Water: Flow & Quality

Storm Water Career: Scientist

All Careers Full- Course Lesson Plan #:
8 of 15

Next Lesson Plan Title (Full-Course):
Designing for Storm Water

Select Career Short-Course Lesson Plan #:
4 of 6

Next Lesson Plan Title (Short-Course):
Scope Quest: Unraveling Project Possibilities

SUMMARY

In this lesson, students will explore how to calculate flow, test or simulate water quality parameters, and integrate their new knowledge into improved monitoring designs.

FOCUS & GOALS

By investigating storm water quantity and quality, students will:

- Understand how flow rate and rainfall influence storm water management
- Evaluate water quality using key biological, chemical, and physical parameters
- Improve storm water sampling designs using quantity and quality metrics

MATERIALS NEEDED

- Water Quality Testing kits, such as the Earth Force® Low-Cost Water Monitoring Kit (or Mock Data Cards)
- Mock samples (using kits): containers, vinegar, dirt, & heat source
- Disposable gloves (using kits)
- Mock Site Sampling Location Map (Lesson 7)
- Activity Worksheets
- Project Based Learning: may need bucket & rope to enable site sampling, other protective gear as needed, see hazards analysis table for details

LEARNING OBJECTIVES

- Calculate storm water flow rates using velocity and channel dimensions
- Evaluate whether a channel performs as designed based on flow estimates
- Analyze and interpret test results for common water quality parameters
- Design sampling plans by applying principles of water quantity and quality metrics

VOCABULARY

Eutrophication - Excessive richness of nutrients in a body of water, frequently due to runoff from the land, which causes a dense growth of plant life and death of animal life due to a lack of oxygen.

Hypoxic - The condition of hypoxia, which refers to low or depleted oxygen in a water body. Hypoxia is often associated with the overgrowth of certain species of algae.

Background

In the previous lesson, students learned the principles of storm water monitoring design and explored why monitoring is important for watershed health. They examined how runoff can transport pollutants to receiving waters, identified key components of a sampling study, and evaluated the accuracy and precision of sampling methods and results. In this lesson, students will expand on that knowledge by exploring how to assess the quantity of storm water moving through a site, as well as the quality of that water. Together, these two elements, flow and quality, provide a more complete picture of how storm water can impact local waterways and overall watershed conditions.

As a reminder, flow rate describes the volume of water that moves past a given point over a period of time. When designing storm water infrastructure, engineers must estimate flow rates based on expected rainfall events to ensure the system can properly manage runoff without flooding or failure. Engineers will then verify that a storm water system performs as intended by conducting on-site rainfall measurements and calculations.

Environmental scientists also play a critical role in assessing flow and water quality. While engineers focus on design, environmental scientists often use tools such as flow meters to measure flow rates within catch basins, channels, and other sampling sites. These measurements help them understand how storm water moves through a system and provides data that can be used to model runoff behavior across larger drainage networks and watersheds. By combining flow data with water quality sampling, environmental scientists can evaluate how pollutants may be transported during storm events and assess the overall health of a watershed.

During this lesson, students will return to their channel designs from Lesson 5 and use mock data to calculate flow rates using velocity and cross-sectional area. This activity helps students evaluate whether their designs could successfully manage a storm event.

In addition to understanding how much water is moving through a system, it is also critical to evaluate what is in the water, that is, its quality. Water quality parameters provide important information about the environmental condition of a water body and can help identify pollutant sources, assess ecosystem health, and guide treatment strategies. As introduced in the previous lesson, water quality parameters can be grouped into three main categories: biological, chemical, and physical. Students also learned about key test parameters within these categories such as Total Nitrogen (TN) and Total Suspended Solids (TSS). In this lesson, they will build on that foundation by exploring additional water quality parameters and parameters.

Chemical parameters provide information about the chemical makeup of storm water. One common parameter is pH, which measures how acidic or basic the water is. Most aquatic species thrive within a relatively narrow pH range, typically between 6.5 and 9. Storm water with pH levels outside of this range can stress or kill aquatic organisms, and can also affect the solubility and toxicity of other pollutants. Other important chemical parameters include nutrients (such as nitrogen and phosphorus), which may enter water bodies from fertilizers and contribute to eutrophication and hypoxic conditions where dissolved oxygen is depleted following decomposition of excessive aquatic plant growth. Others are heavy metals, which can originate from urban runoff, landfills, or industrial discharges and are toxic to aquatic life. As students explore chemical parameters they will test the pH of sample solutions using colorimetric reagents, additives that will change colors based on specific parameters, and relate the results to the potential impacts on water quality.

Physical parameters describe observable characteristics of water, such as turbidity, temperature, and oil and grease presence. Turbidity measures the clarity of water and is affected by suspended solids such as sediment, algae, or organic debris. High turbidity can block sunlight, increase water temperatures, and damage aquatic habitats. Elevated water temperatures can reduce dissolved oxygen levels, which further stresses aquatic life. The presence of oil and grease—common in urban storm water due to vehicle leaks and improper disposal of grease from restaurants—can form surface films that are toxic to aquatic plants and animals and limit oxygen exchange.

To learn more about these physical parameters, students will assess turbidity using visual tests and discuss the consequences of poor water clarity on stream health and aquatic organisms.

Biological parameters, such as aquatic macroinvertebrates, are used in bioassessments to determine the health of aquatic ecosystems. These organisms, animals without backbones that are large enough to be seen without magnification, are sensitive to environmental conditions and respond differently to various pollutants. Because they are benthic, meaning that they live at the bottom of a waterbody, and relatively immobile, their presence or absence can provide insight into long-term water quality trends.

After exploring additional water quality parameters, students will apply their new understanding of flow and water quality to revise the sampling designs they created in Lesson 7. Using their data from the flow rate calculations and water quality sampling, students will consider whether their current monitoring locations are sufficient or whether additional parameters or sites should be included.

I. Catch the Current: Flow Rate Fundamentals Activity

1. Discuss flow rate and why it's critical to storm water management. Share with students that Lesson 5 used formulas to design a storm water channel. Explain that in this activity, they will use mock storm data to determine whether that design still performs as intended under real conditions.
2. Distribute the Flow Rate Fundamentals worksheet.
3. Share that a water flow meter is a device used to measure the velocity or depth of water in open channels or streams. It typically consists of sensors or floats that record how fast water is moving and how deep it is at a specific location. These tools are readily available for storm water professionals and can range from simple mechanical devices to more advanced electronic sensors. They are often used in storm water systems, rivers, and other water bodies to help monitor flow conditions accurately.
4. A less accurate but easily performed method to measure velocity is to place a floating object within the flow stream and time how long it takes to go a given distance. Depth can also be measured using a weighted rope or measuring stick.
5. Explain that Manning's Equation is used by engineers to estimate velocity in open channel designs. Share with students the importance of verifying design assumptions in the field. Explain that during a mock storm event, the depth of the water flow was measured at 1.1 ft. Using Manning's Equation and the channel's design parameters from Lesson 5, students will calculate the expected time for an object to float 10 feet downstream given a flow rate of Q = 17.5 cfs.
6. Given their results, have them consider:
   - What would it mean if the object took twice as long to flow the ten feet downstream?
   - What factors relating to the channel design and maintenance could explain the slower rate (e.g., sediment buildup, debris, inflow from other areas)?
   - Is their original design still effective?
7. Introduce the concept of using on-site rain gauges to verify rainfall intensity. Provide a theoretical example: 1 inch of rainfall over 20 minutes. Lead students through converting this data to inches/hour and then to ft/sec. Then, using the Rational Method, they will calculate the runoff flow rate during that storm.
8. Have students classify the storm as low, moderate, or high intensity for their site and discuss what this means for channel design and storm water planning.
9. Wrap up with a class-wide discussion:
   - What happens when real world conditions don't align with the design assumptions?
   - How can engineers design infrastructure to ensure it functions properly in real world conditions?
   - What adjustments would students make to their method of measuring flow to allow for greater accuracy in predicting real-world performance of the channel?

Example water flow meter and its use in the field. (Photos courtesy of Hydrometag)

II. Dive into Water Quality Analysis! Activity

1. Begin by explaining the importance of water quality monitoring in storm water management. Introduce the three main types of water quality parameters, physical, chemical, and biological,and explain that students will focus on the physical and chemical categories in this lab.
2. Distribute the Water Quality Lab worksheet, along with either commercial test kits or mock water quality data cards. If they are available and you are able to order them, the commercial test kits are a great way for students to test for various chemical and physical water quality parameters, including pH, dissolved oxygen, temperature, and turbidity. These test kits typically include:
   - 1 Instruction booklet

II. Dive into Water Quality Analysis! Activity Continued

- Sample collection jar
- pH test tubes
- Dissolved oxygen vials
- Secchi disk decals
- Temperature strips (5 14-40°C and 5 0-12°C)
- pH reagent tablets
- Dissolved oxygen reagent tablets
- Color charts for determining dissolved oxygen, pH, and turbidity test results

If you are unable to obtain commercial test kits use the mock data cards included with the Water Quality Lab worksheet.

3. If using the test kits, prepare mock samples as indicated in the table provided, divide students into small groups. Have students follow the instructions within the kit using the mock sample buckets as sampling sites. Here is a brief overview of how each test is typically conducted:
   - Samples are collected by dipping the jar into the water at the sampling "location" (aka bucket) and water level adjusted to be at the marked line. **NOTE:** Students should wear disposable gloves to simulate real world sampling safety practices.
   - Turbidity: Use the collection jar with a Secchi disk decal at the bottom. Visually compare clarity of the disk to the chart..
   - pH: Use a pH test strip or reagent tablet. Compare the sample color to the provided pH chart.
   - Temperature: Use a temperature strip to check the water's Celsius reading.
   - Dissolved Oxygen: Add a test tablet to a water sample and compare it to the oxygen level chart. Note, oxygen saturation is dependent on temperature and it is more meaningful to use parts per million (ppm) and temperature readings to determine percent saturation using the chart provided in the kit.

Mock Sample Prep

One gallon of tap water*	Sample 1	Sample 2	Sample 3
Add	1 - 2 Tablespoon vinegar	½ C sieved soil	Heat: set in sun or briefly microwave
Adjusted Parameter	pH	Turbidity	DO + temperature
Runoff type	Chemicals	Erosion	Pavement

* Scale as needed

4. If using mock data, assign each group a different set of sample cards and instruct them to record the values into the worksheet. Once all groups have completed their testing or mock data recording, have them fill out the table.
5. Have students interpret the results and discuss which parameters fall outside acceptable ranges and what could be the possible causes (e.g., fertilizer runoff, low oxygen from warm water, construction sediment).
6. As a class, discuss why we monitor these specific parameters, what pollutants or land uses might contribute to these results, and how the community can help reduce pollution and improve water quality?

III: Streamline Your Strategy Activity

1. Distribute the Building Your Water Monitoring Strategy worksheet and have students review their Mock Site Sampling Location Map (Lesson 7). Students will:
   - Identify the parameters they now wish to monitor at each site (physical, chemical, biological).
   - Determine parameters for deployment, when to sample (e.g. rainfall quantity and timeframe).
   - Identify the types of samples (grab or composite) and the materials needed to collect (e.g. poles, buckets, bottles) and measure samples (e.g. field probes, test kits).
   - Determine volume and quantity of samples to be collected.

III: Streamline Your Strategy Activity Continued

- ○ Develop sample logs and threshold levels for management protocols (i.e. investigate source if sediment levels are high).

2. Conclude the activity with a group or classroom discussion:
    - ○ How has their understanding of monitoring changed since Lesson 7?
    - ○ Do students feel like their monitoring plan is now more complete?
    - ○ How might these changes lead to better storm water management and watershed protection?

Adaptations and Resources

Storm Patrol Project Based Learning Track:

- ○ Students continue working on the Measure & Monitor Section 5 of their workbook. In Part 3, students develop a monitoring plan for their site. Using what they've learned about flow rates, water quality parameters, and site conditions to revise their storm water monitoring strategy.
- ○ If Test Kits are available, students can collect and test samples during rainfall events for their site. This activity relates to Part 4. Be sure to review sampling safety practices listed in the kit, as well as those provided in Water Quality Monitoring Sampling Hazard Analysis table.

Activity-Centric Learning Track:

Conduct Activities I , II, and III.

Tips to Truncate Lesson:

- Assign Activity 3 (Building Your water Monitoring Strategy) as homework.
- Simplify lab stations into a single demonstration-based activity.
- Use prepared example flow rate calculations for discussion in lieu of the first activity.

Tips to Extend Lesson:

- Include rainfall simulation data and ask students to model flow response.
- Have students research the current water quality issues in their local watershed in the news or using the Clean Water Branch's Water Quality Advisories website .
- Introduce a discussion about more advanced chemical parameters (e.g., dissolved oxygen, conductivity). Students may also research these additional chemical parameters as homework.
- Have students conduct the optional Biological Assessment as part of Water Quality Lab worksheet.

Resources:

- Project WET, *Water Quality Indicators Lab*, https://cdn.prod.website-files.com/576a95db81c75aa24d8e16f0/5fa1e8c2ce13fc2a5fe8cad2_Water%20Quality%20Indicators%20Lab.pdf
- Earth Force® Low-Cost Water Monitoring Kit, https://lamotte.com/product/earth-forcer-low-cost-water-monitoring-kit-3-5886/
- Current Water Quality Advisories, https://eha-cloud.doh.hawaii.gov/cwb/#!/event/list
- American Association of State Highway and Transportation Officials Resources, https://transportation.org/