Learn Channel Studio

Water Surface Profiles for Open Channels, Part I

Contents

When it comes to modeling open channels, knowledge is power… translation, "job security". As mentioned before, I want you to be the smartest one in the conference room when topics of H & H are at hand. This article aims to add one more notch in your H & H belt.

In almost every site development project there's an open channel around the corner that needs to be dealt with. Just the mention of "backwater curves" or "floodplain encroachment" intimidates project stakeholders. Like deer in headlights, they instinctively freeze. Some brave sole breaks out the acronyms, HEC-2, HEC-RAS, HEC-[*insert suffix here*], WSPRO, FEMA, and more acronym-based software. Suddenly the project gets complicated and the conference room gets quiet.

> Just the mention of "backwater curves" or "floodplain encroachment" intimidates project stakeholders. Like deer in headlights, they instinctively freeze.

Hands up from all those people who have hand-calculated a water surface profile for an open channel. Anyone?

Fear no more. Open channel hydraulics is not as difficult as its reputation has made it out to be. There are two reasons why many civil engineers fear open channel hydraulics:

1. They didn't get enough training in college. They know what they don't know

2. Governing authorities have created misperceptions, in some ways a stigma, in the industry where only government-issued computer programs are worthy of figuring this out. As if there's some Area 51-type mystery coded into them.

This article will bridge the gap between college and the real world by arming you with knowledge so that you can confidently approach these topics and think on *your own* two feet, without the federal government's interference. You'll also be able to quickly learn any open channel modeling software because you'll better understand the inputs and what they're used for.

It's Easier Than You Think

Yes, calculating water surface profiles for open channels is easier than most engineers think. It's easier than storm sewer systems, where you're having to deal with those pesky junction losses, and it's easier than modeling culverts with all those inlet control, outlet control, submergence concepts. With open channels there are no junctions, no inlets, no inlet control, none of that. There will be a bridge crossing from time-to-time which is discussed in Part III of this series… when completed. But even those procedures are easy work once you understand the basic concepts.

In just a few minutes, you will have a greater understanding of the basic calculation procedure which is the underlying foundation for successful open channel modeling. So here we go…

Three Things You Must Know

I have this advice for anyone in the civil engineering industry, especially those in site development or coming out of college with a BSCE and/or those of you with CFM attached to your title. If you remember only three things from your Fluid Mechanics class, let it be these. Without them in your drainage design toolbox, you'll be walking with a limp.

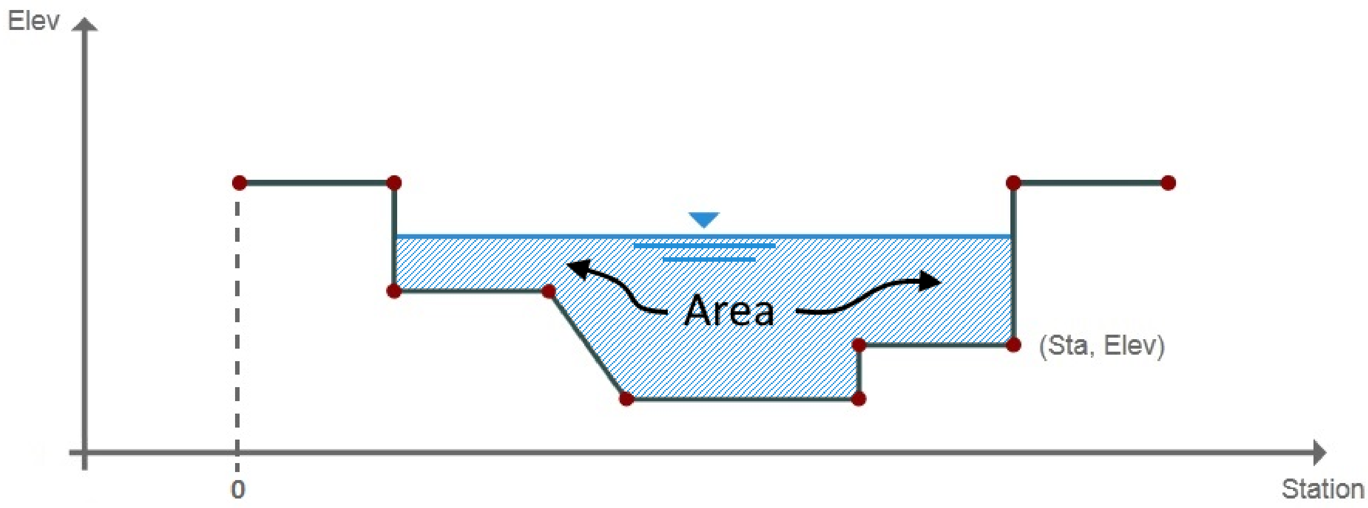
1. The Continuity Equation

$$Q = VA$$

Where:

Q = Flow (cfs)
V = Velocity (ft/s)
A = Cross-sectional area of flow (sqft)

This two-term equation will never fail you.



No matter what, velocity always, always equals the flow divided by cross-sectional area. Don't depend on Manning's equation for this. If you're looking for velocity, look no further than the actual cross-sectional area **of the water** in the channel. Divide Q by that area and you'll always get the correct velocity, guaranteed. What you should be looking for is the water surface, the hydraulic grade Line (HGL), that produced this Area. And to know the Area is to know the Energy Grade Line (EGL).

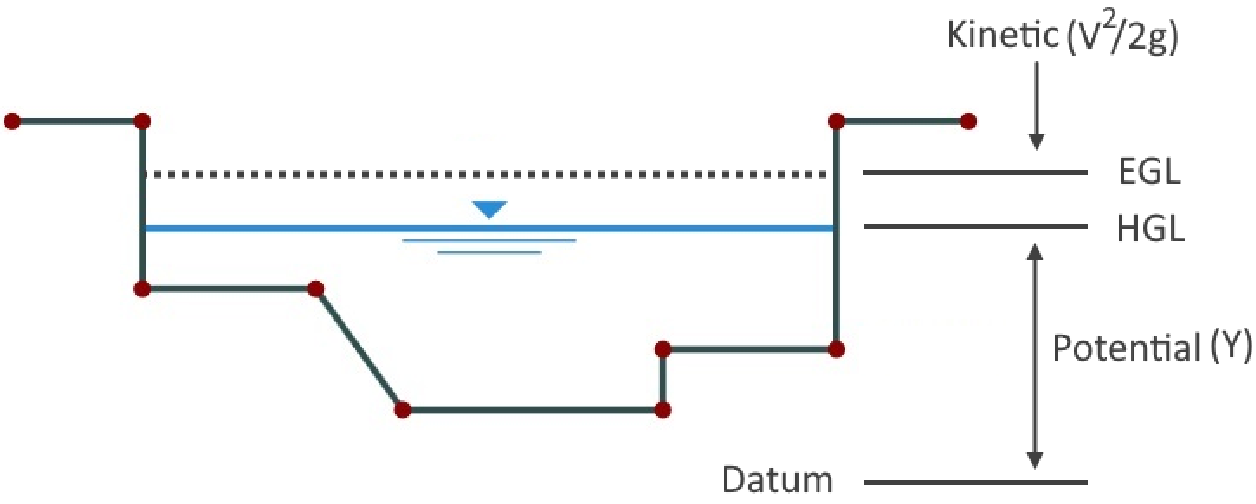
2. The Energy Equation

It's the granddaddy of all H&H equations. There's so much you can do with the energy equation it's mind boggling. But for now, let's stick to H&H for civil engineers. Orifice equations, weir equations, Bernoulli equation, etc., all derive from this Energy equation.

$$\frac{V_1^{\,2}}{2g} + Y_1 = \frac{V_2^{\,2}}{2g} + Y_2$$

And that energy, at any given open channel cross-section, is made up of two parts, Potential and Kinetic. In our world, potential energy is Elevation Head (HGL) in feet (Y) and kinetic energy is $V^2/2g$, a.k.a. Velocity Head. So at any point along an open channel, the energy is:

$$\frac{V^2}{2g} + Y = Energy$$



The total energy, EGL, is the sum of HGL and Velocity Head. What's really cool is that the energy at one cross-section equals the energy at another cross-section, and another, and another. Knowing this, we can predict the water surface elevation pretty-much anywhere.

But there's another visitor at this energy party, known as "Head loss" or HL for short. It's actually not a loss, it just looks that way. It's real energy that gets transformed into heat resulting from the friction between the water and the channel boundary, commonly called *skin-friction drag*. To quantify this loss we employ a special equation and insert it into our energy equation.

3. Manning's Equation

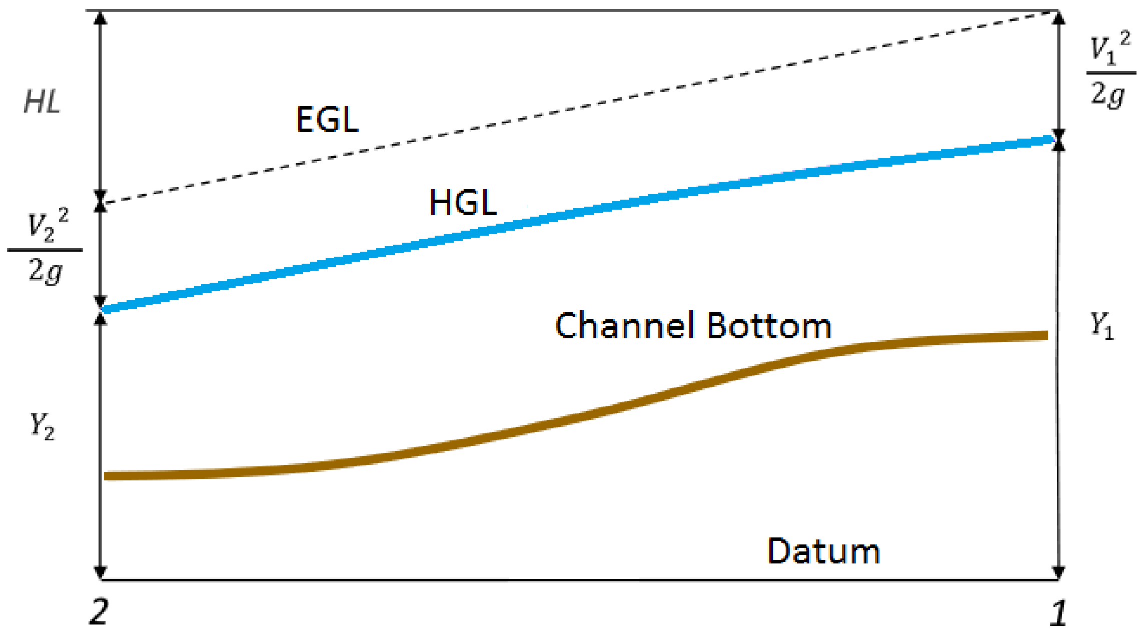
Every civil engineer has seen this equation a time or two and it doesn't need much of an introduction, but it does need an explanation.

$$Q = \frac{1.49}{n} AR^{2/3}\sqrt{S}$$

Manning's equation is used primarily to determine energy loss due to friction implied by the n term, roughness coefficient. The A term is the actual cross-sectional area of flow. R is the hydraulic radius which is A divided by the wetted perimeter of that A. The equation is reliable up to about a 6 percent slope.

S is the slope. But it's not the slope of the channel bed. Always remember this… It is the slope of the energy grade line (EGL).

Choose any two points along an open channel, for example. Add up the kinetic energy, $V^2/2g$, and the potential energy, (Y) at each point. That sum is the total energy or EGL. S is the slope of the line between those two points. The difference between the two EGLs represents the loss of energy due [obscured] distance between these two points (L).



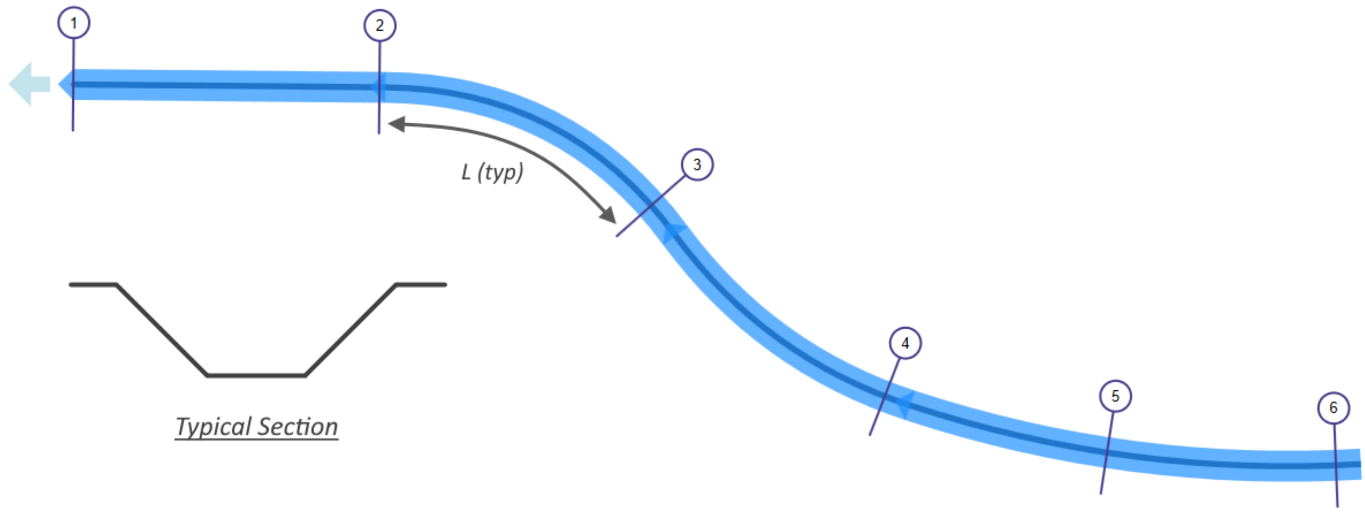
S is the slope of the energy grade line (EGL)

Calculate the Water Surface

Now that we've passed basic fluid mechanics it's time to put that knowledge to work on computing a water surface profile for an open channel. We're simply going to combine the Energy Equation with Manning's equation. Then it's just a matter of solving that equation between two adjacent channel sections.

$$\frac{V_1^2}{2g} + Y_1 = \frac{V_2^2}{2g} + Y_2 + HL$$

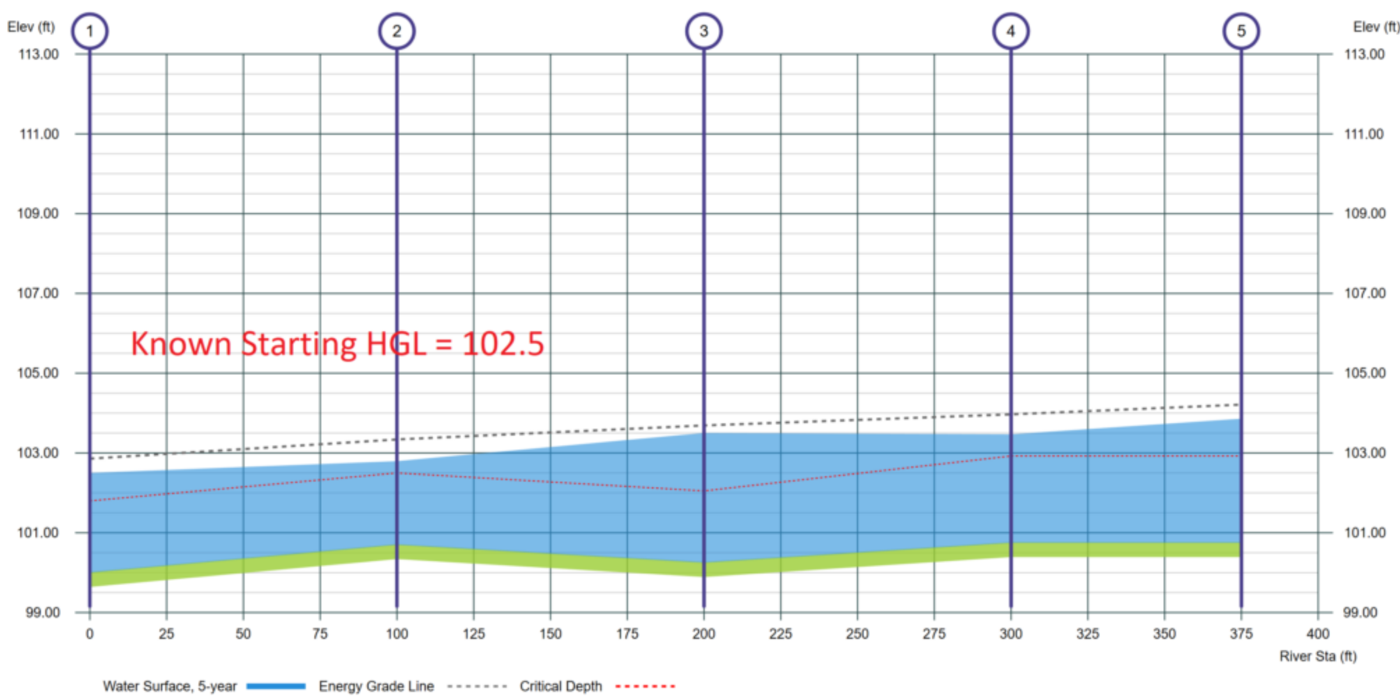
Below is a plan view of an open channel reach that contains six channel cross-sections. The channel sections are simple trapezoidal shapes at differing elevations and bottom widths. Flow rates have been established. All it needs is a water surface profile. We will use what's known as the Standard Step method.



In essence, the process involves just 2 steps, in this order, beginning at the downstream end, Section 1, and working upstream, section-to-section, until we reach Section 6.

1. Setting the beginning water surface elevation for the downstream section.
2. Calculating the water surface elevation for the next upstream section. This becomes the beginning water surface elevation for the next, upstream section.

Repeat for each Section until you've reached the end. Sounds pretty simple. Lets go through these two steps one-by-one.



Step 1. Set the Starting HGL

Questions? Email us.

For the very first section, downstream, you'll have three choices:

1. **Known Elevation** – For the beginning Section, a water surface, HGL, is known, commonly called a tailwater (Tw). For the profile above, 102.5 was used.
2. **Normal Depth** – Use this when you don't have a Known Elevation. This is a depth defined by Manning's equation where S and the slope of the channel invert are assumed equal. Manning's equation can be arranged into the form: $Qn / 1.49S^{1/2} = AR^{2/3}$ where the left hand side of the equation is a constant that can be calculated from the specified values for Q, n, and S. On steep slopes, Normal depth can be less than Critical depth. In these cases use Critical depth instead.
3. **Critical Depth** – This depth is where the Energy (EGL) for your particular Q is at a minimum. In other words, for all of the possible combinations of depth and it's resulting velocity head, this one represents the smallest EGL. Water does not prefer to be at this depth as it is unstable and will tend to quickly shift into higher or lower depths. For this reason, Critical depth as a starting Tw is not always your best choice.

For all other sections, just use the HGL calculated from the previous section.

Step 2. Calculate the HGL for the Upstream Channel Section

This is where we use the Energy Equation with the added Head Loss (HL) component.

$$\frac{V_1^2}{2g} + Y_1 = \frac{V_2^2}{2g} + Y_2 + HL$$

All of the terms on the left side refer to the upstream Section (EGL Up) and those on the right refer to the downstream Section (EGL Dn). HL is given to us by Manning rearranged as S x Reach Length (L) where:

$$S = \left(\frac{Qn}{AR^{2/3}}\right)^2$$

We already know the EGL Dn from Step 1. The goal now is to find the EGL Up using our new energy equation. Here it is in it's completed form with S x L in place of HL.

$$\frac{V_1^2}{2g} + Y_1 = \frac{V_2^2}{2g} + Y_2 + \left(\frac{Qn}{AR^{\frac{2}{3}}}\right)^2 \times L$$

Where:

Questions? Email us.

n = Manning's n roughness coefficient

A = cross-sectional area of flow

R = hydraulic radius

L = channel reach length (distance between the two Sections)

Q = flow rate

g = gravity

V = velocity

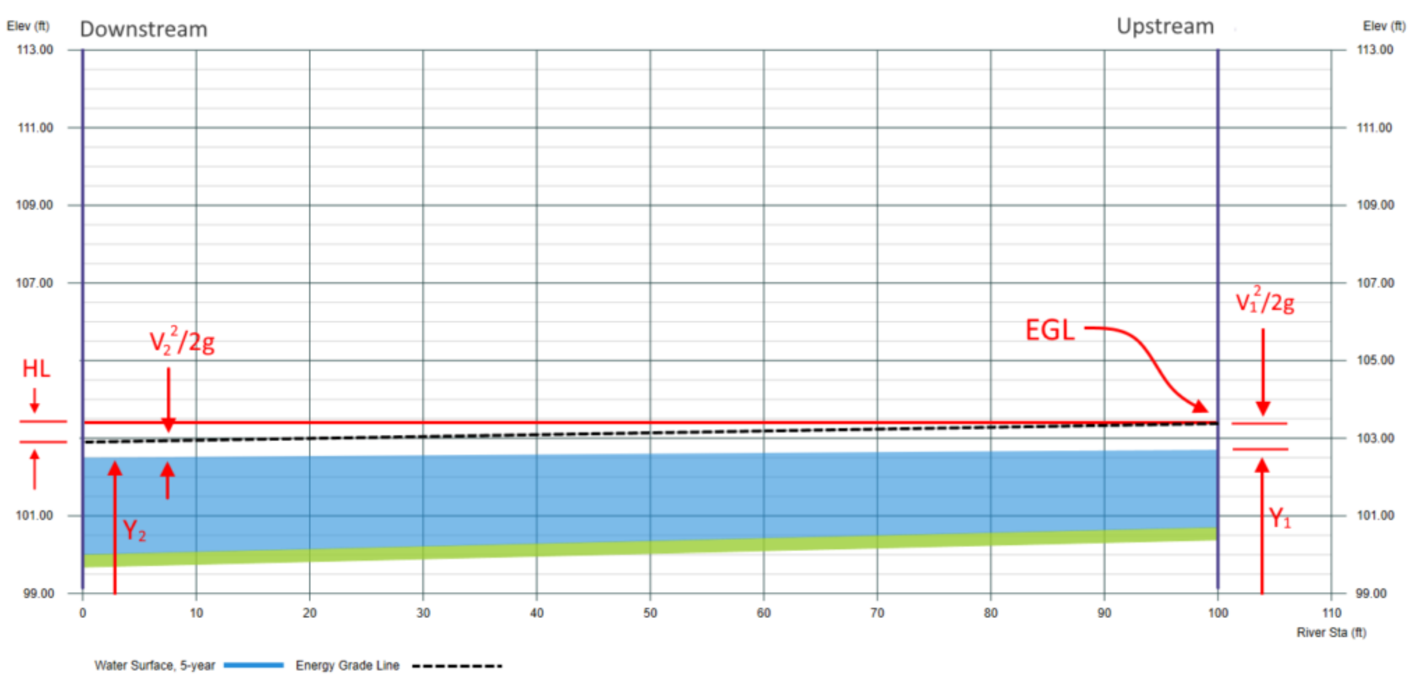
A solution to this equation requires an iterative-based procedure. We only know V and Y at Point 2 (downstream). So we have to assume a water surface elevation, Y, at the upstream end, Point 1. Then compute Area, Velocity and Velocity Head. From that comes the EGL Up. Compare to EGL Dn + HL. If they don't match within a desired tolerance, the assumption was incorrect. Repeat with a new assumed Y.

Once you have achieved an answer, repeat this process with the next upstream section and so on. The newly computed HGL is used for the variables on the left side of the equation.

In the real world, programs like Channel Studio, HEC-RAS, etc. will use an average S in order to better estimate the friction losses between sections. Known as the *Average Friction Slope* method.

$$HL = \frac{(S_1 + S_2)}{2}$$

S1 refers to the upstream section, S2 refers to the downstream section.



Section 1 is downstream (left) and Section 2 is Upstream (right). Water is flowing from Section 2 to 1.

Below are sample calculations from Section 1(downstream) to 2 (upstream) s

The two channel sections are trapezoidal with 1:1 side slopes and 10-foot bottom widths. Manning's n = 0.025. The inverts are 100.00 at Sec 1 and 101.70 at Sec 2. L = 100 ft.

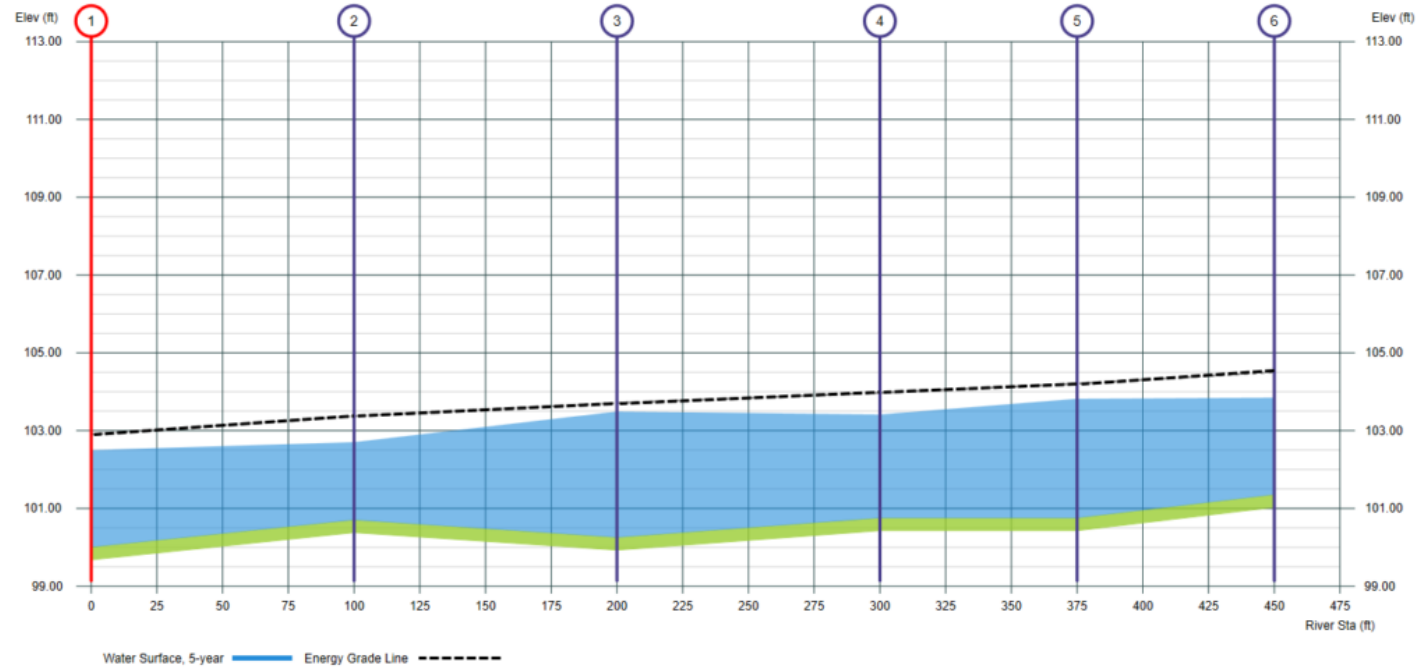
We want to calculate the water surface at Section 2. We set the starting HGL at a known elevation of 102.50. From there we can calculate the parameters for the downstream side of the energy equation. Next we must assume an upstream Y. The first assumed Y is made by adding the depth of the downstream section to the invert of the upstream section, so (102.5 – 100.00) + 100.70 = 103.20. Educated guess, that's all.

From here it's a matter of grinding out the numbers until the absolute "Error" on the far right column is below our tolerance of 0.015 feet. What's cool is that the result(s) is a clue to finding a solution. Simply take 50% of the error and algebraically add it to the previous assumed Y and a solution will be found quickly. For example, in the second iteration, Y = 103.00 was found by 103.20 + -0.399 / 2. (-0.399 was the error on the first try.)

		DOWNSTREAM					**UPSTREAM**						**Error**
Q	L	Y	Area	Vel	Vel Hd	E2	Y	Area	Vel	Vel Hd	E1	HL	E2 + HL - E1
150	100	102.50	31.25	4.80	0.358	102.86	103.20	31.25	4.8	0.358	103.55	0.291	-0.399
							103.00	28.23	5.31	0.439	103.43	0.341	-0.229
							102.88	26.52	5.65	0.497	103.38	0.379	-0.141
							102.80	25.54	5.87	0.536	103.34	0.406	-0.074
							102.77	24.96	6.00	0.561	103.33	0.424	-0.046
							102.75	24.63	6.09	0.576	103.32	0.435	-0.025
							102.73	24.43	6.14	0.585	103.32	0.442	-0.018
							102.72	24.32	6.17	0.591	103.31	0.446	-0.004
150	100	102.72	...	...	...	...							
Units in feet													

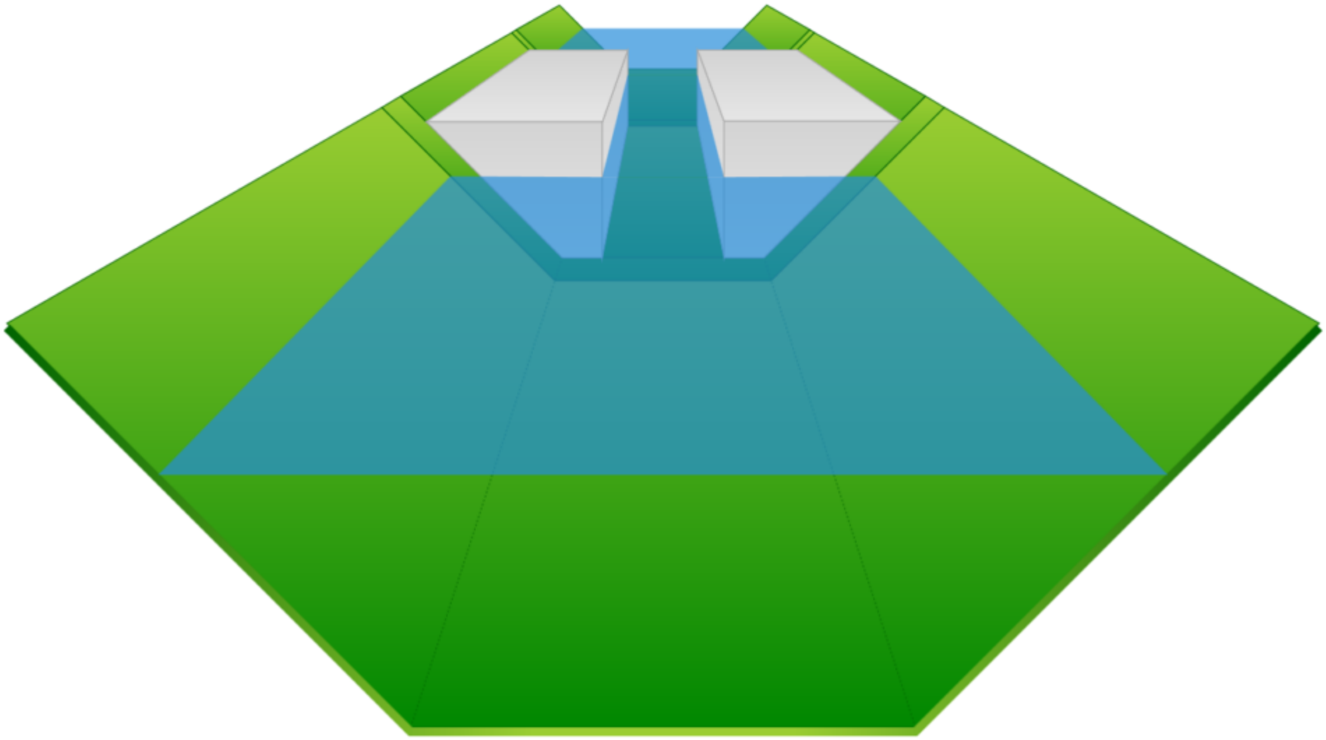
Interpreting Results

So that's the basic calculation process. Applied to the sample six-section plan above reveals these profile results:



This is where the inexperienced modeler can get really confused, really fast. You'll notice the EGL (black dotted line) decreases as you move downstream. That's proper as you cannot gain or create energy. But notice how the water surface fluctuates between sections. The slope of channel bed from Section 2 to 3 is adverse but not the water surface. The water surface between Sections 3 and 4 slopes adversely because the channel width reduces from 10 to 7 feet at Section 4, causing an increase in velocity and velocity head. The water surface is always equal to the EGL minus velocity head. Thus the reduction in water depth.

Below is another interesting example of a simple trapezoidal-shaped channel with obstructions, similar to bridge abutments. Notice how they squeeze and reduce the area of the cross-sections. One would intuitively think that the water surface would rise as it flows through these abutments.

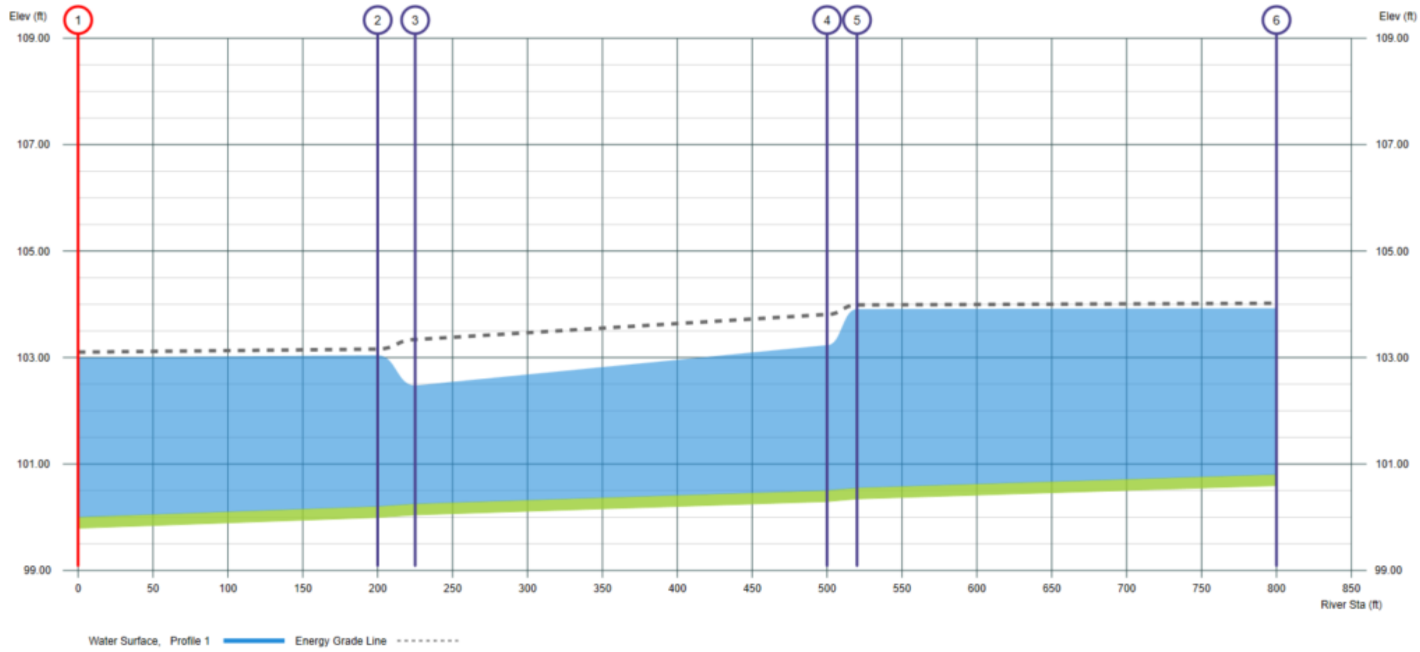


Looking upstream

But in fact, it does just the opposite. The water surface drops!

Remember the Continuity equation, Q = V x A ? The abutments indeed reduced A, so V must increase to maintain Q. Subtracting the increased velocity head (V^2/2g) from the black dotted line reveals the true water surface as shown in the channel's profile below.

Things get back to normal downstream once the cross-sectional area enlarges and velocity slows, velocity head shrinks, HGL goes up.



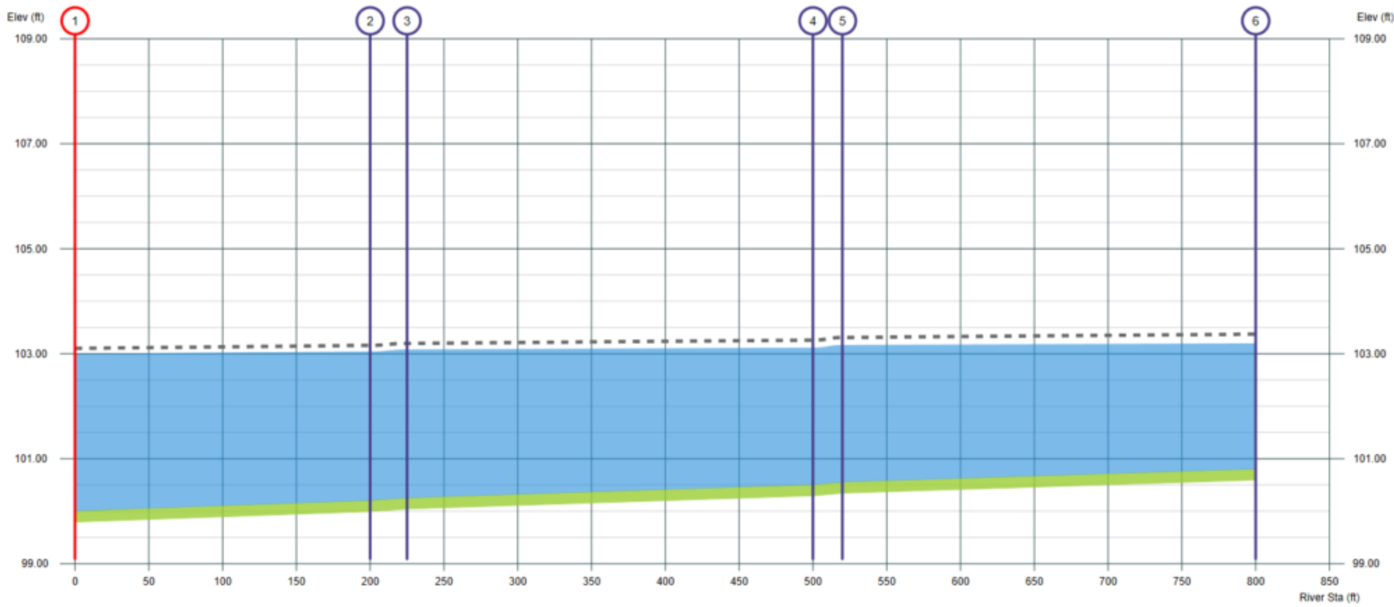
Profile with obstructions

What's interesting is that the water surface did rise. Over 0.50 feet. But not between the abutments. But rather at the sections just upstream, where the cross-sectional area was untouched. How'd that happen?

Remember Manning's equation?

$$Q = \frac{1.49}{n} A R^{2/3} \sqrt{S}$$

Between the obstructions we have a decrease in Area, A, and thus R. So slope, S must increase to maintain Q. Sure enough, the slope of black dotted line between sections 2 and 5 increased. It raised the EGL upstream at sections 5 and 6 where you have a full cross-section, lower velocity, higher HGL.



Profile without the obstructions

Always remember… anywhere along that black dotted line, there can be only one combination of water surface elevation and velocity head. Energy rules and the Energy equation will always provide an accurate answer, regardless of the channel's shape or slope.

Summary

So there you have it. The basic skill and knowledge of how to calculate a water surface profile for an open channel. It's simply repeating a 2-step process which begins at the downstream end of your system working towards the upstream end. The Bernoulli Energy equation is used to compute the EGL. The water surface (HGL) is a *consequence* of the EGL, i.e., EGL minus Velocity Head.

The aim of this lesson was more about understanding the mechanics of water surface profiles than actually crunching numbers. You'll most likely use a computer for that, and you should. But at least now you'll know what goes on inside those black boxes, and have new respect for the EGL. It's valuable knowledge that will have a direct and positive impact on your projects and your career skills.

But the *real* key to success is not crunching numbers, it's knowing how to get the numbers, and when and where to apply them. Because not all open channel systems are as neat and uniform as the example given in this article. Most of the time the channels and sections are irregular in shape and slope with varied roughness.

Part II of this series will teach you how to deal with those *real* open channels.

Water Surface Profiles for Open Channels, Part II

Contents

Part I of this series stepped through the mechanics of calculating water surface profiles for open channels. It introduced concepts of energy and the role it plays in determining the the elevation of the water surface in various conditions. It serves as a backdrop and prerequisite to modeling real open channels where conditions aren't always neat and clean as presented in Part I. Knowing the basics of the computations empowers you to make better decisions in the real world regarding:

1. Locating your cross-sections
2. Describing your cross-sections

Which is what we'll cover here in Part II.

This article is not meant to teach you how to navigate Channel Studio or any other software's user interface, but rather provide you with some key knowledge

This way you will be equipped to successfully tackle any open channel modeling software.

Either way the general process is always the same. You'll draw a river reach; add cross-sections; describe cross-sections; add water and compute.

Crystal river in Colorado during summer

Think Gradually

To get the best results modeling water, you must think like water. Flowing water. Water does not flow making tight turns and sharp corners. Rather it flows smoothly downstream within its natural confines. That's why you don't see sharp or abrupt changes in the banks of natural channels. Natural channels are shaped by the water that flows through them. And when there are abrupt changes, like the upper and lower ends of bridge abutments, the flowing channel water will bypass that abrupt space and fill it with dead water or what we like to call, "Ineffective Flow Area".

The key takeaway here is that water prefers to flow in a gradual state and we as modelers, must honor that fact. We do this by providing only gradual chan

> Maintain a “gradual” mindset and you will always be successful modeling open channels.

And keep in mind, the energy equation is only applicable to “gradually” varied flow.

As you discovered in Part I, water surface profiles are calculated by solving the Bernoulli energy equation in a standard step fashion between *cross-sections* representing the channel’s physical properties. The location of these cross-sections is critical and when not placed properly, your study will be plagued with no-solution errors.

Take the average of the numbers zero and 100. It’s 50. Fifty is a far cry from either of the two inputs, zero and 100. Not very “gradual” is it? This is what commonly happens to the novice open channel modeler. They mis-locate cross-sections, preventing the solution to the energy equation, violating the water’s will and right to flow gradually.

Let’s take a another look at the master equation introduced in Part I.

$$\frac{{V_1}^2}{2g} + Y_1 = \frac{{V_2}^2}{2g} + Y_2 + \left(\frac{Qn}{AR^{\frac{2}{3}}}\right)^2 \times L$$

The section with all the Manning’s equation terms is the friction head, hf.

$$hf = \left(\frac{Qn}{AR^{\frac{2}{3}}}\right)^2$$

The procedure needs to calculate *hf* at both points, 1 and 2 (upstream and downstream) and then average them. If that average is too distant from the original two hf’s, the equation becomes unsolvable. Error.

How to Locate Channel Cross-sections

So how far apart and/or where do you locate cross-sections to insure a solution? After all, hf has a lot of terms referring to various properties like channel roughness, area, wetted perimeter and Q. The answer is conveyance.

Conveyance, K, is computed as:

$$K = \frac{C_m}{n} A R^{2/3}$$

Where:

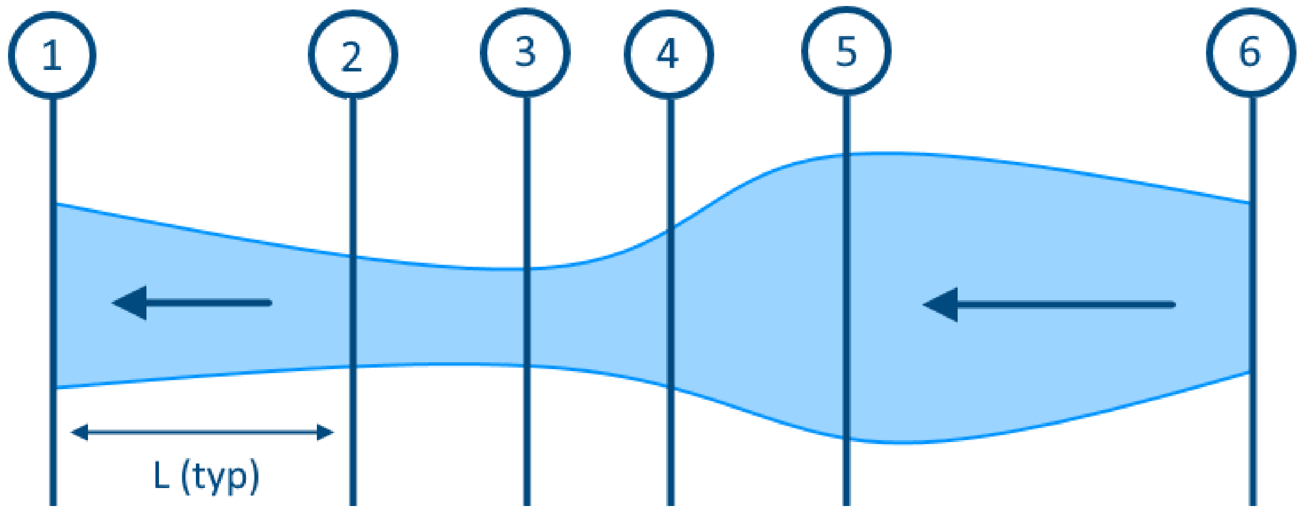
Cm = Manning Coefficient = 1.486 (1.00)
n = Roughness coefficient
A = Cross-sectional area of flow
R = Hydraulic radius = Area/Wetted Perimeter = square foot of Area per foot of Wetted Perimeter

Locate cross-sections along your channel so that conveyance between any two sections does not change by more than about 30%. If the n-values for two subsequent cross-sections are approximately the same then conveyance becomes a function of cross-sectional area, A.

> Locate your sections so that the cross-sectional area does not change by more than 30% between sections.

If it does, insert additional sections. Again, gradual is key. Also keep in mind that channel slope affects area as illustrated in Part I. So you'll want to add sections at any significant changes in slope as well.

To illustrate, consider the hypothetical channel plan below. Remember, your software and the energy equation has no clue what this channel looks like. It's up to you to provide the data that best describes it within the confines of the methodology. Sections are located at key points along the channel as described below. Starting from the most downstream point. Let's discuss them one-by-one.



Sec 1 – Located at the most downstream point in the study area.

Sec 2 – Reduction in section area from Sec 1 by 30%.

Sec 3 – Reduction in section area is less than 30% but indicates narrowest part of channel.

Sec 4 – Increase in section area by 30% from Sec 3.

Sec 5 – Widest part of channel as well as an increase in area by more than 30%.

Sec 6 – Less than 30% change in area but it's the most upstream end.

Notice that Sections 1, 3, 5 and 6 could have been used solely because they indicate key points along the channel but more sections needed to be supplied to honor the 30% conveyance rule.

Place Sections Perpendicular to the Flow

Your cross sections should be placed perpendicular to the direction of stream flow under flood conditions. Notice the large blue line in the plan below. It represents the river Reach.

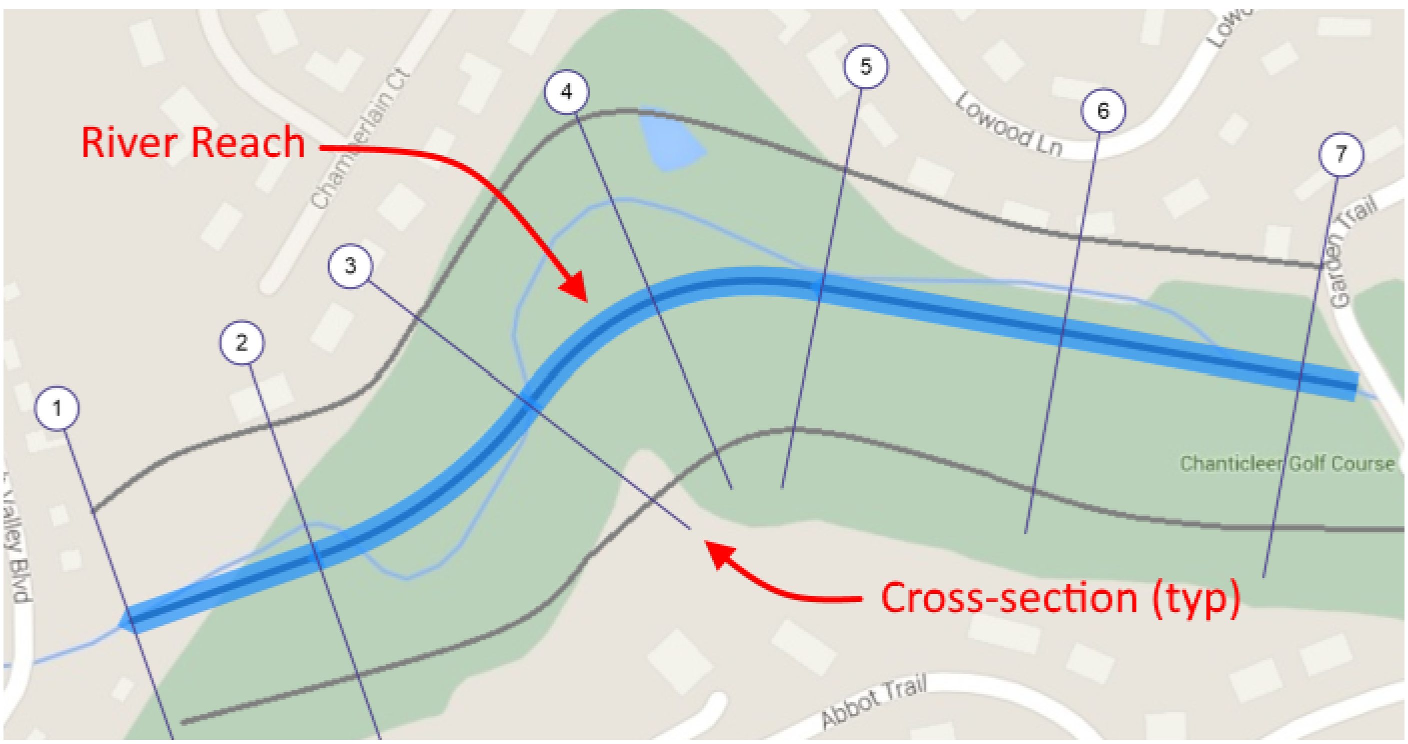
The Reach serves as a placeholder for your Sections so it's equally important that you locate the river reach properly. The best way to do this is to step back
doesn't need to be perfect, you're not building a watch. Visualiz

floodplain or the final outer boundaries of the anticipated water surface. Then draw your Reach through the center of this boundary. Try to favor the main channel or the portion with the most flow or area but don't let it dictate. As shown in the example below, the reach is drawn between the outer gray lines but stays fairly close to the thin blue line (the channel) but yet it stays gradual and smooth.

Note the Sections are not always perpendicular to the smaller blue line (the actual Channel) but *are* perpendicular to the outer gray lines (the main floodway).

If you are working with a floodway or channel that does not contain abrupt changes then follow these suggestions:

- Large uniform rivers with mild to flat slopes require cross sections about every 1,000 ft. (300 m).
- Narrow, confined channels in urban areas need cross sections about every 500 ft. (150 m) or less.
- As a "rule-of-thumb", cross sections can be spaced at about 5 times the channel widths. So if your cross-sections are roughly 100 feet wide, place sections every 500 feet along the Reach.



A curved Reach allows Sections to be placed where neede

Describing Channel Cross-sections

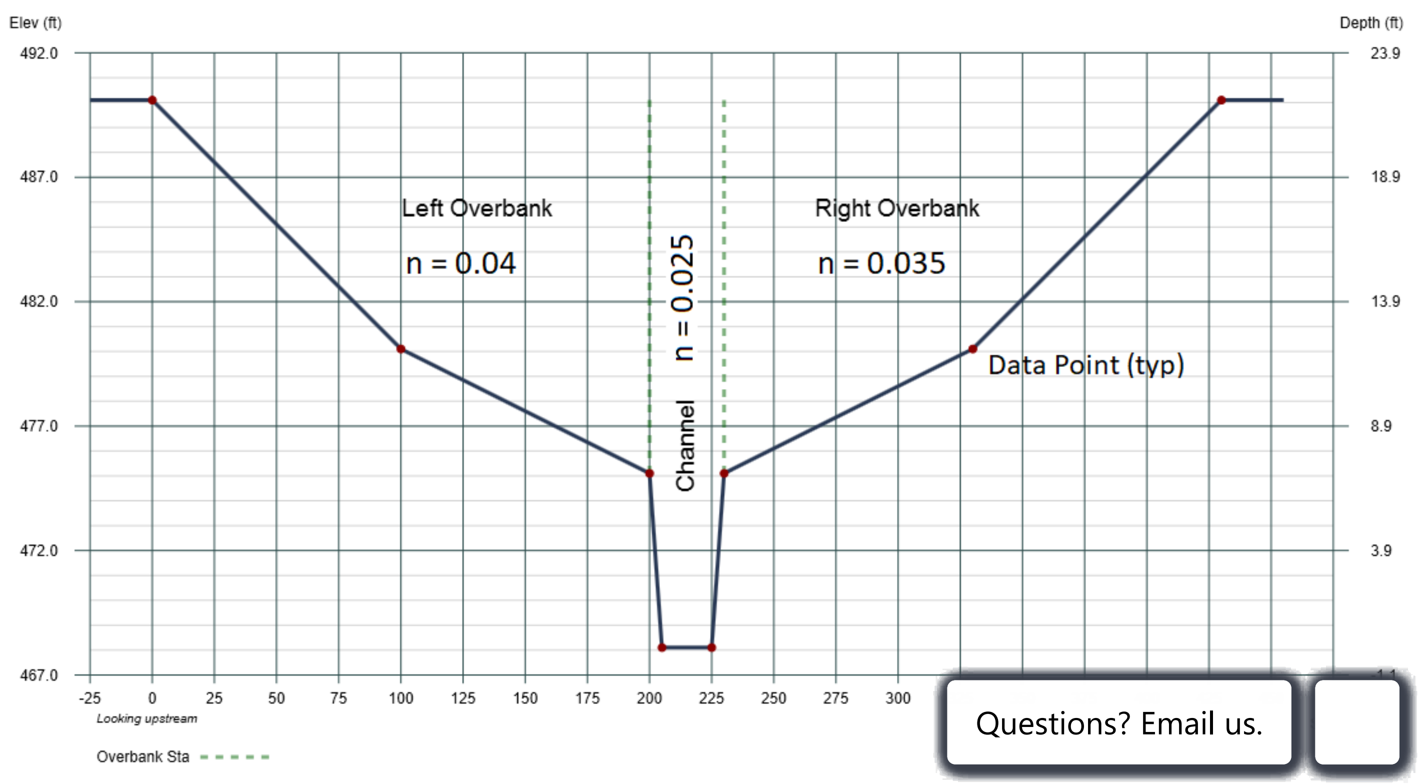
Now that we know *where* to locate the cross-sections, we next need to learn how to properly *describe* the cross-sections.

As you saw above, the computation of conveyance, K, for each water-surface application requires a hydraulic radius, R. The hydraulic radius represents the average depth of conveyance. If there is significant irregularity in the depth across any given section, the hydraulic radius may not accurately represent the flow conditions.

Think Like a Land Surveyor

So again, think gradually but also think like a land surveyor performing a topo survey. Just like in the plan view above, we need to insert data points at strategic locations to give the calculation procedure a clear picture of what the Section actually looks like.

> Remember, your computer is clueless. It's blind and can only feel its way around using supplied data.

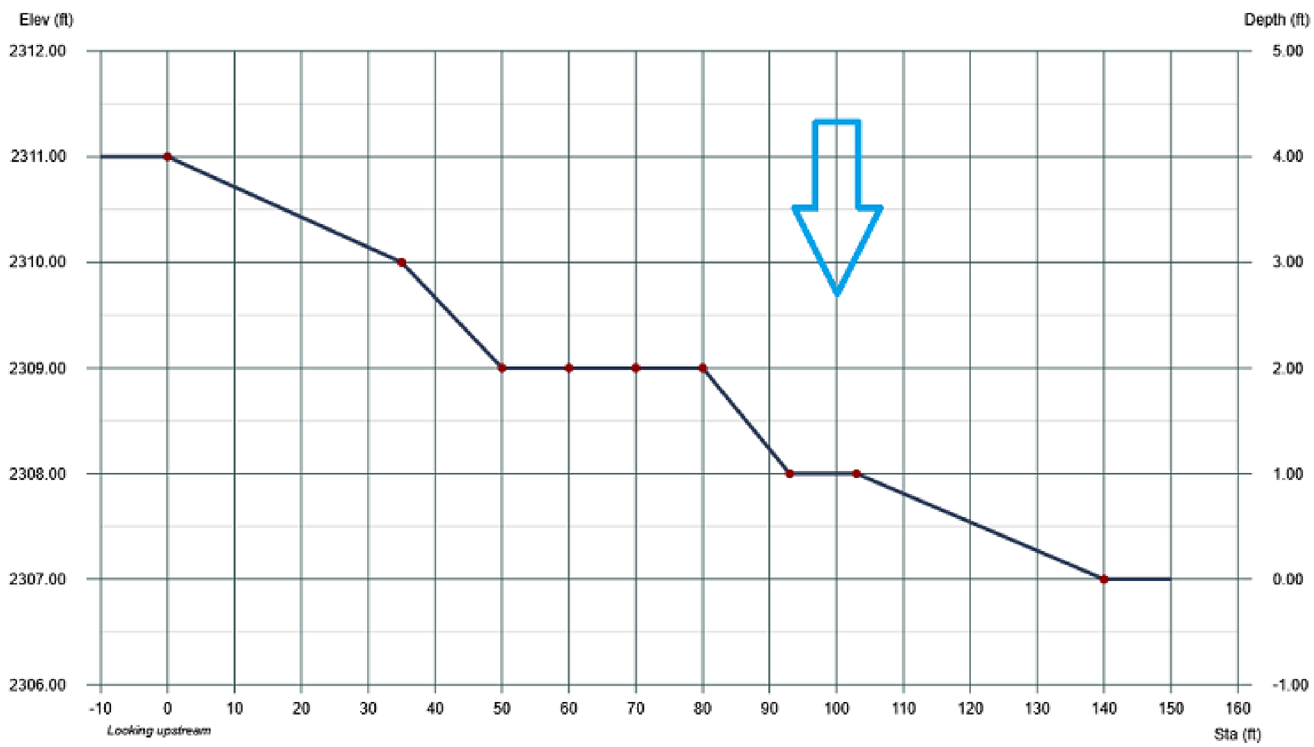


Above is a typical open channel cross-section as looking upstream. The first thing you need to do is gather data points, just like a topographic survey, that indicate changes along the section. Above you'll see where points (station and corresponding elevation) were taken at significant changes in the bank slope. These are indicated by the red dots at stations 0, 100, 200, 210, 225, 230, 330 and 430. Keep in mind the calculation procedure will assume straight lines between your points. If, for example, you left out Station 100, the calculations would assume a straight line between 0 and 200, missing that additional area.

Use only enough points to adequately describe the cross-section. Don't overdo it. Remove any points that seem redundant. Simpler is always better.

Will it Hold Water?

This may sound silly but… before you move upstream, always try to visualize pouring water into the section. Will the described section hold water? At what elevation will the water run off the side? In other words, be sure to complete your geometric data from upper left to upper right. Imagine if the section above was missing that last point at Station 430. The section would be useless above elevation 480.



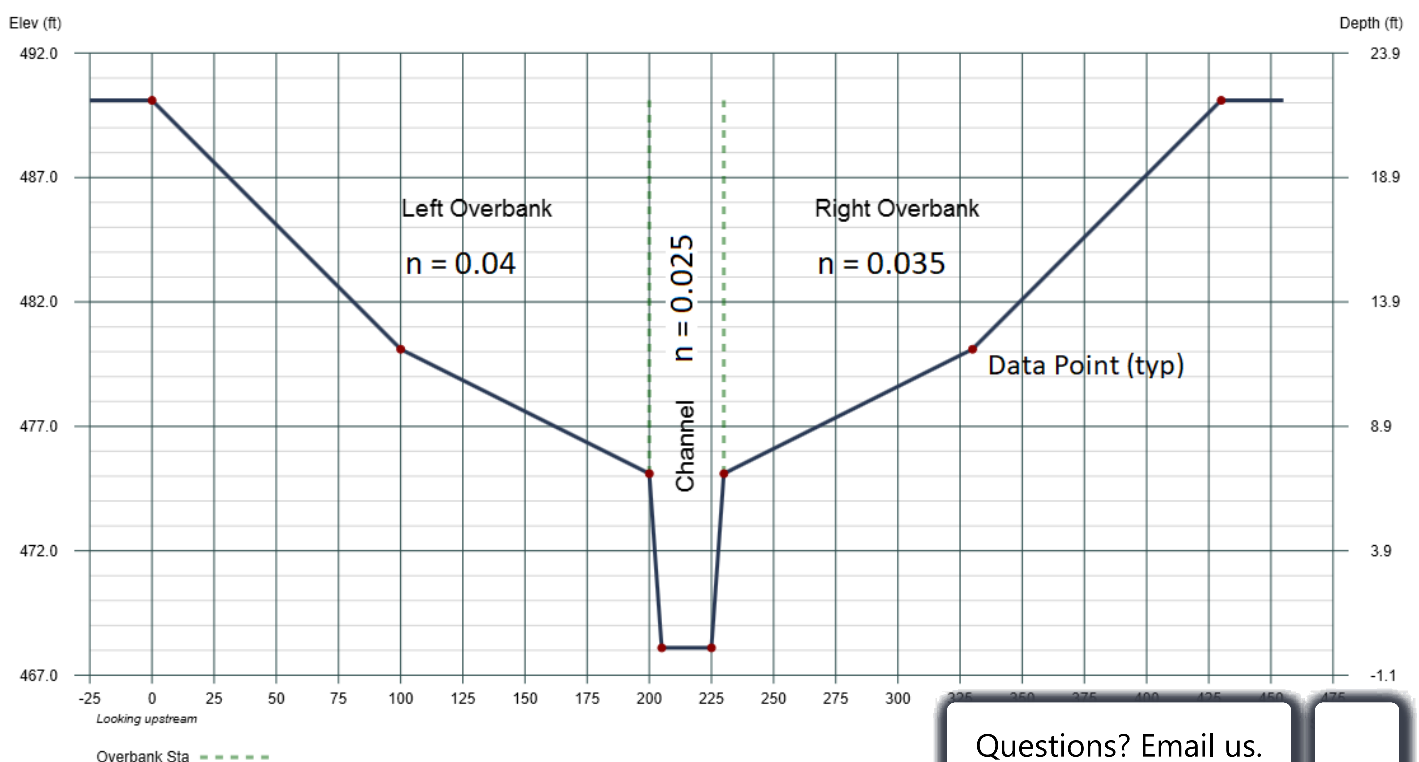
This cross-section is totally useless

The section above was submitted to me by someone who used a TIN surface to describe sections. While a TIN surface will save an enormous amount of time, please take time to inspect each cross section, ensuring that it is wide enough to reach the other side. This section obviously cannot hold water. It would run off to the right.

Subdividing Channel Cross-sections

You've described your section by indicating changes in geometric characteristics. Now you need to indicate any changes in hydraulic characteristics or roughness elements along the section because conveyance is inversely affected by Manning's n. If the geometric boundary has a uniform roughness then just specifying a single n is appropriate. However, if the roughness of the surface varies it may be necessary to break the section up into separate sub-sections, namely Left Overbank, Channel and Right Overbank, in order to get a more accurate read on the conveyance.

The sample cross-section shown below is typical of natural open channels. It has a well-defined channel near the center and is basically bare earth, winding, no vegetation and is kept clean by a constant flow of water. The overbanks rarely see water and consist more of grass and light to dense brush. In this case it will be necessary to provide data that describes these abrupt change of roughness.

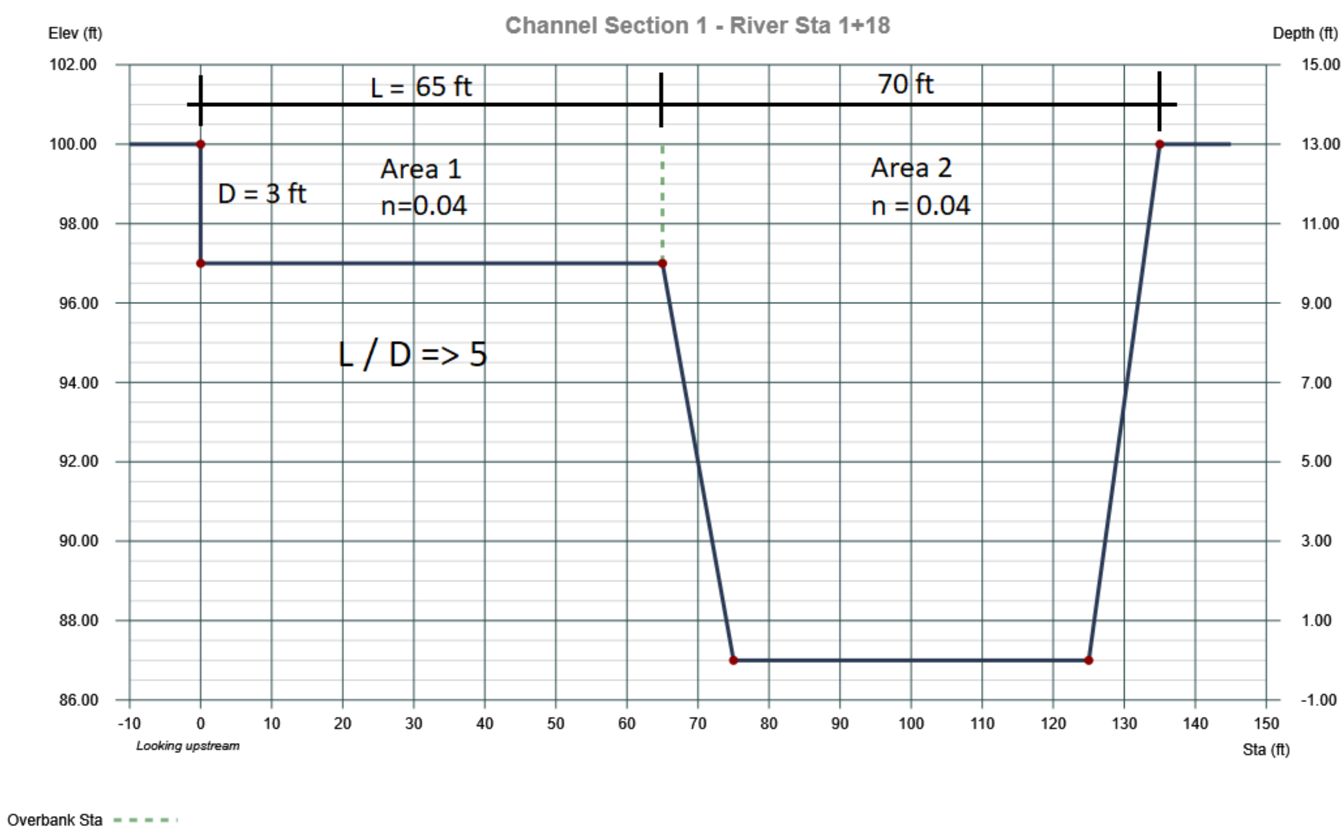


There's not much to it. You simply need to indicate the n-values for each sub-section and the Overbank Station points. In the section above, the Left Overbank has an n-value of 0.04. The Station of the Left Overbank is 200. This tells the software that from Station 0 to 200, the n-value is 0.04. The Channel portion has an n of 0.025. The Station of the Right Overbank is 230. This tells the software that the Channel portion extends between Stations 200 and 230. The Right Overbank runs from station 230 to the very end. It's n-value is 0.035.

Once you have a subdivided a section you should continue to subdivide the remaining sections as you work upstream, even if the n-values are consistent across the section.

Special Cases You Should Be Aware Of

There are certain times when you should subdivide the section even though the n-values are the same across the entire section. One such case is called the Panhandle.



A bench panhandle, or terrace, is a shape where the increase in wetted perimeter, Wp, of the floodplain is relatively large with respect to the area, A. The hydraulic radius (A/Wp) is dramatically reduced, and the calculated conveyance of the ent

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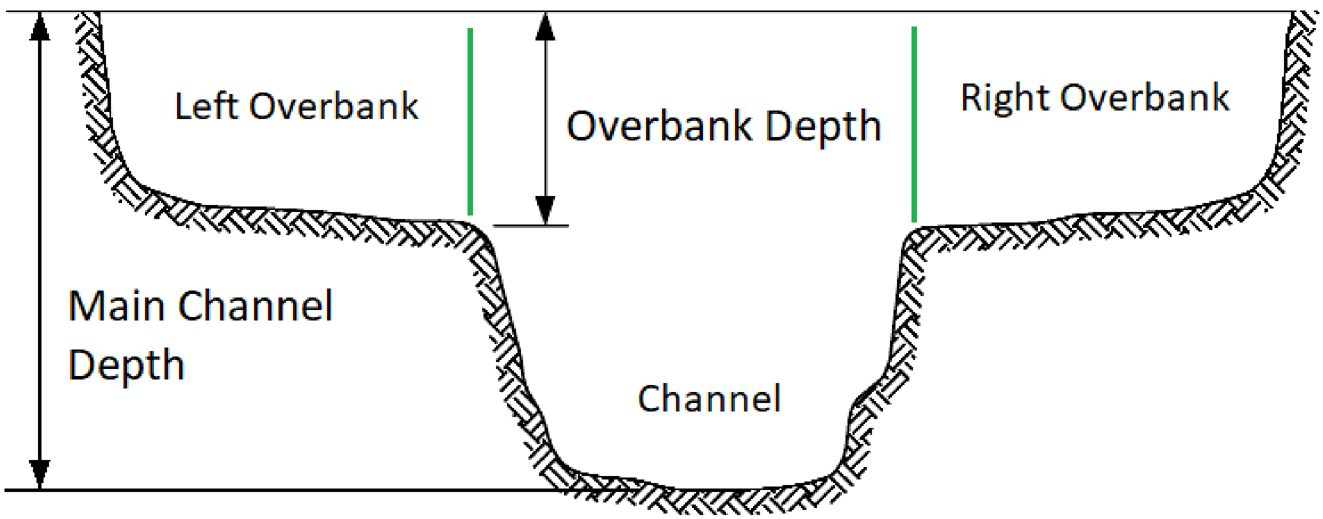
the conveyance of the main channel. To counter this, subdivide panhandles if the ratio L/D is equal to five or greater.

Another shape that causes problems in subdivision is when the main-channel depth is more than twice the overbank depth. In these cases, regardless of n-values, you should subdivide the section into overbanks and channels as shown below.



Manning's n is constant across this section but the Main Channel depth is more than two-times the Overbank depths

Once the sections have been subdivided, the calculation procedure basically converts it into a single reach length by using a discharge-weighted average.

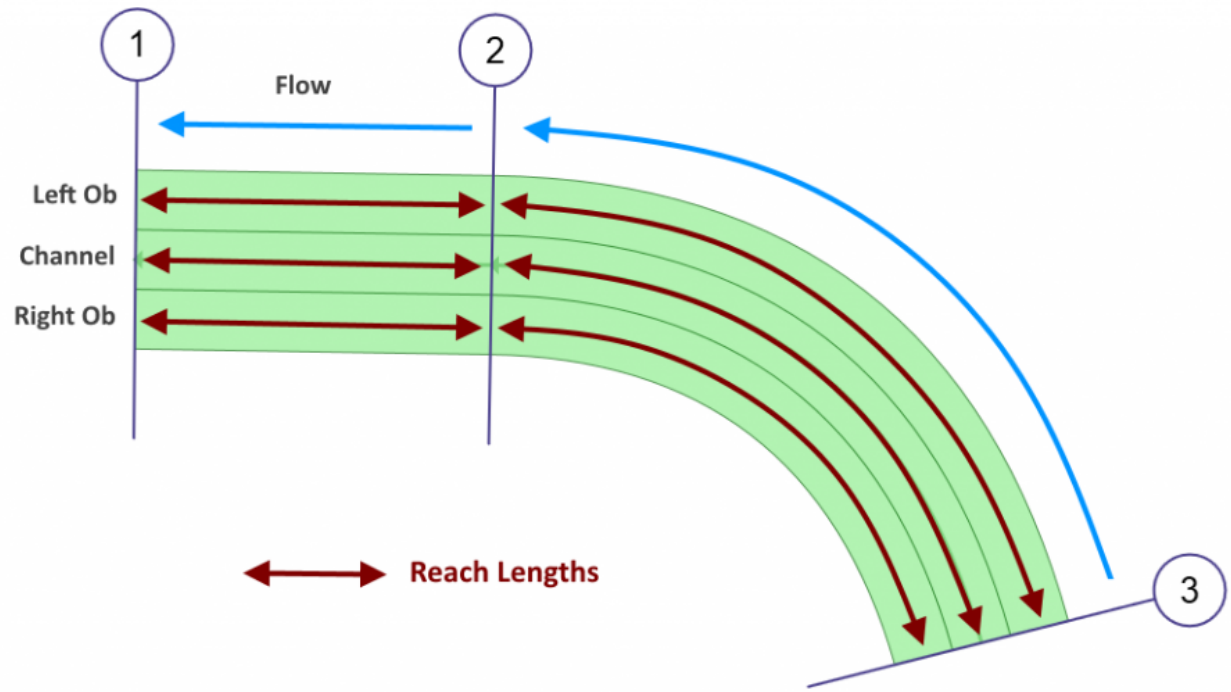
$$L = \frac{L_{LOB}Q_{LOB} + L_{CH}Q_{CH} + L_{ROB}Q_{ROB}}{Q_{LOB} + Q_{CH} + Q_{ROB}}$$

Where:

LLOB, LCH, LROB = Reach lengths for left overbank, main channel, and right overbank, respectively
QLOB, QCH, QROB = Flows for left overbank, main channel, and right overbank, respectively

Setting Reach Lengths

Okay, you now have your reach in place and have located cross-sections along this reach. We have also described how these sections look with accurate geometric data and proper subdividing using Overbanks and Channel locations. Next, you need to specify the distance between your sections, Reach Lengths. If you have subdivided sections then you'll need to indicate the reach lengths for each sub-section. Left Overbank, Channel and Right Overbank.



Remember that your actual Section locations along the reach do not necessarily imply the reach lengths, but rather the location of the Section marker. This allows us to specify any reach length(s), independent of the section markers.

Reach lengths are simply the distance the water travels through the individual sub-sections from one section to the next. As shown above, between Sections 1 & 2, the Overbanks and Channel distances are pretty straightforward and basically equal. However, if the Channel part meanders, and they usually do, the reach length of the Channel would increase and be longer than it's adjacent overbank reach lengths.

Additionally, if the reach is curved as shown between Sections 2 and 3, the outer reach is longer than the inner reach. The point is, specify the actual running distance the water travels between sections.

Summary

Your two main takeaways from this article are:

1. Think gradual, like flowing water when locating your cross-sections along your reach
2. Think like a land surveyor when describing your cross-sections

Now add water. If you're unsure of the starting water surface elevation at the beginning section, use Normal Depth. Otherwise use a known elevation… that is above critical depth. Start your project as far downstream as you can stand. By the time the profile gets up to your site, any possible errors in your beginning assumed conditions will be minimized.

Open channel hydraulics can be tricky and frustrating when you don't know what you don't know. But when you *do* know, it's actually a very rewarding experience. Just follow the guidelines outlined above and you'll be successful in open channel modeling. And when the conference room sounds like crickets at the mention of backwater curves, you'll have something meaningful to contribute.