Hutchinson

Environmental Sciences Ltd.

Lake Clear Capacity Assessment

Prepared for: Township of Bonnechere Valley
Job #: 220081

October 17, 2023

Final Report

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Signatures

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Executive Summary

Lake Clear is considered to be an "at-capacity lake" in the County of Renfrew's Official Plan as it supports a natural Lake Trout (*Salvelinus namaycush*) population and Mean Volume-Weighted Hypolimnetic Dissolved Oxygen concentrations have been measured below the Provincial criterion of 7 mg/L for the protection of Lake Trout habitat. Hutchinson Environmental Sciences Ltd. (HESL) was retained to complete a Lakeshore Capacity Assessment of Lake Clear as the Township of Bonnechere Valley is considering developing a By-law to allow Recreational Vehicles (RVs) to be located on waterfront properties. A Lakeshore Capacity Assessment is required to determine if Lake Clear is at capacity for development through a) completion of a Lakeshore Capacity Model to determine development capacity with respect to the Provincial Water Quality Objective for phosphorus, and b) updated evaluation of MVWHDO concentrations with respect to the 7 mg/L criterion. A background review and field investigations were completed to characterize water quality conditions in Lake Clear. Additional discussion on lake water quality parameter concentrations and trends, and waterfront Best Management Practices was also included to help inform conclusions and recommendations.

Lake Clear is under capacity according to Lakeshore Capacity Modelling results and the total phosphorus (TP) Provincial Water Quality Objective. It is over capacity with respect to Mean Volume-Weighted Hypolimnetic Dissolved Oxygen as concentrations are <7 mg/L but modelling indicates that oxygen concentrations were slightly below 7 mg/L prior to development. Water quality is good and there are no increasing trends in nutrients. Small amounts of cyanobacteria (i.e. blue-green algae) were however observed during site investigations.

Shoreline development, including RV use, can impact a lake through stormwater and wastewater inputs as well as associated recreational uses such as boating. Impacts can be largely mitigated through implementation of BMPs such as properly designed and maintained sewage treatment systems, the retention or establishment of naturally vegetated shoreline buffers and stormwater management features that maximize infiltration and minimize runoff. Currently the use of RVs of Lake Clear is unregulated and therefore it is not known if they are properly serviced via appropriately sized tile beds or holding tanks that are pumped out regularly. We underscore that the impact of RVs on the lake's water quality depends not only on the number of shoreline RVs but also the effectiveness of RV wastewater management in minimizing nutrient loading to the lake.

The following recommendations were developed to help the Township develop science-based planning policy for RV use on Lake Clear:

- Permit the use of 1 or 2 RVs/lot on Lake Clear if appropriate BMPs are developed and enforced to ensure that impacts to Lake Clear are minimized. The modelled impact of two additional RVs/lot results in TP concentrations that are less than the PWQO for TP. The lake is at capacity based on MVWHDO but based on modelling results, it appears that MVWHDO concentrations have always been below the 7 mg/L criterion, and BMPs can be utilized to minimize impacts.

- Sewage treatment systems to service the RVs should meet Ontario Building Code requirements. Systems designed to maximize the amount of phosphorus attenuation should be encouraged such as the Waterloo Biofilter with EC-P unit, EcoFlo Biofilter or the use of a tank and bed system

that incorporates soils that are high in phosphorus retention, aluminum and iron, and low in calcium carbonate.

- A 30 m naturally vegetated shoreline buffer should be required on all lots, especially lots with RVs that have the potential to generate additional stormwater and wastewater. Continued retention or establishment of natural vegetation over time should be encouraged through stewardship actions and enforced as necessary.

- Stormwater management features that maximize infiltration and limit stormwater runoff should be encouraged on all lots, especially those with RVs that have the potential to generate additional stormwater, to minimize development-related impacts on Lake Clear.

- Water quality and the effectiveness of BMPs should be monitored. Water quality should continue to be monitored through the Lake Partner Program, and dissolved oxygen measurements should be collected annually at the end-of-summer (August 15 – September 15) so that Mean Volume-Weighted Hypolimnetic Dissolved Oxygen concentrations can be calculated and tracked over time. The implementation and management of BMPs should be assessed through visual inspections.

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Acronyms

A0	lake area
BMP	best management practice
CWQG	Canadian water quality guideline
DO	dissolved oxygen
HESL	Hutchinson Environmental Sciences Ltd.
LCM	Lakeshore Capacity Model
LPP	Lake Partner Program
MD	maximum distance (fetch)
MECP	Ministry of the Environment, Conservation and Parks
MNRF	Ministry of Natural Resources and Forestry
MOE	Ministry of the Environment
MOECC	Ministry of the Environment and Climate Change
MPAC	Municipal Property Assessment Corporation
MVWHDO	mean volume-weighted hypolimnetic dissolved oxygen
OWIT	Ontario Watershed Information Tool
PWQO	Provincial Water Quality Objective
Rs	LCM coefficient for phosphorus retention by soil
RV	recreational vehicle
TP	total phosphorus
TP_{FUTURE}	total phosphorus concentration assuming vacant lots developed as extended seasonal (LCM prediction)
TP_{LAKE}	total phosphorus concentration during the ice-free season (LCM prediction)
TP_{SO}	total phosphorus concentration at spring overturn (LCM prediction)
VSA	volume-to-sediment-area ratio
z	depth

1. Introduction

Lake Clear (45.44°N, 77.20°W) is a relatively small (17 km^2), deep (~40 m), oligotrophic lake located in the Township of Bonnechere Valley (County of Renfrew), approximately 120 km west of Ottawa. Popular recreational uses of the lake include swimming, canoeing, kayaking, and fishing, and based on a resident survey, water quality is considered the main issue faced by the lake and the top element affecting personal enjoyment of the lake, with algae/aquatic vegetation the main concern (Love Your Lake 2022). Lake Clear's drainage basin is small (76 km^2) and predominantly (~80%) forested, with agriculture and undifferentiated rural land use comprising 10% of the catchment (Ministry of Natural Resources and Forestry [MNRF] 2023). Although shoreline development density is modest, Lake Clear is considered to be an "at-capacity lake" in the County of Renfrew's Official Plan (County of Renfrew 2020); it has been designated as a "Natural Lake Trout Lake" in *Inland Ontario Lakes Designated for Lake Trout Management* (MNRF 2015) and Mean Volume Weighted Hypolimnetic Dissolved Oxygen (MVWHDO) concentrations have been measured below the Provincial criterion of 7 mg/L to protect Lake Trout (*Salvelinus namaycush*) habitat (Ministry of Environment and Climate Change [MOECC] 2016).

Hutchinson Environmental Sciences Ltd. (HESL) has been retained to complete a Lakeshore Capacity Assessment of Lake Clear as the Township of Bonnechere Valley is considering developing a By-law to allow Recreational Vehicles (RVs) to be located on waterfront properties. A Lakeshore Capacity Assessment is required to determine if Lake Clear is in fact at capacity for development through a) completion of a Lakeshore Capacity Model to determine development capacity with respect to the Provincial Water Quality Objective (PWQO) for phosphorus, and b) updated evaluation of MVWHDO concentrations with respect to the 7 mg/L criterion. Best Management Practices associated with shoreline development and RVs are also discussed to inform the development of the By-law and minimize impacts associated with development and RV use on Lake Clear, and, if there is capacity, how development impacts associated with RVs can be minimized.

Ontario's Lakeshore Capacity Model (Ministry of Environment [MOE] 2010) was developed to determine suitable development capacity on lakes through an assessment of phosphorus and the associated modelling procedure of Molot et al (1992) for dissolved oxygen (DO) concentrations. For recreational lakes on the Precambrian Shield, phosphorus and DO concentrations are the parameters of concern for water quality. The revised PWQO for inland lakes on the Precambrian Shield (MOE 2010) allows for a 50% increase in phosphorus concentration from development over levels that would occur in the absence of any development on the lake (i.e., "Background" + 50%) to a maximum concentration of 20 µg/L. The DO guideline for protection of Lake Trout habitat is 7 mg/L as End-of-Summer MVWHDO (i.e. measured between August 15 and September 15).

The Province of Ontario recommends the use of the Lakeshore Capacity Model (LCM) to determine the PWQO for phosphorus and the amount of shoreline development that can occur to maintain phosphorus levels within the phosphorus threshold (MOE 2010). The LCM is a steady-state mass balance model that estimates hydrologic and phosphorus loading from natural (watershed runoff and atmospheric deposition) and human (septic systems and land disturbance) sources and links them together considering lake dynamics to predict total phosphorus (TP) concentrations in lakes. Dissolved oxygen is modelled on the basis of lake morphometry and TP concentrations using the techniques described in Molot et al. (1992) and

Clark et al. (2002) and is commonly used to link phosphorus concentrations with MVWHDO as part of existing and future development scenarios.

A background review and field investigations were completed to characterize water quality conditions in Lake Clear and allow for the determination of development capacity through Lakeshore Capacity Modelling and DO modelling. Additional discussion on lake water quality parameter concentrations and trends, and waterfront Best Management Practices was also included to help inform conclusions and recommendations.

2. Background Review

HESL assembled and reviewed the following existing data for Lake Clear:

- MECP's Lake Partner Program data: TP (2002–2020), calcium (2008–2020), and chloride (2015–2020) concentrations and Secchi depths (1996–2020);
- MECP water quality data (2003, 2010, 2011, 2018): TP, ammonia, nitrite, nitrate, total Kjeldahl nitrogen, dissolved organic carbon, alkalinity, conductivity, calcium, hardness, total suspended solids, total dissolved solids; and
- MECP temperature and dissolved oxygen profiles (2003, 2010, 2011, 2018).

Summaries and visualizations of the existing data are presented in Section 4.

3. Field Investigation

HESL performed a field survey of Lake Clear on 7 September 2022. MOE (2010) recommends that dissolved oxygen measurements are collected between August 15 and September 15 for use in MVWHDO calculations. Six sites were selected that correspond to the deepest areas in the western, central, and eastern areas of the lake (Figure 1; Table 1).

Table 1. Coordinates and Depths of HESL Sites.

Site	Depth (m)	Latitude	Longitude
LC-1	20.7	45.4469	-77.2223
LC-2	25.4	45.4350	-77.2009
LC-3	20.1	45.4442	-77.1876
LC-4	25.2	45.4404	-77.1739
LC-5	35.2	45.4320	-77.1736
LC-6	38.1	45.4364	-77.1609

The Secchi depth was determined using a black-and-white 20-cm disc at each site. Water samples were then collected from the epilimnion by weighted bottle (integrated from the surface to Secchi Depth) and from ~1-m above the lakebed ("1-mob") using a Kemmerer sampling device. Water column profiles of temperature, DO, specific conductance, and pH were measured at a 1-m interval using a YSI sonde. The sonde was calibrated by Pine Environmental Services and the DO sensor was corrected for barometric pressure in the field prior to use. Water samples were shipped to ALS Laboratories for determination of chlorophyll-a, total nitrogen, nitrate, ammonium, dissolved organic carbon, calcium, and chloride (epilimnetic samples only), TP and total suspended solids (both epilimnetic and 1-mob samples), and total iron (1-mob samples only).

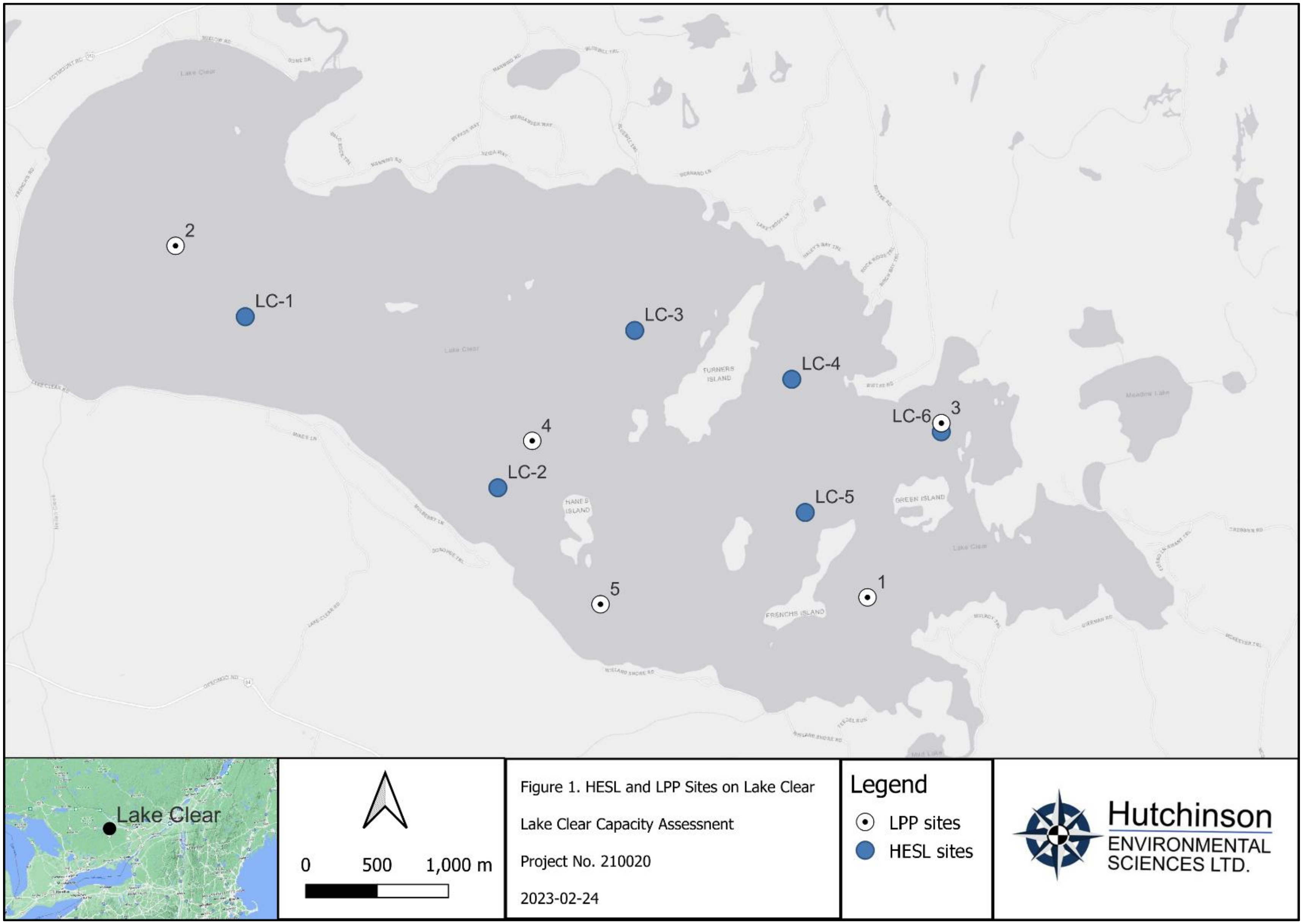


Figure 1. HESL and LPP Sites on Lake Clear

Lake Clear Capacity Assessnent

Project No. 210020

2023-02-24

4. Analysis

4.1 Water Quality

4.1.1 Water Clarity

Lake Clear has high transparency: the average Secchi depth ranged between 6.7 m and 7.2 m across 4 sites based on long-term monitoring via the LPP (Table 2). The longest period of record is for the “N. end, deep spot” (45.4517°, -77.2281); here there was an increasing trend (~5 cm/year) in the annual average Secchi depth over the period 1996–2020 (R^2 = 0.23; p = 0.03; data not shown), indicating increasing water transparency. MECP has reported Secchi depths in the range of 4.5–5.0 m and of 5.5 m, for 2003 and 2011, respectively (MOE 2016). Secchi depths measured during the HESL survey on 7 September 2022 were between 7.7 m and 8.2 m (avg. = 8.0 m), higher than the long-term averages, but still within the range historically observed via LPP monitoring. Consistent with the high clarity, the concentration of total suspended solids has been relatively low in Lake Clear, averaging 1.4 mg/L according to MECP monitoring (range: 0.8–3.0 mg/L; Table 3) and confirmed to be <3 mg/L based on the recent HESL survey (Table 4).

Table 2. Summary of Secchi Depth (1996–2020), TP (2002–2020), Calcium (2008–2020), and Chloride (2015–2020) from Lake Partner Program Monitoring.

***Site #**	**Secchi Depth (m)**				**TP (µg/L)**				**Calcium (mg/L)**				**Chloride (mg/L)**			
	min.	**avg.**	max.	*n*	min.	**avg.**	max.	*n*	min.	**avg.**	max.	*n*	min.	**avg.**	max.	*n*
1	3.1	**6.9**	10.4	79	5.3	**9.0**	12.7	19	33.5	**37.7**	41.1	12	11.8	**13.4**	14.2	6
2	4.6	**6.7**	8.6	89	5.4	**8.6**	11.4	16	30.8	**35.6**	38.9	9	13.1	**13.7**	14.0	4
3	0.6**	**6.9**	9.1	54	5.0	**7.4**	12.4	15	34.5	**36.4**	40.1	9	13.3	**13.6**	13.8	4
4	4.6	**7.2**	10.1	89	5.4	**9.0**	13.0	15	34.1	**37.0**	40.1	12	13.0	**13.5**	14.1	5
5	5.8	**7.0**	8.2	96	6.7	**8.5**	11.0	10	33.3	**36.2**	38.5	10	12.0	**13.7**	14.7	6

**Site numbers correspond to the following descriptions: (1) “E. end, centre”, (2) “N. end, deep spot”, (3) “E end, Hardwood Bay”, (4) “Hanes Island West”, and (5) "South End". **The Secchi Depth of 0.6 m is an outlier (very low) and almost certainly due to an observer error or data entry error.*

4.1.2 Nutrients

Nutrients are relatively low in the upper mixed layer of Lake Clear. Average TP concentrations were 7.4–9.0 µg/L (overall range: 5.0–13.0 µg/L; Table 2) for the period 2002–2020 based on LPP monitoring); the average concentrations are below the interim PWQO of 10 µg/L for “a high level of protection against aesthetic deterioration” (MOEE 1994). There was no significant temporal trend in the annual average TP concentration for any of the LPP sites (all $R^2 < 0.2$; all $p > 0.1$; data not shown). Data provided by the MECP have a comparable median TP concentration of 6.0 µg/L, though with much higher average (15.9 µg/L) and maximum (79.0 µg/L) concentrations than recorded in the LPP dataset (Table 2).

Surface nitrogen concentrations are also relatively low, with almost no nitrite, little ammonium, and nitrate well below the Canadian Water Quality Guideline of 3 mg-N/L (Table 3). Similarly, chloride has never been measured above the CWQG of 120 mg/L, averaging only approximately 13–14 mg/L.

Most water-quality parameters did not differ appreciably between the euphotic zone and directly above the lakebed (compare Table 3 with Table 5); however, nitrate and TP were both much higher "off bottom" (averages of 46.8 µg/L and 0.188 mg-N/L, respectively) than in the upper mixed layer (averages of 15.9 µg/L and 0.021 mg-N/L, respectively).

The TP and total iron concentrations of 1-mob samples from the 7 September 2022 survey were significantly and positively correlated among sites (Pearson's r = 0.81; p < 0.05), and the minimum DO concentration at each site was negatively correlated with the 1-mob concentrations of iron (r = -0.92; p < 0.01) and phosphorus (r = -0.73; p = 0.10); these correlations suggest that phosphorus is liberated from ferric oxyhydroxides in the sediments under anoxic conditions (i.e., that internal phosphorus loading is occurring due to oxygen depletion above the lakebed).

Table 3. Summary of Euphotic Zone Chemistry based on MECP Monitoring (2003–2018).

	n	Min.	10th%ile	25th%ile	Avg.	Median	75th%ile	90th%ile	Max.
Ammonia, Total (mg-N/L)	8	0.006	0.014	0.020	0.063	0.030	0.041	0.128	0.307
Calcium	7	30.8	32.5	33.7	34.7	34.5	36.2	37.6	38.2
Chloride	2	12.8	12.9	13.0	13.1	13.1	13.3	13.3	13.4
Conductivity (µS/cm)	8	245	245	248	262	256	271	289	292
Dissolved Inorganic Carbon	8	23.9	24.5	24.8	26.3	26.7	27.8	27.9	28.0
Dissolved Organic Carbon	8	3.2	3.2	3.4	5.7	3.6	4.6	9.7	18.4
Hardness	7	105	108	112	115	115	120	122	124
Magnesium	7	6.4	6.7	7.0	7.0	7.1	7.2	7.4	7.5
Nitrate + Nitrite (mg-N/L)	8	0.005	0.006	0.009	0.021	0.019	0.024	0.041	0.049
Nitrite (mg-N/L)	8	0.001	0.001	0.001	0.002	0.001	0.003	0.005	0.006
pH	8	8.01	8.08	8.19	8.29	8.32	8.39	8.46	8.57
Potassium	2	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sodium	2	7.5	7.5	7.6	7.7	7.7	7.9	7.9	8.0
Sulphate	2	4.8	4.9	4.9	5.1	5.1	5.2	5.3	5.3
Total Alkalinity	8	99	103	106	110	109	115	119	120
Total Dissolved Solids	5	159	160	162	165	163	170	172	173
Total Kjeldahl Nitrogen	8	0.03	0.16	0.26	0.50	0.29	0.48	1.02	1.76
TP (µg/L)	8	4.0	4.0	4.8	15.9	6.0	9.3	34.9	79.0
Total Suspended Solids	5	0.8	0.8	0.9	1.4	1.0	1.2	2.3	3.0

Note: Units are mg/L except for pH (unitless) and where otherwise specified. Data are for site "Lake Clear – Main Basin".

Table 4. Water quality of Lake Clear on 7 Sep 2022 based on HESL Survey.

	Units	Median	LC-1	LC-2	LC-3	LC-4	LC-5	LC-6
Site Depth	m	25.3	20.7	25.4	20.1	25.2	35.2	38.1
Secchi Depth	m	7.9	8.2	7.7	8.1	7.9	7.9	7.9
Ammonia, Total	mg-N/L	<0.0050	<0.0050	0.0316	<0.0050	<0.0050	<0.0050	0.0081
Calcium	mg/L	30.8	30.6	30.9	30.6	30.6	31.2	31.0
Chloride	mg/L	15.3	15.3	15.3	15.3	15.3	16.1	15.3
Chlorophyll-a	µg/L	0.95	0.84	1.17	0.62	0.62	1.33	1.06
Dissolved Organic Carbon	mg/L	4.14	4.45	4.15	4.05	4.29	3.99	4.12
Dissolved Reactive P	µg/L	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Iron	µg/L	(29)	(14)	(55)	(11)	(15)	(42)	(64)
Nitrate	mg-N/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Total Kjeldahl Nitrogen	mg-N/L	0.258	0.260	0.277	0.238	0.255	0.251	0.267
TP	µg/L	5.6 (17.8)	7.5 (8.0)	4.6 (73.3)	5.1 (8.0)	6.4 (4.2)	4.8 (27.5)	6.1 (35.7)
Total Suspended Solids	mg/L	<3.0 (<3.5)	<3.0 (<3.0)	3.9 (3.5)	<3.0 (<3.0)	<3.0 (<3.0)	<3.0 (4.1)	<3.0 (4.5)

Note: Numbers in parentheses are from 1-m-off-bottom samples; other values are from integrated samples (surface to Secchi depth).

Table 5. Summary of Off-Bottom Chemistry based on MECP Monitoring (2003–2018).

	n	Min.	10th%ile	25th%ile	Avg.	Median	75th%ile	90th%ile	Max.
Ammonia, Total (mg-N/L)	5	0.007	0.025	0.052	0.047	0.052	0.056	0.063	0.067
Calcium	5	33.4	35.5	38.7	38.2	38.9	39.1	40.1	40.7
Chloride	1	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
Conductivity (µS/cm)	5	262	262	263	268	267	273	273	273
Dissolved Inorganic Carbon	5	26.5	26.9	27.6	28.0	27.7	28.3	29.3	29.9
Dissolved Organic Carbon	5	3.0	3.1	3.2	3.3	3.3	3.3	3.6	3.8
Hardness	5	111	117	125	124	126	127	129	130
Magnesium	5	6.6	6.8	7.0	7.0	7.0	7.1	7.2	7.2
Nitrate + Nitrite (mg-N/L)	5	0.133	0.142	0.156	0.188	0.172	0.195	0.248	0.283
Nitrite (mg-N/L)	5	0.001	0.001	0.002	0.004	0.003	0.003	0.007	0.010
pH	5	7.89	7.93	7.99	8.13	8.18	8.28	8.31	8.33
Potassium	1	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sodium	1	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
Sulphate	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Total Alkalinity	5	112	114	116	116	117	118	119	119
Total Dissolved Solids	3	174	175	176	176	177	177	177	177
Total Kjeldahl Nitrogen	5	0.20	0.24	0.30	0.29	0.32	0.32	0.33	0.33
TP (µg/L)	5	24.0	30.8	41.0	46.8	50.0	53.0	60.8	66.0
Total Suspended Solids	3	1.1	1.2	1.3	1.8	1.5	2.1	2.5	2.7

Note: Units are mg/L except for pH (unitless) and where otherwise specified. Samples were collected from 1-m off bottom from site “Lake Clear – Main Basin”.

4.1.3 Phytoplankton

Chlorophyll-a concentrations on 7 September 2022 were approximately 1 µg/L (Table 4), indicative of low phytoplankton biomass. FluoroProbe fluorescence measurements made on this date indicate a phytoplankton community of mixed composition but dominated by algae with very little cyanobacteria (i.e. blue-green algae) (Figure 2). Although cyanobacteria made only a minor contribution to the phytoplankton biomass, HESL did observe macroscopic colonies in the water column at multiple sites during the field survey; the colonies were examined using a compound microscope and identified as a species of the genus *Gloeotrichia* (Photographs 1 and 2); this potentially toxic, colonial cyanobacterium is known to bloom in low-nutrient lakes (Carey et al. 2012).

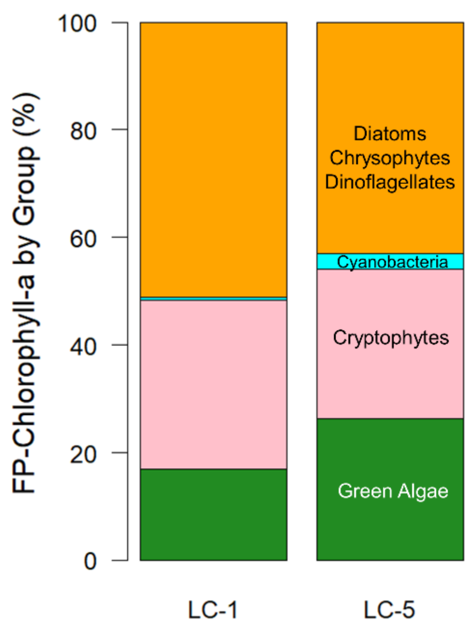
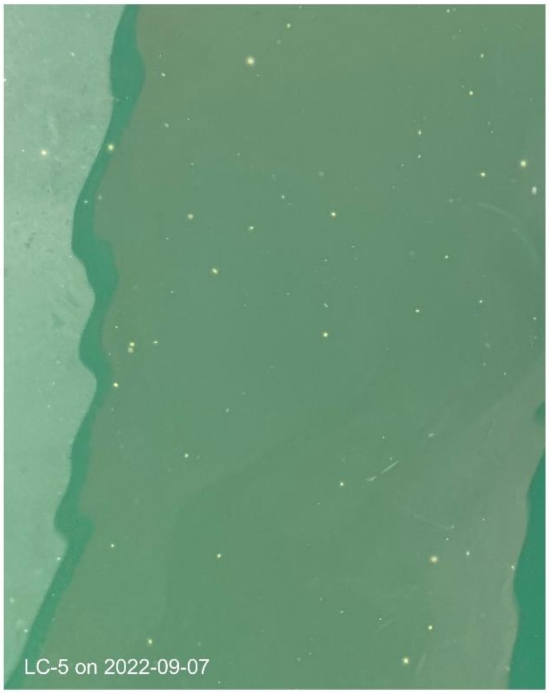


Figure 2. Phytoplankton community composition of Lake Clear on 7 September 2022, as inferred from pigment fluorescence measured by a FluoroProbe.



Photographs 1 & 2. View of the lake's surface at site LC-5 on 7 September 2022 (left) and one of the *Gloeotrichia* colonies collected from the lake, as viewed using compound microscopy (right).

4.1.4 Stratification and Dissolved Oxygen

Late-summer water column profiles of temperature and DO were obtained from MECP (Figure 3) and also measured by HESL during the 7 September 2022 survey (Figure 4). The water column of Lake Clear was always stably stratified in September, with an upper mixed layer (epilimnion), of approximately 10 m depth, separated from the hypolimnion by a strong thermal gradient (i.e., a distinct thermocline). Based on the commonly used 1°C-per-m criterion for defining the thermocline, the top of the hypolimnion was at a depth of 14–15 m. MECP recorded hypolimnetic anoxia (DO < 1 mg/L) on all survey dates, with DO concentrations of 0.29, 0.05, 0.50, and 0.24 mg/L measured immediately above the lakebed (i.e., at 35–37 m) at their deep-water sampling location on 5 September 2003, 16 September 2010, 12 September 2011, and 26 September 2018, respectively. HESL recorded hypoxic (but not anoxic) conditions immediately above the lakebed at the deepest site on 7 September 2022 (1.17 mg/L at 38 m at LC-6), somewhat higher than the concentrations reported by MECP. Off-bottom DO concentrations recorded by HESL at the other sites on 7 September 2022 ranged from 2.55 mg/L to 5.41 mg/L.

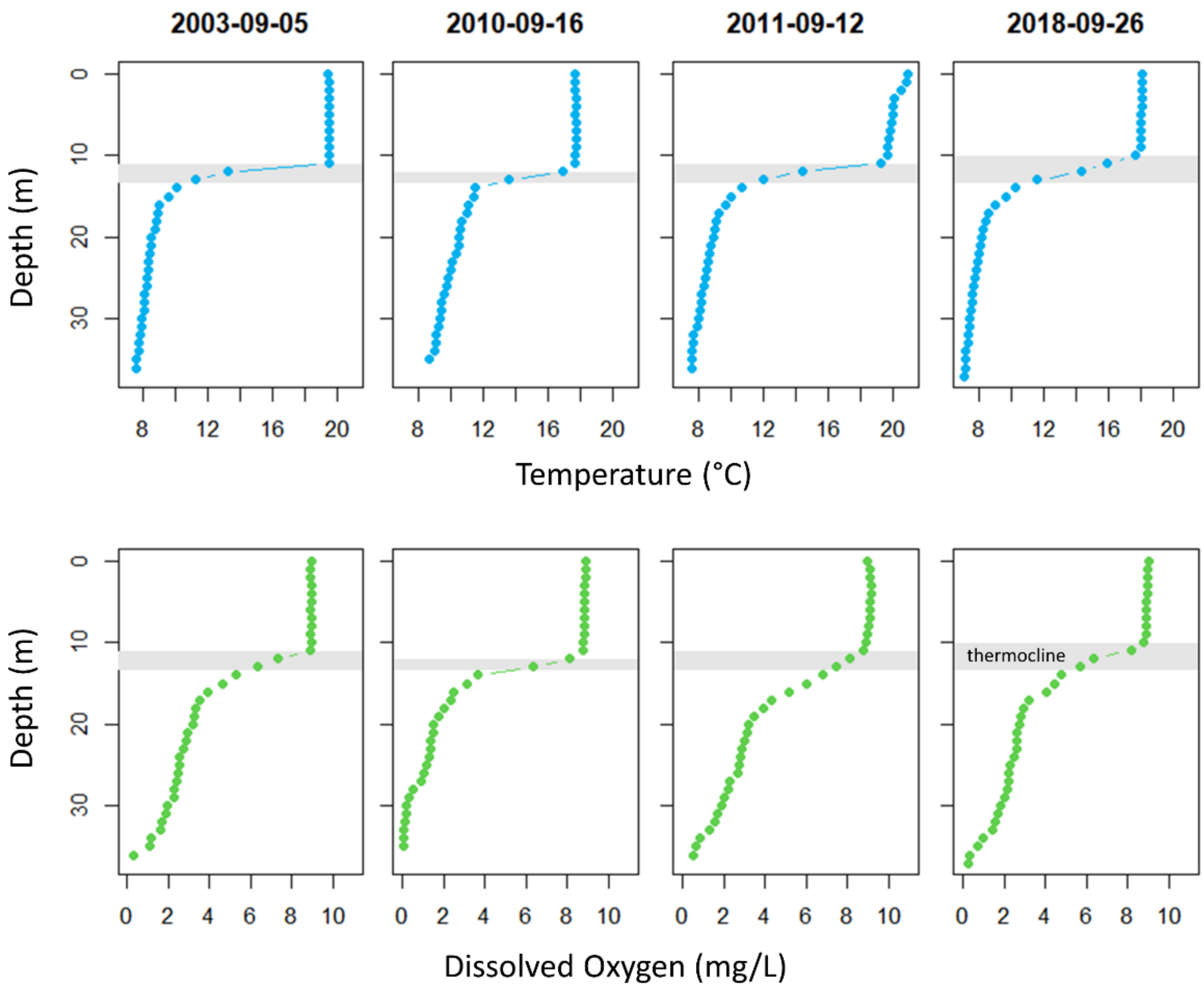


Figure 3. MECP Temperature and Dissolved Oxygen Profiles.

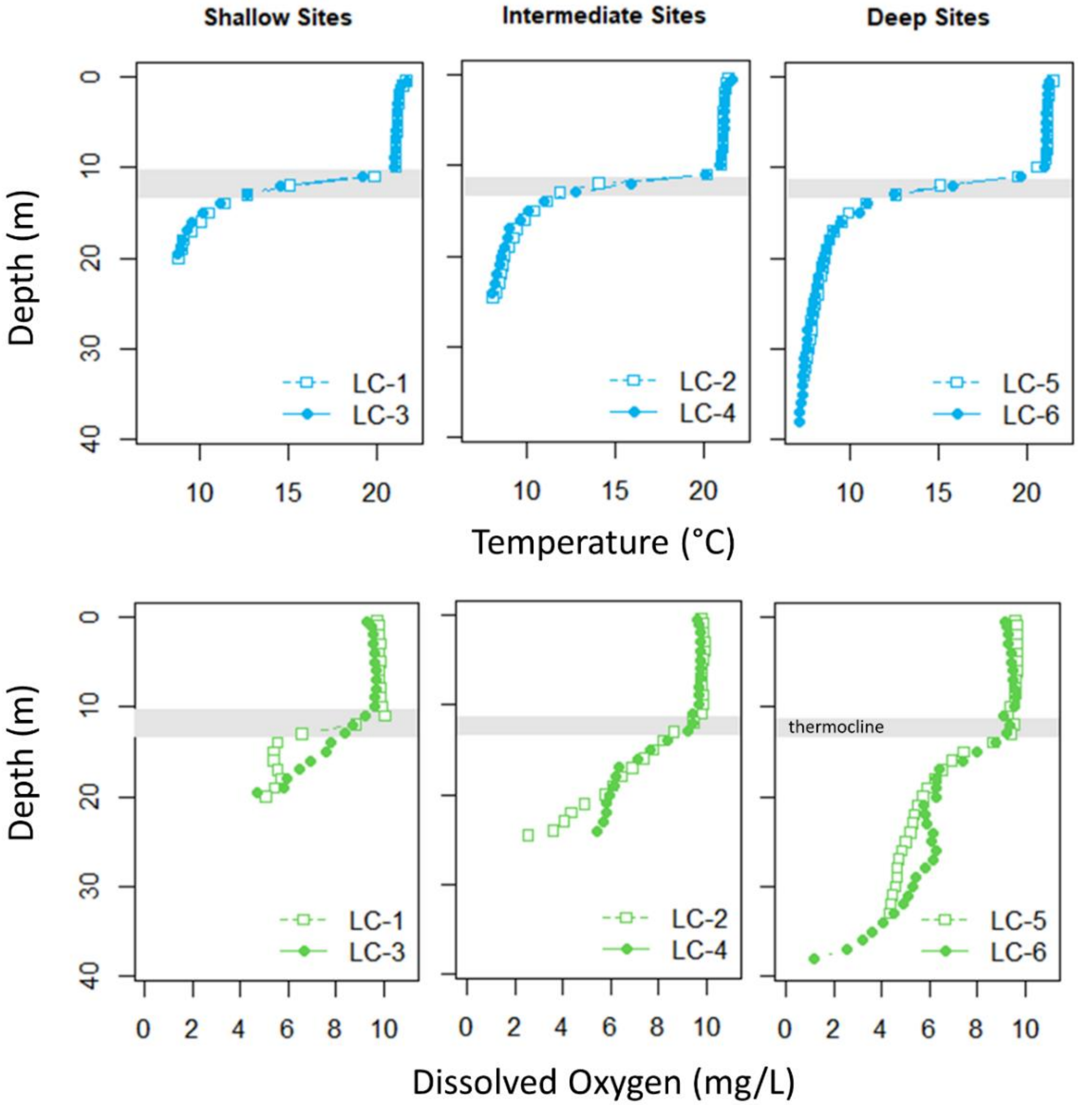


Figure 4. Temperature and Dissolved Oxygen Profiles Measured by HESL on 7 September 2022.

Based on our survey, it is clear that hypolimnetic DO can exhibit considerable spatial (horizontal) variation within Lake Clear, even among locations of comparable depth (i.e., compare the sets of DO profiles in each panel of Figure 4). For this reason, we calculated MVWHDO based on profiles from all six sampling stations by averaging 2 profiles within each of 3 depth ranges (shallow, medium, deep). MVWHDO was calculated separately for each depth range, then weighted by the respective area (based on bathymetry) in order to calculate the MVWHDO for the entire lake (Table 6). The MVWHDO for Lake Clear on 7 September 2022 was determined to be 6.20 mg/L. The MVWHDO would be estimated as 6.58 mg/L (i.e., overestimated by 6%) if calculations were made based only on data from the deepest location of the lake (Table 6). This is because the rate of hypolimnetic oxygen depletion is a function of both the oxygen demand of the sediments and the volume of the hypolimnion; thus, (volumetric) oxygen demand is greater in shallow areas where the hypolimnion is thinner (assuming comparable areal sediment oxygen demand among depths). The MVWHDO of Lake Clear was higher in 2022 than it has been in previous years (Table 7) but all concentrations are less than the Provincial criterion of 7 mg/L that is protective of Lake Trout habitat.

Table 6. Calculation of the MVWHDO of Lake Clear on 7 September 2022.

Sites	Hypolimnion (m)	Min. DO (mg/L)	Depth Range (m)	Area in Depth Range (m^2)	Area (fraction)	MVWHDO (mg/L)	Area × MVWHDO
LC-1, LC-3	14–21	4.70	14–21	4,678,423	0.8288	6.10	5.06
LC-2, LC-4	15–25	2.55	21–25	364,388	0.0646	6.79	0.44
LC-5, LC-6	15–39	1.17	≥25	602,077	0.1067	6.58	0.70
						Lake MVWHDO (mg/L):	**6.20**

Table 7. All Available MVWHDO Estimates for Lake Clear.

Data Collector	Date	Depth Range (m)	Min. DO (mg/L)	MVWHDO (mg/L)
MECP	2003-09-05	14–37	0.29	3.57
	2010-09-16	14–36	0.05	2.15
	2011-09-12	14–37	0.50	4.33
	2018-09-26	14–38	0.24	3.33
HESL	2022-09-07	14–39	1.17	6.20
			Average:	**3.92**

4.2 Lakeshore Capacity Modelling

4.2.1 Model Calibration

The LCM was used to predict natural and anthropogenic phosphorus loads and concentrations for Lake Clear. Lake/catchment-specific input data for the LCM were determined from government sources and the HESL lake survey (Table 9). Municipal Property Assessment Corporation (MPAC) data were provided by the County of Renfrew to determine development inputs. The LCM incorporates P loading from homes/cottages based on either permanent (2.56 capita-years/year), extended seasonal (1.27 capita-years/year), or seasonal (0.69 capita-years/year) occupancy[1], whereas MPAC classifies residences as either permanent or seasonal. Because the actual duration of occupancy of non-permanent residences is not known, the lots categorized as seasonal by MPAC were modelled as extended seasonal as per a conservative approach to lakeshore development and generally consistent with MECP guidance for non-permanent properties with year-round road access[2]. In addition, satellite imagery (Google Earth) and an online campsite map[3] were consulted to determine the number and type of dwellings associated with the Whispering Pines Resort and the Opeongo Mountain Resort, respectively.

4.2.1.1 Phosphorus Retention by Soil

The coefficient for phosphorus retention by soil (Rs) is of particular importance to the LCM. Rs represents the fraction of the septic-system phosphorus load that reaches the lake; thus, the increase in TP concentration above the background concentration predicted by the LCM is linearly dependent on the magnitude of Rs. MECP guidance is to assume Rs is zero unless site-specific soil assessment supports a higher value of Rs (MOE 2010). However, research has shown that septic system phosphorus is immobilized in soils. Mechanistic evidence (Stumm and Morgan 1970; Jenkins et al. 1971; Isenbeck-Schroter et al. 1993) and direct observations made in septic systems (Willman et al. 1981; Zanini et al., 1998; Robertson et al. 1998; Robertson 2003) show strong adsorption of phosphate on charged soil surfaces and mineralization of phosphate with iron and aluminum in soil. Robertson et al. (2019) summarized phosphorus concentrations in groundwater plumes from 24 septic systems throughout Ontario that were monitored over a 30-year period. Phosphorus removal averaged 97% at the non-calcareous sites and 69% at the calcareous sites. Trophic status modelling supports the mechanistic and geochemical evidence: Dillon et al. (1994) reported that only 28% of the potential loading of phosphorus from septic systems around Harp Lake, Muskoka, could be accounted for in the measured phosphorus budget of the lake; the authors attributed the variance between measured and modelled estimates of phosphorus to retention of septic phosphorus in tills that were found in the catchment (Mollard et al. 1980; Gartner Lee Ltd. 2005).

The soils surrounding Lake Clear (and its islands) are predominantly of the Tweed type, with Westmeath and Eganville soils also covering parts of the shoreline (Figure 5; Gillespie et al. 1964). The parent material of these soils is calcareous (Table 8; Gillespie et al. 1964) and the Tweed series that dominates the

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[1] In this context, a capita-year/year represents 1 person living in a residence on an annual basis; e.g., the P loading from a residence with 2.56 capita-years/year would be the P load expected to come from, on average, 2.56 people in a year.

[2] "In cases where usage rates are unknown and where there is no winter road access, MOE recommends using the seasonal rate of 0.69 capita years per year as a default. The extended seasonal rate of 1.27 capita years per year should be used for other non-permanent developments that have reliable year-round access." – MOE (2010)

[3] https://www.omresort.ca/images/Map-Opeongo-Mountain-Resort.pdf

shoreline was described as being "associated with surface outcrops of crystalline limestone" and >25% coverage of bare rock; therefore a value of 0.69 was assumed for Rs, consistent with the aforementioned findings of Robertson et al. (2019). Calcareous inputs were also confirmed through observation of basic lake pH (i.e. pH > 8; see Table 3).

Table 8. Soils Surrounding Lake Clear.

Shoreline Distance (m)	Proportion of Total Excl. Islands	Proportion of Total Incl. Islands	Soil Type	Phases	Soil Parent Material
5,692	18.1%	13.4%	Eganville	loam	Calcareous loam till.
6,233	19.8%	14.6%	Westmeath	gravelly sandy loam	Calcareous fine to medium gravel.
19,488	62.0%	45.7%	Tweed	sandy loam	Calcareous till.
11,194	-	26.3%	Tweed	sandy loam	Calcareous till.

Note: Soil data are from Gillespie et al. (1964); linear shoreline coverage for each soil type was calculated using Google Earth.

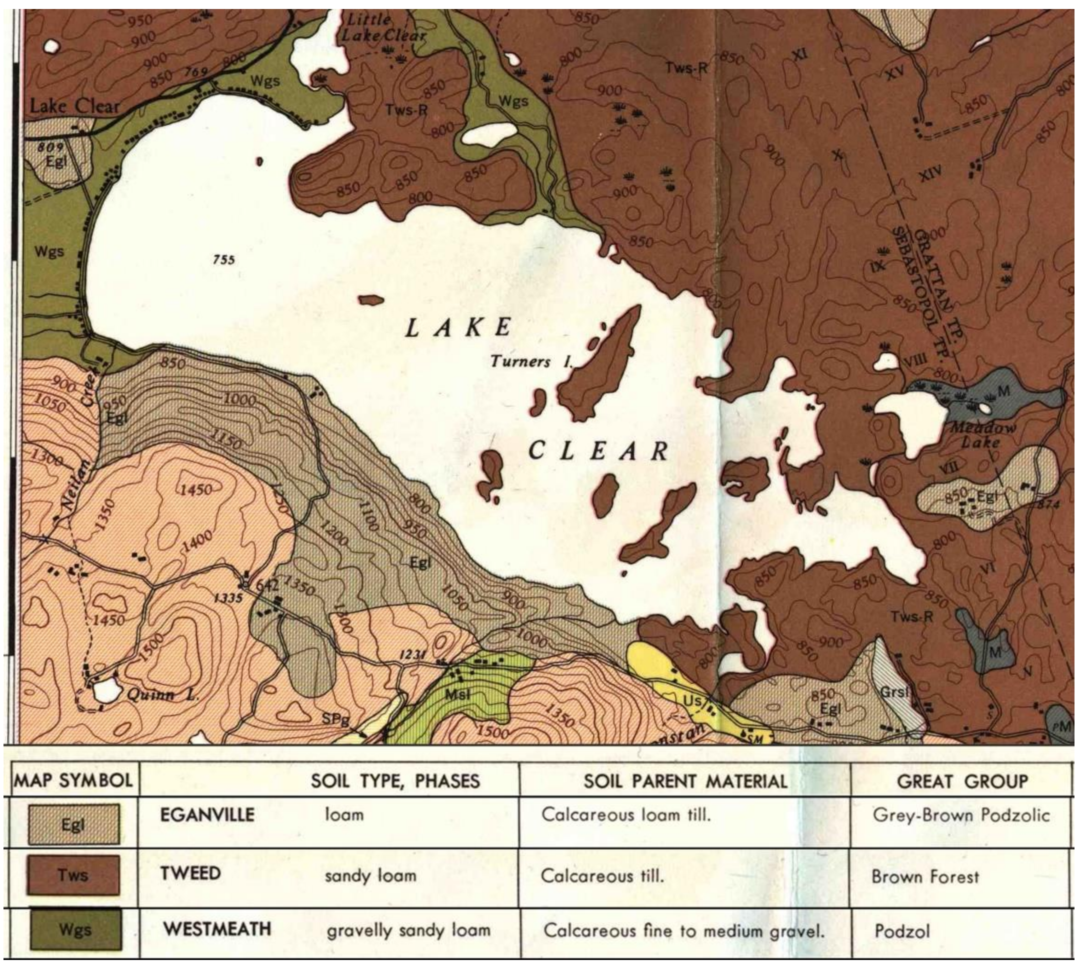

Figure 5. Soils Surrounding Lake Clear.

Note: Map was composed from images in Gillespie et al. (1964).

Table 9. Lakeshore Capacity Model Input Data and Sources.

Category	Input Value	Parameter	Data Source	Note
Shoreline Development	208	Lots occupied all year (1.73 kg-P/lot/y)[1]	MPAC, Google Earth, Opeongo map	Includes 19 farms with residents and the main buildings of each of the 2 resorts.
	267	Lots occupied on an extended seasonal basis (0.88 kg-P/lot/y)[2]	MPAC	
	135	Seasonal lots (0.50 kg-P/lot/year)[3]	Opeongo map	40 from Whispering Pines + 95 seasonal rentals at Opeongo
	46	RVs on existing lots (0.46 kg-P/lot/year)	LCPOA	Same P export as seasonal lots but without stormwater load (largely accounted for in seasonal lot loading as most RVs are on developed lots).
	8	Campgrounds/tent trailers/RV parks (0.28 kg-P/lot/year)[4]	MPAC, Opeongo map	8 rentals of Opeongo Mountain Resort.
	170	Vacant lots of record (0.88 kg-P/lot/year)[5]	MPAC	Vacant lots with RVs included under “RVs on existing lots” (above).
	0.69	Retention by Soil	Gillespie et al. (1964); Robertson et al. (2019)	For calcareous soils.
Catchment	1,727 ha	Lake area	Fish ON-Line (MNRF)	
	7,566 ha	Catchment area	OWIT (MNRF)	Ontario Watershed Information Tool
	10.3 $mg/m^2/y$	Natural P loading	MMA (1986)	P export coefficient for sedimentary watersheds with <15% cleared land
	5.7%	Wetland coverage	OWIT (MNRF)	Wetland export not included in calculation of natural P loading; natural loading based on 10.3 $mg/m^2/yr$ (see above) because of calcareous parent material.
	9.9%	Cleared land	OWIT (MNRF)	Ontario Watershed Information Tool
Hydrological Flow	0.352 m/y	Mean annual runoff	Canada Dept. of Fisheries & Environment	From database recommended for use with LCM.
Sedimentation	7.2 m/y	Settling velocity	MECP and HESL survey data (Section 4.1.4)	Standard settling velocity used in LCM for anoxic hypolimnion.

Monitoring Data	8.72 µg/L	Average TP during spring-overturn	Lake Partner Program (MECP)	Station 2453; Sites #1–5; annual averages (May–June) for 2002–2020.

[1]2.56 capita-y/y × 0.66 kg-P/capita/y + stormwater load of 0.04 kg-P/lot/y; [2]1.27 capita-y/y × 0.66 kg-P/capita/y + stormwater load of 0.04 kg-P/lot/y; [3]0.69 capita-y/y × 0.66 kg-P/capita/y + stormwater load of 0.04 kg-P/lot/y; [4]0.37 capita-y/y × 0.66 kg-P/capita/y + stormwater load of 0.04 kg-P/lot/y; [5]Assumes vacant lots will be converted to extended seasonal.

In addition to the baseline scenario described above (i.e., for the existing lakeshore development density), 4 additional scenarios were modelled based on densities of 1 to 4 RVs per lot (of any type; i.e., permanent + extended seasonal + seasonal lots). In the case of shoreline RVs, the relevant factors are the number of RVs and the method of wastewater treatment and disposal. The modelling assumes that the LCM's recommended phosphorus loading rate for seasonal dwellings of 0.46 kg/year is applicable for the RVs (i.e., 0.69 capita years/year × 0.66 kg-P/capita/year); stormwater loading (0.04 kg/lot/year) is not included for the RVs because it is already accounted for in the model (i.e., because the RVs are assumed to reside on existing lots). The predicted effect of additional RVs on lake TP was also used to predict changes in MVWHDO, as described in Section 4.3.

4.2.2 Model Accuracy

The predicted spring-overturn TP concentration of Lake Clear is 9.27 µg/L, 6.3% higher than the measured spring-overturn concentration of 8.72 µg/L; model output is considered valid if error is ≤20% (MOE 2010).

4.2.3 Predicted Phosphorus Concentrations

The predicted existing TP concentration of Lake Clear during the ice-free season ("TPlake") is 8.64 µg/L. Assuming the vacant lots are converted to extended seasonal use (as recommended by MECP), the predicted future TP concentration ("TPfuture") is 8.99 µg/L. This concentration is ~26% higher than the predicted background (pre-development) concentration of 7.11 µg/L meaning that the lake has additional development capacity based on Lakeshore Capacity Modelling. Without exceeding the PWQO of 10.67 µg/L, the TP load could be increased by 534 kg/y; this is the load that is estimated to come from 146 permanent residences (or 291 extended seasonal residences or 522 seasonal cottages/RVs).

4.3 Dissolved Oxygen Modelling

The empirical models of Molot et al. (1992) were used to predict end-of-summer DO concentrations for Lake Clear and how these would be affected by increases in lake TP concentration from the addition of RVs to existing lakeshore lots.

4.3.1 Modeling Methodology

The lake-specific parameters of the models presented in Molot et al. (1992) are bathymetry, lake area, fetch, and spring TP concentration.

Spring-overturn DO concentration was estimated at a 1-m depth interval based on the relationship:

$$\log_{10}DO(z) = 1.07 - 6.95 \div A_0 - 0.0043 \times z \div MD \quad (1)$$

where A_0 is the area of Lake Clear (1727 ha), z is depth (0–40 m), and MD is fetch ("maximum distance across the lake in any direction on a line through the sampling station"; 8.5 km).

Mean end-of-summer DO concentration was then estimated at a 1-m depth interval for the hypolimnion (14–40 m) based on the relationship:

$$\log_{10}DO(z) = 1.83 - 1.91 \div VSA_z - 7.06 \div DO_z - 0.0013 \times TP^2 \qquad (2)$$

where VSA_z is the ratio of the volume of water to sediment area for each 1-m contour, DO_z is the spring oxygen concentration estimated via equation 1, and TP is the spring TP concentration (either measured or predicted by the LCM).

MVWHDO was calculated from the predicted depth-specific DO concentrations based on the same bathymetric data (contour volumes) used in Section 4.1.4.

4.3.2 Predicted Dissolved Oxygen

Based on the models of Molot et al. (1992) and the *measured* long-term spring-overturn TP concentration of 8.72 µg/L, the predicted end-of-summer MVWHDO of Lake Clear is 6.34 mg/L. Based on the *modelled* TP_{SO} of 9.27 µg/L the predicted MVWHDO is 6.15 mg/L (Table 10). Both MVWHDO estimates are within 2% of the measured value of 6.20 mg/L (Table 6), representing very close agreement between modelled and observed data. Based on the modelled TP_{SO} without anthropogenic phosphorus loading (7.73 µg/L), MVWHDO would have been 6.7 mg/L in the absence of lakeshore development, according to the model, which is notable as it is less than the Provincial criterion of 7 mg/L.

The effect of RVs on Lake Clear's MVWHDO is dependent on the RV density, with the predicted MVWHDO ranging from 5.95 mg/L (-3%) at only 1 RV/lot to 5.32 mg/L (-13%) at 4 RVs/lot (Table 10). At 6.2 mg/L, the current late-summer MVWHDO of Lake Clear is already below the 7 mg/L recommended by MNRF for protection of Lake Trout habitat.

Table 10. Predicted TP and MVWHDO as a Function of Additional RV Density on Existing Lots.

RVs (#/lot)	TP_{SO} (µg/L)	TP_{lake} (µg/L)	TP_{future} (µg/L)	TP_{lake}:TP_{bk} (%)	TP_{future}:TP_{bk} (%)	MVWHDO (mg/L)	Decrease in MVWHDO (%)
0	9.27	8.64	8.99	122	126	6.15	–
1	9.85	9.21	9.73	130	137	5.95	3.3
2	10.43	9.78	10.46	138	147	5.74	6.6
3	11.01	10.36	11.2	146	158	5.53	10.0
4	11.58	10.93	11.93	154	168	5.32	13.4

4.4 Summary

The development capacity of Lake Clear has been assessed with respect to concentrations of TP and MVWHDO using the LCM and the oxygen models of Molot et al. (1992). Based on these models:

- 146 permanent residences (or 291 extended seasonal residences or 522 seasonal cottages/RVs) could be added to Lake Clear's shoreline without exceeding the phosphorus PWQO of background+50%;

- Alternatively, 2 RVs could be added to each existing lot (permanent, extended seasonal, and seasonal) without exceeding the phosphorus PWQO (assuming extended seasonal development of vacant lots);

- At 6.20 mg/L, MVWHDO is currently below the 7 mg/L concentration recommended by MNRF for Lake Trout habitat and is therefore at capacity based on that criterion. Based on the modelled TP_{SO} without anthropogenic phosphorus loading (7.73 µg/L), MVWHDO would have been 6.7 mg/L in the absence of lakeshore development which is less than the Lake Trout criterion of 7 mg/L;

- The addition of 2 RVs to each existing lot is predicted to decrease MVWHDO by approximately 7% (~0.4 mg/L) based on additional phosphorus loading to the lake.

These predictions are highly dependent on the assumed rate of attenuation of septic system phosphorus by soil. We calibrated the LCM using a retention coefficient (Rs) of 0.69, based on the findings of Robertson et al. (2019) and the calcareous nature of the soil parent material in the area surrounding Lake Clear. In practice, the degree to which septic system phosphorus is immobilized by soil will depend largely on the type of sewage treatment and on the specific properties of the soil between the infiltration bed and the lake. Non-native (imported) iron-rich soils can be used in the construction of septic drain fields to enhance phosphorus immobilization. Holding tanks are commonly used in RVs and in theory result in the complete removal of effluent and the associated nutrient load from the study area. The importance of properly designed and maintained sewage treatment systems are further discussed in Section 5.1.

5. Waterfront Best Management Practices

Waterfront Best Management Practices (BMPs) are commonly implemented to minimize impacts of development on adjacent water quality and ecological features. The scientific underpinning of common waterfront development BMPs is described in the following paragraphs to provide an understanding of how the underlying mechanisms relate to reducing development-related impacts; information which can be used to help guide RV policy development.

5.1 Sewage Treatment Systems

Research over the past 20 years has consistently shown that a large proportion of septic system phosphorus is immobilized in soils as discussed in Section 4.2.1.1. Proper septic system design and maintenance is important to maximizing phosphorus attenuation in on-site soils and minimizing impacts to Lake Clear. 60% of respondents identified faulty or poorly maintained septic systems as an issue faced by Lake Clear and 55% ranked a septic reinspection program the top action to benefit the lake (Love Your Lake 2022). Proper sewage servicing of existing residences and cottages, as well as future RVs is required to protect the health of Lake Clear.

The County of Renfrew Official Plan (County of Renfrew 2020) contains a number of policies focused on sewage treatment systems on at-capacity lakes:

9.3(2)The following provisions shall apply to all lands abutting (within 300 metres) of an At Capacity Lake

a) Lot creation shall not be permitted within 300 metres of any at capacity lake unless:

(iii) A site-specific soils investigation prepared by a qualified professional demonstrates that phosphorus can be retained in deep, native, acidic soils on-site. A report, prepared by a qualified professional, is required to demonstrate that there will be no negative impact on the lake water quality as a result of any development. Site plan control may be utilized by the local municipality to implement any recommended mitigation measures.

(d) Development on existing lots with lakeshore frontage shall only be permitted under the following conditions:

(ii) All buildings and structures and associated private waste disposal systems shall have a minimum setback of 30 metres from the high water mark of the lake, or in the case or existing lots, where this setback cannot be met, the setback shall be as remote from the high water mark as the lot will permit to the satisfaction of the Local Council and the applicable approval authority for the private waste disposal system.

(iii) All new permits issued by the applicable approval authority for private waste disposal systems which involve construction of tile beds will be conditional upon the use of a fill material known to have a good phosphorus retention capability.

5.2 Shoreline Buffers

Shorelines link terrestrial and aquatic ecosystems, acting as a transition zone between land and water. They are biological hotspots and highly productive habitats that provide a myriad of ecological services, including maintenance of water quality, flood protection, and wildlife habitat (HESL 2021b). Residential development is often concentrated around shorelines, and most development-related impacts to freshwater habitats occur in the nearshore environment. Natural shoreline vegetation is commonly cleared during development and replaced partially or completely by manicured lawn. If not properly managed, waterfront development can degrade sensitive shoreline habitats, and alter the ecological integrity of adjacent lakes and rivers. Based on a recent survey, 16% of Lake Clear's shoreline is developed, 79% is natural, and the remaining shoreline is manicured, degraded, or regenerative (Love Your Lake 2022). It has been observed that 15% of Lake Clear's properties are mown to the water's edge and recommended that riparian buffer width be increased on 34% of Lake Clear's shoreline (Love Your Lake 2022).

Shoreline buffers can play an important role in protecting lake health. The physical separation they provide between upland human activity and the aquatic environment can aid in mitigating the effects of development and site alteration on water quality and wildlife habitat, while providing erosion and flood control. In general, larger buffers are better at consistently providing a range of protective functions. A 15 m buffer has been found to be the minimum size necessary to maintain physical and chemical functions while 30 m is the minimum necessary to maintain biological functions (Beacon et al. 2012; Castelle et al. 1994; HESL 2021b). Efficient removal of some pollutants (notably sediment) can occur in buffers of 10-20 m width, but other pollutants (such as nutrients) may require buffer widths of 30 m or more for effective attenuation. Water quality improvements generally increase with buffer size (e.g., 10 m removes 65% of sediment from overland runoff while 30 m removes 85% of sediment from overland runoff; Sweeney and Newbold 2014). Larger buffers are also better at protecting the diversity of aquatic and terrestrial species that rely on shorelines.

In Section 2.2 (11) of the County of Renfrew Official Plan (County of Renfrew 2020) it is stipulated that, with certain exceptions, buildings and septic systems are to be set back at least 30 m from the water:

> *Generally all buildings and structures and associated private waste disposal systems will be set back a minimum horizontal distance of 30 metres (or approximately 100 feet) from the normal high water mark of a water body.*

It has been reported (Love Your Lake 2022) that 69% of the properties on Lake Clear are within 30 m of shore (i.e., do not meet the policy requirement).

Section 9.3 (2) discusses shoreline buffer requirements on at-capacity lakes:

2(d)(iv) *The property between the shoreline of the lake and the dwelling or private waste disposal system will be retained where possible in its natural state to serve as a buffer which will assist in minimizing the land-surface transport of nutrient laden silt to the lake. The retention of the natural soil mantle and natural vegetation within 30 metres of the shoreline of the lake will be encouraged.*

The scientific literature demonstrates that a 30 m buffer provides a range of ecological services, and this buffer size is commonly recommended in the peer-reviewed literature focused on shoreline development. Existing planning policy recommends that 30 m naturally vegetated buffers and such buffers should be continue to be required on all lots on Lake Clear.

Stormwater management features that include provisions to maximize infiltration and limit stormwater runoff should also be utilized to minimize development-related impacts on Lake Clear. Specific options include proper re-contouring, discharging of roof leaders, use of soak away pits and other measures to promote infiltration, grassed and vegetated swales, filter strips, roof leaders and French drains. Stormwater management options are often site specific, and the best approach will be dictated by site characteristics and the nature of the proposed development.

6. Conclusions

A Lakeshore Capacity Assessment was completed to determine the development capacity of Lake Clear and inform the development of planning policy for the establishment and use of RVs on the lake. The assessment included Lakeshore Capacity Modelling and comparison with the TP PWQO, measured and modelled MVWHDO concentrations and comparison with the Provincial criterion of 7 mg/L to protect Lake Trout habitat, and examination of water quality data to provide a holistic assessment of lake health and capacity.

Lake Clear is under capacity according to Lakeshore Capacity Modelling results and the TP PWQO. It is over capacity with respect to MVWHDO as concentrations are <7 mg/L but modelling indicates that MVWHDO concentrations were slightly below 7 mg/L prior to development. Water quality is good and there are no increasing trends in nutrient concentrations. Cyanobacteria (i.e. blue-green algae) was however observed during site investigations and climate change is increasing the amount of cyanobacteria in oligotrophic lakes (Reinl et al. 2021). While both factors are known to promote cyanobacterial blooms, the future effects of climate change and anthropogenic nutrient loading on algal blooms in Lake Clear cannot be quantitatively assessed based on available data. However, based on what is generally known about climate change effects on lake stratification and the life cycle of cyanobacteria such as *Gloeotrichia* (Cottingham et al. 2021), it is expected that blooms will become more frequent in Lake Clear even if nutrient loading remains unchanged; increased nutrient loading would be expected to promote more frequent and/or more severe blooms. With respect to the potential for interactive effects between increased nutrients and climate, a large-scale (>1,000 lake) US study (Rigosi et al. 2014) found no synergistic effect of temperature and nutrients on cyanobacterial biovolume in oligotrophic lakes (i.e., the combined effect of increased nutrients and increased temperature was not greater than the sum of the individual effects).

Shoreline development, including RV use, can impact a lake through stormwater and wastewater inputs as well as associated recreational uses such as boating. Impacts can be largely mitigated through implementation of BMPs such as properly designed and maintained sewage treatment systems, the retention or establishment of naturally vegetated shoreline buffers and stormwater management features that maximize infiltration and minimize runoff. Currently the use of RVs of Lake Clear is unregulated and therefore it is not known if they are properly serviced via appropriately sized tile beds or holding tanks that are pumped out regularly. We underscore that the impact of RVs on the lake's water quality depends not only on the number of shoreline RVs but also the effectiveness of RV wastewater management in minimizing nutrient loading to the lake.

6.1 Recommendations

The following recommendations were developed to help the Township develop science-based planning policy for RV use on Lake:

- Permit the use of 1 or 2 RVs on each of the 610 existing lots modelled in this study (i.e., permanent + extended seasonal + seasonal occupancy lots; see Table 9) if appropriate BMPs are developed and enforced to ensure that impacts to Lake Clear are minimized. The modelled impact of two additional RVs/lot results in TP concentrations that are less than the PWQO for TP. The lake is at capacity based on MVWHDO but based on modelling results, it appears that MVWHDO concentrations have always been below the 7 mg/L criterion, and BMPs can be utilized to minimize impacts.

- Sewage treatment systems to service the RVs should meet Ontario Building Code requirements. Systems designed to maximize the amount of phosphorus attenuation should be encouraged such as the Waterloo Biofilter with EC-P unit, EcoFlo Biofilter or the use of a tank and bed system that incorporates soils that are high in phosphorus retention, aluminum and iron, and low in calcium carbonate.

- A 30 m naturally vegetated shoreline buffer should be required on all lots, especially lots with RVs that have the potential to generate additional stormwater and wastewater. Continued retention or establishment of natural vegetation over time should be encouraged through stewardship actions and enforced as necessary.

- Stormwater management features that maximize infiltration and limit stormwater runoff should be encouraged on all lots, especially those with RVs that have the potential to generate additional stormwater, to minimize development-related impacts on Lake Clear.

- Water quality and the effectiveness of BMPs should be monitored. Water quality should continue to be monitored through the Lake Partner Program, and dissolved oxygen measurements should be collected annually at the end-of-summer (August 15 – September 15) so that Mean Volume-Weighted Hypolimnetic Dissolved Oxygen concentrations can be calculated and tracked over time. The implementation and management of BMPs should be assessed through visual inspections.

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Appendix A. Temperature & Dissolved Oxygen Profiles

HESL Profiles - 7 September 2022

	LC-1		LC-2		LC-3		LC-4		LC-5		LC-6	
m	Deg. C	mg-O2/L	Deg. C	mg-O2/L	Deg. C	mg-O2/L	Deg. C	mg-O2/L	Deg. C	mg-O2/L	Deg. C	mg-O2/L
0.5	21.7	9.73	21.4	9.79	21.7	9.31	21.6	9.61	21.5	9.59	21.3	9.15
1.0	21.5	9.78	21.3	9.87	21.4	9.51	21.4	9.70	21.3	9.64	21.2	9.23
2.0	21.3	9.83	21.2	9.89	21.3	9.57	21.3	9.73	21.3	9.65	21.2	9.28
3.0	21.3	9.84	21.2	9.91	21.2	9.58	21.2	9.73	21.2	9.65	21.2	9.32
4.0	21.2	9.82	21.1	9.90	21.2	9.61	21.2	9.77	21.2	9.65	21.1	9.40
5.0	21.2	9.84	21.1	9.85	21.2	9.64	21.2	9.78	21.2	9.65	21.1	9.46
6.0	21.2	9.83	21.1	9.82	21.1	9.66	21.2	9.76	21.2	9.64	21.1	9.50
7.0	21.1	9.82	21.1	9.77	21.1	9.70	21.1	9.75	21.2	9.63	21.1	9.52
8.0	21.1	9.86	21.1	9.82	21.1	9.68	21.1	9.72	21.2	9.58	21.1	9.59
9.0	21.1	9.89	21.0	9.87	21.0	9.65	21.0	9.70	21.1	9.57	21.1	9.60
10.0	21.1	9.93	21.0	9.88	21.0	9.63	20.9	9.66	20.6	9.37	21.0	9.54
11.0	19.9	10.05	20.2	9.83	19.2	9.21	20.1	9.46	19.5	9.30	19.7	9.13
12.0	15.1	8.83	14.1	9.46	14.6	8.71	15.9	9.44	15.1	9.52	15.8	9.37
13.0	12.7	6.57	11.9	8.63	12.7	8.35	12.8	9.21	12.6	9.43	12.5	9.23
14.0	11.4	5.57	11.2	8.17	11.2	7.82	11.0	8.40	10.9	8.69	11.0	8.79
15.0	10.5	5.38	10.4	7.80	10.2	7.62	10.1	7.67	9.9	7.41	10.6	7.96
16.0	10.1	5.38	9.9	7.40	9.6	6.93	9.7	7.16	9.6	6.93	9.5	7.42
17.0	9.6	5.55	9.5	6.92	9.3	6.45	9.0	6.36	9.1	6.53	9.1	6.40
18.0	9.1	5.70	9.2	6.46	9.1	5.94	8.9	6.20	8.9	6.25	8.9	6.25
19.0	9.0	5.44	9.0	6.09	9.0	5.81	8.8	6.16	8.7	5.93	8.7	6.30
19.5	-	-	-	-	8.8	4.70	-	-	-	-	-	-
20.0	8.8	5.06	8.8	5.75	-	-	8.6	5.97	8.6	5.72	8.5	6.29
21.0	-	-	8.6	4.89	-	-	8.5	5.85	8.5	5.54	8.4	5.78
22.0	-	-	8.6	4.36	-	-	8.3	5.81	8.4	5.36	8.2	5.84
23.0	-	-	8.5	4.06	-	-	8.2	5.69	8.3	5.30	8.1	5.90
24.0	-	-	8.3	3.60	-	-	8.1	5.41	8.2	5.21	8.0	6.15
24.5	-	-	8.1	2.55	-	-	-	-	-	-	-	-
25.0	-	-	-	-	-	-	-	-	8.0	5.00	7.9	6.07
26.0	-	-	-	-	-	-	-	-	7.9	4.85	7.8	6.29
27.0	-	-	-	-	-	-	-	-	7.9	4.71	7.8	6.13
28.0	-	-	-	-	-	-	-	-	7.8	4.64	7.7	5.83
29.0	-	-	-	-	-	-	-	-	7.8	4.63	7.6	5.40
30.0	-	-	-	-	-	-	-	-	7.7	4.57	7.6	5.29
31.0	-	-	-	-	-	-	-	-	7.6	4.44	7.5	5.09
32.0	-	-	-	-	-	-	-	-	7.5	4.38	7.4	4.91
33.0	-	-	-	-	-	-	-	-	7.4	4.32	7.4	4.50
34.0	-	-	-	-	-	-	-	-	-	-	7.3	4.07
35.0	-	-	-	-	-	-	-	-	-	-	7.3	3.61
36.0	-	-	-	-	-	-	-	-	-	-	7.3	3.23
37.0	-	-	-	-	-	-	-	-	-	-	7.2	2.52
38.0	-	-	-	-	-	-	-	-	-	-	7.2	1.17

MECP Profiles - Main Basin Site

	2003-09-05		2010-09-16		2011-09-12		2018-09-26	
m	Deg. C	mg-O2/L	Deg. C	mg-O2/L	Deg. C	mg-O2/L	Deg. C	mg-O2/L
0	19.4	8.95	17.7	8.91	20.9	8.98	18.1	9.05
1	19.5	8.91	17.7	8.90	20.8	9.08	18.1	8.97
2	19.5	8.92	17.7	8.88	20.5	9.13	18.1	8.95
3	19.5	8.96	17.7	8.86	20.1	9.19	18.1	8.94
4	19.5	8.94	17.7	8.85	20.0	9.16	18.1	8.94
5	19.5	8.96	17.7	8.85	20.0	9.12	18.0	8.92
6	19.5	8.92	17.7	8.83	19.9	9.10	18.0	8.91
7	19.5	8.96	17.7	8.81	19.9	9.11	18.0	8.90
8	19.5	8.98	17.7	8.81	19.8	9.01	18.0	8.90
9	19.5	8.92	17.7	8.82	19.7	8.97	18.0	8.90
10	19.5	8.95	17.7	8.79	19.7	8.92	17.7	8.75
11	19.5	8.90	17.7	8.77	19.2	8.78	15.9	8.16
12	13.2	7.31	16.9	8.11	14.4	8.11	14.3	6.35
13	11.2	6.32	13.6	6.35	12.0	7.47	11.6	5.68
14	10.1	5.31	11.5	3.68	10.7	6.82	10.3	4.77
15	9.6	4.61	11.4	3.15	10.0	6.00	9.6	4.43
16	9.0	3.90	11.1	2.50	9.6	5.15	9.0	4.03
17	8.9	3.52	11.0	2.37	9.2	4.34	8.6	3.17
18	8.8	3.31	10.7	2.02	9.1	3.92	8.4	2.94
19	8.7	3.28	10.6	1.74	9.0	3.44	8.3	2.80
20	8.5	3.20	10.5	1.52	8.9	3.22	8.1	2.72
21	8.5	2.91	10.5	1.48	8.8	3.16	8.1	2.62
22	8.4	2.86	10.3	1.38	8.7	3.00	8.0	2.61
23	8.3	2.77	10.1	1.34	8.6	2.89	7.9	2.62
24	8.3	2.57	10.0	1.27	8.5	2.79	7.8	2.50
25	8.2	2.52	9.9	1.14	8.4	2.74	7.7	2.28
26	8.2	2.45	9.8	1.03	8.3	2.66	7.6	2.23
27	8.1	2.39	9.6	0.90	8.2	2.29	7.6	2.21
28	8.1	2.29	9.4	0.50	8.1	2.19	7.5	2.16
29	8.1	2.27	9.4	0.34	8.1	2.02	7.5	2.00
30	7.9	1.98	9.3	0.19	8.0	1.86	7.4	1.80
31	7.9	1.88	9.3	0.18	7.9	1.71	7.4	1.71
32	7.8	1.72	9.1	0.09	7.7	1.56	7.3	1.59
33	7.7	1.61	9.1	0.06	7.6	1.31	7.3	1.42
34	7.7	1.18	9.0	0.05	7.6	0.85	7.2	0.99
35	7.6	1.07	8.7	0.05	7.6	0.66	7.2	0.74
36	7.6	0.29	-	-	7.5	0.50	7.1	0.34
37	-	-	-	-	-	-	7.0	0.24

Appendix B. Lakeshore Capacity Model Results

Lakeshore Capacity Model — Lake Clear

Anthropogenic Supply

Shoreline Development Type	Number	Usage (capita years/yr)	
Permanent	208	2.56	
Extended Seasonal	267	1.27	
Seasonal	135	0.69	
Resort	0	1.18	
Trailer Parks	46	0.69	no stormwater runoff incl. (most on non-vacant lots)
Youth Camps	0	0.125	kg/capita/yr
Campgrounds/Tent trailers/RV parks	8	0.37	
Vacant Lots of Record	170	1.27	
Retention by soil (Rs) (0-1)	0.69		

Catchment

Lake Area (Ao)	1727.0	ha	
Catchment Area (Ad)	7566.0	ha	
Wetland	0.0	%	% wetland set to zero; used 10.3 mg-P/m2/yr
Cleared	9.9	%	as recommended for sedimentary watersheds

Upstream Lakes

Hydrological Flow

Mean annual runoff	0.352	m/yr
Lake outflow discharge (Q)	32711360	m3/yr
Areal water loading rate (qs)	1.89	m/yr
Inflow 1		m3/yr
Inflow 2		m3/yr
Inflow 3		m3/yr

Natural Loading

Atmospheric Load	288.41	kg/yr
Runoff Load	779.30	kg/yr

Upstream Loading

Background Upstream Load 1		kg/yr
Background Upstream Load 2		kg/yr
Background Upstream Load 3		kg/yr
Current Total Upstream Load 1		kg/yr
Current Total Upstream Load 2		kg/yr
Current Total Upstream Load 3		kg/yr
Future Upstream Load 1		kg/yr
Future Upstream Load 2		kg/yr
Future Upstream Load 3		kg/yr

Anthropogenic Loading

Current Anthropogenic Load	229.20	kg/yr
Future Anthropogenic Load	282.01	kg/yr

Areal Load Rate

Current Total Areal Loading Rate (L_T)	75.10	mg/m2/yr
Future Total Areal Loading Rate (L_{FT})	78.15	mg/m2/yr

Sedimentation

Is the lake anoxic?	y	
Settling velocity (v)	7.2	m/yr
In lake retention (Rp)	0.79	

Monitoring Data

Years of spring TP data	19	
Average Measured TPso	8.72	µg/L
Measured vs. Predicted TPso	6.3	%
Is the model applicable?	y	
Over or under predicted?	over	

Modeling Results

TPlake	8.64	µg/L
TPout	8.26	µg/L
TPso	9.27	µg/L
TPfuture	8.99	µg/L

Phosphorus Thresholds

TPbk	7.11	µg/L
TPbk+40	9.96	µg/L
TPbk+50	10.67	µg/L
TPbk+60	11.38	µg/L

*if TPbk+40% < TPlake < TPbk+60% cell is orange
*if TPlake > TPbk+60% cell is red

No. of allowable residences to reach capacity:

# Permanent OR	146
# Extended seasonal OR	291
# Seasonal cottages OR	522

Loads

Natural Load w/no development	1067.71	kg/yr
Background + 50% Load	1601.56	kg/yr
Current Load	1296.91	kg/yr
Future Load	1349.72	kg/yr

Outflow Loads

Background Outflow Load	222.38	kg/yr
Current Outflow Load	270.12	kg/yr
Future Outflow Load	281.12	kg/yr