STRUCTURE SELECTION for ROAD STREAM CROSSINGS – To improve decision making when selecting structures for road stream crossings, to reduce maintenance, improve stream continuity, and increase longevity of the new crossing.

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

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:

- ✓ Bankfull width minimum opening at bankfull elevation
- ✓ Stream bed material in the structure that is stable at all flows
- ✓ Passage of aquatic organisms
- ✓ Hydraulic capacity for the 100-year storm

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

STRUCTURE SELECTION CONSIDERATIONS

Longitudinal profile: A longitudinal profile conducted upstream and downstream of the structure is an essential design practice that helps inform structure selection (Stream Continuity 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.

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

Structure Width: Structures must have a finished opening width at least as wide as the measured bankfull channel width at the bankful elevation (Bankfull Bulletin). For some structures with sloped sides, this means a larger than bankful structure must be installed, since establishing streambed in the structure will decrease the effective opening size. It is also sometimes not possible to order structures that exactly match bankful measurements. **It is good practice to order structures 1.2-1.5 times bankful to achieve a structure that can accommodate bank margins and protect the structure to extend longevity.**

Scour Depths: Higher gradient (steeper slope) streams tend to create deeper scour holes and pool depths, which need to be accounted for in both structure selection and in the design of stream bed material. Structures with inverts (bottoms) in higher scour channels will require more depth and larger material to establish a stable streambed. Higher gradient or scour streams are better suited for bottomless structures.

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 if it does not increase the 100-year flood elevation. In other cases, a low-profile structure with a high width/height ratio may be needed.

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.

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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 manufactures for a complete list of options and details.

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. Limited applicability in streams with steep gradients or large scour depths due to the amount of material required in the structure.

Structural Plate Arch with Invert (Bottom): These structures come in a variety of widths and 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.

Bottomless Boxes and Arches: These structures tend to be more expensive and take longer to install due to the addition of concrete footings. Other footing options exist that can reduce cost and installation times. Site characteristics such as soil bearing capacities and the presence of bedrock can greatly affect the cost and footing type required.

Concrete Box Culvert: The smooth bottom of a concrete box requires additional depth of material to maintain coverage in large flow events. These structures are commonly used in situations that require traffic support without adding cover over the structure. Limited applicability in streams with steep gradients or large scour depths due to the amount of material required in 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 10%. Several alternatives exist to standard bridge abutment designs such as spread-footing or Geosynthetic Reinforced Soil abutments.

Round Pipes: Round pipes are not suited for use in stream channels as they concentrate flow and are almost impossible to keep streambed material in the structure. 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 & endwalls?
- If the structure is bolted together, who will assemble?
- Is a geotechnical investigation needed to determine soil bearing capacity?
- What is the minimum cover depth and will structure fit?

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

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

Arch pipe with Invert (bottom) (Cambria)

Bottomless arch pipe (York)

Bottomless box culvert (Cumberland)

GRS-IBS Bridge (Tioga)

Pipe Arch (squash pipes)

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.

Sizes: Typically available up to ~20’ in width. Available in various level of width to height ratio.

Streambed: Can be very difficult to place streambed in the structure, especially on smaller diameter and longer structures where washing material in the pipe can be time consuming and difficult. Streambed depths required to maintain substrate in the pipe are typically higher than the 6-12” required by permitting.

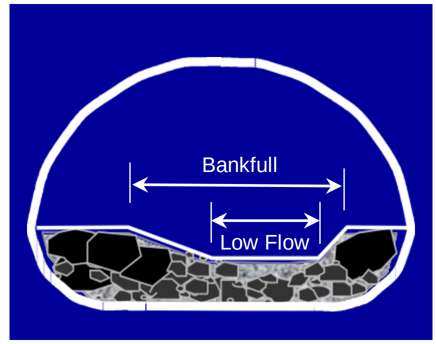
Scour: Limited applicability in streams with steep gradients or large scour depths due to the amount of material required in structure.

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.
- 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 relatively inexpensive and easy to assemble. Contractors and townships are typically familiar installing these structures. Smaller structures can be delivered in one piece. Less excavation required than some other structures.
- **Cons:** Difficult to get material in smaller diameter or longer structures. Larger structures may not fit sites with low cover height. Can be hard to maintain substrate in pipe in steep gradients or where large scour depths exist.



Schematic of a pipe arch with low-flow channel

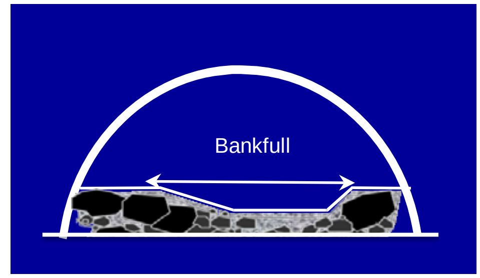
Delivery of a fully assembled 6’ w x 4’ h x 40’ l pipe arch (CDGRS).

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

Completed 6’ w x 4’ h pipe arch (CDGRS).

Structural Plate Arch with Invert

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.



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

<u>Sizes</u>: Typically available in widths between 5' and 23' depending on material. Available in various aspect ratios including low-profile where cover is an issue. Because of the tapered opening, it is often necessary to install a pipe that is larger than the bankfull channel width. This ensures that after streambed material is placed in the pipe, the final opening will still be at least the bankfull channel width.

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

<u>Streambed</u>: Can be difficult to place streambed, especially in smaller and lower-profile structures. Streambed depths required to maintain substrate in the pipe are typically higher than the 6-12" required by permitting.

<u>Scour</u>: Limited applicability in streams with steep gradients or large scour depths due to the amount of material required in the structure.

<u>Other Details</u>:

- 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.
- Headwalls and endwalls can be included with the structure, and can be installed prior to delivery or assembled on site.
- Baffles can be installed by some manufacturers to help maintain streambed material.
- For larger structures, consider using grant funding for 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.
- Consider specifying higher structures or structures with increased vertical wall heights to allow sufficient material to be placed in the structure without compromising width.

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

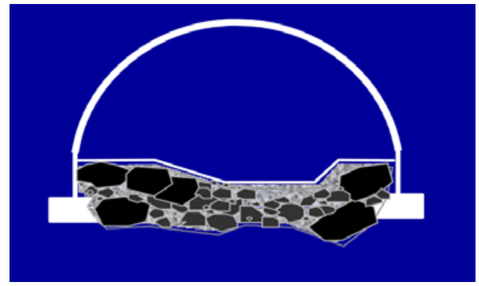
<u>Summary</u>:

- **<u>Pros</u>:** 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 where cover height is a concern.
- **<u>Cons</u>:** Difficult to get material in smaller, longer, and lower-profile structures. Need to be oversized to accommodate bankful channel after installing streambed. Flat plate bottom makes it difficult to hold material, not suited for streams with steep gradients or large scour depths.

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

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. The footings and geotechnical investigation needed to determine soil bearing capacity tend to make these structures more expensive than other options. Of non-bridge structures, they are typically easiest to achieve AOP.



Schematic of a bottomless arch pipe.

Sizes: Typically available in widths 8' to 35' depending on material. Available in various aspect ratios including low-profile where cover is an issue. Walls are typically more vertical than pipe arch structures.

Streambed: One advantage of bottomless structures is that the streambed that is not impacted by footing installation remains intact and it is typically much easier to rebuilding the remaining stream channel, construct bank margins, and wash in fines.

Scour: When designed properly, these structures can typically accommodate streams that are steeper and have larger scour depths than structures with bottoms.

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-fab footings:** Concrete footing poured in pre-fabricated steel forms that remain in place.
- **Precast footings:** Concrete footings blocks are made off site in sections. This can shorten the road closure time.
- **Plate Footings:** Plate footings (no concrete) can be used in special conditions where soil bearing is greater than 4000 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 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 work site instead of using a pump-around diversion.
- Consider specifying higher structures or structures with increased vertical wall heights to allow sufficient material to be placed in the structure without compromising width.

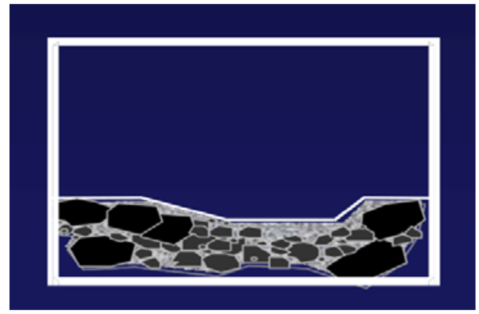
Lower-profile 10' w x 3' h bottomless arch pipe (Jefferson).

Summary:

- **Pros:** By leaving much of the natural streambed intact through the structure, it is much easier to maintain a natural channel and aquatic connectivity.
- **Cons:** Compared to structures with a bottom, these are typically more expensive and take slightly longer to install. They can also be more intimidating to municipal road crews.

Concrete Box Culverts

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 by far the most expensive of the “non-bridge” options. While they provide good longevity and strength, careful consideration is needed to grade control, substrate, and scour depth. Limited applicability in streams with steep gradients or large scour depths due to the amount of material required in the structure.



Schematic of a concrete box culvert.

Sizes: Typically available between 8’ and 20’ in width. Are available in a wide variety of widths and configurations including full boxes and a modular system where boxes can be split in half to aid in streambed construction.

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

Streambed: Streambed depths required to maintain substrate in the pipe are typically higher than the 6-12” required by permitting. On larger structures some material can be put in the structure while assembling the sections or after assembly if structure height allows. Some smaller structures come with a “lid” that allows you to build the streambed before closing the box.

Scour: Limited applicability in streams with steep gradients or large scour depths due to the amount of material required in the structure.

Concrete box with stamped concrete headwall (CDGRS).

Other Details:

- Typically delivered in a few pieces and assembled on site.
- Due to weight, assemble 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. Good longevity and comes in a variety of sizes.
- **Cons:** Very expensive compared to other non-bridge options. Weight of structure requires large equipment for assembly. Flat bottom makes it difficult to hold material, not suited for streams with steep gradients or large scour depths.

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 10% or more. A wide variety of bridge types and options exist to fit a variety of situations.

Streambed: One large advantage of bridges is that the streambed that is not impacted by footing installation remains intact. It is typically much easier to establish a streambed through bridges.

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

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

Bridge Types:

- **Traditional:** Bridge abutments typically built at water's edge 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:** Geosynthetically 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 must be given to soil bearing capacity and scour protection. (Reference)
- **Spread Footing:** Spread footing bridges utilize precast 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 must be given to soil bearing capacity.

Completed 32' span GRS-IBS bridge (Tioga)

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 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. Professional design and installation required. Bridges over 20' require federal inspection. Potential for future maintenance for bridge owner.

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’	5 - 23’	8 - 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.
Stream Slopes	Limited applicability with steep gradients or large scour depths.	Limited applicability with steep gradients or large scour depths.	Can be designed for most slopes	Limited applicability with steep gradients or large scour depths.	Can be designed for most slopes	
Cover	Can be difficult due to structure height	Lower profile structures possible where cover is an issue.	Lower profile structures possible where cover is an issue.	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	
Maintaining Streambed	Must have adequate depth and grade control to resist scour	Must have adequate depth and grade control to resist scour	Better for maintaining streambed material	Must have adequate depth and grade control to resist scour	Best for maintaining streambed material	
Overall	Economical choice, but typically the most difficult to establish and maintain streambed though the structure.	Good choice in lower gradient and scour channels. Establishing and keeping streambed can be difficult.	Often best choice for maintaining a natural streambed, especially in steeper channels.	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.	Not recommended for use in stream channels. Round pipes over 36” not to be used in DGLVR funds.