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Collaborative Outreach to Inspire Interest in Civil and Environmental Engineering Through Stormwater Design using Best Management Practices

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Abstract

This paper presents an engaging activity developed for the outreach event Blue Planet Jobs: Careers in Water, hosted by the nonprofit organization Pure Oakland Water (POW). Approximately 250 high school students participating in career readiness programs explored opportunities in various water-related professions through interactive mini-sessions and displays. This paper focuses on one specific mini-session, which introduced best management practices (BMPs) for stormwater design. The session was collaboratively designed and delivered by practicing engineers and educators. In this mini-session, student teams developed cost-effective site solutions that adhered to county area specifications. After a brief introduction to the topic, teams were provided with a site plan, sheets representing BMP options, a worksheet, and other supplies. The activity was structured into the following steps:

1. Calculate the Impervious Area
2. Calculate the BMP Area
3. Design a Minimum of Two Alternative BMP Solutions
4. Estimate the Cost of the Selected BMP Alternative

Students had the flexibility to select and place BMPs on their site plans, choosing from options such as native plantings, rain gardens/bioretention areas, vegetated roofs, and trees. Facilitators guided the students through each step to ensure they could complete the entire process effectively. Immediate feedback from students and teachers was overwhelmingly positive. Several teachers requested the materials to expand upon the activity in their classrooms. Post-event survey results also highlighted this session as a favorite among participants, with students and teachers alike citing its engaging and hands-on approach. This paper will provide a detailed account of the resources developed for this activity, and outline how the session was delivered.

Introduction

Environmental Engineering and Civil Engineering are among the top professions within the engineering field. Despite their high rankings and critical societal roles, both fields face significant workforce shortages projected to persist over the next decade. Addressing this challenge requires collaborative outreach efforts by industry, academia, government, and nonprofit organizations to attract new talent.

This paper presents a new collaboration among a nonprofit organization, a medium-sized for-profit engineering firm, a government agency, and an academic institution to support one of four tracks in a major outreach event. The event is titled "Blue Planet Jobs: Careers in Water," and it is aimed to inspire high school students to explore careers related to water resources.

Using the planning framework Backward Design, the outreach collaborators developed an activity that showcased the practical applications of engineering knowledge to solve real-world problems. Through the interactive activity, students gained awareness of how engineering professionals address critical issues like stormwater management using best management practices (BMPs).

This activity not only demonstrated the complex nature of environmental and civil engineering but also highlighted the critical trade-offs in decision-making, such as balancing cost, environmental impact, and technical feasibility. By involving students in the design of stormwater management solutions, the outreach activity fostered creativity and collaboration—essential traits for future engineers.

This paper documents the development, implementation, and outcomes of the engineering track for the outreach event. It includes an overview of the participating organizations, the design process for the activity, logistical considerations for running the session, and reflections on feedback received from participants and teachers. The insights and lessons learned from this outreach activity can serve as a model for similar efforts to bridge the gap between aspiring engineers and the opportunities within the engineering profession.

Background

The professions, Environmental Engineering and Civil Engineering, were ranked second and fourth in 2024 by U.S. News and World Report as Best Engineering Jobs, respectively [1]. However, these fields are projected to continue to struggle with unfilled jobs over the next ten years. Collaborative and coordinated outreach efforts by industry and academia are critical to attract new talent to engineering [2]. This paper highlights the collaboration among nonprofit organizations, a medium-sized for-profit company, a government agency, and an academic institution in organizing an activity for a major outreach event. The initiative aimed to raise high school students' awareness of careers related to the natural resource of water.

Collaborative Organizations - The nonprofit Pure Oakland Water (POW) was founded in 2013 by the Oakland County Water Resources Commissioner Jim Nash with the mission of creating

and supporting environmental education and advocacy opportunities in southeast Michigan. Two of the first opportunities POW had to support environmental education were the Clinton and Rouge River Water Festivals. Water festivals are half day field trips where teachers bring their classes to learn about water through interactive games, activities, and presentations. Generally, water education lines up with the 4th and 5th grade curriculum and this field trip enhances what students are already learning about in class. The water festival model has proven to be very successful with over 1,000 students generally attending each festival. This model is now copied across the state.

In 2017 POW began researching ways to expand interactive environmental education opportunities for high school students as POW were seeing and supporting a lot in both the elementary and college spaces and noticed a gap. Around this same time, the office of the Oakland County Water Resources Commissioner (WRC) was looking for creative solutions to the critical problem of staff shortages in the water sector. In 2018, the WRC and POW partnered with Oakland County Schools and the Cranbrook Institute of Science to create "Blue Planet Jobs: Careers in Water." Oakland Schools is able to reach teachers and principals in the schools to promote the event, be the school's liaison for the event, and to manage the registration. The Cranbrook Institute of Science is an established field trip destination with plenty of space to host the event and the infrastructure needed to schedule and staff the event.

Blue Planet Jobs follows the water festival model by scheduling four, 25-minute, interactive presentations for 10th and 11th grade students to come and learn about many of the career fields available in water resources. The focus was on the following career paths: government and nonprofit, engineering, skilled trades, and facility operations. Each presentation is created and facilitated by professionals already working in that field. These professionals are asked to make their presentation interactive but the method for doing so is up to them. A wide variety of water resources professionals' partner on this event to make it a success. Figure 1 shows the promotional material forwarded to Oakland Schools Career Readiness program.

Figure 1. Promotional material for the 2024 Blue Planet Jobs event.

Professionals from the following organizations have been instrumental in creating activities that are memorable, inspiring, educational, and fun: Lawrence Technological University, Drummond Carpenter, the Oakland County Water Resources Commissioner's Office, the Clinton River

Watershed Council, Oakland County Parks, Pipeline Management, the Great Lakes Water Authority, the American Water Works Association, and Michigan Works. Drummond Carpenter is a civil and environmental engineering consulting firm that specializes in using nature-based solutions to address stormwater issues. As an industry partner and supporting the engineering track activity, Drummond Carpenter staff were able to inform the activity development process and provide a real-world component to the activity and insight during the session.

Developing the Outreach Activity

As mentioned above, the event "Blue Planet Jobs: Careers in Water" was designed around four tracks: engineering, non-profit, plant operations, and trades. The students were divided into 8 groups of 25, and each group attended four 25-minute presentations or demonstrations. In addition, students were provided the opportunity to visit an engineering display where students could experiment with a river erosion model and a bridge pier scour model.

This interactive outreach activity was designed to introduce the career path focused on civil and environmental engineering. The activity was designed using the planning framework Backward Design [3] that is based on three stages:

- Identify desired results
- Determine acceptable evidence
- Plan learning experiences and instruction.

Since the event was focused on careers in waters, the outreach collaborators aimed to design an activity that demonstrated the application of engineering knowledge and skills to the stormwater management site design using best management practices (BMPs). Table 1 outlines the Backward Design framework applied to the design of the interactive activity on the application of Best Management Practices for stormwater design. The following section details the work flow.

Several different options for interactive and hands-on activities were discussed including use of the online tool National Stormwater Calculator [4] to experiment with different BMP solutions for a local site. It was determined that an activity using the online stormwater calculator was not the best option for this event. For many high school students who do not have a lot of knowledge on stormwater management design, it would have been difficult to teach them the basics of stormwater management and how to use online tool in the allotted 30-minute sessions. Also, the stormwater tool activity did not encourage group collaboration since it would be hard for all group members to get involved with only one laptop/stormwater tool per group. The team really strived to find an activity that was hands-on, required teamwork, and was provided real life experience of what is civil or environmental engineers do daily. After searching online for an activity that would achieve these goals, the team did not find anything they really liked and were inspired to create their own activity.

Table 1. Design process using the template for Understanding by Design available from Jay McTighe & Associates Consulting [5].

<table>
<tr><th colspan="3">Stage 1 Desired Results</th></tr>
<tr><td rowspan="6">ESTABLISHED GOALS
Example of engineering design activity of Best Management Practices (BMPs) for stormwater design</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">Students will be able to independently use their learning to…
propose BMPs that meet the requirements for a site with impervious surfaces (building and parking lot) and allocated budget.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>UNDERSTANDINGS
Students will understand that…
onsite treatment of rain by BMPs reduces the load on the municipal stormwater system thereby mitigating the risk of flooding and improving water quality.</td><td>ESSENTIAL QUESTIONS
Can meaningful, repeatable, and timed outreach activity be designed that allow the students to create viable solutions for the stormwater site design using BMPs including any mix of native plants, rain gardens, trees and green roofs.</td></tr>
<tr><td colspan="2">Acquisition</td></tr>
<tr><td>Students will know…
how BMP solutions can satisfy the design requirements.</td><td>Students will be skilled at…
Quantifying BMP solutions and their cost.</td></tr>
<tr><th colspan="3">Stage 2 - Evidence</th></tr>
<tr><td>Evaluative Criteria</td><td colspan="2">Assessment Evidence</td></tr>
<tr><td>Completed Site plan</td><td colspan="2">PERFORMANCE TASK(S):
BMPs selected and sized. The solution meets the allocated budget.</td></tr>
<tr><td>Completed Worksheet</td><td colspan="2">OTHER EVIDENCE:
Calculation of required area meeting the local specifications stormwater design with BMPs</td></tr>
<tr><th colspan="3">Stage 3 – Learning Plan</th></tr>
<tr><td colspan="3">Summary of Key Learning Events and Instruction
Introduction to civil and environmental engineering with focus on water resources.
Why stormwater management?
Presentation of project site and example of BMPs for stormwater design
Designing BMPs
Calculate Impervious Area; Calculate BMP area; Create BMP design; Determine BMP Cost Estimate
Final inspection (approval)</td></tr>
</table>

As stated, the outreach collaborators wanted to offer students an activity that was hands-on, required collaboration with peers, and provided a realistic experience of what a civil or environmental engineer may be tasked with in their career. The inspiration for the activity came from newly implemented stormwater management design criteria in WRC's Stormwater Management Engineering Design Standards [6]. The criteria set guidelines for sites where infiltration is deemed impractical (soil infiltration rates less than 0.24 inches per hour). For sites that cannot infiltrate, developers must design stormwater BMPs whose area equates to the same amount of area as 15% of the site's impervious area. This specific design criteria were what the team chose to base the engineering activity on.

For the activity, the team created a mock site plan, stormwater BMP cutout sheets, stormwater BMP fact sheet, and a corresponding worksheet. Each group is given these materials along with pencils, scissors, and glue sticks. The mock site plan is a simple 5,450 square foot building with sidewalks, a parking lot, landscape islands, and open grass area on three sides of the parking lot. There is also a proposed detention basin to show other stormwater management practices that would be required, if it were a real site. The site plans were printed on a 24" x 36" with a 1" = 10' to mimic typical engineering/construction plans and provide enough space to engage the entire group. The ideal group size was around 4-6 students. This group size helped to get all students involved whether they were cutting and pasting, designing BMP shapes and sizes, or tracking the budget.

Each group was tasked with designing multiple stormwater BMPs that have an equivalent area equal to 15% of the impervious area of the site while staying within a budget of $75,000. The activity was split up into the following tasks that are outlined in the worksheet and a corresponding PowerPoint presentation:

1. Calculate the Impervious Area
2. Calculate the BMP Area (15% of the Impervious Area)
3. BMP Design
4. BMP Cost Estimate.

Step 1 Calculate the Impervious Area: The worksheet provided the square footage of the total development area, the building, sidewalk, landscape islands and grass areas. Only the parking lot area was not provided, which the students had to calculate by subtracting the other areas from the total development area. Then they added up the impervious areas (parking lot, building, sidewalk) which totals 33,450 square feet.

Step 2 Calculate the BMP Area (15% of the Impervious Area): The group then had to calculate the required BMP area which is 15% of the total impervious area or 5,000 square feet (rounded to the nearest 100).

Step 3-4: BMP Design and Cost Estimate: Lastly, the group would design a minimum of 5,000 square feet of stormwater BMPs and calculate the costs of those BMPs. The worksheet stated that the group has a budget of $75,000. There were four different BMPs with differing costs shown in Figure 2. The teams were provided with a stack of precut 200 square foot trees and

three scaled grid sheets for the native plantings, bioretention, and vegetated roof. The grid sheets had example BMP shapes that included the square footage of the shape and the cost for the group to cut out and place on their site. See Table 2. They were also encouraged to create their own uniquely shaped BMP.

BMP	Price
Native Plantings	$10/sq ft
Rain Garden/Bioretention	$20/sq ft
Vegetated Roof	$40/ sq ft
Trees	$500/tree

Table 2. Best management practices price breakdown per square foot or per tree.

Pilot Testing and Lessons Learned

Prior to the day of the event, the collaborators met in-person to pilot the activity. A student intern at WRC and a few non-engineer staff members volunteered to complete the activity without any prior knowledge of it. The run-through helped tweak the activity where necessary to stay within the time limit of the session. For example, in Step 1 of the activity, the original intent was to have the team calculate the impervious area of the site plan by using an engineer's scale to measure and add up the impervious area. This would have been a good opportunity to teach the students how an engineer's scale works and how to interpret site plans. However, it was realized that this task would take too long for a 25-minute session, so the worksheet lists the square footage of the total development area, the building, sidewalks, landscape islands and grass areas. Additionally, to save time the tree BMPs were precut for the students.

Since this new activity had never been presented to any students, a large concern was making sure the students would understand the activity. Piloting the activity with a group who were not familiar with stormwater management design was very helpful to the facilitators. The group provided feedback that it still was not fully clear to them what each stormwater BMP was, so we created a stormwater BMP fact sheet that provides information on each of the BMPs. Also based on feedback, the BMP grid sheets were revised to include example BMP shapes that included the square footage of the shape and the cost for the group to cut out and place on their site. On the day of the event, the students found these very helpful to get them started on the activity. Lastly, the in-person pilot helped to standardize the activity's presentation and timing between both teams of facilitators.

Based on feedback and time constraints, the team simplified the activity prior to the event so there were no significant logistical hurdles. However, on the day of the event there were still lessons learned and challenges as we worked through the sessions with the students. One of the challenges we encountered was motivation. Some students weren't motivated to engage or give their best effort on the activity. Some of the groups were too large for everyone to contribute due to some large class sizes. We determined that groups of 4-5 students are ideal to encourage

engagement from everyone. With 4-5 students in a group and only 30 minutes to complete the activity, it encourages all group members to get involved in order to complete the activity on time. In these groups the students would naturally take on different roles. 2-3 group members would focus on the design/aesthetics of the site plans and cutting out the BMPs while the remaining group members would focus on making sure their BMPs met the requirements and stayed within the allotted budget. With larger groups, it was easier for some students to not participate in the site plan design.

Another challenge that some groups encountered was how to start the activity. For high school students, a lot of the material presented in this activity was brand new to them. They were not familiar with stormwater management BMPs, construction site plans, and regulatory requirements that engineers must commonly adhere to. While a strength of the activity is introducing students to real life engineering applications in high school, some groups found it difficult to know how to start the activity with all the new information they were just provided. To assist the students in this the activity is broken down into different steps. The groups first spend around 5-10 minutes calculating the impervious area and the BMP area together. Once all groups accomplished this and the presenters confirmed that each group correctly calculated the BMP area, the students began designing the BMPs and this was the point where some groups were not confident on how to start the BMP design. To assist the students, the presenters would encourage the groups to start simple with the tree BMPs by placing on them on the site plan and to start adding up the cost of the trees placed and the square footage of the trees placed. They were also encouraged to start with the example BMPs on the grid sheets which already had the cost and square footage calculated. The student found this very helpful in starting the BMP design process.

Running the Sessions

With the requirement of accommodating 200+ students in four 25-min sessions, the facilitators decided to target 12-15 high school students per instructor. Two classroom type locations were identified which allowed each room to accommodate about 25 students and their educators per session. The activity was to be repeated four times with 5 minutes of set-up time between student groups.

The room was equipped with a projector, projector screen, tables and chairs for five groups of five students each. Figure 2 shows the site plan used by the students when developing their stormwater design. Figure 3 shows an example site plan with developed stormwater design using BMPs as shared with students at the beginning of the session. Figure 4 shows the worksheet that the students completed during the process. Each group was provided with the material detailed above. The students were allowed to use the calculator app on their phones or the white space on the worksheets for required arithmetic.

The students were seated at the tables at the beginning of the session and the facilitators provided a brief 5 to 7 minutes introduction to the project. Students had the flexibility to select and place BMPs on their site plans, choosing from options such as native plantings, rain gardens/ bioretention areas, vegetated roofs, and trees (see Figure 5). The facilitators guided the students through each step and made a status check after Step 2 and Step 4. The facilitators provided

feedback and support to ensure that the students could complete the entire project within the 25 minutes time slot. As a final step the practicing engineer provided prices (candy) to student teams completing a project solution.

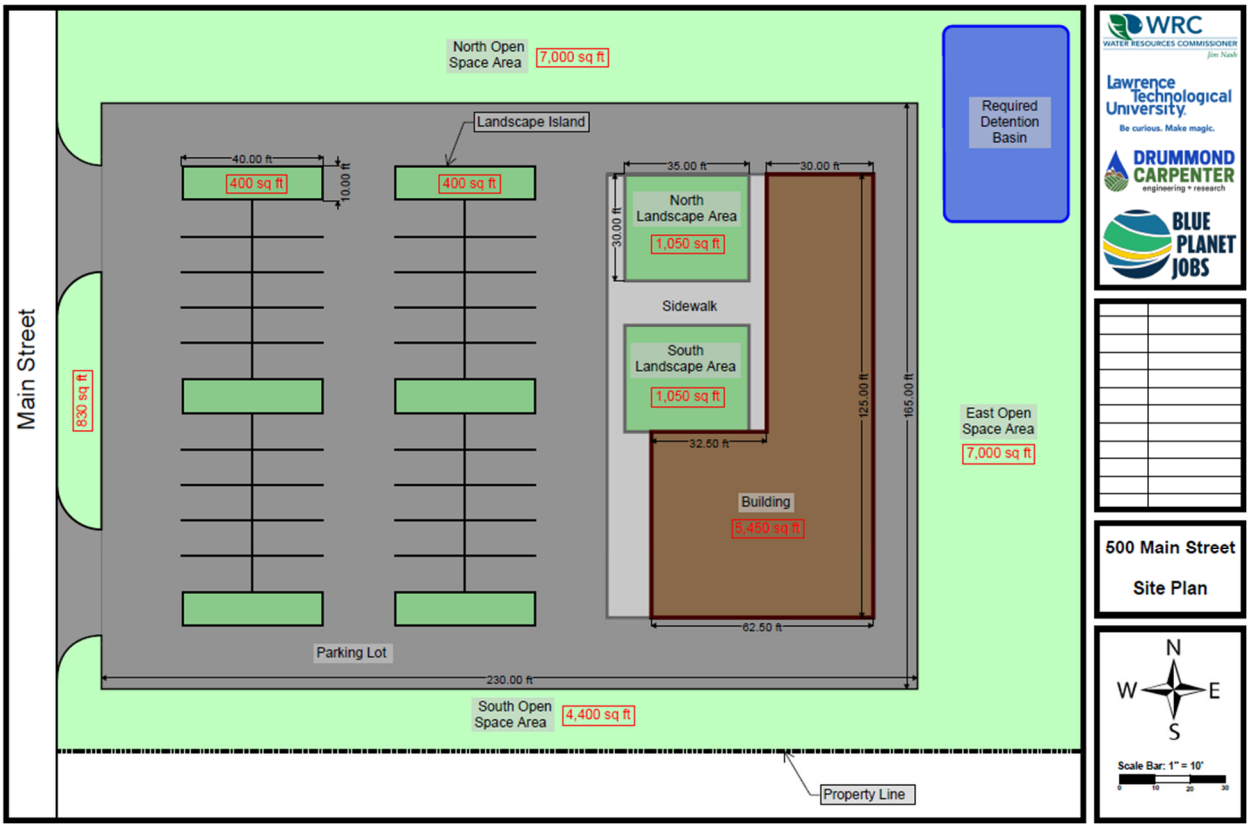

Figure 2. Site plan for developing the stormwater design using Best Management Practices.

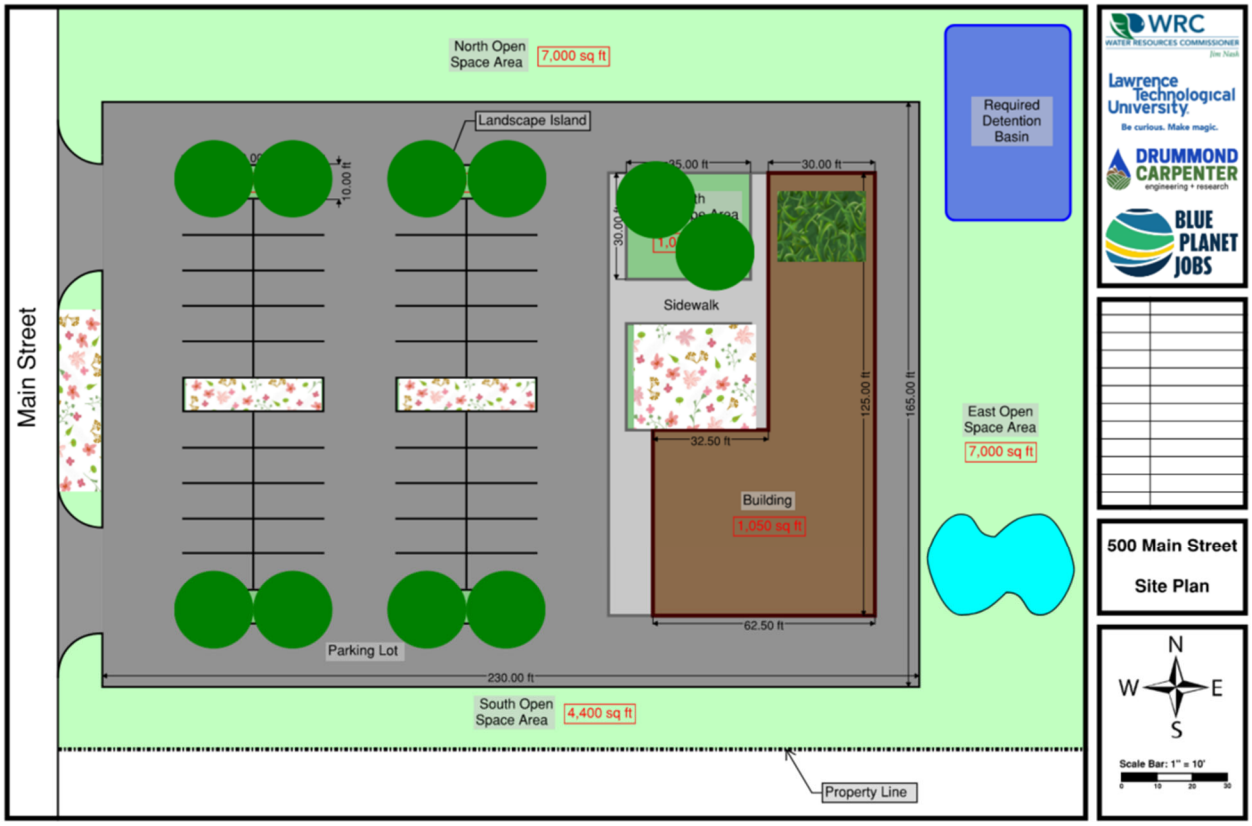

Figure 3. Example site plan with developed stormwater design using Best Management Practices (shared with participants during presentation).

500 Main Street Site Plan Calculations

Step 1: Calculate the Impervious Area

- **Building Area**: 5,450 square feet
- **Sidewalk Area**: 1,820 sq ft
- **Development Area**:
  - Total Development Area: (Length 230 ft) x (Width 165 ft) = 37,950 sq ft
  - Landscape Island: 400 sq ft x 6 Islands = 2,400 sq ft
  - North Landscape Area: (Length 35 ft) x (Width 30 ft) = 1,050 sq ft
  - South Landscape Area: (Length 35 ft) x (Width 30 ft) = 1,050 sq ft
  - Total Development Area:

37,950 (Total Development Area) – 5,450 (Building) – 1,820 (Sidewalk) – 1,050 (North Landscape Area) – 1,050 (South Landscape Area) – 2,400 (Landscape Islands) = **26,180 sq ft Parking Lot Area**

- **Total Impervious Area:**

_____ (Parking Lot Area) + _____ (Building) + _____ (Sidewalk) = **_____ sq ft Total Impervious Area**

Step 2: Calculate the BMP Area

- You must design BMPs on your site plan to reach you BMP Area
- The BMP area = 15% of the total impervious area

_____ (Total Impervious Area) x 15% = **_____ sq ft BMP Area**

Round to the nearest 100

Step 3a: BMP Design

Design #1

BMP	Area
Native Plantings	sq ft
Rain Garden/Bioretention	sq ft
Vegetated Roof	sq ft
Trees (200 sq ft/tree)	sq ft
TOTAL:	sq ft

Design #2

BMP	Area
Native Plantings	sq ft
Rain Garden/Bioretention	sq ft
Vegetated Roof	sq ft
Trees (200 sq ft/tree)	sq ft
TOTAL:	sq ft

Step 3b: BMP Cost Estimate

BMP	Price	Quantity	Cost
Native Plantings	$10/sq ft	sq ft	$
Rain Garden/Bioretention	$20/sq ft	sq ft	$
Vegetated Roof	$40/ sq ft	sq ft	$
Trees	$500/tree	each	$
		TOTAL:	$

Budget = $75,000

Figure 4. Worksheet supporting the BMP calculations including area and costs.

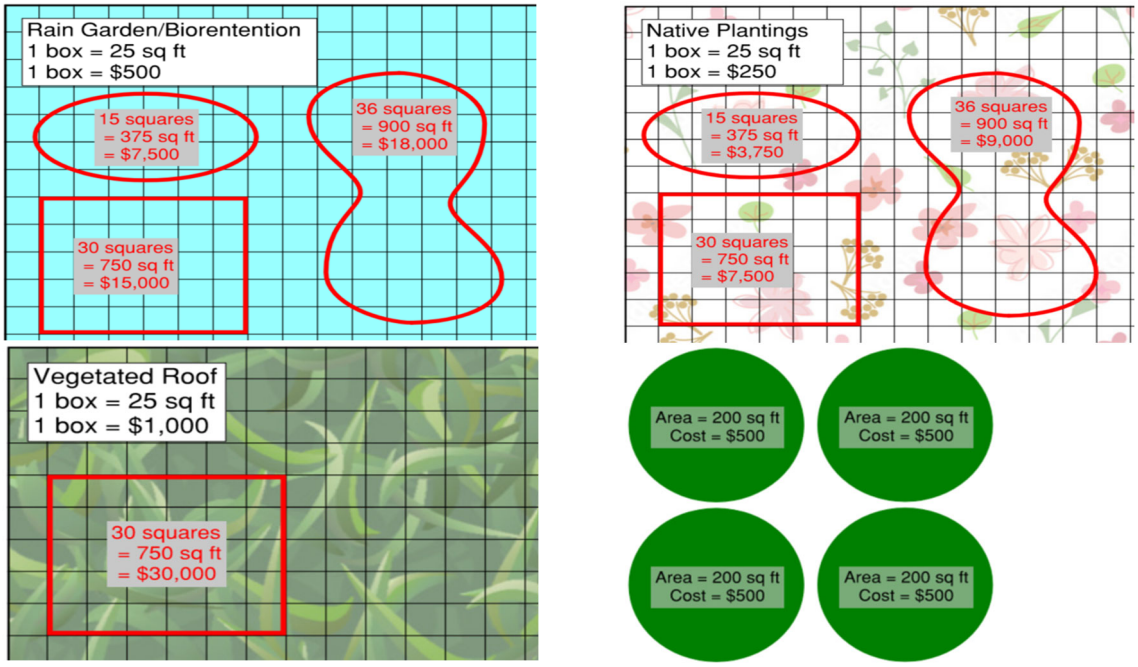

Figure 5. Example Best Management Practices options and example areas: native plants, raingarden/bioretention area, vegetated roof and trees.

Feedback

Immediate feedback from students and teachers was overwhelmingly positive. Several teachers requested the materials to expand upon the activity when returning to their classroom. Post-event survey results also highlighted this session as a favorite among participants, with students and teachers alike citing its engaging and hands-on approach. The participants completed the survey on a voluntary basis and the survey was conducted by the event organizers. The authors do not have IRB approval on the survey instrument and therefore further details are not shared in this paper.

During the session at the Blue Planet Jobs event, several of the student teams had lively discussions about solution strategies of optimizing for cost and BMP areas. The activity lends itself to be conducted in a longer time block where more in-depth discussions of trade-offs can take place as well as all the detailed calculations including measurements using an engineering scale.

The activity was deployed during a 2024 Civil Engineering Summer Camp and a High School Internship Program at Lawrence Technological University. In both later cases, the activity was conducted over a 150-minute session and the session was enriched with an on-campus tour of BMP installations. Figure 6 shows photographs of participating high school students engaged in the interactive project planning and designing the BMPs for the site.


a)

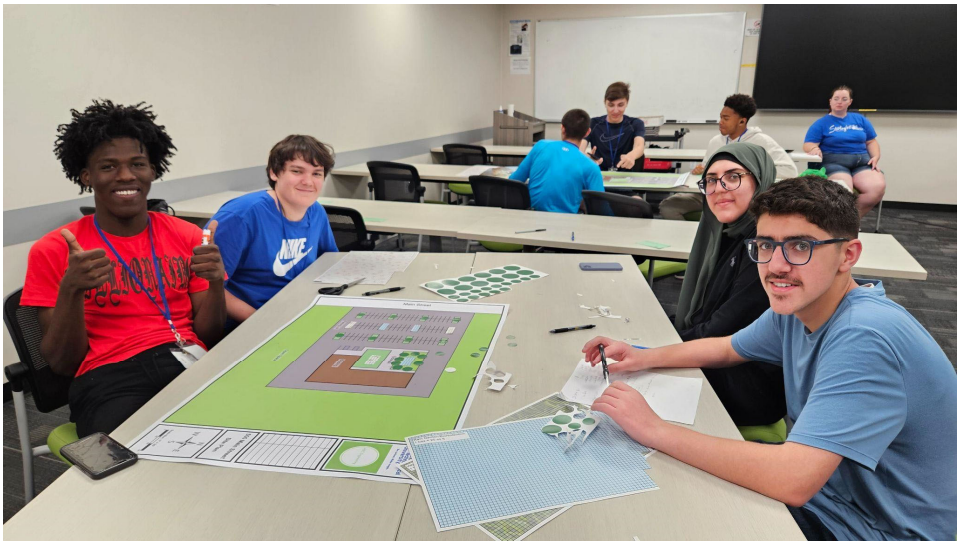
b)

Figure 6. High school students engaged with stormwater site design at a) the Blue Planet Job: Careers in Water event; and c) a civil engineering summer camp.

Concluding Remarks

The hands-on activity developed for "Blue Planet Jobs: Careers in Water" successfully demonstrated how collaborative outreach events can inspire interest in water related jobs as well as civil and environmental engineering among high school students. By blending technical rigor with creativity, the session allowed participants to engage in meaningful problem-solving while gaining an appreciation for stormwater management. The overwhelmingly positive feedback from students and teachers underscores the importance of such initiatives in addressing workforce shortages in engineering fields. Future iterations of this activity could explore extended formats to facilitate deeper discussions on trade-offs and calculations to enrich the learning experience. This effort provides a transferable model for integrating real-world engineering concepts into outreach activities, with the goal to bring awareness about engineering careers in water related job market.

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