Shoreline Study and Water Quality Assessment of Danford, McAuley and Shea lakes

A report presented to the Lakes Association of Kazabazua

by the Agence de bassin versant des 7 (ABV-7)

October 2016

This Report and its three annexes (a selection of photographs of Danford, McAuley and Shea lake shores, with comments in French) can be downloaded from LAK's website at www.kazlakes.com*

This is an abridged English version of the French report tabled by the agency ABV-7 in October 2016. In case of discrepancy between the original French and the English translation, the original French shall prevail.

*Translation of main terms used with photographs in Annexes:
Zone naturelle = No Use by Humans (Natural Vegetation Throughout)
Zone habitée = Zone Used for Construction Purposes
Zone fréquentée = Zone Used for Recreational Purposes
Zone d'infrastructure = Zone Used for Infrastructure

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Please note:
An asterisk* in the text refers to the short Glossary that follows the translation.

SUMMARY

In May 2016, the Lakes Association of Kazabazua mandated the Agence de bassin versant des 7 (ABV7 at www.abv7.org) to establish the characteristics of three of its nine lakes (Danford, McAuley and Shea) in order to determine the condition of their health. This research project had two objectives: to test the three lakes' water quality (in order to determine their trophic status) and to assess the condition of their shores. The three lakes are situated in the Municipality of Kazabazua, MRC de la Vallée-de-la Gatineau, Outaouais Region. Based on the information collected, ABV7 made the following diagnosis and is presenting in this report corrective and preventive measures to ensure preservation of these three lakes.

To assess the current condition of the shore, we used the Protocole established by the Quebec Ministry of the Environment and the Conseil régional de l'environnement des Laurentides (2007).

Danford Lake's shore has 60 so-called *homogeneous zones*[1], McAuley Lake 18, and Shea Lake 52.

Three (out of the five) categories of land use were identified on these three lakes:

1. No Human Use (natural vegetation throughout the zone), 4. Used for Buildings or for Recreational Purposes, and 5. Used for Infrastructure.

Category 4 ('Zone Used for Buildings or for Recreational Purposes') predominates on Danford (68%) and Shea lakes (60%), whereas Category 1 ('No Use by Humans') predominates (66%) on McAuley Lake.

On Danford Lake, 15% of the shore are insufficiently covered with vegetation (i.e. less than 40% natural vegetation). This percentage is 14% on Shea Lake and 13% on McAuley. On Danford Lake, 19% of the shore's natural vegetation are very disturbed (in over 60% of cases, this disturbance is due to bare soils or erosion, but especially to infrastructure). This percentage is only 2% on McAuley and Shea lakes.

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[1] *Translator's Note*:
According to the Quebec Ministry of the Environment's Protocole, five different so-called *homogeneous zones* can be identified on a lake shore, each zone being defined by the predominant use made of the land on the shore:

1. No Use by Humans (natural vegetation throughout);
2. Used for Agricultural Purposes;
3. Used for Forestry Purposes;
4. Used for Infrastructure (road, dam, railway, logging trail)
5. Used for Buildings (cottages, residences, others) or for Recreational Purposes (public access, camping, beach, public park).

The Protocole includes an assessment of the shore's vegetation cover, using this classification:

1. Full Natural Cover;
2. Cover Modified by Humans (Ornemental Vegetation);
3. Presence of Inert Materials (zone partially covered with buildings, asphalt, concrete, sand or gravel);
4. Bare Soil, Signs of Erosion;
5. Presence of Retaining Walls.

Due to the large number of buildings, the human pressure on the three lakes is heavy, especially on Danford and on Shea. Danford Lake's shore is often inadequately covered with vegetation (riprap[2] with insufficient vegetation; retaining walls; buildings set directly on the water line; shore strip less than the mandatory 10 or 15 meters; lawn cover down to the water line; or vegetation not dense enough to fulfill its protective role). Shea Lake is also densely populated, but efforts are being made to maintain or restore some natural vegetation near the water line; there are hardly any retaining walls or buildings set directly on the water line. There are not many buildings on McAuley's shore (only 15), but some of them have lawn down to the water line, which is against regulations.

The water-quality data collected show that Danford and Shea lakes can be considered oligotrophic* (Stage I of III in the lifetime of a lake), whereas McAuley Lake is already showing signs of eutrophication* (Stage III of III). Since no major issue has been found with its shore (the deterioration observed is too localized to impact the lake as a whole), this eutrophication* of McAuley appears to be due mainly to natural causes (run-off, sediment carried from two streams and Danford Lake's outlet feeding the lake).

Two factors should contribute favourably towards preserving these three lakes: the MRC's 2009 regulations on lakeshore protection (http://www.mrcvg.qc.ca/images/reglements/2009-206.pdf), and the fact that the Municipality of Kazabazua is among the MRC's municipalities using the MRC Septic Waste Management Plant.

In the light of this information, ABV7 recommends the following:

1) that the current regulations on lake shore protection be enforced;
2) that natural vegetation be restored on those sections of the shores showing deterioration (especially on Danford);
3) that annual water tests be continued by LAK, adding Chlorophyll a in the case of McAuley;
4) that an annual update on the condition of septic systems be requested from the Municipality of Kazabazua, if possible;
5) that LAK continue to raise lake residents' awareness of good practices (e.g. the use of phosphate-free products, the recovery of ashes from fire pits).

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[2] Translator's Note:
Riprap, as rip rap, rip-rap, shot rock, rock armour or rubble, is rock or other material used to armor shorelines, streambeds, bridge abutments, pilings and other shoreline structures against scour and water or ice erosion. It is made from a variety of rock types, commonly granite or limestone, and occasionally concrete rubble from building and paving demolition. It can be used on any waterway or water containment where there is potential for water erosion. (Wikipedia)

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1. INTRODUCTION

1.1 Mandate

In May 2016, the *Lakes Association of Kazabazua* (LAK) mandated the *Agence de bassin versant des 7* (ABV7 at www.abv7.org) to establish the characteristics of three of its nine lakes (Danford, McAuley and Shea), which have an intermediate size and are situated in the Municipality of Kazabazua, MRC de la Vallée-de-la Gatineau, Outaouais Region.

The *Lakes Association of Kazabazua*, formerly known as the *Danford Lake and District Property Owners Association*, was created in the 1960s and now includes nine lakes: Danford, Little Danford, McConnell, Lyons, McAuley, Shea, Little Shea, Farm, Red Pine and Andy lakes. Its overall goal is to protect and preserve the lakes environment and the quality of their water for present and future generations.

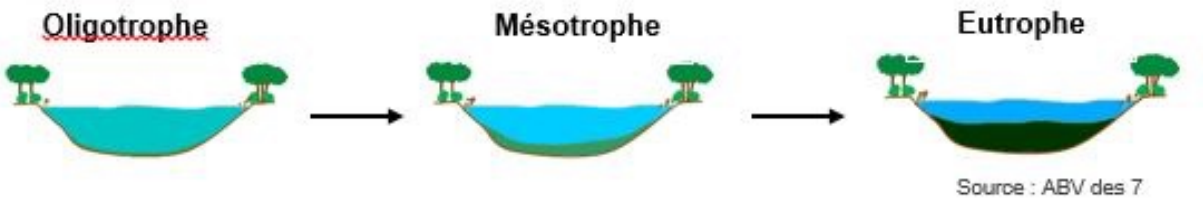
This research project had two goals: to test the lakes' water quality (in order to establish their trophic status), and to assess the condition of their shores.

1.2 Eutrophication and Trophic States

Lakes like other biological systems age over the passage of time. Lakes age naturally over a geologic time scale, and they should not exhibit age-related changes over a human's lifetime. The term 'eutrophication' refers to the change in a lake from having lower level of primary productivity to a higher level of primary productivity, resulting in an increased accumulation of sediment and organic matter and a diminished oxygen concentration which can have impacts on aquatic life. Trophic means nutrition or growth. A eutrophic ("well-nourished") lake has high nutrients and high plant growth. An oligotrophic lake has low nutrient concentrations and low plant growth. Mesotrophic lakes fall somewhere in between eutrophic and oligotrophic lakes. (http://www2.gnb.ca/content/gnb/en/departments/elg/environment/content/water/content/lakes/succession.html)

Preserving the oligotrophic stage of a lake is important in order to prevent its premature aging.

Fig. 1 - The three trophic states of a lake: (I) oligotrophic, (II) mesotrophic and (III) eutrophic



2. METHODOLOGY[3]

2.1 Water quality

The water quality was assessed using the following parameters: E. coli; phosphorus; chlorophyll a; dissolved oxygen, pH and temperature; transparency and turbidity.

In addition to LAK's own E. coli and phosphorus annual data collected since 2007, ABV7 analyzed the data obtained from lab tests with water samples taken:

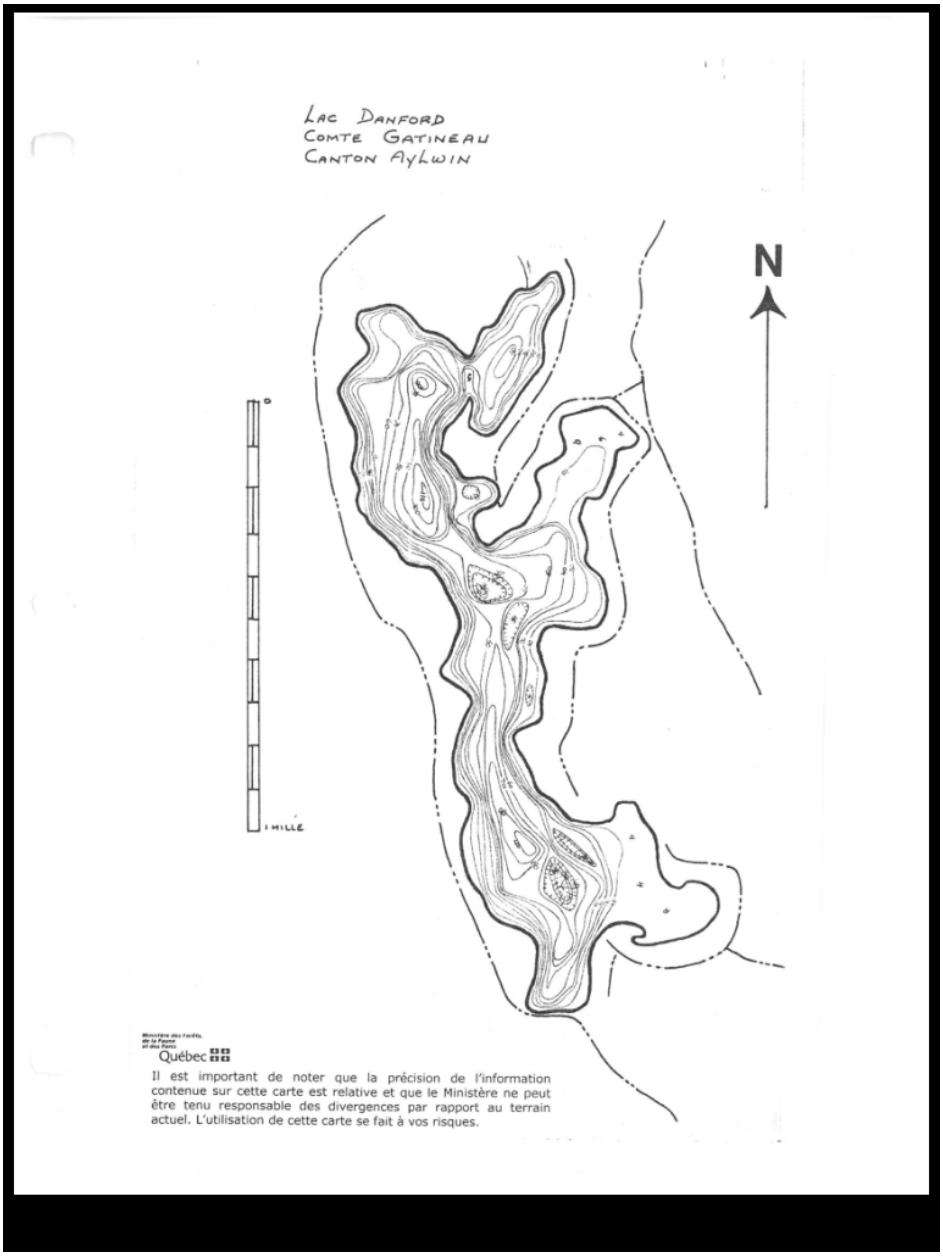
- on June 1 (Danford Lake) and June 6, 2016 (Shea, McAuley) (i.e. after Spring turnover*), and
- on August 18, 2016 (i.e. at the end of summer, once thermal stratification* is in place).

Samples were taken at the greatest depth of each lake in each lake, where conditions are theoretically the least favorable:

[3] Translator's Note:
In the French report, the methodology used for the eight physical and chemical parameters is described in Section 2, and the results obtained are shown in Section 3. In our English translation, we have grouped 'methodology' and 'results' in one and the same section (Section 4 — Results and Discussion) in order to make it easier to compare results against standard values.

Figure 10 - Greatest depth (x *Fosse*) in the three lakes

Danford Lake is the only lake for which a bathymetric map is available (see following page). This map shows a fairly complex bathymetry and an irregular morphology, with large shallow bays to the east and a sharp declivity to the west and the north. The greatest depth is in the northern part of the lake (110 feet = 33.5 m).


LAC DANFORD
COMTE GATINEAU
CANTON AYLWIN
N
0
1 MILLE
Québec
Il est important de noter que la précision de l'information contenue sur cette carte est relative et que le Ministère ne peut être tenu responsable des divergences par rapport au terrain actuel. L'utilisation de cette carte se fait à vos risques.

2.2 Condition of lakeshore

ABV7 used the Protocole established by the Quebec Ministry of the Environment and the Conseil régional de l'environnement des Laurentides (2007). ABV7's team of biologists examined the three lakes' shores (taking pictures for further study—See three Annexes on Danford, McAuley and Shea lakes) on the same dates that they took water samples (June 1 and 6). Seasonal cottages or year-around residences surround all three lakes.

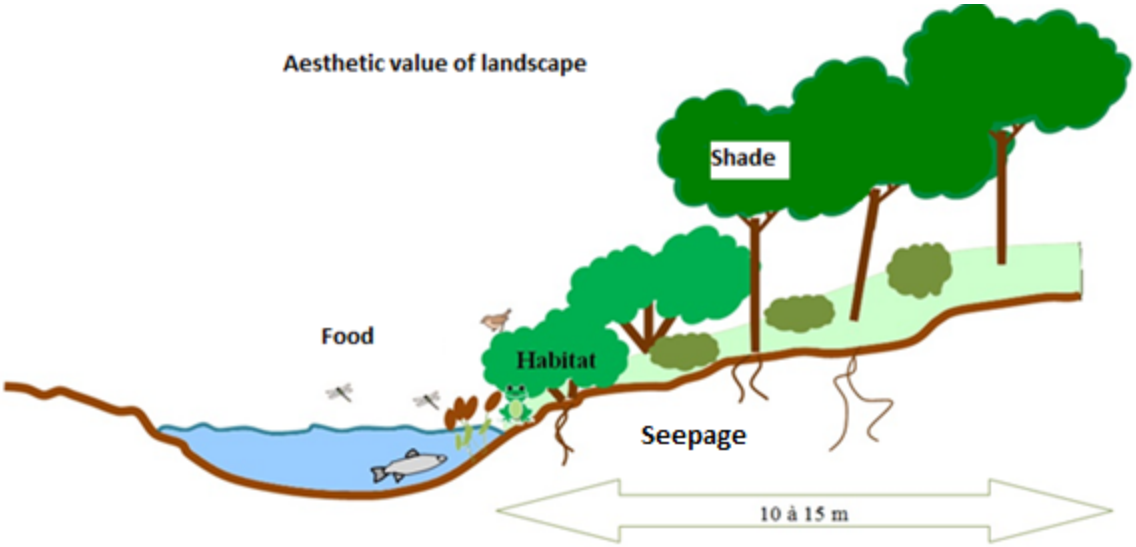


Figure 5 - Lakeshore components

According to the MRC's 2009 regulations on lakeshore protection (http://www.mrcvg.qc.ca/images/reglements/2009-206.pdf), the lakeshore is a 10-meter wide strip of natural vegetation (when the slope is less than 30%) or a 15-meter wide strip (when the slope is greater than 30 % and uninterrupted). Acting as a natural shield, this shore strip fulfills several essential biological functions. Its vegetation:

1. prevents excessive warming of the littoral zone;
2. captures a large part of the sediment and nutrients that otherwise would be washed into the lake, thus limiting the growth of algae;
3. stabilizes the bank, and limits erosion;
4. reduces the speed of run-off and facilitates water seepage into the soil;
5. provides essential habitat and food and shelter for wildlife and flora.

Three factors are taken into account to characterize a lakeshore:

1. the use made of the land;
2. the vegetation cover; and
3. the impact of those two factors on the lake as a whole.

According to the Quebec Ministry of the Environment's Protocole, five different so-called homogeneous zones can be identified on a lake shore, each zone being defined by the predominant use made of the land on the shore:

1. No Use by Humans (natural vegetation throughout);
2. Used for Agricultural Purposes;
3. Used for Forestry Purposes;
4. Used for Infrastructure (road, dam, railway, logging trail)
5. Used for Buildings (cottages, residences, others) or for Recreational Purposes (public access, camping, beach, public park).

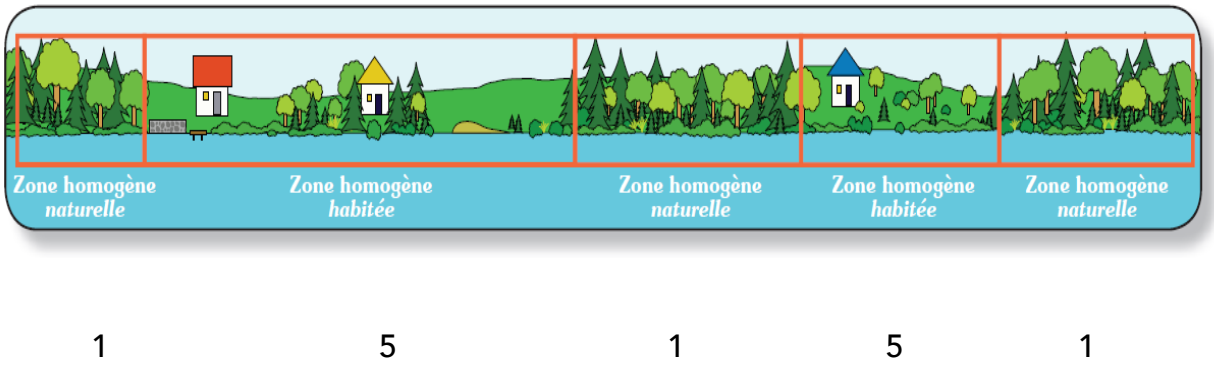


Fig. 6 - Examples of homogeneous zones

Fig. 6 illustrates a typical alternation of homogeneous zones. Ideally, a shore should keep a maximum natural vegetation cover, and no building or structure should be erected in the 15m-wide shore strip.

The Protocole includes an assessment of the shore's vegetation cover, using these categories:

1. Full Natural Cover;
2. Cover Modified by Humans (ornemental vegetation);
3. Presence of Inert Materials (zone partially covered with buildings, asphalt, concrete, sand or gravel);
4. Bare Soil, Signs of Erosion;
5. Presence of Retaining Walls.

There are numerous benefits associated with a well-preserved shore:

Economic	- Saving the costs incurred to combat soil erosion, flooding or drought caused by inadequate shore protection (excessive tree cuts, bare soils, etc.) - Sustaining or stimulating the local economic growth - Increasing property values
Social	- Sustaining or developing recreational and tourism activities - Improving the aesthetic value of the landscape - Generally improving the quality (real and perceived) of one's own living environment
Environmental	- Sustaining biodiversity (diversity of ecosystems, habitat protection) - Stabilizing the shoreline (by limiting erosion) - Preventing excessive warming of the littoral zone - Regulating the hydrological cycle - Filtering pollutants - Moderating the impact of wind and temperature

Based on the information collected, ABV7 made a diagnosis and is presenting in this report corrective and preventive measures to ensure preservation of these three lakes.

3. GEOGRAPHICAL, GEOLOGICAL AND SOCIAL BACKGROUND[4]

About 80 km northwest of the City of Gatineau, Danford, McAuley and Shea lakes, all of an intermediate size, are in the Municipality of Kazabazua (approx. 991 permanent residents in 2016). They are situated in the watersheds of the Picanoc River (McAuley,

[4] Translator's Note:
The general information about recreational activities, demography, road network, geology, and septic systems contained in the French report has not been translated.

Danford) and of the Kazabazua River (Shea). Both rivers flow into the Gatineau River, to the east. The Gatineau flows into the Ottawa River.

The three lakes are between 182 m and 168 m above sea level. The Danford Lake area is in a physiographic region named the Southern Laurentians. This region is part of the southern rim of the Canadian Shield, which covers most of Canada and includes some of the oldest rocks on Earth. Danford, McAuley and Shea lakes are in the Gatineau Valley, which is a former arm of the Champlain Sea.

These geological features may influence the physical and chemical characteristics of the water, especially its pH, which tends to be acidic or alkaline depending on the nature of the underground rock formation[5].

The soil is composed mainly of loam, sands and gravels. The lakes are fed with numerous springs. While Shea Lake flows out southward into the Kazabazua River, Danford Lake, and McAuley Lake flow out northward into the Picanoc River.

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[5]Translator's Note: The French report contains detailed information about the geology of our region. This information in French was translated from the two English sources shown below, which are available in public libraries. Please refer to them if you want to know more on the geology of our region:

Baker, D. R. 1956. Geological report, Aylwin-Cawood area, Pontiac and Gatineau counties, Department of Mines. Québec).

Daigneault, R.-A, Roy, M., Lamothe, M., Milette, S., Dubois Verret, M., Hurtubise, M.-A., Lamarche, 0 ., Leduc, É., Godbout, P.-M. et Horth, N. (2013, août). Deglaciation Pattern in the Outaouais Region, Southwestern Québec. Canadian Quaternary Association (CANQUA), Meeting 2013 - Edmonton, Alberta.

Table 6: Main characteristics of Danford, McAuley and Shea lakes

Danford Lake area (ha)	100.34
Perimeter (m)	12900
Max. Length (km)	3.1
Average breadth (m)	355
Max. Depth (m)	34
Altitude (m)	177
McAuley Lake area (ha)	23.2
Perimeter (m)	3900
Max. Length (km)	1.3
Average breadth (m)	190
Max. Depth (m)	17
Altitude (m)	168
Shea Lake area (ha)	29.3
Perimeter (m)	4500
Max. Length (km)	1.5
Average breadth (m)	245
Max. Depth (m)	34
Altitude (m)	182

The three lakes are heavily populated, with 138 residences/cottages on Danford, 44 on Shea and 15 on McAuley. Founded in 1862, the Municipality of Kazabazua became the heart of the lumbering industry in the region, and human activity around the three lakes dates back a long time. The Municipality of Kazabazua is among the MRC's seventeen municipalities that use the regional Septic Waste Management Plant. In 2014, more than 700 septic tanks associated with Kazabazua residences or cottages were emptied. This service is a major factor in protecting the lakes from pollution.

The three lakes are surrounded mainly by forests. (Farming activities are too far away to the east to have any impact on water quality.) Because vegetation acts as a natural shield, these three lakes' immediate forest environment should have a positive impact on water quality but only if and when the shore's vegetation cover is kept in good condition.

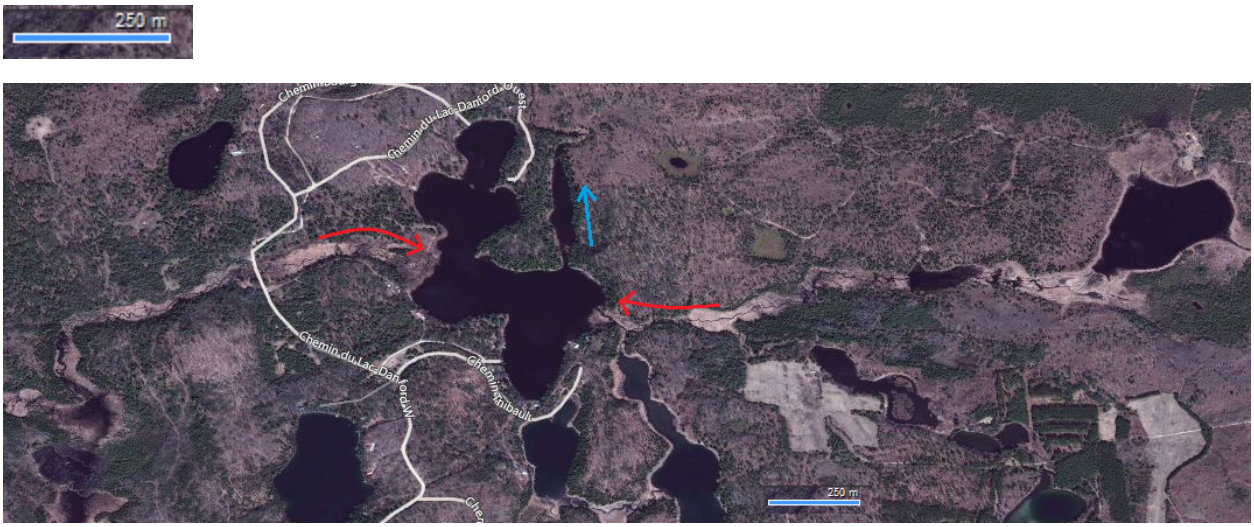


Figure 7 - Aerial photograph of McAuley Lake
(Danford Lake's outlet is shown with a blue arrow, streams flowing into MAuley are shown with red arrows)

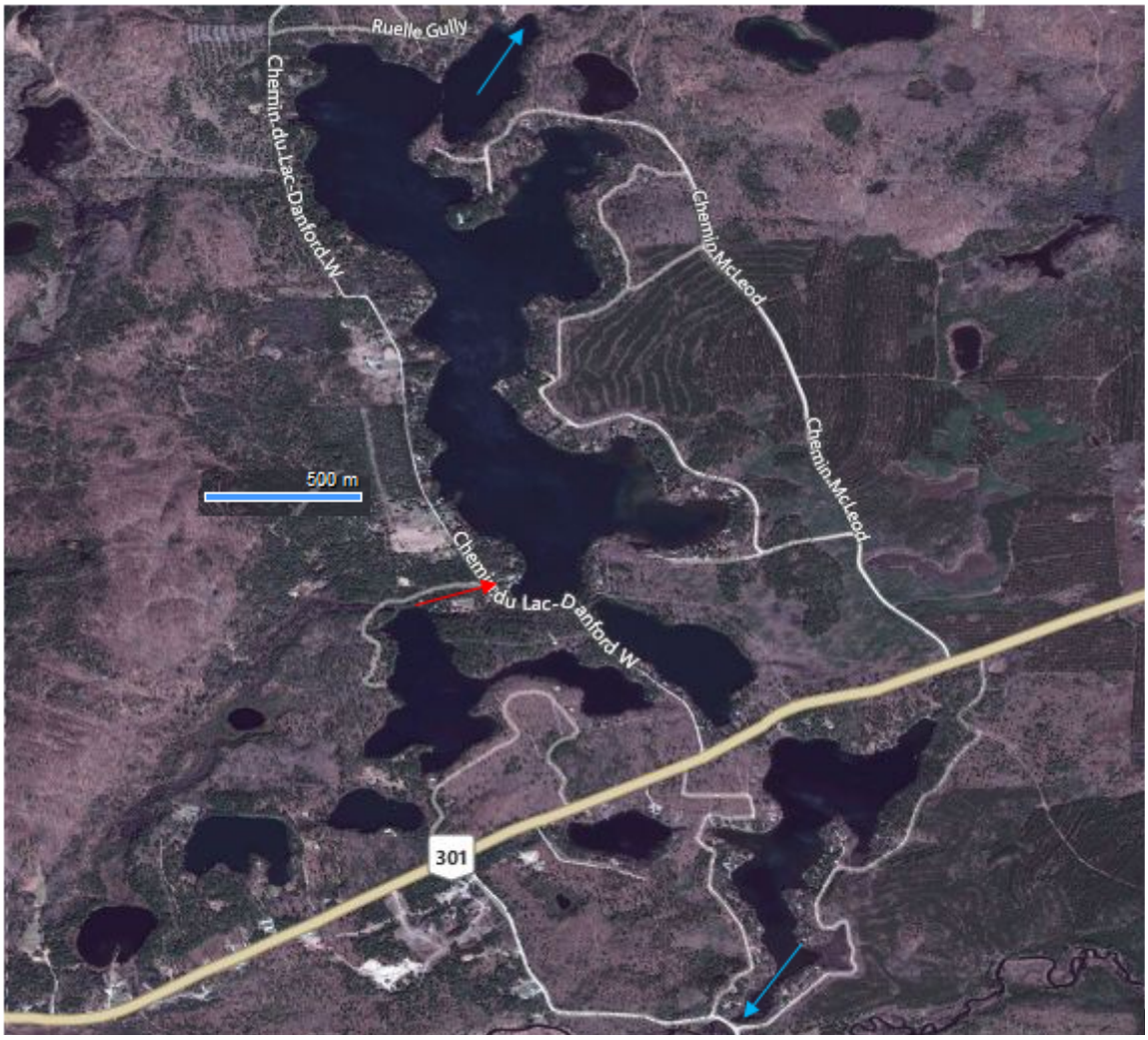


Figure 8 - Aerial photograph of Danford and Shea lakes, showing McConnell intermittent (May-June) stream flowing into Danford (red arrow) and Danford outlet (blue arrow)

4. RESULTS AND DISCUSSION

4.1 Water Quality

4.1.1 E. coli

Methodology

E. coli stands for Escherichia coli, a bacteria which is naturally found in the intestines of warm-blooded animals. The presence of this bacteria in water suggests that the water is contaminated with faeces (https://www.ncbi.nlm.nih.gov/pubmed/21558695).

Table 1: E. coli levels used for water quality assessment (Source: MDDELCC)

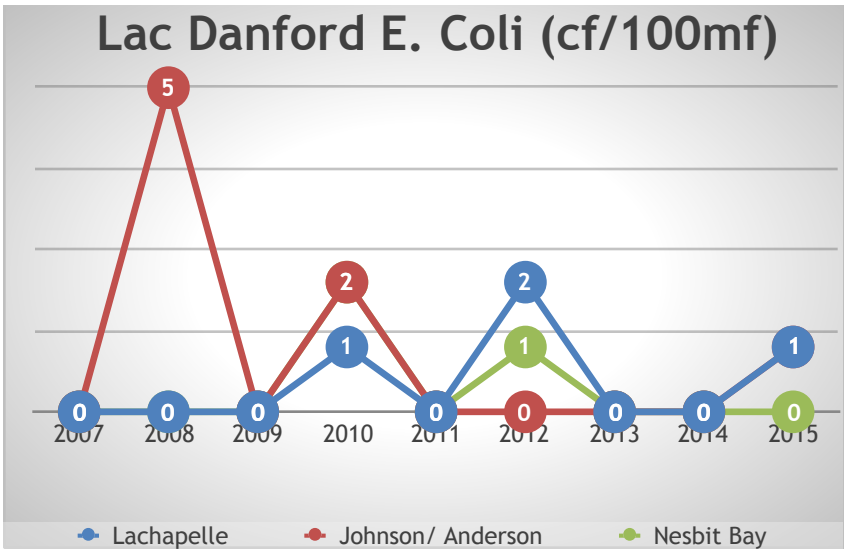
Water Quality	Grade	E. coli / 100mL	What is allowed / What is not
Excellent	A	0-20	all recreational activities
Good	B	21-100	all recreational activities
Mediocre	C	101-200	all recreational activities, but time spent in the water may have to be limited
Poor	D	over 200	Swimming and other forms of direct contact with water are not recommended.
Very poor	E	over 1000	All recreational activities are prohibited.

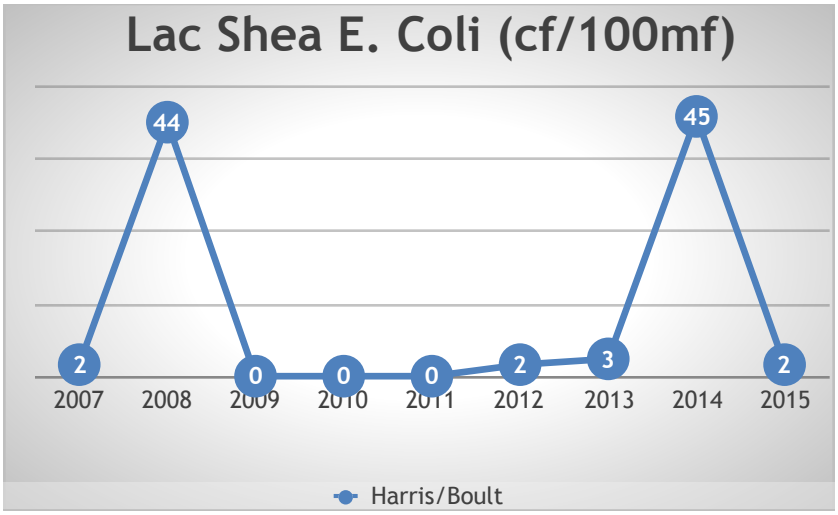
c

Results[6]

LAK has been collecting data on E. coli since 2007. The average levels found in the three lakes are indicative of good—even excellent—water quality. A few high values were found in Shea and McAuley lakes, but they have remained far below the level at which swimming should be prohibited. These peaks can be due to failing septic systems or to high concentrations of animal waste (ducks, beavers, etc.).

[6] Translator's Note:
The results shown here are LAK's own results for the period 2007-2015. Testing for e. Coli in 2016 was not in ABV7's mandate.





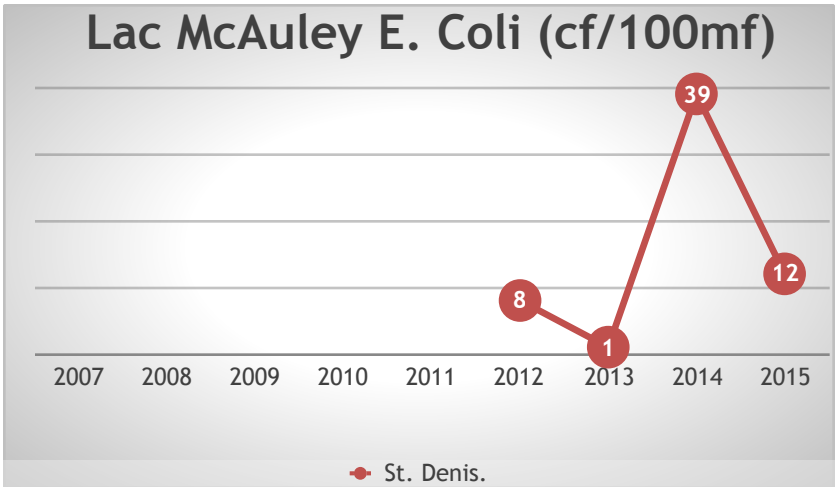


Figure 11 – E. coli levels in Danford, Shea, and McAuley lakes (2007-2015)

4.1.2 Total phosphorus

Methodology

Phosphorus, a biological requirement for plants and algae, is found naturally in small amounts in lake water. Phosphorus normally promotes the growth of

algae and aquatic plants. Although phosphorus is naturally present in a lake, the main sources of this nutrient in lakes are linked to human activity: use of fertilizers, pesticides, and soaps and detergents containing phosphates; failing septic systems; soil erosion as a result of clearing trees or constructing buildings; shores without vegetation; and poorly designed drainage ditches. The concentration of phosphorus in a lake is an indicator of its trophic status, i.e. of its aging. The threshold of eutrophication is 0.03 mg/l of total phosphorus.

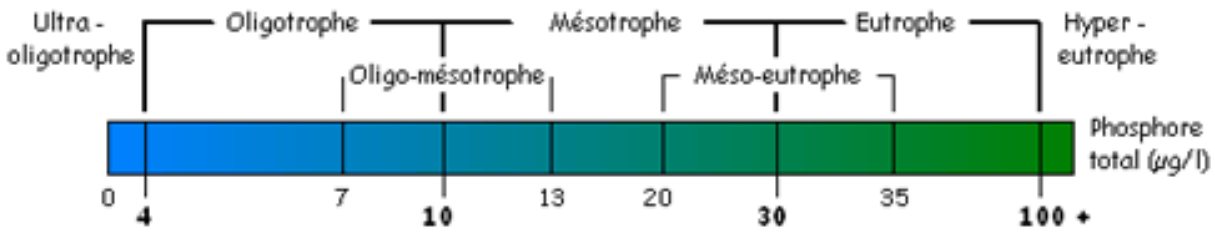


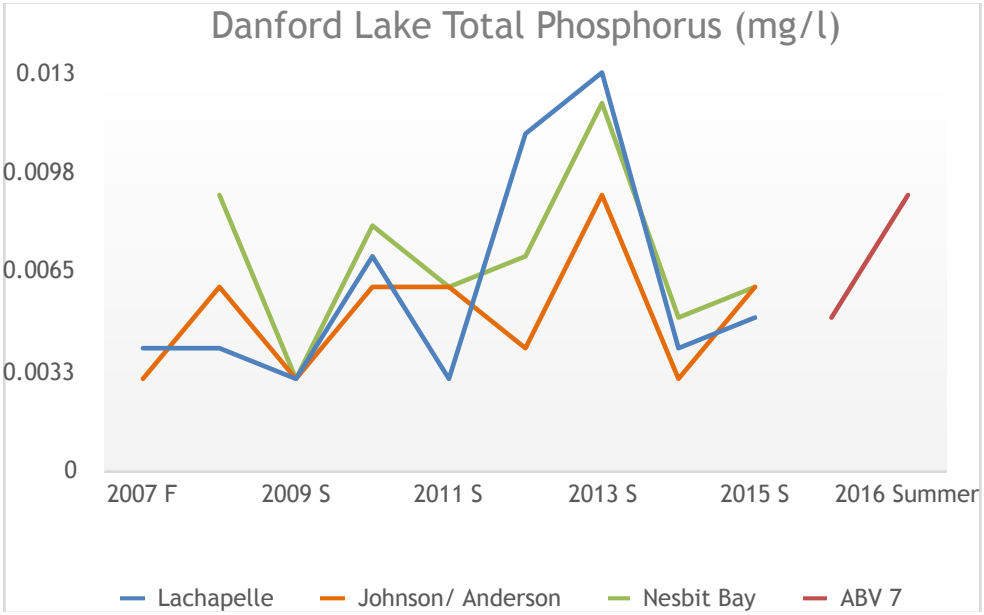
Fig. 2 - Correlation between total phosphorus concentrations and trophic states

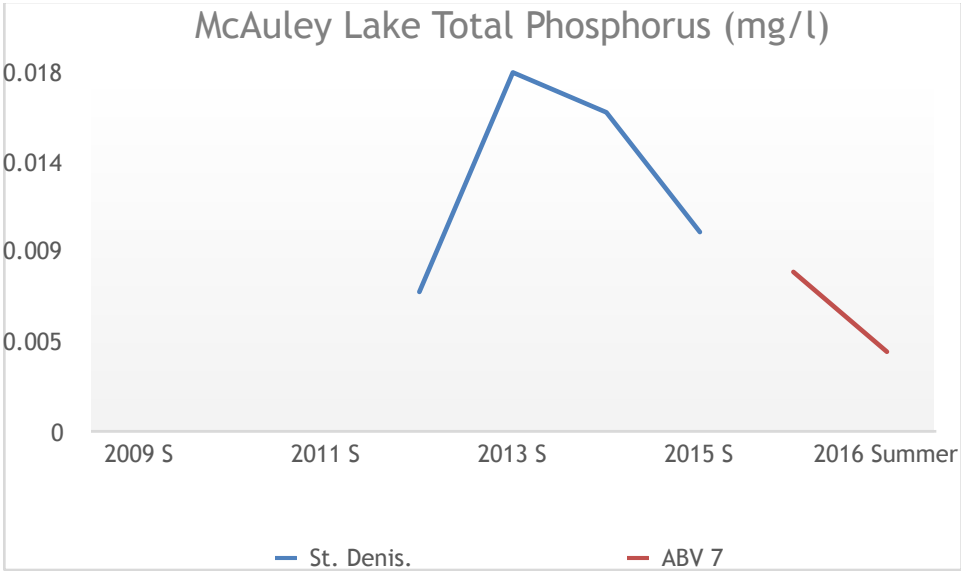
Results

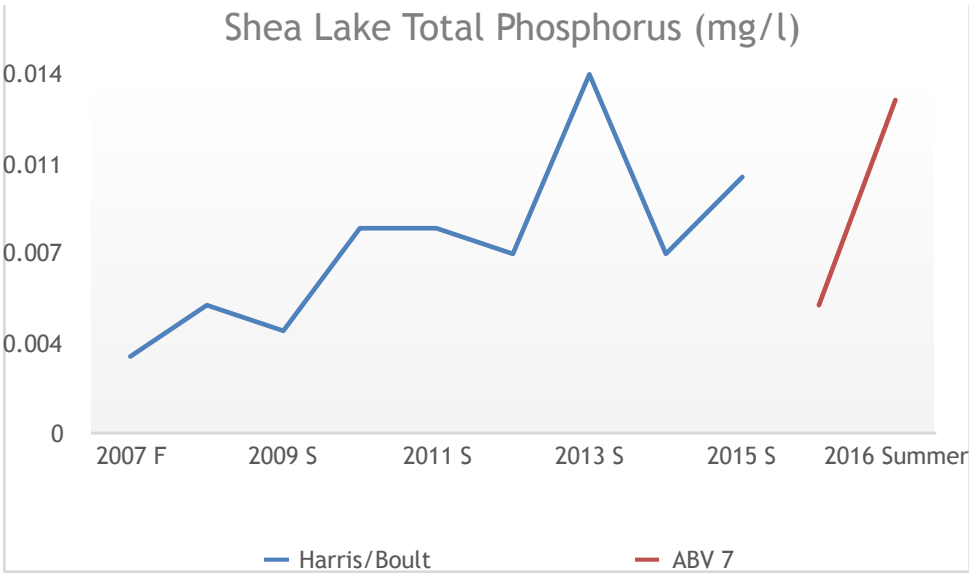
All samples show low to moderate phosphorus levels (typical of oligotrophic* or oligo-mesotrophic* lakes). The average phosphorus level measured since 2007 is 6 µg/l (0.006 mg/l) in Danford Lake and 10 µg/l (0.01 mg/l) in McAuley Lake, which is the only lake of the three lakes to be closer to Stage II (mesotrophic*). In Shea Lake, phosphorus levels have been measured since 2012; the average level is 7 µg/l (0.007 mg/l).

> There are differences between the three lakes. While the quantity of nutrients appears to have increased over time in Shea and Danford lakes, McAuley's concentration of phosphorus decreased in 2016.

All three lakes showed a sharp increase in the Spring of 2013. This peak may have been due to unfavourable weather conditions.


Danford Lake Total Phosphorus (mg/l)
0.013
0.0098
0.0065
0.0033
0
2007 F
2009 S
2011 S
2013 S
2015 S
2016 Summer
Lachapelle
Johnson/ Anderson
Nesbit Bay
ABV 7


McAuley Lake Total Phosphorus (mg/l)
0.018
0.014
0.009
0.005
0
2009 S
2011 S
2013 S
2015 S
2016 Summer
St. Denis.
ABV 7



4.1.3 Dissolved oxygen, pH and temperature

Methodology

Dissolved oxygen is essential for aquatic life. In lakes, it comes from the atmosphere and from the production of phytoplankton. It is consumed through biological activity and the decomposition of organic matter.

ABV7 collected data on the concentration of dissolved oxygen by using a YSI multi-parameter probe (model 600QS) at the deepest point of each lake. The data were measured first on the surface, then the probe was lowered in 1-metre stages until it reached bottom. The data collected in the first layer of lake- bottom sediment were later removed from analysis to avoid a distorted reading.

At the same time, data on temperature and depth were compiled in order to complete analysis.

Dissolved oxygen levels increase with depth in an oligotrophic lake, which typically has low concentrations of mineral and organic matter. This promotes the breakdown of the organic matter produced in the upper layer of the waterbody. A high level of dissolved oxygen at the lake bottom has a chemically stabilizing effect on the sediment layer accumulated there.

Normally, a lake progresses gradually from oligotrophy to mesotrophy. This natural process can be accelerated by the supply of phosphorus resulting from human activity.

An increased phosphorus level promotes the growth of aquatic plants and algae, which diminishes the overall quality of the water when their growth is excessive.

Dissolved oxygen (saturation and concentration), pH, and temperature were measured at various depths in the deepest part of each lake.

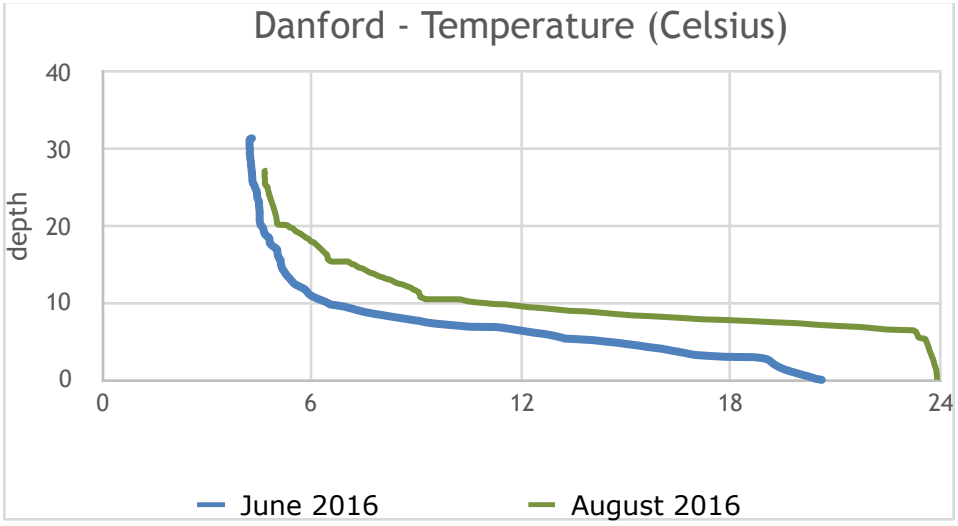
Results

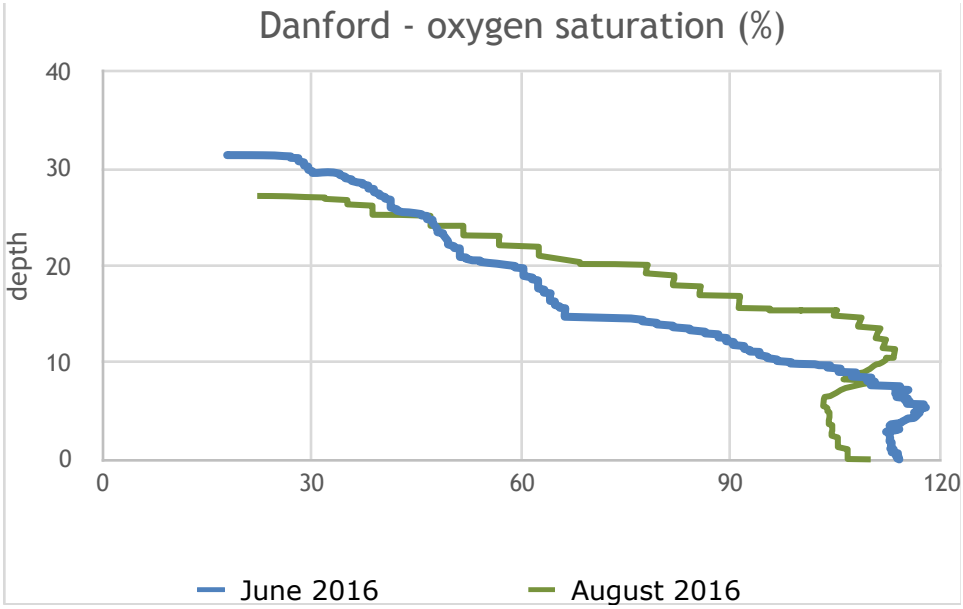
Danford Lake

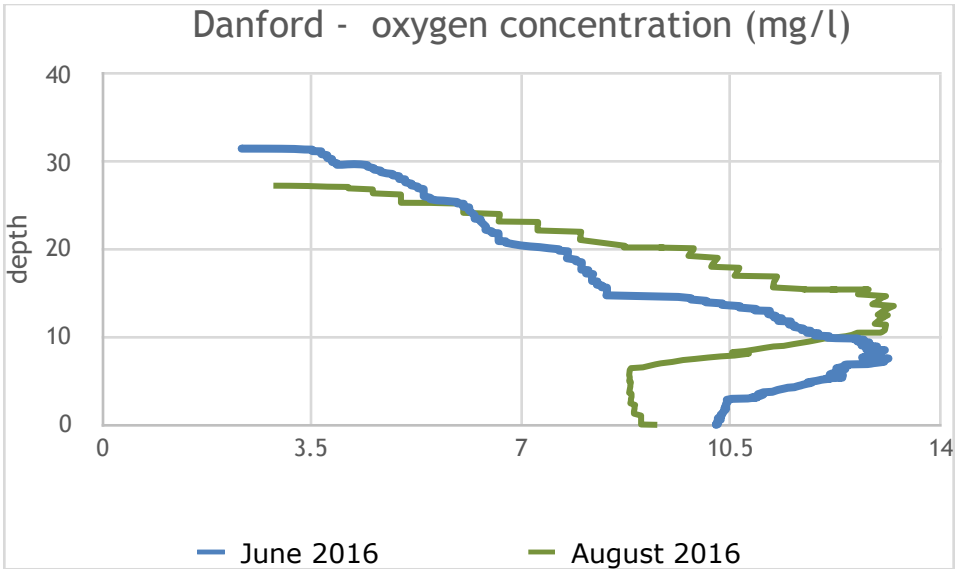
Data collected at the beginning of June 2016 indicate that thermal stratification had already occurred, with a gradient or thermocline* at around 10 m below the surface. The June and August curves are comparable, and oxygen levels remained constant during the season.

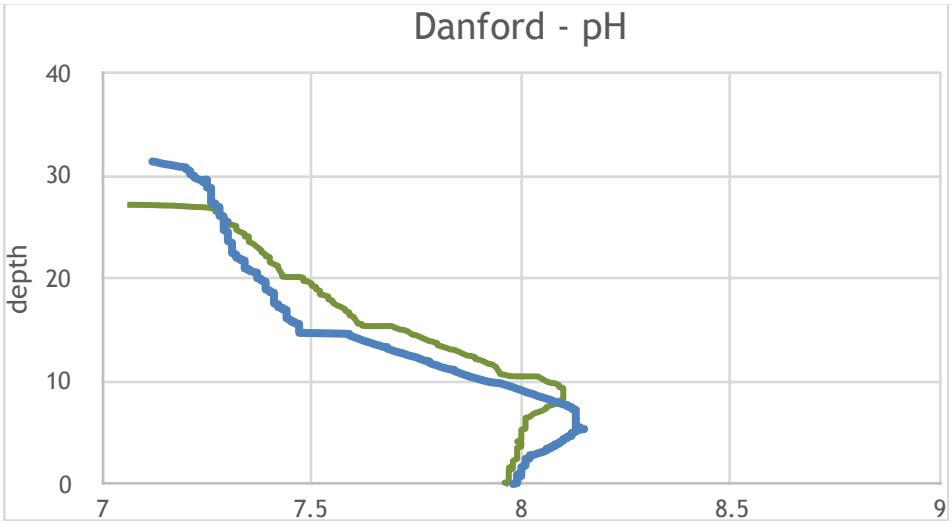
In August, the concentration of oxygen from the surface down to 20 m (66 feet) was above 7mg/l, and the saturation of oxygen was close to 80% , which is excellent for most freshwater organisms, including cold water fish species (ideal range: 80%-125%.) Below 20 m, however, oxygenation levels dropped. (Only three zones are deeper than 20 m, according to the bathymetric map of Danford Lake .)

Danford's pH varied between 7 and 8.2, which is good. The ideal pH range for aquatic life is 6.5 to 9.




Danford - oxygen saturation (%)
depth
40
30
20
10
0
0
30
60
90
120
June 2016
August 2016

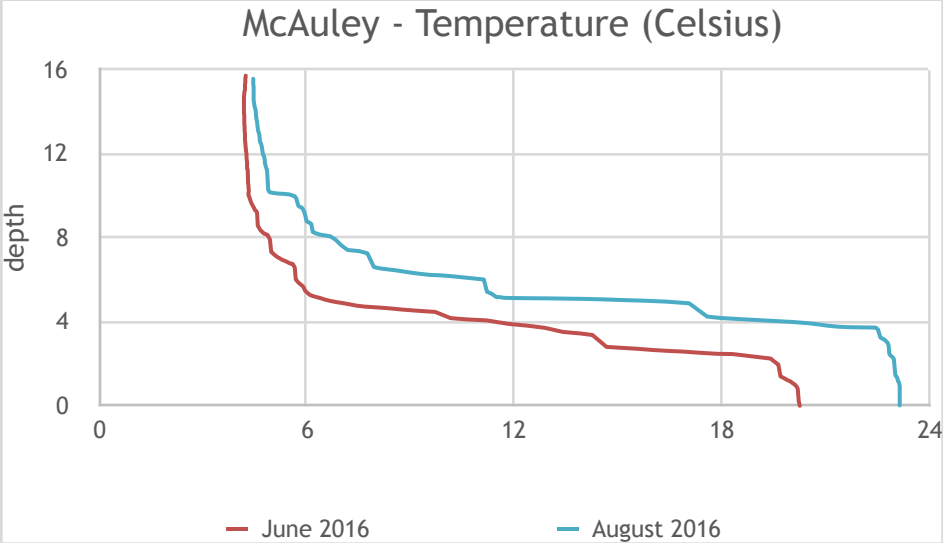

Danford - oxygen concentration (mg/l)
depth
40
30
20
10
0
0
3.5
7
10.5
14
June 2016
August 2016

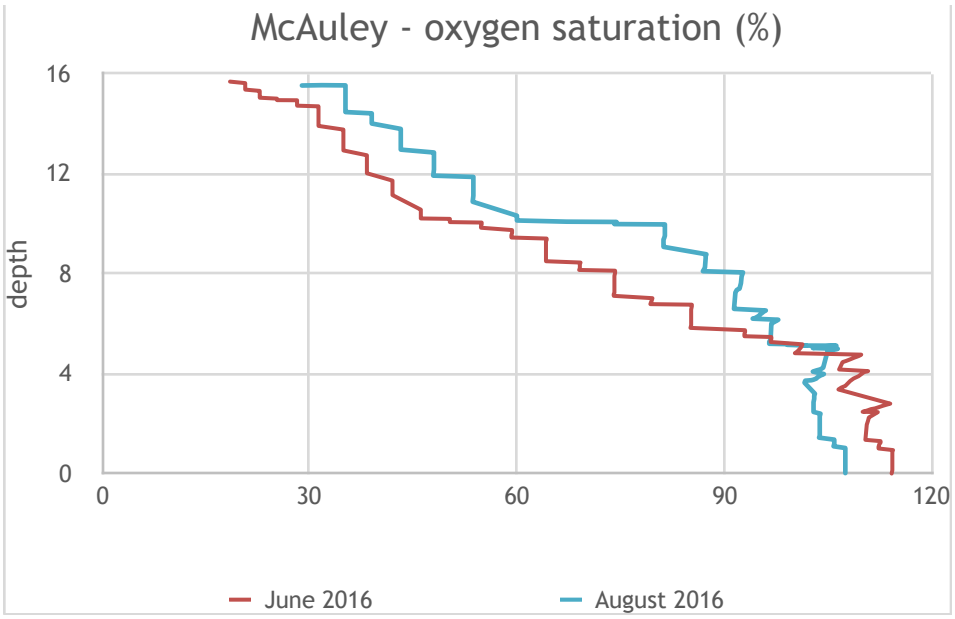

Danford - pH
depth
40
30
20
10
0
7
7.5
8
8.5
9

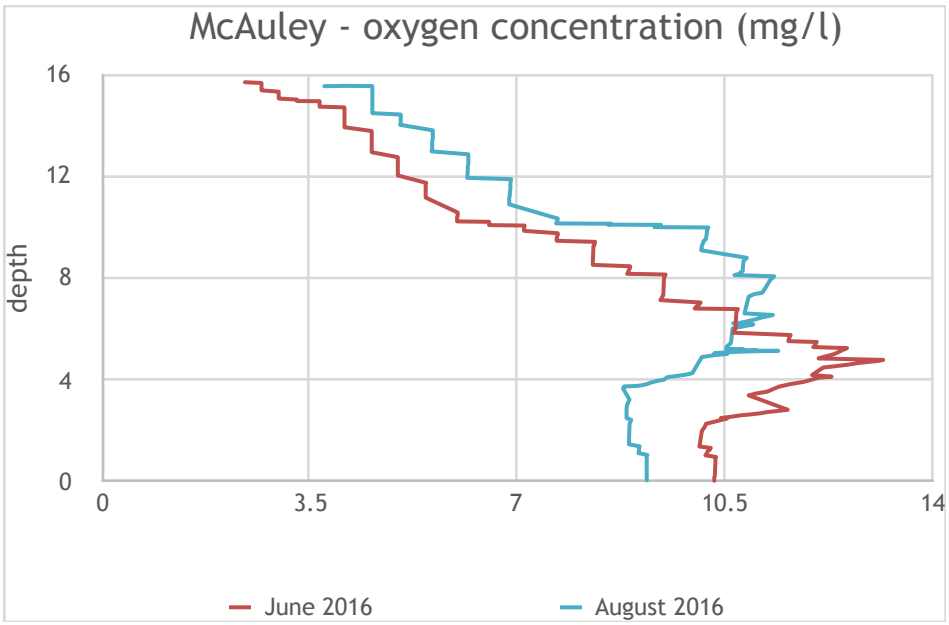
McAuley Lake

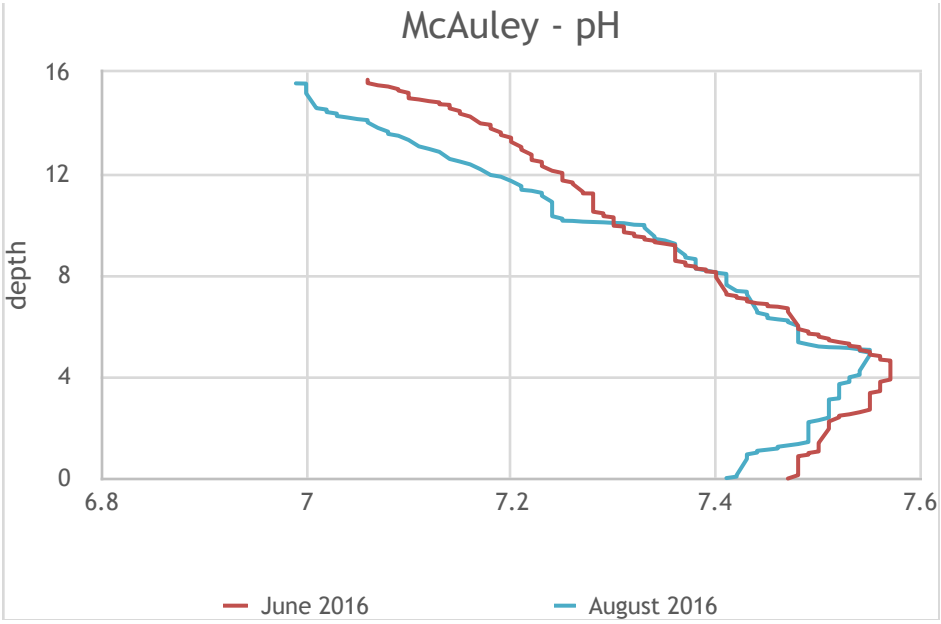
On McAuley Lake, thermal stratification* had already occurred in early June 2016, with a thermocline* at 5-6 m below the surface. This had an impact on the dissolved oxygen values observed in June and August: they were good in the upper water layer (0-10 m), but they began decreasing at 6 m. An oxygen deficit was observed at depths greater than 11 m: dissolved oxygen was less than 7 mg/l on average. Of the three lakes, McAuley has the lowest oxygen level, a fact that is certainly related to the greater quantity of organic matter present.

Measurements of pH showed values between 7.0 and 7.6 units in the water column. These pH values are close to or equal to a neutral pH, which is a good bracket for aquatic life.




McAuley - oxygen saturation (%)
depth
16
12
8
4
0
0
30
60
90
120
June 2016
August 2016


McAuley - oxygen concentration (mg/l)
depth
16
12
8
4
0
0
3.5
7
10.5
14
June 2016
August 2016

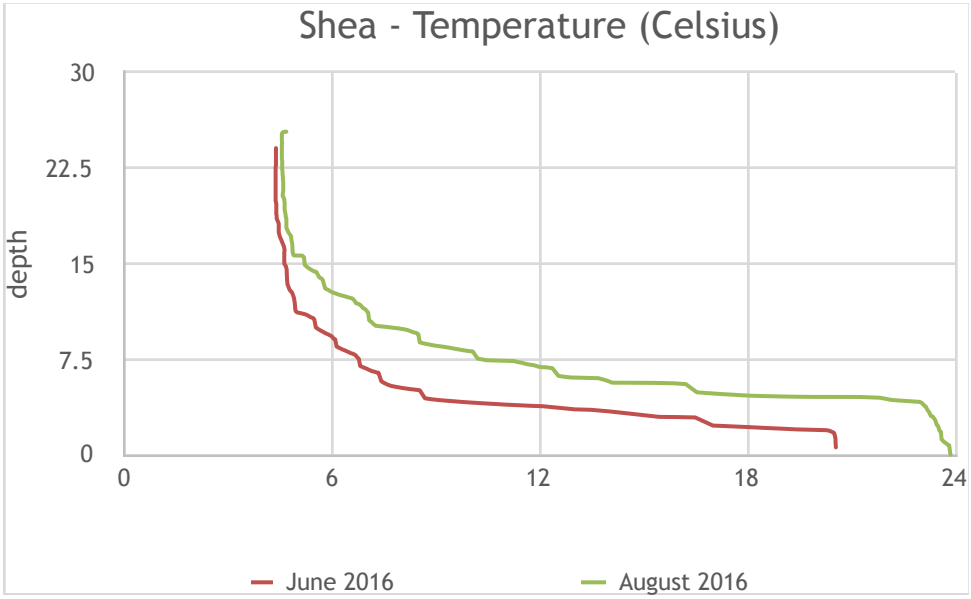


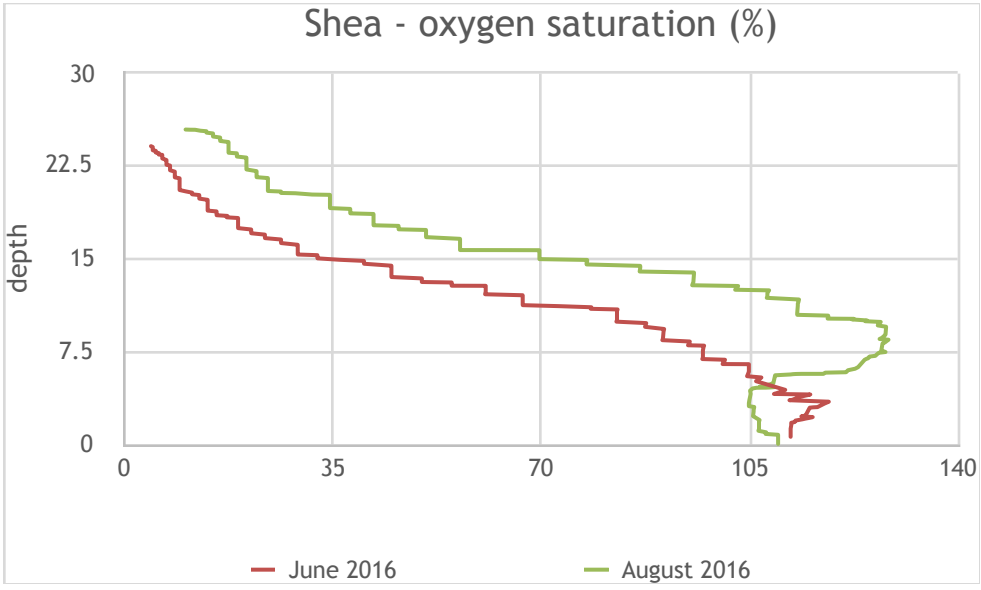
Shea Lake

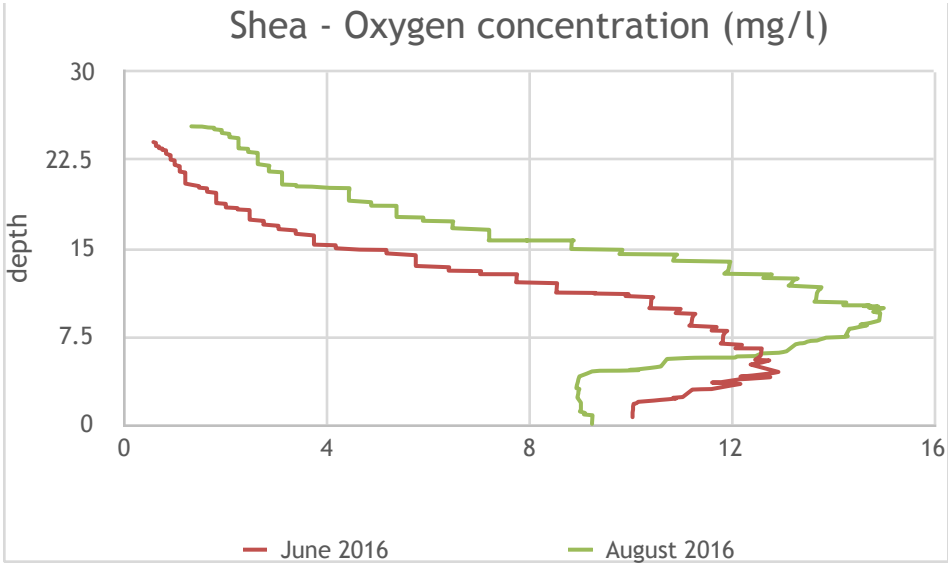
Thermal stratification had already occurred in June, with a thermocline at 7 m below the surface.

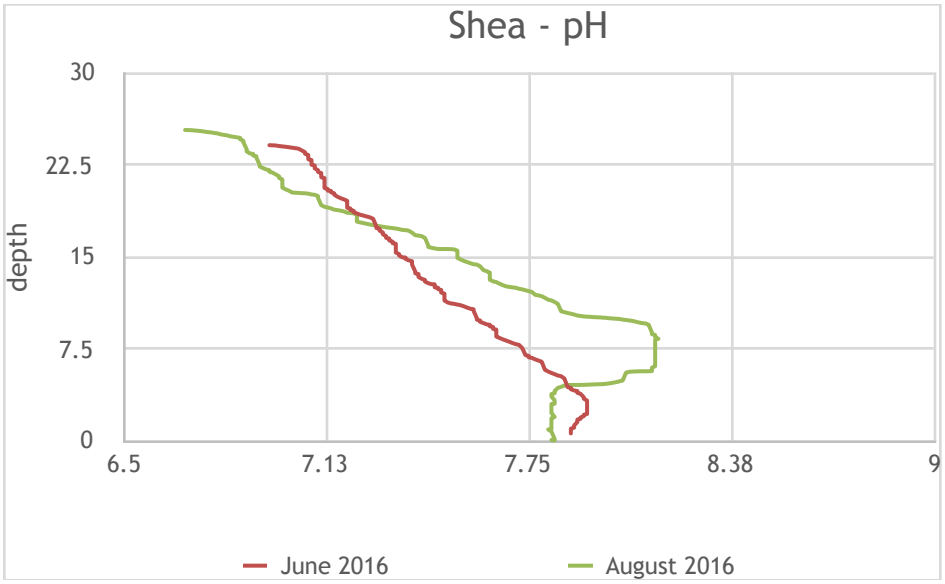
The oxygenation profiles were similar in June and August: the top water layer (0-15 m) remained well-oxygenated, whereas the deeper layers were lacking oxygen (less than 7 mg/l of dissolved oxygen beginning at a depth of 15 m on average).

Shea's pH varied between 7 and 8.1 down to a depth of 20 m. However, in August, it became more acidic than in the other two lakes, reaching 6.7 at the greatest depth measured (recall that below 6.5, aquatic organisms begin to experience some stress). This variation may be explained by the geology of Shea Lake, where we observed areas of sandy shoreline, resulting from the decomposition of the (acidic) granite bedrock of the Canadian Shield. As mentioned earlier in the report, the water of McAuley and Danford lakes is more alkaline.


Shea - Temperature (Celsius)
30
22.5
15
7.5
0
depth
0
6
12
18
24
June 2016
August 2016


Shea - oxygen saturation (%)
30
22.5
15
7.5
0
depth
0
35
70
105
140
June 2016
August 2016





4.1.4 Chlorophyll *a*

Methodology

Chlorophyll *a* is responsible for the green colour in plants. This pigment, which is found in plant cells, is used by plants, along with other pigments, to carry out photosynthesis. This process uses the sun's energy to convert carbon dioxide and water into oxygen and organic matter.

Chlorophyll *a* is a measure of the amount of algae growing in a lake. Algae, at the base of the food chain, determine a lake's productivity, i.e. how much organic matter it can produce. Balanced productivity reflects a healthy lake. When excessive, it reveals the presence of too many nutrients, particularly phosphorus.

Trophic status		Chlorophyll *a* (µg/l)
Status	**Intermediate status**	
Ultraoligotrophic		<1
Oligotrophic		1 – 3
	Oligo-mesotrophic	2.5 – 3.5
Mesotrophic		3 – 8
	Meso-Eutrophic	6.5 – 10
Eutrophic		8-25
Hypereutrophic		> 25

Source : MDDELCC, 2014.

Table 2 - Correlation between chlorophyll *a* levels and trophic states

Results

Table 8 - Chlorophyll *a* levels (June and August 2016) in the three lakes

Chlorophyll *a*	**µg/l**	**µg/l**	**µg/l**
	June	**August**	**Average**
Danford	0.91	1.83	1.37
Shea	1.72	2.09	1.91
McAuley	25.5	1.35	13.43

Chlorophyll *a* levels vary between 0.91 and 2.09 µg/l in Danford and Shea lakes, which is characteristic of oligotrophic lakes* (Stage I of III). Moreover, the levels observed are fairly stable, which is typical of healthy lakes.

In McAuley Lake, the chlorophyll *a* level was very high in June 2016 (25.5 µg/l). Such a level, which indicates a very high density of micro-algae, would place McAuley in the category of eutrophic lakes (Stage III of III). However, the much lower reading in August

is typical of an oligotrophic lake (Stage I of III). If we average both readings, McAuley then moves from an oligo-mesotrophic status to a mesotrophic status.

It is unlikely that these variations are due to a misreading of the June sample, since all samples were taken at about 1 m below surface and using the same method. There may be another explanation: chlorophyll *a* levels naturally vary, with frequent peaks in the spring and in the summer that are caused by phytoplankton and various species of algae.

Two streams (with beaver dams) and Danford Lake's outlet flow into McAuley Lake. Increased nutriment supply and biological productivity may also be caused by Spring ice melt or the removal of a beaver dam. It should also be noted that each sampling was done above the greatest depth in that lake, which happens to be close to one of the stream deltas. Two sets of data are not sufficient to derive definite conclusions, and, in the case of McAuley, the Association should add chlorophyll *a* to its list of parameters in coming years.

4.1.5 Transparency and turbidity

Methodology

Water transparency is another indicator of a body of water's trophic status. It relates to the depth that light will penetrate water and is influenced by the amount of sunlight and the quantity and nature of substances present in the water. These substances can be mineral (sand, silt or clay, and inorganic chemical compounds) or organic (microscopic algae, organic debris and organic chemical compounds); they can be dissolved or present as particles.

To measure the transparency of water, a Seqqui disk is lowered into the water column until it can no longer be seen from the surface. The point at which the disk disappears is a function of the transparency. Turbidity (cloudiness) is related to transparency and indicates the concentration of suspended particles clouding the water. A turbidity reading lower than 1 NTU (Nephelometric Turbidity Unit) is not problematic, but a higher reading should be investigated for possible pollution.

Trophic status		Average transparency (m)
Status	**Intermediate status**	
Ultraoligotrophic		>12
Oligotrophic		12 – 5
	Oligo-mesotrophic	6 – 4
Mesotrophic		5 – 2,5
	Mesa-Eutrophic	3 – 2
Eutrophic		2,5 – 1
Hypereutrophic		<1

Source : MDDELCC, 2014.

Tableau 3 - Correlation between transparency levels and trophic states

Results

Transparency

To ensure similar sunlight conditions, transparency was measured on the same days in June and August for each of the three lakes. The water in Danford and Shea lakes was transparent below 5 meters, which places these two lakes in the category of oligotrophic* lakes.
The water of McAuley Lake was transparent at a depth of between 3.5 m and 4 m, which is indicative of a mesotrophic* status.

Turbidity

Readings showed low turbidity levels in all three lakes. The variations noted in Shea and McAuley lakes remain acceptable since they never exceeded 0.58 NTU. Danford Lake is the only lake with a stable low turbidity level between June and August 2016.

Tableau 7 – Turbidity levels in the three lakes

Turbidity	**NTU**		
	June 2016	August 2016	Average
Danford	0.35	0.36	0.355
Shea	0.37	0.54	0.455
McAuley	0.58	0.22	0.4

4.2 Condition of lakeshore

The condition of the three lakeshores has been assessed using the following three factors: land use, vegetation cover, and level of shore deterioration.

4.2.1 Land Use

According to the Quebec Protocole used by ABV7, five so-called homogeneous zones can be found on a lake shore, each zone being defined by the predominant use made of the land (see Introduction). ABV7 has identified 60 such homogeneous zones on Danford Lake's shore, 18 on McAuley Lake, and 52 on Shea lake.

Three (ouf of the five) categories of land use were identified on these lake shores:

1. No Human Use (natural vegetation throughout the zone),
4. Used for Buildings or for Recreational Purposes, and 5. Used for Infrastructure.

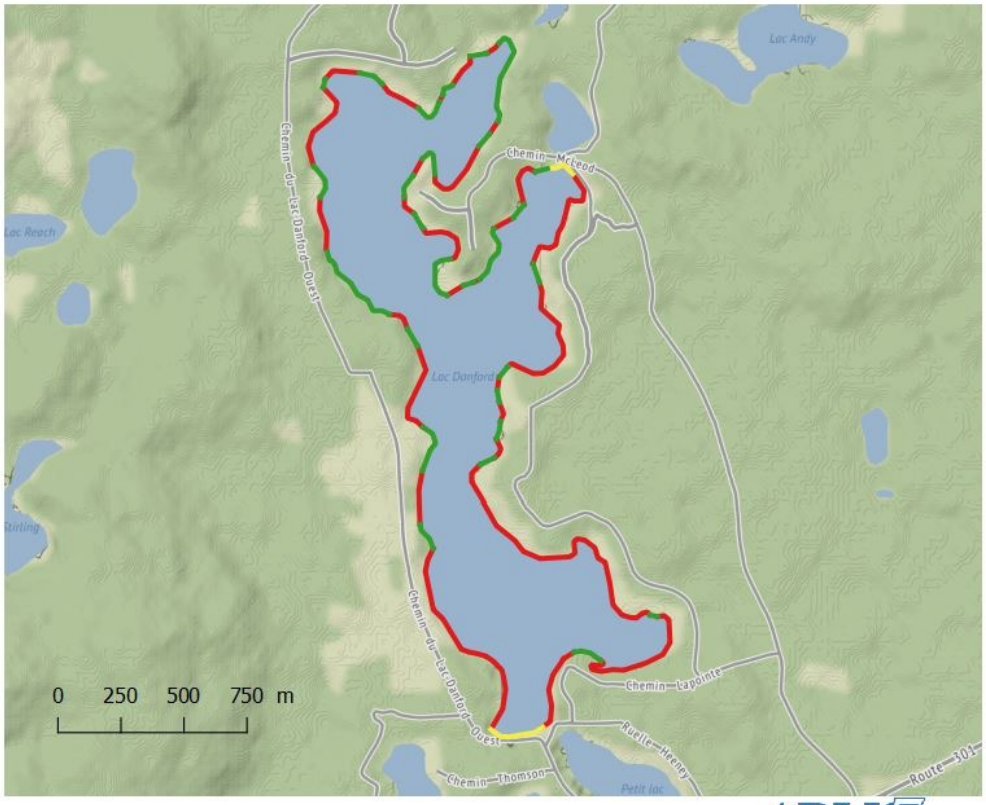
Zone 1	Zone 4	Zone 5
		
McAuley	McAuley	(Mcleod road, along Danford)

Figure 16 - Examples of an homogeneous zone

Zone 4 ('Zone Used for Buildings or for Recreational Purposes') predominates on Danford (68%) and Shea lakes (60%), whereas Zone 1 ('No Human Use') predominates (66%) on McAuley Lake.

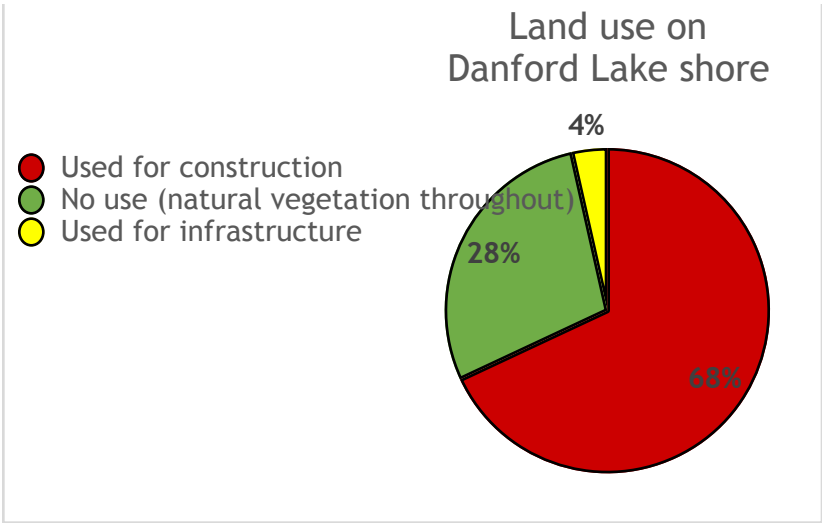
On McAuley Lake, by contrast, only 34% of the shore are built on, and large sectors of the lake (bays, deltas) have kept their natural condition.

Land use zones on Danford Lake shore

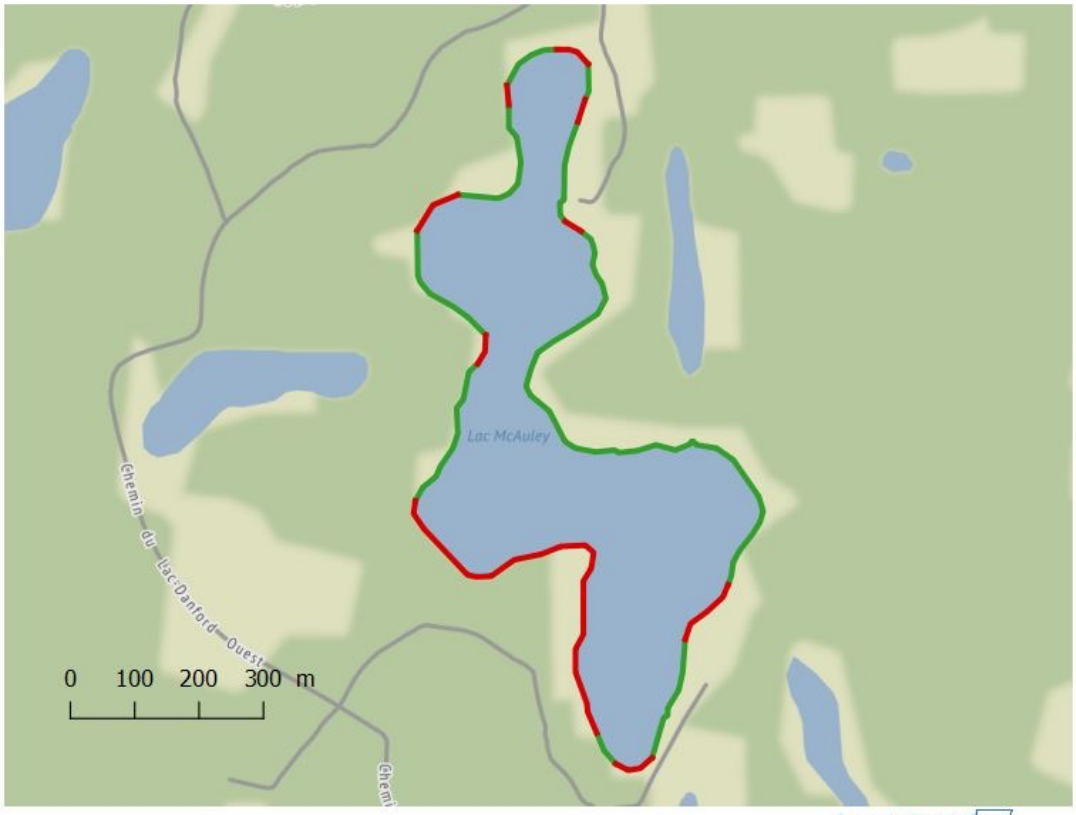


Légende

- No use (natural vegetation throughout)
- Used for infrastructure
- Used for construction



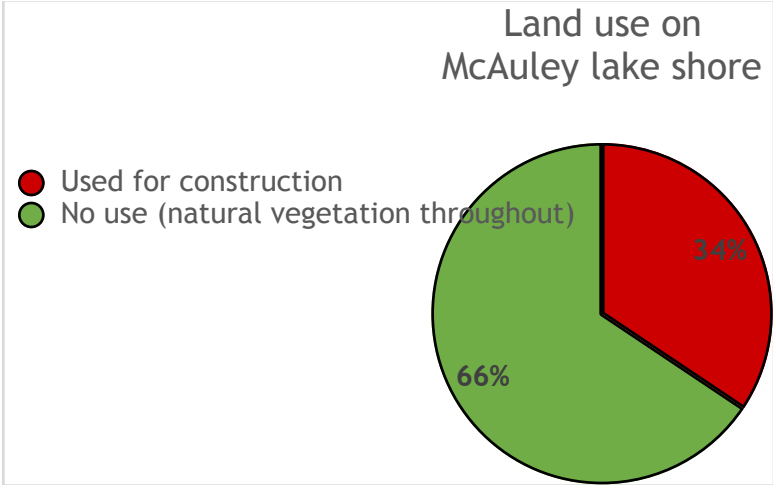
Land use zones on McAuley Lake shore



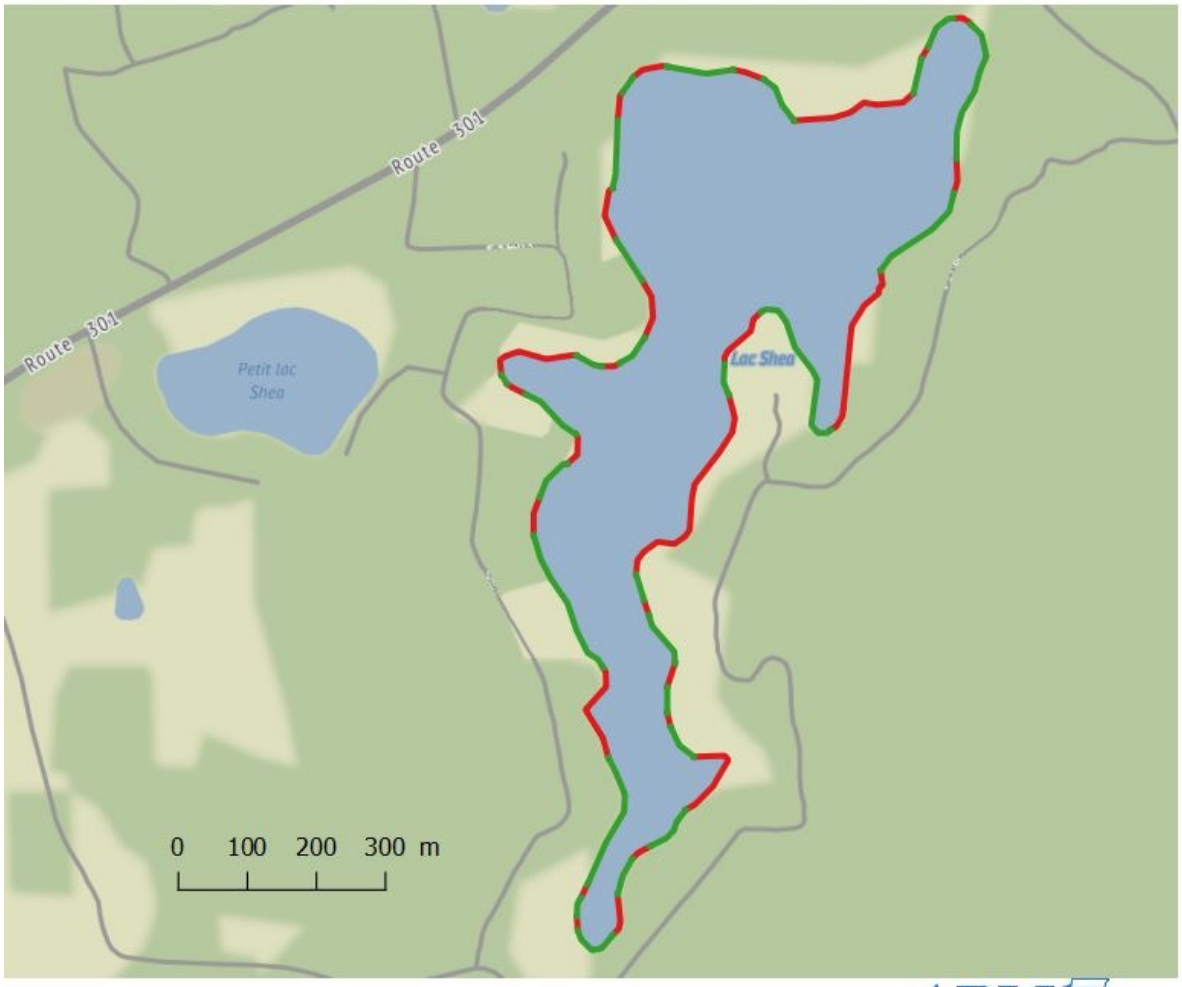
Légende

Used for construction

No use (natural vegetation throughout)



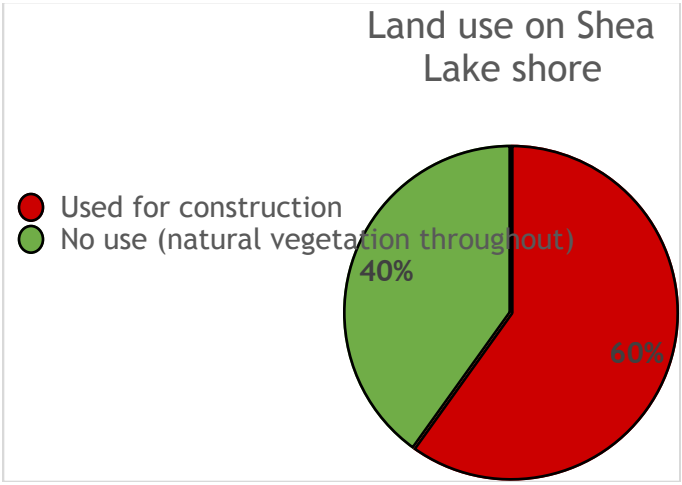
Land use zones on Shea Lake shore



Légende

No use (natural vegetation throughout)

Used for construction



4.2.2 Vegetation cover

Three vegetation cover categories (out of five) have been identified on the shores of Danford, McAuley and Shea lakes: 1. Full Natural Cover, 2. Cover Modified by Humans (Ornemental Vegetation), and 3. Presence of Inert Materials.

Presence of Inert Materials

Lac Shea

Modified Cover (Ornemental Vegetation)

Lac Danford

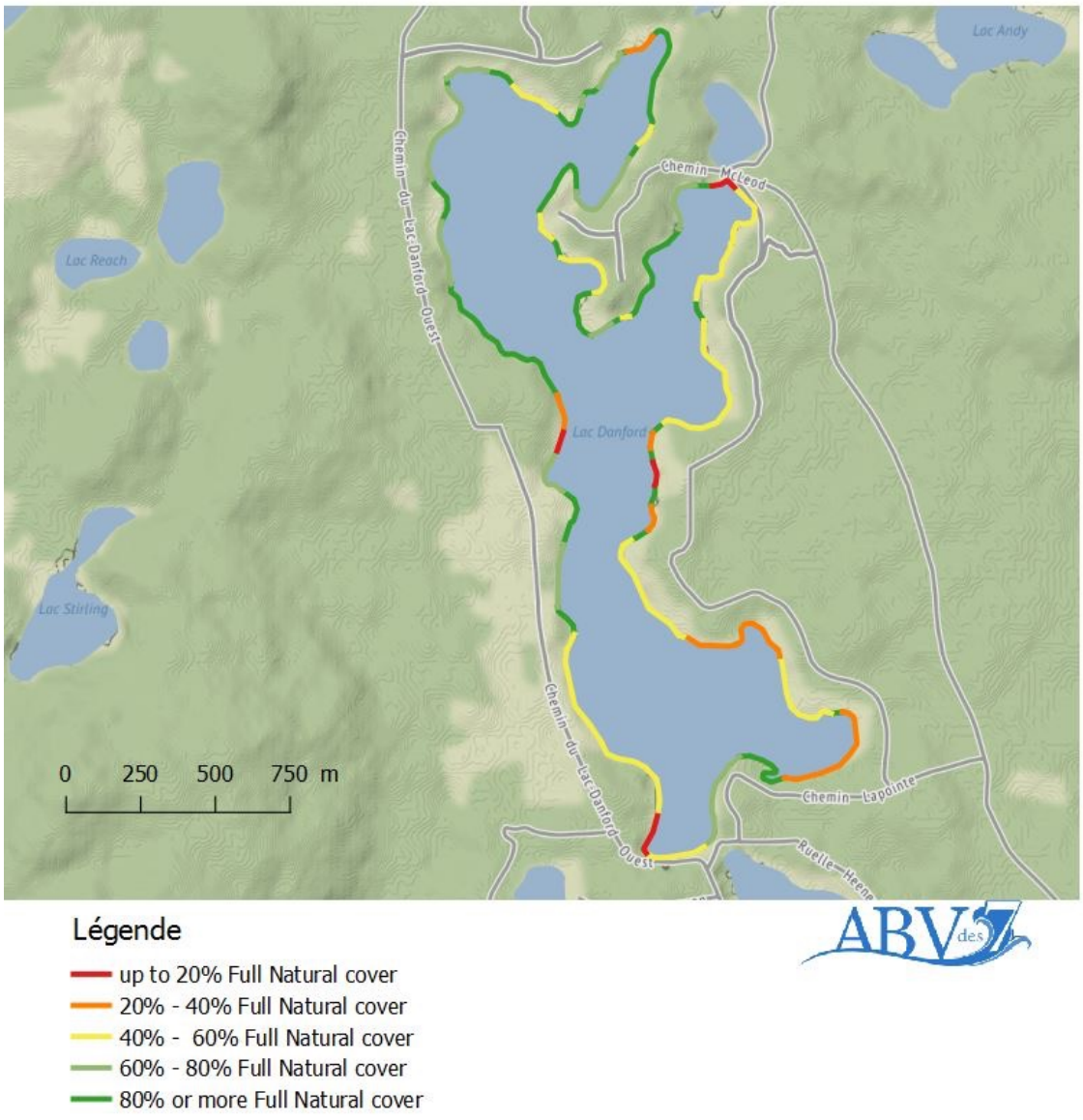
Natural Cover

Lac McAuley

Fig. 20 – Examples of vegetation cover on a lakeshore

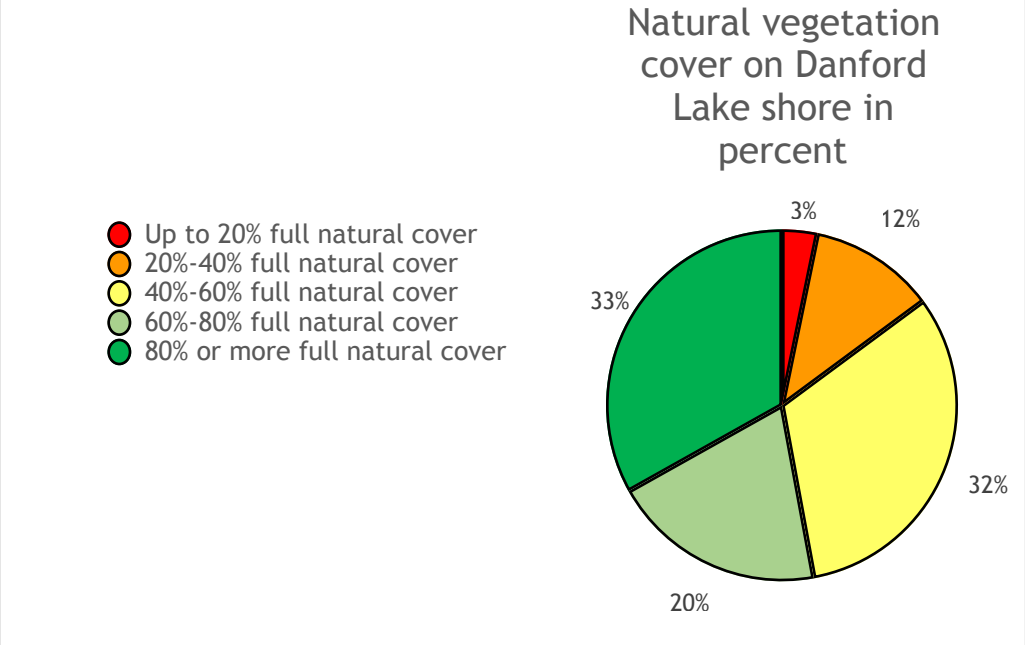
Danford Lake

Natural vegetation cover on Danford Lake shore in percent

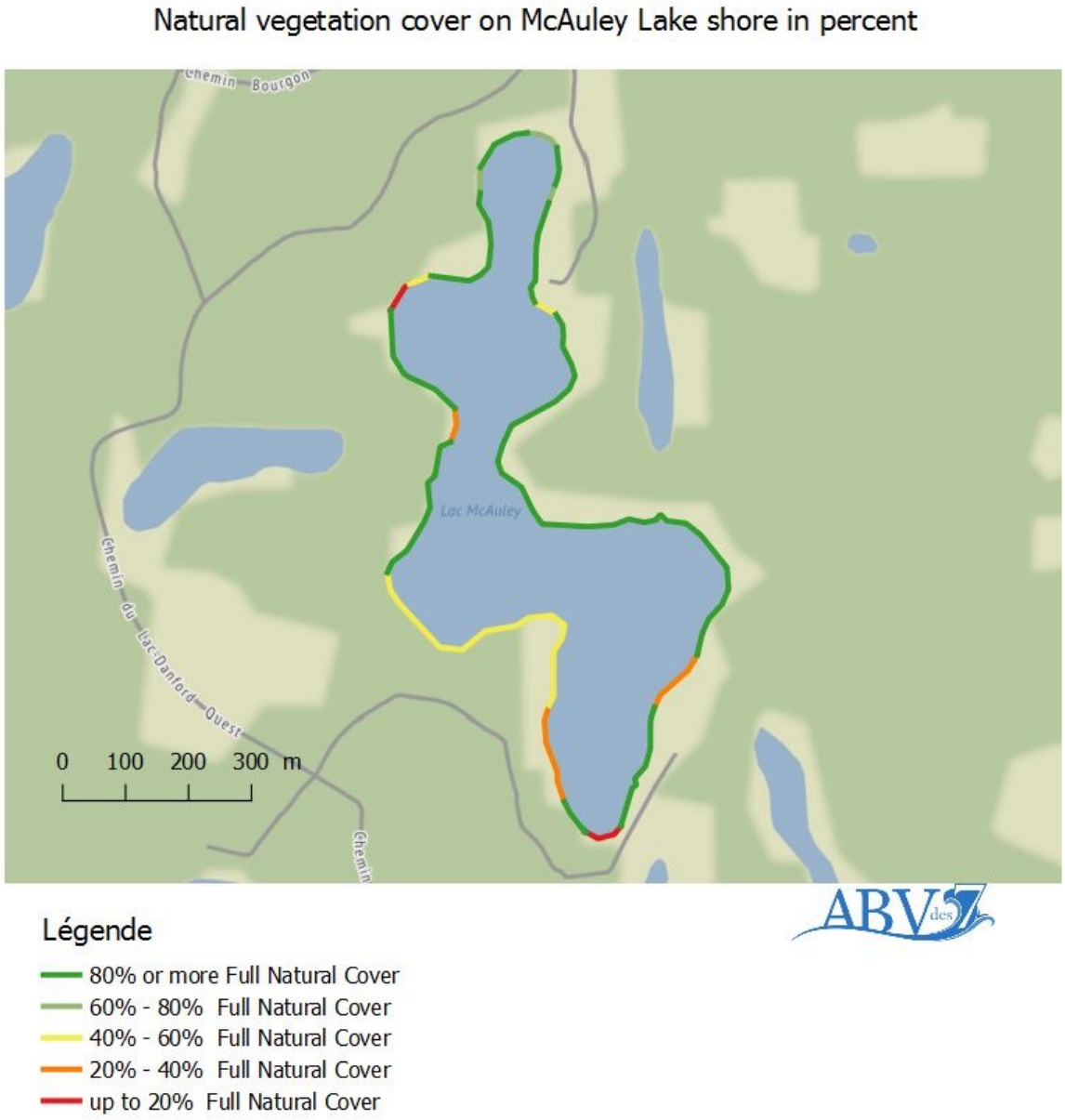


The condition of Danford Lake shore is more or less acceptable, with enough natural vegetation in areas with residences or cottages to preserve 53% of the shore. The large number of these dwellings (138) provides an illustration of good and bad practices on the shore strip.

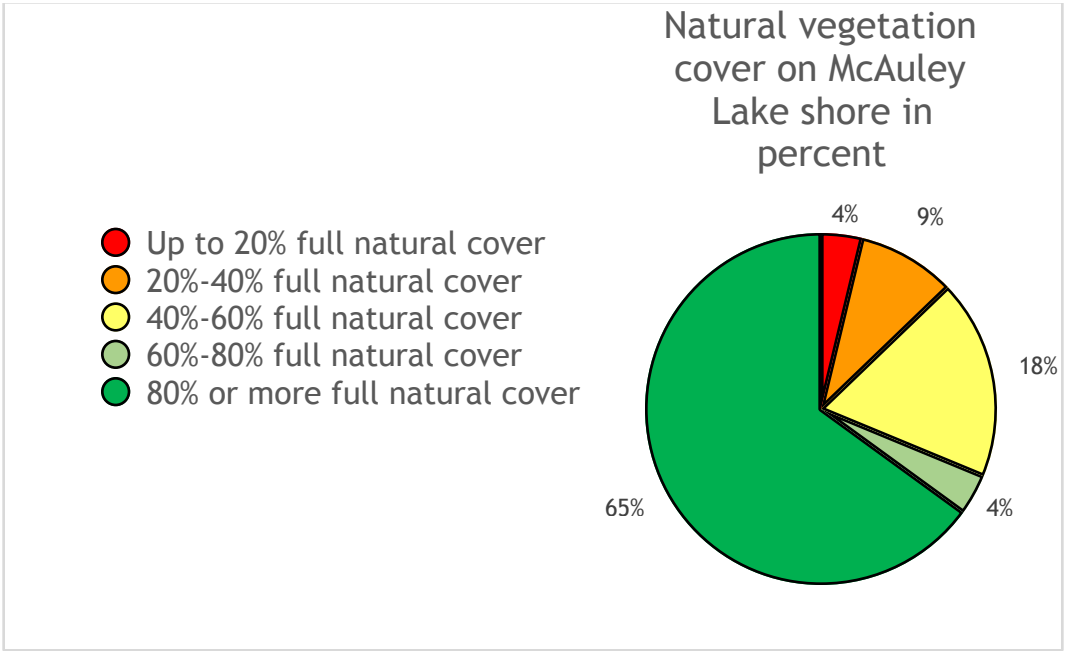
About 15 properties have not done any planting on the shore strip, where lawns go directly down to the water. Such drastic modification of the natural vegetation cover should be prohibited in order to keep the lake healthy. This number should be lowered by encouraging owners to plant and maintain at least bushes and shrubs in the first few meters from the shoreline.



McAuley Lake

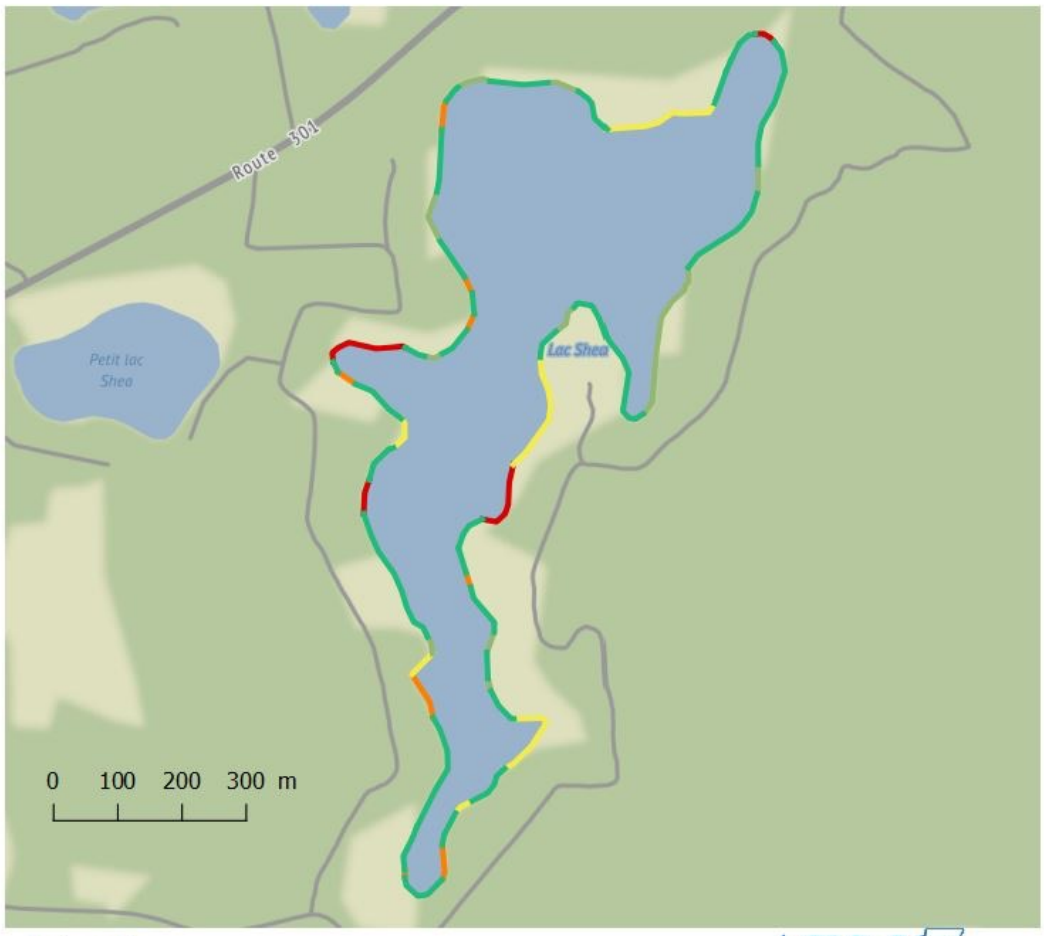


With only about 15 dwellings, McAuley's shore is the least populated. Furthermore, the current property owners are preserving the vegetation fairly well. In three cases, however, there is no natural vegetation, and the shore has lawn down to the water line with only a few shrubs.


Natural vegetation cover on McAuley Lake shore in percent
Up to 20% full natural cover
20%-40% full natural cover
40%-60% full natural cover
60%-80% full natural cover
80% or more full natural cover
4%
9%
18%
4%
65%

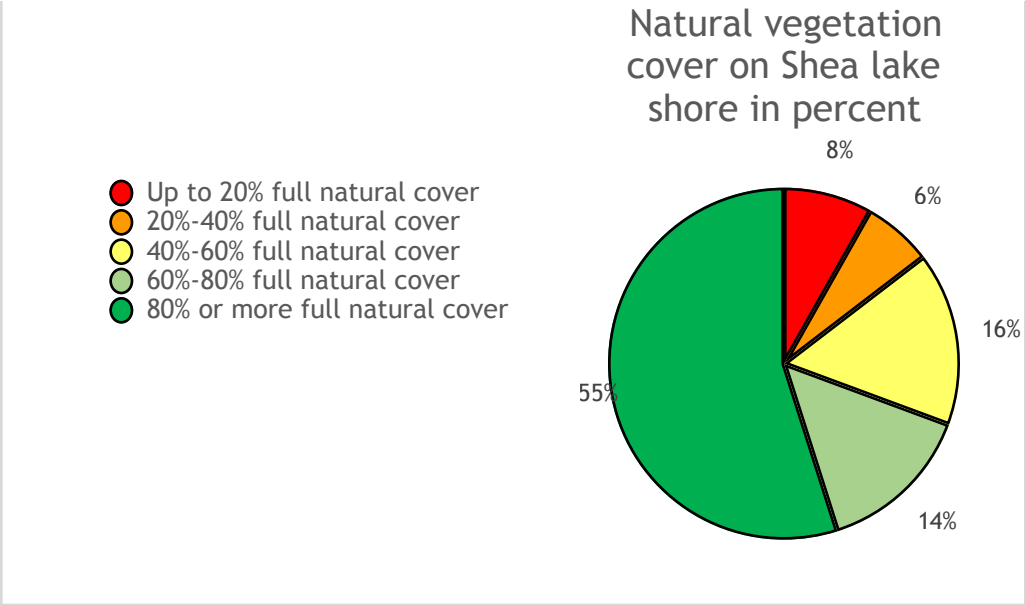
Shea Lake

Natural vegetation cover on Shea Lake shore in percent



Légende

- 80% or more Full Natural cover
- 60% - 80% Full Natural cover
- 40% - 60% Full Natural cover
- 20% - 40% Full Natural cover
- Up to 20% Full Natural cover



On June 6, 2016 during our on-site visit to Shea Lake, we observed that its shoreline was in relatively good condition, considering the number of existing cottages (44). A few properties have lawns down to the waterline, but in many cases, a vegetation strip is maintained along the shoreline. It should be noted that some of these strips of vegetation, although preferable to lawns, remain insufficient to protect the shoreline effectively.

Percent of shore under natural vegetation	% of total shore on Danford	% of total shore on McAuley	% of total shore on Shea
A 80 - 100%	33%	65%	55%
B 60 - 79%	20%	4%	15%
C 40 - 59%	32%	18%	16%
D 20 - 39%	12%	9%	6%
E 0 - 19%	3%	4%	8%

Table 9 – Percent of shore under natural vegetation on the three lakes

4.2.3 Deterioration level of lakeshore

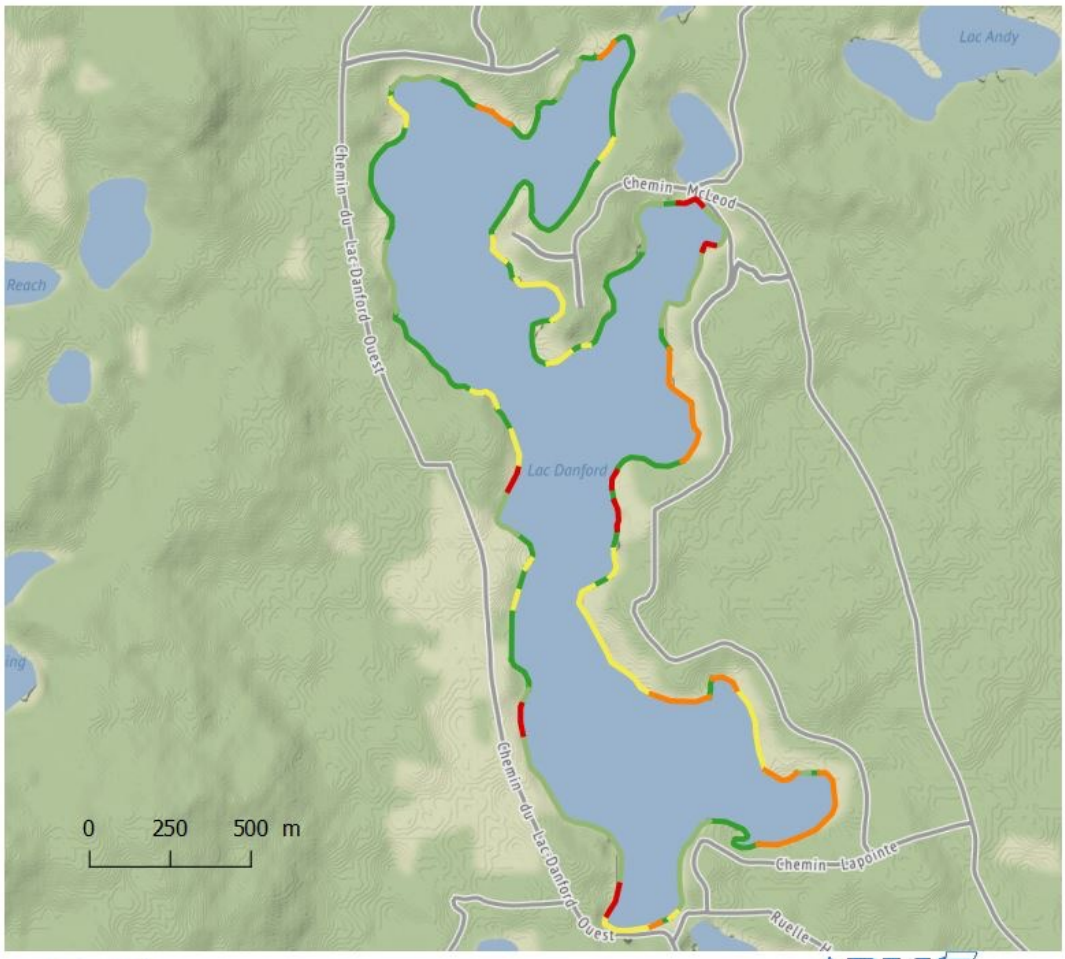
The deterioration of lakeshore is caused by the presence of any type of structure, by the clearing of trees, by any changes to the natural shore, and by any ecosystem disturbance which causes soil degradation or erosion or which can impact, positively or negatively, a landscape's appearance.

Two types of modification to the shore are taken into account for evaluating their level of deterioration:

- **bare soils**, because they increase the risk of erosion and pollution (polluants, sediment, and nutrients are washed into the lake by rain).
- **stone walls and embankments** because they can concentrate run-off, facilitate erosion and contribute to the supply of phosphorus. When stone walls and embankments are present on the lakeshore, waves cannot break against them in the way they do on a natural shore, and this leads to decreased oxygen in the water close to the shore (littoral zone).

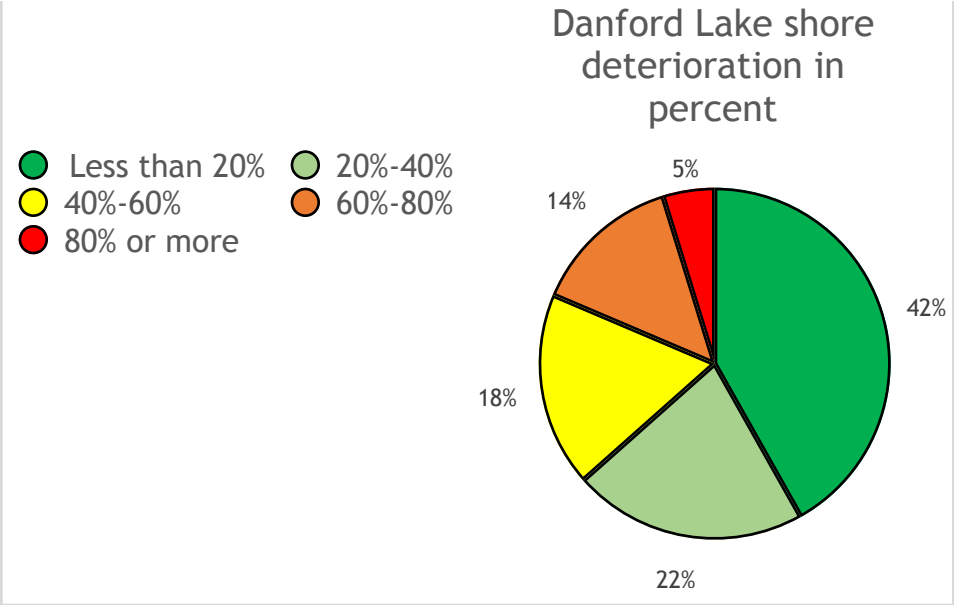
The levels of deterioration on the 15m-wide shore strip are based on the percentage of disturbed shore.

Danford Lake shore deterioration in percent



Légende

- 80% or more deteriorated
- 60% - 80% deteriorated
- 40% - 60% deteriorated
- 20% - 40% deteriorated
- less than 20% deteriorated

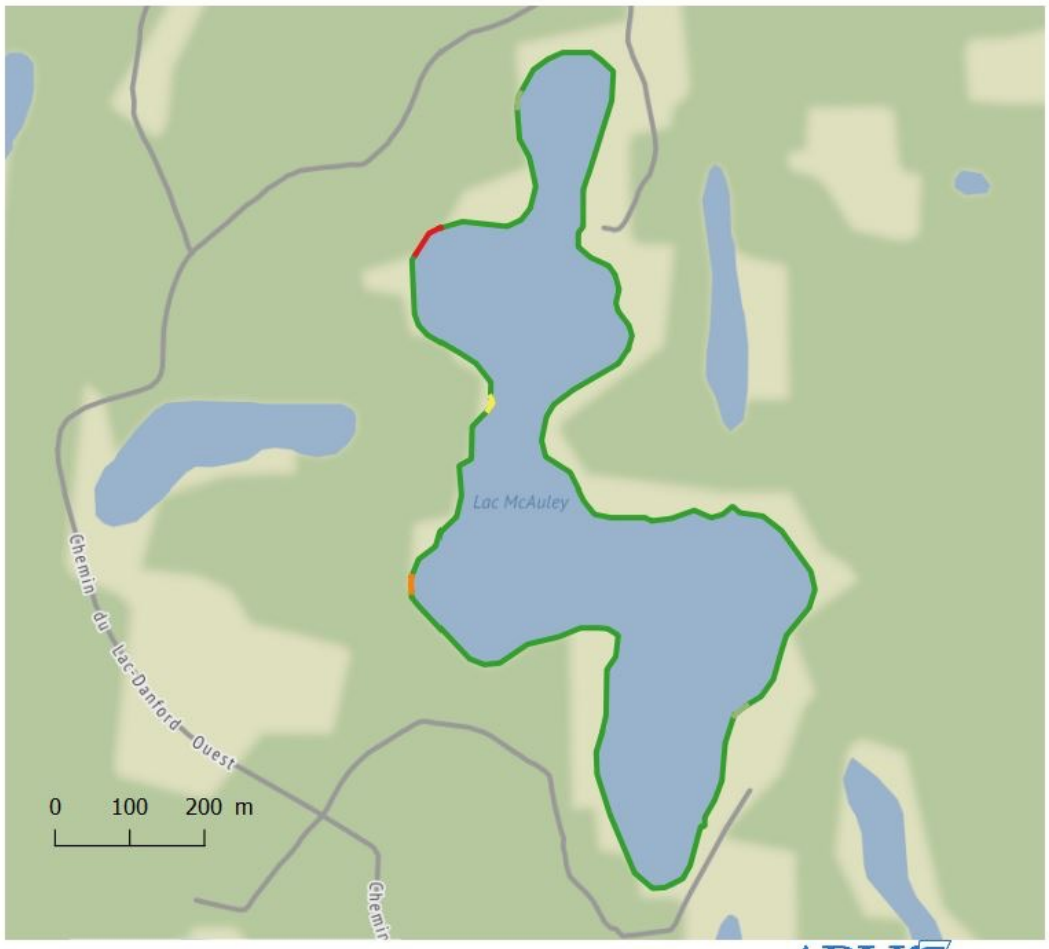


Danford Lake's shores are moderately to greatly disturbed in places, depending on how much the natural vegetation cover has been modified. Some properties have boat launch areas, thereby creating erosion zones (even direct runoff on paved surfaces.) Some properties without any vegetation on shore also show signs of erosion (collapsing banks.) But most shore deterioration is due to inert materials present on the shore strip (retaining walls, embankments, built structures, dwellings).

Indeed, a significant number of small buildings (boat houses, structures on the shore or on the water) are situated directly on the lake shoreline: no less than 44 such cases were documented and photographed. We also counted eight cottages either too close to the shore or partially on the water (some look abandoned). According to local regulations, buildings constructed before 1984 are grandfathered and can even be rebuilt, under certain conditions.

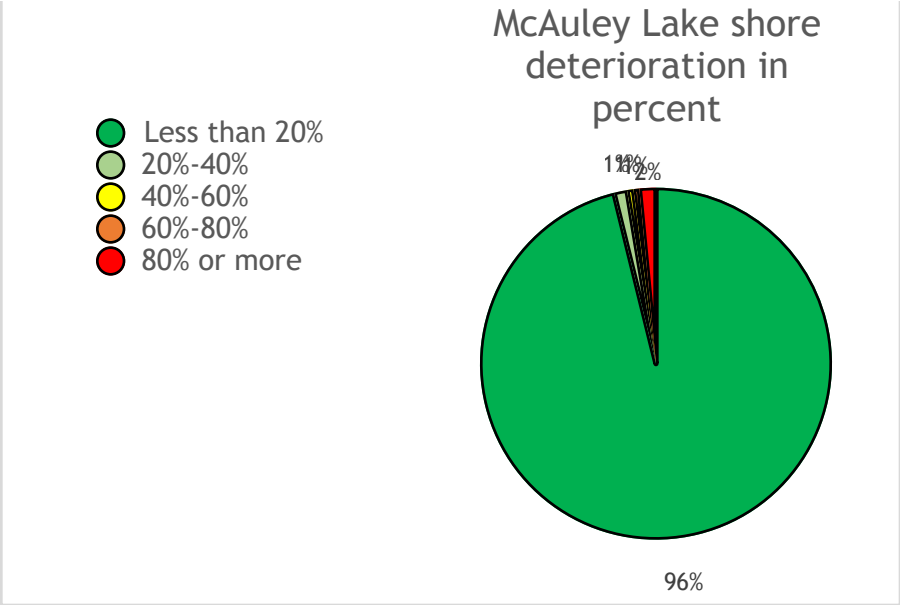
About eight dwellings have mortared stone walls. In some cases, the wall may play a protecting role against erosion. In other cases, however, this is a purely aesthetic choice made at the expense of the natural vegetation cover. Nowadays property owners must obtain a permit before building such walls.

McAuley Lake shore deterioration in percent



Légende

- 80% or more deteriorated
- 60% - 80% deteriorated
- 40% - 60% deteriorated
- 20% - 40% deteriorated
- less than 20% deteriorated



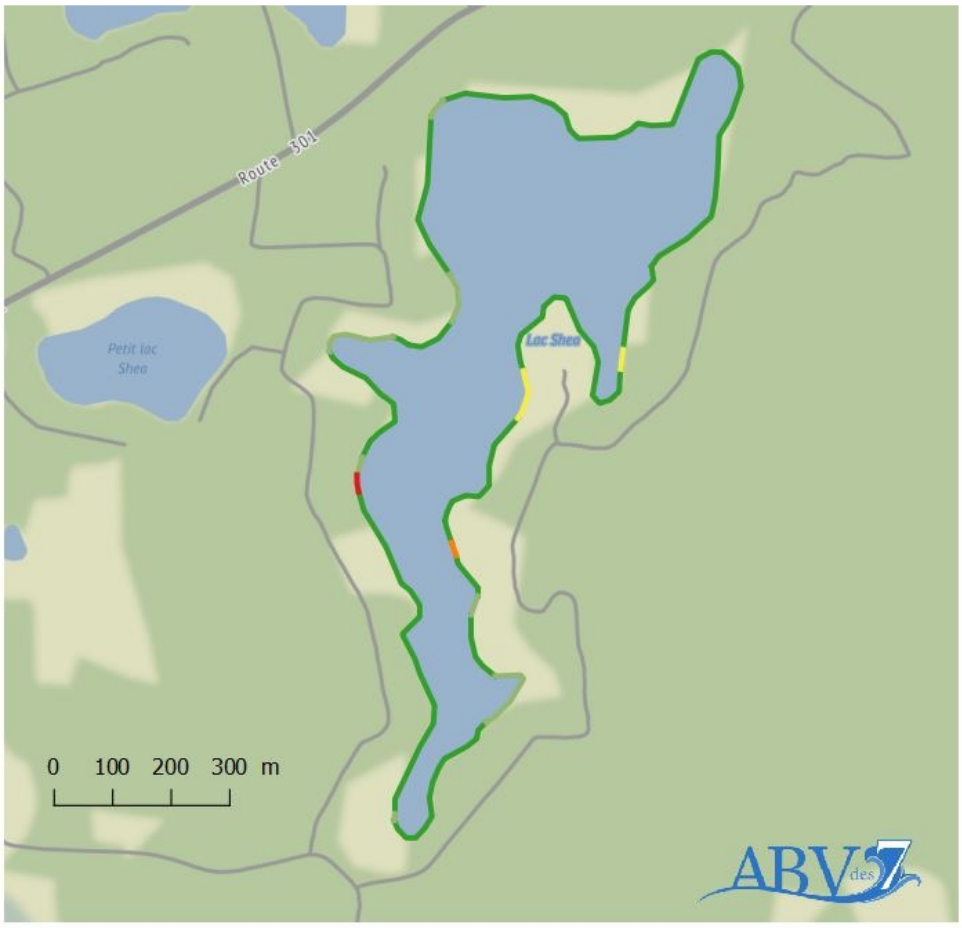
Judging from the data and pictures collected, McAuley Lake's shore is generally well preserved.

We have not observed any retaining walls or large-size embankments. Only a garage and a small building have been built above water or near the water line.

We did note an important eroded zone to the northwest of the lake, with a sandy trail sloping to the water. If possible, the owner should be asked to modify the slope in order to make it less straight, to plant as much vegetation as possible and, particularly, to put gravel or a concrete slatted floor (see Fig. 27) in order to stabilize the shore while permitting water seepage.

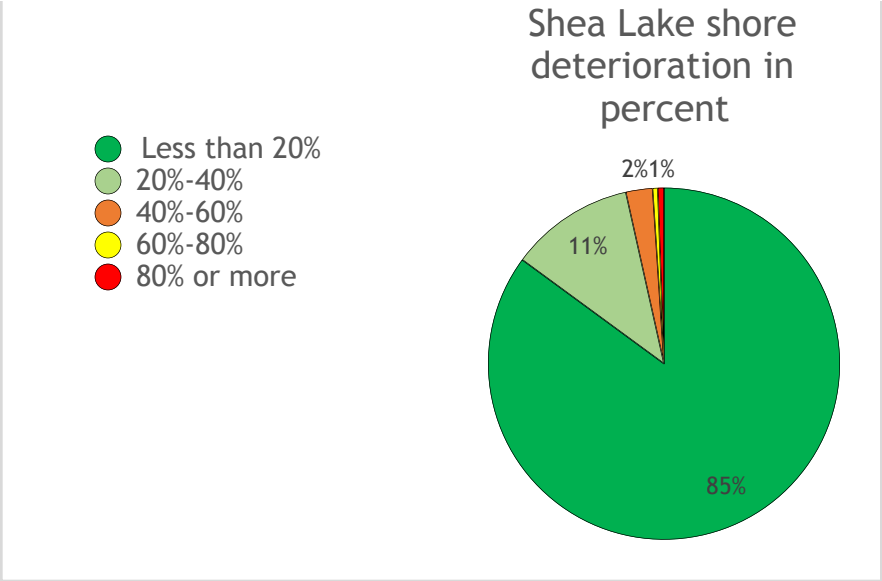
Fig. 27 – Concrete slatted floor

Shea Lake shore deterioration in percent



Légende

- 80% or more deteriorated
- 60% - 80% deteriorated
- 40% - 60% deteriorated
- 20% - 40% deteriorated
- less than 20% deteriorated



We did not note any major deterioration of Shea Lake's shore. We observed only one building in close proximity to the water line (a permit was most probably issued to the owner for this apparently recent construction). We also saw an older cottage erected on the shore strip, but the vegetation cover is sufficient there. There are no zones of erosion on Shea Lake, except on one property where a strip of shrubs was planted to capture part of the sediments washing into the water.

Table 10 - Shore deterioration on the three lakes

Shore deterioration in percent	% of shore on Danford	% of shore on McAuley	% of shore on Shea
A < 20%	42%	96%	85%
B 20-39%	21%	1%	11%
C 40-59%	18%	1%	2%
D 60-80%	14%	1%	1%
E > 80%	5%	1%	1%

Conclusion on the condition of lake shores

Combining land use data and vegetation cover data, we see that natural vegetation predominates on Shea Lake (almost 55% of the total shore) and on McAuley Lake (65%). On those two lakes, the categories *Presence of Inert Materials* and *Erosion* represent only 2% of the total shore. The remaining shore falls into the category *Cover Modified by Humans (Ornemental Vegetation)* with various degrees of vegetation cover.

In contrast, on Danford Lake, natural vegetation covers only 33% of the total shore, and the two categories *Presence of Inert Materials* and *Erosion* represent a significant portion (21%) of its shore.

On all three lakes, but particularly on Danford Lake, we have noted properties which contribute to soil erosion and run-off simply because their shore vegetation cover is insufficient: lawn down to the waterline, absence of trees, inappropriate use of shore (used for storage or decks), scars (completely bare spots), riprap[7] and retaining walls without any vegetation, lakeshore strip too narrow).

The less disturbed the shore, the better the lake's natural protection against erosion, eutrophication, and increased water temperature in the littoral zone. Consequently, efforts should be made (a) to restore natural vegetation on the shore itself, (b) to plant vegetation on any existing infrastructure (riprap, gabions, lawns), and (c) to stabilize eroded slopes (e.g., the slope used for launching boats in the water on McAuley Lake). All these measures would contribute to slowing down the eutrophication process and would prevent the introduction and spread of invasive species.

[7] Translator's Note: See Footnote 2

5. RECOMMENDATIONS

Recommendations	Findings and actions	
1. To enforce regulations on lakeshore protection	**Findings**	Buildings (residences/cottages) occupy a fairly large percentage of the three lake shores (less on McAuley). Considering the impact of such human pressure, it is important, even essential, to preserve a natural vegetation strip there, regardless of the type of zone the property is in.
	Actions	**MRC Vallée-de-la-Gatineau should** - develop tools for monitoring the enforcement of regulations efficiently - remain uncompromising when granting new permits and approving projects which would increase the use of shores or new recreational and tourism activities on shores that might compromise the health of the lakes **Lakes Association of Kazabazua (LAK) should:** - continue raising awareness on good practices and current regulations on lakeshore protection
2. To restore natural vegetation on lakeshore	**Findings**	Natural vegetation is present on a fair percentage of the three lake shores. However, wherever this natural cover is missing, it is *badly* missing. Moreover, in many places, the mandatory (10m or 15m-wide) shore strip is either too narrow or insufficiently covered with vegetation.
	Actions	**MRC, Municipality of Kazabazua (KAZ), and LAK should** - join efforts in initiating projects aimed at (a) restoring natural vegetation on those parts of the lakeshore that do not comply with regulations and (b) raising awareness with regard to existing regulations - encourage lake property owners to apply good practices with a view to maintaining and preserving a healthy lakeshore vegetation cover - encourage lake property owners to *either* restore vegetation on inadequate structures (retaining walls, riprap, buildings, decks, etc.) *or* to replace them altogether with vegetation, thus decreasing their negative impacts on lakes

Recommendations	Findings and actions	
3. To continue water quality testing	**Findings**	LAK's annual water testing is essential for monitoring the situation and implementing corrective measures if needed
	Actions	**KAZ and LAK should** - continue annual water testing at the same locations and using the same method - add parameters (especially for McAuley: chlorophyll *a*, sampling at the greatest depth or reading of dissolved oxygen).
4. To monitor septic systems	**Findings**	KAZ must monitor septic systems on its territory and enforce provincial regulations
	Actions	**KAZ should** - continue present monitoring and explore the possibility of passing stricter regulations - keep a record of every lake property in order to know how often its septic system is emptied and if a new system is required **LAK should** - request from KAZ annual monitoring reports that give the number of failing septic systems for each lake
5. **To raise awareness on good practices aimed at protecting water quality**	**Findings**	Some property owners may have practices that are harmful to the environment. LAK should make them aware of the negative impacts of such practices.
	Actions	**LAK should** . continue (through its website, the use of flyers, newsletters, articles, etc.) - to inform its members of the negative impact of fertilizers and pesticides and to offer alternatives; - to encourage its members to use phosphate-free products, to recover ashes from fire pits, and to take measures aimed at limiting the flow of nutrients and polluants into the water; - to monitor the spread of chemicals on those sections of the roads that are in close proximity (within 15 m) to the water; and . raise awareness with local farmers about the need to limit water pollution caused by animals, and raise awareness with forestry companies about the need to protect the shore of streams or creeks that cross parcels where logging occurs.

6. CONCLUSION

Danford Lake

The physical and chemical quality of Danford Lake's water is good and is characteristic of an oligotrophic* lake (Stage I of III). However, human pressure on this lake is heavy, and its shoreline is very much disturbed in several locations, which makes the quality of this lake's water vulnerable. An eutrophication of this lake is to be expected if no efforts are made to remediate the portions of its shoreline that are excessively deteriorated.

Shea Lake

The physical and chemical quality of this lake's water is also good and typical of an oligotrophic* lake (Stage I of III). Human pressure is less heavy than on Danford Lake, and efforts are being made to maintain or restore natural vegetation. However, the restored strips are sometimes too narrow to be really effective. Efforts should therefore be made to improve the situation. Shea Lake has a distinctive feature: its pH is slightly more acidic as the other two lakes. This is likely due to the fact that the underlying bedrock contains more granite than limestone.

McAuley Lake

Although human pressure is not as heavy as on the other lakes, McAuley is already showing signs of eutrophication*. This may be explained by natural causes: this lake is fed by two streams and by Danford Lake's outlet, which means that it is receiving potentially significant volumes of sediment. It is therefore essential to preserve the natural condition of the inlet areas and to restore natural vegetation on the few portions of the shoreline that are deteriorated (namely, a sandy trail sloping down to the lake, and zones without any vegetation).

7. BIBLIOGRAPHY

See French report.

8. GLOSSARY

Fall turnover	As the weather cools during autumn, the upper layer (epilimnion) cools too, reducing the density difference between it and the lower layer (hypolimnion). As time passes, winds mix the lake to greater depths, and thermocline gradually deepens. When surface and bottom waters approach the same temperature and density, autumn winds can mix the entire lake; the lake is said to "turn over." As the atmosphere cools, the surface water continues to cool until it freezes. A less distinct density stratification than that seen in summer develops under the ice during winter. Most of the water column is isothermal at a temperature of 4°C, which is denser than the colder, lighter water just below the ice. In this case the stratification is much less stable, because the density difference between 0°C and 4°C water is quite small. However, the water column is isolated from wind-induced turbulence by its cap of ice. Therefore, the layering persists throughout the winter.
Spring turnover	In the Spring, the water near a lake's bottom will usually be at 4°C just before the lake's ice cover melts. Water above that layer will be cooler, approaching 0°C just under the ice. As the weather warms, the ice melts. The surface water heats up and therefore it decreases in density. When the temperature (density) of the surface water equals the bottom water, very little wind energy is needed to mix the lake completely. This is called turnover. After this Spring turnover, the surface water continues to absorb heat and warms. As the temperature rises, the water becomes lighter than the water below. For a while winds may still mix the lake from bottom to top, but eventually the upper water becomes too warm and too buoyant to mix completely with the denser deeper water.

Thermal stratification	Lakes are dynamic systems which change during a year, and from year to year. Water in a lake is moving within the water column (surface to bottom), as well as through the length of the lake (inflow to outflow). During a year it is possible for lakes deeper than 5-7 meters to form layers of water having different temperature and oxygen concentrations. This is termed thermal stratification and is due to the changes in the density of water at different temperatures. Shallow lakes however, tend to mix more readily and avoid this stratification. From one season to the next, lake temperatures change creating a cyclical pattern that is repeated year after year. As summer progresses, the temperature (and density) differences between upper and lower water layers become more distinct. Deep lakes generally become physically stratified nto three identifiable layers, known as the epilimnion, metalimnion, and hypolimnion. The epilimnion is the upper, warm layer, and is typically well mixed. Below the epilimnion is the metalimnion or thermocline region, a layer of water in which the temperature declines rapidly with depth. The hypolimnion is the bottom layer of colder water. The density change at the metalimnion acts as a physical barrier that prevents mixing of the upper and lower layers for several months during the summer. The depth of mixing depends in part on the exposure of the lake to wind, but is most closely related to the lake's size. Smaller to moderately-sized lakes (50 to 1000 acres) reasonably may be expected to stratify and be well mixed to a depth of 3–7 meters in north temperate climates. Larger lakes may be well mixed to a depth of 10–15 meters in summer. This pattern (spring turnover — summer stratification — fall turnover — winter stratification) is typical for temperate lakes.
Thermocline	The thermocline is the transition layer between the mixed layer at the surface and the deep water layer. The definitions of these layers are based on temperature. The mixed layer is near the surface where the temperature is roughly that of surface water. In the thermocline, the temperature decreases rapidly from the mixed layer temperature to the much colder deep water temperature. The mixed layer and the deep water layer are relatively uniform in temperature, while the thermocline represents the transition zone between the two.