



Guidebook of Mitigation Measures for Placer Mining in the Yukon

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1.0 PURPOSE AND SCOPE

In April 2005 the Yukon Placer Implementation Steering Committee and the Yukon Placer Working Committee made up of Fisheries and Oceans Canada (DFO), the Yukon government, the Council of Yukon First Nations (CYFN), and the Klondike Placer Miners' Association (KPMA) jointly released the *Integrated Regulatory Regime for Yukon Placer Mining: Final Report to the Minister of Fisheries and Oceans*. To find out more about the fish habitat management system described in the report contact the Yukon Placer Secretariat.

This document is a comprehensive reference Guidebook of mitigation measures for placer mining in the Yukon (steps taken to avoid or lessen the impact of a given activity on the environment). The placer mining activities that may result in negative effects to the environment before mitigation is applied fall into three main categories: site preparation, production, and closure. In many cases all three phases may be taking place at the same time.

The Fish Habitat Management System for Yukon Placer Mining is based in part on the risk management approach; that is to say, adopting measures to eliminate or reduce the potentially negative effects of placer mining. To help put this in perspective, a Pathway of Effects was developed which maps out all of the possible negative environmental effects on the land and the water in all three phases of placer mining. The Pathways of Effects are well defined for each of the development and operational components of placer mining. Potential effects that can be mitigated are then related to standard mitigation and established practices or Best Management Practises (BMPs).

Placer mining activities that can not be entirely avoided or eliminated by employing mitigation measures fall into four categories: construction of diversion channels, in-stream works, water acquisition (water use), and sediment discharges. These activities have been evaluated under DFO's Risk Management Framework, which considers the potential risk posed by the mining activity and the sensitivity of the fish habitat where the activity will occur.

This Guidebook is meant to supply practical mitigation measures that may be applied to all of the potential pathways of effects covering each of the four categories of mining activity that have the greatest potential for disruption.

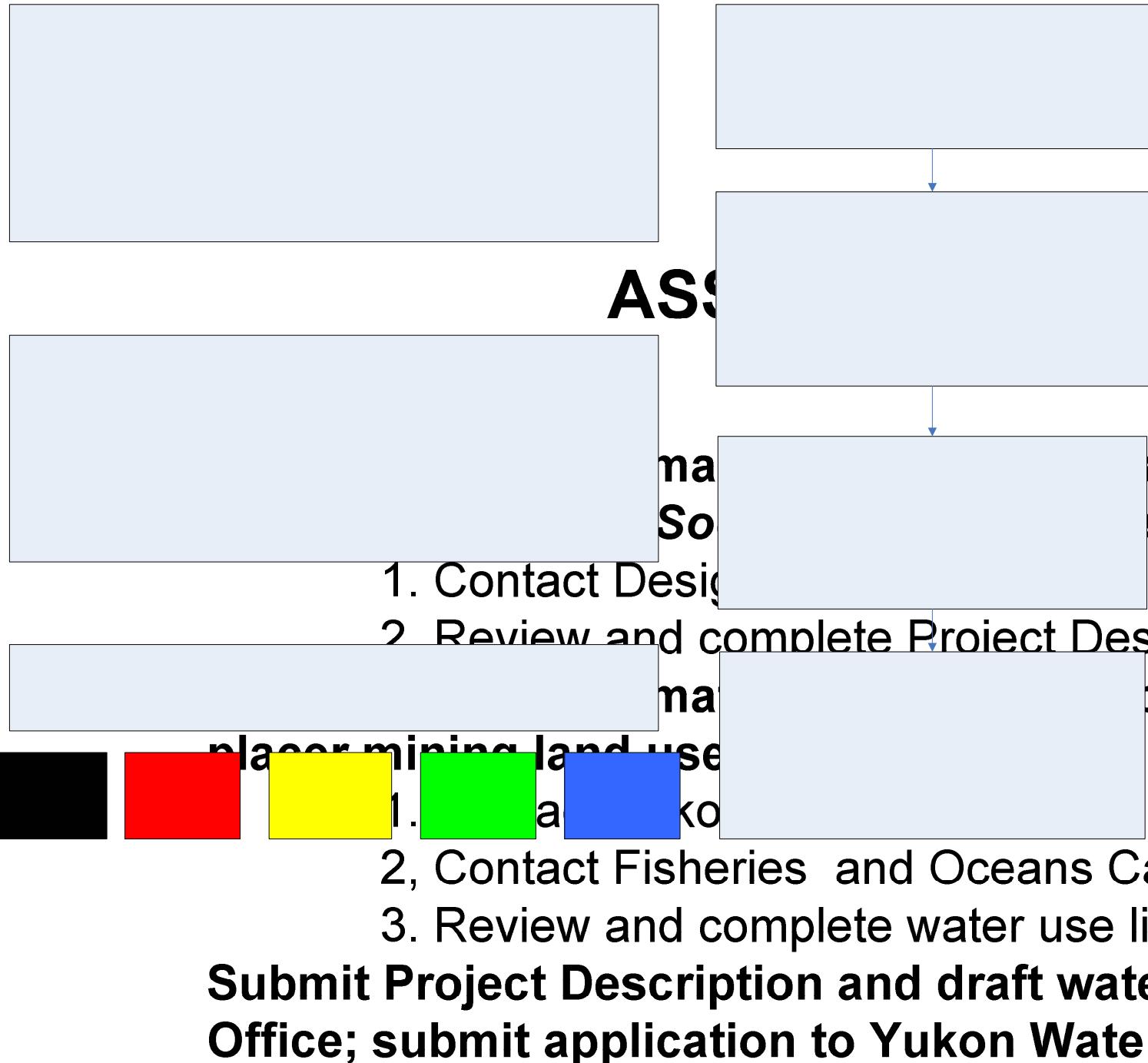
This Guidebook will be useful to those who are evaluating or designing placer mining projects, and to individual placer miners. The companion document *Fish Habitat Design, Operation and Reclamation Workbook and Worksheets for Placer Mining in the Yukon Territory* (the "Workbook") has been prepared to guide proponents and reviewers in the steps taken to prepare an application for review by the Yukon Environmental and Socio-economic Assessment Board (YESAB) and the Yukon Water Board (YWB). The Workbook was prepared by DFO to ensure compliance with the *Authorization for Works or Undertakings Affecting Fish Habitat for Specified Streams in the Yukon Territory* (Federal Fisheries Act) developed for watersheds in the Yukon. Those readers who wish to learn more about the scientific and technical background can refer to the technical reports, papers, and web site information cited in the References section of this Guidebook.

This Guidebook is organized into seven chapters:

1. Purpose and Scope – A brief overview.
2. Development of a Fish Habitat Compensation Plan - In this section, information is presented to enable the completion of the fish habitat design, operation and reclamation requirements for each habitat suitability type. By referring to the Workbook and following the steps outlined under each suitability type, the Guidebook can then be referenced to help with specific design methods. The compensation plan will provide productive fish habitat in situations where existing fish habitat has been or will be lost.
3. Legislation – synopsis of the main laws and policies governing placer mining and the Fish Habitat Management System for Yukon Placer Mining.
4. Introduction to Placer Mining Methods and Primary Issues – Runoff, Erosion and Sediment Control, effect of Permafrost on Placer mining and a discussion of mining and restoration techniques in the three main types of valleys.
5. Mitigation Measures
 - Mitigation measures for Site Preparation – techniques and best practises in preparing an extension to an existing mine or preparing to mine undisturbed ground. These include methods for controlling non-point source sediment, design of diversion channels and best practises for use of equipment around streams.
 - Mitigation Measures for the Production Phase – techniques and best practises for settling facilities, in stream works.
 - Mitigation Measures for the Closure Phase – techniques and best practises for restoration of parts or all of placer mines or areas that should be stabilized and brought back to biological productivity as soon as possible after mining including restoration of fish habitat features in constructed stream channels.
6. References
7. Definitions

The companion Workbook and Worksheets contain examples to help with site specific designs of ponds, channels and reclamation. The Workbook and Guidebook are intended to follow a linear sequence of planning, construction, operation and reclamation of all elements of a placer mine that have effects on the environment. All of the information required for the environmental screening and regulatory processes may be complied by using this Guidebook in combination with the Workbook and Worksheets. The Worksheets may be used for submissions to the Yukon Environmental and Socio-economic Assessment Board (YESAB), the Yukon Water Board, or to DFO.

This Guidebook is organized following the normal stages for a placer mining project, from the feasibility stage through to information gathering, design of the project, operations and reclamation. The emphasis is on “how to” as opposed to “why”. Detailed rationale and explanations of the evolution of environmental regulation of placer mining and the current habitat management system are available from many sources; primarily the Yukon Placer Secretariat. The reader should not look to this Guidebook for details of the Fish Habitat Management System for Yukon Placer Mining. The following Figure, repeated in Chapter 3, shows the process of developing a placer mining project from planning through permitting and reclamation.



Information Retrieval Placer Mining

2.0 DEVELOPMENT OF A FISH HABITAT COMPENSATION/RESTORATION PLAN

Prior to the initiation of a placer mining project, the miner must make an application to the Yukon Water Board (YWB) for a water use licence and mining land use approval. One of the requirements of the licensing process is the development of a Fish Habitat Compensation/Restoration Plan for all affected water bodies at the placer mining site. The guidelines contained in this Guidebook were developed to aid the miner in fulfilling this portion of the requirements of the water use licence application. The wording of the Guidelines has been developed to allow the miner flexibility in developing the plan, however once Fisheries and Oceans (DFO) has approved the miner's plan, and the plan has been submitted to the YWB for incorporation into the water use licence, the miner should be aware that the details of the approved plan will become enforceable terms and conditions of the water use licence.

The completed water use licence application is submitted by the miner to the YWB. The application is then made available for public review, including DFO and Environment Canada. These agencies review the mining plan and may submit formal interventions to the YWB. The Board may schedule a public hearing if requested by the applicant or an intervening party, but this is uncommon for placer mining project proposals.

All persons who are intending to mine must review the companion Workbook and fill out the Worksheets. The worksheets and the required supporting documentation constitute the miner's **Fish Habitat Compensation/Restoration Plan**.

2.1 *Step 1: Determine Watershed and Stream Classifications*

2.1.1 Classification Process

The first step is to identify the location of the proposed placer mine site and determine the Watershed Sensitivity Classification and the Fish Habitat Suitability Classification. This is done by using the color coded Fish Habitat Suitability Classification maps. Once this information is obtained, the engineering standard and level of effort can be determined for design purposes by referring to the applicable section of the Workbook. Information about the location and classification of the proposed placer project are then entered on Appendix A of the Workbook.

2.1.2 Watershed Sensitivity Classification

By using the colour coded Fish Habitat Suitability Classification maps, determine the classification (either Category A or B) of the watershed that the proposed placer mine is located within. Category "A" watersheds are defined as watersheds that contain aquatic ecosystems that are more susceptible to the effects of placer mining activities, and Category "B" watersheds are defined as watersheds that contain aquatic ecosystems that are less susceptible to the effects of placer mining activities (based on a cumulative ranking of selected biological and physical indicators). Depending on the watershed sensitivity classification, different Water Quality Objectives and sediment discharge standards will apply in the respective habitat suitability classes.

2.1.3 Fish Habitat Suitability Classification

The suitability of a watercourse as fish habitat for is required information and can be obtained by using the color coded Fish Habitat Suitability Classification maps. Activities deemed to pose a high risk to fish and fish habitat or those not identified within a watershed-based Authorization will require a site specific review, and a site-specific section 35(2) Fisheries Act Authorization may be issued. The stream classification system for Yukon placer mining streams is as follows:

Water Quality Zones - Those areas within watercourses that are inaccessible to fish but provide water flow and contribute nutrients to downstream habitats. The Water Quality zones will be identified on an individual basis based on confirmed permanent barriers to fish passage. Permanent barriers include creeks that flow underground, waterfalls, and significant velocity barriers, but do not include temporary structures such as beaver dams and log jams.

Tributaries to Lakes Supporting Lake Trout Populations – These are streams flowing into lakes that are likely to contain lake trout.

Low (formally Fresh Water Fisheries Production Zones) – Those areas within watercourses that are typically the most abundant within the watershed. As a function of gradient and distance from Chinook salmon production areas these streams are likely unsuitable for rearing juvenile Chinook salmon, but may be highly suitable for and used by non-anadromous resident fish species, including northern pike and longnose sucker.

Moderate–Low Suitability– Includes habitats that are suitable for rearing juvenile Chinook salmon but are unlikely to support large numbers due to limiting environmental factors. These areas may also be highly suitable for non-anadromous resident fish species such as Arctic grayling.

Moderate–Moderate Suitability - Includes moderately suitable habitats for rearing juvenile Chinook salmon. These areas may also be highly suitable for non-anadromous resident fish species such as whitefish sp. and Arctic grayling.

Moderate–High Suitability – Streams with highly suitable habitats for rearing juvenile Chinook salmon. These areas are also suitable for, and used by non-anadromous resident fish species, such as whitefish sp., Arctic grayling, and burbot.

High Suitability – Stream used by Chinook salmon for spawning and/or migration.

Areas of Special Consideration – Streams that contain ecologically or culturally important fisheries or aquatic resources.

2.1.4 Step 1.1: Guidelines Specific to Habitat Suitability Types

The Workbook outlines the technical information that will be required to guide the construction of stream diversions, as well as the requirements related to water acquisition, instream works and sediment discharges. Depending on the habitat suitability type the proposed placer mine is located within, different information requirements and guidelines will apply. This Guidebook contains the necessary background information and Best Management Practises (BMPs) for all habitat suitability types.

Generally, the information will be gathered in support of a Type B Water Use Licence application and Placer Mining Land Use Operating Plan; a Yukon Environmental and Socio-economic Assessment Board (YESAB) submission, and potentially an application for a Site Specific Authorization from DFO.

2.2 Step 2: Determine Original Channel and Site Parameters

2.2.1 Step 2: Original Channel and Site Parameters

At this point the collection of site specific information is required to proceed. Site characteristics should be based on a site reconnaissance by the proponent or their representatives. Stream channel and valley measurements are needed to design diversion channels.

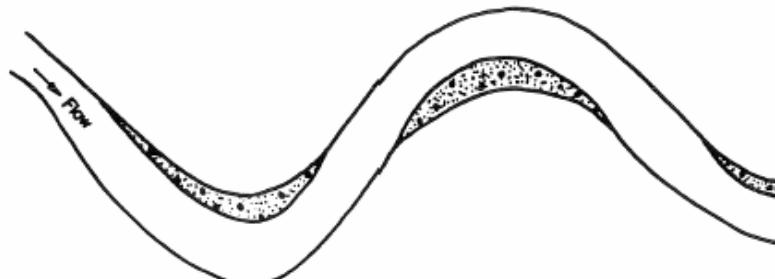
Use the Original Channel and Site Parameters Worksheet (Appendix C).

The reader may be familiar with the *Reference Guidebook for the Design and Construction of Stream Channels for Yukon Placer Mined Streams*, commonly known as the “White Book”. This section provides a summary of information from the most recent version of the White Book as well as additional requirements from the Fish Habitat Management System for Yukon Placer Mining.

The first step in designing water control features on the mine plan is to gather basic information on the existing conditions at the site. These include channel pattern and morphology, floodplain type, size and shape of the existing channel, channel and valley slopes, and the size and type of materials on the stream bed and banks. Once these variables are known, designs can be prepared for stream diversions, fish habitat features, riparian re-vegetation and other reclamation plans.

2.2.2 Channel Pattern/Morphology

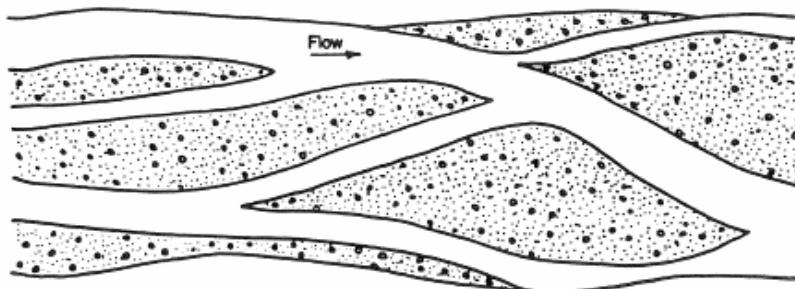
The objective is to determine the appropriate dimensions of diversion channels that will be rehabilitated. Evaluate the stream configuration (for the area of the planned diversion) which exists or existed prior to mining activities. If the stream has been so disturbed that no trace of the original stream bed can be found, this information may be available from aerial photographs, site photos and/or topographic maps. Based on the schematics presented below determine the channel pattern of the portion of stream channel that will be relocated.



(a) MEANDERING CHANNEL



(b) STRAIGHT STREAM



(c) BRAIDED CHANNEL

Braided channels may occur over a wide range of slopes and discharges and occur naturally or in response to watershed stressors (e.g., increased sediment supply from land uses, bank destabilization, and removal of in-channel roughness elements). In some circumstances braided channels are desirable and may provide spawning and rearing habitat for a wide array of fish species. In circumstances where braiding occurs as a result of watershed stressors, habitat quality may be generally poor. Braided streams and rivers occur naturally in the Yukon and are typified by relatively wide, active gravel floodplains and many braided active channels. They typically carry a large quantity of suspended and bed load as many of these systems have glacial sources. In small streams, a braided channel can be the result of an oversupply of sediment to the system. This can occur due to slope failures as well as channel and bank erosion.

2.2.3 Channel Floodplain Type

It is important to understand the concepts of channel setting and channel type so that the appropriate design method can be chosen for the site. For the purposes of this Guidebook there are only three types of channels: *no floodplain* channel, *narrow floodplain* channel, and *wide floodplain* channel.

No floodplain

Typical characteristics include:

- A floodplain width typically less than 1.5 times the channel width
- A single, well-defined channel that is wetted at normal summer flows
- Flows which are within the top-of-bank during a mean annual flood
- Banks that are composed of stable bottom cobble/gravels, bedrock or stream side vegetation
- Stream channels that are laterally and vertically stable
- Few or no point or side bars within the stream channel

No floodplain channels include entrenched or incised channels, which are laterally restrained within the valley, and steep channels in narrow valleys (i.e. gulches and pups).



NO FLOODPLAIN



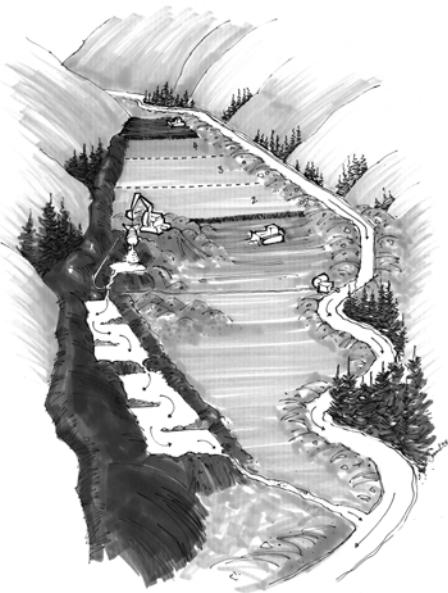
NO FLOODPLAIN
LATERALLY RESTRAINED CHANNEL
HIGH BANKFULL POTENTIAL
SINUOSITY < 1
VALLEY SLOPE > 10°
VALLEY WIDTH < 1.5 x CHANNEL WIDTH

dwg10_p01

Narrow floodplain

Typical characteristics include:

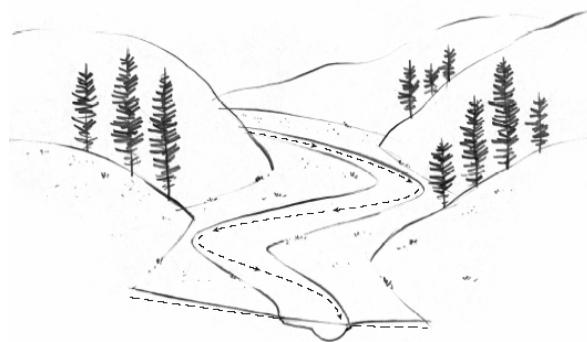
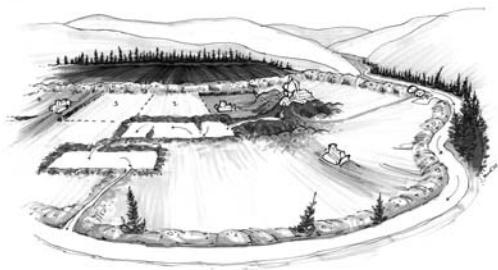
- A floodplain width typically 1.5 to 6 times the channel width
- Single or multiple channel stream with exposed and well-defined bars and banks at normal summer flows
- Flows which may be over the top-of-bank(s) during the mean annual flood
- Lateral channel movement within the floodplain with erosion at the outside of bends and deposition at the inside of bends (i.e. meanders)
- Vertically stable channels that are neither building up or cutting down
- Channels which may be restrained only at the limits of valley walls by bedrock outcroppings, or by alluvial fans or land slides extending from valley wall(s)
- Over bank deposition of sediment with pioneer plants such as willows, shrubs, etc.



Wide Floodplain

Typical characteristics include:

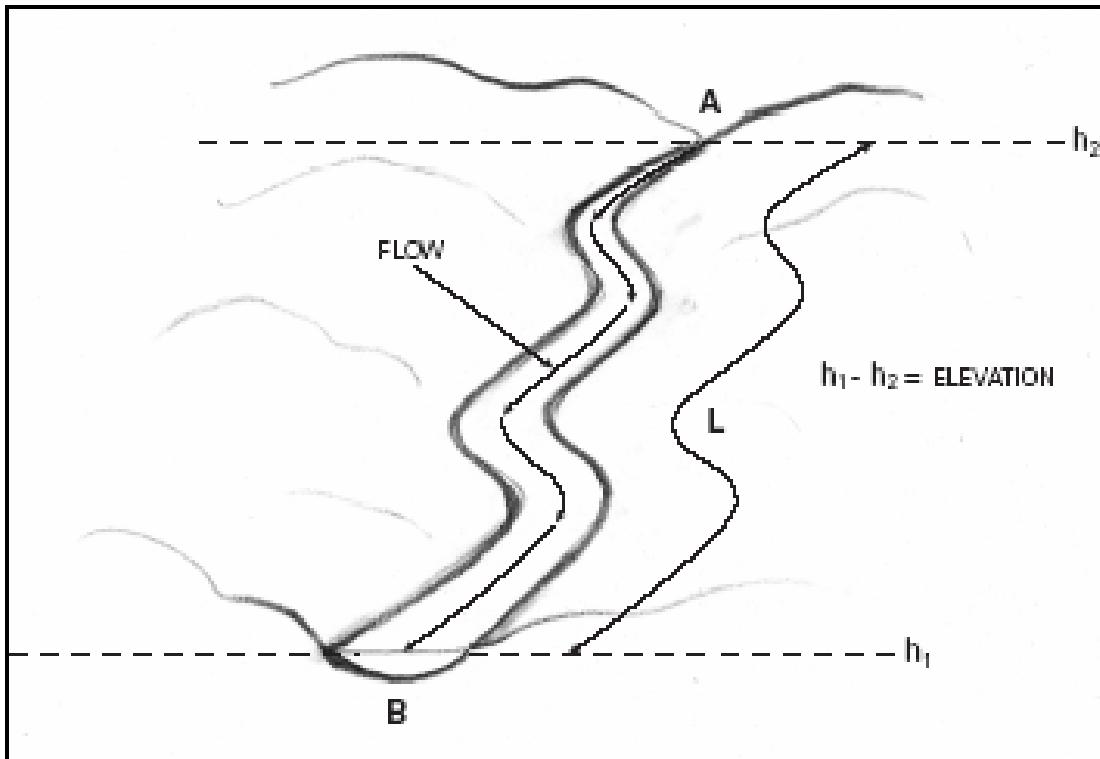
- A floodplain width typically greater than 6 times the channel width
- Unstable channels and wide active floodplains
- Floodplains which are typically submerged during the mean annual flood
- Channels with moderate to flat grades with active floodplains limited by floodplain features or valley width



If the stream channel that requires restoration appears braided, use the largest dominant channel as the design channel. The width of the braided floodplain will also give an indication of the expected floodplain width as the restored channel adjusts over time.

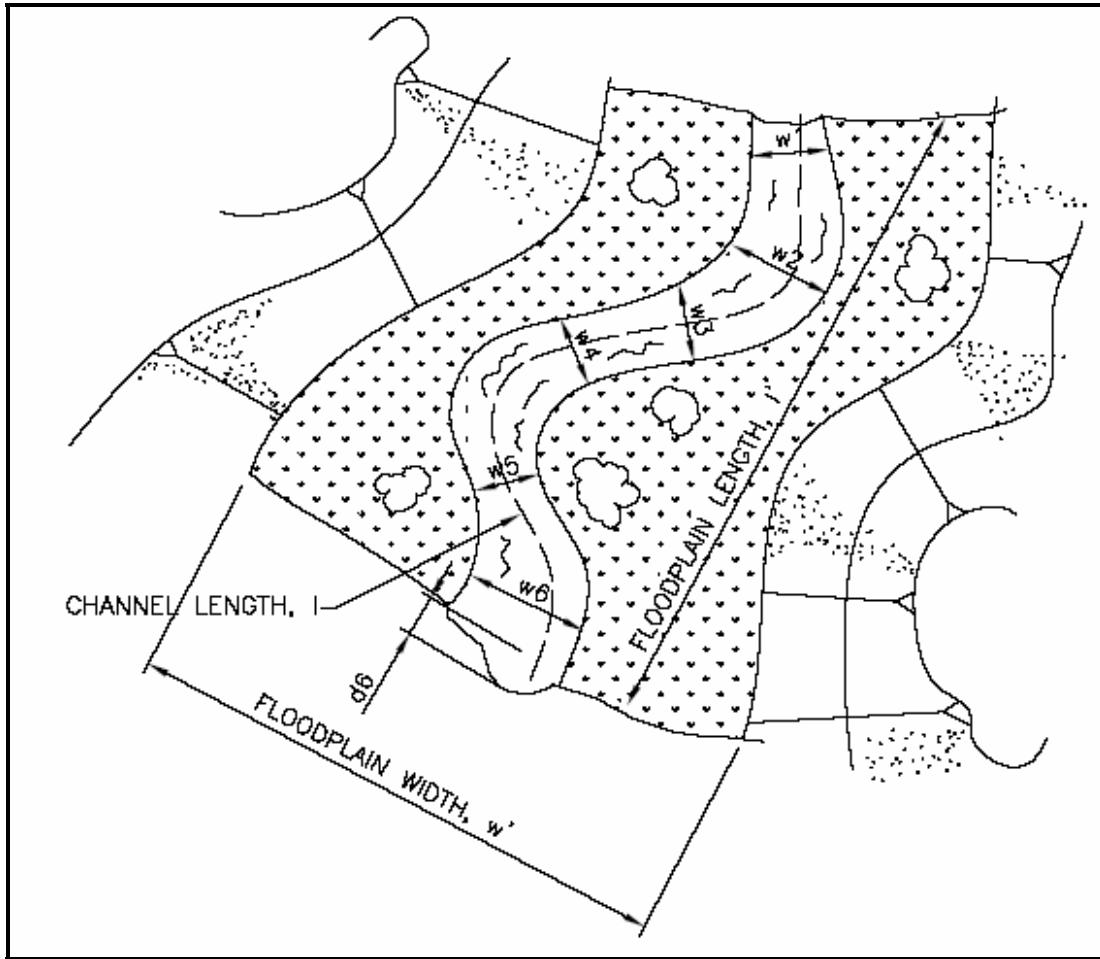
2.2.4 Valley Length – L'

Valley length (L') is to be measured following the fall line of the valley. It can be measured on site with a hip chain, survey chain, tape, vehicle odometer, from a map (1:50,000 scale or smaller) or aerial photograph.



2.2.5 Floodplain Width – w'

The floodplain width is defined as the width of the area flooded under a water surface elevation of two times the average channel depth. In some streams, or in some parts of streams, the floodplain may extend for some distance over the bank(s). Floodplain width may be estimated during a site visit, or measured using similar techniques as those presented for measuring valley length. Six measurements should be taken to obtain an average floodplain width.



2.2.6 Change in Streambed Elevation

The change in streambed elevation is required to determine the grade of the natural or existing channel. It can be determined using a hand-held level or other more precise survey instrument or from topographic maps.

Surveyed elevation drop: This is the preferred method of determining the elevation change between the upstream and downstream ends of the planned diversion channel. For small operations a hand-held level and rod would be adequate. For long or very steep sites, more precise survey levelling equipment may be used. The elevation measurements should be made at the lowest point in the natural channel cross section at the upstream and downstream end of the proposed diversion.

Topographic maps: Obtain a topographic map of the site with the smallest possible contour interval. Determine the locations of the upstream and downstream ends of the planned diversion and mark these on the map. Using the contour lines, determine the streambed elevation at the two ends of the diversion. The change in streambed elevation along the diversion will simply be the elevation at the upstream end minus the elevation at the downstream end.

2.2.7 Natural Channel Grade

The grade of the natural or existing channel is equal to the change in streambed elevation over the length of channel, or:

$$\text{Natural Channel Grade} = \frac{\text{Change in Streambed Elevation}}{\text{Length of Existing Channel}} \times 100\%$$

Using values for Change in Streambed Elevation and Length of Existing Channel previously determined record the natural channel grade on the Field Data Worksheet.

2.2.8 Velocity (v) and Discharge (Q) in Existing Channel

It is important to know roughly how much water is flowing through in the stream channel and the current rate of flow (low, moderate or flood stage). The volume of water passing a point over time is called the discharge or rate of flow, measured in units of volume over time such as gallons per minute or cubic metres per second. There are many methods for estimating the discharge of water through pipes, pumps, and open channels.

To estimate the rate of flow in a tailrace, creek or stream, remember that:

$$\text{Rate of Flow (Q)} = \text{Velocity} \times \text{Area}$$

Following is a simplified method to estimate the discharge:

1. Select a Location to Measure Flow

Pick a stretch of channel which is fairly straight, has an even slope, stable banks, uniform depth and no obstructions (or as close as possible to these conditions). Select two points, A and B say 20 to 100 feet apart.

2. Measure the **Area (A)** of Flow

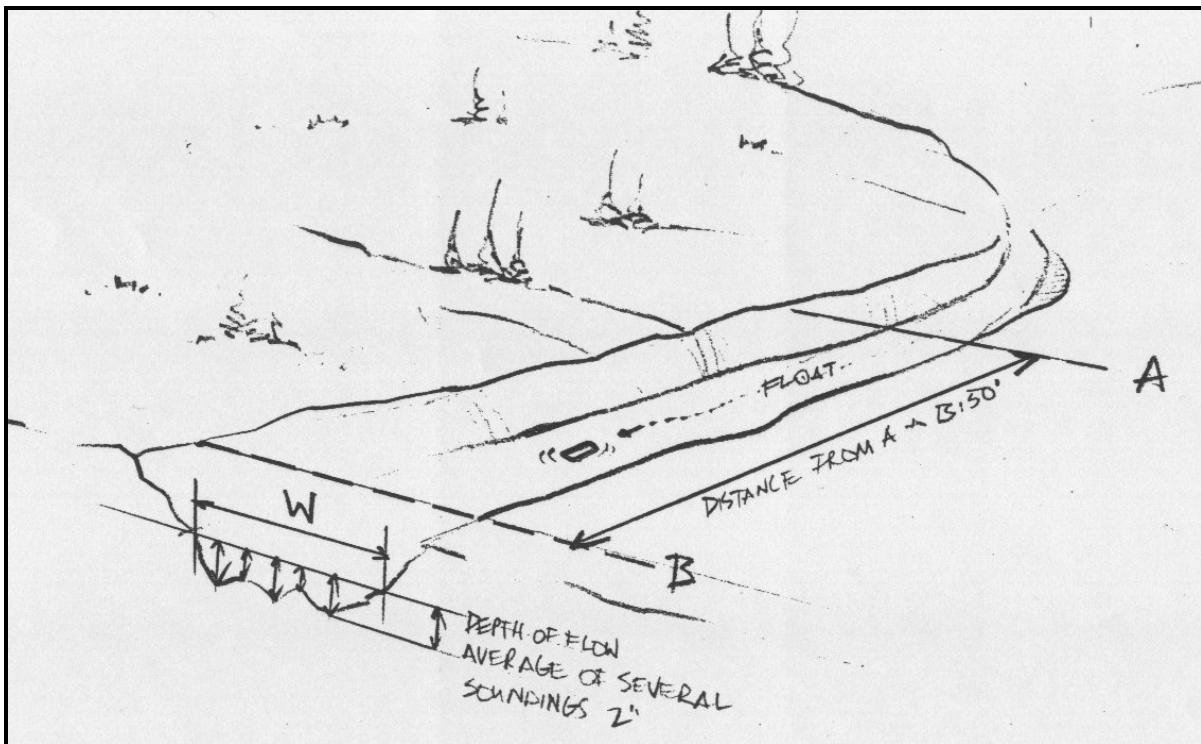
Measure the **width (W)** of the channel at the water line. Measure the **depth (D)** of the channel at a few points and average them. Multiply by width to calculate the area (W in feet x D in feet = A in square feet).

3. Measure the **velocity (V)**

Measure the time it takes in seconds for a float (stick, orange, wood chip, etc.) to travel from point A to B. Average the three trials. Calculate the velocity (V):

Length/average time of travel = Velocity (then multiply by 0.8 to account for faster water at the surface)

4. Calculate the Flow Rate in Cubic Feet per Second



Example:

- Length of channel = **50 feet**
- Average Depth of flow = **2 feet**
- Width of channel at water line = **10 feet**
- Area = $10 \text{ feet} \times 2 \text{ feet} = 20 \text{ ft}^2$
- Velocity = $50 \text{ feet} / 30 \text{ seconds}$ (average of three trials) = $1.6 \text{ feet per second} \times 0.8 = 1.3 \text{ feet per second}$

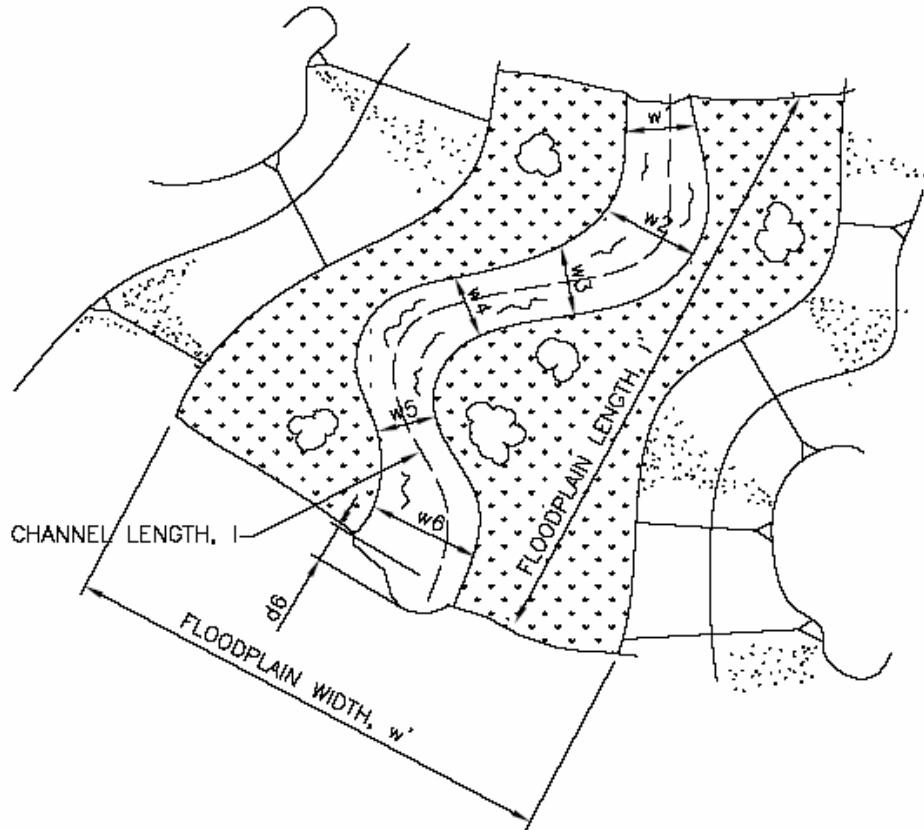
Flow Rate (**Q**) = $1.3 \text{ feet per second} \times 20 \text{ ft}^2 = 26 \text{ cubic feet per second.}$

Convert to Imperial Gallons per Minute (IGPM):

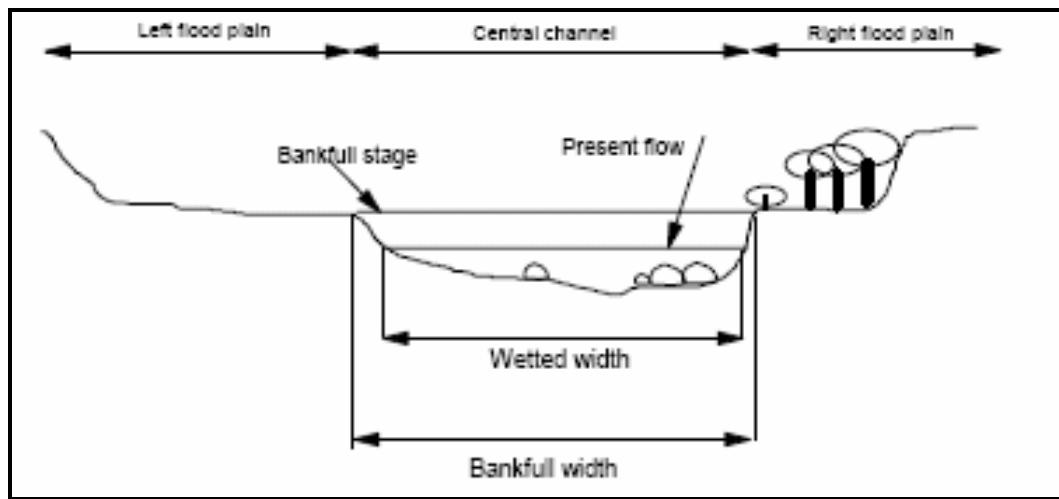
$$26 \times 374 = 9,724 \text{ or around say } 10,000 \text{ IGPM}$$

2.2.9 Channel Length - I

Measure the existing length of channel to be relocated. It is to be measured ideally following the thalweg, or deepest point, in the channel. Channel length may be measured in the field with a hip chain, survey chain, tape, GPS or vehicle odometer if it is possible to drive alongside the creek. Alternatively the channel length may be scaled off a topographical map (1:50,000 scale or similar), a claim map, or an aerial photograph.



2.2.10 Channel Width - w and Depth - d

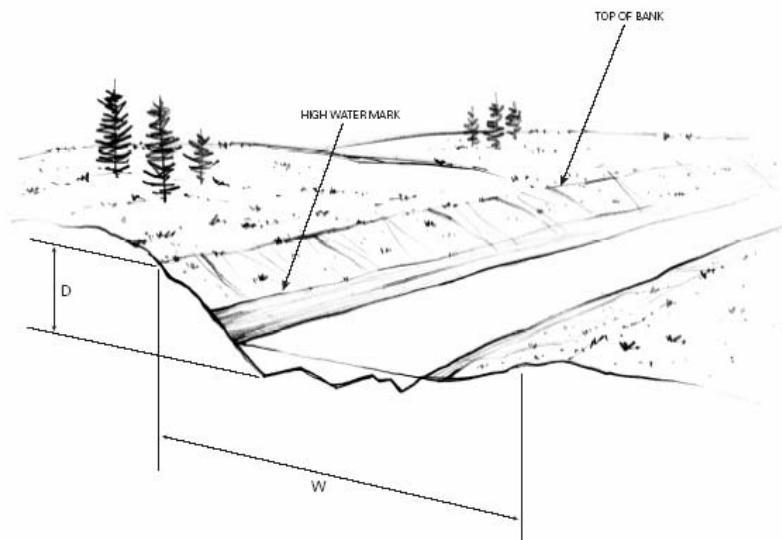


In many stream assessments the wetted width and depth as well as the bankfull width and depth are important criteria. For the purposes of this Guidebook, width and depth at bankfull stage are used.

Measure the typical channel width. This is defined as the distance measured from top-of-bank on one side to the top-of-bank on the other side. Top-of-bank is usually where the bank characteristics change and/or a break in slope of the bank occurs. Where the channel is confined and no obvious "top-of-bank" is present, stream width can be measured to the natural boundary. The natural boundary is defined as:

"where the presence and action of the water are so common and usual and so long continued as to mark upon the soils of the bed of the lake, river, stream or other body of water a character distinct from that of the banks thereof, both in respect to vegetation and in respect to the nature of the soil itself."

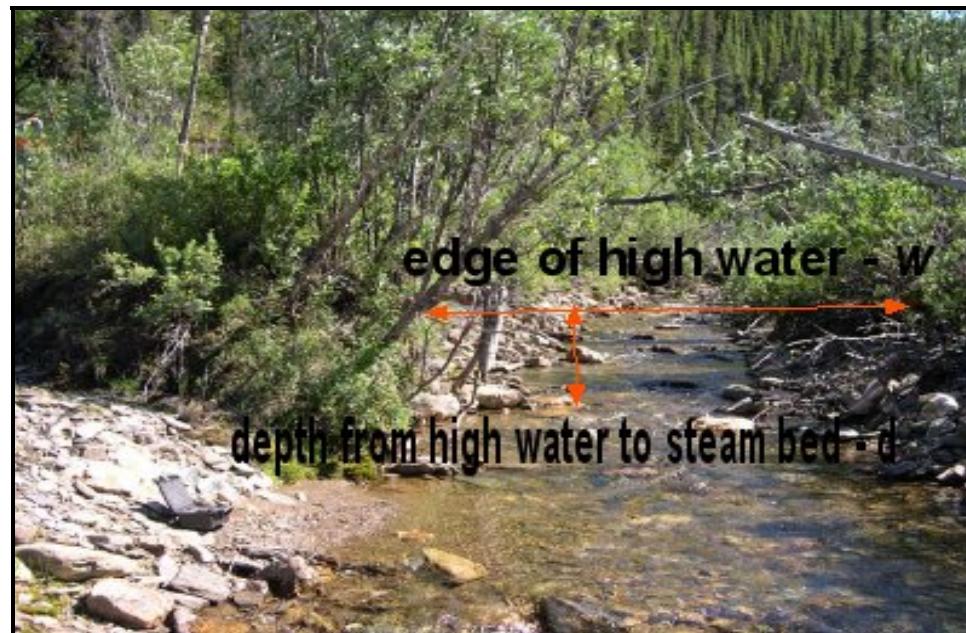
Measure the channel depth. This is the distance measured from the deepest point (thalweg) in the stream to the top-of-bank on the side of the channel with the lowest bank (or natural boundary, where the top of bank is not obvious). Where stream measurements cannot be made because it has been previously altered or is naturally unstable, width and depth can be estimated using Regime Channel method provided in the Workbook (Appendix E3).



Top of bank on lowest side to the top of bank on the other side = width (W). Top of bank to the deepest point in the channel = depth (d).



Here the width is measured from the lowest top of bank to the other side, depth is from this imaginary line to the creek bed at the deepest point.



In this case the top of bank could not be found, so the width is measured at the high water mark instead.

2.2.11 Channel Type

The channel type classification presented here is intended to guide the development of stable channel design elements in the overall channel diversion and stream reclamation process. The utility of a channel type classification system is that it provides a common vocabulary for describing conditions in the field. Classification systems, by definition, are groups of associations with shared traits. Descriptive process-related channel type morphology classifications (e.g., dune-ripple, pool-riffle) are based on universal qualities such as channel slope, bed material, sediment supply and channel pattern.

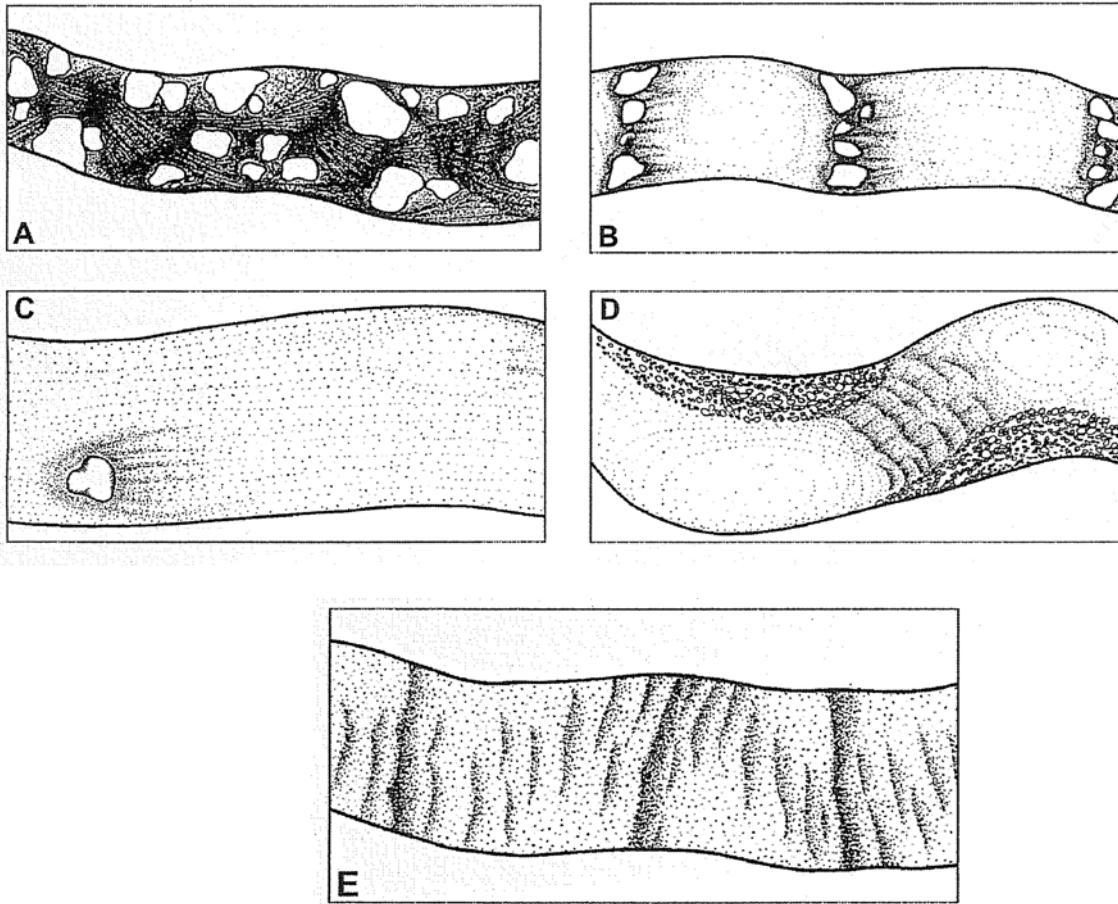
The classification used here for guiding the stream Reclamation process is based on the work of Montgomery and Buffington (1998) and Buffington et al. (2003) and is summarized in the following table:

Channel Type	Typical Slope (%)	Bed Material	Description
Dune-ripple	<0.001	Sand	Low-gradient, unconfined, sand-bed rivers occupying large alluvial valleys and typically decoupled from hill slopes. Variety of mobile bed forms (ripples, dunes, sand waves, plane-bed, and anti-dunes). Well-defined floodplain morphology with bankfull recurrence interval roughly 1-2 years.
Pool-riffle	0.001 – 0.02	Gravel and cobble	Alternating pool and bar topography caused by oscillating lateral flow that forces local flow convergence (pool scour) and divergence (bar deposition). Moderate- to low-gradient, unconfined channels, with coarse bed material and typically extensive floodplains. Bank full discharge has roughly 1-2 year recurrence interval. Potential for extensive salmonid spawning and rearing habitat.
Plane-bed	0.01 - 0.04	Gravel, cobble, and some boulder	Long reaches of glide, run or riffle morphology lacking significant pool or bar topography. Low width-to-depth ratios and moderate values of relative submergence (ratio of bank full depth to median particle size). Moderate-gradient channels susceptible to obstruction-forced pool formation. Moderate-gradient channels with coarse bed materials and variable floodplain extent. Bank full discharge is the effective discharge with an approximate 1-2 year recurrence interval. Potential for extensive salmonid spawning habitat.
Step-pool	0.02 – 0.08	Cobble and boulder	Repeating sequences of steps and plunge pools formed by wood debris, resistant bedrock, or boulders. Steep gradient, confined channels, with little floodplain development, and directly coupled to hill slopes. Limited salmonid spawning may occur in backwater environments and pool tails. Rearing may occur along lateral margins, associated with object cover, or in pools dependant upon geometry and associated hydraulics.
Cascade	0.04 – 0.25	boulder	Chaotic arrangement of boulder-sized bed material and continuous macro scale turbulence. Typically confined by valley walls and directly coupled to hill slopes. Steep gradients and relatively deep, concentrated flow allow efficient transport of cobble- to sand-sized sediment during annual floods, but movement of the channel-forming boulders requires infrequent large floods.

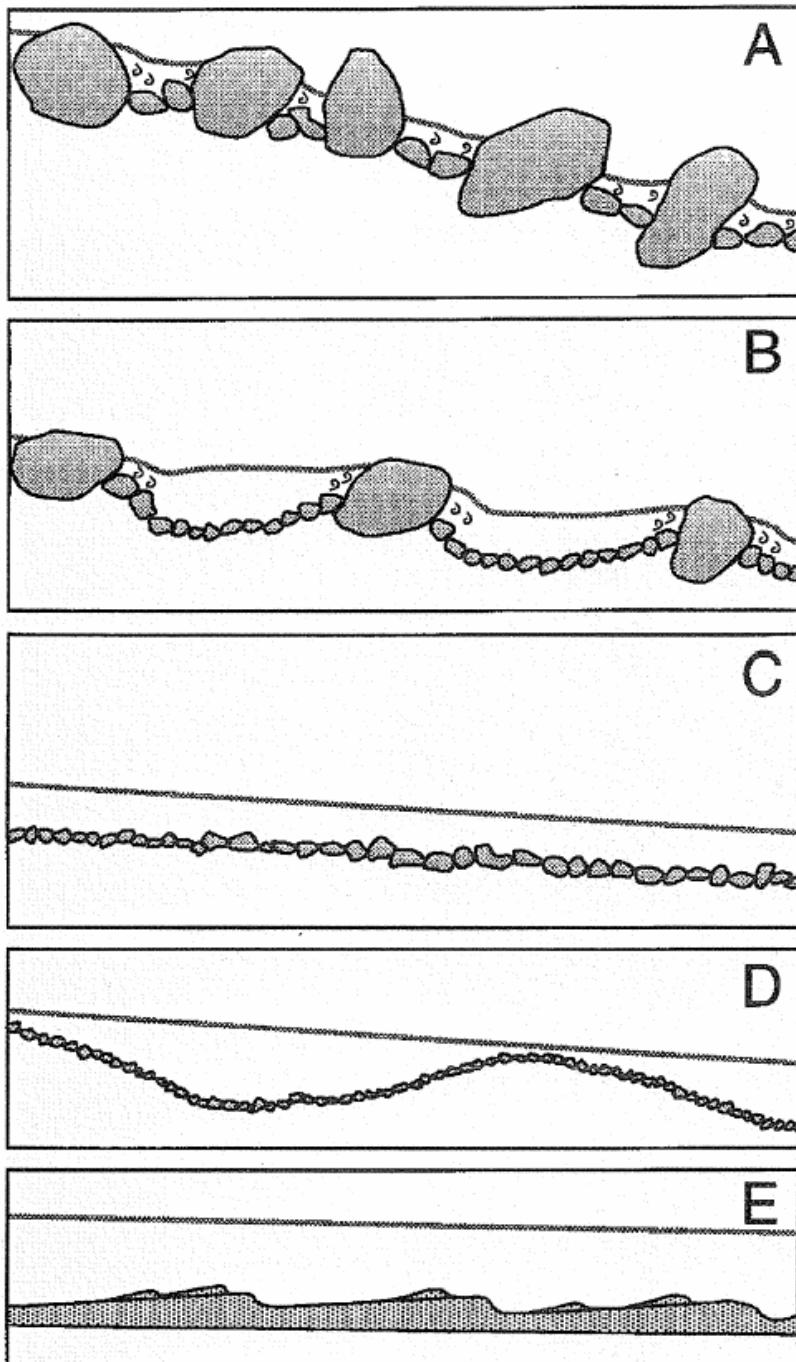
This system is:

- Based on physical processes which have linkages to aquatic habitat;
- Widely accepted by the scientific community;
- Developed for the Pacific Northwest and therefore has some regional relevance; and
- Robust enough to adequately characterize a broad range of conditions.

The following diagrams depict the five categories of channel type:



(A) cascade channel showing nearly continuous, highly turbulent flow around large grains; (B) step-pool channel showing sequential highly turbulent flow over steps and more tranquil flow through intervening pools; (C) plan-bed channel showing single boulder protruding through otherwise uniform flow; (D) pool-riffle channel showing exposed bars, highly turbulent flow through riffles, and more tranquil flow through pools; and (E) dune-ripple channel showing dune



Schematic longitudinal profiles of alluvial channel morphologies at low flow. (A) Cascade; (B) step-pool; (C) plane-bed; (D) pool-riffle; and (E) dune-ripple (From Montgomery and Buffington, 1997).

2.2.12 Channel Bed Material

Bed material is an indication of the energy of the stream and the relative quality of habitat for aquatic organisms, mainly benthic invertebrates. Gordon et al. (1992) offer the following definitions for the various components of sediment transport:

- Wash load: the smaller sediments, primarily clays, silts and fine sands, which are readily carried in suspension by the stream.
- Suspended Load: sediments that are carried with the wash load during high flow events but settle out when velocities drop.
- Bed load: sediment that moves by rolling, sliding, or hopping and is partly supported by the streambed.

The type and amount of sediment transported past a given location in the basin is dependant upon two factors including:

1. The supply of sediment from upland sources (through erosion and transport); and
2. The capacity of the stream to mobilize bed and bank materials and carry washed-in sediments (Gordon et. al. 1992).

For the purposes of placer design, it is important to attempt to describe the bed material because this affects the stream channel design and risk factors. Some judgement and experience are required to assess bed material, however the following method is recommended if advice cannot be found elsewhere.

Use the following steps to determine the dominant, subdominant and surrounding material of the stream channel:

1. Pick a site within the study reach that best represents conditions, taking into account pools, riffles and runs.
2. Start at a randomly selected location within the wetted channel. Take a step forward, without looking, pick up the first particle resting at the tip of your wading boots. Take another step forward and repeat the process until 10 rocks have been measured.
3. Rocks should be measured along the b-axis (intermediate length). If rocks are embedded or too large to pick up - measure the exposed surface in place.
4. Determine the most abundant, second most abundant and third most abundant bed material size classes from the recorded values and record the values on the Original Channel and Site Parameters Worksheet, Appendix C of the Workbook.
5. Note that the larger class sizes are the stones that the stream has not mobilized. This is a good indication of the size of materials that should be used in construction of stable channels.

The following table outlines different common size classes:

Size Class	Size Range (mm)
Sand	< $\frac{1}{4}$ inch, 2 mm
Gravel	1/4 inch to 3 inches, 2 mm to 75 mm
Small Cobble	3 inches to 6 inches, 75 mm to 150 mm
Large Cobble	6 inches to 12 inches, 150 mm to 300 mm
Rocks	12 inches to 24 inches, 300 mm to 600 mm
Boulder	> 24 inches, 600 mm

2.2.13 Detailed Site Description and Maps

Example drawings are provided with the Yukon Water Board placer mining application package, and also in the Worksheets appended to the Workbook. While still in transition, it is anticipated that the required level of detail and information to be depicted will be simplified and harmonized so that a single set of drawings can be used for all regulatory purposes. A thorough description and mapping exercise is required to show the existing conditions of the proposed mine site including areas immediately upstream and downstream. It is critical to establish a clear and concise base map or sketch drawing so that phases of the project can be depicted for regulatory review. Such a drawing must include geo-reference or scale so that features can be identified and evaluated in the review process and in the field.

The proponent should obtain the largest available scale topographic map and/or aerial photo of the site. Sources include Energy Mines and Resources, Yukon Mining Recorder and Yukon Geological Survey. Old and recent air photographs of the site may be invaluable to visualize the mining plan and restoration of the site.

Site map sets augmented with ground or aerial photographs are recommended, and should depict:

1. Pre-mining site conditions
2. General site planning
3. Site preparation plan
4. Site operation plan
5. Site reclamation plan

The map sets should include both temporary and final locations of major site features including:

- Access roads and bridges
- Settling pond systems (including wash plants, pre-settling and main settling facilities, intakes, outlets, tailing piles)
- Stream channels and diversions, bypass channels, site drainage ditches, bedrock drains
- Water acquisition, water pumps, pipelines and other instream structures
- Mine pits, overburden stockpiles
- Size and location of old stream channels and diversions
- Bedrock and stable areas
- Potential site selections for mine pits, settling facilities and routes for bypass channels

Physical Characterization

Describe stream and channel conditions, the local drainage network of the site and its relation to the larger watershed, general water quality conditions based on visual observations, and any knowledge of channel icing occurrence and location (aufeis). Bedrock outcroppings and stable valley limits can often be used to control the stability of temporary diversions and place the stream in an area where it will not have to be moved during the mining plan. For example, it may be possible to locate the restored stream channel against a bedrock valley wall to control stream channel stability.

Describe the type, depth and nature of soils and bedrock. For mining purposes, it will be critical to know the depth to bedrock so a stripping program can be planned. Soil type and vegetation cover will be important in the design of structures and in reclamation plans. Surficial geology maps and vegetation cover maps can be obtained from Energy Mines and Resources (the Yukon Geological Survey).

Determine the location of suitable soils and rock/boulders for dam, dike and stream diversion construction. Determine potential site selections for mine pits, settling facilities and routes for bypass channels.

Previous Mining

Describe and map previous mining activities including the condition, location and size of existing and/or abandoned facilities. Augment this description with research at the Mining Recorders office. Note the size and location of old stream channels and diversions. Generally, old diversions and relic channels may make for stable diversions because they have adjusted to existing stream flows and site grades. Old abandoned stream and dry channels in the floodplain can be used as either diversions or channels to be rehabilitated. Old sediment ponds, areas of frozen ground or black muck should be avoided. Mining history can be obtained from the Yukon Mining Recorders' offices. It will be important to know the location of potentially unstable ground such as abandoned settling facilities and ditches.

Current or historic mining activities may have altered natural stream and riparian conditions and processes. In some cases, the effects of previous development activities are local and minimal so that the mining plan and reclamation/rehabilitation strategies would be similar to those in an un-mined watercourse. For example, previous placer mining activities may have been limited to a single small operation on the floodplain where the main channel was unaffected. In this case, the goal of rehabilitation would be to establish post-mining channel and riparian characteristics similar to the pre-mining condition.

In some cases, however, the effects from previous placer mining activities have resulted in the creation of a wholly different stream environment (compared to pre-mining), so that the goals of rehabilitation cannot be based only on stream and riparian processes from the pre-development conditions. For example, permafrost thawing and subsequent channel incision resulting from mining activities in downstream reaches may result in head cutting through the proposed mine site (erosion of the upper end of the channel as it seeks to dissipate energy and re-establish suitable gradient). Similarly, elevated sediment loading from upstream reaches may increase the likelihood of bank erosion and channel migration, and lead to poorer settling pond performance. The rehabilitation elements employed should be designed to limit these effects, and have practical and realistic goals for creating a stable stream environment.

Legal description

Map the boundaries of mine claims and other pertinent property owners/jurisdictions.

Stockpiling

Describe and map on the mine plan diagram the types, locations and approximate volumes of material to be stockpiled, and describe the methods (e.g., machine spreading) that will be used to build the stockpile and methods or features (e.g., rock armour) used to protect and contain the stockpiles from erosion and degradation. Augment this description with a diagram that illustrates the erosion control measures applied at the various stockpile locations.

Distribution and type of permafrost should be researched because it will have a direct bearing on the design of settling facilities. In cases where there is a permafrost floodplain and valley floor, rehabilitation efforts may not be able to re-establish the permafrost and the associated stream dynamics within the timeframe under consideration. The potential negative upstream and hill slope (valley wall) effects from permafrost degradation should then be weighed against the positive gains from the proposed operation.

The location proposed for mining activity should include consideration of the riparian areas both upstream and downstream of the mine site. The larger the proposed operation, the greater the length of riparian area of surveillance should be. As a rule, for small watercourses consider the entire riparian zone where the proposed operation will involve 10% or more of the total stream length. In larger watercourses, survey the stream corridor upstream and downstream over a distance equal to at least 10 times the proposed length of operation. In either case the objective should be to identify any previous or existing mining operations that could have an effect on the proposed operation and associated rehabilitation.

Site Photographs

It would be of great assistance to both the miner and the regulatory agencies to have photographic documentation of site conditions prior to mining. A series of photographs, showing the channel, channel bed material, the valley and/or floodplain and other site characteristics should be taken. Copies of the photos labelled and located on a mine sketch or placer map should be included with the water use licence application.

2.3 Step 3: Stream Channel Design

2.3.1 Step 3.1: Estimate Design Flood Requirement

Design Flood calculations are required to determine the rate of flow that a channel is designed to contain or up to which various components of channels are designed to be stable. If there is no way to obtain real field measurements, or if the proponent wishes to check the channel dimensions measured in the field, then the hydrology information can be used indirectly to estimate the width and depth of a design channel for a 2-year design discharge (Q^2 (m^3/s)).

Use the Design Flood Estimate Worksheet (Appendix D) to assist with data recording and calculations.

The following pages describe the information required to complete design flood calculations:

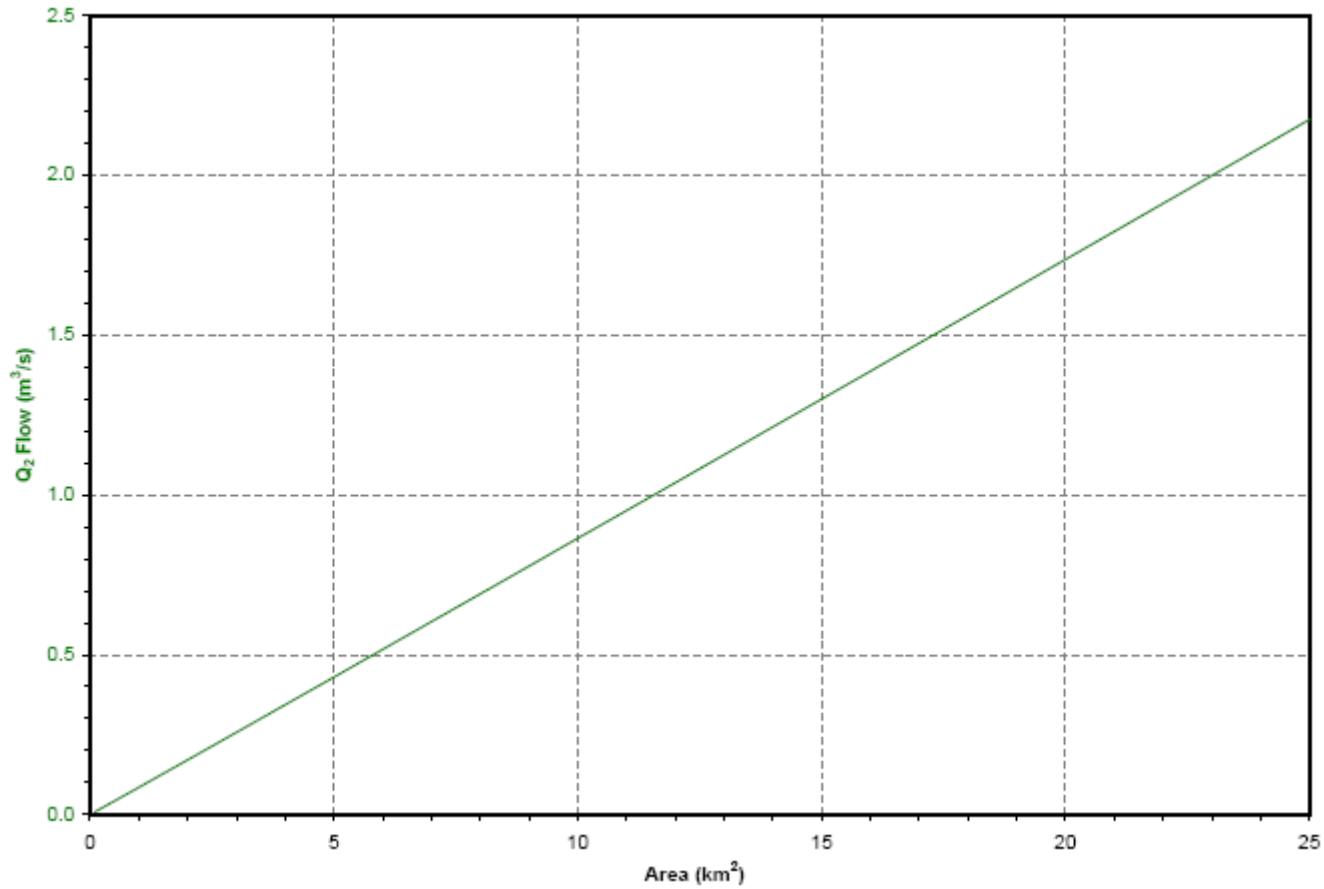
2.3.2 Simulated width and depth design data

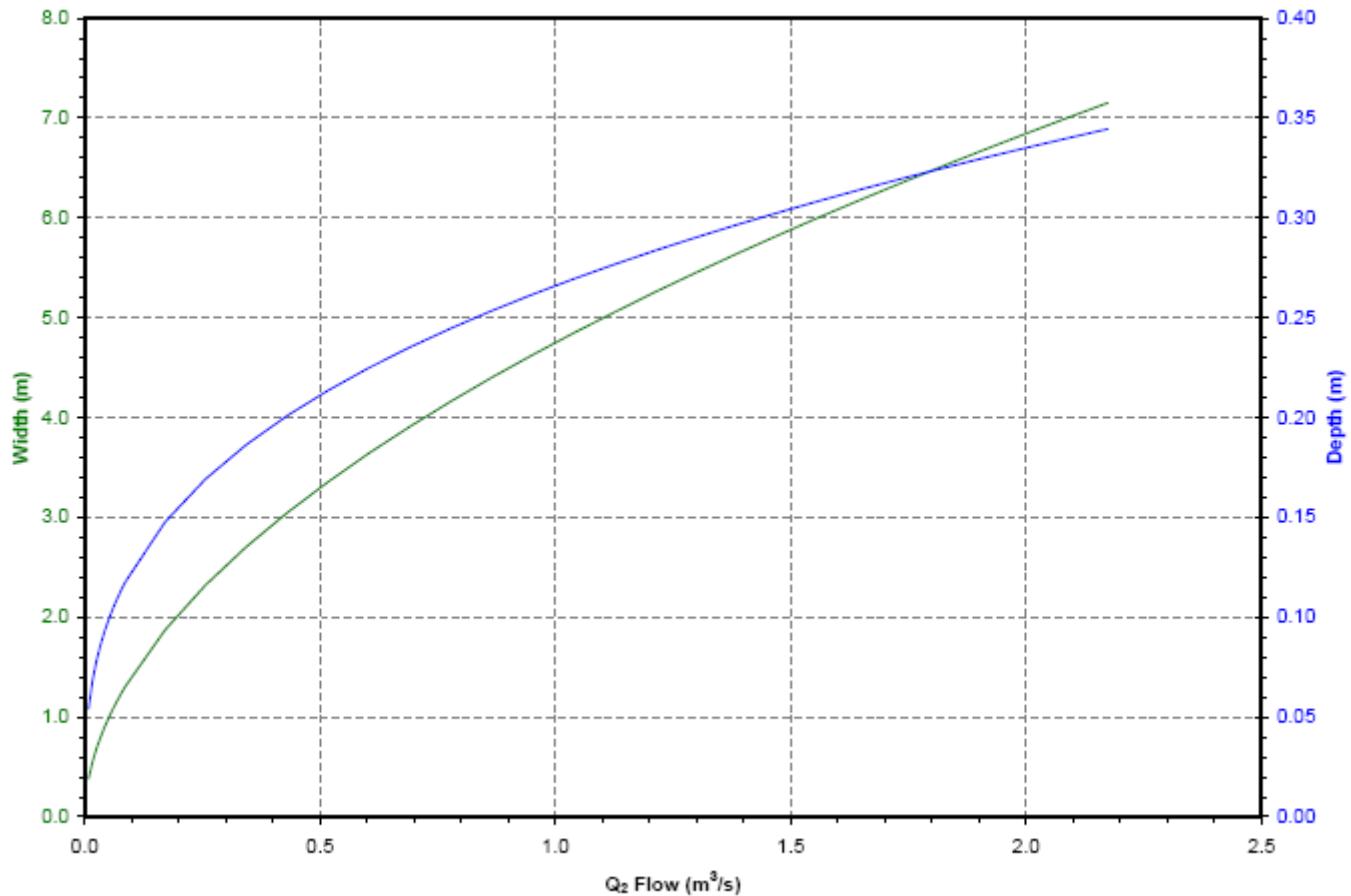
If there is no way to obtain real field measurements, or if the proponent wishes to check the channel dimensions measured, then the hydrology information can be used indirectly to estimate the width and depth of a design channel. With the 2-year design discharge estimated in the hydrology section below, Q_2 (m^3/s), the following channel regime equations can be used to estimate channel width, w (m) and depth, d (m). These equations were originally presented for gravel bed-rivers in Alberta (Bray, 1982) and are very similar to equations developed for Alaskan streams (Emmett, 1972).

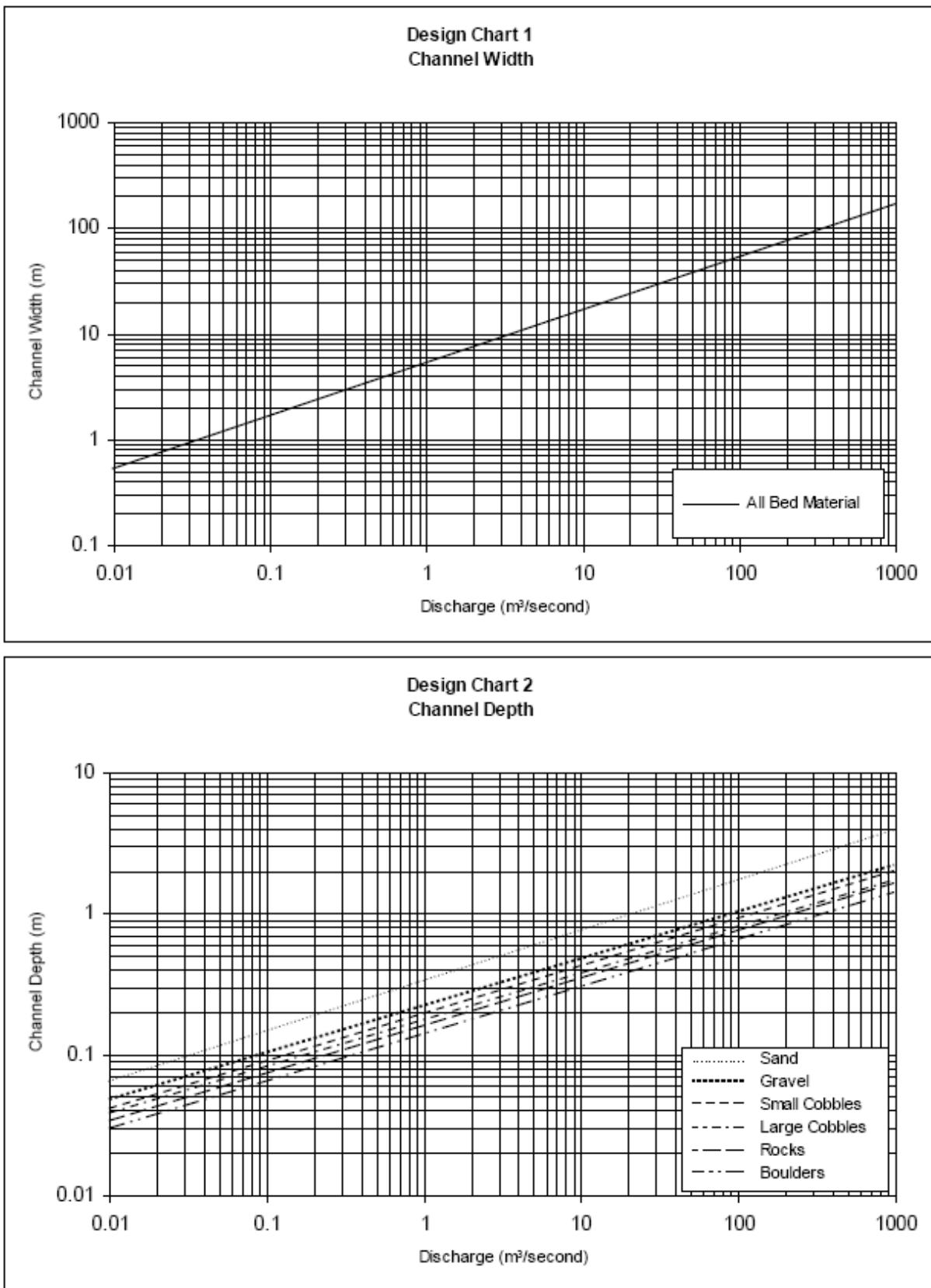
$$w = 4.75 \cdot Q_2^{0.527}$$

$$d = 0.266 \cdot Q_2^{0.333}$$

The estimated width and depth for 2-year design flow for the area and region of the site can be derived from the equation or estimated from the design charts provided. While these numbers are better than nothing, it is always preferred that actual measurements of the stream channel be used in design.







2.3.3 Determine Required Flood Design Interval

Determine the appropriate flood design interval based on the length of time the channel will be in place and the Habitat Suitability Classification as outlined in the Workbook.

Design flood return interval is defined as the period of time over which, in the long run, the given flood discharge will be equalled or exceeded only once. For example, a 10 year flood would be equalled or exceeded, on the average, once every 10 years. The return interval is directly related to the probability that a flood event of a given severity will occur in any given year. Therefore, the greater the return period, the greater the flood discharge (i.e. the 50 year flood will be larger than a 20 year or 10 year return period flood event).

2.3.4 Determine Drainage Area

The area of the watershed upstream of the mine must be determined to estimate the flows at the project site. A drainage area is the area drained by a river and all of its tributaries and is delineated by the height of land, ridge or crest line dividing it from other adjacent drainage areas (also known as a watershed). There are various methods for determining catchments or drainage area, some of which include the use of computer programs. If no alternative methods are available to the operator the following methods can be employed:

1. Obtain a topographic map which includes the downstream end of the site and the entire drainage area upstream of the site. The drainage area is the entire area upstream of the downstream end of the site from which water could drain into either the main stream or one of its upstream tributaries. Use a topographic map with a scale of 1:50,000 (if available) for drainage areas less than 250 square kilometres. Use maps with a scale of 1:250,000 for drainage areas greater than 250 square kilometres.
2. Delineate the drainage area boundary on the map (see example map below). Starting at the downstream end of the site, draw a line following the ridge line (height of land as shown by the contour lines on the map) around the entire drainage area upstream.
3. Place a grid overlay on the map so that the maximum number of solid line squares (1 cm x 1 cm) are within the drainage basin boundary.
4. Count the number of solid line squares totally contained within the drainage basin boundary.
5. Without moving the grid overlay, count the number of dashed-line squares (0.5 cm x 0.5 cm) that are within the drainage basin boundary, but are not included in the solid-line squares counted during in step 4.

6. Use the **Area Factors** in the following table to calculate total drainage area:

		Map Scale	
		1:50,000	1:250,000
Step 1	Solid-Line Count		
Step 2	Solid-Line Area Factor	0.25	6.25
Step 3	Solid-Line Area Total (Step 1 x Step 2) = Step 3		
Step 4	Dashed-Line Count		
Step 5	Dashed-Line Area Factor	0.0625	1.5625
Step 6	Dashed-Line Area Total (Step 4 x Step 5) = Step 6.		
Step 7	Total Drainage Area (Step 3 + Step 6)		



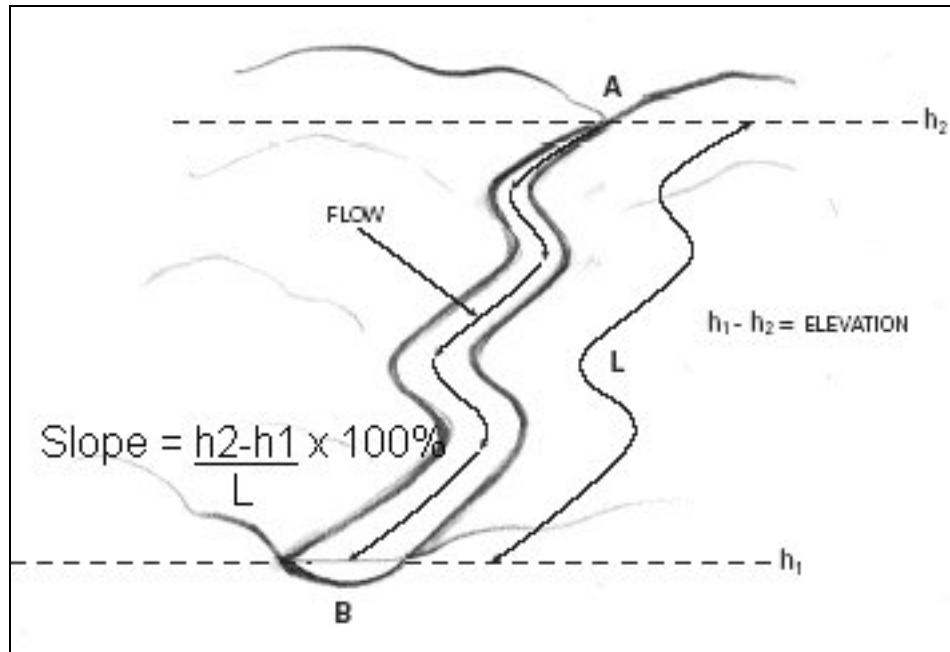
2.3.5 Determine Hydrologic Zone - Interior or Mountain zone

Identify the longest length of channel located within the watershed (drainage area) upstream of the site. Locate the extreme upstream end (headwater) of the channel on the topographic map. Determine the streambed elevation at that point from the contour lines, and record this value. In the same manner, locate and determine the streambed elevation at the downstream end of the site, and record this value. Ensure that if the elevations are read from the map in feet, the elevations are converted to metres for the following calculations.

Measure the length of the channel between the two points of elevation measurement. If measured in centimetres (cm), multiply the measured length by 500 for 1:50,000 scale maps or 2,500 for 1:250,000 scale to obtain the channel length in metres. Record the channel length.

The average upstream channel slope is calculated by dividing the elevation difference between the upstream and downstream ends of the channel by the upstream channel length:

$$\text{Upstream Channel Slope (\%)} = \frac{\text{Upstream Elevation (m)} - \text{Downstream Elevation (m)}}{\text{Channel Length (m)}} \times 100\%$$



Channel slopes greater than 4.5% are presumed to occur in mountain zones, and

Channel slopes less than 4.5% are presumed to occur in interior zones (Janowicz 1989).

2.3.6 Step 3.2: Select Channel Design Method

Based on channel setting, channel type as well as other factors the selection of a channel design method for channel construction is required at this stage. Diversion channel dimensions (width, depth, length) and whether drop structures are required are determined in this step. The channel is designed using the Design Discharge.

Use the appropriate Diversion Channel Design Worksheets (Appendices E1 through E3) to assist with data recording and calculations.

This Guidebook has been developed to assist placer miners to design and construct stable stream channels which will provide productive fish habitat in situations where existing fish habitat has been or will be lost. When the miner diverts a stream channel to a new location, the new channel and nearby land should be stable so that stream and soil erosion do not cause problems for fish, either at the site or downstream. To achieve this, the new (or “diversion”) channel should be built at the right slope and of the right material. The following information provides simple methods of determining the right channel dimensions.

It should be noted that although this Guidebook includes streamside restoration measures, they do not address general land reclamation requirements. The restoration measures are designed only to control sediment addition to the stream from the nearby disturbed lands.

The key site information in previous sections will be required to design any type of stream channel. Additional site information may be obtained from Government of Yukon Energy Mines and Resources Client Services and Inspections Branch, fisheries information from biologists at the Department of Fisheries and Oceans or Yukon Environment Fisheries Management Branch, and water flow information from the Water Survey of Canada and the Water Resources Branch of Yukon Environment. Although site-specific data is preferred over desktop estimates, this reference Guidebook process will allow for gross estimates of channel width and depth based on hydraulic engineering principles.

Principles to consider when designing a stream channel diversion include:

- 1 Plan how to make the channel as stable as possible and resistant to erosion.
- 2 Build a restoration channel that works with natural stream forces to restore the area to biological productivity as soon as possible after mining. *Incorporating a functioning flood plain* is one way to accomplish this goal.
- 3 Divert the stream only once when possible. The diversion should be planned for the life of the mine plan. Planning and layout of mining cuts, settling facilities, overburden stockpiling and access will help determine the ideal location for the required stream diversion.

There are essentially two types of channels commonly designed for placer mining – temporary diversions (bypass channels, ditches and drains) and permanent restoration channels. It is always preferred that the stream only be diverted once, but it is recognized that this is not always possible. A temporary diversion does not normally have to include the kinds of features that would develop into fish habitat in the future. Permanent restoration channels are meant to be built to a higher standard and include more armouring and grade control to

encourage the reformation of natural biological productivity as soon as possible after mining. If the stream is in a higher risk category, then fish habitat features will need to be incorporated into the design. Examples of such features are presented.

Permanent Restoration Channels

One of the main objectives in the design should be the re-construction of functioning floodplains. Typically, permanent restoration channels are constructed at the end of mining during the restoration or reclamation portion of the mine plan. However, it is much more economical to implement this part of the mine plan while heavy equipment is still on location. Permanent restoration channels are built to work with natural stream forces to restore the area to biological productivity as soon as possible after mining; to provide long-term channel stabilization; to prevent erosion and the transport of large amounts of fine and coarse textured sediment downstream; and to ensure fish access and development of fish habitat within the stream corridor.

Temporary Diversion Channels

Temporary diversion channels provide stable, short-term stream diversions during the life of the mining plan, and limit stream erosion and downstream sediment transport.

The miner will use one of three methods to design a stream channel:

1. Channel Replication Design Method
2. Floodplain Design Method
3. Channel Regime Method

It is important to keep in mind that a functioning floodplain is the key to a successfully constructed channel in placer mining applications. It is always better to use the Channel Replication or Floodplain Design Method whenever practical. Structures based on the Channel Regime Method are very conservative and will usually be much larger and more expensive to construct.

Details for each method are provided in the following sections.

2.3.7 The Channel Replication Design Method

Follow the procedure outlined in the Workbook (Appendix E1).

The Channel Replication Design Method is recommended for:

- Temporary stream diversions
- Streams with slopes greater than 2% slope such as steep valley streams, gulches and pups
- No floodplain streams
- Incised or entrenched streams
- Optionally for streams with grades less than 2%

This section provides a simple technique for designing and building a diversion ditch or channel based on the concept of making the diversion wider, deeper and roughly the same length as the original channel. The proponent must decide how deep, how wide, how long and at what grade to build the channel based on data and information about the stream in question. While most placer mining diversions involve relocation of the channel along a new alignment, there are times when old channels, diversions, drains and other works can be used.

In order to make the Channel Replication Design Method work, the proponent must have measurements of the stream width, depth, grade and length and apply the formula below to build a channel between the points of diversion *without a floodplain*.

The channel dimensions are calculated from the natural (original) channel depth (d), width (w) and length (l) that were either measured in the field or estimated from other sources.

Formula for Channel Replication Design Method

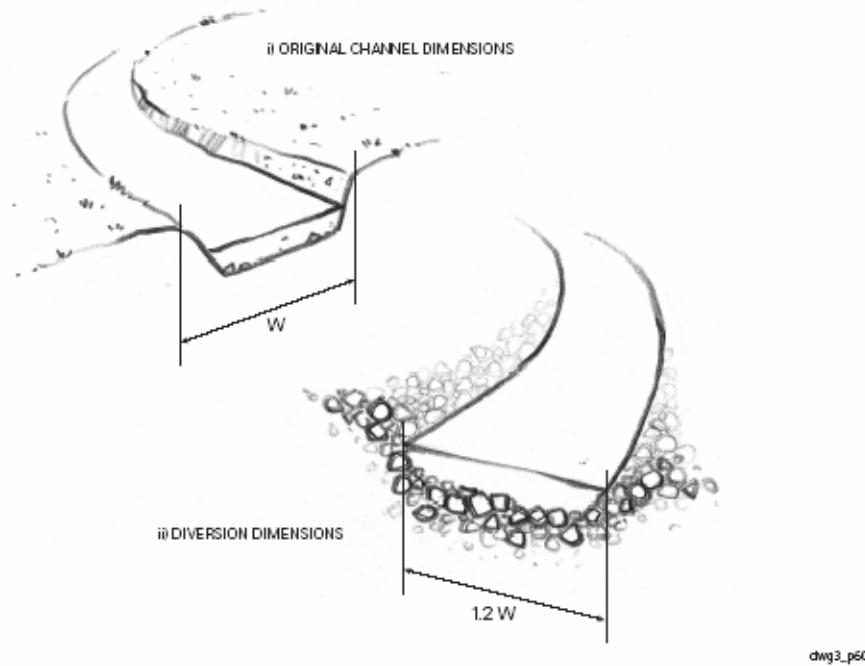
$$\text{Diversion Channel Width:} \quad W = 1.2 \cdot w$$

$$\text{Diversion Channel Depth:} \quad D = 1.5 \cdot d$$

$$\text{Diversion Channel Length:} \quad L = l$$

Where w , d , and l are original channel dimensions

If the channel cannot be made as deep as required, it can be made wider to arrive at the same cross sectional area. Channel side slopes should be graded back to a stable slope, approximately 2:1 - 3:1 Horizontal: Vertical along the banks of the channel.



dwg3_p60

2.3.8 The Floodplain Design Method

Follow the procedure outlined in the Workbook (Appendix E2).

The Floodplain Design Method is recommended for:

- Streams with grades less than 2% slope
- Narrow floodplain streams
- Wide floodplain streams.
- No floodplain streams where the proposed relocation site has enough space for a floodplain.

This design method is used to design channels with slopes up to two percent (2% or 2ft/100ft). The floodplain will follow the general grade of the site (not exceeding 2%). The total length of the floodplain should not be less than 2/3 (66%) of the length of the stream that is being diverted. The floodplain design allows the channel to alter its width, depth and grade within the floodplain in response to stream flow and sediment entering it. Floodplain channels do not require grade control structures, but are wider to accommodate the lateral movement of the stream channel. As a result, the meandering stream channel in the floodplain may be significantly longer than the floodplain channel.

The floodplain design method allows nature do a lot of the work. There is allowance for significant re-distribution and storage of sediments in the floodplain area. The floodplain and stream channel in it are designed using dimensions calculated from the average channel depth and width values, d and w (from Channel Design Worksheet).

Formula for Floodplain Design Method

Floodplain Width: $W' = 6 \cdot w$

Restoration Channel Width: $W = 1.2 \cdot w$

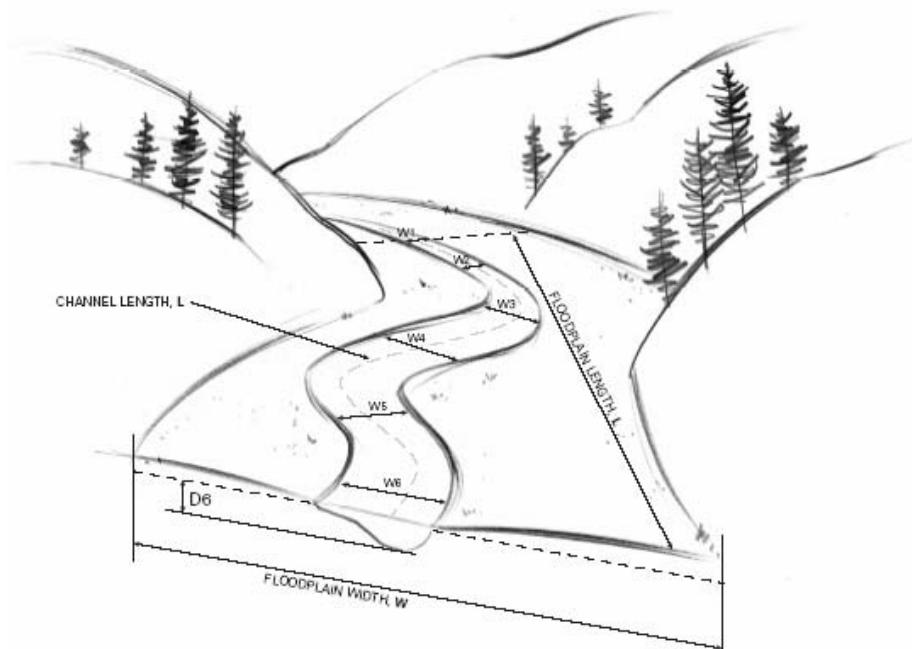
Restoration Channel Depth: $D = 1.2 \cdot d$

Restoration Channel Length: $L = l$

where w , d , and l are original channel dimensions

A channel constructed within the floodplain connects the points of upstream and downstream diversion. The channel swings laterally from one side of the floodplain to the other with a frequency based on six times the channel width. The channel is longer than the floodplain and therefore has a lower gradient.

The existing channel type determines the design floodplain width. Non-floodplain systems will require a design floodplain equal to 3 times the average stream width, while narrow and wide floodplain systems will require a design floodplain equal to or greater than 6 times the average stream width. The edges of the floodplain should be constructed with a 2:1 H:V slope to a minimum height of 3 feet (1.0 metres) above the floodplain surface.



2.3.9 The Channel Regime Method

Follow the procedure outlined in the Workbook (Appendix E3).

The Channel Regime Method is recommended for:

- Locations where there is no long term stable channel (naturally unstable or previous diversions less than 10 years old)
- A method for deriving channel width and depth using design flood estimation techniques
- Where there is insufficient field data to use the replication or floodplain design method

Site hydrology may be employed for two purposes: to estimate the width and depth of a stream when field measurements are not available, and to check whether or not the designed channel will be able to convey the forecasted flood for that site. Design flows can be used for generating width, length, depth, and slope estimates if there is no actual site data; when the stream is wholly disturbed; or for checking estimates provided by others.

Bed and Bank Material

Design Charts 1 to 4 of the Worksheets are used to determine the required channel dimensions and are based upon two variables including design discharge and bed material size.

Six average bed material sizes are indicated on Design Charts 1 to 4, as follows:

Sand	(less than ¼ inch, 2 mm)
Gravel	(1/4 inch to 3 inches, 2 mm to 75 mm)
Small cobbles	(3 inches to 6 inches, 75 mm to 150 mm)
Large Cobbles	(6 inches to 12 inches, 150 mm to 300 mm)
Rocks	(12 inches to 24 inches, 300 mm to 600 mm)
Boulders	(greater than 24 inches, 600 mm)

Enter the bed material type for the diversion channel on the Regime Channel Worksheet (Appendix E3).

Grade control

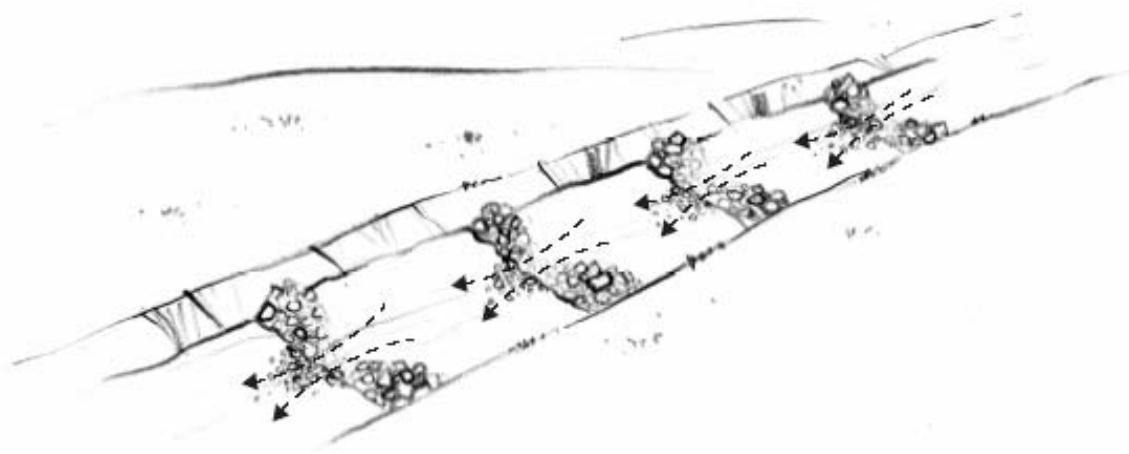
Making the diversion channel at least as long as or longer than the original channel length will result in more stability and less erosion problems. If the diversion channel length is reduced then the overall grade will be steeper than the original. Water will flow faster down the steeper channel and will have more energy. If the energy is not controlled it will erode the channel throughout its length. For either case any difference in elevation and channel grade between the diversion points can be accounted for in four ways:

- Changing the channel length
- Armouring the channel
- Installing grade control structures
- Constructing pools

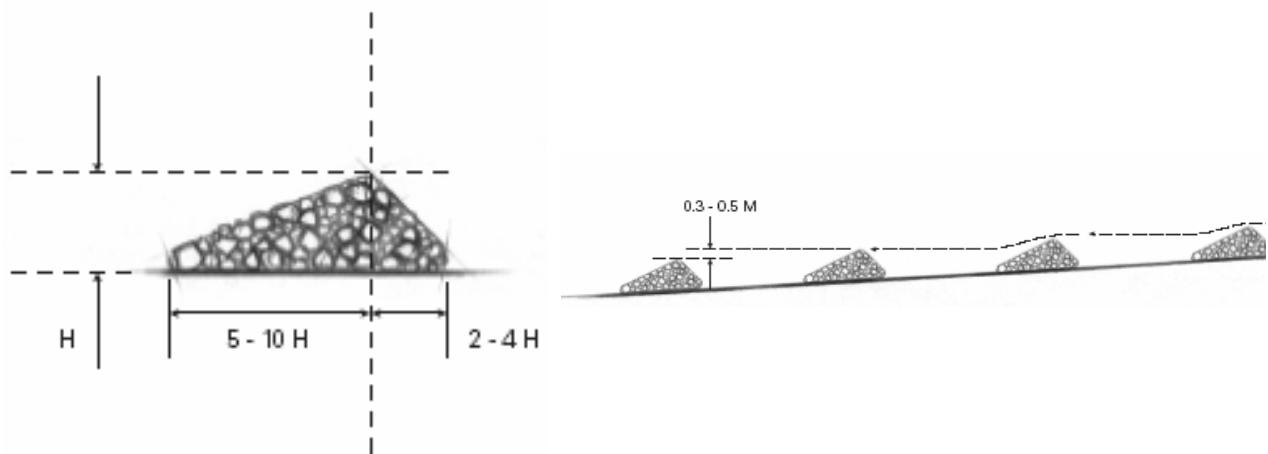
Where the channel becomes steeper there will often be channel erosion. If there are no bedrock outcroppings to utilize to “drop” the channel, grade control structures should be built to limit erosion. These structures should be installed at regular intervals that allow no more than about 20 inches (0.5 metres) of drop between structures. Shorter or steeper channels will need more structures to control the grade. These drop structures are about as wide as they are long, and should be constructed using the coarsest available materials like boulders, coarse washed tailings and broken rock.

Grade control structures are required:

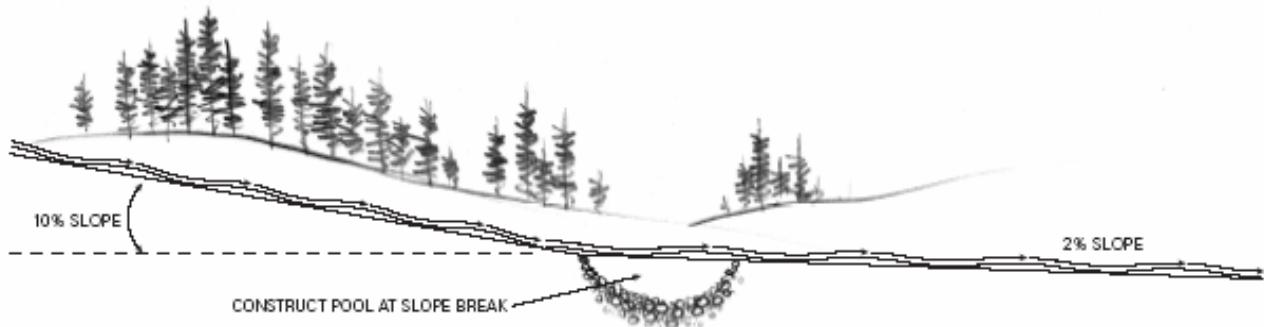
- If the Channel Design Method is used for a restoration channel
- A diversion channel can't be made similar to the original in length



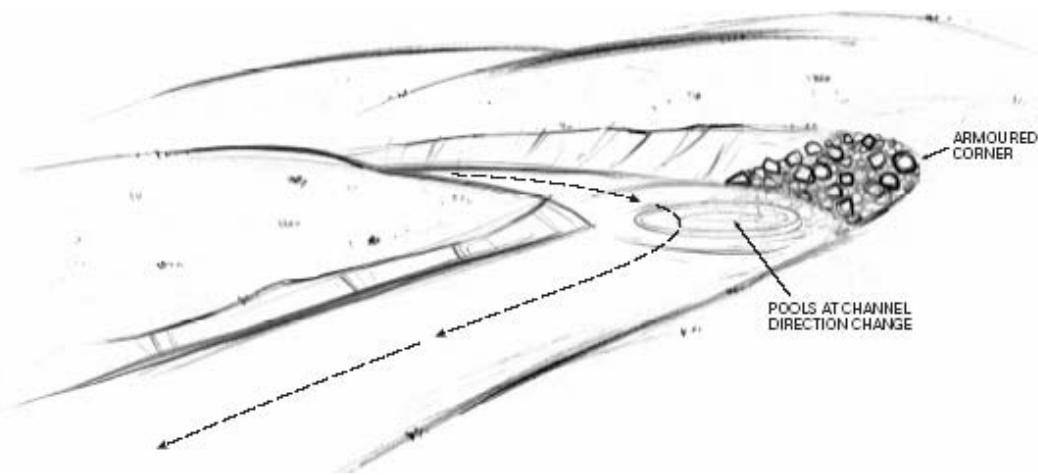
Grade control structures should have about 1 to 1.5 feet (0.3 to 0.5 m) between the tops and be shaped roughly as shown.



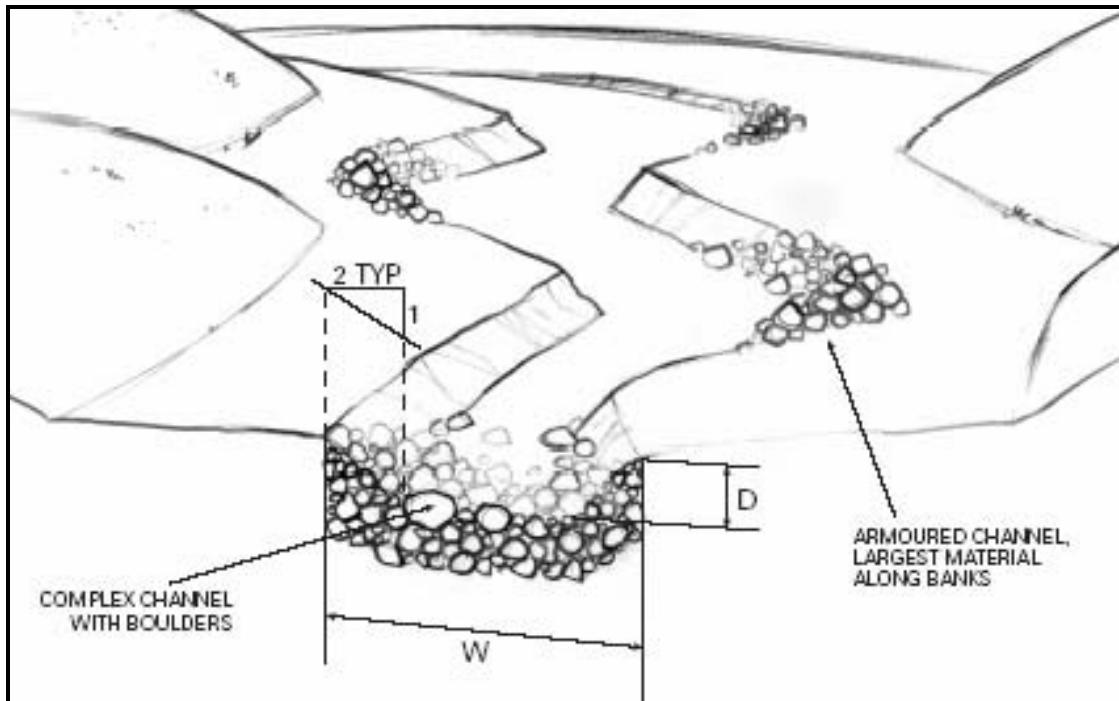
Where the channel becomes *less steep*, there is likely to be *deposition*. Pools should be constructed in the area where the grade of the channel decreases. The *pool structures* will infill and collect sediment. This will assist the stabilization of downstream areas by limiting the movement of sediment. Pools may also be constructed at locations where the channel changes direction. The outlet and outside banks (i.e. opposite the inlet) of the pool should be constructed from the coarsest available materials. This method will minimize bank erosion associated with the change in direction of the stream.



A pool constructed at a break in slope.



A pool constructed at the outside of a sharp bend; note armouring.



A restoration channel using the channel design method.

2.3.10 Step 3.3: Select Fish Habitat Features

In this step, the miner selects the optimum fish habitat features for the diverted stream channel. The selection of the structures and structure spacing is a function of the stream classification and the natural channel condition. The aim is to provide a variety of fish habitat features which replicate, as closely as possible, conditions in the undisturbed channel.

The following section outlines Fish Habitat Rehabilitation methods.

In addition to the methods outlined in the *Reference Guidebook for the Design and Construction of Stream Channels for Yukon Placer Mined Streams* (White Book), a component has been added on the design and construction of features that enhance fish habitat. It should be noted that stream analysis, design of compensation channels, and design of in-stream structures for fish habitat are normally compiled by a qualified professional, and that the techniques summarized below are not a replacement for such professional advice. Drop structures, or submerged rock weirs, also provide fish habitat. However, since the use of drop structures is dictated by stability considerations, drop structures have not been included as specific fish habitat features.

2.3.11 Fish Habitat Reclamation

The objective of the fish habitat reclamation process is to utilize stream reconstruction and reclamation techniques to modify various stream habitat components to achieve the reclamation objectives, although this guideline does not address all elements of aquatic habitat.

The following table identifies some of the basic components of fish habitat (Saldi-Caromile 2004) that are either directly or indirectly addressed:

Fish Habitat Requirements	Directly Addressed?	Indirectly Addressed?	Design Consideration or Criteria
Ecosystem Complexity, Diversity and Change	X	X	Maintain habitat forming processes
Ecological Connectivity	X		Provide fish passage in channel design
Riparian Interactions	X		Rehabilitate the Riparian floodplain
Floodplain Connectivity	X		Rehabilitate the Riparian floodplain
Species Diversity, Adaptation and Survival		X	Build Habitat complexity Over-wintering habitat
Water Quality and Water Quantity	X		Build Channel stability
Invertebrate Production and Sustained Food-Web Function		X	

Not every natural or rehabilitated stream channel is likely to provide all of the habitat requirements of the various fish species. For example, the mobile bed forms typical of dune-ripple channel types may lack substrates of the appropriate size to form scour pools. Therefore, requiring the placement of large bed elements (e.g., boulders, large woody debris) with the intention of forming pool habitat in these channels would be inappropriate.

The following table illustrates some of the expected features of the various channel type morphologies for specified components of salmonid habitat, and typical frequency and magnitude of disturbances due to natural processes:

Channel Type	Pools	Spawning Gravel	Side Channels	Habitat Disturbance	
				Frequency	Magnitude
Dune-ripple	Moderate	None	High	High	Low
Pool-riffle	High	High	High	Moderate	Moderate
Plane-bed	Low	Moderate to High	Moderate	Moderate	Moderate
Braided	Moderate to High	High	Low to Moderate	Moderate	Moderate
Step-pool	High	Low	Low	Low	High
Cascade	Low	Low	Low	Low	High

Note: table is adapted from Buffington et al. (2003).

Stream Reclamation Design

Stream reclamation includes channel design up to the bankfull level. Draw a plan view to scale of the rehabilitated channel showing stream pattern (or channel platform), location within the floodplain and valley, locations of bed configuration (e.g., pools, riffles, glides, steps) and the locations of habitat features. Draw representative cross sections depicting the locations and

configuration of typical stream segments, bed morphology and habitat features. Provide completed Worksheets following the process described above. The information will include design criteria and the data (i.e., drainage basin size, precipitation data, design recurrence interval and discharge, valley and channel slopes, bankfull width to depth ratios, bed material sizes, etc.) used to support these criteria.

Fish Habitat Features

The selection and placement of fish habitat features is a site-specific process. It is recognized that the application of some of the recommended structures will be limited by material availability. The objective is to utilize stream reconstruction and reclamation techniques to modify the structural and functional components of stream habitat to meet the requirements of fish. The process for fish habitat reclamation described below is intended to provide only an overview of habitat features that might be incorporated when rehabilitating stream channels. There are many excellent guides that should be consulted prior to planning and implementing fish habitat reclamation projects including, but not limited to:

- Slaney, P.A., and D. Zaldokas. 1997. Fish habitat rehabilitation procedures. Watershed Restoration Technical Circular No. 9. Watershed Restoration Program. Ministry of Environment, Lands, and Parks. 2204 Main Mall, UBC. Vancouver, BC V6T1Z4.
- Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 1998. California Salmonid Stream Habitat Restoration Guidebook, 3rd Edition. California Department of Fish and Game, Sacramento, California.
- Saldi-Caromile, K., K. Bates, P. Skidmore, J. Barenti, D. Pineo. 2004. Stream Habitat Restoration Guidelines: Final Draft. Co-published by the Washington Departments of Fish and Wildlife and Ecology and the U.S. Fish and Wildlife Services. Olympia, Washington.

Fish habitat consists of several interdependent physical and biological components including:

- High flow refugia
- Over-wintering habitat
- Structural complexity on lateral margins for fry/juvenile rearing
- Food web
- Adult habitat
- Connectivity to other habitat types
- Spawning habitat
- Water quality

Spawning habitat will not be discussed in great detail in this section because streams used for spawning by salmon, trout and char require site-specific mining plans. However, some of the features incorporated in the channel designs may invoke physical processes that may lead to the creation of suitable spawning habitat for other species of fish. Water quality is also not directly addressed because a stable channel design will address water quality concerns (i.e., turbidity and suspended solids) related to placer mining.

- Connectivity to other habitat types

Many of the species that may inhabit the project area are highly migratory. In particular, the anadromous salmonids may migrate thousands of miles to and from Yukon streams. Even resident fish are highly migratory and exhibit distinct patterns of seasonal migration. For example, Ridder (1998) observed Arctic grayling using the main stem Tanana River in Alaska for over-wintering while migrations to clear water systems during the spring and summer in excess of 70 miles were observed, presumably to exploit the availability of food resources or to locate suitable spawning areas. Obstructions limiting fish access to critical stream habitats are both numerous and widespread and are considered one of the most pervasive threats to viability for many populations. Types of obstructions may be classified as those related to road construction (e.g., culverts), those related to channel alterations, and those related to changes in hydrology (increased or reduced flows). Therefore an important objective of the stream reclamation process is to retain connectivity to various habitats so that fish may access important habitats as needed.

Over-wintering habitat

In Yukon, typically those streams that are very large or are influenced by the presence of warm groundwater continue to flow during the winter months. Areas that are not completely frozen to the channel bed are vitally important to the overall survival of fish populations. Where conditions are appropriate, over-wintering habitats should be added as a feature of channel design.

Structural complexity on lateral margins for fry/juvenile rearing

Because habitat requirements for fish species vary with shape, size, and age, structurally complex stream channels are more likely to meet the requirements of multiple species and life stages than structurally simple channels. However, structural complexity is especially important for fry and juvenile fish in the early stages of development when their swimming abilities have not yet fully developed when compared to their adult counterparts. As such, they are frequently associated with shallow, low-velocity areas on the lateral margins of the stream channel. These areas provide refuge from velocities that may exceed swimming capabilities, minimize energy expenditures resulting from swimming effort, and avoid exposure to predators.

Experimental increases in the number of large wood pieces and boulders, and thus velocity refuges, along the lateral margins of small streams in the Oregon Cascades was shown to increase both the growth rate and biomass of juvenile cutthroat trout (Moore and Gregory 1988a, Moore and Gregory 1988b).

In large river systems, habitat features on the lateral margins of the channel can be especially important for juvenile salmonids (Beechie et al. 2005). These edge unit types include the stream banks, the lateral margins of exposed bars, and backwater side channels. Areas such as backwater side channels, deltas at tributary confluences, and pools on slow-moving streams often support the development of aquatic vegetation which provides refugia and foraging opportunities for a wide variety of aquatic species (Cowardin et al. 1979).

Adult rearing habitat

Adult fish are also closely associated with structural complexity (Schlosser 1991) although adults are typically able to exploit deeper, faster habitats than fry or juveniles. Stream reaches where channels have been straightened and cover and roughness elements have been removed (when compared to natural channels) typically have lower overall fish biomass, lower diversity, and altered community structure (Sedell et al. 1990). Therefore, an important component of the stream reclamation process is to provide those elements of structural diversity that maximize ecosystem functionality.

Food Web / Aquatic macro invertebrate production

The type and quantity of biologically available energy resources changes predictably with drainage area (Vannote et al. 1980) resulting in distinct behavioural and morphological adaptations in the species present. For example, most small streams derive the majority of their energy from terrestrial sources in the form of leaf litter whereas instream primary production comprises a small proportion of the total energy budget. Consequently, a high proportion of the total biomass in small streams is comprised of organisms adapted to directly consume leaf litter and its associated microbes. As flow increases, litter from terrestrial vegetation comprises a smaller proportion of the energy budget and fine particulate organic matter becomes an increasingly important component of the food web. In large rivers, this change in energy resources is reflected by a change in the composition of species and functional feeding groups and a high proportion of the total biomass is comprised of organisms adapted to utilize smaller particles of decomposed material.

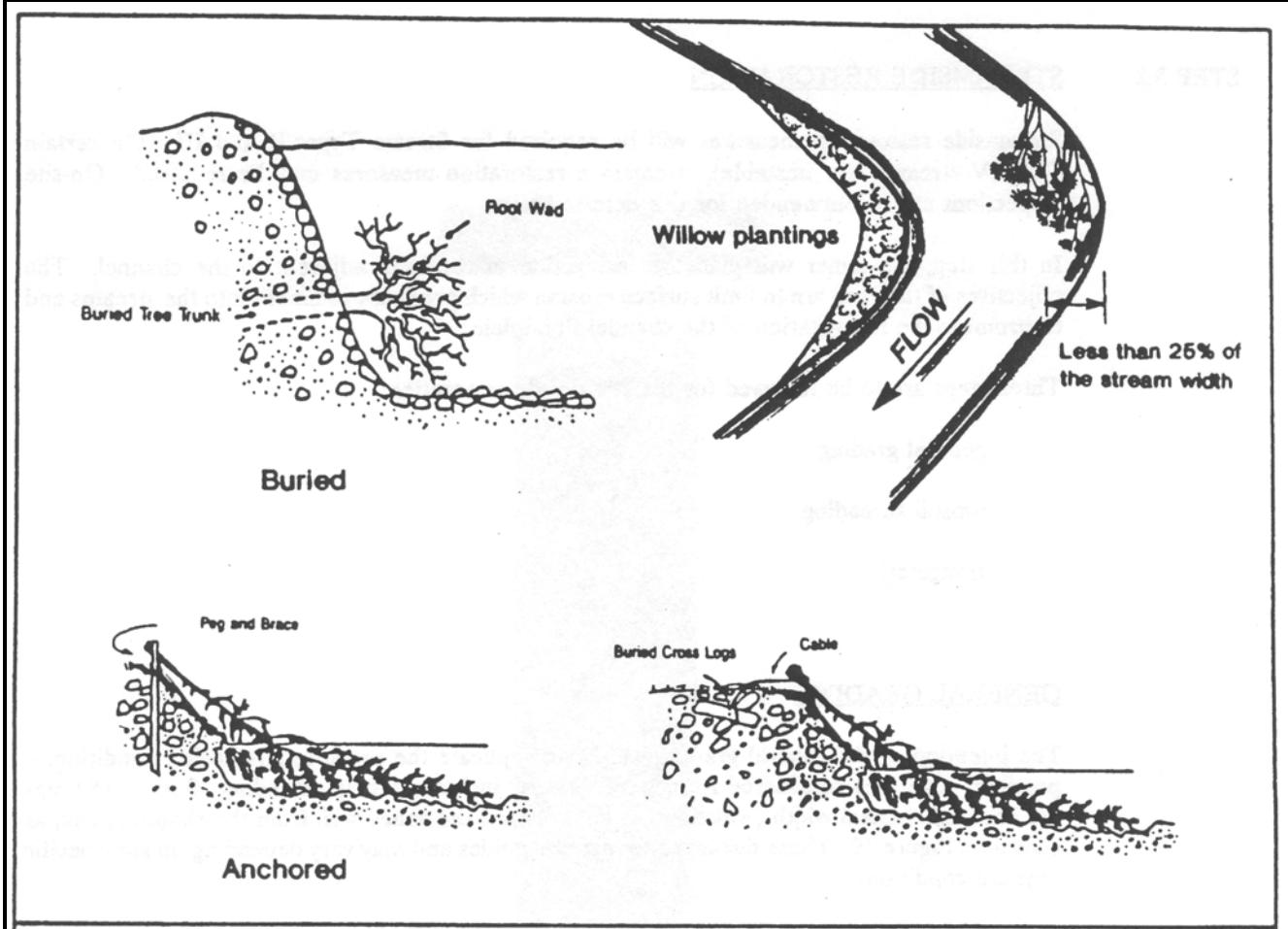
This Guidebook does not provide design criteria to address food web dynamics. However, it is assumed that the design elements described in this Guidebook will improve the structural and functional aspects of stream channel and, if correctly implemented, will result in measurable difference in relevant indicators (e.g., biomass, diversity, etc.) when compared to unimproved simplified or degraded channels.

The following table outlines potential habitat features by channel type morphology and habitat sensitivity classification.

Table - Potential Habitat Features Menu

Potential Habitat Features Menu							
Fish Habitat Sensitivity Classification	Objective	Dune-riffle	Pool-riffle	Plane-bed	Braided	Step-pool	Cascade
Moderate-Moderate Moderate-Low	High flow velocity refugia	<ul style="list-style-type: none"> Access to floodplain during high flows reduces the potential for erosion 	<ul style="list-style-type: none"> Large woody debris Side channels, alcoves, backwaters Rock islands, boulder groupings Access to floodplain during high flows 	<ul style="list-style-type: none"> Access to floodplain during high flows Rock islands, boulder groupings 	Access to floodplain during high flows		N/A
	Over-wintering habitat		Roughness elements that promote the formation of pools (e.g., large woody debris, rock islands, boulder groupings, etc.)	Roughness elements that promote the formation of pools (e.g., large woody debris, rock islands, boulder groupings, etc.)	Roughness elements that promote the formation of pools (e.g., large woody debris, rock islands, boulder groupings, etc.)	Roughness elements that promote the formation of pools (e.g., large woody debris, rock islands, boulder groupings, etc.)	N/A
	Structural complexity on lateral margins for fry/juvenile rearing	<ul style="list-style-type: none"> Overhanging Vegetation Undercut banks Substrates for macrophytes 	<ul style="list-style-type: none"> Roughness elements on the lateral margins such as small boulders, wood pieces, etc. Overhanging Vegetation Side channels, alcoves, backwaters 	<ul style="list-style-type: none"> Roughness elements on the lateral margins such as small boulders, wood pieces, etc. Overhanging Vegetation 	<ul style="list-style-type: none"> Roughness elements on the lateral margins such as small boulders, wood pieces, etc. Side channels, alcoves, backwaters 	Roughness elements on the lateral margins such as small boulders, wood pieces, etc.	N/A

Potential Habitat Features Menu							
Fish Habitat Sensitivity Classification	Objective	Dune-riffle	Pool-riffle	Plane-bed	Braided	Step-pool	Cascade
Aquatic macro-invertebrate production	Aquatic macro-invertebrate production	Overhanging vegetation	<ul style="list-style-type: none"> • Overhanging vegetation • Riffle construction 	Overhanging vegetation	Overhanging vegetation	Overhanging vegetation	N/A
	Adult habitat		Roughness elements that promote the formation of pools (e.g., large woody debris, rock islands, boulder groupings, etc.)	Roughness elements that promote the formation of pools (e.g., large woody debris, rock islands, boulder groupings, etc.)	Roughness elements that promote the formation of pools (e.g., large woody debris, rock islands, boulder groupings, etc.)		N/A
	Adult (non-anadromous) spawning		Pool tail outs for spawning				N/A
	Connectivity to other habitat types		Channel geometry provide sufficient width and depth for passage	Channel geometry provide sufficient width and depth for passage	Channel geometry provide sufficient width and depth for passage	Channel geometry provide sufficient width and depth for passage	N/A
Low	Connectivity to other habitat types		Channel geometry provide sufficient width and depth for passage	Channel geometry provide sufficient width and depth for passage	Channel geometry provide sufficient width and depth for passage	Channel geometry provide sufficient width and depth for passage	
Water Quality Zones	Channel stability						



PURPOSE:

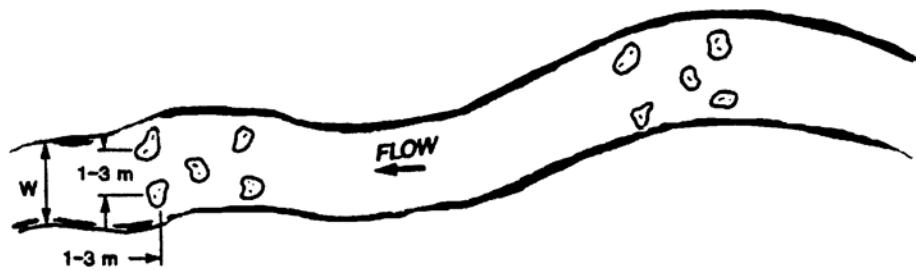
- By providing velocity breaks and protection from predators, improve rearing habitat.

DESIGN:

- Incorporate with rock islands and boulder groupings if possible.
- For meandering streams, use only on the outside of a bend. May be used on either side of straight channel.

CONSTRUCTION:

- Use birch and spruce if possible. Alder, cottonwood and aspen should be avoided.
- Anchor trees as shown.
- Branches should trail downstream.
- Not to occupy more than 25% of the total channel width.
- Preferable to construct in the fall so trees will freeze into the bank prior to the spring freshet.



PURPOSE:

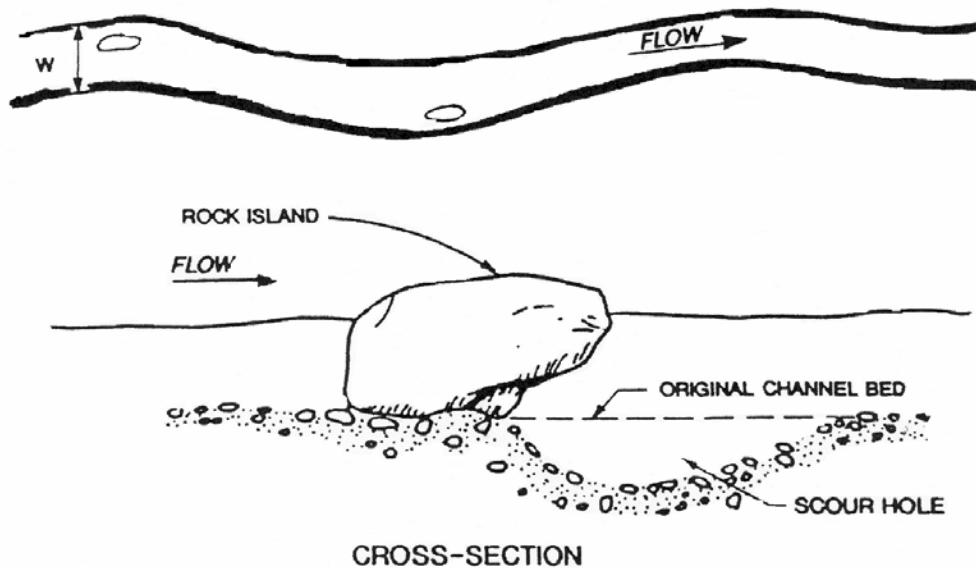
- Similar in purpose to a rock island. Used in wider streams.

DESIGN

- Boulder Spacing along the stream as shown. Optimum Location same as rock islands.
- Spaces between the boulders as shown.
- Use largest boulders available provided they meet the spacing criteria shown and less than 25% of the width of the stream.

CONSTRUCTION:

- Same as rock island.
- Individual gobions may be placed in the channel to simulate a boulder grouping



PURPOSE:

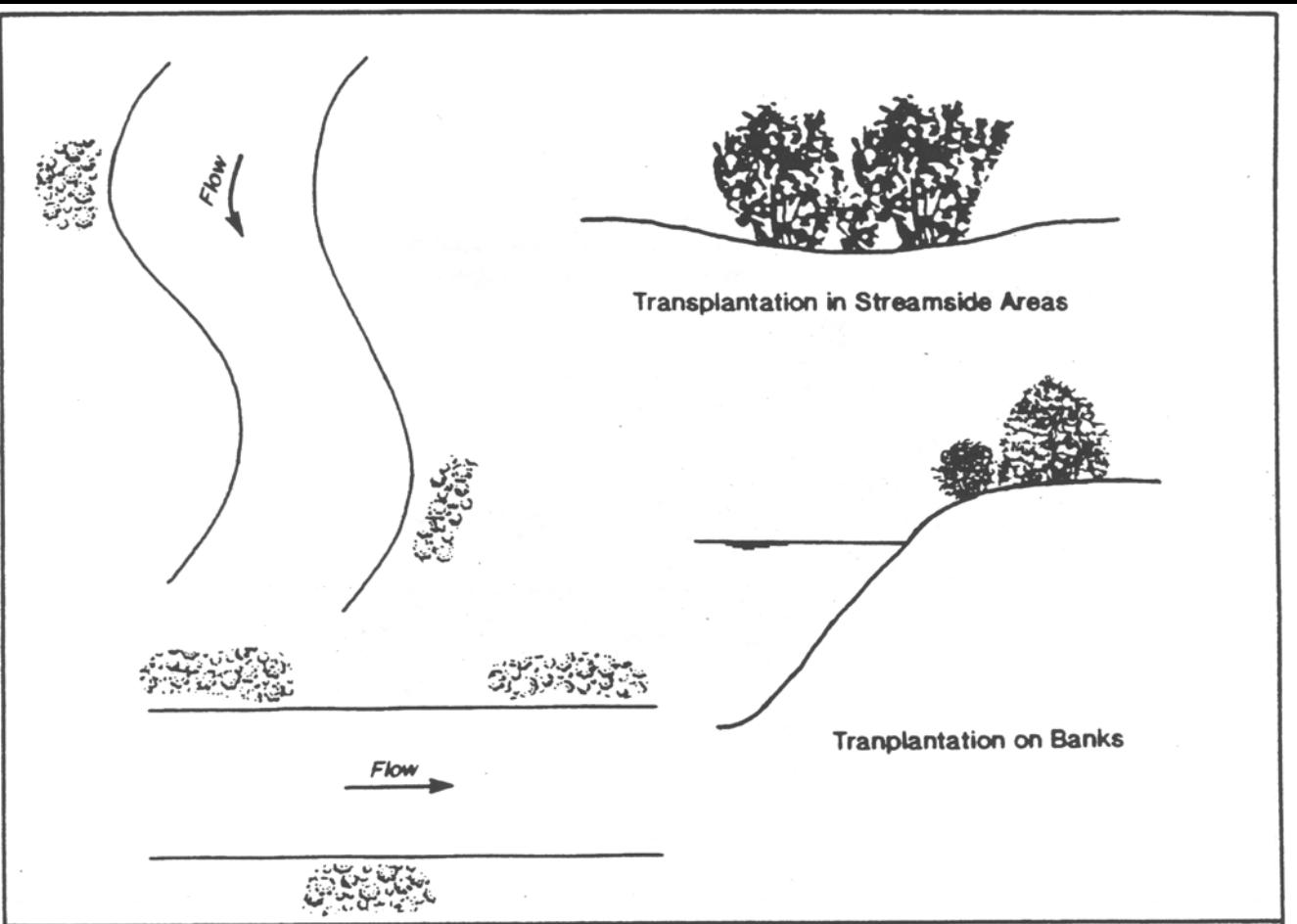
- An effective and simple means of improving fish habitat by providing a resting place and protection for fish from predators.

DESIGN:

- Boulder spacing as shown. Located near the upstream end of a shallow run or pool or in the middle and downstream portions of riffles.
- Use largest boulders available provided they are less than 25% of the width of the stream.

CONSTRUCTION:

- Set the boulder into the streambed.
- If boulders of sufficient size are unavailable, the use of individual gabions is recommended to simulate this habitat feature.



PURPOSE:

- To promote the revegetation of channel bank and streamside area by transplanting live vegetation.

DESIGN:

- Any live vegetation may be used (i.e. grasses, shrubs, small trees).
- Use anywhere in streamside areas. Use on the outside banks of bends on meandering channels and where desired on the banks of straight channels.
- Avoid transplanting large trees since the root system may be extensively damaged by this procedure.

CONSTRUCTION:

- Using a front end loader, excavate soil and vegetation from its original site and place at desired location.
- If placing material on channel banks, keep above the design water level and on a shallow slope.

Armouring of Bends and Structures

All areas subject to erosion should be armoured to prevent channel migration during flood events. Armouring should be placed on the outside of all meander bends, upstream of and through narrowing of the channel (such as at bridges) and at the inlets and outlets of culverts.

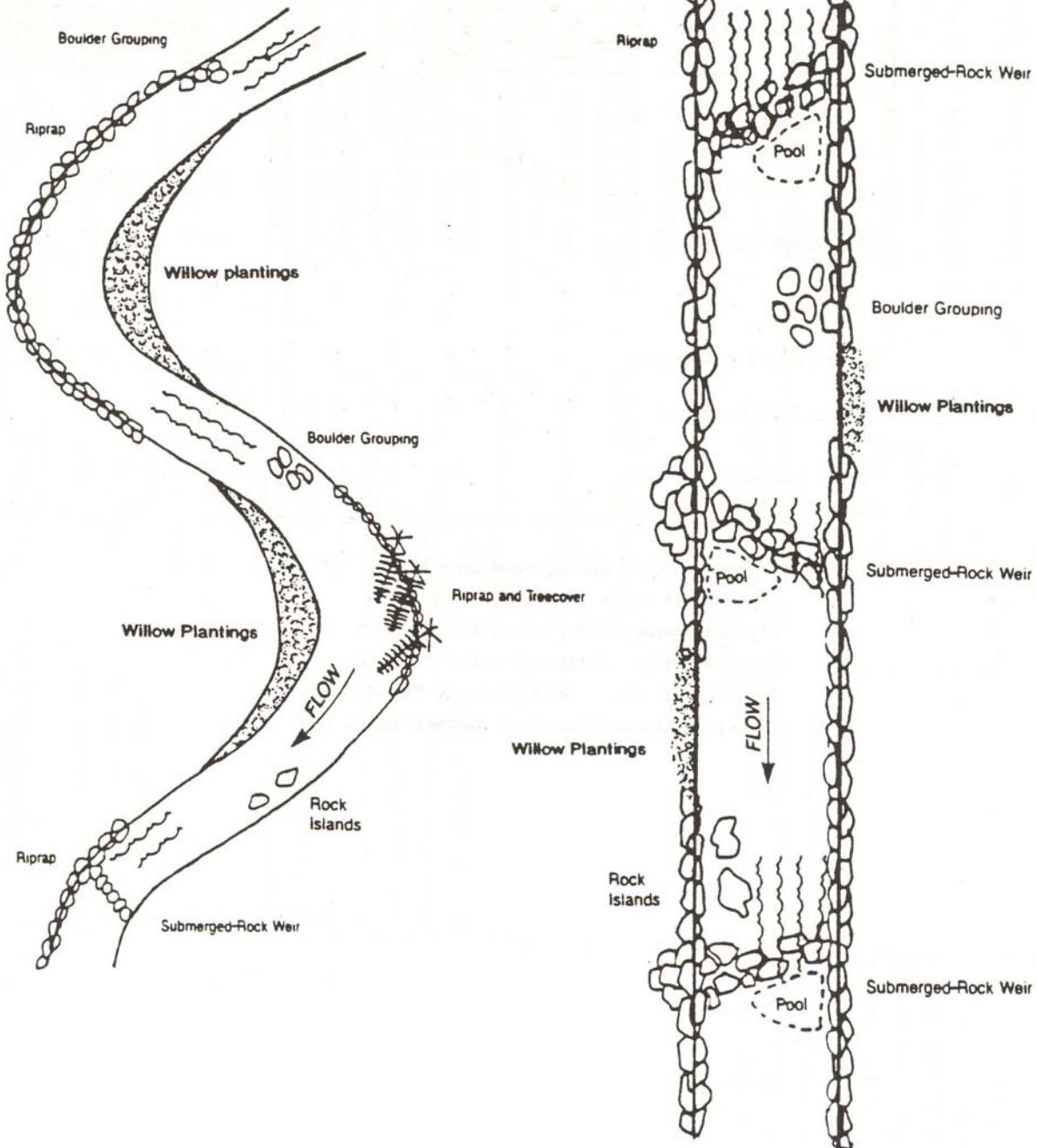
Selection of the appropriate size of armouring material is based upon the velocity of flow in the channel as follows:

Velocity of Flow for Design Flood	Rip Rap Class
<3 m/s	1
3 to 4 m/s	2
4 to 4.7 m/s	3

Stone sizes for the riprap classes and recommended armouring techniques are presented below:

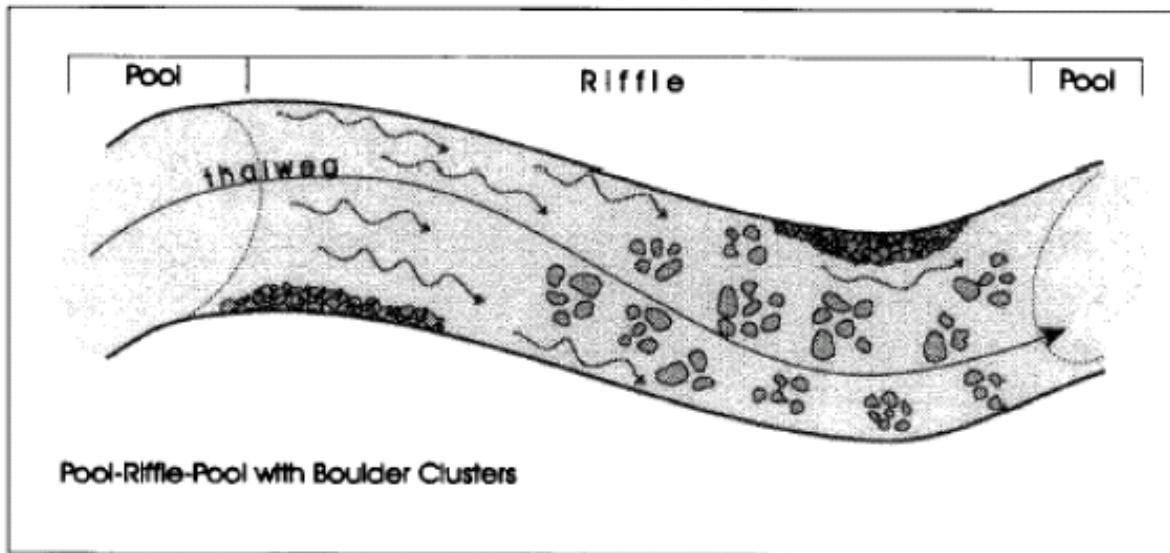
	Riprap Class					
	1		2		3	
	mm	inches	mm	inches	mm	inches
Maximum stone size	450	18	800	32	1200	47
Average stone size	300	12	500	20	800	32
velocity	< 3 m/s		3 to 4 m/s		4 to 4.7 m/s	

In the absence of appropriately sized material for armouring (i.e. boulders/cobbles), an alternate bank armouring technique using trees and brush may be suitable.

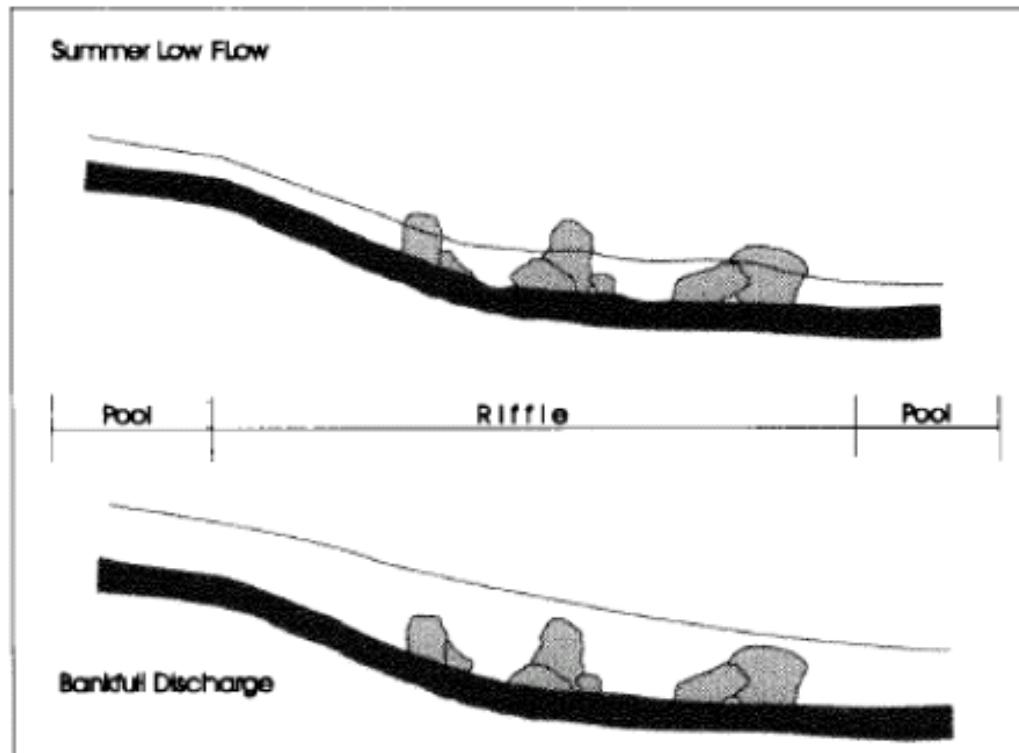


STRAIGHT CHANNEL

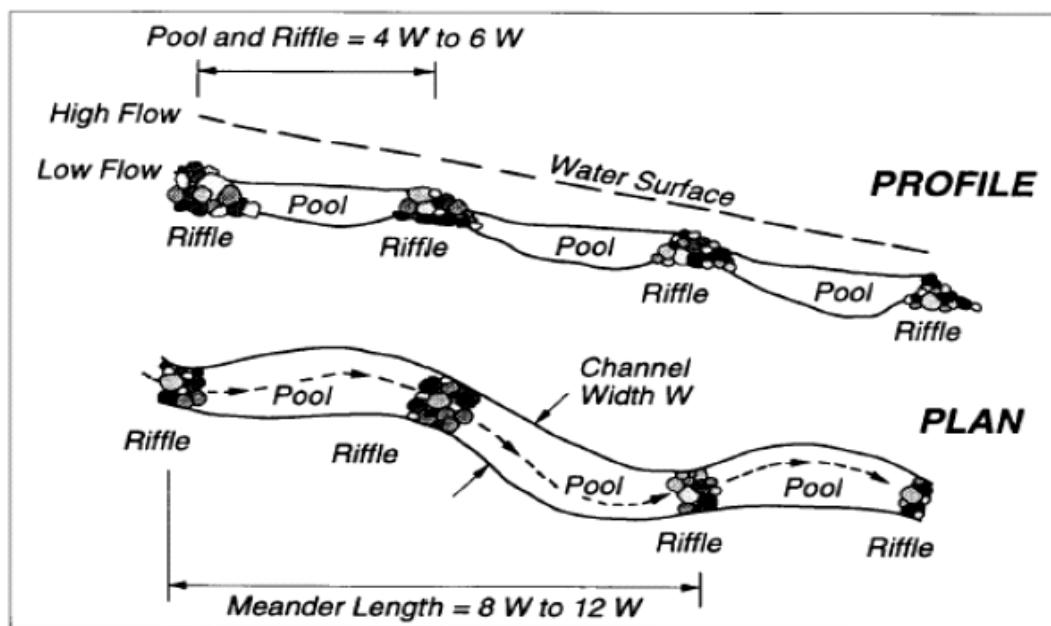
An overhead and longitudinal view of a stream riffle with boulder clusters added is shown in the following figure:



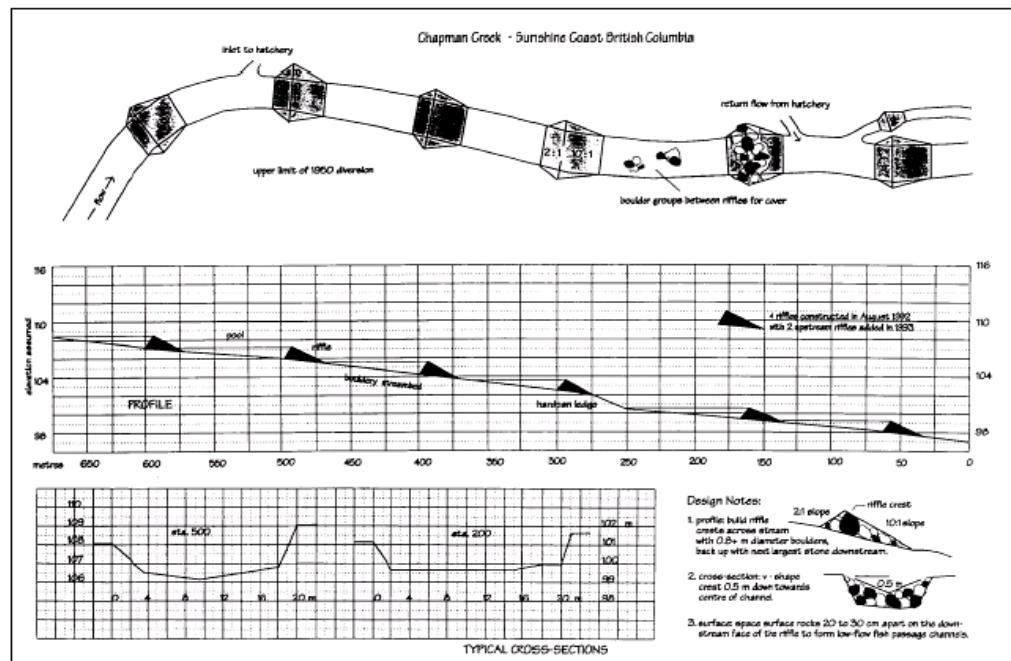
The following figure shows a longitudinal view portrayed at summer low flow and during bankfull discharge, to indicate the hydraulic forces which shape the rehabilitated areas (Figure 10.5, from Ward 1997).



Pool and riffle profiles are formed in erodeable channels with an average spacing of 6 times the bankfull width. In steeper streams, and where logs and tree roots are abundant, spacing decreases (Figure 12-5, from Newbury et al. 1997).



The following diagrams show a condensed plan and profile drawings for riffle construction (Figure 12-14, from Newbury et al. 1997) and a condensed plan and profile drawings for rock rapid construction in step-pool channel (Newbury et al. 1997)



Floodplain and Riparian Area Reclamation

The objectives of the floodplain and riparian reclamation process are to:

- Stabilize floodplain materials;
- Promote rapid recovery and establishment of vegetation communities; and
- Re-establish the structural and functional aspects of riparian zones.

Gregory et al. (1991) defined riparian zones as “the three-dimensional zones of direct interaction between terrestrial and aquatic ecosystems. Boundaries of riparian zones extend outward to the limits of flooding and upward into the canopy of streamside vegetation.” By this definition riparian zones include the full extent of the floodplain. For small streams or for confined high gradient streams, however, the riparian zone may extend far beyond the lateral extent of the floodplain. The terms riparian and floodplain occur in combination throughout the text of this document. Where riparian occurs singly, the inclusion of floodplains is implied.

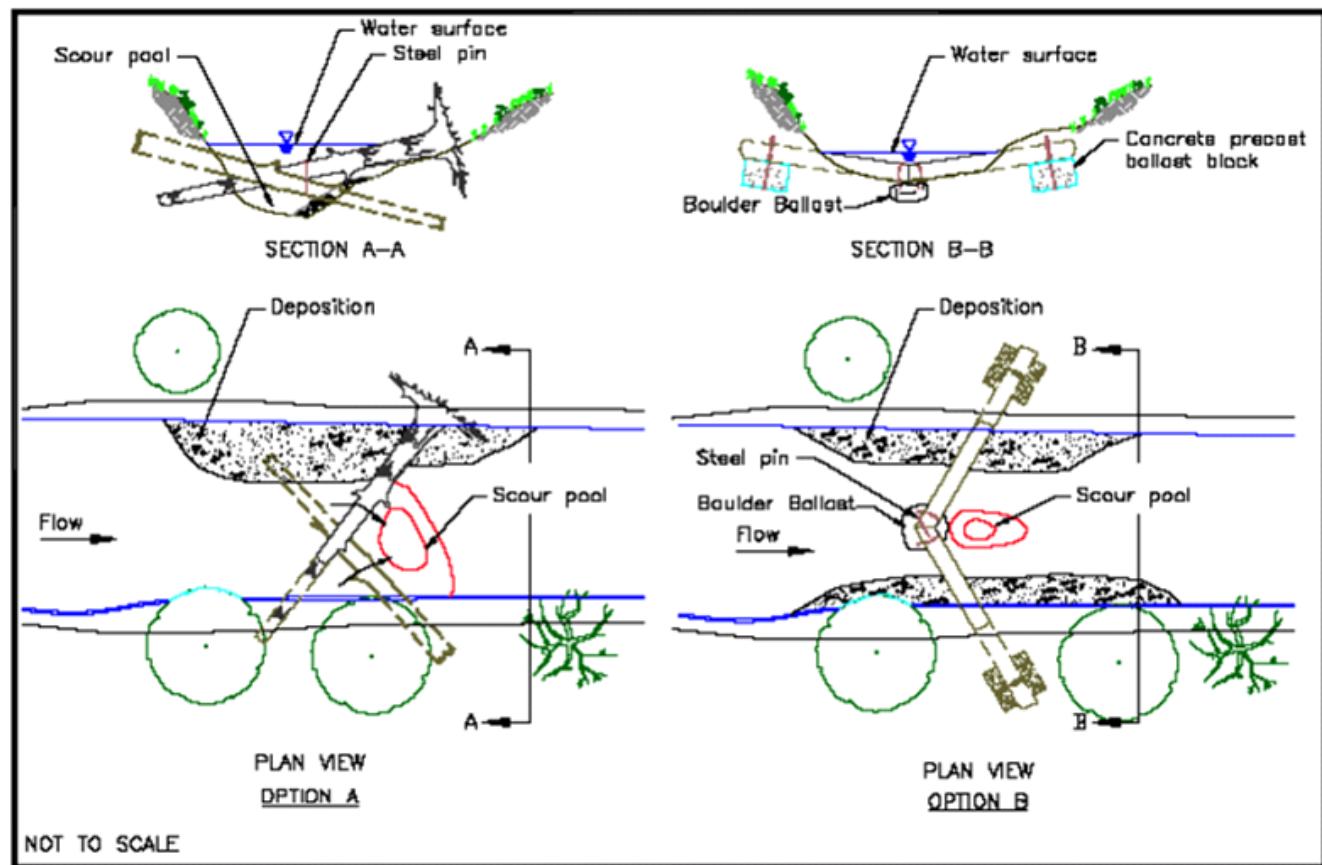
Seasonal changes in discharge (including the effects of break-up and freeze-up) may increase or decrease the lateral extent of the stream. The likelihood that areas on the margin of a stream will be inundated decreases as elevation and distance from the low flow channel increases. Species composition in the lateral dimension reflects the magnitude, intensity, and duration of flood disturbance (Gregory et al. 1991). For example, vegetation within the active channel may consist of only flood tolerant grasses and herbs. Species in close proximity to the active channel may consist of deciduous shrubs and relatively young stands of trees (e.g., willows and alders). With increasing distance from the channel, forest stands may increase in age and the proportion of flood tolerant species decreases. In areas of permafrost, flood tolerant species are generally not present. Junk et al. (1989) and Bayley (1995) suggest that seasonal flood pulses that inundate floodplains of large rivers (i.e. relative size of Klondike or Yukon Rivers) facilitate the exchange of key nutrients, enhance productivity, and maintain biological diversity.

Because of the high number of species that use riparian zones for all or a portion of their life history, researchers have identified these areas as key to the conservation of biodiversity (Gregory et al. 1991; Naiman et al. 1993).

The objective is to stabilize floodplain materials and promote the rapid recovery and establishment of vegetation communities in order to re-establish the structural and functional aspects of riparian zones.

Flood disturbance (i.e., the timing, frequency, and duration of inundation) is one of the primary factors controlling the distribution of plant species in the riparian zone. With increasing distance and elevation from the active channel, the likelihood of inundation decreases. Consequently plant species have adapted to this continuum of hydrologic conditions with some plants able to tolerate prolonged inundation (e.g., bulrushes and sedges), other plants (e.g., willow, alder, dogwood) able to tolerate intermediate conditions, and still others (e.g., spruce, aspen) best adapted to upland conditions.

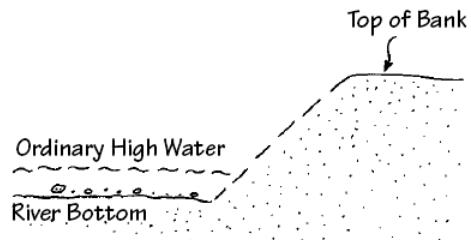
Floodplain and riparian area reclamation includes channel design above the bankfull level to the limits of mining disturbance. Describe the timing and methods for rehabilitating and stabilizing settling pond systems, drainage-control structures and general site topography including slopes, terraces, sediment basins, overflow channels and other relevant features. Prepare plan, end and side views of drainage control structures that will remain on site. Prepare a map depicting the layout of all rehabilitated and natural features, including the re-distribution of stockpiled material and re-vegetation efforts.



Vee log sills conceptual design (Figure 16, from Saldi-Caromile et. al. 2004).

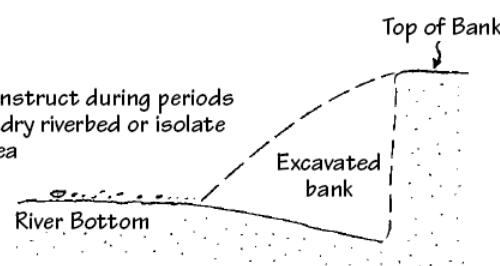
Root Wads Step-by-Step

①



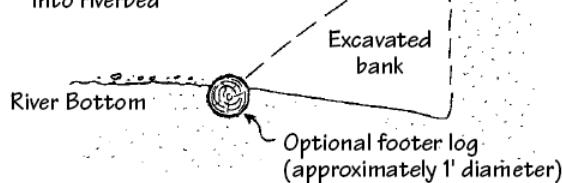
②

Construct during periods
of dry riverbed or isolate
area



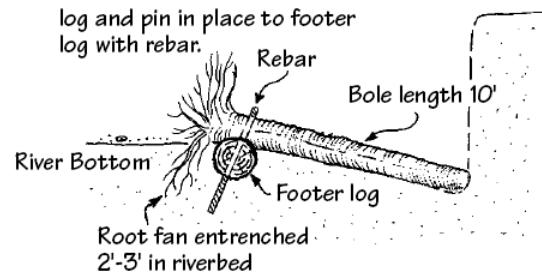
③

Entrench footer log
into riverbed



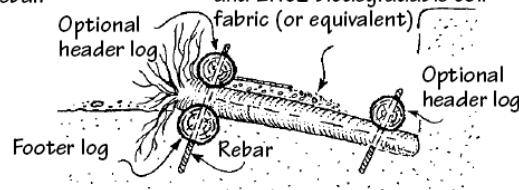
④

Place root wad; drill through
root wad trunk and footer
log and pin in place to footer
log with rebar.

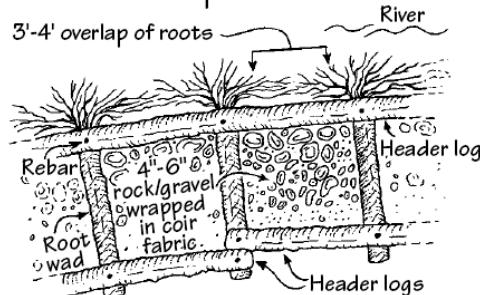


Steps 1 to 4: Root wad stream bank protection process from Walter and Hughes (2005).

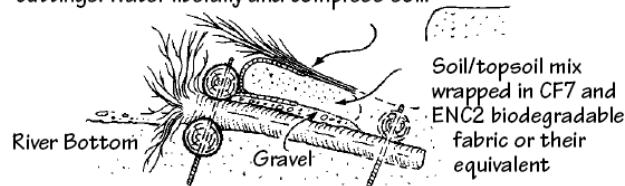
- ⑤ Pin root wad trunks to header and footer log with rebar.



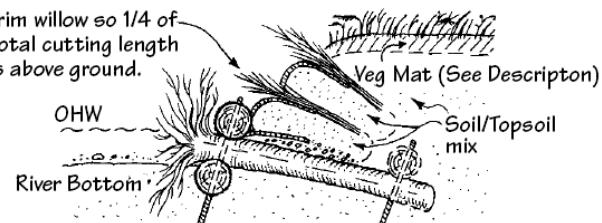
Top View



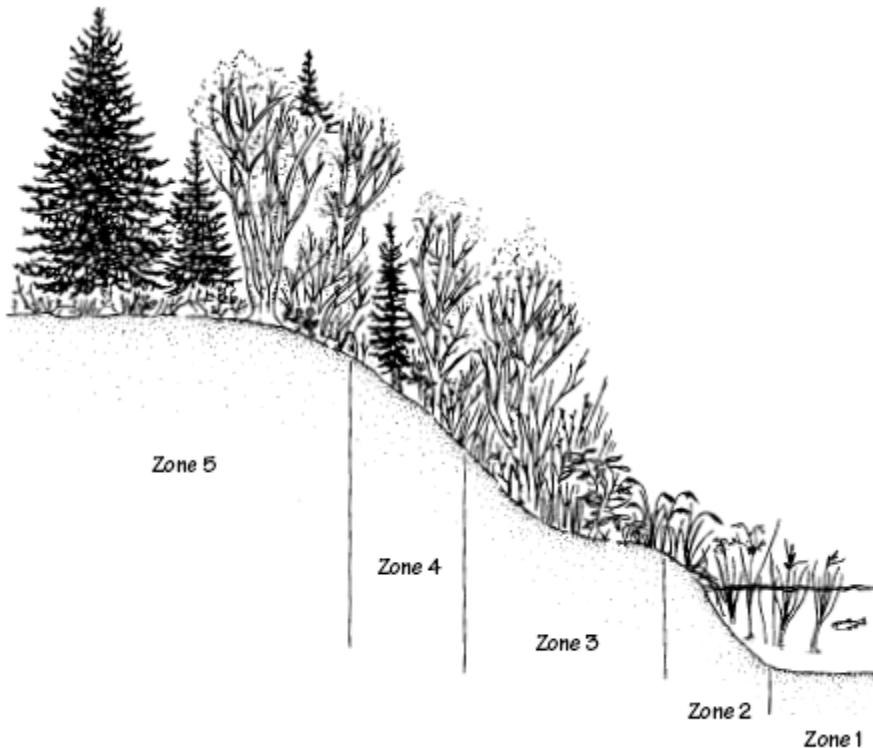
- ⑥ Install dormant cuttings 15 stems per linear foot over wrapped soil. Deposit layer of top soil over cuttings. Water liberally and compress soil.



- ⑦ Repeat step 6 until desired height of bank is reached



Steps 5-7: Root wad stream bank protection process from Walter and Hughes (2005).



Conceptual diagram illustrating zonation of plant species in riparian zones (Walter et al. 2005).

Because riparian zones are an important component of channel stability (Knighton 1988) and because channel stability is the primary objective of the stream reclamation process, many riparian techniques apply equally to all fish habitat suitability classifications.

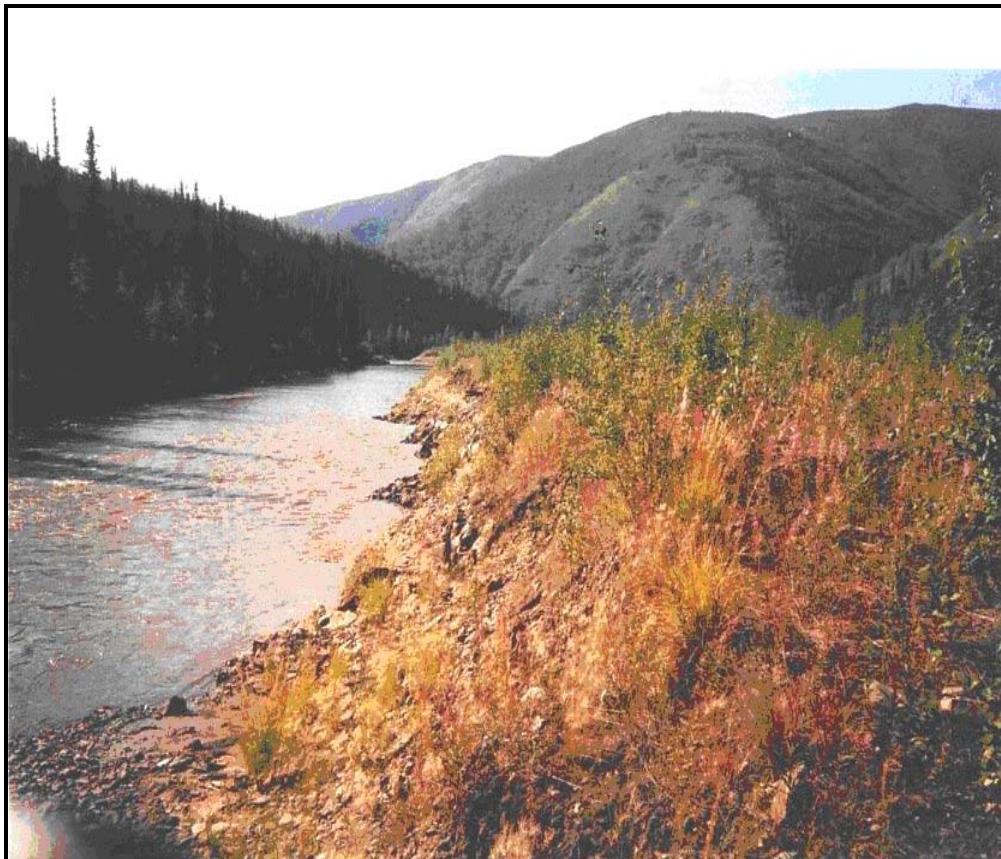
Riparian (Stream Side) Areas

A strip should be developed along each bank (riparian area) to help jumpstart the re-establishment of vegetation. The area should be graded to a low angle (less than 5% in any direction) in order to limit runoff. If the 5% guideline must be exceeded, the surface should be roughened parallel to the slope.

This stream side area should be surfaced with at least 12 inches (30 cm) of fine-grained material – thicker placements are also suitable. Organic overburden is preferred, as it will re-vegetate quickly and retains soil moisture. If the organic overburden has been stripped and stockpiled during the mining process, it will probably have supported a community of native plants. When the stockpiled organic overburden is spread on the riparian area, the roots, seeds, etc. will soon provide a ground cover. The moist soil conditions also provide an excellent medium for wind-borne seeds from local plants and trees. Machine placement of root masses, woody debris and salvaged plant materials is highly recommended. Bioengineering methods for stream bank stabilization can also be used in problem areas.



Channel side armouring and bank restoration using stockpiled organics and groynes.



Same channel after six years.

3.0 LEGISLATION

3.1 Legislative and Policy Context

The purpose of the Fish Habitat Management System for Yukon Placer Mining is to provide an integrated structure that will allow the three levels of government to satisfy their responsibilities under a variety of legislation and other legal and policy requirements.

3.2 Key Legislation, Policies and Agreements

The habitat management system will satisfy and integrate the requirements of key federal, territorial and First Nation legislation, policies and agreements.

3.2.1 Fisheries Act

The *Fisheries Act* is the primary legislation regulating the protection of fisheries resources and their supporting habitat. The Act's principal habitat protection provisions that apply to placer mining are Section 35 concerning the harmful alteration, disruption or destruction (HADD) of fish habitat and Section 36 concerning the deposit of deleterious substances. Other sections may also apply, including those dealing with sufficient flows for fish, fish passage, intake screening and the killing of fish other than by fishing. In particular, the management system for Yukon Placer Mining manages sediment pursuant to section 35, which states:

- (1) *No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat*
- (2) *No person contravenes subsection (1) by causing the alteration, disruption or destruction of fish habitat by any means or under any conditions authorized by the Minister or under regulations made by the Governor in Council under this Act.*

3.2.2 Yukon Environmental and Socio-economic Assessment Act (YESAA)

Under this legislation passed in May 2003, the three levels of government established a new development assessment process that has replaced the *Canadian Environmental Assessment Act* (CEAA) process in the Yukon. YESAA provides for the integration of traditional knowledge (TK) and establishes a single, impartial assessment process throughout the territory. The management system for Yukon placer mining must be compatible with this assessment process as it is implemented in the territory.

YESAA requires the environmental and socio-economic assessment of placer mining projects prior to licensing. Activities governed by watershed authorizations and requiring water use licenses, and placer mining land use approvals will require an evaluation under YESAA, as well as activities that require site specific authorizations under the *Fisheries Act*.

3.2.3 Waters Act

Most placer operations must obtain a Water Use License issued by the quasi-judicial Yukon Water Board (YWB) pursuant to the *Waters Act*. The Board has broad discretion to set terms and conditions of the license. Recommendations from the YESAA review and requirements of the watershed authorization established under the placer regulatory regime will be provided to the Board to ensure that habitat requirements are clearly articulated for miners and harmonized with the Yukon regulatory process.

3.2.4 Placer Mining Act

The *Placer Mining Act* directs the disposition of mineral rights and title and establishes regulations for land use activities that are inspected and enforced by YG mining inspections staff. These land use regulations serve as mitigation for the integrated regulatory regime.

The Act includes a requirement for an approved placer mining land use Operating Plan. The responsibility for administering Class 4 placer mining land use plans has been delegated to the YWB.

3.2.5 Habitat Management Policy

DFO's *Policy for the Management of Fish Habitat*¹ provides the context and guidance for implementing the habitat protection provisions of the *Fisheries Act*. For the fish habitat management system, it is the reference point for maintaining rigor, consistency and effectiveness. In keeping with the policy, DFO's objective is to ensure "No Net Loss" of productive capacity of fish habitat and to improve habitat protection, with the long-term goal of a net gain in habitat on a watershed level basis. Best management practices, habitat compensation and restoration are the primary means by which these goals will be achieved under the system.

3.2.6 Wild Salmon Policy

The draft *Wild Salmon Policy* aims to restore and maintain healthy and diverse salmon populations and their habitat for the benefit and enjoyment of Canadians². Conservation is the first priority for resource management decisions and those decisions should balance biological, social and economic considerations. An important requirement of the policy is the preparation of long-term strategic plans that will integrate fisheries, habitat, other land and water uses, and social and cultural values. Elements of the management system, such as the indicators to monitor watershed health, will help in developing these plans for the Yukon.

3.2.7 Land Claims Agreements

The system is designed to be consistent with the Umbrella Final Agreement and First Nation Self Government Agreements. This is accomplished in a number of ways, including the requirement for active First Nation/community involvement in the design of the watershed authorizations, the application of legislative requirements that flow from the Umbrella Final Agreement (including YESAA) and provisions of the *Waters Act*. The Yukon Fish and Wildlife Management Board is mandated by the Final Agreements to be the primary instrument of fish and wildlife management in the Yukon. The Salmon sub-Committee is mandated to be the main instrument of Salmon management in the Yukon.

¹ DFO (1986), *Policy for the Management of Fish Habitat*.

² DFO (2004), *A Policy Framework for Conservation of Wild Salmon*.

3.2.8 Smart Regulation

The fish habitat management system incorporates recommendations from the final report of the External Advisory Committee on Smart Regulation (EACSR) titled *Smart Regulation: A Regulatory Strategy for Canada*.

The EACSR was established to provide external advice to the Federal Government on how the government could redesign its regulatory system to better serve the needs of Canadians. Many of the features of this management system are consistent with recommendations of this report, including:

- Federal and Territorial Regulatory Cooperation reflected in the creation of the Secretariat to implement this management system.
- Focus on results, as reflected by monitoring, inspection and enforcement;
- Emphasis on risk management that includes risk prioritization, risk assessment, communication and consultation.

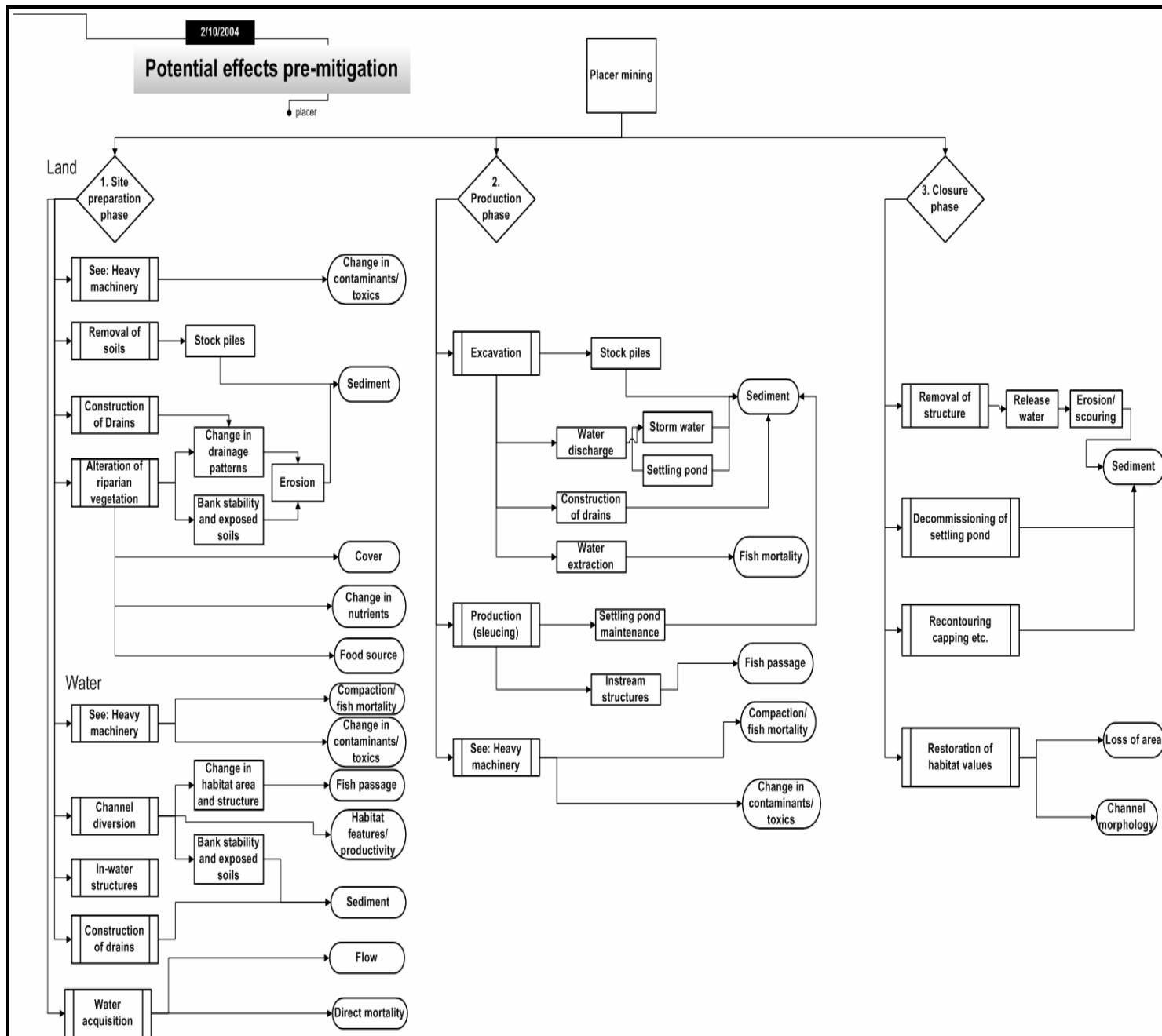
Smart Regulation is about finding better, more effective ways to provide a high level of protection to Canadians, promote the transition to sustainable development and foster an economic climate that is dynamic and conducive to innovation and investment. It must exist in a system that sets clear policy objectives and is transparent and predictable - one that builds public trust in the quality of Canadian regulation and the integrity of the process. The recommendations contained in *Smart Regulation: A Regulatory Strategy for Canada* provide guidance on how to achieve these goals.¹

3.2.9 Environmental Processes Modernization Plan (EPMP)

This fish habitat management system is part of a major initiative by DFO to contribute to a more efficient and effective delivery of its regulatory responsibilities consistent with the principles of sustainable development and smart regulation. It includes a new science-based risk management approach to properly address the various risks to fish habitat presented by various projects. Fundamental tenants of the EPMP are reflected in this system through the risk-management framework; streamlining practices through watershed authorizations; improving coherence and predictability by creating authorization templates in advance with pre-determine regulatory requirements; and a renewed emphasis on partnerships through implementation by the Secretariat.

Table – Pathway of Effects

The pathway of effects model illustrates the cause and effect relationship for activities related to the various phases of a placer mining operation. Mitigation measures identified in the authorization are intended to reduce or eliminate these cause and effect relationships. Four activities have been identified where residual or “left over” effects to fish and fish habitat remain after mitigation measures are applied: **diversion channels, instream works, water acquisition, and settling pond discharge (effluent concentration)**.



4.0 INTRODUCTION TO MINING METHODS AND PRIMARY ISSUES

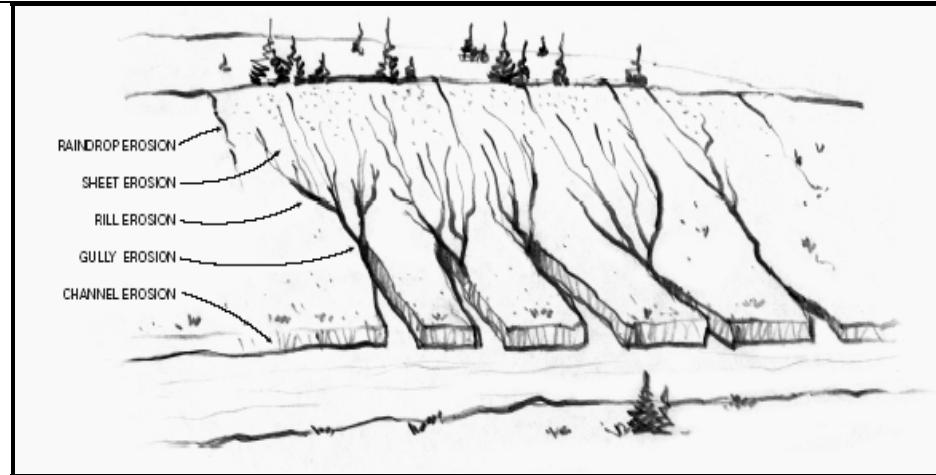
4.1 Runoff, Erosion and Sediment Control

Untreated discharge of mine effluents containing high levels of sediment from placer mining operations may result in a number of negative impacts to fish habitat and fish populations. Effluent standards are put in place for each mining operation in order to protect fish and fish habitat from potentially harmful effects. In order to manage these effects, placer mines must abide by the effluent standards assigned to their operation, in addition to the applicable placer mining land use and water use requirements.

Both point and non-point sources of sediment releases generated from placer mining activities are managed using a risk-based approach within the habitat management system. An integral component of this risk management approach is the initial application of the Pathway of Effects (Pathway of Effects) model to identify where technically and economically feasible mitigation is available to eliminate or avoid adverse effects *before* consideration of risk management related to residual effects. For the Yukon placer mining industry, the Pathway of Effects model demonstrates that specific operating conditions can be applied to prevent or minimize sediment release from non-point sources (e.g. land use activities) into fish-bearing waters.

Controlling the release of sediment at placer mine sites can be divided into two categories: controlling the sediment source with erosion control techniques; and controlling the release and transportation of sediment in water flow, either instream or in process water with settling facilities and discharge controls. The following discussion describes the relative risk of sediment releases resulting from mining activities. Later sections in this Guidebook provide the recommended measures to mitigate the likelihood of sediment releases associated with these activities.

Understanding runoff and soil erosion processes is the first step in controlling sedimentation. The main environmental effects of placer mining have to do with the erosive force of water and the fact that fine particles of soil get transported into streams and rivers. This *sediment load* below placer mines comes from two sources; the settling pond effluent itself and general *runoff* over the whole mine drainage and adjacent un-mined areas. The latter *non-point source sediment* can have more of an impact on downstream water quality than settling facilities. Excessive *sedimentation* (build-up of soil particles in the water and along the stream bed) will result if runoff and erosion are not controlled. The first step is to work out a system of diversion ditches or channels and drains to control runoff and slow down erosion. Placer miners have to take measures to ensure that excess sediment is *not* routinely leaving the site and entering the stream.



This sketch shows the five main types of soil erosion caused by runoff. **Splash (raindrop) erosion** is the detachment of soil particles from the impact of raindrops. **Sheet erosion** is the constant removal of thin layers of soil from sheets of water flowing across a slope. **Rill erosion** is soil being removed by water flowing through small sporadic shallow channels. **Gully erosion** is an advanced stage of rill erosion that happens when rills become enlarged and form gullies, which are longer-lived, deeper channels. **Stream channel erosion** includes the removal of soil along channel banks and riparian areas, as well as the scouring of sediment from the channel bed. These last two forms generate the most sediment.

It is much easier and less expensive to control splash, sheet and rill erosion than it is to stop gullying and stream channel erosion once these processes have begun.

There are two general strategies to control erosion: 1) use the coarsest available materials (rock) to control the force of water, and 2) actively use plant growth in combination with machine work to control erosion. The first strategy may include the use of rock for:

- covering slopes that are difficult to re-vegetate;
- lining ditches that might easily erode;
- weighing the toe (bottom) of slopes to prevent slope failure;
- protecting stream crossing structures;
- protecting outlet areas such as culverts and drainage ditches from scour; and
- protecting stream banks.

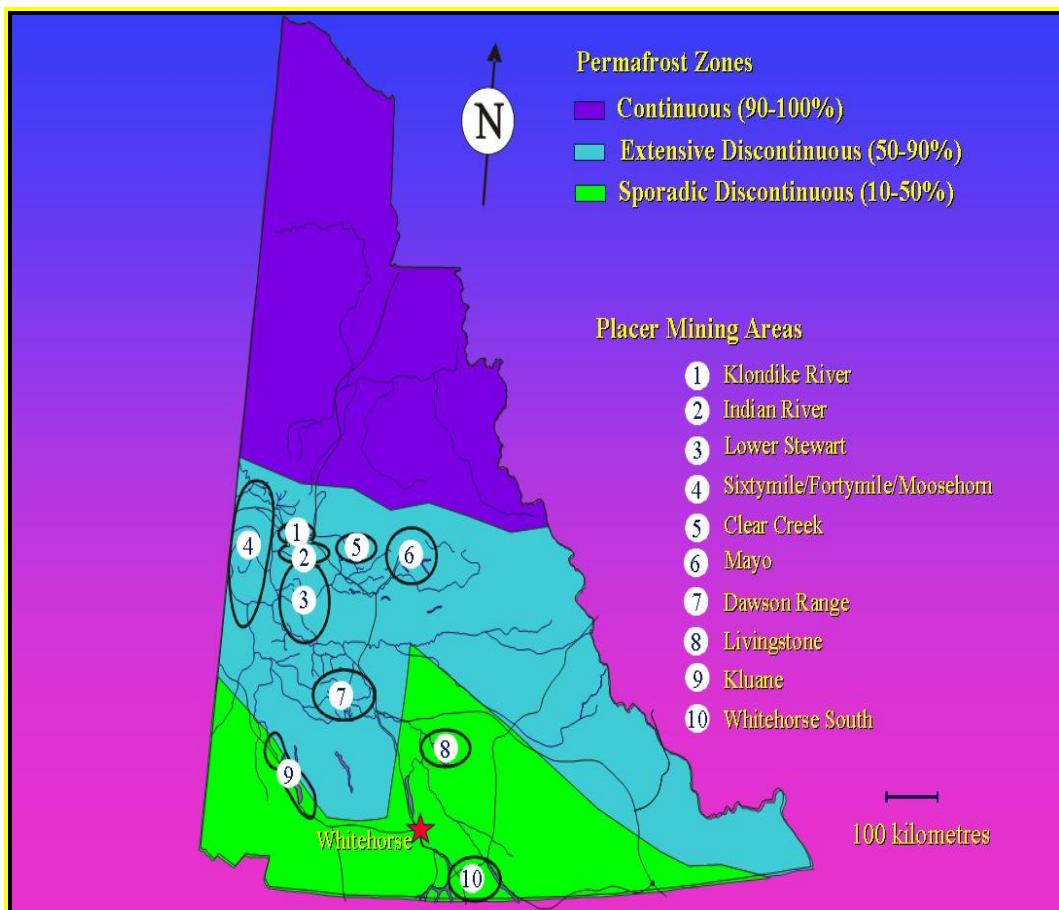
Hill slope, bank failures and other mass wasting processes can also lead to significant sediment contribution to streams. Landslides and soil slips are common where the vegetation cover and hill slope toe have been removed – and commonly occur during break-up and heavy summer storms when precipitation and overland runoff are greatest.

Runoff control is all about controlling the erosive and sediment transport forces of water over the site. Control runoff and there will be less erosion and less costly sediment control measures. Site drainage is the key element in maintaining a stable restored placer mine site. **Erosion control** measures are meant to stop soil particles from getting loose and travelling off site. Keeping as much plant cover as possible and encouraging rapid re-growth of plants is the best defence against erosion. **Controlling sediment** is the last and hardest step because it involves storing and settling before discharge to aquatic habitats. Slowing runoff velocities or holding sediment-laden water in ponds gives gravity time to do its job. Water on slopes adds weight and decreases shear strength. Improper drainage can result in “piping” and collapse of banks.

Small ephemeral (part time) streams result from rainfall, snowmelt, or seasonal springs (groundwater discharges).

4.2 Permafrost and Placer Mining

Permafrost is an important consideration in placer mining runoff, erosion and sediment control. In many cases gold-bearing gravels are situated under a layer of permafrost which must be stripped to gain access to the pay gravel. Therefore the mining plan must account for management of permafrost soils. Rates of erosion and of re-vegetation are quite different among the mining districts depending on the amount of permafrost and climactic characteristics. The approach to erosion control and re-vegetation are different as well. For example, wet decomposing permafrost soil might respond well to natural re-vegetation methods in the Klondike, but in the drier districts, a different approach might be needed. The following map shows how placer mining is distributed among the different permafrost types in the Yukon. The vast majority of placer mining takes place in the Extensive Discontinuous Zone. Mitigation measures for dealing with frozen ground are provided in Chapter 5 of this Guidebook (largely derived from Kotler, E., 2003 - Characteristics of permafrost and ice-rich ground surrounding placer mining operations, Yukon Territory: guidelines for management practices. DFO, Management Sector, Whitehorse, Yukon)



Working with streams in permafrost requires careful planning. Streams behave differently in permafrost because it blocks the flow of water. Water can only flow under, within, or above it in unfrozen zones. When the *active layer* (the top layer of soil that thaws each year) is frozen in winter and spring, sub-permafrost water is sometimes forced to the surface in the form of springs and forms aufeis (thick icings known locally as *glaciers* or *overflow*).

Many of the ephemeral (flow only part of the year) and very small creeks in the western Yukon flow on top of permafrost. Some of these creeks may be “perched” up to 18 m above creek gravel, and flow through fine grained soil rich in ice. Disruption of these types of creeks by placer mining activities leads to accelerated melting and down-cutting of the stream channel that will have to be dealt with by the miner.

Stream diversions or simply moving heavy equipment over permafrost drainages can have a significant effect on patterns of erosion. Poorly planned stream diversions in permafrost can cause accelerated down-cutting and widening of the channel followed by gullying to the base of the ice-rich sediments, widening, undercutting and thaw slumping.

A permafrost disturbance starts to *naturally stabilize* when slump material dries out and vegetation begins to take hold. The first colonizers of this dried silt surface are moss species followed in a couple of years by Mastodon flower and isolated pods of woody plants. Within 2 to 5 years there is diverse vegetation cover with common horsetail, fireweed, wood reedgrass and knotweed. Within 5 to 9 years, the vegetation cover starts to include liquorice-root, raspberry, rose, labrador tea, birch and more willow. If left alone, the original forest floor blanket vegetation might be re established in 20 to 25 years, but at active placer mines this natural stabilization is often interrupted.

Stripping, ripping and/or monitoring permafrost soils can yield a lot of sediment. Permafrost degradation by poorly planned equipment mobilization to new areas and diverting creeks onto frozen ground can also result in sediment loading. *The amount of sediment generated from permafrost soils* depends on the type of permafrost. The worst material for generating sediment is saturated loess (black muck) such as found Quartz Creek and Last Chance Creek. This material is about 65% ice and can generate 0.35 cubic yards of silt for every bank yard monitored. Almost as bad for generating sediment is the Dago Hill muck distinguished by silt and organic material, their dark brown colour and visibly high ice content. This type will yield about 0.20 cubic yards of sediment per bank yard. The remaining types are coarse organic material and sediments with low ice content which don't yield much sediment when thawed.

The best temporary mitigation for controlling sedimentation from stripping and monitoring is to direct the thawed material to low spots or settling facilities prior to discharge into the creek. When planning a placer mine layout, an attempt should be made to *estimate how much sediment may be generated per bank yard monitored*, and provide adequate settling for that material. (Best practises for sizing settling facilities are provided later in this Guidebook). The key is to have enough capacity to hold the expected material long enough to produce an acceptable discharge. More detailed mitigation measures for permafrost soils are provided in Section 5.2.6 under Mitigation Measures for Site Preparation.

Here are some basics for dealing with permafrost:

- *Capture, dewater, re-vegetate.* Catch the thawed muck, and dry it out. Natural re-vegetation will do the rest.
- The area to be stripped or monitored should be *assessed for permafrost type and ice content*
- The mining plan should include a *good photograph of representative vegetation in all areas which are to be disturbed*.
- Keep the footprint as small as required for the job.
- Direct the thawed muck *away* from existing watercourses and dried out settling facilities. This may be accomplished by making levee structures out of coarse tailings or even trees and brush that have fallen to the base. Ultimately, this material must all be channelled into settling facilities.

- Best practises for settling facilities are presented in Chapter 5. Refer to the companion Workbook and Worksheets for details on how to prepare or review the settling pond component of an application. The amount of sediment generated will depend on the type of frozen ground. *If the ground is ice rich the ponds will need to be larger.*



4.3 Mining Methods and Valley Types

In this section drawings are provided that show typical placer mining operations in the three main types of stream valleys. Included in the descriptions of each type of mining are direct and indirect impacts on streams and appropriate restoration techniques. Where applicable, riparian reserves are discussed, placer mining affects valued environmental components other than fish and fish habitat due to its extensive disruption of the surface. While it is critical to restore streams that have been disturbed by mining, it is also important to reclaim the entire footprint of the mine site to restore biological productivity for other parts of the ecosystem.

Harmful environmental effects of sedimentation caused by placer mining are regulated through the *Waters Act* and the *Fisheries Act*. Placer mining is a regulated and licensed industry and with that comes laws and conditions that demand strict adherence by miners. Effluent standards are put in place for each mining operation in order to protect fish and fish habitats in the receiving environment from the harmful effects of sediment. To ensure compliance, and consequently avoid being subjected to prosecution operators must abide by the effluent standard assigned to the operation.

There is no question that excessive sedimentation is harmful to the aquatic environment so controlling it is simply the right thing to do. Excessive erosion and sedimentation from placer mining can result in stiff penalties. Some of the environmental impacts include changes to the channel shape and form (morphology), stream substrates, the structure of fish habitats, and the structure and abundance of fish populations. The amount and quality of aquatic habitats available for all aquatic life depend on the physical characteristics of the stream so changing the structure of the stream can have significant biological effect.

Historically, impacts on the land caused by placer mining have been contentious and have been the subject of numerous investigations and studies on how best to restore and reclaim riparian areas and adjacent land disturbed by placer mining so that overall biological productivity is resumed as soon as possible after a given area is mined out. This Guidebook recognises that land impacts and their mitigation are integral to the overall restoration process and provides mitigation measures for these impacts.

The goal of this Guidebook is to provide enough direct information and references to enable a placer mining proponent to prepare a complete application for a Type B water use licence and Class 4 placer mining land use approval and concurrent submission to the Yukon Environmental and Socio-economic Assessment Board (YESAB). Information herein may also be used to prepare an application for a Site Specific Authorization to DFO if the project or activity is not covered by a watershed-based authorization. In addition, this Guidebook may be used by those charged with assessing placer mining projects in regulatory or public interest bodies.

In reference to placer mining the terms ***gulch, pup, narrow valley*** and ***wide valley*** are often used. Mining methods, mitigation and environmental risk and stream sensitivity tend to follow these three categories as well; i.e. wide valleys containing larger streams have high sensitivity to placer mining impacts and have higher fish habitat values while steep narrow valleys may not have fish habitat but still may contribute to impacts downstream through runoff and sedimentation.

Gulches or Pups are steep creeks with no floodplain or a very narrow one. In these steep narrow valleys, the channels are entrenched or incised; squeezed into the valley. ***Narrow Valleys*** are somewhat wider and have more features than gulches or pups. Mainly, the floodplain is wide enough to allow the stream to move back and forth from rim to rim. These valleys often have a single channel stream with exposed and well-defined bars and banks at normal summer flows and may flow over the top-of-bank(s) during the mean annual flood. ***Wide Floodplain*** streams have much more room to accommodate environmental mitigation features and are usually more environmentally sensitive to mining effects. They have wide active floodplains that are typically submerged during the mean annual flood. The stream channels have moderate to flat grades with active floodplains.

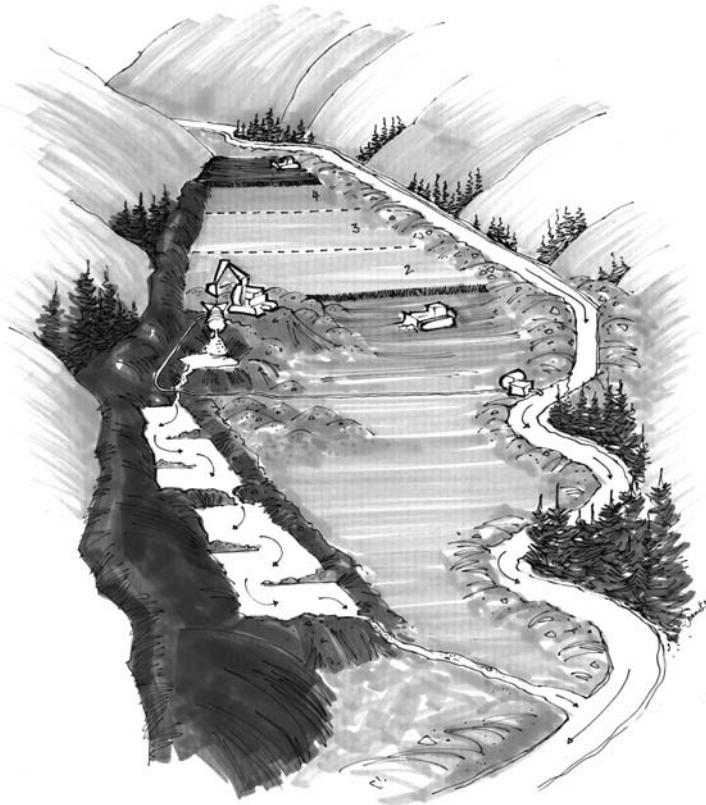
4.3.1 No Floodplain



This diagram shows a typical **gulch** operation. Since there was no room for a bypass channel, the miner has built cross valley dams with stable overflow structures to create in-stream settling facilities. New settling facilities were built in mined out cuts as mining progressed upstream. The front end loader near the centre is feeding stockpiled pay gravel into the wash plant. The bulldozer in the middle background is digging and stockpiling pay gravel from the mine cut at the upstream end. An in-stream reservoir at the top end of the gulch supplies gravity feed water to the wash plant while the pump in the lower settling pond, in the middle foreground, recycles water during dry weather.

The direct impacts to the stream are effluent discharge to the stream from the last pond and non-point source sediment from runoff over disturbed areas entering the creek. The measures to control sedimentation would include erosion control measures and maintenance of the pond system. Restoration of this placer mine would include removal of all in stream structures and rehabilitation of the ponds to encourage re-vegetation of the slopes. The stream's high energy may need to be dissipated through the use of rock-fill dams. The goal of reclamation of this mine would be to have robust re-growth of native plants and a stable channel resistant to long term erosion so that sediment will not contribute to water quality impacts downstream.

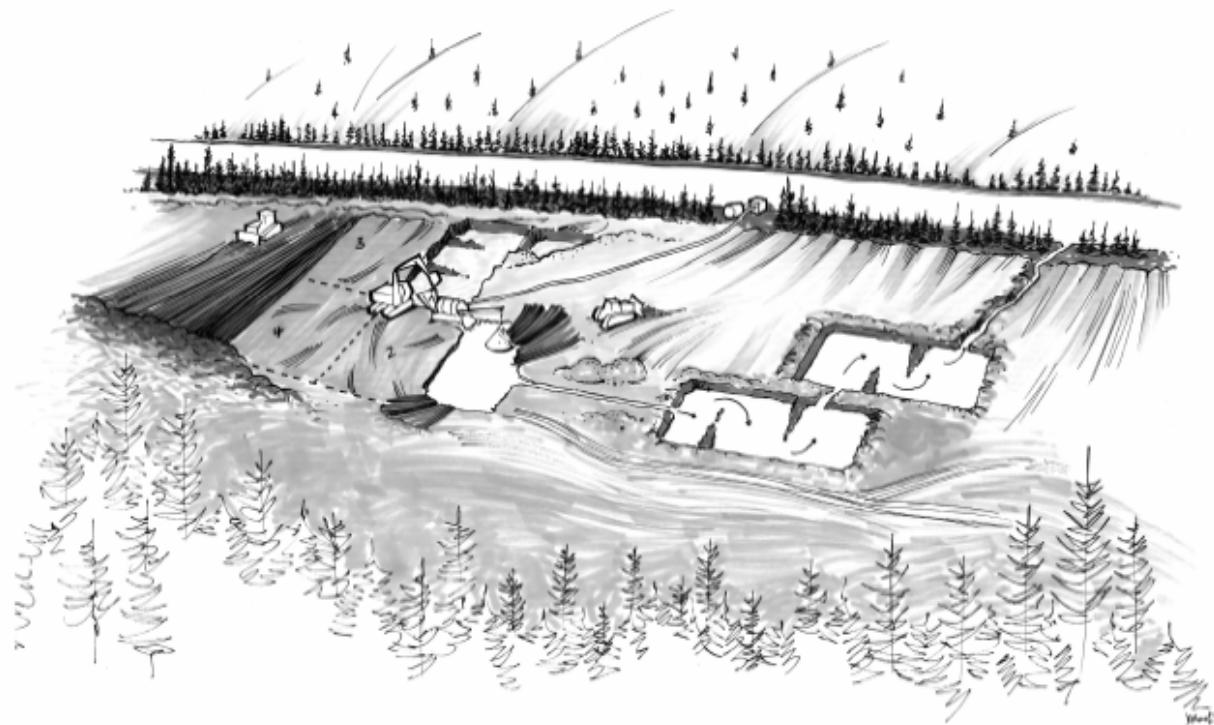
4.3.2 Narrow Floodplain



This diagram shows an operation that is in a narrow valley but still able to mine out of the stream using a **diversion channel**. The operation is mining on the right limit (always looking downstream or down valley) and centre of the valley. To mine here, the miner had to divert the creek over to the left limit. The miner is stripping now on cut #5 moving upstream, and has installed a drain at the top to catch runoff from the stripped area and deliver it to the settling facilities, which are also arranged to catch waste water from the wash plant. The settling facilities contain berms inside to prevent short circuiting by slowing down the flow and holding the wastewater longer to allow more time to reduce the suspended solids load before it is discharged to the creek.

Direct impacts to the stream include point source discharge from the settling facilities and non point source sediment from runoff over the disturbed areas. The creek may have fish habitat potential and thus be in a higher risk category. As a result, restoration of this mine would include the riparian area of the creek and may include installation of fish habitat features that will enhance the stream after mining. The ponds would be drained and all disturbed areas would be graded to gentle angles and re-vegetated to control the potential for long term erosion and enhance wildlife habitat.

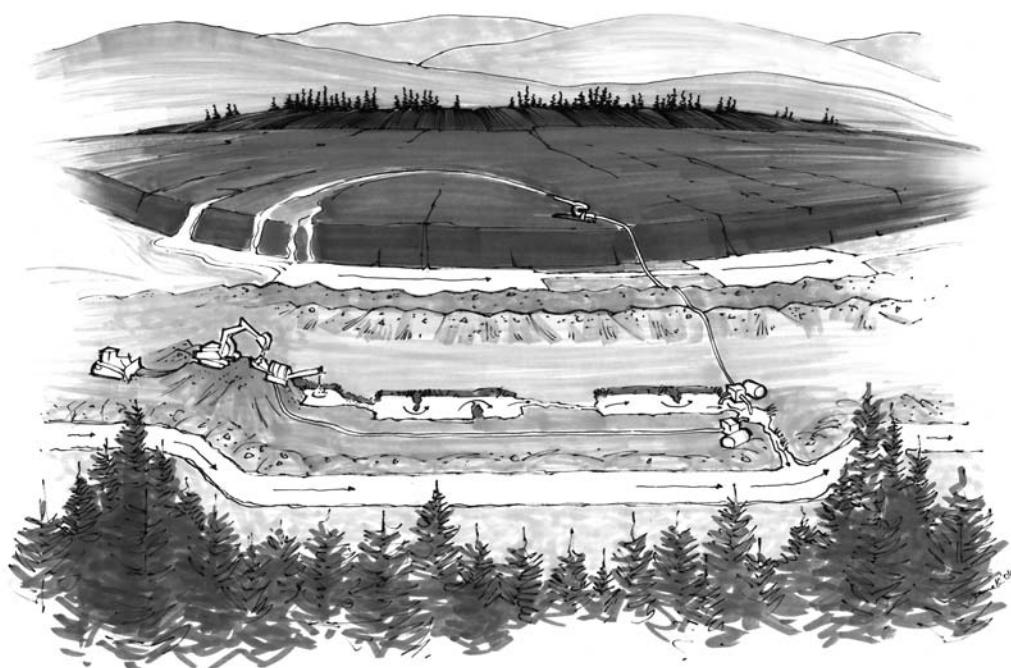
4.3.3 Wide Floodplain



This wide valley operation is required to set aside a **natural leave strip** of about 30 m along the river bank. The above diagram shows the out of stream settling facilities discharging directly back into the receiving stream. A minimum undisturbed leave strip was maintained along the natural bank of the stream in the upper background, following good practise for stripping and stockpiling (essentially conserving the top horizon of soil to the root zone to use for re-vegetation of the slope after the area has been mined out. The bulldozer at the left side is **stripping and stockpiling overburden** from un-mined ground (3&4). The excavator near the centre is digging pay gravel from the prepared mine cuts 1 and 2 and feeding the trommel wash plant. The bulldozer near the middle is flattening tailings gravel piles that were stacked by the trommel conveyor, and re-contouring mined ground as a progressive restoration technique. The settling facilities near the right side are located in old mine cuts.

Direct impacts to the stream include the effluent discharge and runoff from disturbed areas. This creek has not been disturbed so that restoration efforts would concentrate on re-vegetation to control erosion and enhance wildlife habitat. The ponds may be left in place to provide off-channel wetland habitat for waterfowl.

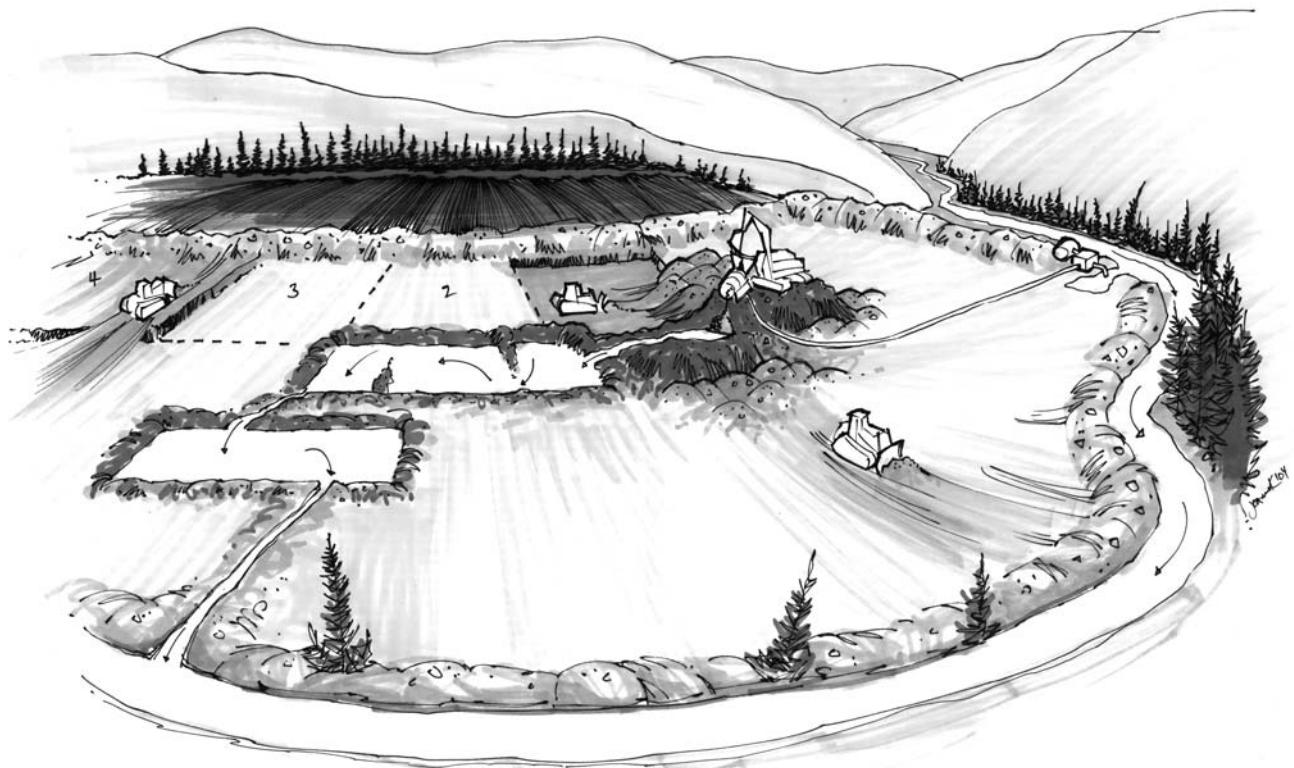
4.3.4 Permafrost Monitoring Wide Floodplain



This operation is mining out of the stream on the left limit of a moderately wide valley. Hydraulic stripping (**monitoring**) is underway at the same time as gold recovery at the wash plant. Water acquisition is from the intake/outflow ditch located at the end of the settling pond system for the wash plant. In this case, the intake will be provided with a fish screen that meets DFO specifications to keep juvenile fish from being sucked in to the pump intake. Partial recirculation is accomplished due to water from the stream and effluent from the sluicing operation mixing in the ditch. A **pre-settling pond** is located immediately below the trommel. Berms have been constructed inside the settling facilities to increase the retention time. A drain connects the primary ponds to a final settling pond. Water is also drawn from the outflow of the settling facilities for hydraulic stripping on the bench. A separate settling pond system is in place for the hydraulic stripping operation. Note that this system is using the warmth and force of water to remove permafrost soil overburden. For this to be planned properly the permafrost would have been assessed and settling facilities designed to accommodate the resulting siltation from the stripping operation. The final discharge point for effluent from the hydraulic stripping operation is not shown on the sketch; it is likely some distance downstream.

Direct impacts on the stream include discharge from both the settling pond system and the settling facilities for the hydraulic stripping operations. A protective berm along the left bank of the creek will need to be stabilized and re-vegetated as riparian habitat after mining is complete. Other restoration measures would include re-vegetation of the stripped area using measures appropriate to the permafrost type. Disturbed areas would be progressively graded and re-vegetated; ponds would be restored and potentially left as off-channel habitat.

4.3.5 Out of Stream Settling Wide Floodplain



This operation is in a wide valley with a protective berm along the stream bank to keep runoff from the freshly exposed ground from entering the stream directly. This is a wide valley operation with **out of stream settling** and **direct discharge** to the receiving stream. The bulldozer at the left side is stripping and stockpiling overburden from un-mined ground (4). The bulldozer near the centre is digging pay gravel from prepared mine cuts 1, 2 and 3. The excavator is feeding stockpiled pay gravel into the trommel wash plant. The bulldozer near the right side is flattening tailings piles and re-contouring mined ground. Settling facilities to the left of centre are located in old mine cuts.

Direct impacts to the stream include discharge from the pond system and site runoff, although the latter has been largely mitigated through the use of the protective berm along the right bank of the stream. Restoration of this mine would include extensive re-vegetation, restoration of the pond system and enhancement of the berm to encourage riparian habitat. Techniques may include live planting or other habitat features.

4.3.6 Recycling System Wide Floodplain



This operation is mining in a wide valley on an old river terrace outside of the current natural stream. The bulldozer in cut number one, is feeding pay gravel to the excavator and wash plant which is supplied by a pump from the end of a recycling pond. Make up water is supplied by the pump at river side. This recycling system has no direct surface discharge to the stream.

There are no direct impacts on the aquatic ecosystem apart from the water acquisition, although runoff over disturbed areas may result in no-point source sediment finding its way to the creek. However, this mine will require extensive land rehabilitation. The restoration of this mine would include extensive grading and re-vegetation of mined areas, and restoration of the settling facilities (perhaps including the option of being left as off-channel wetland habitat). The stripped area would be left to re-vegetate naturally and be protected by a toe berm.

5.0 MITIGATION MEASURES

It is critical to first establish the habitat sensitivity of the site and design accordingly. Streams with highly sensitive habitat such as important fish spawning or rearing habitat may require consultation with DFO to plan for a site specific authorization.

5.1 Fisheries Sensitive Zone Timing Windows

Timing windows are intended to provide general guidelines on allowable operating windows (also known as “work windows”) throughout a given year and within all regions of the Yukon. The timing windows are considered to be the time span presenting least risk of harm to fish, including their eggs, juveniles, spawning adults and/or the organisms upon which they feed.

The table located at the following website address is available to assist you in determining the appropriate timing window to conduct works in or around waters:

http://www-heb.pac.dfo-mpo.gc.ca/decisionsupport/os/timing_yukon_e.htm

In addition to timing windows, a series of Operational Statements are available for use in Fisheries and Oceans Canada’s regulatory review of low risk activities. An Operational Statement can cover an activity from culvert maintenance to clear span bridge installation. Operational Statements are located at the following website address:

http://www-heb.pac.dfo-mpo.gc.ca/decisionsupport/os/operational_statements_e.htm

5.2 Mitigation Measures for the Site Preparation Phase

5.2.1 In-Stream Works

Using heavy equipment in and around streams

Firstly, equipment and machinery must be in good operating condition (power washed), and free of leaks, excess oil, and grease. No equipment re-fuelling or servicing should be undertaken within 30 metres of any watercourse or surface water drainage.

An Emergency Response or Fuel Spill Contingency Plan must be developed in accordance with existing guidelines. A copy of the current Fuel Handling and Storage Guidelines are available from the Yukon Water Board, and Client Services and Inspections Branch offices.

All emergency procedures and practices must be explained to all staff at the camp and the response plan must be clearly posted.

In keeping with the Fuel Handing and Storage plan, a spill containment kit should be readily accessible onsite in the event of a release of a deleterious substance to the environment. All staff at the mine camp should be trained in its use.

Do not use treated wood products in any construction below the high-water mark of the stream channel, to prevent the release of preservatives that are toxic to fish.

Retain large woody debris and the stubs of large diameter trees where it is safe to do so. These are important for preserving fish habitat and wildlife populations.

Do not allow trees or branches to clog the stream channel. If any branches do inadvertently end up in the channel, remove them from the site to where they will not enter the channel during high flows.

5.2.2 Channel Location & Stability

Restoration channels are meant to be more permanent than temporary diversions, so more care should be taken to build in features that work with natural flood events to create a long term stable channel. With the *floodplain design* method, the overall grade of the restoration channel is about the same as the existing channel grade, and the stream slope and length are designed to be stable. If using the *channel replication design* method, the overall grade of the restoration channel should also be about the same as the existing channel, but in reality the slope will vary.

When building temporary diversions the coarsest available material should be used for armouring banks along the outside bends, and where channel grade increases along the toe of banks. If suitable material is not available to line the channel bed and banks, then the stability will have to be increased by reducing the channel slope with grade control structures or by making the channel longer.

When placer mining operations are finished in a given area, the restoration channel should be located in the lowest part of the valley. Overburden should be replaced into the valley and stabilized. The channel should not be directed or diverted through old settling facilities, unless those facilities are situated in a position that is lower in elevation than the floor of the valley or the bed of the restored stream channel immediately downstream (e.g., a cut that is used as a settling pond). The exception to this would be rock-filled dams and cross-valley structures, where such are acceptable.

After selection of the appropriate restoration channel design, the completion of the restoration channel will generally require:

- Determining construction materials
- Sorting and stockpiling construction materials
- Diversion of the stream
- Construction of the restoration channel and related structures
- Re-diversion of the stream into the restoration channel.

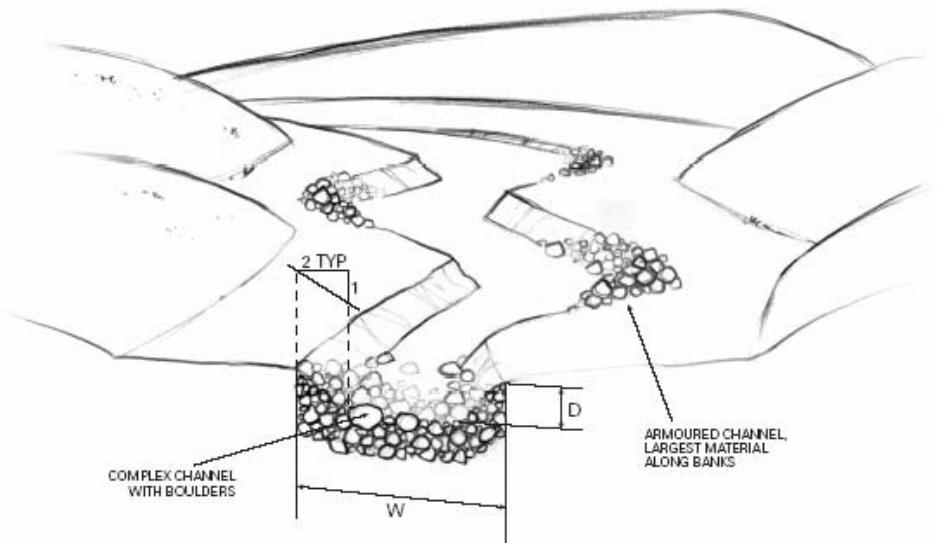
The construction of the restoration channel may require:

- Washed mine tailings to construct the restoration channel bed and banks
- The coarsest available granular materials (e.g. coarse washed tailings, rock, ripped bedrock, large boulders etc.) to construct channel grade control structures, provide bank armouring and construct cross-valley structures,
- Fine-grained materials or stockpiled organics to surface stream side areas after grading
- Live staking or planting of woody species to strengthen the banks and provide riparian habitat
- Granular materials to construct dikes
- Overburden to provide general fill.

The bed and banks of the restoration channel should be built mainly out of washed tailings because these have less fine material. Any fines should be separated and stockpiled for use as subsoil or topsoil during reclamation planting. Coarse pit run gravels with a minimum of silts and clays may be used if washed tailings are not available. The relative depth of the bed and thickness of the banks will depend on the configuration and layout of the channel. Thicker blankets of coarse material should be placed at the outside of bends and in the steeper sections of the channel.

The washed tailings should extend to the top of the freeboard in the channel replication and channel regime design methods and include the outer edges of the floodplain in the floodplain design method.

The following figure illustrates a restored channel with armouring and boulders:



With the channel replication design method, channel grade control structures and pools should be constructed as required by the design and layout of the restoration channel. With the floodplain design method, large boulders can also be placed individually in a random fashion in the stream and floodplain.

This results in scour and accumulation of debris and sediments that assist in the natural physical restoration of the stream channel. Coarse materials can also be used to armour the toe of dikes exposed to stream flow. This is essential for dikes around settling facilities encroaching onto the design floodplain. In some cases, erosion control fabrics, filter fabrics, or plastic lining may be used if rock or tailings are unavailable for lining channels.

The water must be slowed enough to prevent excessive erosion. This is done by reducing slope, increasing roughness or a combination of the two. The channel will for the most part organize the natural materials it is made of and re-create natural armour over time. Roughness can be increased by lining the channel with cobble, existing vegetation, rocks, organic debris (slash windrows, brush barriers), furrows, or a meandering channel plan.

Bedrock outcroppings and stable valley limits can often be used to control the stability of temporary diversions and place the stream in an area where it will not have to be moved during the mining plan. For example, it may be possible to locate the restored stream channel against a bedrock valley wall to control stream channel stability.

5.2.3 Water Acquisition

If the project is obtaining water from a fish bearing stream, either a properly designed fish screen or a properly designed intake channel will be required. Detailed guidance on the design of fish screens can be obtained from DFO's *Freshwater Intake End-of-pipe Fish Screen Guideline*, partially reproduced below.

All water withdrawals other than those occurring in Water Quality zones must be screened to prevent the entrainment of fish. The screen may be constructed at the pump suction, or constructed within the water intake channel or pond.

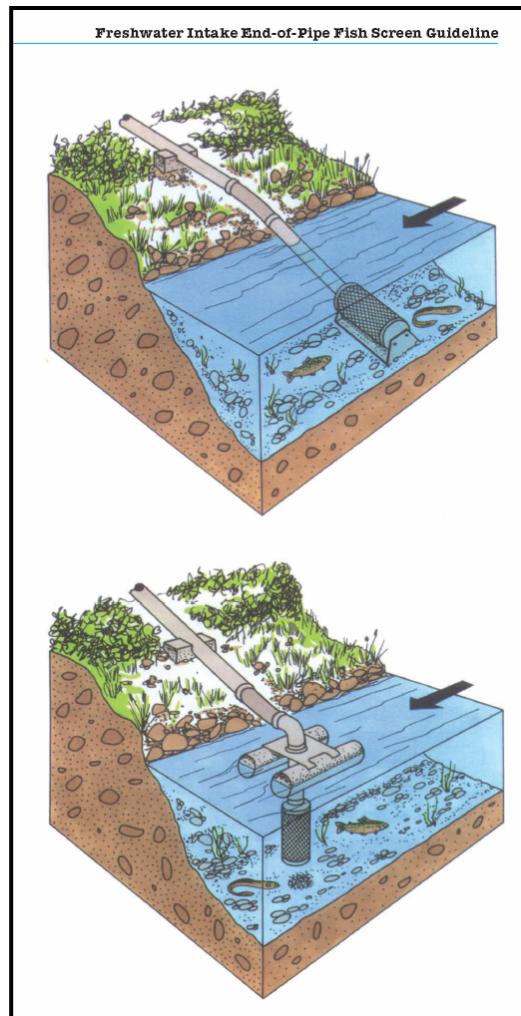
Standards for screening are:

- a. Mesh must have no less than eight openings per linear inch (3.5 openings per cm).
- b. Openings must be no greater than 1/8 inch (3.2 mm) along any given side. If punch plate or similar material is used, openings must be no greater than 1/8 inch (3.2 mm) in length or width.
- c. There shall be no less than one square foot of open screen area for every 45 imperial/55 US gallons per minute withdrawn (in metric, 929 sq. cm of open screen per 205 litres per minute).
- d. Screens shall be kept in good and efficient state of repair.
- e. Water must not be withdrawn at any time that the screen is removed.

Guidance on screen materials is presented below:

- The screen openings may be round, square, rectangular, or any combination thereof, but should not have any protrusions that could injure fish.
- Screen materials may include brass, bronze, aluminium, galvanized or stainless steel, and plastics. The screen material should be resistant to corrosion and UV light.
 - Note: clogging due to corrosion is minimized with the use of stainless steel.
- Welded wedge wire screens offer reduced debris clogging and increased open area and screen stiffness, in comparison to round wire mesh and punch plate.
- Screens should be located in areas and depths of water with low concentrations of fish throughout the year. Screens should be located away from natural or man-made structures that may attract fish that are migrating, spawning, or in rearing habitat.
- The screen face should be oriented in the same direction as the flow. Ensure openings in the guides and seals are less than the opening criteria to make "fish tight".
- Screens should be located a minimum of 300 mm (12 in.) above the bottom of the watercourse to prevent entrainment of sediment and aquatic organisms associated with the bottom area.
- Structural support should be provided to the screen panels to prevent sagging and collapse of the screen. Large cylindrical and box-type screens should have a manifold installed in them to ensure even water velocity distribution across the screen surface. The ends of the structure should be made out of solid materials and the end of the manifold capped.

Heavier cages or trash racks can be fabricated out of bar or grating to protect the finer fish screen, especially where there is debris loading (woody material, leaves, algae mats, etc.). 150 mm (6 in.) spacing between bars is typical.



Use of and Intake Channel for Water Acquisition

Note: the objective is to prevent the destruction of fish through the acquisition of water. If screens of the correct mesh size are deployed between a watercourse and the intake to a water reservoir or gravity feed ditch, it is not necessary to screen the pump intake that removes water from these structures. In the case of total recirculation systems, the operator shall ensure that any areas where fish could enter the system have barriers to prevent the entry of fish (unless a screen is employed at the pump intake).

Many placer mines use an alternative means of acquiring water where an off stream channel or ditch is excavated and provided with a fish screen barrier upstream of the pump intake. This method allows for a wide screen intake at the pump suction avoiding problems such as trash build up and collapse of the suction pipe.

5.2.4 Stripping and Stockpiling Soils

Proper placement and protection of stockpiles will minimize erosion, ensure maximum retention of materials for site reclamation, and minimize distances that stockpiled materials must be moved during site reclamation. Thorough knowledge of the site reclamation plan is required to implement effective techniques for stockpile placement and protection.

Stockpile placement and protection, if properly planned and executed, will help to control erosion. Stockpiles should not be located near an active channel or within the active floodplain where high flows could erode the sediments. Areas of concentrated surface runoff should also be avoided. Organic material and settling pond fines may have high moisture content and may require containment berms around the perimeter of these stockpiles.

Stockpile Placement and Protection Plan

Stockpile locations should consider drainage patterns, mine sequencing and the eventual use of the material in subsequent mining operations or reclamation. Stockpiles should be located in areas where they can be easily protected and where re-handling will be minimized.

The principal objective in stockpile site selection is to find a location where the material is protected from surface flow, including active stream channels and runoff from rain or snow melt. Stockpiles should generally be located in elevated areas away from flood waters such as on the valley walls or in flat areas where flood waters often have shallow depths and low velocities. Armouring the lower slopes of the stockpiles with riprap and large rocks is suggested if further protection is needed.

Materials to be stockpiled should be separated into the following groupings:

Large trees

Large trees require the least protection since surface flow past a stockpile of trees will not substantially contribute to non point-source pollution. Stockpiles of trees should be placed in an area where they will not interfere with the mining operation and be available to enhance stream and floodplain habitats after the site is closed. Trees will be used separately from other types of organic material during site reclamation. Therefore, large trees should be stockpiled separately from other types of material and not mixed with other organic material during temporary storage. In some cases, the trees can be used to construct log crib containment berms for smaller organic material.

Small trees, shrubs, and grasses

The most common forms of vegetation that are removed during a placer mining operation are the small trees and shrubs that occupy previously undisturbed floodplain riparian zones. Proper stockpiling and protection of this material is important since it will serve as the stock for natural re-vegetation, and since the material is easily eroded. The small trees, shrubs, and grasses should be piled with the top layer of organic soil. Placing these two types of materials together accomplishes several objectives. First, the woody material will provide some protection for the organic soil from wind and surface water erosion. Second, many species of shrubs and grasses will continue to grow within the stockpile. This will improve the survival rate of vegetation placed during site closure. Third, when the shrub layer and surface soil are removed together, disturbance of the root zones will be reduced, thus enhancing survival of the vegetation. This material should be kept moist to maintain the viability of the woody slash.

Shallow soils

The shallow soils often consisting of fine organic material, sands, and perhaps some gravel and cobble should be piled separately from the trees and the shrub-organic soil piles. This material should be protected since it can be eroded easily. If necessary, large rocks can be used for containment along the side slopes of the piles. Containment berms may also be constructed around the stockpiles.

Large quantities of fine inorganic material, such as deep loess deposits

At some locations deep deposits of loess, or fine inorganic soil, must be removed to expose placer-bearing gravels. Because of the large volume of material that must be handled, the material should be moved only a short distance and handled once. Typically, the most efficient handling of this material is to push it up the valley side slopes into fan-shaped, flat-topped mounds. At sites where large volumes of this material must be handled, final stockpile locations should provide maximum protection from wind and surface-water runoff since this material is easily eroded. If organic reclamation material is limited at the site, portions of this loess material may be used both as a levelling layer and as a seedbed to enhance vegetative recovery.

In situations where highly erodeable stockpiled material cannot be protected using berms and riprap as described, temporary seeding and fertilizing using annual grasses may be useful to help stabilize this material.

Oversized inorganic material

The oversized inorganic material, including large boulders, should be stockpiled separately. The large rocks available on site may be used to temporarily armour other stockpiles if necessary. During stream reclamation, the large boulders will be useful as riprap for bank and channel stabilization or as fish habitat features. The larger cobble sizes, such as the material segregated by grizzlies, may also be used during stream reclamation as streambed material. Stockpiling this material may not be necessary during bench mining.

Fines removed from settling facilities

If the top layer of organic soil is very thin, the upper six inches of the surface material should be removed and stockpiled with the shrubs and grasses.

Topsoil

Strip only the top horizon of soil (as deep as root penetration) and make windrows of this material parallel to the slope in a convenient place so it can be spread out later. Set aside stripped pods of immature vegetative mat and stockpile for planting later. When the area has been mined out or explored, prepare and grade the slope. Backfill trenches, re-grade piles to acceptable slopes and bench exposed slopes. Then spread the stockpiled material back over the area. Observe the surface roughening rule: cleat marks should be parallel to steeper slopes.

5.2.5 Permafrost (frozen) ground

The vertical face of a steep slope may be left so that natural stabilization can take place. In this case, it is preferable to allow the vegetative mat to drape over the top edge to shade the interface between the slope and original ground, so this part of the area should not be stripped. It may be wise to hand cut the larger trees on the edge because if these collapse onto the exposed slope face they may tear the organic mat and expose more permafrost. On flatter slopes, a windrow of vegetative mat should be stripped and conserved for later machine spreading onto the stripped area. If frozen gravels are exposed, re-grade and stabilize the slope and allow natural re-vegetation processes to reclaim the cut.

Permafrost soils

Following is a list of issues which should be addressed prior to, during, and following development of a placer mining operation that includes frozen soils. These are suggestions based on the information provided in this document and should not be considered limiting. Some of these items are required under current operational guidelines.

Mining Plan

1. General stratigraphy of overburden sediments:

Observations of thickness, colour, abundance of ice, and organic content should be taken for each distinct unit of overburden, if exposed by previous operations.

2. Granular inventory of sediments overlying pay gravel:

If sediments are exposed by previous mining operations, each distinct unit should be bulk sampled for grain size analysis. The relative percentage of gravel (> 2mm), sand (0.063 – 2 mm), and silt (0.002 - 0.063 mm) within dry sediments should be determined.

3. Estimation of pore ice content:

A 5 cm diameter core, or bulk sample of approximate known volume should be taken of frozen sediment of each distinct unit. The sample should be allowed to thaw and dry completely to determine the volume of sediment released.

4. Estimation of bulk ice content:

A photograph of the sediment (if exposed) should be taken, and the *areal* estimation of bulk ice should be determined using the method outlined in 9.2.

5. Proposed routing of roads

The location of any proposed roads, cat trails or permanent structures should be indicated on a photograph. These roads should be located where they minimize damage and removal of surficial vegetation. Preferable locations include those underlain by coarser overburden, and those dominated by *Birch*.

6. Proximity of permafrost to existing watercourse

The location and depth of permafrost should be noted throughout the area proposed to be re-disturbed. This can be accomplished by inserting a 2 m steel pole (1 cm diameter) into the ground from the top, and recording the depth at which ice is encountered. The location of any “perched” streams, flowing on top of permafrost should be noted on photographs or maps.

7. Description of existing vegetation

The mining plan should include a good photograph of representative vegetation in all areas which are to be disturbed.

8. **Establishment of baseline**

A baseline should be established perpendicular to the base of the creek, away from proposed activity. This can be in the form of flagging tape on trees. This facilitates future measurement of permafrost disturbance.

9. **History of previous disturbance**

A history of permafrost characteristics of the area, either through reports or personal communication should be summarized, in order to facilitate the estimation of the volume of ground ice (if any) remaining.

Permafrost Mitigation Plan

1. **Area stripped**

The exact area of vegetation stripped each year should be recorded. It is suggested that this should not exceed 1000 m² per year, since the resulting permafrost degradation can lead to massive failure in sediments which are ice-rich.

2. **Volume of water used per day**

The length of time pumps of known capacity are used for monitoring should be carefully recorded. Extensive monitoring facilitates the transport of fine-grained sediment.

3. **Headwall retreat**

The distance of headwall retreat of slump failures should be measured once per week.

4. **Channelling of debris**

Movement of slump debris, either natural, or facilitated by monitoring, should be channelled away from existing water courses and pre-existing, dried settling facilities. This may be accomplished by piling coarse organic material such as trees and branches which have fallen to the base, into levee structures. Coarser material such as sluice tailings can also be used for this purpose. Ultimately, this material must all be channelled into settling facilities.

5. **Settling facilities**

Settling facilities should be constructed of coarse material, and should be of sufficient volume (preferably longer rather than wide) to allow for sediment to settle out of suspension near the surface (several days). Preferably, several settling facilities are constructed in succession. Settling facilities should be constructed above the highest water level during spring flood.

6. **Behaviour of frozen sediments**

The nature of failure of frozen sediments should be noted, i.e. do sediments slump and drip, fall as blocks or crumble.

Reclamation of Disturbed Permafrost Soils

1. **Relocation of channel**

If part of channel flow was diverted for monitoring, the original channel should be reconstructed, using coarse granular material, so that it is well away from any residual settling facilities and not subject to excessive erosion by spring melt water.

2. Vegetation

Permafrost disturbances re-vegetate readily. However, as much of the original vegetation should be left in place as possible. A disturbed ice-rich area should NOT be covered with gravel, but rather left with its original material. No levelling is necessary.

5.2.6 Site Drainage

Site drainage and run-off can be effectively managed with reasonable effort by redirecting flows into the original drainages or restoring original drainage systems. In order to accomplish this, drains or ditches must be adequately sized and appropriately located, and channel grades and potential erosion trouble spots must be controlled. Good site drainage means a ditching system that works – either to convey runoff or intercept seepage flows from cuts or hill slopes. Once water is collected it must be conveyed to the natural drainages without too much erosion.

The following are the key points to consider:

- To reduce erosion increase the ditch size or line with rock.
- Locate the system in the right place and build it big enough to prevent excessive flow over unprotected or exposed surfaces.
- Care must be taken not to underestimate or neglect drainages that may seasonally be dry. It is good practice to typically increase the size of replacement ditches or drains to ensure adequate capacity.
- Put sediment control measures into place before starting any works that may result in sediment mobilization.
- Construct any ditches, water bars, or water diversions within the work area so they do not directly discharge sediment-laden surface flows into the stream. Divert such flows to a vegetated area where flows can slowly infiltrate.
- *Plant cover is the most important factor* in soil erosion. The faster vegetation cover can be re-established; the sooner erosion can be controlled. Vegetation not only protects the soil from the erosive force of rain, it also holds it together and makes it more resistant to erosion.
- Direct flows to ex-filtration basins located at bottom of slopes or to wetland areas.
- Breach dykes and access roads where failure of those structures would result in deposition of sediment into streams.
- Armour (protect with rock or largest available materials) ditches and small channels where erosion could be expected, such as steep grades or flows through or over fine-grained materials.
- Controlling sediment by filtering water through coarse tailings or other material is *not very effective*. There is no cost effective feasible way to filter fine sediments in placer mining.
- Sensitive areas should be identified and avoided if at all possible.

- Activities like stripping, clearing and building embankments should be avoided during heavy rain.
- Whenever possible, stripping should be scheduled so as to minimize the time in which soils will be exposed.
- Conducting periodic reclamation activities throughout the life of the mine plan instead of leaving everything to the end of the operation can also minimize soil exposure time.
- The area of stripping should be restricted to the bare minimum required.
- Keep the footprint as small as possible.
- It is important to encourage re-vegetation at every stage using locally available plant and organic materials set aside during stripping.
- Limit the exposure of the soil to the water. Diverting runoff away from more erodeable to less erodeable areas is an important preventative measure.
- All tailing piles and exposed side slopes should be contoured to reduce slope length and steepness. The goal is to grade disturbed areas to a stable angle of repose after mining and to re-vegetate those areas to curtail erosion and siltation of watercourses.
- Ensure that material such as rock, riprap, or other materials placed on the banks or within the active channel or floodplain of the watercourse is inert and free of silt, overburden, debris, or other substances deleterious to aquatic life.
- Operate machinery from the bank of the stream and not in the stream channel to minimize impacts and to better enable mitigation of sedimentation.
- Minimize the disturbance to existing vegetation on and adjacent to the stream banks.
- Use mitigating measures to protect excavated material from being eroded and reintroduced into the watercourse. Such measures include, but are not limited to, protecting the material with a toe berm or seeding and planting it with native vegetation.

5.2.7 Site Grading

Grading the tailing piles and steep excavated slopes within the mining site will reduce erosion and encourage re-vegetation (Becker and Mills 1972). A grading plan should describe the site grading to be completed while mining activity is taking place, preferably at the conclusion of each cut, but at a minimum at the end of each mining season. If tailings are properly placed and graded during mining, additional grading may not be necessary upon site closure.

Prepare a temporary and final plan for sloping and contouring. The plan should address the reestablishment of desired elevations within the site, describe any benching or terracing and delineate (map) the proposed drainage directions and patterns. Provide an annotated map and representative cross sections depicting graded slopes and their relation to other features (stream channel, valley walls, and floodplain) in the valley.

The following measures should be considered during the preparation of the grading plan:

- Steep slopes and tailing piles should be graded as soon as possible as surface erosion from slopes is greatest during the first year following disturbance (Cook and King 1983).
- Reducing the steepness of tailing piles is likely to significantly reduce erosion and sediment releases into watercourses (Vesilind and Peirce 1982). A slope of 3 horizontal to 1 vertical or less is recommended (Becker and Mills 1972, Dryden and Stein 1976).
- Large piles of stripped loess with thawing ice lenses should be graded to slopes of 3 to 1 or less when stockpiled (Schwab 1982).
- Slopes that are steeper toward the top and shallower toward the bottom are preferred as they have been shown to have less sediment loss than flat slopes or slopes that are steepest at the base (Haan and Barfield 1978, Meyer and Romkens 1976).
- Exposed permafrost should be excavated as a near-vertical cut face for the duration of adjacent mining operations. This will minimize the surface area of the permafrost exposed to warm air, water, or radiation and will minimize disturbance to the insulating vegetation on the top of the cut bank. Tailings should be pushed up against the cut face following the completion of mining at that location.
- Terracing and furrowing (trenching) should be parallel to elevation contours, particularly outside the active floodplain, to reduce the effective length of the slope and thus decrease further erosion (Figure 3.3-4). Small furrows approximately 0.5 ft in depth and spaced closely together along the contours of the slope can effectively reduce erosion (Doyle 1976, Becker and Mills 1972, Cuskelly 1969).
- Back sloping terraces perpendicular to the slope should have minimum widths of 14 ft and a maximum slope length between terraces of 100 ft (Beasley 1972).
- Tailing piles and steep slopes should be roughened or scarified to minimize slope failures and encourage infiltration and natural re-vegetation (Rutherford and Meyer 1981, Troeh et al. 1980).
- Grading should be conducted throughout the course of mining to minimize the likelihood of runoff from erodeable areas.

The following table shows recommended slope grades for the different soil types:

Table – Recommended Slope Grades for Soil Types

Slope	Soil Characteristics	Ice Content	Recommended Procedure*
Side Slope	Fine, poorly-drained soil	Ice rich	Leave the cut face vertical with an overlapping mat of vegetation if possible.
		Ice present but less than 5%	Grade slope to less than 3:1. Leave overlapping mat of vegetation if possible.
		Ice not present	Grade slope to less than 3:1
Pile	Coarse, well-drained soil	Ice not present	Grade slope to less than 2:1. Bench or terrace if slope is over 15 m high.
	Fine, poorly-drained soil	Ice not present	Grade slope to less than 3:1. Round off, reshape, re-contour top of pile.

Fine textured soils erode easily and require more attention than coarse soil. As water accelerates, it becomes more erosive. Without some sort of a break in the slope, surface erosion develops into rill erosion, followed by gully erosion and channel erosion.

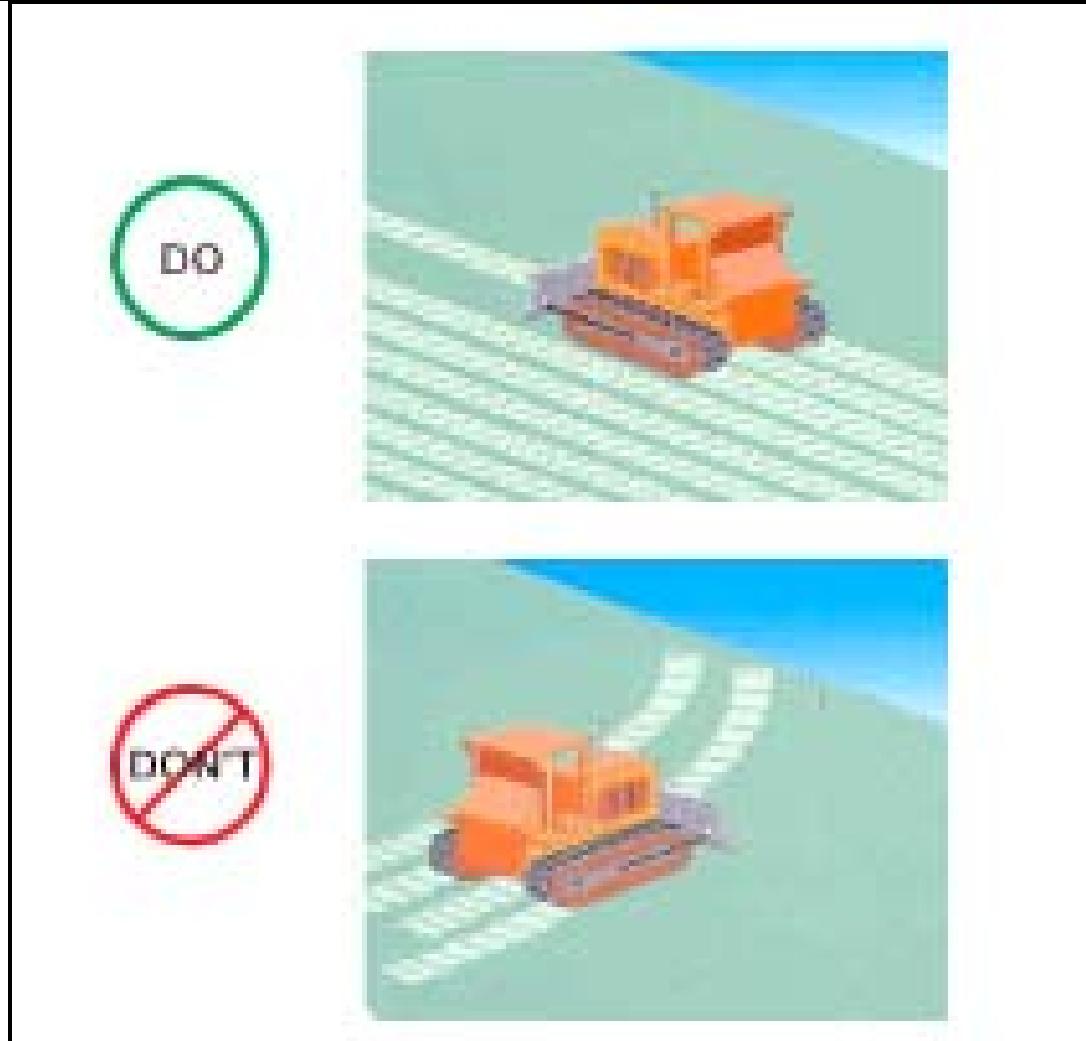
- Terraces or benching allows the gradient of the slope between the terraces to be left steeper.
- Reducing water velocity over exposed soils reduces the potential for erosion by reducing the slope length or steepness.
- Increasing the roughness at the soil surface also reduces the potential for erosion.

Controlling runoff on the placer mine with a good layout of ditches, drains, and diversions is the key. Prevention is easier and less expensive than corrective measures. Controlling sediment should be left as the last thing to do in the mine plan to limit sedimentation off site.

Following are mitigation measures to control runoff, erosion and sediment in placer mining.

Surface roughening

If done properly, surface roughening or “scarification” can cut sediment load from slopes by more than half. Scarification simply means using some kind of implement to scratch the surface parallel to the contour of the slope, like harrowing a farm field. Exposed slopes should not be left smoothly graded and compacted because this practice leads to increased runoff velocities and the formation of rills or gullies. Roughening slows the water down, reduces soil compaction, increases soil infiltration rates and provides micro sites that promote natural re-vegetation. Surface roughening can be accomplished by tracking slopes with machinery or simply placing logs and woody debris on the slope. It has to be done in the *right direction*. The grooves left by the tracks must be normal to the slope (perpendicular to the slope direction), because grooves parallel to the hill will accelerate the runoff and increase the erosion.



Slope benching

Slope benching provides many of the same benefits on a macro scale that are provided by surfacing roughening on a micro scale. Slope length and gradient are reduced and this prevents erosion by slowing the water down. Benching can also enhance infiltration because the slowed water will have time to percolate into the soil. Benches can be constructed to divert runoff into adjacent vegetated areas by allowing for a slight gradient along the length of the bench. In most cases benches constructed horizontally (with no gradient) are very effective at trapping sediment that has eroded from the slope above, with minimal risk of slope failure.



5.2.8 Using rock to control erosion

Ideally, the minimum rock size required to armour an area should be determined prior to use to ensure that the rock used will not wash away. In reality, the ideal size of rock may not be available at a given mine site, and alternatives must be used. Washed coarse tailings are generally the best alternative to the ideal rock size. In some cases wire gabions may be feasible to create erosion resistant structures in problem areas. The selected rock source should be inert and not contain silt, debris or any other substances deleterious to fish. Uses of rock include:

- Covering of slopes that are difficult to re-vegetate
- Lining of erodeable ditches
- Weighing of the toe of slopes to prevent rotational slope failure
- Protection of stream crossing structures
- Scour protection at outlet areas such as culverts and drainage ditches
- Stream bank protection

5.2.9 Using re-vegetation to control erosion

Machine spreading of stockpiled organics is an effective way to use re-vegetation as erosion control and to restore the area at the same time. During stripping and clearing operations the top horizon of soil – as deep as root penetration – should be conserved in windrows parallel to the slope in a convenient place to be spread out later. Stripped pods of immature vegetative mat should be set aside and stockpiled for planting later. (The pod will die off if it dries out or if the roots are exposed). When the area has been mined out or explored the slope should be prepared for re-vegetation. Trenches should be backfilled and conical piles and ramps should be re-graded to acceptable slopes (angle of repose) and exposed slopes should be benched. Finally, the stockpiled material should be spread back over the area. A tracked excavator with a thumb is a very useful piece of equipment for developing pods of organics in small depressions, and can be used to throw larger pieces across the surface. A bulldozer or loader can also be used to spread the organics over wide areas (keep in mind that tracks should be parallel to steeper slopes). Machine spreading is of stockpiled organics should be limited to slopes of 2:1 or less.



The above images show stages of re-grading and machine spreading of stockpiled organics

Bioengineering in Placer Mining Applications

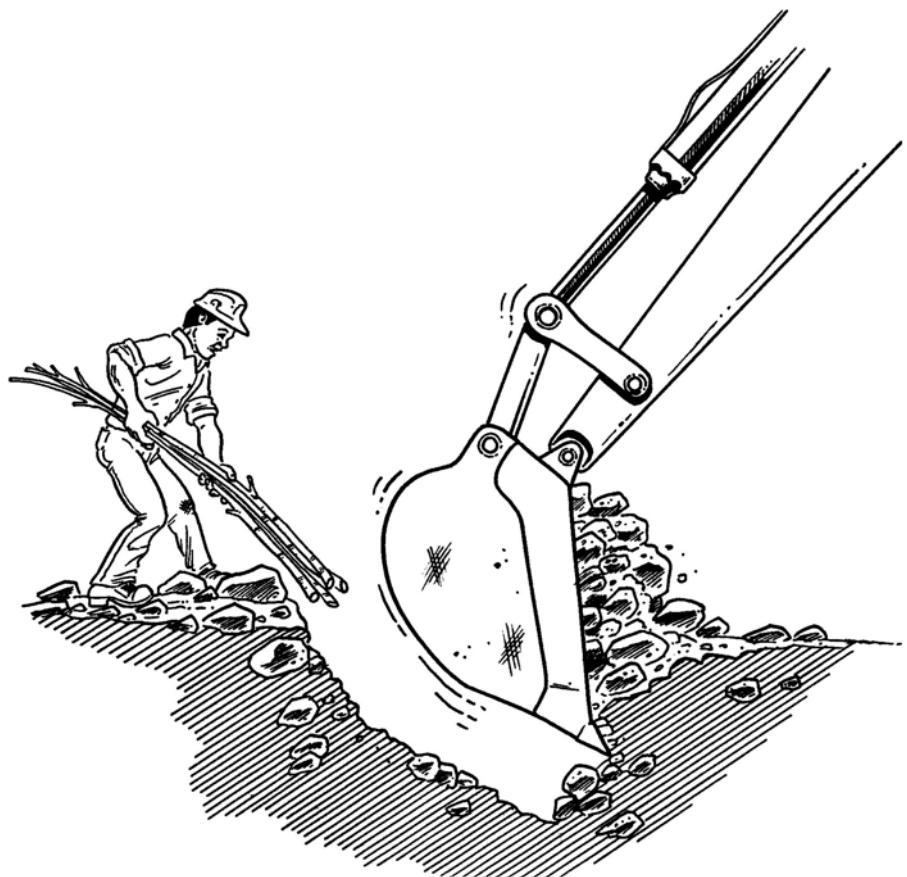
The term bioengineering (sometimes referred to as green or soft engineering) is simply the use of live plant material to stabilize stream banks and prevent erosion. Bioengineering in placer mining applications is fairly new to the Yukon, and is actively being tested by specialists. Some techniques show promise for problem areas. It is labour intensive and has a short window of opportunity in the Yukon. In southern Canada crews of tree planters and other specialists can work at bioengineering projects all winter, but in the Yukon the time is short because most of the methods should be done when plants are dormant in the early spring or fall.

There are many different types of bioengineered structures: brush layers, wattle bundles and fences, pole drains, live staking, gravel bar staking, live brush mattresses and geotextile wraps to name a few.

Planting woody vegetation in the context of placer mining relies mainly on species of willow and alder with some use of poplar. There are numerous ways to employ live willow planting but whatever method is used it will not be effective unless the plants are collected at the right time and installed properly. Live but dormant cuttings of willows and other shrubs should be taken when the plant is dormant: either after the leaves fall off in the fall or before the buds fill out in the early spring. The cuttings have to be kept in a cool, moist dark place till needed, and the roots must not dry out.

Common in road construction a silt fence is usually made of geotextile fabric fastened to wood stakes built along the contour or at the toe of a slope. A *live silt fence* is just a modification that uses live woven cuttings and stakes to achieve the same objective. The benefit of using plant material to make a silt fence is that the plant growth will anchor the soil, form a micro terrace and naturally stabilize and strengthen over time. Little or no maintenance is required. Live silt fences may be useful on overburden piles or on problem exposed slopes such as at the top of a permafrost gully.

Bioengineering techniques for placer mining applications are intuitive and site specific. Field trials and individual placer miners' experiments will eventually develop a group of effective methods. Experiments with live silt fences and pole drains made of willow are under way in the Carmacks and Dawson districts and live planting experiments have been conducted in the Klondike (Mining and Petroleum Environmental Research Group – MPERG). If the results are favourable and labour and timing problems can be overcome, bioengineering in placer mining may be turn out to be very useful in some applications.



Machine assisted gravel bar staking is an effective a simple form of establishing pioneering woody species in areas of instability. The most effective variety is the plane leaf, or stream bank willow.

5.2.10 Roads and Trails

Erosion Control for Access Roads and Trails

Using existing roads and trails and mobilizing equipment to new ground has the potential to generate excessive non-point sedimentation. Following are general principals and recommended mitigation to minimize disturbance and sedimentation when getting to and from a placer site.

Building New Bush Roads

Road construction on and off claims will require the applicable approvals. On placer claims, the road will be included in the Placer Mining Land Use Notification or Operating Plan. Off claims, a Land Use Permit will be required. The information needed in either case will be similar:

- The route must be marked on a topographical map
- The location of existing roads and trails should be noted
- The location of stream crossing and bank conditions
- The location of any proposed culverts or crossings
- The road condition (i.e. 2-wheel drive, 4x4, winter only)
- The start up date for construction
- The method you will use to maintain road

Using Existing Roads and Trails

- If possible, use a low-impact vehicle or ATV rather than moving heavy equipment back and forth to access work site.
- When “significant rutting and gouging” occurs, the surface must be restored by grading the road surface. This avoids the gouges becoming stream channels during heavy rain events and road surface erosion. It also limits the likelihood of finding alternate routes around the damaged road, causing an increase in the footprint of the access clearing and possibly even further surface erosion
- Avoid serious terrain damage by moving heavy equipment when the surface is frozen and has good snow cover.

Use of existing roads and trails are subject to weight restrictions:

- Vehicles greater than 20 ton GVW may only be used if the load limit of the road is known
- Vehicles greater than 20 ton GVW may not be used when severe rutting and gouging of the route results

Route Planning

Carefully planning for the location of your temporary and permanent roads and trails can go a long way towards minimizing the physical effects of your project on the land.

- Review maps and air photos
- Where possible use an aircraft fly-over
- Scout the trail on foot or by ATV to gauge potential pitfalls (grade, swamp, permafrost, etc.)
- Plan routes carefully to avoid areas where degradation will cause erosion

What to Avoid when Selecting a Route

- Avoid areas of permafrost where practicable.
- In areas of discontinuous permafrost, select frost-free, south-facing slopes where possible.
- Where it is not possible to avoid permafrost, select routes that are upslope or on ridges where bedrock is closer to the surface. If you know that you will be traveling in areas where permafrost degradation may occur, you should have a plan for how you will minimize your impact and how you will fix or reclaim the trail. For example in areas of

semi-frozen taiga sensitive to any impacts including low ground pressure vehicles, the tracks made by the vehicle may have to be covered with mosses or local vegetation to ensure that the ground re-freezes and does not become a channel for water to accumulate in.

- Avoid seepage zones by routing to drier elevated ground.
- Avoid areas of erratic slope changes resulting in extensive cut and fill requirements.
- Avoid steep slopes. Select routes to keep slopes as low as possible. Maximum grades of 8 to 10 percent are desirable although short pitches (less than 5 metres) of up to 15 percent are acceptable if required.
- Avoid unnecessary stream crossings.
- Do not use stream beds or channels as part of access route.
- Avoid archaeological and burial sites. First Nation offices and the Heritage Branch of the Government of Yukon can often provide information about where these sites are.
- Avoid duplication of roads and trails. Utilize what is on the ground where possible and if the existing route is acceptable.
- Avoid construction of wide roads. Build the road consistent with safety and traffic needs, while planning for the least reclamation.
- Avoid environmentally sensitive areas, critical wildlife habitat and critical time periods for wildlife.

Fording Streams

Fording low risk streams with no fish

Once stream crossings have been avoided by good route selection, there will still be a need to deal with crossing creeks and gullies, especially if the terrain is steep and there are frequent gulches or if the area has been mined and there are existing established fords. Fords may require permitting from DFO and YWB.

Fords should be safe, erosion free, storm proof and require no maintenance. The stream should be checked to make sure it is not a fish stream. A good ford should let high flows through without erosion, not have gross sediment input from the approaches and keep the stream from jumping its banks at high water. A ford should either pass debris or trap it. The largest cobbles or boulders in the channel are the sizes to look for when making a ford because these have resisted erosion so far.

Fording higher sensitivity streams

Fording is the crossing of creeks, streams or rivers at locations where a bridge, causeway or elevated embankment does not exist or is not utilized by a vehicle or piece of equipment. Fording typically involves driving directly through a watercourse, across the banks and bed.

Fording or the construction of fords can result in habitat degradation in many ways, some of which include sedimentation, channel compaction, infilling, rutting, and the creation of barriers to fish passage or migration. Fording can also result in the destruction of fish, fish eggs or fish food (insects). Additionally, vehicles or equipment undertaking fording are at risk of becoming stuck or being overturned upon entering the waterway.

The construction of fords is typically not authorized by DFO. In most cases, fording is not recommended by DFO although in some instances may be considered as a least preferred option.

If Fording is being considered as a means of crossing a water course, the DFO Habitat and Enforcement Branch should be contacted as early as possible in order to receive advice regarding the proposed activity. Fording during a sensitive period of time for fish (for example during spawning or egg incubation periods) should not be considered.

Winter Access Roads

The following measures apply generally to winter access roads:

- There must be adequate frost penetration and snow cover to support vehicle
- Snow fills must be removed from stream crossings before spring break-up
- Bulldozer blades must be raised to avoid cutting organic layer
- Rubber pads fixed to tracks reduces impact on organic layer

Ice or Snow Bridges are subject to the following DFO Operational Statement:

This Operational Statement applies to freshwater systems in the province of British Columbia and Yukon Territory

Measures to Protect Fish and Fish Habitat when Constructing an Ice or Snow Fill Bridge

1. Minimize the riparian area temporarily disturbed by access activities along the adjacent upland property, and preserve trees, shrubs, and grasses near the shoreline. Use existing trails, winter roads or cut lines wherever possible as access routes to avoid disturbance to the riparian vegetation.
2. Construct approaches and crossings perpendicular to the watercourse using clean, compacted snow and/or ice to a sufficient depth to avoid cuts to the banks of the lake, river or stream.
3. Implement sediment and erosion control measures to prevent the entry of sediment into the watercourse during construction and deactivation activities
4. Operate machinery on land or competent ice and in a manner that minimizes disturbance to the banks of the lake, river or stream.
 - 4.1. Machinery is to arrive on site in a clean, washed condition and is to be maintained free of fluid leaks.
 - 4.2. Wash, refuel and service machinery and store fuel and other materials for the machinery away from the water to prevent any deleterious substance from entering the water or spreading onto the ice surface.
 - 4.3. Keep an emergency spill kit on site in case of fluid leaks or spills from machinery.
5. If water is being pumped from a lake or river to build up the bridge, the intakes should be sized and adequately screened to prevent debris blockage and fish mortality (refer to DFO's [Freshwater Intake End-of-Pipe Fish Screen Guidelines](http://www-heb.pac.dfo-mpo.gc.ca/publications/publications_e.htm#EndofPipe)) (http://www-heb.pac.dfo-mpo.gc.ca/publications/publications_e.htm#EndofPipe). Avoid using small streams as a source for water.
6. Crossings do not impede water flow or fish passage at any time of the year.

7. Where it is safe to do so, create a v-notch in the centre of the crossing during decommissioning, to allow it to melt from the centre and also to prevent blocking fish passage, channel erosion and flooding.
8. While this Operational Statement does not cover the clearing of riparian vegetation, the removal of select plants may be necessary to accommodate the road. This removal should be kept to a minimum and should not be wider than the road surface.
9. Vegetate all disturbed soils, banks and riparian areas by seeding and/or planting trees and shrubs in accordance with the DFO guidance on [Riparian Re-vegetation](http://www-heb.pac.dfo-mpo.gc.ca/decisionsupport/os/riparian-reveg_e.htm) (http://www-heb.pac.dfo-mpo.gc.ca/decisionsupport/os/riparian-reveg_e.htm). Cover seeded and vegetated areas with appropriate measures to prevent soil erosion and to help seeds germinate. During the winter months, the site should be stabilized (e.g., cover exposed areas with erosion control blankets to keep the soil in place and prevent erosion) and vegetated the following spring.

Abandonment or Reclamation of Roads and Trails:

Reclamation is not required if the access road leads to other operations or forms part of a publicly used road system. If reclamation is required the following steps should be taken:

- All culverts should be removed and replaced by non-erosive cross ditches
- On steep accesses, earth breakers may be built upon to divert surface runoff
- Entrance ways into open pit mine sites should be blocked by barriers such as earthen berms, slash, logs or other acceptable means

Sediment control - Sediment traps

For runoff drains and ditches the most common sediments are sands and gravels that are eroded from the bed and banks. Simple traps can be installed at points where channel slopes decrease or before cross drains to allow these materials to settle. These clean-outs or traps can

then be mucked out during low flow. Settling rates are dependant on the size of the particle, but if channel velocities are reduced to 1 foot per second (0.3 m/s) most sands and gravels will settle out in a very short distance. A typical sediment trap in a ditch would be twice as deep as the ditch when full and about three times as long (twice the bankfull depth for a distance of 3 bankfull widths). As a general rule the clean-out or trap should have 0.5-1.0 metres of



sediment storage in the bottom before the materials would impede normal flows.

5.3 Mitigation Measures in the Production Phase

5.3.1 Settling Pond Facilities - General

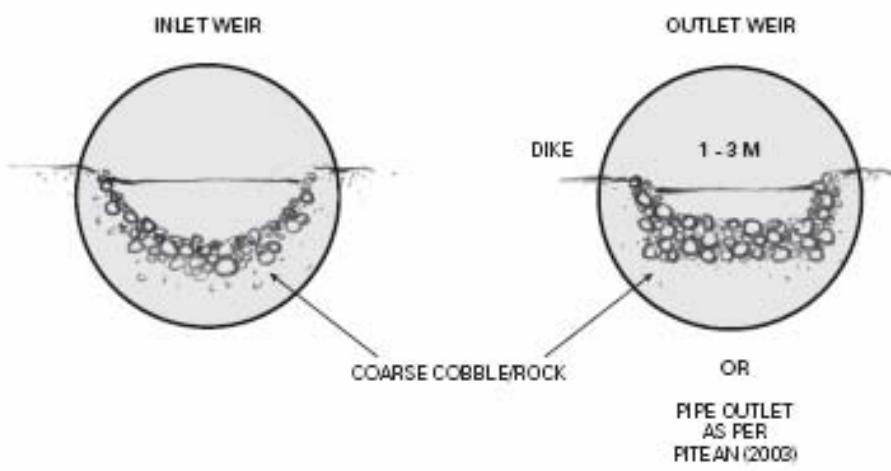
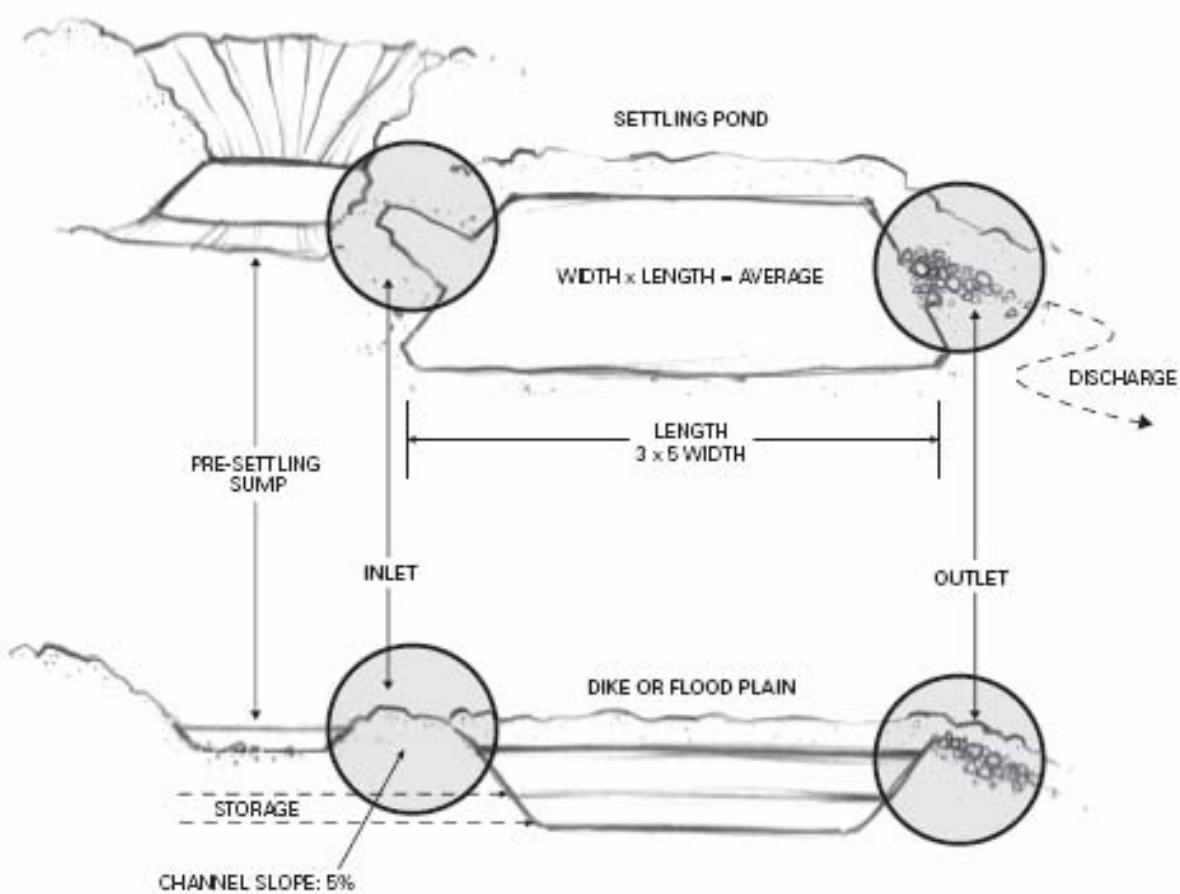
Settling facilities are very important mitigation measures but they are not perfect. Settling facilities cannot remove all particles of soil from water. Every placer mine will need a settling pond system of some kind either to capture and clarify runoff from stripping areas or other parts of the mine that are generating sediment, or to clarify wash plant discharge. If they are properly designed, constructed, operated and maintained they will make a big improvement in effluent water quality.



Out of stream pre-settling, settling facilities with interior baffles

A settling pond is either a simple dugout, a low spot in the land, an old mining cut or a pond with an embankment. They come in different shapes but ideally should be three to five times as long as they are wide.

Most pond systems discharge directly into streams, but in sensitive habitat areas settling facilities may be used in recycling or closed loop systems that are meant to have no discharge of visible effluent into the stream. Settling facilities are made of a "tailrace" or a long rough channel from the wash plant, pre-settling pond, an inlet structure, the main pond, dam or dyke, and outlet structure. In some cases a pipe is used as an outlet structure, but seldom for an intake structure. Often wash plant water can be discharged back through tailings before treatment in a settling pond. In the case of a floating dredge, the fines and tails are deposited within the cut and tailings pond combined and a pre-settling sump is not needed. However, a separate settling pond may be required prior to discharge of the effluent from a floating dredge operation in order to meet placer effluent standards and requirements, unless the pond has sufficient ground water inflows.



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5.3.2 Selecting a site and layout for settling facilities

To avoid wasting time and money, settling facilities must be integrated into the mining plan from the start. The pond system should be built to hold the amount of pay dirt to be washed for the life of the mine plan because cleaning out a settling pond is extremely difficult. Things to consider when selecting a site for settling facilities are as follows:

- Ponds should be used, restored, and decommissioned as part of the mining plan.
- Settling facilities should never be set up on good paying ground where they will have to be ripped up later.
- If possible, the pond system should be located out of stream in the lowest part of the topography.
- Dams over 10 feet high should be designed by a professional.

Ideally, sediment ponds should be developed, used and restored within one or two mining seasons. Otherwise it may be better to design a large pond to accommodate the entire mine lifespan and many claims as one large pond is better than two small ones.



Ponds in series in a narrow valley

Material handing, including overburden, excavations and settled sediments, need to be considered to ensure the placer mining operation is efficient, reduces impacts and is restored effectively.

Depending on the topography, it may be necessary to construct a series of settling facilities or use a combination of excavated pits and low dams to achieve the required storage volumes and area. Additional requirements might be to protect the pond during seasonal abandonment and pond winterization. Low-lying ponds within the floodplain are less likely to fail due to stream erosion or bank failure, and are potentially easier to decommission and restore. While it would be nice if the pond discharged to ground by seepage flows with good quality effluents and low suspended solids, placer miners should not count on this scenario. Pond seepage will often seal off over time.



Settling out of stream with creek bypass

5.3.3 Estimating pond size

Several rules apply when considering the size of a given settling pond:

- Start with the estimate of pay dirt and assume that 25% of this volume will end up in the settling pond if there is pre-settling (40% will go to the pond without pre-settling).
- There should be at least five hours of holding time. Generally, lower overflow rates produce low suspended solids in placer settling pond effluents.
- With the rationale of discharging low to no settleable solids, a design overflow rate of 2,000 Igpm / acre (2,400 USgpm / acre) has been selected as the guideline. The pond area is determined by dividing the mine wash plant water flow rate or pumping rate by the design overflow rate.
- A depth requirement for the settling pond is to have enough depth for sediment storage and water to provide settling conditions in the pond. About 1.0 m (three feet) of water is required above the top of the stored sediment in the pond. If overtopping of the pond would result in potential failure of the embankment and pond itself, a freeboard of 0.6 metres (two feet) should be added.
- As a design check, the total depth of the stored sediment and stored water should not exceed 3.0 metres.

- Sediment ponds function better if they are rectangular or ovoid instead of square. Commonly a length-to-width ratio of 3:1 to 5:1 is used for design purposes.
- Where it is necessary to construct or use a square pond or a pond with a length to width ratio of less than 5:1, it will be necessary to incorporate baffles into the design to increase the effective flow length and reduce short circuiting in the pond. Berms are effective but will reduce the storage volume of the pond. Plastic geo-membrane material has been used successfully for baffles. These are strung as long sheets across the settling pond and tied with ropes to anchors or trees, and do not reduce the storage volume of the pond.

The following is an example calculation of the size of a settling pond. A Guidebook settling pond worksheet is included on the following page for your use.

A mining plan proposing 10,000 m³ of processed pay per season, sluicing with 2,000 Igpm total inflows into a settling pond excavated into the nearby floodplain (no free board required) and must produce little to no settleable solids in the effluent results in the following pond requirements:

Design Area	= Water Use (Igpm) / Design Overflow Rate = 2,000 / 2,000
	= 1 acre or 4,000 m ²
Sediment Storage	= 10,000 m ³ x 0.5
	= 5,000 m ³ (6,500 cu. yards)
Pond Depth	= Design Water Depth + Sediment Storage / Design Area
	= 1.0 m + 5,000 m ³ / 4,000 m ² = 1.0 + 1.25 m
	= 2.25 m (5.25 feet) design check < 3.0 m (10 feet)
Design Area	= L x W = 5W x W = 5W ² with L:W = 5:1
Pond Width, W	= 28 m (92 feet)
Pond Length, L	= 141 m (459 feet)
Pond Depth, D	= 1.6 m (5.25 feet)

SETTLING POND WORKSHEET (1989 version)

POND VOLUME

Sediment Storage Volume:

1. Estimate the total volume of gravel that will be processed while using this pond system: _____ yds³ per year

2. Sediment that will accumulate in ponds:

Value from Line 1 x 0.5 = _____ yds³

Note: 0.5 can be replaced with 0.2 when using good pre-settling facilities; or it can be replaced with a factor based on site experience.

Retention Time Volume:

3. Estimate process water flow: _____ igpm

4. Estimate water gain from surface runoff and seepage: _____ igpm.

5. Line 3 + Line 4 = _____ igpm (total flow through ponds)

6. Line 5 x 0.358 = _____ yds³/hour (water flow through ponds)

7. Select design retention time: _____ Hours (Use 3 hours for estimating purposes)

8. Line 6 x Line 7 = _____ yds³ retention time volume (volume of water that must be stored to get adequate retention time in the ponds).

Storm Surge Volume:

9. Estimate the total surface area that will drain into the ponds (include the area of the mining cut, processing area, and settling facilities themselves as well as any other areas that will drain into the ponds): _____ ft²

10. Assume a 5-year, 6-hour precipitation of 0.7 inches

11. Line 9 x (0.7 / 324) = _____ yds³ (water from storm)

12. Line 2 + Line 8 + Line 11 = _____ yds³

Total pond volume required (sediment storage volume plus retention time volume plus storm surge volume). This volume can be in one large pond or can be divided up into several smaller ponds from the processing plant down to the recycle pond. Pond volume below the recycle pond should be considered extra and should not be included in the total pond volume required.

Pond Area, Flow Through Rate:

- | | | |
|---|----------------------|-----------------------------------|
| 13. Line 12 (yd^3) $\times 27 =$ | <input type="text"/> | ft ³ (unit conversion) |
| 14. Line 13 (ft ³) / desired depth (maximum of 8 ft.) = | <input type="text"/> | ft ² (surface area) |
| 15. Line 14 / 43,560 = | <input type="text"/> | acres - (settling area size) |

Now that the required volume has been established, the surface area can be calculated by assuming a design depth

Check the flow through rate:

16. Line (5) / Line 15 = igpm per acre.

This number should be 3,000 igpm/acre or less. A number much higher than this means the surface area of the settling facilities is too small.

Configuration:

Where possible, settling facilities should have a length to width ratio of at least 3:1. Very narrow ponds are less efficient because water velocity through the ponds causes scouring and re-suspension of sediment. Ideally, the length to width ratio should be 5:1. Therefore, to calculate your length to width ratio you should use the following formulas:

For 3:1

$$x = \frac{\sqrt{a}}{3}$$

For 5:1

$$x = \frac{\sqrt{a}}{5}$$

$$x = \text{_____ ft wide}$$

$$x = \text{_____ ft wide}$$

$$2x = \text{_____ ft long}$$

$$2x = \text{_____ ft long}$$

Where "a" is surface area (ft²) obtained from line 14 and x is width (ft).

5.3.4 Screening, Sorting and Pre-Settling facilities

Placer mines generate large volumes of wastewater compared with the size and resources of the operation. It is very hard to manage such large volumes of waste water without effective runoff and erosion control and without efficient pre-settling and materials screening prior to the settling facilities. Filtration through tailings dams is not adequate as a way to improve on settling pond efficiency. Sorting coarse material (sand, gravel and stones) upstream of the setting facilities makes a big difference in gold recovery and effectiveness of the settling facilities. Screen decks or rotating trommel screens increase gold recovery and decrease the amount of water required. Wash plants with screened feed don't need the higher velocity water necessary to move coarse gravel and cobbles are more effective in breaking up clay balls and have less effluent flowing to the settling facilities. The life of a settling facility is lengthened by removing coarse gravels with screens. Screening can also reduce some of the capital and operating costs of pumping and settling. Lower volumes of water are generally easier to treat in a settling facility with greater efficiency. Greater settling facility efficiency results in a cleaner effluent for recycle or discharge to the environment.



Example of a pre-settling pond

A pre-settling facility or area is a depression at the end of the tailrace designed to remove fine sand (settleable solids) from the wash water prior to the settling facility. Pre-settling facilities make the settling pond system work much better and save a fair amount of money. The pre-settling facility has to be sized properly and cleaned out regularly. The pre-settling facility allows sandy material to accumulate and be removed with equipment, saving the main pond for settling the finer sediments. Pre-settling facilities should be longer than they are wide (2:1 to 5:1). They should be made shallow and should have a hard bottom to allow for easy access with equipment. The pre-settling pond in this picture is in the final stages of its useful life. They should be situated so that the equipment can easily ramp in and out, and be set up so as to have space nearby to store and dewater the solids that are cleaned out.

Pre-settling facilities or areas need only be about 1/5 to 1/10 the size of the main settling facility. The pre-settling facility could be as simple as a large delta shaped depression in the tailrace channel between the sluice box and settling facility or it could be constructed with a shallow berm of tailings across the tailrace, as long as there is enough space to drain and store the cleaned out material. About 50% of the sediment should fall out in screening, 25% in pre-settling, and the remaining 25% in the settling pond.

5.3.5 Settling pond outlets

Outlets should be constructed to limit the level of water to at least two feet (0.6 m) below the top of the dike if freeboard is required. The outlet must be able to pass all the inflows without causing the pond water surface to rise, therefore they are typically wide (outlet weir) or have good flow capacity (large culvert or riser pipe). Overflow weirs should be constructed and designed to avoid erosion or washouts from the pond overflow discharge. Importantly, the outlet should be situated to maximize the useful area of the settling pond, and, have sufficient width or size to draw effluent uniformly and consistently from the pond surface.

A riser type or culvert outlet may also be suitable. Riser outlets are constructed with culverts at least 18" diameter to limit plugging with floating debris. A general rule suggests culverts should be at least one inch in diameter for each 100 USgpm of flow. Cut-off collars or extra compaction should be installed around the pipe portion in the dike to prevent seepage and erosion along the pipe wall. The outlet of the settling pond should be armoured with coarse material to prevent erosion at the toe of the dam. The coarsest available materials (coarse washed tailings, broken rock etc.) should be placed along any slopes exposed to flowing water and extend to an elevation 0.6 m (2 feet) higher than the annual high water mark.

5.3.6 Water Quality from settling facilities

Settling pond discharges are regulated by measuring the soil suspended in the water. There are three traditional ways to quantify this: *suspended solids (mg/L)*, *settleable solids (mL/L)* and *turbidity (NTU)*. Suspended solids is the total mass of sediment carried in the effluent as measured by filtering, drying and weighing a sample in a laboratory; settleable solids is the amount of materials that can be readily settled and it is measured with an Imhoff cone; and turbidity is a measure of the cloudiness or light penetration through the effluent and is measured with a meter in the lab or in the field. Discharge limits are specified in the mine's water use licence.

Placer mining settling facilities have to obey the rules of gravity. Soil particles settle out of water at different rates under the force of gravity depending mostly on their size and weight: the bigger the particle the faster it settles. Placer mine settling facilities are effective at removing sand and coarse silt particles between two and 20 microns and up (the size of the head of a pin to the size of a grain of salt). Anything smaller than that will not settle out in a conventional pond because of electrical forces between the fine particles and the enormous length of time it takes for fine material to settle. As a result, some settling pond discharges have a *high turbidity* but relatively *low suspended solids*. That is why settling pond discharge often appears highly coloured, cloudy or turbid, even though it may be fairly low in settleable and suspended solids. Well designed and maintained settling facilities should be able to consistently reduce settleable solids to less than one ml/L.

5.3.7 Cross valley dams, in-stream ponds and creeks as conduits

There will be situations, such as in gulches and narrow valleys, where out-of-stream settling facilities are just not practical. This raises the issues of creating in-stream ponds by building dams right across the valley using ***cross valley dams***, or using the ***creek as a conduit*** to convey everything downstream to an area where out-of-stream settling is feasible. In-stream ponds have a chequered past; these structures are subject to significant stream processes and have a higher risk of failure, thus sending sediment downstream and negating their purpose. Stable in-stream ponds require substantially more design and protection, and should only be used in appropriate circumstances such as in gulches and pups where stream processes are small. In many cases cross valley dams will have to be higher than three metre (10 feet) and professional engineering design and supervision are recommended.

If a miner has access to wider areas downstream, it may be tempting to locate settling facilities there for cost savings, but the only really acceptable rationale would be for environmental benefit. In-stream ponds are simply not recommended unless the site conditions are such that an off-channel pond can not be constructed and there is no suitable area downstream of the mine to develop settling facilities and connect the sites with a drain. Streams with substantial flows are not suitable for in-stream settling facilities and seasonal decommissioning works will be required to remove stream diversions, stabilize the stream and the settling facilities.

5.3.8 Operating, maintaining and monitoring settling facilities

Settling pond maintenance starts with the mining plan: that is the time to consider where to locate them and how large to make them. The ponds should be sized so that sediment removal is not necessary. When a settling pond is full and the berms cannot be built higher, a new pond should be constructed and the old pond restored and protected from erosion.

If a settling pond “blows out” because of the creek eroding into or through it, more environmental damage might result than it was made to prevent in the first place. Settling facilities should be protected according to the risk of flood by armouring nearby stream banks to prevent the lateral movement of the stream into the pond or by excavating cut-off trenches and ditch work to divert runoff around the pond. If there is excessive groundwater seepage, a buttress/blanket of coarse rock to control piping should be laid down along the toe of excavated slopes. Piping happens when groundwater erodes small particles out of the bank creating pathways or “pipes” that grow bigger and accelerate erosion, sometimes resulting in wash out of the embankment.

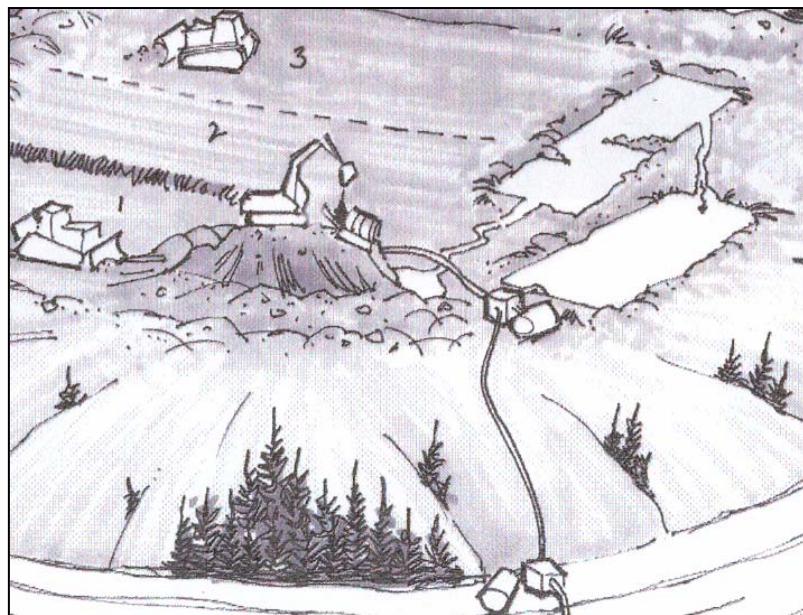
While, not ruled out the cleaning out of settling facilities with equipment is discouraged. In some cases such as starting up a new mine, or when there simply isn’t enough room for the required capacity, clean out may be the only way to keep operating. In those cases, the pond should be dewatered and allowed to drain. Pond sediments or slimes take a long time to dewater, are very difficult to handle, and tend to flow away at very low angles of repose. It may be possible to remove shallow deposits of sediments on flat hard-bottomed ponds with bulldozers or front-end loaders, but an area to store, rework and re-vegetate the sediments is required. It is usually not practical to clean out a settling pond more than once or twice.

The settling pond system should be inspected frequently and certainly after every large rainstorm or flood. A visual inspection should be conducted of the slopes and dykes surrounding the pond both upstream and downstream for evidence of instability, overtopping, erosion or piping. Any damage noted should be repaired as soon as possible to reduce the risk of failure, and debris should be removed. Regardless of the license requirements, the operator should monitor pond effluent on regular basis by using an Imhoff cone. A well operating settling pond will produce low to no settleable solids in the effluent.

5.3.9 Recycling or closed loop systems

Recycling, or closed loop systems re-circulate treated water back to the wash plant from the settling pond system. Systems such as the one illustrated on the next page are applicable to situations where the stream has the highest sensitivity and requires robust mitigation to reduce the risk to the habitat. Another scenario where recycling is applied is when there is a water shortage in the drainage. Recycling reduces make up water requirements and allows mining in drainages where water is scarce. The quantity of effluent is reduced allowing more efficient sedimentation in settling facilities. While it may be difficult to achieve “100% total recycling with zero discharge” due to the problem of water gain from surface and sub-surface inflows, the use of recycling systems is beneficial to sensitive receiving streams.

Constraints to recycling are the effects of the positive water balance, the build up of fine sediments in the process water interfering with gold recovery and challenges with pumping equipment. Recycling generally costs more than a flow-through system so a careful cost analysis should be done during the planning phase to determine whether or not it is a viable option. Experienced miners have overcome many of these obstacles and the practise of recycling continues to expand. While in some cases there may be a need to discharge concentrated effluent in small quantities this should not deter the use of the practise due to environmental benefits outweighing the impact. A tertiary “polishing” pond might be a feasible way to deal with a positive water balance.



Potential recycling pond construction sites should be determined to see if adequate solids removal and retention time will be provided ahead of pump intake. Cut sizes and pond locations should be adjusted until this occurs. The recycle pump should be placed as far downstream in the system as possible and in the last settling pond if there is a series of ponds.

5.3.10 Optimization - Reducing Sediment Loadings from Ponds

If a suspended solids discharge standard is specified in the water use licence even the best conditions in a conventional settling pond might not always meet it. Those placer mines are looking at total recycle (or closed loop) systems, using less water and managing it better, and possibly using flocculants and coagulants to achieve the desired low impact discharge.

Improved Water Use

Good site drainage can be effective in reducing water flows into the settling pond, thereby improving settling pond efficiency. Typically, this involves proper design and construction of ditching and drains to bypass seepage and runoff flows around the settling pond so that it processes only wash plant flows.

A **good mine drain** should be constructed so that it can be used for as many cuts as practical. It should be located as far from the cuts and ponds as possible so that seepage between the bypass and the cut and ponds is minimized. Ditching should be constructed so it intercepts all surface flow from hillside and tributary areas. Groundwater into the pond may be an issue, but commonly the volumes are fairly small relative to the volumes generated from the drains in mine cuts. Improvements in sluice water requirements can also be made by screening pay materials to reduce water quantities required to process them.

Flocculants and Coagulants

The first thing to consider about commercial flocculants and coagulants is the fact that they are chemicals, and therefore not covered under a typical placer mining water use licence. The next consideration is that using flocculants will be a one-off design that is best done in consultation with the supplier. That said, there may be cases where flocculants could provide enough water polishing to make a system viable in sensitive fish habitat areas. In some situations, there may be no other conceivable alternative to allow placer mining with an effluent discharge to downstream streams and rivers containing fish and fish habitats. Of course the cost of the system would have to be weighed against the benefit. There would be little economic incentive unless additional costs can be offset elsewhere in the mining operation. Some cost saving could be realized through smaller pond sizes and more efficient operations during recycling operations, but these are not substantiated or quantifiable at this time.

Introducing settling aids, flocculants and coagulants, into the settling pond system requires field testing, measurement and dosing of product, additional capital and operations costs in addition to the cost of the flocculants materials. Placer mines weighing the options on whether or not to try coagulants should consult with a supplier. Also, the reference section contains a paper on the use of coagulants in placer mining that mentions some promising developments in use of non chemical products.

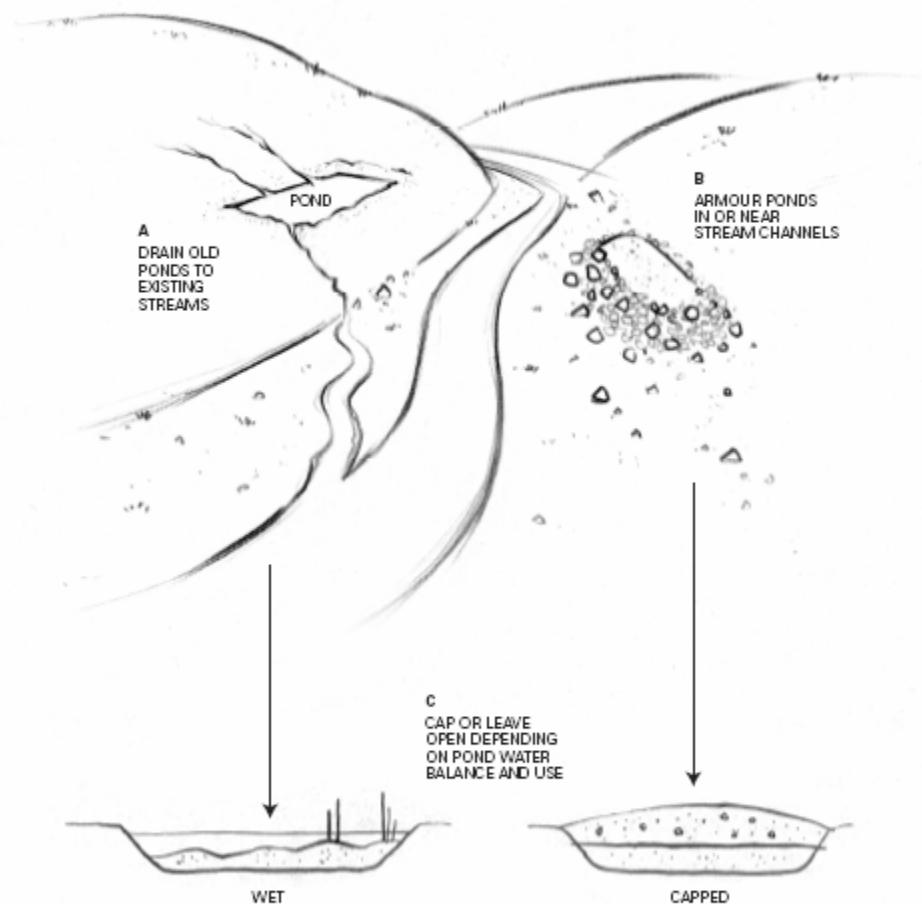
5.3.11 Restoring and Reclaiming Settling facilities

Off channel Settling facilities

The long view should be taken when first locating and designing settling facilities. Miners should think about where the eventual channel and site restoration will be in relation to the reclaimed pond. This helps to ensure that the area may be both mined and restored most efficiently. Settling facilities should be constructed such that, in the long-term, limited risk will be posed to the mine site and environment. Settling facilities located three to six channel widths distance from the active stream channel do not typically pose a large risk. The location and elevation of settling facilities relative to the restoration channel will determine the best strategy for ensuring the long-term stability of the ponds.

These strategies include:

- Settling facilities with a final elevation near or below the grade of the restoration channel may simply be left to fill with water and drain back to the stream. The fine-grained materials in the pond typically re-vegetate with wetland-type plant species within several seasons.
- Settling facilities located next to the stream channel, and with a final pond elevation above the channel should be breached in such a fashion that the fine-grained tailings are not allowed to erode. Ditching should be provided to intercept and control pond drainage.
- Ponds can also be backfilled, sloped and surfaced with fine-grained materials or organics, and allowed to re-vegetate.
- Settling facilities that encroach on the active stream channel should be removed or armoured to prevent erosion of the pond and the sediments.



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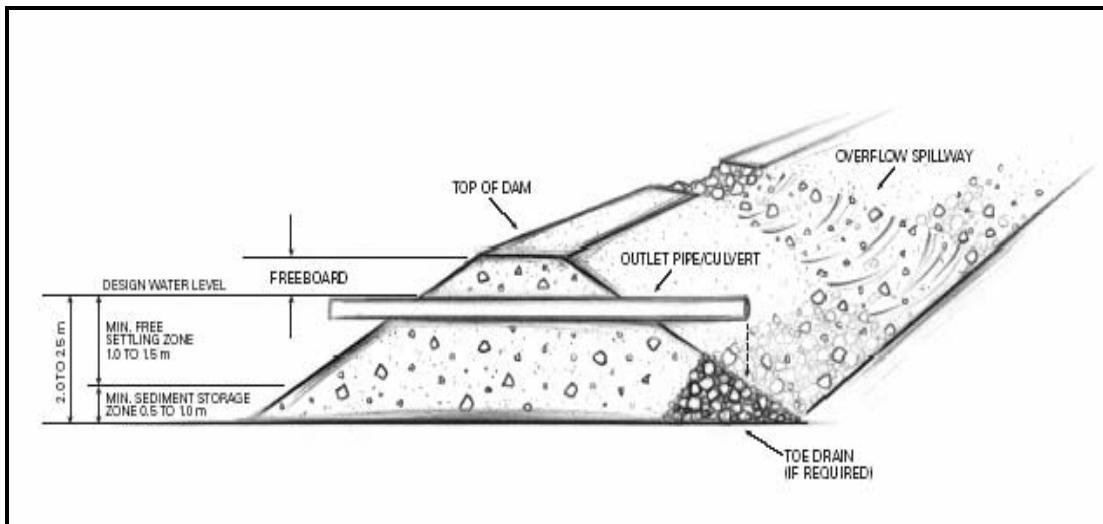
In-stream Settling facilities

In cases where the creek can not be used as a conduit to better settling areas, and in-stream ponds are the only alternative, care must be taken to construct them properly. The construction of new in-stream settling facilities is discouraged on large streams. There will be circumstances when in-stream ponds are built in small creeks that will need to be stabilized after mining, and also at the end of a season. In-stream settling facilities may pose a higher risk to the stream channel recovery because of the potential for the stream channel to erode through the dike or dam and "blow out" the settled sediments. This may result in the transport of previously captured sediment downstream.

To restore in-stream ponds:

- *Cap and decant.* (don't put people at risk) Cover the pond with coarse tailings and divert the stream channel down one side of the pond along the valley wall
- *Build a spillway* down the face of the dyke, dam or structure at the downstream end of the pond to safely convey stream flows
- Divert the channel down one side of the pond without capping the pond surface, and provide a *bedrock spillway at the downstream end* of the pond.

5.3.12 Earth-fill Dam Construction



An ideal dam site is on gently sloping terrain or in a depression that has a thick layer of fairly tight, fine grained hard material underneath. The only type of dam recommended for a settling pond is called a *homogenous earth fill* dam. The fill is made up of well-mixed, well-graded granular material: ideally silty sands to large cobble-size material. The rock tends to hold the dam together while the finer soils help prevent seepage through the dam and generally eliminate the need for an impervious core. Compaction is extremely important in dam construction.

Organic soils, black muck and frozen materials should *not* be used for water retention dams because these materials thaw, can "pipe" or lose their strength and cause failure of the structure. Some seepage is to be expected but excessive seepage may cause failure. Too much coarse grained soils in the foundation will result in more loss of impounded water by exfiltration than if it is made of fine grained soil. However, the dam should tighten up and seepage will tend to diminish somewhat over time as fine sediments accumulate on the base of the pond. If the structure is well built with the proper materials and basic maintenance is observed, problems are not likely. The pond foundation is less critical in flat areas and with excavated ponds. With high berms, on unstable ground, or where specialized designs may be required, a professional engineer should always be consulted to prepare the designs. The Canadian Dam Safety Guidelines recommend that any pond embankments:

- a) greater than three metres (10 feet) high as measured from the downstream toe; or
- b) capable of impounding more than 30,000 m³ of water; or
- c) having a high consequence to human life or infrastructure resulting from embankment failure;

should be designed by a competent professional.

Sometimes it may be necessary to build a series of ponds to result in dams lower than 10 feet, or use a combination of excavated pits and lower dams to stay in the “non-professional” category. Dams should be **compacted** during construction by running back and forth either at right angles or along its length over the entire area with a bulldozer or other heavy construction equipment. The construction materials should be thoroughly mixed and placed in lifts not greater than one foot (0.3 m) and thoroughly compacted before the next layer is placed until a dense firm embankment is achieved. Crest widths should allow access and maintenance and be least three metres (10 feet) with slopes of 2.5:1 (H:V) or flatter when constructed of granular tailing materials. Flatter slopes 3:1 or less may be appropriate where heights exceed three metres (10 feet) or where fine-grained materials are used. The following are Reference Guidebook for good practises when building settling pond dams.

Settling pond dams should:

- Be constructed of mixed granular materials (e.g. well-graded gravel overburden, etc.) with no frozen or organic materials;
- Have side slopes no less than 2.5:1 H:V;
- Be no higher than three metres (10.0 feet);
- Have a minimum top width of three metres (10.0 feet);
- Have a minimum freeboard (from top of impounded water surface to top of dyke) of 0.6 metres (two feet)
- Be constructed of machine-compacted lifts of 0.3 metres (one foot) or less;
- Have tops constructed level, except at spillways
- Be built on competent sub-grade
- Have organic overburden stripped from foundation; and
- Have the coarsest available materials (coarse washed tailings, broken rock, etc.) placed along any slopes exposed to flowing water, and extending to an elevation 0.6 metre (two feet) or higher above the annual high water mark.

Locations for dam sites on a placer claim may be limited but effort should still be made to choose the best available site to prevent failure and subsequent rebuilding. Where dense tight materials occur at the surface or where bedrock has already been reached by mining, no special foundation measures are required. The suitability of the site will also depend on its ability to hold water and its proximity to suitable dam construction materials. The organic overburden should always be stripped from the dam foundation. Care should be taken to locate a dam where its failure would not result in danger to person, property or the environment.

5.4 Mitigation Measures During the Closure Phase

5.4.1 Channel Restoration Criteria

The objectives for reclamation of placer-mined streams are to:

- Design a stable stream channel with natural stream patterns, cross-sectional geometry, longitudinal profile, and sediment-transport characteristics; and
- Meet the standards defined for specific habitat suitability classifications.

The central principle of stream reclamation is that stream channels altered as a result of placer mining activities must be stabilized. Stability is an important concept, as unstable channels may lead to severe, long-lasting impacts that could extend upstream and/or downstream far beyond the mined site.

For example, erosion of materials at a mine site may degrade downstream water quality. The increased sediment load may also cause channel adjustments in downstream reaches that jeopardize the quality of important fish habitat areas (e.g. Chinook salmon rearing habitat). Likewise, the lowering of channel grade by the degradation of permafrost at a mine site can cause upstream incision, bank erosion and slope instabilities, thereby also contributing to increased sediment loads that can affect mine operations (settling pond performance) and downstream water quality and habitat.

5.4.2 Channel Stability

Streams are inherently complex dynamic systems. As such, the notion that stream reclamation will lead to the construction of stable channels is not completely accurate. The intent of reclamation is not to design fixed, unmovable stream channels. Static, unchanging systems that lack periodic natural disturbances (e.g., inundation of the floodplain, bed mobilization, and gravel recruitment from bank erosion) do not necessarily maintain healthy aquatic communities (Poff et al. 1997). For example, floodplain inundation and the associated deposition of fine sediments may lead to increased recruitment of some plant species (Richter and Richter 2000). High flows may cause sediment scour around large wood pieces resulting in the formation of pools and improvement of fish rearing habitat (Montgomery et al. 2003).

In most cases, any previously mined channel may be in disequilibrium (e.g. still adjusting to a new slope and sediment load in the absence of permafrost stream banks and floodplains) so that the existing channel geometry and morphology is not likely to be representative of a stable condition. Thus, the goal of the stream reclamation process is to design stream channels that achieve “dynamic equilibrium”. Dynamic equilibrium is a term that scientists use to describe self-regulating systems that moderate the effects of external factors in such a way that some degree of system stability is established (Knighton 1998). This state occurs when “short-term fluctuations in a given variable occur around a longer-term mean value that is also changing” (Saldi-Caromile et. al. 2004). Dynamic equilibrium and stability will be used interchangeably throughout the text of this document.

5.4.3 Stream Progressive and Final Restoration Measures

Every effort should be made to do progressive restoration once an area is mined out as opposed to leaving these measures to the end. Good site stabilization should be tested and verifiable so that a “walk away” scenario can be met. The goal of restoration and stabilization is to have the former placer mine recover its biological integrity as soon as possible. Land and water use regulations already require measures like contouring, armouring, and re-vegetation to stabilise disturbed ground to prevent erosion and mass failure. The mining site must be stabilized to allow physical and biological processes to be restored. The following are some practises that help the stabilization and restoration process.



Stabilizing Steep Valleys, Pups and Gulches

This restoration option is intended for small steep streams with slopes greater than 10%, where the valley bottom is totally contained by the bed of the stream (i.e. no access along channel). These streams are usually less than two metres (6.0 feet) wide, and often flow for only part of the year (ephemerally) or have very low summer flows. These valleys are often too confined and narrow to provide required settling pond areas so settling occurs downstream. In-stream settling facilities are still possible, but have to be built with great care because the whole flood flow of the creek, such as it is, must be conveyed over the cross valley dams. Ideally, the stream will be restored into a single channel using the *channel design* method. Where it is desirable to control the vertical stability of the channel or to control the movement of bedload in the stream channel, cross-valley structures should be considered (See *Cross Valley Structures*) to ensure stability of the channel (See *Assessing Channel Stability*).

Mining can result in a final drainage or channel located on bedrock or other strong material. If the site is stable, a final channel located on bedrock is ideal. However, overburden may have to be placed into the valley bottom in order to fully stabilize the site. It may be possible to bench the site to minimize the amount of materials handled. In these situations the coarsest available material, such as washed tailings, should be used to construct the final channel bed and banks. Rock-fill dams can be constructed on a site-specific basis.

Valley walls stability should be carefully treated as described in the slope stabilization section. Channel degradation and toe erosion are likely to be a problem within steep confined channels. Bed and banks must be well armoured (check with *Assessing Channel Stability* methods) to an adequate depth with cross-valley structures used to reduce the slope as needed.

If the valley width does not allow a channel to be constructed as wide as suggested by the channel design method, then the depth of channel armouring should be increased.

The following equation could be used to determine how thick the armouring should be:

$$D_2^2 = D_1^2 \times W_1 / W_2$$

where $D_{1,2}$ is the initial design and the new design depth and $W_{1,2}$ is the initial and the available channel width.

5.4.4 Dykes, Dams and Cross-valley Structures

The following are some common structures that enhance long term stability of placer mine features.

Rock-fill Dams

Rock-fill dams are typically used in small gullies and pups to retain sediment and drain water. These small watercourses usually have extremely limited stream flows. Drainage areas are typically less than 150 acres (60 hectares). Rock-fill dams should be constructed of whole and broken durable rock with little or no granular materials smaller than cobbles. Water will flow through the dam (no spillway is constructed) with most sediment retained and stored behind the structure.

Design and construction features of rock-fill dams:

1. Constructed of whole or broken durable rock (e.g. boulders, broken rock, etc.);
2. Upstream toe to upstream shoulder should be constructed of rock with a diameter not less than one foot (0.3 metres);
3. Downstream toe to downstream shoulder should be constructed of rock with a diameter not greater than three feet (0.9 metres) and not less than one foot (0.3 metres);
4. Slope faces are less steep than 1.5:1 H:V;
5. Be no higher than 10 feet (3.0 metres);
6. Minimum top width of 10 feet (3.0 metres);
7. Constructed in machine-placed or bulldozed lifts of five feet (1.5 metres) with the top of dam constructed level;
8. Situated on hard fine grained soils or bedrock with frozen or loose overburden stripped from foundation; and
9. Sides keyed into rock outcroppings or valley walls.

To properly build a rock fill dam the entire footprint of the impoundment area must be cleared, grubbed, and stripped of topsoil and organic materials. Topsoil and organic materials should be stockpiled for use in reclamation activities. If excessive groundwater seepage is encountered in the excavation, it may be necessary to place coarse rock buttresses or blankets to control seepage discharge and to prevent erosion/piping. All disturbed soil should be re-vegetated as soon as possible after construction to limit erosion. Impoundment design and construction should be carried out in such a manner as to provide access to all areas for maintenance and monitoring activities.

Cross-valley dams

Cross-valley structures are placed in steeper stream sections to control channel erosion and bedload movement. They are low, and may be built of tailings or rock. Naturally occurring infilling behind the structure helps to stabilize the stream channel. The structures have a limited capacity to store sediment, and should only be used on a site-specific basis. Design and construction features include:

- constructed of coarsest available granular materials (e.g. oversized overburden, coarse washed mine tailings, etc.)
- side slopes are less than 1.5:1 H:V
- height not to exceed 10 feet (three metres)
- downstream face should be surfaced with largest available materials and include a adequately sized and armoured spillway
- constructed in machine-placed or bulldozed lifts
- built on competent sub-grade with frozen or loose overburden stripped from foundation
- sides keyed into rock outcroppings or valley walls
- walls armoured at structure using similar material as used to construct the structure
- armouring should be $1.5 \times d_{50}$ thick and extend up the entire channel depth (D)

The structure may have a slight “v” or arched shape with the open end facing downstream. This helps to direct flow towards the center of the channel instead of one or the other bank. However, the “v” or arch should be subtle enough not to initiate excessive scour and eventual failure at the downstream toe of the structure.

The rock used to construct such a structure should be sized to remain stable during the 50-year design events (discharge estimated in previous sections). The following rock sizing equation presented by Wittler (1996) of the U.S. Bureau of Reclamation provides a suggested median stable stone diameter, d_{50} (mm) for a particular discharge, Q (m^3/s), width, W (m), and downstream slope of the structure, J (m/m).

$$d_{50} = 500 \times (Q/W)^{0.56} \times J^{0.43}$$

Downstream structure slopes are typically around 0.1 (10%).

If flow data is unavailable, Shields entrainment function can be used once again to estimate stability,

$$d_{50} = 11,000 \times D \times S$$

where depth (**D**) is the channel design depth in metres, slope (**S**) is the channel design slope in metres, and d_{50} is the design median stable stone in millimetres. This coarse material should be placed with a minimum thickness greater than or equal to twice the calculated d_{50} .

If the required size of material is unavailable, slope can be decreased or width increased to reduce the required rock size. To estimate the decrease in channel depth obtained by a decrease in channel width the following equation can be used:

$$D_2^2 = D_1^2 \times W_1 / W_2$$

where $D_{1,2}$ is the initial design and the new design depth and $W_{1,2}$ is the initial and the available channel width.

5.4.5 Slope Stabilization

It is important to stabilize the slopes of piles of overburden or tailings and other disturbed steep bank on the mine that are likely to fail. Slopes fail because the soil is soft or weak; the slope is too wet or too steep for the soil or a combination of these. Factors contributing to slope failures include:

- stability decreases as bank steepness approaches the angle of repose
- large mass or weight of material on top of slope or bank (i.e. stockpiles, ponded water)
- rapid drawdown of open water resulting in high pore water pressures resulting in decreased frictional shear strength and increased mass
- piping of material along layers of sand undermining overlying bank material which then collapse
- expansion and contraction of solids during wet/dry or freeze/thaw cycles resulting in tension cracks and subsequent collapse or toppling of blocks

Hydraulic forces initially result in surface erosion but can start slope failure processes. Surface erosion is increased after property is disturbed because water velocities are increased due to increased slopes, constricted drainages paths or channels, decreased drainage roughness (i.e. through de-vegetation and smoothing of slopes), or increased flow volumes (i.e. due to loss of water storage or consolidating drainage paths). Piles of overburden, tailings and other materials adjacent to restored channels should be left in a stable configuration. They should be graded to a slope that is less than the angle of repose for the type of material of which they are built.

Benching of these slopes may also be effective in decreasing surface water velocities and decreases the overall steepness of the slope.

If surfaced with fine-grained or organic materials, they should quickly re-vegetate and stabilize. To improve stability of any slope, the following should be done:

- vegetate slope to stop surface erosion
- unload top of bank, remove ponds and stockpiles of material, equipment, and dead vegetation from the top of banks
- anchor toe rock can be used to help armour the toe of a slope from erosion and provide mass resistance to transitional and slump failures
- provide surface drainage above the bank to avoid ponding of water this can reduce piping and pore water pressure, improving shear strength
- provide sub-surface drainage to reduce pore water pressures and piping

Grading

The objective of the general grading will be to replicate, as best as possible, an unaltered floodplain and streamside condition. The area considered for general grading includes all disturbed areas of the mine site within the floodplain and riparian corridor up to the valley walls.

If the floodplain upstream or downstream of the mined (i.e. generally disturbed) area is undisturbed, the grading (including the creation of benches and terraces) should approximate conditions observed in the undisturbed sections. If the riparian area and channel are disturbed both upstream and downstream of the site, see the table on Page 92 for recommended maximum slope characteristics by soil type.

Monitoring of Restoration Measures

The schedule and implementation plan for the inspection and maintenance of all mine facilities and restoration measures should be outlined within the mine plan. Routine inspections must be made of drainage control structures, settling and pre-settling facilities, diversion bank stability, in-stream structures, water acquisition structures, dam conditions and watercourse crossings. This monitoring schedule would also include all waste and fuel storage facilities, and the maintenance of camp facilities.

Progressive Reclamation

The progressive reclamation plan must be developed in close conjunction with the chronological sequence of mine development, including the establishment of the permanent location for the stream channel and must include optimal time periods for re-grading to ensure maximum re-vegetation. Measures would also include minimizing vehicle and equipment access to rehabilitated lands. Progressive reclamation plans become more important and should be more developed for longer term (greater than two years) operations.

Seasonal Closure

The success and timing of mining operations are highly dependent upon weather conditions. Proper preparation of drainage facilities at the end of each season including both minor and major diversions and channels will ensure minimal disruption from wintertime *auf'eis* build-up or spring freshet flooding to operational aspects and minimal environmental impacts during the subsequent mining season.

The success of the operation plans, runoff control, diversion and settling pond system designs and monitoring programs should be re-evaluated each year in conjunction with the Client Services and Inspection (CS&I) Branch of Energy, Mines and Resources. The procedures taken to adapt to changing conditions should be documented in the Annual Report required by the water use licence. Any subsequent modifications to various design features must be documented by the proponent and by CS & I.

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7.0 DEFINITIONS

Action Level The end-of-pipe effluent concentrations that must not be exceeded, on average, for the life of the mining operation.

Alluvial Transported and deposited by flowing water. Related to sediment deposits that were originally produced by flowing water.

Bank yard The volume of material, pay dirt, equivalent to one cubic yard in situ (in place) that in its original undisturbed place in the ground. This volume does not include a swell factor or reduction in volume because of screening.

Bedrock Solid rock underlying placer gravels. In many cases the bedrock surface is weathered or decomposed and can be ripped or dozed

Bench A placer deposit in an ancient stream channel at an elevation above the present stream channel.

Bypass Channel A channel diverting unused stream flow and runoff around the mining area and settling facilities.

Best Mining (or Management) Practises Interpretation of what BMPs are range from proactive decision-making and action to engineered infrastructures. In addition, these practices are not only technical or prescriptive, but can encompass planning, education and governance. By definition, BMPs are the best technical works and management practises that represent due diligence and standard of effort that tries to reduce impacts. (Northwest Hydraulics, for DFO. B. Chilibek, 2002)."BMPs are managerial, operational, and structural measures that can be used to help prevent, reduce or mitigate various undesired impacts that an operation may cause to natural water courses." (DFO Pitueau Engineering 2003).

Classification Basically is screening. In placer mining terminology classification commonly refers to mechanical separation of the coarse material from pay dirt according to size. Classification may be used in the mining operation before pay dirt enters the wash plant or within the wash plant itself.

Cleanup Collecting concentrated placer material from the wash plant recovery devices for further concentration of gold particles.

Coarse Tailings Pebble and larger material discharged from a wash plant or classification system.

Coarsest Available Materials In placer mining means stones or rocks in situ (in place) or washed material that has the largest average diameter on the mine site.

Compliance Level A maximum end-of-pipe effluent concentration that shall never be exceeded.

Cut/ Mine Pit The placer mining process in which pay dirt is excavated from the surface of gold bearing gravels to bedrock and beyond. The excavation itself, from which overburden and pay dirt have been removed is called the cut or the open cut.

Decommission To remove from service.

Density The mass per unit volume of a substance in grams per cubic centimetre at 20° C. Placer gold density is about 16 to 19 gm/cc compared to water, which has a density of one gm/cc. Related to specific gravity.

Design Target The best settling facility that can be established at a placer operation, given the prevailing site characteristics.

Design Water Level The normal full level of a settling pond including the needed depth of storage for settled material and the needed depth of water on top.

Discharge The rate of flow, or volume of water flowing by a point in a given period of time. Often expressed as cubic metres per second in metric, or cubic feet per second in English units. A common unit of discharge in placer mining is the Imperial Gallon per Minute (IGPM). One IGPM = 1.2 U.S. GPM. One Cubic foot per second (CFS) = 374 IGPM. 1 Cubic meter per second = 35.315 cfs = 7,812.14 Igpm 1000 Igpm = 0.128 m³/sec = 4.52 cfs.

Effluent In placer mining, means the treated waste water or wash water flowing out of the settling pond system.

Effective Length The shortest distance water can travel in the pond between the inlet and outlet.

Energy Dissipater A structure, usually constructed of rip rap, onto which water may be discharged to reduce its velocity while limiting the potential for erosion.

Erosion For placer means particles worn away by water.

Exfiltration The loss of water from a pond by seepage into the foundation or lower portion of the embankment.

Flocculation The process by which very fine particles suspended in water are assembled into larger particles or floccules that eventually settle out of suspension. This process, while natural, can be accelerated by adding specific chemicals.

Fines The small grained particles of soil referred to as very fine sand, silt and clay.

Freeboard The vertical distance between the design water level and the top of embankment.

Liner An impermeable (waterproof) geosynthetic material (geomembrane) or clay layer installed in the bottom of a settling pond to limit seepage losses.

Minimum Free Settling Zone The zone of water below the decant/discharge level and above the sediment storage zone that contributes to retention time.

Minimum Sediment Storage Zone The zone below the free settling zone that is provided for sediment accumulation.

Make-up Water Water that is added to the system to make up for losses so that flow to the wash plant stays constant.

Muck In placer mining means the frozen overburden on top of pay gravels made of fine silt, organic matter and ice. Black muck is the term reserved for a unique kind of dark coloured muck in the Klondike.

Overburden Any organic material or mineral soil lying on top of pay gravels that must be removed to create the cut.

Pay Dirt The gravels in an alluvial deposit which contain placer gold in economic amounts.

Pre-settling Pond or Coarse Sediment Sump A sump between the wash plant and the inlet end of the settling pond that is generally separated from the rest of the pond by a small berm. This sump can trap up to 80% of the sediment volume, depending on grain size.

Residence Time The shortest period of time it takes water to travel from the inlet to the outlet.

Rip Rap/Armour Coarse rock used for erosion protection.

Settleable Solids These are the sediments that, when measured by an Imhoff cone test for one hour, settle to the bottom of the cone. Usually measured in units of millilitres/litre.

Sediment load The total amount of soil burden transported in the stream that can be comprised of suspended sediment, settleable solids, wash load, bed load.

Suspended Solids These are the solid particles, usually silt and clay size, that move in suspension, usually measured in units of milligrams/litres.