Pipeline Associated Watercourse Crossings
3rd Edition

October 2005

CAPP • CEPA • CGA

Fisheries and Oceans Canada
Oceans
Assistant Deputy Minister

Pêches et Océans Canada
Océans
Sous-ministre adjoint

Your file *Votre référence*

Our file *Notre référence*

September 12, 2005

Re. Pipeline Associated Watercourse Crossings, 3rd Edition

Fisheries and Oceans Canada (DFO) is pleased to endorse the above referenced manual and recognize it as a reference document for use both by industry and department employees in all regions. Under the guidelines of the Natural Resource Industry Associations (NRIA), DFO has worked with staff of the Canadian Association of Petroleum Producers (CAPP), the Canadian Energy Pipeline Association (CEPA) and the Canadian Gas Association (CGA) in the development of this edition.

Based on the recently developed DFO Risk Management Framework, this document is a compilation of modern planning considerations, "best practices" pipeline and vehicle watercourse crossing construction techniques, and available environmental protection methods to meet Provincial and Territorial regulatory requirements and minimize associated fisheries habitat impact.

DFO is committed to work with industry to regularly review this document and revise as appropriate, and ensure it is applied consistently by DFO Regions throughout Canada. This will ensure a streamlined and effective process for both DFO and the pipeline industry.

DFO looks forward to continuing to work co-operatively with the pipeline industry to ensure that fisheries habitat is adequately protected, while contributing to Canada's goal of Sustainable Development.

Sincerely,

Sue Kirby

Sue Kirby
Assistant Deputy Minister
Oceans and Habitat

Ottawa, Canada
K1A 0E6

Canada

The Canadian Association of Petroleum Producers (CAPP) is the voice of the upstream oil and natural gas industry in Canada. CAPP represents 150 member companies who explore for, develop and produce more than 98 per cent of Canada's natural gas, crude oil, oil sands and elemental sulphur.

Our members are part of a $75-billion-a year industry that affects the lives of every Canadian. Petroleum and the products made from it play a vital role in our daily lives. In addition to providing heating and transportation fuels, oil and natural gas are the main building blocks for an endless list of products - from clothing and carpets, to medicines, glues and paints.

Working closely with our members, governments, communities and stakeholders, CAPP analyzes key oil and gas issues and represents member interests nationally in 12 of Canada's 13 provinces and territories. We also strive to achieve consensus on industry codes of practice and operating guidelines that meet or exceed government standards.

The Canadian Energy Pipeline Association (CEPA) represents Canada's transmission pipeline companies. Our members are world leaders in providing safe, reliable long-distance transportation for over 95% of the oil and natural gas that is produced in Canada. CEPA is dedicated to ensuring a strong and viable transmission pipeline industry in Canada in a manner that emphasizes public safety and pipeline integrity, social and environmental stewardship, and cost competitiveness.

The Canadian Gas Association (CGA) is the voice of Canada’s natural gas delivery industry. CGA represents local distribution companies from coast to coast as well as long distance pipeline companies and related manufacturers and other service providers. CGA and its members stand at the junction where Canada’s gas delivery system meets the needs of over five million Canadian natural gas customers. CGA’s members deliver over 25% of the energy used in Canada.

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Overview

In 2004, the Canadian Association of Petroleum Producers (CAPP), Canadian Energy Pipeline Association (CEPA) and Canadian Gas Association (CGA) initiated revision of the Canadian Pipeline Water Crossing Committee (CPWCC) document *Watercourse Crossings, Second Edition* to incorporate regulatory and technological advancements. Feedback was solicited from government and industry regarding the second edition of *Watercourse Crossings*, and those comments were incorporated in this third edition.

This document outlines the present regulatory framework under which pipeline associated watercourse crossings are assessed and constructed in Canada. In addition, it suggests measures to assist pipeline companies, governing agencies and contractors during the planning, construction, operation and maintenance of pipeline associated watercourse crossings. The development of this document is seen as a means to promote a consistent approach to pipeline associated watercourse crossings throughout Canada and to aid in developing a common understanding among industry, government and other stakeholders.

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David Evans, Fisheries and Oceans Canada, Central and Arctic Region
David Harper, Fisheries and Oceans Canada, National Headquarters
Ed DeBruyn, Fisheries and Oceans Canada, Central and Arctic Region
Jeff Johansen, Fisheries and Oceans Canada, Pacific Region
Jim Elliot, Fisheries and Oceans Canada, National Headquarters
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Glossary

Term	Definition
Anadromous	Fish species that travel up freshwater streams to spawn in fresh water, but spend a significant portion of its life in salt water.
Bank Full Width	The width of a watercourse when it completely fills its channel and the elevation of the water reaches the upper margins of the bank. In a natural channel that shows continuous evidence of scouring and sediment deposition, the bank full width is measured at the first break in slope at the top of the bank. In many cases this is delineated by the presence of permanent terrestrial vegetation such as large shrubs and trees.
Bed and Banks	The streambed and the rising slope or face of ground bordering a watercourse, up to the level of rooted terrestrial vegetation.
Compensation	The replacement of natural habitat, augmentation in the productivity of existing habitat or maintenance of fish production by artificial means, where mitigation measures are not adequate to maintain habitats for Canada's fisheries resources.
Corduroy	Nonsalvageable timber laid on the work side of the right-of-way during nonfrozen conditions to improve passage of traffic through wet areas or muskeg.
Cross Ditch	A shallow ditch cut into the surface of the right-of-way. Cross ditches run parallel to and are located on the upslope side of diversion berms.
Crossing Techniques	**Open Trenched/Open Cut**: The excavation of a trench in flowing water. Isolated: The crossing site is isolated from the main watercourse to prevent construction materials and sediment from entering the watercourse outside of the isolated area. **Dam/Pump**: A dam is placed in the stream channel to prevent the main flow of water from flowing through the area that will be subjected to disturbance within the stream channel. A pump is used to pump water from the upstream side of the excavation to the downstream side to bypass the instream construction area. **Flume**: A dam is placed in the stream channel to prevent the main flow of water from flowing through the area that will be subjected to disturbance within the stream channel. A large pipe (flume) is installed to permit the passage of water from the upstream side of the dam to the stream channel downstream of the work area. **Trenchless**: A crossing method in which there is no disturbance to the bed and banks of a waterbody. Trenchless crossing methods include horizontal bores, horizontal punches and directional drills.
Diversion Berm	An erosion control structure installed on slopes to divert surface water from the right-of-way.
Deleterious Substance	(a) Any substance that, if added to any water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water, or (b) Any water that contains a substance in such quantity or concentration, or that has been so treated, processed or changed, by heat or other means, from a natural state that it would, if added to any other water, degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water.
Deposit	Means any discharging, spraying, releasing, spilling, leaking, seeping, pouring, emitting, emptying, throwing, dumping or placing.
Fish	Includes: parts of fish; shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals; and, the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals.
Fish Habitat	Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes.

Term	Definition
Fishery	Includes the area, locality, place or station in or on which a pound, seine, net, weir or other fishing appliance is used, set, placed or located, and the area, tract or stretch of water in or from which fish may be taken by the said pound, seine, net, weir or other fishing appliance, and also the pound, seine, net, weir, or other fishing appliance used in connection therewith.
Frac-Out	The inadvertent seepage of drilling mud onto the ground or into surface waters through fractures in the subsurface. Frac-outs can occur when using pressurized crossing construction methods such as horizontal directional drilling.
Freshet	Rapid temporary rise in stream discharge and water level, caused by heavy rains or rapid melting of snow and ice.
Grubbing	A construction activity that involves removing vegetation, tree roots and stumps and surface soil from the pipeline right-of-way or other areas that will be under development.
HADD	Harmful alteration, disruption or destruction (HADD) of fish habitat is defined by Fisheries and Oceans Canada (DFO) as "any change in fish habitat that reduces its capacity to support one or more life processes of fish". It should be noted that this definition of HADD applies when determining if, or whether, any of the three conditions (*i.e.*, harmful alteration, disruption, or destruction) identified in Subsection 35(1) of the *Fisheries Act*, are likely to result from a project. These conditions do differ, and are differentiated essentially by the severity of impacts and their duration, as follows: harmful alteration - any change to fish habitat that indefinitely reduces its capacity to support one or more life processes of fish, but does not completely eliminate the habitat; disruption - any change to fish habitat occurring for a limited period which reduces its capacity to support one or more life processes of fish; and destruction - any permanent change of fish habitat which completely eliminates its capacity to support one or more life processes of fish.
Instream Activity	Usually interpreted as any activity conducted in a waterbody (*i.e.*, stream, river, lake, pond, isolated pool).
Mitigation	Actions taken during the planning, design, construction and operation of works and undertakings to alleviate potential adverse effects on the productive capacity of fish habitats.
Navigable Waterway	A navigable water is defined by the *Navigable Waters Protection Act* as being "any body of water capable, in its natural state, of being navigated by floating vessels of any description for the purpose of transportation, recreation or commerce, and may also be a man-made feature such as a canal or reservoir".
Net Gain	An increase in the productive capacity of habitats for selected fisheries brought about by determined government and public efforts to conserve, restore and develop habitats.
No Net Loss	A working principle by which DFO strives to balance unavoidable habitat losses with habitat replacement on a project-by-project basis so that further reductions to Canada's fisheries resources due to habitat loss or damage may be prevented.
Obstruction	Means any slide, dam or other obstruction impeding the free passage of fish.
Periphyton	Matrix of algae and microbes attached to submerged strata in aquatic ecosystems.
Productive Capacity	The maximum natural capability of habitats to produce healthy fish, safe for human consumption, or to support or produce aquatic organisms upon which fish depend.
Restoration (of Habitat)	The treatment or clean-up of fish habitat that has been altered, disrupted or degraded for the purpose of increasing its capability to sustain a productive fisheries resource.
Riparian	Pertaining to anything connected with, or immediately adjacent to, the banks of a watercourse or waterbody.
Riprap	A foundation or revetment made of irregularly placed stones or pieces of boulder on earth surfaces (*e.g.* stream banks) to reduce erosion of underlying soil or material by water.

Term	Definition
Shoo-Fly	Temporary access road generally used near watercourse crossings with steep valley slopes, to allow vehicles to traverse the slopes on a gentler grade.
Subdrain	Subsurface drain that is installed at trench depth, or slightly deeper, that is designed to move groundwater away from the trench line and drain the water off the right-of-way.
Thalweg	A line parallel to the direction of flow that defines the deepest and fastest portion of a stream channel.
Total Suspended Solids (TSS)	A measure of the total concentration of suspended solids, (*i.e.* material such as silt, clay, organic matter and microscopic organisms) that is suspended or carried in the water column and not in contact with the bottom substrate in water.
Trench Breaker	An erosion control device consisting of impermeable material that is placed within the trench after the pipe has been lowered in and before backfilling. Trench breakers are designed to block the water movement along the trench line and direct it to the surface where it is directed away from the trench line.
Trench Plug	A small portion of the ditch line that is left unexcavated, to block water flow along the trench or allow wildlife to cross the trench at known and used wildlife trails.

List of Acronyms

Acronym	Definition
AENV	Alberta Environment
ASRD	Alberta Sustainable Resource Development
C&R	Conservation and Reclamation
CAPP	Canadian Association of Petroleum Producers
CCME	Canadian Council of Ministers of the Environment
CEAA	*Canadian Environmental Assessment Act*
CEPA	Canadian Energy Pipeline Association
CGA	Canadian Gas Association
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPWCC	Canadian Pipeline Water Crossing Committee
DAP	Development Assessment Process (Yukon)
DFO	Fisheries and Oceans Canada
GPR	ground penetrating radar
HADD	harmful alteration, disruption or destruction [of fish habitat]
HDD	horizontal directional drill
ILA	Inuvialuit Land Administration
INAC	Indian and Northern Affairs Canada
IOL	Inuit owned lands
ISR	Inuvialuit Settlement Region
MFO	Minister of Fisheries and Oceans (Federal)
MOE	British Columbia Ministry of Environment
MVLWB	Mackenzie Valley Land and Water Board
MWLAP	British Columbia Ministry of Water, Land and Air Protection
NEB	National Energy Board
NIRB	Nunavut Impact Review Board
NLCA	Nunavut Land Claims Agreement
NSA	Nunavut Settlement Area
NTU	nephelometric turbidity units
NWB	Nunavut Water Board
NWT	Northwest Territories
NWPA	*Navigable Waters Protection Act*
NWPP	Navigable Waters Protection Program
OMNR	Ontario Ministry of Natural Resources
OS	operational statement
PEI	Prince Edward Island
PLA	pipeline agreement
POE	pathway of effect
RMF	risk management framework
TC	Transport Canada
TSS	total suspended solids
YESAA	*Yukon Environmental and Socioeconomic Assessment Act*

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1 Introduction

Watercourse crossings are a unique component of pipeline construction projects. Watercourse crossing construction typically requires devoted crews and specialized equipment, specific engineering design and specific planning and regulatory approval considerations. Crossings pose unique risks to the success of pipeline projects, and ultimately to the contractors that construct them.

The regulatory requirements for the approval and construction of pipeline associated watercourse crossings in Canada vary according to the jurisdiction in which the project is being built and the environmental setting within which the project is planned. The Canadian Association of Petroleum Producers (CAPP), formerly the Canadian Petroleum Association, the Canadian Energy Pipeline Association (CEPA) and various committees have been tracking this issue for over twenty-five years. To ensure that regulators, industry and other stakeholders are kept current on new initiatives from a regulatory and technical standpoint, CAPP, CEPA and the Canadian Gas Association (CGA) have updated the Second Edition, *Watercourse Crossings* (1999) with this Third Edition of *Pipeline Associated Watercourse Crossings*.

This document is intended to give regulators, industry practitioners and other stakeholders a summary of aspects of planning and constructing pipeline associated watercourse crossings. Its development is seen as a means to promote a consistent approach to pipeline associated watercourse crossings throughout Canada and to aid in developing a common understanding among industry, regulators and others (*e.g.,* nongovernment organizations). *Pipeline Associated Watercourse Crossings* strives to offer the reader options for consideration in the planning, review, approval and construction, as well as operations and maintenance, of pipeline associated watercourse crossings.

This document does not address any aspect of water withdrawal or discharge associated with hydrostatic testing. CAPP/CEPA have prepared a separate document on the regulatory and environmental requirements for hydrostatic testing in Canada (CAPP 1996a).

1.1 Updates to Document

This edition concentrates on recent regulatory and technical advances in pipeline associated watercourse crossings. Much of the information is repeated from CAPP (1993) and the Canadian Pipeline Water Crossing Committee (CPWCC) (CPWCC 1999), but has been updated with information from a consultation program involving key regulators from all jurisdictions as well as industry representatives. The consultation program attempted to clarify objectives and information requirements from each jurisdiction, as well as tap the field expertise of industry representatives and regulatory agents as to their observations and recommendations regarding pipeline associated watercourse crossing construction.

This Third Edition of *Pipeline Associated Watercourse Crossings* has been revised to incorporate Fisheries and Oceans Canada's (DFO) *Risk Management Framework for Development Projects Impacting Fish Habitat* and the Pathways of Effects (POE) models. As a component of their efforts to streamline the application and approval process for common development projects, DFO has provided detailed comments of the technical aspects of this manual. Commentary on risk management during crossing selection and construction and cumulative environmental effects has also been added to this edition.

Comments on the Second Edition of this document were solicited from a variety of regulatory and industry sources in late 2004 and incorporated into the revisions. A draft of the Third Edition was circulated to those who responded with comments and again their input was incorporated into the document. This final version has since been reviewed by many practitioners active in the planning, construction and inspection of pipeline associated watercourse crossings, and takes into account their many years of collective experience.

1.2 Effects on Aquatic Habitat

Stream channel morphology is influenced by gradient (topography), basin catchment area, surficial and bedrock geology, channel substrate, amount of precipitation (average and extremes) and human and animal activity (beaver and man-made dams or other impoundments). The distance that suspended and bedload sediment is transported along a watercourse is a function of particle size, water velocity and channel configuration. The smaller the particle size and steeper the gradient, the further it travels. Two classes of particles can affect fish habitat adversely: Silt and clay (diameter <62 microns) are readily suspended and travel farther than sand and coarser particles (diameter >62 microns), which are more likely to settle within a short distance of the crossing. Typically, it is the deposition of particles from the water column and the movement of bedload that can compromise aquatic habitat suitability for resident fish.

Elevated total suspended solids (TSS) and accelerated bedload movement can affect water quality, as well as alter channel morphology and streambed composition (Anderson *et al.* 1996). With traditionally trenched crossings, altered channel cross-sectional characteristics can arise following excavation and backfilling. In addition, particles carried by water are abrasive and their movement can physically erode channels (Anderson *et al.* 1996). If TSS levels remain elevated for a prolonged duration (days or weeks) during certain periods of the year, primary productivity of a watercourse can be inhibited downstream of the crossing.

Depending on the amount and type of substrate affected, and the duration of the effect, bedload movement can reduce substrate porosity, pool depth and riffle area. All three aspects can have negative consequences for fauna living downstream of the crossing. Reduced depth compromises a pool's ability to overwinter fish and can render it less suitable as a rearing and foraging habitat for juveniles and summer feeding and holding habitat for adults. Reduced riffle area results in a loss of oxygenated habitat suitable for benthic invertebrates, reduced diversity of benthic invertebrate communities downstream of the crossing, indirect loss of preferred prey for fish within the affected area, loss of spawning areas, loss of interstitial habitat for invertebrates and loss of interstitial nursery and rearing habitat for eggs and young fish.

Interruption or disruption of surface flows during open trenched watercourse crossings can produce areas immediately downstream that are dewatered and/or shallower than before the onset of the crossing. Habitat loss and/or mortality of fish and benthic invertebrates can occur due to stranding or reduced flow volumes. If suitable mitigation measures are not implemented, the timing, degree and duration of the disruption in streamflow dictates the consequences to aquatic resources downstream.

1.2.1 Effects on Fish Populations

In general, fish populations that inhabit coldwater watercourses are more sensitive to changes in TSS than those resident in cool or warm water habitats (Scott and Crossman 1973). Generally, fish populations that inhabit larger, slower flowing watercourses at lower elevations have evolved to tolerate higher suspended sediment concentrations. Since larger watercourses typically remain turbid for longer periods of time, resident fish such as burbot, walleye, sauger, goldeye and sucker have adapted accordingly (Anderson *et al.* 1996).

Elevated TSS can affect fish individually through altered behaviour and/or physiology or, more generally, at the population level. Behavioural and physiological responses in fish are linked. In general, fish exposed to elevated levels of suspended sediment for extended periods experience biological (population) and physical (individual) stress. The degree of response is species and life-history stage specific (*i.e.*, egg, fry, juvenile, adult), and dictated by the magnitude and duration of exposure to the sediment plume.

Behavioural responses experienced by fish exposed to elevated TSS include suspension of territorial behaviour, depressed feeding rate and stimulated cough reflex. On experiencing discomfort, fish will move out of a sediment plume to ease the physical discomfort associated with gill abrasion if possible. Reduced feeding rate occurs in response to decreased instream visibility associated with elevated turbidity, TSS and stress in addition to reduced food supply. Increases in territoriality associated with movement out of the channel elevates biological stress both at the individual and population level as fish compete for less turbid territories, or establish new ones elsewhere within the system.

Physiological effects in fish exposed to elevated TSS are associated with stress, which can weaken an organism's immune system. Over extended periods, depressed feeding rates can be manifested in lower growth rate. Damaged gill filaments impair respiration, lead to elevated stress, changes in blood chemistry, decline in overall fish health, reduced immune system function, increased vulnerability of an individual/population to disease and parasitism and, in the long term, reduced survival. Severe stress can lead to mortality once fish health is compromised.

Elevated sediment concentrations can affect fish further downstream of the crossing location at the population level through increased egg mortality, decreased hatching success and loss of suitable spawning substrate. Like eggs, fish larvae have limited mobility and cannot avoid sedimentation of substrate or elevated TSS. Failed recruitment from eggs to larvae to juveniles ultimately affects annual production of a population within a watercourse. Similarly, loss of suitable spawning habitat as a consequence of sedimentation can adversely affect fish populations that rely on clean substrate for spawning and juvenile rearing.

1.2.2 Additional Consequences of Watercourse Crossings

Loss of riparian vegetation associated with clearing and/or grading of the banks to access a watercourse crossing can affect all life-history stages of fish. Clearing of riparian areas can locally raise water temperature within adjacent nearshore shallow areas reducing their attractiveness as incubation, rearing, foraging and escape habitat for selected species. Loss of instream and overhead cover as a result of right-of-way construction can reduce the habitat quality for resident fish populations. Cleared rights-of-way can become persistent sources of sediment to a watercourse if they are not suitably reclaimed. Introduction of sediment and increased water temperature can compromise water quality and the integrity of downstream aquatic habitat.

Crossings can create movement barriers that reduce fish distribution and abundance. It is common for contractors to place excessive amounts of riprap over a pipeline, which can obstruct fish movement during periods of low flow. Furthermore, clearing and grading of rights-of-way at watercourse crossings can increase fish mortality indirectly, since improved access for anglers can expose previously remote sections of a watercourse to harvest.

The use of explosives can result in harm to fish habitat and/or mortality or injury of resident fish and invertebrates through damage to internal organs and crushing, as a consequence of the pressure wave associated with blasting. Mortality is influenced by factors such as water depth (*i.e.,* in shallow water much of the blast energy is released above the water), as well as the type and amount of explosive detonated, but tends to be limited to the immediate vicinity of the crossing. In addition, an accidental release of hazardous materials (*e.g.,* hydraulic fluid) from equipment or a fuel spill into a watercourse or within the riparian right-of-way, can lead to stress or fish kills at and downstream of the crossing.

Disruption of instream groundwater upwelling through sedimentation or disturbance to groundwater flows can adversely affect spawning habitat for salmonids and overwintering habitat.

The transfer of aquatic organisms between watersheds by dirty equipment or test water can lead to the introduction of weeds such as purple loosestrife and Eurasian milfoil as well as aquatic diseases, parasites or other pests such as whirling disease, zebra mussels or exotic species not previously found in the watershed.

1.2.3 Natural Watercourse Dynamics

Natural storm and flood events can destabilize streambanks, create landslides within riparian zones and alter flow regimes within watercourses. It is the intensity and frequency of these events that ultimately influence channel morphology and the abundance, distribution and composition of resident fish and fish habitat. Natural flushing and stabilization of the system after an event permits recolonization and settlement of fish and benthic invertebrate populations within affected reaches. Watercourses are inherently dynamic and their fish populations have adapted to cope with natural catastrophic events. Landslides and floods both can contribute large quantities of sediment, however, both typically occur when flows are high and dilution of sediment levels facilitates their tolerance by fish populations and transport downstream.

The cumulative effects of human activities within watercourses and riparian areas can magnify the outcome of a storm or flood event and prolonged, unnatural events can stress fish populations. Consequently, when designing pipeline crossings of watercourses, it is important to acknowledge the degree of existing development in the area in conjunction with fish presence, distribution and habitat suitability for spawning, incubating, rearing, foraging, resting and overwintering at and immediately downstream of a proposed crossing.

1.3 Objectives for Watercourse Crossings

The overall goals and objectives of regulatory agencies for pipeline associated watercourse crossings are similar across Canada. However, there may be substantial variation in the construction techniques allowed as well as environmental protection and mitigation measures that are required for project approval among the various jurisdictions. The main guiding principle for all agencies across Canada, however, parallels the DFO guiding principle of "no net loss" of productive capacity of fish habitat.

In addition, and consistent with DFO’s guiding principle, the following goals and objectives have been identified by regional regulatory personnel to prevent or mitigate harmful alteration, disruption or destruction (HADD) on fish and fish habitat at watercourse crossings:

- minimize duration of time spent working instream;
- use the most practical construction method resulting in the least adverse effect;
- abide by instream timing restrictions (*i.e.*, avoid seasonal high risk periods within lifecycles of resident aquatic organisms);

- maintain clean water flow and eliminate where possible the release of sediment or suspended solids;
- minimize disturbance of the watercourse bed and banks;
- minimize erosion of the watercourse bed and banks;
- use sediment control measures where warranted;
- maintain downstream flow;
- restore riparian areas and crossing approaches to prevent or minimize the release of sediments into watercourses;
- maintain fish passage during instream construction activities;
- ensure that no deleterious materials (*e.g.,* sediment, fuel) are deposited into any watercourse;
- minimize cumulative effects of construction activities on the surrounding environment;
- fully mitigate all adverse effects of construction in a watercourse to minimize temporary and permanent fish habitat loss;
- restore hydraulic, hydrologic or hydrogeological characteristics of the watercourse to their original condition; and
- ensure habitat compensation is implemented where harmful effects cannot be avoided or mitigated.

Ideally, proponents should use this list to develop corporate watercourse crossing objectives or to develop site-specific objectives for individual crossings or projects. Explicit watercourse crossing directives have the following benefits:

- facilitate consistent selection of appropriate crossing method;
- facilitate selection of most appropriate crossing locations;
- provide guidance to staff, contractors and regulators for approval, construction and monitoring;
- provide standard performance measures;
- allow proponents and contractors to evaluate crossing success;
- help proponents identify key risk areas and activities; and
- help proponents identify areas where cost or risk can be minimized with no adverse biophysical effects.

2 Regulatory and Information Requirements

The regulatory requirements for the construction, operation and abandonment of pipeline associated watercourse crossings in Canada vary according to the jurisdiction in which a project is being built. Each watercourse crossing may be subject to federal, provincial and territorial review. Many jurisdictional agencies have Codes of Practice, guidelines and policies regarding watercourse crossings, and require application for permits, authorizations and licenses.

Sections 2.1 and 2.2 describe the federal, provincial and territorial regulatory framework. Information requirements for each of these agencies are briefly discussed. This document has been written to reflect the regulatory information requirements at the time of publication. It does not address draft or proposed acts, Codes of Practice, guidelines or policies.

Table 2.1 provides a quick summary checklist of the regulatory framework and the appropriate contacts. Since the regulatory requirements are complex and continually changing across the country, the responsibility to ensure that all requirements are met falls on the proponent. Project planners should confirm with the appropriate agencies that the necessary permit applications are made and the regulatory requirements have been identified. Proponents should consult with regulatory authorities early in the planning process to ensure they understand the regulatory requirements.

2.1 Federal Jurisdictions

There are eight federal acts that are most applicable to pipeline associated watercourse crossings in Canada:

- *Fisheries Act;*
- *Navigable Waters Protection Act;*
- *National Energy Board Act;*
- *Canadian Environmental Assessment Act;*
- *Indian Oil and Gas Act*;
- *Canada Oil and Gas Operations Act;*
- *Species At Risk Act;* and
- *Migratory Birds Convention Act.*

Table 2.1 Regulatory and Information Contacts

Jurisdiction	Legislation	Contact
Federal	*Fisheries Act*	• Fisheries and Oceans Canada, Habitat Management Program, Regional Office
	Navigable Waters Protection Act	• Transport Canada, Navigable Waters Protection Program Regional Office
	National Energy Board Act	• National Energy Board
	Canadian Environmental Assessment Act	• Canadian Environmental Assessment Agency • Responsible Federal Authority (*e.g.,* Fisheries and Oceans Canada, National Energy Board)
	Indian Oil and Gas Act	• Indian and Oil Gas Canada
	Canada Oil and Gas Operations Act	• National Energy Board
	Species At Risk Act	• Environment Canada, Canadian Wildlife Service
	Migratory Birds Convention Act	• Environment Canada, Canadian Wildlife Service
Alberta	*Environmental Protection and Enhancement Act*	• Alberta Environment, Regulatory Approvals Centre, Enforcement and Monitoring Manager, Regional Office • Alberta Sustainable Resource Development, Fish and Wildlife, Regional and District Offices
	Public Lands Act	• Alberta Sustainable Resource Development, Public Lands and Forest, Regional Office
	Water Act	• Alberta Environment, Water Management, Regional Office
British Columbia	*Environmental Assessment Act*	• British Columbia Ministry of Environment, Environmental Protection Division, Regional Operations
	Fish Protection Act	• British Columbia Ministry of Environment, Environmental Stewardship Division, Regional Operations • Land and Water British Columbia Inc., Water Management Branch, Regional Office
	Forest Practices Code of British Columbia Act	• British Columbia Ministry of Forests, Regional Office
	Land Act	• Land and Water British Columbia Inc., Regional Office
	Oil and Gas Commission Act	• British Columbia Oil and Gas Commission, Regional Office
	Water Act	• Land and Water British Columbia Inc., Water Management Branch, Regional Office
Manitoba	*Crown Lands Act*	• Manitoba Conservation, Lands Branch
	Environment Act	• Manitoba Conservation, Environmental Stewardship Division, Environmental Approvals Branch
	Water Resources Administration Act	• Manitoba Water Stewardship - Water Licensing Branch
	Water Rights Act	• Manitoba Water Stewardship - Water Licensing Branch

Table 2.2 Regulatory and Information Contacts, Cont'd

Jurisdiction	Legislation	Contact
New Brunswick	*Clean Environment Act*	• New Brunswick Department of Environment and Local Government, Project Assessment Branch
	Clean Water Act	• New Brunswick Department of Environment and Local Government, Regional Services Branch, Water and Wetland Alteration Program
	Crown Lands and Forest Act	• New Brunswick Department of Natural Resources, Regional Office
	Fish and Wildlife Act	• New Brunswick Department of Natural Resources, Regional Office
	Quarriable Substances Act	• New Brunswick Department of Natural Resources, Regional Office
Newfoundland and Labrador	*Water Resources Act*	• Newfoundland and Labrador Department of Environment and Conservation, Water Resources Management Division
	Environmental Protection Act	• Newfoundland and Labrador Department of Environment and Conservation, Environmental Assessment Division
Northwest Territories *(Unsettled claims areas and transboundary projects)*	*Mackenzie Valley Resource Management Act*	• Mackenzie Valley Land and Water Board
Northwest Territories *(Inuvialuit Lands)*	*Inuvialuit Final Agreement*	• Inuvialuit Land Administration
	Territorial Lands Act	• Indian and Northern Affairs Canada • Land Titles Office
	Northwest Territories Waters Act	• Northwest Territories Water Board
Northwest Territories *(Gwich'in Lands)*	*Gwich'in Final Agreement*	• Gwich'in Tribal Council
	Mackenzie Valley Resource Management Act	• Gwich'in Land and Water Board
Northwest Territories *(Sahtu Lands)*	*Sahtu Dene and Metis Comprehensive Land Claim Agreement*	• Sahtu Land Development Corporation
	Mackenzie Valley Resource Management Act	• Sahtu Land and Water Board
Nova Scotia	*Crown Lands Act*	• Nova Scotia Department of Natural Resources, Land Administration Division
	Environment Act	• Nova Scotia Department of Environment and Labour, Environmental Assessment Branch, Water and Waste Water Branch
Nunavut	*Nunavut Land Claim Agreement*	• Nunavut Planning Commission, Regional Planning Office • Nunavut Impact Review Board
	Territorial Lands Act	• Indian and Northern Affairs Canada, Land Administration Unit
	Nunavut Waters and Nunavut Surface Rights Tribunals Act	• Nunavut Water Board

Table 2.2 Regulatory and Information Contacts, Cont'd

Jurisdiction	Legislation	Contact
Ontario	*Conservation Authorities Act*	• Ontario Conservation Authority • Local Authority
	Environmental Assessment Act	• Ontario Ministry of Environment, Environmental Assessment Branch
	Environmental Protection Act	• Ontario Ministry of Environment
	Lakes and Rivers Improvement Act	• Ontario Ministry of Natural Resources, Regional Office
	Public Lands Act	• Ontario Ministry of Natural Resources
	Ontario Water Resources Act	• Ontario Ministry of Natural Resources Approvals Branch
Prince Edward Island	*Environmental Protection Act*	• Prince Edward Island Department of Environment, Energy and Forestry
Québec	*Conservation and Development of Wildlife Act (Loi sur la conservation et la mise en valeur de la faune)*	• Société de la faune et des parcs du Québec, Direction de la faune et des habitats
	Environmental Quality Act (Loi sur la qualité de l'environnement)	• Ministère de l'environnement, Direction des politiques du secteur municipal
Saskatchewan	*Environmental Assessment Act*	• Saskatchewan Environment, Regional Office
	Environmental Management and Protection Act	• Saskatchewan Environment, Regional Office
Yukon	*Yukon Environmental and Socioeconomic Assessment Act*	• Yukon Government Executive Council Office, DAP Branch • *Yukon Environmental and Socioeconomic Assessment Act* Board
	Territorial Lands (Yukon) Act	• Yukon Department of Energy, Mines and Resources
	Waters Act	• Yukon Water Board

2.1.1 *Fisheries Act*

The *Fisheries Act* was enacted to protect fish, fish habitat and water frequented by fish and to provide for sustainable fisheries in Canada. Responsibility for the *Fisheries Act* rests with the Minister of Fisheries and Oceans (MFO). Fisheries and Oceans Canada (DFO) administers the habitat protection provisions (Section 35) of the *Fisheries Act*, while Environment Canada, under a 1985 Memorandum of Understanding with DFO, administers those provisions of the *Fisheries Act* dealing with the control of pollution (Section 36).

There are nine sections in the *Fisheries Act* (paraphrased below) most likely to pertain to pipeline associated watercourse crossings:

- Section 20 Provides for safe passage of fish.

- Section 22 Provides for flow of water and passage of fish.
- Section 30 Provides for water diversions or intakes to have a fish guard or screen.
- Section 32 Prohibits the destruction of fish by any means other than fishing except as authorized by the MFO or regulation.
- Subsection 35(1) Prohibits works or undertakings that result in harmful alteration, disruption or destruction (HADD) of fish habitat.
- Subsection 35(2) Allows for the authorization of HADD by the MFO.
- Subsection 36(3) Prohibits the deposition of deleterious substances in waters frequented by fish.[1]
- Subsection 37(1) Where HADD of fish habitat or a deposit of deleterious substance results or is likely to result from an existing or proposed work or undertaking, the MFO may request plans and specifications to be submitted for review.
- Subsection 37(2) Where the Minister is of the opinion that contravention of ss.35(1) or ss.36(3) is being or is likely to be committed, the MFO may order modification, restrict or close an undertaking subject to Governor in Council approval.
- Subsection 38(6) Allows for enforcement of inspector's orders.

Additional Sections of the *Fisheries Act* (*e.g.,* Sections 2, 34) provide definitions, such as those summarized in the Glossary. Other Sections (*e.g.,* Sections 40, 42, 78, 79) describe matters such as fines, offences and penalties.

Failure to comply with the habitat protection or pollution prevention provisions of the *Fisheries Act* may result in charges being laid. A court, upon conviction for offences under these provisions, may impose fines and court orders. For example, upon conviction of an indictable offence, a person found guilty of contravening Subsection 35(1) is liable to a fine not exceeding 1 million dollars for a first offence.

DFO has developed tools to promote the protection of fish and fish habitat, the foremost of which is the *Policy for the Management of Fish Habitat* (DFO 1986). Additional guidance and advice is provided in the following documents:

- *Fish Habitat Conservation and Protection: Guidelines for Attaining No Net Loss* (DFO 1995a).
- Fish Habitat Conservation and Protection: *"What the Law Requires - The Directive on the Issuance of Subsection 35(2) Authorizations*: (DFO 1995b).
- *Freshwater Intake End-of-Pipe Fish Screen Guideline* (DFO 1995c).
- *Decision Framework for the Determination and Authorization of Harmful Alteration, Disruption or Destruction of Fish Habitat* (DFO 1998).
- *Habitat Conservation and Protection Guidelines* (DFO 1999).

[1] Enforced by Environment Canada.

In addition, some DFO regional offices have developed specific documents for proposed works or undertakings in a particular geographic area. For example, DFO information requirements for watercourse crossings in Ontario are outlined in the document *Fisheries-Related Information Requirements for Pipeline Water Crossings* (Goodchild and Metikosh 1994) and DFO Prairies Area has published an operational position statement for pipeline crossings that outlines notification and approval requirements (DFO 2005).

In its review of project proposals, DFO applies the guiding principle of "no net loss" of the productive capacity of fish habitat. Under this principle, DFO strives to balance unavoidable habitat loss with habitat replacement on a project-by-project basis. A more detailed discussion of Habitat Compensation appears in Section 6.0 of this document.

Section 35 of the *Fisheries Act* prohibits the HADD of fish habitat except where authorized by the MFO. Documents noted above, such as *What the Law Requires - The Directive on the Issuance of Subsection 35(2) Authorizations* provide additional guidance to proponents. Section 58 and Schedule VI of the Fishery (General) Regulations provide the forms that applicants for Subsection 35(2) Authorizations may use.

Where proponents are planning a watercourse crossing that has a high risk of HADD, they must contact DFO to discuss the project. It should be noted that DFO has developed working relationships with a number of other agencies and initial contact may differ throughout the country (see Section 2.2 of this report). Proponents are advised to familiarize themselves with local working relationships between DFO and other agencies. If after reviewing the information the regulatory decision is that HADD is not likely to result or can be mitigated, a letter of advice may be provided to the proponent that outlines the measures required to avoid HADD. Should the proponent not implement the measures or change the project and HADD occurs, charges under the *Fisheries Act* could be brought against the proponent.

In cases where it is not possible to protect fish habitat by mitigation or project design, a Subsection 35(2) Authorization may be issued. In accordance with DFO’s policy, an Authorization will stipulate the conditions necessary to achieve "no net loss" of productive capacity of fish habitat (*i.e.,* compensation measures). Authorizations may not be issued in all cases.

Section 32 of the *Fisheries Act* prohibits the destruction of fish by means other than fishing except as where authorized by DFO and may apply in those situations where a proponent is planning the use of explosives for a watercourse crossing. Additional details regarding the use of explosives in watercourses are provided in sections 5.2.7 and 7.1.5 of this report.

2.1.2 Navigable Waters Protection Act

The *Navigable Waters Protection Act* (*NWPA*) provides a legislative mechanism for the protection of the public right of marine navigation on all navigable waterways in Canada. This is accomplished through permitting of the construction of works built or placed in, over, through or across navigable waterways and through a legal framework to deal with obstacles and obstructions to navigation. The *NWPA* is administered by the Navigable Waters Protection Program (NWPP) of Transport Canada (TC).

A navigable waterway is defined as being any body of water capable of being navigated by floating vessels of any description for the purpose of transportation, commerce or recreation. This includes both inland and coastal waters. The authority to determine the navigability of a waterway rests with the Minister of Transport or his/her designated representative.

The pertinent sections of the *NWPA* for pipeline associated watercourse crossings are found in:

- Paragraph 5(1)(a) No work shall be built or placed in, on, over, under, through or across any navigable water unless the work, the site and plans thereof have been approved by the Minister, on such terms and conditions as the Minister deems fit, prior to commencement of construction.
- Subsection 5(2) Except in the case of a bridge, boom, dam or causeway, paragraph 5(1)(a) does not apply to any work that in the opinion of the Minister does not interfere substantially with navigation.

Pipelines that cross navigable waters solely within the boundaries of one province or territory require either determination or approval under the *NWPA*. Application guidelines have been prepared by TC (2004). Projects are normally processed under Subsection 5(2) of the *NWPA* and a Subsection 5(2) determination is issued if the project does not interfere substantially with navigation. Proponents must submit a letter of application and plan information to the Regional NWPP Office of TC and notify the NWPP inspector when construction is finished so that a final inspection may be done to verify that all plans and recommendations were followed.

Projects in which construction has the potential to substantially interfere with navigation are dealt with under Subsection 5(1) and require a more formal Approval Process. Initial submissions for this approval include a letter of application, site and construction drawings, authorization by owner and environmental assessment documentation.

In addition to TC approval, watercourse crossings of an international or interprovincial pipeline are subject to review under the *National Energy Board (NEB) Act*. More details regarding this approval are provided in Section 2.1.3.

2.1.3 National Energy Board Act

The *National Energy Board Act* is an independent federal agency established in 1959 by the Parliament of Canada to regulate international and interprovincial aspects of the oil, gas and electric utility industries. The NEB's purpose is to promote safety, environmental protection and economic efficiency in the Canadian public interest within the mandate set by Parliament in the regulation of pipelines, energy development and trade. Under the *NEB Act*, the NEB has assumed a mandate for environmental protection as a component of the public interest. The NEB also has responsibilities under the *CEAA* to ensure that projects receive appropriate levels of assessment before proceeding. The NEB's environmental responsibility includes ensuring that the environment is protected during planning, construction, operation and abandonment of energy projects within its jurisdiction.

The NEB regulates:

- interprovincial and international pipelines
- pipeline transportation, tolls and tariffs
- international and designated Interprovincial power lines
- exports of oil, natural gas and electricity
- frontier oil and gas activities (*Canada Oil and Gas Operations Act*) outside of Accord areas

The NEB also regulates activities on or adjacent to rights-of-way under NEB jurisdiction in the interests of protection of property and the environment as well as the safety of the public and of the pipeline company's employees.

Before a company can do any pipeline construction work on a NEB-regulated project, it must apply for, and receive approval for the project from the NEB before it can build a pipeline, make changes to it, sell it or abandon it. To submit an application, the company must follow the *NEB Act*, the NEB *Rules of Practice and Procedure* (Government of Canada 1995) and the NEB *Filing Manual* (NEB 2004) and other legislation and regulations such as the *CEAA* that may be relevant. Companies preparing an application are required to anticipate the environmental issues and concerns created by the proposed project and to consult with appropriate government bodies, public interest groups, aboriginal persons and affected landowners.

Once the application has been submitted and filed, the NEB becomes directly involved with the project as the application is now a formal request for approval. The application will describe:

- the purpose of the pipeline;
- the pipeline design;
- environmental impacts of the project;
- if any public consultations have been held;
- any land rights needed;

- the adequacy of supply and the market potential for the products it will carry;
- the economics of the pipeline;
- the proposed route corridor; and
- any other factors that may affect the NEB's decision.

It is the responsibility of the NEB to consider all aspects of the project in order to determine if the pipeline project is in the public interest.

The *CEAA* process is initiated when a company provides a preliminary submission or submits an application to the NEB that triggers the *CEAA* and the NEB determines that it is a Responsible Authority (RA). The NEB considers the level of environmental assessment required under the *CEAA* (*i.e.*, screening, comprehensive study or panel review) and identified other possible RAs and Federal Authorities (FAs) who may have an interest in the project. The *CEAA* assessment is conducted within the NEB Act process, which is subject of the rules of natural justice. Any CEAA determination is made prior to the NEB taking any regulatory decision under the *NEB Act*.

Public hearings may be conducted orally or through written correspondence and documents only. Both processes allow for public participation. The public hearing gives all of the people concerned with a project an opportunity to express their point of view, and possibly ask or answer questions. It also provides the Board with the information it needs to make a fair and objective decision. A panel of no fewer than three NEB board members hears the evidence and then makes the decision to approve or deny an application.

The NEB can monitor the company’s performance in several ways, one of which is through field inspections carried out by NEB Inspection Officers and specialized staff. They monitor the company’s activities to make sure it is meeting the conditions that the NEB has set.

2.1.4 *Canadian Environmental Assessment Act*

The *Canadian Environmental Assessment Act* (*CEAA*) came into force in 1995 to ensure environmental review (including cumulative effects assessment and public consultation) on a project specific basis. Subsection 5(1) of *CEAA* states that an environmental assessment under *CEAA* must be prepared under the following circumstances:

- a federal authority is the proponent of a project;
- a project is being financed in whole or part by a federal authority;
- a project is being conducted on federal lands; or
- a federal authority is issuing a permit, license or approval for a project.

The federal department or agency that triggers the environmental assessment becomes a responsible authority under *CEAA* and must ensure that the proponent conducts an environmental assessment for the proposed project. Examples of departments or agencies who may be responsible authorities for watercourse crossings include DFO, NEB, Parks Canada and Indian Oil and Gas Canada. Coordination of such Federal Authorities under *CEAA* is regulated by the Regulations Respecting the Coordination by Federal Authorities of Environmental Assessment Procedures and Requirements (Canadian Environmental Assessment (CEA) Agency 1997b). There are four regulations under *CEAA* specifying which pipeline projects are subject to environmental assessment: the Exclusion List Regulations, the Law List Regulations, the Comprehensive Study List Regulations and the Inclusion List Regulations.

In the event that piece of legislation listed under *CEAA* Section 5 triggers an environmental assessment on a segment of the route (*e.g.,* Indian Reserve or river crossing as a result of a Subsection 35(2) or 32 authorization under the *Fisheries Act*), the Responsible Authority will establish the scope of the project and the scope of the assessment and undertake the appropriate review process under *CEAA*.

Environmental assessments conducted by the RA must consider cumulative effects caused by the project in combination with other projects or activities that have been or will be carried out. Cumulative effects evaluations consider the combined effects now known to take place over larger study areas and longer time frames. The level of effort should be appropriate to the number of crossings being considered, other existing watershed disturbances, and the combined risk to fish and fish habitat. Additional information is provided in Section 4.3.3 of this report.

Exclusion List Regulations identify those physical works that will not require an environmental assessment under *CEAA* due to the lack of significant environmental effects associated with them. All other physical works require an environmental assessment. Based on the Exclusion List Regulations, those watercourse crossing projects that will not require an assessment under *CEAA* include:

- Section 1 — The proposed maintenance or repair of an existing physical work not in a nationally protected area or site.
- Section 33 — The proposed construction, installation, expansion or modification of a fish habitat improvement structure that would not involve the use of heavy machinery.

The Law List Regulations itemize the statutory and regulatory project approvals that trigger an environmental assessment under the *CEAA* before a project proceeds. The main federal acts and regulations which will trigger an assessment for a pipeline associated watercourse crossing include:

- *Fisheries Act*
  - Section 22 — Provision of flow of water and passage of fish.

- Section 32 — Authorization by MFO to destroy fish by means other than fishing (*e.g.*, blasting, dewatering).
- Subsection 35(2) — Authorization by MFO for the harmful alteration, disruption or destruction of fish habitat in a watercourse.
- Subsection 37(2) — The modification, restriction or closure of a project or Order made with the approval of Governor in Council, when an offence under Subsection 40(1) or 40(2) of the *Fisheries Act* is being or is likely to be committed.

- *Navigable Waters Protection Act*
  - Subsection 5(1)(a) — Approval by TC for the construction of works in navigable waters.
- *NEB Act*
  - Section 52 — Approval by the NEB for the pipelines >40 km in length.
  - Section 58 — Approval by the NEB for pipelines <40 km in length.
  - Section 108 — Approval to cross navigable waters.

The Comprehensive Study List Regulations outline which major projects will require a more comprehensive environmental assessment under *CEAA*. Projects which will require comprehensive study include:

- Subsection 14(a) — The proposed construction of an oil and gas pipeline more than 75 km in length on a new right-of-way.

Information regarding content and process for all levels of environmental assessments is described in the *CEAA* document *The Responsible Authorities Guide to the Canadian Environmental Assessment Act* (CEA Agency 1994). Information requirements for comprehensive study are described in the CEA Agency document *Guide to the Preparation of a Comprehensive Study for Proponents and Responsible Authorities* (CEA Agency 1997a).

The Inclusion List Regulations outline the physical activities that may require environmental assessment. This includes, amongst others, activities which may be affected by the:

- *National Parks Act*;
- *Canada Oil and Gas Operations Act*;
- *Fisheries Act*;
- crossing of Aboriginal lands;
- *Migratory Birds Convention Act*; and
- crossing watercourses in the Yukon, Northwest or Nunavut territories.

2.1.5 Indian Oil and Gas Act

The *Indian Oil and Gas Act* is administered by Indian Oil and Gas Canada. The *Act* pertains to all oil and gas activities on Indian reserve land in Canada south of the 60th parallel. Proponents of a pipeline transporting products from a well located on reserve lands that entails a watercourse crossing on reserve lands will require approval from Indian Oil and Gas Canada. It should be noted that proponents of pipelines that traverse reserve lands but do not transport products from a well on reserve lands must conduct an EA under *CEAA* with Indian and Northern Affairs Canada (INAC) serving as the Responsible Authority. In the event that watercourse crossings are proposed within land claim areas, proponents are advised to discuss the project with INAC, Indian Oil and Gas Canada and DFO.

2.1.6 Canada Oil and Gas Operations Act

The *Canada Oil and Gas Operations Act* is administered by the NEB. The *Act* applies to the exploration, drilling, production, conservation, processing and transportation of oil and gas in the Northwest Territories, Nunavut, Sable Island, or offshore waters of Canada (not including interprovincial and international transmission pipelines, which are regulated by the *NEB Act*). Proponents are required to submit an application, as per the regulations, to the NEB, for a watercourse crossing in these areas. Proponents operating in Nova Scotia and Newfoundland and Labrador will also have to recognize the Atlantic Accords between the federal government and these provinces.

2.1.7 Species At Risk Act

The *Species At Risk Act* is administered primarily by Environment Canada, Canadian Wildlife Service with assistance from DFO for aquatic species and Parks Canada Agency for species on federal lands that are protected as defined in the *Parks Canada Agency Act*. The *Act* protects listed terrestrial species at risk on federal lands, all migratory birds listed by the *Migratory Birds Convention Act* on any lands and all listed aquatic species at risk in any waterbody. The *Act* prohibits killing, harming or harassing listed species, trading in the parts of listed species and damaging or destroying the residence of an individual of a listed species. Proponents should ensure that no listed species at risk could be affected by their project.

2.1.8 Migratory Birds Convention Act

The *Migratory Birds Convention Act* is administered by Environment Canada, Canadian Wildlife Service. The *Act* implements a treaty between Canada and the United States that coordinates a system to prevent the indiscriminate harvest or destruction of migratory birds. The *Act* specifically prohibits the destruction of the nest, eggs and young of migratory birds but does not specifically protect habitat.

Disruption of nests located in riparian habitat by watercourse crossing projects may have implications under the *Act*.

2.2 Provincial and Territorial Jurisdictions

Each provincial and territorial jurisdiction has various legislation, regulations, Codes of Practice, policies and guidelines affecting watercourse crossings. Provincial and territorial jurisdiction generally provides for the approval and regulation of the construction, operation and abandonment of oil and gas pipelines by provincially regulated proponents for a pipeline contained within the boundaries of one province. Interprovincial or international pipelines are also regulated at a federal level under the NEB (see Section 2.1), but may still require provincial approval and need to follow provincial legislation.

Most provinces and territories require a permit, license and/or other authorization to use, affect or potentially affect, surface water and/or make alterations to stream beds and banks. The review of applications to alter stream beds and banks will involve the appropriate provincial fisheries management agencies and may include DFO depending on the agreement the province or territory has with DFO (see Section 2.1 for more detail). Various conditions regarding construction schedule and techniques as well as required mitigative and restoration measures are usually appended to the approval document. The issuance of a permit or license generally does not exempt the applicant from the provision of any other applicable provincial or federal legislation, or any other processes of law including municipal by-laws.

The bed and banks of a watercourse are, in most instances, considered public lands in all provinces and territories in Canada. Proponents must apply to the appropriate provincial or territorial land agency for approval to cross these lands.

An overview of the regulatory requirements for each province and territory with regard to watercourse crossings is provided below. These requirements pertain to watercourse crossings only and it is assumed that the proponent will apply for any federal or provincial pipeline and/or oil and gas approvals required in addition to those listed above and below.

First Nations self-government, land claims and protocols are an ever-changing consideration in the approval processes. Documenting these requirements and recommendations are beyond the scope of this document. Nevertheless, to facilitate a timely review and approval, it is important that all proponents and regulators become familiar with the relevant agreements and other requirements. To ensure timely review and approval, it is beneficial that the appropriate applicable First Nations be incorporated into the construction planning process.

2.2.1 Alberta

Alberta Environment (AENV) and Alberta Sustainable Resources Development (ASRD) are the main provincial departments with responsibilities for pipeline associated watercourse crossings. There are currently three acts and their associated regulations and codes of practice under which a crossing may be regulated:

- *Water Act*
  - Codes of Practice
- *Environmental Protection and Enhancement Act*
  - Conservation and Reclamation Regulation
- *Public Lands Act*
  - Public Lands Pipeline Regulations

The *Water Act* and Ministerial Regulations allow for certain activities to be regulated by a Code of Practice. Currently there are two applicable Codes of Practice, *Code of Practice for Pipelines and Telecommunication Lines Crossing a Water Body* and *Code of Practice for Watercourse Crossings* (*e.g.,* culverts and bridges). Projects that fall under these Codes of Practice do not require *Water Act* approval, however, the Director in the Regional Area where the project is located must be given notice that a pipeline crossing(s) or watercourse crossing is going to be constructed.

The Codes of Practice set out engineering and aquatic environment protection standards that must be met for the construction of a pipeline or telecommunications line crossing a waterbody or watercourse crossing. The owner of the crossing must prepare a plan which includes specifications and written instructions as to when and how the crossing is to be constructed and that the standards of the Codes of Practice are met. There is a requirement that the engineering design for the pipeline or watercourse crossing be prepared by a professional engineer. To ensure that the aquatic environment is protected, any adverse impacts on the aquatic environment resulting from the construction of the crossing, must be fully mitigated. The proponent/owner must follow Schedule 1 of the Codes of Practice or have a qualified aquatic environment specialist prepare a plan that would ensure that the aquatic environment is protected. Background information on the Codes of Practice can be obtained from AENV.

Additional permits and approvals for pipeline associated watercourse crossings required under the *Environmental Protection and Enhancement Act* and the *Public Lands Act*, are discussed below.

Conservation and Reclamation (C&R) approval is required under the *Environmental Protection and Enhancement Act* for all Class 1 pipelines (pipeline index = mm O.D. x km ≥2690) in the White Area and requires proponents to submit C&R report. Class 2 pipelines (pipeline index <2690) in the White Area do not require a C&R approval but are still subject to AENV Guidelines (Alberta Environmental Protection (AEP) 1994a,b,c). An Environmental Field Report

(EFR) is required for all pipelines on public land (White and Green Areas) and for any pipeline in the Green Area, regardless of its index or ownership of the land on which it is built.

Approval under the *Public Lands Act* will only be required if public land is adjacent on both sides of the watercourse or if the proponent or ASRD requests an approval. To determine if an approval will be required and to obtain application forms, contact the ASRD Public Lands and Forest office nearest to the proposed activity.

Pipeline Agreements (PLAs) are required under the *Public Lands Act* to use Public land (*i.e.,* bed and banks of a watercourse).

Alberta has several provincial guidelines applicable to pipeline associated watercourse crossings:

- Fisheries Habitat Protection Guidelines
  - *Guideline 3 - Pipeline Construction and Stream Crossing*" (Alberta Forestry, Lands and Wildlife 1987)
  - *Guideline 4 - Vehicular Access Across Watercourses* (AEP 1992a)
  - *Guideline 6 - Timing Constraints on Construction In and Around Watercourses* (Alberta Forestry, Lands and Wildlife 1992c)
  - *Guideline 7 - Timber Harvesting and Fish Habitat* (Alberta Forestry, Lands and Wildlife 1985b)
  - *Guideline 10 - Water Intakes: Screen Requirements for Fisheries* (Alberta Forestry, Lands and Wildlife 1993)
  - *Guideline 15 - Use of Explosives in the Water* (Alberta Forestry, Lands and Wildlife 1987c)
- *Stream Crossing Guidelines: Operational Guidelines for Industry* (Alberta Energy and Natural Resources 1985).
- *Design Guidelines and Application Procedures for a Bridge, Culvert or Other Structure Crossing a Watercourse or Waterbody* (Alberta Environment 1990).
- *Design Guidelines and Application Procedures for Buried Pipeline(s) Crossing a Watercourse or Waterbody* (AEP 1994).
- *Environmental Protection Guidelines for Pipelines - C&R IL 94 5* (AEP 1994b).
- *Guide for Pipelines Pursuant to the Environmental Protection and Enhancement Act and Regulations* (AEP 1994c).
- *Conservation and Reclamation Guidelines for Alberta - C&R IL 97-1* (AEP 1997a).
- *Guidelines for the Application of Fish and Wildlife Conditions to Land Use Activities in Northeastern Slopes Region* (Draft) (AEP 1997b).

As of December 1997, AENV has no longer been actively participating in the federal regulatory processes involving fish habitat and navigable waters protection as they pertain to the *Fisheries Act* and the *NWPA*. Proponents are advised compliance with the Code of Practice or issuance of licences, authorizations and approvals by AENV or ASRD under the *Environmental Protection and Enhancement Act*, *Water Act* or the *Public Lands Act* does not mean the project has federal approval. If concerned about their project meeting the requirements of the *Fisheries Act*, proponents are encouraged to discuss their project with DFO.

2.2.2 British Columbia

In British Columbia (B.C.), the Ministry of Environment (MOE) and the B.C. Oil and Gas Commission are the main provincial regulating agencies for watercourse crossings. Several pieces of legislation which pertain to pipeline associated watercourse crossings are identified below:

- *Environmental Assessment Act*
  - Environmental Assessment Reviewable Projects Regulation
- *Oil and Gas Commission Act*
- *Fish Protection Act*
- *Forest Practices Code of British Columbia Act*
- *Land Act*
- *Water Act*
  - Water Regulation

Pipelines are "reviewable" under the *Environmental Assessment Act* by MOE if the construction of a new facility:

- is a transmission pipeline in accordance with one of the following dimensions;
  - <114.3 mm O.D., 60 km or more,
  - >114.3 and <323.9 mm O.D., 50 km or more,
  - >323.9 mm O.D., 40 km or more; or
- has the capacity to transport in one year an energy resource or solid in a quantity that can yield by combustion 16 PJ or more of energy.

The Minister may require other smaller projects to be reviewed under the *Environmental Assessment Act* if it is felt the project may have a significant adverse effect on the environment or if it is in the public interest to do so. Section 7 of the *Environmental Assessment Act* provides details on what information requirements must be submitted on the application to MOE.

All provincially regulated oil and gas projects are reviewed by the B.C. Oil and Gas Commission. Proponents must complete consultation with government and stakeholders and submit an application form to the Commission. The Commission will then assess the project, conduct further consultation if required and provide a decision or approval for the project. If an environmental assessment is triggered under the *Environmental Assessment Act*, approval from MOE will be required prior to submitting the application to the B.C. Oil and Gas Commission.

The *Fish Protection Act* provides for the protection of water flows for fish, designation of "sensitive streams" requiring stronger management measures, protection of fish habitat and improved riparian protection. Watercourse crossings will be subject to the *Fish Protection Act* and require compliance prior to the issuance of licenses and approvals by regional water managers.

The *Water Act* has undergone some changes with respect to the *Fish Protection Act*. Fish habitat protection must be considered when applying for licenses under the *Water Act*. Proponents are responsible for all debris entering a watercourse and must remediate or mitigate the effects of the introduction, as authorized by the regional water manager.

In B.C., all watercourses are considered to be fish-bearing or have the potential to be fish-bearing unless proven otherwise (generally with at least two sampling seasons). Proponents must conduct a fisheries assessment for each watercourse crossing in which instream construction will take place. Fisheries assessments are also advised for bored or horizontal directionally drilled crossings where a contingency plan with instream construction will be initiated if drilling is not successful. Fisheries assessments must be conducted in accordance with recognized fish and fish habitat sampling methods and standards (Resources Inventory Committee (RIC) 1997, 1999, 2001; B.C. Forest Service 1998).

B.C. has several provincial codes of practices, guidelines and guides applicable to watercourse guidelines that are identified below:

- *Standards and Best Practices for Instream Works* (MWLAP 2004).
- *Stream Crossing Planning Guide* (Northeast B.C.) Version 2.0 – December 15, 2004 (B.C. Oil and Gas Commission 2004a).
- *Fish Stream Identification and Risk Management Tool* (B.C. Oil and Gas Commission 2004b).
- *Fish and Wildlife Timing Windows Document and Table* (B.C. Oil and Gas Commission 2004c).
- *Schedule A, Approved Sources of Water* (B.C. Oil and Gas Commission 2004d).
- *Forest Practices Code of British Columbia: Fish-stream Crossing Guidebook* (B.C. Forest Service, MWLAP, and MEM 2002).
- *Forest Practices Code of British Columbia: Riparian Management Area Guidebook* (B.C. Forest Service 1995a).
- *Oil and Gas Commission Planning Guide for Oil and Gas Operations in British Columbia* (B.C. Oil and Gas Commission 2004e).
- *Forest Road Engineering Guidebook* (B.C. Forest Service 1995b).
- *Northern Interior Region - Peace / Liard Sub-Region Stream Impact Guidelines* (B.C. Ministry of Environment, Lands and Parks 1991).
- *Terms of Reference For Impact Assessments Adjacent To Proposed Pipeline Crossings* (B.C. Ministry of Environment, Lands and Parks 1992).

DFO has developed *Land Use Guidelines for the Protection of Aquatic Habitat*, which are specifically designed for B.C. (DFO 1992). These guidelines pertain to the federal *Fisheries Act*.

2.2.3 Manitoba

The departments of Conservation and Water Stewardship are the main regulatory agencies for watercourse crossings. There are four pieces of legislation noted below which pertain to pipeline associated watercourse crossings:

- *Environment Act*
- *Water Resources Administration Act*
- *Crown Lands Act*
- *Water Rights Act*

A Manitoba *Environment Act* License is required for those projects that are likely to have a significant effect on the environment including construction and replacement of watercourse crossings. To acquire a license, an application must be submitted to the Environmental Approvals Branch of Manitoba Conservation. Manitoba Conservation, Water Stewardship and other relevant federal and provincial departments will review the application. Fish and fish habitat protection measures are often included as conditions to the license for approved projects. Work permits may also be required under the *Environment Act* licenses and are used to ensure habitat is adequately protected in the manner described in the *Environment Act* License. Work permits are issued for a variety of activities including watercourse crossing installation and any activities which may alter the aquatic habitat.

Manitoba Conservation, Programs Division, Lands Branch, under the authority of the *Crown Lands Act*, must be contacted for regulatory approval of watercourse crossings under the *Act*. Most lands in Manitoba below the average annual high water level are Crown lands. Provincial Work Permits are used to authorize activities taking place on Crown land. These permits are generally issued by the District Natural Resources Officer (NRO) where the activity is occurring and the District is also responsible for ensuring that the conditions of the Work Permit are met.

Under the *Water Resources Administration Act*, a proponent must obtain a permit to undertake instream or nearshore construction in a designated river, stream or area (up to 350 feet from the normal summer water mark). Deposition of any material that may impede or restrict the flow of water or affect bank stability as well as the construction of a structure that may affect bank stability is prohibited, unless authorized by issuance of a permit.

Under the *Water Rights Act*, a proponent must obtain a license to use or divert water in any matter, or to construct any works that may divert water. The permit or license application is made to the Water Branch of the Department of Water Stewardship. The Fisheries Branch also reviews the application and will provide recommendations based on fishery resources considerations.

In Manitoba, if an open cut is required within a restricted construction timing window (*i.e.,* spawning and incubation season) an Authorization under Subsection 35(2) of the federal *Fisheries Act* will be required from DFO.

Guidelines for watercourse crossings were published by Manitoba Natural Resources and DFO in 1996: *Manitoba Stream Crossing Guidelines for the Protection of Fish and Fish Habitat*.

Fish habitat management is coordinated between federal and provincial levels in Manitoba by a Memorandum of Understanding between Fisheries and Oceans Canada and Manitoba Conservation. The Memorandum of Understanding establishes the Canada/Manitoba Fish Habitat Committee that has the mandate of developing clear, concise and coordinated principles for fish habitat management by Canada and Manitoba.

2.2.4 New Brunswick

The New Brunswick Department of Natural Resources and Department of Environment and Local Government administer most aspects of pipeline associated watercourse crossings. Crossings are subject to the following legislation:

- *Clean Environment Act*
  - Environmental Impact Assessment Regulation
- *Clean Water Act*
  - Watercourse and Wetland Alteration Regulations
- *Crown Lands Act*
- *Fish and Wildlife Act*
- *Quarriable Substances Act*

The approval and regulation of the construction and operation of oil and gas pipelines in New Brunswick are provided for by the Environmental Impact Assessment Regulation of the *Clean Environment Act*. All oil and gas pipelines exceeding 5 km in length are designated by this Regulation as projects which may result in significant environmental impact. These undertakings must be registered with the Minister of Environment to determine whether the preparation of an environmental impact assessment is required.

DFO retains direct management control of fisheries in New Brunswick. However, authorization for watercourse alteration is required from the New Brunswick Department of Environment and local government through the Watercourse and Wetland Alteration Permit. The New Brunswick Watercourse and Wetland Alteration staff will review the Application and may request input from DFO and/or the New Brunswick Department of Natural Resources. No separate applications to these agencies are required, but both agencies are responsible for their own legislation and attainment of their goals and objectives. The New Brunswick Department of Natural Resources is responsible for the *Crown Lands Act*, the *Quarriable Substances Act* and the *Fish and Wildlife Act*.

The New Brunswick Watercourse Alteration Technical Committee is comprised of representatives from both provincial and federal government agencies and has prepared *Watercourse Alteration Technical Guidelines* (New Brunswick Watercourse Alteration Technical Committee 1987).

2.2.5 Newfoundland and Labrador

The Newfoundland and Labrador Department of Environment and Conservation is responsible for the approval of pipeline associated watercourse crossings in Newfoundland and Labrador. Crossings are subject to the following legislation:

- *Environmental Protection Act*
  - Environmental Assessment Regulations
- *Water Resources Act*

Pursuant to the Environmental Assessment Regulations of the *Environmental Protection Act*, pipelines located a distance greater than 500 m from an existing right-of-way must be registered and reviewed by the Minister of Environment and Conservation. An environmental preview report may be required to determine whether further environmental assessment is required or any significant adverse environmental impact is indicated. Alternatively, a proponent may proceed directly with the preparation of an environmental impact statement.

Any alteration of a body of water, including a watercourse crossing, is an undertaking requiring approval under section 48 of the *Water Resources Act*. The approval must be obtained from the Department of Environment and Conservation, Water Resources Management Division and the application requires pertinent information relating to engineering, hydraulic design, site features, construction operations and anticipated engineering implications.

DFO retains direct management of fisheries of Newfoundland and Labrador. Authorizations may be required under the federal *Fisheries Act*.

2.2.6 Northwest Territories

Approval and regulation of oil and gas pipelines in the Northwest Territories (NWT) is administered by a number of different agencies and is dependent upon which region of the NWT the pipeline project will take place. The following descriptions illustrate the current regulatory environment in the NWT, but should not be considered prescriptive. Besides regional regulation, it is important to consider that overall the NEB administers, approves and regulates oil and gas pipelines and DFO retains direct management control of fisheries resources in the NWT.

Inuvialuit Settlement Region

In the Inuvialuit Settlement Region (ISR), the Inuvialuit Land Administration (ILA), is responsible for administering and managing the lands received under the Inuvialuit Final Agreement. All oil and gas applications involving use of Inuvialuit lands are filed with the ILA, which then forwards the applications to the Inuvialuit Environmental Impact Review Board for review and recommendations. Land use permits are granted by the ILA on Inuvialuit private lands and by INAC on Crown lands according to Territorial Land Use Regulations of the *Territorial Lands Act*. The NWT Water Board issues all water licences according to the *Northwest Territories Waters Act.*

Mackenzie Valley

Developments in the Mackenzie Valley are subject to the regulatory regime established by the *Mackenzie Valley Resource Management Act*. The *Act* establishes regional land and water boards for both the Gwich'in and Sahtu settlement areas for developments that will take place wholly within the settlement area boundaries. In addition, the *Act* designates the Mackenzie Valley Land and Water Board as the authority for unsettled claims areas and transboundary projects.

All land and water boards are responsible for the issuance of land use permits and water licences, both of which would be required for a watercourse crossing. Determination criteria for land use permits are set out in the Mackenzie Valley Land Use Regulations and water licences are issued pursuant to the *Northwest Territories Waters Act*. If necessary, permit and license applications will be forwarded to the Mackenzie Valley Environmental Impact Review Board for environmental assessment and review.

2.2.7 Nova Scotia

DFO retains direct control of the fisheries of Nova Scotia. However, the Nova Scotia Government administers other provincial acts and regulations noted below.

- *Crown Lands Act*
- *Environment Act*
  - Activities Designation Regulations
  - Approvals Procedure Regulations
  - Environmental Assessment Regulations

The *Environment Act* requires that all projects altering a watercourse or its flow obtain a Water Approval for Watercourse Alteration from the Nova Scotia Department of Environment and Labour. Applications may be referred to other relevant provincial agencies or to DFO and TC for assessment.

All proposed pipelines require Environmental Assessment Approval under the *Environment Act*. The Approvals Procedure Regulations provide proponents with the application process to be followed for the assessment. A Use of Crown Lands Permit is required from the Nova Scotia Department of Natural Resources for all right-of-way crossings (*i.e.*, bed and banks).

2.2.8 Nunavut

Land use activities on Crown lands in Nunavut are regulated by the Territorial Land Use Regulations of the *Territorial Lands Act*. Land use permit applications are submitted to INAC who then forwards the application to the Nunavut Impact Review Board (NIRB). The NIRB was set up under Article 12 of the Nunavut Land Claim Agreement to examine potential development impacts for proposed projects. The NIRB may be required to assess the ecosystemic and socio-economic impacts of the project to determine whether the project should proceed to development and if so, under what conditions. NIRB will forward the application to DFO for review.

Applications for land use activities on Inuit Owned Lands (IOL) are submitted to the appropriate regional office of the Nunavut Planning Commission:

- North Baffin Planning Region – Pond Inlet
- North Baffin Planning Region – Iqaluit
- Akunniq Planning Region – Taloyoak
- Keewatin Planning Region – Arviat
- Sanikiluaq Planning Region – Iqaluit (interim)
- West Kitikmeot Planning region – TBA

Water license applications are submitted to the Nunavut Water Board (NWB) pursuant to the *Nunavut Waters and Nunavut Surface Rights Tribunal Act*. The NWB contributes fully to the assessment of development plans as they concern water in Nunavut. All water crossings, water uses or disposals of waste into water must be approved by the NWB.

2.2.9 Ontario

Watercourse crossings in Ontario are administered by the Ontario Ministry of Natural Resources (OMNR) in consultation with DFO and the Ontario Conservation Authority.

OMNR reviews all aspects of a proposed watercourse crossing and all projects will require a Work Permit from their office. If Crown lands are involved the permit is issued under the *Public Lands Act* and if private or municipal lands are involved the permit is issued under the *Lakes and Rivers Improvement Act*. Proponents should follow the procedures described in *Environmental Guidelines for Access Roads and Water Crossings* (OMNR 1993b).

Proponents of large pipeline projects should contact DFO directly to determine whether a crossing requires an Authorization under Subsection 35(2) of the *Fisheries Act*. DFO will either grant an Authorization or supply a letter of advice to the proponent suggesting measures to avoid HADD. If it is not feasible to avoid HADD and the impacts on fish habitat are unacceptable, an Authorization will not be issued. DFO monitors isolated and trenchless crossings and requires a list of the locations of all such crossings from proponents.

In southern Ontario, proponents must also obtain a permit from the appropriate Conservation Authority for all watercourse crossings. The authority will issue a permit provided the construction of the crossing will not affect the control of flooding or pollution, or conservation of land.

OMNR has developed generic drawings for dam/pump and flume crossing techniques and temporary access bridges. All open trenched crossing techniques will require a more extensive application and submission of a Sediment Control Plan. Information requirements for a Sediment Control Plan and copies of OMNR Generic Drawings can be obtained from OMNR offices.

There are several documents regarding guidelines and policies for pipeline associated watercourse crossings in Ontario; they are listed below.

- *Guidelines for Evaluating Construction Activities Impacting on Water Resources* (Ontario Ministry of Environment and Energy 1995).
- *Water Management - Goals, Policies, Guidelines, Objectives and Implementation Procedures of the Ministry of the Environment* (Ontario Ministry of the Environment 1984b).
- *Ontario Generic Sediment Control Plans* (Ontario Ministry of Natural Resources 1993a).
- *Sediment Control Plans for Wet Crossings* (Ontario Ministry of Natural Resources 1993b).
- *Environmental Guidelines for Access Roads and Water Crossings* (Ontario Ministry of Natural Resources 1993b).
- *Ontario Energy Board Guidelines for the Location, Construction and Operation of Hydrocarbon Pipelines and Facilities in Ontario* (Ontario Energy Board 1995).
- *Instream Sediment Control Techniques Field Implementation Manual* (Trow Consulting Engineers Ltd. 1996).
- *Fisheries-related Information Requirements for Pipeline Water Crossings* (Goodchild and Metikosh)

2.2.10 Prince Edward Island

Approval and regulation of pipeline associated watercourse crossings on Prince Edward Island (PEI) is administered by the PEI Department of Environment, Energy and Forestry under the *Environmental Protection Act*. The proponent must provide a written proposal to the department with regard to the project. The

Minister may request further information or ask the proponent to develop an environmental impact statement, as well as provide public notification and input.

DFO retains direct management control of fisheries for PEI; however, a Watercourse Alteration Permit is required from the PEI Department of Fisheries, Aquaculture and Environment. The review process for this permit includes comment from DFO. The Minister has appointed the PEI Watercourse Alteration Advisory Committee to review applications for watercourse alteration permits and to advise the Minister on these proposed projects. The Committee and DFO developed watercourse alteration guidelines in 1989 (PEI Watercourse Alterations Advisory Committee 1989).

2.2.11 Québec

Watercourse crossings in Québec are subject to provisions under the *Loi sur la qualité de l'environnement* and the *Loi sur la conservation et la mise en valeur de la faune*.

Major pipeline associated watercourse crossings in Québec are subject to Articles 22 and 31.1 from the *Loi sur la qualité de l'environnement* and require an Environmental Impact Assessment as well as Public Hearings. Applications for major projects are submitted to the Ministère de l'Environnement. Major projects are defined as one or both of the following:

- Involves dredging, digging, filling, leveling or backfilling of 300 m in length or larger or an area of 5,000 m^2 or more (up to the high water mark) in a "river"; or
- Temporarily or permanently rerouting or diverting a "river".

To determine if the watercourse is classified as a "river" one must consult the Répertoire de ponymique.

Minor pipeline associated watercourse crossings in Québec are subject to Article 22 from the *Loi sur la qualité de l'environnement* and if the watercourse is public property the *Loi sur la conservation et la mise en valeur de la faune*. Applications are submitted to the Regional Directors of the Ministère de l'Environnement for Article 22 and to the Regional Director of La Société de la Faune et des Parcs du Québec if the watercourse is public property. However, if the project follows the regulations set out in the *Loi sur la conservation et la mise en valeur de la faune* then the proponent does not need to obtain authorization from La Société de la Faune et des Parcs du Québec. If the project occurs in a forested area, authorization is still obtained from La Société de la Faune et des Parcs du Québec and not from the Ministère des Resources Naturelles, since the *Loi sur les forêts* includes the regulations from the *Loi sur la conservation et la mise en valeur de la faune* in regard to water crossings.

The Ministère de l'Environnement has guidelines listed in a publication entitled Critères d'analyse des projects en milieux hydrique, humide et riverain assujettis à l'article 22 de la *Loi sur la qualité de l'environnement* published in December 1996 which contains 20 articles on various related subjects such as:

- Fîche 1: Stabilisation naturelle des rives (Natural Stabilization of Creeks);
- Fîche 4: Dragage et creusage (Dredging and Digging);
- Fîche 8: Pont et ponceau (Bridges and Culverts);
- Fîche 9: Traversée de cours d'eau (Water Crossing);
- Fîche 10: Détournement et redressement de cours d'eau (Rerouting and Diversion of Watercourses); and
- Fîche 14: Prises d'eau (Water Sampling)

2.2.12 Saskatchewan

Pipeline associated watercourse crossings in Saskatchewan are regulated by Saskatchewan Environment under the following legislation.

- *Environmental Assessment Act*
- *Environmental Management and Protection Act*
  - Water Regulations, 2002

Saskatchewan Environment requires proponents to apply for a Shoreland Alteration Permit (SAP) and/or an Aquatic Habitat Protection Permit (AHPP) for all watercourse crossings.

Several watercourse crossing guideline documents proposed for Saskatchewan are identified below:

- *Fish Habitat Protection Guidelines: Road Construction and Stream Crossings* (Fisheries and Oceans and Saskatchewan Environment and Resource Management 1995)
- *Environmental Operating Guidelines for the Saskatchewan Petroleum Industry* (Canadian Petroleum Association 1992).
- *Guidelines for Preparation of an Environmental Protection Plan for Oil and Gas Projects* (Saskatchewan Environment 1987).

2.2.13 Yukon

Approval and regulation of the construction and operation of oil and gas pipelines in the Yukon is administered by Natural Resources Canada and the NEB. DFO has management control of marine and anadromous fisheries resources and management of all fisheries habitat. First Nation Renewable Resources Councils are responsible for non-anadromous fisheries and fulfill their responsibilities in consultation with DFO.

Watercourse crossings are subject to the following territorial legislation:

- *Yukon Environmental and Socioeconomic Assessment Act (YESAA)*

- *Territorial Lands (Yukon) Act*
- *Waters Act*
  - Waters Regulations, 2002

The Development Assessment Process (DAP) established by the *Yukon Environmental and Socioeconomic Assessment Act* was negotiated under the Yukon First Nations Umbrella Final Agreement and provides a comprehensive, integrated environmental assessment process that applies to First Nations settlement lands, Commissioner's (Territorial) lands and federal Crown lands. The YESAA Board and the Yukon Government Executive Council Office, DAP Branch oversee the administration of the *Act*.

The Yukon Water Board is responsible for the issuance of all water licences under the *Waters Act*.

Land use permitting of land under the control of the Yukon government is conducted through the Department of Energy, Mines and Resources. Yukon First Nations have control over their individual settlement lands and must be contacted regarding proposed pipeline associated watercourse crossings within their jurisdiction. The Yukon Land Use Planning Council is in place to co-ordinate First Nation and Government land use planning.

3 Description of Crossing Techniques

This section presents two tables summarizing the environmental and engineering/construction considerations for each pipeline and vehicle crossing technique. The intent is to allow the reader to become aware of the advantages and disadvantages of each technique and factor this information into the watercourse crossing planning process.

3.1 Pipeline Crossings

This sub-section outlines the various pipeline watercourse crossing construction techniques commonly used in Canada. **Table 3.1** summarizes the environmental and construction advantages and disadvantages as well as the appropriate uses of each crossing method of construction. Drawings 1 to 11 (see Appendix A) outline the standard protection measures that should be incorporated with each technique. Although the appropriate uses for each technique are identified, implementation of alternative techniques with mitigation measures or a combination of techniques may also be applicable. Since the drawings and measures contained in this document are typical and not site-specific, detailed design drawings might be required with input from an engineer and other specialists.

3.2 Temporary Vehicle Crossings

This sub-section outlines the various vehicle crossing techniques that can be used during the construction of pipeline associated crossings. **Table 3.2** summarizes the environmental and construction advantages and disadvantages as well as the appropriate uses of each technique. Drawings 12 to 15 (see Appendix A) illustrate the more common techniques and outline the standard environmental protection measures that should be implemented with each crossing method. Typical vehicle crossing drawings should be designed by an engineer with input from other specialists to meet regulatory requirements. In most situations, typical drawings similar to those contained in this document will be sufficient; however, where site-specific cases warrant, or where special vehicle crossing techniques are necessary, individual crossing designs by an engineer should be considered.

Table 3.1 Pipeline Watercourse Crossing Construction Techniques

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
OPEN TRENCHED i) Plow (see Dwg. 1)					
• plow-in pipeline without pretrenching • feed or drag pipeline into furrow behind plow	• rapid construction / installation • minimizes period of instream activity • minimizes total sediment release • short period of sediment release • minimal temporary workspace required	• grading of banks required • potential sediment release during grading of banks • sediment release during instream work • removal of riparian vegetation	• reduces instream activity • eliminates backfilling phase • low cost if equipment onsite • rapid construction / installation	• specialized equipment • need access ramps to creek • problematic in boulders and bedrock • depth of cover is limited	• unconsolidated substrate (*e.g.,* sand or gravel) • shallow lakes or watercourses with little or no flow (<1 m) • when pipeline on uplands is also being plowed-in • small diameter lines (<168.3 mm O.D.) • where instream work is permitted but sediment release is to be minimized
OPEN TRENCHED ii) Bucket / Wheel Trencher					
• trench through watercourse with bucket / wheel trencher	• rapid construction / installation • minimizes period of instream activity • short period of sediment release	• potentially high sediment release • spoil pile may block flow • trench is prone to sloughing • requires extensive grading of banks	• no special equipment • not limited by width of watercourse • low cost • rapid construction / installation	• limited by water depth (<1 m) • trench is prone to sloughing • trench may not be wide enough • equipment has trouble on steep banks • difficulty with rocky substrate or bedrock • trench depth may be inadequate	• dry intermittent water-courses with fine-textured substrate where wheel ditcher is being used on uplands • possibly for low flow, low sensitivity streams with low banks • dry creeks and shallow swales

Table 3.1 Pipeline Watercourse Crossing Construction Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
OPEN TRENCHED iii) Hoe (see Dwgs. 2 and 3)					
• trench through watercourse with hoe from banks or instream	• rapid construction / installation • minimizes period of instream activity • generally maintains streamflow • maintains fish passage • relatively short duration of sediment release (<24 hours)	• potentially high sediment release during excavation and backfilling • instream stockpiling of spoil on wide watercourses • may interrupt streamflow	• no need for specialized equipment • rapid construction / installation • low cost • compatible with granular substrates and some rock	• limited to less than 20 m unless hoe works instream • limited by water depth unless hoe works off barge • may require several hoes working together to facilitate excavation	• shallow (<1.5 m) watercourse with unconsolidated granular substrate
OPEN TRENCHED iv) Dragline (see Dwg. 4)					
• trench through watercourse with dragline bucket from either bank	• equipment not in watercourse • spoil on banks • maintains streamflow • maintains fish passage	• potentially high sediment release • slow construction / installation • long duration of sediment release • safety concern with cables strung across watercourse • may require grading of banks leading to sediment release • large area required for equipment	• permits many passes over trench • cleans sloughed material from trench • good for unconsolidated substrate • permits deeper trench	• moderately expensive • inaccurate control on trench width and alignment • slow construction / installation • specialized equipment • trench susceptible to sloughing • need large working space for equipment set up • cables restrict navigational use of watercourse • incompatible with boulders or consolidated bottom material	• wide and deep water-courses with soft substrate and limited navigational concerns • often used to clean out trench initiated with hoes

Table 3.1 Pipeline Watercourse Crossing Construction Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
OPEN TRENCHED v) Dredging					
• dredge trench through watercourse with suction and pump slurry to banks or tanks on barges	• minimal sediment release during trenching • maintains streamflow • maintains fish passage • no instream spoil storage • relies on natural sediment transport for backfill	• settling ponds required for slurry • disposal of settled water • possible mortality or injury to fish	• allows deep water trenching • technique for transporting to shore • no instream spoil storage	• expensive • specialized equipment • settling pond must be constructed • difficult in large granular substrate or bedrock • trench depth may be inadequate	• deep, wide rivers / lakes with fine unconsolidated substrate • where sediment release is a concern
ISOLATED TRENCHED i) Flume (see Dwg. 5)					
• block flow upstream of crossing and divert through flume pipe(s) laid in streambed perpendicular to pipeline • dam downstream side of crossing area to prevent backflow • flume(s) should be properly sized to accommodate flow • high capacity variations constructed out of 2 m x 3 m x 32 m steel box sections • may be augmented with pump bypass	• limited sediment release • maintains streamflow • may allow fish passage • minimal release and transport of sediment downstream; not likely to result in negative effects to fish and fish habitat. • allows for flushing of substrates	• minor sediment release during dam construction, removal and as water flushes over area of construction • slow construction / installation prolongs sediment release • fish salvage may be required from dried up reach • short-term barrier fish passage if water velocity in culvert is too high	• relatively dry or no flow working conditions • ample time for pipeline construction • may be adapted for nonideal conditions • compatible with consolidated substrates • may incorporate bridge • may reduce ditch sloughing and ditch width	• difficult to trench and lay pipe, especially large diameter pipe, under flume pipe • difficult to install properly • flow limited by flume size 2 - 3 m^3/s using multiple flume pipes >20 m^3/s • moderately expensive • work area may not stay dry in coarse, permeable substrate • too short a flume may not be sufficient for unstable trench • flume pipe can be crushed or blocked during pipeline construction • requires relatively long, straight channel to install flume	• small watercourse with defined banks and defined channel with solid, fine-textured straight substrate • where sediment release and fish passage are of concern • works best in nonpermeable substrate • common usage is for flows <1 m^3/s

Table 3.1 Pipeline Watercourse Crossing Construction Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
ISOLATED TRENCHED ii) Dam and Pump (See Dwg. 6)					
• dam flow upstream and downstream of crossing and pump water around via hose(s)	• limited sediment release • maintains streamflow • minimal release and transport of sediment downstream; not likely to result in negative effects to fish and fish habitat.	• minor sediment release during dam construction, dam removal and as water flushes over area of construction • slow construction / installation resulting in extended period instream and prolonged sediment release • fish salvage may be required from dried up reach • short-term barrier to fish movement	• relatively dry working conditions • ample time for pipeline construction • may be adapted for nonideal conditions • hose can be routed around area of construction • multiple pumps can be used • compatible with consolidated substrates • can be used in watercourses with meandering channel • may reduce ditch sloughing and ditch width	• size of watercourse limited to pump capacity • specialized equipment and materials • slow construction / installation • moderately expensive • hose(s) may impede construction traffic • seepage may occur in coarse, permeable substrate • susceptible to mechanical failure • requires standby pump(s)	• small watercourse with low flow, defined banks and channel with no requirement for fish passage • where sediment release is of concern • works best in non-permeable substrate • common usage is for flows <1 m^3/s (max. capacity of 1 pump ~0.3 m^3/s)
ISOLATED TRENCHED iii) High Volume Pump Bypass / Sump and Pump (See Dwg. 7)					
• install high volume pump(s) bypass in pool upstream of crossing and pump watercourse dry, discharging down-stream of crossing • construct work area sump downstream of ditch to permit "washing" of work area • pump silt-laden water from sump onto well vegetated area • partial bypass in high flow situations may be used to reduce instream water velocity	• limited sediment release • maintains streamflow • normal streamflow can be restored instantly • no sediment release as a result of dam construction • minimal release and transport of sediment downstream; not likely to result in negative effects to fish and fish habitat.	• minor sediment release as water flushes over area after construction • dries up short reach of streambed • short-term barrier to fish movement • fish salvage may be required from dried up areas • sump areas are required	• no dams are required • flow can be regulated if necessary • hose(s) can be routed around area of construction • multiple pumps can be used • compatibility with consolidated substrates	• sump(s) may need to be excavated • specialized equipment and materials required • moderately expensive • hose(s) may impede construction traffic • requires stand-by pump(s) • susceptible to mechanical failure	• small to moderate watercourses with low to moderate flow (1 m^3/s) and no requirement for fish passage (max. pump capacity ~0.3 m^3/s • partial bypass in high flow situations may be used to reduce instream water velocity

Table 3.1 Pipeline Watercourse Crossing Construction Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
ISOLATED TRENCHED iv) Coffer Dam (see Dwg. 8)					
• install dam approximately 2/3 into watercourse surrounding work area • pump area dry or work in "still" waters • remove dam and repeat on other side of watercourse • materials such as regular sandbags, sheet piling, oversized (1 m^3) sandbags, rock fill / median barriers, poly water structures or a combination of the above can be used	• maintains streamflow • maintains fish passage • minimal release and transport of sediment downstream; not likely to result in negative effects to fish and fish habitat.	• moderate sediment release based on amount of instream work • may dry up long reach of watercourse • fish salvage required from dried-up reach • increased water velocity and potential scouring • possible increased erosion on opposite bank • potential washout of dam • slow construction / installation • extensive instream activity with heavy equipment may be required to install dams • requires large right-of-way and terrain disturbance	• relatively dry or no flow working environment • ample time for pipeline construction • compatible with consolidated substrates	• source of dam materials needed (*i.e.,* sandbags, rock fill, poly, etc.) • pumping may be required • expensive • specialized materials • difficult to make tie-in • slow construction / installation • potential washout of dam • safety concerns	• moderate to large watercourses too large for flume or pump techniques • where sediment release and fish passage are of concern • braided stream channels • watercourses with low banks • where an extended instream period is required • isolation of stream banks or portions of streambeds for maintenance and repair works

Table 3.1 Pipeline Watercourse Crossing Construction Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
ISOLATED TRENCHED v) Channel Diversion (see Dwg. 9)					
• divert streamflow into existing side channels or abandoned channel or construct a new channel • use rockfill, sheet piling or poly water structures to divert flow • channel may be lined or have a flexible stream diversion conduit installed	• maintains streamflow • maintains fish passage • minimal release and transport of sediment downstream; not likely to result in negative effects to fish and fish habitat.	• unless lined, very high sediment release when new channel is flushed through • dries up long reach of watercourse • fish salvage required from dried-up reach • slow construction / installation • potential washout of diversion dam • damage to streambank and adjacent lands	• relatively dry working area • ample time for pipeline construction • compatible with consolidated substrates	• expensive • source of dam (*i.e.,* sandbags, rock fill, poly, etc.) material needed • may require channel liner or conduit • may require extensive preparation and channel grading / restoration • specialized materials required • slow construction / installation • potential washout of diversion dam	• watercourses too large to flume or pump • best used when new channel is clear of fine substrate and will cause little sediment release • braided stream channels • where sediment release and fish passage are of concern

Table 3.1 Pipeline Watercourse Crossing Construction Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
TRENCHLESS i) Boring (see Dwg. 10)					
• bore under watercourse from bellhole on one side to bellhole on other with or without casing • wet boring with pilot hole and reaming bit can also be performed	• no sediment release • no disturbance of streambed or banks • maintains normal streamflow • maintains fish passage • maintains vegetative buffer on either side of watercourse • not likely to result in HADD	• pump(s) may be required to drain seepage within the bellholes onto surrounding lands • possibility of sump water causing sediment release in watercourse • requires additional workspace for bellholes, spoil piles and sump(s) • potential for borehole cave-in and/or dewatering	• can be fast and economical under the right conditions • minimizes clean-up of bed and banks • road boring equipment may be available • may be able to construct during sensitive fisheries restricted activity windows	• can be slow or not feasible under adverse conditions • difficult with till or coarse material • potential for borehole cave-in • excessive borehole depth on deeply incised watercourses or watercourses with moderate or greater approach slopes • with excessive seepage in course fluvial material it may be impossible to keep bell hole dry • seepage into bellhole may cause sloughing • possible need for specialized equipment and pump(s) • limited to approximately 100 m, however, length varies with borehole diameter	• fine-textured impermeable soils • low water table • where streambed cannot be disturbed • used most often on irrigation ditches • where fish / riparian habitat cannot be disturbed • where the watercourse is only slightly incised and approach slopes are absent or slight

Table 3.1 Pipeline Watercourse Crossing Construction Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
TRENCHLESS ii) Punching / Ramming (see Dwg. 10)					
• ram or punch casing or pipe under watercourse	• no sediment release • no disturbance of streambed and banks • maintains normal streamflow • maintains fish passage • maintains vegetative buffer on both sides of watercourse • not likely to result in HADD	• pump(s) may be required to drain seepage within the bellholes onto surrounding lands • possibility of sump water causing sediment release in watercourse • requires additional workspace for bellholes, spoil piles and sump(s) • ground vibrations and associated pressure waves could be an issue during sensitive life history phases for fish	• can be quick under the right conditions • avoids clean-up of bed and banks • cave-ins of borehole are unlikely • larger pipe diameters can be accommodated • may be able to construct during sensitive fisheries restricted activity windows	• can be slow under adverse conditions • potential bellhole cave-in ahead of ram • seepage into bellhole • with excessive seepage in course fluvial material it may be impossible to keep hole dry • specialized equipment may be required • potential corrosion problems from coating stripping • relatively inaccurate • limited to ~50 m in length • excessive borehole depth on deeply incised watercourses or watercourses with moderate or greater approach slopes	• fine-textured imper-meable soils • low water table • irrigation ditches • where streambed cannot be disturbed • can also be used in coarse-textured substrate • narrow to moderate watercourse (*i.e.,* <30 m) • where the watercourse is only slightly incised and approach slopes are absent or slight

Table 3.1 Pipeline Watercourse Crossing Construction Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
TRENCHLESS iii) Horizontal Directional Drilling (see Dwg. 11)					
• slant drill used to drill under watercourse and, where practical, approach slopes	• no sediment release unless frac-out occurs • no bank disturbance • no streambed disturbance • may avoid approach slope disturbance • maintains normal streamflow • maintains fish passage • not likely to result in HADD • maintains vegetation buffer on both sides of watercourse	• disturbance of drilling and target area • disposal of drilling fluids • fractures in substrate may release pressurized drilling fluids into watercourse • circulating drilling fluid may wash out cavities under the watercourse and banks resulting in sinkholes • possible spills from drilling sump(s) down towards watercourse • large area may be required on floodplains	• eliminates clean-up and reclamation in between entry and exit points • avoids work in repairing and restoring banks • reduction in reclama-tion costs • reduction of long-term maintenance • may be able to construct during sensitive fisheries restricted activity windows • small diameter pipelines successfully drilled across sensitive watercourses or up steep slopes can be cost effective by reducing habitat compensation and reclamation costs	• moderately to very expensive • success depends on substrate • specialized equipment • slow construction / installation • limited to arc that can be drilled for pilot hole (10-20^{o} entry / exit angles) • limited arc that pipe can "rope" through the hole, especially large diameter pipe • may take several attempts • drill stem may get "stuck in the hole" and tools can get lost, especially on large diameter reams • no guarantees that drill will be successful • may damage coating / pipe	• watercourse with sensitive habitat where no instream activity allowed • watercourses where HADD may result from instream activity • areas with very unstable approach slopes • high aesthetic concerns (*i.e.,* parks) • restrict HDD staging in the floodplain, where conditions allow.

Table 3.1 Pipeline Watercourse Crossing Construction Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	**Disadvantages**	**Advantages**	**Disadvantages**	
TRENCHLESS iv) Micro-tunneling					
• use a small tunnel boring machine to create a tunnel for the pipe or casing	• no sediment release • no bank disturbance • no streambed disturbance • no approach slope disturbance • maintains normal streamflow • maintains fish passage • not likely to result in HADD	• tunnel spoil / slurry requires large areas • disposal of tunnel spoil • large space require-ments on flood plains	• can be utilized in most substrates above or below the water table • eliminates clean-up and reclamation in streambed and banks • may be able to construct during sensitive fisheries restricted activity windows	• special equipment and crew are required • limited by length of pipe to be pushed and the friction forces imposed • high cost • may require detailed engineering • tunnel spoil / slurry may require removal or settling tanks and water treatment if chemical lubricants were used	• large diameter pipelines • crossings with ample room for tunnel spoil storage and bellholes • high aesthetic concerns (*i.e.,* parks)
AERIAL i) Bridge Attachment					
• attach pipeline to existing bridge struc-ture	• no sediment release • no bank disturbance • no streambed disturbance • maintains normal streamflow • maintains fish passage • not likely to result in HADD	• possible visual impact • safety and potential introduction of product into watercourse due to third party damage • potential introduction of paint and cleaning products into watercourse during future maintenance	• reduces clean-up and reclamation of bed and banks	• potentially expensive • depends on bridge design • specialized crew and equipment • slow construction / installation • potential for third party damage • regulatory approval may be delayed or denied • ongoing maintenance required	• large watercourse with sensitive habitat where no instream activity is allowed • areas with very unstable approach slopes • high aesthetic concerns (*e.g.,* parks) • where an existing bridge has been built • deep gorges / canyons • urban areas where bridges are abundant

Table 3.1 Pipeline Watercourse Crossing Construction Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
AERIAL ii) Self-Supporting Clear Span Bridge					
• construct bridge or abutments to carry pipeline	• no sediment release • no streambed disturbance • no bank disturbance • maintains normal streamflow • maintains fish passage • not likely to result in HADD	• visual impact • safety and introduction of product into watercourse due to third party damage • instream construction required for bridge abutments • may trigger additional regulatory review • may require removal of potential danger trees within riparian zone to maintain integrity	• reduces clean-up and reclamation of streambed and banks	• very expensive • specialized crew and equipment • slow construction / installation • potential for third party damage • regulatory approval may be delayed or denied • ongoing maintenance required • requires design to meet *Navigable Waters Protection Act* requirements	• large watercourse with sensitive habitat where no instream activity is allowed • areas with very unstable approach slopes • deep gorges / canyons

Table 3.2 Temporary Vehicle Watercourse Crossing Techniques

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	**Disadvantages**	**Advantages**	**Disadvantages**	
EXISTING BRIDGE					
• utilize existing bridge off right-of-way for access across watercourse	• no instream disturbance • no bank disturbance • no approach slope disturbance • maintains regular streamflow • maintains fish passage	• terrestrial disturbance caused by access to and from right-of-way via shoo-flies	• limited const-ruction costs • weight limit probably not an issue	• inefficient to drive around • complications of shuttling equipment • may slow process of construction	• where trenchless crossing methods are used • where crossings are near bridges • on larger rivers where other methods are not feasible • where sediment release is of concern • where streamflow and fish passage must be maintained
TEMPORARY BRIDGE (see Dwg. 12)					
• construct temporary bridge with native timber or import portable bridge	• limited stream disturbance • limited sediment release • maintains streamflow • maintains fish passage	• possible bank and app-roach slope disturbance • sediment release if bank abutments are built to support bridge • cap over timber bridge may cause sediment release in watercourse • may interfere with navigable use of waterway • sediment mobilization from scour if instream abutments are used for multiple bridge spans	• strong • removable • reusable (portable) • can be located at optimal location	• may entail a substantial amount of work to trans-port or construct bridge • moderate costs • specialized equipment / crew • timber bridge may require cap • timber bridge span is limited • regular maintenance and repair of erosion and sediment controls required	• small to moderate size watercourses with stable banks • larger watercourses may be crossed with multiple bridge spans and instream abutments • bridge must be maintained

Table 3.2 Temporary Vehicle Watercourse Crossing Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
ICE BRIDGE (see Dwg. 13)					
• construct bridge over ice on watercourse • remove snow and flood to strengthen if warranted	• limited sediment release • maintains streamflow • maintains fish passage	• susceptible to winter thaw • grading of banks and approach may be necessary • potential safety hazard • possible depression of ice and blockage of flow and fish passage in shallow watercourse • contamination of watercourse may result during thaw	• can be easily constructed where needed	• slow to construct • limited to freezing conditions • potential for thawing • safety concerns • ice must be >0.5 m thick • contingency required for thawing conditions • logs may be required for reinforcement • moderately expensive • must be maintained free of soil	• moderate to large sized watercourses with low approach slopes and banks • location where ice is thick and solid • relatively low velocity and deep watercourses • where sediment release is of concern • where streamflow and fish passage must be maintained • winter projects
SWAMP MATS					
• cabled logs, timbers or prefabricated steel pipes or rails in the form of a mat or grid • tie enough mats together to form crossing	• minimizes sediment release • mat surface less likely to embed into substrate • clean removal • generally maintains streamflow • can be used to span very narrow watercourses • can be used to protect banks where bridge spans are secured	• possible grading of banks required • could restrict flow and fish passage if watercourse is too shallow • introduction of wood/bark into streambed	• easy to install • easy to construct • easy to remove • portable • low cost, local materials • not prone to freezing into substrate	• logs deteriorate and break up with extensive use • susceptible to washout • not as stable as some other crossings • has to be shallow crossing <0.3 m • safety concerns due to instability	• small to moderate size shallow watercourse where disruption of substrate is a concern and ease of removal is important • where fish passage, streamflow and sediment release are not a concern

Table 3.2 Temporary Vehicle Watercourse Crossing Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
LOG / PIPE FILL					
• cable logs or pipes together and fill in channel • cap of snow often used • cable is wrapped around logs or pipes to ease removal	• limited sediment release • pipes maintain flow and may maintain fish passage if installed correctly • clean removal on solid substrate	• can sink into substrate • if they freeze in place, are hard to remove and may impede flow during spring run off • difficult removal may increase effects on bed and banks • small logs may block flow and fish passage	• low cost, local materials • easy to install • easy to construct • easy to remove when not frozen	• will freeze in during winter • difficult to remove • cap may be necessary and difficult to remove • prone to deterioration and break-up	• small steep banked creeks • may be used like corduroy on shallower creeks • where fish passage and flow are not a concern
SNOW FILL					
• plow clean snow into creek channel and pack • logs may be used for reinforcement	• limited sediment release • minimizes bank disturbance	• introduction of soil into snowfill may lead to sediment release during spring break-up • some deterioration of banks may occur • may block flow and fish passage if no ice in watercourse	• low cost • easy to construct • easy to remove • use of local material • only have to be notched open rather than removed to facilitate flow during spring run off	• deteriorates with use • high maintenance • susceptible to thaw • logs may be needed for reinforcement • must be removed prior to spring break-up	• small watercourse in winter where fish passage and streamflow are not a concern • most appropriate for small intermittent drainages • winter project • not practical when snow depth is limited
RAMP AND CULVERT / FLUME (see Dwg. 14)					
• divert flow through culvert laid perpendi-cular to pipeline • use steel pipe not galvanized culvert for flume • build ramp over top	• limited sediment release • maintains stream flow and fish passage • bottomless arch culverts can be used where fish habitat/passage is a concern	• sediment release when filling around culvert and removing culvert • susceptible to washout • icing in winter may block flow and fish passage • may require bank grading	• when used in combination with flume const-ruction tech-nique, flume replaces culvert • forms one dam for dam and pump	• heavy traffic may crush culvert • susceptible to washout • may require specialized materials such as sandbags and select fill	• small to moderate sized watercourses with or without flow • where streamflow and fish passage are of concern • commonly used • watercourses with defined channel and banks

Table 3.2 Temporary Vehicle Watercourse Crossing Techniques, Cont'd

Description	Environmental Considerations		Construction / Engineering Considerations		Comments
	Advantages	Disadvantages	Advantages	Disadvantages	
FORD (see Dwg. 15)					
• drive equipment across streambed	• no instream construction • maintains streamflow and fish passage	• high potential for sediment release depending on substrate • rutting of streambed • requires grading of banks • possible sediment release during grading of banks	• fast • easy • can be located in many places • inexpensive	• watercourse depth is a limitation • vehicles may get stuck • streambed may not be level and may require gravelling or construction of a travel pad (see below)	• coarse-textured substrate • all sizes of shallow watercourses • where sediment release is not a concern • where fish passage needs to be maintained
TRAVEL PAD					
• construct rockfill ford below surface of watercourse • a modified ford crossing	• maintains streamflow and fish passage	• large amount of sediment release during construction and removal • each pass of a vehicle creates sediment release • requires bank grading • may be a barrier to fish if poorly designed • may act as a weir and flood upstream areas	• easy to build • can be placed in most locations • levels out uneven bottom	• potentially expensive • difficult to remove • requires 20 cm (minimum) of water flow to maintain fish passage • may require select material to be imported	• all sizes of shallow watercourses • where sediment release is not a primary concern • useful on wide shallow rivers where no bridges are available • used with cobble sized fill, preferably clean (no fines)
BARGE					
• construct or import barge to carry equipment across watercourse	• no instream construction • no sediment release • maintains streamflow and fish passage	• banks require grading or a loading ramp may be required • may require special restrictions and mitigation for fuel transport	• may be used in conjunction with crossing construction from barge	• may be difficult to obtain or build • slow if multiple shuttles are required • expensive • requires sufficient depth to float barge • specialized equipment • inaccessible in some regions	• large, deep water crossings, generally proximal to urban centres • large, deep water crossings where no alternative form of summer access is available, *e.g.,* northern Canadian rivers

Adapted from Mutrie and Scott 1984

4 Risk-based Watercourse Crossing Selection Process

The success of a pipeline associated watercourse crossing depends upon the selection of an appropriate crossing method to prevent or reduce the adverse environmental effects of crossing construction. The following subsections identify issues and risks that proponents may wish to consider, to assist them in the selection of appropriate water crossing techniques. Since this document is intended to be general in nature, the exact technique and protection measures implemented during a watercourse crossing may vary according to the specific requirements of the project and site-specific conditions at the water crossing.

When highly sensitive or high profile watercourse crossings are anticipated to be a component of a proposed project, it is important that government agencies' representatives and the public be contacted during the initial stages of route and crossing selection. Once established, ongoing feedback between the proponent and the agencies will clarify the concerns and facilitate approvals.

Planning a pipeline watercourse crossing project involves many steps, from route selection to post-construction monitoring. There are several points in the planning process where the details of the proposed project will require it to proceed along a specific regulatory course. Figure 4.1 outlines the key steps in planning watercourse crossing construction projects.

4.1 DFO Risk Management Framework

DFO has established a national Risk Management Framework (RMF) to provide consistency to the determination of potential effects of development projects, including pipeline associated watercourse crossings, on fish and fish habitat. This nationally standardized approach to managing risk allows DFO biologists, partner agencies and proponents to determine what fish habitat concerns are associated with a project, develop appropriate mitigation to address anticipated effects and assess the risk of residual negative effects to fish habitat.

The RMF consists of a Pathways of Effects (POE) model used to determine the potential effects on fish habitat resulting from a work, and a Risk Determination Matrix (Figure 4.2) that incorporates the scale of any residual negative effects and the sensitivity of the specific fish and fish habitat to make a determination of the appropriate regulatory approach. The POE model is a tool used to list the predicted effects on fish and fish habitat caused by specified land- and water-based construction activities. If the POE model identifies any residual negative effects caused by a proposed project that cannot be fully mitigated, then these effects are examined by DFO in the context of the Risk Determination Matrix.

4.1.1 Elements of a Risk Management Program

A risk management program, including the DFO RMF, is composed of three principal parts:

- **risk communication**: description of the elements of risk using common language
- **risk assessment**: determination of the nature and probability of the elements of risk
- **risk management actions**: measures taken to reduce risk to the lowest practical level

Comprehensively managing the environmental risk of a crossing project must include all of the above elements. It is important that the steps taken to communicate, assess and manage risk are well documented.

4.1.2 Process for Assessing Risk to Fish Habitat

The process for assessing the risk to fish habitat posed by a crossing project involves several proponent-directed steps and a final risk evaluation and decision by DFO biologists (Figure 4.3). The proponent must first determine whether the crossing is located in fish habitat that directly or indirectly supports a fishery or has the potential to support a fishery, and whether an operational statement (OS) applies to the proposed crossing method. These OSs specify the crossing method, habitat characteristics and mitigation and monitoring measures under which the project may proceed without further DFO review. If no OS is in force for the proposed crossing project, then the proponent determines the potential effects on fish habitat using the POE model and designs mitigation measures to break the identified pathways.

In the next step of the risk assessment, DFO biologists evaluate the certainty associated with the proposed mitigation measures and the direction (positive, neutral or negative) of any residual effects. If negative residual effects exist, then DFO will use the Risk Determination Matrix to determine the appropriate management approach, which could include an authorization to commit HADD under Section 35 of the *Fisheries Act*. Such authorization may or may not be granted, or may be subject to habitat compensation conditions, depending on where on the Risk Determination Matrix (Figure 4.2) the residual effects fall.

Certainty Associated with Mitigation Measures

In order to determine if the crossing project design, as proposed, is adequate to avoid any negative residual effects on fish and fish habitat, the certainty associated with the proposed mitigation measures will be evaluated by DFO biologists. There are two key factors that are considered when evaluating the level of certainty:

- **effectiveness of proposed mitigation**: many mitigation measures are standard industry practice and have been employed by proponents and contractors for many years and have been proven to be effective. Other innovative mitigation measures can be used in a risk-based approach, however, the uncertainty associated with their effectiveness must be assessed and contingency plans put in place in case of failure.
- **knowledge base of effects**: in some cases the effects of a project on fish and fish habitat are well understood and can be accurately predicted. In other cases, the effects are much less understood and mitigation and contingency planning must acknowledge this knowledge gap.

It is important to note that even a moderate level of uncertainty does not mean that the project cannot proceed. Rather, monitoring, contingency planning and thresholds past which work cannot continue must be considered and incorporated by the proponent into the project design and/or by DFO into the project authorization.

Scale of Negative Residual Effects on Fish and Fish Habitat

A negative effect on habitat may not necessarily be high risk. Some negative effects may be of such short duration, limited spatial extent or small magnitude that they are still considered to be low risk. Examination of the attributes of negative effects permits a qualitative determination of the scale of risk associated with them. These attributes include:

- **intensity**: the amount of change from the baseline conditions that is expected. This attribute is usually considered in the context of quantitative, measurable parameters (*e.g.,* temperature, flow, water quality measures)
- **spatial extent**: the geographic size of the anticipated effect, including zone of influence downstream
- **duration**: the expected duration of the effect, from some lasting only minutes to other effects causing permanent change
- **reversibility**: the likelihood that the effect will reverse as the system re-achieves equilibrium
- **timing**: the time of the year at which the effect takes place. For example, effects during critical spawning windows have a larger scale of negative effect
- **extreme events**: unlikely, but extreme, events may be associated with a negative effect. Such extreme events may be caused by severe weather, failure of mitigation or accidents and malfunctions. The probability and severity of potential extreme events must be considered

An evaluation of the combination of all of these attributes will determine the placement of a negative effect on the y-axis (scale of effect) of the DFO Risk Determination Matrix (Figure 4.2).

Sensitivity of Fish and Fish Habitat at Crossing Location

The second factor in the determination of the overall risk of a negative effect is the sensitivity of the fish and their habitat at the location of the proposed crossing project and within its zone of influence. This factor is of importance as the overall risk of a negative effect of moderate scale will be greater in a habitat or fish community of higher sensitivity. The categorization of the sensitivity of fish habitat includes the following attributes:

- **species**: the species of fish present at a crossing location and in the zone of influence will vary their sensitivity to disturbance
- **flow**: ephemeral systems that only contain water for a short duration after a rainfall event are less sensitive than perennial systems that always contain water
- **thermal regime**: cold water systems are more sensitive to perturbations than warm water systems
- **use of habitat**: spawning and rearing habitats are more sensitive than migratory corridors, although interruption of corridors may diminish the production of fish

An evaluation of the combination of all of these attributes will determine the placement of a crossing location and its zone of influence on the x-axis (habitat sensitivity) of the DFO Risk Determination Matrix (Figure 4.2). Several of the attributes should be rated high for a habitat to be considered to be highly sensitive.

Residual Effects and the Risk Matrix

The Risk Determination Matrix (Figure 4.2) allows proponents and DFO biologists to qualitatively determine what level of DFO management involvement should be applied to a proposed project. The scale of the effect and the sensitivity of the affected habitat, as described above, define where a negative effect falls on the matrix. This approach also guides a proponent's communication with DFO in determining whether an authorization, notification or no contact is required for a particular crossing project.

The levels of management intervention by DFO, in increasing order, are:

- **no risk crossing**: no *Fisheries Act* requirements nor contact with DFO
- **low risk crossing**: follow available OSs and best management practices, submit notification to DFO
- **medium risk crossing**: streamlined authorization process, regulations and class authorizations, letter of advice may be issued

- **high risk crossing**: site specific DFO review and *Fisheries Act* authorization required, habitat compensation if residual negative effects
- **significant negative effects**: activity not permitted without intensive DFO consultation and habitat compensation measures, project approval questionable

Role of Operational Statements in Project Review

DFO biologists spend a great deal of time reviewing project proposals for which there is low or no risk to fish and fish habitat. In order to increase regulatory efficiency, DFO has started to produce OSs for low and no risk works that allow, under specific conditions, proponents to proceed with projects without DFO advice or approval. These OSs specify the crossing method, habitat characteristics and mitigation and monitoring measures under which the project may proceed without DFO review. The most current OSs available in the region where the project is to be constructed should be consulted to determine DFO management intervention.

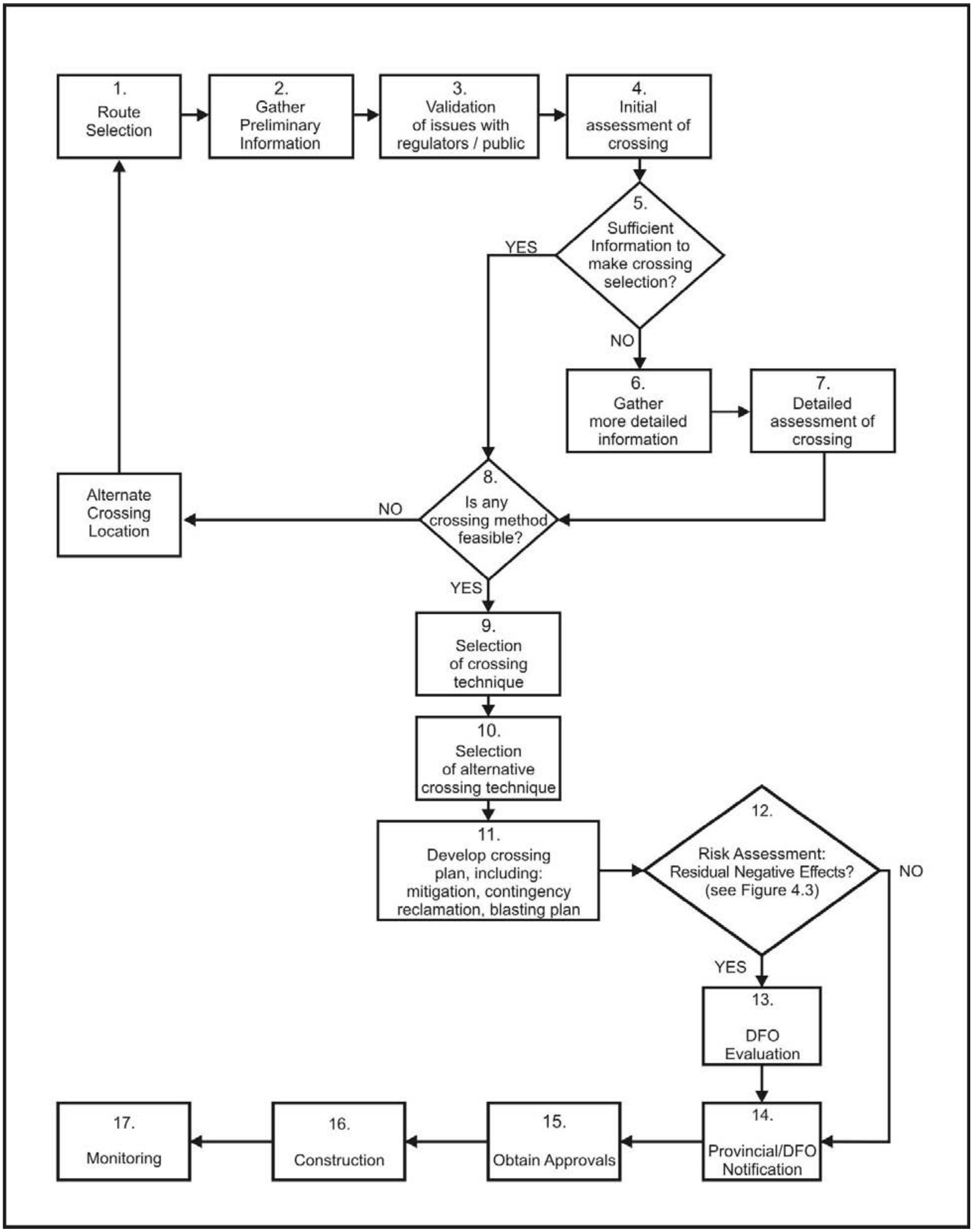

Figure 4.1 Planning Summary for Watercourse Crossings

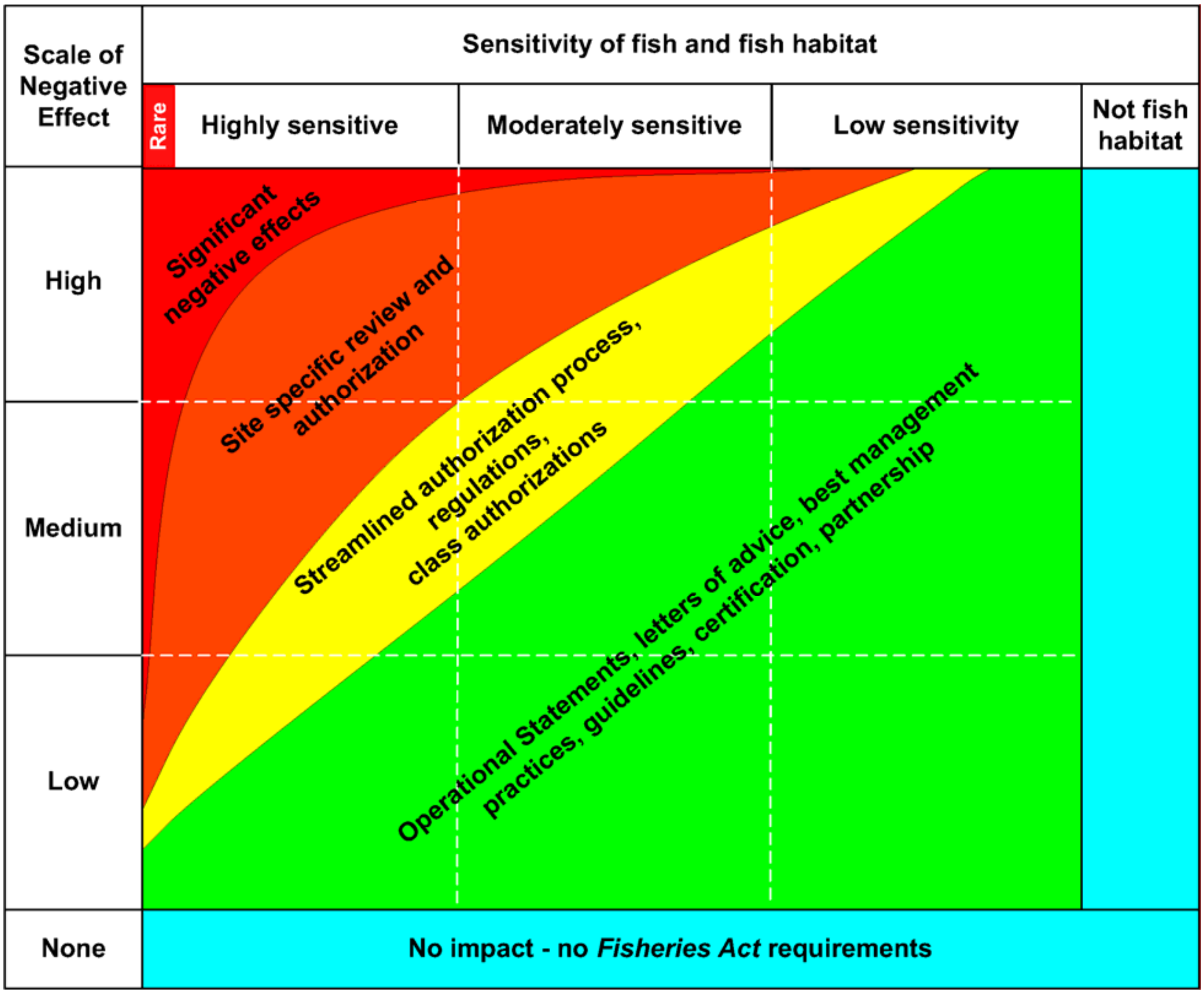

Figure 4.2 DFO Risk Determination Matrix

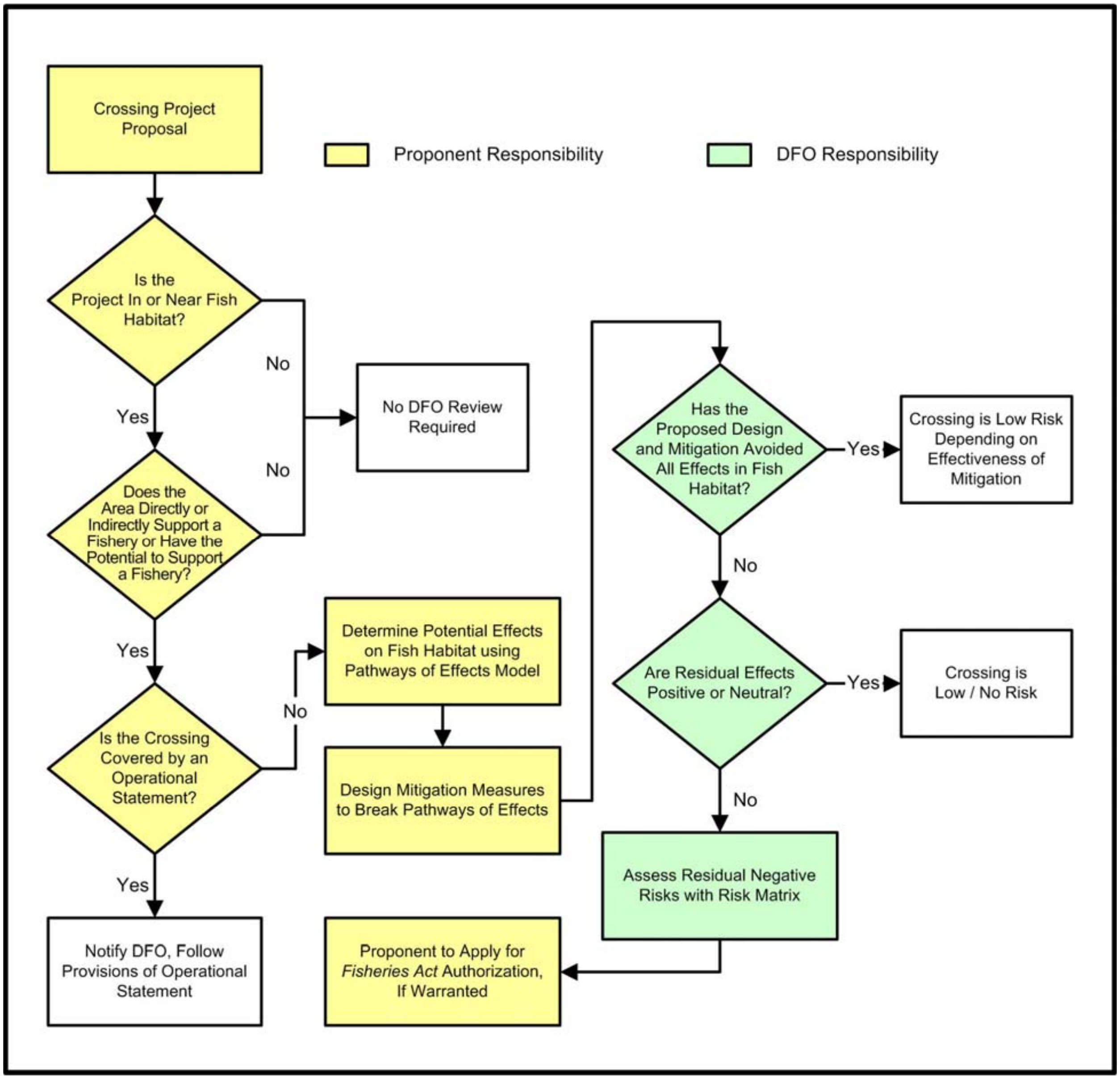

Figure 4.3 Process for Assessing Risk to Fish Habitat

4.2 Crossing Assessment

A site-specific environmental evaluation may be required where there are insufficient available data to adequately assess the risks associated with a crossing. **Table 4.1** summarizes the general environmental considerations to be evaluated during an assessment.

4.2.1 Aquatic Assessment

The primary objective of the aquatic assessment is to identify the level of sensitivity of the watercourse and aquatic resources, and to gather information for routing and crossing method selection, and development of mitigation measures.

In most cases, routine pipeline crossings of watercourses with known sensitivity do not require aquatic assessments since standardized mitigation as outlined in Section 5.0 designed to protect the aquatic resources is implemented during construction. In other situations, where little information is known relative to the sensitivity, further investigations are required.

The level of detail for these investigations will vary according to the watercourse and the construction techniques considered. Where crossing construction will not generally result in HADD of fish habitat (*i.e.*, reaches with limited habitat potential), field data collection should be limited to basic fish habitat information including: type of fish habitat (warmwater or coldwater), common fish species; and a general description of any fish habitat at the proposed crossing and within the zone of influence.

Where little information is available on a specific watercourse, yet regional information and initial routing investigations indicate that the watercourse may support sensitive or critical habitat, a more detailed aquatic assessment may be warranted. **Table 4.2** presents a comprehensive list of parameters that could be evaluated. Generally, most watercourse assessments would include some, but not all those listed. Nevertheless, the greater the detail the more likely that the regulatory authorities will review and approve the crossing without delays caused by further field visits or additional meetings. Prior to conducting any assessments, proponents should discuss the level of detail required with regulatory agencies, at which time they may suggest the type of information and assessment requirements.

Table 4.1 Environmental and Engineering Considerations for Pipeline Crossing Selection

Considerations	Details
Geotechnical / Hydraulic	- depth of bedrock - stability of bedrock - contaminated substrates - slope stability - bank stability - bank height - watercourse discharge, velocities and roughness - channel depths/widths/slope/cross section - flood and low flow prediction/discharges - bank and substrate composition and stability - abandoned channels/flood plains - areas of scour, erosion and deposition - reach morphology - sediment transport potential - flow variation - water quality changes/depth of groundwater - future channel migrations - ice conditions
Soils	- general soil composition - chemical contamination - reclamation suitability
Vegetation	- rare and endangered species - existing disturbance at crossing
Fish and Wildlife	- fish species present - rare and endangered species - existing aquatic and terrestrial habitat - sensitive periods and timing constraints - spawning areas - nursery/rearing areas - fish overwintering areas - fish migration - wildlife overwintering areas - sensitivity of watercourse - existing barriers to fish migration - existing disturbance at crossing
Land Uses	- existing rights-of-way - aesthetics - navigation - recreational, domestic and commercial fishery - First Nations' traditional land use - historical, palaeontological and archaeological resources
Downstream Water Users	- licensed water use - domestic and municipal water supply - irrigation/drainage - water quality changes (appearance, odour, taste, chemical contamination)
Cumulative Effects	- barriers to fish migration - number of adjacent watercourse crossings - number of watercourse crossings and barriers in watershed - total existing riparian clearing in watershed - total existing road network in watershed - public right-of-way use - need for access management - operation and maintenance requirements

Table 4.2 Detailed Aquatic Assessment Evaluation Parameters

General Characteristics
Name of Watercourse
Kilometre Post
Legal Land Location
Topographic Map No.
UTM Coordinates
Watercourse Length Inspected Upstream (m)
Watercourse Length Inspected Downstream (m)
General Terrain Setting
Floodplain Material
Watercourse Navigability
Photographs of Banks and Channel
General Watercourse Characteristics
Mean Wetted Channel Width (m)
Mean Bank Full Width (m)
Depth of Pool / Run / Riffle (m)
General Streambed Characteristics
Parent Streambed Material
Bank and Channel Widths
Bank Material Characterization
Organics (%)
Clay (%)
Silt (%)
Sand (%) (<0.2 cm)
Gravel (%) (0.2 - 8 cm)
Cobble (%) (8 - 25 cm)
Boulder (%) (>25 cm)
Bedrock (%)
Channel Characteristics
Location of Thalweg
Stream Confinement
Channel Cross Section
Side Channel (%)
Streambed Gradient (%)
Turbulence
Natural Drop Offs
Evidence of Bedrock Outcrops

Land Use / Access
Land Use
Access
Recommended Work Side
Waterflow
General Flow Characteristics
Velocity (m/s)
Discharge (m^3/s)
Stage
Bank Characterization
Bank Stability
Bank Height (m)
Bank Slope (%)
Approach Slope (%)
% of Bank with Riparian Vegetation
% of Bank With Overhanging Vegetation
% of Bank With Undercut
Dominant Riparian Plant Species
Substrate Characterization
Bedrock (%)
Boulder (%) (>25 cm)
Cobble (%) (8 - 25 cm)
Gravel (%) (0.2 - 8 cm)
Sand (%) (<0.2 cm)
Silt (%)
Clay (%)
Detritus Present
Water Quality
Temperature (°C)
pH
Conductivity (μs/cm)
Dissolved Oxygen (mg/L)
Total Suspended Solid (NTU)
Turbidity

Table 4.3 Detailed Aquatic Assessment Evaluation Parameters Cont'd

Habitat Features
Fish Habitat Potential and Habitat Features
Aquatic Macrophytes
Algae
Natural Barriers to Fish Movement
Artificial Barriers to Fish Movement
Fish Captured
Species
Number
Fork Length
Life Phase
Erosion
Bank Erosion Potential
Evidence of Slumping on Banks
Evidence of Slumping on Approach Slopes
Evidence of Gullying
Other Erosion Features
Scour Potential
Bed Erosional Potential
Relative Sediment Transport Potential
Relative Suspended Solids Load
Groundwater Seepage

Fish Sampling Results Summary
Fish Collection Card
Fish Reported in the Watercourse
Electrofishing(s)
Gill Netting (panel length x time)
Seining (net length x hauls)
Minnow Trap (number of traps x time)
Available Overhead Cover %
Percentage of Total Overhead Cover
Large Organic Debris
Undercut Bank
Overhanging Trees
Overhanging Shrubs
Overhanging Grass
Available Instream Cover %
Percentage of Total Instream Cover
Pool
Large Organic Debris
Boulder
Instream Vegetation
Turbidity

Sources: Adapted from RIC (1999) and Alberta Transportation (2001).

Note: These parameters should be considered as a very comprehensive list and not those that should be used in all assessments. Aquatic assessments should be tailored to the size and sensitivity of the watercourse. This list should be used as a guideline from which to select those parameters that are appropriate for the size and sensitivity of the watercourse.

4.2.2 Geotechnical and Hydraulic Assessment

The objective of a geotechnical and hydraulic assessment is to identify long- and short-term processes that could affect habitat and water quality as well as the presence of potential hazards that may threaten the integrity of a pipeline and, to a lesser extent, vehicle crossing. In addition, a detailed geotechnical evaluation of subsurface conditions may be required for trenchless techniques (*e.g.,* horizontal directional drill).

Depending on the local conditions, the geotechnical and hydraulic assessment should include:

- river hydrology;
- geology of the approach slopes, bed and banks;
- drainage control on the approach slopes;
- slope stability; and
- bed scour.

In some cases it may be advisable to also consider surficial and fluvial materials.

River hydrology should be evaluated to identify the discharges that could be encountered during the period of construction and the potential discharges that could be encountered during a flood. Other streamflow information indicating which periods would not be suitable for construction should also be included.

The geology and surficial geology of the approach slopes, bed and banks of the watercourse should be identified and evaluated. Information on the type of substrate material aids in the determining of construction techniques, requirements for blasting and the potential for the introduction of sediment into the watercourse. The bank and approach slope geology analysis is used in establishing the stability of the slopes and in evaluating the likelihood of major channel migrations.

A geotechnical engineer should design detailed drainage and sediment control for approach slopes. Examination of the approach slopes and textural classes of soils in the valley aids in the positioning of subdrains, trench breakers, silt fences, netting, cross ditches and diversion berms.

Before planning trenchless techniques, surficial and fluvial materials within the drill or bore path should be evaluated to determine whether they are appropriate for this method. Common techniques include ground penetrating radar (GPR) and drilling of bore holes.

4.2.3 Cumulative Effects

Watercourse crossings often contribute to cumulative effects on fish and fish habitat, wildlife and wildlife habitat and land and resource use. Planners and engineers should be aware of the issues, timing restrictions, mitigation measures, and possible regulatory requirements for assessing and managing cumulative effects.

Cumulative effects evaluations consider the combined effects now known to take place over larger study areas and longer time frames. Cumulative effects must be specifically considered for all individual watercourse crossings where HADD authorizations are required and for all NEB-regulated projects (see Section 2.1.4 of this report). Unlike aquatic assessments that focus on sensitivity and risk during the construction period, the primary objective of cumulative effects analysis is to identify and mitigate long-term effects on fish and wildlife mortality, movements, and maintenance of habitat availability and quality. This recognizes that watercourse crossings and rights-of-way have an 'indirect footprint' that extends well beyond the physical footprint until native vegetation on and immediately adjacent to the right-of-way returns to pre-disturbance conditions. This generally requires decades to achieve.

In recent watercourse crossing applications, some projects have been required to assess the wildlife and vegetation resources of valleys associated with the watercourse. In particular, some jurisdictions pay special attention to overwintering ungulates (*i.e.,* moose, deer, elk), species with special conservation status (*e.g., Species At Risk Act* or the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed species, provincially listed species or migratory birds) or special status vascular plants (*e.g., Species At Risk Act* or COSEWIC listed species or provincially listed species).

Cumulative effect assessment is an evolving practice and no standard accepted method exists for watercourse crossings. The level of effort should be appropriate to the number of crossings being considered, other existing watershed disturbances, and the combined long-term risk to fish and fish habitat. One of the key deficiencies of current approaches is that they typically overlook the long-term cumulative effects risk from: increased harvest; movement barriers (*e.g.,* culverts); and non-point sediment, nutrient, and contaminant input.

A detailed discussion of analysis tools is beyond the scope of this document, however proponents and technical specialists should choose the most appropriate approach from the suite of tools described in **Table 4.4**. Additional information is provided in the *Filing Manual* (NEB 2004) and Hegmann *et al.* (1999).

Table 4.4 Cumulative Effects Analysis Tools for Watercourse Crossings

Approach	Description	Advantages	Disadvantages
Qualitative	• Descriptive evaluation of potential cumulative effects associated with aquatic and terrestrial POE. Should consider construction and operations phases and entire watershed(s).	• Lowest cost and time requirements. • POE can be explicitly discussed.	• Analysis generally not systematic and transparent, increasing long-term risk to fish and fish habitat. • Effects of increased access and mortality (the proximate cause of most cumulative effects) generally not considered.
Species or Habitat Models	• Habitat-based models used to evaluate potential project-specific and cumulative effects on species or habitats of ecological, social, or economic importance (*e.g.,* evaluate loss of brook trout spawning, rearing, and overwintering habitat).	• Based on accepted impact assessment methods that consider habitat loss, the ultimate cause of cumulative effects. • Able to quantify species- and site-specific habitat loss or alteration requiring mitigation or compensation. • DFO guidance documents exist (*e.g.,* Ford *et al.* 1995; Minns 1995, 1997; Minns *et al.* 1995, 1996; Portt *et al.* 1999).	• High cost and time requirements. • Independent analyses of different species or habitats makes direct comparison of trade-offs difficult. • Generally underestimates long-term cumulative effects risk because all POE can not be explicitly considered (*e.g.,* habitat-based approaches generally overlook mortality risk, barriers, and chronic non-point effects; Warren and Pardew 1998; Angermeier *et al.* 2004).
Watershed Evaluations	• Calculate numerical measures of watershed or landscape conditions to evaluate incremental and cumulative effects risk (*e.g.,* determine stream crossing density or area of roads within riparian corridors; IWAP 1999).	• Medium cost and time requirements. • Provides quick test to determine if project modifications or more detailed assessment are necessary. • Best able to document project contribution to long-term cumulative effects risk.	• Does not quantify species-specific habitat loss or alteration. • Value of mitigation strategies may not be quantifiable because underlying mechanisms can differ.
Integrated Evaluations	• Combine habitat-based models with watershed evaluations to consider how local effects contribute to long-term watershed effects.	• Combined benefits of both approaches.	• Highest cost and time requirements; generally only done for very large or contentious projects or for watershed restoration. • Complex.

4.3 Environmental Selection Considerations

Selection and approval of watercourse crossings by the proponent and regulators, respectively, requires a thorough knowledge of the advantages and disadvantages of various crossing methods and techniques. Unfortunately, except for a few senior field personnel, most engineers, planners and regulatory staff do not attain sufficient experience to understand the various techniques to be able to sufficiently evaluate the risks of each. Tables 3.1 and 3.2 summarize the engineering and environmental advantages and disadvantages of the various techniques discussed in this document.

TERA Environmental Consultants (1996) and P.A. Harder and Associates Ltd. (1995) summarized a total of 326 pipeline associated watercourse crossing case histories as background documents to this document (Appendix B). These studies, although largely anecdotal, do portray a good cross section of both successful and poorly constructed crossings.

In summary, unsuccessful watercourse crossing projects had the following problems:

- poor planning;
- no contingency planning;
- selection of an inappropriate construction technique for the conditions experienced during construction;
- inexperienced construction crews and inspectors;
- overestimation by the contractor of his ability;
- underestimation of the energy of a watercourse;
- insufficient quantity and size of equipment onsite;
- inadequate knowledge of the flows and subsurface conditions; and
- unforeseen/unanticipated circumstances.

Risk associated with the environmental aspects of a project can generally be divided into three types: regulatory risk; construction risk; and post-construction risk.

4.3.1 Regulatory Risk

Risks associated with not fulfilling the regulatory requirements during a crossing may be twofold. Firstly, the project may be delayed or rejected if no or insufficient information is submitted. In the event that an application is approved, insufficient information may cause the regulatory agency to invoke restrictive conditions to ensure protection of the resources. Secondly, if a project proceeds without the appropriate approvals, shut downs, charges and potentially convictions may result.

In a regulatory climate in which more emphasis is being placed on codes of practice, OSs and other increasingly independent regulatory tools, industry can expect that any violation of the regulatory requirements may result in more rigid interpretation of the legislation. Therefore, it is imperative that all permits and approvals are obtained and associated approval/permit/code of practice conditions are implemented to ensure compliance.

4.3.2 Construction Risk

Each technique has its own risks, some for which it is very difficult to plan and others for which there is little that can be done once a problem has arisen. Selecting and approving crossing techniques must be done with a full knowledge of the risks and proponents and regulators should recognize the adverse effects that can occur. The risks associated with each technique will vary according to many factors. This includes but is not limited to: project scope; contractor's ability, experience and commitment; pipe size; and season of construction.

Table 4.5 summarizes some of the more common problems associated with various techniques and identifies the environmental risks associated with each. In addition, it gives an indication of the scale of the identified risks as well as general mitigation measures and contingency plans that should be considered in advance of construction during the planning phase.

4.3.3 Post-Construction Risk

Proponents evaluate the short-term risks associated with various crossing techniques, but may not consider some of the longer-term, life-cycle factors. The following considerations should also factor into the planning and crossing design:

- long-term stability of slopes, streambanks and approach slopes;
- erosion and sedimentation;
- maintenance;
- pipeline integrity;
- monitoring;
- ongoing use of the right-of-way by off highway terrain vehicles; and
- other land uses.

In many situations, the long-term implications of operating a pipeline in a particular location may strongly affect the decisions regarding crossing technique, construction methods and reclamation.

Table 4.5 Risk Considerations for Watercourse Crossing Methods

Selected Potential Problems[1]	Environmental Risk(s)	Scale of Risk[2]	Mitigation and/or Contingency Plan(s)
OPEN TRENCHED: Plow, Bucket Wheel Trencher			
Unexpected extended periods in watercourse	Prolonged sediment load and deposition	Medium	Work through the night, ensure approvals are in place for extended periods, utilize larger and more equipment
Erosion of instream spoil storage	Prolonged sediment load and deposition	Medium	Ferry as much spoil to shore as practical
Equipment too small and prolonged instream activity	Prolonged sediment load and deposition	Medium	Bring in larger and more equipment
Fine textured substrate	Increased suspended solids introduced into water column during trench, backfilling and from spoil storage area	High	Prepare a sediment control plan in advance
Loss of ditch as a result of unstable bed materials	Prolonged sediment load and deposition	High	Work through the night, ensure approvals are in place for extended periods, obtain larger and more equipment
OPEN TRENCHED: Hoe			
Unexpected extended periods in watercourse	Prolonged sediment load and deposition	Medium	Work through the night, ensure approvals are in place for extended periods, utilize larger and more equipment
Erosion of instream spoil storage	Prolonged sediment load and deposition	Medium	Ferry as much spoil to shore as practical
Equipment too small and prolonged instream activity	Prolonged sediment load and deposition	Medium	Bring in larger and more equipment
Fine textured substrate	Increased suspended solids introduced into water column during trench, backfilling and from spoil storage area	High	Prepare a sediment control plan in advance
Loss of ditch as a result of unstable bed materials	Prolonged sediment load and deposition	High	Work through the night, ensure approvals are in place for extended periods, obtain larger and more equipment
OPEN TRENCHED: Dragline			
Equipment failures	Prolonged sediment load and deposition	Medium	Ensure sufficient back-up equipment is available
Unexpected extended periods in watercourse	Prolonged sediment load and deposition	Medium	Work through the night, ensure approvals are in place for extended periods, utilize larger and more equipment
Fine textured substrate	Increased suspended solids introduced into water column during trench, backfilling and from spoil storage area	High	Prepare a sediment control plan in advance, ensure approvals are in place for alternate crossing (*i.e.,* isolated)
Loss of ditch as a result of unstable bed material	Prolonged sediment load and deposition	High	Work through the night, ensure approvals are in place for extended periods, utilize larger and more equipment
OPEN TRENCHED: Dredging			
Unexpected extended periods in watercourse	Prolonged sediment load and deposition	Medium	Work through the night, ensure approvals are in place for extended periods, utilize larger and more equipment
Loss of ditch as a result of unstable bed materials	Prolonged sediment load and deposition	High	Work through the night, ensure approvals are in place for extended periods, utilize larger and more equipment

Table 4.5 Risk Considerations for Watercourse Crossing Methods, Cont'd

Selected Potential Problems[1]	Environmental Risk(s)	Scale of Risk[2]	Mitigation and/or Contingency Plan(s)
ISOLATED: Flume			
Leaking dam or flange	Increased water pumping and disposal concerns, flooding of work area and washout of dam	High	Ensure there are sufficient materials on hand to keep dams and flanges sealed
Flume may be of insufficient diameter	Uncontrolled flow through isolated area	High	Ensure that flume is sized to at least 150% of maximum anticipated flows and pumps are on standby to assist in a partial bypass
Flume is too long, straight or large for reach or watercourse	Undue disturbance to riparian habitat, banks and bed	High	Consider switching to an alternative technique Ensure flume is properly sized
Ditch water disposal problem	Water pumped onto land flows back to the watercourse	Medium	Have additional stand by pumps on hand and identify suitable settling ponds/sumps
Icing of flume pipe in winter	Work area flooding	High	Have additional stand by pumps on hand and identify suitable settling ponds/sumps
Flume may be of insufficient length and/or ditch excavation becomes too wide and threatens flume installation	Increased suspended solids introduced into water column in the event of a flume collapse	High	Have additional standby pumps at hand to assist in a partial bypass Consider switching to alternative technique or properly sized flume
Approaches too steep to thread bends in pipe under flume	Excessive grading, reclamation and bank restoration	Medium	Replace flume with high volume pumps or dam and pump to allow easier lowering in of pipe
Groundwater seepage into work area	Increased water pumping and disposal concerns	Medium	Have additional stand by pumps at hand and identify suitable settling areas
ISOLATED: Dam & Pump			
Dam poorly sealed	Increased water pumping and disposal concerns, potential washout of dam and flooded work area	High	Ensure there are sufficient materials at hand to keep dams sealed
Insufficient pump capacity (by design or icing of pump hose)	Work area flooding and increased water pumping and disposal concerns	Medium	Have additional stand by pumps and hoses at hand and identify suitable settling areas
Pump malfunctions	Work area flooding and increased water pumping and disposal concerns	Medium	Have additional stand by pumps and hoses at hand
Dam topped or washed out	Increased suspended solids introduced into water column in the event of a collapse	High	Have additional stand by pumps and hoses at hand and identify suitable settling areas
Ditch water disposal problems	Water pumped onto land flows back to the watercourse	Medium	Have additional standby pumps and hoses on hand and identify suitable settling ponds/sumps
Groundwater seepage into work area	Increased water pumping and disposal concerns	Medium	Have additional stand by pumps and hoses at hand and identify suitable settling areas
ISOLATED: High Volume Pump (Sump and Pump)			
Pump malfunctions	Work area flooding and increased water pumping and disposal concerns	Medium	Have additional stand by pumps and hoses at hand
Insufficient pump capacity (by design or icing of pump hose)	Work area flooding and increased water pumping and disposal concerns	Medium	Have additional stand by pumps and hoses at hand and identify suitable settling areas

Table 4.5 Risk Considerations for Watercourse Crossing Methods, Cont'd

Selected Potential Problems[1]	Environmental Risk(s)	Scale of Risk[2]	Mitigation and/or Contingency Plan(s)
Ditch water disposal problems	Increased water pumping and disposal concerns	Medium	Have additional stand by pumps and hoses at hand and identify suitable settling areas
Groundwater seepage into work area	Increased water pumping and disposal concerns	Medium	Have additional stand by pumps and hoses at hand and identify suitable settling areas
ISOLATED: Coffer Dam			
Ditch water disposal problems	Water pumped onto land flows back to the watercourse	Medium	Have additional stand by pumps and hoses at hand and identify suitable settling areas
Groundwater seepage into work area	Increased water pumping and disposal concerns	Medium	Have additional stand by pumps and hoses at hand and identify suitable settling areas
Insufficient pump capacity (by design or icing of pump hose)	Work area flooding and increased water pumping and disposal concerns	Medium	Have additional stand by pumps and hoses at hand and identify suitable settling areas
Pump malfunctions	Work area flooding and increased water pumping and disposal concerns	Medium	Have additional stand by pumps and hoses at hand
Dam poorly sealed	Increased water pumping and disposal concerns, potential washout of dam and flooded work area	High	Ensure there are sufficient materials at hand to keep dams sealed
Dam failure	Work area flooding, increased suspended solids introduced into water column and safety	High	Have additional dam building materials at hand (*i.e.,* median barriers and water-filled dams)
ISOLATED: Channel Diversion			
Erosion and flushing of large quantities of material in "new" channel - especially if not lined	Flooding and increased suspended solids introduced into water column	High	Line channel or use a water diversion tube/ structure
Dam poorly sealed	Increased water pumping and disposal concerns, potential washout of dam and flooded work area	High	Ensure there are sufficient materials at hand to keep dams sealed
Dam failure	Work area flooding, increased suspended solids introduced into water column and safety	High	Have additional dam building materials at hand (*i.e.,* median barriers and water-filled dams)
TRENCHLESS: Bore			
Caving-in of bellhole	Failure of bore leads to subsequent attempts and possible additional land requirements	Low	Ensure sufficient land is obtained to attempt subsequent attempts and a protection plan is in place to minimize land disturbance
Bellholes fill with water	Inability to de-water bell-holes leading to abandonment of technique	Medium	Ensure measures are in place to handle de-watering and approvals in place for alternative techniques
Boulders prevent punching or ramming tool from progressing	Failure leads to subsequent attempts and possible additional land requirements	Medium	Ensure sufficient land is obtained to attempt subsequent attempts and ensure approvals are in place for alternative techniques
TRENCHLESS: Punch/Ram			
Boulders prevent punching or ramming tool from progressing	Failure leads to subsequent attempts and possible additional land requirements	Medium	Ensure sufficient land is obtained to attempt subsequent attempts and ensure approvals are in place for alternative techniques

Table 4.5 Risk Considerations for Watercourse Crossing Methods, Cont'd

Selected Potential Problems[1]	Environmental Risk(s)	Scale of Risk[2]	Mitigation and/or Contingency Plan(s)
Bellholes fill with water	Inability to dewater bell-holes leading to abandonment of technique	Medium	Ensure measures are in place to handle de-watering and ensure approvals are in place for alternative techniques
TRENCHLESS: Micro-tunneling			
Caving-in of bellhole	Failure of bore leads to subsequent attempts and possible additional land requirements	Low	Ensure sufficient land is obtained to attempt subsequent attempts and a protection plan is in place to minimize land disturbance
Bellholes fill with water	Inability to de-water bell-holes leading to abandonment of technique	Medium	Ensure measures are in place to handle de-watering and approvals in place for alternative techniques
Boulders prevent punching or ramming tool from progressing	Failure leads to subsequent attempts and possible additional land requirements	Medium	Ensure sufficient land is obtained to attempt subsequent attempts and ensure approvals are in place for alternative techniques
TRENCHLESS: Horizontal Directional Drill			
Collapsed hole, stuck drill stem, lost tools	Failure leads to subsequent attempts and possible additional land requirements	Low	Ensure sufficient land is obtained to attempt subsequent attempts and ensure approvals are in place for alternative techniques
Loss of circulation	Failure leads to excavation to find cause of lost circulation and possible additional land requirements	Low	Ensure sufficient land is obtained for excavation and ensure approvals are in place for alternative techniques Activate contingency plan if frac-out is occurring or suspected
Drill mud seepage directly into watercourse	Prolonged sediment load and deposition	High	Ensure a drilling mud contingency plan is in place
Drill mud seepage onto land and then into watercourse	Prolonged sediment load and deposition	Medium	Ensure a drilling mud contingency plan is in place
Washout of cavities and collapse of right-of-way	Sink holes on right-of-way	Low	Ensure sufficient equipment is on site to strip topsoil, grade sink hole and reclaim area
	Sink holes under watercourse	Medium	Ensure a drilling mud contingency plan is in place
AERIAL: Bridge Attachment			
Target for vandalism	Release of product	Low	Ensure company has an emergency response plan tailored to address the issue
AERIAL: Self Supporting Bridge			
Target for vandalism	Release of product	Low	Ensure company has an emergency response plan tailored to address the issue

Notes: 1 Sources: Harder (1995), TERA (1996), authors' experience
2 Scale of risk incorporates probability of occurrence and severity of effect.

4.4 Economic Selection Considerations

In selecting a watercourse crossing technique, proponents and regulatory agencies must evaluate the economic considerations at each particular site. Ideally, the cost of protective measures should be related to the social or environmental "value" of the resource potentially at risk. For this reason, the economic costs associated with various construction techniques must be balanced against the potential adverse environmental effects.

4.4.1 Direct Costs

The direct costs of various crossing techniques are difficult to predict for the following reasons:

- depth of cover, pipe diameter and substrate composition will strongly influence the costs;
- most small crossings are constructed by mainline crews and are built into the line cost for construction of the entire pipeline;
- more difficult crossings bid at a fixed price will have a contingency factor built into the price to allow for subsequent attempts or contingencies;
- all crossings and site conditions are different and the actual costs may vary significantly;
- many contractors are reluctant to give actual prices since the industry is competitive based on bid prices; and
- maintenance costs of fish habitat mitigation /compensation.

Nevertheless, **Table 4.6** outlines the relative cost that can be expected based on various techniques and watercourse sizes.

4.4.2 Indirect Costs

In evaluating the economics of a crossing, possible reductions in indirect costs are often overlooked. For instance, directionally drilling a watercourse may lead to considerable savings since no bank reclamation or ongoing maintenance will be necessary in that location and mitigation requirements for other resources (*e.g.,* wildlife habitat) may be reduced or avoided. Conversely, horizontal directional drilling may be disproportionately expensive if contractors are unavailable, extensive geotechnical evaluation is needed prior to construction or large volumes of drilling fluids require disposal. **Table 4.7** identifies relative costs associated with various activities and requirements of each watercourse crossing method.

Table 4.6 Relative Costs[1,2] of Watercourse Crossing Techniques

Technique	Small Watercourses <10 m Wide	Medium Watercourses 10-20 m Wide	Large Watercourses >20 m Wide
OPEN TRENCHED			
i) Plow	low	n/a[3]	n/a
ii) Bucket / Wheel Trencher	low	n/a	n/a
iii) Hoe	low	low	low to high
iv) Dragline	n/a	high	high
v) Dredging	n/a	high	high
ISOLATED			
i) Flume	low to moderate	moderate	n/a
ii) Dam and Pump	low to moderate	moderate	n/a
iii) High Volume Pump Bypass	low to moderate	moderate	n/a
iv) Coffer Dam	n/a	high	high
v) Channel Diversion	n/a	high	high
TRENCHLESS			
i) Boring	low to moderate	moderate	moderate
ii) Punching / Ramming	low to moderate	moderate	high
iii) Horizontal Directional Drilling	low to high	low to high	low to high
iv) Micro-tunnelling	n/a	very high	very high
AERIAL			
i) Bridge Attachment[4]	low to moderate	low to high	low to high
ii) Self-Supporting Bridge or Span	moderate to high	high	high

Notes:

There are many watercourse characteristics such as width, depth, channel shape, flow volume and substrate composition that affect the cost of each crossing. Most crossings have to be evaluated on a case by case basis. The above relative costs are based on the following assumptions:

- No bedrock is encountered during construction (*i.e.,* drilling and blasting costs are not considered).
- Single pipe, small diameter crossings (4" to 12").
- Larger, more complex crossings should be assessed on a site-specific basis.
- All isolation techniques assume trench excavation by backhoe.

1. This table identifies relative costs of construction methods compared to the lowest cost, technically feasible technique that would be selected if no consideration was made of environmental risk.

2. The provision of relative costs in the table does not imply that the crossing method is generally environmentally suitable - see Table 4.7.

3. n/a = not applicable / practical

4. The bridge used to attach the pipeline to in the 'Bridge Attachment' option must be along the pipeline route or additional costs will be incurred to reach the bridge.

Table 4.7 Economic Considerations of Watercourse Crossing Methods

Activities and Requirements of Watercourse Crossings	Type of Technique															
	Open Trenched					Isolated					Trenchless				Aerial	
	Plow	Trencher	Hoe	Dragline	Dredging	Flume	Dam and Pump	High Volume Pump	Coffer dam	Channel Diversion	Bore	Punch / Ram	Horizontal Directional Drill	Micro-tunnelling	Bridge Attachment	Self-Supporting Clear Span Bridge
Design and geotechnical investigation	L	L	M	M	M	M	M	M	H	H	M	M	H	M	H	H
Availability of experienced contractors and the ability to obtain competitive bids	M	L	M	H	H	M	M	M	H	H	M	H	H	H	H	H
Special permits and approvals	M	M	M	M	M	M	M	M	M	H	L	L	L	L	H	H
Extra temporary workspace	L	L	M	H	H	M	M	M	H	H	M	M	H	M	L	H
Land surveying	L	L	M	M	M	M	M	M	M	H	M	M	H	M	L	H
Clearing	L	L	M	H	H	M	M	M	M	H	M	M	M	M	L	L
Grading	M	M	M	M	M	L	M	M	L	H	L	L	L	M	L	L
Trenching / drilling	L	L	M	H	H	H	M	M	H	H	M	M	H	H	X	X
Special materials	M	M	M	M	M	H	H	M	H	H	M	M	H	M	H	H
Special equipment	M	M	M	H	H	H	H	H	H	H	H	H	H	H	H	H
Disruption of navigation and recreation	L	L	M	H	H	H	H	H	H	H	X	X	X	X	X	X
Dewatering	X	L	M	M	M	H	H	H	H	H	H	H	X	H	X	X
Special instream mitigative measures	L	L	M	M	M	H	H	M	H	H	X	X	X	X	X	X
Bank reclamation and restoration	M	M	M	H	M	M	M	M	H	H	X	X	X	X	X	X
Inspection	L	L	M	H	H	H	H	H	H	H	L	L	H	M	H	H
Site / work area access	L	L	M	H	H	M	M	M	H	H	M	M	H	M	H	H
Operations and maintenance	M	M	M	M	M	M	M	M	M	M	L	L	L	L	H	H
Habitat compensation	M	M	M	M	M	M	M	M	M	M	X	X	X	X	X	X

Notes:

H - High — Greater time and cost requirements than with traditional hoe construction
M - Moderate — Traditional construction costs and time requirements
L - Low — Less than traditional construction costs and time requirements
X - Nil — No costs or time requirements

4.5 Crossing Method Selection

4.5.1 Pipeline Crossings

The selection of a watercourse crossing method often causes the greatest conflict between industry and regulatory agencies. In recent years, the expectations of the regulatory agencies have evolved to the point that in some jurisdictions, proponents are informed that no instream activity is permitted in flowing waters that have the potential to support any fish. In other jurisdictions, industry has become accustomed to a regulatory environment that permits instream activity as long as it is not within restricted activity periods. In either situation, it is prudent to select a crossing method in a logical and reproducible manner based on sensitivity and mitigation potential.

In selecting a watercourse crossing method, many factors must be taken into consideration. These include, among others:

- pipeline diameter;
- crossing width, depth and flow characteristics;
- environmental sensitivity;
- geotechnical concerns;
- substrate composition;
- hydrological data;
- costs;
- navigation;
- amount of working space required and available;
- regulatory constraints;
- equipment availability;
- contractor expertise;
- downstream water users;
- landowner and community issues;
- engineering constraints; and
- season.

The selection of a final method is an exercise in striking a balance among the considerations listed above and potentially others, to derive the most practical solution. The method that is preferred is usually that which is technically feasible and offers the required level of environmental protection for the lowest cost.

Recent projects have related crossing methods to established sensitivity criteria for each watercourse. This leads to a reproducible selection of crossing methods. A more detailed matrix included in the application may allow some regulatory agencies to follow the logic behind the selection process and approve in principle other crossings as long as the proposed methods are used.

Since there are many factors, more complicated crossing selection flow diagrams have usually not been practical. It, therefore, falls upon the planner and engineer to use professional judgment and experience to evaluate all the factors in the final technique selection.

Table 4.8 summarizes considerations that can be used in selecting a watercourse crossing technique. The table is based on generic crossings and, where several techniques are suggested, the decision as to which will be selected will depend on detailed evaluation of specific concerns.

Table 4.8 provides guidance for the selection of a crossing technique. However, the most appropriate technique for a specific project should be determined on a case-by-case basis. Depending on circumstances, regulatory agencies may have different requirements in regard to their preferred method of crossing. For example, DFO may consider such factors as site location, geographic particularities, type of fish communities affected, regional fisheries management priorities, etc., which may lead to regional differences in preferred crossing methods. There is no automatic selection process.

It should be recognized that no one technique is a panacea for environmental protection and both regulatory and industry representatives must be familiar with the advantages and disadvantages as well as the risk(s) associated with each technique. These are discussed in Section 4.4.

In many situations, regulatory agencies are asked to approve crossing methods with insufficient data and, consequently, take a conservative approach. In these situations, the agencies have responded with an assumption that aquatic resources may be adversely affected unless the proponent indicates otherwise. The onus falls on the proponent to undertake a suitable assessment to assist in the selection of the crossing technique and to communicate the probability of success of the method selected to all parties included in the review of the project. Detailed information, extensive site-specific planning and communication of procedures between the proponent and contractors are required to ensure high probability of success. Where insufficient information is submitted, the proponent can expect that the project may not be reviewed in a timely manner or may be approved only with the most restrictive conditions.

Table 4.8 Pipeline Crossing Construction Technique Selection Considerations

Watercourse Construction Method		Small Watercourse <10 m Wide			Medium Watercourse 10-20 m Wide			Large Watercourse >20 m Wide		
		Environmental Sensitivity[1]			Environmental Sensitivity[1]			Environmental Sensitivity[1]		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
OPEN TRENCHED	Plow	Y	x	x	n/a	n/a	n/a	n/a	n/a	n/a
	Wheel Ditcher	Y	x	x	n/a	n/a	n/a	n/a	n/a	n/a
	Backhoe	Y	x	x	Y	Y	x	Y	Y	x
	Dragline	n/a	n/a	n/a	$	$	x	Y	Y	x
	Dredging	n/a	n/a	n/a	$	$	x	Y	Y	x
ISOLATED	Flume	Y	Y	Y	Y	Y	Y	$	Y	Y
	Dam and Pump	Y	Y	Y	Y	Y	Y	$	Y	Y
	High Volume Pump	Y	Y	Y	Y	Y	Y	$	Y	Y
	Coffer Dam	n/a	n/a	n/a	$	Y	Y	$	Y	Y
	Channel Diversion	n/a	n/a	n/a	$	Y	Y	$	Y	Y
TRENCHLESS	Boring	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Punching	Y	Y	Y	Y	Y	Y	$	$	$
	Micro-tunnelling	n/a	n/a	n/a	$	$	Y	$	$	Y
	Horizontal Directional Drill	$	Y	Y	$	Y	Y	$	Y	Y
AERIAL	Bridge Attachment	$	$	Y	$	$	Y	$	$	Y
	Self-Supporting	$	$	Y	$	$	Y	$	$	Y

NOTES:

1. Environmental sensitivity levels of watercourses are dependent on factors that vary regionally across Canada. The proponent, in consultation with provincial, territorial and federal fisheries authorities and other aquatic specialists, should determine the environmental sensitivity of a particular watercourse crossing location. Parameters such as species present, habitat use, season, downstream use by water users, flow, thermal regime and the findings of an aquatic assessment may be included in a determination of sensitivity (see Table 4.2 for detailed assessment parameters).

2. Watercourse sizes are defined below.

Small	Medium	Large
• <10 m bankfull width with flows that can be readily dammed or pumped for isolated crossings	• 10-20 m bankfull width which can be generally dammed, flumed or pumped and can be excavated by backhoes from each bank	• >20 m bankfull width that are too wide to construct from the banks unless specialized equipment is used. These cannot be dammed, flumed or pumped

3. Y - the method is generally environmentally suitable, but may require habitat compensation measures

   $ - the method is environmentally acceptable, however, may not be practical due to the high construction cost

   x - this method is generally not environmentally suitable, but may be permitted if habitat compensation is implemented

   n/a - not usually practical from an engineering or construction standpoint

   Adapted from Alberta Environment 1988a

4.5.2 Vehicle Crossings

In selecting a vehicle crossing technique, many factors must be taken into consideration. These include, among others:

- pipeline construction technique;
- crossing width, depth and flow characteristics;
- environmental sensitivity;
- geotechnical concerns;
- substrate composition;
- hydrological data;
- costs;
- navigation;
- amount of working space;
- regulatory constraints;
- equipment availability;
- contractor expertise;
- construction season;
- engineering constraints;
- season of use;
- proximity of alternative crossing structures;
- frequency of use;
- duration of use;
- weight of equipment; and
- contractor's responsibilities.

As with the selection of pipeline crossing method, the selection of a vehicle crossing technique also involves striking a balance between the considerations listed above and potentially others, to derive the most practical solution. The technique that is preferred is usually that which offers the required level of environmental protection for lowest cost based on the pipeline construction technique selected.

Table 4.9 summarizes considerations that can be used in selecting a vehicle crossing technique. The table is based on a generic crossing where several techniques are suggested. The decision as to which will be selected will depend on detailed evaluation of specific concerns and pipeline construction techniques.

Table 4.9 Vehicle Crossing Technique Selection Considerations

Vehicle Crossing Method		Small Watercourse <6 m Wide			Medium Watercourse 6-15 m Wide			Large Watercourse >15 m Wide		
		Environmental Sensitivity			Environmental Sensitivity			Environmental Sensitivity		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
BRIDGES	Existing Bridge	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Temporary Bridge	Y	Y	Y	Y	Y	Y	$	$	$
	Ice Bridge	Y	Y	Y	Y	Y	Y	Y	Y	Y
FILLS	Swamp Mats	Y	x	x	Y	x	x	n/a	n/a	n/a
	Log/Pipe Fill	Y	x	x	x	x	x	n/a	n/a	n/a
	Snow Fill	Y	Y	x	Y	Y	x	n/a	n/a	n/a
	Ramp and Culvert/Flume	Y	Y	x	Y	x	x	n/a	n/a	n/a
FORDS	Travel Pad	$	x	x	Y	x	x	Y	x	x
	Ford	Y	x	x	Y	x	x	Y	n/a	n/a
BARGE	Barge	n/a	n/a	n/a	$	$	$	$	Y	Y

NOTES:

1. Environmental sensitivity levels of watercourses are dependent on factors that vary regionally across Canada. The proponent, in consultation with provincial, territorial and federal fisheries authorities and other aquatic specialists, should determine the environmental sensitivity of a particular watercourse crossing location. Parameters such as species present, habitat use, season, downstream use by water users, flow, thermal regime and the findings of an aquatic assessment may be included in a determination of sensitivity (see Table 4.2 for detailed assessment parameters).

2. Watercourse sizes are defined below.

Small	Medium	Large
• watercourses <6 m bankfull width	• watercourses 6-15 m bankfull width	• watercourses >15 m bankfull width

3. Y - the method is generally environmentally suitable, but may require habitat compensation measures.

   $ - the method is environmentally acceptable, however, may not be practical due to the high construction cost relative to the sensitivity.

   x - this method is generally not environmentally suitable, but may be permitted with habitat compensation.

   n/a - not usually practical from an engineering or construction standpoint.

   Adapted from Alberta Environment 1988a

5 Environmental Mitigation Procedures

The following subsections outline various environmental mitigation procedures that should be considered and, if necessary, implemented to ensure a successful crossing.

5.1 Planning and Design

The level of planning and design undertaken for a watercourse crossing will depend upon watercourse sensitivity and project magnitude as well as the jurisdictional requirements. Prior to application, the applicant should ensure that the information requirements are clarified with the regulatory agencies and that required information is submitted as part of the documentation. Failure to do so may result in unnecessary delays in review.

Consultation with the appropriate regulatory agencies is advisable in all jurisdictions since it generally simplifies the planning process and facilitates approval of the application. Environmental non-government organizations with an interest in fish, fish habitat or aquatic environments (*e.g.,* Trout Unlimited Canada), other environmental groups, landowners, users (*e.g.,* outfitters and guides), Licensed water users and other interested parties (*e.g.,* Aboriginal groups) should also be consulted when construction is planned in sensitive environments. As with the regulators, failure to undertake appropriate stakeholder consultation may result in unnecessary delays and added costs.

The following detailed plans could be required as part of a complete application, or should be considered for a construction bid package:

Typical Crossing Design[1]	Contingency Plans[2]
Detailed Crossing Design [1]	- Alternative crossing methods
Environmental Protection Plan[2]	- Floods
Environmental Alignment Sheets	- Waste and hazardous material
Crossing Detail Alignment Sheets	- Spills
Reclamation Plan[2]	- Drilling mud release
Erosion and Sediment Control Plan[2]	- Archaeological or palaeontological discovery
Habitat Restoration and Enhancement Measures[2]	- Rare and endangered species discovery
Compensation Agreements	- Fire
Post-Construction Monitoring	- Construction delays

Notes:

1. These generally are engineering documents but may be developed to include environmental protection measures.

2. Components of these plans are included in Section 5.2 of this document. For contract and application purposes it is easier to have these as stand alone documents.

DFO, and other applicable regulators, consider the contents of some of these plans (*e.g.*, Erosion and Sediment Control Plan) to be very important when reviewing and understanding pipeline construction related activities to be undertaken at medium and highly sensitive crossings.

In jurisdictions not requiring such detailed information, proponents should consider inclusion of as much information as possible in the construction bid documents to ensure that the contractors are bidding appropriately and that there will be no "extras". With their inclusion in the bid documents, there is a greater level of confidence that the contractors and inspectors will act in the manner expected by the proponent and regulatory agencies and not "do it the way it is always done".

5.2 Crossing Construction

The following construction procedures are discussed regarding the installation of vehicle crossings and watercourse crossings:

- general;
- surveying;
- clearing;
- topsoil handling;
- grading;
- welding and weighting;
- instream blasting;
- construction of isolated crossings;
- pipe installation;
- instream sediment control;
- subsurface drainage control;
- backfilling;
- surface erosion control;
- clean-up and reclamation; and
- temporary vehicle crossings.

Standard environmental protection measures and procedures (*e.g.*, Alberta Environment 1988a or other region-specific guidance) should be employed during construction although the following specific considerations are examples of additional measures that could be incorporated during each stage of construction where appropriate.

5.2.1 General Mitigation Procedures

The following measures are general in nature and should be considered regardless of construction activities. Such measures should be considered for implementation into the environmental protection plan whenever practical.

- Schedule construction to occur during periods of lowest sensitivity.

- All reasonable efforts should be made to minimize the duration of instream work.
- Abide by all relevant timing constraints (fish, ungulate, avian, etc.). Ensure that no construction activity occurs within the wetted portion of the channel during the restricted activity period.
- Prepare contingency plans for fuel and hazardous waste spills, streambank erosion, storm runoff and floods.
- Prepare an emergency monitoring and response plan for use in the event of a frac-out during a horizontal directional drill. If drilling fluids are entering a waterbody, follow the contingency plan. The appropriate environmental regulatory agencies must be notified immediately.
- Do not discharge or dispose of petroleum products and/or waste into waterways or onto the ground.
- Ensure waste storage areas are sited to prevent blockage of drainage or risk introduction of waste material into a watercourse.
- Change oil, refuel and lubricate mobile construction equipment well away from the normal high water mark of a waterbody to minimize the potential for water pollution.
- Ensure that all oil changes, refuelling and lubrication of immobile equipment well away from the normal high water mark of a waterbody is undertaken in a manner such that any spillage will not enter the waterbody.
- Spent oils, lubricants and filters, etc., are to be collected and disposed of at an approved location and in an appropriate manner.
- Ensure that the following measures are employed to minimize the risk of fuel spills:
  - all containers, hoses and nozzles are free of leaks;
  - all fuel nozzles are equipped with automatic shut-offs;
  - operators are trained and stationed at both ends of the hose during fuelling unless the ends are visible and are readily accessible by one operator; and
  - fuel remaining in the hose is returned to the storage facility.
- Ensure that all fuel and service vehicles carry a spill kit with a minimum of 25 kg of suitable commercial sorbent material, 30 m^2 of 6 mil polyethylene, a shovel and one fuel barrel (lid removed).
- Store fuel within containment berms constructed to a capacity of 110% of the fuel stored or within double-walled tanks.
- Do not store hazardous materials, chemicals, fuels, or lubricating oils, near the normal high water mark of a waterbody or near any surface drainage location. All such storage areas must be suitably contained.
- Fuel trucks, fuel storage areas, pumps, generators and other sources of deleterious substances must be within a containment system of sufficient capacity to ensure that deleterious substances do not enter fish habitat.
- Do not perform concrete coating activities near a watercourse unless suitable isolation from surface drainage and watercourses is ensured.

- Do not wash any type of equipment or machinery in watercourses or lakes. Control wastewater from construction activities, such as equipment washing or concrete mixing, to avoid discharge directly into any body of water.
- Ensure that the hydraulic, fuel and lubrication systems of any equipment working instream are in good repair to avoid leakage. Operate all equipment in a manner that prevents deleterious substances from entering fish habitat.
- Consider using vegetable based hydraulic oils in hydraulic systems working near watercourses or instream.
- Thoroughly inspect and clean equipment of oils, mud and vegetative debris before commencement of project.
- Any aquatic plants uprooted or cut during excavation should be removed and disposed of on land in an approved disposal site. It is important that these plants not be deposited in another body of water.
- Determine the presence of aquatic or riparian noxious weeds which construction equipment could carry forward from an infested to a clean area.
- Hose down, thoroughly wash potentially infested equipment and purge and clean all pumps before proceeding from one area to the next if noxious weeds or other pest species such as zebra mussels are known to be present in the area.
- Locate sources of clean gravel, cobble and riprap, if needed, prior to construction and place onsite for stabilization and restoration.
- Ensure that all material that is placed within the wetted perimeter of a watercourse is not toxic to fish.
- Ensure the appropriate vehicle crossing technique is employed (see Section 4.6.2).
- Wash all equipment transferred between major watersheds to ensure that aquatic pests are not transferred.
- Where water is pumped from fish habitat for any purpose, intakes are to be screened according to DFO's *Freshwater Intake End-of-Pipe Fish Screen Guideline* (DFO 1995c).

5.2.2 Surveying

Since the surveyor may select the initial crossing location, it is important that the following points be considered.

- Verify the final alignment of watercourse crossings to ensure that areas of particular concern are avoided. Environmental staff/consultant and/or project manager should conduct verification.
- Survey parallel to the fall line on approach slopes of watercourses. Avoid side slopes, drainages and unstable terrain. Survey pipeline crossings perpendicular to watercourses, wherever practical.
- Ensure sufficient extra workspace is taken for working area on the approach slopes and at the watercourse crossing. Workspace boundaries should be well marked.
- Locate staging area at least 10 m away from streambanks, where topographic conditions permit.

- Minimize staging area size needed to construct the watercourse crossing.
- Identify and locate existing lines, especially hot lines, including burial depths.
- Mark or flag any sensitive environmental features within construction area.
- Ensure a photographic record is made of all significant features to be protected or restored.

5.2.3 Clearing

Clearing can lead to erosion of the approach slopes, bed and banks as well as sedimentation and the obstruction of the watercourse. The following points are designed to minimize the potential adverse environmental effects of clearing (*e.g.*, increased potential for erosion and sedimentation of the watercourse) and should be considered for inclusion in the environmental protection plan.

- Flag clearing boundaries prior to clearing operations.
- Minimize clearing to prevent erosion and loss of riparian habitat.
- Consider using tracked vehicles on steep terrain to minimize the need for shoo-flies.
- Limit nontracked vehicle traffic to approved shoo-flies on steep approach slopes.
- Postpone clearing of slopes and banks until immediately prior to construction, unless otherwise approved by the regulatory authority/Environmental Inspector and landowner. Avoid preclearing in the vicinity of watercourses.
- Leave a temporary uncleared buffer zone extending back from the crest of erosion prone slopes.
- Postpone disturbance of the vegetated buffer zone of watercourse until necessary.
- Remove trees, debris or soil inadvertently deposited within the high water mark of watercourses in a manner that minimizes disturbance of the bed and banks. Do not fell, stand or yard trees across a watercourse. Do not drive logs into a watercourse even when dry.
- Implement Surface Erosion Control Measures as outlined in Section 5.2.11.
- Avoid long-distance skidding of timber on steep slopes adjacent to watercourses.
- Retain timber for riprap, logfill crossings, temporary bridges, rollback and/or corduroy, if warranted. Only use timber approved of by the applicable government representative or landowner. Place material so as not to hinder crossing construction.
- Chip or mulch slash and spread on steep erosion-prone slopes.
- Leave an undisturbed organic mat on the work side of the right-of-way as a buffer zone to limit the potential for sediment to enter the watercourse.
- Delay grubbing on slopes adjacent to a watercourse or within 10 m of the watercourse banks until construction of crossing is imminent.
- Restrict root grubbing near watercourses. Do not grub within 10 m of a watercourse except along the trench line. Only grub the spoil pile area if absolutely necessary. Leave an undisturbed organic mat on work side to minimize the potential for introduction of sediment into the watercourse.

- Maintain low vegetation within the 10 m buffer of watercourses to the extent practical by walking, storing and constructing over the undisturbed areas.
- Note that clearing and grubbing within 10 m of watercourses may be appropriate if completion of these activities will result in a reduction in erosion and sedimentation risk.
- Dispose of all nonmerchantable timber and slash not used for corduroy or rollback to the satisfaction of the landowner and regulatory authority. Methods of disposal include burning, chipping and mulching, or bucking and stockpiling (firewood). Combinations of methods may be needed depending on site and regulatory conditions.
- Do not locate burn areas within the wetted perimeter of a watercourse and avoid locating burn piles on organic soils. Dispose of all partially burnt stumps and logs above the high water mark to the satisfaction of the landowner and regulatory authority.
- Do not use tires, petroleum products, waste oil, waste chemicals or other wastes to ignite fires.
- Suspend clearing during heavy rains.

5.2.4 Topsoil Handling

Poor topsoil handling can result in increased erosion, sedimentation and possibly blockage of streamflow and insufficient reclamation following construction. The following points should be considered.

- Implement Surface Erosion Control Measures as outlined in Section 5.2.11.
- Strip topsoil under nonfrozen and/or dry conditions, where practical.
- Delay stripping of approach slopes, floodplains and banks until immediately prior to construction.
- Strip topsoil from all areas to be graded.
- Strip topsoil during nonfrozen conditions from all areas to be used for approach slope spoil storage and from where instream spoil sump is to be constructed.
- Ensure graded and excavated subsoil are stored separately from topsoil.
- Stockpile salvaged topsoil in a location that will prevent erosion and siltation of the watercourse.
- Place topsoil in distinct piles above the high water mark in a manner that does not block drainage or runoff, construction activities, or replacement of grade material or trench spoil and prevents erosion and siltation into the watercourse.
- Contour and stabilize with an approved cover crop if topsoil piles are to remain through the winter or for an extended period of time.
- Suspend topsoil handling during wet conditions. Recommence once field conditions improve.

5.2.5 Grading

Poor grading can result in increased erosion, slope instability, sedimentation and blockage of streamflow. The following points should be considered where appropriate.

- Ensure snow graded from the right-of-way is stored in a manner that does not lead to increased erosion during spring melt.
- Ensure that melting "dirty" snow is not allowed to run-off directly into watercourses.
- Implement Surface Erosion Control Measures as outlined in Section 5.2.11 unless approved by a geotechnical engineer.
- Minimize grading on steep slopes. Grading should be limited to only permit access for tracked vehicles. Rubber-tired traffic should be limited to approved shoo-flies.
- Do not place graded material on steep slopes or closer than 20 m to the crests of slopes. Cuts and fills should not exceed 3:1 slope.
- Minimize disturbance of natural drainage channels during grading; avoid blocking channels with graded material.
- Remove bank grade with backhoe and store it a sufficient distance back from the watercourse.
- Grade away from watercourses to reduce the risk of material entering a watercourse. Do not place fill material in a watercourse during grading.
- Grade only the trench line and spoil containment areas. Grade the work side and crossing approaches only if warranted for safe operation of equipment. Grading within 10 m of the watercourse may be appropriate if completion of this activity results in a reduced erosion and sedimentation risk.
- Minimize the area of disturbance along the streambank. Do not grade the entire width of the right-of-way in proximity to a watercourse.
- Minimize grading when constructing bridge, fill or ford crossings.
- Plow and store snow for snowfill crossing prior to earth-moving activity to maintain clean snowfill.
- Contour and stabilize excess grade material if piles are to remain through the winter or for an extended period of time.

5.2.6 Welding and Weighting

Welding and weighting of pipe should be undertaken in a manner that allows quick installation and the least amount of adverse environmental impact. The following points should be considered where appropriate.

- Assemble pipeline in upland area and utilize "push-pull" or "float" technique to place pipe in trench whenever water and other site conditions allow.
- Complete welding, coating, testing and weighting of the pipe prior to commencement of trenching. Completion of welding, coating and weighting of the pipe may be deferred, to a limited extent, at large watercourses where a substantial instream trenching period is anticipated.

- Ensure that sufficient equipment is available to move long heavy sections of pipe efficiently at long crossings.

5.2.7 Instream Blasting

When considering instream blasting as an approach to remove bedrock for the installation of a pipeline watercourse crossing, these measures should be followed:

- Consider less destructive or more controlled methods of removing bedrock, if practical, such as ripping. These methods are preferable to blasting.
- Consult with provincial or territorial fisheries biologists, wildlife biologists and regional DFO representatives in addition to other regulatory agencies early in the planning phase should blasting in or near streams be considered.
- Consult with DFO as early as possible in the planning process if the use of explosives is unavoidable, to identify and discuss practical alternatives, aquatic resources and mitigation measures. DFO may, upon review of a project proposal, provide a letter of advice, issue an Authorization under Section 32 and/or Subsection 35(2) of the *Fisheries Act*, or decide not to issue Authorization(s). In arriving at one of these determinations, DFO will take into account, among other things, whether:
  - the use of explosives is the only technically feasible means of breaking bedrock such that it can be excavated from the trench;
  - sensitivity of habitat, fish presence and timing; and
  - the use of explosives is required to alleviate an emergency situation.

Mitigation measures specific to the use of explosives in or near fisheries water may be implemented in order to effectively minimize the destruction of fish and/or the HADD of fish habitat. These measures could include, but are not limited to the following:

- use of staggered/delayed blasting times in conjunction with decked charges to reduce overall shock wave;
- scheduling of blasting for periods of least biological activity for the watercourse, especially avoiding spawning, incubation, overwintering and migration periods;
- deploying bubble/air curtains to dampen the shock wave;
- displacing fish from blast area (e.g., use small charge blasting caps) and employ shock wave buffers (e.g., air curtains) to minimize adverse effects;
- using confined explosives (i.e., contained within a substrate) instead of unconfined explosives;
- avoiding the use of ammonium nitrate based explosives, specifically nitrate-fuel oil mixtures in or near water due to the potential for toxic by-product production (ammonia).

5.2.8 Construction of Isolated Crossings

The following mitigative measures should be implemented during construction of crossings using an isolation method:

- Maintain 100% of downstream flow at all times.
- Water from flumes, pump-around, diversions or other methods used to maintain downstream flow must not cause erosion or introduce sediment into the channel.
- If a pump-around method is used to maintain downstream flow, back-up pumps with adequate capacity to maintain 150% of downstream flow must be on site at all times and ready to take over pumping should the operating pumps fail. The operating pumps should be continually monitored to ensure downstream flow is maintained at all times until the dam materials are removed and normal flows restored to the channel.
- Pump intakes must not disturb the streambed. Pump intakes used in fish bearing waters must be screened with a maximum mesh size of 2.54 mm and a maximum screen approach velocity of 0.038 m/s.
- Earthen berms should not be used for isolation.
- All berms and material must be completely removed from the channel and the streambed and bank profiles be returned to preconstruction conditions at the end of the project.
- Sediment laden water in the work area should be discharged to an upland vegetated area prior to removal of the isolation dams.
- Fish salvage should be conducted using a seine net, dip net and/or electrofishing and the fish released unharmed upstream. Fish salvage should be undertaken within any isolated areas prior to and during dewatering activities. In addition, fish salvage should be undertaken on any bypass structures such as diversion channels and flumes prior to them being dewatered after use. Fish salvage may require a permit from the province.

5.2.9 Pipe Installation

The specific procedures that may be implemented during pipe installation depend on the crossing technique. See Dwgs. 1 to 11 for specific techniques. Other general measures include:

- Stop trenching activities short of watercourse banks or where deep burial is to occur to prevent silty trench water from entering the watercourse. Leave hard trench plugs in place until the watercourse crossing has been initiated. The recommended minimum plug width is 3 m.
- Construct a sump, with berms, silt fences or straw bale filters to contain excavated instream spoil so that silty runoff does not re-enter watercourse. Prevent instream spoil from flowing off right-of-way (see Dwgs. 16, 17 and 18).
- Ensure subsurface flow along the stream channel is maintained if critical habitats downstream could be affected by a blockage in flow.

- Dewater the trench onto stable surfaces in a manner that does not cause erosion of soils, sedimentation of watercourses, or where icing will not be a problem.
- Dewater the trench or boreholes so that the water is released into a well vegetated area or settling basin and does not directly re-enter any watercourse. Water returning to a watercourse must be equal to or in exceedance of background quality of the watercourse.
- Salvage vegetation plugs from streambank to aid in bank reclamation. Store in a manner that they can be replaced during clean-up.
- Suspend instream work if sedimentation is occurring. Implement further protection measures to control sediment loading.
- Ensure the watercourse is restored to its natural gradient and elevation to prevent barriers to fish movement.
- Install spare lines, where appropriate, for future use.

5.2.10 Subsurface Drainage Control

Drainage along the unconsolidated backfilled trench may cause instability and erosion, resulting in watercourse blockage and/or sedimentation, as well as threaten pipe integrity. Subsurface drainage must be diverted from the backfilled trench. The following points should be considered to ensure appropriate drainage.

- Install trench breakers constructed of sandbags, bentonite, urethane foam or other compacted impervious materials to force bellhole seepage along the pipeline trench to the surface on steep slopes (see Dwg. 19). Determine the location of trench breakers by onsite investigation considering the potential for subsurface flow, erodibility of backfill material and degree of slope. Mark location of trench breaker prior to backfilling.
- Install trench breakers adjacent to watercourses, at edges of wetlands and on other similar sites where unconsolidated backfill or organic materials are prone to washing out.
- Install subdrains or pole drains to divert shallow groundwater flow from the right-of-way and to improve slope stability (see Dwgs. 20 and 21).
- Install trench breakers on each side of a wetland where the pipeline trench crosses and may drain the wetland.

5.2.11 Surface Erosion and Sediment Control

Surface erosion should be controlled prior to, during and following crossing construction to minimize sedimentation. Erosion control measures should be considered as a primary means of sediment control and incorporated into all watercourse crossings during the planning stage. The following measures should be considered to minimize the amount of erosion and sedimentation.

- Regulate drainage from construction areas to prevent erosion and sedimentation.
- Ensure no ditch drains directly into a watercourse without proper sediment control devices.

- Install temporary berms on approach slopes immediately following clearing and grading.
- Install temporary silt fences (geotextiles or hay/straw bales) near the base of slopes if heavy rains or surface erosion could result in siltation of the watercourse (see Dwgs. 17 and 18).
- Install temporary silt fences (geotextiles or hay/straw bales) in any location where run-off from the right-of-way may flow into a watercourse.
- Inspect and clean silt fences on a regular basis, especially after heavy rainfalls.
- Install diversion berms and cross ditches, on disturbed steep approach slopes to divert surface water off the right-of-way (see Dwg. 22). Install sandbag, timber or bale berms on undisturbed pasture or well-sodded right-of-way. Determine location, type and direction of diversion berms in the field based on local topography, drainage patterns and land use. Ensure berms terminate in natural vegetation off the right-of-way. Stagger ends of berms as warranted. Install berms immediately downslope of trench breakers where installed. Ensure trench crown does not impede drainage or that a sunken trench does not act as a drainage ditch. All designs should be made with input from a geotechnical engineer.
- Rollback stored, salvaged or imported small diameter slash (<5 cm) and walk down with dozer on steep erosion prone slopes on non-agricultural land. Install netting, mat binders, tackifiers, pegged sod or other products as warranted.
- Revegetate with an approved seed mix, as soon as practical, at twice the annual standard pasture rate. Incorporate a cover crop seed (*i.e.,* biannual fall rye, annual oats or barley) into mix as a cover crop. Note: Biannual fall rye should be incorporated for summer or fall seeding and annual oats for winter or spring seeding.
- Transplant native shrubs, plant willow stakes, or utilize other bioengineering techniques such as brush layering or wattling as warranted on steep erosion prone slopes on non-agricultural land. Schiechtl (1980) discusses numerous bioengineering techniques (see Dwgs. 26, 27, 28).
- Consider applying netting or tackifier; laying and pegging sod, especially in urban areas; hydroseeding; seed impregnated mats; organic mulches such as straw, wood fibre, peat moss, wood chips or bark; brush matting; or other surface erosion control measures outlined in **Table 5.1**.
- Inspect erosion control structures until well established and stable, after major rainfalls and at least daily during periods of prolonged rainfall.
- Immediately repair erosion control structures that are found to be damaged.

5.2.12 Instream Sediment Control

The generation of sediments cannot always be avoided during the construction of watercourse crossings; however, there are methods that may be used to minimize and control the location, dispersion and extent of sediments transported downstream. These are discussed in detail in *Instream Sediment Control*

Techniques - Field Implementation Manual (Trow Consulting Engineers Ltd. 1996).

The use of filtering devices is not generally recommended since the materials have very low permeability rates, quickly loose their filtering potential and are susceptible to damage from streamflows. The use of geosynthetic textile products to filter silt and clays may only be appropriate in very low velocities ($<0.026\ m^3/s$).

Other instream sediment controls are designed to reduce water velocities and allow for settling of suspended materials in closer proximity to a trench excavation than would naturally occur. These controls are generally limited to controlling the transport of heavier suspended sediments that are temporarily within the water column. Such techniques are normally used in close proximity to the crossing since most of the coarser particles settle out naturally within a few hundred metres of the excavation.

Recent construction experience with sediment mats (*e.g.,* Sedimat) has indicated that placement of these woven mats downstream of the crossing, especially in sensitive habitats, traps large amounts of bedload and suspended sediment. These mats are removed after construction and, if biodegradable, can be used during bank restoration.

Special care is required when designing and installing instream sediment controls, particularly in flowing watercourses. Selection of the appropriate method for a stream, river, wetland or lake crossing is generally based on the following criteria:

- flow velocity and volume;
- crossing depth and width;
- seasonal conditions;
- environmental sensitivity;
- bed material; and
- trench excavation method.

Although conditions may appear suitable for instream sediment controls, their use must be carefully examined as their suitability and effectiveness are often overestimated. The use of instream sediment controls may be prohibited by factors such as: costs; physical obstructions (such as access, instream debris, freezing conditions, blockage of fish passage); potential downstream sedimentation as a result of installation, maintenance and removal; damming of flows; chance of failure; ability to handle floods and increased flows; and their potential to become sources of bed or bank erosion. The type, design and placement of instream sediment controls should only be undertaken by a hydrological engineer or other qualified person.

All instream controls should be installed prior to construction and maintained throughout their installation period. Where possible and practical, accumulated sediment should be regularly removed to prevent accidental transport of collected sediments should the device fail. Disposal should be in a location and manner such that accumulated sediment is not allowed to re-enter any drainage system or receiving waterbody. Where removal would only cause additional sedimentation, the deposited material should be left in place and permitted to be removed naturally during the freshet. Instream controls should be removed before spring freshet if they are used through the winter season and prior to freeze-up if used during the fall.

The following types of instream sediment controls have been used in the past although no information has been collected on the acceptability of these techniques by regulators nor their effectiveness:

- check dam approach using shallow geotextile dams or stone for small streams of low velocity;
- deflector approach by installing logs, rocks or geotextiles to divert sediment-laden flow from sensitive fish habitat and to promote deposition of suspended solids in artificially created back eddy; and
- covering spawning beds with geotextiles, or other suitable material, until construction is complete.

5.2.13 Backfilling

Backfilling should be performed in a manner that ensures erosion does not occur along the trench and that it does not result in a loss of fish habitat.

- Ensure backfill is well compacted on approach slopes and streambanks.
- Backfill with clean coarse material (*e.g.,* 2 cm diameter gravel or larger rock). All fill material is to be obtained from off-site and not from below the average high water level of any watercourse.
- Backfill from the centre of the watercourse towards the bank forcing silt-laden water back towards the ditch plugs. Silt-laden trench water should then be pumped onto vegetated land or into a sump.
- Lower backhoe bucket into water before releasing the backfill.
- Consider not backfilling instream trench, where sediment transport and sloughing will fill in trench and backfilling with existing or select backfill will create excessive downstream sedimentation.

5.2.14 Clean-up and Reclamation

Clean-up and reclamation should be performed to stabilize the disturbed area and to restore its aesthetic appearance.

- Commence clean-up at watercourses immediately following backfill and erosion control operations. Attempt to complete all phases of clean-up as quickly as practical. Where winter clean-up is hampered by frozen spoil and topsoil piles, complete rough clean-up prior to break-up and final clean-up after break-up.
- Remove corduroy from all locations wherever practical. Remove clay or sand caps overlying corduroy and ensure adequately sized culverts or other

methods of cross drainage are present in any capped corduroy that is left in place. Dispose of corduroy, slash and any remaining leaning trees in the same manner as used for disposal of slash from initial clearing.

- Regrade streambanks and approaches to preconstruction profile, or to a maximum of 3:1 unless directed by a geotechnical engineer.
- Replace topsoil and any salvaged trees or shrubs.
- Revegetate streambanks and approach slopes with an appropriate native seed mix or erosion control mix. Seed a cover crop of fall rye, barley, oats or sterile hybrids such as triticale or wheat/wheatgrass.
- Broadcast seed, harrow in or hand rake on slopes. A seed drill should be used on level areas such as floodplains wherever practical. Hydroseeding can be used where access is good.
- Develop specific procedures, in coordination with the appropriate federal, provincial or territorial agency, to prevent the invasion or spread of undesirable non-native vegetation (*e.g.,* purple loosestrife, Eurasian milfoil).
- Do not fertilize in the immediate vicinity of a watercourse unless requested by the landowner and approved by DFO.

5.2.15 Temporary Vehicle Crossings

Temporary vehicle crossings for equipment and materials are commonly associated with pipeline crossings. The following mitigative measures should be implemented to avoid environmental damage.

- Whenever possible, existing watercourse crossings should be used. Secondarily, clear span bridges or ice/snow bridges should be used for temporary crossings.
- Remove crossing structures, where feasible, prior to freeze-up (for summer construction) and prior to break-up (for winter construction). Remove structures by physical means, not blasting. Crossing structures may be left in place only for final touch-up (*e.g.,* reseeding) if no other access is available and if they are designed to withstand high water flows during spring break-up.
- Any temporary crossing and associated debris must be removed immediately after completion of the pipeline crossing and the disturbed area restored to preconstruction conditions.
- Only clean ice/snow should be used for construction of ice bridges.
- Sand or gravel should not be used for the ice bridge approaches. Approaches should be constructed of compacted snow and ice of sufficient thickness to protect the stream and banks.
- Ice/snow bridges must be notched open prior to spring break-up when safe to do so and any associated debris removed from the watercourse. Banks and approaches should be stabilized and restored to preconstruction conditions.
- Ensure that no excavation of the streambed occurs unless approved by DFO.
- If water extraction is necessary for the construction of temporary vehicle crossings, local regulations should be consulted for the maximum permissible withdrawal volume.

5.2.16 Abandonment

There are many factors to consider in deciding whether a section of pipeline crossing a water body should be abandoned in place or removed. More specifically, the risks associated with abandoning the pipeline in place, including the potential for contamination and pipe exposure, have to be weighed against the cost and environmental impact of removal (PASC 1996).

These trade-offs should be assessed on a site-specific basis, taking into account the size and dynamics of the water body, the design of the pipeline crossing, soil characteristics, slope stability, and environmental sensitivities. While these issues must be evaluated, in most cases it can be expected that abandonment-in-place will be the preferred option (PASC 1996).

Table 5.1 Erosion Control Techniques

Technique	Description	Advantages	Disadvantages	Comments
I. CONSTRUCTION PHASE				
Preserve existing vegetation	• maintain vegetation where practical • minimize grubbing and maintain root mat	• inexpensive • permits infiltration by water • native vegetation maintained • minimal surface disturbance	• possible congestion of construction traffic • may create unsafe working conditions • may impair erosion control in some conditions	• applicable for slopes, streambanks and floodplains • aids reclamation practices • good in areas with erodible soils, sensitive vegetation • standard procedure to minimize disturbance
Minimize grading	• reduce cut and fills for minor depressions / gradient changes	• inexpensive • reduces surface disturbance	• may create unsafe working conditions • may impair erosion control in some conditions	• applicable for gentle slopes, small hummocks and rolling topography • standard procedure to minimize disturbance
Silt fences (Dwg. No. 17)	• geotextile fences, partially buried, placed along slopes perpendicular to the fall line used to slow / block sediment transport along a slope • often at the base of slopes adjacent to watercourses • secured with steel rods or wooden posts	• prevents saturated spoil / slopewash from entering a watercourse • minimizes erosion	• possible obstacle to construction traffic • may washout / fail if not properly installed	• temporary measure used on slopes with erodible soils to minimize sediment release into watercourses prior to revegetation
Straw bales (Dwg. No. 18)	• bales used to slow / block sediment transport along a slope • secured with steel rods or wooden posts	• prevents saturated spoil / slopewash from entering a watercourse • minimizes erosion	• possible obstacle to construction traffic • may washout / fail if not properly installed	• temporary measure used on slopes with erodible soils to minimize sediment release into watercourses prior to revegetation

Table 5.1 Erosion Control Techniques, Cont'd

Technique	Description	Advantages	Disadvantages	Comments
Sediment trap	• excavate minor depression(s) to allow sediment to settle	• does not require specialized equipment • prevents large volumes of sediment from being washed away • may be used in conjunction with silt fencing / straw bales	• may obstruct construction traffic • spoil from sediment trap requires additional slope area • may create a bigger mess	• used for isolated areas prior to final clean-up • not common
Sandbag ditch plug (Dwg. No. 19)	• sandbags (not foam or bentonite) are placed in the trench as a ditch plug to prevent washout of organic streambank	• relatively inexpensive • may provide stable base for revegetation techniques	• labour intensive • may fail if incorrectly installed resulting in large sediment volume release	• used for watercourses with organic banks which are susceptible to washing out • must be keyed into trench walls for stability
Subdrains (Dwg. No. 20)	• buried conduits providing surface release of subsurface water • generally gravel wrapped in geotextile fabric or heavy plastic drain pipe(s)	• provides slope stabilization where springs are present • maintains pipeline integrity by preventing trench washout	• expensive / labour intensive • requires correct placement to be effective	• used in conjunction with cross ditches and diversion berms • geotechnical consultation is recommended for correct placement • correct installation is key
Temporary diversion berms	• low subsoil berm across entire right-of-way used to divert surface water flow off the right-of-way	• inexpensive • effective at diverting surface water flow • can be readily installed and repaired	• due to low profile of berm(s), over topping / washout can occur during major precipitation event • must be repaired on a daily basis	• applicable for approach slopes • permanent berms will replace temporary berms during rough clean-up • common practice
II. POST CONSTRUCTION / ROUGH CLEAN-UP PHASE				
Cross ditch & diversion berms (Dwg. No. 22)	• ditches and berms crossing entire right-of-way slowing runoff to minimize erosion	• very effective if constructed correctly • utilizes native materials • aids in reclamation and revegetation	• may impede operations and maintenance activities • not applicable for all soil types	• standard procedure for erosion control • must be correctly placed in relation to slope and natural drainage in addition to trench breaker locations

Table 5.1 Erosion Control Techniques, Cont'd

Technique	Description	Advantages	Disadvantages	Comments
Brush bundles, fascines or wattles	• bundles of live cuttings tied produce sausage shaped bundles • planted in shallow trenches anchored with wooden or live stakes	• can be used to direct or slow water movement and encourage vegetation growth on bank • don't require heavy equipment for installation	• provides very limited structural stability until rooted • least suitable during active growing season • may rot and require extensive maintenance • construction is labour intensive	• can be combined with other erosion control measures
Brush matting	• mattress-like layer of branches placed over slope to protect soil and slow water movement	• provides bank protection and encourages vegetation regrowth • uses readily available, natural materials • can be conducted at time of construction.	• least suitable during active growing season • construction is labour intensive • may accelerate erosion if not properly installed	• can be combined with armouring and other methods
Silt fences (Dwg. No. 17)	• geotextile fence secured with steel rods on banks • may be used in conjunction with other techniques (e.g., straw bales)	• minimized slopewash into watercourse • easy to install	• difficult to work around • requires periodic maintenance	• temporary measure
Slope terracing	• benches are constructed on a slope to reduce overall slope load and gradient	• reduces overall slope and gradient to minimize the potential of slope failure • aids in revegetation	• requires additional work area • expensive and labour intensive	• appropriate on constructed slopes where slope stability is more important than natural contours • not appropriate for most crossings
Live pole drains (Dwg. No. 21)	• bundles of willow branches securely tied partially buried in line with the fall line	• provides natural drainage conduit • eventual establishment of willows helps stabilize soil and reduces water transport	• labour intensive • only applicable in certain circumstances	• not appropriate for steep slopes and/or large volumes of water • not appropriate for stabilization of slumping areas
Restoration of drainage channels	• removal of excess spoil from drainage channel to maintain natural hydrology	• maintains natural channel and vegetation patterns • minimizes changes to downstream river users and potential aquatic habitat	• reduced storage area for spoil at drainage may require additional adjacent areas • lost material inadvertently adds to siltation	• appropriate for minor drainages which may not be flowing during construction

Table 5.1 Erosion Control Techniques, Cont'd

Technique	Description	Advantages	Disadvantages	Comments
III. POST CONSTRUCTION PHASE – FINAL CLEAN-UP				
Revegetation & cover crop	• seed by broadcasting, harrowing or drilling with a suitable mix of species • utilize a quick-growing annual or biannual to establish ground cover	• establishes a root mat and vegetation layer to reduce soil erosion by wind and water • cover crop will establish before permanent cover	• requires some time to establish a root mat and ground cover • native seed may be expensive or unavailable • poor quality seed mix may introduce noxious weed species • vegetation may require extensive efforts before establishing	• verify seed mix composition and quality with appropriate regulatory agencies prior to application • fertilizers and / or organic mulch may or may not be recommended
Organic matting/mulch	• paper or wood fibre spread by hand or by hydro-spray equipment to supplement soil organics	• provides long-term plant nutrition • improves overall quality of soil • if slope is seeded first, mulch provides cover and retains moisture	• mulch and application method may be expensive • access for equipment may be restricted • requires special materials • may wash-off during periods of heavy rain if a tackifier is not added	• may be needed on exposed mineral soil slopes to establish an organic layer • recommended for long-term revegetation projects • recommended for poor quality soils with or without a fertilizer
Rollback	• spread small diameter timber and slash over right-of-way and walk down with tracked equipment	• provides micro-habitats for water and seed catchment • slows surface water and wind minimizing erosion • may also incorporate natural seed as well as organic material	• slash volumes may be limited and salvage of merchantable timber may be required • may limit operations and maintenance access • may require extra right-of-way to permit storage during construction • may accelerate erosion if rollback is too large and not properly walked down	• may be incorporated with most other forms of erosion control • not to be placed in watercourses • recommend seeding after walking down rollback

6 Habitat Mitigation and Compensation

DFO's *Policy for the Management of Fish Habitat* (1986) provides a comprehensive framework for the conservation, restoration and development of fish habitats that contribute directly or indirectly to a fishery or potential fishery. Its long-term objective is to achieve an overall net gain in the productive capacity of fish habitats by conserving the current productive capacity of habitats ("no net loss"), restoring damaged fish habitats and improving and creating fish habitats. Other federal, provincial and territorial legislation, strategies, policies and guidelines also provide guidance to proponents.

Proponents are frequently confused about the distinction between mitigation and compensation. Habitat 'mitigation' is undertaken as a normal part of water crossing construction to prevent impacts on fish habitats and biota. In all cases, the first preference is to avoid potential effects on aquatic and riparian habitat, generally by modifying the route or crossing method. Where this is not possible, the next priority is to reduce potential negative effects through appropriate mitigation measures. These mitigation measures may include changes to project design and timing, environmental protection measures applied during construction, and restoration of riparian, bank and instream habitat disturbed by construction activities.

Habitat 'compensation' is undertaken by proponents to achieve "no net loss" where crossing activities could cause a HADD. The need for compensation is determined as part of the *Fisheries Act* authorization process. Compensation is described more fully in Section 6.1 below.

Riparian, bank and instream habitat restoration and enhancement techniques are summarized in Section 6.2 below. Restoration' is undertaken to restore ecological function lost as a result of disturbance. 'Enhancement' is undertaken to improve the productive capacity or function use of habitat. Restoration and compensation techniques may be applied for both mitigation and compensation purposes.

6.1 Compensation

According to the *Policy for the Management of Fish Habitat* (DFO 1986), compensation is "the replacement of natural habitat, increase in the productivity of existing habitat, or maintenance of fish production by artificial means in circumstances dictated by social and economic conditions, where mitigation techniques and other measures are not adequate to maintain habitats for Canada's fisheries resources". Cash in lieu of compensation is not acceptable.

Compensation is the least preferred option for addressing effects on fish habitat and is only considered when adequate mitigation is impossible or impractical. In these cases, where HADD is likely to occur (typically <10% of crossings reviewed by DFO), a proponent should request a Subsection 35(2) Authorization from DFO. The proponent is within its legal rights to proceed without getting this authorization. However, should this happen and HADD results, the proponent is liable to prosecution under the *Fisheries Act* if an Authorization is not in place.

The Subsection 35(2) Authorization allows a proponent to proceed under prescribed conditions, including the need to achieve "no net loss" by compensating for adverse effects on fish habitat. However, even though a proponent may be willing to undertake compensation, issuance of a Subsection 35(2) Authorization with compensation specified is the least preferred option and may not be acceptable for particularly valuable fish habitat. Authorizations will not normally be issued until adequate compensation measures are specified. Compensation measures may be set out directly in the Subsection 35(2) Authorization via reference in the Authorization or through legal agreement between the proponent and DFO. All costs associated with compensation are the responsibility of the proponent.

Proponents should consult with DFO and as necessary, provincial or territorial representatives, before developing compensation measures to confirm that mitigation is not possible and that compensation is an acceptable option. Proponents will also need to demonstrate that proposed compensation measures are technically and economically feasible and appropriate for each crossing requiring an Authorization.

6.1.1 Compensation Plans

Any instruction, action, intervention, construction or undertaking to offset an unmitigated impact to fish habitat is considered an effort towards compensation. Habitat compensation is intended to improve physical, chemical, or biological factors that are limiting habitat capability. This includes replacing damaged habitat with newly created habitat, increasing the productive capacity of existing natural habitat, or least preferably, maintenance of fish production by artificial means. These must be identified on a crossing-by-crossing basis by the proponent, in consultation with technical specialists, as well as provincial, territorial and federal authorities. Local fisheries management plans should also be used, where they exist, to help determine appropriate compensation options.

A compensation plan is usually submitted by the proponent as part of a development proposal. The plan ideally includes: type, location and extent of habitat to be affected; type, location and extent of compensatory habitat; the results to be achieved; monitoring to be undertaken; how success will be measured; and measures to be taken if success is not achieved.

6.1.2 Habitat Compensation Options

DFO (1999) provides the following hierarchy of preferences to compensate for affected habitat:

- create or increase the productive capacity of similar habitat (**like-for-like**) at or near the development site within the same ecological unit (*e.g.,* gravel placement; instream, bank and riparian habitat enhancement; removal of permanent fish passage obstructions for same species);

- create or increase the productive capacity of different habitat (**unlike**) in the same ecological unit (*e.g.,* gravel placement; instream, bank and riparian habitat enhancement; watershed restoration; removal of permanent fish passage obstructions);
- create or increase the productive capacity of a different ecological unit (**different**); and,
- artificial propagation (the least desirable option).

An ecological unit is defined as "populations of organisms considered together with their physical environment and the interacting processes amongst them." The ecological value of the existing habitat must be considered before moving down the hierarchy of compensation options.

The selection of the most appropriate option or options will depend on the existing watershed conditions, life history of the species affected, factors limiting habitat productivity and technical feasibility and long-term success of restoration and enhancement options. Proponents should consult with provincial, territorial and federal authorities, technical specialists and knowledgeable public representatives to identify appropriate compensation opportunities in or near the affected watercourse. It is important to take into consideration the regional fisheries management priorities or goals that may apply to the affected watercourse.

While proponents are responsible for achieving "no net loss", in some situations there may be advantages for DFO and/or its partners to complete additional measures that would result in net gain of productive capacity at the habitat compensation site by taking advantage of background information and logistical support. An example would be where an area was identified as having potential for significant habitat enhancement that would be far in excess of the requirements to meet "no net loss".

Same Habitat in Same Ecological Unit

DFO's preference is to provide for replacement of the affected habitat with similar habitat as close as possible to the affected area. This is based on the assumption that the supply of suitable habitat ultimately limits fish populations and that like-for-like compensation maximizes the potential for achieving "no net loss", without actually requiring the comparison of productive capacity before and after pipeline construction. In some situations it may not be possible to accept anything other than like-for-like compensation if the importance of the habitat being compensated for is too great.

Habitat at or near the development site can be restored, enhanced or created using riparian, bank and instream techniques discussed in Section 6.2. The selection of a particular technique depends largely on the existing site conditions including life history, stream hydrology, bank stability, icing conditions, soils, surrounding vegetation and reasons for limited productive capacity or observed damage. It is also necessary to understand how habitat will function once work is completed, the maintenance requirements of any structures, the life expectancy of materials used and any problems that could be created. This will help minimize future costs and impacts.

Year-round or seasonal habitat can be created by removing obstructions that prevent access to suitable spawning, rearing, or overwintering habitat. These include old, improperly installed or failed culverts, natural barriers, and debris dams. Channel modifications and gravel placement can be used to create new spawning, incubation and rearing habitat with suitable substrate and flow conditions. Rearing and feeding habitat can be created by installing bank and instream structures that create overhead and lateral cover.

Note however that experience has shown that site-specific projects are much more likely to yield only short-term results, create habitat at the expense of other areas, or fail altogether, than projects that consider the entire watershed. Measures that deal directly with fundamental problems in catchments or watersheds are most beneficial over the long-term.

Different Habitat in Same Ecological Unit

In situations where site-specific issues are well understood, limitations to productive capacity are known, or local management plans provide clear objectives for the fishery, alternative measures lower on the hierarchy may be most appropriate.

For example, a portion of wetland feeding habitat supporting minnow species will be destroyed. However, according to documentation in the local fisheries management plan, this type of habitat is in reasonably abundant supply. In consideration of the fisheries plan objectives, a preferred compensation option might therefore be to enhance a nearby gravel spawning habitat, since it is known to be in limited supply for another species. In many cases, riparian enhancement will be equally or more beneficial than instream habitat enhancement. This may justify unlike compensation.

In other situations, moving down the hierarchy may present a better opportunity for maximizing the amount of habitat gained, particularly where there are known limitations (or bottlenecks). As an example, riparian restoration may be equally or more beneficial than instream habitat enhancement in degraded watersheds. Allowances can be made for these situations, at the discretion of DFO.

The productive capacity of existing habitat at or near the development site can be increased by measures such as: corridor fencing to allow riparian vegetation recovery; instream, bank and riparian habitat enhancement using structures described in Section 6.2; and road deactivation and rehabilitation to control sediment loading. These same measures can also be used to improve habitat in a different ecological unit if opportunities are not available near the development site.

Different Ecological Unit

In the event that habitat restoration or enhancement opportunities do not exist in the same catchment or watershed, proponents may be asked to identify techniques that will improve habitat in another ecological unit. The techniques summarized in Section 6.2 would also be applicable in this case.

Several cumulative effects management measures have been implemented for compensation. These include stewardship or community watershed programs that deal with non-point water quality concerns; riparian fencing programs on grazing lands; and radio-telemetry studies to help quantify productive capacity (*e.g.,* location and extent of critical spawning or overwintering habitat). One challenge with these different approaches is the need to quantify both loss and compensation offsets.

Restoration of Orphan Sites

The clean-up or restoration of altered, disrupted, or degraded habitats for compensation purposes is considered to be a useful practice and is generally encouraged. This option is applicable to any level in the compensation hierarchy. This may be considered for sites with no known responsible owner, where the disturbance occurred with an outdated legal or policy framework, and where legal and liability agreements can be reached. Compensation should be consistent with local fish management plans where they exist, and partner agency objectives should be considered.

Restoration as compensation is not appropriate at "non-orphaned sites," as these should be cleaned up by the responsible party/owner. Neither should it be considered when government is investing in or financing the cleanup.

Habitat Banking

Habitat banking occurs when a proponent creates or improves fish habitat for future use as compensation (*i.e.,* prior to an authorization being issued). The location and design of a habitat bank must first be approved by DFO and proponents must provide data describing the "before" conditions before habitat banking work is begun.

Habitat banking sites should be worthy of restoration or enhancement, land ownership and access should be clear, and all required permits must be in place. Habitat banks are useful in situations where a proponent needs to compensate for several small HADDs, and few compensation options exist at the site(s). Habitat banking may have the benefit of requiring smaller replacement ratios, since effectiveness is already known. During the time between the creation of the new habitat and its use as compensation, fish benefit from the existence of the habitat bank and a net gain of productive capacity occurs.

The creation of a habitat bank does not "pre-approve" any future HADDs as all projects will be reviewed on their own merits. The use of a habitat bank is considered at the request of the proponent, but all on-site compensation options must be explored before using the habitat bank. A habitat bank must be evaluated immediately prior to its use as compensation to ensure that the bank is functioning properly and determine its value relative to original conditions. If only a portion of the bank is to be used in any given year, it is important to document what part of the bank is still available for use as future compensation. If the productive capacity of any bank or part thereof increases after it has been used as compensation, this increase will not be considered additional banked habitat.

Measures of Last Resort

Artificial propagation, deferred compensation, and restoration of chemically contaminated sites are measures of last resort and only where they can effectively achieve "no net loss". Given the risk associated with each of these approaches, approval of a DFO senior regional manager is required.

Artificial propagation is a capital- and maintenance-intensive method to replace a natural habitat's productive capacity and is by far DFO's least preferred option. It is generally not accepted in cases where natural habitat is lost and will only be considered in rare cases where DFO determines that it is in the public interest.

Deferred compensation refers to compensation that is done at some point in the future. For example, there may be no immediate opportunity to compensate for a project in a pristine area. Deferred compensation requires that a detailed strategy and plan be included in the authorization. This approach may require larger replacement ratios to offset the extended loss of productive capacity during the time that compensation is deferred.

6.1.3 Determining the Amount of Compensation Required

The amount of compensation must be determined based on the residual net loss of productive capacity after relocation, redesign and mitigation have been taken into consideration. Compensation usually requires a compensation ratio that exceeds 1:1 to ensure that "no net loss" occurs, allowing for time lags and uncertainty of success. Lower ratios are acceptable where compensation works are completed and functional before habitat loss occurs. In most cases, replacement ratios increase as the proponent moves down the compensation hierarchy and certainty of "no net loss" decreases. Appropriate scientific tools are generally used to determine appropriate compensation ratios (*e.g.,* Minns 1995, 1997; Minns *et al.* 1995, 1996; Portt *et al.* 1999).

6.2 Mitigation and Compensation Techniques

Habitat protection, restoration and enhancement of aquatic and riparian habitat may be conducted in conjunction with pipeline crossings to avoid or compensate the effect of construction activities. Riparian habitat refers to the unique vegetation community found between a waterbody and the surrounding upland. This vegetation develops on banks, floodplains and wetlands with soils that are wet during some portion of the growing season (Meehan 1991). These riparian areas support diverse migratory bird, wildlife and plant communities and are an important component of aquatic habitat because they provide food, shade and cover and help stabilize streambanks.

Habitat restoration and enhancement is most frequently undertaken in sensitive streams with species that are rare, at risk, or of recreational, economic, subsistence, or scientific interest. A variety of protection, restoration and enhancement techniques are available and qualified specialist advice should be obtained to identify what effects could occur, what mitigation is required and to select the most appropriate method or combination. Specific procedures are described for bank and riparian habitat in Section 6.2.1 and instream habitat in Section 6.2.2. The selection of a particular technique depends largely on the existing site conditions including stream hydrology, bank stability, icing conditions, soils, surrounding vegetation and reasons for observed damage or limited productive capacity.

It is also necessary to understand how the restored watercourse will function once work is completed, the maintenance requirements of any structures, the life expectancy of materials used and any problems that could be created. This will help ensure that aquatic and riparian habitat is protected or enhanced in a way that minimizes future costs and impacts.

Considerable cost savings can be realized by using equipment and local materials that are already available at the time of construction. In some cases however, rehabilitation and enhancement work will need to be done at a different time than pipeline installation.

Ideally, proponents should consider their long-term development plans and identify opportunities for sequential or co-operative restoration and enhancement programs within a watershed. Experience has shown that site-specific projects are much more likely to yield only short-term results, or fail altogether, than projects that consider the entire watershed.

Where work is not undertaken by professionals under an established Code of Practice, proponents should consult with the local or regional fisheries biologist, regional DFO representative, other regulatory agencies, qualified technical specialists and public representatives to identify the most appropriate mitigation and compensation procedures. In all cases, proponents must ensure that necessary approvals are obtained for proposed protection, restoration and enhancement work.

6.2.1 Bank and Riparian Habitat Restoration and Enhancement

Bank and riparian habitat is directly affected by grading and clearing, and may also be indirectly affected by changes in surface and groundwater flow patterns, or through trampling, grazing and erosion where animals and recreational users utilize the right-of-way. Disturbance of riparian and bank areas can result in direct and indirect effects on water quality, water temperature, channel patterns, as well as fish and wildlife habitat availability and productivity.

Restoration or stabilization of stream banks may be required to minimize erosion or undertaken to restore or enhance nearshore fish habitat for compensation purposes. Stream bank erosion is a concern where sediment is deposited in downstream habitats such as spawning, rearing and overwintering areas. Special care should be exercised in stabilizing the outside bends of streams, since such areas are subject to greater erosion pressures. The following additional issues or concerns are associated with water crossing construction in riparian areas:

- riparian habitat may be directly affected by siltation resulting from pipeline construction activities; and
- water quality may also be indirectly affected by changes in surface and groundwater flow patterns resulting from pipeline construction, or through trampling, grazing and erosion where animals and recreational users utilize the right-of-way.

A variety of site-specific and watershed management techniques are available to restore or enhance riparian and bank areas. Site-specific techniques are summarized in **Table 6.1**; appropriate Drawings are also referenced. Proponents should consult with technical specialists and public representatives to identify appropriate watershed restoration and enhancement procedures such as riparian fencing or public awareness.

At typical watercourse crossings where the banks are graded to a low angle, nearshore rearing and holding habitat is limited following completion of construction. Natural materials such as boulders (riprap and rock armouring), root balls and trees placed or anchored on streambanks can enhance nearshore habitat by providing hiding and resting places for juvenile and adult fish. The objectives of these methods are to provide economical, short- to long-term bank stabilization structures with a natural appearance and relatively low maintenance requirements.

Methods that increase the angle of the bank can also be installed. These include: fibre and grass rolls; logwalls and cribwalls; overhangs and lunker structures; brush layering, matting and bundles; tree revetments; and shrub planting and transplants. The objectives of these methods are to increase nearshore depth and encourage development of self-sustaining, overhanging plant cover. Many of these structures have a limited life span, so they should be designed to encourage natural bank development. Biodegradable products should be used whenever possible.

A long-term monitoring and maintenance program should be initiated to maintain the integrity of riparian and bank restoration and enhancement projects (Section 7.2).

6.2.2 Instream Habitat Restoration and Enhancement

The key characteristic of productive instream habitat is diversity. When properly used, instream structures and techniques can restore or enhance important or critical features such as spawning and food producing areas, cover and overwintering habitat. Spawning areas must provide a suitable environment during the egg laying, incubation and fry emergence periods. Food producing areas have substrate, depth and flow conditions that support aquatic invertebrates and forage fish. Instream cover provides fish protection from high current velocities and predators. Overhanging vegetation, undercut banks, submerged objects, depth and water turbulence provides cover (Wesche 1985).

A variety of site-specific and watershed management techniques are available to restore or enhance instream habitat. A general discussion of site-specific instream restoration and enhancement techniques is provided below. Additional information is summarized in **Table 6.2** and Drawings are provided in Appendix A. Note that care must be taken to select suitable techniques, particularly for instream enhancement. Experience has shown that installation of ‘enhancement’ features that do not adequately reflect natural waterbody hydrology or ecology can create unwanted and undesirable long-term effects.

Removal of permanent obstructions to fish passage is an effective technique used to compensate for HADD. Instream barriers and debris can be natural (beaver dams, rocks, woody debris, falls) or man-made (garbage, culverts). Removal of barriers to fish movement can restore watershed connectivity by providing access to suitable spawning and rearing areas. Instream debris and barriers can slow stream flow, causing sediment deposition, increased water temperature and erosion where the debris redirects stream flow. Since natural barriers and debris also provide cover and overwintering habitats, technical specialists should be involved to determine whether these structures are beneficial or damaging habitat. Care should also be taken to ensure that removal of barriers or debris does not result in unintended effects on downstream habitat.

Bank rehabilitation and enhancement measures such as boulders, root balls, tree revetments, cribwalls and overhangs described in the previous section also provide or improve instream habitat for juvenile and adult fish. Logs, boulders, root balls and trees can also be placed in the stream channel to provide lateral and overhead cover and rearing habitat, establish meanders or pools and protect eroded banks.

Table 6.1 Bank Restoration and Enhancement

Description	Advantages	Disadvantages	Comments
BOULDER PLACEMENT AND BANK ARMOURING (Dwg. No. 23)			
• Riprap or boulders placed on bank. • Can be combined with geotextiles to prevent undercutting and erosion.	• Stable at almost all flow levels. • Very durable; low upkeep. • Simple to install. • Provides instream cover and macro-invertebrate habitat.	• Requires heavy machinery. • Unnatural appearance. • Suitable material may not be readily available.	• Suitable for all watercourses with coarse bottoms. • Proper placement is critical to avoid undesired effects. • Can be used in combination with most other techniques.
TREE REVETMENTS AND ROOT BALLS (Dwg. Nos. 24, 32)			
• Clean root balls or woody material anchored into streambanks. • Conifers anchored into streambanks with branches intact and butt end upstream.	• Installation is relatively easy and inexpensive. • Provides immediate cover and rearing habitat, bank stability, and sediment collection. • May also be used to improve channel conditions (pool-riffle ratio; meanders) and protect eroding outside bends. • Natural appearance.	• Can be washed away or damaged by high flows and ice. • May not provide long-term stability or habitat. • Tree revetments may be considered unsightly as needles fall off. • Stabilization of opposite bank may be required.	• Most suitable in low to moderate gradient watercourses. • Trees should be largest available. • Can be used in combination with rock clusters for additional protection.
GABIONS AND SHEET PILING (Dwg. No. 25)			
• Rock-filled wire or plastic baskets anchored into streambank. • Sheet piling anchored in streambank.	• Provides long-term stability for bank and slope toe. • Can be used on steep slopes or where suitable riprap material is not available. • Simple to construct.	• Expensive and labour intensive. • Usually requires heavy machinery. • Baskets can deteriorate, leaving unsightly and unsafe wire ends. • Difficult to repair if undermined. • Unnatural appearance. • Susceptible to erosion at upstream end if improperly installed.	• Riprap generally preferred on shallow to moderate slopes. • Appearance can be enhanced with sod or superficial brush / shrub layering.
FIBRE COIR LOGS AND GRASS ROLLS (Dwg. Nos. 26, 27)			
• Fibre coir logs - biodegradable logs constructed of interwoven coconut fibres. • Grass rolls - clumps of sod bound tightly into a sausage shape with burlap. Holes cut to expose shoots.	• Provides temporary stability for bank and slope toe. • Provides growth medium. Do not require heavy equipment for installation.	• Susceptible to dislodging. May not provide long-term stability or habitat. • Labour intensive.	• Most suitable as temporary solution to allow vegetation to become established. • Most suitable for small waterbodies with low banks. • Slow, low gradient watercourses

Table 6.1 Bank Restoration and Enhancement, Cont'd

Description	Advantages	Disadvantages	Comments
LIVE STAKING AND TRANSPLANTS (Dwg. No. 28)			
• Planting of individual dormant cuttings. • Transplanting individual plants or sod from immediate area or nursery stock.	• Uses readily available, native materials. • High success rate with proper species and procedures. • Transplanted shrubs and trees can provide immediate cover. • Provides both aquatic and terrestrial habitat.	• Unsuitable for dry soils. • Large projects may require material from multiple sites. • Heavy machinery required to transplant large shrubs and trees. • Suitable nursery stock may not be available or economic. • Many transplants do not survive as they are eaten by wildlife and cattle.	• Cuttings should be dormant; most successful in early spring. • Watering can increase survival. • Stakes may be used to anchor brush bundles, brush mattresses and erosion control blankets. • Obtain permission if transplants are to be taken from off right-of-way.
LOGWALLS AND CRIBWALLS (Dwg. No. 29)			
• Logwall - a log retaining wall installed to create a vertical bank. Held in place with vertical pilings. • Cribwall - a logwall with a system of offset cross logs that anchor the structure.	• Maintains nearshore stream depth, bank slope and provides erosion control. • Less expensive than rock structures. • Long-term protection if well maintained. • Provides some overhead cover for fish. • Will deteriorate over time to restore “natural” bank.	• Requires heavy machinery and ongoing maintenance. • Somewhat artificial appearance. • Time consuming and labour intensive. • Structure deteriorates over time (e.g., 3 years untreated wood, 12 years treated wood).	• Most suitable in watercourses with eroding banks, stable channel and flows with low to moderate gradient. • Structure will last longer if all wood is submerged. • Can be used in series.
BRUSH LAYERING (Dwg. No. 30)			
• Fill slopes consisting of alternating layers of soil and live branches. • Brush layers of criss-crossed branches angled into slope. • Can be combined with geotextiles on steep slopes.	• Provides erosion control and overhanging cover almost immediately. • Uses readily available, natural materials. • Can be conducted at time of construction. • Provides terrestrial habitat.	• Least suitable during active growing season. • Construction is labour intensive.	• One of best techniques for stabilizing slopes and streambanks. • Can be combined with armouring and other methods.
LIVE SILTATION			
• bury branches along high water mark and backfill with rock	• Promotes silt entrapment along bank. • Produces bank protection and overhead cover. • Relatively easy to construct.	• Least suitable during active growing season. • Construction is labour intensive.	• Can be combined with other erosion control measures.

Table 6.1 Bank Restoration and Enhancement, Cont'd

Description	Advantages	Disadvantages	Comments
BRUSH BUNDLES, FASCINES OR WATTLES			
• Bundles of live cuttings tied to produce sausage shaped bundles. • Planted in shallow trenches anchored with wooden or live stakes.	• Can be used to direct or slow water movement and encourage vegetation growth on bank. • Don't require heavy equipment for installation.	• Provides very limited structural stability. • Least suitable during active growing season. • May rot and require extensive maintenance. • Construction is labour intensive.	• Can be combined with other erosion control measures.
BRUSH MATTING			
• Mattress-like layer of branches placed over slope to protect soil and slow water movement.	• Provides bank protection and encourages vegetation regrowth. • Uses readily available, natural materials. • Can be conducted at time of construction.	• Least suitable during active growing season. • Construction is labour intensive.	• Can be combined with armouring and other methods.
EXCLUSION FENCING			
• Installation of fences to exclude livestock and vehicles.	• Prevents trampling, rutting and erosion. • Allows natural growth or recovery of riparian vegetation and banks. • Most effective technique to restore banks or watercourses damaged by livestock.	• Relatively expensive and labour-intensive. • Requires landowner agreement. • Ongoing inspection and maintenance.	• Fence should be set back far enough to allow for vegetation growth and lateral channel movement. • Livestock watering and crossing sites may be necessary.

Table 6.2 Instream Habitat Restoration and Enhancement Techniques

Description	Advantages	Disadvantages	Comments
INSTREAM COVER Rock Clusters (Drawing No. 31)			
• Boulder groupings placed on streambed.	• Simple and effective technique to provide overhead and lateral cover and rearing habitat. • May also be used to improve channel conditions (pool-riffle ratio; meanders) and catch granular materials. • Natural appearance. • Inexpensive materials.	• Suitable material may not be readily available. • Requires heavy equipment. • Improper placement may cause bank erosion by altering streamflow dynamics.	• Proper placement is critical to avoid undesired effects. • Can be used in combination with most other techniques.
INSTREAM COVER Tree Revetments and Root Balls (Drawing Nos. 24, 32)			
• Clean root balls anchored into streambanks or streambed. • Conifers anchored into streambanks with branches intact with butt ends upstream.	• Installation is relatively easy and inexpensive. • Provides immediate cover and rearing habitat, bank stability, and sediment collection. • May also be used to improve channel conditions (pool-riffle ratio; meanders). • Natural appearance.	• Can be washed away by high flows and ice. • May not provide long-term stability or habitat. • Tree revetments may be considered unsightly as needles fall off. • May require stabilization of opposite bank.	• Most suitable in low to moderate gradient watercourses. • Can be used in combination with most other techniques.
INSTREAM COVER Submerged cover (Drawing No. 33)			
• Submerged log or log slab secured in watercourse to provide cover. • Submerged artificial cover such as swamp weights or irrigation chute.	• Inexpensive and easy to install or adjust. • Can be used as temporary or permanent structure. • Logs have natural appearance.	• Not effective in watercourses with wide fluctuations in flow. • Can catch debris if not installed properly. • Artificial cover has unnatural appearance.	• Most suitable in small to medium sized watercourses with low to moderate gradient and not subject to extreme flooding or ice damage. • Can be used in combination with most other techniques. • Natural cover materials preferred.
BANK COVER Logwalls and Cribwalls (Drawing No. 29)			
• Logwall - a log retaining wall installed to create a vertical bank. Held in place with vertical pilings. • Cribwall - a logwall with a system of offset cross logs that anchor the structure.	• Maintains nearshore watercourse depth. • Less expensive than rock structures. • Long-term protection if well maintained. • Provides some overhead cover for fish. • Will deteriorate over time to restore "natural" bank.	• Requires heavy machinery and ongoing maintenance. • Somewhat artificial appearance. • Time consuming and labour intensive. • Structure deteriorates over time (e.g., 3 years untreated wood, 12 years treated wood.	• Most suitable in watercourses with eroding banks, stable channel and flows and low to moderate gradient. • Structure will last longer if all wood is submerged. • Can be used in series.

Table 6.2 Instream Habitat Restoration and Enhancement Techniques, Cont'd

Description	Advantages	Disadvantages	Comments
BANK COVER Bank Overhangs (Drawing No. 34)			
• Artificial overhang of concrete, timber, or gabion baskets tied into streambank. • Can be covered and revegetated.	• Provides stable overhead cover and offers some bank protection. • Confines streamflow. • Natural appearance once revegetated.	• Construction is labour intensive and can be costly. • If current is diverted, downstream bank stabilization may be necessary. • Not durable in large watercourses. • Can be damaged by ice.	• Most suitable in watercourses with stable channel and flows and low to moderate gradient. • Structure will last longer if all wood is submerged. • Can be used in series or placed opposite deflectors to scour out a pool under the cover. • Should not extend beyond natural stream bank to prevent downstream erosion.
BANK COVER Wing Deflectors (Drawing Nos. 35, 36)			
• Triangular structures made of rock or logs that create a narrower, deeper channel with increased flow velocity.	• Can help keep downstream areas free of sediments. • Can produce cover by scouring pools and creating undercut banks.	• Can be costly, and require heavy equipment. • Can cause erosion problems and bank instability. Downstream bank stabilization may be necessary. • Unnatural appearance.	• Proper placement is critical. • Most suitable in watercourses with low to moderate gradient, especially wide, slow flowing reaches. • Can be used in series or combination with cover on opposite bank. • Contact DFO to determine if *Fisheries Act* Authorization is required.
BANK COVER Groynes (peninsular deflectors) (Drawing No. 37)			
• Peninsular structures made of rock that are used to redirect flow.	• Can help keep downstream areas free of sediments. • Can produce cover by scouring pools and creating undercut banks. • Provides fish habitat. • More effective then continuous bank protection.	• Can cause erosion problems and bank instability. Downstream bank stabilization may be necessary. • Unnatural appearance. • During high flows, results in severe erosion downstream of groyne.	• Proper placement is critical. • Most suitable in watercourses with low to moderate gradient, especially wide, slow flowing reaches. • Can be used in series or combination with cover on opposite bank. • Contact DFO to determine if *Fisheries Act* Authorization is required.

Table 6.2 Instream Habitat Restoration and Enhancement Techniques, Cont'd

Description	Advantages	Disadvantages	Comments
OVERPOUR STRUCTURE Dams (Drawing Nos. 38, 39)			
• Low profile dams constructed of rock or logs. • Log structures include single log dam, K-dam, wedge dam, and plank dam.	• Provides resting habitat and plunge pools in high gradient waters. • Can retain gravel. • Aesthetically appealing. • May increase dissolved oxygen.	• Construction is labour intensive and relatively expensive. • May block sediment transport, filling in area above dam. • Unstable at high flows. • Failure and high liability.	• Proper placement is critical. • Moderate to high gradient watercourses with stable flows where significant impoundment will not occur. • Contact DFO to determine if *Fisheries Act* Authorization is required.
OVERPOUR STRUCTURE V-Weir (Drawing Nos. 40, 41)			
• Log or rock structures placed in a V shape across the watercourse.	• Can create pool habitat, cover and retain gravel. • Economical.	• Can cause erosion problems and some bank instability. • Requires heavy equipment.	• Proper placement is critical. • Most suitable in small watercourses with low gradient. • Contact DFO to determine if *Fisheries Act* Authorization is required.
SUBSTRATE MANIPULATION Gravel Placement			
• Clean gravel placed on streambed. • Minimum depth is 1.0-1.8 m.	• Clean gravel may be used during construction for dams and crossing structures. • Economical.	• Temporary. • Suitable material may not be readily available. • Requires heavy equipment. • Over time, gravel may be easily washed downstream or filled with sediment.	• Most suitable in small to medium watercourses with low to moderate flow and low sediment load.
SUBSTRATE MANIPULATION Excavated Pool, Run (Drawing Nos. 42, 43)			
• Artificial pool or run excavated in streambed with heavy equipment.	• Immediate resting habitat and cover.	• Excavated areas fill easily with transported sediment from run-off. • Temporary. • Requires heavy equipment.	• Most suitable in small to medium watercourses with low sediment transport capability. • May be used in combination with bank cover or current deflectors. • Approval required.

Table 6.2 Instream Habitat Restoration and Enhancement Techniques, Cont'd

Description	Advantages	Disadvantages	Comments
SUBSTRATE MANIPULATION Gravel Cleaning			
• Cleaning of spawning gravel by vaccuuming, mechanical scarification or hydraulic flushing.	• Immediate improvement in gravel quality for spawning and aquatic invertebrates.	• Most techniques require heavy machinery. • Fine sediments washed downstream may degrade habitat and water quality. • Aquatic invertebrate production in cleaned area may decline. • Temporary.	• Employed primarily in spawning channels or lake tributaries. • Limited application in natural watercourses because of potential for downstream effects.
DAMS AND DEBRIS Debris Removal			
• Removal of rocks, trash or woody debris that are damming or blocking the stream channel.	• Can restore channel patterns and provide access to upstream spawning or rearing habitat.	• Can reduce habitat quality if poorly implemented.	• N/A
DAMS AND DEBRIS Culvert Repair			
• Repair or replacement of existing culverts that are barriers to fish movement.	• Can restore channel patterns and provide access to upstream spawning or rearing habitat.	• Constant inspection and maintenance may be necessary. • High maintenance.	• Repair or replacement can be effective compensation technique. Possible 'band-aid' solution if culverts are inappropriate in the first place.
DAMS AND DEBRIS Beaver Management			
• Permanent beaver dam removal or opening passages in dams during critical periods.	• Can provide access to upstream spawning or rearing habitat.	• Constant inspection and dam removal may be necessary. • High maintenance.	• Most beaver dams are best left in place. • Beaver dam removal requires approval in most provinces.

Current deflectors are one of the most commonly used structures to manipulate instream habitat. They are relatively inexpensive and easy to construct and can: be built from a variety of materials; be adapted to site conditions and a variety of stream sizes; be used in conjunction with other techniques; and fulfill more than one purpose. Deflectors can be built to: direct currents to desired locations; develop meander patterns; deepen and narrow channels; deepen pools and scour sediment; increase water velocities; keep flow out of side channels; encourage silt bar formation; maintain low water temperatures; and enhance pool-riffle ratios. Technical specialists should be involved to ensure that unwanted effects do not occur.

Current deflectors can be constructed of logs, rocks, boulders, gabions or various combinations of these materials. These structures are typically angled downstream and include triangular and peninsular shapes (wing deflectors and groynes, respectively). Structure height is generally determined from low flow conditions. Double-wing deflectors combining two current deflectors on opposite banks can also be used in larger streams to narrow the channel.

Low profile dams and weirs are multipurpose structures created from a variety of materials. Overpour structures are used to create pool habitat, raise water levels and collect and hold spawning gravel. They are most often used on small, high gradient streams and are relatively inexpensive, although construction is labour intensive. Their success depends on proper siting and construction; technical specialists should be involved to ensure that unwanted effects do not occur.

Substrate manipulation can be used in both warm- and cold-water habitats and includes placement or capture of suitable spawning materials and excavation of runs and pools. In streams with a natural bedload of granular spawning substrates, instream structures such as current deflectors, weirs and dams may be placed so that granular material is deposited and retained in suitable locations. Spreading clean gravel, especially when already used to construct dams for isolated watercourse crossings, can create spawning habitat if channel characteristics are appropriate. In streams with unstable flows or periodic flooding, catchment devices may be required to stabilize spawning substrates.

Proponents should consult with technical specialists and public representatives to identify appropriate watershed restoration and enhancement procedures. These include: road deactivation and rehabilitation; corridor fencing programs to protect waterbodies; sediment interception and retention; and public education programs to promote awareness of fisheries as well as fish habitat conservation and protection.

Instream structures have a limited life span and are susceptible to damage by floods and ice. A long-term monitoring and maintenance program should be initiated to maintain the integrity of restoration and enhancement projects and minimize unanticipated or unintended damage (Section 7.2). In addition, instream habitat restoration and enhancement may create an impediment to navigation. Before any structures are installed, proponents should contact TC to ensure no concerns exist or the correct approvals are obtained.

7 Monitoring Crossing Project Performance

In sensitive watercourses, or where there is concern regarding impacts on fish or fish habitat, specific watercourse crossing objectives may be specified prior to construction. As discussed in Section 1.3, proponents are also advised to develop corporate or project-specific watercourse crossing objectives for inclusion in environmental protection plans, bid documents and regulatory applications. These crossing objectives may be based on existing legislation, fisheries management objectives for the area, or discussion with appropriate regulatory authorities and could include measurable water quality values or biophysical criteria or thresholds. Construction-related objectives could include duration, location or quantity of instream and riparian construction activities.

Objectives will depend on the watercourse being crossed, the species and habitat present and the time of construction. For example, protection of spawning and incubating habitat will be of primary importance for a crossing proposed during the spawning period. In this case, objectives could specify appropriate flow levels and suspended sediment concentrations, or maintenance of desirable substrate characteristics during the spawning and incubation period.

Section 35 of the *Fisheries Act* refers solely to fish habitat, but DFO's *Policy for the Management of Fish Habitat* makes the link between habitat and productive capacity. Changes to productive capacity are not normally measured or estimated directly. Rather, the inferred change in productive capacity is based on an understanding of how physical, chemical and biological attributes describe habitat. Changes in these attributes are used as an indicator of changes in habitat and ultimately, productive capacity.

Guidance on performance attributes, criteria and objectives can be obtained from:

- existing water quality standards (*e.g.,* Canadian Council of Ministers of the Environment Water Quality Guidelines 1999);
- model outputs (*e.g.,* sediment dose models described in Anderson *et al.* 1996);
- construction monitoring programs; and
- specialist advice from aquatic scientists.

Once crossing objectives have been specified, construction inspection and monitoring and post-construction monitoring programs should be designed to evaluate crossing success (see Sections 7.1 and 7.2).

To identify opportunities where cost or risk can be minimized with no adverse biophysical effects, crossing success should be evaluated both after construction and after post-construction monitoring results are available. Ideally, all parties should be involved in these reviews, including: project managers; onsite inspection staff; environmental staff; contractors; technical specialists; and regulators.

7.1 Environmental Monitoring During Construction

7.1.1 Environmental Inspection

Environmental inspection of construction at watercourse crossings by the proponent is recommended on all watercourses that are rated as having medium or high sensitivity. Inspection during construction on low sensitivity water crossings may be incorporated as part of the construction inspection.

Environmental inspection should be performed to ensure that the mitigation measures warranted at the crossings are implemented in a manner that minimizes the adverse environmental effects of construction. Environmental protection planning is of little value if the protection measures are ignored or poorly implemented during construction. It is critical that inspection start prior to the initial right-of-way preparation to prevent any mistakes early in the construction sequence. Environmental inspectors should have the appropriate authority to take corrective action as warranted including suspending an activity until the contractor complies with approvals or until approval from the appropriate government agency is obtained.

Inspectors should be chosen on the basis of their understanding of environmental requirements, knowledge of construction techniques and ultimately, their ability to integrate the two in the field and under pressure. Inspectors who cannot practically apply their environmental training or deal with the contractors will not likely last long on a construction spread. Inspectors who have little environmental training may not make the correct decision under pressure as they may not have the academic knowledge required to support their decisions. Finally, inspectors need capable contacts in the office that can research or support their decisions when they need assistance in making a decision while in the field.

Roles of the inspectors include ensuring that the following is undertaken:

- all acts, regulations and permits are in place and followed;
- procedures and contingencies are in place including all equipment and back-up equipment;
- siltation and sedimentation are controlled along all segments of the watercourse;
- crossing is completed as quickly as possible; and
- the environment is protected.

Collection of monitoring data during construction allows effects on water quality, habitat, fish and other animals to be documented. This information can help to:

- provide feedback to construction staff;
- confirm the effectiveness of protection measures;
- fulfill legal requirements;
- provide evidence of compliance; and
- validate scientific predictions.

Over time, use of a standardized monitoring procedure will help develop a data set that can be used to validate impact predictions, improve predictive models and help select the most appropriate construction methods. One or more of the following environmental variables may be monitored during construction, depending on the concerns and crossing objectives:

- suspended sediment load before, during and after construction to provide feedback to construction personnel and document the zone of influence and changes in water quality;
- substrate composition before, during and after construction to document areas of sedimentation;
- biological monitoring, including abundance, density and community composition before, during and after construction;
- watercourse flows during construction to ensure that fish passage and minimum flows are maintained; and
- monitoring during blasting and diversion procedures.

The location and number of sampling locations will be a function of the anticipated zone of influence. This can be predicted using sediment deposition models or estimated based on the size and channel characteristics of the watercourse being crossed.

7.1.2 Suspended Sediment Load

Monitoring of suspended sediment load is the most common instream construction monitoring technique. This usually combines field monitoring of stream discharge and turbidity (a measure of transparency of the water column) with laboratory analysis of TSS and settleable solids concentrations. An empirical turbidity-TSS relationship is then derived, so that turbidity measurements can be used as an indicator of actual TSS and settleable solids levels (see Anderson *et al.* 1996). The presence of critical habitats may justify inclusion of additional sample sites, transects or other water quality parameters.

Established quantitative water quality guidelines for TSS and turbidity (*e.g.,* CCME 1999) are based on chronic exposure data and do not represent a realistic objective for short-term instream activities. This is because these long-term, low concentration standards may not be applicable to short-term high concentration events such as those associated with pipeline crossings. For this reason, some specialists have applied sediment-dose models to establish water quality objectives and evaluate actual effects. These models (*e.g.,* Newcombe and MacDonald 1991; Shen and Julien 1993; Anderson *et al.* 1996) predict effects on fish based on the duration and concentration of the sediment event, rather than a pre-established TSS/turbidity threshold.

A single suspended sediment load monitoring protocol has not been accepted due to the number of factors that affect sediment generation and transport and the influence of site-specific conditions. Qualified specialists should be involved to design a suspended sediment monitoring program, but the following discussion outlines some factors to be considered (see for example MacDonald and Bjornson 1993; Anderson *et al.* 1997; Clowater 1998).

Suspended sediment load monitoring should begin prior to construction and continue until water quality returns to control conditions and there is no potential for additional sediment plumes. Sampling immediately downstream of the crossing site (typically <100 m, the initial dilution zone) is important to document maximum sediment loads in the area with the highest potential for adverse effects. Depending on stream width, one or more samples should be taken at regular intervals across the watercourse. Surface samples are adequate in shallow watercourses (<0.5 m). Depth-integrated samples or samples taken from more than one depth may be required in deeper waters.

The first downstream site or transect should be regularly monitored prior to, during and immediately following, instream activities that have the potential to generate substantial sediment. Hourly sampling is appropriate immediately below the crossing site, but frequency can be reduced depending on the length of time of instream construction and when levels return to control conditions (*e.g.,* overnight). Sampling frequency may also be increased when instream activities are of short duration, or a specific sediment generating event is planned. It is recommended that a construction log be kept to allow suspended sediment load data to be compared to construction activities.

Additional samples will generally be required further downstream to monitor plume attenuation and determine the extent of the area affected by sediment release. Samples at these sites or transects may not warrant the same sampling intensity as the sampling sites immediately downstream of the crossing. However, supplementary samples should be added to document the start, peak and passing of sediment plumes.

Sampling should occur upstream of the crossing to provide "control" information on discharge and background levels of sediment load in the watercourse during construction. The upstream site should be located far enough upstream (typically >100 m) that it is not influenced by construction activity. Sampling frequency should be sufficient to detect natural variability in discharge and sediment load before, during and after construction.

7.1.3 Substrate Composition

Analysis of substrate composition downstream of the crossing site can be used to document the deposition of sediments due to construction, monitor the physical recovery of habitats following disturbance and help calibrate sediment transport models. A variety of techniques are available, including grab sampling, freeze-core sampling, sediment traps, visual surveys and direct measures of streambed porosity (see for example Weaver and Fraley 1991; Mudroch and MacKnight 1994; Anderson *et al.* 1996). The selection of the most appropriate monitoring program will depend on the program objectives and logistic considerations such as access, season, equipment availability and budget. Qualified specialists should be involved in program design.

Grab and freeze-core samples remove a small amount of the streambed for size distribution analysis in the laboratory. When samples are taken prior to and following construction at one or more sites, changes in the relative abundance of small diameter sediment particles can be determined and sediment deposition rates can be quantified.

Sediment traps are used to directly monitor the accumulation of small diameter sediment particles. Clean washed aggregates are used to fill a cylinder that is buried flush with the surface of the streambed. Traps are installed prior to construction activities along transects located both above and below the crossing site. They can be removed immediately after construction to assess deposition rates relative to the upstream controls, or be left in place to document sediment deposition and flushing over time.

In some watercourses, changes in channel and bottom profiles can be mapped at specified intervals along established transects. This method can be used to document changes in substrate composition following construction, identify areas of sediment accumulation and monitor recovery.

Standard visual survey or substrate description techniques can be used to compare substrate conditions prior to and after construction. The advantage of visual surveys is that they can be conducted quickly and relatively cheaply. However, they do not provide direct measures of sediment deposition and are affected by surveyor training and experience.

7.1.4 Biological Monitoring

The only way to directly measure effects on aquatic communities is to monitor aquatic invertebrate, fish, algae and riparian communities to detect reductions in biodiversity, abundance, or sensitive species and life stages. Due to the wide variety of habitats and techniques available, qualified specialists should be involved to design a practical and cost-effective biological program. The following discussion outlines some factors that should be considered (see for example Tsui and McCart 1981; Weaver and Fraley 1991; Davis and Simon 1995; Hauer and Lamberti 1996).

Aquatic invertebrates (which mainly consist of aquatic insects, mites, molluscs, crustaceans and worms) are the group of freshwater organisms most often used in aquatic biological monitoring (Resh *et al.* 1996). This is because aquatic invertebrates often live on the substrate, are sensitive to sediment deposition, are easy to monitor, are relatively immobile and are an important food source for fish and other riparian animals. Aquatic invertebrate monitoring can be used to document changes in substrate composition following construction, identify areas of sediment accumulation and track recovery.

Ideally, aquatic invertebrate sampling sites should be located above and below the crossing site in riffle habitats, where communities characteristic of streams and rivers are best represented, fauna diversity is highest and sensitive taxa are most likely to occur. Precise sampling locations should be selected to reflect the sediment plume mixing pattern and to ensure they have similar bottom substrate, depth, velocity, stream width, bank cover, etc. This will help to reduce natural sources of variability in the benthic samples and improve their effectiveness for assessing actual effects of pipeline construction. Benthic invertebrate monitoring data from control sites located upstream of the crossing will allow background natural variability in benthic invertebrate communities to be described.

Fish communities are sensitive, economically and socially important and respond to changes in habitat, water quality and human exploitation. Both community composition and the presence of sensitive species and life stages have been used to identify the responses of fish communities to disturbance. Since fish are relatively mobile and the effects of short-term sediment input are most likely to be sublethal, most surveys of fish communities are conducted prior to and following construction to evaluate effects on distribution, abundance, growth and species composition. Sampling may also be continued over time to evaluate subsequent recovery.

Algae that live on the bottom of waterbodies (periphyton) are at the base of the aquatic food chain and can be affected both directly and indirectly by suspended and deposited sediment. Periphyton have been used to evaluate effects on water quality because they have short life cycles, reproduce rapidly and, therefore, respond quickly to changes in water quality. Sampling design considerations are similar to those for benthic invertebrates, but fewer experienced specialists are available to analyze samples.

Monitoring of riparian habitat and biota may also be appropriate where riparian areas are identified as sensitive or unusual. A discussion of terrestrial monitoring techniques is beyond the scope of this document and qualified technical specialists should be consulted to help design a riparian monitoring program.

In some cases, use of more than one biological group or sampling technique may be required to fulfill legal requirements, evaluate effects on aquatic and riparian communities, or test predictions.

7.1.5 Monitoring During Blasting and Diversions

Specific monitoring requirements are generally specified in authorizations issued under Section 32 and/or Subsection 35(2) of the *Fisheries Act*. These typically include requirements to monitor fish distribution in the vicinity of the crossing prior to, during and following blasting and stream diversion activities as well as requirements to undertake and document fish salvage programs. Further measures may include monitoring to assess compliance and evaluation of effectiveness of fish habitat mitigation and/or compensation program.

Geophone or hydrophone monitoring may also be required to document pressure and impulse velocities during blasting.

7.2 Post-Construction Monitoring

A post-construction monitoring program should be based on specified watercourse crossing objectives and terms of authorizations, permits, licences or compensation agreements. Post-construction monitoring may be undertaken to:

- confirm that specific crossing objectives have been achieved;
- confirm the effectiveness of protection and compensation techniques;
- observe actual effects;
- observe recovery;
- determine the need for maintenance of structures and mitigative measures; and
- fulfill explicit mitigation and compensation requirements.

Typical post-construction habitat and biological monitoring programs last for at least one year and involve periodic monitoring of habitat, aquatic invertebrates, water quality, or fish species and life stage presence and numbers. Typically, measurements of predefined habitat parameters are combined with biological sampling at transects above and below the crossing site. Methods similar to those described above for construction monitoring are used in conjunction with upstream or nearby control areas so that the influence of natural ambient factors can be identified.

Post-construction monitoring should also include periodic inspection of erosion control and habitat restoration/enhancement structures so that necessary maintenance or replacement can be undertaken (Adams and White 1990).

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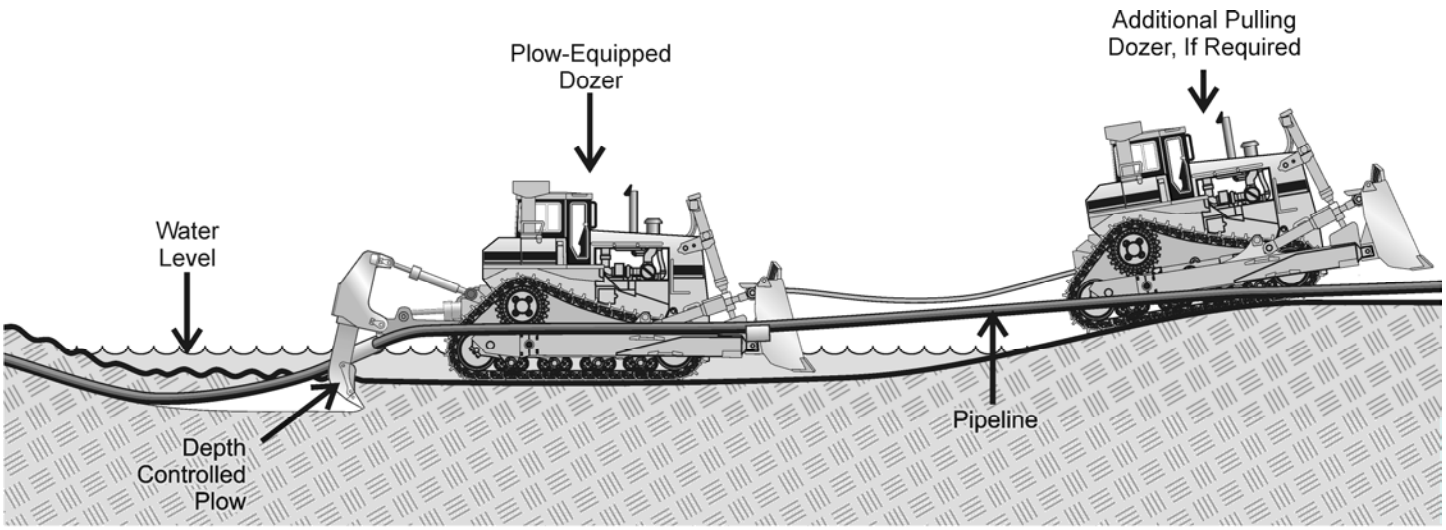
Appendix A Typical Watercourse Crossing Drawings

LIST OF DRAWINGS



PROFILE
(Not to Scale)

Notes:

1. Maintain a vegetation buffer at the crossing to the extent practical.
2. Install sediment and erosion control structures, as required.
3. Grade banks to allow access to watercourse by plowing equipment.
4. Complete construction of the instream pipe section.
5. Assist plow dozer with an additional pulling dozer, if warranted. Ensure adequate pulling power to plow through watercourse substrate is employed.
6. Regrade banks. Restore, stabilize and reclaim watercourse banks and approaches to as close to original grade as practical.

Source: Adapted from TERA 1998

CONSTRUCTION TECHNIQUE – TYPICAL PLOW

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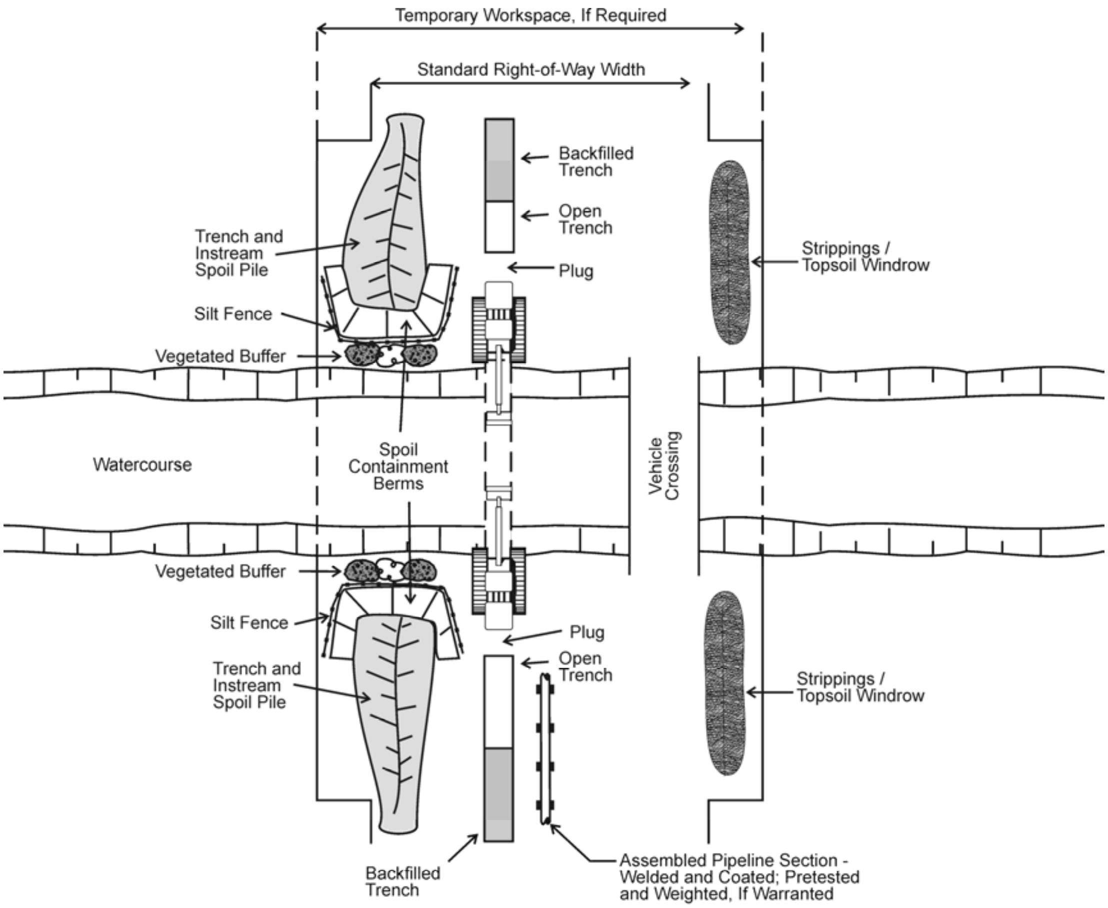

Plan View
(Not to Scale)

Notes:

1. Obtain additional temporary workspace to allow instream spoil to be stored on banks.
2. Install vehicle crossing if warranted.
3. Install sediment and erosion control structures, as required.
4. Leave plugs at end of standard trench.
5. Complete construction of the instream pipe section. Weight and pretest pipe, if warranted, prior to commencement of instream activity.
6. Trench through watercourse retaining hard plugs back from each bank until just prior to pipe installation. Stockpile all instream spoil on banks. Construct berms (*e.g.,* subsoil, saddle weights, shotrock) to prevent saturated spoil from flowing back into watercourse (see Dwg. 16). Maintain streamflow, if present, throughout crossing construction.
7. Lower-in and backfill immediately. Restore stream channel to approximate preconstruction profile and substrate. Attempt to complete all instream activity within 24 hours.
8. If necessary to control water flow and trench sloughing, install temporary soft plugs and dewater trench on to stable vegetated land, not directly to watercourse.
9. Restore, stabilize and reclaim watercourse banks and approaches to as close to original grade as practical.

Source: Adapted from TERA 1998

CONSTRUCTION TECHNIQUE – TYPICAL OPEN CUT OF SMALL WATERCOURSES

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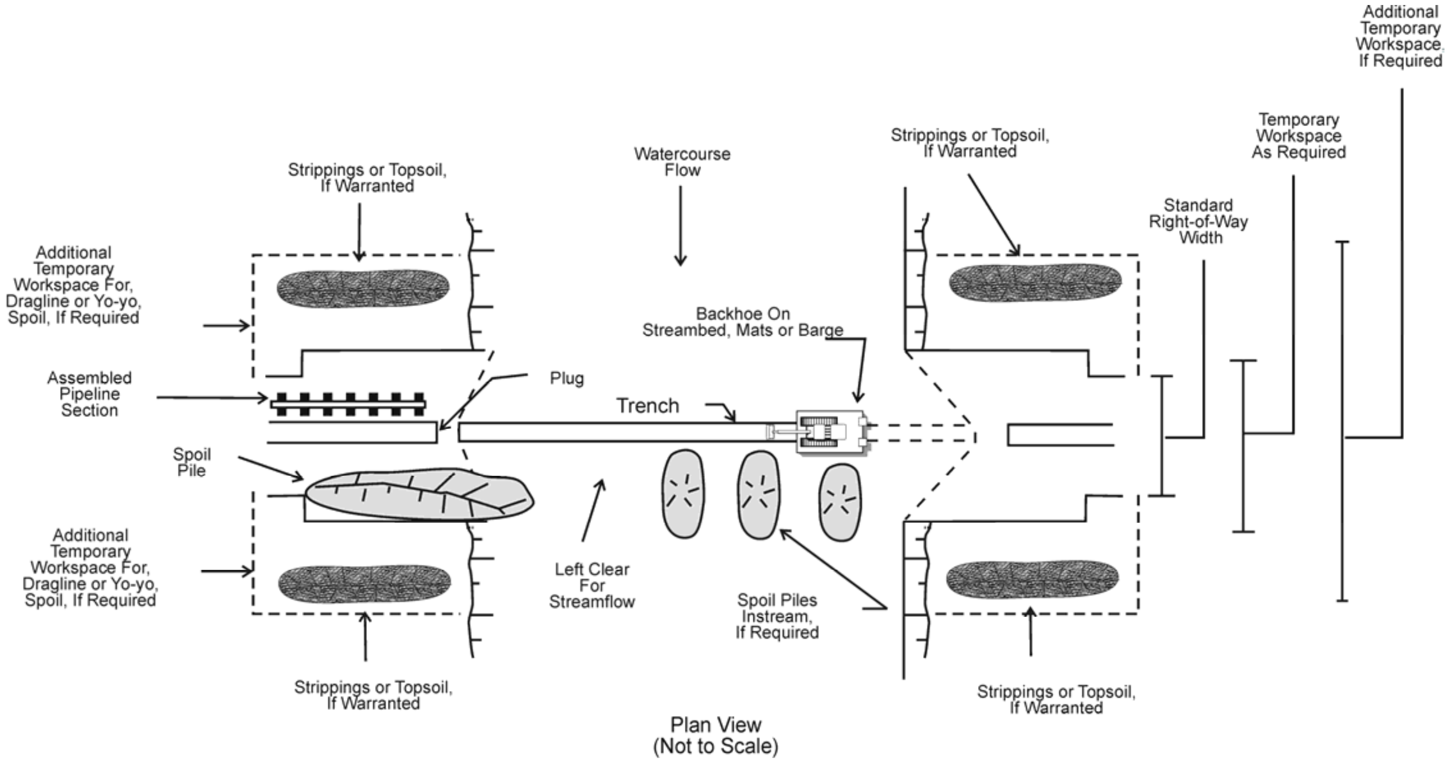

Notes:

1. Obtain additional temporary workspace to allow as much instream spoil to be stored on the banks as is practical.
2. Leave plugs at the end of the standard trench.
3. Install sediment and erosion control structures, as required.
4. Complete construction of the instream pipe section. Pretest and weight pipe well in advance of anticipated completion of instream trenching.
5. Retain plugs back from each bank until just prior to pipe installation. Stockpile as much spoil on banks as possible. Place instream storage spoil in piles avoiding areas of highest water velocity. Instream spoil should be piled in long piles parallel to flow in order to minimize erosion. Do not windrow spoil across the channel or block more than 2/3 of the channel. Maintain streamflow, if present, throughout crossing construction. Exact trenching and spoil storage requirements will depend on local conditions and equipment used.

5. If necessary, to control water flow and trench sloughing, install temporary soft plugs and dewater trench on to stable vegetated land, not directly to watercourse.

6. Lower-in pipe and backfill immediately. Restore stream channel to approximate preconstruction profile and substrate. Attempt to complete all instream activity as quickly as practical.
7. Restore, stabilize and reclaim watercourse banks and approaches to as close to original grades as practical.

Source: Adapted from TERA 1998

CONSTRUCTION TECHNIQUE – TYPICAL OPEN CUT OF LARGE WATERCOURSES

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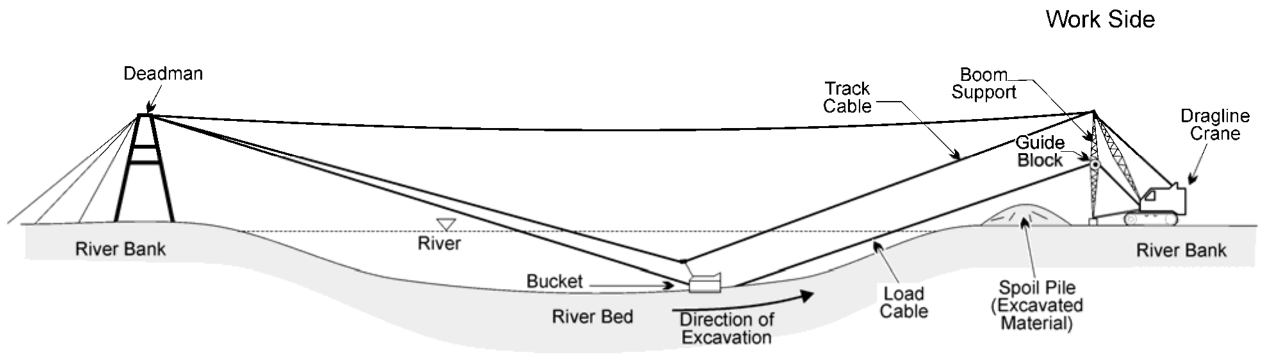
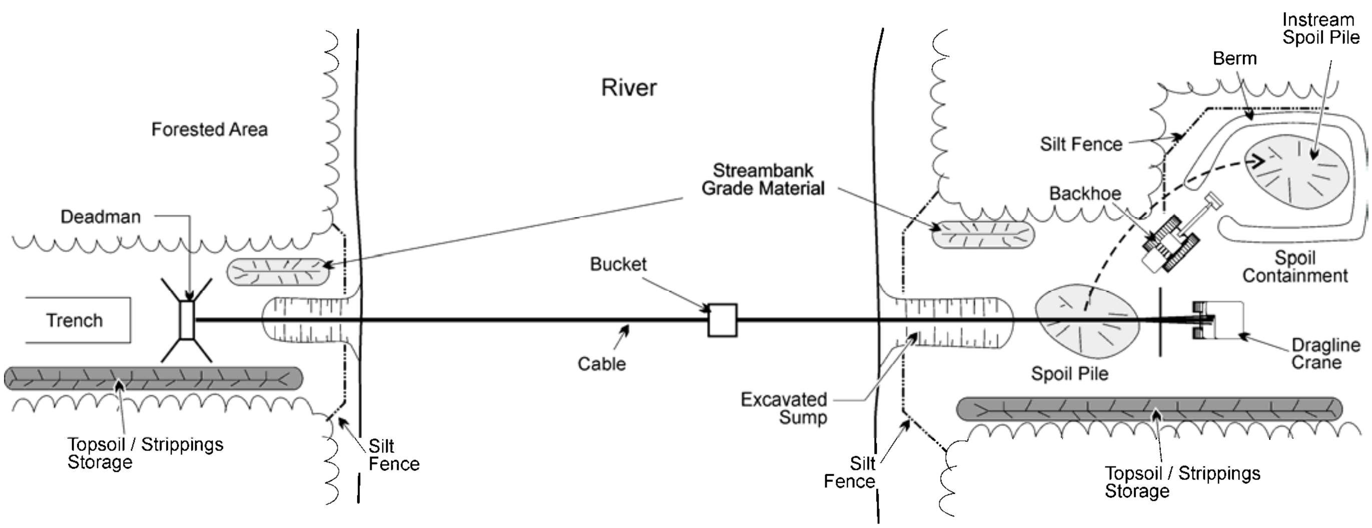
DWG. NO. 3



Profile
(Not to Scale)



Plan View
(Not to Scale)

Notes:

1. Schedule instream activity for low flow periods and for the appropriate timing window, if feasible.
2. Obtain additional temporary work space to allow instream spoil to be stored on banks.
3. Complete construction of the instream pipe section. Weight and pretest the pipe, if warranted, prior to commencement of instream activity.
4. Construct berm and/or sump to prevent saturated spoil from flowing back into watercourse. Use earth moving equipment to move excavated spoil to a remote storage pile. Attempt to complete all instream activity as quickly as practical.
5. Restore stream channel to approximate preconstruction profile and substrate. Restore, stabilize and reclaim watercourse banks and approaches to as close to original grades as practical.

Source: Adapted from Express Pipeline 1995, TCPL 1994

CONSTRUCTION TECHNIQUE – TYPICAL DRAGLINE

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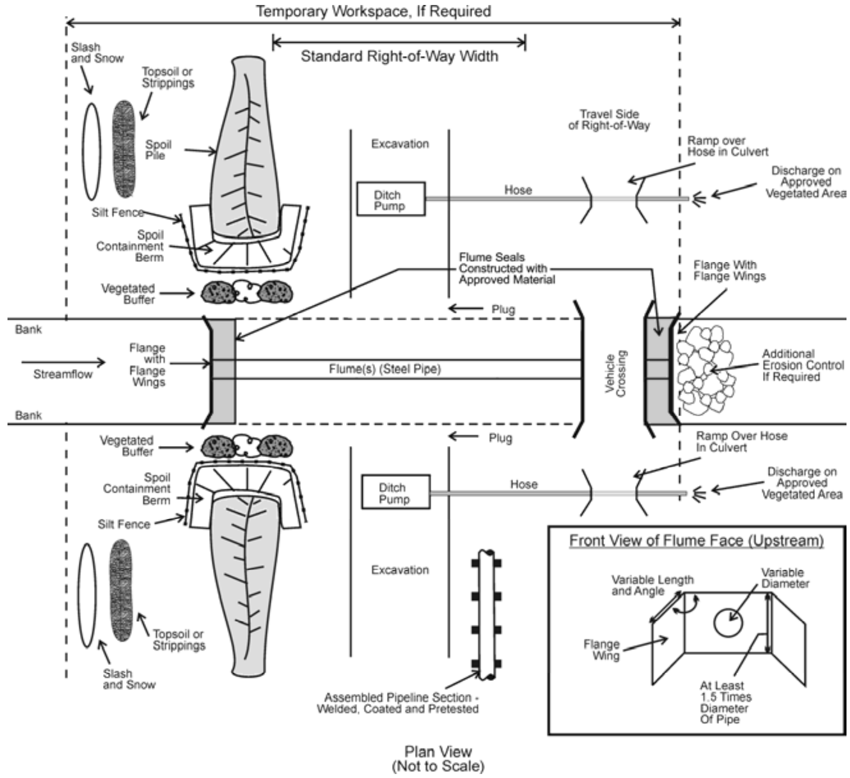
	October 2005
	DWG. NO. 4

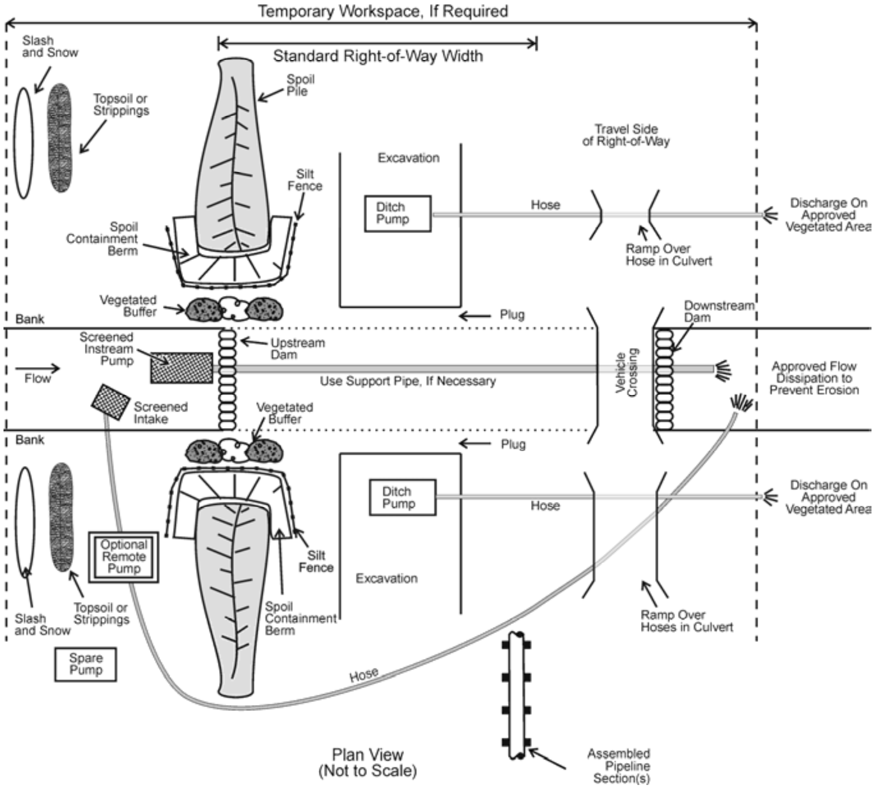


Notes:

1. Install the vehicle crossing, if required, on the work side edge of the right-of-way to allow for a wide excavation.
2. Size flume to handle anticipated flows.
3. Stockpile all required materials prior to beginning instream work. Complete construction of the instream pipe section. Weight and pretest pipe, if warranted, prior to commencing instream activity.
4. Install a pre-assembled flume, or construct a flume and install both an upstream and downstream dam.
5. Install additional erosion control, if required, downstream of the flume outlet.
6. Ensure a tight seal about the dam and flume prior to undertaking trench excavation. Beginning in the early morning, excavate the trench as quickly as practical placing spoil out of the stream channel. Create spoil containment sumps or berms, if warranted, to keep spoil from flowing back into the stream channel.
7. Pump excavation as required to prevent downstream flow of silted water. Direct the pumped water onto vegetated areas well back from the watercourse. Construct water containment sumps, if warranted.
8. Install pipe.
9. Backfill the stream channel first, squeezing the silted water into the bank excavations. Pump or drain the bank excavations while progressively backfilling from the stream channel outward.
10. Complete backfill, leaving a small shallow (< 0.5 m) sump upstream of the downstream dam. Install a pump intake in this sump.
11. Slowly elevate corner of flume (or edge of dam) and/or shut down auxiliary bypass pumps, and allow isolated channel to be flushed with water. Silt-laden water will flow into the shallow sump and then be pumped onto well-vegetated area.
12. Once isolated channel is flushed, remove downstream seal materials.
13. Remove upstream seal materials.
14. Remove the flume.
15. Restore, stablizie and reclaim bed and banks of stream channel to preconstruction profiles.

Source: Adapted from TERA 1998

CONSTRUCTION TECHNIQUE – TYPICAL FLUME



Plan View
(Not to Scale)

Notes:

1. Install the vehicle crossing, if required, on the work side edge of the right-of-way to allow for a wide excavation.
2. Stockpile all required materials and equipment onsite prior to beginning instream work.
3. Complete construction of the instream pipe section. If warranted, weight, coat and pretest pipe prior to the commencing of instream activity.
4. Begin the operation in the early morning to allow for same day installation, if practical.
5. Install pumps in natural pool upstream of the excavation. Excavate temporary sump within right-of-way if no natural pool exists. Check pump operation to equalize flow.
6. Ensure pumps can handle anticipated flow. Have standby pumps and generators capable of handling 100% of anticipated flow onsite and ready to be used if operating pumps fail.
7. Construct the upstream dam on the edge of the temporary workspace to allow for a wide excavation. Ensure dam is impermeable. Construct dam using sand bags, aquadam, sheet piling or other approved material that ensures a tight seal of the bed and banks.
8. Plug the vehicle crossing culvert or construct the downstream dam. Where a bridge is used, the bridge and dam should be installed as close to the edge of the temporary workspace as practical to allow for a wide excavation.
9. Assess the need to dewater isolated section of the watercourse and ensure tight seal about dams prior to trenching.
10. Excavate trench as rapidly as possible. Create spoil containment sumps, if warranted, to keep spoil from flowing back into the stream channel.
11. Install pipe.
12. Backfill the stream channel first pushing the silted water back into the bank excavations. Pump or drain the bank excavations while progressively backfilling from the stream channel outward. Construct water containment sumps if warranted.
13. Complete backfill, leaving a small, shallow (< 0.5 m) sump just upstream from the downstream dam. Install a pump intake in this sump.
14. Temporarily suspend pump bypass and/or slowly elevate corner of upstream dam and allow isolated channel to be flushed with water. Silt-laden water will flow into the shallow sump and then be pumped onto well-vegetated area.
15. Remove the downstream dam or vehicle crossing plug.
16. Remove the upstream dam or vehicle crossing plug.
17. Restore, stabilize and reclaim bed and banks of stream channel to preconstruction profiles.

Source: Adapted from TERA 1998

CONSTRUCTION TECHNIQUE – TYPICAL DAM AND PUMP

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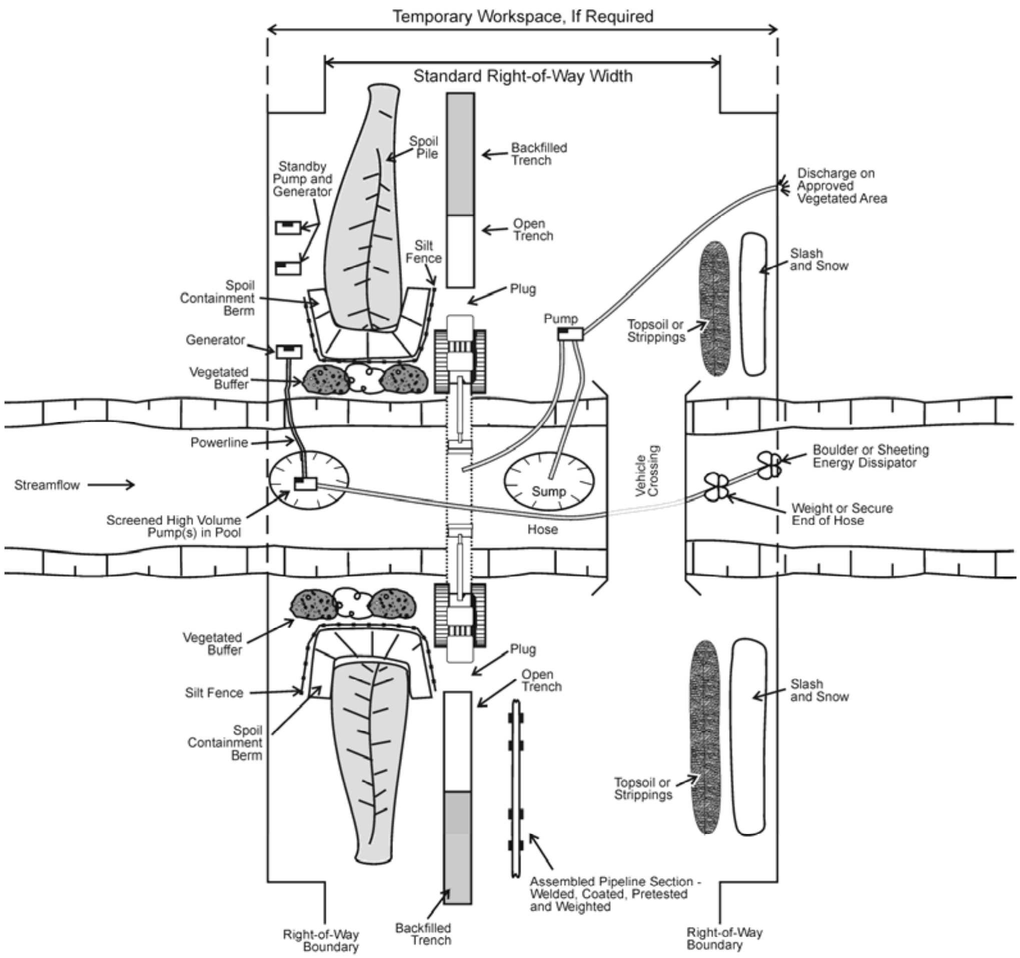

Plan View
(Not to Scale)

Notes:

1. Install vehicle crossing, if required, on the work side edge of the right-of-way to allow for a wide excavation.
2. Ensure adequate electric power supply and adequately sized pumps to handle anticipated flow. Have standby pumps and generators capable of handling 100% of anticipated flow onsite and ready to be used if the operating pumps fail.
3. Install high volume pump in pool located upstream of the excavation. Excavate temporary upstream sump in the right-of-way if no natural pool exits. Add additional pumping capacity if required. Discharge water through or into an energy dissipator into the channel sufficiently downstream of the trench to prevent water flowing back into the excavation.
4. Immediately initiate fish salvage from isolated pools. Ensure fish salvage permit(s) are acquired prior to installing pump.
5. Excavate a small sump downstream of crossing to collect silt laden waters. Install small pumps in sump and trench to discharge silt-laden water on to well vegetated soils away from watercourse.
6. Excavate trench, complete installation and backfill trench. Move hose if warranted to maintain streamflow.
7. Wash backfilled trench area into sump. Pump silt-laden water from trench onto a well vegetated area off right-of-way. Complete this step each evening prior to shutting off upstream pump, if instream work is to occur on successive days.

Source: Adapted from TERA 1998

CONSTRUCTION TECHNIQUE – TYPICAL HIGH VOLUME PUMP BYPASS

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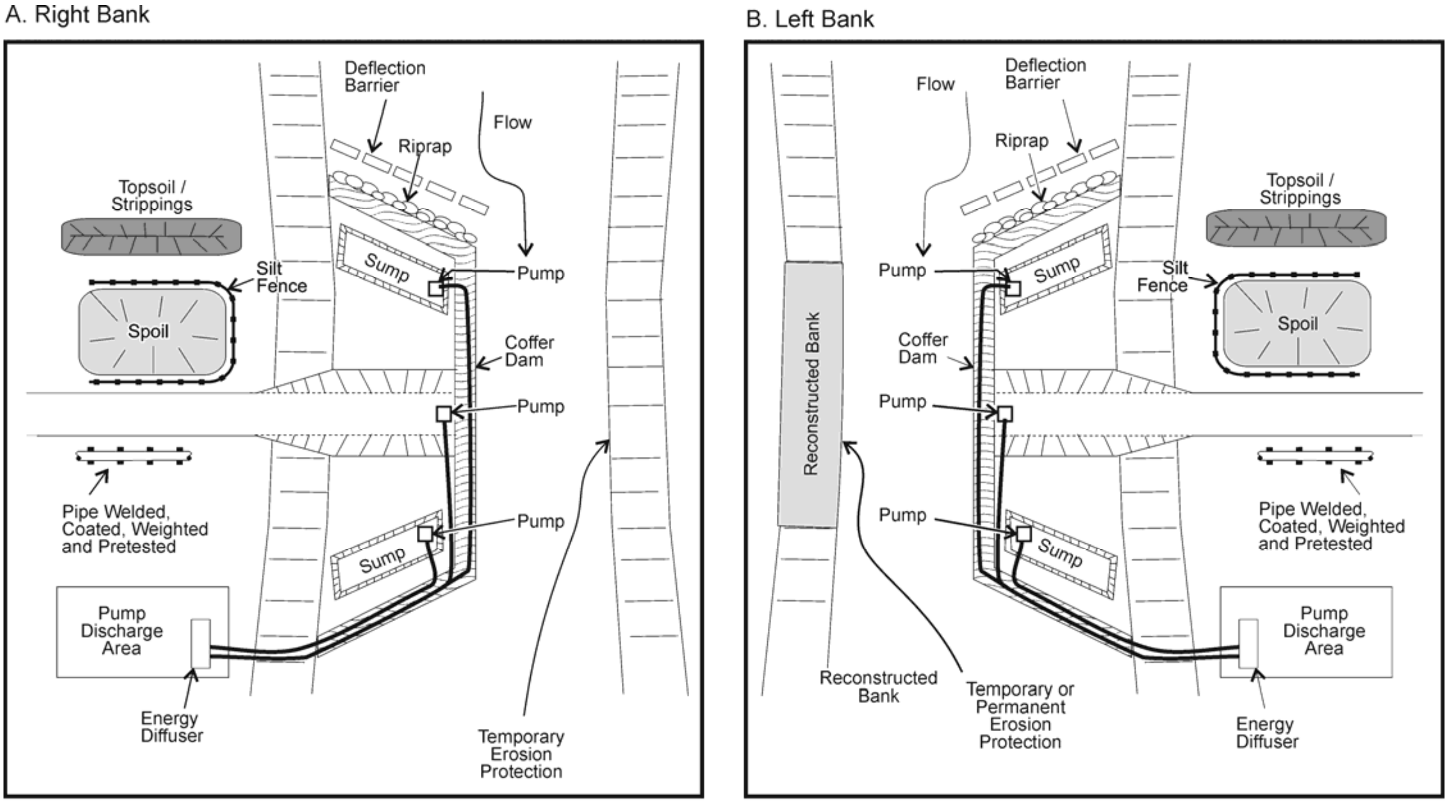

Plan View
(Not to Scale)

Notes:

1. A crossing-specific drawing to supercede this typical should be prepared for implementation during construction.
2. Ensure sufficient working space within the coffer dam to accommodate a wide unstable ditch.
3. If there is a high velocity streamflow, install deflection barrier (*e.g.,* median barriers) to permit construction of coffer dam outside full streamflow.
4. Construct coffer dam from local materials, sandbags, 1 m^3 sandbags, aquadams, sheet piling, median barriers, gravel or other appropriate material to extend over halfway across the watercourse.
5. Install impermeable barrier within coffer dam.
6. Install riprap on upstream side to protect the dam from erosion if dam is constructed of loose material.
7. Install sumps to collect seepage and then pump to dewatering area.
8. Ensure discharge area can handle the volume of water and silt pumped to shore.
9. Complete trenching, lowering in, backfilling and mark end of pipe.
10. Remove coffer dam, reconstruct bank.
11. Install similar structure on opposite side of watercourse enclosing the marked pipe end.

Source: Adapted from TERA 1996

CONSTRUCTION TECHNIQUE – TYPICAL TWO STAGE COFFER DAMS

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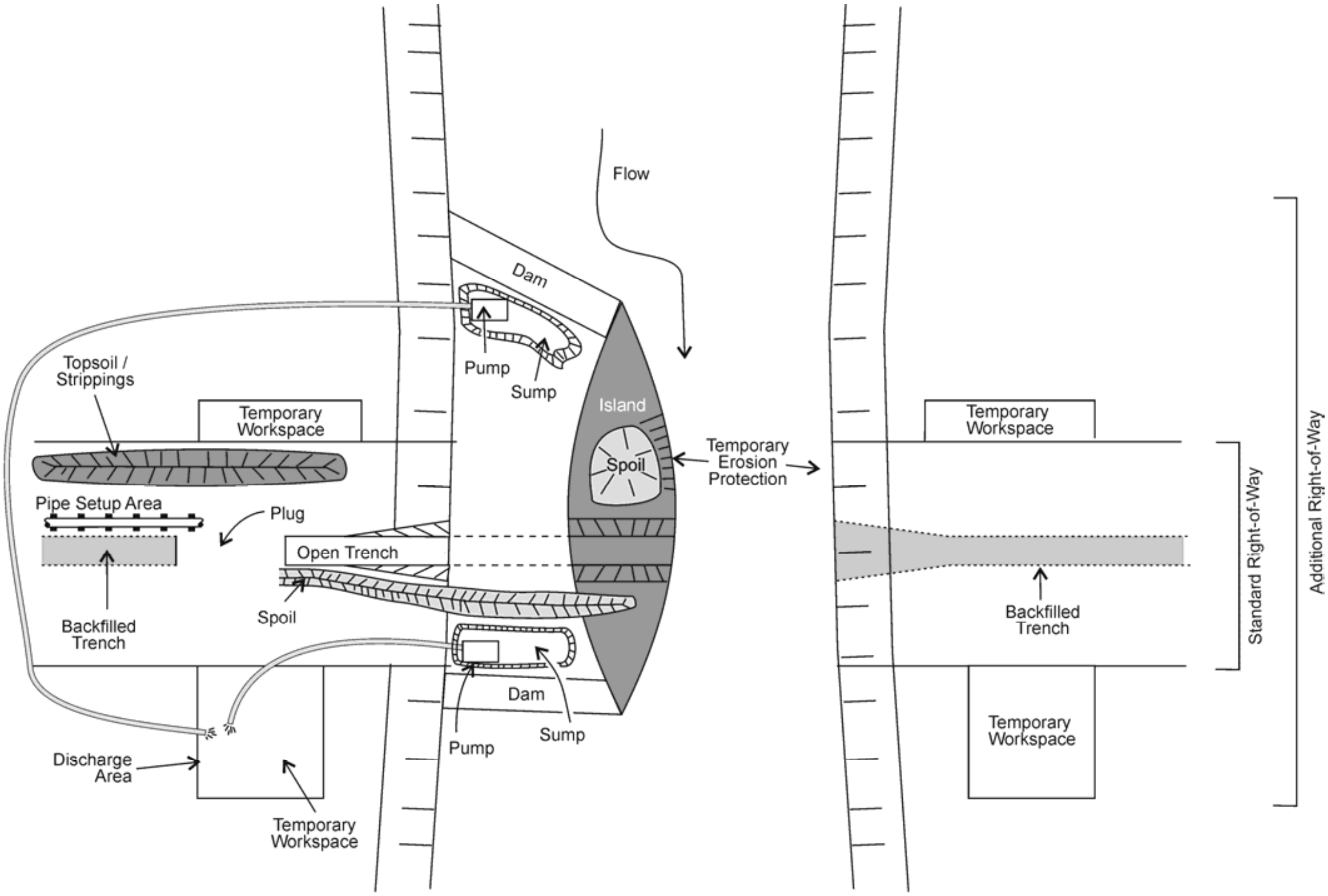
	DWG. NO. 8



Plan View
(Not to Scale)

Notes:

1. If there is a high velocity streamflow, install deflection barrier (*e.g.,* median barriers) to permit construction of dam outside full streamflow.
2. Construct dam from local materials, sandbags, 1 m^3 sandbags, water-filled dams, sheet piling, median barriers, gravel or other appropriate material to extend over halfway across the watercourse.
3. Install impermeable barrier within dam.
4. Install riprap on upstream side to protect the dam from erosion if dam is constructed of loose material.
5. Spoil storage shall be above the high water mark or protected by erosion control measures to ensure that, when the water level rises after all flow has been channelized into one channel, spoil is not washed away.
6. Install sumps to collect seepage and then pump to dewatering area.
7. Ensure discharge area can handle the volume of water and silt pumped to shore.
8. Complete trenching, lowering in and backfilling.
9. Remove dam, reconstruct bank.
10. Repeat process for other channel.
11. Temporary diversion also may be made through abandoned channels as long as steps are taken to minimize a flush of sediment once the watercourse is redirected through the "new" channel.
12. Temporary diversion through a channel excavated into a flood plain is possible if lined or passed through a flexible conduit to prevent excessive erosion along the "new" channel.

Source: Adapted from TERA 1996

CONSTRUCTION TECHNIQUE – TYPICAL CHANNEL DIVERSION

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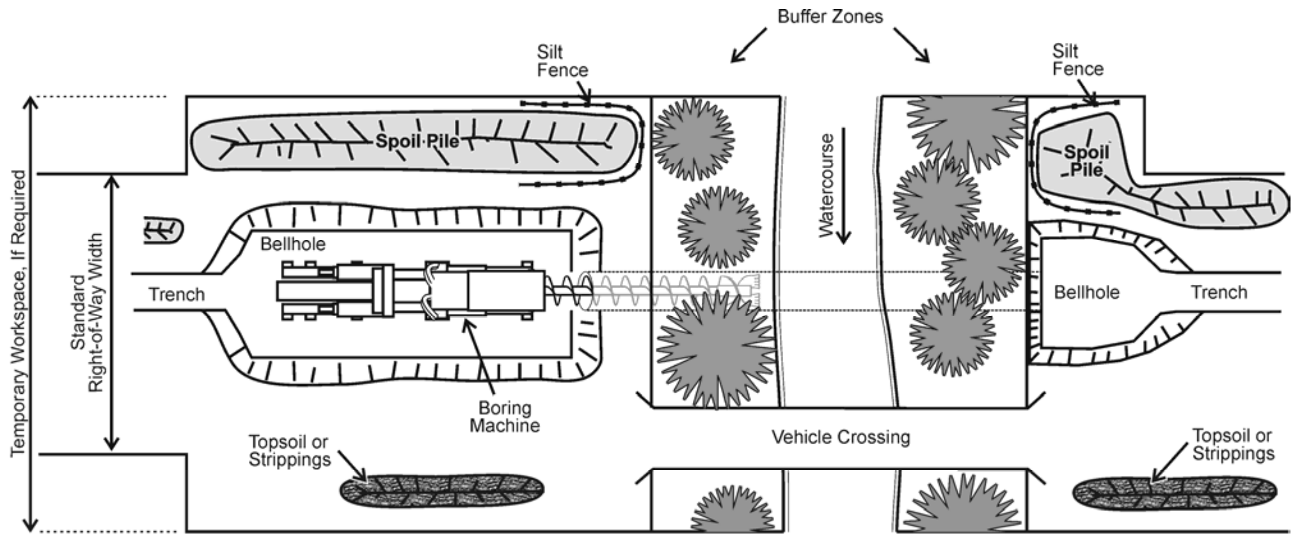
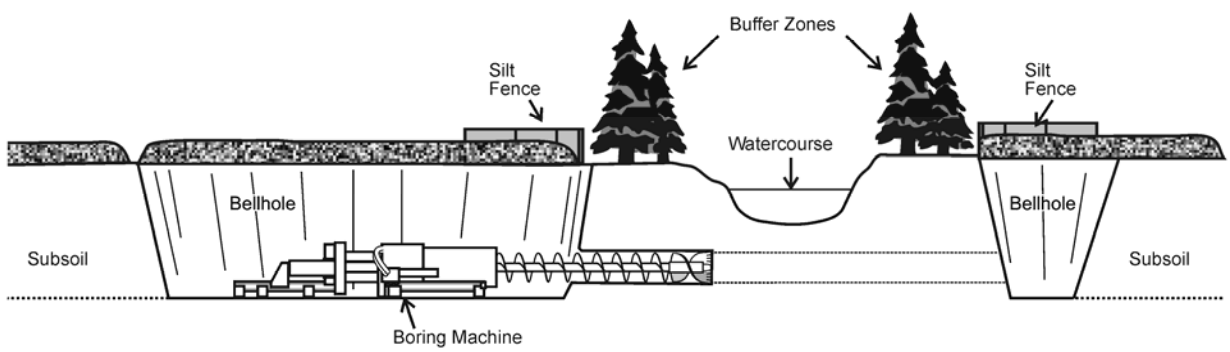


Plan View
(Not to Scale)



Profile
(Not to Scale)

Notes:

1. Acquire and mark additional temporary workspace.
2. Set up equipment back from the edge of the watercourse; do not clear or grade within buffer zone except along the work side, if temporary vehicle crossing is installed.
3. Excavate bellhole. Store spoil on opposite side of right-of-way.
4. Complete boring and tie-in to mainline.
5. Pump bellhole dry if seepage becomes a problem. Dewater bellholes onto stable, vegetated land, not directly back into watercourse.
6. Backfill and compact. Leave a crown to allow for subsidence.

Source: Adapted from TERA 1998

CONSTRUCTION TECHNIQUE – TYPICAL BORE OR PUNCH

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October 2005	
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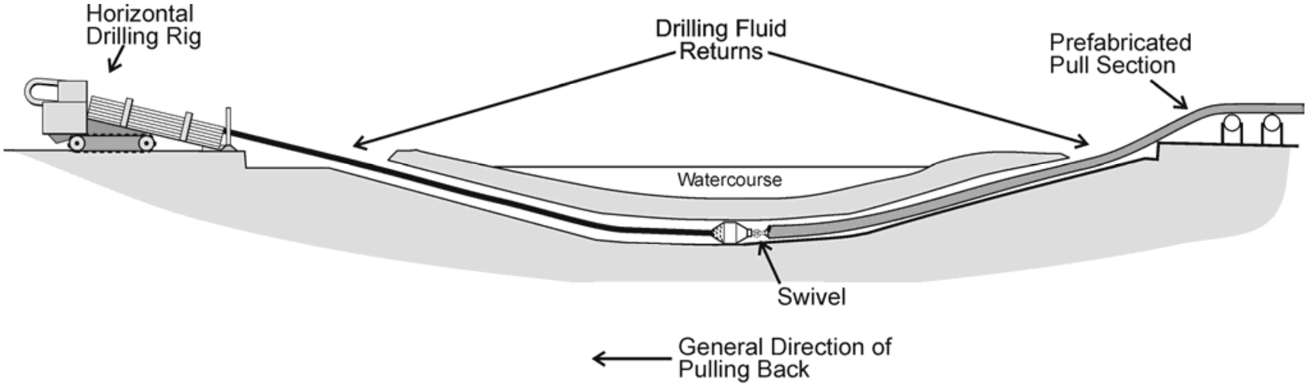


Profile
(Not to Scale)

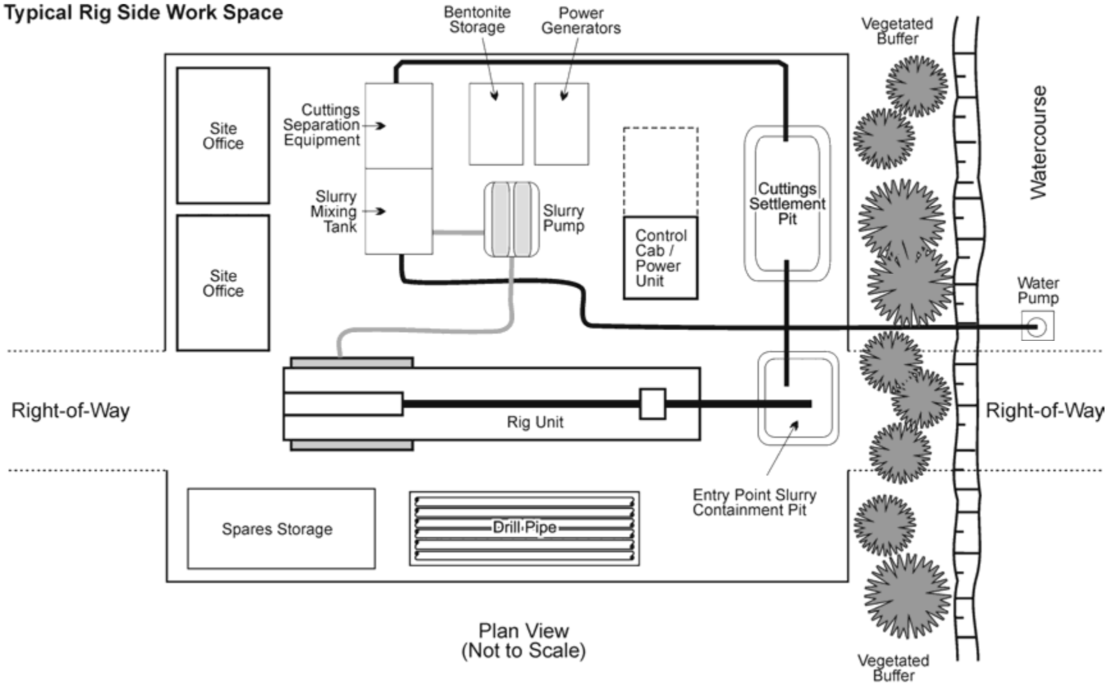
Notes:

1. Obtain geotechnical data prior to initiating drilling. Drilling may not be feasible in some materials such as unconsolidated gravels.
2. Ensure temporary workspace rights have been obtained to conduct monitoring and that access is available for monitoring activities.
3. Set up drilling equipment back from the edge of the watercourse; do not clear or grade within the buffer zone.
4. Employ full time inspectors to observe for an inadvertent mud release into the watercourse.
5. Ensure that only bentonite based drilling mud is used. Do not allow the use of any additives to the drilling mud without the approval of appropriate regulatory authorities.
6. Install suitable drilling mud tanks or sumps to prevent contamination of watercourse.
7. Install sumps downslope from the drill entry and anticipated exit points to contain any release of drilling mud.
8. Dispose of drilling mud in accordance with the appropriate regulatory authority requirements.
9. Prepare a drilling mud release contingency plan.

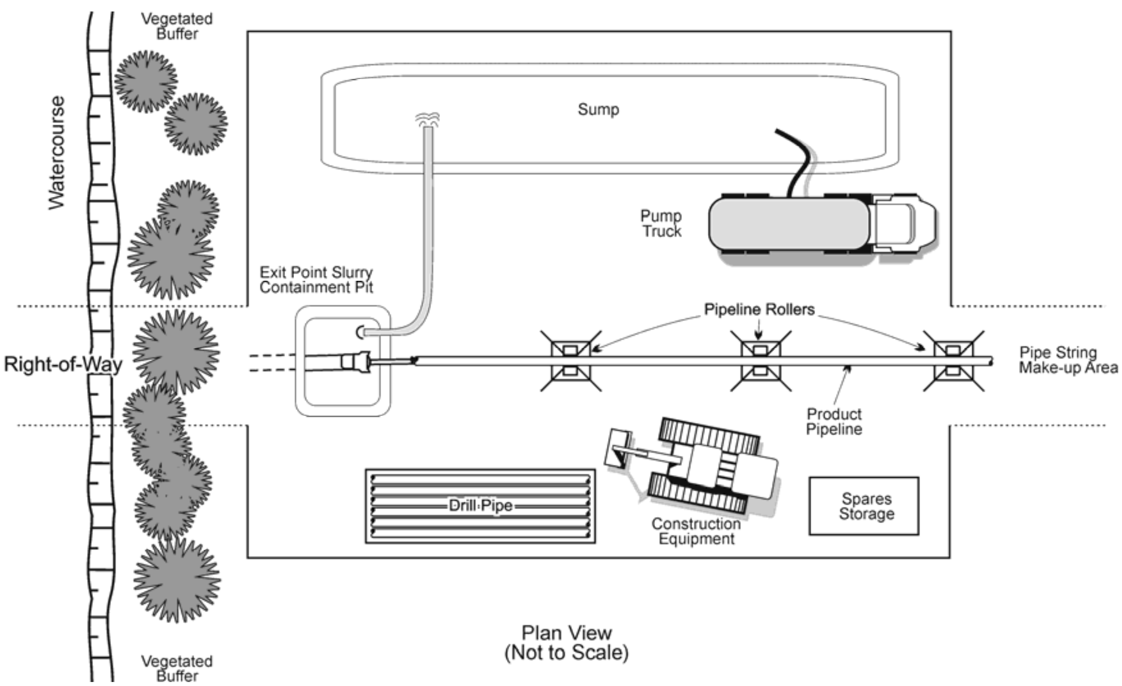
Source: Adapted from ASCE 1996, TERA 1998

CONSTRUCTION TECHNIQUE – TYPICAL HORIZONTAL DIRECTIONAL DRILL

(A) Typical Rig Side Work Space



(B) Typical Pipe Side Layout



Source: Adapted from ASCE 1996

CONSTRUCTION TECHNIQUE – TYPICAL HORIZONTAL DIRECTIONAL DRILL

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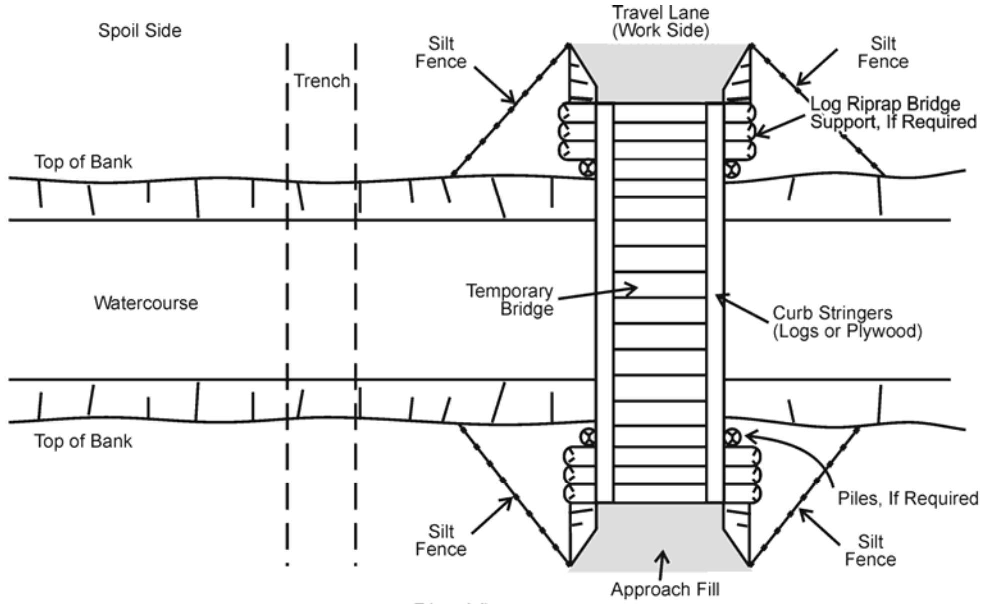
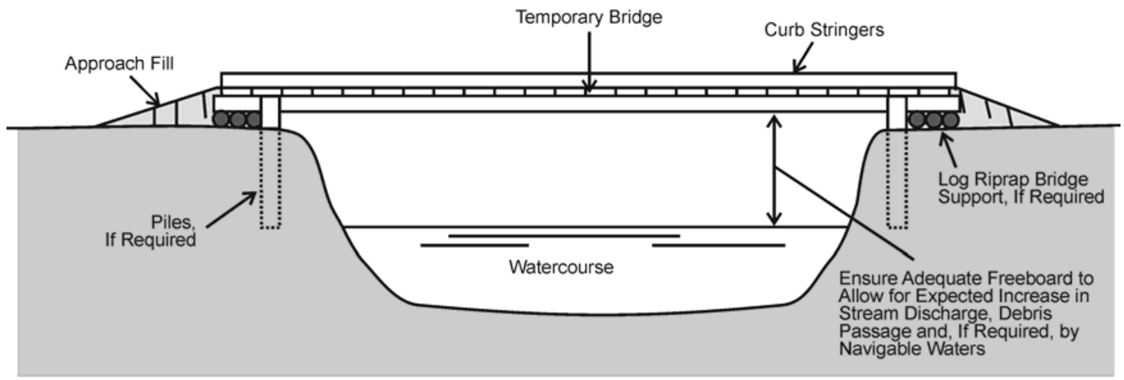
	October 2005
	DWG. NO. 11 (b)



Plan View
(Not to Scale)



Profile
(Not to Scale)

Notes:

1. Install a temporary bridge (e.g., log, pre-fabricated span) to allow vehicles to cross watercourses that are sensitive or that have unstable bed and banks. Bridges are also used where watercourses are too deep, wide or fast to permit an alternative crossing structure. This method minimizes sedimentation of the watercourse, and bank and bed restoration work. It is generally limited to watercourses less than 30 m in width.
2. Utilize approach fills rather than cuts in banks to minimize erosion potential. Do not constrict flow with approach fill or support structures. Ensure adequate free-board to handle anticipated streamflows. Use a geotextile liner to prevent fine material from entering watercourse.
3. Remove bridge immediately after use. If bridge is to remain in place through spring break-up to access final clean-up, it must be designed for spring floods and ice jams. Remove support structures and approach fills. Restore and stabilize banks.
4. Install curb stringers of logs or plywood to ensure that fill material does not spill into the watercourse, where required.

Source: TERA 1998

VEHICLE CROSSING – TYPICAL TEMPORARY BRIDGE

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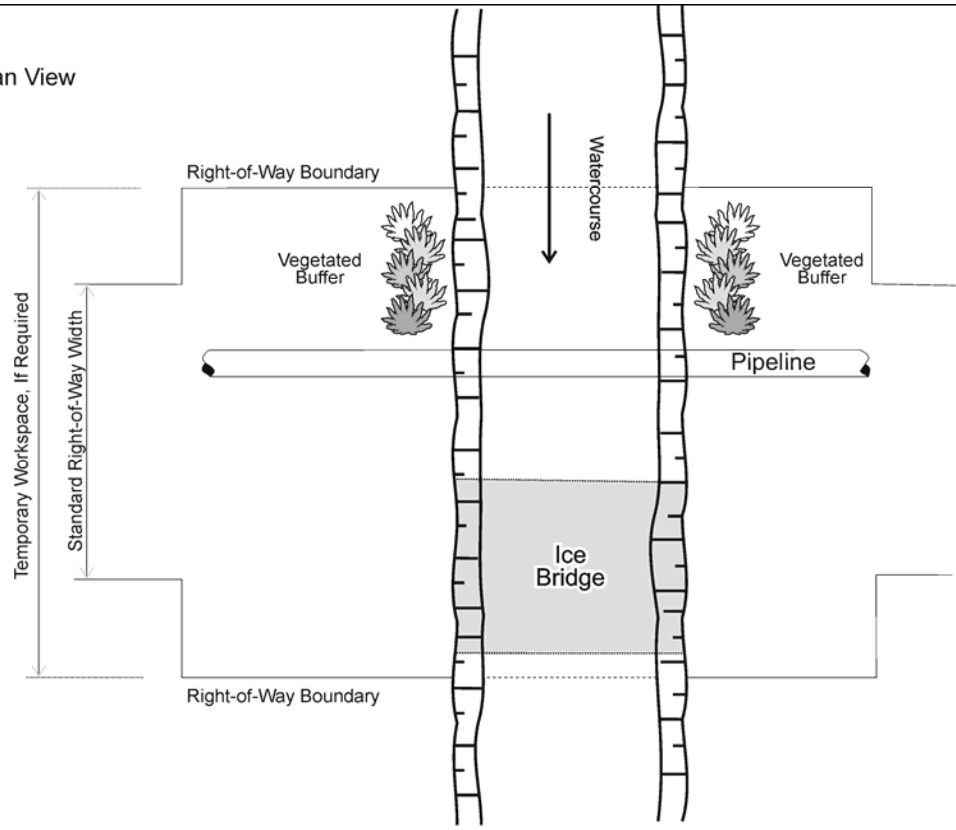
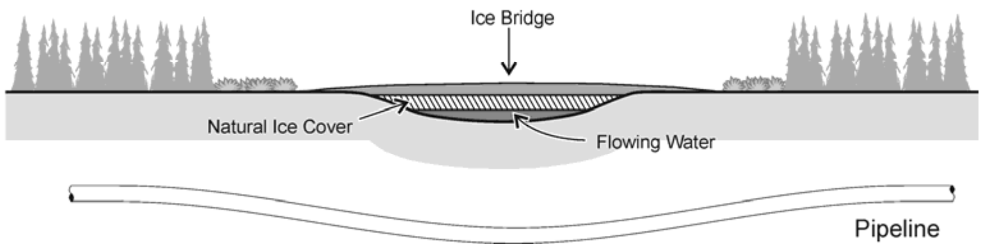
DWG. NO. 12

A. Plan View



B. Profile View

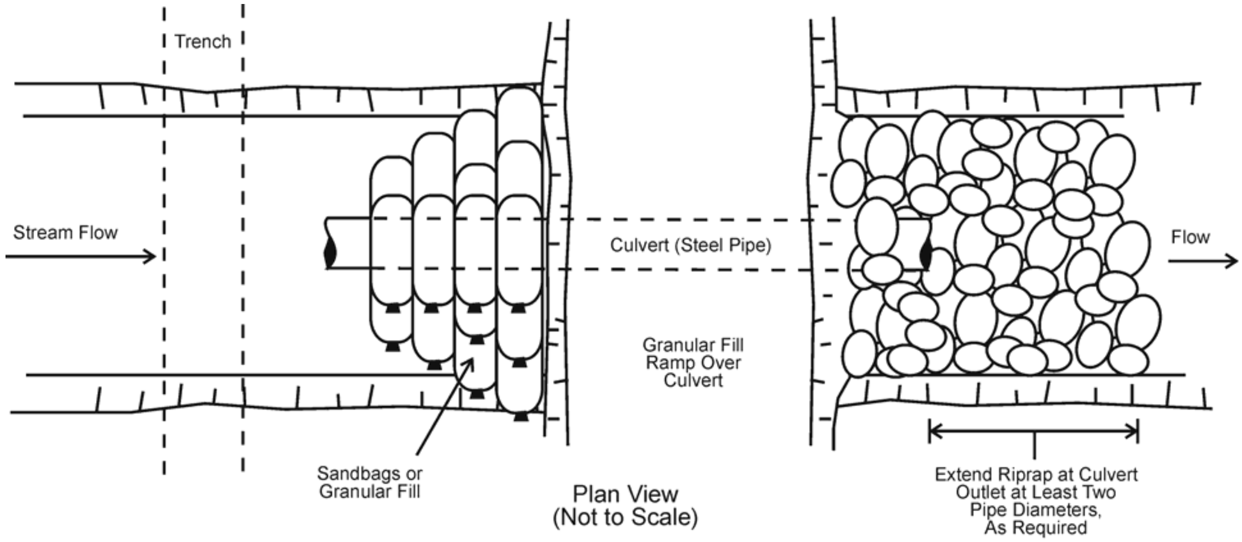


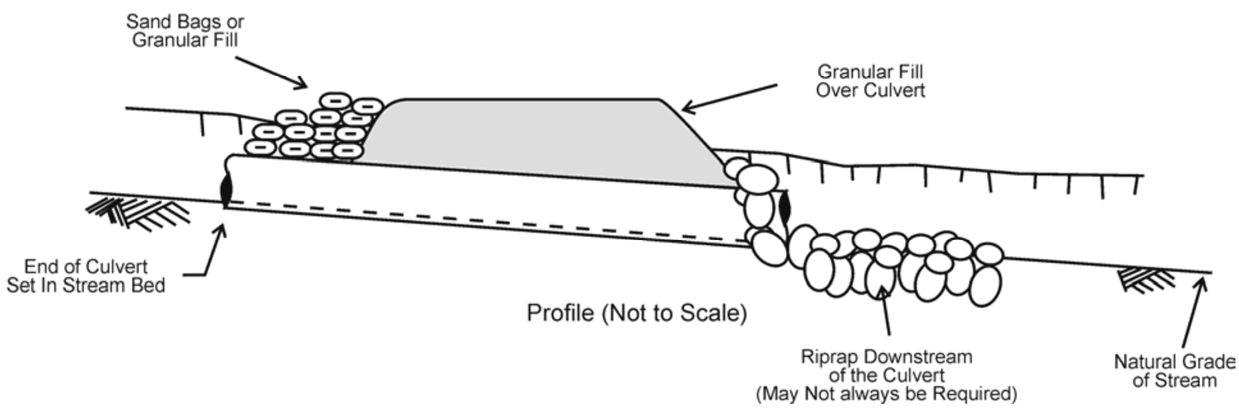
Notes:

1. Install ice bridges on winter projects when a safe ice thickness can be maintained.
2. Locate ice bridges at sites with gently sloping banks to minimize cuts in watercourse banks. Use snow and ice to slope approaches, rather than cut banks.
3. Flood ice surface with water and cover with snow to increase load bearing capacity. Logs may be used as a base to strengthen the bridge. The ice bridge should not impede flow.
4. Maintain ice regularly and remove all debris from the ice surface.
5. Remove broken ice from trench area to prevent ice jamming against and under the ice bridge.
6. Remove logs and breach ice bridge by physical means prior to spring break-up.
7. Restore and stabilize banks and approaches prior to spring break-up.

Source: TERA 1998

VEHICLE CROSSING – TYPICAL ICE BRIDGE





Notes:

1. Install ramp and culverts to allow vehicles to cross relatively narrow watercourses where sedimentation must be minimized or fish passage allowed.
2. Design culverts to handle 150% of maximum anticipated flows or to a five year flood level and according to specific guidelines where fish passage (i.e., migration) is required. Contact government authorities for minimum water depth specifications, and maximum water velocities. Ensure dam is impermeable.
3. Place ends of culverts below the natural grade of watercourse at an angle that does not exceed normal watercourse gradient. Depth of placement is dependent upon bed type, culvert size and expected flow conditions.
4. Remove temporary culverts and ramp materials when no longer required. Remove culvert and ramp prior to freeze-up (summer construction) and prior to spring break-up (winter construction).
5. Restore and stabilize bed and banks.

Source: Alliance 1998

VEHICLE CROSSING – TYPICAL RAMP AND CULVERT

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	October 2005
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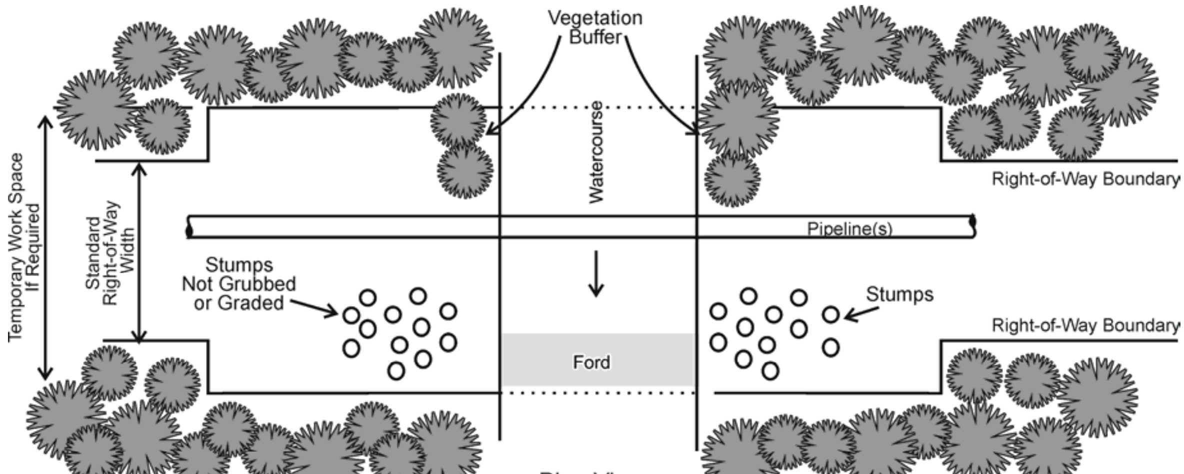
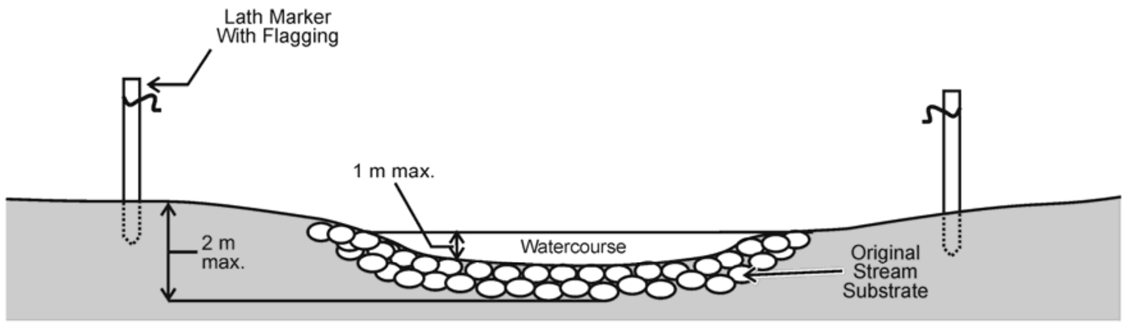


Plan View
(Not to Scale)



Profile
(Not to Scale)

Notes:

1. Use fords to provide vehicular access across relatively shallow (less than 1 m) and narrow watercourses with granular beds and stable banks. Where water depth, streambed composition or banks slopes could pose trafficability problems for rubber tired vehicles, limit ford traffic to tracked equipment.
2. Do not use ford during fish spawning, incubation or migration periods.
3. Minimize grading in proximity to watercourse. Grade and grub only along the trenchline and an area immediately adjacent to the trenchline. Pull soil and debris away from watercourse, if banks require sloping.
4. Minimize use of ford.
5. Stabilize banks and approaches with granular blanket underlain by a geotextile, if warranted.
6. Mark boundaries of ford on both sides of crossing to confine all vehicle traffic to ford.
7. Restore and stabilize beds and banks to original contour when ford is no longer needed. Granular blanket need not be removed if it is not a barrier to fish during low flow conditions.

Source: TERA 1998

VEHICLE CROSSING – TYPICAL FORD

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	October 2005
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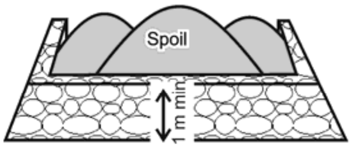
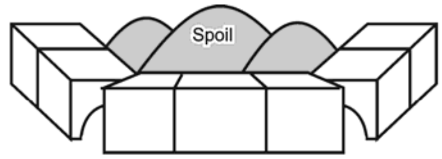
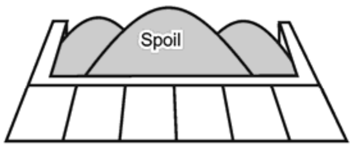


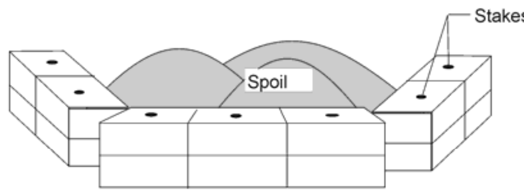
1. Windrow Boulders and Shot Rock



2. Saddle Weights



3. Subsoil Berm



4. Straw Bales (staked)

Not to Scale

Notes:

1. Construct sump or berms to contain excavated instream spoil so that silty runoff does not enter watercourse or flow off right-of-way.

2. Strip topsoil from area to be used as spoil storage.

3. Maintain sufficient buffer from the top of the streambank.

4. Berms which do not adequately prevent leakage, such as those made of boulders, shotrock or saddle weights may need a geotextile liner to prevent silty water from entering watercourse.

Source: Adapted from Alliance 1998

SEDIMENT CONTROL – TYPICAL SPOIL BERMS

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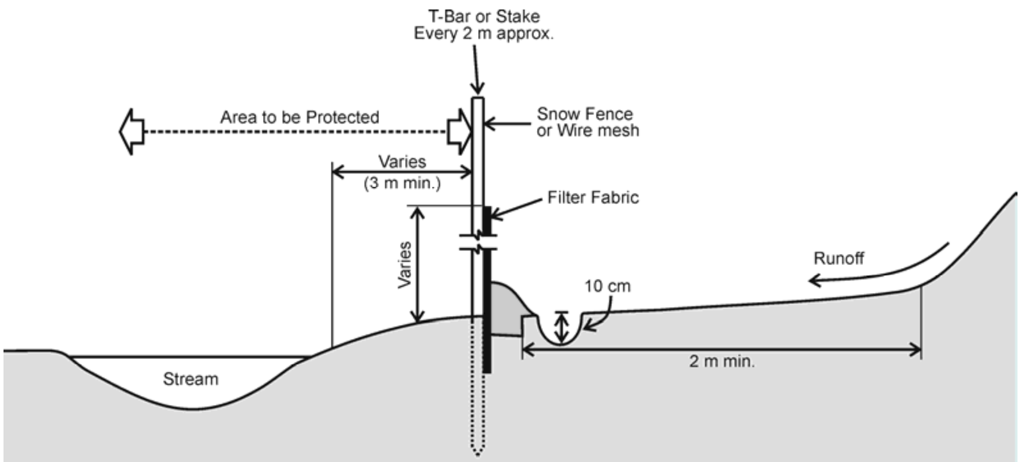
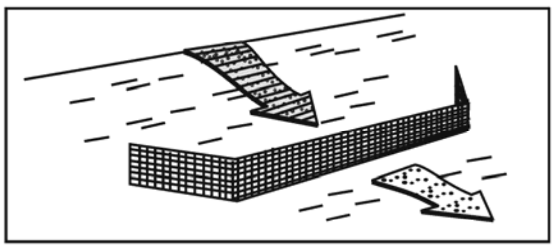
DWG. NO. 16



Side View of Silt Fence
(Not to Scale)



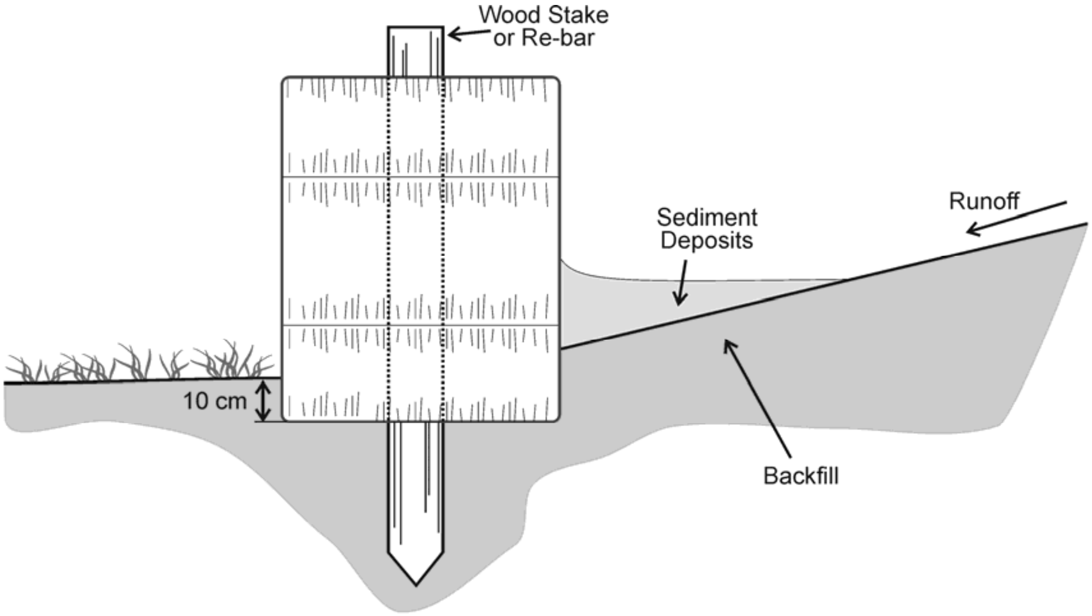
Oblique View
(Not to Scale)

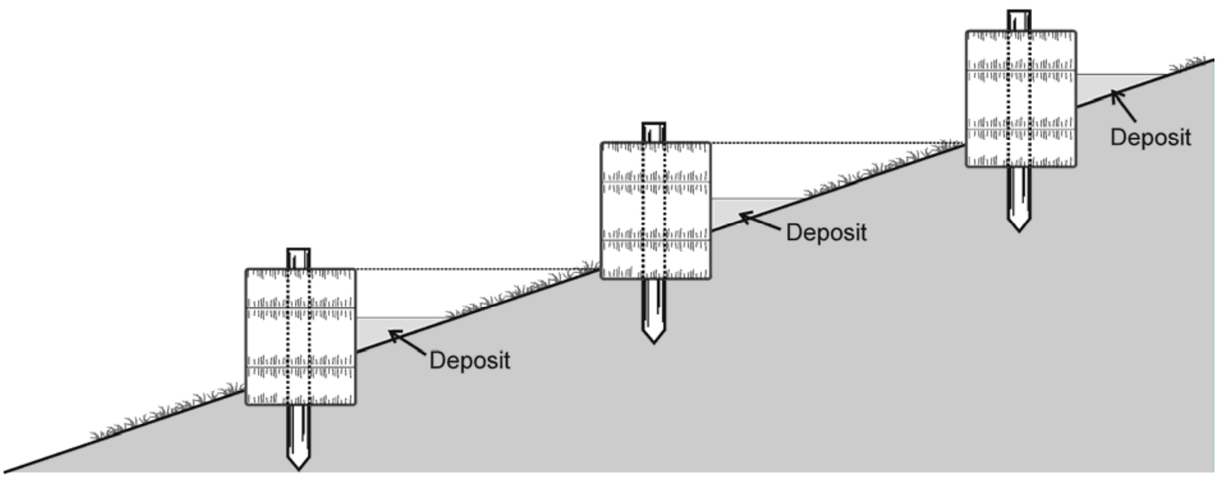
Notes:

1. Watercourses that have moderate to high sensitivity of fish habitat and/or have steep approach slopes at the proposed crossings may need silt fences during construction, as determined by the Environmental Inspector.
2. Install silt fences at the base of approach slopes following clearing and grading using the method and materials above or other approved designs.
3. Ensure silt fence is keyed into the substrate. Excavate a narrow trench, place the base of the silt fence in the trench and place the fill back into the trench, securing the silt fence in place.
4. Place silt fences a minimum 2 m, if feasible, from the toe of the slope in order to increase ponding volume.
5. Maintain silt fences throughout construction.
6. Ensure that silt fences, if removed or damaged, are reinstalled or repaired prior to the end of the work day.
7. Maintain silt fences in place at the base of the approach slopes until revegetation of the right-of-way is complete.
8. In areas with frequent traffic, install two or more silt fences in a staggered and overlapped configuration to allow vehicle passage without removal or opening of the silt fence.

Source: Adapted from TERA 1998, Alliance 1997

SEDIMENT CONTROL – TYPICAL SILT FENCES





Profile
(Not to Scale)

Notes:

1. Construct straw bale filters to contain excavated instream spoil so that silty run off does not enter watercourse or flow off right-of-way.
2. Use straw bale filters on long unprotected slopes to prevent surface erosion from entering watercourse.
3. Where several lines of bales are installed on a slope in a more permanent application, erosion will be minimized if the top of the downslope bale is on the same level as the bottom of the next line up.

Source: TERA 1998

SEDIMENT CONTROL – TYPICAL STRAW BALES

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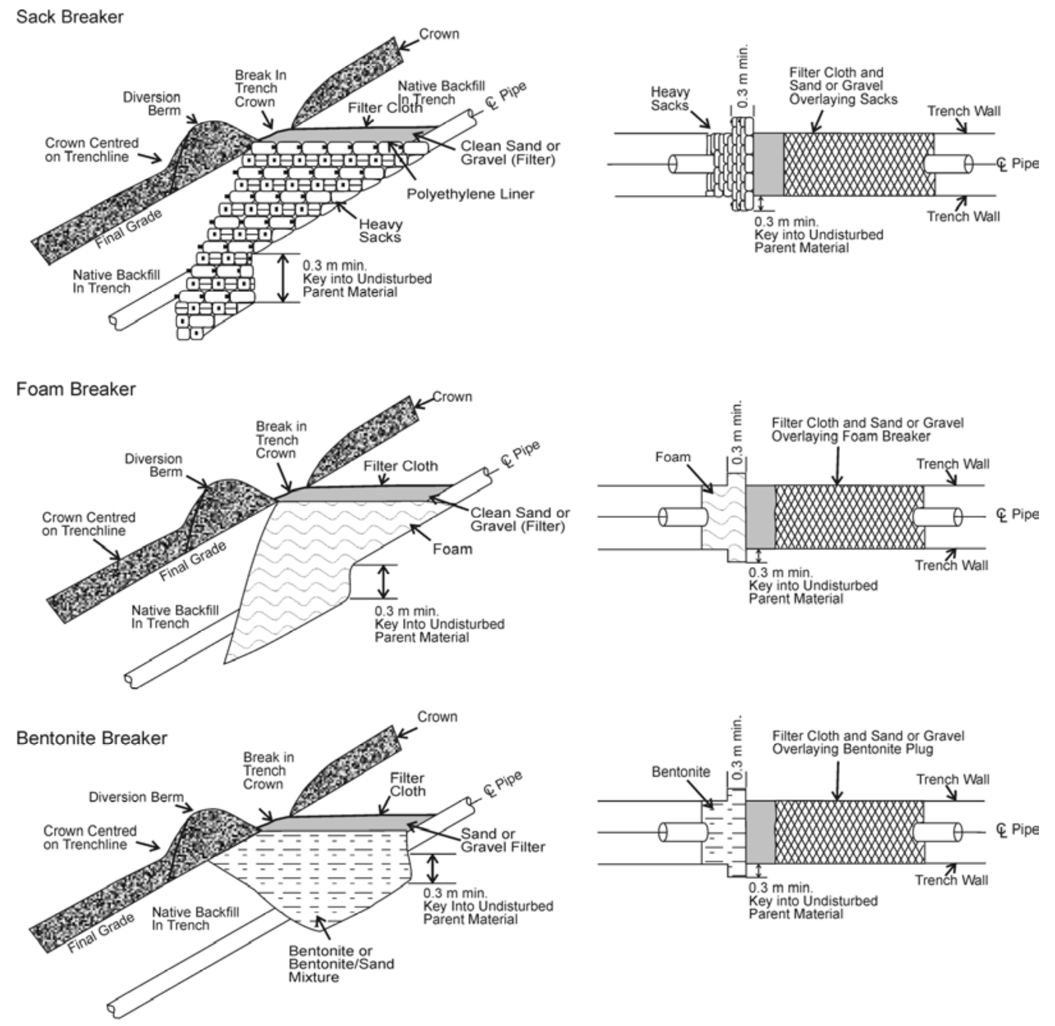
	DWG. NO. 18



Profile
(Not to Scale)

Plan View
(Not to Scale)

Notes:

1. Install trench breakers to control water seepage along the trench line and prevent erosion of backfill materials.
2. Trench breakers may be constructed using earth filled sacks, bentonite, foam or equivalent materials to provide a barrier to water seepage.
3. The drawings above provide a schematic representation of trench breaker installation. Final locations and design of trench breakers will be determined by the project engineer based on site specific conditions at the time of construction.
4. Dig keys into trench bottom and sides to the extent feasible for added stability.
5. Install a prefabricated drain or a layer of sand or gravel covered with filter cloth over the breaker.
6. Backfill native material and mark location of breaker.
7. Ensure cross ditches are located over the end of the drain.
8. Construct diversion berms downslope from the breaker but not over the end of the drain.
9. Ensure that trench crown does not encroach upon the breaker drain or cross ditch.
10. Backfill trench on downslope side of breaker before upslope side.

Source: Adapted from Alliance 1997

SUBSURFACE DRAINAGE CONTROL – TYPICAL TRENCH BREAKERS

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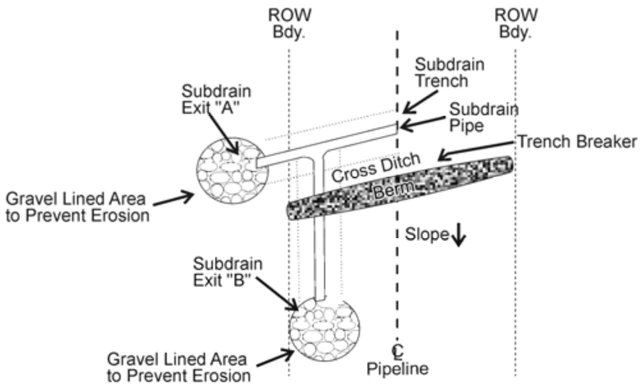
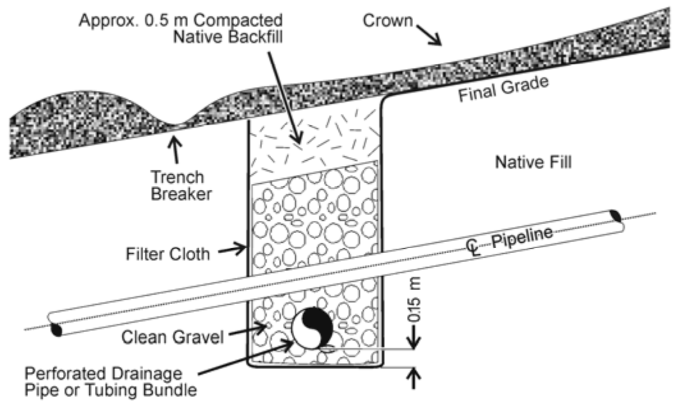


Plan View
(Not to Scale)



Profile
(Not to Scale)

Notes:

1. Install a subdrain to divert shallow groundwater flow away from the pipeline, to improve slope stability. Clean gravel and a filter cloth ditch liner, permits drainage aiding in retention of backfill. In certain circumstances, a parallel drain may be installed lengthwise down the slope underneath the pipeline. A geotechnical engineer can advise as to which method is most appropriate.
2. Install trench breaker downslope of drain, where drains cross pipeline trench, to prevent drain water flowing down pipe trench.
3. Determine the location of drain by on-site investigation considering such factors as groundwater conditions in trench, soil types, local topography, and drainage patterns. Discharge may either be off right-of-way on the downslope side of the subdrain (see Subdrain Exit "A"), or on right-of-way downslope of the berm (see Subdrain Exit "B"). Special permission will be required from the appropriate regulatory authority and landowner to construct a subdrain exit off right-of-way. Ensure discharge is into a well protected area with gravel, riprap or vegetation.
4. Skew cross drain 5^{o} off horizontal to ensure sufficient drainage.
5. The above drawing is a schematic diagram. A geotechnical engineer should be consulted for the detailed site specific drain design and the incorporation of the trench breaker.

Source: Adapted from Alliance 1997

SUBSURFACE DRAINAGE CONTROL – TYPICAL SUBDRAIN

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October 2005	
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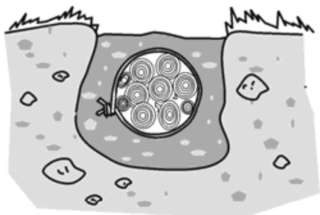

Profile
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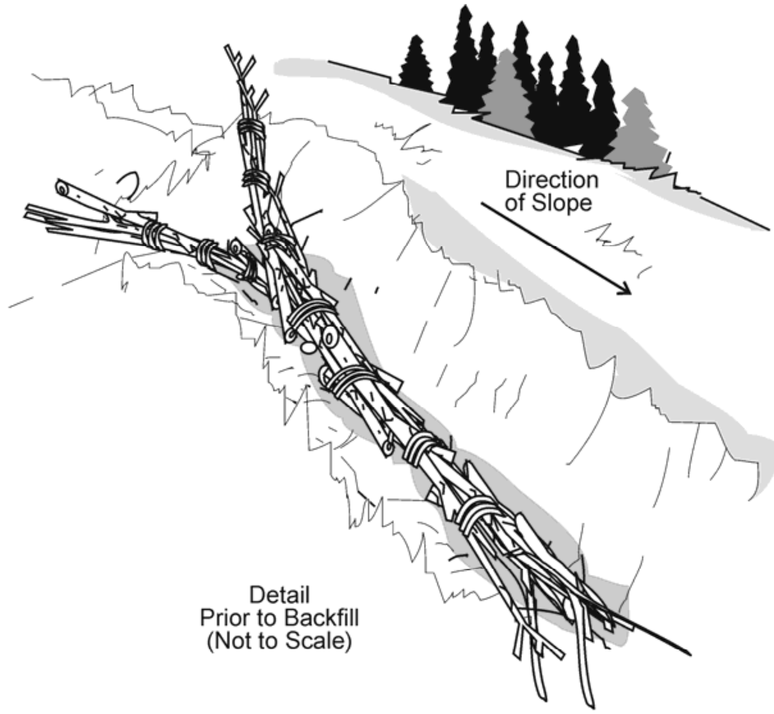
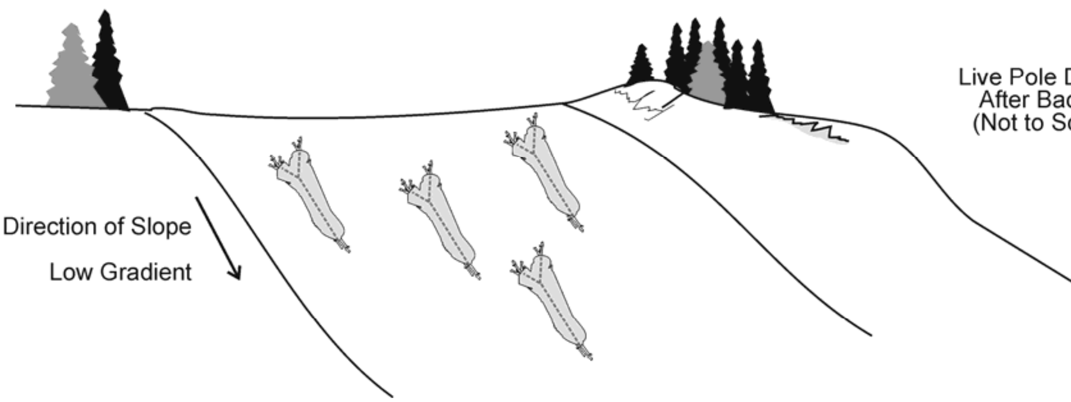


Detail
Prior to Backfill
(Not to Scale)



Live Pole Drains
After Backfill
(Not to Scale)

Notes:

1. Excavate a shallow trench parallel with the slope and within regions of excessive moisture.
2. Construct a bundle of willow cuttings, alternating tips and butts, by tying with twine as tightly as practical. Twigs and branches should not be trimmed unless inhibiting the tightness of the bundle.
3. Backfill over the bundle except for bundle ends. Tamp to compact the soil. The bundles may be anchored or staked on erosion prone slopes.

Source: Adapted from CAPP Third Edition (TERA 2005)

SUBSURFACE DRAINAGE CONTROL – TYPICAL POLE DRAINS

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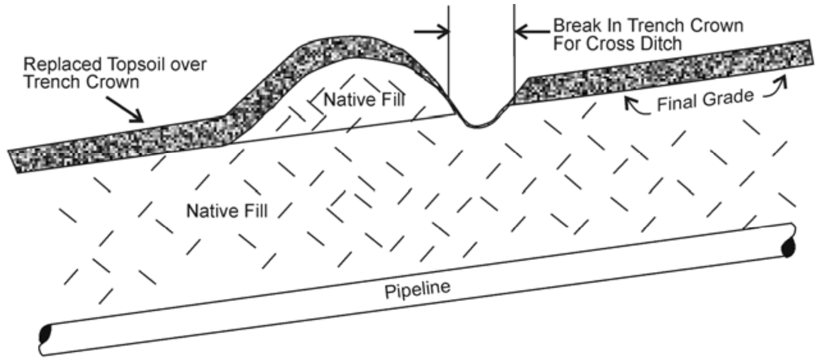
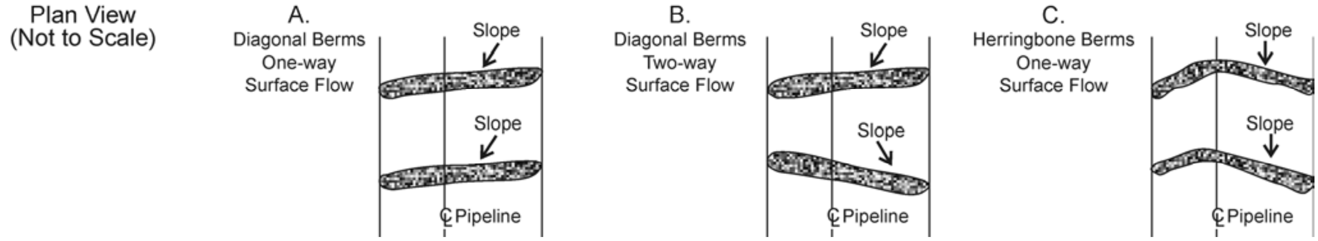
October 2005

DWG. NO. 21





Notes:

1. Install diversion berm and cross ditch in conjunction with final clean-up and reclamation on moderate and steep slopes to divert surface water off the right-of-way. Also install berms immediately downslope of trench breakers to collect seepage forced to the surface.
2. Construct diversion berm of compacted native soils where extensive disturbance of the sod layer has occurred. Diversion berms should be constructed of timbers, imported logs, wattles (interwoven twigs and branches), straw bales or sandbags if disturbance of the sod layer is limited. Avoid use of organic material. Where native material is highly erodible, protect upslope of berm and base of cross ditch with sod or by burying a geotextile liner 16 to 20 cm below the surface or armour upslope face of berm with earth filled sand bags.
3. Typical diversion berm height is approximately 30 to 75 cm. Inspect berms after heavy rains and the first spring following construction; replace or restore berms if warranted.
4. Leave a break in trench crown immediately upslope of diagonal berm and cross ditch to allow passage of water across right-of-way.
5. Use diagonal berms where direction of slope and surface water movement is oblique to pipeline right-of-way.
6. Use herringbone berm and cross ditch where direction of slope and surface water movement is parallel to right-of-way so runoff does not cross ditch line.
7. Determine location and direction of berm based on local topography and drainage patterns. Skew berms with downhill gradient of 5-10%.
8. Typical diversion berm spacing

Slope Gradient (%)	Typical Spacing (m) *
<8; <15	as required
8-14; 15-25	45
14-17; 25-30	34
17-20; 30-35	20
>20; >35	10-15

* Rely on field judgment to determine appropriate spacing. For example - install berms approximately 50% closer than indicated on highly erodible materials such as glacial-lacustrine deposits.

9. To facilitate traffic on the right-of-way during temporary applications, straw bales may be inserted in the berm as a "gate". The bales may be removed for access, but replaced each night.

Source: Adapted from Alliance 1997

SURFACE EROSION CONTROL – TYPICAL CROSS DITCHES AND DIVERSION BERMS

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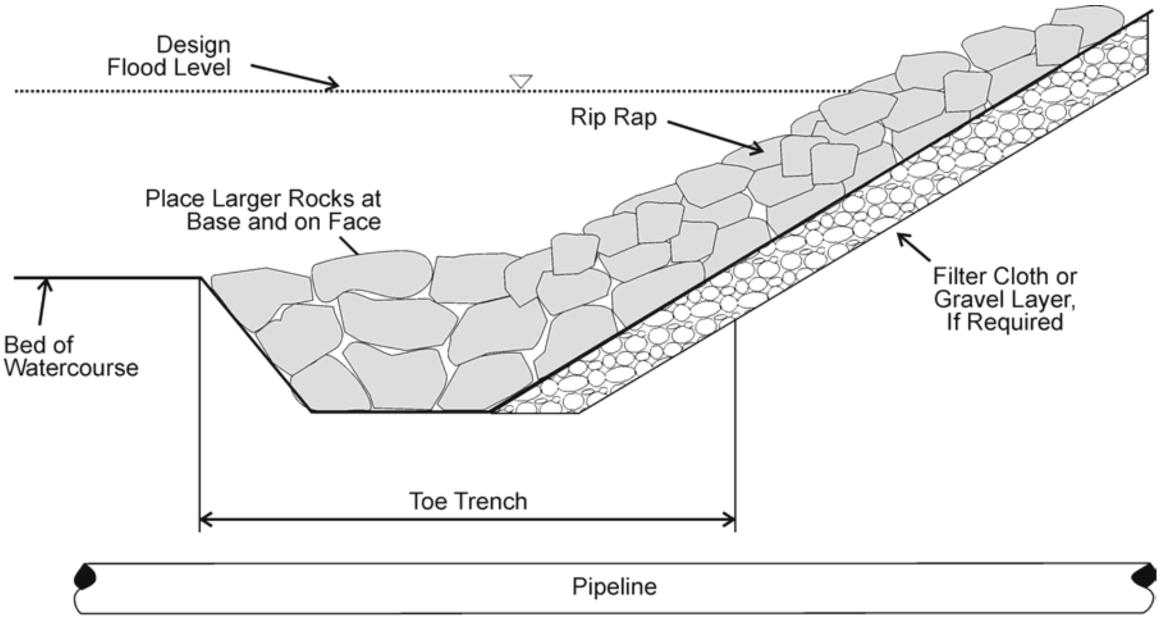


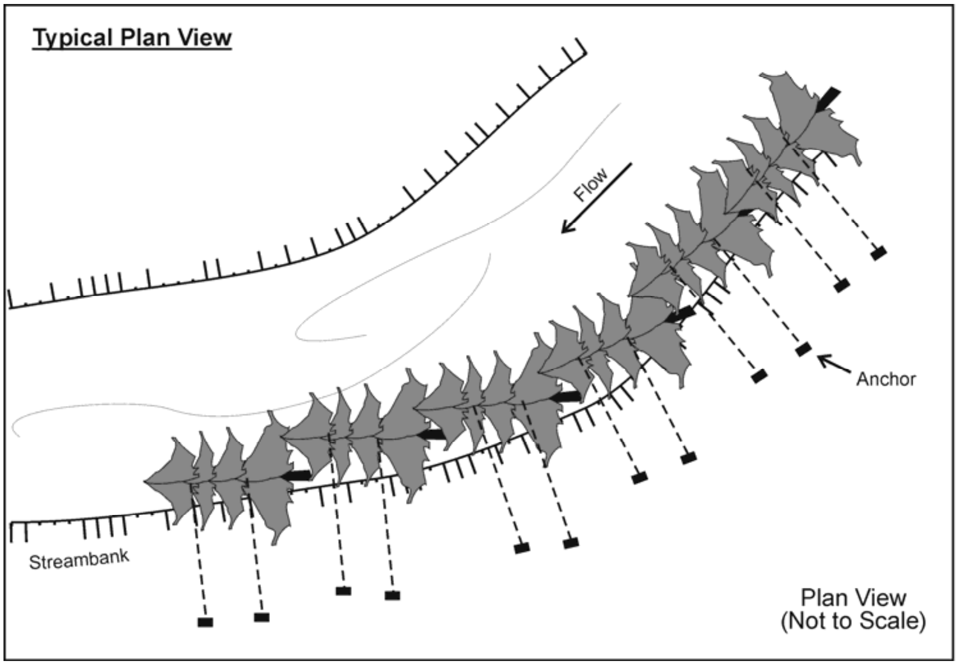
Profile
(Not to Scale)

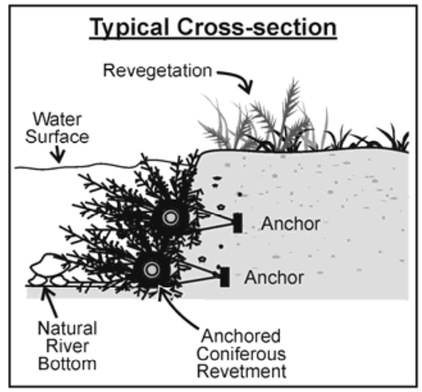
Notes:

1. Proper placement and design is critical and qualified specialists should be involved.
2. Remove all stumps, organic matter and work material and grade/prepare banks to a maximum slope as directed by a geotechnical engineer.
3. Construct toe trench to key in bottom of armour protection, or adopt thickened toe option.
4. Install filter cloth (geotextile) or gravel filter layer.
5. Place rip rap on slope to be protected such that a well-interlocked, smooth layer is produced.
6. Rip rap should be dense, durable, roughly equidimensional (not flat and thin), angular and clean.
7. Size of rip rap used is dependent upon slope of bank and water velocity.
8. The minimum thickness of a rip rap layer shall be 1.5 to 2 times the approximate dimensions of rock being used.
9. Key in up and downstream ends of the armoured bank in a manner such that it will not be outflanked.
10. Rip rap should extend 0.5 m (min) above design flood level. If design flood level is above the top of the bank, rip rap should be placed to the top of the bank.
11. Rip rap should be flush with bank adjacent to the right-of-way.

Source: Alliance 1998

STREAMBANK PROTECTION – RIP RAP ARMOUR





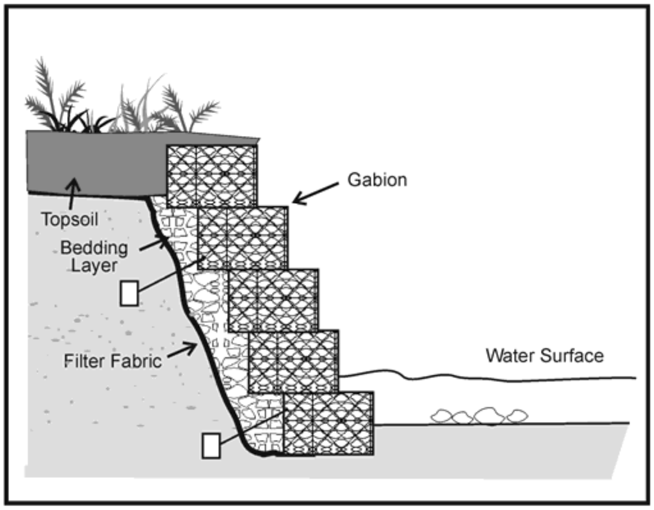
Notes:

1. Proper placement and design is critical and qualified specialists should be involved.
2. Select only good, sound, straight coniferous trees with adequate branches and a minimum length of 10 m.
3. Do not trim any branches and handle with care. Leave root ball intact if possible and transport the trees to the site with a minimum of handling to reduce damage to the branches. To the extent practical, remove soil material from the rootball before placing the tree instream. Place the trees lengthwise along or across the eroding bank to be protected beginning at the downstream end with the tips of the trees pointed in the downstream direction.
4. Begin assembly of the tree revetment at the downstream end and place tie back cable on the tree butt (largest end). Attach the cable to a suitable deadman or large armour rock with a drilled hole. Bury the anchor securely in the adjacent bank.
5. Place the butt of the next tree one-half the length of the previous tree or less upstream along the bank, so there is an overlap of the trees. If possible, cable the trees together in addition to cabling to an anchor buried in the bank.
6. Rock armour may be added along the toe of the slope, beneath the trees to reinforce the level of protection provided.
7. Maintenance, consisting of replacing severely damaged trees, will extend the life span.
8. Coniferous tree revetments also may be used as instream cover.

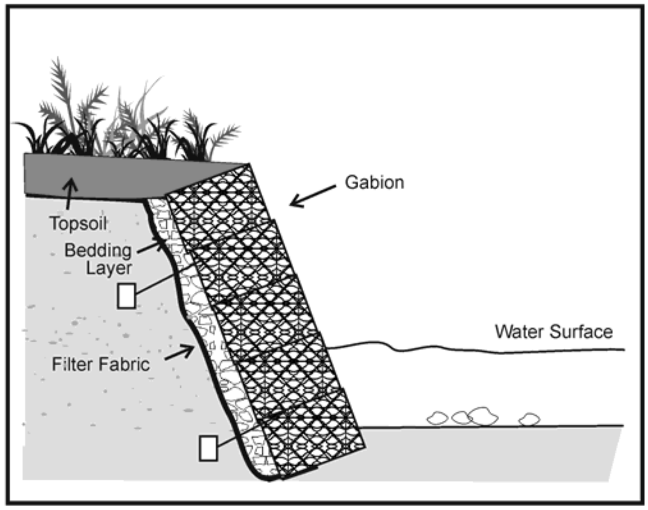
Source: Alaska Department of Fish and Game (n.d.)

STREAMBANK PROTECTION – TYPICAL CONIFEROUS TREE REVETMENT

(A) Gabions Offset to Maintain Bank Slope



(B) Gabions Installed Flat Against Streambank



Profile
(Not to Scale)

Notes:

1. Proper placement and design is critical and qualified specialists should be involved.
2. Gabions can be installed on slopes that exceed 1.5:1. Installation flat to slope is preferred on high banks.
3. Gabions should be installed to a height of about 1 m above high water level.
4. Care should be taken not to restrict stream channel capacity, particularly on smaller watercourses.
5. A key trench is to be excavated along the toe of the bank to a point below anticipated scour depth. Place filter fabric and a bedding layer of coarse gravel on excavated slope as gabions are installed.
6. Gabions should be tied together with heavy gauge wire and anchored into the banks at the up and downstream ends.
7. Fill gabion baskets in layers with angular rock larger than the mesh openings. Close and tie down the first row and repeat. Backfill behind baskets and cap with topsoil.

Source: Adapted from Envirowest 1990

STREAMBANK PROTECTION – TYPICAL GABION BASKETS

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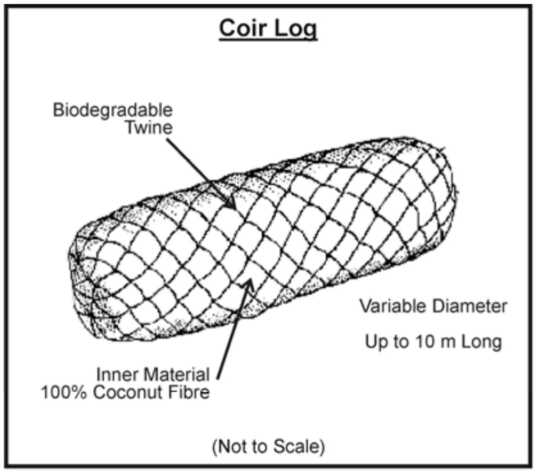

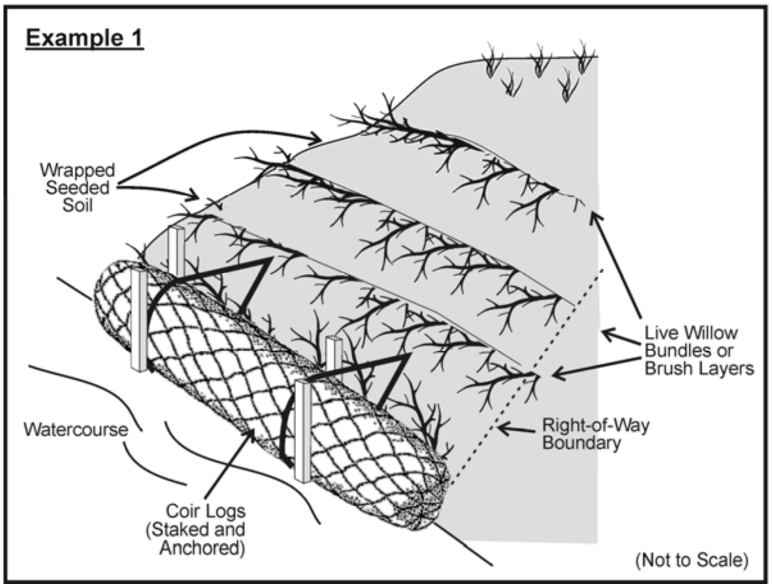

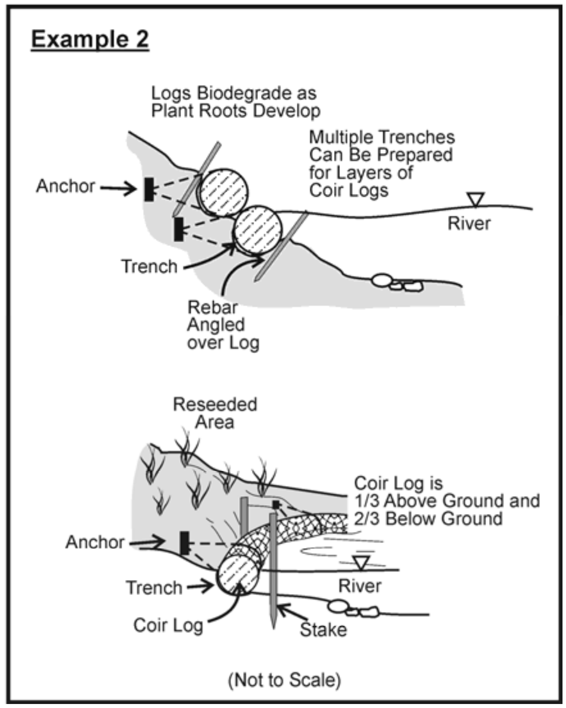

Notes:

1. Proper placement and design is critical and qualified specialists should be involved.
2. Install partially buried coir logs across entire width of disturbance. Anchor logs securely to prevent damage from ice and/or streamflow. Wooden/live stakes, curved rebar or earth anchors may be used. Additional cable anchors may be warranted.
3. Store, move and install when dry.
4. Coir logs may be seeded or cuttings may be inserted.

Source: Adapted from Alaska Department of Fish and Game 1997

STREAMBANK PROTECTION – TYPICAL COIR LOGS

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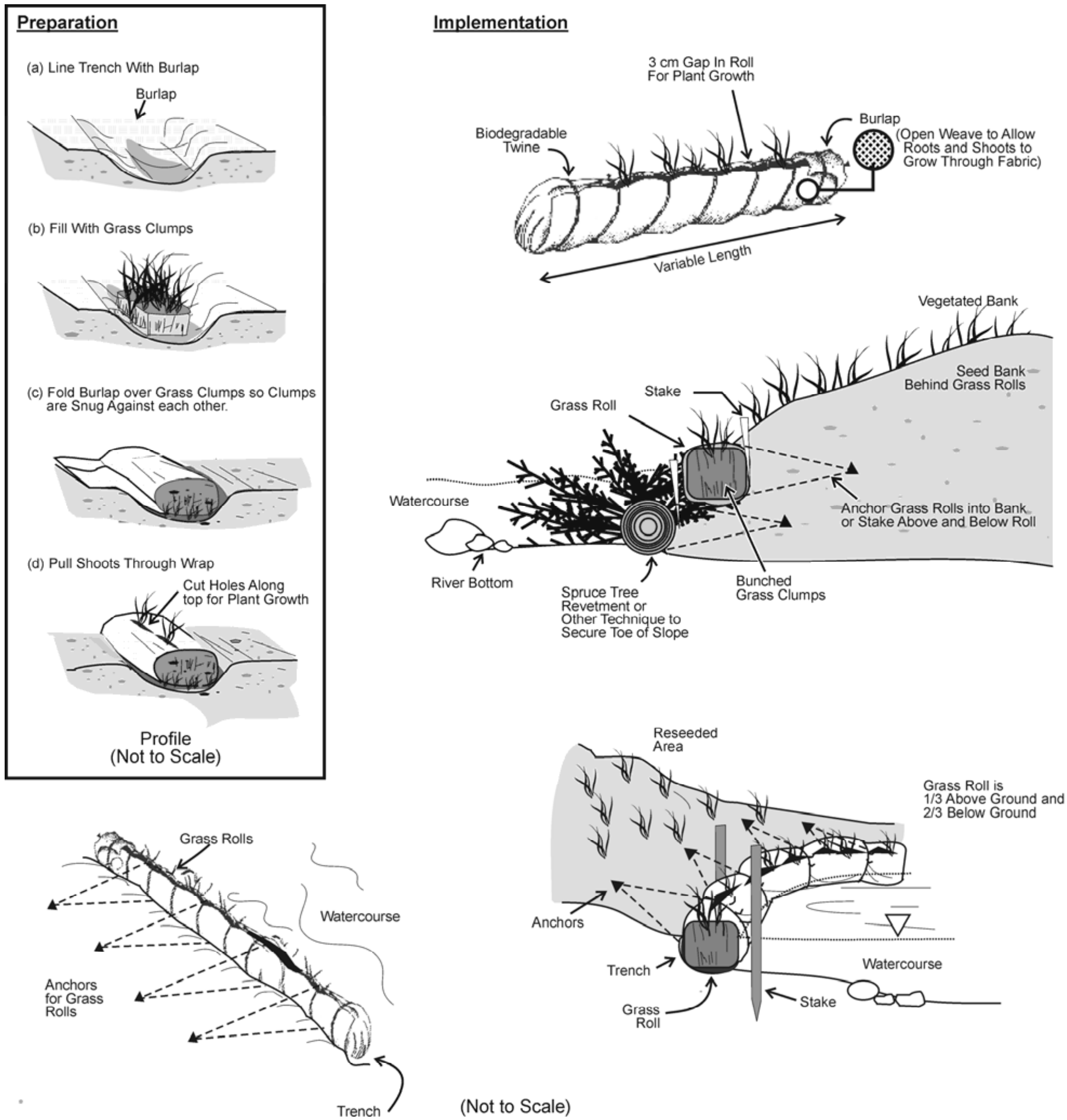

(Not to Scale)

Notes:

1. Proper placement and design is critical and qualified specialists should be involved.
2. Excavate a shallow trench along the high water mark parallel to the toe of the bank and line with burlap.
3. Install sod in the middle of the roll and wrap with burlap covers. Tie with twine and cut slits to expose sections of sod.
4. Stake or anchor firmly ensuring up and downstream ends are secured to prevent washing out.

Source: Adapted from Alaska Department of Fish and Game 1997

STREAMBANK PROTECTION – TYPICAL GRASS ROLL

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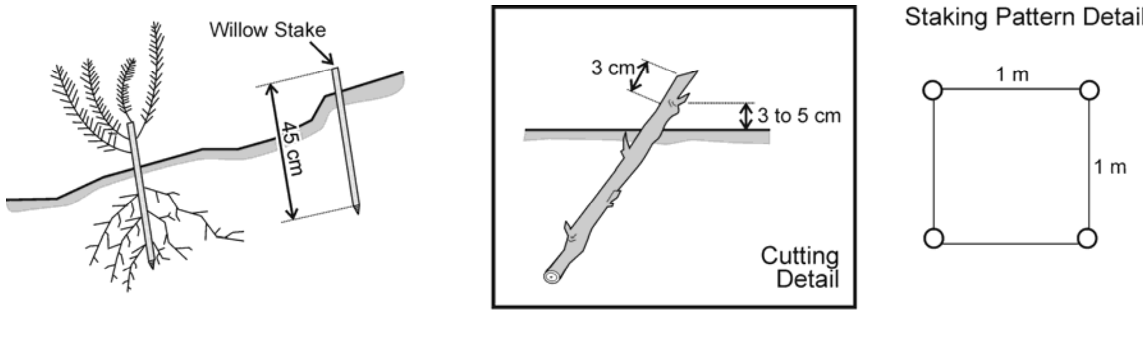


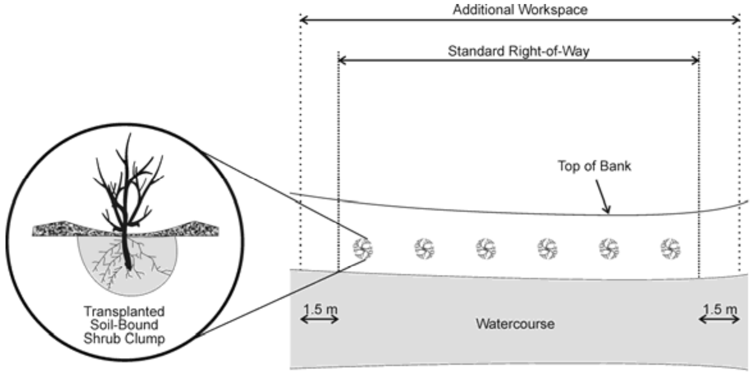
Profile
(Not to Scale)

Profile
(Not to Scale)

Plan View
(Not to Scale)

Notes:

1. Install stakes of suitable species (*e.g.* willow, dogwood) on watercourse banks.
2. Make clean cuts with unsplit ends using pruning shears, hand saw or chain saw.
3. Select stock from bottom of branches not tips.
4. Mark basal ends to ensure correct installation.
5. Ensure at least one lateral bud above surface and three below. Plant cutting at an angle.
6. Protect material from drying out. Install as quickly as practical.
7. Trim side shoots close to main stock.
8. Use frost pin to make pilot hole. Minimize damage to stake when driving by using a neoprene lined post hole pounder or rubber mallet.
9. Install live stakes on banks and 1.5 m (approximately) back from banks for entire disturbed width of right-of-way.



Profile
(Not to Scale)

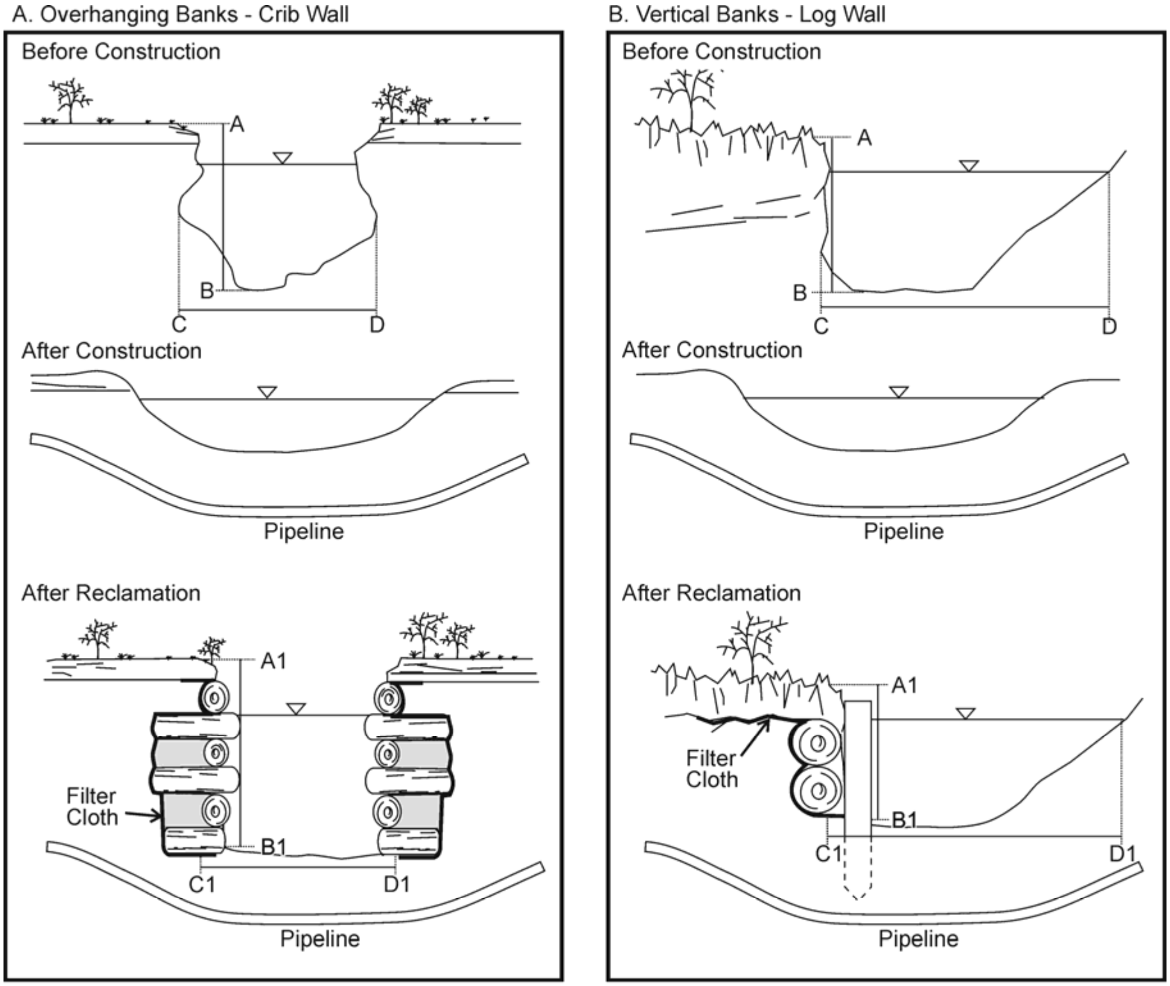
Plan View
(Not to Scale)

Notes:

1. Salvage and replace shrubs on all watercourse banks where shrubs are present on the right-of-way.
2. Salvage whole bushes from the right-of-way during grading of banks. Ensure bulk of root mass is surrounded by soil.
3. Store salvaged shrubs on edge of right-of-way, cover with soil and do not let dry out.
4. Transplant as quickly as practical when reconstructing watercourse banks.
5. Soak the ground around the transplant with water.

Source: Adapted from TERA 1998

STREAMBANK PROTECTION – TYPICAL SHRUB RESTORATION



Profile View
(Not to Scale)

Notes - Overhanging Bank Crib Walls:

1. Proper placement and design is critical and qualified specialists should be involved.
2. Install overhanging bank cribwalls to provide overhead cover and erosion control.
3. Install log overhang greater than 30 cm.
4. Install native timber (coniferous where possible).
5. Ensure A1, B1 is not less than A-B.
6. Ensure C1-D1 is not greater than C-D.
7. Backfill with coarse, nonerodible material.
8. Replace subsoil and topsoil.
9. Transplant native vegetation. Sow appropriate seed mix.
10. Live willows may be laid perpendicularly to streamflow within and projecting from the crib wall above the water line. This will create a live crib wall.

Notes - Vertical Bank Log Walls:

1. Proper placement and design is critical and qualified specialists should be involved.
2. Install bank log walls to maintain bank slope and provide erosion control.
3. Install vertical posts 3 times length of exposed height.
4. Utilize native timber or lumber for horizontal structure.
5. Ensure A1-B1 is not less than A-B.
6. Ensure C1-D1 is not greater than C-D.
7. Anchor posts if warranted.
8. Backfill with coarse nonerodible material.
9. Replace subsoil and topsoil.
10. Transplant native vegetation. Sow approved seed mix.
11. Live willows may be laid perpendicularly to streamflow within and projecting from the log wall above the water line. This will create a live log wall.

Source: Adapted from TERA 1998

STREAMBANK PROTECTION – TYPICAL LOG AND CRIB WALLS

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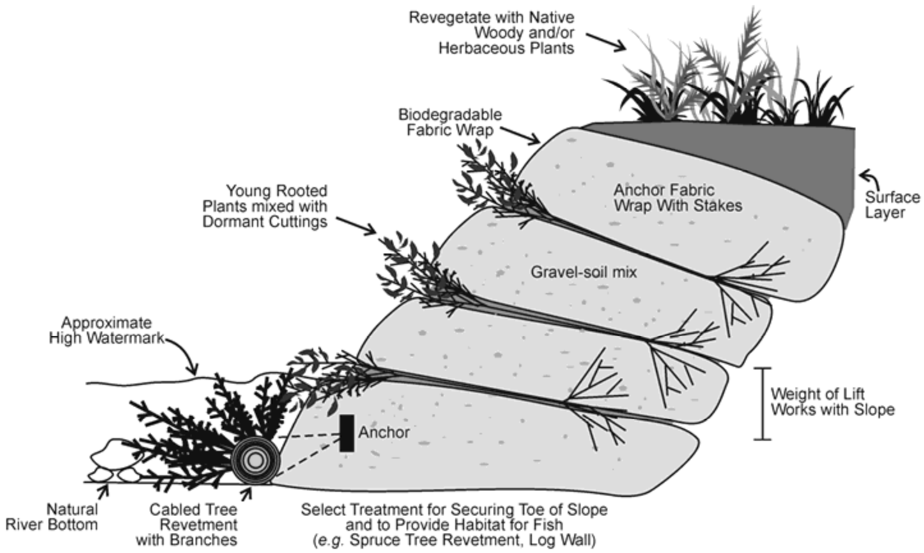

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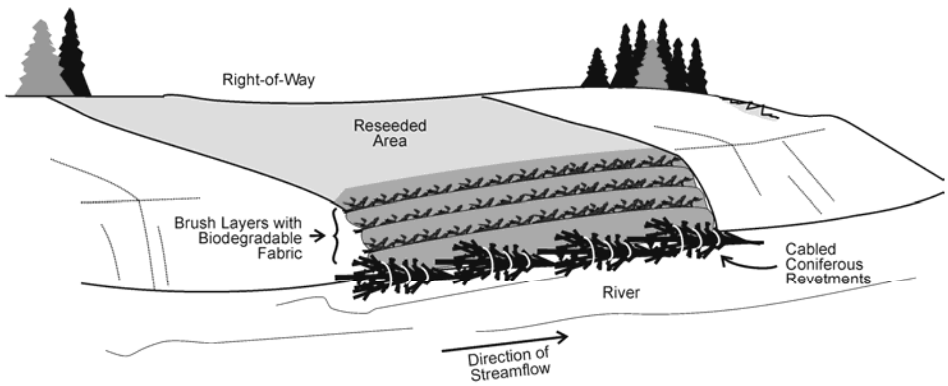

Oblique View
(Not to Scale)

Notes:

1. Proper placement and design is critical and qualified specialists should be involved.
2. Secure the toe of the slope with appropriate technique (coniferous tree revetments, log wall, riprap, etc.).
3. Begin layering at the bottom of slope with first hedge/brush layer situated at the approximate high water mark or lower. Select plant species suitable for site conditions.
4. Excavate the first bench 0.5-1.0 m deep, ensuring not to damage the pipeline, angled slightly down into the slope. Lay branches and transplants on the bench, slightly criss-crossing, with shoots extending beyond the edge of the bench by approximately 20% of their length.
5. Plant 18-25 stems per metre, using higher densities for more erosive sites or if the cutting's diameter is small. Cover with 5-10 cm of soil and tamp into place.
6. Continue building layers with damp soil and cuttings until bank height is reached. Vary spacing between layers based on erosion potential.
7. For best results dig transplants in spring or late summer and plant the same day. Keep transplants moist. A mixture of plant species can mimic adjacent undisturbed vegetation.

Source: Adapted from Alaska Department of Fish and Game 1997

STREAMBANK PROTECTION – TYPICAL HEDGE / BRUSH LAYERING

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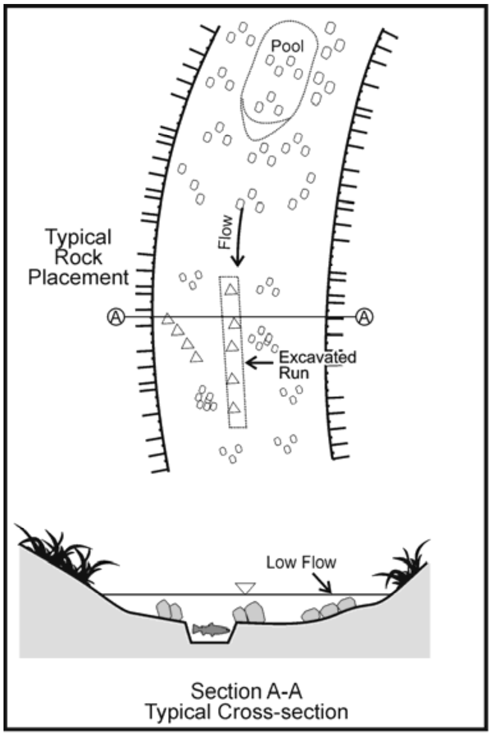

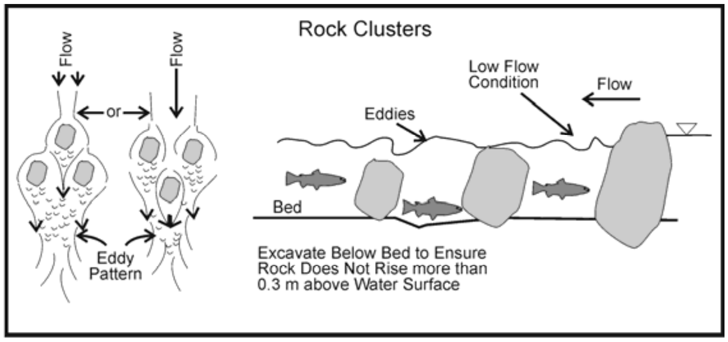

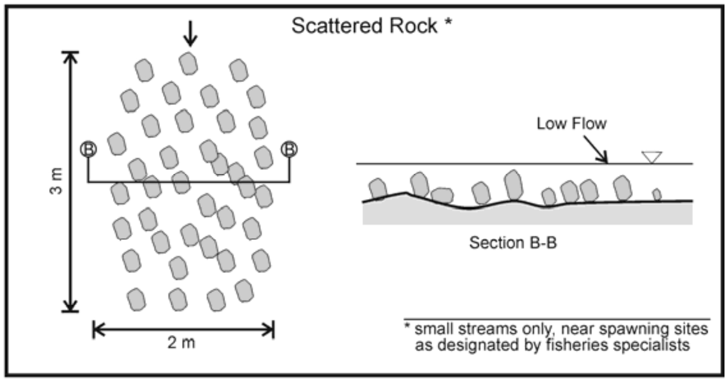

(Not to Scale)

Construction Notes - Rock Clusters (adult shelter):

1. Proper placement and design is critical and qualified specialists should be involved.
2. Navigable Waters approval may be required prior to installing rock clusters.
3. Individual rocks may be in clusters of 2 to 5 (generally 3), placed in various patterns as shown or as directed in the field. Place rocks in the middle 3/4 of the watercourse such that they do not direct current against an existing unprotected bank.
4. Pre-excavate holes so that the rocks are at or below, but not to exceed 0.3 m above existing water level at the time of installation.
5. Arrange the rocks within clusters, averaging 0.8-1.5 m apart, with a minimum space of 2.5 m between each of the clusters.
6. Individual rocks or rock clusters may be placed within a resting pool, excavated run or natural pool or run to enhance shelter and feeding opportunities.
7. For small watercourses, use only small material (0.2-0.4 m) for normal rock clusters. Placement will depend upon flow velocities, depths and location of riffles and pools.
8. For mid size watercourses, large individual rocks are preferred (0.8-1.2 m).
9. For large watercourses (width 50 m) individual rocks in the range of 2.0-3.0 m in diameter are recommended. Exact placement of these rocks is more critical to avoid encouraging bank erosion and specialist advice should be obtained.
10. All rock used must be angular, hard, durable and preferably (not necessarily) weathered for visual acceptance.

Construction Notes - Scattered Rock (Fry Shelter):

1. Proper placement and design is critical and qualified specialists should be involved.
2. Navigable Waters approval may be required prior to installing rock clusters.
3. All rock to be 300 mm or less in diameter, placed in shallow fast moving flow areas such that the top of the rock is at/below normal low water levels.
4. The rock fragment grouping is very loose with an overall size of 2 x 2 m with individual pieces of rock 0.3 m apart.
5. Scattered rock groups to be placed approximately 2.0 m apart, preferably in shallow water near banks to benefit young-of-year and maintain open flow areas.

Source: Adapted from CAPP 1993

INSTREAM COVER – TYPICAL ROCK CLUSTERS

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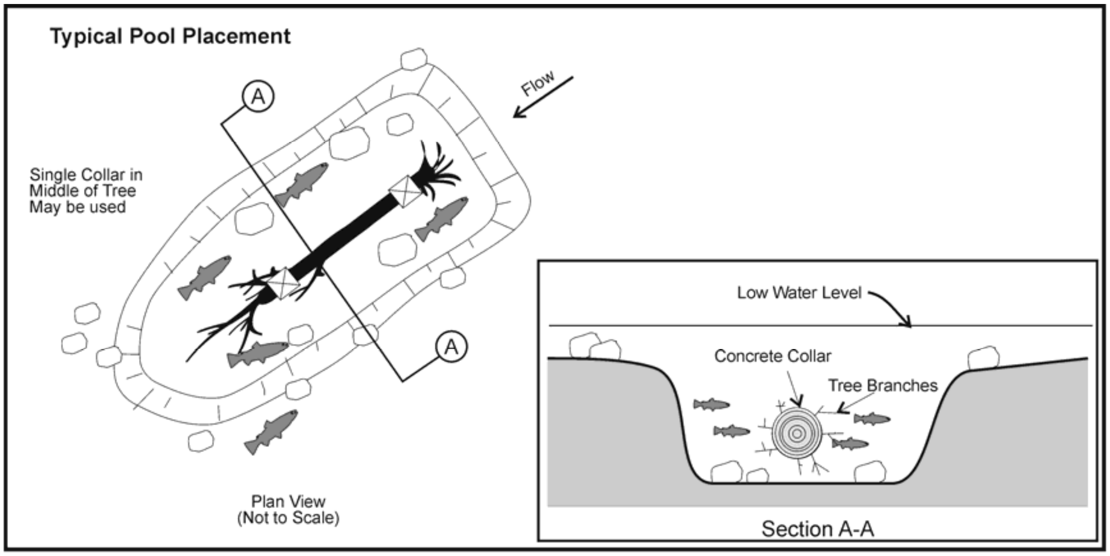

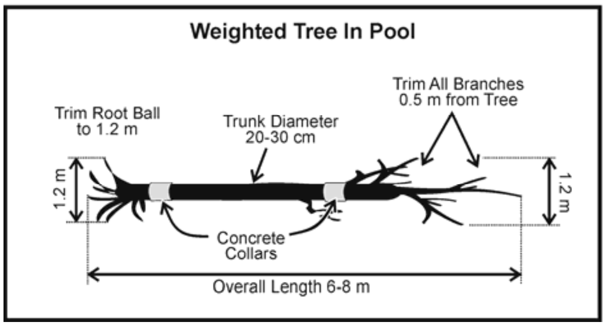

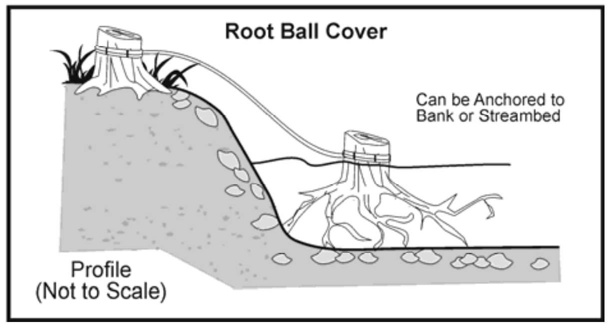

Construction Notes - Weighted Tree in Pool:

1. Proper placement and design is critical and qualified specialists should be involved.
2. Navigable Waters approval may be required prior to installing log or root balls.
3. Use only sound, straight coniferous trees with adequate branches and root ball, 6-8 m in length, with a minimum diameter of 0.4 m.
4. Trim the root ball and all branches so that they remain 0.6 m below the surface of the pool and will not snag any boat traffic or debris.
5. Place 50 kg or more concrete pipe weights on each end of the tree, where the trunk will support the heavy weights, and move the tree into the pool area utilizing two backhoes, if feasible. Carefully lower the tree to the bottom of the upstream end of the pool (breakage may occur due to heavy pipe weights).
6. Place Rock Clusters in and around the pool as desired.
7. Weighted trees may be added to or removed from pools at any time after construction to change shelter provisions.

Construction Notes -Root Ball Cover:

1. Proper placement and design is critical and qualified specialists should be involved.
2. Navigable Waters approval may be required prior to installing log or root balls.
3. Select and clean large coniferous root balls.
4. Trim and anchor root balls securely to bank or streambed so that they remain 0.6 m below the water surface.

Source: Adapted from CAPP 1993

INSTREAM COVER – TYPICAL LOG / ROOT BALLS

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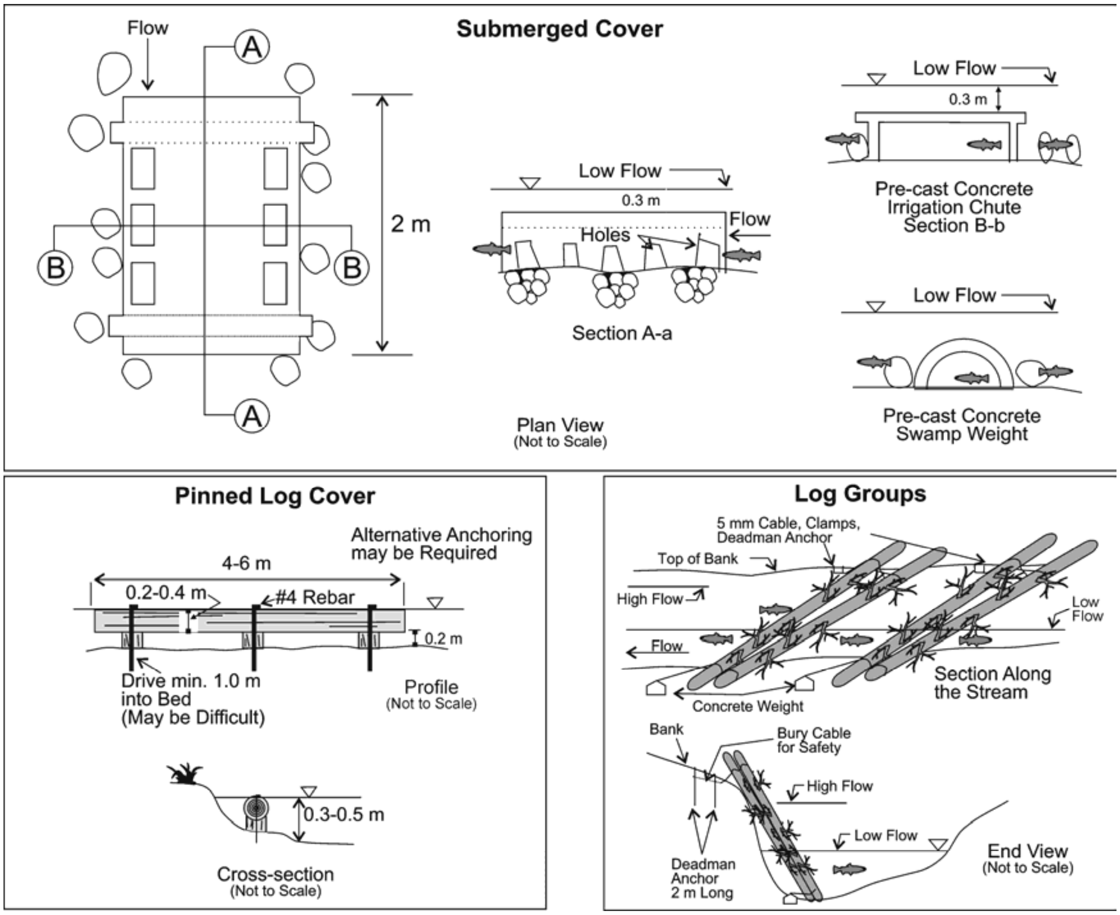

Construction Notes

Submerged Cover

1. Proper placement and design is critical and qualified specialists should be involved.
2. Navigable waters approval might be required prior to installing a submerged cover.
3. Prior to installation, punch several holes in the upper area of the concrete pipe to allow numerous shelter/water interfaces and visual access to the inside of the half pipe.
4. Concrete sections may be set together or placed individually on 2 m triangular steel bars to reduce the amount of settlement into the instream gravels.
5. Place the precast section in the lowest point of the watercourse, parallel to the direction of flow so there will be smooth flow conditions through the pipe section. Water depth at low flow should equal or exceed the structure height.

Pinned Log Cover

1. Proper placement and design is critical and qualified specialists should be involved.
2. Select sound coniferous trees and remove all limbs within 0.2 m from the trunk of the tree and transport to the site.
3. Cut three small logs (0.3 m long) from the tree and drill lengthwise to accept 3/4" reinforcing steel rod. Drill 3 similar holes in the tree to accept the steel rods as shown in the drawing.
4. Select a location, 0.3-0.5 m depth. Place the rebar through main log, and support logs and drive rebar a minimum of 1.0 m into the streambed for good anchorage. Bend the top section of the rebar as shown to anchor the log to the streambed. Additional rebar may be warranted. An alternate anchoring system may be reqired if unable to drive the reinforcing steel into the streambed.

Log Groups

1. Proper placement and design is critical and qualified specialists should be involved.
2. Select sound straight coniferous trees, remove tree limbs 0.3 m from the trunk and transport to the site.
3. Select 2-3 trees and tie into a loose bundle. Overlap the tree lengths by at least 1/2 their length or more.
4. Cable log tips to a 20 kg (or more) concrete weight, which will be placed on the streambed to hold the tips in place.
5. Anchor the base of the logs on the bank with a 5 mm tieback cable to several deadman anchors to prevent movement. Bury the cable tieback to avoid safety hazard to fishermen.
6. Log groups can also be placed with rock clusters by using a short log deadman anchor buried beneath a large rock (1.5 m+) in the middle of the streambed. The log groups are oriented in the downstream direction.

Source: Adapted from CAPP 1993

INSTREAM COVER – TYPICAL SUBMERGED COVER

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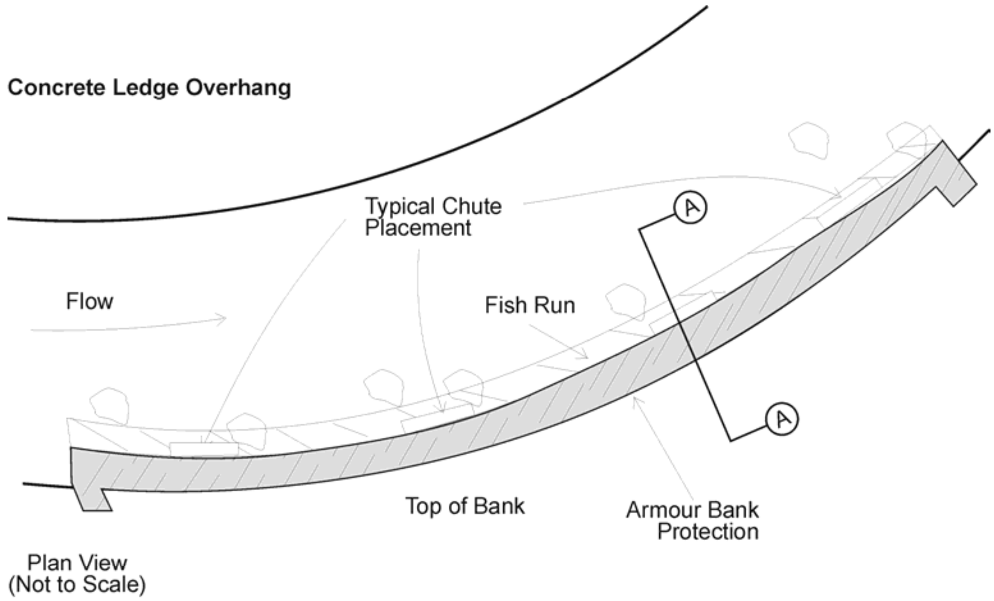
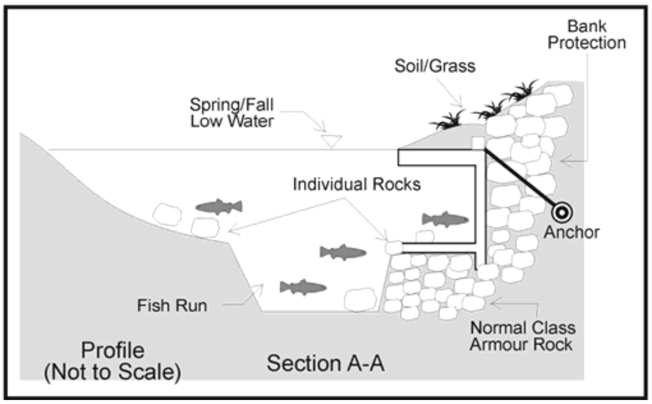




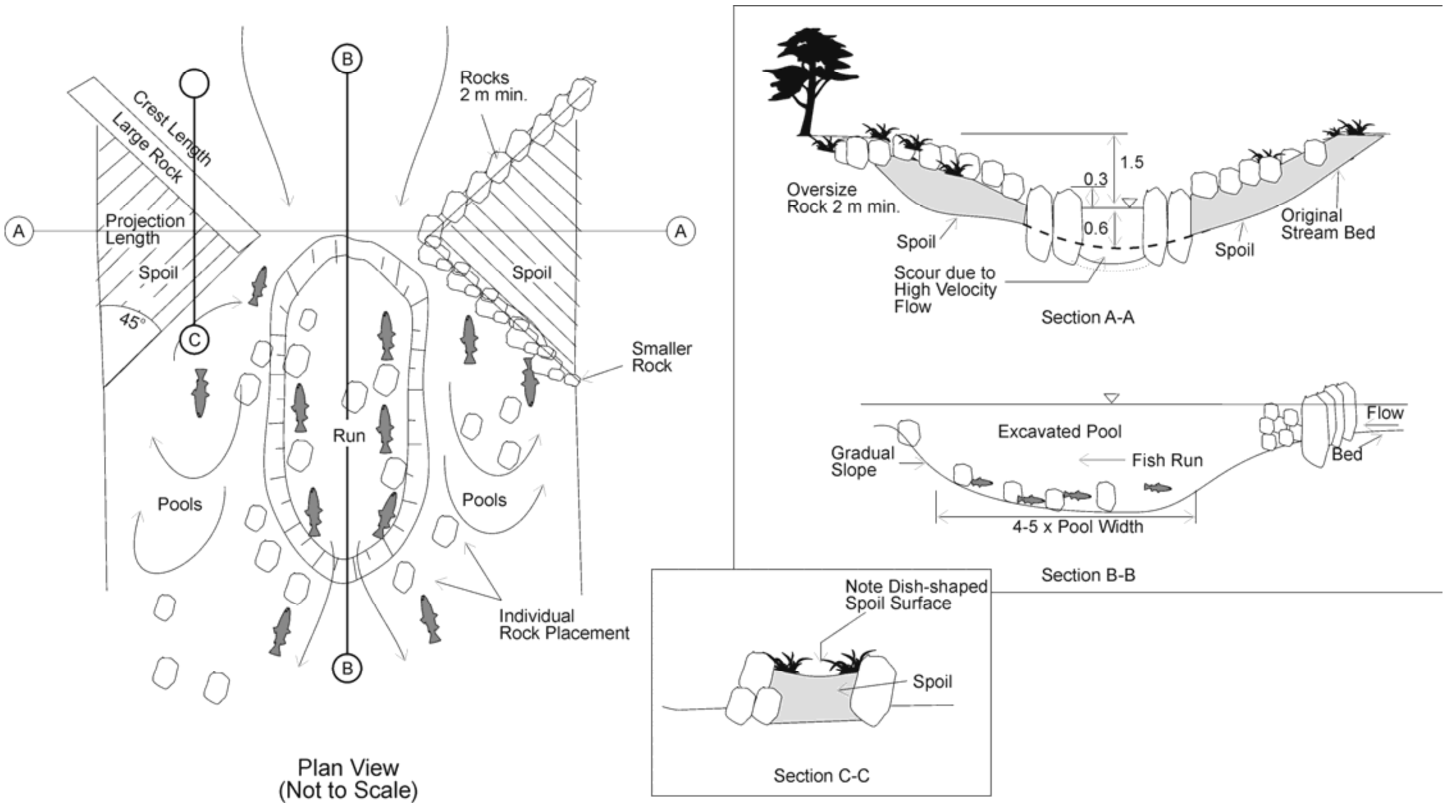
Construction Notes - Concrete Ledge Overhang:

1. Navigable Waters approval might be required prior to installing bank overhang.
2. Proper placement and design is critical and qualified specialists should be involved.
3. If the Concrete Ledge section is added before bank armour rock installed is complete, place only lower portion of rock upon which concrete chute sections will rest. Install all necessary tiebacks, anchors and individual rocks within the flume, taking great care that the flume sections line up horizontally and are well supported.
4. If the flume section is added to an existing armour rock bank, keep the disturbance of the armour rock to a minimum, removing only enough rock to set the flume sections firmly in place. Install the needed tiebacks, anchors and individual rocks within the flume, ensuring the flume sections line up horizontally.
5. Replace the armour rock around the back and ends of the chute, ensuring that no change in horizontal alignment takes place.
6. Backfill the top of the structure with light armour rock. Add soil grass and trees where possible on or near the embankment.
7. This structure may be placed at any location whether there is existing bank protection or not. The method of construction will keep the disturbance of the armour rock to a minimum.
8. Maintenance may be required to maintain proper horizontal alignment of the sections to avoid damage occurring to the structure when a strong current catches an edge separation.

Source: Adapted from CAPP 1993

INSTREAM COVER – TYPICAL BANK OVERHANG

CAPP • CEPA • CGA



Construction Notes:

1. Navigable Waters approval might be required prior to installing opposing rock wing deflectors.
2. Proper placement and design is critical and qualified specialists should be involved.
3. All rocks must slope down to the middle of the watercourse to the point of the deflector.
4. The upstream face must contain the largest rocks so that the pressure of the flow may be resisted. Smaller rocks may be placed on the downstream face. Each rock is to be placed in the shadow of the previous rock from the point to the bank. All rock must fit tightly together and be jammed together by machinery.
5. Place the upstream rock face in a trench, then place the downstream rock face in a similar trench, taking care that the rocks slope upwards to the side of the watercourse such that the point of the deflector is about 0.3 m above the water level and the root is at least 1 to 1.5 m above current water level. Ensure the pipeline is not damaged during this excavation.
6. Excavate the downstream run, placing much of the spoil material within the confines of the two rock faces. The top surface of the spoil must be below the level of the adjacent rock faces. All remaining spoil must be deposited 10 m outside the streambanks and preferably 1.5 m above the water level.
7. In very large watercourses, a double row of rocks will be required for both the up and downstream faces of the deflectors.
8. The open area in the middle of the watercourse must be about 1/4 of the watercourse width or less, so that a section of the rapid flow conditions exists to funnel the water into the downstream run. On occasion the opening must be constricted even more to provide higher flow velocities when necessary.
9. The instream point of the deflectors shall be 0.6 m above the streambed. Ensure that the root of the deflectors is 1.0 to 1.5 m above current water levels and firmly imbedded in the streambank.
10. All elevations relate to low streamflow in the spring or fall.

Source: Adapted from CAPP 1993

CURRENT DEFLECTORS – TYPICAL OPPOSING ROCK WING DEFLECTORS

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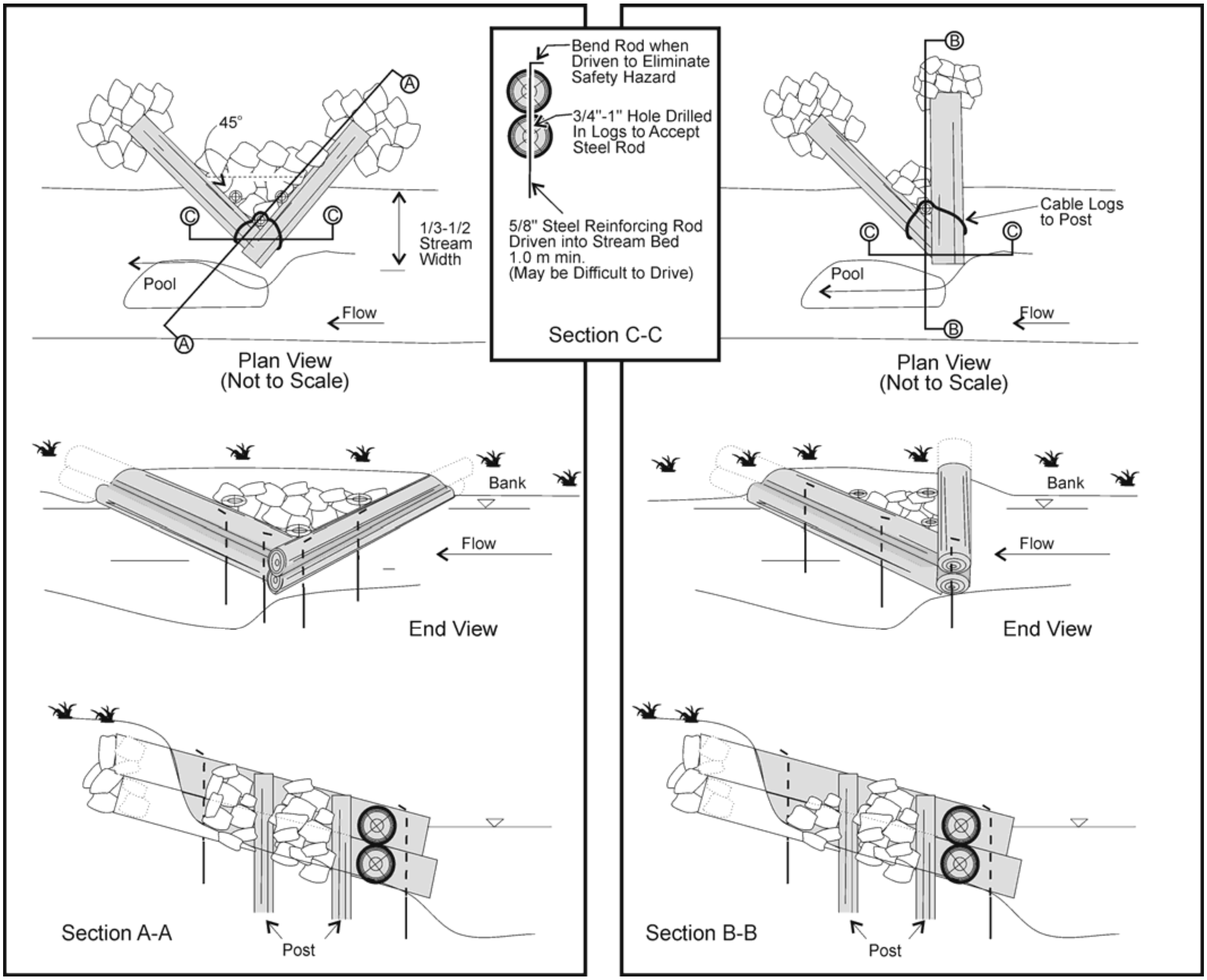
Third Edition

October 2005

DWG. NO. 35



Construction Notes:

1. Navigable Waters approval might be required prior to installing a log deflector.
2. Proper placement and design is critical and qualified specialists should be involved.
3. Select sound, straight coniferous trees; trim all branches; debark all logs and transport to the site. Cut logs to the required length.
4. The main deflector logs are set into a pre-excavated trench in the streambed. The base of the logs must be on the bank, and the points of the deflector on the streambed. Where only smaller logs are available, one log is set on top of another and pinned together for support and correct alignment. A 15 cm (minimum) diameter post is to be driven deeply into the streambed at the inside point of the deflector logs for additional support. The logs may also be pinned to the streambed with reinforcing steel.
5. The deflector logs must extend from a low point in the watercourse (about 1/3 to 1/2 the watercourse width) up and into the banks a distance of 1.5 - 2 m. Additional logs are placed on top of the initial logs if necessary and pinned to the bottom log and cabled to the post for additional support.
6. Place large rocks around and against the base of the deflector logs and on the inside point to hold them firmly in place.
7. The top of the log deflector shall not be more than 0.6 m above the streambed, unless a more effective deflector is required.

Source: Adapted from CAPP 1993

CURRENT DEFLECTORS – TYPICAL LOG DEFLECTOR (Small Watercourses, Width <5 m)

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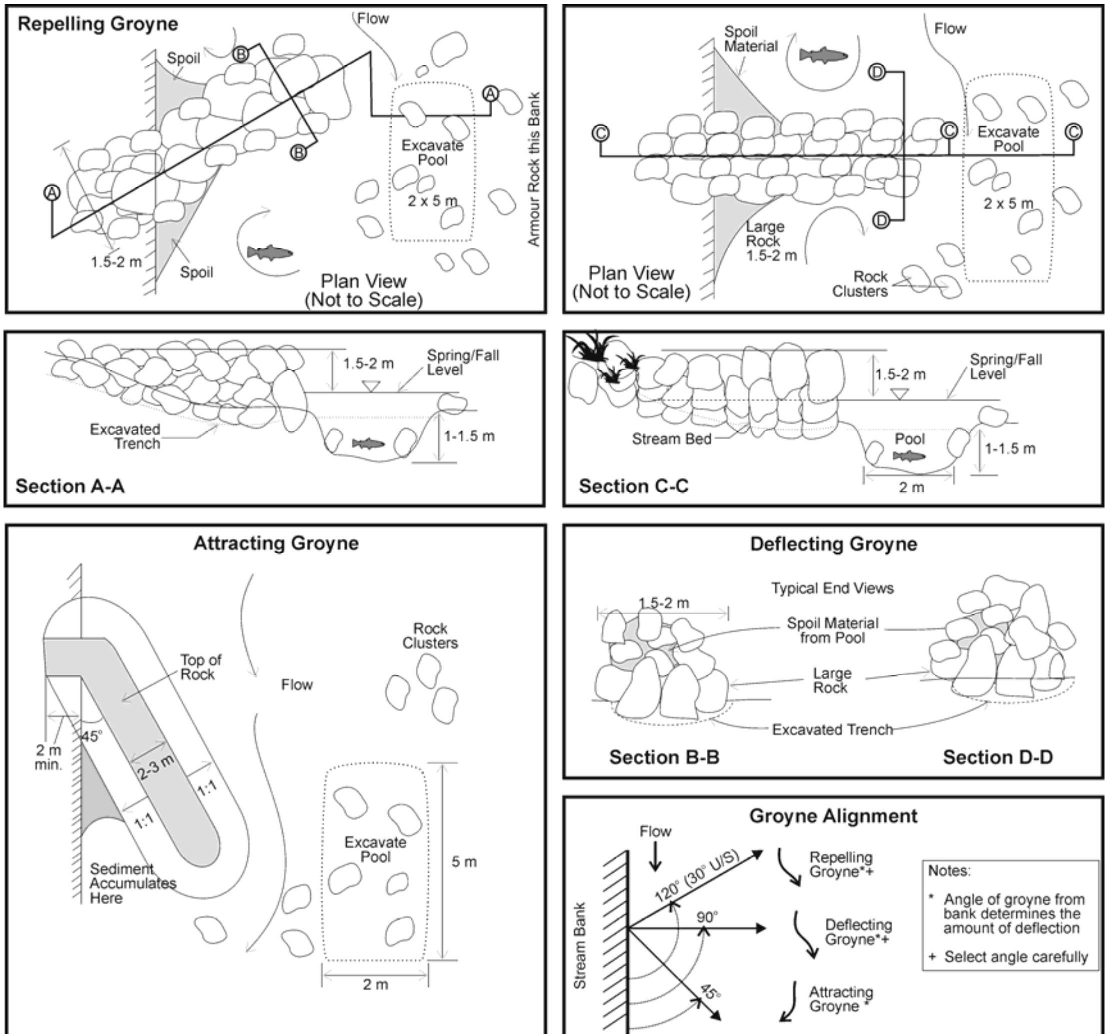
Third Edition
October 2005
DWG. NO. 36



Construction Notes:

1. Navigable Waters approval might be required prior to installing a groyne.
2. Proper placement and design is critical and qualified specialists should be involved.
3. The largest rocks are always to be placed at the tip of the groyne.
4. Projecting length must not exceed 1/2 watercourse width.
5. Groynes are always to be countersunk into the bank.
6. Only a minimum amount of spoil material is to be placed on the groyne to fill holes and soften appearance. All remaining spoil material is to be placed 10 m outside the channel.

Repelling Groynes - 30° upstream

1. Deflects the main current toward the opposite bank. Heavy armour bank protection is required on the opposite bank.
2. This structure will protect a length of eroding bank up to 3.5 times the projecting length. They are normally utilized to deflect flows away from an eroding bank under severe erosion conditions, large flows or unstable banks.

Deflecting Groynes - 90° to the bank

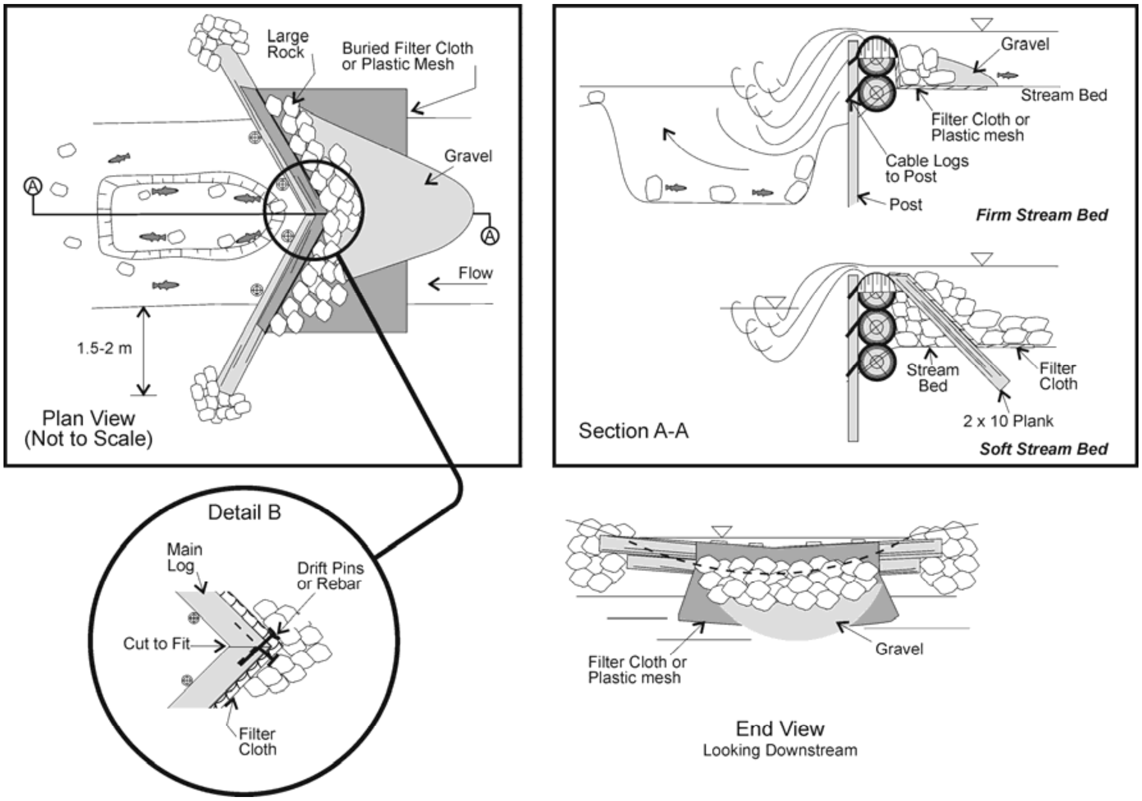
1. Deflects the current from along the bank into mid-stream away from the groyne. The opposite bank requires protection when the projection length approaches 1/2 the watercourse width. These are used to provide economical channel narrowing in wide shallow reaches.
2. Typical design is a series of groynes, each 3 m long at 10 m spacing around the outside bend of a watercourse, with a small pool at the tip of each groyne. Excavated material from fish runs must be properly spoiled or placed on the bank between groynes.

Attracting Groyne - 45° downstream

1. Deflects flow slightly, pulling it downstream behind the groyne.
2. These are normally used to confine rapid, shallow flow to the middle 1/2 of a watercourse or installed on alternating banks to provide a deeper meandering channel pattern in a straight reach when combined with a large Excavated Run and Rock Clusters.

Source: CAPP 1993

CURRENT DEFLECTORS – TYPICAL GROYNES – FULL SIZE



Construction Notes:

1. Navigable Waters approval might be required prior to the installation of a Log V Weir.
2. Proper placement and design is critical and qualified specialists should be involved.
3. Select sound, straight coniferous trees for all main and support logs, trim all branches, debark all logs and transport to the site.
4. Main support logs are set into a pre-excavated trench (avoiding the pipeline) in the streambed and must slope down to the middle of the weir to confine the flow to the middle of the watercourse. Where the selected logs are small in size two layers are required. One layer is set on top of the bottom layer and pinned together as needed for stability. Four to six, 15 cm diameter posts are to be driven deeply into the streambed on the downstream side of the weir crest for additional stability. Two posts are located near the notch while the others are spaced out along the weir crest. The posts are tightly cabled and pinned to the main logs for additional support.
5. Main support logs must extend upstream against the direction of flow from the banks to the middle point of the weir. The logs are deeply buried in the banks for a distance of 1.5-2 m.
6. The central logs are pinned together with drift pins driven through one log into the opposite log. Posts are pinned to the main logs.
7. Approved filter cloth is attached to the upstream side of the main logs and extended down to the streambed. The filter cloth is then extended upstream at least 2 m. This filter cloth will prevent the migration of cobbles beneath the log structure. This migration of cobbles is to be avoided at all costs since it eliminates the effectiveness of the structure. Repairs will center on this area.
8. Large rocks (0.5 m) are placed on the filter cloth against the main logs to keep the cloth and logs in place. Smaller material (cobbles) is placed on and upstream of the rocks to provide a smooth upstream bed surface and fill in the voids.
9. An alternative is to place short (0.75 m) pieces of 2" x 10" planking extending from the weir crest upstream and down into the channel bed to form a barrier to movement of material similar to the cloth described above. It is recommended to add the cloth as well. The space under the planking is filled with rock and cobbles to eliminate any voids.
10. The upstream notch on the weir must be within the middle third of the watercourse, but may be placed at any point within to move the current from side to side. Bank armouring may be needed in such cases.
11. **The** top of the log sill at the notch of the weir is not to be more than 0.6 m above the streambed, unless a deeper upstream pool is required. Locate the bank tie-in 1.0 m+ above the watercourse elevation or 0.5 m above the notch. Ensure that logs shall taper gradually from the notch to the tie-in point on the bank.

Source: Adapted from CAPP 1993

OVERPOUR STRUCTURES – TYPICAL LOG V WEIR (Small Watercourses, Width <5 m)

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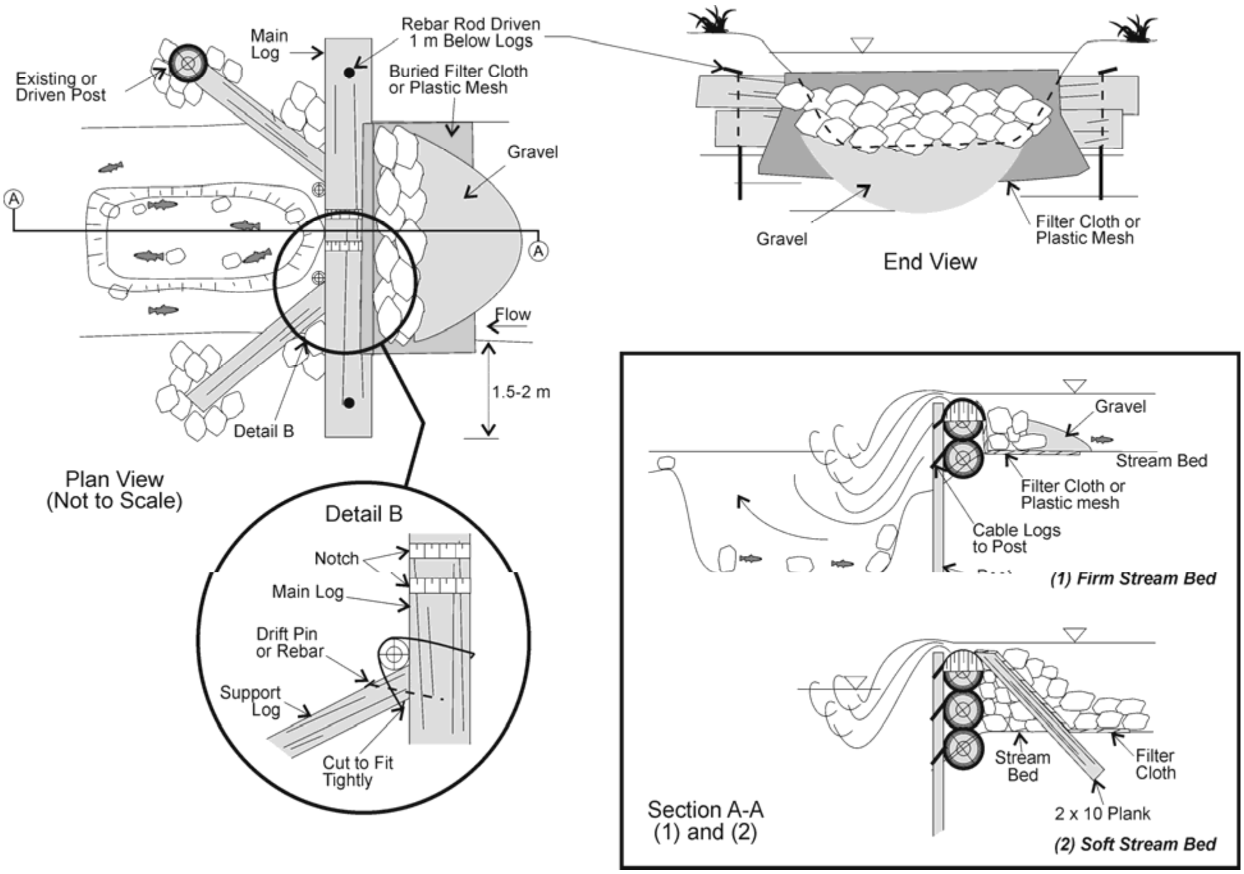
	Third Edition
	October 2005
	DWG. NO. 38



Construction Notes:

1. Navigable Waters approval might be required prior to the installation of a Log K Dam.
2. Proper placement and design is critical and qualified specialists should be involved.
3. Select sound, straight coniferous trees for all main and support logs, trim all branches, debark all logs and transport to the site.
4. Main support logs are set horizontally into a pre-excavated trench in the streambed. Where only small logs are available, one log is set on top of another and pinned together for support and correct alignment. Fifteen centimetre diameter posts are to be driven deeply into the streambed on the downstream side of the weir crest for additional stability. The posts are tightly cabled to the main logs for support.
5. The main weir crest log must extend across the watercourse and into the banks a distance of 1.5-2 m. Additional logs are placed on top and pinned to the bottom log and cabled to the posts.
6. The support logs are pinned to the main log with long nails.
7. Approved filter cloth is attached to the upstream side of the main log and extended down to the streambed. The filter cloth is then extended upstream at least 2 m. This filter cloth will prevent the migration of cobbles beneath the log structure. This migration of cobbles is to be avoided at all costs since it eliminates the effectiveness of the structure.
8. Place large rocks on the filter cloth against the main log to keep the cloth and log in place. Smaller material (cobbles) is placed on the upstream of the rocks to provide a smooth upstream bed surface and fill in the voids.
9. An alternative is to place short (0.75 m) pieces of 2" x 10" planking extending from the weir crest upstream and down into the channel bed to form a barrier to movement of material similar to the mesh described above. It is recommended to add the cloth as well. The space under the planking is filled with rock and cobbles to eliminate any voids.
10. The top of the log sill is not to be more than 0.6 m above the streambed, unless a deeper upstream pool is required. A notch is to be cut in the middle of the weir crest to concentrate very low discharges. The notch is to be less than 1/2 the top log depth and about 0.4 m wide measured at the top of the log (see drawing).

Source: Adapted from CAPP 1993

OVERPOUR STRUCTURES – TYPICAL LOG K DAM (Small Watercourses, Width <5 m)

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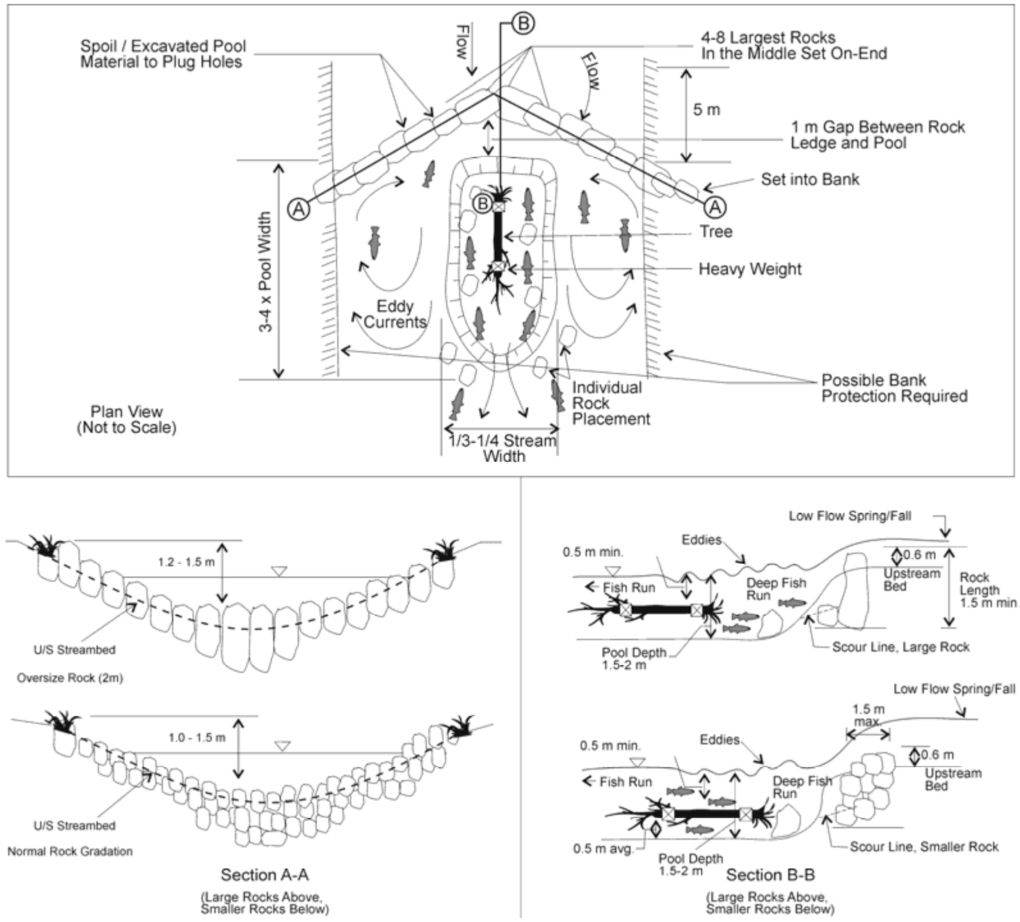
Third Edition

October 2005

DWG. NO. 39

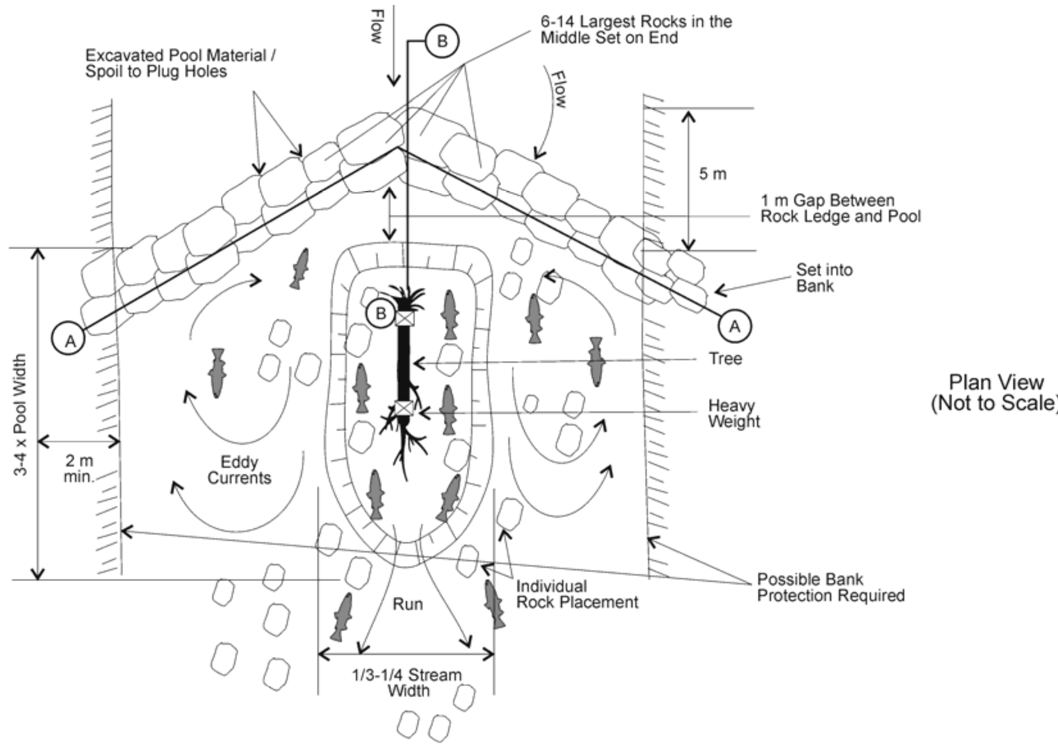


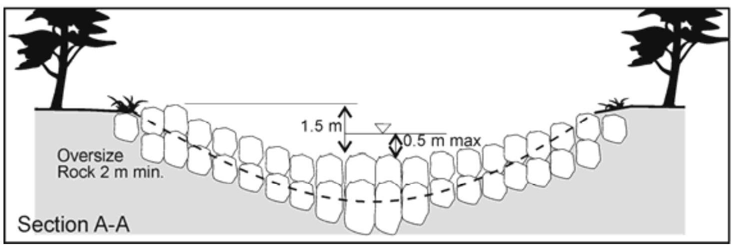
Construction Notes:

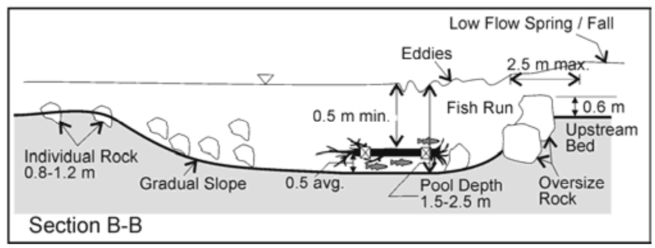
1. Navigable Waters approval might be required prior to the installation of a Single Crest V Weir.
2. Proper placement and design is critical and qualified specialists should be involved.
3. All weir crest rocks must slope down from the banks to the upstream point of the weir to confine the main flow to the middle 1/3 of the watercourse.
4. All rock must extend upstream from the bank where they are buried deeply to the middle point of the weir.
5. The largest (4-8) rocks must be placed at the point of the weir and set in place with the longest side pointing down (as shown) in a trench already excavated for this purpose. All rock is to be jammed together by machinery to provide tight-as-practical fit. Additional stabilizing rocks and spoil are to be placed around these rocks. Then the remainder of the weir crest may be built. The weir crest width should be 1.5 m wide.
6. The upstream notch on the weir must be within the middle third of the watercourse, but may be placed at any point within to move the current from side to side. Bank armouring may be necessary in such cases where potential bank erosion exists.
7. The top of the rocks in the notch of the weir is not to be more than 0.6 m above the streambed, unless an upstream pool is required. The bank tie-in location is to be 1.5 m above the watercourse elevation. Ensure that the rocks taper gradually from the notch to the tie-in point on the bank.
8. Only a minor amount of spoil material may be used to fill in the voids in the weir crest to prevent water from flowing through the weir. The spoil is only to ensure relative water tightness. All remaining spoil material must be placed 10 m beyond the streambanks, preferably 1.5 m above current water level.
9. All elevation differences shall relate to the low streamflow conditions in the spring or fall, or at time of inspection, whichever is less.
10. All individual placed rocks to be a uniform size.
11. Pool depth to be 1.5-2.0 m maximum due to watercourse width.

Source: Adapted from CAPP 1993

OVERPOUR STRUCTURES – TYPICAL V WEIR - SINGLE CREST (Small Watercourses)







Construction Notes:

1. Navigable Waters approval might be required prior to the installation of a Double Crest V Weir.
2. Proper placement and design is critical and qualified specialists should be involved.
3. All weir crest rocks must slope down from the banks to the upstream point of the weir to confine the main flow to the middle 1/3 of the watercourse.
4. All rock must extend upstream from the bank where they are buried deeply to the middle point of the weir.
5. The largest (8-16) rocks must be placed at the point of the weir in a double row and set in place with the longest side pointing down (as shown) in a trench already excavated for this purpose. All rock is to be jammed together by machinery to provide tight as practical fit. Additional stabilizing rocks and spoil are to be placed around these rocks. Then the remainder of the weir crest may be built. The weir crest width should be 2.0 m wide.
6. The upstream notch on the weir must be within the middle third of the watercourse, but may be placed at any point within to move the current from side to side. Bank armouring may be necessary in such cases where potential bank erosion exists.
7. The top of the rocks in the notch of the weir is not to be more than 0.6 m above the streambed, unless an upstream pool is required. The bank tie-in location is to be 1.5 m above the watercourse elevation. Ensure that the rocks taper gradually from the notch to the tie-in point on the bank.
8. Only a minor amount of spoil material may be used to fill in the voids in the weir crest to prevent water from flowing through the weir. The spoil is only to ensure relative water tightness. All remaining spoil material must be placed 10 m beyond the streambanks, preferably 1.5 m above current water level.
9. All elevation differences shall relate to the low streamflow conditions in the fall, or at time of inspection, whichever is less.
10. All individual placed rocks to be a uniform size.
11. Pool depth to be 1.5-2.5 m maximum due to watercourse width.

Source: Adapted from CAPP 1993

OVERPOUR STRUCTURES – TYPICAL V WEIR – DOUBLE CREST (Larger Watercourses)

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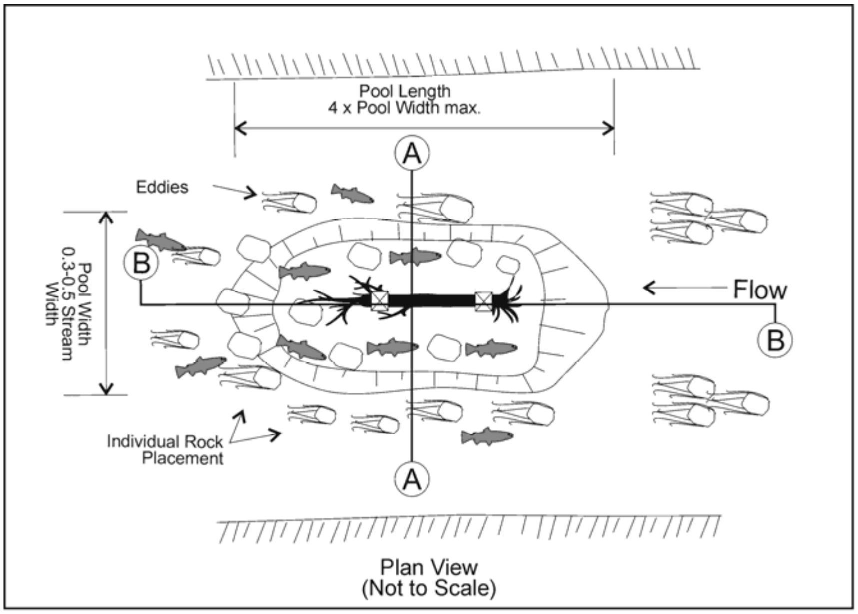
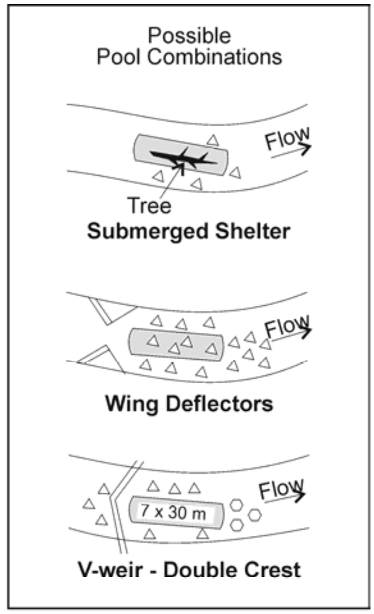
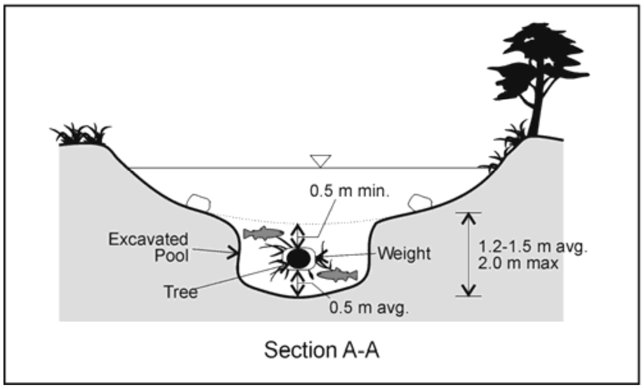
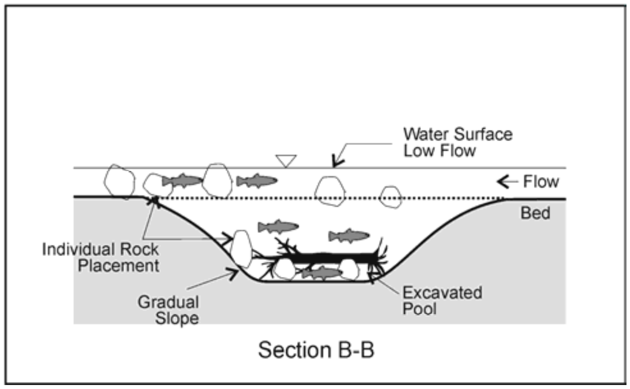
October 2005

DWG. NO. 41









Construction Notes:

1. Navigable Waters approval might be required prior to the installation of a typical resting pool.
2. Proper placement and design is critical and qualified specialists should be involved.
3. Locate the pool in a relatively straight section of the watercourse. Moderate existing depth is best indicator.
4. Centre the pool in the deepest part of the channel.
5. Pool width is not to exceed 2/3 of the channel width.
6. Pool depth must be a minimum of 1.5 m, but not to exceed 2.5 m.
7. Pool length is not to exceed 4 pool widths, normally about 3 times pool width is recommended.
8. Typical pool dimensions range from 2 m x 4 m on a small watercourse to 10 m x 40 m for a large watercourse. Excavations normally produce a water depth of 2 m or greater during low flow conditions in most watercourses, and greater than 2 m in large watercourses.
9. All spoil material is to be placed 10 m outside the channel limits at the time of construction (low flow) preferably in an abandoned dry side channel, a minimum of 1.5 m above current water level. This will avoid the material being washed back into the pool with the first high water.
10. Individual rocks 0.8 to 1.2 m in diameter may be placed at or below but no greater than 0.3 m above current water level at the time of work.

Source: Adapted from CAPP 1993

SUBSTRATE MANIPULATION – TYPICAL RESTING POOL

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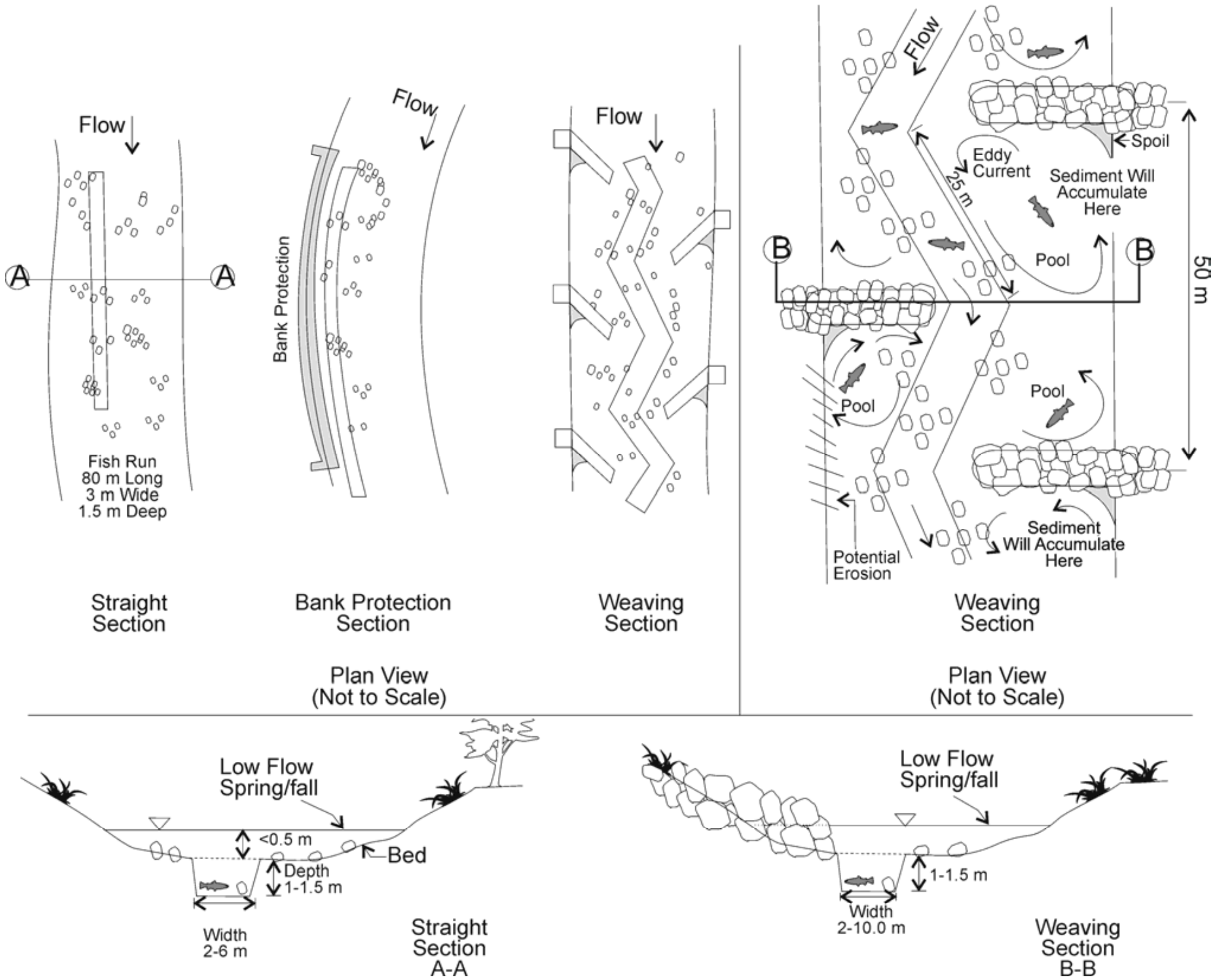
DWG. NO. 42	



<u>Construction Notes</u>:

1. Navigable Waters approval might be required prior to the installation of an excavated fish run.
2. Proper placement and design is critical and qualified specialists should be involved.
3. Excavated run is located within the middle 1/2 of the watercourse, crossing the deepest section, or as directed in the field.
4. The excavated run is composed of several straight sections, placed at angles to each other to provide a deep meandering channel in an otherwise straight, wide and shallow reach.
5. Individual rocks or rock clusters may be placed within the excavated run (width permitting) or along the outside to deflect the main current into the excavated run and maintain higher velocities to reduce sediment deposition within the trench.
6. With this structure, care of spoil is important since improperly disposed of material could easily be swept back into the excavated run. Spoil material is to be removed 10 m from the channel, 1.5 m above current water level.
7. Excavated run structures may be accompanied by rock clusters, deflectors and overhang structures to provide high quality habitat.

Source: Adapted from CAPP 1993

SUBSTRATE MANIPULATION – TYPICAL EXCAVATED FISH RUN

CAPP • CEPA • CGA

Appendix B Watercourse Crossing Case History Summaries

The following summarizes 326 case histories of open cut, dam and pump, flume, temporary diversion and two-stage coffer dam watercourse crossings that have been taken from TERA Environmental Consultants (Alta.) Ltd. (1996) with the exception of directional drilling, which was taken from P.A. Harder and Associates Ltd. (1995).

Open Cut Case History Summary

Fifty-nine examples of open cut crossings are summarized. These examples discuss water crossing construction at various sized watercourses using the plow, hoe, clamshell dragline, yo-yo dragline and dredge techniques.

All small watercourses (<10 m wide) were excavated by hoes with the exception of one which was plowed-in. Construction of all small watercourses were completed in less than one day with the exception of the plowed-in crossing, which required an extra day for bank preparation. Sedimentation and water quality were monitored at several crossings. No detectable changes in water chemistry or composition of streambed materials were recorded when the plow method was used. A dramatic increase in suspended sediments and increased benthic drift were reported during an open cut crossing with hoe excavation. However, it was concluded that the negative impacts to the benthic community were limited to the period immediately following construction and no negative impacts on the benthic community were detected after peak spring flow.

All medium-sized watercourses (10-20 m in width) were excavated with hoes, although draglines were used to assist at three crossings. Most crossings of this size were completed in two days. However, four days were required where trucking of spoil was conducted and three additional days were needed when blasting was required.

A high suspended sediment load was common in those crossings which were monitored for TSS or turbidity as well as those with anecdotal observations. One crossing with very coarse sediments had a "very large percentage" of sediment deposited within the first 200 m, while another in coarse sediments indicated that construction did not result in a significant sediment load. Other observations indicated that after 24 hours very little or no sediments remained in suspension and that, in general, most impacts seemed to be very short-lived and substrate composition returned to preconstruction conditions within nine months. Only two references to biotic impact are referenced in the case histories for open cut trenching. One monitoring program found that after one month there had been no significant increase in mountain whitefish egg mortality downstream of the crossing and juvenile whitefish continued to use pool habitats. It was also noted that although the high level of suspended solids was injurious to some fish, the relatively short-term nature of the disturbance minimized effects on downstream fish. Another anecdotal comment points out that extra time spent trucking spoil offsite resulted in increased instream activity that likely caused more disturbance than would have occurred with instream spoil storage.

Large watercourses, over 20 m in width, are constructed with a variety of methods. Of 22 open cut trenching examples in watercourses ranging from 20 m to 1000 m in width, hoes were generally used to excavate the trench. However, clamshell draglines, yo-yo draglines and dredges were also commonly used. The length of instream activity ranged from 1 day for 40 to 60 m wide crossings, to 60 days working 24 hrs/day for an 885 m wide crossing. Most watercourses less than 50 m in width took 1-3 days. Those crossings that took longer than one week tended to have adverse conditions such as extreme width (885 m) and very sandy substrates (60 days); very steep and long approach slopes (6 weeks); or a deep channel requiring construction of pads for hoes (2.5 weeks).

The comments related to impacts on biotic resources and water quality at larger water crossings were similar to those of smaller watercourses.

In general, open cut crossings are always successful although they range in difficulty and the degree of success. No examples of abandoned attempts of open cut crossings were encountered. Those crossings which were well constructed and successful were well planned, had sufficient equipment onsite, had experienced crews and were completed in as little time as practical. Crossings tended to have low success where: the floodplain or staging area was too wet or too small, the substrates were too soft or sandy, the contractor was disorganized and had no plan, there was an inappropriate use of instream sediment control devices; poor advice from inspectors and government representatives undersized equipment; or flood conditions.

Dam and Pump Case History Summary

Thirty examples of the dam and pump water crossing method were considered in the case history summary.

The dam and pump method was most commonly used on watercourses that were less than 10 m in width although examples of watercourses 15, 30 and 75 m in width are also summarized. In most cases, dams were constructed with conventional sandbags, although the larger 1 m^3 sandbags have been used in many of the higher energy watercourse crossings in British Columbia. One example of an aquadam is cited. Pea gravel bags used in conjunction with an impermeable liner have been used in several U.S. crossings. One company in southern Ontario as well as contractors in Alberta made many of their dams from plate steel pressed into the bed and banks, effectively sealing the streamflow. Other examples include gravel and rock dams, with and without impervious materials. In some situations, the channel morphology and substrate composition allowed pumps to be placed in upstream pools without the need for dam construction. In one situation, a partial pump around with no dams was used to minimize flow over the ditch area during an open cut crossing.

The degree of success experienced at many crossings was determined by the ability to seal the watercourse or work in dry conditions. Plate steel dams worked very well when conditions were appropriate. Where no dams were constructed and the watercourses were pumped dry above the crossing and discharged below, excellent results were obtained. Conventional sandbags and 1 m^3 sandbag dams seemed to have worked well although seepage became a problem if not constructed properly.

Inadequate pump capacity can be problematic with the dam and pump crossing technique. There were several examples of insufficient capability, pumps breaking down, and pumps running out of fuel. All three situations can be prevented with better pre-planning. Where subsurface flow is a concern, additional pumping from the trench area is required and two upstream dams may be warranted. Common pump sizes include 3", 4", 6", 10" and 12" pumps. In one instance, the limiting factor was the number of pumps which could fit in the pool upstream of the dam.

Pump discharge locations vary depending upon water quality and the standards for water quality. Bypass water, although usually pumped directly back into the watercourse, was discharged on to the ice downstream of the crossing in one situation. Silty trench water was usually pumped on to shore, either into surrounding vegetation or with sumps, settling ponds or silt fence lined areas. In certain situations, water was discharged into silt bags.

Instream activity at most water crossings where the dam and pump method was used required one day or less. Some took one day to set up and one day to construct the crossings. Other examples required 2.5, 3 and 5 days. In the case of the latter, the job was considered to have been poorly conducted by the government inspector with inadequate dams and pumps as well as a poor choice of discharge location.

Apart from environmental protection measures relating to the pump discharge areas and bank reclamation, special measures included a full contingency plan in case the crossing was not successful, fish salvage from the isolated areas and secondary upstream dams to trap seepage which in turn was pumped out. Silt curtain or filter fabric/hay bales were installed downstream of the flume with limited success at some crossings.

The total suspended sediment targets were not exceeded during construction of one crossing where monitoring was conducted and results are available.

In general, dam and pump crossings appear to be successful. Those crossings where difficulties were encountered, were the result of poor planning. In particular it is important to: construct high quality impermeable dams; calculate streamflows and have on hand enough pumps for at least 150% of the anticipated flow; have spare generators, fuel and pumps onsite; and finally, a contingency plan in case unforeseen problems arise. One environmental inspector that had been involved at numerous crossings where the sump and pump [high volume pump] method (*i.e.,* no dams constructed) had been used successfully, believed the term dam and pump was archaic. He felt that the term led many contractors or government representatives to install dams when their use was not warranted.

Flume Case History Summary

Twenty-eight examples of the flume water crossing method were considered in the case history summary.

The flume method was most commonly used on watercourses less than 10 m in width although examples of 30 m, 100 m and two channels of 200 m are included in the case histories. In most cases the flumes were preconstructed large diameter pipes welded to a flange plate. Many of the crossings had multiple pipes, the largest being 4 x 42" and 1 x 48" flumes welded side by side with a single flanged plate on the upstream side. At many crossings where the flume method was used, supplemental pumping was required to handle the flows. In one case the flume method was used in a partial temporary diversion. A channel on one side of an island was flumed and then the other.

Most flumes were sealed by conventional sandbags with an impermeable liner, although dams constructed of 1 m^3 sandbags filled with sand or gravel, dirt, land fill and clay were also used. In one case aquadams were used to dam and direct flow toward the flume while at another crossing, median barriers served to direct a portion of the streamflow into an old stream channel, thereby reducing the flow through the flume.

Most flume crossings require some degree of pumping to minimize or remove the water in the isolated area. In a number cases, several pumps were required to handle the groundwater flow despite a good seal on the dams.

There were several examples of the flumes being installed prior to the crossing construction to allow vehicle access or to avoid instream timing restrictions.

Instream activity at flumed water crossings ranged from four hours for a 2 m wide drainage to eight days for a large river. However, most smaller crossings were completed in three days or less.

Apart from the environmental protection measures relating to pump discharge, fish salvage between the dams and bank reclamation, no special measures were usually employed. Silt curtain or filter fabric/hay bale dams were installed downstream of the flume at some crossings.

Water quality and sedimentation monitoring was conducted at several crossings where the flume method was used with limited success. In one case the short-term total suspended targets were met but the 48 hour targets were surpassed. This crossing was also the largest flume project, encountered problems with unfiltered discharge water re-entering the watercourse and required eight days of instream activity.

The success rate of the flumed crossings indicates that it may not be the best choice for an isolated technique unless conditions are ideal. Problems that created poor, difficult or disastrous crossings included: poor planning; lack of experience; a sinuous stream channel; an unstable ditch and flume which was too short to allow for a wide ditch; poor seals on dams; undersized equipment; organic banks and substrates; insufficient pump discharge area or sump; high groundwater seepage; improperly installed sandbag dams; difficulty threading pipe bends under the flume; steep approach slopes that prevented threading pipe under flume; insufficient flume capacity; pump failure; and leaking hoses.

In general, the degree of success at watercourses crossed using the flume method seems to be less than other crossing techniques. As one construction superintendent confessed, "he has done about a dozen, was only proud of one..."

Temporary Diversion Case History Summary

Seven examples of watercourses crossed using the temporary diversion method were considered in the case history summary. All but two of the examples were on large rivers where alternative techniques to limit sedimentation of downstream areas were limited. Two of the examples required excavation of new channels in old high water or abandoned channels, one had an entirely new channel excavated between meanders in a silty floodplain, and the other four were diversions around islands and gravel bars using existing active channels.

Of those crossings which required excavation of a new channel, one was a last minute decision with no planning and no erosion protection of the new channel. The other two were well planned and had sufficient geotextile and riprap onsite to prevent erosion of the new channel. Those crossings that used existing channels only had erosional concerns as a result of increased water velocity and depth. One example indicated that gravel displacement from a change in flow patterns was noted 900 m downstream of the diversion. At one crossing, flumes were installed to allow flow in the new channel to cross over the previously excavated trench. Flumes were also installed at one crossing as a contingency in the new channel.

The diversion techniques ranged from damming the old channel with soil from the hard plug on the upstream end of the new channel, to imported sandbags and liner, aquadams and median barriers, as well as instream cobbles and material from the gravel bars. Aquadams were used on three of the seven projects although they required reinforcing with median barriers on one large diversion where the aquadams kept washing away. In one instance, a second dam was installed immediately downstream of a sandbag and liner headwall dam to collect seepage which was subsequently flumed over the excavation.

The isolated area was pumped into abandoned channels in two cases although, in one of the instances, large volumes of discharge water resulted in water flowing out of the abandoned channel into the watercourse. Silt fences were erected in the old channel to filter the sediment.

The periods of instream construction when the temporary diversion method was used varied according to the size of the watercourse. The two smallest crossings resulted in two and four days of instream activity. Instream periods of 5 and 17 days were reported for the other two crossings where an instream period was indicated.

Of the three crossings where sedimentation and water quality observations were provided, results indicated that: water quality objectives were met; turbidity was not noticeable while constructing the dams; and only a minimal increase in silt load occurred due to heavy silt load already present in the river. On one crossing it was observed that sedimentation increased after diverting streamflow into an unlined new channel.

Special environmental measures undertaken include: special protection for banks and spoil piles to accommodate increased flow after the diversion into one channel; fish salvage from the isolated channel; and in one instance retaining eagle watchers to let the blasting crew know when eagles had left the area so blasting could proceed.

Generally the temporary diversions, if planned and implemented appropriately, were considered successful. The one crossing where difficulty was encountered was the result of a sudden change in methodology from the open cut trenching method to temporary diversion. Therefore, thorough planning of the procedure and appropriate protection measures were not in place. Difficulties that arose during construction of the crossings considered to be successful were problems associated with the efficient diversion of water; the erosion of the new channels; and the correct placement of spoil so as to avoid susceptibility to erosion caused by increased volumes.

Two-Stage Coffer Dam Case History Study

Five examples of two-stage coffer dams are summarized, although one reference is a generic reference to approximately 40 coffer dam crossings which were undertaken over a several year period and another is similar to five other crossings undertaken by the same construction superintendent.

All examples were constructed within large rivers between 25 m and 100 m in width, with substrates of coarse textured materials. Dams were constructed from various materials including clean pitrun, 1 m^3 sandbags, washed gravel with plastic liner and conventional sandbags. At one crossing where 1 m^3 sandbags were installed, an upstream deflection dam was also constructed to reduce the water velocity in the vicinity of the dam construction. Seepage and infiltration of water into the coffered area posed a problem in all cases. This was generally handled by installing numerous pumps. In one case, a sheet piling dam was installed inside the coffer and sealed with sand. Unfortunately, trench sloughing caused the sheet piling to fall into the trench and cables were installed to hold the sheet piling back. Riprap was installed at one watercourse on the upstream face of the coffer to prevent erosion. Dewatering was either onto the banks or into settling ponds within the coffers. In one example, where silty water from inside the dam was percolating out into the river, a deflection dam was constructed to increase the water pressure on the downstream face of the dam. This prevented any outflow of turbid water by allowing water to infiltrate the coffer. The water was then pumped into a discharge area on the bank.

Instream activity ranged from one week to 72 days. The instream period of 72 days appears to be the exception due to problems encountered during excavation. The other two crossings completed took two and three weeks. One crossing was aborted and open cut in a week after flooding and dam failure endangered the crews.

Special environmental measures employed included downstream silt monitoring, and the installation of sorbent booms in the even of an accidental spill.

Downstream siltation in most cases seems to have been reduced by installation of the coffers although the increased instream period produces a longer duration of silt loading.

In general, coffer dams seem to work well as long as they are well planned and installed by an experienced crew. The engineering manager of the company which had completed 40 coffer dam crossings indicated that once the crew was experienced, construction was very successful. One superintendent also indicated great success once the system had been worked out but also indicated it was very costly and did increase the instream period. The expense was confirmed by one quote of $300,000 for a 100 m crossing. Many of those interviewed during the case history review indicated that they did not have any experience with this crossing method and noted strong reservations related to the mid stream tie-in due to safety and constructability. Two respondents indicated that they would only consider this technique in the event that instream repairs were required.

Horizontal Directional Drilling

Directional drilling can be an effective method for installing pipelines beneath watercourses with relatively low environmental impact to streambanks and water quality. Potential impacts associated with directionally drilled installations include land clearing affecting visual and wildlife values, possible loss of drill mud and the effect on water quality during construction as well as disposal of used drilling mud. The feasibility of using directional drilling techniques is strongly limited by site conditions, including soil characteristics, and available workspace and geometric constraints. The case history review indicated that drill mud seepage can occur for all soil types and is most likely when highly permeable zones are present with minimal cover between the drill path and the bed of the watercourse. There was a higher incidence of drill mud seepage for sites characterized by larger grain sized materials (gravels, cobbles and boulders) than for sites characterized by fine-grained and consolidated materials. The incidence of significant technical difficulty (*i.e.,* loss of equipment, collapsed bore holes and damaged pipes) was higher for sites characterized by the presence of large gravels, cobbles and/or boulders. The feasibility of directionally drilled pipe installations generally decreases for larger diameter pipes and is further compounded when suboptimal soil characteristics are present. There were relatively few large diameter pipe installations in all regions examined in this study.

The significance of potential drill mud seepage into the watercourse is typically limited to point sources along the drill path. In some instances there is the opportunity to reduce or arrest seepage by decreasing the pressure of the drill mud. Depending on where these point sources occur, it may also be possible to implement mitigative measures such as containment berms and vacuum trucks to control water contamination. These measures can be effective for mud seepage occurring along the approach slopes and in some cases, shallow near-shore areas. Significant leakage of drilling mud can also occur at the drill entry or exit point due to different pressure heads if there is a large change in elevation between the two points as well as during reaming or pull-back.

Drill mud seepage was reported for 36 of the 146 cases reviewed. The reported incidence of drill mud seepage was 8% for Alberta and Saskatchewan and 20% for the continental U.S. The incidence of drill mud seepage was 43% for the 37 case histories reviewed in British Columbia. Drill mud seepage occurred at all five crossing reviewed for Ontario and Québec. Drill mud seepage occurred in all soil types including fine- and coarse-grained unconsolidated materials and hard rock. The incidence of drill mud seepage was less than 14% for both the small and medium diameter pipe size categories. Drill mud seepage was reported for 85% of the large diameter pipe installations.

There are a number of site-specific engineering and geological constraints that may preclude the use of drilling as a viable crossing alternative. These include available workspace, pipeline specifications (length and diameter), site geometrics and soil conditions. The technology is particularly well suited for sites with fine-grained soil characteristics (sands, silts and clay and consolidated soil types such as rock and sandstone. Unconsolidated materials with large gravels, cobbles and boulders are extremely difficult to drill and are one of the main limitations to directional drill applications. Potential problems with these materials include deflection of the drill bit, drill bit damage and equipment losses, removing boulders/cobbles from the bore, possible collapse of the bore hole and pipe damage during the pull-back operation. The potential for these problems generally increases with the size of the bore. Although directional drilled installations have been completed through mixtures of gravel, cobble and/or boulders, the installation failure rate and incidence of serious technical difficulties is high. This was particularly true for sites where large cobble and boulders were present. The number of successful installations through these conditions was relatively low. These potential problems are further compounded for installations of large diameter pipes and increased crossing width. The small number of installations involving large diameter pipe identified in this review, coupled with the relatively high incidence of technical difficulty experienced further supports this conclusion.

Significant technical difficulties were reported for 8 of the 37 case histories reviewed for British Columbia. These difficulties included loss of the borehole, pipe damage during the pull-back operation, equipment losses through jamming or breakage, and inaccurate steering control. Three of these incidents required a second bore hole to be drilled before the crossing could be completed. Soil conditions were gravels and cobbles at two of these crossings and shale/rock at the third crossing site. Two other drilled crossings were unsuccessful and were abandoned in favour of alternative crossing methods.