"WALKING THE RIVER"

A Citizen's Guide to Interpreting Water Quality Data

Nova Scotia Salmon Association

NSLC Adopt-a-Stream Program

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Introduction

The water in our wetlands, streams, lakes, rivers and estuaries is a soup of chemicals that combine with the physical properties of the water to produce constantly changing conditions, the bounds of which determine the species that can live there, their numbers and their health. Water of course is not just for the life that lives in it; all life depends on the availability of good quality water and all uses must be considered. Determining water quality for the productivity and health of aquatic life is complex and is the subject of ongoing research, but standards can be set for defined objectives.

The science of surface water quality and aquatic ecology is known as limnology and is practiced by biologists, chemists, hydrologists and engineers. In the past government agencies and university researchers have conducted much of the scientific investigation of surface waters but industries, municipalities, non-government organizations and community volunteers are now active partners.

What is surface water quality and why is it important?

Surface water quality encompasses a wide range of conditions that are part of the aquatic environment. In turn, the aquatic environment provides diverse habitats and a clean water supply for all aquatic life, wildlife and humans.

There is no single or simple measure of water quality. Water may be tested for a few characteristics using hand held electronic meters to monitor for change, but the water sampling plan almost always includes collecting water samples that are then sent to a lab to be tested for numerous natural substances and contaminants to gain a good understanding of the specific watercourse and to identify stressors on the aquatic ecosystem. Generally a water sampling plan includes the combination of both approaches.

Water quality measurements fall into three broad categories

- **physical characteristics** such as temperature, colour, suspended solids and turbidity;
- **chemical characteristics** such as nutrients, minerals, metals, oxygen, organic compounds and a wide range of pollutants (e.g., pesticides, hydrocarbons, pharmaceuticals, metals, & PCBs); and
- **biological characteristics** such as the types and quantities of bacteria, protozoan, emergent plants, algae, invertebrates, fish and other aquatic and terrestrial animals that live in or adjacent to the watercourse.

Physical, chemical and biological measurements can be used together to describe the overall quality or health of an aquatic ecotype.

What influences water quality?

Many factors influence water quality including climate and precipitation, soil type, geology, vegetation, groundwater input and runoff flow conditions. For example, fast-flowing streams have different physical, chemical and biological characteristics than slower-moving streams. Similarly, the freshwater lakes and wetlands in the Province vary in water characteristics. There are three rock formations in Nova Scotia that influence fresh water quality. Most areas have a thin soil (glacial till) overlying granite rocks, meguma or acid generating slates, and limestone rock which is basic. The Tangier River on Eastern Shore is an example of a river flowing over meguma. An example of a river flowing over glacial till covered granite would be East River Chester, and an example of a river flowing over limestone would be the West River in Antigonish

Human activities also influence water quality.

Point source impacts are associated with activities like the discharge of treated and untreated wastewater from individual homes, municipalities and industries.

Non–point impacts are associated with activities on the land. Rain and snowmelt can move materials from the land surface into nearby watercourses or groundwater. Intensive land-use activities like logging, agriculture, mining and urban development can result in the movement of sediment, nutrients, in surface runoff and metals and toxic contaminants that are leached from the soil. In an urban environment, non-point source pollutants enter watercourses through the storm-drain networks. These pollutants typically include sediment, salt and hydrocarbons from paved areas plus pesticides, bacteria and fertilizers from lawns and parks. Land use also affects the quantity of water that runs off the land in a storm event. The hardening of the surface prevents infiltration into the ground water and improved drainage due to ditches, paved areas and roofs speeds the rate of runoff resulting in erosion of the banks of watercourses.

Certain pollutants originating from urban, industrial and agricultural activities can also be transported long distances by atmospheric processes, and deposited directly onto land and watercourses within a drainage basin. Acid rain is one of the best known examples of this type of impact depositing inorganic sulphur and nitric acids. This long-range transport can also include soil minerals, nutrients and numerous man-made chemicals.

The quantity of water also affects quality. Major rains and high-flow events typically wash sediment, nutrients, pesticides, bacteria and other substances off the land and into rivers, lowering water quality. The first flush in a storm usually has the highest concentrations of contaminants. Conversely, the less water there is, the lower the capacity of a watercourse to dilute and assimilate wastes. Climate change, groundwater supply (and quality) and increased water use by activities affects water quality. These factors also influence the timing of river flows, which often impact the suitability of habitat for aquatic life.

Historical perspective on monitoring and issues

Scientists and government managers use surface water quality data, collected in monitoring and research programs, to assess the condition of aquatic ecosystems and the effectiveness of environmental policies and management practices. They also use this data to estimate the assimilative capacity of the watercourse when planning or permitting new land use development. This sampling is not as extensive as it needs to be so there is a great need for community monitoring programs that use standard techniques in a defined sampling plan. The WetPro program and kit (http://wetpro.smu.ca/) and Guide to Writing a Water Quality Monitoring Plan provide the tools and training for community volunteers to collect data that is acceptable for use in management programs.

Why do we monitor water quality?

Water quality measurements provide essential data and knowledge to:

- evaluate the condition and functions of aquatic ecosystems, including spatial patterns and temporal trends;
- evaluate the influences and impacts of human activities, and the risks to human and ecosystem health;
- support planning initiatives, decision-support tools such as water quality modeling, and cumulative effects management;
- support stakeholder education and capacity building; and
- measure environmental performance, support the development of water polices and management practices.
- support plans to restore the health and productivity of the aquatic ecosystem

How is surface water quality evaluated?

Data from monitoring programs are compared over time, from place to place, to expected conditions, and the requirements for aquatic life, to evaluate impacts on aquatic ecosystems. The data are also compared to surface water quality guidelines to evaluate the suitability of the water for specific uses. Such guidelines are developed following scientific protocols and are based on habitat suitability indexes for indicator species or for health and safety for human use. Water quality is usually deemed to be acceptable when the values are within the selected guidelines. Surface water quality guidelines should not be used as a "pollute up to" limit.

Canadian Council of Environment Ministers (http://ceqg-rcqe.ccme.ca/) has established water quality guidelines to protect:

- aquatic life
- agricultural uses (stock watering and irrigation)
- recreational and aesthetic purposes

A single variable or substance may have different numerical guidelines for different uses. For example, the acceptable amount of fecal coliform bacteria in water used for irrigating vegetable crops is different from the guideline that is applied to waters used for shellfish harvesting or swimming or drinking. Fecal coliform bacterial levels are not usually a direct concern for the protection of aquatic life just for their use; therefore, there is no guideline established for the aquatic life itself. The guidelines for aquatic life are in most cases more stringent than for the other uses.

The final evaluation of water quality for a particular site or watercourse is typically based on the most stringent levels for all the uses.

The quality of the water is often determined by a combination of variables. For example the effect of pH on aquatic life has to be considered in the context of total organic carbon (TOC) and the metal levels in the water.

Note that drinking water is not one of the uses discussed here. It should always be assumed that surface waters are unsafe to drink unless treated. Once surface water is treated, it can be evaluated against the Canadian Drinking Water Quality Guidelines. Of course, the cleaner the raw water is to begin with, the easier and less costly it is to treat.

Reports and data

Water quality data collected by WetPro volunteers is stored on a web database (http://curah2o.com/water-quality/). The water quality data provided by the lab analysis can be stored in spreadsheet format and backed up on CD or DVD or on your group's website and noted in the WetPro database.

How is water quality protected?

In Nova Scotia the Nova Scotia Department of the Environment has the main mandate to protect water quality (http://www.gov.ns.ca/nse/surface.water/) although Environment Canada and Fisheries and Oceans Canada also have mandates specific to their jurisdiction. Industrial and municipal as well as most other point sources are well regulated and monitored.

Non-point source pollution control remains a challenge in the sense that no single agency or level of government has sole responsibility for the integration of land use activities into water quality and aquatic habitat protection. Co-operation between all levels of government, industries, and all other stakeholders and interested parties is required to ensure water quality plans are developed and implemented so that all aspects of water pollution are understood and integrated into the protection of our watercourses. Appropriate levels of monitoring and reporting are required to measure performance of the plan and the cumulative effects of point and non-point sources on water quality and ecosystem health. Community participation and awareness of these issues and government jurisdictions is critical in achieving water quality goals.

Water sampling plan

Your water quality sampling plan should be designed to meet the objectives and address concerns identified for your watercourse.

- If road salt is an issue you should follow the conductivity closely and take water samples for laboratory analysis to confirm that the change in conductivity or salinity is due to road salt.

- If acidity of the water for fish is your concern you should follow the pH readings closely with the WetPro meter and take water samples at normal and extreme flows for the lab to find the metal levels particularly aluminum (Al), Iron (Fe), Copper (Cu), and zinc (Zn), calcium (Ca), and magnesium (Mg), and total organic carbon TOC or DOC in filtered samples, to assess the impact on the fish.

- If nutrients are of concern the secchi disc readings in lakes and macrophyte (emergent plant) mapping are your indicators. Conductivity will give you an indication of sources and where samples should be taken and sent to the lab for total phosphorous and total nitrogen levels.

- Dissolved oxygen is one of the most important indicators of water quality and should be monitored directly with the WetPro YSI meter.

- Temperature is another important variable that is easily monitored with low cost data loggers that record temperature continuously for months.

No matter what your objectives are and what the expected impacts are you need to have broad based chemical analysis of the water to understand the watercourse you are monitoring.

Over time you will gain an understanding of the water quality variability of your watercourse and that will guide adjustments to your sampling plan to focus on the extremes that control the productivity and health of the aquatic life and to react to unusual readings that require more detailed sampling. If you find unusual readings use the YSI to sample upstream to find the source of the problem. The conductivity readings are particularly good for finding the source of contaminants. These readings will not tell you what the contaminant is but it will identify sources.

Streams/Rivers

Water samples for the laboratory analysis should be taken in the spring (mid-April to mid-May) and during summer low flow usually in late July or August.

WetPro readings should be taken on a regular basis, perhaps every two weeks at the same locations plus during extreme events like heavy rain falls and very low flows. If your stream is found to have summer temperatures above 20 ^{0}C consider placing a temperature data logger in a pool to get detailed readings.

Lakes

Water quality readings need to be taken at each inflow to the lake including storm water drains as noted above for streams and rivers.

Regular WetPro sampling in lakes should focus on vertical profiles in the deepest part of the lake. If you find the water temperature at the surface is more than a couple of degrees warmer than the bottom water in the summer, sampling every two weeks is needed to define the stratification and the oxygen levels throughout the water column.

Water samples for laboratory analysis should be taken 0.5 to 1 m below the surface and as close to the spring and fall turn over as possible. That is the time when the lake water is the same temperature from surface to bottom in the deepest part of the lake.

Summer samples should be taken in late August or early September 1 m below the surface and near the bottom in the deepest part of the lake. If there is more than one deep basin do each one separately.

WetPro YSI water monitoring

The WetPro monitoring kit and training gives community groups the tools and recognition to do water quality sampling that will be acceptable for use in management planning. This sampling of a few parameters is good for monitoring change in the system. If these variables move out of the range typical for your watercourse then additional water samples are needed for laboratory analysis to identify the cause.

pH

- pH is a term used to indicate the alkalinity or acidity of a substance as ranked on a scale from 1.0 to 14.0. Acidity increases as the pH gets lower.
- The pH scale measures the logarithmic concentration of hydrogen (H+) and hydroxide (OH-) ions, which make up water ($H^+ + OH^- = H_2O$). When both types of ions are in equal concentration, the pH is 7.0 or neutral. Below 7.0, the water is acidic (there are more hydrogen ions than hydroxide ions). When the pH is above 7.0, the water is alkaline, or basic (there are more hydroxide ions than hydrogen ions). Since the scale is logarithmic, a drop in the pH by 1.0 unit is equivalent to a 10-fold increase in acidity. So, a water sample with a pH of 5.0 is 10 times as acidic as one with a pH of 6.0, and pH 4.0 is 100 times as acidic as pH 6.0.
- pH is always measured in the field. If it is analyzed in the lab, you must measure the pH within 2 hours of the sample collection. This is because the pH will change due to the carbon dioxide from the air dissolving in the water, which will bring the pH toward 7.

Dissolved Oxygen

- Watercourses both produce and consume oxygen. They gain oxygen from the atmosphere and from plants as a result of photosynthesis. Running water, because of its churning, dissolves more oxygen than still water.
- Respiration by aquatic animals, decomposition, and various chemical reactions consume oxygen.
- The decomposition of organic materials by microorganisms uses oxygen in the process. The amount of oxygen consumed by these organisms in breaking down the waste is known as the biochemical oxygen demand or BOD. Sources of oxygen-consuming waste include storm water runoff from farmland or urban streets, feedlots, and failing septic systems.
- Oxygen is measured as dissolved oxygen (DO). If more oxygen is consumed than is produced, dissolved oxygen levels decline and animals may move away, weaken, or die.
- DO levels fluctuate seasonally and over a 24-hour period. They vary with water temperature. Coldwater holds more oxygen than warm water.
- Thermal discharges, such as water used to cool machinery in a manufacturing plant or a power plant, raise the temperature of water and lowers its oxygen content.
- The lowest DO levels are in the early morning on hot summer days when stream flows are low, water temperatures are high, and aquatic plants have not been producing oxygen since sunset.
- In lakes DO levels are most likely to vary vertically in the water column,
- The DO in rivers and streams changes more horizontally along the watercourse. This is especially true in smaller, shallower streams. In larger, deeper rivers, some vertical stratification of dissolved oxygen might occur.
- The DO levels in and below riffle areas, waterfalls, or dam spillways are typically higher than those in large pools and slower-moving stretches.
- Since DO levels are critical to fish, a good place to sample is in the pools that fish tend to favor or in the spawning areas they use.
- An hourly time profile of DO levels at a sampling site is a valuable set of data because it shows the change in DO levels from the low point just before sunrise to the high point sometime in the midday. However, this might not be practical for a volunteer monitoring program. It is important to note the time of your DO sampling to help judge when in the daily cycle the data were collected.
- DO is measured either in milligrams per liter (mg/l) or "percent saturation." Milligrams per liter" is the amount of oxygen in a liter of water. Percent saturation is the amount of oxygen in a liter of water relative to the total amount of oxygen that the water can hold at that temperature
- The YSI probe is designed for moving water of 30 to 40 cm/sec. In the standing water of lakes or ponds it must be moved up and down at this speed to get an accurate reading
- Dissolved oxygen should always be measured in the field and recorded as mg/l. Oxygen levels and oxygen saturation readings vary with temperature of the sample and decomposition of organics can also lower the levels in lab samples.

Conductivity

- Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize when washed into the water. On the other hand, streams that run through areas with glacial till or clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water. Ground water inflows can have the same effects depending on the bedrock they flow through.
- Discharges to streams can change the conductivity depending on their make-up. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity. Conductivity is a measure of the ability of water to pass an electrical current.
- Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge).
- Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water.
- Conductivity is also affected by temperature: the warmer the water, the higher the conductivity.
- Each ion conducts electricity differently and its conductivity varies at a different rate with temperature. In freshwater each watercourse is going to have a unique mixture of ions and so conductivity is going to vary differently with temperature between watercourses. For this reason, the only way readings can be standardized for temperature is to develop curves for your own watercourse.
- Conductivity should always be measured on site.
- The YSI uses linear equation to estimate specific conductance for a potassium chloride (KCl) solution approximates the curve for these ions. It is a good estimate for sea water at a temperature you set between 16 and 25 ^{0}C. The WetPro standard sets this at 25 ^{0}C.
- Specific conductance can be used to compare samples from different locations and at different temperatures in sea water or where watercourse specific curves have been developed.
- The basic unit of measurement of conductivity is the mho or siemens. Conductivity is measured in micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µs/cm). Distilled water has conductivity in the range of 0.5 to 3 µmhos/cm. The conductivity of rivers in the Nova Scotia generally ranges from 20 to 500 µmhos/cm.
- Fresh water that supports good fisheries have a range between 100 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro-invertebrates. Industrial waters or road salt runoff can range as high as 10,000 µmhos/cm.
- Changes in conductivity from the normal readings in your watercourse are an excellent way to track down the source of a pollutant.

Salinity

- Salinity is a calculation made by the YSI based on water temperature and conductivity and is the total of all anions and cations.
- All salinity calibrations are based on a comparison with standard sea water. This measurement is useful in coastal and estuarial parts of the watercourse but freshwater has ion composition with conductivity far different than sea water, total dissolved solids measurement should be used in freshwater particularly if there are visible levels of organics (tea coloured water).
- Conductivity, and in turn the salinity reading, can change based on several factors other than salt, for example increased metal or nutrient levels.
- It is not a measure of the chloride levels from road salt although this salt will change conductivity it may not be the only cause of change.
- Coastal watercourses may show increased conductivity / salinity when storms have carried sea water spray inland.

Air pressure

- Air pressure is used by the YSI to calculate oxygen concentration.

Temperature

- Temperature is perhaps the single most important variable.
- The rates of biological and chemical processes depend on temperature.
- Aquatic organisms from microbes to fish are dependent on certain temperature ranges for their optimal health. Optimal temperatures for fish depend on the species: some survive best in colder water, whereas others prefer warmer water.
- Benthic macro-invertebrates are also sensitive to temperature.
- If temperatures are outside of the species optimal range they will move in the stream or lake to find their optimal temperature if they cannot find that temperature for a prolonged period of time they become stressed and can die.
- High daily fluctuations in temperature are stressful on all aquatic life.
- Temperature is always measured in the field.
- The best way to understand the effects of temperature is to use a data logger so you can see the daily fluctuations and temperature extremes.
- Temperature is measured in degrees Celsius (^{0}C).

Secchi disc

- A freshwater Secchi disk is a 20 cm diameter, flat disk with alternating black and white quarter-circles. Marine versions are often all white. It is used to provide a visual measure of water clarity, by lowering it into the water and determining the depth where the disk disappears from view.
- The optimal time for taking a Secchi measurement is mid-day.
- Ideally the Secchi disk measurement should be accurate to within ± 1 cm.
- Take the Secchi reading on the shaded side of the boat and do not wear sunglasses.

- Slowly lower the disk into the water until it disappears from sight and note the depth (Depth 1).
- Lower the disk down a further 1 m (or until it is well out of sight) then slowly raise the disk until it is visible again and note this depth (Depth 2).
- The Secchi disk reading is the average of the two recorded depths (Depths 1 and 2). Record the time of sampling.
- The photic zone (the depth to which algae and green plants have enough light to grow) of a lake is 2 times the secchi disc reading.
- Fish use the secchi disc depth as the depth below which they have suitable overhead cover. The depth at which there is cover for the fish varies with the light level. In full sun it is deeper than on a cloudy day and it also varies with the time of day.

Macrophyte Sampling Methods

- Macrophytes are aquatic plants that grow in or near water and are either emergent, submergent, or floating.
- Aquatic macrophytes have historically received less attention than other aquatic components, and standardization of field sampling protocols is generally lacking. Standardized sampling protocols do not currently exist within any agency.
- Aquatic macrophytes are sampled for a variety of purposes, including:
    - species inventories (presence/absence);
    - identifying invasive species;
    - biodiversity studies;
    - aquatic health assessments;
    - primary productivity assessments; and
    - bio-monitoring to determine the effects of environmental change or anthropogenic stressors.
    - In shallow lakes where more than 5 percent of the lake area is shallower than twice the secchi disc reading in full sun, these plants contain and play a major role in the phosphorous and nitrogen nutrient cycle of the lake. Lakes of this type are very common in Nova Scotia.

- Surface inventories provide a qualitative method of collecting data for production of plant species or community distribution maps.
- Surface inventories serve as reconnaissance surveys that are adequate to document gross changes in community structure or extent of plant beds over time.

Sampling method

- Perform a preliminary determination of the littoral zone; the shallow, usually nearshore, regions of a water body, where light penetrates to the bottom permitting colonization by rooted aquatic macrophytes and benthic algae, use 2 times the secchi disc reading.
- Littoral regions around lake shores or along river banks are surveyed by wading or navigating the boat along the outer edge of the vegetation with the WetPro GPS on tracking mode, from shallow nearshore waters out along the extent of plant beds.

- All key features, such as plant bed boundaries or transitions from one plant community type to another, should be recorded as GPS waypoints and described in a notebook or on field sheets.
- Water depth, Secchi depth, and turbidity and bottom light level (if equipment is available) should be recorded at all key feature waypoints.
- Water temperature or temperature profiles should be recorded at several shallow and deep sites.
- To the extent possible, plants occurring within beds should be identified to species and recorded.
- In shallow water with adequate visibility, plants may be identified by observation from the boat. In deeper or murkier water, or where a canopy of plants obscures plants at lower levels, an underwater viewer is a useful aid.
- If you can't identify the plants then samples should be collected with the rake sampler for closer examination. Collected plants should be placed in a sealable plastic bag, along with a label providing all pertinent information. Sample collections should also be recorded in a notebook or on field sheets, along with a sample number, all pertinent site information and GPS location.
- The end products for a surface inventory include a map showing the distribution of plant bed types, and a list of species for each plant bed type and the water body or study area as a whole.

Lab testing and water sampling

The above approach is good for monitoring of your watercourse but, as mentioned before, to understand the underlying conditions you need to take water samples and have them tested in a laboratory. Analysis of these samples will tell you what is causing the changes you see in conductivity and oxygen levels not related to temperature change. More importantly they will show in detail the makeup of the water so you can see how each constituent meets or exceeds guidelines.

This will provide an understanding of the health of the watercourse for living resources and provide important clues to the sources of contamination. For example if your conductivity rises during rain events in the winter and the lab results show an increase in chloride you know the source is road salt. If the lab results show an increase in nitrate and phosphorous then the source is sewage or manure or fertilizer. If the increase is a metal and the pH has dropped the source is disturbed acid generating shale.

Generally you can track down sources of pollution using the WetPro YSI but will need to take water samples for lab analysis to identify the problem.

Water testing labs in Nova Scotia http://www.gov.ns.ca/nse/water/waterlabs.asp .

Sample bottles are supplied by the Laboratory and sampling protocols are generally provided as well for sampling procedures visit: http://www.gov.ns.ca/nse/water/sample_chemical.asp or http://samplingh2o.ccme.ca/ .

Typical water analysis parameters are listed in Appendix 1.

What do these Lab results mean?

The elements you get readings for from the lab can be compared to the Canadian Council of Ministers of Environment (CCME) guidelines at http://st-ts.ccme.ca/ . Levels outside the recommended ranges in these guidelines should be cause for concern but may or may not be bad in context of the full mix of chemicals in your watercourse.

The elements listed in lab results are not all in the watercourse in that ion form. The element ions are all highly reactive and form compounds the nature of which is dependent on pH and to a lesser extent with temperature. This is why we find streams with element levels well outside the guidelines that have good populations of trout and aquatic insects. Also some of the guidelines vary with the pH of the water.

The effect of pH on the aquatic life depends on the acid or base that is changing the pH from the neutral value of 7. In Nova Scotia streams we have a wide variety of acids from organic acids leached from the soils and wetlands that give the water a distinctive tea colour, to inorganic acids like sulphuric and nitric acids from acid rain. Organic acids are not as harmful to aquatic life and also act to neutralize the toxic effects of metals such as copper, zinc and aluminum. With the typical mix of acids in Nova Scotia, trout do well down to a pH around 4.7 and Atlantic salmon do well down to a pH of 5. However if the pH was lowered by sulfuric acid alone the fish would be gone by a pH of 5.5.

Aluminum Example

- Aluminum (Al) is the most common element in the world and is very abundant is Nova Scotia soils. It is normally found in the form of Aluminum silicates.
- Acid rain lowers the pH of the soil and the lower it gets the faster the Al is released in to the streams. Increases in Al concentration is associated with the declines in fish populations.
- Inorganic compounds of Al are toxic. Which compound and the mix of compounds depends on pH and temperature – $AlOH$, $AlOH_2$ and $AlOH_3$ are the most toxic forms and are found in pH of 4.5 to 7.0. The most toxic form is found between pH 5.1 and 5.4 and generally toxicity is high from pH 5.0 to 6.5.
- Samples should be filtered through a 45 μm filter to remove dust and clay particles that contain Aluminum that contributes to the overall levels in the analysis but are non toxic.
- Al reacts with organic acids before forming AlOH compounds so it can be neutralized where there are sufficient organic acids but Fe, Cu, and Zn bind with the organic acids first so their concentrations have to be taken into consideration

- Fluoride is also available in some parts of Nova Scotia and it forms with Al to make AlF compounds that are not toxic so fluoride concentration must also be taken into consideration. This also affects the total F available lowering its toxicity.

- If the sample is filtered or contains no dust or clay fraction – the total of Fe+Cu+Zn is close to the total concentration of Al and it usually is in NS – then we can calculate the organic forms of Aluminum using the formula Al organic = 166.5 + 0.5Al total +5.06TOC -23.5 pH. Knowing the Al organic we can then subtract this from the Al total to give Al inorganic for which there are guidelines.

Guideline

Inorganic aluminum concentrations in freshwater with pH between 5 and 6.5

- No effects below 6 µg/l
- 6 to 10 µg/l enzyme effects
- 10 to 12 µg/l increased glucose
- 12 to 40 µg/l reduced plasma salts
- Above 40 µg/l death

If the freshwater levels of inorganic Aluminum are at the levels listed below for the 2 months prior to going to sea then survival both short and long term is affected.

- Below 6 µg/l OK
- 6 to 15 µg/l increased mortality
- Above 15 µg/l death, no returns

pH is the controlling factor when it falls below 5.0 but in the pH ranges above that the impacts are a combination of pH and Al effects.

Habitat survey and fish population sampling

The physical and biological characteristics of a watercourse can tell you a lot about the long term and life cycle quality of the water. Habitat survey methodology is available through Adopt-a-Stream (AmyWeston@adoptastream.ca). Fish sampling requires a licence from the Province or Fisheries and Oceans depending on the technique used. This information can be obtained from Licensing Dartmouth Licensing.Dartmouth@mar.dfo-mpo.gc.ca for all fishing methods other than angling. Angling licenses can be obtaining at several locations throughout the province http://www.gov.ns.ca/fish/sportfishing/angling/vendors.shtml.

What does the water quality data mean?

The NSLC Adopt-a-Stream program uses brook trout or Atlantic salmon as the main indicator species. This of course depends on the objectives set for your particular watercourse and we would encourage the use of multiple indicator species in setting objectives for natural and biodiverse aquatic life. Life cycle habitat requirements for many species are available.

Habitat requirements for Maritime freshwater fish can be found on pages 44 through 63 in Ecological Restoration of Degraded Aquatic Habitats at http://adoptastream.ca/sites/default/files/321286.pdf . This manual also provides information on aquatic habitat restoration techniques and watershed function.

What water quality readings are in the normal range in Nova Scotia?

Introduction

This information was compiled by the Soil & Water Conservation Society of Metro Halifax (SWCSMH) using (http://lakes.chebucto.org/) historical data on several variables, both for overall provincial and Halifax Metro averages as well as for pristine and relatively undisturbed lakes. With some exceptions, these may be used for comparing any field data. The relevant guidelines from Environment Canada, 2004, the CCME (Canadian Ministers of the Environment), OME (Ontario Ministry of the Environment), Health and Welfare Canada, and the NRCC (National Research Council of Canada), have also been included.

Parameters

Surface Area (ha)

Lake Means & Guidelines	Lake & Specifics	References & Notes
85 ±SD 192	175 Halifax Co. lakes	Alexander et al, 1986
89 ±SD 279	781 Nova Scotia lakes	Alexander et al, 1986

Maximum Depth (m)

Lake Means & Guidelines	Lake & Specifics	References & Notes
10.6 ±SD 8.4	175 Halifax Co. lakes	Alexander et al, 1986
8.2 ±SD 6.8	772 Nova Scotia lakes	Alexander et al, 1986

Mean Depth (m)

Lake Means & Guidelines	Lake & Specifics	References & Notes
3.1 ±SD 2.4	118 Halifax Co. lakes	Alexander et al, 1986
2.8 ±SD 2.1	660 Nova Scotia lakes	Alexander et al, 1986

Total Phosphorus, TP (as Phosphorus µg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
mean=2.7 (<1 - 5)	22 pristine Halifax Co. clear-water lakes (Dec. 1984)	Data from John Underwood (pers. comm. Feb. 1994); Lakes Jack, Bayers, Susies, Bell, Paces, Kearney, Grand [Preston], Eagle, Long [Preston], Horseshoe, Uniacke, Cochran, Lewis [Kearney watershed], McQuade, Anderson, Spruce Hill, Ragged, Cooper, Otter, Land of Laziness, Coxs, and Long
4	Clear-water Pockwock Lake (1991-92; 4 events; TSI[TP]=24, TSI[Cha]=24])	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
5	Clear-water Bell Lake (1991-92; 30 events; TSI[TP]=27, TSI[Cha]=34)	Clear-water, urban lake in Dartmouth, Mandell (1994)
6	Clear-water Bell Lake (1990; 3 events; TSI[TP]=30, TSI[Cha]=26)	Clear-water, urban lake in Dartmouth, SWCS (1991)
2	Clear-water Chocolate Lake (1991-92; 4 events; TSI[TP]=14, TSI[Cha]=11])	Clear-water, urban lake in Halifax, Mandell (1994)
3.8	Clear-water Beaverskin Lake (near surf. yearly means; TSI[TP]=23, TSI[Cha]=34])	Undisturbed clear-water lake in a National Park, Kerekes (1975)
6.6, 6.0	Clear-water Beaverskin Lake (May-April 1979-80: TSI[TP]=31, TSI[Cha]=32]; May-April 1980-81: TSI[TP]=30, TSI[Cha]=31]; wtd. means)	Undisturbed clear-water lake in a National Park, Beauchamp and Kerekes (1989)
mean= 7.1 (3- 17)	14 Halifax County Coloured-water lakes (Dec. 1984)	Data from John Underwood (pers, comm. Feb. 1994), Lakes Spectacle, Howe, O'Brien, Kidston, Hubley's Big, Peters [Eastern Shore], Big Bridge Bog Pond, Welsh, Long Canal, Purcell's Pond, Duncan's Pond, Fink Pond, Black, and Silver
9.1	Coloured-water Kejimkujik Lake (near surf. yearly means)	Undisturbed, colored-water lake in a National Park, Kerekes (1975)

10.4, 10.4	Coloured-water Kejimkujik Lake (May-April 1979-80, May-April 1980-81, wtd. means)	Undisturbed, colored-water lake in a National Park, Beauchamp and Kerekes (1989)
5 to 10	17 Keji Park lakes	Kerekes. 1975
Environment Canada, 2004: Canadian Guidance Framework		
< 4	Ultra-oligotrophic	Almost nil impairment of multi-purpose use of lake
4-10	Oligo-mesotrophic	Little impairment of multi-purpose use of lake
10-35	Meso-eutrophic	Variable impairment of multi-purpose use of lake
35-100	Eutrophic	Great impairment of multi-purpose use of lake
> 100	Hypereutrophic	Extreme impairment of multi-purpose use of lake
OECD Management Model: There is no possibility of defining strict boundary values between trophic categories. This model incorporates the class midpoints for mean TP and mean Ch-*a*		
mean < 2.5	Ultra-oligotrophic	Almost nil impairment of multi-purpose use of lake
mean = 2.5-8	Oligotrophic	Little impairment of multi-purpose use of lake
mean = 8-25	Mesotrophic	Variable impairment of multi-purpose use of lake
mean= 25-80	Eutrophic	Great impairment of multi-purpose use of lake
mean > 80	Hypertrophic	Extreme impairment of multi-purpose use of lake

TP (mg/l) in sediments

Lake Means & Guidelines	**Lake & Specifics**	**References & Notes**
1.2	Natural lakes of Nova Scotia	Underwood and Josselyn, 1979

PO_4-P (mg/l)

Lake Means & Guidelines	**Lake & Specifics**	**References & Notes**
0.001 ±SD 0.001	234 N.S. lakes	Underwood et al, 1986

Mean Chlorophyll-*a* (µg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
0.53	Clear-water Pockwock Lake (1991-92; 4 events; TSI[TP]=24, TSI[Cha]=24)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
1.41	Clear-water Bell Lake (1991-92; 30 events; TSI[TP]=27, TSI[Cha]=34)	Clear-water, urban lake in Dartmouth, Mandell (1994)
0.6	Clear-water Bell Lake (1990; 3 events; TSI[TP]=30, TSI[Cha]=26)	Clear-water, urban lake in Dartmouth, SWCS (1991)
0.14	Clear-water Chocolate Lake (1991-92; 4 events; TSI[TP]=14, TSI[Cha]=11])	Clear-water, urban lake in Halifax, Mandell (1994)
1.4	Clear-water Beaverskin Lake (near surf. yearly means; TSI[TP]=23, TSI[Cha]=34])	Undisturbed clear-water lake in a National Park, Kerekes (1975)
1.20, 1.03	Clear-water Beaverskin Lake (May-April 1979-80: TSI[TP]=31, TSI[Cha]=32; May-April 1980-81: TSI[TP]=30, TSI[Cha]=31)	Undisturbed, clear-water lake in a National Park, Beauchamp and Kerekes (1989)
2.1	Coloured-water Kejimkujik Lake (near surf. yearly means)	Undisturbed, colored-water lake in a National Park, Kerekes (1975)
1.16, 0.93	Coloured-water Kejimkujik Lake (May-April 1979-80, May-April 1980-81, wtd. means)	Undisturbed, colored-water lake in a National Park, Beauchamp and Kerekes (1989)
1.8 (1 to 3)	17 Keji Park lakes	Kerekes, 1975
1.3	5 Terra Nova Park lakes, NFLD	Kerekes, 1975
3	Lakes in the Canadian Shield in NW Ontario	Kerekes, 1975

Environment Canada, 2004: Canadian Guidance Framework

< 1	Ultra-oligotrophic	Almost nil impairment of multi-purpose use of lake
< 2.5	Oligo-mesotrophic	Little impairment of multi-purpose use of lake
2.5-8	Meso-eutrophic	Variable impairment of multi-purpose use of lake
8-25	Eutrophic	Great impairment of multi-purpose use of lake
> 25	Hypereutrophic	Extreme impairment of multi-purpose use of lake

OECD Management Model: There is no possibility of defining strict boundary values between trophic categories. This model incorporates the class midpoints for mean TP and mean Ch-*a*		
mean < 0.7	Ultra-oligotrophic	Almost nil impairment of multi-purpose use of lake
mean = 0.7-2.1	Oligotrophic	Little impairment of multi-purpose use of lake
mean = 2.1-6.25	Mesotrophic	Variable impairment of multi-purpose use of lake
mean= 6.25-19.2	Eutrophic	Great impairment of multi-purpose use of lake
mean > 19.2	Hypertrophic	Extreme impairment of multi-purpose use of lake

Maximum Chlorophyll-*a* (µg/l)		
Lake Means & Guidelines	**Lake & Specifics**	**References & Notes**
0.73	Clear-water Pockwock Lake (1991-92; 4 events; TSI[TP]=24, TSI[Cha]=24)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
3.33	Clear-water Bell Lake (1991-92; 30 events; TSI[TP]=27; TSI[Cha]=34)	Clear-water, urban lake in Dartmouth, Mandell (1994)
0.74	Clear-water Bell Lake (1990; 3 events; TSI[TP]=30, TSI[Cha]=26)	Clear-water, urban lake in Dartmouth, SWCS (1991)
0.23	Clear-water Chocolate Lake (1991-92; 4 events; TSI[TP]=14, TSI[Cha]=11])	Clear-water, urban lake in Halifax, Mandell (1994)
3.27, 2.24	Beaverskin Lake (May-April 1979-80: TSI[TP]=31, TSI[Cha]=32; May-April 1980-81: TSI[TP]=30, TSI[Cha]=31)	Undisturbed, clear-water lake in a National Park, Beauchamp and Kerekes (1989)
2.80, 1.92	Coloured-water Kejimkujik Lake (May-April 1979-80, May-April 1980-81)	Undisturbed, colored-water lake in a National Park, Beauchamp and Kerekes (1989)
Environment Canada, 2004: Canadian Guidance Framework		
< 2.5	Ultra-oligotrophic	Almost nil impairment of multi-purpose use of lake
< 8	Oligo-mesotrophic	Little impairment of multi-purpose use of lake
8-25	Meso-eutrophic	Variable impairment of multi-purpose use of lake

25-75	Eutrophic	Great impairment of multi-purpose use of lake
> 75	Hypereutrophic	Extreme impairment of multi-purpose use of lake

Total Nitrogen, TN (mg/l)

Lake Means & Guidelines	**Lake & Specifics**	**References & Notes**
0.19 ±SD 0.09	37 pristine Halifax Co. lakes (Dec. 1984)	John Underwood (pers. comm.), Jan. 1994
0.09	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
0.06	Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth. Mandell (1994)
0.2	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)
0.145, 0.152	Beaverskin Lake (May-April 1979-80, May-April 1980-81, wtd. means)	Undisturbed, clear-water lake in a National Park, Beauchamp and Kerekes (1989)
0.17, 0.17	Coloured-water Kejimkujik Lake (May-April 1979-80, May-April 1980-81, wtd. means)	Undisturbed, colored-water lake in a National Park, Beauchamp and Kerekes (1989)
≤0.3	Oligotrophic systems	Underwood & Josselyn, 1979

Nitrate-N (mg/l)

Lake Means & Guidelines	**Lake & Specifics**	**References & Notes**
0.02 ±SD 0.03	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.) Jan, 1994
<0.19	Susies Lake (1980-83)	Undisturbed lake in Halifax Metro, Kerekes et al, 1986
10.0 as N	Drinking Water- Maximum Acceptable Concentration	CCME- Where both nitrate and nitrite are present the total nitrate- plus nitrite-nitrogen should not exceed 10

Nitrite-N (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
0.06	Freshwater Aquatic Life	CCME guidelines
1.0 as N	Drinking Water- Maximum Acceptable Concentration	CCME- Where both nitrate and nitrite are present the total nitrate- plus nitrite-nitrogen should not exceed 10

Ammonia, NH_4-N (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
0.007 ±SD 0.019	37 pristine Halifax Co. lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994

Clarity (as Secchi disk depth in m)

Lake Means & Guidelines	Lake & Specifics	References & Notes
2.9	N.S. Average	Underwood & Josselyn, 1979
Minimum visibility at 1.2	Recreational Water Quality	CCME guidelines
Environment Canada, 2004: Canadian Guidance Framework		
mean > 12 min. > 6	Ultra-oligotrophic	Almost nil impairment of multi-purpose use of lake
mean > 6 min. > 3	Oligo-mesotrophic	Little impairment of multi-purpose use of lake
mean = 6-3 min. = 3-1.5	Meso-eutrophic	Variable impairment of multi-purpose use of lake
mean= 3-1.5 min. = 1.5-0.7	Eutrophic	Great impairment of multi-purpose use of lake
mean < 1.5 min. < 0.7	Hypereutrophic	Extreme impairment of multi-purpose use of lake

Turbidity

Lake Means & Guidelines	Lake & Specifics	References & Notes
0.92 ±SD 0.45 NTU	37 pristine Halifax Co. lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994
1.05 ±SD 0.60 NTU	234 N.S. lakes	Underwood et al, 1986
1	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
1	Clear-water Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth, Mandell (1994)
0	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)
5.0 NTU maximum increase	Recreational Water Quality	CCME guidelines- Maximum allowable increase over natural turbidity when turbidity is low (<50 NTU)

TSS (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
3	Average background conc. of N.S. lakes	Hinch & Underwood, 1985 (SS is the component of total residue retained by a 0.45 µm filter and may consist of clay, silt, finely divided organics and inorganics, planktonic and microscopic organisms)
Maximum increase of 10.0	Freshwater Aquatic Life	CCME guidelines- when background suspended solids ≤100.0
Maximum increase of 10% above background	Freshwater Aquatic Life	CCME guidelines- when background suspended solids >100.0

TDS (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
<30	Natural background levels as a result of land drainage from natural	Hinch & Underwood, 1985 (TDS is the component of total residue that passes

	sources such as weathering of rock, `waters in contact with granite`, siliceous sand, well-baked soil, or other relatively soluble material	through a 0.45 µm filter and refers primarily to inorganic salts and organic matter dissolved in water. Principal ions that contribute to TDS include: CO_3, HCO_3, Cl, SO_4, NO_3, Na, K, Ca, and Mg)
20 (12.45-86.14)	Average for pristine N.S. lakes	Hinch & Underwood, 1985
500	Maximum Canadian objective drinking water standard	Hinch & Underwood, 1985

Colour

Lake Means & Guidelines	**Lake & Specifics**	**References & Notes**
45 ±SD 48 TCU	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.). Jan. 1994 (True color [TCU] results from dissolved substances in solution. One source, the humic substances [resulting from decay or aqueous extraction of natural vegetation] are of environmental significance since they tend to absorb a variety of organic substances as well as bind aluminum, many of which have toxic properties. Apparent color [Hazen U] results from suspended or colloidal matter [Health & Welfare Canada, 1980 per Hinch & Underwood, 1985])
5	Susies Lake (1980-83)	Undisturbed lake in Halifax Metro. Kerekes et al, 1986
5	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
2	Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth. Mandell (1994)
4	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)
44.5 ±SD 54.6 TCU	234 N.S. lakes	Underwood et al, 1986
15 TCU	Drinking Water-Maximum Acceptable Concentration	CCME guidelines

TOC (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
8 (0.7 - 20)	Pristine N.S. lakes	Hinch & Underwood, 1985 (TOC= suspended + dissolved organic constituents. High TOC values are commonly due to humic substances. Although not in itself a hazard, organic material may provide precursors of potentially harmful contaminants since humic acids tend to firmly adsorb or complex organic and inorganic pollutants and metals)

DOC (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
6.5 ±SD 6.4	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm. Jan, 1994)
2.7	Susies Lake (Dec, 1985)	Undisturbed lake in Halifax Metro. Urban et al, 1990
1.8	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
0.3	Clear-water Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth, Mandell (1994)
0.45	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)
5.73 ±SD 3.57	234 N.S. lakes	Underwood et al, 1986
5.0	Drinking Water	OME- Aesthetic Objective

Conductivity (µS/cm)

Lake Means & Guidelines	Lake & Specifics	References & Notes
62.5 ±SD 32.0	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994. (Conductivity is the ability of a substance to conduct an electric current [per Hinch & Underwood, 1985])
45.6	Susies Lake (Dec. 1985)	Undisturbed lake in Halifax Metro. Urban et al, 1990
58.0 ±SD 74.8	159 Halifax County lakes	Alexander et al, 1986

33	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
49	Clear-water Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth, Mandell (1994)
500	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)
69.5 ±SD 493.0	638 N.S. lakes	Alexander et al, 1986
46.9 ±SD 23.8	234 N.S. lakes	Underwood et al, 1986
<5	Distilled water	
20 to 40	Keji Park lakes	Tordon (Environment Canada)
70 to 90	Halifax City tapwater	McCarthy
30,000 +	Seawater	

pH

Lake Means & Guidelines	**Lake & Specifics**	**References & Notes**
4.9 ±SD 0.56	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994
4.8 (calculated from µeq/l)	Susies Lake (1980-83)	Undisturbed lake in Halifax Metro. Kerekes et al, 1986
5.32	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
5.67	Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth. Mandell (1994)
5.21	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)
5.7 ±SD 0.57	234 N.S. lakes	Underwood et al, 1986
6.2 ±SD 0.6	167 Halifax County lakes	Alexander et al, 1986
6.2 ±SD 0.8	730 N.S. lakes	Alexander et al, 1986
5.0 to 9.0	Recreational Water Quality	CCME guidelines
6.5 to 9.0	Freshwater Aquatic Life	CCME guidelines
6.5 to 8.5	Drinking Water- Maximum Acceptable Concentration	CCME guidelines

SO_4 (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
5.9 ±SD 2.2	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994
4.79 (calculated from μeq/l)	Susies Lake (1980-83)	Undisturbed lake in Halifax Metro. Kerekes et al, 1986
6	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
9.6	Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth. Mandell (1984)
39	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)
500	Drinking Water- Maximum Acceptable Concentration	CCME guidelines

Alkalinity (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
0.19 ±SD 0.38	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994 (Alk. is the capacity of a solution to neutralize acid to a designated pH [per Hinch & Underwood, 1985])
0	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
0.09	Clear-water Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth, Mandell (1994)
0	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)
No decrease >25%	Water Quality Objectives	OME- should not be decreased by more than 25% of the natural concentration

Hardness as $CaCO_3$ (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
80-100	Acceptable balance between corrosion and incrustation	Hinch & Underwood, 1985 (Hardness is a traditional measure of the capacity of water to react with soap. In freshwaters, the principal hardness-causing ions are Ca and Mg neither of which are considered concerns to health)
0-60	Soft water	Health & Welfare Canada, 1980 (per Hinch & Underwood, 1985)
60-120	Medium hard Water	Health & Welfare Canada, 1980 (per Hinch & Underwood, 1985)
120-180	Hard water	Health & Welfare Canada, 1980 (per Hinch & Underwood, 1985)
180 and above	Very hard water	Health & Welfare Canada, 1980 (per Hinch & Underwood, 1985)
7.1 ±SD 4.1	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994

Cl (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
10.3 ±SD 6.7	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994 (At 250 mg/l, salty taste may occur when the cation is Na. A high Cl content is known to harm metallic pipes as well as agricultural plants. Environmentally, Cl is a useful indicator of the effectiveness of lake mixing and dilution [per Hinch & Underwood, 1985])
4.08 (calculated from µeq/l)	Susies Lake (1980-83)	Undisturbed lake in Halifax Metro. Kerekes et al, 1986
6.2	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
9	Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth. Mandell (1994)

148	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)
250	Drinking Water-Maximum Acceptable Concentration	CCME

Na (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
6.3 ±SD 4.1	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994
3.6 (calculated from µeq/l)	Susies Lake (1980-83)	Undisturbed lake in Halifax Metro. Kerekes et al, 1986
3.8	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
4.9	Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth. Mandell (1994)
88	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)

K (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
0.41 ±SD 0.15	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994
0.14 (calculated from µeq/l)	Susies Lake (1980-83)	Undisturbed lake in Halifax Metro. Kerekes et al, 1986
0.39	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
0.73	Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth. Mandell (1994)
4.5	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)

Ca (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
1.6 ±SD 0.95	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994
0.88 (calculated from µeq/l)	Susies Lake (1980-83)	Undisturbed lake in Halifax Metro. Kerekes et al, 1986
1.4	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
2.6	Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth.Mandell (1994)
13	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)

Mg (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
0.78 ±SD 0.41	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994
0.44 (calculated from µeq/l)	Susies Lake (1980-83)	Undisturbed lake in Halifax Metro. Kerekes et al, 1986
1	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
1	Bell Lake (1991-92; 30 events)	Relatively undisturbed, clear-water, urban lake in Dartmouth. Mandell (1994)
2	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)

Fe (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
0.073 (calculated from µeq/l)	Susies Lake (1980-83)	Undisturbed lake in Halifax Metro. Kerekes et al, 1986

0.06	Clear-water Pockwock Lake (1991-92; 4 events)	Clear-water, water supply lake in Hammonds Plains, Mandell (1994)
0.04	Clear-water Bell Lake (1991-92; 30 events)	Clear-water, urban lake in Dartmouth, Mandell (1994)
0.1	Clear-water Chocolate Lake (1991-92; 4 events)	Clear-water, urban lake in Halifax, Mandell (1994)
0.3	Freshwater Aquatic Life	CCME
0.3	Drinking Water- Maximum Acceptable Concentration	CCME

Mn (mg/l)

Lake Means & Guidelines	**Lake & Specifics**	**References & Notes**
0.06 (<0.01-1.2)	Average in N.S. lakes	Hinch & Underwood, 1985 (Mn does not occur naturally as a metal but is present in over 100 common salts and minerals in rocks, soils, and on the floors of lakes and oceans. In natural waters, generally <0.05. Higher levels are either associated with industrial pollution or with reducing conditions such as exist underground and in some lakes and reservoirs [per Health & Welfare Canada, 1980])
0.0715	Susies Lake (Dec. 1985)	Undisturbed lake in Halifax Metro. Urban et al, 1990
0.05	Drinking Water-Maximum Acceptable Concentration	CCME (Mn is one of the elements least toxic to mammals. At levels exceeding 0.15, Mn stains plumbing fixtures and laundry and causes undesirable tastes in beverages. It is difficult to remove Mn at conc.<0.05 [Health & Welfare Canada, 1980 per Hinch & Underwood, 1985])
<0.01	Objective conc. (because of potential deposition and staining even at the max. acceptable level)	Health & Welfare Canada, 1980 (per Hinch & Underwood, 1985)

Al (mg/l)		
Lake Means & Guidelines	**Lake & Specifics**	**References & Notes**
0.145 (0.008-0.55)	Average background level for N.S. lakes	Hinch & Underwood, 1985 (Al- the third most abundant of elements in the earth's crust)
0.230 (calculated from µeq/l)	Susies Lake (1980-83)	Undisturbed lake in Halifax Metro. Kerekes et al, 1986
0.005	Freshwater Aquatic Life	CCME (pH<6.5; Ca^{2+}<4.0 mg/l; DOC<2.0 mg/l)
0.1	Freshwater Aquatic Life	CCME (pH≥6.5; Ca^{2+}≥4.0 mg/l; DOC≥2.0 mg/l)

As (mg/l)		
Lake Means & Guidelines	**Lake & Specifics**	**References & Notes**
<0.002	37 pristine Halifax County lakes (Dec. 1984)	John Underwood (pers. comm.). Jan, 1994
≤0.005	Objective conc. in drinking water	Hinch & Underwood, 1985
0.05	Maximum acceptable conc. in drinking water	Hinch & Underwood, 1985

Ba (mg/l)		
Lake Means & Guidelines	**Lake & Specifics**	**References & Notes**
0.017	Average conc. in N.S. lakes	Hinch & Underwood, 1985 (Ca and SO_4 are commonly associated with Ba as CO_3 and sandstones)
1.0	Maximum acceptable conc. in drinking water	Hinch & Underwood, 1985
≤0.1	Objective conc. in drinking water	Hinch & Underwood, 1985

Cd (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
0.005 - 0.008	Average value in natural waters is less than the detection limit	Hinch & Underwood, 1985. (Cd is a relatively rare element and is nonetheless commonly found in association with Cu, Pb, and Zn. Surface waters having more than a few µgCd/l have probably been contaminated by industrial wastes [from metallurgical plants, plating works, plants manufacturing cadmium pigments, textile operations, cadmium-stabilized plastics or nickel cadmium batteries], or by effluents from sewage treatment plants)
0.7	Average value in N.S. lake sediments	Hinch & Underwood, 1985
0.005	Maximum acceptable conc. in drinking water	Hinch & Underwood, 1985
≤0.001	Objective conc. in drinking water	Hinch & Underwood, 1985

Co (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
<0.01 - 0.08	N.S. lake averages	Hinch & Underwood, 1985 (majority of Co readings in N.S. lakes are below the detection limit of 0.01)

Cu (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
0.011 (<0.005 - 0.17)	Average conc. in N.S. lakes	Hinch & Underwood, 1985 (Cu is ubiquitous [found everywhere] in the environment)
1.0	Maximum acceptable conc. in drinking water	Hinch & Underwood, 1985 (At higher concentrations Cu stains laundry and plumbing fixtures, and may also impart an undesirable taste to the water and enhance corrosion of Al and Zn)

<1.0	Objective conc. in drinking water	Hinch & Underwood, 1985

Pb (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
0.008 (<0.05-0.03)	N.S. lake averages	Hinch & Underwood, 1985 (Lead is considered a ubiquitous element in the environment)
0.05	Maximum acceptable drinking water standard	Hinch & Underwood, 1985
≤0.001	Objective conc. in drinking water	

Zn (mg/l)

Lake Means & Guidelines	Lake & Specifics	References & Notes
0.014 (<0.01-0.22)	Average in N.S. lakes	Hinch & Underwood, 1985 (Zn is an abundant element in the earth. In addition, various industrial and domestic emissions contribute considerable amounts to the air and water environment [primary iron and steel production, primary copper and nickel production, fuel combustion of coal and heavy oils, solid waste incineration, transportation, and pesticide application are all potential contributors])
5.0	Maximum acceptable conc. in drinking water	Hinch & Underwood, 1985 (In excess of 5 mg/l, water has an undesirable taste, and may develop a greasy film when boiled)
<5.0	Objective conc. in drinking water	Hinch & Underwood, 1985

Dissolved Oxygen (DO) (mg/l)

Freshwater Aquatic Life DO conc. in mg/l (CCME)		
Categories of biota	**Early life stages**	**Other life stages**
Warm-water	6	5
Cold-water	9.5 (6.5)	6.5
(6.5- interstitial water of the gravel)		

Freshwater Aquatic Life DO limits (Davis, NRCC in CCME)						
Temperature	**Warm-water biota**		**Cold-water biota**		**Primarily salmonids**	
°C	**% Sat.**	**mg/l**	**% Sat.**	**mg/l**	**% Sat.**	**mg/l**
0	47	7	54	8	57	8
5	47	6	54	7	57	7
10	47	5	54	6	57	6
15	47	5	54	6	59	6
20	47	4	57	5	65	6
25	48	4	63	5	72	6

E. coli and fecal coli

Guidelines	**Specifics**	**Reference**
The geometric mean of at least 5 samples taken during a period of 30 days should not exceed 2000 E. coli per litre	Recreational Water Quality	CCME

Enterococci

Guidelines	**Specifics**	**Reference**
The geometric mean of at least 5 samples taken during a period of 30 days should not exceed 350 enterococci per litre	Recreational Water Quality	CCME

Microorganisms

Guidelines	Specifics	References
a) No sample should contain more than 10 total coliform organisms per 100 ml; b) not more than 10% of the samples taken in a 30 day period should show the presence of coliforms; c) not more than two consecutive samples from the same site should show the presence of coliforms; and d) none of the coliform organisms detected should be fecal coliforms	Drinking Water- Maximum Acceptable Concentration	CCME

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Appendix 1 Typical Lab Analysis

Typical Laboratory analysis includes:

Community/ location
Date & Time (DD/MM/YYYY HH:MM)
FIELD DATA collected at the time of sampling

Secchi Depth (lakes)
Temp
Dissolved Oxygen
pH
Specific Conductance
Salinity

INORGANICS
Total Alkalinity (Total as $CaCO_3$)
Dissolved Chloride (Cl)
Colour
Total Kjeldahl Nitrogen (TKN)
Nitrate + Nitrite
Nitrate (N)
Nitrite (N)
Nitrogen (Ammonia Nitrogen)
Total Organic Carbon (C)
Orthophosphate (P)
pH (Lab)
Total Phosphorus (1 m depth or mid water)
Total Phosphorus Deep (if a stratified lake)
Reactive Silica (SiO_2)
Total Suspended Solids
Dissolved Sulphate (SO_4)
Turbidity
Conductivity

CALCULATED PARAMETERS
Anion Sum
Bicarb. Alkalinity (calc. as $CaCO_3$)
Calculated TDS
Carb. Alkalinity (calc. as $CaCO_3$)
Cation Sum
Hardness ($CaCO_3$)
Ion Balance (% Difference)

Langelier Index (@ 20 ^{0}C)
Langelier Index (@ 4 ^{0}C)
Saturation pH (@ 20 ^{0}C)
Saturation pH (@ 4 ^{0}C)

METALS (ICP-MS)
Total Aluminum (Al)
Total Antimony (Sb)
Total Arsenic (As)
Total Barium (Ba)
Total Beryllium (Be)
Total Bismuth (Bi)
Total Boron (B)
Total Cadmium (Cd)
Total Calcium (Ca)
Total Chromium (Cr)
Total Cobalt (Co)
Total Copper (Cu)
Flouride (F)
Total Iron (Fe)
Total Lead (Pb)
Total Magnesium (Mg)
Total Manganese (Mn)
Total Molybdenum (Mo)
Total Nickel (Ni)
Total Phosphorous (P)
Total Potassium (K)
Total Selenium (Se)
Total Silver (Ag)
Total Sodium (Na)
Total Strontium (Sr)
Total Thallium (Tl)
Total Tin (Sn)
Total Titanium (Ti)
Total Uranium (U)
Total Vanadium (V)
Total Zinc (Zn)

MICROBIOLOGICAL
E. Coli
Fecal coliform
Chlorophyll A - Acidification method
Chlorophyll A - Welschmeyer method

Appendix 2 Sampling for lab analysis basics

There are several very important procedures regarding sampling *fresh water quality* that are critical in order to get the data you need:

- Use the proper bottles and beware of dirty bottles. Plastic bottles are the best.
- The Chemistry Laboratory will supply you with the proper bottles.
- The cost for a full analysis is about $300 but it is well worth it. Most NGOs can negotiate a lower price so shop around and tell them who you are and why you are doing the sampling
- You will need a one liter plastic bottle, a 500 ml plastic bottle, a bottle for bacteriological analysis and a special glass bottle for analysis of phosphorus (P).
- Be sure to rinse the 1 liter bottle, both the cap and bottle 3 times. Repeat this process with the 500 ml bottle.
- DO NOT RINSE THE BOTTLE FOR BACTERIOLOGICAL ANALYSIS. It contains a preservative; just fill it.
- The glass bottle for PHOSPHORUS ANALYSIS should *not* be rinsed either.

Appendix 3 Examples of water quality issues in Nova Scotia

Fresh water is approximately 2% of all the water in the world. Approximately 99% of that water is bound in glaciers leaving about 0.02% to provide for the terrestrial (land), and fresh water aquatic species of this earth

Fresh water is therefore a precious and limited resource critical for all life and must be preserved. It is assumed by many industries that the water is somehow "free" and that they can use as much of it as they want, in any way they wish to use it, without financial cost. This is not true there is a high environmental cost that should be taken into consideration.

A human can live for weeks without food, but humans can only survive three days without fresh water to drink. The preservation of excellent quality fresh water supply is a critical prerequisite for the survival of humans and other species on Earth.

Examples of the importance of freshwater:

Fish stocking

When 25,000 trout fingerlings were introduced into a river and they all died. Why? They had been reared in a hatchery containing excellent fresh water quality but the river was stressed and the water quality parameters were outside what they could adjust to, therefore all the trout died.

Mercury

Loons living in lakes in the Kejimkujik Park ecosystem have the highest level of mercury in their blood than any other population of Loons in Canada. Mercury is a heavy metal that causes behaviour disturbances and nerve damage that makes loons unable to fly and reduces reproduction.

This is how the bioaccumulation of mercury occurs:

- Mercury gets into the water due to human activities and is converted by natural biological processes into methyl mercury that is taken up by plants and small fish. Each higher level in the food web concentrates more mercury until it reaches toxic levels in the top predators.

- The unusually high mercury in the loons in Nova Scotia is likely the result of high mercury concentrations in the soil being released by acid rain.

- Mercury also becomes available when streams or lake outfalls are dammed. Mercury that has been tied up in the soils becomes oxidized and then becomes methyl-mercury.

- This phenomenon was being investigated in the *Experimental Lakes Area in Northern Ontario.* However dams are continuously being built and the mercury released possess a serious threat to Human health; especially to First Nation people whose main food supply is the contaminated fish. It is ironic that fish that contain mercury do not exhibit symptoms of mercury poisoning but as mentioned earlier, loons, other species of birds, and humans are at risk.

For more information
http://www.ec.gc.ca/mercure-mercury/default.asp?lang=En&n=67E16201-1

pH

Let us look at two different rivers and their pH levels.

The pH of the Tangier River flowing over meguma or acid slates is 4.2. This is very acidic and will not support trout or salmon in spite of the good spawning and nursery habitat. It should be pointed out that all that lives in the Tangier River are eels, which can survive at low pH levels. It should also be pointed out that the Tangier River has the same pH level as East River Chester even though they are on different geologies. The glacial till covering granite has a limited supply of neutralizing capacity which when exhausted by acid rain causes the same or similar pH level of the Tangier River.

The West River Antigonish County has a pH of 6.6 due to the high presence of limestone that neutralizes any inputs of acidity. The West River Antigonish has excellent spawning and nursery habitat and supports a healthy population of Atlantic salmon, sea trout and brook trout.

Freshwater Colour

The Tangier River water is dark brown, or tea coloured because of the humic acids from nearby wetlands. Water colour is measured using Hazen Units (HU) and can range from 5 HU to approximately 400 HU. In cases where water is very dark samples are diluted and the reading is adjusted depending on the diluting factor. The Tangier River has a colour of 220 HU.

The West River Antigonish County has a colour of 20 HU indicating that it is quite colourless and free from inputs of humic/organic acids. Colour is important because it is an indicator of humic/organic acidic inputs. Low pH due to humic/organic acids, are not as damaging to the ecosystem as the inorganic acids from industrial pollution that comes as acid rain. In fact the organic acids can bind and mitigate some of the impacts of metals released from the soil by acid rain.

pH and Conductivity

A river or a lake with a low pH and high conductivity could indicate that there are high levels of metals in the water. This may be the result of exposing acid producing shales. When pyrite (ferric sulphide) found in shales is exposed to water and air it becomes the home to bacteria that break down the pyrite into sulphuric acid and iron. The iron raises the conductivity and the sulphuric acid lowers the pH with severe effects on aquatic life.

Acid Rain

The acidification of rain is one of the most serious problems in preserving freshwater quality in Nova Scotia. Recent studies have shown that even though emissions of sulfur dioxide (SO_2) and other emissions causing acid rain have been reduced by 50 %, Nova Scotia rivers and lakes continue to be susceptible to stress by acidification. These rivers and lakes have not responded with an increase in pH and lower acidity values. These emissions are mainly due to coal fired electrical plants in the mid-western and eastern United States and central Canada. Nova Scotia is the end of the pipe for these emissions but almost one third of the acid rain is generated locally.

The mechanism by which acid rain injures fish populations in rivers and lakes is well understood. Fish eggs contain enough buffering so that acid rain does not injure them. The problem arises when the eggs hatch and swim up occurs. The inorganic acids literally suck the calcium and magnesium out of the emergent fish. They have curved backbones (scoliosis), cannot swim properly, nor can they hunt for food, and they die.

Turbidity and Sedimentation

Sediments, sand and silt, from land clearing and other sources cause turbidity. Turbidity clouds the water with fine soil particles limiting photosynthesis, reducing visibility for site feeding fish, damaging gills, and detaching aquatic insects. The heavier materials for example, sands that roll and bounce along the bottom of streams in-filling the spaces between the rocks and gravel on the stream bed have a long term damaging effect by destroying fish spawning beds, and clogging instream cover used by fish for escape from predators and over wintering.

An intact watershed will absorb rain and will not pulse sediment into the river or a lake. Trees and shrubs hold the water and slowly release it into the river or lake. After deforestation mineral soil is exposed, leaving nothing to hold the sediment back, therefore it all flows into the streams, rivers or lakes. Other sediment inputs occur at highway construction sites, housing developments, and other events that loosen the earth near a river or lake wherever mineral soil is exposed. The impacts of sedimentation on streams is explained in more detail at http://adoptastream.ca/sites/default/files/Irish-Cove-Brook-report-2012_0.pdf.

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