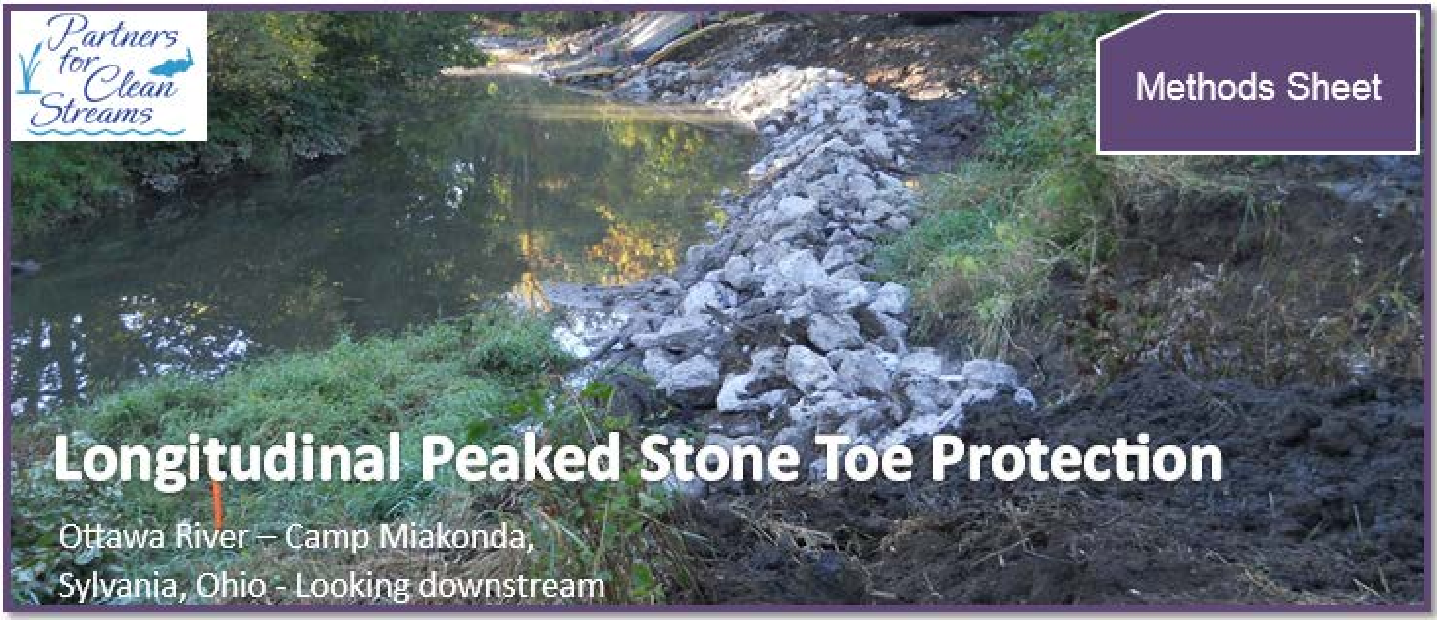


Definition and Purpose

Longitudinal Peaked Stone Toe Protection (LPSTP) is a continuous stone dike placed longitudinally at, or slightly stream-ward of the toe of an eroding stream bank. The cross-section of the LPSTP is triangular, which results in the ability to self-adjust into scour holes created by flowing water. The LPSTP does not necessarily follow the toe exactly, but can be placed to form a "smoothed" alignment through the bend. Smoothed alignment might not be desirable from the environmental or energy dissipation points of view, however. This method does not have a formulaic method for installation or creation, yet some typical practices are included in this document.

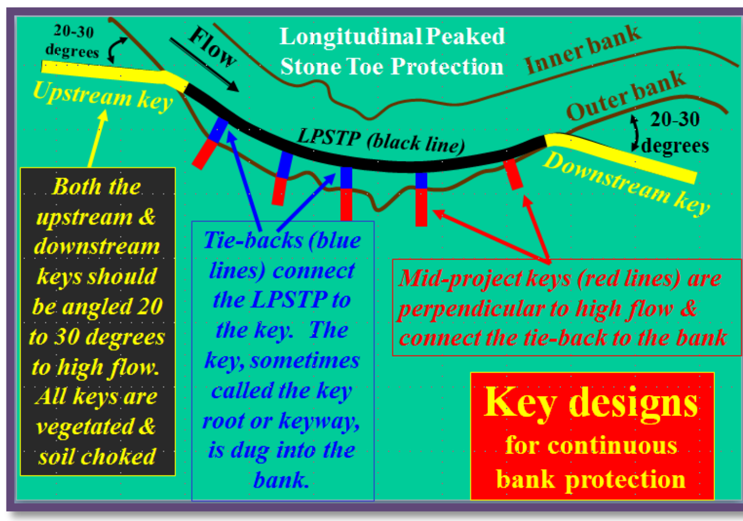


Image 1: Example Longitudinal Peaked Stone Toe Protection placement and associated supporting structures. Dave Derrick.

Longitudinal Fill Stone Toe Protection (LFSTP) is exactly the same as LPSTP except that the crest has a width. All stone for the width of the crest can launch into the scour hole, but the crest height is unchanged from the constructed height. Cross-section is a trapezoid. LFSTP can be located, and is applicable to the same sites as LPSTP, but it has the advantage of more stone volume available to adjust into the calculated scour hole.

Success of this method depends on the ability of stone to self-adjust, or "launch," into the scour hole formed on the stream side of the LPSTP/LFSTP. The stone must be well graded so as to launch properly. The weight of the stone also resists geotechnical bank failure and mass wasting.

Methods typically combined with, or connected to, LPSTP/LFSTP:

- Tie-backs
- Keys
- Locked Logs
- Bendway Weirs

Practice Applicability


Image 2: LPSTP along the Ottawa River, Camp Miakonda, Sylvania, OH. Kyle Spicer

- With the proper sized stone, LPSTP/LFSTP resists the erosive flow of the stream and stabilizes the toe, but does not provide direct protection to mid and upper bank areas.
- This method is not foundation dependent.
- Success depends on the ability of stone to launch into any scour holes formed on the river side of the LPSTP. A well-graded stone that will launch, or self-adjust (self-heal) must be used in LPSTP construction.
- "Smoothed" longitudinal alignment results in improved flow alignment near the bank.
- Weight of stone in the LPSTP (loading of toe) might resist some shallow geotechnical bank failures.
- LPSTP captures alluvium and upslope failed material (colluvium) on the bank side of structure, thus providing a foundation for vegetation to become established, or these areas could be re-vegetated with selected species.
- Provides solid substrate for benthic macro invertebrates.
- Voids between individual stones provide some refugia and cover for fishes.
- Tie-Backs block flow that has jumped landward of the LPSTP.
- Vegetation in keys, or within or above the LPSTP can slow flood flow waters and deposit sediment, organics, nutrients and seed. Deposited seed could be problematic if invasive and noxious weeds are growing upstream.

By definition LPSTP only provides toe protection and does not protect mid and upper bank areas. LPSTP does however work extremely well in zoned and blended configurations with bank paving or bio-engineering in mid to upper bank areas, or Bendway Weirs streamward of the LPSTP.


Image 3: LPSTP and Bendway Weirs at Camp Miakonda in Sylvania, OH. Kyle Spicer

Variations on LPSTP/LFSTP have been successfully used with several restoration projects within the Maumee Area of Concern. The Ottawa River bordering Camp Miakonda in Sylvania, Ohio, has over 650 feet of Longitudinal Peaked Stone Toe Protection helping reduce its erosional impact along the banks it shares with Lake Sawyer. Bank protection was also utilized in stabilizing two other local tributaries on camp property using similar methods as LPSTP, but on a smaller scale. LPSTP allows for stream bank stabilization without detrimentally impacting the rest of the surrounding ecosystem. Other local restoration projects include the Secor Dam removal project and at Hill Ditch at Toledo Botanical Gardens.

Dave Derrick, Potomologist
River Research and Design, Inc
C: (601) 218-7717
d_derrick@r2d-eng.com
www.r2d-eng.com

Partners for Clean Streams, Inc
(419) 874-0727
admin@partnersforcleanstreams.org
www.partnersforcleanstreams.org

Preparing for Longitudinal Peaked Stone Toe Protection

LPSTP acts as an armoring technique, resisting erosional forces of water. This continuous bank protection technique resists the erosive flow of the stream, thereby stabilizing the toe of the bank. The "smoothed" longitudinal alignment results in improved stream flow near the toe of the eroding bank. The LPSTP captures alluvium and upslope failed material (colluvium) on the bank side of the structure, thus providing a foundation for vegetation to become established. If the mid-to-upper bank is left untreated, these areas will fall to a stable slope (at the angle of repose of the bank material), and usually within a short period of time become invaded and naturally re-vegetated by native, or possibly invasive, plants.

Maximum stone size and correct gradation can be generated using any of many available riprap sizing design programs ("ChanlPro", WEST Consultants "RIPRAP", etc.)

Image 4: Ottawa River at Camp Miakonda, Sylvania, OH. Kyle Spicer

- Consideration #1: The minimum amount of stone that would have a launch-able component to any degree would be ½ to ¾ of a ton of stone per ft. The ½ ton/ft. amount would provide a triangular section of stone approximately 2 ft. tall.
- Consideration #2: Maximum scour depth in the bend should be numerically calculated, or estimated from field investigations (depths might be underestimated due to in-filling of scour holes during the falling side of the high-water hydrograph). Typically 1 ton of stone will protect against every 3 ft. of scour. Amount of stone required to armor the estimated maximum scour depth should be calculated, and a factor of safety added.
- Consideration #3: If there is a vegetation line, the mature well-established section of the vegetation line should be analyzed, and if Considerations #1 and 2 are met, then the vegetation line elevation would be the absolute minimum crest elevation. But, since plants immediately above the vegetation line are typically not very robust, and there is no factor of safety included, this minimum crest height should be increased at least 2 to 4 ft. or more, dependent on the situation.
- Consideration #4: The height of the bend's opposite bank point bar bench should be analyzed. If the point bar bench height is taller than the crest of the designed LPSTP, then consideration should be addressed as to whether the LPSTP height should be raised to a height equal to, or taller than, the point bar bench elevation.

Limitations

- With the proper sized stone, LPSTP/LFSTP resists the erosive flow of the stream and stabilizes the toe, but does not provide direct protection to mid and upper bank areas.
- This method is not foundation dependent.
- Success depends on the ability of stone to launch into any scour holes formed on the river side of the LPSTP. A well-graded stone that will launch, or self-adjust (self-heal) must be used in LPSTP construction.
- Weight of stone in the LPSTP (loading of toe) might resist some shallow-fault geotechnical bank failures.

Guidelines and Tips for Construction

If there is the opportunity to build a demonstration project do so. Either test different heights of LPSTP in a number of similar bends, or for testing in a single bend start at the upstream end with a reasonably tall 50 ft. long section of LPSTP (take the amount of stone calculated from consideration #2 and add 4 ft. to the height). Continue in the downstream direction reducing height in 1 ft. increments until an unusually small amount of stone is used (3 ft. below low-flow water surface elevation for example, or below the vegetation line if one exists). After a reasonable time and at least two flood or long-duration high-flow events the sections that failed will provide some guidance for the minimum effective crest height.

- At this time, no specific design criteria exists that relates the crest elevation of LPSTP to the channel forming discharge, effective discharge, or dominant discharge.
  - One ton of LPSTP per lineal ft. is approx. 3 ft. tall (using well-graded limestone @110lbs/cu ft.)
  - Two tons per lineal ft. is approx. 5 ft. tall
  - Three tons per lineal ft. is approx. 6 ft. tall; 7.5 tons is 9.5 ft. tall
  - Four tons per lineal ft. is approx. 7 ft. tall; 10 tons is 11 ft. tall
  - Six tons per lineal ft. is approx. 8.5 ft. tall; 14 tons is 13 ft. tall

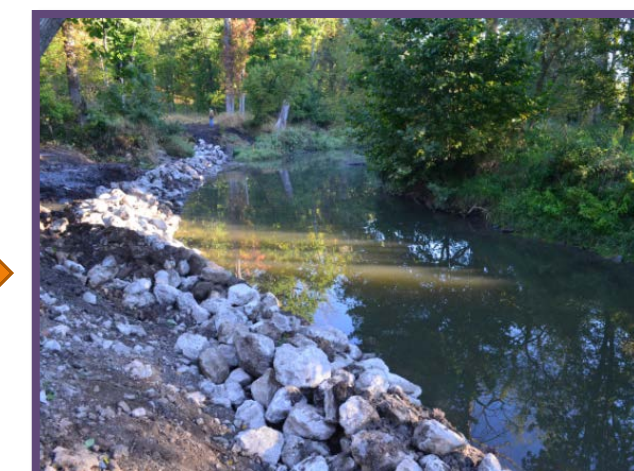
- LPSTP must be deeply keyed into the bank at both the upstream and downstream ends and at regular intervals along its entire length. Charlie Elliott's spacing rules-of-thumb for keys in flat-sloped sand bed water bodies: 50 to 100 ft. intervals on smaller streams, 1 to 2 bank-full widths on larger waterways.
- Keys at the upstream and downstream ends of LPSTP should not be at a 90 degree angle to the LPSTP structure, but at 20 to 30 degrees to HIGH FLOW.
- Keys should go far enough back into the river bank, and tied into the existing stable bank so river erosion and migration will not flank the key and the LPSTP.
- Keys should be vegetated if possible. Key length can be extended with vegetation alone in some cases.
- Volume of material per ft. of key should equal or exceed the volume of material per ft. in the LPSTP. Stone max size and gradation should be the same as the stone used in the LPSTP and Tie-Backs.
- Minimum key width should be three times the D-100 of the stone used.

Example Construction Sequence

Construction begins by moving the stream bank material to position the LPSTP into a smoothed alignment.

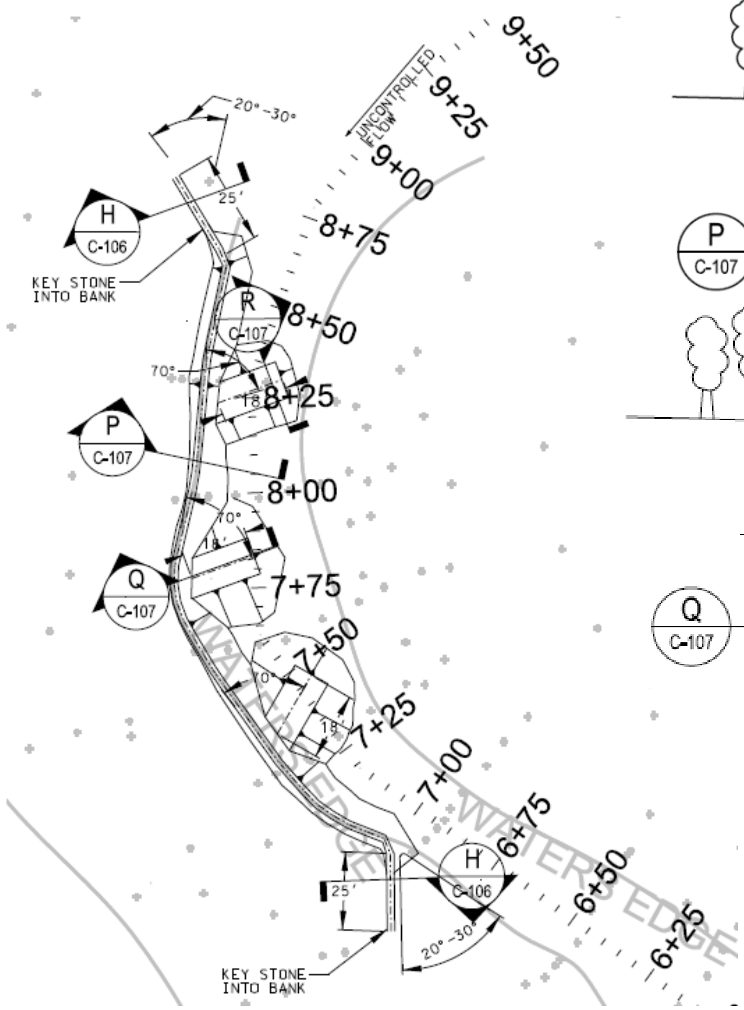
Stone is then deposited, depending on the size of the stream, over the bank with a skid loader or dump truck.

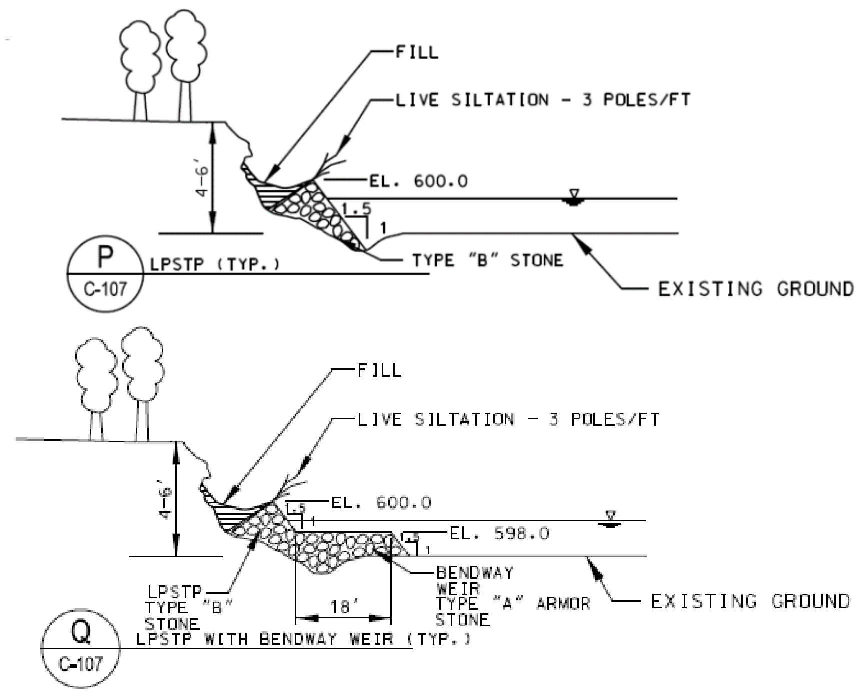
Excavator then positions the stone into the triangular shape, or otherwise if installing LFSTP. Behind the excavator's work, Live Siltation is installed against the stone.



The area behind is then backfilled to create a contoured bank. The stone will self-adjust over times, further stabilizing the bank and looking more evenly contoured.

Example Plan Drawings





Estimating Time and Materials

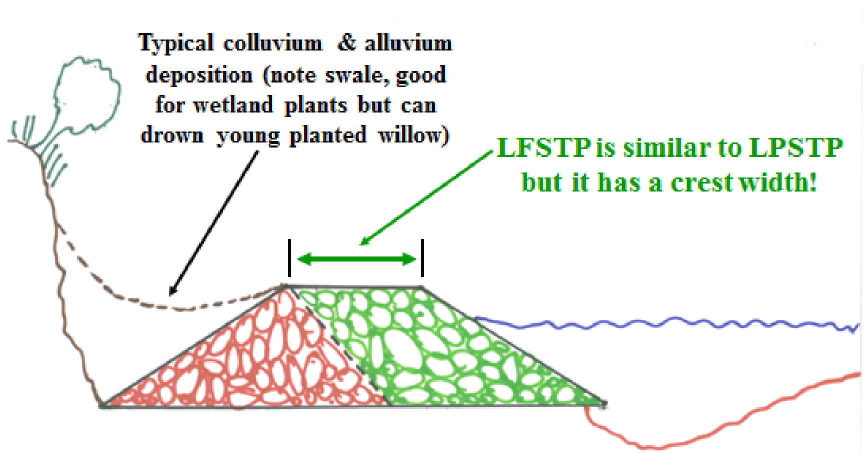
LPSTP has a relatively low cost in terms of volume of material and installation. The design, construction, inspection, and monitoring are quick and straight forward. These attributes make this a method widely applicable in a wide range of settings from small to medium-large streams, and many bends. LPSTP is useful in most bends, but a vector analysis should be undertaken to determine attack angles and associated scour. Enough stone must be placed to mitigate the anticipated scour and possible super elevation of water in small radius bends.

Monitoring and Maintenance

Monitor overall condition (especially height), any scour on the bank immediately above the crest, scour at the connection to the key, and location of thalweg. Do the BW's need modification to increase functionality?

Monitor for excessive scour on the river side. Analyze and measure the river side slope of the LPSTP/LFSTP. It should range from 1 on 1.25, to 1 on 1.5. If steeper, then stone has launched as designed. Is more stone needed for launching, or to build height back up to As-Built specs?

Monitor any Large Woody Debris captured. Will it impact the design or function of the structures? Does it need removed?



Longitudinal Fill Stone Toe Protection (LFSTP)