Local Road Bridge Design Guidelines

Version 1.0

Bridge Engineering Section
Technical Standards Branch
Alberta Transportation

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Foreword

These guidelines cover all aspects of bridge engineering for local road bridge projects. These guidelines apply to all bridges (including bridge size culverts) on public roads that are not part of the provincial highway system.

Although this document is intended to be thorough, certain cases may arise where specific guidance is not provided or not applicable. Those working on these projects must exercise good engineering judgment in the application of these guidelines. As stated in section 1.1, these guidelines form a recommended practice, but are not intended to restrict optimal and innovative solutions.

Any feedback or technical clarification requests relating to this document should be directed to the Director, Bridge Engineering Section, Technical Standards Branch, Alberta Transportation.

Approved:

D Williamson

Date: 2014.5.8

Des Williamson
Director, Bridge Engineering Section
Technical Standards Branch
Alberta Transportation

Moh Lali

Date: MAY 9/14

Moh Lali
Executive Director,
Technical Standards Branch
Alberta Transportation

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1 Introduction

1.1 Overview

As guidelines, the information in this document is intended to represent a recommended practice. This practice should result in value, consistency, and efficiency in the process, and confidence on the part of the infrastructure manager. However, all possible scenarios and options cannot be covered in a set of guidelines, and the intent is not to stifle innovative solutions. The infrastructure manager can make judgments on deviations from these practices, where appropriate. Alberta Transportation is available to provide technical advice on these judgments. Any deviations should be documented to defend decisions that have been made.

1.2 Roles in Project Delivery

According to the Municipal Government Act, local road bridges are under the direction, control, and management of the municipality. It is the responsibility of the municipality to follow these guidelines, and all contact for consultants on local road bridge projects should be with the project administrator (municipal staff or representative). Alberta Transportation provides technical support to municipalities in the delivery of local road bridges, including development and update of standards and guidelines. Alberta Transportation also supports the use of the Bridge Inspection and Maintenance (BIM) System, which is a requirement for all public local road bridge structures. The municipality is responsible for delivery of inventory and inspection data to the system.

1.3 Bridge Design Process

The need for work activities on a bridge structure is typically triggered by a bridge inspection or an external incident (flood, slide, collision…). Identification of the appropriate work activity is done by assessing and evaluating all strategic options for the crossing, including repair, rehabilitation, replacement, and restricted use. In some cases, budgets will impact the selection of a strategy. If bridge replacement is selected, the bridge design process can be initiated. Appropriate engineering effort at the design stage can result in significant cost savings in construction and operation of a bridge. The typical major components of the bridge design process are as follows:

- Conceptual design - find the most suitable solution for a roadway to cross a stream or road (or other facility). This solution will include crossing

location, type, opening size, roadway alignment and profile, and protection works.
- Detailed design – structural analysis, component selection and sizing, and development of detailed drawings, documents, and specifications to completely define all project requirements for the tendering process. The initial phase typically involves assessment of span arrangements and material types, with decisions made before proceeding with detailed drawing and tender preparation. Predicted service life should be considered in this decision.
- Construction Quality Assurance – monitor fabrication and construction activities to ensure compliance with contract requirements and record the final details of the structure.

1.4 Delivery Method

Several methods are available for delivering a new bridge or bridge replacement. Selection of the delivery method is up to the infrastructure manager. The most common option on Alberta Transportation bridge construction projects is 'Design-Bid-Build'. This method involves preparation of detailed tender documents for the client followed by an open bidding process and contract management. This approach relies on market competition for pricing and allows for more control and certainty on the details of the final product.

Another approach is referred to as 'Design-Build'. Alberta Transportation has limited experience with this approach. This method involves undertaking the conceptual design (plus a portion of detailed design) and preparing technical requirements documentation. This is followed by a bidding process which may involve contractor qualification (not open to all bidders). The contractor will complete the design and deliver the project. Potential advantages of this approach include the increased opportunity for value added by the contractor, and possibly a compressed schedule for complex projects. Potential disadvantages include less certainty and control over the final product. Resource companies have commonly used this type of approach for bridges on private roads. Alberta Transportation has used a variation of this method, the Design-Build-Finance-Operate model, in delivery of portions of the ring roads near Edmonton and Calgary. This approach is typically viewed as only being applicable to very large and expensive projects.

Another approach that has been used previously for delivery of local road bridges is the use of a bridge crew staff and equipment that work directly for the municipality. Some specialized actions may require sub-contractors. This approach may require less contract preparation effort. This may be an attractive option for relatively simple projects (standard bridges and culverts) for municipalities who have invested in equipment and have staff with related experience. Detailed record keeping would still be required to facilitate future decisions on the structure during its life cycle.

1.5 Reference Documents

This document contains some guidelines specific to local road bridges. However, many of the engineering requirements are in common with requirements for provincial highway bridges. Portions of the following documents will still be of value on most local road bridge projects, with overrides as specified in this document.

- Alberta Transportation ***'Bridge Conceptual Design Guidelines'*** (***BCDG***) - this document applies to the conceptual design phase. It includes guidelines for hydrotechnical design, bridge opening geometry, and road geometric requirements.
- Alberta Transportation ***'Highway Geometric Design Guide'*** (***HGDG***) – this document provides road geometric design parameters, such as curve radii and vertical curve 'K' values, for a given design speed. These parameters are often very important components of the bridge conceptual design.
- The current version of the Canadian Standards Association (CSA) ***'Canadian Highway Bridge Design Code'*** (***CHBDC***) - this document details design load and structural analysis requirements for bridge projects.
- Alberta Transportation ***'Bridge Structures Design Criteria'*** (***BSDC***) – this document provides some additional structural constraints to those specified in the ***CHBDC***. One key aspect is the use of the CL800 design truck, which exceeds the basic design truck weight in the CHBDC.
- Alberta Transportation ***'Design Guidelines for Bridge Size Culverts'*** (***DGBSC***) – this document provides additional structural detail constraints to those specified in the ***CHBDC***. An example is the requirement for burial and the design life (specified at 50 years, rather than the 75 year requirement in ***CHBDC***).
- Alberta Transportation has developed *Standard Drawings* for corrugated steel culverts and precast concrete girder bridges. Additional standard drawings are in development for cost effective bridges with mostly pre-fabricated components for use on local roads. Standard drawings reduce duplication of design effort for common solutions and increase consistency across the system.
- Alberta Transportation ***'Standard Specifications for Bridge Construction'*** (***SSBC***) – this document contains quality control specifications for use in the delivery of bridge construction projects.
- Alberta Transportation '*Bridge Construction Inspector Manual*' (***BCIM***) – this document provides detailed guidance for monitoring and reporting on bridge construction activities.

- Alberta Transportation '*Engineering Consulting Guidelines for Highway, Bridge and Water Projects Vol. 1*' (***ECGv1***) – consultant requirements for project design and tender document preparation.
- Alberta Transportation '*Engineering Consulting Guidelines for Highway, Bridge and Water Projects Vol. 2*' (***ECGv2***) – consultant requirements for contract administration.

1.6 Design Team Qualifications

Engineering activities in Alberta are governed by the *Engineering and Geoscience Professions Act*. Clause 2(1) of 'Part 1 – Scope of Practice' requires that certified professionals only shall engage in the practice of engineering. Clause 2(4)(e) allows for an exemption if the work is for the sole use of an individual on his property, and public safety is not involved. This is clearly not the case for local roads. Therefore, certified professionals (Association of Professional Engineers and Geoscientists of Alberta (APEGA) or Alberta Society of Engineering Technologists (ASET)) with appropriate scope of practice are required for design of local road bridges. These professionals may belong to the staff of the municipality or work as a consultant/contractor. Additional qualifications may apply for meeting regulatory requirements (e.g. Qualified Aquatic Environmental Specialist as specified in the Alberta *Water Act*).

1.7 Regulatory Requirements

In addition to these guidelines, stream crossings may also be subject to requirements under other legislation. These may include the Fisheries Act (Department of Fisheries and Oceans, DFO), the Navigation Protection Act (Transport Canada), the Water Act (Alberta Environment and Sustainable Resource Development, AESRD), and the Public Lands Act (AESRD).

As of Apr. 1, 2014, all proponents have the option to opt out of the Navigation Protection Act for crossings on 'non-scheduled" streams. In Alberta, this is the vast majority of stream crossings. Alberta Transportation has exercised this option. The only known crossings managed by rural municipalities are one over the Bow River and two over the Athabasca River.

If a municipality elects to opt out of the Navigation Protection Act, approvals from Transport Canada will no longer be required for most local road bridge projects. In order to provide a reasonable level of protection from civil law suits for interference to navigation, Alberta Transportation has developed a practice for assessing potential navigation impact at a site. This practice includes a map of known navigation use within the province. It is recommended that municipalities follow this practice. In most cases, it is not anticipated that a structure that meets these guidelines will result in an obstruction to navigated use of streams.

TRANS have also been working with DFO to establish a framework for handling projects while meeting the requirements of the Fisheries Act. A practice will soon be developed and published that provides guidance on when and how to apply for approvals, as well as how to collect the necessary data to make this determination. Guidance on how to incorporate fish passage into culverts is available in section 2.3.4 of the ***BCDG***. Guidance on assessing offsets (compensation for loss of habitat) is also being developed. These practices should provide significant benefit in managing the Fisheries Act requirements of stream crossings for local road bridge projects.

Following the requirements of the *Code of Practice for Watercourse Crossings* means not having to apply for an approval under the Water Act, and only notification prior to construction is required. If the code does not apply (e.g. low level crossings) then a Water Act application is required. The code requirements vary with structure type, class of stream, and timing of construction (relative to the restricted activity period). Public Lands Act approval may also be required if the project requires use of public land outside of the right of way.

2 Specific Guidelines for Local Road Bridges

2.1 Design Speed and Road Geometrics

As per section H.2.3 of the ***HGDG***, un-posted rural roads in Alberta have a legal speed limit of 80 km/hr. However, the design speed for any given portion of a local road can be selected by the infrastructure manager. It is recommended that this be done by assessing a range of options and selecting the optimal solution (see ***BCDG***). The horizontal alignment and road profile are significant components of the overall bridge concept.

For any given design speed, a minimum horizontal curve radius and vertical curve K parameter must be met for safety reasons. The minimum curve radius can be found in ***HGDG*** Table H.3.1. Minimum vertical curve ‘K’ values can be found in ***HGDG*** H-4.3.2a for crest curves, and H-4.3.2c for sag curves.

Bridges can result in additional impacts on road geometry due to preferential icing of a bridge deck and sight distance reduction due to bridge barriers. Guidelines on considering these factors are presented in section 3.2.1 of the ***BCDG*** document.

2.2 Hydrotechnical Design

Alberta Transportation guidelines for determination of design flow parameters for stream crossings are presented in section 2.2 of the ***BCDG*** document. These parameters are intended to represent a flood event, with the channel delivering flow at its full capacity. The ***BCDG*** guidelines also provide guidance on how to size a bridge or culvert opening based on these parameters. This involves an optimization process, considering a range of sizing options and evaluating them based on cost, performance, and other factors. The ***BCDG*** design flow parameters and opening sizing process should be appropriate for use in sizing the opening of a bridge or culvert whether on a local road or a provincial highway. The desired level of hydraulic performance and acceptable risk of damage may vary, however.

For culverts, the range of sizing options may mean a range of diameters, multiple culverts, or different shapes. For bridges, this may mean raising or lowering the gradeline and moving the headslopes in and out. Some of the main factors to consider in selecting the optimal opening size include:

- Project cost (structure, road, protection works)
- Probability and consequence of significant damage to the structure
- Potential flooding impact on upstream developments
- Potential environmental impact (e.g. fish passage)

Openings that constrict the flow (opening smaller than the typical channel) will result in higher mean velocity (V) through the opening (increased erosion potential), higher water levels upstream of the crossing, and an increased risk of drift blockage. Openings that are larger than the typical channel should have no hydrotechnical impact, but may result in increased bank attack and/or deposition of sediment.

In general, the mean velocity (V) of flow in the typical channel at design conditions can be used as an indicator for the relative sensitivity of hydraulic performance to the opening size. If $V < 2$m/s, hydraulic performance will be relatively insensitive to the size of the opening and a constricted opening may be acceptable. If $V > 3$m/s, hydraulic performance will be very sensitive to sizing and a constricted opening may be problematic.

For bridges, if highwater levels exceed the bottom flange of the bridge, there is a risk of damage to the structure (buoyancy, lateral forces from water and drift). For culverts, if highwater levels exceed the upstream crown, there is a risk of uplift failure and piping (loss of soil support adjacent to the barrel). Some of these risks can be mitigated, particularly if $V < 2$m/s. In cases where the consequence of failure are considered to be relatively minor (low traffic volume, alternate access, suspect relatively easy repair), these scenarios (including water over the road) may be acceptable.

2.3 Bridge Width

The basic bridge width for a 2 way local road bridge is 8.5m. This value provides theoretical 0.75m shoulders on each side, is within the ***CHBDC*** code requirements for low volume roadways (note there are other requirements), and should provide sufficient clearance for all but the widest equipment (e.g. seed drill). The closest matching width for an SL girder standard bridge is ~ 9.0m.

Modifications to the basic bridge width can be considered based on traffic volume, design speed, and projected traffic types. The proposed local road bridge standard drawings will be based on a clear roadway width of 8.5m for a two way bridge. Any deviation from this width will preclude the use of these drawings, resulting in a site specific design and associated increase in design effort. The width of a standard SL girder bridge may be adjusted by adding or removing a line of girders.

While the 8.5m wide two way bridge is the recommended solution, a one lane bridge may be a cost effective solution in some cases. One lane bridges have the potential to provide a significant cost savings over a two way bridge. It should be noted, however, that the safety of a one lane bridge is dependent on driver behavior and expectations. This is particularly important in the case of replacing a two way bridge with a one lane bridge. If a one lane bridge is considered, the following recommendations apply:

- The bridge width should be in the range of 5.0m to provide sufficient width for trucks but with a clear visible indication that 2-way traffic is not supported.
- Vehicle speed should be restricted to 50km/hr, and there should be significant visual cues and signage to ensure significant compliance with the posted speed limit. Visual cues may include sharp horizontal curves on the approach road.
- Daily traffic volume should be less than 200vpd if replacing a two way bridge, and less than 400vpd if the existing structure is a one lane bridge. Note that the risk of encountering an oncoming vehicle increases exponentially with increasing traffic volume.

Bridge length should also be considered, as longer bridges increase the potential for encountering an oncoming vehicle, and one vehicle may need to back up to clear the bridge. One lane bridges may also be too restrictive for some equipment (e.g. folded width exceeds bridge width and cannot clear the bridge barriers, ~0.7m high). The comfort level of drivers on a narrow bridge under icy conditions may also be affected.

2.4 Bridge Design Load

The ***BSDC*** specifies a CL-800 design truck for provincial highway bridges, based on the design truck configuration in the ***CHBDC***. The basic design truck in the CHBDC is a lighter CL-625 truck. The CL-800 design has proven to be cost effective in Alberta, considering the volume of permitted overload vehicles on the network. Designing for a reduced loading appears to offer little cost savings, while potentially limiting the use of the structure. It is recommended that all local road bridge structures be designed to ***CHBDC*** load criteria (CL-625), with consideration given to the CL-800 truck.

2.5 Bridge Barriers

The ***CHBDC*** specifies crash tested bridge barrier configurations only. It appears that most available bridge superstructures can be readily configured to test level TL-2, which should meet the needs for all local road bridges. A TL-1 barrier configuration is also available in the ***CHBDC***, and may result in a small cost savings but comes with additional constraints on traffic volume and design speed. It is recommended that all bridge barriers meet the CHBDC criteria (at least TL-1 with consideration given to TL-2).

3 Structure Options

3.1 Structure Types

Bridges and bridge size culverts are common structure types on the local road system. Bridges typically consist of girders that transfer loads to abutments and piers while spanning an area below. Bridges can range from relatively simple standard bridges to complex major bridges with extensive engineering details.

Bridge size culverts typically involve an opening in the road fill with the perimeter made of an engineering material (e.g. corrugated steel, concrete). In the case of corrugated steel, the strength of the structure is highly dependent on interaction with the adjacent compacted soil.

Another potentially cost-effective option for some sites is a low level crossing. These structures typically consist of a battery of relatively small culverts, capped with a concrete deck. Alberta Transportation standard drawings S1614 and S1615 show typical details for these structure types (these drawings may contain limitations on use, which can be considered as guidelines). This type of structure will typically be impassable for a period of time on a somewhat frequent basis (possibly every year), and frequent maintenance can be expected. Due to the low height above streambed, the road geometry will offer a low design speed. These structure types have often not been viewed favourably by environmental regulators. In some cases, it may be a cost effective option (e.g. a relatively wide stream with low traffic volume and relatively short detour length).

3.2 Bridge Superstructure

Alberta Transportation currently has standard drawings for precast concrete girders (type SL). These are available for a range of lengths between 8m and 14m, and for up to 3 spans (S1723 – S1749). The drawings currently cover a number of set skew angles (0, 15, 30, and 40), although other skew values can be used with interpolations of the parameters on these drawings (would result in a site specific girder design). Standard drawings are also available for the SLW type of girder, which is applicable for paved roadways (likely to see road salt application in winter). This type of structure requires cast in place approach slabs.

Several pre-fabricated steel girder bridges have been used in Alberta for oil-field roads and land access roads. Multiple local suppliers are available for these bridge types. Decks options have included precast concrete deck panels and timber. There are additional pre-fabricated bridge options available in industry, including modular structures. Other deck material options (e.g. steel) are also available.

Standard drawings are currently being developed for a structure type that appears to be the most cost effective option for local road bridges. These drawings are proposed to cover a range of span lengths and widths (5.0m and 8.5m). Only square end girder (no skew) and single span (no pier) options are being considered at this time, as most sites can be configured to work with these options with substructure modifications. Designs for other structure types may be considered for any given site, although increased site specific design effort compared to standard designs may be required. Consideration can be given to developing additional standard drawings in the future for options that prove to be cost effective.

3.3 Bridge Substructure

Standard drawings are currently available for several substructure types that are compatible with the SL type girders. These include steel (S1753 – S1756), cast in place concrete (S1762 – S1764), precast concrete (S1765 – S1770), and steel with high backwalls (S1793 – S1796). These options all involve piled foundations. Multiple span options use groups of piles for piers.

Bridge substructure designs often require site specific design elements, including geotechnical investigation and analysis. Abutment support options include piled foundations, spread footings, and geotextile reinforced earth (GRS) systems. The availability of materials and access for equipment should be considered in selection of foundation type.

The proposed standard drawings may include information for piled foundations. Many of the pre-fabricated steel standard type bridges built on resource roads in Alberta have been built on piled substructures. Piled systems provide more certainty against settlement and washout. They can also be designed to meet criteria that can be easily checked during installation, without geotechnical analysis (drive to refusal, pile driving formulae). However, pile driving can be an expensive undertaking, especially in remote areas.

As such, spread footings and other systems should not be excluded. Some of the temporary bridges built as detours in response to recent flood damage have been built on large precast concrete blocks and appear to be quite robust, even though they are intended for a short duration. Spread footings have also been used on forestry roads in BC, although rock foundation conditions are more likely to be present there. In general, if a long-term spread footing option is to be considered, geotechnical analysis is recommended. Footings should also be designed to ensure durability and strength (consider CHBDC requirements).

A higher risk approach may be to not undertake geotechnical analysis and make field adjustments to abutment design during construction, with removal of soft soils that are encountered. This risk may be considered acceptable by some municipalities in certain circumstances. Risks associated with insufficient spread footing design include settlement or sliding of the abutment, with potential failure under non-flood conditions. These systems would obviously be more susceptible to failure under flood conditions as well. Structural failure due to insufficient thickness and reinforcing is also a possibility. The extent of damage and need for repair to the bridge may be relatively low for pre-fabricated bridges, as they could potentially be lifted back up and placed on a re-built abutment if they are not damaged. These risks should be well understood by the infrastructure manager while making the abutment foundation selection.

3.4 Culverts

The most common type of bridge size culvert used in Alberta is a corrugated steel round pipe. This type of culvert is a soil-steel structure, meaning that it relies on the compacted soil surrounding the steel for its strength. The most structurally efficient shape is round, although other shapes are available (e.g. arch, ellipse, box). However, as the span (width) to rise (height) ratio increases, culverts tend to act more like bridges and structural enhancements (such as relieving slabs) may be required. Other culvert materials are also available, such as precast concrete box culverts.

Alberta Transportation standard drawing S1418 is available for corrugated steel round culverts up to 3m in diameter, and is often used as a reference in design of larger culverts. ***CHBDC*** Section 7 (Buried Structures) governs structural design of culverts and ***DGBSC*** provides addresses design details to ensure successful installations. The ***SSBC*** document includes details that will be of value in installation of corrugated steel culverts (section 18) and precast concrete box culverts (section 26) on local road bridge projects.

Although many people have the perception that culverts have limited hydraulic capacity, culverts can often be designed to provide similar hydraulic performance to bridges. In many cases, existing bridges are only bridges because culverts were not considered an option at the time of design. Culverts are more prone to drift blockage than bridges. Culverts are also commonly perceived to be inferior to bridges by many regulators. However, culverts can be designed to accommodate fish passage and minimize impact on fish habitat at many sites.

Most culverts can be configured to avoid the need for bridge barriers, eliminating width restrictions on equipment. Culverts typically also minimize preferential icing due to the insulation provided by the soil cover. Culverts can have issues with hanging outlets, corrosion, piping failure, and bevel end uplift if not designed properly. The design details provided in the ***DGBSC*** document address most of these issues.

4 Deliverables

Details of project deliverables, including engineering reports and drawings, used in the management of Alberta Transportation projects, can be found in section 10 and Appendix J1 of ***ECGv1***. Many of these items will be of value for local road bridge projects also.

In order to support and defend optimal selection of functional items and structure options, a range of options, with pros/cons/risks/costs, should be provided to the infrastructure manager, along with a recommendation. This is typically done in an engineering report.

The extent of contract documents required will vary with the delivery method (section 1.4). For many standard structures, the package typically consists of standard contract documentation including reference to standard specifications, a few site specific drawings, copies of the standard drawings, and site specific special provisions. In the case of small (up to 3m diameter) corrugated steel culverts, a standard "Culvert Design Sheet" is available to use instead of site specific drawings.

Keeping thorough and accurate construction records is of great value in resolving claims, identifying sources of problems, facilitating repair and rehabilitation options during the bridge life cycle, and managing system issues such as identifying structures that use a certain detail or material. Guidelines on construction inspection and record keeping are available in the ***BCIM***. On Alberta Transportation projects, construction inspection data is typically summarized in Final Details reports and record (as-constructed) drawings, as per the ***ECGv2***.

In order to support bridge inspection activities under the Bridge Inspection and Maintenance system, a certain minimum amount of structure inventory data is required to be delivered to Alberta Transportation. This inventory information is required to generate and populate the inspection forms that will be used throughout the life cycle. Much of this information can be extracted from site specific drawings, if available.