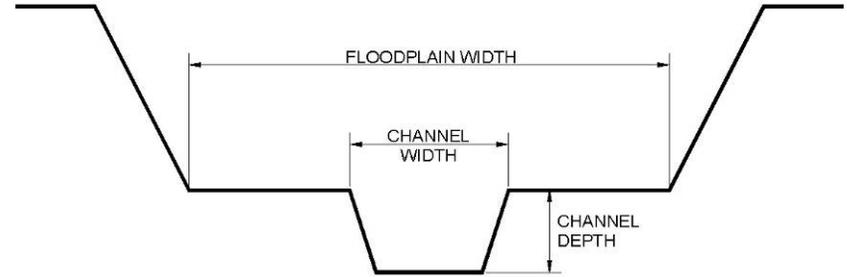


# Bankfull Depth Determination



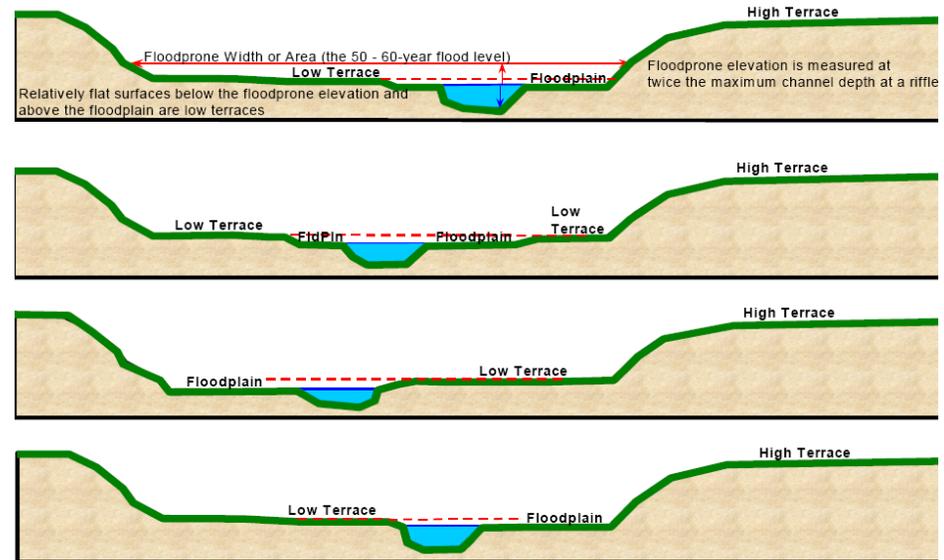
## Channel Dimensions



**BANKFULL ELEVATION** is the elevation at which water has filled the principal channel and just begins to flow onto the floodplain.

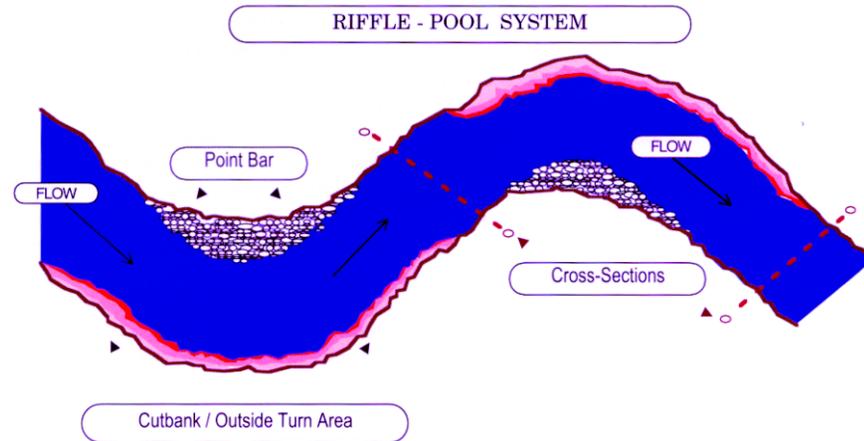
**BANKFULL DISCHARGE** is considered to be the channel forming or effective flow. Over time it performs the most work, transporting the most sediment, moving bedload as well as suspended sediment. Bankfull flow shapes the channel. As used here, the bankfull elevation is considered to be synonymous with the channel forming or effective flow. In unstable or modified channels indicators of the bankfull elevation, if present, will be found where the channel forming flow is attempting to build a new floodplain.

For stable streams the bankfull flow is associated with the 1-2 years event. In Michigan, the bankfull flow for most streams is the 1.5 year flow. This number represents a statistical analysis of stream flows over 10 or more years. To the observer, bankfull flow can occur several times a year.



STANDARD BANKFULL MEASUREMENTS – Stream width, depth and cross sectional area are measured at the bankfull elevation. These measurements are used to;

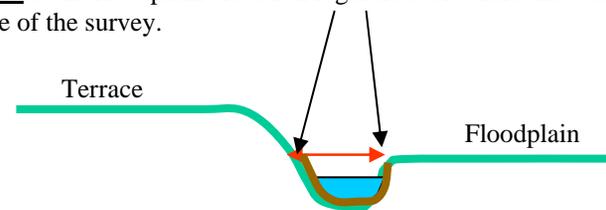
- Design stream BMPs such as Cross Vanes and Jhooks.
- Stream restoration design.
- Stream relocation.
- Sizing culverts and bridges.
- Assessing channel stability



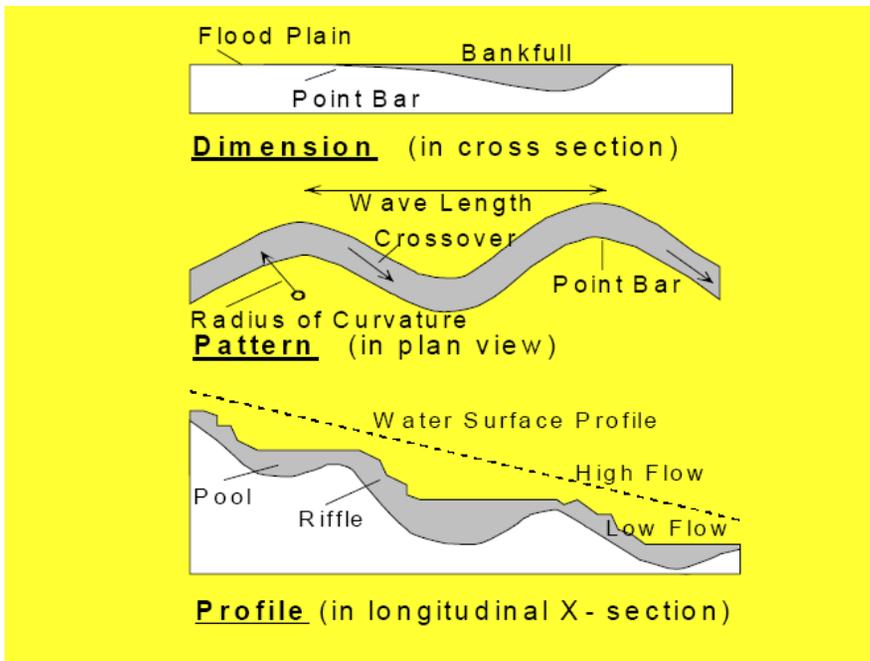
Bankfull elevation can be fairly easy to determine in streams with little to moderate entrenchment (streams with wide, accessible floodplains). With streams that are highly entrenched, determining bankfull elevation may be difficult.

The flats on top of the depositional features such as point bars are the best indication of bankfull elevation. To measure bankfull width, measure the width of the stream in the riffles (straight sections) from bankfull elevation to bankfull elevation. This measurement should be taken in the narrowest part of the stream. The riffles are the hydraulic control points on the stream, so the cross-sectional area in riffles is the minimum area needed to maintain stream stability.

**Measure** at the floodplain elevation regardless of where the water level is at the time of the survey.



Be careful not to interpret a terrace, when present, as the bankfull elevation. A terrace is a remnant geomorphic feature. Also, do not measure bankfull width near culverts or bridges.



## Bankful Indicators

### Stable Streams or Ditches with low to moderate entrenchment

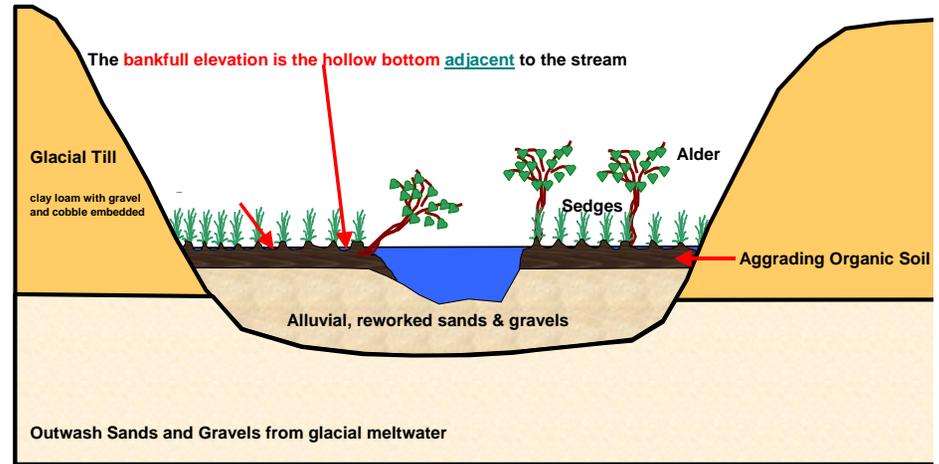
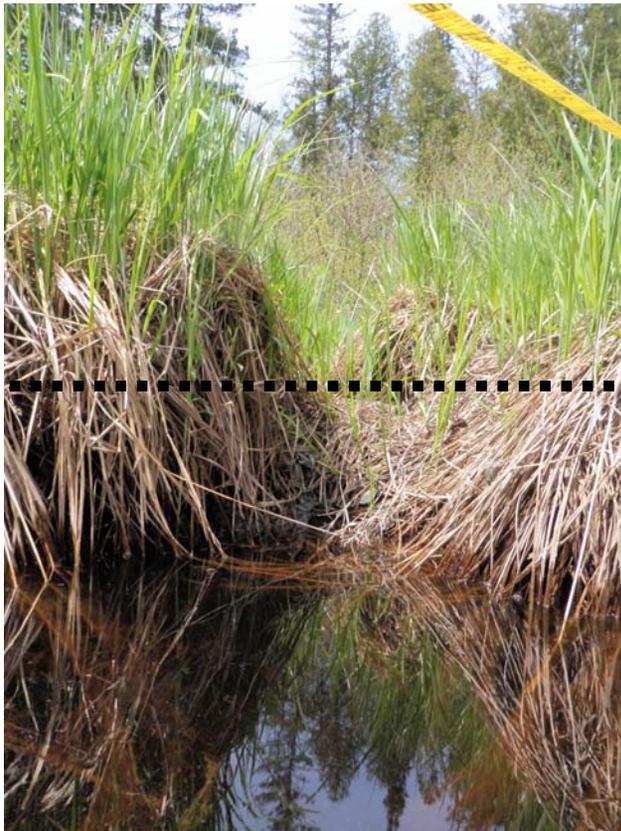
- First depositional flat above the waterline.
- Top of point bars.
- If no riffles (sand bed stream) measure in straight runs at narrowest part.



# Determining Bankfull Elevation in Difficult Circumstances or Stream Types

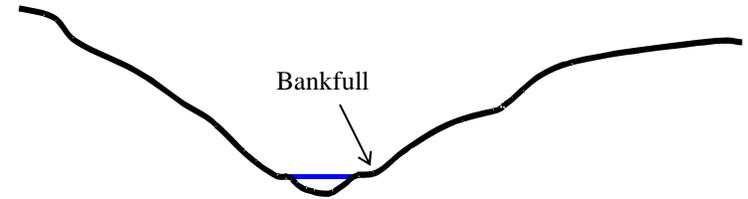
## Stream with low, wetland floodplain (E and C Channel)

The majority of the stream channels will be type C and E channels, low gradient, highly meandered streams with wide floodplains (low entrenchment). Identifying bankfull elevation is relatively easy in these channel types. Many channels will flow through wetland areas, with hummocky sedge growth and perhaps alder. In this case, the low points (hollows), between the hummocks will be the bankfull elevation.



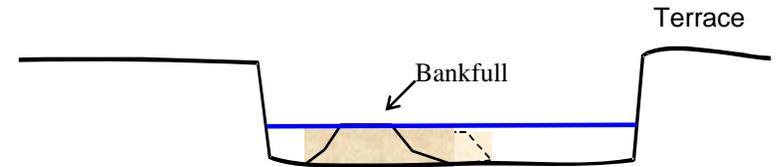
Bankfull elevation = Lowest elevation  
between sedge hummocks

**Moderately Entrenched Stream Types**  
(B Channel)



Look for small, footprint-sized floodplain flats adjacent to the channel in B stream types

**Highly Entrenched Stream Types (Wide and shallow channel)**  
(F Channel)



The highest mid-channel bar may be the elevation of the bankfull stage.



In Michigan, F channels are often unstable sections of stream that have become overwide and are in an intermediate stage of channel evolution in reaction to a past or current disturbance to hydrology or sediment load. F channels have little or no floodplain (highly entrenched), are wide and shallow and are low gradient with moderate sinuosity. The tops of mid-channel bars may be the only indicator of bankfull elevation.

## Incised or Over-Widened Streams or Ditches

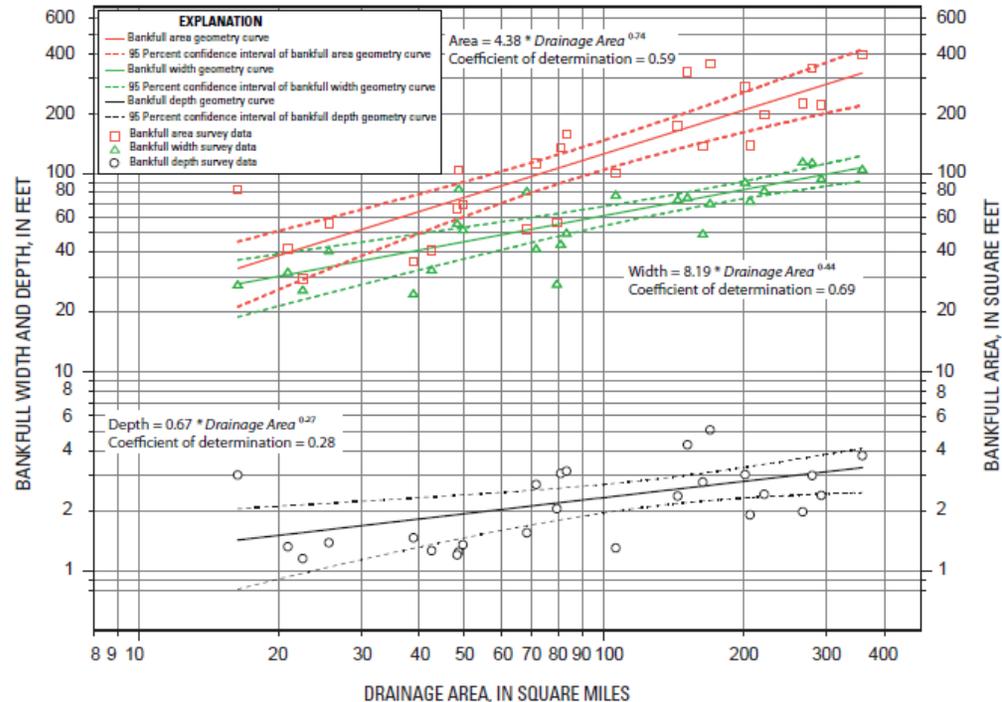
Natural floodplain benches below top of bank, or top of point bar on inside bends.



## Reference Reaches and Regional Reference Curves

Bankfull indicators cannot always be found. If indicators are absent in the study reach, try looking further upstream or downstream for a reach similar to the study reach that has indicators.

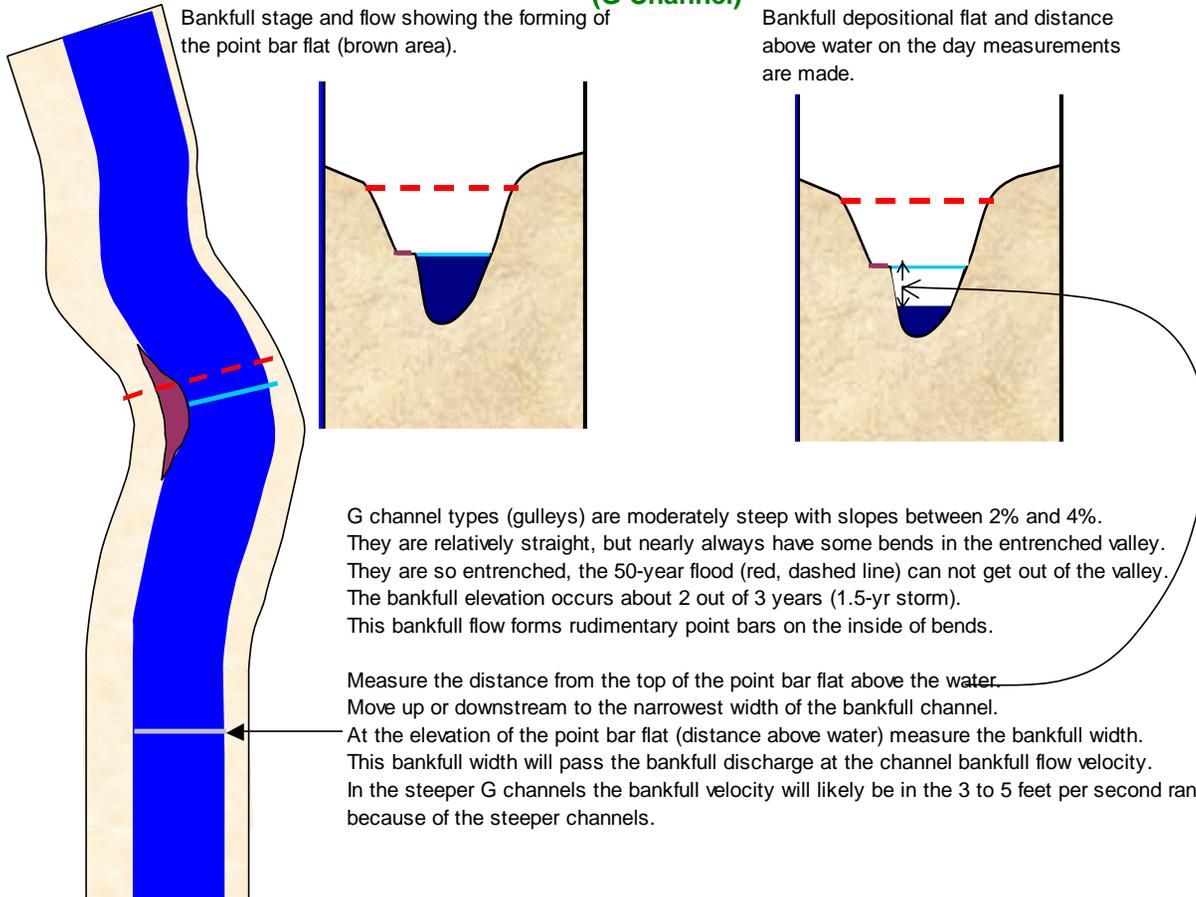
Regional reference curves are plots of bankfull depth, width and cross section vs watershed area. If curves exist for the channel reach of interest, determine the drainage area to the channel at the point of interest and find bankfull depth and width from the curve.



# Determining Bankfull Elevation in Difficult Circumstances or Stream Types (Cont.)

## Highly Entrenched Stream Types (Narrow and deep channel)

### (G Channel)



## Highly Entrenched Stream Types (Narrow and deep channel- steep slopes)

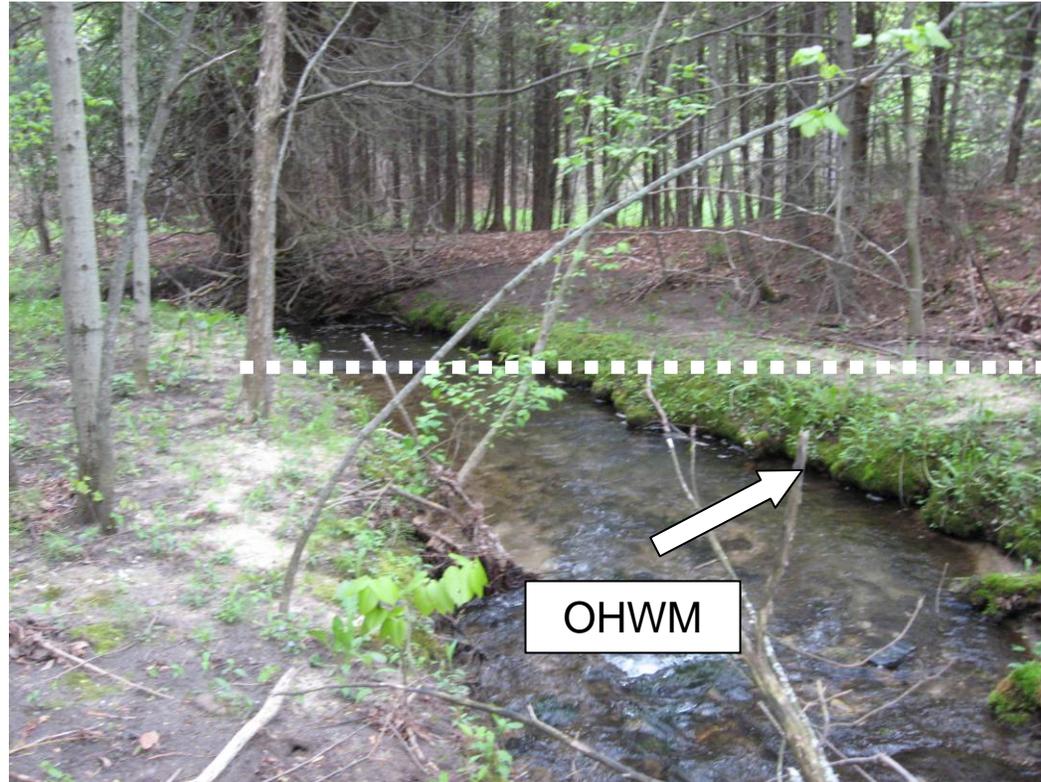
### (A Channel)

A (and A+) channels are high gradient (>4% slope), entrenched channels that are relatively narrow and deep. There is no easy, reliable way to determine bankfull elevation on these types of stream channels. Because A channel segments are rare and likely short in Minnesota, the best technique would be to go upstream or downstream of the A channel and measure bankfull width at that location.

## Difference Between Bankfull and Ordinary High Water Mark

Bankfull is usually higher than the Ordinary High Water Mark.

Vegetation is not a good indicator of bankfull.



Bankfull

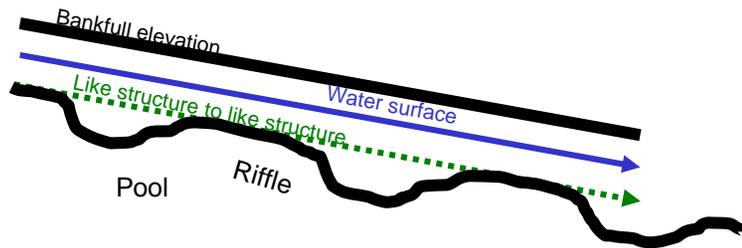
OHWM

# Determining Slope and Elevation

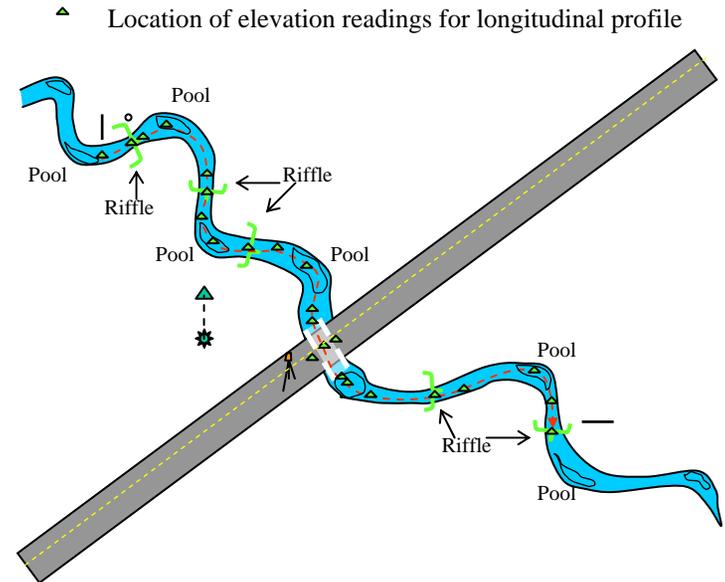
Unaltered streams follow a predictable pattern with pools forming in the outsides of bends and riffles (shallowest points in the longitudinal profile of the stream) forming in the straight sections. Riffles control the elevation and slope of the stream; therefore, the riffle elevations (as measured in the thalweg\*) should be used to determine culvert elevation and slope. Culverts are usually set in riffles because it is easier to cross a stream in a straight stretch than in a bend and the banks tend to be more stable.

## SURVEYING RIFFLES

The easiest way to determine culvert invert elevations is to measure a minimum of two riffles upstream and two downstream of the crossing (avoid the riffle immediately downstream of the culvert). (Every effort should be made to increase the length of your longitudinal profile to get as many riffle elevations as possible.) Elevations should be measured at least at every change in depth, ensuring that all riffles are measured. Measure the stream distance between each reading so slope (elevation vs. distance) can be calculated and record station distance of each existing or proposed culvert invert. Three elevations should be measured at each location; 1. Thalweg \* 2. water surface and 3. bankfull elevation (although not necessary, recording bankfull elevations when possible can help in the analysis).



There are three ways to measure stream slope. Water surface, bankfull and like structure slopes will be the same in stable streams. Culvert elevation determination, is based on riffle elevations (like structure to like structure), as measured in the thalweg.



If you are not confident you can identify pools and riffles, record thalweg elevations frequently through at least three bends both upstream and downstream of the crossing.

Remember to establish a benchmark to tie all your readings together and to use when setting the culvert at the proper elevation.

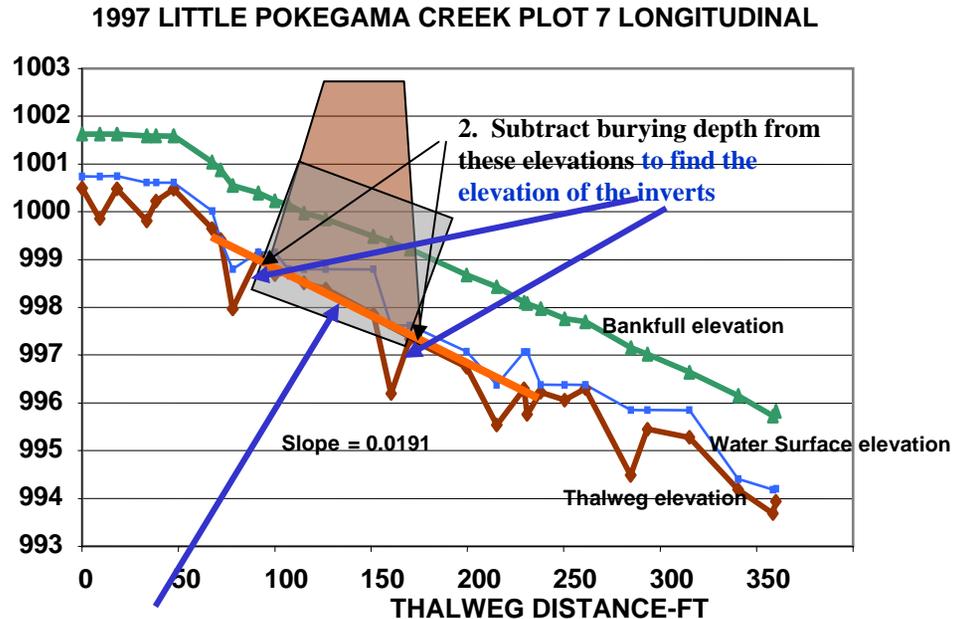
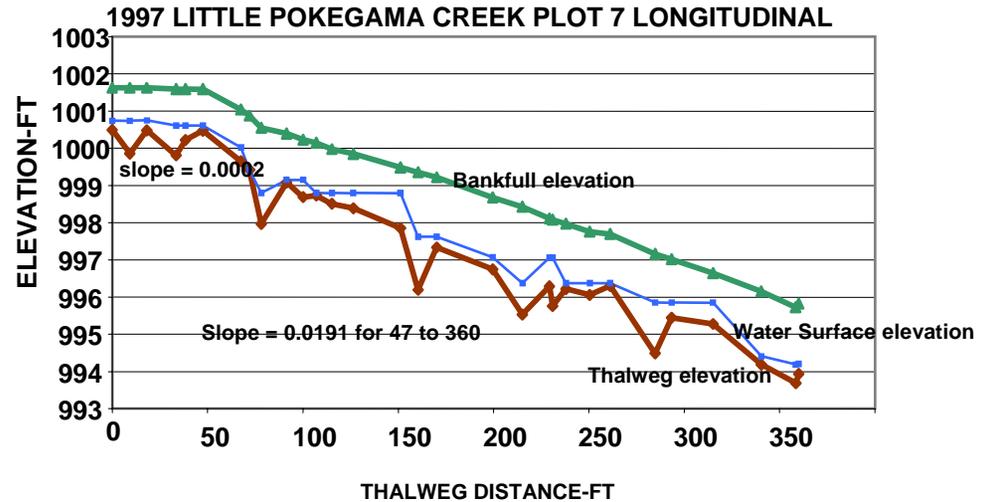
\*Thalweg = Deepest point in a channel cross-section, usually found near the center of the channel in riffles and near the outside of the bend in pools.

# Determining Slope and Elevation (Cont.)

## PLOTTING

Once longitudinal profile elevations have been collected, plot the elevations versus distance to calculate the slope (regress). Thalweg, water surface and bankfull slopes should be similar. It should become evident which points are riffles, which are pools and which are intermediate points. To calculate riffle slope and determine elevations of culvert inverts, regress only the riffle points. The invert distances can be inserted into the regression to calculate the stream bottom elevation at the inverts. Once this is done, subtracting 1/6<sup>th</sup> the bankfull width (1/5<sup>th</sup> in higher gradient, large substrate streams) from this elevation will yield the proper invert elevation.

If there was an obvious scour pool immediately downstream of the culvert, then there will often be an unusually high riffle immediately downstream of the scour pool. This is likely an indication that the current culvert is undersized and/or set too high. In this case, disregard this riffle when calculating riffle slope and culvert invert elevations.



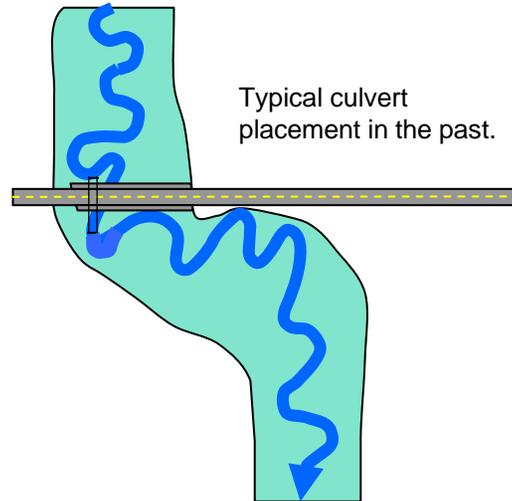
1. A line connecting the thalweg riffle points from above and below the crossing site is the most accurate estimate of stream bottom

# Alignment

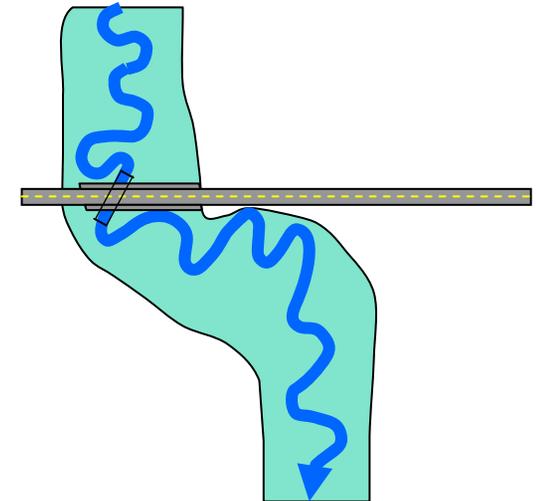
In the past, culverts were typically placed perpendicular to the road, regardless of stream alignment, to minimize the length of the culvert. This saved money in the short term by allowing the shortest possible culvert and was believed to have less impact on fish passage because the distance fish had to swim through the culvert was minimized. However, shortening the stream length increases slope locally, which can destabilize the stream. In addition, the outlets of such culverts often direct the outflow into a bank, rather than down the channel, thus causing bank erosion. These concerns are alleviated by following the channel alignment and other requirements of the permit. By matching bankfull width with culvert width, and burying to allow the culvert to fill with native substrate, fish passage should not be impacted by a longer culvert, and designing for a stable stream will reduce maintenance costs in the long run.

Exceptions to the requirement may include replacing culverts that were not in alignment when first installed or situations where the stream is naturally directed into a steep valley wall leading to erosion of the valley wall. An example of the first situation is shown to the right, where a channelized section of stream was removed and the proper alignment was restored. When the stream is being directed into a valley wall at the outlet of a culvert, it may be beneficial to redirect the channel away from the valley wall, although each situation is unique and should be looked at individually. Benefits of realigning the channel should be balanced with the impact of installing a longer culvert. Culverts exceeding 100 feet should be avoided.

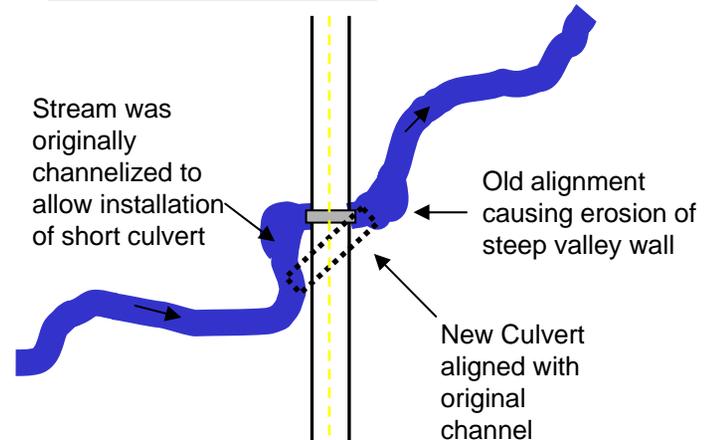
## IMPROPER ALIGNMENT



## CORRECT ALIGNMENT



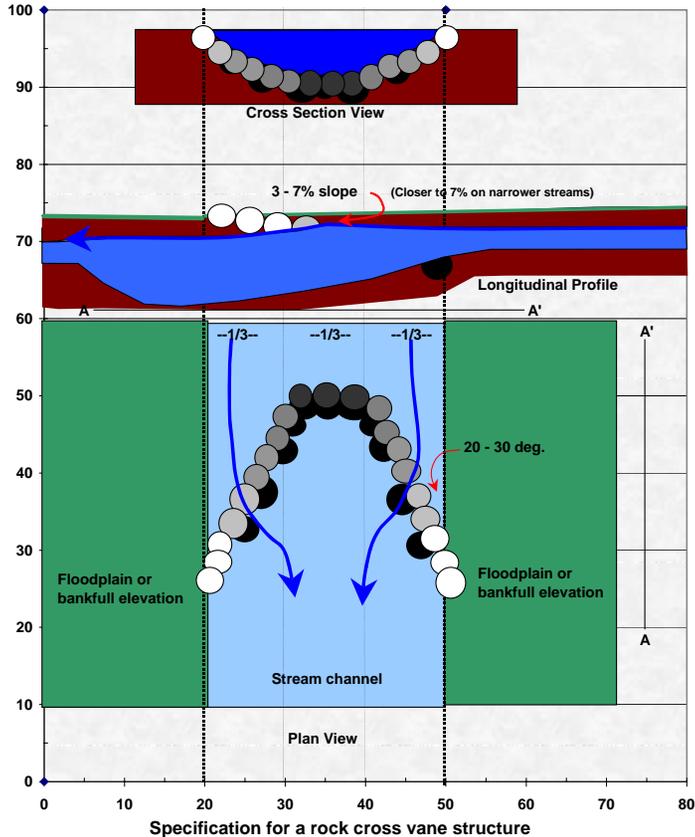
## EXAMPLE OF EXCEPTION



# Other Considerations

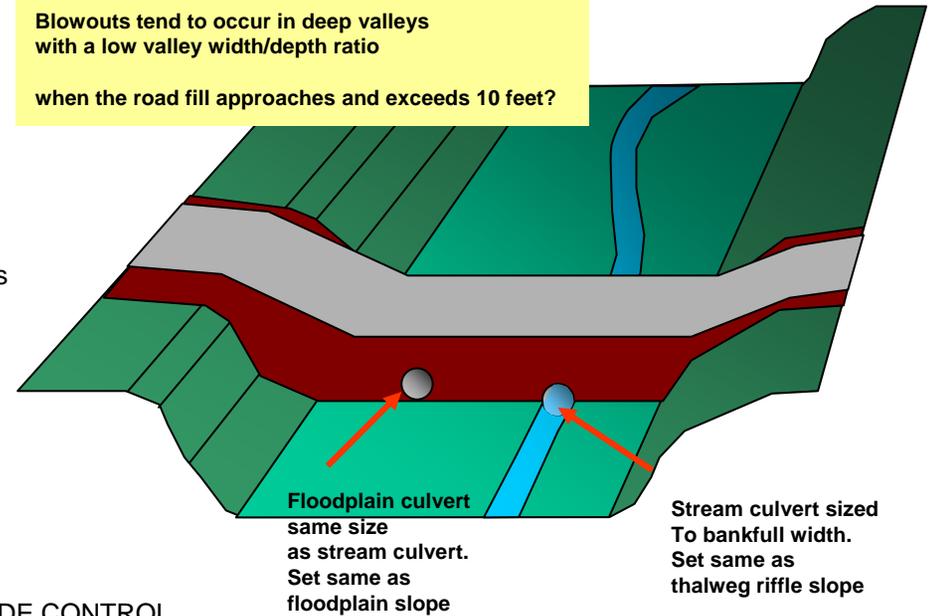
## FLOODPLAIN CULVERTS (See diagram to right)

There are circumstances that may require additional design. A healthy stream has full use of its floodplain to release the energy of floods and fish also use the slower velocities in floodplains during extreme floods. In deep valleys, especially narrow, entrenched ones, adding floodplain culverts not only increases stream stability and aids in fish passage, but reduces the likelihood of road washout. Always consider floodplain culverts in crossings with a history of washouts, or where fish passage is especially critical.



Blowouts tend to occur in deep valleys with a low valley width/depth ratio

when the road fill approaches and exceeds 10 feet?



## GRADE CONTROL

Grade control structures may be beneficial to add to a stream crossing design. They can be used to protect single span bridge pilings from scour, provide grade control to prevent head-cutting where past undersized and/or perched culverts have cause aggradation of the channel upstream of the culvert and degradation downstream, to backwater into existing culverts to slow velocities for fish passage, or to direct flow away from a bank. ( See [www.wildlandhydrology.com/assets/cross-vane.pdf](http://www.wildlandhydrology.com/assets/cross-vane.pdf) for design specifications) W-weirs can be used to protect instream bridge pilings from scour. If grade control greater than about one foot is needed, a rock arch rapids will need to be installed.

