Government of Alberta

Transportation

TECHNICAL STANDARDS BRANCH

DESIGN GUIDELINES

FOR

BRIDGE SIZE CULVERTS

Last Revision: April 2012

PREFACE

IMPORTANT NOTE

The information contained in this Document has been compiled for use and guidance on Alberta Transportation projects, to supplement existing design practices. It is intended that the use of these guidelines will help to ensure that safe, consistent and appropriate minimum standards are adopted throughout the Province. It is not intended to be used as a sole source for design, or to be a substitute for engineering design or judgement.

It is the responsibility of those using this information to ensure that it is suitable for their use and to supplement it as necessary. The design of the project must be in accordance with all relevant codes, current engineering practices and specifications. It is the responsibility of the engineer to ensure that all Provincial and Federal permits and licences are obtained and that work is carried out in accordance with the terms and conditions of those permits and licences.

Alberta Transportation assumes no responsibility for errors or omissions and will not accept liability of any nature whatsoever that may be suffered by use of the information contained in this document.

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1.1 INTRODUCTION

The Design Guidelines for Bridge Size Culverts have been developed by Alberta Transportation (AT), and are based on International & National Codes of Practice, Manuals, Technical Books and Papers, etc. A 'best practice' approach has been used to incorporate practical design and construction experience that has been developed by Alberta Transportation and their consultants over the years. It is anticipated that the use of these Guidelines will result in the uniform design and construction of culverts throughout the province of Alberta. It should be noted that subsequent guidelines/design bulletins/best practice guidelines may be published, which would superseded the information presented in this guideline.

Each design topic is presented in three parts:

1) Background: to serve as an introduction to the issue, to review current practices, and to identify any concerns that have been identified.

2) Considerations: a brief summary of the engineering concerns that were reviewed prior to making recommendations are outlined. It is recognized that site specific factors additional to those identified may exist that could affect design recommendations.

3) Recommendations: typically these should be considered a minimum desirable standard. However, it is recognized that for some situations, it may be desirable to reduce (or enhance) a standard.

   Typically requests for modifications to a design standard should be handled in the following manner:

   - The request to modify a guideline must be fully supported by valid reasons, including due regard to public safety, associated risk factors, performance, and economic justification.

   - The request must be fully documented and presented to AT for acceptance as a Design Exception, as per Design Bulletin 72: Design Standards/Practice Exception Request Process.

1.2 CONSTRUCTION (OR 'P') DRAWINGS

Background:

Historically, culverts were installed by in-house Bridge Crews using Culvert Authorizations, with design information being provided in the form of sketches, written instructions, or site specific 'P' drawings. A substantial amount of supplementary design information was also provided on the standard drawing S-1418, "Installation of Large Steel Pipes". Since AT currently outsources culvert design and construction, it is appropriate that the process for handling the design and installation be reviewed.

Considerations:

- Site specific drawings provide an accurate representation of actual conditions (channel slope, geometry, geotechnical conditions, etc.), and can emphasize the size and/or complexity of a structure when required.
- Drawings substantially reduce ambiguities that cannot be clarified easily through written instructions.
- Culverts may be installed by an inexperienced workforce.
- "As constructed" details provide useful records for future maintenance and design.

Recommendations:

- In addition to the current version of standard drawing S-1418 'Installation of Large Metal Pipes', a site specific 'P' drawing(s) should be produced for all bridge size culverts.
- Drawing S1418 is not applicable to bridge culverts of greater than 3000mm diameter.
- All details shown on the 'P' drawing should be to scale.
- Drafting standards and standard details shall be in accordance with Section 2– Guidelines for Bridge Projects of the "Engineering Drafting Guidelines for Highway and Bridge Projects".

http://www.transportation.alberta.ca/2651.htm

(Links to the most frequently used standard drawings have been provided in Section 1.32 of this document).

1.3 RIGHT-OF-WAY AND EASEMENTS

Background:

The department (or owner) can be held responsible for problems whose cause can be attributed to, or associated with, the structure. Construction or maintenance at a culvert site generally results in disturbance of stream banks and/or streambed. As such, there is a tendency for erosion to occur adjacent to a structure. Streams, in general, are considered active features which evolve in time, often time independently of any manmade infrastructure. Such processes include lateral stream mobility, degradation, and bed sediment transport.

Considerations:

- Ensure structure(s) and associated protection works are not on private property.
- Ensure right of way for construction entry and maintenance.
- During design, allow for natural process, such as lateral movement of the watercourse.
- Shape of the right of way should be convenient for surveying and tying-in.
- Future construction such as road widening, or slope improvement.

Recommendations:

- The Responsible Road Authority (MD, County, AT) should provide the right of way or easement required for the structure, associated protection works, and future maintenance. This should be shown on site specific 'P' drawings and/or stated in the written instructions.
- In general, an allowance of approximately 5.0 m should be taken beyond the limits of protection work when establishing the right of way area. The shape of the area should be kept simple and defined by limits that can be conveniently tied into the survey.

1.4 HYDROTECHNICAL DESIGN FLOW

Background:

In order to properly size a bridge culvert, it is necessary to determine the design flow or range of flows that the culvert is expected to operate under.

Considerations:

- Drainage Area
- Channel Geometry
- Historical Information
- Topographic Survey Information
- Basin runoff Potential

- Channel Capacity

Recommendations:

The design flow for bridge size culverts is to be estimated as per the current version of the AT "Hydrotechnical Design Guidelines for Stream Crossings". This document outlines the use of three techniques: Channel Capacity, Historic Highwater Observations, and Basin Runoff Potential in determining hydrotechnical design parameters, namely flow depth (Y), mean channel velocity (V) and flow (Q). This document, and further reference documents, is available at:

http://www.transportation.alberta.ca/2646.htm

1.5 CULVERT SIZING

Background:

Sizing of bridge size culverts based on hydrotechnical design parameters requires consideration of the expected performance, cost, and associated risks of various culvert options under design flow conditions. Fixed rules such as specified amounts of freeboard or degrees of constriction can be easily applied to determine a culvert size but do not necessarily optimize the crossing dimensions or take all of the site specific factors into account.

Considerations:

- Hydrotechnical design parameters
- Cost
- Potential flooding impacts (land use, AADT)
- Fish passage
- End protection works
- Geotechnical conditions (uplift, slope stability)
- Barrel opening blockage (drift, beaver dams, icing)
- Future maintenance/rehabilitation (lining for high traffic roads/high fills)

Recommendations:

The following list can be used to guide the assessment of predicted performance, although not all of these considerations will apply for all sites:

-minimize impact on flood sensitive upstream developments
-headloss through structure should not increase flood impacts under design conditions
-must meet DFO requirements for fish passage
-velocity increases at inlets/outlets may require extensive rock protection (costs)
-downstream scour holes and bank erosion should be minimized

-culvert ends should be checked against hydrostatic uplift failure, often associated with excessive headloss at the inlet; weighted culvert ends or cutoff wall as remediation
-differential head across the road embankment should be limited (to prevent road from acting as a dam) by minimizing the headloss across a structure.
-if ponding/road overtopping is acceptable, impact to nearby landowners and the travelling public should be considered; the roadway should be designed to minimize failure risk.
-if ponding/road overtopping is not acceptable, consider gradeline revision and/or adjusting opening size
- if drift or ice blockage is considered significant, a more generous opening may be considered
- for high fill and high traffic crossings, consideration should be give to allow future lining.

Reference documents can be found within the "Hydrotechnical Reference Documents" folder on AT's website. Reference tools can be found within the "Guide to Bridge Planning Tools" document.

http://www.transportation.alberta.ca/565.htm

1.6 FISH PASSAGE

Background:

The department supports the initiative that culverts on fish bearing streams should be designed to allow for the movement of fish.

Considerations:

- Provincial *Water Act*,
- Federal *Fisheries Act* (DFO requirements),
- Minimizing environmental impact,
- QAES assessment,
- Culvert velocities,
- Culvert embedment (burial depth)

Recommendations:

- Guidance on assessment of fish passage at culverts can be found in the current version of the "Fish Habitat Manual". This document can be found within the Environmental Management folder on AT's website:

  http://www.transportation.alberta.ca/571.htm

- A QAES assessment will typically dictate the requirements of fish passage, in terms of fish type, habitat suitability, and environmental suitability.
- The current practice, at sites where fish passage is not specifically required, involves ensuring stream continuity, which is typically achieved by a proper slope and embedment.
- In some cases, other techniques such as substrate holders, roughness elements, and off-site compensation may need to be considered.
- Fisheries and Oceans Canada (DFO) authorization is required prior to instream construction activity on streams identified as fish bearing.

1.7 BURIAL DEPTH

Background:

Historically, culverts were installed to match the existing streambed elevation, oftentimes with little or no end protection works. With many Alberta streams being classified as "geologically young", the bed of these streams naturally degrade as the stream matures. As well, culvert installation can result in locally increased velocities at the culvert outlet. The combination of these factors has, in the past, led to scour holes, bank erosion and ‘hanging’ or perched outlets developing, resulting in a permanent barrier to upstream fish passage.

Considerations:

- Natural stream maturation (degradation).
- Perched outlets or piping,
- Velocities at the culvert outlet.
- Hydraulic efficiency of culvert,
- Costs.

Recommendations:

Culvert inverts should be buried one quarter of the rise (D/4) below the average natural streambed up to a maximum depth of 1 m. Exceptions to the recommended burial depth may be considered when site specific features require special attention. This may include reducing the burial depth if competent bedrock is encountered.

1.8 SCOUR/EROSION PROTECTION

Background:

At some culvert sites (particularly older ones), erosion protection is not in place resulting in scour and/or erosion issues. These issues can lead to such problems as impeded fish passage, scour holes, piping, and slope failure. Unless remedial measures are taken, the culvert's structural integrity may be compromised, potentially leading to failure.

Considerations:

- Design hydrotechnical parameters,
- Culvert velocities,
- Streambed material and susceptibility to scour/erosion.
- Embankment slopes
- Fish Passage

Recommendations:

- Provide riprap protection on slopes that are trimmed back to no steeper than 2:1.

- Use a non-woven geotextile filter fabric under all riprap in accordance with the following table of minimum average roll value properties (MARVs) for each specific Class of riprap:

Non-woven Geotextile Filter Fabric		
Specifications and Physical Properties		
	Class 1M, 1 and 2	Class3
Grab Strength	650 N	875 N
Elongation (Failure)	50%	50%
Puncture Strength	275 N	550 N
Burst Strength	2.1 MPa	2.7 MPa
Trapezoidal Tear	250 N	350 N
Minimum fabric lap to be 300 mm		

- For culverts with a diameter of less than 3.0 m, the current version of standard drawing S-1418 should be used as a guideline for minimum requirements.

- For culverts with a diameter greater than 3.0 m, an engineering design of the culvert end protection is required.

The following Table should be used to determine the class and thickness of rock riprap required:

Riprap Class	Allowable Local Velocity*	Thickness (mm)
Class 1M	2.0 m/s	300
Class 1	3.0 m/s	450
Class 2	4.0 m/s	800
Class 3	4.6 m/s	1100

* Allowable local velocity = Average velocity at culvert end multiplied by 1.25.

- If allowable local velocities exceed those specified above, a modified Class 3 riprap material, with an appropriately larger D_{50}, should be used.

- Bio-engineering works, such as willow staking, are not recommended in the vicinity of bridge structures.

Refer to the current version of Section 10 "Heavy Rock Riprap" of the "Specifications for Bridge Construction" for additional information regarding minimum thickness and size gradations.

http://www.transportation.alberta.ca/2653.htm

1.9 BACKFILL MATERIAL FOR FLEXIBLE CULVERTS

Background:

Structural integrity of flexible culverts comes from the backfill material placed around the structure and the manner in which it is placed. Structural issues arising in culverts are often the result of unsuitable backfill material (unacceptable gradation, plasticity, moisture content, etc.), poor compaction, or the use of frozen material, all experienced during the construction phase. Structural integrity can also be compromised by such instances as freeze/thaw cycles, piping, and inlet/outlet scour. When selecting a backfill material, it should be recognized that granular material has higher shear strength, compacts more readily, and requires less control or effort to place than clay material.

Considerations:

- Compaction and moisture content,
- Shear strength,
- Bearing strength, settlement, and consolidation,
- Drainage ,
- Potential for frost heave (soil plasticity),

- Temperature during installation.

Recommendations:

Approved granular backfill should be placed around the barrel of all flexible culverts to form a structural backfill envelope along with an approved clay material to form seals. Refer to the current version of the “Specifications for Bridge Construction”, Section 2 ‘Backfill’ and/or the current version of standard drawing S-1418, for the required gradation and quality control for backfill materials.

***Note**: The use of only crushed aggregate material for the backfill envelop may be considered if any of the following conditions exist:*

- *Little or no difference in price between pit run gravel and crushed aggregate,*
- *Quality of locally available pit run is known to be of poor quality,*
- *High cover and/or weak foundation material,*
- *Presence of natural springs in the material above the culvert (can be problematic during freeze/thaw cycles).*
- *Corrosive environment*

1.10 STRUCTURAL BACKFILL ENVELOPE FOR FLEXIBLE CULVERTS

Background:

In addition to using compacted granular fill on a firm foundation, the shape and size of the backfill envelope is a critical factor in ensuring structural integrity of a flexible culvert. The shape shown on the current version of standard drawing S-1418 has performed well under “normal” conditions. Special consideration to the structural envelope must be taken with large diameter (greater than 3.0 m) culverts and/or adverse geotechnical conditions exist.

Considerations:

- Size of backfill envelope,
- Practical installation procedures,
- Bearing capacity of foundation,
- Economics vs. structural performance.

Recommendations:

- In general, the backfill envelope shape shown on the current version of standard drawing S-1418 should be used for flexible culverts.

- For structures with an equivalent diameter of 3000 mm or less, the shape and dimensions shown on drawing S-1418 should be used.

- For structures with an equivalent diameter between 3000 mm and 4500 mm, a similar, but structurally enhanced envelope should be used and specified on site specific drawings. Enhancements could include increased width and/or depth of excavation and/or increased thickness of granular material above the crown.

- For structures with an equivalent diameter greater than 4500 mm, a site specific backfill shape should be designed.

- When soft foundations exist, the use of a woven geotextile filter fabric at the base of the excavation between the clay seals, as shown on the current version of standard drawing S-1418 is recommended. Refer to the following table of minimum average roll value properties (MARV) for the geotextile materials specifications:

Woven Geotextile Filter Fabric	
Specifications and Physical Properties	
Grab Strength	1275 N
Elongation (Failure)	15%
Puncture Strength	275 N
Burst Strength	3.6 MPa
Trapezoidal Tear	475 N
Minimum fabric lap to be 1000 mm	

1.11 CLAY SEALS

Background:

From a strength perspective, it is desirable to have compacted granular material placed around a flexible culvert structure especially beneath roadway travel lanes. Clay seals are typically provided at the ends of culverts to impede seepage around the exterior walls of the culvert and prevent piping. However, on large diameter culverts, especially those with low to medium cover, clay seals may extend beneath the roadway a significant amount.

Considerations:

- Potential for piping to occur,
- Competency of granular backfill,
- Potential for frost heave,
- Attainability of suitable clay material.

Recommendations:

- At natural streams, where cover is greater than span/2.25, clay seals should be constructed as per the current version of standard drawing S-1418.
- At sites where cover is less than or equal to span/2.25, or where suitable clay material is unattainable, clay seals as per standard drawing S1418 with a modified slope interface should be installed. The slope interface between the clay and the granular backfill material should be placed at 1H: 2V.

1.12 ROAD GEOMETRICS

Background:

Oftentimes, the design of a culvert also includes the design of the approach roadway over the culvert. The Responsible Road Authority may request that a lower design standard for some roads be adopted due to low AADT, road use, costs, location, etc.

Considerations:

- Current and potential traffic volumes,
- Initial and future construction (detours, culvert extensions, etc.),
- Costs,
- User safety,
- Future roadway classification

Recommendations:

- Roadway design in the vicinity of a bridge structure should be flexible enough to allow for future roadway improvements within the structure's lifespan (typically 50 – 75 years).

- Guidance is provided in AT's "Highway Geometric Design Guide" (specifically Chapter A - Basic Design Principles and Chapter H – Local Roads), and AT's "Roadside Design Guide".

***Note**: Where it is believed that a reduction in a design guideline is deemed to be economically advantageous, the justifications for the reduction should be fully substantiated and documented (in the form of a Design Exception – Design Bulletin 72) with due regard to public safety, associated risk factors, performance, etc. Any mitigation, and/or future responsibilities (signage) etc. that may be required as a result of a reduction in a recommended design guideline should also be identified as part of the process, and be incorporated into the final design and construction of the structure.*

1.13 ROADWAY WIDTH

Background:

In general, the design width for roads is based on roadway design life of 15 to 20 years whereas culvert structures has are based on a design life of 50 to 75 years. Extending the length of an existing metal culvert due to road widening has resulted in structural and fish passage issues, oftentimes developing from the original culvert installation. For guardrails on local roads, TAC recommends that a shy distance of 0.5 m be added to each side (Travel lanes + shoulders + 0.5 m each side).

Considerations:

- Provision of additional width for future widening,
- Land impacts/Right of Way needs
- Safety
- Design speed/AADT
- Desirable clearzone/barrier warrants
- Fill height (construction costs/accessibility)
- Shy distance if guardrail installed,
- Economics of installing a longer culvert now versus lengthening in the future

Recommendations:

- Provide a distance of 1.0 m on each side of a culvert requiring guardrails. This allows for a shy distance of 0.5 m in front of the post, 0.25 m for the post, and 0.25 m behind the post for lateral support. The length of this additional width should be in accordance with site specific guardrail design, and extend to either side of the centreline of the culvert as appropriate. The guardrail should transition to correspond to the typical roadway width.
- Refer to the Chapter C 'Cross-Section Elements' of the Highway Geometric Design Guide and the Roadside Design Guide for additional information.
- Provide additional length if future widening has been identified.

1.14 SIDESLOPES

Background:

For economic reasons, older culverts were often constructed with sideslopes steeper than 3:1. Problems such as slumping and crushed bevel ends have been identified at older culvert sites. This is often associated with poor foundations and/or unstable sideslopes.

Considerations:

- Safety of the travelling public and roadside obstacles,

- Slope stability and/or structural integrity,
- Economy, (guardrail protection versus clear zone limits),
- AADT/road classification,
- Aesthetics,
- Access path above structure (wildlife, pedestrians, etc.)

Recommendations:

Road Type	**Embankment Height.**	**Sideslope**
Local Road with AADT < 400*	less than 9.0 m greater than 9.0 m	3:1 (assess need for barrier). 4:1 (assess need for barrier). 3:1 (barrier required). 2:1 (barrier and 3.0 m berms required).
Provincial Highways and Local Roads with AADT > 400	All	4:1 (assess need for barrier) 3:1 (barrier required)

**Consideration of steeper sideslopes than noted may be warranted on very low traffic volume roads.*

For all locations, the minimum horizontal distance between the edge of the shoulder and the end of the barrel is 4.0 m.

Note: *2:1 sideslopes should only be used on well constructed embankments known to have a stable foundation.*

Refer to AT's 'Roadside Design Guide' for additional information on roadway sideslopes, and hazards to be considered for mitigation:

http://www.transportation.alberta.ca/3451.htm

1.15 LENGTH OF CSP & SPCSP STRUCTURES

Background:

Structure length calculations are based on subgrade width and elevation, sideslopes, berms, bevel ends, invert elevations, slope, skew, and other site specific details, as applicable.

Considerations:

- Roadway width ,

- Future roadway upgrades including overlays,
- Roadway geometrics,
- Sideslope stability,
- Bevel ends,
- Burial depth,
- Fill height,
- Site specific details.

Recommendations:

- Use the recommendations concerning sideslopes, berms, bevel ends and burial depth given elsewhere in this Guideline. Refer to the current version of Section C 'Cross-Section Elements' of the Highway Geometric Design Guide for guidance on the appropriate roadway subgrade width.

Note: *Due consideration should be given to structures located within horizontally curved sections of highway, where the road width is variable, where an adjacent intersection could affect the length required, or where fish passage is a known concern.*

1.16 MINIMUM COVER REQUIREMENTS FOR STEEL CULVERTS

Background:

The current version of AASHTO specifies the minimum cover for steel culverts as being span/8 or 300 mm, whichever is greater. The exceptions to this rule are long span culverts, which are governed by special design considerations.

The Ontario Bridge Design Code and the Canadian Highway Bridge Design Code (CHBDC) CAN|CSA-S6-00 specify the minimum cover as being the larger of:

$$\frac{Dh}{6}\left(\frac{Dh}{Dv}\right)^{0.5} \text{ or } 0.6\left(\frac{Dh}{Dv}\right)^{2} \text{ metres, with a minimum of } 0.6 \text{ m}$$

Where Dh = Span (metres)
Dv = Rise (metres)

The SCI Design Method recommends that the minimum cover be not less than span/1.5.

Considerations:

- Live load impact effect on structures with cover less than 600 mm,

- Questionable shear strength of shallow depth of soil over crown (particularly on horizontal ellipsed culverts),
- Potentially reduced cover due to rutting,
- Top plate bending, and not ring compression, may develop in long span culverts as defined by AASHTO Clause 12.6,
- Minimum cover for construction equipment,
- Alberta Transportation has adopted the provisions of Canadian Highway Bridge Design Code (CHBDC) "CAN/CSA-S6-00" for the design of culverts: "Unless noted otherwise the design live load is CL 800 plus Dynamic Load Allowance."

Recommendations:

- Minimum cover provided shall be in accordance with the requirements of the current version of the CHBDC or 600mm, whichever is the greater. The minimum cover should be taken as the least dimension between the crown of the culvert and the edge of the shoulders.
- If the highway is to be paved within the same construction season that the culvert is installed, then pavement structure depth may be considered as cover provided that a factor of safety of 1.5 is maintained during paving operations.

Note: *For strength requirements during construction, refer to Clause 7.6.2.3 of the CHBDC. Where the above criteria cannot be met, special considerations to mitigate the lack of cover (such as a concrete distribution slab) may be required. These recommendations do not apply to concrete structures.*

1.17 BEVEL ENDS

Background:

Bevel ends retain the sideslopes and transition slopes at the ends of a culvert, and are designed to enhance hydraulic performance by minimizing entrance and exit losses. They also provide an aesthetically pleasing termination to a structure.

Considerations:

- Stability of sideslopes, transition slopes and protection works,
- Aesthetics and serviceability,
- Termination of fences,
- Difficulty in pouring concrete,
- Temporary support for large diameter CSPs.

Recommendations:

- Bevel slopes should be no steeper than 2:1 for stream culverts.
- Depending on site specific geometry, or fencing requirements, use square ends, 1:1 or 2:1 for terminating cattlepass culverts.
- All bevels are to be cut perpendicular to the longitudinal axis (i.e. do not cut top arc on a skew).

1.18 GEOTECHNICAL CAMBER

Background:

Many older culverts have sagged over the centre sections of their length, often leading to ponding within the barrel section. These situations are most evident at sites with high fill, poor foundations, or yielding ground.

Considerations:

- Ponding at culverts,
- Site specific geotechnical information,
- Fill height,
- Backfill material,
- Settlement and/or consolidation (if not previously loaded),
- Positive and negative settlement on large diameter culverts.

Recommendations:

Complete a geotechnical investigation and undertake foundation design including anticipated settlements, camber requirements, etc. if any of the following conditions apply:

- Embankment height above the existing ground is greater than 6 metres and the foundation material has not been previously pre-consolidated.
- Foundation and/or embankment material is known, or suspected to be, poor.
- Proposed culvert diameter is greater than 4.5 m.
- A life expectancy in excess of 50 years is highly desirable (high AADT, high fills, strategic crossings, long detours, etc.)

Define the camber requirements by calculating at least five stations along the stream bed.

1.19 BED PRESHAPING

Background:

Prior to placing the bottom plates, a layer of loose, fine granular material matching the curvature of the bottom plates is usually placed between the inside faces of the clay seals. Bed preshaping reduces pipe deflections during assembly, minimizes pipe rotation during backfilling, and helps ensure uniform contact between the bottom surface of the pipe and the bed.

Considerations:

- Flexibility during assembly,
- Difficulty in placing and compacting,
- Rotation during backfilling,
- Improved uniform contact between bed material and pipe.

Recommendations:

- A preshaped bed should be used for the installation of round culverts with a diameter greater than 3.0 m, horizontally ellipsed culverts, and shapes with flat radius bottom plates.
- Prior to placing the bottom plates, a layer of loose, fine granular material (200 mm thick) should be placed above the granular portion of the bed to match the curvature of the plates over the preshaped bed. Clay seals at culvert ends should be shaped similarly before bottom plate placement.
- It should be ensured that granular material does not penetrate through the clay seals.

1.20 CONCRETE END TREATMENT

Background:

Uplift forces from hydrostatic pressures have in the past resulted in culvert failure due to bending as well as ‘hanging outlets’. Contributors to this issue include dead load reductions at culvert ends (amount of fill), structurally inferior ends, scour/erosion issues, and construction issues. Pipe ends have also known to become damaged/deformed from maintenance activities such as grass cutting.

Considerations:

- Potential for piping,
- Potential for uplift ,
- Slope stability,
- Icing and/or drift problems,
- Reduction of hydraulic losses,
- End stiffening,
- Aesthetics.

Recommendations:

The following table should be used as guidance. The equivalent diameter (d) is to be based on the total pipe area (A); $d = \sqrt{\frac{4A}{\pi}}$

Equivalent Pipe Diameter (m)		
< 3.0	3.0 to 4.5	> 4.5
Should consider concrete end treatment if: (a) Sideslopes and/or transition slopes prone to sliding, (b) Heavy ice or ice jams are likely, (c) Potential for ponding to occur, (d) Drift problems likely. (e) Steep culvert slope.	Typically provide concrete end treatment at the upstream end only. Provide concrete end treatment at both ends under the following conditions: (a) If velocities are greater than 2.0 x average stream velocity under design conditions (b) For aesthetic reasons.	Provide concrete end treatment at both ends.

***Note**: Concrete end treatment to be constructed in accordance with the current version of standard drawings S-1444 and S-1445*.

1.21 SPACING OF MULTIPLE CULVERTS

Background:

Multiple culvert installation can be an appropriate and acceptable engineering solution in low cover situations, for wide channels, or in culvert icing situations. Minimizing culvert spacing to reduce the amount of granular and clay material needed while still maintaining structural integrity is desirable.

Considerations:

- Gradeline (low cover, unbalanced loads),
- Channel Geometry,
- Cost,
- Passage of drift,
- Icing,
- Fish passage,
- Construction
- Skewed and/or staggered culverts

Recommendations:

- Multiple culverts should be a good fit to the natural channel (i.e. equivalent bed width created should be similar to that of the natural channel bed). Flow expansion should be avoided.
- Overflow culverts outside of the natural channel (typically placed at a higher elevation or lateral distance away) should be considered when icing concerns are noted.
- Horizontal spacing between adjacent culverts should be at least 1.0 m or span/3 of the larger span, whichever is the greater.
- Placement and compaction of crushed granular material (Des. 2, Class 40) between pipes should be in accordance with drawings and specifications.

1.22 SITE INSPECTIONS DURING INSTALLATION

Background:

Historically, culverts were designed by the Department, and installed by Road Authorities using their own forces, contractors, or bridge crews. Currently, the design, tender, and construction of all Provincial bridge structures are preformed by Consultants.

Metal culverts are complex structures that rely heavily on the surrounding backfill for structural integrity. Under loading, the flexible metal pipe deflects slightly, and through this movement transmits radial forces to the surrounding backfill. This interaction results in the development of ring compression in the pipe, leading to a state of static equilibrium. The soil component of this 'system' provides the majority of the load carrying capacity. As long as the integrity of the surrounding backfill remains, the culvert will perform satisfactorily.

Poor installation practices have lead to foundation and backfill failures, resulting in excessive bending, deflection, or ultimate structural failure of the pipe. Typically these problems result in remedial action, and/or premature replacement of the structure. There are several factors which contribute to a poor installation including an inexperienced workforce, unstable or weak foundation material, poor bed preparation, inappropriate or frozen backfill material, poor compaction, incorrect assembly of plates etc. Past experience has shown that one of the most effective methods of combating the likelihood of these problems is to ensure that an appropriate level of inspection is carried out at all stages of the culvert installation.

Considerations:

- Quality control
- Cost

- Performance and structural integrity
- Future maintenance

Recommendations:

The Consultant shall provide a qualified bridge inspector to provide a complete and proper inspection service. Inspection services may not be required during 'gaps' in the contractors work and during non-critical operations. The bridge construction inspector should be present on site and ensure quality assurance during the following key phases:

- Site mobilization (traffic accommodation plan, etc).
- Implementation of channel diversion works,
- Completion of foundation excavation,
- Completion of bed preparation (preshaping, compaction),
- Completion of culvert plates assembly,
- Placement of the structural backfill (compaction, shape),
- Concrete placement,
- Site trimming, riprap placement, clean up, restoration of water flow,
- Semi-final inspection.

Note: *See "Bridge Design Bulletin #2, 2004" for reference to installation of culverts under high fill conditions.*

http://www.transportation.alberta.ca/1807.htm

1.23 WATERPROOFING CONCRETE STRUCTURES

Background:

Protecting structures from the corrosive effects of de-icing salt is an ongoing issue. Measures currently being taken to protect concrete structures include waterproofing systems, protective sealers, extra cover for reinforcement and epoxy coated reinforcement. Exterior surfaces of buried concrete structures typically receive a protective sealer which has been considered adequate to date. Concern has been expressed that over time buried concrete structures under low fill situations may be adversely affected by salt to the same degree as concrete decks.

Considerations:

- Future maintenance,
- Inability to inspect exterior concrete surfaces or those covered by structural plates.

Recommendations:

- Apply an approved Type 1C sealer to all surfaces that may be in contact with de-icing salts. The sealer shall be applied in accordance with the current version of B351 'Cast-In-Place Concrete' Section 4 of the Specifications for Bridge Construction. Special conditions (high salt usage, minimum cover, narrow structure, etc.) may warrant the application of a protective sealer to the entire structure (including the roof slab).
- Consider the use of epoxy coated reinforcement, corrosion inhibitor, or increased cover for exposed concrete elements (headwalls, curbs, etc.) where de-icing salts are likely to be used.

***Note**: See the 'Alberta Transportation Products List' for further details regarding proven products and trial products.*

http://www.transportation.alberta.ca/689.htm

1.24 EXTENSIONS

Background:

Placement of additional fill over an existing culvert can lead to problems such as further settlement of the embankment and/or foundation. The resulting redistribution of loads can cause the pipe to become distressed, resulting in cracked seams or barrel deformation. Once in contact with soil, a culvert will start to lose its galvanic protective coating, with the amount and rate depending on the culvert age and soil corrosion potential. When a culvert extension is placed, dissimilar metals (with different degrees of galvanic protection) come into contact. This can result in a corrosion cell, causing more rapid corrosion in the area of contact between the original culvert and the extension.

Considerations:

- Structural adequacy,
- Condition of existing culvert (deformations, cracked seams, corrosion),
- Hydraulic adequacy,
- Fish Passage
- Cost (extension, replacement, detours),
- Existing soil conditions (moisture content, corrosion potential).

Recommendations:

A detailed engineering assessment including life cycle costing should be preformed prior to extending any culvert. Metal culverts should not be extended if any of the following criteria apply:

- The BIM general rating for the barrel is 4 or less,
- The culvert is structurally or hydraulically inadequate,
- The proposed grade raise exceeds 2.0 m,
- The resulting culvert length is greater than deemed acceptable for fish passage.

***Note** Further information on culvert management strategies can be found within the 'Bridge Management Strategy Guideline/Manual'*

http://www.transportation.alberta.ca/565.htm

1.25 LOW LEVEL CROSSINGS

Background:

Under certain conditions, it may be considered appropriate to install a low level crossing. Typically, this would be on extremely low volume traffic roads where loss of roadway use for a short period of time would not be a major inconvenience, or where it is considered uneconomical to replace a bridge for occasional traffic such as land access or seasonal farm equipment.

Considerations:

- Acceptable level of inconvenience,
- Safety,
- Hydrotechnical design parameters,
- Cost,
- Potential for drift and ice,
- Environmental concerns, including fish passage,

Recommendations:

- When feasible for low AADT and non-critical routes, the use of a low level crossing may be considered. Typically land access and temporary crossing situations would fall into this category.
- Low level crossings are to be designed and constructed in accordance with the current version of standard drawings S-1614 or S-1615, as appropriate.

***Note:** Typically low level crossings are an encumbrance to navigation, and unlikely to be approved for use on navigable waterways.*

1.26 CATTLE PASSES

Background:

The provision of a cattlepass, (which may sometimes also include accommodation for small vehicles and/or pedestrians), typically forms part of the right-of-way negotiations and agreement. To reach an equitable solution, several factors are considered (size, costs, land severance implications, land values, etc.). Based on the outcome of these considerations and discussions with the landowner, a recommendation as to whether to offer the owner a cattlepass, other benefits, or a cash payout is made by the right of way buyer.

Considerations:

- Traffic volume,
- Animal volume,
- Frequency of crossing,
- Land severance,
- Right-of-way acquisition,
- Costs
- Stormwater management and highway drainage.

Recommendations:

- Minimum rise of cattlepass structures should be 2200 mm.
- A concrete floor, to a minimum depth of 150 mm, with a rough textured surface or a compacted granular floor should be considered.
- Length should be determined such that sideslopes terminate at the top of the floor level when no bevel is used.
- Surface water should not pond inside the structure. This could be achieved by setting the inverts slightly above adjacent ground, by longitudinally sloping or crowning the inverts, or by employing ditch drainage when necessary.

1.27 OPENING MARKERS

Background:

Pedestrians or others travelling along the right-of-way may be at risk if the inlet/outlet of a bridge size culvert is concealed by vegetation or snow.

The Attorney General's office has recommended that, to minimize liability, some type of guardrail or fence system be installed when it is known that people will frequently be in the vicinity of a culvert and possibly suffer a serious injury from a fall.

Considerations:

- Safety,

- Proximity to residential or recreational areas,
- Height of cover,
- Liability.

Recommendations:

- Consider installing a marker system and/or warning signs at all culvert sites located within or near residential or recreational areas.
- Provide railings for all pedestrian walkways located immediately adjacent to culvert ends.

1.28 CORROSION SURVEY AND SERVICE LIFE PREDICTION

Background:

Corrosion is a natural process that breaks steel down into its constituent components, and can govern the effective service life of steel culverts. A corrosion survey and analysis can be used to identify appropriate material type, thickness, and coating to reach the minimum service life of 50 years.

Considerations:

- Soil resistivity and pH values in the area,
- Existing structure's performance, if applicable,
- Potential for future lining – AADT, height of cover
- Lifecycle costs.

Recommendations:

A corrosion survey should be completed for sites where a bridge-size metal culvert is a likely solution. Corrosion survey and design life estimation shall be carried out by a qualified Corrosion Specialist, at sites known or suspected to have a corrosive environment, with moderate to high traffic volumes and/or a considerable height of cover.

Resistivity and pH values of the soil should be taken on the road sideslopes (each side) and from the upstream and downstream banks. Resistivity and pH values of the water should be taken upstream and downstream of the site. If the existing structure is a metal culvert, static potential reading should be carried out at 3, 6, 9, and 12 o'clock positions at the upstream and downstream ends.

These values can be used with prediction tools to assess the ability of a range of culvert configurations (material type, thickness, and coating) to obtain the expected minimum service life of 50 years. The predicted service life will be the lesser of time to first perforation based on soil side (based on average of soil pH and resistivity values) and water side (based on average of water pH and resistivity values) corrosion. For analysis, a 50 year life may be assumed for metal culverts and a 75 life for concrete culverts.

Tools that can be used to estimate service life for various steel culvert configurations are available in the current version of the CSPI *"Handbook of Steel Drainage & Highway Construction Products – Canadian Version" (http://www.cspi.ca/resources/technical-information?keyword=Technical Bulletins).* Additional information can be found in the AT document *"Best Practice Selection of Culvert Types".* If static potential readings are available for the existing pipe, they can be used to estimate the rate at which the existing galvanizing is being consumed, and confirm the predicted life values from these tools.

Guidance on available culvert types can be found in the AT Products List and Section 18 of the Bridge Construction Specifications. Selection of the optimal culvert configuration that meets the required service life should be based on life cycle economic analysis. Oversizing to allow for future lining may be a cost effective strategy at sites where open-cut replacement would be expensive or require extensive traffic accommodation (high fills, high traffic volume). Cathodic protection systems are not endorsed by the department as service life extension strategies, as they have historically proven to be difficult and costly to maintain/operate.

1.29 CULVERT DESIGN PROCESS

See Section 10 and Appendix "J1" of the current version of the "Engineering Consultant Guidelines for Highway and Bridge Projects – Volume 1" for requirements.

http://www.transportation.alberta.ca/930.htm

1.30 SITE SURVEY REQUIREMENTS

The site survey for bridge size culverts should be consistent with the current version of standard drawing S-1434 "Sample Information Sheet Bridge Site Survey for Standard Bridges and Culverts". Normally this information is sufficient for design purposes but there may be occasions when additional information is required.

The site survey data is used to assess the water flow characteristics of the existing channel and to determine the location and dimensions of the existing and/or proposed crossing or improvement works. It is necessary that all the survey information gathered be accurate in order to optimize the bridge design. The site survey information sheet submitted for bridge culvert design is to include a site plan, natural scale profile, stream profile, road profile, and horizontal alignment along with other pertinent site specific information.

Site Plan:

The site plan is used to correctly position the structure, to determine the skew, and to aid in the location of any required river training works or other temporary works. The site plan identifies possible constraints which may affect the culvert design at the proposed crossing location. These constraints include such things as access roads, buildings, utilities, right-of-way, tree lines, fence lines, beaver dams, and ditches. The site plan should also include the location of the proposed centreline and baselines, existing centreline, benchmarks, existing bridge or culvert location and dimensions, bank traverse showing edge of water or ice, bottom and top of banks, and location of any test holes or test piles.

The site plan should extend a sufficient length upstream and downstream of the crossing to encompass the pertinent aforementioned features and establish the channel geometry.

The following information should be shown on the site plan:

- Location of existing bridge or culvert structures and approach roads. Show dimensions of the existing structure including ends of bridge, clear roadway, out-to-out width of curbs, centreline of bearing at the piers and abutments.

- Proposed access roads and intersections.

- Location of proposed centreline and baselines.

- Bank traverse showing water/ice edge, bottom and top of banks.

- Location of benchmarks, utilities, proposed and existing right-of-way boundaries, tree lines, fence lines, etc.

- Location of boreholes

Natural Scale Profile

The natural scale profile is helpful in determining flow conditions and assist in designing the waterway opening, abutments, headslopes, pier(s) and culvert ends. The natural scale profile is an elevation view of the crossing on proposed centreline plotted to the same horizontal and vertical scale. The profile should show all breaks in the ground particularly in the vicinity of the stream, including streambed. The profile plots should also show elevations of existing structures, any high water/ice marks, boreholes, and test piles. It is important to outline how and where the high water/ice marks were obtained in order for the designer to compare this information with historic records. The profiles should be compared with the bank traverse as a check. Occasionally, additional cross-section data is requested to supplement centreline and sodline profiles to evaluate the effect that the proposed structure will have on the existing stream and environment.

The natural scale profile should show the following:

- All breaks in natural ground on centreline and along sodlines.
- Streambed profile and water level elevation.
- Profile over and under the existing bridge deck (if applicable).
- Upstream and downstream invert elevations of existing culvert(s) (if applicable).
- Elevation of high water/ice marks and their locations.

Streambed and Water/Ice Level Profile

The streambed and water/ice level profile can be used to assist in determining the design flow depth and ice levels by giving an elevation view of the channel bed and water/ice levels at the time of survey. Survey features should include high-water marks, scour holes, waterfalls, beaver dams, utility crossings, and any other unusual features.

The streambed and water/ice level profile should extend appropriate lengths to encompass all pertinent features in the area.

The profile should show the following:

- Shots to be taken on both sides of beaver dams, drops, or other obstructions.
- High water/ice marks and their corresponding locations and elevations.

Highway/Road Profile

The highway/road profile is used to establish the gradient and elevation of the bridge and approaches. This profile gives an elevation view of the proposed centreline and sodlines. It is desirable to obtain sufficient ground profile information to establish a gradeline that optimizes bridge and highway geometrics design standards together with grading quantities.

The highway/road profile is to extend along the proposed centreline and along 15 m (increase offset as required, e.g. high fills) left and right sodlines.

Cross-sections

Cross-sections are used to define channel geometry, assess channel capacity, and assess natural bank stability. These sections can be used to assess the overbank storage potential during peak flow or flooding situations.

Cross-sections are to be taken upstream and downstream from the proposed centreline and perpendicular to the stream. The cross-sections should extend to a ground elevation above the stream banks. In addition, two cross-sections perpendicular to the proposed roadway should be taken, ensuring that the width encompasses the extent of the proposed right-of-way.

Accuracy of Survey

Horizontal control should be established using bench marks located close to the crossing but sufficiently away from the construction area to ensure they will not be disturbed by construction or maintenance activities. Supplemental hubs should be established near the crossing to provide backup reference for alignment and stationing in the event the primary hubs are lost following the survey. Vertical control should be established using accurate benchmarks in the vicinity of the crossing. It is desirable that elevations be geodetic. All benchmarks, hubs, and control points should be clearly indicated on the plots taken from the survey information along with any grid to ground correction factors.

In order to maintain consistency in bridge survey information between surveys, all chainage equations and bench mark equations should be clearly shown on the plots and in the notes. It is essential that the horizontal and vertical components of survey be accurate, as they will affect the dimensions and performance of the structure. Horizontal measurements should be to the nearest decimetre while elevations should be to the nearest millimetre.

1.31 FREQUENTLY USED STANDARD DRAWINGS

S-1418-03	Installation of Large Steel Pipes	REV 1
S-1434-92	Sample Information Sheet Bridge Site Survey Std Bridges & Culverts	REV 1
S-1435	General Layout and End Treatment	REV -
S-1444-93	Concrete End Treatment for Large Steel Culverts – Sheet 1	REV 2
S-1445-93	Concrete End Treatment for Large Steel Culverts – Sheet 2	REV 3
S-1476	Culvert Repair Shotcrete Beam Details	REV 5
S-1620	Maintenance Procedure for Steel Strutting of Metal Culverts	REV 1
S-1621	Installation of Liners for Metal Culverts – Sheet 1	REV -
S-1622	Installation of Liners for Metal Culverts – Sheet 2	REV -

Current Bridge Standard Drawings can be found at:
http://www.transportation.alberta.ca/1286.htm