Technical Bulletin
Structure Selection for Stream Crossings

7/2022

Center for Dirt and Gravel Road Studies

STRUCTURE SELECTION for ROAD STREAM CROSSINGS – Selecting an appropriate structure for crossing replacement will reduce maintenance, improve stream continuity, and increase longevity of the

WHY DOES STRUCTURE SELECTION MATTER?

Every site presents unique challenges and structure selection is a critical component to the success of any stream crossing project. Selecting the proper structure is important in providing continuity of the stream through the road crossing and providing a long-term, low-maintenance solution to the road owner. A properly selected and designed crossing will meet the following objectives:

- ✓ 1.25 bankfull width minimum opening at bankfull elevation
- ✓ Stable grade controls and stream bed in the structure
- ✓ Stream continuity and passage of aquatic organisms
- ✓ Capacity to pass 100-year discharge (Q100) at 80% of the finished opening height

Figures in this document are general guidelines and vary by material and design. Always consult manufacturer for actual specifications.

Bank margins established to create a low-flow channel and protect the structure from scour.

Conducting a longitudinal profile is **essential** to making the best structure selection.

STRUCTURE SELECTION CONSIDERATIONS

Longitudinal Profile: A longitudinal profile conducted upstream and downstream of the structure is a required design practice that helps inform structure selection (see Longitudinal Profile Technical Bulletin). These surveys provide valuable information that can guide structure selection, such as: stream slope, scour depth, grade control spacing, vertical offsets of the existing structure, and potential depth or cover issues for the new structure.

Structure Width: Structures must be of adequate width to accommodate the bankfull flow width of the stream at the final bankfull flow elevation with bank margins, and account for bank slopes, road approaches, and site conditions. Under no circumstances can the structure width be less than 1.25x the bankfull width of the stream at the bankfull elevation (see Measuring Bankfull Technical Bulletin). For some structures with sloped sides, this means a larger than 1.25x bankful structure must be installed, since establishing streambed in the structure will decrease the effective opening size.

Capacity Requirements: All new structures must be designed to pass the Q100 discharge at a water surface elevation not to exceed 80% of the finished opening height.

Substrate Depths: As defined in the DGLVR Stream Crossing Standard, minimum requirements for establishing streambed through structures with inverts are based on pool depth and stream slope and are typically greater than permit requirements. Bottomless structures are encouraged and **required where the continuity slope of the channel to be reconstructed through the project area will be greater than 4.0% or the bankfull width is over 20'**, as determined by the longitudinal survey. Bank margins must be comprised of rock sized for stability at the Q100.

Depth of Cover: In situations with limited cover over the existing structure, structure choices may be limited. In some cases, additional cover may be used to elevate the road over a larger structure.

Alignment: New structures should be better aligned with the stream channel when possible. This often requires installing a longer structure to account for the skew across the road.

Other Factors: Proximity to bedrock, public utilities, expected traffic loading, who is installing the structure,

equipment limitations, bearing capacity of the local soil, private property issues, underground utilities, and other such complications may play a role in determining structure type and installation details.

COMMONLY USED STRUCTURE TYPES

Structures come in a wide variety of materials, widths, heights, and strengths to meet a variety of site conditions. Below are some commonly used structures. These are not the only options; contact manufacturers for a complete list of options and details.

> **Reminder**: The DGLVR Stream Crossing Standard requires bottomless structures if the reconstructed stream slope through the structure is over 4.0% or the bankfull width is greater than 20'.

Pipe Arch (squash): Pipe arches tend to be the most economical choice for smaller crossings, and most municipalities and contractors are familiar with them. They can be delivered assembled or in sections in a variety of sizes and materials.

Structural Plate Arch Pipe with Invert (Bottom): These structures come in a variety of materials, widths, and configurations. Placement of streambed material can be difficult, especially in low-profile structures, and special attention at bank margins is needed. Structures with sloped sides (see pictures at right) may need to be oversized (beyond 125%) to achieve a final 125% bankfull channel after establishing the streambed through the pipe.

Bottomless Boxes and Arches: A wide variety of structure materials, shapes, and designs fit this category. Several footer options also exist such as precast, express, or poured onsite. Site characteristics such as soil bearing capacities and the presence of bedrock can affect the cost and footing type required. These are typically easier to achieve and maintain stream continuity than structures with inverts or bottoms.

Concrete Box Culvert: These structures are heavy and expensive, but are commonly used in situations that require traffic support without adding cover over the structure.

Bridge: In larger stream systems, the best choice is often a bridge. It is recommended that a bridge is used when bankfull widths exceed 20 feet or stream slopes exceed 7-8%. Several alternatives exist to standard bridge abutment designs such as spread-footing or Geosynthetic Reinforced Soil abutments.

Round Pipe: Round pipes are not suited for use in stream channels. No round pipes over 36" in diameter are permitted to be used on DGLVR projects.

Other Structure Selection Considerations:

- How long can the road be closed?
- What are traffic loading requirements?
- Will structure have pre-fabricated headwalls and endwalls?
- What is the grade control size and streambed depth required?
- If the structure is bolted together, who will assemble?
- Is a geotech investigation needed to find soil bearing capacity?
- What is the minimum cover depth and will structure fit?

Pipe arch or "squash pipe" (6' wide) (CDGRS)

Arch pipe with invert/bottom (Cambria)

Bottomless arch pipe (York)

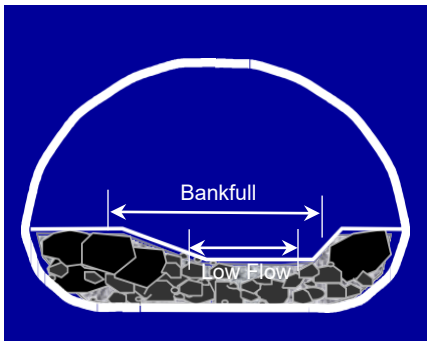
Bottomless concrete box culvert (Cumberland)

Spread footer bridge installation (Indiana)

Often the best way to get answers to questions about required cover, spans, shapes, etc. is to work directly with structure manufacturers.

Pipe Arch (squash pipes)

These structures come in a variety of widths and assembly configurations. Placement of streambed material can be difficult, especially in smaller structures, and special attention at bank margins is needed.



Schematic of a pipe arch with low-flow channel.

> **Reminder: The DGLVR Standard:**
> - Requires bottomless structures if the reconstructed stream slope through the structure is over 4.0% or the bankfull width is greater than 20'.
> - Defines required depth of streambed in the structure.

Delivery of a fully assembled 6' w x 4' h x 40' l pipe arch (CDGRS).

Sizes: Typically available up to ~20' in width. Available in various width-to-height ratios. The structure may need to be oversized (in excess of 1.25 times bankfull) in order to account for the required streambed materials, bank margins, and grade control.

Streambed: It can be difficult to place streambed in the structure, especially on smaller-diameter and longer structures where getting equipment into the structure is difficult. Washing fine material into the pipe can also be time consuming and difficult.

Other Details:

- Assembly options include delivery in one piece, several pieces, or assembly on site.
- Make considerations for who will be doing assembly. Bolt-together structures are very labor intensive.
- With adequate lifting equipment, some structures can be assembled on site, then lifted into place (reduces road closures).
- Headwalls and endwalls can be included with the structure, and can either be installed prior to delivery, for small structures, or assembled on site.
- Baffles can be installed by some manufacturers to help maintain streambed material in the pipe.
- For larger structures, consider paying for some on-site assistance from the manufacturer, especially if it is being assembled on site or if the municipality or contractor is unfamiliar with the process.
- Due to the large footprint of the structure, a geotechnical investigation is usually not needed.

Installation of a 15' w x 10' h pipe arch that was assembled on site (CDGRS).

Completed 16' w x10' h pipe arch (Crawford).

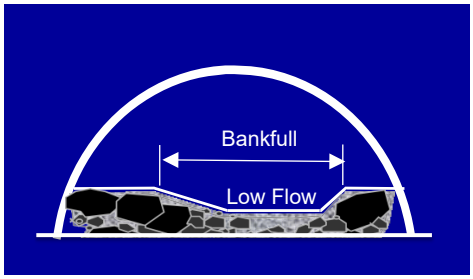
Summary:

- **Pros:** Structures are relatively inexpensive and easy to assemble. Contractors and townships are typically familiar with installing these structures. Smaller structures can be delivered in one piece. Less excavation is required than for some other structures.
- **Cons:** Difficult to get material in smaller diameter or longer structures. Larger structures may not fit sites with low cover height. Limited to stream slopes 4.0% or less.

Structural Plate Arch with Invert (Bottom)

These structures come in a variety of widths and assembly configurations. Placement of streambed material can be difficult, especially in low-profile structures, and special attention at bank margins is needed. Limited applicability in streams with steep gradients or large scour depths due to the amount of material required in the structure.

Reminder: The DGLVR Standard:
- Requires bottomless structures if the reconstructed stream slope through the structure is over 4.0% or the bankfull width is greater than 20'.
- Defines required depth of streambed in the structure.



Schematic of an arch pipe with invert with low-flow channel.

Washing fines into the streambed on a 12' w x 4' h pipe arch (Jefferson).

19' w x 6' h structure showing low flow channel and bank margins (Northampton)

Assembly in-place of a 12' w x 5' H pipe arch (Elk).

Sizes: Typically available in widths between 6' and 23' depending on material. Because of tapered sides, it is often necessary to install a strucutre that is larger than 1.25 times bankfull width at the base. This ensures that after streambed material is placed in the structure, the final opening will still be at least 125% of the bankfull channel width.

Streambed: It can be difficult to place streambed in the structure, especially on smaller-diameter and longer structures where getting equipment into the structure is difficult. Washing fine material into the pipe can also be time consuming and difficult.

Other Details:

- Assembly options include delivery in one piece, several pieces, or assembly on site.
- Make considerations for who will be doing assembly. Bolt-together structures are very labor intensive.
- With adequate lifting equipment, some structures can be assembled on site, then lifted into place (reduces road closures).
- Headwalls and endwalls can be included with the structure, and can either be installed prior to delivery, for small structures, or assembled on site.
- Baffles can be installed by some manufacturers to help maintain streambed material in the pipe.
- For larger structures, consider paying for some on-site assistance from the manufacturer, especially if it is being assembled on site or if the municipality or contractor is unfamiliar with the process.
- Due to the large footprint of the structure, a geotechnical investigation is usually not needed.

Summary:

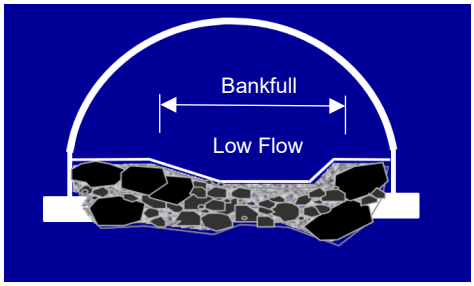
- **Pros:** Structures are economical and easy to assemble. Smaller structures can be delivered in one piece or partially assembled. Lower profile (than squash pipe) and can be used in some locations where cover height is a concern.
- **Cons:** Difficult to get material in smaller, longer, and lower-profile structures. Most need to be oversized to accommodate 1.25x bankful channel after installing streambed. Flat plate bottom creates a "slip plane" and makes establishing stable streambed extremely important. Limited to stream slopes 4.0% or less.

Bottomless Boxes and Arches

These structures come in a variety of types such as metal arches or 3-sided concrete boxes and are typically placed on concrete footings that are either precast or cast-in-place. Compared to other structures with inverts, these are typically easier to achieve stream continuity.

Sizes: Typically available in widths from 5' to 35' depending on material type. Available in various aspect ratios and materials, including concrete where cover is an issue. Walls are typically more vertical than pipe arch structures with inverts.

Streambed: One advantage of bottomless structures is that the streambed that is not impacted by footing installation can be left intact. This typically makes it easier to rebuild the remaining stream channel, construct bank margins, and wash in fines. Grade controls and additional streambed can often be placed inside the structure between the footers before the top is bolted or grouted in place. This can greatly reduce the time needed to reestablish the streambed.



Schematic of an arch pipe with invert with low-flow channel.


Assembly of a 15' w x 6' h bottomless arch pipe on cast-in-place footings (Juniata).

Footings:

- **Cast-in-place footings:** Forms are framed, and concrete is poured in place. The process will require the road to be closed for a longer period of time for curing.
- **Pre-fabricated footings:** Concrete footing poured in pre-fabricated steel forms that remain in place.
- **Precast footings:** Concrete footing blocks are made off site in sections and fastened together on-site. This method can speed installation and shorten road closure time.
- **Plate footings:** Plate footings (no concrete) can be used in conditions where soil bearing is >4,000 psf and scour is minimal.


Walk-behind equipment being used to place streambed in 12' w x 6.5' h bottomless concrete box (Cumberland).

Other Details:

- Assembly options include delivery in one piece, several pieces, or assembly on site.
- Geotechnical investigation is generally needed to determine the footing depths and bearing capacity in the underlying soil.
- Make considerations for who will be doing assembly. Bolt-together structures are very labor intensive.
- Headwalls and endwalls can be included with the structure.
- With no bottom, sometimes the stream can be flumed through the work site instead of using a pump-around diversion.
- Consider specifying taller structures or structures with increased vertical wall heights to allow sufficient material to be placed in the structure without compromising 1.25x bankfull width.

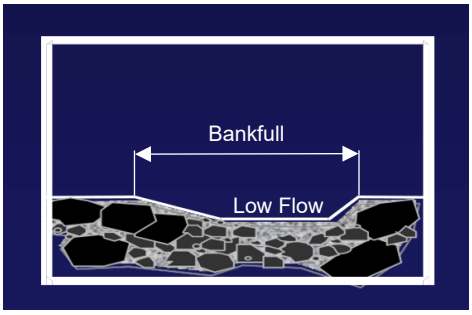

10' w x 4' h bottomless arch pipe (Jefferson).

Summary:

- **Pros:** By leaving the natural streambed intact through the structure and eliminating the potential "slip plane" created by an invert, it is much easier to maintain a natural channel and stream connectivity. Can simplify stream diversion with flume through the worksite.
- **Cons:** Compared to structures with a bottom, these are typically slightly more expensive and take slightly longer to install. Construction requirements can be intimidating to municipal road crews.

Concrete Box Culverts (with inverts)

These structures consist of a simple rectangular box made of concrete. These structures are commonly used in PA and are sometimes the "default" structure choice of some engineers. These are the most expensive of the "non-bridge" options due to the cost of materials and the need for large equipment or a crane during installation. While they provide good longevity and strength, careful consideration is needed to grade control, substrate, and scour depth.



Schematic of a concrete box culvert.

Reminder: The DGLVR Standard:
- Requires bottomless structures if the reconstructed stream slope through the structure is over 4.0% or the bankfull width is greater than 20'.
- Defines required depth of streambed in the structure.

Assembly of a 16'w x 6' h concrete box culvert (Montgomery).

Sizes: Typically available between 8' and 20'+ in width and are available in a wide variety configurations, including full boxes and modular systems that are split in half to aid in streambed construction.

Streambed: It can be difficult to place streambed in the structure, especially on smaller and longer structures where getting equipment into the structure is difficult. For larger structures, some material can be put in the structure while assembling the sections. Some smaller structures come with a "lid" that allows the streambed to be placed before closing the box.


Concrete box with stamped concrete headwall (CDGRS).

Other Details:

- Typically delivered in multiple pieces and assembled on site.
- Due to weight, assembly will require large equipment, and larger structures may require a crane for assembly.
- Headwalls, endwalls, and wingwalls are options from many manufacturers.
- Baffles can be installed by some manufacturers to help maintain streambed material.
- Due to the large footprint of the structure, a geotechnical investigation is usually not needed.
- Minimal cover is needed over these structures because of their inherent strength. They may be a good option where cover is an issue and raising the road elevation is not an option.

Summary:

- **Pros:** Can be installed quickly and easily (with proper equipment). Can accommodate minimal cover heights.
- **Cons:** Expensive compared to other non-bridge options. Weight of structure requires large equipment for assembly. Limited to stream slopes 4.0% or less.

Bridges

Typically the best choice for larger stream systems, especially those with a bankfull width over 20'. Bridges are also recommended in streams with very large scour depths and systems with gradients of 7-8% or more. A wide variety of bridge types and options exist to fit a variety of situations.

Streambed: One significant advantage of bridges is that the streambed between the abutment installations remains intact. It is typically much easier to get the needed equipment and material under a bridge to establish streambed, banks, and bank margins compared to other structure options.

Scour: When designed properly, these structures can accommodate streams that are steeper with larger scour depths.

Traditional 22' precast concrete deck bridge on poured-in-place concrete footings (TU).

Completed 32' span GRS-IBS bridge (Tioga).

Completed 50' span (~25' channel) spread footer bridge (Indiana).

Bridge Types:

- **Traditional:** Vertical abutments typically built near the 1.25x bankfull channel and extend many feet below stream bed scour depth potential. Design may even include driven pilings. Design is effective, but additional footer material and time for construction is expensive.
- **GRS:** Geosynthetic Reinforced Soil bridges replace standard concrete abutments with abutments made of layers of compacted fill and geosynthetic fabric. The abutments are faced with stacked concrete blocks. While more labor intensive, GRS bridges can cost less than bridges with traditional concrete abutments. Careful consideration should be given to soil bearing capacity and scour protection.
- **Spread Footer:** Spread footer bridges utilize precast or cast-in-place concrete footings set back further out of the stream channel. Establishing footings far from the stream means stream disturbance is kept to a minimum and scour is usually not an issue. While these structures require a longer span than typical bridges, they can cost less than bridges with traditional abutments. Careful consideration should be given to soil bearing capacity.

Inspection Requirements:

- **Spans under 8':** No inspection requirements.
- **Spans between 8' and 20':** Some local policies or ordinances require regular structure inspection.
- **Spans over 20':** Federal inspection required every two years at a cost of $2,000-$3,000. Note that this applies to all structures over 20' (boxes, arch pipes, etc.), not just bridges.

Summary:

- **Pros:** Spans streambed and banks, and makes it easier to establish streambed and stream continuity through the road. Most AOP friendly design. Come in a wide variety of designs that can be customized for site conditions. Can be designed to accommodate heavy loads and work in almost any conditions.
- **Cons:** Bridges are often more expensive than most other options. Additional design and installation requirements. Potential for future maintenance for bridge owner, and bridges over 20' require federal inspection.

Figures in this document are general guidelines and vary by material and design. Always consult manufacturer for actual specifications.

Summary of Structure Characteristics

Structure Type	Pipe Arch (Squash)	Structural Plate Arch w/Invert	Bottomless Arch/Box	Concrete Box	Bridge	Round Pipe
Sizes	3 – 20’	6 - 23’	5 - 35’	8 - 20’	8’+, recommended if bankful >20’	Not recommended for use in stream channels. Round pipes over 36” not to be used in DGLVR funds. Not recommended for use in stream channels. Round pipes over 36” not to be used in DGLVR funds.
Stream Slopes	**Less than 4.0%** (DGLVR Standard)	**Less than 4.0%** (DGLVR Standard)	Can be designed for most slopes	**Less than 4.0%** (DGLVR Standard)	Can be designed for most slopes	
Cover	Can be difficult due to structure height	Often a better choice than squash pipes where cover is an issue	Wide variety of cover requirements based on material and design	Minimal cover required	NA	
Cost	low	low-med	med	high	med-high	
Establishing Streambed	Difficult in smaller structures	Difficult in smaller structures	Easier, can be done before arch/box is installed	Easier, can be partially done during installation	Easiest, typically spans existing channel	
Stream Substrate Depth	24” min, more depending on scour potential (DGLVR Standard)	24” min, more depending on scour potential (DGLVR Standard)	Footing depth to be determined by engineer	24” min, more depending on scour potential (DGLVR Standard)	NA - bottomless	
Overall	Economical choice, but typically the most difficult to establish and maintain streambed though the structure.	Good choice in lower gradient and scour channels. Often must be oversized (over 1.25 bankfull) to account for streambed material.	Often best choice for maintaining a natural streambed.	Typically expensive, but quick and require minimal cover. Establishing and keeping streambed can be difficult.	Wide range in cost and types. Best for maintaining streambed as it spans the channel.	

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