C-2. Overflow Reduction Efficiency Technical Memorandum

TECHNICAL MEMORANDUM

Overflow Reduction Efficiency Modeling Approach and Application for the ALCOSAN Service Area

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1.0 Introduction and Overview

ALCOSAN seeks to maximize the impact of green stormwater infrastructure and source control (GSI/SC) measures to reduce the volume of overflows to receiving systems. CH2M has developed an approach for applying existing hydrologic and hydraulic models automatically, for a range of alternative system conditions, to quantify overflow reduction impacts. This memorandum summarizes this modeling approach and how it was applied throughout the ALCOSAN service area.

2.0 Overflow Reduction Efficiency Modeling Technical Approach

This section describes the objective of Overflow Reduction Efficiency (ORE) modeling, how the ORE is calculated, the geographic scale at which OREs are estimated, the baseline condition and model used for ORE modeling, and how the impacts of GSI/SC measures were represented in the model.

2.1 Objective of ORE Modeling

The objective of Overflow Reduction Efficiency (ORE) modeling is to estimate the effectiveness of GSI/SC to reduce overflow volumes, across a range of geographies (discussed in Section 2.3) and implementation levels (Section 2.6). GSI/SC measures evaluated include green stormwater infrastructure (GSI), inflow and infiltration (I/I) reduction, and direct stream inflow removal (DSIR).

The ORE estimate (reduction in overflow volume per unit reduction in inflow) provides ALCOSAN, municipalities, and planning teams a hydraulically informed estimate of overflow impacts of different projects, so that effort and attention can be focused in those geographic areas with the greatest overflow impacts. The ORE estimate is an early-stage planning tool; as projects and evaluations progress, more detailed modeling of both the baseline system condition (that is, existing, future, with plant expansion, etc.) and proposed project(s) will involve case-by-case modeling evaluations at a greater level of detail.

2.2 ORE Calculation

The ORE is calculated according to the following equation:

$$Overflow\ Reduction\ Efficiency = \frac{Overflow\ Reduced}{Inflow\ Reduced}$$

Where:

- Overflow reduced (mgal) = $\text{Overflow}_{\text{baseline}}$- $\text{Overflow}_{\text{ore\_scenario}}$
- Inflow reduced (mgal) = $\text{Inflow}_{\text{baseline}}$- $\text{Inflow}_{\text{ore\_scenario}}$

For example, if a certain scenario resulted in 10 mgal of stormwater inflow reduction and 7 mgal of overflow reduction, the ORE for that scenario would be 0.7 or 70% (7 divided by 10). OREs were estimated for GSI, separate sanitary sewer inflow and infiltration (I/I) reduction, and direct stream inflow removal (DSIR), using distinct modeling approaches as needed based upon the type of source control (see Section 2.6). A specific implementation level for a specific geographic area was tracked by a unique identifier, represented by the ore_scenario subscript in the equation above.

ORE values typically would be expected to be no more than one (or 100%) because in a simple system, inflow reductions would at most result in one-for-one reductions in the downstream overflows. However, actual ORE modeling results in some ORE values greater than one. This could potentially be the result of inflow reduction in one sewershed having overflow reduction benefits at multiple overflows (because of hydraulic interactions between them) or it could be the result of minor numerical instabilities (model “noise”). Therefore, OREs above one should be used cautiously.

2.3 Geographic Scale of Evaluation

ORE estimates were produced at a geographic scale that identified specific areas with higher and lower relative impact on overflow reduction. Modeled areas were grouped into “geographic units”, which were evaluated jointly to develop a single ORE estimate for a specific implementation level. Grouping areas reduces the number of modeling simulations required and also results in larger inflow and overflow reductions, so that the resulting ORE is a better estimate of anticipated overflow reduction benefits, and relatively less influenced by minor numerical differences between model simulations. Modeled areas (subcatchments in the combined system and sewersheds in the separate sanitary system) were grouped together in a geographic unit using the following rules:

- Drain to the same drainage node
- Drain to the same outfall
- Areas drain to the same point of connection (POC)

Geographic units were defined with the intent to isolate drainage to a given outfall, and specific POC, where possible. However, preliminary testing also demonstrated that ORE estimates were less reliable for geographic units that resulted in very small inflow and overflow reduction; minor numerical variations in the SWMM results can significantly influence the OREs since both the numerator and denominator are small. The amount of inflow reduction sufficient to produce a reliable overflow reduction was investigated during the Chartiers Creek planning basin pilot. In general, it was found that grouping areas such that inflow reduction was at least 0.1 mgal during the 09/14-9/30 potential proxy period (see Section 2.5) produced reliable ORE estimates. This was used as a guideline throughout the planning basins, with some judgment depending upon particular system characteristics. Therefore, in some cases areas draining to different outfalls and/or POCs were grouped together to produce a sufficient hydraulic impact for a reliable ORE estimate. Two typical cases where geographic units were defined that do not isolate drainage to an outfall/POC to produce a sufficient hydraulic impact for a reliable ORE include:

- Case A: Geographic unit contains area that drains to more than one outfall (see Figure 1):
  - Example: Geographic unit II_C-48-00 contains three RTK unit hydrograph sewersheds. While all three sewersheds drain to POC C-48, two sewersheds are upstream of SSO H-30-2C, and one sewershed is upstream of SSO H-30-2.
- Case B: Geographic unit contains area that drains to more than one outfall, and more than one POC (see Figure 2):
  - Example: Geographic unit GSI_C-08-00_C-06-00 contains two subcatchments. One of the subcatchments drains to POC C-08, and is upstream of CSO C-08-OF. The other subcatchment drains to POC C-06, and is upstream of CSO C-06-OF.

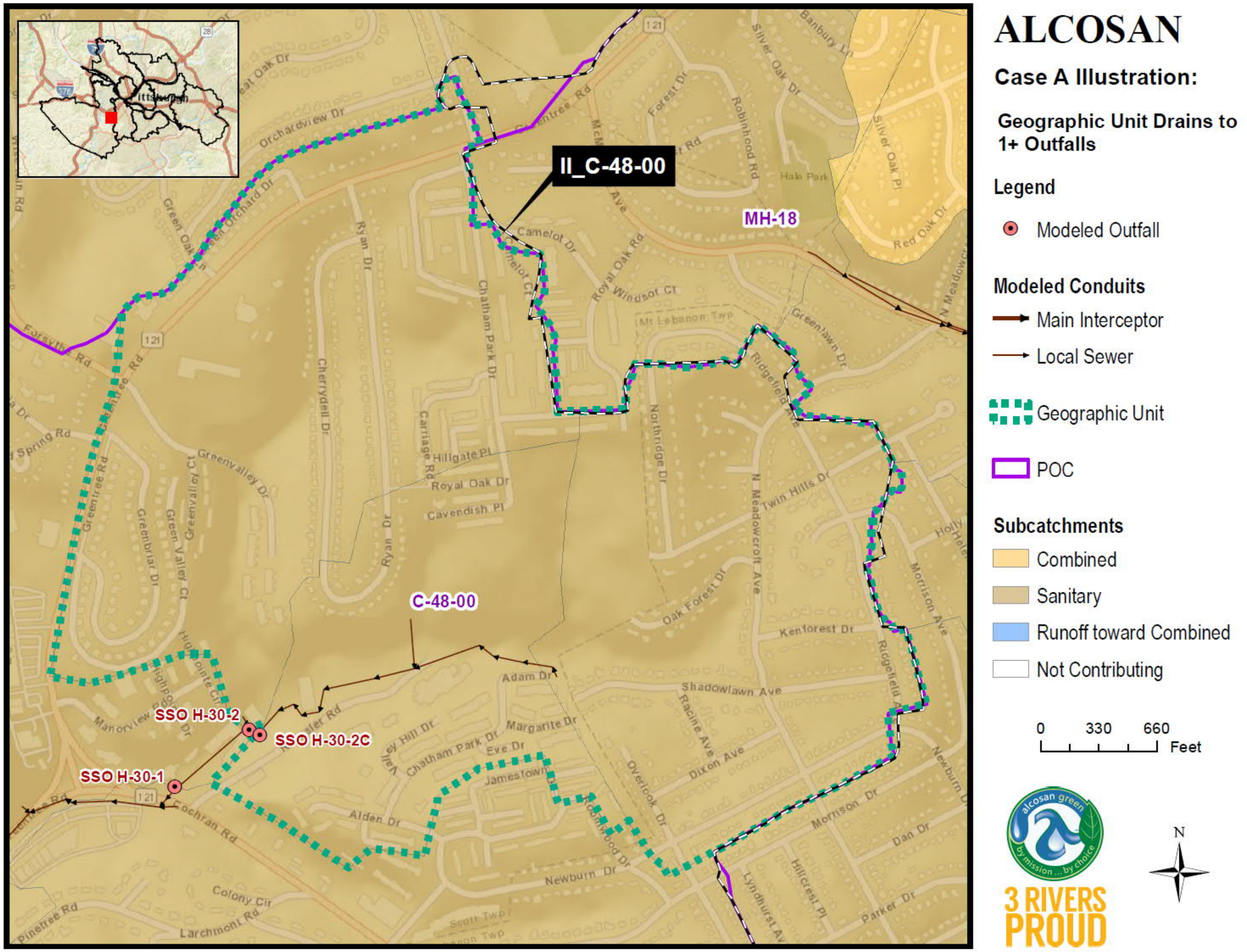

Figure 1. Case A Illustration: Geographic Unit Drains to 1+ Outfalls

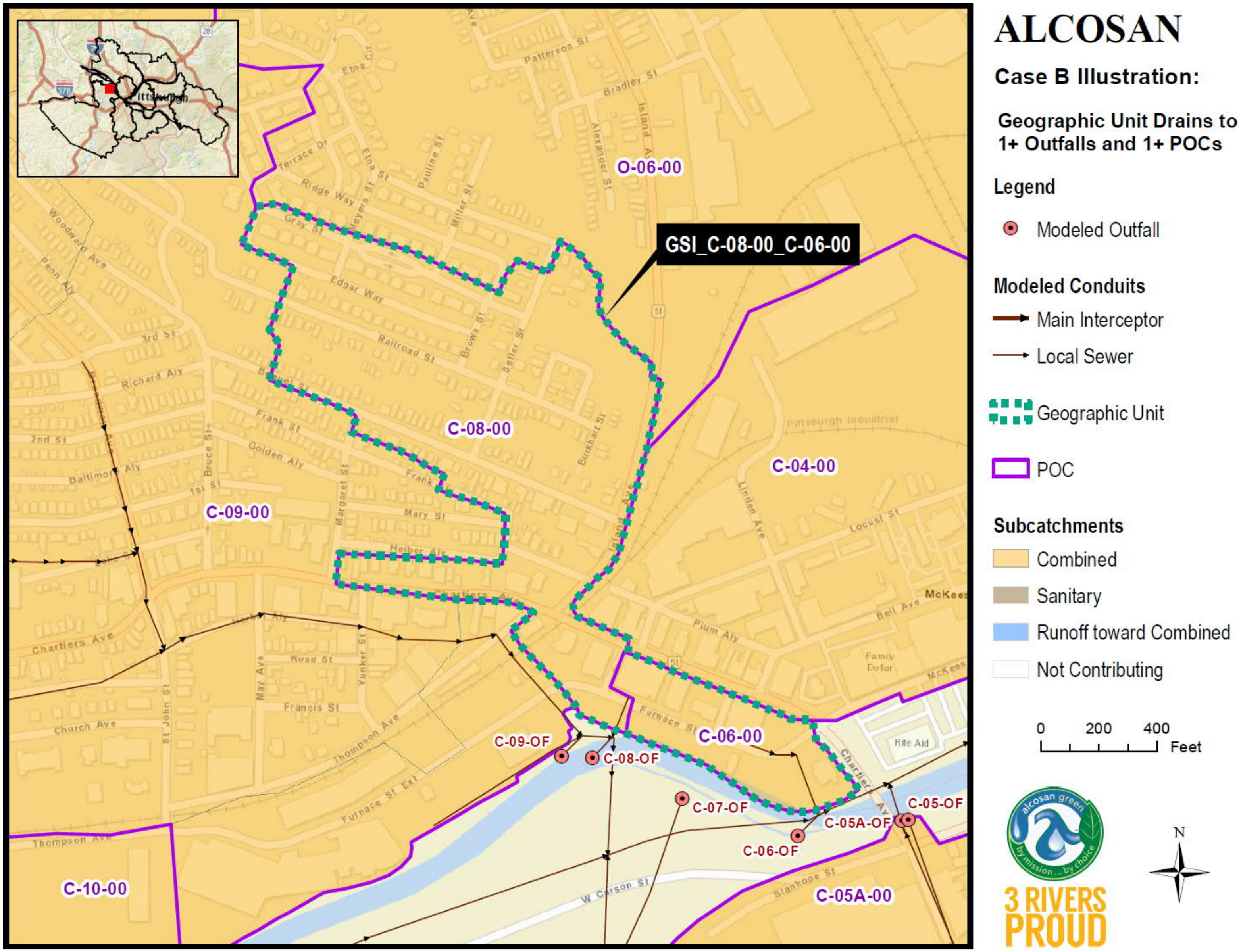

Figure 2. Case B Illustration: Geographic Unit Drains to 1+ Outfalls and 1+ POCs

Geographic unit IDs were assigned based on ORE GSI/SC type and the POC location. The following list describes the geographic unit ID naming conventions:

- If a geographic unit contains an entire POC, the ID begins with the GSI/SC type as the prefix, followed by the POC name (for example: GSI_C-07-00).
- If there were multiple geographic units within a single POC, numerical suffixes were added to the IDs (for example, the two geographic units that make up POC C-19-00 have IDs GSI_C-19-00_01 and GSI_C-19-00_02).
- If a geographic unit spans multiple POCs, the largest POC area is listed first, followed by the second largest POC area, and, if applicable, followed by the third largest POC area (for example, GSI_C-27-00_C-28-00_C-26A-00). Note that geographic unit IDs were limited to a maximum of three POCs.

2.4 Baseline Condition and Model

ALCOSAN is evaluating a range of alternative system conditions, including Existing Conditions, Interim Clean Water Plan, and the Selected Plan. Since the ORE estimate is a distillation of inflow reduction impacts in the context of local sewer and system hydraulics, the ORE estimates may vary significantly depending on the modeled baseline condition. For instance, if a storage tank were included in a future alternative condition, it would be sized to manage a significant percentage of overflows in its tributary area; therefore, OREs developed without the tank in place would be unrepresentative of the impacts with the tank in place.

The ORE evaluation simulations were completed within the existing conditions models. Simulation assumptions include:

- Existing system condition
- Plant capacity: 250 million gallons per day (mgd)
- Scale: Basin model
- Model Version: SWMM 5.1.011

ALCOSAN is defining future grey infrastructure plans, which will necessitate the reevaluation of the ORE models to include alternative baseline conditions. Since much of the time-consuming setup will already be performed at that time (e.g., definition of geographic units and identification of reporting nodes and links) the level of effort for estimating OREs under alternative model conditions is significantly lower than the initial evaluation described in this memorandum.

2.5 Evaluation Storm

Many ALCOSAN planning evaluations for both GSI (e.g., Green Revitalization of our Waterways [GROW] Program) and Preliminary Planning are based upon performance for the typical year. Due to the number of simulations required for ORE estimates across geographic units, an analysis was performed to identify a potential proxy period, that is, a subset of the typical year that provides a reasonable estimate of alternative conditions performance for the typical year at significantly reduced runtimes (CH2M, 2018). It is recognized that no subset of the typical year will perfectly recreate the range of hydraulic conditions for the typical year as a whole; ideal characteristics of a potential proxy period include:

- Strong correlation between proxy period ORE estimates and corresponding estimates for the typical year
- Minimal scatter or outliers, where the proxy period estimate is unrepresentative of typical year performance
- Shorter runtimes

Importantly, the suitability of a proxy period for ORE analysis requires comparison of proxy period ORE estimates versus the corresponding estimates for the typical year. It is documented in the ALCOSAN

Proxy Period Analysis Technical Memorandum (CH2M, 2018) that, while the 09/14-09/30 potential proxy period demonstrates high correlation between proxy period and typical year OREs in the Chartiers Creek planning basin pilot, no proxy period was defined that reliably predicts the typical year ORE across all basins. The lack of strong correlation observed during the validation process suggests that none of the potential proxy periods suitably replicates the range of storm characteristics that drive overflow volume reduction on an annual basis. Thus, the entire typical year simulation was used to produce ORE estimates.

2.6 Model Representation of GSI/SC Impacts

As discussed in Section 2.1, the GSI/SC measures evaluated include green stormwater infrastructure (GSI), inflow and infiltration (I/I) reduction, and direct stream inflow removal (DSIR). This section describes how the impacts of each of the GSI/SC measures were represented in the model.

2.6.1 Green Stormwater Infrastructure

The impact of inflow reduction from GSI is simulated by modifying the impervious area percentage of each subcatchment contained within the geographic unit. Two implementation levels are considered: 25% and 50% of impervious area managed by GSI. This approach assumes that the GSI elements (which are not modeled explicitly) manage runoff produced by the impervious areas removed from the model for that specific ORE scenario. Table 1 provides an example of the model parameter adjustments made for the two GSI implementation levels in a geographic unit in Main Rivers planning basin.

Since impervious area is converted to pervious area, runoff may still be produced for converted impervious area (i.e., the approach does not assume that 100% of runoff is managed by the hypothetical GSI). More detailed future evaluations in high-benefit areas may represent GSI more explicitly, so that actual performance is constrained by available storage and infiltration capacity.

Table 1. Example of Model Subcatchment Parameter Adjustments for the GSI ORE Scenarios
Main Rivers Planning Basin Subcatchments within Geographic Unit ID GSI_M-29-00_1

Subcatchment Name	Area (acre)[1]	Percent Impervious (%) Existing Conditions	ORE Scenario: 25% of Impervious Area Managed by GSI	ORE Scenario: 50% of Impervious Area Managed by GSI
M-19B-C-10-B	6.3	76.875	57.656	38.438
M-19B-C-11-A	6.9	76.875	57.656	38.438
M-19B-C-11-B	20.9	92.250	69.188	46.125
M-19B-C-4	2.4	82.000	61.500	41.000

[1] Subcatchment area is not adjusted in GSI ORE scenarios.

2.6.2 Rainfall-Derived Inflow and Infiltration Reduction

The impact of inflow reduction from rainfall-derived inflow and infiltration (I/I) reduction is simulated by reducing the R values from the RTK unit hydrographs in the sanitary system. RTK unit hydrographs are used to represent the response of a sewershed to rainfall through a series of up to three triangular unit hydrographs. The three unit hydrographs (fast, medium, and slow response) are characterized by the following parameters:

- R: the fraction of rainfall volume that enters the sewer system and equals the volume under the hydrograph
- T: the time from the onset of rainfall to the peak of the unit hydrograph

- K: the ratio of time to recession of the unit hydrograph to the time to peak.

The separate sanitary system R values were extracted from the Existing Conditions model and reviewed to understand their variation by basin, response type (i.e., fast, medium, and slow), and month. The existing R values in the separate sanitary system vary significantly by response type and month, as shown in Figures 3 and 4, respectively. Note that the amount of I/I volume depends not only on the R values, but also the sewershed area. Thus, a basin with a high R value and low sewershed area could have less I/I volume than a basin with a low R value and high sewershed area.

Separate sanitary sewersheds were grouped into geographic units in the manner described in Section 2.3. Then, for each evaluation, R_{fast}, R_{medium}, and R_{slow} values for each sewershed within a geographic unit were reduced by 30%. This reduction was considered an approximate lower limit for R values after aggressive I/I reduction is implemented and is consistent with past I/I reduction modeling approaches. Table 2 provides an example of the model parameter adjustments made for the I/I reduction implementation in a geographic unit in Chartiers Creek planning basin.

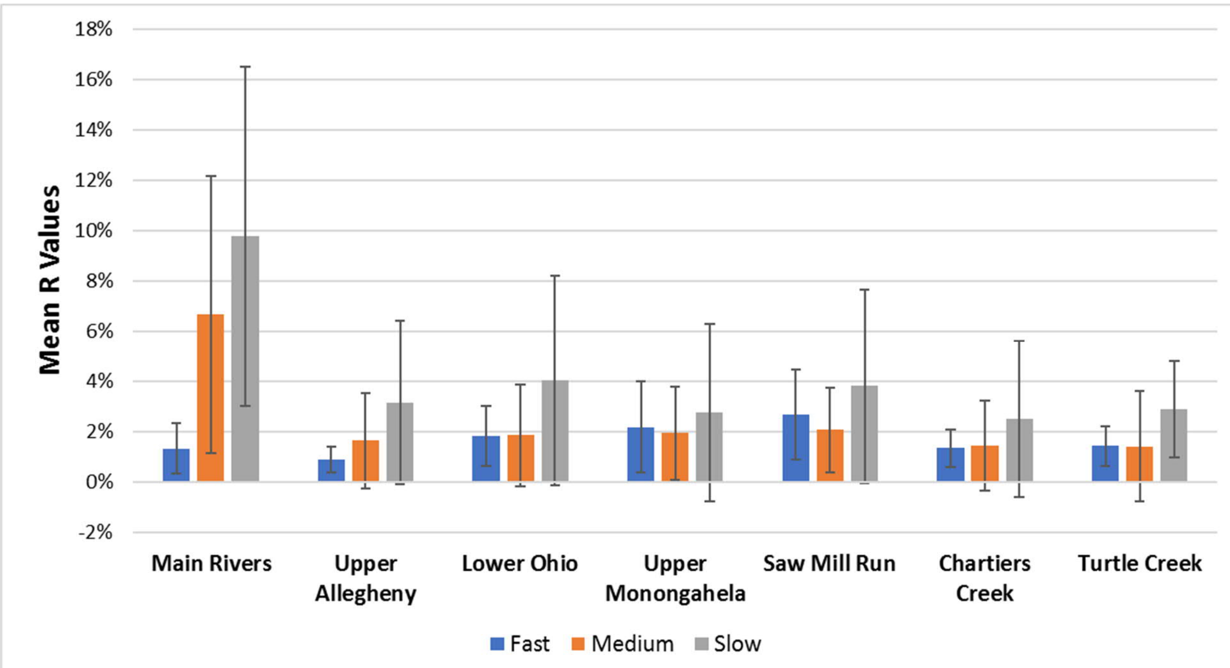

Figure 3. Separate Sanitary System Mean R Values and Standard Deviations, by Basin and Response Type

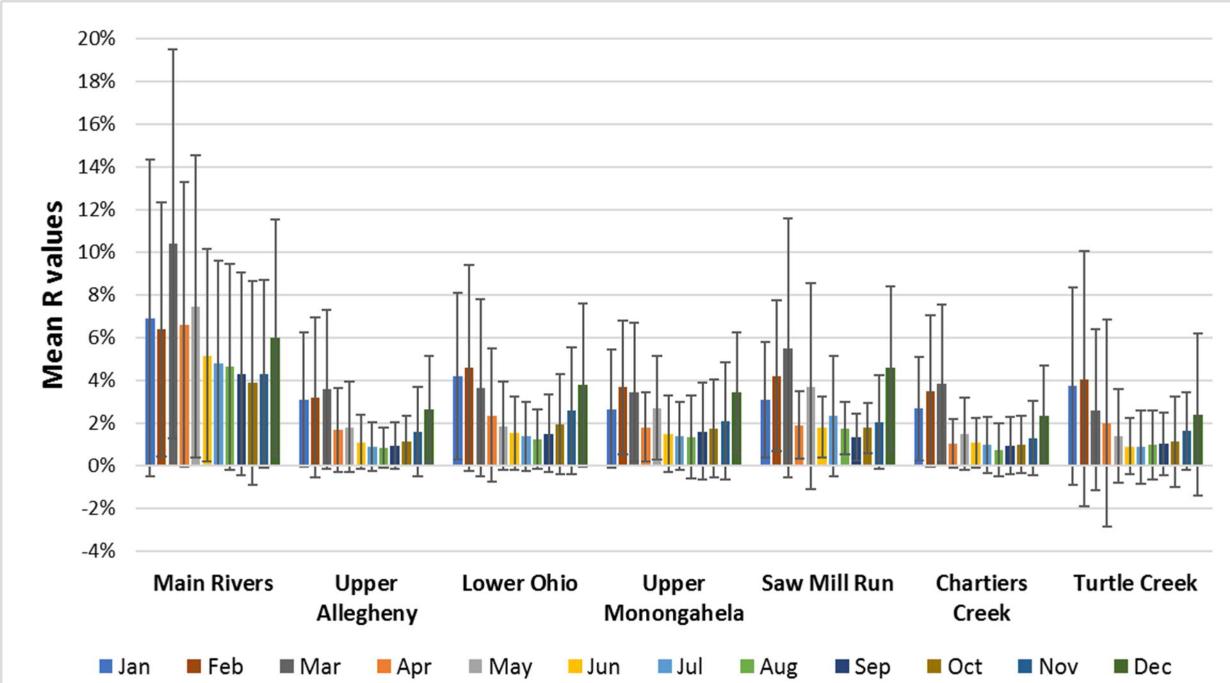

Figure 4. Separate Sanitary System Mean R Values and Standard Deviations, by Basin and Month

Table 2. Example of Model Unit Hydrograph Parameter Adjustments for the I/I Reduction ORE Scenario: January[1]
Chartiers Creek Planning Basin Sewersheds within Geographic Unit ID II_C-48-00

Node Name	Sewershed Area (acre)[2]	Unit Hydrograph	Existing Conditions			ORE Scenario: I/I Reduction Implementation		
			R_{fast}	R_{medium}	R_{slow}	R_{fast}	R_{medium}	R_{slow}
324395S014	130.9	RDII_C4800-SITE-05	2.69%	1.47%	1.64%	1.88%	1.03%	1.15%
325395S011	70.9	RDII_C4800-SITE-06	0.53%	0.65%	1.43%	0.37%	0.46%	1.00%
326395S902	103.5	RDII_C4800-SITE-07	2.04%	2.40%	3.86%	1.43%	1.68%	2.70%

1: For clarity, this table only shows the R value model adjustments for the month of January. The R values for the other eleven months were also adjusted in the same fashion.

2: Sewershed area is not adjusted in I/I reduction ORE scenarios.

2.6.3 Direct Stream Inflow Removal

A direct stream inflow (DSI) is defined as a surface watercourse that discharges into municipal combined sewer systems. The impact of direct stream inflow removal (DSIR) was estimated in areas where DSI locations were previously identified by ALCOSAN (and have not already been removed by projects). Table 3 summarizes the ALCOSAN-identified DSIs that currently discharge into municipal combined sewer systems that were included in the ORE modeling. Figure 5 shows the inflow points and inflow areas for these DSIs. For DSIR, the source control area is defined according to the tributary area to the DSI location. The geographic unit for DSIR simulation may therefore be significantly smaller, or much larger, than typical geographic units for combined and separate sanitary areas.

The impact of DSIR is simulated with the following model adjustments:

- Reducing subcatchment area associated with the DSI tributary area. Based on aerial inspection, areas tributary to DSIs tend to consist of pervious cover. Therefore, the DSI tributary area was removed from the model by first reducing subcatchment pervious area. Then, if necessary, any remaining DSI tributary area was reduced from the subcatchment impervious area. Table 4 provides an example of the model subcatchment parameter adjustments made for the DSIR implementation in a geographic unit in Turtle Creek planning basin. Note that area reductions for the various subcatchment slope categories were applied based on the distribution of existing area within each subcatchment slope category.
- Reducing the stream baseflow from the relevant node by modifying the dry weather flows represented in ALCOSAN's Existing Conditions external inflow file. For ORE modeling purposes, it was assumed that the stream baseflow associated with the DSI tributary area was equal to the groundwater infiltration (GWI). The process of removing stream baseflow associated with the DSI involved the following steps:
  - Running a "dry" typical year simulation in the planning basin model without rainfall impacts
  - Extracting the simulated total inflow (or lateral flow, depending on the hydraulic network connectivity) timeseries for the "dry" typical year from the relevant node(s)
  - Processing the timeseries to identify the daily minimums (which were assumed to equal the GWI)
  - Applying a new inflow timeseries to the relevant node(s) that contains the simulated values from the "dry" typical year reduced by the GWI
  - Modifying the name of the relevant node(s) so that the flows from the external inflow file are not applied to this node

This process allows the stream baseflow reduction to be simulated without modifying the external inflow file. Table 3 provides the assumed inflow node and the annual GWI volume for each of the ALCOSAN-identified DSIs currently discharging to municipal combined sewer systems; Figure 5 shows the assumed inflow node locations. Note that the inflow node for each DSIR was assumed as the model node with the highest amount of annual dry weather flow volume (during a "dry" 2003 typical year simulation) near ALCOSAN's Inflow Point GIS data.

Note that since a significant portion of the estimated inflow reduction associated with DSIRs is related to stream baseflow (which contributes flow during periods when overflows are not occurring), DSIRs may have lower ORE values than other GSI/SC measures. Although OREs may be lower, significant overflow reductions can still be achieved. DSIRs have additional value not quantified by the model, such as reduction of sediment and debris to the Regional Collection System.

Table 3. ALCOSAN-Identified DSIs Currently Discharging to Municipal Combined Sewer Systems

DSI Name[1]	Planning Basin	Tributary Area (acre)[1]	Assumed Inflow Node[2]	Annual GWI Volume (mgal)[3]
Ella Street	Chartiers Creek	25	324424S910	774
Spring Garden	Main Rivers	390	JCT078E002	91
Panther Hollow	Main Rivers	216	MH028M002	18
Woods Run Valley	Main Rivers	503	MH162P017 MH115K070 MH115L003 MH076L021 MH077A002 JCT077E003	305
Delafield Avenue	Upper Allegheny	95	AD-1	140
Sharpsburg	Upper Allegheny	96	MH246	98
Tassey Hollow	Upper Monongahela	356	LBs_1296687	142
Verner Avenue	Lower Ohio Girtys Run	42	O-26-00-M1	20
Dooker Hollow	Turtle Creek	162	LBs_1265379	250

[1] Source: ALCOSAN Inflow Point and Inflow Area GIS data.

[2] Assumed as the model node with the highest amount of annual dry weather flow volume (during a “dry” 2003 typical year simulation) near ALCOSAN’s Inflow Point GIS data (see note 1).

[3] Annual GWI volume based on the daily minimum dry weather flow of each day during a “dry” 2003 typical year simulation. For ORE modeling purposes, it was assumed that the stream baseflow associated with the DSI tributary area was equal to the GWI.

Table 4. Example of Model Subcatchment Parameter Adjustments for the DSIR ORE Scenario
Turtle Creek Planning Basin Subcatchments within Geographic Unit ID DSIR_T-01-00: Dooker Hollow

Subcatchment Name[1]	Percent Impervious (%)[2]	Area (acre)	
		Existing Conditions	ORE Scenario: DSIR Implementation
T-01_CPhgh	0	301.12	156.35
T-01_CPlow	0	0	0
T-01_CPmed	0	8	4.15
T-01_CPzero	0	27.94	14.51
	TOTAL	388.11	226.06

[1] T-01 impervious subcatchments were not adjusted.

[2] Subcatchment percent impervious was not adjusted for this particular DSIR. However, subcatchment percent impervious was adjusted for other DSIRs, for example, in Main Rivers where subcatchments are not represented by various impervious and slope categories, and in DSIRs in which the area tributary to the DSI is larger than the previous area of the corresponding subcatchment(s).

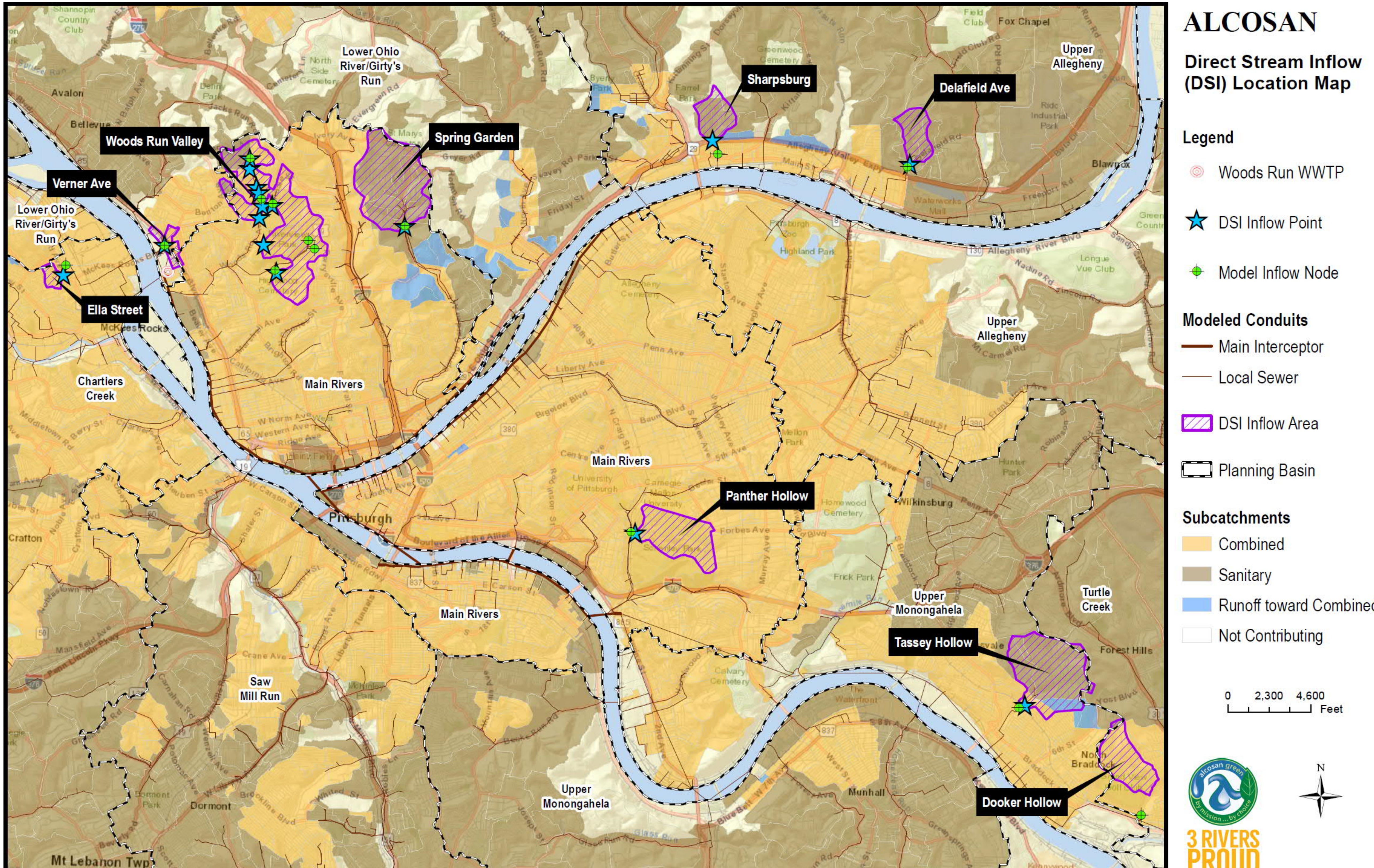

Figure 5. ALCOSAN-Identified DSIs Currently Discharging to Municipal Combined Sewer Systems
Note: DSI Inflow Point and DSI Inflow Area from ALCOSAN GIS data

3.0 Overflow Reduction Efficiency Summaries by Basin under Existing Conditions

3.1 Chartiers Creek

3.1.1 Overview

The Chartiers Creek (CC) planning basin covers 93.7 square miles in the southwest portion of the ALCOSAN service area. There are 24 municipalities that are located completely or partially within the Chartiers Creek basin. Wastewater flows generated within the basin are conveyed to the ALCOSAN Woods Run Wastewater Treatment Plant (WWTP) via a deep tunnel interceptor that begins at the Chartiers/Ohio Junction drop-shaft structure and extends under the Ohio River.

As shown in Figure 6, approximately 8% of Chartiers Creek basin is served by combined sewer systems, 43% is served by separate sanitary sewer systems, 0.2% contributes runoff toward combined areas, and 49% is non-contributing area that is either undeveloped or served by individual on-lot septic systems. The sewered area within Chartiers Creek basin also includes a DSI identified by ALCOSAN that has not yet been removed (Ella Street, see Table 3 and Figure 5). The DSI tributary area is about 0.1% of the Chartiers Creek basin sewered area. Figure 6 shows the wet weather flow volume produced in areas tributary to combined sewers and separate sanitary sewers during the typical year. Note that the wet weather flow volume associated with DSIs and a portion of the area contributing runoff toward combined areas shown in Figure 6 have been removed from the system through the implementation of several completed DSI removal projects; the removal of these flows is not reflected in the existing conditions model.

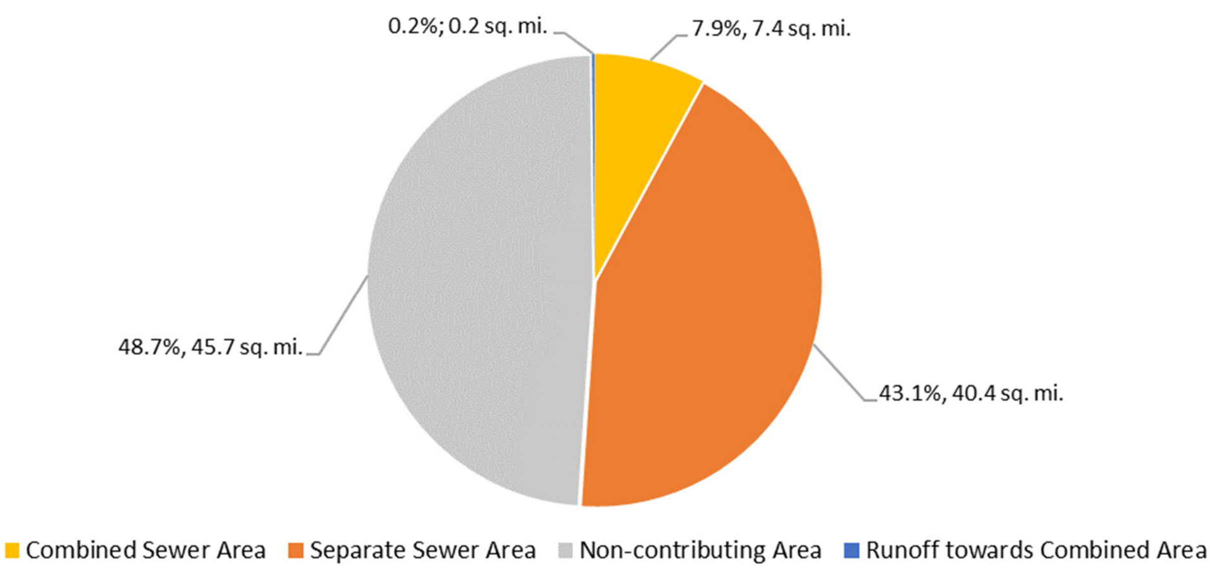

Figure 5. Summary of Drainage Area by Type in Chartiers Creek Basin
Note: Areas based on ALCOSAN's subcatchment GIS data

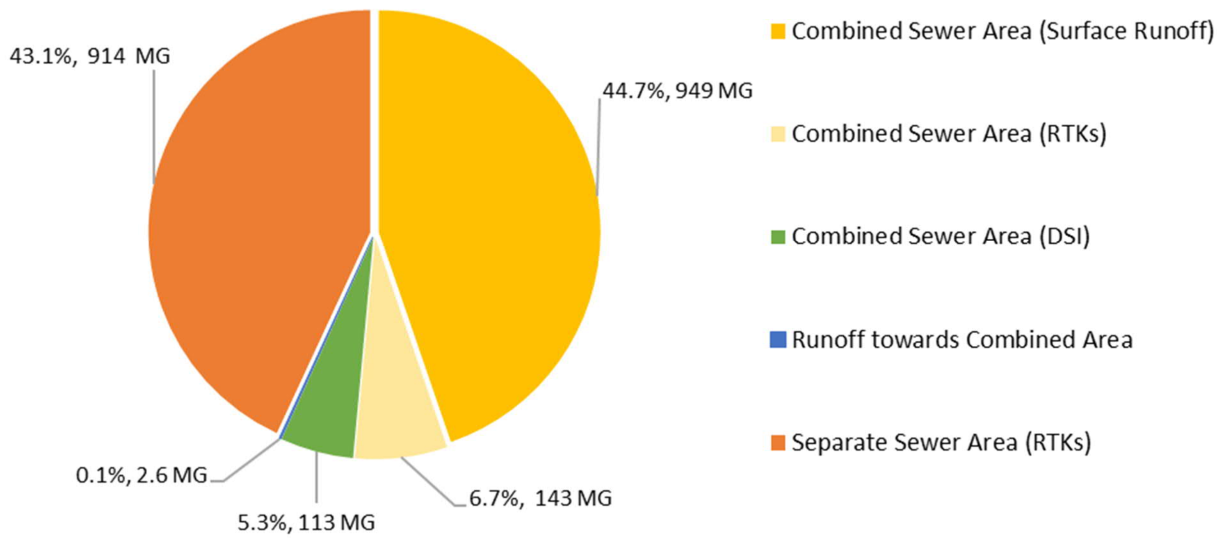

Figure 6. Summary of Annual Wet Weather Flow Volume by Type in Chartiers Creek Basin
Note: Wet weather flow volume based on Chartiers Creek Existing Conditions Model Typical Year Simulation

3.1.2 ORE Analysis Setup

Subcatchments were grouped into geographic units for the ORE analysis, following the rules identified in Section 2.3. Figures A-1a, A-1b, and A-1c in Appendix A show the GSI, I/I reduction, and DSIR geographic units for Chartiers Creek basin. Table A-1 in Appendix A summarizes the geographic units defined for Chartiers Creek basin. Table A-2 in Appendix A includes a cross-reference table between modeled subcatchments and geographic units for GSI and DSI OREs, and model nodes/unit hydrographs and geographic units for I/I OREs.

3.1.3 Results

Simulations were performed for the 2003 typical year in Chartiers Creek to represent the conditions of interest. Table 5 provides ORE estimate statistics for each of the GSI/SC measures evaluated, and Figure 8 shows the ORE and typical year annual overflow reduction for each geographic unit's ORE scenario.

Figures 9 and 10 show the correlation between OREs for the GSI 25% and 50% impervious area managed implementation levels. Shown in Figure 10, the coefficient of determination (R^2) value of 0.94 indicates relatively low variation between the OREs for the two GSI implementation levels.

Figure 11 presents overflow reduction direct fractions by GSI/SC type to illustrate indirect impacts within the planning basin. The direct fractions are calculated for each geographic unit's ORE scenario as the ratio of the maximum overflow volume reduced at a single outfall (the most directly impacted outfall) to the total amount of overflow volume reduced at all impacted outfalls. A value close to 1 indicates that an ORE scenario had little indirect overflow reduction impacts; a value close to 0 indicates large indirect overflow reduction impacts.

Figures A-2a, A-2b, and A-2c in Appendix A show the geographic distribution of ORE estimates throughout the Chartiers Creek basin. To aid review of ORE variation in smaller geographic units, the Chartiers Creek basin contributing area was split into three maps, with the first (Figure A-2a) containing the majority of the combined sewer areas.

For reference, Table A-3 in Appendix A shows the calculated ORE for the GSI, I/I reduction, and DSIR scenarios evaluated, as well as the corresponding inflow reduction volume, overflow reduction volume, and direct fraction. Note that overflow reduction volumes were summed across all outfalls for each simulation. Due to hydraulic interactions along the interceptor, overflow reductions may occur beyond the outfall directly associated with the POC. Table A-4 in Appendix A lists all reductions in overflow volume by outfall for each simulation.

Table 5. Chartiers Creek ORE Summary and Statistics

GSI/SC Type ORE Statistic	GSI: 25% Impervious Area Managed	GSI: 50% Impervious Area Managed	I/I	DSIR
Average	0.76	0.74	0.45	0.03
Median	0.80	0.79	0.43	0.03
Maximum	1.05	0.98	0.77	0.03
Minimum	0.34	0.34	0.23	0.03
Standard Deviation	0.16	0.16	0.13	-
Count	56	56	26	1

Figure 8. Chartiers Creek OREs by GSI/SC Type

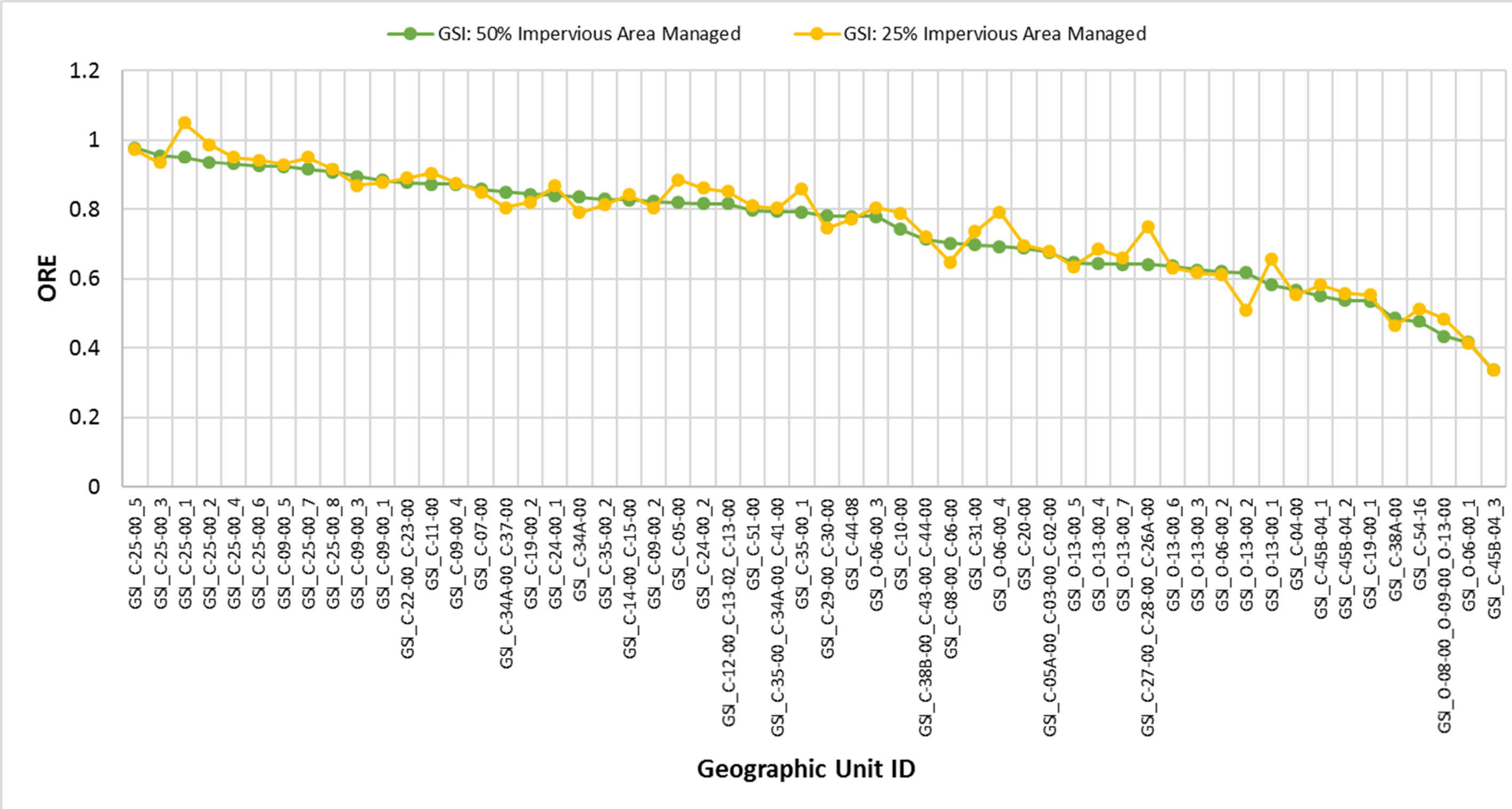

Figure 9. Chartiers Creek GSI OREs by Implementation Level

Sorted by GSI 50% Impervious Area Managed ORE in decreasing order

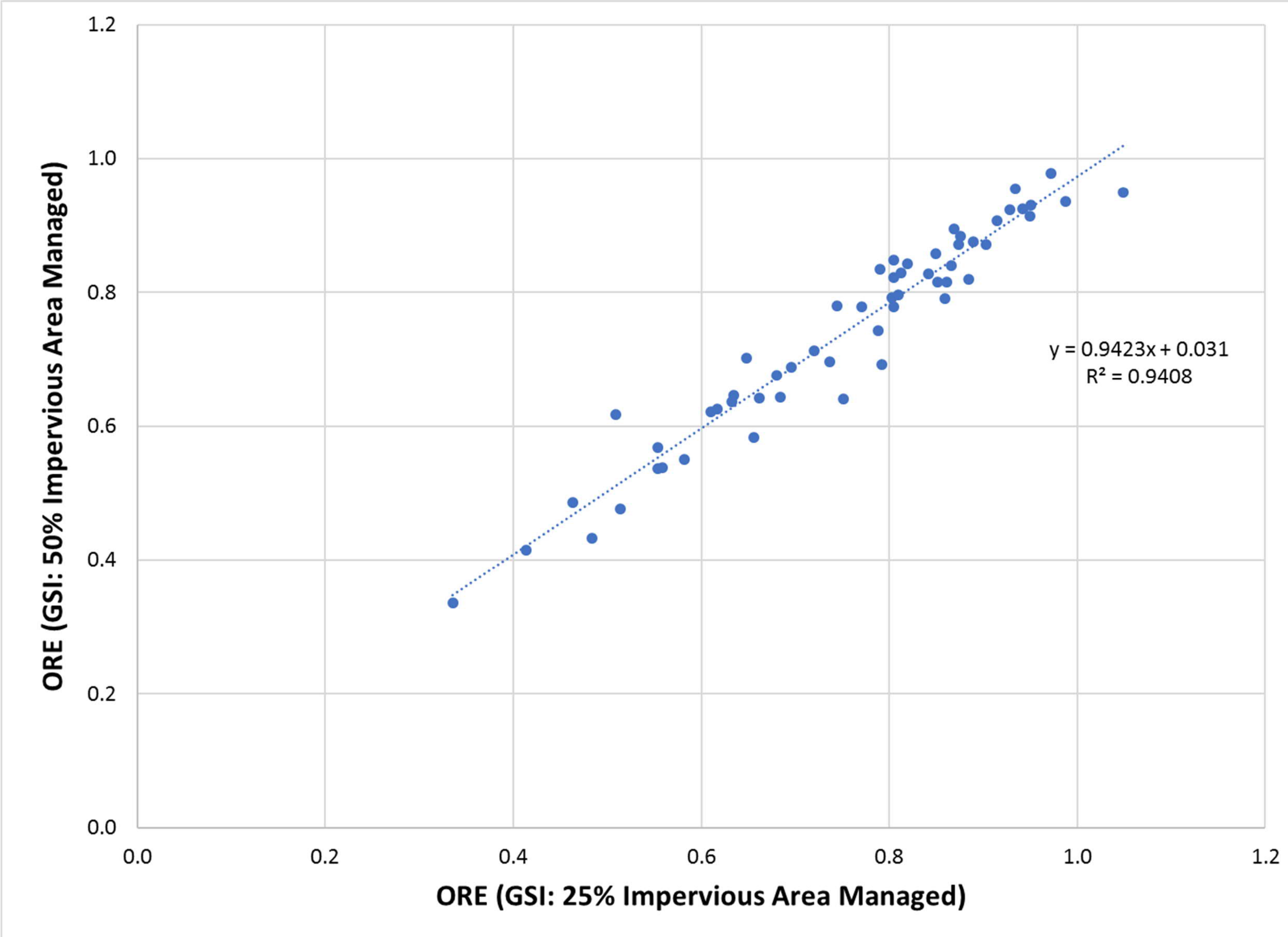

Figure 10. Chartiers Creek GSI OREs: Correlation Between Implementation Levels

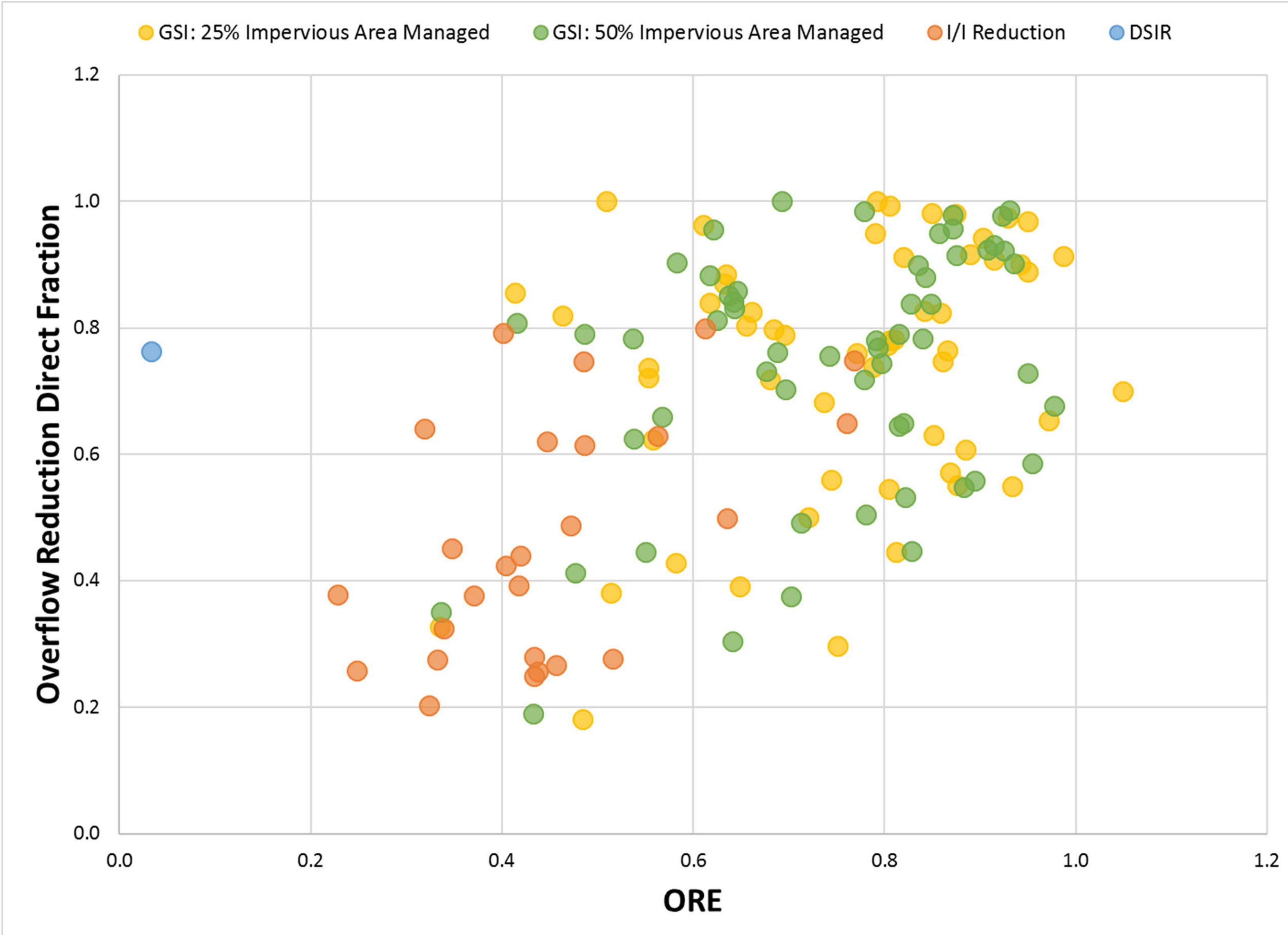

Figure 11. Chartiers Creek ORE Direct Fractions, by GSI/SC Type

3.2 Main Rivers

3.2.1 Overview

The Main Rivers (MR) planning basin covers 23.4 square miles centrally located in the ALCOSAN service area. The basin serves portions of the City of Pittsburgh, Reserve Township, and Ross Township. Wastewater flows generated within the basin are conveyed to the ALCOSAN Woods Run WWTP via deep tunnel interceptors that extend along the Allegheny, Monongahela, and Ohio Rivers.

As shown in Figure 12, approximately 88% of Main Rivers basin is served by combined sewer systems, 9% is served by separate sanitary sewer systems, 1% contributes runoff toward combined areas, and 2% is non-contributing area that is either undeveloped or served by individual on-lot septic systems. The sewered area within Main Rivers basin also includes three DSIs identified by ALCOSAN that have not yet been removed (Woods Run Valley, Spring Garden, and Panther Hollow; see Table 3 and Figure 5). The DSI tributary area is about 8% of the Main Rivers basin sewered area. Figure 13 shows the wet weather flow volume produced in areas tributary to combined sewers and separate sanitary sewers during the typical year.

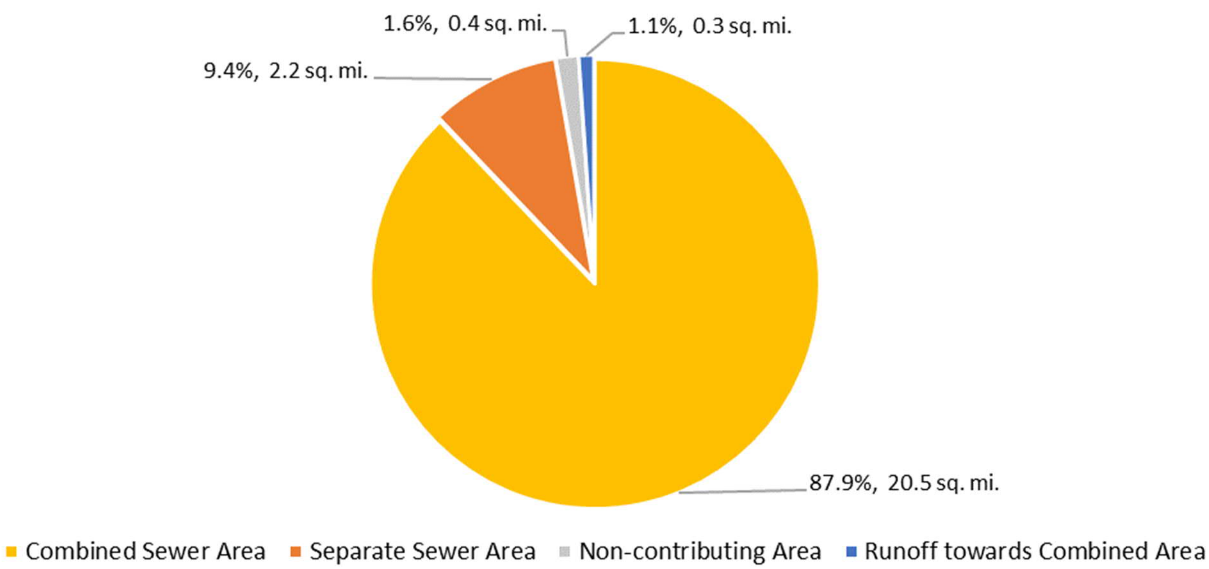

Figure 12. Summary of Drainage Area by Type in Main Rivers Basin
Note: Areas based on ALCOSAN's subcatchment GIS data

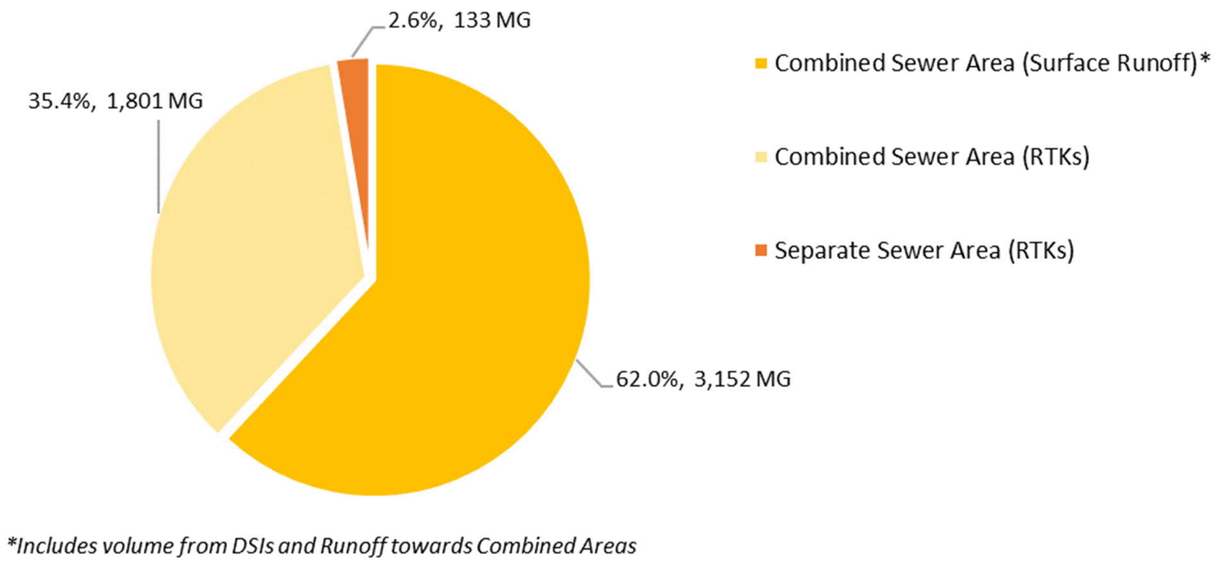

Figure 13. Summary of Annual Wet Weather Flow Volume by Type in Main Rivers Basin
Note: Wet weather flow volume based on Main Rivers Existing Conditions Model Typical Year Simulation

3.2.2 ORE Analysis Setup

Subcatchments were grouped into geographic units for the ORE analysis, following the rules identified in Section 2.3. Figures B-1a, B-1b, and B-1c in Appendix B show the GSI, I/I reduction, and DSIR geographic units for Main Rivers basin. Table B-1 in Appendix B summarizes the geographic units defined for Main Rivers basin. Table B-2 in Appendix B includes a cross-reference table between modeled subcatchments and geographic units for GSI and DSI OREs, and model nodes/unit hydrographs and geographic units for I/I OREs.

3.2.3 Results

Simulations were performed for the 2003 typical year in Main Rivers to represent the conditions of interest. Table 6 provides ORE estimate statistics for each of the GSI/SC measures evaluated, and Figure 14 shows the ORE and typical year annual overflow reduction for each geographic unit's ORE scenario.

Figures 15 and 16 show the correlation between OREs for the GSI 25% and 50% impervious area managed implementation levels. Shown in Figure 16, the coefficient of determination (R^2) value of 0.10 indicates relatively high variation between the OREs for the two GSI implementation levels in Main Rivers planning basin.

Figure 18 presents overflow reduction direct fractions by GSI/SC type to illustrate indirect impacts within the planning basin. The direct fractions are calculated for each geographic unit's ORE scenario as the ratio of the maximum overflow volume reduced at a single outfall (the most directly impacted outfall) to the total amount of overflow volume reduced. A value close to 1 indicates that an ORE scenario had little indirect overflow reduction impacts; a value close to 0 indicates large indirect overflow reduction impacts.

Figures B-2a, B-2b, and B-2c in Appendix B show the geographic distribution of ORE estimates throughout the Main Rivers basin. To aid review of ORE variation in smaller geographic units, the Main Rivers basin contributing area was split into three maps.

For reference, Table B-3 in Appendix B shows the calculated ORE for the GSI, I/I reduction, and DSIR scenarios evaluated, as well as the corresponding inflow reduction volume, overflow reduction volume, and direct fraction. Note that overflow reduction volumes were summed across all outfalls for each simulation. Due to hydraulic interactions along the interceptor, overflow reductions may occur beyond the outfall directly associated with the POC. Table B-4 in Appendix B lists all reductions in overflow volume by outfall for each simulation.

Table 6. Main Rivers ORE Summary and Statistics

GSI/SC Type ORE Statistic	GSI: 25% Impervious Area Managed	GSI: 50% Impervious Area Managed	I/I	DSIR
Average	1.04	0.96	0.66	0.18
Median	1.0	0.96	0.64	0.08
Maximum	1.5	1.5	0.88	0.40
Minimum	0.67	0.64	0.52	0.06
Standard Deviation	0.16	0.12	0.15	0.19
Count	141	141	5	3

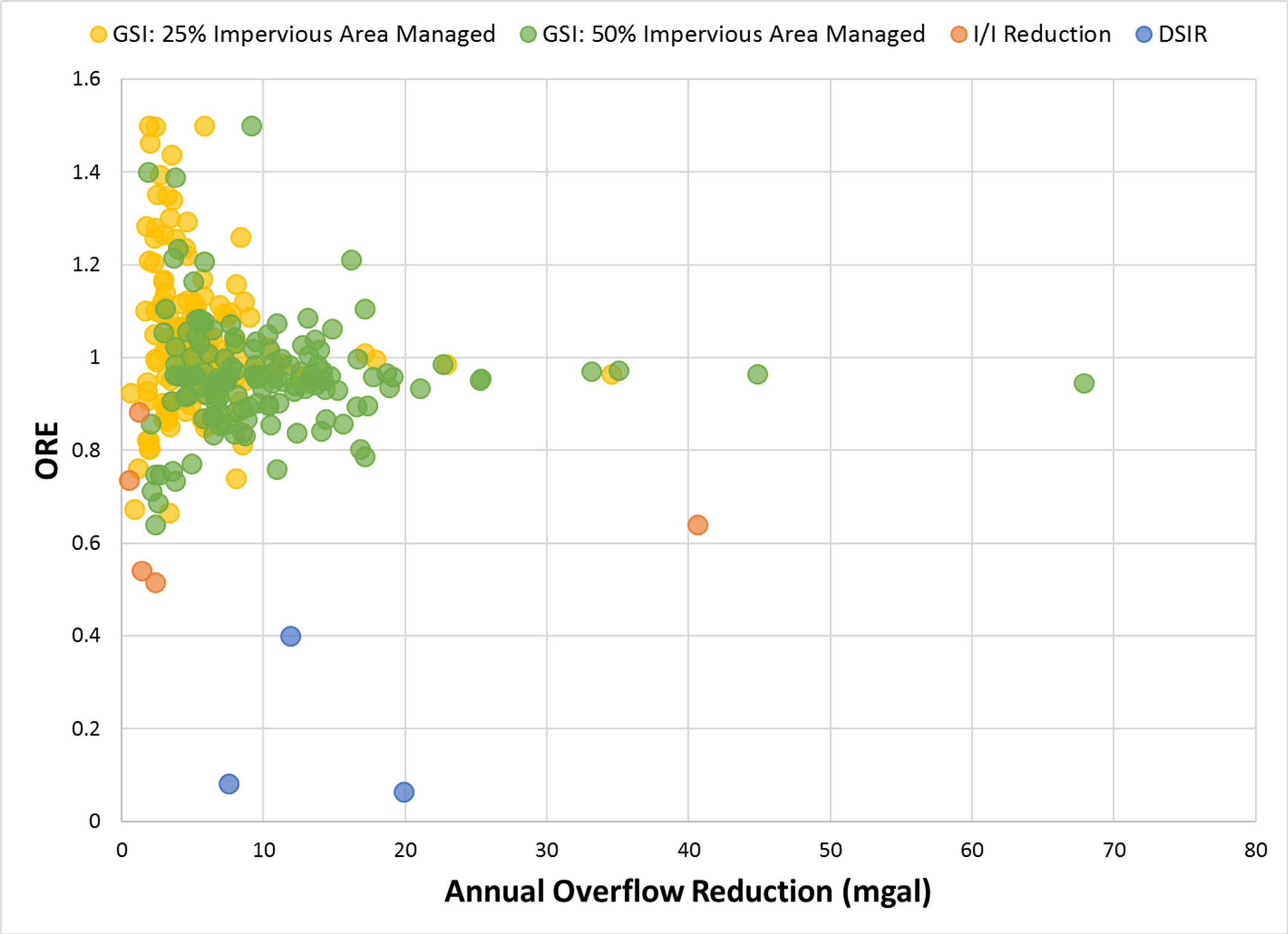

Figure 14. Main Rivers OREs by GSI/SC Type

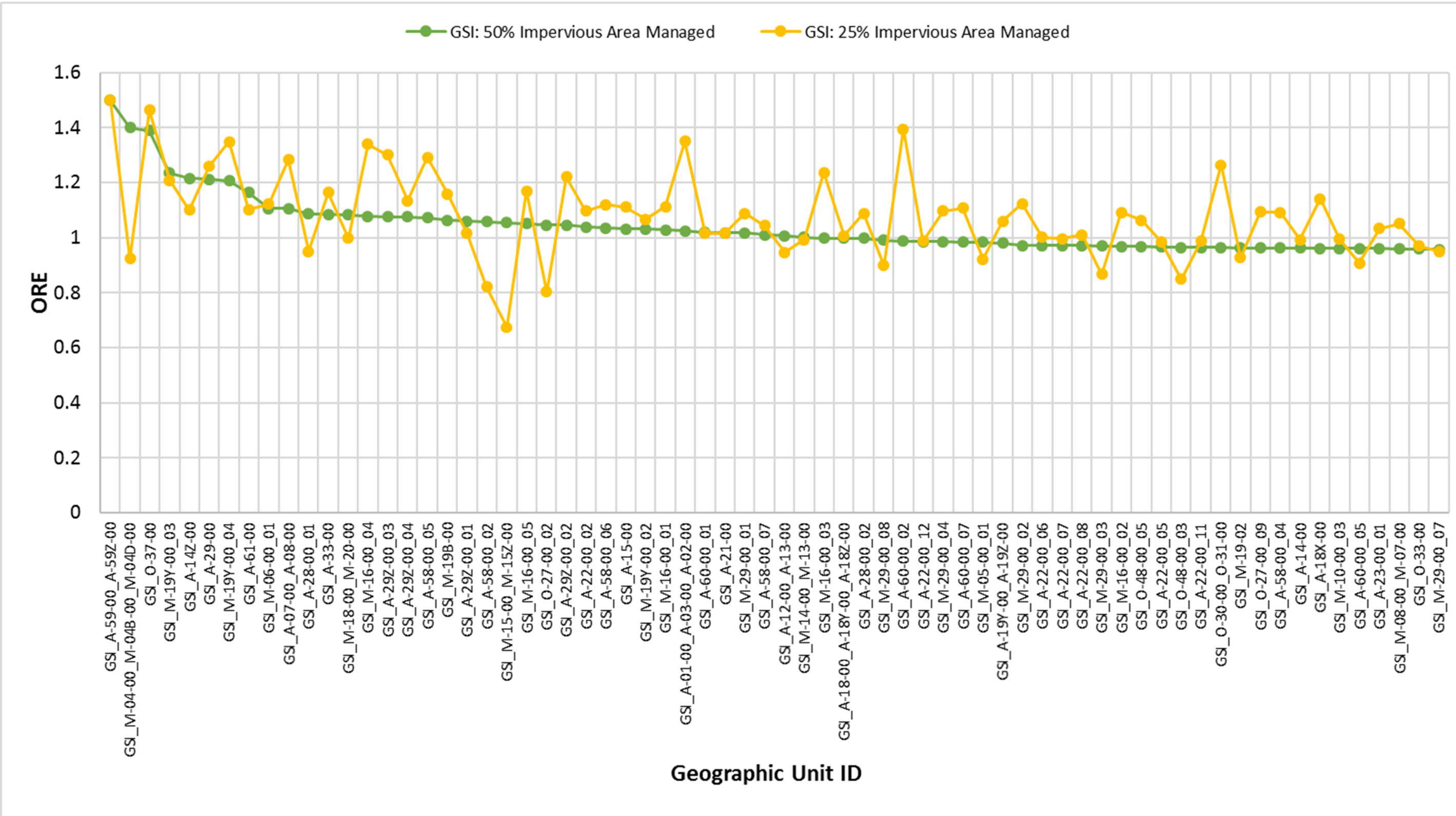

Figure 15. Main Rivers GSI OREs by Implementation Level

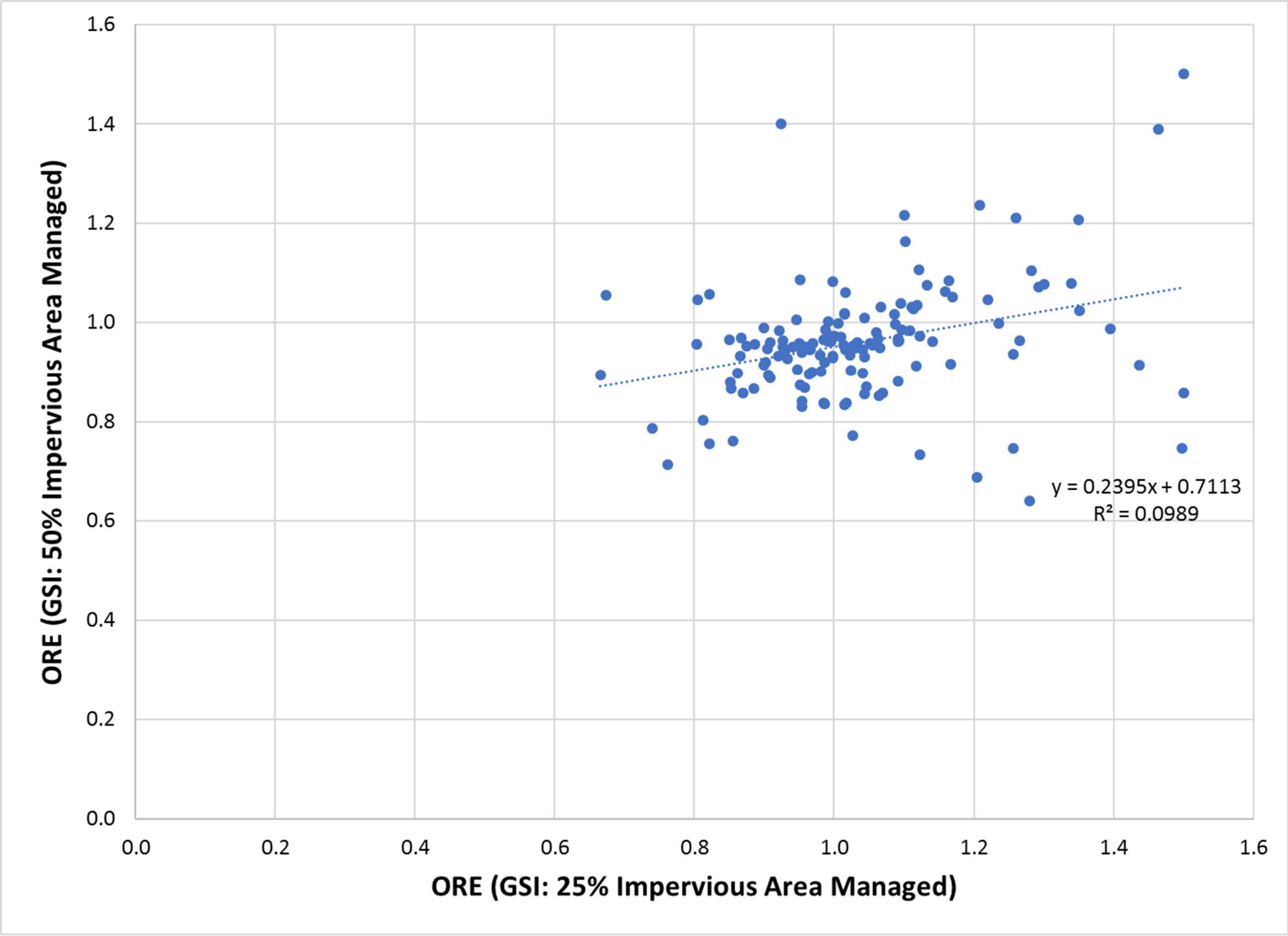

Figure 16. Main Rivers GSI OREs: Correlation Between Implementation Levels

Figure 17. Main Rivers ORE Direct Fractions, by GSI/SC Type

3.3 Upper Allegheny

3.3.1 Overview

The Upper Allegheny (UA) planning basin covers 42.6 square miles in the northeast portion of the ALCOSAN service area. There are 15 municipalities that are located completely or partially within the Upper Allegheny basin. Wastewater flows generated within the basin are conveyed to the ALCOSAN Woods Run WWTP via deep tunnel interceptors that extend along the Allegheny and Ohio Rivers.

As shown in Figure 18, approximately 17% of Upper Allegheny basin is served by combined sewer systems, 64% is served by separate sanitary sewer systems, 0.4% contributes runoff toward combined areas, and 18% is non-contributing area that is either undeveloped or served by individual on-lot septic systems. The sewered area within Upper Allegheny basin also includes two DSIs identified by ALCOSAN that have not yet been removed (Delafield Avenue and Sharpsburg; see Table 3 and Figure 5). The DSI tributary area is about 0.9% of the Upper Allegheny basin sewered area. Figure 19 shows the wet weather flow volume produced in areas tributary to combined sewers and separate sanitary sewers during the typical year.

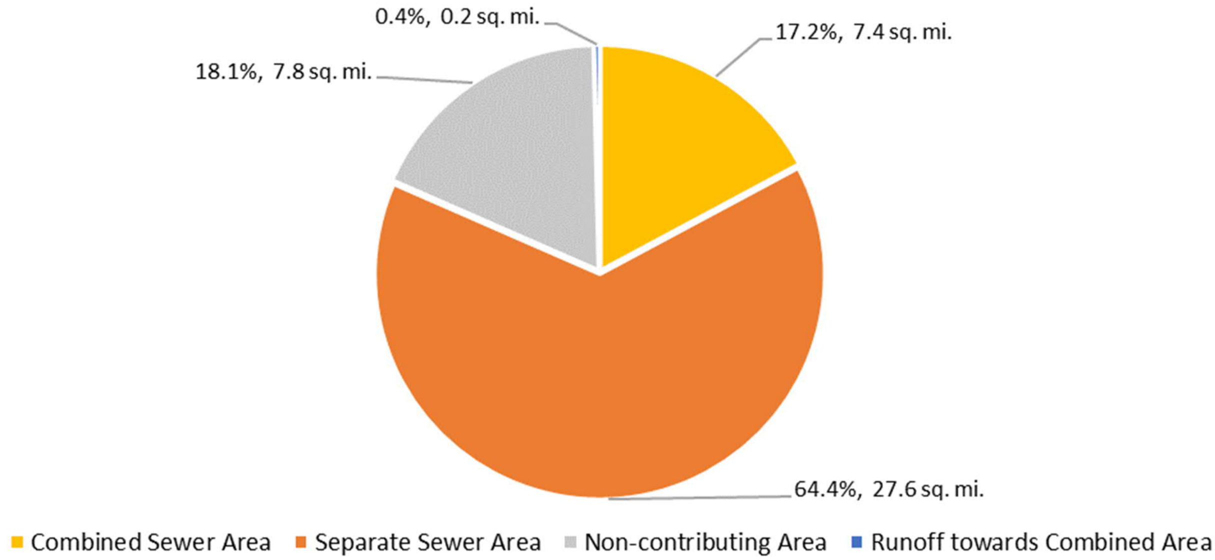

Figure 18. Summary of Drainage Area by Type in Upper Allegheny Basin
Note: Areas based on ALCOSAN's subcatchment GIS data

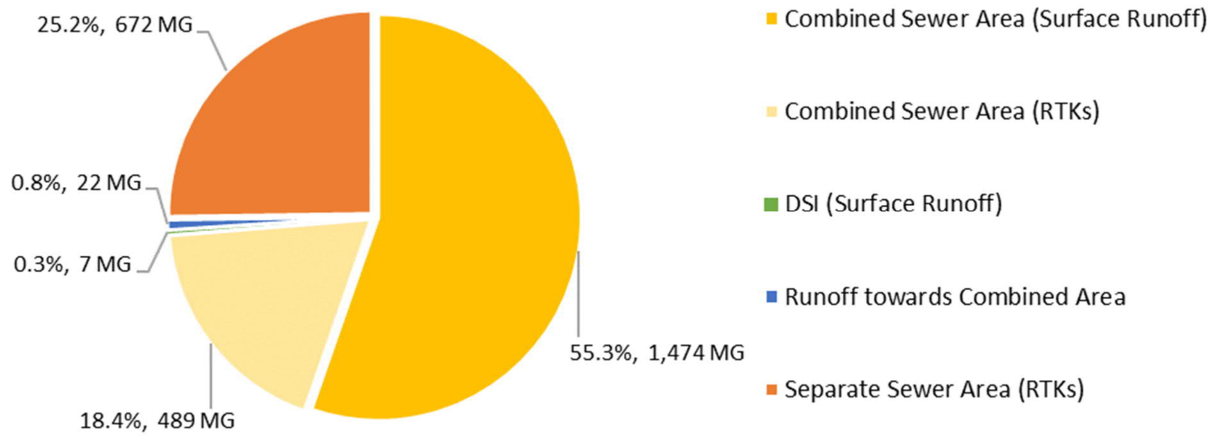

Figure 19. Summary of Annual Wet Weather Flow Volume by Type in Upper Allegheny Basin
Note: Wet weather flow volume based on Upper Allegheny Existing Conditions Model Typical Year Simulation

3.3.2 ORE Analysis Setup

Subcatchments were grouped into geographic units for the ORE analysis, following the rules identified in Section 2.3. Figures C-1a, C-1b, and C-1c in Appendix C show the GSI, I/I reduction, and DSIR geographic units for Upper Allegheny basin. Table C-1 in Appendix C summarizes the geographic units defined for Upper Allegheny basin. Table C-2 in Appendix C includes a cross-reference table between modeled subcatchments and geographic units for GSI and DSI OREs, and model nodes/unit hydrographs and geographic units for I/I OREs.

3.3.3 Results

Simulations were performed for the 2003 typical year in Upper Allegheny to represent the conditions of interest. Table 7 provides ORE estimate statistics for each of the GSI/SC measures evaluated, and Figure 20 shows the ORE and typical year annual overflow reduction for each geographic unit's ORE scenario.

Figures 21 and 22 show the correlation between OREs for the GSI 25% and 50% impervious area managed implementation levels. Shown in Figure 22, the coefficient of determination (R^2) value of 0.17 indicates a relatively high variation between the OREs for the two GSI implementation levels in Upper Allegheny planning basin.

Figure 23 presents overflow reduction direct fractions by GSI/SC type to illustrate indirect impacts within the planning basin. The direct fractions are calculated for each geographic unit's ORE scenario as the ratio of the maximum overflow volume reduced at a single outfall (the most directly impacted outfall) to the total amount of overflow volume reduced. A value close to 1 indicates that a ORE scenario had little indirect overflow reduction impacts; a value close to 0 indicates large indirect overflow reduction impacts.

Figures C-2a, C-2b, and C-2c in Appendix C show the geographic distribution of ORE estimates throughout the Upper Allegheny basin. To aid review of ORE variation in smaller geographic units, the Upper Allegheny basin contributing area was split into three maps.

For reference, Table C-3 in Appendix C shows the calculated ORE for the GSI, I/I reduction, and DSIR scenarios evaluated, as well as the corresponding inflow reduction volume, overflow reduction volume, and direct fraction. Note that overflow reduction volumes were summed across all outfalls for each simulation. Due to hydraulic interactions along the interceptor, overflow reductions may occur beyond the outfall directly associated with the POC. Table C-4 in Appendix C lists all reductions in overflow volume by outfall for each simulation.

Table 7. Upper Allegheny ORE Summary and Statistics

GSI/SC Type / ORE Statistic	GSI: 25% Impervious Area Managed	GSI: 50% Impervious Area Managed	I/I	DSIR
Average	1.02	0.96	0.71	0.40
Median	1.00	0.97	0.69	0.40
Maximum	1.33	1.22	1.18	0.51
Minimum	0.74	0.73	0.24	0.29
Standard Deviation	0.13	0.10	0.22	0.16
Count	30	30	36	2

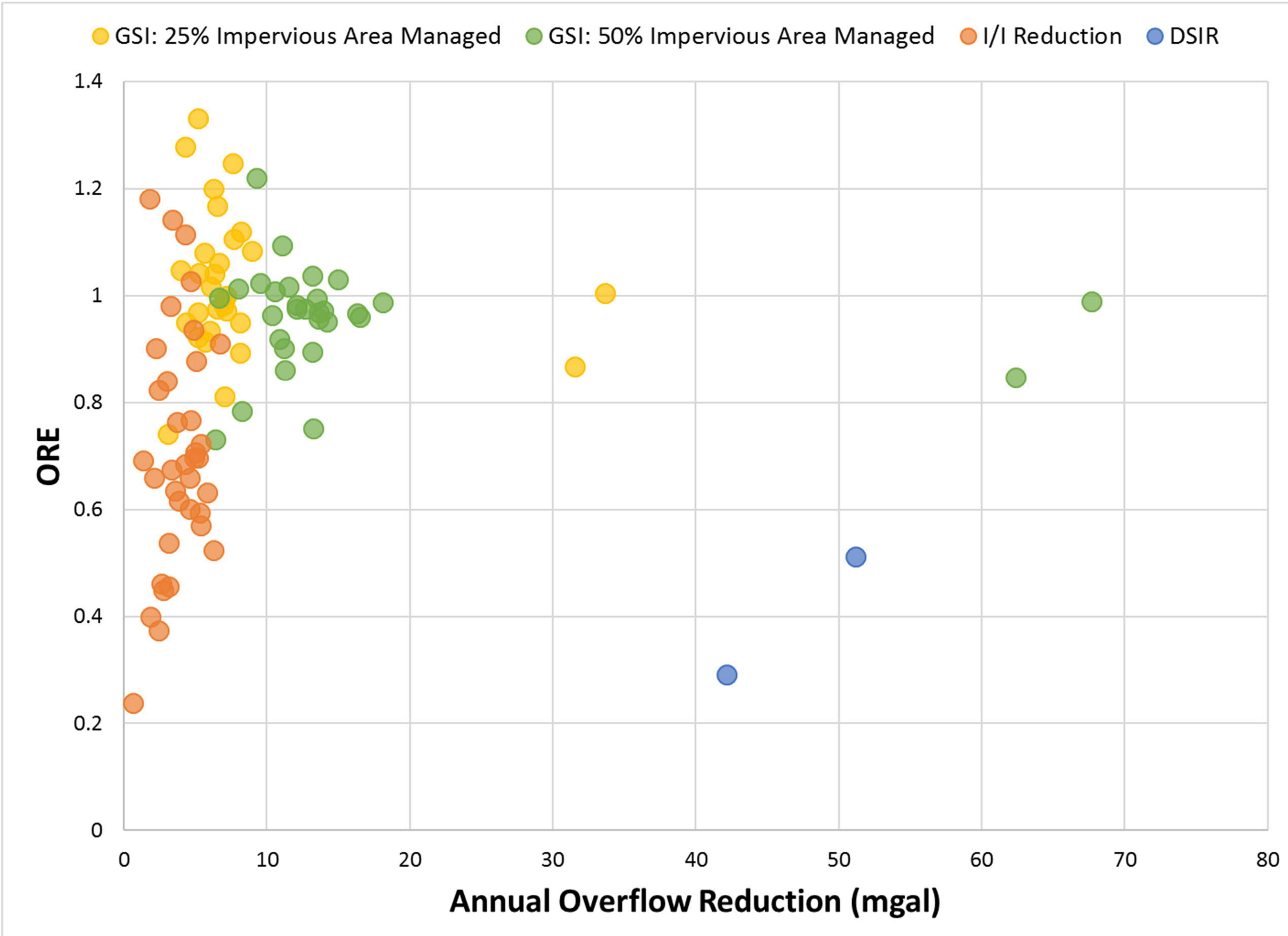

Figure 20. Upper Allegheny OREs by GSI/SC Type

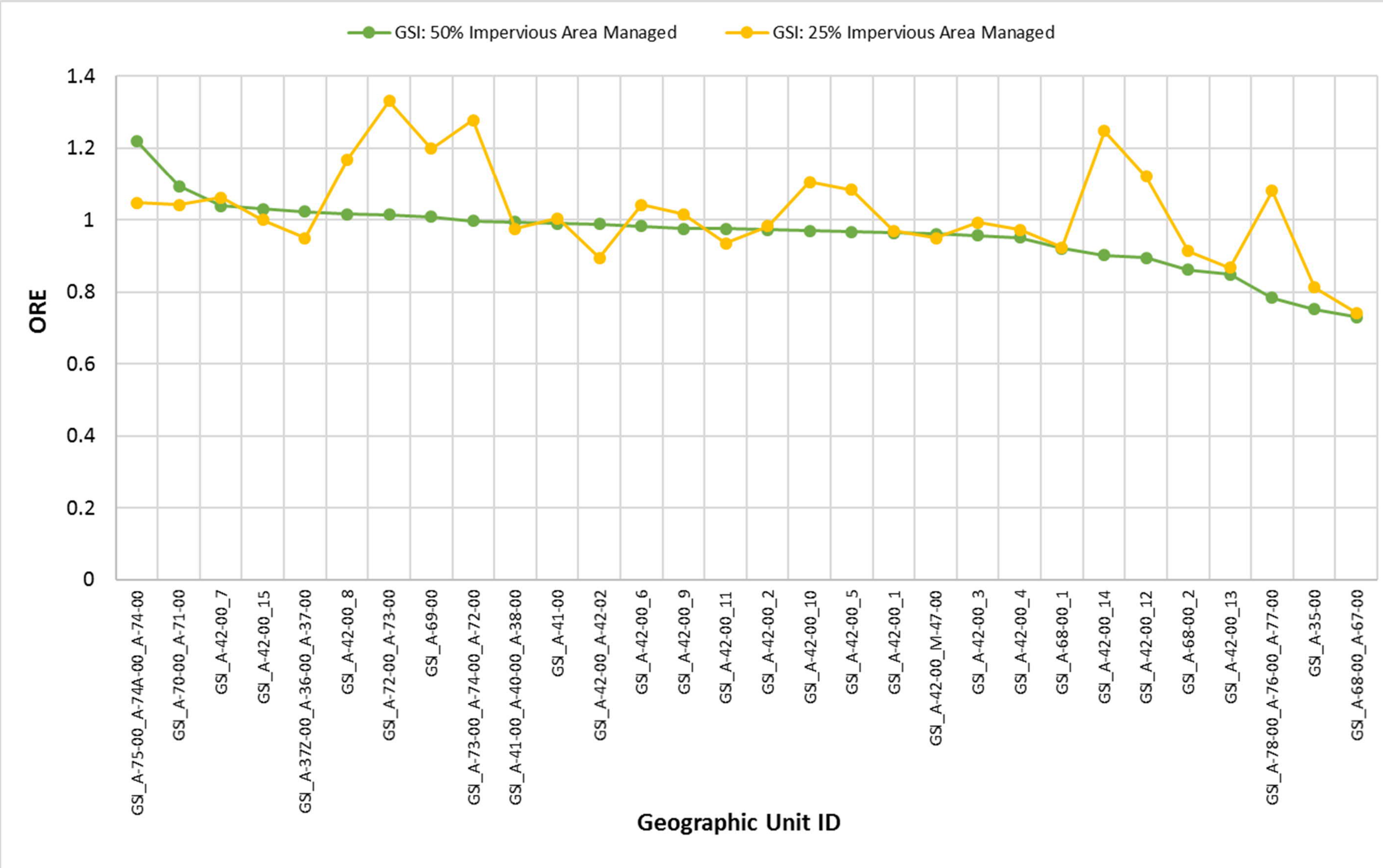

Figure 21. Upper Allegheny GSI OREs by Implementation Level

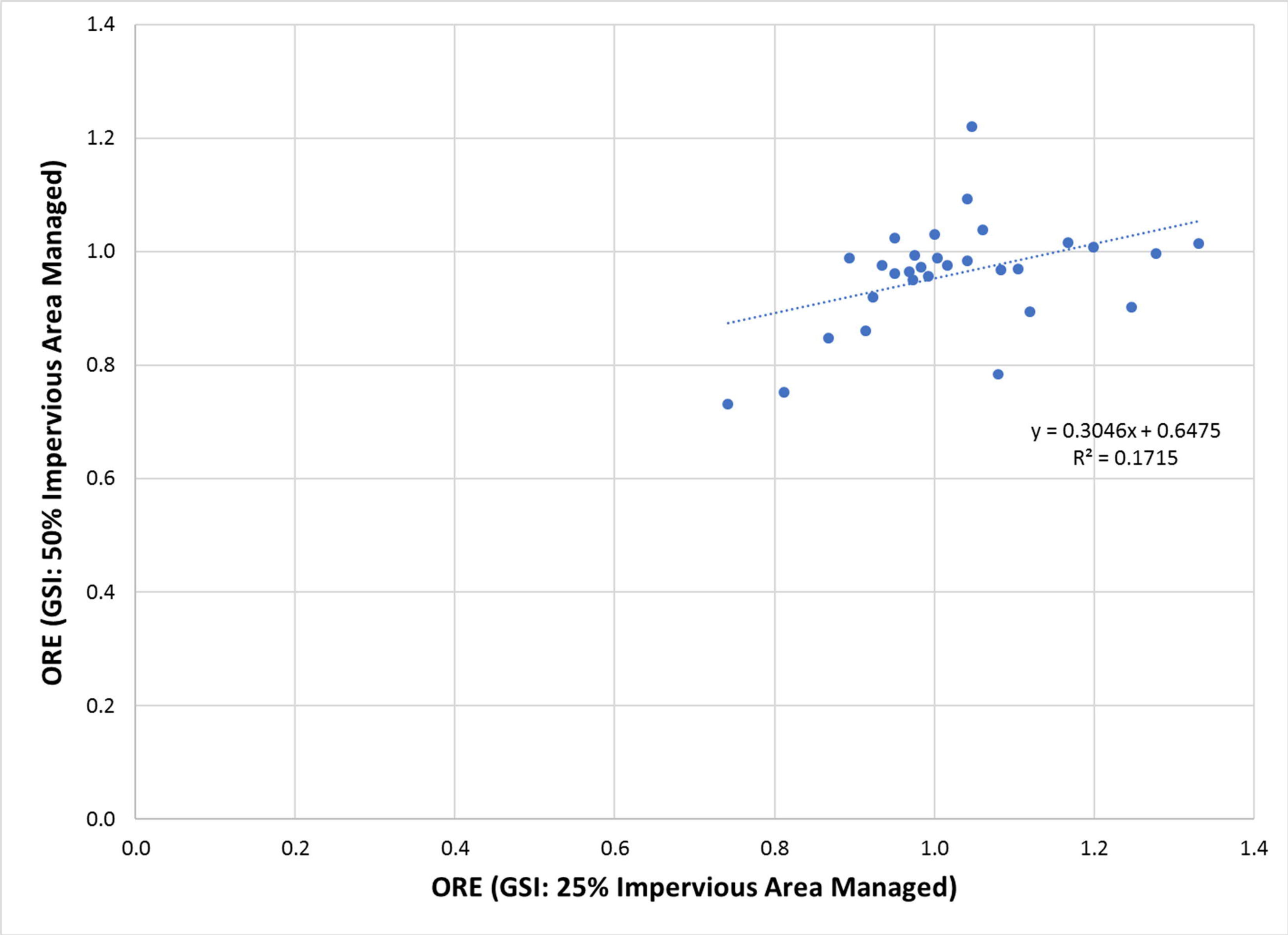

Figure 22. Upper Allegheny GSI OREs: Correlation Between Implementation Levels

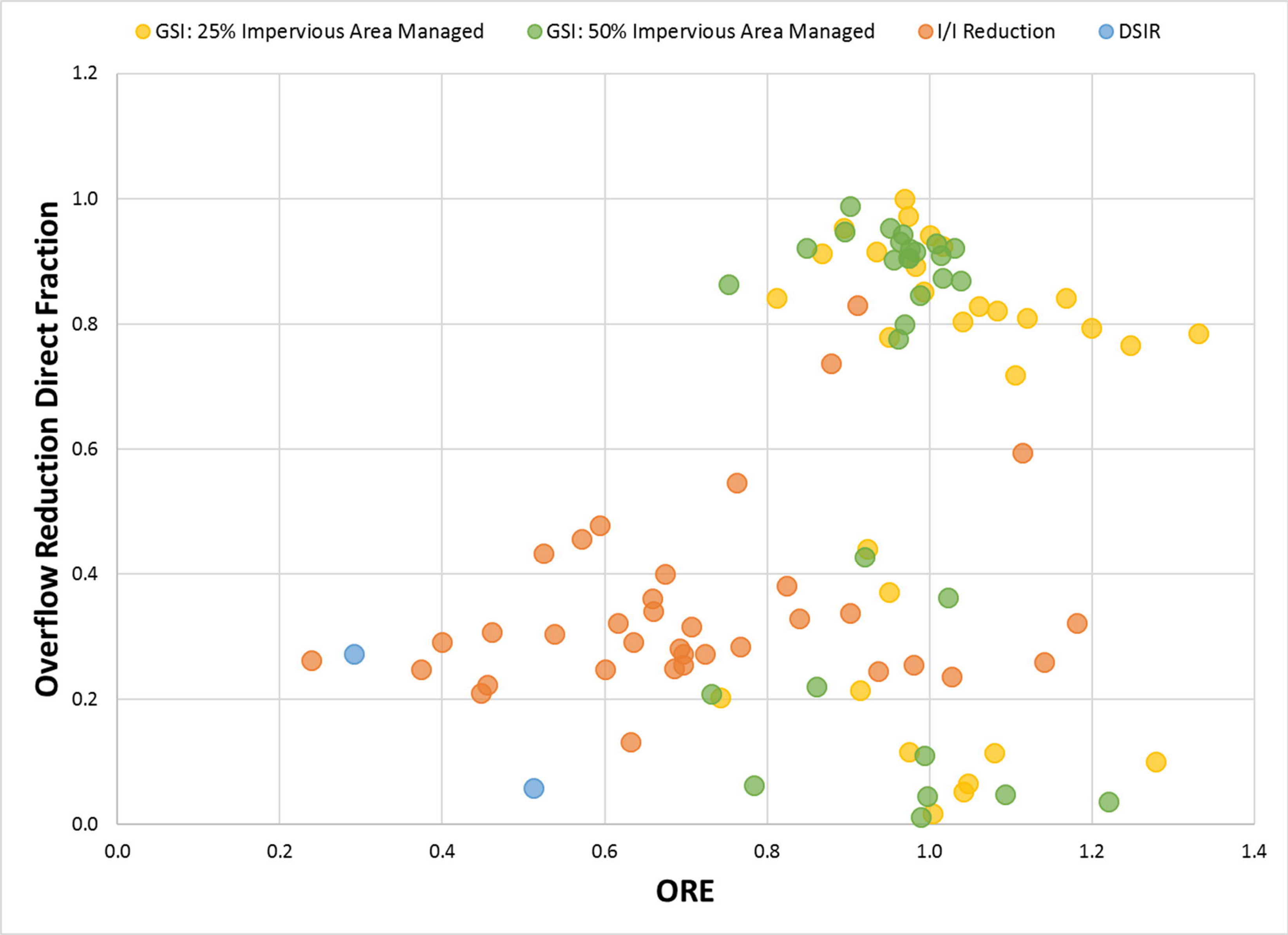

Figure 23. Upper Allegheny ORE Direct Fractions, by GSI/SC Type

3.4 Saw Mill Run

3.4.1 Overview

The Saw Mill Run (SMR) planning basin covers 19.7 square miles in the south central portion of the ALCOSAN service area. There are 12 municipalities that are located completely or partially within the Saw Mill Run basin. Wastewater flows generated within the basin are conveyed to the ALCOSAN Woods Run WWTP via a deep tunnel interceptor that extends along the Ohio River.

As shown in Figure 24, approximately 26% of Saw Mill Run basin is served by combined sewer systems, 67% is served by separate sanitary sewer systems, and 7% is non-contributing area that is either undeveloped or served by individual on-lot septic systems. Note there are no ALCOSAN-identified DSIs that have not yet been removed in Saw Mill Run basin. Figure 25 shows the wet weather flow volume produced in areas tributary to combined sewers and separate sanitary sewers during the typical year.

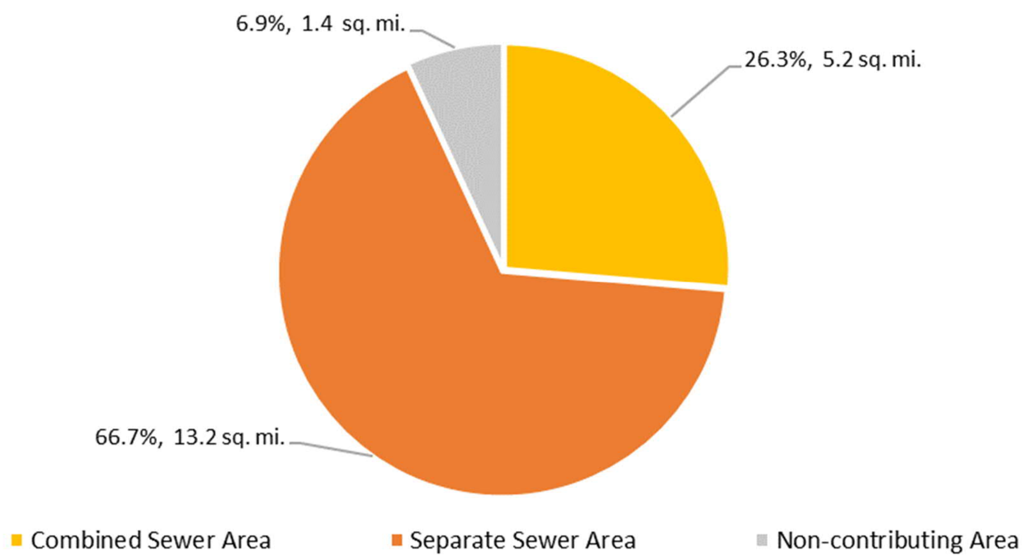

Figure 24. Summary of Drainage Area by Type in Saw Mill Run Basin
Note: Areas based on ALCOSAN's subcatchment GIS data

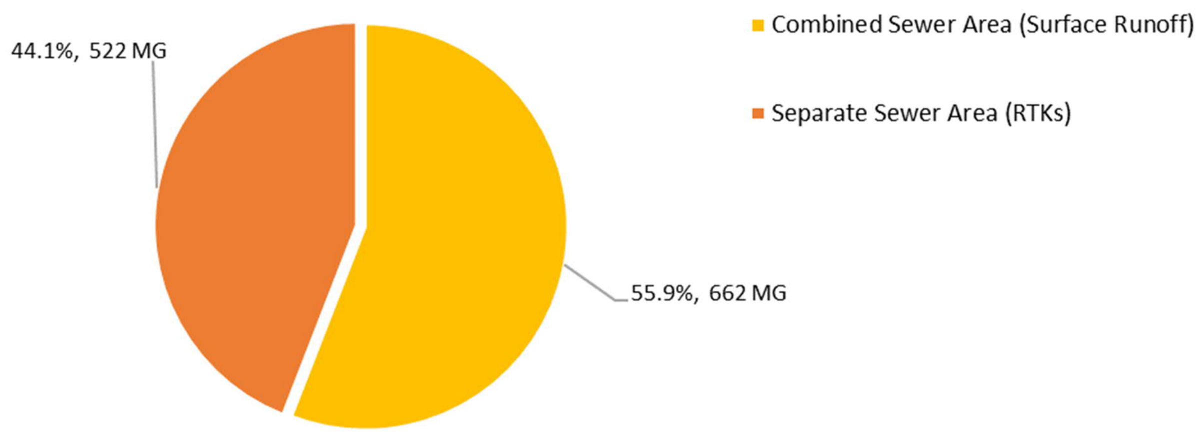

Figure 25. Summary of Annual Wet Weather Flow Volume by Type in Saw Mill Run Basin
Note: Wet weather flow volume based on Saw Mill Run Existing Conditions Model Typical Year Simulation

3.4.2 ORE Analysis Setup

Subcatchments were grouped into geographic units for the ORE analysis, following the rules identified in Section 2.3. Figures D-1a, D-1b, and D-1c in Appendix D show the GSI, I/I reduction, and DSIR geographic units for Saw Mill Run basin. Table D-1 in Appendix D summarizes the geographic units defined for Saw Mill Run basin. Table D-2 in Appendix D includes a cross-reference table between modeled subcatchments and geographic units for GSI and DSI OREs, and model nodes/unit hydrographs and geographic units for I/I OREs.

3.4.3 Results

Simulations were performed for the 2003 typical year in Saw Mill Run to represent the conditions of interest. Table 8 provides ORE estimate statistics for each of the GSI/SC measures evaluated, and Figure 26 shows the ORE and typical year annual overflow reduction for each geographic unit's ORE scenario.

Figures 27 and 28 show the correlation between OREs for the GSI 25% and 50% impervious area managed implementation levels. Shown in Figure 28, the coefficient of determination (R^2) value of 0.34 indicates a relatively high variation between the OREs for the two GSI implementation levels in Saw Mill Run planning basin.

Figure 29 presents overflow reduction direct fractions by GSI/SC type to illustrate indirect impacts within the planning basin. The direct fractions are calculated for each geographic unit's ORE scenario as the ratio of the maximum overflow volume reduced at a single outfall (the most directly impacted outfall) to the total amount of overflow volume reduced. A value close to 1 indicates that a ORE scenario had little indirect overflow reduction impacts; a value close to 0 indicates large indirect overflow reduction impacts. Note that it is possible to have a direct fraction value greater than 1 if there are any small increases in overflow volume at nearby indirectly impacted outfalls. For example, if the most directly impacted outfall during an ORE scenario has an overflow volume reduction of 1 mgal, and the outfall downstream has a small overflow volume increase of 0.01 mgal, the direct fraction would be calculated as 1 mgal divided by 0.99 mgal = 1.01. In these cases, the direct fraction value was capped at the value of 1. As shown in Figure 29, several GSI overflow reduction direct fractions were capped at 1 in Saw Mill Run. Note that almost all overflow volume increases in Saw Mill Run occur at O-14 outfalls (O-14-00-EAST-OF and O-14-00-WEST-OF).

Figures D-2a, D-2b, and D-2c in Appendix D show the geographic distribution of ORE estimates throughout the Saw Mill Run basin. To aid review of ORE variation in smaller geographic units, the Saw Mill Run basin contributing area was split into three maps.

For reference, Table D-3 in Appendix D shows the calculated ORE for the GSI, I/I reduction, and DSIR scenarios evaluated, as well as the corresponding inflow reduction volume, overflow reduction volume, and direct fraction. Note that overflow reduction volumes were summed across all outfalls for each simulation. Due to hydraulic interactions along the interceptor, overflow reductions may occur beyond the outfall directly associated with the POC. Table D-4 in Appendix D lists all reductions in overflow volume by outfall for each simulation.

Table 8. Saw Mill Run ORE Summary and Statistics

GSI/SC Type ORE Statistic	GSI: 25% Impervious Area Managed	GSI: 50% Impervious Area Managed	I/I	DSIR
Average	0.75	0.82	0.30	-
Median	0.76	0.84	0.32	-
Maximum	0.98	0.99	0.76	-
Minimum	0.21	0.53	0.00	-
Standard Deviation	0.17	0.12	0.20	-
Count	30	30	35	-

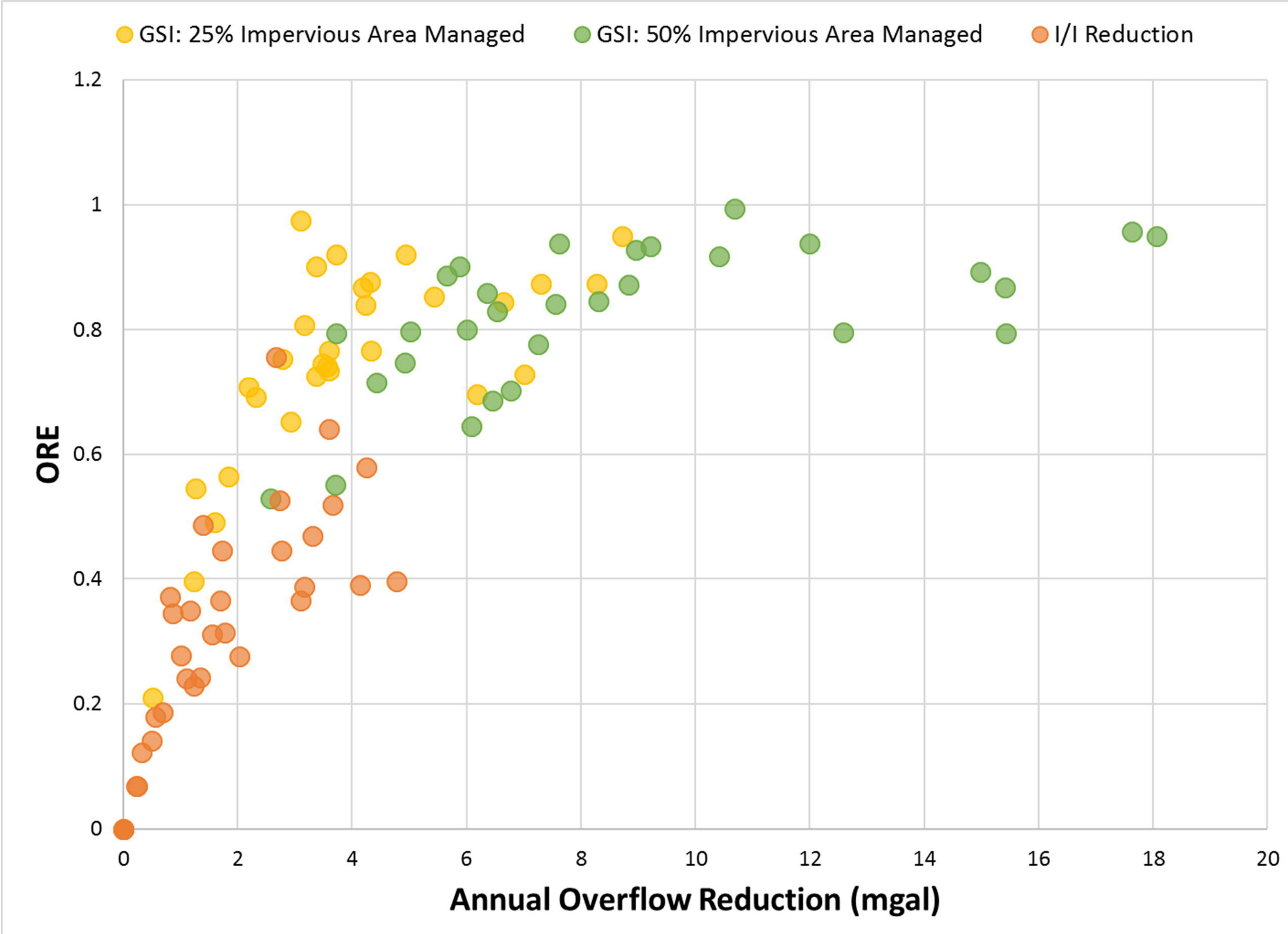

Figure 26. Saw Mill Run OREs by GSI/SC Type

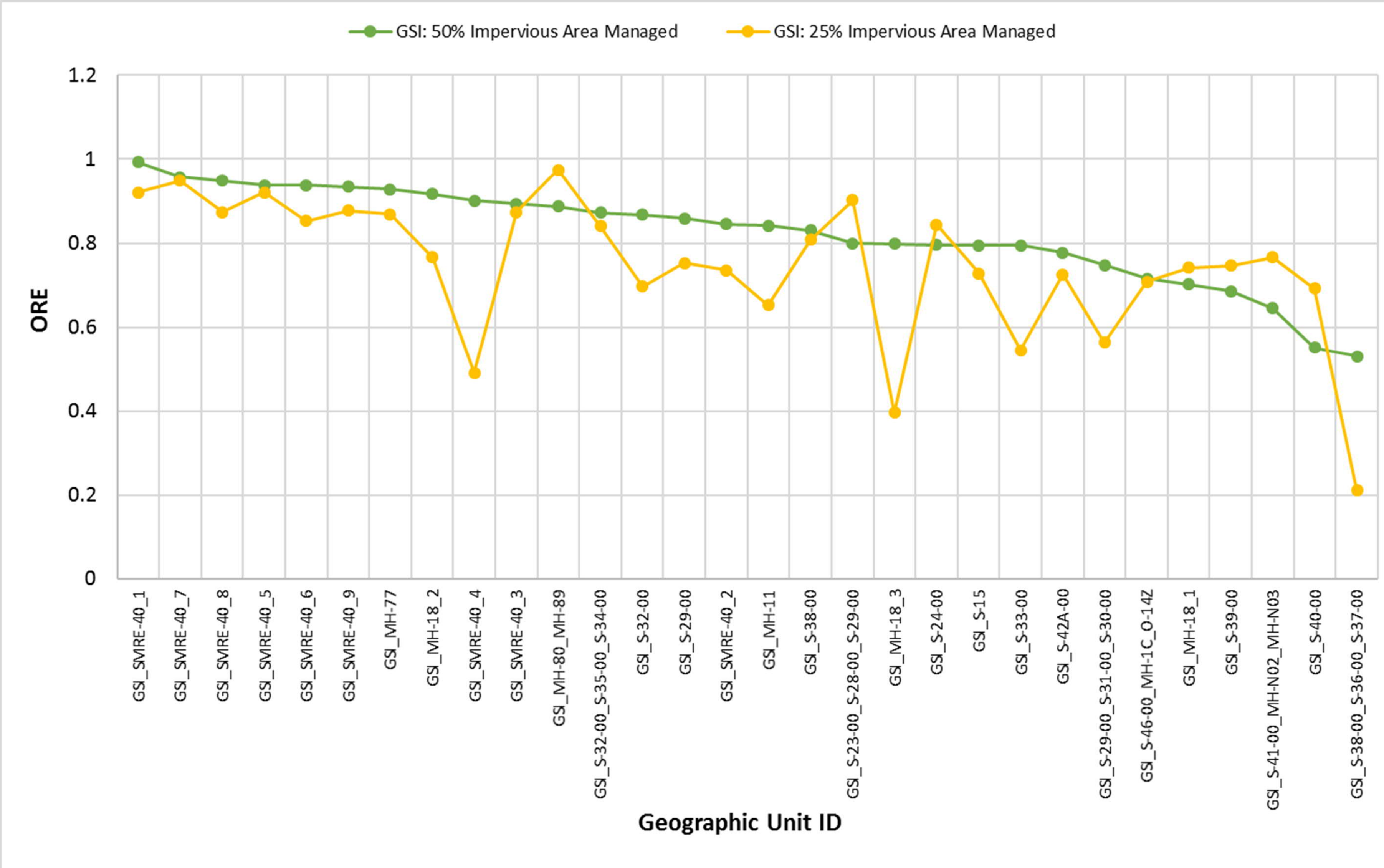

Figure 27. Saw Mill Run GSI OREs by Implementation Level

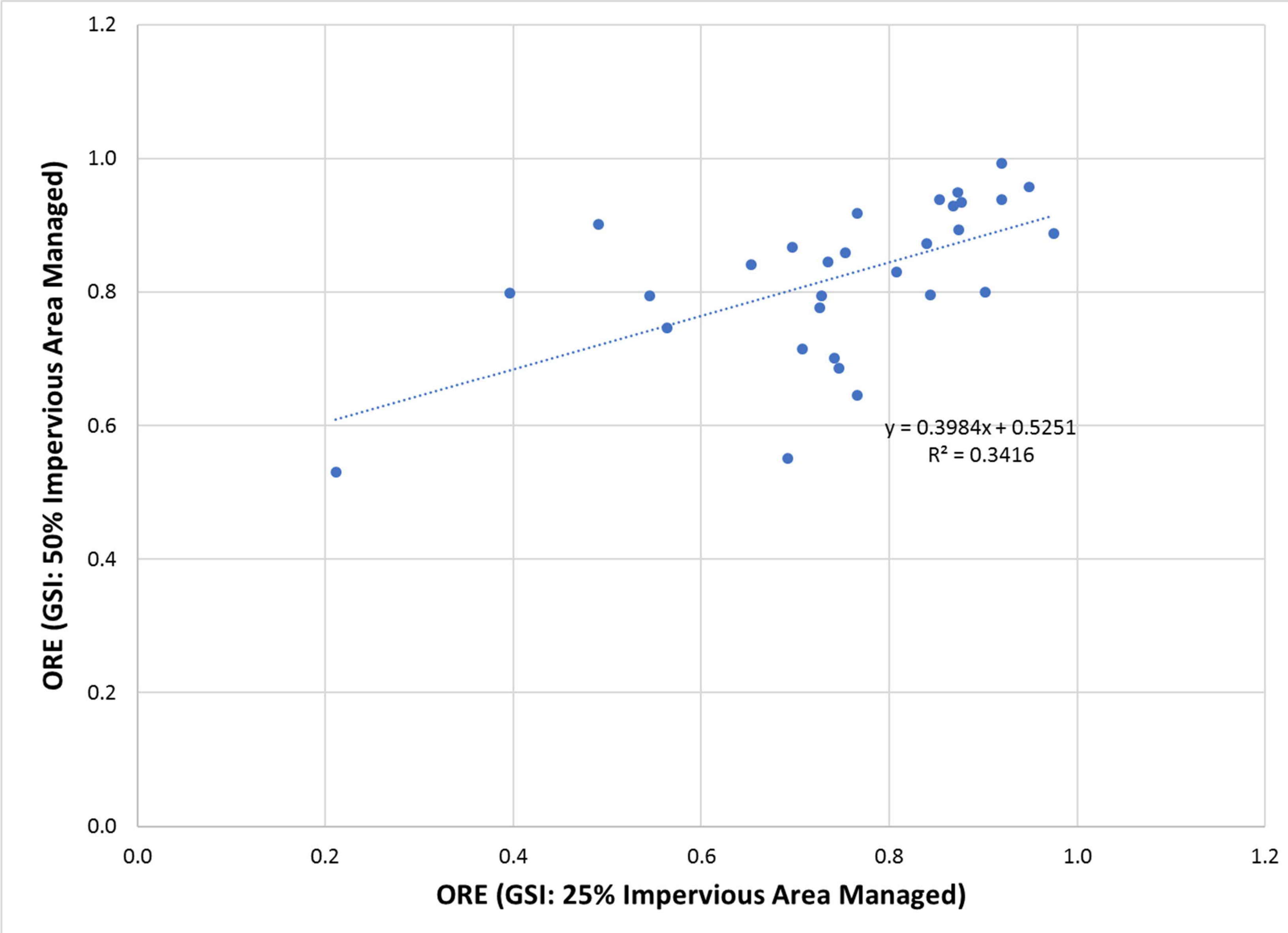

Figure 28. Saw Mill Run GSI OREs: Correlation Between Implementation Levels

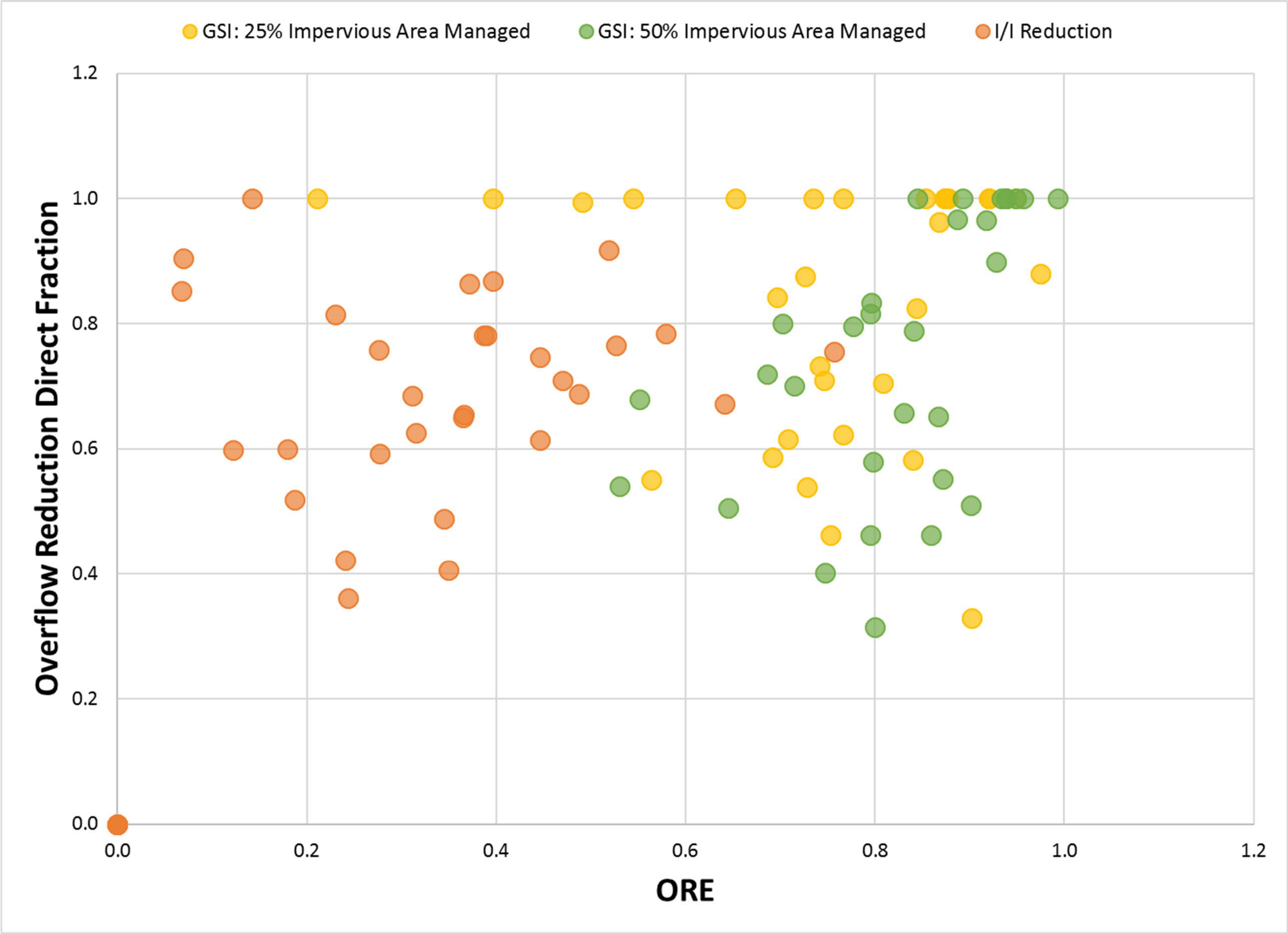

Figure 29. Saw Mill Run ORE Direct Fractions, by GSI/SC Type

3.5 Upper Monongahela

3.5.1 Overview

The Upper Monongahela (UM) planning basin covers 30.3 square miles of the ALCOSAN service area. There are 21 municipalities that are located completely or partially within the Upper Monongahela basin. Wastewater flows generated within the basin are conveyed to the ALCOSAN Woods Run WWTP via deep tunnel interceptors that extend along the Monongahela and Ohio Rivers.

As shown in Figure 30, approximately 18% of Upper Monongahela basin is served by combined sewer systems, 65% is served by separate sanitary sewer systems, 0.4% contributes runoff toward combined areas, and 15% is non-contributing area that is either undeveloped or served by individual on-lot septic systems. The sewered area within Upper Monongahela basin also includes one DSI identified by ALCOSAN that have not yet been removed (Tassey Hollow; see Table 3 and Figure 5). The DSI tributary area is about 2% of the Upper Monongahela basin sewered area. Figure 31 shows the wet weather flow volume produced in areas tributary to combined sewers and separate sanitary sewers during the typical year.

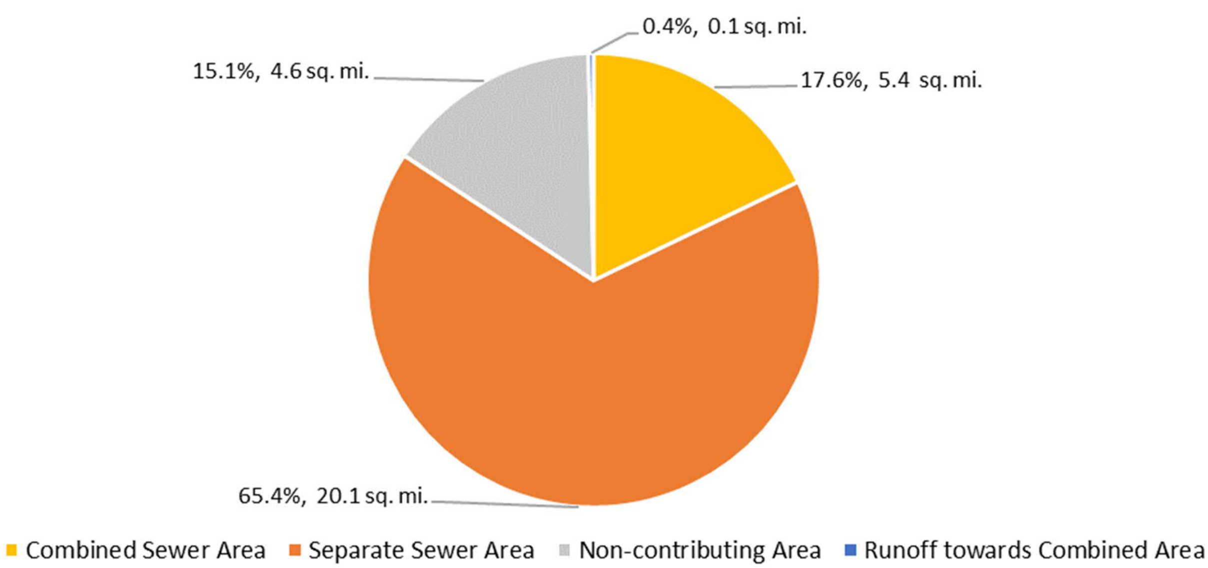

Figure 30. Summary of Drainage Area by Type in Upper Monongahela Basin
Note: Areas based on ALCOSAN's subcatchment GIS data

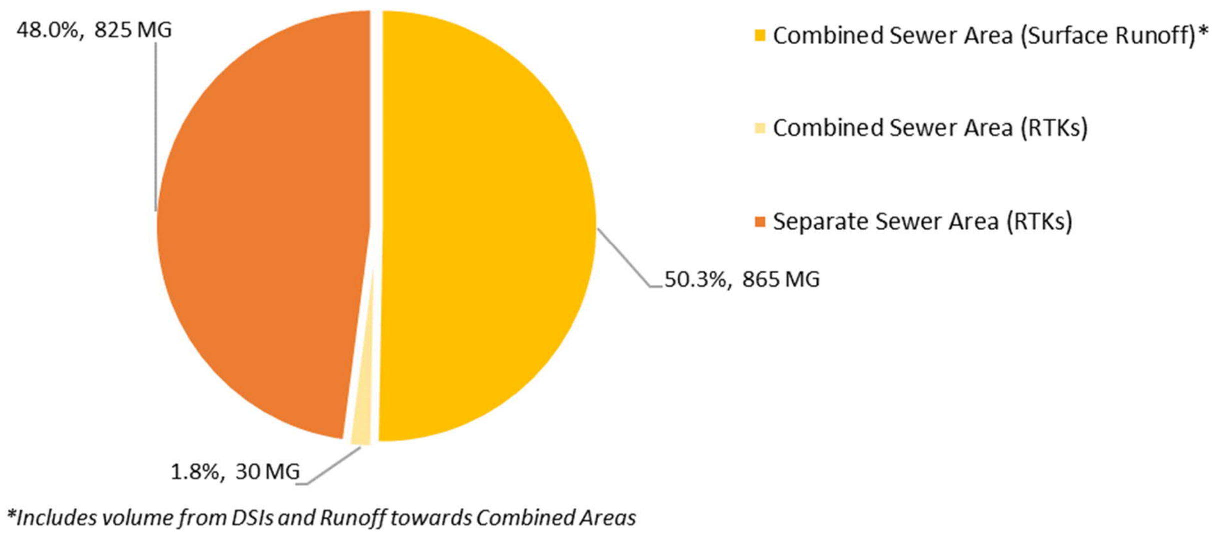

Figure 31. Summary of Annual Wet Weather Flow Volume by Type in Upper Monongahela Basin
Note: Wet weather flow volume based on Upper Monongahela Existing Conditions Model Typical Year Simulation

3.5.2 ORE Analysis Setup

Subcatchments were grouped into geographic units for the ORE analysis, following the rules identified in Section 2.3. Figures E-1a, E-1b, and E-1c in Appendix E show the GSI, I/I reduction, and DSIR geographic units for Upper Monongahela basin. Table E-1 in Appendix E summarizes the geographic units defined for Upper Monongahela basin. Table E-2 in Appendix E includes a cross-reference table between modeled subcatchments and geographic units for GSI and DSI OREs, and model nodes/unit hydrographs and geographic units for I/I OREs.

3.5.3 Results

Simulations were performed for the 2003 typical year in Upper Monongahela to represent the conditions of interest. Table 9 provides ORE estimate statistics for each of the GSI/SC measures evaluated, and Figure 32 shows the ORE and typical year annual overflow reduction for each geographic unit's ORE scenario.

Figures 33 and 34 show the correlation between OREs for the GSI 25% and 50% impervious area managed implementation levels. Shown in Figure 34, the coefficient of determination (R^2) value of 0.55 indicates a moderate variation between the OREs for the two GSI implementation levels.

Figure 35 presents overflow reduction direct fractions by GSI/SC type to illustrate indirect impacts in the planning basin. The direct fractions are calculated for each geographic unit's ORE scenario as the ratio of the maximum overflow volume reduced at a single outfall (the most directly impacted outfall) to the total amount of overflow volume reduced. A value close to 1 indicates that a ORE scenario had little indirect overflow reduction impacts; a value close to 0 indicates large indirect overflow reduction impacts.

Figures E-2a, E-2b, and E-2c in Appendix E show the geographic distribution of ORE estimates throughout the Upper Monongahela basin. To aid review of ORE variation in smaller geographic units, the Upper Monongahela basin contributing area was split into three maps.

For reference, Table E-3 in Appendix E shows the calculated ORE for the GSI, I/I reduction, and DSIR scenarios evaluated, as well as the corresponding inflow reduction volume, overflow reduction volume, and direct fraction. Note that overflow reduction volumes were summed across all outfalls for each simulation. Due to hydraulic interactions along the interceptor, overflow reductions may occur beyond the outfall directly associated with the POC. Table E-4 in Appendix E lists all reductions in overflow volume by outfall for each simulation.

Table 9. Upper Monongahela ORE Summary and Statistics

GSI/SC Type / ORE Statistic	GSI: 25% Impervious Area Managed	GSI: 50% Impervious Area Managed	I/I	DSIR
Average	0.93	0.89	0.72	0.17
Median	0.91	0.88	0.71	0.17
Maximum	1.32	1.14	1.11	0.17
Minimum	0.72	0.67	0.08	0.17
Standard Deviation	0.15	0.10	0.18	-
Count	33	33	36	1

Figure 32. Upper Monongahela OREs by GSI/SC Type

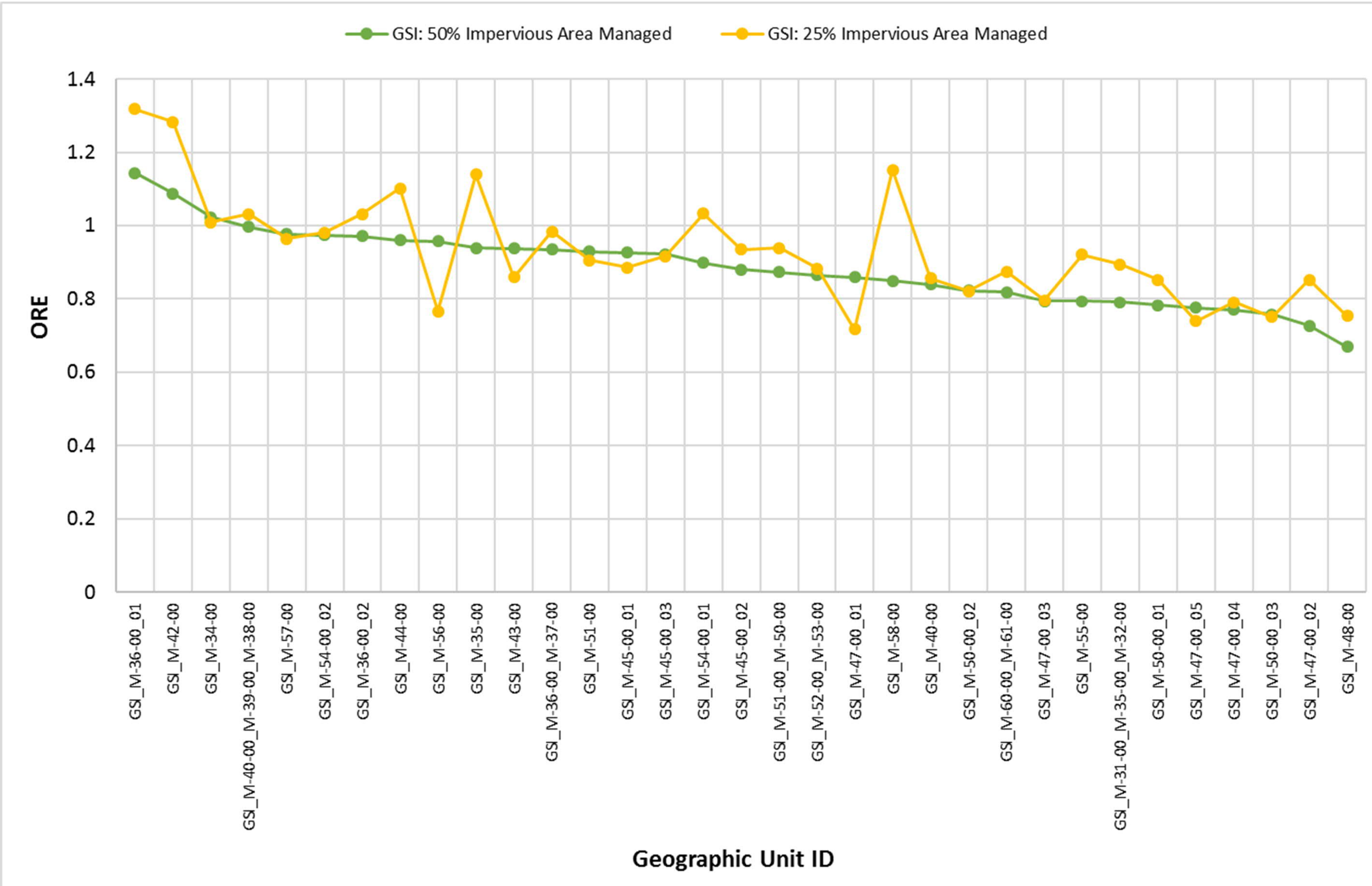

Figure 33. Upper Monongahela GSI OREs by Implementation Level

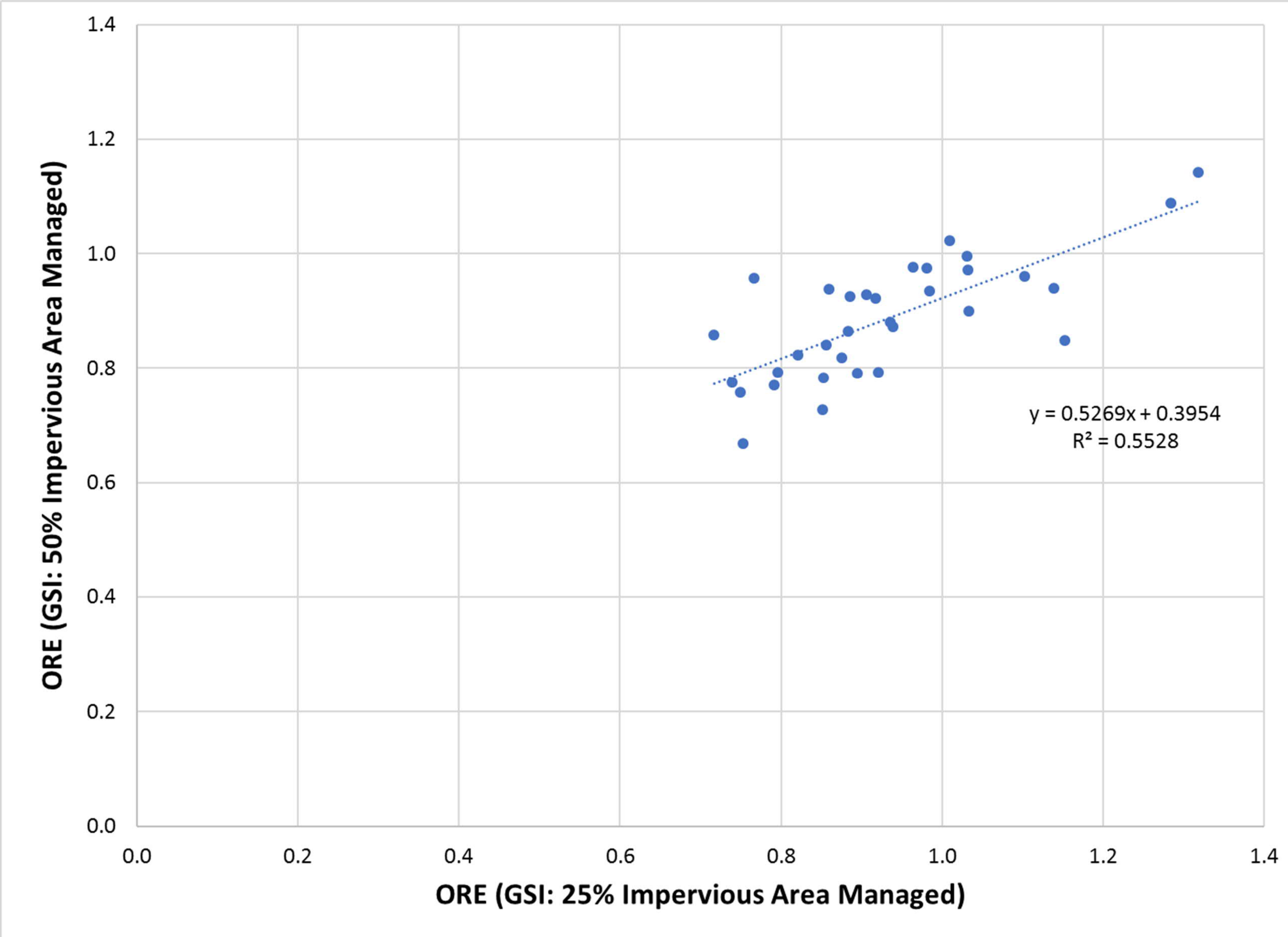

Figure 34. Upper Monongahela GSI OREs: Correlation Between Implementation Levels

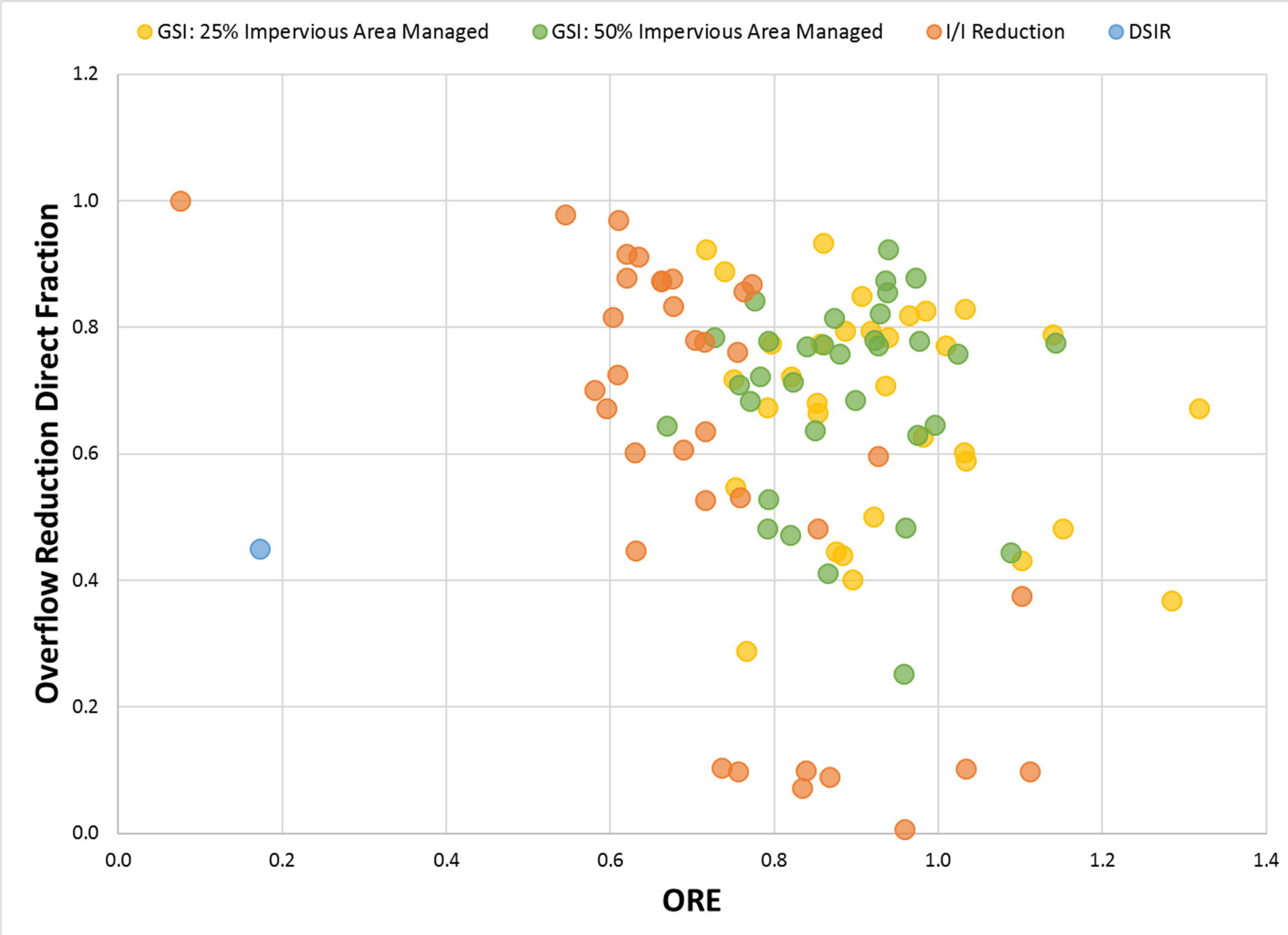

Figure 35. Upper Monongahela ORE Direct Fractions, by GSI/SC Type

3.6 Lower Ohio-Girty's Run

3.6.1 Overview

The Lower Ohio-Girty's Run (LOGR) planning basin covers 42.1 square miles of the ALCOSAN service area. There are 20 municipalities that are located completely or partially within the LOGR basin. Wastewater flows generated within the basin are conveyed to the ALCOSAN Woods Run WWTP via deep tunnel interceptors that extend along the Ohio and Allegheny Rivers.

As shown in Figure 36, approximately 6% of LOGR basin is served by combined sewer systems, 59% is served by separate sanitary sewer systems, 0.5% contributes runoff toward combined areas, and 34% is non-contributing area that is either undeveloped or served by individual on-lot septic systems. The sewered area within LOGR basin also includes one DSI identified by ALCOSAN that have not yet been removed (Verner Avenue; see Table 3 and Figure 5). The DSI tributary area is about 0.2% of the LOGR basin sewered area. Figure 37 shows the wet weather flow volume produced in areas tributary to combined sewers and separate sanitary sewers during the typical year.

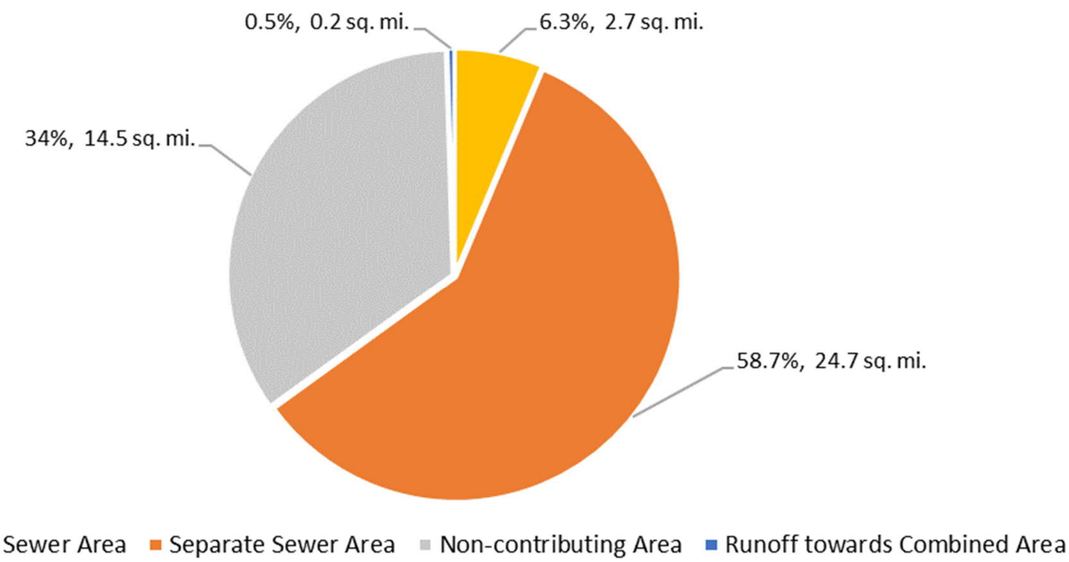

Figure 36. Summary of Drainage Area by Type in Lower Ohio Girty's Run Basin
Note: Areas based on ALCOSAN's subcatchment GIS data

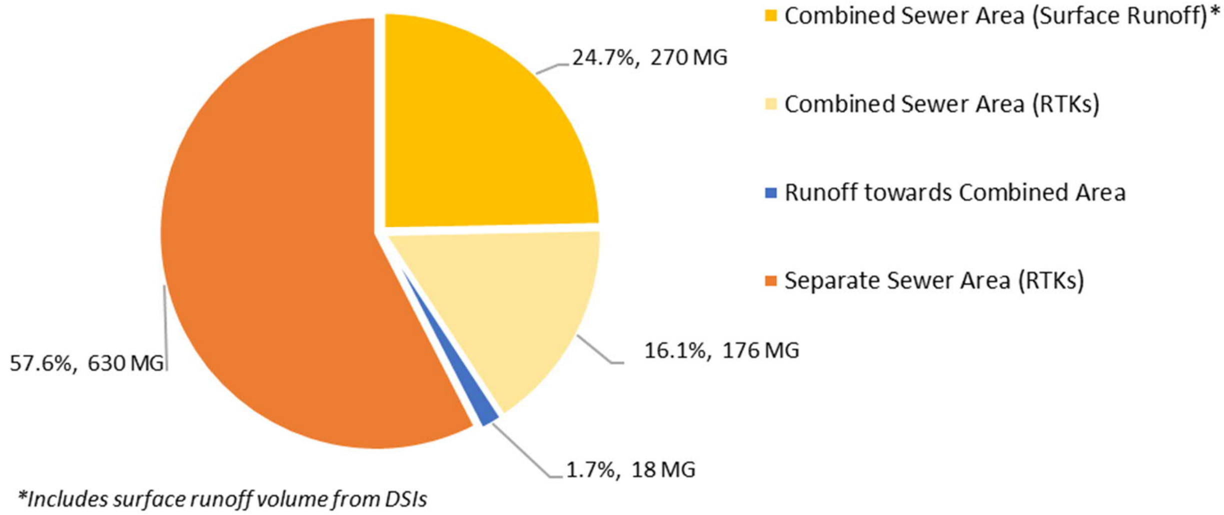

Figure 37. Summary of Annual Wet Weather Flow Volume by Type in Lower Ohio Girty's Run Basin
Note: Wet weather flow volume based on Lower Ohio and Lower Northern Allegheny Existing Conditions Model Typical Year Simulation

3.6.2 ORE Analysis Setup

Subcatchments were grouped into geographic units for the ORE analysis, following the rules identified in Section 2.3. Figures F-1a, F-1b, and F-1c in Appendix F show the GSI, I/I reduction, and DSIR geographic units for Lower Ohio Girty's Run basin. Table F-1 in Appendix F summarizes the geographic units defined for Lower Ohio Girty's Run basin. Table F-2 in Appendix F includes a cross-reference table between modeled subcatchments and geographic units for GSI and DSI OREs, and model nodes/unit hydrographs and geographic units for I/I OREs.

3.6.3 Results

Simulations were performed for the 2003 typical year in Lower Ohio Girty's Run to represent the conditions of interest. Table 10 provides ORE estimate statistics for each of the GSI/SC measures evaluated, and Figure 38 shows the ORE and typical year annual overflow reduction for each geographic unit's ORE scenario. Note that DSIR_O-26-00 (Verner Avenue) model results did not show any overflow reduction, therefore it was assigned an ORE of 0.

Figures 39 and 40 show the correlation between OREs for the GSI 25% and 50% impervious area managed implementation levels. Shown in Figure 40, the coefficient of determination (R^2) value of 0.71 indicates a moderately low variation between the OREs for the two GSI implementation levels.

Figure 41 presents overflow reduction direct fractions by GSI/SC type to illustrate indirect impacts in the planning basin. The direct fractions are calculated for each geographic unit's ORE scenario as the ratio of the maximum overflow volume reduced at a single outfall (the most directly impacted outfall) to the total amount of overflow volume reduced. A value close to 1 indicates that a ORE scenario had little indirect overflow reduction impacts; a value close to 0 indicates large indirect overflow reduction impacts.

Figures F-2a, F-2b, and F-2c in Appendix F show the geographic distribution of ORE estimates throughout the Lower Ohio Girty's Run basin. To aid review of ORE variation in smaller geographic units, the Lower Ohio Girty's Run basin contributing area was split into three maps.

For reference, Table F-3 in Appendix F shows the calculated ORE for the GSI, I/I reduction, and DSIR scenarios evaluated, as well as the corresponding inflow reduction volume, overflow reduction volume, and direct fraction. Note that overflow reduction volumes were summed across all outfalls for each simulation. Due to hydraulic interactions along the interceptor, overflow reductions may occur beyond the outfall directly associated with the POC. Table F-4 in Appendix F lists all reductions in overflow volume by outfall for each simulation.

Table 10. Lower Ohio Girty's Run ORE Summary and Statistics

GSI/SC Type ORE Statistic	GSI: 25% Impervious Area Managed	GSI: 50% Impervious Area Managed	I/I	DSIR
Average	0.78	0.74	0.49	0.00
Median	0.83	0.80	0.50	0.00
Maximum	1.50	0.99	0.71	0.00
Minimum	0.47	0.46	0.10	0.00
Standard Deviation	0.26	0.19	0.14	-
Count	19	19	34	1

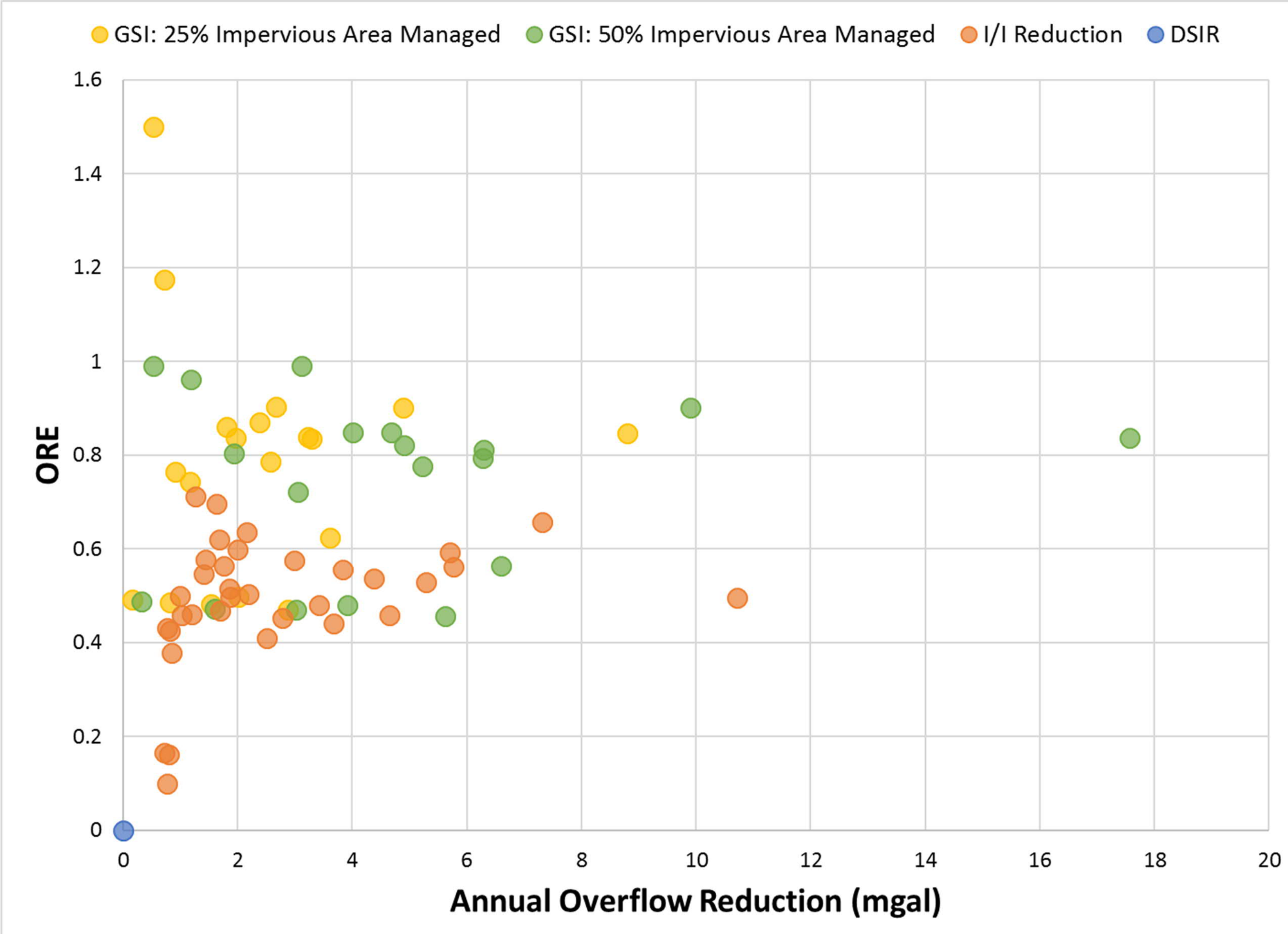

Figure 38. Lower Ohio Girty's Run OREs by GSI/SC Type

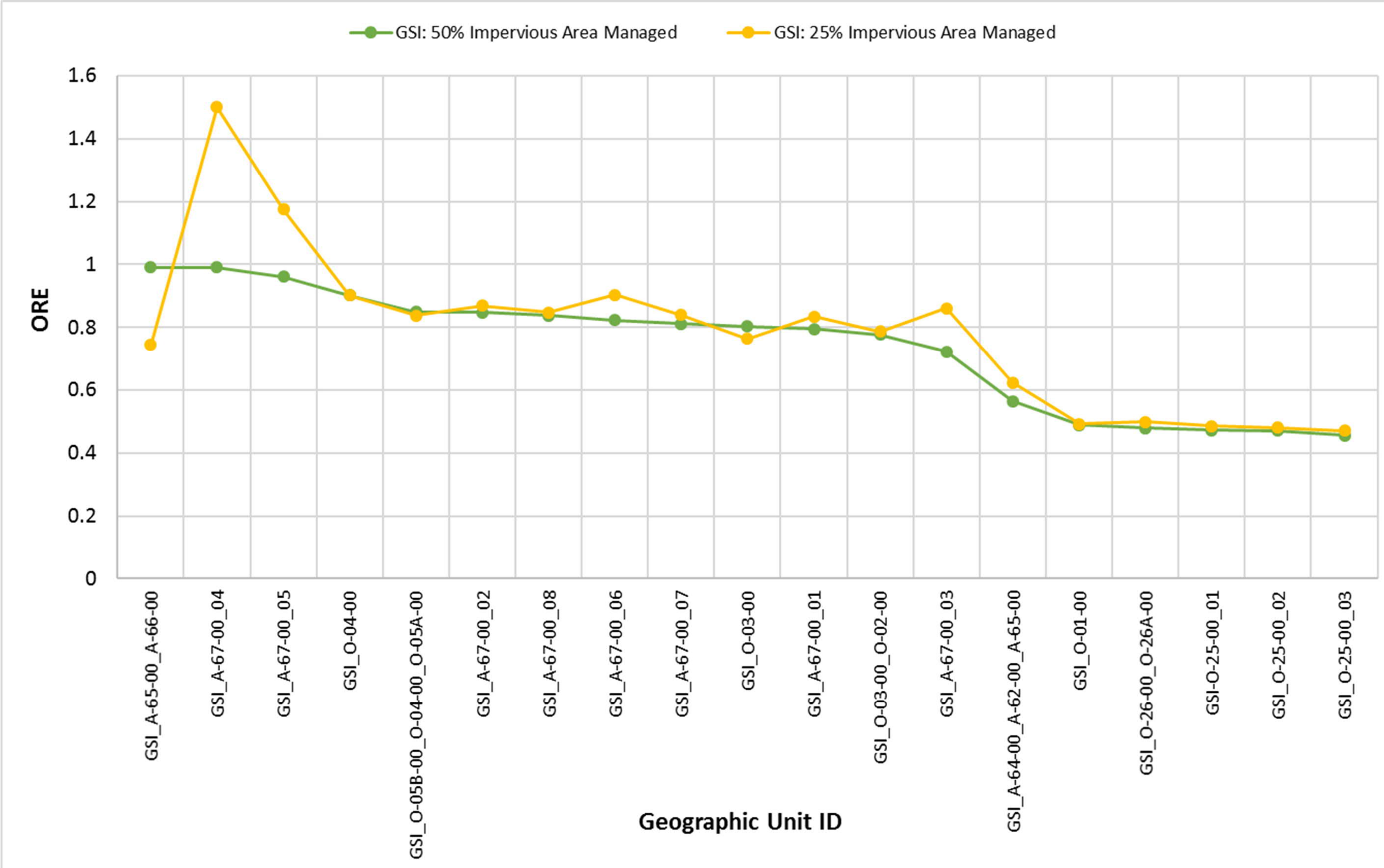

Figure 39. Lower Ohio Girty's Run GSI OREs by Implementation Level

Note: GSI_A-67-00_04 25% Impervious Area Managed ORE value is an outlier due to its low inflow reduction for the typical year (< 0.3 MG)

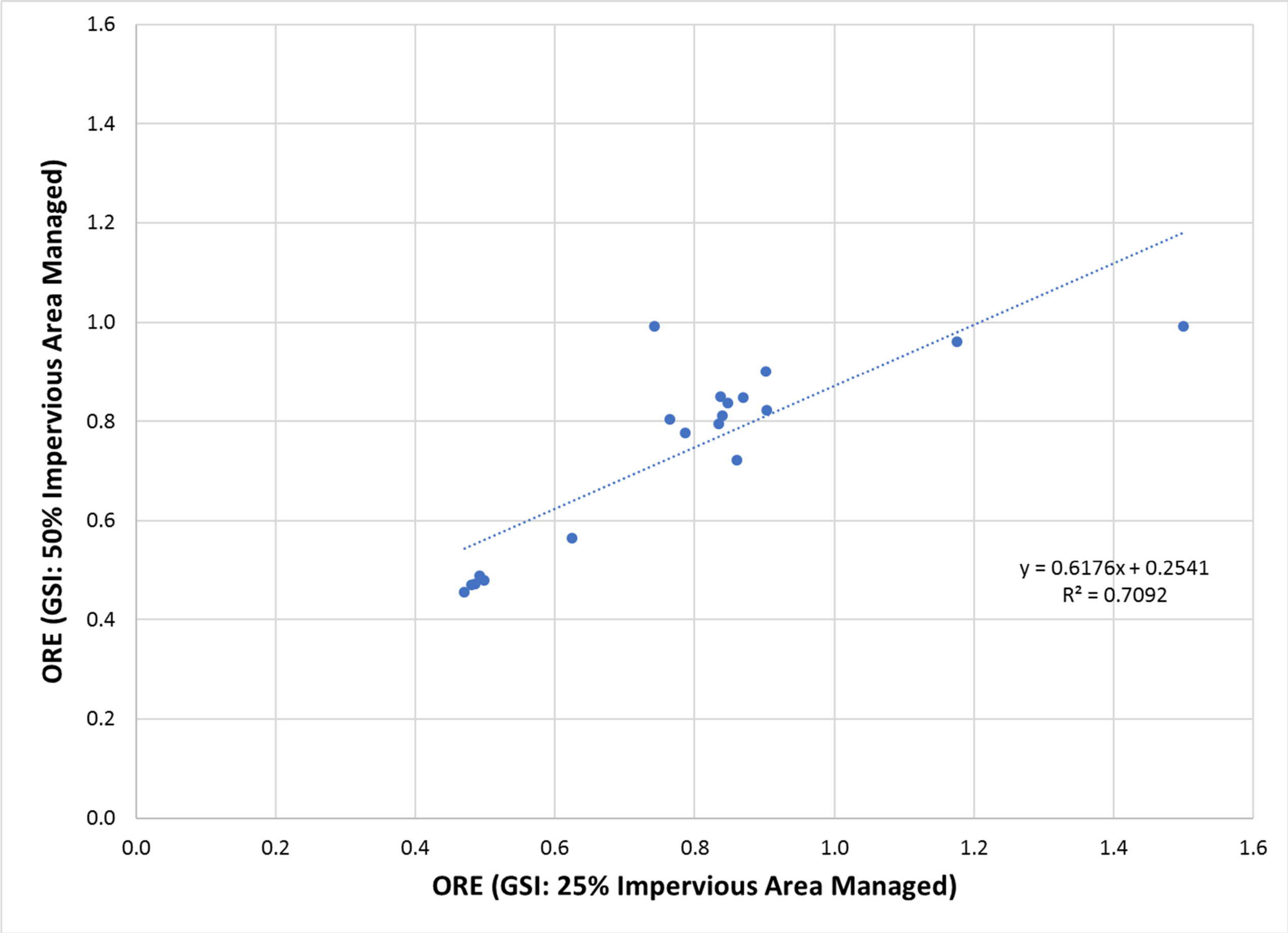

Figure 40. Lower Ohio Girty's Run GSI OREs: Correlation Between Implementation Levels

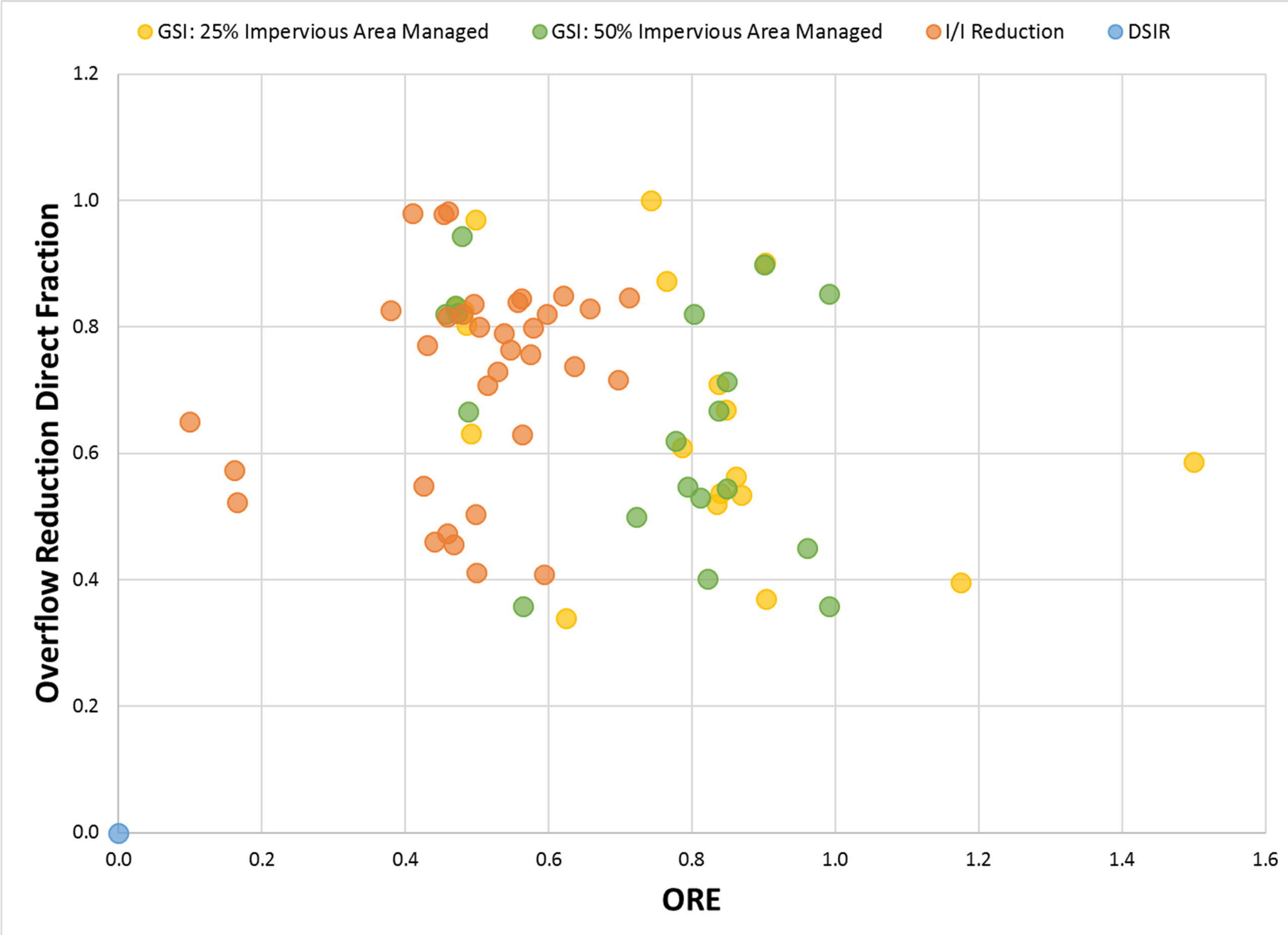

Figure 41. Lower Ohio Girty's Run ORE Direct Fractions, by GSI/SC Type

3.7 Turtle Creek

3.7.1 Overview

The Turtle Creek (TC) planning basin covers 57.2 square miles in the eastern part of the ALCOSAN service area. There are 20 municipalities that are located completely or partially within the Turtle Creek basin. Wastewater flows generated within the basin are conveyed to the ALCOSAN Woods Run WWTP via deep tunnel interceptors that extend along the Monongahela and Ohio Rivers.

As shown in Figure 42, approximately 5% of Turtle Creek basin is served by combined sewer systems, 58% is served by separate sanitary sewer systems, 0.6% contributes runoff toward combined areas, and 37% is non-contributing area that is either undeveloped or served by individual on-lot septic systems. The sewered area within Turtle Creek basin also includes one DSI identified by ALCOSAN that have not yet been removed (Dooker Hollow; see Table 3 and Figure 5). The DSI tributary area is about 0.7% of the Turtle Creek basin sewered area. Figure 43 shows the wet weather flow volume produced in areas tributary to combined sewers and separate sanitary sewers during the typical year.

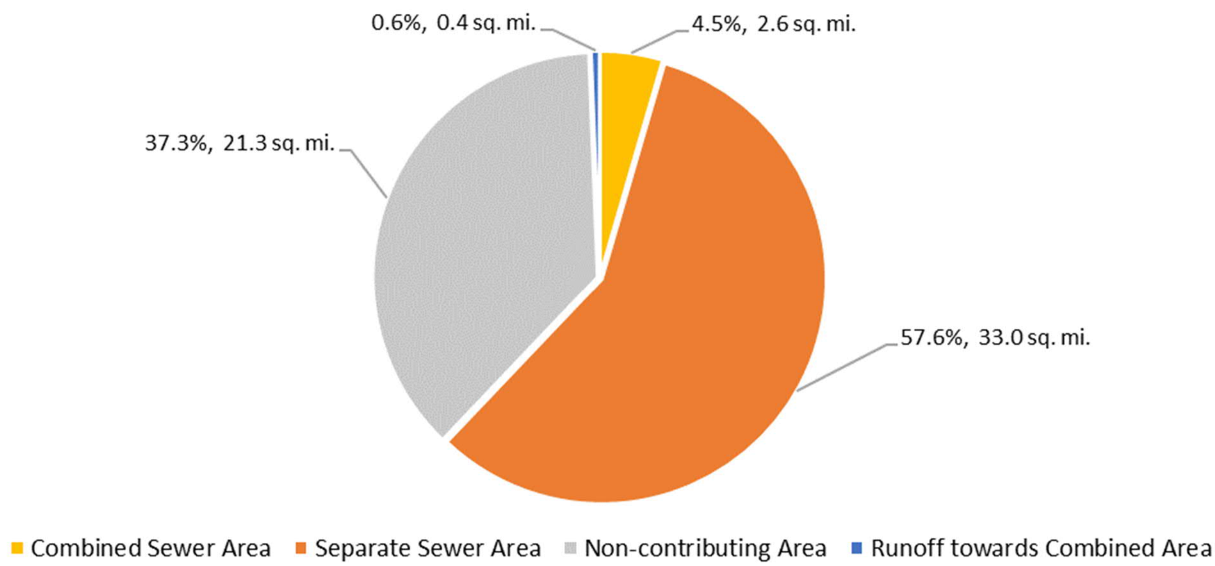

Figure 42. Summary of Drainage Area by Type in Turtle Creek Basin
Note: Areas based on ALCOSAN's subcatchment GIS data

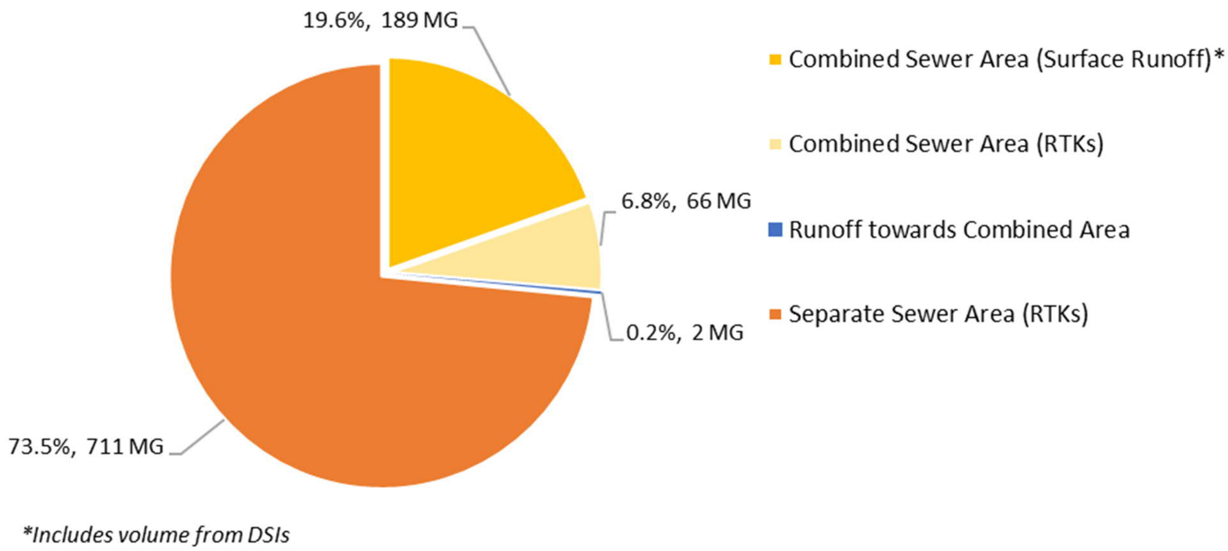

Figure 43. Summary of Annual Wet Weather Flow Volume by Type in Turtle Creek Basin
Note: Wet weather flow volume based on Turtle Creek Existing Conditions Model Typical Year Simulation

3.7.2 ORE Analysis Setup

Subcatchments were grouped into geographic units for the ORE analysis, following the rules identified in Section 2.3. Figures G-1a, G-1b, and G-1c in Appendix G show the GSI, I/I reduction, and DSIR geographic units for Turtle Creek basin. Table G-1 in Appendix G summarizes the geographic units defined for Turtle Creek basin. Table G-2 in Appendix G includes a cross-reference table between modeled subcatchments and geographic units for GSI and DSI OREs, and model nodes/unit hydrographs and geographic units for I/I OREs.

3.7.3 Results

Simulations were performed for the 2003 typical year in Turtle Creek to represent the conditions of interest. Table 11 provides ORE estimate statistics for each of the GSI/SC measures evaluated, and Figure 44 shows the ORE and typical year annual overflow reduction for each geographic unit's ORE scenario.

Figures 45 and 46 show the correlation between OREs for the GSI 25% and 50% impervious area managed implementation levels. Shown in Figure 46, the coefficient of determination (R^2) value of 0.98 indicates a relatively low variation between the OREs for the two GSI implementation levels.

Figure 47 presents overflow reduction direct fractions by GSI/SC type to illustrate indirect impacts in the planning basin. The direct fractions are calculated for each geographic unit's ORE scenario as the ratio of the maximum overflow volume reduced at a single outfall (the most directly impacted outfall) to the total amount of overflow volume reduced. A value close to 1 indicates that an ORE scenario had little indirect overflow reduction impacts; a value close to 0 indicates large indirect overflow reduction impacts.

Figures G-2a, G-2b, and G-2c in Appendix G show the geographic distribution of ORE estimates throughout the Turtle Creek basin. To aid review of ORE variation in smaller geographic units, the Turtle Creek basin contributing area was split into three maps.

For reference, Table G-3 in Appendix G shows the calculated ORE for the GSI, I/I reduction, and DSIR scenarios evaluated, as well as the corresponding inflow reduction volume, overflow reduction volume, and direct fraction. Note that overflow reduction volumes were summed across all outfalls for each simulation. Due to hydraulic interactions along the interceptor, overflow reductions may occur beyond the outfall directly associated with the POC. Table G-4 in Appendix G lists all reductions in overflow volume by outfall for each simulation.

Table 11. Turtle Creek ORE Summary and Statistics

GSI/SC Type ORE Statistic	GSI: 25% Impervious Area Managed	GSI: 50% Impervious Area Managed	I/I	DSIR
Average	0.45	0.43	0.22	0.05
Median	0.42	0.35	0.21	0.05
Maximum	0.87	0.86	0.48	0.05
Minimum	0.12	0.15	0.02	0.05
Standard Deviation	0.21	0.21	0.13	-
Count	12	12	25	1

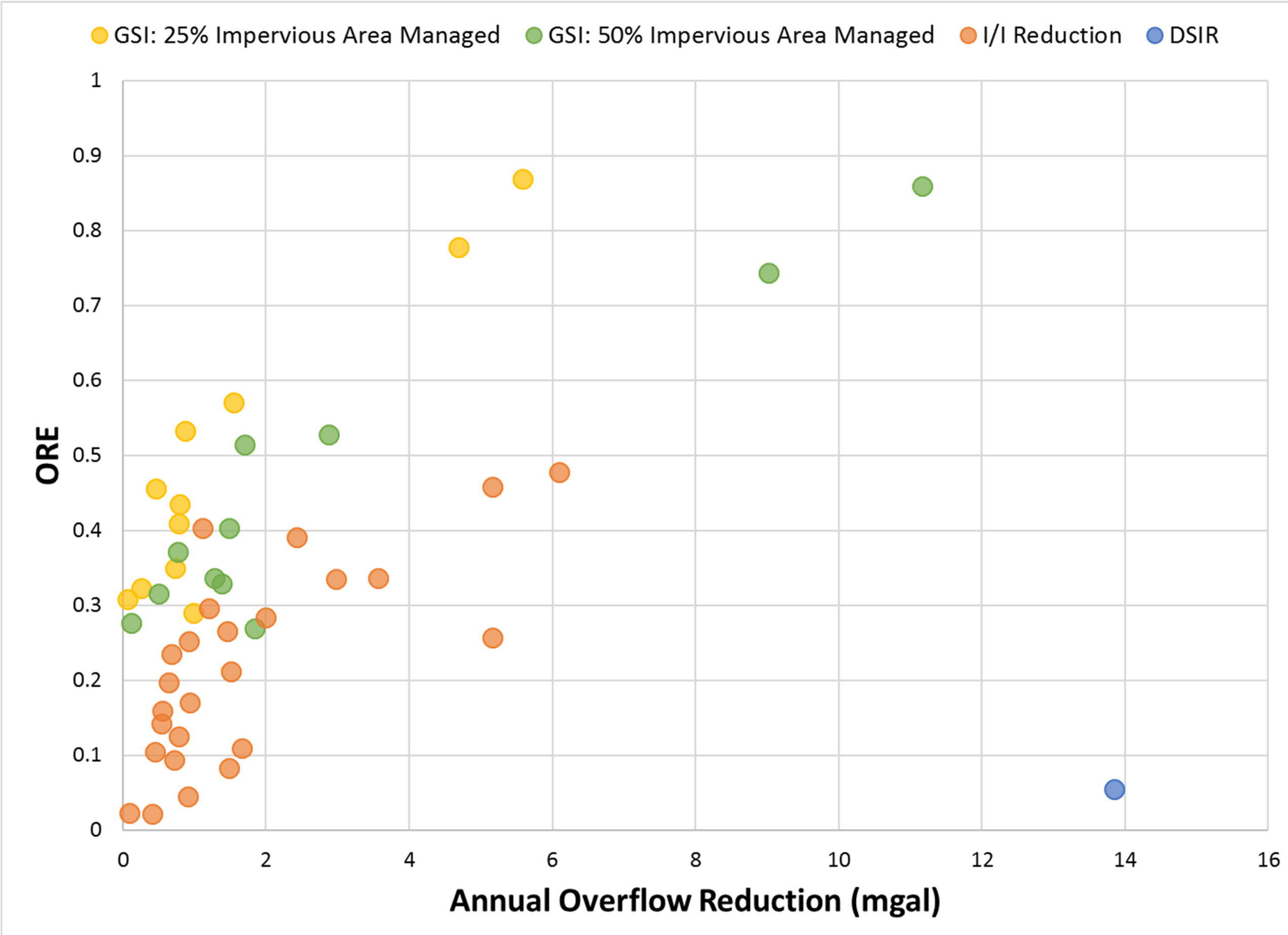

Figure 44. Turtle Creek OREs by GSI/SC Type

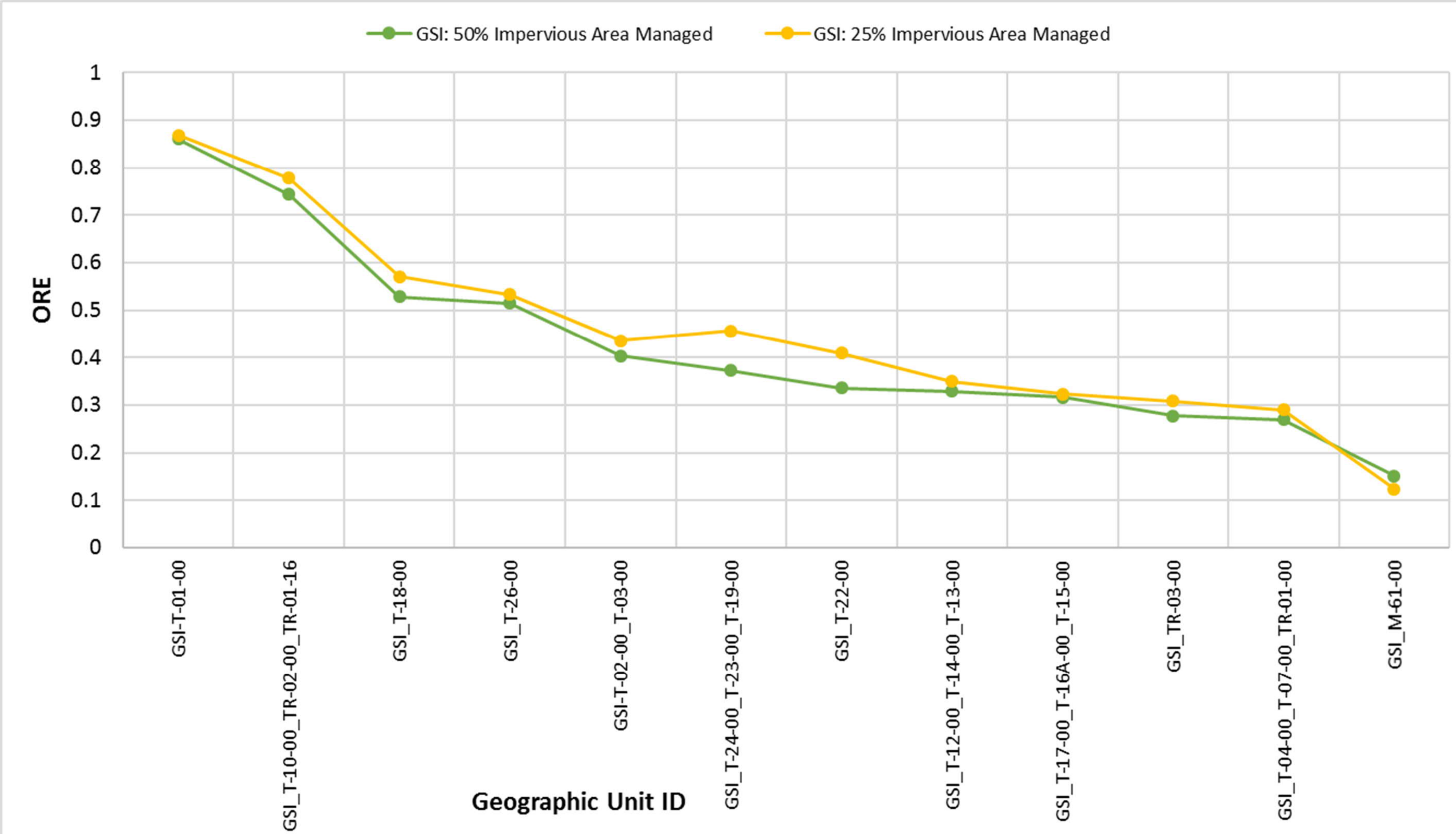

Figure 45. Turtle Creek GSI OREs by Implementation Level

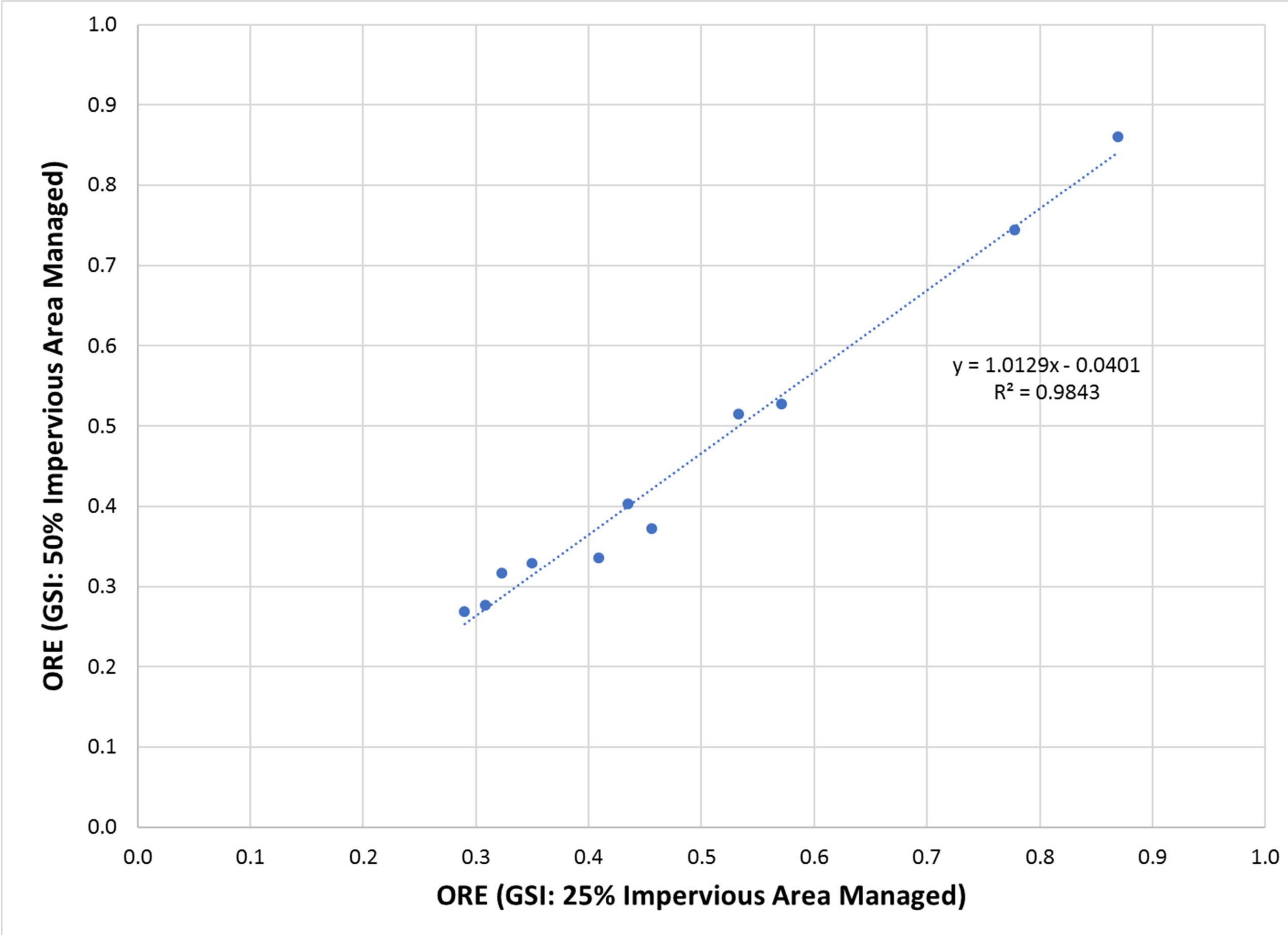

Figure 46. Turtle Creek GSI OREs: Correlation Between Implementation Levels

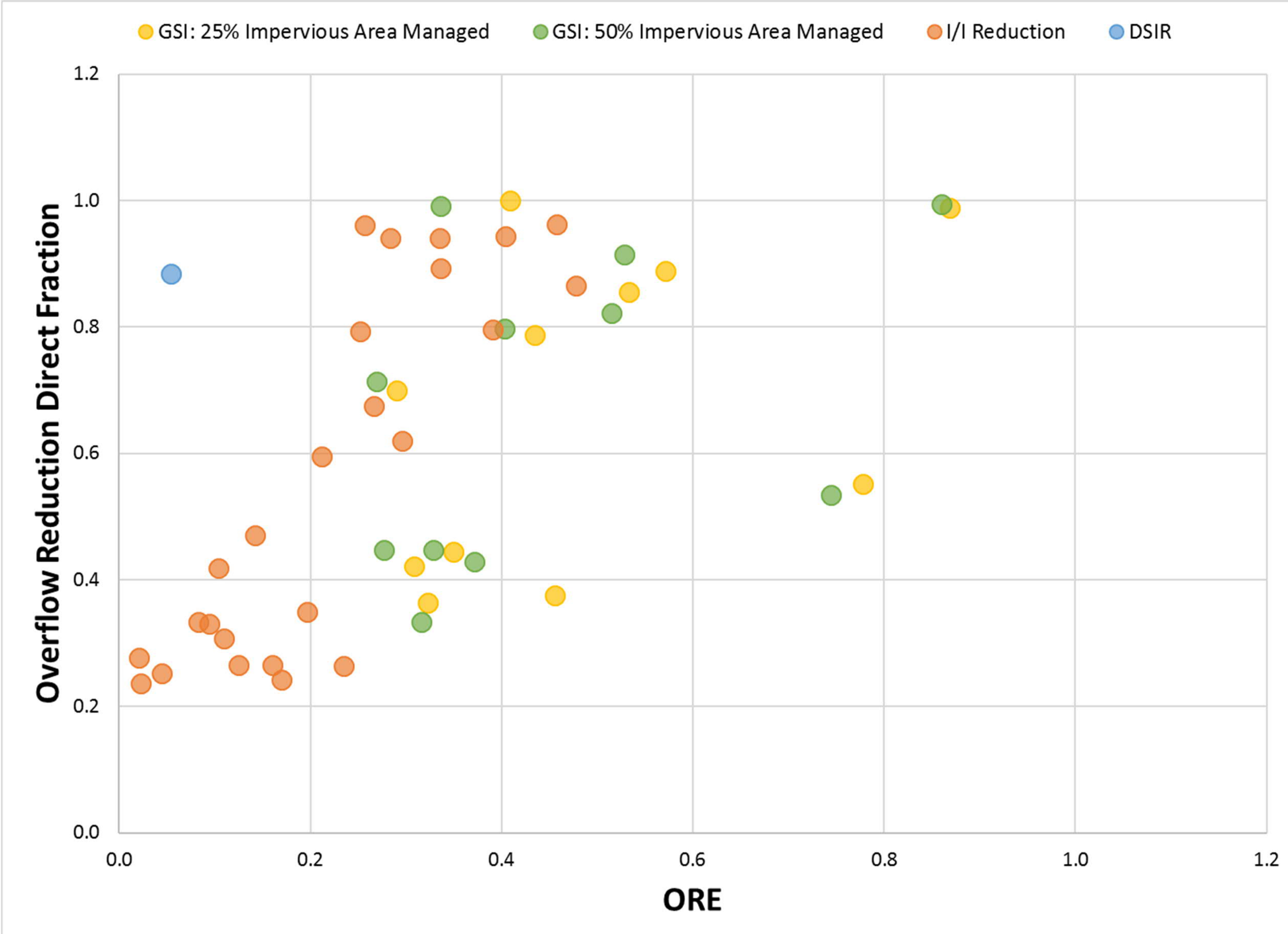

Figure 47. Turtle Creek ORE Direct Fractions, by GSI/SC Type

4.0 Summary & Conclusions

The preceding sections describe the variation in ORE estimates both within and between basins in the ALCOSAN service area. These ORE estimates help to identify locations where reducing system inflow contributes to the greatest overflow reduction. ORE data can be combined with additional information (for instance, the opportunities and constraints analysis data) to identify areas where GSI/SC projects would not only be feasible, but also have the highest potential to cost-effectively reduce overflows.

Significant variation in OREs was identified, underscoring the importance of location of the GSI/SC within the hydraulic context of the sewer network. Several factors contribute to ORE variation, including:

- The amount of existing overflow volume
- The number of active outfalls
- Outfall density (i.e., a higher density of outfalls may contribute to more indirect overflow reduction)
- Network hydraulics (i.e., the aggregate impact of flow routing and hydraulic limitations, which connect the impact of decreased flows with the timing of downstream overflow occurrence)

Figure 48 shows the average and standard deviation of ORE estimates by basin and GSI/SC type. Several trends stood out from the ORE analysis:

- GSI ORE estimates were higher than I/I reduction ORE estimates (within a basin).
- DSIR ORE estimates were lower than both GSI and I/I reduction, even though DSIRs have significant inflow reduction. DSIR ORE estimates are generally lower because a significant portion of their estimated inflow reduction is related to stream baseflow, which contributes flow during periods when overflows are not occurring. Although OREs may be lower, significant overflow reductions can still be achieved. DSIRs have additional value not quantified by the model, such as reduction of sediment and debris into the Regional Collection System.
- Much of the overflow reduction impact occurs outside of the principal impact overflow. The overflow reduction direct fraction averaged 0.67 across the system, ranging from 0.007 to 1.
- Average OREs varied considerably between basins, ranging from 0.43 in Turtle Creek to 0.96 in Main Rivers and Upper Allegheny (for 50% GSI implementation).
- The variation of ORE estimates is considerable within basins. Even in Turtle Creek, which has the lowest average OREs, OREs as high as 0.86 were identified (for 50% GSI implementation). Conversely, in Upper Allegheny, which has the highest average OREs, OREs as low as 0.73 were identified (for 50% GSI implementation).

The ORE estimate is an early-stage planning tool to help identify priority areas and focus attention on locations with the greatest potential for overflow reduction. As GSI/SC projects are identified and developed, projects can be evaluated more directly with greater levels of detail. Indeed, project-level details and GSI type (e.g., bioretention, porous pavement, infiltration trench) may cause variation in overflow reduction impacts in the same geographic unit (with the same ORE), due to differences in the timing of how they store, infiltrate, and/or discharge flow back to the combined system. Review of past GROW application modeling provides some examples of such variation. Lastly, ORE estimates are affected by the infrastructure included in the baseline conditions simulation. For instance, if a storage tank were built to reduce upstream overflows, OREs in the affected tributary areas would likely be significantly reduced. As the Wet Weather Plan is refined and finalized, it may be worthwhile to evaluate OREs under alternative baseline conditions to identify the most beneficial areas for GSI/SC with planned infrastructure improvements in place.

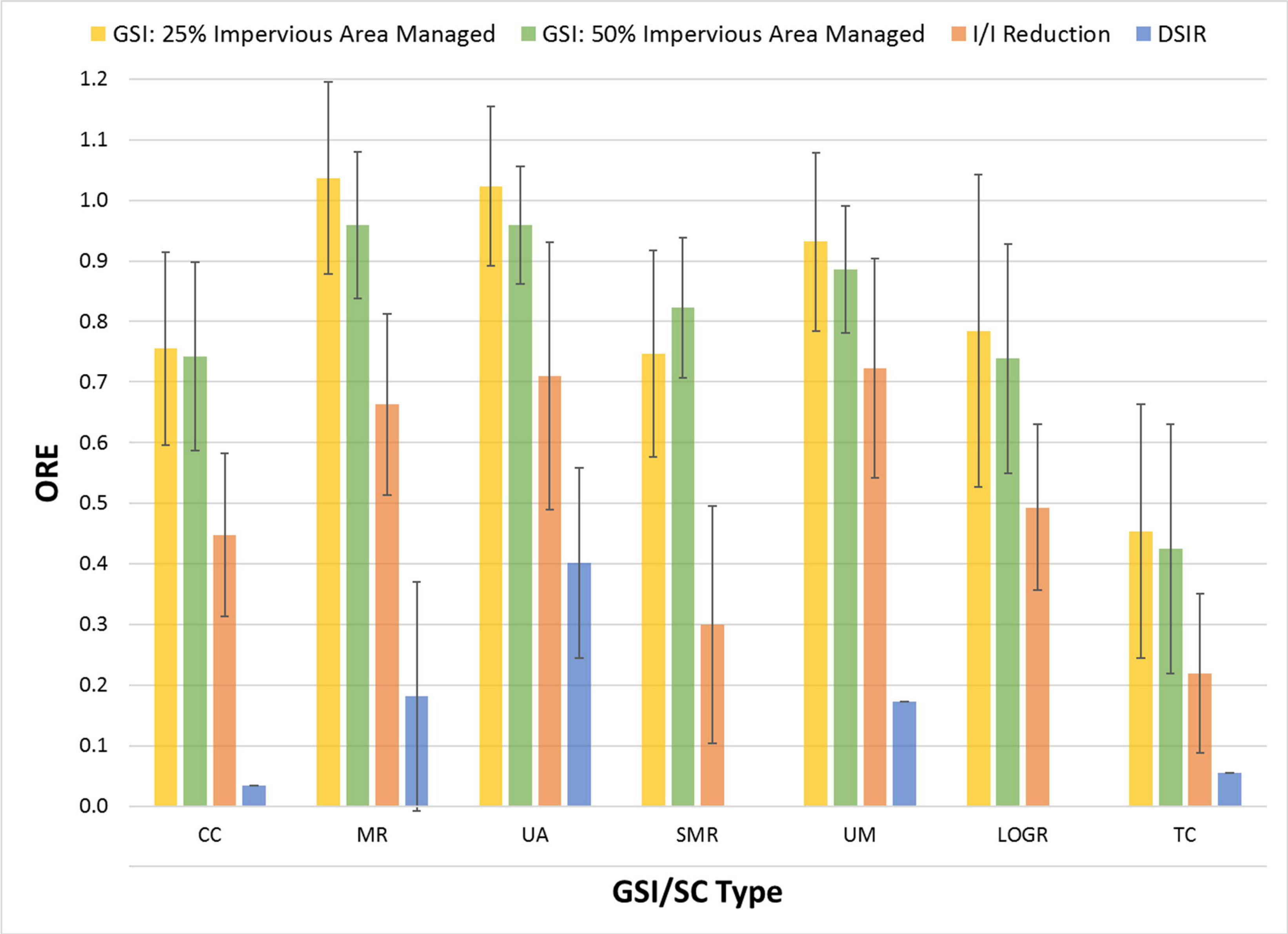

Figure 48. Mean ORE Estimates and Standard Deviations, by Basin and GSI/SC Type

5.0 References

CH2M, 2018. ALCOSAN Proxy Period Analysis Technical Memorandum. March, 2018.