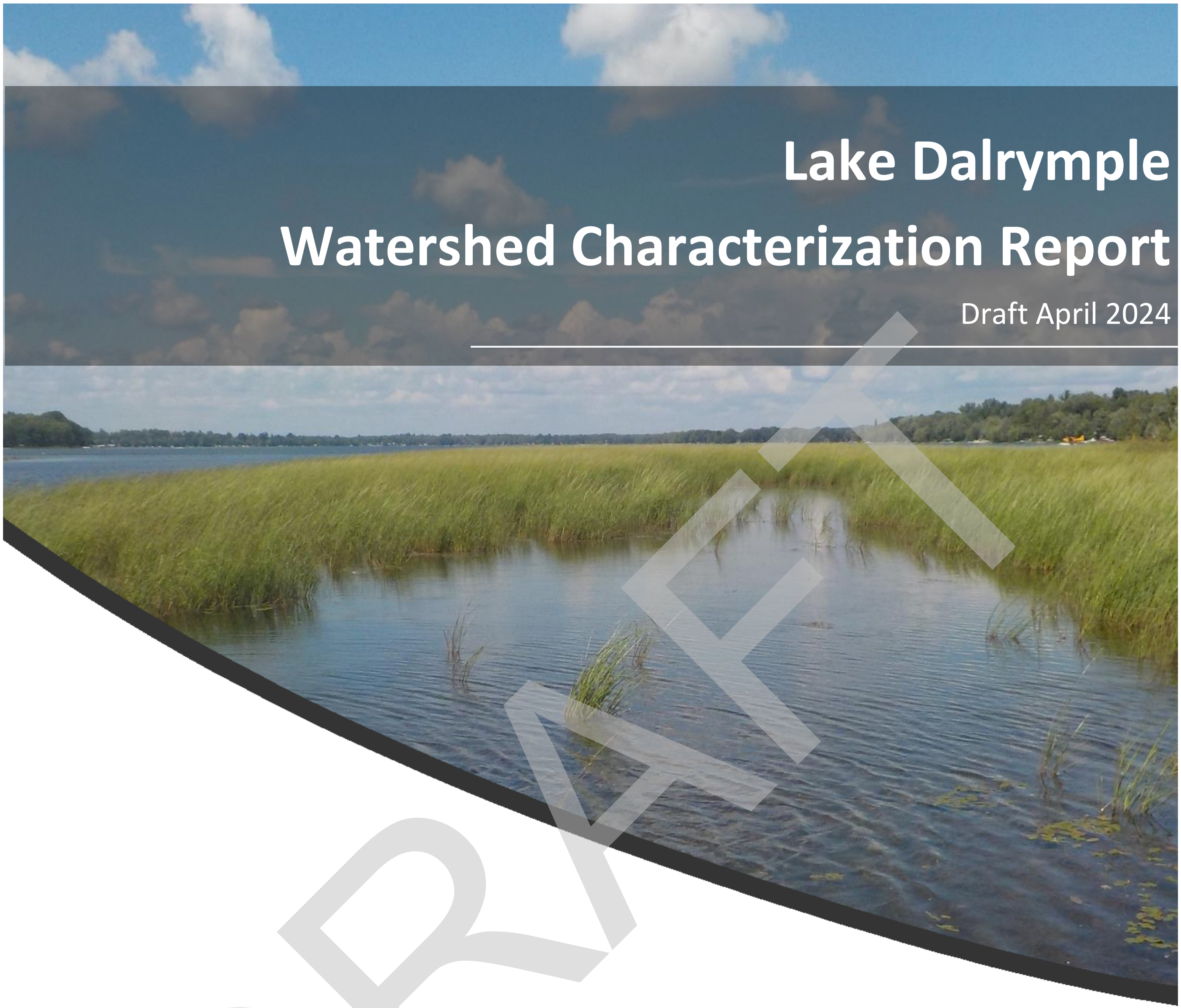
Lake Dalrymple

Watershed Characterization Report

Draft April 2024



KAWARTHA CONSERVATION

Discover · Protect · Restore

About Kawartha Conservation

Who we are

We are a watershed-based organization that uses planning, stewardship, science, and conservation lands management to protect and sustain outstanding water quality and quantity supported by healthy landscapes.

Why is watershed management important?

Abundant, clean water is the lifeblood of the Kawarthas. It is essential for our quality of life, health, and continued prosperity. It supplies our drinking water, maintains property values, sustains an agricultural industry, and contributes to a tourism-based economy that relies on recreational boating, fishing, and swimming. Our programs and services promote an integrated watershed approach that balance human, environmental, and economic needs.

The community we support

We focus our programs and services within the natural boundaries of the Kawartha watershed, which extend from Lake Scugog in the southwest and Pigeon Lake in the east, to Balsam Lake in the northwest and Crystal Lake in the northeast – a total of 2,563 square kilometers.

Our history and governance

In 1979, we were established by our municipal partners under the *Ontario Conservation Authorities Act*.

The natural boundaries of our watershed overlap the six municipalities that govern Kawartha Conservation through representation on our Board of Directors. Our municipal partners include the City of Kawartha Lakes, Region of Durham, Township of Scugog, Township of Brock, Municipality of Clarington, Municipality of Trent Lakes, and Township of Cavan Monaghan.

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Executive Summary

The Lake Dalrymple Watershed Characterization Report supports the development of the Lake Dalrymple Management Plan.

The Lake Dalrymple Management Planning project is a collaborative effort led by Kawartha Conservation, funded by City of Kawartha Lakes, and with input provided from a broad range of local individuals, communities, and stakeholders.

The science-based project was undertaken over 4-years (2021-2024) and involved routine monitoring of water quality and water quantity conditions, and focused studies on important lake watershed features to local communities such as: land use, fish habitats, aquatic plants, and landscape ecology. The project also included comprehensive public engagements to better understand the lake management priorities of local communities and lake management organizations.

The Lake Dalrymple Watershed Characterization Report is a 'technical' publication that provides detailed background information on the current state of the aquatic and terrestrial ecosystems within the Lake Dalrymple watershed, as well as a summary of lake-based community concerns and values identified through public consultation.

The report provides a summary of key observations, issues, and information gaps, as well as detailed information on the following themes: Land Use and Lake Use, Water Inputs and Water Levels, Water Quality, Sediment Quality, Aquatic Habitats and Fish, and Landscape Ecology.

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1.0 Introduction

[Information Session for Lake Dalrymple Management Plan, Carden Recreation Centre, May 28, 2022]

1.1 Background

The Lake Dalrymple Management Planning project is a collaborative effort led by Kawartha Conservation, funded by City of Kawartha Lakes, and with input provided from a broad range of local individuals, communities, and stakeholders.

The science-based project was undertaken over 4-years (2021-2024) and involved routine monitoring of water quality and water quantity conditions, and focused studies on important lake watershed features to local communities such as: land use, fish habitats, aquatic plants, and landscape ecology.

The project also included comprehensive public engagements to better understand the lake management priorities of local communities and lake management organizations. A 'Working Group', made up of local community members and organizations met on a regular basis to help guide the project.

1.2 Project Objectives

The following objectives were developed at the project onset to guide the Lake Dalrymple Management Planning project.

- Implement and maintain for the duration of the study comprehensive water quality and water quantity sampling networks to provide a scientific basis to identify current and potential threats/stressors, hotspots, evaluate trends and key management issues, and identify options for priority actions.
- Provide a current and baseline scientific basis to support and inform municipal land use planning and policy tools within the City of Kawartha Lakes.
- Design and implement management activities to maintain or achieve Provincial Water Quality Objectives for the lake and its streams, as well to reduce beach closures and create greater confidence in the lake health in general.
- Protect and improve water quality for all uses.
- Foster community participation in the project and understanding of the Kawartha Lakes, their natural and historic heritage, and human impacts.
- Develop and coordinate the necessary partnerships for effective collaboration on all aspects of the planning process and plan implementation.
- Promote a greater dialogue and understanding of issues, conflicting needs, visions and resource uses.

- Identify specific items for ongoing monitoring and advanced university research, for example: quantifying impacts to the nearshore zone, identifying specific sources of pollution, considering impacts of climate change, and invasive species.

1.3 Existing Technical Studies

Prior to this project, Lake Dalrymple was relatively understudied. Below are the key findings from two technical reports that address certain aspects of lake management.

- Water Quality Report for Lake Dalrymple (Ministry of Environment 1972).
    - Surveys were carried out in summer of 1972 to evaluate the present status of water quality with respect to bacteria, algae, and aquatic plant growth. Bacteriological was determined to be 'good' overall, but there were several localized areas with moderately high bacterial levels. Chemical water quality was also considered 'good', with no evidence of any serious dissolved oxygen depletion, and a moderate status of enrichment. The southern half of the lake (Upper Lake Dalrymple) was heavily populated by aquatic plants.
- Cumulative Impacts Assessment for Groundwater Takings in the Carden Plain Area (Golder 2012).
    - Due to the recent level of aggregate extraction activity in the Carden Plain Area, the Ontario Ministry of the Environment requested an impact assessment to evaluate the potential cumulative impacts of quarry dewatering at multiple sites on groundwater, surface water and ecological receptors. In summary, based on the analysis presented for the 20-Year Development scenario, cumulative effects of the quarries considered in this study, on groundwater drawdown, drinking water wells, wetland function, low flows in creeks and rivers, flooding and erosion in creeks and rivers and most water quality parameters are expected to be negligible. Increases in concentrations of boron, iron, sulphate and chloride are expected as a result of dewatering groundwater (which naturally contains these parameters) from quarries. Describe why the project is needed and how it accomplishes the larger goals of the program.

1.4 Project Outcomes

Key outcomes of the project are the Lake Dalrymple Management Plan (LDMP) and the Lake Dalrymple Watershed Characterization Report (LDWCR).

The LDMP is a ‘public-friendly’ publication that provides a high-level overview of key science-based and community-based issues and opportunities, and details numerous management recommendations that, if implemented, will help to maintain and where possible improve the health of the lake. Management recommendations are organized within the themes: Land Securement, Regulations and Enforcement, Stewardship Projects, Communications and Outreach, and Research and Monitoring.

The LDWCR, is a ‘technical’ publication that provides detailed background information on the current state of the aquatic and terrestrial ecosystems within the Lake Dalrymple watershed, as well as a summary of lake-based community concerns and values identified through public consultation. The report includes information on Land Use and Lake Use, Water Inputs and Water Levels, Water Quality, Sediment Quality, Aquatic Habitats and Fish, and Landscape Ecology.

1.5 Summary of Community Values and Concerns

As part of initial project scoping, efforts were undertaken to characterize the lake management values and issues that were important for local individuals and communities that live in the Lake Dalrymple watershed. This information helps the project management team to ‘hone-in’ on the issues that are relevant to people, to ensure they are captured within the Lake Watershed Characterization Report and/or the Lake Dalrymple Management Plan.

In 2022, a public survey and open houses were made available for local communities to learn more about the project, and to provide feedback to the project management team in terms of their core management concerns. The survey was available in person at both Lake Dalrymple Open Houses at the Carden Recreation Centre on May 26 and May 28, 2022, as well as online for a period of May 16 to June 30, 2022.

The survey saw 48 respondents, 83% of which were lakeshore residents (40 people), and 17% off the shore (8 people). 28 of the responses were completed online, while the remaining 20 were completed in person at the Lake Dalrymple Open Houses.

The following questions were asked:

1. *Are you providing comments on behalf of a specific organization?*
2. *Is your cottage/house/business located on the shoreline of Lake Dalrymple?*
3. *What do you value most about Lake Dalrymple?*
4. *What issues about the lake are you most concerned about?*
5. *What major changes have you noticed over the years on the lake, and its watershed?*

Figure 1.1 provides a high-level summary of results for questions 3 to 5. The top values, concerns, and changes were related to Nature and Habitat, Water Quality and Quantity, and Fishing and Hunting, respectively (Table 1.1, Table 1.2, and Table 1.3).

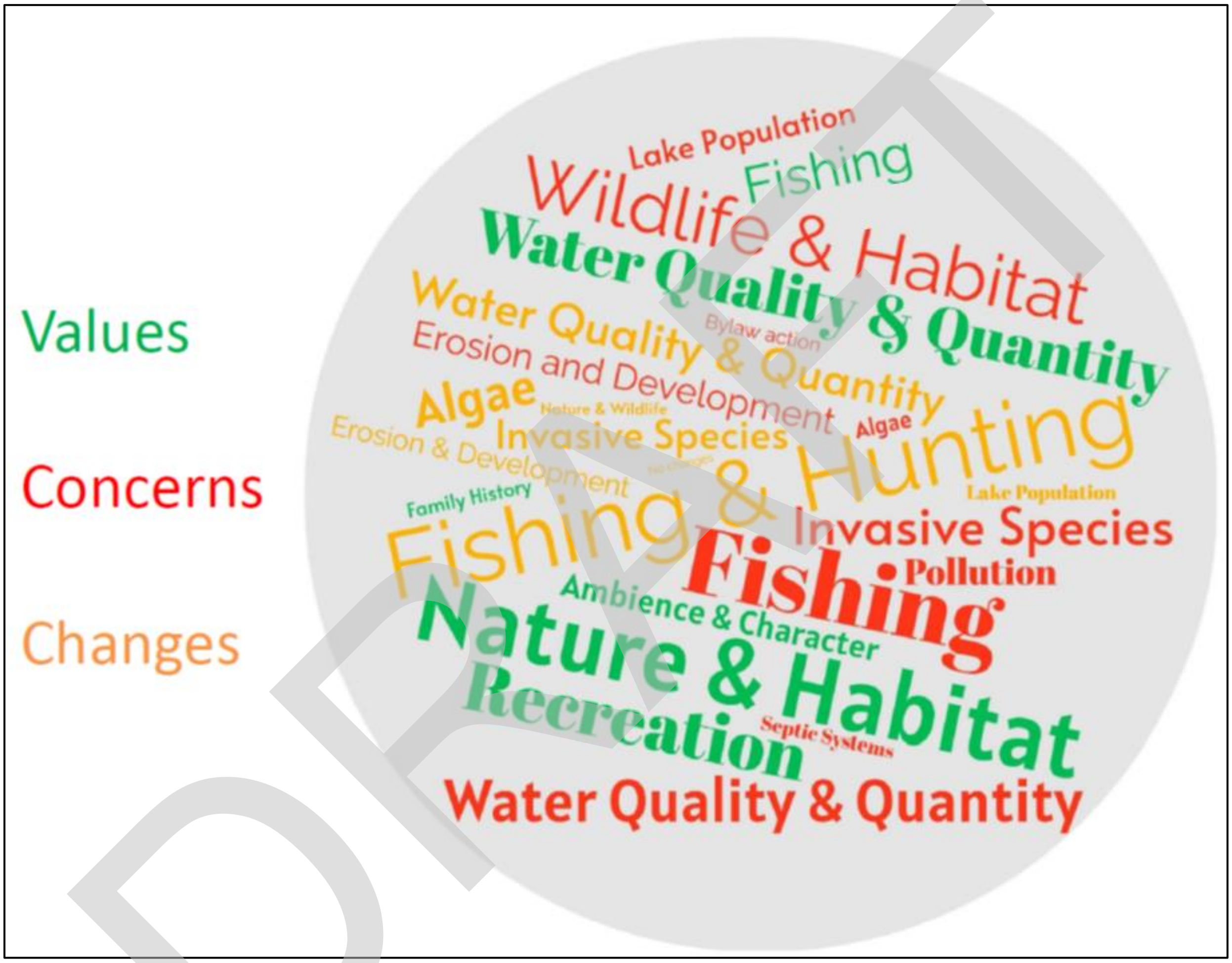

Figure 1.1. Word cloud diagram of responses of values (green), concerns (red), and changes (orange). The larger the word, the more frequently it was mentioned in the feedback survey.

Table 1.1. List of lake values provided by the community. Number of responses in brackets.

Values	Responses
Ambience and Character (23)	• Community feeling; family friendly (5) • Natural beauty of the area (5) • Peaceful, quiet, and safe (13)
Family History (5)	• Family history and memories on lake (3) • Protection of the lake for future generations (2)
Nature and Habitat (40)	• Geography, habitat, and nature (12) • Wildlife, plants, and biodiversity (28)
Recreation (18)	• Boating, kayaking and water sports (9) • Swimming and other recreational lake activities (9)
Water Quality and Quantity (25)	• Clean water (16) • Comfortable water temperature (2) • Water quality, clarity, level, and health (7)

Table 1.2. List of lake concerns provided by the community. Number of responses in brackets.

Concerns	Responses
Algae (4)	• Increased algae and eutrophication (4)
Bylaw Action (6)	• Little of no action from bylaw or ministry on pollution, fishing regulations, etc. (4) • Need more balanced recreational conservation and interest from outside agencies (2)
Pollution (8)	• Pollution, leakage, runoff, and contamination in and around lake (4) • Residents dumping fill and making property alterations (4)
Erosion and Development (12)	• Increased development near shorelines and waterfront properties (10) • Need more prevention of shoreline erosion (2)
Fishing (30)	• Changes in fish populations (13) • Need to protect fish health (3) • Overfishing including ice fishing putting pressure on lake resources (14)

Lake Population (6)	• Increased population, boaters, and noise (6)
Septic Systems (4)	• Inspections are needed for poorly installed, illegal, and old septic systems on the lake (4)
Water Quality and Quantity (30)	• Use of water for drinking and swimming (6) • Maintaining healthy lake and good water quality for years to come (11) • Water level fluctuation (13)
Wildlife and Habitat (15)	• Protecting wildlife, habitat, and natural areas (15)
Invasive Species (11)	• Increase of invasive species and aquatic plants (11)

Table 1.3. List of lake changes provided by the community. Number of responses in brackets.

Changes	Responses
Algae (10)	• Algae appearing sooner each year (1) • Increased algae in the lake (9)
Erosion and Development (13)	• Beavers impacting water flow (1) • Increase in shoreline development, erosion, and loss of natural shoreline (12)
Fishing and Hunting (35)	• Changes in fish populations (20) • Fishing, hunting, and boating rules not effectively enforced, increased fishing year-round (7) • Overfishing causing pressure on fish (8)
Lake Population (11)	• Community feel resonates (1) • Changes in boat traffic and population (10)
Invasive Species (17)	• Increase in invasive species and aquatic plants (10) • Changes in zebra mussel population (7)
Nature and Wildlife (5)	• Changes in wildlife and plant populations (3) • Healthy and plentiful bird population (2)
No Changes (6)	• New to the area (3) • No major changes (3)
Water Quality and Quantity (17)	• Changes in water level (15) • Water clarity decreasing (2)

2.0 Study Area

[The 'narrows' of Lake Dalrymple, looking south from the Osprey Lane boat launch, August 11, 2021]

2.1 Lake Description

Lake Dalrymple is in southern Ontario, Canada, just north-east of Lake Simcoe, and east of the Town of Orillia. It is on the far western boundary of what is locally referred to as the 'Kawarthas' region.

The project study area is the Lake Dalrymple watershed, which is 150.5 km^2 (Figure 2.1) This includes the lake, and all lands and waters that drain into the lake outlet, which exists at the north-west end of the lake. The surface area of the lake is 13.9 km^2, and its shoreline length is 40.6 km, making it the 6th largest lake wholly or partially within City of Kawartha Lakes in the Kawarthas (Table 2.1).

Table 2.1: Size of all major lakes in the 'Kawarthas' with the City of Kawartha Lakes.

Lake Name	Watershed Area (km^2)	Lake Area (km^2)	Shoreline Length (km)
Balsam	1636	48	98
Cameron	3100	15	43
Canal	256	9	40
Dalrymple	**150 [8th]**	**14 [6th]**	**41 [6th]**
Four Mile	51	8	21
Head and Rush	130	9	19
Mitchell	44	3	23
Pigeon	5287	57	145
Scugog	530	68	172
Shadow and Silver	1346	4	22
Sturgeon	4600	47	97

There are two distinct lake 'basins' of Lake Dalrymple, separated by the 'narrows' at Kirkfield Road. Upper Lake Dalrymple lies south of Kirkfield Road, is smaller and shallower, and flows north into Lower Lake Dalrymple (Figure 2.2).

Upper Lake Dalrymple is 5.8 km^2, with a shoreline length of 16.4 km. Its maximum depth is approximately 6 m, within two 'trenches' in the south-east section of the lake. Most of the lake is shallow (1-2 m), with gradually sloping nearshore areas, except near the south-east shore.

Lower Lake Dalrymple is 8.1 km^2, with a shoreline length of 24.2 km. Its maximum depth is approximately 10 m, within a deep 'basin' at the south-east section of the lake. Most of the lake is much deeper (greater than 3 m), with steeper nearshore areas and several islands.

The Lake Dalrymple watershed is located within two municipalities. Just over half of the watershed (54 % of total), including the entire Lower Lake Dalrymple, and one-third of Upper Lake Dalrymple, lies within the single tier municipality of the City of Kawartha Lakes. Additionally, most of the shoreline (78 % of total) is within City of Kawartha Lakes. The remaining lands lie with the Township of Ramara, a lower tier municipality with the County of Simcoe.

Lake Dalrymple is a 'headwater lake', meaning it exists near the top of its drainage basin and does not have any major inputs of water from upstream sources, such as large lakes or rivers. The size of the lake relative to its watershed is high. It is a unique lake in the Kawarthas in that it exists through natural processes and is not regulated by human-made structures (dams). Lake Dalrymple outlets into the Head River, which drains in north-westerly direction into the Black River, and eventually into Georgian Bay.

2.2 Local Features of Interest

The closest named hamlets to Lake Dalrymple include Dalrymple, Udney, and Sebright. These are rural communities with low population densities. There are several small shoreline communities including: McCrackins Beach, Avery Point, and Fox's Beach on Lower Dalrymple, and Campbells Beach, Sylvan Glen, and Black Beach on Upper Dalrymple. There are two trailer parks, both on Lower Lake Dalrymple: Layzee Acres Park and Meadows End.

There are three public boat launch areas. The most popular access, which is also a popular shore-fishing spot, is off Osprey Lane at the Narrows. The other two public launches are located off Day Drive (Geraldine Park) and Dalrymple Drive. The Carden Recreational Centre is a public event hall and grounds located on the east shore. It is owned by the City of Kawartha Lakes and coordinated by a local volunteer Board of Directors.

The Carden Alvar Provincial Park is in the eastern part of the watershed. This protected area is characterized by thin soils and sparse vegetation, on top of limestone bedrock, and poor drainage. It is recognized nationally and provincially as an Important Bird Area, supporting unique assemblages of species, many of which are identified as provincially and/or nationally rare.

Several active quarries exist in the watershed because of easy access to the shallow limestone bedrock. These include Beamish Quarry, Dufferin Quarry, Tomlinson Quarry, and Miller Quarry. There are two historic, now-closed landfills. Ramara landfill (located on Concession 5, west of Side Road 5 in the Township of Ramara), and Carden Landfill (located on Kirkfield Road, east of County Road 46). Several streams drain into Lake Dalrymple, all of which have no formal names. Kelly Lake and Cranberry Lake are large 'ponds' that exist along two of these streams.

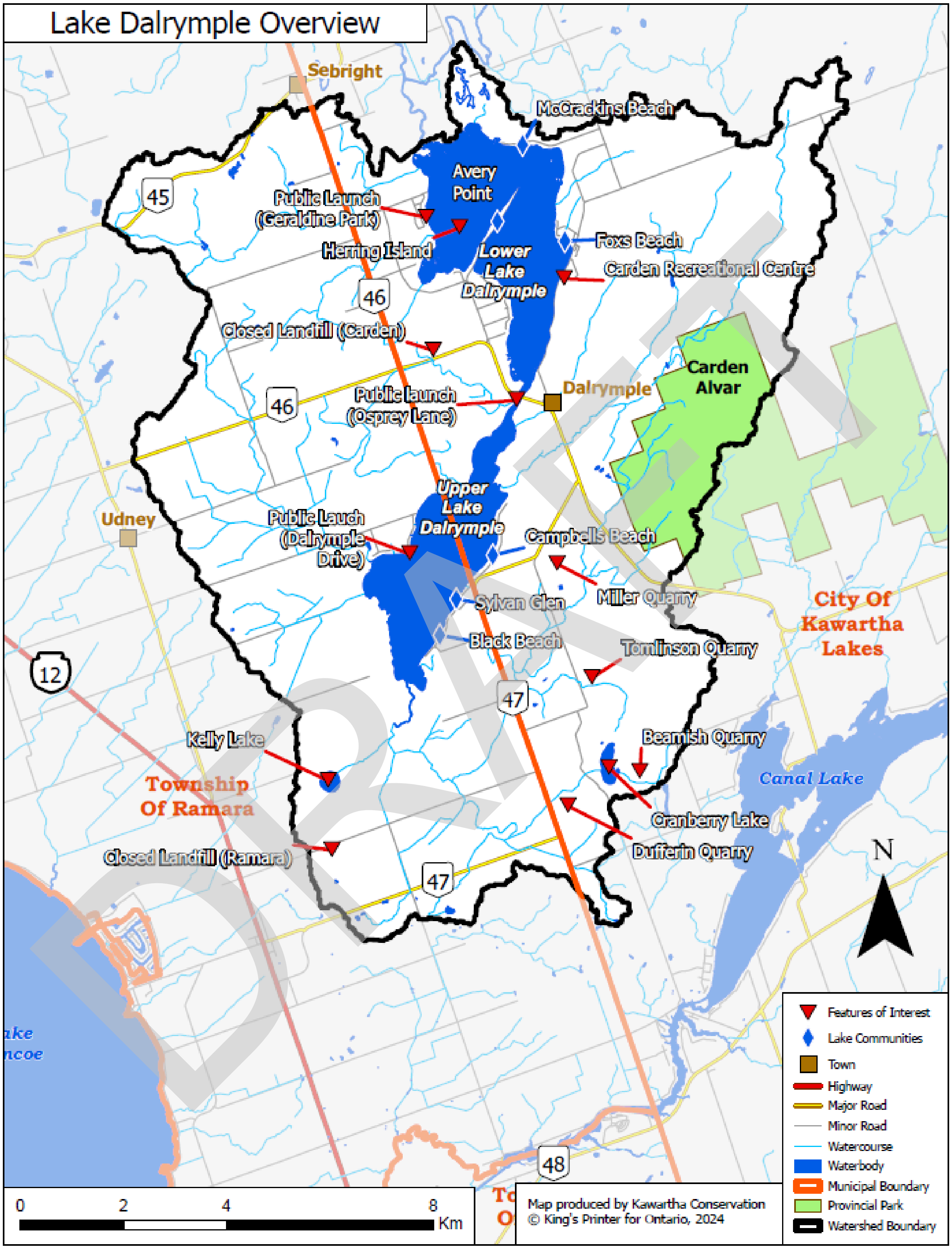

Figure 2.1. Map of study area, showing features of interest.

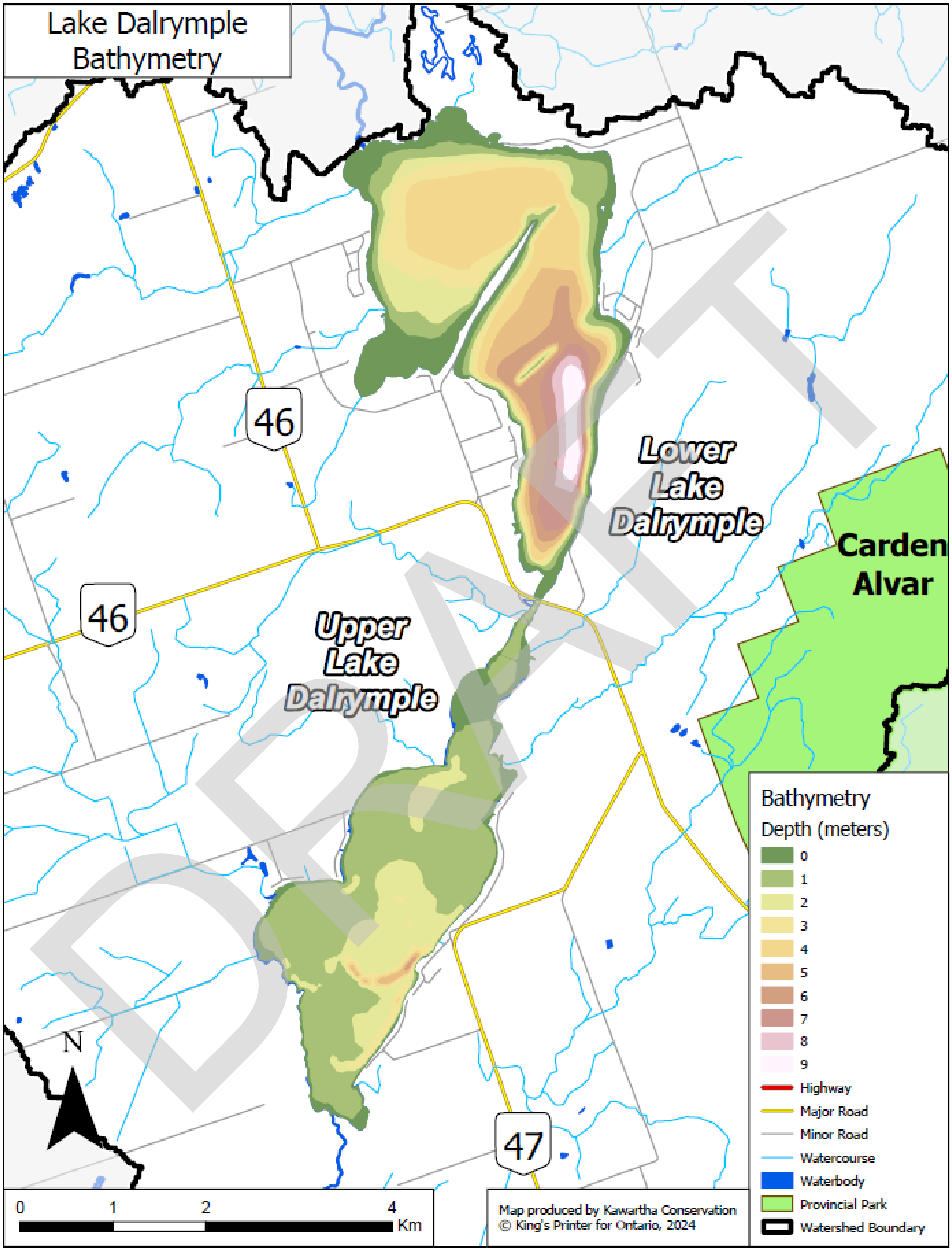

Figure 2.2. Map of water depths (bathymetry).

2.3 Geographic Context

The Lake Dalrymple watershed lies within the 'Land Between', a geological transition area between the Canadian Shield (a region characterized by relatively hard, Precambrian bedrock with bare or shallow soils), and the St. Lawrence Lowlands (a region characterized by relatively soft, sedimentary bedrock with shallow to deep soils).

The landscape features observed today in the Lake Dalrymple watershed are a product of the most recent period of glacial activity, from 10,000 to 100,000 years ago, when large glaciers advanced and retreated across the landscape.

Evidence of Canadian Shield like conditions can be seen along the northern shoreline of Lower Lake Dalrymple, which has exposed granite islands. In contrast, exposed limestone exists along the south, and south-east shoreline along Upper Lake Dalrymple.

The dominant 'landform' in the watershed is the Limestone Plains. This area is also referred to as Carden Alvar and consists of mostly continuous limestone bedrock having extremely shallow soils. Limestone has high levels of calcium carbonate and as such is highly alkaline, which means that the lake is well buffered (prevented) from acidification, a water quality stressor that has affected many lakes within the Canadian Shield that do not have buffering capacity.

An important and unique feature of the limestone bedrock in this area is the presence of 'karst' physiography, characterized by underground crevices, hollows, and fissures underground that formed over geologic time as soft sections of the bedrock were worn away. This landform directly affects surface and sub-surface drainage within the watershed (see Chapter: Water Inputs and Water Levels).

Another notable feature on the landscape is the presence of drumlins; humps of land orientated in a northeast to southwest orientation, created by glacial advances and retreats dating back 100,000 to 10,000 years ago. The most prominent drumlin exists on Lower Lake Dalrymple: Avery Point. The following is an excerpt from 'The Ancient Origins of Avery Point' by a local naturalist (Reid, Unknown Date):

> *"The origin of these drumlins is well understood by geologists. As the glaciers build up their thickness, in this area to about 2 kilometers depth of ice, their tremendous weight causes them to squeeze forward. At their base, they pick a mix of rocks and oil which slowly grinds along the bedrock – a process that has been called "God's great plough". But in some areas, perhaps where a particularly resistant piece of bedrock refuses to budge, the bottom of the glacier heaves upwards a little, and leaves a long smooth smear of debris in its wake. If you look at the landscape nearby, you can find many examples of long low hills, all oriented in a northeast-southwest direction. These drumlins are*

especially common on the clay plain farmland [to the west of Lake Dalrymple], but there are also small clusters under the farms around [the east side of Lake Dalrymple]."

2.4 Governance

The lakebed is considered provincial crown land, and therefore primarily managed by the Ministry of Natural Resources and Forestry. Unlike most of the lakes within the Kawarthas, the lake is not part of the Trent-Severn Waterway National Historic Site and therefore not managed by Parks Canada. Shoreline development is primarily managed by City of Kawartha Lakes and Township of Ramara, in partnership with the province.

Several other agencies play a role in managing the lake, depending on circumstances (e.g., Fisheries and Oceans Canada manages in-water works that could result in a harmful alteration, disruption, or destruction of fish habitat; Ministry of Environment, Conservation, and Parks manages contaminant spills).

Kawartha Conservation has no jurisdiction within the Lake Dalrymple Watershed but can offer advice to the City of Kawartha Lakes for *Planning Act* development proposals related to the management of natural hazards (e.g., flooding).

3.0 Land Use and Lake Use

[Avery Point, Lower Lake Dalrymple, July 18, 2023]

3.1 Summary of Key Observations

- The region has a long history of human activity, including First Nations peoples and more recently European settlement. The close proximity to the Greater-Toronto-Area makes Lake Dalrymple an attractive development and recreational location.
- Land use within the lake watershed is comprised mostly of natural areas which includes expansive areas of forests and wetlands and includes the 'Carden Plain' alvar. Agriculture is a dominant feature in the landscape, as is quarry operations.
- There are 21 distinct 'subwatersheds' that drain into the lake; 13 of which drain into Upper Lake Dalrymple, and 8 drain into Lower Lake Dalrymple. The largest four subwatersheds are ULDT-6, ULDT-3, ULDT-8, and LLDT-7, and account for 69 % of the drainage area in Lake Dalrymple.
- There are 780 individual lots along the shoreline, with an approximate ratio of 50:50 seasonal homes to permanent homes, not including vacant lots. A recreational capacity assessment suggests that the lake is not over-crowded based on a 1.6 waterfront lots/ha threshold.
- Fishing is an extremely popular activity on the lake, and fishing pressure is higher on Lake Dalrymple in winter months than on other lakes within the Kawarthas. The Ministry of Natural Resources and Forestry advises that there is no concern regarding the lake being 'overfished'.

3.2 Summary of Key Issues and Information Gaps

- Shoreline development is a priority concern for lake management. Developed areas are concentrated along the shoreline, with approximately 35 % of the shoreline being developed.
- A development capacity assessment was undertaken but unfortunately the model did not predict water quality, therefore it remains unclear the relationship between water quality and development. However, the Ministry of Environment, Conservation and Parks advises that Lake Dalrymple may have already exceeded its capacity.
- There are several activities associated with human use that could negatively impact the health of Lake Dalrymple, including vegetation removal and grading, aggregate extraction, building construction, roads, use of septic systems, human occupation, recreation (e.g., boating, fishing, hunting, etc.), agriculture, and climate change.

3.3 Historical Context

First Nations peoples have a long cultural history in the area, and have resided on Turtle Island (North America) since long before the arrival of Europeans. They have (and still do) called this land home for millennia, and recognize that they are stewards of land, protectors of water and sustainers of life.

The study area is located within the Williams Treaties, who were signed by Alderville First Nation, Beausoleil First Nation, Curve Lake First Nation, Hiawatha First Nation, Georgina Island First Nation, Scugog Island First Nation and Chippewas of Rama First Nation.

The Chippewas of Rama First Nation are the closest to Lake Dalrymple and have called this territory 'the gathering place' where travelers rested before continuing on their journey. This area is also where great meetings were held, and important agreements were signed. From the earliest of times, their people have been entrepreneurs, artisans, craftsmen, hunters and fishermen, and still are. Lake Dalrymple is known as Kechebedobegoog, and First Nation burial grounds are locally recorded as being present on Herring Island.

Early European interests in the area focused primarily on the fur trade. The Kawarthas, with its 'abundance' of lakes and river, was an ideal location for trapping beaver and trading with the First Nations communities in the area. These early explorers and fur traders paved the way for the settlers that were soon to follow. During the early 1800s, European settlers moved progressively north from Lake Ontario. Early settlement revolved around two activities: agriculture and forestry. Settlers, once having purchased land, were eager to clear the forests and begin agricultural practices. Clearing of the land for agriculture was often indiscriminate and wasteful of the timber resources.

The colonization of the shoreline of Lake Dalrymple was undertaken in earnest in the mid-to-late 1800's. The Lake was referred to as 'Mud Lake' at this time. Its proximity to the Greater-Toronto-Area made it an attractive cottaging and vacationing destination.

Water level fluctuations have been an 'issue' for locals since shoreline settlement. There are several news articles from as far back as the late 1800's related to people undertaking 'improvements' (i.e., dredging and blasting) at the outlet. In the late 1960's, to regulate (stabilize) water levels in Lake Dalrymple, locals constructed 'sandbag-barrier' dams at two locations: across the narrows between Upper and Lower Lake Dalrymple, and across the river at the outlet of Lower Lake Dalrymple. This was a failed undertaking; the dams did not last long. The underwater remains of these barriers still exist today.

3.4 Current Context

Land use within the Lake Dalrymple Watershed was primarily evaluated using Ecological Land Classification methodology (Lee et al., 1998) based on May 2018 aerial imagery interpretation (Figure 3.1).

Watershed land use is comprised mostly of natural areas (78 % of total land area), which includes expansive areas of forest, wetlands, and meadows. This includes the expansive 'Carden Plain' alvar areas in the eastern area, which is a popular area for birdwatchers.

Agriculture is a dominant feature of the landscape (17 % of total) in the western and southern areas and is predominantly row crops that are typically grown in the region (wheat, soybeans, corn, hay), and to a lesser extent pasture lands.

Developed areas account for 5 % of the watershed area and include five aggregate operations in the southern area, dense seasonal and permanent residential properties along the shoreline, and rural residential properties scattered throughout.

Land use percentages are relatively even across Upper and Lower Lake Dalrymple, with Lower Lake Dalrymple having slightly more developed areas and agriculture, and less natural areas. Compared to other major lakes within the City of Kawartha Lakes, Lake Dalrymple ranks in the middle (i.e., 5th or 6th highest) in terms of relative surface area of natural, agriculture, and developed lands (Table 3.1). More detailed information on land use types in the watershed is provided in Chapter 8: Landscape Ecology.

Table 3.1. Major land use types in study area, and along shorelines of lakes in the Kawarthas.

Lake Name	Study Area (lands draining into lake)			Shoreline (30 m buffer around the lake)		
	Developed (%)	Agriculture (%)	Natural (%)	Developed (%)	Agriculture (%)	Natural (%)
Balsam	6	34	60	54	1	45
Cameron	6	34	60	50	<1	50
Canal	2	12	86	33	5	58
Dalrymple	**5 [6th]**	**17 [5th]**	**78 [5th]**	**40 [7th]**	**1 [7th]**	**59 [3rd]**
Four Mile	4	6	90	73	<1	27
Head	2	3	96	61	2	37
Mitchell	2	12	86	25	9	64
Pigeon	7	27	66	29	1	69
Scugog						
Shadow and Silver	25	8	66	54	1	45
Sturgeon	8	51	41	53	<1	48

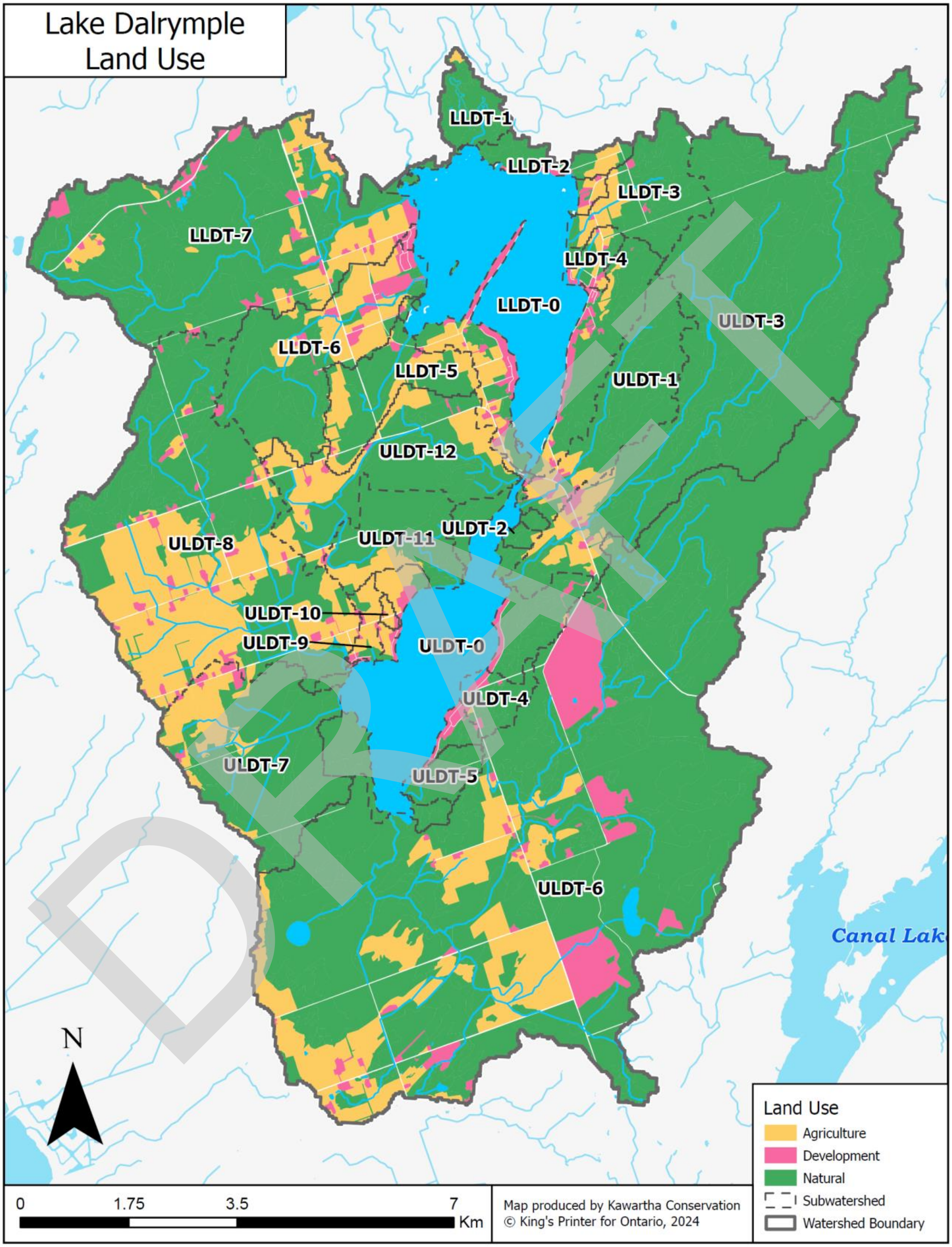

Figure 3.1. Major land use types within the study area.

3.5 Subwatershed Land Use

Land use percentages within each of the 21 subwatershed are shown in Figure 3.2. The largest four subwatersheds are ULDT-6, ULDT-3, ULDT-8, and LLDT-7, and account for 69 % of the drainage area in Lake Dalrymple. The remaining 17 are relatively small, with each contributing 5 % or less of the total land area.

Three of the four largest subwatersheds account for 77 % of drainage into Upper Lake Dalrymple. ULDT-6 is by far the largest. It outlets into a large wetland at the southern shore of Upper Lake Dalrymple (north of Concession Road 5) and accounts for 34 % of the total and 44% of lands draining into Upper Lake Dalrymple. The subwatershed includes all aggregate operations, and large areas of agriculture. ULDT-3 outlets into the eastern shore of Upper Lake Dalrymple (west of Kirkfield Road) and accounts for 14 % of the total and 18 % of lands draining into Upper Lake Dalrymple. This subwatershed is almost entirely natural, with some agriculture and rural developments around the hamlet of Dalrymple. ULDT-8 outlets into the western shore of Upper Lake Dalrymple (south of Concession Road 9), and accounts for 11 % of the total and 15 % of Upper Lake Dalrymple. It drains a significant area of concentrated agriculture.

The last of the 'top four' subwatersheds drains into Lower Lake Dalrymple (LLDT-7). It outlets into the north-western shore of the lake (just north of Meadows End Trailer Park) and accounts for 10 % of the total, and 43 % of Lower Lake Dalrymple. It is mostly natural lands, with some agriculture and scattered rural development.

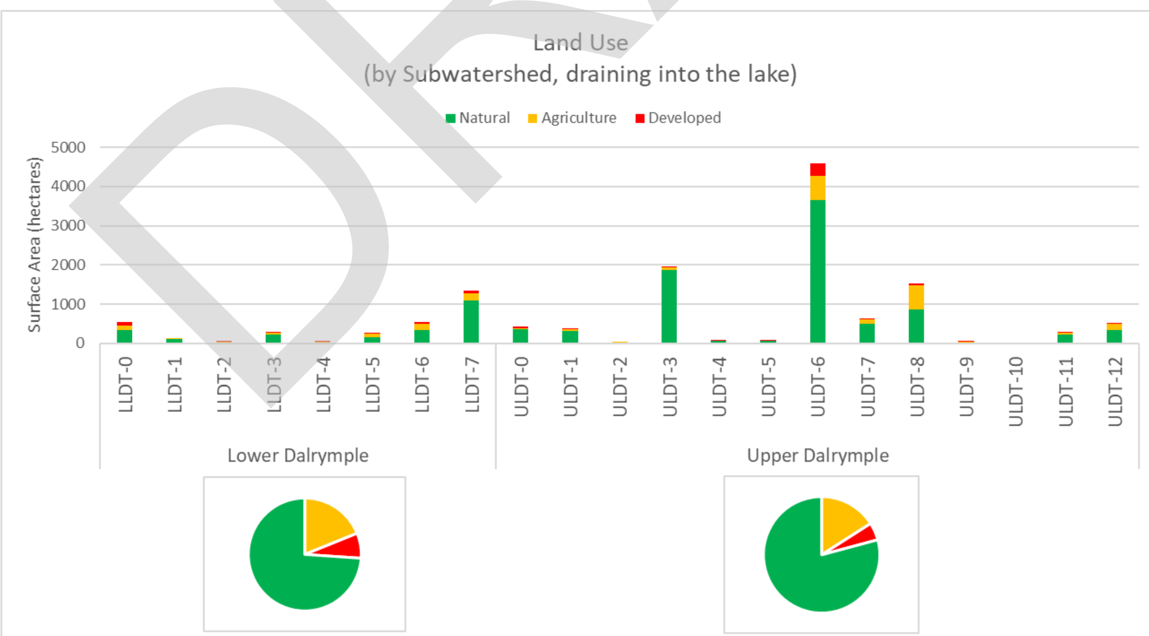

Figure 3.2. Major land use types by subwatershed.

3.6 Shoreline Land Use

Land use along the shoreline within 120 m inland of the lake includes: natural (61 %), developed (35 %), and agriculture (4 %) (Figure 3.3). Thicket swamp and urban development comprise over 50 % of the shoreline land use. The shoreline is an area of concentrated development; it is 12 times higher than the rest of the watershed (35 % compared to 5 %) relative to their surface areas.

Compared to other lakes within the City of Kawartha Lakes, the shoreline of Lake Dalrymple has slightly higher percentages of agriculture and developed areas (7th highest out of 11) and has the 3rd most natural cover (Table 3.1). Lower Lake Dalrymple shoreline has 56% natural cover, and Upper Lake Dalrymple has 67 %. Lower Lake Dalrymple has slightly more developed areas than Upper Lake Dalrymple (38 and 31 %, respectively), and more agriculture (6 and 2 %, respectively).

To augment the aerial interpretation information, a rapid shoreline survey was undertaken by boat in summer of 2022, to estimate land use immediately at and adjacent to the shore-water interface. These data provide an 'under the tree canopy' perspective in terms of existing shoreline development.

Results indicate that this area has extremely high percentages of natural lands (96% of total), of which three-quarters are vegetated areas of marsh, swamp, meadow and forest, and one-quarter of which is cobble, sand, boulder, or bedrock (Figure 3.4).

Artificial shorelines are low (4 % of total), which indicates most of the existing development is 'set-back' from (e.g., above) the typical summer lake level (Figure 3.5). However, within the area immediately above the land-water interface the shoreline was heavily modified with 31% manicured lawn (Figure 3.5), which corresponds well with percentages of development within 120 m as per aerial interpretation. The shoreline survey also identified the locations of relatively steep (i.e., greater than 2:1 horizontal to vertical) shorelines, many of which co-occur in areas of concentrated development (Figure 3.5).

Also noted were 380 docks, and 11 areas with evidence of significant shoreline erosion.

3.7 Shoreline Properties

Based on 2023 municipal assessment information, there are approximately 780 individual parcels (i.e., property lots) within 300 m of the lake, most of which (585) extend right to the water's edge.

On Upper Lake Dalrymple, this includes 98 permanent homes, 148 seasonal homes, and 73 vacant lots of record. On Lower Lake Dalrymple, this includes 209 permanent homes, 202 seasonal homes, 1 resort, and 2 trailer parks (281 total trailers). A home was considered 'permanent' if a dwelling was present on the parcel and the personal mailing address matched the property address.

This results in a slightly higher than 50:50 ratio of seasonal homes to permanent homes, not including vacant lots. It is estimated that all these properties are on private septic systems and private water wells (drilled, dug, or lake-drawn).

The following excerpt from Kawartha Realty (2024) provides additional information:

> *"While still one of the more affordable lakes in the western Kawarthas, prices on Lake Dalrymple have outperformed other lakes in recent years. You can expect to pay in the neighbourhood of $600,000 to $750,000 for a three-season cottage, and $750,000 to $1,500,000 for a year-round cottage or home.*
>
> *It is important to note that owners along Avery Point Road and Lake Dalrymple Road on Lower Dalrymple Lake generally do not own the waterfront on the other side of the municipal road in front of their property. The waterfront is owned by the City of Kawartha Lakes, although the property owners generally use the waterfront as if it is their own, and have docks and other waterfront structures there."*

3.8 Infrastructure

The primary infrastructure in the Lake Dalrymple watershed are municipal roads, and most of these are public. There are no railways, no large-scale drinking water services, and no large-scale wastewater services (except those at the trailer parks, as licensed by Ministry of Environment, Conservation and Parks). There are 111 km of roads within the watershed, which equates to a density of 0.81 km/km^2 which is relatively low. These roads intersect the watercourses at approximately 57 locations.

3.9 Lake Recreation

Lake Dalrymple is a popular recreation attraction for locals and visitors. Its large areas of open water with no major navigation hazards (except for the point shoal off the tip of Avery Point, and shoals in the Narrows) makes it conducive to pleasure craft use. The lake is good in terms of swimming accessibility, because it has good water quality, sand-dominated substrates, and lack of dense aquatic plants in the shallow nearshore areas adjacent to developed areas.

Recreational fishing is extremely popular on the lake and includes an open water and winter fishery. Lake Dalrymple exists within Fisheries Management Zone 17, which includes most lakes within the Kawarthas. Targeted fishes include walleye, muskellunge, northern pike, largemouth bass, smallmouth bass, black crappie, and yellow perch. According to the Ministry of Natural Resources and Forestry, their Broad-scale Monitoring program angler activity assessments in 2008 and 2013 indicate Lake Dalrymple experiences extremely higher pressure relative to other lakes within Zone 17 (Figure 3.6). The open water activity is slightly higher than average across Zone 17, while the winter activity is several times higher.

Fall waterfowl hunting is also popular, particularly in the south end of the lake within the expansive shallow marshes in Upper Lake Dalrymple that provide exceptional habitat (e.g., food and cover provided by mature wild rice) for resident and migratory waterfowl.

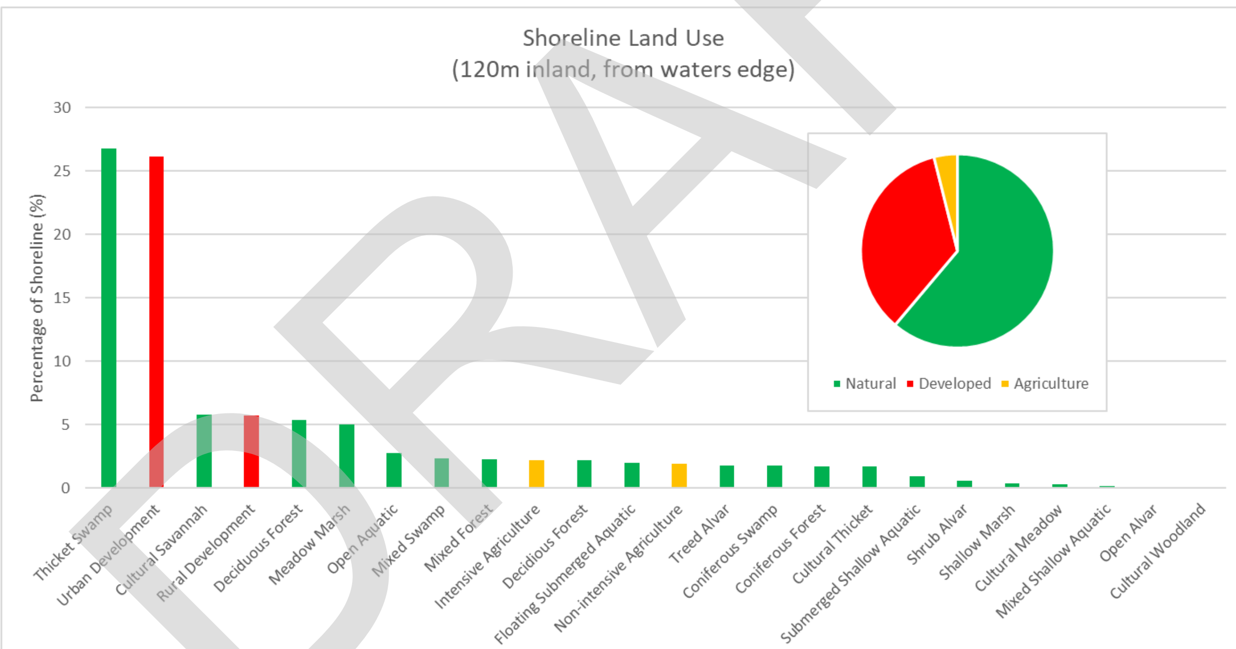

Figure 3.3. Shoreline major land use types, along 120 m buffer.

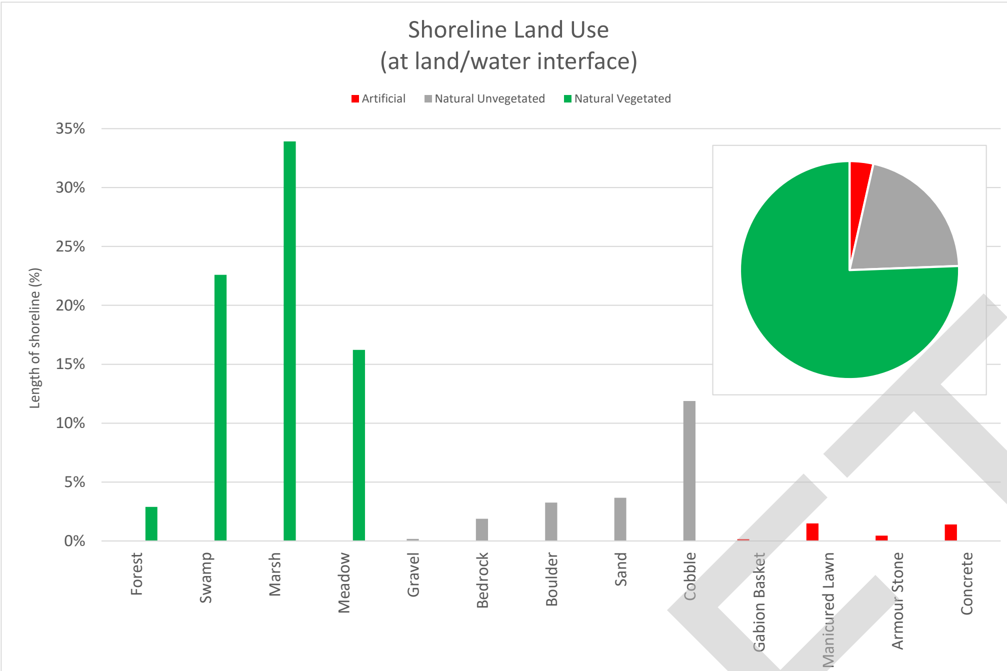

Figure 3.4. Shoreline major land use types, at land/water interface.

Figure 3.5. Shoreline survey results: manicured lawn (left), slope (center), and artificial (right).

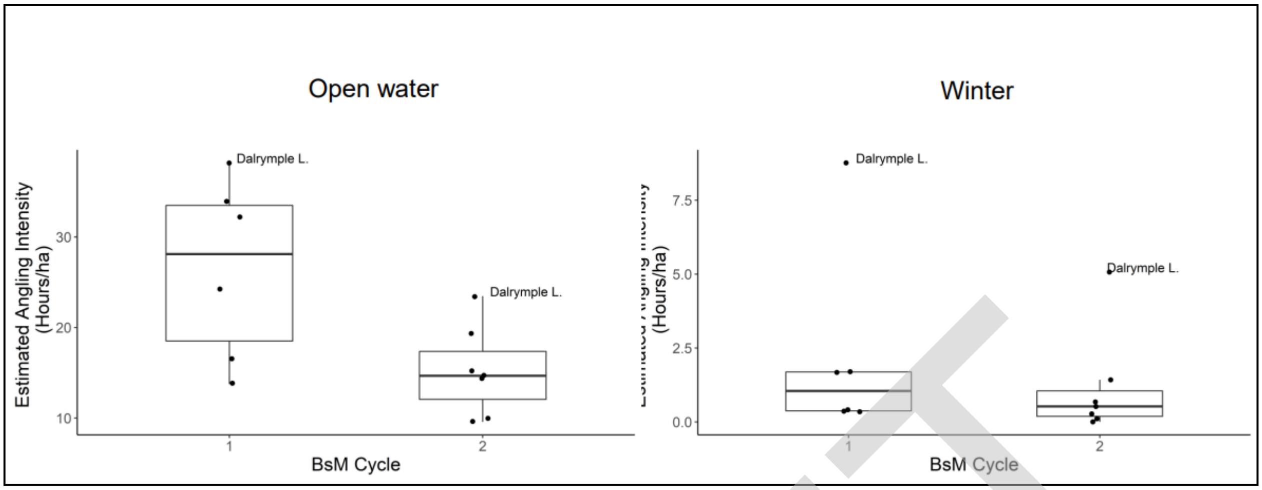

Figure 3.6. Estimated angler intensity, for open water and winter fishery.

3.10 Recreational Carrying Capacity

An assessment of 'recreational carrying capacity' was undertaken following guidance in the Township of Seguin Official Plan (Township of Seguin, 2015). It is the number of users that can be accommodated on the surface of a lake while maintaining the recreational amenity of the waterbody, that would otherwise be lost due to 'crowding'. Recreational carrying capacity is based on the principle that the lake functions as a common space. Estimates of recreational carrying capacity are based on the size of the 'offshore waters' of the lake (referred to as the 'net surface area', meaning the lake surface area minus the 30 m nearshore area) compared to the number of waterfront lots around the lake. If densities are greater than one waterfront lot for every 1.6 hectares net lake surface area the lake is considered at recreational capacity.

Based on an input of 780 waterfront lots (this assumes all existing waterfront lots within 300 m are developed, which they are not), and a net lake surface area of 1,273 hectares, Lake Dalrymple has 0.61 lots per hectare (lots/ha). This value is well below 1.6 lots/ha and therefore not considered at recreational capacity. Similar calculations for Upper Lake Dalrymple and Lower Lake Dalrymple are 0.60, and 0.62 lots/ha, respectively, which likewise are well below the 1.6 lots/ha threshold.

3.11 Development Carrying Capacity

An assessment of 'development carrying capacity' was undertaken following guidance in the Lakeshore Capacity Assessment Handbook (Province of Ontario, 2010). This approach was developed and calibrated for application on Lake Trout lakes on the Canadian Shield and quantifies the linkages between the natural contributions of phosphorus to a lake, the contributions of phosphorus to a lake from shoreline development, the water balance of a watershed, the size and shape of a lake and the resultant phosphorus concentration.

Unfortunately, the model did not predict well the phosphorus concentrations for Lake Dalrymple, therefore cannot be used for lake capacity assessment purposes. This was not unexpected, given the subject lake is outside the range of the original study lakes (i.e., it is not a shield lake, it is shallow with calcareous bedrock). However, guidance from the Ministry of Environment, Conservation, and Parks (Baxter, 2024) suggests that the Lake is already at capacity:

> *"…based on different lines of evidence, a case could be made that Lake Dalrymple has already exceeded its development capacity. This is based on measured phosphorus levels, existing development pressures and vacant lots of record, observed algae blooms and water quality conditions in mid-summer, and soil types in the surrounding watershed (calcareous) which only retain a portion of the phosphorus from septic systems and other sources."*

Additional information on this approach is found in Chapter 5: Water Quality.

3.12 Fishing Carrying Capacity

Unfortunately, standardized means of assessing whether or not a lake is 'over-fished', are unavailable. However, guidance from the Ministry of Natural Resources and Forestry (Challice, 2023) suggest that the lake can likely support current levels:

"Overall, while angling effort has been relatively high (as noted in the presentation materials previously provided), the fish community indicators don't raise any urgent alarm bells, suggesting no additional waterbody-scale management actions be taken at this time on Dalrymple."

For information on the status of Lake Dalrymple fishes in found in Chapter 7: Fish and Aquatic Habitat.

3.13 Summary of potential impacts from human activity

Table 3.2 provides a high-level summary of potential impacts to Lake Dalrymple that are associated with common human activities, including: vegetation removal and grading, aggregate extraction, building construction, roads, use of septic systems, human occupation, recreation, agriculture, and climate change. Information was adapted from the Natural Heritage Reference Manual (Ministry of Natural Resources, 2010) and Government of Canada (2020).

Table 3.2. List of potential impacts to Lake Dalrymple from activities associated with human land use.

Examples	Potential Physical Impacts	Potential Impacts on Lake Features and Functions
Vegetation removal and grading	Loss of shade, possibly resulting in increased water temperatures	Changes in fish species and abundance
	Reduced input of leaves, twigs and insects to waterbodies	Reduced food supply for aquatic life
	Reduced bank stability, increased erosion, sedimentation, and turbidity	Loss of fish habitat, avoidance of areas by fish, toxic effects on fish
	Loss or disturbance or riparian wildlife species	Reduced cover and food supply for species such as otter, mink, beaver and wintering deer
	Changes in natural drainage, including elimination of streams and wetlands, and increased surface runoff	Loss of fish habitat, changes in wetland plant communities, channel erosion
	Disturbance of wildlife, particularly sensitive species	Loss of rare species or species of conservation concern
Aggregate extraction	Alteration of destruction of landforms	Alteration of subsurface flow regime
	Increase inputs of nutrients and contaminants	Loss of fish habitat, avoidance of areas by fish, toxic effects on fish
	Changes in natural drainage, including altered surface runoff, altered stream flows	Loss of fish habitat, channel erosion and changes in geomorphology
	Changes in groundwater flows	Reduced baseflow in streams, loss of groundwater inputs to wetlands
	Disturbance of wildlife, particularly sensitive species	Loss of rare species or species of conservation concern
Building construction	Increase in impervious surfaces, increased surface water runoff and reduced infiltration	Loss of fish habitat, changes in wetland vegetation communities
	Water contamination by oils, gasoline, grease and other materials	Lethal or sublethal toxic effects on aquatic life and vegetation

Examples	Potential Physical Impacts	Potential Impacts on Lake Features and Functions
	Disturbance of wildlife, loss of wildlife (e.g., mortality due to collisions with buildings)	Avoidance of the area by wildlife species, gradual attrition
Roads	Realignment of stream channels, changes in water velocity	Barriers to fish movement, downstream erosion
	Loss of riparian vegetation	Loss of habitat for certain wildlife species
	Obstruction of lateral flows in wetlands	Significant alterations in wetland vegetation communities
	Interruption of linkage along a watercourse	Increased roadkill as animals cross roads to follow a watercourse
	Attraction of nesting turtles and other wildlife to roadsides	Roadkill
	Pollution from roads	Introduction of heavy metals, oils, and grease from vehicles, and increased levels of salt from de-icing
	Increase in impervious surfaces, increased surface water runoff and reduced infiltration	Loss of fish habitat, changes in fish species and composition and abundance
Use of septic systems	Increased inputs of nutrients and contaminants, increased algal growth	Loss of fish habitat (e.g., reduced oxygen), lethal or sublethal effects on aquatic life
Human occupation	Increased inputs of nutrients and contaminants from use of fertilizers, pesticides, etc.	Increased productivity, increased algal growth, lethal or sublethal effects on aquatic life
	Trampling of vegetation and soil compaction, dumping of debris and compost in natural areas	Loss of fish habitat, loss of sensitive plant species
	Increased predation on wildlife by pets, introduction of non-native plants	Reduced numbers of wildlife, reduced biodiversity and wildlife reproductive success
Recreation (e.g., boating, fishing, hunting, etc.)	Increase in shoreline alterations (e.g., docks, dredging, beach creation), removal of aquatic vegetation	Changes in productivity, loss of fish habitat, changes in fish species composition and abundance
	Disturbance of wildlife, especially during critical periods	Loss of wildlife species and reduced numbers of wildlife
	Increased harvest of fish	Reduced numbers of fish
	Impacts of trail development, trampling of vegetation, and chasing of wildlife by off-leash dogs	Loss of wildlife habitat, impacts of vegetation, tree removal

Examples	Potential Physical Impacts	Potential Impacts on Lake Features and Functions
	Introduction of invasive plants and animals	Loss of fish and wildlife habitat, reduced biodiversity, loss of sensitive species
Agriculture	Tile drainage impacts to surface water runoff, changes in shallow groundwater	Loss of groundwater inputs to wetlands, increased erosion
	Crop application of manure, fertilizer, herbicides, and pesticides	Loss of fish habitat (e.g., reduced oxygen), lethal or sublethal effects on aquatic life
	Land conversion eliminating of streams, wetlands, and forests	Loss of fish and wildlife habitat, reduction in water quality buffering capacity, increase in runoff
	Cattle grazing causing bank disturbance, loss of riparian vegetation, and manure inputs	Loss of fish habitat (e.g., reduced oxygen), lethal or sublethal effects on aquatic life, increased algal growth
Climate Change	Increased air temperature, increased water temperature, increased large precipitation events, reduced snow	Changes in fish communities, increased runoff and erosion, changes in lake ice cover, expansion of invasive species

4.0 Water Inputs and Water Levels

[Lake level monitoring gauge at the ‘narrows’, Kirkfield Road bridge, May 25, 2021]

4.1 Summary of Key Observations

- Lake Dalrymple is composed of two waterbodies: The upper lake, which is relatively shallow receives 77% of overland drainage, drains into the lower lake which then drains into the Head River to the north.
- Much of Lake Dalrymple's catchment area sit atop the Carden Plain, and area known to exhibit Karstic features.
- With so much of the sub-watersheds under natural cover, it is not anticipated that land use disturbance has had much of an effect on the hydrology of the Lake Dalrymple watershed.
- It is suspected that groundwater inflow (i.e. baseflow) directly into the lake may be a notable input to Lake Dalrymple.
- Over the 2021-2023 monitoring period, the lake levels generally stayed the same and the water inputs and outputs to the lake are assumed to remain balanced.
- Both precipitation and air temperature are projected to increase in the Lake Dalrymple region under a changing climate—the impact this will have is uncertain.

4.2 Summary of Key Issues and Information Gaps

- No long-term gauges bring large uncertainty to the results. Due to logistical difficulties, there was no gauge placed at the outlet of Lake Dalrymple; this can be the main source of error in water balance estimation.
- The eastern stream monitoring location had some technical issues in 2022 such that large parts of the flow record are missing.
- Inflows to the lake have only been measured at two streams that cover 17% of the Lake Dalrymple catchment area—much of the catchment is ungauged.
- No groundwater measurements have been made in this study.

4.3 General Characterization

Separated by a narrows where Kirkfield Rd crosses the lake, there are two distinct waterbodies that make up Lake Dalrymple: the "upper lake" is the more southerly portion that drains toward the "lower lake". The lower lake then drains northward toward the Head River. Drainage from Dalrymple Lake eventually flows north of Lake Couchiching eventually discharging into Georgian Bay. The upstream catchment area of Lake Dalrymple, as measured from the outlet at the lower lake and includes the lake area is approximately 140 km^2.

Lake Dalrymple is fairly shallow, with depths in the lower lake ranging from 5 to 10 m (Figure 2.2). The upper lake is even more shallow, and as such is mapped as an evaluated Provincially Significant (swamp) Wetland. According to the Ministry of Natural Resources and Forestry (MNRF) there are no reported dams within the Lake Dalrymple watershed nor are there any dams downstream of the lake that can influence Lake levels.

To facilitate the calculation of water inputs, Lake Dalrymple's drainage area has been divided into five general areas (Figure 4.1), three of which drain into the Upper Lake (Upper South, Upper West and Upper East), and two that drain into the Lower Lake (Lower West and Lower East). The shallower Upper Lake has a much larger share (77 %) of the drainage area when compared to the Lower Lake. Table 4.1 reflects some of the important characteristics of each of these five catchment areas.

Table 4.1: Characterization of five drainage areas feeding Lake Dalrymple.

Region	Drainage Area (km^2)	Stream Network Length (km)	Main Channel Length (km)	Main Channel Gradient (m/km)	Natural Cover (%)	Agriculture (%)	Rural/Urban Development (%)	Stream Density (km/km^2)	Average Watershed Slope (%)
Lower East	8.4	7.1	4.9	5.6	78	14	6	0.8	2.6
Lower West	23.8	33.3	10.6	3.1	71	21	8	1.4	1.2
Upper East	27.5	31.7	13.2	4.5	93	4	2	1.2	1.4
Upper South	46.5	60.3	12.4	1.0	78	14	7	1.3	1.2
Upper West	32.5	56.5	20.4	1.0	65	31	3	1.7	0.9

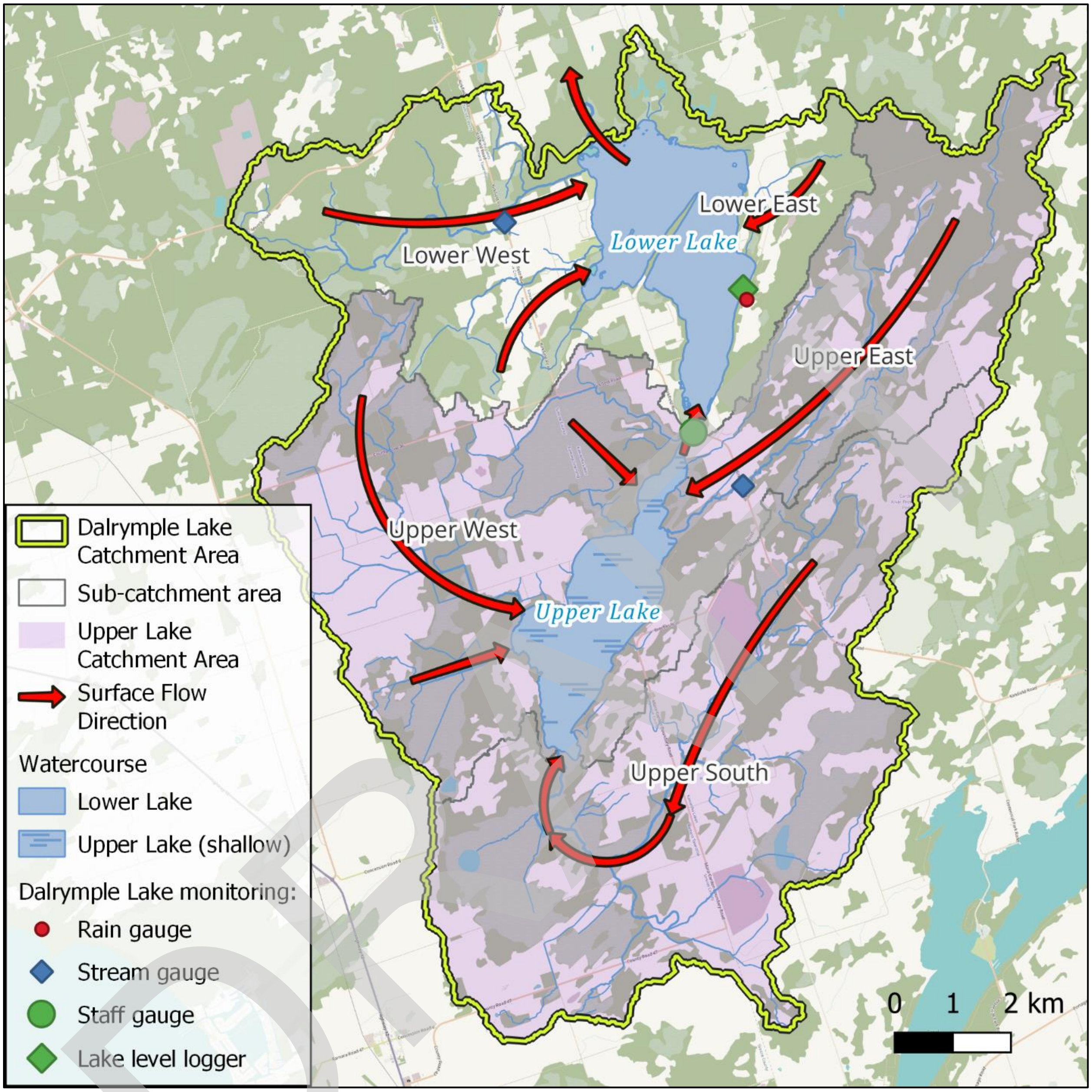

Figure 4.1. Monitoring Locations, drainage network and flow directions within the Lake Dalrymple catchment area.

Often the surface water network and the flow regime reflect the geology of an area. For example, in areas of coarse sand and gravel much of the precipitation in an area could infiltrate, leading to the generation of fewer streams on the landscape, such as on the Oak Ridges Moraine to the south. In contrast, areas with tighter clay rich sediments would tend to have a denser drainage network owing to the lack of water moving into the subsurface.

Lake Dalrymple sits in an interesting area from a geological perspective. It sits on the Carden Plain, an area of thin glacial sediment overlying limestone bedrock. The area is known to have karst. With respect to the bedrock geology that underlies the surficial glacial sediment, the geological boundary between the Canadian Shield to the north and the Paleozoic sedimentary rocks to the south also runs through the centre of the upper lake.

A cursory examination of the streams in the vicinity of the lake shows that many of the streams flow in a northeast to southwest direction (Figure 4.2), reflecting the fabric of the land which comprises a number of drumlinized uplands that trend in this direction. Streams tend to flow in the lows between these features. Lake Dalrymple itself also reflects this NE-SW trend.

Figure 4.3 shows the surficial geology in the Lake Dalrymple catchment, while Table 3.2, readily obtained from the Oak Ridges Moraine Groundwater Program (ORMGP) website, shows the surficial geology cover distribution across the Lake Dalrymple watershed, as well as across the two streams monitored between 2021 and 2023. Figure 4.4 shows the bedrock geology as well as areas of known or suspected karst and Figure 4.1 more clearly shows the streams that flow into Lake Dalrymple as well as the wetlands within the catchment. Figure 4.5 shows the simplified land use within the Lake Dalrymple catchment area.

It is readily observed that the eastern side of the lake is dominated by Paleozoic bedrock (purple coloured area). Examination of Figure 4.3 and Figure 4.4 reveals that all the dark purple areas have been mapped by the Ontario Geological Survey (OGS) as areas of known or suspected karst. The lower parts of the Bobcaygeon Formation are fossiliferous and in other areas near to the Canadian Shield boundary the unit is karstified with some stream reaches disappearing into the subsurface. None of the streams in the Lake Dalrymple drainage basin were noted to exhibit this behaviour.

Karst occurs when limestones are dissolved as water passes through them. This leaves large voids and opportunities for water to flow through subsurface caverns, in directions that might not necessarily be reflected by the ground surface topography. In contrast, the drainage area to the west side of the lake looks to be covered with glacial sediment, generally about 10 m or less in thickness.

Table 4.2: Distribution of surficial soils across Dalrymple Lake catchment areas.

Surficial Sediment Cover	Lake Dalrymple		West Streams		East Streams	
	Area (Ha)	% Cover	Area (Ha)	% Cover	Area (Ha)	% Cover
Coarse-Textured Glaciolacustrine Deposits	1518.2	10.6	604.8	60.5	5.5	0.6
Fine-Textured Glaciolacustrine Deposits	1735.0	12.1				
Glaciofluvial Deposits	28.0	0.2				
Ice-Contact Stratified Deposits	159.8	1.1	29.2	2.9		
Man-Made Deposits	9.7	0.1				
Organic Deposits	2297.4	16.0	48.6	4.9	12.0	1.3
Paleozoic Bedrock	4922.0	34.3	307.7	30.8	790.2	87.9
Paleozoic Bedrock-Drift Complex	1606.6	11.2	5.9	0.6	37.3	4.2
Precambrian Bedrock	118.4	0.8				
Stone-Poor, Carbonate-Derived Silty to Sandy Till	1928.7	13.4	3.4	0.3	54.1	6.0
Stony, Carbonate-Derived Silty to Sandy Till	21.4	0.1	0.6	0.1		
TOTALS	**14345**	**100**	**1000**	**100**	**899**	**100**

The headwaters of the streams flowing into Lake Dalrymple are local to the lake with the largest subwatershed being the 'Upper South' catchment having an area of 46.5 km^2. 78% of this subwatershed is in natural cover, with only 15% under agriculture and 7% having been developed (Figure 4.5).

There are two main streams that drain this catchment, one that drains a large part of the Paleozoic bedrock, running in a NE-SW direction, roughly parallel to the upper lake shoreline but some 1.5 to 2 km from the shore. In the upper reaches, as well as in the lower reaches, just as the stream turns to the west to join the second stream, wetlands can be found adjacent to both sides of this stream. The second stream also drains a large part of the Paleozoic bedrock; however, wetlands are not as pervasive in this stream.

After the two streams meet, together they flow through another large wetland area that extends to the lake shore. A review of the Table 4.1 reveals that the drainage density values in the catchments draining to Lake Dalrymple from the east (including the Upper South catchment) are slightly lower than those draining from the glacial sediments in the west, perhaps reflecting the infiltration of more water into the subsurface in the karstic areas. Figure 4.5 shows the locations of three active quarries that mine the Paleozoic bedrock within the Upper South catchment. These quarries would likely draw groundwater towards them and, if there is a strong connection between the groundwater and surface water systems, then some surface waters could also be drawn towards the quarries.

The second largest catchment for Lake Dalrymple is the Upper West area at 32.5 km^2. This catchment drains into the upper lake, and has very little exposed Paleozoic bedrock, however given the thin glacial sediment that overlies the bedrock in the area, parts of this subwatershed are also mapped as suspected karst areas. The soils within the catchment, particularly in the more elevated headwater areas to the west, are more suitable for agriculture and as a result this catchment has more agricultural land use (31 %) than the others. Only 65 % of the catchment is under natural cover with large parts of the natural cover being wetlands (Figure 4.5). All four of the streams that drain this catchment pass through large tracts of wetlands before draining into the lake. Stream density in this catchment is the greatest at 1.7 km/km^2, perhaps indicating that any effects of karst are less than the other catchments.

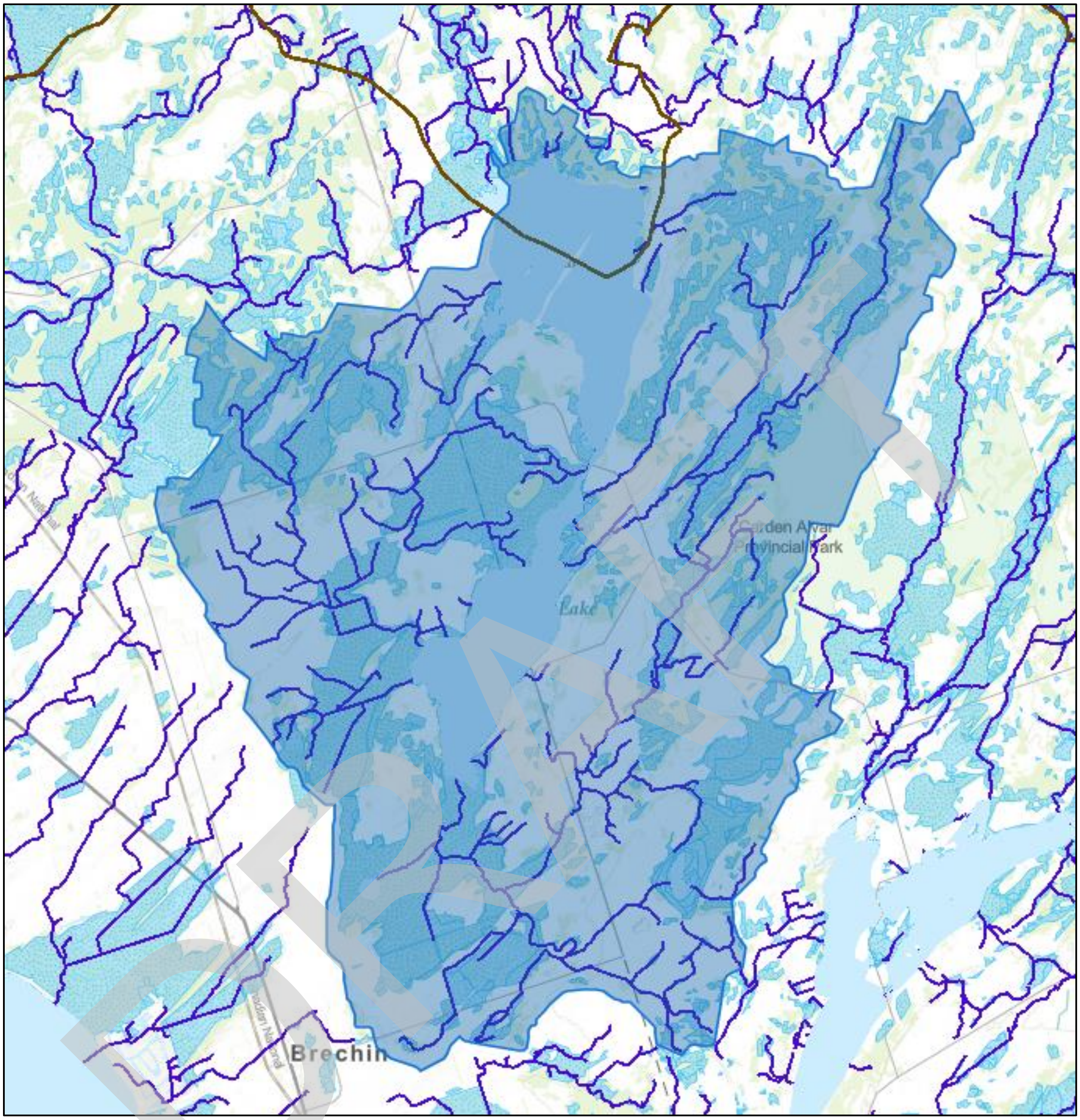

Figure 4.2. Drainage network around Lake Dalrymple with wetland cover shown in light blue. Note the strong NE-SW pattern in the streams reflecting the underlying geology.

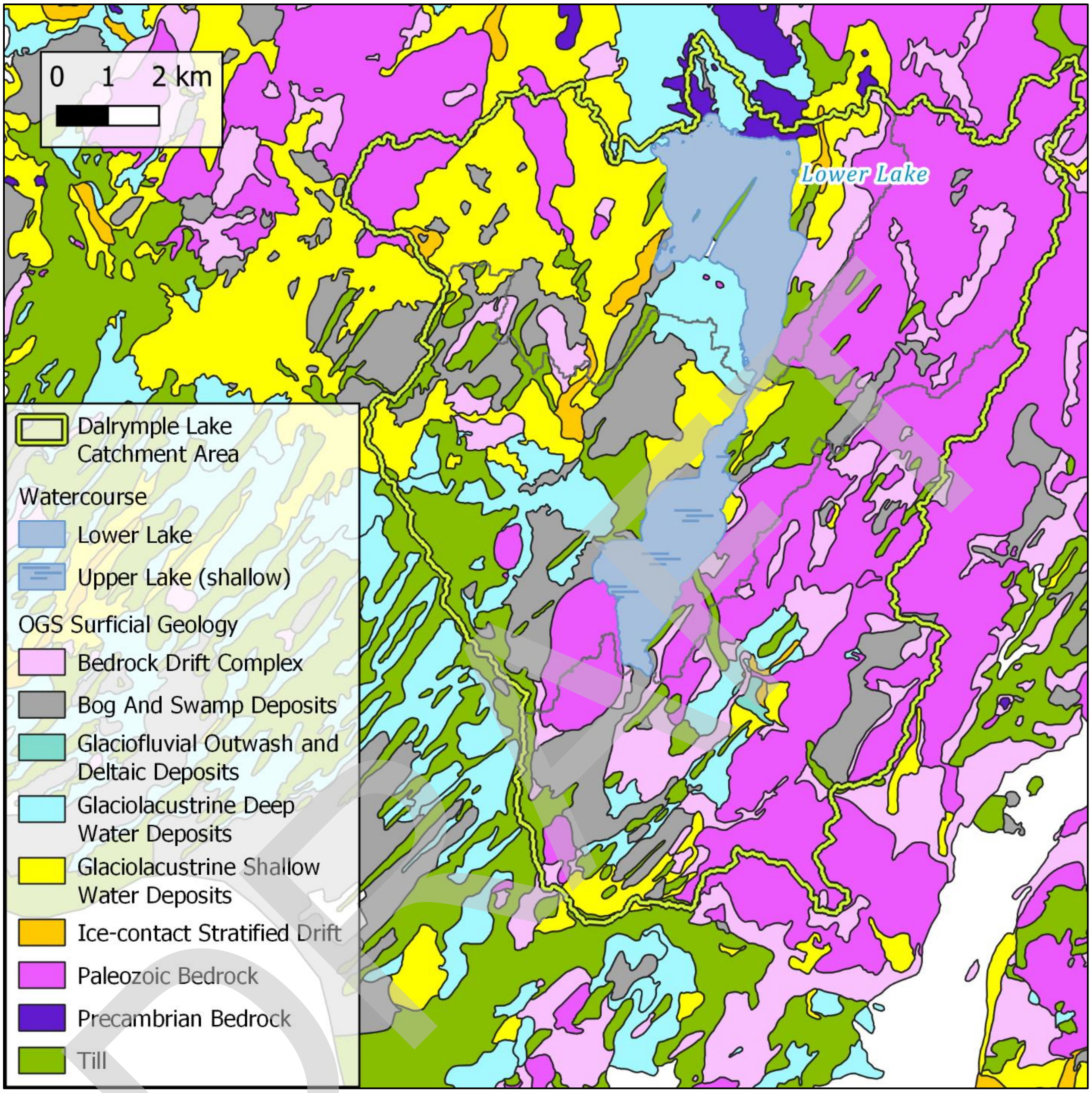

Figure 4.3. Surficial Geology of the Lake Dalrymple area.

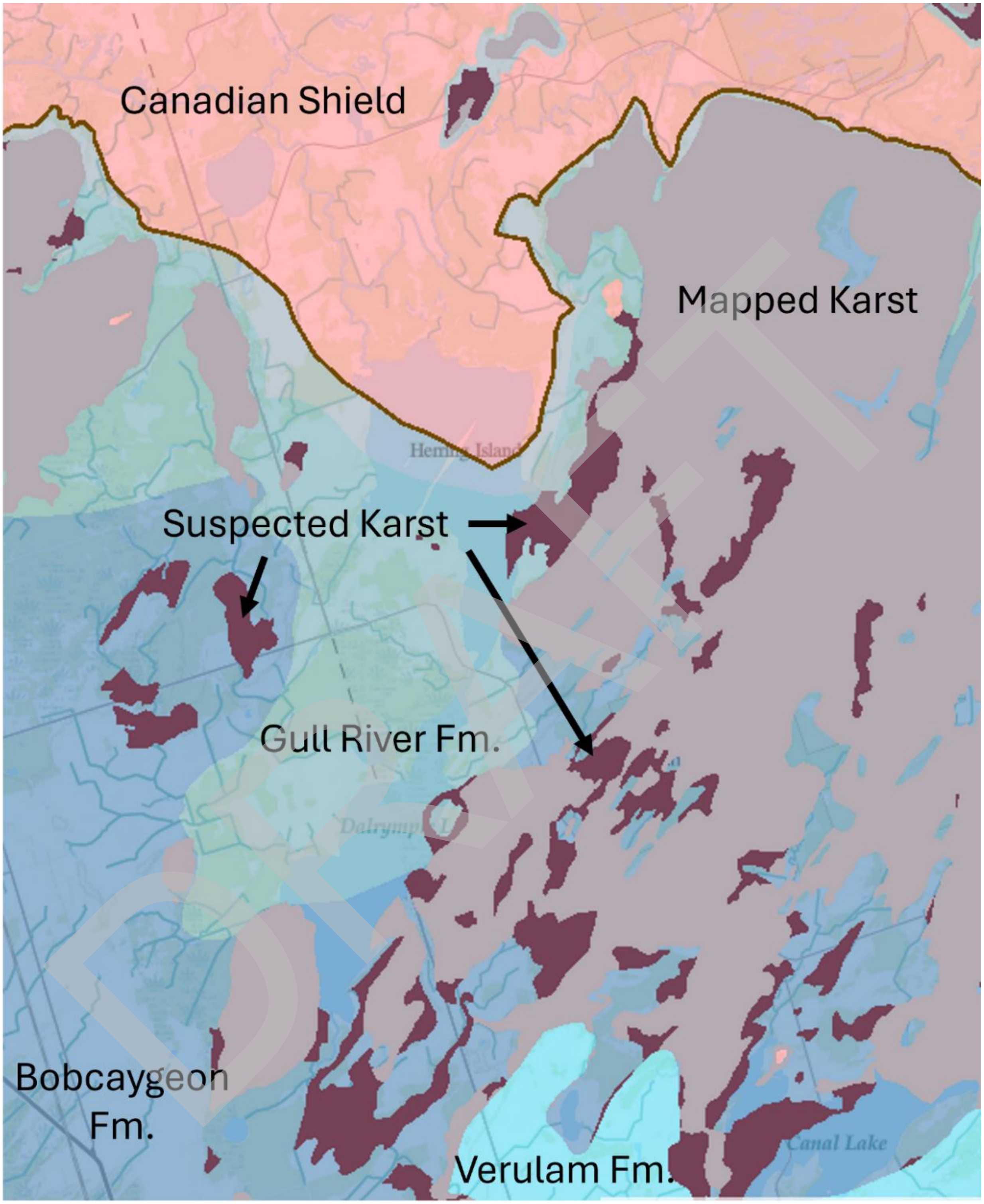

Figure 4.4. Bedrock geology showing areas of known (grey) and suspected (maroon) karst.

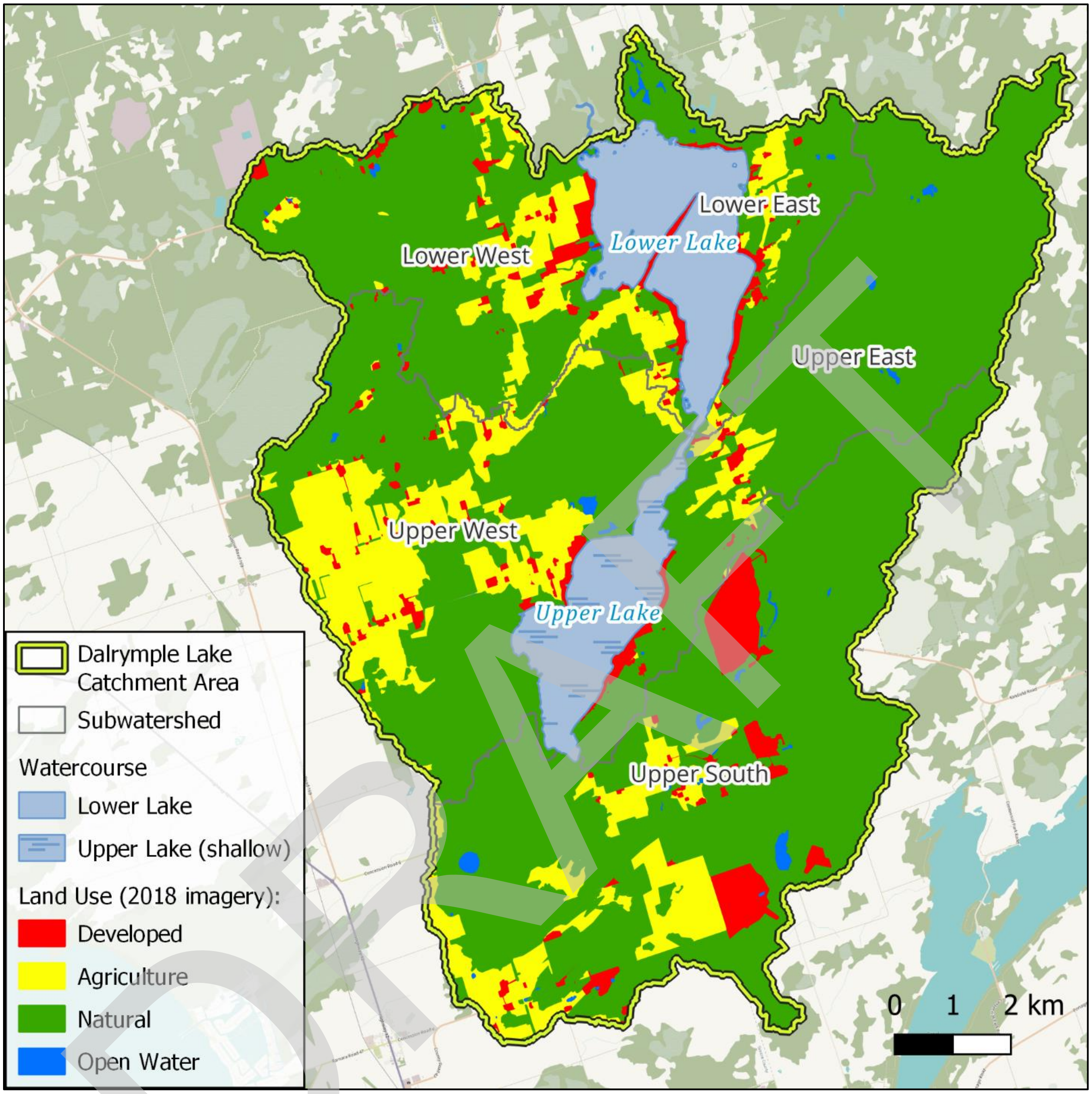

Figure 4.5. Major land use types in relation to the five catchments.

The Upper East catchment is the third largest catchment draining to Lake Dalrymple. It also empties into the upper lake, and similarly to the Upper South catchment, the main stream in this catchment also flows in a northeast to southwest direction and has wetlands adjacent to the channel for much of its length. This catchment has 93 % natural cover with only small areas used for agriculture or development. The drainage density, at 1.2 km/km^2, is relatively low.

Two smaller catchments drain directly into the lower lake. On the east side the Lower East catchment is fairly small (8.4 km^2) and largely drains a small area of glaciolacustrine sands (yellow coloured area in Figure 4.3) and some exposed Paleozoic rock. A small part of this catchment to the north of the lower lake is underlain by Precambrian shield rocks. The catchment is 78 % natural cover with 14 % of the area, primarily near the lake shore, used for agriculture. Only one smaller stream drains this area. The Lower West catchment is somewhat larger at 23.8 km^2 of which 71 % is under natural cover and 21 % under agricultural practice. Two streams drain this catchment and flow into the lower lake. Wetlands are also prominent in this catchment.

4.4 Water Levels and Flow Regime

This section describes the variability in water levels and stream flows within the Lake Dalrymple watershed to better understand how the watershed responds to seasonal change and storm events. In general, watersheds that have strong connections to the groundwater system, exhibiting high recharge rates in uplands and significant discharge into lakes and streams, tend to have more stable water levels and stream flows. In contrast, watersheds that have weaker groundwater connections tend to see more flashy responses to seasonal change and precipitation events.

The data obtained through the long-term measurements of water levels and stream flows can be used to better characterize and understand the watershed, and can help to make decisions pertaining to water budgeting, water allocation, and water quality. The data can serve as an input into more sophisticated modelling of the watershed, should that be needed. Changes observed in the measurement data can reflect changes in climate, land use, water allocation or some other alterations in the watershed. Data is key to long term water resources management.

Water level data is very important for flood forecasting and emergency management, floodplain mapping and other applications. Starting in the fall of 2021 and running through to the fall of 2023, Kawartha Conservation staff have been monitoring Lake Dalrymple water levels as well as stream flows at two locations. The monitoring locations are shown in Figure 4.1. One stream from the Upper West catchment that empties into the north part of the lower lake near where the lake empties out towards the Head River was monitored, as was the main stream in the Upper East catchment. This stream terminates in the upper lake just south of the narrows between the lakes. Lake levels were manually monitored along the east shore of the lower lake, while the lake water level logger was installed near the narrows between the upper and lower lakes. At three monitoring locations, sensors were installed to continuously measure the water level.

Table 4.3 shows the details regarding the monitoring of the two streams. The sensors measure water levels, or the height of water above the sensor. However, to develop a water budget, or to calculate the amount of pollutants carried by the streams into the lake, the volume of water that flows through the watercourse is required. Water flows or discharges can be determined by initially calibrating measured water levels to stream flows by developing a rating curve. This involves repeatedly measuring the discharge (i.e. volume of water that flows through a cross section of a watercourse in one second) and the corresponding water levels at a monitoring location. To establish a reliable water level vs discharge relationship at the two Lake Dalrymple monitoring locations, these calibration measurements were taken (as much as possible) over a wide range of water levels. They were then graphed to develop a water level vs discharge relationship. A rating curve (an equation that describes the water level vs discharge relationship) is applied to measured water level values to convert them to discharges (water volume per unit time) at the gauged locations, typically in cubic metres per second (m^3/s).

Table 4.3. Details of Stream Flow Monitoring Locations.

Stream	Sub-watershed	Drainage Area (km^2)	% of total sub-watershed area	Measuring interval	Data record	Instrument Type
East	ULDT-3	14.1	58%	hourly	2021-2023	ISCOS (depth logger)
West	LLDT-7	9.9	73%	hourly	2021-2023	ISCOS (depth logger)

Figure 4.6, Figure 4.7 (a and b) and Figure 4.8 show the results of the 2021-2023 monitoring program at the three Lake Dalrymple monitoring locations, as well as the interpolated precipitation record obtained from the ORMGP website (Figure 4.8). Unfortunately, the logger at the east monitoring location had some technical issues in 2022 such that large parts of the flow record are missing.

Figure 4.6 shows the three years of recorded water levels in Lake Dalrymple. Over the three-year period the lake level was observed to fluctuate by about 1 m in range, from a high of about 227.70 metres above sea level (mASL) to a low of about 226.65 mASL. The highest water levels were recorded in the spring (April/May) shortly after snow melt, and the lowest levels recorded through the summer months (June through October). Although the 2021 spring water levels are missing, it is assumed that they would likely reflect the same trend or pattern that was observed in 2022 and 2023. Continuous water level data was only collected through the summer of 2022 and that record (blue line, Figure 4.6) shows consistently low lake levels from August through to October, before rising into the winter months. Although measurements were only taken manually on occasion through the summer of 2021, the water levels appear to show more variability, fluctuating by about 30 cm, possibly due to more frequent higher intensity rainfall events in 2021.

Figure 4.7a shows the stream flow record at the west stream where it crosses Kirkfield Road before emptying into the north part of the lower lake, whereas Figure 4.7b shows the flow record at the east stream, slightly upstream of the lake. Although the magnitude of the flow is greater in the east stream, the flows from the two stations reflect similar trends. For example, the flows in 2023 show similar peak flows in the early part of the year: a high peak flow in January, a lower peak in February and again a bit of a higher peak in April. Through the remainder of 2023 both monitoring stations show similar timing when it comes to increases and decreases in flows.

Through the spring, summer and fall months, when the three sets of monitoring data are examined together, the lake levels reflect the flow data in both the east and west streams, high flows in the streams correspond to high lake water levels. This is interpreted to reflect climate conditions (i.e. snow melt and precipitation events) in the Lake Dalrymple watershed. Closer examination of Figure 4.8 reflects this interpretation. The figure highlights the April 2022 and April 2023 climate conditions (blue lines representing precipitation; grey lines reflecting snowfall; and green lines reflecting snowmelt). Highlighted in the figure, in both 2022 and in 2023 there were significant snowmelt events (green lines) resulted in high flows in both streams as well as in high April lake levels. The significant July 2023 precipitation event, also highlighted on Figure 4.8 is similarly reflected in the stream flow and lake level monitoring. The monitoring data confirms the strong link between snowmelt and precipitation and Lake Dalrymple water levels.

With respect to seasonality, the data show mixed results. Typically, one would expect to see high flows and water levels in the spring. These would then tail off through the summer months as evaporation increases in the warm weather, and rigorous vegetation growth results in greater transpiration in the watershed. This type of response is generally reflected in the 2022 Lake Dalrymple water level data, however the 2021 and 2023 data show more variability, especially through the summer months. The stream flow data for the east stream also appears to reflect this seasonal pattern, with the odd precipitation event being reflected in the stream flow data. The western stream exhibits slightly different behaviour, especially in 2023. For 2022, the summer flows generally reflect low streamflow conditions except for a single rise in flow in June 2022. However, in 2023 the flow rate in the west stream is variable and much flashier. In examining Figure 4.8 it can be seen that in the summer months of 2023, when compared to 2022, there appears to be a greater number of higher intensity precipitation events (>20 mm) that might explain some of this 2023 flashy response.

Land use is another factor that can influence the hydrology within the watershed. Table 1.4, also obtained from the ORMGP website, shows the distribution of more detailed land use across the Dalrymple catchment and the two monitored sub-watersheds. Very little of the land use across any of the three areas is categorized urbanized (e.g. built up, aggregate extraction, transportation in Table 1). These types of land use can alter natural recharge and runoff rates, thereby modifying the original hydrology of the watershed. With so much of the sub-watersheds under natural cover, it is not anticipated that land use disturbance has had much of an effect on the hydrology of the Lake Dalrymple watershed.

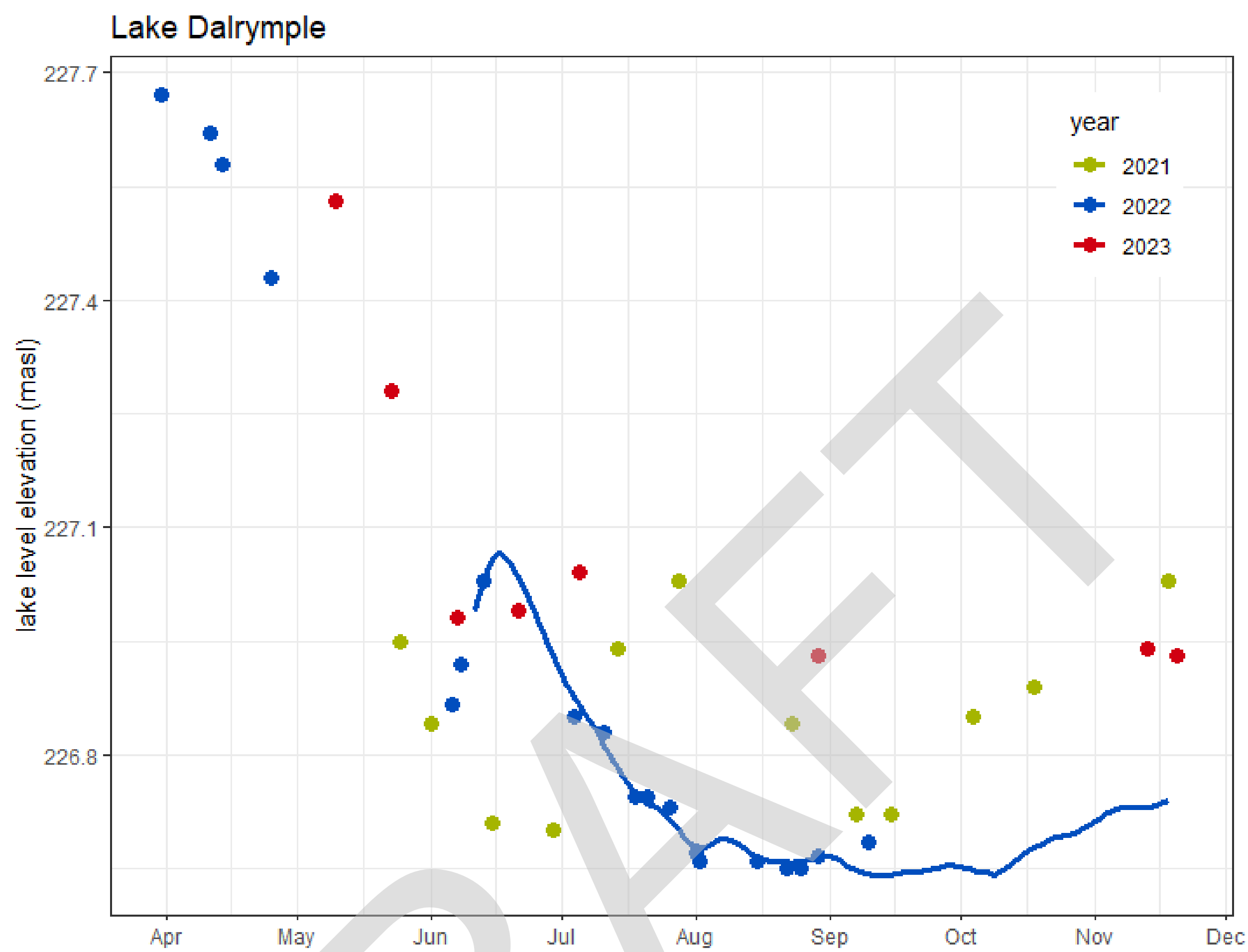

Figure 4.6: Water level monitoring data in Lake Dalrymple.

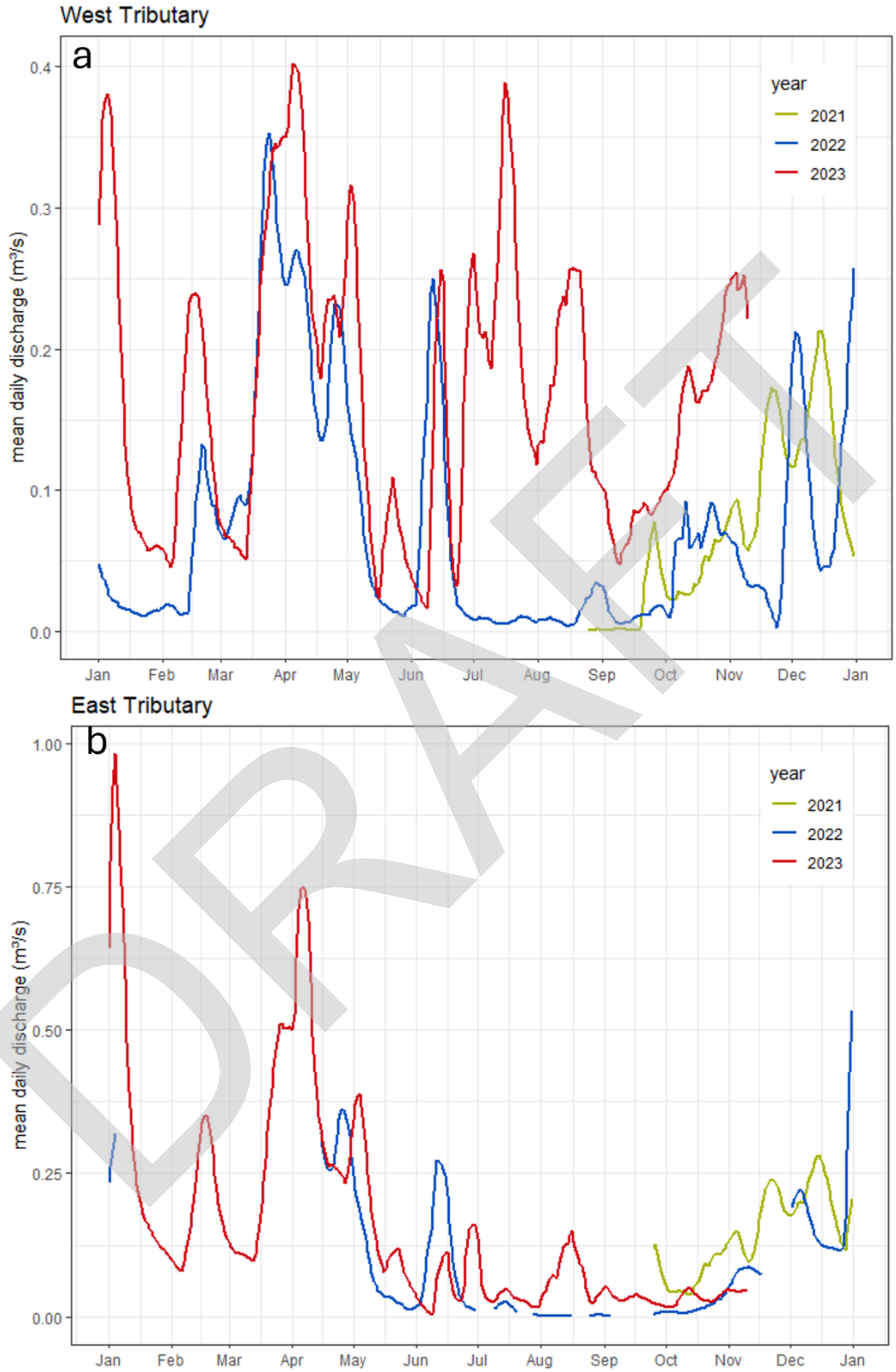

Figure 4.7: Stream flow monitoring results: a) West stream to lower lake; b) east stream to upper lake.

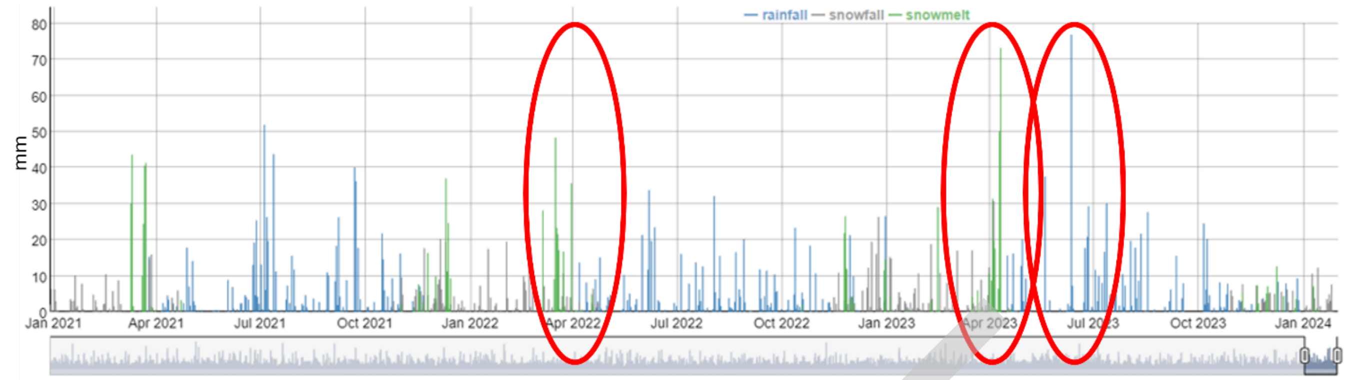

Figure 4.8: Interpolated precipitation in Lake Dalrymple watershed.

Table 1.4: Land Cover estimation across Lake Dalrymple catchment areas.

Land Cover	Lake Dalrymple		West Stream		East Stream	
	Area (Ha)	% Cover	Area (Ha)	% Cover	Area (Ha)	% Cover
Bog	24.8	0.2				
Built Up Area - Impervious	37.5	0.3				
Built Up Area - Pervious	14.8	0.1				
Coniferous Forest	493.8	3.4	51.6	5.2	72.0	8.0
Deciduous Forest	1368.6	9.5	352.9	35.3	139.8	15.5
Extraction - Aggregate	233.1	1.6				
Forest	45.2	0.3	2.9	0.3	2.1	0.2
Hedge Row	19.1	0.1	0.6	0.1		
Marsh	595.8	4.2	6.8	0.7	27.3	3.0
Mixed Forest	40.9	0.3	3.2	0.3	9.6	1.1
Open Alvar	275.7	1.9			4.9	0.5
Open Water	1011.9	7.1	2.6	0.3	0.5	0.1
Plantation	14.7	0.1	3.0	0.3		
Shrub Alvar	110.8	0.8				
Thicket Swamp	950.4	6.6	100.7	10.1		
Tilled	310.9	2.2	5.9	0.6		
Transportation	225.3	1.6	18.4	1.8	3.9	0.4
Treed Alvar	14.3	0.1			7.8	0.9
Treed Swamp	3284.3	22.9	263.0	26.3	297.0	33.0
Undifferentiated	5273.2	36.8	188.4	18.8	334.2	37.2
TOTALS	**14345**	**100**	**1000**	**100**	**899**	**100**

4.5 Flushing Rate

The major morphometric and hydrologic characteristics of Lake Dalrymple are as follows:

- Surface Area: 7.58 km^2
- Lower Lake Volume: 28,942,304 m^3
- Upper Lake Volume: 9,783,805 m^3
- Total Lake Volume: 38,726109 m^3
- Flow out of lake: 70,870,740 m^3/yr
- Residence time: 0.55 yr
- Maximum Depth: 10.4 m

Lake flushing rate is a rate at which water (or some dissolved substance) enters and leaves a lake relative to lake volume. It is usually expressed as time needed to replace the lake volume with inflowing water. Using inflow volumes, calculated as part of the lake water budget, the flushing rate is 1.8 times per year. Therefore, on average, the water mass in Dalrymple Lake changes every 200 days.

4.6 Baseflow

Baseflow is the portion of flow in a watercourse that comes from groundwater discharge, rather than direct runoff related to rain or snowmelt events. In the case of Lake Dalrymple, the connection to the groundwater system might also be reflected in direct groundwater discharge into the lake, rather than inflow via the lake's streams. During most of the year, stream flow is composed of both groundwater contribution and surface runoff. However, during the summer months, after periods of little or no precipitation, the flow in many area streams can be entirely contributed by groundwater. Ultimately, sustained groundwater inflow into Lake Dalrymple's streams, and/or the lake itself, generally leads to sustained water levels and more healthy conditions for the lake.

Natural land cover typically leads to higher recharge rates, thereby serving an important role in recharging aquifers and hence sustaining baseflows. Within a watershed, human activities such as wetland drainage, deforestation, and urbanization with associated increases in impervious surfaces, can significantly reduce recharge to the groundwater system and related baseflows. Regular monitoring of baseflow conditions throughout the Lake Dalrymple catchment can provide the baseline spatial and temporal overview allowing for the determination of areas and stream reaches with significant groundwater discharge. This can be useful information for fish and water resources management.

For the 2021–2023 Lake Dalrymple work, specific baseflow monitoring was not a component of the investigation. However, the two sets of stream monitoring data (Figure 4.7) do provide an indication of the magnitude of baseflow within the watershed. For the west stream, the stream flow measurements began in August and the flow was very close to 0 until mid-September. Similarly in 2022, after the one large precipitation event in June, the streamflow dropped very close to no flow, and it remained at very low levels through most of the summer months until recovering in early October. Monitoring in the east stream started a bit later in 2021 so that no summer flows were really measured. In 2022, the stream flow looks to be at 0 from late June right through to mid-October. 2023 was somewhat different and the measured streamflows through the summer months were generally above the levels observed in the previous two years.

Further monitoring would be needed to confirm that 2023 was an unusual year, however, based on the limited three-year data set from only two streams, it is believed that the groundwater baseflow contribution via stream streams to Lake Dalrymple through the summer months is minimal. However, an examination of the spring lake levels shows, over the three-year monitoring period, an approximate 1 m rise in spring lake levels. This might be reflected in the winter 2022 to 2023 stream inflows (see Figure 4.7), which are generally high, however in the winter 2021 through 2022 the measured stream flows do not reflect higher additional inflows to the lake.

It is suspected that there therefore might be some groundwater inflow (i.e. baseflow) directly into the lake, likely as a result of both the karstic nature of the area and the large percentage of the watershed that is under natural cover. It also might be that some of the groundwater that recharges within the Dalrymple Lake catchment is also moving to depth and not necessarily re-emerging locally within Lake Dalrymple's streams nor the lake itself.

There are very few long-term stream flow gauges in the vicinity of Dalrymple Lake with which to generally characterize the baseflow conditions in the regional area. The two closest stations are Black River near Washago and Head River near Sebright. Although not ideal since it is draining much more of the Canadian shield area, nevertheless data from the Head River gauge station at Sebright has been used as a surrogate to estimate the potential baseflow for the Lake Dalrymple water budget (below). Unfortunately, a third station (Talbot River) located to the south, is situated along the Trent-Severn Canal system and the flows are controlled in the summer months to allow for boating. Therefore, flows at this station do not reflect the average conditions in the uncontrolled smaller streams situated further away from the canal and its influence.

4.7 Water Taking

The Ministry of the Environment, Conservation and Parks (MECP) Permit to Take Water Program (PTTW) requires that for water withdrawals greater than 50,000 L/day a permit must be obtained. Within the Lake Dalrymple watershed, there are a number of water taking permits that are currently active, all associated with quarries in the southeastern parts of the watershed. Whereby the actual permit itself puts a maximum limit on how much water a permit holder can take in a given day/month/year, it is only fairly recently that the MECP has required permit holders to report to MECP the actual amount of water that they extracted in any given year. To date, the MECP has only provided taking data from 2020 and 2021. Table 4.5 shows the amount of water extracted by the active PTTW holders in the Lake Dalrymple watershed. Only three PTTW holders, the larger quarries, have reported any water takings during the 2019-2020 period, and one of these reported taking no water at all. Typically quarries use the water they take for two purposes: to keep the quarry dry so that they can work the quarry, and/or for washing the aggregate that they produce. With respect to both water uses, the small amount of water loss to the watershed would be through evaporation. Most of the extracted water is redirected back to local surface water streams that then flow into Lake Dalrymple. Therefore, the values reported in Table 4.5 are somewhat misleading. The various sources attached to one permit reflect the shifting of water from different ponds on the quarry site as part of their overall operations.

Figure 4.9 shows the locations of the active permits within the Lake Dalrymple watershed as well as all the private water wells that are registered with the MECP. These wells are where residents obtain domestic quantities of groundwater to supply their homes/cottages. Some lakeshore homes/cottages might also still obtain water supplies directly from the lake. The amount of water taken by homeowners (either on wells or directly from the lake) on an annual basis would typically be so low as to not have a measurable effect on the water budget in the watershed or on Lake Dalrymple water levels. Typical domestic use is estimated to be around 250-450L/day per person, with most homes determined to have 4 residents.

Table 4.5: Water Takings Reported for 2019 and 2020.

PTTW Name	Source ID	Reporting Year	No. of Days Reported	Volume Taken (m^3/yr)
7721-B62S6M	1230438225	2019	365	9225
7721-B62S6M	1230438225	2020	366	6903
7721-B62S6M	947426944	2019	365	155896.26
7721-B62S6M	947426944	2020	366	1014.582
7721-B62S6M	1380440406	2020	366	1112625.013
7721-B62S6M	1380440406	2019	365	974677.57
7721-B62S6M	-1971307391	2019	365	0
7721-B62S6M	-1971307391	2020	366	0
7721-B62S6M	-251802819	2020	366	0
7721-B62S6M	-251802819	2019	365	0
1057-BLCPCM	-771459069	2020	366	278116.8
1057-BLCPCM	-1573666506	2020	366	73894.1
1057-BLCPCM	1221844237	2020	366	0
1057-BLCPCM	610344741	2020	366	0
1057-BLCPCM	-1366457979	2020	366	0
1057-BLCPCM	262871861	2020	366	0
1057-BLCPCM	-1667103301	2020	366	0
1057-BLCPCM	2103028263	2020	366	0
1057-BLCPCM	-1691548217	2020	366	0
1057-BLCPCM	1966103938	2020	366	0
1057-BLCPCM	-1737503528	2020	366	0
1057-BLCPCM	-2023460684	2020	366	0
3658-AP8Q94	684830969	2020	366	0
3658-AP8Q94	684830969	2019	365	0
3658-AP8Q94	1630227732	2019	365	0
3658-AP8Q94	1630227732	2020	366	0
3658-AP8Q94	-1094442075	2019	365	0
3658-AP8Q94	-1094442075	2020	366	0

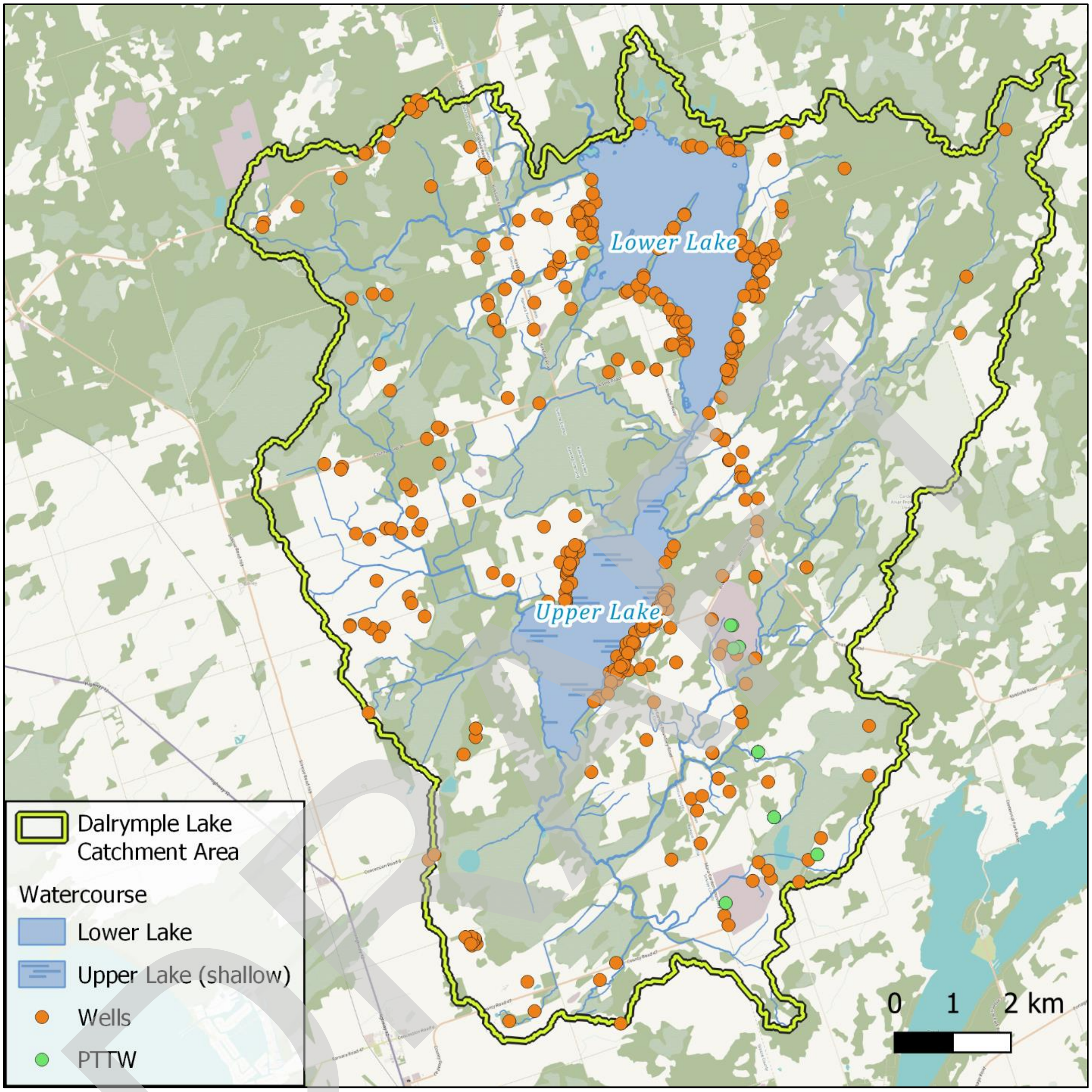

Figure 4.9: Groundwater wells and Permit-To-Take-Water (PTTW) locations.

4.8 Water Budget

A water budget is an essential component of any hydrological and water quality study, as it allows for a more complete understanding of the flows of water into and out of the lake and what components might be the most important in terms of both water levels and water quality. In the framework of the Dalrymple Lake Management Plan, the water budget might be used, for example to: evaluate cumulative effects of land uses on the water quality of the streams flowing into the lake and on lake water quality; determine priority areas for future environmental monitoring; or, estimate phosphorus and nitrogen loadings and balances for the lake.

A water budget for any given water body or watershed is a sum of all water inputs, outputs and changes in storage. For Lake Dalrymple, over the 2021-2023 monitoring period, the lake levels generally stayed the same and the water inputs and outputs to the lake apparently remained balanced—changes in lake storage are assumed negligeable. However, in any given year there might be the case, water levels can show small annual changes.

Water inputs to the lake include direct precipitation into the lake, as well as surface and groundwater inflows, which would incorporate discharges from any local septic systems that drain into the groundwater system as well as any net groundwater removals or surface water inputs associated with the local quarry water takings in the southeast. Overall, these inputs should be equal to the total water outputs from the lake, including evaporation, surface and groundwater outflows, and any direct water extraction from the lake for water supply purposes. Note that direct water extraction has not been measured but should be considered negligible relative to the lake's overall water budget.

The water budget equation for Lake Dalrymple can be written as:

$$P + Q_{in} + G_{in} - (E + Q_{out} + G_{out}) \pm \Delta S = 0$$

Where:

P – precipitation on the water surface of the lake,
E – evaporation from the water surface of the lake,
Q_{in} – sum of all surface inflows into the lake,
Q_{out} – sum of all surface outflows (in this case there are no measurements of outflows),
G_{in} – groundwater inflow into the lake (in this case no measurements have been done for the groundwater inflows),
G_{out} – groundwater outflow from the lake (in this case no measurements have been

done for the groundwater outflows),

ΔS – change in lake storage, typically zero over the long term.

Determining the water budget for Dalrymple Lake is complicated by the fact that the outflow from the lake has not been measured because the surface water outflow channel is situated low-lying wetland area with a poorly defined channel. Therefore, for the current water budgeting, the lake outflow is assumed to be equal to the lake inflows minus direct evaporation from the lake. In addition, the inflows to the lake have only been measured at two streams, the drainage areas of which only cover about 17 % of the Lake Dalrymple catchment area. No groundwater measurements have been made in this study. For all these reasons, there is considerable uncertainty in the water budget estimates presented below.

Table 4.6 presents the water budget terms as can best be determined with the available data. Interpolated precipitation in the Lake Dalrymple area can be obtained from the ORMGP website and is presented for the three-year period. The average precipitation was estimated to be 997 mm/yr which was applied to the area of Lake Dalrymple to obtain the first input value of 1.4×10^7 m^3/yr. The flow data from the east stream was used to characterize the east and south drainage areas of Lake Dalrymple, while the west stream flow was used to characterize drainage to the lake from the west side. The average measured flow over the monitoring period was obtained and then was divided by the catchment area to obtain a normalized flow value across the measured catchment in terms of $m^3/s/km^2$. This value was then extrapolated across each of the two areas (east/south and west) to arrive at the surface water inputs to Lake Dalrymple: 2.0×10^7 m^3/yr from each of the east/south and west areas of the watershed.

The final input needed was the groundwater baseflow. Although no groundwater data was available in the Dalrymple Lake watershed, flow gauges in the lake's vicinity can be used as a surrogate to reflect the groundwater conditions. In this case the Head River gauge to the northeast of Lake Dalrymple was chosen as the most suitable, albeit not ideal. The ORMGP website provides a wealth of statistical analyses, including information on baseflow. For the 2021-2023 season, the minimum baseflow of 14 estimates (to be conservative) was an average of 1.5 m^3/s. Over the 235.3 km^2 contributing area to the Head River gauge yields a normalized baseflow of 0.06 m^3/s/km. Applying this value across the Lake Dalrymple watershed area gives an inflow value of 2.8×10^7 m^3/yr.

The outflows from the lake were more difficult to estimate. Evaporation was determined across the lake using a Penman wind function with a pan evaporation coefficient of 1.3. This provided an outflow from the lake of 1.1×10^7 m^3/yr. The ~1 m drop in the lake water level from April through to June was determined as a separate number, assumed to be spring freshet outflow from the lake. A 1 m drop in Lake Dalrymple amounts to a volume of 1.4×10^7 m^3. Given that there were no outflow measurements available, the remaining outflow could only be estimated to balance the outflows with the inflows. This outflow (Q_{out}) would include groundwater outflow (G_{out}) but there's no way to determine by what proportion, and thus was lumped together. Figure 4.10 shows the estimated proportion of inflows and outflows to Lake Dalrymple.

Table 4.6. Water Budget Overview.

INFLOWS				
Precipitation	**mm/yr**	**Area (km^2)**		**m3/yr**
2021	987			
2022	903			
2023	1103			
3 year Average	997			
Precip on Lake Dalrymple	997	13.854		**1.38E+07**
Surface Water	**Measured Flow (m3/s)**	**Area (km^2)**	**m^3/s/km^2**	**m3/yr**
West Trib	0.111	9.9	0.011	
East Trib	0.108	14.1	0.008	
West Total		56.3	0.011	**1.99E+07**
East/South Total		82.4	0.008	**1.99E+07**
Groundwater	**Estimated Baseflow (m3/s)**	**Area (km2) Head River Watershed**	**m^3/s/km^2**	**m3/yr**
Use Head River Gauge as a surrogate)	1.5 (2021-2023 min (ORMGP Website)	235.3	0.006	
Groundwater inflow to Lake Dalrymple		138.7	0.006	**2.79E+07**
ESTIMATED TOTAL INFLOW TO LAKE DALRYMPLE				**8.15E+07**

OUTFLOWS				
	mm/yr	**Area (km^2)**		**m3/yr**
Evaporation	770	13.854		**1.07E+07**
Spring Outflow (1 m in 4 months)	1000	13.854		**1.39E+07**
Estimated Remaining Outflow				**5.70E+07**
ESTIMATED TOTAL OUTFLOW TO LAKE DALRYMPLE				**8.15E+07**

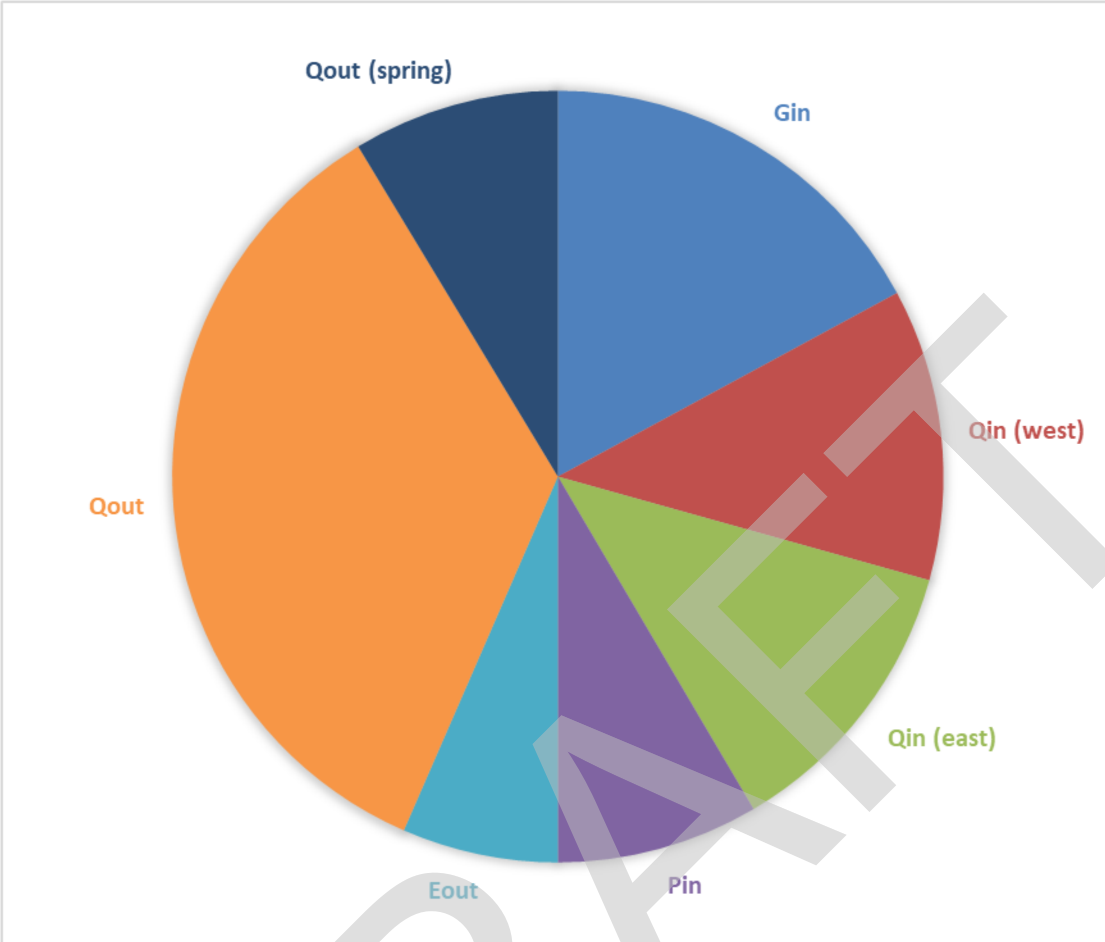

Figure 4.10. Proportion of water budget components.

4.9 Climate Change

The MECP and York University host the Ontario Climate Data Portal that provides ensemble results of climate projections all over the province of Ontario. Two metrics of importance that could affect future lake levels would be i) precipitation and ii) air temperature that would translate into rates of potential evaporation. There is an increasing trend of precipitation amounts projected into the future of up to 7 % under the "business as usual" scenario by 2080. The range of ensembles vary greatly from -17 to 35% of current rates, but overall, the bulk of climate projections show and increased precipitation.

Contrast that with mean air temperature, which is also projected to increase by 5.1°C by 2080 under the "business as usual" scenario. Here, the ensemble range is tighter at 2.9 to 8.3°C. This would suggest two circumstances: rates of evaporation would increase countering the increased precipitation, and the persistence of snowpack would decrease dampening out spring freshets.

So, there are countering results under a changing climate: increases in both precipitation and evaporation. Ultimately, whatever dominates could impact lake hydrology and it would remain difficult to quantify without hydrological modelling.

5.0 Water Quality

[Water quality sampling, August 2021]

5.1 Summary of Key Observations

- From 2021 to 2024, Kawartha Conservation staff conducted a water quality monitoring at 10 sites across the Lake Dalrymple watershed with 4 sites within the lake and 6 sites on its streams.
- Lake Dalrymple and some of its streams exhibits good water quality for water clarity, dissolved oxygen, nutrients (phosphorus and nitrogen), pH, and chloride, and can be used as a reference lake when comparing to other similar size lakes in the area.
- Phosphorus is the limiting nutrient (compared to nitrogen) and is predominately input through subwatersheds with much of the phosphorus entering the lake through shoreline septic systems. With an abundance of rooted native aquatic plants and natural cover, we expect that the risk of harmful algae blooms is low for Lake Dalrymple.
- Internal loading from thermal stratification does occur in Lake Dalrymple and was calculated and represents only 2% of the phosphorus budget.

5.2 Summary of Key Issues and Information Gaps

- Phosphorus did not meet provincial water quality objectives from 25 to 46 % in the lake, and from 2 to 100% in streams.
- Site LDT6 had a 100% failure rate for phosphorus when compared to provincial water quality objectives. Other streams show some signs of degradation; 3 sites are classified as fair, and 1 site can be classified as marginal.
- Chloride levels in the lake and in the streams have increased since 1972, from continuous domestic and transportation salt usage for the winter period, but chloride levels have not reached lethal doses.
- Shoreline septic represents a large portion (30 %) of the estimated phosphorus input into the lake.
- Winter water quality conditions (e.g., internal load, dissolved oxygen, etc.) are unknown, and groundwater water quality is unknown.
- Fecal indicator bacterial was measured in 1972 and its current level is still unknown. Historical records indicate that higher bacteria was found at the outlet of LDR4 in Upper Dalrymple and at Loon Drive in Lower Dalrymple.

5.3 Introduction

Water quality is the combination of the physical, chemical, and biological condition of the water and can include surface water (lakes, rivers, and streams), precipitation (rain and snow), and groundwater. All forms of life, including that of humans, depend on the existence of water. The quality of the water has a direct influence on the user (animals, plants, or humans), where the poor water quality can cause adverse effects on the health of the user often leading to sickness and death.

Water quality of a system can be driven by internal processes (i.e., internal loading, plant uptake of nutrients, decaying of organics within the lake, fish foraging), or external processes (i.e., stormwater runoff, atmospheric deposition, and industrial discharge). These processes can be natural or human driven, and can be of physical, chemical, and/or biological origins. Generally, the water quality of lakes and streams are primarily governed by the geological setting (bedrock) and activities that occur within its watershed. When materials are eroded by wind and water or inputted by biological means, they accumulate in the water, creating a unique set of characteristics for that waterbody. These materials can also settle out and create sediment which often holds the layers of the waterbody's character at the time. Similarly to water quality, sediment quality is an important component as many rooted plants use this media for anchoring, while fish often nest on lake sediment, and the sediment can often release nutrients and contaminants back into the water.

Thus, the objective of this chapter is to assess the water quality of Lake Dalrymple and its streams for key patterns and trends and to provide foundation knowledge for educational and decision-making purposes (such as the Lake Dalrymple Management Plan).

5.4 Methodology

A total of four lake, six stream, and one precipitation site was used to collect water quality information (Figure 6.1; Table 6.1). For each lake and stream site, surface water samples were collected by triple rinsing with the targeted water from the before sampling. Surface water samples were obtained from a depth of 0.15 to 0.3 m below the water's surface, while bottom lake water samples were collected 1.0 m above the sediment with the use of a Van Dorn sampler. Samples were then sent to Caduceon Environmental Laboratories for chemical analysis, including Chloride (Cl), Nitrite-N (NO_2-N), Nitrate-Nitrogen (NO_3-N), Ammonia-Nitrogen (NH_3-N), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), and Total Suspended Solids (TSS).

Water quality for precipitation samples were collected through a precipitation collected outfitted with coarse 18 by 16 mesh.

Field parameters such as Water Temperature (Temp.), pH, Conductivity (Cond), Dissolved Oxygen (DO), and Turbidity (Turb) were measured using a water quality multimeter during all sampling events. For the vertical lake profiles (VLPs) field parameters were measured and recorded every 0.5 m from the surface. Water clarity was measured at each lake site through a Secchi disc. Lake water temperature was also monitored through temperature (HOBO Pendant MX Water) and a water level logger (HOBO U20).

All data analysis was conducted utilizing the statistical software R (R Core Team, 2021). The calculation of the Percent Coefficient of Variation (%CV) for pH adhered to the methodology outlined by Canchola *et al.*, (2017). In instances where observations were absent, values were marked as NA, while those falling below detection limits were addressed using the R package NADA (Lopaka, 2020). Total Nitrogen (TN) values were derived through the sum of Nitrite-N, Nitrate-N, and Total Kjeldahl Nitrogen. Prior to TN calculation, both nitrate-n and nitrite-n were converted to their nitrate and nitrite forms, respectively. Total Nitrogen (TN) was calculated through the sum of nitrate, nitrite, and TKN. Prior to TN calculation, both nitrate-n and nitrite-n were converted to their nitrate and nitrite forms, respectively. The TN to TP (Total Phosphorus) ratios were computed as TN / TP.

It is important to note that most parameters deviated significantly from a normal distribution and did not conform to linearity assumptions. The relationships between these parameters were assessed through a spearman's correlation matrix and principal component analysis. Visual representations of individual datasets are presented in the form of boxplots.

Water quality results were compared to the following Provincial Water Quality Objectives (PWQO) and the Canadian Water Quality Guidelines (CWQG) (Table 6.2).

Air temperature and precipitation data was obtained through nearby weather and water stations (Lagoon City and Indian Point Provincial Park), through the Ministry of Natural Resources and Forestry's Surface Water Monitoring Centre by the R package kiwisR (Whaley, 2020).

Table 6.1. Water quality site IDs, description and location (easting and northing) across Lake Dalrymple and its streams.

Waterbody Type	Region	Site ID	Description	Easting	Northing
Lake	Upper	LDR1	Deepest section of upper Dalrymple	647980	4940918
	Lower	LDR2	Deepest section of lower Dalrymple	650233	4946140

	Lower	LDR3	Northeast basin between outflow and Avery Point	648844	4949196
	Lower	Outflow	Outflow of Lake Dalrymple	648844	4949195
Stream	Upper	LDT1	Unnamed stream on Mara/Carden Boundary Rd.	649722	4938810
	Lower	LDT2	Unnamed stream (East) on Kirkfield Rd.	650702	4943911
	Upper	LDT3	Unnamed stream (West) on Kirkfield Rd	646521	4948251
	Upper	LDT4	Unnamed stream on Concession Rd 9	646121	4941946
	Lower	LDT5	Unnamed stream on Lake Dalrymple Rd.	650912	4948969
	Lower	LDT6	Unnamed stream on McNabb Rd	647446	4947531
Precipitation	Lower	LDP1	Precipitation site at the recreational centre	649722	4938810

Table 6.2. Selective water quality parameters and their associated provincial objective and or federal guideline values.

Parameter	Value
Dissolved Oxygen	6.0 mg/L for warm water early life stage (CCME, 1999); Temperature dependent (PWQO, MOEE, 1994)
pH	< 6.5 and > 8.5 (PWQO, MOEE, 1994)
Turbidity	8 NTU above background (CCME, 2002)
Phosphorus	0.03 mg/L for rivers and streams; 0.02 mg/L for lakes (PWQO, MOEE, 1994)
Ammonia	Water temperature and pH dependent (CCME, 2010); 0.02 mg/L as un-ionized ammonia (PWQO, MOEE, 1994)
Nitrate	3.0 mg/L as Nitrate-nitrogen (CCME, 2012)
Chloride	Long-term Exposure: 120 mg/L; Short-term Exposure: 640 mg/L (CCEM, 2011)
Total Suspended Solids	25 mg/L above background (CCME, 2002)
Water Clarity	1.2 m minimum Secchi Disc (PWQO, MOEE, 1994)

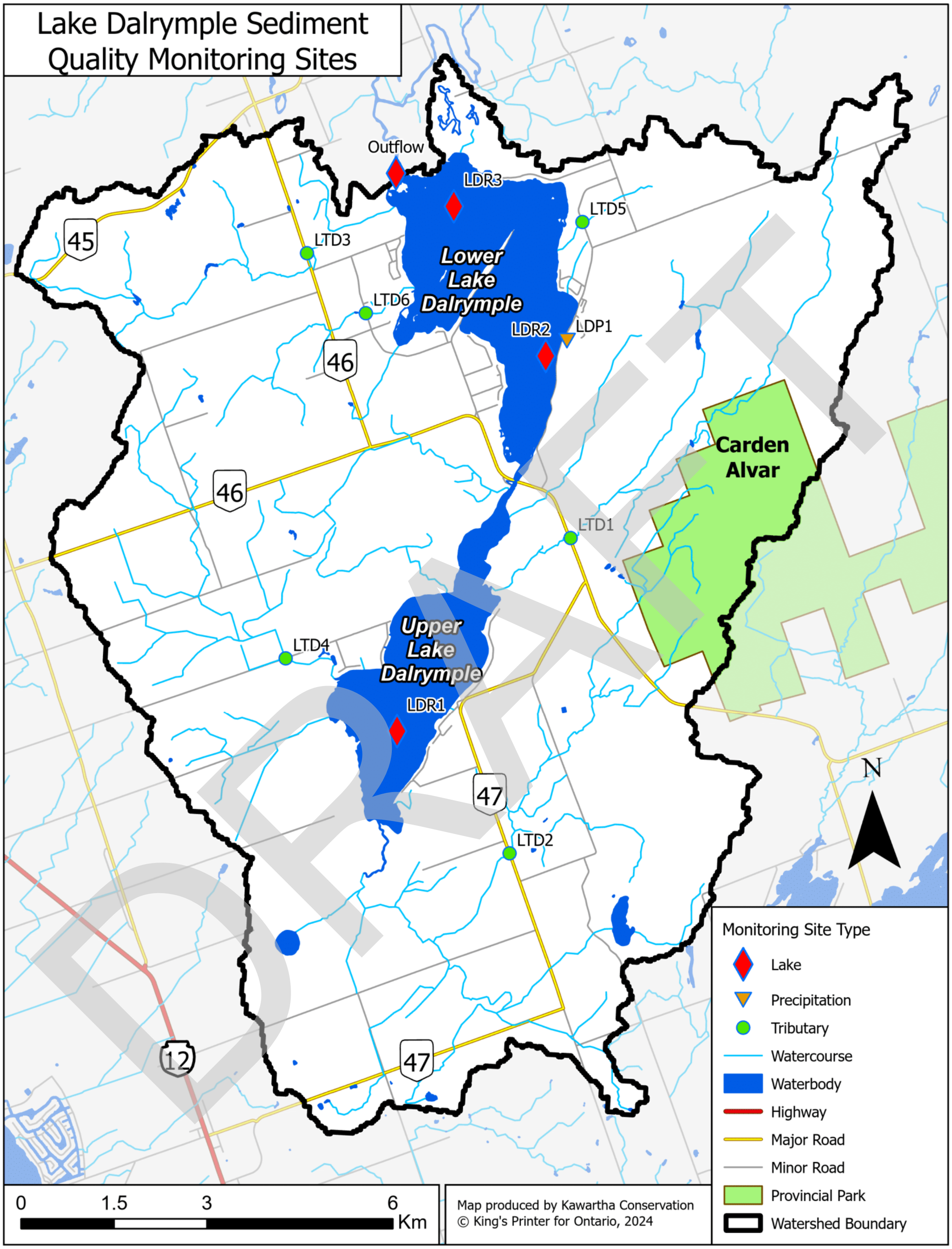

Figure 6.1. Map of the Lake Dalrymple watershed and the locations of water quality sampling sites.

The CCME Water Quality Index (WQI) (CCME, 2017) program was used to provide a convenient mean to summarize all water quality results. The WQI assesses the overall health of the site based on the number of parameters (such as those outlined above) that fail to meet guidelines, the frequency of the failure, and the total number of observations that fail to meet the guideline. The WQI digested the results and is able to assign the site to different categories based on the final score.

A phosphorus budget was determined using land use information (see Chapter 3: Land Use and Lake Use), water budget (see Chapter 4: Water Inputs and Water Levels) and followed that of Patterson (2006). In addition, certain inputs to the phosphorus budget were calculated through using the Ministry of the Environment, Conservation and Park's Provincial Groundwater Monitoring Program (PGMN) for groundwater input, and from Grøterud and Haaland (2012) for internal loadings. Groundwater input into the lake was calculated from Chapter 4: Water Inputs and Water Levels and groundwater data from PGMN station W44-1 (there were no PGMN wells within the Dalrymple watershed) which had similar geology and is located away from major roadways and urban centers.

5.5 Water Temperature and Dissolved Oxygen

The temperature of the water is driven by the latitude, elevation, time of day, water speed, and depth, where higher latitude and elevation can contribute to colder temperatures, along with periods of darkness (night), faster flowing water and greater depths. Groundwater is usually consistent with its temperature and groundwater fed streams also follow this characteristic. Also, groundwater fed streams are often found to be much colder than surface driven streams and is most predominate during the hottest periods of the year (see Chapter 6: Aquatic Habitats and Fish). Lower (colder) temperatures can limit biological growth (think of your refrigerator) but can hold more oxygen as the water is denser, which can result in more sensitive life occurring in colder waters (see Chapter Aquatic 6: Aquatic Habitat and Fish).

Dissolved oxygen is the amount of oxygen in the water. This characteristic is critical for all aquatic life, aquatic bugs, fish, and amphibians. Low oxygen (below 2-3 mg/L; Kalff, 2002) can cause hypoxia for most aquatic organisms. But water is oxygenated through the atmosphere (wave action or ripples over obstructions) or by aquatic plants. As mentioned above, colder waters have the capacity to hold more oxygen content, and in addition to the physical drivers, critical biological processes can also drive dissolved oxygen levels. Aquatic plants and algae produce oxygen through photosynthesis and a study by Unmuth *et al. (*1999) found that large dense masses of aquatic plants were able to elevate surface dissolved oxygen levels by at least 1.0 mg/L. Similar results were found by Cater *et al.*, (1991) where fluctuations of DO in areas without vegetation were contributed by phytoplankton. Biological processes can enhance levels of DO but can also deplete DO levels when the decomposition of organic matter occurs.

Unlike temperature, there are provincial and federal levels of water quality guidelines and objectives where both are targeting the protection of fish communities (Table 6.2). Generally, cold water fish species, i.e., Brook Trout (*Salvelinus fontinalis*), Sculpin (*Myoxocephalus sp.),* and early life stages (egg and fry) regard higher levels of dissolved oxygen.

The threshold for DO is to protect the most sensitive stage of aquatic organisms, i.e. young fish and fish eggs. For this report, we compared measured DO levels to both PWQO and CWQG values.

For deep and large systems, factors such as inflow, current, season, and depth are amplified to bring oxygenated rich waters towards the bottom. During the summer period, water at the surface is heated by the sun and raised up the water column, while cooler water (deeper) sinks toward the bottom. Thus, water at the surface (warmer) tends to be less oxygenated during the summer period than during the spring and fall periods (Figure 6.3).

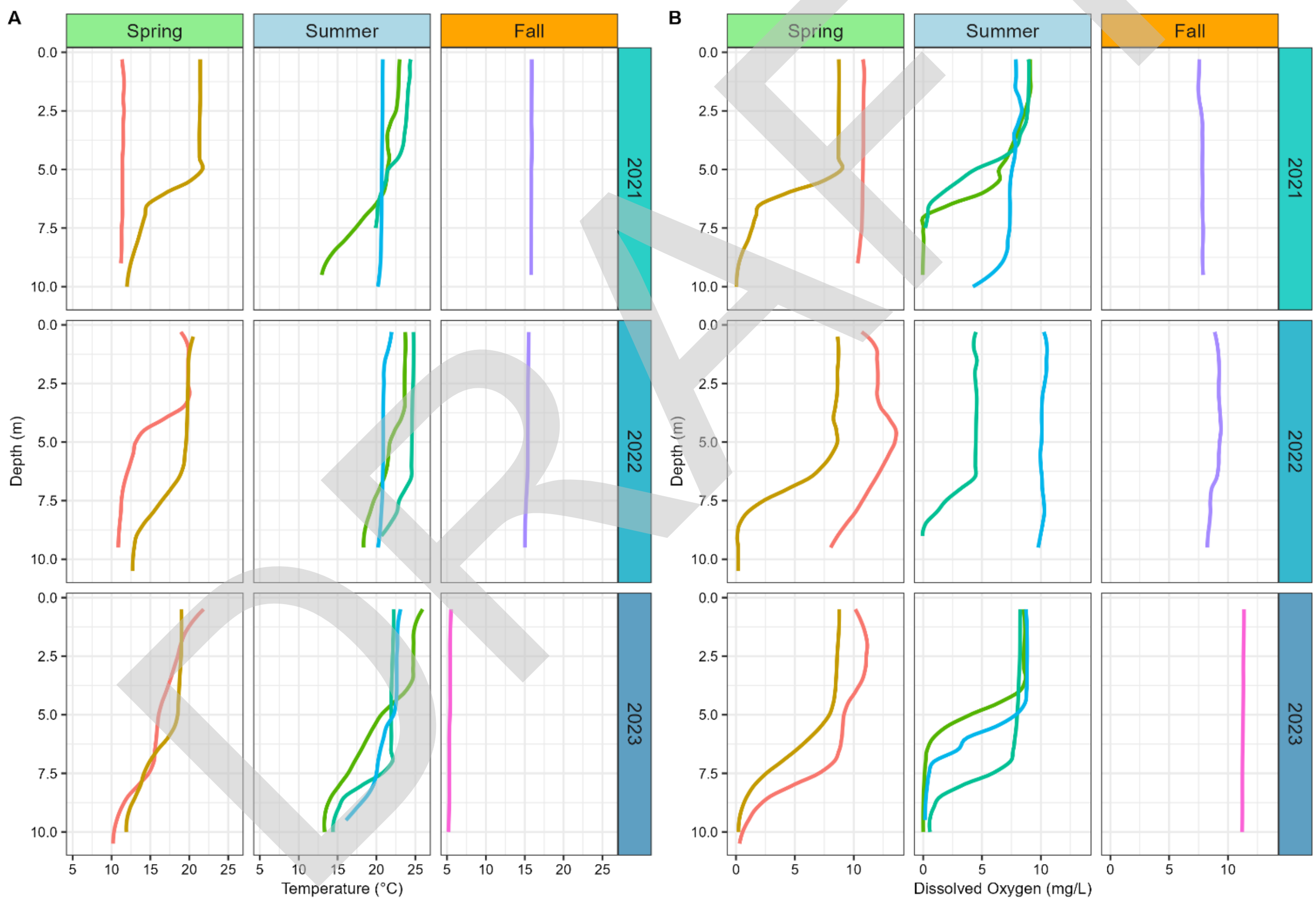

Figure 6.2. Vertical Lake profiles for temperature (°C; left panels) and dissolved oxygen (mg/L; right panels) at the deepest basin in Lake Dalrymple (LDR2; Figure 6.1). Profiles are separated by season (Spring = May & Jun; Summer = Jul, Aug, Sep; Fall = Oct & Nov) and by sampling year.

The thermal difference between surface (warmer) and subsurface (colder), creates a separation of water layers (thermal stratification), where the warmer water at the surface (epilimnion) loses its ability to hold oxygen, resulting in lower DO levels whereas the colder water near the bottom (hypolimnion) has more DO levels. The layer in between the epilimnion and hypolimnion is called the thermocline. However, the DO level near the bottom tends to decrease as the season progresses as organic matter settles to the bottom. This results in a sharp decrease in temperature and DO during the height of summer.

This pattern is flipped during the spring and fall where cooler air temperatures allow the surface to cool down and hold more oxygen. When the surface water is cooler than the bottom, the water column flips and mixes, this process is called turn-over. During the winter, the opposite of summer occurs where air temperatures below 0 °C cause the surface to freeze, as the water becomes cooler and denser, it sinks until it reaches its maximum density at 4 °C, leaving much of the bottom slightly warmer than the 0 °C at the surface. Similarly, to the summer, prolonged periods of ice cover (preventing mixing from the atmosphere and inputs from streams) can cause depletion of oxygen, causing winter fish kills.

During our lake monitoring, we collected 61 single sample observations of DO and 35 vertical lake profiles (at each lake water quality site, except the outflow). For surface waters, Lake Dalrymple is well oxygenated with low failure rates, <10 % of samples. Mean and median values are 8.20 mg/L and 8.7 mg/L for all lake sites and observations (Figure 6.3; Table 6.4). Of the 61 observations of DO, only 1 observation failed to meet the PWQO while 4 observations failed to meet the CWQG (Figure 6.3; Table 6.4). The abundance of values that meet the PWQO and CWQG DO thresholds are due to a healthy amount of plant growth and mixing from the wind.

For subsurface observation, vertical lake profiles were completed at each lake site. Multiple measurements across different seasons and years indicate that the lake does experience thermal stratification (Δ °C >= 2 °C/ 1 m), which is a natural process (Figure 6.2). Thermal stratification was found back in 1972 (MOE, 1972). From our observations, thermal stratification can occur in the spring (May) and can last until fall (September) and turn-over does occur in the fall where both temperature and dissolved oxygen are stabilized across depths (Figure 6.2).

Although thermal stratification is a natural phenomenon, pro-long stratification owing to hotter and extended hot days can strengthen the thermocline which could further promote anoxia near the bottom of the lake. This can result in a larger internal release of phosphorus from the sediment. In addition, hotter and extended hot days owing from climate change has resulted in less dissolved oxygen (warmer waters hold less oxygen) in both surface and subsurface environments (Jane et al., 2021). We expect that with hotter and extended hot days that the number of days with an established thermocline will be greater (happening earlier and longer) which would result in more anoxic conditions to occur near the bottom. These conditions can impact phosphorus release and cold-water fish habitat.

Table 6.4. Summary statistics (count, mean, median, min, max) of physical and chemical characteristics of lake sites. Exceedances (Ex.) count and percentage are also shown, where two values indicate comparison to the PWQO and CWQG.

Site	Statistic	Temp. (°C)	pH	Conductivity (uS/cm	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Secchi (m)	Chloride (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)
LDR1	Count	22	19	19	15	20	18	27	27	27	27	27	27
	Mean	20.5	8.5	270.5	2.2	8.6	2.5	10.6	0.041	0.049	0.8	0.018	4.1
	Median	20.1	8.4	222.6	0.5	8.7	1.9	10.7	0.025	0.03	0.8	0.015	4
	Min	10.4	8	190	0	4	1.4	8.6	0.025	0.001	0.005	0.004	1
	Max	25.8	9	575	6	10.9	4	13.7	0.2	0.42	1.5	0.044	11
	Ex. Count	n/a	8	n/a	0	0|1	0	0	0	1|1	n/a	7	0
	Ex. Percent	n/a	47	n/a	0	0|6.3	0	0	0	5|5	n/a	46.7	0
LDR2	Count	24	21	21	16	21	19	31	31	31	31	31	30
	Mean	19.6	8.2	304.9	2.4	7.6	3	9.8	0.042	0.073	0.6	0.025	3.9
	Median	19.9	8.1	257	0.4	7.8	2.3	9.7	0.025	0.03	0.5	0.019	3
	Min	5.5	7.4	230	0	0	1.8	8.8	0.025	0.002	0.4	0.003	0.846
	Max	25.6	8.6	584	5.7	12.2	4.9	11.1	0.2	0.43	1.2	0.168	14
	Ex. Count	n/a	2	n/a	0	0|1	0	0	0	0	n/a	8	0
	Ex. Percent	n/a	11	n/a	0	0|5.9	0	0	0	0	n/a	36.4	0
LDR3	Count	23	20	20	15	21	19	26	26	26	26	26	26
	Mean	19.9	8.3	301.2	1.7	8.4	3.1	9.9	0.047	0.034	0.5	0.019	2.6
	Median	20.9	8.3	270.5	0.7	8.3	3	9.7	0.025	0.019	0.5	0.015	2.3
	Min	4.8	8	236	0	2.9	1.7	8.7	0.025	0.002	0.4	0.004	0.949
	Max	25.6	8.6	563	4.1	12.2	4.7	11.7	0.2	0.43	1.2	0.062	6
	Ex. Count	n/a	3	n/a	0	0|1	0	0	0	0	n/a	5	0
	Ex. Percent	n/a	16	n/a	0	0|5.9	0	0	0	0	n/a	25	0

Table 6.4… continued.

Site	Statistic	Temp. (°C)	pH	Conductivity (uS/cm	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Secchi (m)	Chloride (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)
Outflow	Count	12	11	11	7	11	12	12	12	12	12	12	12
	Mean	18.3	7.9	314.6	0.4	8.1	1.1	10.2	0.042	0.024	0.6	0.03	2
	Median	20	8	275.7	0.2	8	1.1	9.5	0.025	0.015	0.55	0.016	20
	Min	4.8	8	236	0	2.9	1.7	8.7	0.025	0.001	0.4	0.008	0.706
	Max	25.6	8.6	563	4.1	12.2	4.7	11.7	0.2	0.43	1.2	0.062	6
	Ex. Count	n/a	0	n/a	0	1|1	0	0	0	0	n/a	3	0
	Ex. Percent	n/a	0	n/a	0	9.1|9.1	0	0	0	0	n/a	25	0
All	Count	81	71	71	53	73	68	96	96	96	96	96	95
	Mean	19.7	8.3	296.1	1.8	8.2	2.5	10.1	0.043	0.05	0.622	0.022	3.4
	Median	21.1	8.3	279	1.6	8.7	2.7	0.03	0.03	0.02	0.60	0.65	3
	Min	4	7.4	190	0	0	0.6	8.6	0.025	0.001	0.005	0.003	0.7
	Max	25.8	9	584	6	12.6	4.9	14.6	0.2	0.4	1.5	0.2	14
	Ex. Count	n/a	13	n/a	0	1|4	0	0	0	1|1	n/a	23	0
	Ex. Percent	n/a	20	n/a	0	1.6|6.6	0	0	0	1.4|1.4	n/a	33.3	0

Table 6.5. Summary statistics (count, mean, median, min, max) of physical and chemical characteristics of stream sites. Exceedances (Ex.) count and percentage are also shown, where two values indicate comparison to the PWQO and CWQG.

Site	Statistic	Temp. (oC)	pH	Conductivity (uS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)
LDT1	Count	37	37	37	29	36	41	41	41	41	41	41
	Mean	16.2	7.9	580.6	1.5	8.1	26.6	0.2	0.04	0.52	0.02	5.6
	Median	16.1	7.9	529	0.3	8.1	27.1	0.17	0.03	0.5	0.02	1.62
	Min	4.3	7.7	256.4	0	2.6	3.3	0.005	0.003	0.3	0.001	0.3
	Max	23.4	8.3	1189	8	12	59.6	0.53	0.12	1.05	0.071	70
	Ex. Count	n/a	0	n/a	0	3|7	0	0	n/a	8	8	2
	Ex. Percent	n/a	0	n/a	0	8.1|18.9	0	0	n/a	19.5	19.1	4.9
LDT2	Count	37	37	36	24	36	42	42	42	42	42	42
	Mean	14.4	7.9	455.6	1.2	8.7	13.7	0.18	0.04	0.32	0.01	2.2
	Median	13.7	7.9	388.1	0.3	8.9	3.6	0.08	0.03	0.3	0.01	1.88
	Min	7.4	7.3	263	0	4	0.7	0.004	0.008	0.1	0.001	0.3
	Max	21.1	8.5	797	9.5	11.3	69.5	0.73	0.1	1.3	0.09	10
	Ex. Count	n/a	1	n/a	0	1|6	0	0	0|0	n/a	1	0
	Ex. Percent	n/a	2.7	n/a	0	2.7|16.2	0	0	0|0	n/a	2.4	0
LDT3	Count	37	38	38	30	37	41	41	41	41	41	41
	Mean	16.5	7.6	287.7	2.1	8	10	0.12	0.03	0.58	0.01	3.5
	Median	17.2	7.6	270.9	1.5	7.8	10.4	0.11	0.03	0.6	0.02	2
	Min	3.9	6.8	184.1	0	2.9	1	0.01	0.004	0.2	0.001	0.2
	Max	23.4	8.3	484	5.6	11.7	15.1	0.28	0.08	0.8	0.032	25
	Ex. Count	n/a	0	n/a	0	3|4	0	0	0|0	n/a	2	0
	Ex. Percent	n/a	0	n/a	0	7.9|10.5	0	0	0|0	n/a	4.9	0

Table 6.5… continued

Site	Statistic	Temp. (°C)	pH	Conductivity (uS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)
LDT4	Count	28	28	28	21	25	29	29	29	29	29	29
	Mean	14.8	7.2	430.6	4.8	3.5	19.1	0.12	0.17	1.46	0.17	9.4
	Median	15.6	7.2	402	1	2.4	12.6	0.05	0.08	1.2	0.14	5
	Min	2.2	7	214.2	0	0	2.2	0.015	0.003	0.05	0.007	0.1
	Max	20.9	7.6	834	18.1	9.5	73.4	0.78	0.84	3.3	0.444	38
	Ex. Count	n/a	0	n/a	6	20|20	0	0	0|0	n/a	26	2
	Ex. Percent	n/a	0	n/a	21	71.4|71.4	0	0	0|0	n/a	89.7	7
LDT5	Count	29	29	29	22	28	31	31	31	31	31	31
	Mean	11.6	7.9	424.3	1.8	9.4	3.5	0.09	0.03	0.19	0.01	4.3
	Median	11.5	7.9	392	0.7	9.5	2.2	0.07	0.03	0.2	0.01	3
	Min	6.6	7.5	223	0	3.9	1.2	0.022	0.002	0.05	0.001	0.2
	Max	17.2	8.3	690	19.2	12.7	29.9	0.56	0.06	0.61	0.083	20
	Ex. Count	n/a	0	n/a	1	1|2	0	0	0|0	n/a	4	0
	Ex. Percent	n/a	0	n/a	3	3.4|6.9	0	0	0|0	n/a	12.9	0
LDT6	Count	16	16	16	12	15	17	17	17	17	17	17
	Mean	14.6	7.7	295.8	1.7	9.5	10.6	1.06	0.07	0.96	0.07	4.5
	Median	14.2	7.7	287.2	0.6	8.7	10.9	0.97	0.06	0.9	0.06	2
	Min	4.9	7.4	188.1	0	8.2	0.9	0.33	0.002	0.6	0.043	0.2
	Max	20.4	8.1	393.1	14.3	12.1	16.6	2.1	0.28	1.5	0.104	20
	Ex. Count	n/a	0	n/a	1	0	0	0	0|0	n/a	17	0
	Ex. Percent	n/a	0	n/a	6	0	0	0	0|0	n/a	100	0

Table 6.5… continued

Site	Statistic	Temp. (°C)	pH	Conductivity (uS/cm	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)
All	Count	184	185	184	138	177	201	201	201	201	201	201
	Mean	14.8	7.7	423.4	2.1	7.8	14.5	0.22	0.06	0.61	0.04	4.7
	Median	15.4	7.8	385.1	0.8	8.6	10.6	0.1	0	0.5	0.015	2.3
	Min	2.2	6.8	184.1	0	0	0.7	0.004	0.002	0.05	0.001	0.1
	Max	23.4	8.5	1189	19.2	12.7	73.4	2.1	0.8	3.3	0.4	70
	Ex. Count	n/a	1	n/a	8	28|39	0	0	0|0	n/a	58	4
	Ex. Percent	n/a	0.5	n/a	4	15|21	0	0	0|0	n/a	28.9	2

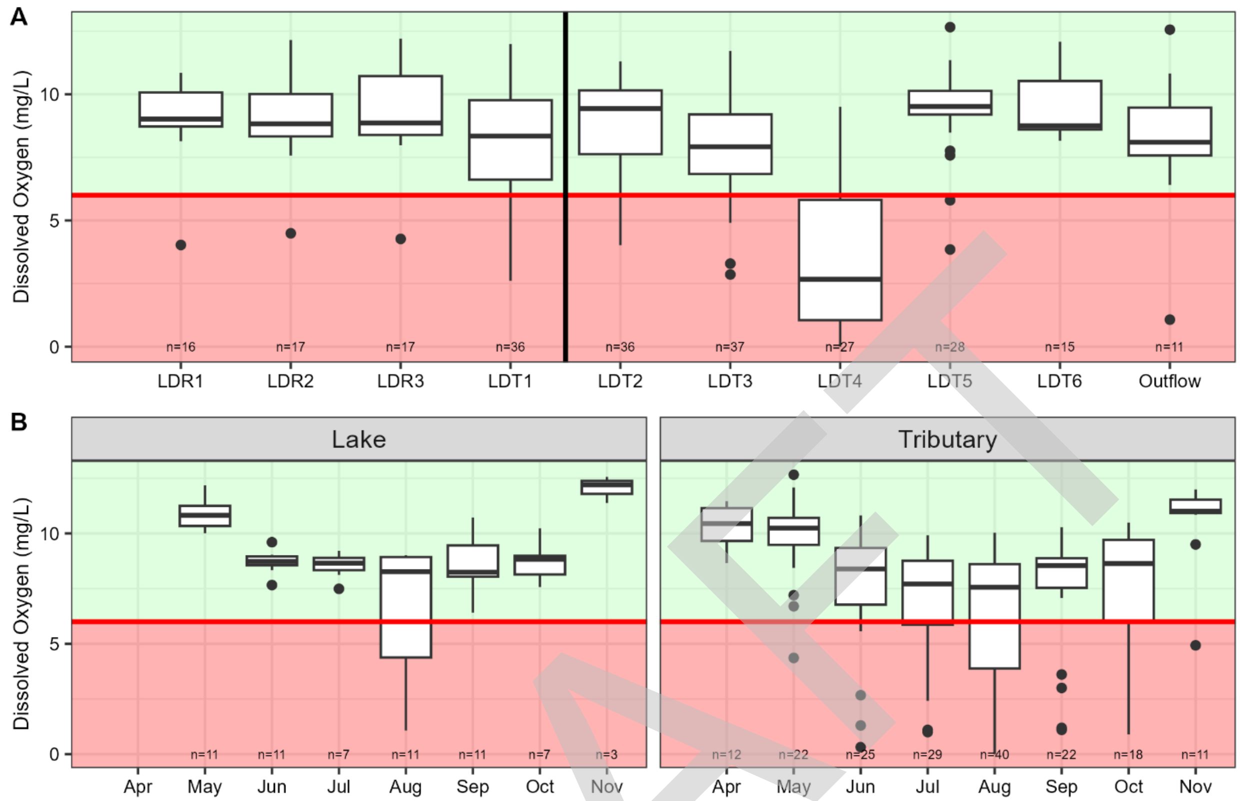

Figure 6.3. Dissolved oxygen levels for all water quality sites (A: lake site = left, stream sites = right of vertical line). Dissolved oxygen per month (April to November) are also shown and are separated by site type, i.e., lake site = left, stream sites = right.

For streams of Lake Dalrymple, we recorded 185 observations of DO and found that mean and median values for all sites were 7.8 and 8.6 mg/L (Table 6.5). Similarly to lake sites, we found that there was a seasonal pattern where DO is highest during the cooler months of April and May and lower during the summer months of June – October (Figure 6.3). This seasonal pattern was also found in Coastal Wetland in Ontario (Larocque *et al.*, 2021). Although there were failures to meet CCME guidelines, which represents required DO levels for the incubation of eggs and/or house sensitive organisms, we see that 60 % of all observation are within those guidelines during the incubation period for cool water and warm water fish species (during the months of May to June, and Sept to November).

When compared per site, we found that site LDT4 had the lowest mean (3.5 mg/L) and median (2.4 mg/L) (Figure 6.3, Table 6.5) where 50% of observation can be classified as anoxic with risk to hypoxia (2 to 3 mg/L; Kalff, 2002). When compared against the PWQO and CWQO, we found that 15 and 21 % did not meet PWQO or CWQG for warm water fish or sensitive life stages, i.e., during egg incubation. Much of the observations that did not meet PWQO or CWQG were driven by observations at LDT4 (Figure 6.3, Table 6.5). This site is characterized as a flat (<0.5 % grade) slow moving stream surrounded by wetland, may be better representative of a wetland than a stream. As a wetland with an abundance of organic matter, it is expected that with warmer temperatures will result in increased biological oxygen demand which creates periods of low oxygen (Larocque *et al.*, 2021).

Following LDT4, LDT1 was found to have the second highest level of failure for both PWQO (8.1 %) and CCME (18.9 %). Higher failure rates (when compared against CCME; 6.4 mg/L) are suggested during egg incubation periods and early life stages, for this warm water watercourse we see that there is enough DO during the months of May-June. Site LDT5 was found to have the highest level of DO (mean = 9.4 mg/L, median 9.5 mg/L; Table 6.5; Figure 6.2). This was expected as this site has the coolest temperature (mean = 11.6 ºC, median = 11.5 °C; Table 6.5) and was also found to be a cold-water stream (see Chapter 7: Aquatic Habitats and Fish) where colder waters have the capacity to hold more oxygen.

In conclusion, DO across streams had observations that did not meet PWQO or CWQG. These guidelines are for warm water fish species (PWQO) and for sensitive life stages (i.e., egg incubation and early life stages). We found that LDT4 had higher failure rates, but this was result of the site acting as a wetland where an abundant of organic matter and warmer temperature can cause microbial decomposition and lowering of DO. This process is natural and has been found in other wetlands across Ontario. The cold-water site, LDT5, displayed typical cold-water characteristics with lower temperatures and higher DO when compared to the other sites.

5.6 Water pH

Water pH serves as a critical indicator of acidity or alkalinity within aquatic environments. It plays a pivotal role in regulating the availability of certain metals and influencing the suitability of aquatic ecosystems for various life forms. In freshwater systems, water pH is predominantly influenced by the underlying geological composition. However, human activities, such as effluent discharge, smelting, and mining, can also alter pH levels, making the water either more acidic or more alkaline. The Provincial Water Quality Objective (PWQO) for pH, as established by the Ministry of Environment (MOEE, 1994), falls within the range of 6.5 to 8.5.

A total of 71 observations of pH were recorded, with a total of 13 observations exceeding the PWQO, representing ~20 % of observations (Table 6.4; Figure 6.4). Exceedances were driven by high pH readings >8.5 and were found at all three lake sites (exceedance count: LDR1 = 8, LDR2

= 11, LDR3 = 16), which aligns with the subsurface geology, i.e., Limestone bedrock (see Chapter 2: Study Area), which is responsible for the Carden Alvar and the high pH found in the lake. Between sites, LDR1 (located in Upper Lake Dalrymple), had the highest mean and median pH, at 8.3 (Table 6.4). This was not expected as 77 % of the watershed drains into Upper Lake Dalrymple (see Chapter 3: Land Use and Lake Use).

For streams, 185 observations of pH were documented and found only one instance where pH was found outside of the PWQO (Table 6.5). This represents a 0.5% failure rate across all sites and all monitoring events. Similarly to lake pH, stream pH is governed by its geology. Having been located on limestone bedrock, we see that the observation that failed to meet PWQO was 8.52, just 0.02 pH units higher. When compared to historical data by MOE (1972), we see that 7 of 10 sites are still within the historical range (Figure 6.4). Three sites, LDT3, LDT4, and LDT6, all have more acidic pH when compared to historical inlet streams but are still within the PWQO (Figure 6.4). Both LDT3 and LDT4 are heavily wetland influence and thus are expected to have lower pH due to organic acids. It is unknown to LDT6 to have lower pH than other sites as it is not adjacent to a large wetland. Based on all observations, higher pH across Lake Dalrymple and its streams are not of significant water quality concern.

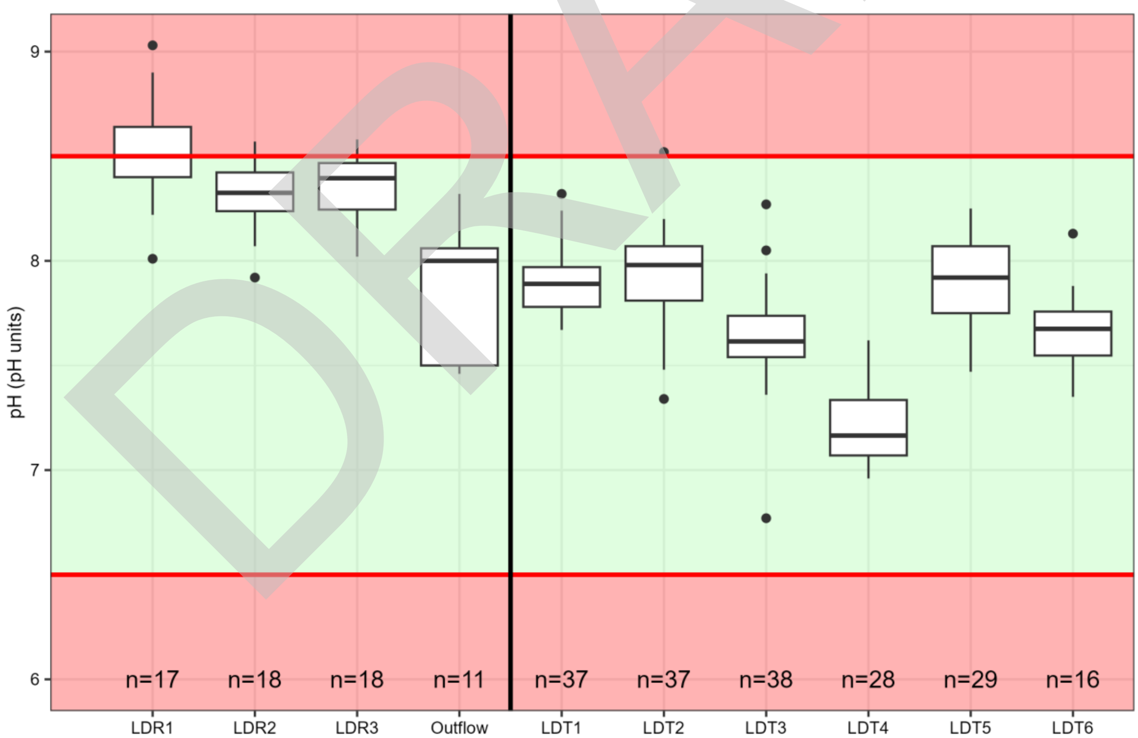

Figure 6.4. Water pH of lake (left) and stream (right) sites. Areas highlighted in red are outside of the Provincial Water Quality Objective (PWQO) for pH, while the area in green is within the PWQO.

5.7 Water Clarity (Turbidity, Total Suspended Solids, and Secchi Depth)

The clarity of water can significantly influence the aesthetic appeal of aquatic environments and the health of the organisms that live within it. Murky waters commonly indicate high levels of suspended solids originating from biotic (e.g., phytoplankton, algae) and abiotic (e.g., sedimentary particles such as sand, silt, clay) sources. These particulates serve as carriers for both organic and inorganic contaminants (Bodo, 1989), facilitating their dispersion through the aquatic food web via processes like bioaccumulation and biomagnification. Land-based inputs of suspended solids are frequently intensified during precipitation events, spring thaws (Danz *et al.*, 2013), and human-induced activities such as construction (Barton, 1977), agriculture (Rutledge and Chow-Fraser, 2019), and urbanization (Winter and Duthie, 1998).

The input of suspended solids into water bodies poses challenges to aquatic life, including physiological stress, altered behavior, and death among various species (Bash *et al.*, 2001; Kjelland *et al.*, 2015; Tuttle-Raycraft and Ackerman, 2019). Moreover, sediment deposition can smother critical spawning grounds and incubating eggs (Bash *et al.*, 2001). While certain fish species demonstrate a degree of tolerance to murky waters with high suspended solids, others exhibit heightened sensitivity. For instance, species like walleye (*Sander vitreus*) and brown bullhead (*Ameiurus nebulosus*) can thrive in turbid waters (Trebitz *et al.*, 2007), whereas muskellunge (*Esox masquinongy*) is intolerant to turbidity exceeding 25 NTUs (Trebitz *et al.*, 2007; Ontario Ministry of Transportation, 2009). See Chapter 7: Aquatic Habitats and Fish for a full list of fish found across Lake Dalrymple).

Reduced water clarity levels have been observed to impact fish behavior and performance, underscoring the significance of robust erosion and sediment control measures in maintaining both aquatic ecosystem integrity and pollutant mitigation efforts. Kawartha Conservation measured three aspects of water clarity: Secchi disc (depth of water clarity in m), total suspended solids (total amount of suspended solids in mg/L), and water cloudiness (in NTUs). Provincial Objectives and Federal Guidelines outline that water clarity should be >1.2 m (Secchi disc), or < 25 mg/L + background, or < 8 NTUs + background (OMEE, 1994, CCME, 2015). For background values of TSS and turbidity, we used a value of 0 mg/L or NTU.

Kawartha Conservation took over 190 observations and measurements related to water clarity in Lake Dalrymple. In addition, we looked at 47 Secchi disc readings from MECP's LPP that range from 1997 to 2022. All observations were found to be within Provincial Objectives and Federal Guidelines (Figure 6.5, Table 6.4). One note is that Secchi disc readings below the PWQO of 1.2 m is the result of the shallow nature of the site, e.g., outflow and LPP sites, and indicate that the full water column was clear.

Across months, we see that water clarity is best during the spring and in the fall and a reduction of 1 to 2.5 m in clarity during the summer months (Figure 6.5). For example, TSS levels are around 2 mg/L during the spring which coincides with a Secchi level of 3.1 m, where both numbers are inversed in the summer with a TSS level of 5 mg/L and Secchi level of 2.0 m. Boat traffic have been found to cause higher TSS during the recreational summer months (Murphy and Eaton, 1983) but our sampling events only occurred during the week day, where we would expect low boat users. In addition, we would expect higher TSS levels with the resuspension of sediment from boat traffic, on the magnitude of ~18 mg/L as found by Murphy and Eaton (1983). Thus, from our results and sampling timing, we did not expect boat traffic to be a driver of TSS during the summer period.

As opposite to boat traffic, it is suggested that higher TSS levels in the summer are driven by phytoplankton growth, which are driven by TP levels. Although Lake Dalrymple did not display a strong summer peak for TP, other Kawartha Lakes have, i.e., Pigeon Lake (Kawartha Conservation, 2016), Sturgeon Lake (Kawartha Conservation, 2014), Balsam and Cameron Lake (Kawartha Conservation, 2015).

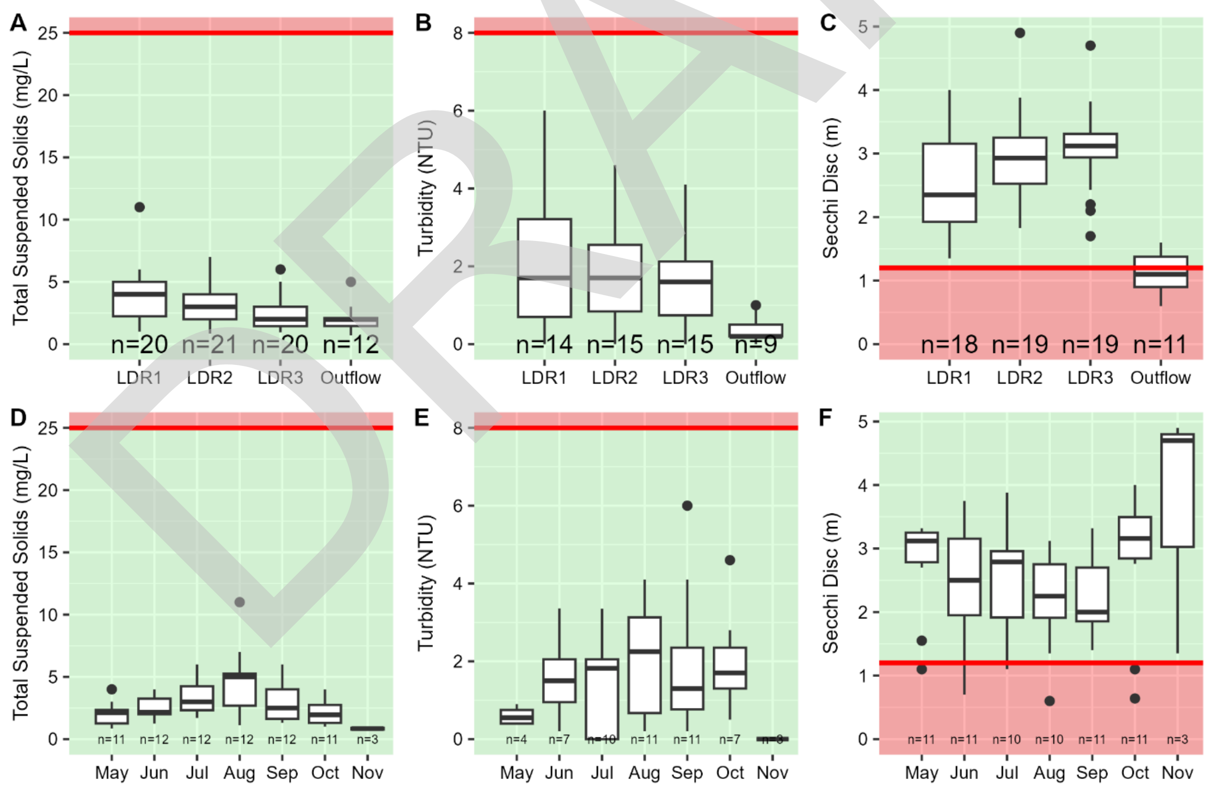

Figure 6.5. Water clarity parameters (total suspended solids – Left, turbidity – center, and Secchi – right) for each lake sampling site (top) and by month (bottom). Guidelines are shown as a red line, below (green area) and above (red area) the threshold value.

This higher TP level in the water and better growing conditions (more light and warmer waters) can promote the growth of phytoplankton which can reduce water clarity, which was found across the Kawartha Lakes in Smith (2022), where it was also found that TSS was associated with periphyton. Although nutrient input can cause the growth of naturally occurring phytoplankton, Lake Dalrymple has a healthy establishment of native aquatic plants which can limit the growth of phytoplankton (Scheffer, 1998). If Lake Dalrymple were to experience excessive nutrient input, we would expect a great reduction in water clarity and an increase in TSS and turbidity, especially during the summer to early fall months. This reduction in water clarity would limit aquatic plant growth, which would not hold down the sediment nor be able to compete with excessive phytoplankton growth, which would contribute to a reduction in water clarity.

Lake Dalrymple displays excellent water clarity when compared to existing guidelines and objectives. Although there is a reduction in water clarity during the summer period (owning from phytoplankton growth), we still see excellent water clarity conditions.

In streams with little to no human pressures, we can expect some level of suspended solids. For both turbidity and suspended solids, we used the work of Maude and DiMaio (1996) for turbidity (Background = 2.25 FNU), and from Culp et al. (2013), and Kawartha Conservation (2023) (Background = 3.5 mg/L) for total suspended solids. Using those values, we compared over 185 observations of turbidity and 201 results of TSS. Results show that <4 % of all turbidity and <2 % of all TSS results exceeded the CWQG. Generally, the number of exceeded observations were less than 10 % except for LDT4, where exceedances for turbidity was 21 % and exceedances of TSS was 7 % (Table 6.5; Figure 6.6).

Given the wetland nature of site LDT4, we would expect higher turbidity and suspended solids due to higher algae growth owning from higher nutrients (see phosphorus below). Other inputs of suspended solids / or processes to cause increase turbidity may originate from clay or silt dominated substrates, input from nearby gravel-based road, or biological growth of algae and the existence of natural dyes. Seasonal patterns of water clarity in streams are not strong. However, we do see that turbidity becomes more variable in the later summer to early fall when compared to the spring (Figure 6.6). This may be the result of biological processes such as algae growth and the release of organic dyes from decomposing plants (think tea bags). The lack of development adjacent to LDT4 may indicate that exceedances in water clarity may be driven by biological processes.

In conclusion, monitored streams that feed into Lake Dalrymple have excellent water clarity and have rare occasions that exceed the CWQG for turbidity and TSS. One site in particulate, LDT4, had more exceedances for both water clarity parameters and may be the result of natural biological processes as there is an absence of development at the site.

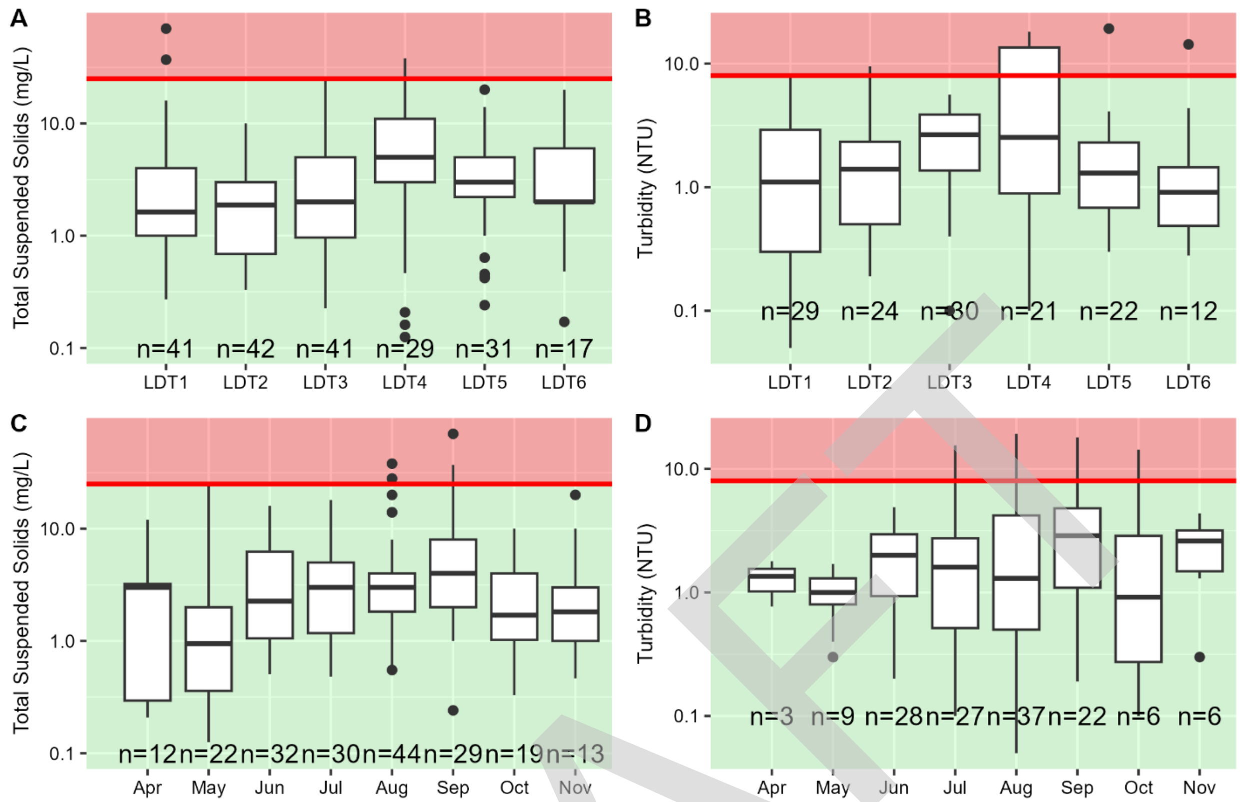

Figure 6.6. Water clarity, total suspended solids (left; A & C), and turbidity (right; B & D), by stream site (top) and by month (bottom). Areas highlighted in red indicate exceedances of the CWQG and areas highlighted in green are within the CWQG.

5.8 Phosphorus

Phosphorus is a naturally occurring mineral, commonly found in sedimentary rocks such as limestone, mudstone, and sandstone. In the Kawarthas, the limestone geology that originated from historical ocean floors is a key component to providing this essential nutrient for the formation of DNA in all living organisms. Phosphorus containing bedrock has resulted in fertile lands, prime for agriculture. Due to its great ability to provide growth, especially for algae, too much phosphorus in aquatic ecosystems can result in large algae-blooms, which can degrade water quality, cause fish to die-off, and reduce the overall aesthetic of the area. The PWQO for total phosphorus indicates an acceptable level no greater than 0.02 mg/L for lakes and 0.03 mg/L for rivers and streams, which should eliminate excessive algae growth within these waterbodies (OMEE, 1994).

Throughout the monitoring, a total of 70 surface samples were taken across Lake Dalrymple. For this section, the sites are the three lake sites and the outflow (Table 6.4; Figure 6.7). In addition to our monitoring, 25 TP results were obtained through the MECP LPP, resulting in a TP dataset of 100 samples. Total phosphorus results indicate that most samples (>62 %) were at mesotrophic (TP = 0.01 to 0.02 mg/L), which indicate an intermediate level of productivity. This is followed by 19.1 %, which are meso-eutrophic, meaning more productive. When broken up by site, all sites had a greater portion of samples within the mesotrophic class, followed by meso-eutrophic.

When compared to the PWQO, exceedances occurred from 25 % (LRD3 and Outflow) to 46.7 % (LDR1), LRD2 had an exceedance percentage of 36.4 % (Table 6.4). However, many of these samples are not representative of the site (and broader, the lake) as much of the variation is below the PWQO as seen in Figure 6.7, which results in the mean and median to also be below the PWQO (mean range = 0.018-0.03 mg/L, median = 0.15 to 0.19 mg/L; Table 6.4). When compared to historical values by MOE (1972), we find that mean TP levels across all sites were identical to 0.02 mg/L. Seasonal changes in TP (Figure 6.7 C) across the sites are generally below the PWQO, with some extreme values (that are not representative). Higher TP values for Upper Dalrymple (Figure 6.7) are influence by the shallow nature of this section which is predominately dominated by native aquatic plants (see Chapter 7: Aquatic Habitats and Fish) and is little concern as these wetland type landscapes are more productive (and thus more phosphorus) than open water systems.

When compared to other lakes (through the Lake Management Plans by Kawartha Conservation), we see that Lake Dalrymple is ranked 6th of 11 lakes when using the percentage of exceedances (Table 6.6). However, it should be noted that some lakes ranked higher (less phosphorus) are on unproductive geology or are driven by inputs from unproductive streams.

The monitoring of the lake included taking subsurface samples near the bottom of the lake, paired with the vertical lake profiles, we can see that during thermal stratification DO is low near the bottom, which creates an environment for phosphorus release from the sediment. Subsurface samples (when compared to surface samples taken at the same event) indicate that there is a significant increase in subsurface phosphorus levels (Figure 6.9), which is most apparent in the month of July. This release of phosphorus is a common phenomenon in freshwater systems (lakes, ponds, reservoirs) across Canada (Orihel et al., 2017) and is influence by the lack/abundant of oxygen and can even occur in natural lakes that are deeper (Nurnberg, 1997).

Table 6.6. Total phosphorus concentration ranking (in lake surface water only) by lake through Kawartha Conservation's Lake Management Plans (Kawartha Conservation, 2010,). Mean and median values (mg/L), associated PWQO limit, and exceedances (count and percentage of total samples) are also shown.

		Year					Exceedance	
Lake	**Count**	**Min**	**Max**	**Mean**	**Median**	**PWQO**	**Count**	**Percentage**
Four Mile Lake	26	2014	2016	0.005	0.005	0.01	0	0
Head Lake	36	2015	2016	0.012	0.01	0.02	2	5.6
Shadow Lake	26	2015	2016	0.007	0.006	0.01	4	15.4
Canal Lake	153	2013	2015	0.025	0.014	0.02	27	17.6
Mitchell Lake	62	2013	2015	0.032	0.014	0.02	14	22.6
Lake Dalrymple	**74**	**2021**	**2023**	**0.022**	**0.016**	**0.02**	**17**	**23.0**
Sturgeon Lake	87	2010	2015	0.017	0.015	0.02	22	25.3
Pigeon Lake	80	2012	2015	0.049	0.016	0.02	21	26.3
Cameron Lake	80	2011	2014	0.021	0.008	0.01	29	36.3
Lake Scugog	174	2004	2008	0.018	0.018	0.02	65	37.4
Balsam Lake	107	2011	2014	0.018	0.009	0.01	45	42.1

Using the approach by Grøterud and Haaland (2012), we were able to estimate the amount of phosphorus released from the sediment during thermal stratification. Results indicated that in 2021, ~40 kg of P was released, followed by 54 kg in 2022, and 148 kg in 2023. These numbers are estimates based on the approach by Grøterud and Haaland (2012), the surface area where we expected to see anoxic conditions (based off of the vertical lake profiles), and the duration of the stratification.

Although internal loading is a natural process, constant excessive input of phosphorus from the watershed would allow for a greater banking of phosphorus in the sediment in which would be released during periods of thermal stratification. This banking and release of phosphorus will limit the recovery of the lake even if all phosphorus inputs are regulated as Welch and Cooke (1999) found that even 10 years after severe reduction in external phosphorus input, that internal loading was persistent when flushing rates were lower. To combat persistent internal loading of phosphorus, external phosphorus inputs would need to be greatly reduced to reduce the banking of phosphorus in the sediment, and that flushing rates would need the be high to flush out the released phosphorus.

In conclusion, TP levels across Lake Dalrymple are representative of its productivity as mesotrophic (intermediate productive), which has contributed to lower exceedances of ~33 % and is ranked 6th when compared to other Lake Management Plan Lakes. Low oxygen levels

Figure 6.7. Total phosphorus levels in Lake Dalrymple by site (top/A), by year class (middle/B), and by month (C/bottom). Area in red indicate above the PWQO (0.02 mg/L) while area in green indicate within PWQO.

during thermal stratification does cause phosphorus release from the sediment and is of a naturally process.

Similarly to the lake, many of the 201 samples taken can be classified as mesotrophic (30 %), intermediate productive, but unlike the lake, the second most common classification of samples is oligotrophic (18.9 %), indicate not productive (0.004 to 0.01 mg/L). Mean and median values for all stream observations were 0.04 mg/L and 0.015 mg/L (Figure 6.8; Table 6.5). Compared to the historical range (0.016 to 0.058 mg/L; MOE, 1972), we found that the range found in this study was from 0.002 mg/L (detection level) to 0.44 mg/L, much more variable that before, especially the max where it has increased more than 7 times the historical max. This suggests that increases in phosphorus input have occurred since 1972.

When compared to the PWQO of 0.03 mg/L, we see that around 30 % of all samples have exceedances. Between sites, LDT6 had all samples exceed the PWQO, followed by LDT4 at 89 %, and lastly, LDT1 at 19.5 % (Table 6.5). The remainder of the sites all had exceedances <15 %. Higher exceedances found at LDT6 and LDT4 are driven by its immediate and upgradient surroundings, where intensive agriculture and wetland at the immediate around, and agriculture upstream (both sites have agriculture land use > 600 ha) of both sites contribute to its highly productive nature. Since LDT6 is well oxygenated, we do not suspect internal loadings to occur, however, anoxic conditions do occur at LDT4 and thus we do expect some internal loadings to occur at LDT4. Higher levels of P will contribute to an abundance of plants and algae, however, with the establishment of native rooted aquatic plants, there are some reductions in algae growth. If rooted plants were to be removed then only algae can uptake the phosphorus, thus it will lend itself to the risk of rapid eutrophication, causing degradation of water quality, fish die-offs, and poorer habitat.

In summary, phosphorus levels across streams of Lake Dalrymple indicate that much of the streams are intermediately productive with some results indicating less productiveness. Higher levels of phosphorus and exceedances of the PWQO were found at two sites where agriculture land cover was >600 ha. Higher levels of P at these sites can cause uncontrollable algae growth if native aquatic plants are removed.

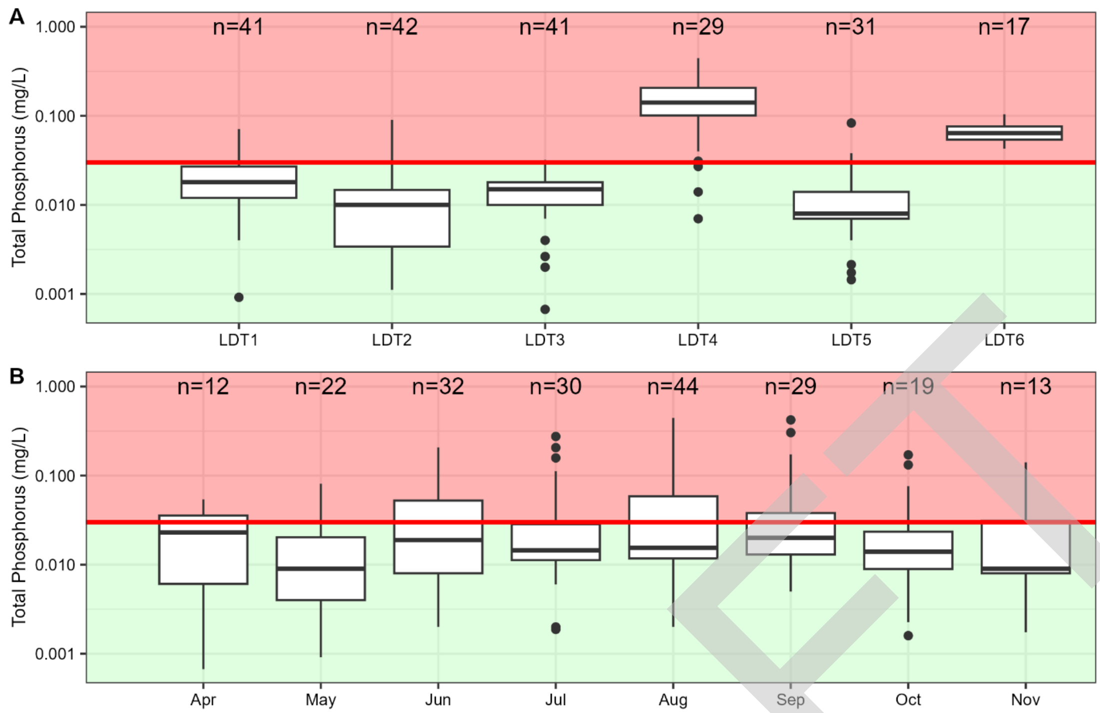

Figure 6.8. Stream total phosphorus levels per site (top, A) and by month (bottom, B). Areas highlighted in red are outside of the PWQO for streams and river (0.03 mg/L) and the area highlighted in green are within.

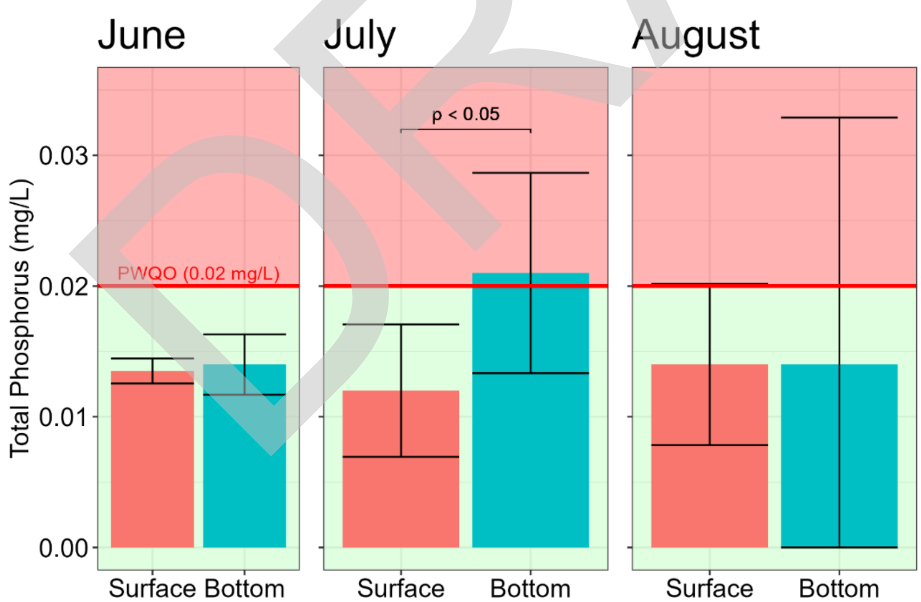

Figure 6.9. Surface (pink) and bottom (≤1 m above sediment) median total phosphorus levels at LDR2 (deepest basin in Dalrymple) for the months of June, July, and August. Standard deviation is also shown with significant differences (p <0.05).

5.9 Nitrogen

Similar to phosphorus, nitrogen is an essential nutrient vital for the growth of both aquatic plants and animals. Nitrogen can exist in various forms within water, depending on the biological and chemical conditions. Within the nitrogen group, we assessed the water for ammonia-nitrogen, Total Kjeldahl nitrogen (TKN), and nitrate-nitrogen.

For ammonia and nitrate, almost all results were within the PWQO and/or CWQG. Only one observation of ammonia was found to be higher than the threshold values were 0.019 mg/L for CWQG and 0.02 mg/L for PWQO. This can be seen as an extreme case and is not reflective of the lake in general. For nitrate, the limit is set at 3 mg/L (CCME, 2012), which is much higher than the max level at 0.18 mg/L. In conclusion, Lake Dalrymple exhibits excellent water quality for ammonia and nitrate and that from the results, have no significant concern.

Total nitrogen was calculated from the sum of nitrate, nitrite, and TKN. Total Kjeldahl Nitrogen (TKN) is the total of organic nitrogen and ammonia nitrogen and generally comprise of 66 to 96 % of total nitrogen in the lake. This indicates that much of the nitrogen in the lake is from decomposing organic matter such as plants and animal waste. The mean TKN value for all lake surface observations is 0.6 mg/L (Table 6.4) which is almost identical to 0.59 mg/L found by MOE (1972). Aquatic plant uptake is an important bioprocess to limit the growth of harmful algae blooms.

For all streams and observations of ammonia and nitrate (n=201), no observations exceeded the PWQO and CWQG. When converted, un-ionized ammonia levels were found to be 0.0028 mg/L, much lower than the 0.02 mg/L PWQO and 0.019 mg/L CWQG threshold. The highest nitrate level found was 0.63 mg/L (Table 6.5), much lower than the 3.0 mg/L CWQG limit. Unlike lake water, TKN was more variable and lower for the amount contributed to total nitrogen, ranging from 14 to 97 %. Less TKN and more nitrate is common for undisturbed water and is attributed to microorganism converting ammonia into nitrate. The historical range of TKN by MOE (1972) is 0.59 to 1.6 mg/L which is lower than the range found in our monitoring (range = <0.1 to 3.3 mg/L) (Table 6.5), suggesting that increases in nitrogen input has occurred since 1972. Similarly to the above, the establishment of rooted plants is an important intake for nitrogen, this uptake by rooted plants helps keep rapid algae blooms controllable. In conclusion, Lake Dalrymple streams exhibit excellent water quality for ammonia and nitrate and that from the results, have no significant concerns.

5.10 Limiting Nutrient

Since both phosphorus and nitrogen are limiting factors for aquatic systems, it is important to note which is the limiting factor to better mitigate against drivers of poor water quality, e.g., harmful algae blooms. It is generally accepted that TN:TP ratios >20 refer to phosphorus limitations while ratios <10 refer to nitrogen limitations (Guildford and Heckly, 2000; USEPA, 2000). Ratios across all sites were >20 and thus indicate that Lake Dalrymple is phosphorus limited and that much of the productivity is limited by the availability of phosphorus. Although Lake Dalrymple does not have a nutrient issue, if uncontrolled phosphorus input were to occur, productivity, especially algae, would grow uncontrollably, leading to anthropogenic eutrophication.

For Lake Dalrymple and its streams, all TN:TP results indicate that phosphorus continues to be the limiting nutrient (lake: mean =100, median = 95; stream: mean = 140, median = 85), suggesting that currently phosphorus levels is the primary driver for primary productivity such as algae and plant growth. The reduction of phosphorus input would reduce algae and plant growth which would cause reduction of organism in the food chain/ trophic level (Jeppesen et al., 2005). However, in a lake without major nutrient management concerns, a reduction of phosphorus would greatly affect the phytoplankton (fish food) and macrophyte (fish habitat) community and thus would affect recreationally important fish species.

5.11 Chloride and Conductivity

Salt minerals and seawater usually contain a significant amount of chloride ions, while freshwater systems tend to contain less (around 8 to 30 mg/L range; McNeely et al., 1979; Evans and Frick, 2001 for lakes across Canada). Many freshwater organizations are not accustomed to high chloride levels and have not developed natural mechanisms to handle them. When released into the environment, chloride salts easily dissolve in water, releasing chloride ions that become mobile within aquatic systems. The CWQG for Cl is set at 120 mg/L for long-term exposure (CCME, 2011).

A total of 74 samples were taken across the four lake sites. Results indicate that no sample exceeded the CWQG of 120 mg/L (Figure 6.10), were the highest observations of Cl in lake samples was 14.6 mg/L. Median and mean range across sites were 9.5 to 10.7 mg/L and 9.8 to 10.7 mg/L, more than 100-fold less than the CWQG (Table 6.4). Similarly, LPP data of Cl were well below the 120 mg/L threshold, 9.1 to 9.8 mg/L. These low values are attributed to low developed areas across Lake Dalrymple, about 5 % of Lake Dalrymple’s watershed is developed (see Chapter 8: Landscape Ecology).

Compared to the survey of 1972, Cl levels have increased from 3 to 6 mg/L to 8.6 to 14.6 mg/L in Lake Dalrymple (Figure 6.10; Table 6.4). This is most likely due to increased salt usage from adjacent properties (residential and roadway) across the lake and its streams. It is expected that as more impervious surface (asphalt and concrete) occurs in the Lake Dalrymple watershed that chloride levels would increase in the lake. This was found to be true in Lake Simcoe (Winter et al., 2011), Muskoka (Yao et al., 2020), Toronto Region (Lawson and Jackson, 2021), Ontario (Sorichetti, et al., 2022), and across Canada, the United States, and Europe (Dugan, et al., 2017). For Lake Dalrymple, continued development of the shoreline will contribute significantly to chloride as a recent study suggest that shoreline inputs can contribute as high as 80 % of Cl loadings into the lake (Yao et al., 2020).

When more chloride is added into the water, the conductivity of the was also increased. In urban areas, freshwater systems often have higher conductivity as there are more dissolved salts, which in turn results in the water conducting more electricity. When compared to other Lakes Management Plans, Lake Dalrymple is ranked 9th of 11th (Table 6.7). This does not mean that Lake Dalrymple has more development (which results in higher chloride and conductivity). Lake Dalrymple is 6th in terms of development areas (See Land and Land Use) and the higher conductivity is primarily driven by the natural limestone bedrock which is an historical ocean bed. We expect that Lake Dalrymple will continue to increase its lake water conductivity if more development and salt usage occurs within its watershed.

Similarly to the lake water, chloride across Lake Dalrymple streams did not exceed the CWQG of 120 mg/L. The highest level of Cl found was 73.4 mg/L at LDT4 (Table 6.5), much lower than the 120 mg/L outlined by CCME, 2012. When compared to historical records of Cl, we do see that levels found in this study (range = 0.7 to 73 mg/L) have increased since 1970s (range = 4 to 5 mg/L) (Figure 6.10; Table 6.5). Of all the stream sites, only LDT2 and LDT5 are found to be within or below the historical range found by MOE (1972), which is due to their natural cover and few developments in their watersheds. Higher Cl found is reflected by more usage of salt during the winter periods. Another possible input is the use of chloride compounds for dust suppressants for gravel roadways and quarry usage. Increase development will cause more Cl to enter the way and has been found across rural areas of Ontario (Sorichetti, et al., 2022), with most of the Cl input (as much as 83 %) originating from shorelines (Yao et al., 2020).

Table 6.7. Conductivity ranking (in lake surface water only) by lake (Kawartha Conservation, 2010,). Mean and median values (uS/cm).

		Year			
Lake	**Count**	**Min**	**Max**	**Mean**	**Median**
Shadow Lake	43	2015	2017	79.9	73.2
Balsam Lake	104	2011	2014	118.9	123.8
Head Lake	35	2015	2017	124.1	138
Cameron Lake	64	2011	2014	129.6	128.9
Mitchell Lake	43	2013	2015	166.4	154.6
Four Mile Lake	89	2014	2016	197.1	196.6
Canal Lake	144	2013	2015	207.4	185
Pigeon Lake	105	2012	2015	243.5	236
Lake Dalrymple	**64**	**2021**	**2023**	**299.3**	**279.5**
Lake Scugog	122	2005	2008	372.4	346
Sturgeon Lake	24	2015	2015	402.4	398.5

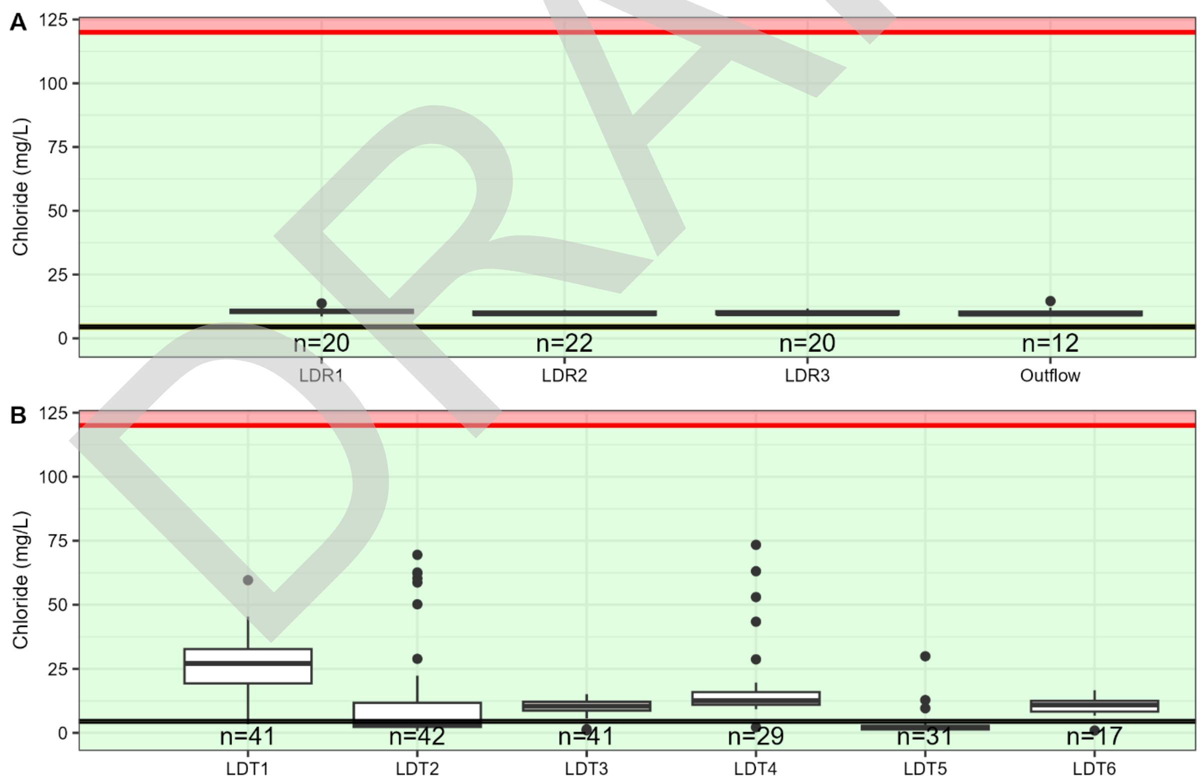

Figure 6.10. Chloride levels for lake (top/A) and stream (bottom/B) sites with area covered in red as exceeding the CWQG and the area in green as being within the CWQG. Horizontal black line indicates the historical range (1972) of chloride by MOE (1972).

5.12 Water Quality Index

Using the Water Quality Index (WQI) (CCME, 2017) with the water quality results, we can provide a general statement of the site's health. The WQI assesses the overall health of the site based on the number of parameters (such as those outlined above) that fail to meet guidelines, the frequency of failure, and the total number of observations that fail to meet the guideline.

A total of six of ten sites had good water quality and can been described as having minimum degree of impairment and rarely depart from natural levels (Table 6.8). Three sites are fair for water quality with occasionally impaired characteristics that sometimes depart from desirable levels (Table 6.8). One site, LDT4, was considered to have marginal water quality which is frequently impaired with conditions that depart from desirable levels (Table 6.8). However, as mentioned above, that site LDT4, is more representative of a wetland than a flowing stream or river and thus are not accurate when comparing against PWQO and CWQG that are fitted for lakes, streams, and rivers. Table 6.8 should not be used in detailed for management (specifically for LDT4) but can give a brief insight to the water quality of the site. In conclusion, many of the watercourses that were monitored showed desirable levels that are on par with what is expect in natural settings.

Table 6.3. Water Quality Index category, associated score, and description.

WQI Category	WQI Score	Index Description (Taken from CCME, 2017)
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
Good	80-94	Water quality is protected with only a minor degree of threat or impairment: conditions rarely depart from natural or desirable levels.
Fair	65-79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
Marginal	45-64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor	0-44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

Table 6.8. Water Quality Index scores and associated category results for each water quality sampling site.

Waterbody Type	Site	WQI Score	WQI Category
Lake	LDR1	80.1	GOOD
	LDR2	80.3	GOOD
	LDR3	80.6	GOOD
	Outflow	85.3	GOOD
Streams	LDT1	78.1	FAIR
	LDT2	78.3	FAIR
	LDT3	85.5	GOOD
	LDT4	52.1	MARGINAL
	LDT5	78.3	FAIR
	LDT6	81.5	GOOD

5.13 Phosphorus Loads and Budget

Since Lake Dalrymple is a headwater lake, there are three major inputs to the lake, they are: 1) precipitation (snow and rain), 2) local subwatersheds (runoff from shorelines, and streams), and 3) groundwater (see Chapter 4: Water Inputs and Water Levels). Of the three inputs, surface water inputs are the largest and so, it was expected that input from load subwatersheds contribute to 64 % of phosphorus into the lake, this is followed by groundwater at 20% and lastly, atmospheric deposition (17 %) (Figure 6.11). Within local subwatersheds, the three highest contributors are ULDT-6 (632 kg/yr), ULDT-8 (305 kg/yr), LLT-7 (143 kg/yr), which also has the largest intensive agriculture land cover at 635 ha (ULDT-6), 622 ha (ULDT-8), and 185 ha (LLDT-7). Atmospheric deposition accounted for 470 kg and was derived from the median TP concentration from all three years, 0.03 mg/L. The median phosphorus level for groundwater from 2005 to 2022 was 0.02 mg/L, which resulted in approximate 558 kg of P from groundwater inputs.

Having a large influence in the lake's total phosphorus level, runoff from local subwatersheds were explored by land use/major sectors, i.e., natural, development, agriculture (Figure 6.11). Results indicate that shoreline septic systems contribute the most at 30 % (951 kg), followed by agriculture at 26 % (800 kg) (Figure 6.11). Natural cover consists of a larger portion of inputs at 21 % (645 kg) and was much higher than rural development (surface runoff) at 1 % (41 kg)

(Figure 6.11). This is not surprising as ~80 of the Lake Dalrymple watershed is natural. Lastly, Active aggregate contributed about 7 % (230 kg) of the P input into the lake (Figure 6.11).

Phosphorus budget aims to category all inputs and outputs of phosphorus in the lake. We found that surface runoff from development and agriculture (26 %), and septic systems (25 %) contribute to over half of the P input into the lake (Figure 6.12). Natural runoff from wetlands and forest accounts for 21 % of P input, while the naturally occurring internal loading contributes to 2 % (Figure 6.12). Semi-natural inputs that could be influenced by human activity such as atmospheric deposition (13 %) and groundwater (15 %) contribute to 28 % of P input (Figure 6.12).

5.14 Conclusions

From 2021 to 2023 Kawartha Conservation staff monitored 10 sites, 4 lakes and 6 stream sites within the Lake Dalrymple watershed. In general, Lake Dalrymple exhibits good water quality for pH, water clarity, dissolved oxygen, phosphorus, nitrogen, and chloride.

Phosphorus was determined to be the limiting nutrient (than nitrogen) but the abundance of plants within the lake has most likely kept harmful algae blooms contained. Thermal stratification (separation of layers in the lake from temperature differences) does occur in Lake Dalrymple and does cause internal loading of phosphorus from the sediment, which is not of concern now. If excessive phosphorus input into the lake occurs then the banking of phosphorus in the sediment would occur and would result in a *phosphorus bomb* to occur every later summer/early fall, releasing a large quantity of phosphorus during the hottest periods of the year, which would drive harmful algae blooms to occur.

Most of the phosphorus that enters the lake are from subwatersheds (64 %). Within the subwatershed, most of the phosphorus originates from shoreline septic (30 %), followed by agriculture (25 %), and then natural sources (21 %). Runoff from rural development is small at 1 %, whereas aggregates contribute to 7 %. When added together, they are much smaller than what falls out of the sky (precipitation = 15 %).

Other observations found were that chloride concentrations in the lake have increased since 1972, which is the result of continued salt usage for winter periods. Water clarity is best during the spring and fall months and a reduction in clarity is attributed to biological processes such as algae growth, but levels continue to meet Provincial Water Quality Objectives and Canadian Water Quality Guidelines.

Similarly to the lake, streams that flow into Lake Dalrymple also exhibits fair to good water quality and for similar explanations above. One site does show marginal water quality characteristics but only because the site is more representative of a wetland and not as a stream/river (which the PWQO and CWQG are for). One key observation was that site LDT6 had a 100 % failure rate for phosphorus which can be explained by the agriculture dominated landscape adjacent to the site.

Similarly to lake water, chloride levels have increased dramatically at four of six stream sites with two sites (LDT2 and LDT5) showing similar levels as those found in 1972, against most likely driven by salt usage along roadways.

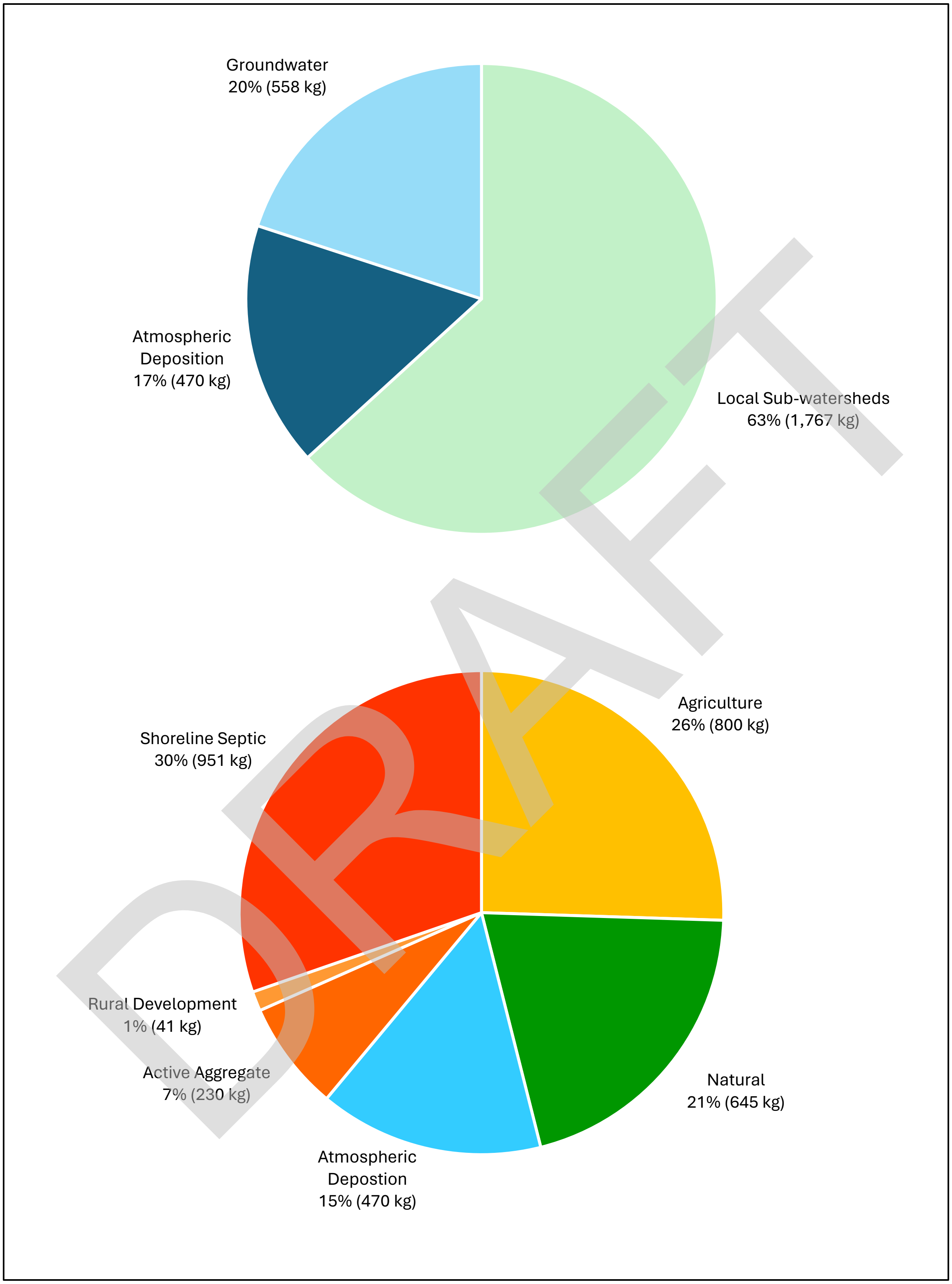

Figure 6.11. Phosphorus loads (kg) and percentage input by major water source (top) and by sector (bottom).

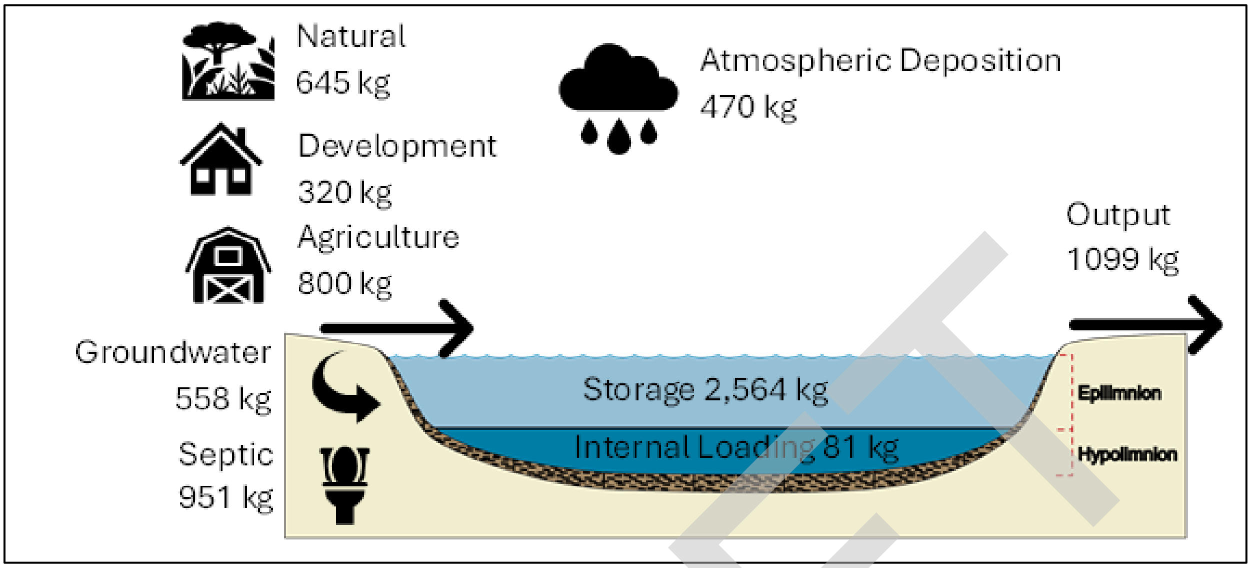

Figure 6.11. Visualization of the phosphorus budget for Lake Dalrymple. Inputs are atmospheric deposition, land export (natural, development, and agriculture), groundwater, shoreline septic, and internal loadings. Storage is calculated by subtracting the input from the output.

6.0 Sediment Quality

[Lake sediment sampling, September 2023]

6.1 Summary of Key Observations

- In 2022, Kawartha Conservation staff conducted a sediment survey at 10 sites across Lake Dalrymple. Generally, most reported metal results are below the Provincial Sediment Quality Guideline's Lowest Effect Level or the Canadian Sediment Quality Guideline's Interim Sediment Quality Guidelines.
- Species of polycyclic aromatic hydrocarbons were below the Provincial Sediment Quality Guideline's Lowest Effect Level or the Canadian Sediment Quality Guideline's Interim Sediment Quality Guidelines, with most being below the detection limit.

6.2 Summary of Key Issues and Information Gaps

- Species of polycyclic aromatic hydrocarbons were below the Provincial Sediment Quality Guideline's Lowest Effect Level or the Canadian Sediment Quality Guideline's Interim Sediment Quality Guidelines, with most being below the detection limit.
- Some exceedances of Cd, Cu, Fe, Mg, Ni, Pb, and Zn were found at six sites.
- Exceedances occurred for 10 species of polycyclic aromatic hydrocarbons, with the majority found at site LDS5, the public boat launch on Osprey Lane.
- Some exceedances of parameters were found; however, it is unknown if Lake Dalrymple has naturally higher levels of those parameters, thus background values for those parameters are needed. Background studies should focus on areas without known point source pollution or through the sediment horizon (within a core) of the 'pre-colonial' horizon. This is also needed as the background values in the PSQGs are those of the Great Lakes and are not applicable for inland lakes.
- Sources of heavy metals, such as Cd, Ni, Pb, may originate from atmospheric deposition (dry or wet, or both), or local soils. Soil quality information will help determine sources of metals.
- The sediment found at the public boat launch (Osprey Lane) was found to be marginally polluted with PAHs. Although sources are unknown, it is expected that consistent boat launching has exposed the area to artificial organic compounds (oils, grease, petroleum) and engine emissions. An intensive sediment survey should occur at the site to determine the extent of the PAH contamination, the PAH variability within the site, and the risk to organisms. Only after a proper management decision can be made.

6.3 Introduction

Lake sediment acts as a record keeper for all activities and processes that occur within and outside of the lake. The accumulation of toxic substances in the sediment can provide a gateway for contaminants to be biologically absorbed in lower trophic organisms, which can then be biomagnified up the food chain when organisms are preyed upon. Primary sources of contaminants in the sediment are direct discharge of concentrated waste, non-point sources such as the application of pesticides and fertilizers, and runoff from roads and cities. Other sources can be from the buildup of the shoreline from materials that originate outside of the local area, and dust particulates from long-range emissions.

The objective of this chapter is to assess the sediment quality of Lake Dalrymple for general physical and chemical characteristics and for contaminant concentration.

6.4 Methodology

A total of 10 sites were sampled during the sediment survey in 2022, 5 for each region (Upper Lake Dalrymple and Lower Lake Dalrymple). Sites were selected based on three conditions: 1) existing water quality/fish survey sites, 2) feedback from the Lake Dalrymple Working Group (local concerns), and 3) known anthropogenic pressured areas (Figure 6.12, Table 6.9).

At each sampling location, physical water quality measurements were taken (pH, Conductivity, Turbidity, Dissolved Oxygen, Water depth, and Oxygen Reduction Potential). A petite Ponar grab sampler (sampling area of 0.05 m^2) was then rinsed with the target water. A composite sample of two (one from each side of the boat) was taken with the Ponar, where sub-samples were placed into a mixing bowl and mixed prior to sampling. Sediment characteristics (woody debris, color, texture, etc.) and sampling depth were also recorded. All samples were taken at or greater than 0.05 m deep.

Samples were kept cool (<4 °C) and away from sunlight during field transportation and storage. Samples were sent to private labs (Caduceon, Bureau Veritas, and SGS) for the following parameters: nutrients (carbon, nitrogen, and phosphorus), metals (heavy and trace), and polycyclic aromatic hydrocarbons.

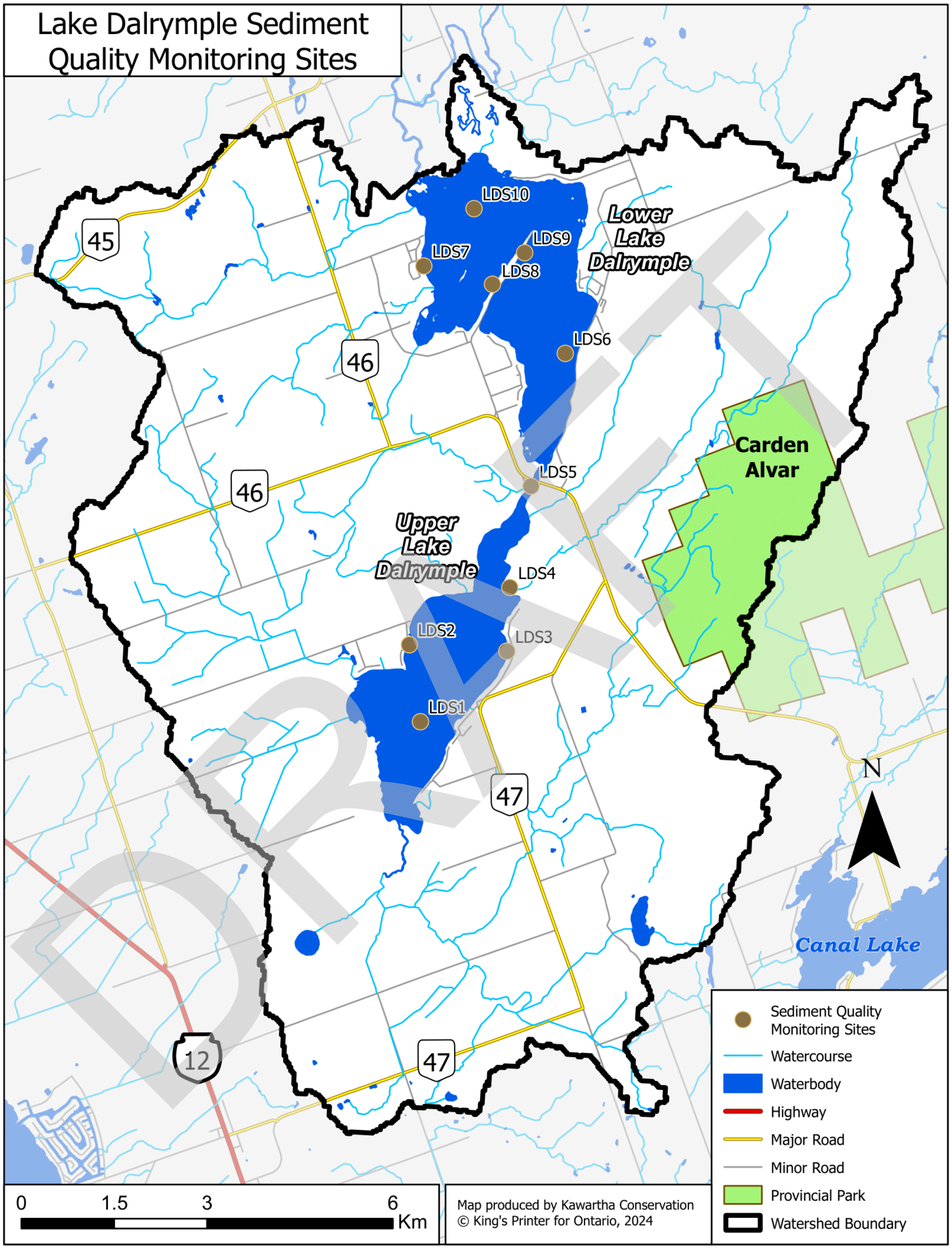

Figure 6.12. Sediment sampling locations across Upper and Lower Lake Dalrymple.

Sediment quality results were compared to the following objectives and guidelines:

- Provincial Sediment Quality Guidelines (PSQGs) for the protection of the aquatic environment (short-term), namely benthic species (MOE, 1993).
- Canadian Sediment Quality Guidelines (CSQGs) for the Protection of Aquatic Life (CCME 1999a,b,c,d,e,f,g)

Table 6.9. Site ID, description and coordinates of the 10 sites assessed in the 2022 Lake Dalrymple sediment survey.

Region	Site ID	Description	Easting	Northing
Upper	LDS1	Co-located with water quality site. Deepest basin in Upper Dalrymple.	647980	4940918
	LDS2	Co-located with fish survey site. Public access.	647697	4941755
	LDS3	Co-located with fish survey site.	649370	4942056
	LDS4	Outflow of unnamed stream.	649418	4943084
	LDS5	Co-located with fish survey site. Public access.	649765	4944719
Lower	LDS6	Co-located with water quality site. Deepest basin in Lower Dalrymple.	650319	4946860
	LDS7	Co-located with fish survey site. Public access.	648035	4948270
	LDS8	Located adjacent to Avery Point.	649144	4947975
	LDS9	Located adjacent to Avery Point.	649660	4948484
	LDS10	Co-located with water quality site. Second deepest basin in Lower Dalrymple.	648845	4949196

6.5 Nutrients (Carbon, Nitrogen, Phosphorus)

Nutrients such as carbon, nitrogen, and phosphorus are essential for the growth of plants and animals. Natural and productive water bodies have higher nutrient content and thus can support greater biomass of fish and plants. Sediment can store and release nutrients back into the water, allowing for a secondary source of nutrients which can promote the growth of algae. Natural areas (without known anthropogenic inputs) with high organic and nutrient content can be readily distinguished from anthropogenic sources and thus are not of concern for human and ecosystem health. The process of storing and releasing nutrients back into the water column is natural; however, excess nutrient input into the lake can cause an accumulation of nutrients in the sediment, which may be released under certain chemical conditions (lack of oxygen), leading to rapid algae growth. Consistent export of nutrients from the sediment can delay long-term water quality recovery.

For comparison, nutrient levels were compared against the PSQGs for TOC, TKN, and TP. Generally, sediment quality for nutrients exceeds the PSQGs at most sites except for LDS5 (Figure 6.12). The high nutrient content across most sites reflects a natural shallow lake with an abundance of aquatic plants.

This is most evident in Upper Dalrymple, where carbon content (mean = 144,840 ug/g) was almost double that of Lower Dalrymple (mean = 79,500 µg/g) (Table 6.10). Supporting this is the vegetation survey (see Chapter 7: Aquatic Habitats and Fish), where plant coverage in Upper Dalrymple is more prominent (due to its shallow nature) than in Lower Dalrymple (deeper). More plants ensure consistent nutrient cycling, resulting in nutrient-enriched sediment. The opposite can be seen at LDS5 where consistent usage of the boat launch has eliminated the establishment of aquatic plants, resulting in less organic matter and nutrient production and lower nutrient content in the sediment.

When aligned with water quality results, a greater proportion of surface water quality samples of TP (see Chapter 5: Water Quality) indicate good water quality. In addition, water quality results of bottom samples (collected < 1 m above sediment) indicate phosphorus release from the sediment. Being in the deepest section of Lake Dalrymple, we expect higher nutrient levels at LDS1 (TKN 26,500 µg/g, TP = 1,050 µg/g), LDS6 (TKN = 28,800 µg/g, TP = 1,190 µg/g), and LDS10 (TKN = 30,500 µg/g, TP = 1,690 µg/g) than at the rest of the sites (mean TKN = 6,883 µg/g, TP = 847 µg/g) (Table 6.10), and thus the late summer/early fall phosphorus buildup below the thermocline (within the water column) is expected to originate from phosphorus from the sediment. We expect that phosphorus is not released during mixing when oxygen levels are higher. Again, this is a natural process; however, it is important that we do not load the sediment with excess phosphorus from unmanaged land use practices.

In conclusion, nutrient content in the sediment is higher than the PSQGs but is reflective of the productivity and shallow nature of Lake Dalrymple and is not of concern for remediation.

6.6 Metals

Metals are naturally occurring elements associated with geology; however, at excessive levels resulting from unnatural processes and sources, they can cause severe harm to human and ecosystem health. Physical and chemical conditions, such as low oxygen and acidity, can cause metals to become more mobile and available for uptake by organisms, which can accumulate greatly in higher trophic organisms such as humans, predatory fish, and piscivorous birds. This has resulted in the Ontario Guide to Eating Fish encompassing harmful contaminants such as Arsenic, Lead, and Cadmium, etc., in the guide's development.

When compared to existing guidelines (SCSs, PSQGs, CSQGs), the following were found to be higher: Cadmium, Copper, Nickel, Lead, Manganese, and Zinc, but only exceeding the lowest thresholds, i.e., interim sediment quality guidelines/lowest effect level, suggesting that the exceeded parameters have no effect on most benthic organisms and are deemed to be marginally polluting.

Zinc and Copper were found to be within the expected natural ranges of Canadian lakes (Zn = 106 ug/g, Cu = 31 ug/g; CCME 1999d,g). Since zinc, copper, and manganese are associated with soil particles and the lack of point source pollution located within the Lake Dalrymple watershed, we suspect that the source of elevated zinc, copper, and manganese is associated with terrestrial activities and inputted through runoff.

Others, such as cadmium and lead, are naturally low, and elevated concentrations are mostly governed by human activities. For example, levels of Arsenic results for this survey ranged from below the detection limit (Table 6.10) of 0.5 to 4.8 and are within the natural range found across Canada (CCME, 1999 a). Sources of cadmium, lead, and nickel are unknown but may result from non-point sources such as land use (Das et al., 2009) or atmospheric deposition (Jeffries et al., 1981; Wiklund et al., 2020).

When looking at site specifics, we see that LDS10 (Figure 6.12) had many exceeded parameters, which may result from the site being the lowest basin between two heavily developed areas, i.e., Avory Point and Fulsum Cres. area, and that the sediment is organic in nature, which often binds to heavy metals. Metal results in sediment suggest that some sites have exceedances of the CSQG's ISQG or PSQG's LEL, suggesting that exceeded metals have no effect on most bottom dwelling organisms and are deemed to be marginally polluting. It is unknown if exceedances are the cause of anthropogenic or natural sources.

6.7 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds commonly associated with the burning of materials, such as wood, aluminum (smelting), and petroleum products. These compounds are generally poorly soluble and nonvolatile (do not gas off or dissolve in water), thus they are removed from the water column and incorporated into lake sediment.

Kawartha Conservation tested for 19 species of PAHs at 10 sites across Lake Dalrymple. Most were below the detection limit, and only ~30 % of all results were found to be above the detection limit (Table 6.10). This was expected as there are no point sources nor large historical disposal sites. Among all results above the detection limit, only ~11 % were found to be at or exceeded the CSQG's ISQG or PSQG's LEL, suggesting that exceeded parameters have no effect on most bottom dwelling organisms and are deemed to be marginally polluting.

Of the 10 sites assessed, we found LDS5 to have the most PAH exceedances (8 species), followed by LDS6 and LDS10 (Figure 6.12) with 2 species each. Site LDS5 is the public boat launch near the Narrow, on Osprey Lane off Kirkfield Road (Figure 6.12), which experiences heavy use during the ice-free period. This may be a source of PAHs through boat launching, where motorized vehicles entering the lake can release PAHs through engine exhaust, lubricants, gas and oil drips and spills, paint flakes, etc. At LDS5 and LDS10 (Figure 6.12), higher PAH levels may be the result of the physical characteristics of the site (deepest basin), where most particulates that enter the lake will eventually settle at the bottom of the basin, making those sites natural collector basins for all contaminants. The results indicate that there are inputs of PAHs through non-point sources.

6.8 Conclusion

In 2022, Kawartha Conservation staff conducted a sediment survey across Lake Dalrymple at 10 sites to assess the nutrient, metal, and PAH content. Sediment quality results indicate that the nutrient content in the sediment reflects the productivity of the natural state of Lake Dalrymple. Sources of metals and PAHs are unknown but may be driven by non-point sources, such as erosion and land management practices. For PAHs, one site was found to have several PAH species, the public boat launch on Osprey Lane. Levels of metals and PAHs were not near the SEL or PEL, and no concerns for remediation are recommended. However, additional information regarding the local background levels is helpful to determine if exceedances are of concern. If there are discrepancies between background and LEL/ISQG, then additional steps are needed to determine the variability of the contaminated area and the extent, followed by a risk assessment.

Table 6.10. A list of chemical parameters analyzed through the 2022 Lake Dalrymple Sediment survey, and their units, laboratory detection limits, Provincial Sediment Quality Guideline (MOE, 1993) and Canadian Sediment Quality Guideline values (CCME 1999a,b,c,d,e,f,g). Number of samples and detections are also shown per parameter.

					Provincial Sediment Quality Guidelines (PSQG)			Canadian Sediment Quality Guidelines (CSQG)	
Parameter	Unit	Detection Limit	No. Samples	No. Detect	Background Sediment	Lowest Effect Level (LEL)	Severe Effect Level (SEL)	Interim Sediment Quality Guidelines (ISQG)	Probable Effect Levels (PEL)
Moisture	%	1	10	10					
Nitrogen (N)	%	0.01	10	10					
Total Organic Carbon (TOC)	µg/g	500	10	10		100,000	1,000,000		
Nitrite (N)	µg/g	0.5	10	2					
Nitrate (N)	µg/g	2	10	0					
Nitrate + Nitrite (N)	µg/g	3	10	1					
Total Kjeldahl Nitrogen (TKN)	µg/g	10	10	10		550	4,800		
Phosphorus-Total (TP)	µg/g	10	10	10		600	2,000		
Arsenic (As)	µg/g	0.5	10	7	4	6	33		
Cadmium (Cd)	µg/g	0.05	10	8	1	0.6	10	5.9	17
Chromium (Cr)	µg/g	0.5	10	10	31	26	110	0.6	3.5
Copper (Cu)	µg/g	0.1	10	10	25	16	110	37.3	90
Iron (Fe)	µg/g	1	10	10	30,000	20,000	40,000	35.7	197
Manganese (Mn)	µg/g	0.5	10	10	400	460	1,100		
Nickel (Ni)	µg/g	0.5	10	10	31	16	75		
Lead (Pb)	µg/g	0.1	10	10	23	31	250	35	91.3
Zinc (Zn)	µg/g	0.7	10	10	65	120	820	123	315
Methylnaphthalene, 2-(1-)	µg/g	0.071	10	6					

					Provincial Sediment Quality Guidelines (PSQG)			Canadian Sediment Quality Guidelines (CSQG)	
Parameter	Unit	Detection Limit	No. Samples	No. Detect	Background Sediment	Lowest Effect Level (LEL)	Severe Effect Level (SEL)	Interim Sediment Quality Guidelines (ISQG)	Probable Effect Levels (PEL)
Acenaphthene	µg/g	0.05	10	0					
Acenaphthylene	µg/g	0.05	10	1				0.00587	0.128
Anthracene	µg/g	0.05	10	1		0.22	370	0.00671	0.0889
Benzo(a)anthracene	µg/g	0.05	10	2		0.32	1,480	0.0317	0.385
Benzo(a)pyrene	µg/g	0.05	10	4		0.37	1,440	0.0319	0.782
Benzo(b/j)fluoranthene	µg/g	0.05	10	5					
Benzo(g,h,i)perylene	µg/g	0.05	10	5		0.17	320		
Benzo(k)fluoranthene	µg/g	0.05	10	3		0.24	1,340		
Chrysene	µg/g	0.05	10	3		0.34	460	0.0571	0.862
Dibenzo(a,h)anthracene	µg/g	0.05	10	1		0.06	130	0.00622	0.135
Fluoranthene	µg/g	0.05	10	7		0.75	1,020		
Fluorene	µg/g	0.05	10	1		0.19	160	0.0212	0.144
Indeno(1,2,3-cd)pyrene	µg/g	0.05	10	5		0.2	320		
1-Methylnaphthalene	µg/g	0.05	10	0					
2-Methylnaphthalene	µg/g	0.05	10	7				0.0202	0.201
Naphthalene	µg/g	0.05	10	0				0.0346	0.391
Phenanthrene	µg/g	0.05	10	2		0.56	950	0.0419	0.515
Pyrene	µg/g	0.05	10	5		0.49	850	0.053	0.875

7.0 Aquatic Habitats and Fish

[Emergent aquatic plants (wild rice) on Upper Lake Dalrymple, August 2023]

7.1 Summary of Key Observations

- Aquatic habitat conditions are different between Upper Lake Dalrymple and Lower Lake Dalrymple, with Upper Lake Dalrymple providing shallower, and more productive aquatic habitats because it is dominated by shallow marsh wetland conditions.
- Lake Dalrymple is considered a warmwater lake. The deep basin on Lower Lake Dalrymple remains deep enough to provide coldwater habitat in the summer at depths >6 m, but temperature and dissolved oxygen conditions are limiting available habitat for resident coldwater fishes.
- There were 19 types of aquatic plants found in the lake, occupying 64% of surface area of Lake Dalrymple in the summer. Upper Lake Dalrymple is heavily vegetated with wild rice, an intolerant plant that is important culturally and for fish and wildlife habitat.
- Streams flowing into Lake Dalrymple provide important habitat corridors for aquatic life. The outlets are biodiversity hotspots. There is at least one sensitive coldwater stream that drains into the north-east shoreline of Lower Lake Dalrymple.
- Approximately 38 fish species have been found within the Lake Dalrymple Watershed, many of which support a popular open water and winter fishery. The fish community is characteristic of other warmwater lakes in the Kawarthas, but the lake does have some unique fishes given its hydrological connection to Black River. The warmwater fish community has started to increase its overall representation of the fish community, which is consistent with much of Southern Ontario's fish communities and is expected to continue with climate change.

7.2 Summary of Key Issues and Information Gaps

- There are at least three perched culverts that provide seasonal impediment to the free movement of fishes in streams and to the lake.
- There is a historical record of grass pickerel being caught in the lake, which is a fish species of conservation concern. Given this fish has not been detected since, it is currently unknown whether this fish has been misidentified or if it no longer exists.
- Fish spawning habitat locational information is dated, and limited in geography, especially for connected streams. The status of muskellunge populations is also not well understood.
- Although most streams meet minimum recommended guidelines for aquatic habitat conditions, those within subwatersheds ULTD-8, LLDT-3, and LLDT-6 do not meet these guidelines. They have large sections lacking natural vegetation that flow through croplands.
- There are at least six aquatic invasive species in the lake. These organisms, once established, are nearly impossible to eradicate and can cause large-scale shifts in aquatic habitat conditions.

7.3 Broadscale Habitat Features - Lakes

Lake Dalrymple is unique lake in the Kawarthas because its water levels are not regulated: water levels follow a 'natural' pattern. Unregulated lakes generally provide higher quality and more productive aquatic habitats than regulated lakes (Zohary and Ostrovsky, 2011).

Upper Lake Dalrymple and Lower Lake Dalrymple have very different aquatic habitat conditions. Bathymetry highlights the difference in habitat across both 'lakes' (Figure 2.2). Lower Lake Dalrymple is larger and deeper than Upper Lake Dalrymple and provides three times as much 'volume' (i.e., physical space). However, Upper Lake Dalrymple provides a more productive aquatic environment, given its abundance of aquatic plants, warmer water temperatures, and higher nutrient concentrations (see Chapter 5: Water Quality).

Ecological land classification (Lee et al., 1998), based on May 2018 aerial photography, was used to delineate major aquatic habitat types within the lake, and along its streams (Figure 7.1). This provides a good generalization of existing habitat conditions.

The dominant habitats in Upper Dalrymple include an almost an equal mix of shallow marsh (45% of total; areas dominated by emergent aquatic plants) and open water (43% of total); areas devoid of aquatic plants) (Table 7.1). Given its shallow depths, soft substrates, and abundance of emergent aquatic vegetation, the Ministry of Natural Resources and Forestry has classified the entire Upper Lake Dalrymple as a wetland. In contrast, the dominant habitat in Lower Dalrymple is open water (81% of total), which includes the deepest basin of Lake Dalrymple. There are only small sections of wetlands (10% of total) located just north of the narrows, south-west of Avery Point, and near the lake outlet.

Table 7.1. Major aquatic habitat types in Upper Lake Dalrymple, and Lower Lake Dalrymple.

ELC type	Characteristics	Upper Dalrymple (%)	Lower Dalrymple (%)
Open Water	Limited aquatic plants, plankton dominated	42.9	81.0
Shallow Marsh	Dominated by emergent aquatic plants	45.4	10.2
Submerged Shallow Aquatic	Dominated by submerged aquatic plants	10.6	8.8
Floating Submerged Aquatic	Dominated by floating-leaved aquatic plants	1.1	-

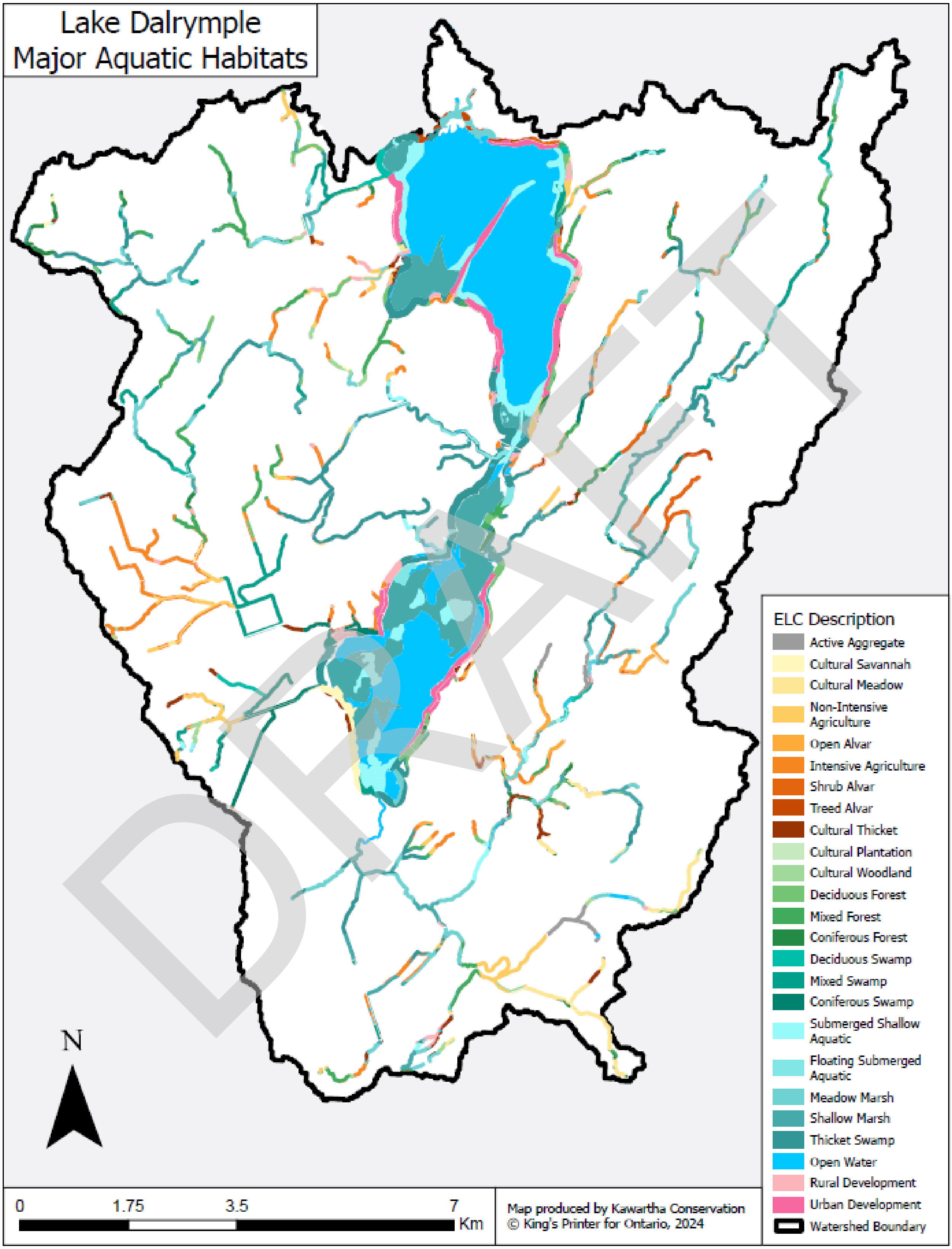
Lake Dalrymple
Major Aquatic Habitats
ELC Description
Active Aggregate
Cultural Savannah
Cultural Meadow
Non-Intensive Agriculture
Open Alvar
Intensive Agriculture
Shrub Alvar
Treed Alvar
Cultural Thicket
Cultural Plantation
Cultural Woodland
Deciduous Forest
Mixed Forest
Coniferous Forest
Deciduous Swamp
Mixed Swamp
Coniferous Swamp
Submerged Shallow Aquatic
Floating Submerged Aquatic
Meadow Marsh
Shallow Marsh
Thicket Swamp
Open Water
Rural Development
Urban Development
Watershed Boundary
N
0
1.75
3.5
7
Km
Map produced by Kawartha Conservation
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Figure 7.1. Major aquatic habitat types in Lake Dalrymple, and along its streams, based on 2018 aerial imagery.

7.4 Broadscale Habitat Features – Streams

There are approximately 19 individual streams that outlet into Lake Dalrymple. When combined they total 176 km in length. All these streams provide either direct or indirect fish habitat and provide important corridors for the movement of aquatic organisms, water flow, food and energy transport which all contribute to the aquatic biodiversity of Lake Dalrymple. The location at which streams enter lake are biodiversity hotspots. Stream outlets are regarded as providing important spawning habitats for lake-based migratory fishes (e.g., muskellunge, walleye, common white sucker).

To provide a general assessment of aquatic habitat conditions along Lake Dalrymple's streams, land use types were compared against guidance provided in How Much Habitat is Enough (Environment Canada, 2013). Guidance indicates that, in general, a 30 m width of natural vegetation on both sides of a stream (also known as the 'riparian area') will provide beneficial functions such as aquatic habitat, bank stability, and sediment removal. In addition, sensitive aquatic organisms are afforded a high degree of protection when at least 75% of the total length of streams have natural riparian areas. At 82% natural cover along their length within 30 m, Lake Dalrymple streams meet recommended guidelines (Figure 7.2). Streams within the subwatersheds ULTD-8, LLDT-3, and LLDT-6 do not meet these guidelines, and have large sections lacking natural vegetation that flow through croplands.

Most streams (60 % of total) are small 'first order' streams which are typically intermittent streams that dry up after prolonged periods of no precipitation. These small streams still provide seasonal aquatic habitat, particularly in late winter and spring. Figure 7.3 shows the locations of permanent and intermittent streams (MNR, 2013) as classified by Kawartha Conservation staff in 2021.

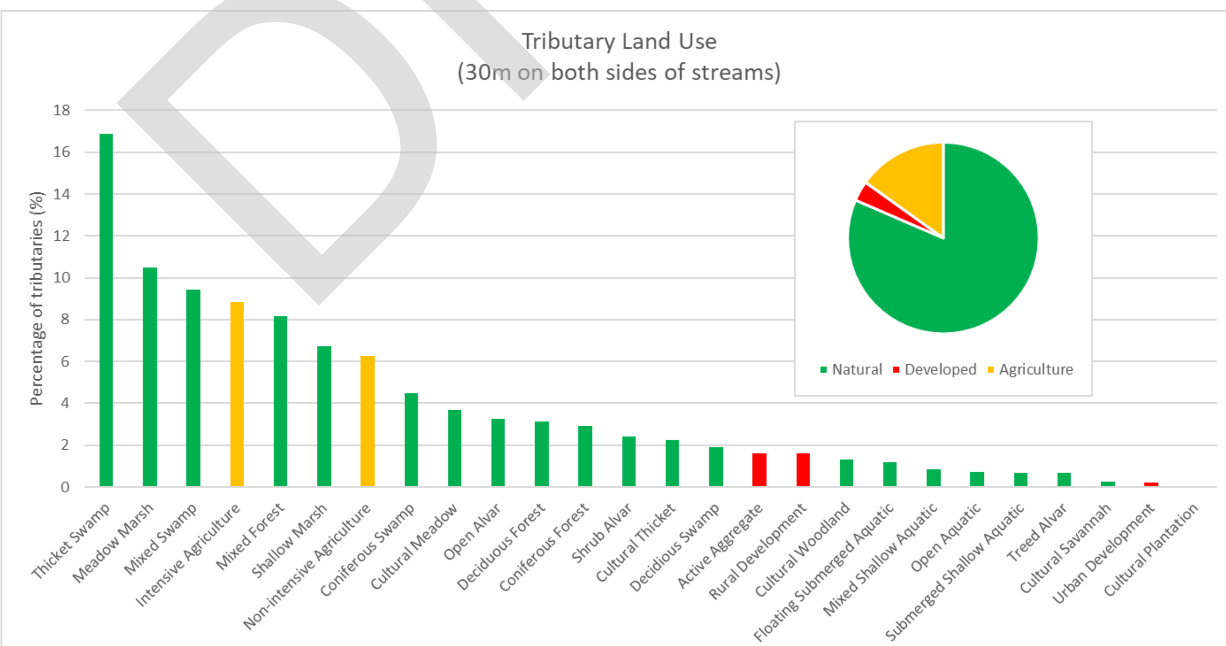

Figure 7.2. Land use types along 30 m of either side of Lake Dalrymple streams.

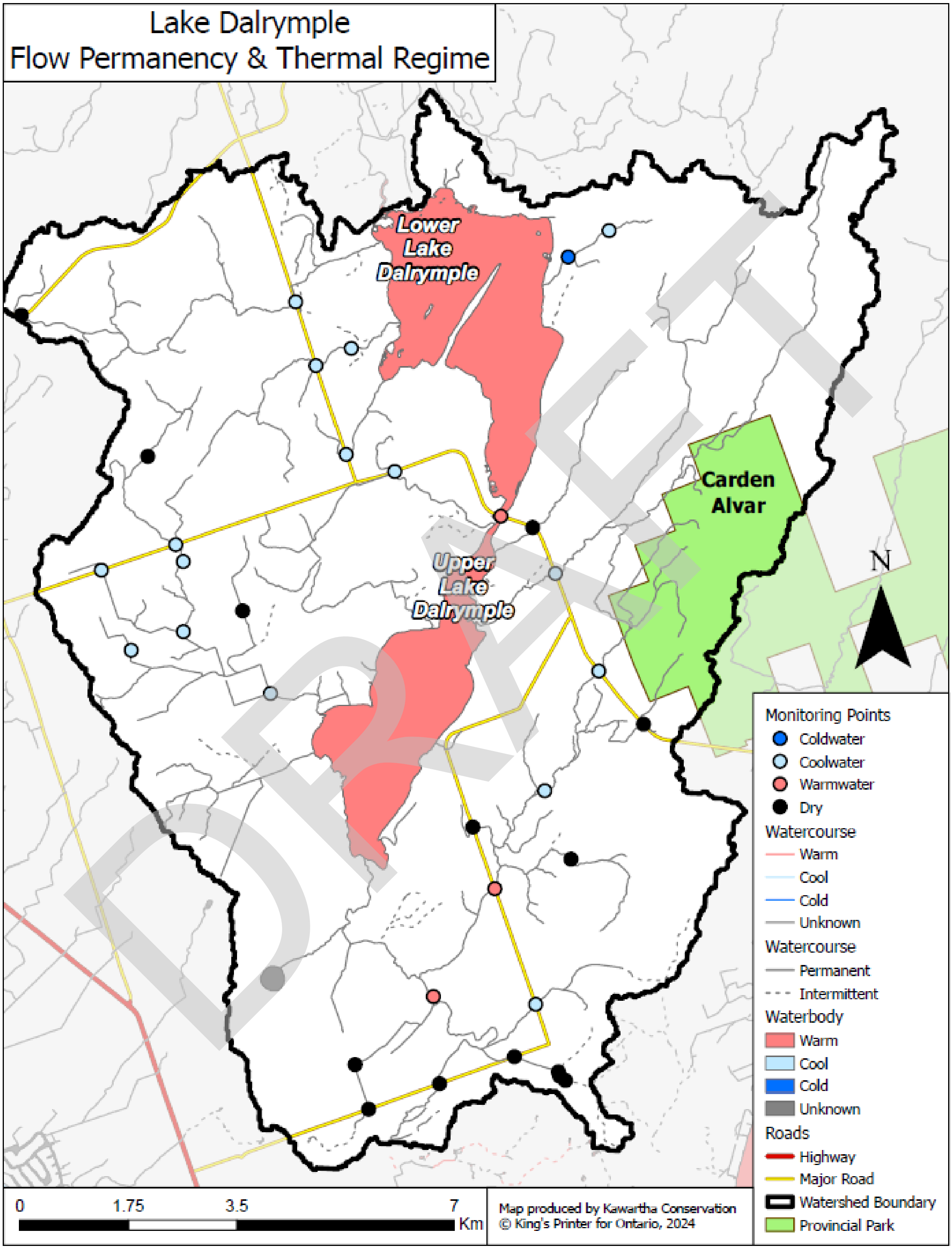

Figure 7.3. Thermal regime and flow permanency classification of Lake Dalrymple and streams.

7.5 Thermal Regime

Lakes and streams can be classified into three major ‘thermal’ habitat categories: coldwater, coolwater and warmwater, based on their summer (June, July, August) water temperatures and resident fish communities. Coldwater habitat supports species that are best adapted, prefers or usually occurs at water temperatures less than 19 ^{o}C, coolwater between 19 and 25 ^{o}C, and warmwater greater than 25 ^{o}C (Eakins, 2024). Thermal regime habitat maps for Lake Dalrymple are managed by the province of Ontario (MNRF, 2024a).

Lake Dalrymple is considered a warmwater lake (Figure 7.3). Daily summer water temperatures at the surface (1 m depth) collected by Kawartha Conservation in 2022 and 2023 in Lower Lake Dalrymple indicate that warmwater habitat conditions are met 65 % of the time, and coolwater habitat conditions are met 35% of the time (Figure 7.4). Although there are no coldwater conditions at the surface, vertical temperature profile data collected during the summer of 2021, 2022, and 2023 indicate that the deep basin on Lower Lake Dalrymple can contain coldwater conditions at depths of 6 m or deeper (Table 7.3). However, as summer progresses and water temperatures increase, the ‘availability’ of coldwater habitat diminishes at depth and can be completely non-existent. In 2021 and 2022, coldwater conditions were unavailable by August and July, respectively, and in 2023 were only available at depths greater than 8.5 m (Table 7.3). Water temperatures and dissolved oxygen availability are limiting factors for coldwater fishes in Lake Dalrymple (see Chapter 5: Water Quality).

The streams of Lake Dalrymple are currently of ‘unknown’ thermal regime, according to available mapping (Figure 7.3). To fill this gap Kawartha Conservation undertook water temperature ‘point-in-time’ surveys during summer of 2022 at 34 road-stream crossings (out of 42 total crossings) as per methodology in Stanfield et al. (2010). Warmwater conditions were found at 17 sites (includes 14 dry sites), coolwater conditions at 16 sites, and coldwater conditions at 1 site (Figure 7.3). These data indicate that the streams should be mapped as either warmwater or coolwater, except for streams within subwatersheds ULDT-7 and ULDT-11 (they remain unknown), and LLDT-3 (the only coldwater stream, north of Alvar Road).

Table 7.2. Depths at which coldwater habitat condition (less than 19 ^{o}C) are met, based on vertical lake profile sampling. Grey indicates conditions not met.

Month	2021	2022	2023
June	> 6 m	> 7.5 m	> 6.5 m
July	> 9 m		> 7.5 m
August			> 8.5 m

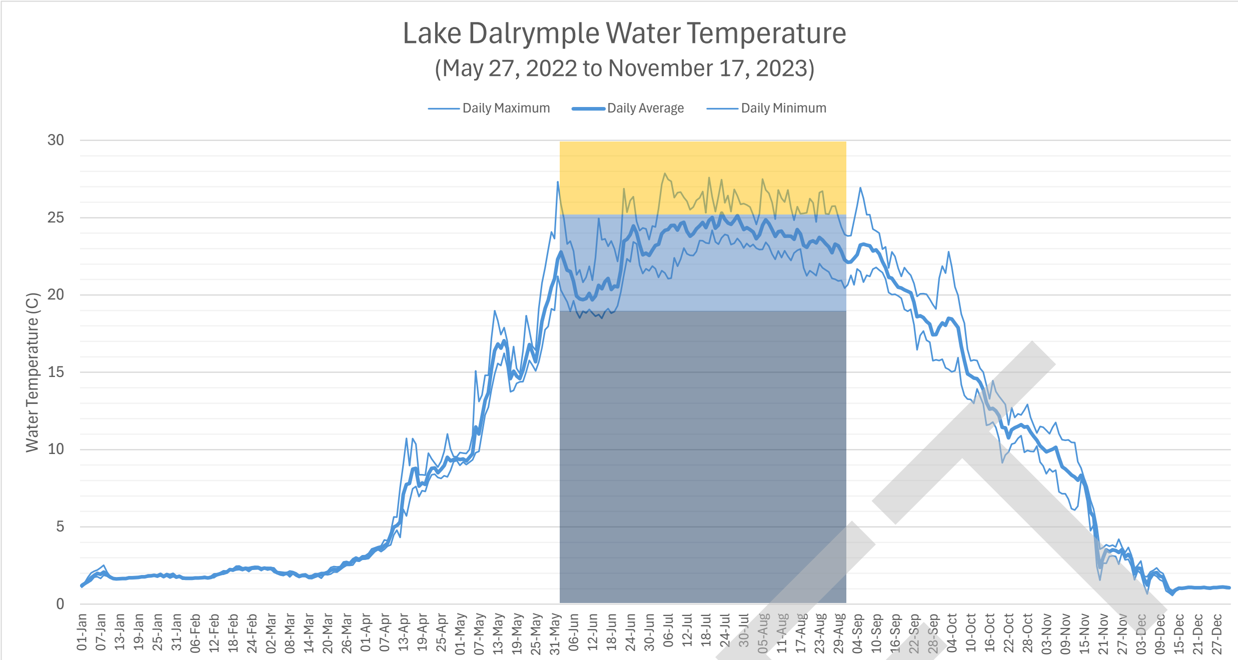

Figure 7.4. Surface water temperatures in Lake Dalrymple from 2022 and 2023, showing daily maximum, average, and minimum. Colour highlight shows range of warmwater (orange), coolwater (light blue), and coldwater (dark blue) habitat conditions.

7.6 Aquatic Plants

Aquatic plants are extremely productive habitats for aquatic life including fish, invertebrates, and other aquatic animals including beavers, muskrats, and waterfowl. They provide food, cover, shade, and help stabilize sediments and dissipate wave energy.

In August 2022, Kawartha Conservation undertook an aquatic plant assessment by boat of the lake at 333 locations using the point-intercept method as per (Madsen, 1999). Sample sites were the approximate centre of a systematic grid of 200 m^2 squares over Lake Dalrymple. Aquatic plants were sampled by tossing a double-sided hard rake onto the lakebed and pulling the vegetation to the surface. If no plants were found on the first rake toss, then one more rake toss was made to ensure that plants were not present at that site. A qualitative assessment of rake fullness (none, sparse, moderate, or dense) as per Hauxwell et al. (2010) by plant species (where possible) was then undertaken at each site. In areas where traversing by boat was not possible, for example within dense stands of emergent plants, site conditions were approximated using binoculars. Most sites (95%) were assessed for some form of aquatic vegetation.

Sampling resulted in 19 unique taxa being documented (Table 7.2). All these aquatic plants are characteristic in lakes within the Kawarthas, and all are naturally occurring to Lake Dalrymple except two invasive taxa: Eurasian watermilfoil and starry stonewort.

The plant community includes several taxa that are considered ‘sensitive’, including wild Rice, bulrush, water marigold, and water shield. These taxa are listed as very intolerant to degradation as per Croft and Chow-Fraser (2007).

Aquatic plants occupied a large portion (approximately 64 %) of the lake surface area, with the top three by frequency being wild rice, tapegrass, and pondweeds (Figure 7.4). Emergent, floating, and submerged plants occupy 38, 10, and 44 % of the lake, respectively. The distribution of aquatic plants corelates well with water depth, as they were generally absent in waters deeper than 5 m.

Upper Lake Dalrymple and Lower Lake Dalrymple have very different aquatic plant distributions and communities. Aquatic plants occupy 86 % of Upper Lake Dalrymple and are dominated by emergent taxa (81 %). In contrast, aquatic plants in Lower Lake Dalrymple only occupy 51 %, and are dominated by submerged plants (34 %). Upper Lake Dalrymple was dominated by wild rice, naiad sp., and pondweed sp., whereas Lower Dalrymple was dominated by tapegrass, coontail, and pondweed.

Emergent vegetation results are shown in Figure 7.6. These aquatic plants are characteristic of ‘marsh wetlands’ and provide optimal aquatic habitat. Most emergent aquatic plants in Lake Dalrymple are Wild Rice, which is particularly abundant in Lower Lake Dalrymple, within the ‘narrows’ (heavily associated with Pickerelweed), and south-west of Avery Point. Wild rice, also known as Manoomin, is considered ‘intolerant’ of degradation, therefore its presence is indicative of high-quality habitat conditions. It is also the preferred ‘spawning’ habitat of muskellunge and northern pike, food for waterfowl, nesting material for muskrats, and is significant culturally to First Nations communities. The lack of extensive cattail emergent marshes in Lake Dalrymple is rare for lakes in the Kawarthas. Cattails are more tolerant of degradation and their ‘absence’ in Lake Dalrymple is a consequence of natural water level fluctuations and good water quality conditions.

Floating vegetation results are shown in Figure 7.7. Their presence is limited to the ‘protected’ areas along the western shore of Upper Lake Dalrymple, around the ‘narrows’, and at the lake outlet. The dominant species in these areas are yellow pond-lily, and white water-lily. These aquatic plants provide excellent cover and shade habitat for fish and are a preferred food for the American beaver.

Submerged vegetation results are shown in Figure 7.8. These aquatic plants occupy significant areas of both lakes, with the dominant taxa being tapegrass, pondweed, naiad, coontail, and bladderwort. Tapegrass, coontail, and bladderwort were more commonly found in Lower Lake Dalrymple, whereas naiad and pondweed were more commonly found in Upper Lake Dalrymple. Eurasian watermilfoil, an invasive species, was abundant near the developed shorelines in the north-west section of Lower Lake Dalrymple along Avery Point and along Fulsom Crescent. Starry stonewort, the other invasive submerged plant, was abundant in the ‘narrows’ just north and south of Kirkfield Road.

Table 7.3. Frequency (percent 'present' out of 333 samples) of aquatic plants in Lake Dalrymple, August 2022, * indicates invasive species. Bold indicates top 3 plants. Tolerance (1 = very tolerant to degradation, 5 = very intolerant) based on Croft and Frasier (2007).

Aquatic Plant (common name)	Aquatic Plant (scientific name)	Type	Lake Dalrymple	Upper Dalrymple	Lower Dalrymple
Wild Rice sp.[4]	*Zizania sp.*	Emergent	**37**	**78**	11
Tapegrass[3]	*Vallisneria americana*	Submerged	**28**	14	**36**
Pondweed sp.[1]	*Potamogeton sp.*	Submerged	**21**	**28**	**17**
Naiad sp.[3]	*Najas sp.*	Submerged	16	**39**	2
Coontail[1]	*Ceratophyllum sp.*	Submerged	15	2	**22**
Bladderwort sp.[3]	*Utricularia sp.*	Submerged	10	3	14
Canadian Waterweed[2]	*Elodea canadensis*	Submerged	9	4	12
*Eurasian Watermilfoil[1]	**Myriophyllum Spicatum*	Submerged	8	2	11
White Water-lily[2]	*Nymphaea odorata*	Floating	8	18	2
Muskgrass/Stonewort[3]	*Chara/Nitella*	Submerged	7	3	9
Watermilfoil sp.[1]	*Myriophyllum sp.*	Submerged	4	4	3
Bulrush sp.[4]	*Scirpus sp.*	Emergent	3	6	1
Pickerelweed[3]	*Pontederia cordata*	Emergent	3	7	0
Water Marigold[4]	*Bidens beckii*	Submerged	2	0	2
Yellow Pond-lily[2]	*Nuphar lutea*	Floating	2	4	1
*Starry Stonewort	**Nitella Obtusa*	Submerged	1	1	1
Cattail sp.[1]	*Typha sp.*	Emergent	<1	1	0
Watershield[4]	*Brasenia schreberi*	Floating	<1	2	0
Duckweed sp.[1]	*Lemna sp.*	Floating	<1	2	0
TOTAL: Aquatic Vegetation			64	86	51
TOTAL: Emergent			38	81	12
TOTAL: Floating			10	20	3
TOTAL: Submerged			44	60	34
TOTAL: Unassessed			5	11	1

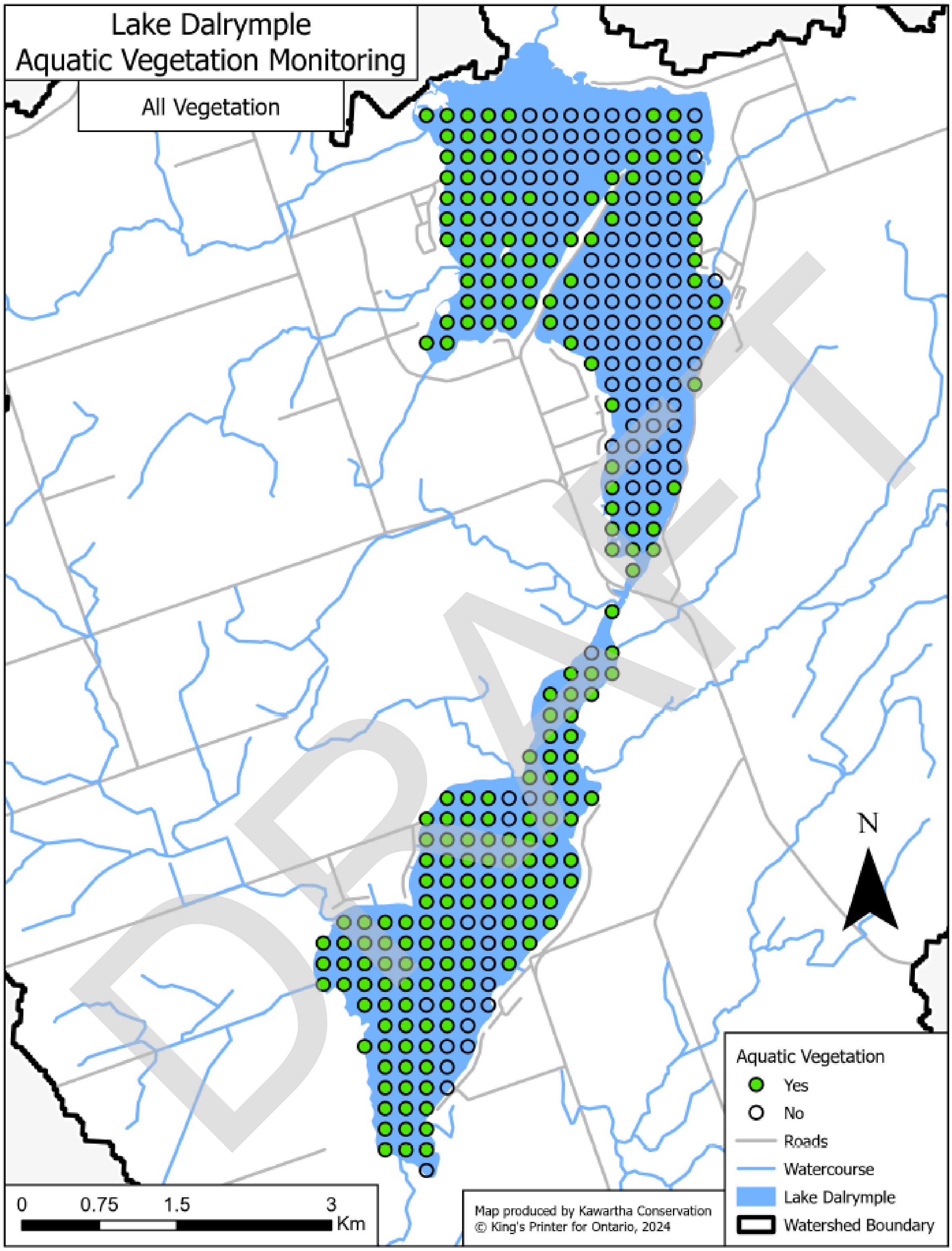

Figure 7.5. Aquatic plant sampling locations, and presence.

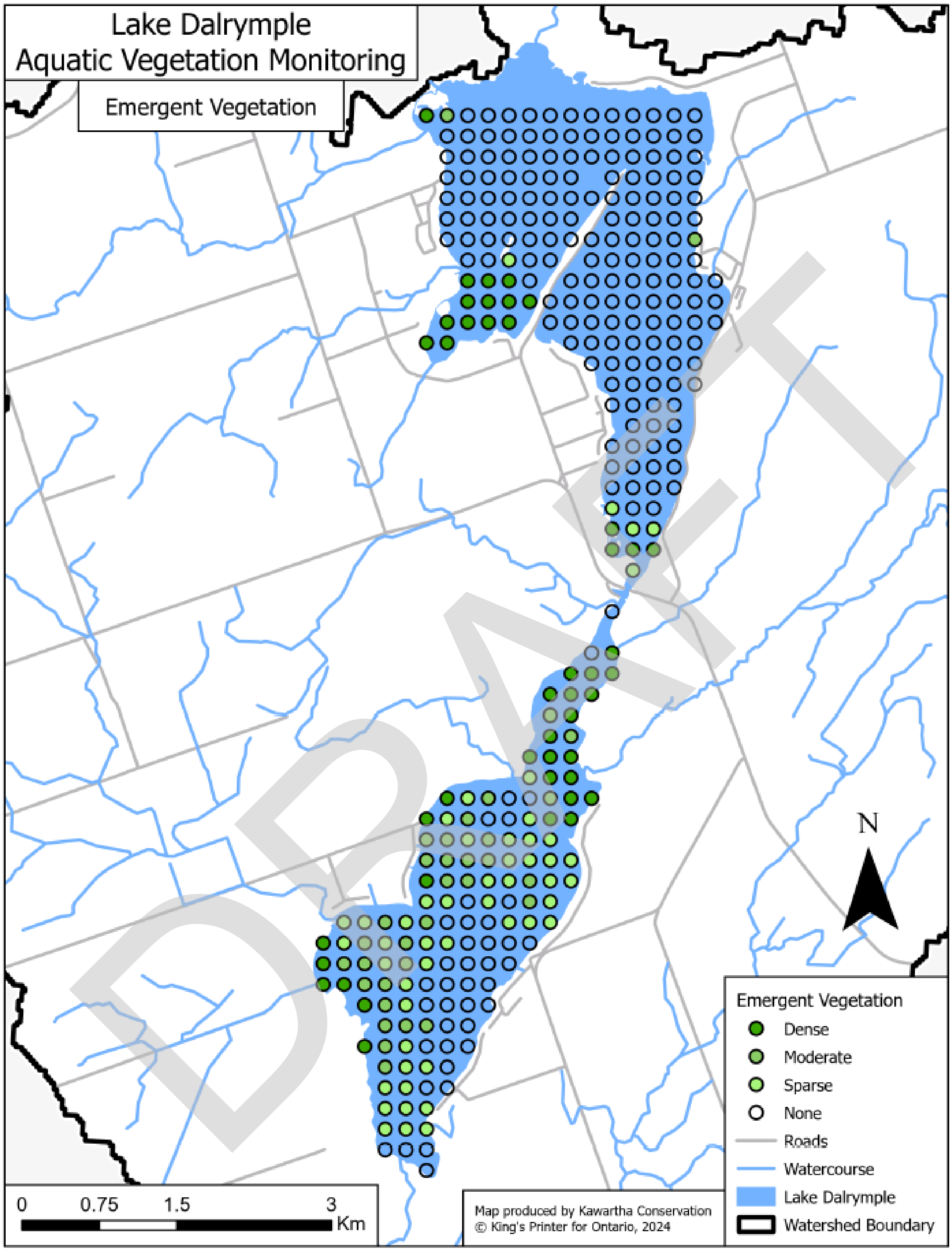

Figure 7.6. Emergent aquatic plant locations and abundance.

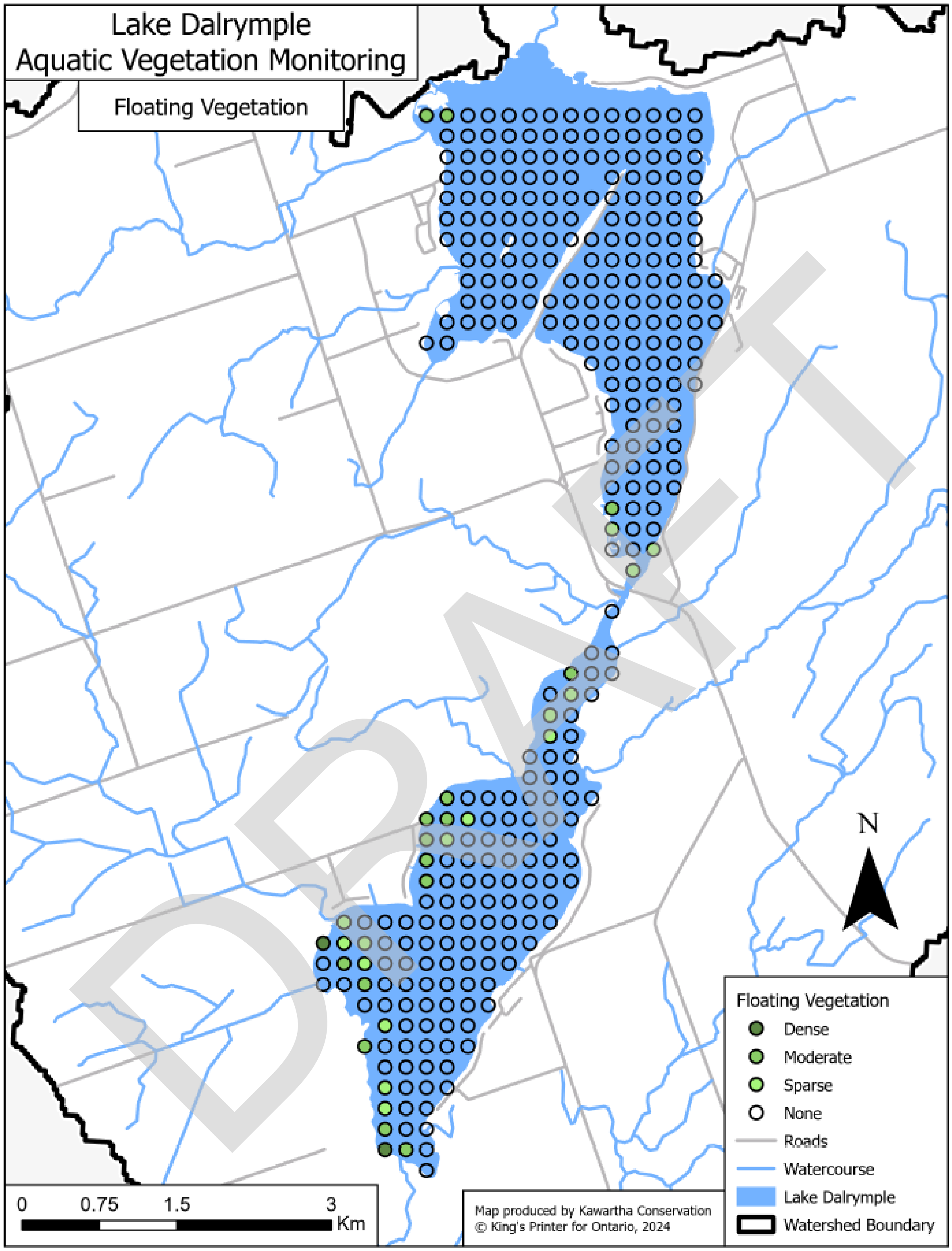

Figure 7.7. Floating aquatic plant locations and abundance.

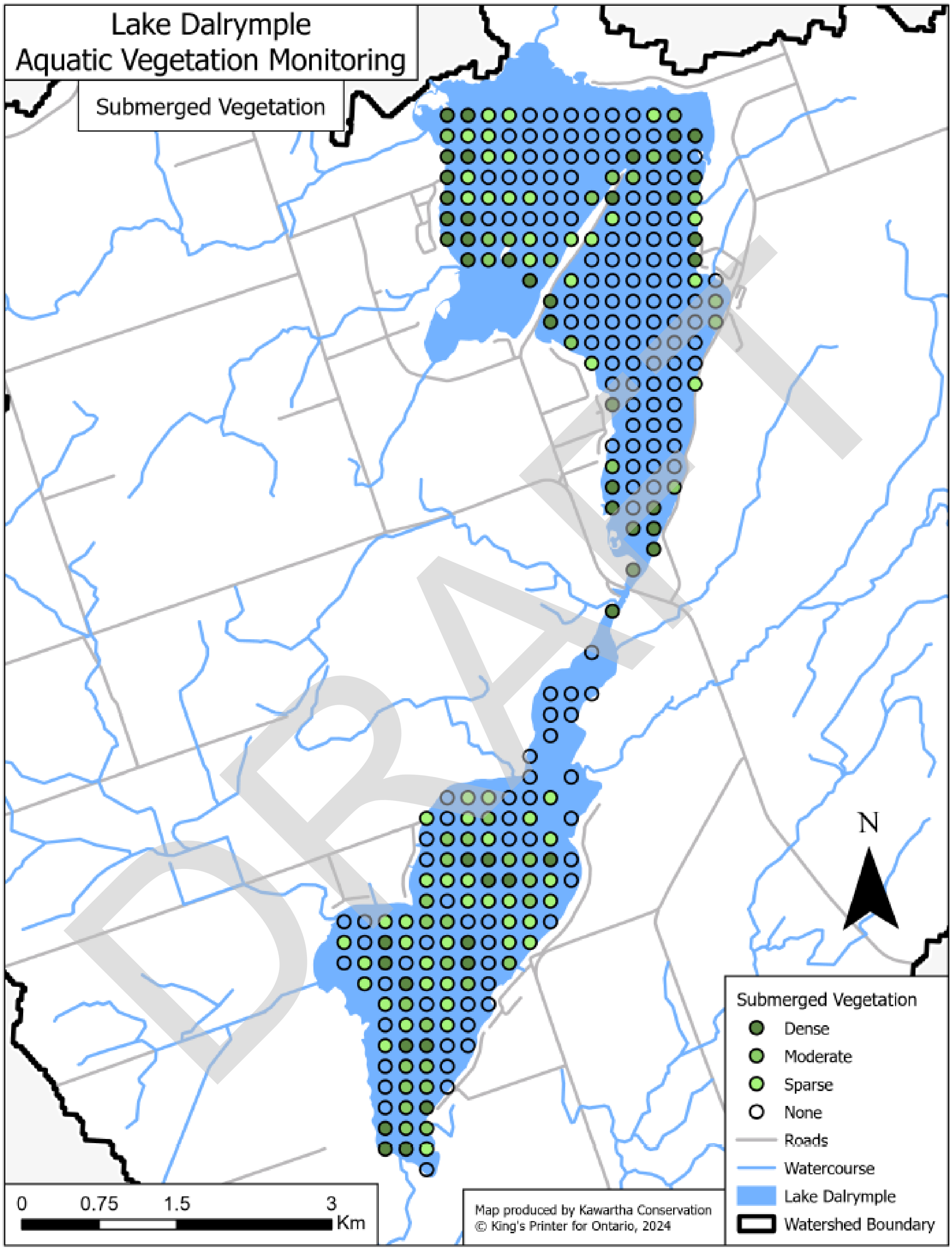

Figure 7.8. Submerged aquatic plant locations and abundance.

7.7 Spawning Habitat

Information on the locations of spawning habitat is limited. Existing data was accessed from the province of Ontario (MNRF, 2024b), but is based on data collected in the mid 1990's. Data shows several sections of shoreline have been 'confirmed' spring spawning habitat for three top predator fishes important to the recreational fishery (Figure 7.9). On Lower Dalrymple, there are seven sections for walleye (Herring Island, Avery Point, along the east shore, and at the narrows), two sections for smallmouth bass (east shore), and one section for largemouth bass (north-west shore at the lake outlet). On Upper Lake Dalrymple, one section for smallmouth bass has been identified (south-west shore).

Fishes in Lake Dalrymple are undoubtedly using areas not listed above for spawning; most of the spawning locations remain undocumented. Spawning habitat can be variable, with heavily vegetated areas (wetlands), wind-swept shorelines, and stream outlets being traditional 'spawning hotspots'. Species such as northern pike and muskellunge spawn in flooded vegetated areas (e.g., wild rice marshes), while walleye prefer wave-washed rock or rubble shorelines and shoals, and bass prefer sandy, mud, gravel, or rocky lake bottoms. Most of the fishes found in Lake Dalrymple spawn in the spring (except cisco and burbot which are extremely rare, and spawn in the fall and winter, respectively) and all fishes spawn in shallow waters. In Lower Lake Dalrymple, shallow water spawning habitat is generally limited to areas close to shore (nearshore), but in Upper Lake Dalrymple it has the potential to be more widespread (i.e., nearshore, and offshore) based on local bathymetry.

7.8 Nursery and Overwintering Habitat

Nursery habitat can be generally defined as the habitat used by young-of-the-year fish (i.e., post-spawn small fish), and is associated with waters less than 2 m deep. Shallow marshes and wetlands are prime nursery habitat because aquatic plants offer protection from predators and food sources. Fishes also use the cover provided by the interstitial spaces between cobble and gravel as nursery habitat. Upper Lake Dalrymple provides exceptional nursery habitat conditions. Areas less than 2 m in depth account for 76 % of its surface area, and most of which is heavily vegetated. Upper Lake Dalrymple has 24 % of its surface area less than 2 m, therefore nursery areas are more limiting.

During winter, fishes tend to move to deeper depths to avoid freeze-up (ice) and to take advantage of stable water temperatures and year-round growth of aquatic plants. In streams this means taking advantage of deep pools, groundwater upwelling areas, or migrating to deeper waters within the lake. Given existing bathymetry, and given that ice thickness can be up to 1 m thick across the whole lake, 13 and 20 % of Upper Lake Dalrymple and Lower Lake Dalrymple, respectively, is inaccessible due to ice. Given that water depth at the 'narrows' is around 1 m, there would likely be limited fish migration back and forth between Upper Lake Dalrymple and Lower Lake Dalrymple under thick ice conditions.

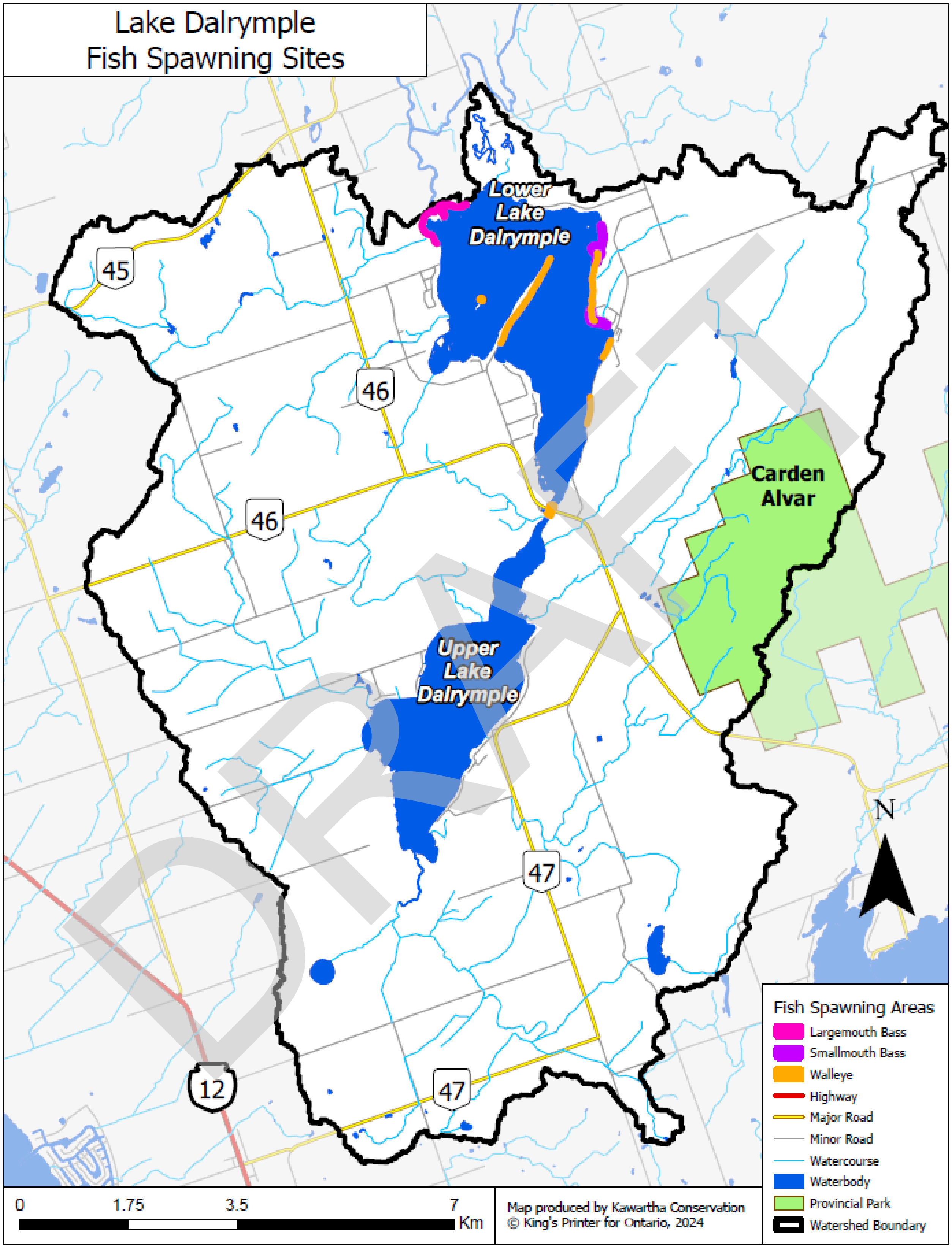

Figure 7.9. Location of documented fish spawning habitat within Lake Dalrymple.

Under-ice dissolved oxygen concentrations can also affect overwintering habitat, and there is at least one historically documented case of a large die-off of yellow perch in Upper Lake Dalrymple involving greater than 10,000 fish (MNR, 1969) which was attributed to winterkill (dissolved oxygen depletion). There are no data available with respect to winter 'under-ice' dissolved oxygen concentrations.

7.9 Migration Routes

Fish move regularly over the course of the year, accessing habitat that are preferable for reasons including: life stage transitions involving moving from nursery habitats to adult feeding habitats, refuge migrations involving moving to a preferred temperature or flow conditions, and reproductive migrations to access spawning habitats. Several fishes in Lake Dalrymple are known to have 'migratory' habits, including walleye, white sucker, and muskellunge. Although not documented in Lake Dalrymple, these fishes can move long distances to access spawning habitat, for example swimming up inter-connected streams in the spring.

During the thermal regime surveys in 2022, Kawartha Conservation identified three barriers to fish migration, within close proximity to the lake. These were three road culverts, two within subwatershed LLDT-6 (at McNabb Road and Kirkfield Road), and one within LLDT-3 (Lake Dalrymple Road). All of which had outlets that were elevated above stream flows (perched condition).

7.10 Fish Community

There are approximately 38 unique species of fish in Lake Dalrymple and its streams (Table 7.4). This list is a compilation of records from the Ministry of Natural Resources and Forestry (samples dating back since the 1950's), Kawartha Conservation (sampling in 2022), Lake Simcoe Region Conservation (sampling in 2003), and University of Windsor (2003 to 2005). Figure 7.10 shows the approximately locations of sampling sites within the last 20 years.

Within Lake Dalrymple, 29 fishes have been documented, which include 15 coolwater, 12 warmwater, and 2 coldwater species. Lake Dalrymple's fish community is characteristic of lakes within Fisheries Management Zone 17. Recreationally important fishes include yellow perch, muskellunge, northern pike, smallmouth bass, largemouth bass, walleye, black crappie, bluegill, and pumpkinseed. There are two known species of freshwater mussels in the lake, Eastern elliptio (*Elliptio complanate*) and Fatmucket (*Lampsillis siliquoidea*), which were captured incidentally by Kawartha Conservation in 2022; both of which are common to the region. Within the streams of Lake Dalrymple, 14 fishes have been documented, which includes 11 coolwater, and 3 warmwater species.

Channel catfish, grass pickerel, and northern pike are unique to Lake Dalrymple compared to most other lakes within the Kawarthas, which is likely due to Lake Dalrymple's hydrological connectivity with the Black River. Grass pickerel is especially unique, because it is listed as an aquatic species of Special Concern (meaning a species that may become threatened or endangered because of a combination of

Table 7.4. List of fishes documented in Lake Dalrymple and streams. Bold are sport fishes.

Fish Common Name	Fish Scientific Name	Thermal Guild	Lake	Streams
Banded Killifish	*Fundulus diaphanus*	Cool	X	
Black Bullhead	*Ameiurus melas*	Warm	X	
Black Crappie	***Pomoxis nigromaculatus***	**Cool**	**X**	
Blackchin Shiner	*Miniellus heterodon*	Cool	X	
Blacknose Shiner	*Notropis heterolepis*	Cool	X	
Bluegill	***Lepomis macrochirus***	**Warm**	**X**	
Bluntnose Minnow	*Pimephales notatus*	Warm	X	
Brassy Minnow	*Hybognathus hankinsoni*	Cool		X
Brook Stickleback	*Culaea inconstans*	Cool		X
Brown Bullhead	*Ameiurus nebulosus*	Warm	X	X
Burbot	*Lota lota*	Cold	X	
Central Mudminnow	*Umbra limi*	Cool		X
Cisco	*Coregonus artedi*	Cold	X	
Channel Catfish	*Ictalurus punctatus*	Warm	X	
Common Carp	*Cyprinus carpio*	Warm	X	
Common Shiner	*Luxilus cornutus*	Cool	X	X
Creek Chub	*Semotilus atromaculatus*	Cool		X
Emerald Shiner	*Notropis atherinoides*	Cool	X	
Fathead Minnow	*Pimephales promelas*	Warm		X
Golden Shiner	*Notemigonus crysoleucas*	Cool	X	
Grass Pickerel	*Esox americanus vermiculatus*	Warm	X	
Iowa Darter	*Etheostoma exile*	Cool		X
Johnny Darter	*Etheostoma nigrum*	Cool	X	
Largemouth Bass	***Micropterus nigricans***	**Warm**	**X**	
Logperch	*Percina caprodes*	Warm	X	
Muskellunge	***Esox masquinongy***	**Warm**	**X**	
Northern Pearl Dace	*Margariscus nachtriebi*	Cool		X
Northern Pike	***Esox lucius***	**Cool**	**X**	
Northern Redbelly Dace	*Chrosomus eos*	Cool		X
Pumpkinseed	***Lepomis gibbosus***	**Warm**	**X**	**X**
Rock Bass	***Ambloplites rupestris***	**Cool**	**X**	
Smallmouth Bass	***Micropterus dolomieu***	**Cool**	**X**	
Spotfin Shiner	*Cyprinella spiloptera*	Warm	X	
Spottail Shiner	*Hudsonius hudsonius*	Cool	X	
Walleye	***Sander vitreus***	**Cool**	**X**	
Western Blacknose Dace	*Rhinichthys obtusus*	Cool		X
White Sucker	*Catostomus commersonii*	Cool	X	X
Yellow Perch	***Perca flavescens***	**Cool**	**X**	**X**

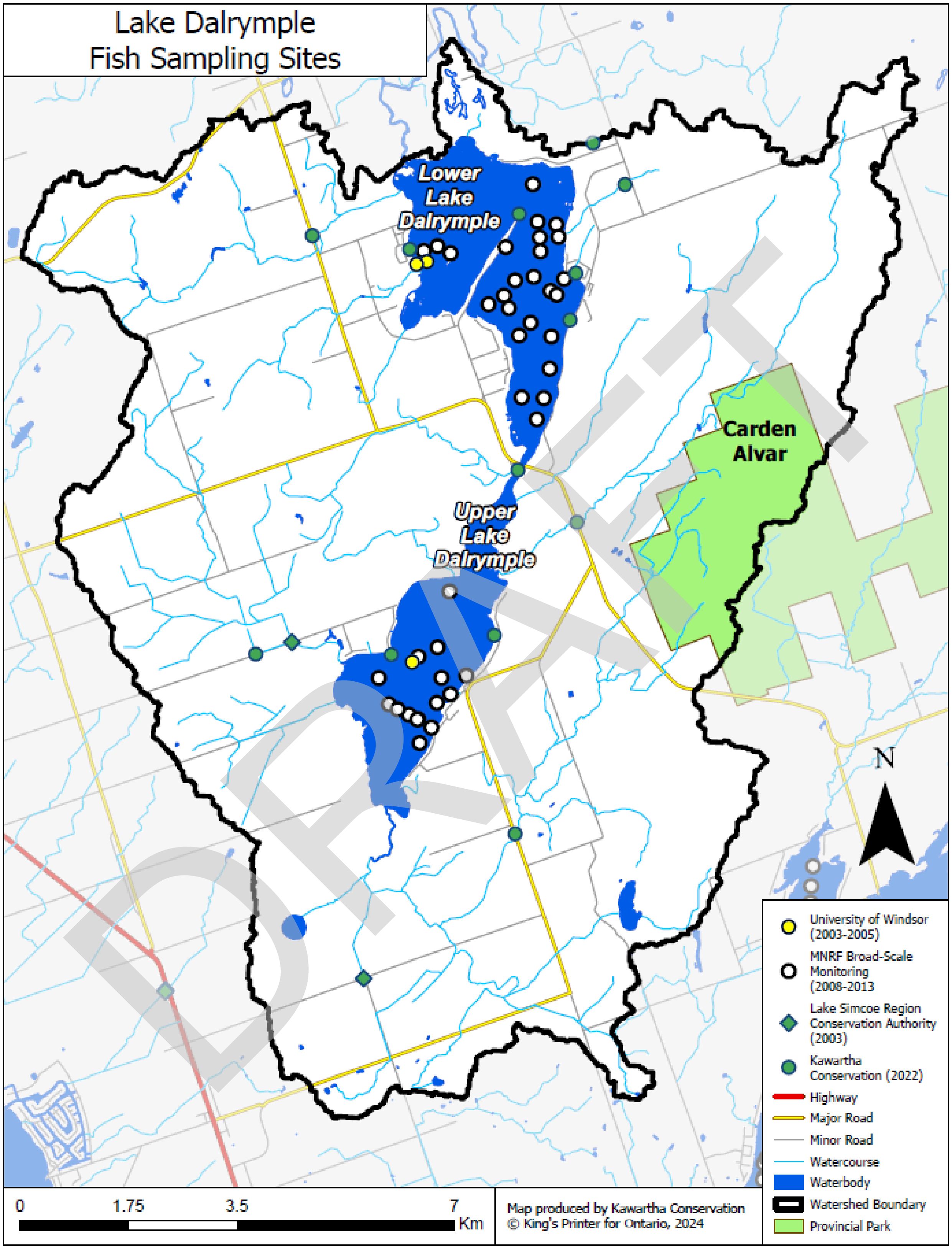

Figure 7.10. Location of fish sampling stations from 2003 to present. The most recent Broad-scale Monitoring (cycle 3) stations are not shown.

biological characteristics and identified threats). It is not clear if this record is erroneous, or if this fish has been extirpated (no longer present) from the lake, or present but misidentified. Provincial netting records from 1972 indicate its presence in the lake (MNR, 1974) but recent netting surveys have not detected it. This cryptic fish could be misidentified as a northern pike or muskellunge.

Lake Dalrymple contains two coldwater fish species: burbot and cisco. These fishes have only been caught sporadically and in extremely low abundances. They are sensitive fishes, able to only tolerate relatively high dissolved oxygen (greater than 5 mg/L) and relatively cold water temperatures (less than 19 °C). Therefore, water quality conditions in the late summer period can limit their habitat availability to the deepest parts of the lake which as shown in Chapter 5: Water Quality is marginally supportive.

Lake Dalrymple is managed as a ‘self-sustaining’ warmwater fishery. No fish stocking currently takes place. Historically, muskellunge, walleye, smallmouth bass, and largemouth bass have been stocked in Lake Dalrymple. Walleye was stocked for the longest period, from 1922 (DLF, 1963) to 2005 (MNR, 2008).

The status of the lake fishery is tracked by the Ministry of Natural Resources and Forestry, through their Broad-scale Monitoring Program. This program is intended to track the status of fishes at a zone-wide level of detail (i.e., Fisheries Management Zone 17) across the province.

Figure 7.10 provides a summary of the proportion of large-bodied fishes caught in Lake Dalrymple per cycle since the beginning of the program (3 cycles; 2008, 2013, and 2018). Yellow perch always dominates the fish community, representing 27 to 58 % of the catch. In terms of general trends, yellow perch are consistently high, brown bullhead and smallmouth bass are on an increasing trajectory, walleye are on a decreasing trajectory, and northern pike and largemouth bass are stable. The decline in walleye is mitigated by strong age structure foundation and modest improvements shown in cycle 3 (MNDMNRF, 2022). Common fishes in the most recent cycle included yellow perch, brown bullhead, northern pike, white sucker, and smallmouth bass, which collectively comprised 90 % of the total catch.

Figure 7.11 provides a summary of biomass (weight) for four important sport fish in Lake Dalrymple (walleye, largemouth bass, smallmouth bass, and northern pike), relative to all lakes within Fisheries Management Zone 17. Largemouth bass biomass in Lake Dalrymple is consistently within ‘average’ for Fisheries Management Zone 17 lakes. Walleye and northern pike started off much higher than average but have since been comparable. Smallmouth bass started off consistently below average, but have approached average in the most recent cycle. Generally, the warmwater fish community has started to increase its overall representation of the fish community from cycles 2 to 3, which is consistent with much of Southern Ontario’s fish communities and is expected to continue with climate change (reference).

Muskellunge is an important native top predator in Lake Dalrymple, and throughout the Kawarthas are under threat from northern pike (MNR, 2008). Unfortunately, the Broad-scale Monitoring program does not effectively track muskellunge populations therefore the status of muskellunge is unknown.

Hybrids between muskellunge and northern pike (known as 'tiger muskie') have been found in the lake. Northern pike has coexisted with muskellunge in Lake Dalrymple since at least 1963 (DLF, 1963).

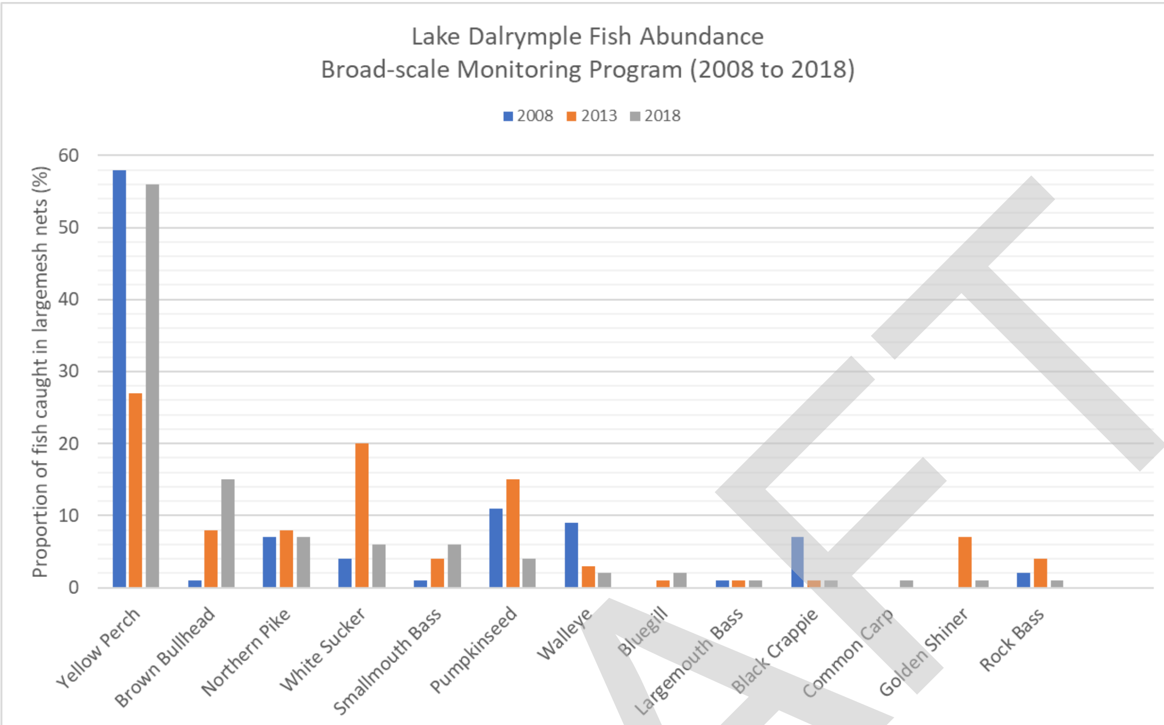

Figure 7.11. Proportion of fish caught in Lake Dalrymple, in large mesh nets by cycle.

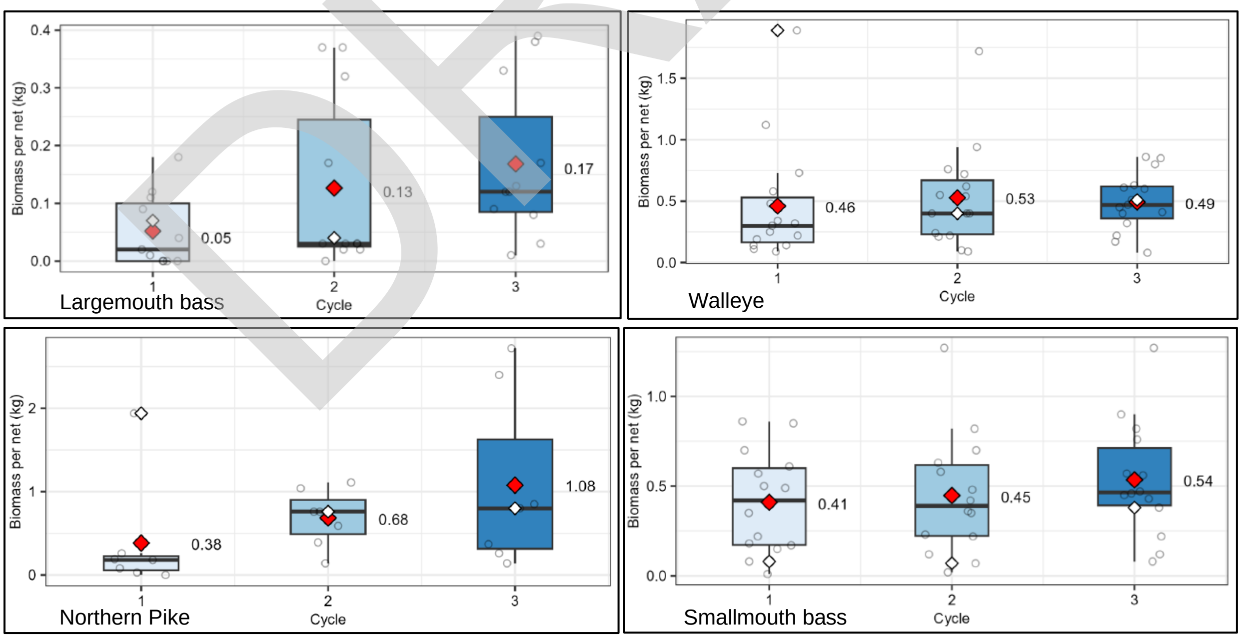

Figure 7.12. Summary of biomass per net (fish >350 mm total length) in comparison to all lakes in Zone 17 according to cycle. Red diamond is the mean value for all lakes with the numeric value displayed beside the box. White diamond is mean value for Lake Dalrymple.

7.11 Aquatic species of Conservation Concern

Aquatic species of conservation concern include fishes and mussels listed as 'Special Concern', 'Threatened', or 'Endangered', as per the federal *Species at Risk Act* or provincial *Endangered Species Act*. As previously described, in terms of fishes, grass pickerel has been documented as occurring in the lake in 1972 (MNR, 1976) but hasn't been found since. Its preferred habitat is wetlands, ponds, slow-moving streams and shallow bays of larger lakes with warm, shallow, clear water and an abundance of aquatic plants (MECP, 2021).

Terrestrial species of conservation concern (e.g., mammals, birds, reptiles, amphibians, invertebrates, and plants) are detailed in Chapter 8: Landscape Ecology.

7.12 Aquatic Invasive Species

There are six documented aquatic invasive species in Lake Dalrymple, all of which have been recorded since 2019, but have been well-established in Ontario lakes for decades (EddMapS, 2023). They include Chinese mystery snail (*Cipangopaludina chinensis*), banded mysterysnail (*Viviparus georgianus*), zebra mussel (*Dreissena polymorpha*), quagga mussel (*Dreissena bugensis*), starry stonewort (*Nitellopsis obtusa*), and Eurasian watermilfoil (*Myriophyllum spicatum*). It is not clear how they were introduced to Lake Dalrymple. They most-likely were transferred from other inland water bodies in Ontario, and 'hitched-a-ride' on boats, people, and equipment.

Zebra and quagga mussels are invasive invertebrates, originally from eastern Europe. They have been documented to cause dramatic shifts in lake ecosystems through filter-feeding whereby they 'clear' the water column and depositing feces on the lakebed, which in turn causes increases in aquatic plants, and a transfer of nutrients from offshore to nearshore waters (Hecky et al., 2004). They are sharp-bodied and pose a safety hazard for swimmers, and also can accumulate in great numbers and outcompete native mussels.

Chinese and banded mystery snails are invasive invertebrates, originally from eastern Asia, and east-central United States, respectively. They generally live in depths less than 3 m where currents are slow, with mud, sandy, or gravelly substrates. They outcompete native snails, can alter food webs, and can experience large die-offs, where thousands of individuals wash ashore and cause odour and aesthetic issues (Invasive Species Centre, 2024).

Starry stonewort and Eurasian watermilfoil are invasive plants, originally from Europe and Asia. Starry stonewort is a plant-like form of algae. They often form large dense mats called "pillows" which can displace native plants and algae, and potentially alter the water chemistry and nutrient cycling (Ginn et al., 2021). Eurasian watermilfoil often forms thick mats that prevent other native plants and native fish species from thriving, and have been implicated in reducing dissolved oxygen when large mats die off (Invasive Species Centre, 2024). Both plants were 'formally' documented for the first time in Lake Dalrymple through Kawartha Conservation's aquatic plant survey in 2022. Eurasian Watermilfoil was abundant near the developed shorelines in the north-west section of Lower Lake Dalrymple along Avery Point and along Fulsom Crescent, and starry stonewort was abundant in the 'narrows' just north and south of Kirkfield Road (Figure 7.13).

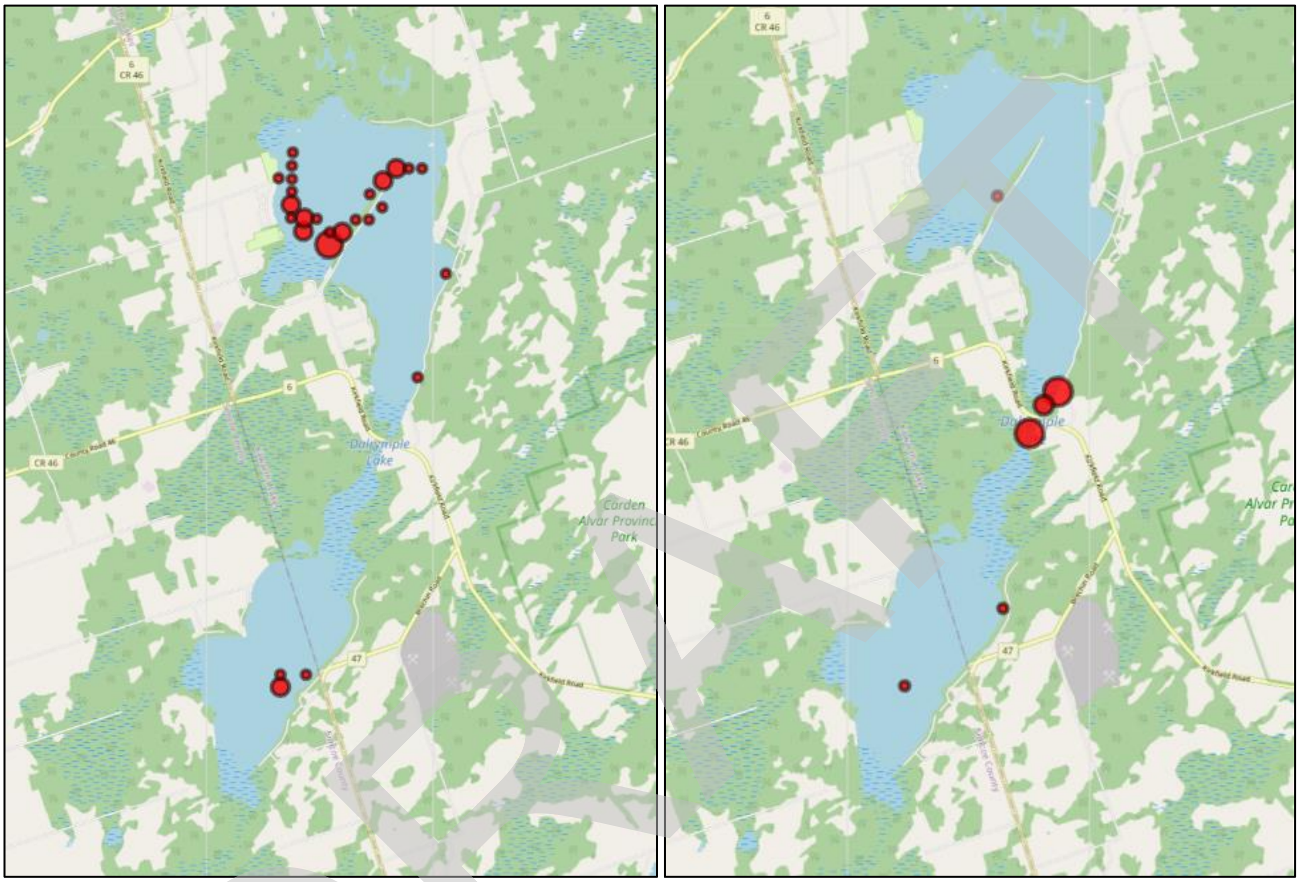

Figure 7.13. Location of known invasive aquatic plants in 2023, including Eurasian watermilfoil (left), and starry stonewort (right).

8.0 Landscape Ecology

[North-west shore of Lower Lake Dalrymple, August 2021]

8.1 Summary of Key Observations

- The Lake Dalrymple Watershed contains extensive natural heritage systems supporting both healthy and diverse terrestrial and aquatic ecosystems. The areas around Lake Dalrymple contain large tracts of forest, wetland and alvar and have benefitted from Couchiching Conservancy, the Nature Conservancy of Canada and the formation of the Carden Alvar Provincial Park and their combined efforts to set aside lands for protection and stewardship.
- The Lake Dalrymple Watershed has an abundance of wetlands, the majority being swamp. Wetlands serve several functions within a watershed, especially functioning to improve water quality. Swamps often contain dense forests, which act to slow the movement of water through watersheds and act as groundwater recharge areas.
- Wetlands are particularly important for providing fish and wildlife habitat, for example providing the source flow (headwaters) of the coldwater stream in the north-east. Marsh type wetlands are abundant in the lake, and help to reduce erosion around lakes and provide habitat for numerous fish, bird, reptile, amphibian, mammal, and invertebrate organisms.

8.2 Summary of Key Issues and Information Gaps

- Thirty-six species of conservation concern have been identified in the Lake Dalrymple study area. More information on the location and habitats is required to properly protect and potentially restore healthy populations of each species.
- Development in and adjacent to natural features is not common in the Lake Dalrymple watershed. However, the incremental pressure on these areas over time leads to portions of forests and wetlands being removed to make room for houses and cottages. Lakeshore properties continue to be sought after for development and less desirable areas such as swamps are targeted.
- Climate change alters terrestrial ecosystem conditions. The impacts of climate change will emanate from well beyond the watershed, but they can affect physical and biotic attributes and ecological functions within the watershed. Forests, already stressed by invasive plant and insect species, will continue to degrade due to climate change pressures. Without healthy natural heritage systems, diversity will decline, and species will be less resilient to the changes that occur to them.
- Limited understanding of the health and quality of terrestrial ecosystems. The terrestrial ecosystems have not been inventoried in detail to determine their health. No assessment of the resiliency of the terrestrial ecosystem to climate change has been completed.

8.3 Introduction

Landscape Ecology looks at the diversity in an area and includes both the biological and geological components and their interdependence on one another. Looking at areas that are completely natural and areas that are influenced by human activities and how the interaction of the two influences the abundance of organisms, as well as the behavior and function of the landscape.

Areas of natural cover provide many benefits and perform a variety of functions that are essential to overall watershed health including:

- filtering nutrients, sediments and pollutants from surface water runoff;
- improving air quality through filtration and oxygen generation;
- improving the natural aesthetic of communities thus contributing to the wellbeing of local citizens;
- maintaining aquatic and terrestrial wildlife habitat;
- performing flood attenuation;
- providing opportunities for recreation and for people to connect with the natural world through activities such as hiking, nature viewing, biking, fishing, and hunting;
- providing wildlife habitat & preserving biodiversity;
- reducing shoreline erosion by slowing and reducing surface water runoff;
- sequestering carbon to reduce atmospheric carbon dioxide levels, thus contributing to the mitigation of the effects of climate change; and,
- moderating summer temperature extremes through transpiration.

Alteration of natural cover within the Lake Dalrymple Watershed may affect some or all the above functions.

The entire Lake Dalrymple watershed contains 105 km^2 of natural cover, representing 77 % of the total terrestrial area. This includes areas classified as forest, wetland (all types), open water and cultural cover types such as plantations and fields that have become overgrown with shrubs and woodlands.

Figure 8.1 demonstrates the cover types existing within the sub-watersheds that drain into Lake Dalrymple.

8.4 Major Habitat Types

For management purposes, ecologists have created a hierarchy for the naming of ecosystems to reduce the complexity of managing the ecological resources on our planet. The area that the Lake

Dalrymple watershed falls in has been separated into management units known as eco-districts. Eco-districts, 71 of which are found in Ontario, are distinguished by their characteristic pattern of landscape features, with similar climate, soils and elevation. Eco-district 6E-9 represents the Four Lake Dalrymple watershed. Ecodistrict 6E-9's northern boundary follows the southern edge of the Canadian Shield and includes the limestone Carden Plains in the west, the Napanee Plain in the east and the till plains of the Dummer Moraine. Ecodistrict 6E-9 is primarily deciduous and mixed forests as well as swamp wetlands.

Ecological Land Classification (ELC) is a method to further classify natural cover types into vegetation community types within the Lake Dalrymple watershed. Vegetation communities for the watersheds were classified and mapped in 2023 based on the ELC System for Southern Ontario (Lee et al., 1998). All areas of the watershed were classified through interpretation of 2018 aerial photography. In total, 27 unique areas, based on the community series level of detail, were identified for the Lake Dalrymple watershed. Cultural areas refer to communities that have resulted from or are maintained by human-based influences. Cultural areas are often disturbed and, where plant species are present, a high proportion are of non-native origin and often invasive. Developed areas are in active and continuous use for purposes that do not support or are in direct conflict with naturally occurring ecosystems. Natural areas refer to natural cover that has not been subject to recent severe human-based disturbance, and therefore offer higher quality habitat and are a valuable resource in supporting healthy ecosystems. Vegetation community types are mapped in Figure 8.1.

The ELC assessment shows that the Lake Dalrymple watershed contains 5 % developed areas, 16 % agricultural, and 77 % natural community types. Forests in the Lake Dalrymple watershed, at 65 %, encompasses the greatest area of the natural cover community types, with mixed forest and deciduous forest being the two most dominant forest community types. Eight wetland types have been identified within the Lake Dalrymple watershed and account for 31 % of the total study area. The watersheds contain mostly coniferous swamp, deciduous swamp, and shallow marsh.

Table 8.1. Area and percentage of each land use type within the Lake Dalrymple watershed.

Land Use	Watershed Area (km^2)	Watershed Area (%)
Watershed (terrestrial portion)	**137**	**100**
Forest	32	24
Forested wetland	33	24
Alvar	22	16
Non-forested wetland	9	7
Meadow	6	4
Savannah	3	2
Total Cover (including plantations, meadows, and thickets)	**105**	**77**

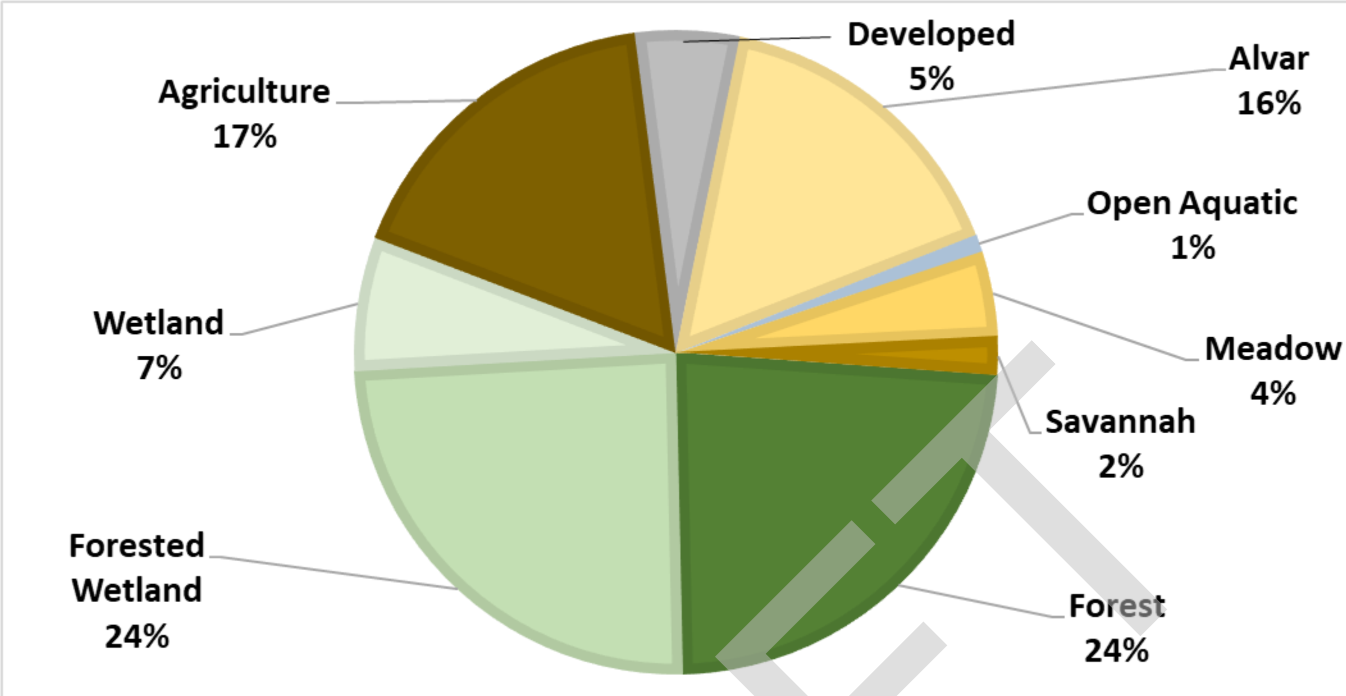

Figure 8.1. Lake Dalrymple Watershed Land Cover Based on Ecological Land Classification.

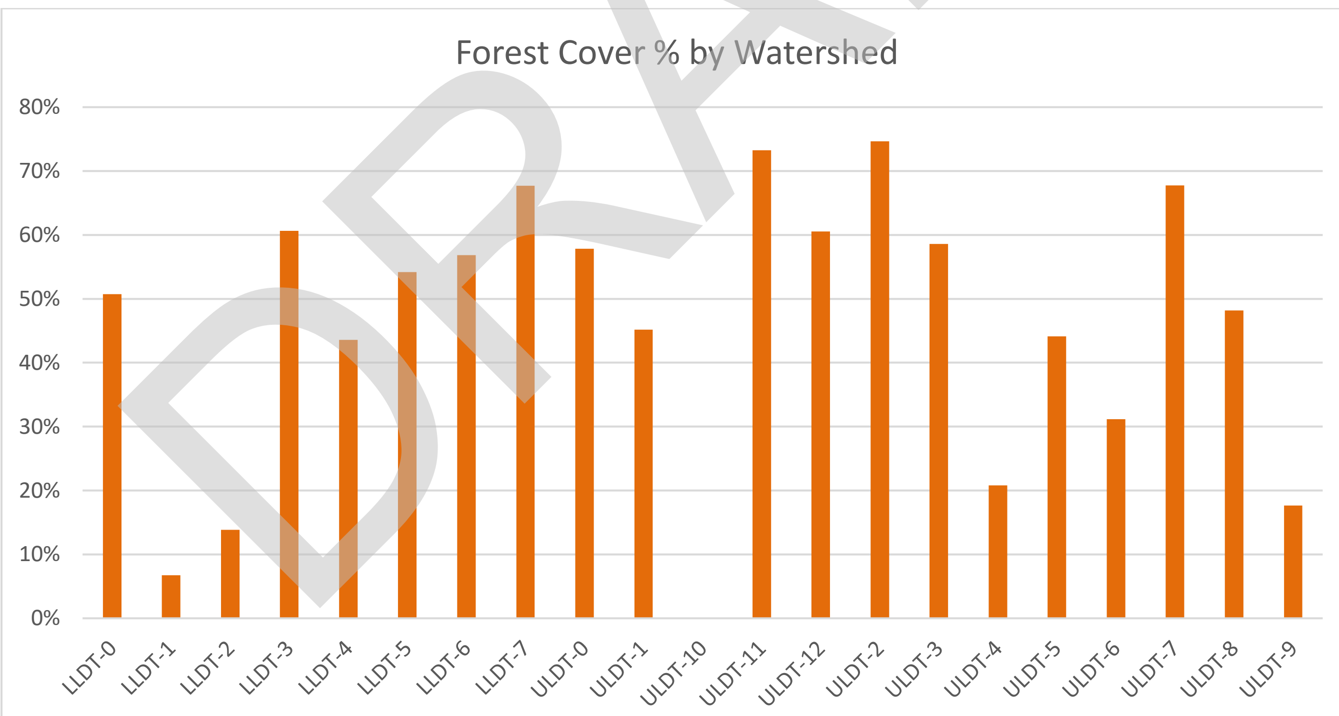

Figure 8.2. Forest Cover in Lake Dalrymple Watershed.

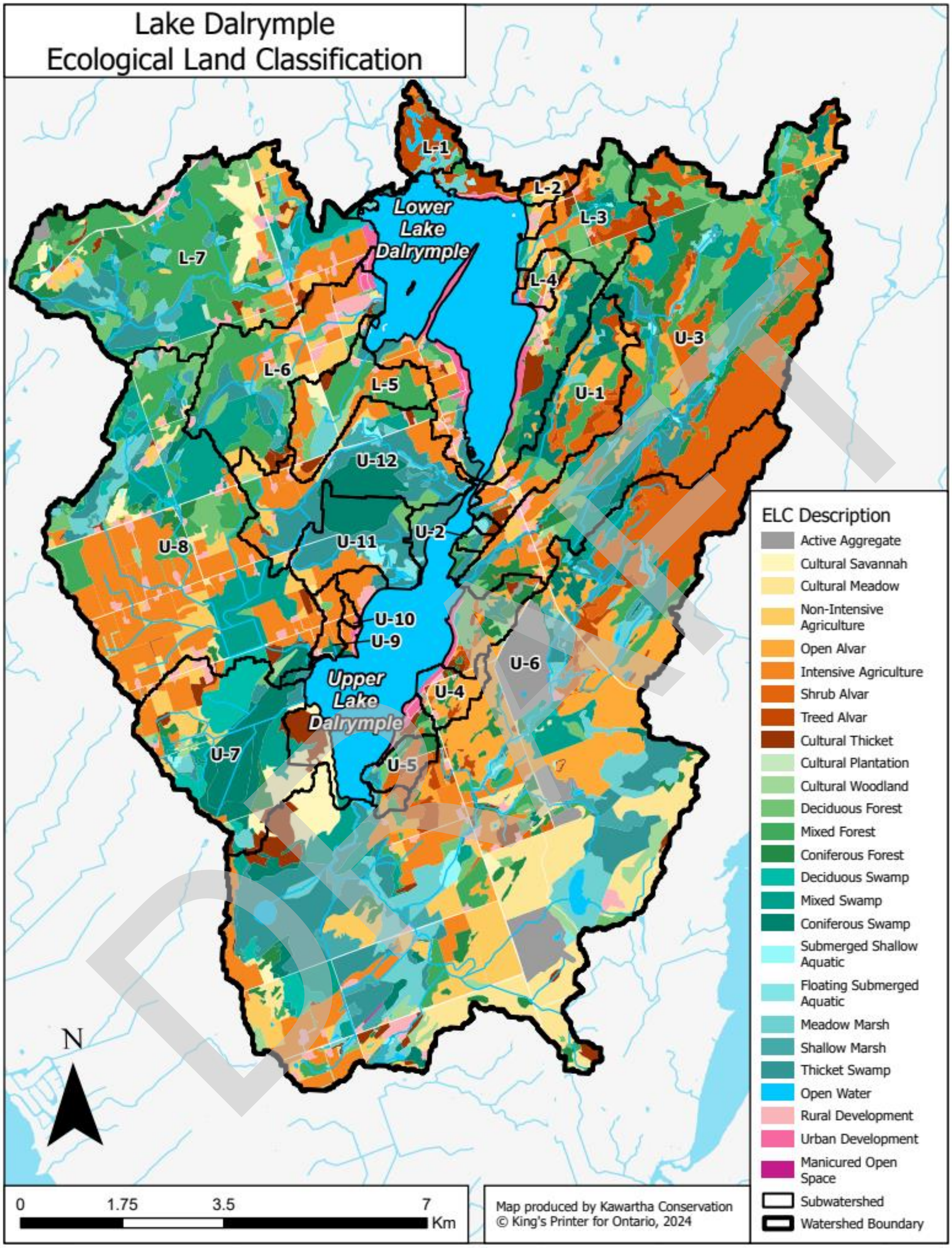

Figure 8.3. Ecological Land Classification in the Lake Dalrymple Watershed.

Forests covered more than 90 % of Southern Ontario prior to European settlement *(*Larson et al, 1999*)* and naturally occurring forests currently account for 65 % of the terrestrial portion of the Lake Dalrymple watershed (a combination of upland forests (32 %) and forested/treed wetlands (33 %). The forests that are found in the Lake Dalrymple watershed are mostly regrowth of forests that were cleared during European settlement. Today most of the forests and woodlands found in this area are relatively young and quite different from older forests that survived the clearing of the landscape and are now rare in Ontario. Today's forests are found in areas that are unsuitable for agriculture or development, such as swamps and river valleys that are prone to flooding, and the Canadian Shield, where granite bedrock is unsuitable for cropland. Due to the intermittent nature of some of these landscapes forests are often quite fragmented, however the Lake Dalrymple watershed has a large amount of natural cover, and fragmentation is not as extensive in this area as it is in other parts of southern Ontario.

The entire Lake Dalrymple watershed is currently 35 % higher than the target of 30 % forest cover for Areas of Concern watersheds within the great lakes basin (Environment Canada, 2004). Lake Dalrymple is 30 % higher than the Conservation Ontario target (Conservation Ontario, 2011) of 35 % forest cover for watersheds in Ontario.

Comparing the amount of forest cover with target levels suggests that conservation of forest and efforts to monitor and maintain forest health would be beneficial for overall watershed health. The areas of the watershed available for forest restoration are minimal with much of the watershed already under natural cover.

8.5 Features of Provincial Significance

Identifying significant natural heritage features provides an understanding of the unique conservation values associated with the watershed. This understanding allows natural heritage management efforts within the watershed to be focused on areas where they are most needed and can be most effective. Significant natural heritage features applicable to the terrestrial ecology of the watershed are discussed in the following sections.

Areas of Natural and Scientific Interest (ANSI's) are areas that have been identified by the Ontario Ministry of Natural Resources as having provincially or regionally significant representative ecological or geological features. Life Science ANSI's are designated based on ecological significance, and Earth Science ANSI's are designated based on geological significance. There are 2.53 km^2 of ANSI sites within the Lake Dalrymple watershed, consisting of a portion of the Carden Alvar, which extends a further 9.61 km^2 beyond the Lake Dalrymple watershed boundary.

There are several locally significant areas of natural and scientific interest located in the Lake Dalrymple watershed that have not been classified or identified by the province or Kawartha Conservation as regionally or provincially significant. These locally significant areas are an opportunity for further study, characterization, and potentially, inclusion into a natural heritage system.

The identification of significant wildlife habitat (SWH) areas for the watershed is guided by the Significant Wildlife Habitat Technical Guide (OMNR, 2000), and mapping provided by the OMNRF.

SWH is defined as: an area where plants, animals and other organisms live or have the potential to live and find adequate amounts of food, water, shelter, and space to sustain their population, including an area where a species concentrates at a vulnerable point in its annual or life cycle and an area that is important to a migratory or non-migratory species (OMMAH, 2002).

This discussion of SWH excludes types of habitats addressed in other sections of this report. SWH identified in this section includes seasonal concentration areas, rare vegetation communities and animal movement corridors.

Seasonal concentration areas are areas where a particular wildlife species congregates or that a species relies on during a certain time of year such as deer wintering yards, migratory bird stop-over areas, or reptile hibernation areas. Known seasonal concentration areas for wildlife within this watershed include deer wintering yards.

Animal Movement Corridors are typically long, narrow areas used by wildlife to move from one habitat to another. Such corridors facilitate seasonal migration, allow animals to move throughout a larger home range, and improve genetic diversity in species populations. To effectively serve their purpose, animal movement corridors must meet the needs of the species using the corridor. This includes consideration of corridor width, length, percent natural vegetation cover, and species composition.

The areas of the Lake Dalrymple watershed that are natural heritage features such as wetlands and forests, are composed of Core (large, unbroken areas that support a greater number of species and diversity) and linkages in the form of corridors. These areas of natural cover are found widely throughout the Lake Dalrymple watershed. The natural areas within the Lake Dalrymple watershed tend to be only minimally fragmented; maintaining core areas should be a planning priority.

Woodlands are considered significant because of the features and functions that they provide. Significant woodlands may include areas that have supported a treed community for more than 100 years, contain significant species, contain, or support other significant natural heritage features (such as significant wildlife habitat), provide supporting habitat for another KNHF (Key Natural Heritage Features), or act as an ecological linkage between KNHFs. Significant woodlands within the watershed make up an area of 25.6 km^2 and are illustrated in Figure 8.4.

Wetlands are key natural heritage and hydrologically sensitive features that occur on the landscape as single contiguous entities, or as complexes made up of a grouping of several small wetlands. All wetlands have high ecological value and are significant to the management of the watershed; however, the classification of provincially significant wetlands assists with prioritizing wetlands for conservation and protection under the Ontario Provincial Policy Statement. Figure 8.4 illustrates the location of provincially significant wetlands within the watershed. Figure 8.3 shows the location of all wetlands (provincially significant or otherwise), as classified by 2018 imagery aerial interpretation.

Environment Canada guideline on wildlife habitat recommends that approximately 10 % of each watershed and 6 % of each subwatershed in the Great Lakes basin should be wetland (Environment Canada, 2004). This guideline is based on evidence that occurrences of high flows and floods decrease significantly as the amount of wetland in a watershed increases. This inversely proportional relationship holds true until the amount of wetland reaches 10 % of the watershed, at which point the decrease in flood occurrences begin to level off.

The Lake Dalrymple watershed contains approximately 42 km^2 of wetland representing 31 % of the terrestrial area; this exceeds the 10 % minimum recommended percentage of wetland cover. There is a large area of wetlands that have been designated as provincially significant and represent 30 km^2 (71 %) of the total wetland area. The wetlands around the Lake, primarily Upper Lake Dalrymple are called Lake Dalrymple wetland RM3, the area to the west of Lake Dalrymple contains the Mara County Forest Wetland. All provincially significant wetlands (PSWs) are illustrated in Figure 8.4.

Wetlands have also been classified through air photo interpretation to a community series level using the ELC System for southern Ontario, first approximation (Lee et al., 1998).

Forested wetlands, including headwater wetlands, have high species diversity and are home to a complex food web that includes various microbes, bacteria, invertebrates and larger life forms. These include mammals, birds, reptiles, amphibians, fish, insects and other invertebrates that use wetlands as habitat for all or part of their life cycle, including for breeding and nesting seasons, migratory stopovers, resting and shelter, and food. In addition, wetlands perform these valuable functions within a watershed:

- Wetlands play a significant role in water filtration, having the capacity to remove harmful impurities, bacteria and excess nutrients. A study conducted on 57 wetlands from around the world concluded that 80 % of wetlands studied reduced nitrogen loadings and 84 % of wetlands studied reduced phosphorus loadings in water (Fisher and Acreman, 2004).
- Wetland plants are effective for stabilizing shoreline areas, trapping sediments and lessening the effects of erosion.
- Wetlands store water, reduce flood events, and help to replenish groundwater. After storms or spring snow melt, water is gradually released into streams, and can provide a critical function by maintaining stream flow during periods of drought.
- Wetlands are critical to the spawning success of many fish species and function as the nurseries of the lake and streams.

8.6 Important Bird Area

Important Bird Area (IBA) is a designation given to specific sites or areas around the world that are recognized for their significance in supporting and maintaining bird populations. The IBA program was developed by BirdLife International, a global partnership of bird conservation organizations, to identify and protect critical habitats for birds.

The criteria for designating an area as an Important Bird Area typically include considerations such as:

- Significant Bird Species: The area must support a substantial number of one or more bird species that have international, regional, or national conservation significance. This includes species that are rare, endangered, or have restricted ranges.
- High Bird Diversity: The site should host a diverse assemblage of bird species, contributing to overall biodiversity. The variety of species may include migrants, breeding residents, and other seasonal visitors.
- Habitat Quality: The quality and diversity of habitats within the area are crucial. This can include natural ecosystems like forests, wetlands, grasslands, or coastal areas that provide essential resources for birds, such as nesting sites, food sources, and migration stopovers.
- Vulnerability and Threats: The IBA program considers the vulnerability of bird populations in the designated area and the potential threats they face. This could include habitat loss, pollution, climate change, or other factors that may impact bird species.
- Global Significance: Some IBAs are designated as globally significant, meaning they play a crucial role in the conservation of bird species on an international scale.

Due to its proximity to the Carden Alvar, Carden Alvar Provincial Park and the wide range of core natural heritage features found the Lake Watershed, over 75 km^2 of the watershed area falls within the Carden IBA. The recognition of this area as an IBA has served as a focal point for conservation efforts. Conservation organizations such as Couchiching Conservancy and the Nature Conservancy of Canada have worked collaboratively to manage and protect these areas, implementing measures to mitigate threats and promote sustainable practices.

By recognizing and conserving Important Bird Areas, the IBA program contributes to the broader goal of safeguarding global bird biodiversity and the ecosystems they depend on, which complement many of the objectives that will be identified in the Lake Dalrymple Management Plan.

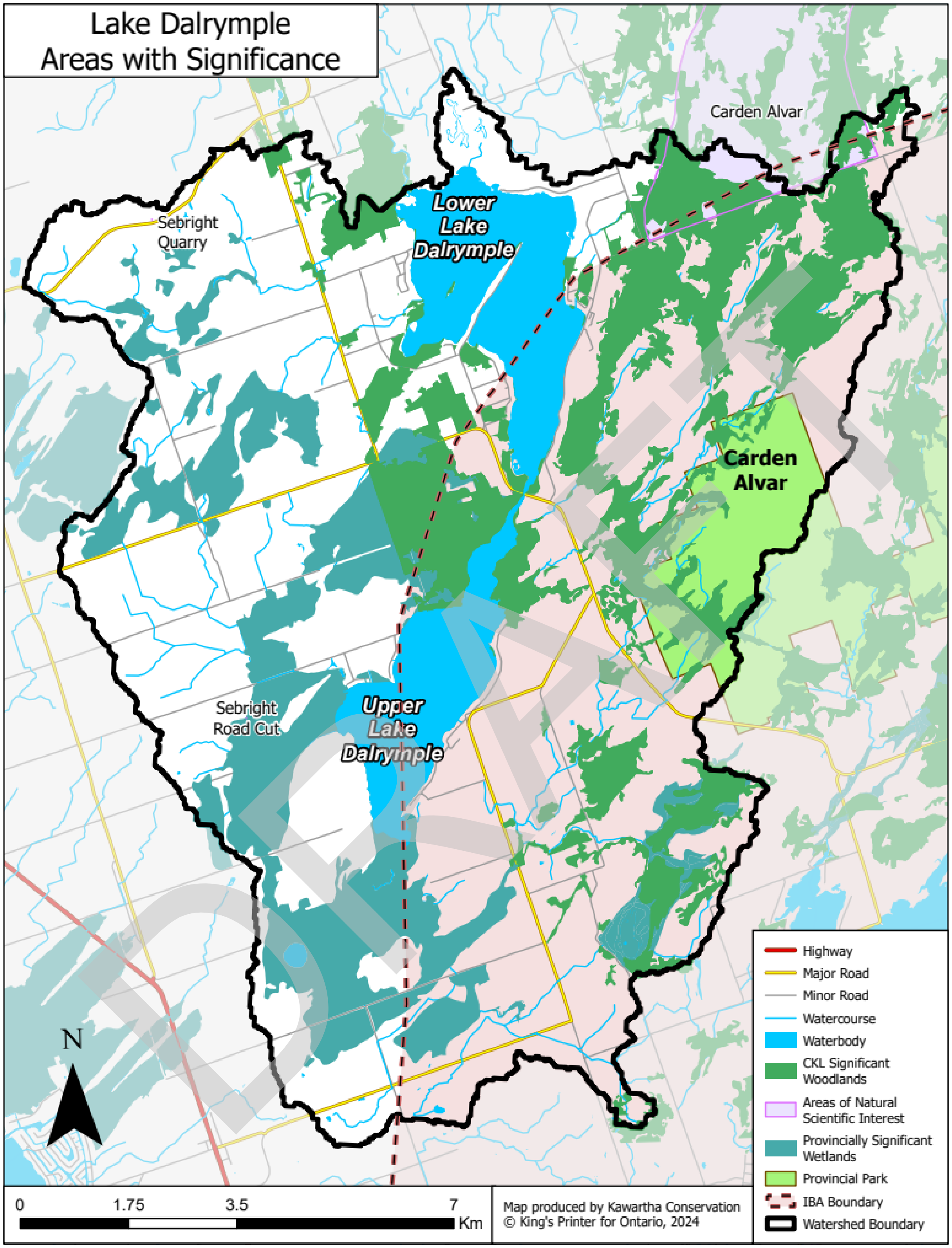

Figure 8.4. Features of provincial significance.

8.7 Natural heritage systems

A Natural Heritage System is the interconnected network of natural features and areas across the landscape. Natural heritage systems are composed of natural landscape features, wildlife, and areas such as wetlands, woodlands, valleylands, lakes, rivers, and creeks. Natural Heritage Systems are identified to help maintain biological and geological diversity, maintain ecological functions, movement corridors for wildlife, endangered species habitat and sustain ecosystem services that we all depend on such as pollination, clean water, and flood damage reduction. All of the provincially significant features identified in the previous section are key components of a natural heritage system and overlapping areas of significance are the core areas of importance in these systems.

The Provincial Policy Statement, 2020, states that “Natural heritage systems shall be identified in Ecoregions 6E & 7E1, recognizing that natural heritage systems will vary in size and form in settlement areas, rural areas, and prime agricultural areas.” It is up to each municipality in the identified Ecoregions to apply Ministry accepted Natural Heritage Systems in their Official Plans.

The Lake Dalrymple watershed has two separate natural heritage systems mapped, both developed through the Ministry of Natural Resources and Forestry. The firs Natural Heritage System project, Kawarthas Naturally Connected, was developed with input from local stakeholders, while the second, the Regional Natural Heritage System - Growth Plan for the Greater Golden Horseshoe, extends across much of southern Ontario and occupies most of the Lake Dalrymple Watershed area. The City of Kawartha Lakes has yet to amend their Official Plan to include natural heritage system mapping.

The Kawarthas, Naturally Connected project is a collaborative engagement process in which community members, practitioners, and other stakeholders in the Kawartha Lakes region developed a natural heritage system (NHS) using the best available data and tools (Figure 9.8).

Kawarthas, Naturally Connected is a multi-partner initiative established in 2011 by community members, practitioners, and other stakeholders in the City of Kawartha Lakes, Peterborough County, and the City of Peterborough, to ensure the protection of the cultural, social, ecological, and economic attributes of the area.

Kawarthas, Naturally Connected provides support for Lake Management Plan implementation through identification and prioritization of areas for stewardship activities. The Natural Heritage System has included natural features that are the highest priority for protection and restoration to achieve or sustain a healthy ecosystem that supports sustainable use of the land. Currently the Kawarthas, Naturally Connected system consists of a map of this system that has not been incorporated into any municipal planning documents. In addition to municipal planning, the natural heritage system can be applied to stewardship prioritization and land acquisition for long term protection of natural features.

For more information on the Kawarthas Naturally Connected system you can visit http://www.kawarthasnaturally.ca/

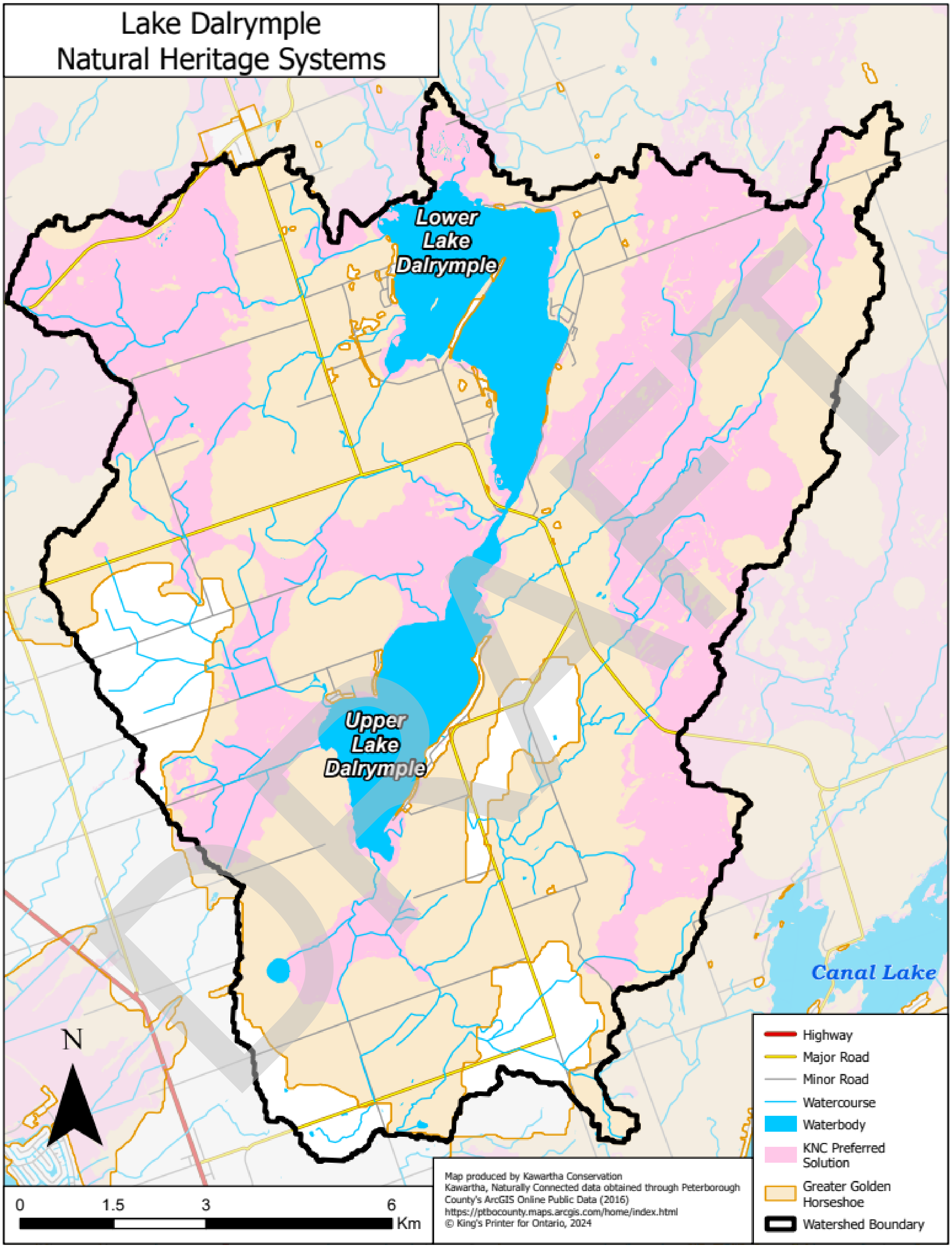

Figure 8.5. Natural Heritage Systems coverage in the study area.

8.8 Endangered, rare and threatened species and their habitats

Significant numbers of endangered, rare, and threatened species and their habitat exist within the Lake Dalrymple watershed. A full list of species, occurrences and their habitats are available on the OMNRF Natural Heritage Information Centre web site. Species that have been historically present within the Lake Dalrymple watershed are listed in Table 8.2.

Table 8.2. List of species of conservation concern within the Lake Dalrymple watershed.

Common Name	Scientific Name	SARO Status	COSEWIC Status
American Bumble Bee	*Bombus pensylvanicus*		SC
Barn Swallow	*Hirundo rustica*	THR	THR
Black Tern	*Chlidonias niger*	SC	NAR
Blanding's Turtle	*Emydoidea blandingii*	THR	END
Blushing Scale Lichen	*Psora decipiens*		
Bobolink	*Dolichonyx oryzivorus*	THR	THR
Canada Warbler	*Cardellina canadensis*	SC	THR
Common Nighthawk	*Chordeiles minor*	SC	SC
Eastern Meadowlark	*Sturnella magna*	THR	THR
Eastern Ribbonsnake	*Thamnophis sauritus*	SC	SC
Eastern Whip-poor-will	*Antrostomus vociferus*	THR	THR
Eastern Wood-pewee	*Contopus virens*	SC	SC
Field Thistle	*Cirsium discolor*		
Golden-winged Warbler	*Vermivora chrysoptera*	SC	THR
Grasshopper Sparrow	*Ammodramus savannarum*	SC	SC
Great Plains Ladies'-tresses	*Spiranthes magnicamporum*		
Horned Clubtail	*Arigomphus cornutus*		
Jelly-strap Lichen	*Thyrea confusa*		
Least Bittern	*Ixobrychus exilis*	THR	THR
Loggerhead Shrike	*Lanius ludovicianus*	END	END
Midland Painted Turtle	*Chrysemys picta marginata*		SC
Mottled Darner	*Aeshna clepsydra*		
Neglected Milk-vetch	*Astragalus neglectus*		
Northern Threetooth	*Triodopsis tridentata*		
One-sided Rush	*Juncus secundus*		
Pine Imperial Moth	*Eacles imperialis pini*		
Prairie Dropseed	*Sporobolus heterolepis*		
Prairie Warbler	*Setophaga discolor*	NAR	NAR

Purple Crystalwort	*Riccia beyrichiana*		
Shaly Tarpaper Lichen	*Enchylium polycarpon*		
Short-stalked Chickweed	*Cerastium brachypodum*		
Snapping Turtle	*Chelydra serpentina*	SC	SC
Soil Ruby Lichen	*Heppia adglutinata*		
Western Chorus Frog - Great Lakes - St. Lawrence - Canadian Shield population	*Pseudacris maculata pop. 1*	NAR	THR
Wood Thrush	*Hylocichla mustelina*	SC	THR
Yellow Rail	*Coturnicops noveboracensis*	SC	SC

THR – Threatened, END – Endangered, NAR – Not at Risk, SC – Special Concern, SX – Presumed Extirpated, SH – Possibly Extirpated, S1 – Critically Imperiled, S2 – Imperiled, S3 – Vulnerable, S4 – Apparently Secure, S5 – Secure (B – Breeding, N – Nonbreeding, M – Migrant, ? – Inexact/Uncertain)

One of the species on the list above is Endangered in Ontario, loggerhead shrike, and four species are threatened, Blanding's turtle, least bittern, bobolink, and Eastern whip-poor-will. Loggerhead shrike is given the highest level of protection for both the animal and its habitat under the Endangered Species Act, 2007. The loggerhead shrike's presence in the Carden Alvar has supported extensive areas being identified and protected as Conservation Lands by the Couchiching Conservancy and the Nature Conservancy of Canada, and significant efforts to safeguard and support the recovery of this species are in place. Fortunately, conservation efforts targeting one species support many others that are at risk, however further efforts to identify specific incidences of the various species and their habitats to better protect them and support their recovery should be initiated.

8.9 Terrestrial invasive species

Invasive terrestrial species pose significant ecological threats across various ecosystems, including forests, grasslands and wetlands, all of which are found in the Lake Dalrymple Watershed. These invaders, often introduced through human activities, can rapidly establish themselves, outcompeting native flora and fauna and disrupting the delicate balance of ecosystems. The impacts of invasive species are far-reaching, affecting biodiversity, ecosystem services, and even economic activities.

Invasive terrestrial species can lead to a decline in biodiversity by outcompeting native plants for resources such as sunlight, water, and nutrients. This competitive advantage often results in the displacement of native species, which can have a trickle-down effect on other organisms within the ecosystem. Additionally, invasive plants may alter soil composition, nutrient cycling, and water availability, further contributing to ecological imbalances. The invasion of non-native species can also disrupt important ecological processes like pollination and seed dispersal, affecting the overall health and resilience of ecosystems.

Invasive Species can have economic impacts, affecting agriculture, forestry, and other industries. In agriculture, invasive plants can reduce crop yields and increase the cost of pest control. In forestry, they can compromise timber quality and negatively impact the regeneration of native tree species, for example, Emerald Ash Borer. The costs associated with managing and controlling invasive species, whether through herbicides, manual removal efforts, or other means, pose a significant financial burden on affected regions, communities, and governments.

Sensitive alvar habitats in Ontario, characterized by limestone plains and thin soils, are particularly vulnerable to the impacts of invasive terrestrial species. The introduction of invasive plants threatens the unique biodiversity of alvars, disrupting the specialized plant communities adapted to these challenging environments. Invasive species can outcompete and displace native flora, including rare and endangered species, leading to the degradation of the delicate balance that makes alvar habitats ecologically significant. Conservation efforts in alvar habitats must prioritize prevention, early detection, and effective management strategies to protect these sensitive ecosystems from the detrimental impacts of invasive terrestrial species.

The five most significant invasive species impacting the terrestrial areas in the Lake Dalrymple Watershed are:

- European common reed (Phragmites australis): This invasive grass poses a severe threat to wetlands by forming dense monocultures that outcompete native vegetation. The aggressive growth of Phragmites alters the hydrology and nutrient cycling of the area, negatively wetlands.
- Wild parsnip (Pastinaca sativa): Wild parsnip is a highly invasive plant that has spread across Ontario, including the Lake Dalrymple watershed. Its toxic sap can cause skin burns upon contact, posing a threat to both humans and wildlife. Wild parsnip disrupts native plant communities and can outcompete native vegetation crucial for local ecosystems.
- Garlic mustard (Alliaria petiolata): Garlic mustard is an aggressive invasive herb that has the potential to dominate the forest understory in the Lake Dalrymple watershed. Its allelopathic properties inhibit the growth of native plants, particularly spring ephemerals, which are vital to native forest plant diversity.
- Common buckthorn (Rhamnus cathartica): Common buckthorn is a woody shrub that invades open spaces. Its dense thickets can displace native vegetation, reducing habitat quality and impacting the biodiversity of ecosystems. Common buckthorn is widespread in Ontario and very difficult to remove once established.
- Dog-strangling vine (Vincetoxicum rossicum): This invasive vine poses a significant threat to ecosystems by climbing and smothering native vegetation. It creates dense mats that hinder the growth of other plants.

Addressing the threat of these and other invasive species in Lake Dalrymple watershed requires a comprehensive and coordinated conservation approach. Efforts should include early detection and rapid response strategies, community engagement in invasive species removal projects, and ongoing monitoring to assess the effectiveness of management efforts. Additionally, public education and awareness campaigns are essential to prevent the unintentional spread of invasive species.

8.10 Ecological goods and services

Natural areas such as wetlands and forests are a critical part of any terrestrial ecosystem. However, the value of natural areas goes far beyond the role they play in the local ecosystems, and recently it has become more common to identify the benefits that are produced by the ecological functions and translate those benefits into the monetary value of the ecological goods and services that they produce. Examples of ecological goods and services are clean air, fresh water, maintaining biodiversity, renewal of soil and vegetation, carbon storage, pollination and natural biological controls.

The type of natural area may influence its ecological goods and services value, but its location on the landscape is also a major factor. For example, wetlands found in non-urban, non-coastal areas are valued at $15,170/ha, however an urban wetland is valued at $161,420/ha (Troy and Bagstad, 2009). The values placed on various land cover types were estimated by looking at the benefits that people obtain directly or indirectly from ecological systems. Some examples are food production, climate stabilization and flood control, aesthetic views, and recreational opportunities to name a few. A study by Ducks Unlimited determined that wetlands provide phosphorous removal that equates to $27,664 per hectare in water treatment services (DUC, 2011).

8.11 Capacity assessment (landscape targets)

The Lake Dalrymple Watershed has a rich collection of natural heritage features and would require stewardship and conservation efforts to meet the landscape targets that have been identified in both federal Environment Canada's How Much Habitat is Enough (HHE) (Environment Canada, 2011) and by the Ontario provincial government's Great Lakes Conservation Blueprint (GLCB) for Terrestrial Biodiversity (Province of Ontario, 2005).

HHE provides habitat guidelines for several natural feature categories, which provide straightforward targets for conservation planning. Forest cover targets are a good example, with HHE identifying 30 % forest cover at the watershed scale as "the minimum forest cover threshold. 30 % forest cover is considered a high-risk approach and may only support less than half of the potential species richness, and marginally healthy aquatic ecosystems." (Environment Canada, 2013). Therefore, due to the number of sensitive species and habitats found in the Lake Dalrymple Watershed, a "no net loss" approach should be taken, and the most protective conservation guidelines should be applied. Therefore, with forest cover as an example, the guideline would be a 50 % forest cover threshold (currently 48 % of the terrestrial area is wetland), which "equates to a low-risk approach that is likely to support most of the potential species, and healthy aquatic systems." (Environment Canada, 2013).

Wetland targets set by HHE are 10 % of major watersheds and 6% of small subwatersheds. The Lake Dalrymple Watershed has over 31 % wetlands, with over three quarters being swamp type wetlands. Nineteen out of 23 sub-watersheds within the Lake Dalrymple watershed achieve the 10 % target for wetlands, therefore, a sensible guideline for wetlands would be to maintain the existing wetland cover and strive for “no net loss”. Further data could be collected on the wetlands within the Dalrymple watershed to determine wetland types, e.g. Fens and Bogs and rarity of wetland types could guide further protection and restoration measures.

The Great Lake Conservation Blueprint would require that 23 % of the remaining natural cover, and over 40 % of all species and vegetation community targets be set aside in order meet conservation targets. Therefore, due to the extent of natural existing natural cover and based on the targets from How Much Habitat is Enough, the Lake Dalrymple Watershed would successfully meet these targets.

The table below provides the basis for landscape targets to achieve a low-risk approach that would support species diversity and healthy ecosystems in the Lake Dalrymple Watershed.

Table 8.3. Landscape cover targets.

Feature Type	Target for the Watershed	Existing Conditions in Dalrymple Watershed
Forest/Woodlands	50% forest cover	48 % Forest Cover (24 % forested wetland)
Wetlands	No net loss	31 % Wetland Cover (24 % forested)
Alvar	No net loss	16 % Alvar
Core Natural Heritage Features	No net loss of identified Core Areas	Two identified Natural Heritage Systems, Greater Golden Horseshoe and Kawartha Naturally Connected
Species at Risk	No net loss of species or habitat	36 Terrestrial Species at Risk identified

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