MANITOBA STREAM CROSSING GUIDELINES FOR THE PROTECTION OF FISH AND FISH HABITAT

Fisheries and Oceans
Pêches et Océns

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Manitoba Natural Resources
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Preface

This document is an update of the previous *Recommended Fish Protection Procedures for Stream Crossings in Manitoba.* The guidelines provide practical advice and information on mitigation measures to protect fish and fish habitat. The guidelines have been developed for use by individuals, corporations, and government agencies involved in the design, construction, and maintenance of stream crossings.

Stream crossings refer to any temporary or permanent structure that is built to cross a waterbody. Emphasis has been placed on stream crossings for temporary and permanent access roads. However, the concepts presented are also relevant for other types of stream crossings such as those associated with transmission lines, cable crossings, pipelines and railroads.

This manual describes the impacts of development activity on fish and fish habitat as well as the pertinent legislation and application procedures involved (Section 1). Section 2 outlines good practices for the protection of fish and fish habitat throughout the route planning, design, scheduling, construction, maintenance, and clean-up phases of the crossing. Section 3 describes erosion and sedimentation mitigation techniques that should be incorporated as a part of stream crossing design and construction.

The guidelines are intended for a wide audience. Technical terms used in the guidelines are listed in the glossary at the end of the document.

This document was prepared for the Department of Natural Resources (DNR) and the Department of Fisheries and Oceans (DFO) by Marr Consulting & Communications Ltd. We would like to thank the individuals and organizations who provided valuable comments on the draft document. Acknowledgements are extended to the Ontario Ministry of Natural Resources (OMNR) for allowing liberal use of figures from their guidelines and to other Canadian jurisdictions for providing relevant information in their guidelines.

1.0 Introduction

The Need for Guidelines

The Province of Manitoba has an abundance of natural streams which support a rich variety of freshwater fish and other aquatic life.

Development activities such as access roads, electrical transmission lines, cables and pipelines must cross natural streams. When these crossings are poorly designed, constructed, or maintained, negative impacts on fish and fish habitat can result. These impacts can be eliminated or reduced with careful planning, design, and construction of stream crossings.

These stream crossing guidelines are intended to provide information to biologists, engineers, contractors, corporations and government agencies involved in stream crossing construction. The guidelines apply to any waterbody that is used by migratory or resident fish during any period of the year, as well as to any waterbody which is linked to downstream waters which support fish. They apply to new crossings, poorly designed crossings that must be corrected, and existing crossings which must be repaired, replaced or removed.

These stream crossing guidelines are intended to meet the following fisheries protection objectives:

i) To allow free and unobstructed fish passage through stream crossings so that fish may migrate to spawning, rearing, feeding, overwintering, or other important areas without harmful delay.

ii) To protect stream bottom and banks from accelerated erosion processes thereby minimizing disturbance to fish habitat.

iii) To avoid damage to fish and their habitats which may result from the introduction of deleterious substances into the stream.

These guidelines are not regulations. There may be situations where they are not applicable or other regulations take precedence. As well, detailed specifications for crossings can vary in each situation. Proponents should consult with the Regional Fisheries Manager (Appendix 1) regarding these guidelines and the specifics of a stream crossing project.

The guidelines in this document apply to the proponents or owners of a stream crossing. It is their responsibility to ensure that their agency or firm, and its contractors and subcontractors, adhere to the intent of these guidelines.

The Need to Protect Fish and Fish Habitat

Fish and fish habitat are defined under the Fisheries Act as follows:

Fish: all fish, shellfish, crustaceans and marine animals, and the eggs, spawn, spat and juvenile stages of fish, shellfish, crustaceans and marine animals.

Fish habitat: the spawning grounds, nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in rder to carry out their life processes.

In Manitoba, fish habitat is found in lakes, reservoirs, rivers, streams, marshes, ponds, and swamps. It can even be a hay meadow that floods for only a few weeks in spring - as long as it supplies the food, shelter, and water that fish need.

Fish live where they can best satisfy their needs. If some of their requirements are not met, through damage or loss of habitat, their numbers drop, and in time the entire population may die out. No habitat eventually means no fish.

Fish habitat, the ultimate source of future-fish catches, is important to commercial and sport fishing. By protecting fish and fish habitat in Manitoba, we are safeguarding sport fishing and commercial industries annually worth millions of dollars.

Fish and fish habitat have a special significance for aboriginal peoples who have fished for centuries as a way of life. For some, fishing is still a traditional pursuit that provides a source of food and income.

Fish habitat is vulnerable to land uses of all kinds, from forestry and agriculture to cottaging and road construction. As the pressure on fish habitat increases, the efforts of individuals, corporations and agencies will become more important in the struggle to conserve and protect our fisheries habitat.

1.1 Impacts of Stream Crossings on Fish and Fish Habitat

Improperly designed, constructed, and maintained stream crossings can impact fish and fish habitat either directly or indirectly by blocking migration, causing sedimentation, removing vegetation, and adding deleterious substances to the water.

Migration Blockage

Fish migrations are most commonly associated with spawning, feeding, or finding suitable overwintering habitat. Improperly constructed stream crossing structures can block normal fish movements and migrations. This can lead to reduced spawning success because fish may abandon their spawning run or spawn in less suitable habitat. If blockage is complete and permanent, some fish species could be eliminated from portions of the drainage basin. Blockage of fish migration could also result in the fish being more vulnerable to predators or exploitation by man.

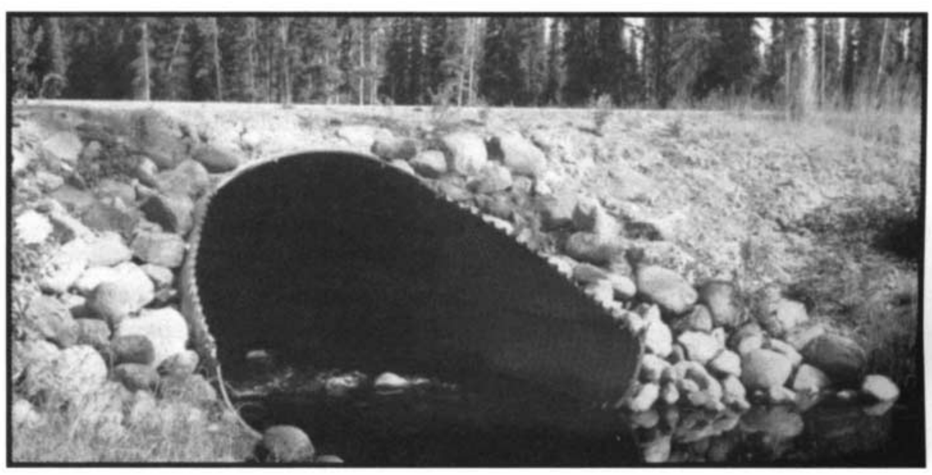
One of the most common problems associated with stream crossings is increased water velocity caused by water flow constriction. In undisturbed watercourses, the stream bottom configuration intersperses zones of high and low water velocities. The low velocity areas are used by fish for resting spaces. In elliptical and circular culverts, the absence of bottom substrates often creates a velocity barrier. If the water velocity exceeds the swimming ability of the fish, migration will be effectively blocked. This is particularly true for spring spawners such as walleye, pike and suckers, whose migration runs often coincide with peak water flows from April to June.

Even if some fish manage to pass through the culvert, they may be weakened or injured by strong currents. Injured fish are vulnerable to fungus, disease, and predators. If the energy needed to swim through the crossing is excessive, then spawning may not occur or the spawn may have a reduced chance of survival.

The second way a stream crossing can halt migration is by physically blocking the opening under a crossing. For example, sediment, gravel, logs, vegetation, or ice jams can accumulate at the entrances of an installation, making it impossible for fish to pass. Beaver activity can also block a crossing.

The third way a stream crossing could halt migration is by lowering the water levels at the crossing. Fish require a certain depth of water to be able to swim through a culvert. The larger the fish, the deeper the water must be. Fall spawners, such as whitefish and cisco, are particularly at risk since fall water levels may already be low. If erosion is not checked at the culvert outlet this may also, over time, lead to lower water levels at the crossing.

Inadequate opening size can lead to washout during floods.



Washed out culvert replaced with a new arched culvert having sufficient opening.

Culverts which are installed without regard for the natural stream slope may be perched and cause a waterfall effect at the outlet. If the outlet is higher than the jumping ability of the fish, then upstream migration is effectively blocked. Improperly placed culverts may also cause a drop in water level and high velocities at the culvert inlet.

Sedimentation

Construction activities which remove vegetation and topsoil without proper erosion control measures cause an increased sediment load in the stream. As well, improperly designed stream crossings, particularly culverts, can alter water velocities, leading to scour of the stream bed and banks.

Suspended sediments directly impact fish because they clog and abrade fish gills, causing suffocation. Suspended sediments also reduce water clarity, making it difficult for some fish to find food or detect predators.

Sediment may have an indirect effect on fish by altering or destroying their habitats. For many fish species, eggs are deposited in the spaces among gravel on the stream bottom. When the spaces become clogged with sediment, the free flow of oxygenated water and removal of wastes is impaired, resulting in egg suffocation and mortalities.

In some fish species, fry also need the spaces between gravel in the stream bed for protection. If sediments fill the spaces, fry are vulnerable to predation.

Sediments may also have an indirect impact on fish by altering their food supply. For example, benthic invertebrates which are a food source for some fish species may become smothered or displaced by sediments.

Sedimentation may also alter photosynthesis or primary production by plants and microorganisms in the stream. In some cases, sediments can screen out available sunlight which decreases primary production. In other cases, nutrients attached to sediment can increase primary production. A change in primary production will alter the food supply for many organisms.

Removal of Vegetation

The removal of bank vegetation during activities such as stream crossing construction increases the amount of sunlight that reaches a stream which then increases water temperature. An increase in temperature of a few degrees may cause stress in some fish species. Heat also reduces the amount of dissolved oxygen available to fish in the stream.

The removal of vegetation also reduces the amount of food sources entering the system. For example, leaf litter is a source of essential nutrients to benthic organisms and the fish that eat them. Also, when there is no bank vegetation, there will be a loss of terrestrial insects falling into the stream.

Deleterious Substances

Grease, oil, gas, and other hazardous materials may enter streams from accidental leaks or spills during equipment maintenance. If fuel or other materials are stored near streams, leaks or spills can impact the stream and cause fish kills. Construction camp sewage and garbage which is accidentally washed into adjacent streams can cause contamination. Accidental spills of road salts used for de-icing during construction and maintenance can also have a negative effect on water quality, while waste water produced during concrete preparation may detrimentally increase instream pH levels.

1.2 Legislation

The federal Fisheries Act regulates the environmental impacts of projects and activities which may affect fish and fish habitat. The sections of the Fisheries Act which may apply to stream crossings include:

- Section 20 - Construction of Fishways at Obstructions
- Section 22 - Need for Adequate Instream Flows
- Section 30 - Fish Guards and Screens on Water Intakes
- Section 32 - Destruction of Fish Prohibited
- Section 35 - Harmful Alteration, Disruption or Destruction of Fish Habitat Prohibited
- Section 36 - Pollution of Fish Habitat Prohibited

Protection of fish depends on the protection of fish habitat. The Fisheries Act prohibits any person from carrying on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat, unless authorized. The Act also prevents any person from depositing a deleterious substance in waters frequented by fish, unless authorized. In Manitoba, various provisions of the Fisheries Act are administered by Manitoba DNR, DFO, Manitoba Environment, and Environment Canada.

The Fisheries Act or the publication entitled *Canada's Fish Habitat Law* (DFO, 1991) should be referenced for further information on any of the above sections.

Proponents planning to conduct work in or near water must ensure that they meet the requirements of federal, provincial and municipal legislation (Table 1).

Table 1: Partial list of legislation potentially affecting development activity in or near water. Adapted from Sentar Consultants (1994).

Authority	Legislation	Description
Federal:		
Department of Fisheries and Oceans	Fisheries Act	Regulates activities that impact fish and fish habitat in Canada.

Transport Canada	Navigable Waters Protection Act	Regulates activities that are liable to interfere with navigation.
Environment Canada	Canadian Environmental Protection Act (CEPA)	Provides the framework for protecting Canadians from all forms of pollution caused by toxic substances. It encompasses the entire life cycle of toxic substances including their transport, use and storage.
Environment Canada	International River Improvements Act	Regulates activities affecting water quality and environment of international rivers flowing from Canada.
Provincial:		
Manitoba Environment	Environment Act	Provides for an environmental licencing process for developments that are likely to have a significant effect on the environment.
Department of Natural Resources (DNR)	Endangered Species Act	Provides for the protection of endangered and threatened species in the province; enables the reintroduction of extinct species; and the designation of species endangered or threatened with extinction.
DNR	Rivers and Streams Act	Provides for the protection of the whole or any portion of any river or stream in the province. This Act also prohibits depositing of material that would impede the flow of water or endanger the stability of the banks.
DNR	Water Power Act	The Water Power Act applies to all provincial water powers, all lands and properties still used or required in connection with the provincial water powers, and the power and energy produced or is producible from the waters or within those lands.
DNR	Water Rights Act	Provides for the administration of matters related to the construction or operation of certain water control works.
DNR	Forest Act	Provides for the regulation and administration of forests within Crown lands and provincial forests.
DNR	Provincial Park Lands Act	Provides for development and maintenance of provincial park lands for the conservation and management of their flora and fauna; and for preservation of specified areas and objects of geological, cultural, ecological, or other scientific interest; and facilitation of the use and enjoyment of outdoor recreation.
DNR	Conservation Districts Act	Provides for the conservation, control and prudent use of resources through the establishment of conservation districts, and for protection of the correlative rights of owners.

DNR and Department of Agriculture	Crown Lands Act	Provides for the protection, control and prudent use of "Crown Lands". This includes land vested in the Crown and includes "Provincial Lands".
Department of Municipal Affairs	Planning Act	Provides for the protection and conservation of the environment and natural resources such as lakes, rivers, shore lands, forests, agricultural lands and recreational lands, and anything else for the purpose of preventing damage to and destruction of lands, sites or buildings, or preventing interference with their use within municipal lands.
Department of Health	Public Health Act	Provides for the regulation of potable water supplies, sewage disposal, sanitation and food supply operations, and in general for the preservation of life and health of the people of the province.
Municipal:		
Local Municipal Councils	Municipal By-laws	Permits construction, clearing and burning; approves zoning or re-zoning; regulates local land use and building codes; owns and controls shore land in municipal (public) reserves.

1.3 Policy

The Department of Fisheries and Oceans has developed a Policy for the Management of Fish Habitat. The Policy is designed to achieve an overall Net Gain of the productive capacity of fish habitats. The Policy, which is endorsed by Manitoba DNR (Fisheries Branch) has three goals: the conservation, restoration and development of fish habitat.

The conservation goal is guided by the principle of No Net Loss of productive capacity, and is aimed at maintaining the current productive capacity of fish habitats supporting Canada's fisheries resources, so that fish suitable for human consumption may be produced. Under this goal, DNR and DFO will strive to balance unavoidable habitat loss with habitat replacement on a project by project basis so that further reductions to fisheries resources due to habitat loss or damage may be avoided.

The restoration goal is aimed at rehabilitating the productive capacity of fish habitats in selected areas where economic or social benefits can be achieved through the fisheries resource.

The development goal is aimed at improving and creating fish habitats in selected areas where the production of fisheries resources can be increased for the social or economic benefit of Canadians.

Proponents planning to conduct work in or near water should ensure that their development activities result in No Net Loss.

1.4 Environmental Review Process and Approvals

Manitoba Environment Act

A Manitoba Environment Act Licence is required for those developments that are likely to have a significant effect on the environment including construction and replacement of stream crossings. Proponents should contact Manitoba Environment to determine whether an Environment Act Licence is required.

To acquire a licence, an application must be submitted with a description of the proposed development including land ownership, existing land use, previous studies, proposed development, potential impacts and proposed environmental management practices. The application must also include work schedules and dates for commencement of construction and operation, and source of funding, if applicable.

The proposal will be reviewed by Manitoba Environment and other federal and provincial departments. Fish and fish habitat protection measures are often included as Environment Act Licence conditions for approved projects.

Work Permits

Provincial Work Permits are used to authorize activities taking place on Crown Land. Generally they are issued by the Natural Resources Officer (NRO) in the District where the activity is occurring and the District is responsible for ensuring that the conditions on the Work Permits are met. Work Permits are often required under Environment Act Licences and are used to ensure habitat is adequately protected in the manner described in an Environment Act Licence.

Work Permits are issued for a variety of activities including stream crossing installation and any activities which may alter aquatic habitat. Site specific conditions to protect natural resources or mitigate resource concerns are attached to the Work Permit. These are developed on site in consultation with the Permittee, and address site specific concerns.

Fisheries Act Authorizations (Section 35)

If the harmful alteration, disruption, or destruction of fish habitat cannot be avoided through project redesign, relocation, rescheduling or the use of mitigation measures, proponents should contact DFO (Appendix II) regarding authorization and compensation options for lost or damaged habitats.

Other

Costs associated with meeting information requirements as well as installing and maintaining mitigation and compensation measures are the responsibility of the project proponent. Proponents may also be required to conduct follow-up monitoring programs to determine the effectiveness of mitigation measures. For larger projects, a financial guarantee may be required.

2.0 Good Practices: Protection of Fish and Fish Habitat

The potential impacts of stream crossings on fish and fish habitat can be eliminated or reduced by using appropriate mitigation measures during every phase of the design and construction process from scheduling and route planning to clean-up and maintenance.

2.1 Route Planning

Give consideration to the environment when planning the route of the road or development as well as the location of stream crossings. Use the guidelines below for selecting the best route to eliminate or reduce impacts.

- Consult with the Regional Fisheries Manager during the planning stage so that environmentally sensitive areas are identified and avoided.
- Begin planning the route well in advance of construction. Allow time to collect and analyze fisheries data if necessary for making informed decisions.
- Design routes that are consistent with the topography. Avoid wetlands and marshes, steep slopes, and unstable or erodible soils.
- Minimize the number of streams to be crossed, as each crossing involves potential environmental damage and increased costs.
- As a general rule, keep roads a minimum of 100 m away from a watercourse except when crossing the watercourse. This often forces the alignment onto drier sites.
- If a 100 m distance is not possible, allow a buffer zone of undisturbed vegetation between the road and the waterway, using a buffer zone width of approximately 10 m plus 1.5 times the slope gradient (see Table 2).

Table 2: Recommended widths for buffer zones. Adapted from McCubbin, et al. (1985).

Slope of land entering waterway (%)	Width of buffer zone (m)
0	10
10	25
20	40
30	*55*
40	70
50	85

2.2 Crossing Site Selection

- Crossings should be located at least 500 m upstream of spawning areas, or important rearing, feeding or overwintering areas. If important habitats cannot be avoided, use a bridge with a high approach such that no instream activities will be required.
- Maintain a distance of at least 500 m upstream from a river mouth and downstream from lake outlets. Fish often congregate in these areas.
- Place crossings upstream from existing natural barriers to fish passage. For example, a high waterfall imposes a barrier to fish, so a water crossing that is placed upstream of the waterfall will not affect fish passage.
- Utilize existing crossings if possible.
- Avoid crossing at the braided portion of a stream to prevent flooding, stream siltation, or crossing failure.
- Choose a straight reach with relatively shallow water depths (i.e. less than 2 m).
- Minimize the crossing length by selecting a narrow section and constructing the crossing at right angles to the channel.
- Select stream areas where the bed and banks are stable and resistant to erosion.
- Avoid crossing where actively slumping banks are evident or suspected.
- Crossing sites should be selected where the approach slopes are minimized for at least 15 m on each side of the watercourse. A grade of greater than 10% is generally considered too steep.

2.3 Design

Once a suitable crossing site has been identified in the route plan, the appropriate design for the crossing structure must be selected.

The proponent is responsible for the stream crossing design. The Regional Fisheries Manager should be consulted at this stage for advice in developing a site-specific crossing that allows unhindered fish passage through the watercourse.

Several alternative crossing structures are listed below in order of preference for protection of fish and fish habitat.

1) bridge
2) open-bottom arch culvert
3) open-bottom box culvert
4) horizontal ellipse culvert
5) closed-bottom arch culvert
6) closed-bottom box culvert
7) round culvert(s)

Table 3 illustrates the stream crossing structures listed above and their characteristics.

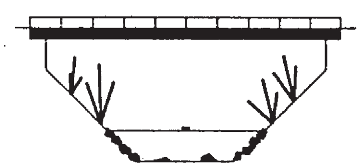
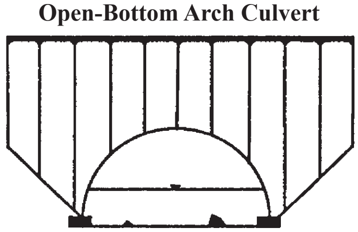
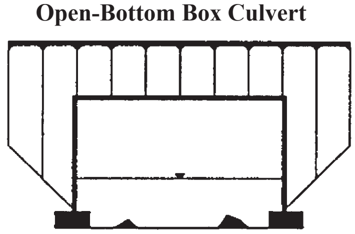
Crossing design should ensure that the stream flow velocity through the crossing is below the maximum prolonged swimming capability of the fish species in that stream. This is particularly important in the design of culverts. Maximum prolonged swimming capacity will vary depending on the species, size, and age of the fish as well as crossing length, water temperature, and dissolved oxygen level. Typical maximum flow velocities for some fish species are given in the figure below.

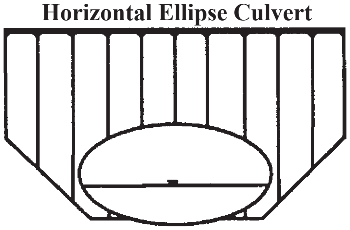
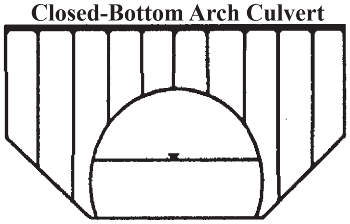
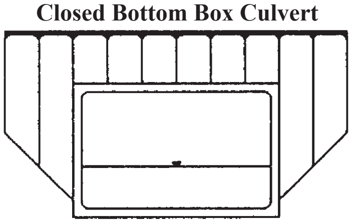
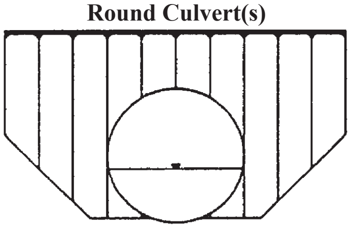
As a general rule, crossing design should ensure that the stream flow velocity through the crossing does not exceed 1 m/s for culverts less than 25 m in length and 0.8 m/s for culverts greater than 25 m in length. Lower velocities may be required for weaker swimmers such as northern pike and juvenile fish.

Prevent or avoid delays in fish migration by designing the crossing to have a sufficiently large opening and a minimum of debris-catching structures.

Use a large safety factor in the water crossing design to protect fish and fish habitat, especially if hydrological and biological information is lacking or unavailable.

Table 3: Fisheries and design considerations for stream crossing guidelines. Source: Chilibeck et al. (1993) and McCubbin et al. (1985).

Type of Structure	Fisheries Considerations	Design Considerations
Bridge 	• Can retain existing bottom substrate, bank structure and riparian vegetation. • Does not alter bed load transport capacity of stream reach. • Can retain natural fish passage stream qualities.	• No limit to stream hydraulic capacity if encroachment of piers or footings is limited. • Ability to cross large streams and rivers. • Structure can often be designed with no instream work required.
Open-Bottom Arch Culvert 	• Does not limit fish passage if properly designed and constructed. • Retains natural stream substrate. • Water velocities are not significantly increased if culvert is as wide as the natural stream. • Potential loss of riparian vegetation.	• Design to normal stream width. • Wide bottom area provides good flow capacity with limited depth increase. • Large waterway opening for low clearance installations.
Open-Bottom Box Culvert 	• Does not limit fish passage if properly designed and constructed. • Retains natural stream substrate. • Water velocities are not significantly increased if culvert is as wide as the natural stream. • Potential loss of riparian vegetation.	• Design to normal stream width. • Can be placed in multiple units to provide wider section and larger end area. • Provide suitable footing for wall section to prevent undermining by stream erosion.

Horizontal Ellipse Culvert 	• Avoid use in fish bearing stream or incorporate appropriate design modifications. • Stream substrate not easily retained in culvert. • Loss of natural steam substrate beneath culvert.	• Squat profile useful in low fill situations. • Shape results in deeper water depth than a closed-bottom arch culvert, but does not offer as broad a bottom area.
Closed-Bottom Arch Culvert 	• Can limit fish passage at low flows due to reduced water depth in culvert. • Baffles can be installed to provide fish passage. • Wide bottom area allows retention of bottom substrates. • Loss of natural stream substrate beneath culvert.	• Design wide bottom area for good flow capacity with limited depth increase. • Good for low clearance installation. • Multiple units can be installed to provide greater capacity. • Reduced depths at low flows may require backwatering.
Closed Bottom Box Culvert 	• Can limit fish passage at low flows by reduced water depth in culvert. • Baffles can be easily installed to provide fish passage. • Wide bottom area allows retention of bottom substrates. • Loss of natural stream substrate beneath culvert.	• Can design to maintain stream width. • Can be placed in multiple units to provide wider section and larger end area. • Precast units can be installed quickly limiting instream construction time.
Round Culvert(s) 	• Generally poor for fish passage situation. • Difficult to provide passage in small diameters. • Concentrates flows and velocities. • Loss of habitat because of infilling around culvert. • Loss of natural stream substrate beneath culvert.	• Concentrates flows and increases velocities and potential scour at high flows. • Reduced depths at low flows may require backwatering. • Can have poor bed load transport through culvert.

2.4 Scheduling

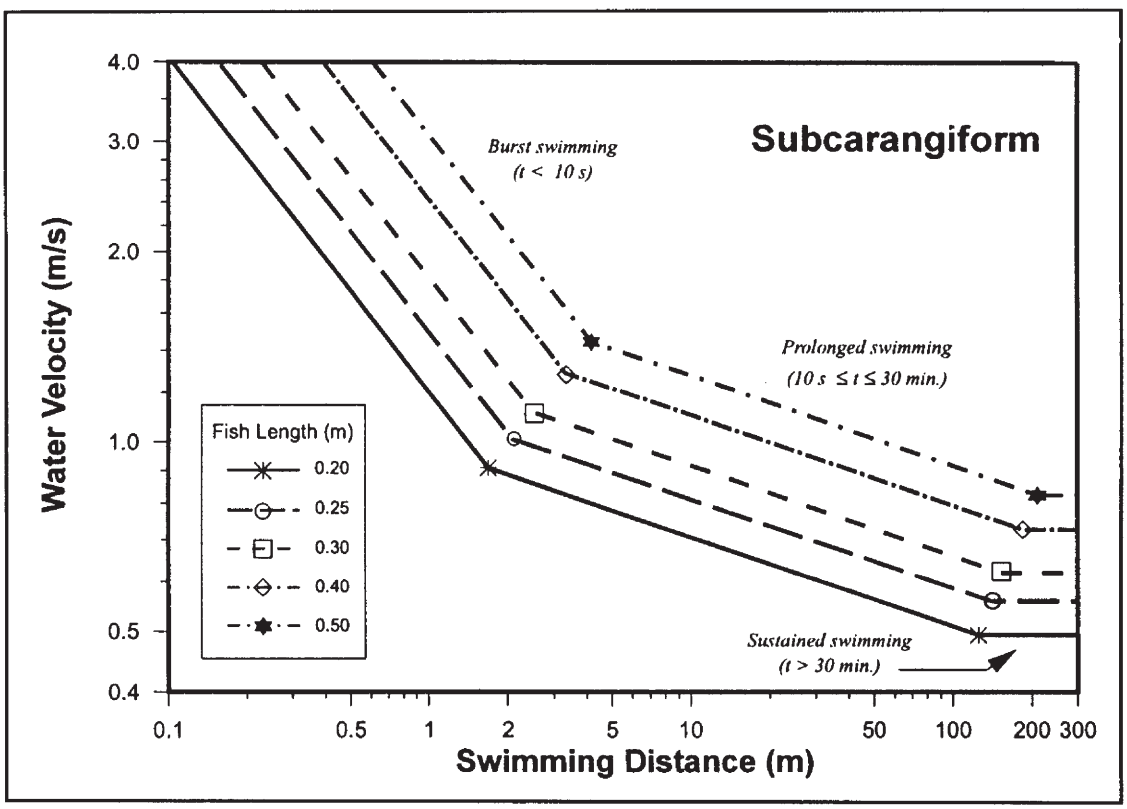
A well-planned schedule will not only provide efficient construction of the water crossing, but also the first, and most effective defence against damage to fish habitat and populations.

Fish are the least tolerant of construction activity during spawning, migration, and incubation periods. Blockage and stream disturbance must be avoided during these periods, which will vary according to which species are present. Fish spawning periods are given in the spawning calendar (see Table 4). Although the dates given in the table are generally accurate, streams should be individually considered in consultation with the Regional Fisheries Manager.

Construction should be planned for times with the lowest stream flow, usually during the hot, dry months of July and August. Winter construction is also reasonable and even preferable in some situations.

The release of sediments into water courses can be minimized by constructing when the ground is frozen. However, some species of fish such as brown, lake and brook trout spawn in the fall, leaving eggs vulnerable to construction activities all winter. In areas where these fish are found, winter construction is restricted.

Once initiated, water crossing construction should be completed as quickly as possible. As long as construction site are active, soils are exposed to erosion. Begin reclamation activities as soon as possible after construction is complete. Give priority to areas with the greatest potential for erosion.



Swimming distance curves which apply to all Manitoba commercial and sport fish species except northern pike and burbot. Source: Katopodis (1993).

Table 4: Spawning and incubation periods and spawning sites for some fish species found in Manitoba streams. Spawning and incubation periods may vary depending on latitude and annual weather conditions. Source: Newbury and Gaboury (1993), Scott and Crossman (1979), and KGS Group and North/South Consultants Inc. (1992).

Species	**Spawning Period**	**Incubation Period**	**Spawning Site**
Lake Sturgeon	late May to late June	5-10 days	In rivers in swift water or rapids 0.3-5 m deep; at base of impassable falls; in large clean rubble; areas of upwelling currents; outside bends and rapidly moving water of rivers; near dams; in lakes on rocky shoals
Lake Trout	September-October over a two week period	15-21 weeks	In lakes, depth range: 15 cm - 55 m, usually <12 m; rubble substrate; angular rock; exposed shores facing prevailing winds; may occur in rivers among coarse gravel and large boulders
Brook Trout	September-October	7-14 weeks	Typically stream spawners, but also lakes/ponds at stream upwellings; coarse sand, gravel and stones
Northern Pike	April-May shortly after ice-out	12-14 days	Over dense vegetation in calm, shallow water i.e. flooded marsh, wetland, shallow pool or backwater; depths of 0.2-0.45 m
Channel Catfish	late May to mid-June	6-1 0 days	Dark and secluded areas for nesting, usually cavities, burrows, under rocks; in shallow flooded areas in large rivers; near shore; in muddy ponds; in undercut banks; under logs at depths of 2-4 m
Smallmouth Bass	mid-April to early May or July	4-10 days	Rocky lake shoals, river shallows, or backwaters, or move into creeks or tributaries to spawn; require clean stone, rock or gravel for spawning; or coarse sand
Yellow Perch	early April-late June	8- 10 days	Over sand, gravel, rubble, submerged vegetation, or debris covered bottoms; depths range from 0.6-3 m
Walleye	April-late May	12-18 days	Selects moving water and clean substrate; rocky areas in whitewater, shoals and shorelines of lakes and streams; also utilize dense mats of vegetation
Sauger	late May-early June	12-18 days	Spawns in shallows, 0.6-3.7 m, sand and gravel shoals or bars in turbid lakes or stream
Lake Whitefish	September-December	up to 25 weeks	Hard stony bottom, sometimes sand; shoals of lakes
Goldeye	late May-early July	1-2 weeks	Spawn on gravel shoals in turbid pools and ponds; prefer firm substrates

2.5 Construction: General Guidelines

Construction includes a variety of activities, each with potential to be detrimental to fish and fish habitat. The very nature of construction is to alter the environment, but with proper precautions the negative effects of construction can be prevented or minimized. Guidelines to protect fish and fish habitat during general construction activities are itemized below.

Foundation Investigations

Any major culvert or bridge will require instream foundation investigations (such as test holes, pits and piles) prior to construction. When undertaking foundation investigations, fish habitat damage can be minimized by creating the least disturbance possible as follows.

- Clear the narrowest access road possible and limit access to one location on each bank.
- Backfill test pits using the excavated material, plug test holes using soil and logs, and remove or pull out test piles at stream bed level.
- Clean-up the investigation site by removing temporary facilities, equipment, and waste construction materials (see Section 2.9: Clean-Up and Reclamation).

Clearing, Grubbing, and Stripping

Clearing, grubbing, and stripping often exposes the soil and leaves it vulnerable to erosion. Erosion damage can be minimized as follows.

- Minimize right-of-way clearing within the buffer zone (see Table 2).
- Avoid clearing slopes unless adequate erosion protection measures are used.
- Preserve vegetative cover for as long as possible (i.e. no pre-cutting).
- Halt clearing operations during heavy rainstorms.
- Utilize hand clearing instead of mechanical clearing where possible to prevent disturbance of organic soil layer.
- Retain slash and debris that is collected during clearing operations and use it to temporarily protect erosion-prone slopes.
- Prevent sediment from entering the stream by placing overburden or topsoil stockpiles well above the high water mark. Use appropriate control measures to control erosion of stockpiles .

Grading

Grading is the process of reshaping the land. This activity, which can cause both erosion and sedimentation, can be mitigated as follows.

- Prevent sedimentation by grading soils in the direction away from the watercourse and never into the stream itself.

- Minimize erosion by contouring slopes to an appropriate steepness ratio and installing erosion controls quickly (further details in Section 3.0: Erosion and Sedimentation).

Blasting

Blasting in or near water produces shock waves that can kill or damage fish and their eggs or larvae. Explosives should not be detonated in or near.fish habitat. Adequate distances must be maintained between the detonation site and fish habitat to ensure the pressure change does not harm or kill fish.

Proponents planning to use explosives in or near fish habitat should refer to the *Guidelines for the Use of Explosives in Canadian Fisheries Waters* (1994) or contact DFO for further information.

Gravel Removal

No gravel should be removed from stream beds or below the normal high water mark. Gravel removal should be limited to areas where effects on local water tables and flows in adjacent streams will not occur. Limit gravel removal to a minimum of 100 m from a stream.

Deleterious Substances

Construction activity, especially when it involves heavy machinery, has the potential to release deleterious substances into the water with detrimental effects to fish populations.

It is far easier to prevent the release of deleterious substances on a site than it is to clean it up. Pollution can be prevented as follows.

- Store chemicals, fuels, and other harmful materials at least 100 m away from the normal high water mark.

- Keep equipment in good repair to prevent leakage of fuel, oil, etc. Avoid fuelling, changing oil, or repairing equipment within 100 m of the normal high water mark.

- Construct temporary water crossings to keep equipment out of the watercourse.

- Do not wash buckets and equipment in the watercourse. It is acceptable to wash equipment with hoses if the runoff is prevented from entering the watercourse.

- The instream use of creosote or PCP treated timbers or wood materials should be avoided.

- Prevent construction materials, such as lumber, nails, etc. from entering the watercourse.

2.6 Stream Alterations

In larger streams, proper installation of a bridge or culvert may require a temporary diversion of flowing water so that stream crossings can be built under dry conditions. In order to attain dry conditions, options for stream alterations include the construction of partial or complete diversions, and the use of elevated pipes.

Partial diversions are often used in the construction of bridges while full diversions are most common for building culverts. Partial diversions consist of sheet piling or cofferdams which block the flow in a portion of the stream, and pumps that keep the work area dry. Complete diversions direct stream flow into a new temporary channel. Once the crossing is installed, the temporary channel is closed and the natural channel is rewatered. Permanent diversion of stream flow into the constructed channel is discouraged because of damage to existing fish habitat. Compensation for lost or damaged habitats may be required in these cases.

Another alternative that can be used to keep a work area dry is the use of elevated pipes. These are pipes used to divert water in a controlled manner over the area that is to be kept dry. Elevated pipes can only be used when stream flows are low and must be removed in times of fish migration as they can impede fish movement.

Temporary channel diversions are acceptable if they are built properly and do not impact fish habitat. Any stream alteration should employ the following general guidelines.

- Ensure that fish passage will be possible even in low flows.

- Construct any instream structure out of erosion resistant materials. Sheet piling is preferred followed by cofferdams built out of rows of sandbags with plastic in between rows. Clean rock fill may also be used.

- Refrain from constricting the flow by more than one third (33%) of the original stream width.

- Avoid stream cutoffs. Bypassing a meander loop increases the stream gradient causing higher stream velocities and increased erosion.

- When excavating the diversion channel, work in dry conditions where possible, beginning at the downstream end and moving upstream. The diversion channel should have gentle curves and the same approximate slope gradient as the natural stream.

- Protect the diversion channel with an erosion-resistant lining (i.e. plastic sheathing). Hold the lining in place with stones and stakes to keep water from getting underneath.

- The point where the old and new channel meet will be very susceptible to erosion. Protect vulnerable areas with erosion controls and energy dissipating measures (see Section 3.0: Erosion and Sedimentation).

- Utilize stream diversions only when stream flow is low but ensure that diversions are deep enough to withstand storm events.

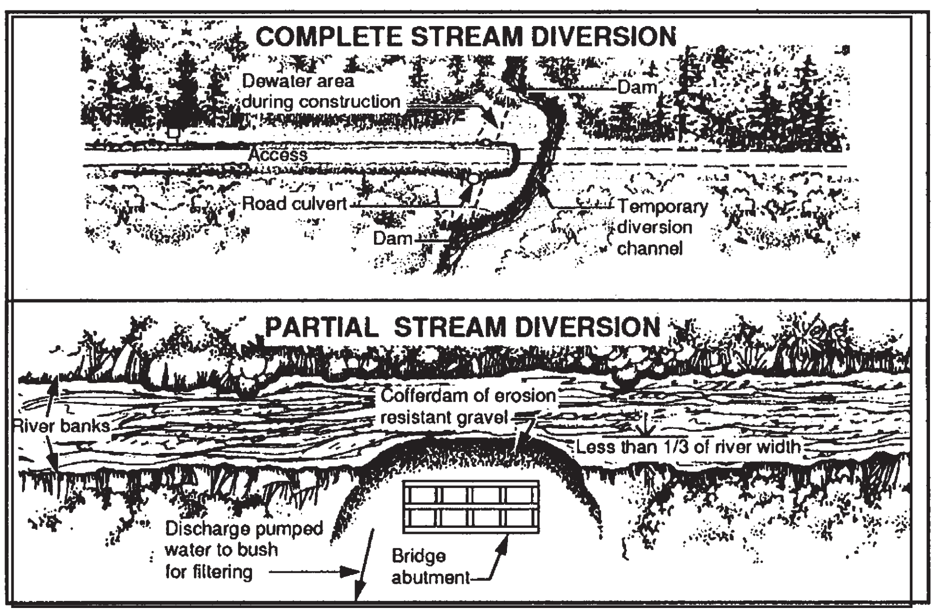
- Prevent siltation by directing pumped water into settling ponds, a filter fabric dam, or a vegetated area that will provide filtration before returning the water to the stream.

- Place a “splash pad” of gravel or straw bales under the outfall of pumped water to protect erodible soil.

- Remove all diversions upon completion of the crossing.

- Do not remove instream structures during spawning and incubation seasons to minimize damage from siltation.

- When a temporary channel is no longer required, it should be infilled and erodible soils stabilized.

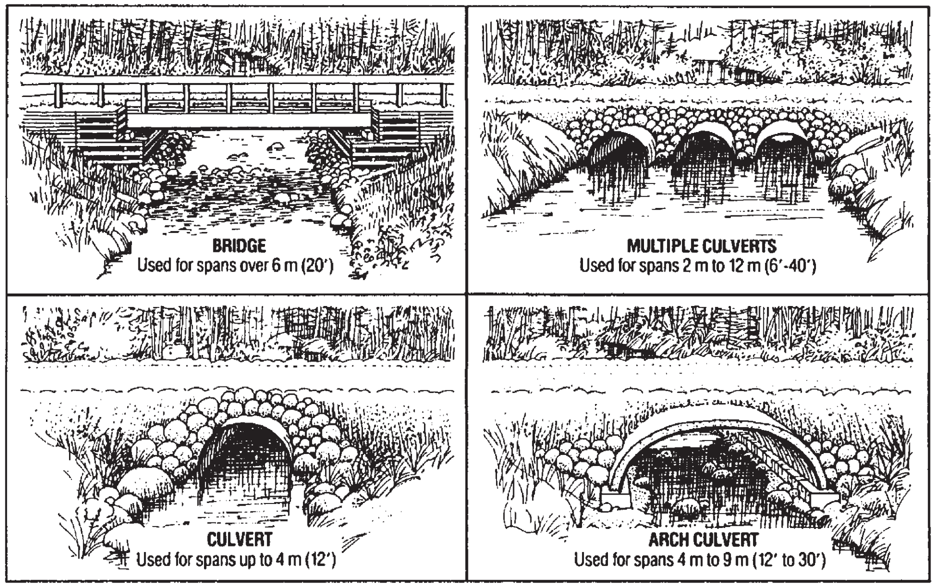


Stream diversion for dry crossing construction. Source: OMNR (1990).

2.7 Permanent Crossings

Either bridges or culverts can be used for permanent crossings; each option has disadvantages and advantages.

Bridges are the preferred structural type for fish and fish habitat protection but they are generally more expensive to build. In the long run, bridges may be less expensive because culverts may have to be replaced more often due to wash-outs, damage or deterioration.



Some alternative permanent crossing structures. Source: OMNR (1990).

Bridges

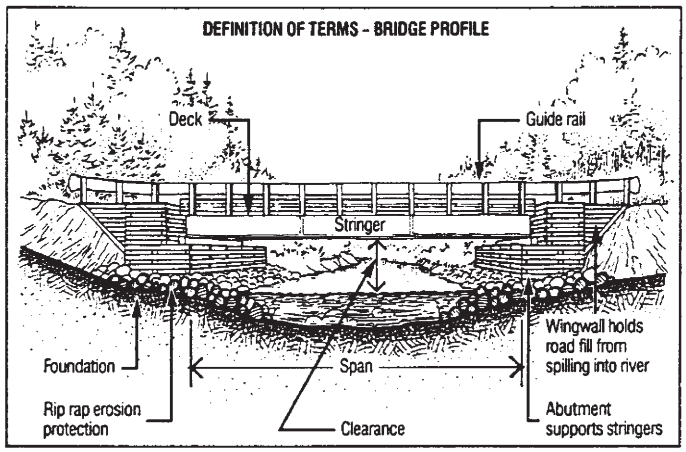
The following mitigation measures can be used during bridge construction to minimize impacts on the environment.

- Where possible build piers and footings outside of the stream and above the high water line.
- If it is not possible to build piers and footings outside of the stream, construct them parallel to the stream flow so as not to direct water into the banks.
- Separate instream work from the water with a cofferdam or other structure. (see Section 2.6: Stream Alterations).
- Construct bank protection and wingwalls to prevent bank erosion. Extend bank protection only as far as necessary to protect bridge approaches.
- Avoid the use of concrete aprons. If this is not possible, allow fish passage by building a fishway, or by maintaining stream grade through use of a weir or sill immediately downsteam to backwater the apron.

- Prevent water from pouring over an apron in fast, shallow flows by sloping the apron to the centre or to one side, thereby concentrating flows.

- Cover vulnerable bridge slopes with concrete, rip rap, vegetation, or another nonerodible material.

- Ensure that bridge slopes do not directly receive highway drainage and that the slope is not too steep (see Table 6).



Components of a bridge. Source: OMNR (1990).

Culverts

A culvert is a conduit used to allow the passage of fish and water through an embankment or under a road. Culverts can be designed in a variety of shapes and sizes (see Table 3 for details).

When fish passage is a factor, the best type of culvert is the open bottomed arch culvert or box culvert because they maintain the natural stream bottom.

Multiple culverts are not recommended for fish-bearing streams because they are more likely to become blocked than a single large culvert. However, if more than one culvert is required, establish a minimum of 2 m between adjacent culverts to provide adequate downstream resting areas for fish. There should be no more than three culverts at any one crossing.

When culverts are placed in crossings that will support fish movements, use the guidelines below.

- Culvert velocity should not exceed the maximum prolonged swimming capacity of fish. As a general rule, the average crosssectional velocity should not exceed 0.8 m/s for culverts longer than 25 m and 1.0 m/s for culverts less than 25 m. Lower culvert velocities will be required for weaker swimmers such as pike or juvenile fish. Specific considerations for each stream should be determined in consultation with the Regional Fisheries Manager.

- When designing a crossing structure, consider the maximum period of delay that can be tolerated by fish. There should be no delay if the spawning grounds are located immediately upstream of a stream crossing and no delay during the average annual flow. The crossing should not be impassable for longer than seven consecutive days once in 50 years.

- Ensure that normal water levels rise no higher than half the diameter of the pipe during fish migration periods.

- Choose a culvert that does not significantly constrict the width of the stream bed. Culverts with diameters of less than 1.0 m are not recommended.

- Ensure that the culvert opening size is sufficiently large to allow the passage of debris.

- Minimize culvert length to aid fish passage. Fish swimming capabilities under high velocity conditions decrease rapidly with distance.

- Align the crossing perpendicular to the direction of flow to minimize crossing length.

- Maintain a culvert gradient as close to the natural stream grade as possible. The maximum culvert slope that may be installed when employing baffles is 5%.

- Position culverts where there are no sudden increases in water velocity above, below, or at the crossing location.

- Install culverts a minimum of 30 cm or 10% of culvert diameter (whichever is greater) below the normal stream bed. Fill with granular material to stream bed level.

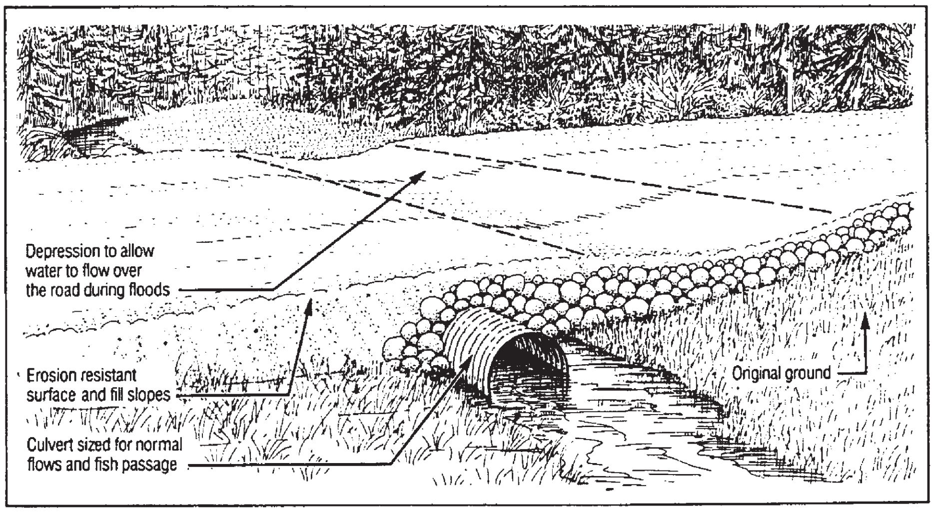
- Position culverts to fit the stream channel alignment on a straight section of the stream so that discharge is not directed at a potentially unstable riverbank.

- Protect stream banks, and stream bed at culvert openings with erosion-resistant material such as rip rap (see Section 3.7: Rip Rap).

- Ensure that culverts are installed on a firm bed and avoid wet muck, muskeg, sod, frozen earth, permafrost or large rocks. Soft, unsuitable foundation material should be excavated below gradeline and backfilled with compacted granular material.

- Avoid using frozen backfill. Compact backfill to avoid settling, hydrostatic uplifting or side movements of the culvert that may lead to blockage of fish passage or washouts.

- Considering safety factors, a depression may be carved in low traffic access roads to allow water to spill over the road in time of flood. Ensure the depression is protected from erosion.



Culvert with erosion protection and a depression to allow spillage over the road. Source: OMNR (1990).

Culvert Fishways

Fishways aid fish passage through culverts by slowing the water velocity and providing places to rest. They are baffles made of wood, metal or concrete placed along the bottom of a culvert. Fishways work best when water depth and velocities are matched to the swimming capabilities of the species.

Avoid constructing fishways in culverts unless all other alternatives are unsatisfactory, as there is a risk that they will become ineffective over time.

If a fishway is required in a crossing with multiple culverts, install it into one culvert near the stream bank. Make it as easy as possible for fish to find the culvert that allows for safe passage.

For fishways to be effective they must be routinely maintained. For example, the resting areas created by baffles can become filled with sediment. Baffles may also catch large debris, causing flooding or washout and preventing fish passage.

Other options to slow the velocity in a culvert include replacing the culvert or constructing low head weirs downstream to create a backwater effect into the structure. For additional information on the design of fishways, consult Clay (1995).

2.8 Temporary Crossings

Temporary crossings can be very practical during short-term forestry and mineral explorations, transmission line and pipeline construction, or for use while a permanent crossing is under construction. Although they are only used on a short-term basis, temporary crossings should be constructed using the same general guidelines for fish habitat protection as permanent crossings. Examples of temporary crossings include fords, summer crossings, and ice bridges.

Fords

Fords are temporary or permanent stream crossings that allow vehicles to drive directly through a watercourse. They are formed by lowering the road grade to the stream bed level from bank to bank. Fording is only recommended with the appropriate fish habitat protection measures as described below.

- Construct and use fords during the driest time of year and when there will be infrequent traffic.
- Ensure that fords will not be used during fish spawning, incubation, or migration periods. Choose fording areas that are well away from spawning and nursery areas.
- Seek fording sites with low, stable approaches and a firm stream bed of rock or coarse gravel.
- Select an area with a natural water depth of less than 100 cm but maintain a minimum water depth of 20 cm to allow fish passage.
- Minimize the area disturbed by building crossings that are perpendicular to the stream and not more than 10 m wide.
- Prevent erosion by minimizing the amount of vegetation removed from the stream bed and banks.
- Stabilize approaches if necessary with non-erodible material 15 m up the bank on both sides.
- Log corduroy, coarse gravel, and rock fill can be used to improve the roadway through the stream.
- Construction equipment and vehicles crossing the ford should be free of contaminants and leaks.
- When the ford is no longer in use, any materials added to the stream bed should be removed and banks should be contoured to their original condition.

Temporary Bridges and Culverts

Temporary bridges and culverts are a viable alternative where fording is inappropriate. However, it is important to maintain the natural stream flow and prevent stream blockage. Temporary crossings can be made out of preconstructed standard components (i.e. Bailey bridge) or out of available metal, and logs.

Bailey bridges are patented bridges that are made into a variety of lengths out of standard components and then lowered into position. They should be used on low volume roads only.

All temporary bridges and culverts should give due consideration to the protection of fish and fish habitat.

- Time the placement and removal of the bridge to avoid periods of high fish movement.

- Temporary bridges and culverts are not intended to survive extreme floods so it is acceptable that they span just above normal water level.

- Culverts and bridges should be sized to accommodate flows expected during the period of use and to provide for fish passage.

- Ensure that there are sufficient openings for fish and water to pass and to prevent excessive water backup.

- When the temporary bridge or culvert is no longer required it should be removed and the site should be restored to its original condition.

- When logs are used to create temporary bridges, the logs should be delimbed. Untreated log poles are acceptable for temporary bridges. Chain logs together on the ends for stability and to facilitate removal of the logs when the temporary bridge is no longer required.

- If material such as gravel is used to fill in gaps between planking on the bridge deck, it should be held in place and separated from the decking by geotextile fabric or a natural mat. This will allow fill material to be removed when the bridge is eventually dismantled without adding excessive sediment to the stream.

Ice Bridges

Ice bridges are temporary crossings constructed of ice, snow, and logs for reinforcement.

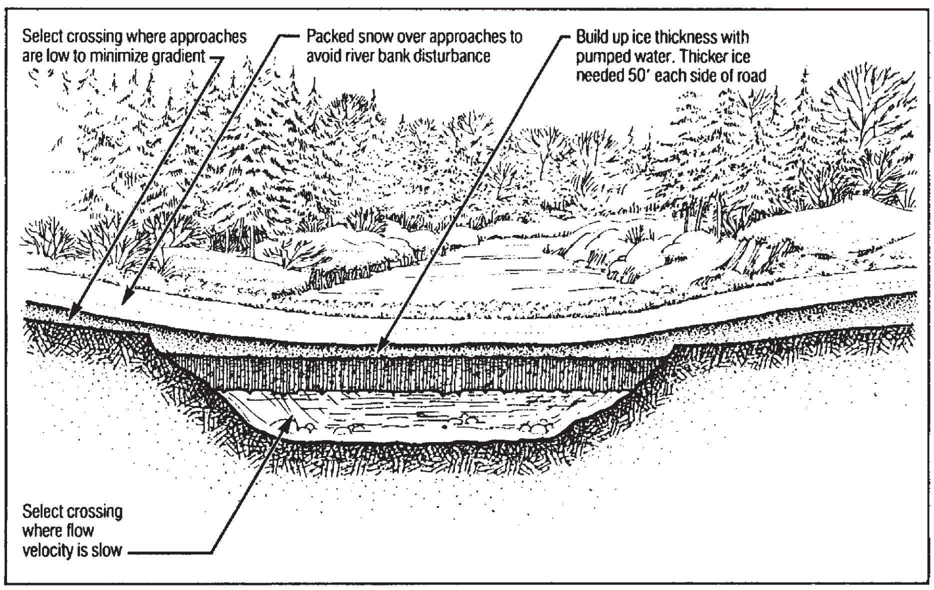
- Locate ice bridges where the winter stream flow is slow.

- Minimize disturbance by locating ice bridges at an area that requires the minimum approach grading and the shortest crossing route.

- Avoid using debris as reinforcement material, to prevent downstream siltation problems during spring break up.

- Ensure that any logs used for reinforcement are clean, delimbed, and placed on the surface of the ice. Chain logs together to facilitate removal.

- Prevent spring ice jams and flooding by removing any reinforcement logs and cutting a V-shaped notch into the middle of the ice bridge before thaw begins.



Ice bridge - temporary water crossing for winter access. Source: OMNR (1990).

2.9 Post-Construction Activities

Clean-Up and Reclamation

When construction is completed, the site should be cleaned-up as quickly as possible to protect the site from environmental degradation and to improve the aesthetic quality of the site. Most clean-up activities take only a few days and are worthwhile compared to future costs of returning to the site to repair on-going damage.

Reclamation becomes more effective if care has been taken to prevent environmental disturbance throughout the construction period, using the guidelines listed below.

- Begin reclamation and clean-up as soon as possible after construction is complete.
- Remove temporary stream crossings or diversions.
- Replace topsoil and salvaged vegetation plugs.
- Stabilize slopes with contouring, rip rap, and revegetation (see Section 3.0: Erosion and Sedimentation).
- Remove all material that was brought onto the site and collect any debris that may have floated downstream. Dispose of all materials in an approved manner.
- Mitigation or compensation of construction impacts may require that fish habitat be restored or enhanced. For more information on fish habitat enhancement, see Newbury and Gaboury (1993), Goodchild and Metikosh (1994), or contact the Regional Fisheries Manager.

Maintenance

Maintenance includes post-construction inspections and repair or replacement of stream crossings. Throughout the life of the crossing, structures must be inspected periodically, especially prior to and during spring breakup and prior to the winter freeze. During inspection and maintenance activities the general good practices for construction identified in Section 2.5 should be adhered to, as well as the following.

- Inspect after the crossing has sustained its first heavy rains to check on the condition of the stream bed and banks. If heavy erosion has occurred, additional control measures should be immediately installed (see Section 3.0: Erosion and Sedimentation).
- Look for and remove any debris caught on piers or at the entrance to culverts to prevent flooding upstream, reduce stress on the structure, and allow for fish passage.
- If blockage of the stream crossing is the result of beaver activity, the method of beaver control should be determined in cooperation with the local Natural Resources Officer.
- Stabilize slopes of approaches with erosion-resistant material if inspection shows that vegetation will not grow.

- Clean out check dams and sediment traps at least once a year to maintain effective sediment control.

- Use mechanical vegetation control instead of herbicides where possible to prevent the release of chemicals into the stream.

- If herbicides must be used, maintain a safe distance from the stream, depending on the method of application. Maintain a distance of 100 m from the stream when aerial spraying, 50 m when using mechanical application from the ground, and 30 m when using hand application.

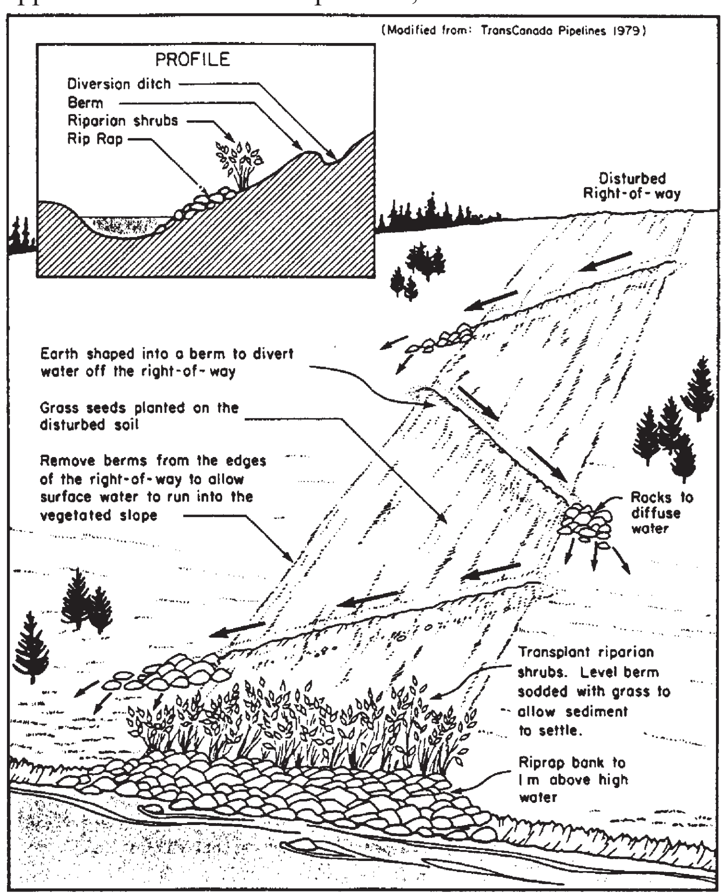
- Consider wind velocity and direction prior to herbicide spraying to prevent contamination of waterbodies.

Decommissioning

When a road is no longer required, stream crossings should be removed. Crossings that are left unmaintained are prone to erosion and decay and leave the stream vulnerable to sedimentation or blockage. Decommissioning procedures are very similar to those listed under the 'Clean-up and Reclamation' subsection on page 27.

Removal of abandoned water crossings includes the excavation of all structures below the high water mark, with the exception of erosion protection works. Materials used in the construction of the crossing should be disposed of at least 100 m away from the water and in an approved manner. Where possible, use overburden and vegetation taken from the stream crossing to reconstruct stream banks and approaches. In the case of steep approaches where revegetation may be difficult, diagonal berms may be constructed across the abandoned roadway to prevent erosion (see following figure).

Prevent erosion at the abandoned crossing using the techniques described in Section 3.0: Erosion and Sedimentation. Begin stabilization and revegetation as quickly as possible, particularly when seeding and planting is required. The abandoned crossing should be clearly marked to prevent vehicle access and subsequent environmental damage.



Erosion control on sloped approaches to streams. Source: British Columbia Ministry of Environment (1986).

3.0 Erosion and Sedimentation

Erosion is the weathering of land surfaces by the action of moving water, wind, or other geological processes. Sedimentation, or, siltation, is the deposition of soil particles that fill in waterbodies. Erosion and sedimentation processes occur naturally in any area over time. However, construction activity at stream crossings can accelerate erosion rates.

Erosion rates are affected by precipitation, soil characteristics, topography, and vegetation. When constructing a stream crossing, use the eight principles of erosion and sediment control as follows:

1) Fit the road to the terrain and ensure road bed material will prevent erosion of roadway surface.
2) Minimize the duration of soil exposure.
3) Retain existing vegetation where feasible.
4) Grade disturbed soil to a stable slope.
5) Encourage revegetation.
6) Divert runoff away from exposed soil.
7) Keep runoff velocities low.
8) Trap sediment before it can cause damage.

The objective of implementing mitigation measures is to prevent excessive erosion and sedimentation from occurring and to eventually restore the site to pre-disturbance conditions.

In the short term, erosion cannot be entirely avoided on construction sites. Sedimentation controls such as sediment traps, silt fences, brush barriers, forest floor filters, and check dams are very effective for arresting the migration of erodible soils.

Revegetation, rip rap, and slope modification are primarily considered long-term erosion control techniques. They also control sedimentation either directly by trapping sediments or indirectly by preventing soils from becoming detached and transported.

The erosion and sedimentation control techniques described below are generalized and it is possible to use variations and combinations. No attempt has been made to provide an exhaustive list of techniques as each individual site will present problems that require unique solutions. In particular, erosion problems associated with the disturbance of permafrost have not been addressed in these guidelines. Experts should be consulted when dealing with construction activities in permafrost areas.

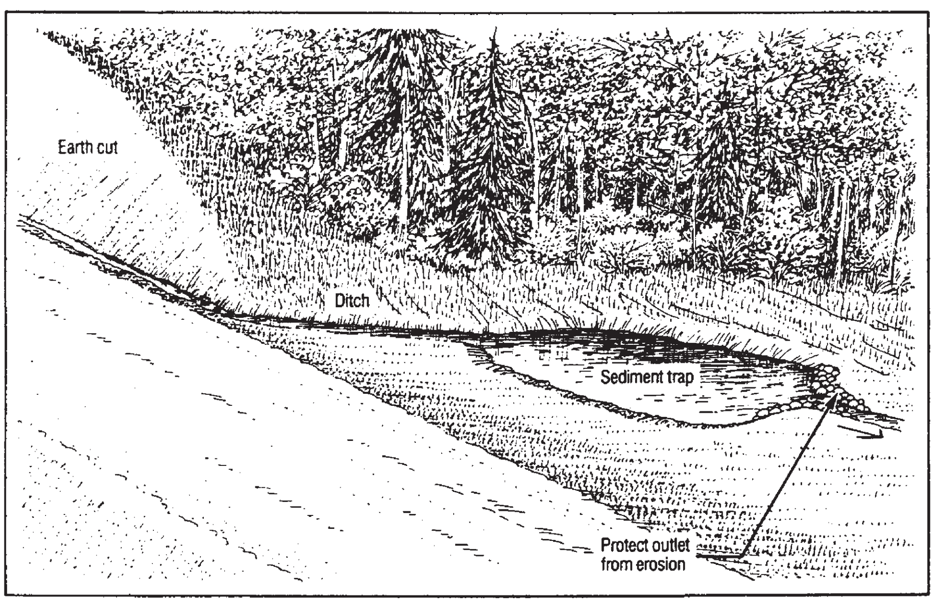
Erosion and sedimentation control measures should be part of the planning and design of a stream crossing. Sediment control plans should be developed well in advance of any construction activity. Discuss mitigation measures with the Regional Fisheries Manager, including any changes to plans.

3.1 Sediment Traps

Drainage from a disturbed area containing excessive sediment load must not enter the stream through surface runoff. One way to control siltation is to divert runoff into sediment traps, or small ponds, that are constructed downstream from the sediment source. The water velocity slows when it reaches the trap, allowing large suspended particles to settle out before the water enters a stream.

Sediment traps are intended as temporary measures in erodible soil sites. They are to be used only until more permanent erosion controls and vegetation are in place. Use the guidelines below when designing and constructing sediment traps.

- Situate sediment traps in low-lying areas that are close to an earth cut or any other source of sediment. Do not place sediment traps in or near the watercourse.
- Plan the size and spacing between traps carefully, so that they will fill in at the same time vegetation is established preventing further erosion.
- Design each trap to have a ratio of length to width of approximately 2:1. For example, a two hectare (2 ha) drainage area typically requires a trap of approximately 4 m long by 2 m wide by 0.6 m deep.
- Construct a sediment trap by excavating a hole in the ground or utilizing a borrow pit.
- If necessary, install temporary weirs at the downstream end to impound the water.
- Protect the outlet end of the sediment trap against erosion.



Dug sediment trap. Source: OMNR (1990).

- Maintain sediment traps throughout their use by cleaning out silt, sand and debris regularly.

- Upon completion of work, remove all temporary structures and stabilize the area.

If the drainage area is larger than two hectares, a more sophisticated version of a sediment trap known as a sediment control pond must be used. For instruction on building a sediment control pond, see Chilibeck, et al. (1993) or consult a geotechnical engineer.

3.2 Silt Fences

Silt fences are filtering devices that trap sediments and slow the velocity of water runoff to encourage deposition. Silt fences consist of woven geotextile fabric or straw bales.

Straw bales, if available, are useful as short-term sediment barriers, but they will degrade after three to six months. Silt fences made of geotextile fabric, with proper installation, have a longer life expectancy than straw bales.

Both brush barriers (see Section 3.3) and silt fences halt the migration of sediments, but silt fences are not as effective as brush barriers in protecting exposed soils from erosion.

It is imperative that silt fences are only placed in areas with small volumes or low flow velocities, and are installed correctly, using the following guidelines.

- Build silt fences before construction activity begins by placing straw bales or geotextile fabric directly in the path of runoff.

- Utilize silt fences to trap sediments from small drainage areas, on the lower one half to one third of a slope, or where erodibility is high (i.e. downstream from an earth cut, on the toe of a slope, or surrounding a temporary stockpile of erodible soil).

- Install silt fences on a slope that is no longer than 30 m and no steeper than about 2:1.

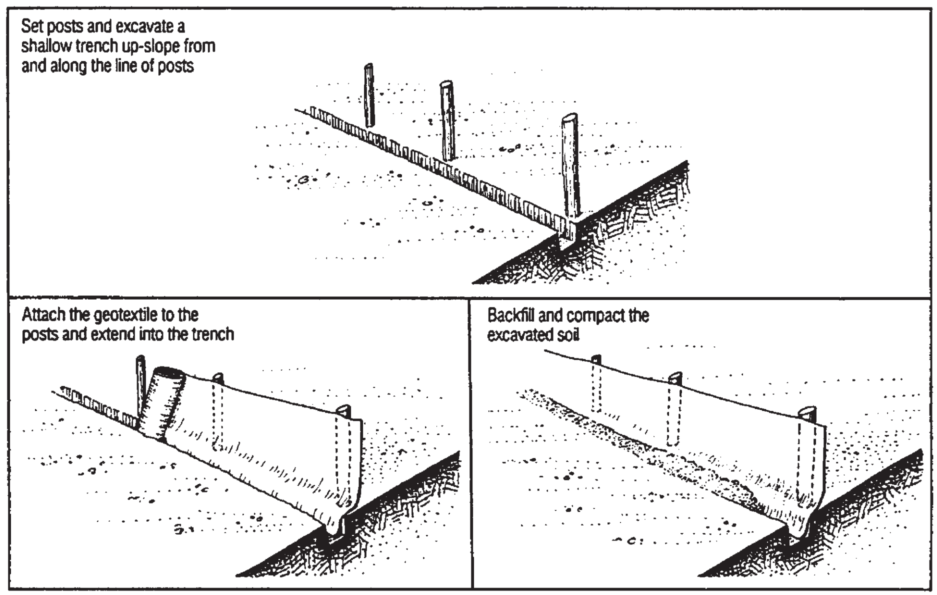
- Support geotextile fabric with vertical wooden posts that are spaced not more than 3 m apart.

- Dig a trench along the upstream side of the posts that is 10 cm deep and 10 cm wide.

- Attach the geotextile fabric to the upstream side of the posts and anchor it in the trench. The trench prevents water from flowing under the fence.

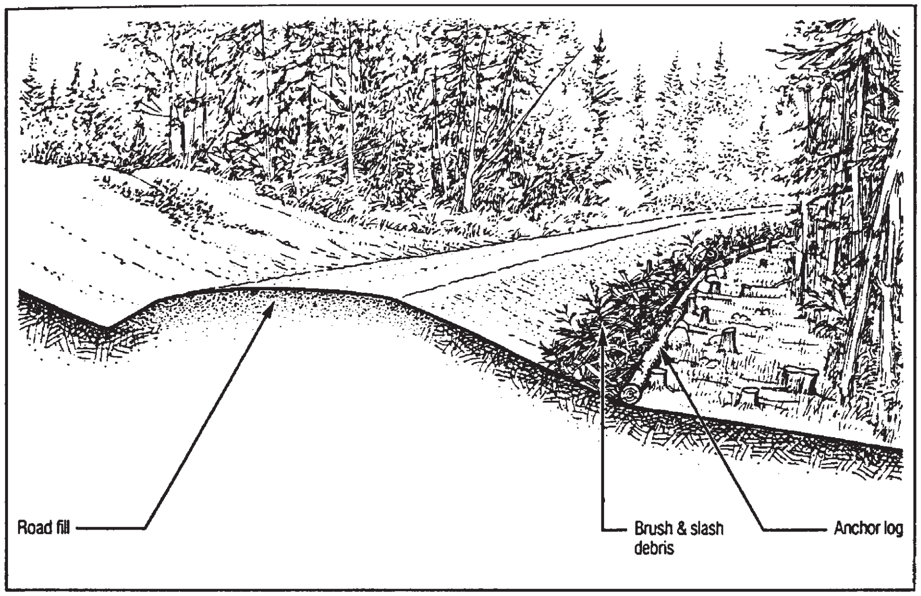
- When one silt fence becomes full, maintain sediment control by installing another fence further downhill.

- Repair or replace old, ineffective geotextile fabric and degraded straw bales immediately.



Construction of a silt fence. Source: OMNR (1990).

3.3 Brush Barriers



Brush barrier at toe of fill. Source: OMNR (1990).

Brush barriers are piles of slash debris that control short-term erosion and sedimentation. The materials in the barrier, such as logs, limbs, and branches, act as filters to slow the velocity of runoff water and trap sediments. Barriers of this kind have been estimated to be 75 to 85% efficient at trapping sediments.

- Utilize brush barriers on water crossing approaches and for at least 100 m along the roadsides before and after a crossing
- Install brush barriers on slopes that are not longer than 30 m.
- Begin preparation of brush barriers during the clearing phase of construction.
- Stockpile large anchor logs and any slash debris that is no larger than 4 m long and 15 cm in diameter.
- Ensure that the stockpiles are accessible for later use but are not blocking drainage or located below the high water mark.
- Place the brush barrier as soon as any necessary contouring and backfilling on the slopes has been completed.
- Employ large anchor logs when the barrier is being used on the toe of an earth fill slope. Anchor logs against rocks, trees, or stumps and lay them parallel to the road.
- Place slash from the stockpile on the fill slope above the anchor logs or on any other erodible soils.
- Ensure that all slash piles are dense enough to prevent flow from going underneath by embedding them with a backhoe bucket or trampling them with tracked construction equipment.

3.4 Forest Floor Filter

Undisturbed natural terrain has a high resistance to erosion and is very effective as a filter for removing silt load from water. Take advantage of natural filters by dispersing drainage water over the terrain instead of steering it into the stream.

The use of a forest floor filter will prevent stream crossings from directly receiving large volumes of highly turbid runoff water. Ensure that the forest floor filter is most effective by following the guidelines below.

- Ensure that the forest floor area is large enough for effective filtering. The minimum length of undisturbed area or buffer is listed in Table 2.

- Divert water from the ditches into the forest floor with the use of a diversion berm and excavated channel if necessary.

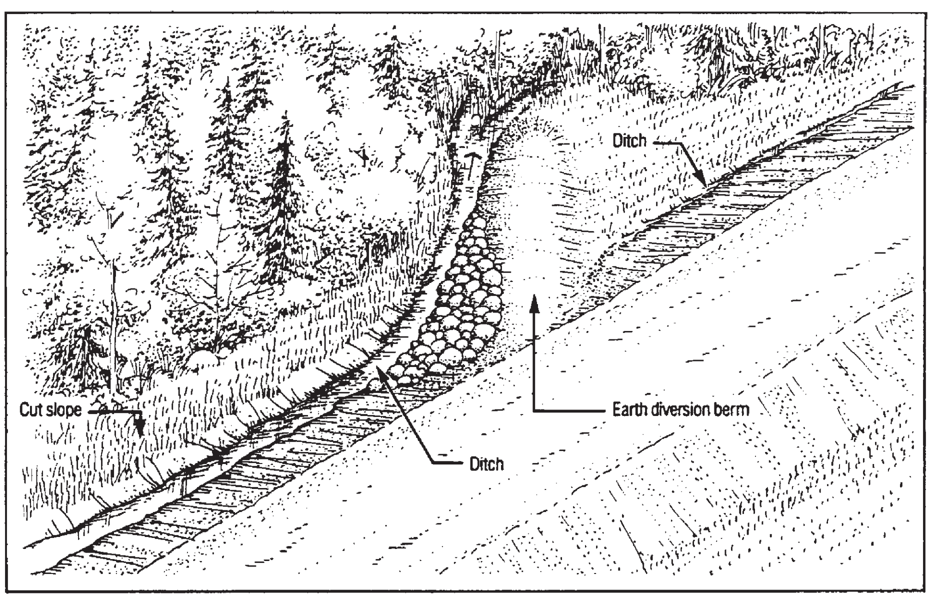
- Place diversions so that the drainage area upstream of the berm is less than 2 ha.

- Ensure that the terrain has a downhill slope of at least 1% to prevent pooling behind the berm.

- Construct the diversion berm to be at least 50 cm in height and width and strong enough to resist the expected flow velocities.

- Prevent erosion of the berm by constructing side slopes at a steepness of 2:1 or flatter and utilizing erosion-resistant material.

- Space ditch outlets from between 100 to 600 m apart, depending on slope steepness and soil type. For example, a slope that is steep (over 10%) with highly erodible silt-clay soil will need the smallest space between ditches (100 m).

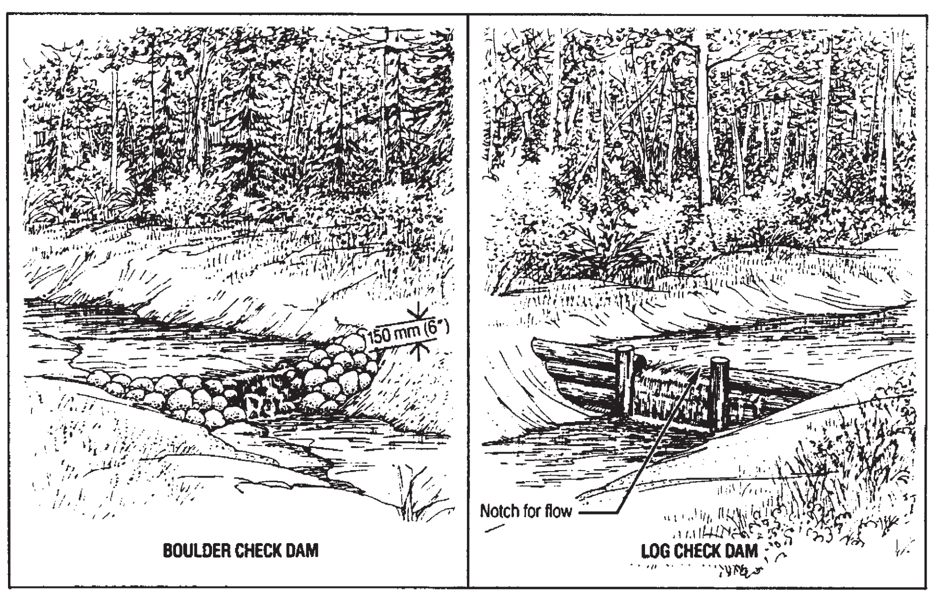


Forest floor filter - flow directed off right-of-way using a diversion berm. Source: OMNR (1990).

3.5 Check Dam

Check dams are overflow weirs that are placed across channels, alone or in series, to reduce erosion until vegetation is established. They maintain a low water velocity in sloping ditches by forcing water to pass over a series of steps instead of flowing directly downhill.

- Minimize erosion around a stream crossing site by installing a series of check dams in the roadway ditches.
- Use check dams to service a maximum drainage area of 4 ha. Steeper ditches will require a greater frequency of check dams to control the water velocity. On average, space the check dams at an interval of six times the width of the check dam.
- Construct check dams out of erosion-resistant material such as logs, boulders, straw bales, and sandbags.
- Build dams to a maximum height of 60 cm.
- Avoid washout by making the check dam large enough to keep water from flowing past the outside edges or through the soil.
- Make a notch in the centre of the dam that is at least 15 cm below maximum height. Water should only flow over the notch in the centre.
- Embed construction materials securely into the channel bottom to prevent water from flowing underneath the dam.
- Clean accumulated sediments out of the dam regularly.



Two types of check dams. Source: OMNR (1990).

3.6 Revegetation

Vegetation provides very effective protection against erosion and sedimentation processes. Even after the best efforts have been made to minimize the loss of vegetation, it may be necessary to revegetate exposed areas. This will not only prevent further erosion but may also improve aesthetics of the stream crossing site.

Revegetation occurs naturally over time under favourable conditions, but techniques such as seeding, mulching, and fertilization will speed up the growth process and improve chances of success.

Mulch prevents erosion before vegetation is established and assists germination by holding seeds, soil, and moisture in place. Examples of mulch include straw, shredded paper, wood chips, matting, and slash debris.

Fertilizer helps to speed the establishment of vegetation by providing necessary nutrients for growth.

Use the guidelines below when undertaking revegetation.

- Choose species that are fast-growing, well-adapted to the local environment, and easy to plant and maintain. When seeding, mixtures of grass and legumes in a variety of species tend to be the most successful.

- Roughen the surface if necessary to hold seed and mulch by scarifying up to a maximum depth of 2.5 cm.

- Distribute the seeds as evenly as possible, making certain that they come in contact with the soil.

- Utilize hand broadcast seeders in small areas and hydraulic seeders in large areas. Hydraulic seeders have an added capability of spraying water, fertilizer, and mulch at the same time.

Hand broadcast seeding helps to establish vegetation in the area of water crossings.

- Cover the seeds with a shallow layer of soil about 1 cm thick.

- Apply any fertilizer used according to the manufacturer's instructions and prevent it from entering the watercourse.

- A mulch of straw or another plant matting may be used to cover and stabilize exposed slopes to allow time for vegetation to reestablish.

3.7 Rip Rap

Rip rap refers to a layer of boulders and rock fragments that are placed over exposed soil to slow the flow of water and trap sediments. This prevents erosion by not only protecting the soil but also allowing for the infiltration of water into the ground and encouraging vegetative growth between particles.

Rip rap is necessary for erosion control at most water crossings. Areas of particular concern are those with steep slopes, high water velocity, and any place where vegetation is inadequate to prevent erosion.

Rip rap usually consists of blasted rock fragments or borrow pit boulders. Blasted rock fragments are the most desirable because they have a rough, angular shape and they can be made to a specified size range. Borrow pit boulders are rounder and may require a flattened surface to prevent them from rolling out of place. Use rip rap according to the guidelines below.

- Grade the surface before placing a rip rap layer to ensure that the slope receiving the rip rap has an appropriate steepness (see Section 3.8: Slope Modification).

- Do not use mine slag or acid generating rock.

- Choose the size of rip rap to ensure that particles cannot be displaced by the stream flow. Particle size of rip rap ranges from about 1 to 50 cm, depending on the type of application, water velocity, and steepness of slope (see Table 5).

Table 5: Size of rip rap materials that various velocities of water can transport*. Source: Ontario Conservation Authorities (1981).

Mean Velocity (m/sec)	Mean Diameter (cm)
<2.0	8-11
2.0-2.5	11-18
2.5-3.0	18-22
3.0-3.5	22-33
>3.5 * *	

*Assuming a graded channel Manning's roughness of 0.030.
**Velocities greater than 3.5 m/sec require a more extensive design in consultation with a geotechnical engineer.

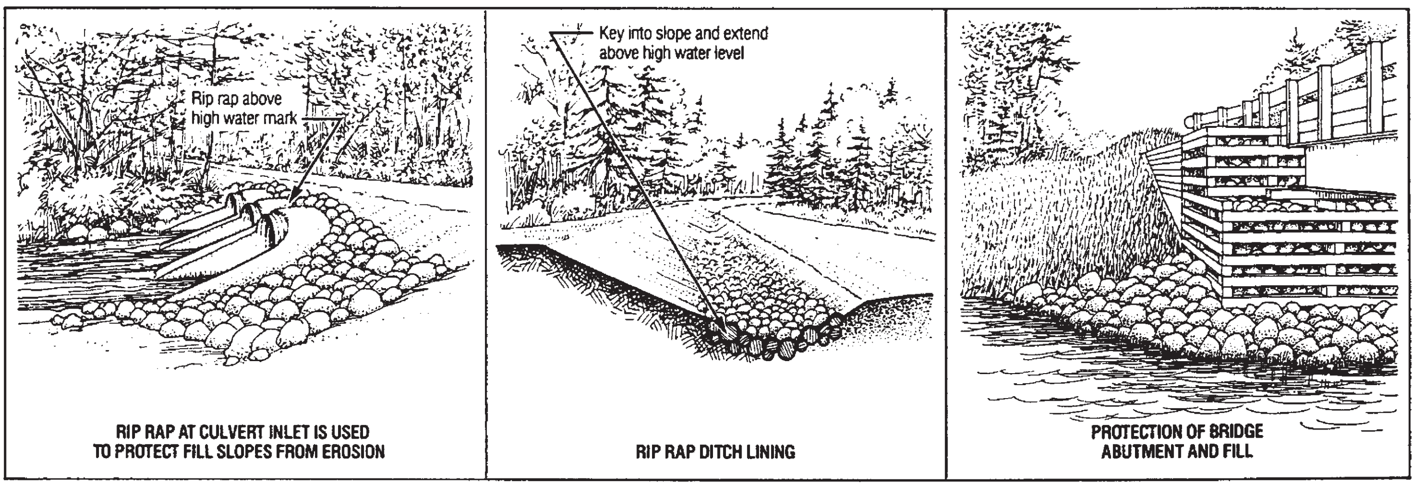
- Install a filter under the rip rap layer in areas where ground water rises from the soil under the rip rap or where velocities are excessive. Filters should be either granular or geotextile material, and should be accompanied by a sand or gravel filler.

- Lay the rip rap using a backhoe or other machine.

- Make rip rap layers uniform with a thickness at least 1.5 times the median rock size and no less than 30 cm.

- Position rip rap on the bottom of the stream bed to 0.3 m above normal high water mark, or to the top of the existing bank, whichever is less.

- Rip rap only those areas requiring erosion protection.



Erosion control using rip rap in three different situations. Source: Ontario Ministry of Natural Resources (1990).

Rip rap and a check dam.

3.8 Slope Modification

Steep slopes are very vulnerable to erosion because they are unstable and unable to hold vegetation. Generally, a slope is considered to have a high risk of erosion if it has a steepness of greater than 2:1. Slopes with smooth surfaces and erodible soils (i.e. fine sand, clay, or silt) are also at a high risk. Prevent erosion in these areas by flattening steep slopes to a gentler angle and roughening the surface to encourage vegetative growth.

- Conduct necessary slope modification during initial rough grade construction, as it is usually easier to construct a gentle slope the first time than to flatten a steep slope later.
- Flatten a graded slope that is too steep by adding fill or cutting the slope to a stable angle.
- Construct fill slopes by starting from the bottom and working up.
- Try to build a slope that is short but not too steep, and gentle but not too long. Further flattening beyond a stable angle is unnecessary and only increases the area of soil that is exposed to erosion.
- Recall that soil type affects slope stability (see Table 6). The most stable soils contain coarse particles, mixed particle sizes or cohesive clay while soils with particles that are fine and uniformly sized are the most unstable.

Table 6: Recommended side slope for major soil types. Source: Ontario Conservation Authorities, 1981.

Soil	Recommended Side Slope
hard clay	2.5:1
clay loam	2:1
silty loam	2:1
sandy loam	3:1
sand	3:1

- Protect any slopes that cannot be effectively graded using rip rap or a retaining wall.
- Round off slopes to blend with the natural landscape, especially at the top of cut excavations.
- Roughen the surface of graded areas in order to slow or prevent the movement of water, sediment, and seeds downslope.

Roughening can be accomplished by using a technique called track walking. This is when a tracked machine such as a bulldozer is driven on the slopes to create tread indentations in the surface. Ensure that the indentations run parallel to the contours of the slope otherwise they create vertical channels that actually increase the erosional potential of runoff water.

4.0 Glossary

Abutment	The structure supporting the ends of a bridge and retaining the approach fills.
Active Floodplain	The portion of the floodplain that contains flowing channels, high water channels, sand bars and land that floods frequently.
Alignment	The horizontal route or direction of an access road. It is made up of straight line sections and curves.
Angle of Repose	The maximum slope or angle at which a material such as soil or loose rock remains stable.
Apron	Erosion protection placed below the stream bed in an area of high flow velocity, such as downstream of a culvert.
Backwater	The rise in water level at an upstream location arising from a downstream constriction.
Baffles	An obstruction used for deflecting, checking or slowing fluid flow. Sometimes used in culverts to provide areas of slower velocity, which act as resting places for fish.
Bailey Bridge	A patented pre-fabricated type of bridge used since 1942 on low volume roads. A variety of bridge lengths and configurations can be assembled from standard components and the unit can be "launched" into position.
Benthic Organisms	Organisms living at the bottom of a stream, or lake.
Berm	A low earth fill constructed in the path of flowing water to divert its direction.
Braided Stream Channel	The stream pattern found where deposition of sand and gravel bars on the channel floor causes the stream to split into two or more channels which shift sideways toward lower adjacent ground.
Buffer Zone	A strip of vegetation along a stream or around a lake which is left to protect the water body from disturbances on adjacent land.
Catchment	The topographic area which drains into a stream at a specific location as defined by all land sloping towards the channel and its tributaries.

Check Dam	A low head dam structure constructed in a stream in the path of flowing water to reduce erosion. Water flows over a check dam.
Cofferdam	A temporary enclosure built in a watercourse and pumped dry to permit work on bridge abutments or piers.
Compensation	The creation of new fish habitat as habitat **Measures** replacement in-kind for losses attributed to a development.
Corduroy	Logs placed over a swamp to reinforce the natural root mat for the purpose of minimizing the risk of settlement or foundation failure. Corduroy is also used in winter road and ice bridge construction.
Culvert	A conduit used to convey water through an embankment.
DFO	Department of Fisheries and Oceans
DNR	Manitoba Department of Natural Resources
Debris	Any material including floating woody material or suspended sediment that is moved by flowing water.
Deleterious Substance	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 (Fisheries Act).
Deposition	Accumulation of material dropped due to a slower movement of the transporting agent such as water.
Discharge	The volumetric rate of flow of water in a stream.
Diversion	A new channel constructed to replace the existing channel for temporary or permanent use. Diversions can create dry conditions for construction or divert water from areas which cannot dispose of it safely.
Drainage Basin	The area contributing water to a selected point along a stream channel.
Erosion	The wearing away of the land surface by detachment and transport of soil and rock material through the action of moving water, wind or other geological processes.

Fish	Includes parts of fish, shellfish, crustaceans, marine animals and any parts of the shellfish, crustaceans or marine animals, and the eggs, sperm, spawn, larvae, spat, and juvenile stages of fish, shellfish, crustaceans and marine animals (Fisheries Act).
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 (Fisheries Act). Habitat includes the water and the physical and biological components such as stream bed, banks, vegetation, etc.
Fishway	A structure that produces pockets of low velocity water flow throughout a given distance to enable fish movement past obstacles.
Floodplain	That portion of a river valley, adjacent to the river channel, which is covered with water when the river overflows its banks during floods.
Foundation	The foundation for a bridge may include the underlying soil and the lowest levels of any pier or abutment resting on it.
Geotextile	A recently-developed product used as a soil reinforcement agent. Sheets are made of polyethylene and supplied in rolls about 2 m wide.
Grade or Profile Grade	The elevation of the top of the finished road is called grade or profile grade.
Grubbing	The removal and disposal of all vegetation material within the topsoil.
Guideline	A recommended or acceptable course of action which is not a regulation.
Hydraulic Gradient	The slope of the water level profile along the channel, and is indicative of the energy of the flow system.
Hydrology	Pertaining to the study of the occurrence, circulation, distribution and properties of waters of the earth and its atmosphere.
Incubation Period	The period from egg deposition to hatching.
Invert	The floor or bottom plates of the culvert.

Legumes	Plants with nitrogen-fixing nodules on the roots, which makes them capable of using atmospheric nitrogen.
Manning's Roughness	A factor which represents roughness or channel resistance to flow and varies with different sizes of bed paving material and depths of flow.
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.
Mulching	The practice of placing organic or inorganic materials on topsoil to facilitate the germination of seed by holding seeds, soil and moisture in place. Examples of mulch include straw, shredded paper, wood chips, matting and slash debris.
Net Gain	An increase in the productive capacity of habitats for selected fisheries brought about by government and public efforts to conserve, restore and develop habitats.
No Net Loss	A working principle by which Department of Fisheries and Oceans and Department of Natural Resources strive 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.
Normal High Water Mark	The location on the stream bank which visibly marks the end of terrestrial vegetation and the beginning of effects due to high flows (e.g. scouring) or aquatic vegetation.
Pier	Intermediate supports between abutments on bridges of more than one span.
Pools and Riffles	The naturally undulating profile of most streams, formed by coarse materials that accumulate on stream beds at intervals. Upstream from the accumulations, a shallow pool is impounded. Downstream from the crest of the accumulation, a local increase in slope causes the flow to accelerate, forming a riffle or rapids.

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.
Prolonged Swimming Speed	The intermediate level of swimming performance which fish can maintain for periods of 15 seconds to 20 minutes. The level of swimming performance varies with species and size of fish, and decreases proportionately with the length of time.
Proponent	A person, business, corporation or government body who proposes to undertake a development.
Protection (of habitats)	Prescribing guidelines and conditions, and enforcing laws for the purpose of preventing the harmful alteration, disruption or destruction of fish habitat.
Reclamation	The process of returning a disturbed area to a condition approximating its original condition.
Restoration (of habitats)	The treatment or clean-up of altered, disrupted, or degraded fish habitat for the purpose of increasing its capability to sustain a productive fisheries resource.
Revegetation	Re-establishment of vegetation in disturbed areas.
Right-of-way	The cleared area along the road alignment which contains the roadbed, ditches, road slopes and back slopes.
Rip Rap	A layer of boulders or rock fragments placed over a soil to protect it from the erosive forces of flowing water.
Riparian	Along the banks of rivers and streams; riparian vegetation is stream side vegetation.
Scarify	The process of loosening or stirring the soil to shallow depths without turning it over.
Scour	Term used to describe soil erosion when it occurs under water, as in the case of a stream bed or river bottom.
Sediment	Fragmentary material, originating from the disintegration of rocks, which is suspended, transported or deposited by water.
Sediment Traps	Temporary water retention ponds used to trap and retain sediments.

Sedimentation	The filling-in of lakes, reservoirs, streams, channels, etc. with soil particles, mainly sand and silt resulting from erosion. Also called siltation.
Slash	Debris remaining after tree cutting.
Spawning Grounds	A specific site in a water body that is utilized by a particular fish species for reproduction.
Spawning Period	The period of fertilization and subsequent deposition of eggs.
Stream	A general term referring to natural bodies of flowing water without regard to the volume of water transported, including intermittent and ephemeral (lasting only a short while) streams.
Subcarangiform	Fish with a fusiform body shape, e.g. trout, whitefish and walleye.
Substrate	The base on which organisms live, i.e. the material forming the stream bed.
Suspended Sediment	Sediment that is supported by the buoyancy and drag forces of flowing water and that stays in suspension for an appreciable period of time.
Ten-year Flood	The maximum quantity of water flow per second expected at a particular water crossing, on average, once every ten years. It has a 10% probability of occurring in any given year.
Toe (of slope)	Where the slope stops or levels out; the bottom of the slope.
Undercutting or Undermining	Occurs when channel flow at a high velocity is concentrated along one bank as a result of meanders or an obstruction forcing the flow against the opposite bank: bank becomes vertical as soil is washed away by channel flow.
Velocity	The distance travelled per unit of time.
Watercourse	A natural or artificial channel that conveys water continuously or intermittently.
Wingwall	An extension of a bridge abutment, constructed to retain the roadway fill material and prevent its entry into a water course.

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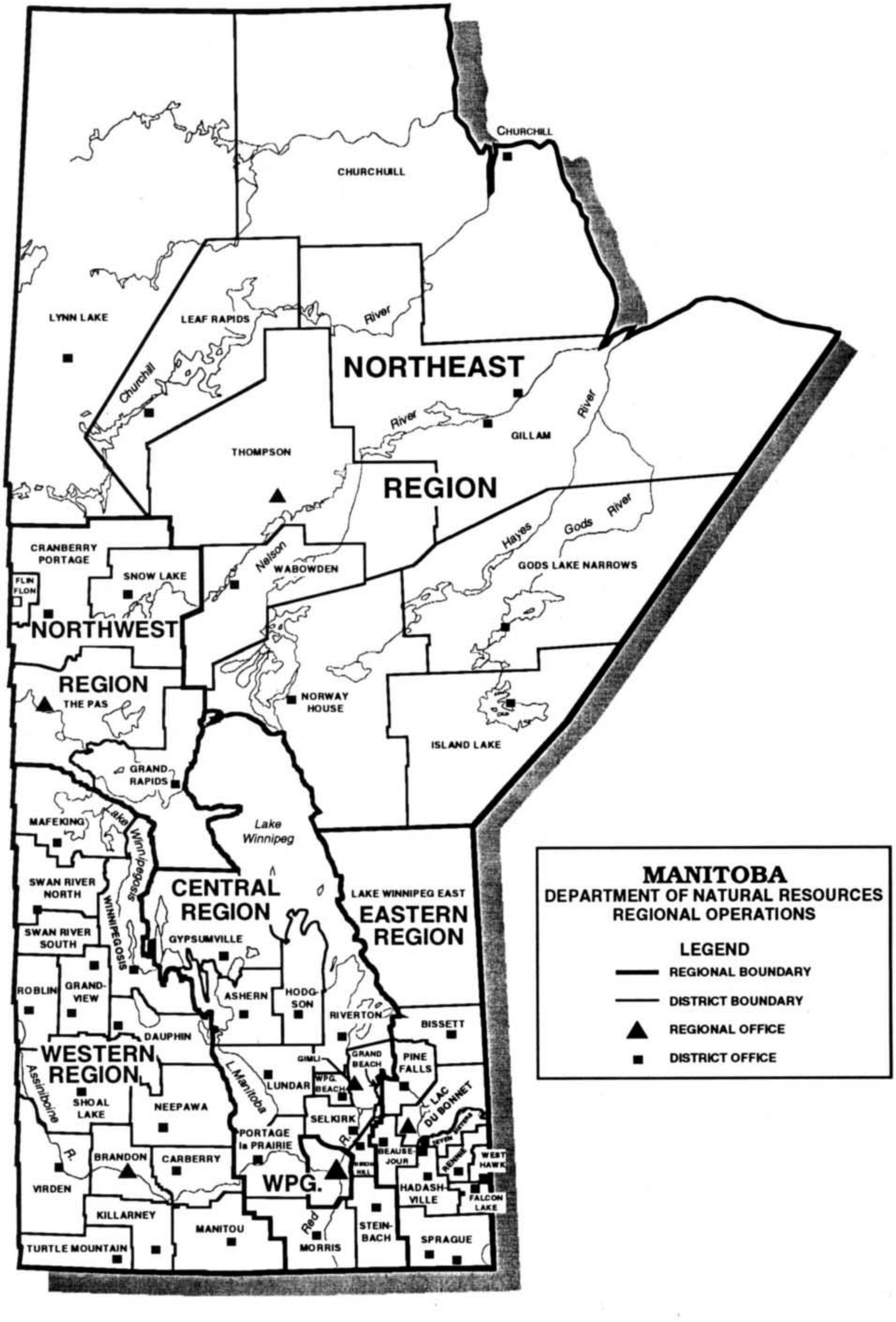
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