Storm Water Drainage Design

Environmental Engineer Skills

Innovative Collaboration, Information Analysis & Organization

In this activity, you will finalize designs for an open channel and assess its effectiveness, ensuring the mock Waikele campus is better protected during stormy weather!

Standard Specifications of an Open Drainage Channel		
To prevent overflow, use a 10% freeboard (vertical distance from the design water surface elevation to top of channel)	Min. slope: 0.5%	Max. velocity: $18\frac{ft}{s}$
DIMENSIONS OF THE MOCK CHANNEL DESIGN	Width (b) = 3.0 ft	Height (y) = 1.5 ft

Manning's equation is used to calculate the flow rate of water in open channels.

$$Q = VA = \frac{1.49}{n} \cdot A \cdot R^{2/3} \cdot S^{1/2} = \frac{ft^3}{s}$$

V: Velocity of flow
n: Roughness Coefficient (e.g., smooth concrete vs. grass)
A: Cross-sectional area of flow
R: Hydraulic radius
S: Slope of the channel

PART I: Let's determine the flow rate when the channel is built with the minimum slope. **Fill in this table:**

Formula	$\frac{1.49}{0.015}$ *n=coefficient for smoothed concrete	$A = b \cdot (y \cdot 0.9)$ *0.9 is to account for a 10% freeboard	$R = \frac{b \cdot (y \cdot 0.9)}{b + 2(y \cdot 0.9)}$ ft Now calculate $R^{\frac{2}{3}}$	$S = 0.005^{\frac{1}{2}}$ *0.5% is the standard minimum	Solve for Q *multiply answers 1-4
Answer	1 $\frac{1}{s}$	2 ft^2	3 ft	4 $\frac{ft}{ft}$	$\frac{ft^3}{s}$
Think About It	Would the rough concrete coefficient be higher or lower than smoothed concrete?	If want to keep the same area but widen the channel what must happen to the height?	Does decreasing height (y) affect the wetted perimeter in the same ratio as decreasing width (b)?	Since S is square rooted, will making the slope 1% make the flow twice as fast?	Is this rate very fast?

Bonus: Determine the maximum slope to stay under the maximum velocity.

Solve for S (slope) when V = $18\frac{ft}{s}$ the maximum standard for velocity	$S = \left(18 \cdot \frac{0.015}{1.49} \cdot 0.71\frac{2}{3}\right)^2$	**Answer:**
Given the answer, would you recommend a slope greater than the minimum?		

Estimate Storm Water Runoff

Now that you've designed your channel, let's see if it can survive a '100-Year Storm' - the kind of rain that only happens once in a century!

Use the Rational Method to calculate runoff from the parking area of the mock "Campus" site:

Rational Method: $Q = C \cdot A \cdot I$

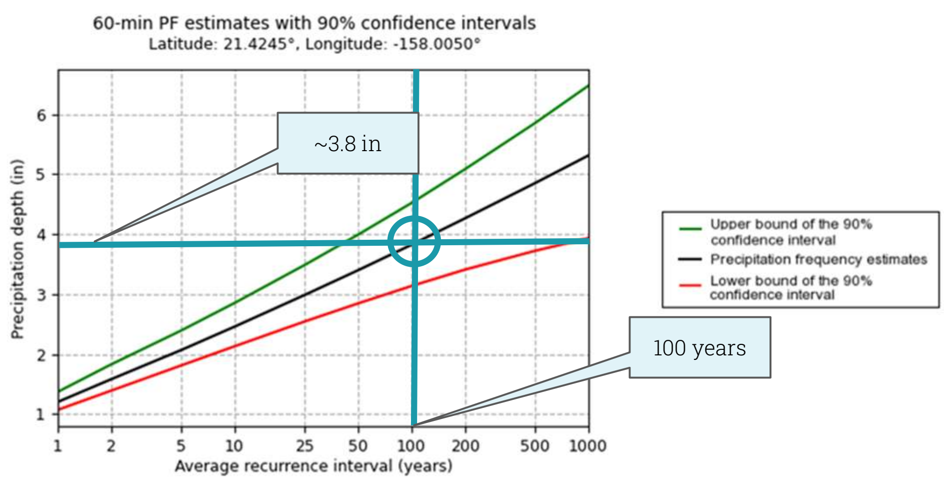
Q (Peak Runoff): The volume and speed of water flow (cfs)
C (Runoff Coefficient): How much water runs off vs. soaks in
A (Area): How big of a space is capturing the rain
I (Intensity): How hard is it raining

PART II: Determine peak runoff during a typical storm. Fill in this table to calculate *Q*.

Land Type & Runoff Coefficient	Mock site runoff is ⅛ of the 25 acre campus with a 15% portion of parking lot	Typical Storm is 0.04 in/hr	Peak Mock Site Runoff into Proposed Channel Design
Urban, Parking Lot; C = 0.9	$A = \frac{25\, acres \cdot 0.15}{8} \cdot 43560\, ft^2$	$I = 0.04 \frac{in}{hr} \cdot \frac{1\, ft}{1\, in} \cdot \frac{1\, hr}{3600\, s}$	Multiply together each answer to the left.
	A =	*I* =	*Q* = cfs

NOTE: *0.04 inches per hour is a typical storm with one inch in 24 hours*

The National Oceanic and Atmospheric Administration (NOAA) keeps historical data of rain events and shares charts like this one where engineers can estimate the precipitation depth (in) per hour in storms that typically occurs or repeats every 50 or 100 years.



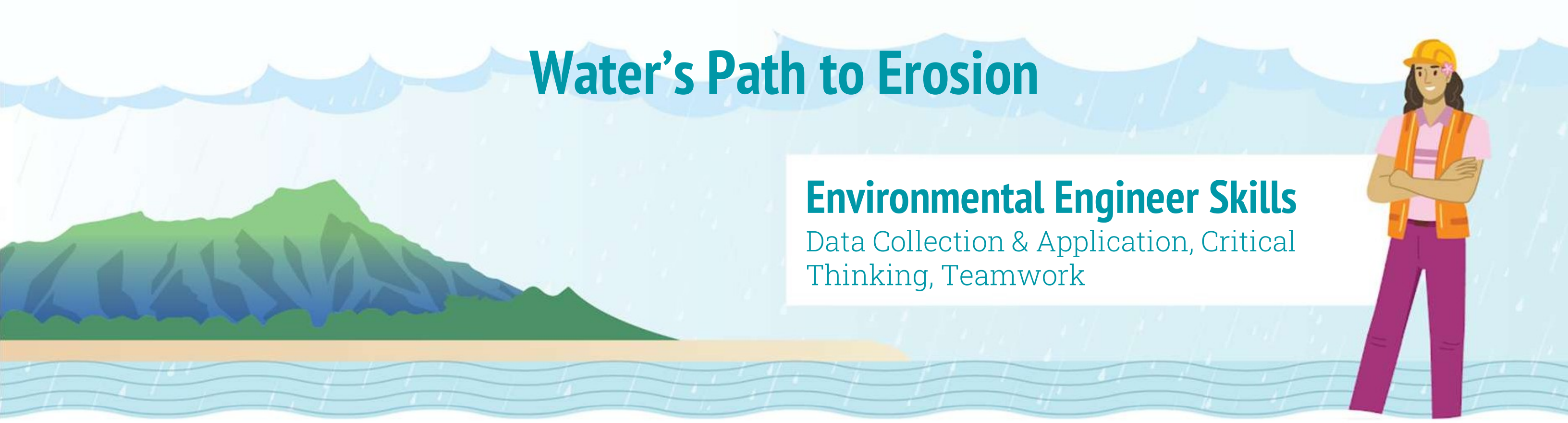
PART III: Determine if the channel design can handle a 50 year & 100 year storm. Fill in this table:

50 year storm of 3.4 inch/hour *Use same calculation above to solve for Q but switch **0.04 in/hr** above with **3.4 in/hr** to solve for **I***	100 year storm of 3.8 inch/hour *Use same calculation switching **3.4 in/hr** with **3.8 in/hr** to solve for **I***

The Verdict: My flow rate from **PART I** __________ cfs is (check one):

- ❑ Safe (capacity > runoff)
- ❑ A Flood Hazard! (runoff > capacity)

Water's Path to Erosion



Environmental Engineer Skills

Data Collection & Application, Critical Thinking, Teamwork

> *"Erosion is a process of detachment and transport of soil particles by erosive agents."*
>
> *Ellison, 1944*

Rip Rap and Outfall Design

Substrate	Time Waited	Observation
Original Sand		
Coarse Gravel		
Other Gravel		
Stratified Gravel		

1. As directed, pour the cup of water into the "channel" and observe the water flow through the sand and the resulting liquid collected in the tray.
    a. What path does the water take? Straight, meandering, pooling, or splitting.
    b. What seems to influence the water's path and speed?
2. Place a collection cup under the hole, tilt the tray, and unplug to drain out the water.
3. As directed, add the course gravel provided on top of the hill of sand at the "channel" outlet and repeat steps 1 and 2.
4. Repeat step 3 using the other gravel (optional).
5. Finally, repeat step 4 but trial using a stratified configuration, where a section of other gravel and a section of course gravel are used (optional).

Given the outcomes from your trials, consider the outfall of the Mock Site Drainage Design. What, where, and how much of these gravels would you recommend being added to the area around the outfall to reduce erosion?

Rate of Soil Erosion at Drainage Outfall

Another important design consideration when designing storm water drainage is to assess the impact of flow rates on the existing soils at the outfall or exit.

> The Revised Universal Soil Loss Equation (RUSLE) is a model that estimates the average annual rate of soil erosion due to water and considers six main factors that control soil erosion:
>
> Rainfall erosivity (R); Soil erodibility (K); Slope length (L); Slope (S); Cropping (C) ; Conservation practice (P)

In calculating the sediment loading from urban lands in the PLET model from Lesson 4, the following RUSLE coefficients were assigned:

User Defined				
R	K	LS	C	P
239	0.180	0.458	0.215	1.00

The LS in this equation is a factor of the predominant topography of the area, using the length (L) and slope (S).

Let's explore how the length and slope of the outfall area can influence the rate of erosion when the outfall area of the Mock Site Channel Design is 20 ft x 3 ft

Parameter	User Defined LS (0.458)	0.5% slope with 20 ft length	5.1% slope with 20 ft length
Formula	239(0.180)(**0.458**)(0.215)(1)	239(0.180)(20)(**0.005**)(0.215)(1)	239)(0.180)(20)(**0.051**)(0.215)(1)
Answer (tons/acre/year)			

The Cropping or 'C' coefficient is influenced by changes to the surface of the soils.
Estimate the tons of sediment eroding from the outfall area in a year if treated with rip rap that results in a C coefficient of 0.2:

R	**K**	**LS**	**C**	**P**	**ANSWER 1** **(tons/acre/year)**	Outfall area in acres is (20)(3)(0.000023) =	(ANSWER 1) (Outfall area in acres) = tons/year
239	0.180	(20)(0.005) = 0.1	0.200	1.00		0.00138	