Engineering Hydrology

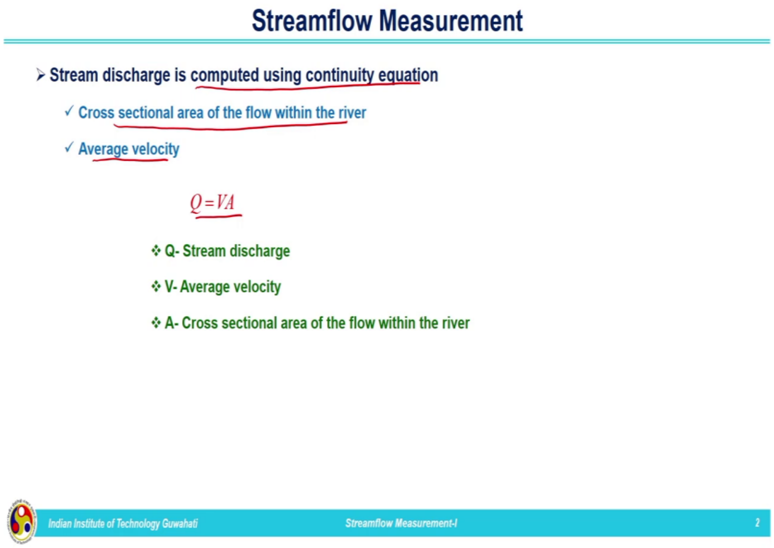
Dr. Sreeja Pekkat
Department of Civil Engineering
Indian Institute of Technology, Guwahati

Lecture – 48
Stream flow Measurement - 2

Hello all, welcome back. In the previous lecture, we were discussing about streamflow measurement. This lecture is the continuation of the previous one. We have seen the streamflow measurement; the direct measurement of stream flow is expensive and also time consuming. We found that streamflow measurement can be done or streamflow calculation can be done by knowing the water level at different locations in the stream.

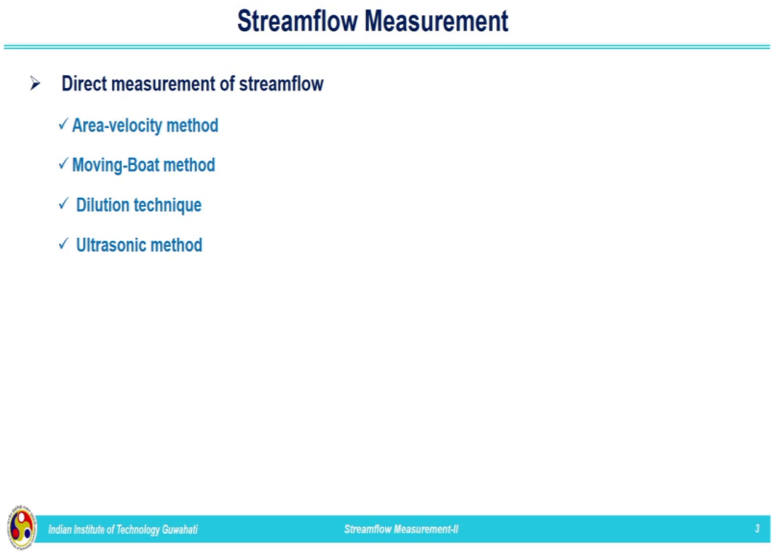
So, the water level measurement we have seen in the previous lecture by using the manual methods and also automatic method. After that we have seen the measurement of velocity by means of current meter. If water depth is known to us, and the width of the stream is also measured, then we can get the area of the cross-section and the velocity which is measured by means of current meter or by any other means can be utilized for the computation of average velocity. When we talk about average velocity, we have seen two ways to express average velocity. The average velocity in the case of shallow rivers can be considered as the velocity at a depth of 0.6 times the water depth or in the case of deeper rivers, it is considered as the, average velocity is calculated by taking the average of the velocities at depth 0.2 times the water depth and the 0.8 times the water depth. So, that way we can compute the average velocity.

(Refer Slide Time: 02:38)



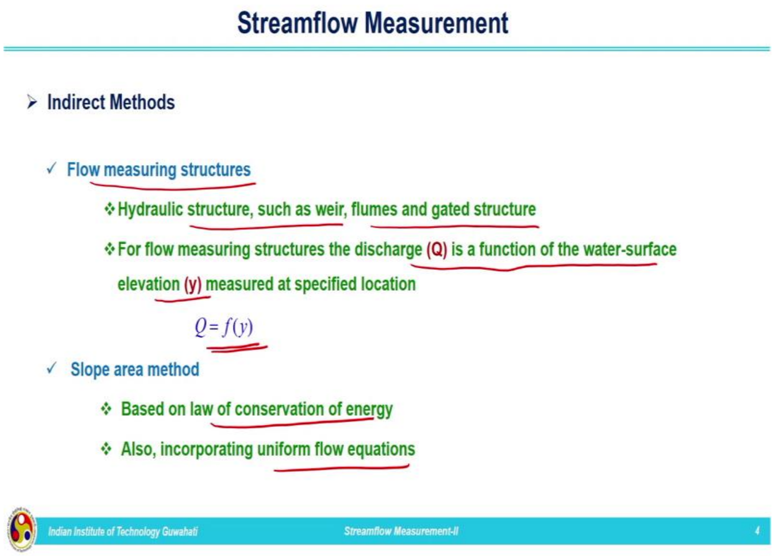
Now, let us move on to the streamflow measurement. Stream discharge is computed using continuity equation. As I have explained in the previous lecture, once we know the area of cross section and the average velocity, we can easily compute stream discharge or streamflow by making use of the continuity equation. We are very well aware of the continuity equation for that we need to have the cross-sectional area of the flow within the river and average velocity. So, if both these values are known to us, we can calculate the stream discharge by using the continuity equation $Q = VA$. Q is the stream discharge, V is the average velocity and A is the cross-sectional area of the flow within the river. So, this particular formula or the continuity equation will be utilized for the calculation of streamflow. So, for that we need to have the average velocity value and also the cross-sectional area. How can we get the cross-sectional area? We are measuring the stage or water level at different locations across the cross-section. Corresponding to that we will be measuring the width of the river and width and depth is known to us we can calculate the cross-sectional area and velocity is measured by making use of the cross-sectional area and velocity of flow we can calculate the stream discharge.

(Refer Slide Time: 04:14)



When we talk about streamflow measurement, there are two ways: one is direct measurement of streamflow, second one is the indirect measurement of streamflow. Direct measurement of stream flow includes different techniques: area velocity method, moving boat method, dilution technique, ultrasonic method. So, some other techniques are also there, but I am discussing here these four techniques.

(Refer Slide Time: 04:43)



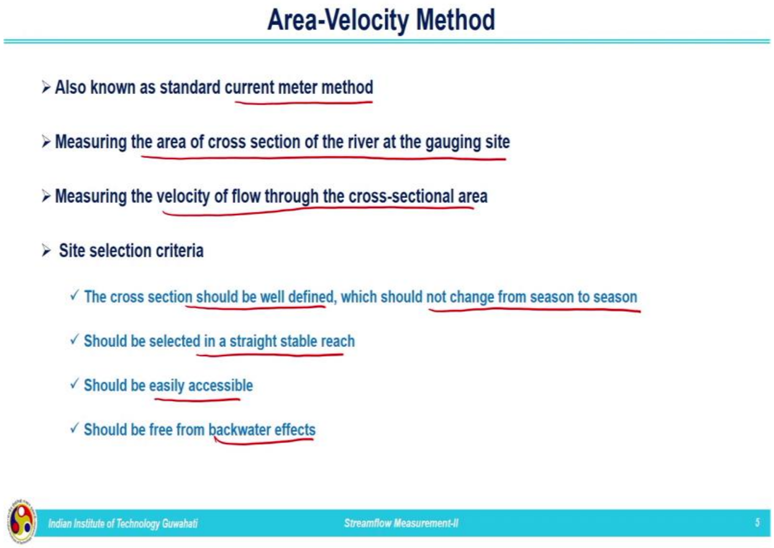
When we talk about indirect method, those include floor measuring structures. In the rivers at different locations we will be having different hydraulic structures. So, hydraulic structures such as weir, flumes and gated structure can be considered as the control section, and we can measure the discharge by making use of the measurements at these control sections. So, indirect method of measuring stream discharge is by means of flow measuring structures which are present in the river. For flow measuring structures the discharge Q is considered as the function of water surface elevation, y. Water surface elevation is measured with respect to an arbitrary datum. So that depth y is measured and Q is considered as the function of this water surface elevation. So, for different hydraulic structure different relationships will be there between Q and depth of flow. So,

$$Q = f(y)$$

So, by making use of the corresponding mathematical representation of the relationship between the water depth and the discharge corresponding to a particular hydraulic structure we can calculate the streamflow. So, that is coming under indirect methods, I am not going deep into the hydraulic structure and computation of streamflow, because this you might have already studied in open channel hydraulics.

Second method coming under indirect method of streamflow measurement is slope area method. In slope area method, it is based on the law of conservation of energy and we can make use of uniform flow equations such as manning's equation. If it is a flume, we can make use of the manning's equation to calculate the discharge. Water surface elevation will be measured and the cross-sectional area at the corresponding structure will be known to us and making use of the slope area method, we can calculate the discharge corresponding to a particular stream. It is more related to hydraulics, I am not covering the detail topics related to this indirect measurement, that is flow measuring structures and slope area method. We will move on to the direct method of streamflow measurement.

(Refer Slide Time: 07:09)

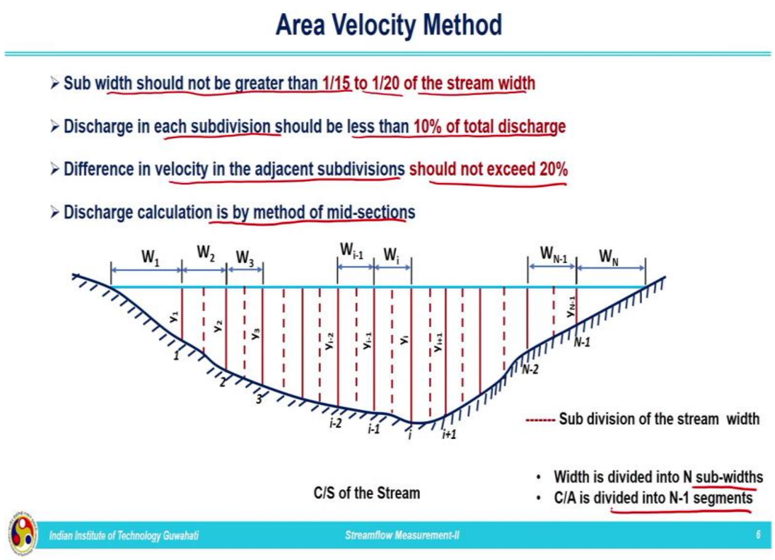


First, we will start with the area velocity method. This area velocity method is also known as current meter method. We have seen two types of current meters: horizontal axis current meter and the vertical axis current meter. By making use of current meter, how the velocity can be measured, we have seen in the previous lecture. So, velocity measurement is ready with this. Now, we need to have an idea about the area computation.

So, in this method, we will see how to calculate the area and once area and velocity is available to us, we can calculate the streamflow. That is why this area velocity method is also known as current meter method. So, measuring the area of cross section of the river at the gauging site is required. So, in the case of measurement of area also, we are not going to directly measure the area. Water level or stage at different location across the cross section will be measured and corresponding width also will be measured. So, based on that we need to calculate the area of cross section and measuring velocity through each cross section will be done by using current meter.

Coming to site selection criteria, the cross section should be well defined and should not change from season to season. The site should be selected in such a way that the cross section of the stream where we are measuring the stages and also velocity, that cross section should be stapled it should not change from season to season. During monsoon season sometimes, some river cross sections will be changing. But in the case of matured rivers, it will be attained a stable cross section. In other cases, also, the cross section should be selected in such a way that there is not much changes taking place in the cross section as season changes. It should be selected on a straight stable reach and side should be easily accessible and should be free from backwater effects. Because, if backwater effects are there it will be affecting the velocity measurement. That is why it should be free from backwater effects. It should be in a straight stable reach and the cross section should not be changing from season to season and also the site should be accessible.

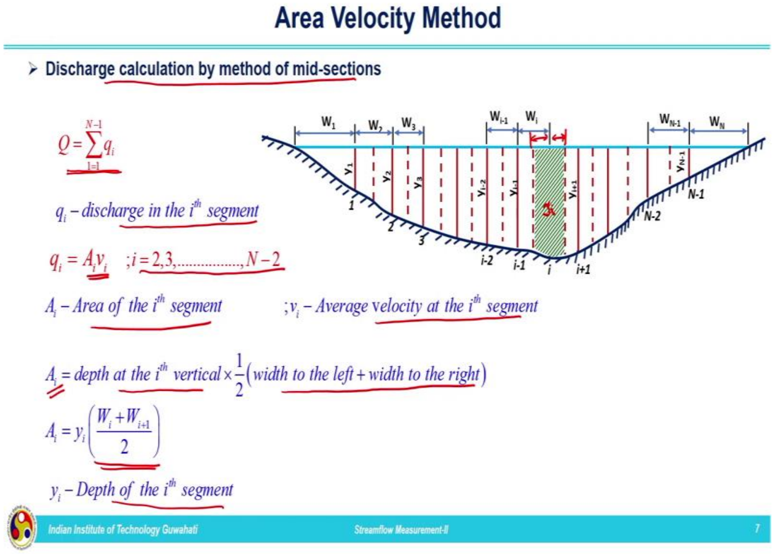
(Refer Slide Time: 09:47)



Now, let us have a look into the cross section of the stream. Schematically it can be represented like this. Non- prismatic shape we are considering, it is not a prismatic channel like rectangular cross section or trapezoidal cross section. So, this is a non-prismatic stream, natural stream. So, the cross section can be schematized like this and what we are going to do we are going to divide the width into N sub-widths. The entire width of the stream is divided into N parts and the subdivision is marked by dotted red line, this way we can divide the entire width of the river. There are certain criteria to be followed while dividing the width, that is the width of each subsection or the sub-width should not be greater than $\frac{1}{15}$ to $\frac{1}{20}$ of the stream width. Total width is there, each sub-width should not be more than $\frac{1}{15}$ to $\frac{1}{20}$ of the total width, it should be less than that. Second criteria is that, discharge in each sub division should be less than 10 percentage of total discharge. This will come with experience only. When we see a river cross section, we cannot easily understand whether 10 percentage of discharge will be coming within this sub-width. So, this comes with experience only, but the width of the cross section can be divided in such a way that it should be lesser than $\frac{1}{15}$ to $\frac{1}{20}$ of the total width of the stream. One more condition is that the difference in velocity in adjacent subdivisions should not exceed 20 percentage. So, we are dividing the cross section of the stream or river in such a way that the sub width should be less than $\frac{1}{15}$ to $\frac{1}{20}$ of the total width and the discharge through each sub width corresponding to that area through that should be less than 10 percentage of the total discharge and also the difference between the velocity between two nearby sub-section should not be greater than 20 percentage. So, these conditions should be considered while dividing the width of the river.

Now, the discharge calculation is done by method of midsection. So, each width is again divided at the midpoint. The method which we are using for the computation of discharge is based on method of mid-section, that is why we need to divide each width at the midpoint. So, that way the entire cross section is divided into $N-1$ segment. So, we can look into the figure. So, this way we are dividing each sub-width. It is named in such a way that it starts from 1, 2, 3 and it goes to i^{th} segment and it will be coming up to $N-1$, because the total width is divided into N small segments and at each midsection, the depth is measured, stage measurement is carried out at each midsection. So, those are marked by y_1, y_2, y_3, y_{i-2}, this way it will go up to y_{n-1}. Last midsection is coming as $N-1$ section that will be the depth at that particular section will be y_{n-1} and total width is divided into N sub width.

(Refer Slide Time: 14:05)



So, now we will move on to the discharge calculation by method of midsection. So, here when you look at the subsection except the first and last, each subsection can be approximated to a rectangle. So, area can be considered by means of multiplying the depth and the width. So, that way we can get the area. The velocity corresponding to each segment is measured and you can calculate the discharge in each segment by multiplying velocity and the area. Area can be calculated by considering it as a rectangle. But when talking about the first segment and the last segment, it is not like a rectangle. So, the area should be calculated by considering it as a triangle. Total discharge can be calculated as

$$Q=\sum_{1=1}^{N-1} q_i$$

Small q_i is representing the discharge through each segment, q_i is the discharge in the i^{th} segment and q_i can be calculated by

$$q_i = A_i v_i \qquad ;i = 2,3,\ldots\ldots\ldots\ldots, N-2$$

A_i is the area of the i^{th} segment and V_i is the velocity measured within the i^{th} segment, i varies from 2 to N-2. Why it is from 2 to N-2? First segment and the last N-1 segment are in triangular shape and others segments can be considered as rectangle and the area can be calculated by using the formula for area of rectangle. So, $q_i = A_i v_i$. A_i is the area of the i^{th} segment and A_i can be schematized like this. So, you can see here we are having the area marked by this hatched diagram. So, this is approximately looking like a rectangle. V_i is the average velocity at the ith segment and area can be calculated as

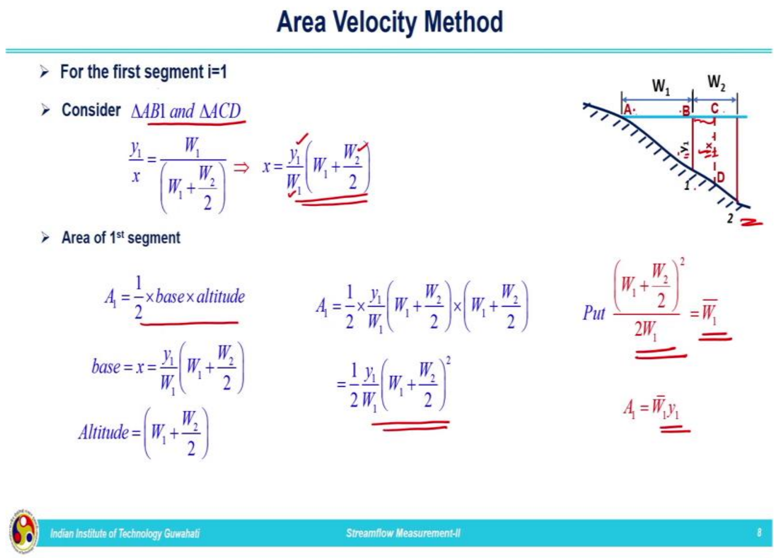
$$A_i = depth\ at\ the\ i^{th}\ vertical \times \frac{1}{2}\left(width\ to\ the\ left + width\ to\ the\ right\right)$$

Since, this is a method of midsection, width how we are taking? Our section is there, half to the left and half to the right we are taking and here you can see towards this side and towards this side, half width you are considering and area is calculated multiplied by the depth. So, that is what is written over here A_i is depth corresponding to the ith vertical that is y_i multiplied by width is taken half width towards the left and half width towards the right. So, that way you will get the total width and also depth is already measured that is the stage which is measured and it will give us the area of the ith segment. Now, A_i can be written as

$$A_i = y_i\left(\frac{W_i + W_{i+1}}{2}\right)$$

Here it is W_i and the other one is W_{i+1}. So, half if you consider towards the left and right, so, half of $W_i + W_{i+1}$ will be coming as the width multiplied by y_i. y_i is the depth of the ith segment. So, this is applicable to the segments with i varying from 2 to N-2. Now, we have to look at the segment $i=1$ and $i = N-1$, that is the segment areas corresponding to $i=1$ and $i = N-1$ we need to see those are in triangular shapes.

(Refer Slide Time: 18:05)



Now, for the first segment, that is $i = 1$ and $i = N - 1$ it cannot be considered as a rectangular area, those are in approximate triangular shapes. So, how can we get the area corresponding to these two segments? So, when we talk about this first section, first segment, segment $i = 1$ the area which we need to have is given by this hatched area. When you look at this figure, you are having depth at the section 1 that is y_1, but when we are talking about the area, we need to have the depth at this point that is it with $W_1 + \frac{W_2}{2}$ that depth of water, that stage is required to be calculated. But that measurement is not there with us. So, what we are going to do? We are going to compute the depth at that particular mid-section by making use of the similar triangle principles. So, we are going to name different points A, B, C, D. So, that way, we need to get the value corresponding to CD, that is marked as x. Now, consider triangle AB1 and triangle ACD. These two triangles triangle AB1 and ACD can be considered as similar triangles and based on the known values of width and depth, we can compute the depth at the midsection corresponding to segment 1. So, we can write

$$\frac{y_1}{x} = \frac{W_1}{\left(W_1 + \frac{W_2}{2}\right)}$$

That $\frac{y_1}{x}$ is equal to AB divided by AC. What is AB. W_1 divided by W_1 plus this much part BC will be equal to W_2 by 2 that is what is written over here

$$\frac{y_1}{x} = \frac{W_1}{\left(W_1 + \frac{W_2}{2}\right)}$$

From this, we can get the value of *x* as

$$x = \frac{y_1}{W_1}\left(W_1 + \frac{W_2}{2}\right)$$

So, the base of the triangle is calculated now. We have already measured the stage y_1, W_1 and W_2 are also known to us. So, based on that you can get the value of *x*. So, once *x* is known to us, area of the first segment can be calculated as area of the triangle A1 is equal to

$$A_1 = \frac{1}{2} \times base \times altitude$$

Base is nothing but our *x* that is

$$x = \frac{y_1}{W_1}\left(W_1 + \frac{W_2}{2}\right)$$

Altitude is the width corresponding to that segment that is

$$Altitude = \left(W_1 + \frac{W_2}{2}\right)$$

Now, area can be calculated as area is equal to

$$A_1 = \frac{1}{2} \times \frac{y_1}{W_1}\left(W_1 + \frac{W_2}{2}\right) \times \left(W_1 + \frac{W_2}{2}\right)$$

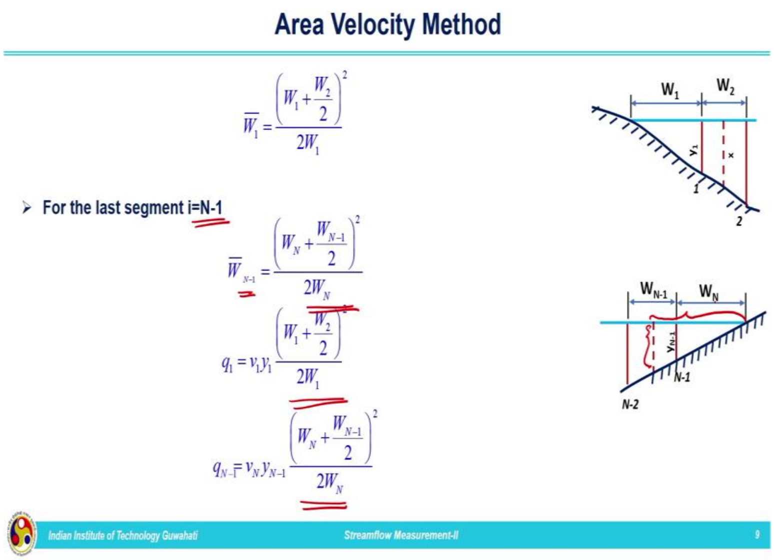
So, this is the formula which needs to be used for computing the area for the first section. In the similar way we can calculate the area for the last segment also. So, this area expression can be simplified by substituting $\frac{\left(W_1 + \frac{W_2}{2}\right)^2}{2W_1}$ as $\overline{W_1}$. So, we can write A_1 is equal to

$$A_1 = \overline{W}_1 y_1$$

that is just as in the case of rectangular how we are calculating the area: depth into width.

In the similar way y_1 multiplied by, width is not exactly obtained from the figure, we need to calculate that expression is given by this $\frac{\left(W_1+\frac{W_2}{2}\right)^2}{2W_1}$. That will be giving you the expression for the width for the triangular section.

(Refer Slide Time: 22:22)



In the similar way, when $i = N - 1$ for the last segment, we can calculate the width corresponding to that, this is the schematic representation of the last segment. We do not know this dimension because we our base of the triangle is this and altitude is given by this. Altitude is not an issue $\frac{W_N + W_{N-1}}{2}$. So, this we need to calculate by using the method of similar triangles written as

$$\overline{W}_{N-1} = \frac{\left(W_N + \frac{W_{N-1}}{2}\right)^2}{2W_N}$$

And the discharge through this triangular section can be written as

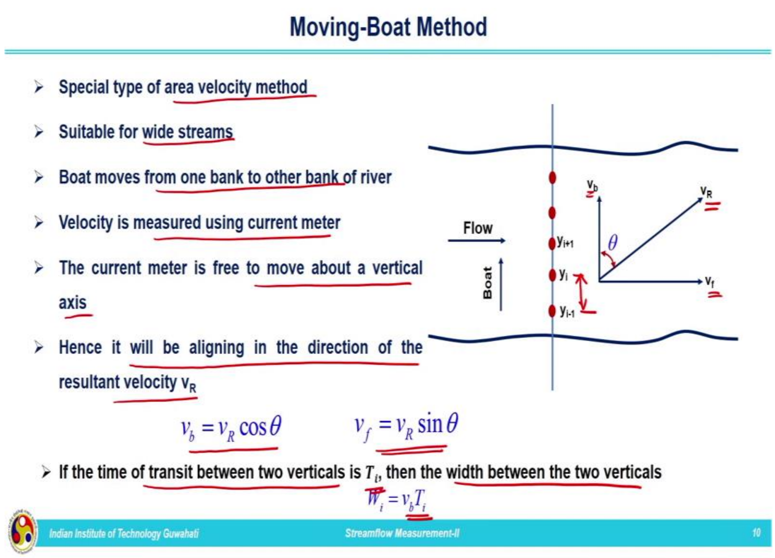
$$q_1 = v_1 y_1 \frac{\left(W_1 + \frac{W_2}{2}\right)^2}{2W_1}$$

q_{N-1} is written as

$$q_{N-1} = v_N y_{N-1} \frac{\left(W_N + \frac{W_{N-1}}{2}\right)^2}{2W_N}$$

So, we got q_1 and q_{N-1} for i varying from 2 to *N-2*. So, all the discharges through these segments are being calculated given by q_i and summation of these discharges will be giving us the total discharge through the entire cross section of the stream. So, this is the method known as the area velocity method. Velocity at different locations, different segments will be measured corresponding to each depth we have marked we will be measuring the stage and also velocity. Velocity measurement should be done in such a way that if it is a shallow river, the velocity measurement is done at 0.6 times the depth of water level at that particular location and if it is a deeper river, we need to measure the depth that two sections at *0.2y* and also *0.8y* and then we will be calculating the average velocity. So, average velocity is corresponding to each segment is measured and then we will be calculating the discharge through each segment. Finally, all these discharges will be summed up to get the total discharge through the entire cross section of the stream.

(Refer Slide Time: 24:47)



Now, next is the moving boat method. This is a special type of area velocity method suitable for wide streams. Moving boat method, we commonly use in the case of wide streams. because, for example, rivers like Ganga and Brahmaputra, if you are doing the measurement by using the stationary boat, because of the velocity of the flow, the current meter cannot be held in a particular position. So, what we will be doing in the streams which are having heavy currents we will be making use of the moving boat method, because it is difficult to maintain the boat in stationary position that is why moving boat method is preferred in such reverse for the measurement of velocity.

So, let this be the river, river flow is taking place in this direction and the boat moves from one bank to the other bank. Boat is moving in this direction. The velocity of boat is given by v_b and the velocity of the stream is given by v_f. Velocity is measured by using a current meter which is taught to a boat. So, the current meter is held in such a way that it is free to move about the vertical axis. So, definitely the boat is moving with the velocity across the river v_b and also the flow is along the river, flow velocity is represented by v_f.

So, the current meter will be held in a position resultant to the velocity of v_b and v_f. The current meter will be aligning in the direction of the resultant velocity v_R. It is free to move about the vertical axis the boat is moving with a velocity v_b and the flow is with a velocity v_f. So, definitely the current meter will be held in the direction of the resultant velocity, resultant velocity is represented by the notation v_R. This is the direction of resultant velocity and the current meter we will be measuring v_R. The angle between the direction of boat and the resultant velocity is marked by θ. So, we can write the velocity of boat v_b is equal to

$$v_b = v_R \cos\theta$$

and the velocity of flow v_f is equal to

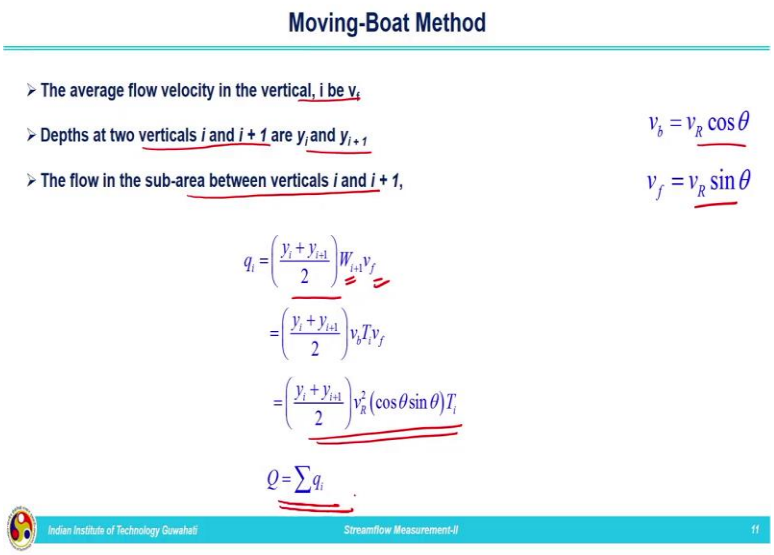
$$v_f = v_R \sin\theta$$

Whenever we are measuring the velocity along with that we will be measuring the stage also because we need to get the stage in order to compute the area cross sectional area of the river. So, the stage measurements are done at different locations corresponding to that velocity also measured. The stage at different sections will be $y_{i-1} - y_i$ that way it will be marked and we will be measuring that. Now if the time of transit between two verticals, the time taken is T_i, then the width between these two sections can be calculated by

$W_i = v_b T_i$

Where v_b is the velocity of the boat that we can calculate from the velocity measured by the current meter and the time taken to travel this much of distance is noted. So, the width can be calculated by using the formula $W_i = v_b T_i$, velocity multiplied by the time.

(Refer Slide Time: 28:29)



The average flow velocity in the vertical *I* be v_f, that is v_f we can calculate from the velocity measured by the current meter V_R and the depths that at two verticals *i* and *i+1* are y_i and y_{i+1}. So, by knowing the depth and velocity, and also knowing the width, we can calculate the flow through each segment. So, we can get the flow in the sub area between *i* and *i+1* verticals as

$$q_i = \left(\frac{y_i + y_{i+1}}{2}\right) W_{i+1} v_f$$

that is here we are considering each sub areas are rectangular sub areas and at the end points it may have to be considered as triangular. So, we may have to calculate the dimensions accordingly. So, q_i can be calculated by making use of this formula

$$q_i = \left(\frac{y_i + y_{i+1}}{2}\right) W_{i+1} v_f$$

Here we are going to substitute for W and v_f because we know the formula.

$$q_i = \left(\frac{y_i + y_{i+1}}{2}\right) v_b T_i v_f$$

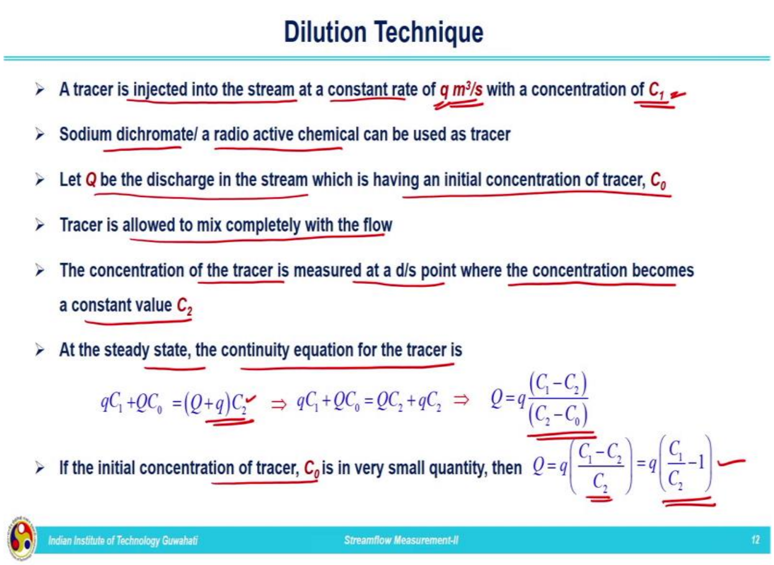
$v_b T_i$ that is width between two sections can be calculated by knowing the velocity and also time taken for that much of distance to be covered. So, $v_b T_i$ multiplied by v_f and we know v_b and v_f,. We know, $v_b = v_R \cos\theta$ and $v_f = v_R \sin\theta$. This we will substitute over here

$$q_i = \left(\frac{y_i + y_{i+1}}{2}\right) v_R^2 \left(\cos\theta \sin\theta\right) T_i$$

This is the expression for discharge through that particular sub area and *i* will be varying from *2* to *N-2* and initial and ending section that is initial triangle and at the end of the cross section, those two segments are triangular in shape and those areas can be calculated by means of the formula for triangle. So, we can get the total discharge through the cross section by using the summation of q_i. So, total discharge *Q* is given by

$$Q = \sum q_i$$

(Refer Slide Time: 30:56)



Now, let us see the third technique that is the dilution technique for measurement of streamflow. In this case a tracer is injected into the stream at a constant rate *q* meter cube per second and the tracer is having a concentration of C_1. So, this tracer can be sodium dichromate or a radioactive chemical. So, this is injected into the stream with a concentration C_1 at a constant rate of *q*.

Sometimes at a constant rate of q also injected or together all the element all the tracer will be together it will be injected, it depends on the study in which we are carrying out.

Let Q be the discharge in the stream which is having an initial concentration of tracer C_0. Stream discharge is Q and we are assuming that there is small amount of tracer present in the stream that concentration is given by C_0 and the tracer is chosen in such a way that the tracer will be mixing completely with the flow. The concentration of the tracer will be measured at a downstream point where the concentration becomes a constant value C_2. So, in this method what we are doing we are injecting the tracer at an upstream point and the concentration of the tracer is C_1 and already the water is having certain concentration of the same tracer as C_0. Tracer is allowed to completely mixed with water and we will be measuring the concentration of tracer at the downstream point. So, that is represented by a constant value C_2. At the steady state we will be making use of the continuity equation for the tracer and the continuity equation can be written as qC_1 that is q multiplied by C_1 that is the amount of the tracer added, the rate at which the tracer is added is small q and the concentration was C_1. So, qC_1 plus and already in the stream some tracer is there with a concentration of C_0 and the discharge is capital Q.

So,

$$qC_1 + C_0 = (Q + q)C_2$$

This is the concentration at the downstream sample station and the rate will be written as Q+q. This equation is rearranged like this

$$qC_1 + QC_0 = QC_2 + qC_2$$

and we can write Q as

$$Q = q\frac{(C_1 - C_2)}{(C_2 - C_0)}$$

So, here in this case, if C_0 that is the concentration of the tracer which is present in the water is of very small quantity, we can neglect it. So, the equation can be rewritten as

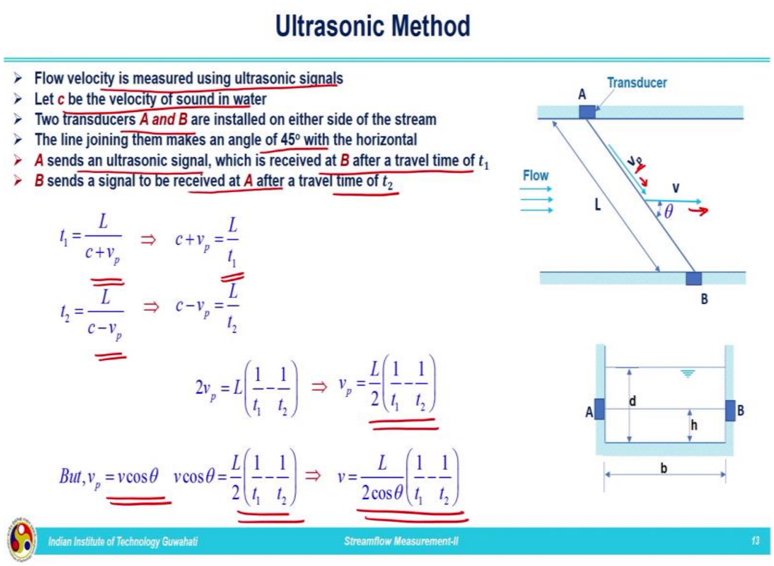
$$Q = q\left(\frac{C_1 - C_2}{C_2}\right)$$

It can be rewritten again as

$$Q = q\left(\frac{C_1}{C_2} - 1\right)$$

So, initial concentration of the traces C_0 is a very small quantity, that we are neglecting the stream discharge can be calculated by using this formula. So, we know the rate at which the tracer is added and the concentration of the tracer is known to us and C_2 is the concentration at the downstream and where the sample collection is done. So, based on these values we can calculate the stream discharge.

(Refer Slide Time: 34:45)



Now, next method is the ultrasonic method. In this what we are doing, flow velocity is measured using ultrasonic signals. This is less time consuming and this is very commonly used also. In this we are making use of the ultrasonic signals. How it is done, let us see. This is the river section we are considering and the flow is taking place along the river and the cross section of the stream is marked like this. It may not be always rectangular it will be having irregular cross-section also, in such cases we have to provide a regular cross section for the measurement convenience.

Water level is up to a depth of small d in the river and the base width of the river is small b and the velocity of the flow is represented by v and c be the velocity of sound in water, because it is based on the ultrasonic signals so, we are assuming the velocity of sound in water as small c and velocity of flow is represented by v. Now, what we are going to do? We are installing two transducers A and B on either side of the stream like this and these are installed in such a way that the line joining them makes an angle of 45 degrees with the horizontal. The length between these two transducers is capital L and it is making an angle of θ or it can be 45 degrees with a horizontal. It is provided installed at a water depth of h on both the sides of the stream. So, A and B are the transducers, it is installed at a depth of h from the bed. Now, A sends an ultrasonic signal which is received at B after a travel time of t_1. When A is sending a signal that is received by the transducer at B. The time taken for the signal to travel up to B is marked by t_1 and at the same time B is sending a signal and that is received by the transducer A. So, the time taken for that is represented by t_2 and the velocity of the signal along the flow path is marked by v_p. B sends a signal to be received at A after a time of t_2. So, A is sending signal and that is received there at B and when B is sending the signal it is received at A. So, we can write

$$t_1 = \frac{L}{c + v_p}$$

Why $c + v_p$? because the velocity along the flow path is along the sound, velocity of the sound and we can write

$$c + v_p = \frac{L}{t_1}$$

And now as far as t_2 is considered it will be

$$t_2 = \frac{L}{c - v_p}$$

Because opposite to the flow path. So, it is

$$c - v_p = \frac{L}{t_2}$$

Now, what we are going to do, we will subtract the second equation from the first equation. So, we will get

$$2v_p = L\left(\frac{1}{t_1} - \frac{1}{t_2}\right)$$

and v_p can be written as

$$v_p = \frac{L}{2}\left(\frac{1}{t_1} - \frac{1}{t_2}\right)$$

But we know $v_p = v\cos\theta$. v_p is in this direction and v is along the flow direction. So, $v_p = v\cos\theta$. What we want we want to get the value corresponding to v that is the velocity of flow. So, v is $\frac{v_p}{\cos\theta}$. So,

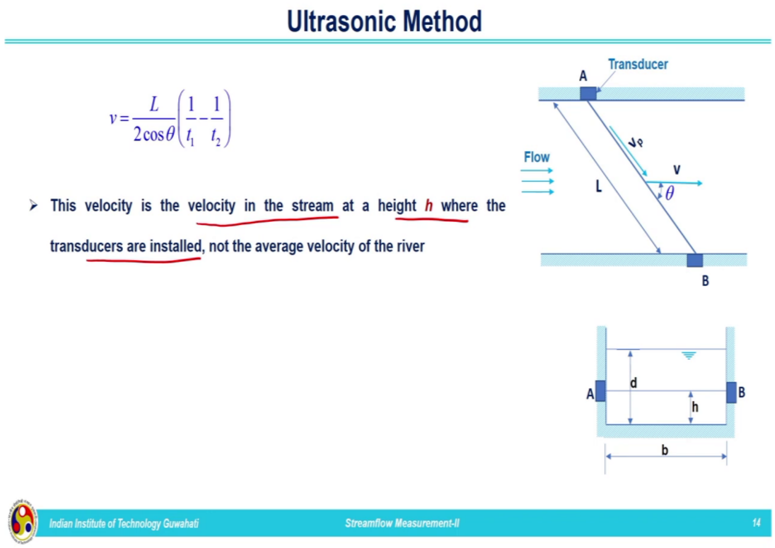
$$v\cos\theta = \frac{L}{2}\left(\frac{1}{t_1} - \frac{1}{t_2}\right)$$

Which gives the velocity of flow as

$$v = \frac{L}{2\cos\theta}\left(\frac{1}{t_1} - \frac{1}{t_2}\right)$$

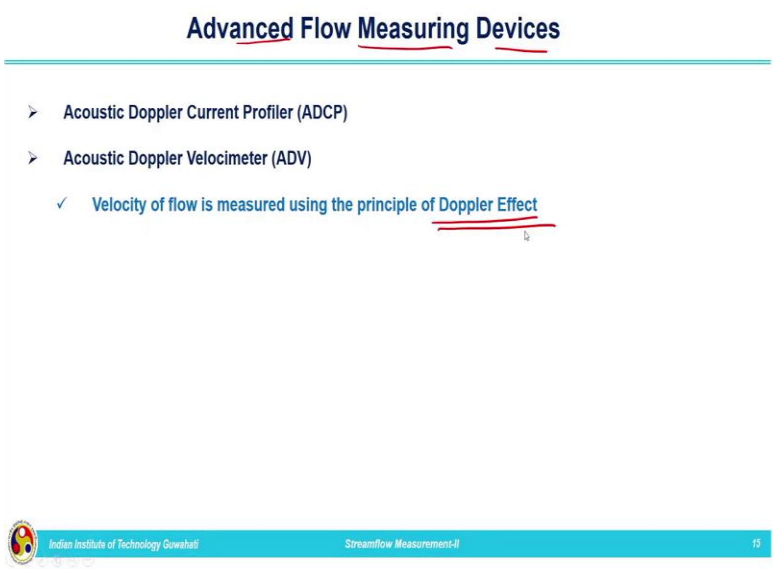
So, velocity of flow can be obtained by using this formula by using the ultrasonic method.

(Refer Slide Time: 39:21)



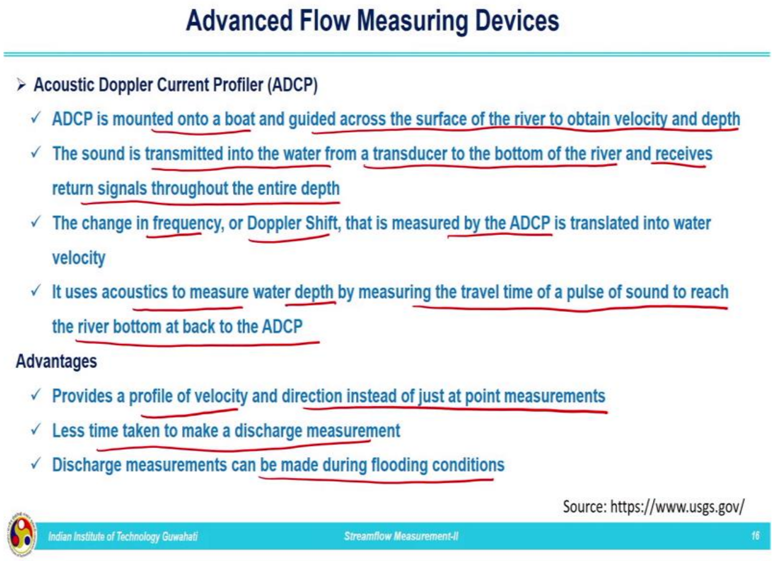
So, v is given by this expression. This velocity is the velocity in the stream at a height of h where the transducers are installed. It is not giving us the average velocity it is the velocity at a water depth of h, where the transducers are installed. So, we need to install these transducers in such a way that it will give us the average velocity. So, this need to be considered, in the ultrasonic method the velocity which we are obtaining is based on the position of the transducers which are installed within the stream.

(Refer Slide Time: 40:00)



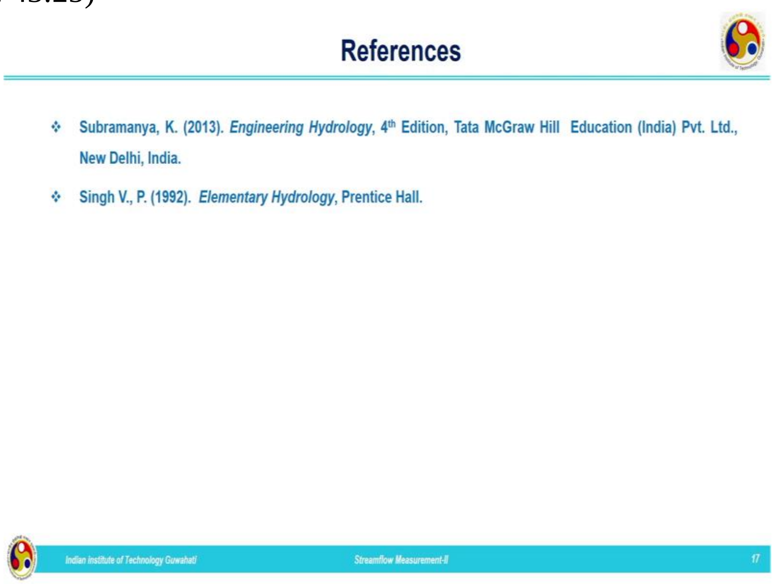
Now coming to the advanced flow measuring devices. Nowadays we are having so many advanced techniques. Some of them are acoustic Doppler current profiler, which is represented by ADCP and Acoustic Doppler Velocity meter ADV. Both are working on the principle of Doppler effect, that is the difference in frequency which is taking place as it moves away from the source. So, that Doppler effect principle is considered and based on that we will be getting the velocity of flow. I am not going deep into the methodology related to that, but you should be aware of these instruments which are used for measuring velocities nowadays.

(Refer Slide Time: 40:46)



So, coming to acoustic Doppler current profiler, the advantage in this case is that it is not giving us the point velocity, it is giving us the velocity across the cross section. So, ADCP is mounted onto a boat and guided across the surface of the river to obtain the velocity and depth. We will be getting the water depth and also the velocity. The sound is transmitted into water from a transducer to the bottom of the river and receives return signals throughout the entire depth, entire depth it will be sending the signal. The change in frequency or the Doppler shift is measured by ADCP and that will be translated to water velocity and it uses the acoustics to measure the water depth by measuring the travel time of a pulse of sound to reach the river bottom and back to the ADCP. ADCP on the surface of the water and it sends a signal to touch the river bottom and it comes back and based on this it will be calculating the depth of the stream also. So, we will be getting the depth of stream and also, we will be getting the velocity across the depth of the stream we will be getting. So, the advantages in this case is that it provides a profile of velocity and also direction instead of just point measurements. In the previous case, when we were talking about current meter case, at a particular point where we are intending to measure we will be getting the velocity at that point. But in this case, we will be getting the velocities across the entire depth and based on that whichever location velocity we need to use or we need to find out the average velocity we can calculate from this. It takes less time compared to any other method of discharge measurement and discharge measurements can be made during flooding condition also. In this case, we do not have to worry about the position of current meter. Whatever be the condition, whether it is the lean period or high flood condition, we can make the measurements and compute the streamflow in a river. So, we do not have to bother about the season. During flooding condition by making use of other techniques, it is very difficult to get the velocity or streamflow, but by making use of ADCP we can calculate the streamflow during the high flood conditions also.

(Refer Slide Time: 43:25)



So, here I am winding up this topic and the references related to this streamflow measurement are given over here and today's lecture we have seen different methods of streamflow measurement: direct method and indirect method. In the indirect method, we were making use of the hydraulic structures present over the site and in the direct method, four different methods have been explained in this lecture and based on that we have seen stage measurements and velocity measurements will be done in the field and the area calculation will be done by making use of different principles. Since different strips we are considering middle portion, we can consider it as rectangular strips and extreme ends can be considered as triangle and the corresponding areas and the velocities are known to us, based on that by making use of the continuity principle we can calculate the discharge. Total discharge across the stream can be calculated by using the summation of the individual discharges. So, here I am winding up this lecture. Thank you.