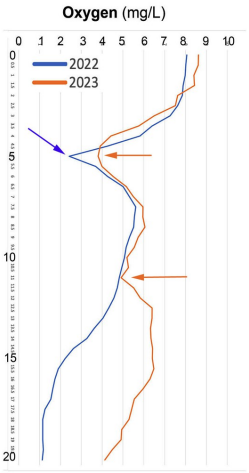
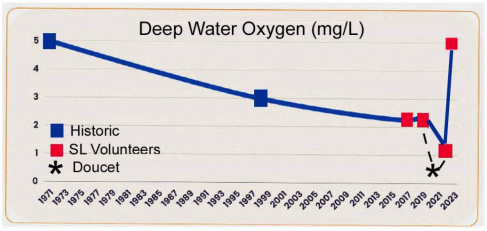
Re: HALIFAX REGIONAL MUNICIPALITY - FUTURE SERVICED COMMUNITIES DRAFT REPORT - VOLUME 2: SANDY LAKE STUDY AREA REPORT – LAND SUITABILITY ANALYSIS

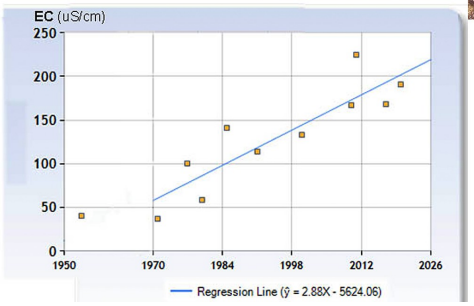
Comments on Watercourses, Wetlands and Water Quality

by David Patriquin
(Prof of Biology, Dalhousie University, retired)

May 22, 2024







1. Introduction

There are many aspects of this Draft LSA, released on Apr 19, 2024 [1] that are of concern to me, but I am restricting my comments to aspects addressing Watercourses, Wetlands and Water Quality as I have made related field observations that I consider are particularly relevant [2]. I provided details of my observations to and discussed them with Stantec staff in conjunction with virtual meetings on May 3 and June 22, 2023 [3]. For whatever reason, this information was not made use of in preparing the Draft LSA. In the brief comments below, I highlight the relevance of the information I presented to and discussed with Stantec to the LSA.

2. On Section 3.2.1.3 WATER QUALITY

My major concern is that Stantec's assessment of WQ (Water Quality) does not include reference to limnological data that I and volunteers Ed G. and Derek S. collected annually beginning in 2017 and continuing to present, except for 2022-2023 when we conducted the same observations in conjunction with and as volunteers with the newly formed HRM Lake Watchers Program (see Stantec Draft LSA Table 3.10: Historical Water Quality Data Sources). As well, no use was made of limnological observations of Sandy Lake made entirely independently by Casey Doucet in 2021 [4] which I had brought to the attention of Stantec staff [3].

Regardless, under "Parameters Sampled" in Table 3.10 Historical Water Quality Data Sources (p. 23) they do not include "oxygen", a critical WQ variable [5].

> **"T**he relationship between phosphorus and oxygen is implicit in any lake management activities and should, at least, be considered in formulating the PWQO [Provincial Water Quality Objective]".

The Deep Water Oxygen level of Sandy Lake in late summer was measured in historical studies in 1971 and 1998; and in our observations conducted in 2017, 2019, 2022, 2023; and by Casey Doucet for her Masters of Applied Science research at Dalhousie University in 2021 [4].

As described in meetings with Stantec and in the associated documents [3] and in Casey Doucet's thesis [4], the decline in deep water oxygen over time and the near anoxic levels occurring in recent years indicate the Water Quality of Sandy Lake is in far worse or far more precarious condition than predicted by AECOM (2014) based on Lakeshore Capacity/Total P modelling [6].

The Stantec authors comment (p. 24)

> "The median concentration of total phosphorus is 12 ug/L which is indicative of mesotrophic conditions"

They make no mention of the implications or nuances of use of Total P as a predictor of WQ [5, 7]. Then in the same paragraph, they go on to conclude:

> "The low chloride and TSS concentrations suggest that Sandy Lake is not significantly affected by urban runoff or erosion within the watershed."

That conclusion ignores entirely:

- the oxygen data as cited above;
- the trends of increasing salt levels in Sandy Lake [8] and a wealth of publications related to rising salt levels in HRM lakes generally [9];
- the underlying assumptions of AECOM (2014) - and of the many studies making use of Total P as a predictor of limnological conditions/WQ - related to the influence of land runoff on Total P and water quality.

Indeed, if Sandy Lake were not significantly affected by urban runoff, it would still be in an oligotrophic (pristine) condition as it was historically! [10]

3. On Section 3.2.2 LAND SUITABILITY ANALYSIS – WATERCOURSES AND WATER QUALITY

In turn, the Stantec authors give no consideration to the *currently* precarious state of Sandy Lake, let alone the additional effects of envisaged future development when they discuss appropriate buffer widths for watercourses, rather they simply assign a buffer width of 30 meters, stating

> "...the buffer width beyond the minimum standard must also consider the growing need for residential units and the limited land available within Halifax; therefore, the 30 m setbacks established in the Bedford Land Use By-Laws were considered an appropriate starting point."

4. On Section 3.4 Land Connectivity

Likewise, Stantec considers a 30 m buffer adequate to preserve wetland functioning without consideration of the *currently* precarious state of the lake or the additional effects of envisaged future development.

6. On Extreme Weather Events

The Draft LSA makes several references to limitations to the study due to "multiple extreme weather events throughout the 2023 field season", but the authors do not comment on the likelihood that such extreme events are associated with climate warming and will be repeated in the future. That has important implications, in particular that increased buffer widths on wetlands and watercourses are likely to be required to address these new challenges.

The second document that I submitted to Stantec - 2023 Limnological Profiles & effects of episodic precipitation [3] – is relevant: the observations illustrate a dramatic change in lake conditions associated with the extreme precipitation in summer of 2023, and confirmed the repeated appearance in recent years of a new phenomenon of concern: a *Metalimnion Oxygen Minimum.*

SUMMARY
After extreme precipitation events earlier in the summer of 2023, the entire water column had lower conductivity values (a measure of salt content) on Aug 14 compared to May 22 and bottom waters on Aug 14 were better oxygenated than on 6 other occasions in the past when deep water oxygen levels were measured in late summer/early fall. This flushing and oxygenation could be good news if there weren't other adverse effects of the heavy precipitation. Observations in the latter half of August in 2021, 2022 and 2023 show the presence of a "Metalimnion Oxygen Minimum" at 5-6 m; it appears that it reformed quickly after the high precipitation events in 2023. The occurrence of a Metalimnion Oxygen Minimum in Sandy Lake represents significant deterioration in water quality of the upper layers of the water column and adds yet more reason to be concerned about the state of the lake currently and the possible impacts on lake water quality if the proposed major development on its headwaters was to proceed.

As well as the possibility/likelihood of more extreme precipitation events in the future, the warming of waters introduces further sensitivity of lakes due to reduced solubility of oxygen in water with increasing temperature and stimulation of blue-green algae by increasing temperature [11]. Such climatic induced changes require that we increase our precautionary measures to protect lakes, e.g. through wider buffers such as those cited in the McCallum Report and recommended specifically for Sandy Lake by Regional Council, i.e., " all identified wetlands with a 50 metre buffer for riparian areas, and all identified watercourses with a 100 metre buffer for riparian areas [12]

7. To Conclude

Perhaps it is the intention of Stantec/HRM to review the buffer width requirement again once the watershed study is completed and that study will include consideration of the oxygen data and other concerns I have raised based on the limnological data, i.e. Stantec fully intends that their recommended 30 m buffers on watercourses and wetlands is simply a "starting point", and could be revised when the Watershed Study becomes available.

For the sake of this precious lake remaining an asset to all of us, I hope so.

View from Sandy Lake Beach Park, Oct 13, 2017.

8. Notes, References

1. The Draft LSA is posted on an HRM webpage at https://www.shapeyourcityhalifax.ca/futureservicecommunities; see Draft SandyLake LSA Apr18_2024.pdf (38.5 MB) (pdf)

2. **Qualifications & Background to the Observations** As a retired biologist and active member of several trail and natural history organizations (view CV etc at www.versicolor.ca/davidGpatriquin), in the spring of 2017 I responded to a request from the SLCA (Sandy Lake Conservation Association) for a volunteer to conduct a "floral survey" of the Sandy Lake area in connection with their efforts to protect more of the landscape in the Sandy Lake Watershed. I agreed to do a descriptive study of the mostly forested landscape. In the course of determining what was already known, I reviewed the AECOM (2014) Watershed study and realized there was a dearth of info. on the current status of the lake, in particular that no limnological profiles of oxygen had ever been conducted. My graduate degrees are in Marine Sciences, so I was familiar the basic principles and methods of Limnology; as well I had recently conducted limnological observations on Williams Lake (https://dalspace.library.dal.ca/handle/10222/65254) so I knew where to borrow equipment, how to use it etc. With the help of two volunteers form the SLCA, I obtained limnological profiles of Sandy Lake in 2017, 2019, 2022, 2023 and continuing; since Aug 2022 in conjunction with the HRM lake Watchers Program. I maintain an ongoing report on my observations on a publicly accessible website - see www.versicolor.ca/sandylakebedford

3. On May 3 and June 22, 2023 Stantec staff met virtually with Sandy Lake Coalition Board members and participants they invited which included myself. Printed documentation I provided to Stantec for the June 22 meeting is attached; see: A1PatriquinSandyLakeWQforStantec22Jun2023.pdf **(On the precarious state of Sandy Lake).** On Sep 2, 2023, I sent an e-mail to a Senior planner at Stantec titled "Recent monitoring of Sandy Lake (Bedford NS) raises more concern about the state of the lake" and provided a link to the documentation, also attached here (A2_2023 LimnologicalProfiles&effectsOfEpisodic Precipitation.pdf (**2023 Limnological Profiles & effects of episodic precipitation).**

4. Identifying lake water quality trends and effective monitoring strategies in a rapidly urbanizing region. Doucet, C., 2022, [Master of Applied Science, Dalhousie University] Profiles for Sandy Lake are shown in Electronic Supplement 3. https://dalspace.library.dal.ca//handle/10222/82119

5. E.g., see (i) Canadian Environmental Indicators – Water Quality by Joel Wood. Fraser Institute of Environmental Policy, July 2013. Available at https://www.fraserinstitute.org/sites/default/files/canadian-environmental-indicators-water.pdf; (ii) Lakeshore Capacity Assessment Handbook: Protecting Water Quality in Inland Lakes on Ontario's Precambrian Shield Appendix A: Rationale for a Revised Phosphorus Criterion for Precambian Shield Lakes in Ontario. Ontario Ministry of Environment May 2010. Available at https://www.ontario.ca/page/lakeshore-capacity-assessment-handbook-protecting-water-quality-inland-lakes-ontarios-precambrian "**"T**he relationship between phosphorus and oxygen is implicit in any lake management activities and should, at least, be considered in formulating the PWQO [Provincial Water Quality Objective].*

6. AECOM 2014 Sandy Lake Watershed Study Final Report 131 pages. http://sandylake.org/wp-content/uploads/2017/11/SandyLakeFinalReport26Aug20141.pdf

7. E.g. see discussion in Canadian Water Quality Guidelines for the Protection of Aquatic Life" Phosphorous. Canadian Council of Ministers of the Environment, 2004 Available at https://ccme.ca/en/res/phosphorus-en-canadian-water-quality-guidelines-for-the-protection-of-aquatic-life.pdf "Currently, no national environmental quality guidelines exist for phosphorus, although individual provinces may have guidelines or objectives (Environment Canada 2004). The Protocol for the Derivation of Guidelines for the Protection of Aquatic Life (CCME 1991) is intended to deal specifically with toxic substances, and provide numerical limits or narrative statements based on the most current, scientifically defensible toxicological data. Phosphorus does not fit this model because it is non-toxic to aquatic organisms at levels and forms present in the environment; however, secondary effects, such as eutrophication and oxygen depletion are serious concerns..."

8. **SL Fig 10: Historical values of Sandy Lake EC (electrical conductivity).** Values are for near surface samples on single days in each of the years shown, except for 2020 value which is a an average for values (11) over a whole year. View sources. (More values to be added from Appendix C of AECOM 2014 but that will not change the overall trend.

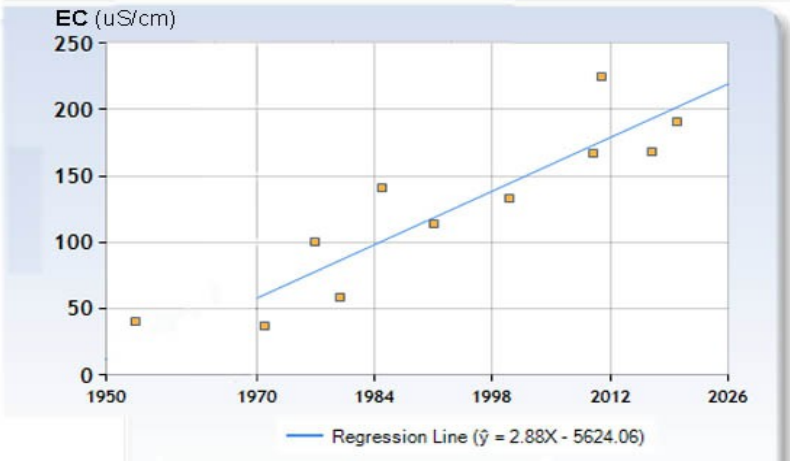


Figure is from **A DRAFT Report On the State of Sandy Lake, the Historical Trends and its Future Trajectory**, Feb 23, 2021 Posted at http://versicolor.ca/sandylakebedford/waters/lakes/

9. E.g. see - Synoptic snapshots: monitoring lake water quality over 4 decades in an urbanizing region
C. Doucet et al., 2023. In Lake Reservoir Management.
https://www.tandfonline.com/doi/full/10.1080/10402381.2023.2205355

- Assessing and predicting Lake Chloride Concentrations in the Lake-Rich Urbanizing Halifax Region, Canada
Tessa Bermarija et al., 2023. in Journal of Hydrology: Regional Studies Volume 47, June 2023 https://www.sciencedirect.com/science/article/pii/S2214581823000642

10. See Fig 8, p. 22 in AECOM 2014 Sandy Lake Watershed Study Final Report
http://sandylake.org/wpcontent/uploads/2017/11/SandyLakeFinalReport26Aug20141.pdf

11. For a recent review, see **Lakes in Hot Water: The Impacts of a Changing Climate on Aquatic Ecosystems** by Woolway, Sharma & Smol. 2022 In BioScience Abstract "Our planet is being subjected to unprecedented climate change, with far-reaching social and ecological repercussions. Below the waterline, aquatic ecosystems are being affected by multiple climate-related and anthropogenic stressors, the combined effects of which are poorly understood and rarely appreciated at the global stage. A striking consequence of climate change on aquatic ecosystems is that many are experiencing shorter periods of ice cover, as well as earlier and longer summer stratified seasons, which often result in a cascade of ecological and environmental consequences, such as warmer summer water temperatures, alterations in lake mixing and water levels, declines in dissolved oxygen, increased likelihood of cyanobacterial algal blooms, and the loss of habitat for native cold-water fisheries. The repercussions of a changing climate include impacts on freshwater supplies, water quality, biodiversity, and the ecosystem benefits that they provide to society." https://academic.oup.com/bioscience/article/72/11/1050/6639495

12. 72 page document prepared for HRM by McCallum Environmental Ltd. June 27, 2022 https://cdn.halifax.ca/sites/default/files/documents/city-hall/regional-council/220712rc15110.pdf. HRM Regional Council passed the boundary study motion unanimously Council passed the boundary study motion unanimously (motion below, moved by Counc. Blackburn, Seconded by Counc. Outhit):
That HaliSandy Lake Ecological Features Assessmentfax Regional Council direct the Chief Administrative Officer to:
1. Incorporate the analysis and findings of the Sandy Lake Ecological Features Assessment in the planning and development of Sandy Lake Park.
2. Review and use the findings of the Sandy Lake Ecological Features Assessment in the background studies being undertaken for the Sandy Lake Special Planning Area, including organizing the form and location of development to best protect *at least*:
a. the suggested widths for important corridors,
b. the suggested riparian and watercourse buffers, and
c. the identified areas of predicted old or mature forest.
3. Explore the use of conservation easements as part of the Sandy Lake Provincial Special Planning Area background studies to manage ecological features or corridors that extend outside of the conceptual park boundary.
4. Assess how to best organize land use and green infrastructure as part of the Sandy Lake Provincial Special Planning Area Background Watershed Study to mitigate any downstream impacts to the Sackville River and Sackville River Floodplain.

From the Discussion: Water Quality In considering water quality preservation, the report identifies that the aquatic and riparian features in the study area generally scored highest in the overall analysis of the various environmental features. Figure 6 of Attachment B shows all identified wetlands with a 50 metre buffer for riparian areas, and all identified watercourses with a 100 metre buffer for riparian areas. The Assessment identifies the importance of Sandy Lake, Marsh Lake, Jack Lake and the Sackville River and their associated tributaries and riparian areas in protecting water quality.

Link to Council discussions vote:
https://www.youtube.com/watch?v=Lc_IcYMRJ44

10. Attachments

A1PatriquinSandyLakeWQforStantec22Jun2023.pdf **(On the precarious state of Sandy Lake).**

A2_2023 LimnologicalProfiles&effectsOfEpisodic Precipitation.pdf **(2023 Limnological Profiles & effects of episodic precipitation)**

On the precarious state of Sandy Lake

David Patriquin for discussion with Stantec, June 22, 2023

The points are numbered to facilitate discussion. Related charts are attached.

1. AECOM (2014) applied the Lakeshore Capacity Model (Dillon and Rigler 1975) as elaborated by Brylinski (2004) and MOE (2011) to predict the effects of the proposed development on lake water Total P. They concluded that a development to the west of the lake accommodating up to 15,000 people and occupying circa 350 ha would be compatible with maintaining water and fish habitat quality.

2. There are four serious problems with the manner in which AECOM (2014) applied the model:

(i) **As cited by AECOM (2014), modelled phosphorus concentrations differed by far more than 20% of the measured concentrations (it was 67% higher), indicating the model is not valid,** but the recommended procedures to revise the model were not followed.

(ii) **Setting the Water Quality Objective (WQO) for Total P in Sandy Lake at 50% above the "current value" rather than at the "predevelopment level" is not justified**, as concluded also by professional limnologist S. Mandaville in documents submitted to HRM in 2013 and 2014. Had AECOM used a "predevelopment level" of Total P in their model estimated from the earliest available total P value, by "hindcasting" the Total P value by computer modelling (as conducted by S. Manadaville), or by using the paleolimnological values for Sandy Lake available from a Queens University study - none of these options were considered in AECOM 2014 - most or all of of the predicted outcomes with development would likely have been shown to be not acceptable.

(iii) **AECOM 2014 presents but does not highlight evidence showing that in its current state (at 12 ug P/L), Sandy Lake is already seriously degraded,** notably in relation to the elevated deep water P values, discussed briefly on p22, not elsewhere in AECOM 2014)

(iv) **Varying the phosphorus export coefficient, rather than increasing the lake retention coefficient would be a more realistic "fix" to make the model work** and would likely increase the predicted impacts of development on Total P.

View details here: http://versicolor.ca/sandylakebedford/waters/lakes/sl-report-more-details/critique-of-predictions-lack-of-follow-up/

3. Regardless of those issues, AECOM (2014) recognized practical limitations to their predictions and proposed "a robust water quality monitoring plan... for the Sandy Lake watershed to provide a further assessment of current conditions and to evaluate the impacts of development on the water quality". Such monitoring was not subsequently initiated.

4. With assistance of volunteers from the Sandy Lake Conservation Association, I initiated some monitoring in 2017, obtaining to date 6 limnological profiles in the deepest area of the lake. Those profiles of temperature, oxygen, and specific conductivity (a measure of salt concentration), in combination with some historical data, illustrate clearly two troubling trends (see Fig 1, attached):

(i) Deep water oxygen levels during the period of summer stratification have already declined to levels inhospitable to salmonids (circa 5 mg/L and less) and low enough (2 mg/L and less – Nurnberg 2004) to cause anoxia and release of phosphorous from sediments (sometimes described as "internal P loading"), accelerating eutrophication.

Two limnological profiles obtained in Sandy Lake by Casey Doucet in relation to her research for a Masters in Applied Science at Dalhousie University provide some independent verification of these observations. (View thesis on Dalspace). She sampled two sites on Sandy Lake in the latter half of August 2021, one at the deepest point or close to it; her max. depth sampled was approx 19 m; and a second site with max. depth sampled approx 5.5 m. At the 19 m site, the oxygen value for deepest sample was approx 0.41 mg/L. She also measured total P at 0, 3, 7, 10 and approx 18 meters; values 0-10 m were close to 10 ug/L; the 18 m value was approx. 22 ug/L, i.e. there appears to have been significant internal P loading. At the shallower site, oxygen declined between 3 and 5.5 m from approx 8 mg/L down to close to 2 mg/L; and there was an overall increase in total P with depth.

(ii) Salt levels have risen continuously since 1971 and some salt stratification is occurring. Based on studies by Scott et al. (2019) on changes in salt levels in local lakes over time and my rough estimates of the increase in hard cover expected with development, salt stratification could increase to levels observed to inhibit spring turnover in a lake in NY state with similar dimensions; such an outcome would further accelerate decline of Sandy Lake (see Fig 2, attached)

5. There have been some early warning signs of deterioration in the health of Sandy Lake:

– Elevated deep water Total P levels were noted by AECOM (2014) for two of three samplings in 2008, 2010 and 2011; these were suspected to be associated with low oxygen levels. And as noted above, Casey Doucet's observations in 2021 showed highly elevated deep water Total P.

– An intense algal and to swimmers, a very unpleasant bloom – the beach was closed - occurred in August of 2019. It coincided with a rapid drop in lake water level, and subsided as the water level stabilized; I later found out that the drop in water level was associated with removal of a beaver dam in Peverill's Brook. I have suggested the bloom was caused by some transient "destratification" and movement of phosphorous-rich deep waters into the photosynthetic zone.*

*In the document circulated to an earlier meeting with Stantec, I cited also a BGA Warning in 2022 which had been announced on the novascotia.ca website and in the local newspaper. When I mentioned the BGA bloom at a meeting with the NW Commnity Council on June 12, 2023, Councillor Tim Outhit said that HRM sampling showed these blooms were in fact due to pollen. I followed this up with provincial and HRM personnel: the warning was issued publicly by the province based on a citizen report in latter June, but they did not do any follow-up. HRM personnel followed up with sampling at Sandy Lake Beach Park; that did not reveal BGA. The followup sampling was not announced publicly because the swim season had not yet opened. HRM personnel confirmed that the 2019 bloom was associated with diatoms, i.e. it was an "algal bloom" (as I had described it), not a BGA bloom and not pollen. To date there have been no confirmed BGA blooms at Sandy Lake. To put this in perspective: BGA blooms

have been less common in NS than in many other places because our lakes are generally quite acidic which is not favourable for BGA. However, BGA blooms have been increasing in recent years likely due at least in part to increasing anthropogenic inputs, also because of S emission controls.

6. Ongoing development already approved to accomodate approx. 2400 people in Bedford West Area 12 and new development to accommodate approx. 15,000 people west of the lake (AECOM, 2014) would increase the settled area from approx 29% of the watershed in 2014 to about 45%. Further it would occur, as I understand it, in the area to the SW where surface waters entering the lake are concentrated (see attached Fig. 3) and could involve loss of a significant wetland (see attached Fig 4) in the headwaters. Climate warming is another emerging stressor (re: lower oxygen solubility, increased BGA blooms, and earlier development of summer stratification).

7. Water quality of Sandy Lake has already declined to precarious levels and the trend is for further decline, i.e., remedial measures are required even without further development. I cannot see how these issues can be addressed and collapse of the lake with attendant loss of its substantive recreational and ecological values prevented if development on the scale being discussed goes ahead. At a minimum, the buffer zones recommended in the **McCallum Report** must be respected (50 m for wetlands, 100 m for watercourses).

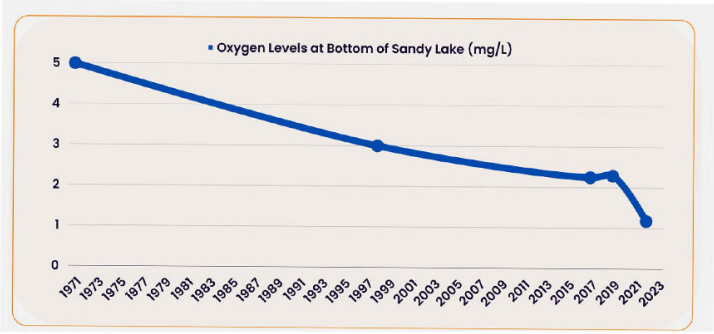
8. It's important to note that as well as Sandy Lake being potentially very negatively affected by a major development in its headwaters, the health of Marsh Lake and Peverills Brook downstream and the seagoing fish those (salmon, trout, gaspereau, American eel) are pretty well entirely dependent on the health of Sandy Lake.

9. Another concern: the possible impacts of significant additional development in the Sandy Lake Watershed on downstream flooding were NOT modelled in the 2018 Sackville River Floodplain study. I was told by consultant Alexander Wilson at an open house that's because they had not been instructed to model the Sandy lake watershed, presumably, he said, because it was assumed by HRM that there would be no significant additional development over the next 100 years! (Sandy lake is the largest or 2nd largest sub-watershed in the Sackville River Watershed, depending on how they are aggregated.) Surely that is a major issue that needs to be addressed.

10. For details including references, view **A DRAFT Report On the State of Sandy Lake, the Historical Trends and its Future Trajectory** and associated web pages; also this post: Deep water oxygen levels in Sandy Lake (Bedford, NS) fall to precariously low levels 21Mar2023

Fig 1.

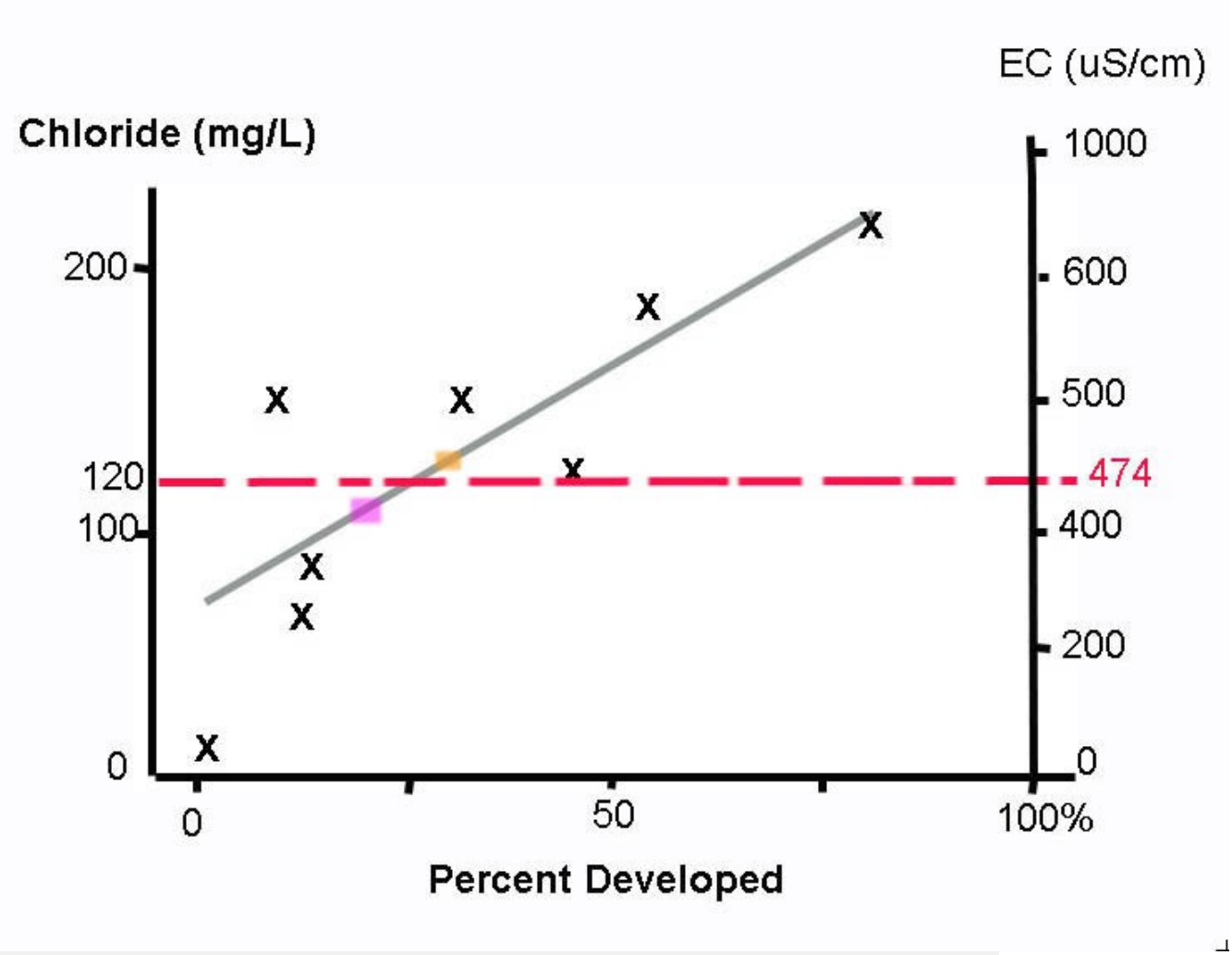
Variable	1971	1998	2017	2019	2022	2021*
Temp (^{o}C):						
Surface	21	22	17.1	16.9	24.7	**25**
Bottom	-	6	5.7	7.2	7.6	**6.5**
Conductivity (µS/cm)						
surface	37	125	169	159	209	
bottom	39	146	248	204	229	
Oxygen (mg/L)						
Surface	7.25	8.6	9.42	8.85	8.06	**9**
Bottom	5.0	3	2.25	2.29 **6.5**	1.18	**0.4**



* From Casey Doucet. 2022. **Identifying lake water quality trends and effective monitoring strategies in a rapidly urbanizing region.** Masters in Applied Science thesis, Dalhousie University. Values were interpolated from graph in Fig. B 1. She also plots vlaues for total P, interpolated values below:

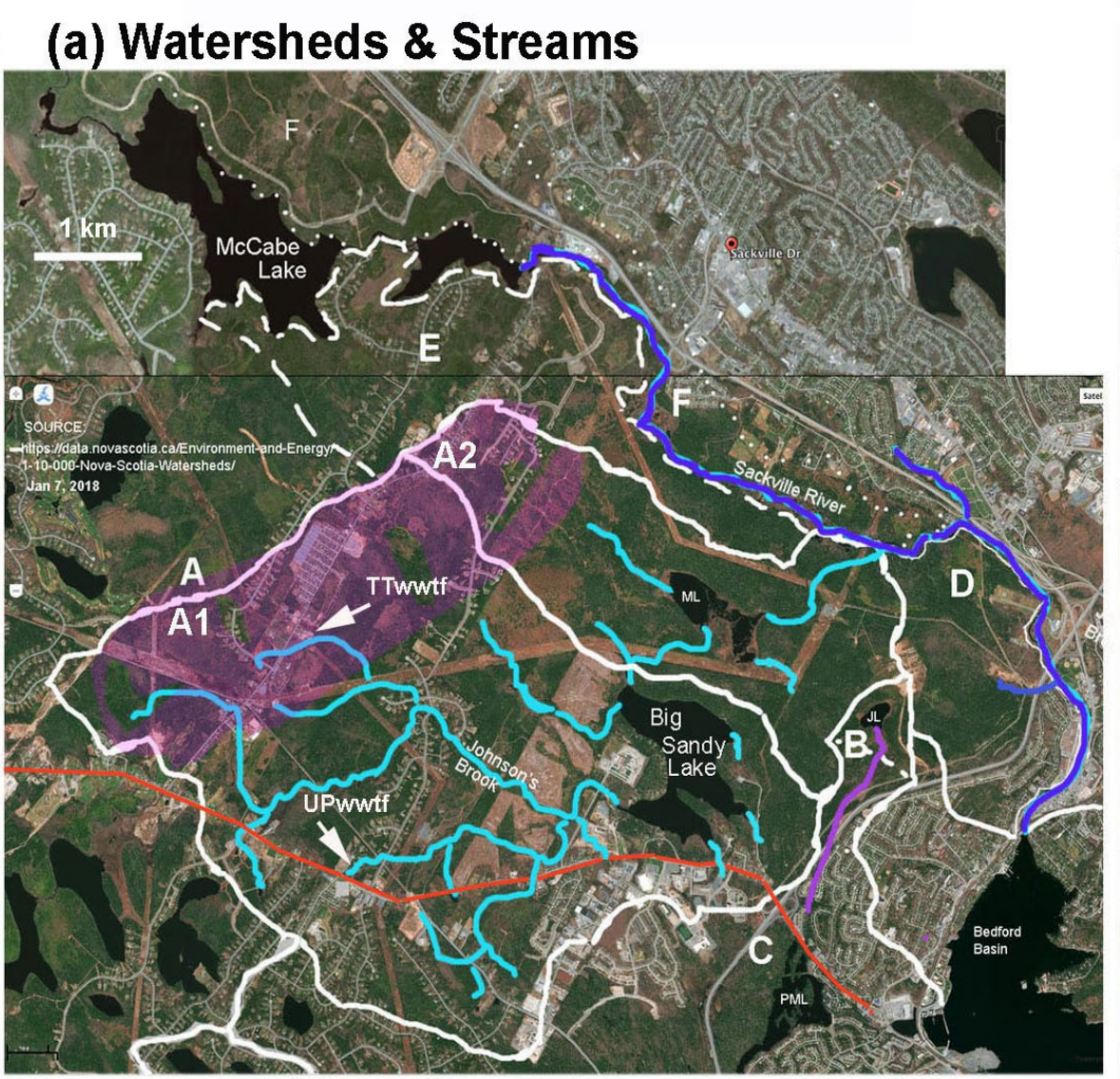
Depth (m)	Total p (ug/L)
0	4.5
3	5
7	5
10	5.2
18	22

Fig. 2



Relationship of Chloride and EC to Percent Land Area Developed. Graph adapted from Fig 6 in Scott et al., 2019.. The orange-filled rectangle shows where 30% Development (the approx. current level at Sandy Lake*) would fit on the Scott et al., 2019 regression line relating chloride concentrations in the spring of 2013-2017 to the percent watershed developed for 9 Halifax lakes. EC values on the right correspond to the chloride values, based on the relationship given in AECOM (2020). The current spring EC value for Sandy Lake is approx 190 uS/cm. The CCME Guideline for long term exposure to chloride is 120 mg/L (the dashed red line). So if Sandy Lake behaves like the other lakes, it would achieve a steady state value just above (orange rectangle) or just below (purple rectangle) 120 mg/L chloride – at the current level of development, higher if further developed.* My estimate based on measurements shown under Land Use; the purple square represents 21% Developed, the approximate (interpolated) value cited by Casey 2022, Fig 2.2 for Sandy Lake in 2020

Fig 3. **Surface Waters and location of Acid Slates within the Sandy Lake Watershed.**



A1 Sandy Lake and **A2 Marsh Lake** are in the **Sandy Lake subwatershed** of the **Sackville River watershed**. **E South McCabe Lake** and **F North McCabe Lake** subwatersheds also lie in the Sackville River watershed. **B Jack Lake** subwatershed of **C Papermill Lake watershed**. The **purple-highlighted area** contains bedrock with acid-generating potential. **TTwwtf: Timber Trails** and **UPwwtf: Uplands Park waste water treatment facilities**. **Turquoise-highlighted streams** are the major streams in the Sandy lake subwatershed as identified in the AECOM 2014 Report.

The developments being considered would be located to the west and southwest of Sandy Lake where surface waters entering the lake are concentrated.

Fig. 4. **Significant wetland on headwaters that could be lost to development.**

The wetland NIA1 (No Information Available - as cited on NS Provincial Landscape Viewer), more recently known as “Walters Marsh”, would, according to scenarios cited in AECOM (2014), be eliminated and replaced by residential landscape.

For more info., view Wetlands SW of Sandy Lake.

2023 Limnological Profiles & effects of episodic precipitation

Contents

Water sampling on Sandy Lake, Aug 14, 2023, here by the outlet. Insets: At left the YSI Probe with weight attached; right: YSI Instrument panel. A portion of the Van Dorn water sampling bottle can be seen by the anchor.
Click on images for larger versions

SUMMARY

After extreme precipitation events earlier in the summer of 2023, the entire water column had lower conductivity values (a measure of salt content) on Aug 14 compared to May 22 and bottom waters on Aug 14 were better oxygenated than on 6 other occasions in the past when deep water oxygen levels were measured in late summer/early fall. This flushing and oxygenation could be good news if there weren't other adverse effects of the heavy precipitation. Observations in the latter half of August in 2021, 2022 and 2023 show the presence of a "Metalimnion Oxygen Minimum" at 5-6 m; it appears that it reformed quickly after the high precipitation events in 2023. The occurrence of a Metalimnion Oxygen Minimum in Sandy Lake represents significant deterioration in water quality of the upper layers of the water column and adds yet more reason to be concerned about the state of the lake currently and the possible impacts on lake water quality if the proposed major development on its headwaters was to proceed.

BACKGROUND

Sandy Lake was identified as a 'future growth area' for Halifax Regional Municipality in the first (2006) Regional Plan and again in the second (2014) **Regional Plan**. The lands west of Sandy Lake were zoned as "Urban Settlement" which in turn called for a Watershed Study as defined by Policy E17.

The Watershed Study for Sandy Lake was completed by AECOM in 2014. Except for a few surface water samples collected in 2013/2014, it was entirely a desktop study (as requested by HRM). Based on their use of the Lake Capacity Model – a phosphorus load model – AECOM (2014) predicted that up to approx. 12,000 people and new development on 56% of the area of the Sandy Lake sub-watershed would be compatible with maintaining desirable water quality in Sandy Lake, providing certain mitigative measures are followed.

There are significant issues I and others have raised concerning AECOM's use of the Lake Capacity Model that should raise serious doubts about the validity of the model as applied by AECOM for Sandy Lake, and hence its predictions. Regardless, AECOM (2014) acknowledged that the modelling provides only a first approximation to

reality and recommended "a robust water quality monitoring plan...for the Sandy Lake watershed *to provide a further assessment of current conditions* and to evaluate the impacts of development on the water quality." (Italics inserted)

In the spring of 2022, lands to the west of Sandy Lake were identified by the Province/HRM as a *Special Planning Area* "for the purpose of accelerating housing development in the Municipality". View Doc

Such monitoring was not subsequently implemented by HRM, which nonetheless continued to plan for a major development; more recently the provincial Task Force on Housing in HRM has named the land West of Sandy Lake a "Special Planning Area" to be fast tracked for development. In other words, such planning is proceeding on the unproven and very uncertain assumption that new development could proceed without serious impacts of the recreational and ecological well-being of Sandy Lake.

In 2017, with the help of volunteers Ed G., Derek S., and Bruce S. of the Sandy Lake Conservation Association, we began to monitor some key limnological variables in Sandy Lake, in particular the vertical profiles of temperature , oxygen, conductivity and pH at or close to the deepest spot on the Lake.

We borrowed the required equipment from the Community Based Environmental Monitoring Network based at St. Mary's University in Halifax for sampling vertical profiles on Oct 3, 2017, Sep 30, 2019; and Apr 19, 2021; from the Atlantic Water Network on May 7, 2022. On Aug 22, 2022; Apr 21, 2023 and Aug 14, 2023 and thereafter we conducted observations in conjunction with the newly established Halifax LakeWatchers Program.

These observations, combined with some historic data, revealed two phenomena that raise serious concerns about the state of Sandy Lake *currently*, and the impacts of further development:

(i) **Rising salt levels and "salt stratification" of the water column**. Such increases are well documented more generally for lakes in HRM and elsewhere in areas where road salt is used. It has been shown that the percentage of development and associated factors is the major driver of these increases. Development on the scale proposed for Sandy Lake would very likely drive salt levels into the chronic toxicity range; it could increase salt stratification to the point that normal spring turnover is inhibited, resulting in more prolonged anoxic conditions in deepwater and "internal phosphorus loading" which would accelerate eutrophication and deterioration of Sandy Lake. The "salt issue" was not identified in the AECOM (2014) Report. For more details see DRAFT Report On the State of Sandy LakeSandy Lake: Temporal Trends in EC (salt); & Road Salts

(ii) **Falling and now very low deep water oxygen levels**

Ours were the first complete limnological profiles obtained for Sandy Lake, however top and bottom values for the same variables were obtained in studies conducted in 1971 and 1998, giving us a set of 5 top-and-bottom measurements during the period of summer stratification covering a span of 51 years:

Variable	1971	1998	2017	2019	2022
Temp (^{o}C):					
Surface	21	22	17.1	16.9	24.7
Bottom	-	6	5.7	7.2	7.6
Conductivity (µS/cm)					
surface	37	125	169	159	209
bottom	39	146	248	204	229
Oxygen (mg/L)					
Surface	7.25	8.6	9.42	8.85	8.06
Bottom	5.0	3	2.25	2.29	1.18

Table 1. **Historic Shallow and Deep Water Temperature, EC and Oxygen values for Sandy Lake (Bedford) during the summer stratification period.**
1**971**: from Metropolitan Area Planning Committee 1971-1972: Water Quality Survey for Selected Metropolitan Area Lakes. Lake sampled on Aug 30, 1971. Deep sample at 59 feet (18 m). Chloride was 8.0 at surface, 12.0 at 59 feet (18 m). EC and chloride were elevated in the Southern Inlet sample (57.0 µS/cm, 11.0 mg/L). **1998**: Nova Scotia Lake Inventory Program Sep 2, 1998. Deep sample at 19 m. Chloride at surface was 29 mg/L at 19 m, 34 mg/L. **2017**: Sampled Oct 3, deep sample at 17.5 m. **2019**: Sampled Sep 30, Deep sample at 21 m. **2022** Sampled Aug 22. Two profiles, averaged the values (at 19,5 and 20m)

Although the data are limited, it's clear that there have been big changes in deep water (bottom) dissolved oxygen and in conductivity (both top and bottom) over the 51 year period. Of particular concern is the progressive decline in bottom oxygen values over the 5 sampling dates, going from 5.0 mg/L in 1979 to 1.18 mg/L in 2022. This has two major repercussions:

(i) **Deterioration of the cool deep water refuge for salmonids in summer.**

(ii) **There is increased likelihood that intervals of hypoxia (low oxygen) in deep water could result in anoxic conditions (no oxygen) at the sediment surface and associated mobilization of phosphorous, accelerating eutrophication and marked deterioration of water quality**

Two limnological profiles obtained in Sandy Lake by Casey Doucet in relation to her research for a Masters in Applied Science at Dalhousie University provided some independent verification of our observations. (View thesis on Dalspace). She sampled two sites on Sandy Lake in the latter half of August 2021, one at the deepest point or close to it; her max. depth sampled was approx. 19 m; and a second site (the southern basin) with max. depth sampled approx. 5.5 m. At the 19 m site, the oxygen value for deepest sample was approx 0.41 mg/L, lower than any of our values. She also measured total P at 0, 3, 7 ,10 and approx. 18 meters; values 0-10 m were close to 10 ug/L; the 18 m value was approx. 22 ug/L, i.e. *there appears to have been significant internal P loading*. Even at the shallower site, oxygen declined between 3 and 5.5 m from approx 8 mg/L down to close to 2 mg/L; and there was an overall increase in total P with depth.

THE AUGUST 2023 OBSERVATIONS

On Aug 14, we conducted our late summer profile for 2023.

We had very high rainfall events in July and August with flash floods associated with the rainfall on July 21 & 22and Aug 5 affecting the Sandy Lake/Bedford area, the latter much less so than the earlier dates (Weather Network Aug 5, 2023; Reuters July 24, 2023). Sandy Lake was impacted by overflow from a sewage pumping station on Farmers Dairy Lane during the July event (CTV news July 24, 2023); the overflow was contained by July 26 (HalifaxWater message July 26, 2023). The water level in Sandy Lake increased by 5-6ft and remained well above historic levels until late in Aug (personal communication from two lakeside residents).

On Aug 14, 2023 there was freshening of the whole water column (indicated by lower Conductivity values) and the thermal stratification was much less pronounced compared to the Aug 2022 profile:

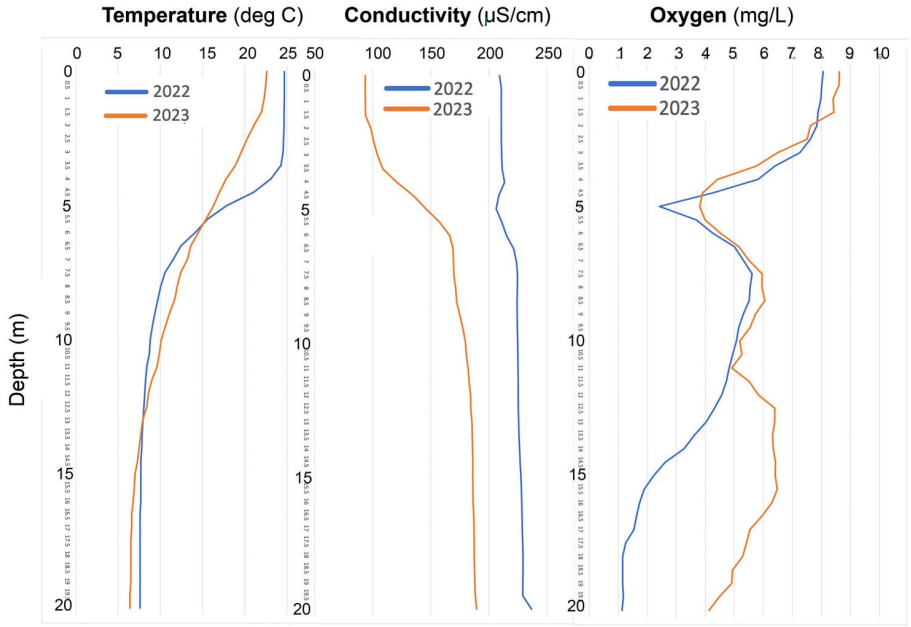


Fig. 1. **Temperature, conductivity and oxygen profiles on Aug 22, 2022 (blue) and Aug 14, 2023 (orange).** Note the gradual decline in temperature in 2023, versus the existence of a distinct zone of large temperature change (the "**thermocline**" or the "**metalimnion**") between 3 & 7 m in 2022; however there is a much sharper change in conductivity in that depth interval in 2023 compared to 2022, i,e. more pronounced salt stratification. Conductivity values in 2023 were much lower than in 2022 through the entire water column. View Dimictic Lakes on Wikipedia for a brief description of the type of lake stratification we have in Sandy Lake, and the zones (epilimnion, metalimnion, hypolimnion).

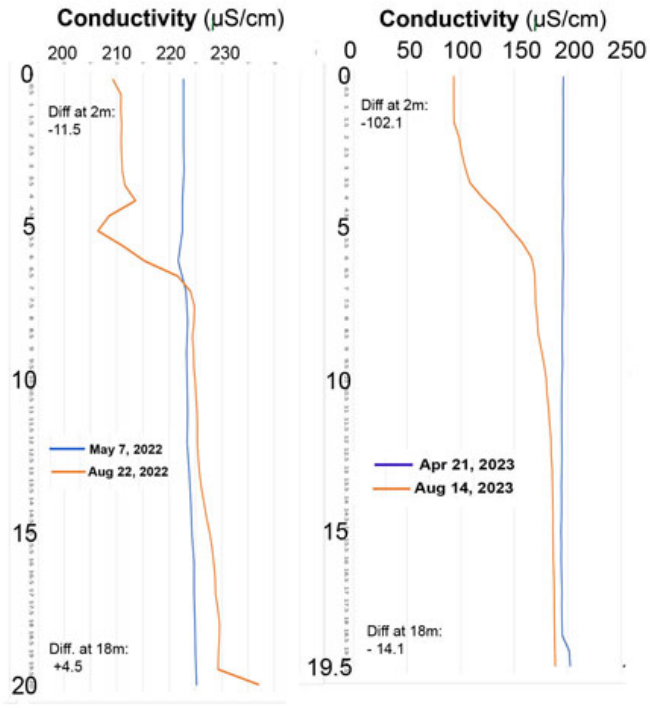


Fig. 2. **Conductivity values in spring and late summer in 2022 (left) and 2023 (right)**
Note differences in horizontal scales. "Diff" is the late summer value minus the spring value. At 18 m the late summer value exceeded the spring value in 2022 by 4.5 uS/cm but was less than the spring value in 2023 by 14.1 uS/cm – further evidence that some freshening occurred even in the deeper water in 2023. It was much more pronounced at 2 m. In our seasonal sampling, the conductivity of the surface water on July 7 2023 was 187 uS/cm; on Aug 2, 2023 it was 101 uS/cm.

Deep water oxygen levels in Aug of 2023 were approx. 3-4 mg/L higher than in 2022 (see Fig 1, above)* reaching a value close to 5 mg/L at 18 meters depth, a clear break from very low values observed since 1997:

*In the earlier, spring sampling in both years, the water column was well oxygenated, see Limnological Profiles

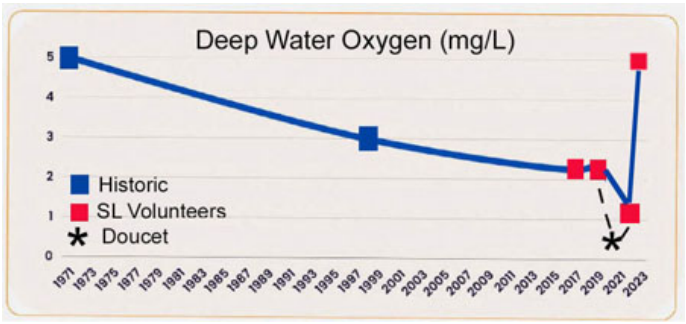


Fig 3. **Near-bottom oxygen levels in deepest area of Sandy Lake 1971 to 2023**. Observations on Aug 30, 1971; Sep 2, 1998; Oct 3, 2017; Sep 30, 2019; Aug 22, 2022; Aug 14, 2023; & (Doucet) Aug 16-23 interval in 2021. View Post Mar 21, 2023 for details.These are dramatic changes, and are attributable to the episodic rainfall events in mid-summer of 2023.

This increase could be viewed as good news, and we might even speculate that if heavy precipitation in mid-summer continues in future years because of warmer ocean waters near NS, that would be good for Sandy Lake. BUT, there's a lot about the episodic event we don't know. For example, did the the massive flushes of water carry

with them a lot of organic debris and sediment that sunk to the bottom and that will increase oxygen consumption in the deeper layers in future? The Secchi disk reading on Aug 14, 2023 was 1.5 m compared to 2 m on April 21, 2023, and 2.5 m on Aug 22, 2022 and the water was noticeably browner than usual. One of the commonly documented effects* of episodic precipitation is an in increase in the DOC (Dissolved Organic Carbon, made up largely of humic substances) which can push a lake to a higher level of heterotrophy/oxygen consumption.

*See e.g., Effects of weather-related episodic events in lakes: an analysis based on high-frequency data, E. Jennings et al. 2012 in *Freshwater Biology*; Extreme weather years drive episodic changes in lake chemistry: implications for recovery from sulfate deposition and long-term trends in dissolved organic carbon, KE Strock et al., 2016 in *Biogeochemistry*.

Occurrence of a "Metalimnetic Oxygen Minimum"

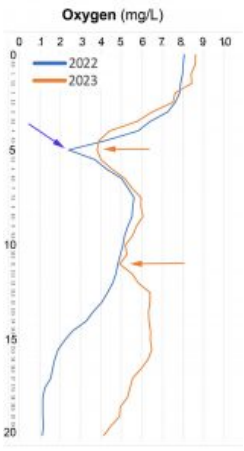


Fig 4. **Oxygen Profile in Aug 22, 2022 and Aug 14, 2023.** Arrows point to oxygen minima in the upper part of the water column. The top two occur in the metalimnion, the bottom one is below it. (See Fig 1 for the temperature profiles.)

One characteristic of these August profiles that changed very little between 2022 was a dip in the oxygen level with a local minimum of at 5-6 meters in the metalimnion in both 2022 and 2023; the minimum value in 2023 (3.8 mg/L) was higher than in 2022 (2.4 mg/L)

When I first observed this dip (Aug 22, 2022), I was skeptical about its reality as the oxygen readings were taking too much time, I felt, to equilibrate; I wrote a note to the organization from which we had borrowed the equipment to suggest that perhaps the sensor membrane needed to be replaced.

In the late fall of 2022, Casey Doucet reported on limnological observations she had conducted on a suite of lakes in HRM, including Sandy Lake, in 2021, for her Masters of Applied Science research at Dalhousie University. Her plot of oxygen versus depth for Sandy Lake in mid August 2021* showed almost exactly the same thing: a dip in oxygen to approx. 3.2 mg/L at 6 meters, in the metalimnion. So I knew this dip was real. Then we observed the dip again in Aug 2023.*Identifying lake water quality trends and effective monitoring strategies in a rapidly urbanizing region. Doucet, C., 2022, [Master of Applied Science, Dalhousie University] Profiles for Sandy Lake are shown in Electronic Supplement 3.

I checked my "bible" on lakes – Wetzels Limnology, 3rd ed. (2001). It turns out that *increases* in oxygen in the metalimnion or "Metalimnetic Oxygen Maxima" are relatively common, *dips* in oxygen or "Metalimnetic Oxygen Minima" much less so.

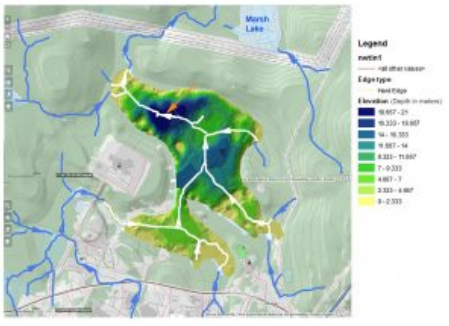


Fig. 5. **Bathymetric Map of Sandy Lake** (Ed Glover, 2006) with an overlay of the WAM Predicted Flows from the NS Provincial Landscape Viewer; streams are

The precise cause of Metalimnetic Oxygen Minima may vary; it is more commonly observed in eutrophic (nutrient rich) lakes than in oligotrophic (nutrient-poor) lakes*. Interestingly, of the 4 lake profiles presented by Doucet 2022 that were 15 m and greater, distinct dips in the metalimnion were present in the two (one of them Sandy Lake) that also exhibited very low oxygen and highly elevated total P levels near the bottom.

Lake morphometry and benthic oxygen consumption in shallower waters can be contributing or pre-disposing factors to the formation of

highlighted. The orange arrow point to the location of the deep water profiles. *Click on image for larger version*

Metalimnetic Oxygen Minima*.

*View Surface Waters.Lit & Links/Metalimnetic Oxygen Minima for some of the scientific literature consulted.

It is probably relevant that at Sandy Lake, a lot of surface water flows into the lake over extensive shallower areas (Fig 5, above) and thus is exposed to the sediment surface in the southern basin well before it reaches the area of our profile. also that some of these waters come from the more developed areas and areas where new development is planned or proposed. Climate warming could be expected to enhance the effect by increasing rates of respiration in shallower waters and sediments.

Curiously, there was a second minimum at about 12 m in 2023, not observed in 2022 or in Casey Doucet's Profile. Did the massive flushes of water essentially push the shallower water minimum deeper, and then the shallower minimum reform? We can't say of course, but the fact that a shallower (5 m) Metalimnetic Oxygen Minimum was still evident in fresher water than had prevailed earlier in the summer, suggest that the processes leading to its formation were very active throughout and/or *after* the freshening.

Metalimnetic Oxygen Minima in 2021 (Casey Doucet), 2022 and 2023 (our observations) were below the requirements of both warm water and cold water aquatic life (CCME, 1999) and thus represent significant deterioration in the Water Quality of Sandy Lake beyond that associated with low oxygen in the hypolimnion. Because Metalimnetic Oxygen Minima are usually associated in some way or another with enhanced respiration in shallower waters, it may also accelerate nutrient cycling and production in the upper waters (i.e. speed eutrophication).

It's not clear whether the occurrence of a Metalimnetic Oxygen Minimum at Sandy Lake is a recent phenomenon. It was not present in profiles of Oct 3, 2017 (the earliest available for Sandy Lake) and Sep 30, 2019, but these were later in the season (in the early fall) versus the late summer observations of 2021 (Casey Doucet), 2022 and 2023 (our observations); on those later dates, the waters had not turned over but they had cooled significantly and higher temperatures (which would increase respiration rates) are likely necessary for its formation.

Unfortunately, climate warming is likely to enhance the Metalimnetic Oxygen Minimum in Sandy Lake, resulting in even lower metalimnion oxygen values in future.

I have not been able to locate any studies specifically referencing Metalimnetic Oxygen Minima in Nova Scotia which may indicate that to date it has not been a common phenomenon. Regardless, climate warming and increasing urbanization could lead to its more common occurrence. In Brylinski's 2002 report on the Nova Scotia Lake Hypolimnion Project, Metalimnion Oxygen Minima appear to present in 4 of the 20 lakes surveyed (profiles are given in Appendix III). As mentioned above, of the 4 lake profiles for HRM area lakes presented by Doucet 2022 that were 15 m and greater, distinct dips in the metalimnion oxygen were present in the two (one of them Sandy Lake) that also exhibited very low oxygen and highly elevated total P levels near the bottom.

In regard to Sandy Lake, the occurrence of a Metalimnion Oxygen Minimum and its apparently quick re-formation after the episodic flooding unfortunately adds yet more reason to be concerned about the state of the lake currently and the possible impacts on lake water quality if the proposed major development on its headwaters was to proceed.

SOME RELATED PAGES & POSTS

Surface Waters/Sandy Lake: **A DRAFT Report On the State of Sandy Lake, the Historical Trends and its Future Trajectory**
Feb 23, 2021. A syntheses. Updates are made

Surface Waters/Sandy Lake/**Limnological Profiles**
All of our profile observations, including data files

Surface Waters/Lit & Links/**Metalimnetic Oxygen Minima**
Scientific Literature related to the discussion of the Metalimnetic Oxygen Minima above

Surface Waters/Sandy Lake/SL Report More Details/**Critique of Predictions/No Followup Monitoring**
More details on Sandy Lake re: section 4.2 Critique of the AECOM (2014) Predictions/No Followup Monitoring

Surface Waters/Sandy Lake/SL Report More Details/**Policy E-17**
Text from Pages 30 and 31 of HRM Regional Municipal Planning Strategy (2006) This policy specifies the requirements of lake studies required as part of secondary planning for lands zoned as Urban Settlement. “These studies shall determine the carrying capacity of the watersheds to meet the water quality objectives which shall be adopted following the completion of the studies.”

Surface Waters/Sandy Lake/SL Report More Details/**Mirror Lake – Sandy Lake comparison**
Cases of impairment of spring turnover when salt levels/conductivity get very high are well documented, locally Oat Hill Lake is a prime example; in 2017 deep water EC was circa 1200 uS/cm March through October, compared to values in the range 250 to 550 uS/cm on the surface. However, there is very little documentation of the minimum differences in salt/conductivity that can impair regular turnover in dimictic lakes; obviously local factors such as area of lake, exposure to wind are important as well. Mirror Lake in New York state is similar to Sandy Lake in many respects and impairment of spring turnover for this lake has recently been documented.

Deep water oxygen levels in Sandy Lake (Bedford, NS) fall to precariously low levels 21Mar2023
Post, Mar 21, 2023.

Regarding Case 23307 – Bedford West subareas 12 & 1 Special Planning Area 25Jul2023
Post, Mar 21, 2023. The impacts of already approved development for this area on Sandy Lake have not been taken into account. It is currently a mostly undeveloped treed landscape with significant wetlands.

Page created Sep 2, 2023
