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Assignment D4

Sustainable Stormwater Drainage Alternatives for University of Illinois Parking Lots

Executive Summary

The purpose of this project is to determine the feasibility of installing Sustainable Urban Drainage Systems in the parking lots situated between Oak Street on the west, Lincoln Avenue on the east, Florida avenue on the North and St. Mary's Road on the south. The university has recognized the need to renovate these lots because the presence of excess stormwater runoff in urban areas due to poor urban drainage systems is prevalent issue. Urbanization interrupts the water cycle by covering naturally permeable soil with an impermeable, artificial ground like asphalt. Then, stormwater is not absorbed by the ground at its usual rate, which results in excess stormwater runoff, especially in places that are typically completely covered in asphalt such as parking lots (Jamal, 2017). To remedy this problem, the university has proposed three potential solutions: using a combination of impervious and pervious interlocking-block paving systems, installing a subsurface detention system and retaining our current system of stormwater management. If we were to repave the lots using a combination of impervious and pervious interlocking-block paving systems, all the runoff from the impervious pavement would be directed to pervious areas where it can infiltrate. If we were to install a subsurface detention system, we would repave the lots with conventional pavement over a subsurface detention system where stormwater runoff would be stored and slowly released after the storm event.

In this report we analyzed the three proposed solutions regarding affordability and environmental impact. Our main tasks include performing a literature review where we research previous projects and compare it to ours to estimate our costs. Then we calculate our estimates like the amount of runoff and what fees and maintenance costs we would need to pay with each of the proposed solutions. Then we would check the durability and design life of each of our solutions. Finally, we would evaluate our data and finalize our plan by doing various types of analysis like an environmental analysis and using our analyses we would about two weeks to create a deliverable highlighting our recommended sustainable urban drainage solution and how to move onwards with it.

We then performed two types of cost estimations, a parametric (top-down) cost estimate for both permeable pavers and a subsurface detention system, and a detailed (bottom-up) cost estimate for only permeable pavers. For permeable pavers we found the cost estimate to be around $18.5 million (parametric) to $46.1 million (detailed). For a subsurface detention system, we found the cost estimate to be around $55 million (parametric).

Using the information we have found from our research and cost estimates, we believe that the best solution to deal with excess stormwater runoff would be the interlocking pervious and impervious pavers. The first reason being that pervious pavers are going to be more affordable overall in comparison to a subsurface detention system as we can see from our cost-benefit analyses. The second reason is that pervious pavers infiltrate a considerable amount of runoff, in fact, a permeable pavement system designed to capture 1 inch of runoff from impervious surfaces will capture 89% of annual runoff (Minnesota Stormwater Manual, 2021).

Introduction

As one of the world's leading research institutions, the University of Illinois at Urbana-Champaign (UIUC) requires more sustainable Stormwater Management on practices for rainwater in core campus and agricultural areas including Parking Lots Serving Athletic Facilities on the University of Illinois Campus while adhering to a comprehensive rainwater management plan and doubling the number of on-campus green infrastructure installations. The Institute for Sustainability, Energy, and Environment (ISEE) at UIUC has developed the Illinois Climate Action Plan (ICAP) (ISEE, 2020) describing campus goals that will maintain our leadership in sustainability. Urban drainage is a problem because with urbanization, humans have interrupted the natural water cycle by covering permeable land, that absorbs most of the stormwater, with an impermeable surface like asphalt that diverse water away from the natural drainage system and lends itself to flooding buildings instead causing very expensive water damage (Jamal, 2017). By implementing more sustainable stormwater management practices on parking lots serving athletic facilities, we could see substantial reduction in stormwater runoff for future storms. Sustainable Drainage Systems (SuDS) are the best stormwater management system that we can use because they manage runoff volumes are flow rates from hard surfaces in a way that minimizes the damage inflicted on urbanization, reduce the amount of pollution in runoff, provide ways to use runoff in the area that it is collected, protect natural water flow, attract people by providing an aesthetic habitat for wildlife in urban settings etc (susdrain.org). The Cities of Champaign and Urbana have enacted Stormwater Ordinances that charge a Stormwater Utility Fee (City of Champaign, 2016; City of Urbana, 2012) based on the impervious area of land parcels. These ordinances also provide for credits for practices that reduce the volume or peak flow from these parcels.

One proposed solution is repaving these lots with a combination of conventional (impervious) and pervious interlocking-block paving systems. All runoff from the impervious pavement would be directed to pervious areas where it can infiltrate. This solution is a good option because it would be less expensive to implement than a situation where we would replace the entire lot with permeable pavement. Cost wise, permeable pavement is significantly more expensive to install, about 50% more than conventional asphalt and concrete pavement (Un, 2010). The interlocking block look would also be visually interesting enough to attract people. The cons of such pavement would be that we might not be able to get maximum utility with impervious pavements so it would be less effective than having all permeable pavement. Permeable pavement can infiltrate as much as 70-80% of annual rainfall so a combination of permeable pavement and impermeable pavement should be able to infiltrate at least 50% of annual rainfall (Un, 2010) and a permeable pavement system designed to capture 1 inch of runoff from impervious surfaces will capture 89% of annual runoff (Minnesota Stormwater Manual, 2021).

Another solution is to repave these lots with conventional pavement over a subsurface detention system. The runoff from the lots can be stored and slowly released after the end of the storm event. This could be a good solution because runoff will go into the subsurface detention system where they can use the water later as needed or slowly release it back into the water cycle. The cost of this solution would be less than the previous solution because you wouldn’t need to install expensive permeable pavement.

The last solution would be to do nothing. This is not a good solution because what we have been doing so far hasn’t been working. The costs from doing nothing would be very large, at least a few million dollars, incase of flooding to university buildings. Additionally, not addressing the problem at all is problematic because then the problem worsens to a point where fixing it would be too great of a task.

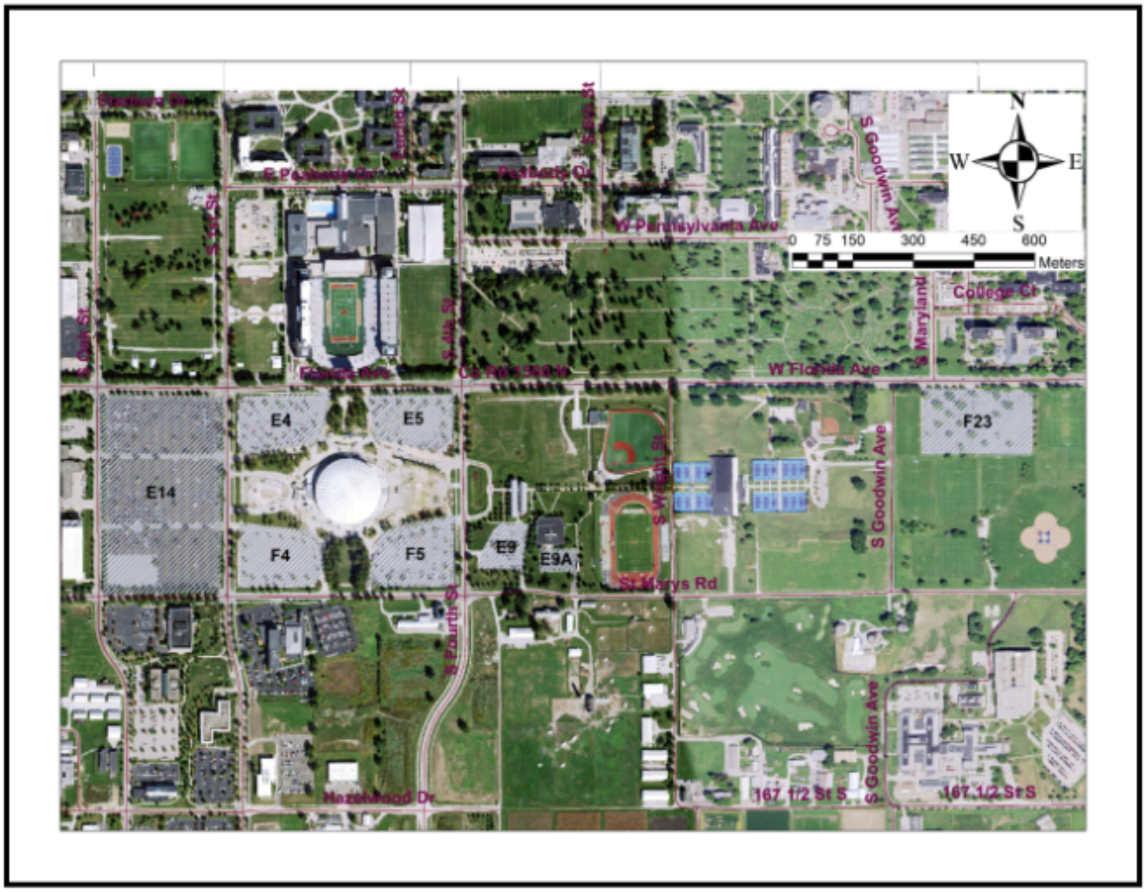

Figure 1. Map showing the location of the UIUC parking lots to be considered in this RFP.

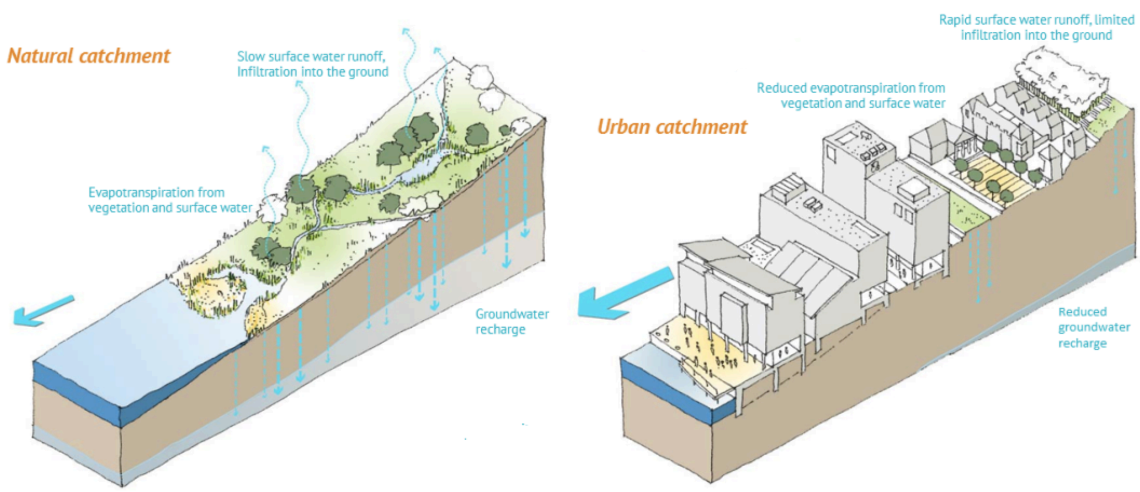

Figure 2. Because of urbanization, the natural permeable layer has been covered by an impermeable layer like asphalt which causes flooding and a lot of runoff (susdrain.org, n.d.)

Objectives

The objective of our project is to determine the feasibility of implementing permeable paving block pavement or subsurface detention for parking lots on the University of Illinois at Urbana-Champaign campus. Specifically, we will be considering the parking lots situated between Oak Street on the west and Lincoln Avenue on the east between Florida avenue on the North and St. Mary's Road on the south. We are reviewing the benefits and downfalls of three SUDS alternative solutions for the parking lots in respect to financial affordability, and environmental impacts. Our potential solutions include repaving the lots with a combination of pervious and impervious interlocking paving systems, repaving the lots with conventional pavement over a subsurface detention system and doing nothing. By end of ~6 months we plan to research the potential solutions by estimating the construction costs, comparing environmental impacts, examining the feasibility of all three alternatives and identifying the most beneficial solution. Our final assessment will include construction costs as well as a predicted timeline/ schedule that outlines the steps that will be taken to implement the changes over a twenty-year timeline. At the end of six months, we will take two weeks to provide a deliverable that states our recommended SUDS alternative and provides an outline for what to do next.

Scope

We plan to do a literature review by reviewing previous projects and inspecting their successes and downfalls. Then we will calculate our individual and total project costs and create estimates about various issues like environmental impacts. Then we will do a cost benefit analysis to figure out what the best solution would be regarding financial affordability and volume of stormwater stored. Finally, we plan to draft and write a cumulative report that states our preferred choice along with a course of action.

Task 1: Perform literature review of previous projects

To begin, we will perform a literature review of previous projects where we take two weeks to research and find previous projects that include parking lots that used pervious and impervious interlocking pavements and parking lots that used conventional pavement over a subsurface detention system. We will analyze these projects to find out how large of a project they were, how much stormwater runoff they held and how expensive they were. This type of analysis helps us get a better understanding of the limitations of our materials and gives us insight into how successful they may be for our project.

Given that the selected parking lots are the ones situated between Oak Street on the west and Lincoln Avenue on the east between Florida avenue on the North and St. Mary's Road on the south, we plan to do a site inspection and look at the blueprints to determine how large the parking lot is (in square feet), how many cars it can hold and record how much stormwater is currently present and how much stormwater it can hold.

The last step of our literature review will be to find a twenty-year analysis of each type of infiltration tech online that measures the infiltration rate and the maximum volume of water (in gallons) stored per square foot and how much stormwater (in gallons) is typically stored per square foot for each type of infiltration tech.

Task 2: Calculate estimates

Our next task would be to do some math to calculate some base estimates and do a cost-benefit analysis. Some basic knowledge that we would need to find would be how much annual precipitation the Champaign-Urbana area experiences. Then we would need to search the *Stormwater Utility Fee Credit and Incentive Manual* for both the City of Champaign and the City of Urbana to find out how much they charge for each unit of stormwater runoff. Then we would need to calculate how much we pay each city in stormwater runoff charges annually.

For our next step we would need to find out what is the cost per square foot for pervious pavement and using that we would need to calculate how much it would cost to install the pervious and impervious interlocking pavement. Then we find out the cost per square foot of traditional pavement and using that we need to calculate how much it would cost to excavate the area and install a subsurface detention system and then repave the parking lots with traditional pavement. This helps us determine the costs for each type of tech so that when we are evaluating the data and finding out what is the best option, we can see if the alternative is worth the price.

After that we need to find out the maintenance costs. This is helpful because even though one solution might have lower initial costs, it may need more maintenance and in the long run it may be more expensive than another solution with higher initial costs but less maintenance. Our first step here would be to find out the maintenance costs, durability and design life for traditional asphalt pavement. After that, we would need to find out the maintenance costs, durability and design life for pervious pavement and for an area with pervious and impervious interlocking pavement. Finally, we would need to see the maintenance costs, durability and design life for a subsurface detention system.

Our last step in Task 2 would be to calculate how much stormwater is conserved in gallons of water detained. To do this we would need to go on site or talk to the current site manager about whether or not we conserve any stormwater runoff from the parking lots right now and if we do then how much. Then we need to find out how much stormwater runoff we would save if we had pervious and impervious interlocking pavement and how much stormwater runoff we would save if we installed a subsurface detention system. This helps us see which stormwater management system is the best solution because it conserves the most runoff for us to reuse in the future.

Task 3: Evaluating and finalizing our plan

Our final task is to evaluate all our data and finalize our plan by choosing one management system. Our first step would be to organize all our data in a clean manner, separated by the three options that we are given. Then we analyze it to find out which option is the best choice given the following criteria: Affordability (because we need to have the funds to support our choice), Environmental impact (because water is a precious resource and we want a solution that conserves the most water that we can reuse in the future) and feasibility (because we want to take on a project that we know that we can complete). After analyzing the data we will draft and finalize a report in two weeks showcasing our recommendation and why it is the best solution for this project along with a course of action with next steps.

To reiterate, we will begin our project by doing a literature review where we research previous projects utilizing our three solutions. Then we will collect some data to get our base information to do a cost benefit analysis then we will use that data to create a report showcasing our recommendation and a course of action

Schedule for sustainable drainage system alternatives

The following section contains a preliminary schedule which includes a detailed timeline for the 13 weeks we estimate is needed for the completion of this project as well as a brief description of the tasks and subtasks we plan to complete. In Fig. 3, the black shading indicates the time and length of each overarching task and green shading indicates the proposed time for each subtask. The critical path for the proposed work is shaded in orange. As the project progresses, we plan to use blue to indicate tasks that are on-schedule, red for tasks that are behind schedule, and use purple for completed tasks.

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Dates	9/16	9/23	9/30	10/7	10/14	10/21	10/28	11/4	11/11	11/18	11/25	12/2	12/9
Task 1: Review Literature													
1.1 Review codes													
1.2 Review previous projects													
1.3 On Site visit													
3.1.1.1 Inspect local utilities and hazards													
1.4 Collect survey data													
1.5Summarize results in fig/tables													
Task 2: Calculate Estimates													
2.1 Annual rainfall and how much conserved (volume in gallons)													
2.2 City charges (per unit of runoff)													
2.3 Maintenance charges													
2.4 Check durability/design life													
Task 3: Evaluating and Finalizing Plan													
3.1 Analyze data and choose a solution													
3.1.1 Environmental/sustainability analysis													
3.2 Write report with course of action													

Figure 3.—Timeline for feasibility study of SUDS for UIUC parking lots.

The duration of this project will be 13 weeks with tasks 1.1, 2.1, 2.2, 3.1 on the critical path to complete this project. Task 1.1 is critical because we should not continue with any aspect of the project without making note of our legal limitations. Task 2 is where we start to get our quantities and has a lot of uncertainty given it requires data from at least one third party before we can analyze it and make assessments. Tasks 2.1 and 2.2 are critical because the rest of our calculations are determined based on the amount of rainfall experienced and conserved. We then use this data to calculate how much we pay each city and how much we can save if we try a different drainage system. Task 3 is our final task and this is where we analyze all our data and finalize our solution. Task 3.1 is critical because this is when we go through all of our collected data and analyze it from all aspects like the financial aspect, environmental aspect, and if it is a feasible project to take on. Only after we analyze our data can we move on to produce our final report.

Cost Estimation for Permeable Pavers and Subsurface Detention on UIUC Parking Lots

This section includes a parametric cost estimation for two of our proposed solutions: permeable pavers and a subsurface detention system. Here we will find similar projects that have been performed using our proposed solution and with the help of those, we will estimate the cost of using those solutions on our parking lots. A parametric cost estimation is not a detailed estimation, just a comparison of overall costs that we will adjust to fit our location and size. It isn't as accurate as a detailed cost estimation, but it takes much less time if we are looking for a quick estimate.

This section also includes a detailed cost estimation where we calculate our material cost by listing all our materials, their quantity and unit cost to estimate how much it would cost us to use it. Then we estimate our labor costs by listing out all the tasks we want done, how long it would take and how much would be done per hour. Then using that information, we would calculate our total costs. This type of cost estimation is more accurate because are going through each individual step and there is less that is unknown. However, this approach takes a lot longer than parametric cost estimation.

We are doing these two types of cost estimation to compare the two types of Sustainable Urban Drainage Systems (SUDS) to see which one is the most cost-efficient option.

Parametric Cost Estimation (Top-down)

To create parametric cost estimation for the pervious paver system, we used the project completed at the University of Tennessee (Interlocking Concrete Pavement Institute 2019), where they reconstructed the Student Union building, renovated the exterior plaza and build a new pedestrian walkway and bridge using an intricately designed permeable interlocking paver system. The total cost of the pavers, bas and labor for both phases of the was around $720,000 for an area of 56,000 ft^2. My second source is the project conducted at The University of California, Davis (Terhell 2015). Here, they performed a cost benefit analysis for permeable pavements to prove that the installation of permeable pavements will yield greater monetary benefits than using standard asphalt. They found out that the estimate cost for pervious pavers will be around $160,350 for an area of around 21,780 ft^2.

Table 1: Parametric cost estimation for pervious paver system.

Project	Total cost of pervious pavers from source (USD$)	Total area of pervious pavers placement (ft^2)	Total area of pervious pavers for UIUC parking lot upgrades (ft^2)	Scaled cost for pervious pavers for UIUC parking lot upgrades (USD$)
University of Tennessee (Knoxville)	$725,000	56,500	1,800,000	$23,100,000
UC Davis	$165,350	21,780	1,800,000	$13,700,000
			Average Estimated Cost	**18,400,000**

To do this cost estimation, we assumed that the total area that we would need to install pervious pavers for our UIUC parking lots is around 1.8 million ft^2 and we found this value by using the measure tool on google maps to find each individual area and added them together to get our total area. We then found out our scaled costs by dividing the total area of each project by its respective cost to get the cost per ft^2. Then we multiplied that cost per square foot with our total area for the UIUC parking lots and got our scaled costs. Then we found our average by taking the average of the two scaled costs and rounded up based on our confidence with our answer. Our final answer is closer to the scaled estimate of the University of Tennessee estimate because location wise, we are closer to Tennessee so the costs would be similar to that in Tennessee and area wise, our project is closer to that done at the University of Tennessee.

Average Parametric estimate: $18,500,000

To create parametric cost estimation for the pervious paver system, we used the projects provided to us in the EPA document (U.S. Environmental Protection Agency 2001). Towards the end of the document we are provided a chart which provides us with the total cost for both projects along with the volume of the detention system of both projects.

Table 2: Parametric cost estimation for subsurface detention system.

Project	Total cost of subsurface detention from source (USD$)	Total volume of subsurface detention from source placement (ft^3)	Total volume of subsurface detention for UIUC parking lot upgrades (ft^3)	Scaled cost for subsurface detention for UIUC parking lot upgrades (USD$)
Boneyard Creek	9,000,000	868,741	7,200,000	74,590,700
Jordan Landing	1,200,000	251,440	7,200,000	34,362,074
			Average Estimated Cost	**54,476,387**

To do this cost estimation, we assumed that the total volume of the detention system for our UIUC parking lots is around 7.2 million ft^3 and we found this value by using the measure tool on google maps to find each individual area and added them together to get our total area and measured them by our assumed depth of 4 ft. We got the assumed depth of 4 ft by doing research on google. We then found out our scaled costs by dividing the total volume of each project by its respective cost to get the cost per ft^3. Then we multiplied that cost per cube foot with our total volume for the UIUC parking lot detention system and got our scaled costs. Then we found our average by taking the average of the two scaled costs and rounded up based on our confidence with our answer.

Average Parametric estimate: $55,000,000

Detailed (Bottom-Up) Cost Estimation

Table 3: Detailed material estimation for pervious paver system.

Item	Quantity	Units	Unit Cost	Total Cost
Pervious pavers	1,800,000	Ft^2	$6.66	$11,988,000
Underdrain to storm sewer	1	Ft^2	$7500	$7500
Aggregate subbase	1,800,000	Ft^2	$0.66	$1,188,000
Filter Fabric	7,200,000	Ft^3	$0.11	$792000
			Total Material Subtotal	$13,975,000

Table 4. Labor estimate estimation for pervious paver system.

Labor Activity	Total labor hours	Labor Rate ($/hr)	Total Cost ($)
Excavate soil	**86,400**	**$93**	**$8,035,200**
Install porous aggregate subbase	**48,000**	**$50**	**$2,400,000**
Install subdrain	**48,000**	**$400**	**$19,200,000**
Install pervious pavers	**48,000**	**$50**	**$2,400,000**
		Total Labor Subtotal	**$32,035,200**

Final Detailed (Bottom-up) cost estimate: $46,100,000.

After we have calculated our detailed cost estimate given the total material costs and the total labor subtotal we arrive at a grand total of around $46 million. This value is significantly more than the estimated cost calculated in the parametric cost estimate but it may not be completely wrong. We calculated our parametric cost estimate using other projects and we are unsure of their individual costs of labor and materials and given the size of our project, we are bound to have very different numbers as even a small difference in an individual material or labor cost scaled up will result in a large overall difference in total costs.

Conclusions

Our objective was to determine the feasibility of implementing permeable paving block pavement or subsurface detention for parking lots on the University of Illinois at Urbana-Champaign campus. Over the course of this report, we can conclude that of the proposed solutions, repaving the parking lots between Oak Street on the west, Lincoln Avenue on the east, Florida avenue on the North and St. Mary's Road on the south, with a combination of conventional (impervious) and pervious interlocking-block paving systems is the best solution. As per our parametric cost analysis, permeable pavers may cost around $18.5 million for this project and a subsurface detention system may cost around $55 million for this project. As per our detailed cost estimate, permeable pavers may cost around $46.1 million. This means that permeable pavers may cost anywhere between $18.5 million and $46.1 million. This wide range in cost for permeable pavers is justified because costs are dependent on location, materials and where they came from, and who provided labor. Even if the difference in costs is nominal for unit costs, when applied to a project of our scale, the minor differences add up to result in a large change resulting in a very wide range of costs. Either way, permeable pavers are still significantly less expensive than a subsurface detention system so from a financial point of view, permeable pavers are the better choice.

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