Alberta
TRANSPORTATION
TECHNICAL STANDARDS BRANCH

DESIGN GUIDELINES

FOR

BRIDGE SIZE CULVERTS

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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

These Design Guidelines 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 also been used to incorporate the practical experience in the design and construction of culverts that has been developed within Alberta Transportation 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.

Each design topic is presented in three parts.

1) Background; to serve as an introduction to the issue, to review current practice and any the concerns or problems that have been identified.

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

3) Recommendation; 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 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.

1.2 CONSTRUCTION (OR `P') DRAWINGS

Background:

Historically culverts were installed by Bridge Crews using a Culvert Authorizations with the design information being provided in the form of sketches and/or written instructions, or from 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 now outsources all culvert design and construction supervision it is appropriate that the 'historical' process for handling the design and installation be reviewed.

Considerations:

Site specific drawings provide an accurate representation of actual on-site condition, 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,

Recommendations:

- In addition to standard drawing S-1418 'Installation of Large Metal Pipes', a site specific 'P' drawing(s) should be produced for all bridge size culverts.
- 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.trans.gov.ab.ca/Construction/DoingBusiness.asp

(For convenience links to the most frequently used standard drawings for culverts have also been provided Section 1.32 of this document).

1.3 RIGHT-OF-WAY AND EASEMENTS

Background:

Construction or maintenance at a culvert site generally results in disturbance of the stream banks or streambed, and there is a tendency for scour holes and slumping of banks to occur adjacent to a structure. The department (or owner) can be held responsible for problems whose cause can be attributed to, or associated with, the structure.

Considerations:

Ensure structure(s) and associated protection works are not on private property,
Ensure right of entry for construction and maintenance,
Allow for potential lateral movement of watercourse,
Area and shape of the R/W to be convenient for surveying and tying-in,
Future road widening, grade raise, slope improvement.

Recommendations:

- The Responsible Road Authority (MD, County, AT, etc) should provide the R/W or easement required for the structure, associated protection works, and future maintenance. This should be shown on the drawing and/or stated in the written instructions.
- An allowance of approximately 5.0 m should be taken beyond the limits of protection work when establishing the R/W area. The shape of the area should be kept simple and defined by limits that can be conveniently tied into the survey.

1.4 HYDROLOGIC 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 throughout its expected life.

Considerations:

- Drainage Area
- 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” document. The document is available in the “Hydrotechnical Design Guide” folder at the AT FTP site:

ftp://www.tu.gov.ab.ca/bridge/pub

1.5 HYDRAULICS AND CULVERT SIZING

Background:

Sizing of bridge size culverts based on hydrotechnical design parameters requires consideration of the expected performance of various culvert options under design flow conditions.

Considerations:

- Hydrologic Design Flow
- Hydraulics
- Upstream Flooding Impacts
- Fish Passage
- End Protection Works
- Uplift Potential
- Embankment Stability
- Roadway Overtopping Potential
- Barrel Opening Blockage
- Future Rehabilitation

Recommendations:

- Guidance on factors to be considered for hydrotechnical based sizing of bridge size culverts is provided in the document "Culvert Sizing Considerations". Hydraulic calculations for bridge size culvert sizing should be done in accordance with the current AT document "Hydrotechnical Design Guidelines". Additional guidance is also provided in the document "Practical Hydraulic Modelling Considerations". Hydrologic Design Flow is referenced in Section 1.4 above.

1.6 FISH PASSAGE

Background:

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

Considerations:

Water Act,
Fisheries Act,
Public awareness of environmental issues,
Minimizing environmental impact.

Recommendations:

- Culverts on all fish bearing streams must be designed to pass fish in accordance with the current version of the "Fish Habitat Manual".

http://www.trans.gov.ab.ca/Content/doctype123/production/fishhabitatmanual.htm

1.7 BURIAL DEPTH

Background:

It is a natural process that the bed of a "geologically young" stream will degrade as the stream matures, and many of the streams within the Province are classed as being young. Typically, installing a culvert tends to locally increase the velocity of the stream at the culvert outlet. The combination of these factors can result in scour holes, bank erosion and "hanging outlets" developing at the downstream end of a culvert. Hanging outlets are never desirable, and form a permanent barrier to upstream passage of fish.

Considerations:

Correct burial:
Reduces the likelihood of "hanging outlets" or undermining of the culvert occurring,
Reduces the water velocity at the outlet,
Usually enhances fish passage,
Improves hydraulic efficiency of culvert,
Encourages natural sediments to settle on the culvert floor,
Cost associated with excavating bed in wet conditions.

Recommendations:

- Culvert inverts should be buried at least one quarter of the rise 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 would require special attention. For example:

  Burial depth may be reduced if:
  (a) bedrock is encountered,
  (b) streambed is prone to aggradation.

  Burial depth may be increased if:
  (a) fish passage is of concern,
  (b) the unit cost of excavation (for culverts with equivalent diameter >4000 mm) does not increase with increased depth of excavation.

1.8 SCOUR/EROSION PROTECTION

Background:

At some culvert sites the riprap is lost and large scour holes tend to form at the outlet end. Unless remedial measures are taken the integrity of the structure can be affected.

Considerations:

Design flow
Loss of fine materials from beneath riprap,
Steep and unstable sideslopes,
Estimation of local inlet and outlet velocities relative to natural stream velocities,
Estimation of local scour at outlet,
Streambed material type.

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 (MARV's) 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 use the current version of standard drawing S-1418 as a guideline for minimum apron length requirements.
- For culverts with a diameter greater than 3.0 m an engineering design of the culvert end protection is required.

Use the following Table to determine the Class of rock riprap required:

Riprap Class	Allowable Local Velocity*
Class 1M	2.0 m/s
Class 1	3.0 m/s
Class 2	4.0 m/s
Class 3	4.6 m/s

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

***Note**: Refer to the current version of B354 "Heavy Rock Riprap", Section 10 of the Specifications for Bridge Construction for additional information regarding minimum thickness and size gradations.*

1.9 BACKFILL MATERIAL FOR FLEXIBLE CULVERTS

Background:

Good support from the backfill is essential to the structural integrity of all flexible culverts. Most of the structural problems that culverts experience are the result of unsuitable backfill material, poor compaction, or frozen material being incorporated into the structural envelope during construction. The support provided by the backfill may be also reduced through freeze/thaw cycles, piping, etc. When selecting a backfill material it is 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 compressibility,
Shear strength,
Bearing capacity and settlement,
Drainage characteristics and void ratios,
Potential for frost action,
Installation at low temperatures.

Recommendations:

- Granular backfill should be used around the barrel of all flexible culverts, with an approved clay fill material at the ends forming the seals. Refer to the current version of B327 "Earthwork" in Section 2 of the Specifications for Bridge Construction, or the current version of standard drawing S-1418, for the gradation of granular 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 already known to be of poor quality,*
  - *High cover and/or weak foundation material,*
  - *Presence of natural springs in the material above the culvert, (these can be problematic during freeze/thaw cycles).*
  - *Corrosive environment*

1.10 BACKFILL ENVELOPE FOR FLEXIBLE CULVERTS

Background:

In addition to using well compacted granular fill on a firm foundation, the shape and size of the backfill envelope is a critical factor in ensuring the structural integrity of a flexible culvert. The shape shown on the current version of standard drawing S-1418 has performed well under "normal" conditions, but special care must be taken where large diameter culverts are to be installed and/or if adverse geotechnical conditions are encountered.

Considerations:

Adequate size of backfill envelope,
Practical installation procedures,
Structural competency of foundation,
Economics vs. structural performance.

Recommendations:

- Use the shape shown on the current version of standard drawing S-1418 for the backfill envelope around flexible culverts.
- Use the shape and dimensions shown on the drawing when installing culverts with an equivalent diameter of 3050 mm or less.
- Use a similar, but structurally enhanced, envelope when designing culverts with an equivalent diameter between 3050 mm and 4500 mm. (Typical enhancement to the standard shape could include increased width and/or depth of excavation below the invert and/or increased thickness of granular material above the crown).
- Design a site specific backfill shape for culverts with an equivalent diameter greater than 4500 mm.

For all culvert sites with soft foundations, consider placing 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. Refer to the following table of minimum average roll value properties (MARV's) 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:

It is always desirable from a strength perspective to have compacted granular material around a flexible structure. It is particularly important that this be achieved under the travel lanes. Clay seals are normally provided at the ends of culverts to reduce the possibility of seepage flow adjacent to the culvert wall, which can cause piping to occur. However, on large diameter culverts, especially those with low to medium cover, the clay seals may extend under the travel lanes by a significant amount.

Considerations:

Potential for piping to occur,
Structural competency of backfill,
Potential for frost heave,
Difficulty in obtaining suitable clay material.

Recommendations:

- At natural streams where cover is greater than span/2.25 provide clay seals at both ends in accordance with 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 difficult to obtain, provide clay seals as per the standard drawing but slope the interface between the clay and the granular at 1 horizontal to 2 vertical.

1.12 ROAD GEOMETRICS

Background:

Typically, 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. This type of request is usually made for roads with low AADT, such as little used local roads, land access, etc.

Considerations:

Current use of road and potential for increased traffic volumes,
Consequences of initial construction of a lower standard road than will ultimately be required,
Problems associated with culvert extension,
Is there a possibility of future roadway classification being higher than current classification?

Recommendations:

- Use the standards established in the current version of Table A-7 'Design Standards for Rural Highways' – Section A (Basic Design Principles) of Alberta Transportation's 'Highway Geometric Design Guide'.
- If the roadway is to be improved in the foreseeable future provide sufficient pipe length to enable the proposed improvement to be accommodated, and use berms to stabilize and protect the pipe in the interim period.

***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 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 a 15 to 20 year life, whereas the structure has a design life of 45 to 75 years, depending on the structure choice. The practice of extending the length of an existing metal culvert has resulted in structural problems developing in the original installation at some sites.
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 anticipated future widening,
Safety of the travelling public,
Shy distance if guardrail installed,
Economics of providing longer pipe now versus possible problems with future extensions.

Recommendations:

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

1.14 SIDESLOPES

Background:

For economic reasons many older culverts often were constructed with sideslopes steeper than 3:1. Problems such as slumping sideslopes and crushed bevel ends were fairly common at culvert sites situated on yielding foundations or with unstable sideslopes.

Considerations:

Safety of the travelling public and roadside obstacles,
Slope stability and/or structural integrity,
Economy, (guardrail protection versus clear zone limits)
Aesthetics,
Access path above structure i.e. cattle, hiking, etc.

Recommendations:

Road Type	Embankment Height.	Sideslope	
Local Road with AADT < 400	less than 9.0 m	3:1	(assess need for barrier).
	greater than 9.0 m	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		4:1	(assess need for barrier)
		3:1	(barrier required)

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

For all locations the minimum horizontal distance between the edge of the shoulder and the end of the barrel is 4.0 m.
Refer to Chapter C, Section C.5 'Roadside Design' of the Highway Geometric Design Guide for additional information on roadway sideslopes, and hazards to be considered for mitigation (C5.3).

1.15 LENGTH OF CSP & SPCSP STRUCTURES

Background:

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

From time to time confusion has arisen concerning the factors and values to be used, and the need for uniformity between design engineers has been identified.

Considerations:

Roadway width as defined,
Future upgrades including overlay systems
Road geometrics,
Sideslope stability,
Bevel ends,
Adequate burial depth,
Site specific details as may be applicable.

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, or where an adjacent intersection could affect the length required.*

1.16 LENGTH OF ABC & CAB STRUCTURES

Background:

Structure length calculations are based on finished roadway width and elevation, sideslopes, bevel ends, invert elevations, skew (if applicable), headwall configuration and wingwall flare angle, and other site specific details as may be applicable. Additionally these structures can have several unique features, and interpretation of design criteria can vary

Considerations:

Roadway width,
Roadway geometrics,
Sideslopes,
2:1 bevel ends,
Adequate burial depth.

Recommendations:

- Use the recommendations concerning roadway width, sideslopes, bevel ends and burial depth given elsewhere in this document to calculate the length of the structure. Due consideration should also given to any site specific features which could affect the length requirement.

  Note: *For the structural design of ABC structures reference should be made to the "Bridge Structures Design Criteria", Appendix "B": Arch-Beam-Culvert Structural Design Guidelines'*

http://www.trans.gov.ab.ca/Content/doctype30/production/AppendixB.pdf

1.17 MINIMUM COVER REQUIREMENTS

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 (CHBD) 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 significant on horizontal ellipsed culverts),
Reduced cover due to possible rutting on local roads,
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 now adopted the provisions of Canadian Highway Bridge Design Code "CAN/CSA-S6-00" for the design of culverts. *Unless noted otherwise the design live load for AT structures 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 span/4, 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.

1.18 BEVEL ENDS

Background:

Bevel ends retain the sideslopes and transition slopes at the ends of a culvert, and are designed to enhance hydraulic performance. They are also provided to give a neat and 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 CSP's.

Recommendations:

- Slope of bevel should be no steeper than 2:1 for all culverts on streams.
- Depending on site specific geometry, or fencing requirements, use square ends, 1:1 or 2:1 for terminating cattlepasses
- All bevels to be cut perpendicular to the longitudinal axis (i.e. do not cut top arc on skew).

1.19 GEOTECHNICAL & CAMBER

Background:

With time many older culverts have sagged over the centre sections of their length and ponding within the barrel section often occurs. Culverts under high fill, on poorly prepared foundations, or on yielding ground are the most likely candidates for this problem to occur.

Considerations:

Ponding at culverts,
Little or no geotechnical information available at culvert sites,
All culvert beds (with the exception of those founded on rock) undergo settlement and/or consolidation if not previously loaded,
Positive and negative settlement on large diameter culverts.

Recommendations:

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

- The height of the embankment above existing ground is greater than10metres and the foundation material has not been previoiusly pre-consolidated.
- The foundation and/or embankment material is known, or suspected to be poor.
- The diameter of the culvert is greater than 4.5 m.
- A life expectancy in excess of 35 years is highly desirable, i.e. high AADT, strategic crossings, alternate routes involve long detours, etc
- Define the 'positive' camber requirements by calculating at least five stations along the bed.

1.20 BED PRESHAPING

Background:

Preshaping the bed of a culvert reduces pipe deflections during assembly, minimizes pipe rotation during backfilling, and helps to ensure uniform contact between the bottom surface of the pipe and the bed. 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.

Considerations:

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

Recommendations:

- A preshaped bed should be used for round culverts with a diameter greater than 3.0 m, horizontally ellipsed culverts, and other shapes with flat radius bottom plates.
- Prior to placing the bottom plates, place a layer of loose, fine granular material (200 mm thick) above the granular portion of the bed to match the curvature of the plates over the preshaped bed. Clay seals should also be shaped to match the curvature of the bottom plates.
- Ensure the granular material does not run through the clay seals.

1.21 CONCRETE END TREATMENT

Background:

Uplift forces from hydrostatic pressures have in the past caused the ends of culverts to fail in bending. Reduced dead load and the weaker section at the bevel end, coupled with high uplift forces at the upstream end, can contribute to this problem.

Considerations:

Potential for piping,
Potential uplift at upstream end,
Stability of slopes,
Ice and/or drift problems,
Reduction of hydraulic entrance losses,
End stiffening,
Aesthetics.

Recommendations:

Equivalent Pipe Diameter (m)		
1.5 to < 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 considered 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 velocity greater than 2.0 x average stream velocity for design discharge, (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*.

Equivalent diameter to be based on total pipe area (A), i.e. $d = \sqrt{\frac{4A}{p}}$

1.22 SPACING OF MULTIPLE METAL STRUCTURES

Background:

Multiple culvert installation is often an appropriate and acceptable engineering solution in low cover situations, for wide channels, or in high outlet velocity situations.
Minimizing the space between the culverts to reduce the amount of granular material and clay seals is desirable. The decision on how close the culverts can be placed is subjective, and a need for clarification has been identified.

Considerations:

Gradeline (low cover),
Width of channel,
Economics,
Passage of drift, ice, etc.
Fish passage,
Compaction equipment,
Unbalanced loads due to gradeline,
Skewed culverts with staggered ends may require more space.

Recommendations:

- Horizontal space between two adjacent culverts should be at least 1.0 m or span/3 of the larger span, whichever is the greater.
- Place and compact crushed granular material (Des. 2, Class 40) between the pipes in accordance with the drawings and specifications.

1.23 SITE INSPECTIONS DURING INSTALLATION

Background:

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

Metal culverts are complex structures which employ the interaction between soil and steel for their load carrying capability. This interaction is achieved when under load; the flexible metal pipe deflects slightly, and through this movement transmits radial forces to the surrounding backfill. Through this interaction, ring compression develops in pipe, and the structure reaches a state of static equilibrium. The soil component of this 'system' provides most of the load carrying capabilities, and as long as the integrity of the surrounding backfill remains intact, the culvert will perform satisfactorily.

It is known that poor installation practices will probably lead failure of the foundation or movements within the surrounding backfill. These movements will likely result in the metal culvert being subjected to excessive bending, or deflection. If the failure mode continues, it will eventually threaten the structural integrity of the steel pipe. Typically these problems require some form of remedial action, and in an extreme case premature replacement of the structure. There are several factors which contribute to a poor installation i.e. 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 arising is to ensure that an appropriate level of inspection is carried out at all stages of the installation.

Considerations:

Ensuring an appropriate level of quality control
Prudent expenditure of funds
Satisfactory performance, and structural integrity
Reduced potential for 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:

- Start of the job to observe commencement of traffic accommodation, and other bridge project related issues,
- Implementation of channel diversion works,
- Completion of the excavation of the foundation,
- Completion of the bed preparation (the consultant shall assure that appropriate compaction is obtained),
- Completion of the assembly of the culvert plates,
- Placement of the structural backfill (the consultant shall assure that appropriate compaction is obtained),
- Concrete operations for the concrete end treatment,
- Completion of the site trimming, riprap placement, clean up etc as related to the bridge project, restoration of water flow,
- Semi-final inspection.

Note: *See "Bridge Design Bulletin #2, 2004"*
http://www.trans.gov.ab.ca/Content/doctype30/production/DesignBulletinNo2.pdf

1.24 WATERPROOFING CONCRETE STRUCTURES

Background:

Protecting structures from the corrosive effects of de-icing salt is an ongoing problem for the department. Measures currently being taken to protect concrete structures include waterproofing systems, protective sealers, extra cover to reinforcement and epoxy coated reinforcement.

The exterior surfaces of buried concrete structures typically receive a protective sealer and this has been considered adequate to-date.

Concern has been expressed that, given time, buried concrete structures under low fill situations may be adversely affected by salt to the same degree as concrete decks.

Considerations:

Reducing the potential for future maintenance,
Inability to inspect exterior concrete surfaces or surfaces covered by structural plate.

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.

1.25 EXTENSIONS

Background:

Experience has shown that placing additional fill over an existing culvert usually leads to problems. The weight of additional fill causes further settlement of the embankment and foundation, which results in a redistribution of loads. Often the original pipe becomes distressed. In older culverts this typically shows up as cracked seams or deformation of the barrel.

Once in contact with soil, a culvert will start to lose its galvanic protective coating. The amount and rate of corrosion depends on age and how corrosive the soil conditions are. Additionally, when an extension is added with its fresh coat of galvanizing, two dissimilar metals come into contact. This can set up a corrosion cell and cause the culvert extension to corrode more rapidly in the area of contact between the two culverts.

Considerations:

Structural adequacy of culvert to take additional load,
Condition of culvert (deformations, cracked seams, corrosion),
Hydraulic adequacy,
Cost of extension versus cost of replacement,
Cost of detours,
Inconvenience to travelling public,
Condition of existing foundation (saturated, eroded).

Recommendations:

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,
- Grade raise exceeds 2.0 m.

***Note**: A detailed engineering assessment should be carried out prior to extending any culvert.*

1.26 LOW LEVEL CROSSINGS

Background:

Under certain conditions it may be considered appropriate to install a low level crossing. Typically this would be on very 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' i.e. land access situations, seasonal farm equipment etc.

Considerations:

Acceptable level of inconvenience,
Safety of the travelling public,
Design flow frequency,
Cost share arrangements,
Warning signs,
Potential for drift and ice,
Environmental concerns including fish passage,
Benefit/Cost analysis,
Navigable Waters Protection Act.

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 crossing 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. It is important therefore that whenever a low level crossing is being considered, the Coast Guard be contacted at the earliest opportunity for a ruling on navigability.*

1.27 CATTLE PASSES

Background:

The provision of a cattlepass, (which may sometimes also include accommodation for small vehicles), typically forms part of the right-of-way negotiations and agreement. To reach an equitable solution several factors are considered i.e. the size (diameter and length) of the structure that will be needed, site-specific requirements, capital costs, user costs (land and highway), 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 ROW buyer.

Considerations:

Traffic volume on the highway,
Number of animals crossing the highway,
Frequency of crossing,
Land severance,
Right-of-way acquisition.

Recommendations:

- Minimum rise should be 2200 mm.
- Provide concrete floor to a minimum depth of 150 mm at the invert with rough textured surface or, alternatively, consider a compacted granular floor.
- Length should be determined so that the sideslope terminates at the top of the floor level when no bevel is used.
- Ensure surface water does not pond inside the structure by setting the inverts slightly above adjacent ground, by longitudinally sloping or crowning the inverts, and by employing ditch drainage when necessary.

1.28 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 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 concerns,
Proximity to residential or recreational area,
Height of cover,
Minimizing liability.

Recommendations:

- Consider installing a marker system and/or warning signs at all culvert sites located within or near residential or recreational areas.

- Provide railing for all pedestrian walkways located immediately adjacent to the ends of the culvert.

1.29 CORROSION & CATHODIC PROTECTION

Background:

Corrosion is a natural process that breaks steel down into its constituent components. Based on the 1990 corrosion survey it is estimated that about 50% of the culverts on the primary highway system have corroded to an extent which warrants cathodic protection. The estimated cost of providing the level of protection recommended is approximately $8M, excluding annual operating costs.

Cathodic protection (CP) is an electrical method of preventing soilside corrosion on new steel culverts or arresting corrosion on existing culverts. The overriding consideration when deciding whether or not to provide CP is economics, i.e., is the cost of providing and maintaining CP less than the cost of prematurely replacing the culvert?

There are two types of CP system, the impressed (or rectifier) system and the passive (or galvanic) system. The choice of which to use is dictated by current requirements, availability of an external power source, and cost. Currently there are 18 CP systems in operation in Alberta

Considerations:

Structural integrity and remaining life,
Age, condition of coating, and static potentials,
Hydraulic adequacy,
Ground resistivity and pH values,
Power requirements,
Cost of CP versus early replacement.

Recommendations:

Arrange for a corrosion survey to be carried out by a qualified Corrosion Specialist at sites known or suspected to have a corrosive environment. A corrosion survey should also be considered for new ‘metal culvert’ sites where a significant capital expenditure of funds is being proposed i.e. >$200K, or where a life expectancy in excess of 35 years is highly desirable i.e. high fill situations, high AADT, strategic crossings, etc.

Typically a corrosion survey should include but not limited to:

- Collection of resistivity and pH values of the soil and water. (Suggestions that further data be collected i.e. sulphide, sulphates, and chlorides may made by the Specialist as a follow-up to the initial survey, and any such requests would have to be justified and evaluated on a site specific basis).

- If the existing structure is a metal culvert static potential readings should also be taken between the soil and the culvert to establish the condition of the soilside galvanizing, and the rate (lbs./annum) at which the existing galvanizing has been consumed. (This type of information is probably the most realistic method for estimating the remaining life of a metal culvert, and of predicting the future performance of a new installation).

- Evaluation of the life expectancy of the proposed culvert, possible options to mitigate corrosion i.e. alternative coatings or materials, cathodic protection etc. (All recommendations should include associated costs, together with the estimated increase in life expectancy).

If the evaluation includes a recommendation that cathodic protection be provided to arrest soilside corrosion, the following additional work will be required:

- Site investigation and survey. This survey would identify a possible power source, location of utilities in the vicinity that may be affected by the proposed work, and/or the operation of a cathodic protection system i.e. stray currents.
- Site specific design, construction drawings, specifications and SP's, materials list, etc. The 'package should also include estimated capital and operating costs, installation instructions, operating procedures, and maintenance recommendations.
- If the system requires an impressed current then a standard electrical service agreement with the appropriate Utility Company will be drawn up, and a method of payment put in place. (These steps are not required for a passive system).

Note: *Based on experience and past performance it is recommended that cathodic protection is not placed on existing culverts that are hydraulically and/or structurally inadequate, or are already in an advanced stage of corrosion.*

Also see Best Practice Guidelines – Corrosion Survey for Metal Culverts
http://www.trans.gov.ab.ca/Content/doctype30/production/BPG1.pdf

1.30 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.

1.31 SITE SURVEY REQUIREMENTS

The **site survey** for bridge size culverts is generally requested by Regional Bridge Staff, in writing, with reference to 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. This additional information will be requested at the same time as the request is made for the site survey.

The Regional Bridge Staff should be contacted if any questions or problems occur regarding the survey request.

The **site survey** data is used to assess the water flow characteristics of the existing channel and to determine the location of the proposed crossing or improvement works and dimensions of the proposed structure. It is necessary that all the survey information gathered be accurate in order to optimize the bridge design.

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** to be drawn at a scale of 1:500 and to extend a minimum of 100 m upstream and downstream from the proposed centreline and a minimum of 25 m beyond top of banks.

The following information should be shown on the plan:

a. 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.

b. Proposed access roads and intersections.

c. Location of proposed centreline and baselines.

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

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

f. Location of test holes (check with Geotechnical Services Section, Technical Standards Branch).

Natural Scale Profile

The **natural scale profile** is also used to determine natural flow conditions and assist in designing the waterway opening. The locations of abutments, headslopes, pier(s), culvert ends, as well as the hydraulic gradeline are determined from these profiles. The profiles should be plotted at the scale noted in the request. The natural scale profile is an elevation view of the crossing on proposed centreline plotted to the same horizontal and vertical scale. The profiles 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, test holes, 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** is to be drawn at a scale of 1:100 (or 1:200) and to extend along proposed centreline and along 15 m left and right sodlines for a minimum distance of 25 m each direction from the centre of the creek.

The profile should show the following:

a. All breaks in natural ground on centreline and along sodlines particularly at the river.

b. Streambed profile and water level elevation.

c. Profile over and under the existing bridge deck (if applicable). This should include shots at centreline of bearing at the piers and abutments.

d. Upstream and downstream invert elevations of existing culvert (if applicable).

e. Elevation of high-water marks and their locations.

Streambed and Water/Ice Level Profile

The **streambed and water/ice level profile** is used to assist in determining the design water and ice levels. They also assist in determining flow velocities through the proposed crossing. The streambed and water/ice level profiles give an elevation view along the deepest part of the channel. They show the channel bed and water/ice levels at the time of survey. Shots should include high-water marks, scour holes, waterfalls, beaver dams, utility crossings, and any other unusual features. Due to the variability of streambed elevations, often a substantial length of profile may be required to obtain an accurate estimate of the channel gradient.

The **streambed and water/ice level profile** is to be drawn to a scale of 1:1000 horizontal and 1:100 (or 1:50) vertical and to extend a minimum of 260 m upstream and downstream of proposed centreline (survey should extend 500 m in each direction if structure is to be placed on a diversion). Shots on water level and streambed may be taken at 20 m intervals along the deepest part of the stream.

The profile should show the following:

a. Shots to be taken on both sides of beaver dams, drops, or other obstructions.

b. Note high-water marks and their corresponding locations and elevations.

Highway/Road Profile

The **highway/road profile** is needed to establish the final 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 be drawn at a scale of 1:5000 horizontal and 1:100 (or 1:200) vertical and to extend along proposed centreline and along 15 m left and right sodlines for a minimum of 500 m each direction from centre of creek.

Cross-sections

The **cross-sections** are used to define the shape of the channel and the width of the bed. They also help to assess flow capacity and indicate the natural stability of the banks. These sections can be used to assess the overbank storage potential during peak flow or flooding situations.

The **cross-sections** are to be drawn to a scale of 1:200 and to be taken at 40 and 60 m upstream and downstream from the proposed centreline and perpendicular to the stream. The cross-sections should extend to a ground elevation of 3 m above streambed or if the ground is level the profile can be terminated and a note indicating such should be put in the notes. In addition, two cross-sections perpendicular to the proposed roadway should be taken at a distance of 15 and 30 m from each end of the bridge. They should extend the width of the proposed right-of-way.

Accuracy of Survey

Horizontal control should be established using locatable hubs. Bench marks should be located close to the crossing but sufficiently away from the construction area to ensure they will not be disturbed. 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. 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.

1.32 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-1436	Installation of Precast Concrete Baffles	REV 3
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-1611	Cathodic Protection Steel Culverts Impressed Current System Types 1, 2 & 3	REV -
S-1612	Cathodic Protection Steel Culverts Thermoelectric Generator System Types 4 & 5	REV -
S-1613	Cathodic Protection Steel Culverts Sacrificial Anode System Types 6 & 7	REV
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 -

http://www.trans.gov.ab.ca/Content/doctype30/production/stddwgsapr04.htm