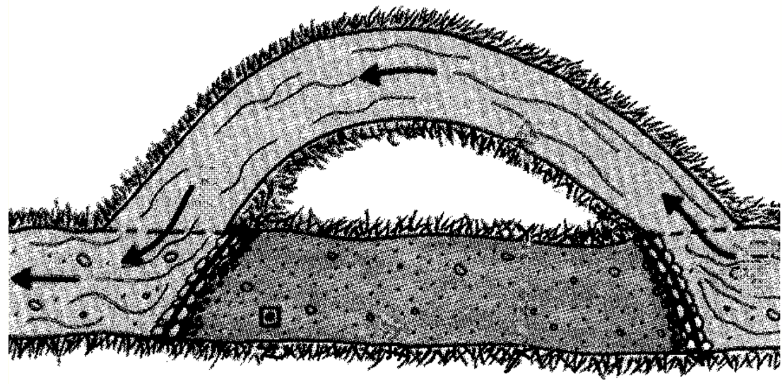
Chapter 7: Environmental Guidelines for Diversions, New Channels, Major Alterations



Water Resources Management Division
Water Rights, Investigations, and Modelling Section
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Newfoundland Labrador

Government of Newfoundland and Labrador
Department of Environment and Climate Change
Water Resources Management Division
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A1B 4J6

Chapter 7

Environmental Guidelines For

DIVERSIONS, NEW CHANNELS, MAJOR ALTERATIONS

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7.l General

The need for new channels, diversions, and major watercourse alterations often arises from land development such as urban, residential, industrial and commercial land use. In areas where such developments are proposed, new channels may be required to accommodate increased volumes of flow from developed areas, to lower the water table, to accommodate drainage and storm water systems, and to maximize land use. In many instances the restoration of existing watercourses can accommodate the needs of storm water management in developing areas.

Many other needs arise where major watercourse alterations are required. Watercourse diversions or new channels are sometimes required to temporarily reroute flow so that work in the original channel may be carried out in the dry. New channels may be constructed adjacent to existing watercourses to act as overflow channels to safely contain high flows and help prevent erosion or overtopping in the original channel. New channels are sometimes constructed to provide controlled conditions for agriculture and fish enhancement strategies. Hydroelectric projects often require diversions and new channels.

Extensive manipulation of natural watercourses can cause very serious and costly problems due to unforeseen circumstances even if carried out properly. In many instances alternatives to diversions can accomplish the same objective, avoiding major disruption of natural channels. The provision of undeveloped buffer strips on watercourses, overflow channels, and storm water detention facilities, can provide beneficial, convenient, low cost and environmentally satisfactory results, especially in urban areas. For these reasons proposed alterations to watercourses should be properly justified.

It has been demonstrated in the past that inappropriate and shortsighted planning often results in improper and sometimes unnecessary alterations to natural watercourses. This has been displayed most noticeably in areas where extensive "channelization" has resulted in the total removal of the stream side vegetation and natural channel bed and bank material. Serious long term problems in bank and bed erosion, downstream deposition and costly maintenance are but a few of the problems associated with such work. Such watercourses are virtually lost as a natural resource and are unsightly. When properly protected and maintained watercourses in both rural and urban settings are a valuable resource and an amenity in providing storm water control, and attractive and useful space for leisure or recreational activity

7.1.1 Regulations and Regulatory Bodies

Diversions and major watercourse alterations are regulated under provincial legislation. Federal and municipal statutes and regulations also apply in most situations.

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The Province has the mandate to protect all water resources from potential impact such as pollution, changes to domestic, municipal or industrial water supplies, flooding, aesthetic damages, changes in the flow regime, impact to wildlife, or any other alteration. Prior written approval must be obtained from the Department for diversions and watercourse alterations because of the potential to adversely affect water resources or the environment in general. In addition to this, the Department of Fisheries and Oceans retains direct management of fisheries and, accordingly, their regulations apply, but only if fish habitat is affected; and the Canadian Coast Guard requires approval of all construction in navigable waters under the *Navigable Waters Protection Act*.

A certificate of environmental approval for watercourse alterations includes terms and conditions which are binding on the proponent and any persons working for the proponent. An application for approval must be completed by the proponent or the proponent's agent or consultant and submitted to the Department.

7.2 Planning

7.2.1 Alternatives to Watercourse Alterations

Before a decision is made by a proponent to seek approval for any alteration of a watercourse, other possible alternatives should be examined which would mitigate environmental impact and maintain the features of the natural watercourse. Existing bodies of water within a proposed development area should be included in the overall development concept and adequate protection provided.

Flood protection may be provided on watercourses without substantially altering existing channels. The preferred approach is the construction of elevated banks or levees set well back from the existing channel which would provide an outer channel or flood plain to safely hold and convey flood water during times of very high flow conditions.

7.2.2 Ensure proper Channels are Provided for All Flow

A watercourse should not be diverted into an undefined channel. The flow must be diverted into a properly designed and constructed channel which has been adequately stabilized. Diverted streams not confined within a proper channel can cause serious erosion and siltation downstream.

7.2.3 Maintain Watercourse Through Existing Property

The relocation of watercourses outside existing property boundaries to provide more easily developed land, accommodate development of property, or other such purposes, is not considered a proper environmental approach. Watercourses passing through a property must be maintained through that property and not rerouted so as to cause any adverse effects on adjacent properties.

7.3 Design of New Channels

7.3.1 General

It is important that new channels be properly designed according to established engineering principles. The hydrologic and hydraulic design parameters must be based on the physical geographic features of that particular drainage basin. The climatic conditions, geology and drainage basin features will determine such factors as quantity of flow, peak water levels, discharge patterns, ice formation, etc. These factors will then determine what specific channel dimensions and features will be required to provide a stable channel which can safely accommodate predicted flow conditions from that drainage area. The completed channel must also adequately address aesthetic and ecological concerns in reinstating fish habitat, vegetation, and features which blend attractively with the surroundings.

Where a simple diversion is proposed which involves the rerouting of a section of a watercourse, extensive hydrologic design may not be necessary. In such cases, the hydraulic design must at least ensure that capacity equivalent to or greater than the capacity of the original channel is provided.

Tributaries that feed into the original channel must be made to tie into the new channel. The same design and construction procedures used for the diversion must also be used for altering these tributaries.

7.3.2 Capacity of New Channels (Hydrologic Design Criteria)

The term "return period" is used to indicate the 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 in 100 years. The return period for a diversion is often determined in conjunction with other related works that are being undertaken. A diversion as part of a dam construction, for instance, must be designed to the same return period as the dam to be able to handle the design outflow from the dam. If there are no significant works associated with the diversion, the designer should use his discretion in determining the appropriate return period. A 100 year return period should be used as the hydrologic design criteria of a diversion unless there is a valid reason for using a lesser return period.

In general, this hydrologic design criteria means that the channel must be able to safely convey the flood flow without overtopping. The selected return period must take into account possible damages to adjacent properties and environmental consequences of overtopping of the channel. An economic analysis or cost-benefit analysis should be considered in determining the most economical design of diversions.

New channels should provide adequate capacity to safely discharge the design flow. In determining the channel capacity the drainage basin should be examined in regard to land use zoning and plans for future development of land within the basin. Adequate capacity should be provided to safely accommodate future flow conditions, as land development often results in increased volumes of storm water and higher stage of flow within natural or existing channels.

7.3.3 Specified Channel Dimensions

New channels should be designed and built to predetermined dimensions which specify the following:

- Bottom width
- Depth of channel
- Bank slope
- Flow area
- Bed slope
- Freeboard

A new channel need not be uniform throughout its length. In fact it is desirable to recreate natural channel variabilities, if possible. The performance of a channel can be determined using Manning's Equation if the channel is uniform. Channels with variable dimensions should be modelled using an appropriate computer model such as HEC-2 or HEC-RAS.

7.3.4 Specified Channel Features

New channels should be designed and constructed with specific features that address hydraulic, aesthetic considerations, and where applicable, fish habitat requirements. These may include but are not limited to the following:

- channel banks and bed with a compacted substratum
- lower channel banks stabilized with protective rock

- upper banks stabilized and revegetated with topsoil, seeding or sodding and shrubs or trees
- channel bottom of clean coarse gravel
- in-stream rock placement
- pools, falls or riffles, meanders, etc.

7.3.5 Flow Velocity in New Channels

New channels should provide flow velocities which are similar to those that occurred in the original channel. High flow velocity contributes to sediment transport and erosion. If the new channel reduces the velocity, sedimentation will occur and eventually the new channel may become blocked. Alternatively, where low velocities occur in the natural channel, the new channel may be designed to provide higher velocities to reduce the probability of flooding.

7.3.6 Freeboard Required

An adequate freeboard must be provided between the design high water level and the top of the embankments to prevent overtopping. The amount of freeboard to be provided is developed with consideration of the design flow volume, return period, future flow conditions in the channel, and the potential impact of an overtopping on surrounding properties and lands.

7.3.7 Channel Embankment Slope

To ensure adequate stability and prevent slumping of bank materials, the channel embankments should be no steeper than two horizontal to one vertical. Where fine grained or erodible soils are present, bank slopes should not exceed three horizontal to one vertical.

7.3.8 Emulate Existing Flow and Channel Conditions

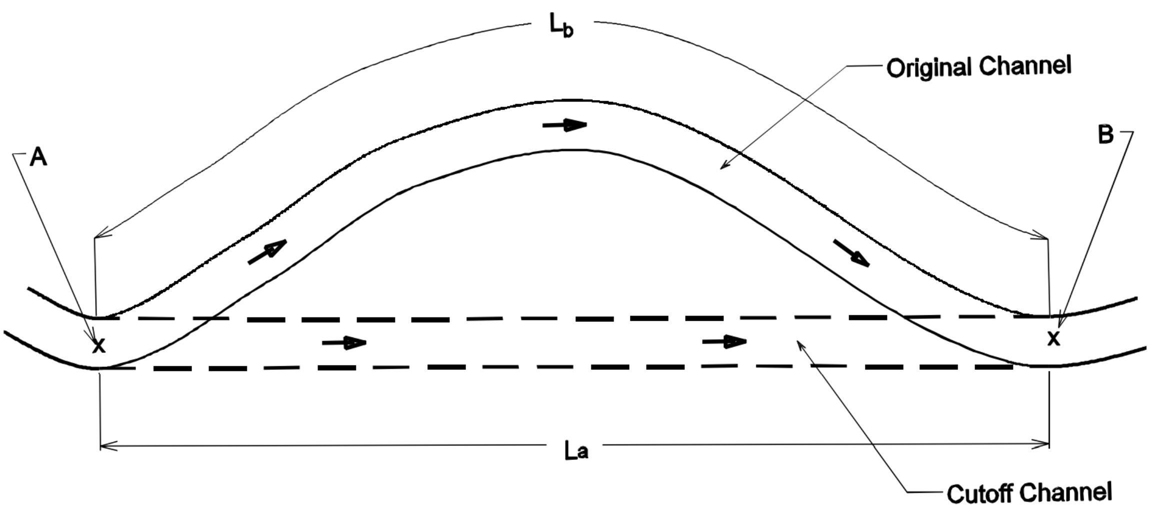
Major channel alterations may disrupt the natural system regime. The effect of these changes may vary from negligible to significant. The time/effect relationship depends on the magnitude, duration and frequency of floods, stream morphology, and the nature or extent of the alteration. When dealing with channel modifications, the preferred procedure is:

- establish the nature of the present regime (slope, section, meander pattern, stage-discharge relationship)
- determine thresholds for changes in the various regime parameters
- duplicate the existing regime, where possible, or keep within the established tolerances for change, where duplication is not practical or possible.

In short, the discharge and velocity at either end of the diversion should be the same as that of the old channel at the same locations.

7.3.9 Channel Length and Storage Capacity

Channel realignment or diversion should result in no net loss of channel storage capacity or channel length. The new alignment or new channel should provide equivalent or greater storage capacity and channel length, as existed in the original channel. "Cut off" channels or straight line diversions have a shorter length than the original channel resulting in loss of storage capacity and increased flow velocities as well as larger volumes of flow in downstream areas. This can result in destabilization of banks or overtopping and flooding in downstream areas (See **Figure 7.1**).



$$s_a = \frac{(A-B)}{L_a} \qquad s_b = \frac{(A-B)}{L_b}$$

$$s_a > s_b$$

$$v = \frac{1}{n} R^{2/3} s^{1/2}$$ (Manning's)

Therefore: $v_a = v_b$

Figure 7.1 Cutoff channels cause increase in velocity and downstream problems.

7.3.10 Channel Gradient

Stream realignment or diversions, and especially cut off channels always increase the channel gradient. This may induce channel responses which can create problems upstream and downstream of the project. A cut off channel usually results in abrupt changes in the channel slope which can cause erosion and degradation of the upstream channel section and aggradation downstream. This increase in gradient will also tend to increase the flow velocity, further contributing to the problems of degradation and aggradation.

7.3.11 Meandering Channel

New channels should be designed with a meandering pattern which would simulate or reinstate the original channel as opposed to a straight channel. This provides a more beneficial flow regime of convergence and divergence which more closely emulates natural watercourses, facilitates the development of pools and riffles and increases aesthetic quality.

7.4 Erosion Control, Stabilization, and Protective Works

New or altered channels usually require appropriate erosion control works to ensure that adequate stability of the channel is maintained.

Channels can be affected by erosion in a number of ways which can cause serious and costly damage to property. Channel bed erosion or "degradation", the undercutting of the toe of channel embankments, or the erosion of the upper portion of channel embankments are common forms of erosion in watercourses. The erosive process, once started, will progress rapidly.

Properly designed and constructed channels which are engineered to resist erosion are necessary, coupled with frequent inspection for early identification of potential problems so that appropriate remedial measures can be taken. The causative factors of an erosive process are usually complex and require detailed examination for effective solutions. "Quick and easy" solutions to such problems are often ineffective or of short duration.

A number of design features and stabilization or erosion control structures are used to ensure channel stability. Stabilization and erosion control in channels should be examined and addressed on a site specific basis.

7.4.1 Low, Non-Erosive Flow Velocities

An important factor to consider in planning a new channel in regard to concern over erosion is providing a low flow velocity which is not capable of eroding the channel bed and bank material. Coarse gravel and cobbles can withstand moderate velocities but exposed fine or light materials require lower velocities to ensure stability.

7.4.2 Channel Linings

New or man-made channels should be designed and constructed with appropriate non-erosive material. In most cases the use of a coarse gravel over a well compacted substratum will provide an adequate channel bed. For steeper channel grades coarser rock may be used which will resist erosion and provide greater channel roughness to reduce flow velocity. The use of concrete, asphalt, gabions, or similar materials for lining channels is not preferred. Such materials usually provide a flow regime inconsistent with that of the natural channel, result in maintenance problems and loss of the ecological amenity of flora and fauna, and are aesthetically inferior.

7.4.3 Channel Banks at Drainage Ditches

Where drainage ditches or streams enter a channel, adequate erosion protection is required. Low approach grades in the ditches or streams are preferred. In-stream rock placement or protective rock may be required to prevent erosion of bank areas where steeper approach grades are present.

7.4.4 Surface Runoff From Adjacent Areas

Where extensive surface runoff is likely to enter the channel, the runoff should be confined and allowed to enter the channel through properly protected drainage ditches. Other means such as rip rapped bank sections or half-culvert sections can be used to prevent erosion or slumping of the channel embankment.

7.4.5 Protective Rock at Toe of Channel Embankments

Protective rock should be installed at the toe of channel embankments to prevent undercutting of the embankments and erosion due to rapid or high flows. The size of rock used will be dependent upon the velocity and direction of flow in relation to the bank, the flow stage, and volumes of flow anticipated in the watercourse. The size of rock used will vary from "one-man-stones" to armour stone.

7.4.6 Armour Stone

Where the potential exists for bank erosion, particularly where flow is directed toward an embankment, velocity and stage are high, and erodible bank material is present, large rocks should be installed which will safely resist erosion. These rocks should be set into the bed and bank material so as to resist undermining. The rocks should also be leaned into the bank at an inclination of at least 1/6 from the vertical axis to ensure stability.

7.4.7 Gabions

Where gabions are used for stabilization of channel embankments the structures should be installed according to the manufacturer's specifications. The structures should be set on a solid foundation, adequately anchored and leaned into the embankment at an inclination of at least one horizontal to six vertical, to ensure stability. The structures should be surfaced with soil and revegetated.

7.4.8 Deep-Rooted Plants

Deep-rooted type plants such as trees and shrubs should be planted along channel embankments to provide stability for the channel, shade for water temperature control, ecological value, and aesthetic value in creating an attractive watercourse. Willow and alder are fast growing plants, which develop substantial root systems, helping to prevent slumping of embankments. Alder is also a nitrogen fixing plant which makes it a good starter shrub for other plant succession. See *Chapter 11, "Restoration and Stabilization"*.

7.4.9 Seeding, Hydro-Seeding and Sodding

The upper section of channel embankments should be stabilized with fine rooted plants such as grasses and clovers to bind the topsoil and prevent surface rutting and deposition in the watercourse. Details on the application and use of seeding, hydro-seeding, and sodding are provided in *Chapter 11, "Restoration and Stabilization*".

7.4.10 Rock Filled Timber Cribs

The use of rock-filled timber cribs or timber retaining walls for channel bank stabilization is not recommended as these structures contribute to watercourse siltation and deposition, and do not provide long term stability.

7.5 Construction Procedures

The construction of new channels, diversions and major alterations to bodies of water has the potential to cause environmental damage and create serious problems in siltation, pollution, erosion and deposition. Many of these problems occur during the construction phase of the work and are often the result of inappropriate construction procedures. These problems can be mitigated or prevented by following preferred construction procedures and techniques. Further detailed information on construction practices is presented in *Chapter 10, "General Construction Practices"*.

7.5.1 Heavy Equipment

The use of heavy equipment in streams or bodies of water is generally not permitted. The operation of heavy equipment should be confined to dry, stable areas.

7.5.2 Excavate in the Dry from the Downstream End

New channels should be excavated in the dry, beginning at the downstream end and working in the upstream direction to the point of diversion.

7.5.3 Maintain Upstream and Downstream Cofferdams

Upstream and downstream cofferdams should be maintained during construction to prevent flow from entering the new channel under construction and to prevent silted water from entering the watercourse downstream.

7.5.4 Prevent Water from Entering the Channel Under Construction

Small drainage courses and surface runoff should be intercepted and diverted around the construction area by such means as pumping or temporary culverting, to allow construction to take place in the dry.

7.5.5 Control of Stream Flow for Culvert Placement

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"*.

7.5.6 Divert Flow After All Work is Complete

Flow should be diverted into the new channel only after all excavation, lining, and bank stabilization work has been completed. Flow should be introduced into the new channel gradually and the channel should be monitored visually for any indications of failure, excessive siltation or other problems.

Care should be taken when diverting flow from the old channel that any fish that are stranded be relocated to the new channel.

7.5.7 Closure of Old Channel

Where flow is completely and permanently diverted from an old channel to a new channel, the old channel should be completely closed to all flow of water. The fill material or structure diverting flows into the new channel should be adequately constructed and protected to prevent erosion or washout and an adequate freeboard be provided to prevent overtopping of the structure.

The old channel should be backfilled with good quality fill, compacted and provided with a vegetative cover to prevent erosion.

7.6 Inspection and Maintenance

7.6.1 Frequent Inspections

Diversions, new channels and reconstructed channels require frequent inspection to ensure they are performing satisfactorily. Subsequent to visual monitoring of the initial introduction of flow into the channel, frequent spot checks should be carried out to ensure that the stability of the channel bed and bank is such that erosion is prevented.

7.6.2 Annual Inspections

Annual inspections should be carried out after the spring runoff or after the major peak flow in the channel during that year, to determine:

- if the channel is functioning properly;
- if erosion is being adequately prevented in all areas; and
- where maintenance may be required.

7.6.3 Comprehensive Inspections to Verify Design Parameters

A comprehensive inspection should be carried out during the first major high flow event to determine if flow characteristics are according to design, with particular regard to flow velocity, stage, flow direction, etc.

7.6.4 Regular Maintenance

Regular maintenance such as removal of debris in the channel should be carried out to ensure there is no flow blockage or constriction which could cause erosion or washout. Debris removal should be carried out by hand to prevent destabilization of the channel.

7.6.5 Area Vulnerable to Erosion

Any bank sections which have become exposed and appear vulnerable to erosion should be immediately protected in an appropriate manner so as to prevent or arrest the erosive process before further damage to the channel can occur.