Memorandum

Date: **January 3, 2017**

To: **Dominique O'Brien, Manager of Community Services, Seguin Township**

From: **Tammy Karst-Riddoch**

Re: **J100033 – 2016 Water Quality Monitoring Summary**

In 2016, Seguin Township completed the ninth year of sampling for its Water Quality Monitoring Program. This program collects total phosphorus (TP) concentration data and other pertinent lake information (e.g., Secchi depth, dissolved oxygen concentration, lake depth, dissolved organic carbon, etc.) in support of the water quality model developed to predict phosphorus concentrations in Township[1]. Continued monitoring will also allow the Township to identify potential problems in lake water quality as they emerge.

The 2016 monitoring was conducted by summer students employed by Seguin Township. HESL staff provided sampling instructions, a half day training session and ongoing technical guidance, and assisted coordination with the laboratory at Dorset Environmental Science Centre (DESC). From May 11th to June 3rd, 2016, duplicate water samples were collected from 44 lakes for analysis of spring overturn TP concentration and in August, 35 of those lakes were revisited to measure dissolved oxygen and temperature profiles, Secchi depth and lake depth.

Spring total phosphorus data are also collected by volunteers for several of the lakes in the Township under the province's Lake Partner Program using the same sampling protocols as Seguin's program and analyzed at DESC. As with previous years, available LPP total phosphorus data collected since 2002 were compiled, reviewed and added to the Seguin data set to provide more data for more lakes and years. Combined, these two monitoring programs provide spring overturn total phosphorus data for 76 of the 129 lakes in Seguin Township that have a surface area of at least 10 ha. The LPP data for 2016 have not yet been posted, but these data should be reviewed and included in future updates to the total phosphorus summaries.

The major findings from the 2016 Seguin monitoring and the results of the combined data from Seguin's monitoring program and the LPP are summarized below, and recommendations are provided for future sampling.

[1] *Hutchinson Environmental Sciences, Ltd., 2016.* Review, Update and Refinement of Seguin Township's Water Quality Model (SWQM) and Phosphorus Management Approach. *Final report prepared for Seguin Township.*

1. Spring Total Phosphorus

1.1 Data Screening

Contamination of samples can occur during sample collection or as a result of zooplankton biomass, which can produce elevated TP concentrations and 'bad splits' between field duplicates. Even with careful sampling, bad splits are common and occur for approximately 10% of sample submissions to DESC (pers. comm., Bev Clark). All sample pairs that differed by more than a) 40% from the minimum of the two values, and b) 4 µg/L, were flagged and the higher of the two values was removed, assuming contamination.

There was one bad split identified in the 2016 samples collected by Seguin Township (Table 1). This represents continued good sampling practices as the percentage of bad splits has remained below the average for samples submitted to DESC (10%) since 2012. Samples collected by the LPP also demonstrated good sampling practice with only 5.8% of samples with bad splits. We recommend continued vigilance in following sampling protocol when collecting water samples to minimize the potential for sample contamination.

Table 1. Bad Splits between Duplicate Samples Collected by the Seguin Township Monitoring Program (ST) and the Lake Partner Program (LPP) for Seguin Township Lakes

Year	# of Bad Splits (>40% and >4 µg/L difference between sample pairs)	Total # of Samples	% Bad Splits
2008 (ST)	3	25	12
2009 (ST)	7	37	19
2010 (ST)	4	36	11
2011 (ST)	8	47	17
2012 (ST)	4	50	8
2013 (ST)	1	53	2
2014 (ST)	1	46	2
2015 (ST)	0	40	0
2016 (ST)	1	49	2
ST (08-16)	29	383	7.6
LPP (02-15)	22	381	5.8

Outliers between years of data were identified using the Dixon's Q and Grubbs' outlier tests[2] at a significance level of $\alpha = 0.05$. Ten values were identified as outliers and were removed from the dataset for further analysis (Table 2). We note that these values should be reassessed as outliers each year as additional data are collected because their outlier status may change. For example, the phosphorus

[2] *For lakes with 3 to 10 years of data, a sample was considered to be an outlier based on both the Dixon and Grubb's test. For lakes with more than 10 years of data, only the Grubb's test was used to identify outliers.*

concentration for Scott Lake in 2010 was previously identified as an outlier, but is no longer an outlier with the addition of the 2015 LPP data and the 2016 Seguin Township data.

Table 2. Outlier Total Phosphorus Values (2002-2016)

Lake	Year	Outlier TP (µg/L)	Mean 2002-2016 TP (µg/L) (outlier excluded)
Baby Lake	2016	16.2	7.6
Cosh Lake	2008	21.0	6.7
Gilbank	2006	13.9	7.4
Isabella	2011	12.5[1]	9.6
Lane	2013	10.0	4.9
Little Whitefish Lake	2006	10.1	4.7
McDonald	2009	10.8	8.1
McNutt Lake	2008	16.5	8.6
Oastler	2014	17.0[2]	7.0
Salmon Lake	2002	13.2	5.7

Notes: [1] Value collected on 30-May-2011 by the LPP. Other values collected in 2011 (9-May-2011 and 3-Jun-2011) by ST were not outliers. [2] Value collected on 2-Jun-2014 by the LPP. Three other samples collected that year were not outliers.

1.2 Summary

Mean spring total phosphorus concentrations for the 79 lakes with data from 2002 to 2016 ranged from 3.4 to 14.5 µg/L, with an overall average of 7.3 µg/L (Table 3). Sixty-seven (67) of the lakes had spring TP concentrations <=10 µg/L, which provides a high level of protection against aesthetic deterioration due to excessive algal production in lakes[3].

The MOECC recommends a minimum of two years of spring overturn TP data to be 95% confident of being within 20% of the mean spring concentration of a lake. Seventy (70) lakes in Seguin Township now have at least two years of monitoring data to provide reliable estimates of long term, spring total phosphorus concentrations.

Simple linear regression was used to determine whether TP concentrations were changing significantly over time (2002-2016) in lakes with at least 5 years of data. No lakes displayed a significant trend in TP over time ($p<0.05$).

[3] *Ontario Ministry of Environment and Energy, 1994. Water Management Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy. Queen's Printer for Ontario, 1994, reprinted March 1995.*

Table 3. Mean Spring Total Phosphorus (TP) Concentrations in Seguin Township Lakes (n=79)

Lake	TP 2016 (µg/L)	# of Years Sampled (02-16)	Mean TP (02-16) (µg/L)
Anselmi Lake		1	8.9
Armishaw Lake		4	5.3
Baby Lake	16.2	7	7.6
Back Lake		4	7.2
Black Water Lake		8	10.5
Blue Lake	3.0	8	3.9
Brennan Lake	6.8	4	9.4
Brush Lake		1	5.8
Burr Lake	4.2	1	4.2
Capton Lake	6.6	4	7.1
Carruthers Lake		1	4.9
Clear Lake		12	3.4
Cosh Lake	6.1	5	6.7
Diamond Lake	7.7	6	9.6
Draper Lake	5.8	5	6.8
Dyson Lake		7	4.7
Fair Lake	5.9	4	7.0
Faris Lake	4.2	4	3.8
First Lake		5	6.9
Flaxman Lake	4.3	4	4.4
Forget Lake		5	5.6
Gilbank Lake	5.9	7	7.4
Haines Lake	7.0	5	7.7
Hooton Lake	5.7	1	5.7
Horseshoe Lake	5.8	15	7.3
Isabella Lake		14	9.6
Joselin (Burnt) Lake		13	5.9
Kight Lake		4	10.1
Kingshott Lake	8.2	5	10.0
Lane Lake	5.4	4	4.9
Lieback Lake		4	5.4
Linger Long (Napken) Lake		5	8.9

Lake	TP 2016 (µg/L)	# of Years Sampled (02-16)	Mean TP (02-16) (µg/L)
Little Seguin/Duck Lake		10	9.2
Little Whitefish Lake	3.7	9	4.7
Long Lake	3.7	4	7.3
Long Lake 1	4.2	3	4.3
Lower Fry Lake	10.7	6	13.0
Manitouwaba Lake	4.5	13	5.8
Maple Lake	7.6	11	11.1
Martin Lake		7	6.8
McDonald Lake	7.2	5	8.1
McGowan Lake	4.4	13	5.2
McKechine Lake	4.3	5	4.0
McLean Lake	7.9	5	7.4
McNutt Lake	8.5	8	8.6
Mirror Lake		4	6.5
Mohan Lake		1	5.4
Murdock Lake	9.0	4	11.2
Mutton Lake	8.9	5	10.2
Neville Lake		4	10.8
Oastler Lake		11	7.0
Otter Lake		14	6.2
Pender Lake	5.9	4	5.4
Pickering Lake		4	13.4
Portage Lake		7	5.9
Rankin Lake		13	8.4
Richmond Lake	6.1	2	6.5
Roberts Lake		6	7.1
Salmon Lake		13	5.7
Scime Lake	9.6	2	9.3
Scott Lake	3.8	4	6.1
Second Lake	13.4	5	10.9
Sovereign Lake	6.5	1	6.5
Star Lake		14	10.0
Storm Lake		4	6.1
Sucker Lake		7	6.1

Lake	TP 2016 (µg/L)	# of Years Sampled (02-16)	Mean TP (02-16) (µg/L)
Sugar Lake		13	7.0
Ten Mile Lake	9.9	4	9.5
Third Lake	10.7	4	11.5
Three-Legged Lake		9	5.2
Tiffin Lake/Silver	6.4	6	6.5
Trout Lake		5	4.8
Tub Lake	6.1	4	6.8
Tucker Lake		6	8.2
Turtle Lake		11	7.9
Upper Fry Lake	15.2	12	14.5
Whitefish Lake		7	4.5
Windfall Lake		4	7.3
Yarrow Lake	6.1	4	8.4

2. August Field Sampling

Dissolved oxygen and temperature profiles, lake depth, Secchi depth and water colour (qualitative) were monitored at 35 study lakes in August 2016 (Table 4).

Of the lakes monitored, 15 were shallow and mixed to the bottom. Eight lakes were weakly stratified and could potentially mix to the bottom during strong wind events. These lakes have potential for internal phosphorus loading and would also have lower rates of phosphorus loss to the sediments due to wind mixing and resuspension of sediments into the water column.

The water of 28 lakes was noted as being tea-stained, “yellow”, “orange” or ‘brown’ with relatively shallow Secchi depths indicating that they likely have high dissolved organic carbon (DOC) concentrations. Lakes with high DOC concentration (i.e., >10 mg/L) may not model well because they fall outside the range of DOC in lakes that were used to develop and calibrate the Province’s Lakeshore Capacity Model (Ontario, 2010) which was used as the basis of the Seguin Water Quality Model.

Several of the lakes displayed low oxygen concentrations (<0.1 mg/L) within 1 m of the lake bottom. Only one lake (Pender Lake), however, was considered to potentially develop an anoxic (no oxygen) hypolimnion as mean dissolved oxygen concentration was low throughout the hypolimnion (mean dissolved oxygen in the hypolimnion was <0.1 mg/L). Dissolved oxygen concentration in the hypolimnion of lakes can continue to decline until fall overturn and so anoxia and internal phosphorus loading can potentially occur in this lake.

Table 4. Summary of August 2016 Field Sampling Results

Lake Name	Depth (m)	Surface Water Temperature (˚C)	Dissolved Oxygen (1-m off bottom) (mg/L)[1]	Potentially Anoxic Hypolimnion?[2]	Shallow Mixed Water Column?[3]	Secchi Depth (m)	Water Colour
Baby	1.5	23.9	7.24	No	Yes	1.5	yellow
Blue	15	24.2	0.6	No	No	7.5	blue
Brennan	3.4	24.2	5.6	No	Yes	2.475	orange
Capton	12.2	23.6	5.98	No	No	5.2	yellow
Cosh	4.4	23.7	6.3	No	Yes	3.95	orange
Diamond	4	23.4	7.33	No	Yes	3.15	yellow/brown
Draper	4	24.2	7.55	No	Yes	3.675	yellow
Fair	4.3	23.6	6.69	No	Yes	3.035	orange/brown
Faris	11	26.3	3.85	No	Weak Stratification	6.1	green
Flaxman	18.5	23.9	4.93	No	No	4.9	green
Gilbank	18	24.8	0.07	No	No	5.25	Yellow
Haines	11.5	23.6	3.22	No	No	4.375	yellow
Kingshott	2.85	24.5	6.88	No	Yes	2.85	yellow
Lane Lake	7	24.7	4.6	No	Weak Stratification	6.25	green/clear
Little Otter	4.9	24.5	6.89	No	Yes	3.3	yellow
Little Whitefish 1	26	23.7	4.72	No	No	5.15	green
Little Whitefish 2	11	23.7	4.95	No	Weak Stratification	5.9	green
Little Whitefish 3	7	23.9	6.91	No	Weak Stratification	4.5	green
Little Whitefish 4	14	24.2	0.06	No	No	5.85	green
Long	20	24.3	0.52	No	No	4.8	yellow
Lower Fry	10	22.7	0.08	No	Weak Stratification	2.15	orange/brown
Manitawaba	14	22.9	6.02	No	No	5.4	yellow
Maple	16	24.3	0.26	No	No	4	yellow/brown
McDonald	2.5	23.7	7.82	No	Yes	2.5	yellow
McGowan	12	24.2	0.57	No	No	5.4	green

Lake Name	Depth (m)	Surface Water Temperature (˚C)	Dissolved Oxygen (1-m off bottom) (mg/L)[1]	Potentially Anoxic Hypolimnion?[2]	Shallow Mixed Water Column?[3]	Secchi Depth (m)	Water Colour
McKechnie	6	25.3	6.77	No	Yes	4.775	Yellow
McLean	13	23.6	0.09	No	No	3.275	yellow
McNutt	10.1	23.9	0.1	No	No	3.95	orange
Murdock	2.4	23.5	7.52	No	Yes	2.4	orange
Mutton	4.1	23.7	6.92	No	Yes	2.9	Yellow
Pender	10	23.8	0.08	Yes	Weak Stratification	5.6	yellow/green
Scott	18	23.9	0.63	No	No	8.8	light blue
Second	3.2	23.9	7.35	No	Yes	3	orange/yellow
Silver	8.5	24.8	5.77	No	No	4.2	yellow/orange
Ten Mile	9	24.2	0.45	No	Weak Stratification	4.2	yellow/orange
Third	7	24	5.34	No	Weak Stratification	3.25	yellow
Tub	3.3	24	6.91	No	Yes	3.05	yellow/orange
Yarrow	4.1	23	3.7	No	Yes	2.7	orange

[1]depth in brackets is provided where DO was measured at a depth greater than 1-m off bottom; [2]mean hypolimnetic dissolved oxygen concentration <0.1 mg/L; [3]Weak Stratification refers to lakes that have a thermocline (>1°C change/1 m depth) that extends to the lake bottom.

*dissolved oxygen profile is suspect.

Lakes with a shallow mixed water column, high DOC, and potentially anoxic hypolimnia should be identified in future revisions of the Seguin Water Quality Model to explain possible error in model predictions and to adjust the model accordingly.

3. Summary and Recommendations

- A total of 79 of 129 lakes (61%) in Seguin Township have measured spring total phosphorus concentration data, and 70 of these lakes have at least 2 years of data as of the end of the 2016 sampling season (and excluding 2016 data from the LPP).
- August monitoring of dissolved oxygen, temperature, lake depth and Secchi depth has been completed for 35 lakes in 2015. These data have been useful to flag shallow lakes, high DOC lakes and lakes that potentially undergo anoxia for future refinements of the Seguin Water Quality Model and to explain potential error in model predictions.
- Now that at least 2 years of data exist for the 'A' Lakes monitored by the program (Table 5), a new monitoring schedule could be developed to sample these lakes every three years instead of every other year to allow sampling of additional lakes that presently do not have data ('B' lakes, Table 6).
- We recommend that the monitoring program continue, as developed, with the addition of more lakes that have little or no data ('B' lakes, Table 6).
- Due to the complex lake shape and bathymetry of Horseshoe Lake and Little Whitefish Lake, we recommend that spring total phosphorus sampling should be conducted within each of the major distinct basin (3 basins in Horseshoe lake and 4 basins in Little Whitefish Lake) to assess potential differences in water quality between basins in the future.
- A large percentage of the Seguin Township monitoring lakes potentially have high dissolved organic carbon concentrations that could result in error in model predictions. If additional time or funding is available, we recommend that a subset of lakes be sampled for dissolved organic carbon. HESL will work with Seguin Township to select the most appropriate lakes for additional sampling if this is possible.

Table 5. Seguin Township Lake Monitoring List

'A' Lakes	
Even Years (2016, 2018…)	**Odd Years (2015, 2017…)**
Baby Lake	Armishaw Lake
Blue Lake	Back Lake
Brennan Lake	Black Water Lake
Capton Lake	Clear Lake
Cosh Lake	Dyson Lake
Diamond Lake	First Lake
Draper Lake	Forget Lake
Fair Lake	Horseshoe Lake
Faris Lake	Isabella Lake
Flaxman Lake	Joselin (Burnt) Lake
Gilbank Lake	Kight Lake
Haines Lake	Lieback Lake
Kingshott Lake	Linger Long (Napken) Lake
Lane Lake	Little Lake Joe
Little Otter Lake	Little Seguin/Duck Lake
Little Whitefish Lake	Martin Lake
Long Lake	Mirror Lake
Long Lake 1	Neville Lake
Lower Fry Lake	Oastler Lake
Manitouwaba Lake	Otter Lake
Maple Lake	Portage Lake
McDonald Lake	Rankin Lake
McGowan Lake	Roberts Lake
McKechine Lake	Salmon Lake
McLean Lake	Star Lake
McNutt Lake	Storm Lake
Murdock Lake	Sucker Lake
Mutton Lake	Sugar Lake
Pender Lake	Three-Legged Lake
Scime Lake	Trout Lake
Scott Lake	Tucker Lake
Second Lake	Turtle Lake
Ten Mile Lake	Virtue Lake
Third Lake	Whitefish Lake
Tiffin Lake/Silver	Windfall Lake
Tub Lake	
Upper Fry Lake	
Yarrow Lake	

Table 6. Seguin Township Monitoring Program Lakes ('A' Lakes) and Additional Lakes ('B' Lakes)

2009 Model Lake No.	Lake Name	Watershed Code	Upstream Lakes	'A' Lakes	'B' Lakes
87	5	S3	0		x
26	1	GB (end)	0		x
95	10/Good Lake	S6	0		x
27	2	GB (end)	28		x
1	3	B (end)	7		x
100	4	LJ	0		x
88	6/Vinett Lake	S3	92		x
89	7	S3	0		x
126	8	OT	0		x
127	9	OT	0		x
54	Aikman Lake	MC	56		x
101	Anselmi Lake	LJ (end)	0		x
102	Armishaw Lake	LJ (end)	0	x	
61	Baby Lake	S1	0	x	
49	Back Lake	H	0	x	
28	Bennett Lake	GB	0		x
97	Black Water Lake	S8	0	x	
2	Blue Lake	B	0	x	
15	Brennan Lake	BS	25	x	
103	Brush Lake	LJ (end)	0		x
104	Burr Lake	LJ	113		x
50	Capton Lake	H	0	x	
62	Carruthers Lake	S1	0		x
105	Carter Lake	LJ (end)	0		x
29	Catfish Lake	GB (end)	0		x
63	Clear Lake	S1	61	x	
30	Clear Lake 1	GB (end)	0		x
106	Clubbe Lake	LJ (end)	0		x
51	Cochrane Lake	H	0		x
64	Cosh Lake	S1	0	x	
65	Dainty Lake	S1	0		x
44	Dell Lake	H	0		x
66	Diamond Lake	S1	0	x	

2009 Model Lake No.	Lake Name	Watershed Code	Upstream Lakes	'A' Lakes	'B' Lakes
107	Dick Lake	LJ (end)	0		x
108	Draper Lake	LJ (end)	0	x	
109	Dyson Lake	LJ (end)	0	x	
110	Fair Lake	LJ (end)	0	x	
67	Faris Lake	S1	0	x	
16	First Lake	BS	18	x	
17	Flaxman Lake	BS	22	x	
31	Forget Lake	GB (end)	0	x	
90	Fume Lake	S3	87,88,91		x
111	Gerow Lake	LJ (end)	0		x
68	Gilbank Lake	S1	72b,83	x	
42	Haines Lake	H (end)	47,48	x	
112	Hamer Lake	LJ	0		x
32	Heaslip Lake	GB (end)	0		x
33	Hines Lake	GB (end)	40		x
45	Home Lake	H	43		x
55	Hooton Lake	MC	0		x
84	Horn Lake	S2	0		x
18	Horseshoe Lake (includes Virtue Lake)	BS	17,19	x	
113	Hurst Lake	LJ	0		x
60	Isabella Lake	S (end)	70,85,90,93,94,95, 96,97,98	x	
91	Jelso Lake	S3	0		x
34	Joselin (Burnt) Lake	GB (end)	37	x	
52	Kight Lake	H	0	x	
35	Kingshott Lake	GB	0	x	
114	Krapek Lake	LJ to Portage	0		x
43	Lane Lake	H	0	x	
69	Lieback Lake	S1	0	x	
3	Linger Long Lake/Napken	B	0	x	
19	Lioness Lake	BS	15		x
56	Lipscombe Lake	MC	58		x
98	Little Manitouwaga Lake	S9	99		x

2009 Model Lake No.	Lake Name	Watershed Code	Upstream Lakes	'A' Lakes	'B' Lakes
70	Little Seguin/Duck Lake	S1	66,73	x	
71	Little Whitefish	S1	63	x	
53	Long Lake	H	0	x	
72	Long Lake 1	S1	0	x	
115	Loucks Lake	LJ (end)	0		x
4	Lovell Lake	B	0		x
85	Lower Fry Lake	S2	86	x	
99	Manitouwaba Lake	S9	0	x	
73	Maple Lake	S1	74,78,81	x	
74	Martin Lake	S1	62,65,67,75,76,77	x	
116	McCan Lake	LJ (end)	0		x
75	McCauley Lake	S1	0		x
57	McCoy Lake	MC (end)	54,59		x
5	McDonald Lake	B	3,6	x	
36	McGowan Lake	GB	0	x	
46	McGruther Lake	H	0		x
37	McKechine Lake	GB	0	x	
76	McLean Lake	S1	0	x	
47	McNutt Lake	H	49,50,51,52,53	x	
117	McTaggart Lake	LJ	112,121,124		x
118	Mirror Lake	LJ (end)	0	x	
77	Mohan Lake	S1	69		x
119	Motley Lake	LJ	104		x
6	Murdock Lake	B	0	x	
78	Mutton Lake	S1	80	x	
48	Neville Lake	H	44,45,46	x	
38	Oak Lake	GB (end)	0		x
7	Oastler Lake	B	4,5,8	x	
39	One Island Lake	GB (end)	0		x
8	Otter Lake	B	2,9,10,11,12,13,14	x	
40	Payne Lake	GB	0		x
20	Pender Lake	BS	0	x	
120	Pickering Lake	LJ (end)	0		x
79	Ponsford Lake	S1	0		x

2009 Model Lake No.	Lake Name	Watershed Code	Upstream Lakes	'A' Lakes	'B' Lakes
128	Portage Lake	LJ (end)	0	x	
9	Rankin Lake	B	0	x	
41	Richmond Lake	GB (end)	36		x
121	Roberts Lake	LJ	0	x	
10	Salmon Lake	B	0	x	
96	Santa Lake	S7	0		x
11	Scime Lake	B	0	x	
12	Scott Lake	B	0	x	
21	Second Lake	BS	16,24	x	
13	Sovereign Lake	B	0		x
22	Spectacle Lake	BS	0		x
80	Star Lake	S1	79,82	x	
94	Storm Lake	S5	0	x	
122	Sucker Lake	LJ (end)	125	x	
81	Sugar Lake	S1	0	x	
58	Tarver Lake	MC	0		x
92	Ten Mile Lake	S3	89	x	
23	Third Lake	BS (end)	21	x	
59	Three-Legged Lake	MC	55	x	
123	Tiffin/Silver Lake	LJ (end)	117	x	
72.5	Trout Lake	S1	72	x	
93	Tub Lake	S4	0	x	
124	Tucker Lake	LJ	0	x	
82	Turtle	S1	68	x	
86	Upper Fry Lake	S2	84	x	
125	Watson Lake	LJ	119		x
83	Whitefish Lake	S1	71,64	x	
24	Windfall Lake	BS	0	x	
14	Wright Lake	B	0		x
25	Yarrow Lake	BS	20	x	

TKR