Fish Habitat Management System for Yukon Placer Mining

Water Quality Objectives Monitoring Protocol

Prepared by

The Yukon Placer Water Quality Working Group

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1.1 INTRODUCTION AND OBJECTIVES

A new system for managing placer mining activity under the *Fisheries Act* is being implemented by the Yukon Placer Secretariat. Founded on principles of adaptive management and incorporating a risk-based approach to decision-making, the Fish Habitat Management System for Yukon Placer Mining is intended to balance the objectives of a sustainable Yukon placer mining industry with the conservation and protection of fish and fish habitat supporting fisheries.

As part of the new management system, a set of protocols have been designed to guide three effects-monitoring programs. These are the Aquatic Health Monitoring Protocol, the Water Quality Objectives Monitoring Protocol and the Economic Health Monitoring Protocol. The monitoring programs will assist in verifying the effectiveness of the management system in meetings its objectives and provide a rational basis for future changes, if appropriate.

The primary objectives of the Water Quality Objectives Monitoring Protocol are as follows:

- To provide ongoing information on the water quality in the various watersheds;
- To provide the data required to determine whether the Water Quality Objectives set within the management system are being achieved;[1]
- To describe how Water Quality Objectives will be monitored; and
- To ensure water quality information supports the adaptive management process.

Water quality objectives and a new water quality model were developed as management tools to support the sediment discharge standards for Yukon placer mining. While the Water Quality Objectives are not legally enforceable, they are one of several considerations, (including sediment loading and bed load) taken into account when establishing sediment discharge standards.

The Water Quality Objectives were developed specifically for Yukon placer mining with reference to the European Freshwater Fish Water Quality Criteria and the Canadian Council of Ministers of the Environment Water Quality Guidelines. The Water Quality Objectives will be set for all habitat types, regardless of fish species present.

[1] A Water Quality Objective (WQO) is a measure of the concentration of sediment in fish-bearing waters that is established and monitored in order to prevent unacceptable risk to fish habitats of varying sensitivity (sediment concentrations will be measured as total suspended solids). The location of WQO monitoring sites will vary depending upon the sensitivity of the fish habitat receiving protection.

The Water Quality Objectives are risk-based in that the degree of protection or level of acceptable risk varies with habitat sensitivity. Water Quality Objectives in highly sensitive habitats will be set to eliminate risk entirely (i.e. no sediment discharges from placer mines), while those in habitats of lower sensitivity will balance the protection of fish and fish habitat with the viability of a sustainable placer mining industry. The Water Quality Objectives have been developed primarily for juvenile Chinook salmon because this species has the most specific and demanding requirements for suitable habitat. Given that other fish species will thrive in habitat suitable for Chinook salmon, protecting salmon habitat also protects other fish habitat. Water Quality Objectives have also been developed for habitats that are far less likely to support Chinook salmon, but where other species are known to thrive.

Preliminary surveys of water quality have been conducted, beginning in 2004. By 2006 these surveys employed the methods described in this Protocol. The preliminary surveys provided an opportunity for monitoring staff to gain hands-on experience and to confirm whether components of the program could be implemented as planned. They also provided an opportunity to assess the sampling network and provide indications of whether more (or possibly fewer) samples are needed in order to gain knowledge of the water quality at various points throughout the watershed.

Preliminary surveys also helped refine the logistical aspects of monitoring. Operational approaches were tested and aspects such as the means of transport, on-site testing techniques, and sample preservation and transport methods were evaluated. Sample volume requirements and preservation methods were refined, based upon experience gained from the preliminary surveys.

The results of monitoring water quality at specific locations in each watershed together with the results of aquatic health monitoring, will feed into an adaptive management process to evaluate the effectiveness of end-of-pipe sediment discharge standards and Water Quality Objectives in protecting fish and fish habitat. Adaptive management has been defined as the process whereby management is initiated and then incrementally evaluated and refined.[2] Unlike traditional management, an adaptive approach recognizes uncertainty and the constraints of knowledge. It provides a process that utilizes new information gathered from monitoring and research to modify management practices. In particular, high-quality monitoring data from both successes and failures should lead to improved decision-making.

Careful annual monitoring will form the basis of any recommendations for change. At least three to five years of monitoring the management system's performance will likely be required before adjustments are made. In the interim, changes may be considered in response to unforeseen circumstances of an exceptional nature. The Yukon Placer Secretariat's Inter-governmental Management Group (IMG) will be responsible for evaluating the monitoring results on an annual basis. A final

[2] Kershner (1997), "Monitoring and Adaptive Management."

annual monitoring report will be completed and provided to the IMG no later than December 31st of each year. This monitoring report will be used in the evaluation and adjustment phases of the adaptive management process and will be part of the Secretariat's annual Adaptive Management report.

1.2 KEY QUESTIONS TO BE ADDRESSED

The strategy for the sampling design, data collection and data analysis methodology outlined within this Protocol focuses on these two key questions:

1) Are the Water Quality Objectives established in the new fish habitat management system being achieved?

2) If not, is this due to placer mining activity or to other causes?

1.3 SAMPLING DESIGN

It is beyond the scope of any monitoring program to sample for every condition that can be found in a lake or in a stream. This outline discusses stream and river conditions that make good candidates for monitoring as well as the methods and procedures that will be implemented in order to obtain samples that are representative of these conditions. Water Quality Objectives will be monitored by water quality research staff and inspectors employed by the Client Services and Inspections Branch (CS&I) of the Yukon's Department of Energy, Mines and Resources. Samples will also be collected using automated sampling equipment deployed by CS&I.

Water quality can be described by a single variable or by any combination of more than 100 variables. The variables chosen in this monitoring program are based on the program objectives and on both existing and anticipated uses of the water. The simplest combination of variables is temperature, electrical conductivity, pH, settleable and total suspended solids (TSS). These give the bare minimum of information on which an assessment of overall water quality can be based. In time, more parameters may be added to the list of variables monitored (i.e. dissolved metals, alkalinity, Total Organic Carbon (TOC), nutrient concentrations) if it is determined that the results from these additions have merit and aid in the determination of water quality.

The field work associated with the collection and transport of samples is the most costly element of this monitoring program. Sampling expeditions will, therefore, be planned and carried out in such a way that efforts are not wasted. The sample collection process will be co-ordinated with the laboratory so that analysts know how many samples will be arriving, the approximate time of their arrival and the analyses that are to be carried out. Personnel who collect water or sediment samples will be fully trained in both sampling techniques and field test procedures. They will also be aware of the objectives of the monitoring program since these will have some influence on the sampling procedures. The choice of a representative sampling point and the use of appropriate sampling techniques are of fundamental importance.

Two different types of sample can be taken from surface waters: *grab* samples and *composite* (integrated) samples. The simplest, a grab sample, is taken at a selected location, depth and time. Normally, the quantity of water taken is sufficient for all the physical and chemical analyses that will be done on the sample. A composite sample is a physical mix of individual sample units or a batch of unblended individual sample units that are tested as a group. In this protocol, all samples obtained by field personnel will be grab samples. When automated samplers are employed time-integrated grab samples will be taken.

Eighteen watersheds within the Yukon Territory will be managed by class authorizations under the new management system. Due to logistical constraints, however, only some of these watersheds can be monitored during any given year.

The watersheds chosen for sampling will be subdivided into ***Major*** watersheds (high frequency, multi-site, mechanized water quality sampling) and ***Minor*** (low frequency, single site mechanized and multi-site non-mechanized water quality sampling). Mechanized sampling refers to monitoring repeatedly at fixed sites in a watershed using automatic sampling equipment supplemented with grab sampling at various intervals throughout the season. Non-mechanized sampling refers to sampling less frequently at fixed sites in a watershed using grab sampling techniques described within this protocol.

The level of monitoring devoted to each watershed will be based on several factors, including overall habitat sensitivity, the amount of historical and current mining activity, and to some extent the financial constraints inherent to environmental monitoring in remote locations. Initially, monitoring will be focused in areas where comparative data has historically been collected and in new areas where little or no background information is available but the potential for future exploration and mining is high (See Table 1).

Table 1

Watershed	*2006*	*2007*	*2008*	*2009*
Major (Multiple site automation & grab sampling)	Indian River, Sixty Mile River, Klondike River, McQuesten River	Yukon River North, Yukon River South, McQuesten, Mayo River	Stewart River, Big Creek, Klondike River	*White River, Indian River, Sixty Mile River, Mayo River*
Minor (Automated Sampling at Mouth of Mainstem only)		Indian River, Sixty Mile River, Klondike River	Indian River, Sixty Mile River, McQuesten River	*Stewart River, Big Creek, Klondike River*
Non-mechanized (grab sampling at multiple, fixed sites, within the watershed)	Big Creek	Stewart River, White River, Big Creek, 40 Mile River, Big Salmon	Indian River, Sixty Mile River, Klondike River, McQuesten River, 40 Mile River, Yukon River North, Yukon River South, Mayo Rive	*Indian River, Sixty Mile River, Klondike River, McQuesten River, 40 Mile River, Yukon River North, Yukon River Stewart River South, Mayo River*

<u>Table 1:</u> This table outlines the yearly progression of the Water Quality Objectives sampling design. The watersheds denoted in *italics* are only shown to provide an example of how the sampling design will develop from year to year; the actual watersheds that will be sampled at that time have not yet been decided.

The monitoring program will concentrate on the main stem of each watershed. It may also cover the watercourse system of the watershed (i.e. a main river and all its tributaries, streams, creeks, drainage ditches, etc., as well as any lakes or ponds that discharge into the river or tributaries) if it is deemed to be necessary in order to monitor overall watershed health and aquatic habitat.

A description of the catchment area will include its size (in km^2), its geographical location and the identification of each water body in the watercourse system. Environmental conditions in the catchment area will be described as fully as possible, because these have an effect on water quality and it may be useful to refer to this material when data are being evaluated. The natural processes that affect water quality will also be described.

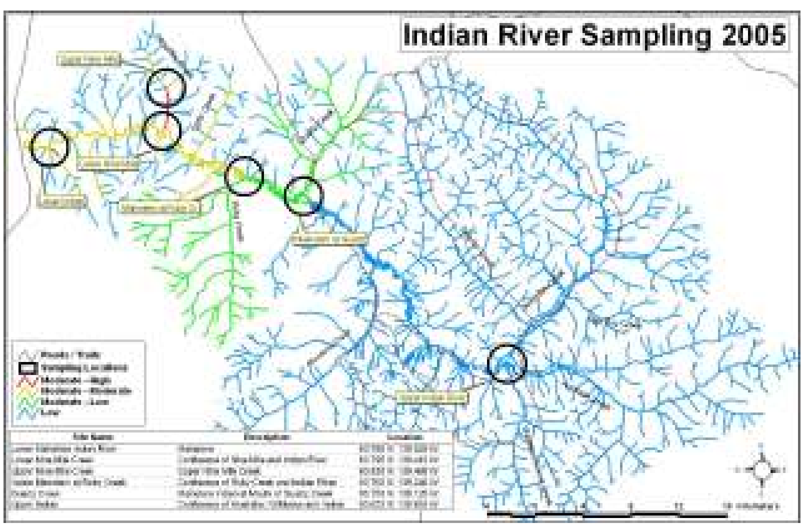
Reference will be made to these processes when the description of environmental conditions is prepared. In particular, stream bank composition, vegetation (both terrestrial and aquatic), land form, climate and mining activities in the catchment area will be reported. Mining activities will be described mainly in terms of claim location, water use, water use structures and land use. Rivers and streams will be described by their dimensions and their flows whenever possible.

Rainfall and ensuing run-off are of vital importance, especially when the program includes the monitoring of fluxes or suspended loads of eroded materials. For this reason, portable environmental monitoring stations will be deployed in conjunction with automated sampling equipment to monitor rainfall, air, water and ground temperature in each of the targeted watersheds. Some data interpretation techniques also require reliable hydrological information. If there is a gauging station operated by Water Survey of Canada or Environment Yukon near a sampling location, reliable data on river flow should be available. If not, estimates of flow will be based on data from the closest stream gauging station or by using portable flow gauging equipment to measure the flow at each sampling site. Maps and hydrographs for each watershed will be prepared from any available data and will be adjusted as new information is collected each year.

1.3.1 SPATIAL DISTRIBUTION OF SAMPLING

The selection of sampling sites takes into account such considerations as the habitat suitability classification, actual and potential water uses, actual and potential sources of sediment from natural sources and from human activities, sediment control operations (settling ponds), local geological conditions, and type(s) of water body.

The spatial distribution of water quality monitoring sites will be the same for both Category A and B watersheds. In each watershed, at least five different locations along the main stem of rivers will be selected as seasonal monitoring sites. One site will always be at the mouth of the main stem, and four or more of the sites will be situated along the main stem, downstream of habitat class change points (Figure 1) or at the confluence of major tributaries.



<u>Figure 1</u>: This figure illustrates the proposed spatial distribution of the Water Quality Objectives monitoring locations within a watershed. The river will be subdivided into reaches of varying habitat suitability (labelled here as Moderate-

High, Moderate-Moderate, Moderate-Low and Low). One sample site will be located at the mouth of the mainstem river, while four other sample sites will be located downstream of habitat sensitivity class change points. Additional sampling sites may be added to monitor areas of special interest, like the site shown here on upper Nine Mile.

In addition to the sites mentioned above, water quality samples will be taken at various locations within each watershed during the aquatic health monitoring program (see Aquatic Health Monitoring Protocol), and in association with the compliance monitoring activities of inspectors. The results from all these sampling programs will be considered together in the evaluation phase of the adaptive management process.

Sampling sites on rivers and streams will, as a general rule, be established at places where the water is sufficiently well-mixed for only a single sample to be required. The lateral and vertical mixing of wastewater effluent or a tributary stream with the main river can be rather slow, particularly if the flow in the river is laminar and the waters are at different temperatures. Complete mixing of tributary and main stream waters may not take place for a considerable distance downstream of the confluence. The zone of complete mixing may be estimated, but if there is any doubt the extent of mixing will be checked by measurements of temperature or some other characteristic variable like electro-conductivity, or by using other handheld instrumentation (i.e. the Partech Model 740 portable suspended solids meter) at several points across the width of the river. If there are rapids or waterfalls in the river, the mixing will be sped up and representative samples may be obtained downstream.

To verify there is complete mixing at a sampling site it will be necessary to take several samples at points across the width and depth of the stream or river and to have them analysed and the results compared. If the results do not vary significantly from one sample to another, a station can then be established at the location and single grab sampling can then commence. If the results are significantly different, it will be necessary to obtain a composite sample at the site by combining samples taken at several points in the cross-section of the stream. Generally, the more points that are sampled, the more representative the composite sample will be. Sampling at three to five points in a cross-section is usually sufficient (fewer points are needed for narrow and shallow streams).

1.3.2 TEMPORAL DISTRIBUTION OF SAMPLES

Most water quality sampling for the Water Quality Objectives monitoring program will begin in May and continue until the end of September. Inspectors will routinely sample at Water Quality Objectives monitoring points until the extreme end of the placer mining season (late October in some years).

1.3.2.1 OVERALL APPROACH TO INSPECTIONS

Yearly inspection plans are designed to prevent or reduce the risk of adverse environmental effects resulting from placer mining activities, and to ensure compliance with all relevant legislation, regulations, and the terms and conditions of permits and licenses. Inspectors will emphasize education and encouragement, and will promote operator-generated solutions to on-site challenges. Inspectors will be prepared to assist with recommendations, and will issue enforceable directions to perform remedial measures when necessary.

In all matters related to fish and fish habitat, inspectors will be guided by "The Protocol Concerning the Inspection and Monitoring of Yukon Placer Mining" between Energy, Mines and Resources and Fisheries and Oceans Canada. Water samples will be collected for the purpose of determining compliance with effluent discharge standards, and for the purpose of monitoring Water Quality Objectives (WQO).

1.3.2.2 WATER SAMPLING: COMPLIANCE

1. Samples will be collected for compliance purposes following procedures detailed in the Water Quality Monitoring Protocol.
2. Grab samples will be taken any time an operation discharges sediment-laden water into a watercourse and a Natural Resource Officer/Mining is on site.
3. In addition to effluent samples, samples will be taken upstream and downstream of any point of discharge and samples will be collected that are representative as 'background' or most upstream above all inputs from human activity inputs (e.g. mining).
4. All samples will be analyzed for settleable solids, total suspended solids, turbidity, conductivity, and pH.

1.3.2.3 WATER SAMPLING: WATER QUALITY OBJECTIVES

1. Samples will be collected for the purpose of monitoring WQO following procedures detailed in the Water Quality Monitoring Protocol.
2. Samples will be collected at locations within the watershed where there is a change in habitat sensitivity. These points will be established by the watershed modeling that has been prepared for the habitat management system.
3. The WQO sampling sites will be monitored with enough frequency to provide reliable data about the overall water quality in the stream and the watershed during periods of high and low flow.
4. The sampling will be comprehensive enough to provide representative information about water quality at each site. Additional information regarding channel morphology, flow and water temperature will be gathered whenever it is physically possible.
5. All samples will be analyzed for settleable solids, total suspended solids, turbidity, conductivity, and pH.

1.3.2.4 FLOW MEASUREMENTS

Flow measurements of effluent discharge streams and receiving waters will be taken whenever practicable by inspectors, in order to provide data related to overall sediment loading in a watershed.

1.3.3 SAMPLING FREQUENCY

Sampling frequency at stations where water quality varies considerably should be higher than at stations where quality remains relatively constant.

The time interval between sampling events depends on the water body and its specific characteristics. An interval of one month between the collection of individual samples at a station is generally acceptable for characterizing water quality over a long time period (e.g. over a year in a river), whereas for control purposes weekly sampling may be necessary. If significant differences are suspected or detected, samples may have to be collected daily or on a continuous basis. In extreme cases, time- integrated, composite samples may have to be made up by mixing equal portions of samples taken at regular intervals over a 24-hour period.

Individual samples taken at a given station will be obtained at approximately the same time of day if possible, because water quality often varies over the course of the day. However, if detection of daily quality variations or of the peak concentration of a contaminant in an effluent is of interest, sampling at regular intervals (e.g. every two or three hours throughout the day) will be necessary. Exceptional conditions of stream flow are frequently of interest because it is at maximum and minimum flow rates that extreme values of water quality are reached. For example, when flowing at its peak rate, a river usually carries its greatest load of suspended material, while sediment will be the least diluted when a river is at minimum flow. For this reason, flow measurements will accompany every water sample collected, when safe stream measuring conditions exist.

The fundamental difference between the sampling programs conducted on Major versus Minor watersheds is the intensity by which they are sampled. At each of the five sites along the mainstem of a Minor watershed (see figure 1), sampling will occur at a minimum of four times per year (capturing 2 high and 2 low flow events). All sampling conducted within Minor watersheds will be grab samples collected by hand, with the exception of samples collected at the mouth of the main stem that will be collected by automated sampling equipment as these sites are generally less frequently accessible.

In contrast, sampling within Major watersheds will be both automated (ISCO samplers) and collected by field personnel. Due to differences in the timing of the high and low flow events for each of the Major watersheds, water sampling activity will be conducted throughout the season in order to collect data during both events.

1.3.4 DATA COLLECTION

Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic, since these affect the quantity and the quality of water available. Their influence is generally greatest when available water quantities are low and maximum use must be made of the limited resource. Although the natural ecosystem is in harmony with natural water quality, significant changes to water quality from human activity may be disruptive to the ecosystem.

The results of analyses performed on a single water sample are only valid for the particular location and time at which that sample was taken. One purpose of a monitoring program, therefore, is to gather sufficient data (by means of regular or intensive sampling and analysis) to assess spatial and/or temporal variations in water quality.

For each site where personnel collect the water samples, field measurements of pH, conductivity, temperature (see appendix A) and stream flow (see Appendix B) will be conducted. During installation and upon each field visit to empty the automated samplers, personnel will also conduct pH, conductivity, temperature and stream flow measurements. Automated weather stations capable of collecting rainfall; air, soil and water temperature will be strategically located within each watershed. Laboratory analyzes of each water sample will include, total suspended solids (TSS), settleable solids and turbidity.

1.4 DATA ANALYSIS

The data analysis component of the Water Quality Objective monitoring protocol addresses the two key questions listed in section 1.2. The first step of the assessment process is to determine whether or not the Water Quality Objectives are being achieved (key question 1). The Water Quality Objectives (above background levels), categorized by habitat sensitivity, will be defined in watershed authorizations.

The next step in the assessment process is to establish whether or not an exceedence of the Water Quality Objectives is due to placer mining activity (key question 2). Additional information will be required to determine if the exceedence is caused by placer mining or natural processes, including:

- Inspection reports on the effluent compliance on upstream placer mines;
- Information on other potential anthropogenic (industrial activities) or natural (landslides) sources of sediment; and
- Local climatic and flow data in efforts to understand the seasonal and inter-annual variations in sediment loading.

1.4.2 ANALYTICAL METHODS

All laboratory analysis and water sample collection will adhere strictly to the methodology described in *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association, American Water Works Association, and the Water Pollution, Control Federation, 1992).

1.4.3 QUALITY ASSURANCE / QUALITY CONTROL

It is very important to include a field quality assurance/quality control component in a sampling program. It must be well defined and supported by accepted standardized practices. Quality assurance (QA) in the field usually refers to a broad plan for maintaining quality in all phases of a program, including how the samples are to be collected, documented and handled. Possible sources of error and of variation should be listed, as well as quality control (QC) checks for each.

QC checks can include *field replicates, laboratory blanks, travel blanks* and *travel spiked blanks*. Procedures for collecting these samples are described in **Appendix A**. Each individual season's sampling program plan will state the number and type of field QA/QC checks to be included in the study. The way to document the results of these QC checks will also be stated.

Field QC procedures are not always performed at the same site. The number of QC locations will provide a general overview from all sections of the watershed being sampled. The total number of QC sites should be no less than 10 percent of the total number of sampling locations. This is a minimum number of QC samples needed to provide meaningful sample results. Up to as many as 30 percent is acceptable, especially at the beginning of a project.

Field QC plans should also list all field observations that are to be made at the time of sampling. These include meteorological conditions and exceptional circumstances, such as debris in a river. Field observations can be important in the interpretation of sample results.

Similar QC samples are also used in the laboratory, as well as the field. Laboratory QA/QC procedures are more elaborate and may use many spiked samples or standards.

Many water quality personnel believe that the collection of two samples from a location is enough for checking the quality of the sampling. This approach presents a problem if the two samples show considerable difference when the laboratory results come back. There is then no way of deciding which sample is right and which is wrong, unless one is so severely contaminated that it is clearly not valid. The collection of three or four samples gives a better indication of how much variation can be expected for a given aspect of water quality. More samples also help indicate how much can be attributed to sampling, handling, storage and analyses. It is also better for any statistical analysis to have more samples.

Please refer to the following document for information regarding field sampling methodology and Quality Assurance / Quality Control procedures:

***BRITISH COLUMBIA FIELD SAMPLING MANUAL: For Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples* (2003 Edition)**

Prepared and published by:

Water, Air and Climate Change Branch, Ministry of Water, Land and Air Protection, Province of British Columbia, January 2003

Revisions to a program's design may be necessary at any time. From the beginning to the end, it is necessary to examine the various parts of the program to make sure the objectives are being met. It is often necessary to adapt to changing conditions, whether they are environmental, related to a new development, to financial considerations or result from changes in the program's objectives. Recognising when and how to make changes is an important part of a program's success.

APPENDIX A

DETAILED SAMPLING METHODS

Sampling is a vital part of studies of natural water composition and is perhaps the major source of error in the whole process of obtaining water quality information. This fact is not well enough recognized, and some emphasis on it seems desirable. In any type of study in which only small samples of the whole substance under consideration may be examined, there is inherent uncertainty because of possible sampling error. The extent to which a small sample may be considered reliably representative of a large volume of material depends on several factors. These include, first, the homogeneity of the material being sampled and, second, the number of samples, the manner of collection, and the size of the individual samples. The sampling of a completely homogeneous body is a simple matter, and the sample may be very small.

Because most material is not homogeneous, obtaining truly representative samples depends to a great degree on the sampling technique. A sample integrated by taking small portions of the material at systematically distributed points over the whole body represents the material better than a sample collected from a single point. The more portions taken, the more nearly the sample represents the whole. The sample error which would reach zero when the size of the sample becomes equal to the original volume of material being sampled, but for obvious reasons this method of decreasing sampling error has practical limits.

To determine adequately the instantaneous composition of a flowing stream, the sample, or sets of samples taken simultaneously, must be representative of the entire flow at the sampling point at that instant. Furthermore, the sampling process must be repeated if the results of analysis are to be extrapolated in time, and the sampling interval chosen must represent adequately any changes that might occur. Changes occurring along the length of the stream can be evaluated by adding more sampling points.

The homogeneity of a stream at a cross section is determined by such physical factors as proximity of inflows and turbulence in the channel. Locally, poor lateral or vertical mixing can be observed in most stream systems. Immediately below the confluence of a stream and a tributary there may be a distinct physical separation between the water of the tributary and that of the main stream, and, particularly in large rivers, this separation may persist for many kilometres downstream. The effect is more pronounced if the water of the tributary differs markedly from the water of the main stream in concentration of dissolve or suspended solids or in temperature.

These effects may be of special interest in some studies, but if the average composition of the whole flow of a stream or its changes in composition over a period of time are the factors of principal significance, sampling locations where mixing is incomplete should be avoided.

A composite sample that will represent accurately the water in a vertical cross section of a stream can be obtained by combining appropriate volumes of sample taken at a series of points along the cross section. At each point, samples should be obtained at enough different depths to compensate for vertical homogeneity. Obviously, it is physically impossible to obtain all these samples at one instant. The water in the stream is in motion at different rates in different parts of the cross section, and this further complicates the problem.

Sampling Techniques

There are three commonly used sampling techniques for the collection of stream and river water samples: *Grab, Composite, and Continuous*

A ***grab*** sample is collected at a point in time and space. If you open a tap and fill a sample bottle from it you have collected a grab sample of the tap water, at that moment in time. This is the simplest method of sampling and serves many purposes such as the analysis for bacteria and certain unstable substances like dissolved oxygen and radioactive nuclides. The disadvantage of this method is that, if an event happens before or after the grab sample has been taken, it may go unnoticed and your sample will be of no value.

When fluctuations occur in the system, such as a tailing or effluent outfall, ***composite*** (or pool) sampling is more appropriate. A composite sample is made up of several grab samples, taken at regular intervals of time and space. Consider a tailing line outfall. If every hour on the hour, you collect equal portions of the discharge and pool them into one container, you have collected a composite sample of the tailings effluent over a time element.

When dealing with the three-dimensional space element, there are two ways of collecting a composite sample. Imagine yourself in a boat at a stationary point on a stream. If you collect equal portions of water at various depths, and pool them into one container for analysis, you have collected a composite sample of the water column at that point on the stream. If, however, you are in a boat moving along the stream and every so often collect equal portions of water at the surface of the stream and pool them into one container for analysis, you have collected a composite sample of the surface water of the stream.

A composite sample is a mean sample. It evens out fluctuations in a system. It gives an overview and is a good method to sample a fluctuating or inhomogeneous system like tailing pond discharge. A limitation of this method is that it does not identify the magnitude and duration of a fluctuation.

In some industrial operations, like mining, effluents come as slugs and the composition of the waste effluent changes continuously throughout the day. ***Continuous*** sampling is used to identify this kind of fluctuation. It is almost invariably done by attaching an automatic sampling device, like an ISCO sampler or floating monitoring device, to the discharge outlet.

CHOICE OF SAMPLING TECHNIQUE

The method of sampling chosen, whether grab, composite, or continuous depends on one or more of the following factors: the objectives; fluctuations in the system; type of water to be sampled (i.e. lake, stream or a discharge pipe); nature and stability of the parameter to be analysed; the wording of licences or authorization that is being enforced.

For example, all water licences granted under the former *Northern Inland Waters Act*, specified grab sampling for tailing effluent. It is important to remember that the method of sampling is site specific and depends on the parameter to be analysed. However, some general observations can be made:

- For lakes and streams, grab samples may be collected. Composite samples may be used to get an overview;
- For effluents, best results are obtained by collecting continuous samples. Composite samples are the next best but if you have no other choice collect grab samples; and,
- Samples that are collected for the determination of suspended and settleable solids should be made up from pooled water samples collected at fixed site locations but at various depths.

SAMPLING OF STREAM WATER

Stream and river sampling can be accomplished using a variety of methods. Three cases will be considered:

1) sampling a stream from a bridge or overpass;
2) sampling a stream shallow enough to wade in; and,
3) sampling from a stream bank.

(1) When sampling from a bridge, the following steps should be observed:

- choose a sampling point midway across the stream;
- determine the approximate depth of the stream by lowering the grab sampler to the bottom of the stream;
- retrieve it and wait a few minutes, until all the stirred sediments have been carried away;
- using a swinging motion upstream and parallel to the flow, lower the sampler into the stream;
- retrieve it when it reaches a point perpendicular below you;
- rinse and discard the wash water;
- repeat this procedure until the bottle is filled; and
- transfer the contents into your sample bottle.

Note that an integrated sample can be collected by lowering the sampler to various depths in the stream. A good rule is to sample at 60% of the total depth, 40% of the total depth and, at the water surface.

(2) When sampling a shallow stream, the following steps should be observed:

- Choose a place where the water is flowing freely and is clear of floating debris. Attach safety line if conditions have any significant risk.
- Obtain labeled bottles and wade into the middle of the stream, downstream from the point at which you will collect the samples, then wade upstream to the sample site (this ensures that you will not disturb sediments upstream of the sample point. Wait until all the sediments stirred have been carried away.
- Stand perpendicular to the flow and face upstream.remove the cap of the sample bottle and hold it aside without touching the inner surface. If rinsing is required for the type of bottle, fill and rinse three times[3].
- With your other hand, grasp the bottle well below the neck. Plunge it beneath the surface in front of you with the opening facing directly down, then immediately orient the bottle into the current. Avoid collecting surface scum and film. Point the mouth towards the current and allow it to fill.
- Once the bottle is full, remove it from the water by forcing it forward (into the current) and upwards.
- Replace the cap immediately.

Never sample the edge of the stream from the bank as it usually contains a large portion of stagnant water and always sample upstream and if possible up wind of your position in the water.

Whenever practical, samples should be collected at mid-point rather than near shore. Samples collected from mid-point reduce the possibilities of contamination or alteration (i.e. shores effects, back eddies, seepage from near shore soils). Samples should not be taken in back-eddies or brackish waters. The most important issue to consider when deciding where the sample should be collected from is **SAFETY**.

If the flow is sufficiently slow that you can wade into the stream without risk, then the sample can be collected at a depth that does not pose a threat.

□ Note: If sample bottles have not been pre-cleaned by the laboratory, then they must be rinsed 3 times with either de-ionized water or sample water. The exception to this is when a sample is to be analyzed for suspended sediments, for contaminants likely associated with the suspended solids, or for oil and grease. In these cases, the bottles should not be rinsed with sample water as suspended particles or grease-like materials are retained on the interior surface of each bottle with each rinsing. For specialized analyses (trace metal, organics) and pre-cleaned bottles, containers should not be rinsed. Rinsing is not a recommended practice. Use of pre-cleaned bottles is recommended, where practical. Where bottles are rinsed, the rinsate should be discarded.

(3) When conditions dictate that the sample is taken from the stream bank, the following steps should be observed;

- secure yourself to a solid object on shore (with a safety harness and line if necessary); remove the lid from the sample bottle and place it into a clean zip lock bag;
- secure the sample bottle to a pole grab sampler;
- reach out as far as possible with the pole sampler and plunge the bottle under the water and immediately orient it into the current;
- when the bottle is full pull it up through the water while forcing it into the current; and,
- immediately recap the bottle

TOTAL SETTLEABLE SOLIDS DETERMINATION

In order to determine total settleable solids in an aqueous solution, a well-mixed sample is placed in a special settling device called an Imhoff cone, and allowed to settle under quiescent conditions for some specified time. The standard method calls for a settling period of one hour and a cone having a volume of one liter. It is necessary to gently rotate the cone, or stir the contents **slowly**, after a period of 45 minutes to prevent the deposition of matter on the inside surface of the cone. At the end of the prescribed settling period, the volume of the settled material is read from a scale etched on the outside of the cone.

Total settleable solids concentrations are usually reported in terms of ml/L. Do not estimate any floating material. The lowest measurable level on the Imhoff cone is 0.1 ml/l. Any settleable material below the 0.1 ml/l mark should be recorded as *trace* or <0.1 ml/l.

SAMPLE HANDLING

Deteriorated samples negate all the efforts and cost expended in obtaining good samples. In general, the shorter the time that elapses between the collection of a sample and its analysis, the more reliable will be the analytical results. For certain constituents and physical values, immediate analysis in the field is required in order to obtain reliable results because the composition of the sample almost certainly will change before it arrives at the laboratory.

Determination of temperature, pH, settleable solids and specific conductance should be made in the field.

Samples must be transferred to sample bottles immediately after collection if they are collected in the container of a pole sampler. If analysis of settleable solids concentration is to be carried out in the field, it should be started as soon as possible.

Sampling staff must have a field notebook in which all details of relevance are recorded at the time. The field book should be hard-bound and not loose-leaf. Full books must not be discarded but stored for future reference because they represent data in original form and are sometimes invaluable for reference purposes.

Details recorded should include: those details noted on the sample bottle, what samples were collected, what measurements were made, how they were made, and the results obtained.

All supporting information (any unusual local features at the site and time of sampling) should also be noted. If there has been any variation from the agreed sampling station, this should be noted, with reasons. Any need for a permanent change in sampling station should be brought to the attention of the program coordinator.

If a standard field record layout is used in place of a plain notebook, adequate space should be available for comments and observations. To facilitate field work, the layout and content of the pages should reflect the sequence in which the various procedures will be carried out.

Each sample bottle must be provided with an identification label on which the following information is legibly and indelibly written:

- Name of the study / Reason for sampling
- Sample station identification and/or number.
- GPS Location of the sampling site
- Date and time of sampling.
- Name of the individual who collected the sample.

Sample bottles should be placed in a cooler for transport to the laboratory and will protect samples from sunlight, prevent the breakage of sample bottles, and should allow temperatures of < 20 °C to be attained and maintained during transport.

Samples that are to be used for the determination of suspended solids must not be frozen in as much as it is not always possible to reconstitute the original sample exactly as it was before freezing. Freezing can also affect the particle size of some solid constituents in a solution, thus distorting any analysis.

SAMPLE PRESERVATION METHODS FOR SPECIFIC PARAMETERS IN WATER QUALITY SAMPLES

Parameter	**Preservation**	**Maximum holding period**
Acidity-alkalinity	cool to 4°C	24 hours
pH holding	None available	Should be determined on site
Solids	cool to 4°C	7 days
Specific conductance	cool to 4°C	7 days
Turbidity	None available	7 days
Clarity/ colour	cool to 4°C	7 days

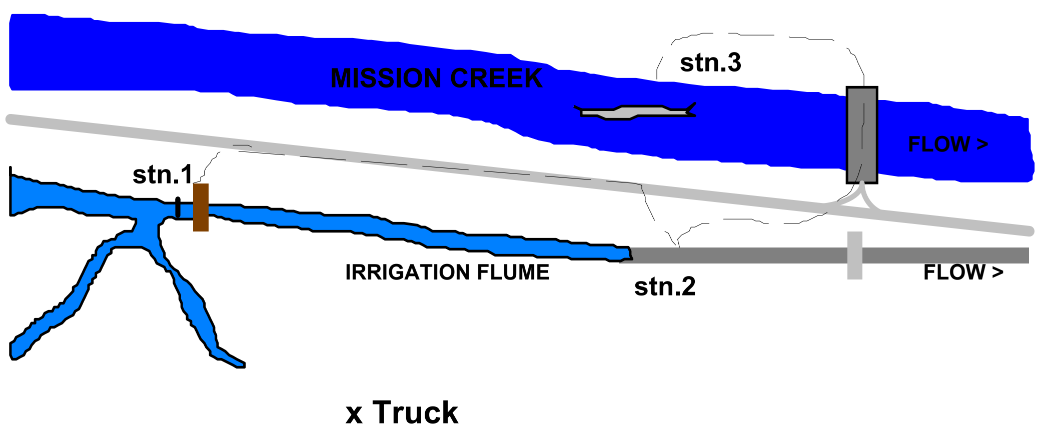
For additional information on field sampling and sampling techniques, refer to:
The Inspectors Field sampling Manual, 2nd edition, Environment Canada ISBN 0-662-38953-0

APPENDIX B

FLOW MEASUREMENTS

The flow of a stream or river can be determined using a variety of methods. Three different examples of flow measurement are provided in this appendix as a reference. Of the three described methods, the third using a digital water velocity meter is the most practical and accurate method available to us. The other two methods are less practical in application as we don't have many channels that are flumed or have weirs in the Yukon.

SITE PLAN AND STATION LOCATIONS



Three different flow-measuring stations are located along the creek:

Station 1 is the first of two stations involving weirs. Station 1 is located at a wooden footbridge, which crosses an irrigation flume, approximately 150m [E] of the truck. The weir consists of a 2" x 4" board placed across the irrigation flume, theoretically obstructing the flow of water, causing it to rise in the channel until it is high enough to spill over the weir.

Station 2 is the second of the two stations involving a weir. Station 2 is located approximately 350m down stream from Station 1 along the same irrigation flume. This weir consists of a "V" notch channel approximately 500m in length. The entire flow of the irrigation flume goes through this channel. (Station 2 can be reached via a cat track that is located south of the flume, and runs [E-W] parallel with Mission Creek.)

Station 3 is located on Mission Creek proper, approximately 60m upstream from the railroad flat car bridge that spans the creek. Station 3 is on the south side of Mission Creek and required descending the rocky bank in order to reach the waters edge.

Method 1 & 2, FLOW MEASUREMENTS USING WEIRS

Method 1 Station 1: Wooden Weir Across A Stream

A weir is usually constructed in a slow moving section of a waterway and consists of a sharp ledge over which the entire flow must pass.

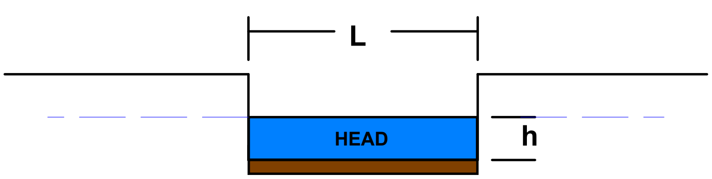
The discharge can be measured by knowing the length of the weir passage way (L) and the depth of flow, or "head", over the weir (h).

Several conditions must be met for this calculation to be accurate:

All the flow must pass over the weir.
The approach velocity to the weir must be less than 0.15m/s.
The water falling over the weir must fall unimpeded into a pool below.

Station 1 - Data:

WOODEN 2X4 WEIR



L = 1.77m

h_{LHS} = 3.7cm = 0.037m
h_{RHS} =5.3cm = 0.053m

Station 1 - Analysis:

$Q = 1.69\ h^{1.47}\ L^{1.02}$

$= 1.69\ \left(\frac{0.037m + 0.053m}{2}\right)^{1.47} (1.77m)^{1.02}$

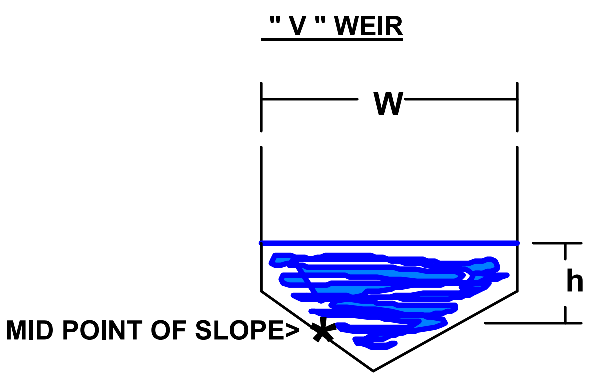
$Q = 0.032m^3/s$

Method 2 Station 2: Flow Measurement Using A V Notch Weir

A much less accurate method of estimating the flow in a small even flowing flume or creek is based on the surface speed of a channel. In this case the surface speed of water passing through a "V" notch weir is determined by floating an object, a small stick, leaf or orange (yes I do mean the fruit), down the weir and timing the run over a 10m distance. The surface speed is adjusted to account for the fact that the average speed will be about 60% of the calculated value.

The cross sectional area of the channel (or weir) must also be determined. The width and depth of water in the "V" shaped weir must be measured with a tape and the cross sectional area calculated from these measurements.

Station 2 - Data:



(w) WIDTH = 1.44 m
(h) HEIGHT = 0.145 m

Floating Object distance = 10 meters
time = 20 seconds

Station 2 - Analysis:

Cross Section $A = W h$
$= (1.44m) (0.145m)$

A = 0.21m²

$$A = 0.21 m^2$$

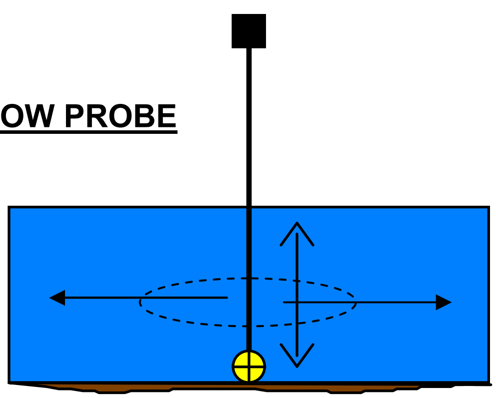
$V = \frac{d}{t}$ $\quad V = \frac{10.0m}{20.0s}$ $\quad V = 0.50m/s$ $\quad$ **60%V = 0.30m/s**

$Q = VA$ $\quad Q = (0.30m/s) (0.21m^2)$ $\quad$ **$Q = 0.063\ m^3/s$**

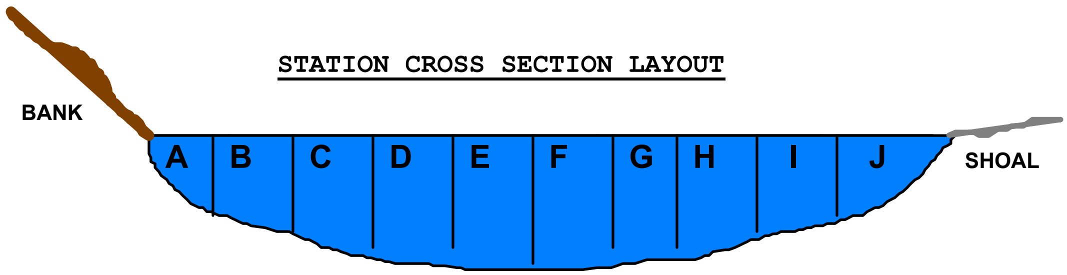
Method 3 Station 3: Flow Measurement Using A Digital Water Velocity Meter

The use of an electronic instrument in order to measure flow is similar to the surface speed method but has improved accuracy. This is due to the fact that the velocity of the stream is measured through the entire water column rather than just at the surface. The stream width is measured and then divided into equal width segments (W) or stations for measuring. In this method the flow of the entire stream is determined then the flow calculated at each of the stations is added together. The velocity measurement (V) determined by the instrument is the average of **V** through the water column calculated by the flow meters on board computer. This measurement is obtained by repeatedly raising, lowering and sweeping the head of the instrument up and down, side to side in the water column, for at least one minute, allowing the on board computer to make multiple velocity measurements and compile an average. The instrument displays this calculated average when the head is raised above the water surface and the propeller in the head stops turning. In order to complete the flow calculation an average depth (D) of the water in each station must be measured, usually at the center of each station, and the depth recorded.

GLOBAL FLOW PROBE



Station 3 – Stream cross-sectional diagram:



Station 3 - Recorded Data:

STATION	WIDTH (m)	AVERAGE DEPTH (m)	AVERAGE V (m/s)
A	1.0	0.20	5.5m/s
B	1.0	0.20	4.9m/s
C	1.0	0.20	6.1m/s
D	1.0	0.24	6.1m/s
E	1.0	0.20	4.9m/s
F	1.0	0.22	6.7m/s
G	1.0	0.25	7.3m/s
H	1.0	0.30	8.2m/s
I	1.0	0.40	6.7m/s
J	1.0	0.33	6.7m/s

Station 3 - Analysis:

Station Discharge (Q_S) = ($V^{m/s}$) (W^{m}) (D^{m})

Where **V = Average Velocity**

W = Width of station

D = Average depth of station

STATION	A	B	C	D	E	F	G	H	I	J
Q m^3/s	**1.10**	**0.98**	**1.22**	**1.46**	**0.98**	**1.47**	**1.83**	**2.46**	**2.68**	**2.21**

Total Discharge (Q_T) = discharge station A+B+C+D+E+F+G+H+I+J

= 16.38 m^3/s