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Mire Solutions: Expanding Permeable Pavement in Edmonston, Maryland

COURSE

ENST481: Ecological Design

PALS

An initiative of the National Center for Smart Growth
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Partnership for Action Learning in Sustainability



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ABOUT PALS

The Partnership for Action Learning in Sustainability (PALS) is administered by the National Center for Smart Growth at the University of Maryland, College Park (UMD). It is a campus-wide initiative that harnesses the expertise of UMD faculty and the energy and ingenuity of UMD students to help Maryland communities become more environmentally, economically, and socially sustainable. PALS is designed to provide innovative, low-cost assistance to local governments while creating real-world problem-solving experiences for University of Maryland graduate and undergraduate students.

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EXECUTIVE SUMMARY

Edmonston, Maryland is a small town in Prince George's County, a few miles from the nation's capital. It has a diverse community of just over 1,500 people with nonprofits and small businesses headquartered in town. In the hundred years since its inception, Edmonton has successfully pioneered green initiatives, including its keynote initiative: green streets.

Green streets feature green energy, recycled materials, and importantly, permeable pavement. Edmonston is in a flood plain, which, in 2020, experienced flash flooding (Town of Edmonston, 2020). Exact numbers aren't available, but many residents' homes were damaged. Edmonston has already taken steps to improve its flood resilience, with levees installed protecting much of the town (United States, 2025).

Prototyping permeable paving for Edmonston required several steps. The first step was creating SketchUp and CAD designs (see Appendixes D and E). Resources that fit the prototyping budget were researched. Simulating traditional pavement designs like permeable interlocking concrete pavement on a budget would be difficult. This led to testing several permeable pavers based on their percentage of impervious surface coverage.

This research and testing led to permeable interlocking concrete pavers (PICP). They are solid concrete paving units whose joint connection patterns create surface openings. The joint openings are filled with permeable aggregates and allow water to pass through the pavement. With regular maintenance infiltration rate can be up to 3.38 inches per hour (Bean et. al., 2007).

The goals of installing permeable pavement are to reduce flooding and the resulting costs for the Edmonston. PICP has a high initial upfront cost, ranging from four to twelve dollars a square foot (Noel, 2021). To install a road segment 580 feet long and 15 feet wide (8,700 square feet) would cost between $34,800 and $104,400 for concrete grid pavers. However, the cost of installation should be considered against the cost of prevented flood damage. FEMA estimates that three inches of flood water in a 1,000-square-foot single-story home, would cost $12,000 (FEMA, 2021) to repair.

In Edmonston, nine houses along 49th Avenue, from 4902 to 4914, have basements and are at risk of flooding. These houses are larger than the FEMA-estimated 1,000 square feet and damage costs would be higher.

Edmonston should install PICP on 49th Avenue where houses are in the floodplain area and not protected by the levee.

INTRODUCTION

The town of Edmonston, Maryland traces its roots to the initial purchase of the land in 1742 by a man known as Capt. Edmonston of Bladensburg, Maryland. The town is named either for him or after the road along the town's eastern border that

bears his family name. Throughout its history, the town has gone through many changes in terms of settlements, dwellings, and demographics, until it was incorporated as a part of Prince George's County in 1924. It was during this time in Edmonston's history that the State of Maryland became aware of major flash flooding occurring in the town.

Flooding in Edmonston is not a new issue; town minutes as far back as 1938 detail conversations between town officials and the War Department about flooding problems. This perpetual flooding is attributed to the flooding of the nearby Anacostia River and its tributaries in the Hyattsville-Bladensburg-Edmonston area. Climate change exacerbates current flash flooding in Edmonston today (Town of Edmonston, n.d.). And while the town has adopted flood mitigation efforts since issues were recorded in the 1930s, this report proposes an expansion and reinterpretation of a current ecological technology already extant in the community: permeable pavement.

Permeable pavement is pavement-construction material engineered to retain and percolate rainfall, unlike traditional impermeable pavement that results in high rates of stormwater runoff (Ongaga, et al., 2024). Stormwater runoff, beyond flooding, can lead to other issues in urban areas, such as combined sewer overflows (CSOs), which release pollutants collected in urban runoff into local waterways, impacting both aquatic life and human health (Roseboro, et al., 2021).

Studies have shown that implementing permeable pavement in flood prone urban areas can effectively mitigate flooding by reducing stormwater runoff accumulation. A mixed methods study researched the efficacy of permeable pavement in mitigating urban flooding and enhancing community resilience (Mohamad, 2024). The study combined quantitative data, field measurements and hydrological simulations, and qualitative data, surveys and stakeholder interviews. The research was conducted in urban areas already prone to flooding and where permeable pavement had already been installed.

The findings suggest that permeable pavements are highly effective in reducing surface runoff during heavy rainfall and significantly decreased its rate and volume, thereby mitigating the risk of urban flooding. Additionally, the researcher pointed out that by design, permeable pavement allows for water infiltration through its surface, allowing these systems to alleviate burdens on traditional drainage infrastructure. This is particularly pertinent to current conditions as flash flooding events are further exacerbated by climate change.

This report proposes a permeable interlocking concrete pavement (PICP) system. In a study, researchers created an artificial rainfall simulator to investigate the behavior of different surface concrete brick patterns under different rainfall intensities (Hashim, et al., 2022). The variables used to compare different patterns were runoff levels and the infiltrated water volume.

This report's experiment is modeled on the concepts proposed in Hashim, with

three configurations of a PICP system that could be implemented in Edmonston—a three-brick configuration, a four-brick configuration, and a five-brick configuration. Each was examined for their effectiveness in allowing water infiltration, a sign of retention.

OBJECTIVES

The goal of this study was to determine the best way for Edmonston to incorporate green technology to alleviate flooding. The chosen technology needs to fit the town's goals: flood risk reduction, climate resilience and adaptation, environmental sustainability, low-maintenance and long-term viability, equity and community benefit, replicability and educational value, and alignment with local and national sustainability goals.

PICP meets the criteria for each of these goals, and it also meets the goals of the Green New Deal (GND). The GND emphasizes upgrading infrastructure to be climate-resilient (Ocasio-Cortez & Markey, 2019), which PICP does by reducing surface runoff, improving flood resilience, and modernizing infrastructure with green technology. The GND also emphasizes sustainable and equitable urban development (Ocasio-Cortez & Markey, 2019); PICP helps alleviate disproportionate flood risks and models how green technology can support environmental justice. PICP also aligns with two other GND goals, job creation and environmental sustainability (Ocasio-Cortez & Markey, 2019). PICP is a scalable green technology that could lead to local manufacturing, installation, and maintenance jobs. It also supports innovation in civil engineering and urban planning. PICP is environmentally sustainable because it recharges groundwater, reduces pollutant runoff, and mitigates urban heat islands by allowing moisture to permeate and cool surfaces.

METHODS

Prototypes of three paver configurations were created to find the best PICP design for Edmonston.

For the prototypes, 2-inch by 8-inch concrete pavers were placed on top of Miracle-Gro moisture control potting mix, which acted as soil, inside a 320-ounce (2.5 gallon) plastic container. These containers were drilled on the bottom with the same size and number of holes to allow water to percolate through the soil and out the bottom. The bricks were arranged in different patterns depending on the number of bricks in each container. The most successful pattern would be recommended for Edmonston.

Three paver patterns were tested: three-brick, four-brick, and five-brick (see Appendix B). These designs were put through a five-step test to determine which most efficiently allowed water infiltration.

Prototypes were sprayed with a hose to mimic a rain event for two minutes. The prototypes sat for five minutes, then they were placed on water collectors for two minutes. The collected water was run through filter paper (to catch any soil) and the water was measured in a graduated cylinder.

The three-brick design captured 109.5 mL of water, the four-brick design captured 78 mL of water, and the five-brick design captured 112 mL of water. The five-brick design was the most effective and became the recommended design. It also accommodates walking and smooth riding of wheeled objects.

This prototype test is small, but this small-scale design can be repeated in a larger area or even sized up to use larger bricks.

Bean, Hunt, and Bidelspach (2007) found that regular maintenance can significantly improve infiltration rates and that the choice of fill material affects performance. This finding indicates that solid bricks or a system filled with pea gravel might fit. Regardless, the implementation of a PICP system will significantly reduce total runoff, anywhere between 24 and 75 percent (Al-Hamdan & DaSilva, 2023).

RESULTS

Initial design concepts are shown in Appendixes D and E. We initially envisioned toying with the material used to construct the permeable pavement as evidenced in Appendix E, before settling on a PICP system instead as depicted in Appendix B.

Initial designs left space between the pavers for grass to grow with the intention of increasing potential water retention (see Appendix D), however, further research showed a negative correlation between the amount of grass grown between permeable bricks and the amount of water retained, so grass wasn't included in the final design.

The three-brick PICP system was expected to allow for the highest water infiltration, but the five-brick system had a slightly higher infiltration rate. The results were: three-brick PICP system = 109.5 mL, four-brick PICP system = 78 mL, five-brick PICP system = 112 mL.

Due to the unique characteristics of PICP, implementation costs can be high. Installation can range from four to twelve dollars a square foot (Noel, 2021). The stretch of 49th Avenue from 4902 to 4914, is 8,700 square feet, and is estimated to cost $87,000 for materials.

Labor costs were estimated using a standard multiplier: labor costs = material costs × two. The labor for this project would be about $174,000.

The timeline for implementation would depend on several factors including, policy and legal discourse, materials transport, residential inconvenience, and weather conditions. Given that Edmonston is proposing construction of a Green Street project that includes permeable pavement as a core feature of bioretention, it's hard to say how long the implementation of a PICP system would take.

As for expected greenhouse gas reduction, one study found that permeable pavement emitted 75 to 95 percent less greenhouse gases, mainly due to the lower use of electricity during its life cycle (De Sousa, et al., 2012). Additionally, a case study in China showed that 73.48 percent of energy consumption, 46.70 percent of greenhouse gas emissions, 98.33 percent of lead emissions and 99.70 percent of zinc emissions could be avoided by using permeable pavement instead of conventional pavement (Wang, Y., Li, H., et al., 2018) (Antunes, et al., 2018).

DISCUSSION

Edmonston's goal in installing permeable pavement is to reduce localized flooding and minimize losses for residents, particularly in flood-prone areas. The literature consistently supports the effectiveness of permeable pavement systems in managing stormwater, with reduction effectiveness from 26 to 98 percent (Lee et al., 2023).

Permeable pavements can also reduce surface runoff, recharge groundwater, and improve water quality, especially when used in areas with moderate rainfall and appropriate subsoils. Furthermore, literature has shown that urbanization increases runoff; the more pervious surfaces are implemented, the worse it is for infiltration and runoff (Ongaga et al., 2024).

This principle was used in the prototype to test different brick configurations with each model using a different number of bricks. Existing literature has already touched on more commonly used pavement patterns: stretcher bond, 90-degree herringbone, and 45-degree herringbone (see Appendix A). The stretcher bond pattern performed best in reducing surface runoff, while the angled herringbone patterns were superior in terms of durability (Hashim et al., 2022). These findings were useful in designing new patterns to test.

The prototype experiments conducted using small-scale models used different numbers of bricks and different patterns. The three-brick model was in H-shaped, the four-brick model was O-shaped, and the five-brick model was laid out in a Roman numeral three shape (see Appendix B). The herringbone patterns inspired the three-brick and four-brick models, while the five-brick model combined stretcher bond and herringbone. However, these patterns are original and not found in the literature search, so the findings are new.

After applying water, it was expected that the three-brick model would allow the most infiltration because it had the most exposed soil, and that the five-brick model would allow the least, due to more brick coverage. However, the results defied expectations. The five-brick model captured the most volume, at 112 mL, while the four-brick model captured 78 mL, and the three-brick model captured 109.5 mL.

There are a few theories on this deviation. Most basic is that there were errors in

the experiment. For example, the prototype used a moisture-controlled potting mix that holds water very effectively. This was used because the soil releasing water slowly is less than ideal, and it would give a better idea of the effectiveness of the brick patterns. According to the Web Soil Survey, most of the soils in Edmonston are moderately to well-drained, so the prototype phase soils would work better with Edmonston's soils (Appendix C). This type of potting soil may have led to more inconsistent flow depending on compaction and distribution. In other words, if the bricks were packed differently across the boxes and compressed the soil unevenly, some boxes may have had a more open structure and quicker drainage.

Simpler errors, including differences in pouring rate, timing, or measurement accuracy, could also cause discrepancies. Another mistake was planting grass seeds in the soil between the bricks, an error based on misleading literature. The grass wasn't grown when the experiment was conducted, but it may have absorbed some water, which could have affected the result. A future prototype wouldn't include grass between the bricks.

Finally, only a single trial was conducted due to time constraints, but additional trials could have reduced errors. In the future, repeating the experiment at least five times would yield more accurate results.

These findings also suggest that brick arrangements create preferential flow paths. More bricks might create channels or gaps between bricks and soil, allowing water to flow faster and more directly through the soil layer and out the bottom holes. This points to the possibility of a threshold in the impervious-to-pervious surface ratio. In other words, increasing impervious coverage might enhance infiltration due to more pronounced preferential pathways.

It's not as simple as increasing the amount of pervious surface; rather, it's how the impervious elements are arranged that controls infiltration and runoff dynamics. One piece of literature that supports this idea also found a threshold; if the impervious area is small enough, all the water can be absorbed by the pervious area, with little runoff. However, once the pavement exceeds that threshold, runoff increases steadily as pavement area grows (Wang et al., 2024).

While the prototype was helpful in comparative testing, it lacks key elements of a proper permeable system, such as sub-base layers of graded aggregate essential for filtering, storing, and gradually infiltrating stormwater. A proper Permeable Interlocking Concrete Pavement (PICP) would be more effective at combating runoff. PICP has been successfully implemented in cities such as Chicago and Toronto, which saw reduced stormwater runoff while supporting pedestrian and vehicular traffic (FHW, 2015).

For meaningful impact in Edmonston, PICP installation should target areas in the floodplain where infrastructure is vulnerable. These areas include a stretch of 49th Avenue. PICP can have a high upfront cost, with installation ranging from four to twelve

dollars a square foot (Noel, 2021). The proposed stretch is approximately 8,700 square feet, and the PICP cost would range between $34,800 and $104,000. According to FEMA (2021), three inches of floodwater in a 1,000-square-foot single-story home, can generate up to $12,000 in damages. If the nine homes on 49th Avenue with basements experience flooding, the damage could reach $108,000 from one flood event.

Planning and zoning for the Town of Edmonston is handled by the Maryland-National Capital Park and Planning Commission, so any actions require their approval and support (Town of Edmonston, 2025). In the future, conducting more trials will be necessary. Also, research into the effectiveness of biocement as a sustainable alternative to traditional concrete pavers will inform long-term resilience plans for infrastructure. Furthermore, examining permeable asphalt compared to PICP is a worthwhile comparative literature review.

RECOMMENDATIONS

The prototype pattern would be unlikely to work in the field because it lacks crucial aspects of permeable interlocking concrete pavement, including several layers of permeable aggregates. Additionally, the prototype had a lot of open soil that could be eroded by wind.

To scale up, permeable interlocking concrete pavers should be installed on 49th Avenue, from 4902 to 4914. That road section is in the floodplain without protection from the levee. Additionally, many of the houses on the street have basements (visible on Google Street View), which puts them at a greater risk of flooding.

Even when installed appropriately, PICP is not without flaws. All these systems can have issues with clogging if fine sediment enters the pavement (Federal Highway Administration, 2019). PICP requires regular maintenance, like vacuum sweeping, to maintain the infiltration rate of the pavers. Edmonston would need to actively maintain the system to protect residents' property.

It would be valuable to take a cue from the town and its efforts in installing their Green Street, Decatur Street, which features a variety of green initiatives. Edmonston realized they had the opportunity to replace crumbling infrastructure with more sustainable options. PICP should be installed on a timeline that would coincide with scheduled repaving of 49th Avenue.

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APPENDIX

Appendix A.
Permeable pavement patterns



a- Stretcher bond



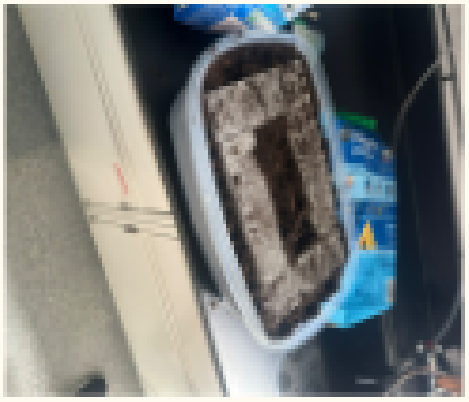
b- 90° Herringbone



c- 45° Herringbone

Appendix B.
Prototype configurations: three-brick, four-brick, five-brick







Appendix C.
Edmonston soil types

Description of Codorus

Setting

Landform: Flood plains
Landform position (two-dimensional): Toeslope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mica bearing loamy alluvium

Typical profile

A - 0 to 1 inches: silt loam
Bw - 1 to 57 inches: loam
Bg - 57 to 63 inches: loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Runoff class: Low

Description of Christiana

Setting

Landform: Drainhead complexes, swales, interfluves, hillslopes
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Clayey fluviomarine deposits

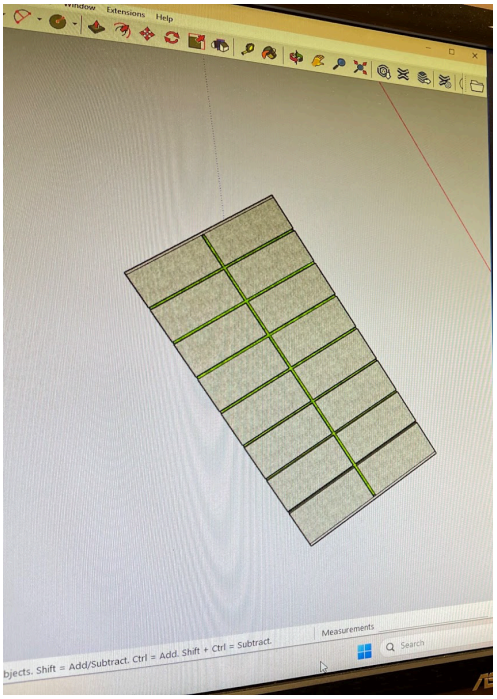
Typical profile

A - 0 to 6 inches: silt loam
BE - 6 to 10 inches: silt loam
Bt1 - 10 to 21 inches: silty clay loam
Bt2 - 21 to 49 inches: silty clay
BC - 49 to 80 inches: clay loam

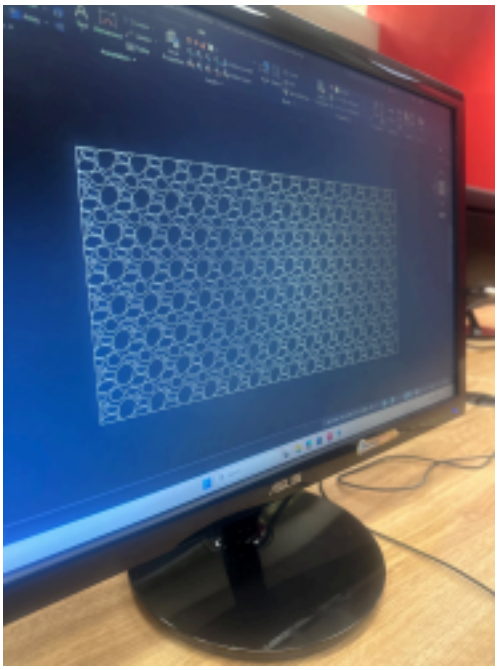
Properties and qualities

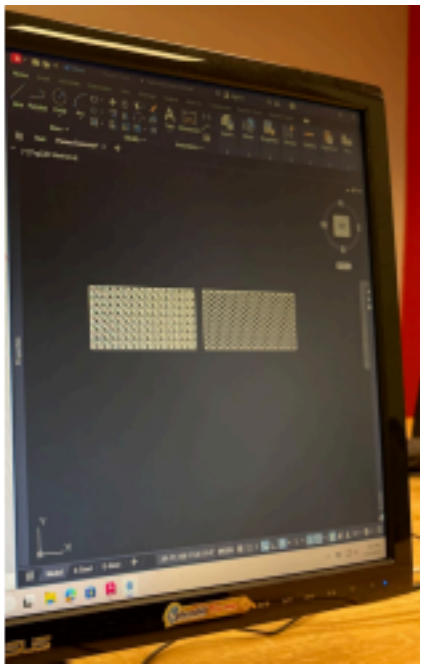
Slope: 5 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Runoff class: High

Appendix D.
SketchUp design



Appendix E.
AutoCAD design





Appendix F.
Team Contribution

Tafor Acho: My objectives on this project were to establish the material best suited for permeable pavement. With Josh Marlowe, I created two concept designs in AutoCAD and SketchUp of surface designs for the permeable pavement as well as the potential layout of the pavement. When the group changed its design idea from dealing with type of material to a PICP system, I aided in the packing of soil and planting of grass seed within the prototype. As it pertains to the Powerpoint presentation, I handled two slides: Possible solutions to flooding in Edmonston and Best solution chosen. In the report, I wrote and did literature reviews for the Introduction and Results sections.

Aryan Hadaegh: My work in the project's first phase included background research on permeable pavement and Edmonston. I used the Web Soil Survey to determine the soil types and drainage levels to find appropriate soils for our prototype. I did a literature review for the background research that included pavement configurations, which the team used to determine a new, innovative permeable pavement pattern. I helped create the budget and find materials for the prototype. I helped test the prototype during the lab by simulating rainwater through a hose on top of the soil. We watered, timed, and collected the infiltration volume before filtering out debris and recording our results. For the presentation, I did the Applicability, Replicability, and Sustainability of the Proposed Solution and SWOT Analysis sections. Finally, for the technical report, I wrote the Discussion section.

Joshua Marlowe: My contributions included performing site assessments in the town, using Web Soil Survey to analyze the area soil, assisting with prototype building, using autoCAD and SketchUp to design the prototype, watering the prototype to allow for the grass seeds to grow, and completing/presenting the specifications and calculations and results portion of the presentation. For the final report I completed the objectives and methods section.

Isabella Wahl: My contributions to the prototype included making budget/adding materials, making the prototype, watering the prototype, and testing the prototype. My contribution for the report included the title page, executive summary, and recommendations.





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