Technical Bulletin
Site Assessment - Longitudinal Profile & Cross-Section

7/2022

PENNSTATE
Center for Dirt and Gravel Road Studies

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 required 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

Equipment: 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.

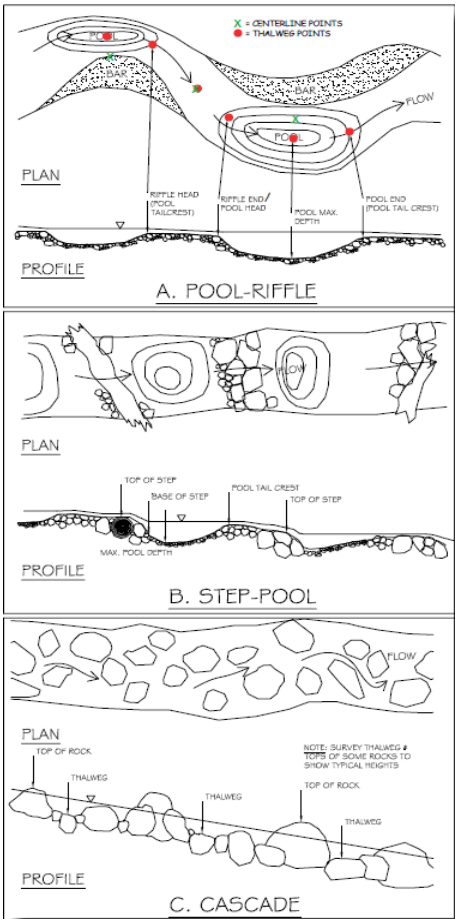
When conducting the longitudinal profile and cross-section assessments, three pieces of information should be recorded for each data point collected. These include:

- **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)

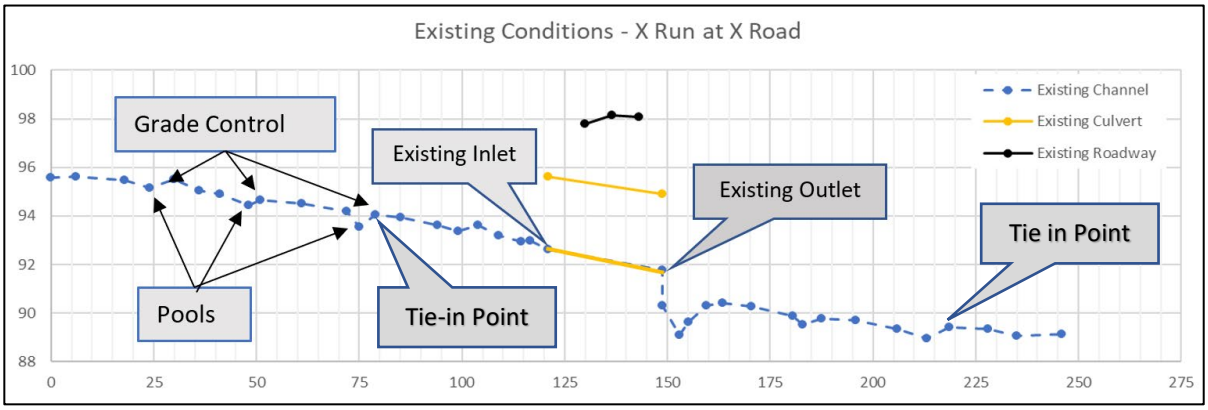
Surveying in difficult conditions: A wide variety of "abnormal" conditions may exist that can complicate the long-pro survey, such as:

- **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

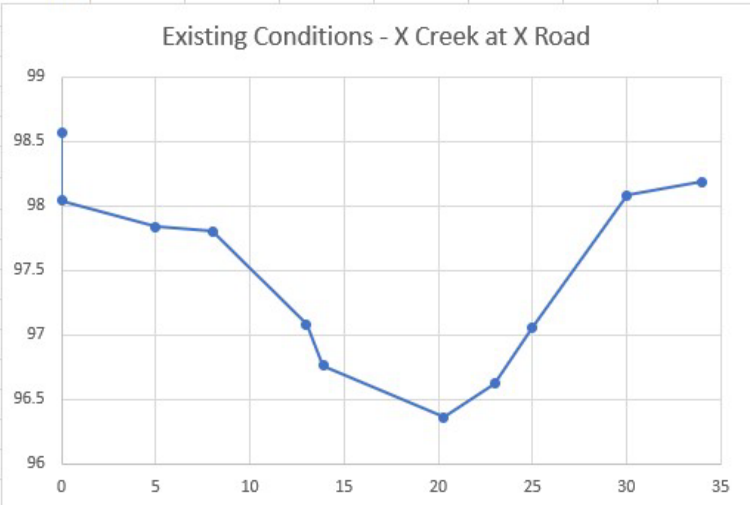
minimum, each surveyed cross section must include data points on both streambanks capturing top-of-bank, bankfull, and right/left edge of water. Instream data points must include a minimum of three streambed points, including the thalweg (low-flow channel).

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