Course Name: Watershed Hydrology

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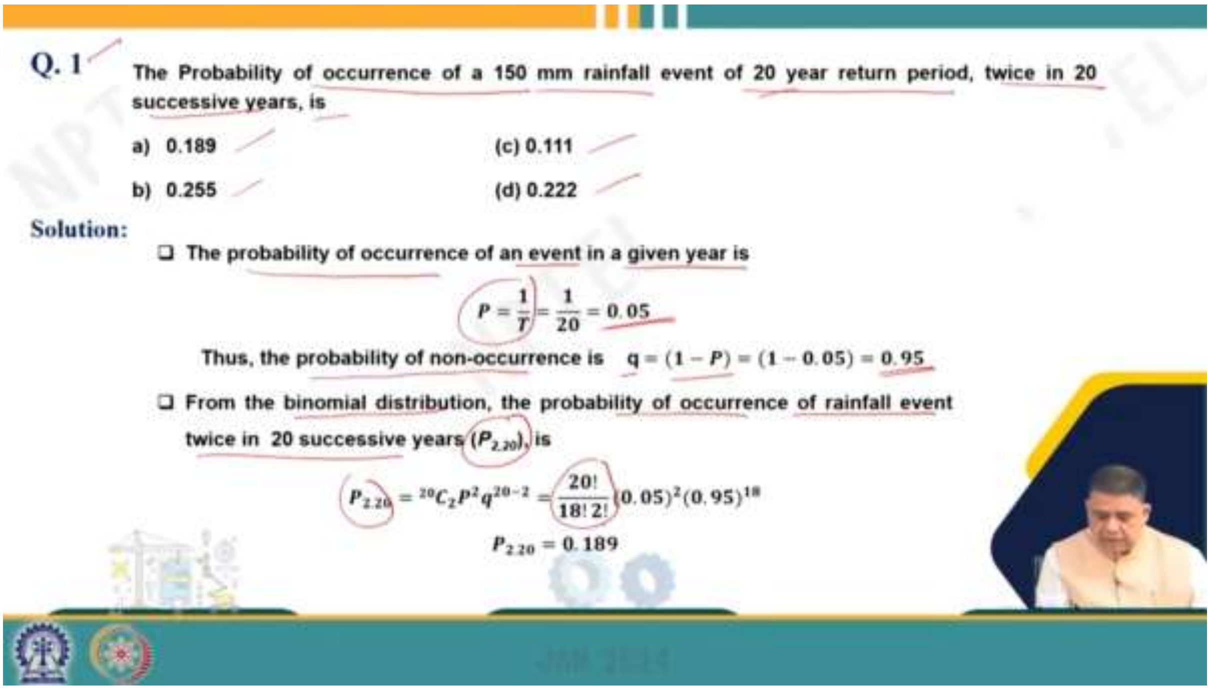
Institute Name: Indian Institute of Technology Kharagpur

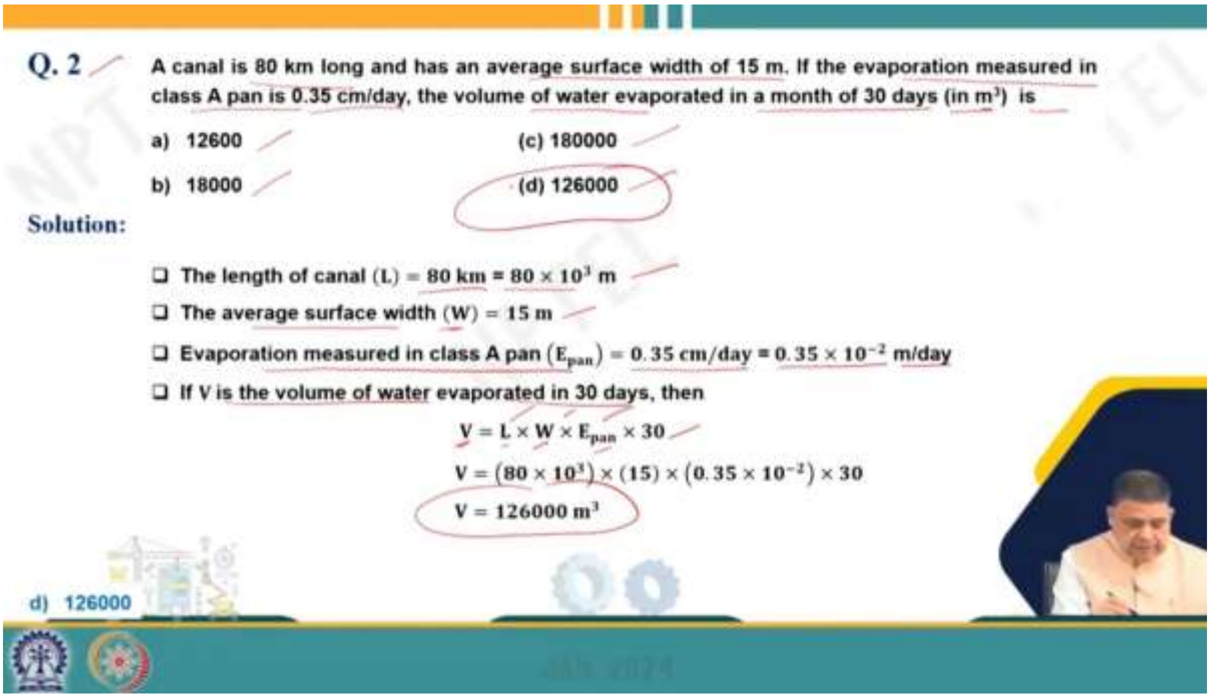
Week: 12

Lecture 60: Solution of Numerical Problems in Assignments

Hello friends, welcome back to this online certification course on watershed hydrology. I am Rajendra Singh, a professor in the Department of Agriculture and Food Engineering at the Indian Institute of Technology, Kharagpur. This is Module 12, Lecture 5, where we will solve numerical problems from assignments in Modules 1 through 11.

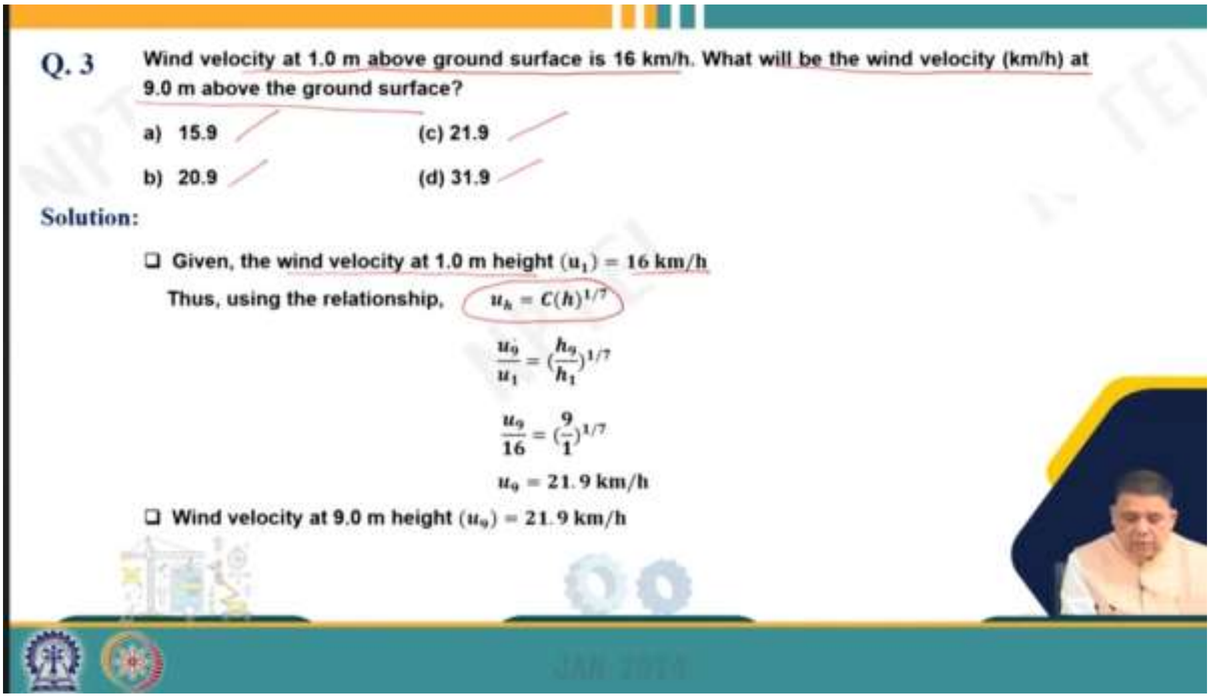


Let's begin with question number 1: The probability of occurrence of a 150 mm rainfall event of a 20-year return period twice in 20 successive years is 0.189, 0.255, 0.111, 0.222. To solve this, we use the binomial distribution. The probability of occurrence of an event in a given year is given by 1/T, where T is the return period (given as 20 years), so the probability is 0.05. The probability of non-occurrence of an event (Q) is (1 – P), or 0.95. Using the binomial distribution formula, we calculate the probability of rainfall event occurring twice in 20 successive years (P2.20) as 0.189.

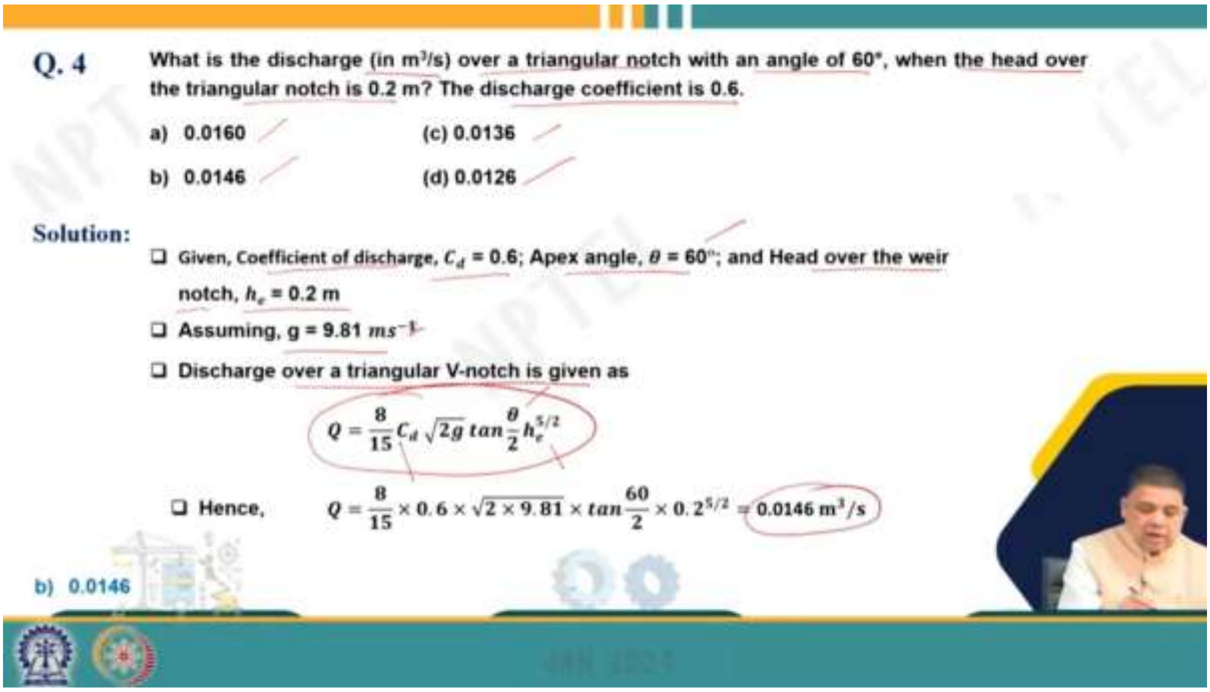


Question 2: A canal is 80 kilometres long and has an average surface width of 15 meters. If the evaporation measured in a Class A pan is 0.35 centimetres per day, the volume of water evaporated in a month of 30 days in cubic meters is 12600, 18000, 1,80,000, or 1,26,000. We

calculate the volume of water evaporated (V) using the given dimensions and evaporation rate, resulting in 1,26,000 cubic meters.



Question 3: The wind velocity at 1 meter above the ground surface is 16 kilometres per hour. What will be the wind velocity at 9 meters above the ground surface? The options are 15.9, 20.9, 21.9, or 31.9 kilometres per hour. We use the standard relationship for wind velocity at different heights and find that the velocity at 9 meters height is 21.9 kilometers per hour.

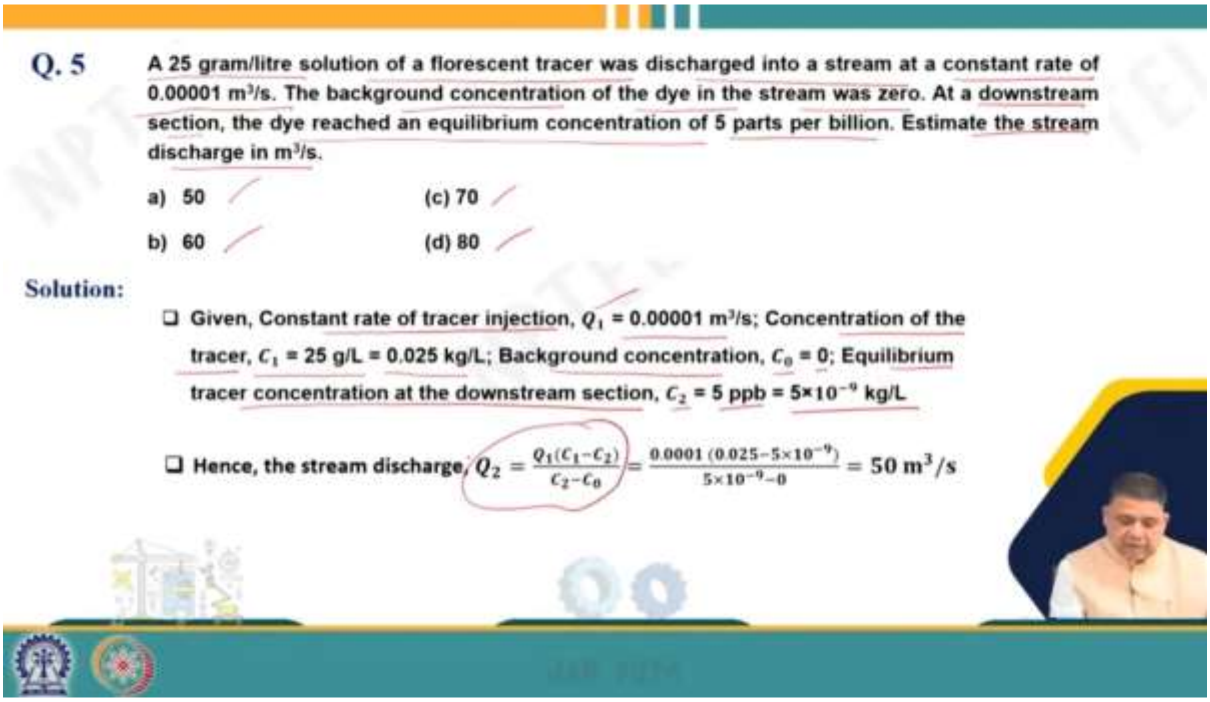


Question 4: What is the discharge in cubic meters over a triangular notch with an angle of 60 degrees when the head over the triangular notch is 0.2 meters and the discharge coefficient is 0.6? The options are 0.0160, 0.0146, 0.0136, and 0.0126. We calculate the discharge using the given parameters, resulting in 0.0146 cubic meters.

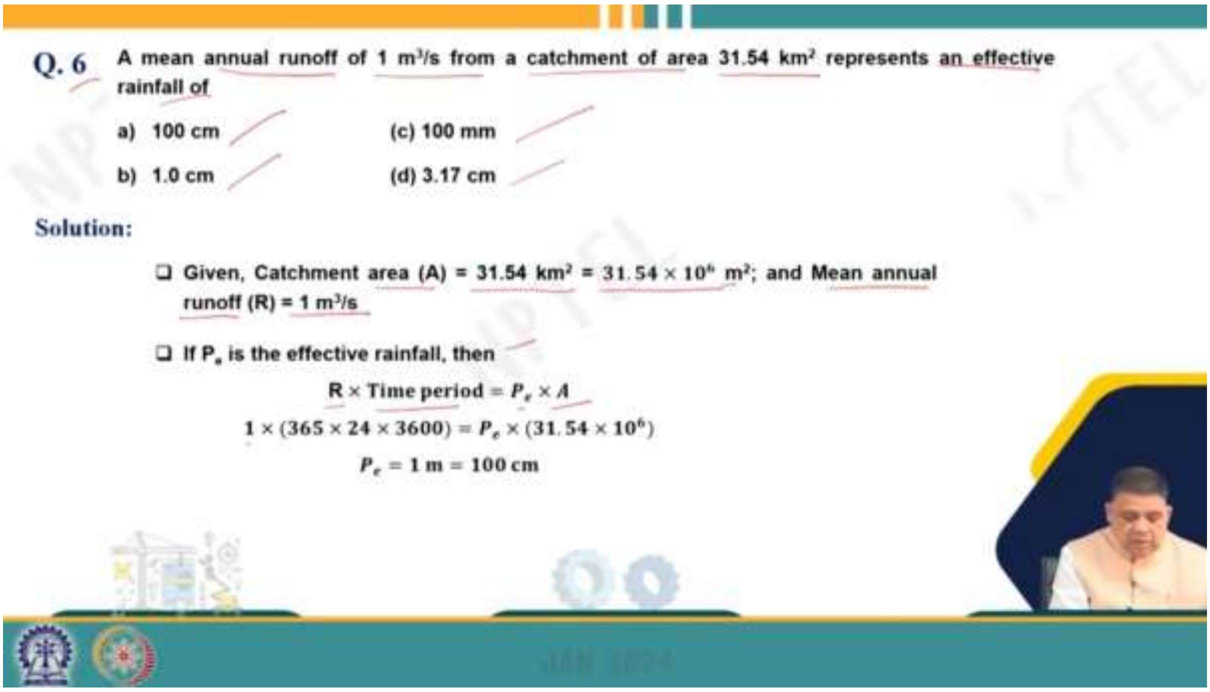
Thus, assuming acceleration due to gravity g=9.81 m/s2g=9.81m/s2, we can find the discharge over a triangular V-notch using the relationship:

$$Q=\frac{8}{15}Cd\sqrt{2g}\tan\frac{\theta}{2}he^{5/2}$$

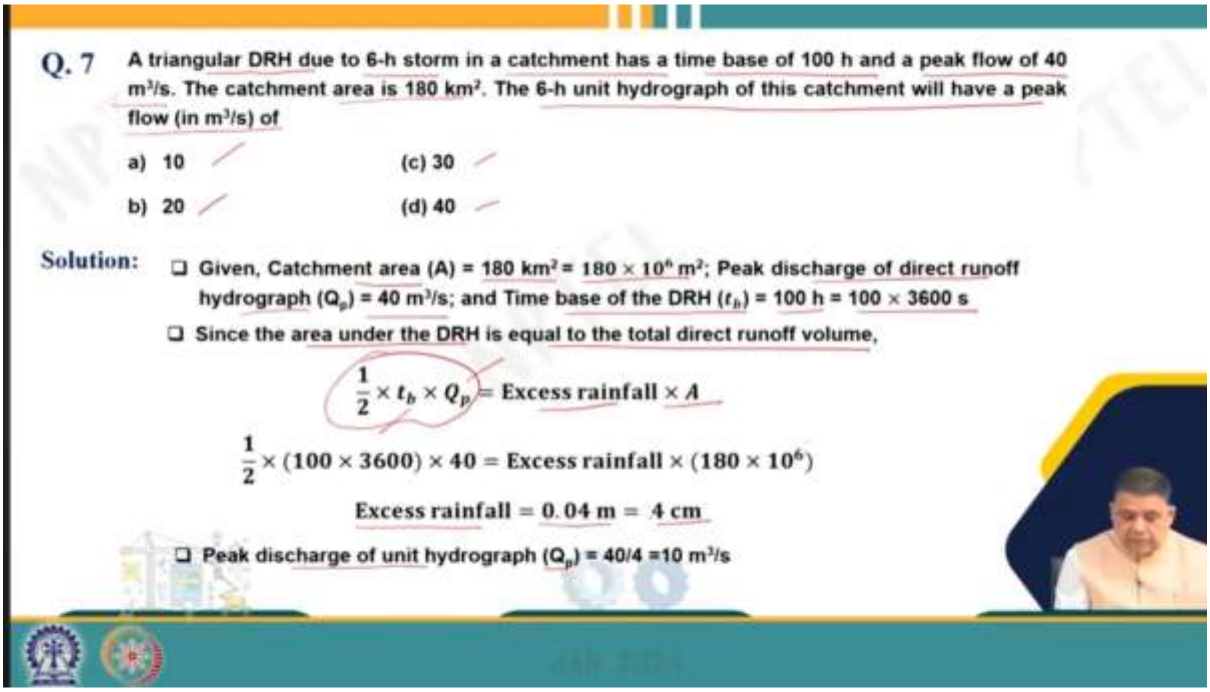
Given that CD, θ, and H are known, we can calculate Q. Substituting the known values, we find Q=0.0146 cubic meters per second, indicating that option B is the correct answer.



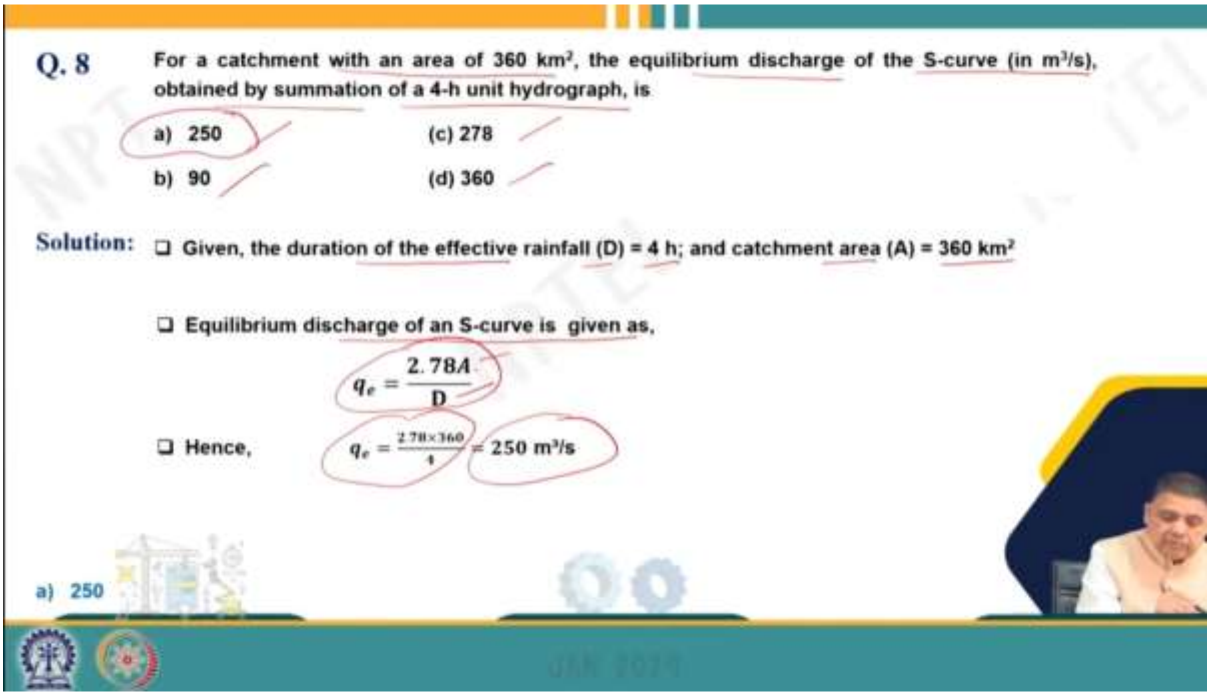
Moving on to question number 5: A 25 gram per liter solution of a fluorescent tracer was discharged into a stream at a constant rate of 0.0001 m3/s. The background concentration of the dye in the stream was 0. In a downstream section, the dye reached an equilibrium concentration of 5 parts per billion. We are asked to estimate the stream discharge in cubic meters per second. With the given parameters, we apply the constant injection method formula $Q_2=Q_1(C_1-C_2)/(C_2-C_0)$. Upon calculation, we find Q_2=50 cubic meters per second, making option A the correct answer.



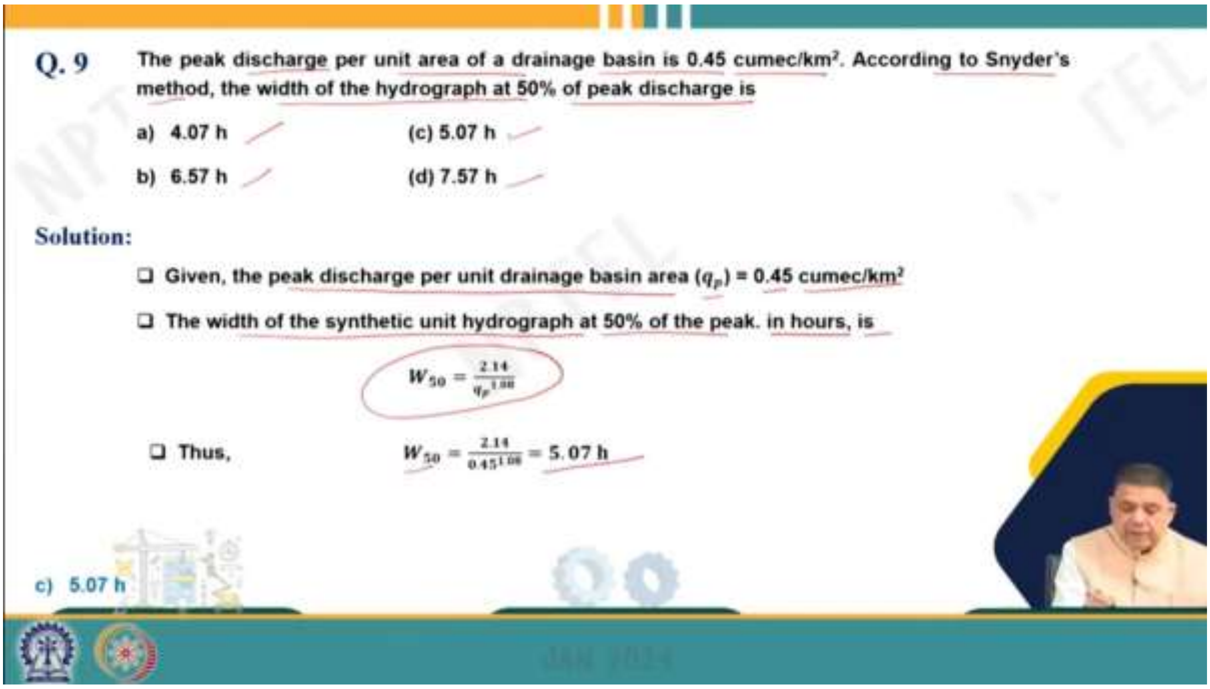
Next, question number 6 states: A mean annual runoff rate of 1 cubic meter per second from a catchment of area 31.4 square kilometers represents an effective rainfall of 100 centimeters. Given the catchment area and runoff rate, we calculate the effective rainfall, resulting in 100 centimeters per year, hence option A is correct.



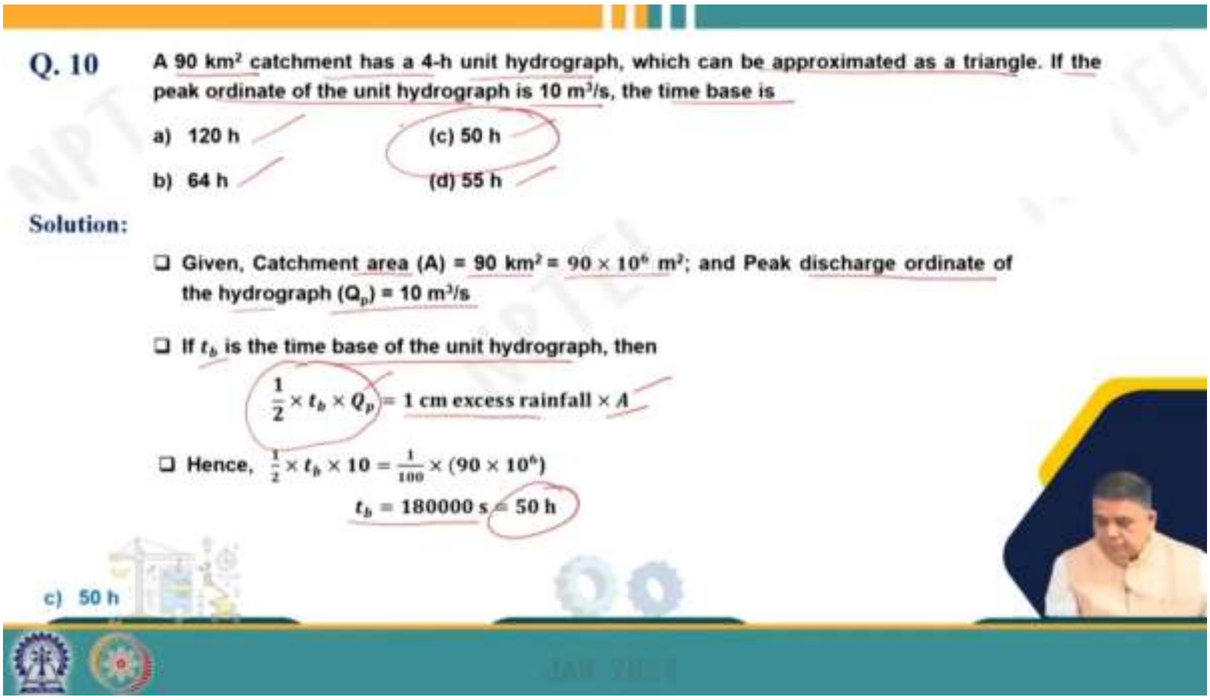
Question number 7 involves a triangular direct runoff hydrograph (DRH) due to a 6-hour storm in a catchment with a time base of 100 hours and a peak flow of 40 cubic meters per second. We are asked to determine the peak flow of the 6-hour hydrograph. Using the area under the DRH and the peak discharge, we find the excess rainfall, then calculate the peak flow of the unit hydrograph, which results in 10 cubic meters per second, making option A correct.



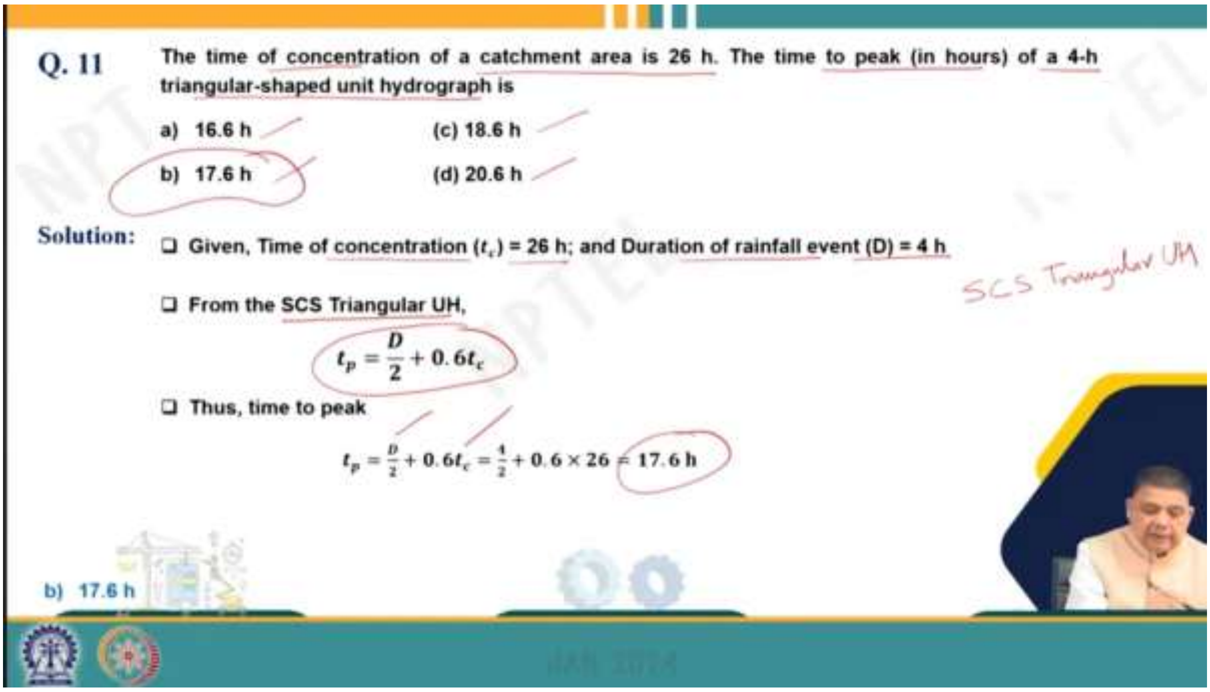
For question number 8, given a catchment area of 360 square kilometers, we are tasked with finding the equilibrium discharge of an S-curve obtained by summation of four unit hydrographs. Using the provided formula, we calculate the equilibrium discharge to be 250 cubic meters per second, making option A the correct answer.



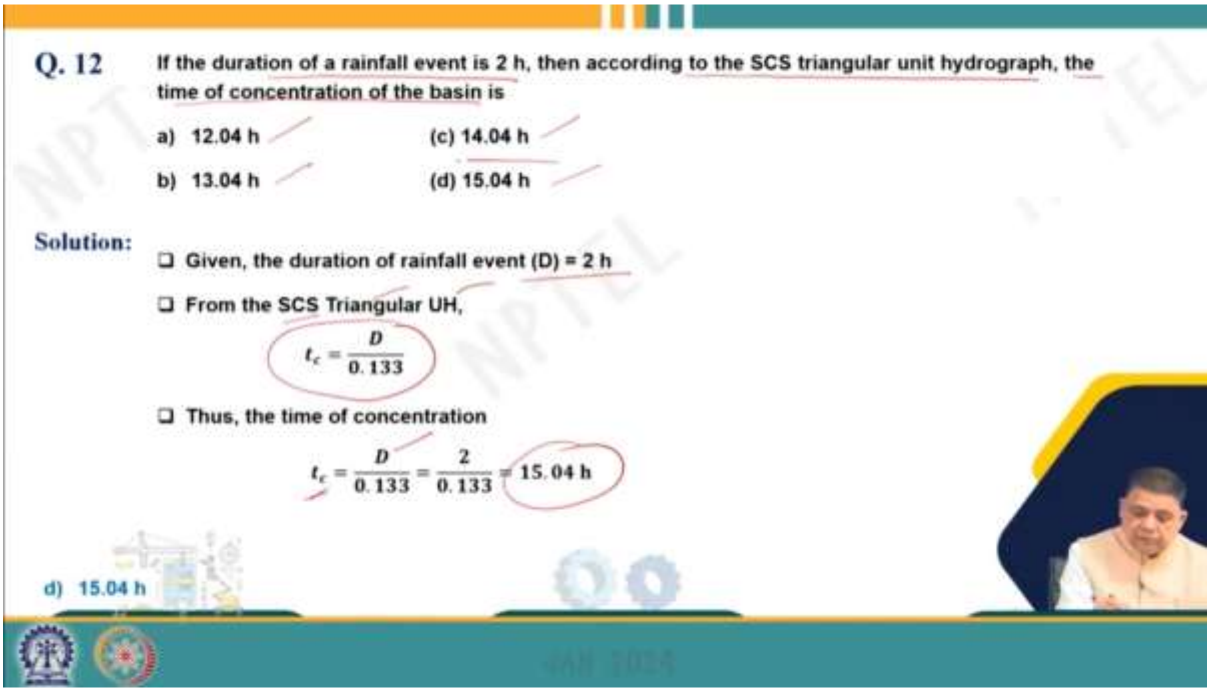
Finally, question number 9 asks about the width of the hydrograph at 50 percent of peak discharge, according to Snyder's method, given the peak discharge per unit area of the drainage basin. The correct answer is 5.07 hours.



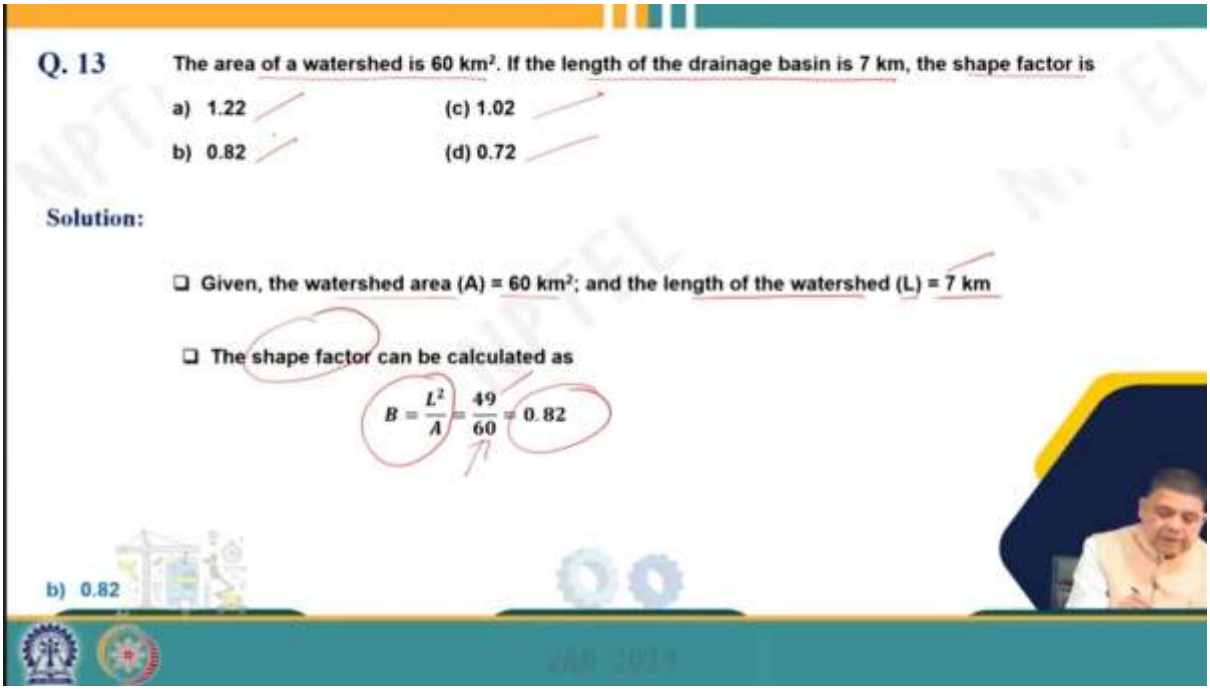
In question number 10, we are given a 90 square kilometre catchment with a 4-hour unit hydrograph approximated as a triangle. The peak ordinate of the unit hydrograph is 10 cubic meters per second, and the time base is to be determined. Using the relationship that the area under the curve, equivalent to the excess rainfall or total direct runoff volume, is 11 centimetre multiplied by the catchment area, we can find the time base. Thus, by substituting the known values into the formula $\frac{1}{2} \times tb \times Qp = \frac{1}{100} \times$ (90×10^6)square meters, we can solve for t_b, resulting in 50 hours, making option C the correct answer.



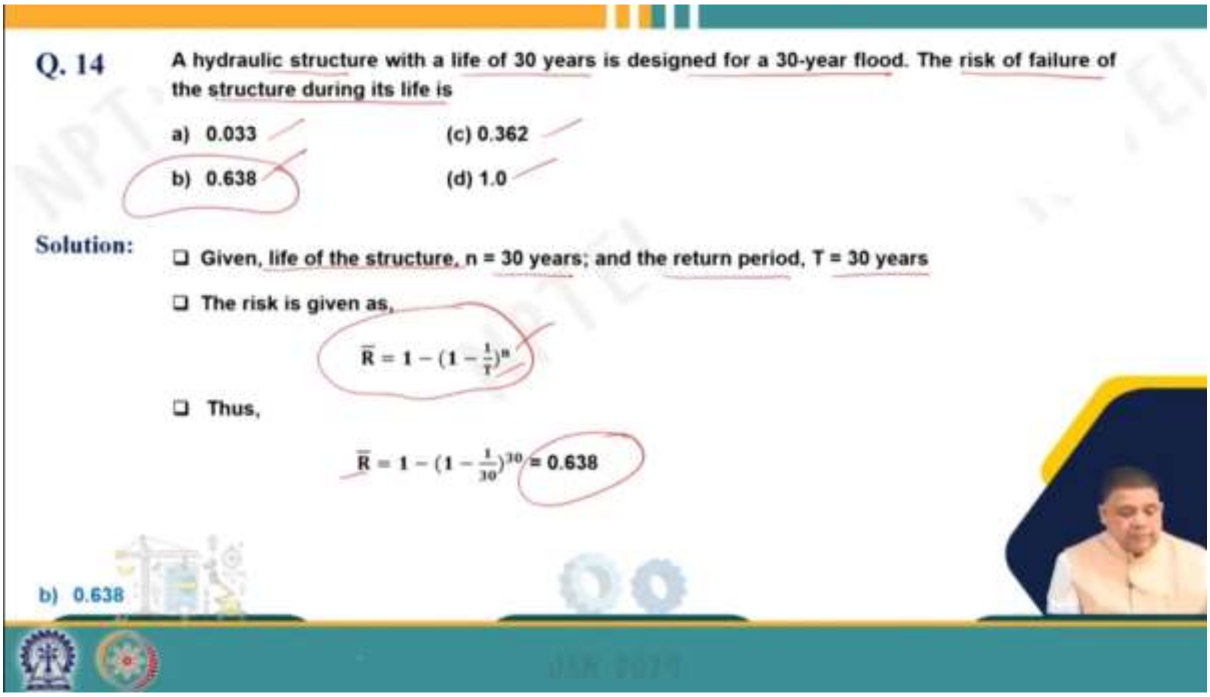
Moving on to question number 11: The time of concentration of a catchment area is 26 hours, and the time to peak of a 4-hour triangular shaped unit hydrograph is to be determined. Using the SCS triangular unit hydrograph formula $t_p = D/2 + 0.6t_c$, where D is the duration of the rainfall event and t_c is the time of concentration, we can calculate the time to peak. Thus, substituting the given values, we find $t_p = 17.6$ hours, making option B the correct answer.



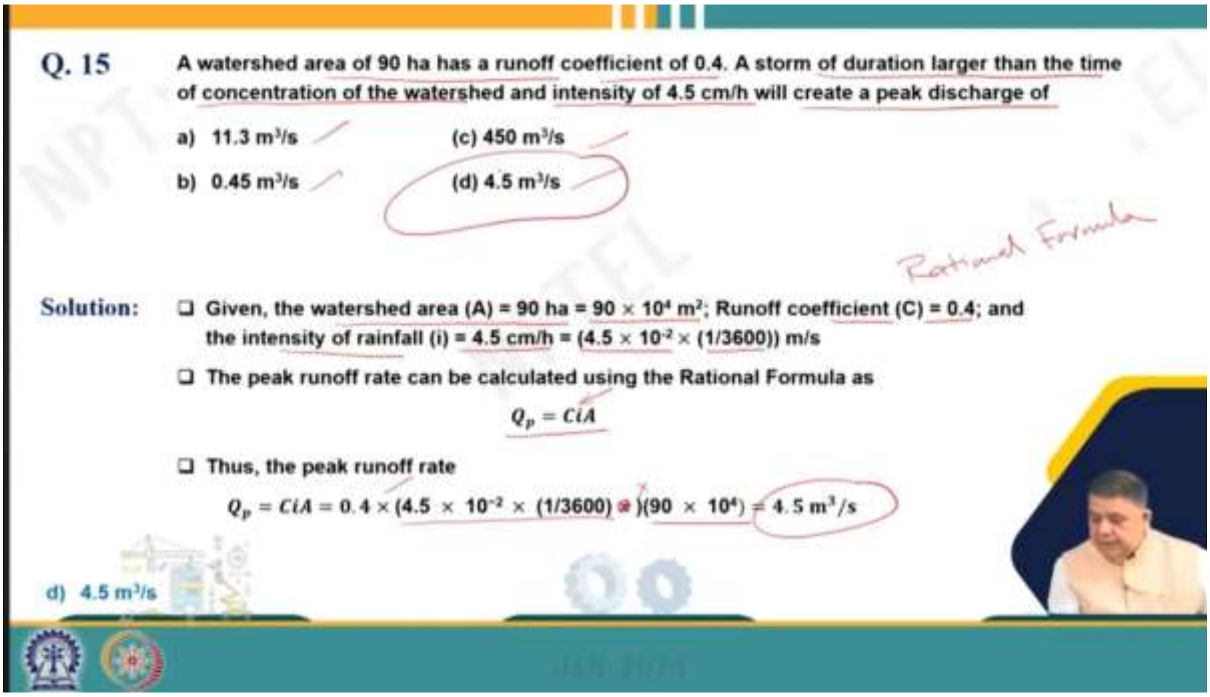
For question number 12, if the duration of a rainfall event is 2 hours, according to the SCS triangular unit hydrograph, the time of concentration of the basin can be calculated using the formula $t_c = D/0.133$, where D is the duration of the rainfall event. Thus, by substituting the given duration, we find $t_c = 15.04$ hours, indicating that option D is the correct answer.



So, now we go to the next question, question 13. The area of a watershed is 60 square kilometers. If the length of the drainage basin is 70 kilometers, the safety factor is 1.22, 0.82, 1.02, or 0.72. Again, it is an application of a direct formula. Here, we have been given that the watershed area is 60 square kilometers and the length of the watershed, L, is 70 kilometers. We know that the safety factor is expressed as B divided by L squared by A, where L is 70. So, L squared is 49. Given that A is already given as 60, putting the values, B comes out to be 0.82. Therefore, the safety factor of the watershed for the given data is 0.82, meaning option B is the correct answer.



We move on to the next question, question 14. A hydraulic structure with a life of 30 years is designed for a 30-year flood. The risk of failure of the structure during its life is 0.033, 0.638, 0.362, or 1. We have been given that the life of the structure, N, is 30 years, and the return period, T, is also 30 years. So, both are 30 years. We know that the risk is given as R bar equals to $1-(1-1/T)^n$, and the values of n and T are both 30, as given. By putting these values, where 1 by T is 30 and n is 30, we get R bar value as 0.638. This means the risk of failure of the given hydraulic structure is 0.638, or 63 percent. Option B is the correct answer.

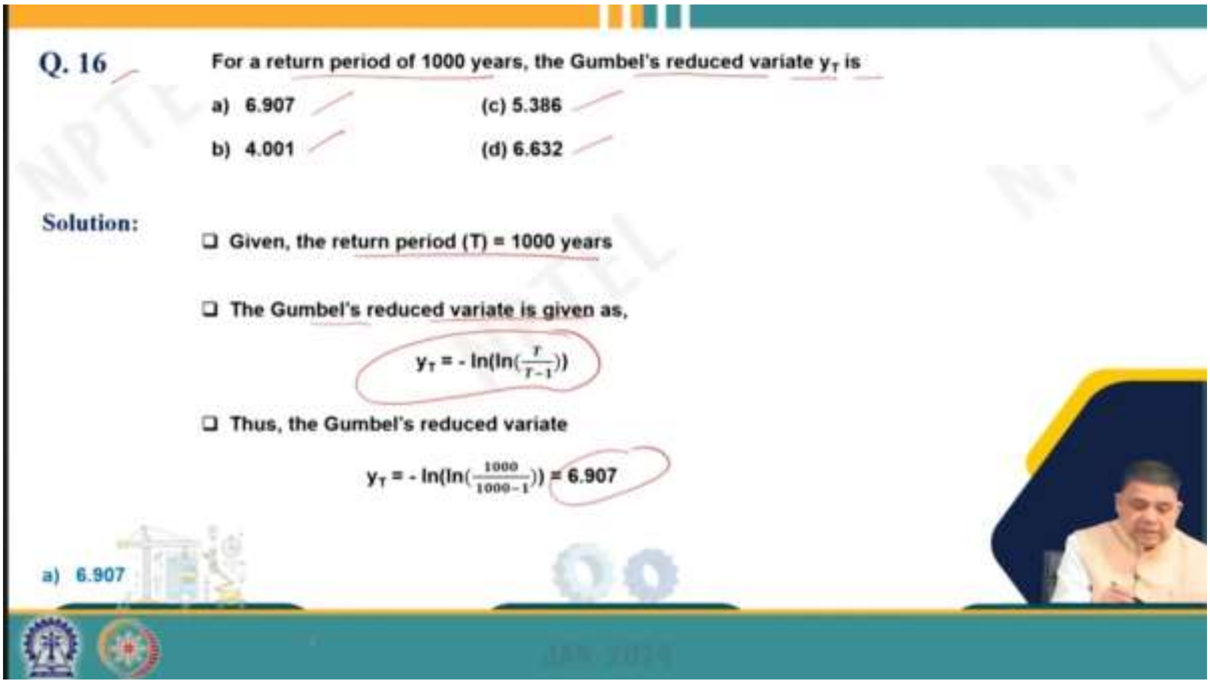


In question 15, we have a watershed area of 90 hectares with a runoff coefficient of 0.4. Given a storm of duration longer than the time of concentration of the watershed and an intensity of 4.5 centimeters per hour, we need to determine the peak discharge. This problem is directly related to the rational method or rational formula.

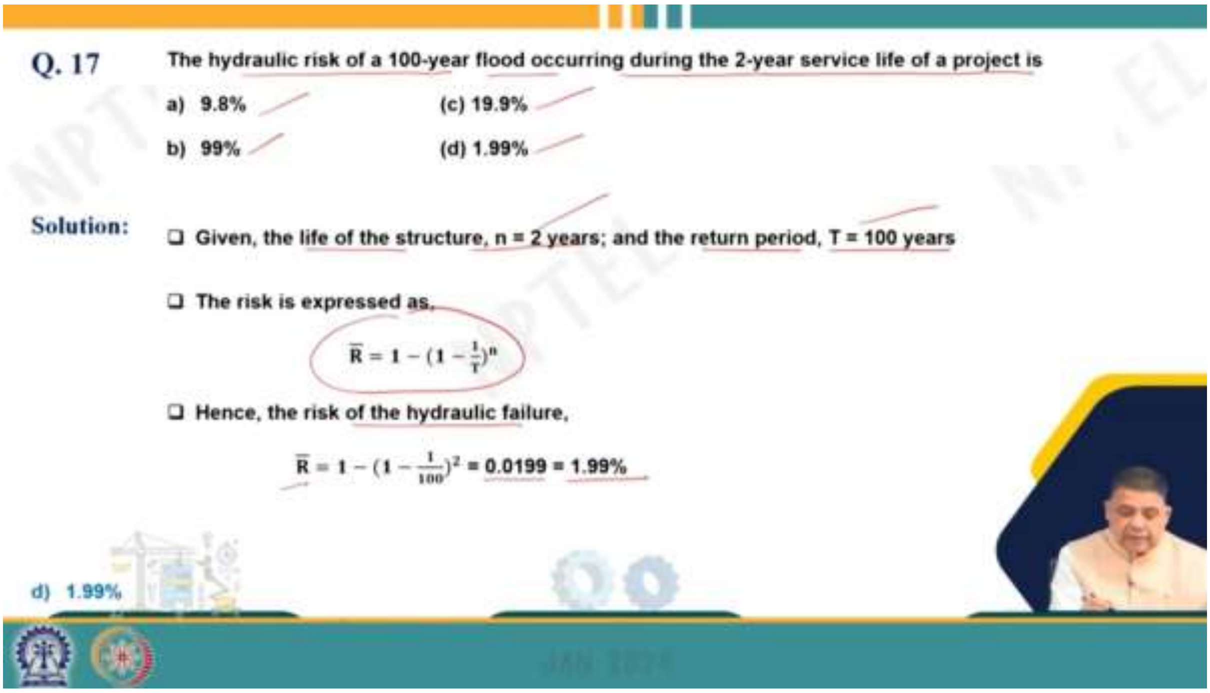
The provided data includes the watershed area A, which is 90 hectares or 90×10^4 square meters, the runoff coefficient C, which is 0.4, and the rainfall intensity i, given as 4.5 centimeters per hour. To use this intensity in meters per second, we convert it to 4.5×10^{-2} meters per hour, then further convert it to $(4.5\times10^{-2})\times(1/3600)$ meters per second.

Now, applying the rational formula $Qp=C\times i\times A$, where the rainfall duration must exceed the time of concentration, we substitute the known values. Thus, $Qp=0.4\times(1/3600)(4.5\times10^{-2})\times(90\times10^4)$, resulting in $Qp=4.5$ cubic meters per second.

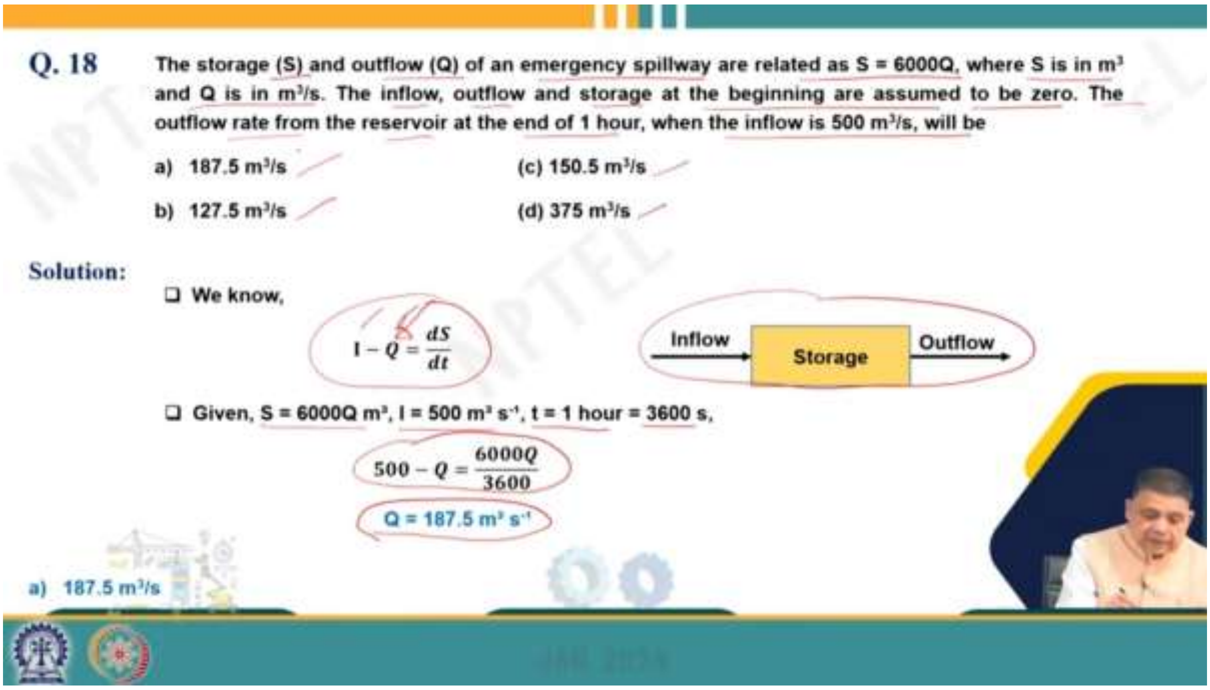
Therefore, the peak discharge for this scenario is 4.5 cubic meters per second.



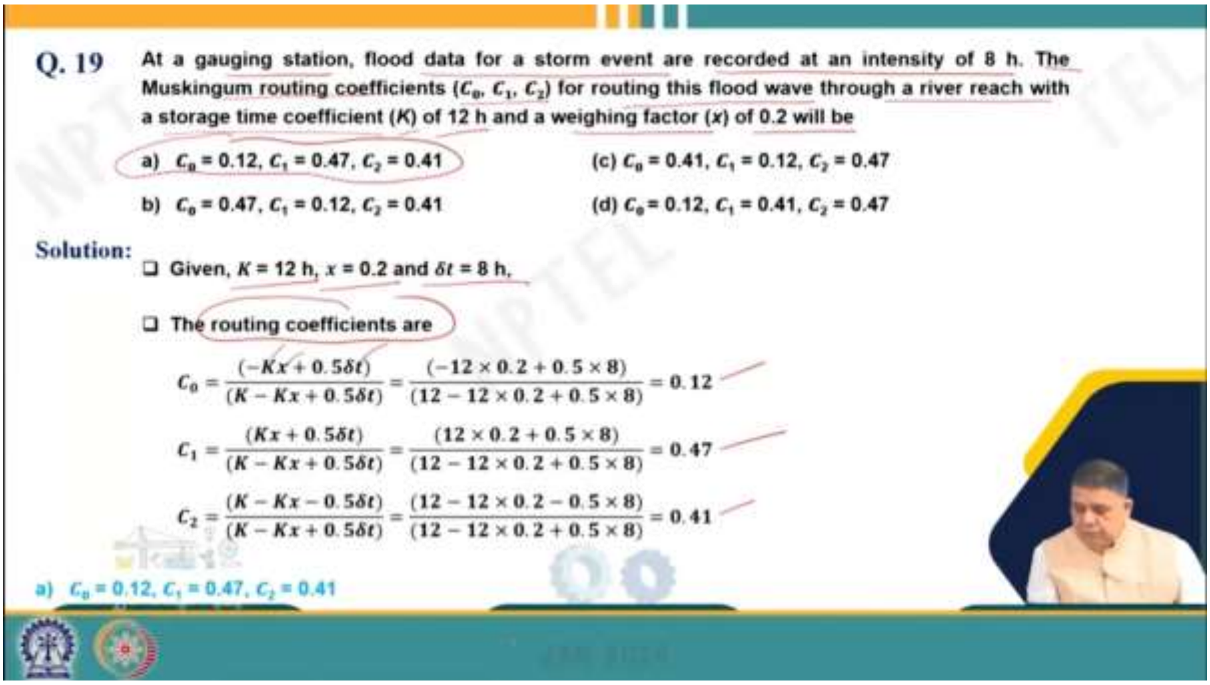
Now, we go to question number 16. For a return period of 1000 years, Gumbel's reduced variate y t is 6.907, 4.001, 5.386, or 6.632. The return period given is 1000 years, and we know that Gumbel's reduced variate can be calculated using this relationship: y_t=-ln (ln ($\frac{T}{T-1}$). Here, t is the only variable given as 1000 years. So, putting the value of t as 1000 years, we get = ln (ln ($\frac{1000}{1000-1}$), which results in 6.907. Therefore, the Gumbel's reduced variate for a return period of 1000 years is 6.907. Option A is the correct answer.



Moving on to question 17, the hydraulic risk of a 100-year flood occurring during a 2-year service life of the project is 9.8 percent, 99 percent, 19.9 percent, or 1.99 percent. Here, the life of the structure, n, is given as 2 years, and the return period given, t, is 100 years. We have already seen the formula for risk: $\bar{R}$= 1-(1-1/T)^n, where t is the return period and n is the life of the structure. We have both the unknown values given here. So, by putting the value of t as 100 and n as 12 in this formula, the risk of hydraulic failure, r bar, can be calculated, resulting in 0.0199 or 1.99 percent. Therefore, for the given data, the risk of hydraulic failure of the structure is 1.99 percent. Option B is the correct answer.



Next, we move to question number 18. The storage S and outflow Q of an emergency spillway are related as equal to 6000 Q, where S is in cubic meters and Q is in cubic meters per second. The inflow, outflow, and storage at the beginning are assumed to be 0. The outflow rate from the reservoir at the end of 1 hour when the inflow is 500 cubic meters per second will be 187.5 cubic meters per second, 127.5 cubic meters per second, 150.5 cubic meters per second, or 375 cubic meters per second. Obviously, we know that we have to simply use the standard mass balance equation because it is a simple case of hydrological routing. Here, we know that inflow minus outflow equals change in storage. So, that's how this relationship is expressed: $I-Q = dS/dt$. In this problem, S is given as 6000Q, I is given as 500 cubic meters per second, and t is given as 1 hour or 3600 seconds. The only unknown is Q. So, by putting the values here, where I equal 500, S equals 6000Q, and time is 3600 seconds (1 hour), the value of Q comes out to be 187.5 cubic meters per second. Therefore, the outflow for the given data is 187.5 cubic meters per second. Option A is the correct answer.



In question 19, we are provided with flood data for a storm event recorded over an intensity of 8 hours. We need to determine the Muskingum routing coefficients C_0, C_1, and C_2 for routing this flood wave to a river, each with a storage time coefficient k of 12 hours and a weighing factor x of 0.2. We are given four combinations of C_0, C_1, and C_2, and we need to find the correct values.

The Muskingum routing method is based on a set of coefficients used to route flood waves through a river reach. These coefficients can be calculated using various methods, including trial and error or optimization techniques. Here, we are provided with the values of k and x, which are essential for the calculation.

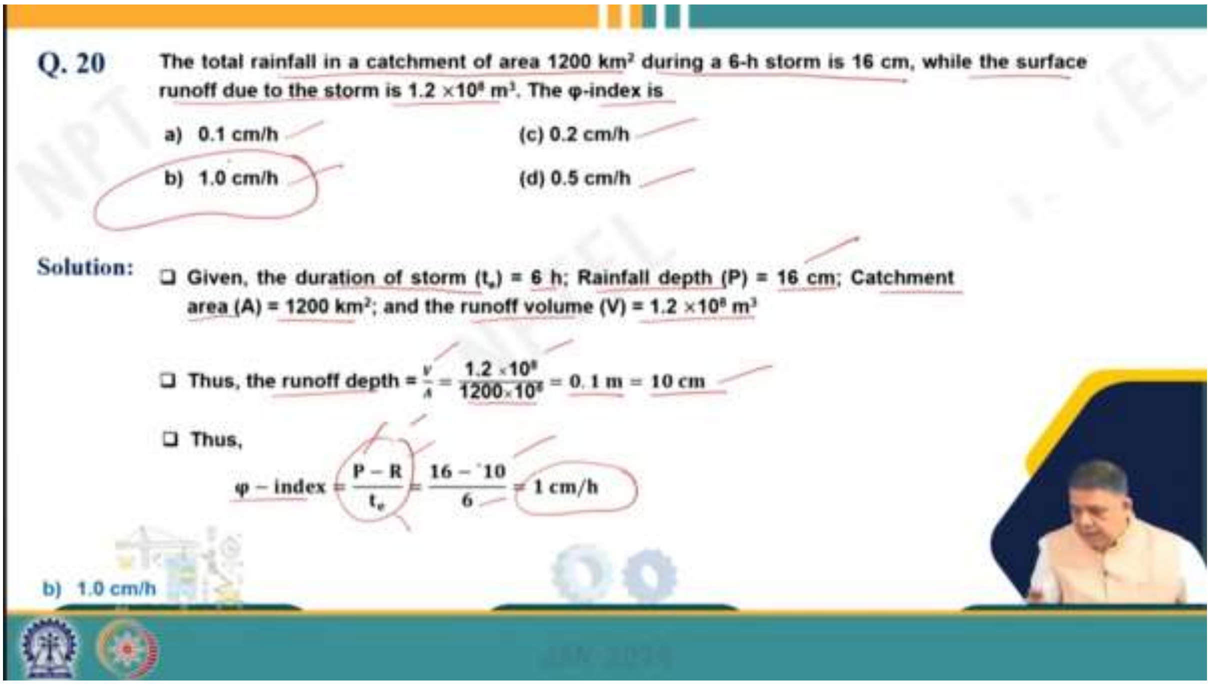
We need to apply the Muskingum routing formula, which relates the outflow at a gaging station to the inflow and storage changes, incorporating the coefficients C_0, C_1, and C_2. The specific calculation method will depend on the context and data provided for the storm event.

Given the combinations of C_0, C_1, and C_2, we can evaluate each combination using the provided information and select the one that best fits the given conditions for the storm event. The correct combination will result in an appropriate routing of the flood wave to the river. Therefore, we need to assess each combination and choose the one that yields the most suitable results based on the provided parameters.

Once we identify the combination that satisfies the conditions of the storm event and routing requirements, we can determine the corresponding Muskingum routing coefficients. The correct coefficients will ensure an accurate representation of the flood wave propagation through the river reach, considering the specified storage time coefficient and weighing factor.

So, obviously here, **k** is given as 12 hours, **x** is given as 0.2, and **delta t** is 8 hours. We know that the routing coefficients follow standard equations where **C_0**, **C_1**, and **C_2** all share a common denominator: **k - kx + 0.5 * delta t**. The numerators vary for each coefficient: for **C_0**, it's **-kx + 0.5 * delta t**; for **C_1**, it's **kx + 0.5 * delta t**; and for **C_2**, it's **k - kx - 0.5 * delta t**. The known values of **k**, **x**, and **delta t** provide three unknowns.

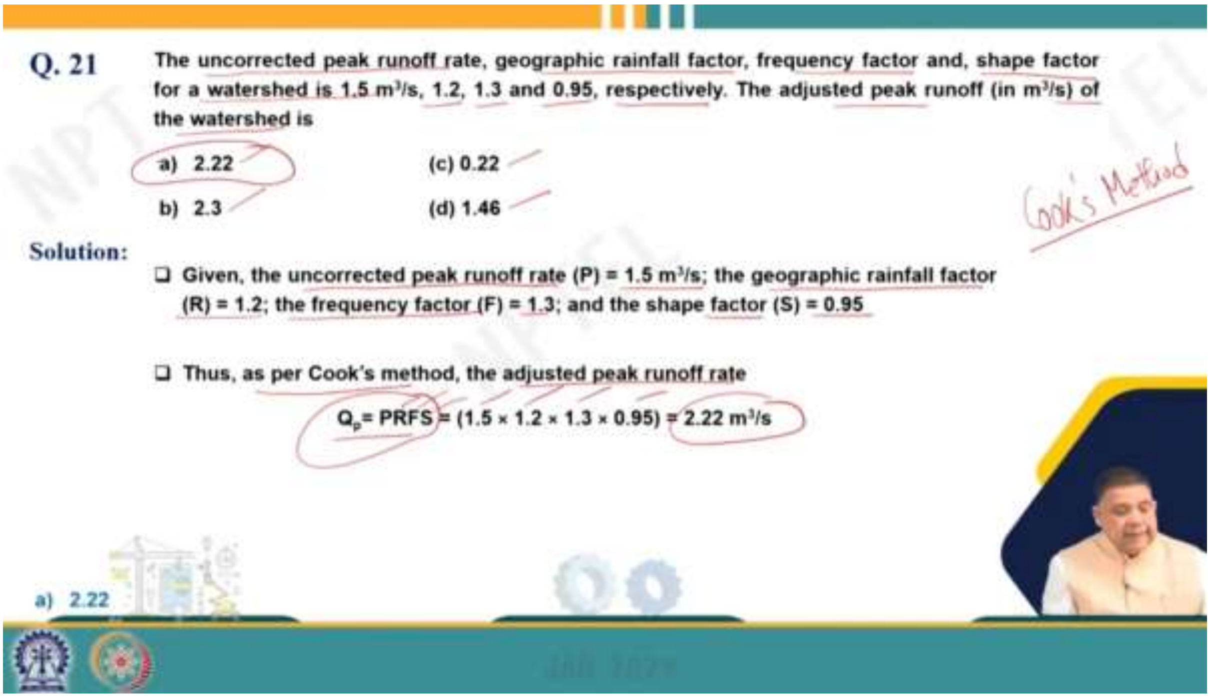
After inputting these values into the equations, we obtain **C_0** as 0.12, **C_1** as 0.47, and **C_2** as 0.41. Note that the sum of these coefficients should be 1, which is confirmed in this case. The correct answer, based on these calculations, is option **A**: **C_0 = 0.12**, **C_1 = 0.47**, and **C_2 = 0.41**.



The next question, question 20, involves a catchment area of 1200 square kilometers. During a 6-hour storm, a total of 16 centimeters of rainfall was measured, while the surface runoff volume was recorded at 1.2 * 10^8 cubic meters. We are tasked with determining the infiltration rate for the area, with options of 0.1, 1, 0.2, and 0.5 centimeters per hour.

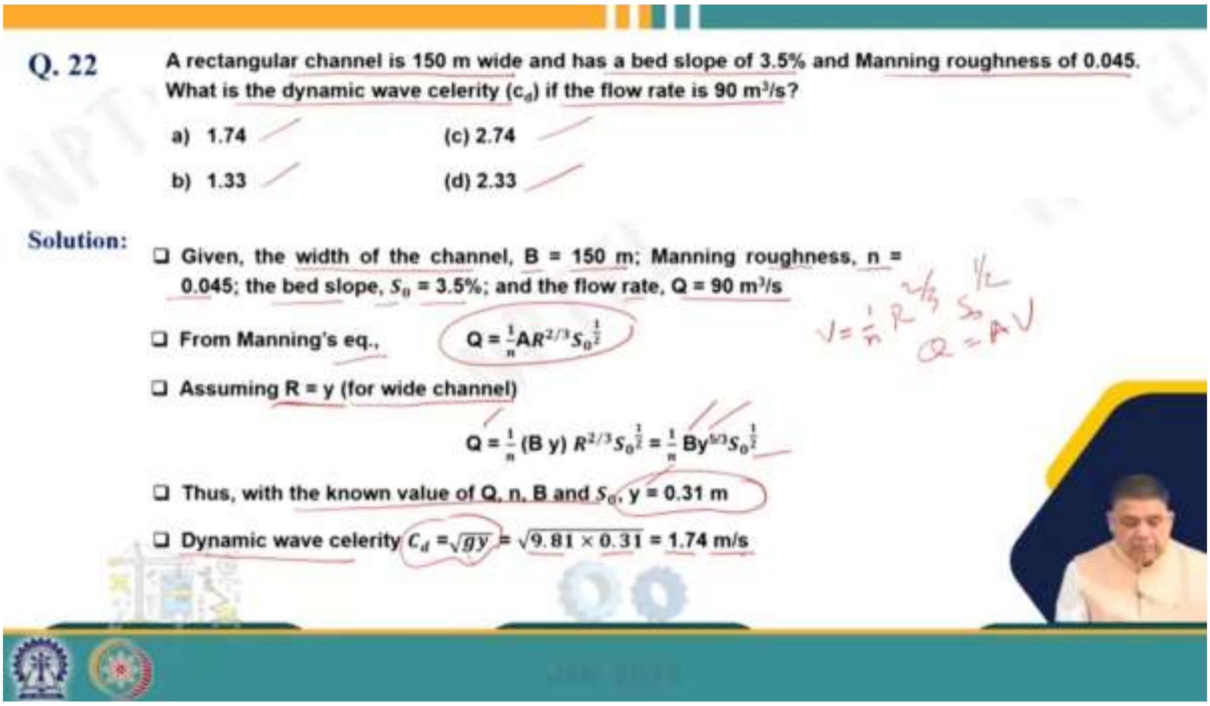
Given that the storm lasted for **t** = 6 hours and the rainfall depth **P** was 16 centimeters, the runoff volume is **V** = 1.2 * 10^8 cubic meters. The catchment area is **A** = 1200 square kilometers, which we convert to square meters. Therefore, the runoff depth **R** is **V/A** = 1.2 * 10^8 m^3 / (1200 * 10^6 m^2) = 0.1 meters or 10 centimeters.

Using the equation **Phi = (P - R) / T**, where **P** = 16 centimeters, **R** = 10 centimeters, and **T** = 6 hours, we calculate **Phi** = (16 - 10) / 6 = 1 centimetre per hour. Thus, the infiltration rate for the catchment area is 1 centimetre per hour, meaning option **B** is the correct answer.



In question 21, the uncorrected peak runoff rate, geographic runoff factor, frequency factor, and shape factor for a watershed are 1.5 cubic meters per second, 1.2, 1.3, and 0.95 respectively. The options provided are 2.22, 2.3, 0.22, and 1.46. This problem is solved using Cook's method of estimating runoff. According to Cook's method, the adjusted peak runoff rate $\mathbf{Q_p}$ is given by **PRFS**, where **P** is the uncorrected peak runoff rate, **R** is the geographic rainfall factor, **F** is the frequency factor, and **S** is the shape factor.

Given the values **P** = 1.5, **R** = 1.2, **F** = 1.3, and **S** = 0.95, substituting these values into the formula yields $\mathbf{Q_p}$ = 1.5 * 1.2 * 1.3 * 0.95 = 2.22 cubic meters per second. Thus, the adjusted peak runoff, according to Cook's method, is 2.22 cubic meters per second, making option **A** the correct answer.



In the next question, question 22, a rectangular channel is 150 meters wide and has a bed slope of 3%

The bed slope is 3.5 percent, and Manning's roughness coefficient is 0.045. What is the dynamic wave celerity, **C^d**, if the flow rate is 90 cubic meters per second? The options given are 1.74, 1.33, 2.74, and 2.33.

The information provided includes the channel width, **b**, which is 150 meters, Manning's roughness coefficient, **n**, is 0.045, and the bed slope, **S_0**, is 3.5 percent. The flow rate, **Q**, is 90 cubic meters per second.

According to Manning's equation, **Q** = $\frac{1}{n} \times R^{2/3} \times S^{1/2}$. The velocity equation is **V** =$\frac{1}{n} \times R^{2/3} \times S^{1/2} \times A$. Thus, **Q = A * V**.

For wide channels, the hydraulic radius **R** approximates to the depth of water, **y**. The equation becomes $Q = (1/n) \times B \times y^{(5/3)} \times S_0^{(1/2)}$. Here, the width, **b**, **n**, and slope, **S_0**, are known, while y is the unknown variable. Plugging in the known values, we find **y** equals 0.31 meters.

To find the dynamic wave celerity, we use **$C^d = \sqrt{(g * y)}$**, where **g** is the acceleration due to gravity. With **g** = 9.81 m/s² and **y** = 0.31 m, the dynamic wave celerity is 1.74 m/s. Therefore, for the given data, the dynamic wave celerity is 1.74 m/s, making option **A** the correct answer.

With this, we come to the end of the lecture and the course. Thank you for being part of this wonderful journey, and I hope you enjoyed the course. Please feel free to share your feedback on the forum, even after the course is over, as we'd like to improve the content and material. Wishing you all the best in your final exams and your future endeavours. Goodbye, and thank you very much.