Maya: Environmental Architect Career Pathway Lesson

Designing for Storm Water

Storm Water Career: Architect

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

Next Lesson Plan Title (Full-Course):
Backyard Investigation

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

Next Lesson Plan Title (Short-Course):
Backyard Investigation

SUMMARY

In this lesson, students will learn about designing storm water-friendly landscapes, which capture, filter, and infiltrate storm water using landscaping and engineering approaches. They will explore the different site-specific factors that influence landscape design plans and the role of landscape architects in creating functional outdoor spaces.

FOCUS & GOALS

In learning about landscape design, students will:

- Understand how landscaping design plans can create functional, storm water-friendly outdoor spaces
- Explore infiltration and how it is impacted by different media
- Evaluate a site, its issues, and its storm water needs to create landscaping solutions

MATERIALS NEEDED

- 9x13-inch aluminum tray
- 6 sponges, cut in half
- 2 quart-size plastic bags
- Plastic collection container
- Measuring cup or graduated cylinder
- Scissors
- 2 Dice
- 1 quart deli containers with small drainage holes
- Ruler
- Permanent marker
- Various media, such as sand, potting soil, school ground soil, compost, or gravel
- Stopwatch
- Calculator
- Activity Worksheets
- Mock Site GSI Map
- BMP Cards (from Lesson 4)

LEARNING OBJECTIVES

- Describe different types of best management practices and green storm water infrastructure
- Analyze how a site's characteristics, such as soil type and topography, impact landscape design
- Create landscaping design plans that support local water quality and reduce storm water runoff

VOCABULARY

Biofiltration - The process wherein living materials degrade or absorb pollutants.

Green Storm Water Infrastructure (GSI) - BMPs that capture, filter, and infiltrate storm water using or mimicking natural processes.

Infiltration - The process by which rainfall and storm water runoff is captured and absorbed into the ground and enters subsurface soil or rock.

Vocabulary Continued

Infiltration Rate - The speed at which water is absorbed into the ground.

Low Impact Design (LID) - a sustainable land planning and engineering design approach that manages storm water runoff at its source by preserving or mimicking a site's natural pre-development hydrology.

Media - The materials or substances used to enhance or increase the efficiency of storm water infiltration and filtration.

Retention and Detention - An approach that captures storm water runoff to let it infiltrate naturally or release it in smaller quantities.

Background

In the beginning of this curriculum, we discussed how best management practices (BMPs), green storm water infrastructure (GSI), and low-impact development (LID) can support storm water management efforts and reduce storm water runoff pollution. In this lesson, we will delve more deeply into the different types of BMPs, GSI, and LID that can be incorporated into a site's landscape to directly address a community's storm water-related issues and the considerations that should be made when creating a storm water-friendly landscaping design.

When designing for storm water, landscaping is a particularly important part of storm water management. Land cover, as we have learned, can determine how storm water flows depending on its permeability or impermeability. Landscape architects determine what a site's land cover will look like through their landscaping design plans, which are maps, drawings, and models that detail the locations, designs, and construction of the physical features within a site's outdoor space. They create designs for a variety of outdoor spaces, such as school campuses, private residences, businesses, and public parks, all with the goal to create functional, aesthetically pleasing, and safe greenspaces. To create a design plan, landscape architects use their knowledge of site design, grading and drainage, horticulture, storm water management, and environmental planning, as well as the needs and desires of their clients, the space, and the community.

Landscape architects often incorporate BMPs into their landscaping design plans to address storm water impacts and discharges. As a reminder, BMPs describe the wide array of strategies aimed at minimizing the impacts of storm water runoff. One category of BMPs is GSI, which uses natural processes or engineered systems that mimic those processes to enhance water quality and reduce flooding by capturing, filtering, infiltrating, and reducing storm water flows. Some BMPs are also LID strategies that preserve water quality by using or mimicking the site's pre-development hydrology to manage storm water runoff through sustainable planning and engineering practices. The main goals of GSI and LID are infiltration, biofiltration, and retention or detention. Infiltration describes the process by which rainfall and storm water runoff is captured and absorbed into the ground and enters subsurface soil or rock. Biofiltration utilizes living materials to degrade or absorb pollutants. Retention or detention captures storm water runoff to let it infiltrate naturally or release it in smaller quantities. Some examples are rain gardens, permeable pavements, and rainwater harvesting.

A landscape design that is effective at storm water management should maximize infiltration to reduce the volume of storm water runoff and pollutant loading to receiving waters. The rate and volume of infiltration is impacted by a site's soil conditions and soil infiltration rate, which should be considered in a site's design when determining where certain BMPs would be most effective. Soils with higher proportions of sand and gravel, such as sandy or loamy soils, have a high overall infiltration rate, while soils with high proportions of clay and silt typically have low infiltration rates. Landscape architects must understand soil conditions and conduct testing to determine the infiltration rates specific to a site. To improve infiltration rates in areas, the soil can be amended, or mixed, with different media. Media are the materials or substances used to enhance or increase the efficiency of storm water infiltration and filtration.

In addition to infiltration rates, there are many other factors that should be considered to create an effective landscape design plan:

1. **Pollutants of concern** Knowing which particular pollutants to target can direct which BMPs or media to use. For example, you might install a bioswale with activated carbon media to target the removal of total nitrogen.
2. **Site terrain and flowpath of storm water** Placing BMPs in the flowpath, or the surface path that storm water runoff takes, can facilitate more effective infiltration and treatment of storm water.
3. **Nearby above ground or underground utilities and proximity to structures** Tall vegetation, ground disturbance during construction, the depth of BMPs, and vegetation roots can disrupt above ground or underground utilities, like electricity lines or water supply pipes. Infiltration and consistently saturated soils too close to structures can also threaten building foundations and ground stability.

4. **Vegetation selection** Vegetation should be carefully selected to accommodate the site's local seasonal and climatic conditions and variability. Other growing conditions, such as a plant's irrigation and sun exposure needs, and vulnerability to sustained inundation, should be considered. These characteristics can be used to create a plant palette, which describes a selection of plants that grow well together based on growing requirements and aesthetics. Plants that support local pollinators or are native and non-invasive should be prioritized to support the site's local ecosystem. Finally, the byproducts produced by the selected vegetation should be considered, as they may create green waste, such as fallen leaves, flowers, or fruits, that clog storm drains or require additional maintenance, or release biogenic volatile organic compounds that contribute to air and water pollution.
5. **Future maintenance requirements** Landscapes should be designed to maintain, meaning that the requirements for maintenance of BMPs is not difficult or extremely burdensome. Additionally, an Operations and Maintenance Plan that considers funding, equipment, materials, and staff availability should be developed to ensure the longevity and effectiveness of the landscape and its BMPs.

To explore the field of landscape design and architecture in this lesson, students will first conduct an activity about the infiltration of water into a common absorptive material, the kitchen sponge. They will then apply that knowledge to test and calculate the infiltration rates of various media and consider how those infiltration rates might impact landscaping design plans. Finally, they will learn about different types of BMPs and their benefits and drawbacks, and brainstorm ways to incorporate them into their site's landscaping design plan. The next lesson will build off of this knowledge base to explore the multi-benefits of BMPs beyond storm water management.

I. Soaking in Infiltration Activity

1. Introduce the topic of infiltration and explain that this activity will explore how landscape surfaces might impact infiltration.
2. Direct the students to form groups and distribute an 9x13-inch aluminum tray, scissors, 12 sponges, 2 plastic bags, a collection container, two dice, and a copy of the Soaking in Infiltration worksheet to each group.
3. Have the students cut a drainage hole into one side wall of the aluminum tray, near its base and prop the non-cut edge of the tray up to create a slope. They should place the collection container below the tray's hole to collect water that runs off during the activity.
4. The students will then place 6 sponges into each plastic bag, so that they are adjacent to each other, and fit the plastic bags flat on the bottom of the tray. Explain to the students that the current setup represents a highly impermeable landscape, where the soil (the sponges) are covered by impermeable pavement (the plastic).
5. Each group will pour 200 mL of water into the aluminum tray, measure the collected runoff, and answer the corresponding questions in their worksheet.
6. Direct two students from each group to roll the set of dice. The numbers they roll will determine the number of sponges that the group will remove from each of the plastic bags and place back flat into the tray, outside of the plastic bag.
7. Once the appropriate number of sponges have been unwrapped, explain that the exposed sponges represent permeable surfaces, where the exposed soil (the sponges) can now absorb runoff.
8. Each group will then pour another 200 mL of water into the tray, measure the amount of runoff, and answer the corresponding questions in their worksheet.
9. Ask the students to compare the infiltration of their first trial without the exposed sponges and their second trial with the exposed sponges.
10. To conclude, conduct a class-wide discussion with these guiding questions:
    - Where do you see infiltration happening on your school campus or in your neighborhood?
    - What materials or substances are present in those infiltration areas?
    - What do you notice about the flow of storm water in those areas compared to concrete or asphalt-covered areas?

II. A Media Investigation Activity

1. To prepare for this activity, poke drainage holes in the deli containers beforehand and source the various media to be used, such as sand, potting soil, school ground soil, compost, gravel, or clay. The container's holes should be small enough so that they allow water to drain out while also retaining the media within.

II. A Media Investigation Activity Continued

2. Explain the definition of media to the students and how different media can have different rates of infiltration. Infiltration rate of types of media is largely determined by pore space, or the empty space between media particles. If a particular media has more pore space, it can absorb more water into those empty spaces, meaning that it has a higher infiltration rate. Media with larger grain sizes, such as gravel or coarse sand, cannot compact tightly and thus, have more pore space, while media with smaller grain sizes, such as clay or silt, can compact close together, resulting in less pore space.
3. Distribute the A Media Investigation worksheet. Have the students complete the first part of the worksheet individually by feeling the texture of the different media to be used in the activity.
4. Direct the students to form groups and select a media to test. Distribute 1 quart deli containers with drainage holes, a ruler, a permanent marker, a collection container, and a stopwatch to each group.
5. To set up the activity, the students should fill deli containers with 2 cups of their selected media and spread the surface of the media so that it is relatively flat.
6. They will then use the ruler and permanent marker to mark inch measurements on the outside of the container from the surface of the media to the top of the container.
7. Before beginning testing, each group should ensure that the media is fully saturated by pouring water through the container and allowing it to drain fully into the collection container. This will allow the media to mimic the minimum infiltration rate during a rain event.
8. Once the media is saturated, direct the students to measure 2 cups of water and pour it into the container. They will immediately begin the stopwatch to record the amount of time it takes for the water level to drop by a measured amount of inches.
9. The students should repeat Steps 5-8 for all the chosen media and document their results on the worksheet.
10. Using their results, direct the students to complete Step 3 the worksheet, dividing the change in water level (in inches) by the time (in seconds) that the water level took to drop to calculate the media's infiltration rate.
11. The students should use their calculations to complete the last part of the worksheet individually.
12. To conclude, discuss each group's results as a class and consider the following:
    - How might a high infiltration rate affect storm water runoff?
    - How might a low infiltration rate affect storm water runoff?
    - How could the infiltration rate of a site's soil impact its approaches to storm water management?

III. To BMP, or not to BMP Activity

1. Divide students into small groups or pairs. Distribute the activity worksheet and the BMP Cards (introduced in Lesson 4).
2. Direct groups to review the site scenarios on their worksheet. Based on site constraints (space, location, runoff type, and primary pollutants), have groups select two candidate BMPs from their cards for comparison
3. Instruct students to pull the numerical criteria scores from each candidate BMP Card and fill out the Performance Matrix on their worksheet. Sum the scores to find the total performance score for each BMP.
4. Have students calculate estimated pollutant load reductions and runoff volume reductions using data provided on the BMP Cards (e.g., percentage volume captured, unit removal metrics).
5. Guide students to compare total performance matrix scores alongside calculated reduction metrics against site parameters. The option with the highest balanced score and feasibility is selected as the recommended BMP.
6. Students compare the Performance Matrix score and reduction percentages of the BMPs to each sites' parameters, considering space, location, type of runoff, and issues that need to be addressed.
7. Have groups present their selected BMPs, total scores, and calculated load reductions. Facilitate a class discussion on trade-offs (e.g., Does a higher-cost BMP offer significantly better load reduction? How does maintenance ease affect long-term viability?).

Adaptations and Resources

Storm Patrol Project Based Learning Track:

- Students work on the Design & Innovate section of their workbook (Section 6, Parts 1- 3). In which they map site pollutants and identify areas needing Best Management Practices (BMPs). Then, analyze proposed BMPs by weighing their pros, cons, and impact on storm water runoff.

BMP Resources:
Web Soil Survey (https://websoilsurvey.nrcs.usda.gov/app/)

- *Students can use this tool to learn about their site's soil and infiltration rates. On the Area of Interest tab, define the site area using the AOI polygon tool in the toolbar. The Soil Map tab will show a map of the soil types for your site. Other site soil information can be found on the Soil Data Explorer tab. Under the "Soil Qualities and Features" dropdown, clicking "View Rating" will provide information about infiltration rates for each soil type. Group A soils have the highest infiltration rate, followed by Group B soils, Group C soils, and Group D soils, which have the lowest infiltration rate.*

Plant Pono (https://plantpono.org/)

- *Students can use this tool to identify vegetation to utilize in their landscape design plan. The plants can be queried by sunlight, water, and drainage requirements, as well as native and non-invasive species.*

Activity-Centric Learning Track:

Conduct Activities I , II, and III.

Tips to Truncate Lesson:

- Eliminate or assign the Project Based Learning Activity as homework.
- Demonstrate the Soaking in Infiltration activity for the whole class instead of groups completing it individually and hold a short reflection discussion.
- In the A Media Investigation activity, have each group of students conduct the activity with one type of media and share their results with the class.

Tips to Extend Lesson:

- In the A Media Investigation activity, have students create their own mixtures of the different media and conduct the same experiment.
- In the To BMP, or not to BMP activity, have students determine if the BMPs selected for the three sites fits the financial budget and pollutants budget (applied credits) as introduced in Lesson 4.

Resources:

- American Society of Landscape Architects, *What is Landscape Architecture?*, https://www.asla.org/aboutlandscapearchitecture.aspx.
- City and County of Honolulu Department of Planning and Permitting, *Storm Water BMP Guide for New and Redevelopment*, https://www.honolulu.gov/swq/wp-content/uploads/sites/32/2023/10/sw-bmp-guide.pdf.
- Hawaiʻi Department of Transportation, *Storm Water Permanent Best Management Practices Manual*, https://www.stormwaterhawaii.com/wp-content/uploads/2022/07/2015-Storm-Water-Management-Permanent-Best-Management-Practices-Manual-for-projects-initiated-prior-to-July-1-2022.pdf.
- Minnesota Stormwater Manual, *Green Stormwater Infrastructure (GSI) and sustainable stormwater management*, https://stormwater.pca.state.mn.us/index.php?title=Green_Stormwater_Infrastructure_%28GSI%29_and_sustainable_stormwater_management.
- Minnesota Stormwater Manual, *Overview of stormwater infiltration*, https://stormwater.pca.state.mn.us/index.php/Overview_of_stormwater_infiltration.
- Minnesota Stormwater Manual, *Soils with low infiltration capacity*, https://stormwater.pca.state.mn.us/index.php/Soils_with_low_infiltration_capacity.
- Office of Water Programs (OWP) at California State University, Sacramento, *Guidance for Stormwater and Dry Weather Runoff Capture at Schools*, https://www.waterboards.ca.gov/publications_forms/publications/legislative/docs/2018/stormwater_capture_at_schools_with_appendices.pdf.
- US Environmental Protection Agency, *Stormwater Management Technologies: Treatment Media*, https://www.epa.gov/emergency-response-research/stormwater-management-technologies-treatment-media.