PWSA CITY-WIDE GREEN INFRASTRUCTURE ASSESSMENT EXECUTIVE SUMMARY

1. "GREEN FIRST" – AN OVERVIEW

Pittsburgh Water and Sewer Authority (PWSA, or Authority) has been developing its "Green First" program which, as the name implies, consists of implementing Green Infrastructure ahead of other stormwater management alternatives. This "Green First" approach will:

- Maximize the reduction of combined sewer overflows in the conveyance system;
- Reduce basement sewage backups, localized surface flooding, and direct stream inflows, and improve water quality; and,
- Accrue myriad associated local community and regional benefits, including economic, social, and environmental, often referred to as Triple Bottom Line (TBL) benefits.

Green Infrastructure, or GI, is defined as ecologically engineered measures that reduce and treat stormwater at its source while delivering environmental, social, and economic benefits. GI uses vegetation, soils, and other natural elements to restore the natural processes required to manage water locally and create healthier urban environments. GI typically can provide habitat, flood protection, and cleaner air and water. GI also includes stormwater management systems that mimic nature by absorbing, storing, and either removing or detaining water for slow release to a local waterway, or back into the sewer system when it is not overloaded. Prioritizing GI implementation (implementing GI first) can provide the information and data essential to the cost-effective implementation of any required "gray infrastructure," such that a combination of both approaches can meet regulatory requirements.

Gray Infrastructure is defined as man-made, engineered components of a system designed to collect and treat sewage or stormwater. For stormwater, gray infrastructure can include gutters, storm sewers, tunnels, culverts, detention basins, pipes and mechanical devices used in a system to capture and convey runoff. Historically, as land developed and cities grew, gray infrastructure was used to move stormwater away from homes, businesses, and streets as quickly as possible. Many times, sanitary sewage and stormwater systems were combined, or stormwater was diverted to systems planned only for sewage. Over time, with factors such as increased development and increased storm intensities and frequencies contributing to increased runoff flows and volumes, the sewer systems frequently exceed their current capacities. As a result, combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) have been occurring at significant and unacceptable magnitudes.

PWSA's Green First program involves identifying and implementing innovative ways to reduce stormwater runoff, reduce CSOs and SSOs, improve in-stream water quality, reduce localized surface flooding, reduce basement sewage backups, restore habitats, enhance urban settings, and stimulate economic growth. The Authority seeks to inspire and implement GI projects that will have multiple benefits, such as managing stormwater runoff, increasing infiltration to the ground, reducing peak flows to streets and storm sewers, improving water quality, and helping to protect people and property from flooding. The resulting protection and enhancement of stream corridors and other green spaces can be an important component of an overall stormwater strategy, helping create places where people want to live, work, and recreate.

2. CITY-WIDE GI ASSESSMENT PROJECT BACKGROUND AND SCOPE

In 2015, the Mayor of the City of Pittsburgh tasked PWSA with evaluating the benefits of incorporating GI approaches throughout the City. This analysis would be incorporated into a Green First Plan of green and gray infrastructure to address regulatory requirements as well as provide triple bottom line (TBL) benefits. Applying a TBL approach can result in more holistic, and possibly cost-effective, decisions that acknowledge the co-beneficial aspects of the project.

This work started with the assessment of the Shadyside neighborhood of the City within the A-22 sewershed. The Shadyside/A-22 Flooding Solutions and Green Infrastructure Assessment evaluated gray, green, and watershed scale infrastructure solutions to reduce occurrences of localized surface flooding and basement sewage flooding in the sewershed during intense rain events. The A-22 Assessment determined that improvements to the existing sewer system, coupled with GI alternatives, could cost-effectively reduce localized surface flooding, basement sewage backup flooding, and CSOs. This approach could also have positive effects downstream of these system improvements by reducing peak flows and combined sewage volume.

Building upon the success of the A-22 Assessment, the City-Wide GI Assessment was developed to analyze the benefits of GI if implemented in targeted areas in the combined sewer system within the City and the hydraulically-connected surrounding municipalities. PWSA and City leaders recognized that implementing a Green First stormwater management program could address multiple issues facing the City and surrounding municipalities, such as:

- Chronic street flooding and associated hazard areas.
- Direct Stream Inflows (DSI), which are surface streams that flow into the combined sewer system, contributing to extraneous flows, lost sewer system capacity, high loads of sediment and debris in the existing deep tunnel interceptors, and increased conveyance and treatment costs.
- Poor water quality in streams and rivers.
- Limitations on recreation caused by sewage/pollution in the rivers or other factors.
- Regulatory requirements:
  - The Consent Orders and Agreements (COAs) for wet weather overflows required each municipality in Allegheny County Sanitary Authority (ALCOSAN)'s service area to prepare a Wet Weather Feasibility Study (WWFS) to bring sewer systems into compliance with the Pennsylvania Clean Streams Law and the Clean Water Act, eliminate SSOs, and fulfill the Pennsylvania and U.S. Environmental Protection Agency (USEPA) CSO Policy obligations. PWSA completed its WWFS in July 2013, and is moving forward with its Adaptive Management approach, which is an iterative approach to decision-making and project implementation to meet overall regulatory requirements with opportunities to adjust decisions and projects based on subsequent monitoring and previous project assessment, in-stream water quality, and the sewer system's performance.
  - In fall 2015, the regulatory agencies issued Consent Orders and Agreements (COAs) to 82 municipalities in the ALCOSAN service area, which require evaluation by December 2017 of the effectiveness of source reduction and GI in reducing CSOs

and SSOs. The City and PWSA received similar mandates through a 308 Information Requirement letter from the USEPA in January 2016.

The overall objective of the City-Wide GI Assessment is to consider Green First strategies, that is, to develop cost-effective uses of GI and to highlight the associated benefits compared to the gray infrastructure options that have been considered.

The City-Wide Assessment is intended to be a lens to guide and inform future capital improvement projects and urban planning decisions in the City.

The tasks associated with accomplishing this objective included:

1. Analyzing high priority combined sewersheds (that is, those considered to be "high yield" drainage areas that would generate higher volumes of stormwater runoff) to determine the locations within the City that are the most suitable for GI implementation.
2. Conducting outreach activities, in collaboration with the Mayor's Office, other City departments, municipal representatives, regional organizations, multi-municipal organizations, and others to collaborate and coordinate the GI Assessment work.
3. Evaluating the feasibility and cost-effectiveness of separating and daylighting streams that currently flow into the combined sewer system.
4. Identifying and quantifying the benefits of the identified GI implementation and stream daylighting.
5. Urban planning and alignment with the City's ongoing redevelopment and resilience initiatives.

3. PROJECT APPROACH – PLANNING AND SEQUENCING THE WORK

The Authority followed a detailed process to identify and select the priority areas for the City-Wide GI Assessment. The project team collected and reviewed numerous local and regional data sets, including the sewer system and sewershed characteristics; stream inlet locations; catch basin inlet data; planned and ongoing new and redevelopment sites; historical hazard and public safety information for flooding locations; previous wet weather and stream reports; urban planning activities across the City and connected municipalities; and seven collection system hydrologic and hydraulic (H&H) basin models provided by ALCOSAN.

The team evaluated candidate locations and opportunities for inclusion in the GI Assessment, and considered the following factors:

- Benefit of CSO reduction.
- Combined sewer outfalls that were indicated to be connected to the proposed tunnel in ALCOSAN's Recommended Plan described in its Wet Weather Plan Report in 2013;
- Top hazard and public safety mitigation areas in the City.
- Urban planning/redevelopment sites.
- Direct stream inflow locations to the combined sewer system.

Upon review and discussion of the candidate opportunities, the following areas of the City were identified for the City-Wide GI Assessment:

- Thirty high priority sewersheds were selected to align with potential CSO reduction, flood hazard, and direct stream inflow locations in the City. These 30 high priority sewersheds account for just over 3 billion gallons (BG) of CSO discharge in a typical year, representing about one-third of the CSO discharge from the entire ALCOSAN service area. Most combined sewage in the 30 high priority sewersheds is generated within the City. Three of the sewersheds (A-42, A-60, and O-27) have contributing flows from other municipalities, but these flows are primarily sanitary flows.

- The 10 largest direct stream inflow contributors to the combined sewer system.
- Top 10 City hazard locations, as identified by the City's Office of Emergency Management.

Of the 30 high priority sewersheds, six were selected for strategic urban planning. They were primarily selected to align with new and redevelopment initiatives in sewersheds estimated to have larger CSO volumes. These six sewersheds are:

  - M-29 sewershed, including Junction Hollow and Panther Hollow Lake and stream, with connection to the Monongahela River at Almono.
  - M-16 sewershed, including the South 21st Street Corridor and South Side Park and East Carson Street.
  - A-42 sewershed, including Negley Run and the Washington Boulevard corridor, Larimer, and Homewood;
  - A-41 sewershed, including Heth's Run;
  - M-19 sewershed, including eastern areas of or portions of the Hill District and Uptown;
  - O-27 sewershed, including Woods Run.

Figure ES-1 shows the locations of the 30 high priority sewersheds.

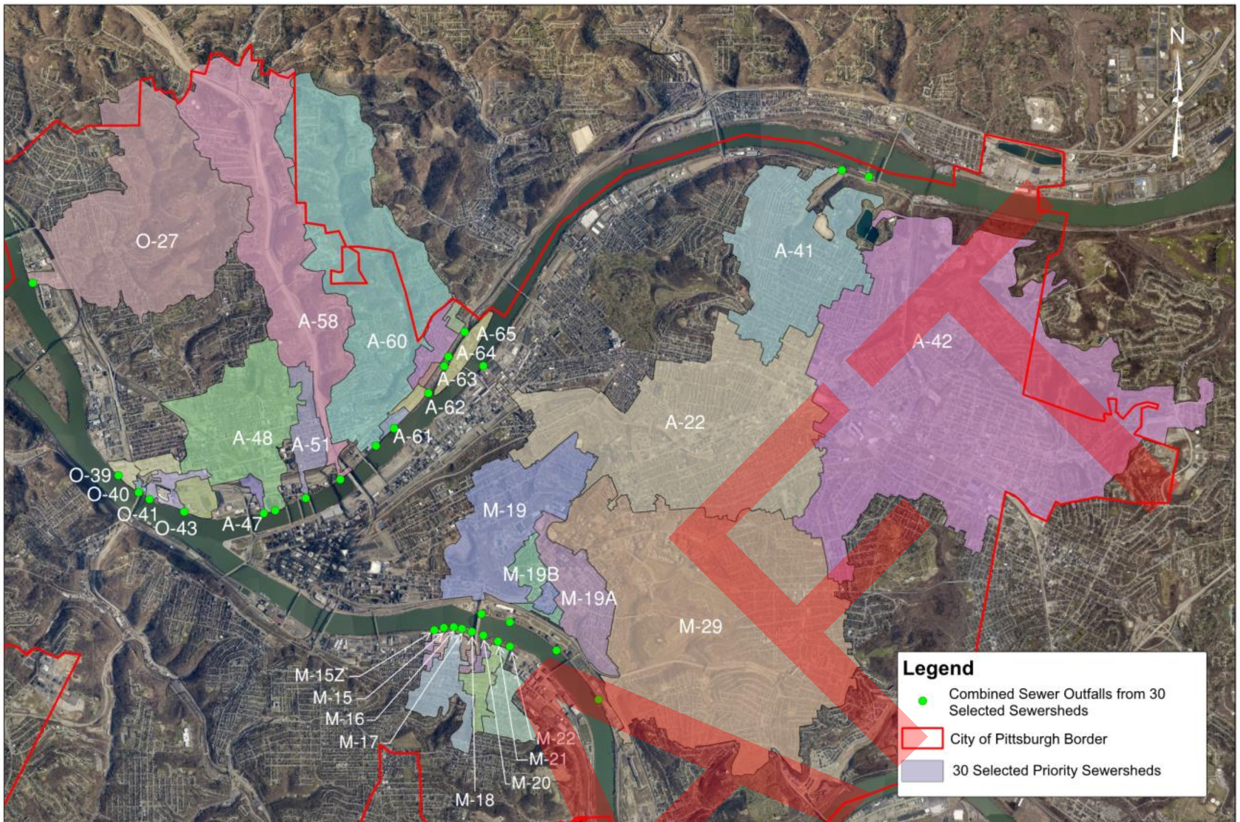

Figure ES-1: City-Wide 30 High Priority Sewersheds

4. ESTABLISHMENT OF GREEN INFRASTRUCTURE MANAGEMENT LEVEL GOALS

To establish CSO control targets for the 30 priority combined sewersheds, it was necessary to establish the baseline CSO performance and the influence of other system components, such as ALCOSAN's Woods Run Wastewater Treatment Plant (WWTP) and existing interceptors. PWSA obtained regional hydrologic and hydraulic (H&H) models used by ALCOSAN, and compiled the seven separate Basin-level models into a single comprehensive system-wide model of the ALCOSAN conveyance system. This system-wide model allowed PWSA to seamlessly simulate system hydraulic response to applied flow conditions.

The GI Assessment approach was to evaluate the potential volume of GI stormwater management needed to meet specific performance and regulatory goals across the 30 high priority sewersheds. The EPA's CSO Control Policy requires that at least 85% combined sewage capture be achieved within combined sewer systems as part of a CSO long-term control plan. For this project, 85% capture was the target selected, as it is consistent with the CSO Control Policy and other approved long-term control plans across the United States. The 85% combined sewage capture target is not meant to presume a final level of control for the region's CSOs, but simply to define a target that has been a compliance goal or requirement for other cities like

> The EPA's CSO Control Policy requires that at least 85% combined sewage capture be achieved within combined sewer systems as part of a CSO long-term control plan.

Pittsburgh. This approach allows the flexibility needed to scale to future GI investment levels (in conjunction with necessary gray infrastructure), to meet whatever CSO target is ultimately agreed upon with regulators.

5. GREEN INFRASTRUCTURE MODELLING APPROACH AND RESULTS

5.1 Simulation of Four System Configuration Scenarios and Effects on the 30 Priority Sewersheds

Four system configuration scenarios, defined in Table ES-1, were developed for modeling simulations to determine the degree to which existing and potential future infrastructure can influence the amount of GI needed to achieve the 85% capture goal. Simulating each of the four system configuration scenarios, the effects on the 30 priority sewersheds in this Assessment were analyzed. Table ES-1 lists the annual CSO and SSO discharges from the entire ALCOSAN service area (including municipal CSO and SSO discharges) in a typical year for these four system configurations. A typical year was developed based on 2003 precipitation data.

TABLE ES-1
SYSTEM CONFIGURATIONS EVALUATED TO DETERMINE GI SENSITIVITY

Configuration	Description	System-Wide Annual CSO and SSO Discharge Volume (Billion Gallons), Typical Year
Existing Conditions	This represents the current state of the collection system and the wastewater treatment plant (WWTP) treatment capacity. The WWTP has a 250 million gallons per day (MGD) treatment capacity and its influent pump station wet well operates at a hydraulic grade line (HGL) level of 670 feet. The existing interceptors have the sediment levels as defined in the current ALCOSAN model.	10.2
480 MGD (WWTP Expansion) [1]	This system state is the same as the existing conditions, except the capacity of the WWTP has been expanded to 480 MGD and its operating wet well HGL level reduced to 660 feet.	7.3
600 MGD (WWTP Expansion & System Improvements) [1]	This system state is the same as the existing conditions, except the capacity of the WWTP has been expanded to 600 MGD and its operating wet well HGL level reduced to 660 feet. Also, the existing interceptors are modeled with their sediment removed to maximize wastewater conveyance to the WWTP and regulator structures for 19 of the 30 high priority sewersheds have modified tipping gate settings to allow more flow to enter the interceptors.	6.0

Lowered HGL Operation During Wet Weather Conditions [1]	This system state represents an attempt to maximize the performance of the existing infrastructure. This alternative is not currently planned to be implemented by ALCOSAN. In this scenario, the WWTP is modeled as a free outfall to represent lowering the water level at the existing pump station during wet weather conditions such that it is below the crown of the connecting deep tunnel. This provides for the existing conveyance capacity to be maximized. This scenario also assumes that the necessary high rate treatment infrastructure is constructed at the WWTP to process any flows above 600 MGD (modeling results indicate peak flows at or above 600 MGD occur 29 hours in a typical year). The necessary infrastructure to accomplish this scenario is discussed in Section 3.3. The existing interceptors are modeled with their sediment removed and regulator structures for 19 of the 30 high priority sewersheds have modified tipping gate settings to allow more flow to enter the interceptors.	5.5

[1] The technical feasibility of all potential treatment plant wet weather capacity scenarios is currently under discussion between PWSA and ALCOSAN.

5.2 Simulation of Three System Configuration Scenarios and Effects with GI Applied in Priority Sewersheds

For the three potential system configuration scenarios, GI modeling was conducted in the 30 priority sewersheds to evaluate how much GI (managing runoff from impervious area) would be required to meet the 85% capture goal in those sewersheds. The Existing Conditions scenario was not modelled with GI applied, because it was assumed that this condition would not continue in the future. The GI modeling results indicate that at least an 85% combined sewage capture in the 30 priority sewersheds (aggregated as a group) can be achieved, along with at least 85% capture at most of the 30 sewersheds individually. Under the Existing Conditions scenario with typical year precipitation, the 30 priority sewersheds convey a combined sewage volume of 10,327 MG to the regulators, 3,067 MG of which is CSO. Modeling results for the 30 priority sewersheds (aggregate) in a typical year, with simulation of the three system configurations and GI applied, indicate:

a. *480 MGD Configuration defined in Table ES-1*: With improvements in this system configuration and GI impervious area management of 1,835 acres,
   - CSO volume in the 30 sewersheds can be reduced from 3,067 MG to 1,534 MG.
   - Combined sewage capture for the 30 high priority sewersheds would be 8,793 MG, or 85%.

“Impervious Acres Managed” refers to the total impervious area from which runoff is managed by GI, not to the area of the GI site itself.

b. *600 MGD Configuration defined in Table ES-1*: With improvements in this system configuration and GI impervious area management of 1,835 acres,
   - CSO volume in the 30 priority sewersheds can be reduced from 3,067 MG to 910 MG.
   - Combined sewage capture for the 30 high priority sewersheds would be 9,417 MG, or 91%.

c. *Lowered HGL Operation During Wet Weather Configuration defined in Table ES-1*: With improvements in this system configuration and GI impervious area management of 1,286 acres,
    - CSO volume in the 30 priority sewersheds can be reduced from 3,067 MG to 970 MG.
    - Combined sewage capture for the 30 high priority sewersheds would be 9,357 MG, or 91%.

d. *Lowered HGL Operation During Wet Weather Configuration defined in Table ES-1*: With improvements in this system configuration and GI impervious area management of 1,835 acres,
    - CSO volume in the 30 priority sewersheds can be reduced from 3,067 MG to 766 MG.
    - Combined sewage capture for the 30 high priority sewersheds would be 9,561 MG, or 93%.

The GI modelling results include a computation of the impervious area that would need to be managed with GI (not the GI footprint) to achieve the overflow reduction goal in the 30 priority sewersheds. A depiction of impervious area managed is shown in Figure ES-2. Table ES-2 shows a summary of the overflow reduction results for impervious area managed with GI applied in priority sewersheds, in conjunction with the three modeled system configurations. In addition to analyzing the overflow volume reductions in the 30 priority sewersheds, the total ALCOSAN service area systemwide overflow reduction results were also analyzed, and the results from this analysis are shown in Table ES-2.

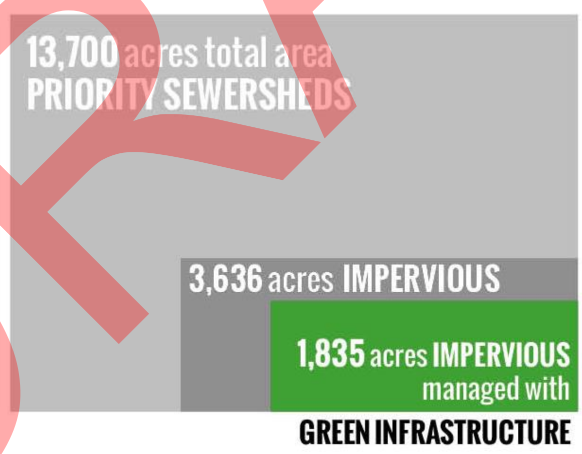

Figure ES-2: Example of Impervious Area Managed with GI

TABLE ES-2 OVERFLOW REDUCTION RESULTS FOR THREE SYSTEM CONFIGURATIONS WITH GREEN INFRASTRUCTURE IN PRIORITY SEWERSHEDS AND STREAM INFLOW REMOVAL, TYPICAL YEAR, SYSTEMWIDE[1]			
Stormwater Management Scenario	**480 MGD WWTP Expansion**	**600 MGD WWTP Expansion, Sediment Removed, and 19 Regulator Modifications**	**Lowered HGL Operation During Wet Weather, Sediment Removed, and 19 Regulator Modifications**
Number of Priority Sheds Retrofitted with GI	18	18	13
Impervious Acres Managed	1,835	1,835	1,286
Overflow Volume Reduction Attributable to GI (BG)	0.97	0.97	0.69
Aggregate Combined Sewage Capture (30 Sewersheds)	85%	91%	91%
Total ALCOSAN Systemwide Overflow Volume Reduction (BG)	4.09	5.00	5.20

[1] Systemwide model results include overflow reduction that may occur in neighboring sewersheds as a result of the improvements in the priority sewersheds.

6. FLOOD HAZARD MITIGATION ANALYSIS

PWSA coordinated with the City of Pittsburgh Office of Emergency Management and Homeland Security to identify the top 10 most hazardous locations in the City. Of the ten hazard locations, four are flooding-related hazard locations that were selected for analysis:

1. Morange Road - located in the Chartiers Creek Basin in the C-25 sewershed.
2. Frankstown Avenue - located in the Upper Allegheny Basin in the A-42 sewershed.
3. Streets Run - located in the Monongahela Basin in the M-42 sewershed.
4. Nine Mile Run - located in the Monongahela Basin in the M-47 sewershed.

The flooding areas at Morange Road and Frankstown Road were found to result from sewer capacity issues and were analyzed using the H&H system model. The flooding areas at Streets Run and Nine Mile Run were found to result from the stream overtopping a culvert or the stream banks, and were analyzed using open channel stream models obtained from ALCOSAN.

Analysis was completed for flooding mitigation through management with GI BMPs. Estimates were developed, assuming GI would be designed for a flooding level of protection up to the August 31, 2014 event condition, with a peak rainfall intensity of 1.05 inches in 15 minutes, and a rainfall volume of 2.25 inches in 10 hours.

Estimates and recommendations for the Morange Road and Frankstown Road flooding hazard areas were carried forward in the GI Assessment. For the Streets Run and Nine Mile Run flooding areas, the order of magnitude capital costs were estimated, assuming an average of regional detention and distributed GI BMP costs. Regardless of the type of overflow reduction solution selected in these areas, additional studies to address flooding and asset management of the existing sewer system are required, and demonstration projects to holistically address the stormwater are recommended.

7. STREAM INFLOW IMPROVEMENTS ANALYSIS

Direct Stream Inflow (DSI) is defined as a surface stream that connects into the combined sewer system. DSI takes up conveyance capacity in the collection system as well as a portion of the treatment plant capacity. Removing DSI from the collection system can restore significant wastewater conveyance and treatment capacity, resulting in reduced CSOs. An analysis of the 10 largest DSIs was conducted, with alternatives developed for detaining and/or removing the DSI (stream base flow and stormwater runoff during wet weather conditions) from the sewer system to estimate the most cost effective option for CSO reduction. Recommended solutions for each of the locations are as follows:

Woods Run – Detention with slow release of flows into the combined sewer system using GI BMPs to address the 8 inflow locations.

Spring Garden – Detention with slow release into a shallow storm sewer that ultimately discharges to the Allegheny River.

Panther Hollow – Detention with daylighted surface channel and discharge into the Monongahela River.

Table ES-3 presents the results for the three stream removal/detention solutions, and estimated capital costs. Further study and coordination with other projects in the areas adjacent to these DSI opportunities are needed to confirm estimated costs.

Table ES-2, previously introduced, includes direct stream inflow removal as described above, as well as GI applications in the high priority sewersheds.

TABLE ES-3
STREAM INFLOW REMOVAL/DETENTION RESULTS

Category	Spring Garden	Woods Run	Panther Hollow	Total
Capital Cost (millions)	$10.7	$10.5	$25 - $40	$46.2 - $62.0
Overflow Volume Reduced (MG), Typical Year	52.9	15.0	31.9 [1]	99.8
Capital Cost per Overflow Gallon Reduced ($/gallon)	$0.20	$0.70	$0.78 - $1.25	$0.46 - $0.61
Stream Volume Removed (MG), Typical Year	168.8	19.7	98.7 [2]	267.5
Capital Cost per Stream Volume Removed ($/gallon)	$0.06	$0.53	$0.25 - $0.41	$0.16 - $0.21

[1] Current SWMM model shows 14.0 MG/year stream base flow, while a base stream flow of 68 MG/year was estimated based on 2015 ALCOSAN flow monitoring. Calculations are based on field measured flow from 2015 ALCOSAN flow monitoring. Additional flow monitoring and model calibration should be performed to confirm the CSO reduction.
[2] Based on field measured flow from 2015 ALCOSAN flow monitoring. A base dry weather stream flow of 68 MG/year was estimated. It appears from field investigation that the majority of the wet weather flow is diverted around the existing lake.

8. URBAN PLANNING AND GREEN INFRASTRUCTURE PLAN

To integrate the results of the priority sewersheds and GI analyses with the City's planning of urban development, PWSA coordinated with several City agencies, and considered existing community-driven redevelopment plans, stakeholder development plans, and City Department progress reports on initiatives being pursued. Six priority sewersheds were selected where GI would best complement the strategic urban development plans, existing characteristics, and high yield areas:

1. Four Mile Run (M-29 sewershed)
2. Washington Blvd. and Negley Run (A-42 sewershed)
3. South Side (M-16 sewershed)
4. Woods Run (O-27 sewershed)
5. Heth's Run (A-41 sewershed)
6. Hill District/Uptown (M-19 sewershed)

The team established a set of Guiding Principles to assist in the selection of the GI locations within the respective sewersheds:

- Cost-effective public realm investment
- Create workforce development opportunities
- Re-establish riverfront connections
- Complete streets approach

- Focus on healthy, walkable communities
- Resilient infrastructure
- Align with people, planet, place and performance (P4) metrics

These principles were used to develop plans for each of the six sewersheds that show how stormwater could be managed in a way that generates long-term benefits for each neighborhood.

9. CITY-WIDE GI ASSESSMENT SUMMARY

9.1 Estimated Costs and Benefits

The volume of untreated overflow and stormwater flow from the 30 sewersheds analyzed represents approximately one-third of the total untreated overflow discharged from the ALCOSAN service area. The analyses completed during the project revealed that the level of GI investment needed to achieve the goal of 85% combined sewage capture would be highly influenced by the capacity and operation of ALCOSAN's Woods Run WWTP and the conveyance capacity of ALCOSAN's existing interceptors. With this understanding, the high yield GI analysis was evaluated with four different potential scenarios of this existing gray infrastructure. Under existing conditions, 13 to 17 of the 30 sewersheds analyzed already meet the 85% combined sewage capture goal and therefore would not need any GI implementation.

> The level of GI investment needed to reach the 85% combined sewage capture target is highly influenced by the capacity and operation of the existing WWTP and the interceptors.

The GI capital cost to achieve the 85% combined sewage capture goal in 30 priority sewersheds, for differing system configurations, as modelled, is:

- 480 MGD WWTP Expansion and 600 MGD WWTP Expansion & System Improvements scenarios: $594 million - $792 million. Manage runoff from 1,835 impervious acres with GI.
- Lowered HGL Operation During Wet Weather scenario: $417 million - $555 million. Manage runoff from 1,286 impervious acres with GI.

The purpose of the City-Wide GI Assessment was to determine the opportunities for implementing large scale GI across the City to address a variety of issues, including combined sewer and sanitary sewer overflows, stream inflow removal, flood hazard reduction, and basement sewage backup reduction during rain events. The results indicate that maximizing the treatment plant capacity and optimizing the existing tunnel assets have great value. The GI that is needed for additional overflow reduction to meet the 85% combined sewage capture goal can also reduce basement sewage backups and localized surface flooding. The estimated costs and system flow reduction quantities for the developed Green First Approach are summarized in Tables ES-4 and ES-5.

TABLE ES-4
CAPITAL COSTS AND OVERFLOW REDUCTIONS FOR THE 30 PRIORITY SEWERSHED GREEN FIRST APPROACH

System	Plant Capacity (MGD)	480 MGD WWTP Expansion	600 MGD WWTP Expansion & System Improvements	Lowered HGL Operation During Wet Weather
	Sediment Removed From in Existing Tunnel?	No	Yes	Yes
	19 of 30 CSO Regulators Modified to Allow More Flow to Tunnel?	No	Yes	Yes
City-Wide	GI Impervious Area Managed (acres)	1,835	1,835	1,286
	Flood Hazard Reduction and Overflow Reduction Costs included?	Only Frankstown Road and Morange Road Included		
	Stream Removal/Detention Costs included?	Panther Hollow, Woods Run, and Spring Garden Included		
	Surface Flooding and Basement Sewage Backup Reduction Costs Included?	In sewersheds where GI is located, it was assumed that GI would be designed for a flooding level of protection up to a rainfall intensity of 1.05 inches in 15 minutes.		
System Improvements	WWTP Upgrade Capital Cost ($ M) [1]	$334	$378	$378
	Existing Tunnel Cleaning and Modernization ($ M) [2]	$0	$200	$200
	New Wet Weather Pump Station Cost to Allow Lower HGL Operation ($ M) [3]	$0	$0	$150
	High Rate Treatment at WWTP to treat flows above 600 MGD ($ M) [2]	$0	$0	$70-$100
GI + Stream Removal	Green Infrastructure ($ M) [4]	$690 – 920	$690 – 920	$490 – 660
	Stream Removal/Detention ($ M)	$46 – 62	$46 – 62	$46 – 62
	Total Capital Cost ($ M)	**$1,070 – 1,310**	**$1,310 – 1,560**	**$1,340 – 1,550**
	Total System Wide Overflow Reduction (BG), Typical Year	**4.09**	**5.00**	**5.20**

[1] From ALCOSAN Wet Weather Plan Report (2013).
[2] Allowance.
[3] From ALCOSAN Wet Weather Plan Report (2013). Used cost for new tunnel dewatering pump station.
[4] Includes costs for GI, downspout disconnections, Frankstown Road (part of the A-42 estimated cost), and Morange Road flooding reduction ($33 M).

TABLE ES-5
TOTAL COSTS (INCLUDING O&M) FOR THE 30 PRIORITY SEWERSHED GREEN FIRST APPROACH

30 PRIORITY SEWERSHEDS RESULTS

	480 MGD WWTP Expansion	600 MGD WWTP Expansion & System Improvements	Lowered HGL Operation During Wet Weather Conditions
GI Impervious Area Managed (acres)	1,835	1,835	1,286
Total Capital Cost ($ Million)	$1,070 – $1,310	$1,310 – $1,560	$1,340 – $1,550
Total System Wide Overflow Reduction (billion gallons), Typical Year	4.09	5.00	5.20
Total Capital Cost Per Overflow Gallon Reduced	$0.26 – $0.32	$0.26 – $0.31	$0.26 – $0.30
Annual O&M Cost for GI (at buildout) ($ Million)	$8.1	$8.1	$5.7
50-Year Net Present Value (Annual O&M + GI Replacement at Year 25) ($ Million)	$288	$288	$202
Total Net Present Value Cost ($ Million)	$1,358 – $1,598	$1,598 – $1,848	$1,542 – $1,752

Some of the components from the City-Wide GI Assessment have many similarities to, but also many important differences from, ALCOSAN's Recommended Plan. Both plans are composed of a combination of projects to help mitigate ALCOSAN's and the region's CSOs and SSOs. It is important to note that ALCOSAN is still in negotiations with the USEPA regarding the details of the plan to be implemented. When the analyses were being conducted for this Assessment, the Recommended Plan (2013) and Starting at the Source (2015) were the most recent ALCOSAN public documents available.

9.2 City-Wide GI Implementation Benefits

The following additional benefits are derived from the results of the City-Wide GI Assessment. The three Green First scenarios:

1. **Acknowledge additional clean water regulatory requirements for the City.** Large-scale GI investment is attractive because it provides multiple benefits and addresses multiple regulatory requirements, including overflow reduction and water quality improvements.
2. **May achieve nearly equal overflow volume reduction and potentially reduce costs compared to ALCOSAN's 2013 Recommended Plan.** Large scale GI investment

across a subset of the selected 30 priority sewersheds combined with key gray infrastructure investments can result in a feasible and cost-effective solution. A reduction of between 4.1 BG and 5.2 BG of untreated CSO and SSO volume in the ALCOSAN conveyance and treatment system could possibly be achieved by investing in the existing WWTP, the existing interceptors, and GI in a subset of the 30 priority sewersheds evaluated in this project.

3. **Address reduction in overflows, localized surface flooding, and basement sewage backups during wet weather, and increase the resiliency of the existing sewer infrastructure.** The City and the region have a stormwater problem that causes each of these individual issues, and this Green First approach will reduce these issues.
4. **Remove or detain streamflow from the ALCOSAN system.** Removing or detaining the 10 largest sources of direct stream inflow can reduce overflows and reduce the amount of sediment entering the ALCOSAN deep interceptors**.**
5. **Provide significant TBL benefits.** The calculated TBL benefits range from $390 million to $850 million from the distributed GI implementation. A majority of the benefit value comes from the flood risk reduction benefit (reduction of basement sewage backups during rain events). It is expected that other TBL benefits, such as the creation of green jobs to construct, operate, and maintain the GI, could also be significant.
6. **Support the development of local community plans.** GI projects can support resilient infrastructure strategies and can be catalytic redevelopment opportunities.
7. **Demonstrate the value of source control to the entire region. The benefits from this project extend to the municipalities beyond the City.** The results show that overflow volume is reduced system-wide, and a Green First scenario may provide nearly equivalent overflow volume reduction to ALCOSAN's Recommended Plan.
8. **Provide methodologies and "blueprints" that can be applied region-wide.** This adaptive, resilient approach establishes a framework and stormwater overlay for guiding future policy, codes, and ordinances for the present and into the future. The results support and re-affirm a regional approach to stormwater management and investment of the limited available ratepayer funds at the locations that maximize stormwater management, overflow reduction, and community benefits.
9. **Underscore the concept that implementing GI does not limit any future gray or green infrastructure investment.** The nature of GI projects allows them to be implemented incrementally while evaluating their effectiveness. GI can be complementary to any future infrastructure investment.
10. **Employ GI technologies that reduce peak flows during and after wet weather events.** The region will not be paying to treat excessive rainwater at the wastewater treatment plant.

9.3 Recommendations

The following recommendations are based upon the results of the City-Wide GI Assessment. It is recommended that PWSA:

1. **Work with ALCOSAN and support efforts to maximize the ultimate capacity of the Woods Run Wastewater Treatment Plant (WWTP).** The system improvement modeling simulations during this project determined that the most cost-effective improvement for reducing untreated overflows in the ALCOSAN service area is expanding the Woods Run WWTP wet weather treatment capacity.
2. **Work with ALCOSAN and support efforts to maximize the conveyance capacity and develop effective asset management options for ALCOSAN's existing deep interceptors.** After the Woods Run WWTP, improving the conveyance and asset management condition of the existing deep interceptors is the next most effective investment to reduce untreated overflows and increase the viability of GI alternatives. The construction of new access shafts to the existing deep interceptors would improve accessibility, address issues with entrained air, enable proper cleaning and maintenance, and with improved access for inspection and maintenance, reduce the risk of a failure. PWSA can proactively assist by supporting removal of influent streams and building grit traps to keep sediment carried by streamflow out of the interceptors.
3. **Advocate, support, and investigate the application of real time controls to PWSA diversion chambers as a potential additional cost-effective effort to increase performance of the existing collection system infrastructure.** Adding real time control to the existing flow control devices at the interceptors could allow optimized flow control and could provide even greater overflow reduction.
4. **Implement several green infrastructure projects and evaluate their performance.** The GI projects will provide local data on how well the various GI practices/technologies perform and confirm the modeling assumptions used. Evaluation of these initial results will serve as a checkpoint to determine if the GI practices/technologies are performing as expected or if course correction is needed.
5. **Implement large-scale targeted GI installations based on the intelligence from the evaluated GI projects.** Assuming the GI projects provide positive results, it is recommended that the highest yield stormwater locations identified in the 30 priority sewersheds be targeted first in a broader GI implementation. This implementation would provide the first large-scale results and an important check of GI performance to evaluate if it continues to represent a cost-effective investment to meet PWSA's and the region's regulatory requirements.
6. **Improve the ALCOSAN SWMM model based on the collected data, to enable the model to be effectively used for PWSA, the City, and the region.**
7. **Work with neighboring municipalities to implement projects in both the combined sewer and the sanitary sewer systems to illustrate the value of source control.** High yield stormwater capture locations, both within the combined sewer and the sanitary sewer systems, exist across the entire ALCOSAN service area. The region's stormwater management challenge knows no political boundaries. Siting and implementing projects that can demonstrate the different types and effectiveness of source control that benefit the local municipality, but also PWSA and ALCOSAN, is an important next step.

9.4 Additional Findings

During the performance of this City-Wide Assessment, it was also found that:

- Different GI applications provide different types of benefits.
- An integrated plan that includes GI is also dependent on key gray infrastructure improvements.
- Because a sizable portion of the value of a GI project may derive from factors other than volume of untreated overflow reduced, GI projects need to be evaluated against capital cost and the overall value (co-benefits) that they provide. The next steps should include a life cycle analysis.
- The results provided in the Assessment are important for understanding the effectiveness of applying large-scale GI within the City at high yield and high benefit locations. Although this project focused on 30 high priority sewersheds within the PWSA system, the results can be applied to the entire collection system tributary to ALCOSAN's Woods Run WWTP.
- The benefits from this project extend to the municipalities beyond PWSA service area and the City. Having PWSA and the City adopt an integrated plan which includes GI to meet target regulatory goals may also provide multiple benefits to tributary and hydraulically connected municipalities.
- The methodologies and "blueprints" from this Assessment can be applied region-wide to identify opportunities to reduce the stormwater problem as a whole - not just one symptom of the problem.

The results of the Assessment support and re-affirm a regional approach for targeted stormwater management and investment at high-yield locations that maximize stormwater management, overflow reduction, and community benefits.