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QUINTE CONSERVATION BRIDGE AND CULVERT DESIGN GUIDELINES

**Approved by the Board of Directors
Motion QC 70/09**

This guideline is a living document. It is date stamped and will be updated and posted on the Authority web site when alterations are made to reflect changes and innovations that are occurring in the engineering community. Users of this document are advised to always check our website (www.quinteconservation.ca) for the latest version.

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INTRODUCTION

Quinte Conservation, under the Conservation Authorities Act, reviews applications pertaining to bridge and culvert replacements and new road watercourse crossings, and issues permits to commence the proposed work. Previous technical reviews of permit applications have highlighted the need to create guidelines to provide engineering consultants and municipalities with a clear understanding of the submission requirements. By creating the guidelines, the permit approval process will be expedited and consultants can have clarity in their scope of work at the start of the project.

In addition to a permit from Quinte Conservation, bridge and culvert replacements may require approval from Transport Canada and Ministry of Natural Resources.

The guidelines were developed to provide a fair, reasonable and consistent submission requirement to any bridge or culvert replacement permit. The guidelines will present policies specific to Quinte Conservation (QC), summarize typical application information required for QC technical review and outline examples of approved methods to be applied to any technical analysis. The guidelines have been based partly on the following documents:

- Conservation Authorities Act R.S.O. 1990 (CAA);
- Provincial Policy Statement (2005) – issued under Section 3 of the Planning Act;
- Natural Channel Systems: Adaptive Management of Stream Corridors in Ontario, including Natural Hazards Technical Guides for River and Stream Systems: Flooding Hazard Limit, Erosion Hazard Limit and Hazardous Sites Technical Guides (MNR 2002);
- Natural Hazards Technical Guides for River and Stream Systems: Flooding Hazard Limit, Erosion Hazard Limit and Hazardous Sites Technical Guides (MNR 2002);
- Great Lakes – St. Lawrence River System and Large Inland Lakes Technical Guides for Flooding, Erosion and Dynamic Beaches in support of Natural Hazards Policies 3.1 of the Provincial Policy Statement (MNR 2002).

Design Standards

The Ontario Ministry of Natural Resources provides the design guidance for impacts on flooding by bridges and culverts in their Technical Guide, River & Stream Systems: Flooding Hazard Limit, 2002. Section 4.2 states that “bridges and culverts are primarily designed based on economic consideration”. Impacts on upstream flooding must be understood and if “backwater effects caused by the structure ... result in unacceptable conditions the culvert should be replaced, or alternatively, where feasible, the two zone concept should be introduced”.

Section 6 contains the design standards for structures. It states, “waterway openings for culverts, bridge crossings and other drainage facilities for provincial highways should be designed in accordance with the pertinent policies and guidelines established by the Ministry of Transportation. Commonly used flood frequencies for sizing bridges, culverts, storm drainage systems and related stream channels are shown in Table B-3. Municipal and private stream crossings should also be designed to similar criteria”.

Table B-3 is the same as Directive B-100 from the MTO Guidelines.

Downstream floodlines should not make allowance for the temporary ponding and peak flow reduction introduced by the structure.

Therefore, the design guideline for bridge/culvert replacement is Table B-3 (or MTO's Directive B-100). This table takes into account the economic considerations of the crossing by provision of a higher flow capacity for larger opening size and significance of road classification. If the crossing design results in unacceptable increase in flood risk, then a change in design or adoption of special policy can be considered.

The guidelines do not define "unacceptable conditions", but an earlier version of the technical guidelines stated more clearly what is intended here:

"If a drainage facility designed to the criteria specified in the table would increase flooding of buildings or developable land during Regulatory Flood, the facility shall be designed to the Regulatory Flood Criteria, unless otherwise approved. The overall benefit (tangible and intangible) of designing to the Regulatory Flood shall be commensurate with the additional cost of the facility, and the proposal should be discussed with the municipality and with the landowners adversely affected".

This introduced the principle of increasing the crossing design if buildings or developable lands would be adversely affected by the proposed crossing improvement during a flood event.

Definition of buildings and developable land was included:

"For the purposes of these criteria, buildings are defined as residential, commercial, institutional or industrial buildings or buildings of comparable value. Developable land is defined as land on which there is a high probability that buildings will be constructed within 20 years of design of the facility."

Quinte Conservation interprets developable land to mean land that is currently designated in an Official Plan for development.

Should the proposed infrastructure replacement result in infrequent, short-term inundation on lands that are not slated for development there would be no need to exceed the Table B-3 (Directive B-100) guideline.

In summary, Quinte Conservation will undertake our review of bridge and culvert replacement projects using the provincial guidelines. Further design requirements are contained below

TECHNICAL REQUIREMENTS

When QC technical staff are reviewing a submission for a bridge/culvert replacement or a new road crossing, there are two primary constraints that need to be met to be approved. The first is that the **new structure will not cause an increase in flood risk** to buildings or developable land. The second constraint is that the new structure **will not cause degradation to the watercourse, adjacent wetland and/or fish habitat.**

FLOOD RISK

The replacement of an existing structure with a new bridge/culvert or the construction of a new conveyance structure has the potential of changing how flows are conveyed through the road crossing and alter the depth and extent of flooding in the vicinity of the crossing during flood flows. An increased flood depth could cause existing structures and/or property to be flooded that were never flooded before the proposed work was completed or exacerbate existing flooding conditions.

Furthermore, during a flood event, it may no longer be safe for vehicles and pedestrians to pass over the road crossing during a flood event with the new structure in place.

QC staff will not approve a bridge or culvert replacement or a new road crossing that results in an increase in flood risk to:

1. persons,
2. buildings, and
3. developable lands.

The above three points will be collectively referred to as the design constraints.

For proposed work that results only in an increase in the extent of flooding on undeveloped lands, the work can be approved provided that all affected parties agree to the increased inundation. This is typically achieved via a letter that explicitly outlines the flooding implications caused by the new crossing and is signed by all affected parties.

Reducing flood risk and depth/velocity of flow over the road is encouraged by the Conservation Authority, where possible.

Bridge to Bridge and Culvert to Culvert Replacement

Replacing a bridge with a new bridge or a culvert with a new culvert is generally the simplest type of submission. Generally, if the overall dimensions of the bridge are maintained, the soffit (low chord) elevation is matched, the road profile is the same, and the entrance configuration (i.e. headwall, projecting, etc.) is the same or hydraulically more efficient than the scope of work required to meet the submission requirements can be reduced. Generally, bridge or culvert hydraulic calculations will be sufficient.

If the new bridge or culvert design deviates from the existing bridge or culvert with respect to dimensions, soffit elevation or road profile, hydrologic and hydraulic analyses will be required to demonstrate that the new bridge meets the design constraints.

Bridge to Culvert Replacement

Typically, there exists a short-term financial incentive to replace a bridge with a culvert(s) as culverts are less expensive from both a material and installation cost perspectives. However, replacing bridges with culverts can introduce flow conveyance issues causing increased flood risk or stream morphology changes.

Matching the proposed culvert end area with the existing bridge end area is not an acceptable means to demonstrate that the culverts meet the constraints. Head losses are typically much greater with culverts than with bridges and the flow end area is vertically distributed differently as compared to the bridge.

Hydrologic and hydraulic analyses will be required for any bridge to culvert replacement.

HYDRAULIC ANALYSIS

From the Conservation Authority's perspective, the purpose of the hydraulic analysis is to demonstrate that the proposed structure meets the design constraints when passing the regulatory

flow (100-year return period). However, the Conservation Authority also recommends that the hydraulic analysis demonstrates that the structure replacement adheres to the MTO's B-100 directive (1980).

Engineering judgment is required to determine the appropriate methods employed in a given application. However, the following is a list of methods that are acceptable to the Conservation Authority.

- The latest version of HEC-RAS,
- Culvert Master or other culvert design software, and
- Design charts found in the MTO Drainage Management Manual (1997) or design charts found in the MTC Drainage Manual (1986).

Other methods may be accepted provided that it can be demonstrated that culvert and/or bridge hydraulic theory is followed.

Manning's equation is not an acceptable method since entrance/exit head losses and pressure flow are not adequately accounted for in the method except for bridge flow where there is no contact with the soffit.

The hydraulic analysis needs to determine if the structure is inlet or outlet controlled. If the structure is under outlet control, an appropriate hydraulic technique must be used to determine an applicable tailwater elevation at the design flow. The tailwater elevation will need to be accounted for in the design calculations.

Flow depth over the road during the 100-year event needs to be determined, if applicable. The above-mentioned MTO Drainage Management Manuals provide methods to calculate flow depth over a road. HEC-RAS is also a suitable method to determine flow depth over the road. Other methods may be accepted.

HYDROLOGIC ANALYSIS

A hydrologic analysis is required to determine the return period peak flows that would occur at the subject road crossing.

For gauged watersheds, peak flows may be determined by flood frequency analysis provided that the duration of the flow data record is sufficiently long and that the gauge is reasonably close to the road crossing. The Ministry of Natural Resources' "Flood Plain Management in Ontario : Technical Guidelines" and "Hydrology of Floods in Canada: A Guide to Planning and Design" (1989) by the National Research Council Canada provides guidance in the use of flood frequency analysis in determining peak flows.

Extracting data from an already approved calibrated hydrologic model is another means to determine peak flows.

For ungauged watersheds or for gauged watersheds that have insufficient flow data to conduct a flood frequency analysis, peak flows should be determined by at least three different methods. This is in an effort to reduce the inherent uncertainty in determining peak flows for a watershed using only one method. The results from the various methods should have a reasonable level of

agreement commensurate to the application or a discussion explaining the deviations in the results should be provided.

Table 1 below provides some examples of various methods to calculate peak flows and the associated references. Please note that the consultant is not restricted to the methods listed in Table 1. Other methods may be acceptable but will be reviewed on a per application basis. Care should be taken in applying any particular method by ensuring that the application meets any limitations imposed on the method. A typical limitation is the drainage area of the watershed.

TABLE 1: SUMMARY OF HYDROLOGIC METHODS

Method	Reference
Regional Frequency Analysis (Regression Method)	MNR Flood Plain Management in Ontario : Technical Guidelines (Appendix 4)
Regional Frequency Analysis (Index Flood Method)	MNR Flood Plain Management in Ontario : Technical Guidelines (Appendix 5)
Rational Method	MTO Drainage Management Manual (1997)
Regional Frequency Analysis (Modified Index Flood Method)	MTO Drainage Management Manual (1997)
Hydrograph Methods	MTO Drainage Management Manual (1997)
Hydrograph Simulation Model – Single Event	Various
Hydrograph Simulation Model –Continuous	Various
Completed Subwatershed/Watershed Studies	Various

Pre-consultation meetings are encouraged to discuss the proposed methods of conducting the hydrologic analysis.

WATERCOURSE, WETLAND AND/OR FISH PASSAGE DEGRADATION

Bridges and culverts can cause increased scour to occur in the watercourse, erosion of the road embankment, degradation of fish habitat and blockage of fish passage if poorly designed and constructed. Submissions need to adequately address which of these issues apply to the proposed road crossing and clearly provide mitigation measures. The MTO Drainage Management Manual (1997) provides guidance on how to incorporate mitigation measures into the design of the bridge or culvert(s).

Consultants are encouraged to have a pre-consultation meeting to discuss whether or not fish passage and habitat are a concern with the subject road crossing.

SUBMISSION REQUIREMENTS

Technical reports are to be prepared such that the entire work can be recreated by any qualified person without the need to refer to any additional material. Further, any qualified person must be able to recognize and understand all of the methods, approaches, basic data, and rationale used in the calculations.

A printed copy of the Design Report must be submitted with each development proposal. The report must be signed and sealed by a Professional Engineer of Ontario and meet, as a minimum, the submission requirements outlined below.

With the exception of copy written or proprietary models, equations should be given for all provided calculations. Calculations are to be provided in at least paper form. All formulas and values used by the program must be clearly identified on the paper copy.

QC must be circulated a complete set of drawings outlining all of the proposed works. Engineering plans and drawings must be signed and sealed by a Professional Engineer registered with the Association of Professional Engineers of Ontario.

The engineering drawings should clearly show or note:

- the soffit elevation, invert elevation, and dimensions of the existing and proposed structure,
- existing and proposed road profile,
- revetment materials,
- the dewatering and flow diversion plan (can be provided by the contractor),
- the proposed construction sequence (can be provided by the contractor), and,
- erosion and sediment control measures (can be provided by the contractor).