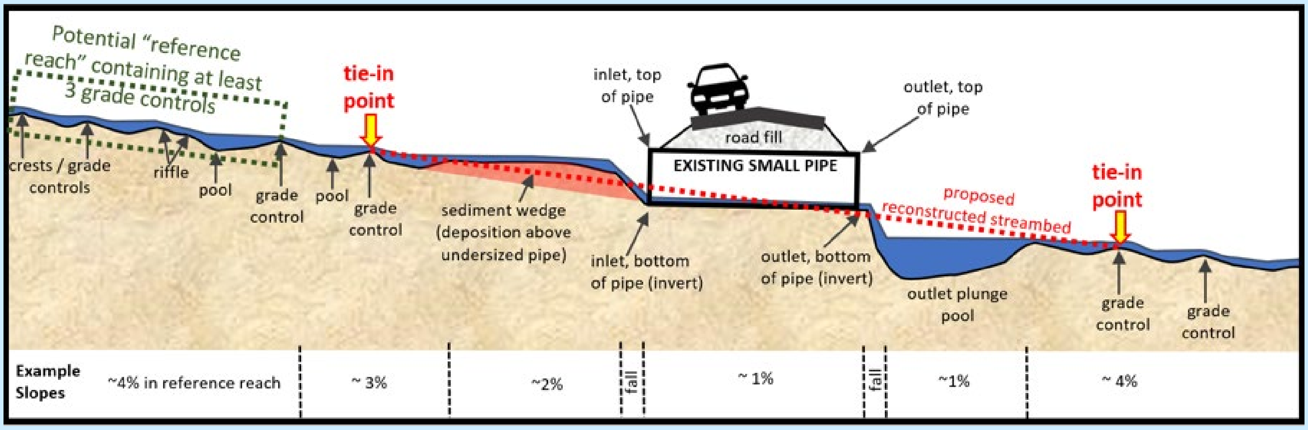
Pennsylvania Dirt, Gravel, and Low Volume Road Maintenance Program

Stream Crossing Replacement Technical Manual

Provided by:

The Pennsylvania State Conservation Commission

and The Pennsylvania State University Center for Dirt and Gravel Road Studies



7/2022

Acknowledgements

Information in this *Stream Crossing Replacement Technical Manual* has been compiled and created by the PA State Conservation Commission and The Pennsylvania State University Center for Dirt and Gravel Road Studies. Thanks to other entities who were involved in the development and review process, including: Trout Unlimited, many of Pennsylvania's county conservation districts, several DGLVR Program Advisory Workgroups, the PA Department of Environmental Protection, and the Pennsylvania Fish and Boat Commission.

Primary Contributors:
- **Steve Bloser**, *Penn State Center for Dirt and Gravel Road Studies*
- **Wade Brown**, *Penn State Center for Dirt and Gravel Road Studies*
- **Justin Challenger**, *PA State Conservation Commission*
- **Eric Chase**, *Penn State Center for Dirt and Gravel Road Studies*
- **Maria Dreese**, *Penn State Center for Dirt and Gravel Road Studies*
- **Sherri Law**, *PA State Conservation Commission*
- **Shaun McAdams**, *Penn State Center for Dirt and Gravel Road Studies*
- **Roy Richardson**, *PA State Conservation Commission*

Many of the concepts and the overall approach utilized in this manual are based on practices employed and taught by the United States Forest Service as part of their comprehensive "*Designing for Aquatic Organism Passage at Road-Stream Crossings*" methodology to achieving channel continuity and aquatic passage through road stream crossings. Thanks to USFS personnel for their support and review. More information: https://www.fs.fed.us/biology/education/workshops/aop/ **.**

Several sections of this manual were modeled after publications from the Vermont Department of Fish and Wildlife (*Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in Vermont*) and the Massachusetts Department of Fish and Game (*Massachusetts Stream Crossings Handbook*). Thank you to those entities for their support.

Vermont Guidelines: https://vtfishandwildlife.com/conserve/aquatic-habitat-conservation/aquatic-organism-passage-at-road-stream-crossings

Massachusetts Handbook: https://www.mass.gov/doc/massachusetts-stream-crossing-handbook/download

For more information on Pennsylvania's Dirt, Gravel, and Low Volume Road Maintenance Program see the following websites.

- https://www.agriculture.pa.gov/Plants_Land_Water/StateConservationCommission/DGRMP/Pages/default.aspx
- https://www.dirtandgravel.psu.edu/

Please contact the Pennsylvania State Conservation Commission with issues or comments related to this manual at 717-787-2103.

Preface

This manual is intended for use for stream crossing replacement projects funded by the PA Dirt, Gravel, and Low Volume Road Maintenance Program (DGLVR Program). The key to a successful stream crossing replacement project is a well-defined plan with a series of steps that occur in a certain order. The chapters in this manual are intended to walk all parties involved in a DGLVR grant-funded stream crossing replacement through the optimal lifecycle of a project. **Chapters 1 through 11 are written with conservation district staff in mind. Chapter 12 is written with designers and engineers specifically in mind**. Some of the language presented in Chapter 12 is repeated from other preceding sections of this Manual.

Manual Overview:

Chapter 1: Introduction: Provides the background, goals, and purpose of replacing stream crossings under the DGLVR Program, including background on channel continuity and aquatic organism passage.

Chapter 2: DGLVR Stream Crossing Standard Details: Provides detailed walkthrough, background, and explanation of the DGVLR Stream Crossing Design & Installation Standard.

Chapter 3: Initial Site Assessment and Project Planning: Includes guidance for initial site evaluations such as eligibility for funding, determining bankfull, and initial considerations for discussion with the potential applicant.

Chapter 4: Site Assessment: Highlights the importance of the initial longitudinal profile and cross section assessments and analysis of field data in understanding the existing conditions and determining a plan for replacement.

Chapter 5: Grant Application: Provides guidance for estimating costs to create a grant application, including structure selection, aggregate selection, and streambed material.

Chapter 6: QAB Ranking and Review: Reviews considerations for the process that conservation districts and their Quality Assurance Board use to rank projects for funding.

Chapter 7: Contracting: Discusses key elements to consider before a conservation district and grant recipient sign a contract for DGLVR funding.

Chapter 8: From Contract to Construction: Covers key components that should occur once a contract for DGLVR funds is signed by a conservation district and grant recipient but before construction begins, such as bidding and pre-construction meetings.

Chapter 9: Construction and Inspection: Details the responsibilities of conservation districts for inspection and oversight during the stream crossing replacement.

Chapter 10: Final Inspection and As-builts: Provides guidance on "project closeout" after the new structure has been installed, including final inspections, payments, and dealing with deficiencies.

Chapter 11: Monitoring and Maintenance: Discusses post-project considerations to monitor and maintain connectivity through the crossing.

Chapter 12: Engineering Design Considerations: While the previous chapters are intended for conservation district use (but would also be helpful to others), **this chapter is written with the project engineer in mind**. The repetition in this chapter from previous chapters is intentional. The purpose of this chapter is to provide an overview of the process from the engineer's perspective, with links to where more information can be found if needed.

Table of Contents

List of Figures

1. INTRODUCTION:

Terms defined in **Appendix B** are in **bold text** the first time they appear in this manual. Click on these terms to view the definition in Appendix B.

Although public awareness of environmental issues is high in Pennsylvania, few people consider the effects of road **crossings** and other road infrastructure on the quality of stream habitat. Stream conditions may be quite different upstream and downstream of a road crossing, and a crossing may look different during low or high water. The design and condition of a stream crossing determines whether a stream behaves naturally and whether animals, both aquatic and terrestrial, can migrate along the stream channel. **Channel continuity** has not often been considered in the design and construction of stream crossings (culverts and bridges). Many crossings are barriers to fish and wildlife. Even crossings that were not barriers when originally constructed may now be barriers because of stream channel erosion, mechanical breakdown of the crossings, or changes in the upstream or downstream channel shape. Undersized or deteriorating stream crossings can also cause significant issues with erosion, maintenance, flooding, and even road washouts.

Fortunately, options exist to design stream crossings that allow wildlife unrestricted access to a **watershed**, maintain natural stream conditions, and help protect roads and property from some of the damaging effects of floods (Figure 1.1). This *DGLVR Stream Crossing Replacement Technical Manual* is intended to summarize DGLVR Policy and provide additional guidance related to stream crossing replacements funded through the PA Dirt, Gravel, and Low Volume Road Maintenance Program (DGLVR Program).

Figure 1.1 Example Stream Crossing
A 13' diameter pipe arch with a low flow channel and bank margins through the structure provides long-term channel stability, reduced road erosion and maintenance, and aquatic organism passage.

1.1 PA Dirt, Gravel and Low Volume Road (DGLVR) Program

The PA Dirt, Gravel, and Low Volume Road (DGLVR) Program is a statewide $28 million annual grant program that is administered by the PA State Conservation Commission (SCC) under the PA Department of Agriculture. The DGLVR Program is administered at the local level by county conservation districts in 66 of Pennsylvania's 67 counties. Local public-road owning entities, largely townships, apply to their conservation district for grant funding to make road and environmental improvements on specific sections of their roads. The DGLVR Program, born out of an initiative from Trout Unlimited (TU) in 1997, focuses grant funding on projects that provide environmental benefits to the waters of the Commonwealth of Pennsylvania. For more information about the DGLVR Program visit https://www.dirtandgravel.psu.edu/pa-program-resources/scc-program-overview. The Pennsylvania State University Center for Dirt and Gravel Road Studies (**CDGRS**) provides technical guidance and education for the DGLVR Program.

The majority of projects funded by the DGLVR Program focus on sediment reduction from road surfaces and ditches. Undersized stream crossings also generate excessive erosion and sediment in large flow events. These undersized crossings can also lead to plugging and catastrophic loss of the road surface and the surrounding fill material. More frequent high flow events that do not overtop the **structure** can still cause erosion and sedimentation issues related to the downstream streambed and banks. Additionally, undersized crossings can cause significant sediment delivery when the hydraulic capacity is exceeded and water is diverted down adjacent ditches, causing gullying and road edge erosion. These failures lead not only to disruptions due to loss of the road, but also to significant sediment inputs to the downstream system (Furniss et al., 1998). Undersized stream crossings also lead directly to sediment deposition at the inlet of a structure as water velocity slows due to backwatering. These sediment deposits, often mislabeled as "gravel bars", can clog stream crossing structures and create the need for frequent maintenance and dredging to keep the structure open. Restoring a stable stream channel and re-establishing channel continuity upstream, through, and downstream of bottomless and properly designed full-**invert** structures can reduce bed and bank sediment erosion to natural background levels. Reducing overtopping, structure loss, and road closures by upsizing is the best way to reduce large sediment inputs to the downstream system. Sediment impacts from roadway issues such as this are the core issue the DGLVR Program seeks to mitigate.

The majority of the 6,000+ grants that the DGLVR Program funded prior to 2014 have not been for stream crossing replacements. Most DGLVR Program grant projects focus on road drainage, base, and surface improvements to reduce the impact of road runoff while providing improvement to the road itself. After a significant increase in funding to the DGLVR Program in 2014, many entities began requesting grant funding for culvert and bridge replacement projects. In order to ensure that funding is focused on crossing replacements that provide environmental improvements, the DGLVR Program implemented several policies limiting which crossings could be replaced and defining considerations for newly installed structures.

1.2 Consequences of Poor Stream Crossings

The most common cause for "poor" stream crossings is undersized structures. Culverts and bridges that are undersized for the stream channel width create a wide variety of additional problems for both the road and the stream. Additional concerns such as structure type, elevation, skew, and slope also come into play, but good stream crossings are almost impossible without an adequately sized structure.

Traditionally, the structures used for stream crossings in Pennsylvania have focused on ease of installation, ability to quickly move water through the roadway, and reducing the up-front cost of installation. This has resulted in decades of undersized structures that are typically installed at 90-degree angles to the road to reduce overall length. While this mentality may save money during installation, **undersized or poorly installed stream crossings often have much higher costs, both environmentally and financially, over the long term** (See Figure 1.2 and Figure 1.3) from various entities in other regions of the United States.

Scour of Pipe Bottom

Pipes without a natural streambed create a variety of issues. The lack of streambed often creates velocity barriers for aquatic organisms. The life expectancy of these structures is also significantly reduced because the pipe is "sandblasted" with the rocks and debris that move in every large storm event.

Perched Outlet:

Crossings with significant outlet drops create complete aquatic barriers in the stream. It is a classic symptom of a significantly undersized pipe. This can also create a significant scour hole that can eventually threaten to undermine the structure and the road itself.

Erosion / Scour Hole

Large plunge pools or erosion/scour holes are often present at the outlet of undersized crossings due to the severely increased flow velocity caused by the structure. In addition to being constant sources of sediment, they can grow to threaten the structure, road, and nearby property.

Road Washouts

In the worst-case scenarios, at least for the road and nearby property owners, structures can overtop and completely wash the road out. This is typically due to undersized structures either becoming clogged with debris or being overwhelmed by large storm events.

Backwatering / Ponding

Undersized structures are often prone to clogging or filling in, sometimes causing ponding and backwatering above the road. This can lead to saturated road bases, deposition of gravel bars, and eventually road overtopping and washout.

Flow Barriers

Flow barriers prevent organisms from using the structure, typically because flow is too shallow and/or too fast. These same structures are usually a barrier at higher stream flows, too, since velocity is significantly increased.

Gravel Deposition

At high flows, undersized pipes often backwater, which causes the bedload they naturally carry to drop out above the pipe inlet. This "gravel bar" is a constant source of maintenance, since it is often removed by the road owner after each large storm, only to be re-deposited after the next high flow event. *Photo: Bradford County Conservation District*

Clogging

Undersized pipes are prone to clogging during large events. Once a single log spans the opening of a pipe, subsequent logs and streambed material will start to deposit and potentially completely clog and bury the inlet of the structure.

Channel Erosion

Undersized pipes can scour and lower streambed elevation for hundreds of feet downstream of the structure. Water downstream of an undersized crossing is often moving unnaturally fast and can cause erosion to the stream bed and banks. Eventually, it can even lead to the failure of the stream crossing itself.

Figure 1.2 Issues Associated with Undersized or Poorly Installed Road-Stream Crossings

The nine photos above show various problems caused by road-stream crossing structures that are too small for their respective streams.

Environmental costs of undersized stream crossing structures include barriers to aquatic connectivity and accelerated erosion and sedimentation. Undersized stream crossings typically create a partial or complete barrier to the natural movement of aquatic organisms as well. When thinking about aquatic organisms, be sure to consider species beyond fish, such as amphibians, reptiles, small mammals, crayfish, and other macroinvertebrates. Undersized and poorly installed structures can also cause excessive erosion to the area around the crossing due to the unnatural increase in flow velocities. They can also cause stream bed and bank erosion for hundreds of feet up and down the stream channel.

Undersized stream crossing structures are much more likely to fail than structures greater than **bankfull width** that accommodate continuous stream channels (USFS 2008). A failed stream crossing structure inputs a huge sediment load into the stream, can accelerate stream bed and bank erosion, causes a road closure that interrupts business, can damage adjacent and downstream properties, and can create public safety hazards.

From a financial standpoint, undersized and poorly installed structures can increase the long-term cost of maintaining the crossing, despite being cheaper for the initial installation. Severely undersized structures often cause gravel deposits to form upstream, which must be constantly maintained by the road owner to keep the crossing functioning. The same erosion that causes environmental issues can also cause financial issues when they begin to threaten the crossing. For example, if metal-bottomed structures are installed without streambed material, then streambed movement through the structure during large flow events will "sandblast" the pipe bottom, which will significantly decrease the lifespan of the structure. Catastrophic failures like clogging and road washouts are very costly and are most common in structures that are significantly undersized.

Cost-benefit analyses from multiple states and the U.S. Forest Service show that modest increases in the initial investment of road-stream crossing structures designed to achieve channel continuity yield substantial economic and societal benefits in the long term (Levine, 2013). These benefits include cost reductions associated with increased **flood resiliency** and fewer catastrophic failures, reduced annual maintenance costs to the road owner, reduced erosion and sedimentation, and improved habitat conditions and stream health. Because of this, many U.S. states and organizations, including most New England states, have been incorporating channel continuity into stream crossing guidance and standards in the previous decades, as shown in Figure 1.3.

State	Type	Entity	Year	Minimum Structure Width	Minimum Embedment (material in structure)
PA	Guidance	PA DCNR	2022	1.25 Bankfull Channel Width	20%
PA	Regulation	PA DEP	2013	x	6" or 1' depending on permit
CT	Guidance	CT DEP	2008	1.2x Bankfull	1', or 20% if over 10'
MA	Regulation	Riverways Prog.	2012	1.2x Bankfull, + dry passage	2', or 25% for round pipes
ME	Regulation	ME DEP	2008	25-year flow	
ME	Guidance	USFWS	2017	1.2x Bankfull	2' or 20% (salmon areas only)
NH	Regulation	NH DES	2009	1.2x Bankfull +2' (bridge over 16')	1' – 2', 25% for round pipes
NY	Guidance	NY DEC	?	1.25x Streambed width	20%
VT	Guidance	VT FWD	2007	Bankfull + size of bank rocks	
GA	Guidance	GA DNR	2012	Average channel width	20%
NC	Standard	NC DOT	2003	x	1', or 20% if under 4'
SD	Guidance	SD DOT	2011	1.2 Bankfull	1'
CA	Regulation	CA F&G	2007	1.5x Active channel width	20%
OR	Standard	OR DOT	2014	1.25 Ordinary high water width	20%
WA	Regulation	?	?	1.2x Bankfull +2'	20%
AZ	Guidelines	AZ F&G	?	Span floodplain with dry passage	17% (1/6 structure height)
RI	Guidance	RI DOT	2019	1.2x Bankfull	2' or 20%
FHWA	Guidelines	US FHWA	2010	X	Structure dependent (2', 20%, 30%)

Figure 1.3 Minimum Structure Size and Minimum Embedment (Depth of Material) from Various Entities in Other Regions of the United States

Information compiled by the U.S. Fish and Wildlife Service, Chesapeake Bay Field Office (Leah Franzluebbers) and the Maryland Fish and Wildlife Conservation Office (Julie Devers) in March 2019, updated in September 2020.

1.3 Benefits of Good Stream Crossings

A "good" stream crossing is one that is adequately sized and installed to be resilient and maintain channel continuity through large storm events. The importance of channel continuity and **aquatic organism passage** are described in the next section. In addition to these environmental benefits, installing larger, more stable structures makes more financial sense in the long term. While larger structures may cost more up front when installed, they are much more resilient to larger flows over the lifespan of the structure. Climate change means that storms are increasing in both frequency and intensity (Hayhoe, 2018). The flood resiliency of these larger structures means that over the lifespan of the structure, which may be 50 to 100 years, structure owners will realize long-term cost savings.

The benefits of greater than bankfull width structures and channel continuity were clearly seen in New England following Tropical Storm Irene in 2011 when "damage was largely avoided at two road–stream crossings where stream simulation design was implemented and extensive at multiple road–stream crossings constructed using traditional undersized hydraulic designs" (Gillespie et al., 2014).

An analysis of stream crossing replacement data supplied by state departments of transportation, federal agencies, and non-governmental agencies from across the country showed that there are significant long-term savings from stream crossing designs that are designed to achieve channel continuity and provide aquatic organism passage (AOP) vs. traditional hydraulic design. Despite the increased upfront cost of channel continuity designs, over a 50-year lifecycle they are less expensive than traditional hydraulic designs because the increased flood resiliency reduces maintenance needs and saves on costs associated with road closures and catastrophic failures (NCHRP, 2017).

1.4 Importance of Channel Continuity and Aquatic Organism Passage

The goals of "channel continuity" and "aquatic organism passage" are to allow the stream to function as naturally as possible through the road corridor, as it would if the road were not present.

1.4.1 Channel Continuity

Achieving channel continuity means passing a stream through a road crossing while keeping all of the functional features of the stream system the same upstream, downstream, and through the structure. See Figure 1.4 for examples of stream crossing structures that achieve channel continuity. Maintaining channel continuity through a road crossing will create lasting environmental improvements and financial savings.

Figure 1.4 Channel Continuity Example Photos

Two examples of stream continuity through a road crossing with adequate size, slope, and channel characteristics. 19' aluminum box in Northampton County (top), and 15' concrete box in Crawford County (bottom).

- **Stream width:** A natural stream has a **low flow channel**, a bankfull channel (see Section 1.5 for more details on bankfull), and access to a floodplain where floodwaters can spread out and reduce velocity. By their nature, road crossings often create a bottleneck for flood flows where water velocities are artificially increased. Providing channel continuity through a road crossing requires larger structures with an opening wide enough to accommodate a low flow channel, the bankfull stream channel, and **bank margins** along the edges of the crossing.
- **Stream slope:** The slope of the stream should be maintained as consistently as possible above, below, and through the structure. A crossing that is installed at a lower-gradient slope than the adjoining stream channel will often tend to accumulate material and require maintenance to prevent plugging or loss of capacity. A crossing that is installed at a steeper slope than the adjoining channel will often cause erosion and **headcutting** issues and make it impossible to maintain a stable stream channel through the crossing. Establishing the proper **continuity slope** through a new structure may require instream work upstream and downstream of the crossing and right-of-way, especially in areas where the existing crossing has caused extensive streambank erosion, gravel deposition upstream, or a large plunge pool and lowering of the channel elevation downstream.
- **Grade control and streambed:** The material that makes up the streambed should be relatively continuous above, below, and through the structure. **Grade control** refers to very large "**key pieces**" of streambed that serve as long-term elevation controls that prevent the stream from downcutting or

headcutting. Grade controls as large as or larger than those naturally existing in the channel should be installed through a structure and at a similar spacing to naturally existing grade controls. Streambed material composition should be adequately sized to withstand higher erosion (scour) potential inside the structure. In a properly constructed stream crossing, the grade control will set the elevation of the channel.

- **Aquatic Organism Passage (AOP):** Aquatic organism passage refers to the ability of a road stream crossing to convey a wide variety of aquatic and semi-aquatic species, both upstream and downstream. Aquatic organism passage is typically achieved when channel continuity is reestablished and maintained through a crossing. The next section provides additional details on the importance of aquatic organism passage.

The concepts of channel continuity and aquatic organism passage are being pushed more to the forefront in recent years. While initial concerns revolved around salmon passage in the Pacific Northwest, the many environmental and long-term cost-saving benefits of designing for channel continuity quickly helped the concepts and practices spread nationwide. To increase flood resiliency and AOP, states such as Massachusetts, New York, Maryland, and Connecticut require new or replacement stream crossing structures to be at least 1.2 times bankfull width or greater (USFWS, 2019). While the United States Forest Service (USFS) Stream Simulation does not specify a minimum width, it states that the "*first estimate of culvert width is simply the width needed to span the simulated bankfull channel plus the size of the rocks used to construct the banks* (USFS, 2008)." Additionally, many states and the USFS require that stream bed material in the structure be designed to accommodate the maximum scour depth of the channel or greater to prevent loss of material and potential failure of the structure.

1.4.2 Aquatic Organism Passage

Many species inhabit streams and adjacent forests and wetlands. Effective stream protection requires considering the needs of all species, including invertebrates such as crayfish and insects, fish such as brook trout and eels, amphibians such as spring salamanders, reptiles such as turtles, and mammals such as muskrats and otters. Streams, and the interconnectedness of different parts of a stream or watershed, are essential to these animals. Many riparian animals that inhabit riverbanks, such as amphibians and reptiles, are more tolerant of stream discontinuity, yet may be affected by road crossings, especially if forced to cross roads where they are vulnerable to traffic and other dangers. For various reasons, including maintaining genetic diversity, animals living in or along streams need to be able to move unimpeded both upstream and downstream through the watershed. This collective need for habitat corridors that extend beyond just fish is referred to as "aquatic organism passage."

Benefits of maintaining Aquatic Organism Passage (AOP)

- **Access to stream habitats:** Small streams with groundwater seeps and springs provide thermal refuge during the summer. Species such as brook trout will travel to these areas and congregate there. Fish that cannot make it there, perhaps because of road crossing barriers, may be more susceptible to heat stress and mortality. If barriers restrict the size of a refuge, then animals may be overcrowded and vulnerable to disease, predators, and even anglers.
- **Access to feeding areas:** Different habitats provide different feeding opportunities throughout a day or season, and species regularly travel to exploit these resources. Both coldwater and warmwater species will take advantage of different areas of the watershed in different times of the year. Insect communities in small ponds and riparian wetlands can be abundant at times, and stream fish will move into these habitats to feed. Restricting access to prime feeding areas will ultimately hurt the fishery.
- **Access to breeding and spawning areas:** Some species travel miles to reach spawning areas in streams. Fish may encounter many barriers when adults travel to spawning areas, offspring disperse into juvenile and eventually adult habitat, and juvenile anadromous (live at sea but spawn in freshwater) species swim to the ocean.
- **Natural dispersal:** Some salamanders, turtles, and frogs spend most of their lives near streams and

travel in and along a stream's length. Poorly designed crossings may force them to climb over an embankment and cross a road, where they are vulnerable to road mortality and predators. Freshwater mussels disperse by having larvae that attach to the fins of a fish, so if a stream crossing blocks fish then it may also prevent upstream dispersal of mussels.

Impacts of Poor Crossings on Aquatic Organism Passage (AOP)

- **Excessive water velocity:** Water velocities can be too high to pass fish or other organisms during some or all of the year. As stream discharge increases, velocities within culverts increase accordingly. Average velocities can easily exceed 10 fps, which is far too fast for the prolonged swim speed of most fish. Additionally, poorly installed culverts usually contain no rest areas for aquatic species attempting to pass through them, thus causing them to swim the entire length of the structure at burst speeds, which often creates an aquatic organism barrier or filter (selective barrier).
- **Absence of bank margin areas:** Certain organisms utilize the edges of stream banks for movement in stream channels. If those bank margins are absent, it may inhibit or even prevent passage by the weak-swimming or crawling organisms.
- **Excessive turbulence:** A typical corrugated bottom structure can create more turbulence than is found in a natural channel. The aeration and chaotic flow pattern can disorient aquatic species, inhibit their swimming ability, and block their passage. These turbulence barriers are also often found downstream of perched culverts and prevent some species from even approaching the culvert. If improperly installed, baffles, rip-rap, or other roughness elements that are typically used to reduce water velocity can create turbulence that blocks movement as well. This turbulence can also be found at inlets of structures.
- **Insufficient water depth:** The lack of a defined low-flow channel can result in water depth too shallow to allow for aquatic organism passage. For streams with highly variable flows, it can be challenging to select a structure capable of passing high flows while still maintaining a defined low flow channel similar to the natural streambed.
- **Discontinuity of channel substrate:** Crossings that lack natural stream **substrate** or have substrates that contrast with the natural channel (rip-rap, baffles) can create discontinuities in streambed habitat if poorly installed. Many stream-dwelling organisms are confined to the streambed and can only move through or over the surface of appropriate substrates. Saturated stream sediments below the surface of the streambed typically support a host of invertebrate species. These species are an important contributor to nutrient cycling and food-chain support in river and stream systems (USFS Stream Simulation).
- **Habitat loss and disconnection:** The sum of all of these issues with undersized pipes can lead to complete habitat disconnection for many species. This disconnection can cut migratory species off from breeding and feeding areas and can create different types and populations of organisms above and below crossings.

1.5 "Bankfull Width" of a Stream

The DGLVR Program uses the "bankfull width" of a channel as the major factor in determining the eligibility of a structure for replacement and for informing the size of the new structure. The bankfull width of a stream is determined by the elevation point at which the stream accesses the floodplain (Figure 1.5). This point is typically indicated by deposits of sand or silt at the active scour mark, a break in stream bank slope, perennial vegetation limit, rock discoloration, or root hair exposure. The bankfull flow is also known as the channel-forming or dominant discharge, which is the

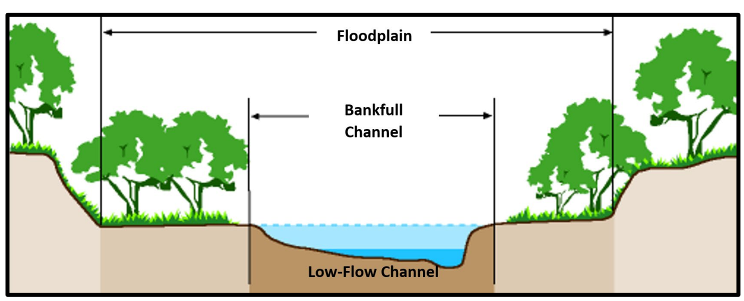


Figure 1.5 Bankfull Width
The bankfull width of a stream is typically equivalent to the width at the elevation where water begins to access its floodplain, and is usually associated with a 1.5 to 2 year recurrence interval for PA. (Graphic: US Forest Service)

flow that transports the most sediment over time and is the most effective in shaping and maintaining the natural stream channel. In general, floods greater than the bankfull flow will start to access their floodplain and the amount of further in-channel erosion compared to a bankfull event is minimal. The bankfull flow roughly corresponds to a 1.5-2 year recurrence interval for most of Pennsylvania. For more information on determining and measuring bankfull channel widths, see the "Bankfull Width Determination" Technical Bulletin in Appendix H.

1.6 Replacing a Stream Crossing with DGLVR Funding

The DGLVR Program has established a set of policies and procedures for replacing stream crossings with DGLVR Program funds. Any stream crossing replacement funded in whole or in part with DGLVR funds or counted as in-kind toward DGLVR projects must follow these policies and procedures. The purpose of these policies and procedures is to ensure that DGLVR funds are focused on replacing stream crossings with the maximum environmental benefit and reestablishing channel continuity through the road. The information below is provided as a summary/overview of the entities involved and documents and policies available pertaining to DGLVR funded stream crossing replacements:

DGLVR Program: Overview of Roles

- **Local Entities**
  - **Conservation District:** Provides grant funding and administers DGLVR Program within each county. The conservation district is the main point of contact for review of project documents and project oversight.
  - **Grant Recipient:** Road-owning entity that receives DGLVR grant funds from the conservation district and performs or subcontracts work to be done. All grant recipients are public entities, and most are townships or boroughs.
  - **Contractor:** (if applicable) Contracts with the grant recipient to perform project work.
  - **Engineer:** (if applicable) Contracts with the grant recipient to perform project design and inspection.
- **Statewide Supporting Entities**
  - **State Conservation Commission (SCC):** Entity at the PA Department of Agriculture that administers the DGLVR Program statewide.
  - **The Pennsylvania State University Center for Dirt and Gravel Road Studies (CDGRS):** Provides education and technical support to all entities of the DGLVR Program.
  - **Trout Unlimited (TU):** Provides education and technical support to all entities of the DGLVR Program.

DGLVR Program: Overview of Documents and Policies

- **DGLVR *Administrative Manual* (Admin Manual)**
  - This manual sets statewide policy requirements for the PA Dirt, Gravel, and Low Volume Road Program. Section 7.1 of this manual sets statewide DGLVR Program Policy for Stream Crossing Structural Replacements.
  - When the DGLVR *Stream Crossing Replacement Technical Manual* references "DGLVR Policies" or "DGLVR Policy," the referenced policy/policies include everything in the *Administrative Manual.*
  - The *Administrative Manual* is available online at https://www.dirtandgravel.psu.edu/pa-program-resources/program-specific-resources/administrative-guidance-manual.
- **DGLVR Stream Crossing Design & Installation Standard (DGLVR Stream Crossing Standard):**
  - The DGLVR Stream Crossing Standard lists requirements for any new stream crossing structures funded in whole or in part by DGLVR funds or counted as in-kind on a DGLVR project. In-kind contributions refer to costs incurred by the grant recipients for a project that are not reimbursed as part of the grant.

- When the DGLVR *Stream Crossing Replacement Technical Manual* references "standards" or "Stream Crossing Standards," those refer to the DGLVR Stream Crossing Design & Installation Standard.
- The DGLVR Stream Crossing Standard is incorporated by reference in Section 7.1.2 of the *Administrative Manual* and can be found in Appendix A of this DGLVR *Stream Crossing Replacement Technical Manual.*

- **County-Specific DGLVR Policies:**
  - Each county conservation district has a set of local policies for its county DGLVR Program set by its Quality Assurance Board (QAB) and conservation district Board of Directors. The local county DGLVR Policy may be more strict than statewide DGLVR Policy and must be considered for all DGLVR projects based on the county funding the project.
  - Contact the relevant county conservation district for its local policies.

1.6.1 DGLVR Stream Crossing Replacement Policy

The DGLVR Program's full stream crossing replacement policies can be found in chapter 7.1 of the DGLVR *Administrative Manual*. A brief overview of the purpose and highlights of the policy is below:

Eligibility: The policy limits funding of stream crossing replacements to structures that are undersized for the stream channel they convey (existing opening of 75% bankfull channel width or less). Existing crossing structures that are 4' or less in width or that consist of multiple (side-by-side) pipes are also eligible for replacement. The impacts of these undersized crossings are outlined above in the introduction. Since Pennsylvania has tens of thousands of road stream crossings, this part of the policy was intended to focus DGLVR Program funding on crossings that were more likely to be causing environmental (and flooding and maintenance) issues.

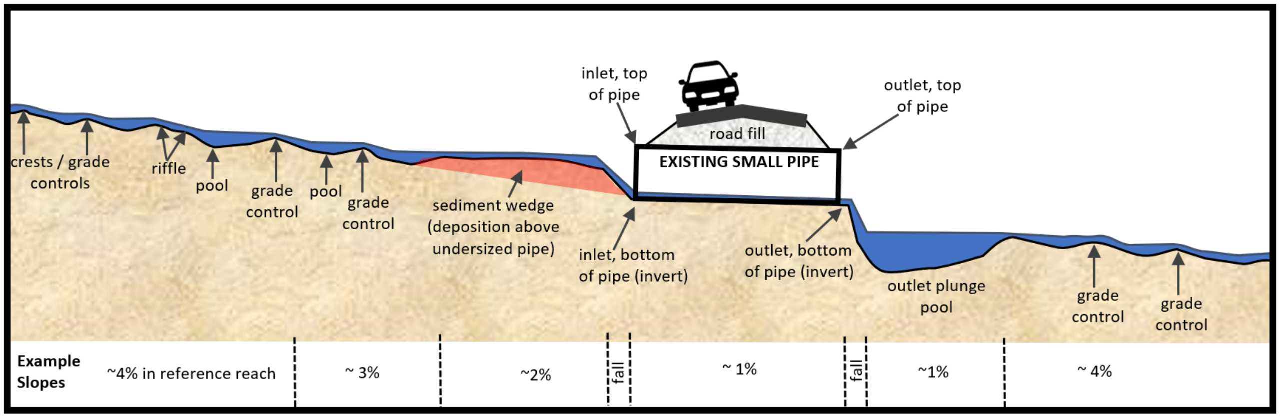
Replacement Guidance: When a new structure is installed with DGLVR funds, it must meet the DGLVR Program's Stream Crossing Design and Installation Standard to ensure long-term stability and channel continuity through the road. These requirements are outlined in the DGLVR Stream Crossing Standard described in Chapter 2.

Exemptions from the DGLVR Stream Crossing Standard: The DGLVR Program may fund a stream crossing without following the full DGLVR Stream Crossing Standard if specific criteria are met (see Section 3.3 of this Manual). This occurs most often on very small headwater streams or on crossings with significant **vertical offset** that make channel reconnection unreasonably challenging. The policy outlines the case for some "automatic" exemptions from the DGLVR Stream Crossing Standard for small channels and provides a mechanism to request exemptions from the DGLVR Stream Crossing Standard for other structures as well.

1.6.2 DGLVR Stream Crossing Design and Installation Standard

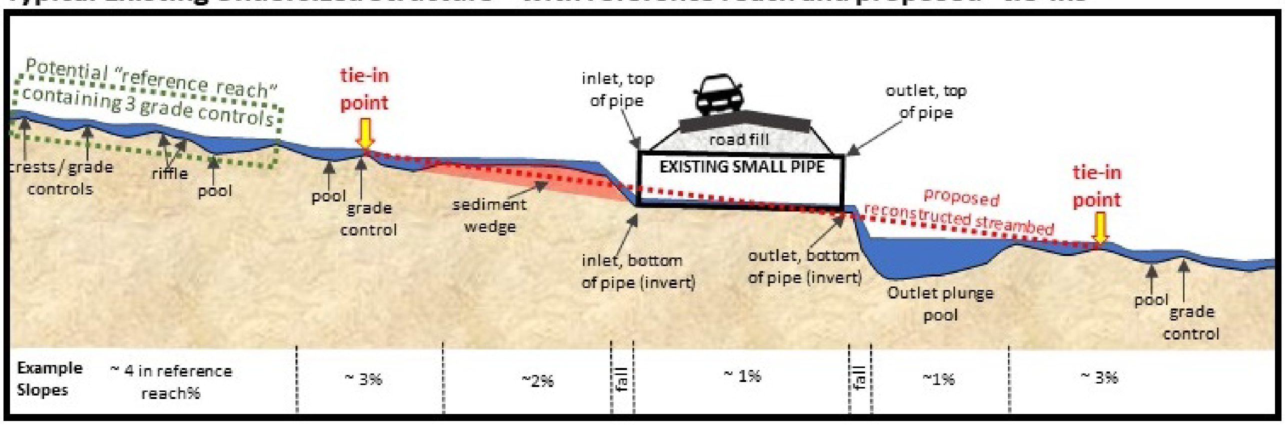
All new stream crossings installed with DGLVR funds or counted as in-kind on a DGLVR project must adhere to the DGLVR Stream Crossing Design & Installation Standard (DGLVR Stream Crossing Standard) unless the site qualifies for an exemption from the DGLVR Stream Crossing Standard as mentioned in Section 3.3 and detailed in the DGLVR Policy. The purpose of the DGLVR Stream Crossing Standard is to ensure that structures funded by the DGLVR Program are adequately designed and constructed to reestablish and maintain channel continuity and a stable, continuous streambed through the life of the structure. See Figure 1.6 for example channel continuity sketches and see Chapter 2 for a complete discussion of the DGLVR Stream Crossing Standard.

Typical Existing Undersized Structure



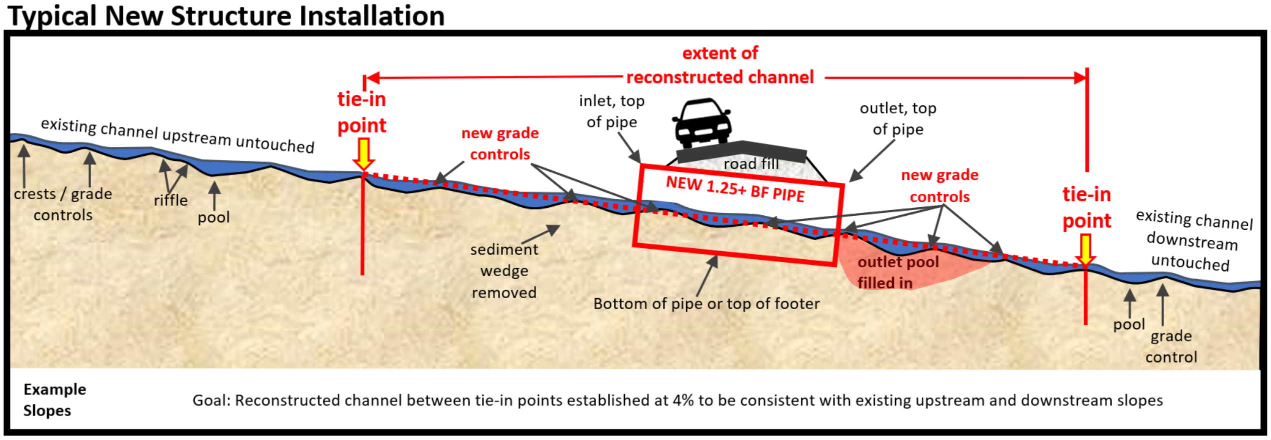
A "typical" undersized culvert will cause **Aggradation** (**Sediment Wedge**/ gravel deposition) upstream and a scour hole / plunge pool downstream. It will also alter the slope of the channel, making it flatter near the structure and often causing a vertical offset or drop at the outlet.

Typical Existing Undersized Structure – with reference reach and proposed "tie-ins"



A "reference reach" should contain at least three grade controls and be located outside of the influence of the culvert. Determine tie-in points that provide the best continuity of slope through the structure, upstream, and downstream.

Typical New Structure Installation



The new larger structure contains sufficient streambed material. The channel between the tie-in points and through the structure is reconstructed to restore channel continuity through the entire stream reach. Grade controls are established in the new channel at a frequency that matches the reference reach.

Figure 1.6 Stream Continuity Sketches

The three sketches above show a "typical" undersized structure replacement before and after replacement. The middle sketch shows the before or existing condition, but identifies a reference reach, tie-in points, and the proposed reconstructed channel segment (reconstructed reach) through the crossing.

2. DGLVR Stream Crossing Design and installation Standard

All stream crossing replacements funded in whole or in part with DGLVR funds, or listed as in-kind on a DGLVR project, must follow the DGLVR Stream Crossing Design & Installation Standard (DGLVR Stream Crossing Standard) unless an exemption from the DGLVR Stream Crossing Standard is applicable (see Section 3.3). This chapter of the manual walks through the DGLVR Stream Crossing Design and Installation Standard and provides additional background and guidance.

Italicized shaded text **below is quoted directly from the DGLVR Stream Crossing Design & Installation Standard. Additional explanation and background are provided on the major points.**

IV. B*. All stream crossing projects shall be authorized in accordance with local, state and federal laws and all applicable permits must be obtained prior to construction.*

Most stream crossing projects funded by the DGLVR Program will require a permit. The type of permit required will vary from one project to another. Conservation district staff should know who to consult to ensure the proper permits are obtained. Conservation district DGLVR technicians are required to review permit applications and/or site plans for stream crossings to ensure the application complies with the DGLVR Program requirements before they are submitted to the PA Department of Environmental Protection (DEP) or the conservation district for permit review.

Achieving channel continuity will typically require some channel work upstream and downstream of the replacement structure. Large vertical offsets caused by the previous structure may require extensive work up and down the channel. For many replacements, work may extend upstream or downstream of the new structure more than 50 feet. Additional permits may be required to authorize in-stream grade control and streambank restoration efforts. Conservation districts should look at the recommendations developed from the **Site Assessment longitudinal profile** data produced before contracting to determine the anticipated reach of restoration. This will aid in determining if a meeting with additional conservation district or DEP staff is necessary to discuss additional permit authorizations such as GP-1, GP-3, GP-11, or a Joint Permit.

Because the DGLVR Program's requirements can be more stringent than permit requirements, it is possible to have a project with an approved permit that will not meet the DGLVR Stream Crossing Standard. Therefore, it is very important to have a good understanding of the DGLVR Stream Crossing Standard and to review the design before a permit application is submitted. An approved permit is not a guarantee that a project can be paid for with DGLVR Program funds. A project may only be paid for with DGLVR Program funds when it meets the DGLVR Program Policy and Stream Crossing Standard.

IV. C. *All stream crossing structures shall be comprised of one single-opening structure installed at each crossing. Projects shall not utilize multi-opening structures or the placement of multiple single-opening structures at any one crossing location. Additional floodplain conveyance structures may be installed a minimum of one bankfull-width distance outside of the bankfull channel.*

When stream flow is directed through multiple structures, channel continuity is interrupted and debris can clog the inlet more easily. Installing additional floodplain conveyance structures too close to the stream crossing structure can act in a similar way to interrupt channel continuity and increase maintenance needs. Such practices do not meet DGLVR Program goals and are not eligible for installation with DGLVR funds.

IV. D. *New stream crossing structures shall be designed to pass, at a minimum, the 100-year discharge (Q100) at a water surface elevation not to exceed 80% of the finished opening height.*
A Hydrologic and Hydraulic (H&H) Study is required that includes:
1. Finished thalweg elevations, and
2. Clearly labeled discharge values and water surface elevations at the proposed crossing inlet for Q2, Q10, Q25, Q50, and Q100.

This defines the flow capacity requirements for newly designed stream crossing structures. By limiting the 100-year discharge to 80% of the **finished opening height**, the structure should also maintain some capacity for passing debris. The finished opening height is defined as the vertical distance measured from the **thalweg** elevation at the crest of a constructed grade control feature inside the replacement structure, upward to the top of the culvert opening or bottom of bridge beam. In some cases, structures may need additional width, and/or the road elevation may need to be raised to accommodate this requirement.

One of the purposes of this requirement is to discourage the use of lower-profile structures, which are poorly suited to natural stream systems. This is due to difficulty placing adequate streambed in the structure without compromising the hydraulic capacity of the structure. In other words, there is not enough room for both streambed and water flow in lower-profile structures.

An H&H Study is required to clearly demonstrate that the **Q100** water surface elevation does not exceed 80% of the finished opening height. Additionally, it must be demonstrated that any necessary raising of the roadway elevation will not result in a corresponding increase in flood elevations.

IV. E. *Grade controls, bank margins and key pieces shall, at a minimum, be designed to be stable at the 100-year discharge.*

The purpose of this requirement is to ensure that grade controls, bank margins, key pieces, and low flow channels remain intact after a large storm event. Even structures that are wider than the bankfull width still restrict the channel and have higher velocities and scours during high flow events than sections of the stream that have floodplain access. This often means that grade control within a structure must be sized larger than normally occurring grade control outside of the structure. These requirements are intended to ensure that the streambed, bank margins, and grade controls will remain stable through a large flow event. Sometimes this will mean choosing a larger or different structure to accommodate the stability of the bank margins and/or grade controls. For more details on grade control, refer to Section 12.1.6 and the Grade Control Technical Bulletin.

IV. F. *Structures must be of adequate width to accommodate the bankfull width of the stream at the final bankfull elevation with stable bank margins. Once these design criteria are met, the structure width shall not be less than 1.25x the bankfull width of the stream at the bankfull elevation.*

The width of new structures must take into account the need for a low flow channel and bank margins within the structure. This often requires structures that are significantly wider than the bankfull channel width. The width of the structure should be determined based on the site conditions that allow a stable channel and bank margins to be created through the crossing, but in no circumstances can the structure width be less than 1.25 times the bankfull width of the stream at the **bankfull elevation**. The “at the bankfull elevation” language comes into play for structures with sides that slope in, such as arch pipes. When sizing structures with sides that slope inward immediately from the bottom, remember to account for the depth of fill in the pipe when figuring opening widths. An 18’ wide arch pipe may only have a finished opening width of 15’ once 2’ of streambed material is established at the thalweg elevation through the structure, and may only have 14’ of width at the bankfull (bank margin) elevation. In this example, the latter width (14’, measured at the bankfull elevation) must not be less than 1.25-times the project bankfull width. Each site is unique, and while the DGLVR Stream Crossing Standard states that under no circumstance can the structure be less than 1.25 times the bankfull width of the stream at bankfull elevation, there will be many instances where the design will require a structure greater than 1.25 times the bankful width in order to meet the requirements of the DGLVR Stream Crossing Standard. See Figure 2.1 for an example detail showing the bankfull width channel, bank margins, and minimum 1.25 times bankfull width structure.

IV. G. *In project design and construction, bankfull channel dimensions must be based upon project site-specific field measurements. Channel dimensions derived from other methods, such as modeling of estimated bankfull discharge, shall not be utilized.*

In order to restore continuity with the existing stream channel upstream and downstream of the **reconstructed reach**, dimensions of the reconstructed reach must be based on measurements from the **reference reach**.

IV. H. *New structures must be properly aligned with the channel, unless not feasible due to permitting restrictions or other constructability restraints.*

Alignment refers to the layout of the structure in relationship to the stream channel as seen from a plan (overhead) view. Historically, stream crossings were often installed at a 90-degree angle to the road in an effort to save money by using the shortest structure possible. Unless the stream and road are perpendicular, this often forces the flow to turn at the inlet, outlet, or both, causing stability and erosion issues. Proper alignment of structures can reduce long-term maintenance and erosion issues caused when flow is turned at sharp angles. To the greatest extent possible, new structures should be aligned with the flow of the stream to minimize hard turns at the inlet or outlet. This often requires purchasing longer structures that are placed at an angle through the road. The DGLVR Program has discussed permitting of stream crossing replacements designed to meet the DGLVR Standard. The SCC GP-11 Permit Memo (Appendix E) clarifies when stream realignment can be authorized under a DEP GP-11. Contact DEP to discuss any proposed realignments and permitting requirements.

IV. I. *Consider floodplain connectivity when necessary (e.g., high water by-pass, overflow pipes, etc.). Floodplain- or overflow pipes must be placed a minimum of one bankfull-width distance outside of the bankfull channel.*

In most cases, a wider-than-bankfull width structure will be sufficient to accommodate high flow events. There are situations, however, such as wetland complexes and braided channels, where additional floodplain connectivity should be implemented. This could be accomplished using additional pipes (floodplain pipes, not a multiple pipe crossing), a French mattress, a highwater bypass, or other conveyance. However, it is important that such structures are not placed close enough to the new stream crossing structure to function as a multiple-opening stream crossing structure, which is why the DGLVR Stream Crossing Standard specifies a minimum distance from the bankfull channel for installed floodplain- or overflow pipes.

IV. J. *Structures must be designed and constructed to accommodate the passage of aquatic organisms through the structure.*

In most cases, aquatic organism passage will be obtained by achieving channel continuity upstream, through, and downstream of the structure by following the requirements of the DGLVR Stream Crossing Standard related to reestablishing slope, low-flow channels, bank margins, grade control, and **bedforms** reflective of the reference reach.

IV. K. *Round pipes over 36” in diameter may not be utilized for stream crossings.*

Round plastic pipes, by design, are intended to move water rapidly and flush the pipe clean. While this is ideal for stormwater pipes and road drainage cross pipes, it is the opposite of what the DGLVR Program is trying to accomplish with stream crossings. Larger round pipes also have the disadvantage of having the widest part of the pipe elevated above the bankfull channel unless they are buried halfway into the stream channel. Round pipes are not recommended for any stream crossings, regardless of size, but round pipes over 36” in diameter are not allowed for purchase or use for stream crossings in the DGLVR Program. Consider oval (“squash”) pipes or pipe-arches for small crossings, and consider plate arch pipes or other alternatives for larger crossings. See additional discussion on structure types in Chapter 5 and in the Structure Selection for Stream Crossings Technical Bulletin in Appendix H.

IV. L. *Low flow channels with well-defined bank margins must be built through the structure.*

The low-flow channel is the portion of the channel commonly wetted during stream base flow. See Figure 2.1 for an example detail showing a low-flow channel to be constructed within a stream crossing structure. If a structure is installed without a low-flow channel, the stream will likely be over widened as it enters the structure. This will cause it to lose energy and begin dropping bedload causing deposition issues inside the structure. The size and shape of the low-flow channel is determined by surveying cross-sections of the stream channel as described in Sections 4.2 and 12.1.2.2, as well as the Site Assessment Technical Bulletin (Appendix H).

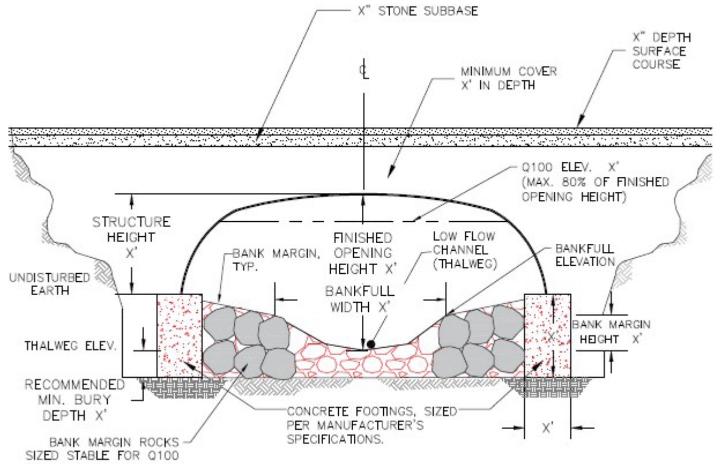


Figure 2.1 Bottomless Culvert Example Detail

Example detail of a bottomless arch culvert showing low flow channel and structure-to-bankfull ratios. Additional standard drawings of culvert cross sections are available in Appendix A and at https://www.dirtandgravel.psu.edu/general-resources/stream-crossing-replacements.

IV. M. *Site Assessment:*

1. *A longitudinal profile survey is required for each site prior to project design and/or permitting. The surveyed stream segments must extend far enough to capture existing channel slopes upstream and downstream of the crossing and must include an appropriate reference reach to support project design. To determine applicability, reference reach slope must be +/- 25% of the proposed continuity slope of the reconstructed streambed, unless otherwise approved by the SCC. If an appropriate reference reach is not located near the crossing, a separate survey may be conducted on an appropriate reference reach further upstream or downstream of the crossing. The reference reach must begin and end at existing grade control features and must, at minimum, include two consecutive sequences of repeating bed features (ex.* ***riffle/pool****/riffle/pool/riffle). A longer reference reach including additional bedform sequences is encouraged in order to provide more reliable design criteria.*
   - i. *The longitudinal profile survey must extend both upstream and downstream of the crossing and include data points associated with the existing structure and roadway surface.*
   - ii. *Sufficient number and locations of data points must be collected to determine the stream channel features that are critical to a successful structure replacement, such as:*
     1. *channel and structure slope,*
     2. *grade control types, lengths, and spacing,*
     3. *pool scour depth,*
     4. *potential* ***tie-in points****,*
     5. ***aggradation*** *wedges,*
     6. *plunge pools,*
     7. *vertical offset of the streambed adjacent to the structure, and*
     8. *available roadway cover.*
   - iii. *The longitudinal profile survey must extend a minimum of 150' upstream and 150' downstream of the existing crossing. Additional length of survey may be necessary to capture a suitable reference reach to support project design. Actual length of the longitudinal profile survey is dependent upon the site conditions, availability of a suitable reference reach, channel size and distance necessary to accurately capture existing channel slopes both upstream and downstream of the crossing. The longitudinal profile survey must extend from an existing grade control upstream of the crossing feature to an existing grade control feature downstream of the crossing.*
2. *Cross-section surveys are required at a minimum of two locations. At minimum, surveys must be*

completed at a grade control crest within the reference reach and at the deepest point in the ***outlet scour pool*** *(if present). If no outlet scour pool exists, this survey should capture the maximum depth of a pool feature from the reference reach. At minimum, each surveyed cross section must include data points on both streambanks capturing top-of-bank, bankfull, and right/left edge of water. Instream data points must include a minimum of three streambed points, including the thalweg (low-flow channel).*

3. *Refer to the DGLVR Stream Crossing Replacement Technical Manual for more guidance on Site Assessment requirements.*

IV. N*. The engineer is responsible for the Site Assessment data they use. If conservation districts provide Site Assessment data, the engineer has discretion to use the provided data or conduct their own surveys. If a Site Assessment is completed by the design engineer to support their project design, the conservation district technician is required to be on-site while the surveys are being performed by the engineer and/or surveyor. The engineer shall provide the completed survey and Site Assessment data to the conservation district technician. The Site Assessment data provided to the conservation district shall include stationing, elevations, and notations of key stream features as outlined in (M.) above.*

The design Site Assessment is a critical step that must be used to guide project design. It is described in Chapters 4 and 12. Detailed guidance for completing a Site Assessment can be found in the Site Assessment Technical Bulletin (Appendix H). Engineers may choose to use data from the preliminary Site Assessment performed by the conservation district (if provided), but in many cases may want to conduct their own survey. If an engineer or surveyor is going to conduct their own design survey, the conservation district must be onsite when the survey is being performed. The technician should ensure that the survey is of adequate length and includes important survey points (grade controls, inlet, outlet, road profile), etc.

IV. O. *The Site Assessment data (from longitudinal profile and cross section surveys) described above shall be used to inform project design considerations, including the following:*

1. Minimum stream substrate depth (measured below the low flow channel at a grade control crest, to the structure invert or bottom of the footings) is to be based on the maximum pool depth in the reference reach with a minimum safety factor multiplier as listed in Table 1. Alternatively, minimum bury depth can be determined using industry-accepted scour analysis and modeling tools for stream system analysis and/or bridges (storm sewer models are not acceptable for stream crossing scour analysis).

Table 1: Pool Depth Safety Factor Multiplier to Establish Anticipated Scour Depth

Stream Slope	Pool Depth Multiplier
0% - 2.0%	1.5
2.1% - 4.0%	2.0
> 4.0%*	2.5

** Structures installed on reconstructed reach stream slopes >4.0% must be bottomless. The 2.5 safety factor multiplier is to establish the recommended minimum bottom of footing buried depth. The final footing buried depth is to be determined by the engineer in project design.*

Adequate substrate (streambed) depth within a structure is critical to provide long-term stability. Simply meeting permit requirements, which are typically only 6-12” of material, is not sufficient to ensure long-term stability of substrate through the structure. There are two options to determine the substrate depth for stream crossing structures with a bottom or invert: “**Anticipated Scour Depth (ASD)**” or Industry Accepted Scour Analysis.

The “Anticipated Scour Depth” (ASD) of the stream, using information from the longitudinal profile survey, follows the following steps:

- Determine the maximum pool depth within the surveyed stream reach, exclusive of the outlet scour pool, as determined from the longitudinal profile survey.
- Determine the factor of safety multiplier from the table above based on the planned slope of the reconstructed reach of stream through the structure.

- Multiply the maximum pool depth by the factor of safety to get the Anticipated Scour Depth.

Example: a site with a channel continuity slope of 2.5% and a maximum pool depth in the reference reach of 1.2' would use the multiplier 2.0 (from the table above) for a minimum bury depth of 2.4' below the low flow channel at a grade control crest, to the structure invert (or bottom of the footings).

If the ASD method is used, the value returned (2.4' in the above example) is the minimum bury depth of the invert (or bottom of footings) of the new structure below the low-flow channel (thalweg) of the reconstructed channel at a grade control crest. The ASD therefore also represents the minimum amount of streambed that must be established between the structure invert and the bottom of the low flow channel. Note that all bury depths are measured from the bottom of the low-flow channel (thalweg), so additional material above the ASD value will need to be imported to establish the bankfull channel and bank margins.

Bottomless structures shall be used for all structure replacements where the continuity slope of the channel through the project area will be greater than 4.0% or the bankfull width is over 20', as determined by the longitudinal survey. As the slope increases, it becomes increasingly difficult to maintain streambed long-term through structures with inverts. The engineer may consider the Anticipated Scour Depth method as a starting point for designing depth of footings or may utilize another applicable method. The engineer of record is ultimately responsible for final design of footing depths and placements.

Scour analysis can be conducted by an engineer to determine the depth of scour that can be expected within the structure. The substrate depth must be sufficient to withstand that amount of scour without exposing the structure invert or bottom of footings. Engineers must use models and analysis designed for streams and bridges, as they differ from models for other civil engineering uses such as storm sewers or drinking water.

See Chapter 12 for additional details.

IV. O. 2. *Minimum substrate depth (measured below the low flow channel at a grade control crest, to the structure invert or bottom of the footings) shall be 24 inches, or the depth determined with scour analysis models or the Anticipated Scour Depth, whichever is greater.*

In no case will less than 24" of material (between the pipe invert and the bottom of the low flow channel at a grade control crest) be used inside a pipe with an invert. If industry-accepted scour analysis or ASD calculations above return a value of less than 24", 24" of material is still required.

IV. O. 3. *The design shall identify stable tie-in points at grade control features (either existing or to be constructed). The distance between the upstream- and downstream tie-in points must extend far enough in both directions to restore channel continuity upstream, through, and downstream of the structure.*

Channel continuity is achieved by reconnecting the disconnected segment of stream far enough upstream and downstream of the crossing to eliminate the vertical offset caused by the existing undersized structure. This reconstructed reach needs to extend far enough in both directions to reconnect the adjoining channel segments at a relatively consistent slope. The tie-in points where this reconstructed reach begins and ends (connects with the adjoining stream channel) must be at existing grade control locations. If these existing grade control features are stable, they can be left as-is. If they are unstable, or potentially not substantial enough to prevent eventual headcut development, constructed grade control features should be installed at these tie-in locations.

IV. O. 4: *In-stream channel grade control(s) are required for re-constructing the stream channel and/or stabilizing the stream bed and channel through the reconstructed stream reach. Types of grade control features utilized must be the same type as those within the appropriate reference reach. Design of grade control feature length and spacing shall be based upon the Site Assessment data.*

Grade controls are permanent features placed at certain intervals in the channel to control streambed elevation and slope and hold the stream substrate in place. Grade controls are discussed in Section 12.1.6 and are discussed extensively in the Grade Control Technical Bulletin (Appendix H).

IV. O. 5: *Design of the cross-sectional shape of the reconstructed reach must be based on Site Assessment data.*

The design **cross sections** are essential to project design. Cross sections are described in Chapter 4 and 12, and detailed guidance for completing the cross sectional assessments can be found in the Site Assessment Technical Bulletin (Appendix H). Engineers may choose to use cross section data from the preliminary Site Assessment performed by the conservation district, if provided, but in many cases may want to conduct their own survey. If an engineer or surveyor is going to conduct their own design survey, the conservation district representative must be on site when the survey is being performed. The conservation district's role during the engineer's site assessment is to observe and assist with the longitudinal profile and cross sections and ensure that all important data points are obtained.

***IV. P**. Stream crossing projects will likely require work outside of the right-of-way to reconstruct the stream channel, install grade controls, and/or allow for construction access to the stream and structure. Before working outside the right-of-way, the grant recipient must obtain written permission from the landowner(s). In instances when written off right-of-way permission cannot be obtained to do work necessary to achieve channel continuity, the project cannot be completed with DGLVR funds.*

Nearly every stream crossing replacement will involve work in the stream channel outside the road right of way. Written off-right-of-way permission should be sought early in project design, as it may impact the ability to implement a successful project. Written off-right-of-way permission is required before work can begin outside of the right-of-way. More details on off-ROW in Section 3.4.3.

***IV. Q.** The grant recipient or engineer must provide all plans and specifications to the conservation district. The conservation district must review the documents and provide written confirmation to the grant recipient or engineer that those plans and specifications comply with DGLVR Policy and Stream Crossing Standard before they are submitted (or resubmitted) for permit review.*

Historically, permit registrations or applications, and associated design plans, are often submitted to DEP without a consultation or review by the conservation district. This can result in a host of miscommunication issues and permits being issued for project designs that do not meet the DGLVR Program Policy and Standard. This requirement ensures that conservation districts are given the opportunity to ensure that the proposed project plans and specifications meet the requirements of the DGLVR Stream Crossing Standard before submittal for permit approval. A "Design Package Review Checklist for Stream Crossings" is provided in Appendix G. Contact the SCC or CDGRS for assistance in reviewing plans, either in-person or remotely, if necessary.

***IV. R.** Side Slopes: Make all finished cut and fill road slopes stable for the materials involved. Make the side slopes in soil materials no steeper than 2 horizontal to 1 vertical (2:1) in cut slopes or 3 horizontal to 1 vertical (3:1) for fill slopes. Make rock cuts or fills no steeper than 2 horizontal to 1 vertical (2:1)).*

These requirements are consistent with common practice to ensure the long-term stability of final cut and fill road slopes established during structure replacement.

***IV. S.** All stream crossing replacement structures must include a headwall and endwall.*

Headwalls and endwalls are essential to support and protect the road edge, backfill areas, and the ends of the structure.

***IV. T.** Quarried aggregate rip-rap for use as grade control, bank margins, or bank stabilization: Use only rock that is sound, durable, and able to withstand exposure to air, water, and freezing and thawing. Aggregate must be obtained from a Pennsylvania Department of Transportation approved source, or must be tested and meet the following criteria:*

1. *Abrasion Resistance: The loss of mass (LA Abrasion) shall be less than 45%: Determine the resistance to abrasion using the Los Angeles Abrasion test, ASTM C131.*
2. *Soundness: Determine the percentage of mass (weight) loss of each fraction of the coarse aggregate after five cycles of immersion and drying using a sodium sulfate solution according to PTM No. 510. The maximum weighted percent loss allowed is 20%.*

Large, quarried rock that is imported for use as grade control, bank margins, or bank stabilization must meet these requirements in order to resist breakdown over time. These requirements do not apply to material imported for streambed substrate or to onsite materials that are reused as part of the project. These requirements only apply to materials imported for grade controls, bank margins, and bank stabilization. Rock with a high abrasion resistance will be less likely to break down under the high sheer stresses often seen in stream channels. Rock that is of sufficient soundness will be resistant to breakdown under repeated freeze-thaw cycles. Because rock used for bank stabilization and grade control are specified at a certain size, these requirements ensure that they will remain at the appropriate size and not be broken down over time.

IV. U. *Vegetation: Revegetate and permanently stabilize all disturbed areas as soon as practical after construction activities are complete. Revegetation and site stabilization shall comply with the PA Chapter 102 Erosion Control requirements (see the PA Erosion and Sediment Pollution Control Program Manual for additional guidance).*

In addition to seed and mulch, conservation districts should consider native plantings such as live stakes, fascines, live crib walls, and brush mattresses as additional vegetative bank stabilization methods.

IV. V. *Road Approaches to Stream Crossings: Ensure that the roadway approaches are stable and road drainage systems have been addressed and are adequate to divert road drainage (e.g., ditches, turnouts, etc.) away from the stream and structure in a manner that prevents erosion*.

Conservation districts are encouraged to make stream crossing replacements part of a more comprehensive drainage project on the surrounding road. When possible, redirect drainage away from the stream or provide additional drainage outlets. At a minimum, ensure that road ditch drainage does not pose a threat to the new structure and contribute accelerated erosion to waters of the Commonwealth.

IV. W. *Project work cannot start until all federal, state, and local permits are obtained, if needed. In particular, any required DEP 102/105 permits must be obtained before construction may begin.*

Most DGLVR Stream Crossing projects will likely utilize a DEP Chapter 105 GP-11 or GP-7. Depending on the scope of work, additional authorizations under GP-1, GP-3, and GP-5 may be needed. See the SCC GP-11 Permit Memo (Appendix E) for additional clarification. Consult with DEP as needed on permitting questions, as well as with other entities involved in any required federal, state, or local permits that may be needed.

V. STRUCTURE SELECTION

V. A. *Bottomless structures shall be used for all structure replacements 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.*

V. B. *Structures with inverts / bottoms may be used for structure replacements where the continuity slope of the channel to be reconstructed will be 4.0% or less (as determined by the longitudinal survey) or on sites over 4.0% where it is determined by a geotechnical investigation report that soil bearing pressure cannot support structure abutments or footings.*

As stream slope increases, so does potential scour, requiring larger grade control and additional streambed material in the structures to prevent washouts. Bottomless structures shall be used for all structure replacements where the continuity slope of the channel through the project area will be greater than 4.0% or the bankfull width is over 20', as determined by the longitudinal profile. The stream slope that determines this is the "continuity slope" that connects the upstream and downstream tie-in points through the structure. This is determined from the longitudinal profile.

VI. CONSTRUCTION PLANS AND SPECIFICATIONS

Construction plans and specifications shall be designed and prepared in accordance with the Stream Crossing Standard. Construction plans and specifications shall be prepared for all stream crossing projects, regardless of who the contractor or installer may be (applies to projects installed by the grant recipient, such as a municipality). Clearly describe the *requirements for applying the practice to achieve its intended purpose in the plan and specifications. At a minimum, the plan and specifications must include the following…(see Stream Crossing Design and Installation Standard for full text)*

Section VI outlines the requirements for plans and specifications for project design by engineers. These specifications apply to both contractor-installed and grant recipient-installed structures. These requirements are detailed in the "engineering section" of this manual in Section 12.2.1.

VII. CONSTRUCTION

VII. A. *The grant recipient or engineer must provide all draft bid packages (if applicable) to the conservation district. The conservation district must review the draft bid documents and provide written confirmation to the grant recipient or engineer that those draft bid documents comply with DGLVR policy and Stream Crossing Standard before they are provided to potential bidders. All bid documents and practices must conform with municipal codes and other standard procurement requirements of the grant recipient.*

Bid packages have often been released without a consultation or review by the conservation district. This can result in a host of miscommunication issues and bids for practices that may not align with DGLVR Program Policy and Stream Crossing Standard. This requirement ensures that conservation districts are given the opportunity to ensure that the draft bid document meets the DGLVR Policy and Stream Crossing Standard. Also, this allows districts to ensure that the draft bid document adequately addresses aspects of construction that might not typically apply to a more traditional crossing replacement. These might include reconstruction of a streambed with bank margins, grade control features, and defined thalweg through the crossing, or extension of instream work upstream and downstream beyond the right-of-way to reestablish channel continuity. Review of the bid documents before they are shared with interested bidders can often save a lot of time and expense caused by change orders to inadequate bids. Contact the SCC or CDGRS for assistance in reviewing bid documents, either in-person or remotely, if necessary.

VII. B. *Final construction documents shall include, at a minimum, the following items:*
1. *Bidding Documents (if applicable).*
2. *Construction Plan.*
3. *Erosion and Sedimentation Control Plan.*
4. *Construction Specifications.*

This section outlines the minimum **construction documents** required for DGLVR projects. These requirements are detailed in the "engineering section" of this manual in Chapter 12.

VII. C. *At a minimum, two benchmarks must be set by the engineer or surveyor in an area outside of the zone of construction and disturbance.*

This section requires the design engineer or surveyor to establish two benchmarks outside of the work zone. This will allow the contractor/engineer/installer to re-establish stakeouts and elevations if they are disturbed during construction. The benchmarks provide reference points to allow for spot-checking of critical elevations during construction.

VII. D. *Critical Stages of Construction to be inspected by the engineer (and/or engineer's designee) at the time of installation is required. Critical Stages include, but are not limited to, the following:*
1. Installation of structure subgrade and bedding materials and establishing inverts/elevations.
2. Installation of footings, abutments and structure ***appurtenances****.*
3. Installation of grade control features, bank margins, and streambed substrate.
4. Installation or placement of stream crossing structure.
5. Compaction and backfill of stream crossing structure.

This section requires the design engineer or their designee to be on site at critical stages of project installation to ensure that key aspects of the project are installed as designed, or to be able to modify the design as issues arise. These requirements are detailed in the "engineering section" of this manual in Chapter 12.

Any changes to the scope of work of the construction plans must meet DGLVR Policy and Stream Crossing Standard and be approved by the engineer and road owner before implementation. Keep in mind that changes to construction plans may also require approval from DEP and/or landowners.

VII. E. *Conservation districts must be on-site regularly during construction to ensure that DGLVR Program Policy and Stream Crossing Standard are being met. Conservation districts must be onsite during installation of the Critical Stages of Construction defined in VII. D, above.*

Conservation district involvement throughout the process is key to successful installations. Conservation district staff best understand DGLVR Policy and often serve as the central point of contact for the many entities involved in a project. At a minimum, conservation districts must be onsite during installation of Critical Stages of Construction. Additionally, the conservation district should be on site whenever the project begins a new phase of installation, as well as whenever the engineer is on site. Conservation districts are recommended to be on site as much as possible during construction.

VII. F. *Certification and Documentation of Critical Stages of Construction: The engineer shall provide the project owner a signed and sealed certification form (Attachment B) indicating that the critical stages of construction outlined in Section VII.D were inspected and installed in accordance with the construction documents and DGLVR Stream Crossing Standard. The engineer must also provide the project owner with red-lined construction documents that indicate any changes in the as-built conditions of the project compared to the design plans.*

Attachment B to the DGLVR Stream Crossing Standard is a signed and sealed document to be provided by the engineer at project closeout. It allows the engineer to supply notes on the critical stages of construction and the overall project. The “red-lined” construction drawing is typically a set of plans with red ink used to identify things that were not implemented according to the design plan. These documents will help provide an “as-built” picture of the project for review in the future should issues arise.

3. Initial Site Assessment and Project Planning

Typically, a stream crossing replacement project starts with the applicant contacting the conservation district well in advance of the county's grant application cycle. Each conservation district should clearly communicate its own local policies and deadlines and make them easily accessible to applicants. It is very important that conservation districts and potential applicants build a working relationship and understand local funding priorities well in advance of developing a grant application.

Once contact is made by a potential applicant, the conservation district should schedule a site visit at the potential project location to review existing site conditions. During this meeting, conservation district staff should determine the road owner's eligibility and road eligibility for DGLVR Program funds. Applicant and road eligibility are covered in the DGLVR *Administrative Manual* in Section 3.7, "Program Eligibility."

When working with an applicant, it is important to have a candid conversation early during the initial site assessment about the Stream Crossing Replacement Policy as well as the DGLVR Stream Crossing Standard. The policy can be found in chapter 7.1 of the DGLVR *Administrative Manual*, and the Stream Crossing Standard can be found in Appendix A of this document. Not only does this policy limit the replacement of stream crossings to those that are negatively impacting streams, but it also sets the minimum requirements for the replacement structure. This process is specific to the DGLVR Program and frequently differs from traditional recommendations received from engineers, particularly regarding the need to rebuild and reconnect the stream channel through, and beyond, the replacement crossing. Conservation district staff should study the requirements for eligibility and new structure replacement and be able to explain to the potential applicant the details, requirements, and benefits of this design approach.

3.1 Stream Specific Discussion Points

When talking with applicants, it is important to convey the benefits of flood resiliency, optimal structure lifespan, and reduced maintenance requirements of properly installed structures. These projects also represent a large time investment for the applicant to see a successful project through to completion.

Conservation district staff should talk with the applicant to understand the history of the existing stream crossing and what occurs at the site during high flow events. Undersized structures eligible for replacement may not be the initial cause of roadway flooding. Occasionally, streams breach their streambanks upstream of the structure. Taking the time to understand the site-specific history and constraints will provide insight in developing the project.

3.2 Stream Measurements and Structure Eligibility

Before entering the stream channel to take bankfull measurements, verbal permission should be sought from the adjacent landowner(s) to avoid potential trespassing issues that could sour relationships and make the landowner less likely to agree to the eventual project.

During the initial site visit, conservation district staff should measure the width of the existing structure(s) with the applicant and record it on the Stream Crossing Eligibility Determination Form (Appendix C). When measuring the width of an existing structure, measure the most limiting width (for example: the narrowest pipe in a series of "necked-down" or "end-to-end" pipes, or the narrowest point between abutments of a skewed bridge perpendicular to the flow). If the existing crossing is less than 4' wide or consists of multiple side-by-side structures, the structure is automatically eligible for replacement. Conservation district staff should record the type and opening width of the multiple structures for reference on the Stream Crossing Eligibility Determination Form and keep it in the project files.

The group should walk the stream corridor upstream and downstream of the existing structure to determine the optimal location to take bankfull width measurements outside of the influence of the existing crossing. Bankfull width is measured perpendicular to the channel thalweg at bankfull elevation. In unconfined channels, bankfull elevation is the point where water fills the channel just before beginning to spill onto the floodplain. This elevation and break-point onto the floodplain typically corresponds to the 1.5 – 2-year recurrence streamflow event. For full explanation and details on how to measure bankfull width, refer to the Bankfull Width Determination Technical Bulletin in Appendix H.

3.2.1 Stream Crossing Eligibility Determination Form

A Stream Crossing Eligibility Determination Form must be completed for each stream crossing to be replaced with DGLVR funds. The Stream Crossing Eligibility Determination Form is used to record the bankfull width measurements taken at the project site, and to identify the type and width of the existing structure. It also contains the qualifications for project eligibility for DGLVR funding. This form must be completed by the conservation district and kept in the project file for every stream crossing, even those that receive an exemption from the DGLVR Stream Crossing Standard (Section 3.3).

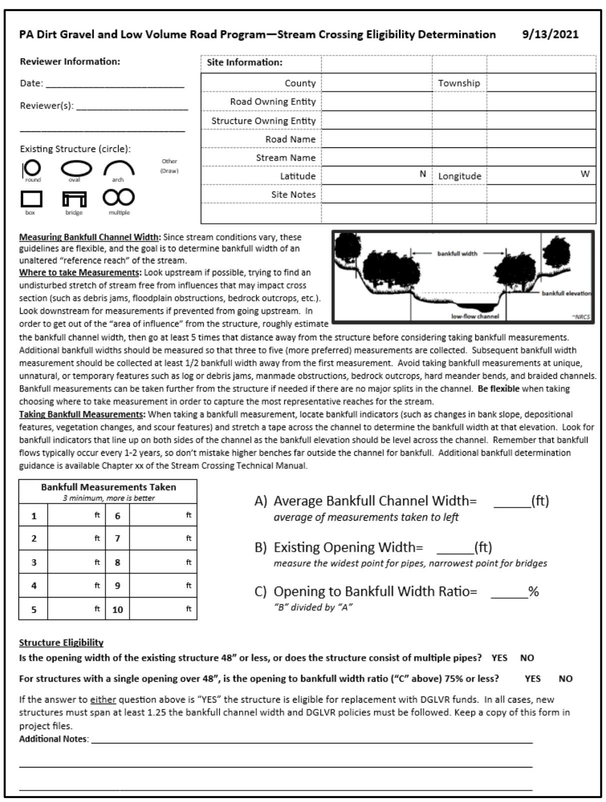
The back of the Stream Crossing Eligibility Determination Form contains room for an aerial sketch of the stream. The sketch should show the layout of the crossing, any significant features (bedrock, side channels, houses, etc.), and indicate where bankfull measurements were taken. Often, bankfull measurements are recorded significantly in advance of an application or contract, and this detailed information will help in the event of turnover in staff that collected the original data.

3.2.2 Determining Structure Eligibility

After staff have completed existing structure measurements and recorded bankfull width measurements, follow the instructions on the Stream Crossing Eligibility Determination Form to determine the "Opening to Bankfull Width Ratio." An image of the Stream Crossing Eligibility Determination Form is provided in Figure 3.1, and the form is available in Appendix C. From the information gathered up to this point, structure eligibility for replacement can be determined. As defined in DGLVR Policy, a structure is eligible for replacement if:

- The opening width of the existing structure is 48" or less.
- The structure consists of multiple side-by-side pipes or openings.
- A structure with a single opening over 48" has an opening-to-bankfull width ratio of 75% or less (letter "C" on the Stream Crossing Eligibility Determination Form).

This form must be completed and kept in the project file for every stream crossing, even those that receive an exemption from the DGLVR Stream Crossing Standard.



PA Dirt Gravel and Low Volume Road Program—Stream Crossing Eligibility Determination **9/13/2021**

Reviewer Information:

Date: ____________________

Reviewer(s): ____________________

____

Existing Structure (circle): round, oval, arch, Other (Draw), box, bridge, multiple

Site Information:			
County		Township	
Road Owning Entity			
Structure Owning Entity			
Road Name			
Stream Name			
Latitude	N	Longitude	W
Site Notes			

Measuring Bankfull Channel Width: Since stream conditions vary, these guidelines are flexible, and the goal is to determine bankfull width of an unaltered "reference reach" of the stream.
Where to take Measurements: Look upstream if possible, trying to find an undisturbed stretch of stream free from influences that may impact cross section (such as debris jams, floodplain obstructions, bedrock outcrops, etc.). Look downstream for measurements if prevented from going upstream. In order to get out of the "area of influence" from the structure, roughly estimate the bankfull channel width, then go at least 5 times that distance away from the structure before considering taking bankfull measurements. Additional bankfull widths should be measured so that three to five (more preferred) measurements are collected. Subsequent bankfull width measurement should be collected at least 1/2 bankfull width away from the first measurement. Avoid taking bankfull measurements at unique, unnatural, or temporary features such as log or debris jams, manmade obstructions, bedrock outcrops, hard meander bends, and braided channels. Bankfull measurements can be taken further from the structure if needed if there are no major splits in the channel. **Be flexible** when taking choosing where to take measurement in order to capture the most representative reaches for the stream.
Taking Bankfull Measurements: When taking a bankfull measurement, locate bankfull indicators (such as changes in bank slope, depositional features, vegetation changes, and scour features) and stretch a tape across the channel to determine the bankfull width at that elevation. Look for bankfull indicators that line up on both sides of the channel as the bankfull elevation should be level across the channel. Remember that bankfull flows typically occur every 1-2 years, so don't mistake higher benches far outside the channel for bankfull. Additional bankfull determination guidance is available Chapter xx of the Stream Crossing Technical Manual.

Bankfull Measurements Taken *3 minimum, more is better*			
1	ft	**6**	ft
2	ft	**7**	ft
3	ft	**8**	ft
4	ft	**9**	ft
5	ft	**10**	ft

A) Average Bankfull Channel Width= _____(ft)
average of measurements taken to left

B) Existing Opening Width= _____(ft)
measure the widest point for pipes, narrowest point for bridges

C) Opening to Bankfull Width Ratio= _____%
"B" divided by "A"

Structure Eligibility

Is the opening width of the existing structure 48" or less, or does the structure consist of multiple pipes? YES NO

For structures with a single opening over 48", is the opening to bankfull width ratio ("C" above) 75% or less? YES NO

If the answer to either question above is "YES" the structure is eligible for replacement with DGLVR funds. In all cases, new structures must span at least 1.25 the bankfull channel width and DGLVR policies must be followed. Keep a copy of this form in project files.

Additional Notes: ____________________

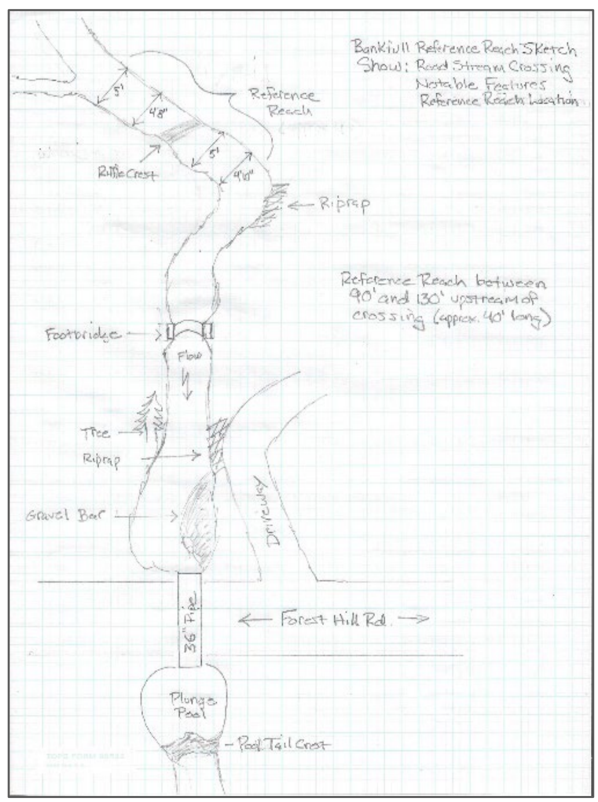


Figure 3.1 Stream Crossing Eligibility Determination Form

This form is to be completed by the conservation district to quantify the bankfull measurements taken and determine project eligibility. This form is available in Appendix C, and must be kept in project files.

3.3 Exemptions from the DGLVR Standard

The SCC has created an "exemption" process that may apply to very small channels or to channels where achieving continuity is not possible. This exemption applies to DGLVR Policy only. It does not exempt any project from following any local, state, or federal permit or other requirements. The exemption process is detailed in Section 7.1 of the DGLVR *Administrative Manual*.

Automatic Exemption: Streams with a bankfull width of 4 feet or less and a drainage area less than 20 acres or a bankfull width of 4 feet or less and a defined "bed and bank" channel coming to the road of less than 500 feet can be automatically exempted from following the DGLVR Stream Crossing Standard by the conservation district. The conservation district must complete the "Automatic Exemption from the DGLVR Stream Crossing Standard" form in the DGLVR *Administrative Manual* and keep it in the project file.

SCC-Approved Exemption: Stream crossings that do not meet the automatic exemption criteria above may still be given an exemption, but the exemption must come from the State Conservation Commission. The "SCC Approval for Exemption from the DGLVR Stream Crossing Standard Request" form in the DGLVR *Administrative Manual* must be completed and submitted to the SCC. If approved, the signed exemption form must be kept in the project file.

Requirements for exempt crossings: Projects receiving an exemption from the DGLVR Stream Crossing Standard still require that consideration be given to streambed and streambank stabilization. Even if channel continuity cannot be achieved, steps must still be taken to ensure stream crossings that receive an exemption from the DGLVR Stream Crossing Standard will result in a stable crossing that will not lead to accelerated erosion or other issues.

- Any requirements from local, state, and federal laws and all applicable permits are not waived as part of this exemption and must be followed.
- New structures must still be a single span at a minimum of 1.25 times or 125% of the bankfull channel width unless otherwise approved by the SCC.
- Ensure the stability of the channel upstream and downstream. Grade controls must be shown on plan drawings if drawings are required.
  - Upstream: Grade control(s) are required above the inlet of the new structure to prevent headcutting (headward erosion lowering channel elevation that moves upstream over time). If a larger structure is installed in a channel with road height limitations, installing a larger structure below the existing streambed elevation without grade control(s) will likely cause a headcut.
  - Downstream: Outlet stabilization is required in the form of grade controls, bank armoring, and/or filling in scour holes. Pipes may need to be extended further off the road, and the erosion potential caused by any elevation drops must be considered.
- New structures must be properly aligned with the channel, unless not feasible due to permitting restrictions or other constructability restraints.
- Consider floodplain connectivity when necessary (e.g., high water by-pass, overflow pipes, etc.).
- If permits and engineered plans are required, conservation districts are required to review all plans and specifications to ensure that the project complies with DGLVR Policy and the Stream Crossing Standard before they are submitted for permit review.
- Divert surface runoff and road drainage away from the stream and structure in a manner that prevents erosion and prevents direct discharges to the stream.
- All stream crossings must include a headwall and endwall.

3.4 Proposed Project Scope of Work

Stream crossing replacements are complex and time-consuming projects. Discussing many of these potentially complex logistics early in the process, before a grant application is even developed, is the best way to prevent unforeseen future problems. Some highlights of important discussion topics during the initial site visit are listed below. Refer to the "Pre-Application Meeting Checklist for Stream Crossings" in Appendix G.

3.4.1 Potential Project Timeline

Conservation district staff should clearly discuss realistic expectations for a potential project timeline if funded. Stream crossing replacements can take significantly longer to plan and implement than drainage projects. Some factors influencing the potential project timeline that should be discussed with the applicant include:

- Local factors such as application deadlines and the conservation district's application review, ranking, and contracting process.
- Permit requirements, including time to prepare and submit, and time for required reviews (conservation district and DEP).
- Allowing time for bidding and material acquisition (especially the structure itself).
- Contractor availability and scheduling.
- Regulatory restrictions prohibit instream work on streams that support natural reproduction of trout (wild trout streams) between October 1 and December 31. This restriction includes tributaries to wild trout streams.
- Regulatory restrictions prohibit instream work on stocked trout streams between March 1 and June 15.
- Regulatory restrictions prohibit instream work on Class A Wild Trout Waters October 1 – April 1.
- Depending on stream and site conditions, it may be advisable to schedule construction during times of typical seasonal low-flow conditions.
- Avoid scheduling construction during times where freezing temperatures can complicate excavation and make accurate stream channel reconstruction very difficult.
- Other complicating factors such as utility relocation, potential threatened or endangered species conflicts, especially as identified by the Pennsylvania Natural Diversity Inventory (PNDI), or lack of landowner consent for off-right-of-way work.

3.4.2 County-Specific Policies

Applicants should be informed of county-specific policies, such as required in-kind contributions or paying for the road surface over the crossing, before they develop their application.

3.4.3 Off-Right-of-Way (off-ROW) Permissions

Before working outside the road right-of-way, the grant recipient must obtain written permission from the landowner. The full DGLVR off-ROW policy can be found in the DGLVR *Administrative Manual,* Section 3.7.4. With typical rights-of-way of 33' in Pennsylvania, nearly all stream crossing replacements will require channel work outside the ROW to be successful. It is important to have the conversation with the applicant very early in the process about obtaining these off-ROW permissions. This written off-ROW permission should be obtained before the project is contracted and designed, as it may impact the design considerations or even the ability to successfully implement the project. An (editable) example off-ROW consent form to obtain permission from a landowner to perform work and/or outlet water onto their property can be found here: https://www.dirtandgravel.psu.edu/pa-program-resources/program-specific-resources/blank-forms.

Where off-ROW permission is needed to achieve channel continuity and meet the DGLVR Stream Crossing Standard, landowner permission must be obtained in order to fund the project. If landowner permission is required but cannot be obtained, the project cannot be funded. Contact the SCC in questionable circumstances where a lack of landowner permission may hinder successful project implementation.

3.4.4 Prevailing Wage

When developing the grant application, it is also important to determine early on if the project will be implemented by the applicant, subcontracted, or completed through a mix of a contracted and in-house labor/equipment. The DGLVR Program is subject to the Pennsylvania Prevailing Wage (PW) Act (1961, August 15, P. L. 987, No. 442), 43 P.S. Section 165-1 et seq. Prevailing wage rates apply to DGLVR projects when the total estimated or actual project cost is $25,000 or more (not $100,000). If federal funds are also involved in the project, the project may also be subject to the Davis-Bacon Act. Additional details on PA prevailing wage can be found in the DGLVR *Administrative Manual* Section 3.7.4 or through the PA Department of Labor and Industry at: https://www.dli.pa.gov/Individuals/Labor-Management-Relations/llc/prevailing-wage/Pages/default.aspx

3.4.5 Professional Design Services

Not all engineers share the same background and specialties. When possible, seek out an engineer or design firm with experience in stream environments as opposed to more urban disciplines such as stormwater and wastewater management. Many grant applicants such as municipalities have engineers they typically use on retainer. Having an engineer on retainer is a commitment to that engineer but does not obligate the municipality to use that engineer for every project. Just like a municipality would not hire a nuclear engineer to design their new municipal building, an urban stormwater engineer may not the best choice for designing stream restorations and stream crossings. Ensure that the applicant understands that the requirements of the DGLVR Program exceed those associated with traditional crossing-replacement practices. The applicant needs to be aware of the corresponding increase in the engineer's scope of work. Additionally, the applicant needs to be aware of how DGLVR grant funding can be utilized to help pay for engineering, permitting, and similar consulting costs:

- Engineering costs paid with DGLVR grant funds are limited to 20% of the total contract, up to a cap of $25,000. More details can be found in Sections 3.7.4.7 and 7.1.2.4 of the DGLVR *Administrative Manual*.
- Any engineering costs above that limit will be the responsibility of the grant recipient and can be counted as in-kind toward the project.
- Engineering costs incurred before a contract is signed with the conservation district cannot be paid with DGLVR funds (but can count toward in-kind).
- Refer to Chapter 12 of this document for more details on engineering requirements.

When is an Engineer Needed?

- An engineer is needed for all stream crossing replacement projects subject to the requirements of the DGLVR Stream Crossing Standard.
- An engineer is needed for all projects that will require a GP-7 or GP-11 permit on a publicly traveled roadway. The plans specification and reports must be sealed by a professional engineer (P.E). This includes any project that may be covered by an exemption from the DGLVR Stream Crossing Standard, but still requires a PA DEP permit.
- Any project that will be authorized under a PA DEP/USACE Joint Permit will required an engineer.

When is an Engineer Not Needed?

- An engineer may not be needed if the project is covered by an exemption from the DGLVR Stream Crossing Standard *AND* requirement of a GP-7, GP-11, or Joint Permit has been waived by PA DEP.

3.4.6 The Engineer's Scope of Work

The engineer's scope of work must be consistent with the requirements of the DGLVR Policy and the Stream Crossing Standard. It will be beneficial for the conservation district to provide these documents to the grant recipient as early in the project lifecycle as possible to assist the grant recipient and engineer in defining a scope of work and fee for the engineering services needed. While not required for use, the template Request for Proposals (RFP) form (Appendix F.) provides the framework for a generalized scope of work that should fit most stream crossing replacement projects funded through the DGLVR Program. Additional scope items, to be added at the discretion of the grant recipient, might include construction survey stakeout or additional meetings and plan revisions during the conservation district plan review process. These work elements are not required by the Program but contribute greatly to project success and are strongly recommended.

3.4.7 Permitting

The DGLVR Stream Crossing Standard requires that the engineer submit design plans and specifications to the conservation district for review (see Chapter 12 for more information). This review must be completed by the conservation district to ensure that the plans and specifications comply with DGLVR policy and the requirements of the Stream Crossing Standard. The grant recipient (or their engineer) may not submit materials for permit review and issuance until written notification is received from the conservation district that a satisfactory review has been completed by the conservation district and all DGLVR Program requirements have been met. Upon receipt of this notification, the grant recipient (or their engineer) may then submit to the appropriate regulatory agencies for the permits needed to authorize the project.

Any required project permits must be obtained by the grant recipient before site / installation work (construction) can begin on the portion of the project related to the permit. The DGLVR Program does not have any special permits or permit exemptions, and all applicable permit requirements must be followed (even for sites given an exemption from the DGLVR Stream Crossing Standard described in 3.3).

3.4.8 Local Ranking and Evaluation

Applicants should also be notified of the evaluation and ranking process completed by the quality assurance board and conservation district staff. If the scope of work an applicant is proposing would benefit from revisions such as addressing other roadway base and stormwater drainage improvements, staff should make these recommendations. Stream crossing projects should not only address the stream but should address all drainage and roadway base problems that contribute to the sedimentation of the water resource at that proposed project location. If the scope of work is too great for one funding cycle, conservation districts should consider in their local policy how to handle phased projects and provide that information to the applicant.

3.5 SCC Notification

Conservation districts are required to notify the SCC of proposed stream crossing replacements as soon as practical before a contract is signed. An online notification system is available by logging in to the CDGRS website (same log-in as accessing the GIS system) at www.dirtandgravelroads.org. For projects covered by an exemption from the DGLVR Stream Crossing Standard, an online notification is still required.

4. Site Assessment

This chapter concerns the preliminary Site Assessment that is typically conducted by the conservation district and is used to determine details for the grant application. The conservation district's Site Assessment also provides a valuable tool for later review of the engineer's design plan for consistency with DGLVR Program Policy and the Stream Crossing Standard.

The DGLVR Stream Crossing Standard also requires the design engineer to either utilize the Site Assessment completed by the conservation district (if provided) or conduct their own separate Site Assessment (after a contract is established) to inform stream crossing replacement design. The conservation district must be on site while the Site Assessment is being performed by the engineer and/or surveyor. The conservation district must observe and assist with the Site Assessment and ensure that all important field data are obtained. More information on the design survey requirements for engineers can be found in Chapter 12 of this document.

A Site Assessment (longitudinal profile (long-pro) and cross sections) must be collected from the project site by the conservation district before QAB recommendation for funding. This site assessment is necessary to develop an accurate grant application, including scope of work and materials list.

A longitudinal profile involves an elevation survey along the length of the stream channel thalweg (lowest point of streambed) upstream, downstream, and over the existing structure/roadway. The long-pro guides a variety of decisions from structure selection, to determining the length of stream to be restored (reconstructed reach) to the amount and type of streambed material and grade control features needed. The long-pro includes a "reference reach," representative of the typical, relatively unimpacted condition of the stream channel beyond the immediate influence of the existing undersized structure. Cross sections collected from the reference reach provide guidance on the shape and dimensions of the channel to be reconstructed. Cross sections from the outlet scour pool help determine the amount of material and labor needed to restore a stable stream channel downstream of the crossing outlet.

This chapter provides a brief overview of the Site Assessment and its importance. Comprehensive instructions for completing the Site Assessment can be found in the Site Assessment Technical Bulletin (Appendix H).

The Site Assessment should be done as early in the project lifecycle as possible and must be completed by the conservation district prior to the QAB recommending projects for funding. Once a site is determined to be eligible and the road owner has expressed interest in applying for a grant, the Site Assessment should be completed. The Site Assessment can be completed by conservation district staff or their designee. A Site Assessment must be completed for every prospective stream crossing project for which a grant application will be submitted. Projects where an SCC approval for exemptions from the DGLVR Stream Crossing Standard is requested must also have a Site Assessment completed to assist the SCC in the decision-making process. Staff from the SCC or CDGRS are available to assist with Site Assessments as needed. Stream crossing replacement projects for which an automatic exemption from the DGLVR Stream Crossing Standard apply do not require a Site Assessment to be performed.

4.1 Longitudinal Profile

A longitudinal profile (long-pro) can usually be collected with two 300' tapes, a laser level/stadia (survey rod), field book, flagging, and stakes. If available, other equipment such as total station or survey-grade GPS could be used. These tools make it possible to record distance and elevation data points defining key elements of the streambed, existing structure, and roadway that can later be plotted on a graph.

The longitudinal profile survey captures important data points along the channel thalweg that define existing channel slope and bedform. Critical data to be collected include start and end of grade control features, deepest point of pools, existing structure elevations (invert and top), and profile of the roadway. The longitudinal profile is used to determine the extent of instream work (length of reconstructed reach) necessary to reestablish channel continuity through the project site. Materials, quantities, labor, and equipment needed to complete the anticipated instream work can then be reflected in the grant application. Aspects of the project that directly influence structure selection (size and type) such as width, rise, and minimum required bury depth are derived from the longitudinal profile (and cross sections, see below). Reference Chapter 5 for more information on the grant application process.

Figure 4.1 shows a graphical representation of a longitudinal profile at a project site. While DGLVR Policy requires that the longitudinal profile assessment must extend a minimum of 150' upstream and 150' downstream of the crossing, the actual extent needed may be greater, in order to capture an appropriate reference reach and to establish start/end points at grade control crests. Consider determining the length of the longitudinal profile as a function of the stream size (20-30 bankfull-widths, for example). This will help make the assessment more site-specific and applicable and help ensure that the needed types of field data are collected. More detailed information regarding the methods for completing a longitudinal profile assessment can be found in the Site Assessment Technical Bulletin and in Chapter 12 of this manual.

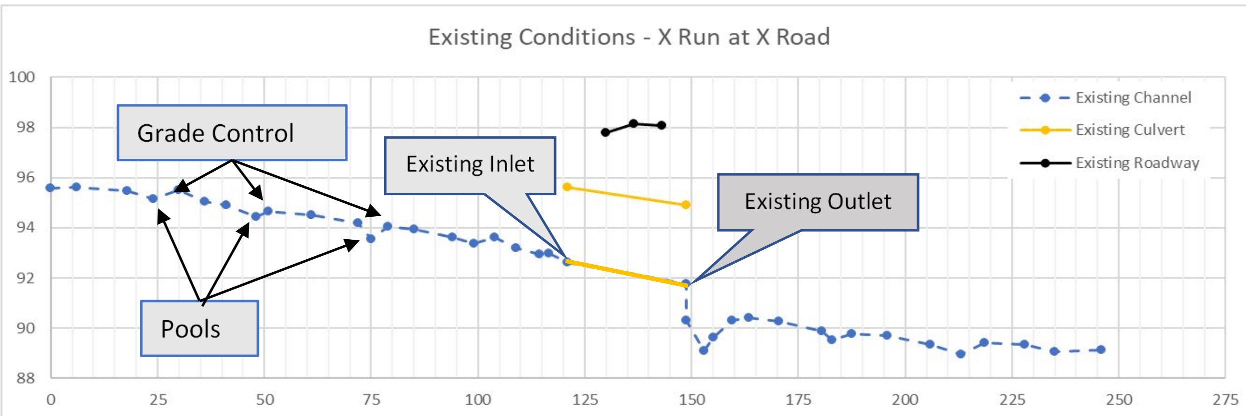


Figure 4.1 Longitudinal Profile Example Graph
An example of a long-pro survey plotted in Microsoft Excel. Stream features such as slope, grade control spacing, and average pool depths can be obtained from the data in this long-pro.

4.2 Cross Sections

As part of the Site Assessment, at least two cross-sectional surveys must also be completed. A cross-sectional survey is run perpendicular to the channel thalweg. At minimum, these cross sections should be located at a grade control crest within the reference reach and across the deepest part of the outlet scour pool. If no outlet scour pool is present, locate this cross section through a pool in the reference reach. The cross-section assessment will identify features defining channel width and depth such as the thalweg, bankfull elevations, and bankfull width (see Figure 4.2). In the grant application process, this information is used to estimate the materials, labor, etc. necessary to address project needs such as construction of bank margins and reclamation of channel width and depth through the outlet scour pool (and in some instances, further downstream).

For consistency in sharing and evaluating Site Assessment data, cross sections should be surveyed starting from the left bank (facing downstream) and moving across the channel toward the right bank. More information regarding cross-section assessments, including field methods and critical data points to be captured, are included in Chapter 12 of this manual and in the Site Assessment Technical Bulletin (Appendix H).

Existing Conditions - X Creek at X Road

XS #	1
LP STA	46
HI (ft)	103.7

STA	FS	NOTE	ELEV
0	5.13	Top of Left Pin	98.57
0	5.66	Base of Left Pin	98.04
5	5.86	Floodplain	97.84
8	5.9	Bankfull	97.8
13	6.62	Left Edge of Water	97.08
13.9	6.94	Bottom of Left Bank	96.76
20.3	7.34	Thalweg	96.36
23	7.08	Bottom of Right Bank	96.62
25	6.64	Right Edge of Water	97.06
30	5.62	Top of Right Bank	98.08
34	5.51	Floodplain	98.19

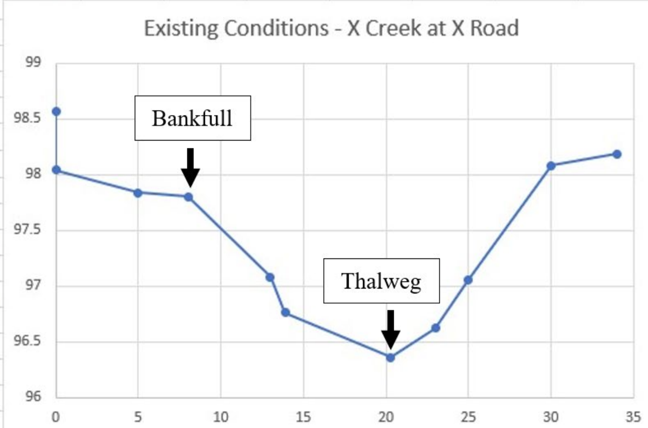


Figure 4.2 Cross Section Example Graph

An example plot of a surveyed stream channel cross section. Surveyed sections at the reference reach inform elements of reconstructed reach design such as bankfull (bank margin) height and thalweg depth.

4.3 The Reference Reach

The reference reach serves as a representation of the ‘typical’ physical characteristics of the stream channel beyond the area impacted by the existing undersized crossing. These impacts may include excessive sediment deposition or bed / pool scour, channel braiding, increased bank erosion, and/or over-widening of the channel. As long as the slope of the reference reach is relatively similar (+/-25%) to that of the stream reach to be constructed for channel continuity, aspects of the reference reach such as grade control feature type, length, and spacing can be copied from the reference reach to the design and construction of the reconstructed reach. Cross-sectional dimensions such as bankfull width, bankfull depth, and cross-sectional shape in the reference reach can also be applied to the reconstructed reach.

To find an appropriate reference reach, look both upstream and downstream of the area where impacts associated with the undersized crossing are evident. During the site walkthrough, look far enough upstream and downstream of the impacted area to determine what “typical,” relatively unimpacted conditions look like. Using the upper and lower limits of the impacted stream segment as an initial guide, estimate the approximate slope of the reconstructed reach necessary to reconnect those two potential tie-in points upstream and downstream of the roadway. An appropriate reference reach will have a slope that approximates the estimated slope of the reconstructed reach (+/- 25%). In instances where a reference reach with the appropriate slope cannot be identified within reasonable proximity to the project site, contact CDGRS for assistance.

Width and depth of the reference reach channel, both at grade control locations and the pools in between, will be reflective of the “typical” pattern of widths and depths through the unimpacted portions of the stream channel. Similarly, the reference reach should exhibit the same dominant bedforms and grade control types as those present through the overall unimpacted stream reach. As a rule, avoid selecting a reference reach that will include anomalies or deviations from the “typical” character of the portion of stream channel not impacted by the crossing.

Extending the length of the longitudinal profile provides an opportunity to include multiple potential reference reaches, which can help choose the best-applicable reference data for developing the grant application. If an appropriate reference reach is not located in proximity to the crossing, one could be established at a separate location on the same stream. In this case, a separate reference reach survey may be conducted that is not continuous with the longitudinal profile survey at the project site. An appropriate “disconnected” reference reach must still meet the criteria listed above.

Additional information regarding reference reach selection and data collection can be found in the Site Assessment Technical Bulletin (Appendix H) and in Chapter 12 of this manual.

4.4 Recording Site Assessment Data

When conducting the longitudinal profile and cross-section assessments, three pieces of information should be recorded for each data point collected. These include:

- *Station*: the distance along the transect being assessed. If a laser level and measuring tape are being used, this would be the tape reading. The assessment typically begins at Station "0" (the start of the tape).
- *Foresight*: if using a laser level, this is the reading taken from the stadia rod. If using more-advanced survey equipment, this might be recorded as an actual elevation. Foresight readings collected in the field can be translated to elevations later, based on the benchmark and laser (height of instrument) elevations.
- *Notes*: a brief description of the feature of interest where the data point is being collected.

Consistency in the way field data are recorded by the conservation district, CDGRS, and the engineer/surveyor can go a long way in streamlining communication and the sharing of information among the project participants. Clarity and consistency of field notes and good organization of Site Assessment data can greatly assist the conservation district in completing the required design plan review in a timely manner. Specifically, using a standardized system for noting typical features collected during the Site Assessment will help understand how the field data translate to the recommendations prepared by the conservation district for grant estimating, as well as to the design criteria developed by the engineer. The Site Assessment Analysis Tool (Section 4.5, below) utilizes a standardized list of notations for designating common features collected in the field. Utilizing this same notation system when recording field notes during the Site Assessment will streamline use of the Tool and collaboration between partners.

The Site Assessment Technical Bulletin (Appendix H) provides more information on recording field data and includes the standardized list of notations referenced above.

4.5 Site Assessment Analysis Tool

The CDGRS has worked with Trout Unlimited to develop a Site Assessment Analysis Tool for entering and analyzing site assessment information. Based on the field data entered into the tool, recommendations are generated for reestablishing channel continuity through the project site by predicting the necessary length and slope of the reconstructed reach. From the reference reach assessment data, the tool can predict grade control feature spacing through the reconstructed reach and the minimum bury depth of the invert or bottom of footings. This information can be used to estimate materials, quantities, and labor/equipment needed for streambed reconstruction. The tool will also produce a graph similar to the one in Figure 4.1 that displays the relationship between streambed, invert/footing, and roadway elevations. This information can be used to estimate approximate dimensions of a replacement structure that meets the DGLVR Stream Crossing Standard. This preliminary estimate of structure size is intended to support the cost estimation for the grant application. It is understood that in most cases, final structure selection and dimensions will be determined by the engineer during project design. The final structure selection often may vary slightly in size and cost from the preliminary estimate derived from the conservation district's site assessment.

The Site Assessment Analysis Tool includes detailed instructions for its use. The Stream Crossing Certification Training provided by CDGRS provides in-depth guidance regarding use of the tool. Additionally, assistance is available for project-specific use of the tool through CDGRS.

5. GRANT APPLICATION FOR REPLACEMENT STRUCTURES

The previous two chapters walk through how to collect site-specific assessment data and generate site recommendations from the data. Stream crossing projects typically require much more pre-application and pre-ranking work than a typical DGLVR project. The Site Assessment results inform structure selection, depth of burial, structure width, proposed replacement slope, roadway cover, grade control type (step, **riffle**, etc.), and suggested spacing. The results also account for maximum scour depth for pool features to provide for the stream channel to naturally adjust, regardless of the structure having an invert or not. This chapter provides additional context for grant applications and cost estimates. Additional training and guidance are available through the CDGRS and SCC for assistance with cost estimates.

5.1 Structure Selection

The type and size of the new stream crossing structure is a major cost and logistical factor in developing the grant application.

5.1.1 Opening Width

Per DGLVR Program Stream Crossing Standard, structures must be of adequate width to accommodate the following:

- Construction of a parabolic-shaped, bankfull-width channel within the structure that includes a defined low-flow channel (thalweg), measured at the bankfull (bank margin) elevation.
- Installation of robust bank margins, comprised of rock sufficiently sized to be stable at the Q100.

Additionally, the replacement structure must have sufficient rise (must be "tall" enough) to allow for the minimum bury depth of the invert and ensure that the Q100 water surface elevation does not exceed 80% of the finished opening height. The fact that manufacturers provide structures in a range of standardized "height-x-width" sizes may also influence final structure width in order to ensure the rise height needed. Once these sizing criteria are met, the **effective structure width** must be no less than 1.25 times the bankfull width of the stream at the bankfull (bank margin) elevation. In design, the shape of the selected structure and required bury depth (Section 12.1.12) both influence the effective structure width. In most instances, effective structure width (at the bankfull elevation) will be narrower than the vendor's listed structure width, which is commonly measured at the widest point of the structure. Effective structure width and the various sizing criteria to be met must be considered whenever a conservation district discusses potential structure size requirements with the grant recipient or engineer for a given project. In most instances, structures greater in width than the minimum 125% bankfull width will be necessary in order to meet all sizing requirements. Figure 5.1 shows the difference between a structure's effective width at bankfull elevation and the width listed by the manufacturer.

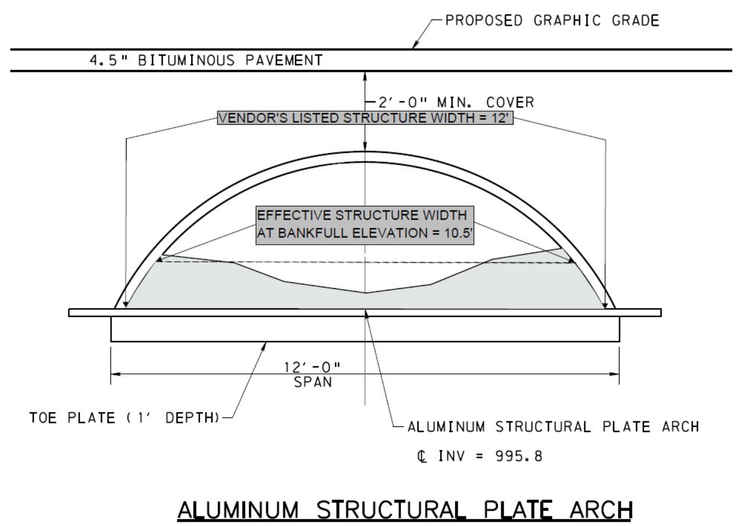


Figure 5.1 Effective Structure Width

This figure shows the difference between the manufacturer's listed structure width (12', measured at the plate invert) versus "effective" structure width (10.5', measured at the design bankfull channel / bank margin elevation). To meet DGLVR Program Policy, the effective structure width cannot be less than be 1.25 times the bankfull channel width.

Some consideration should also be given to constructability when determining a structure size. Wider structures allow for increased streambed stability by reducing flow depth and velocity at a given discharge. Wider structures with a corresponding "taller" rise may also make construction of grade controls, streambed, and bank margins easier by allowing the use of larger equipment.

The DGLVR Stream Crossing Standard also requires that "New stream crossing structures shall be designed to pass the 100-year discharge at a water surface elevation not to exceed 80% of the finished opening height," (see Figure 5.2 for a visual representation).

The conservation district and grant recipient are not expected to calculate the 100-year discharge or rock sizes stable at Q100 during the grant application phase. At this point in the grant application process, the estimated structure dimensions will be based largely off the bankfull channel width, estimated rock size for stable bank margins, minimum bury depth required, and existing streambed and roadway elevations. Once the 100-year discharge calculations are provided by the engineer, adjustments to structure size (width, height, or both) may be necessary. The engineer will typically specify a final structure size during project design.

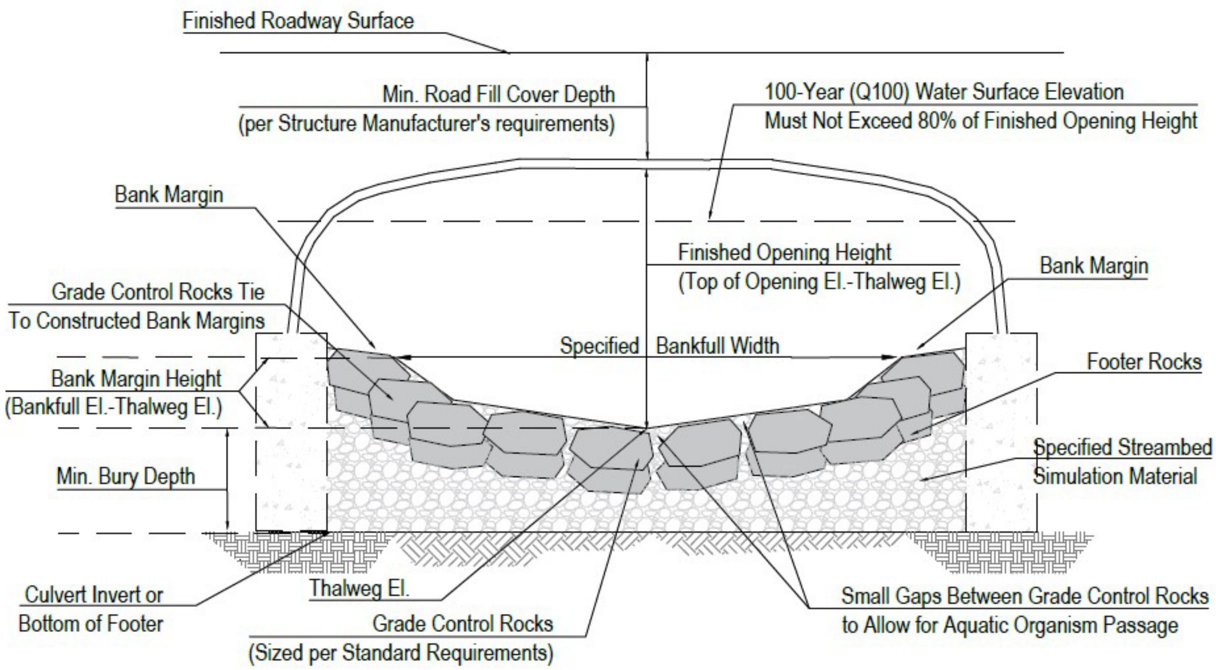


Figure 5.2 Example Structure Cross Section showing the 100-year (Q100) discharge at 80% of the finished opening height

A typical cross section ***at a grade control crest inside the replacement structure****, showing channel shape through a culvert. The bottom line represents invert or recommended bottom of footing burial depth. The dashed line shows the water surface elevation of the 100-year discharge.*

5.1.2 Other Considerations Affecting Structure Selection

In addition to the information gathered from the Site Assessment and subsequent design recommendations, applicants should take into consideration any factors in addition to the site data that might influence stream crossing structure selection, such as:

- Applicants may be guided by local municipal policy that encourages the use of concrete structures due to lifespan estimates.
- An applicant may propose completing the work in-house (such as with a municipal workforce) and may have equipment or skilled labor limitations.
- Often, sites considered for a grant application are remote and have weight restrictions, limited turn radius, or other impediments to access to the site for oversized deliveries.
- Material selection also considers the cost and time to manufacture, acquire, and install a structure.
- Dead-end roads may warrant consideration of structures that can be installed quickly, such as structures delivered in place, or that can be assembled adjacent to the project site and lifted into place.

Applicants and conservation districts should become familiar with structure material suppliers or distributors in their local area and utilize sales consultants for structure estimates. Often, recommendations developed from a Site Assessment may reference a product number from a catalog with span, rise, and length information that can be cross referenced to structures offered by various manufacturers. Applicants should discuss with manufacturers the minimum and maximum road cover requirements of the suggested structure and inform the manufacturer of the proposed cover recommended from the Site Assessment and design recommendations. Per the DGLVR Stream Crossing Design Standard, bottomless structures shall be used for all structure replacements where the continuity slope of the channel through the project area will be greater than 4.0% or the bankfull width is over 20', as determined by the Site Assessment.

If a structure, regardless of type (metal pipe, concrete box, bridge), exceeds 20 feet of clear span opening (measured along the centerline of the road), the structure is subject to Federal Highway Administration inspection requirements. Local ordinances may require inspection for structures with less than 20 feet of clear span opening as well. Often the inspection entity will request computations for all commonly accepted design loads to report to the PennDOT Bridge Management System (BMS). HS20, HS25, and PHL93 are all acceptable load ratings, but the most current rating is PHL93. Calculations for ML-80 and TK-527 ratings may also be required for the BMS. The structure manufacturer can often provide these rating factors as part of their engineer-sealed shop drawing and supporting calculations. These calculations may add additional cost to the structure, but this often offsets greater costs than if ratings were to be developed by the project engineer. If load calculations are going to be required, indicate this when obtaining an estimate. For more information about federal highway inspection, contact the county's Municipal Services Representative or the PennDOT District Area Bridge Department.

Headwalls, endwalls, and wingwalls are key components of a successful stream crossing replacement. These appurtenances to the replacement crossing structure should not be underestimated for their importance in guiding stream flow into the structure during high flow events and their role in protecting the structure backfill from being eroded. Headwall and endwall materials that closely fit the curvature or angles of the replacement structure have the greatest chance of preventing stream flow from piping between the structure and the backfill. Headwalls and endwalls can be pre-fabricated, cast-in-place, or can be constructed from native rock or other materials so long as adequate measures are taken to prevent the loss of backfill material. Because they are required for all DGLVR stream crossing replacement projects, applicants should include a headwall and endwall in their cost estimate for their grant application. Wingwalls should also be included, if project needs warrant their use. During the design phase of a project, final details of height, length, or angle of wing wall departure can be modified by the engineer as needed.

Some manufacturers also offer pre-assembly or onsite assembly of their product. Often, there is also an option for onsite assistance provided by the manufacturer to help the local or subcontracted labor with product assembly and backfill. With a structure cost estimate, manufacturers can also provide an estimated weight of the structure based on its width and length. This is helpful during the development of a grant application to determine if a crane or other specialized piece of equipment is required to set the structure in place.

Additional structure material options may include utilizing baffles, toe plates, polymer coatings, etc. to address various site conditions. Utilizing these types of additional features should be discussed thoroughly with the manufacturer. Additionally, CDGRS or Trout Unlimited (TU) staff can help determine the applicability of these options to a project. For additional information on structure types and selection, see the Structure Selection for Stream Crossings Technical Bulletin in Appendix H.

5.1.3 Baffles

In some situations, baffles can be used to enhance streambed retention within the replacement structure. When properly applied, baffles can increase the long-term persistence of the streambed within the structure by bolstering the ability of constructed grade controls, key pieces, and larger foundational components of the streambed material to withstand higher flood flows. This can be especially beneficial in smaller structures, where optimal placement of these stream restoration components is often more logistically challenging. The use and application of baffles should be considered on a project-by-project basis. Baffles, if used, should be designed to supplement, and not replace, the functions provided by constructed grade controls, key pieces, and other essential components of proper streambed reconstruction through the structure. Applied correctly, baffles serve to hold grade control and streambed material in the pipe. Properly applied baffles should not be visible in the finished channel. When applied incorrectly, baffles can lead to problems such as increased streambed scour downstream and/or excessive accumulation of sediment upstream. These issues can significantly disrupt channel continuity and aquatic organism passage through the crossing and can contribute to further channel adjustments upstream and downstream of the culvert.

5.2 Aggregates

Aggregate is often a significant component of a grant application budget. Various types of aggregate may be used for a range of applications during a stream crossing replacement project. Aggregates can be referred to using different standardized classification systems or by local terminology. For a breakdown of aggregate gradations and reference to the AASHTO and PA Specification System, see the Technical Bulletin: Aggregates 101 – Common Aggregates in PA at www.dirtandgravel.psu.edu.

Cost estimates should include aggregate proposed for:

- Foundation bedding material (PennDOT 2A, 2RC, etc.)
- Structure backfill (2A, 2RC, etc.). Aggregate must meet manufacturer's recommendations for backfill requirements.
- Grade Control material (rock, native stone, etc.)
- Materials to fill plunge pools (rock rip-rap, bankrun gravel, native excavation, etc.)
- Streambank stabilization material (rock rip-rap, logs, mud sills, root wads, large woody additions, etc.)
- Roadway surface material (Driving Surface Aggregate (DSA), 2A, asphalt, etc.)
- Backfill material for other drainage practices such as road fill for entrenchment, stormwater cross pipes, underdrains, French mattresses, high water bypasses, etc.

Quarried rip-rap for use as grade control, bank margins, or bank stabilization shall be sound, durable and able to withstand exposure to air, water, freeze and thaw as outlined in the DGLVR Stream Crossing Standard. This requirement is in place because rock used as stabilization, bank margins, or grade control is specified by the engineer to be a minimum stable size and should not break down to smaller sizes over time.

In many cases, material excavated during construction can be reused on the project. However, the viability of such material is often not known until construction begins. When preparing a grant application, the grant applicant should assume all new material will need to be purchased when developing cost estimates. This will help avoid cost overruns during project construction.

Compaction is an important consideration when estimating aggregate quantities. Aggregates that are well-graded, which contain multiple particle sizes and smaller "fines," will compact. Open-graded or "clean" aggregates with little to no fines will not compact. When developing material quantities for grant application development, remember that field measurements are often taken in feet or meters and will produce a volume of aggregate needed, but aggregate is typically sold by the ton. When converting between volume and weight, it is important to know whether the aggregate will be compacted or not.

CDGRS maintains an online material calculator on its website that can be used to estimate quantities and costs: https://www.dirtandgravel.psu.edu/general-resources/dglvr-materials-calculator This calculator can be used to determine volumes of compacted or uncompacted aggregates.

5.3 Streambed (Substrate)

Streambed material is a critical component of a successful stream crossing. As part of the grant application, it is important to estimate the potential volume of material to be purchased. As noted above, in many cases, material excavated during construction can be reused on the project. However, the viability of such material, especially for use in the stream bed, is often not known until construction begins. At best, this material may be useful as an added component to the substrate used to reconstruct the stream channel. In most cases, native streambed material alone (excavated from the project site) should not be the sole component of the substrate specified by the engineer. For this reason, assume new material will need to be purchased when developing cost estimates to avoid cost overruns, and to prevent the use of undersized substrate material for streambed reconstruction.

An initial estimate of streambed material quantity can be derived from the Site Assessment Analysis Tool, once the length of reconstructed reach, preliminary structure dimensions, and minimum structure bury depth have been determined.

- Compare the average difference in elevations between the existing and proposed streambeds to determine an estimated depth of streambed material needed.
- Multiply by the estimated structure width and length of the reconstructed reach to estimate a conservative volume of streambed material needed.

When reconstructing the streambed through the structure and reconstructed reach, it is critical to estimate materials needed not only for the low flow and bankfull channels, but also the bank margins. The size and composition of the material will vary from site to site, but a good starting point for estimating the size of material needed is by replicating what is observed within the reference reach. This will provide a good initial estimate that will help avoid cost overruns during construction. In final design, the project engineer will specify material sizes and substrate gradations necessary to meet the requirements of the DGLVR Stream Crossing Standard. Be sure to account for compaction of streambed materials in the volume estimate. If use of excavated native streambed material might be considered for a project (depending on the quality of the material), plan accordingly by arranging for onsite stockpiling of the material so the material is not taken to an off-site location. Additionally, during development of the grant application, careful consideration should be given to specialized equipment needs that may be required to place material within the proposed structure. For more specific guidance on streambed materials and placement, refer to Section 12.1.8 and the Streambed Restoration Technical Bulletin in Appendix H.

5.4 Erosion and Sediment Control Materials

Unless determined early in the project lifecycle that the applicant's local work force will construct the stream crossing replacement project, it is often difficult to anticipate an engineer or a contractor's preferred methods for erosion and sediment (E&S) controls. However, the conservation district's familiarity with common E&S methods and Best Management Practices (BMPs) for stream projects should help guide development of the grant application.

Many times, an engineer will provide options for managing stream flow during construction, which will include bypass pumping, fluming through or around the project work area, or some combination of these. Applicants should make an educated estimate of the types of materials that may be needed for E&S and the length of time they may be needed. The cost of using a 6" bypass pump 24 hours a day for three weeks is very different from fluming through the site with a cofferdam and plastic pipe.

Applicants should include anticipated materials needed as part of the grant application. If the project will be subcontracted, at a minimum a line item for E&S controls should be provided in the grant application that shows the conservation district and QAB that a budget consideration has been made for this component of the project. A list of items to consider for E&S controls includes:

- Flume pipes (bypass pipe free-flowing through or around crossing)
- Bypass pumps and trash pumps

- Cofferdam materials (sandbags, jersey barriers, plastic sheeting, sheet pile, etc.)
- Silt fence, super silt fence, compost filter sock, drop inlet bags, filter bags, rock filters, energy dissipaters, etc.
- Topsoil, soil amendments, seed and mulch or hydroseeding, reinforced vegetation matting, etc. (*PA Erosion & Sediment Control Manual*)

5.5 Drainage and Other Support Materials

Applicants are encouraged to look beyond the immediate area of a stream crossing replacement and determine if the scope of work should include additional ESM practices to disconnect stormwater from directly discharging to a stream without a buffer. Materials that might also be included in the cost estimate include:

- Stormwater pipe (HDPE smooth bore, concrete, etc.)
- SDR 35 or SCH 40 underdrain (perforated and solid sections as needed)
- Pipe couplers, bands, pipe cleaner and glue, animal guards, etc.
- Drop boxes, bicycle or leaf grates, hydraulic cement, etc.
- Flared end sections, geotextile fabrics, geogrids, geo cells
- Guide rails, posting signage and delineators
- Traffic control, barricades, road construction notification signs

5.6 Equipment

Estimates for equipment to complete a project are also subject to the decision of who will complete the project (in-house workforce, subcontractor, or combination). Depending on the complexity of the project, the equipment required, and skilled operators available, the equipment detailed in the grant application may vary greatly. Often for a subcontracted project, a preliminary estimate that includes equipment, labor, and materials can be obtained by providing a qualified contractor with a brief description of the project. Applicants may also be able to use actual costs from similar projects completed in the area to estimate equipment (or equipment and labor).

If an applicant intends to complete the project on their own, the use of applicant equipment can be reimbursed at the FEMA rates. Those rates can be found at https://www.fema.gov/assistance/public/schedule-equipment-rates. Specialized equipment that is rented by the applicant to complete the project can be reimbursed based on the rental rate. Reimbursement must be limited to the time the rental equipment is utilized on the project site.

As discussed in the structure section, specialized equipment such as a crane may be required. The need to utilize a crane on site should be determined early and reflected in the project budget. A list of equipment to consider includes:

- Excavator(s), crane (depending on site conditions and structure type/size)
- Compaction equipment (vibratory plates, jumping jacks, rollers, etc.)
- Water pumps (bypass pumps, trash pumps, etc.)
- Air compressors, or generators for hand tools required for structure assembly
- Trucking (spoils material, backfill, etc.)
- Specialized equipment to place stream bed substrate (motorized wheel barrel, skid steer, conveyor belt, fire hose, etc.)

5.7 Labor

When developing the grant application, it is also important to determine early if the project will be implemented by the applicant, subcontracted, or completed through a mix of contracted and in-house labor/equipment. The DGLVR Program is subject to the Pennsylvania Prevailing Wage (PW) Act. If federal funds are also involved in the project, the project may also be subject to the Davis-Bacon Act. Prevailing wage applies to subcontracted labor. Prevailing wage rates apply to DGLVR projects when the total estimated or actual project cost is $25,000 or more (not $100,000). Prevailing wage estimates for grant application purposes can be determined by submitting a PW determination to the PA Department of Labor and Industry or by looking at recently submitted projects in your area. Note that a prevailing wage rate determination is only good for 120 days from the date of issuance. If there is no signed contract within 120 days between the applicant and the contractor, a new project serial number must be requested. A "Prevailing Wage & the Dirt, Gravel, and Low Volume Road Program Frequently Asked Questions for Municipalities" document is available at: https://www.dirtandgravel.psu.edu/pa-program-resources/program-specific-resources/reference-material.

5.8 Engineering

Engineering costs paid with DGLVR grant funds are limited to 20% of the total contract, up to a cap of $25,000. More details can be found in Section 3.7.4.7 of the DGLVR *Administrative Manual*.

- Any engineering costs above the limit will be the responsibility of the grant recipient and can be counted as in-kind toward the project.
- Engineering costs incurred before a contract is signed between the grant recipient and the conservation district cannot be paid with DGLVR funds (but can count toward in-kind).
- Refer to Chapter 12 of this document for more details on engineering requirements.

Applicants are encouraged to utilize the Stream Crossing Request for Proposal (RFP) for Design Services to solicit cost proposals for all DGLVR projects. In the case where an applicant has an appointed engineering firm or in-house engineer staff member, the RFP and the DGLVR Stream Crossing Standard should be carefully reviewed to determine the scope of engineering services required to meet DGLVR Program Policy for an accurate budget number. See Appendix F for the Request for Proposals.

5.9 Budgeting for Cost Increases

There are several reasons why actual project costs may be more than the estimate in the DGLVR grant application, such as:

- Inflation of material, equipment, and labor costs in the time between grant application preparation and project construction.
- Changes between the grant application and final project design. Successfully achieving stream continuity through road-stream crossings requires significant design by an engineer. However, in most instances there is no engineer involvement in the development of the grant application since engineering costs incurred before a DGLVR grant contract is signed are not eligible for reimbursement. All parties involved in DGLVR stream crossings should understand that once an engineer begins design work for a funded DGLVR project, aspects of the design may differ from the preliminary recommendations used to develop the grant application. In this regard, project design may incur additional, unanticipated costs.
- Changes to the project plan may be needed at any point in the project due to unforeseen circumstances, such as complications encountered during construction or material shortages. Changes needed to adapt to such circumstances may incur additional costs.

While it is impossible to predict exactly how project costs may change during project design and implementation, conservation districts and grant applicants can plan for some potential cost increases. Conservation districts and grant applicants can prepare for cost increases by discussing potential contingencies and how they might be handled. Conservation districts may choose to add contingencies of potentially 5%-15% to grant applications, either as a standard practice (such as local policy) or on a project-by-project basis.

Before and during application development, conservation districts should clearly discuss the timeline and complexities of stream crossing projects with applicants (see Section 3.4.1 for information about project timelines). They should also discuss local funding availability and grant amendments. Statewide DGLVR Policy allows conservation districts to add up to 40% of the total contract amount to a DGLVR contract, but conservation districts may have local amendment policies or limited funding availability for amendments. It is important that conservation districts and grant applicants understand the availability (or lack thereof) of additional DGLVR grant funds and the potential ability of the applicant to cover cost overruns.

6. Quality Assurance Board (QAB) Ranking and Review

The QAB is an advisory group impaneled to advise the local conservation district board on matters related to the DGLVR Program. Chapter 4 of the DGLVR Administrative Manual details the QAB and its role in the conservation district DGLVR Program. Stream crossing replacement projects are ranked and reviewed by the QAB like all other DGLVR projects and contracts. The QAB will determine project eligibility, rank projects for funding, and make recommendations to the conservation district Board of Directors on project funding and local policies. Each QAB should determine a procedure to rank stream crossing projects effectively.

While the procedures are the same as other DGLVR projects, stream crossing replacements are often more expensive and much more complicated and time consuming for conservation district staff than typical drainage improvement projects. The project ranking process is locally controlled, and the ideas presented below are suggestions and are not required.

6.1 Considerations for Ranking Stream Crossing Projects

Stream crossing replacements can be funded as stand-alone projects or can be part of a larger DGLVR road project. It can be difficult to rank stand-alone stream crossing replacement applications against other projects, since they do not fit into the ranking criteria that many counties have adopted. It is up to individual counties to decide how much emphasis they want to put on stream crossing replacements and how to rank them against drainage projects. Ranking stream crossing projects separately (from drainage/road projects) could be effective to identify which crossings would provide the most environmental benefit. QABs can choose to rank stream crossing projects along with their normal drainage-style DGLVR projects as well. Either way, the QAB decides what local factors are important in their county and develop an appropriate ranking procedure based on those factors.

6.1.1 Potential Local Policies Regarding Stream Crossing Replacements

Conservation districts may enact policies at the county level that are more restrictive and do not conflict with statewide policies. Some examples of potential local policies include:

- Stream crossing replacements typically require a larger investment of conservation district staff time than drainage projects. For this reason, conservation districts may consider reducing or limiting the number of stream crossing projects. The number of projects funded can be limited in a number of ways, such as: only a certain number of crossings over a certain size will be funded per year; only a certain percentage of a county's allocation will be used to fund stream crossings; etc.
- The QAB may choose to enact a policy to not accept grant applications for stream crossing replacement projects.
- Consider using established aquatic connectivity standards to rank stream crossings against each other. The North Atlantic Aquatic Connectivity Collaborative (NAACC) has an approach that can be used to quantify an "aquatic passability score" on existing stream crossings. More info available at: https://streamcontinuity.org/naacc/assessments/aquatic-connectivity-non-tidal
- Conservation districts that receive a high number of stream crossing replacement applications may consider implementing a "pre-screening" as described in Section 6.2 below.

6.1.2 Other Project Evaluation Tools

A wide variety of tools and resources exist that conservation districts may want to consider using in project rankings, such as:

- **PNDI:** search for endangered species (https://conservationexplorer.dcnr.pa.gov/)
- **Chapter 93 Stream Designation:** Lists waters by their designated use (coldwater fishery, warmwater fishery, etc.) (https://gis.dep.pa.gov/emappa/)
- **Stocked or Wild Reproducing Trout:** Identifies waters where seasonal restrictions are in place for in-stream construction activities: (https://pfbc.maps.arcgis.com/apps/webappviewer/index.html?id=65a89f6592234019bdc5f095eaf5c6ac)
- **Stream Stats:** Estimates watershed area, average bankfull width, and average bankfull elevation (https://streamstats.usgs.gov/ss/)

- Evaluation of Potential for Acid Mine Drainage (AMD) Impacts
- **DEP eMap:** GIS application with a wide variety of information from the PA Department of Environmental Protection (https://gis.dep.pa.gov/emappa/)
- **DGLVR Geographical Information System (GIS):** a wide variety of information and mapping tools are available in the DGLVR GIS system (https://www.dirtandgravel.psu.edu/general-resources/cdgrs-mapper-geographic-information-system-gis)

6.2 Pre-screening Stream Crossing Replacements (optional)

Stream crossing projects require much more pre-application and pre-ranking work than a typical DGLVR project. Stream crossing projects are often very detailed and require close review by conservation district technicians to ensure DGLVR Program Policy and the Stream Crossing Standard are being met appropriately. An effective pre-screening of stream crossing projects may help reduce the amount of time spent on each potential application. This process involves pre-screening potential projects to determine which ones have a high likelihood of funding. Moving only those projects to the application phase could save time and effort for both applicants and the conservation district by focusing on projects that are more likely to be funded.

7. Contracting

When an application has been approved by a conservation district board, the conservation district will enter into a contract with the successful applicant. The contract with the attachments, when signed by both parties, is a legally binding document between the applicant and the conservation district that describes in detail the responsibilities of both parties. No funding transfers can take place with grant applicants, and no project work can begin, without a signed contract. Any work or engineering costs incurred before a contract is signed are not eligible for reimbursement with DGLVR funds. The contract states the terms and conditions for the project. For more information on contracting, see the DGLVR Program's *Administrative Manual* at (https://www.dirtandgravel.psu.edu/pa-program-resources/program-specific-resources/administrative-guidance-manual)

7.1 Prior to Contracting

Prior to entering into a contract, there are several things for the conservation district and the project participant to consider. Applications and workplans will typically change from the original draft to the final version that will be included in the contract. The final workplan and application for funding must accurately reflect how the project will be completed. The conservation district and project participants should work together to ensure the application and workplan that are included with the contract are the version that will be legally binding in the contract. Any edits or changes discussed during the pre-application and pre-design meetings must be included in the final workplan.

A full engineering design plan is usually not needed to get a potential project through the application and contract phase. Remember that engineering done before a contract is signed cannot be paid for with DGLVR grant funding (it could count as in-kind). The data gathered from longitudinal surveys and discussions with the applicant (and if necessary, their engineer or other outside assistance) should be enough to determine the basic project design parameters such as structure type and size. A simple project sketch and estimation of structure and material costs is usually sufficient to get a project through the application phase and ready to contract. Assistance in providing cost estimates can usually be obtained from structure manufacturers, or with assistance from the SCC or CDGRS.

7.2 Writing a Contract

All contracts must be made using the "Dirt, Gravel, and Low Volume Road Maintenance Program Contract Agreement" form that has been approved by the SCC. When a contract is signed, the attachments listed on the contract and described below become a legally binding part of that contract. The contract and project-specific attachments must be retained with project files. The contract and attachments can be found at https://www.dirtandgravel.psu.edu/pa-program-resources/program-specific-resources/blank-forms.

More information regarding proper contracting procedures is available in the PA DGLVR *Administrative Manual,* Section 3.8.

7.3 Reviewing and Signing a Contract

After the contract has been written and reviewed for accuracy, the contract should be reviewed with the grant recipient. The purpose of this review is for both the conservation district and the grant recipient to fully understand the roles of the conservation district and the grant recipient. It is imperative that the conservation district clearly explain the requirements of the DGLVR Program and the DGLVR Stream Crossing Standard to the grant recipient and their engineer (if one has already been selected). Once the grant recipient and conservation district have reviewed the contract with attachments, and both entities agree to enter into the agreement, the contract may be signed by both parties. The conservation district and the grant recipient must keep a copy of the final version of the complete contract.

7.4 Amending a Contract

In some cases, the grant recipient may request an amendment to the original contract for additional time and/or additional funding. The DGLVR Program allows for contracts to be amended. Amendments up to 40% of the original contract value can be approved at the discretion of the conservation district Board of Directors. Contract amendments over 40% of the original contract value require SCC approval. More information on contracting amendments can be found in the DGLVR Program's *Administrative Manual,* Section 3.5.3.

8. From Contract to Construction

Once a DGLVR contract is signed, there are a variety of tasks to be completed before breaking ground on the project. This chapter outlines the major steps in taking a project from contract to construction.

8.1 Request for Proposal for Engineering / Design

It is the responsibility of the grant recipient to solicit and obtain the necessary engineering and design work for stream crossing replacement projects. Grant recipients may use their appointed engineers or advertise for proposals from other engineering firms. To assist in this process, a model Stream Crossing Request for Proposal (RFP) is available on the CDGRS website at https://www.dirtandgravel.psu.edu/general-resources/stream-crossing-replacements. This model RFP is in Microsoft Word format and must be customized to fit individual grant recipient and project needs. The RFP specifically communicates the scope of work to the engineer and the required deliverables to meet the DGLVR Stream Crossing Standard. This allows for the grant recipient to solicit more competitive pricing by allowing multiple engineering firms the opportunity to offer their services. The RFP also establishes clear expectations of the engineering work to be performed. The template RFP form can be modified for individual projects. The following modifications are highly recommended:

- Request a project schedule from the bidding engineer, which helps ensure the deliverables will be provided in a timely manner.
- Require the engineer to attend the pre-design and pre-construction meetings that the conservation district is required by DGLVR Policy to hold.
- Require the engineer to attend the bid site showing, if the grant recipient chooses to hold one.
- Require the engineer to cover additional meetings and revisions, such as during the conservation district review process when multiple iterations of review, comment, and plan edits might be necessary.

The conservation district can assist the grant recipient with modifying the RFP form to best fit the needs of their project. CDGRS is available to provide technical assistance to the conservation district and grant recipient to help develop a project-specific RFP.

The template RFP form is structured to request itemized fees from the bidding engineer for each of a series of listed engineering tasks. The RFP advertisement can be modified to also request a statement of qualifications as part of the engineer's proposal. Use of the RFP is encouraged for all stream crossing replacement projects but is not required. All bidding practices must comply with the grant recipient's procurement policies and requirements. Engineering costs paid with DGLVR grant funds are limited to 20% of the total contract, up to a cap of $25,000.

8.2 Pre-Design Meeting

After the grant recipient selects an engineer, a pre-design meeting must be held. The purpose of this meeting is for the engineer, grant recipient, municipality, and conservation district to discuss the requirements of the DGLVR Program Policy and Stream Crossing Standard, and how these apply to the specific details and needs of the stream crossing replacement project. This should include whether the grant recipient intends to complete the installation using their own workforce or subcontract the work out. The pre-design meeting should be held before the engineer begins any permitting or design work for the project.

During the pre-design meeting, the preliminary Site Assessment data already collected by the conservation district and the recommendations from that data used to develop the grant application should be reviewed and discussed. Conservation districts may choose to provide their written Site Assessment data to the design engineer at their discretion. The engineer is responsible for the Site Assessment data they use, whether provided by the conservation district or collected through their own Site Assessment. Should the engineer choose to conduct their own Site Assessment to support their design of the project, it is required that the conservation district technician be onsite while the engineer's Site Assessment is performed.

During the pre-design meeting, conservation districts should again discuss with the engineer and grant recipient that the conservation district is required to review all plans and specifications prepared by the engineer. The engineer may not submit materials to regulatory agencies for permit review and approval until the conservation district has provided written confirmation to the grant recipient that the reviewed plans and specifications meet DGLVR Policy and the Stream Crossing Standard. Details about draft submittals, including electronic or hard copy, should be discussed during the pre-design meeting. All parties should leave the meeting with a clear understanding of deliverables and a timeline for completing design plans, permit applications or registrations, and bid packages (if applicable). A checklist has been developed to assist with facilitating a pre-design meeting agenda and can be found in Appendix G.

The engineer is solely responsible for the content of the final design product and corresponding construction documents. Throughout the lifecycle of the project, the conservation district is responsible for determining that the project administration, design, and implementation are consistent with DGLVR Program Policy and the Stream Crossing Standard.

8.3 Design Site Assessment (Survey)

Chapter 4 of this manual provides details on the Site Assessment that is completed by conservation districts before an application is developed. For most crossings, the project engineer or their designee will also conduct a detailed survey of the worksite as part of the design process after a contract is in place. This usually includes surveying site elevations, wetland delineation if needed, etc. The DGLVR Stream Crossing Standard requires that a Site Assessment, including a longitudinal profile and cross sections, be conducted for all stream crossing replacements.

If the engineer chooses to conduct their own Site Assessment, the conservation district is required to be onsite while the Site Assessment is being performed by the engineer and/or surveyor to ensure that all important data points are obtained. The engineer shall provide their completed Site Assessment to the conservation district. This can be done at the time the design plans are submitted to the conservation district for review, or any time prior. The conservation district should take the initiative to request the Site Assessment data from the engineer once it has been collected, and then check to see if it is consistent with their Site Assessment. If the conservation district provided their Site Assessment to the design engineer, then the engineer should also see if their Site Assessment is consistent with the district's Site Assessment. The conservation district and engineer should also check to see if their subsequent recommendations / design criteria are consistent, including bedform, grade control characteristics, reference reach selection and applicability to the design (slope), and potential tie-in locations for reestablishing channel continuity.

Chapters 4 and 12 provide more information on the types of field data to be collected during a Site Assessment. The DGLVR Stream Crossing Standard establishes various criteria required in the Site Assessment.

8.4 Conservation District Review of Plans and Specifications

Most commonly, stream crossing replacements funded through the DGLVR Program can be authorized through registration of a PADEP General Permit (GP) #7 or #11. The requirements of the DGLVR Program are generally more stringent that PADEP permit requirements. As such, DGLVR Program requirements meet, and often exceed, the required conditions of the General Permits. In no instance should the issuance of a regulatory permit serve as assurance that DGLVR Policy and Stream Crossing Standard are adequately addressed in the project design. The conservation district review process outlined here is intended to provide that assurance.

The DGLVR Program requires that the engineer provide the conservation district with all plans and specifications for review before submitting for permit approval. The conservation district must review the documents and provide written confirmation to the grant recipient or engineer that these submitted documents comply with DGLVR Policy and the Stream Crossing Standard before they are submitted (or resubmitted) for permit review. If during the conservation district's review, deficiencies or questions arise, they must be communicated to the design engineer and the grant recipient in writing. Template deficiency letters are available for conservation district use (see Appendix F). Conservation districts should consider providing red-line markups on proposed plan drawings and standard details to help illustrate points documented in writing. Some reviews may prompt a design meeting with the applicant and engineer to discuss complex deficiencies or concerns.

Checklists have been developed to assist conservation districts in reviewing design packages and bid packages (if applicable). These checklists can be found in Appendix G. Once conservation district comments have been satisfactorily addressed to meet DGLVR Policy and the Stream Crossing Standard, the conservation district will notify the grant recipient in writing that their review for DGLVR Policy compliance is satisfied. Template cover letters are available for conservation district use (see Appendix F).

NOTE: It is strongly recommended that the replacement structure not be purchased until the conservation district review of the design package has been satisfactorily completed and a permit has been received. Purchase of a structure prior to satisfactory completion of the conservation district design review and permit approval may lead to the purchase of an improper structure and potential non-payment with DGLVR funds.

8.5 Bidding for Materials and Project Implementation

Stream crossing installations that will be completed by a contractor will most likely require bidding. The threshold for formal bidding for municipalities in PA is adjusted annually. The 2022 bidding threshold in PA is $21,900 (as of 4/2022 - check PA Department of Labor and Industry for current rates). DGLVR projects do not have any special bidding requirements or exemptions and must follow standard bidding practices based on the requirements of the grant recipients such as municipal codes, etc. It is the responsibility of the grant recipient to adhere to their bidding requirements.

Bid documents may be prepared by the grant recipient, their engineer, solicitor, a PennDOT municipal service representative, county conservation district, etc. Bid documents do not require a PE seal. Bid documents, in addition to contract terms and conditions, should clearly detail the scope of work and the requirements to meet the DGLVR Stream Crossing Standard and Policy. Specific to DGLVR stream crossing replacements, it is critical that aspects of the construction work not typical of more "traditional" crossing replacement projects (such as stream channel restoration beyond the right-of-way, detailed reconstruction of the stream channel inside of the structure, etc.) are clearly identified and explained in the bid documents.

A single bid or multiple bids may be utilized to complete one project. Grant recipients may bid materials and placement together in one bid, or they may choose to bid for materials directly from a manufacturer and advertise a separate bid for equipment and labor to implement a project. Municipalities may also utilize the Commonwealth of Pennsylvania's cooperative purchasing program (COSTARS) and state contract programs to obtain materials for DGLVR projects.

The grant recipient or engineer must provide all bid packages (if applicable) to the conservation district. The conservation district must review the documents and provide written confirmation to the grant recipient or engineer that those bid documents comply with DGLVR Policy and the Stream Crossing Standard before they are advertised to potential bidders.

In some cases, the grant recipient may have materials on hand from a bulk purchase, such as 2A stone or pipes. These materials can be utilized on DGLVR projects as long as documentation of the cost/value can be provided to the conservation district.

8.6 Site Showing for Installation

A pre-bid site showing involves the grant recipient, potential bidders, and the conservation district to ensure all parties are aware of DGLVR Policy and the Stream Crossing Standard. Pre-bid site showings are required for DGLVR stream crossing replacements. Conservation districts are required to participate in these site showings. The grant recipient may determine whether contractor attendance at site showings is mandatory to submit bids. Requiring contractors to attend the pre-bid site showing in order to be eligible to submit a bid can help identify oversights in the plan details, cover project expectations, and reduce the potential for change orders (edits to the scope of work, often including additional financial compensation) after a bid has been awarded. It should also ensure more accurate and competitive bidding, since bidders will have a better knowledge of project requirements. Be sure to remind grant recipients and potential bidders of Prevailing Wage requirements. A "Bid Site Showing Checklist for Stream Crossings" is available in Appendix G.

8.7 Grant Recipients Replacing a Structure Using Their Own Workforce

Grant recipients may elect to install a stream crossing using their own workforce. These installations must also follow the DGLVR Stream Crossing Standard. The DGLVR Program may reimburse the grant recipient for materials, equipment, and labor. This may include rented equipment. The municipal workforce is not subject to prevailing wage regulations, but all contracted labor may be.

It is important to have detailed discussions with the grant recipient to ensure they understand the details of the DGLVR Stream Crossing Standard. They need to understand the appropriate materials, equipment, and labor needed to complete the project (structure replacement and instream work) to meet DGLVR Stream Crossing Standard and Policy. Many applicants overlook the specialized equipment or manual labor necessary to establish streambed through new structures, or the attention to detail needed to restore channel continuity beyond the footprint of the structure and the right-of-way.

8.8 Pre-Construction Meeting

After a construction contract is awarded, the conservation district is required to hold an onsite pre-construction meeting. Pre-construction meetings typically involve the grant recipient and any contractors and engineers. This onsite meeting provides an opportunity to review the construction plans, specifications, and sequence. The meeting should include a walkthrough of the site and discuss schedules, permit requirements, limits of work and disturbance, etc. The group should attempt to identify any potential issues before work begins. During the pre-construction meeting it is important that the conservation district, contractor, engineer, and grant recipient establish roles, responsibilities, and a clear chain of communication to last through the construction process. If the engineer has developed a plan for concrete inspection and testing, responsibilities for this should be discussed in advance. A “Pre-Construction Meeting Checklist for Stream Crossings” is available in Appendix G to assist conservation districts in conducting a pre-construction meeting.

8.9 Traffic Control

The requirements and responsibility of traffic control will be determined during the planning and design phases of a project and will be included in the bid document if applicable. Road closures or restricted travel lanes are disruptive to normal traffic patterns and may affect local business or public services such as busing, garbage pickup, or mail delivery. It is important that the municipality and/or the contractor notify all emergency services of the closure or restricted access. To help alleviate frustration, notification to the public with posts in the newspaper, through social media, door hangers, or roadside signage can help the public prepare for a disruption. These notifications should be made as far in advance as possible. Immediately after the pre-design meeting is a good time to plan for detours or road closures, and to start notifying the local community. However, definitive timing of traffic disruptions may not be fully known until construction schedules are set during the pre-construction meeting.

9. CONSTRUCTION AND INSPECTION

Conservation districts are required to be onsite regularly during construction of a stream crossing replacement project to ensure DGLVR Program Policy and the Stream Crossing Standard are being met. At minimum, conservation districts are required to be onsite during installation of the critical stages of construction outlined in the DGLVR Stream Crossing Standard and Chapter 2 of this manual.

9.1 General Inspection and Contract Authority

Routine site inspection is an important aspect of a successful DGLVR stream crossing replacement project. Through careful consideration of the plan and detail drawings, specifications, observation of site conditions, photo documentation, elevation checks, and detailed field note recordings, conservation district technicians can often bring to light potential problems before they occur.

During the planning phases of the project lifecycle it is important that the conservation district, contractor, engineer, and grant recipient develop a good working relationship. Conservation districts should understand their contract authority for the project. In many instances, unless the grant recipient is installing the project with their own workforce, conservation districts will have no contract authority onsite with a contractor. If a circumstance arises where modifications are required or site work needs to stop in order to provide time to address a critical situation, conservation districts should discuss their concerns with the onsite contractor and then immediately notify the grant recipient and the project engineer. In a subcontracted project, only the grant recipient or the project engineer acting as the grant recipient's designee have the contractual authority to change a contract for project construction. Change orders often include an increase in payment to the contractor, so careful consideration should be given to any changes that arise for budget purposes.

Any changes proposed to a plan or specification must be reviewed and agreed upon by all parties and must be approved by the design engineer. Any changes to plans that alter permit acknowledgments must also be submitted to the reviewing entity for revised approval. It is the responsibility of the conservation district to ensure that any proposed changes to a plan or specification meet DGLVR Program policy and the requirements of the DGLVR Stream Crossing Standard. In questionable situations, consult immediately with the SCC before implementing changes.

9.2 Engineers' Inspection Requirements

As required by the DGLVR Stream Crossing Standard, the design engineer or their designee must be present onsite to inspect critical stages of construction. The engineer shall provide the project owner a signed and sealed certification form indicating that the critical stages of construction outlined in Section VII.D of the DGLVR Stream Crossing Standard were inspected and installed in accordance with the construction documents and DGLVR Stream Crossing Standard. The engineer must also provide the project owner with red-lined construction documents that indicate any changes in the as-built conditions of the project compared to the design plans. At a minimum, the following must be inspected:

- Installation of structure subgrade and bedding materials and establishing inverts/elevations.
- Installation of footings, abutments, and structure appurtenances.
- Installation of grade control features, bank margins, and streambed substrate.
- Installation or placement of stream crossing structure.
- Compaction and backfill of stream crossing structure.

The requirement for construction inspection by the engineer or the engineer's designee does not minimize the importance of the conservation district being onsite regularly during construction. For more details on these engineering requirements, refer to Section 12.6.1.

9.3 Safety

While safety measures are not the inspection responsibility of the conservation district, it is important to be observant of job surroundings, especially on an active construction site. Conservation district staff should be equipped with the appropriate Personal Protective Equipment (PPE) required by their employer and/or by the project owner or their contractor. Conservation district staff who arrive onsite for inspection should make their presence known to the construction crew and stand in a visible location out of the way of active equipment. Conservation district staff should also announce when they are leaving the site.

If conservation district staff observe unsafe working conditions, such as a potential for an excavated trench side slope failure, conservation district staff should speak up and alert the onsite work crew and project engineer. Consider written notification to the grant recipient regarding any safety issues onsite.

At the end of each active workday, the project owner or their contractor should adequately secure the construction site to ensure traffic or the public does not access the road-closed areas.

9.4 Erosion and Sedimentation Control

Each construction plan must provide for erosion and sedimentation (E&S) control best management practices (BMPs) during and after construction. After mobilization onsite, the construction crew should install initial E&S BMPs before earth work begins. Conservation district staff should compare E&S BMP placement throughout the construction sequence to the details on the E&S plan and evaluate the overall effectiveness onsite during construction. If an E&S BMP is not effectively addressing erosion or sedimentation during construction, conservation district staff should bring this to the onsite crew's attention and note it in their field notes. Often the onsite crew can make minor adjustments or improvements to the existing E&S BMPs to improve their effectiveness. Sometimes the contractor may need to consult with the owner, the project engineer, and/or regulating authorities for alternative E&S BMPs that go beyond what is in the scope of work in the E&S Plan. Significant changes such as this may result in a change order to the contract with the contractor. For additional guidance on E&S BMPs, see the Pennsylvania Department of Environmental Protection (DEP)'s *Erosion and Sediment Pollution Control Program Manual* at http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4680.

9.5 Dewatering

Dewatering is a critical component of a stream crossing replacement project. E&S BMPs include detailed plans for handling stream flow as well as water that collects in the project area, such as around footings. Stream water and site-collected water should be handled separately. Stream flow is often coffer dammed and either flumed (gravity flowed) through/around the worksite or pumped around the worksite. Water collected from the excavation area is often pumped through a filtration bag and discharged separately away from stream flow to a vegetated or stabilized area.

Once construction begins, it is important to remain mindful of the weather forecast and be prepared for precipitation events. Conservation district technicians should routinely discuss with the onsite construction crew their schedule, upcoming weather forecasts, and dewatering materials and equipment staged on site to ensure enough equipment and capacity is available.

Depending on how long the installation will take, the crew may need to make improvements or adjustments to the dewatering BMPs to maintain their effectiveness. Conservation district staff should look for large leaks in cofferdam materials that may jeopardize footing construction or bedding material for the new structure or may negatively impact backfill material, and they should report it to the construction crew. In some stream systems comprised of coarse bed material, it can be difficult to contain all of the stream flow with a cofferdam. This makes BMPs such as sumps and pump systems more critical to the construction sequence. Over-saturated material cannot meet optimal compaction and can threaten the structural integrity of a new stream crossing replacement. For detailed information on individual E&S BMPs and their inspection, refer to the Pennsylvania DEP*'s Erosion and Sediment Pollution Control Program Manual* https://www.dep.pa.gov/Business/Water/CleanWater/StormwaterMgmt/Stormwater%20Construction/Pages/E-S%20Resources.aspx

9.6 Excavation

One of the stages of construction is excavation of the existing structure and preparation of the opening for the new structure. Because of the DGLVR Stream Crossing Replacement Policy requirements, excavation for the replacement structure will be much wider than the original structure width. The engineer is required to be onsite to ensure the new structure, headwall, endwall, and wingwalls are installed per the locations, alignment, and elevations provided in the design plans and specifications. It is important that the excavation is wide enough to accommodate the structure, planned backfill, and required compaction equipment between the side walls of a structure and the native material. Due to the depth of excavation for some structures, the width of excavation may need to be increased to provide stable side-slopes and safe working conditions for any crew within the excavation area.

9.7 Construction Survey Stakeout and Accurate Surveys

An accurate construction survey stakeout is critical to ensuring that site excavation and installations are consistent with the construction plans and is strongly recommended. This should be identified in the engineer's scope of work prior to the engineer being contracted. It may be most effective for a surveyor to stake out the project site once the existing crossing structure has been removed, in order to lay out design elevations, cuts, fills, etc. to be constructed.

Survey benchmarks should be well marked and protected from construction equipment or traffic. If a benchmark has been impacted by construction, alert the construction crew, project owner and project engineer immediately so it can be reset. A survey error can lead to inadequate structure cover, shallow foundations, exposed pipe inverts, reduced hydraulic capacity, etc.

During the project, conservation district staff should check elevations of the critical stages of construction, such as the subgrade and bedding materials, footings, abutments and in-ground appurtenances, grade control and streambed substrate, bridge decking or stream crossing structure placement, and backfill/roadway final elevation.

Conservation district staff should have a good working knowledge of survey equipment and be capable of checking elevations in the field as part of their inspection duties. If conservation district staff determine there may be an elevation or field placement issue, they must alert the construction crew, project owner, and project engineer immediately. The final responsibility of field placement or elevation accuracy rests with the construction crew and the project engineer, but through the checks and balances of conservation district inspection, potential problems may be brought to light before they occur. The mandatory Stream Crossing Certification Training to be completed by conservation district staff provides in-depth guidance on how to perform spot-checks of critical stages of construction. Additional assistance in this process is available to conservation districts on a project-specific basis through CDGRS.

9.8 Structure Foundation / Bed Preparation

As excavation for the structure foundation nears final depth, conservation district staff should pay particular attention to the quality of materials coming from the excavation and the saturation level of the base material. If subgrade materials are heavily saturated and pumping water, additional dewatering measures may be warranted. If unsuitable materials are encountered, the conservation district should consult with the engineer to develop a remedial plan for foundation material. Routine survey checks should be done by the contractor during the placement and shaping of foundation bedding material to ensure correct grade and cross-sectional shape. The engineer is required to provide inspection and certification of the structure subgrade and bedding materials in accordance with the construction documents and per the DGLVR Stream Crossing Standard.

9.9 Streambed Reconstruction

Reestablishing channel continuity upstream, through, and downstream of the roadway is the means by which stream crossing replacement projects meet the DGLVR Program's goals and objectives. In order to achieve continuity, reconstruction of the streambed through the project site is essential. This includes reconstructing the streambed within the replacement structure. The criteria and requirements of the DGLVR Stream Crossing Standard list the steps and elements to be addressed through design and installation of the reconstructed portion of the stream channel.

The placement method of stream bed material depends on structure size (dimensions), material, and type. Specialized equipment such as a conveyor belt, a wheelbarrow, or a walk-behind loader may be required to convey material into the structure. Hand placement of grade controls, bank margins, and key pieces may be necessary to achieve the specified streambed profile (step/pool, riffle run, etc.) and cross-section shape (bank margins, bankfull-width channel, defined thalweg). For structural-plate structures, leaving select panels disassembled from the top may provide openings through which material can be placed from above.

Streambed reconstruction is typically easier with bottomless structures than those with an invert. By setting the top of footing elevation higher than the bankfull (bank margin) elevation, the streambed can be reconstructed between the structure's footings after they are set in place. After the streambed is constructed, the superstructure (typically aluminum plate or concrete) can be set upon the footings to complete the structure installation. During project design, the engineer should consider constructability when selecting a replacement structure and corresponding opening height (rise) to allow for ease of access into the structure for installation of the streambed.

Stream bed material should be placed and compacted in lifts to maximize compaction and minimize void space. Stream crossing replacements regularly include both mechanical and hydraulic compaction. Mechanical compaction techniques include plate compactors, sheepsfoot rollers, vibratory rollers, and static rollers. Hydraulic compaction typically means using pressurized water, such as from a pump or fire hose, to wash finer material into the void spaces in coarser aggregate. Construction crews should make a practice of marking structures for locations of the channel and bank margin elevations as well as grade control features. Constructed bank margins within the structure should be tied into the existing bank margins outside of the structure.

Quarried aggregate rip-rap for use as grade control, bank margins, or bank stabilization may only be rock that is sound, durable, and able to withstand exposure to air, water, and freezing and thawing. Quarried rock used for grade control, bank margins or bank stabilization must be obtained from a PennDOT-approved source or be tested and meet the criteria in the DGLVR Stream Crossing Standard. These requirements do not apply to material imported for streambed substrate or to onsite materials that are reused as part of the project.

Conservation district staff should become familiar with the streambed material (substrate mix) specified by the engineer for the project. As a general rule, the material should be reflective of the existing streambed composition within the reference reach but will often be sized slightly larger to help it persist longer within the crossing structure. In the engineer's specifications, the streambed material may be expressed as a thickness, gradation, and type of rock or stone rather than an AASHTO Standard. Salvaged materials from the site may be utilized for streambed material if they meet the design specifications. This would have to be determined by the project engineer on a project-by-project basis. Materials for streambed reconstruction must be of the gradation specified by the engineer and should be uniformly mixed to avoid segregation before placing inside the replacement structure.

Installation / reconstruction of the streambed is an identified Critical Stage of Construction, during which the engineer and conservation district are required to be onsite for inspection. The conservation district should work with the engineer to inspect this aspect of project construction. Additional information about streambed material and placement can be found in the Streambed Restoration and Grade Control Technical Bulletins in Appendix H.

9.10 Material Inspection

As materials are delivered to the site, conservation district staff should make a general observation and note of quantities arriving and their condition. Often, materials such as pipe may be delivered to a site before the contractor has been mobilized. This may result in materials being unloaded through the use of gravity rather than carefully lifted and placed in the staging area. Damage to materials such as cracking, denting, or removal of protective coatings such as galvanization can reduce material life span and overall affect the quality of a project. Materials found to be damaged should be reported to the project engineer and addressed.

Stream crossing replacement projects often require onsite assembly of structure materials. The seam between overlapping (or "shingled") joints will typically face downstream. If any joints face upstream, consult the manufacturer's plans and recommendations. Pipe materials requiring bands to join pipe sections should have as tight a seal as possible. This may require the use of watertight gasket seals such as mastic. Bands should be fit to the corrugations of the pipe. Bands should be tightened evenly and not over-tightened such that they cause deflection in the structure or break the band closures. It is anticipated that some small gaps may be present in some pipe shapes. To the best extent possible, these should be filled with gasket material or buried under the reconstructed streambed if located within the streambed establishment area. Ultimately, construction crews should follow the manufacturer's recommendations for addressing any pipe gap areas to prevent piping failures.

Structural plate (multiplate pipe) assembly requires careful study of assembly shop drawing details. Often manufacturers will provide onsite assembly guidance for a fee. Smaller structures may be assembled at the factory and delivered in one piece. The seam between overlapping or "shingled" joints will typically face downstream. If any joints face upstream, consult the manufacturer's plans and recommendations. The use of pry bars is often required to align multiple plates for assembly. Attention to the length of bolts used for multiple plate junctions is also critical. Often, manufacturers recommend keeping all bolts loose for structure flexibility until all plates are assembled. Once fully assembled, bolts are required to be torqued to manufacturer's specifications. Occasionally, minor misalignments may require a slight reaming of the stamped holes. If major misalignments are observed, stop and study the shop drawings. Often this is an indication that the wrong plates have been utilized in the wrong locations.

More structure installations will involve concrete work for footings or abutments due to the DGLVR Stream Crossing Standard. Installation of footings or abutments is a Critical Stage of Construction, during which the conservation district is required to be onsite with the engineer or their designee. Conservation district staff should be familiar with the crossing's concrete structures' standard details and compare onsite forming and reinforcement placement with the plan drawings. Forms should be free of standing water and have good soil contact to prevent seepage from the base of the form. Just before concrete placement, it is advisable that elevations are checked one final time before the commitment to pouring is made. Concrete shall comply with the mix design (compressive strength and other special requirements) specified in the construction plan drawings. Concrete must be installed according to the structure manufacturer or design engineer's specifications. Concrete cure times for form removal, backfilling, and load testing should be specified in the design plans. Once forms are removed, conservation district staff should work with the project engineer to perform a visual inspection of the structures and note any spauling, honeycomb, or other defects and bring it to the attention of the construction crew, project owner, and design engineer to determine if remedial action is needed.

9.11 Backfill for the Replacement Structure

Backfill for stream crossing replacement structures shall comply with the manufacturer's recommendations. Backfill material around the replacement structure should be placed and compacted in a series of lifts, instead of a single, full-depth placement. Lift depth is typically 12" or less, but may also be driven by manufacturer requirements, soil types, or other considerations.

Conservation district staff should be familiar with the aggregates specified in the construction plans and manufacturer's shop drawings for backfill. Placement of backfill around the replacement structure is an identified Critical Stage of Construction, during which the engineer and conservation district are required to be onsite for inspection. The conservation district should work with the engineer to inspect this aspect of project construction.

9.12 Restoring Stream Flows to the New Structure

After the stream channel and structure have been installed and the streambed has been re-established, the cofferdam or stream channel diversion may be removed. Re-watering the structure with stream flow should be a slow release for larger streams to prevent any undesired erosion from a quick breach of the coffer dam. Conservation district staff and others involved in construction should look for indications of stream flow going subsurface in the restored stream channel reach. Pay particular attention to areas immediately upstream and downstream of the structure inlet/outlet, and around constructed grade control features. In some stream systems, subsurface channel flow may be a naturally occurring condition. However, in most locations, subsurface flow is an indication of improperly placed and compacted stream bed material. If conservation district staff observe subsurface stream flow, excessive erosion of the reconstructed stream channel, increased footing exposure from design plan specifications, or **degradation** of stream bed material (rock or stone failure), immediately notify the construction crew, project owner, and design engineer.

9.13 Headwall, Endwall, and Wingwall Installation

Headwalls, endwalls, and wingwalls are integral components of a stream crossing replacement. These structures help to direct high flows through the crossing while protecting the stream crossing structure's backfill from erosion. Headwalls and endwalls should closely fit the crossing structure's shape or otherwise protect any embankments from erosion. Headwalls, endwalls, and wingwalls often need to be assembled on the stream crossing before or during the backfill process to attach soil anchors and tie-backs. Often these materials come from the manufacturer with some "fit in the field" instructions, as their degree of departure from the structure may need to be adjusted. Per the DGLVR Stream Crossing Standard, headwalls and endwalls are required for all stream crossing replacement structures. Constructed bank margins within the structure should be tied into the existing bank margins outside of the structure.

9.14 Site Restoration and Clean Up

In addition to the stream crossing replacement installation and stream reconstruction, the scope of work may include additional road fill, drainage, or stabilization work in order to address contributing stormwater and sedimentation issues.

Conservation district staff should continue to provide routine onsite inspection until the entire scope of work is complete. There may be other aspects of the project included in the contract that go beyond the structure installation and instream restoration work. The site must remain protected by temporary E&S BMPs until the site has reached a uniform 70% vegetated cover. Once permanent stabilization is achieved, the construction crew or grant recipient is responsible for removing and recycling or disposing of any temporary E&S BMPs.

9.15 Federal Highways Structure Inspection (>20 Feet Clear Span Opening)

Sales consultants may inquire what load rating the structure should be designed for. HS20, HS25, and PHL93 are all acceptable load ratings, but the most current rating is PHL93. If a structure, regardless of type (metal pipe, concrete box, bridge), exceeds 20 feet of clear span opening, the structure is subject to Federal Highway Administration inspection requirements. Local ordinances may require inspection for structures less than 20 feet of clear span opening as well. Often, the inspection entity will request computations for all commonly accepted design loads to report to PennDOT's Bridge Management System (BMS). This includes H20, HS20, ML-80, TK-527, and PHL-93. The structure manufacturer can often provide these rating factors as part of its PE sealed shop drawing and supporting calculations. These calculations may add a nominal additional cost to the structure but it is often cheaper to be developed by the manufacturer than by the project engineer. If load calculations are going to be required, indicate this at the time of obtaining an estimate. For more information about federal highway inspection, contact the county's Municipal Services Representative or the PennDOT District Area Bridge Department. More information regarding PennDOT design guidelines including design loads can be found in PennDOT Publication 15M, *Design Manual, Part 4,* https://www.dot.state.pa.us/public/PubsForms/Publications/PUB%2015M.pdf.

10. Final Inspection and As-Built Notes

This section contains a summary of guidance for closing out a project and final payment, including some items that are specific to stream crossing replacements. For more guidance on final inspections and closing out DGLVR projects, see Section 3.8 of the DGLVR *Administrative Manual*.

10.1 Final Onsite Inspection

Prior to final payment, the conservation district and grant recipient must conduct a final onsite inspection. The contractor may be asked to be present at this meeting. Grant recipients are encouraged to schedule a final inspection immediately after work is complete, so any remediation can be done while equipment is still onsite if needed. During this final inspection, the conservation district may find aspects of the project that were not installed, or not installed according to DGLVR Program Policy and the Stream Crossing Standard and/or construction documents. If this occurs, the conservation district must discuss any project shortcomings and potential remediations, then provide the grant recipient with a list of the items that need to be completed prior to making final payment. A second site inspection may be required to ensure any outstanding issues have been resolved. If the project is acceptable to the conservation district during the final inspection, the Project Completion Report can be completed (see Section 10.2).

10.2 Project Completion Report

Once the project is acceptable to the conservation district, the conservation district and grant recipient should complete the "Project Completion Report" together. Stream crossing replacement projects have a stand-alone location on the form for recording project details. Once the form is completed, both the conservation district and the grant recipient must sign it to verify that the project has been satisfactorily completed. The Completion Report must be filled out in the DGLVR Program's online GIS reporting system.

10.3 Habitat Re-connectivity

While not a required reporting element for the DGLVR Program, conservation districts may wish to quantify the length of restored or reconnected habitat (i.e., "stream miles") that was achieved by replacing (and restoring aquatic organism passage (AOP) through) a structure that was formerly an AOP barrier. In some cases, miles of stream habitat may be reconnected by replacing a single crossing. There are many factors that influence the length of reconnected habitat, such as:

- What was the level of AOP barrier that existed with the old crossing?
- How far upstream or downstream is it to the next AOP barrier (human-made or natural), and what is the extent of that barrier?
- How far upstream or downstream does usable habitat extend for the species of interest?

The "North Atlantic Aquatic Connectivity Collaborative" (NAACC) has developed a protocol for assessing road/stream crossings and quantifying the level of connectivity that exists. For more information see www.streamcontinuity.org

10.4 Final Engineering Documentation

Prior to final payment, the project engineer is required to provide the project owner with a signed and sealed "Inspection and Documentation of Critical Stages of Construction Certification Form" indicating that the critical stages of construction were inspected and installed in accordance with the construction documents and the DGLVR Stream Crossing Standard (Appendix A). The engineer must also provide the project owner with red-lined construction documents that indicate any changes in the as-built condition of the project compared to the design plans (field changes).

10.5 Final Project Payment

DGLVR Policy requires that at least 30% of the grant amount be withheld until satisfactory project completion. The final payment can be made by the conservation district once all of the following conditions are met:

- Construction is complete and the conservation district verifies this during a final inspection.
- The conservation district has satisfactorily completed the Final Project Inspection and Project Completion Report.
  - The Completion Report must be filled out in the DGLVR Program's online GIS reporting system.
  - The Completion Report must be signed by the grant recipient and conservation district.
- The engineering documentation (Inspection and Documentation of Critical Stages of Construction Certification Form and red-line drawings) is received.
- Financial documentation (receipts) for all grant expenses are received.
- Required documentation as per the SCC's Hard File Project Checklist is received.
  - The Completion Report and Hard File Project Checklist are available online at https://www.dirtandgravel.psu.edu/pa-program-resources/program-specific-resources/blank-forms

11. Monitoring and Maintenance

There are no statewide DGLVR Program requirements for monitoring or maintenance after projects have been completed. Conservation districts, however, may set local policy on maintenance requirements for completed projects in their county. Maintenance of past projects may also factor into a conservation district's application ranking criteria.

Stream crossing projects implemented according to the DGLVR Stream Crossing Standard may eventually need maintenance. Instances may occur both before and after large storm events where maintenance should be completed to ensure the full lifespan of the crossing and associated project elements. A successful monitoring plan highlights items that need to be evaluated (and potentially maintained) in order to meet DGLVR Program Policy and the Stream Crossing Standard over the long term.

11.1 Monitoring the Crossing

Streams are dynamic systems and will continue to change and evolve over time. Conservation districts and project participants should consider routine post-construction monitoring of stream crossing projects implemented by the DGLVR Program. Routine monitoring of the project site provides important insights into how the crossing is functioning and changing over time. Monitoring also helps to identify any repair measures that may be needed to keep the project functioning properly. Each conservation district / project participant should determine what level of monitoring is needed. Monitoring should include evaluation of both the crossing structure and the stream channel throughout the reconstructed reach. Failures in the streambed can lead to failure of the structure, particularly if footings are undermined or structural plates are exposed to elements, causing corrosion.

11.2 Monitoring the Physical Structure

One method available for monitoring the condition and function of the stream crossing structure is to utilize PennDOT's template bridge inspection forms. These forms can be found at http://www.dot.state.pa.us/public/Bureaus/BOMO/BMS2/Templates/FormsTemplateList.pdf

Forms are available for monitoring of both bridges and culverts. The forms list specific "red-flag" items to be evaluated, such as changes in the culvert shape, settlement in the roadway surface, headwall and endwall defects, and corrosion of metal surfaces. The forms also provide guidance for establishing maintenance priorities. These forms are largely for evaluating the structural integrity of the crossing, not for evaluating continuity, streambed, or aquatic passage.

11.3 Monitoring the Streambed

The project design, built upon the requirements of the DGLVR Stream Crossing Standard, is intended to provide the best-informed framework for restoring a stable channel and continuity through the reconstructed stream reach. Post-construction, the restored channel reach will change and evolve toward a stable condition through a series of adjustments to its width, depth, slope, and alignment after each high-water event. These adjustments may occur in small increments over time, or all at once due to an abnormally large event. The degree to which these adjustments occur depends on how closely the design and construction of the project were able to match the "stable" condition. Minor adjustments are natural and expected. Major adjustments are usually more problematic.

The goal of a successful post-construction monitoring or maintenance plan should be to evaluate whether the stream restoration component of the project continues to meet the requirements of the DGLVR Stream Crossing Standard, even if some minor post-construction adjustments have occurred. Instances where channel adjustments have caused aspects of the reconstructed stream reach to no longer meet these requirements may trigger a discussion on repair options.

Post-construction monitoring does not need to be complex or time consuming. However, it should be comprehensive enough to adequately determine if the project continues to meet the requirements of the DGLVR Stream Crossing Design and Installation Standard.

When evaluating the post-construction condition of a project, consider the following:

- Has the reconstructed channel already "stabilized," even after some initial adjustments following the first few high-flow events, or is the channel continuing to adjust with each new flood?
- Has slope continuity been maintained through the project reach? (Is there a continuous channel through the culvert, without excessive jumps or velocity barriers?)
- Has a bankfull-width channel been maintained, with defined bank margins and low-flow thalweg?
- Do the reconstructed channel and the tie-in points to adjoining upstream/downstream channels allow for aquatic organism passage (AOP) across the full range of stream flows?
- Are the constructed grade controls, bank margins, and key pieces intact, stable, and functional?
- Is streambed material present through the entire structure? Is it aggrading or degrading compared to the initial placement?

A more detailed and in-depth monitoring protocol can provide a better picture of how the crossing is performing and how post-construction adjustments are trending over time. This can be useful for quantifying channel changes or for identifying and proactively correcting progressive issues early, before they devolve into failures. Elements of a more comprehensive monitoring plan might include replicate surveys of longitudinal profile and cross sections through the project reach, replicate photos taken at key locations, and measurements of streambed material depth within the structure. The U.S. Forest Service culvert-assessment procedure (Clarkin et al. 2005) provides a template for more in-depth post-construction monitoring.

11.4 Maintenance and Repair

The goal of the DGLVR Program is to implement stream crossing projects that require very minimal maintenance. However, over the long lifespan of an average stream crossing, maintenance or repair may become necessary.

11.4.1 Regular Maintenance

Once a project has been completed and the contract is closed out, regular maintenance of the structure and crossing is the responsibility of the road owner (grant recipient). Regular maintenance may include activities such as debris removal, fixing fallen bank protection, and minor channel work. PA Department of Environmental Protection (DEP) permits allow maintenance within 50 feet upstream and downstream of structures. If stream work is needed outside the 50-foot limit, additional permits could be required. Maintenance of the stream crossing structure, road approaches, and streambed may be necessary to avoid long-term problems. Regular maintenance is a cost-effective way to ensure the lifespan of the structure and ensure its flood resiliency. Simple items like removing debris from the stream could save thousands of dollars of future maintenance costs after a large storm event. Maintenance activities should not cause the constructed aspects of the project to no longer comply with DGLVR Policy or requirements or to no longer function properly.

11.4.2 Repair

In some circumstances, such as after extremely large flow events, repair of the project may be necessary. Repair work may include activities such as repairing or replacing grade control, adding grade control or bank stabilization, or significant alterations to the streambed. Early repair of small issues could prevent future failures, for example: the partial loss of a grade control feature could lead to a cascading set of failures of adjacent streambed and grade control if not addressed. The road owner may wish to apply for a DGLVR grant for more significant repair tasks, such as reestablishing grade control or bank stabilization. Applications to address these repair issues may be submitted to the conservation district. It is up to individual conservation districts to determine policies and priorities for repair work to completed projects. Repair projects funded by the DGLVR program must comply with the requirements of the DGLVR Stream Crossing Standard.

Repairs should be considered to correct aspects of the completed project that have deviated from the designed and constructed condition over time and are trending toward or no longer meeting DGLVR Program goals or requirements. Some potential repair items might include, but are not limited to:

- Adding or repairing scour protection for headwalls and endwalls.
- Restoring streambed material and/or re-constructing the streambed shape due to excessive post-flood scour or deposition.
- Improving, rebuilding, and/or increasing the number of grade control features through the reconstructed reach.
- Channel modifications to address head cut development at the upstream or downstream tie-in points.

Note that additional permitting may be needed depending on the scope of repair work.

12. ENGINEERING DESIGN CONSIDERATIONS

> Terms defined in **Appendix B** are in **bold text** the first time they appear in this manual. Click on these terms to view the definition in Appendix B.

The principal objective of **stream crossing** replacement projects funded through the Dirt, Gravel, and Low Volume Road Program (DGLVR Program) is to reconnect and stabilize the stream segments immediately upstream and downstream of the roadway. Design of stream crossing replacement projects funded by the DGLVR Program must provide for the reestablishment, restoration, and long-term maintenance of **channel continuity** and **aquatic organism passage (AOP)** upstream, through, and downstream of the replacement **crossing**. This will maximize the environmental benefits and improve **flood resiliency**. For more information on the goals and objectives of DGLVR stream crossing replacements, see Chapter 1.

Stream systems are, by their very nature, dynamic and diverse. No single guidance document or set of standards or specifications can provide a comprehensive and concise "roadmap" for optimal design of a successful road/stream crossing replacement at every project site. The technical guidance provided in this chapter is intended to establish the fundamental framework and lay out the critical steps for successful design of projects that meet (or exceed) the DGLVR Program Policy and Stream Crossing Standard.

Ultimately, the project engineer is solely responsible for the content of the final design product. The engineer, conservation district, and grant recipient are responsible for determining that the project design and implementation is consistent with DGLVR Program Policy. In addition to the guidance provided in this chapter, the Penn State Center for Dirt and Gravel Road Studies is available to provide technical assistance to the conservation district, grant recipient, and engineer through the design process.

This chapter is written to provide detailed design guidance, primarily for engineers. Some of this information is replicated from other sections of this manual. Likewise, other parts of this manual provide additional information regarding various stages of a typical project lifecycle.

DGLVR Program: Overview of Roles

- **Local Entities**
  - **Conservation District:** Provides grant funding and administers the DGLVR Program within each county. The conservation district is the main point of contact for review of project documents and project oversight.
  - **Grant Recipient:** Road-owning entity that receives DGLVR grant funds from the conservation district and performs or subcontracts work to be done. All grant recipients are public entities, and most are townships or boroughs.
  - **Contractor:** (if applicable) Contracts with the grant recipient to perform project work.
  - **Engineer:** (if applicable) Contracts with the grant recipient to perform project design and inspection.
- **Statewide Supporting Entities**
  - **State Conservation Commission (SCC):** Entity at the PA Department of Agriculture that administers the DGLVR Program statewide.
  - **The Pennsylvania State University Center for Dirt and Gravel Road Studies (CDGRS):** Provides education and technical support to all entities of the DGLVR Program.
  - **Trout Unlimited (TU):** Provides education and technical support to all entities of the DGLVR Program.

DGLVR Program: Overview of Documents and Policies

- **DGLVR *Administrative Manual* (Admin Manual)**
  - The Admin Manual sets statewide policy requirements for the PA Dirt, Gravel, and Low Volume Road (DGLVR) Program. Section 7.1 of the Admin Manual sets statewide DGLVR Program Policy for Stream Crossing Structural Replacements.
  - When the DGLVR *Stream Crossing Replacement Technical Manual* references "DGLVR Policies" or "DGLVR Policy," the referenced policy/policies include everything in the *Administrative Manual*.

- The *Administrative Manual* is available online at https://www.dirtandgravel.psu.edu/pa-program-resources/program-specific-resources/administrative-guidance-manual.

- **DGLVR Stream Crossing Design & Installation Standard (DGLVR Stream Crossing Standard):**
    - The DGLVR Stream Crossing Standard lists requirements for any new stream crossing structures funded in whole or in part by DGLVR funds or counted as in-kind on a DGLVR project. In-kind contributions refer to costs incurred by the grant recipients for a project that are not reimbursed as part of the grant.
    - When the DGLVR *Stream Crossing Replacement Technical Manual* references "standards" or "Stream Crossing Standards," those refer to the DGLVR Stream Crossing Design & Installation Standard.
    - The DGLVR Stream Crossing Standard is incorporated by reference in Section 7.1.2 of the *Administrative Manual* and can be found in Appendix A of this DGLVR *Stream Crossing Replacement Technical Manual*.
- **County-Specific DGLVR Policies:**
    - Each county conservation district has a set of local policies for its county DGLVR Program set by its Quality Assurance Board (QAB) and conservation district Board of Directors. The local county DGLVR Policy may include requirements that exceed statewide DGLVR Policy and must be considered for all DGLVR projects based on the county funding the project.
    - Contact the relevant county conservation district for its local policies.

12.1 Project Design

Successful design of a stream crossing replacement project is based upon information obtained from a **Site Assessment** of existing site conditions, to include longitudinal profile and **cross sections**. The steps listed below provide a chronological approach to collecting and applying the site-specific data needed to produce a project design that meets DGLVR Program Policy and the Stream Crossing Standard.

12.1.1 Pre-Design Meeting

Pre-design meetings are required to be held at the project site prior to design and permitting. At a minimum, the grant recipient, the engineer, and the conservation district should attend. The pre-design meeting is a chance for the engineer to get background information on the site and better understand DGLVR Program requirements before beginning the design process.

The conservation district will have performed a preliminary Site Assessment prior to the grant application. The conservation district may choose to make this Site Assessment information available to the engineer. If provided, the engineer will have discretion to use the Site Assessment data provided by the conservation district or conduct a new assessment of their own. During the pre-design meeting the engineer and the conservation district should review data collected by the conservation district and determine if an additional Site Assessment will be performed by the engineer.

A walkthrough of the project reach upstream and downstream of the roadway crossing is recommended. Identify survey bounds for data collection and potential project / construction limits, including possible stream channel **tie-in points** upstream and downstream of the road. Determine dominant **grade control** feature type. Reference Chapter 3 in this manual for more detailed guidance on Site Reconnaissance / Walkthrough. A "Pre-Design Meeting Checklist for Stream Crossings" is available in Appendix G.

12.1.2 Site Assessment

A Site Assessment is used by the engineer to inform various aspects of stream crossing replacement design. If an additional Site Assessment will be conducted by the engineer to support project design, conservation district staff are required to be onsite during field data collection. Regardless of the source of site assessment data, the engineer is responsible for the data they base their design upon.

For the DGLVR Program, a Site Assessment consists of longitudinal profile and cross-section surveys. To adequately support the project design, these surveys must capture essential aspects of the road-stream crossing and the adjoining upstream and downstream channel segments. Reference the DGLVR Standard (Appendix A) for site assessment requirements and Chapter 4 of this manual for additional information on Site Assessments.
At a minimum, two benchmarks must be set by the engineer or surveyor in an area outside of the zone of construction and disturbance.

12.1.2.1 Longitudinal Profile Survey (Long-Pro):

The **longitudinal profile survey:**

- captures data points along the channel **thalweg**, at the **invert** and top of the existing **structure**, and across the roadway.
- begins upstream of the crossing and continues in the downstream direction, extending far enough upstream and downstream of the roadway to identify prevailing channel slopes beyond the portions of the channel impacted by the effects of the undersized structure.
- extends far enough upstream or downstream to capture an appropriate "**reference reach"** (see below), which provides a blueprint for reconstruction of channel profile through the project site (including upstream, through, and downstream of the replacement crossing).
- begins and ends at the crest of a grade control feature.
- records and notes, at minimum, the following key data points:
  - crest of grade control feature (**riffle** crest, for example)
    - for each grade control crest, note a relative stability rating that compares the stability of each grade control to the other grade control features present within the surveyed reach (good, moderate, or poor, for example).
  - end of grade control feature (end of riffle, for example)
  - bed at maximum **pool** depth
  - streambed at structure inlet
  - invert at structure inlet
  - top of structure inlet
  - upstream, centerline, and downstream edges of roadway
  - top of structure outlet
  - invert at structure outlet
  - streambed at structure outlet

See Figure 12.1 for a graphical representation of a longitudinal profile survey. While DGLVR Policy requires that the longitudinal profile survey must extend a minimum of 150' upstream and 150' downstream of the crossing, the actual extent of survey needed may be greater, in order to capture an appropriate reference reach and to establish start/end points at grade control crests. Consider determining the length of the longitudinal profile as a function of the stream size (20-30 bankfull-widths, for example). This will help make the assessment more site-specific and applicable and help ensure that the needed types of field data are collected.

The Reference Reach

The reference reach is a section of the stream channel that best reflects the typical, natural, minimally impacted characteristics (profile, dimension, planform, and dominant **bedform**) of the channel. For stream crossing projects, the reference reach is located beyond (upstream or downstream of) the extent of channel impacts associated with the existing structure. These impacts may include excessive sediment deposition or bed / pool scour, channel braiding, increased bank erosion, and/or over-widening of the channel. During the site walkthrough, identify the limits of these immediate impacts, and consider the "typical" condition of the stream channel beyond these. As part of the walkthrough, identify one or more "preliminary" or "potential" reference reaches. An appropriate reference reflects the general character of these typical conditions.

Site assessment (survey) of the reference reach is used as a blueprint for design of the **reconstructed reach**. The reference reach:

- is located beyond the extent of evident channel impacts associated with the undersized structure.
- begins and ends at the crest of a grade control feature and includes a minimum of two bedform sequences (i.e., riffle/pool, riffle/pool, riffle).
- must have a slope of +/- 25% of the proposed **continuity slope** of the reconstructed streambed, unless otherwise approved by the SCC. In instances where a reference reach with the appropriate slope cannot be identified within reasonable proximity to the project site, contact CDGRS for assistance.
- must reflect the overall typical condition of the natural, minimally impacted channel, and should not include significant anomalies in width, depth, slope, or bed features.
- should exhibit the same dominant bedforms and grade control types as those present through the overall project reach.
- should be in a location that contains reliable bankfull indicators.
- should not be located within braided channel segments or the confluence of tributaries. The reference reach should be located on the same single-thread channel as the crossing.
- should generally reflect the same sizes and distribution of bed materials visible in sections of the streambed located beyond the extent of immediate impacts.
- locations, sizes, and composition of individual (or clusters) of **key pieces** that provide periodic grade control along the length of the reference reach between more pronounced grade control features.

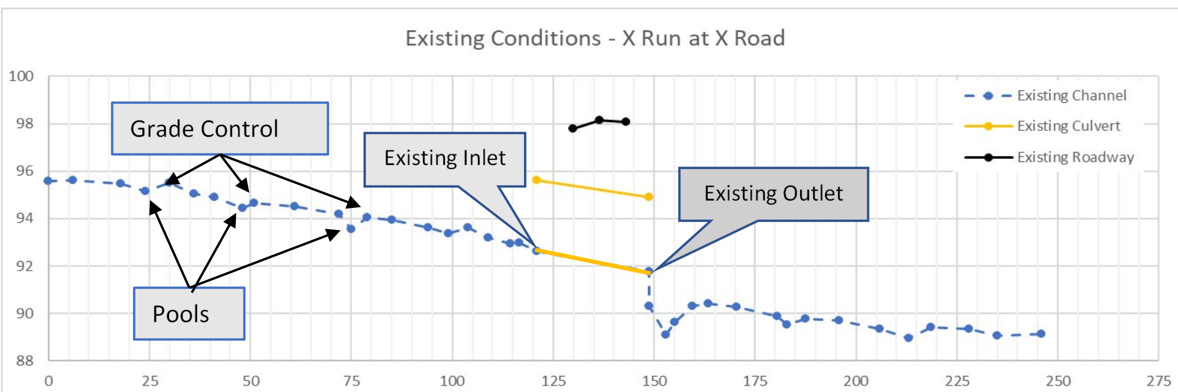


Figure 12.1 Longitudinal Profile Example Graph

An example of a long-pro survey plotted in Microsoft Excel. Stream features such as slope, grade control spacing, and average pool depths can be obtained from the data in this long-pro.

Extending the length of the longitudinal profile provides the opportunity to include multiple potential reference reaches, which can help choose the best-applicable reference data during the design criteria process (see Section 12.1.3). Extending the length of the reference reach survey to include additional bedform sequences will better represent typical stream conditions and provide more reliable design criteria.

If an appropriate reference reach is not located in proximity to the crossing, one could be established at a separate location on the same stream. In this case, a separate reference reach survey may be conducted that is not continuous with the longitudinal profile survey at the project site. To be applicable to the project design, an appropriate "disconnected" reference reach must still meet the criteria listed above.

Comprehensive instructions for completing a long-pro and collecting key measuring points can be found in the Site Assessment Technical Bulletin (Appendix H). A comprehensive long-pro survey provides the information that will be used in project planning, design, and permitting, as described throughout this chapter, including:

- existing slopes of upstream and downstream channel segments

- locations of tie-in points (upstream and downstream limits) and overall length of the reconstructed reach
- existing and proposed structure dimensions and slopes
- replacement structure selection
- grade control type, length, and spacing
- existing pool depths
- anticipated pool scour depths within the replacement structure
- restoration of plunge pools and **vertical offsets**
- materials estimation (streambed, road fill, etc.)
- existing and proposed roadway elevations

12.1.2.2 Cross Sectional Survey

When completing the Site Assessment, at least two cross sectional surveys must also be conducted. These cross sections should be collected at the crest of a grade control feature within the reference reach, and at the maximum depth of the **outlet scour pool**. If no significant outlet scour pool is present, a cross section should be surveyed at the deepest point of a reference reach pool. For cross sections surveyed at grade control crests, try to situate these in locations where reliable bankfull indicators are visible. See Figure 12.2 for a graphical representation of a channel cross section. If more than one "potential" reference reach is identified during the walkthrough, survey a cross section at grade control crest in each.

A cross section is a survey conducted across the channel (perpendicular to the thalweg) to produce a graphical representation of channel dimensions including shape, depth, and width. Typically, cross sections are stationed from left bank to right bank (left to right, facing downstream). At minimum, each surveyed cross section must include data points on both streambanks capturing top-of-bank, bankfull, and right/left edge of water. Instream data points must include a minimum of three streambed points, including the thalweg (low-flow channel). Key measurement points that should be collected and noted during the cross section survey include:

- **Floodplain:** Collect one or more data points along the floodplain extending beyond the tops of both banks. These should capture inflection points where noticeable changes in elevation or slope occur.
- **Top of Banks:** Take a reading at the top of both streambanks.
- **Bankfull Elevation:** Take a reading at the bankfull elevation, using the best-available bankfull indicator on the survey transect. Each cross section surveyed should include at least one bankfull data point. See the Bankfull Width Determination Technical Bulletin for additional information on identifying bankfull elevation (Appendix H).
- **Edges of Water:** Take a reading at the water's surface where it meets both streambanks.
- **Bottom of Banks:** collect a data point along the toe of both banks, where the streambank transitions to the stream bed.
- **Streambed:** Take a reading at three or more locations within the wetted portion of the stream channel. Include a point representing the thalweg, along with two or more additional points. These points should be positioned to best depict the general shape of the streambed.

The surveyed cross section should contain sufficient data points to reflect channel dimensions and shape. Depending on site conditions, additional points may need to be collected. Comprehensive instructions for completing a cross sectional survey and collecting key measuring points can be found in the Site Assessment Technical Bulletin (Appendix H).

Existing Conditions - X Creek at X Road

XS #	1
LP STA	46
HI (ft)	103.7

STA	FS	NOTE	ELEV
0	5.13	Top of Left Pin	98.57
0	5.66	Base of Left Pin	98.04
5	5.86	Floodplain	97.84
8	5.9	Bankfull	97.8
13	6.62	Left Edge of Water	97.08
13.9	6.94	Bottom of Left Bank	96.76
20.3	7.34	Thalweg	96.36
23	7.08	Bottom of Right Bank	96.62
25	6.64	Right Edge of Water	97.06
30	5.62	Top of Right Bank	98.08
34	5.51	Floodplain	98.19

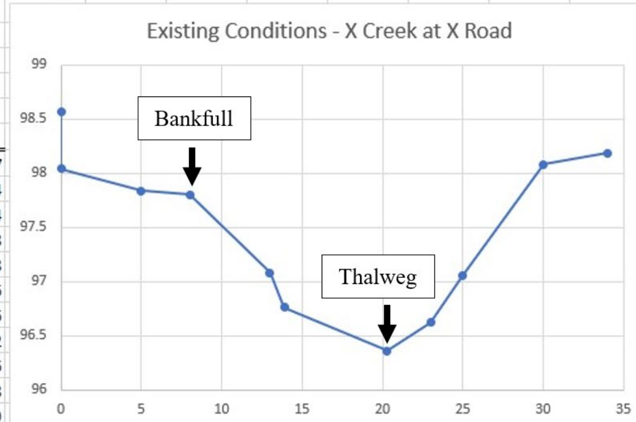


Figure 12.2 Cross Section Example Graph

An example plot of a surveyed stream channel cross section. Surveyed sections at the reference reach inform elements of reconstructed reach design such as bankfull (bank margin) height and thalweg depth.

Recording Site Assessment data

When conducting longitudinal profile and cross section surveys, three pieces of information should be recorded for each data point collected. These include:

- *Station*: the distance along the transect being assessed.
- *Foresight*: if using a laser level, this is the reading taken from the stadia rod. If using more advanced survey equipment, this might be recorded as an actual elevation. Foresight readings collected in the field can be translated to elevations later, based on the benchmark and laser (height of instrument) elevations.
- *Notes*: a brief description of the feature of interest where the data point is being collected. These should be standardized to assist the conservation district during their required review of the design plans.

Consistency in the way field data are recorded by the conservation district, CDGRS, and the engineer/surveyor can go a long way in streamlining communication and the sharing of information among the project participants. Clarity and consistency of field notes and good organization of Site Assessment data can greatly assist the conservation district in completing the required design plan review in a timely manner. Specifically, using a standardized system for noting typical features collected during the Site Assessment will help understand how the field data translate to the design criteria developed by the engineer. The Site Assessment Analysis Tool (Section 4.5 of this manual) utilizes a standardized list of notations for designating common features collected in the field. While use of this Tool by the engineer is not a DGLVR Program requirement, utilizing this same notation system when recording field notes during the Site Assessment will streamline collaboration between project partners.

The Site Assessment Technical Bulletin (Appendix H) provides more information on recording field data and includes the standardized list of notations referenced above.

Supplementary Survey Data

Collect supplemental survey data as needed to satisfy any other project-specific design needs. These might include:

- Topographic survey of cross sections to support flood modeling / H&H analysis
- Topographic survey to identify roadway profiles, drainage, etc.
- Topographic survey of roadway embankments to determine headwall / wingwall configurations
- Topographic survey to support cut/fill or other materials estimates, proposed channel realignments, etc.
- Wetland determination, if applicable, to determine project impacts

12.1.3 Site Assessment Data Analysis

Reference Reach: A relatively natural section of channel outside the impact of the crossing used to determine stable slope, grade control, and more.
Reconstructed Reach: The section of channel between the tie-in points that is to be modified as part of the crossing replacement to achieve continuity. This reach extends upstream, downstream, and through the structure.
Channel Continuity: Reestablishing connectivity and consistent channel profile, slope, and bedform upstream, though, and downstream of the replacement structure. This provides for aquatic organism passage and meets DGLVR Program Policy and objectives.

Stream channel continuity is obtained by basing project design on data derived from longitudinal profile survey of the stream segments adjacent to the crossing to be replaced.

- Determine existing channel slopes upstream and downstream of the existing crossing, excluding areas immediately impacted by the undersized structure.
- Determine tie-in points upstream and downstream of the roadway that establish the limits of stream channel reconstruction ("reconstructed reach"). The slope between tie-in points must be consistent with prevailing slopes of the existing channel segments upstream and downstream in order to achieve channel continuity. If necessary, extend the distance between tie-in points to obtain the continuity slope needed.
- Tie-in points must be situated at the location of existing grade control crests. Depending on the relative stability rating assigned during the longitudinal profile survey, these tie-in points might consist of existing, stable grade control elements or could be constructed.
- Identify a "reference reach" from the longitudinal profile survey data. The reference reach should be located outside of the bounds (tie-in points) of the reconstructed reach. Design criteria derived from the reference reach will be used to design the reconstructed reach to be restored upstream, through, and downstream of the roadway crossing. The slope of the reference reach must be +/-25% of the reconstructed reach slope. Including additional bedform sequences in the reference reach will better represent typical stream conditions and provide more reliable design criteria.
- Determine the following stream design criteria from the "reference reach" portion of the Site Assessment (longitudinal profile and cross section surveys):
    - Minimum, maximum, and typical (average) spacing of grade control features
    - Typical longitudinal length of grade control features (riffle length, for example)
    - Maximum and typical pool depths
- From the cross section survey data, identify average bankfull maximum depth at a grade control feature.

12.1.4 Stream Channel ('Reconstructed Reach') Design

The "reconstructed reach" of the stream is the section of the stream between the tie-in points with the natural channel upstream and downstream, including the section through the new structure. The overall goal is for the reconstructed reach to achieve continuity with the adjoining upstream and downstream channel segments in terms of stream slope, grade control type and spacing, and streambed material through the new crossing (see Figure 12.3).

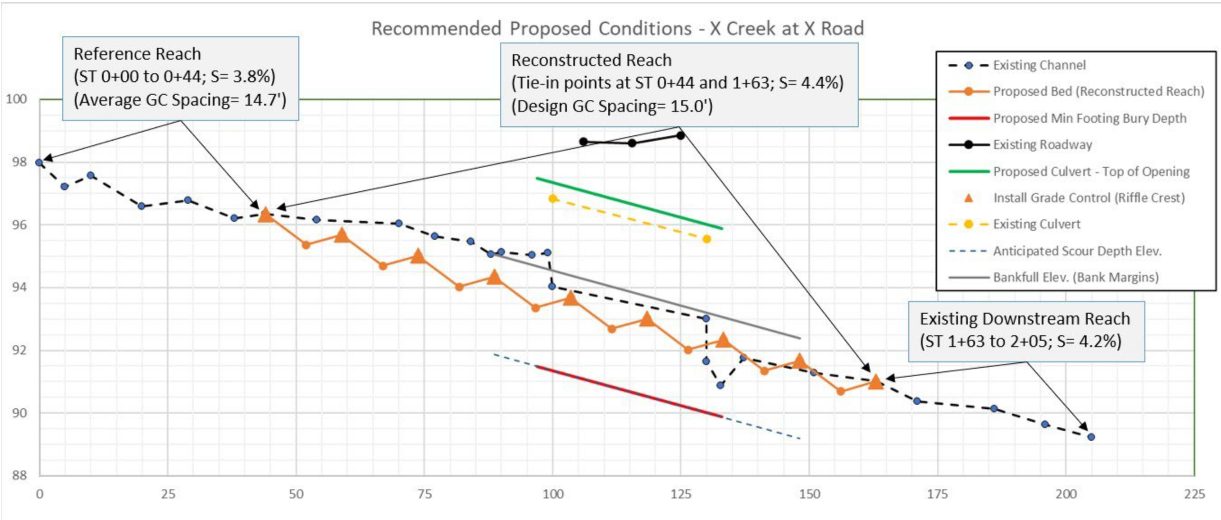


Figure 12.3 Longitudinal Profile with Proposed Reconstructed Reach
Grade control type, length, and spacing from the reference reach inform design of grade control placement through the reconstructed reach. Slope continuity and channel reconnection is achieved when the reconstructed reach extends far enough to establish relatively consistent channel slopes upstream, through, and downstream of the replacement crossing. The orange line shown reflects the thalweg elevation of the proposed reconstructed reach.

12.1.5 Slope Design in the Reconstructed Reach

The slope of the reconstructed reach must be +/- 25% of the reference reach slope. Slope of the reconstructed reach should achieve continuity between slopes of the natural channel segments upstream and downstream of the project area. Abrupt changes in channel slope produce significant impacts to streambed and bank stability, triggering increases in erosion and sedimentation. A sudden decrease in stream slope is likely to result in material being deposited as water velocity decreases, while a sudden increase in stream slope is likely to result in excessive erosion and scour as water velocity increases.

12.1.6 Grade Control Design in the Reconstructed Reach

> **Grade Control**: Natural or human-made structures that control channel elevation and channel slope such as riffles, steps, rock clusters or large wood features.

The type, length, and spacing of grade control features in the reconstructed reach are determined from design criteria derived from the reference reach. They must be constructed of suitably sized rock to ensure long-term immobility and keyed into adjacent streambanks/**bank margins**. Sufficient burial depth and/or placement of footing rocks must be considered to prevent the likelihood of undermining and failure. Stable grade controls are essential to minimizing scour potential, both within the replacement structure and through the adjoining project reach. Failure of one or more grade control features through the reconstructed reach can trigger vertical adjustment of the adjoining streambed, particularly upstream (i.e., **headcutting**). This can greatly enhance scour potential and scour depth. This can create vertical obstructions to AOP at the upstream limit of the headcut. Grade control spacing is typically a function of channel slope; as stream slope increases, the spacing between grade control features typically decreases.

- Design a channel profile through the reconstructed reach that mimics that of the reference reach to the greatest extent possible. Specify the installation of grade control features of the typical reference reach type, length, and spacing through the full length of the reconstructed reach. Typical spacing from the reference reach may need to be adjusted slightly to fit the length of the reconstructed reach and ensure that the start and end points fall at the locations of existing grade control crests. Unless representative of the reference reach conditions, avoid using grade control types that may induce excessive bed scour (namely drop structures) inside the structure, since this can increase the risk of **substrate** loss through the crossing. Drop-type structures will likely be limited to bottomless structures on projects with relatively steeper reference / reconstructed reach slopes.

- To meet the DGLVR Program Stream Crossing Standard, instream grade control features, bank margins, and key pieces of the substrate must be designed to be stable at the 100-year discharge. In design, the engineer must use an appropriate method for calculating a stable rock size for construction of grade control features, bank margins, and key pieces through the reconstructed reach, including within the replacement structure. A variety of methods are available to calculate stable rock size in stream channels. The engineer should evaluate which method is most applicable to the specific project elements and conditions being designed for.
- Construction details for grade control sizing are required as part of the DGLVR Stream Crossing Standard. Stable rock size should be specified as a “minimum diameter” (such as “24 inches”) instead of a gradation class (such as “R-6", for example). The engineer may specify a gradation class of rock to be used to simplify estimates, procurement, etc., but additional guidance should be provided in the Project Specifications instructing the contractor to select rocks of the specified minimum diameter from the gradation for use.
- If quarried rock is used for construction of instream features (grade controls, bank margins, key pieces), the material must be sourced from a Penn DOT-approved quarry, or otherwise tested per DGLVR Stream Crossing Standard requirements.
- In locations where exposed bedrock is the dominant grade control feature, design and placement of additional constructed grade control structures may not be necessary. The extent and locations of bedrock control will dictate the need for supplemental grade control features on a site-by-site basis.

See the Grade Control Technical Bulletin in Appendix H for additional information.

12.1.7 Channel Shape (Cross Section) in the Reconstructed Reach

In order to achieve continuity through the project reach, designed channel dimensions through the reconstructed reach and the new structure should be similar to the surveyed reference reach and cross sections in regard to the following:

- Parabolic shape to define a low-flow channel, including at and between grade control locations (Figure 12.4 and Figure 12.5).
- Define bank margins to establish and maintain bankfull channel width and depth through the crossing for the entire length of the structure. Bank margin height should be consistent with the constructed bankfull elevation through the structure. Bank margin height information can be derived from cross-section survey of a grade control crest in the reference reach.
- A minimum stable rock size should be specified for construction of the bank margins through the crossing.

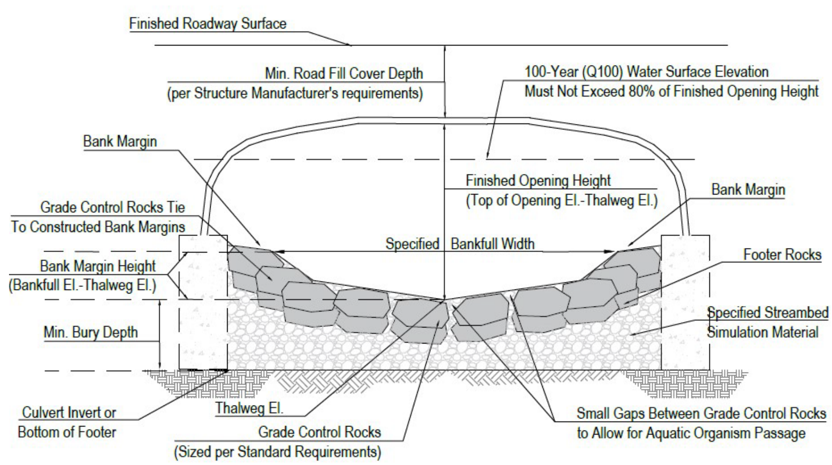


Figure 12.4 Typical Cross Section at a Grade Control

*A typical cross section **at a grade control** showing channel shape through a culvert. The bottom line represents invert or recommended top of footing depth. The dashed line shows the water surface elevation of the 100-year discharge.*

Additional Considerations for Channel Shape

- Additional streambank restoration may be necessary upstream and downstream of the crossing to establish and maintain the project **bankfull width** through the reconstructed reach, and/or transition between existing channel width and the width of the bankfull channel to be constructed through the structure.
- Placement of inlet / outlet protection (such as rip-rap) should not constrict or reduce the bankfull width of the channel.
- At a minimum, constructed grade controls and key pieces of the substrate, including constructed bank margins within the structure, shall be designed to be stable at the 100-year discharge.
- Bank margins within the structure should transition to existing upstream and downstream streambanks. If a structure must be placed on a meander bend in the stream, the thalweg of the channel will tend to be on the outside of the bend. Consider designing a channel through the structure with the thalweg on the outside bend (not in the middle of the structure), to accommodate this natural tendency. Design of bank margins in these cases should account for any additional scour potential along the outside of the bend to protect structure wall, footings, etc. Consider further expanding the structure width to accommodate the curvature of the stream and the need to construct and maintain defined bank margins.
- The width and depth of the existing outlet scour pool should be reclaimed to better reflect those of the reference reach. Restoring appropriate channel depth typically requires placement of fill to elevate the streambed. Restoring appropriate channel width can be accomplished through installation of wood structures such as root wads or mud sills to define the new bank margins. In some situations, placement of rock can be used to adjust the channel width as needed.

12.1.8 Substrate Design in the Reconstructed Reach (Streambed Reconstruction)

Specification of a suitable substrate mix through the reconstructed reach should consider the natural tendency of streams to move bedload as well as the need to maintain material in the structure over time. Streambed reconstruction should utilize a specified substrate mix that provides the functionality of a natural streambed, with a gradation that provides for both mobility of finer particles and persistence of larger pieces that are more resistant to higher flows. As per the DGLVR Stream Crossing Standard, the constructed grade controls, bank margins, and key pieces of the substrate in the structure shall be designed to be stable at the 100-year discharge. When specifying a substrate mix for the reconstructed reach, the engineer should consider and account for confinement of the channel through the structure and any corresponding increases in velocity and bed shear.

In most stream settings, a well-graded mixture of very fine, fine, and coarse bed material provides for both sediment transport and bed resiliency. Although substrate mix design will be site specific, the engineer might consider the following three-part mix as a framework for specifying a suitable substrate for the reconstructed reach:

1. **The large component of the substrate that is stable at higher flows.** Consider the size of the rock and corresponding void spaces between them. While larger rock is more stable, the larger voids between them are more difficult to fill with smaller material, which is necessary to provide adequate compaction and prevention of sub-surface streamflow.
2. **A smaller, well-graded aggregate to fill voids in larger pieces.** Consider an imported aggregate that fills voids in the larger pieces and approximates the range and variety of gravels and finer particles that comprise the natural streambed.
3. **Natural ("native") streambed material.** Consider the composition of the native material that will be excavated from the site during construction. This material can often be included in the mix to provide additional size variability and to incorporate sufficient fine materials to aid in compaction and subsurface flow prevention.

Methods for Specifying a Substrate Gradation

In most situations, the substrate size distribution in the reference reach provides the best site-specific indication of a suitable substrate mix for the prevailing stream setting and should serve as a starting point for specifying a design streambed material gradation. The reference reach provides a picture of substrate gradation that is relatively stable and functional in unconfined, open-channel conditions through the project site. Due to a variety of factors, however, including increased bed shear and scour potential within the confined conditions of the replacement crossing structure, bed material gradation derived from the reference reach should be adjusted to provide additional resistance and longevity through the reconstructed reach. The methods listed below provide a range of approaches that can be used to determine moveable substrate particle sizes, develop appropriate gradations for stream crossing replacements, and "upsize" gradations to provide enhanced stability through crossing structures.

Many predictive methods for specifying a substrate gradation rely on comparison with the streambed composition in the reference reach. The most common and reliable method for characterizing the streambed surface is by conducting a pebble count. Wohlman (1954), and Bunte and Abt (2001) provide guidance on conducting and recording a pebble count. Similar guidance is also available through a wide variety of other technical sources, including the USFS Stream Simulation document referenced below.

The DGLVR Program requires that the engineer specify a suitable streambed material composition. To meet DGLVR Program objectives, the substrate placed must provide a persistent streambed that supports the same surface flow regime as the reference reach. However, the DGLVR Program does not identify any particular method that must be used. Common accepted methodologies include:

1. **U.S. Forest Service Method:** The USFS provides a methodology (modified critical shear stress method) for determining streambed mobility and stability based upon particle distribution (pebble counts) from the reference reach. The substrate size distribution from the reference reach is used as a starting point and evaluated for stability. If needed, the reference gradation is adjusted until calculated stability is achieved.

   Appendix E of the USFS Stream Simulation document outlines the process for specifying a suitable substrate gradation using this method. More information is available at https://www.fs.fed.us/eng/pubs/pdf/StreamSimulation/

2. **Washington Department of Fish & Wildlife Methods:** WDFW provides three methods for determining a streambed substrate gradation. These include the reference reach method (similar to the USFS method above), the unit-discharge method, and the paleohydraulic analysis method. All three methods are described in the *2013 WDFW Water Crossing Design Guidelines*. This document also provides guidance for developing a bed material gradation from a single known particle size/gradation class (D_{100}, D_{50}, etc.).

   Chapter 3 of this WFDW document contains guidance regarding determination of a suitable substrate gradation. More information available at https://wdfw.wa.gov/sites/default/files/publications/01501/wdfw01501.pdf

   Overall, both documents listed above serve as good general resources for understanding many of the concepts described in this Technical Manual and the criteria required in the DGLVR Stream Crossing Standard. It is strongly recommended that practitioners review both documents to better understand the application of these concepts to stream crossing replacement projects funded through the DGLVR Program.

Material Placement Specification

Proper placement and compaction of the specified substrate mix is critical to project success. Streambed construction methods (especially through the replacement structure) will vary from project to project. Preparation of bid documents, pre-bid site showings for contractors, and project contracting should clearly identify the importance of placing and compacting the streambed through the reconstructed reach as being an essential aspect of the project.

See Chapter 8 and the Streambed Restoration Technical Bulletin in Appendix H for further guidance and information.

12.1.9 Structure Selection

The emphasis of the DGLVR Program is to restore channel continuity through the roadway. Primary consideration in structure selection should be dictated by the need to reestablish channel continuity upstream, through, and downstream of the roadway. Additionally, the engineer must evaluate opportunities to improve flood resiliency and compatibility with the roadway by considering existing site conditions and constraints that might include:

- Roadway profile and elevations
- Stream/road alignments (planform)
- Required structure width to accommodate channel continuity
- Constructability concerns
- Other adjoining or nearby infrastructure
- Minimum cover requirements over the replacement structure

Replacement structures must be sized to accommodate the following:

- Construction of a bankfull-width channel through the structure.
- Construction of bank margins along both edges of the bankfull-width channel. Bank margins must be comprised of rock sized for stability at the 100-year discharge (**Q100**).
- Conveyance of the 100-year discharge at an elevation not to exceed 80% of the **finished opening height** (measured from the thalweg elevation of the reconstructed streambed at the crest of a grade control structure to the top of the structure opening).
- Upon meeting the three criteria above, the resultant structure must not be less than 125% of the bankfull width. Structure opening width must be measured at the bankfull (bank margin) elevation. Bottomless structures are required for all structure replacements where the continuity slope of the channel through the project area will be greater than 4.0%, or the bankfull width is over 20’, as determined by the Site Assessment. For general information on different types of structures, consult the Structure Selection for Stream Crossings Technical Bulletin in Appendix H or structure manufacturers. It is strongly recommended that the replacement structure not be purchased until the conservation district review of the design package has been satisfactorily completed and a permit has been received. Purchase of a structure prior to receipt of the conservation district consistency letter and permit acknowledgement may lead to the purchase of an improper structure and potential non-payment with DGLVR funds.

In some situations, baffles can be used to enhance streambed retention within the replacement structure. When properly applied, baffles can increase the long-term persistence of the constructed streambed within the structure by bolstering the ability of constructed grade controls, key pieces, and larger components of the streambed material to withstand higher flood flows. Baffles can be especially beneficial in smaller structures where placement of grade controls, streambed, and streambanks is often more difficult. Baffles should always be intended to supplement, and not replace, the functions provided by constructed grade controls, key pieces, and other essential components of proper streambed reconstruction through the structure. Applied correctly, baffles serve to hold grade control and streambed material in the pipe and are not visible in the finished channel. When applied incorrectly, baffles can lead to problems such as increased streambed scour downstream and/or excessive accumulation of sediment upstream. These issues can significantly disrupt channel continuity and aquatic organism passage through the crossing and can contribute to further channel adjustments upstream and downstream of the culvert. The use and application of baffles should be considered on a project-by-project basis.

12.1.10 Structure Opening Width

Per the DGLVR Program Stream Crossing Standard, structures must be of adequate width to accommodate the following:

- Construction of a parabolic-shaped, bankfull-width channel within the structure that includes a defined low-flow channel (thalweg), measured at the bankfull (bank margin) elevation.
- Installation of robust bank margins comprised of rock sufficiently sized to be stable at the Q100.

Additionally, the replacement structure must have sufficient rise (must be "tall" enough) to allow for the minimum bury depth of the invert and ensure that the Q100 water surface elevation does not exceed 80% of the finished opening height. The fact that manufacturers provide structures in a range of standardized "height-x-width" sizes may also influence final structure width in order to ensure the rise height needed. Once these sizing criteria are met, the **effective structure width** must be no less than 1.25-times the bankfull width of the stream at the bankfull (bank margin) elevation. In design, the shape of the selected structure and required bury depth both influence the effective structure width. In most instances, effective structure width (at the bankfull elevation) will be narrower than the vendor's listed structure width, which is commonly measured at the widest point of the structure. Effective structure width and the various sizing criteria to be met must be considered whenever a conservation district discusses potential structure size requirements with the grant recipient or engineer for a given project. In most instances, structures greater in width than the minimum 125% bankfull width will be necessary in order to meet all sizing requirements. Figure 12.5 shows the difference between a structure's effective width at bankfull elevation and the width listed by the manufacturer.

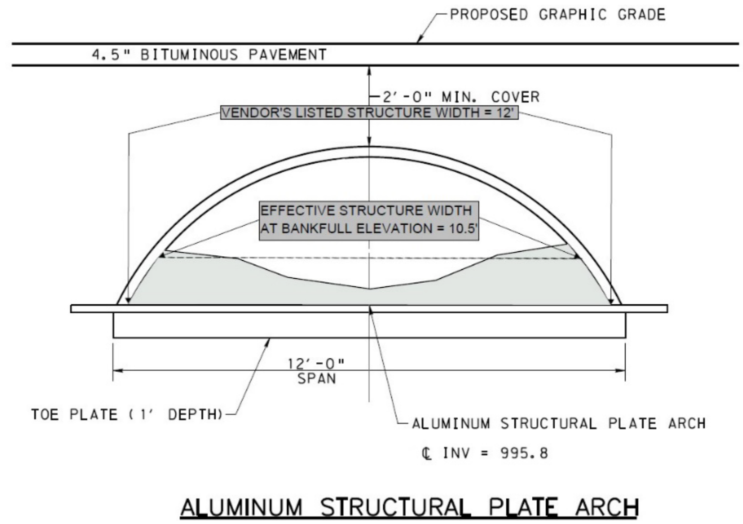


Figure 12.5 Effective Structure Width

This figure shows the difference between the manufacturer's listed structure width (12', measured at the plate invert) versus "effective" structure width (10.5', measured at the design bankfull channel / bank margin elevation). To meet DGLVR Program Policy, the effective structure width cannot be less than be 1.25 times the bankfull channel width.

Some consideration should also be given to constructability when determining a structure size. Wider structures allow for increased streambed stability by reducing flow depth and velocity at a given discharge. Wider structures with a corresponding "taller" rise may also make construction of grade controls, streambed, and bank margins easier by allowing the use of larger equipment.

The DGLVR Stream Crossing Standard also requires that "New stream crossing structures shall be designed to pass the 100-year discharge at a water surface elevation not to exceed 80% of the finished opening height" (see Figure 5.2 for a visual representation).

The conservation district and grant recipient are not expected to calculate the 100-year discharge or rock sizes stable at Q100 during the grant application phase. At this point in the grant application process, the estimated structure dimensions will be based largely off the bankfull channel width, estimated rock size for stable bank margins, minimum bury depth required, and existing streambed and roadway elevations. Once the 100-year discharge calculations are provided by the engineer, adjustments to structure size (width, height, or both) may be necessary. The engineer will typically specify a final structure size during project design.

12.1.11 Structure Alignment and Length

If the alignment of the existing culvert provides for relatively uninterrupted channel continuity in the plan view (aerial view) upstream, through, and downstream of the roadway, consider utilizing the existing alignment for the new structure.

Many older structures were placed perpendicular to the road to save on costs. In such instances, the engineer must evaluate opportunities to restore proper channel alignment by positioning the new structure accordingly (see Figure 12.6). In this case, consultation with the conservation district and PA **DEP** will be necessary to address regulatory concerns and permitting requirements prior to advancing with design.

Depending on the degree of skew at the roadway and increased width of the replacement structure, structure length may need to be increased to locate the inlet, outlet, and any headwall / wingwall features sufficiently off the roadway edges. Structure length should be limited to what is necessary to adequately restore planform continuity, support the roadway and embankment, provide for public safety, and accommodate reconstruction of the stream channel upstream, through, and downstream of the crossing (see Figure 12.6).

The SCC GP-11 Permit Memo (Appendix E) clarifies when stream realignment can be authorized under a DEP GP-11. Contact DEP to discuss any proposed realignments and permitting requirements.

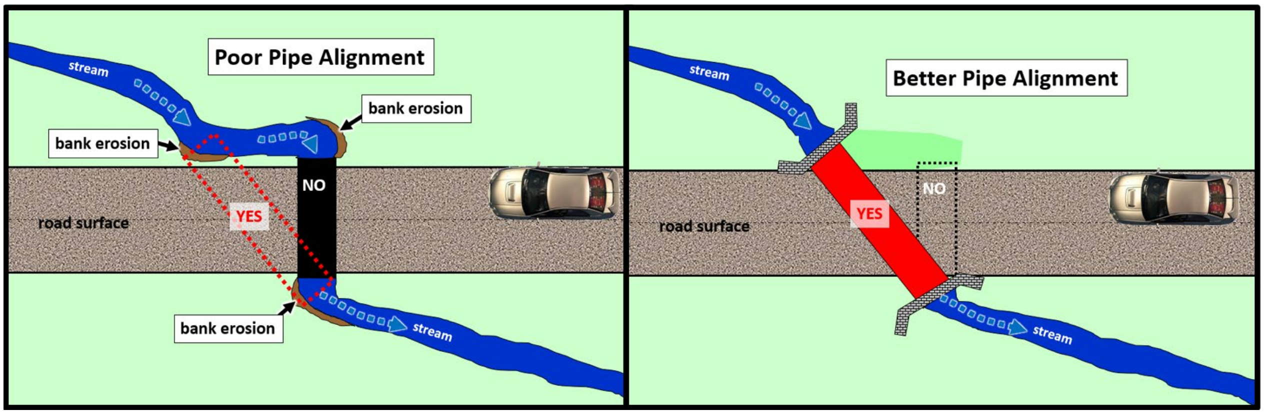


Figure 12.6 Structure Alignment

New crossings should be properly aligned with the stream channel if possible.

12.1.12 Structure Embedment (Bury Depth)

The potential for bed scour and pool formation varies from project to project and is influenced by a variety of site-specific factors. Per the DGLVR Stream Crossing Standard, bottomless structures shall be used for all structure replacements where the continuity slope of the channel will be greater than 4.0%, or the bankfull width is over 20', as determined by the Site Assessment.

The engineer may use the **Anticipated Scour Depth (ASD)** approach or another industry-accepted method to determine the minimum substrate (bury) depth for stream crossing structures. Regardless of the method used, the minimum substrate depth requirement of 24" will apply if ASD or scour analysis returns a lower value. All bury depths listed below are to be measured from the bottom of the **low flow channel** or thalweg at the grade controls, to the structure invert or bottom of footings.

The DGLVR Stream Crossing Standard states that:

A. *(IV. O. 1) "Minimum stream substrate depth (measured below the low flow channel at a grade control crest, to the structure invert or bottom of the footings)is to be based on the maximum pool depth in the reference reach with a minimum safety factor multiplier as listed in Table 1. Alternatively, minimum bury depth can be determined using industry accepted scour analysis and modeling tools for stream system analysis and/or bridges (storm sewer models are not acceptable for stream crossing scour analysis)."*

B. *(IV. O. 1) Structures installed on reconstructed reach stream slopes >4.0% must be bottomless. The 2.5 safety factor multiplier is to establish the recommended minimum top of footing buried depth. The final footing buried depth is to be determined by the engineer in project design.*

C. *(IV. O. 2) "Minimum substrate depth (measured below the low flow channel at a grade control crest, to the structure invert or bottom of the footings) shall be 24 inches, or the depth determined with scour analysis models or the Anticipated Scour Depth, whichever is greater."*

Anticipated Scour Depth (ASD)

Maximum Pool Depth

Using the longitudinal profile survey, calculate the maximum pool depth in the reference reach of the stream. Pool depth is measured from the bed elevation at the deepest part of a pool to the crest of the grade control feature immediately upstream.

Factor of Safety

Because structures confine stream flow, increasing velocity and shear stress compared to the natural channel, the DGLVR Program applies a factor of safety to maximum pool depth based on the slope of the stream to calculate the Anticipated Scour Depth. This factor of safety will allow for deeper pool formation than is seen in the reference reach without exposing the invert of the structure or bottom of the footings. Using the "continuity slope" of the reconstructed reach, select the corresponding minimum Pool Depth Multiplier from the table below (from the DGLVR Stream Crossing Standard Section IV. O.). The values in this table represent the minimum multipliers required by the DGLVR Program.

Stream Slope	Pool Depth Multiplier
0% - 2%	1.5
2.1% - 4.0%	2.0
> 4.0%*	2.5

*Structures installed on stream slopes >4.0% must be bottomless. The 2.5 safety factor multiplier is to establish the recommended minimum bottom of footing bury depth. The final footing bury depth is to be determined by the engineer in project design.

Calculating Anticipated Scour Depth (ASD)

Multiply the "Maximum Pool Depth" from the reference reach by the "Pool Depth Multiplier" determined in the table above. For example, a site with a continuity slope of 2.5% and a maximum pool depth in the reference reach of 1.2' would use the multiplier 2.0 (from the table above) for a minimum bury depth of 2.4' (measured below the low flow channel at a grade control crest, to the structure invert or bottom of the footings).

If the ASD method is used, the value returned (2.4' in the above example) is the minimum bury depth of the invert or bottom of footings of the new structure below the low-flow channel (thalweg) of the reconstructed channel. The ASD therefore also represents the minimum amount of streambed that must be established between the structure invert or bottom of footings and the bottom of the low flow channel during streambed reconstruction. Note that all bury depths are measured from the bottom of the low-flow channel (thalweg) at the crest of a grade control feature to the structure invert or bottom of the footings.

Industry-Accepted Scour Analysis

Scour analysis can be used to determine the bury depth of structures. Industry-accepted scour analysis and modeling tools for stream system analysis and/or bridges must be used. Models designed for storm sewer analysis are not acceptable for scour analysis in natural stream systems.

Bottomless Structures

The engineer may consider the Anticipated Scour Depth approach as a starting point for designing depth of footings or may utilize another applicable method. The engineer of record is ultimately responsible for final design of footing depths and placements.

12.1.13 Structure Height (Rise) and Roadway Elevation

Consider opportunities for further increasing conveyance capacity and flood resiliency by maximizing structure height (open rise) wherever possible. The DGLVR Stream Crossing Standard requires new stream crossing structures to be designed to pass the 100-year discharge at an elevation not exceeding 80% of the finished opening height (see Section 12.1.9). The engineer needs to consider minimum required bury depth of the invert, the effective width of the structure at the bankfull elevation, the elevation of the reconstructed streambed, minimum road fill cover requirement, and finished road surface elevation when determining structure height.

In situations where available cover height over the new structure is limited due to site constraints, it may be necessary and advisable to raise the elevation of the road over the stream crossing. Where necessary and possible, the engineer should consider raising the roadway elevation over the crossing to improve conveyance and meet the DGLVR Stream Crossing Standard. In many situations, raising of the roadway elevation can be authorized, so long as no increase in flood elevation occurs (typically the use of a larger structure can reduce existing flood elevations). The engineer should consult with PA DEP about raising the road elevation where necessary on DGLVR projects. An H&H analysis report, as required by the DGLVR Stream Crossing Standard, may prove beneficial in consulting with DEP regarding allowances for raising the roadway elevation. The SCC GP-11 Permit Memo (Appendix E) clarifies when road elevation raises can be authorized under a DEP GP-11. Contact DEP to discuss any proposed elevation changes and permitting requirements.

12.2 Construction Documents

The engineer must provide a set of construction plans for the project. All critical locations and elevations should be clearly noted on the drawings, not left to be scaled or interpreted. Include sufficient notations or narrative to ensure proper installation.

Because the DGLVR Stream Crossing Standard is more stringent and expansive than the minimum PA DEP permit requirements, design plans must not only satisfy regulatory criteria but must also include sufficient detail to ensure DGLVR Program Policy is met. The DGLVR Stream Crossing Design & Installation Standard provides a list of specific elements to be included in the plan drawings (See Appendix A).

12.2.1 Plan Drawings and Specifications

Construction plans and specifications shall be prepared for all stream crossing projects, regardless of who the contractor or installer may be (applies to projects installed by the grant recipient, such as a municipality). At a minimum, the plan and specifications must include the following per the DGLVR Stream Crossing Standard Section VI:

Note: *shaded italic text* is directly from DGLVR Stream Crossing Standard

VI. B. 1. *Existing conditions of the project site, including but not limited to the full longitudinal profile survey and cross sections of the stream, existing stream crossing, stream crossing and channel slope, road approaches, and delineated wetlands (if applicable).*

Construction plans should include clear and concise depiction of all existing conditions on plan, section, and profile drawings.

- Profile drawings should show the existing streambed profile along the thalweg, extending beyond the upstream and downstream project limits (tie-in points). Indicate existing channel slopes upstream and downstream of the existing culvert, beyond the areas impacted by the undersized structure.
- Plan view should clearly show the existing structure, structure alignment, dimensions, road approaches, cross section locations, and any wetlands.
- Section drawings should show the existing structure dimensions, elevation, and depth of road cover.
- Provide existing roadway elevation, and elevation and location of benchmarks.

***VI. B. 2.** Geographic location and bankfull width of stream.*

The plan view drawings should note and depict the bankfull width of the stream, bankfull elevation(s), and the location of cross-sectional measurements.

***VI. B. 3.** Proposed stream crossing structure width, length, and height with profile and typical cross sections.*

- Provide proposed structure dimensions and elevations, including inlet and outlet invert elevations and locations, on the plan, section, and profile views.
- Provide proposed alignment of replacement structure on the plan view.
- If applicable, provide footing dimensions, elevations, and depth of bury.
- Provide finished roadway elevation over structure on profile and section views.

VI. B. 4. Elevations and locations of abutments, footings, wingwalls and other associated appurtenances.

On the proposed conditions drawings, provide the locations and elevations of all structure features such as abutments, footings, wingwalls, and other associated **appurtenances**.

***VI. B. 5.** Details for stream bed reconstruction (e.g., channel width, proposed channel alignment, channel side slopes, stream bed slope, and location of tie-in points).*

The proposed-conditions plan view and profile drawings should adequately inform reconstruction of a stable stream channel that reestablishes and maintains longitudinal continuity upstream, through, and downstream of the replacement crossing.

- Clearly show on the profile drawing the design slope and depth of streambed material in the proposed reconstructed reach.
- Provide design of streambed and bank margin, including rock sizing and elevations at structure inlet and outlet and extending upstream and downstream of the crossing as needed to tie into existing streambed and banks.
- Show locations and elevations of tie-in points at upstream and downstream limits of the reconstructed reach. These should occur at existing grade control features.
- The proposed bankfull width of the reconstructed reach should be shown to scale, with design bankfull width noted.
- Identify method for stabilizing transition areas at upper and lower project limits.
- Type, locations, lengths, and elevations of grade control features. Stationing and elevations for grade control crests (at the thalweg) should be noted on the plan drawings.

***VI. B. 6.** Location and details for low flow channel width, depth, and material size and types.*

On the proposed section view, provide low flow channel dimensions from the cross-sectional surveys. This should include the width and depth of the channel and information on the stream bed materials used in constructing the low flow channel.

***VI. B. 7.** Locations and construction details, including rock sizing, in-stream structures, grade controls, and/or bank stabilization structures (if applicable).*

- Provide plan, section, and profile drawings where applicable for all grade control features and instream structures, including locations and elevations of grade control features (at crest / thalweg) through the reconstructed reach.

- Provide indication of whether grade control features at the tie-in points will be maintained as existing (stable) or will be reconstructed. For constructed grade control features, indicate the design feature length.
- Detail drawings for grade control structures should clearly indicate material type, minimum (stable) material size, installation slopes, and overall structure length.

VI. B. 8. *Depth, gradation, and composition of material for streambed restoration. Refer to the DGLVR* Stream Crossing Replacement Technical Manual *for more guidance on determining substrate gradation and composition.*

- On the proposed section and profile view, provide the streambed material thickness and inlet and outlet bed elevations.
- Note material gradation and composition. Note any existing onsite rock materials to be repurposed.
- Include gradation, composition, and guidance for proper placement and compaction of materials used to construct the low flow channel, bankfull channel, and the bank margins.
- See Section 12.1.8 for additional guidance on substrate design in the reconstructed reach.

VI. B. 9. *Specification for compaction of placed streambed material.*

- Provide details on compaction (mechanical or hydraulic) of materials used to construct the streambed through the reconstructed reach to prevent subsurface flow down through the substrate.
- Note that substrate is thoroughly compacted when water stays on top of the newly constructed stream bed and does not go subsurface.

VI. B. 10. *Details for scour hole restoration and reestablishing channel cross section.*

- If applicable, provide details to indicate material type, size, and depth to restore the scour hole to width, depth, and profile that is consistent with dimensions of proposed reconstructed reach.
- Reconstruction of the channel cross section through the scour hole should be shown to tie into the existing or reconstructed stream bed and banks.

VI. B. 11. *Structure manufacturer's details, specifications, and installation instructions.*

- Typically in the form of manufacturer's shop drawings and specifications for the replacement structure.
- Typically include but not limited to: applicable structural details of all components; reinforcing steel, type of materials, thickness, anchorage requirements, backfill lift thickness, etc.

VI. B. 12. *Thickness, compressive strength, reinforcement, testing, and other special requirements for concrete according to the manufacturer specifications, if applicable.*

- If applicable, provide concrete specifications and manufacturer's requirements.
- Include details for concrete sampling and testing as required by the manufacturer.

VI. B. 13. *Load limits for bridges and/or culverts, including signage and guide rail per state or local codes.*

Provide all details related to structure load limits, related signage, guide rail, etc. per municipal and PA code.

VI. B. 14. *Location of all utilities and notification requirements (PA One Call).*

Provide detailed locations of all utilities on the plan drawings and specify contractor notification requirements for PA One Call.

***VI. B. 15.** Location and elevation of survey benchmarks.*

- Provide the elevations and locations of benchmarks, including a written description of the location to assist others in finding the benchmark in the field at a later date.
- Note all locations and elevations on the design plans.

***VI. B. 16.** Method of surface water diversion and dewatering during construction.*

- Provide clear detail drawings for diversion of the stream flow and dewatering of the construction site.
- Provide details for control of sediment during diversion and dewatering.

***VI. B. 17.** Erosion and Sedimentation Control Plan, if applicable.*

- Include an E&S Plan with detail drawings for all BMPs to be used during construction.
- For additional details see Section 12.2.2 below and reference the *PA DEP Erosion and Sediment Pollution Control Program Manual* for guidance on preparation of the E&S Plan.

***VI. B. 18.** Vegetative requirements that include seed and plant materials to be used, establishment rates, and season of planting.*

Provide details on reseeding and establishment rate. Note if any specialized bank stabilization or soil amendments will be needed to ensure establishment.

***VI. B. 19.** Cross section view of the proposed structure that clearly notes proposed streambed thalweg elevation (at the crest of a constructed grade control feature), Q100 water surface elevation, and top of structure opening elevation.*

- Sample standard drawings for various structures are provided in Attachment C to the Stream Crossing Replacement Standard in Appendix A.

***VI. B. 20.** Additional site-specific requirements.*

- Because stream crossing replacements through the DGLVR Program include many aspects that differ from more basic culvert replacement projects, project specifications should be included with the bid package.
- If not provided as notations to the detail drawings, separate site-specific specification documents should be provided for unique construction elements. This allows prospective contractors a clear sense of the project goals and needs, establishing a clear understanding of construction requirements.

12.2.2 Erosion & Sediment Pollution Control (E&S) Plan

Construction documents will include preparation of an E&S Plan. Reference the *PA DEP Erosion and Sediment Pollution Control Manual* for guidance on preparation of the E&S Plan. Consider the following when developing an E&S Plan for a stream crossing replacement project:

- Streambed compaction (washing the streambed material): From the E&S perspective, this can create increased discharge of sediment downstream if not adequately addressed. To do so may require creative sequencing of work and placement of additional BMPs (pumps, filters, etc.) to reduce sedimentation to the adjoining waterway.
- Bank stabilization: Consider method and extent of placement for bank stabilization features, including instream structures that might be specified to reclaim appropriate channel width. Ensure

adequate BMPs are specified to reduce discharge of sediment to the stream during installation, including equipment access needed to do the work.

- Stockpiling of materials: Consider designating material staging and stockpile areas, especially for rock material to be used in reconstruction of the streambed through the project reach. This will likely include stockpiling of native fill / streambed material excavated from the site that will later be added into the substrate mix. Depending on the work schedule, additional BMPs may be needed to stabilize stockpiled materials.
- Use of equipment in stream: Consider a construction sequence, dewatering plan, and construction access routes that limit the need for equipment in the flowing stream channel. Plan the sequence, dewatering, and access to accommodate the use of equipment for installing grade controls and substrate within the replacement structure.

12.3 Design Submittal for Conservation District

The DGLVR Program requires that the engineer provide the conservation district with the plans and specifications for review before submitting for permit approval. The conservation district will review the package to determine whether the design, as presented, meets the DGLVR Program Policy and Stream Crossing Standard. If discrepancies exist within the design package that do not align with the DGLVR Program Policy and Stream Crossing Standard, these must be corrected. Upon completion of the review, the conservation district will notify the grant recipient in writing that this review has been satisfactorily completed. The engineer may not submit to regulatory agencies for permit approval(s) until the conservation district review is completed.

12.4 Permitting

Most commonly, stream crossing replacements funded through the DGLVR Program can be authorized through registration of a PA DEP Chapter 105 General Permit (GP) #7 or #11. The requirements of the DGLVR Program are generally more stringent than PA DEP permit requirements. As such, DGLVR Program requirements meet, and often exceed, the required conditions of the General Permits. In no instance should the issuance of a regulatory permit serve as assurance that DGLVR Program Policy and Stream Crossing Standard are adequately addressed in the project design. The conservation district review process outlined above is intended to provide that assurance. Once the conservation district reviews the plans and specifications and is satisfied that they meet DGLVR Policy and the Stream Crossing Standard, the conservation district will provide the engineer with a consistency letter (Appendix F). Per DGLVR Program Policy, the permit application shall not be submitted for permit review until this consistency letter is received.

When planning and designing a project, the project scope and extent should not be minimized for the sole purpose of fitting the thresholds allowable under a general permit. Project scope, extent, and design should be driven by what is necessary and essential to achieve project success and should not be limited by the type of permit(s) needed. **Some examples where additional permits (aside from GP #7 or 11) may be needed include:**

- Significant channel modifications may be necessary to reestablish proper stream/structure alignment, resulting in “retiring” and filling of a small section of the existing stream channel. This might occur where a stream is realigned from an existing perpendicular crossing to its historic diagonal alignment through the roadway.
- Permits required when work involves disturbance of jurisdictional wetlands.
- Channel modifications beyond the permit-allowed distance upstream and downstream of the crossing:
  - For the GP #11, PA DEP may consider channel modifications beyond the conditional threshold of 50’ upstream and downstream of the crossing inlet/outlet, so long as the modifications can be justified as essential to the performance and stability of the crossing.
  - For channel modifications beyond 50’ upstream and downstream of the inlet/outlet that are limited to grade control construction and do not involve substantial channel fill or excavation (beyond that incidental to installation of grade controls), PA DEP may consider the use of an additional GP-1 to authorize placement of these features.

See the SCC GP-11 Permit Memo (Appendix E) for additional clarification. Consult with DEP as needed on permitting questions, as well as with other entities involved in any required federal, state, or local permits that may be needed.

The attachments to the standard include drawings showing a range of "typical" installations for a variety of structure types. These drawings are avilable on the CDGRS website as CAD drawings for use and customization https://www.dirtandgravel.psu.edu/general-resources/stream-crossing-replacements.

12.5 Bid Documents

DGLVR stream crossing replacement projects emphasize reestablishing channel continuity through reconstruction of a stable stream channel through the new crossing and modification of adjoining upstream and downstream channel segments. This may require specific items to be added to bid documents that may not typically be associated with more traditional crossing replacement projects.

12.5.1 Project Narrative

Consider including a narrative or cover letter in the bid documents to highlight special considerations for the DGLVR Program that may not be seen in typical stream crossing replacements, such as:

- The degree of instream work required outside of the structure, which may extend a substantial distance upstream and downstream through the reconstructed reach.
- The need to place a large amount of rock and aggregate inside of the structure to construct a streambed, grade control features, and bank margins to specified dimensions. This often requires working within a confined space using manual labor or specialized low-profile equipment.
- The need for hydraulic washing of fine material to fill voids and establish a compacted streambed through the structure. This includes considerations for time and labor, water supply, pumping, and additional E&S controls.
- The completed streambed (including inside of the structure) should have:
  - a parabolic cross-sectional shape that defines a low-flow channel (thalweg),
  - defined bank margins that establish the specified bankfull channel width,
  - a finished slope consistent with the specified continuity slope, per the project design, and
  - grade control elements constructed of the specified minimum stable rock size.

12.5.2 Roles and Responsibilities

The bid documents should clearly define roles and responsibilities of all parties through the construction phase of the project. These parties might include the engineer, grant recipient (typically a municipality), conservation district, and contractor. In some instances, technical assistance and oversight may be provided by CDGRS during construction. Outlining roles and responsibilities in the bid documents becomes important in situations where the grant recipient will be contributing part of the construction labor, materials, and/or equipment.

12.5.3 Project Schedule

Bid documents should clearly define the project schedule and establish timetables and deadlines to be met in consideration of the following:

- Construction sequencing should be coordinated with the project engineer and conservation district to allow them to fulfill required oversight and inspection requirements as outlined in the DGLVR Stream Crossing Standard.
- Regulatory restrictions prohibit instream work on streams that support natural reproduction of trout (wild trout streams) between October 1 and December 31. This restriction includes tributaries to listed wild trout streams.
- Regulatory restrictions prohibit instream work on stocked trout streams between March 1 and June 15.
- Regulatory restrictions prohibit instream work on Class A Wild Trout Waters Oct 1 – April 1.

- Depending on stream and site conditions, it may be advisable to schedule construction during times of typical seasonal low-flow conditions.
- Avoid scheduling construction during times where freezing temperatures can complicate excavation and make accurate stream channel reconstruction very difficult.

12.5.4 Prevailing Wage

The DGLVR Program is subject to the Pennsylvania Prevailing Wage (PW) Act (1961, August 15, P. L. 987, No. 442), 43 P.S. Section 165-1 et seq.” Prevailing wage rates apply to DGLVR projects when the total estimated or actual project cost is $25,000 or more (not $100,000). Most stream crossing replacement projects funded by the DGLVR Program will exceed this threshold. The need to meet and document the prevailing wage requirement should be clearly outlined for prospective bidders in the bid documents. If federal funds are also involved in the project, the project may also be subject to the Davis-Bacon Act. Additional details on PA prevailing wage can be found in the DGLVR Administrative Manual, Section 3.7.4 or through the PA Department of Labor and Industry at: https://www.dli.pa.gov/Individuals/Labor-Management-Relations/llc/prevailing-wage/Pages/default.aspx

12.5.5 Providing the Structure

The bid documents should clearly outline who is responsible for structure delivery, assembly, and placement, including:

- Purchase of structure
- Delivery of structure: fully assembled, partially assembled, or unassembled
- Storage of structure (if applicable)
- Assembly of structure
- Placement of structure (large or fully assembled structures may require specialized equipment)
- Coordination with subcontractors and vendors

12.5.6 Bid Site Showing

Bid meetings (site showings) are highly recommended for DGLVR stream crossing replacements, but are left at the discretion of the grant recipient. Schedule the bid meeting in consideration of all parties vested in the project. Attendance by the grant applicant and engineer is strongly recommended. Participation and assistance from CDGRS can be of benefit in describing some of the more detailed aspects of construction. These meetings are essential to ensuring that prospective bidders clearly understand the scope of work and additional requirements to meet DGLVR Policy and the Stream Crossing Standard and can account for these in preparing a bid.

12.5.7 Bond Requirements

Bond requirements (if any) must be clearly defined for prospective bidders in the bid documents. Ensure that bond requirements meet the project owner’s procurement guidelines and requirements. These guidelines may require a bid bond, payment bond, and/or performance bond executed by an authorized surety company.

12.5.8 Fee Proposal

All bidding procedures must conform with the project owner’s procurement guidelines and requirements. Where allowable, consider structuring the fee proposal to request unit costs, not just lump sum bids.

12.6 Construction Inspection and Certification

The engineer (or their designee) is required to be present onsite during critical aspects of construction (detailed in Section 12.6.1). They must also verify that these critical aspects are completed according to the final construction documents and the DGLVR Stream Crossing Standard. Installations that deviate from the construction documents ("field changes") must be noted in the certification red-line plan set provided by the engineer at project closeout (see Section 12.6.2). The engineer is responsible for ensuring that any field changes made comply with DGLVR Program Policy and the Stream Crossing Standard in consultation with the conservation district.

12.6.1 Onsite Inspection

At a minimum, aspects of construction to be inspected by the engineer at critical stages are identified in the DGLVR Stream Crossing Standard and described below (See DGLVR Stream Crossing Design & Installation Standard, Section VII.D. in Appendix A). Inform the conservation district of any changes made to the plan during implementation to ensure that DGLVR Policy and the Stream Crossing Standard are still being met.

Note: *shaded italic text* is directly from DGLVR Stream Crossing Standard

VII. D. *Critical Stages of Construction to be inspected by the engineer (and/or engineer's designee) at the time of installation is required. Critical Stages include, but are not limited to, the following:*

1. *Installation of structure subgrade and bedding materials and establishing inverts/elevations.*
Recommendations: Check that the excavated subgrade is suitable for placement of the specified bedding materials and ensure that the finished surface of the bedding is adequate to allow for design elevations and slope of invert or footings to be met per construction documents.

2. *Installation of footings, abutments or in-ground appurtenances.*
Recommendations: Check that final design elevations are met once these features are installed. For structures that include toe plates at the inlet and/or outlet, ensure that trenches are deep enough to allow for proper installation and that backfill is properly placed and compacted per the construction documents and manufacturer's specifications.

3. *Installation of grade control features, bank margins, and streambed substrate.*
Recommendations: Confirm that grade control features are constructed of the stable minimum rock size and that thalweg elevations, locations, slopes, and lengths specified in the construction documents and detail drawings are met. For the reconstructed reach, ensure that the specified substrate mix is used and that substrate depth and compaction methods follow the construction documents.

4. *Installation or placement of stream crossing structure.*
Recommendations: Ensure that the structure is set in accordance with the construction documents, shop drawings, manufacturer's specifications, and other governing standards that may apply, and that final design elevations and slopes are achieved.

5. *Compaction and backfill of stream crossing structure.*
Recommendations: Ensure that the structure is backfilled in accordance with the construction documents, shop drawings, manufacturer's specifications, and other governing standards that may apply.

12.6.2 Certification

Per the DGLVR Stream Crossing Standard, the engineer must provide to the project owner a signed and sealed certification form ("Inspection and Documentation of Critical Stages of Construction Certification Form") and a red-line set of construction drawings (See Appendix A).

The certification indicates that the critical stages of construction were inspected and installed in accordance with the construction documents and DGLVR Stream Crossing Standard. See Section 12.6.1 above and Section VII. D. of the DGLVR Stream Crossing Standard for details on the inspection requirements.

Red-lined construction documents indicate any changes in the as-built conditions of the project compared to the design plans. Field changes must be clearly noted as such, including revised elevations, etc. that deviate from the construction documents. The red-line plan set submitted with the final engineering certification serves as the engineer's documentation of the finished project conditions. For field changes that result in notable deviation from the construction documents, a brief written description of cause, justification, and changes made should be provided. Certain changes may warrant a pause in construction until those changes can be verified as being consistent with DGLVR Program Stream Crossing Standard and Policy.

REFERENCES

Bunte, K., S. R. Abt. 2001. *Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring*. Gen. Tech. Rep. RMRS-GTR-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 428 p.p.

Furniss, M. J., T. S. Ledwith, M. A. Love, B. McFadin, and S. A. Flanagan. *Response of road–stream crossings to large flood events in Washington, Oregon, and Northern California.* USDA Forest Service, Technology and Development Program. 9877-1806- SDTDC. San Dimas Technology & Development Center, San Dimas, California. 1998.

Gillespie, N., A. Unthank, L. Campbell, R. Gubernick, D. Cenderelli, M. Weinhold, P. Anderson, D. McKinley, S. Roy, B. Austin, S. Wells, J. Rowan, C. Orvis, R. Kirn, M. Hudy, A. Bowden, J. Levine, A. Singler, and E. Fretz. 2014. Flood Effects on Road-Stream Crossing Infrastructure: Economic and Ecological Benefits of Stream Simulation Designs. *Fisheries,* 39(2): 63-76.

Hayhoe, K., D.J. Wuebbles, D.R. Easterling, D.W. Fahey, S. Doherty, J. Kossin, W. Sweet, R. Vose, and M. Wehner. 2018: Our Changing Climate. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 72–144. doi: 10.7930/NCA4.2018.CH2

NCHRP 25-25 Task 93: *Long Term Construction and Maintenance Cost Comparison for Road Stream Crossings: Traditional Hydraulic Design vs. Aquatic Organism Passage Design*. March 2017.

Levine, J. 2013. *An Economic Analysis of Improved Road-Stream Crossings*. The Nature Conservancy, Adirondack Chapter, Keene Valley, NY.

Pennsylvania State Conservation Commission. 2022. *Dirt, Gravel, and Low Volume Road Maintenance Program Administrative Manual*. July 2022.

Pennsylvania Department of Environmental Protection. 2012. *Erosion and Sediment Pollution Control Program Manual*. Technical Guidance Number 363-2134-008.

Singler, A., B. Graber, and C. Banks. 2012. *Massachusetts Stream Crossings Handbook*. Division of Ecological Restoration, Massachusetts Department of Fish and Game.

Table 3.1: Minimum Structure Size and Minimum Embedment (Depth of Material) from Various Entities in Other Regions of the United States. Data Summarized from USFWS. Information compiled by the U.S. Fish and Wildlife Service, Chesapeake Bay Field Office (Leah Franzluebbers) and the Maryland Fish and Wildlife Conservation Office (Julie Devers) in March 2019, updated in September 2020.

U.S. Fish and Wildlife Service, Chesapeake Bay Field Office (Leah Franzluebbers) and the Maryland Fish and Wildlife Conservation Office (Julie Devers). Road Stream Crossing State Comparison. March 2019.

U.S. Forest Service Stream Simulation Working Group. 2008. *Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road–Stream Crossings*. Publication 0877-1801. San Dimas Technology and Development Center, U.S. Department of Agriculture, Forest Service.

Vermont Department of Fish and Wildlife (VT DFW). 2009. *Guidelines for the Design of*

Stream/Road Crossings for Passage of Aquatic Organisms in Vermont.

Washington Department of Fish and Wildlife (WDFW). 2013. *Water Crossing Design Guidelines*.

Wolman, M.G. 1954. A Method of Sampling Coarse River-Bed Material. *Transactions—American Geophysical Union*, 35: 951-956.

APPENDICES

Appendix A. DGLVR Stream Crossing Design and Installation Standard
Appendix B. Definitions and Acronyms
Appendix C. Stream Crossing Eligibility Determination Form
Appendix D. Stream Continuity Sketches
Appendix E. SCC GP-11 Permit Memo
Appendix F. Editable Forms and Templates
Appendix G. Checklists
Appendix H. Technical Bulletins

Appendix A. DGLVR Stream Crossing Design and Installation Standard

All stream crossing replacements funded in whole or in part with DGLVR funds, or listed as in-kind on a DGLVR project, must follow the DGLVR Stream Crossing Standard, unless an exemption from the DGLVR Stream Crossing Standard (see Section 3.3) is applicable. This appendix includes the DGLVR Stream Crossing Design and Installation Standard with attachments.

PA STATE CONSERVATION COMMISSION
DIRT, GRAVEL AND LOW VOLUME ROAD PROGRAM

STREAM CROSSING DESIGN & INSTALLATION STANDARD

I. DEFINITIONS

Aggradation: Deposition of sediment and corresponding increase in streambed elevation, often due to inability of the stream to adequately convey its sediment load during flood.

Anticipated Scour Depth: Depth of expected scour used to determine structure bury depth based on observed maximum reference reach pool depth and a factor of safety.

Aquatic Organism Passage: Unimpeded movement of aquatic organisms through the road/stream crossing.

Bankfull Elevation: In non-confined channels, the elevation point at which the stream typically accesses the floodplain. Channel dimensions at the bankfull elevation convey the channel-forming or dominant discharge.

Bankfull Width: A site-specific, field-derived measurement of channel width at the bankfull elevation.

Bank Margins: Large rock placed along the outside edges of the reconstructed bankfull channel within the stream crossing structure. Placement of the bank margins define bankfull channel width and bank margin (bankfull) elevation/height through the structure.

Bedform: Typical sequence of streambed features through the project reference reach (riffles/pools, step/pool, etc.).

Channel Continuity: Relative consistency and connectivity of a stream channel upstream, through, and downstream of a road/stream crossing, in regard to physical characteristics of the channel such as slope, planform, dimensions, profile, and bedforms.

Continuity Slope: Slope of the reconstructed section of streambed necessary to re-establish a relatively continuous slope, profile, and bedforms (channel continuity) along the entire length of stream extending upstream, through, and downstream of the new crossing.

Crossing: Refers to the location of a road/stream crossing structure.

Cross-Section Survey: A survey conducted across the channel (perpendicular to the thalweg) to produce a graphical representation of channel dimensions including shape, depth, and width.

Degradation: Accelerated erosion and transport of sediment from the streambed and banks, and corresponding lowering of the streambed elevation. Often associated with increased scour potential due to channel constriction or abrupt increase in channel slope.

Finished Opening Area: The unobstructed area within the structure after accommodating for stream bed material, low flow channel, and bank margins.

Finished Opening Height: Vertical distance measured from the thalweg elevation at the crest of a constructed grade control feature inside the replacement structure, upward to the top of the culvert opening or bottom of bridge beam.

Flood Resiliency: Reducing the risk of flood damages to people and infrastructure by planning and implementing measures that improve floodwater conveyance and provide for long-term stability of a self-maintaining stream corridor.

Grade Control: Natural or manmade structures that control channel elevation, dictate channel slope, and maintain bedforms. Common types include riffles, cascades, steps, rock clusters, and large wood features.

Intermittent Watercourse: A stream or waterway with surface flow during various times of the year when groundwater inputs are sufficient to provide streamflow. At other times of the year, when there is insufficient groundwater input, the stream channel may be dry.

Invert: Interior bottom elevation of stream crossing structure.

Key Pieces: Largest rocks in the reconstructed streambed substrate. Often these can be clustered to provide areas of minor, frequent grade control along the length of the channel bed in-between more robust constructed grade control features.

Longitudinal Profile Survey: Survey of the stream channel, typically measured from upstream to downstream along the channel thalweg, to capture prominent features such as channel elevations, depths, and slopes at bedform features such as riffles, pools, runs, glides, and step/pools.

Low Flow Channel: Portion of the channel commonly wetted during stream base flow.

Outlet Scour Pool: An overly widened and deepened pool bedform feature often (but not always) located immediately downstream of an undersized crossing.

Perennial Watercourse: A stream or waterway with surface flow throughout the entire calendar year.

Q100: The 100-year recurrence interval of stream flow. In any given year, there is a 1% probability that a flow of that magnitude or greater would occur.

Reconstructed Reach: Section of stream to be constructed upstream, through, and downstream of the new structure to re-establish channel continuity between the tie-in points.

Reference Reach: Section of stream channel that best reflects the "typical" natural, minimally impacted physical characteristics (profile, dimension, planform, and dominant bedform) of the channel. For stream crossing projects, the reference reach is located beyond the extent that the channel impacts are associated with the existing structure. Site Assessment (survey) of the reference reach is used as a blueprint for design of the reconstructed reach.

Site Assessment: Survey of longitudinal profile and cross-sections through, and adjoining to, the project site used to inform project design.

Structure: A road/stream crossing structure, such as a culvert or bridge, constructed across a stream to provide controlled access for vehicles.

Substrate: Mixture of rock that composes the streambed.

Thalweg: The line of lowest elevation along the flowpath of a stream channel. Dimensionally, this is reflected as the lowest point of elevation in the channel cross-section.

Tie-in Points: Locations of existing or constructed grade control features where the upstream and downstream limits of the reconstructed reach transition to the existing stream channel. Tie-in points define the limits of the reconstructed reach necessary to achieve channel continuity upstream, through, and downstream of the crossing.

II. PURPOSE

This standard is applied for the purposes of:

A. Providing greater flood resiliency at road stream crossings and reducing maintenance of undersized crossings.
B. Improving water quality by reducing sediment and erosion occurring at the road and stream interface.
C. Reducing streambed and streambank degradation.
D. Constructing and maintaining stream channel continuity through the road profile.
E. Accommodating aquatic organism passage upstream, downstream, and through the road crossing.
F. Repairing and stabilizing stream channels damaged by undersized stream crossings.

III. CONDITIONS WHERE PRACTICE APPLIES

This practice applies to stream crossing structure replacements and installations on state or local publicly owned roads where:

A. DGLVR funding is used, in whole or in part, to fund a stream crossing replacement.

B. An intermittent or perennial watercourse exists.

C. A defined bed and bank convey water to a roadway.

IV. GENERAL CRITERIA APPLICABLE TO ALL STREAM CROSSING INSTALLATIONS

A. Refer to the Dirt, Gravel, and Low Volume Roads (DGLVR) Program *Stream Crossing Replacement Technical Manual* for additional design and construction guidance and details regarding implementation of the standards and requirements listed below.

B. All stream crossing projects shall be authorized in accordance with local, state, and federal laws. All applicable permits must be obtained prior to construction.

C. All stream crossing structures shall be comprised of one single-opening structure installed at each crossing. Projects shall not utilize multi-opening structures or the placement of multiple single-opening structures at any one crossing location. Additional floodplain conveyance structures may be installed a minimum of one bankfull-width distance outside of the bankfull channel.

D. New stream crossing structures shall be designed to pass, at a minimum, the 100-year discharge (Q100) at a water surface elevation not to exceed 80% of the finished opening height.

   A Hydrologic and Hydraulic (H&H) Study is required that includes:

   1. finished thalweg elevations, and
   2. clearly labeled discharge values and water surface elevations at the proposed crossing inlet for Q2, Q10, Q25, Q50, and Q100.

E. Grade controls, bank margins, and key pieces shall, at a minimum, be designed to be stable at Q100.

F. Structures must be of adequate width to accommodate the bankfull width of the stream at the final bankfull elevation with stable bank margins. Once these design criteria are met, the structure width shall not be less than 1.25x the bankfull width of the stream at the bankfull elevation.

G. In project design and construction, bankfull channel dimensions must be based upon project site-specific field measurements. Channel dimensions derived from other methods, such as modeling of estimated bankfull discharge, shall not be utilized.

H. New structures must be properly aligned with the channel, unless not feasible due to permitting restrictions or other constructability restraints. See Attachment A and the SCC GP-11 Permit Memo (Appendix E of the *DGLVR Stream Crossing Replacement Technical Manual*) for additional clarification of permitting, including minor channel realignments that might be authorized with a GP-11 for stream crossings designed to this Standard.

I. Consider floodplain connectivity when necessary (e.g., high water by-pass, overflow pipes, etc.). Floodplain or overflow pipes must be placed a minimum of one bankfull-width distance outside of the bankfull channel.

J. Structures must be designed and constructed to accommodate the passage of aquatic organisms through the structure.

K. Round pipes over 36” in diameter may not be utilized for stream crossings.

L. Low flow channels with well-defined bank margins must be built through the structure.

M. Site Assessment:

1. A longitudinal profile survey is required for each site prior to project design and/or permitting. The surveyed stream segments must extend far enough to capture existing channel slopes upstream and downstream of the crossing and must include an appropriate reference reach to support project design. To determine applicability, the reference reach slope must be +/- 25% of the proposed continuity slope of the reconstructed streambed, unless otherwise approved by the SCC. If an appropriate reference reach is not located near the crossing, a separate survey may be conducted on an appropriate reference reach further upstream or downstream of the crossing. The reference reach must begin and end at existing grade control features and must, at minimum, include two consecutive sequences of repeating bed features (eg., riffle/pool/riffle/pool/riffle). A longer reference reach, including additional bedform sequences, is encouraged in order to provide more reliable design criteria.
   i. The longitudinal profile survey must extend both upstream and downstream of the crossing and include data points associated with the existing structure and roadway surface.
   ii. A sufficient number and locations of data points must be collected to determine the stream channel features that are critical to a successful structure replacement. These include:
      1. channel and structure slope,
      2. grade control types, lengths, and spacing,
      3. pool scour depth,
      4. potential tie-in points,
      5. aggradation wedges,
      6. plunge pools,
      7. vertical offset of the streambed adjacent to the structure, and
      8. available roadway cover.
   iii. The longitudinal profile survey must extend a minimum of 150' upstream and 150' downstream of the existing crossing. Additional length of survey may be necessary to capture a suitable reference reach to support the project design. Actual length of the longitudinal profile survey is dependent upon the site conditions, availability of a suitable reference reach, channel size, and distance necessary to accurately capture existing channel slopes both upstream and downstream of the crossing. The longitudinal profile survey must extend from an existing grade control upstream of the crossing feature to an existing grade control feature downstream of the crossing.
2. Cross-section surveys are required at a minimum of two locations. At minimum, surveys must be completed at a grade control crest within the reference reach and at the deepest point in the outlet scour pool (if present). If no outlet scour pool exists, this survey should capture the maximum depth of a pool feature from the reference reach. At minimum, each surveyed cross section must include data points on both streambanks capturing top-of-bank, bankfull, and right/left edge of water. Instream data points must include a minimum of three streambed points, including the thalweg (low-flow channel).
3. Refer to the *DGLVR Stream Crossing Replacement Technical Manual* for more guidance on Site Assessment requirements.

N. The engineer is responsible for the Site Assessment data they use. If conservation districts provide Site Assessment data, the engineer has discretion to use the provided data or conduct their own surveys. If a Site Assessment is completed by the design engineer to support their project design, the conservation district technician is required to be on-site while the surveys are being performed by the engineer and/or surveyor. The engineer shall provide the completed survey and Site Assessment data to the conservation district technician. The Site Assessment data provided to the conservation district shall include stationing, elevations, and notations of key stream features as outlined in (M.) above.

O. The Site Assessment data (from longitudinal profile and cross section surveys) described above shall be used to inform project design considerations, including the following:

1. Minimum stream substrate depth (measured below the low flow channel at a grade control crest, to the structure invert or bottom of the footings) is to be based on the maximum pool depth in the reference reach with a minimum safety factor multiplier as listed in Table 1. Alternatively, minimum bury depth can be determined using industry-accepted scour analysis and modeling tools for stream system analysis and/or bridges (storm sewer models are not acceptable for stream crossing scour analysis).

Table 1: Pool Depth Safety Factor Multiplier to Establish Anticipated Scour Depth

Continuity Slope	Pool Depth Multiplier
0% - 2.0%	1.5
2.1% - 4.0%	2.0
> 4.0%*	2.5

* Structures installed on reconstructed reach stream slopes >4.0% must be bottomless. The 2.5 safety factor multiplier is to establish the recommended minimum bottom of footing buried depth. The final footing buried depth is to be determined by the Engineer in the project design.

2. Minimum substrate depth (measured below the low flow channel at a grade control crest, to the structure invert or bottom of the footings) shall be 24 inches, or the depth determined with scour analysis models or the Anticipated Scour Depth, whichever is greater.
3. The design shall identify stable tie-in points at grade control features (either existing or to be constructed). The distance between the upstream and downstream tie-in points must extend far enough in both directions to restore channel continuity upstream, through, and downstream of the structure.
4. In-stream channel grade control(s) are required for re-constructing the stream channel and/or stabilizing the stream bed and channel through the reconstructed stream reach. Types of grade control features utilized must be the same type as those within the appropriate reference reach. Design of grade control feature length and spacing shall be based upon the Site Assessment data.
5. Design of the cross-sectional shape of the reconstructed reach must be based on Site Assessment data.

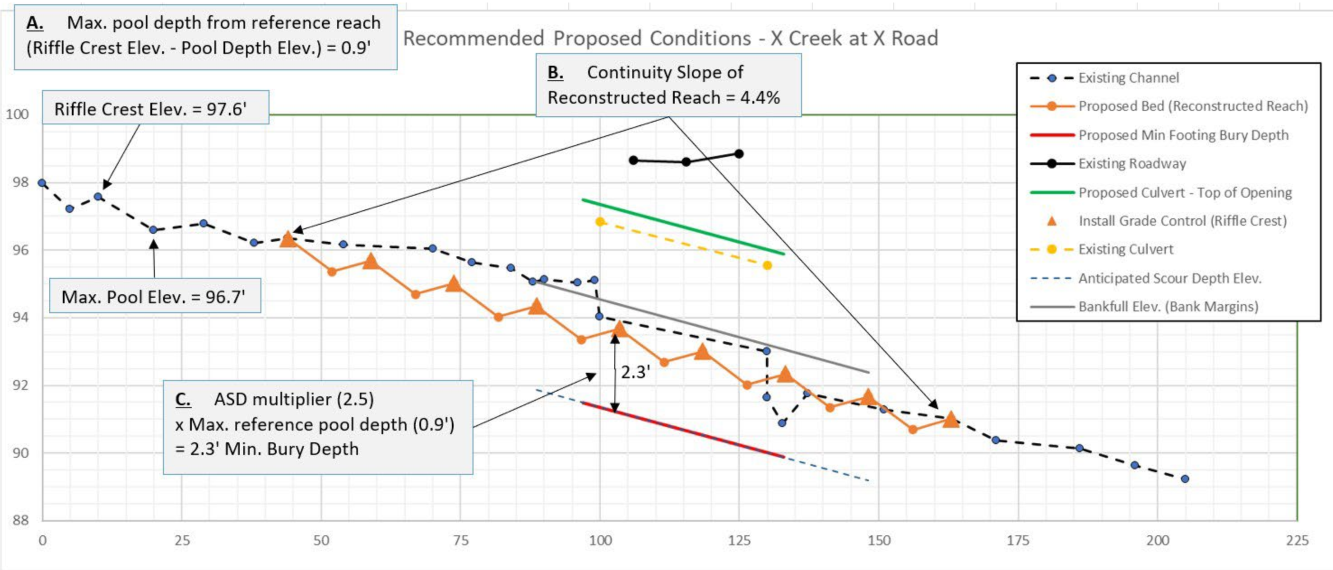


Figure 1. Determining Minimum Bury Depth through the Anticipated Scour Depth / Pool Depth Multiplier Method. **A.** Maximum reference reach pool depth is defined as the greatest vertical difference between each pool bottom elevation and the elevation of the corresponding grade control crest immediately upstream (in this example, 0.9’). **B.** The slope of the stream segment to be reconstructed in order to reestablish channel continuity upstream, through, and downstream of the replacement crossing (“continuity slope”) determines the multiplier value to be applied. In this example, a continuity slope of 4.4% corresponds to a pool depth multiplier value of 2.5 (see Table 1, above). **C.** Minimum bury depth is the product of the maximum reference pool depth x pool depth multiplier. In this example, 0.9’ x 2.5 = 2.3’ minimum bury depth. The minimum bury depth defines the minimum depth to which the bottom of footings (or structure invert) must be installed. This depth is measured downward from the thalweg elevation at the crest of a constructed grade control feature within the replacement structure.

P. Stream crossing projects will likely require work outside of the right-of-way to reconstruct the stream channel, install grade controls, and/or allow for construction access to the stream and structure. Before working outside the right-of-way, the grant recipient must obtain written permission from the landowner(s). In instances where written off right-of-way permission cannot be obtained to do work necessary to achieve channel continuity, the project cannot be completed with DGLVR funds.

Q. The grant recipient or engineer must provide all plans and specifications to the conservation district. The conservation district must review the documents and provide written confirmation to the grant recipient or engineer that those plans and specifications comply with DGLVR policy and the Stream Crossing Standard before they are submitted (or resubmitted) for permit review.

R. Side Slopes: Make all finished cut and fill road slopes stable for the materials involved. Make the side slopes in soil materials no steeper than 2 horizontal to 1 vertical (2:1) in cut slopes or 3 horizontal to 1 vertical (3:1) for fill slopes. Make rock cuts or fills no steeper than 2 horizontal to 1 vertical (2:1).

S. All stream crossing replacement structures must include a headwall and an endwall.

T. Quarried aggregate rip-rap for use as grade control, bank margins, or bank stabilization: Use only rock that is sound, durable, and able to withstand exposure to air, water, and freezing and thawing. Aggregate must be obtained from a Pennsylvania Department of Transportation approved source, or must be tested and meet the following criteria:

   1. Abrasion Resistance: The loss of mass (LA Abrasion) shall be less than 45%: Determine the resistance to abrasion using the Los Angeles Abrasion test, ASTM C131.
   2. Soundness: Determine the percentage of mass (weight) loss of each fraction of the coarse aggregate after five cycles of immersion and drying using a sodium sulfate solution according to PTM No. 510. The maximum weighted percent loss allowed is 20%.

U. Vegetation: Revegetate and permanently stabilize all disturbed areas as soon as practical after construction activities are complete. Revegetation and site stabilization shall comply with the PA Chapter 102 Erosion Control requirements (see the *PA Erosion and Sediment Pollution Control Program Manual* for additional guidance).

V. Road Approaches to Stream Crossings: Ensure that the roadway approaches are stable and road drainage systems have been addressed and are adequate to divert road drainage (e.g., ditches, turnouts, etc.) away from the stream and structure in a manner that prevents erosion.

W. Project work cannot start until all federal, state, and local permits are obtained, if needed. In particular, any required DEP 102/105 permits must be obtained before construction may begin. See the SCC GP-11 Permit Memo (Appendix E of the *DGLVR Stream Crossing Replacement Technical Manual*) for additional clarification.

V. STRUCTURE SELECTION

A. Bottomless structures shall be used for all structure replacements 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.

B. Structures with inverts/bottoms may be used for structure replacements where the continuity slope of the channel to be reconstructed will be 4.0% or less (as determined by the longitudinal survey) or on sites over 4.0% where it is determined by a geotechnical investigation report that soil bearing pressure cannot support structure abutments or footings.

VI. CONSTRUCTION PLANS AND SPECIFICATIONS

A. The grant recipient must provide all permit applications, Site Assessment data, design plans and specifications (per the *DGLVR Stream Crossing Design and Installation Standard*) to the conservation district for review. The conservation district must review the documents and provide written confirmation to the grant recipient that these submitted documents comply with DGLVR policy and the Stream Crossing Standard before they are submitted (or resubmitted) for permit review.

B. Construction plans and specifications shall be designed and prepared in accordance with this Stream Crossing Standard. Construction plans and specifications shall be prepared for all stream crossing projects, regardless of who the contractor or installer may be (applies to projects installed by the grant recipient, such as a municipality). Clearly describe the requirements for applying the practice to achieve its intended purpose in the plan and specifications. At a minimum, the plan and specifications must include the following:

1. Existing conditions of the project site, including but not limited to the full longitudinal profile survey and cross sections of the stream, existing stream crossing, stream crossing and channel slope, road approaches, and delineated wetlands (if applicable).
2. Geographic location and bankfull width of stream.
3. Proposed stream crossing structure width, length, and height with profile and typical cross sections.
4. Elevations and locations of abutments, footings, wingwalls, and other associated appurtenances.
5. Details for stream bed reconstruction (e.g., channel width, proposed channel alignment, channel side slopes, stream bed slope, and location of tie-in points). See Attachment A and the SCC GP-11 Permit Memo (Appendix E of the *DGLVR Stream Crossing Replacement Technical Manual*) for additional clarification of permitting, including minor channel realignments that might be authorized with a GP-11 for stream crossings designed to this Standard.
6. Location and details for low flow channel width, depth, and material size and types.

7. Locations and construction details, including rock sizing, in-stream structures, grade controls, and/or bank stabilization structures (if applicable).
8. Depth, gradation, and composition of material for streambed restoration. Refer to the *DGLVR Stream Crossing Replacement Technical Manual* for more guidance on determining substrate gradation and composition.
9. Specification for compaction of placed streambed material.
10. Details for scour hole restoration and reestablishing channel cross section.
11. Structure manufacturer's details, specifications, and installation instructions.
12. Thickness, compressive strength, reinforcement, testing, and other special requirements for concrete according to the manufacturer specifications, if applicable.
13. Load limits for bridges and/or culverts, including signage and guide rail per state or local codes.
14. Location of all utilities and notification requirements (PA One Call).
15. Location and elevation of survey benchmarks.
16. Method of surface water diversion and dewatering during construction.
17. Erosion and Sedimentation Control Plan, if applicable.
18. Vegetative requirements that include seed and plant materials to be used, establishment rates, and season of planting.
19. Cross section view of the proposed structure that clearly notes proposed streambed thalweg elevation (at the crest of a constructed grade control feature), Q100 water surface elevation, and top of structure opening elevation.
20. Additional site-specific requirements.

VII. <u>CONSTRUCTION</u>

A. The grant recipient or engineer must provide all draft bid packages (if applicable) to the conservation district. The conservation district must review the draft bid documents and provide written confirmation to the grant recipient or engineer that those draft bid documents comply with DGLVR policy and the *Stream Crossing Design and Installation Standard* before they are provided to potential bidders. All bid documents and practices must conform with municipal codes and other standard procurement requirements of the grant recipient.

B. Final construction documents shall include, at a minimum, the following items:
   1. Bidding Documents (if applicable).
   2. Construction Plan.
   3. Erosion and Sedimentation Control Plan.
   4. Construction Specifications.

C. At a minimum, two benchmarks must be set by the engineer or surveyor in an area outside of the zone of construction and disturbance.

D. Critical Stages of Construction to be inspected by the engineer (and/or engineer's designee) at the time of installation is required. Critical Stages include, but are not limited to, the following:
   1. Installation of structure subgrade and bedding materials and establishing inverts/elevations.
   2. Installation of footings, abutments and structure appurtenances.
   3. Installation of grade control features, bank margins, and streambed substrate.
   4. Installation or placement of stream crossing structure.
   5. Compaction and backfill of stream crossing structure.

E. Conservation districts must be on-site regularly during construction to ensure that the *DGLVR Program Policy and Stream Crossing Standard* are being met. Conservation districts must be onsite during installation of the Critical Stages of Construction defined in VII. D, above.

F. Certification and Documentation of Critical Stages of Construction: The engineer shall provide the project owner a signed and sealed certification form (Attachment B) indicating that the critical stages of construction outlined in Section VII.D were inspected and installed in accordance with the construction documents and DGLVR Stream Crossing Standard. The engineer must also provide the project owner with red-lined construction documents that indicate any changes in the as-built conditions of the project compared to the design plans.

References:

1. *Dirt, Gravel, and Low Volume Road Maintenance Program Administrative Manual.* May 2022.
2. *Dirt, Gravel, and Low Volume Road Stream Crossing Technical Manual*. May 2022.
3. *U.S.D.A. Forest Service Stream Simulation Manual: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings*. May 2008.
4. *Pennsylvania Department of Environmental Protection Erosion and Sediment Pollution Control Program Manual.* Technical Guidance Number 363-2134-008. March 2012.

Attachments:

Attachment A: Chapter 105 General Permit Types Most Applicable to Stream Crossing Replacements

Attachment B: Inspection and Documentation of Critical Stages of Construction Certification Form

Attachment C: Typical Detail Drawings

Attachment A:

Chapter 105 Permits that are Most Applicable to Stream Crossing Replacements

Attachment A:

Chapter 105 Permits that are Most Applicable to Stream Crossing Replacements

- GP-1 Fish Habitat Enhancement Structures, 3150-PM-BWEW0501
- GP-3 Bank Rehabilitation, Bank Protection, and Gravel Bar Removal, 3150-PM-BWEW0503
- GP-7 Minor Road Crossings, 3150-PM-BWEW0507
- GP-11 Maintenance, Testing, Repair, Rehabilitation or Replacement of Water Obstructions and Encroachments, 3150-PM-BWEW0511

Additional information on PA Chapter 105 permitting can be found at https://www.dep.pa.gov/Business/Water/Waterways/Pages/ePermitting.aspx

See the SCC GP-11 Permit Memo (Appendix E of the *DGLVR Stream Crossing Replacement Technical Manual*) for additional clarification on potential stream realignments and increasing road elevations.

Consult with DEP as needed on permitting questions, as well as with other entities involved in any required federal, state, or local permits that may be needed.

Attachment B:

Inspection and Documentation of Critical Stages of Construction Certification Form

Attachment B:

DGLVR Stream Crossing Replacement

Inspection and Documentation of Critical Stages of Construction Certification Form

Project Title: ____

Road Name: ____

Municipality, County: ____

Professional Engineer Certification
I hereby certify that the Critical Stages of Construction were inspected and installed in accordance with the Construction Documents and DGLVR Stream Crossing Standard:

____________________________, _________
Signature of Professional Engineer *Date*

Professional Engineer Seal

Notes:____

____

____

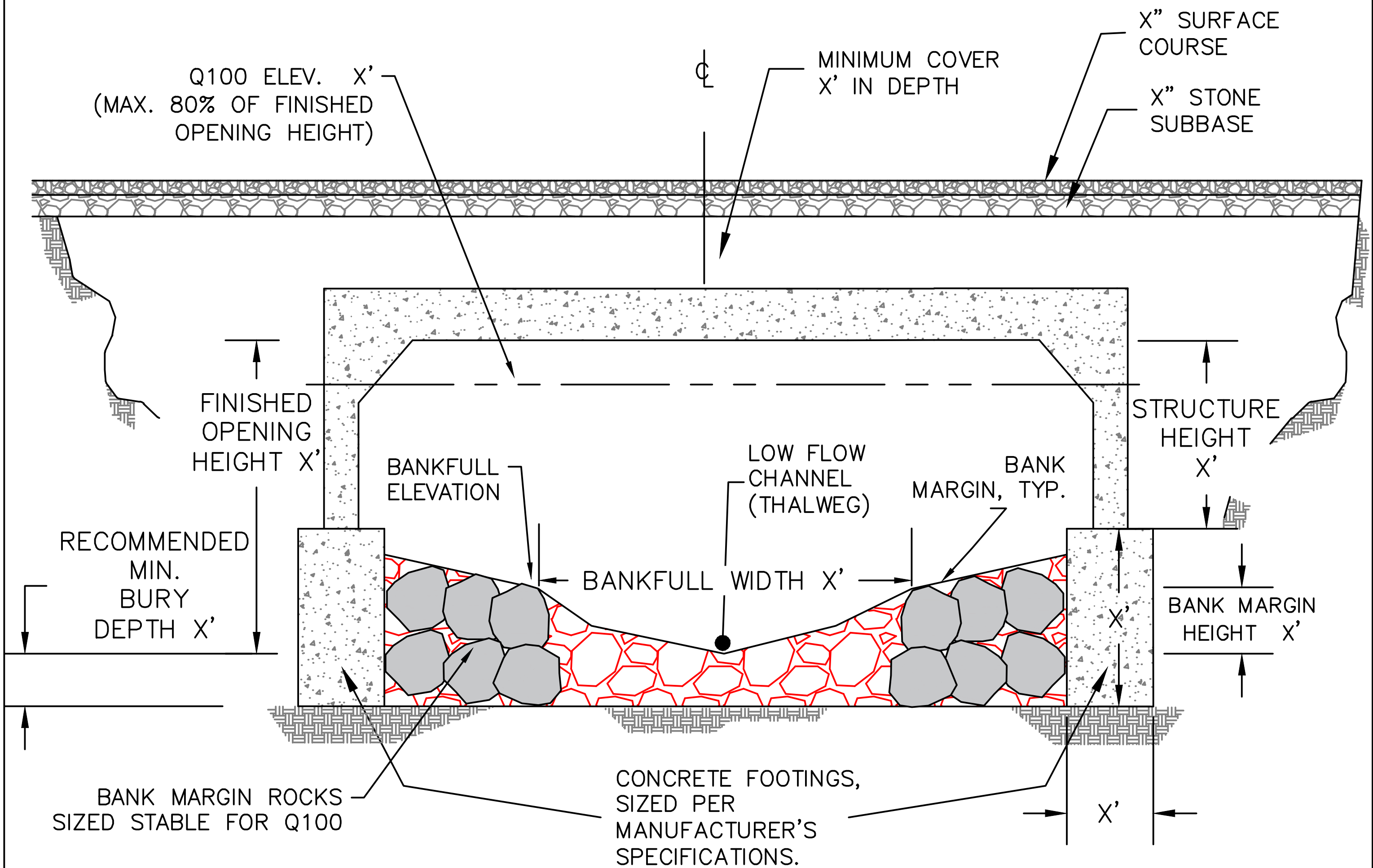
____

____

____

____

Attachment C:
Typical Detail Drawings



GENERAL NOTES

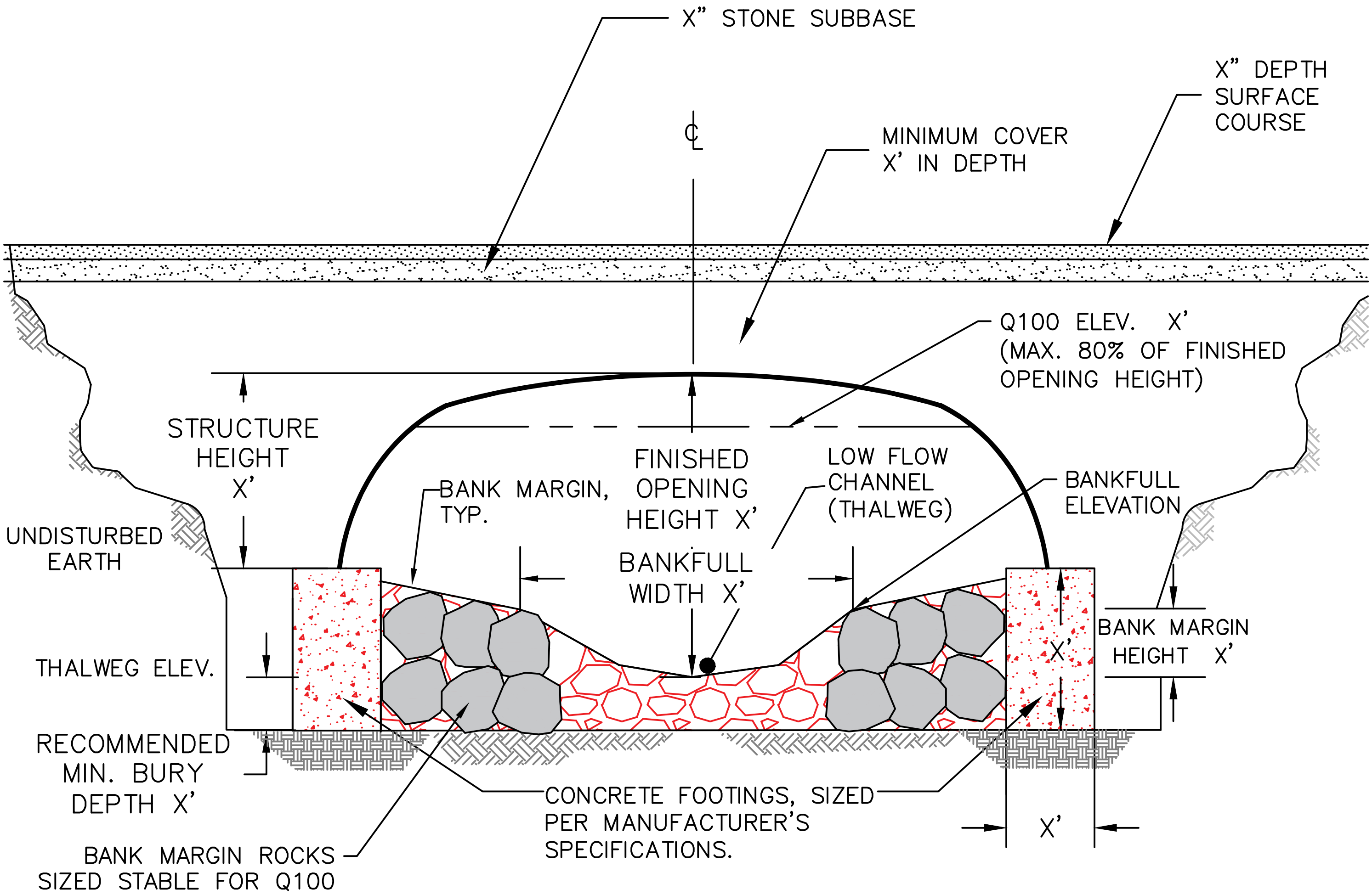
1. REPLACEMENT STRUCTURE MUST BE SIZED CONSIDERING THE FOLLOWING CRITERIA, PER DGLVR DESIGN & INSTALLATION STANDARD:
   1.1. CONSTRUCTION OF A PARABOLIC–SHAPED, BANKFULL–WIDTH CHANNEL WITHIN THE STRUCTURE THAT INCLUDES A DEFINED LOW–FLOW CHANNEL (THALWEG)
   1.2. INSTALLATION OF ROBUST BANK MARGINS, COMPRISED OF ROCK SUFFICIENTLY–SIZED TO BE STABLE AT THE Q100
   1.3. BURIAL DEPTH OF THE STRUCTURE INVERT OR BOTTOM OF FOOTINGS BENEATH THE RECONSTRUCTED STREAMBED (WITHIN THE STRUCTURE) MUST MEET OR EXCEED THE MINIMUM BURY DEPTH REQUIRED BY THE DGLVR PROGRAM
      1.3.1. MINIMUM REQUIRED BURIAL DEPTH IS MEASURED DOWNWARD FROM THE THALWEG ELEVATION AT THE CREST OF A CONSTRUCTED GRADE CONTROL FEATURE WITHIN THE STRUCTURE (NOT SHOWN IN TYPICAL DRAWING)
   1.4. CONVEYANCE OF THE Q100 AT AN ELEVATION NOT TO EXCEED 80% OF THE FINISHED OPENING HEIGHT (CLEAR RISE BETWEEN THALWEG ELEVATION AT THE CREST OF A CONSTRUCTED GRADE CONTROL FEATURE WITHIN THE STRUCTURE AND THE TOP OF THE STRUCTURE OPENING).
2. REPLACEMENT STRUCTURES MUST MEET ALL SIZING CRITERIA LISTED IN (1.) ABOVE, AS WELL AS ALL OTHER REQUIREMENTS OF THE DGLVR DESIGN & INSTALLATION STANDARD, IN ORDER TO BE ELIGIBLE FOR DGLVR PROGRAM FUNDING.
3. UPON FIRST MEETING THE CRITERIA LISTED IN (1.) ABOVE, AND OTHER REQUIREMENTS OF THE DGLVR DESIGN & INSTALLATION STANDARD, THE REPLACEMENT STRUCTURE SHALL NOT MEASURE LESS THAN 125% (1.25X) THE PROJECT BANKFULL WIDTH, MEASURED AT THE CONSTRUCTED BANKFULL ELEVATION WITHIN THE STRUCTURE.

PENNSTATE
Center for Dirt and Gravel Road Studies

BOTTOMLESS CONCRETE BOX CULVERT

NOT TO SCALE

11/10/2021



GENERAL NOTES

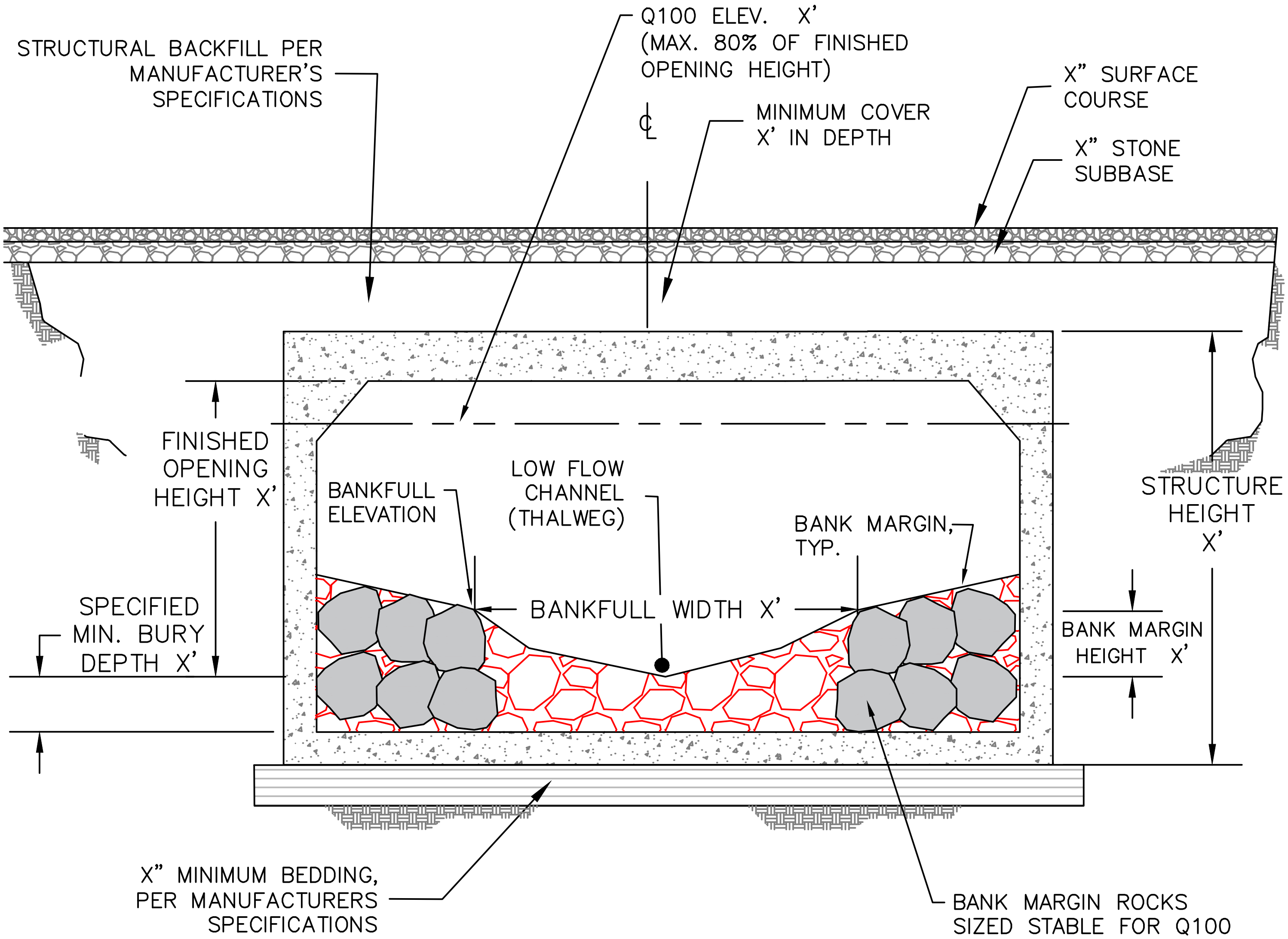
1. REPLACEMENT STRUCTURE MUST BE SIZED CONSIDERING THE FOLLOWING CRITERIA, PER DGLVR DESIGN & INSTALLATION STANDARD:
   - 1.1. CONSTRUCTION OF A PARABOLIC-SHAPED, BANKFULL-WIDTH CHANNEL WITHIN THE STRUCTURE THAT INCLUDES A DEFINED LOW-FLOW CHANNEL (THALWEG)
   - 1.2. INSTALLATION OF ROBUST BANK MARGINS, COMPRISED OF ROCK SUFFICIENTLY-SIZED TO BE STABLE AT THE Q100
   - 1.3. BURIAL DEPTH OF THE STRUCTURE INVERT OR BOTTOM OF FOOTINGS BENEATH THE RECONSTRUCTED STREAMBED (WITHIN THE STRUCTURE) MUST MEET OR EXCEED THE MINIMUM BURY DEPTH REQUIRED BY THE DGLVR PROGRAM
     - 1.3.1. MINIMUM REQUIRED BURIAL DEPTH IS MEASURED DOWNWARD FROM THE THALWEG ELEVATION AT THE CREST OF A CONSTRUCTED GRADE CONTROL FEATURE WITHIN THE STRUCTURE (NOT SHOWN IN TYPICAL DRAWING)
   - 1.4. CONVEYANCE OF THE Q100 AT AN ELEVATION NOT TO EXCEED 80% OF THE FINISHED OPENING HEIGHT (CLEAR RISE BETWEEN THALWEG ELEVATION AT THE CREST OF A CONSTRUCTED GRADE CONTROL FEATURE WITHIN THE STRUCTURE AND THE TOP OF THE STRUCTURE OPENING).
2. REPLACEMENT STRUCTURES MUST MEET ALL SIZING CRITERIA LISTED IN (1.) ABOVE, AS WELL AS ALL OTHER REQUIREMENTS OF THE DGLVR DESIGN & INSTALLATION STANDARD, IN ORDER TO BE ELIGIBLE FOR DGLVR PROGRAM FUNDING.
3. UPON FIRST MEETING THE CRITERIA LISTED IN (1.) ABOVE, AND OTHER REQUIREMENTS OF THE DGLVR DESIGN & INSTALLATION STANDARD, THE REPLACEMENT STRUCTURE SHALL NOT MEASURE LESS THAN 125% (1.25X) THE PROJECT BANKFULL WIDTH, MEASURED AT THE CONSTRUCTED BANKFULL ELEVATION WITHIN THE STRUCTURE.

PENNSTATE
Center for Dirt and Gravel Road Studies

BOTTOMLESS ARCH CULVERT

NOT TO SCALE

11/10/2021



GENERAL NOTES

1. REPLACEMENT STRUCTURE MUST BE SIZED CONSIDERING THE FOLLOWING CRITERIA, PER DGLVR DESIGN & INSTALLATION STANDARD:
   1.1. CONSTRUCTION OF A PARABOLIC-SHAPED, BANKFULL-WIDTH CHANNEL WITHIN THE STRUCTURE THAT INCLUDES A DEFINED LOW-FLOW CHANNEL (THALWEG)
   1.2. INSTALLATION OF ROBUST BANK MARGINS, COMPRISED OF ROCK SUFFICIENTLY-SIZED TO BE STABLE AT THE Q100
   1.3. BURIAL DEPTH OF THE STRUCTURE INVERT OR BOTTOM OF FOOTINGS BENEATH THE RECONSTRUCTED STREAMBED (WITHIN THE STRUCTURE) MUST MEET OR EXCEED THE MINIMUM BURY DEPTH REQUIRED BY THE DGLVR PROGRAM
      1.3.1. MINIMUM REQUIRED BURIAL DEPTH IS MEASURED DOWNWARD FROM THE THALWEG ELEVATION AT THE CREST OF A CONSTRUCTED GRADE CONTROL FEATURE WITHIN THE STRUCTURE (NOT SHOWN IN TYPICAL DRAWING)
   1.4. CONVEYANCE OF THE Q100 AT AN ELEVATION NOT TO EXCEED 80% OF THE FINISHED OPENING HEIGHT (CLEAR RISE BETWEEN THALWEG ELEVATION AT THE CREST OF A CONSTRUCTED GRADE CONTROL FEATURE WITHIN THE STRUCTURE AND THE TOP OF THE STRUCTURE OPENING).
2. REPLACEMENT STRUCTURES MUST MEET ALL SIZING CRITERIA LISTED IN (1.) ABOVE, AS WELL AS ALL OTHER REQUIREMENTS OF THE DGLVR DESIGN & INSTALLATION STANDARD, IN ORDER TO BE ELIGIBLE FOR DGLVR PROGRAM FUNDING.
3. UPON FIRST MEETING THE CRITERIA LISTED IN (1.) ABOVE, AND OTHER REQUIREMENTS OF THE DGLVR DESIGN & INSTALLATION STANDARD, THE REPLACEMENT STRUCTURE SHALL NOT MEASURE LESS THAN 125% (1.25X) THE PROJECT BANKFULL WIDTH, MEASURED AT THE CONSTRUCTED BANKFULL ELEVATION WITHIN THE STRUCTURE.

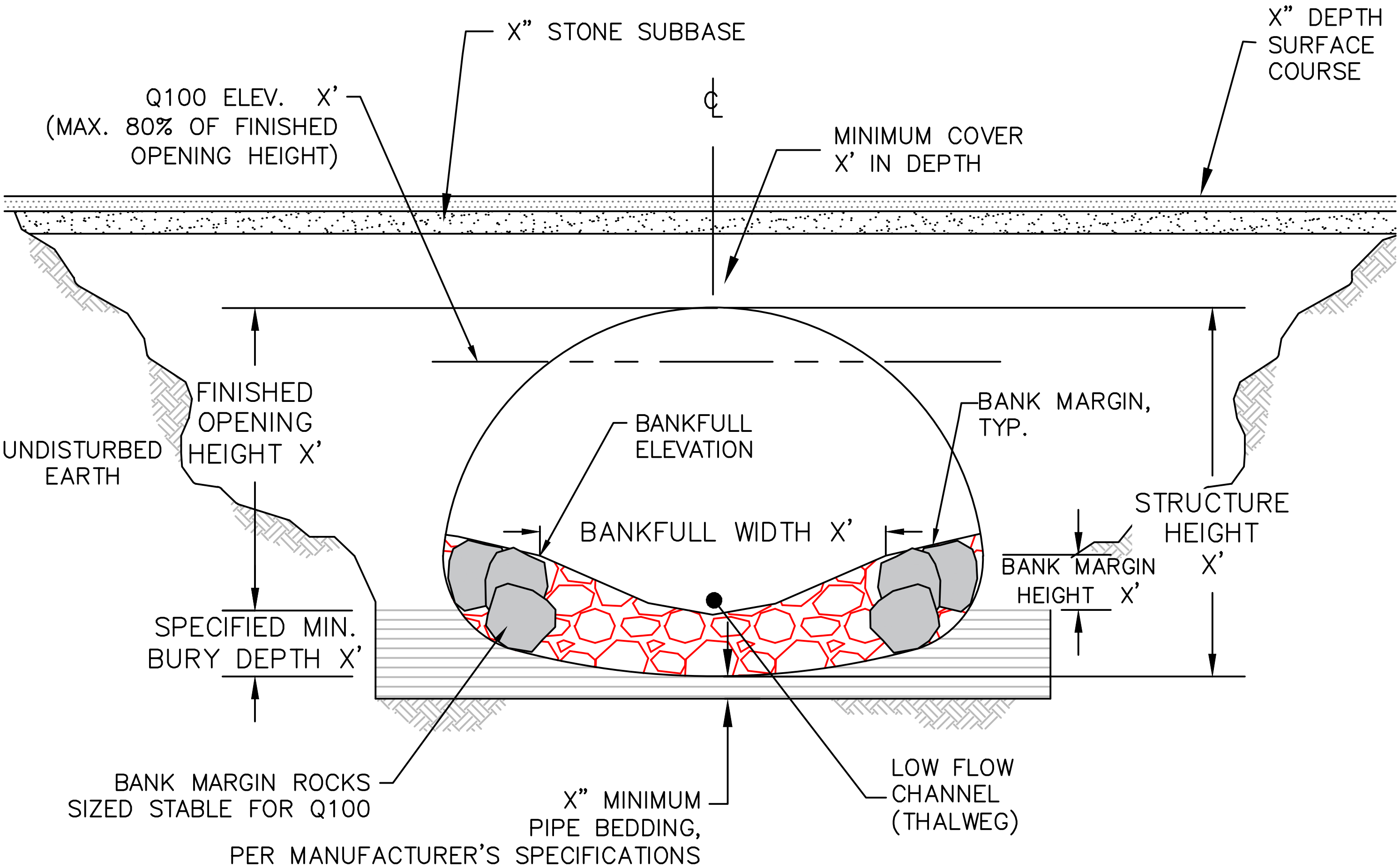
PENNSTATE

Center for Dirt and Gravel Road Studies

CONCRETE BOX CULVERT

NOT TO SCALE

11/10/2021



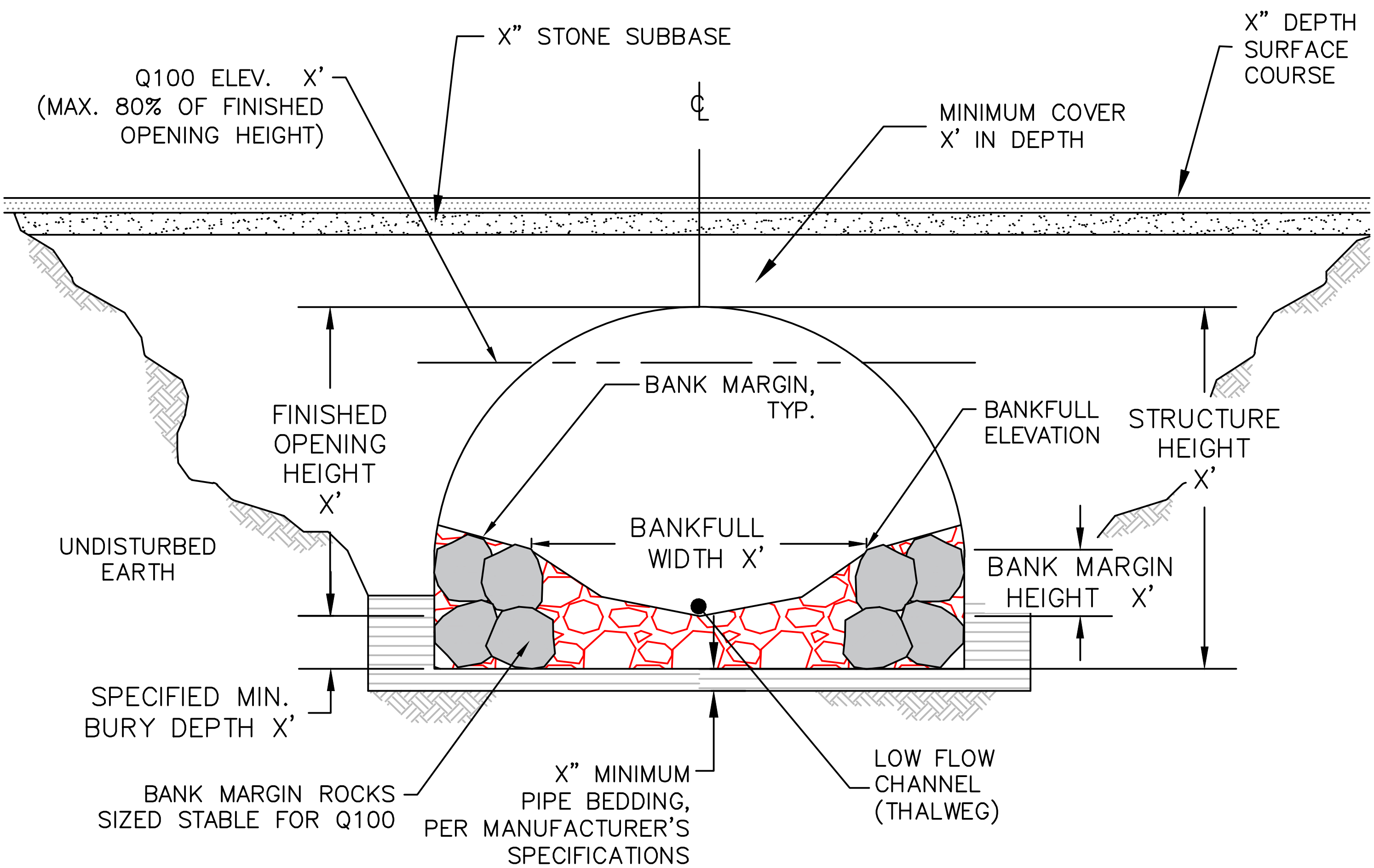
GENERAL NOTES

1. REPLACEMENT STRUCTURE MUST BE SIZED CONSIDERING THE FOLLOWING CRITERIA, PER DGLVR DESIGN & INSTALLATION STANDARD:
   1.1. CONSTRUCTION OF A PARABOLIC-SHAPED, BANKFULL-WIDTH CHANNEL WITHIN THE STRUCTURE THAT INCLUDES A DEFINED LOW-FLOW CHANNEL (THALWEG)
   1.2. INSTALLATION OF ROBUST BANK MARGINS, COMPRISED OF ROCK SUFFICIENTLY-SIZED TO BE STABLE AT THE Q100
   1.3. BURIAL DEPTH OF THE STRUCTURE INVERT OR BOTTOM OF FOOTINGS BENEATH THE RECONSTRUCTED STREAMBED (WITHIN THE STRUCTURE) MUST MEET OR EXCEED THE MINIMUM BURY DEPTH REQUIRED BY THE DGLVR PROGRAM
      1.3.1. MINIMUM REQUIRED BURIAL DEPTH IS MEASURED DOWNWARD FROM THE THALWEG ELEVATION AT THE CREST OF A CONSTRUCTED GRADE CONTROL FEATURE WITHIN THE STRUCTURE (NOT SHOWN IN TYPICAL DRAWING)
   1.4. CONVEYANCE OF THE Q100 AT AN ELEVATION NOT TO EXCEED 80% OF THE FINISHED OPENING HEIGHT (CLEAR RISE BETWEEN THALWEG ELEVATION AT THE CREST OF A CONSTRUCTED GRADE CONTROL FEATURE WITHIN THE STRUCTURE AND THE TOP OF THE STRUCTURE OPENING).
2. REPLACEMENT STRUCTURES MUST MEET ALL SIZING CRITERIA LISTED IN (1.) ABOVE, AS WELL AS ALL OTHER REQUIREMENTS OF THE DGLVR DESIGN & INSTALLATION STANDARD, IN ORDER TO BE ELIGIBLE FOR DGLVR PROGRAM FUNDING.
3. UPON FIRST MEETING THE CRITERIA LISTED IN (1.) ABOVE, AND OTHER REQUIREMENTS OF THE DGLVR DESIGN & INSTALLATION STANDARD, THE REPLACEMENT STRUCTURE SHALL NOT MEASURE LESS THAN 125% (1.25X) THE PROJECT BANKFULL WIDTH, MEASURED AT THE CONSTRUCTED BANKFULL ELEVATION WITHIN THE STRUCTURE.

PENNSTATE
Center for Dirt and Gravel Road Studies

ELLIPTICAL CULVERT
NOT TO SCALE

11/10/2021



GENERAL NOTES

1. REPLACEMENT STRUCTURE MUST BE SIZED CONSIDERING THE FOLLOWING CRITERIA, PER DGLVR DESIGN & INSTALLATION STANDARD:
   - 1.1. CONSTRUCTION OF A PARABOLIC-SHAPED, BANKFULL-WIDTH CHANNEL WITHIN THE STRUCTURE THAT INCLUDES A DEFINED LOW-FLOW CHANNEL (THALWEG)
   - 1.2. INSTALLATION OF ROBUST BANK MARGINS, COMPRISED OF ROCK SUFFICIENTLY-SIZED TO BE STABLE AT THE Q100
   - 1.3. BURIAL DEPTH OF THE STRUCTURE INVERT OR BOTTOM OF FOOTINGS BENEATH THE RECONSTRUCTED STREAMBED (WITHIN THE STRUCTURE) MUST MEET OR EXCEED THE MINIMUM BURY DEPTH REQUIRED BY THE DGLVR PROGRAM
     - 1.3.1. MINIMUM REQUIRED BURIAL DEPTH IS MEASURED DOWNWARD FROM THE THALWEG ELEVATION AT THE CREST OF A CONSTRUCTED GRADE CONTROL FEATURE WITHIN THE STRUCTURE (NOT SHOWN IN TYPICAL DRAWING)
   - 1.4. CONVEYANCE OF THE Q100 AT AN ELEVATION NOT TO EXCEED 80% OF THE FINISHED OPENING HEIGHT (CLEAR RISE BETWEEN THALWEG ELEVATION AT THE CREST OF A CONSTRUCTED GRADE CONTROL FEATURE WITHIN THE STRUCTURE AND THE TOP OF THE STRUCTURE OPENING).
2. REPLACEMENT STRUCTURES MUST MEET ALL SIZING CRITERIA LISTED IN (1.) ABOVE, AS WELL AS ALL OTHER REQUIREMENTS OF THE DGLVR DESIGN & INSTALLATION STANDARD, IN ORDER TO BE ELIGIBLE FOR DGLVR PROGRAM FUNDING.
3. UPON FIRST MEETING THE CRITERIA LISTED IN (1.) ABOVE, AND OTHER REQUIREMENTS OF THE DGLVR DESIGN & INSTALLATION STANDARD, THE REPLACEMENT STRUCTURE SHALL NOT MEASURE LESS THAN 125% (1.25X) THE PROJECT BANKFULL WIDTH, MEASURED AT THE CONSTRUCTED BANKFULL ELEVATION WITHIN THE STRUCTURE.

PENNSTATE

Center for Dirt and Gravel Road Studies

STRUCTURAL PLATE ARCH CULVERT

NOT TO SCALE

11/10/2021

Appendix B. Definitions and Acronyms

Aggradation: Deposition of sediment and corresponding increase in streambed elevation, often due to inability of the stream to adequately convey its sediment load during flood.

Anticipated Scour Depth (ASD): Depth of expected scour used to determine structure bury depth based on observed maximum reference reach pool depth and a factor of safety.

Appurtenances: accessory components to a stream crossing structure, such as headwall, endwall, wingwalls, toe plates or bank protection features.

Aquatic Organism Passage (AOP): Unimpeded movement of aquatic organisms through the road/stream crossing.

Bankfull Elevation: In non-confined channels, the elevation point at which the stream typically accesses the floodplain. Channel dimensions at the bankfull elevation convey the channel-forming or dominant discharge.

Bankfull Width: A site-specific, field-derived measurement of channel width at the bankfull elevation.

Bank Margins: Large rock placed along the outside edges of the reconstructed bankfull channel within the stream crossing structure. Placement of the bank margins define bankfull channel width and bank margin (bankfull) elevation / height through the structure.

Bedform: Typical sequence of streambed features through the project reference reach (riffles/pools, step/plunge pool, etc.)

CDGRS: Penn State University Center for Dirt and Gravel Road Studies. Provides education, outreach, and technical assistance to all entities involved in the DGLVR Program.

Channel Continuity: Relative consistency and connectivity of a stream channel upstream, through, and downstream of a road/stream crossing, in regard to physical characteristics of the channel such as slope, planform, dimensions, profile, and bedforms.

Construction Documents: typically consists of the plan drawings, detail drawings, specifications and bid documents prepared for a project.

Continuity Slope: Slope of the reconstructed section of streambed necessary to re-establish a relatively-continuous slope, profile and bedforms (channel continuity) along the entire length of stream extending upstream, through, and downstream of the new crossing.

Crossing: Refers to the location of a road/stream crossing structure.

Cross Section Survey: A survey conducted across the channel (perpendicular to the thalweg) to produce a graphical representation of channel dimensions including shape, depth and width.

Degradation: Accelerated erosion and transport of sediment from the streambed and banks, and corresponding lowering of the streambed elevation. Often associated with increased scour potential due to channel constriction or abrupt increase in channel slope.

DEP: Pennsylvania Department of Environmental Protection

Effective Structure Width: the width of a replacement stream crossing structure, measured at the bankfull elevation of the stream channel to be reconstructed through the structure. The bankfull elevation inside the structure corresponds to the elevation of the constructed bank margins along the immediate edges of the bankfull channel.

Finished Opening Height: Vertical distance measured from the thalweg elevation at the crest of a constructed grade control feature inside the replacement structure, upward to the top of the culvert opening or bottom of bridge beam.

Flood Resiliency: Reducing the risk of flood damages to people and infrastructure by planning and implementing measures that improve floodwater conveyance and provide for long-term stability of a self-maintaining stream corridor.

Grade Control: Natural or human-made structures that control channel elevation, dictate channel slope and maintain bedforms. Common types include riffles, cascades, steps, rock clusters and large wood features.

Headcut: headward erosion lowering of channel elevation that moves upstream over time.

Invert: Interior bottom elevation of stream crossing structure.

Key Pieces: Largest rocks in the reconstructed streambed substrate. Often these can be clustered to provide areas of minor, frequent grade control along the length of the channel bed in-between more robust constructed grade control features.

Longitudinal Profile Survey (Long-Pro): Survey of the stream channel, typically measured from upstream to downstream along the channel thalweg, to capture prominent features such as channel elevations, depths, and slopes at bedform features such as riffles, pools, runs, glides, and step/pools.

Low Flow Channel: Portion of the channel commonly wetted during stream base flow.

Outlet Scour Pool: An overly-widened and deepened pool bedform feature often (but not always) located immediately downstream of an undersized crossing.

Pool: An area of the stream characterized by deeper depths and slower current. Pools are typically created by the vertical force of water flowing over logs, boulders, or other grade control structures. The movement of the water carves a deeper indentation in the stream bed. Pools typically occur between grade control features along the length of the channel.

Q100: The 100-year recurrence interval of stream flow. In any given year, there is a 1% probability that a flow of that magnitude or greater would occur.

Reconstructed Reach: Section of stream to be constructed upstream, through, and downstream of the new structure to re-establish channel continuity between the tie-in points.

Reference Reach: Section of stream channel that best reflects the "typical" natural, minimally-impacted physical characteristics (profile, dimension, planform and dominant bedform) of the channel. For stream crossing projects, the reference reach is located beyond the extent channel impacts associated with the existing structure. Site Assessment (survey) of the reference reach is used as a blueprint for design of the reconstructed reach.

Riffle: The shallower, faster moving sections of a stream. Look for areas with a fast current where rocks break the water surface. In channels dominated by riffle/pool bedforms, the upstream crest (high point) of the riffle represents the dominant grade control type.

Sediment Wedge: Deposited material upstream of an undersized crossing caused by water backing up and dropping material. Commonly mistakenly called a "gravel bar" and frequently removed by road owners.

SCC: State Conservation Commission. Entity housed at the PA Department of Agriculture that administers the Dirt, Gravel, and Low Volume Road Program statewide.

Site Assessment: Survey of longitudinal profile and cross-sections through, and adjoining to, the project site used to inform project design.

Stream Crossing: A structure that conveys streamflow through the roadway.

Structure: A road/stream crossing structure, such as a culvert or bridge, constructed across a stream to provide controlled access for vehicles.

Substrate: Mixture of rock that composes the streambed.

Thalweg: The line of lowest elevation along the flowpath of a stream channel. Dimensionally, this is reflected as the lowest point of elevation in the channel cross-section.

Tie-in Points: Locations of existing- or constructed grade control features where the upstream- and downstream limits of the reconstructed reach transition to the existing stream channel. Tie-in points define the limits of the reconstructed reach necessary to achieve channel continuity upstream, through, and downstream of the crossing**.**

Vertical Offset: An unnatural and abrupt change in streambed elevation sometimes caused by undersized culverts, often characterized by sediment wedges upstream and plunge pools downstream.

Watershed: A region or area contributing to the supply of a stream or lake; drainage area, drainage basin or catchment area.

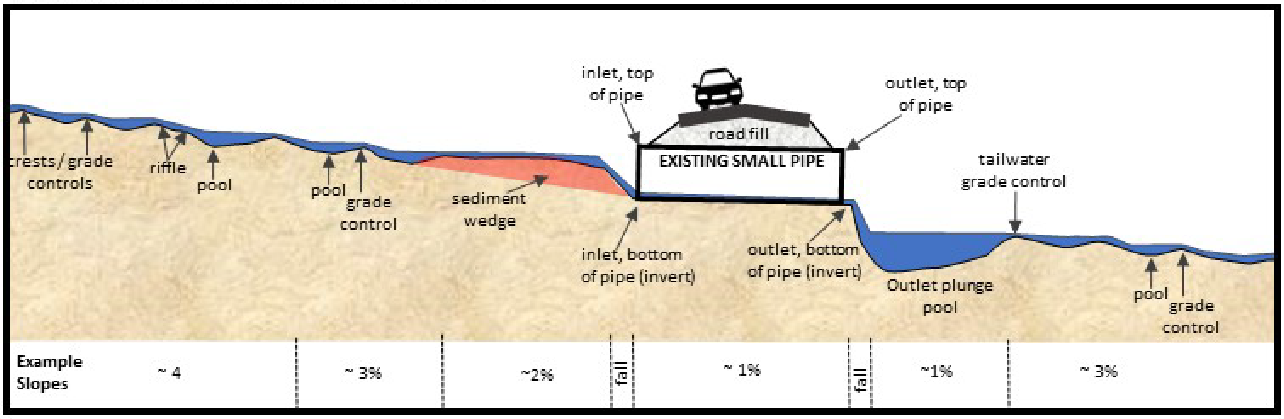
Appendix C. Stream Crossing Eligibility Determination Form

This form is to be completed by the conservation district to record the bankfull measurement and structure size to determine eligibility for replacement. See Section 3.2 of this Manual, or Chapter 7.1 of the DGLVR Administrative Manual (stream crossing policy) for more details on eligibility determination. This form must be kept in project files.

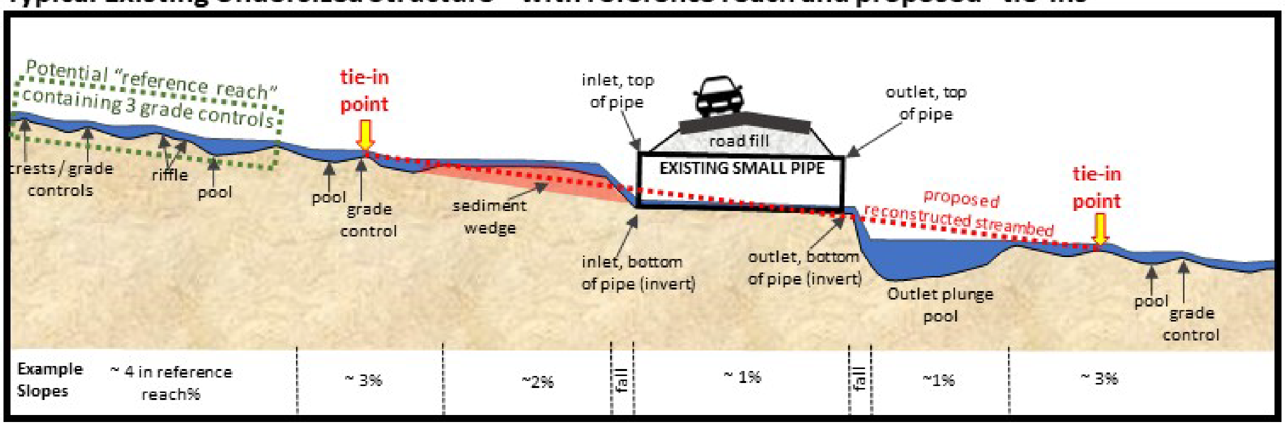
Appendix D. Stream Continuity Sketches

The sketches below show a “typical” undersized structure replacement before and after replacement. The middle sketch shows the before or existing condition, but identifies a reference reach, tie-in points, and the proposed reconstructed channel slope through the crossing.

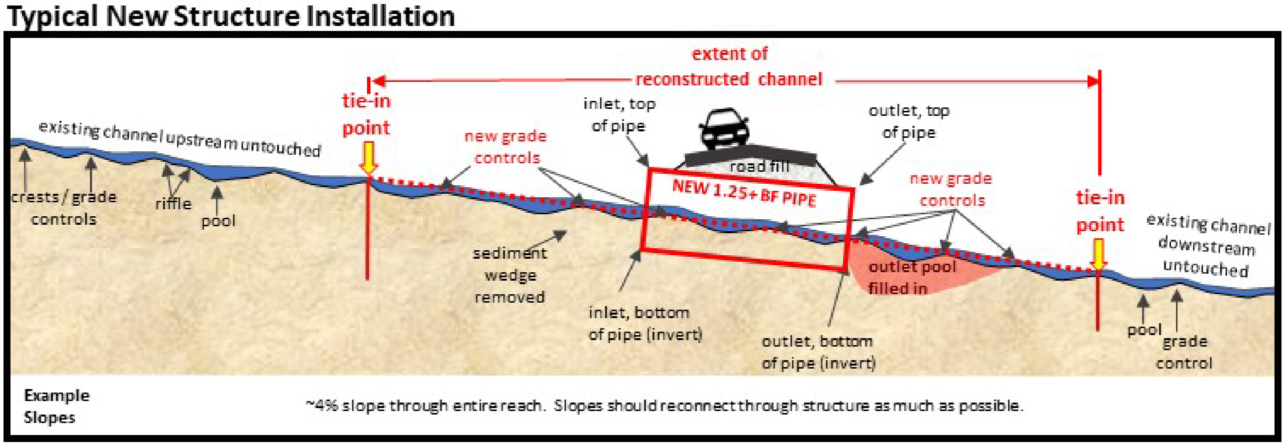
Typical Existing Undersized Structure



Typical Existing Undersized Structure – with reference reach and proposed “tie-ins”



Typical New Structure Installation



Appendix E. SCC GP 11 Permit Memo

PA State Conservation Commission staff, working in conjunction with Department of Environmental Protection staff, have developed this clarification letter related to DGLVR-funded projects receiving a General Permit 11. The letter clarifies the ability to address structure skew (alignment changes) and raise the road elevation over the crossing in certain circumstances.

COMMONWEALTH OF PENNSYLVANIA
STATE CONSERVATION COMMISSION

April 8, 2022

RE: Clarification of Authorization of General Permit No. 11 (GP-11) for Bridge and Culvert Replacement Projects Receiving Dirt, Gravel & Low Volume Road (DGLVR) Program Funding

Design Engineers,

Many of the Stream crossing projects funded by the DGLVR program will require a PA Chapter 105 permit and can seek authorization under a GP-11. The Department of Environmental Protection is the agency with the authority to review and acknowledge these permits. After coordination with DEP Bureau of Waterways Engineering and Wetlands, it has been determined that DGLVR stream crossing replacement projects consistent with the DGLVR Stream Crossing Design and Installation Standard (Standard) are consistent with design techniques utilized under a GP-11 with specific consideration of design methodologies. The intent of this memo is to clear up some misunderstandings as to what design techniques may or may not be utilized under the GP-11. These clarifications are provided with specific consideration of the design methods utilized in the DGLVR Stream Crossing Standard.

Specifically, changes in the skew of bridges and culverts can be authorized under GP-11 in conjunction with associated stream realignments immediately upstream and downstream of the structure. The change in skew and associated incidental stream realignment associated with the change in skew, may be authorized in circumstances where:

1. The culvert or bridge skew changes maintain or re-establish stream flow patterns consistent with the natural regime upstream and downstream of the road or bridge/culvert.
2. The proposed structures maintain either the inlet or outlet at the same location as the existing structure, or the location of both the inlet and outlet change but the proposed structure rotates on a horizontal axis of the existing structure, or the proposed structure is immediately adjacent to the existing structure.
3. Stream realignments associated with the new structure are incidental and are generally limited to 50 feet upstream and downstream of the structure. DEP may consider realignments a limited distance beyond 50 feet in special circumstances, but any realignments must still be incidental and necessary to support the structure.

In accordance with the Standard and with DEP’s design criteria, please note that the skew changes must maintain or re-establish stream flow patterns consistent with natural regime upstream and downstream of the bridge or culvert, and that the conditions of GP-11 must still be met.

Also, changes in roadway approach grades and overtopping characteristics can be authorized by

GP-11, provided that the changes do not result in significant risk to public safety, structural stability and/or the environment. In coordination with DEP Bureau of Waterway Engineering and Wetlands, no additional information will be required if it is obvious that the proposed change to the approach grades and overtopping characteristics do not result in significant risk (e.g. by observation, a substantial increase in the hydraulic conveyance of the structure may obviously compensate for an increase in the approach grade elevation needed to accommodate the larger structure). When the proposed changes to the approach grades and overtopping characteristics are not obviously insignificant, the Hydrology and Hydraulic analysis required by the design standard is acceptable documentation to show that the proposed changes do not result in a significant risk.

The following list depicts the minimum items specific to this design approach that should be included with most GP-11 registrations for the DGLVR Program utilizing the Standard. Additional site-specific requirements may also be required.

1. A description of the proposed work, existing structure, and purpose of proposed structure changes and any minor channel realignments.
2. A scaled plan showing the existing and proposed structures including any proposed channel realignments.
3. Scaled cross section(s) of the existing and proposed culvert structures depicting dimensions of the existing and proposed waterway opening, and the existing and proposed depth of fill and roadway elevations in the approaches and over the existing and proposed structures.
4. Scaled cross sections of streams in any areas of proposed minor stream realignments.
5. Photographs of proposed stream realignments depicting areas of proposed work, channel and geomorphic conditions, eroded banks, deposition, etc.
6. Scaled drawings for any proposed grade control structures in and/or upstream and downstream of the proposed structure, if applicable.
7. Scaled cross sections of any reference reach data (upstream or downstream of proposed work) collected to determine bankfull characteristics or reference reach information, if applicable.
8. Scaled profiles of the existing and proposed culvert structures and a stream channel section extending sufficiently up and down stream to show proposed minor channel realignments, if applicable. When possible, it is recommended the length of the realigned channel be comparable to the length of the existing channel. However, where the project is correcting a ninety-degree bend in the stream, the realigned channel will likely have a shorter length than the existing channel and is therefore still permissible.
9. Details on the proposed stream bed material.
10. If applicable, a hydraulic analysis demonstrating that the changes in the approach grades or overtopping characteristics will not increase the risk of flooding.
11. A P.E. Seal and certification provided on the hydrologic and hydraulic report and on plans and specifications for proposed structures on public roads.

It is important that the plans, profiles, cross sections, description, and other information contain sufficient details and plans depicting the existing and proposed conditions, stream bed, stream banks, bankfull elevation, low flow channel and overall geomorphic conditions and other details as appropriate for DEP to review, consistent with the proposed activities. The coordination between the State Conservation Commission, DEP's Bureau of Waterways Engineering and Wetlands and regional DEP Waterways and Wetlands Programs has identified criteria for most projects to qualify for GP-11 authorization. Questions should be directed to the DEP regional offices for clarity.

While most projects designed under the Standard should qualify for a GP-11, every project will not fit into this category. The SCC has coordinated with DEP Central office staff and the DEP regional staff. If there are questions about a permit review, DEP regional staff should be contacted. The SCC and local conservation districts are also available to discuss or assist when needed.

Sincerely,

Roy Richardson
Program Manager
Dirt, Gravel, and Low Volume Roads Program

Appendix F. Editable Forms and Templates

These documents are <u>not provided</u> in this appendix because they need to be modified for use. They are templates or samples and must be edited by the PA county conservation districts to meet local conditions and individual projects. Microsoft Word versions of all of these forms can be found at https://www.dirtandgravel.psu.edu/general-resources/stream-crossing-replacements.

A. **Conservation District Cover Letter for Permit Review Consistency**: Sample letter for conservation district to acknowledge that the permit application is consistent with DGLVR Policy and Stream Crossing Standard. Use of this letter is not required, but some form of written acknowledgement to grant recipient is required.

B. **Conservation District Cover Letter for Permit Review Deficiencies**: Sample letter for conservation district to list changes needed for the permit application to meet DGLVR Policy and Stream Crossing Standard. Use of this letter is not required, but some form of written acknowledgement to grant recipient is required.

C. **Conservation District Cover Letter for Bidding Review Consistency**: Sample letter for conservation district to acknowledge that bid documents are consistent with DGLVR Policy and Stream Crossing Standard. Use of this letter is not required, but some form of written acknowledgement to grant recipient is required.

D. **Conservation District Cover Letter for Bidding Review Deficiencies**: Sample letter for conservation district to list changes needed for the bid documents to meet DGLVR Policy and Stream Crossing Standard. Use of this letter is not required, but some form of written acknowledgement to grant recipient is required.

E. **DEP GP-11 Permit Memo Cover Letter:** Optional cover letter when applying for GP-11 that references both the DGLVR Program.

F. **DEP GP-7 Permit Memo Cover Letter**: Optional cover letter when applying for GP-7 that references both the DGLVR Program.

G. **Request for Proposal (RFP)**: Template RFP for use in bidding for engineering services. The RFP is fully customizable and must be adapted to individual projects. Use of the RFP is encouraged for all projects but is not required.

Appendix G. Checklists

The checklists contained in this appendix are provided as tools for conservation districts to use when implementing stream crossing replacement projects.

Required

- **Project Lifecycle Checklist:** Overall checklist with notes on major milestones throughout project. This checklist is required and must be kept in the project file.

Optional: the checklists below are optional for use by the conservation district

- **Pre-Application Meeting Checklist for Stream Crossings:** Summary of points to discuss with potential grant applicant on initial site visit.
- **Pre-Design Meeting Checklist for Stream Crossings:** Summary of points to discuss with grant applicant and engineer prior to project design.
- **Design Package Review Checklist for Stream Crossings:** Guide to use when reviewing drawings and plans before permit submittal.
- **Bid Package Review Checklist for Stream Crossings:** Guide to use when reviewing drawings and plans before bid package advertisement.
- **Bid Site Showing Checklist for Stream Crossings:** Summary of points to discuss with potential bidders during site showing.
- **Pre-Construction Meeting Checklist for Stream Crossings:** Summary of points to discuss with grant recipient, engineer, and contactor prior to starting work.
- **Construction Inspection Checklist for Stream Crossings:** Summary of things for conservation districts to look for onsite visits during construction.
- **Completion / Final Inspection Meeting Checklist for Stream Crossings:** Summary guide to final inspection and project closeout.

Stream Crossing Replacement Project: Lifecycle Checklist

7/2022 ☐ DGR ☐ LVR

Applicant: ______________________ **Road Name:** _______________________ **Crossing Identifier:**_____________

This checklist is meant to summarize the major events in development and implementation of a stream crossing replacement. This form (but not individual checklists) is required to be completed and kept in project file.

Contact List	Contact Name	Phone Number	E-mail Address
Grant Applicant			
Grant Applicant			
Engineer			
Engineer			
Contractor			
Contractor			
______________			
______________			

☐ **Pre-Application Meeting:** The District is required to hold a preapplication meeting prior to a grant recipient applying for program funds for a stream crossing project. Initial site visit and subsequent follow up visits for project planning. See *Pre-Application Meeting Checklist* for meeting talking points. As a reminder, a longitudinal profile / cross-section survey must be completed prior to QAB recommendation for funding (see below). Submit online notification to SCC if project is likely to be funded.

- **Initial Site Visit Date:**_______________
- **Attendees:** ____
- **Notes:** ____

  ____

☐ **Longitudinal Profile Survey:** A longitudinal profile survey must be conducted for each stream crossing prior to the QAB recommending the project for funding. Engineer may utilize the District survey for design or conduct another survey, in concert with the District. Refer to DGLVR Program's Stream Crossing Standard for survey requirements. See *Chapter 4 of Stream Technical Manual* and *Longitudinal Profile Technical Bulletin* for guidance.

- **Initial Survey Date:**_______________
- **Participants:** ____
- **Notes:** ____

  ____

Was a second (engineer's) survey completed (in concert with the District)? YES NO

- **Engineer's Survey Date:**_______________
- **Participants:** ____
- **Notes:** ____

  ____

- [ ] **Contract and Attachments:** Grant recipient reviews the contract and attachments. Acknowledge attachments and sign contract. Return to the County Conservation District.
    - **Application Submitted Date: _____________** **Request: $___________________**
    - **Contract Date:________________** **Contract Amount: $___________________**
    - **Notes: ____**

      ____

- [ ] **Professional Design Services**: Program funds can be used to cover engineering, permitting, or similar consultant costs, but such costs are limited to a maximum of 20% of the total contract amount between the district and the grant recipient, with a maximum of $25,000 total. The use of the DGLVR Program's *Stream Crossing Replacement Request for Proposal Template* or an alternative which incorporates the required service details is highly recommended. Preparation or design costs such as engineering or surveying that are incurred before the contract is signed are not eligible for grant reimbursement but can be counted as in-kind.
    - **Project Engineer: _______________________**

- [ ] **Pre-Design Meeting**: The District, Project Participant, and Engineer/Consultant of record for the project are required to meet on site prior to the start of the design. District staff may ask technicians from TU, CDGRS or others to attend and provide assistance. See *Pre-Design Meeting Checklist* for meeting talking points.
    - **Pre-Design Meeting Date:_________________**
    - **Attendees: ____**
    - **Notes: ____**

      ____

- [ ] **Pre-Permit/Design Submittal Review:** The DGLVR Program's Stream Crossing Standard requires that draft final project design package (permit, E&S Plan, construction drawings, etc.) be submitted (or resubmitted) to the conservation district for review prior to permit submittal. The district may ask for assistance in reviewing the plans from outside sources such as the SCC, CDGRS, and TU. This package must include all drawings necessary for construction. See *Design Plan Review Checklist* for review guidance.
    - **Date of plan submission:________________** **Date of Review:______________________________**
    - **Plan Reviewers:____**
    - **Notes: ____**

      ____

- [ ] **Bid Package Review**: If any subcontracted work is needed, grant recipients should follow their own bidding requirements. Bid packets or purchase orders and associated shop drawings for made to order products (ex. Stream crossing structures) must be provided to the conservation district for review and approval that they meet program policy and the DGLVR Standard prior to acknowledging an order or advertising the bid. See *Bid Package Review Checklist* for review guidance.
    - **Date of bid package submission:___________________** **Date of Review:_____________________________**
    - **Bid package reviewer:____**
    - **Notes: ____**

      ____

- [ ] **Bid Site Showing:** It is recommended that the Grant Recipient hold a bid site showing and invite the engineer, district, any potential bidders. The district is required to attend if a bid site showing is held. The purpose of the meeting is to walk through the project plan and allow potential bidders to ask questions in order to receive better bids for project work. See *Bid Site Showing Checklist* for meeting talking points.
    - **Bid Site Showing date:___________________**
    - **Attendees:____**

      ____

- **Notes:** ____

  ____

- ☐ **Construction Notification:** The project participant is required to notify the Conservation District ____ days prior to the start of construction.
  - **Date of notification:**_________________ **Proposed Start Date:**________________________

- ☐ **Pre-Construction Meeting:** The District is required to hold an on-site meeting prior to project work beginning and should include the grant recipient, contractor (if applicable), and the project engineer. The purpose of this meeting is to ensure all parties understand the construction plans and to answer any questions before project work begins. See *Pre-Construction Meeting Checklist* for meeting talking points.
  - **Pre-Con Meeting date:**______________________ **Proposed Start Date:**__________________________
  - **Attendees:**____

    ____
  - **Notes:** ____

    ____

- ☐ **Project Inspection:** District must be on site regularly to ensure program policies and standard are being met. Ensure any proposed "field changes" to what is on the plan are approved by the design engineer. See *Construction Inspection Checklist* for guidance. Note inspection visits on the log on this form.

- ☐ **Project Completion:** District and the grant recipient must meet onsite for a final project walkthrough. It is advantageous to do this immediately following construction with the contractor and engineer, so that minor issues can be addressed while equipment is still on site. See *Project Completion Checklist* for guidance.
  - **Completion date:**_______________________ **Inspection Date:**________________________________
  - **Attendees:**____
  - **Notes:** ____
  - ____

EVENT LOG (Log phone calls, site visits, inspections, etc.)		
DATE	**EVENT**	**NOTES**

Pre-Application Meeting Checklist for Stream Crossings ☐ DGR ☐ LVR Date: ________

Applicant: ___________________ **Road Name:** ___________________ **LAT/LONG:**___________________________

Applicant Reps: ____

CD Reps: ____

Additional Attendees: ____

Summarizes discussion points for an initial on-site meeting prior to application. More information in Chapter 3 of the DGLVR Stream Crossing Technical Manual.

Site Eligibility

- ☐ **Publicly owned road** (Is road open to public vehicles at least 2 weeks per year?)
- ☐ **LVR** <500 ADT (count required before contract can be signed)
- ☐ **ESM certification** (person in charge of project for applicant has recent (last 5 years) ESM certification)
- ☐ **Stream Crossing Eligibility**
    - **Complete stream crossing evaluation form and keep copy in file**
    - Automatically eligible (Existing Structure under 4', see section 7.1.2.2)
    - Existing Structure over 4' equivalent
        - Structure opening to bankfull channel width ratio of 75% or less?
            - Structure Width: _____________Ft
            - Bankfull Width: ______________Ft
            - Structure to Bankfull Width Ratio:______________%
- ☐ **DGLVR Standard Exemptions (section 7.1.3)**
    - Automatically Exempted if a bankfull width of 4' or less and:
        - Defined bed and bank not more than 500' upslope of the road, or,
        - 20 acres or less drainage area
    - SCC DGLVR Standard Exemption available on a case by case basis for crossings that don't meet automatic exemption criteria

Logistical Discussion Points

- ☐ **Timelines** (application deadline, permits, bidding, contracting, and construction)
- ☐ **Ranking** (discuss ranking process with applicant)
    - If you know this project will/will not be competitive based on-site conditions or budgets, be realistic with potential grant applicant.
- ☐ **Phased Projects** (large projects may be funded in separate phases (road fill, drainage, DSA))
- ☐ **County-specific policies** (ranking criteria, in-kind, maintenance policies, paying for asphalt, etc.)
- ☐ **Work performed by?** Applicant ___ Contractor ___
- ☐ **Reminders** (standard bidding**,** prevailing wage ($25,000 project value threshold), PA One-Call, Utilities)

Project-Specific Discussion Points

- ☐ **Discuss/Introduce Goals & Objectives of DGLVR Program Stream Crossings**
    - Restore stream through road profile
    - Protects structure and ensure lifespan
    - Flood Resiliency
    - Reduced Maintenance
    - Full Aquatic Organism Passage
    - Ensure applicant understands level of effort and equipment to get material into crossing structure and extent of work upstream and downstream
- ☐ **Professional Design Services**
    - See predesign meeting checklist
    - Discuss DGLVR Stream Crossing Standard (see checklist):
        - opening size
        - streambed work needed, (grade controls, low flow channel, bank margins)
        - streambed material needs to be specified (replicate size of natural streambed)

        - continuity and reconstructed reach length
    - Provide DGLVR Stream Crossing Replacement Technical Manual
    - The cost of engineering is limited 20% of the contract amount, with a maximum amount of $25,000
    - engineering inspection and finalization requirements
- ☐ **Off-ROW Permission**
    - Written Landowner agreements **recommended** prior to contracting and design
    - Written Landowner agreements **required** prior to beginning work
        - Applicant and/or conservation district may need to meet with landowners to discuss project benefits
    - Determining how far off ROW and what needs to be done off ROW. May need to do Long Pro first.
    - **SCC approval required?** (>500' off road or off-ROW cost is over 35% of project value?)
- ☐ **Permitting**
    - Discuss chapter 105 permitting
        - Waived activity: <100 acres, reviewed case by case
        - GP-7,
        - GP-11,
        - Other GPs, as needed
        - Joint Permit, etc. Add general info on permit triggers
- ☐ **Additional drainage improvements** (Disconnect direct drainage from stream around crossing)
- ☐ **Optional outside assistance** (CDGRS, TU, SCC, PAFBC, etc.)
- ☐ **Discuss next steps if applicant wants to proceed**
    - Longitudinal Profile Survey
    - Structure and cost estimates
    - Outside assistance

Meeting Notes:

____

____

____

____

____

____

____

____

____

____

____

____

____

____

Pre-Design Meeting Checklist for Stream Crossings ☐ DGR ☐ LVR Date: _____________

Applicant: ___________________ **Road Name:** ___________________ **LAT/LONG:**__________________________

Applicant Reps: ____

CD Reps: ____

Additional Attendees: ____

Summarizes discussion points for an on-site meeting prior to project design. More information in Chapter 12 of the DGLVR Stream Crossing Replacement Technical Manual.

Project-Specific Discussion Points

- ☐ **Discuss/Introduce Goals & Objectives of DGLVR Program Stream Crossings**
  - Restore stream through road profile (stream continuity)
  - Flood resiliency and ensures lifespan
  - Reduced Maintenance
  - Full Aquatic Organism Passage
- ☐ **Provide Design Engineer with a copy of:**
  - Stream Crossing Design & Installation Standard
  - Stream Crossing Replacement Technical Manual

Project Management and Meetings

- ☐ **Design engineer is required to attend the pre-design meeting at the location of the road/stream crossing replacement project**
- ☐ **Design engineer may be required to attend the following additional meetings by the conservation district:**
  - Bid site showing
  - Bid selection / award meeting
  - Pre-construction meeting
  - Others: ____
- ☐ **Communications from the grantee or Design engineer may be directed to:**
  - Contact Information: ____

Off Right of Way (ROW)

- ☐ **Discuss who will obtain permission for project related Off ROW work**
  - Grantee ______________________ Design Engineer ____________________________
  - Stream channel modifications including reference reach survey work
  - E&S controls areas and staging areas
  - Template Off ROW Consent Form on website

Site Survey & Mapping

- ☐ **Must provide sufficient topographic survey and mapping to define or support the following:**
  - Project boundaries and disturbance areas
  - Existing roadway elevations, grades and profiles
  - Wetlands and other jurisdictional or regulated resource areas
  - Design of replacement structure and appurtenances
- ☐ **Must establish two permanent benchmarks, located outside of disturbance area**
- ☐ **Must collect sufficient site survey to support H&H analysis**

Hydraulic Analysis

- ☐ **Must prepare an Hydrologic and Hydraulic (H&H) study that includes:**
  - Finished thalweg elevations and
  - Clearly labeled discharge values and water surface elevations at the proposed crossing inlet for Q2, Q10, Q25, Q50, and Q100
- ☐ **Provide any additional H&H analysis necessary for applicable regulatory / permit requirements**

Geomorphic Assessment

- ☐ **Required to base the project design on a longitudinal profile survey and cross-sectional surveys of existing conditions.**
  - o Conservation district completed longitudinal profile and cross sections may be provided
  - o Design Engineer may conduct their own longitudinal profile and cross sections
    - ▪ Conservation district must be present during engineer/surveyor collected long-pro
  - o Details to be collected in the longitudinal profile and cross sections listed in the Stream Crossing Design & Installation Standard

Channel Design

- ☐ **Using the longitudinal profile survey of existing site conditions, must provide a stream channel design extending upstream, through, and downstream of the replacement crossing that achieves the following:**
  - o Provides long-term channel continuity and aquatic organism passage
  - o Specifies essential channel features based upon survey of a reference reach condition
    - ▪ Bankfull width and cross-sectional shape with well-defined low flow channel (thalweg) and bank margins
    - ▪ Specified streambed material composition and placement thickness through the structure
    - ▪ Type, number, length, location and elevations of grade control features. A minimum rock size for grade controls must be specified

Structure Design

- ☐ **Structure must be of adequate width to accommodate the bankfull width of the stream at the final bankfull elevation with stable bank margins.**
  - o Typical bankfull channel width is _________feet
- ☐ **Replacement structure must be properly aligned with the stream channel**
- ☐ **Must include types and placements of all associated structure appurtenances such as abutments, footings, wingwalls, etc.**
- ☐ **Headwalls and Endwalls are required on all stream crossing structures**
- ☐ **Sizing and installation of the structure and its appurtenances must provide long-term channel continuity and AOP and shall not reduce the minimum effective opening to less than 125% bankfull width at the structure inlet or outlet**
- ☐ **Structure must pass the Q100 flow at an elevation not to exceed 80% of the finished opening height at the structure inlet**

Roadway Design

- ☐ **Must provide design services as needed to address any change to roadway elevations and drainage patterns**
  - o Stream Crossing Design & Installation Standard may require increasing the existing roadway elevation. See GP11 DEP Permit Memo for additional guidance
- ☐ **Must consider additional floodplain connectivity (high-water bypass, floodplain pipes, etc.) where necessary**

Permitting & Construction Documents

- ☐ **This project is located in HQ, EV, CWF, or WWF _____________________**
- ☐ **The drainage area for this project location is _________________________**
- ☐ **Design engineer must complete all required permit registrations and application materials needed to meet all State, Local and Federal requirements**
- ☐ **Design engineer must prepare a set of construction documents meeting the DGLVR Stream Crossing Design & Installation Standard.**
  - o Detailed drawings
  - o Technical specifications for project implementation
  - o Existing and proposed conditions comparison
  - o Erosion and sediment control plan including dewatering measures
  - o All critical elevations, grades, slopes and other design criteria
- ☐ **Design engineer must provide all plans and specifications to the conservation district for consistency review with the DGLVR Policy and Stream Crossing Standard before submitting (or resubmitting) materials to regulatory agencies for permit registration / authorization.**
  - o Submitted materials will be reviewed by the conservation district for consistency with the Stream Crossing Design and Installation Standard

- All comments must be addressed to the satisfaction of the conservation district prior to receiving a consistency letter and a cover letter for submission to the regulatory reviewing entity.

Bid Documents and/or Shop Drawings

- ☐ **Conservation district must be provided any bid documents or shop drawings associated with the project before advertisement or acknowledgement for fabrication of materials**
  - Conservation district will review for consistency with permit and construction drawings and with the Stream Crossing Design and Installation Standard
  - If needed a list of deficiencies will be provided to the applicant and their design engineer to address
  - All comments must be addressed to the satisfaction of the conservation district prior to receiving a consistency letter. A consistency letter must be granted before advertisement of a bid or acknowledgement of shop drawings for material fabrication
- ☐ **Grantee or Design Engineer must coordinate with the conservation district to be present at the mandatory bid site showing meeting (if applicable).**

Construction Inspection and Certification

- ☐ **Design Engineer is required to provide onsite inspection of critical aspects of construction which include but are not limited to:**
  - Installation of structure subgrade and bedding materials and establishing inverts/elevations
  - Installation of footings, abutments or in-ground appurtenances
  - Installation of grade control features, bank margins, and streambed substrate.
  - Installation or placement of stream crossing structure
  - Compaction and backfill of stream crossing structure
- ☐ **Conservation districts must be on-site regularly during construction to ensure DGLVR Policy and Stream Crossing Standard are met. At a minimum, the conservation district must be onsite during the installation of "Critical Stages of Construction"**
- ☐ **Design engineer shall provide a signed and sealed certification form (attachment B)**

Meeting Notes:

____

____

____

____

____

____

____

____

____

____

____

____

____

<u>Design Package Review Checklist for Stream Crossings</u> ☐ DGR ☐ LVR

Applicant:_______________________ Road Name:_____________________ LAT/LONG:______________

Engineer: _______________________ Reviewer:____________________ Date:________________

The DGLVR Program requires that all plans and specifications be submitted to the conservation district for review prior to permit submittal. The conservation district review is to confirm that DGLVR Policy and Stream Crossing Standard are met. The conservation district may ask for assistance in reviewing the plans from outside sources such as the SCC, CDGRS, and Trout Unlimited (TU). This package must include all drawings necessary for permitting and construction.

<u>**Documents submitted for this review**</u> shall include, at a minimum, the following items:

- ☐ **Construction Drawings** including plan, profile, cross-section and detail drawings.
- ☐ **Hydrologic and Hydraulic (H&H) Study**
- ☐ **Proposed E&S Plan**
- ☐ **Construction Specifications**

At a minimum, the plans must include the following per the DGLVR Stream Crossing Standard section VI:

☐ ***A. Existing conditions of project site, including but not limited to the full longitudinal profile survey and cross sections of the stream, existing stream crossing, stream crossing and channel slope, road approaches and road fill cover, and delineated wetlands (if applicable).***

- Construction detail drawings include clear and concise depiction of all existing conditions on plan, section, and profile drawings.
- Profile drawings show the existing streambed profile along the thalweg, extending beyond the upstream and downstream project limits (tie-in points). Existing channel slopes noted upstream and downstream of the existing culvert.
- Plan view should clearly show the existing structure, structure alignment, dimensions, road approaches, cross section locations and any wetlands.
- Section drawings should show the existing structure dimensions, elevation, and depth of road cover.
- Drawings include existing roadway elevation, and elevation and location of benchmarks.

☐ ***B. Location and bankfull width of stream.***

- The plan view drawings note and depict the bankfull width of the stream, bankfull elevation(s) and the location of all cross-sectional measurements.

☐ ***C. Proposed stream crossing structure width, length and height with profile and typical cross sections.***

- Plans show structure dimensions and elevations, including inlet and outlet invert elevations and locations, on the plan, section and profile views.
- Proposed alignment of replacement structure is shown on the plan view.
- If applicable, footer dimensions, elevations and depth of bury are provided.
- Finished roadway elevation over structure depicted on profile and section views.
- Clearly labeled discharge values and water surface elevations at the proposed crossing inlet for the Q2, Q10, Q25, Q50, and Q100.

☐ ***D. Elevations and locations of abutments, footings, wingwalls and other associated appurtenances.***

- The proposed conditions drawings show the locations and elevations of all structure features such as abutments, footings, wingwalls and other associated appurtenances.

☐ ***E. Details for stream bed re-construction (e.g. channel width, proposed channel alignment, channel side slopes, stream bed slope and location of tie-in points).***

- The proposed-conditions plan view and profile drawings adequately inform reconstruction of a stable stream channel that reestablishes and maintains longitudinal continuity upstream, through, and downstream of the replacement crossing.
- Clearly shows on the profile drawing the design slope and depth of streambed material in the proposed reconstructed reach.

- Shows design of streambed and bank margin including rock sizing and elevations at structure inlet and outlet and extending upstream and downstream of the crossing as needed to tie into existing streambed and banks.
- Notes locations and elevations of tie-in points at upstream- and downstream limits of the reconstructed reach (these should occur at existing grade control features).
- The proposed bankfull width of the reconstructed reach shown to scale, with design bankfull width noted.
- Identifies method for stabilizing transition areas at upper and lower project limits.

☐ ***F. Location and details for low flow channel width, depth, and material size and types.***
- Low flow channel dimensions from the cross-sectional surveys are shown on the section view.
- Details should include the width and depth of the channel and information on the stream bed materials used in constructing the low flow channel.

☐ ***G. Locations and construction details, including rock sizing, of in-stream structures, grade controls, and/or bank stabilization structures (if applicable).***
- Plan, section and profile drawings clearly show all grade controls and instream structures, including locations and elevations of grade control features (at crest / thalweg) through the reconstructed reach.
- Plans should note whether grade control features at the tie-in points will be maintained as existing (stable) or will be constructed. For constructed riffles, the design riffle length should be specified.
- Detail drawings for grade control structures should clearly indicate material type, size, installation slopes and overall structure length.

☐ ***H. Thickness, gradation and composition of material for streambed restoration.***
- On the proposed section and profile view the streambed material thickness, inlet and outlet bed elevations should be shown.
- Material gradation and composition should be specified. Note if native material onsite will be reused or if material will need to be imported.
- Gradation, composition and construction details included for the low flow channel, bankfull channel and the bank margins.

☐ ***I. Specification for compaction of placed streambed material.***
- Details provided on compaction (mechanical or hydraulic) of materials used to construct the streambed through the reconstructed reach to prevent subsurface flow down through the substrate.
- Note that substrate is thoroughly compacted when water stays on top of the newly constructed stream bed and does not go subsurface.

☐ ***J. Scour hole restoration details and reestablishing channel cross section.***
- If applicable, details are provided to indicate material type, size, and depth to reconstruct the scour hole.
- Reconstruction of the channel cross section through the scour hole should be shown to tie into the existing or reconstructed stream bed.

☐ ***K. Structure manufacturer's specifications, details, and installation instructions.***
- Submittal includes all structure specification drawings, including applicable structural details of all components, including but not limited to reinforcing steel, type of materials, thickness, anchorage requirements, backfill lift thickness, etc.

☐ ***L. Thickness, compressive strength, reinforcement, testing, and other special requirements for concrete according to the manufacturer specifications, if applicable.***
- If applicable, concrete specifications and manufacturer's requirements are provided.
- Includes details for concrete sampling and testing as required.

☐ ***M. Load limits for bridges and/or culverts including signage per local codes.***
- All details related to structure load limits and related signage per Township and PA code are provided.

☐ ***N. Location of all utilities and notification requirements (PA One Call).***

- Drawings show locations of all utilities and specifies contractor notification requirements for PA One Call.

☐ ***O. Location and elevation of survey benchmarks.***
- Elevations and locations of benchmarks are clearly shown on design plans.

☐ ***P. Method of surface water diversion and dewatering during construction***.
- Submittal includes detail drawings for diversion of the stream flow and dewatering of the construction site.
- Provides details for control of sediment during diversion and dewatering.

☐ ***Q. Approved Erosion and Sedimentation Control Plan***.
- Construction documents will include an approved E&S Plan with detail drawings for all BMPs to be used during construction.

☐ ***R. Vegetative requirements that include seed and plant materials to be used, establishment rates, and season of planting.***
- Plans include details on reseeding and establishment rate. Should note if any specialized bank stabilization or soil amendments will be needed to ensure establishment.

☐ ***S. Additional site-specific requirements.***
- Stream crossing replacements through the DGLVR Program include many aspects that differ from more basic culvert replacement projects, therefore project specifications should be included with the bid package.
- If not provided as notations to the detail drawings, separate site-specific specification documents should be provided for unique construction elements. This allows prospective contractors a clear sense of the project goals and needs, establishing a clear understanding of construction requirements.

Notes:
____

____

____

____

____

____

____

____

____

____

____

Bid Package Review Checklist for Stream Crossings ☐ DGR ☐ LVR

Applicant: ______________________ Road Name: ________________________ LAT/LONG: ________________

Engineer / Consultant / Bid Preparer: ____ Date: _____________

Conservation district Reviewer: ____

Administrative

- ☐ Project Name provided
- ☐ Project Location provided
- ☐ Project Owner listed
- ☐ Contact person(s) identified
- ☐ Bid Advertisement release date listed
- ☐ Brief project narrative provided, including general scope of work
- ☐ How, when and where prospective bidder can obtain Construction Documents and Bid Forms
- ☐ Proposal submittal deadline (date and time)
- ☐ Method of delivery accepted (mail, email, fax, hand-delivered, etc.)
- ☐ Bid withdrawal limitations
- ☐ Bid type (lump sum, unit cost, not to exceed, etc.) is listed
  - ☐ If unit cost, unit cost form is provided
- ☐ Statement that submittal of bid acknowledges full knowledge of site conditions, content of construction documents and understanding of scope of work.
- ☐ Bid opening / award date is listed

Bid Site Showing

- ☐ Bid Site Showing information is provided, including date, time and location
- ☐ Note whether or not attendance is mandatory.

Provisions and Requirements

- ☐ Notice of Road Bonds (if applicable)
- ☐ Notice of Project Bonds (if applicable)
  - ☐ Payment Bond
  - ☐ Performance Bond
- ☐ Prevailing Wage requirements are provided

General Conditions

- ☐ General Work Items (scope of work) to be completed by successful bidder are listed
- ☐ General work items to be completed or provided by others are listed
- ☐ Contract Time (start/end date) is stated
- ☐ List any seasonal work restrictions
- ☐ Engineer, conservation district, CDGRS, TU and project owner will have full access to the construction site.
- ☐ References portions of Construction Documents specifying “critical aspects of construction” that must be completed under direct oversight

Proposal Form provides for the following information from the bidder:

- ☐ Name, contact information, bid price and signature
- ☐ Written acknowledgement of construction documents and addenda (if applicable)
- ☐ Statement of Qualifications (if required)
- ☐ References to similar services rendered or projects completed (if required)

Unit Cost Sheet (if applicable)

- ☐ Lists pay items, units, and estimated quantities
- ☐ Provides space for bidder to enter unit cost and total item bid price

<u>Notes</u>:

____

____

____

____

____

____

____

____

____

____

____

Bid Site Showing Checklist for Stream Crossings

☐ **DGR** ☐ **LVR** **Date:** ______________

Applicant: ___________________ **Road Name:** ___________________ **LAT/LONG:** ___________________________

Applicant Reps: ____

CD Reps: ____

Engineer Present: ☐ **Yes** ☐ **No** **Engineer Rep:** ____

Is prospective bidder attendance mandatory for eligibility to submit a bid?: ☐ **Yes** ☐ **No**

Summarizes discussion points for bid advertisement meeting and site showing held prior to receiving bids. More information in Chapter 8 of the DGLVR Stream Crossing Replacement Technical Manual.

Administration

- ☐ **Provide sign-in sheet** (all attendees provide contact info)
- ☐ **Write down questions / points for clarification** (for preparing Addendum)
- ☐ **Designate a contact person and provide contact information** (for bidders to submit additional questions)

Discussion Points

- ☐ **Bid submittal deadline:** ____________________________ **Bid award date:** _______________
- ☐ **General scope of work:** (excavation, structure removal / installation, stream restoration, rebuild stream through culvert, etc.)
- ☐ **Roles and Responsibilities**
  - **In-kind contributions:** (labor, equipment, materials from applicant/owner)
  - **Sub-contractor work:** (subbed to the project owner, if applicable)
  - **Successful bidder's responsibilities**
- ☐ **Emphasize instream aspects of work**
  - **Dewatering Plan:** (method, timing, E&S, etc.)
  - **Stream Continuity:** (reconstructed slope, tie in points, grade control details, instream structures, etc.)
  - **Structure:** (elevations, backfill / road fill cover requirements, bury depth, headwall/endwall/wingwalls)
  - **Streambed:** (material, methods, and equipment for placement, shaping and compaction within structure)
- ☐ **Project limits:** (how far upstream / downstream, extent of roadway/drainage work, etc.)
- ☐ **Notification requirements:** (when to notify CD and project owner/applicant prior to start of work)
- ☐ **Project schedule and timeline:** (expected start/completion dates, project phases, structure delivery, road closure duration, seasonal / regulatory time restrictions, etc.)
- ☐ **Traffic control**: (road closure, lane closure, signage, etc.)
- ☐ **Oversight:** (CD involvement (regularly during construction), CDGRS, SCC, TU, others that may oversee / inspect)
- ☐ **Engineer inspection requirements and timing:** ("critical stages of construction" from DGLVR Stream Crossing Standard and/or Construction Documents)
- ☐ **Prevailing wage requirements**
- ☐ **Permits:** (status/issuance, permit conditions addressed in the Construction Documents)
- ☐ **Erosion and sediment controls** (overview of plan, sequence, BMPs, etc.)
- ☐ **Landowner agreements** (written approval prior to work outside the ROW)
- ☐ **Staging areas, storage areas, and proposed construction access routes**
- ☐ **Structure delivery and assembly** (who is responsible; when will it be delivered; where will it be stored; will it be delivered pre-assembled; who will assemble; will it be assembled in-place, or outside of the road cut and then installed)
- ☐ **Road drainage improvement locations** (review location and installation of other drainage BMPs)

Meeting Notes:

____

____

____

Pre-Construction Meeting Checklist for Stream Crossings ☐ DGR ☐ LVR Date: _______

Applicant: ____________________ **Road Name:** ____________________ **LAT/LONG:** ____________________________

Applicant Reps: ____

CD Reps: ____

Additional Attendees: ____

Summarizes discussion points for an on-site meeting prior to construction. More information in Chapter 8 of the DGLVR Stream Crossing Replacement Technical Manual.

Logistical Discussion Points

- ☐ **Proposed start date:** ________________ **Proposed completion date:** _______________
- ☐ **CD Notification:** __________days before project work begins by applicant
- ☐ **Timelines** (mobilization, demobilization, project phases)
  - Deadlines for instream work restrictions
- ☐ **Project Overview / Changes:** (overview workplan, procedures for changes in project scope, timeline, cost)
- ☐ **Notifications:** (PA One-Call, 911 services, notify impacted landowners, road closures, signage)
- ☐ **Site Marking**: (Considerer painting or flagging features on the road before or during the meeting)
- ☐ **Oversight:** Level of on-site CD involvement (at a minimum, the CD must be on site regularly during construction)
- ☐ **Engineer inspection requirements and timing:**
  - Installation of structure subgrade
  - Installation of footings, abutments, etc.
  - Installation of grade control features, bank margins, and streambed substrate.
  - Installation or placement of stream crossing structure
  - Compaction and backfill of stream crossing structure
- ☐ **Discuss chain of contact between all entities:**
  - Point of contact for each entity
  - Who initiates each step or verifies each step prior to moving forward
- ☐ **Receipts:** (receipts, invoices, or other appropriate proof of expenses)
- ☐ **Prevailing wage:** (copy of certified payroll needed prior to making final payment)
- ☐ **Permits:** (in place before work begins, meet any seasonal restrictions)
- ☐ **Final inspection:**
  - The design engineer must provide the project owner with a signed and sealed certification for that certifies the critical stages were inspected and installed in accordance with the DGLVR Stream Crossing Design and Installation Standard and construction documents.
  - Engineer must provide red-lined construction document indicating the as-built conditions

Project-Specific Discussion Points

- ☐ **Erosion and sediment controls** (what is needed and who is responsible)
  - Review the approved plan and discuss provision for any necessary changes
- ☐ **Landowner agreements** (written approval prior to work outside the ROW)
- ☐ **Staging or storage areas** (for equipment and materials storage if necessary)
- ☐ **Waste sites**
- ☐ **Structure**
  - Delivery: when, where
  - Assembly: when, where (in channel or out), who
  - Installation: when, who, equipment needed
- ☐ **Stream Crossing Construction Plans**
  - **Stream Continuity**
    - Reconstructed slope
    - Tie in points
    - Grade control details
    - In stream structures

        - Etc.
    - **Structure**
        - Elevations
        - Backfill / Cover over new structure
        - Transitions
        - Headwalls / endwalls
    - **Streambed**
        - Filling in scour hole / streambank stabilization
        - Streambed material reconstruction (composition, equipment)
        - Compaction and washing fines (how, water source)
- ☐ **Road drainage improvement locations** (review location and installation of other drainage BMPS)

Meeting Notes:

____

____

____

____

____

____

____

____

____

____

Construction Inspection Checklist for Stream Crossings ☐ DGR ☐ LVR

Applicant: ____________________ **Road Name:** ____________________ **LAT/LONG:** ____________________

Applicant Reps: ____

CD Reps: ____

Contractors Present: ____

Others Present: ____

- ☐ Conservation districts must be on-site regularly during construction to ensure DGLVR Policy and standards are being met
- ☐ Safety: Wear proper PPE and follow standard safety practices on site
- ☐ Ensure all local, state, and federal requirements must be met before starting construction
  - Permits, PA One-Call, written landowner permission for off-ROW work, etc.
- ☐ Verify 2 benchmarks were set by the engineer or surveyor in an area outside of the zone of construction and disturbance
- ☐ Survey Stakeout for critical stages of installation
- ☐ Inspection of critical stages of construction by Engineer and/or Engineer's designee. Critical Stages include, but are not limited to, the following:
  - Installation of structure subgrade and bedding materials and inverts/elevations.
  - Installation of footings, abutments or in-ground appurtenances.
  - Installation of grade control features, bank margins, and streambed substrate
  - Installation or placement of stream crossing structure.
  - Compaction and backfill of stream crossing structure.
- ☐ Changes: If any party believes modifications are required or site work needs to stop to address a critical situation, they should discuss their concerns with the onsite contractor and then immediately notify the road owner, project engineer, and conservation district.
  - Proposed changes to a plan or specification should be reviewed and agreed upon by all parties and must be approved by the design engineer.
  - Any changes to plans that alter permit acknowledgments must also be submitted to the reviewing entity for revised approval.
- ☐ Follow manufacturer's recommendations for structure installation, including assembly, bedding, and backfill.
- ☐ Verify the project is being constructed in accordance with the approved bids and plans
  - Verify appropriate structure is being utilized as per approved plans
  - Structure properly aligned with channel
  - floodplain connectivity
  - Project will be constructed to accommodate AOP
  - Low flow channel with well-defined bank margins must be constructed through the structure
  - Minimum substrate depth is installed through the structure
  - Restore Stream Continuity through the structure and extend as far as needed to reconnect with the natural channel and, to the greatest extend possible, match existing stream bed slope
    - In-stream channel grade controls installed at proper location, elevation, and spacing to reconstruct the stream channel
  - Stable Side Slopes per DGLVR Stream Crossing Standard
- ☐ Quarried aggregate was tested and meets requirements of the DGLVR Stream Crossing Standard
- ☐ Vegetation Standard Requirements in DGLVR Stream Crossing Standard Met
- ☐ Road Approaches Requirements in DGLVR Stream Crossing Standard Met
- ☐ For additional guidance, see the PA DGLVR Program Stream Crossing Design & Installation Standard, Stream Crossing Technical Replacement Manual and Technical Bulletins

Notes:

Completion/Final Inspection Meeting Checklist for Stream Crossings ☐ DGR ☐ LVR

Applicant: ____________________ **Road Name:** _____________________ **LAT/LONG:**_________________________

Applicant Reps: ____ **Date:** _______________

CD Reps: ____

Additional Attendees: ____

Summarizes discussion points for an on-site closeout meeting. More information in Chapter 10 of the DGLVR Stream Crossing Replacement Technical Manual, and 3.8.9 of the DGLVR Administrative Guidance Manual.

Final Site Inspection

- ☐ **All stream crossing components properly installed**
  - See Site Inspection Checklist
  - Stream crossing structure and appurtenances installed according to plan, permit requirements, and DGLVR requirements
  - Stream restoration completed according to plan, permit requirements, and DGLVR requirements: including low flow channel, stream banks, and grade control structures, continuity
- ☐ **Other ESM Practices** –all other ESM Practices installed according to plan and DGLVR requirements
  - Cross pipes, ditch disconnection, French mattress, underdrain, Driving Surface Aggregate, etc.
- ☐ **Engineer Certification**
  - Signed and sealed by the engineer
  - Includes redline mark-of construction documents or as-built drawings
  - Provided to conservation district and grant recipient
- ☐ **Erosion and Sedimentation (E&S) controls**
  - E&S controls such as pumps, dams, filter bags, and silt fence are removed and properly disposed of
  - Disturbed earth is stabilized (minimum 70% uniform vegetative cover, rip-rap, etc.)
- ☐ **General Site Clean Up**
  - Equipment and excess material are removed from (or planned to be removed from) the site
  - Note: It is helpful to complete the final site inspection while equipment is still on site in case touch-ups are needed. It is also good to remind the grant recipient and contractor that they are responsible for cleaning up and stabilizing the site upon completion.
- ☐ **Follow Up Inspection** – (if applicable) Issues identified in the final inspection are corrected.

File Requirements

- ☐ **Completion Report:** filled out appropriately and signed by conservation district and grant recipient
- ☐ **Financial Documentation:** provided and matches the Completion Report
- ☐ **PA One-Call Number**
- ☐ **Prevailing Wage Weekly Payroll and Certified Statement of Compliance (if applicable)**
- ☐ **Other paperwork: See "Hard File" Project Checklist** for full list of required and recommended documentation
- ☐ **Final Payment** cannot be made until the site and file meet all requirements
  - If applicable, provide local maintenance policies or recommendations with payment to grant recipient
- ☐ **Copy of Checks:** included in the conservation district project file
- ☐ **Update CDGRS Mapper -** enter the payment, fill out the completion report, and mark the project as "complete"

Meeting Notes:

____

____

Appendix H. Technical Bulletins

The technical bulletins provide additional details to specific topics contained in the DGLVR Stream Crossing Replacement Technical Manual.

- **Bankfull Width Determination:** Guidance and examples for determining the bankfull width of a variety of stream types in Pennsylvania.

- **Site Assessment - Longitudinal Profile & Cross-Section**: Guidance for conducting a longitudinal stream survey to determine channel slope and other characteristics to guide project design.

- **Structure Selection for Stream Crossings**: Guidance and "pros and cons" of various common stream crossing structure types.

- **Grade Control**: Guidance on the use, design, and installation of large rock or other structures that are immobile in the channel and set the slope and form of the stream.

- **Streambed Restoration**: Guidance on the re-establishment of streambed material through a new crossing structure and the reconstructed reach of the stream.

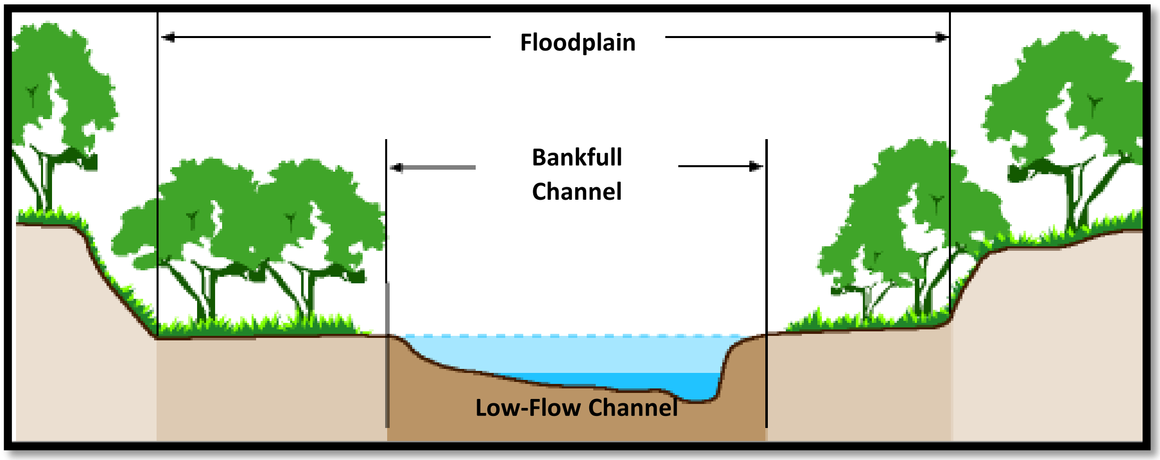
Technical Bulletin

Bankfull Width Determination

Center for Dirt and Gravel Road Studies

7/2022

BANKFULL FLOW (STAGE OR ELEVATION) – This flow stage is determined by the elevation point at which the stream accesses the floodplain. This point is typically indicated by deposits of sand or silt at the active scour mark, a break in stream bank slope, perennial vegetation limit, rock discoloration, and root hair exposure. The bankfull flow is also known as the channel-forming or dominant discharge, which is the flow that transports the most sediment over time and is the most effective in shaping and maintaining the natural stream channel. The bankfull flow roughly corresponds to a 1.5-2 year recurrence interval. The **BANKFULL CHANNEL WIDTH** is the width of the channel at the bankfull flow elevation.



Bankfull Width: The average width of the channel at the bankfull elevation. (image credit USFS)

Finding the Natural Channel of a Stream:

Because streams vary widely in composition, slope, and human-made impacts, it is impossible to create a set of “instructions” for determining bankfull that will work on every channel. The goal when determining bankfull flow is to find an area that represents natural channel conditions either upstream or downstream of the crossing. This sometimes means moving further upstream or downstream away from the structure, or skipping sections of stream that are unnaturally widened or constricted. **Be flexible and think logically in choosing your bankfull measurement stream section in order to get the best representation of the natural channel.**

Procedure for Determining Bankfull Width Near a Road / Stream Crossing Structure:

Location: Start at a location away from the influence of any culvert or bridge, since they often impact channel width. To do this, roughly estimate bankfull channel width, then go at least 5 times that distance away from the structure. Looking upstream is preferred, but downstream reaches can be used if necessary *(see locations to avoid below).* **Be sure to notify landowners and receive permission before entering private property.**

Determine Bankfull: Because the bankfull flow does the greatest amount of work forming the channel, the bankfull stage is identifiable in the field. Using the indicators listed below, begin by looking up in the floodplain and then work down toward the stream. Using both sides of the channel, find the elevation of the best bankfull indicators and mark those locations, using flags if necessary. Stretch a measuring tape across the stream at your bankfull mark(s), noting that the tape should be level, to measure the bankfull channel width. Continue moving upstream or downstream, taking successive measurements that are at least 1/2 bankfull width apart (for example, if the first bankfull measurement is 16 feet, move at least 8 feet away before taking another measurement). Collect at least 5 measurements and average them together. More than 5 bankfull measurements can be used to obtain a better average if needed. This is only a general guide; note the “locations to avoid” section that follows.

Be flexible and think logically in choosing the best indicators for your bankfull measurement locations.

Field Indicators of Bankfull Flow: *(listed in order from most to lease reliable indicators)*

1. Change in Bank Slope: Bankfull flows are often associated with "benches" or the top of the stream bank, unless the stream is entrenched or has been altered in the past.

2. Depositional Features: The top of features such as point bars and mid-channel bars are often indicators of the bankfull flow elevation. Use these elevations to look for additional clues on each bank at the same elevation.

3. Changes in Particle Size: Streams drop sediment when they start accessing their floodplain. A Change in particle size along a stream bank (from gravelly, to silty or sandy) often indicates bankfull elevation.

4. Vegetation Changes: Although not as reliable, changes in vegetation can indicate bankfull elevation.

5. Scour Features: Erosion and scour lines can be used if other features cannot be located.

Locations to Avoid in Determining Bankfull Flow: *(if possible)*

Logjams or Fallen Trees: These structures tend to increase the bankfull width in their immediate vicinity.

Human-made Impacts: Avoid locations with wall, weirs, dams, rip-rap, pipes, etc.

Bedrock Outcroppings: Bedrock can hide indicators of bankfull flow and alter channel width.

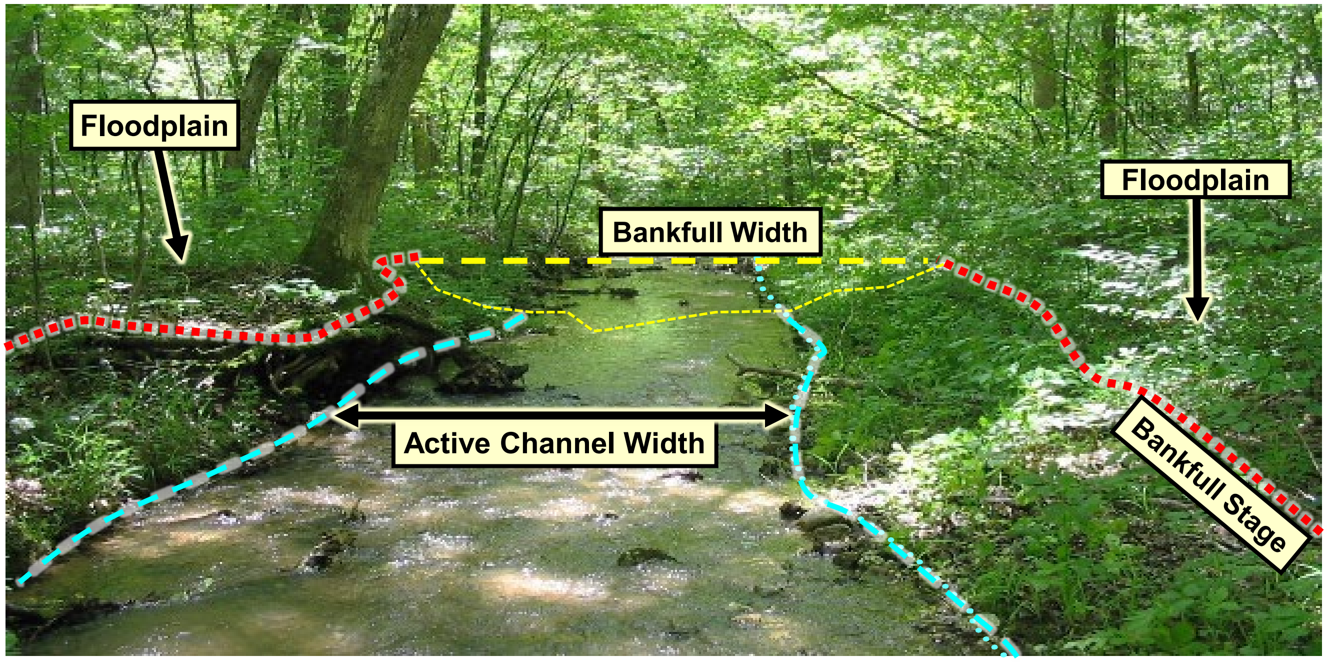
Braided Channels: Measure upstream or downstream of any braided channels, if at all possible.

Tributaries/Springs: Measure bankfull between road crossing and any incoming flows that may increase width.

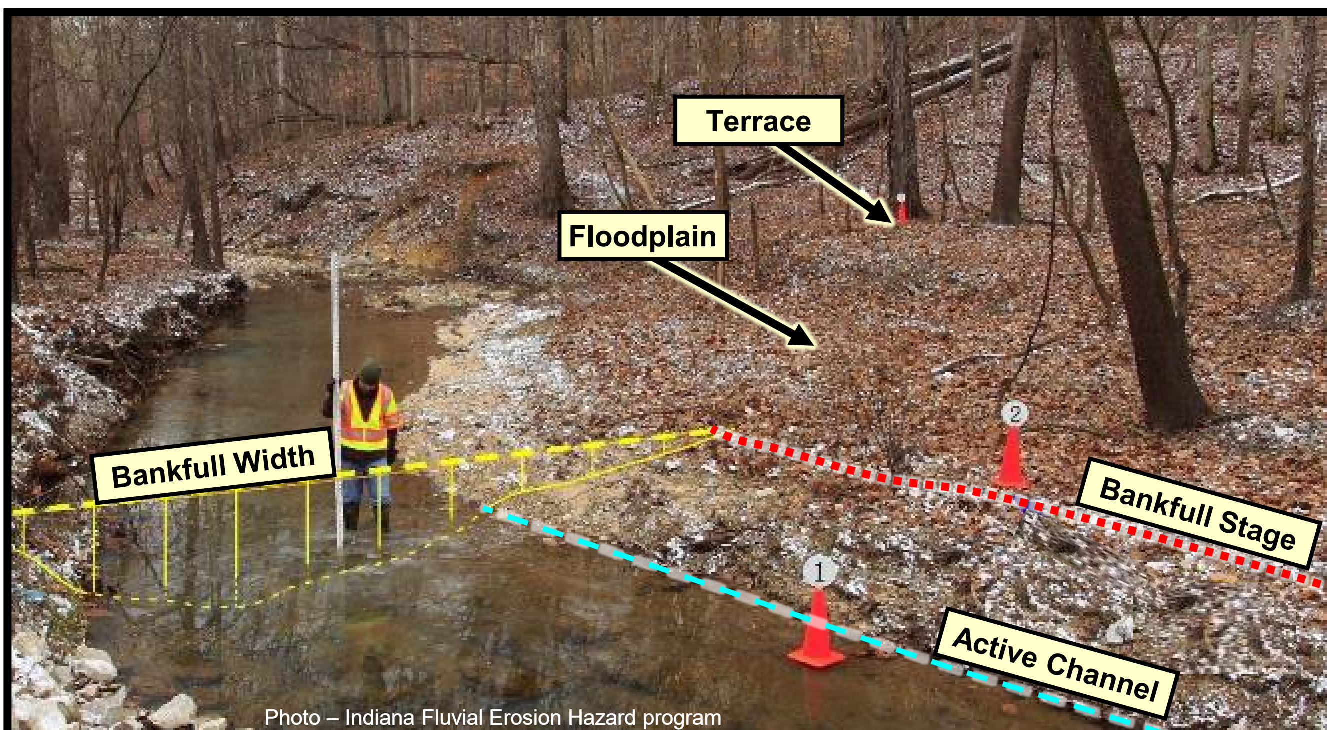
Hard Meander Bends: Hard bends make it difficult to find good indicators, since the stream is moving laterally.

Additional Bankfull Determination Tips:

- Bankfull flows will be level across the channel, so ensure the tape is level when measuring bankfull widths. If you find strong indicators on one bank, you can stretch your tape level across the stream to get the width.
- When looking for bankfull indicators, think logically about a 1.5-2 year recurrence interval. Does it make sense that the points you are measuring as bankfull will see flow with that frequency?
- When changes in bank slope are strong field indicators, cross sections collected in the same reach can be used to verify bankfull width by comparing the location of slope changes from the cross section with those in the field.
- On entrenched streams, or streams with historically high sediment impacts (legacy sediments), bankfull elevation is often below the elevation of the "top of stream bank" due to many years of human-made impacts.
- Note that tree roots and other vegetation can exist below the bankfull elevation, especially in dry years.
- Measuring bankfull is often easier during Spring and Fall when vegetation is dormant.
- As long as there are no major tributaries, channel splits, or changes in stream type, you can go as far as needed upstream and downstream of the crossing to find "natural" spots to take bankfull measurements.
- **Be flexible in your measurement locations to find the best representation of the natural channel.**



This photo shows a typical forested stream in the summer. Bankfull width is significantly wider than the stream bed width. Bankfull indicators are obscured by vegetation on the right side of the photo and complicated by roots and vegetation growth on the left side of the photo.

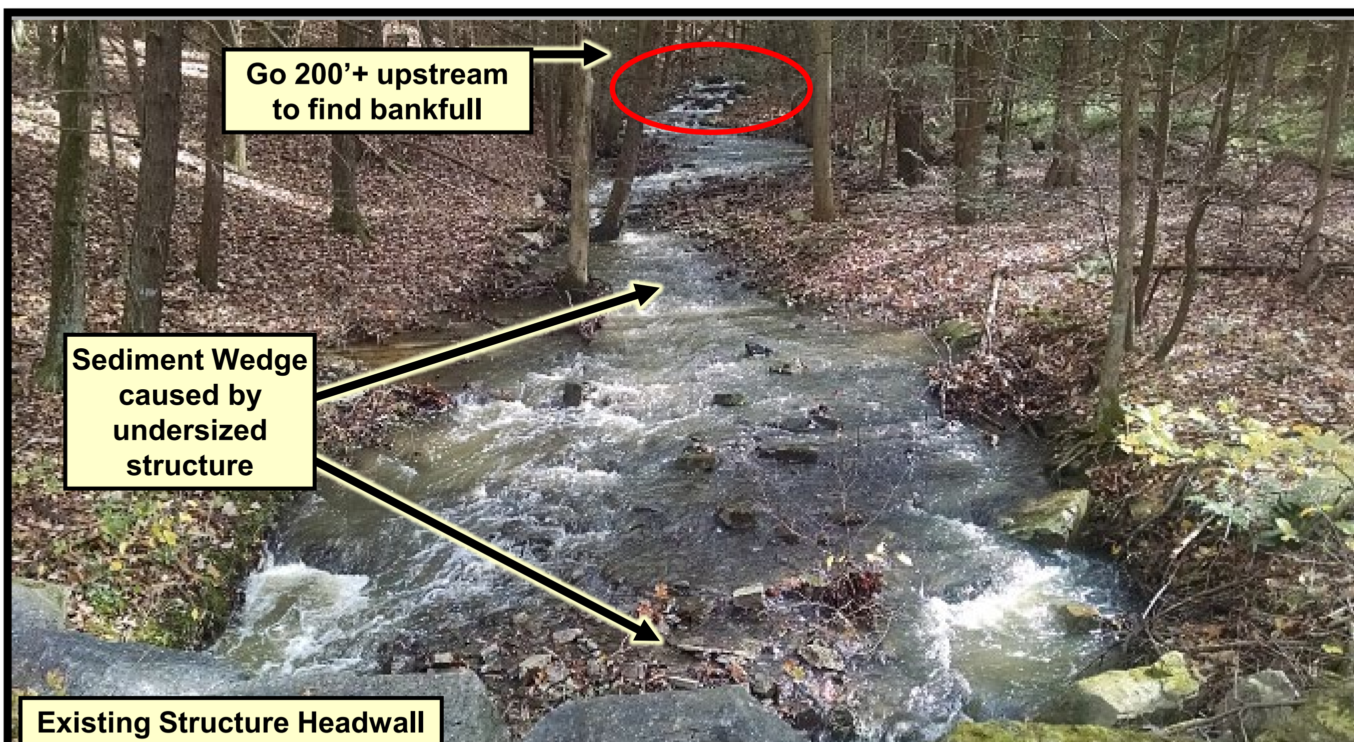


This photo shows a typical forested stream in the winter. Bankfull indicators such as changes in slope, depositional features, and changes in particle size are more obvious due to lack of vegetation.

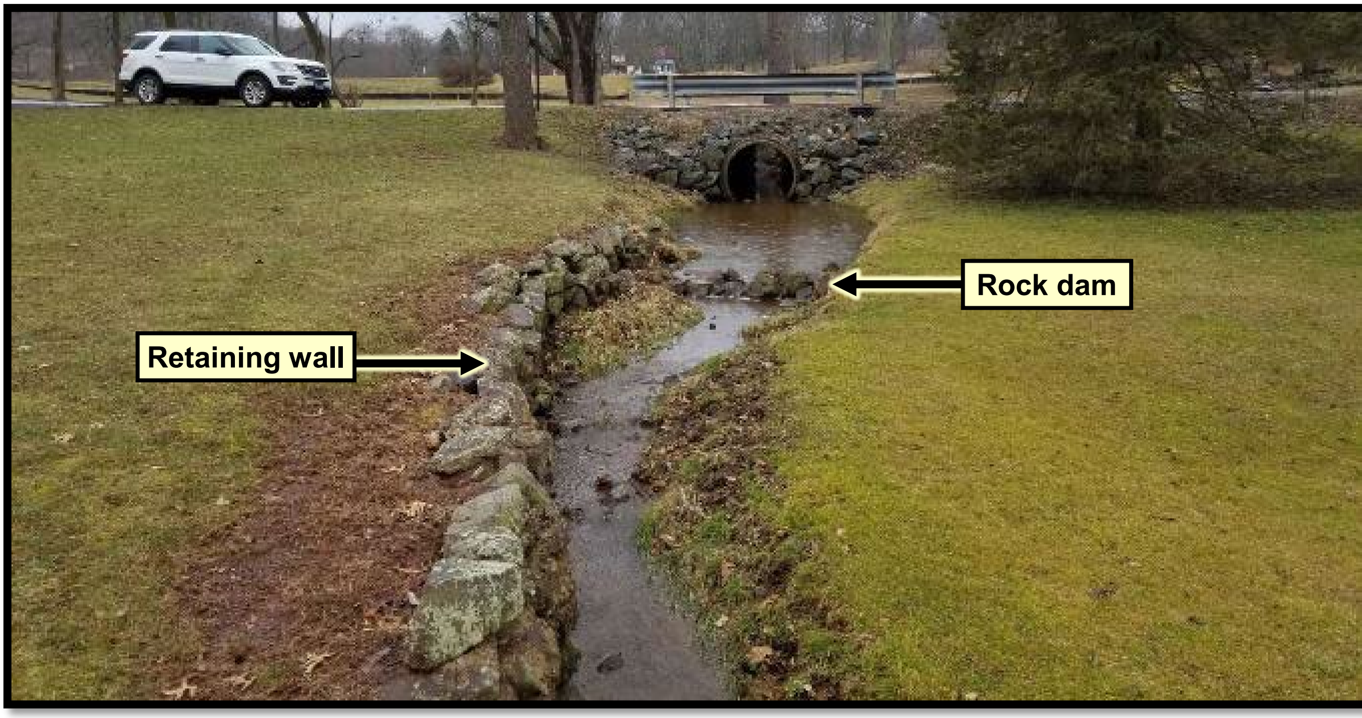
Entrenched channels are often found in agricultural settings and in high gradient channels. When measuring entrenched channels, the bankfull width and channel width are often the same.

Additional water sources such as tributaries, springs, or tile drains add additional flow and change the bankfull width. If additional water enters above the crossing, then measurements should be taken downstream of the crossing. If additional water enters below the crossing, then measurements should be taken upstream of the crossing. Bankfull measurements of tributaries cannot simply be “added” to get an accurate bankfull width of the combined channel.

This photo shows a stream section with **locations to avoid when measuring bankfull**. In the foreground, the channel is over-widened and there is noticeable vegetation in the stream. Upstream there is a log jam and downed trees impacting the stream channel. Remember to be flexible when locating the best representation of the natural channel.



This photo shows a sediment wedge that has formed upstream of an undersized structure, causing over-widening of the channel. The impacts from the undersized structure extend approximately 150 feet upstream, and this section should be avoided when measuring bankfull. The red oval shows where the natural channel begins.

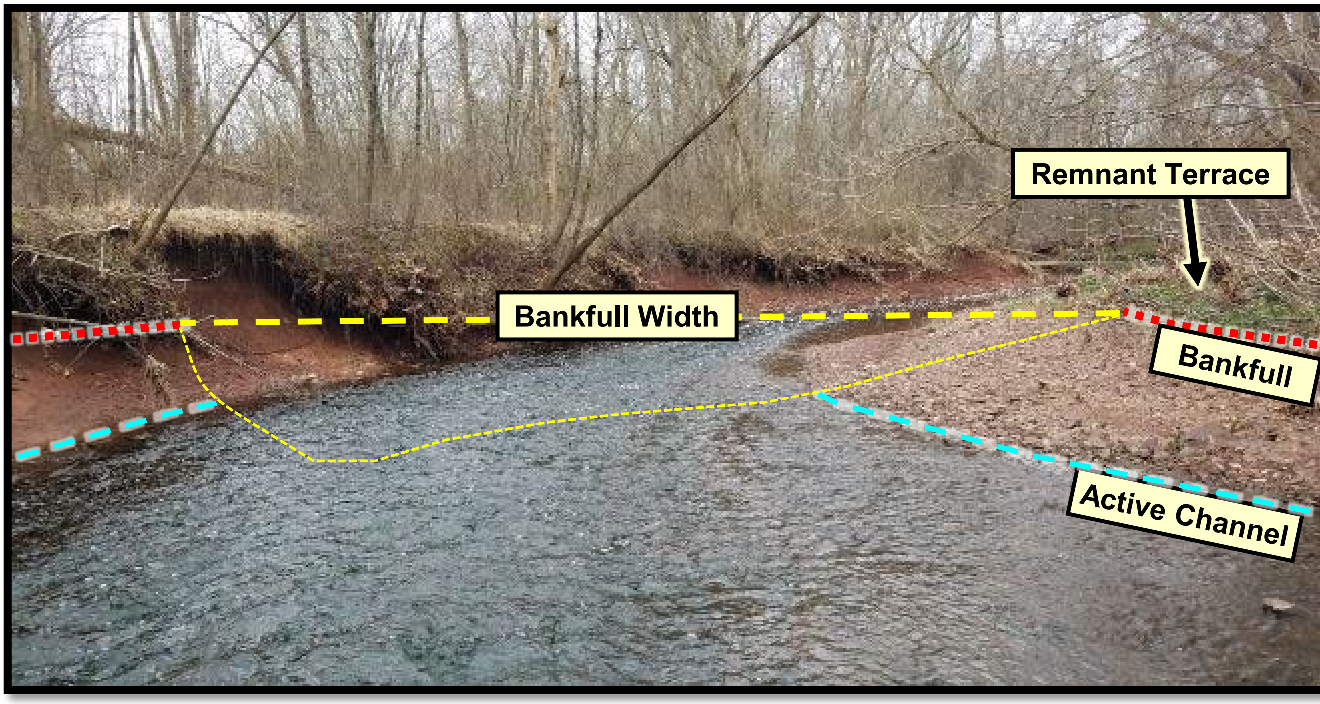


Urban settings pose unique challenges due to human channel modifications. In areas with significant disturbance near the structure, it is necessary to start looking for bankfull indicators more than 5 bankfull widths away from the crossing.

This creek flows through a park and shows impacts from channel modification and failed bank stabilization attempts due to channel downcutting. In areas with significant human-caused bank disturbance, it is necessary to start looking for bankfull indicators more than 5 bankfull widths away from the crossing.

In bedrock and boulder channels, bankfull indicators typically include scour lines on the rocks, fine sediment deposition, and potentially vegetation changes.

Some settings call for creative bankfull measurement. This small entrenched channel in an agricultural field has a bankfull width equal to the stream bed width of just over 1’.



This stream is aggressively adjusting both laterally and vertically. Bankfull elevation is at the top of the gravel point bar shown with the red line on the right, not at the more obvious grade break at the top of the grassy bench where the stream engages its floodplain. This elevation of the grade break is the top of a remnant terrace that is engaged at flows higher than bankfull. This is also a difficult place to measure bankfull due to being on a bend. Avoid measuring bankfull on meander bends like this if possible.

This stream has multiple braids of the main channel and is impacted by significant amounts of large woody debris. Bankfull measurements should not be taken in this section.

Technical Bulletin
Site Assessment - Longitudinal Profile & Cross-Section

PENNSTATE — Center for Dirt and Gravel Road Studies

7/2022

LONGITUDINAL PROFILE (LONG-PRO) – A survey conducted upstream, downstream, and through an existing structure to determine the stream channel features that are critical to a successful structure replacement, such as: channel and structure slope, grade control types and spacing, scour depth, tie in locations, aggregation wedges, plunge pools, vertical offset of the structure, available cover, and more.

CROSS-SECTION SURVEY – A survey conducted across the channel (perpendicular to the thalweg) to produce a graphical representation of channel dimensions including shape, depth, and width.

Other Useful Definitions:

- ✓ **grade control:** instream features such as large rocks, logs, or human-made structures that control channel elevation and slope
- ✓ **grade control spacing:** the average spacing between grade controls in the channel
- ✓ **vertical offset:** vertical difference in existing inlet and outlet streambed elevations
- ✓ **plunge pool:** the large scour hole often caused at the outlet of undersized crossings
- ✓ **sediment wedge:** aggregation of sediment at the inlet of undersize crossings; often in the form of a gravel bar
- ✓ **thalweg:** the deepest part of the channel cross-section

STREAM CONTINUITY

During high water, natural stream channels move sediment (rock, gravel, sand, etc.), large wood, nutrients, and debris downslope through the landscape. Over time, undersized road/stream crossings often disrupt this natural channel movement or continuity by depositing sediment at the inlet, creating a plunge pool at the outlet, and therefore creating a 'vertical offset' between inlet and outlet streambed elevations.

When replacing undersized structures, it is necessary to survey upstream and downstream of the structure itself. Stream characteristics such as slope, grade control size and spacing, channel shape, and bed composition should be consistent through and beyond the project area. **Re-establishing and maintaining channel continuity is essential for the long-term function, durability, aquatic organism passage, and flood resiliency of the new crossing, as well as meeting DEP permit and DGLVR Program requirements.**

LONGITUDINAL PROFILE SURVEY (long-pro)

Developing a longitudinal profile is one of the most important steps to providing the information necessary to implement a successful stream crossing replacement and restore connectivity. The long-pro encompasses an elevation survey upstream, downstream, and through/over the existing structure. It informs a variety of decisions from structure selection to the amount and type of streambed material and grade control needed. It also includes cross-sectional surveys across the channel to identify channel shape and characteristics.

A long-pro is typically done by the conservation district very early in the project development process, and is <u>required</u> for each site prior to the QAB recommendation for funding. The long-pro survey is intended to provide enough detail on stream slope, grade control, structure cover, and other factors to be able to develop realistic cost estimates for developing a grant application. The project engineer has discretion to use a survey provided by the conservation district or conduct a new survey for final design and permitting. A long-pro is required for each site prior to permitting. A conservation district technician is required to be onsite while the survey is being performed by the engineer and/or surveyor to observe and ensure that all required points are obtained. The engineer shall provide the completed survey and stream longitudinal profile to the district technician to assist in determining substrate depths and grade control types and spacing.

PLANNING A LONGITUDINAL PROFILE SURVEY

<u>Equipment</u>: A simple long-pro can usually be done with a tape (recommended 300'), a laser level, field book, flagging, and stakes. These tools will allow you to measure and record distance and elevation values that can later be plotted on a graph to determine stream characteristics. To reduce the number of times the survey laser must be moved, it is recommended that a laser be used that can accurately shoot 300' and at least a 20-foot-long survey rod. **Be sure to notify landowners and receive permission before starting the survey.** This is also an opportunity to explain the project to the landowner and gauge their level of support, since off-right-of-way channel work is required in most stream crossings.

Site Walkthrough: Prior to setting up equipment to perform the survey, begin with a walkthrough of the project site and adjoining stream sections upstream and downstream of the road/stream crossing. During the walkthrough, consider what is the extent of up and downstream channel impacted by the existing crossing structure (aggradation, bed scour, over-widening, bank erosion, etc.)? Larger impacts will likely require surveying a longer reach to determine stable tie-in locations. These are the locations where the constructed channel slope through the structure can be reconnected or "tied-in" to the existing channel, typically at a stable riffle crest, step, or cascade. Additionally, the following should be taken into consideration during the initial walkthrough and survey setup.

- Optimal setup location for the survey instrument to maximize the line-of-sight to the upstream and downstream limits of survey, as well as to the benchmark. The goal is to not have to move the instrument during the survey, greatly reducing the possible introduction of error.
- Extent of survey needed to capture typical channel conditions beyond the areas of impact from the existing crossing (reference reach).

Survey Extent: The extent of the stream segment to be surveyed is best determined based on site-specific conditions observed during the walkthrough (above). At a minimum, the longitudinal profile survey must extend 150' upstream and 150' downstream of the existing crossing. Additional length of survey may be needed to capture potential stable tie-in locations and to include the channel above and below these tie-ins. Begin and end the survey at existing grade control crests (see below). The survey must extend far enough upstream and downstream of the crossing to determine existing channel slopes and elevations in both directions and include data points associated with the existing structure and roadway surface. For additional guidance, refer to the *Stream Crossing Replacement Technical Manual*.

Conducting a longitudinal profile survey

In situations where other obstructions or channel splits are nearby, it may not be possible to go 150'. In other cases, it may be necessary to go more than 150' from the crossing, especially in situations with extensive channel impacts due to the structure (large vertical offsets, plunge pools, sediment wedges).

The survey must extend far enough to include a stream segment unimpacted by the existing crossing structure that reflects "typical" channel conditions (reference reach). This reference reach can be used as a basis for design and reconstruction of the stream channel upstream, through, and downstream of the replacement crossing. The reference reach must begin and end at existing grade control features and must, at minimum, include two consecutive sequences of repeating bed features (e.g., riffle/pool/riffle/pool/riffle). A longer reference reach that includes additional bedform sequences is encouraged in order to provide more reliable design criteria. Avoid designating your reference reach in a stream segment that differs greatly from the "typical" conditions. Examples might include areas that are influenced by debris jams, or obvious abnormalities in width, depth, slope, etc.

Remember, the reference reach is intended to reflect "typical" character of the stream channel beyond the influence of the existing road crossing. It is not meant to capture "pristine" conditions. To determine applicability, the reference reach slope must be +/- 25% of the proposed continuity slope of the reconstructed streambed, unless otherwise approved by the SCC. If an appropriate reference reach is not located near the crossing, a separate reference reach survey may be conducted further upstream or downstream of the crossing. To generate data useable for design, the slope, bankfull width, and dominant bedform (riffle/pool, step/pool, etc.) of the "off-site" reference reach must be relatively similar to those at the project site.

CONDUCTING A LONGITUDINAL PROFILE

Setup: Set the laser in a position to see the largest extend of the channel both upstream and downstream. Meandering channels or forested settings may require setting up the laser multiple times and establishing turning points (see below). Be sure the laser is set high enough to be able to take a reading at the top of the planned survey. Establish a minimum of 2 permanent benchmarks such as a nail in a tree, metal stake, or other stable structure that will not be disturbed during construction.

Survey Terms:

- **Benchmark (BM):** A benchmark is anything with a constant elevation that can be used as a reference. Identify two or more locations outside of the anticipated limits of construction disturbance to establish a benchmark. Mark the benchmark location and record a detailed description so that it can be relocated later in the field, potentially by another surveyor.
- **Backsight (BS):** A rod reading taken on a point of known elevation. It is the first reading taken on a benchmark to start a survey or the turning point if the laser has been moved.
- **Foresight (FS):** Rod reading taken on any point on which an elevation is to be determined (see "key measuring points" below).
- **Turning Point (TP):** A point, either temporary or permanent, on which the elevation is determined for use as a pivot between sequential instrument locations. Typically used when needing to move the instrument to complete a survey. The turning point elevation is determined, the instrument is moved, then a backsight is taken from the new location. The difference in the readings will be added/subtracted to all future foresights when plotting to make one continuous graph.

Starting Survey: Begin the survey upstream at a grade control that is well outside the influence of the structure. Start the tape measure at "zero" at this uppermost grade control, and use a survey partner, stake, rock, or tree branch to secure the start of the tape. Consider using a stake or flagging to mark the survey starting point, well out of the channel, in case you need to return for additional measurements. Unroll the tape directly down the deepest part of the channel (thalweg) with "zero" being at the upper end. Lay the tape over the roadway and existing structure and continue downstream. If road fill height will greatly impact the measured length, consider placing the tape through the existing structure.

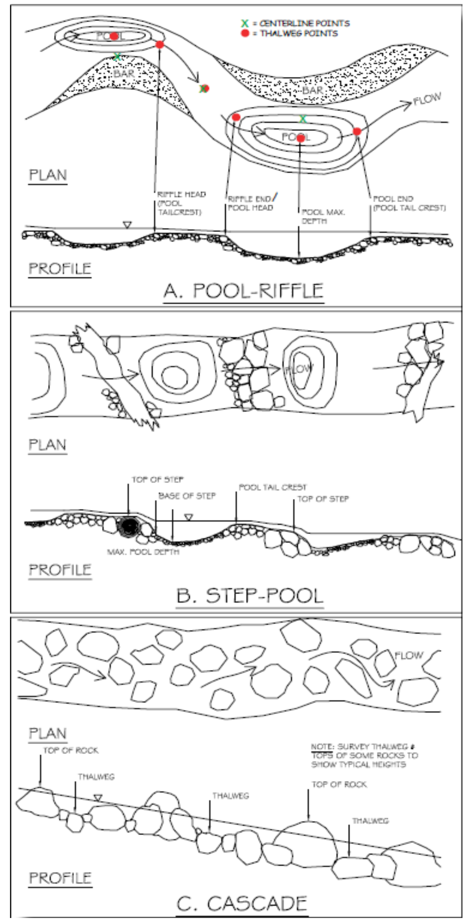
When conducting the longitudinal profile and cross-section assessments, three pieces of information should be recorded for each data point collected. These include:

- **Station:** the distance along the transect being assessed. If a laser level and measuring tape are being used, this would be the tape reading. The assessment typically begins at Station "0" (the start of the tape).
- **Foresight:** if using a laser level, this is the reading taken from the stadia rod. If using more advanced survey equipment, this might be recorded as an actual elevation. Foresight readings collected in the field can be translated to elevations later, based on the benchmark and laser (height of instrument) elevations.
- **Notes:** a brief description of the feature of interest where the data point is being collected.

Consistency in the way field data are recorded by the conservation district, CDGRS, and the engineer/surveyor can go a long way in streamlining communication and the sharing of information among the project participants. Clarity and consistency of field notes and good organization of Site Assessment data can greatly assist the conservation district in completing the required design plan review in a timely manner. For more information on survey field notes and site assessment data analysis, see the *Stream Crossing Replacement Technical Manual.*

Key Measuring Points:

- **Grade controls**: Record a survey data point - station (tape distance) and elevation (rod height) - along the thalweg at each grade control feature in the channel. Rate the grade controls as to their perceived relative stability (low/med/high or poor/moderate/good), based on their expected longevity in relation to other grade control features within the surveyed reach. Some grade controls such as large rocks (particularly with moss growing on them) are very stable, whereas grade controls from downed tree or debris jams may not last as long.
- **Pool bottoms:** Record a survey point at the deepest part of each pool (thalweg).
- **Existing Structure**: Record data points for the existing structure inlet and outlet elevations (top and bottom of structure opening). Collect additional data points for stream bed elevations at the inlet and outlet if different from the structure bottom elevations (if the structure inlet/outlet is perched above the streambed or is buried).
- **Road and Fill**: Stretch the tape over the road (not through the structure). Take several shots over the structure and across the road, including the edges and the centerline. These will help in analyzing the available cover and fill at the site.
- **Other features**: Note and take readings at features such as bedrock, rock clusters, large woody debris, etc.
- **Take readings at any changes in channel slope. The goal is to take a representative survey of the channel both upstream and downstream outside of the structure influence. <u>When unsure</u>, take extra readings.**



Ideal locations to take measurements during long-pro (credit USFS)

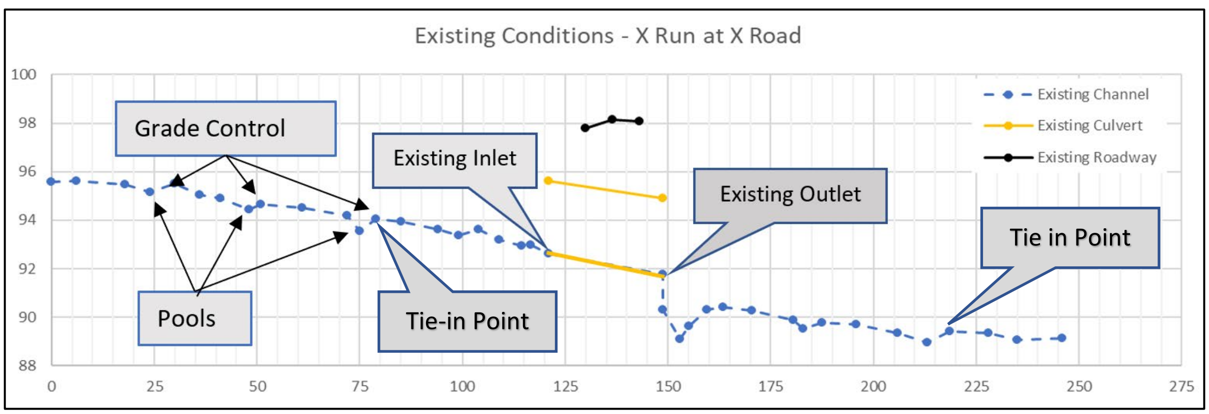
Surveying in difficult conditions: A wide variety of “abnormal” conditions may exist that can complicate the long-pro survey, such as:

- **Split channels upstream**: In a case where a feeder stream flows into the channel upstream of the structure, the longitudinal profile should be conducted in the larger, main channel. If feeder streams are significant, another “arm” of the long-pro can be shot up that channel for future reference.
- **Braided channels**: Braided channels can present issues in determining where to conduct a longitudinal profile. Long-pros should be conducted in the thalweg or deepest part of the channel, so try to identify the main flow channel in braided systems and conduct the survey there. If unclear, multiple braids can be surveyed.
- **Proximity to stream mouth:** If the stream being surveyed empties into a larger stream below the crossing, conduct the survey into the other channel to a grade control if possible, noting where the streams meet in survey notes.
- **Wetland / beaver issues:** Wetland- or beaver-influenced channels may make a longitudinal survey difficult or impossible. The survey should extend up and downstream to the greatest extent possible.
- **Huan-made obstacles:** Note the location and elevation of any human-made barriers or stream impacts during your survey such as dams, retaining walls, or other culverts on the stream.

LONGITUDINAL PROFILE SURVEY RESULTS

The long-pro survey will be used to determine a variety of factors that will impact the project moving forward, including:

- **Existing grade control spacing**: The distance between existing grade controls should be similar to the planned grade control spacing of the constructed reach.
- **Tie-in points:** Tie-in points will be determined where stable grade controls exist to tie the "reconstructed channel" through the crossing back into the natural channel and establish continuity.
- **Proposed bed and structure slope:** Once tie-in points are established, the slope of the reconstructed channel through the structure can be calculated. This will impact both structure selection, and streambed depth and composition.
- **Maximum pool and anticipated scour depth**: The maximum pool depth (excluding plunge pool) can be used to establish the anticipated scour depth in order to estimate streambed quantities.
- **Road cover and height issues**: The survey will identify the amount of cover over the existing structure and can be used to determine the amount of fill available for a new structure based on structure type and size.
- **Structure selection**: All of these factors above can be used to help with structure selection. Bottomless structures are encouraged for all structures and <u>required</u> for stream channels where the continuity slope of the reconstructed reach is greater than 4.0% or the bankfull width is over 20', as determined by the longitudinal survey.



Example of a longitudinal survey once plotted out. This survey starts approximately 120' above the existing structure, extends over the road and structure, and extends approximately 100' below the structure.

CROSS-SECTIONAL SURVEYS

When completing a long-pro survey, a minimum of 2 cross-sectional surveys must also be completed. Surveys must be completed at a grade control crest within the reference reach and at the deepest point in the outlet scour pool (if present). If no outlet scour pool exists, this survey should capture the maximum depth of a pool feature from the reference reach. A cross-sectional survey is run perpendicular to the long-pro survey and will produce a graphical representation of the channel. These surveys will identify features such as the thalweg (deepest channel point), low flow channel, bankfull elevations, and bank margins. This information will then be used when designing the newly constructed channel through the new stream crossing structure.

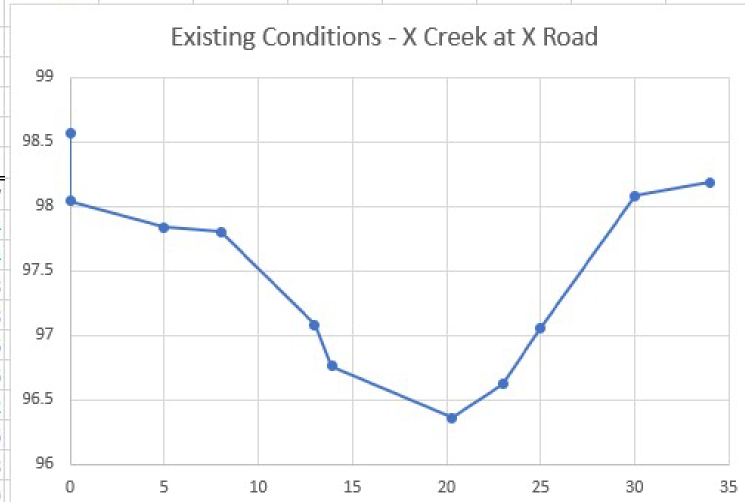
<u>Process</u>: Identify a grade control crest and a pool feature adjacent to reliable bankfull indicators, outside of the portion of channel impacted by the crossing structure. Survey a cross-section of the channel and floodplain at these locations by placing a tape perpendicular to the channel thalweg. The tape should pass over the same point along the thalweg where the grade control (top of peak) or pool (max depth) data point would be collected in the longitudinal profile survey. Orient the tape so that the start (station 0') is over the left bank of the stream (facing downstream). Extend the tape far enough to capture a portion of the floodplain beyond the top of bank on both sides of the stream. The tape should be stretched level above the stream channel. At minimum, each surveyed cross section must include data points on both streambanks capturing top-of-bank, bankfull, and right/left edge of water. Instream data points must include a minimum of three streambed points, including the thalweg (low-flow channel).

Optimally, cross-sections can be surveyed at multiple grade control crests and max pool depth locations. As noted above, survey cross sections must be completed at one grade control crest and one max pool depth. Record the location (tape reading) along the longitudinal profile where it intersects with each of the cross-sections.

Existing Conditions - X Creek at X Road

XS #	1
LP STA	46
HI (ft)	103.7

STA	FS	NOTE	ELEV
0	5.13	Top of Left Pin	98.57
0	5.66	Base of Left Pin	98.04
5	5.86	Floodplain	97.84
8	5.9	Bankfull	97.8
13	6.62	Left Edge of Water	97.08
13.9	6.94	Bottom of Left Bank	96.76
20.3	7.34	Thalweg	96.36
23	7.08	Bottom of Right Bank	96.62
25	6.64	Right Edge of Water	97.06
30	5.62	Top of Right Bank	98.08
34	5.51	Floodplain	98.19



An example plot of a surveyed stream channel cross-section. Surveyed sections at the reference reach inform elements of reconstructed reach design such as bankfull (bank margin) height and thalweg depth.

Key measuring points:

- **Floodplain:** Collect one or more data points along the floodplain extending beyond the tops of both banks. These should capture inflection points where noticeable changes in elevation or slope occur.
- **Top of Banks:** Take a reading at the top of both streambanks.
- **Bankfull Elevation:** Take a reading at the bankfull elevation, using the best-available bankfull indicator on the survey transect. Each cross-section surveyed should include at least one bankfull data point. See the Bankfull Width Determination Technical Bulletin for additional information on identifying bankfull elevation**.**
- **Edges of Water:** Take a reading at the water's surface where it meets both streambanks.
- **Bottom of Banks:** Collect a data point along the toe of both banks, where the streambank transitions to the stream bed.
- **Streambed:** Take a reading at three or more locations within the wetted portion of the stream channel. Include a point representing the thalweg, along with two or more additional points. These points should be positioned to best depict the general shape of the streambed.

The surveyed cross section should contain sufficient data points to reflect channel dimensions and shape. Depending on site conditions, additional points may need to be collected. For information on site assessment data analysis for the longitudinal profile survey and the cross-sectional surveys, refer to the *Stream Crossing Replacement Technical Manual.*

ADDITIONAL REFERENCES

https://training.fws.gov/courses/csp/csp3200/resources/documents/TeamSurveyPE/LongPro-2019.pdf

https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=46252.wba

https://www.fs.fed.us/rm/pubs_rm/rm_gtr245.pdf

Technical Bulletin
Structure Selection for Stream Crossings

PENNSTATE
Center for Dirt and Gravel Road Studies

7/2022

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

<u>Longitudinal Profile</u>: 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.

<u>Structure Width</u>: 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.

<u>Capacity Requirements</u>: 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.

<u>Substrate Depths</u>: 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.

<u>Depth of Cover</u>: 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.

<u>Alignment</u>: 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.

<u>Other Factors</u>: 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)

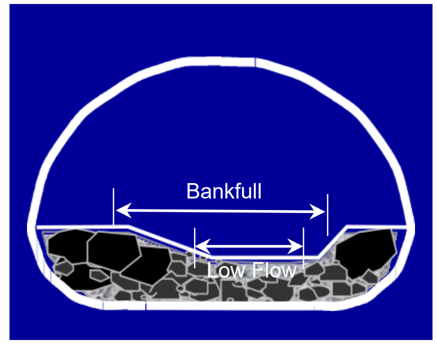
Bottomless concrete box culvert (Cumberland)

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.

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.

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

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).

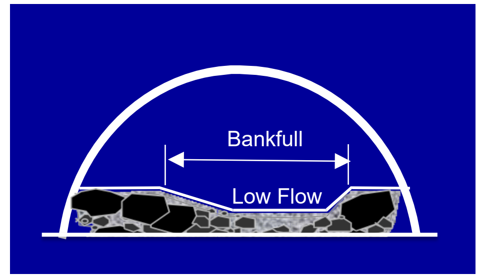
Completed 16' w x10' h pipe arch (Crawford).

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.



Schematic of an arch pipe with invert 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.

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.

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

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.

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).

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.

Footings:

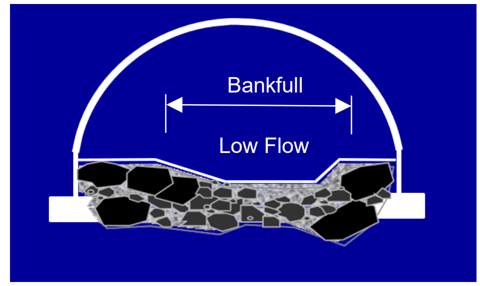
- **Cast-in-place footings:** Forms are framed, and concrete is poured in place. The process will require the road to be closed for a longer period of time for curing.
- **Pre-fabricated footings:** Concrete footing poured in pre-fabricated steel forms that remain in place.
- **Precast footings:** Concrete 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.

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.

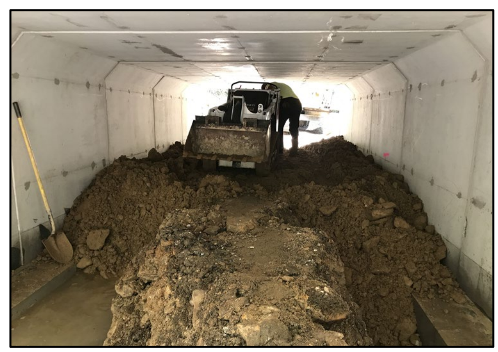
Summary:

- **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.



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

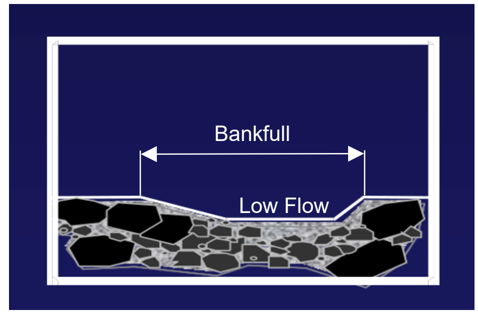

Assembly of a 15' w x 6' h bottomless arch pipe on cast-in-place footings (Juniata).


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


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

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.

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

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.

Bridge Types:

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

- **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.

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

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’	
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	Not recommended for use in stream channels.
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	Round pipes over 36” not to be used in DGLVR funds.
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	Not recommended for use in stream channels.
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.	Round pipes over 36” not to be used in DGLVR funds.

The publishers of this publication gratefully acknowledge the financial support of the PA State Conservation Commission. For additional information or assistance, contact: Center for Dirt & Gravel Roads Studies, Penn State University, 215 Transportation Research Building, University Park, PA 16802 (Toll-Free Phone: 1-866-668-6683, Fax: 814-863-6787, Email: dirtandgravel@psu.edu). Additional copies available on our website at: https://www.dirtandgravel.psu.edu.

Technical Bulletin

Grade Control

7/2022

Center for Dirt and Gravel Road Studies

GRADE CONTROL – Grade controls are natural or human-made structures that control channel elevation and channel slope such as logs, riffles, or rock cascades. Grade controls can be used to stabilize the material in the structure, prevent head cutting, create habitat, and maintain the slope and continuity of the channel. Field data collected during the longitudinal stream profile survey and additional stream stability analysis are used to inform the size, spacing, and type of grade control to be used during stream bed reconstruction.

WHY GRADE CONTROL IS IMPORTANT

Grade controls are instream structures that control channel elevation and channel slope. Typically, these structures are made of large rock or logs and simulate naturally occurring grade controls. It is important to simulate these natural grade controls through the entire reconstructed stream reach to:

- Minimize channel adjustments such as head cutting
- Maintain channel slope, elevation, and stability
- Increase flood resiliency of the crossing
- Maintain stream continuity and aquatic organism passage (AOP)
- Provide continuity of slope and reconnect the stream channel

WHEN TO USE GRADE CONTROL

Grade controls are required to be used in and around the replacement structure to stabilize the stream material and maintain channel slope and bed elevation. Additionally, stable grade controls are required to “tie-in” the reconstructed reach to the adjoining natural channel segments. Grade control structures can also be used to:

- Prevent upstream head cutting
- Provide instream aquatic habitat
- Define channel cross section and low-flow channel
- Prevent streambank erosion

TYPES OF GRADE CONTROLS

Channel slope dictates the natural bedform and type of grade controls in a stream channel. As channel slope increases (steeper channel), stream energy is dissipated through vertical drops, and the grade controls are more frequent and robust. The longitudinal profile survey completed in the reference reach of the channel will help determine the best type of grade control and spacing for your project. Grade control structures typically used in stream crossing projects include:

- **Cross vanes (rock or log):** These structures extend completely across the channel and tie into the stream banks. They are used for grade control, centering flows in the thalweg and can also be used to create pool habitat if desired.
- **Constructed riffles:** These are used to set stream grade and upstream pool depth, and to stabilize the streambed through a riffle feature. These consist of a constructed riffle crest and series of ribs or sills spanning the channel width.
- **Rock clusters and cascades:** These structures are typically used in high gradient streams to set the stream channel grade and dissipate stream energy.
- **Buried rib:** These structures are typically buried at or below the stream bed and used to prevent headcutting and streambed material loss if the reconstructed channel adjusts beyond what is anticipated.
- **J-hook:** These structures extend partially into the stream channel and are used to help center the flows, provide control grade, and move energy away from the bank.

Figure 1: From left to right, log cross vane with throat log; rock clusters and cascade; and constructed riffle.

For channel modifications such as grade controls outside of the 50' upstream and downstream GP-7/11 permit construction boundary, additional permitting may be needed. For grade control construction that does not involve substantial channel fill or excavation (beyond that incidental to installation of grade controls), consider the use of an additional GP-1 to authorize placement of these features. For more information on types of grade controls and their uses, see the PA Fish and Boat Commission document "Habitat Improvement for Trout Streams," https://www.fishandboat.com/Resource/Documents/habitat_improve_trout.pdf

DESIGN OF GRADE CONTROLS

Stable grade control features need to be appropriately sized and spaced for the prevailing stream size and slope, which is determined from the longitudinal profile survey of a reference reach (see Site Assessment Technical Bulletin and *Stream Crossing Replacement Technical Manual*). They must be designed and constructed to be stable at the 100-year discharge (Q100) to ensure long-term immobility and should be keyed into adjacent streambanks/bank margins. Stable grade controls are essential to minimizing scour potential, both within the replacement structure and through the adjoining project reach. Sufficient burial depth and/or placement of footer rocks must be considered to prevent the likelihood of undermining and failure. Failure of one or more grade control features through the reconstructed reach or spacing grade controls too far apart can trigger vertical adjustment of the adjoining streambed, particularly upstream (i.e., headcutting). This can create vertical obstructions to AOP at the upstream limit of the headcut and affects water quality by contributing large amounts of sediment, which otherwise would not have been introduced into the system. For more information on design, see the *Stream Crossing Replacement Technical Manual*.

Determine the following stream design criteria from the "reference reach" portion of the longitudinal profile survey:

- Minimum, maximum, and typical (average) spacing of grade control features
- Typical longitudinal length of grade control features (riffle length, for example)
- Type of grade control
- Maximum and typical pool depths
- Stream slope and channel profile

The project designer or engineer must specify a channel profile and continuity slope with grade control spacing through the reconstructed reach that mimics that of the reference reach to the greatest extent possible. Specify the installation of grade control features similar in type, length, and spacing through the full length of the reconstructed reach. Typical spacing from the reference reach may need to be adjusted slightly to fit the length of the reconstructed reach. Avoid using grade control types that may induce excessive bed scour (namely drop structures) inside the structure, since this can increase risk of substrate loss through the crossing.

To meet the DGLVR Stream Crossing Design & Installation Standard (DGLVR Stream Crossing Standard), any constructed grade controls and key pieces of the substrate, including constructed bank margins within the structure, shall be designed to be stable at the Q100 discharge. In design, the engineer must use an appropriate method for calculating a stable rock size for construction of grade control features, bank margins and key pieces through the reconstructed reach, including within the replacement structure. Construction details for grade control sizing are required as part of the DGLVR Stream Crossing Standard. Stable rock size must be specified as a “minimum diameter” (such as “24 inches”) instead of a gradation class (such as “R-6", for example). Additionally, quarried aggregate used for grade control must meet aggregate testing requirements outlined in the DGLVR Stream Crossing Standard.

CONSTRUCTION DESIGN DRAWINGS

The DGLVR Stream Crossing Standard requires that construction plans include *“(VI. B.7.) Locations and construction details, including rock sizing, in-stream structures, grade controls, and/or bank stabilization structures (if applicable).”* Grade control elements should be depicted in the construction drawings as follows:

- Detail drawings showing plan-, section-, and profile views (where applicable) for all grade controls and instream structures. Notations must clearly indicate material type, size, installation slopes, and overall structure length.
- Site Plan and profile drawings including locations and elevations of grade control features (at crest, thalweg, and bankfull) through the reconstructed reach. Notations must indicate whether grade control features at the “tie-in” points will be maintained (as existing) or will be constructed.

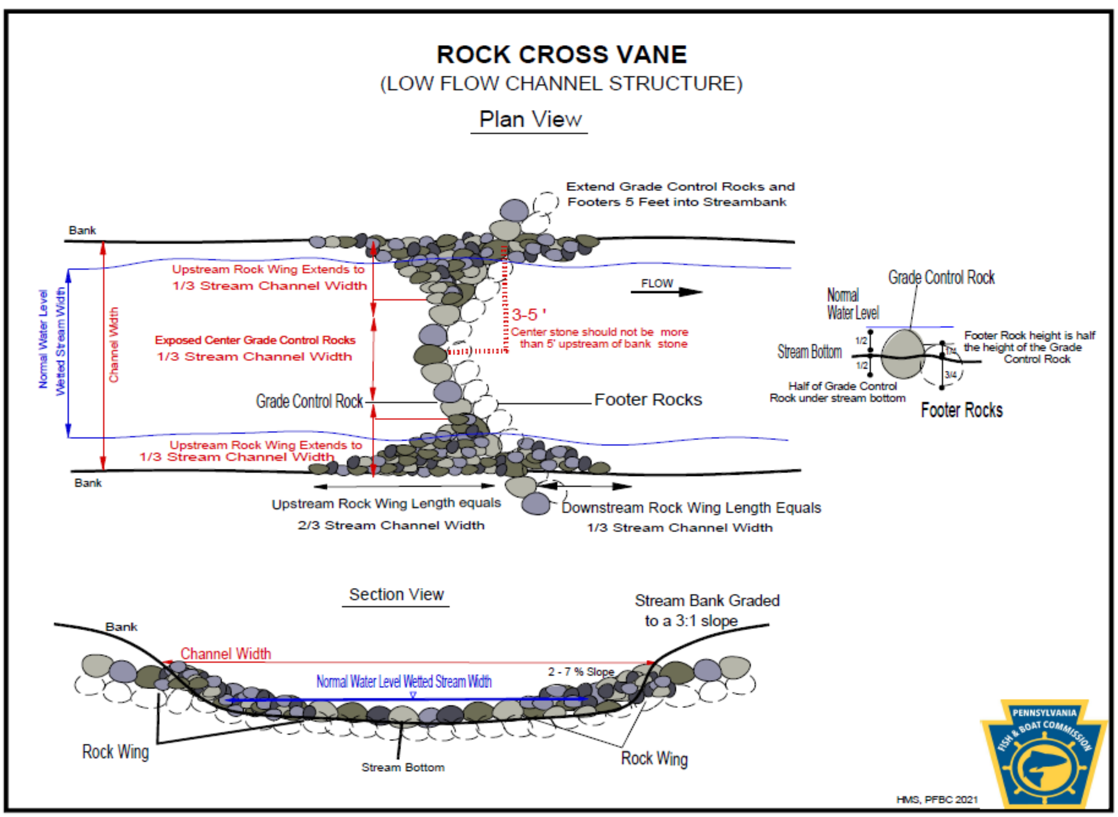


Figure 2: Example rock cross vane plan and section views standard drawing. PA Fish and Boat Commission, 2021. https://www.fishandboat.com/Resource/Documents/habitat_improve_trout.pdf

HOW TO PLACE GRADE CONTROLS

Planning is an important part of a successful grade control installation. Some questions to consider if grade control is needed within the structure are:

- Is the structure tall enough to use standard or specialized equipment to place? (Photo 1)
- Is it possible to place the grade control material while assembling the pipe? (Photo 2)

If structure height is limiting, consider renting a walk-behind skid steer. In smaller pipes, the only option may be hand placement of the larger grade control material and washing of fines between the grade controls.

Photo 1: Placing grade control material in a 15’w x 10’h pipe arch (squash pipe).

Photo 2: Placing large material during pipe assembly.

<u>Placement of Grade Controls</u>

Consider the optimal method for placing both grade control rocks and substrate (streambed) material inside the structure. If a machine or some other mechanical method can be used to move and place material, it may be best to build the streambed and grade controls simultaneously from structure inlet to outlet. In this case, streambed material is placed until each grade control location is reached and then the grade control is installed. If material cannot be placed mechanically, consider placing grade control and key pieces within the structure first along with any larger substrate material needed to prevent scour. Whenever possible, grade control and key pieces used should be placed into a bed of smaller aggregate and not directly on the invert of the structure (Photo 3). Additionally, when placing material use caution not to damage the structure bottom with machine tracks or buckets. Inside the structure, grade controls should extend all the way to the edges of the structure and tie in with the bank margins. Outside of the structure, grade controls should be keyed into the banks for stability at high flows.

Photo 3: Grade control placed inside of a 15’ wide arch pipe before placing final streambed.

Except for the j-hook, the structures described in this document should span the entire bankfull width channel. The constructed grade control should mimic the channel cross-sectional shape from the reference reach as best as possible (Figure 2). This should include a low flow channel with a bottom elevation that matches the stream bed elevation from the construction plans.

After placement of the grade controls, the designed smaller substrate matrix should be placed in lifts to bring the streambed up to the designed elevation and slope. In most stream settings the streambed material will consist of a well-graded aggregate of very fine, fine, and coarse bed material that provides for both sediment transport and bed resiliency. For more information on design and placement of streambed materials, refer to the Streambed Restoration Technical Bulletin and *Stream Crossing Replacement Technical Manual*.

Aspects of construction to be inspected by the engineer must include the installation of grade control structures and bank margins. This inspection must confirm and document that grade control features and bank margins are constructed of the stable minimum rock size, and that thalweg elevations, locations, slopes, and lengths specified in the construction documents and detail drawings are met.

Technical Bulletin

Streambed Restoration

7/2022

Center for Dirt and Gravel Road Studies

RESTORING NATURAL STREAMBED MATERIAL – Restoring the natural streambed material through a stream crossing replacement is a critical component of a successful project. Natural streambed material is the substrate that makes up the stream channel bottom. Field observations, longitudinal stream profile survey, grade control features, and shear stress calculations within the identified survey reach can all be used to inform decision making on depth and sizing of material.

WHY STREAMBED MATERIAL IS IMPORTANT

It is important to simulate the natural streambed through the reconstructed crossing to:

- Control permeability to prevent the streamflow from going sub-surface
- Provide continuity of slope and reconnect the stream channel
- Provide grade control
- Create varied velocities across the cross-section of the stream
- Dissipate energy and prevent excessive scour and material loss in the structure.
- Increase the lifespan of the structure

Maintaining streambed material in the structure is the only way to accomplish full Aquatic Organism Passage (AOP).

Figure 1: Streambed material is made up of surface and subsurface layers. The surface layer is typically coarser than the subsurface layer because of the scour of fines between the larger particles. The subsurface layer is finer than the surface layer because fines are present in the voids between the larger particles.

LOW FLOW CHANNEL AND BANK MARGINS

When reconstructing the streambed through the replacement structure, it is critical to build a low flow channel, bankfull channel, and bank margins (Figure 2). The cross section of the reconnected channel shall be designed to replicate the channel cross section shape that was collected during the site assessment (see Site Assessment Bulletin and *Stream Crossing Replacement Technical Manual*). A low flow and bankfull channel plus bank margins:

- reconnect the constructed channel to the existing channel
- allow for natural sediment movement
- ensure that AOP is possible through a range of flows and velocities

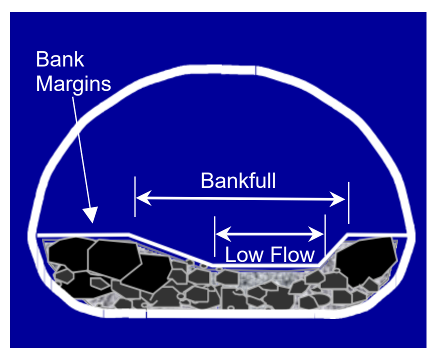


Figure 2: Schematic of a pipe arch with low-flow channel, bankfull channel, and bank margins.

It is easier to establish bank margins and low flow channels in structures that are larger than bankfull. If a low flow channel and bank margins are not established, it will increase the chance of sediment deposition within the structure due to a wide flat channel (Figure 3). If the channel inside the structure is wider than the natural streambed, then the stream will lose velocity inside the structure and its ability to transport the sediment through the crossing will decrease. The resulting sediment deposition can force water to the sides and increase velocities at the edge of the structure. The increased velocities encourage scouring in the structure, can jeopardize footers, and ultimately impact structural integrity.

Figure 3: The photo on the left shows a properly constructed streambed with a low flow and bankfull channel, along with bank margins. The photo on the right shows a structure that did not have a properly constructed channel, and the resulting sediment deposition at the inlet is forcing the flow to the side of the structure.

DESIGN AND CONTRACT CONSIDERATIONS FOR STREAMBED MATERIAL

- The DGLVR Stream Crossing Design & Installation Standard requires construction plans to include *“(VI. B.8.) Depth, gradation, and composition of material for streambed restoration.”* Elements that must be depicted in the construction drawings include the streambed material thickness, and inlet and outlet bed elevations. The material gradation and composition must be noted, and if the native material onsite will be reused or if material will need to be imported. Drawings must include gradation, composition, and construction details for the low-flow channel, bankfull channel, and the bank margins.

- Minimum stream substrate depth (measured below the low flow channel at a grade control crest, to the structure invert or bottom of the footers) is to be based on the maximum pool depth in the reference reach with a minimum safety factor multiplier, as listed in Table 1. Alternatively, minimum bury depth can be determined using industry-accepted scour analysis and modeling tools for stream system analysis and/or bridges (storm sewer models are not acceptable for stream crossing scour analysis).

- The minimum substrate depth required shall be 24 inches or depth determined with scour analysis models or using the Anticipated Scour Depth, whichever is greater.

Table 1: Pool Depth Safety Factor Multiplier to establish Anticipated Scour Depth

Stream Slope	Pool Depth Multiplier
0% - 2.0%	1.5
2.1% - 4.0%	2.0
> 4.0%	2.5

- Structures installed on stream slopes >4.0% <u>must</u> be bottomless. The 2.5 safety factor multiplier is to establish the recommended minimum bottom of footing buried depth. Final footing buried depth is to be determined by the engineer in project design.

- The cross-sectional survey shall inform dimensions of features such as the low-flow channel, bankfull width, and bank margins to be used when reconstructing the channel through and around the new structure.

- The size of bed material and key grade control pieces will inform how wide bank margins need to be. At a minimum, the new structure must be 125% of bankfull width of the stream at the bankfull elevation. This allows space for proper construction of the low-flow channel, bankfull channel, and bank margins within it (see Structure Selection Technical Bulletin and *Stream Crossing Replacement Technical Manual*).

- To meet DGLVR Policy and the Stream Crossing Design & Installation Standard, grade controls and key pieces, including bank margins within the structure, shall be designed to be stable at the 100-year discharge (Q100). In design, the planner or engineer must use a suitable method for calculating a stable rock size to specify for construction of grade control features through the reconstructed reach, including within the replacement structure.
- Apart from sand- and silt-bed streams, natural streambeds typically consist of a well-graded substrate with a wide range of particle sizes. Among other functions, coarser (larger) particles provide roughness, and grade control, while finer particles contribute to compaction of the bed. This mix of particle sizes should replicate the natural stream bed and is critical to managing flood velocities and creating aquatic organism habitat. When specifying a bed material gradation, consider a mix that provides this natural range of small and larger particles to best mimic natural channel performance. For additional streambed material design guidance, see the *Stream Crossing Replacement Technical Manual.*
- During development of a grant application, careful consideration should be given to additional labor requirements and specialized equipment needs to place material within the proposed structure, such as mini excavators or walk-behind skid steers (Photos 1 and 2). If needed, a budget line item in the grant application should be provided to address these specialized equipment needs.
- It is also important to consider the extent of stream channel modifications or reconstruction required up and down gradient of the proposed replacement structure to reconnect the stream channel. This is determined by looking at a longitudinal profile to tie the proposed project into existing or constructed grade control features and ensure proper stream slope through the structure. If this work is performed outside of the stream crossing permit boundary, off-right-of-way permission must be obtained from the landowner in accordance with SCC policy, and additional permitting may be required.
- During the planning and design phase, identify the potential methods for placement and compaction of streambed material, including the appropriate water source for washing fines into the structure (see "Placement and Washing of Fine Material" below). Account for this construction activity in the grant application budget, Erosion and Sediment Control Plan (including a plan for stream diversion during construction and washing), and all subsequent plans and bidding documents.
- Once contracted, details pertaining to the grade control sizing, streambed mix design, and suggested methods of construction should be incorporated within the permit application and construction drawings. This information also needs to be detailed in the bid or contract documents as well.
- When installing structure without inverts (bottomless structures), it is critical to only disturb the part of the stream channel that is necessary to set and properly backfill the footers. The considerations described above, including minimum substrate depth, and the material placement process described below are applicable to structures with or without inverts.

STREAMBED MATERIAL AND PLACEMENT

Planning is an important part of a successful streambed restoration. Some questions to consider are:

- Is the structure tall enough to use standard or specialized equipment to place stream bed material? (Photos 1, 2)
- Is it possible to place material while assembling the pipe? (Photo 3)

If structure height is limiting, consider renting a walk-behind skid steer. In smaller pipes, the only option may be hand placement of the larger material and washing of fines.

Specification of a stable substrate matrix through the reconstructed reach should consider the natural tendency of streams to mobilize and transport bedload as well as the need to maintain material in the structure over the long term. Streambed reconstruction should include a mobile component as well as a larger component more capable of withstanding the anticipated range of flows over the lifespan of the new crossing. Fine materials (such as native streambed material excavated from the project site) can be added to provide compaction of void spaces in the larger rock and supplement the mobile surface layer of the finished streambed. Robust key pieces and/or grade controls sized for Q100 establish and maintain the finished streambed elevation, slope, and spacing of bed features through the reconstructed stream reach. The designer must develop a specified substrate mix that adequately reflects these components. In most stream settings, a well-graded aggregate of very fine, fine, and coarse bed material provides for both sediment transport and bed resiliency. These are augmented with placement of larger key pieces and grade controls at locations informed by the longitudinal profile. Refer to the *Stream Crossing Replacement Technical Manual* for recommended methods for streambed substrate design.

Photo 1: Placing larger material in a 15'w x 10'h pipe arch (squash pipe).

Photo 2: Placing fine material in a 8'w x 6'h bottomless arch with a walk-behind skid steer.

Photo 3: Placing fine material inside a bottomless concrete culvert with walk behind skid steer.

Photo 4: Large material placed in a 12'w x 6'h arch pipe before placing streambed.

<u>Placement of Grade Control and Key Pieces</u>:

Often, the first step is placement of the large rock used as grade control and key pieces within the structure that will be stable at Q100 (Figure 4). In some cases, it may be best to build the streambed and grade controls simultaneously from structure inlet to outlet. In this case, streambed material and key pieces are placed until each grade control location is reached, and then the grade control is installed (Figure 5). All large material should be placed on a small amount of finer stream bed material to prevent damage to the structure invert during placement. Typically, the key pieces and grade control material should be larger than any visible native material to ensure stability under sheer stresses found at the maximum hydraulic capacity of the structure (Photo 4) (see Grade Control Technical Bulletin).

<u>Placement of Bed Material</u>:

Streambed reconstruction should include a mobile component as well as a larger substrate that is stable at higher flows but not expected to be stable at Q100. In most stream settings, this is a well-graded mixture of very fine, fine, and coarse bed material that provides sediment transport and bed resiliency. Although substrate mix design will be site-specific, a three-part mix can be used as a framework suitable substrate for the reconstructed reach. An example would be a mix of R4 rock, 2A or 2RC stone with fines, and native material if deemed acceptable by the onsite construction supervisor or engineer. Refer to the *Stream Crossing Replacement Technical Manual* for recommended methods for streambed substrate design. This aggregate should be mixed, in equal parts, from stockpiles prior to being placed in the culvert or stream channel (Photo 5). In areas that require significant depth of fill, such as the outlet scour pool or streams with large scour potential, place the streambed material in lifts of approximately one foot. After placement, thoroughly compact mechanically and hydraulically in place before starting the next lift (Photo 4).

Mechanical compaction can be achieved with equipment such as a jumping jack tamper, vibratory plate compactor, or even the weight of machinery used to place the material such as a walk-behind skid steer. If the structure is too small for machinery, the fine material should still be hydraulically washed between lifts.

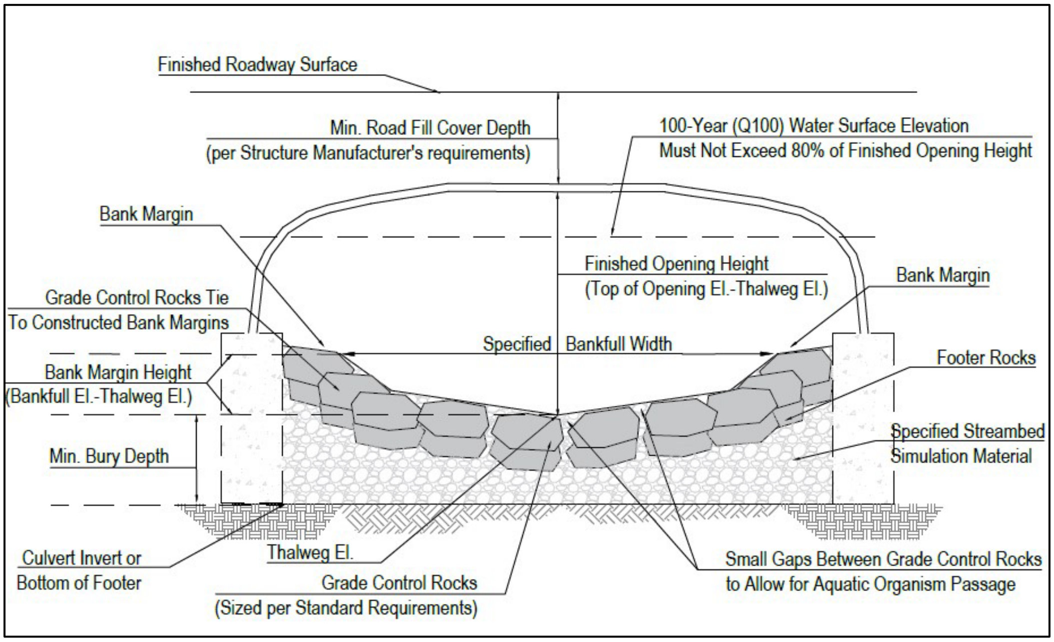


Figure 4: A typical cross section **at a grade control** showing channel shape through a culvert. The bottom line represents invert or recommended top of footing depth. The dashed line shows the water surface elevation of the 100-year discharge.

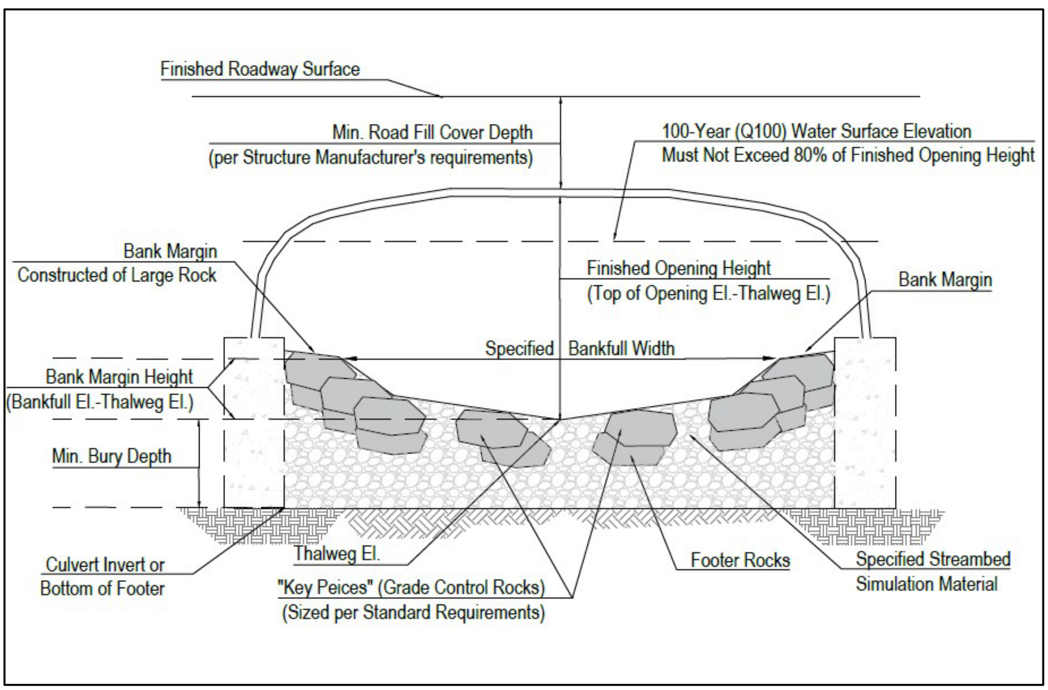


Figure 5: A typical cross section **between grade controls** showing channel shape through a culvert. The bottom line represents invert or recommended top of footing depth. The dashed line shows the water surface elevation of the 100-year discharge.

Placement and Washing of Fine Material:

Washing the fines is a critical part of rebuilding the streambed properly during a culvert replacement. Fine material such as native stream bed material or similar quarried material with adequate fines (e.g., 2RC) is placed on top of the larger material and compacted mechanically or hydraulically, as described above, to force fine sediments into the voids between larger particles. If not done properly, water will go subsurface and you will lose the ability to successfully reconnect aquatic organism passage. It is also important to consider and specify Erosion and Sedimentation requirements for washing materials in the plans.

Photo 5: Mixing native material and larger foundational stone prior to placement.

If significant depth of fill is required, place the large material and fines in lifts of approximately one foot and compact as described previously. If machinery cannot be used, it is typically easier to wash material in from the inlet of the structure (Figure 6). On longer crossings it might be necessary to wash from both the inlet and outlet. To begin washing, have the excavator place a bucket or two of fines at the inlet/outlet and wash the material into the structure until the fines are gone. Place a couple more buckets of material at the inlet/outlet and repeat as many times as needed. The best way to determine if the fines have filled the void spaces is when the water stays on top of the newly constructed stream bed and does not go subsurface.

The amount of water needed to properly wash the fines will vary from site to site. There are several variables that dictate the amount of water needed: size of stream crossing (length and width), composition of fines, quantities (tons/yards) of fines, and the number of lifts needed. During the planning phase it is critical to determine if an adequate water supply and pump capacity exists onsite, or if you will need a local water truck or fire company to supply the water. A tanker truck of 1,500 gallons or more from the local fire department is a great way to wash fines (Figure 4). If using the local fire company, plan accordingly, as they may not be able to provide a water truck during normal business hours if they are a volunteer service and they may be called away from the job site for emergency calls. Typically, a 3-inch pump with a fire nozzle or straight stream nozzle work well in most applications. If the stream is large enough to supply the water, a 6-inch pump is preferred because of the large volume of water they can provide. However, a 6-inch pump line can be extremely difficult to handle. There is a delicate balance between having enough pressure and volume of water. When in doubt, go with the pump that moves the greatest volume of water.

Figure 6: The photo on the left shows washing of fine material into a 6'w x 4'h pipe arch (squash pipe) using a fire truck. The photo on the right shows the washing process between tanker loads and view of a baffle grade control.

The publishers of this publication gratefully acknowledge the financial support of the PA State Conservation Commission. For additional information or assistance, contact: Center for Dirt & Gravel Roads Studies, Penn State University, 215 Transportation Research Building, University Park, PA 16802 (Toll-Free Phone: 1-866-668-6683, Fax: 814-863-6787, Email: dirtandgravel@psu.edu). Additional copies available on our website at: https://www.dirtandgravel.psu.edu.