Connecting Industry to Mathematics Instruction
NSF ATE Award # 1954291

Stormwater Management

A (Solidify) Understanding Task

Purpose: *To determine if an area needs a stormwater management system after it has been developed into a new use.*

Career Field: Civil Engineers

Company: CLH Design, PA

In partnership with

WTCC Associate Program of Study and Contact Person:
Civil Engineering Technology
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NC Math 4 Standards:
AF.1 ***Apply properties of function composition to build new functions from existing functions.***
AF.1.1 Execute algebraic procedures to compose two functions.
AF.1.2 Execute a procedure to determine the value of a composite function at a given value when the functions are in algebraic, graphical, or tabular representations.

Unit Alignment:
NC Math 4 - Unit 2: Functions

Common Core State Standards for Mathematical Practice

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
7. Look for and make use of structure.

Prerequisite Skills

- Sum notation ($\sum$)
- Unit conversions
- Compare and analyze mathematical findings

Time Required
The time required to complete **Activity 1 (90 minutes)**, **Activity 2 (45 minutes)**.

Materials Needed
- Calculator

The Teaching Cycle:

Launch: (35 minutes)

Suggested Warm Up
1. Tatyana is 14 years old, Mary is 26 years old, Mohammed is 18 years old, and Julio is 10 years old. Calculate $\sum \quad ages$.

2. Using a 10 ft by 12 ft rectangle and a square with side length of 8 ft, calculate $\sum \quad area$.

3. Convert 30 yards into inches.

4. Convert 54,000 seconds into hours.

5. Convert 4.2 acre-inch into ft^3 (1 acre = 43560 ft^2)

Begin the activity by showing the video to introduce CLH Design, a Civil Engineering firm, that specializes in stormwater management. Stop video at time
Video Link

Stormwater management systems must be designed so that post-development water management is equal to or better than pre-development water management to prevent adverse effects on the environment. This lesson will specifically investigate how a Civil Engineer plans for stormwater management through the construction process.

In the video, the engineer explained what runoff is, ask if there are any questions about this terminology before students begin the task. Brief discussion on impervious and pervious surfaces. Present students with the 4 images provided and ask students to order the images from least runoff to greatest runoff. After students have had a chance to order the images, show the slide with the correct order, description of surface, and coefficient of runoff.

Show students the paired images of sample pre-development and post-development sites. Discuss if students think a stormwater management system is needed for the post-development site based on the picture.

Distribute student activity sheet and have the students read the given task. Give students time to digest the reading and have a brief discussion in pairs to allow students to confirm they understand what the task is

expecting them to do. If warm-up was not used, be prepared to answer questions regarding sigma notation and unit conversion.

Activity 1 – Water Quantity (55 minutes)

Explore (35 minutes): Depending on the number of students in your class, have your students work in groups of 2-3 students.

Questions 1 and 2, students may need a reminder of the application of independent and dependent variables. The last part of question 1 is meant to guide students in making the connection to composing functions. Question 2 is designed to be more of a rhetorical question to start student thinking for question 7.

Students will need to apply the correct function for questions 3 - 6. Questions 3 and 5 will use the runoff coefficient function, and questions 4 and 6 will use the peak runoff function. Circulate and monitor groups to ensure students are on the right track. Students may need guidance in understanding the concept of sigma notation. ***Cfs*** (**c**ubic feet per **s**econd) is an alternate expression for $\frac{ft^3}{s}$. If students are struggling and the warm-ups were used, remind the students of the warm-up problems for sigma notation.

Questions 3 and 5, look for students who add the area values and the coefficient values and then find the product of those sums. You will need to remind students of PEMDAS if this error occurs. As you are walking around, note groups who may be struggling with later questions but solved earlier questions correctly. Ask these students to share solutions with the class for problems 3 - 6. Let these students know they will be presenting, so they can clearly outline their work and be prepared to present.

To prepare for discussing question 7 and 8, look for groups with a variety of explanation, correct or incorrect. Be mindful of how students may react when their work is proven incorrect in front of the class. Possibly have a discussion with the student or group before asking them to present.

Regarding question 8, if students are struggling to connect the task with a class topic, have students reference question 1. If students continue to have questions, remind students that the idea of a composition of functions is the solution of one function used as the input for another function.

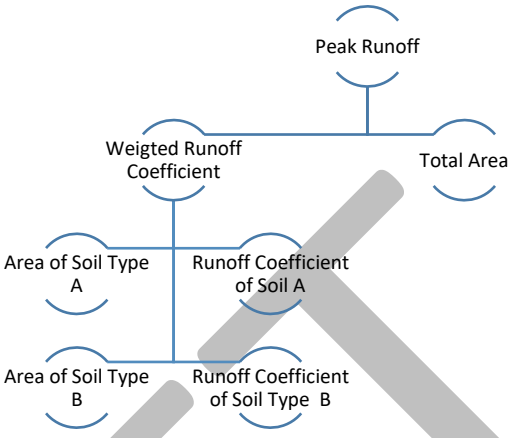
Discuss (20 minutes): Allow students to share solutions to questions 3 – 6 but focus discussion on questions 7 and 8. Encourage the importance of a conversation between students, not just hearing a statement from individual groups. Bring in a discussion on soft skills that CLH and other companies seek from potential employees.

Potential follow-up question (can reference question 2):
Why is the post-development runoff greater than the pre-development runoff?

For question 8, select a group that has made the connection to composition of functions. If students established other connections, ask those groups to share. Below is a possible representation of the connection students may make.

Runoff coefficient and area of soil type builds the weighted runoff coefficient.

The weighted runoff coefficient and the total area build the peak runoff.



If only doing activity 1, all groups should have an opportunity to share. If completing both activities, it is not necessary that all groups present during activity 1, they will have the chance to share during activity 2.

If only doing activity 1, show the video with the interview of landscape design architect and WTCC degree options. Begin video at time

Activity 2 – Water Quality (45 minutes)

Explore (20 minutes):
Circulate and monitor groups to ensure students are on the right track. Students should be solving for the runoff value, to then compute the volume and area of the wetland.

Watch for students who may use the decimal equivalence instead of the actual percentage when solving for the runoff value. For students who ask why, respond with "that is the industry standard for computing the runoff value function."

If students are struggling with unit conversions and the warm-ups were used, remind the students to reference the warm-up problems for unit conversions.

If a group used the decimal value when solving for runoff and then correctly used the percentage, ask this group to share during the discussion to highlight the difference in the two values they found.

If a group is having a discussion on connecting the second activity to the composition of functions, ask this group to share during the discussion. If not, select a group and guide them through the discussion so they can then share out with the class.

As students are starting to wrap-up their work, look for groups who are discussing the difference/importance of volume and surface area.

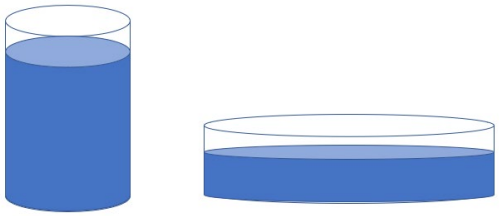
Discuss (25 minutes):
During the discussion, have one group explain how they solved for the runoff value (preferably a group that used the decimal equivalence for the percentage). Students should highlight the value they used for the % impervious in the discussion. Encourage students to share how they found the % impervious value and then substituted that value into the equation to solve for the runoff value. This is another connection to composition of functions.

You can then have a group explain their thought process for solving for volume and a different group explain solving for area. Ask students why we might need to know both the volume and the surface area for the wetland. Try to encourage students to continue making the connection to composition of functions.

Possible student responses:

- Expected (desired) response – "The same volume can fit in different dimensions."
- "I didn't realize we need to know both."
- "Volume measures how much can fit into something."
- "Surface area measures the total area covered by an object."
- "Volume tells you how much stormwater can be held within the wetland."
- "Allows the engineers to plan for overflow."

If students are struggling to make the connection, consider including the provided image comparing the same volume in objects with different surface areas. The focus is not on the exact volume and surface area measurements of the images. The images illustrate equivalent volume can fit in different surface area dimensions.



Connect the surface area back to the launch video where Steve discussed the different systems used to manage stormwater.

Make sure every group has a chance to share with the class at least once.

Exit Ticket/Homework: If time allows, ask the class to begin brainstorming why the design team's plan will or will not work if the design provides **18,000** ft^3 **of volume** (question 10 on activity sheet). This will allow students to start building ideas where they are asked to construct a proposal to the client. During the discussion, students are sharing general ideas as to why the design will or will not work. Their homework is to construct a detailed proposal to the client. Students can upload their written proposal for teacher to review.

End class by showing interview of landscape design architect and WTCC degree options. Begin video at time

Link to Student Activity Sheet (download to word doc for proper formatting) OR see below.

Connecting Industry to Mathematics Instruction
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Stormwater Management - Student Activity Sheet

In partnership with

WAKE TECH

WAKE COUNTY PUBLIC SCHOOL SYSTEM

WakeEd PARTNERSHIP

Quantity: Is a stormwater management system needed?

CLH Design specializes in school site development and is contracted to develop stormwater management plans for the construction of South Lakes Elementary School. They have hired you to run the analysis for the pre- and post-development peak run-off of stormwater.

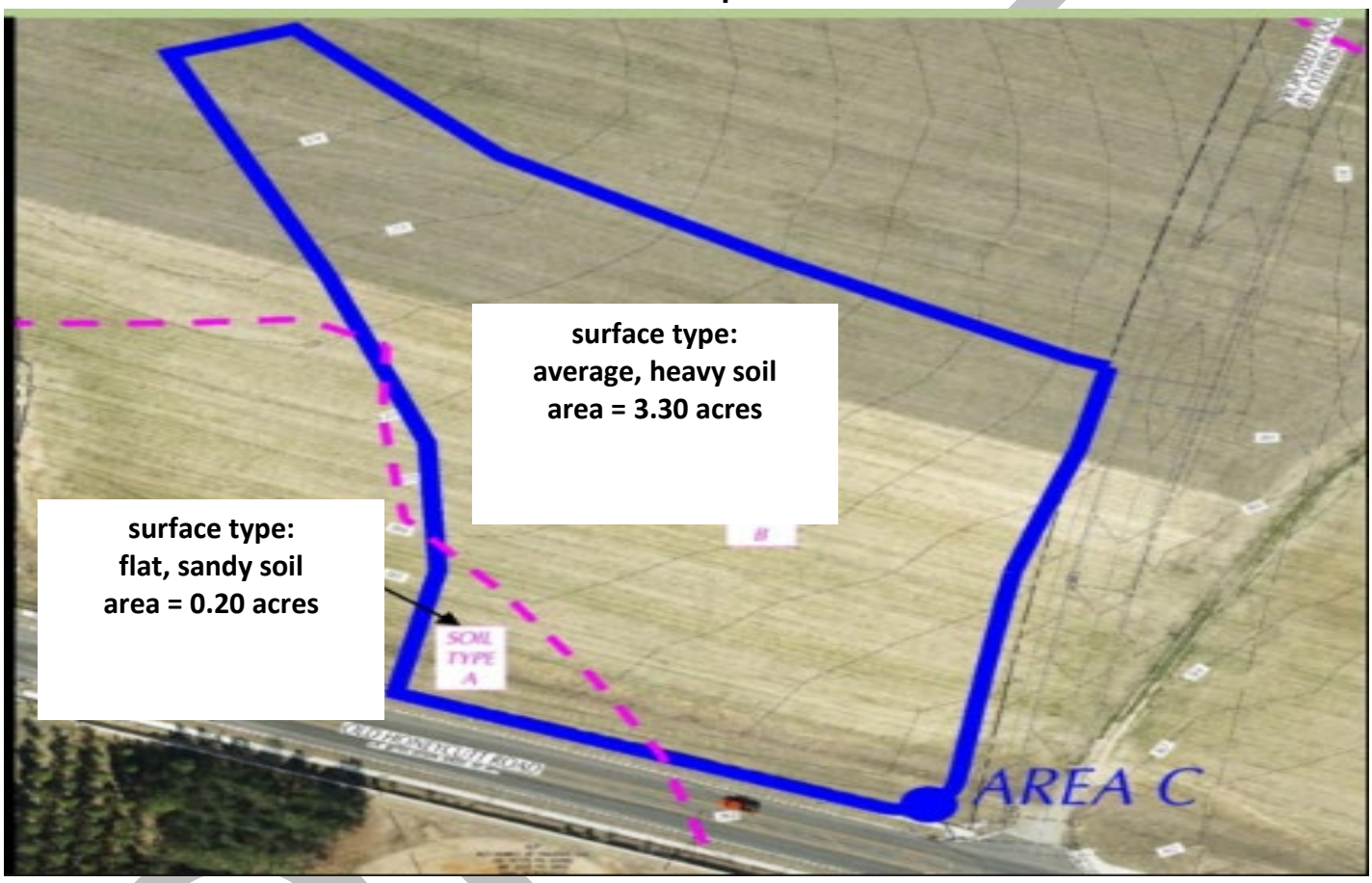
You need to analyze the pre-development peak run-off versus the post-development peak runoff at South Lakes Elementary School. This will allow you to determine if strategies need to be put in place for holding water back and releasing water at a slower, pre-development rate. Strategies for doing this include stormwater detention ponds (wetland), above-ground cisterns to capture roof runoff, and below ground cisterns to capture parking lot runoff.

$C = \frac{\sum (A_i C_i)}{\sum (A_i)}$ C: Weighted Average of **Runoff Coefficient** A_i: $Area\ of\ Soil\ Type\ [acre]$ C_i: Runoff Coefficient of Soil Type	$Q = C \times i \times A$ Q: Peak Runoff [cfs] i: Rainfall Intensity of Design Storm [in/hr] (7.08-in/hr. for Wake County) A: Total Area

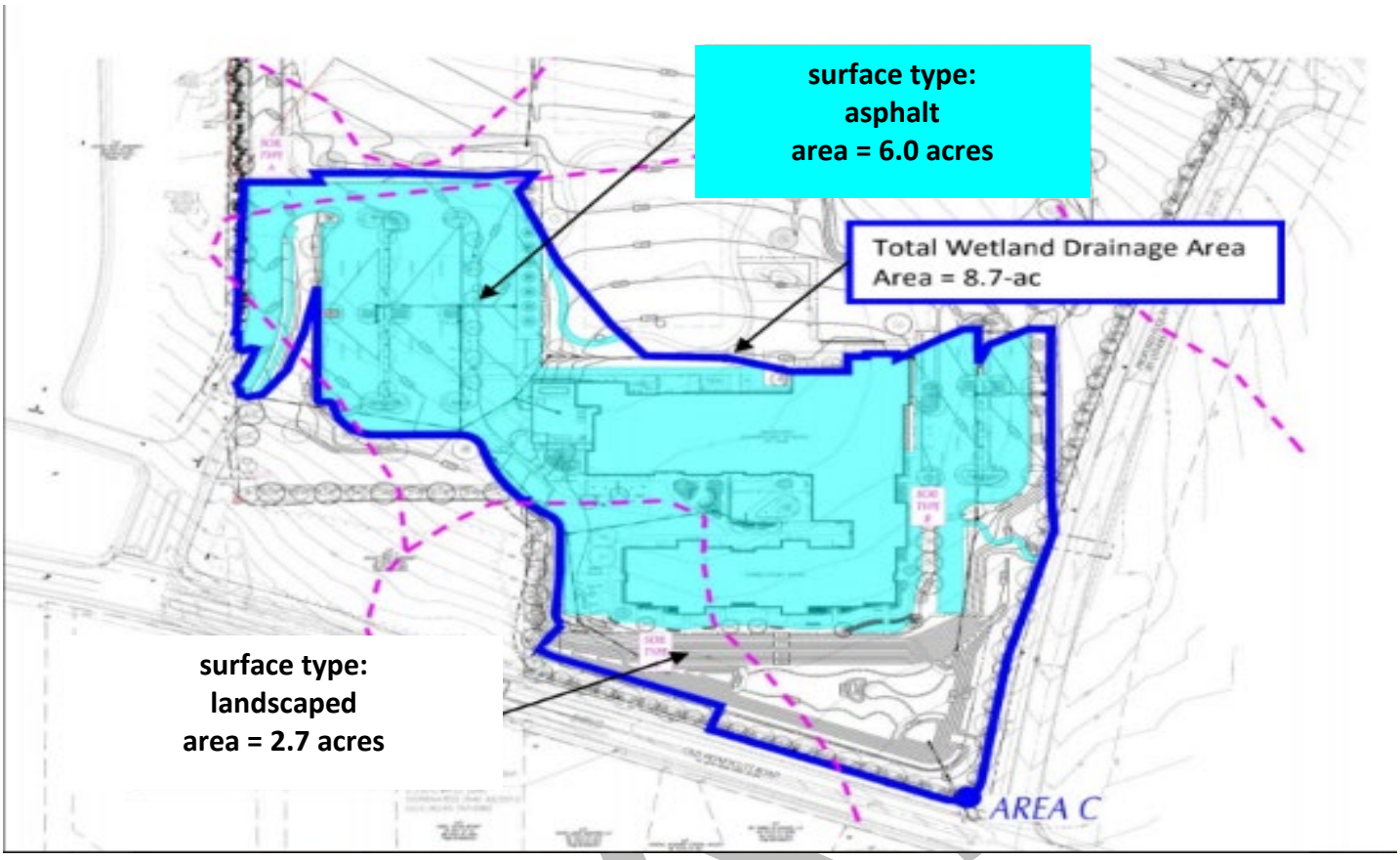
Description of Surface	Rational Runoff Coefficient, C	Water Penetration
Lawns, sandy soil, flat (<2%)	0.1	Pervious
Lawns, sandy soil, average (2-7%)	0.15	Pervious
Lawns, heavy soil, flat (<2%)	0.15	Pervious
Wooded areas	0.15	Pervious
Lawns, sandy soil, steep (>7%)	0.2	Pervious
Lawns, heavy soil, average (2-7%)	0.2	Pervious

Lawns, heavy soil, steep (>7%)	0.3	Pervious
Unimproved Areas	0.35	Pervious
Landscaped Areas	0.35	Pervious
Brick	0.85	Impervious
Roofs, flat	0.9	Impervious
Asphalt	0.95	Impervious
Concrete	0.95	Impervious
Roofs, inclined	1	Impervious

Pre-Development



Post-Development



Activity 1: Use the given pictures, reference charts, and functions to solve the following problems.

1. Identify the variables in the C function as dependent or independent. Identify the variables in the Q function as dependent or independent. How does the role of the C variable change from the first function to the second function?

2. Based on the images of the pre-development and post-development of South Lakes Elementary School, do you anticipate a stormwater management system being needed? Explain why or why not.

3. Determine the pre-development run-off coefficient for the marked area.

4. Determine the pre-development peak run-off for the marked area.

5. Determine the post-development run-off coefficient for the marked area.

6. Determine the post-development peak run-off for the marked area.

7. Analyze your results to determine if a stormwater management system is needed and explain why or why not.

8. Explain how this task relates to recent topics in class.

Activity 2: Now that you have determined a stormwater management system is needed, calculate the required wetland surface area and volume before you hand the project off to the landscape design architect team.

$$R = 0.05 + 0.009 \times \%\ Impervious$$

$$\%\ Impervious = \frac{Impervious\ Area\ within\ Wetland\ Drainage\ Area}{Total\ Area\ of\ Wetland\ Drainage\ Area}$$

R: Runoff Value [in/in]

*% Impervious: use actual percentage, not decimal equivalence, i.e. 4.25%, use 4.25 not 0.0425
**0.05 and 0.009 are industry given standard values

$$V = Design\ Storm\ \times R \times Drainage\ Area$$

V: Volume Required [make sure result is measured in ft^3]
Design Storm: 1-in for Raleigh
Drainage Area: Total Wetland Drainage Area [acre]

*Note: Unit conversions are required (1-ac = 43,560 ft^2)

$$SA = \frac{V}{d}$$

SA: Surface Area of Wetland [ft^2]
d: Depth = 15-inches maximum (industry standard)

*Note: Unit conversions are required

9. Calculate the volume and surface area of the wetland.

10. The landscape architect team has a design that provides **18,000** ft^3 of volume for the wetland. Construct a proposal to the client justifying why the team's plan will or will not work.

Answer Key

Stormwater Quantity Part 1

1. C Function Independent: A_i (area of soil type) and C_i (runoff coefficient of soil type)
   Dependent: C (weighted runoff coefficient)
   Q Function Independent: C (weighted runoff coefficient) and A (total area)
   Dependent: Q (peak runoff)
   The C value changes from the dependent (output) variable to the independent (input) variable.

2. A stormwater management system is needed because the total area has increased, and the paved area has increased.

3. $C = \frac{(0.20 \times 0.10) + (3.30 \times 0.20)}{0.20 + 3.30} = \frac{0.68}{3.5} = 0.19$

4. $Q = 0.19 \times 7.08 \times 3.5 = 4.708$ ≈ 4.7 cfs

5. $C = \frac{(6.0 \times 0.95) + (2.7 \times 0.35)}{6.0 + 2.7} = \frac{6.645}{8.7} = 0.76$

6. $Q = 0.76 \times 7.08 \times 8.7 = 46.818$ ≈ 46.8 cfs

7. A stormwater management system is needed. The post-development peak storm runoff is greater than the pre-development peak storm runoff.

8. Composition of functions is applied when the output values from question 3 and 5 are used as the inputs to solve questions 4 and 6, respectively.

Stormwater Quality Part 2

9. $\%\ Impervious = \frac{6.0}{8.7} = 0.6897 \times 100 = 68.97\% = 69\%$ used as 69 in the next function

   $$R = 0.05 + 0.009 \times 69 = 0.67\ in/in$$

   $V = 1\ in \times 0.67 \frac{in}{in} \times 8.7\ acres = 5.83$ acre-inch *Conversion to ft^3 is now required.

   $V = 5.83$ acre-inch $\times\ 43{,}560 \frac{ft^2}{acre} \times \frac{1\ ft}{12\ in} = 21{,}159\ ft^3$

   $SA = \frac{21{,}159\ ft^3}{1.25\ ft} = 16{,}927\ ft^2 = 17{,}00\ ft^2$ $d = 15\ inches\ \times \frac{1ft}{12\ inches} = 1.25\ ft$

   *Round solution to 17,000 ft^2 to accommodate for a margin of error buffer.

10. The landscape architect team's plan will not work, but student justification may vary.

Assessment Items

1. Using the formulas below for runoff value, volume, and surface area, explain in detail how you would use the formulas to calculate the final surface area for a given project.

$$R = 0.05 + 0.009 \times \%\ Impervious$$

$$\%\ Impervious = \frac{Impervious\ Area\ within\ Wetland\ Drainage\ Area}{Total\ Area\ of\ Wetland\ Drainage\ Area}$$

R: Runoff Value [in/in]

*% Impervious: use actual percentage, not decimal equivalence, i.e. 4.25%, use 4.25 not 0.0425
**0.05 and 0.009 are industry given standard values

$$V = Design\ Storm\ \times R \times Drainage\ Area$$

V: Volume Required [ft^3]
Design Storm: 1-in for Raleigh
Drainage Area: Total Wetland Drainage Area [acre]

*Note: Unit conversions are required (1-ac = 43,560 ft^2)

$$SA = \frac{V}{d}$$

SA: Surface Area of Wetland [ft^2]
d: Depth = 15-inches maximum (industry standard)

*Note: Unit conversions are required

2. You have been hired to analyze the pre-development stormwater runoff and post-development stormwater runoff at a construction site and have determined the following information:

Pre-Development

soil type A: C_i = 0.3
A_i = 1.6 acres
soil type B: C_i = 0.1
A_i = 2.2 acres

Post-Development

soil type C: C_i = 0.8
A_i = 2.4 acres
soil type B: C_i = 0.1
A_i = 4.4 acres

$$C = \frac{\sum (A_i C_i)}{\sum (A_i)}$$

C: Weighted Average of **Runoff Coefficient**
A_i: $Area\ of\ Soil\ Type\ [acre]$
C_i: Runoff Coefficient of Soil Type

$$Q = C \times i \times A$$

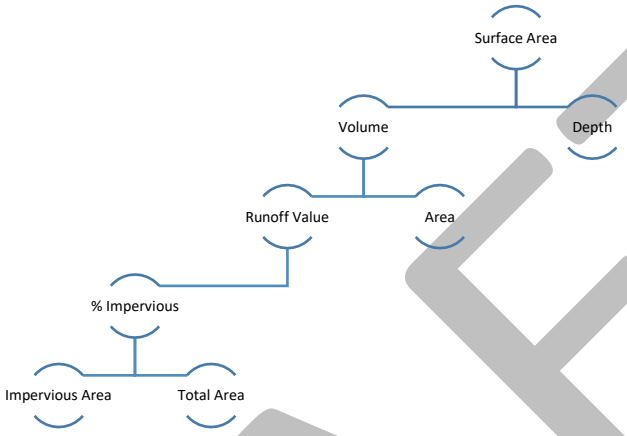
Q: Peak Runoff [cfs]
i: Rainfall Intensity of Design Storm [in/hr] (7.08-in/hr. for Wake County)
A: Total Area

Calculate the peak stormwater runoff for pre-development and post-development to determine if a stormwater management system is needed (i.e. post-development > pre-development).

Assessment Answer Key

1. Below is a visual representation of the solution. Student descriptions will vary but should reflect the diagram.

   Impervious area and total area build % impervious.
   % impervious builds runoff value.
   Runoff value and drainage area build volume.
   Volume and depth build surface area.



2. Pre-development peak runoff 4.84 cfs
   Post-development peak runoff 16.85 cfs

   Yes, a stormwater management system is needed.