Agriculture and Agri-Food Canada
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Watershed Monitoring:

An Introduction to Water Sampling

Reference Guide

December, 2004

Canada

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Watershed Monitoring: An introduction to water sampling

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Section 1

What is the reason for sampling?

Designing a sampling plan

The first question to address is “Why sample the water?” The answers should be more focussed than ‘because it’s there’. Is the sampling being done to:

- set up a long term monitoring program?
- determine water chemistry at one point, or over a broad area?
- establish a baseline for a water body or system?
- locate areas that might be causing changes in water quality?

A sampling program should be tailored to whatever issues are being addressed. Do not be afraid to start small. It is cheaper to gradually increase sample sizes and analysis costs than to try and sample everything right from the start. Many good programs begin with a **pilot study**, a small-scale version of monitoring effort. This short guide will provide some basic starting points for water quality sampling and monitoring. It will also explain the common parameters in a routine sample, and how to appropriately collect the water. What it will NOT provide is adequate safety training for working in and around water. It is advisable to take a certified class.

Sampling for a long-term monitoring program

Relative to watersheds, ‘long-term’ usually means *at least* three years and preferably much longer. Agencies or watershed groups often establish long-term programs to continually monitor the characteristics of a particular watershed. This is usually accomplished through repeated sampling at designated sites. The frequency of sampling and the parameters sampled are often limited by funds and required effort.

The main purpose behind a long-term program is to establish what is usual for the system. This is like someone visiting a doctor for regular check-ups, regardless of whether or not they are sick. It allows a researcher to know a system very well. Regular monitoring helps determine what is ‘normal’ (a true **normal**, in meteorological terms, is usually a 30 year average). If it is affordable in terms of time and money, long-term programs are encouraged for the amount of familiarity that they provide.

Sampling to determine water quality

Sometimes a user group just wishes to know what the water quality is in their stream and whether it is generally good or bad. It is possible to determine this with a small sampling effort, but caution must be taken. Aquatic systems change dramatically as part of their nature, and results can be easily misinterpreted. Data quality is linked not only to how carefully samples are taken, but also to how many samples are taken. Usually, more samples over an extended period will provide better information than a few samples over a short period.

If a quick look at water quality is all that is desired, it is very important to choose **representative sites** at which to sample. Although this is true for any sampling, it is crucial if a rapid, generalized assessment is all that is being made. The sampling sites should look similar to what most of the system looks like. If a stream is pretty much treed along its entire stretch except for one beaver dam, do not choose to sample at the dam.

Sampling to establish a baseline

Establishing a baseline is often part and parcel of a long-term monitoring program. However, it is being distinguished here to illustrate that monitoring efforts can be shifted over time.

A baseline for a system is usually determined by sampling at least once per season at the same sampling locations for at least one year. This provides the researcher with characteristics particular to each period. From this information, future sampling can be targeted to times when the system is most sensitive (*i.e.* when it will show the greatest response to impacts). This allows a researcher to streamline sampling efforts after the baseline is established. The importance of this is magnified when funds are limited and time needed for sampling is at a premium.

Sampling to identify particular sites

Aquatic systems are sampled to pinpoint specific areas for one of two reasons:

1. There is a suspected source of contamination somewhere in the system, or
2. There is a desire to show that a remediation effort has been successful

This type of sampling design often requires several sampling points within the system, in which all points radiate from the target site. It can also require sampling a **paired system**. This is a system that is as similar as possible to the

primary system, but without the target impact. The paired system acts as a control.

Proper sampling design is probably most critical for this type of program. Statistics will be required to show that target sites are significantly different from the rest of the system. The type, location, and number of samples taken will need to suit the intended statistical analyses.

Section 2

What does the system look like?

Surface water falls into two main categories: lentic (standing water) and lotic (flowing water) systems. The type of system must be considered when designing a sampling plan. Frequently, natural systems are some combination of the two surface water types. How are all these variations handled? Three examples are presented below:

Example 1

A water user wishes to sample a stream at one point. The user is near the headwaters of the stream. This means that water is entering this stream from the following primary sources:

- run-off from surrounding land
- inputs from groundwater
- rainfall

The user would be safe to sample at one point in the stream. In this instance, it is acceptable to assume that the water flowing past the sampling point is the same as any water upstream, since the sampler is actually at or very near the source.

Example 2

A water user wishes to sample a stream that originates far above the proposed sampling point. There are no lakes in the system, but other streams feed into the main stream. Thus water is entering this system from these points:

- run-off from surrounding land
- inputs from groundwater
- rainfall
- feeder streams

Now the user has to carefully consider the water being sampled. At any given point below a feeder stream, the water has potentially changed greatly from what it was like at its own source. Remember, any feeder stream will also have water entering it as run-off, groundwater inputs and rainfall. The most thorough sampling regime would include points at the headwaters of the main stream and each feeder stream, at points downstream of each confluence (where the streams join), and at a point downstream of all confluences. Immense effort!

Example 3

A water user wishes to sample a stream that is part of a complex network of feeder streams and lakes, all varying in size and volume. Each stream and lake in the network is receiving inputs from land, groundwater and rainfall. This example is usually what is found on the prairies. The thorough sampling regime from example two would result in possibly hundreds of sampling points. Although it would be thorough, it is neither realistic nor cost effective. The original question of “How are all these variations handled?” has now evolved into “How can a sampling program be developed to address MOST of these variations?”

Section 3

Assessing the Sampling Effort

Many people don't realize that a single water sample will not answer many questions. The results from a single water sample are akin to taking a photo of baby. One photo reveals what the baby looks like *at that moment*. In two weeks, another photo might look similar, but not the same. In two months, another photo would certainly look different than the first, even though it is of the same person. Single water samples are the same way. They provide good information about the water and its chemistry *at that moment*.

The examples of stream complexity described in the previous section, and the example of the photo reveal two important points about watersheds:

Watersheds can change over space and through time.

Water can change as it moves away from its source and through the landscape (space). Water can change as the seasons progress and as the whole system ages (time).

A sampling program should incorporate the primary reason for sampling while considering as much of the variation as possible within the watershed. This is a tall order, but not one that is impossible. To account for variations in space, the water may be sampled at more than one point along its course. To account for variations in time, water may be sampled at different periods during the year, and for more than one year. However, it is almost impossible to prescribe one specific design that will work for all watersheds. Sampling programs should be unique to the problem they are addressing.

Section 4

Conducting the water sampling

Taking the water samples

For any sample being collected, at no time should anything other than sample water touch the insides of the bottle. This means no sticking fingers inside the bottle mouth to get a better grip, and no wearing the bottle lid on the end of a thumb. The inside of any sample bottle, including the inside of the lid, should be thought of as radioactive. Don't touch them, even if you are wearing gloves. Often people wear gloves and think they have a super-barrier on their hands. Gloves don't stay clean if you scratch your head or rub your nose while wearing them. The chemicals in shampoo, hand cream or soap will contaminate a water sample and ruin the results.

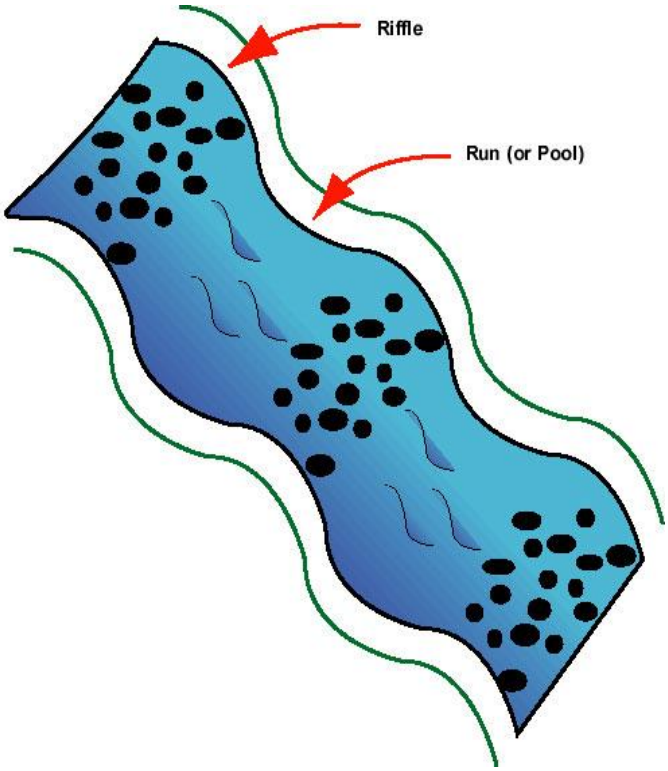
Most samples require that the bottle be rinsed prior to filling. Rinsing involves partially filling the bottle, capping, shaking vigorously for a few seconds and pouring out the rinse water in the downstream flow. Repeat this a minimum of three times. Collect an actual sample by placing the rinsed bottle completely under the water's surface and allowing it to fill. Cap tightly and store well. Water samples should be stored and transported at as low a temperature as possible *without freezing the sample*. Samples that freeze may be ruined for some analyses. It always is best to check with the laboratory for sampling protocols.

Some samples require the bottle to be filled without rinsing. In this instance, the bottle is placed under the water surface as above, filled, capped and stored immediately. Certain samples require filling with 'no headspace'. This means that large air gaps between the top of the bottle and the cap are not allowed. The bottle must be rinsed as usual, and filled to overflowing before it is capped. Small air bubbles may form on the insides of the bottle; this is all right as long as the bottle originally had no large airspace at the top.

Sometimes sample bottles arrive with reagent inside them. Never rinse these bottles. They frequently require filling to a set point - either to the top of the bottle or to a marked line. It is allowable to fill these sample bottles from a second bottle that has already been well rinsed. This makes it easier to fill the marked bottle to the correct level.

General sampling considerations for flowing water

A healthy stream or river is composed of riffles regularly spaced between runs or pools.



Riffles are areas where the water is usually shallower, faster, and more turbulent. Flow in a riffle is often over gravel beds, past rocks or around boulders.

Runs or pools are areas where water is deeper, slower, and much less turbulent relative to the riffle areas. Water moves at a range of speeds through runs and pools—water moving at the quicker end of the scale is often called a run. Water moving at the slower end of the scale is usually called a pool. Water not moving much at all is said to be ponded—this can occur behind beaver dams or log jams.

For sampling purposes, in small streams riffles are often great places to collect water. The turbulent flow through a riffle means that water is well-mixed. Through runs, pools, or ponded areas, the slower flow of water causes suspended particles to settle out. This is not considered representative of the water traveling down the stream.

A riffle is best sampled in a spot deep enough to accommodate the largest sampling bottle. It is best to pick a spot that looks like most of the riffle. For example, don't sample directly behind the only large boulder in the entire stretch of riffle.

In large streams, riffles may be too turbulent to access safely. Water samples are usually collected in runs when sampling large streams.

Rivers and streams can be dangerous places in which to work, especially in riffle zones. Water is moving quickly and any rocks present are usually quite slippery. If conditions look safe, move into the water *parallel to flow*. This means

that if the sampler wades into the water with arms extended to the sides, one arm should be pointing upstream and one arm should be pointing downstream. This way, water is only pushing on one leading edge, the upstream leg. Wading into a mid-thigh deep stream perpendicular to flow results in big forces on the sampler's legs. Not only is this much less stable, your legs get tired!

In strong flow, the safest way to leave the stream is to walk out backwards, parallel to flow. This may seem awkward, but it is far safer to walk backwards than to risk trying to turn around in a quickly moving stream. If the bottom of the stream is not visible, do not trust vague memories to suggest where it should be. Things change. Get a long stick or rod and test it out.

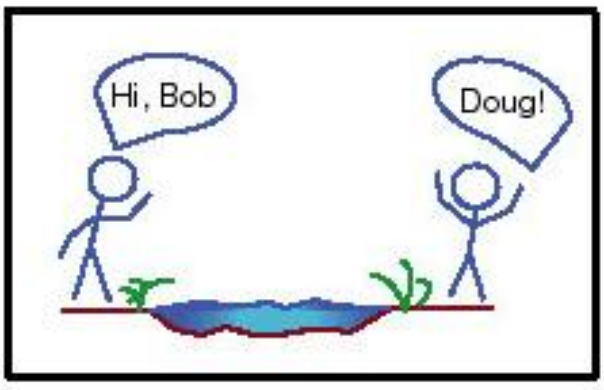
Sampling a shallow stream

Let's assume that a watershed group has formed, and wants to get a general feeling for the water chemistry in their stream. They want to start by taking a grab sample. A grab sample is taken when the exact depth of the sampling point is not important. This is appropriate for many of the small streams found on the Prairies. For most purposes, a stream is small if:

- it is easily wadeable at normal levels (*i.e.* not during flood conditions)

OR

- it is possible to hear your field partner talking to you from the opposite bank.



The appropriate bottles are obtained from a water lab. In each location on the stream, a spot is selected where water is moving in a steady, even flow. This will provide a water sample that is well mixed and theoretically represents all the water in the stream at that point. The water should be deep enough to completely submerge the sample bottles. While collecting a sample, work reaching upstream and place the bottles into the water above where you are standing. This way, any sediments dislodged from the stream bed will float

downstream and will not contaminate the sample.

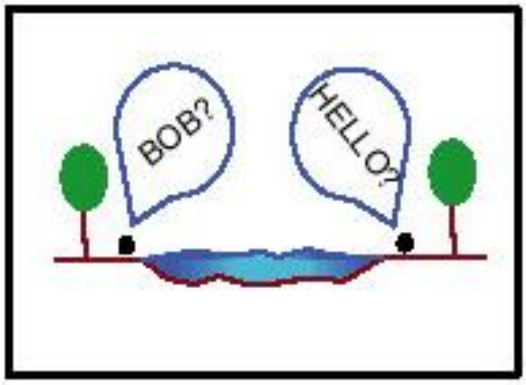
Sampling a river or large stream

The watershed group's sampling effort went well on the small stream. Now they want to sample the river their stream feeds. This presents a different situation, no longer appropriate for a single grab sample. The water in a river or large stream cannot be assumed to be the same either across the channel or at all depths. For most purposes, a stream is large if:

- it is not easily wadeable at normal levels (the channel is too deep or the water is too fast)

OR

- your field partner has to yell from the opposite bank to make themselves heard



(*Extremely* large rivers will not be dealt with here. They present an entirely different suite of challenges, since rivers that are very large tend to start behaving like lakes; they are often monitored by big agencies who have the ability to sample them effectively)

With a large stream, water sampling can be approached in two ways. If the stream is wide, but not deep, two or more grab samples can be collected at different points. Often, a specific volume of water is collected from each side of the stream. The water is then mixed together to form a **composite sample**. The mixed water should contain two parts of equal volume (*eg.* 2L from one side and 2L from the other side). Sample bottles are rinsed and filled as usual from the mixed water. The container holding the mixed water should be large enough to allow sample bottles to be submerged.

If the stream is also deep, multiple samples can be made *at different depths*. For example, a large stream that is 1.0 metre deep could be sampled just below water surface and just above the bottom. Samples taken at distinct depths are called **discrete samples**. They represent the water at one particular point.

Discrete samples are always labelled with the depth at which they were taken. It is also useful to record the total depth of the stream at the sampling point as well. Make sure each sample is distinguished from any others by labelling well.

Taking discrete samples in a large stream can be difficult, especially if the flow is strong. Lowering the bottles must be done so that only the water at the desired sampling depth enters them. It must also be done safely so that the sampler is not swept away in the current. Samplers are far more expensive to replace than the samples. To eliminate the need for expensive equipment, and for safety's sake, deep, flowing water should not be sampled at discrete depths if an average-sized person cannot safely walk into the strongest flow *and then return to shore*. If both cannot be done with ease, just take the grab sample.

If it is safe to do so, discrete samples may be taken by rinsing and filling bottles at the desired depth. The sampler should submerge the bottle to the correct depth and then uncap it. Rinse with a small portion of water as before, but each time cap the bottle while it is submerged. Final filling of the sample bottle is done at the same depth and also capped under water. In this way, only water from the desired depth ever enters the sample bottle.

Sampling a lake

Now the watershed group wishes to sample the lake where their stream originates. They know how to sample flowing water from their previous work. Sampling the lake is new territory.

Far more than streams and rivers, lakes require specialized sampling gear. Explaining the mechanics of the gear is easy; explaining how water acts in a lake and when to use what gear is much more difficult. This is because water in lakes tends to shift between being **stratified** and being **mixed (**or **unstratified).** Thorough sampling of a lake often involves taking some discrete samples and some composite samples. The location and amount of each can vary greatly depending on the time of year and the condition of the lake in any given year.

Water in lakes is divided into zones, which are sampled individually. The zones are dependent on **light, temperature** and in special cases **dissolved oxygen**. They are usually determined at the deepest point in the lake, which is where most of the samples are collected. This means that the **bathymetry** or shape of the lake bottom should be known, as well as the **deep water spot.** This is often marked with a float and weight so that it may be returned to quickly on subsequent trips.

Photic zones are defined by light**.** The photic zone of interest in lake sampling is usually the **euphotic zone.** This is where **primary production** occurs (*i.e.* algal growth, plant growth). The euphotic zone begins at the lake

surface and ends where light penetration into the water is at 1% of what it is at the surface. The lower limits of the euphotic zone is officially called the **1% light compensation level**. If the lake bottom can be clearly seen, the euphotic zone is equal to water depth. If the lake bottom is obscured, the euphotic zone can be calculated with the use of a **light meter**, or as two times **Secchi disk** depth. The euphotic zone water is usually taken as a composite sample, with portions from the deep water site and from two or more other points on the lake. The total number of composite sampling points depends on lake size. Water is collected using a **composite tube**, and is stored in a **composite bucket** until all water has been collected. Sample bottles are rinsed and filled as usual, but must include euphotic zone depth.

The **limnetic zones** are defined by temperature. There are three primary ones: **the epilimnion**, the **thermocline** (sometimes called the **metalimnion**), and the **hypolimnion**. All the limnetic zones are present when a lake has stratified. This occurs when a layer of warmer surface water forms over cooler, denser bottom water. In early spring, lakes are usually mixed: the water is about the same temperature from top to bottom. As the air warms up, so does the water at the surface. Since warmer water is less dense, it remains at the surface as the epilimnion, and colder water sinks to the lake bottom and forms the hypolimnion. They are separated by the thermocline, a narrow zone where water temperature changes faster than it does at any other depth in the lake. For practical purposes, this is often where the temperature drops more than one degree over one metre in water depth, measuring from the surface down.

Moderately deep lakes are stratified in the summer, and mix or turn over in the spring and fall (**dimictic** lakes). Shallow lakes may be mixed for the whole year, or be only weakly stratified throughout the hottest months (**polymictic** lakes). Very deep lakes can have a hypolimnion that never completely mixes at any time (**meromictic** lakes).

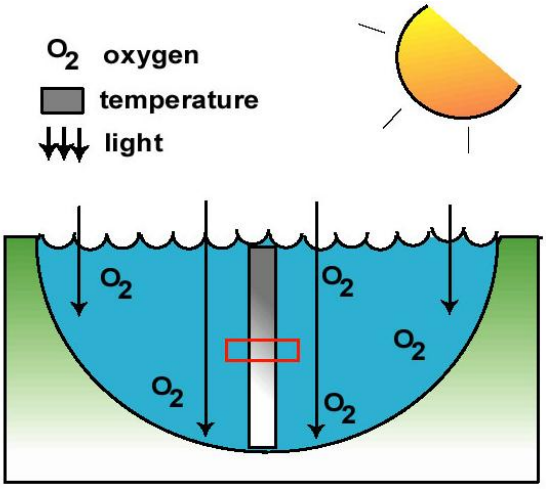
In special circumstances, the hyplimnion is sometimes defined by dissolved oxygen (or **DO** for short). One example is early spring, just after ice-off. Lakes are frequently still mixed in terms of temperature at this time. However, water near the lake bottom can have greatly depleted DO levels from the lack of oxygen inputs over the winter. This is called **anoxia**. A lake with a sharp anoxic zone at its bottom is said to have a **chemically defined** hypolimnion.

Sampling limnetic zones involves first determining where they are. This is done by taking oxygen and temperature **profiles** with electronic meters. Probes for each parameter are lowered into the water at determined depths: just below surface, and at regular intervals thereafter until just above the lake bottom. Once their depths have been calculated, discrete samples can be taken at roughly the midpoint of each zone. The samples must be collected with specialized equipment that ‘cuts out’ individual pieces of water. Some examples include Van Dorns, Kemmerers, and dropsleeves.

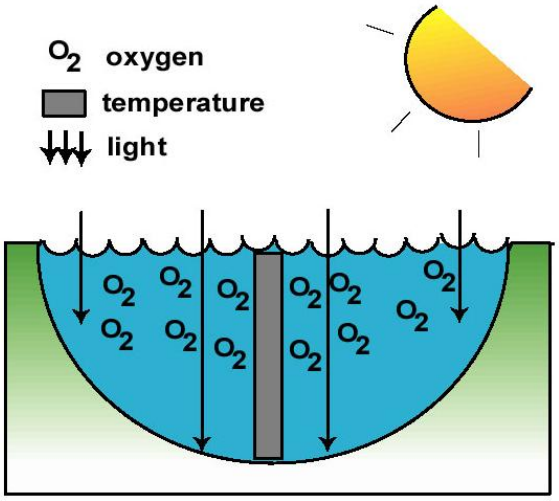
Lake sampling is always done from the top down. This is to prevent mixing deep water with surface water, or from mixing water between different zones. There are no set rules as to which sample to take first. It all depends on where the zones fall out in the water column. Just remember to collect the samples closest to the surface first and then work down to deeper samples. Samples are usually only collected to within 1 m of the lake bottom. Collecting water closer to the bottom risks disturbing sediments that will skew the results of the sample.

Not all zones are sampled at all times. When both the epilimnion and hypolimnion are present, they are usually only sampled at the deep water spot, not again at the extra spots for the composite euphotic sample. The hypolimnion is not always present or sometimes it is very small, so no sample is taken. The epilimnion and euphotic zones are sometimes very similar in depth. Generally, if the lower limits of these two zones are within 1 m of each other, only the composite sample from the euphotic zone is collected. This saves money by not sampling the same water twice.

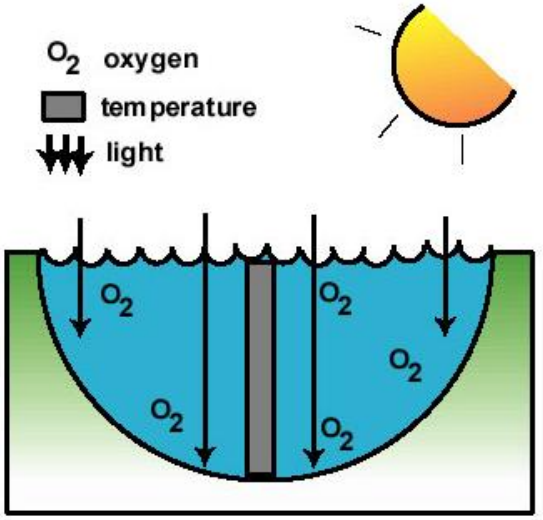
Lake Sampling Examples



This lake has good oxygen mixing and light penetration. However, the temperature is warmer at the surface than at the bottom, and there is a narrow band (red box) where temperature drops rapidly. Thus there are defined epilimnetic, hypolimnetic and euphotic zones. In this instance, three samples are taken. The euphotic and epilimnetic zones are different enough that water from each should be collected.

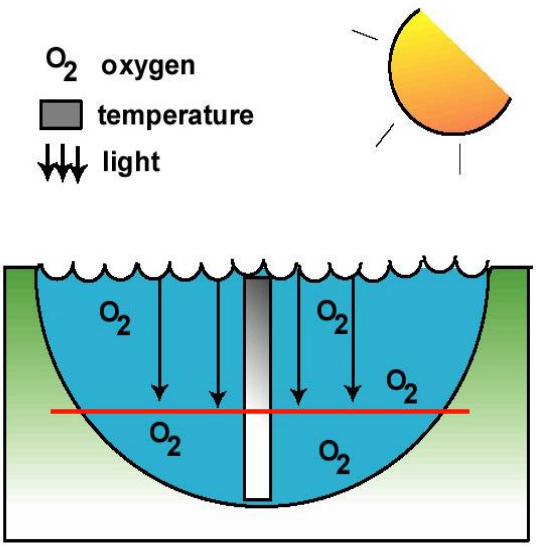


This lake has no true hypolimnetic zone because the temperature does not drastically change from top to bottom. Normally, since light is also penetrating to the bottom, only one composite sample would be collected. However, there is a zone near the lake bottom where oxygen is greatly depleted. This translates into a chemically defined hypolimnion. Thus, one composite sample is collected to within 1 m of the top of this zone, and one discrete sample would be collected within it.



This lake is completely mixed and unstratified. Temperature and dissolved oxygen are similar in value from the surface to the bottom. Light is reaching the lake bottom without falling below 1% of its intensity at the surface.

In this example, there is no hypolimnion. The epilimnion and euphotic zones represent the exact same water (since the light is penetrating so well). Only one composite sample would be taken to within 1 m of the lake bottom.



The oxygen in this lake has no dramatic drops in level, even at lower depths. However, the surface water has warmed, and temperature is markedly lower on the lake bottom. There are true epilimnetic zones (above the red line) and hypolimnetic zones (below the red line).

Light is only penetrating to about where the temperature changes. This means that the euphotic zone is similar in depth to the epilimnetic zone. One composite sample is all that is needed for both of these zones because of the overlap. A discrete sample would still be required in the hypolimnetic zone.

Section 5

Making the samples mean the most...

...in flowing water

The watershed group has sampled the stream four times throughout the spring. Some of their results have come back from the lab. Looking at some of their values, they notice that a few numbers are the same from trip to trip. They wonder how this could be, since the stream was flooding during one sampling trip. Why would the values be so similar if there was so much more water in the stream that one time?

The watershed group has started to discover that sometimes individual stream samples aren't as meaningful as they could be. For example, a nutrient sample collected during a high water event might be 100 mg/L. During normal flow, another sample for the same nutrient might also be 100 mg/L. However, this would not mean that the stream had the same amount of nutrients flowing through it, because we inherently know that there was more water during the flood. How much more could have been calculated by measuring the **discharge** during each sampling trip. Discharge is a measure of how much water is flowing past a fixed point at a given rate. The units are often cubic metres per second or m^3/s. Discharge can be determined directly using a **flow meter** (either manual or automated), or indirectly from a **stage-discharge curve** (a graph relating stream depth to previously recorded discharges).

Knowing the discharge would allow for **weighted comparisons** between nutrient values. Let's say that 1.3 m^3/sec of water was moving past the sampling point during the flood, but only 0.3 m^3/sec of water discharges at normal levels. Therefore:

at high water: $\frac{100\ mg}{L} \times \frac{1.3\ m^3}{sec} =$ **130 kg/sec** of nutrient (1 m^3 = 1000 L)

at normal flow: $\frac{100\ mg}{L} \times \frac{0.3\ m^3}{sec} =$ **30 kg/sec** of nutrient

This gives weight to each nutrient value by incorporating the total amount of water flowing past the sampling point. Identical nutrient values from different trips do not mean the same thing if flow rate is not considered.

Discharge is difficult to obtain during high flows and without the proper equipment. The example above was given to illustrate its importance. It is wise to have properly trained field staff create a stage-discharge curve for a sampled stream. Maximum depth or **stage** is then only ever needed to obtain an

estimated discharge. This can be safely done from shore if a **staff gauge** is installed at the deepest point in the stream. A staff gauge is essentially a giant ruler that can be easily read from a distance. It is perfectly acceptable to install a staff gauge and start recording levels before the discharge curve is created. The numbers will still be valuable.

...in standing water

Staff gauges are also useful in lakes being sampled, since lake levels change over time. The water level should be recorded for every sampling visit. Determination of lake volumes requires a greater initial investment of time, and is only recommended if the lake is a reasonably small size. To measure lake volume, an accurate outline of the lake must first be obtained from a map or other source and **transect lines** should be plotted.

To calculate a lake volume, transect lines must be traversed across the lake roughly perpendicular to the shoreline. This involves piloting a boat in a straight line from point A on one shore to point B on the far shore. Along the transect line, often at 2m intervals, lake depth is measured with a **sounding device**. At least three transects should be completed per lake as a minimum. The more transect lines and the smaller the depth intervals, the more detailed the final information will be. However, this should be balanced against the time required to take all the initial measurements. Five or six lines of 2m intervals often provide good detail (see Appendix 1 for an example of how to develop a bathymetric map).

Once the transects are complete the depth data are plotted on the lake map as points along the transect lines. Points of equal depth are then included continuously to create **contour lines**. The lake surface area of each contour must then be calculated using a **planimeter**. Volume can then be calculated for each contour depth or **stratum** using the following formula:

$$\text{Volume of each stratum} = 1/3\ h\ [(a_1 + a_2) + \sqrt{\ } a_1 a_2\ ]$$

where h = height of each contour layer
a_1 = area of the contour upper surface
a_2 = area of the contour lower surface

Adding all the volumes for each stratum will provide the total lake volume. To calculate the average or **mean depth** for a lake, divide the total lake volume by lake surface area. The mean depth is a number that can be used as an indicator of some water quality characteristics. For example, a low mean depth (< 5m) indicates that the lake is wide and shallow, and may be either unable to support fish or at risk of **summer**- or **winterkill**.

Section 6

Knowing what chemical analyses to ask for

Water samples are expensive to analyse. The type of analyses to be performed will depend on why the sampling plan has been designed. Although it is tempting to ask for every analysis possible when sending in a sample, keep this in mind: costs range from about $6.00 for pH to about $400.00 per sample for certain pesticides. Other prices fall somewhere in between this range. It is the cost of sample analysis that usually determines the number of samples taken.

The characteristics or effects of water quality fall into one of three broad categories: **physical**, **chemical**, or **biological**.

Physical properties include things such as:

- dissolved and suspended solids
- turbidity/clarity
- depth
- taste/odour*
- temperature
- colour
- sediment type and size
- rate of discharge (lotic systems)

*it is not recommended that anyone taste raw surface water

Chemical properties include things such as:

- pH
- hardness
- alkalinity
- carbonates
- dissolved metals
- dominant ions
- conductivity
- phosphorus
- nitrogen
- carbon
- dissolved oxygen
- oxygen demand
- pesticides
- silica

(see Table 1 for some common parameters and abbreviations)

Not all chemical parameters need to be sampled at the same frequency. Things like dominant ions don't change very rapidly compared to nutrients like phosphorus and nitrogen. Also keep in mind that most chemicals have more than one form in water (*eg*. they may be dissolved or in particulate form or be bound to something else). As such, there may be a variety of different analyses that can be requested for just one chemical. It may be more economical and easier to ask for something like *total* nitrogen as opposed to one or two of its many forms.

Biological properties include characterizing things such things as:

- algae
- bacteria (fecal coliforms, total coliforms, *E. coli, etc*)
- invertebrates
- fish
- vegetation

Most biological parameters are measured using a combination of **qualitative** and **quantitative** sampling. A qualitative sample will reveal what's in the system (*eg*. a stream may have mayflies and stoneflies in a sample grid). A quantitative sample will show how much of a particular item is in the system (*eg*. 50 mayflies per sample grid *versus* 10 stoneflies).

Table 1. Some analyses of chemical properties and their common laboratory abbreviations*:

Chemical Compound	Test (abbrev.)
Phosphorus	Total Phosphorus (TP)
	Total Dissolved Phosphorus (TDP, DP)
	Soluble Reactive Phosphorus (SRP)
Nitrogen	Nitrate ($NO_3^{-)}$ + Nitrite (NO_2^-)
	Ammonium (NH_4^+)
	Total Kjeldahl Nitrogen (TKN)
	Total Nitrogen (TN)
	Particulate Nitrogen (PartN)
Carbon	Dissolved Inorganic Carbon (DIC)
	Dissolved Organic Carbon (DOC)
	Particulate Carbon (PartC)
Dominant ions	Cations (Ca^+, K^{2+}, Mg^+, Na^{2+})
	Anions (SO_4^{2-}, Cl^-)
Bacteria	Total coliforms
	Fecal coliforms
	E. coli

*some abbreviations may change between labs

Section 7

Other analysis options

Field instruments and kits

Sending water samples to a lab is not the only way to monitor stream health. Many of the parameters measured in a lab can be measured in the field with affordable instruments. A watershed group could realistically afford some of the simple instruments or kits currently available for things like pH, dissolved oxygen, conductivity, temperature, turbidity, or even some dissolved nutrients.

Other indicators of water quality

Stream health is also reflected by the plant growth around the stream and what is living within the stream. Thus, a monitoring program could also include shoreline vegetation assessments, visual estimates of anything growing in the water, and regular checks on what bugs live in the water. All of these things together give a good picture of relative stream health. For example, some bugs will not survive in low-oxygen waters. If regular checks start to reveal that there are fewer of these bugs in a stream every year, a problem could be indicated. Sites for these types of examinations can be chosen by the same method as for water samples. They can be relied upon if water analyses prove to be too costly on a regular basis.

The US EPA has constructed an excellent guide for stream habitat analysis entitled ‘Rapid Bioassessment Protocols’. It contains outlines, sample field sheets and photographic examples of how to compare the relative health of streams. It is available as a free, 369-page PDF document from their web site, or it may be purchased from their library. Anyone interested in performing a stream assessment of water quality without relying strictly on water samples should access this document.

Glossary

anoxia - in aquatic systems, a complete lack of dissolved oxygen in the water column

aphotic zone - if present, a zone found below the 1% light compensation level where no detectable light penetrates

bathymetry - the process of characterizing the shape of the lake bottom, the product of which is a map displaying depth contours

biological properties - measurements of water quality related to the types, numbers, size, and distribution of different organisms within the system.

chemical properties - measurements of water quality related to the response of water to specific, chemical reactions; often performed in a laboratory or with a field kit requiring appropriate reagents

composite tube - a device used for collecting integrated samples of the water column in a lake; often constructed of some form of potable water tubing (*eg*. Tygon™) fitted to a foot valve

composite sample - a sample comprised of two or more equally sized portions of water, well mixed together

composite bucket - a clean, potable water container used for mixing water portions that will comprise a composite sample

deep water spot - a point assumed to be the deepest spot in the lake; determined by mapping the lake bathymetry

dimictic - a lake whose water column mixes completely twice per year, usually once in spring and once in fall

discharge - the amount of water in a lotic system flowing past a static plane; measured in cubic metres per second

discrete sample - a sample that represents one particular point or depth in the water column, collected without mixing in water from above or below the sampling point

dissolved oxygen (DO) - atmospheric oxygen that is dissolved within the water column, measured in either mg/L or %saturation; dissolved oxygen is directly correlated with changes in temperature and atmospheric pressure

epilimnion - a warmer, upper layer of water within a lake whose lower limits are

marked by the thermocline

euphotic zone - a zone within the water column of a lake marked by light penetration, the lower limit of which is called the 1% light compensation level; virtually all primary production occurs in the euphotic zone

flow meter - a device used to measure stream velocity (how quickly the water is moving in the stream); transects of velocity measurements across channels can be converted mathematically to calculate discharge

hypolimnion - a cooler, lower layer of water within a lake whose upper limits are marked by the thermocline

hypolimnion, chemically defined - a lower layer of water defined by at or near zero levels of dissolved oxygen, occurring most often in spring; the lower water may or may not be significantly colder than upper waters in this instance

light - in aquatic systems this usually refers to the ultraviolet (uv) wavelengths required for photosynthesis

light meter - a device used to measure the penetration of uv wavelengths into the water column; measured in lumens or microsiemens

limnetic zones - zones of measurable depths within the water column distinguished on the basis of water temperature (*eg*. epilimnion, metalimnion, hypolimnion)

mean depth - lake volume divided by lake surface area; since a cubic measure is divided by a square measure, the result is in linear units, usually metres

meromictic - a lake system with a hypolimnion that never completely mixes with warmer, upper water layers; usually a very deep water body

mixed (unstratified) - a water column that has no drastic drop in temperature from surface to bottom; a water column with no thermocline

normal - a long term average used to establish baseline values for a system; often a 30 year mean

one percent (1%) light compensation level - the lowest level to which light useable for photosynthesis can be detected in the water column; defines the lower limits of the euphotic zone

paired system - a system with as many similarities as possible to an original system; often used to compare or contrast response to an impact present in the original but missing in the paired system

photic zone - a zone defined by the presence or absence of detectable light, especially in the ultraviolet range (*eg*. euphotic zone, aphotic zone)

physical properties - loosely, properties that can be gauged or measured by observation or with an instrument without involved, chemical analyses (*eg*. vegetation types, temperature, depth, sediment type); there is always some overlap between physical and chemical properties

pilot study - a non-scientific study run to determine the most effective way of constructing and sampling for a true, scientific design; often used to test equipment, sampling methods, site selection and analyses

planimeter - a manual or electronic hand-held device used to calculate surface area; it consists of a wheel that registers rotational clicks as it is pushed over the outline of the area to be measured

polymictic - a lake system that is either completely mixed year-round or only weakly stratified during very hot weather; often very shallow

primary production - in the purest sense, a measurement of the metabolic rate of autotrophic organisms; in the ecological sense, this usually translates into the growth rates of green plants, algae and cyanobacteria (organisms that rely on photosynthesis)

profiles - measurements taken in the water column that move from surface to bottom at regular depth intervals; depth itself is a profile, as can be temperature, dissolved oxygen, pressure, *etc*.

qualitative - a measurement of quality, or what kinds and types of things are being considered (eg. tall plants, short plants, land beetles, water beetles)

quantitative - a measurement of quantity, or specifically how many or how much of each individual thing is being considered (*eg.* 12 tall plants, 5 short plants, 6 land beetles, 8 water beetles)

representative site - a site chosen for sampling that is characteristic of a much larger area

Secchi disk - a flat disc evenly divided into quarters that are alternately shaded black and white; Secchi depth is determined by lowering the disc into a standing water column until it disappears, and then drawing it up until it just reappears - the midpoint between these two depths is Secchi depth; two times Secchi depth is roughly the euphotic zone depth

sounding device - any device used to determine bottom depth, most often in

standing water; may involve reading electromagnetic or radio-wave bounce backs or may be as simple as using a line and weight

staff gauge - any easily read, vertical measuring device that can be installed in a stream or lake in a stationary position to reflect changes in water level

stage - a measure of water level relative to a fixed point

stage-discharge curve - a graph that establishes a relationship between stage height and discharge so that one measurement may be used to estimate the other

stratified - an aquatic system, usually a lake, that has developed recognizable zones of differing temperatures (*eg*. surface water that has warmed greatly relative to deeper water - see limnetic zones)

temperature - a measurement of sensible heat energy, usually in Celsius or Fahrenheit

thermocline (metalimnion) - a narrow zone, usually in lakes, where temperature drops faster than it does at any other depth while moving from surface to bottom; for practicality, it is often considered to occur where temperature in degrees Celsius drops one degree or more in one metre

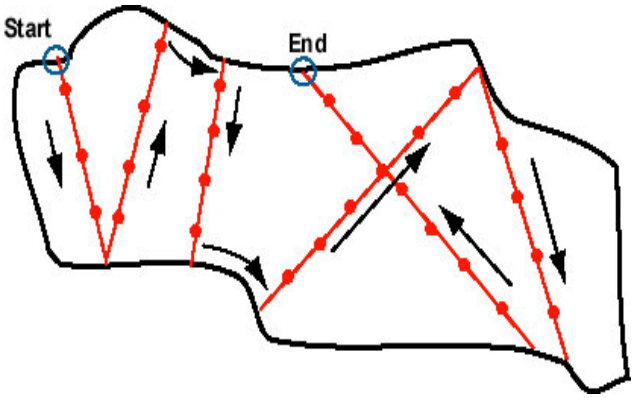
transect line - a line of continuous, evenly-spaced sample points that usually either parallels a system or bisects it at a right angle

weighted comparison - a measurement that has been related to a second unit of measure (*eg*. weight, distance, time, volume) to give it more meaning

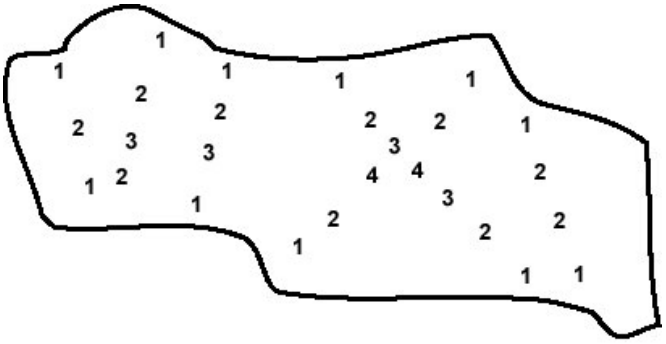
Appendix: Determining Lake Bathymetry

Bathymetry is a five-dollar term for characterizing the bottom of a lake. It requires a bit of time, a marked line and weight, an aerial map of the lake, a friend with a boat, and the ability to drive in a straight line. A GPS unit can help immensely with that last point. Given the ability of most people to drive in a straight line, a GPS unit could prevent a big fight and someone having to swim back to shore. It might be a worthy investment to dig one up.

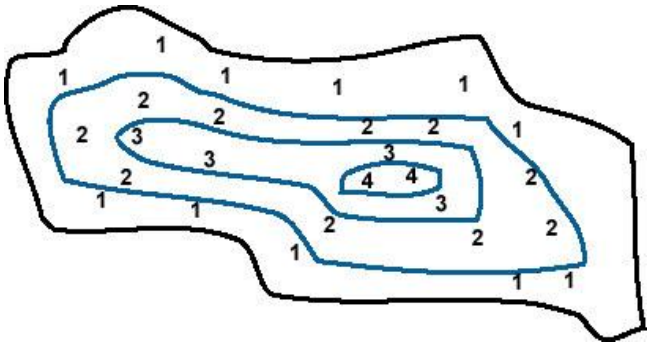
To start construction of a bathymetric map, depth points need to be recorded along several transect lines across the lake. The points should be evenly spaced along each line.



At each point, lower the marked line and weight, and record the depth. Continue in this fashion until there are several transect lines traversing the lake from shore to shore. The more points the better, although there is a trade-off between good data and the amount of time willing to be spent driving back and forth across the lake. Balance the two needs.



You must know where you are on the lake at each depth point. Once all the data are collected, the lake contour should be redrawn, and the depths should be written on at the points where they were measured. Now you are left with the outline of the lake and a lot of numbers marked in it. The next step is to make sense of how all the numbers relate to one another. This takes a bit of fiddling.



Depth contours need to be drawn inside the main lake contour. Each depth contour should contain all the points for each measured depth: the 1m depth contour should contain all the 1m depth points, the 2m contour all the 2m points, and so on. The points should be plotted to scale, and the actual distance traveled on the lake between depth measurements should be provided. Voila! One bathymetric map.