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January 23, 2013

KANSAS ENGINEERING TECHNICAL NOTE NO. KS-2 (Revision 1)

SUBJECT: ENG–Design of Rock Weirs

Purpose. To provide guidance on the design of rock weirs

Effective Date. Upon receipt

Background

Rock weirs have been used by the Natural Resources Conservation Service (NRCS) for river and streambank protection since the 1990s. Oregon Technical Note Engineering 24, Design of Rock Weirs (2000), and Idaho NRCS Technical Note 13, Design of Rock Weirs (2001), were developed to provide field personnel with guidance. This Kansas technical note utilizes the information contained in the aforementioned Oregon and Idaho NRCS technical notes to provide guidance for the design of rock weirs in Kansas.

Description

Porous and solid rock weirs are channel-spanning rock structures that are installed to (1) center—and sometimes create—a stream thalweg; (2) protect streambanks by redirecting stream flow; (3) establish and maintain a lower width-to-depth ratio; (4) provide fish passage by concentrating low flows in flat-bottomed channels into narrower, deeper channels; (5) increase sedimentation along streambanks; (6) control flow direction and, therefore, minimize meandering; (7) raise water surface elevations to provide water to diversions and channel alcoves; (8) stabilize stream gradient; (9) provide energy dissipation; (10) create pool habitat; and (11) buttress the bole of a rootwad for aquatic habitat cover.

Rock weirs are very low structures that should be completely overtopped during channel-forming flow events (approximately a 1.5-year flow event). Channel-forming flow (or bankfull discharge) is defined as the flow that transports the greatest amount of sediment over a long period of time and controls the channel geometry. Porous weirs have spaces between the exposed rock near the middle of the channel to further accommodate fish passage for some species, while solid weirs are continuous across the channel. Both porous and solid rock weirs are designed in a “V” or “U” shape with the trough oriented upstream. (See Figures 1, 2, and 3.)

Each stream channel and project site is unique. Geomorphic characteristics (such as meander pattern, width-to-depth ratio, radius of curvature, particle size distribution, channel gradient, and pool/riffle spacing) all impact the effectiveness of rock weirs. On-site evaluation of the appropriateness and utility of rock weirs is necessary. They are most effective in gravel- and cobble-bed streams with slopes less than 3 percent. These structures should NOT be used in sand-bed streams.

(more)

DIST: A, F

For streams with a channel-forming flow width greater than 100 feet, “V”- or “U”-shaped weirs are not recommended; “W”-shaped weirs are more effective in very wide streams but are more complex to design and build and are not covered in this technical note.

Rock weirs redirect stream flow to the center of the stream channel and disrupt the velocity gradient in the near-bank region. They utilize a low weir section pointed upstream to force water flowing over the weir into a hydraulic jump. Flowing water turns to an angle perpendicular to the downstream weir face causing the flow to be directed away from the streambank. The weir effect continues to influence the bottom currents even when submerged by flows greater than the channel-forming discharge. The length of the thalweg created downstream varies with slope and radius of curvature but is typically 100 to 200 feet. The disruption of the velocity gradient reduces channel bed shear stress and interrupts sediment transport in the near-bank region.

Using rock weirs in conjunction with bioengineering methods is the most favorable combination. The weirs provide direct streambank protection from flow, and vegetation provides for energy dissipation and sediment deposition.

General Material Specifications

Rock for weirs shall be durable and of suitable quality to assure permanence in the climate in which it is to be used. The rock shall be sound and dense, free from cracks, seams, and other defects that would tend to increase deterioration from weathering, freezing and thawing, or other natural causes. The rock fragments shall be angular to sub-rounded in shape. The least dimension of an individual rock fragment shall not be less than $\frac{1}{3}$ the greatest dimension of the fragment. Rock will have a minimum specific gravity of 2.5.

Depending on availability, large rock (generally greater than 3 feet in diameter) can be less expensive by weight and can take less time to install. If large rock is not available or is not preferred, follow the rock sizing criteria listed below.

Material sizing should follow standard riprap sizing criteria for turbulent flow (Far West States-Lane Method) for the design flow and be modified with the following formulas from [Chapter 16 of National Engineering Handbook \(NEH\) 650, Engineering Field Handbook](#):

$$D_{50\text{-barb}} = 2 \times D_{50\text{-riprap}}$$

$$D_{100\text{-barb}} = 2 \times D_{50\text{-barb}}$$

$$D_{\text{minimum}} = 0.75 \times D_{50\text{-riprap}}$$

Note that the Far West States-Lane method gives the riprap D_{75} and not the D_{50} —a gradation is required to obtain the riprap D_{50} . Once the riprap D_{50} is obtained, use the gradation listed above. When the ratio of curve radius to channel width is less than 6, rock sizes become extremely large and result in a very conservative design.

Rock in the weir should be well graded in the D_{50} to D_{100} range for the weir section (the smaller material may be incorporated into the bank key). The largest rocks should be used in the exposed weir section. **DO NOT** use the Isbash Curve when sizing rock for rock weirs as it results in sizes too small for this application.

Rock sizing depends on the size of the stream, maximum depth of flow, plan-form, entrenchment, and ice and debris loading. Adjustments may be necessary for your local area.

General Design Guidance

See Figures 1, 2, and 3 for reference.

Location

Rock weirs are typically placed in straight reaches of a stream channel near the downstream end of a riffle section. The upstream tip of the weir should be located at least 1 to 2 channel widths downstream of the crossover. They should be placed in areas where pools would naturally form. Rock weirs will not protect banks that are eroding due to rapid drawdown or mass slope failure; other techniques should be employed.

Height

The height of the weir section near the streambank (H) is generally determined by the elevation of channel-forming discharge (approximately a 1.5-year event). For ungaged streams, channel-forming discharge can be determined using field indicators such as bed features and the presence or absence of vegetation. The channel-forming elevation is not necessarily the top of the bank; for most streams, the channel-forming elevation is equal to or slightly above average annual peak flow.

To achieve proper weir function, the slope is nearly flat (slope should not exceed 5 horizontal to 1 vertical [5:1]) but **MUST** always have a positive slope toward the center of the channel. Rock weirs that are constructed with flat sections may lose a few rocks in the near-bank region, resulting in a negative slope essentially forcing water closer to the bank.

Relative height of weirs used in a series is very important. Generally, the slope between the weir crests should not be flatter than the pre-project water surface slope at low flows. The center of the weir should be at grade with the channel bed to allow for sediment transport and fish passage. To reduce scour depths, decrease the weir height. Higher weirs cause greater flow convergence and, thus, greater scour depths.

Spacing

Rock weirs are typically used in a series if the intended purpose is fish passage or grade control with an elevation change (headcut) greater than 1 foot. For fish passage, the spacing depends on slope, length of backwater effects created and associated depth, and length of thalweg created downstream. For grade control, the rock weirs should be placed no closer than the net drop divided by the channel slope. For example, a 1-foot high weir in a stream with a 2 percent gradient will have a minimum spacing of 50 feet ($1/0.02$).

Angle and Offset

The structure should project upstream such that the flow is directed away from the streambank. The angle from a tangent to the bank can vary from 20 to 60 degrees although a hydraulic analysis is necessary for weirs with arm angles approaching 60 degrees. (Refer to Figure 3.) Once the arm length reaches 50 to 60 feet, it is necessary to truncate the "V" and cross the channel in more of a horseshoe shape.

Profile

The rock weir transitions from the exposed weir section to the bank key on a slope of 1.5:1 to 2:1. The weir section at the streambank should not exceed the channel-forming flow level (1.5-year flow). The bank key must be long enough and high enough to prevent water from flowing around and eroding behind the structure. Banks that are frequently overtopped will require a more extensive

key that extends further back into the bank. Bank material will also need to be considered when designing the dimensions of the key.

The exposed weir section slopes from the channel-forming flow level at the banks down toward the center of the channel. The center of the weir should be at grade. The legs of the weir can be maintained at the channel-forming level into the stream channel if the purpose is to reduce channel width and concentrate stream flow. This may be advantageous in streams where fish passage is a concern during low flow periods.

Width

The top width of a rock weir generally ranges from 1 to 3 times the $D_{100\text{-weir}}$. The weir width may need to be increased to accommodate construction equipment in large rivers because of the rock weight and trackhoe reach. Wider structures will result in a more uniform, stronger hydraulic jump. Wider structures should be used if a deep scour hole downstream of the weir is expected.

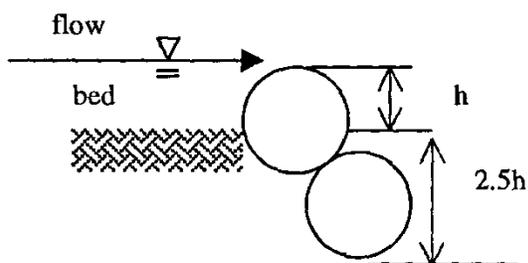
Length of the Bank Key

The purpose of the bank key is to protect the structure from flanking due to near bank erosion. The length of the bank key is 4 times the $D_{100\text{-weir}}$ and should not be less than 1.5 times the height to the top of the bank or 8 feet (whichever is greater). Buried cutoff logs or rocks can be used in conjunction with the bank key. The buried log or rock should be oriented perpendicular to the direction of flood flows. Leftover rock (or rock that is too small for the in-stream portion of the barb) can be used in the cutoff trench. Permanent seeding of the bank key area with perennial vegetation is recommended to provide slope/soil reinforcement and bank protection.

Depth of the Bed Key

The bed key depth should be determined by calculating expected scour hole depth downstream of the weir. The bed key is typically placed to a depth of $D_{100\text{-weir}}$. However, channel excavation depth in a live stream is sometimes limited because of sloughing; a very large rock often works better than trying to place 2 large rocks on top of one another. Note that scour depth will likely exceed the depth of the thalweg (deepest part of the channel). Scour depths will be greater in streams that are relatively deep or have higher gradients.

In lieu of a scour analysis, scour depth can be estimated using the following:



Expected scour depth for gravel or cobble bed streams can be estimated by:

$$\text{Scour} = 2.5 \times h$$

where:

h = height of exposed rock relative to bed elevation

For sand, use 3 to 3.5 x h .

To reduce scour depths, decrease the weir height. Higher weirs cause greater flow convergence and, thus, greater scour depths.

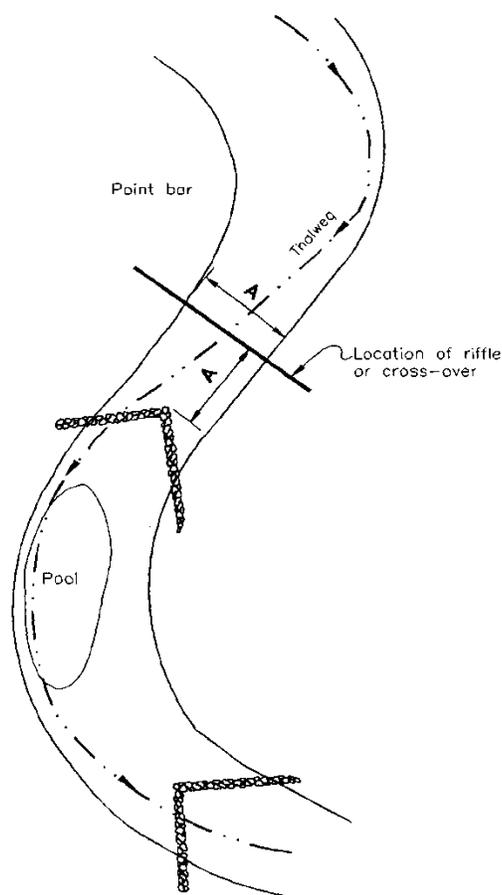
Vegetation

The use of vegetative practices with rock weirs is recommended for stabilizing streambanks. Vegetative conservation practices that relate directly to streambank protection include [342, Critical Area Planting](#); [391, Riparian Forest Buffer](#); and [393, Filter Strip](#).

Construction

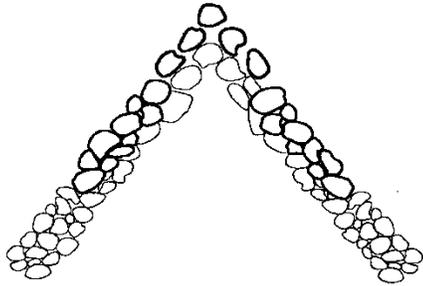
Rock weirs should be constructed during low flow conditions to minimize in-stream disturbances. It is usually necessary to work in the stream channel while constructing rock weirs. The rock should never be dumped. The rock should be placed with the proper equipment to ensure that the rocks are interlocked and stable. It is critical that the designer or an inspector experienced in these structures be present during installation.

Figure 1—Location for rock weirs

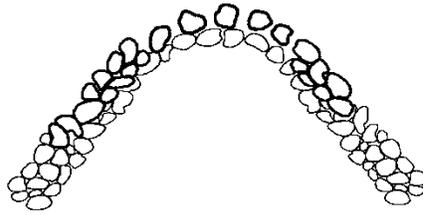


ROCK WEIR

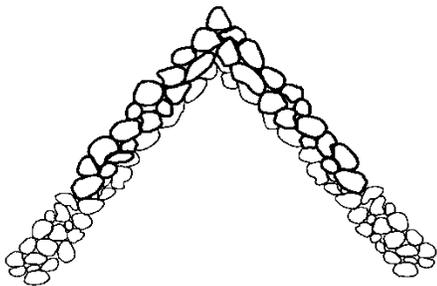
Figure 2—Types of rock weirs



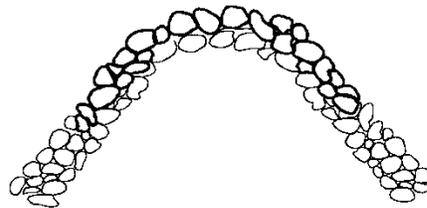
POROUS
"V" WEIR



POROUS
"U" WEIR

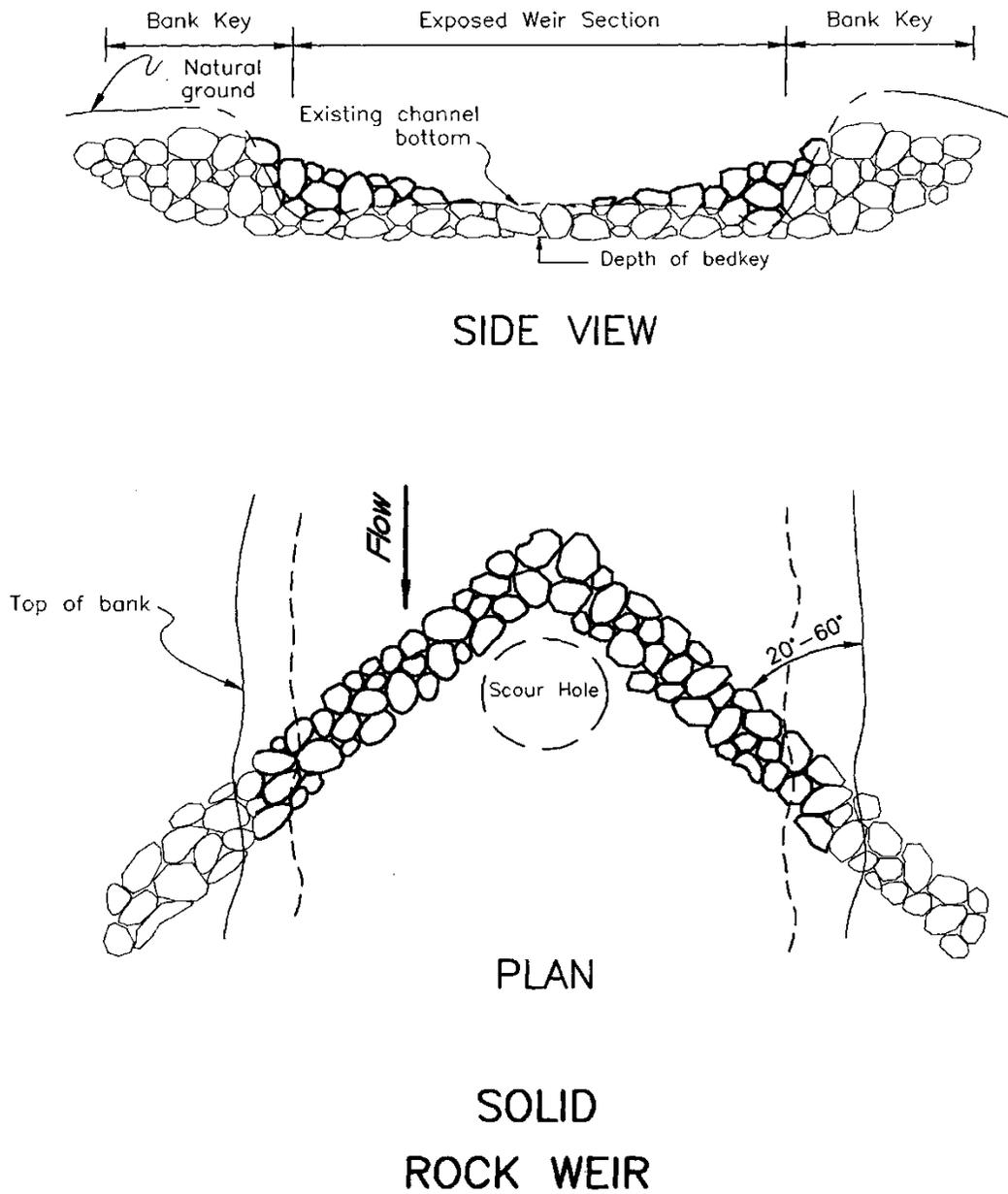


SOLID
"V" WEIR



SOLID
"U" WEIR

Figure 3—Typical rock weir



References

Davinroy, Robert B., and Redington, Stephen L., 1996, Bendway Weirs on the Mississippi River, A Status Report, Proceedings of the Sixth Federal Interagency Sedimentation Conference, March 10 - 14, 1996, Las Vegas, Nevada, Pg. 11-32 to 11-37

Derrick, David, 1996, Harland Creek innovative bank stabilization demonstration project, Proceedings of the Sixth Federal Interagency Sedimentation Conference, March 10 - 14, 1996, Las Vegas, Nevada, Pg. 11-1 to 11-5

LaGrone, D.L., 1996, "Bendway Weir General Guidance Memorandum," U.S. Army Corps of Engineers, Omaha, NE, revised from 1995

Natural Resources Conservation Service, Idaho Engineering Technical Note 13, *Design of Rock Weirs*, United States Department of Agriculture, 2001

Natural Resources Conservation Service, Oregon Engineering Technical Note 24, *Design of Rock Weirs*, United States Department of Agriculture, 2000

Reckendorf, F.R., 1996, Bear Creek, Oregon, Fish Habitat Enhancement, Report by Reckendorf and Associates, Salem, OR, for the Wallowa County Conservation District, Enterprise, OR

Reichmuth, D.R., 1993, Living with fluvial systems, Seminar on February 23 - 25, 1993, ODFW, Portland, Oregon, GEOMAX, Bonners Ferry, Idaho

Rosgen, D.L., 1998, River Assessment and Monitoring: fluvial geomorphology short course, Pagosa Springs, CO, September 21 - 25, 1998

Rosgen, D.L., 1999, Natural Channel Design and River Restoration: fluvial geomorphology short course, Pagosa Springs, CO, October 5 - 14, 1999

Saele, L.M., 1994, Guidelines for installing stream barbs, Streambank Protection and Restoration Conference, September 22 - 24, 1994, Red Lion, Portland, Oregon, Sponsored by Oregon Water Resources Research Institute, Corvallis, Oregon

Contact

Technical assistance is available from NRCS at your local USDA Service Center (listed in the telephone book under United States Government). More information is also available on the Kansas Web site at www.ks.nrcs.usda.gov.

(signed)

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