3. GREEN INFRASTRUCTURE MODELING APPROACH USING GIS AND SWMM

This section describes the process used for modeling the performance of green infrastructure (GI) for stormwater management, and resultant combined sewer overflow (CSO) reductions within the 30 high priority sewersheds. Section 3.1 details the process for selecting the highest yield stormwater capture locations for GI placement using ArcGIS software. Section 3.2 outlines how the selected high yield stormwater capture locations were then integrated into SWMM hydrologic and hydraulic (H&H) modeling software (v5.1.009) and modeled for GI performance using the SWMM low impact development (LID) Tool. Specific GI sizing criteria, subsurface infiltration, and underdrain model representation are also discussed in Section 3.2. A summary of the CSO benefits are then presented in Section 3.3. The results presented within this section demonstrate the performance of GI using a conservative infiltration rate assumption and a capture and slow release back into the combined sewer system (CSS) methodology that would most likely be implemented in most areas throughout the CSS.

3.1 Identification of Target Green Infrastructure Locations Using GIS

The first step in determining the high yield GI locations was to identify the areas where the greatest volume of stormwater runoff enters the CSS through mapped PWSA drainage inlet locations. These areas were considered to be the “highest yield” target opportunities for GI, and were determined using the following tools and procedures. Stormwater runoff drainage areas to each PWSA inlet were determined by creating a surface level hydrologic model to represent the 30 high priority sewersheds. The surface level hydrologic model was created using the ESRI based Arc Hydro Data Model and existing GIS data from PWSA, ALCOSAN, and publicly available data from the Pennsylvania Spatial Data Access. The existing GIS data used to create the surface level hydrologic model is summarized in Table 3-1.

TABLE 3-1
ARC HYDRO DATA OVERVIEW

Data	Description	Source	Year
Digital Elevation Model	LiDAR-derived rasters with one meter cell size	Pennsylvania Spatial Data Access	2006
Breaklines	Polyline defining boundaries for roads, bridges, parcels, and water bodies	Pennsylvania Spatial Data Access	2006
Building Footprints	Polygons of footprints of buildings, houses, and other structures	Pennsylvania Spatial Data Access	2013
Allegheny County Parking Areas	Polygons of parking lot areas in Allegheny County	Allegheny County Division of Computer Services	2000
City of Pittsburgh Drainage Inlets	Point file of grate drainage inlets within the City of Pittsburgh boundary	Pittsburgh Water and Sewer Authority	2008
SWMM Sewershed Boundaries	Polygons of sewershed boundaries based on CSO outfalls	Allegheny County Sanitary Authority	N/A

Using the surface level hydrologic model, the contributing drainage area of each PWSA known stormwater drainage inlet location within the 30 high priority sewersheds was delineated based on the surface topography. As an example, the delineated drainage areas for the PWSA inlets within the A-22 sewershed are shown in Figure 3-1. This figure illustrates the delineated PWSA inlet drainage areas (blue areas) overlain on the 2006 Digital Elevation Model (in shades of grey); the lighter the grey shade shown equals a higher elevation in the digital elevation model. It should also be noted that the black area in the middle of the figure clearly delineates the location of the historic stream valley before being filled in (current location of existing trunk combined sewer and Busway).

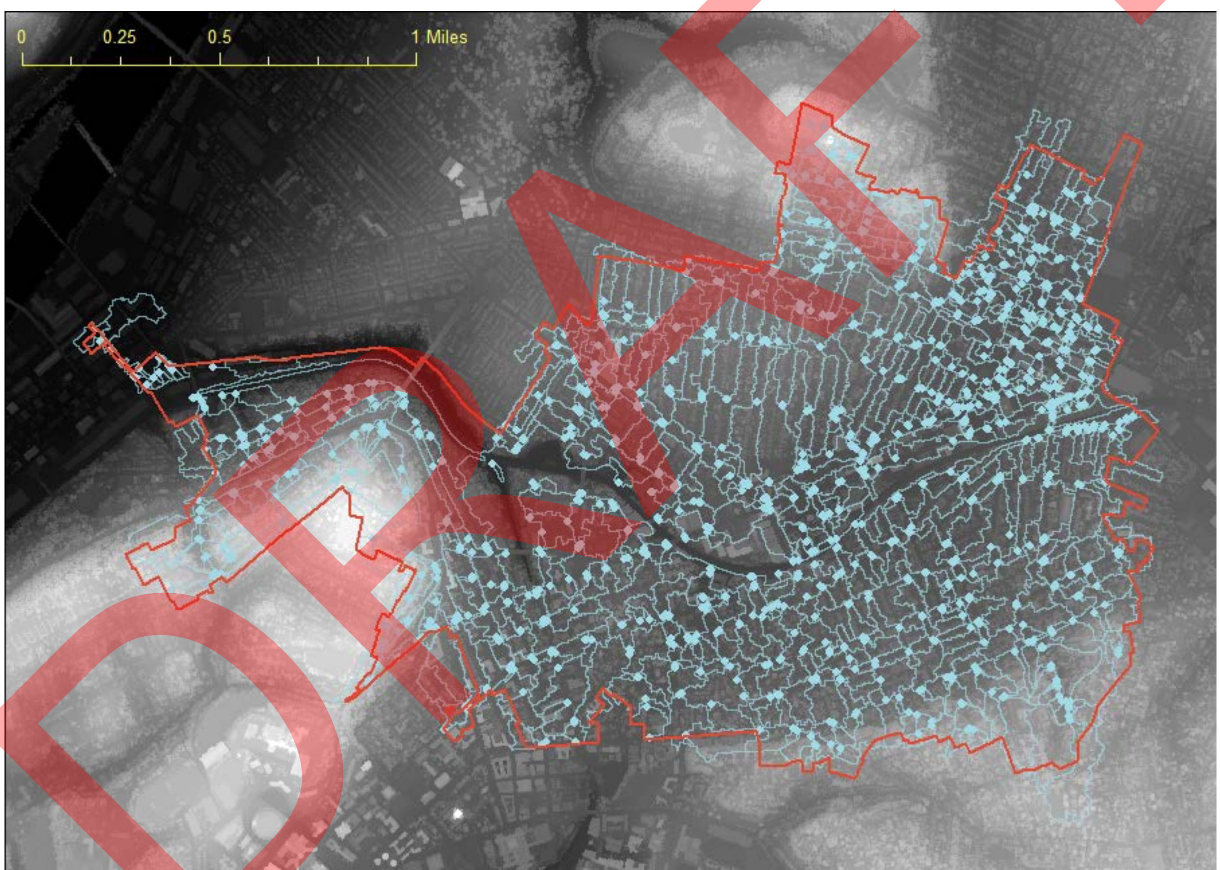

Figure 3-1: Arc Hydro Surface Level Hydrologic Output Results for the A-22 Sewershed

For each individual drainage area in the 30 high priority sewersheds (example shown in blue in Figure 3-1), the contributing impervious area was calculated using the road, roof, and parking lot shapefiles from the Pennsylvania Spatial Data Access database. The stormwater drainage inlets were then ranked highest to lowest based on the total contributing impervious area to the inlet. The highest ranking inlets were used to determine the most effective locations for "high yield" stormwater management utilizing GI best management practices (BMPs). Figure 3-2 provides an example map showing the stormwater inlets ranked by highest contributing impervious area for the A-22 sewershed.

The process of developing a surface level hydrologic model, creating drainage areas for the PWSA stormwater drainage inlets, and ranking the inlets based upon the contributing impervious surface was then repeated for each of the 30 high priority CSO sewersheds. Among these 30 sewersheds, the contributing impervious area per stormwater drainage inlet ranged from less than 0.5 acre to 27.5 acres. The ranking results were instrumental in identifying "high yield" target areas of focus for subsequent GI analysis and evaluations.

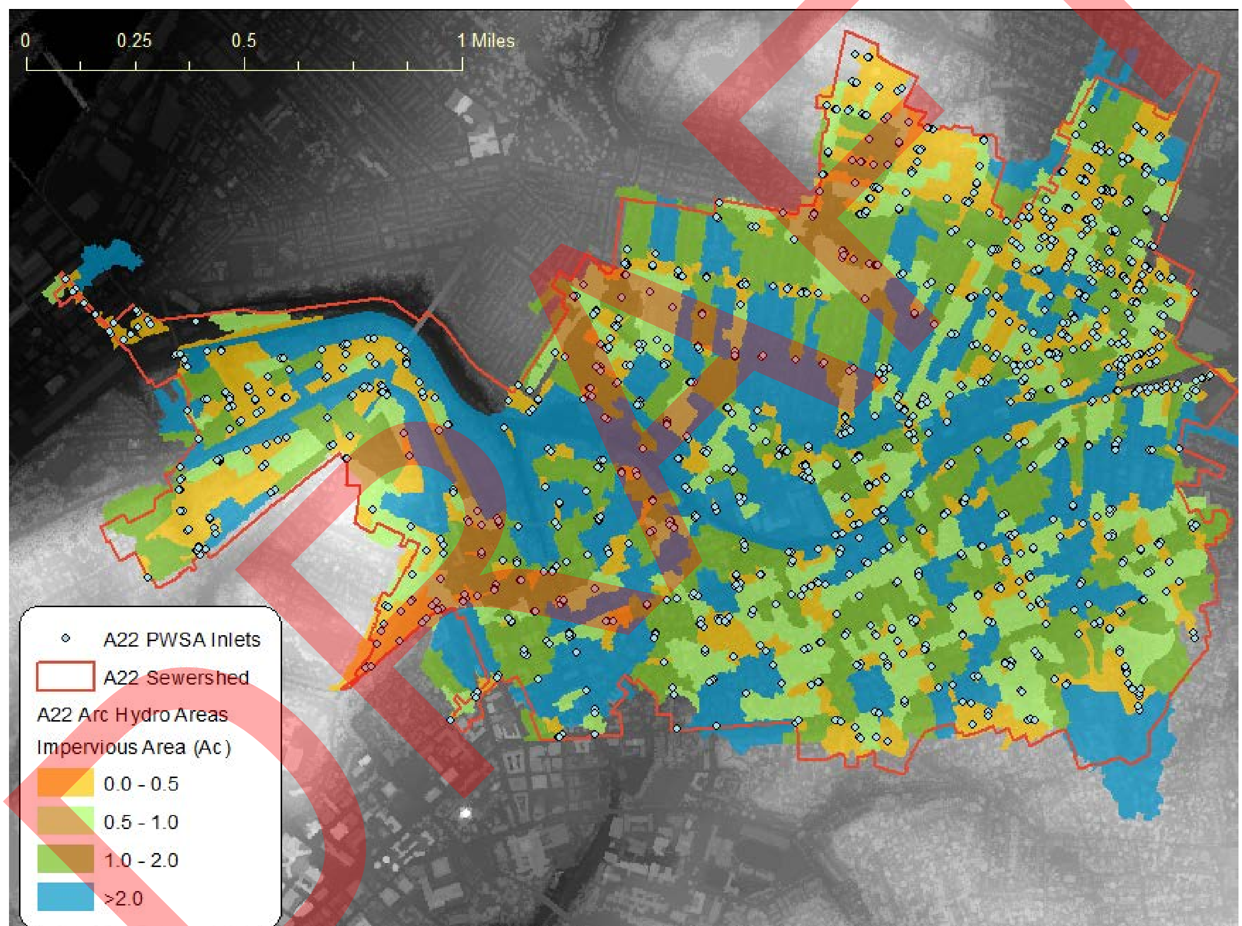

Figure 3-2: Highest Ranking PWSA Stormwater Inlet Areas in the A-22 Sewershed Based on Tributary Impervious Area

3.2 Incorporate High Yield GI Locations into SWMM

This section outlines the process for incorporating the high yield GI locations within the 30 high priority sewersheds (as described in Section 3.1) into the regional SWMM H&H sewer system model to determine the resultant stormwater and CSO reduction benefits. This process consisted of the following four steps:

Figure 3-3: Process for Incorporating High Yield GI Locations into SWMM

Figure 3-3 illustrates the four step process results for the A-22 sewershed. It was determined that management of 30% of the impervious surface stormwater runoff area is needed to achieve the goal of 85% combined sewage capture, along with surface flooding and basement sewage backup mitigation for a specific storm condition, in the A-22 sewershed. For A-22, 30% of the impervious surface is approximately 271 acres. The highest yield PWSA stormwater drainage inlets and associated drainage areas were then selected to meet the 30% target impervious surface management value. The 30% target areas were then overlain on the existing combined sewer subcatchments represented in the regional SWMM sewer system model.

Appendix A provides maps for each of the 30 high priority sewersheds, showing the target high yield drainage areas and the sewer subcatchment areas for impervious surface area management.

As shown in Figure 3-3, many of the high yield drainage areas encompass multiple combined sewer modeled subcatchment boundaries and are rarely an exact 1:1 match. To address this conflict, a simple process flow diagram was developed for incorporating the SWMM LID Tool into the overlapping sewer subcatchments in the SWMM model. The process flow diagram for incorporating the high yield drainage areas into the SWMM LID Tool is shown in Figure 3-4. This process is further illustrated in Figure 3-5 using an example high yield drainage area within the A-22 sewershed. The high yield drainage area GI location presented in Figure 3-5 is presented for example purposes only and should not be considered a definitive GI implementation area as of the authoring of this study.

Using the process outlined in Figure 3-4 and further illustrated in Figure 3-5, each combined sewer modeled subcatchment that overlapped with a high yield drainage area was modified for the SWMM LID Tool.

Figure 3-4: Target High Yield Drainage Areas (Blue Areas) and SWMM Subcatchment Areas (Red Outlines) for A-22 Sewershed for 30% Impervious Surface Area Management

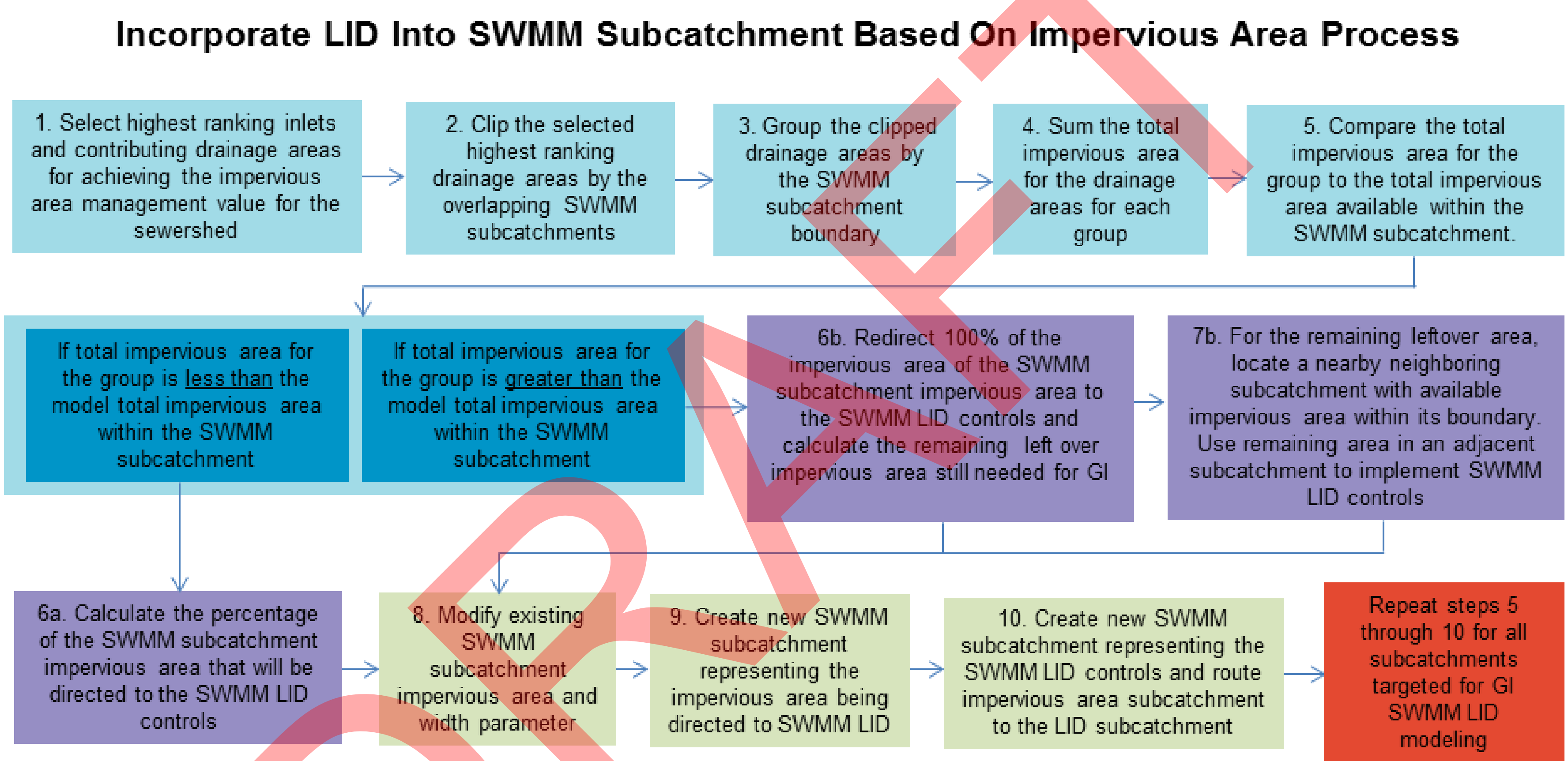

Figure 3-5: Process Used for Incorporating Arc Hydro Results into the SWMM LID Tool for Combined Sewer Subcatchments in the 30 High Priority Sewersheds

Figure 3-6: Example Illustration for Incorporating Arc Hydro Results into the SWMM LID Tool for Combined Sewer Subcatchments in the 30 High Priority Sewersheds

Once all of the target high yield drainage areas were successfully incorporated into the regional SWMM model, the specific parameters within the LID Tool were standardized across all of the 30 high priority sewersheds. Table 3-2 shows the SWMM LID Tool parameters used for each of the 30 high priority sewersheds. The SWMM LID Tool parameters were selected based upon a sensitivity analysis conducted as part of a previous GI study conducted within the A-22 sewershed. A brief summary, including the results of this sensitivity analysis, are presented in Appendix B.

TABLE 3-2
SUMMARY OF SWMM LID TOOL MODELING PARAMETERS AND ASSUMPTIONS (PERFORMANCE CRITERIA)

SWMM LID Tool Parameter	Model Assumption
SWMM LID GI Type	Infiltration Trench
GI Rainfall Depth Sizing	1.5 inches over contributing impervious drainage area
Assumed Infiltration Rate	0.1 inches per hour
Assumed Depth of GI	4 feet
Assumed Width of GI	4 feet
Assumed Length per GI Unit	200 feet
Underdrain Height Offset	6 inches
Underdrain Coefficient – Optimized for 72 Hour Emptying Time to the CSS from BMP Full	0.082

The basic functioning principal of GI is to serve as a storage facility to temporarily store runoff with a portion of the runoff being infiltrated or evaporated and the remainder returned to the existing CSS via an under drain. ALCOSAN's Starting at the Source report (2015), which also evaluated the CSO reduction effectiveness of GI within the region, assumes the same basic principles. However, there are slight differences between PWSA's and ALCOSAN's GI modeling approach. ALCOSAN primarily relied upon a 1.0-inch rainfall depth GI sizing requirement for the basis of their investigation, but they did perform a "limited number of model simulations" under 1.5-inch rainfall depth size. Likewise, ALCOSAN also utilized a 24-hour return period for the GI emptying time for the bulk of their analysis and also performed a limited number of model simulations under a 72-hour return period. Generally, the approaches between PWSA and ALCOSAN are very similar in terms capturing and storing runoff in a distributed manner and slowly releasing it back into the CSS, however there are slight differences in GI sizing and optimized underdrain slow release return time as part of the model simulations. For the infiltration parameters, it is unclear from the Starting at the Source report exactly what infiltration approach and parameters were used to model the GI infiltration losses.

As previously stated, the underdrain coefficient for the SWMM LID tool modeling analysis was optimized to the 72-hour return time. This is based upon typical year modeling of the hydraulics of the existing ALCOSAN interceptor system. Typical year modeling results indicate that generally the interceptors return to dry weather flow after a large rain event after 72-hours of operation. Using these findings, the 72-hour return time was found to be optimal as a target drain down time to slowly empty the detained stormwater back into the existing CSS. The infiltration rate of 0.1 inches per hour was selected to be conservative and corresponds to fine and very fine clay type soil particles according to the United States Department of Agriculture[1]. There is concern from regulatory agencies, municipalities and municipal engineers that infiltrated stormwater may potentially return back into the sewer system as inflow and/or infiltration (I/I) from groundwater. To account for this potential effect, a conservative and relatively low infiltration rate of 0.1 inches per hour based on clay type soils was assumed, with the rest of the captured stormwater being returned back to the existing CSS through an underdrain system. In the field and practice, larger infiltration rates will likely be experienced with potentially some of the infiltrated water reentering the CSS as I/I. The demonstration projects currently being designed and implemented are being monitored to understand the effects of infiltration and the resultant flow balances.

The SWMM LID Tool allows for the simulation of various GI technologies including rain gardens, infiltration trenches, bioinfiltration, bioswales, and rain barrels/cisterns directly within the SWMM model. Each GI technology within the SWMM LID Tool has varying functional components based on the technology simulated. For this study, all GI locations were simulated using subsurface infiltration trenches. Infiltration trenches were selected as the GI modeled technology for the 30 high priority sewersheds because it was assumed that the stormwater would be captured in the GI BMP and slowly released over a 72-hour time period back into the CSS. Infiltration trenches within the SWMM LID Tool during rain events allow for transfer of captured stormwater runoff to an underground detention facility with a slow release underdrain. While the infiltration trench was modeled within SWMM, any BMP that can capture the stormwater runoff, transfer the water to an underground detention reservoir (rock trench or modular storage) and utilize an underdrain to slowly release the captured stormwater back into the CSS can be constructed in the field. This includes bioretention, rain gardens and the variations thereof, green roofs, and porous pavement.

The 30 high priority sewersheds with LID Tool parameters were then integrated into the system wide model, which was created by stitching together the eight ALCOSAN planning basin models. The creation of the system wide model allowed for wastewater treatment plant (WWTP) capacity scenarios and GI to be modeled together to observe the changes in GI performance with WWTP capacity changes and hydraulic modification

[1] http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/office/ssr10/tr/?cid=nrcs144p2_074846

to the existing interceptor system. Section 2 of this report provides a detailed discussion of the system wide model and the capacity scenarios selected. In order to simulate GI flow reduction benefits using the SWMM LID Tool, SWMM Version 5.1.009 was used for all 30 high priority sewersheds. The GI was also modeled in tandem with direct stream removal (see Section 5). The CSO reduction benefits of GI and direct stream removal within the 30 high priority sewersheds are presented in Section 3.3.

3.3 Summary of Green Infrastructure Modeling Results

The following provides a discussion of the GI modeling results using the SWMM LID Tool within the 30 high priority sewersheds. All results presented in Section 3.3 include direct stream removal locations in addition to GI using SWMM LID. The direct stream removal locations are presented in Section 5.

The GI modeling analysis examined the impervious area management to achieve 85% combined sewage capture at each individual CSO, as well as the area required to achieve aggregate 85% capture for all 30 high priority sewersheds. See Section 2 for a detailed discussion of the 85% combined sewage capture target value. The required impervious area GI management is influenced by the ALCOSAN WWTP wet weather capacity, the hydraulic capacity of the combined sewer regulators, and the conveyance capacity of the existing ALCOSAN interceptor system. Two potential WWTP capacity and conveyance system configurations were selected to evaluate the GI management that may be required for those scenarios:

- The 480 million gallons per day (MGD) (WWTP Expansion) configuration (as described in Section 2 of this report) consists of 480 MGD WWTP capacity combined with GI. This scenario resulted in the need to manage approximately 1,835 acres of directly connected impervious area (DCIA) within the 30 high priority sewersheds to meet at least 85% combined sewage capture at each individual CSO.
- The Lowered Hydraulic Grade Line (HGL) Operation During Wet Weather Conditions configuration (as described in Section 2 of this report) represents the Lowered HGL Operation During Wet Weather Conditions combined with GI. This scenario resulted in the need to manage approximately 1,286 acres of directly connected impervious area within the 30 high priority sewersheds to meet at least 85% combined sewage capture at each individual CSO.

The Lowered HGL Operation During Wet Weather Conditions scenario was selected to understand the maximum available conveyance capacity of the existing ALCOSAN interceptors. In order to match the wet weather treatment capacity of the WWTP to this potentially available conveyance capacity, the Lowered HGL Operation During Wet Weather scenario would need further investigation in coordination with ALCOSAN. The Lowered HGL Operation During Wet Weather Conditions scenario would likely require a new influent pump station installed deeper than the current PS to pump additional wet weather flow, additional access shafts along the existing deep tunnel interceptors to facilitate maintenance and cleaning of the existing tunnels, and potential mitigation of surge/transient pressures would be required. A new influent pumping station is proposed as part of ALCOSAN's Recommended Plan to dewater the proposed regional wet weather tunnels. The technical feasibility of all potential treatment plant wet weather capacity scenarios is currently under discussion between PWSA and ALCOSAN. This GI Assessment includes evaluating removal or detaining the existing streams entering the CSS, including adding grit/sediment traps, which are reported to be a large source of the sediment entering the existing tunnels contributing to the need to remove the accumulated sediment.

The GI management results for the 480 MGD (WWTP Expansion) configuration and the Lowered HGL Operation During Wet Weather Conditions configuration compared with existing conditions are shown in Table 3-3. The results in Table 3-3 provide the directly connected impervious area that would need to be managed in each of the 30 high priority sewersheds to achieve the target 85% combined sewage capture at each CSO.

The two GI management scenarios of 1,286 and 1,835 directly connected impervious acres were then modified for SWMM LID using the approach as outlined in Section 3.2. Each GI management scenario was then simulated in the system wide model under four ALCOSAN WWTP and interceptor hydraulic capacity scenarios as shown in Table 3-4 and previously summarized in Section 2.

The aggregate 30 high priority sewershed typical year results of the SWMM LID Tool model simulations are presented in Table 3-5. The results from Table 3-5 are also presented graphically as "performance curves" in Figure 3-6. The performance curves in Figure 3-6 are a visual representation of the typical year CSO results for the SWMM LID GI modeling analysis.

Modeling results on an individual sewershed basis are provided in Appendix C.

TABLE 3-3
GI MODELING MANAGEMENT ACREAGES FOR THE 30 HIGH PRIORITY SEWERSHEDS FOR TWO SYSTEM CONFIGURATIONS: 480 MGD (WWTP EXPANSION) AND LOWERED HGL OPERATION DURING WET WEATHER CONDITIONS

		480 MGD (WWTP Expansion)		Lowered HGL Operation During Wet Weather Conditions, Sediment Removed, and 19 CSO Regulators Modified	
High Priority Sewershed	Existing Conditions Directly Connected Impervious Acres (DCIA) (Ac)	% Impervious Acres Modeled Using SWMM LID	Total DCIA Modeled Using SWMM LID (Ac)	% Impervious Acres Modeled Using SWMM LID	Total DCIA Modeled Using SWMM LID (Ac)
A-22-OF	898.0	43%	387.7	30%	271
A-41-OF	234.7	85%	199.5	60%	140.8
A-42-OF	839.7	73%	614.1	58%	485.1
A-47-OF	9.0	0%	0	0%	0
A-48-OF	167.1	25%	41.8	25%	41.8
A-51-OF	34.6	0%	0	0%	0
A-58-OF	151.7	25%	37.9	25%	37.9
A-60-OF	175.2	25%	43.8	25%	43.8
A-61-OF	10.7	37%	4.0	0%	0
A-62-OF	5.7	0%	0	0%	0
A-63-OF	1.0	0%	0	0%	0
A-64-OF	18.4	0%	0	0%	0
A-65-OF	4.6	15%	0.7	0%	0
M-15-OF	3.7	65%	2.4	0%	0
M-15Z-OF	3.1	0%	0	0%	0
M-16-OF	100.0	85%	85.0	25%	25.2
M-17-OF	6.2	0%	0	0%	0
M-18-OF	5.1	0%	0	0%	0
M-19A-OF	142.6	41%	58.4	35%	49.9
M-19B-OF	32.1	28%	9.0	33%	10.6
M-19-OF	119.1	55%	65.7	25%	29.8
M-20-OF	6.2	0%	0	0%	0
M-21-OF	29.2	8%	2.3	0%	0
M-22-OF	16.4	0%	0	0%	0
M-29-OF	362.3	60%	217.7	25%	90.5

TABLE 3-3
GI MODELING MANAGEMENT ACREAGES FOR THE 30 HIGH PRIORITY SEWERSHEDS FOR TWO SYSTEM CONFIGURATIONS: 480 MGD (WWTP EXPANSION) AND LOWERED HGL OPERATION DURING WET WEATHER CONDITIONS

		480 MGD (WWTP Expansion)		Lowered HGL Operation During Wet Weather Conditions, Sediment Removed, and 19 CSO Regulators Modified	
High Priority Sewershed	Existing Conditions Directly Connected Impervious Acres (DCIA) (Ac)	% Impervious Acres Modeled Using SWMM LID	Total DCIA Modeled Using SWMM LID (Ac)	% Impervious Acres Modeled Using SWMM LID	Total DCIA Modeled Using SWMM LID (Ac)
O-27-OF	195.6	22%	43.7	22%	43.7
O-39-OF	23.8	21%	5.1	0%	0
O-40-OF	2.8	0%	0	0%	0
O-41-OF	27.9	56%	15.6	56%	15.6
O-43-OF	9.8	0%	0	0%	0
Totals =	3,636.2	50.45%	1,834.5	35.35%	1,285.7

TABLE 3-4 VARIOUS SYSTEM CONFIGURATIONS EVALUATED TO DETERMINE GI SENSITIVITY	
Existing Conditions	This represents the current state of the collection system and the WWTP treatment capacity. The WWTP has a 250 MGD treatment capacity and its influent pump station wet well operates at an HGL level of 670 feet. The existing interceptors have the sediment levels as defined in the current ALCOSAN model.
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.
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. Based on typical year modeling analysis under this scenario, it is anticipated that the full 600 MGD capacity would be utilized approximately 24 to 48 hours annually.
Lowered HGL Operation During Wet Weather Conditions [1]	This system state represents an attempt to maximize the performance of the existing infrastructure. This system state 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 technical feasibility of all potential treatment plant wet weather capacity scenarios is currently under discussion between PWSA and ALCOSAN. 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.

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

TABLE 3-5
AGGREGATE TYPICAL YEAR CSO GI AND STREAM REMOVAL MODELING RESULTS FOR THE 30 HIGH PRIORITY SEWERSHEDS

	Existing Conditions (250 MGD Capacity)			480 MGD (WWTP Expansion)		
	CSO Remaining (MG)	CSO Reduced (MG)	Percent Combined Sewage Capture (%)	CSO Remaining (MG)	CSO Reduced (MG)	Percent Combined Sewage Capture (%)
Plant Capacity Alone	3,067	0	70%	2,480	587	76%
With GI Management 1,286 impervious acres	2,400	667	77%	1,795	685	83%
With GI Management 1,835 impervious acres	2,083	984	80%	1,534	946	**85%**

	600 MGD WWTP Expansion with Interceptor Hydraulic Improvements and Open Tipping Gates at 19 CSO Regulator Structures (Feasibility would need to be evaluated)			Lowered HGL Operation During Wet Weather with Interceptor Hydraulic Improvements and Open Tipping Gates at 19 Regulator Structures (Feasibility would need to be evaluated)		
	CSO Remaining (MG)	CSO Reduced (MG)	Percent Combined Sewage Capture (%)	CSO Remaining (MG)	CSO Reduced (MG)	Percent Combined Sewage Capture (%)
Plant Expansion Alone	1,701	1,366	84%	1,542	1,525	**85%**
With GI Management 1,286 impervious acres	1,124	576	**89%**	970	572	**91%**
With GI Management 1,835 impervious acres	910	790	**91%**	766	775	**93%**

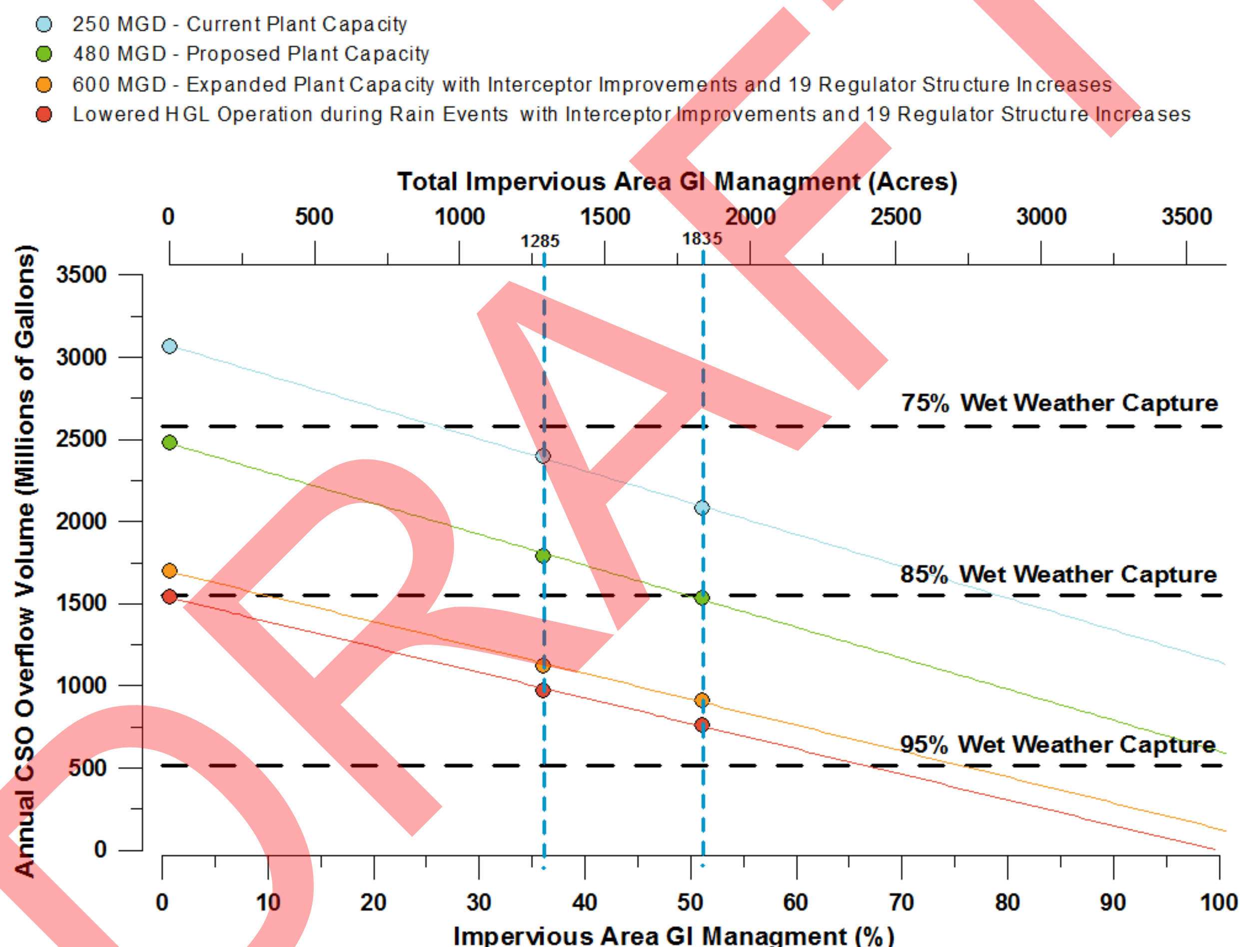

Figure 3-7: Aggregate Typical Year CSO GI and Stream Removal Modeling Performance Curves for the 30 High Priority Sewersheds

In addition to analyzing the overflow volume reductions at the individual 30 high priority sewersheds as presented in Table 3-5 and Figure 3-6, the total ALCOSAN service area systemwide overflow reduction results were also analyzed. This was done to observe any potential overflow reductions within neighboring sewersheds that were not part of the 30 high priority sewersheds. The total ALCOSAN systemwide overflow was determined by calculating the net overflow reduction change within the SWMM outfall loadings report with and without GI implemented. The total ALCOSAN service area systemwide overflow reductions were calculated using three of the four system configuration scenarios:

- 480 MGD conditions with 1,835 impervious acres managed by GI within the City of Pittsburgh and direct stream removal,
- 600 MGD conditions with 1,835 impervious acres managed by GI within the City of Pittsburgh and direct stream removal, and
- Lowered HGL Operation During Wet Weather Conditions with 1,286 impervious acres of GI managed by GI in the City of Pittsburgh and direct stream removal.

The results from the systemwide overflow reduction analysis are shown in Table 3-6.

TABLE 3-6
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 & System Improvements, Sediment Removed, and 19 Regulator Modifications	Lowered HGL Operation During Wet Weather Conditions, Sediment Removed, and 19 Regulator Modifications
Impervious Acres Managed with GI	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) [2]	4.09	5.00	5.20
Total ALCOSAN Systemwide Overflow Volume Remaining (BG) [2]	5.89	4.98	4.78

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

[2] SWMM Model Version 5.1.009 Results (as described in Section 2 of this report).

3.4 Discussion of Green Infrastructure Modeling Results

The following are some observations based upon the modeling results presented in Section 3.3:

- An increase in the ALCOSAN wet weather treatment capacity from 250 MGD to 480 MGD will:
    - Reduce annual CSO volume in the 30 high priority sewersheds from 3,070 MG to 2,480 MG exclusive of GI investment, and representing approximately 76% aggregate capture of combined sewage for the sewersheds.
    - With a GI impervious area management of 1,286 acres, CSO volume can be further reduced to about 1,790 MG, representing approximately 83% aggregate capture for the 30 high priority sewersheds.
    - With a GI impervious area management of 1,835 acres, CSO volume can be further reduced to 1,530 MG, representing 85% aggregate capture for the 30 high priority sewersheds.
    - Reduce CSO volume for two of the 30 CSOs, A-47 and O-43, representing 99.8% capture.

- An increase in the ALCOSAN wet weather treatment capacity to 600 MGD with additional interceptor hydraulic increase from sediment removal, and opening the existing tipping gates at 19 CSO regulator structures will:
    - Reduce the annual CSO to 1,700 MG; yielding approximately an 84% capture exclusive of GI investment for the 30 high priority sewersheds.
    - With a GI impervious area management of 1,286 acres, CSO volume can be further reduced to 1,120 MG, yielding an aggregate 89% capture for the 30 high priority sewersheds.
    - With a GI impervious area management of 1,835 acres, CSO volume can be further reduced to 910 MG, yielding an aggregate 91% capture for the 30 high priority sewersheds with at least 85% capture at each individual CSO, except A-41 and M-19B with 80.1%, and 82.7% captures, respectively.
    - Reduce CSO volume for four CSOs, O-43, M-15, A-47, and A-48, each representing 99% or greater capture.
    - Reduce CSO volume for three other CSOs, O-27, O-39, and A-51, each representing at least 98% capture.

- An increase in the ALCOSAN wet weather conveyance and treatment capacity in the Lowered HGL Operation During Wet Weather Conditions scenario with additional interceptor hydraulic increase from sediment removal, and opening the existing tipping gates at 19 CSO regulator structures will:
  - Reduce the annual CSO volume to 1,540 MG; yielding an aggregate 85% combined sewage capture exclusive of GI investment for the 30 high priority sewersheds.
  - With a GI impervious area management level of 1,286 acres, CSO volume could be further reduced to 970 MG; yielding an aggregate 91% combined sewage capture for the 30 high priority sewersheds.
  - With a GI impervious area management of 1,835 acres, CSO volume can be further reduced to 770 MG; yielding an aggregate 93% capture for the 30 high priority sewersheds with at least 85% capture at each individual CSO, except M-19B with 83.1% capture.
  - Reduce CSO volume for six CSOs, O-43, M-15, A-47, A-48, A-60, and A-65, representing 99% or greater capture.
  - Reduce CSO volume for four CSOs, O-27, O-39, M-19, and A-51, representing at least 98% capture.

In summary, the results of the GI modeling analysis for the 30 high priority sewersheds indicate:

- GI integrated with wet weather WWTP capacity increases can achieve at least an aggregate 85% combined sewage capture in the 30 high priority sewersheds along with at least 85% capture at each individual CSO.
  - 480 MGD treatment plant wet weather capacity: With a GI impervious area management of 1,835 acres, CSO volume can be reduced from 3,067 MG to 1,500 MG, representing an 85% aggregate capture for the 30 high priority sewersheds.
  - 600 MGD treatment plant wet weather capacity with interceptor hydraulic increase from sediment removal, and opening the existing tipping gates at 19 CSO regulator structures (not currently planned and needs further evaluation): With a GI impervious area management of 1,835 acres, CSO volume can be reduced from 3,067 MG to 910 MG remaining, yielding an aggregate 91% capture for the 30 high priority sewersheds with at least 85% capture at each individual CSO, except A-41 and M-19B with 80.1% and 82.7% captures, respectively. Regulator modifications or slight increases in the amount of GI within each shed could increase the capture for each of these 2 CSOs to 85% capture.
  - Lowered HGL Operation During Wet Weather Conditions scenario with interceptor hydraulic increase from sediment removal, and opening the existing tipping gates at 19 CSO regulator structures (not currently planned and needs further evaluation): With a GI impervious area management of 1,835 acres, CSO volume can be reduced from 3,067

MG to 766 MG remaining, yielding an aggregate 93% capture for the 30 high priority sewersheds with at least 85% capture at each individual CSO, except M-19B with 83.1% capture. Regulator modifications or slight increases in the amount of GI within this shed could increase this CSO to 85% capture.

- The two selected levels of impervious area management with GI (1,286 acres and 1,835 acres) across the 30 high priority sewersheds represent feasible amounts of area that could be controlled with GI – representing just 9% and 13% of the total area, respectively.
- The listed WWTP capacity scenarios are currently under discussion between PWSA and ALCOSAN and need further coordination.

The cost analysis results using the CSO reduction benefits results outlined in this section are presented in Section 9.