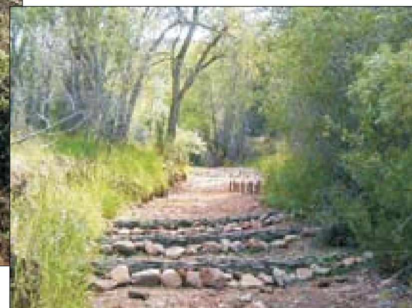
An Introduction to Induced Meandering:

A Method for Restoring Stability to Incised Stream Channels

by Bill Zeedyk



A Joint Publication from Earth Works Institute
The Quivira Coalition and
Zeedyk Ecological Consulting

Third Edition ~ April 2006

Contents

This document describes riparian restoration techniques, such as those used for several demonstration sites in the Galisteo watershed as part of the Galisteo Watershed Restoration Project—phase 2 (GWRP-II). This project is sponsored by the New Mexico Environment Department with financial support under Clean Water Act Section 319(h) administered by the U.S. Environmental Protection Agency. The project attempts to ameliorate surface water quality in New Mexico waters by reducing non-point source pollution in Galisteo Creek.

An Introduction to Induced Meandering is an illustrated field guide for use by participants of riparian restoration educational workshops and field tours, along with contractors and volunteers (during installation of structures). It is a general promotion for Bill Zeedyk's techniques for a broad audience that includes project managers, government officials, and others. This field guide is not to be used or interpreted as a design manual.

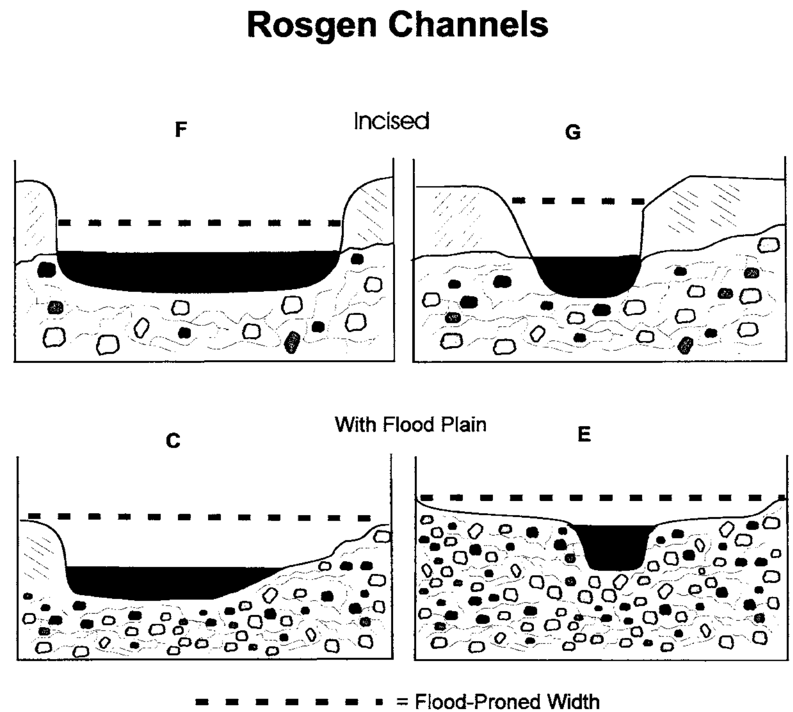
I. Induced Meandering: Concepts and Terminology

Streams naturally meander and the meandering process eventually results in the evolution of a floodplain adjacent to the stream channel, except where valley characteristics prevent floodplain formation. In alluvial valleys, floodplains are desirable because they dissipate flood energies across a wide area, reduce flood peaks as flood flows spread out, facilitate sediment retention, and provide habitats for streamside vegetation and wildlife.

Stream channels impeded by roads, railroads, livestock trailing, mining, or other disturbances may become incised if straightened or steepened. An increase in the frequency or magnitude of flood events due to deteriorating watershed conditions in headwater areas may also trigger channel incision. An incised channel is one that no longer has access to the adjacent floodplain.

A stream channel will change its dimensions and pattern in response to any change in flood frequency, magnitude, or sediment supply. Given sufficient time, consistent weather cycles, and a return

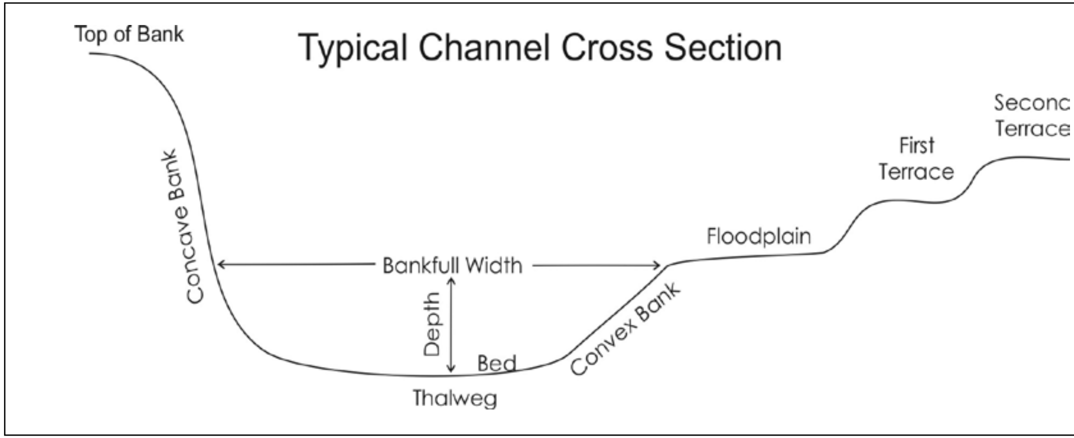
Figure 1.



Rosgen, D.L, 1994. "A Classification of natural Rivers". Catena, No. 11 (3), pp. 169-199.

to watershed equilibrium, incised channels will tend to widen (due to lateral erosion of their banks), flatten, become more sinuous, and develop a meander pattern along with floodplain characteristics similar to the pre-disturbance condition. In other words, disturbed channels tend to evolve toward a state of dynamic stability appropriate to watershed geology, sediment characteristics, the climate, flood frequency, and magnitude.

Figure 2.



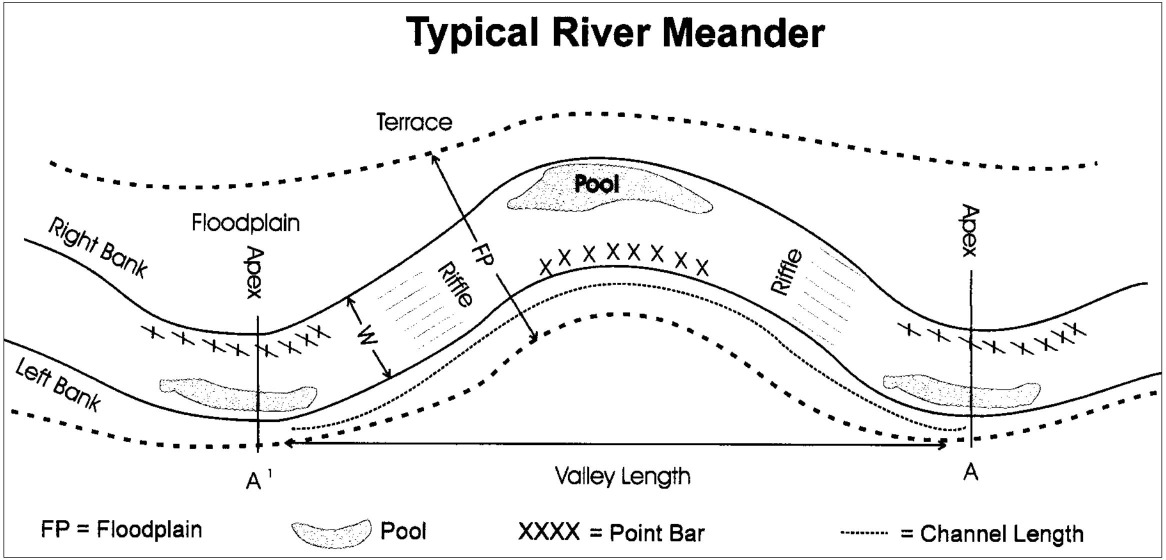
Two methods are available to speed the recovery of disturbed channels to the dynamically stable form and meander pattern and reconnect the channel with its floodplain. One is to excavate or reconstruct a meandering channel having the width, depth, slope, sinuosity, and other characteristics appropriate to the watershed and landform. The other is the *Induced Meandering Method*—letting the river do the work.

The *Induced Meandering Method* uses artificial instream structures, manipulation of streambank vegetation, and the power of running water to expedite channel evolution and floodplain development. Key components of induced meandering are the proper sizing and spacing of structures and the selective introduction or removal of streambank vegetation.

Induced Meandering is recommended for the treatment of incised channels **ONLY**; specifically Rosgen Channel Types G, F, and some B Channels (Figure 1). The purpose of treatment would be to speed evolution toward the Rosgen C or E Type as appropriate to valley type and bedload characteristics.

Since an incised channel entrenched in valley alluvium is naturally attempting to increase its width and re-establish a

Figure 3.



floodplain, it is important to remember that doing anything to stop meandering or to stabilize the bank will only frustrate channel evolution toward the stable form.

Efforts to keep a stream too straight will delay evolution of a stable channel while efforts to stabilize eroding banks of incised channels may be self-defeating in an evolutionary sense, because the stream has to create, through lateral erosion, sufficient space for a meandering channel to reach its equilibrium meander amplitude. Similarly, it would be inappropriate to modify a dynamically stable channel by attempting to increase its width, flatten its slope, or increase its sinuosity because such alterations would interfere with the ability of the stream to accommodate flood flows or transport its bedload.

Low-flow periods are important; they are not down time, but permit maximum growth of riparian vegetation when point bars and side banks are stabilized. The stream is still at work since growth of vegetation creates plant diversity and the biomass necessary to capture and retain sediment during subsequent storm events. Water stored in evolving point bars, floodplains, and terraces nourishes the desirable riparian plant community.

Channel response to the installation of instream structures, such as vanes, baffles, and weirs, is variable for each stream reach because of variability in such factors as:

- channel width, depth, and slope;
- resistance of streambed and banks to erosion;
- sediment supply;
- roughness of bed materials; and
- the type, dimensions, spacing, structural integrity, competence, and roughness of installed structures.

When instream structures are properly designed, placed, and installed, *Induced Meandering* is a feasible and effective method for modifying the shape, pattern, and dimensions of incised channels in the Southwest. Rocks alone can be used, but the use of wooden pickets or stakes in these structures improves their effectiveness to capture sediments and seed stock, and reduce maintenance needs. Depending on channel dimension, functional instream structures can be economically constructed with hand labor using freely available local materials such as sticks and rocks.

This method of channel reconstruction "let's the river do the work" of re-forming the shape of the river, its slope, dimensions, and floodplain, although the rate of progress toward meeting management goals is variable because of the natural variability in the timing and magnitude of flood events.

Terminology

(Refer to Figures 2 and 3.)

W or W$_{BKF}$ = Channel Width at bankfull stage.

FPA = Width of Flood Prone Area at twice maximum depth of bankfull channel at thalweg.

A – A^1 = *One Meander.*

A – A^1 along the channel = *Meander Length.*

A – A^1 straight line distance = *Valley Length.*

Bankfull is the stage at which the channel begins to spill onto its floodplain at flood stage.

Floodplain is a relatively flat area adjacent to the bankfull channel.

Thalweg is the deepest part of the channel.

A **Terrace** is an abandoned floodplain.

Maximum Depth is the depth at the thalweg when the river is flowing at bankfull.

Mean Depth is the average depth of the river at bankfull. As a rule of thumb, mean depth is approximately equal to 0.6 times *maximum depth*.

Sinuosity is the ratio of channel length to valley length.

An **Ephemeral** stream derives its water exclusively from precipitation.

A **Perennial** stream derives water from direct precipitation and from groundwater.

II. Induced Meandering Procedures

Step 1. Select a Reference Reach.

A stable reference reach is selected to determine potential ***Rosgen channel type*** (Figure 1), ***meander length, bankfull width, width:depth ratio, mean depth, bedload and bank materials, channel slope, meander radius, flood prone area, and sinuosity*** (Figures 2 and 3). These parameters are used to set management objectives and design criteria for proper spacing and sizing of structures to be installed in the treated reach.

Step 2. Determine Your Restoration Goals and Management Objectives.

Restoration goals should include landscape or ecosystem parameters, such as health of riparian, woodland, or grassland areas, or sediment retention and build-up in the channel. Management objectives should be formulated for the desired Rosgen channel type and channel characteristics to be attained. All goals and objectives should be attainable in about five years after implementing induced meandering work.

Monitoring channel response to treatment, Rio Galisteo. (Photo courtesy of Bill Zeedyk.)

Step 3. Select the Type and Location of Structures.

Handmade restoration structures are used to deflect flows to invoke lateral erosion of streambanks or to stabilize channel slope and bed elevation. They are described on pages 7-16.

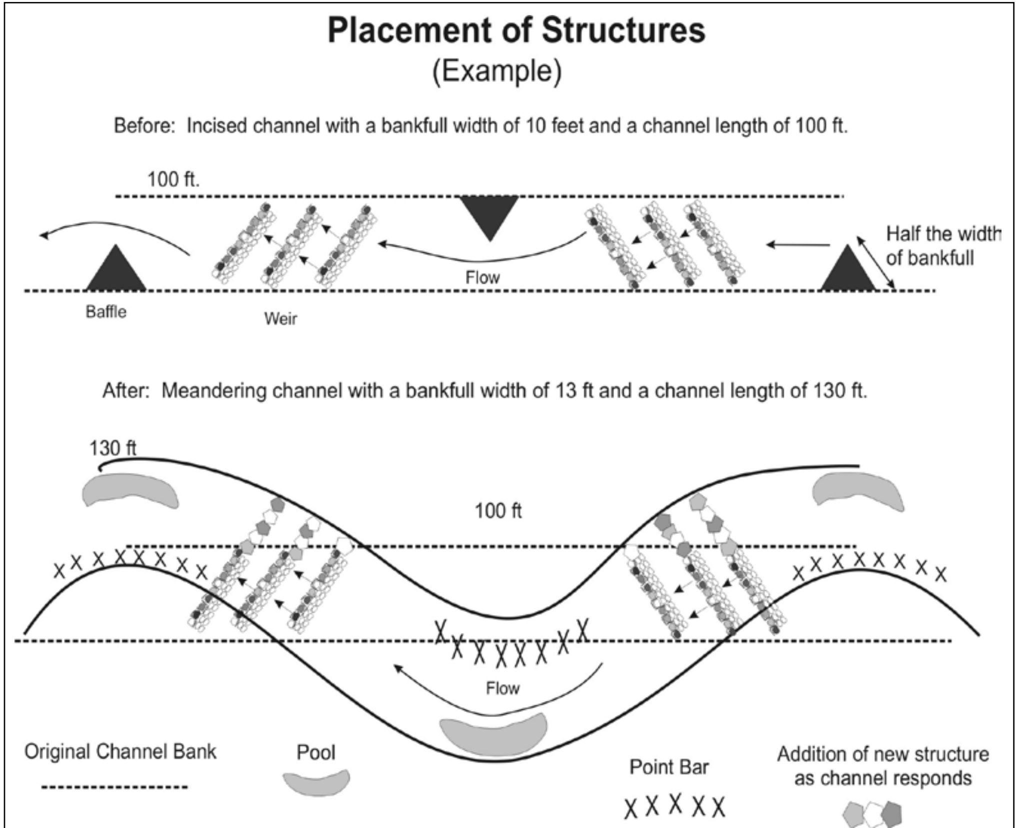
Step 4. Monitoring Plan and Baseline Data Collection.

Scheduled monitoring is absolutely essential to the successful conclusion of an induced meandering project. Monitoring is done to assess structure performance, determine channel response, and gauge progress toward meeting plan objectives. Key parameters include, at a minimum, ***bankfull width, mean depth, flood prone area width, channel length, and slope.***

Step 5. Follow-up Monitoring and Maintenance.

Key parameters should be re-measured in a disciplined way and photo points re-photographed to record progress. Initially, monitoring should be done immediately after each storm event. Over the long term,

Figure 4.



scheduled routine monitoring should be done at the end of the snow melt run-off period and at the end of the monsoon season to allow enough time to repair or modify structures prior to the next upcoming wet season.

Monitoring will detect needed repairs or indicate needed modification, relocation, or removal of structures not performing according to plan. For example, additional pickets or rocks may be needed to strengthen a weir or extend a baffle.

With time, the bank opposite a baffle or vane will erode. At that point additional posts or pickets should be added to the structure in order to "chase" the receding streambank.

Similarly, monitoring may indicate the need to raise or lower the height or width of a wicker weir to establish the desired channel slope gradient.

Eventually management objectives, such as bankfull width, mean depth, meander length, channel slope and sinuosity will be attained. At that point, it should no longer be necessary to modify or maintain structures and, instead, it may then become important to stabilize eroding banks by planting woody trees and shrubs such as willows and cottonwoods. Stabilization will keep the evolving meander from "scrolling" downstream.

III. Types and Location of Structures

Deflectors are used to direct streamflow left or right. Types of deflectors include:

- Vanes (more resistant to flow)
- Picket Baffles
- Boulder Baffles

Weirs are used to stabilize bed elevation and channel slope. Types include:

- One-Rock Dams
- Wicker-Weirs
- Rock Arch Dams

The location, design, and sizing of structures are important factors to the success of the restoration effort (Figure 4).

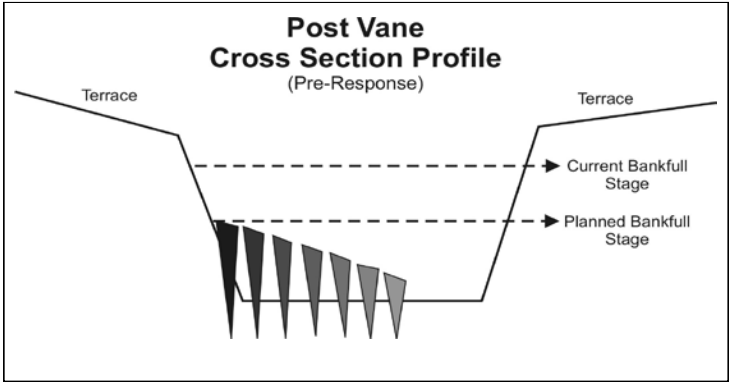
To calculate a new **Meander Length**, multiply the **bankfull width** by **10** for cohesive streambanks (well vegetated or clay banks) or **14** for loosely consolidated banks (gravelly banks). If unsure of the streambank type, multiply the bankfull width by the average, **12.**

Structures are spaced appropriately to the desired meander length and sized proportionally to the desired bankfull width of channel and mean depth at bankfull. To correct for sinuosity, divide the planned meander length by the present sinuosity to determine the distance between structures in the existing channel.

Vanes and Baffles are different types of structures used to deflect streamflow toward the opposite bank. As flows are deflected, energies are concentrated and the concentrated force is focused at the base of the opposite bank causing it to erode, collapse and recede. As the bank recedes, the channel widens, the thalweg deepens and shifts toward the receding bank, bed materials are flushed away, and a pool forms at the base of the bank opposite the structure (Figures 5 and 6).

> ***Deflectors, like vanes and baffles, widen the channel and induce meandering.***

Figure 5.

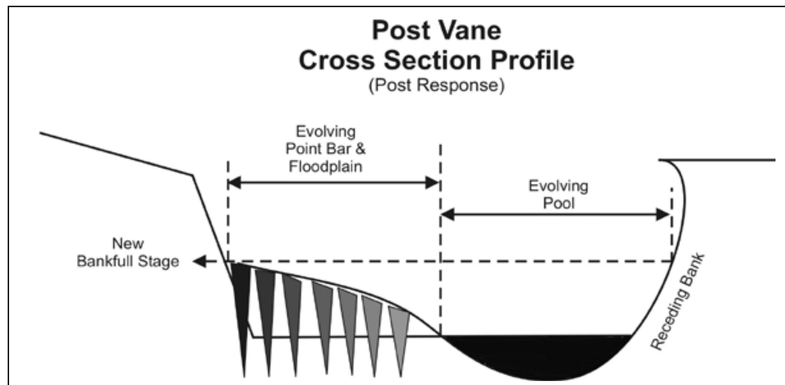


Point bar evolving downstream of properly installed post vane with trimmed posts. (Photo courtesy of Bill Zeedyk.)

However, the receding bank resists erosion to some degree depending on its stability and repels the concentrated flow. The repelled flow then rebounds toward mid-channel, gradually crossing over and impinging on the other bank. In other words, a baffle installed on the left bank will deflect flows toward the right bank only to be rebounded again toward the left bank farther downstream.

Just as flow velocity accelerates opposite the deflector, it slows along the bank adjacent to the structure. As the velocity slows, sediments drop out of suspension and a point bar begins to form adjacent to the structure.

Figure 6.



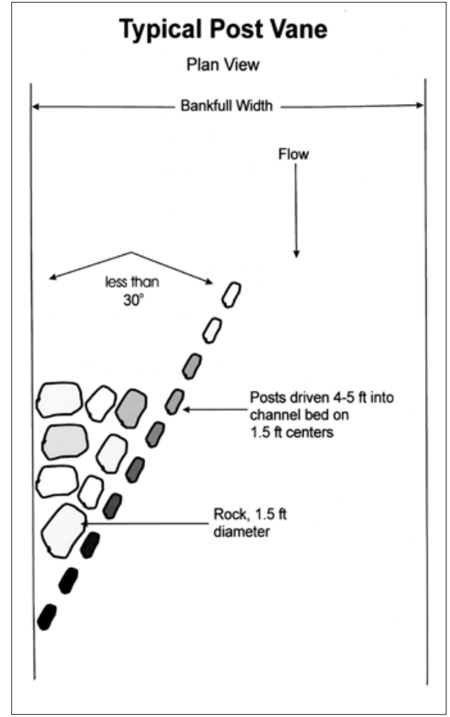
When a series of structures is installed at appropriately spaced intervals, materials eroded from the concave bank, opposite one deflector, will tend to be deposited adjacent to or on top of the next downstream deflector, thus forming a convex bank. These deposited materials are soon stabilized by encroaching streambank vegetation and a new floodplain evolves where none existed before (Figure 6).

The effectiveness of a deflector will depend on its size relative to the width and depth of the channel, its competence to withstand the shear forces generated by increasing flow velocities, and the relative stability of the receding bank. In some situations, bank stability can be decreased by removing protective streambank vegetation.

To promote sediment deposition on the evolving point bar, the heights of posts for both vanes and baffles should taper gradually downward from the planned bankfull elevation toward the bed at mid-channel. Taller structures generate turbulence which tends to flush away point bar deposits so the tops of the deflectors should not be higher than planned bankfull elevation.

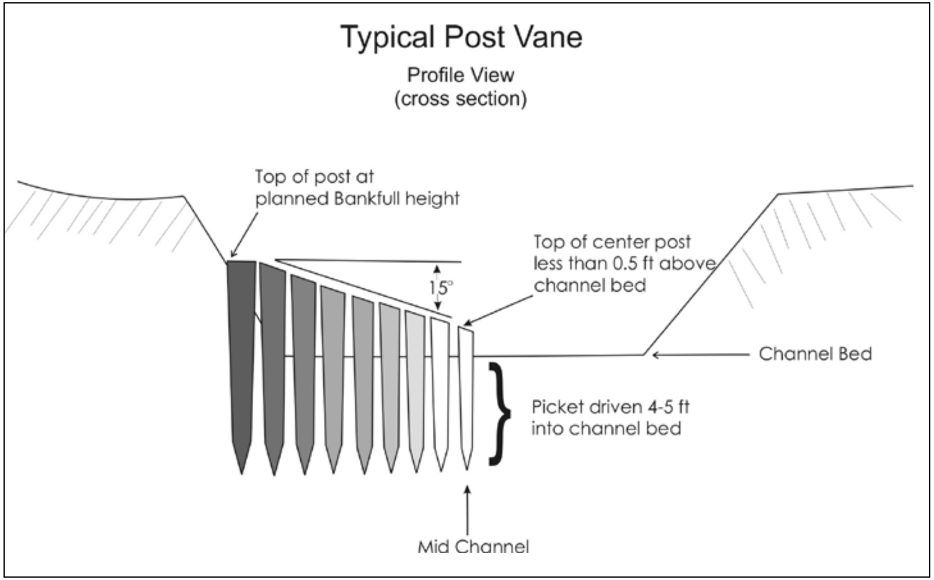
Vanes can be built of rock, boulders, logs, or posts. However, to have sufficient mass to resist flood flows, the size of required boulders and logs would be too large and not practical for hand-made structures or manual labor. This guide emphasizes **post vanes**, which can be installed by hand labor, although in some situations machinery may expedite construction.

Figure 7.



A vane is a straight-edged structure protruding from the streambank into the oncoming current at an angle from the streambank not exceeding 30°. The top edge of the vane dips downward at a 15° angle from horizontal, beginning at bankfull level of the streambank to streambed elevation at mid-channel. It is important that the base of the vane, where

Figure 8.



Trimmed posts, upstream view, Dry Cimarron, Rainbow Ranch, Folsom, NM. (Photo courtesy of Courtney White.)

it is embedded in the streambank, not extend above planned bankfull level (see Figures 7 and 8 and photos on pages 9 and 10).

For post vanes, use straight sturdy wooden posts 6-8 inches in diameter and 6-8 feet long for most applications. Posts are driven into the streambed, using a sledge hammer, to a depth of 3-5 feet, depending on cohesiveness of bed materials. Opening a start hole with a digging bar or auger may facilitate installation. Six-inch posts should be spaced on 18 inch centers, leaving a space of about 12 inches between posts. After all posts have been driven to the right depth, scribe a line from the bank to mid-channel at about 15° from horizontal; then cut off the excess with a saw (see photos on pages 9 and 10). Optimally, the apex of the angle between the vane and the bank can be filled with rocks too large to slide between the posts. In no case should the rocks be piled higher than the vane edge.

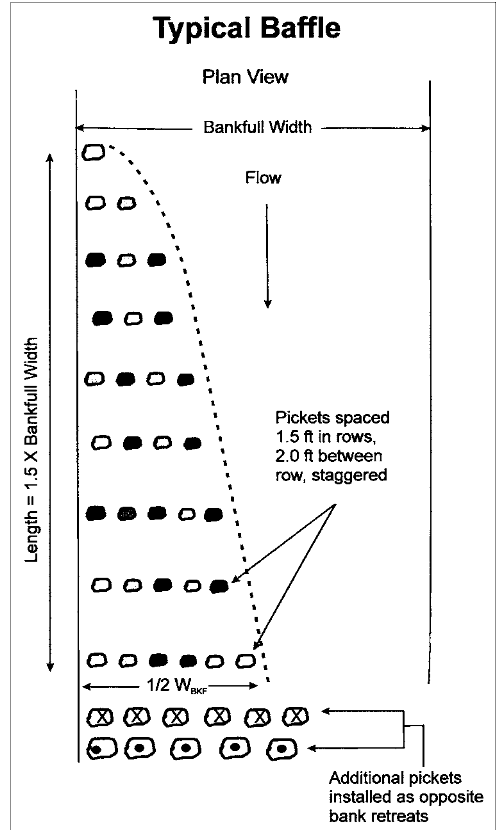
To size a vane at a 30º angle to the bank, place a mark on the bank at the planned bankfull apex of the meander and measure out to not more than mid-channel. This is the width of the vane. Multiply the width by 2 and measure downstream from the first mark. The second mark will be the base of the vane. To be sure that the angle does not exceed 30º (depending on channel characteristics), multiply the width by 3, and install the base of the vane at that point.

When the opposite bank begins to recede in response to treatment, the vane can be extended into the channel to "chase" the opposite bank. A point bar will evolve downstream from the vane on the same side of the channel. If the vane is too tall, turbulence will prevent formation of a point bar.

Baffles are designed to wedge streamflow toward the opposite bank and to be easily overtopped by flood events. An efficient baffle has the shape of a 30/60⁰ right triangle (Figure 9). The base of the triangle is at right angles to the streambank and extends outward to or beyond mid-channel depending on Rosgen channel type (Figure 10, page 13). In the case of a G Type channel, the baffle should not

Picket Baffle on Galisteo Creek.
(Photo courtesy of Earth Works Institute.)

Figure 9.



A newly installed rock baffle at Hubbell Trading Post, Arizona, June 1997.

Channel response to the rock baffle at Hubbell by October 1999. (Photos courtesy of Bill Zeedyk.)

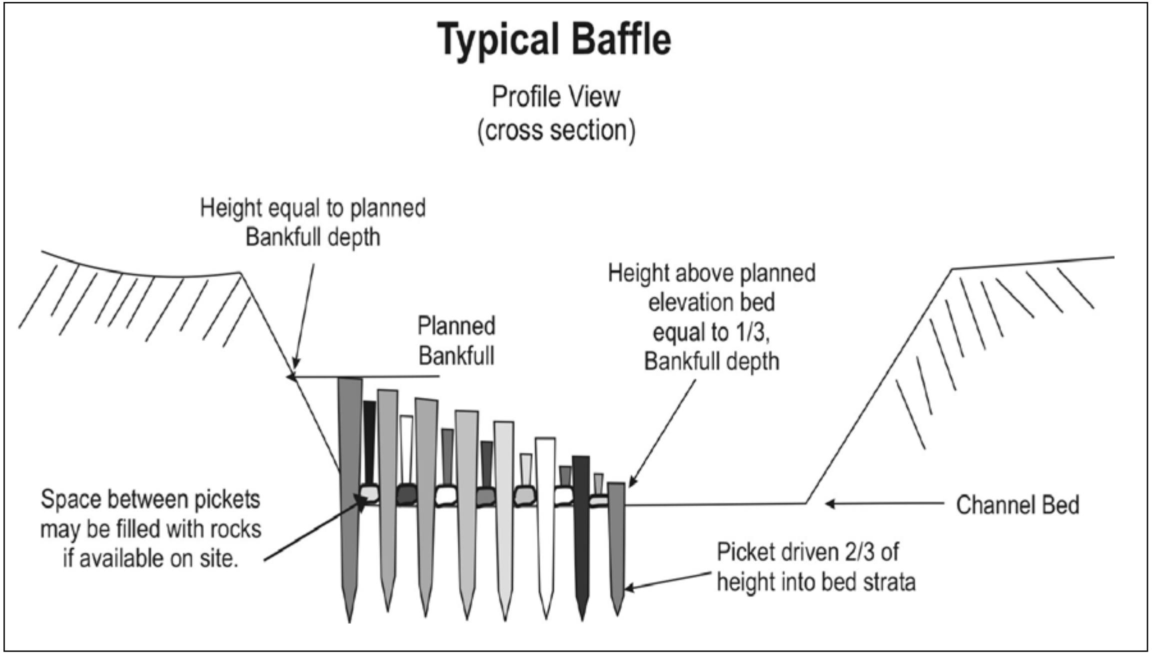
occupy more than 40% of the channel width. For an F channel, the baffle can take up to 70% of the channel width.

For example, when laying out a baffle, place a mark at the planned bankfull elevation on the bank where the structure will be built. Measure out into the channel the appropriate distance (40-70%). This distance is the width of the structure. Double the width and place a mark on the streambank at the distance upstream of the starting point. This is the length of the structure parallel to the channel. The hypotenuse of the triangle becomes the face of the wedge which deflects the oncoming flow toward the opposite bank.

Baffles can be built using wooden stakes, or **pickets,** driven into the channel bottom, or rocks may be used if their mass exceeds expected shear stress forces developing during flood peaks. Generally, pickets have greater shear stress resistance than rocks alone and are easier to handle using manual labor.

Pickets can be cut from trees like juniper, Russian olive, and even salt cedar and should be approximately 40 inches in length and 2-3 inches in diameter. Pickets should be driven about 2/3 their length into the channel bottom and spaced from 12 to 18 inches apart on center (Figure 10, page 13). A picket baffle with a width of 10 feet and a length of 20 feet will

Figure 10.



When choosing between rocks or pickets as baffle-making material, pickets are more appropriate to clay, sand, or gravel bedded channels while rocks are more appropriate to cobble or boulder-bedded channels. Rock baffles are especially appropriate to smaller, steeper ephemeral and intermittent streams and arroyos, where the properly sized materials are usually readily available and driving pickets is difficult.

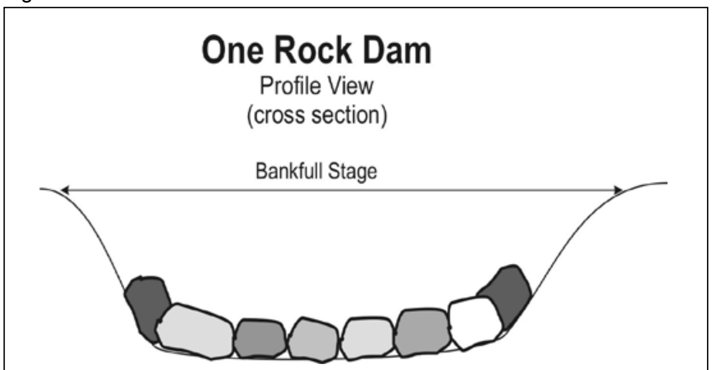
require about 30-50 pickets. Whether built of rock or pickets, the height of the baffle' should taper down from bankfull to a mid-channel height of about 1/3 bankfull. It is easier to cut pickets at the appropriate height above the channel bed than to drive them to appropriate height.

The tip of a baffle in mid-channel becomes the apex of the evolving meander. As the opposite bank recedes, an additional row of pickets can be added to the base of the triangle and extending further into the channel in order to "chase" the receding bank (Figure 9).

Weirs are artificial structures installed to stabilize the streambed at desired elevation and to establish the desired channel slope. When used in the induced meandering method, a weir is temporary in nature and will eventually be replaced by an evolving riffle if the weir is properly located and sized relative to planned channel dimensions and meander pattern.

Three types of weirs are regularly used for handmade induced meandering structures. These are **one-rock dams, wicker weirs**, and **rock arch dams**. Other structures such as ***Rosgen vortex rock weirs*** and ***w-weirs***, could be used if machine applications are appropriate, but will not be discussed in this guide.

Figure 11.



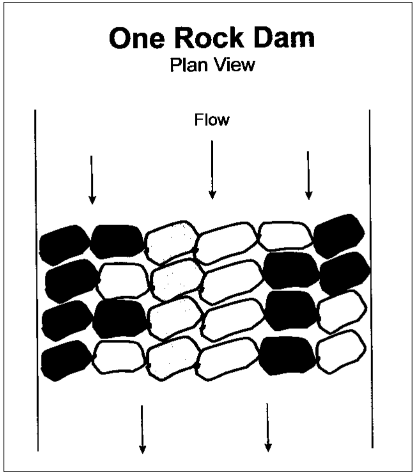
Weirs establish bed elevation and channel slope gradient.

When implementing an induced meandering project, weirs are installed mid-way between tips of the deflectors as measured at the upstream edge of the weir (Figure 4). A weir should be as wide as the bankfull width of the channel and as long as it is wide. Normally, the top of a weir should not be taller than 1/3 planned bankfull depth of the planned channel.

One-rock dams are used to raise channel bed elevation and control or modify slope gradient. One-rock dams are best suited to rocky channels, especially ephemeral or intermittent streams and arroyos. Wicker weirs are more suited to gravel, sand, or clay bottom channels. A one-rock dam is so named because it is only one rock tall. The dam should be several rows of rock across from the upstream to the downstream edge. The dam should not be taller than 1/3 bankfull depth of the planned channel (Figure 11). The dam is installed, not perpendicular, but at a 15-30° angle to the existing channel in order to route flow around the tip of the next downstream baffle or vane in anticipation of the evolving channel meander (Figure 4).

Stones should be selected, sized, and placed so that the completed structure ends up relatively level from bank to bank and flat from the upstream edge to the downstream edge. This

Figure 12.



can be accomplished by placing larger rocks in the deepest part of the channel, smaller ones to either side. (Figure 12.) Do not stack rocks on top of one another to get the needed height. The stacked rocks will be swept away by flood flows. Placing greatly oversized rocks in the structure will generate turbulence that could undermine it. Rocks should be sized proportionately to the 1/3 bankfull depth of the channel, 20-40 pound rocks for a channel one foot deep, 60-80 pounds for streams one and a half feet deep. Flood flows will pack smaller-sized bedload particles between the rocks, gradually strengthening the structure over time as a new riffle begins to develop at the site.

Maintenance and repair should focus on replacing any rocks scoured away by flood flows or on widening the structure along the banks if flows are beginning to go around it.

One rock dam on a side drainage of Holman Creek, Valle Vidal, Carson National Forest, New Mexico. (Photo courtesy of Tamara Gadzia.)

Wicker Weirs are small dams across a creek made from wooden stakes and rocks and are designed to control streambed elevation, channel slope, and pool depth while enabling free passage of bedload (Figures 13 and 14).

Stakes can be made from local vegetation such as juniper, salt cedar, and Russian olive. Driving the stakes upside

Figure 13.

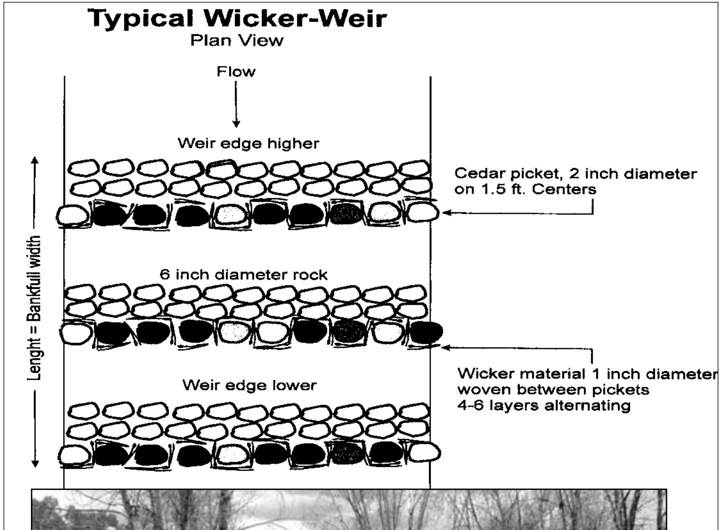
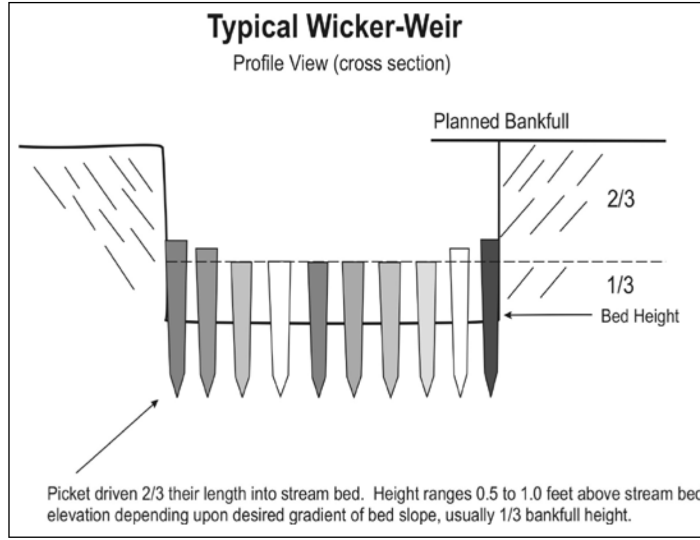


Figure 14.



Workshop volunteers build a wicker-wier on Largo creek, Williams Ranch, Quemado, NM. August 2004. (Photo courtesy of Tamara Gadzia)

down will prevent sprouting. Wicker weirs can be reinforced with the use of wicker materials woven between the stakes and are installed midway between baffles, and placed at an angle to anticipate the future course that the water will flow (see photos on front cover).

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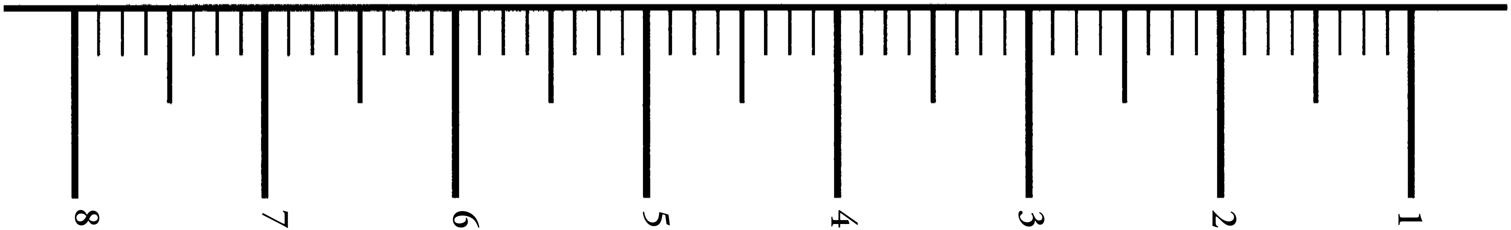
Cover Photos:
Front: [left] Galisteo Creek in Lower Canoncito, Cummings property, before restoration (May 2001); [middle] Wicker weirs installed on Galisteo Creek (June 2001); [right top] Close-up of wicker weirs; [right] Galisteo Creek after first flood event (August 2001). (Photos courtesy of Earth Works Institute.)

Back: Bill Zeedyk and participants during a workshop on Largo Creek near Quemado, NM. (Photo courtesy of Courtney White.)

For a list of locations of Induced Meandering projects in the Southwest, please visit: *www.earthworksinstitute.org*

For assistance with detailed design guidelines, contact Bill Zeedyk, Earth Works Institute, or The Quivira Coalition.



The production of this document was made possible through a grant from the Environmental Protection Agency and the New Mexico Environment Dept–SWQB-WPS, with additional contributions from the Rio Puerco Management Committee, Bill Zeedyk, and The Quivira Coalition.