General Measures

SPEAKER Charles Berenbrock: Welcome to Lesson 12. This lesson is determination of flow resistance in open channels. We're going to look at the measure of flow resistance. There are several flow resistance equations that are used. The most popular in the United States is using the Manning's equation, and Manning's equation is V is equal to k sub-1 (k_1) divided by n, that's the Manning's n, times R to the 2/3rd power times S to the 1/2 power. K sub-1 is equal to one when we're using the metric or SI units. "k" sub-1 is equal to 1.486 when you're using the inch-pound units. If you're doing this equation by hand, I would recommend maybe using 1.49. But if you have a computer or calculator, go ahead and use the 1.486. It's a little more accurate and it doesn't take any longer for the computer or the calculator to use it.

Let's look at the Manning's equation here. Again V is equal to k sub-1 (k_1) or 1.486 divided by n times R to the 2/3rd power times S to 1/2 power. V in that equation is the mean flow velocity. "n" is your Manning's coefficient, that's the flow resistance, and R is the hydraulic radius. R is determined by the area, your cross sectional area divided by the perimeter, A/P. And S is the friction slope or the energy grade line.

If you look at this next slide, you'll see the different units in inch-pound units and the metric units here where each variable has for each unit. We'll be looking mainly at the inch-pound units 'cause that's what where we're working in. V has units of feet per second that's what ft divided by s is. "k" sub-1 again is 1.486. It has the unit of feet to the 1/2 power divided by S. "n" which is the flow resistance has unit of feet to the 1/6th power. R has units of feet and S has units of feet divided by feet. If you use the correct units for S, R, n and k sub-1, you get the correct units for V which will be feet per second. If you look to the right side of that screen, you'll see that the equivalents units in metric. There are other flow resistance equations that are used. Chezy is the most popular outside the United States. It's mainly used a lot in Europe. The Chezy's equation is velocity is equal to C times the square root of R times S. C is the flow resistance coefficient there. R again is the hydraulic radius and S is your friction slope at the energy grade line.

Another question that is used quite a bit is the Darcy-Weisbach. This equation was used mainly in open conduits and pipe flow. And this equation is the velocity is equal to the square root of 8 times g, times R times S, all that divided by f. "f" is the flow resistance variable there. In this next

slide were going to be preparing these flow resistance equation to one another. On the left hand side, we'll see the Darcy-Weisbach equation and in the middle you'll see Manning's n and then you'll see Chezy's on the right hand side. But we did is we set the velocity equal to each other and you can get the equation like that. Now if we rearrange the equations and simplify it, you'll see the bottom equation there. And its left hand side is the square root of 8 divided by f is equal to 1.486 times R to the 1/6th power divided by n times the square root of g. And it's equal to C times the square root of g.

Now let's look at the relationship between Manning's n and Chezy's C coefficient. And if you look at this graph, you'll see that as Manning's n increases, Chezy's C decreases. And the relation is shown in the upper part of that graph where n is equal to 1.486 times R to the 1/6th power divided by Chezy's C coefficient.

It's not uncommon to have single value of n, let's say, for your cross section or your channel reach. The greatest difficulty in applying the Manning's equation is the determination of n. "n_0" only represents the friction on the sides and the bottom of the channel but all other types of irregularities in your channel which adds to your flow resistance and also the other things let's say like vegetation. "n" can be highly variable in your reach or along your cross section of study.

This slide has many sources of roughness that can increase roughness in your channel, for example, like particle size or your particle angularity, how about your sinuosity or the meandering or channel curvature of your channel. Also, other sources are due to, let's say, suspended materials and the bed load that the stream is carrying and also maybe two bed forms or bar forms in your channel. Vegetation can add lots of roughness to your reach under consideration and also wooden debris, let's say, like logs and you can see many others that are listed there that can add to the roughness in your channel. In the next sections, we're going to be looking at four different methods in estimating resistance to for Manning's n.