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.

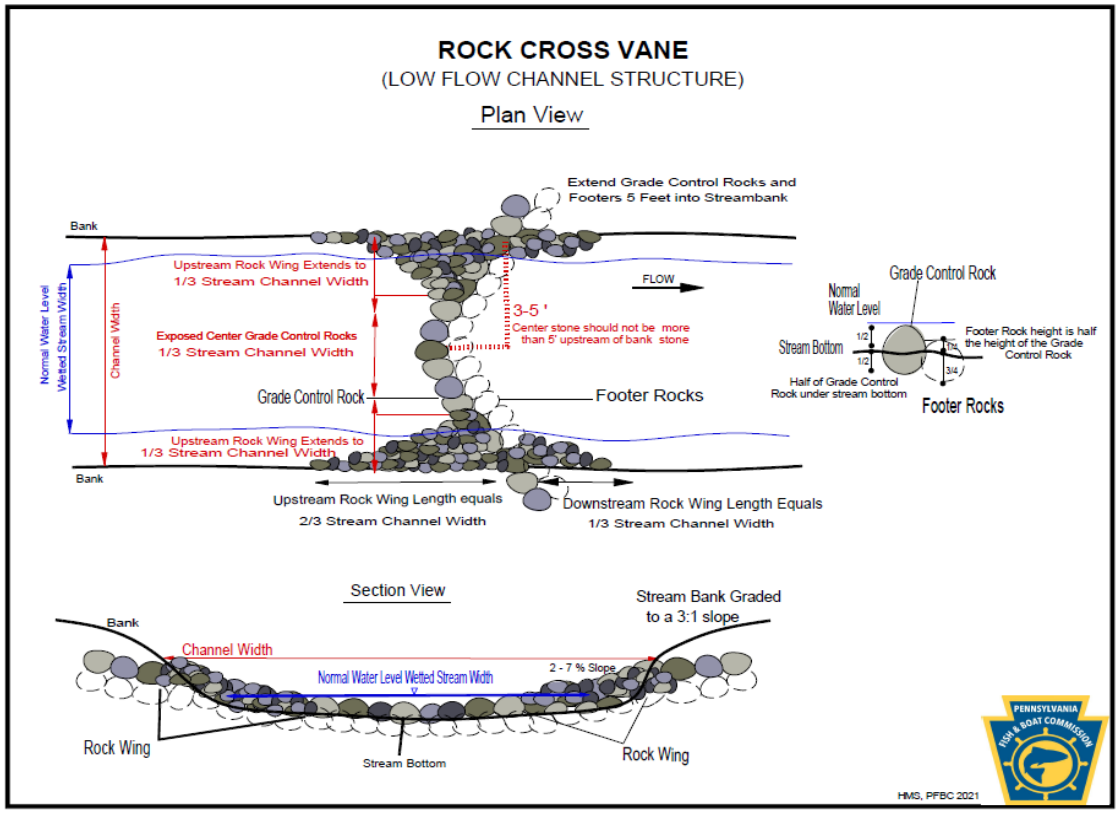

Figure 2: Example rock cross vane plan and section views standard drawing. PA Fish and Boat Commission, 2021. https://www.fishandboat.com/Resource/Documents/habitat_improve_trout.pdf

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.

Photo 3: Grade control placed inside of a 15' wide arch pipe before placing final streambed.

Placement of Grade Controls

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.

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.