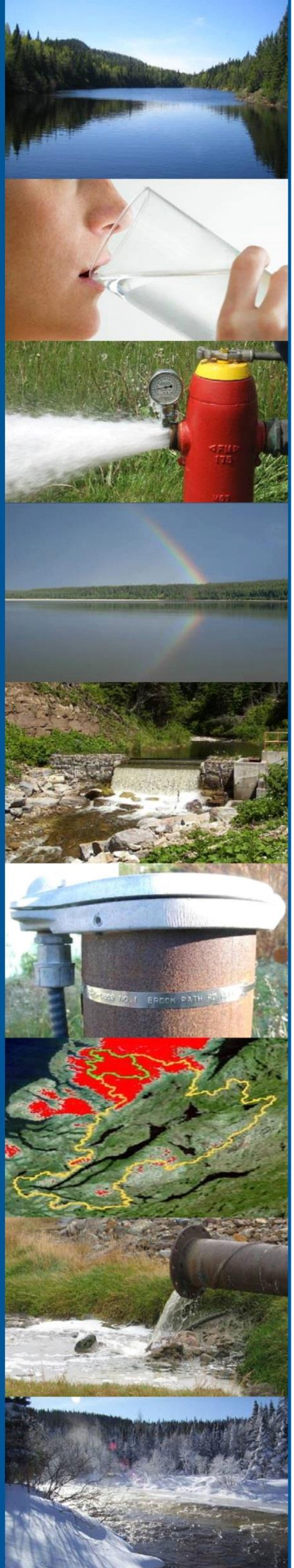

Chapter 4: Environmental Guidelines for Bridges

Water Resources Management Division
Water Rights, Investigations, and Modelling Section
November 29, 2018

Newfoundland Labrador

Government of Newfoundland and Labrador
Department of Municipal Affairs and Environment
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Chapter 4

Environmental Guidelines For

BRIDGES

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4.0 BRIDGES

Table of Contents

4.0 BRIDGES

4.0 BRIDGES

List of Tables

List of Figures

4.0 BRIDGES

4.1 General

Bridges are often required to provide access across large rivers, and streams, to cross wetland or flood plain areas, or to cross narrow lakes, ponds or ocean inlets. There is obviously a direct economic and social benefit for a bridge in that it shortens the time of travel between two points or it replaces an inconvenient mode of travel such as by ferry. Most bridges are constructed to carry traffic, however, bridges may also be constructed for railways, pedestrians, conveyors, pipes or other special uses. Not all bridges are new; sometimes there is a need to replace an old bridge or to improve a bridge to carry more traffic or heavier loads.

It is environmentally desirable, even on small streams, to construct bridges instead of other alternatives such as culverts because only bridges can avoid the alteration of flow regimes. (See **Figure 4.1**). Such problems as flooding, erosion, and siltation are avoided through the use of properly designed and constructed bridges. Bridges are recommended for all watercourses supporting anadromous fishes because there is no need to disturb the streambed and sufficient capacity will ensure that flow velocities are kept to a level where fish passage is maintained. Bridges are also recommended where the natural channel is too steep to accommodate maximum culvert slopes or where steep banks would necessitate a great deal of infilling if culverts were used.

Consideration of such factors as channel gradient, flow velocity, channel cross-section, channel roughness, discharge patterns, peak water levels, quantity of flow, ice formation, etc., are required for comprehensive hydraulic and hydrological design. Physical geographic and geotechnical considerations such as channel morphology, geological history, bed and boundary materials, sedimentation, and erosion are other points to be considered.

The completed bridge should safely accommodate reasonably predictable levels of flow and ice buildup as well as the forces of moving water and ice upon the structure without causing any adverse environmental impact at the crossing or in upstream or downstream areas. **Table 4.1** lists the major points for consideration of a proposed bridge design.

Improper or inadequate design and construction of bridges have caused problems of considerable magnitude. The erosive action of flowing water, high rates of discharge, and the movement of ice can be adversely affected by bridges and cause environmental damage, flooding, great expense in loss of property and even loss of human life. Usually the first thing to fail in a poor bridge design is the bridge itself. **Figure 4.2** shows bridge failures resulting from unanticipated bed scour.

4.0 BRIDGES

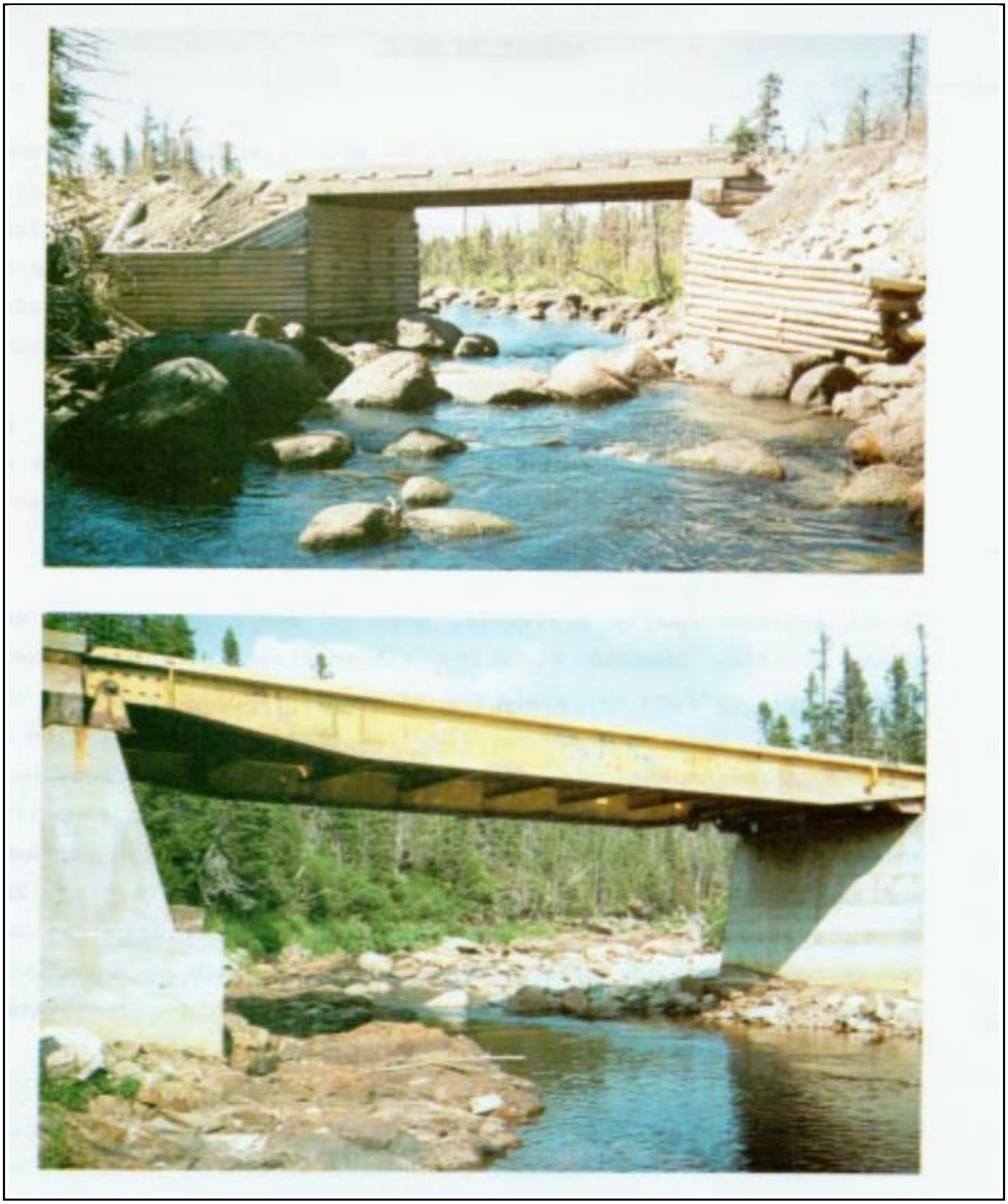


Figure 4.1 Bridges can avoid alterations to the flow regime

4.0 BRIDGES

Table 4.1 Points for Review of Bridge Design Proposals

Bridge Location and Alignment	- Is the need for a bridge in this area economical and fully justified? - Do plans show the relationship of the bridge to the river, floodplain, valley, etc.? - Does the location and alignment appear appropriate, having regard to the nature of the stream and to routing requirements? - Has attention been given to effects on adjacent works and property or effects of existing works on the proposed structure?
Bridge Height and Waterway Opening	- How have design high-water level and discharge been determined? - Has adequate clearance been allotted in excess of the design high-water level? - How well would the bridge withstand a flood in excess of design flows? - What is the estimated velocity and scour through the waterway opening? - Is the bridge opening at least as large as the natural waterway? - Is blockage by ice or other debris possible?
Road Approaches	- Are approach embankments, guide banks, or other training works secure against erosion or sliding failure following erosion at the toe? - If approach roads are liable to submergence in extreme floods, has adequate protection against washout been provided? - Have possible backwater effects of the project been estimated? - Has allowance been made for possible future shifting of the channel? - Are materials and workmanship for erosion protection adequately specified?
Pier and Abutment Details	- Are foundations secured against general and local scour? - Are piers, abutments and foundations properly aligned with the principal direction of flow and are they adequately streamlined? - Do foundations require specification of backfill material, or scour protection aprons?

4.0 BRIDGES

Construction	-	Will construction procedures cause partial blocking of the waterway and if so, what would be the consequences of high flows or ice runs during the construction period?
	-	Has provision been made for complete removal of temporary construction works such as cofferdams, sheet piling, berms, etc.?
	-	Has attention been given to scour around cofferdams?
Approvals and Standards	-	Have all statutory requirements been met and approvals obtained from all authorities having jurisdiction?
	-	Does the project as a whole meet desirable standards for environmental preservation and have possible alternatives been sufficiently considered and evaluated?

4.0 BRIDGES

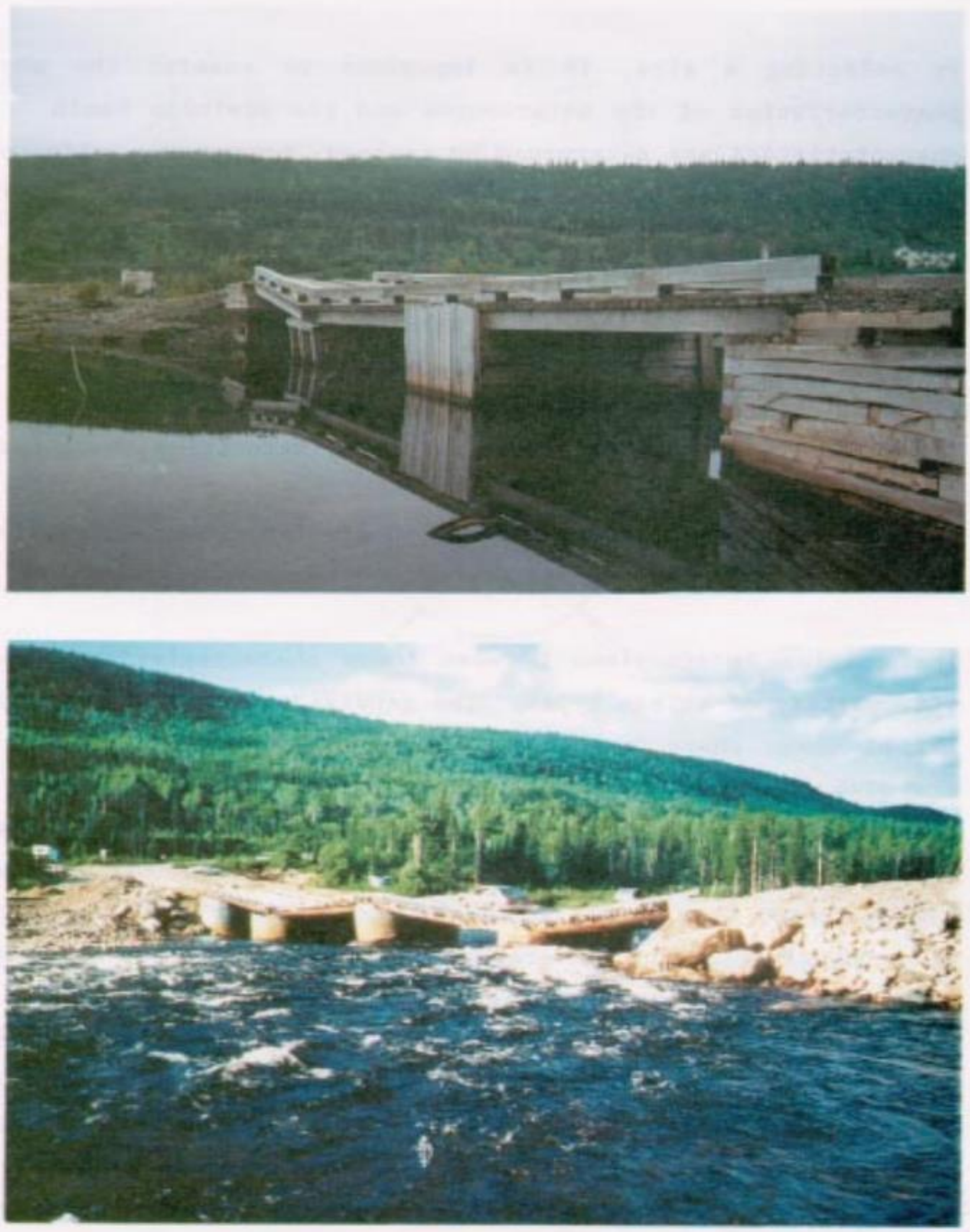


Figure 4.2 Bridge failure caused by scour around piers

4.0 BRIDGES

It is therefore imperative that all bridge installations be properly designed and constructed to perform safely and adequately under varying natural conditions. This always involves the use or application of proven methods of hydraulic and hydrological design.

4.2 Site Selection

The site selected should enable construction of a safe, economical, and easily maintained crossing, having regard to routing and approach requirements, to the nature of the waterway and its environment, and to minimize the use of such training works as may be necessary to deal with adverse natural channel features.

In selecting a site, it is important to examine the physical characteristics of the watercourse and its drainage basin. These characteristics are determined by geology, topography, climate, and land use, and may be divided into four groups. (Also see **Figure 4.3**).

- geographic: physiographic setting, geological history, channel pattern, etc.
- hydrologic: discharge patterns, water levels, ice etc.
- hydraulic: slopes, cross-sections, velocities, roughness, etc.
- geotechnical: boundary materials, erosion, scour and sedimentation, etc.

The complex interactions between these characteristics produce a wide variety of stream types. The general patterns of variation in all of these characteristics, and the relationships between them, are often referred to as the river's "regime", in the same sense that "climate" is used in considering meteorological variables. In regard to scour and erosion, behavior of a stream may fall within a wide range, from a very stable bedrock channel to a highly mobile alluvial river. Many rivers exhibit complex changes in behavior from point to point, because of the strong influence of local features associated with glaciation. Careful investigation of past behavior at a particular site is therefore important. The choice of site may greatly affect the difficulties and expense of building a crossing as well as its long term performance, stability, and amount of maintenance required. It is therefore necessary that field studies be conducted during route selection to choose the best location for the bridge installation.

4.2.1 General Route Selection

Bridges are a significant component of any new road especially in terrain where streams or flood plains are numerous. A new route should minimize the number and length of crossings required, thereby keeping environmental disruption as well as overall costs to a minimum.

4.0 BRIDGES

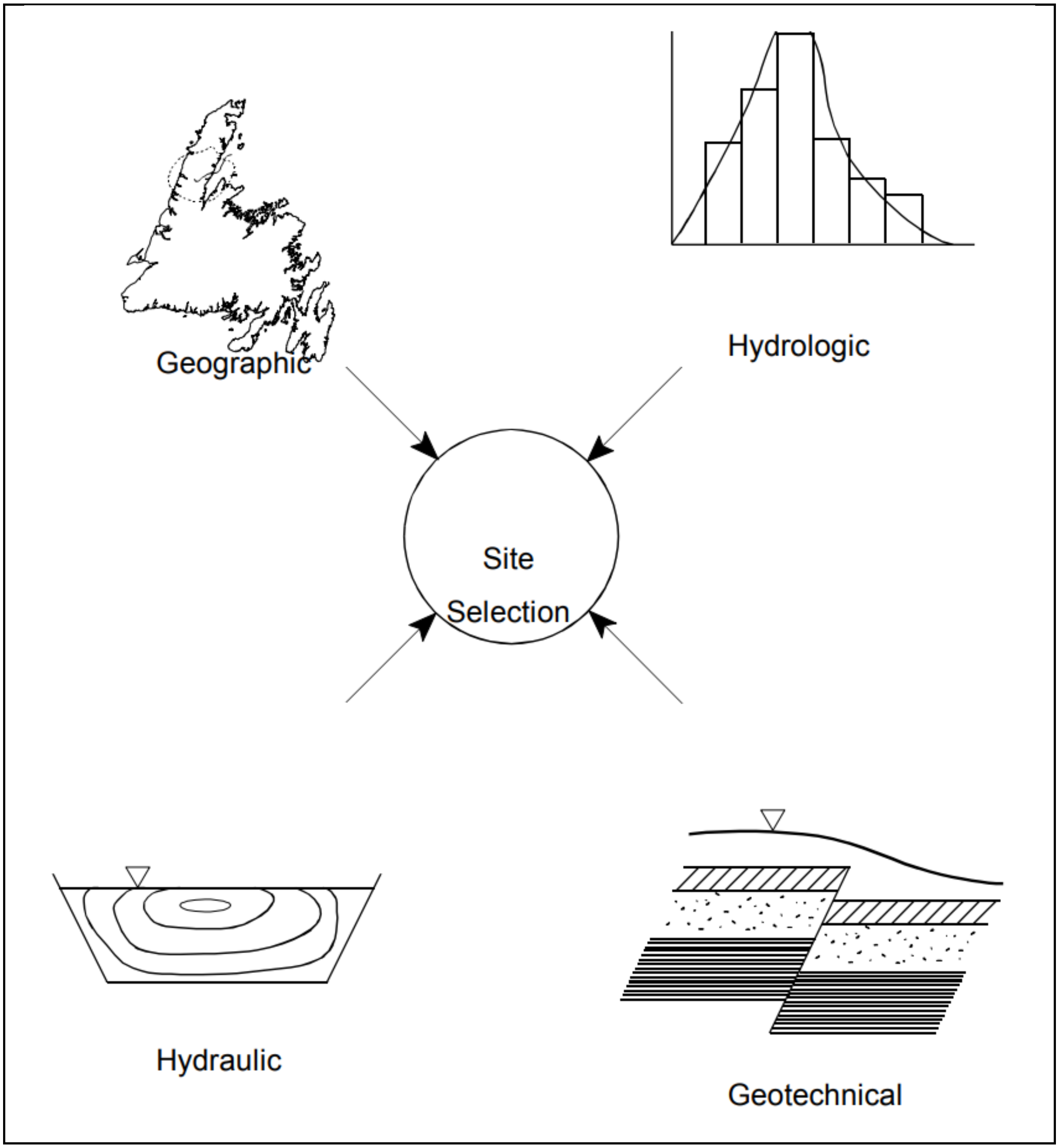


Figure 4.3 Bridge failure caused by scour around piers

4.2.2 Suitable Site Characteristics

Stream characteristics and geology often vary significantly over short lengths of river. A suitable crossing site should be at a stable reach having good flow alignment. The liability of scour or bank erosion must be investigated and should be an important site selection criterion. When streams are braided, ie., split into two or more channels, a single channel location is preferred.

4.2.3 Bridge Alignment

The alignment of a bridge relative to the waterway should be at right angles. This will reduce the length of bridge required to cross. In meandering and shifting streams attention must be given to past trends to ensure that the stream at the selected location will not shift. In some instances it may be necessary to construct training works. Straight lengths of channel are preferred for the crossing. Crossings on abrupt bends should be avoided except when the stream is in erosion resistant materials.

4.2.4 Alluvial Fans

Crossings of alluvial fans should be avoided because of the aggradation of the channel. The preferred crossing location is near the apex or head of the fan.

4.2.5 Sites of Flooding

Bridges should not be located in areas which are known to flood periodically. The presence of a bridge often aggravates the problem. One should also be aware of typical ice jam locations and these should be avoided.

4.2.6 Location of Other Structures

There are so many possibilities here that possible precautions can only be discussed in general terms. The presence of other structures can have a significant bearing upon site selection. For instance other crossings may affect or be affected by the proposed bridge. Dams, both upstream and downstream obviously have considerable bearing. In some cases other structures are not even built but are proposed and may influence a bridge site.

4.2.7 Approaches

Approaches to the proposed bridge must meet requirements of grade and alignment for safety reasons.

4.0 BRIDGES

4.3 Bridge Design

a) Design Flood Frequency - The hydrologic and hydraulic design of a bridge is essentially a two-step process. The first step is to estimate all of the forces or quantities which would impact on the installation for an appropriate return period. The second step is to design all the structural components to accommodate these forces or quantities with some margin of safety. While such factors as the weight of traffic, earthquakes, wind and other forces are of great importance, these guidelines are primarily concerned with the flow and quantity of water, hence the hydrologic and hydraulic design.

Obviously no structure is designed to last forever. Equally true however, is the fact that the more valuable or important the bridge is, the longer it should be expected to last. The longer a bridge is expected to last, the more likely it is that it will be subjected to an extreme event or flood. The term "return period" is used to indicate a probability that a flood of a certain magnitude will occur. For example a 100 year return period flood is a flood whose flow would be exceeded on average once every 100 years.

The selection of an appropriate return period as mentioned above depends on the value of the bridge. This includes the cost of repair or replacement if the actual flows exceed the design flow and cause damage to the structure. However the selected return period must also reflect the importance of the reliability of structure, possible secondary damages to other property and environmental consequences of bridge failure. An economic analysis or cost-benefit analysis should be considered in determining the most economical design of bridges.

4.3.1 Return Periods for Hydrologic Design

Return periods for bridges should be selected with reference to **Table 4.2**.

b) Capacity - The bridge opening is the product of the width and height plus the cross-sectional area of the stream as shown in **Figure 4.4**. The rate of flow that can pass through this opening without overtopping is referred to as the capacity. It must be noted however that width and height are independent of capacity requirements meaning that a bridge dimension may need to be larger than required by the design flow. For purposes of designing the bridge waterway opening and of calculating velocities, scour, and afflux, the design discharge arising from floods, tidal flows, or both in combination should be selected after due consideration of the following:

4.0 BRIDGES

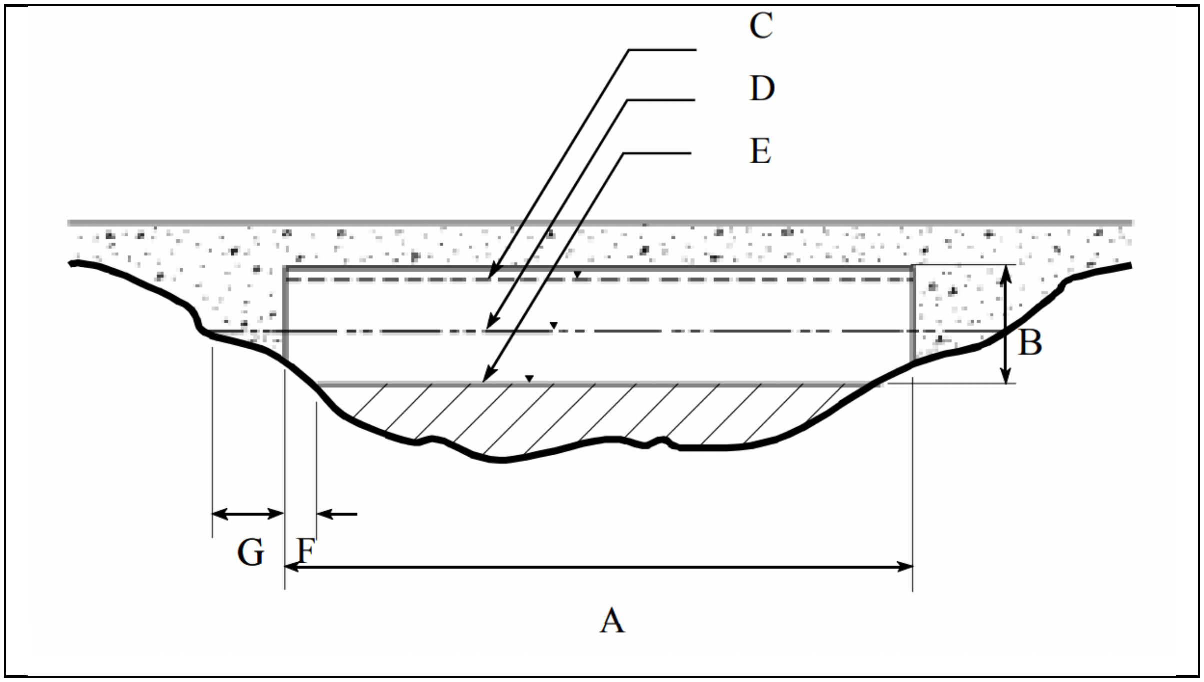
Table 4.2 Recommended Design Return Periods For Bridges

Road Classification	Return Period in Years
Freeways, (Trans-Canada Highway)	100
Urban Arterials	100
Rural Arterials	50
Collector Roads	50
Urban Local	50
Rural Local	25
Forest Access Roads	20
Any Bridge Exceeding 6.0 m Span	20

Modification of these recommended return periods should be considered in the following cases:

- If flood hazards in the area are known to be unusually severe.
- If the road is the only route to a community or essential services such as a hospital.
- If the road classification is likely to be upgraded.
- If there is property or facilities which apart from the bridge itself, could be damaged in the event of flooding, scour or other damage related to the bridge failure.
- If the bridge is located in a 1 in 100 year flood zone as designated under the Canada Newfoundland Flood Damage Reduction Agreement.

4.0 BRIDGES



A -	Length =	normal stream width + (2 x 0.5 m), or, 1:10 year stream width - 10%
B -	Height =	sufficient to pass design flow along with waves, ice, and debris, without contacting the bridge
C -	Maximum Design Flow	
D -	1:10 year high water level	
E -	Normal water level	
F -	Abutment Placement =	set back 0.5 m from normal water's edge
G -	Permissible Flow Constriction =	total flow constrictions of no more than 10% of the 1:10 year flow width

Note: Capacity of Bridge = (Length x Height) + (Shaded Area in Figure)

Figure 4.4 Typical bridge dimensions to be determined in bridge flow capacity design.

4.3.2 Historical Flows

The maximum historical flows as recorded at the site, or as calculated on the basis of recorded water levels, or as calculated on the basis of measured discharges at other points on the river from which corresponding site discharges can reasonably be inferred, may be used.

4.3.3 Flood Frequency Analysis

The discharge derived from a frequency analysis and corresponding to flood and/or tidal conditions of a frequency appropriate to the importance and value of the structure. Results of Regional Flood Frequency Analysis (RFFA) are available from this department.

4.3.4 Other Discharge Estimates

Where insufficient information is available to yield an estimate of the actual maximum discharge at the site over a historical period of reasonable length, or to provide an adequate frequency analysis, the design discharge may be estimated by any other reasonable method such as regional flood frequency, unit hydrograph, maximum probable storm, rational method, etc. Estimates may be made of maximum flow rates based on the area of the drainage basin, rainfall intensity-duration, and other appropriate data, which would indicate the flows that could be anticipated.

4.3.5 Anticipated Land Use Changes

The marginal cost of increasing a proposed design parameter may be small enough to warrant over sizing in order to be assured of good future performance. This is especially true if land use changes are likely to occur in the drainage basin upstream of the bridge.

4.3.6 Design Discharge Verification

When the design discharge is based on historical maxima, frequency analysis, or other empirical methods, it is advisable to check whether the historical record reflects trends or discontinuities in the flow regime resulting from land use changes, engineering works, or other causes; and to consider whether such changes are likely to occur in the foreseeable future.

4.3.7 Discharges Controlled by Reservoir Releases

Before counting on significant reductions in natural flood peaks because of storage reservoirs or other upstream works, the probable operating and routing procedures should be investigated. Where possible, a written statement should be obtained from the competent authorities.

4.3.8 Flow Duration

The probable duration as well as the magnitude of large flows may be significant, especially with reference to scour.

c) Bridge Height - The height of the deck should be such that the superstructure is not endangered by the action of flowing water, ice, floating debris, or waves, and the roadway is not rendered impassable except under clearly understood and permitted conditions. The selection of design values and safety margins for high water level and discharge raises difficult questions. The approach recommended here is to adopt design values which set limits of serviceability for the structure, and then ensure that under design conditions the margins of safety against structural failure are sufficient. This margin should be set by the engineer in each case, having regard to the reliability of the data on which the design values are based, to the probability of occurrence of greater values, to the consequences of failure, to the type of structure chosen, and to economic factors.

For the purpose of selecting a minimum height for the bridge superstructure, the design high-water level should normally be selected after due consideration of the following:

4.3.9 Maximum Historical Water Level

The maximum historical water level as observed or recorded at the site, or as inferred from observed or recorded levels at another point on the river or waterway from which levels can reasonably be transferred to the site in question may be used.

4.3.10 Frequency Analysis

The water level derived from frequency analysis and corresponding to flood, tidal, or ice conditions of a frequency appropriate to the importance and value of the structure may be used for design parameters. The peak stage of flood flows may also be estimated using methods indicated in part (b) above.

4.3.11 Clearances

Additional height should be included if there is a history of ice accumulation, or if floating debris poses a potential problem. On navigable water courses sufficient clearance for vessels must be provided.

d) Bridge Length - The length of bridge works should be such that the opening is able to pass the maximum flows that may be expected without endangering the bridge or appurtenances by scour, without creating major maintenance problems, without causing unacceptable backwater effects upstream, and without causing currents, waves, or turbulence unacceptable to navigation or other legitimate interests. It should be possible to pass expected quantities of ice, logs, and other debris without endangering the structure or adjacent property as a result of jams and accumulations.

4.3.12 Width on Regular Channels

Where a stream has a single, well defined channel of fairly regular width, and flood flows are more or less confined to the channel, the bridge should clear the entire channel with abutments set back 0.5 m from the normal high water edge. Also, in no case should the bridge reduce the channel width by more than 10% of the 1:10 year flood flow width.

4.3.13 Width on Flood Plains

In situations with low flood plains, where a substantial portion of the design discharge normally flows across the overbank areas, the question arises of whether to divert all the overflow through a single waterway opening in the main channel, or to provide relief spans on the flood plain. The former solution is usually more economical, but if the road crosses the valley at an angle, relief spans or culverts may be necessary to prevent excessive backwater effects.

4.3.14 Width on Irregular Streams

In the type of stream where the channel width varies greatly from point to point, the narrower sections may normally be used as a guide to determine a suitable bridge length, provided overbank flow is taken into consideration.

4.3.15 Overtopping

In flat, low-lying terrain subject to widespread flooding it may be acceptable to allow overtopping of roadways in extreme floods, thereby reducing the discharge to be passed through the bridge waterway opening. In such design, provision must be made to prevent any road washout by having a designated overflow section which is suitably protected against erosion.

4.3.16 Existing Bridges

The hydraulic performance and capacity of existing bridge waterway openings should give valuable guidance on the required length of a new bridge at another site on the same stream. In some cases experience may indicate that an existing bridge has been too short, allowing approach washouts, overtopping of the approach roadways, or unacceptably deep scour to occur. The weight to be given to such evidence depends of course on how long the existing bridge has stood, to what extent it has endured severe floods and ice conditions, and to what extent stream bed conditions at the new site conform to those at the existing site. A new or replacement bridge will generally be larger than an existing bridge.

e) Bridge Type - Having selected a site for the bridge and having established height and width requirements of the superstructure, the designer must then choose a type of bridge. This choice depends on the functional requirements of the bridge in regard to the hydrologic and hydraulic regime, the economics of construction, live-load requirements, foundation conditions, environmental constraints, maintenance considerations, policies of the owner, availability of materials, and preference of the project designer.

Some variables in bridge design include:

- the geometry and length of the approaches,
- the type and location of the abutments,
- the number and location of piers.

Commonly used bridges consist of fairly simple timber, steel or concrete spans, such as those seen in **Figure 4.5**. Certain applications may call for arch, truss or suspension design.

4.3.17 Environmental Impact of Bridge Type

The arrangement and details of piers, abutments, approaches, training works, and temporary construction facilities, so far as it is compatible with requirements of structural adequacy, safety, economy, and aesthetics, should be designed to minimize local scour, obstruction of flow, and inconvenience to legitimate interests.

4.0 BRIDGES

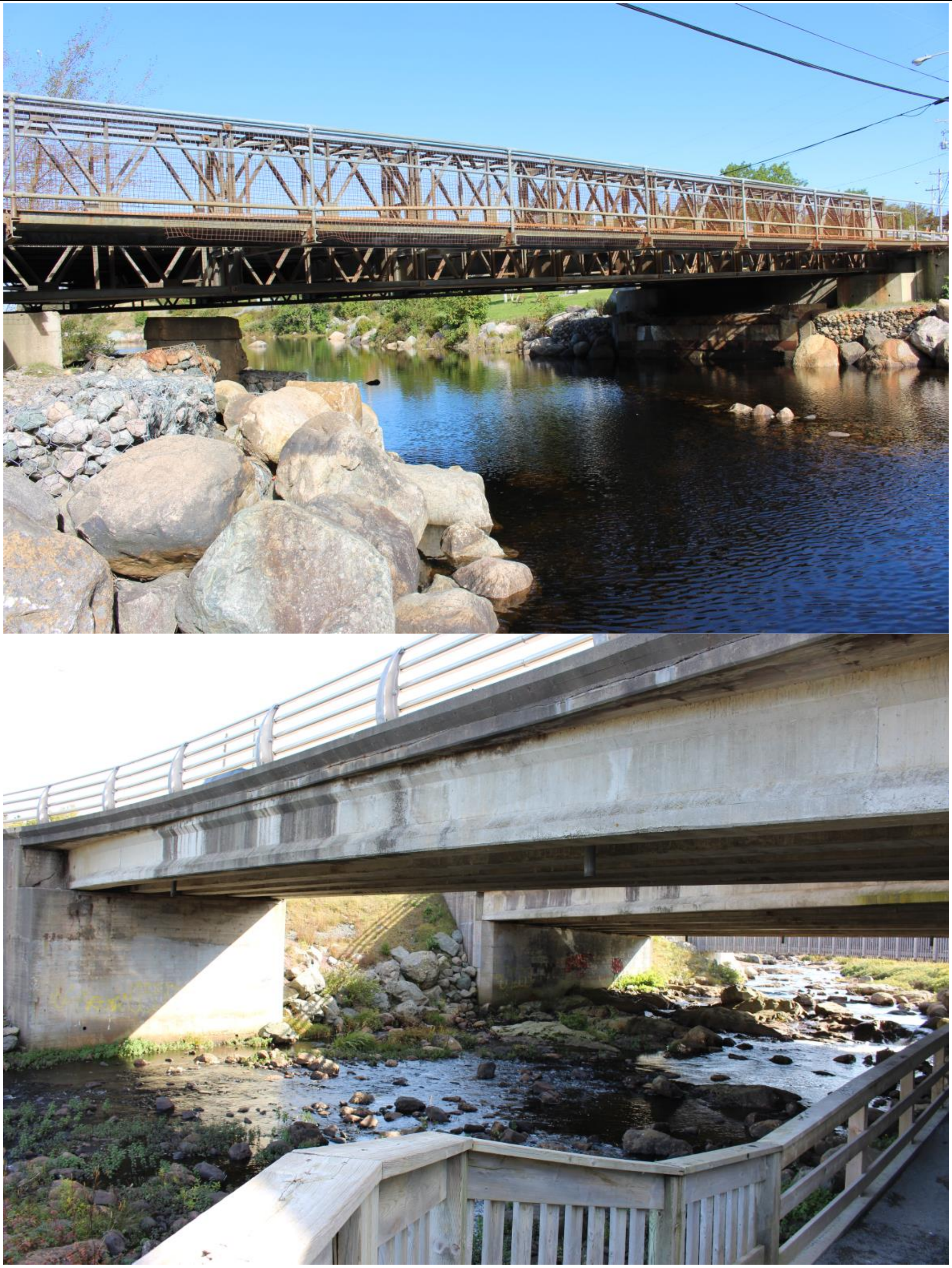


Figure 4.5 A steel span bridge (top) and a concrete span bridge (bottom)

4.0 BRIDGES

4.4 Abutments and Piers

The erosive action of running water in streams resulting in the carrying away of material from around bridge piers and abutments has long plagued persons responsible for bridge design, construction and maintenance. Bridge embankments projecting into wide flood plains may cause concern because they can produce scour problems in two ways; first, by concentrating the flow at the upstream corners of the embankments, and second, by constricting the flow with a resulting increase in water levels. (See **Figure 4.6**).

4.4.1 Abutment Location

Abutments should be set back from the normal wetted perimeter of the watercourse to avoid constriction of the channel and reduction of the flow area. For the same reason, the bridge design should use as few in-stream piers as possible and the width of the piers, perpendicular to the direction of flow, should not be in excess of what is necessary for safe and adequate structural support.

4.4.2 Foundation Depth

All foundations for abutments and piers should be set well into the substratum to provide a solid base for the structures. The foundations should also extend below the estimated lowest scour levels.

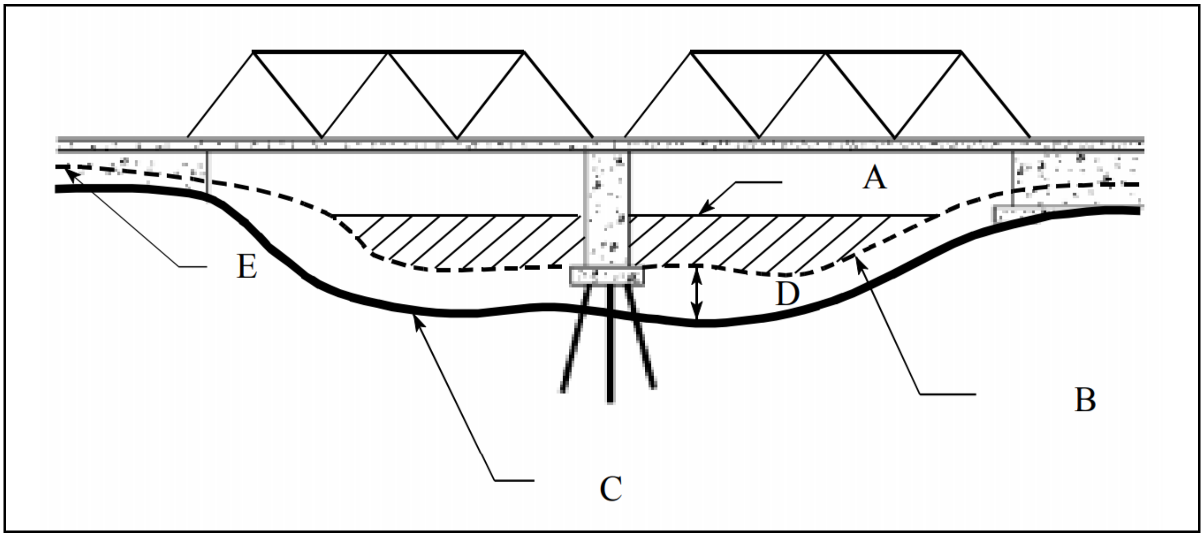
4.4.3 Hydraulic Design

Abutments and piers should be designed and constructed to provide the least amount of hydraulic resistance. Abutments should be constructed with tapered wing-walls upstream and downstream of the bridge and preferably be inclined into the embankment at a 1/16 angle to the vertical axis for increased structural stability. Piers should be constructed with ends which are tapered upstream and downstream in the direction of the main flow.

4.4.4 Erosion Protection

Where scouring around abutments or piers may occur, erosion protection should be provided. For this purpose a protective apron of rip-rap or other suitable material may be installed, preferably at a depth below the expected general scour level. Simply heaping stones around abutments is often unsatisfactory because this type of protection tends to require continual replacement.

4.0 BRIDGES



A - Normal Water Level

B - Original Stream Bed

C - Scoured Bed at Flood Risk

D - Depth of Scour

E - Flood Plain

Figure 4.6 Bed load movement at times of high flow and general scour require careful consideration to prevent abutment or pier failure

4.4.5 Concrete Components Vs. Wood Components

Where a solid rock foundation is available, concrete structures are strongest, most erosion resistant, and provide a longer term of service. Concrete abutments and piers are therefore preferred from an environmental standpoint to wooden structures.

4.4.6 Wooden Abutments and Piers

If wooden abutments and piers are to be used, squared timber is preferred to round logs. Squared timber can provide relatively tight, uniform surfaces which provide less hydraulic resistance. Filler timbers should be used between the corner-lapped crib timbers to close all openings in the abutments or piers. The timber cribs should be filled with gravel and small rock and consolidated. Protection from ice damage should be provided where timber cribs are exposed to moving river ice, by surfacing vulnerable portions of the structure with steel plating.

4.4.7 Log Cribs

Log crib abutments and piers should only be used for temporary bridges and should be completely removed at project abandonment. Where possible, avoid the use of log cribs. Where log crib abutments and piers are used, such as on forest access roads, the following guidelines should be taken into account to mitigate environmental impact:

- Avoid constricting the watercourse between abutments or with large instream piers.
- Minimize crib pier width and ensure that the pier design prevents the accumulation of debris on the pier.
- Place the lower crib logs deep enough below the streambed to prevent undermining by scour.
- Backfill the lower section of the crib with clean, broken rock.
- Provide well graded rip-rap or armour rock around the structure for protection from scouring or erosion.
- Use "filler" logs between the timber crib logs to completely enclose the sides of the structure.
- All logs should be peeled.

4.5 Recommended Construction Practices

It is during the actual construction of a bridge that there is the greatest danger of causing environmental disruption. Common problems can be categorized as pollution, siltation or disruption of environmentally sensitive areas. Poor bridge construction practices having no regard for these potential problems are liable to cause destruction of habitat for fish, wildlife and vegetation as well as degradation of water supplies used for human consumption. These problems may be temporary or long term, or may not become evident until later. For instance, the loss of natural stream bank stability may cause erosion which in turn may create long term problems of channel instability.

The following guidelines cover the most typical areas of bridge construction where the engineer, contractors and site personnel must be made aware of good construction techniques and precautions. However, because of the similarity of all construction near water, the reader is directed to more detailed discussion of the various topics in the appropriate chapters.

4.5.1 Work in the Dry

Operation of heavy equipment should be confined to dry stable areas in order to reduce the amount of mud and heavily silted water at the construction site which could enter the watercourse.

4.5.2 Fording

The operation of heavy equipment in a watercourse or fording of watercourses with heavy equipment should be avoided wherever possible as this can contribute to destabilization of the channel bed and banks resulting in erosion and downstream deposition, and can also cause serious downstream siltation and water quality problems. If fording of the watercourse with heavy equipment is required this should be carried out according to the guidelines of *Chapter 6, "Fording"*.

4.5.3 Use of Cofferdams During Channel Excavation

When excavation is required within the channel, as in the placement of footings for abutments or piers, measures should be taken to separate the excavation area from the flow by cofferdams. *Chapter 10, "General Construction Practices"*, contains information on the construction and use of cofferdams.

4.5.4 Prefabricated Structures

Bridges do not have to be completely constructed on site. Prefabricated structures that can be transported to the site are preferred as they minimize the work adjacent to the watercourse. Precast or prefabricated superstructures also avoid extensive use of fresh concrete on site which can cause serious water quality problems and pollution.

4.5.5 Concrete Work

When fresh concrete is to be used in components of a bridge structure, all necessary precautions should be taken to prevent the fresh concrete from coming in contact with the watercourse and should be carried out according to the guidelines of *Chapter 10, "General Construction Practices"*.

4.5.6 Use of Wood Preservatives

If creosoted or preservative treated wood is used in the bridge components, every precaution should be taken to prevent such toxic substances from entering a body of water. Any such substance should be applied to the wood at a site which is not environmentally sensitive and away from any water bodies. The treated material should be brought to the site and installed only after proper curing and drying has been achieved. Creosoted wood must not be used in bridges crossing over fresh water.

4.5.7 On-Site Use of Petroleum Products or Hazardous Substances

Where fuels such as gasoline, diesel fuel, kerosene or any other petroleum distillates or other substances which could cause pollution are being handled, stored or applied, containers containing in excess of 20 litres should be kept a minimum of 100 metres from any surface body of water. The storage and handling of gasoline and any petroleum derivative must be carried out according to *The Storage and Handling of Gasoline and Associated Products Regulations, 2003*.

4.5.8 Avoid Bank Disturbance

At all times, every necessary precaution should be taken to prevent the disturbance of channel banks, bank vegetation, and land within the high water zone, flood zone, or recommended buffer strip of any body of water outside of the land designated for construction of the roadway and bridge abutments. Further information is contained in *Chapter 10 "General Construction Practices"*.

4.5.9 Containment And Treatment of Silted Water

Where silted or muddied water has been generated, settling ponds, filtration or other suitable treatment must be provided to remove silt and turbidity before discharging into a body of water. Effluent discharged into receiving waters must comply with environmental regulations. Further information on reducing the amount of silted water generated by construction operations and methods for treatment are contained in *Chapter 10 "General Construction Practices"*.

4.0 BRIDGES

4.6 Site Rehabilitation and Stabilization

4.6.1 The Necessity of Site Rehabilitation

Toward the completion of the bridge installation, site rehabilitation should be carried out to stabilize slopes, disturbed areas and other areas vulnerable to erosion, to provide revegetation, and to ensure the site is left in a condition which is environmentally acceptable. *Chapter 10, "General Construction Practices"*, contains detailed information on site rehabilitation.

4.6.2 Protect Bridge Abutments

Bridge abutments should be protected from erosion or scouring by the careful placement of armour stone or rip-rap at vulnerable areas upstream and downstream of the abutment wing walls.

4.6.3 Stabilize Road Embankments and Ditches

The roadside embankments and roadside ditches near the watercourse should be stabilized by providing low side slopes and low grade and by providing rip-rap.

4.6.4 Protect Vulnerable Areas

Where river banks or other vulnerable areas have been disturbed, rehabilitation should be carried out to reinstate these areas and ensure adequate erosion protection. Protective rock or vegetative covering should be provided, as appropriate.

4.7 Inspection, Maintenance and Other Concerns

4.7.1 Frequent Inspection Needed

Bridges require frequent inspection to determine if they are performing satisfactorily without causing any environmental problem and to identify any problems which may threaten the bridge structurally.

4.7.2 Comprehensive Annual Inspection

A full inspection should be carried out annually after peak flow as well as periodic spot checks during times of high flow conditions. The annual inspection should involve examining the stream channel above and below the bridge to determine if any significant changes in the channel are evident. Sounding around piers and abutments to assess scour and deposition should be carried out.

4.7.3 Periodic Spot Inspections

Periodic spot checks during peak flow should identify:

- The adequacy of the bridge's capacity to safely pass peak flows with sufficient freeboard to the bridge deck,
- The extent of backwater effects or flow constriction,
- Flow velocity,
- The high water mark,
- Locations where the hydraulic characteristics of the peak flow may induce scour or erosion,
- Locations where debris has caught on piers or abutments,
- If roadside and bridge deck drainage are working correctly and,
- Any apparent problem which may require further investigation or remedial measures.

4.7.4 General Maintenance

General maintenance work should be carried out as required from time to time. Grouting or resurfacing of structural components as well as the removal of debris which may become caught at piers, abutments, or locations upstream of the bridge will extend the useful life of the bridge and minimize the risk of failure.

4.7.5 Remedial Works

Where serious problems are evident such as extensive bed degradation, pier scour, bank erosion or considerable flow constriction, remedial measures may be required. Such problems are often the result of inadequate capacity or lack of erosion protection and preferably should have been addressed in the design stage. If, however, erosion control or river training works are to be carried out subsequent to the development of such problems, a comprehensive investigation or evaluation of the problem should be conducted. Prior to the installation of such works the effectiveness and the implications of the hydraulic changes must be determined. The use of scaled hydraulic models may be appropriate. Usually, a new environmental approval will be required because the work may be carried out by different contractors and because of the stream flow alterations involved.

4.7.6 Recreational Use

Some bridges are located at a junction of a major watercourse and a major transportation route. These sites may attract people who wish to gain access to the watercourse for fishing, boating, or other recreational activity. It is therefore desirable to provide off-road parking at a safe location near the bridge along with a foot path to provide ease of access and reduce the slumping of roadside embankments by foot traffic.