STREAM CROSSINGS INTRODUCTION

Stream crossings have the potential to limit natural stream function, contribute to degraded water quality, and hinder movement of fish and other aquatic organisms. This chapter addresses issues specific to design of road crossings (e.g., culverts, bridges, and fords) that include factors such as channel stability, sediment, icing, and road approaches. Selection of the approriate type of stream crossing depends on several factors including frequency of use, channel size and type, fish passage, and cost. Crossing designs for a range of flows and channel types, including flood conveyance and fish passage criteria are covered. Funding is available through state programs for improving stream crossings to increase natural stream function and fish passage.

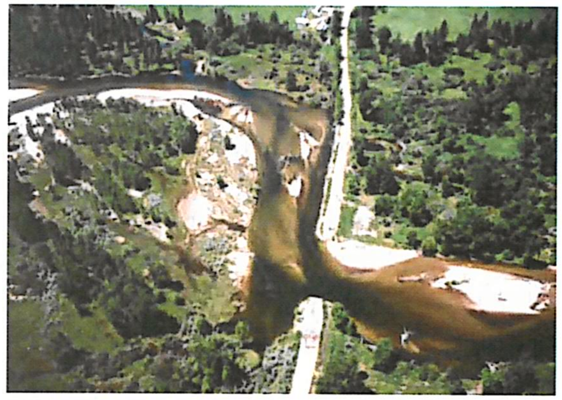
Readers are encouraged to consult with a qualified professional to insure requirements for road crossings are meet.

Contents

ROAD CROSSINGS AND CHANNEL GEOMETRY

Stream crossings on perennial streams include:
- Bridges
- Culverts
- Fords

Stream-crossing designs must consider:
- Channel geometry
- Peakflow capacity, scar, and erosion
- Bedload, ice, woody debris passage
- Fish passage
- Road approach grades
- Floodplain impacts (such as diking with fill)
- Relative cost
- Potential upstream and downstream effects



Choosing a location with a stable cross section is critical to project success. This failed bridge had inadequate span and was located on an actively migrating river reach. Over time, the river migrated to the west (top of photo) and the bridge location no longer matched the river alignment.

Channel Stability and Crossing Location

Channel stability and geometry must be evaluated for all stream crossings. Specifically, the design must take into account vertical (degrading or aggrading) and lateral (bank erosion and channel migration) instability.

Vertical Instability

- Downcutting can scour and undermine bridge abutments.
- Culverts control streambed elevation upstream, but downcutting may leave the outlet perched above channel. This tends to restrict fish passage.
- Aggrading channels can fill bridge and culvert cross sections and reduce channel capacity.

Lateral Instability

- Channel migration results in poor alignment of culverts and bridges over time.
- Abutments and road fill may erode with poor alignment.
- Sediment transport is interrupted by poor alignment.

Location

- Choose a crossing site in a stable, relatively straight reach of channel where possible.
- An incised (deep, narrow) channel cross section is preferred to a wide, shallow location.
- Look up and downstream of the crossing for signs of overall channel stability.
- Choose a location where the road approach will be level or slightly rising.

ROAD APPROACHES

Road approaches require planning

- Road approaches at stream crossings should be graded to rise slightly to meet the abutments. This reduces the potential for storm runoff to deliver road sediments to the channel.
- Long, steep grades and side cast fill may deliver substantial amounts of sediment to streams.
- Install proper drainage features such as rolling dips, cross drains, road crown, and ditches.
- Follow state BMPs to minimize sedimentation.
- Avoid long road approaches that form a dike across the floodplain.

Stream crossings with long, steep downhill approaches often route sediments directly to the channel.

Stream crossings on shallow channels with broad floodplains must rise to meet the bridge, or the bridge will end up being too low, like this one.

Guidelines

- Maintain road approaches at 2 percent grade or less, preferably rising to meet the abutment.
- Drainage features should be provided every 200 feet on long downhill approaches; route drainage through a filtration zone before entering a stream.
- Select a crossing location to avoid long road segments that sidecast road fill into the floodplain.
- Stabilize road fill with reseeding, slash windrows, hay bales, erosion fabric, or silt fence to prevent sedimentation of channels.

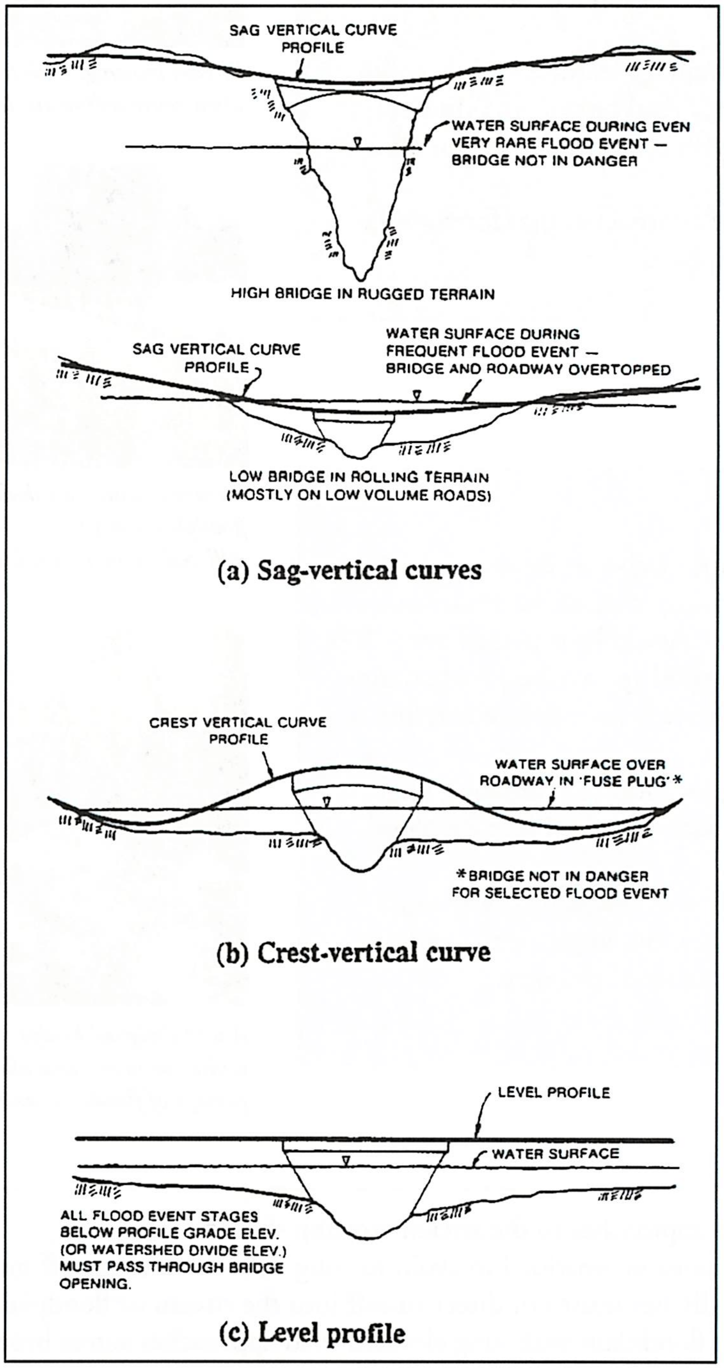
A well designed bridge spans the bankfull channel width (or more) and allows sufficient clearance for passage of flood, ice, and debris.

CAUTION

- Long, steep road approaches to the stream crossing should be avoided
- Proper drainage must be provided to avoid routing surface water runoff into stream channels
- Long, in-sloped ditches must not direct runoff into the stream or floodplain
- Avoid diking the floodplain with long elevated road approaches across broad flat valley bottoms

ROAD APPROACHES (continued)

When possible, road approach fill for bridges and culverts should be placed low and near the floodplain elevation so the road will be overtopped before the bridge or culvert is washed out. This allows the relatively inexpensive repair (replacing road fill or surface) instead of replacing a bridge or large culvert. By placing road approaches low, the road approach acts like an emergency spillway, passing flood waters that the bridge or culvert is unable to pass. Examples of road approach fills across floodplains and channels are shown below.



From FHWA HEC-20, Stream Stability at Highway Structures

ROAD CROSSINGS AND SEDIMENTATION

Roads can contribute significant amounts of sediment to streams

Erosion from roads near streams can be a significant source of sediment, harming water quality and fish habitat.

Some studies suggest that in the mountainous West, forest roads contribute as much as 85-90 percent of the sediment reaching streams in disturbed forest land.

Main Sources of Sediment

- Stream crossings (improperly designed approach grades, poorly armored culvert inlets or outlets)
- Side casting during road maintenance
- Unstable fill slopes on roads parallel to streams
- Poorly designed or ineffective drainage features (ditches, cross drains, water bars)
- Erosion from cut slopes

To avoid harm to fisheries and water quality, roads and stream crossings should be designed to reduce the potential for sediment delivery. Such projects warrant careful attention to grading and drainage. Road approaches should be kept below 6 percent grade if possible, and provided with drainage relief every 200 feet on the approach to the crossing. Vegetated swales and filter zones can reduce sediment before runoff reaches the stream. Drainage relief swales may need to be armored for long-term stabilization.

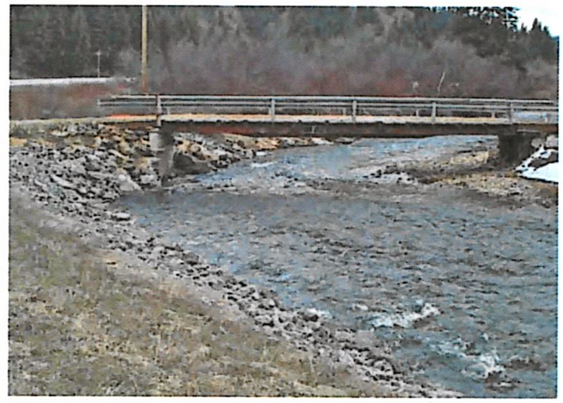
For more guidance, see Forestry Best Management Practices and the Sediment and Erosion Control Manual, which are both available from DNRC.

Poor drainage on granitic soils can deliver large amounts of sediment to streams.

Silt fence helps prevent sediment delivery on newly constructed roads, but does not substitute for proper drainage features.

FLOW CAPACITY

Instream hydraulic structures should generally be sized to handle the 100-year flood and, at a minimum, the 25-year flood. Flood peaks are estimated from regional regression equations, stream gaging stations, or measurements of channel geometry and high water marks. Regional regression equations for Montana provide a reasonably good first approximation. The USGS website includes a method called StreamStats, and enables estimation of peak flows.



This bridge is set slightly above bankfull, but does not have wingwalls. Location on a meander is not ideal, although upstream rip-rap limits lateral movement. Note, point bar is still growing under bridge.

Bridges

Sizing is accomplished by modeling with hydraulic programs, and evaluating backwater conditions on rivers with official floodplain mapping. County floodplain regulations generally allow no more than 0.5 foot of backwater for bridge designs.

Smaller bridge structures should seek to accommodate the bankfull channel width with a clear span, and avoid constricting the channel during major flood events (25-year or greater). Designs should pass estimated flood peaks without substantial backwater (pooling) upstream. Relief culverts may be needed in side channels or floodplain.

This arch pipe is sized to carry the predicted 25-year flow, but causes backwater at the 100-year flow.

Culverts

At a minimum, drainage culverts should be sized to allow passage of a 25-year flood event with a full inlet. On perennial streams, consider sizing the pipe to pass the 100-year event to minimize backwater conditions. Adequate capacity is especially important on streams with high bedload transport, icing potential, or large amounts of woody debris. Culvert designs with arch, box-shaped, or round pipes with flared inlets provide better peak flow passage than standard round pipes.

Fords

Properly sited and constructed fords can replicate natural channel geometry and thus do not normally have peak flow capacity or debris problems. For this reason, fords may be a viable alternative to fixed structures in some situations.

A well-designed box pipe enables fish passage by retaining a natural channel bottom substrate.

PLANNING FOR BEDLOAD / WOODY DEBRIS / ICE

In river systems with high bedload transport ice jams, or large amounts of woody debris, the crossing structure must allow for passage of these materials. High bedload transport channels have characteristically large width-to-depth ratios. A bridge or culvert cross section has a much lower, fixed width-to-depth ratio. Even in the absence of large backwater effects, the change in channel hydraulics through a structure can interfere with sediment transport.

This undersized culvert caused large amounts of gravel to deposit in the channel upstream. Woody debris must be cleaned frequently from the inlet.

Bridge and culvert design must account for:

- Probable reductions in bridge cross section and flow area with gravel deposition (or debris on piers)
- Bedload conveyance through the bridge cross section
- Potential changes in channel alignment and bank erosion in adjoining reaches
- Ice jams

Bridges are generally preferred to culverts where debris, ice, and bedload sediment concerns are substantial. Proper sizing for targeting 100-year flood conditions generally addresses bedload, debris, and ice concerns by ensuring adequate peak flow capacity. Woody debris passage generally requires 1 or 2 feet of clearance between the bottom of the bridge stringer and the high water surface. Ice passage also requires extra clearance.

A rule of thumb on smaller bridges is to allow at least 2 feet of clearance between the top of the stream bank or floodplain and the bottom of the stringer. If debris jams and icing are a problem, increase the span, do not use centerpieces, and include ice breakers on the front of piers.

This bridge stringer was set below bankfull, and had problems with ice jams and flow capacity.

Debris jams are often associated with center piers on bridge crossings. A clear span is preferable to piers.

CULVERTS

Culverts can perform well on stream crossings, provided they are properly sized to handle peak flows. Fish passage must be considered when selecting and placing a pipe.

Undersizing pipes to save money is a poor strategy.

Culvert Styles

- Round – standard corrugated metal or concrete pipe
- Pipe Arch/Squash – less backwater and lower final fill elevation than round pipe
- Arch – wide open bottom facilitates passage of fish, debris, and sediment
- Structural Plate – larger size of arch pipe, bridge substitute
- Plastic Round – similar to round corrugated culvert, easy to handle, but can be harder to install properly
- Concrete Box – flat concrete bottom is poor for fish passage, unless the pipe is specifically designed to retain channel bed material

Bottomless arch or box pipes (shown here) promote fish passage and create less backwater than round pipes of the same size, but can be susceptible to scour.

Design and Installation

- Size culverts to handle a 100-year flood, if possible.
- Culverts must be long enough to accommodate road fill slopes.
- Sizing is generally adequate when bankfull cross sectional area is equaled.
- Inlet water elevation at design flow should not exceed the elevation of top of pipe (no headwater).
- Place culverts on grade, or slightly below grade of stream bed ensuring natural substrate can pass through and fill the bottom
- Footings for bottomless culverts must be set well below the expected scour and frost depths.

CAUTION

- Proper siting of culvert crossings in a stable, relatively straight reach is critical.
- Culverts must adequately pass peak flows, debris, ice, and allow fish passage.
- Culvert crossings should be avoided in aggrading streams, or on laterally unstable stream locations.
- Fisheries considerations may require natural streambeds or structures to ensure passage of certain species or age classes.
- Corrosive soil or water conditions may damage metal pipe.

CULVERTS (continued)

Culvert Placement

Headwater Channels (Rosgen A)
- Typically steep gradient channels with deep fill over pipe
- Culvert length must be adequate to accommodate fill slopes

Mid-Valley Channels (Rosgen B)
- Moderate gradient channels, often cobble bottom with narrow floodplains
- Adequate ice and debris passage can be difficult to accommodate with pipes

Valley Bottom Channels (Rosgen C/D)
- Low gradient channels often with poor lateral stability
- Undersized pipes can cause gravel deposition and channel instability upstream
- Site selection in stable reach is critical
- Bridges and open bottom arches should be considered to accommodate channel dynamics and debris

Valley Bottom Channels (Rosgen E)
- Sinuous, narrow, deep channels, often silt or fine gravel beds with broad floodplains
- Round and especially arch pipes can work well
- Avoid raising fill across floodplain on approach road to crossing

Downcutting Channels (Rosgen G)
- Vertically unstable channels with downcutting
- Scouring downstream of pipe will leave the "downcutting" pipe perched above grade at the outlet unless the stream grade is stabilized

Appendix 1 has a complete description of Rosgen Stream Types

A well designed culvert allows for passage of flood events, and ideally, retains channel substrate material in the culvert to promote fish passage.

The shotgun (or perched outlet) culvert impedes fish passage, and can result from placing the culvert too high, or installing the culvert in a channel that has a tendency to downcut without grade control downstream of the outlet.

Multiple pipes are sometimes acceptable, but they can catch debris. Consider aluminum box or squash pipes.

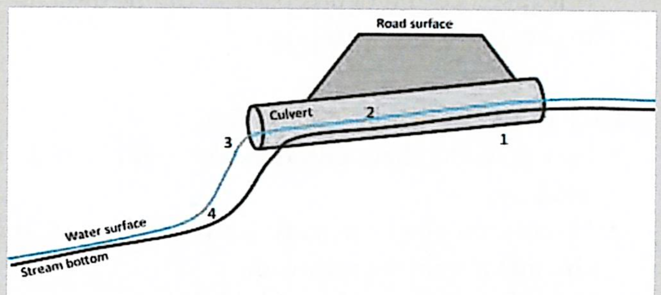
CULVERT DESIGN AFFECTS FISH PASSAGE

A fish passage barrier can be anything that hinders any life stage of fish from moving through a waterway. Barriers are classified as jumping (it is too high), velocity (the water is too fast), or both. They can be considered full barriers (inhibit fish movement year-round) or partial barriers (part of the year, typically depending on streamflow). Barriers can vary based on species and life stage.

Culverts are designed to allow water to flow through them, but often do not provide adequate passage for fish or other aquatic organisms. The drawings below demonstrate key components to designing fish friendly culverts. The program FishXing is helpful when considering fish passage in a project. Information on design for fish passage, including no-slope and stream simulation culverts, are found in the following pages.

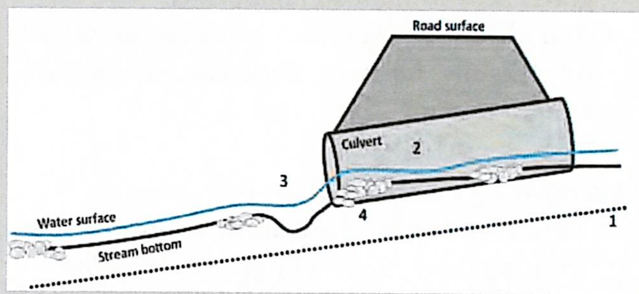
Poor Fish Passage

1. Steep culvert without grade controls to reduce slope and provide rest.
2. Flow too fast for fish to swim through.
3. Jump too high at outfall.
4. No pool at outfall entrance to assist a jump.



Optimal Fish Passage

1. Culvert that matches slope of channel.
2. Grade controls that provide slower flow and resting areas.
3. No jump at outfall or minimal jump with a pool.
4. Natural streambed, either with embedded or arched culvert.



Optimal fish passage

Steeper gradient streams may require rock pools. All things being equal, shorter culverts are easier for fish to pass.

CULVERT DESIGN FOR FISH PASSAGE

No-Slope Culverts

No-slope culverts (and stream simulation culverts on the next page) are designed to simulate a natural stream-bed allow for a stable streambed inside and natural movement of bedload in some settings. Large streams over 15 feet wide will usually require a bridge.

Suitability of the site

- Small channels generally < 10 ft Bankfull Width (BFW)
- Low gradient channels generally < 3% but higher gradients may be acceptable
- Culvert installed at zero gradient
- Width of the bed in the culvert is equal to the bankfull width

Culvert type and size

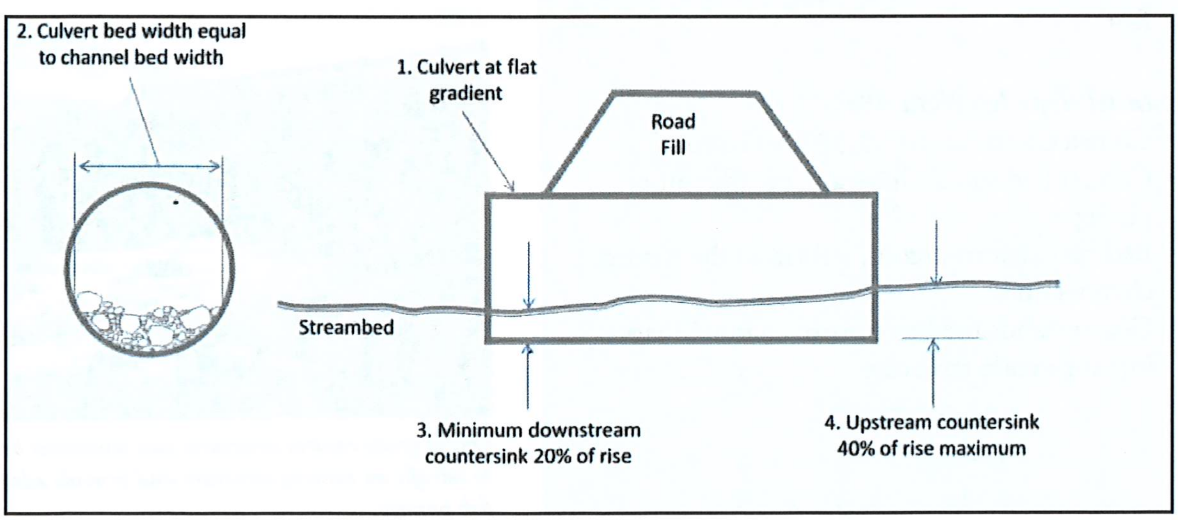
- Culvert length generally < 75 ft
- Round pipes preferred to achieve embeddedness

Application

- Bottom of the culvert is set below the down-stream bed 20% of its rise
- Limit the inlet countersink to 40% of the rise
- Bed placed in the culvert that is composed of material similar to the bed of the adjacent stream
- Adequate clearance between the culvert bed and crown is provided to pass expected debris during flooding events

Pipes must be designed to retain bed material. This generally requires sizing the pipe not just for hydraulic capacity but to accomodate flood events and retain bed material in the pipe.

Open bottom arches work well for larger channels, although accomodating spans more than 10 feet becomes challenging.



CULVERT DESIGN FOR FISH PASSAGE

Stream Simulation Culvert

Stream simulation designs create a natural channel bed and maintain channel processes within the culvert, similar to the adjacent channel. The idea being, if fish can migrate through the natural channel, they can also migrate through a man-made channel that simulates it.

Application

- Moderately confined channels
- Bankfull width less than 15 ft, with exceptions, or slope > 3%
- Any equilibrium stream slope
- Stream simulation culverts with a length-to-width ratio > 10 are considered long and need special design consideration and an increase in recommended width

Suitability of the site

- Design requires geomorphic assessment of stream reach
- Method tolerates little or no lateral channel movement
- Method tolerates moderate vertical instability
- Culvert bed slope should not be greater than 1.25 x upstream channel slope

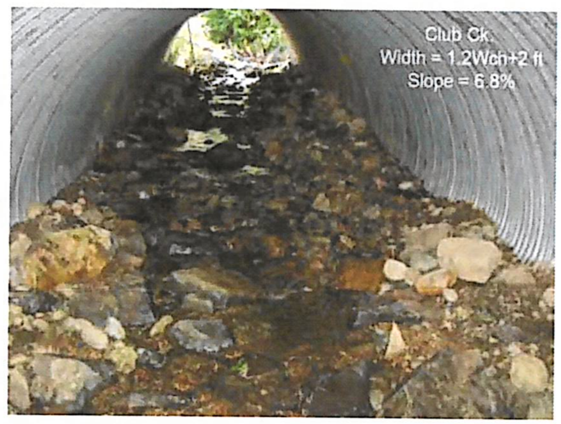
Culvert type and size

- Any culvert type may be used for stream simulation
- Width of bed inside culvert = 1.2 x BFW + 2 feet

Channel slope less than 4%

- Countersunk culvert 30-50% of its rise
- Culvert bed should have a pool-riffle morphology
- Bed may deform, scour, reform as the natural channel does
- Coarse bands used to control channel shape, initiate stream structure

Stream simulation must ensure that bed material can be retained inside culvert. This may require hydraulic modeling and specific design criteria for material within pipe.



Note that stream simulation culverts must be 120% of bankfull width plus 2 feet.

Outlet grade control structures can sometimes be used to retrofit an existing structure and provide adequate fish passage.

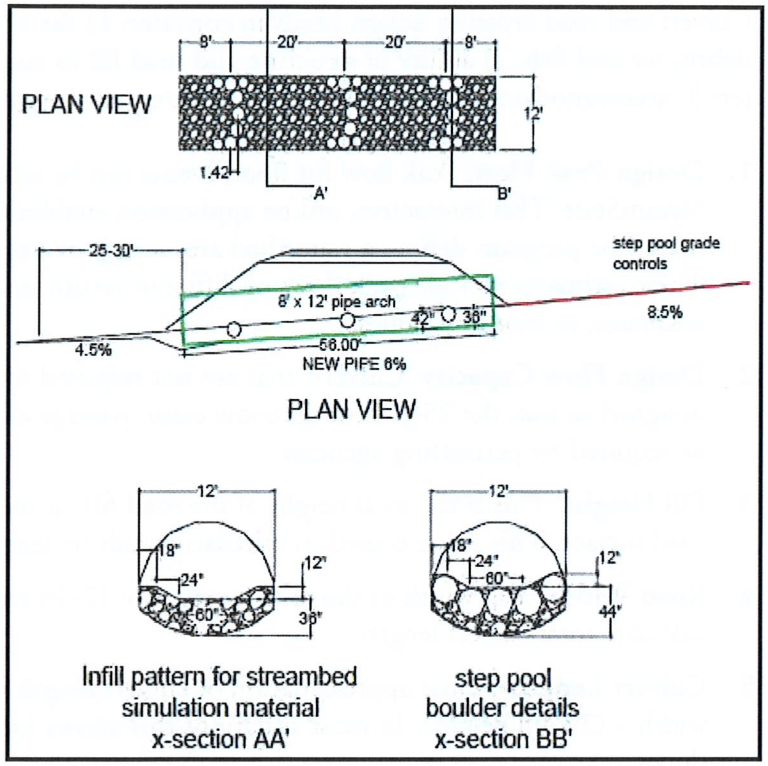
CULVERT DESIGN FOR FISH PASSAGE

Channel slope greater than 4%

- Countersunk culvert 30-50% of its rise
- Culvert bed should have a cascade or step-pool morphology
- Bed tends to be stable over time
- Bed structure is built-in at the time of construction

Bed substrate design and specification

- Bed material is similar to the natural channel, although coarser substrate may be needed to increase stability
- Sediment distribution should be well-graded, non-porous, with 5-10% fines
- Sediment size can be determined by measuring the adjacent channel sediment size and/or using sediment stability analysis



Grade control may be required at culvert outlet to prevent downcutting.

CAUTION

- Culverts must be carefully sized to retain bed material at peak flows
- Undersized culverts will impair fish passage and potentially result in channel downcutting
- In general, culverts are unsuitable for streams greater than 15 feet wide, and 10 feet may be the practical upper limit in some circumstances
- Culverts longer than 75 feet will normally require resting pools to meet fish passage criteria for all life stages
- Resting pools are difficult to incorporate into most designs; and, therefore, bridges are a preferred option

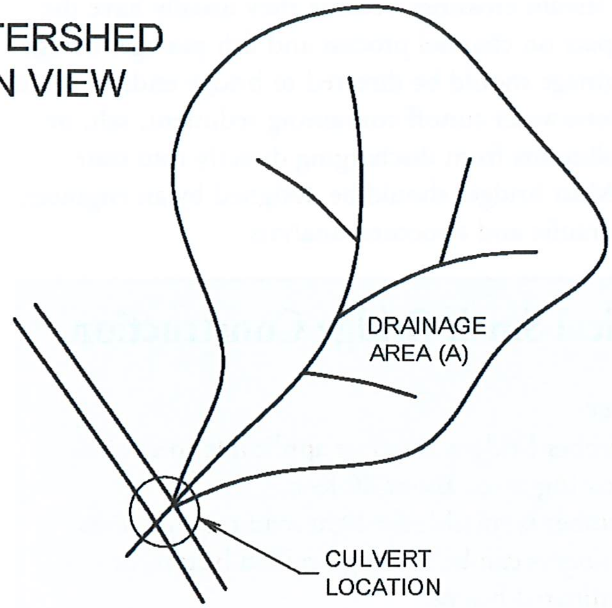
GUIDELINES FOR CULVERT DESIGN

Culvert and road crossing design needs to consider: 1) the ability to pass peak flows, sediment, woody debris, ice and fish; 2) ability of structure and road fill to accommodate flooding and minimize backwater; 3) accommodate specific provisions for fish/aquatic organism passage as required by agencies.

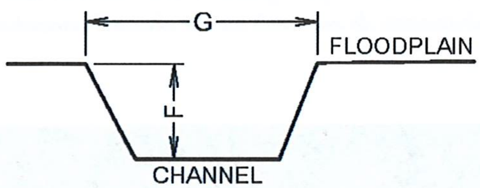
1. **Design Peak Flow.** Peak flow for flood events can be estimated from the USGS program called StreamStats. This interactive, online application enables the user to select a stream location from a map. The program defines a watershed area and provides estimates for a range of flow conditions. These estimates include peak flows of different return intervals (e.g. 25-yr and 50-yr flood), low flow estimates, or monthly values.
2. **Design Flow Capacity.** Culverts that are not required to provide fish passage should generally be designed to pass the 25-yr flow. In some cases, passage of the 100-yr flood is recommended, or may be required by permitting agencies.
3. **Fill Height.** This is the total height of the road fill, as measured from the channel bottom to the road surface. This value is used in calculating culvert length.
4. **Road Width.** Top width of the road is typically 12-14 feet for single lane road. This value is used to calculate total culvert length.
5. **Culvert Length.** A first approximation of culvert length with fill slopes of 1.5:1 is equal to road width + (3 x fill height). In most situations this allows for sufficient length to accommodate road fill slopes.
6. **Channel Depth.** Bankfull depth as measure from the channel bottom to the active bankfull floodplain. Identifying bankfull depth from the channel bottom can help define the width of channel that will be expected to flood every 1.5 to 2 years.
7. **Channel Width.** Culverts should span the entire bankfull width at a minumum to allow passage of fish, peak flow, sediment, debris and ice. Guidelines for fish passage may require widths in excess of bankfull (i.e., stream simulation culverts) for channels > 5 ft wide, or slopes > 2%.
8. **Culvert Type.** Culvert shape (round, arch, box) and material (metal, concrete, plastic) should be identified.
9. **Culvert Diameter (span).** The width of the culvert should generally span the bankfull width, particularly if fish passage is required, or heavy woody debris loads/icing are common.
10. **Culvert Embeddedness.** The depth the culvert will be embedded into the streambed, if required for fish passage. Note, a culvert should not be buried below stream grade if it is not properly sized to accommodate flood events, or the full bankfull width of the channel. An undersized culvert can result in scour and stream bed downcutting in alluvial channels.
11. **Provision for Fish Passage.** Culverts should be designed to provide a means of fish passage. This is particularly important in high value fisheries including tributaries that provide spawning and rearing habitat. Guidelines for fish passage are found in the road crossing section of this guide, and also in the State of Washington Water Crossing Design Guidelines (2013). In general, the upper practical limit for culverts is a 10-12 foot span at which point bridges become the preferred approach. The MFWP fish biologist that consults on the 310 permit can help select options.

Culvert Design

WATERSHED PLAN VIEW



CROSS SECTION



1) DRAINAGE AREA (sq. miles) A = __________

2) PRECIPITATION (IN) ppt = __________

3) DESIGN 25 YR. 100 YR. FLOOD, (cfs) Q = __________

4) FILL HEIGHT (ft) (CHANNEL BOTTOM TO ROAD) B = __________

5) ROAD WIDTH (ft) C = __________

6) CULVERT LENGTH (C+(3xB)) (ft) E = __________

7) CHANNEL DEPTH (ft) F = __________

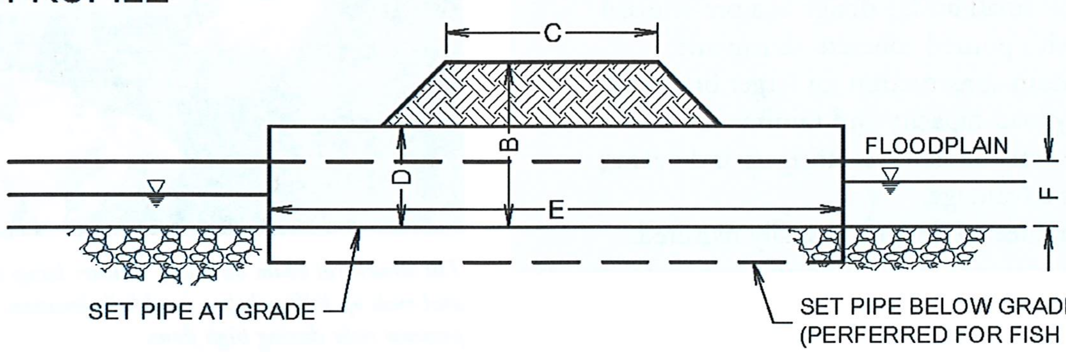
8) CHANNEL WIDTH (ft) G = __________

9) CULVERT TYPE (ROUND, ARCH, BOX, __________)

10) CULVERT DIAMETER (in) D = __________

11) PROVISION FOR FISH PASSAGE __________
ZERO SLOPE PIPE, STREAM SIMULATION PIPE, AT GRADE

PROFILE



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DRAWN BY:	CHECKED:	FIGURE:	DRAWING TITLE: CULVERT DESIGN TEMPLATE

BRIDGES

Well designed bridges are the preferred option for permanent stream crossings because they usually have the least impact on channel process and fish passage. Bridge deck drainage should be directed to bridge ends to avoid direct stormwater runoff containing sediment, salt, or other pollutants from discharging directly into state waters. Most bridges should be designed by an engineer, with hydraulic and structural analysis.

Typical Small Bridge Construction

Timber

- Timber bridges are most applicable to stream crossing up to about 30 feet.
- Timber is suitable for light load requirements.
- Stringers can be raw logs, milled beams, or laminated beams.
- Raw log abutments can be labor intensive.
- Equipment needs for construction are modest.

Steel

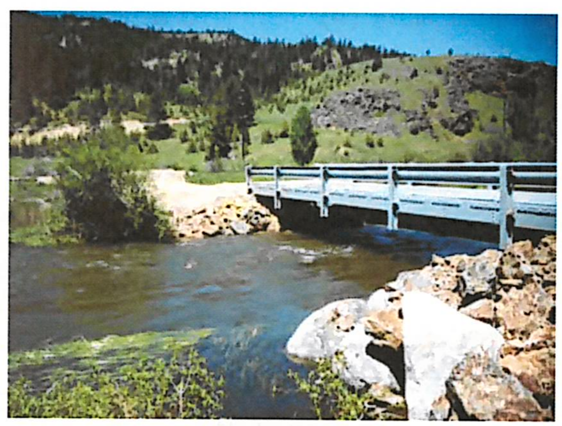
- Railcars can be used for bridges 30 to 65 feet. Longer spans usually require piers.
- Use steel I-beam, wood, or corrugated steel decking for 20 to 100+ ft. spans.
- Long project life is an advantage of steel.
- Steel allows a longer clear span than timber, reducing need for center piers, which can catch debris.

Concrete

- Typical small bridge design is a pre-stressed slab with poured concrete abutments.
- Use beam construction for larger bridges.
- Heavy load capacity and minimal beam depths for the slab (vs. stringers and beams) are an advantage.
- An engineered design is usually required.

This well-designed bridge has adequate clearance for ice, debris, and peak flows. Note, however, that the abutments do encroach on the channel somewhat.

Railcar bridges are popular and fairly solid, but often are not installed properly. This one is set low relative to bankfull, but it is a temporary installation.



The structural beam on many railcars hangs low and ends up falling below bankfull elevation, which presents risks during high flows.

BRIDGE ABUTMENTS AND PIERS

Abutments

- Abutment design must account for scour depth in the stream bed to prevent undermining of footings.
- Generally, the minimum depth for footings is below the frost line and piers should be well below the lowest point of the streambed at the crossing.
- Footings may need to extend 10 feet deep or more in unstable rivers.
- For most smaller bridge projects, observing the depth of nearby pools gives a good indication of minimum footing depth.
- Abutments can be constructed from a variety of materials, and should include wingwalls to stabilize road fill on the approaches.

Bridge Piers

Avoid designs with piers if possible because they tend to catch debris, causing scour and channel instability during peak flows.

- Wood spans exceeding 30 feet, or steel spans approaching 50-60 feet, require piers for support.
- Longer bridge spans requiring heavy load capacity should have an engineering review.

A well-constructed abutment has adequate wingwalls to support road fill.

Concrete can make good abutments, provided the footing is placed below scour depth. This footing should be 2 feet lower.

A low stringer in an aggrading channel does not leave much room for water. Note that the beam hangs low in the center and restricts peak flow capacity and debris passage.

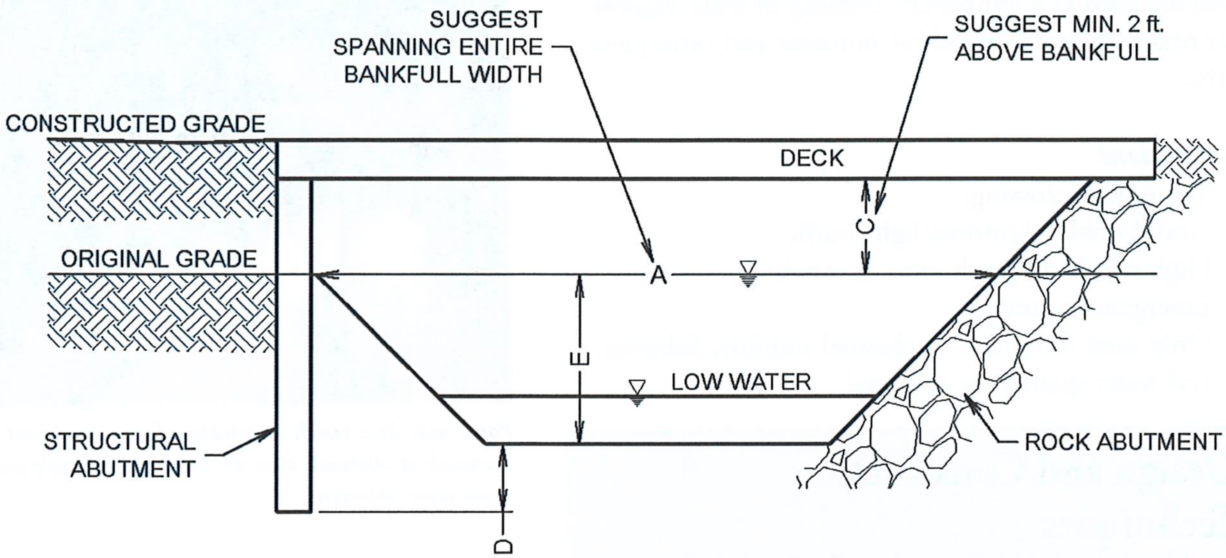
Concrete abutments are generally preferred, and must be protected from scour at the toe. Note the silt fence in place during construction to minimize turbidity.

GUIDELINES FOR BRIDGE DESIGN

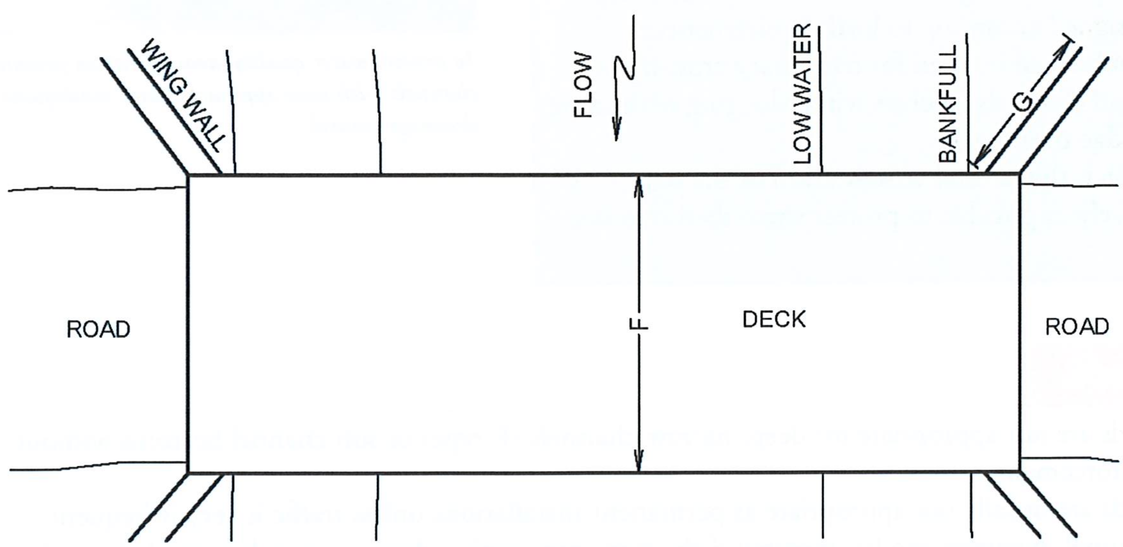
Bridge and road crossing design needs to consider 1) the ability to pass peak flows, sediment, woody debris, ice and fish, 2) ability of structure and road fill to accommodate flooding and minimize backwater, 3) accommodate specific provisions for fish/aquatic organism passage as required by agencies.

1. **Design Peak Flow Capacity**. Peak flow for flood events can be estimated from the USGS program called StreamStats. This interactive, online application enables the user to select a stream location from a map. The program defines a watershed area and provides estimates for a range of flow conditions. These estimates include peak flows of different return intervals (e.g. 25-yr and 50-yr flood), low flow estimates, or monthly values. In larger streams and rivers, flood flows and elevations may already have been established FEMA studies and maps (Digital Flood Rate Insurance Maps). Contact your local floodplain administrator to determine if your project is in a mapped floodplain. Specific design criteria and hydraulic analyses are required in mapped floodplains. Bridges that are not required to provide fish passage or meet FEMA criteria should generally be designed to pass the expected 25-yr flow. In most cases, unimpeded passage of the 100-yr flood is recommended, and may be required by permitting agencies.
2. **Bankfull Width**. At a minimum, bridges should generally span the entire bankfull width to allow passage of fish, peak flow, sediment, debris and ice.
3. **Span**. The bridge span is the length of the deck after subtracting any fill slopes beneath the bridge. Note that the deck length and the available room for the channel may differ greatly if the abutment fill slopes encroach on the channel. Plan to make the span wide enough so the fill slopes do not encroach on the channel.
4. **Stringer/Bankfull Clearance or Freeboard**. The clearance between the bottom of the bridge and the design high flow flood event should allow for sufficient room to allow passage of ice, woody debris, and floaters. A rule of thumb is to allow a minimum of 2 feet between high flow and the bridge stringer.
5. **Abutment Footing Depth**. The footings should be placed below the expected scour depth of the stream. The deepest pool in adjoining stream reaches can give an idea of probable minimum scour depth.
6. **Bankfull Depth**. Bankfull depth as measured from the channel bottom to the active bankfull floodplain. Identifying bankfull depth from the channel bottom can help define the width of channel that will be expected to flood every 1.5 to 2 years. This is generally a minimum width for bridges.
7. **Road Width**. Top width of the road is typically 12-14 feet for single lane road.
8. **Wingwall Length**. A first approximation of minimum wingwall length with fill slopes of 1.5:1 is equal to (bankfull height + clearance) x 1.5. In most situations this allows for sufficient length to accommodate road fill slopes.
9. **Bridge Type**. Bridge type and materials should be identified. A Professional Engineer or qualified professional should be consulted to insure bridges will support required loads.
10. **Abutment Type**. Abutments can be constructed as retaining walls, re-inforced fill slopes, pilings, or a combination or techniques.

Bridge Template



1) BANKFULL WIDTH (ft) A = ______
2) SPAN (ft) B = ______
3) STRINGER/BANKFULL CLEARANCE (ft) C = ______
4) ABUTMENT FOOTING DEPTH (ft) D = ______
5) BANKFULL DEPTH (ft) E = ______
6) ROAD WIDTH (ft) F = ______
7) WINGWALL LENGTH (D+E+C)x1.5 (ft) G = ______
8) BRIDGE TYPE ______________
9) ABUTMENT TYPE ______________



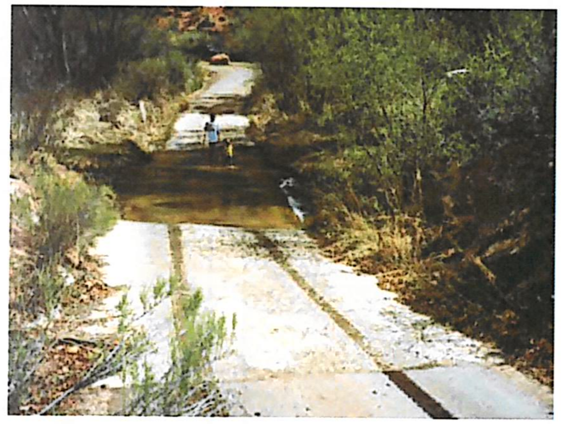
	PERMIT NO.:	DATE:	LOCATION:	PROJECT NAME: CD Manual
	PROJECT MANAGER:	NOT TO SCALE	FILENAME:	DRAWING TITLE: Bridge Template
	DRAWN BY:	CHECKED:	FIGURE:	

FORDS

Fords are used as a temporary crossing in wide shallow channels with gravel or cobble bottoms and infrequent traffic.

Applications

- Temporary crossings
- Gravel/cobble bottoms/light traffic
- High width-to-depth ratio channels
- Emergency access
- Only used if impacts to channel stability, fisheries, and water quality are minimal



Fords may be a viable alternative for intermittent channels or channels that are shallow and wide and resist other solutions.

Design and Construction Techniques

- Unreinforced fords can be effective in solid substrate with light traffic.
- With heavier traffic or softer gravel channel bottoms, channels generally require some type of reinforcement.
- Reinforcement materials include rock, timber, concrete plank, geogrid, and filter fabrics.
- Size rock to resist scour and stream shear stress.
- Use filter fabric to prevent pumping rock into soft channels.
- Geogrid rock/gravel filled mats, or fabrics are designed according to load requirements.
- Timber can be used for temporary crossing on small channels (such as winter logging with snow bridge over logs).
- Match the natural cross-section of the stream as closely as possible to protect streambed stability.

To protect water quality, avoid fords on perennial channels with poor approaches and inadequate drainage control.

CAUTION

- Fords are not appropriate for deep, narrow channels (E type) or soft channel bottoms without reinforcement.
- Fords are usually not appropriate as permanent installations unless traffic is very infrequent.
- Channel dynamics can be impaired if the ford cross section does not match natural channel cross section.
- Sediment releases, associated with traffic, may cause unacceptable harm to fisheries.
- Fords may be subject to travel restrictions.
- Road approaches must not direct road surface runoff into channel.