and to maintain a drinking water supply for the town of Bonnyville. The weir, constructed of steel sheet-pile, rock and timber eventually deteriorated and by 1984 the lake had dropped to its lowest recorded level of 532.6m. In 1986, a new weir was installed but it was ineffective, due to low precipitation, and water levels continued to decrease to a low of 531.95m in 1993. A few years of increased precipitation followed and lake level rose but subsequent drought years reduced average lake level. The average lake level in 2003 was 532.05m, 0.62m below the long term average. Overall, water levels in Moose Lake have only decreased by about 1 metre since 1980 (Rippin, 2004). Water withdrawal from Moose Lake for the town of Bonnyville has been set to 3 million m^3/year (Mitchell & Prepas, 1990). This would equate to approximately 0.08m of depth if the entire allocation was extracted all at once and there was no runoff from the watershed or groundwater contribution to the lake.

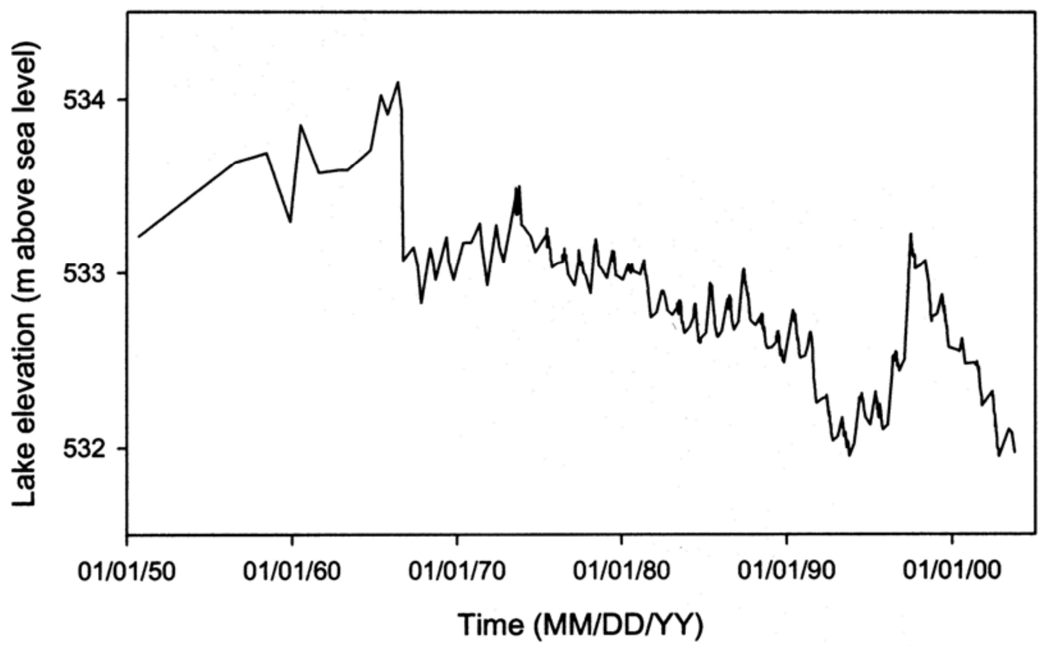

Figure 3. Moose Lake water levels, 1950-2003. Adapted from ALMS (2003).

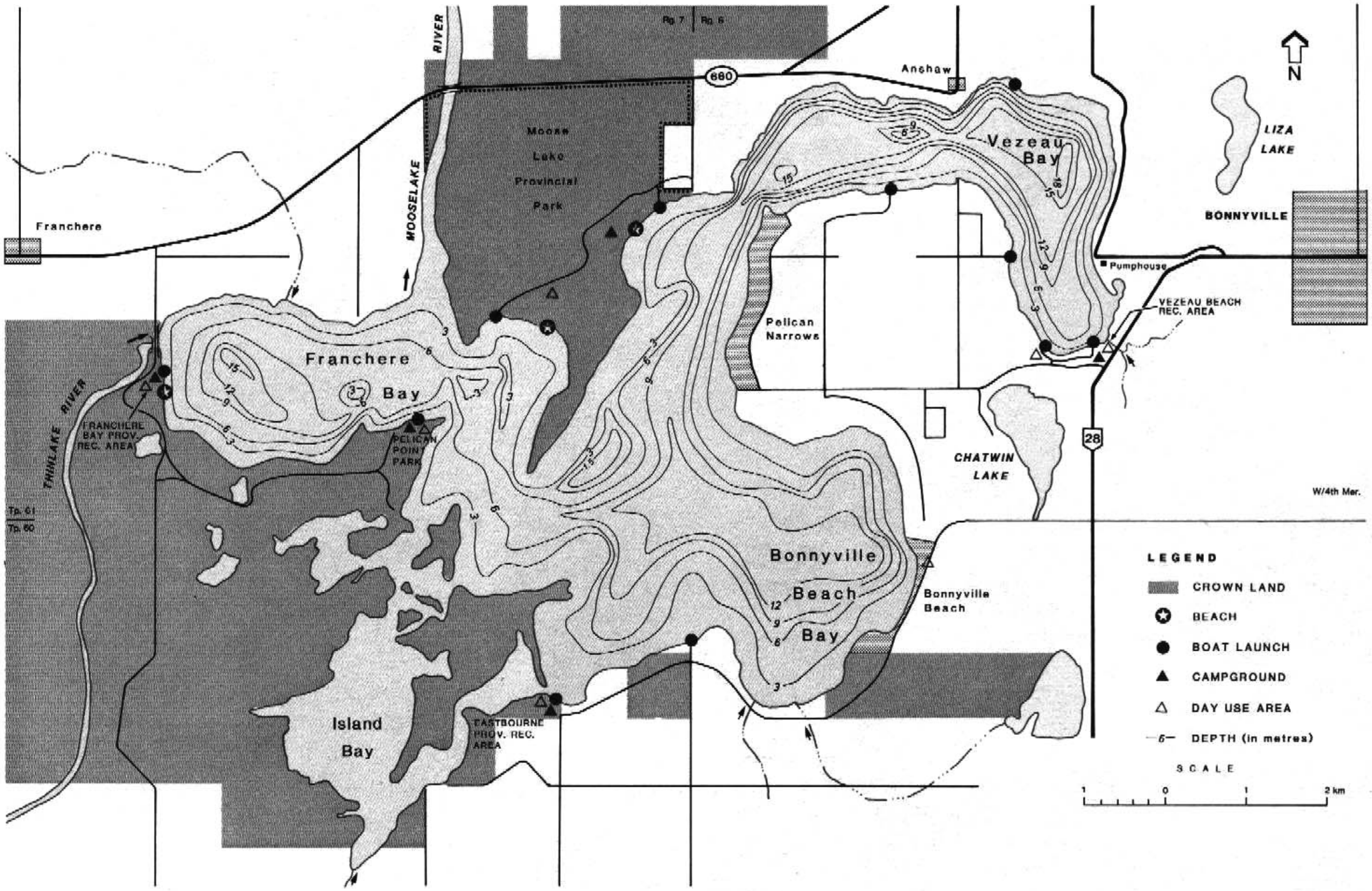

Figure 4. Outline and bathymetry of Moose Lake. Adapated from Alberta Environment (1989).

3. PREVIOUS MANAGEMENT PLANS

Moose Lake was chosen as a prime cottage destination because of its natural beauty, good fishing, good highway access, close proximity to "home" and clean water (Runge & Wilcox, 1976). Cottage owners and other users of the lake were concerned about unrestricted land development around the lake. The process to develop a land development and management plan began in the 1970's (Provincial Planning, 1972). Ideally, a land management plan is developed first at the regional or watershed scale, then at the individual lake scale and finally at the scale of distinct stretches of shoreline (Provincial Planning, 1972). Cottage development had already started around Moose Lake before any land plan was developed so the best case scenario would have to involve controlling any future development until a plan had been approved. Residents of Moose Lake continued to express concern over rapid development and water quality for recreational uses (Alberta Municipal Affairs, 1979). To develop the most appropriate area plan studies were undertaken to assess water quality, current land use and potential land use based on soil and landscape features.

Lakes are classified by trophic state (or fertility) using measures of total phosophorus, algal pigment concentration (i.e., Chlorophyll *a*) and water clarity. The trophic state classification method groups lakes from oligotrophic (low fertility) to hyper-eutrophic (high fertility) based on measured concentrations of these variables (Table 2). Along the scale of increasing fertility, there is an increase in water greenness (or algal growth) and a concomitant decrease in water clarity. In order to support abundant fish production, at least moderate levels of nutrients, or overall fertility, are required. Good sport fish production is a recreational benefit to a lake. However, excessive nutrients (eutrophic to hyper-eutrophic state) can lead to algal blooms and low oxygen concentrations thereby limiting "desirable" fish or total fish survival (Figure 5).

Table 2. Trophic state classification of lakes based on lake water characteristics.

Trophic State (Fertility)	Total Phosphorus (µg/L)	Water Greenness (Chlorophyll *a* µg/L)	Water Clarity (Secchi Disk Depth [m])
Oligotrophic (low fertility)	< 10	< 3.5	> 4
Mesotrophic (moderate fertility)	10 – 30	3.5 – 9	4 – 2
Eutrophic (high fertility)	30 – 100	9 – 25	2 – 1
Hyper-eutrophic (very high fertility)	> 100	> 25	< 1

Note: These values are from a detailed study of global lakes reported in Nurnberg (1996).

Lakes in the central region of Alberta show a typical pulse of nutrients and algae sometime during the spring to summer growing season. The intensity and duration is directionally proportionate to lake fertility. According to this classification system, Moose Lake was eutrophic in the mid 1970's (Gallup, 1977). Phosphorus concentrations peaked in July and August, planktonic algae responded (peak in chlorophyll concentrations between July to August) and water clarity was at its lowest in August.

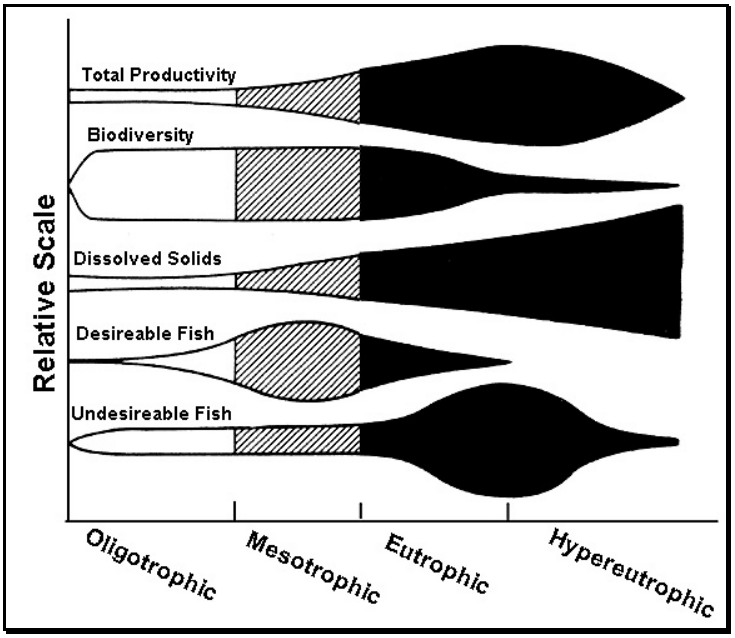

Figure 5. Suggested changes in various lake characteristics with eutrophication. Modified from Welch (1980).

Poor water quality of the whole lake, but more importantly in Vezeau Bay, was a major concern for lake users because the water in this bay is the source of drinking water for the Town of Bonnyville. Vezeau Bay, in the Northeastern most portion of the lake, is relatively isolated from the rest of the lake. Although not yet proven, it is very likely that there is reduced flushing of lake water in this bay as compared to other reaches of the lake. Since the 1970's the land surrounding Vezeau Bay has been used for agriculture, seasonal and permanent residences and resorts. Runge (1977) recommended investigating the effect of these land uses on water quality in this bay.

By the late 1970's, there were approximately 700 registered recreational lots, one provincial park, four institutional camps, two private resorts and a number of public campsites and municipal parks around the lake (Alberta Municipal Affairs, 1979). Development pressure was on the rise since the 1950's, but was intense between 1967 and 1976 just prior to activation of Alberta Environment development regulations. Of the 700 registered lots, over 500 were developed between 1967 and 1976. Residents expressed concern over unrestricted future development, pollution and declining fishing quality (Runge & Wilcox, 1976) thus, a lake management plan was required.

Land use potential was assessed as part of the lake management planning process. Most of the shoreland around this lake (72%) was of moderate to moderately low capability for outdoor recreational uses (Alberta Municipal Affairs, 1979). Land that could best support high intensity use (e.g., campgrounds) was the east shore of the lake while the land best suited for cottage development was the west shore (Figure 2; Runge, 1977). However, cottages had already been developed on the eastern shore thereby reducing the total potential for future high intensity developments.

The area around Island Bay was identified as prime wildlife, waterfowl and fish habitat and its immediate protection from shoreline development and power boats was recommended (Runge, 1977). The shallow waters and islands in Island Bay were identified as "wildlife preserve" (Figure 2; Runge, 1977). Recommendations were made to prohibit any development in this area (Runge, 1977) and furthermore "intense use of these lands are discouraged" (Alberta Municipal Affairs, 1979). Currently, the land surrounding Island Bay is Crown land but has not received official designation as protected area or a provincial park (pers. comm. A. Nicol, Comm. Devel.).

Development of cottages, residences and intensive recreational facilities need to consider land capability (Alberta Municipal Affairs, 1979). Nutrient loading was identified as a potential issue in Moose Lake and future developments would need to include non-effluent releasing sewage disposal mechanisms and a future study would need to be conducted to identify nutrient loading sources. It was also suggested to conduct an intensive study on Vezeau Bay (drinking water source for the Town of Bonnyville) to determine if there are any links between land use and water quality. Poor water quality was identified in Vezeau Bay but the link between land use around this bay and the quality of water in this bay is unknown. It was also recommended to not permit further residential development around Vezeau Bay but two intensive recreation areas along with boat launching facilities at Vezeau Bay were recommended (Alberta Municipal Affairs, 1979).

The first Moose Lake Area Plan considered and incorporated the recommendations made on land use capability, development within land capability classes, deteriorating water quality, protection of source drinking water and protection of wildlife habitat (Alberta Municipal Affairs, 1979). The plan was officially adopted in 1980 and then reviewed in 1984 to determine if the objectives were still applicable. The plan did not change much in content but was modified to a more easily understood document (Municipal District of Bonnyville, 1985). As far as it is known, the 1985 Moose Lake area structure plan is the most recent version.

4. <u>CURRENT ENVIRONMENTAL INFORMATION ABOUT MOOSE LAKE AND THE WATERSHED</u>

4.1. Water Quality and Land Use

4.1.1. Water Quality

Since the retreat of the glaciers from the landscape of Alberta, nutrients, such as phosphorus, along with other components such as salts and ions have slowly entered lakes from surrounding glacial till and soils. In general, the concentration of nutrients and other components is higher in lakes of Alberta as compared to lakes from other regions with very little glacial till. Even though nitrogen and phosphorus concentrations are naturally elevated within many of Alberta's lakes, human activities (urban and agricultural development) exacerbate the transport (loading) of these nutrients to lake basins. In most areas, nitrogen is often in excess of that required for growth by aquatic plants and algae and phosphorus is the main nutrient limiting primary production in many lakes (Trimbee & Prepas, 1987). In Alberta, deep fertile soils, thick glacial till rich in nutrients, and human activities in the watershed have provided our lakes with naturally high concentrations of phosphorus. Excessive phosphorus is conducive to promoting blooms of nitrogen fixing, or nuisance, algae. Moose Lake has been no exception (Gallup, 1977; Mitchell & Prepas, 1990) and it continued in the summer of 2003 with high (i.e., eutrophic) to very high fertility (i.e., hypereutrophic) and greater fertility than an average Alberta lake (Figure 6). Indeed, total nitrogen and phosphorus concentrations often surpassed Surface Water Quality Guidelines for the Protection of Freshwater Aquatic Life (Table 3), which is consistent with many fertile lakes in the Province. Also, due to high productivity and biological decomposition at the lake bottom, deepwater oxygen concentrations were often below guidelines in late summer 2002 (Table 3; Figure 7).

Deep lakes from temperate regions often have stratified water column profiles. Upper waters (epilimnion) are different from lower waters (hypolimnion) for parameters such as temperature and oxygen. Some lakes show defined and persistent thermoclines (zone of rapid change between isolated upper and lower layers). Moose Lake has shown evidence of stratification for temperature and oxygen (Gallup, 1977; Mitchell & Prepas, 1990; ALMS 2002, 2003) although there is discrepancy in evidence of thermal stratification. This may be explained by year to year variation in climate (affect heating of waters, surface runoff, etc.), internal variability, intensity of sampling and location of sampling. However, all studies reported evidence of oxygen stratification in the summer. In 2002, a clear oxygen differential had started to form by late June while temperatures were gradually starting to show a difference between upper layers and lower layers (Figure 7). By mid July a strong thermocline had developed and oxygen was not recorded below 10-12 metres. In 2003, the lake did not show evidence of thermal stratification but the lower water layers did become anoxic by August. Lack of a thermocline allows for mixing of the entire water column. Interestingly, average nutrient concentration (nitrogen and phosphorous) along with chlorophyll *a* (proxy for algal primary production) were higher in 2003 as compared to 2002 (although not statistically higher). Mixing of the water and re-distribution of nutrients could have led to increased algal growth in the summer of 2003 as compared to 2002.

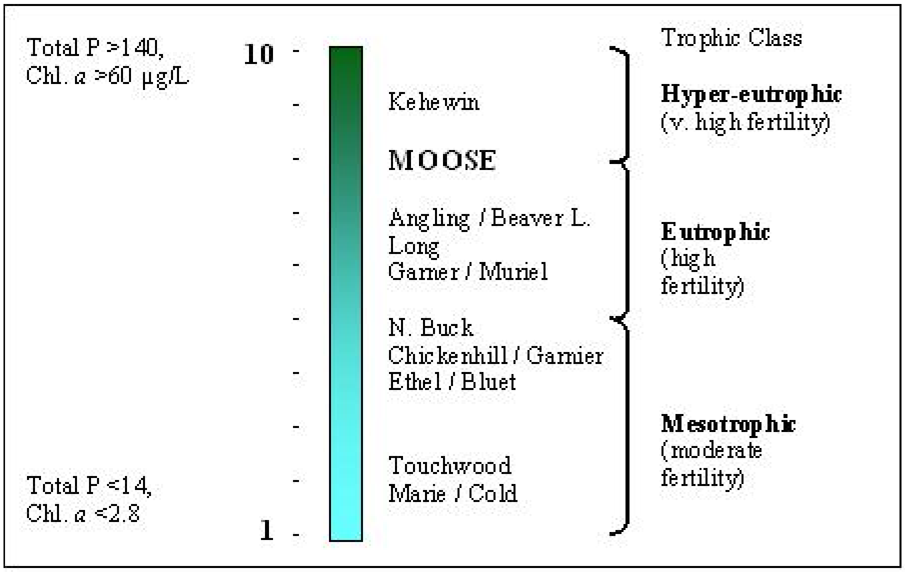

Figure 6. Fertility of Moose Lake compared to 170 other lakes across Alberta. Lakes are scaled from 1 (lowest productivity) to 10 (highest productivity) based on water greenness (algal biomass) and nutrients (phosphorus).

Oxygen throughout the vertical profile of a lake is important to the aquatic organisms in multiple ways. Oxygen is required for basic respiration but the presence of oxygen also influences and controls the chemical composition in a lake. Nitrogen, phosphorus, iron, manganese and chloride are chemical components that react differently in the presence of oxygen versus in the absence of oxygen. Nitrogen and phosphorus concentrations exceed guideline values in this lake (Table 3). Water becomes anoxic due to high production and subsequent decomposition. In the presence of oxygen, ammonia does not form and phosphorus is bound to the sediments. When water at the sediment surface becomes anoxic, ammonia nitrogen and phosphorus is released from the sediments. Ammonia concentrations can increase over time and become toxic to aquatic organisms such as benthic invertebrates, zooplankton and fish. Soluble-reactive phosphorus can also be released from the sediments allowing for continued production of algae. Nuisance algae can form dense blooms because they have abundant nutrients, they can effectively out-compete other algae and they are not eaten by invertebrates (e.g., they have defense mechanisms such as mucilage or the vitality of the grazers is reduced due to toxic ammonia concentrations). The high biomass of algae eventually will decompose, further reducing oxygen, further enhancing nutrient release from the sediments, further enhancing primary production and so on. This is a common problem in eutrophic lakes and is one of the components that needs to be identified and quantified when determining a nutrient budget for a lake.

Table 3. Number of samples that exceeded Provincial and Federal Water Quality Guidelines for the Protection of Freshwater Aquatic Life in Moose Lake (from 1980 to 2003).

Water Quality Parameter	Guideline (µg/L)	No. Exceeded Values (1980 to 2003)	Water Quality Parameter	Guideline (µg/L)	No. Exceeded Values (1980 to 2003)
Aluminum (2003)	100	0	Nickel (2003)	150	0
Ammonia (2003)	1370	0	Nitrite	60	0
Arsenic (2003)	5	0	Oxygen (from depth profiles)	5.0	40
Cadmium (2003)	0.06	0	pH	6.5-9.0	0
Chloride	230	0	Nitrogen, total	1000	60
Copper (2003)	32	0	Phosphorus, total (1983-2003)	50	22
Iron	300	0	Selenium (2003)	1	0
Lead (2003)	7	0	Silver (2003)	100	0
Molybdenum (2003)	73	0	Zinc (2003)	30	0

Note. Concentrations are in µg/L, unless otherwise noted. Concentrations compared to guidelines are those of vertically integrated samples from the euphotic zone, except for oxygen. Oxygen concentrations compared to guidelines are from depth profiles. Guidelines for metals are for 200 mg/L $CaCO_3$.

To date there has been no detailed study done to determine nutrient loading into Moose Lake, however it has been estimated based on a standard relationships determined from other lakes (Mitchell, 1992). To determine a nutrient budget for a lake, values need to be derived for inflow and outflow rates, run-off, precipitation, and contribution by the sediments. If climate warms and lake levels drop then there are more sediments exposed to shore wave action, but also more sediments underlying a very shallow water column. There is a greater chance to warm the water column and warm the sediments. Warmer water holds less oxygen than colder water. Phosphorus is easily released from the sediments in anoxic conditions. During the assessment on the water quality of Moose Lake, a mass balance approach was used to determine internal versus external contributions of phosphorus to the lake (Mitchell, 1992). Sewage input was considered negligible (see below), outflow losses were considered negligible. Flow-weighted phosphorus concentrations for inflow streams were calculated (equations based on studies done at other lakes) and phosphorus input via precipitation were calculated (again based on equations derived from other studies). Finally, it was determined that internal loading is the major component of the nutrient budget in Moose Lake (Mitchel, 1992; Reid Crowther, 2000). Restoration work could involve removing phosphorus-rich water from the lake bottom as has been successfully completed at Pine Lake. However, before any restoration technique is attempted a thorough diagnostic study should be done (Reid Crowther, 2000). Internal nutrient cycling, or sediments as a major nutrient source, is a very common problem of many shallow, productive lakes, but the actual contribution for this lake and in the different bays of the lake is unknown. It is also important to note that a large proportion of the internal nutrient loading came originally from external sources. Therefore, it is important to identify and minimize current external loading to the lake.

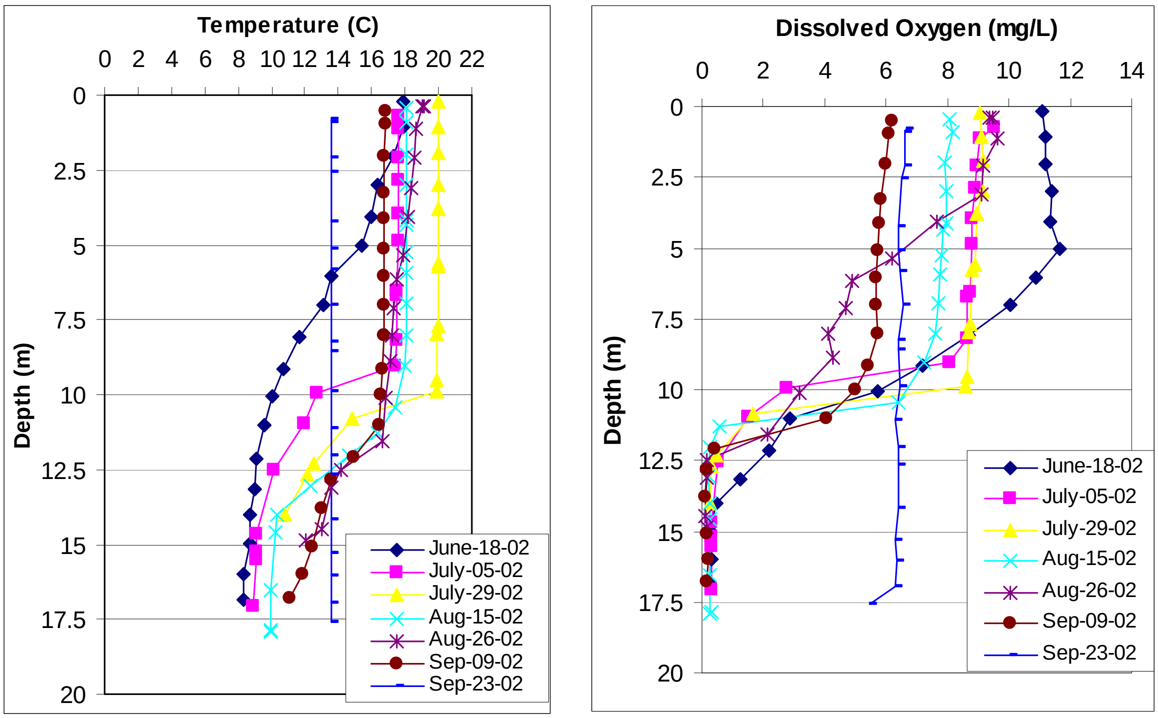

Figure 7. Temperature and Dissolved oxygen profiles form Moose Lake between June and September 2002 (ALMS, 2002).

A septic leachate survey was conducted on this lake in the early 1990's (Mitchell, 1992). Twelve shallow water stations were sampled around the lake including Franchere Bay, Bonnyville Beach Bay; Vezeau Bay and Pelican Narrows. All stations, except two, had nutrient concentrations within background conditions. The two stations with elevated nutrient concentration were near creeks that drain agricultural areas. Agricultural run-off may be causing slightly elevated nutrients and bacteria. However, further investigation of run-off and contributing streams is required since the cause of the elevated nutrients and bacteria could not be linked exlusively to leaking septic systems or to agricultural runoff. Sewage, at the time of the study (1992), was not a major problem to nutrient loading, as it was estimated that it only contributed <1% of total external supply. However, nutrients contributed by septic systems are in a bio-available form for immediate use by algae and plants, whereas nutrients contributed through run-off or precipitation are not in an immediately bio-available form for primary production. Follow-up studies may be needed to identify leaking or malfunctioning septic systems.

Caffeine is used as an indicator for human waste detection in the natural environment. Caffeine is not used in agricultural operations nor is it found in any North American plants. Humans consume caffeine through a variety of drinks, food and medical products. Caffeine in the aquatic environment can only come from untreated human sewage and is an ideal tracer of this contaminant. Moose Lake was sampled in August 2004 for the presence of caffeine in the surface waters (Aquality, 2005). Samples were collected offshore of developments or parks around the lake. Caffeine was not detected in any of the samples. A "non-detect" does not necessarily indicate that caffeine, or human waste, is not in the water because the degradation rate and chemistry of caffeine is complex. Caffeine degrades very quickly in sunshine and during dry periods, there is no runoff water that could enhance seepage from septic tanks. As a follow-up, Aquality recommended that additional samples be taken during or just after heavy rainfall events to eliminate the latter possibility.

4.1.1.1. Summer Patterns

Water quality in a lake can be measured from a composite sample of water collected all over the lake or from discrete samples taken from multiple stations and analyzed individually. The first approach gives an overall assessment of the lake. The latter approach can be used to identify problem areas in a lake. In the previous sections, Moose Lake was quantified as eutrophic but the ultimate value came from analysis of composite samples with one value being reported. From a study done in 2003 we know that out of the three bays on Moose Lake, Franchere Bay is the most fertile and Vezeau Bay, location of the Town of Bonnyville raw water intake, is the least fertile (Figure 8) (New Paradigm, 2003). Seven tributaries flow into Moose Lake. Most of these are intermittent and only flow during high runoff events. Two exceptions, Thinlake River and Valers Creek typically flow year-round.

In Moose Lake, water circulation is not strong enough to move warm oxygenated water much deeper than about 10m during summer. As a result, and in conjunction with high biological decomposition at the lake bottom, oxygen concentrations were often under guidelines below 10m in depth (Figure 7). Water column stratification usually occurs from late June to early September, followed by a breakdown in stratification in response to cooler weather (Figure 7), but data from 2003 indicated that the lake did not stratify (ALMS, 2003). Instead of stratification or non-stratification of the whole lake in one summer season versus another it is more likely that there are spatial differences within Moose Lake. The study by New Paradigm Environmental Services illustrated that there are differences in nutrient, chlorophyll and cyanobacterial toxin concentration across the lake in one summer (Figure 8).

Moose Lake water develops seasonal patterns in clarity (Figure 9). The best water clarity in Moose Lake occurs in late spring/early summer. At this time secchi disk depths can be as deep as 4 to 5 m. Water clarity then decreases to its lowest in late summer (late Aug / early Sept.), when Secchi disk depths have been as shallow as 1 m.

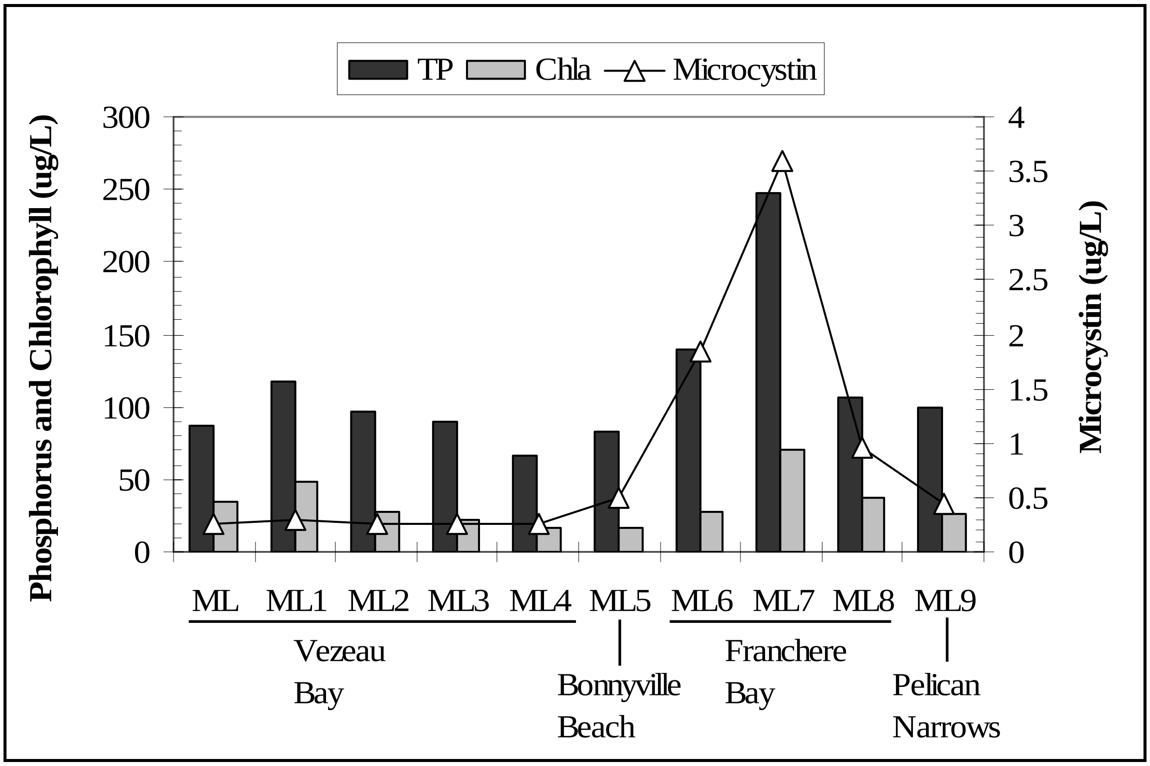

Figure 8. Spatial distribution of phosphorus, chlorophyll and algal toxins in Moose Lake 2003. Modified from New Paradigm (2003)

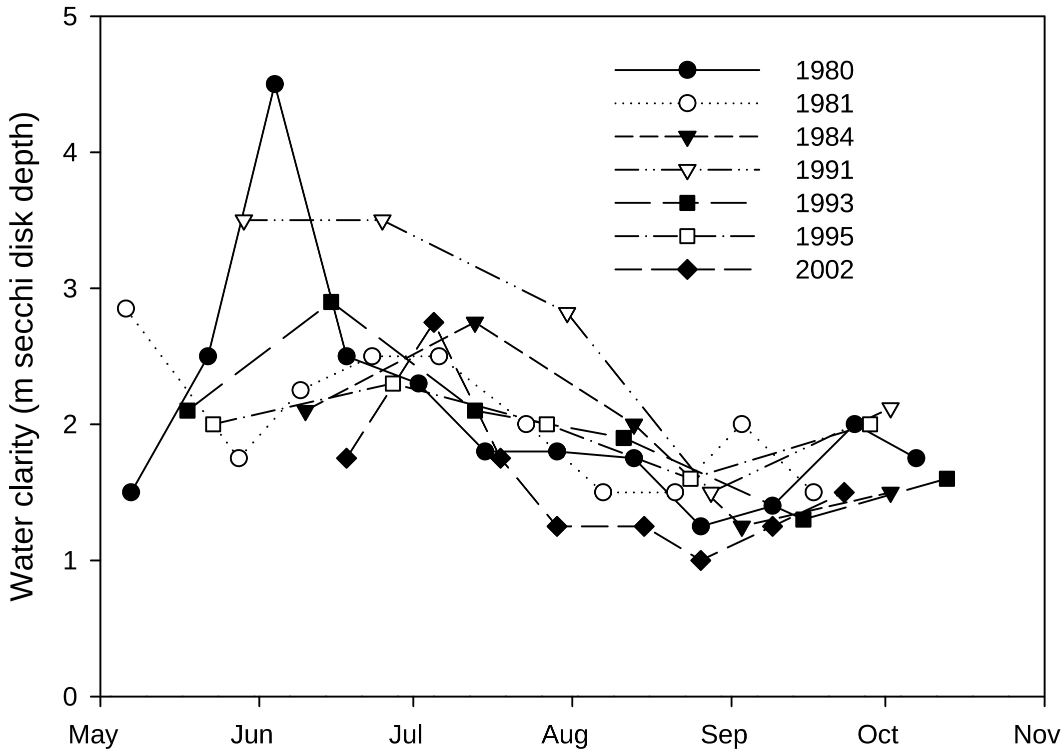

Figure 9. Water clarity variation in Moose Lake.

Phosphorus is the most important nutrient limiting the growth of most organisms in lakes. Thus, total phosphorus concentration (Total P) is often used as a measure of a lake's capacity to produce biological matter. Even a slight increase of phosphorus in a lake can, given the right conditions, promote algal blooms causing the water to turn green in the summer and impair recreational uses. In Moose Lake, total P is lowest in late spring / early summer and increases gradually up to late summer, when it is highest (Figure 10, early September). Over this time, total P generally doubles. An increase in total P over the summer normally indicates increased P inputs from sediment where thermal stratification is weak.

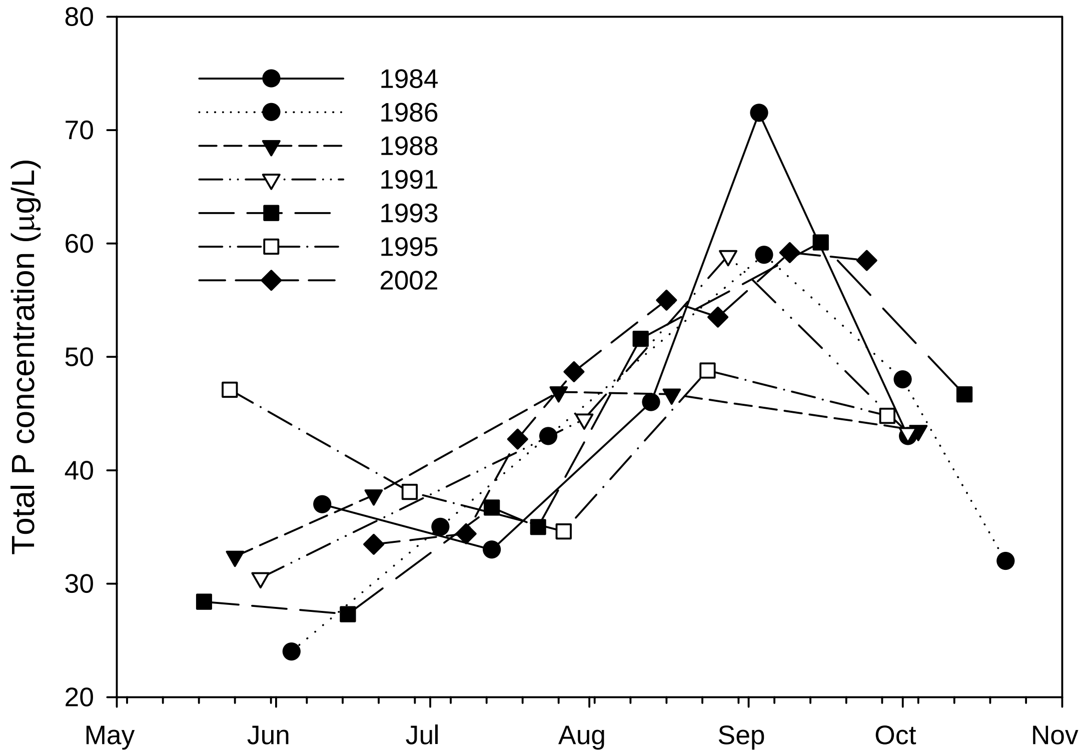

Figure 10. Summer productivity (total P concentration) variation in Moose Lake.

Residents and users of Moose Lake have long been concerned about the quality of the water and the presence and excessive abundance of floating algae (Alberta Municipal Affairs, 1976; Runge 1977) and management plans have addressed these concerns through goals to maintain or improve water quality (Alberta Municipal Affairs, 1979; Municipal District of Bonnyville, 1985). Chlorophyll *a* is a photosynthetic pigment that green plants, including algae, possess enabling them to convert the sun's energy to living material. Chlorophyll *a* can be easily extracted from algae in the laboratory. Consequently, chlorophyll *a* is a good estimate of the biomass of algae in water. Earlier studies on Moose Lake indicated high levels of chlorophyll *a* in the lake, but no further description of the phytoplanktonic composition was given (Gallup, 1977). Even in the 1970's, the algal concentration in Moose Lake was high in comparison to other lakes in Alberta. In Moose Lake, algal biomass follows patterns similar to total P (Figure 11). It is lowest in late spring / early summer and generally triples up to late summer (early September). Other studies confirmed that Moose Lake had abundant phytoplankton but there was no evidence that water quality or algal standing crop had increased over the last few decades (Alberta Environment, 1989; Mitchell, 1992; ALMS, 2003). Furthermore, Moose Lake experiences high variability in year to year abundance of phytoplankton which is a common trait for eutrophic lakes (Mitchell & Prepas, 1990).

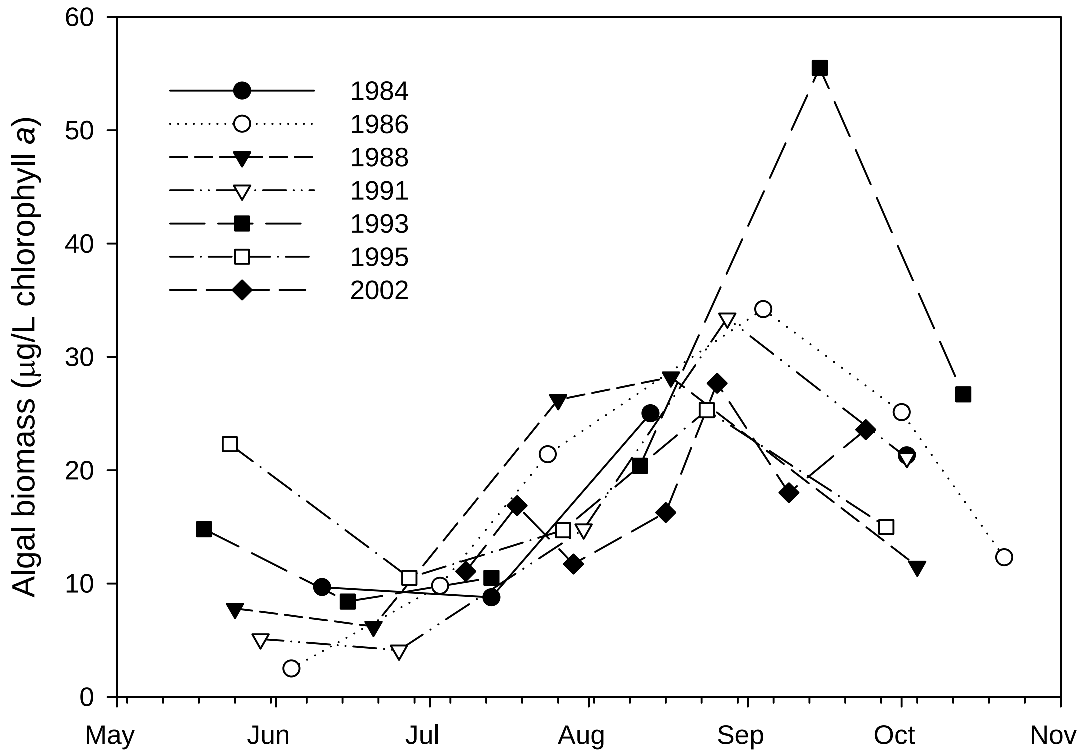

Figure 11. Summer greenness (algal biomass) variation in Moose Lake.

4.1.1.2. Changes over Time

Trends in water quality were examined over the past two decades using statistical trend analysis techniques. Overall, dissolved ions and associated parameters (e.g., sodium, magnesium, chloride, potassium, sulphate, carbonate, bicarbonate, alkalinity, pH, hardness, conductivity, total dissolved solids) increased significantly over the past two decades (Table 4). In brief, Moose Lake has become more concentrated with salts. Most indicators of lake fertility (e.g., total P, greenness) have not changed (Table 4, Figure 12), except for decreasing nitrate/nitrite concentrations. The lack of fertility change is consistent with little watershed disturbance over a similar time frame. These results are consistent with those of most lakes in the Beaver River Basin (T. Charette, unpubl. rep.).

A significant overall increase in ions and salinity over the past two decades reflect the fact that, due to drier climate over the past two decades, many lakes in the area have properties similar to evaporating pans, with little inflow and outflow. As less fresh water enters Moose Lake, flushing of "old" waters is reduced and solutes become concentrated. Indeed, the more water levels have decreased over the past two decades, the more saline Moose Lake has become (Figure 13). Lakes in the Beaver River Basin with stable water levels had stable ions/salinity over time (T. Charette, unpubl. rep.). Most of these water bodies had very large contributing areas, or watershed areas compared to their surface areas, indicating the potential for significant freshwater supply. Increased salt is often a sign of lowering lake levels, such as those in Moose

Lake (Figure 3), which results in part from consistently lower inflows as compared to evaporation. Moose Lake water now has total dissolved solid levels indicative of a slightly saline system (Mitchell & Prepas 1990).

Table 4. Significant changes in water quality over the last two decades in Moose Lake. ↑ = significant positive trend, ↓ = significant negative trend, "nd" = trend not detected.

Parameter	Trend	Parameter	Trend
Total P	nd	HCO_3	↑
Algal biomass (Chl. *a*)	nd	CO_3	nd
NO_{2+3}	↓	Hardness	↑
Na	↑	Alkalinity	↑
Cl	↑	Conductivity	↑
Mg	nd	TDS	↑
Ca	↑	pH	↑
SO_4	↑		

Note: Trends were deemed significant at a 95% confidence level. Chl. *a* = chlorophyll *a*, NO_{2+3} = nitrate+nitrite, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulfate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate, TDS = total dissolved solids

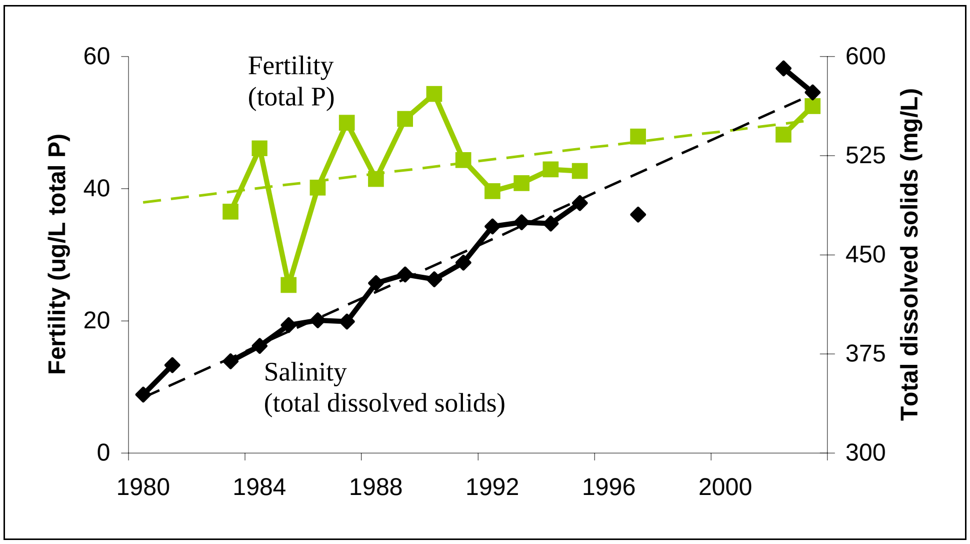

Figure 12. Trends in fertility and salinity in Moose Lake, 1980 to 2003.

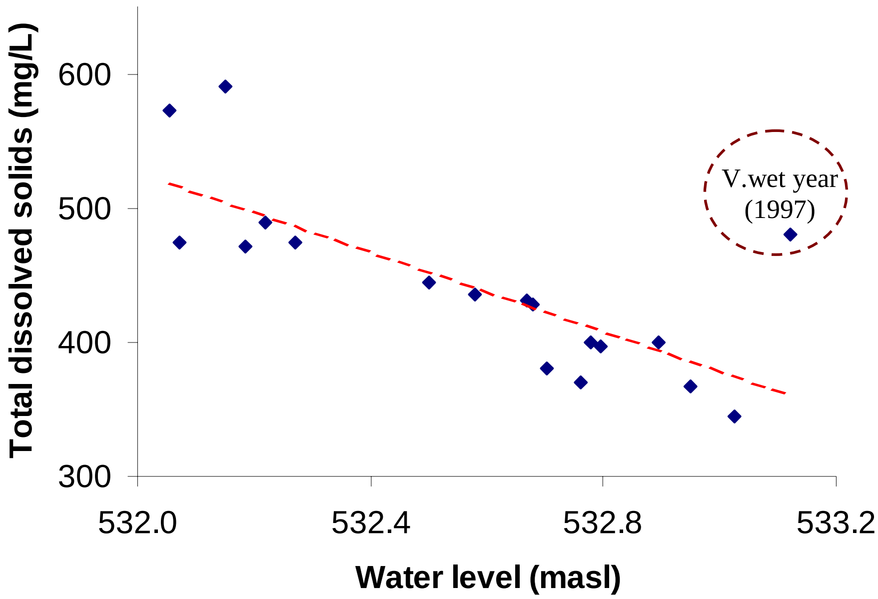

Figure 13. Relationship between salinity (measured as total dissolved solids) and water levels of Moose Lake.

4.1.2. Watershed Land Cover

Precipitation not absorbed into the soil is carried through surface run-off to lakes and wetlands. Water that is absorbed by land filters down into the underground aquifer. The surface and groundwater sources contribute to the quantity and quality of water in a lake basin. Since water flows through landscape features before it enters aboveground or underground aquifers, any changes or alterations that are made to the natural landscape or to the flow of water on the landscape could potentially have an effect on downstream sources. There is much research being done on the link between landscape alterations and water quality (e.g., Carignan & Steedman, 2000; Devito et al., 2000). Studies from Eastern and Western Canada are demonstrating that the land-water linkages differ between regions and even between catchments within the same regions. One reason is the sensitivity of soil to change. Sensitivity of land and receiving basins is complex but is determined, in part, by parameters such as degree of alteration, acid buffering capacity of soils, proportion of ground water versus surface water in the total water budget, and size of the watershed in relation to the size of the open water body.

Current and historical land cover in the Moose Lake watershed was examined to investigate linkages between this landscape and patterns in water quality. Ducks Unlimited and AAFC-PFRA (Agriculture and Agri-Food Canada, Prairie Farm Rehabilitation Administration) provided interpretation of satellite imagery of this watershed as a means to classify the land cover based on vegetation. Satellite images from 1986 and 1988 (DUC) and 1994 (PFRA) were interpreted for land cover. The goal was to delineate watershed area and total land cover for different land classifications. Distinctions must be made between: a) entire watershed area and land base, b) disturbed versus undisturbed lands and c) agricultural versus non-agricultural lands (pers. comm., C.Vanin, PRFA). Disturbed lands include cropland (arable lands, including annually cropped lands and tame forages or improved pasture), settlement and cleared lands. In the DU land classification system, cropland was lumped as one classification with no distinction of tame/seeded forages. In the PFRA classification system, cropland and tame forages were split to reflect arable lands with permanent or perennial cover. Undisturbed land is defined as native habitat or native vegetation and includes grasslands (native or unimproved pasture or non-arable land), shrubs, trees and wetlands. A problem with classifying lands as “agriculture” is that they may include cropland, grasslands, shrub, trees and wetlands and also encompass both undisturbed and disturbed land.

To simplify the interpretation and classification of the images, land cover was condensed into two classes (disturbed and undisturbed) and expressed as a percentage of the watershed. There was little change in the land cover of the Moose Lake watershed from 1986 to 1998 (pers. comm.., C. Vanin, PFRA). Most of the disturbance occurred prior to the past two decades as only 4% of the watershed changed from undisturbed land to disturbed between 1986 and 1998. Land classification using the two classification systems are summarized in the following figures (Figure 14, Figure 15). The total area of the watershed is 93,111 ha (91% land 9% water). This equates to 84,581 ha of land separated as:

A) Disturbed Land (49,702 ha; 59% of land base):
- Cropland (50%)
- Settlement (5%)
- Cleared Forest (3%)

B) Undisturbed Land (34,879 ha; 41% of land base):
- Grasslands (3%)
- Wetlands (2%)
- Shrubs (3%)
- Trees (33%)

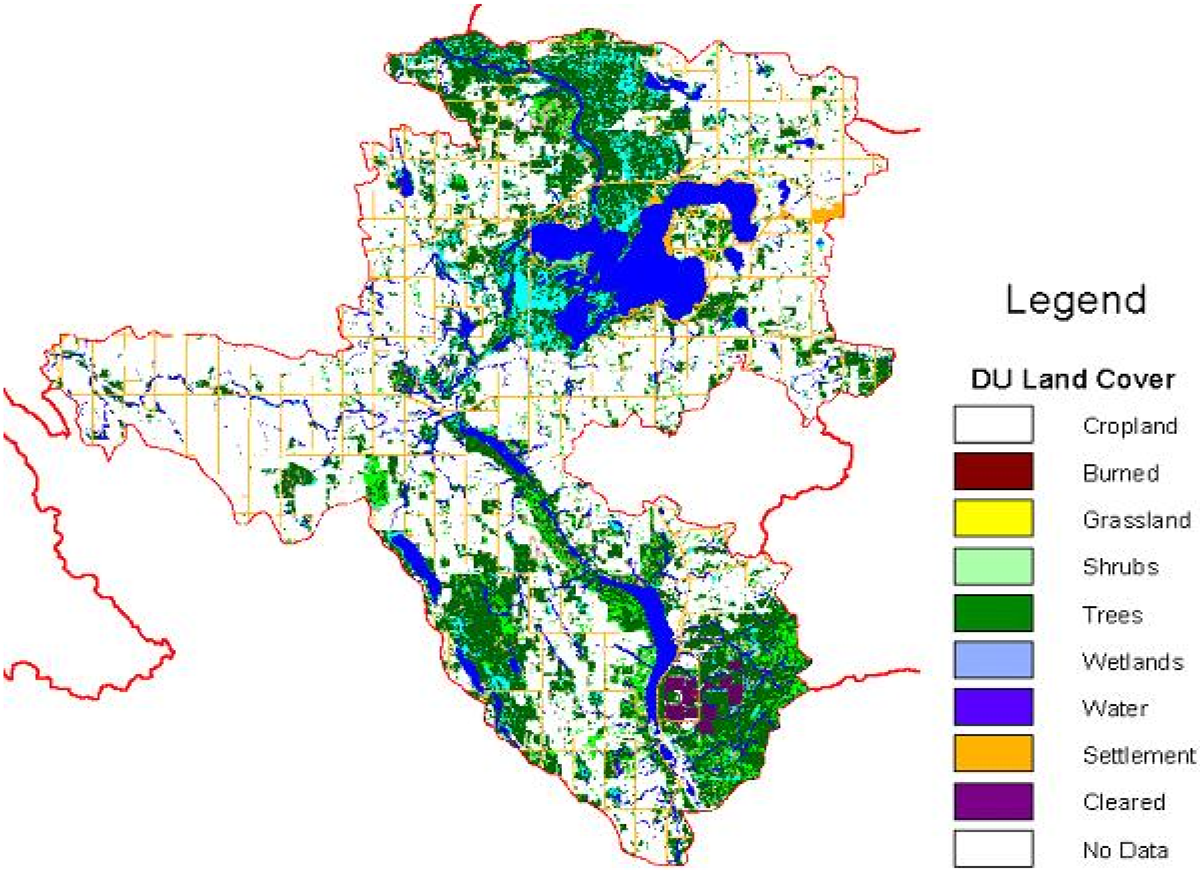

Figure 14. Moose Lake watershed, 1:50,000 Land Cover 1998. Source: Ducks Unlimited Canada and AAFC-PFRA.

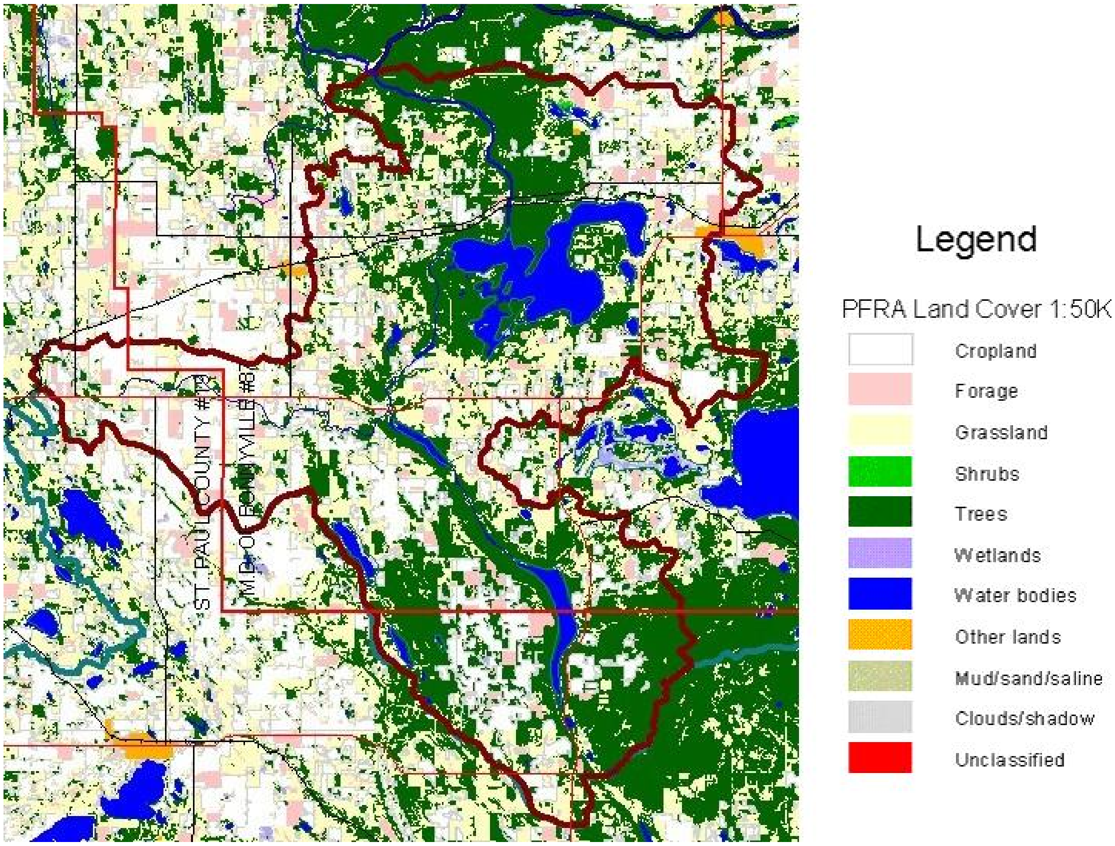

Figure 15. Moose Lake watershed, 1:50,000 Land Cover 1994. Source: AAFC-PFRA.

4.2. Aquatic Resources

4.2.1. Fisheries

Moose Lake has supported commercial fish harvests since the 1940's but was also well known as an excellent sport fishing lake in central Alberta (McDonald, 1967; Sustainable Resource Development, 2004). Species supported by this lake include Walleye, Cisco, Northern Pike, White Suckers, Longnose Suckers, Lake Whitefish, Burbot and Yellow Perch. Whitefish populations in the lake are limited by the summer oxygen concentrations in the hypolimnion. Walleye, Northern Pike and Yellow Perch are the most popular species for recreational fishing, while Lake Whitefish and Cisco are preferred for Aboriginal subsistence. Important habitat for these fish includes the littoral region (spawning, feeding, young-of-the-year rearing), inflowing streams and deep, cool oxygenated hypolimnetic water.

The major fish species within Moose Lake grouped into cold-water species, Lake Whitefish and Cisco, and cool-water species, Northern Pike, Walleye and Yellow Perch. Optimum water temperature for the cold-water species is between 5 to 18 ^{o}C and between 10 to 25 ^{o}C for the cool-water species. Epilimnetic (0-8 m) water temperatures often exceed 18 ^{o}C from mid July to mid August. Potential habitat for cold-water species is limited in the summer months. Of the major fish present in this lake, Yellow Perch can best tolerate low oxygen concentrations.

Important spawning and feeding habitat is in the littoral zone of lakes (shallow waters near the lake edge) and in the streams. Submersed plants within these shallow regions provide food, spawning substrates and habitat for invertebrates, frogs, and forage fish. The "weedy" areas are important habitat. Streams provide surface water connectivity to wetlands that are used as spawning and rearing habitat. Blockages of streams or low water conditions effectively remove critical fish habitat and potential fish productivity of a lake. Some land use practices and shoreline development have altered the natural state and ecological functioning of shorelines (Sustainable Resource Development, 2004). These practices result in loss of fish and aquatic habitat and decreased water quality.

The status of the major fish species populations have been summarized (Table 5). This information has been summarized from a fisheries report prepared by Alberta Sustainable Resource Development (Sustainable Resource Development, 2004). Most fish populations are in serious trouble. Even by the mid 1980's, lakes were starting to experience significant declines in fisheries. The two predominant causes for these declines are harvests exceeding production levels and the early trend of decreased water levels.

Fisheries health of lakes in this watershed is below the level to accommodate the demands for Aboriginal, recreational and commercial fisheries. All existing fisheries need to be recovered to optimal productive capacity. This can be achieved through combined efforts of controlling harvest and maintaining, or improving, the health and integrity of the water quality, water quantity and habitat.

Table 5. Summary of the population status of the major fish species in lakes of the Moose Lake Watershed. Summarized from Sustainable Resource Development (2004).

Major Fish Species	Bangs Lake	Chickenhill Lake	Kehewin Lake	Moose Lake
Northern Pike	Collapsed	Vulnerable	Collapsed	Vulnerable
Walleye	Collapsed	Collapsed	Collapsed	Vulnerable
Yellow Perch	Low	Low	Unclassified	Unclassified
Lake Whitefish		Unclassified		Unclassified
Cisco			Unclassified	

4.2.2. Wildlife

Water-associated bird species and populations in the Moose Lake watershed area were surveyed, in relation to habitat, in the 1980's and again in 2003 (Nelson, 2004). There were five general habitat types described. 1) open water; 2) non-vegetated beaches; 3) emergent vegetation; 4) shoreline vegetation; and 5) backshore vegetation. On the three main lakes in the Moose Lake watershed, the number of water-based birds and species generally rose between 1980 and 2003 (Table 6). However, across this same 23 year period, within the larger Cold Lake – Beaver River Basin, there was a decrease of almost 50% in the number of water based birds observed and a very small increase in bird diversity, in large part due to the region drying trend. The decrease in white-winged scoter, lesser scaup and coots and the increase in pelicans and cormorants are consistent with continental and regional populations changes, respectively (Rippin, 2004).

At Moose Lake and Chickenhill Lake (within the Moose Lake Watershed) the number of individual birds and number of bird species increased from the 1980 survey to the 2003 survey. Water levels had dropped somewhat at Moose Lake and very markedly at Chickenhill Lake. At Kehewin Lake, the number of individual birds decreased, the number of bird species increased but lake levels were interpreted to have been relatively stable between the two time periods.

Marsh wetlands or shallow lakes with extensive marsh cover can support abundant wildlife however these types of habitats are most susceptible to declines in water levels (Rippin, 2004). Deep lakes have overall less variability in habitat change over time but under drought conditions, decreased water levels in these deeper lakes may result in improved habitat for some wildlife (Rippin, 2004). Declined lake levels expose new shallows with more opportunity for emergent vegetation for foraging and nesting (Nelson, 2004).

On Kehewin Lake, the distribution and composition of shoreline vegetation was unchanged, on Moose Lake the shoreline vegetation was only slightly changed, and on Chickenhill Lake the shoreline vegetation was dramatically changed because of the very extensive drawdown of the lake level. There has been an increase in recreational activity on Moose Lake including additional cottage development, boating, angling and swimming. The combined effect of all these activities will at some point approach the capacity of the lake to maintain water levels, maintain aesthetic values and maintain wildlife habitat.

Table 6. Summary of changes in the main water-based bird numbers in the Moose Lake Watershed from 1980 to 2003. Modified from Rippin (2004).

Lake	**Kehewin**		**Chickenhill**		**Moose**	
Species	1980	2003	1980	2003	1980	2003
White Pelican	4	151	0	4	31	191
Common Tern	3	0	0	13	31	119
D.C. Cormorant	0	32	0	42	0	14
C. Goldeneye	14	18	6	2	8	108
Mallard	400	56	23	32	445	42

Lake	Kehewin		Chickenhill		Moose	
B.W. Teal	6	6	25	9	219	34
L. Scaup	12	4	24	0	273	2
Franklin's Gull	70	103	0	0	217	1591
R.N. Grebe	5	47	4	19	39	195
W.W. Scoter	75	0	33	0	64	8
Total Birds	776	566	144	283	1859	2620
Total Species	19	23	13	24	25	33

Along with the water-based birds, at the smaller wetlands in the watershed, muskrats have mostly been displaced as these wetlands dried up during the recent drying trend. Similarly, as lake levels dropped and creeks became intermittent or dry, the number of beavers in the watershed also dropped markedly.

During the past two decades a number of wildlife species have experienced increases due to a variety of factors not directly related to water or drought. Osprey (conspicuously at Moose and Kehewin Lakes) and common ravens have increased, perhaps as a result of less shooting. Cougars have become resident in the broad area from Edmonton to the Saskatchewan border, probably because of historically high numbers of white-tailed deer. Also, the numbers of mule deer and moose have increased considerably, apparently because of the long string of "soft" winters that have allowed good over-winter survival. Hunting seasons are being adjusted to try to "level off" the increases in deer and moose through this broad area, to reduce vehicle strikes, agricultural depredation, and starvation losses from occasional hard winters.

A variety of land use activities harm wildlife species. Agricultural clearing of forested land and riparian vegetation along creeks and wetlands eliminates a number of species of birds, amphibians, and mammals. Drainage of wetland similarly is disastrous for many species. Lakeside cottaging and associated disturbance of vegetation on shorelines and in shallows also removes habitat that is valuable for a number of species. And power-boating near bulrush and cat-tail beds can be terribly destructive of the floating nests of grebes and several other less conspicuous waterbirds. In general, in the Moose Lake watershed a wide variety of wildlife species, both water-based and upland-based, persist today despite wide-spread human-caused and drought-caused changes on the landscape. If these changes continue, not only will the numbers of individuals of many species be further reduced, but it will become more important (and more difficult) to mitigate disturbances in order to allow more sensitive species to survive here. Within the watershed, wildlife provide many benefits and are attractive, interesting, and valuable indicators of environmental health.

4.2.3. Riparian

Water levels in Moose Lake have generally decreased by about 1 metre since 1980, however many other lakes have had much greater changes in water level. A broad band of forest cover has been retained along the upstream inlet and this may have protected Moose Lake from extreme or dramatic yearly changes in water level (Rippin, 2004). The retention of the native tree cover has allowed the watershed to maintain some of its ecological integrity. The forested land and riparian areas along Thin Lake River may have minimized loss of surface water and disturbance due to erosion. Conditions in Moose Lake may be very different as this important habitat and portion of the watershed is lost to disturbance.

In 2004, the Alberta Conservation Association assessed the health and integrity of the Moose Lake shoreline through aerial surveys (Table 7). A visual assessment of the shoreline for total vegetation cover, amount of shrub cover, emergent vegetation cover, disturbed area and removed vegetation was made.

An assessment was made for the entire shoreline of Moose Lake and the more intensely used area of the Summer Village of Pelican Narrows. Almost two-thirds of the shoreline around Moose Lake is healthy but almost one-quarter of it is highly impaired (Figure 16). As a whole functioning unit, the lake should be able to respond to water runoff and water level fluctuations. However, there are severe problems along short sections of the shoreline where there has been intense development. The summer village of Pelican Narrows was assessed using the same methods. This short section of shoreline, 4 to 5 km, does not follow the pattern of the entire lake. Most of this stretch of shoreline is highly impaired (Table 7; Figure 16). Since there is such a high proportion of altered shoreline in this small region there is significantly reduced capacity for this area to respond to runoff events. If the same amount of highly impaired shoreline was distributed around the entire lake, as opposed to one small area, there would be much less cause for concern.

Table 7. Results of 2004 shoreline assessment of Moose Lake by Alberta Conservation Association (Draft material ACA).

Assessment	Moose Lake Shoreline	Pelican Narrows Shoreline
Healthy	63 %	11 %
Moderately Impaired	13 %	19 %
Highly Impaired	24 %	70 %

It is often wondered how much the public understands about the linkages between riparian health and a healthy, functioning aquatic ecosystem. In 2004, the Alberta Conservation Association led a survey to determine the user's perception about the quality of Moose Lake. Participants were asked to rate the importance of water level, riparian areas, waterfowl and wildlife, fishing quality, water clarity and a variety of other characteristics. This survey was based on one completed earlier on Vincent Lake (McMillan, 2000; Bateman, 2003). The survey was given to residents of the Summer Village of Pelican Narrows. Results from that survey are currently unavailable but should be available to any interested party after early April 2005 (B. Mills, pers. comm., ACA). The results of the survey need to be presented to the Summer Village participants before they can be released to the public. However, when the Moose Lake Watershed Management Plan is being develop, the Moose Lake user's perception survey report should be reviewed and considered.

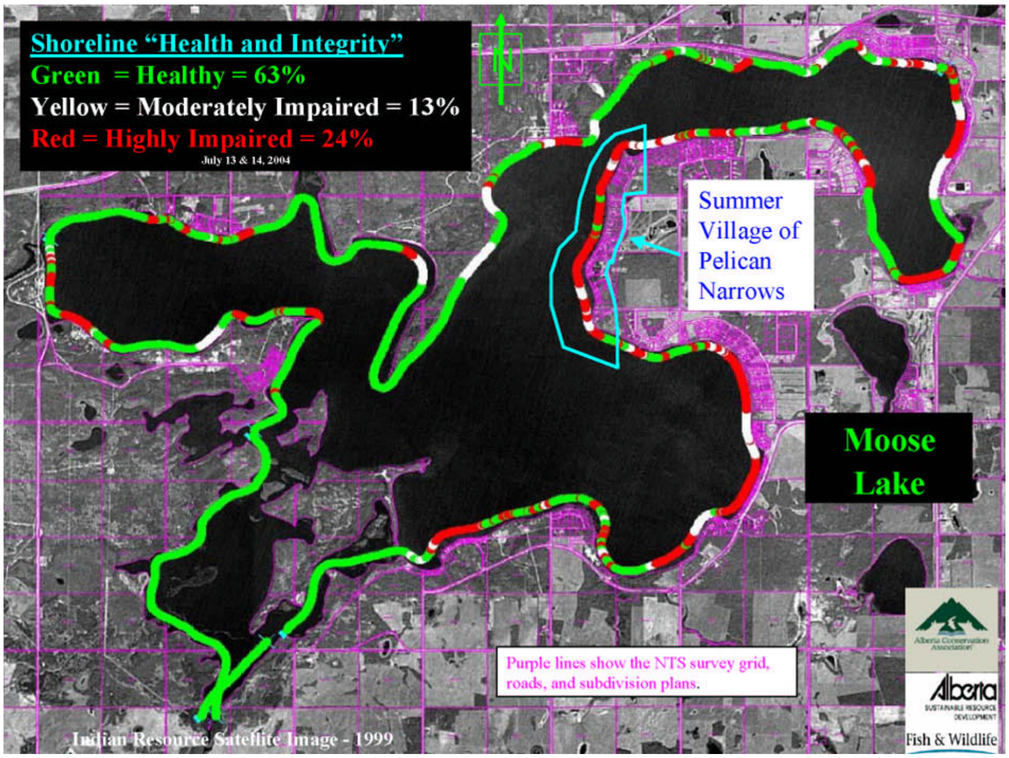

Figure 16. Shoreline health and integrity assessment, 2004. Draft material from ACA.

5. DATA GAPS

Many technical reports, summary reports and other information sources were reviewed in order to develop this report. Despite the quantity of information that was available to develop this report, there is still a significant amount of information that is required to develop a comprehensive integrated watershed management plan.

Information that is currently missing and is thought to be essential to better understand this complex ecological system is summarized below.

- **Surface and groundwater contributions.** A complete hydrology assessment is currently underway for the entire Cold Lake – Beaver River watershed. In order to understand the natural dynamics of Moose Lake and to determine total allowable water withdrawals, the quantity of water supplied by ground and surface water sources must be known. Models for the Cold Lake – Beaver River basin are not publicly available yet, but initial interpretation suggests that Moose Lake is a discharge lake (CLBR Technical Team, 2004a). There is little groundwater discharge on a month to month basis but there is a positive contribution over the long-term. Although stream inflow and outflow rates have not been directly measured, surface water contribution to Moose Lake is estimated based on measured streamflow and runoff in a similar, nearby lake. These proxy rates are used to estimate surface runoff yields, precipitation, evaporation, lake outlet flow and simulated lake levels (CLBR Technical Team, 2004a). The simulated lake levels for Moose Lake show good correlation with actual measurements, therefore, estimates of surface water runoff to the lake are also considered good.

- **Surface and groundwater quality.** Along with determining the quantity of water entering and leaving this watershed, the quality of the water must also be known. To completely assess impacts to water quality and potential for reducing additional loading rates the current condition of water quality entering the water must be determined. Nutrient loading from tributaries is currently unknown. Groundwater quality was assessed and aquifer sensitivity maps were developed to identify areas that may potentially release contaminants (CLBR Technical Team, 2004b). The sensitivity maps are currently unavailable for public viewing but they should be consulted during the preparation of the Moose Lake Watershed Management Plan.

- **Total nutrient budget for the lake.** Moose Lake is eutrophic. The sources of nutrient inputs need to be determined and quantified. Sources to consider include nutrient loading from tributaries, sewage effluent inputs and internal loading from the sediments. Quantification of nutrient loading via tributaries was previously recommended (Reid Crowther, 2000). Since there has been continued increase use of the lake over the last 14 years, another septic leachate survey should be conducted to determine if there has been any change in the contribution of sewage effluent to the lake. Nutrients in sewage are in a bio-available form and are readily used by algae and aquatic plants but sewage effluent also contains bacteria that can be harmful to human health. Previous studies suggested that internal loading from the sediments was the major source of nutrients in the lake but it has not been quantified. The contribution of the various sources to the annual nutrient budget needs to be quantified before management recommendations can be made.

- **Human use in the watershed.** Updates on the human populations and use in the watershed, in and around the lake are required. To address this issue, data should be collected on the number of seasonal/permanent cottages, private campground utilization rates, number of lake users per day, and use of water and sewage treatment facilities. Surveys could be sent to all residents of the lake and to all users of the lake through the campgrounds to gather information to address this data gap.

- **Link between landuse and water quality.** The initial land use plan (Alberta Municipal Affairs, 1979) recommended an investigation of the links between land use around Vezeau Bay and the water quality in Vezeau Bay. No such study or report has been completed or undertaken. Since this is the source drinking water for the Town of Bonnyville, it is still recommended that a comprehensive study investigating seasonal changes in water quality and land use changes be conducted. GIS techniques should be used to quantify land cover and land use changes. The quality of water in relation to the water intake pipe should also be investigated. The ideal location of the intake pipe would be below the euphotic zone, above the thermocline and approximately 150-200m from its existing location (Reid Crowther, 2000). Further sampling and testing of source water is required before any changes to the location of the intake pipe are made (Reid Crowther, 2000).

- **Water quality.** In the water management planning process, water quality must be managed in conjunction with other natural resources.
    - **Pre-development water quality.** Palaeolimnology is the study of lake development. A comprehensive palaeolimnological study will provide information on lake level fluctuations, nutrients, aquatic productivity, aquatic community structure, riparian habitat and land cover. Remains of algae, invertebrates, seeds and pollen are studied from lake sediment cores. Multiple points in the lake should be assessed and both long-term (post-glacial) and short-term (post *ca.* 1850) assessments should be made. Results from this type of study can be used to establish pre-development water quality.
    - **Spatial variability in the lake.** Previous studies have suggested that there are spatial differences in water quality parameters. Further work should be done to determine how water quality varies both spatially and seasonally. It should be determined if problem areas are always the same or if there is variability in the "hot-spots" over the season. Types of parameters that could be analyzed in a spatial and seasonal study include dissolved oxygen, temperature, phosphorus, nitrogen, chlorophyll, algal toxins, human sewage indicators and adjacent land use.

- **Wetland cover.** The type and distribution of wetlands in the watershed is unknown as well as the type and area of wetlands that have been lost. There needs to be a comprehensive evaluation of previous land cover of wetlands, uplands and riparian areas as well as current land cover of the same. This would provide information on potential areas for wetland and land restoration if critically areas are identified.

- **Fisheries.** As suggested by SRD (2004), fisheries management plans need to be basin specific in order to maintain the productive capacity of the waterbody. Requirements of all fish species need to be quantified for survival and then for population increase. Part of the basin specific planning process needs to determine if current fisheries could be maintained or even increased given the current water quality conditions, decreased water levels and shoreline alterations.

- **Wildlife.** There is a good summary of the waterfowl and birds in the watershed but there is no information on other wildlife in the watershed. Surveys on the ungulate, herbivore and carnivore populations should be made if maintenance of those populations will fall under the watershed management plan. Habitat for these upland wildlife species can be assessed as part of the land cover analysis. Recreational users and boaters may have an effect upon the survival of wildlife. Excessive boating activity can disrupt nests and cause some species to cease nesting and dogs off leash can disturb ground-nesting birds (Nelson, 2004). Investigations into the effect of recreational activities on wildlife can be done however; quantifiable effects are hard to measure (Nelson, 2004).

- **Riparian.** It is recognized that the shoreline in cottage dense areas is highly impaired. A survey, investigating people's perception about their use of the lake, alteration of shoreline, and the links of shoreline and disturbance to lake health has been conducted for Pelican Narrows. The final report was not currently available but should be consulted during the development of the watershed management plan (B.Mills, pers. comm., Alberta Conservation Association).

6. RECOMMENDATIONS AND CONCLUSIONS

Rippin (2004) best summarizes the problems associated with Moose Lake: The collective effect of recreational actions and activities on the lake is approaching the lake's capacity to maintain water level and quality along with aesthetic and wildlife habitat values. Many of the problems could be addressed with a comprehensive and integrated watershed management plan. However, there is also evidence to suggest that climatic factors have the largest influence of lake water level (CLBR Technical Team, 2004a). The combination of natural climatic variability and human use pressures on lake water quality and quantity need to be considered together.

The premise behind an integrated watershed management plan is that all stakeholders within a natural drainage basin will be involved in the planning, preparation and implementation of a management plan. All members have to be committed to the goals and objectives. The next step is for the Moose Lake *Water for Life* Committee and all other stakeholders within the watershed to develop a management plan that addresses some the issues identified in the management plan Terms of Reference (Water for Life, 2004).

Even though a large source of reports and experts were consulted during the preparation of this report, there are still some data gaps that need to be filled prior to the completion of a watershed management plan. The data gaps that need to be filled are summarized:

- The total contribution of surface water and groundwater to the hydrological cycle of Moose Lake needs to be quantified.
- Baseline water quality needs to be quantified using palaeolimnological techniques.
- The amount of riparian and wetland area lost through disturbance needs to be quantified
- A phosphorus nutrient budget, with total contributions from all sources, especially the sediments, needs to be developed.
- Human use of the lake and watershed needs to be determined.
- Accounting of all septic systems in use and confirmation that they are functioning properly is needed.
- During the development of the watershed management plan, the goals and objectives for fisheries and wildlife, as part of the functioning watershed, needs to be defined.
- A user's perception survey has been completed for one summer village but additional surveys should be considered for the remaining summer villages and campground users.

Work is currently underway to update the Cold Lake Beaver River Basin Water Management Plan. This is coordinated and managed through Alberta Environment. Planning efforts in the Moose Lake Watershed should align with the Management Plan being developed for the larger basin.

In addition to the generation of more data the following is required for watershed planning:

- **<u>Public outreach and education.</u>** The community around Moose Lake has been very active with public meetings and such but further environmental education is necessary to fully inform all users of lakes.

- **<u>Habitat protection.</u>** Through education and policy, aquatic habitat can be protected. Multiple benefits to habitat protection include less degradation of water quality, protection of drinking water sources, improved human health, better retention of water on the landscape, high capability of the landscape to moderate extreme climatic events, and improved reproductive success of fish and waterfowl.

7. References

Alberta Environment. 1989. Moose Lake A brochure prepared by Alberta Environment. Edmonton, Alberta. 12pp.

Alberta Environment. 1999. Framework for Water Management Planning. Alberta Environment. Edmonton, Alberta. ISBN No. 0-7785-1738-1

Alberta Geological Survey. 2004. Alberta Geological Survey, Geological Map of Alberta. http://www.ags.gov.ab.ca/GIS/gis_and_mapping.shtml

ALMS (Alberta Lake Management Society). 2002. Moose Lake – Lakewatch Report 2002. Editor: P.McEachern. The Alberta Lake Management Society Volunteer Lake Monitoring Report. 9pp.

ALMS (Alberta Lake Management Society). 2003. Moose Lake – Lakewatch Report 2003. Editor: P.McEachern. The Alberta Lake Management Society Volunteer Lake Monitoring Report. 11pp.

Alberta Municipal Affairs. 1979. Moose Lake Area Structure Plan. Prepared by: Regional Planning Section, Planning Services Division, Alberta Municipal Affairs. 20 pp.

Alberta Municipal Affairs. 2004. Municipal Profiles. Alberta Municipal Affairs. http://www.municipalaffairs.gov.ab.ca/cfml/profiles/index.cfm

Aquality. 2005. Results of caffeine testing in Moose Lake, August 2004. Prepared for: The Mosse Lake *Water for Life* Committee, Bonnyville Alberta. Prepared by Aquality Environmental Consulting Ltd. *Draft Document.*

Bateman, N.G. 2003. Vincent Lake Working Model Evaluation Report. Submitted to: Gerry Ehlert, Vincent Lake Working Group, St. Paul, Alberta. Submitted by: Nancy Bateman, NGB Evaluation Solutions, Inc., Lethbridge, Alberta.

Carignan, R. and Steedman, R.J. 2000. Impacts of major watershed perturbations on aquatic ecosystems. Can. J. Fish. Aquat. Sci. 57(Suppl. 2): 1-4.

CLBR Technical Team. 2004a. Surface Water Quantity and Aquatic Resources, State of the Basin Report. Prepared for: Cold Lake-Beaver River Basin Water Management Plan Update. Prepared by: Surface Water and Aquatic Resources Technical Team. *Draft Document.*

CLBR Technical Team. 2004b. Groundwater Quality, State of the Basin Report. Prepared for: Cold Lake-Beaver River Basin Water Management Plan Update. Prepared by: Groundwater Quality Technical Team. *Draft Document.*

Devito, K.J, Creed, I.F., Rothwell, R.L. and Prepas, E.E. 2000. Landscape controls on phosphorus loading to boreal lakes: implications for the potential impacts of forest harvesting. Can. J. Fish. Aquat. Sci. 57: 1977-1984.

Environment Canada. 1996. A National Ecological Framework for Canada. http://www.ec.gc.ca/soer-ree/English/Framework/default.cfm

Environment Canada. 2004. Canadian Climate Normals or Averages 1971-2000. Last reviewed 2004-02-25. www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html

Gallup, D.N. 1977. The Limnology of Moose Lake: An initial report including excerpts from studies of several other central Alberta lakes. Supervised and Edited by: Dr. D.N. Gallup, Department of Zoology, University of Alberta. Compiled by: J. Weisgerber and J. Rasmussen. Submitted to Alberta Environment, February 1977. 55 pp.

McDonald, D. 1967. Moose Lake Twp 61, Rg. 7, W4th. Internal Report. Fish and Wildlife Division, Alberta Forestry, Lands and Wildlife, Edmonton.

McMillan, B. 2000. Perceptions and Expectations of Lakeside Property Owners in Northeastern Alberta, Summary Report. Prepared for: Gerry Ehlert, The Vincent Lake Working Group, St. Paul, Alberta. Prepared by: Bill McMillan, Equus Consulting Group, Edmonton, Alberta.

Mitchell, P.A. 1992. Status Report on the Water Quality of Moose Lake. Environmental Quality Monitoring Branch, Environmental Assessment Division, Alberta Environment. 20pp.

Mitchell, P. and E.E. Prepas, eds. 1990. Atlas of Alberta Lakes. University of Alberta Press. 675pp.

Muncipal District of Bonnyville, 1985. Municipal District of Bonnyville No. 87, Moose Lake Area Structure Plan. Bylaw No. 923-1985. 10 pp.

Nelson, R.W. 2004. The State of the Cold Lake – Beaver River Basin, Water-based Wildlife Assessment. A summary report of waterfowl, birds and habitat in the Cold-Lake Beaver River Basin. Fish and Wildlife Division, Alberta Sustainable Resource Development.

New Paradigm. 2003. Moose Lake Water Quality Study, Town of Bonnyville. Presentation given to: Water for Life Committee, Town of Bonnyville. Prepared by: New Paradigm Environmental Services Ltd.

Nurnberg, K. G. 1996. Trophic state of clear and colored, Soft and Hardwater Lakes with Special Consideration of Nutrients, Anoxia, Phytoplankton and Fish. J. Lake Reserv. Man. 12(4): 432-447.

Provincial Planning. 1972. Interim Planning Report: Moose Lake Development Policy Plan. Provincial Planning Branch. 33pp.

Reid Crowther 2000. Town of Bonnyville Water Quality Study Final Report. Prepared for: Town of Bonnyville. Prepared by: Reid Crowther & Partners Ltd. October 17, 2000. Project No. 4371101.

Rippin, B. 2004. An assessment of change in habitat and associated wildlife on 28 lakes in the Cold Lake – Beaver River Watershed from 1980 to 2003. A review paper prepared as part of the development of the Cold Lake – Beaver River watershed plan update. E 5 Environmental Inc.

Runge, R. 1977. Moose Lake Management Study. Regional Planning Section, Planning Branch, Planning Services Division, Alberta Municipal Affairs. 73pp.

Runge, R.A. and Wilcox, C.V. 1976. Cottage Owner Survey: Moose and Muriel Lakes. Regional Planning Section, Planning Services Division, Alberta Municipal Affairs. 21 pp.

Stantec. 2005. Groundwater Quantity Report. Prepared for: Cold Lake-Beaver River Basin Water Management Plan Update. Prepared by: Stantec. *Draft Document.*

Sustainable Resource Development. 2004 Moose Lake Watershed Management Plan, Fisheries "State of the Basin Report". A brief and non-technical summary of the current fisheries information for Moose Lake. Fish and Wildlife Division, Alberta Sustainable Resource Development.

Trimbee, A.M. and E.E. Prepas. 1987. Evaluation of total phosphorus as a predictor of the relative biomass of blue-green algae with emphasis on Alberta lakes. Can. J. Fish. Aquat. Sci. 44:1337-1342.

Water for Life Committee. 2004. Moose Lake Watershed Management Plan, Terms of Reference. Prepared by Municipalities of the Summer Village of Pelican Narrows, Summer Village of bonnyville Beach, Town of Bonnyvile and The Municipal District of Bonnyville No. 87. 18pp. .

Welch, E.B. 1980. Ecological Effects of Waste Water. Cambridge University Press, Cambridge, England. 337 p.