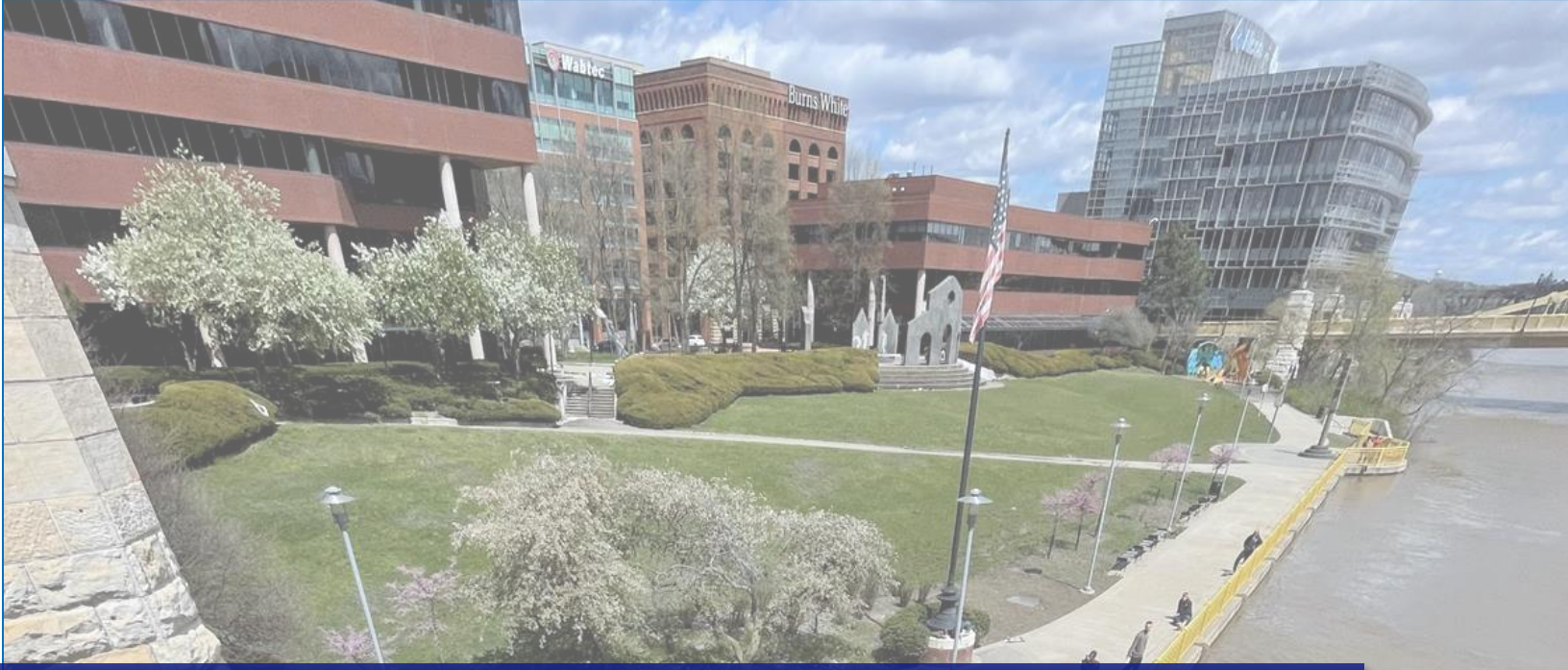

RECOMMENDATION REPORT

A Consideration of Stormwater Runoff Mitigation Solutions

Pittsburgh Department of Mobility and Transportation

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April 18, 2024

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Executive Summary

Stormwater runoff presents significant challenges to urban areas, contributing to pollution, flooding, and erosion. In Pittsburgh, a city with an aging infrastructure and a diverse topography, these challenges are particularly troubling. In addition, as the effects of climate change become more pronounced and the frequency of extreme weather conditions increases, addressing stormwater runoff in Pittsburgh has become an urgent priority. Current stormwater management practices in Pittsburgh are insufficient to effectively mitigate the impacts of runoff. This inadequacy exacerbates pollution in the Monongahela, Allegheny, and Ohio rivers, places excessive strain on existing urban infrastructure, and heightens flood risks. These practices actively impede traffic and pose threats to both the environment and public safety.

Central Oakland, and specifically the University of Pittsburgh campus, is a well trafficked area that experiences considerable stormwater runoff due to dense urban development and impervious surfaces. The Pitt campus contributes to this runoff through its wide infrastructure and continually growing student body. As the University of Pittsburgh expands, stormwater poses an increasing threat to the safety of students and travelers along the major streets which pass through campus.

To better understand and assess the current effectiveness of stormwater practices in Central Oakland and their impact upon residents, a survey was conducted along with direct field observation. The survey was made available to both Pitt students and staff members, and was imagined to contribute to collaborative efforts between Allegheny County government, University of Pittsburgh administrators, and Central Oakland residents. Field studies were conducted to analyze flooding along Fifth Avenue, Bigelow Boulevard, and Allequippa Street. The results of the survey and observations made were then analyzed to develop potential courses of action.

The primary finding is that 89% of Pitt students and staff members surveyed notice excessive flooding despite runoff systems in place. This analysis concludes that the current stormwater systems have been noticed to be ineffective by Pitt residents. Additionally, no action has been observed to alleviate flooding problems. These survey results underscore the need for reformed stormwater infrastructure in Central Oakland.

Two primary recommendations ought to be considered. First, increasing public education and outreach campaigns through collaboration with the University of Pittsburgh can raise awareness about the importance of sustainable stormwater practices. In conjunction with this partnership, the implementation of rain gardens and bioswales should be considered in and around Central Oakland. After assessing the budgets of past public work projects in Allegheny County, bioswales prove to be not only effective methods of runoff management, but also cost considerate. Refitting existing infrastructure and investing in management projects may also be considered. However, restructuring current roadways to account for permeability will be time consuming and disruptive. The recommendations presented offer a practical solution that can be implemented immediately to help control excessive stormwater runoff.

By investing in green infrastructure and fostering Pittsburgh community engagement, the Department of Mobility and Transportation can help reduce the adverse effects of stormwater runoff. These actions will ensure resiliency in our urban communities for future generations.

Introduction

Stormwater runoff presents a significant challenge for urban areas, and Pittsburgh, with its hilly terrain and aging infrastructure, is no exception. In recent years, the city has especially grappled with the adverse effects of stormwater runoff. Excess runoff has led to increased pollution, flooding, and erosion throughout Allegheny County. These impacts disrupt the flow of traffic in Pittsburgh, and present serious safety concerns for the public's well-being.

Central Oakland, a densely populated urban area, experiences considerable stormwater runoff. The University of Pittsburgh, as a major institution situated within Central Oakland, plays a significant role in stormwater management through the campus' expansive footprint and impermeable surfaces.

Due to an increase in precipitation over the past decade as well as the looming threat of extreme weather conditions due to climate change, Allegheny County must implement effective stormwater management systems in Central Oakland and throughout the rest of the city. Despite this timely issue, current stormwater management in Central Oakland has not been particularly successful.

A survey and direct observation were conducted among University of Pittsburgh students and staff which assessed the public opinion on the quality of stormwater management on campus. The survey inquired whether Pitt residents had observed excessive flooding on campus, whether the flooding impacted their routes traveled on campus. The survey also asked whether Pitt residents were satisfied with the current drainage systems on campus and if residents had ever observed water runoff maintenance being performed. Additionally, a field study analyzing the current stormwater mitigation systems in place and their effectiveness was performed along Fifth Avenue, Bigelow Boulevard, and Allequippa Street. Detailed observations and photos were taken to better understand the implementation of runoff management on campus.

Furthermore, research was conducted on Pittsburgh's current stormwater practices and their efficacy. Secondary sources included data from Team PreciPITTation, a group of environmental scientists at the University of Pittsburgh; a pilot study from The RAND Corporation assessing Pittsburgh's acute vulnerability to flooding; and a community consensus report on approaches to flooding in Southwestern Pennsylvania published by the Pittsburgh Collaboratory for Water Research, Education, and Outreach.

This report encompasses the current issues in stormwater management within Pittsburgh and provides recommendations for future sustainable infrastructure solutions within Central Oakland. Recommendations for water management for the whole of Allegheny County are not considered in this report. The suggested courses of action pertain specifically to the University of Pittsburgh with respect to Pittsburgh Department of Public Works budget and prior university spending towards campus infrastructure. For broader recommendations and stormwater assessments, consult the Allegheny County Conservation District or current municipality stormwater regulations.

Based on the data collected in this report, existing stormwater management systems fail to mitigate excessive flooding. The survey found that 60% of Pitt residents had never observed stormwater maintenance being performed on campus. Furthermore, it is expected that

stormwater volumes will continue to rise due to climate change, and increased runoff will contribute to pollution in Pittsburgh's rivers.

The data collected supports two primary recommendations. First, increasing public education and outreach campaigns through collaboration with the University of Pittsburgh can raise awareness about the importance of sustainable stormwater practices. Although simple, this recommendation will actively bolster attention towards the growing problems arising from poor stormwater management. The second recommendation applies to the enactment of sustainable infrastructure on the University of Pittsburgh campus and in the surrounding neighborhood of Central Oakland. While a redesign of major roadways within Central Oakland was considered to adjust for the sloping and direction of runoff flow, this solution presents several challenges with respect to time and budget. Instead, the expansion of bioswales is highly recommended to absorb runoff and filter pollution before stormwater enters public waterways.

In the following sections, the research methods pursued, results, and recommendations offered are described in further detail.

Research Methods

The research methods used in this study included surveying, direct observation, and a literature review of published studies related to stormwater management and urban planning. The analysis of the efficacy of current stormwater management systems was broken down into tasks:

1. understand the current stormwater management systems utilized in Central Oakland
2. determine the University of Pittsburgh's student and staff attitudes and knowledge towards current stormwater management systems in Central Oakland
3. establish goals for future stormwater management
4. develop criteria for selecting runoff mitigation solutions and determine future action

Task 1: Understand the current stormwater management systems utilized in Central Oakland

Direct observation was used to assess the current state of stormwater management infrastructure and practices within Central Oakland and the University of Pittsburgh campus. Field visits to major sites of vehicle and pedestrian traffic around campus during heavy rainfall were conducted. Fifth Avenue, Bigelow Boulevard, and Allequippa Street were the primary locations visited to observe stormwater drainage, impervious surfaces, green infrastructure installations, and areas prone to flooding.

Significant flooding was determined based upon the depth and frequency of water collection observed obstructing vehicle and pedestrian lanes of transportation. The depth of puddles was determined using a ruler, and a puddle was indicative of excessive flooding if it was at least five inches in depth in a vehicle roadway, or of at least two inches in depth in a pedestrian walkway. Detailed observations were recorded using photographs and notes to document existing conditions and identify potential areas for improvement. Observational notes and all photos taken can be found in the Appendix on page 14.

Task 2: Determine the University of Pittsburgh's student and staff attitudes and knowledge towards current stormwater management systems in Central Oakland

A survey was conducted to gather data on perceptions, attitudes, and behaviors related to stormwater runoff among students and staff within Central Oakland. The survey included questions about awareness of flooding issues, the impact of stormwater runoff on campus transportation, attitudes towards current stormwater initiatives, and frequency of observed runoff maintenance. The survey also included a notes section for participants to include any additional details regarding their knowledge of current stormwater management on campus.

The survey was open to both Pitt students and staff members. It was delivered electronically through email lists and social media platforms to gain broad participation. The full survey can be found in the Appendix on page 17.

Task 3: Establish goals for future stormwater management

To develop goals for future stormwater management, a review of academic and research reports related to stormwater management, urban planning, and green infrastructure was completed to provide context for the recommendations of this study. The review included both University of Pittsburgh specific research from the institution's repository and research reports from third-party groups including The RAND Corporation. The review also included

previous stormwater management plans published by the Pittsburgh Water and Sewage Authority and insights from a community consensus report sponsored by the Pittsburgh Collaboratory for Water Research, Education, and Outreach. All insights were synthesized to contextualize the current challenges associated with stormwater runoff in Pittsburgh and used as a basis for future steps to mitigate runoff issues.

Task 4: Develop criteria for selecting runoff mitigation solutions and determine future action

After significant analysis of the current stormwater management systems, a set of criteria was used to dictate the further steps that should be taken in order to mitigate the current runoff issues.

The first criterion established was cost. The operating budgets for the Department of Public Works in Pittsburgh for the years 2023 and 2024 were analyzed to determine a reasonable budget for any proposed solutions. In 2023, the Department of Mobility and Infrastructure set a total budget of $11,313,840, specifically with a materials budget of $316,000 and an engineering budget of $50,000 (Pittsburgh City Council, 2023). Similarly, in 2024, a total budget of $11,767,762 was established with $316,000 reserved for materials and $50,000 for engineering (Pittsburgh City Council, 2024). These budgets encompassed all neighborhoods within the city of Pittsburgh, thus the proposed budget for stormwater systems in Central Oakland would have to account for the presence of 90 total neighborhoods within the region (Pittsburgh City Council, 2024). A final budget of $45,000 was chosen to guide future recommendations.

The second criterion established was time. An immediate resolution to current runoff issues was preferred, so stormwater solutions which could be fulfilled within a year to date were prioritized.

The third criterion established was displacement and work input. This criterion was selected like the second criterion of time with respect to the efficiency of implementing a new runoff management system. Solutions should require the least disturbance to the environment and existing infrastructure in Central Oakland.

The final criterion established was longevity. Longevity ensures that stormwater management solutions may remain effective over time. Solutions with great longevity contribute to the sustainability of infrastructure and may reduce future costs and resource consumption. Long-lasting infrastructure ensures continued benefits, so stormwater systems which could withstand the test of time were selected.

Future action steps were determined by using a decision matrix with the established criteria. See ***Table 1*** in the Appendix on page 18 to view the completed matrix.

Results

Only the most significant results of the research conducted have been included as they pertain to the tasks defined.

Task 1: Understand the current stormwater management systems utilized in Central Oakland

The direct observation research conducted in Central Oakland provided valuable insights into the current stormwater management systems and practices utilized on the University of Pittsburgh's campus. The observations revealed several findings regarding the infrastructure and effectiveness of current stormwater management.

1. Infrastructure Overview
    - Storm Drains: Central Oakland is equipped with an extensive network of storm drains. These drains are designed to channel rainwater away from streets and buildings and are typically along roadways and in low-lying areas. Storm drains were spotted in several locations along Fifth Avenue and Bigelow Boulevard.
    - Inlets: Numerous inlets are scattered within Central Oakland to catch surface runoff and direct it to the storm sewer system. The storm drains observed were often accompanied by inlets.
    - Bioswales: Bioswales are channels made of native vegetation designed to guide runoff into drains while removing pollutants. The University of Pittsburgh campus has two bioswales observed during the site visit—one on Allequippa Street in front of Sutherland Hall, and one adjacent to Bigelow Boulevard.
    - Combined Sewer System: Much of Central Oakland is serviced by a combined sewer system, where stormwater runoff and sanitary sewage are conveyed through the same pipes to wastewater treatment plants.
2. Effectiveness
    - Maintenance Challenges: Despite the presence of stormwater infrastructure on campus, roughly fifteen sites of excessive flooding were located on the site visit. The largest flooding was spotted on Bigelow Boulevard and measured about eleven inches (see ***fig. 2***). Several instances of excessive flooding were also observed on pedestrian walkways, particularly on Fifth Avenue in front of the Towers Lobby as shown in ***fig.1***. While there was a storm drain present, it appeared that the slots in the drain had been overwhelmed and thus could not provide adequate runoff dispersion. Poorly maintained infrastructure can diminish the effectiveness of stormwater management systems and exacerbate flooding issues.

Figure 1 Flooding observed in pedestrian walkway on Fifth and Thackeray intersection. Puddle depth measured to approximately five inches.

- Limited Green Infrastructure: While some areas feature green infrastructure elements such as vegetated bioswales, these features are relatively scarce compared to traditional grey infrastructure. This lack of green infrastructure contributes to increased stormwater runoff and reduces opportunities for natural infiltration and filtration.

Figure 2 Large pool of water observed on Bigelow Boulevard. Pooling due to overwhelmed drainage system as indicated by red blocking over the sewer grates. Puddle depth measured to approximately eleven inches.

The direct observation research highlighted the strengths and weaknesses of the current stormwater management systems in Central Oakland. These observations were used in the analysis of runoff mitigation systems.

Task 2: Determine the University of Pittsburgh's student and staff attitudes and knowledge towards current stormwater management systems in Central Oakland

37 participants completed the digital stormwater survey. Although this number is shy of the university's total population, both student and staff responses were recorded. The survey yielded insights regarding awareness, perceptions, and areas for improvement.

1. Awareness of Stormwater Runoff
    - Approximately 89% of respondents indicated that they had noticed excessive flooding after rain while on campus. The remaining 11% of respondents reported no excessive flooding after rainfall (see ***fig. 3***).

- Interestingly, despite most respondents reporting excessive flooding, only 31% of respondents stated that flooding had impacted their routes to and around campus. 69% of respondents reported that flooding had no effect on their routes to and around campus.

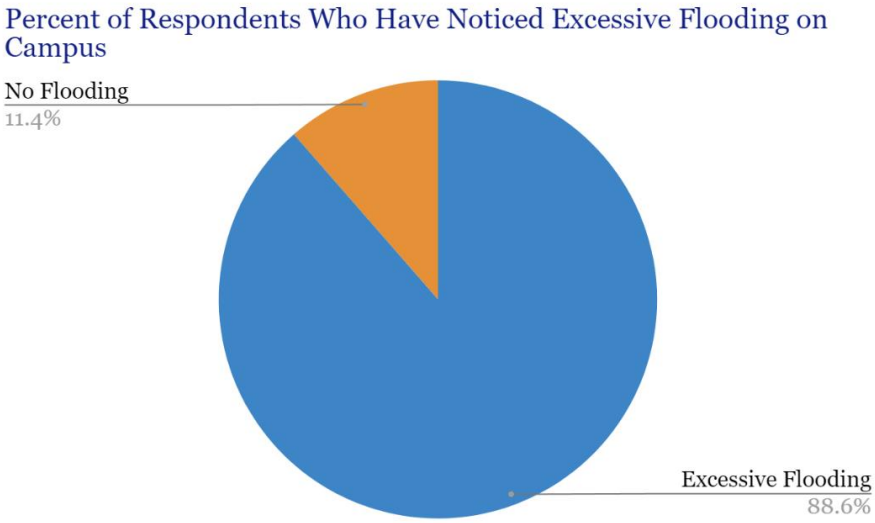

Figure 3 Survey results among 37 Pitt students and staff members when asked whether they had noticed excessive flooding (puddles and/or pooling after rain) while on campus.

2. Perception of Current Systems
    - As seen in ***fig. 4***, On a scale from one to five, with one being extremely dissatisfied and five being extremely satisfied, respondents were asked to select how satisfied they are with the current drainage on campus during heavy rainfall. 5% of respondents were extremely dissatisfied, 55% of respondents were dissatisfied, and 40% of respondents were neutral. No responses were satisfied with the current drainage on campus during heavy rainfall.
3. Areas for Improvement
    - The survey identified significant gaps in the observance of maintenance and active stormwater mitigation.
    - When asked how often water runoff maintenance was observed being performed on campus, about 60% of respondents reported they had never seen maintenance being done. The remaining 40% of respondents reported that they had rarely seen maintenance being done.
    - Approximately 33% of respondents noted that while they did not have much knowledge on stormwater runoff, they would be interested in more information and educational resources. There was a consensus among respondents that educational initiatives focusing on the importance of sustainable stormwater practices and individual actions could help foster a culture of environmental stewardship within the University of Pittsburgh community.

Overall, the survey results indicated that raising awareness, promoting education, and implementing sustainable stormwater management practices in Central Oakland were favorable among the University of Pittsburgh staff and student population. Addressing maintenance issues, knowledge gaps, and enhancing public engagement are essential steps towards a more resilient stormwater management framework.

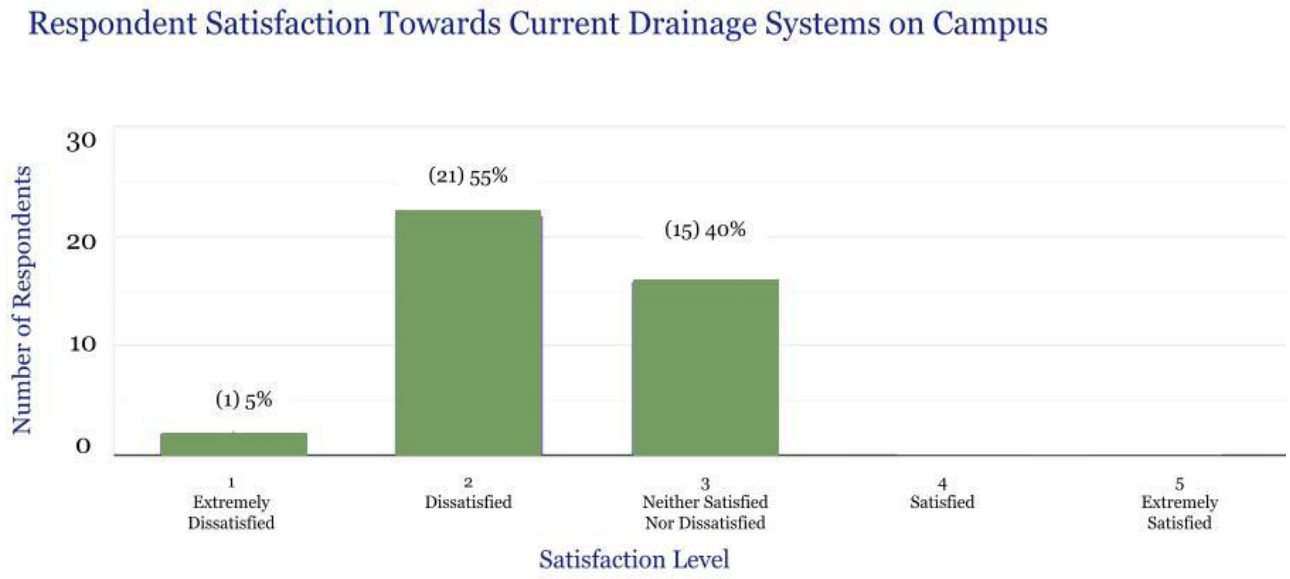

Figure 4 Survey results among 37 Pitt students and staff members when asked to select their satisfaction level with the current drainage systems on campus during heavy rainfall.

Task 3: Establish goals for future stormwater management

The sustainability and longevity of any proposed solutions stands as a considerable factor when considering future effectiveness. Quantitative frameworks such as the Robust Decision-Making analytic model has predicted that as of 2017, sewer overflow volumes over the past fifteen years have increased by approximately 15% (Fischbach et al. 34). As of this month, Pittsburgh has experienced its wettest April, and has continually been receiving greater amounts of rainfall ("Precipitation Records for Pittsburgh"). Inflow and infiltration can contribute up to an additional 3,000 gallons of stormwater per person per day to the already overwhelmed sewage system. This mass influx of water contributes to roughly 9 billion gallons of combined stormwater and wastewater entering Pittsburgh's rivers annually (Rosen 43). It is likely that future increases in precipitation could contribute to increased sewage overflow, so runoff solutions ought to be dynamic by design to account for a variety of runoff volumes. Demand forecasting may be extremely beneficial when developing stormwater runoff solutions.

An innovative solution to stormwater runoff also ensures the health and safety of the people and the environment. An effective stormwater management system in Central Oakland should help provide clean water for the community and adhere to the ASCE Standard Practice for Sustainable Infrastructure (Brewster et al. 3). Access to the full Practice may be found in the Appendix on page 19. Given the billions of gallons of wastewater entering Pittsburgh's rivers, an efficient runoff mitigation system should not simply dispose of stormwater, but rather use it as a tool for purification.

Finally, based upon the prevalence of stormwater within Central Oakland and more specifically the University of Pittsburgh campus, it is essential that community members are made aware and feel empowered to actively participate in stormwater management initiatives. Citizen-updated maps of flooding and areas of high-precipitation can further advance the mitigation of runoff (Elliot et al. 11). Fostering community involvement can also contribute to improved maintenance and monitoring of stormwater management infrastructure (Elliot et al. 17). Regular inspection and maintenance protocols for storm drains along with monitoring programs rely on community support to identify future areas of improvement. Greater collaboration and partnership between the Pittsburgh Department of Mobility and Transportation and the University of Pittsburgh may prove to be beneficial when implementing stormwater management strategies that benefit the entire Central Oakland community.

Task 4: Develop criteria for selecting runoff mitigation solutions and determine future action

The cumulation of research used to analyze the current stormwater management systems resulted in four necessary criteria and one desirable criterion for future modifications and improvements. When determining further action, if a mitigation solution failed to meet the four necessary conditions, it would be removed from consideration.

1. Cost: The total budget including all materials, labor, and first year maintenance costs must be no greater than $45,000.
2. Time: Any solution proposed must feasibly be completed within one calendar year of the starting date.
3. Displacement and Work Input: Proposed solutions should not require mass displacement or extreme modifications to pre-existing buildings, public spaces, or infrastructure. Additionally, the work input should correspond with that of the time constraint. The work input required should not require labor or supplies which would exceed the set budget, nor should it require significant outsourcing.
4. Longevity: Due to the mass amounts of precipitation Pittsburgh has experienced in recent years as well as the aging grey infrastructure, stormwater mitigation solutions should be sustainable and dynamic in their ability to account for changing weather conditions.

In addition to the four major criteria, aesthetics and appearance were also considered in the analysis of potential solutions. Like the third criteria of displacement, runoff solutions should not substantially impact pre-existing infrastructure, nor should they detract from the allure of the University of Pittsburgh campus. Implementing unsightly or otherwise overbearing runoff collection on campus would also act against the established goal of fostering involvement between the Pittsburgh Department of Mobility and Transportation and the University of Pittsburgh.

With these criteria in mind, the implementation of permeable pavers, the placement of rain barrels, the replacement of drainage gates, and the expansion and relocation of bioswales, were considered as potential solutions. Although extensive stormwater management solutions act to modify preexisting infrastructure, each solution considered be implemented within a year and demanded minimal input, so budget and time did not act as limiting factors. The selection process utilized a decision matrix which can be found in the Appendix on page 18.

The primary finding was that displacement criterion would severely limit the opportunity to implement green infrastructure that was starkly different from the current stormwater management systems in place. While initially the repaving of major roads and walkways using permeable pavement was considered, even a conservative estimate of the cost would exceed the available budget. Thus, the implementation of permeable pavers was removed as a solution.

A significant concern regarding the placing of rain barrels in an urban area was that pedestrians and residents would use the barrels as trash cans. This concern would disservice the aesthetics of the University of Pittsburgh campus and reduce the effectiveness of the barrels. Ultimately, rain barrels were eliminated as a potential option.

Finally, the longevity of the final two runoff solutions was compared. While the replacement of sewage grates could serve to fix the current blocked drainage issues, it was doubtful that this solution would withstand the test of time. The grates could simply become blocked again, and replacing the grates would not serve to prevent sewage overflow. Clearly, the expansion of bioswales around Central Oakland would be the viable option to pursue. Additionally, bioswales would contribute to the natural aesthetics of the region. The final recommendations are included in the following section.

Recommendations

Based on this analysis, it seems logical to pursue the expansion of bioswales within the Central Oakland and specifically the University of Pittsburgh region. Bioswales would not detract from preexisting transportation infrastructure, would serve to filter stormwater before it entered sewage systems, and would fit within budget constraints.

While there are a few bioswales on campus, an expansion of bioretention facilities is recommended. Specifically, bioswales should appear more frequently in low-laying ground. It is recommended that a small bioswale is added in the central region in front of the William Pitt Union. Not only would this addition reduce flooding in pedestrian walkways, but it would contribute to the aesthetics of the University of Pittsburgh campus. It is also recommended that an additional bioswale is built in front of Benedum Hall, ideally to replace the current mulch and shrubs. This bioswale would be particularly effective in preventing excess runoff from flowing from upper campus to Fifth Avenue and the remaining lower campus.

Aside from the implementation of physical infrastructure, social infrastructure can also be improved to bolster community engagement pertaining to sustainable water systems. Forging a partnership with the University of Pittsburgh would enable the Department of Mobility and Transportation to target students, faculty, and staff to reach broader audiences. Organizing stormwater management workshops, seminars, and hands-on demonstrations would raise social awareness about Pittsburgh's infrastructure and could help to support potentially larger green infrastructure projects in the future.

By expanding the use of bioswales and establishing a partnership with the University of Pittsburgh for education events, Central Oakland can take significant strides towards improving stormwater management practices and fostering community engagement. These recommendations offer practical and effective strategies for enhancing drainage, promoting sustainability, and building a more resilient urban environment.

References

Bowers, Rachel. *Exploring the Equity Implications of Green Stormwater Planning in Pittsburgh, PA*. Tufts University, 2021. https://www.proquest.com/docview/2545969578?pq-origsite=gscholar&fromopenview=true&sourcetype=Dissertations%20&%20Theses

Brewster, Brandon et al. *Team PreciPITTation: Addressing Our Urban Campus Stormwater Needs*. Environmental Protection Agency, 2019. https://www.epa.gov/sites/default/files/2021-04/documents/m35-project_narrative.pdf.

City of Pittsburgh, Pittsburgh City Council. *2023 Operating Budget & Five-Year Plan*. City Council Budget Division, 2 May 2023, Accessed 17 Apr 2024. https://apps.pittsburghpa.gov/redtail/images/23254_2023_Operating_Budget.pdf

City of Pittsburgh, Pittsburgh City Council. 2024 Operating Budget & Five-Year Plan. City Council Budget Division, 6 Mar 2024, Accessed 17 Apr 2024. https://apps.pittsburghpa.gov/redtail/images/24607_2024_Operating_Budget.pdf

Darby, William P. and Small, Mitchell J. "Identifying Urban Flash Flooding Problems." *Journal of the Water Resources Planning and Management Division,* vol. 102, no. 2. https://doi.org/10.1061/JWRDDC.0000028

Elliot, Emily et al. *Flooding in Southwestern Pennsylvania: Knowledge Gaps and Approaches. D-Scholarship at Pitt, 2020.* https://d-scholarship.pitt.edu/38237/

Fischbach, Jordan et al. *Robust Stormwater Management in the Pittsburgh Region.* The RAND Foundation*, 2017.* https://www.rand.org/pubs/research_reports/RR1673.html

"Precipitation Records for Pittsburgh." *National Weather Service*, National Oceanic and Atmospheric Administration, 1 Jan. 2023. www.weather.gov/media/pbz/records/prec.pdf

Rosen, Amy. *An Integrated Methodology for Developing Urban Metabolism through Pittsburgh's Storm Waters*. Carnegie Mellon University, 2023. https://kilthub.cmu.edu/articles/thesis/An_Integrated_Methodology_for_Developing_Urban_Metabolism_through_Pittsburgh_s_Storm_Waters/23932743?backTo=/collections/_/5757920

United States, Congress, House. Green Infrastructure and Issues in Managing Urban Stormwater. Congressional Research Service, 2 May 2016. Accessed 17 Apr 2024. https://crsreports.congress.gov/product/pdf/R/R43131

"Urbanization and Stormwater Runoff." *EPA*, Environmental Protection Agency, Accessed 18 Apr 2024. www.epa.gov/sourcewaterprotection/urbanization-and-stormwater-runoff#:~:text=Local%20government%20officials%20can%20use%20subdivision%20growth%20controls%2C,sources%2C%20or%20facilitate%20cluster%20development%20to%20reduce%20runoff.

Note: All figures are self-produced—including the image used in the title page—and therefore are not cited as per MLA guidelines.

Appendices

Observational Notes and Photos

The following photos were taken during the field study conducted on the University of Pittsburgh's campus. The depths of puddles are included as observational notes.

Illustration A
Drainage slots implemented along sidewalk on Fifth Avenue near the William Pitt Union. Water depth approximately half an inch. Effective draining in most sections, though significant blockage was noted at two points along the sidewalk.

No maintenance was observed being performed during the field visit.

Illustration B
Large puddle observed along Fifth Avenue in front of Towers Lobby stairs. Water depth approximately four and one quarter inches. Water primarily pooled in the street causing excessive splash onto pedestrian walkway.

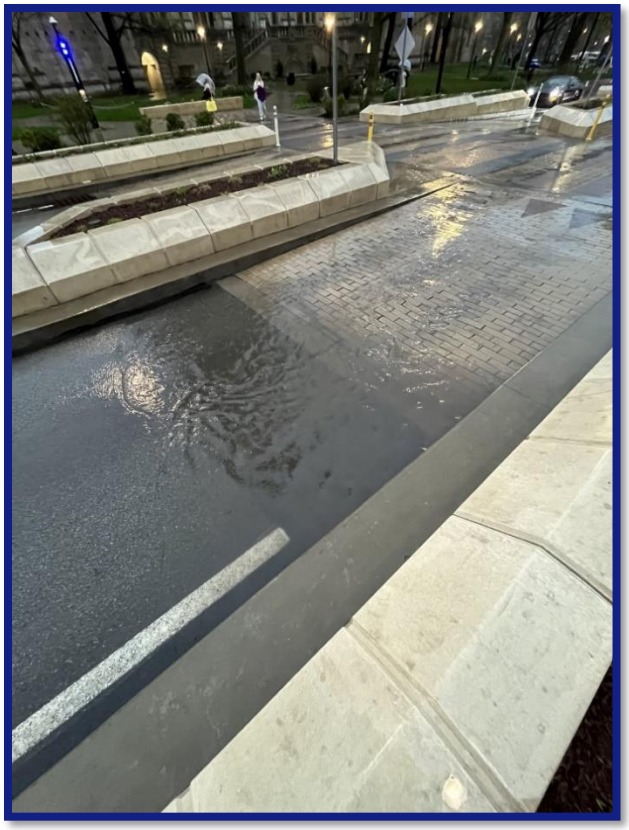

Illustration C (left) and Illustration D (right)

Extremely large pool observed on Bigelow Boulevard. Pool depth measured approximately eleven inches. Water is observed to pool on top of an overwhelmed storm drain. Drain grates are slightly visible in Illustration C. Pooling takes place near a preexisting bioswale, which seems inefficient due to concrete curbing surrounding the bioretention facility.

Illustration E

Flood stream observed on Fifth Avenue flowing from Thackeray Avenue and Benedum Hall. Water was observed to be rushing rapidly towards a sewage grate. Despite unclogged grate slots, water still overflowed onto the street. Puddle depth approximately three inches.

Illustration F
Drainage grate located in front of the William Pitt Union. The small size of the drainage slots resulted in debris clogging and prevented runoff from properly flowing into sewage system. Water pooled to roughly two inches around the site.

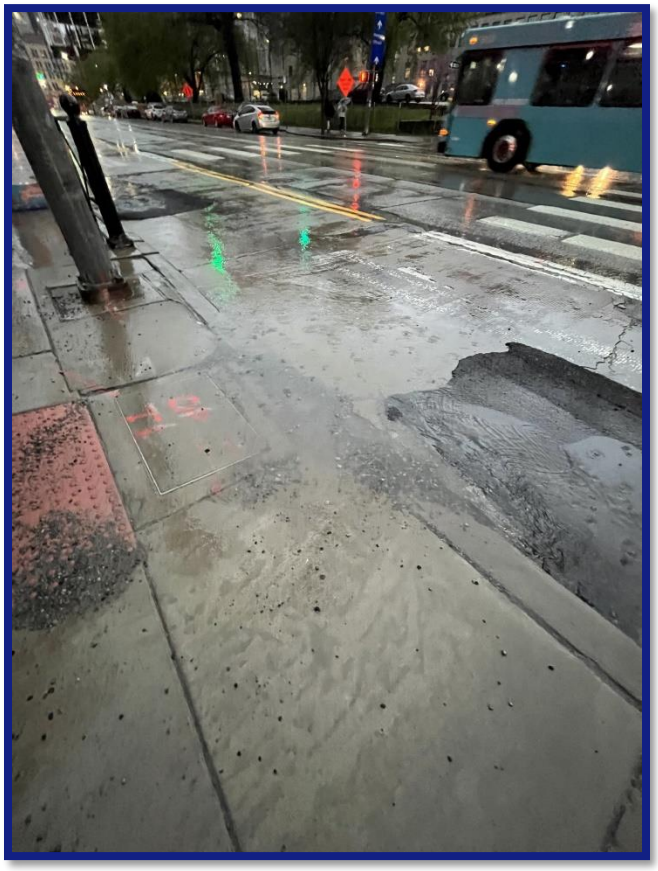

Illustration G
Large pooling observed on Fifth Avenue at the bottom of the Tower Lobby stairs. Runoff water pooling in recently filled pothole. Water depth measured approximately five inches. The filled pothole seems to collect water rather than act as an inlet into drainage located further down the street. As a result, puddling flows onto the sidewalk and soaks pedestrian shoes.

Survey Questions

The survey conducted was formatted through Google Forms and posted on Slack, Discord, Snapchat, and distributed through email. Resulting percentages are noted in boldface.

Stormwater Survey

Please complete all questions based upon your personal experience on campus.

1. What is your primary means of transportation while on campus?
    a. Walk **94.5%**
    b. Bike **2.7%**
    c. Personal Vehicle **0%**
    d. Pitt Shuttles **2.7%**

2. Have you ever noticed excessive flooding (puddles and/or pooling after rain) while on campus?
    a. Yes **88.6%**
    b. No **11.4%**

3. Has flooding impacted your routes to and around campus?
    a. Yes **31%**
    b. No **69%**

4. How satisfied are you with the current drainage on campus during heavy rainfall?

    1: Extremely satisfied **5%**

    2: Satisfied **55%**

    3: Neither satisfied nor dissatisfied **40%**

    4: Dissatisfied **0%**

    5: Extremely Dissatisfied **0%**

5. How often do you see water runoff maintenance being performed on campus?
    a. Never **59.5%**
    b. Rarely **40.5%**
    c. Sometimes **0%**
    d. Often **0%**

6. Would you like to include any additional notes on your understanding of current stormwater runoff systems on campus?

Optional open-ended question – 33% responded.

Thank you!

Decision Matrix

The attached decision matrix was used to select a stormwater drainage solution.

Criteria	Weight	Permeable Pavers		Rain Barrels		Drainage Gate Replacement		Bioswales	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Cost	5	1	5	5	25	3	15	4	20
Time	3	3	9	5	15	4	12	4	12
Displacement/Work Input	4	2	8	5	20	3	12	3	12
Longevity	4	5	20	1	4	3	12	5	20
Aesthetics	2	4	8	1	2	2	4	5	10
Total Score			**50**		**66**		**55**		**74**

Table 1 Decision matrix generated through research methods described on page 4. Each criterion received a weight on a scale from one through five. The solutions considered were ranked based upon each piece of criteria. The solution with the greatest total score was selected since it matched the criteria most adequately.

ASCE Standard Practice for Sustainable Infrastructure

The recommendations provided largely relied on concepts developed in the ASCE Standard Practice for Sustainable Infrastructure. The full contents of the guidelines may be accessed at the link provided.

https://sp360.asce.org/personifyebusiness/Merchandise/Product-Details/productId/309314929