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Southeast Michigan Council of Governments
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Green Infrastructure Targeting in Southeast Michigan

An Outcome-based Strategic Planning Framework to Identify and Evaluate Green Infrastructure Opportunities

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About the Green Infrastructure Technical Assistance Program

Stormwater runoff is a major cause of water pollution in urban areas. When rain falls in undeveloped areas, soil and plants absorb and filter the water. When rain falls on our roofs, streets, and parking lots, however, the water cannot soak into the ground. In most urban areas, stormwater is drained through engineered collection systems and discharged into nearby water bodies. The stormwater carries trash, bacteria, heavy metals, and other pollutants from the urban landscape, polluting the receiving waters. Higher flows also can cause erosion and flooding in urban streams, damaging habitat, property, and infrastructure.

Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, *green infrastructure* refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, *green infrastructure* refers to stormwater management systems that mimic nature by soaking up and storing water. Green infrastructure can be a cost-effective approach for improving water quality and helping communities stretch their infrastructure investments further by providing multiple environmental, economic, and community benefits. This multibenefit approach creates sustainable and resilient water infrastructure that supports and revitalizes urban communities.

The U.S. Environmental Protection Agency (EPA) encourages communities to use green infrastructure to help manage stormwater runoff, reduce sewer overflows, and improve water quality. EPA recognizes the value of working collaboratively with communities to support broader adoption of green infrastructure approaches. Technical assistance is a key component to accelerating the implementation of green infrastructure across the nation and aligns with EPA's commitment to provide community-focused outreach and support in the President's Priority Agenda Enhancing the Climate Resilience of America's Natural Resources. Creating more resilient systems will become increasingly important in the face of climate change. As more intense weather events or dwindling water supplies stress the performance of the nation's water infrastructure, green infrastructure offers an approach to increase resiliency and adaptability.

For more information, visit *http://www.epa.gov/greeninfrastructure*.

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Miller Avenue Rain Garden (Ann Arbor), Plumbrook (Sterling Heights), Easy Street Pervious Pavers (Ann Arbor), Tonquish Creek (Plymouth Township)

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Acronyms and Abbreviations

BMP	best management practice
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
HSG	hydrologic soil group
HSPF	Hydrologic Simulation Program FORTRAN
HUC	hydrologic unit code
LSPC	Loading Simulation Program C++
MDEQ	Michigan Department of Environmental Quality
MDOT	Michigan Department of Transportation
MS4	municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
R-B Index	Richards-Baker Flashiness Index
ROW	right-of-way
SEMCOG	Southeast Michigan Council of Governments
SUSTAIN	System for Urban Stormwater Treatment and Analysis INtegration
SWAG	Subwatershed Advisory Group
SWMM	Storm Water Management Model
TMDL	total maximum daily load
USGS	U.S. Geological Survey
WQS	water quality standards

Executive Summary

Recognizing the value of the Lake Huron—Lake Erie corridor to the region (economically, environmentally, and socially), southeast Michigan faces some unique challenges regarding stormwater management. The region is home to approximately 5 million people, over half of Michigan's entire population. The region also houses all or part of 16 major watersheds that drain directly to Lake Huron and Lake Erie. The connecting corridor between the two Great Lakes includes Lake St. Clair, the St. Clair River, and the Detroit River, which share an international border with Canada. Having a concentrated urban population located directly on two of the state's Great Lakes highlights the significant need to properly manage stormwater to protect water quality.

Within the 16 watersheds, priorities include addressing urban runoff and nonpoint source pollution such as the effects of excessive stormwater runoff volume and pollutant loading. In 2014, the Southeast Michigan Council of Governments (SEMCOG) published the *Green Infrastructure Vision for Southeast Michigan* (SEMCOG 2014). An important focus underlying development of this document was strategically implementing green infrastructure practices that will achieve multiple desired outcomes. Stakeholder visioning and public polling in the region confirmed that a priority outcome for green infrastructure implementation is improved water quality. As green infrastructure is implemented, both runoff volume and pollutant loading will be reduced. In the long term, biological communities within the watersheds will improve.

SEMCOG recognized that a priority need in moving forward with the *green infrastructure vision* was a framework to estimate the amount of green infrastructure necessary to demonstrate substantial improvements in local water resources. With that need as a driving force, a project was initiated to determine the role green infrastructure can play in working towards meeting water quality standards in southeast Michigan and in protecting western Lake Erie. The project used a regionalized, outcome-based strategic planning approach for green infrastructure targeting based on local ambient monitoring, land use, and impervious cover information. Key activities conducted include:

- *Hydrologic analysis* using flow data from 40 U.S. Geological Survey gages in southeast Michigan to bracket the range of local conditions and identify key metrics to guide the green infrastructure targeting process.
- *Selection of pilot subwatersheds* based on land use/land cover characteristics representative of green infrastructure planning challenges and opportunities in southeast Michigan to support development and testing of the green infrastructure targeting process.
- *Establishment of green infrastructure targets* based on local monitoring data that focus on stormwater runoff volume reduction using stream flashiness to connect aquatic biology and stream channel concerns with total maximum daily loads and stormwater management activities.
- *Opportunity assessment* highlighting priority catchments within each pilot subwatershed based on impervious cover density/composition and using desktop screening analyses to estimate the relative benefit of different implementation strategies.
- *Incorporation of the results into the green infrastructure vision* by evaluating and identifying options to achieve stream flashiness and stormwater volume reduction targets and developing plans to implement them across the region. Key strategies in the *Green Infrastructure Vision for Southeast Michigan* include native plant grow zones, increasing tree canopy, and the use of constructed practices (e.g., bioretention, pervious pavement, and bioswales) (SEMCOG 2014).

The process for developing the framework detailed in this report involved setting targets for green infrastructure that hopefully can be implemented in other southeast Michigan watersheds. As a separate project, the framework will be extended to other Detroit area subwatersheds in support of efforts to develop a broader strategy for implementing water quality programs and aligning Michigan Department of Transportation infrastructure goals with watershed management plans. In addition, this framework will serve as a baseline from which to evaluate progress for urban watershed restoration in the region.

1 Overview

The Southeast Michigan Council of Governments (SEMCOG) published the *Green Infrastructure Vision for Southeast Michigan* in 2014 (SEMCOG 2014). *Green infrastructure* encompasses both natural features such as wetlands and woodlands, as well as constructed features such as rain gardens and bioswales. A crucial component of a successful green infrastructure program involves strategically implementing its features to achieve multiple desired outcomes. Stakeholder visioning and public polling in the southeastern Michigan region confirmed that a priority outcome for green infrastructure implementation is improved water quality. Recognizing the value of the Lake Huron—Lake Erie corridor to the region (economically, environmentally, and socially), SEMCOG focused this project on estimating the amount of green infrastructure necessary to be implemented to demonstrate improvements in local water resources.

When it comes to stormwater management, southeast Michigan faces a unique set of circumstances compared with other regions in the nation. Nestled in the lower corner of Michigan's Lower Peninsula, the region is home to approximately 5 million people, which constitutes over half of the state's entire population. The region also houses all or part of 16 major watersheds that drain directly to Lake Huron and Lake Erie. The connecting corridor between the two Great Lakes includes Lake St. Clair, the St. Clair River, and the Detroit River, which share an international border with Canada. Additionally, five Areas of Concern[1] are located within the southeast Michigan region. Location of the large, concentrated urban population directly on two of the state's Great Lakes highlights the significant need to properly manage stormwater to protect water quality.

Within the 16 watersheds, addressing urban runoff and nonpoint source pollution, including the effects of excessive stormwater runoff volume and pollutant loading, is a priority. Many existing watershed plans in the region identify implementing green infrastructure as one method for addressing those effects. The watersheds plans also contain approved total maximum daily loads (TMDLs) for biota, total suspended solids, dissolved oxygen, phosphorus, and *E. coli*. As green infrastructure is implemented incrementally, runoff volume and pollutant loading are reduced. In the long term, biological communities within these watersheds will improve.

1.1 Project Objective

The overall objective of this project was to determine the role green infrastructure can play in achieving water quality standards (WQS) in southeast Michigan and protecting western Lake Erie. In three pilot subwatersheds, hydrologic stormwater runoff reduction targets were identified to protect aquatic biology and help address concerns with TMDLs and stormwater management activities. The targets were used to examine alternative green infrastructure implementation techniques that could achieve WQS and protect biological communities. The project involved four tasks:

- Task 1: Establish baseline flow-duration curves for selected subdrainage areas.
- Task 2: Establish stormwater runoff volume targets.
- Task 3: Assess green infrastructure opportunities.
- Task 4: Incorporate results into the *green infrastructure vision*.

[1] A 1978 agreement between the United States and Canada identified 43 Areas of Concern (AOCs) on the Great Lakes, including 14 in Michigan. AOCs are locations where beneficial uses are impaired, such as the loss of fish and wildlife habitat. (SEMCOG 2014)

SEMCOG intends to transfer the outcome-based strategic planning process established for the pilot subwatersheds to other SEMCOG area subwatersheds. Michigan will use the information from this project as a tool to evaluate progress for urban watershed restoration statewide.

1.2 Background

Successfully managing stormwater runoff is a significant component of the water system infrastructure challenges facing southeast Michigan. The demographic and economic changes that have taken place in the region over the last decade, combined with aging distribution, treatment, and other systems and the decline in revenue to maintain them, have led to an infrastructure crisis. Roads are deteriorating at an alarming rate, and the vast majority of water and sewer systems are more than 50 years old—well past their useful life.

Investment in infrastructure must be strategic and based on the region's economic reality. The southeast region of Michigan wants to install high-quality, functional infrastructure that is also fiscally sustainable and supports the region's economy and quality of life. Strategic investment includes having a defined target for stormwater management and green infrastructure implementation. The target will facilitate focused investments in high-priority areas to realize demonstrated improvements in local stream water quality.

1.2.1 Watershed Planning in Southeast Michigan

Watershed planning efforts in southeast Michigan can help set the stage for implementing green infrastructure. Aligning watershed planning with other infrastructure planning efforts will lead to more strategic implementation opportunities for defined targets.

Numerous watersheds and subwatersheds blanket the region and primarily drain to the Lake Huron—Lake Erie Corridor (Figure 1). The water quality of the rivers and lakes within the watersheds as well as of the Huron—Erie Corridor is directly connected to activities on the land.

Watershed management plans developed over the last decade—which consider all uses, pollutant sources, and impacts within a drainage area—serve as guides for communities, counties, and watershed groups to protect and improve water quality and related natural resources. More than 150 watershed management plans exist at the local level across the state, many funded through Michigan Department of Environmental Quality (MDEQ) nonpoint source grant opportunities (see *http://www.michigan.gov/deq/0,4561,7-135-3313_3682_3714---,00.html*).

The three largest watersheds in southeast Michigan that are located almost entirely within the region are the Clinton, Huron, and Rouge watersheds (Figure 1). Within those watersheds are subwatersheds with active stakeholder groups working towards enhancing the quality of local water resources. Elements of the subwatershed management plans in the Clinton, Huron, and Rouge watersheds include goals, objectives, and actions to address water quality and water quantity challenges in addition to identifying protection and restoration opportunities. The basis of those planning efforts is the underlying theme for defining runoff reduction targets.

Both land use and land cover play significant roles in directly impacting the quality of rivers and streams in local watersheds. Historic landscapes in southeast Michigan serve multiple purposes that provide various functions and values benefiting water resources. Wetlands, woodlands, grasslands, prairies, and riparian corridors all play integral parts in the overall water cycle. Those landscapes also filter and reduce stormwater runoff entering local streams. As development has progressed across the region, the expanse of urban area and associated impervious cover has increased, while the area of the historic landscapes has decreased.

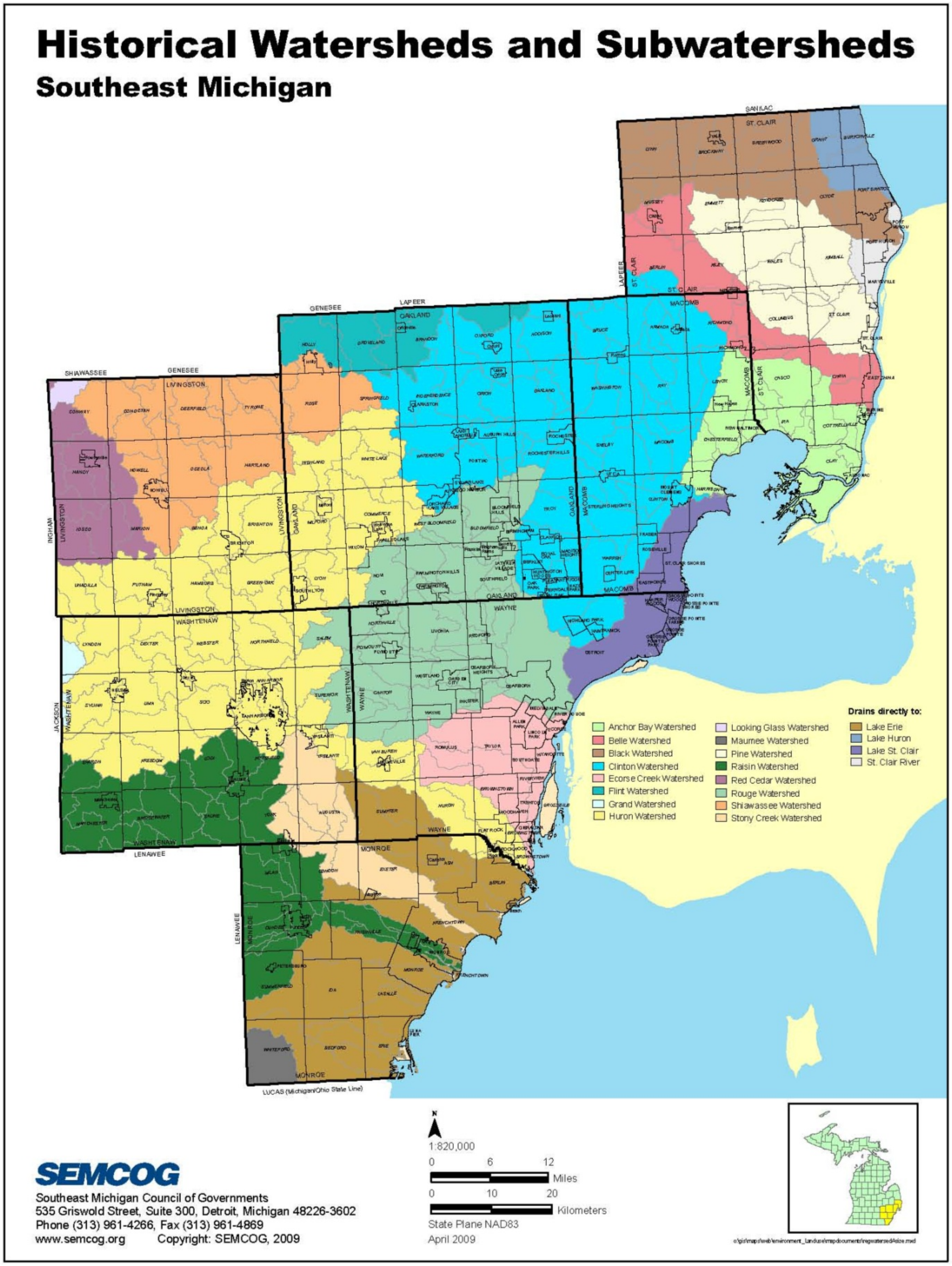


Figure 1. Southeast Michigan watersheds and subwatersheds.

1.2.2 Green Infrastructure Vision for Southeast Michigan

In southeast Michigan, green infrastructure consists of two broad categories: the natural, undisturbed environment—wetlands, woodlands, trees, prairies, lakes, rivers, and streams—and constructed, or *built*, environment—rain gardens, bioswales, community gardens, and agricultural lands.

SEMCOG (2014) recently completed the *Green Infrastructure Vision for Southeast Michigan*, which, for the first time:

- Benchmarks green infrastructure in southeast Michigan,
- Envisions where communities want to go, and
- Contains regional policies on how to get there.

Reducing the volume of stormwater runoff is a common priority in southeast Michigan watersheds. Within both the natural and built categories of green infrastructure, the connection to water quality is significant. Wetlands, woodlands, and prairies naturally capture, filter, and infiltrate rainwater, while constructed techniques aim to replicate natural systems. These systems work together to improve water quality in local lakes, streams, and rivers in southeast Michigan and, by extension, in the Great Lakes. Results from stakeholder visioning sessions and public surveys supported the connection between green infrastructure and the region's water by identifying "protecting water quality" as the top-rated green infrastructure benefit.

Watersheds in southeast Michigan contain more than 10 percent impervious cover, which presents many opportunities to implement green infrastructure in the region. More than 25,000 acres of open space designated for institutional land uses could also be evaluated for the potential for managed turf areas to be converted to native plant grow zones and trees. Table 1 summarizes by land use type the areas of opportunity that should be considered for constructing green infrastructure. The following section provides detailed information on opportunities in the region by watershed and subwatershed. Figure 2 depicts long-term green infrastructure implementation opportunities across the region.

Table 1. Land use types in southeast Michigan watersheds with potential for implementing green infrastructure

Institutional Land Use *(publicly owned acres)*			Roadways *(publicly owned acres)*		Privately Owned Parking Lots *(acres)*	Riparian Corridor *(acres)*	
Impervious Surfaces: Buildings	Impervious Surfaces: Parking Lots	Open Space (turf & trees)	Impervious Surfaces: Pavement	Open Space (turf & trees)		Tree Canopy Existing	Open Space
4,354	9,553	25,598	39,935	17,393	51,192	11,167	3,815

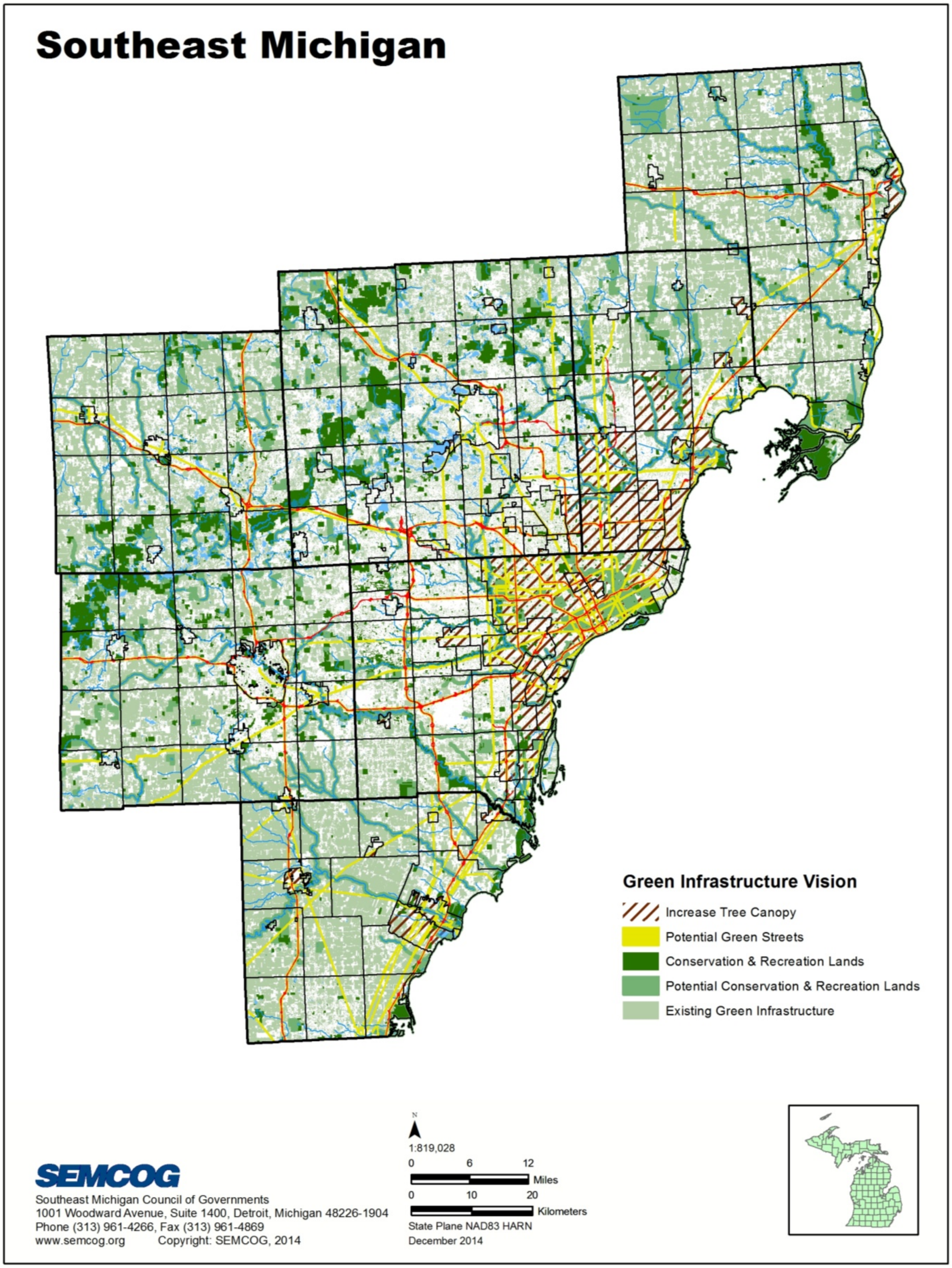


Figure 2. Green infrastructure vision in southeast Michigan.

1.3 Outcome-based Strategic Planning

The outcome-based strategic planning framework used by SEMCOG aligns watershed needs with available green infrastructure opportunities to enable project implementation to result in measurable improvements in mitigating the adverse effects of stormwater (Figure 3). Task 1 (Establish baseline flow-duration curves for selected subdrainage areas) and task 2 (Establish stormwater runoff volume targets) involve an assessment of *receiving water* conditions, which determines green infrastructure *project needs*. The first part of task 3 (Assess green infrastructure opportunities) involves an analysis of the *drainage system* (e.g., land use/land cover, natural channels, storm sewer network) to identify green infrastructure *opportunities*. The second part of task 3 uses a screening analysis of *proposed projects* in "areas of opportunity" to conduct a *feasibility/effectiveness assessment* of stormwater runoff reduction targets.

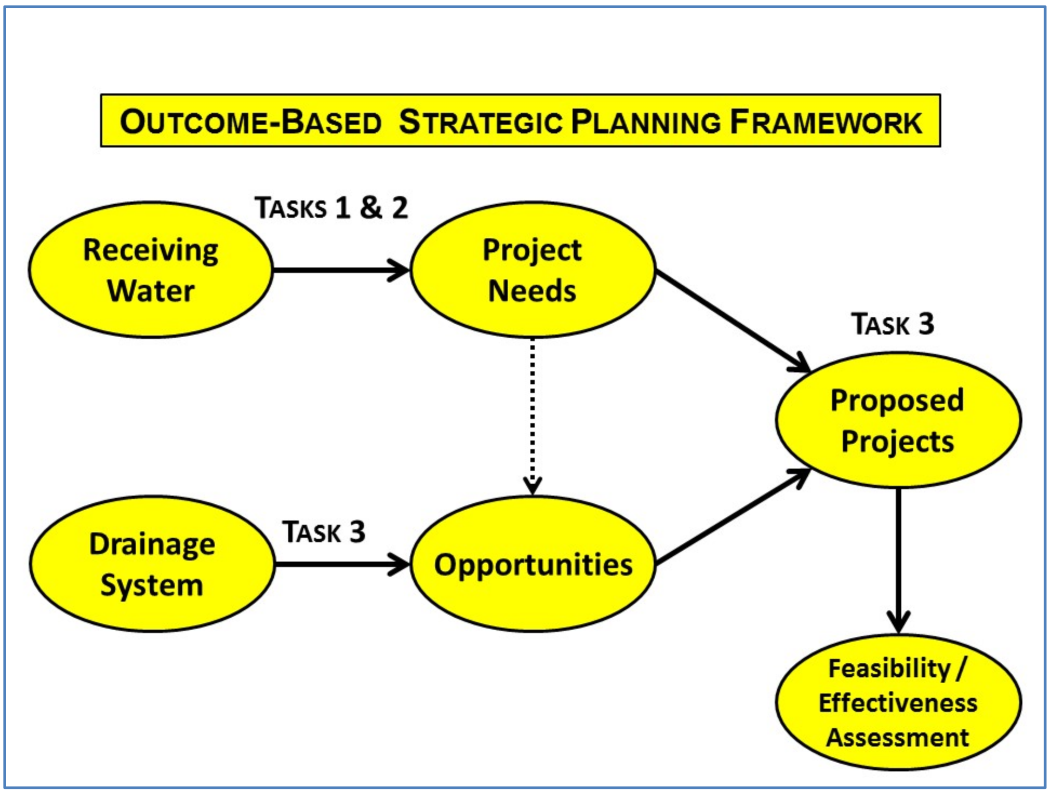


Figure 3. Outcome-based strategic planning framework.

2 Technical Approach

Baseline flow-duration curves were established for selected subdrainage areas. Subwatersheds across the seven-county region were identified by hydrologic unit code (i.e., a 12-digit hydrologic unit code, or HUC). Those with U.S. Geological Survey (USGS) gage data with a sufficient number of flow records to conduct a hydrologic analysis and develop meaningful duration curves were selected. Based on the results of this analysis, five subwatersheds were considered for pilot testing. Working with SEMCOG and the Southeast Michigan Partners for Clean Water, final selection was narrowed to three project pilot subwatersheds.

Methods to connect hydrologic and water quality concerns to green infrastructure were examined. Hydrologic targets were developed to guide green infrastructure planning in the region. Development of the targets was important because hydrology affects stream stability, habitat, aquatic biology, and the delivery of pollutant loads.

2.1 Hydrologic Analysis

Several indicators can be used to evaluate historic streamflow patterns in southeast Michigan, including key points on the flow-duration curve such as the flow or volume associated with the 1-day recurrence interval (i.e., 1 day divided by 365 days, or the 0.274 percentile). This is a common indicator used to calculate TMDLs based on the hydrology of a water body. This limit represents a daily maximum value and reflects conditions in which the most erosion and sediment transport occur, resulting in the highest pollutant concentrations and loading rates.

The Richards–Baker Flashiness Index (R-B Index) is an indicator of how frequently and rapidly short-term changes in stream flow occur. Increased *flashiness* often reflects unstable watersheds and degraded habitat that adversely affects aquatic life. Stable flow regimes support the establishment of healthy macroinvertebrate populations (thus influencing bioassessment scores). *Flashy* flows—caused by increased peak flow rates and volumes from urban runoff—disrupt aquatic community structure and increase the delivery and transport of pollutant loads that exacerbate downstream water quality problems. The R-B Index typically increases as watershed impervious cover becomes greater. Table 2 presents a brief summary of these indicators.

Table 2. Description of hydrology-based indicators

Metric	Name	Description
2-year Peak	2-year Peak Flow	*Instantaneous maximum peak flow associated with a 2-year recurrence interval*
Annual Average	Annual Average Runoff Volume	*Annual average runoff volume expressed as either cubic feet per second per square mile or as inches of runoff*
$FDC_{1\text{-day}}$	Flow-Duration Curve	*Average daily maximum flow associated with 1-day recurrence interval from flow-duration curve*
TQ_{mean}	Annual Average Flow Exceedance	*Percentage of time that daily average flows exceed the annual average flow*
R-B Index	Richards-Baker Flashiness Index	*Indicator of frequency and rapidity of short-term changes in stream flow*

Forty USGS gage sites with a sufficient number of flow records to develop meaningful duration curves were identified within the seven-county SEMCOG area (Figure 4). Data were downloaded from the USGS National Water Information System to conduct the hydrologic analysis for this project using Microsoft Excel spreadsheets for each gaged location.

A study by the University of Michigan established hydrologic targets for southeast Michigan and determined that watershed size, characteristic land use, and underlying geologic features produce a significant hydrologic response (Wiley et al. 1998). A report by the MDEQ examines gaged streams and rivers across Michigan, and provides an opportunity to incorporate flashiness into the stormwater assessment process (Fongers et al. 2007). That study also included a summary of R-B Index quartile rankings based on the size of the drainage area for Michigan watersheds.

Fongers et al. (2007) determined that smaller watersheds tend to naturally have flashier flows. Flashiness tends to decrease as drainage area increases as a result of the varied timing of tributary flows. Such varied timing helps attenuate main channel peak flows. Factors such as soil, land use, and the influence of ground water become more varied as watershed size increases.

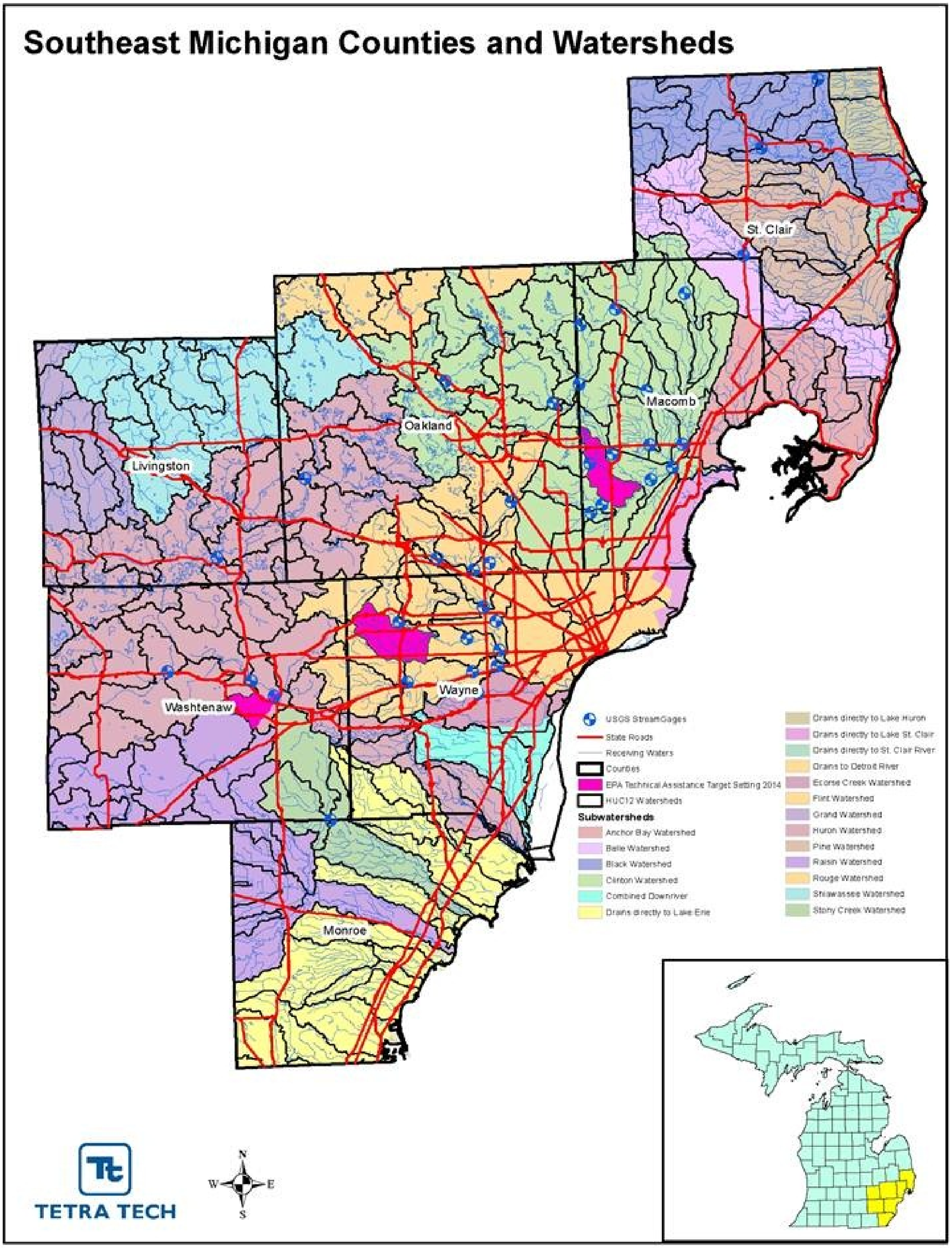


Figure 4. USGS stream gage sites examined.

Recognizing the effect of watershed size, Table 3 summarizes results of the hydrologic analysis by drainage area class (the same size classes used by Fongers et al. [2007]). Values for each parameter reflect the range (i.e., minimum to maximum). The effect of watershed size is most noticeable for the 2-year peak, the 1-day flow-duration curve recurrence interval ($FDC_{1\text{-day}}$), and the R-B Index. A comparative analysis of flow-duration curves for several gages is shown in Figure 5; the graph also summarizes the distribution using a box-and-whisker format of duration curve statistics at the midpoint of each zone (high, moist, mid-range, dry, low) for all 40 gages examined across the seven-county SEMCOG region.

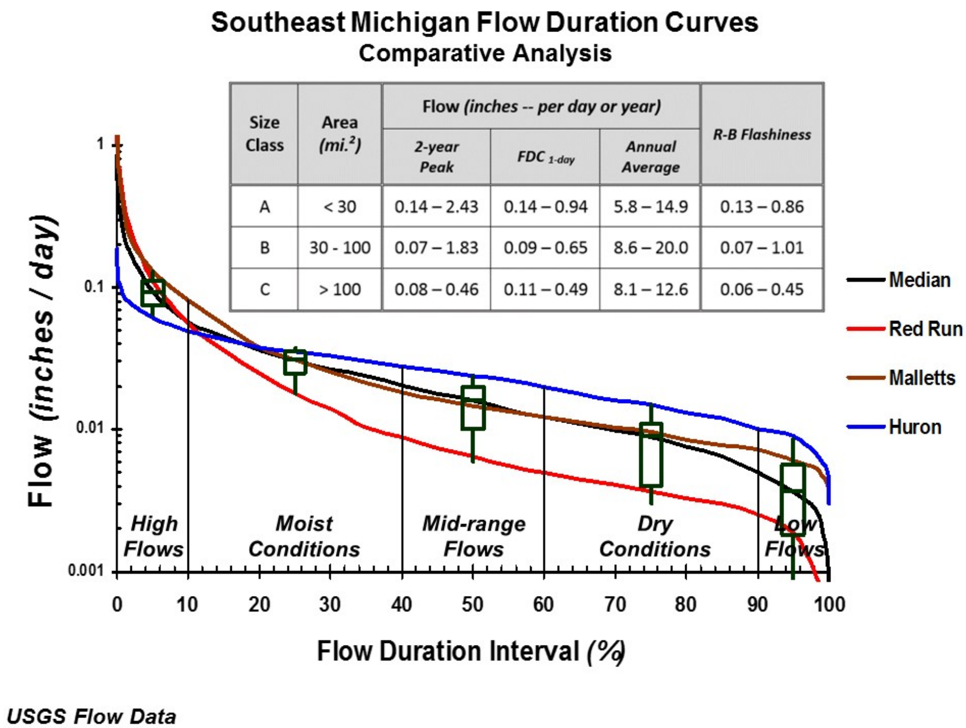
One exception to the general pattern for each indicator is the maximum R-B Index value for group B (1.01). This maximum occurred at the Red Run near Warren gage, which appears to be an outlier for this size class. The land use for this particular site is highly impervious.

Relationships between different parameters can be examined to determine if one or more indicators is particularly well suited for target development that would address multiple concerns. An example relationship using the R-B Index and 2-year peak is shown in Figure 6, using data from the 40 gages included in the hydrologic assessment. In this case, an R-B Index target also could address peak flow concerns. This information is helpful because the period of record needed to calculate R-B Index values is significantly less than the amount of data required to determine the 2-year peak flow rate.

Table 3. Hydrology-based indicator summary by watershed size

Size Class	**Drainage Area *(mi^2)***	**Flow *(inches)***				**Metric Comparison**	
		2-year Peak	***Annual Average***	***$FDC_{1\text{-day}}$***	***$FDC_{5\%}$***	***TQ_{mean}***	***R-B Flashiness***
A	< 30	0.14–2.43	5.8–14.9	0.14–0.94	0.06–0.13	*16–37%*	*0.13–0.86*
B	30–100	0.07–1.83	8.6–20.0	0.09–0.65	0.06–0.14	*19–44%*	*0.07–1.01*
C	> 100	0.08–0.46	8.1–12.6	0.11–0.49	0.06–0.11	*20–42%*	*0.06–0.45*

Note: mi^2 = square miles.



Size Class	Area (mi.^{2})	Flow (inches -- per day or year)			R-B Flashiness
		2-year Peak	FDC $_{1\text{-}day}$	Annual Average	
A	< 30	0.14 – 2.43	0.14 – 0.94	5.8 – 14.9	0.13 – 0.86
B	30 - 100	0.07 – 1.83	0.09 – 0.65	8.6 – 20.0	0.07 – 1.01
C	> 100	0.08 – 0.46	0.11 – 0.49	8.1 – 12.6	0.06 – 0.45

Figure 5. Comparative analysis of flow-duration curves for several southeast Michigan sites.

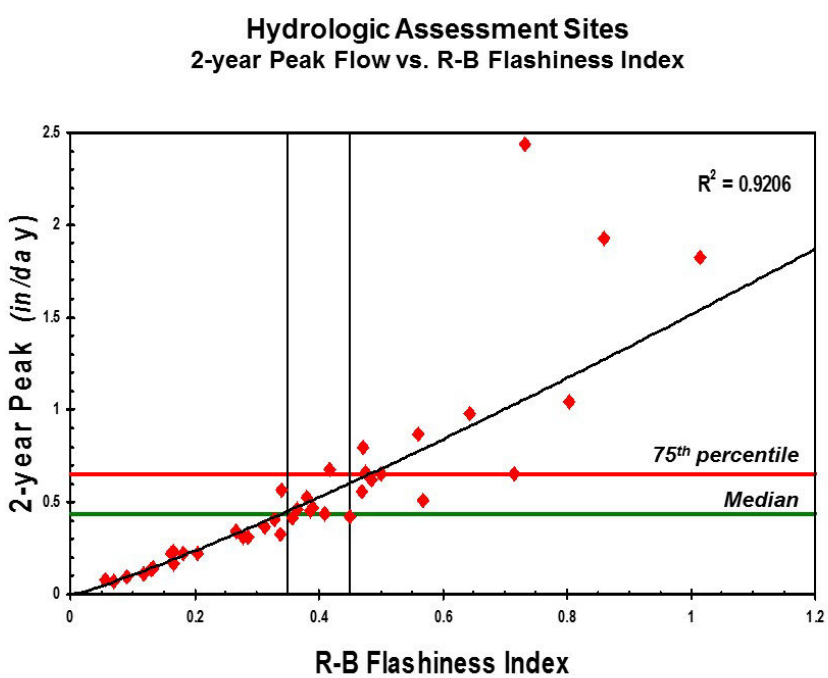


Figure 6. Relationship between R-B Index and 2-year peak flow.

2.2 Pilot Subwatersheds

The project's use of pilot subwatersheds establishes a process for identifying, prioritizing, and implementing green infrastructure projects; a process that is transferable across the SEMCOG area. The approach uses multiscale analysis, specifically by scaling down to progressively smaller geographic areas based on priority concerns and implementation opportunities (Figure 7). Scale of analysis is an extremely important aspect of stormwater management. Any size land area can be selected for assessment and strategic planning.

At the broadest scale (e.g., region or county), analyses of stormwater problems provide the context for policy formulation, regulations, codes, and ordinances. At the finest scale (e.g., specific streets or parcels), technical analyses provide the basis for project implementation and can be used to evaluate site-specific impacts. Midscale analyses (e.g., at the subwatershed or catchment level) provide the context for management through a description and understanding of typical stormwater problems as well as examining the capabilities that exist to address those problems.

The multiscale analysis evaluates geographic information system (GIS) data to identify high-priority catchments for best management practice (BMP) implementation. *High-priority catchments* are critical areas that have a disproportionate effect on hydrology and water quality. This approach is consistent with a focus advocated by EPA and a number of states—one that recognizes that BMPs placed in critical locations can help treat small areas that produce disproportionate amounts of excess stormwater runoff and pollution. The multiscale analysis framework provides a solid foundation for identifying priority catchments and assessing green infrastructure opportunities.

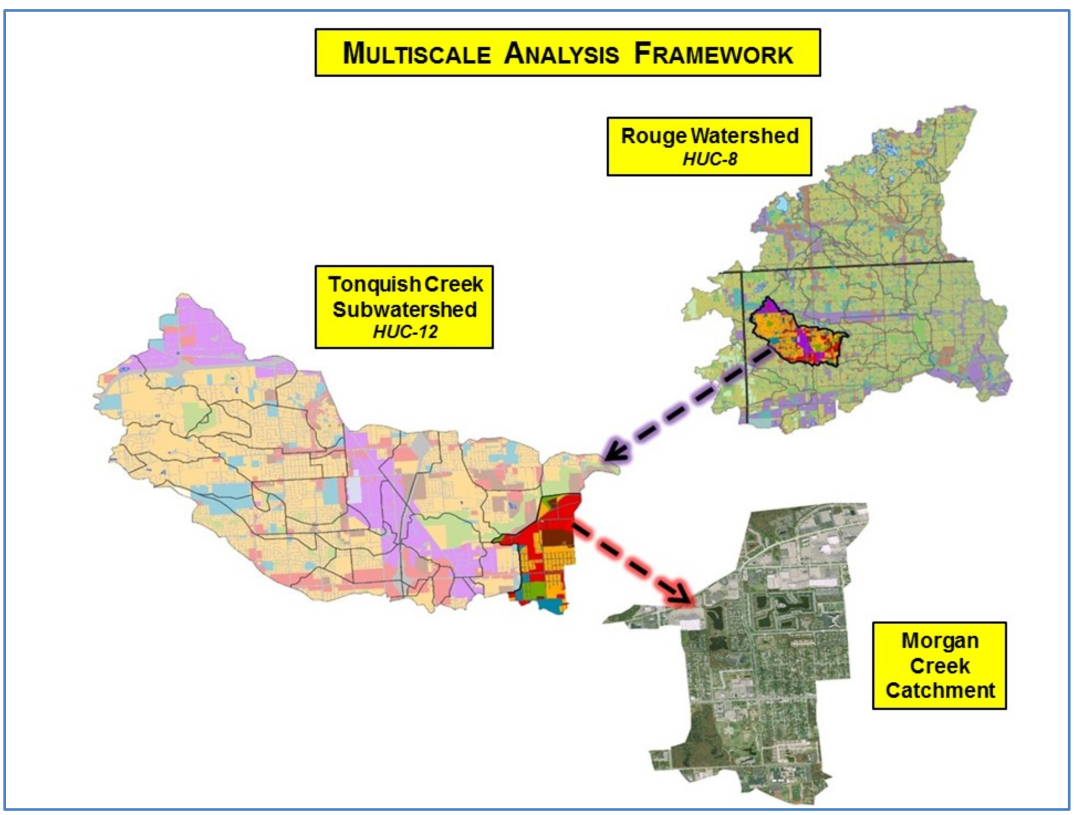


Figure 7. Multiscale analysis framework.

The following five watersheds, representing a range of land use and land cover conditions within the region, were identified for consideration as project pilots:

- Malletts Creek (Huron watershed; Washtenaw County)
- Plumbrook Drain (Clinton watershed; Macomb County and Oakland County)
- Tonquish Creek (Rouge watershed; Wayne County)
- Gloede Drain (Clinton watershed; Macomb County)
- Bell Branch (Rouge watershed; Wayne County and Oakland County)

Flow data were available in three of the watersheds (Table 4): Malletts Creek (2009–14 at site 04174514, 1999–present at site 04174518), Plumbrook (1968–present), and Gloede Drain (1959–64).

Table 4. Hydrologic statistics for potential pilot watersheds

Location	Area (mi^2)	Gage ID	Flow *(inches)*			Metric Comparison	
			2-year Peak	*Annual Average*	*FDC $_{1\text{-}day}$*	*T_{Qmean}*	*R-B Flashiness*
Malletts Creek at Ann Arbor *(below Mary Beth Doyle Park)*	8.48	04174514	n.a.	14.6	0.820	*23.7%*	*0.700*
Malletts Creek at Ann Arbor *(above mouth)*	10.9	04174518	2.447	12.9	0.567	*21.7%*	*0.724*
Plumbrook Drain	16.5	04163400	0.868	12.3	0.554	*23.8%*	*0.560*
Gloede Drain	16.0	04165200	0.662	6.3	0.302	*24.6%*	*0.475*

Note: mi^2 = square miles.

Discussions between SEMCOG staff and Southeast Michigan Green Infrastructure Partners led to selecting Malletts Creek, Plumbrook Drain, and Tonquish Creek as the project pilot subwatersheds (Figure 8). Each pilot subwatershed has land use/land cover characteristics representative of green infrastructure planning challenges and opportunities for southeast Michigan. Although Tonquish Creek does not have gaged discharge data, it is indicative of other subwatershed situations where green infrastructure planning is needed in spite of the absence of flow information.

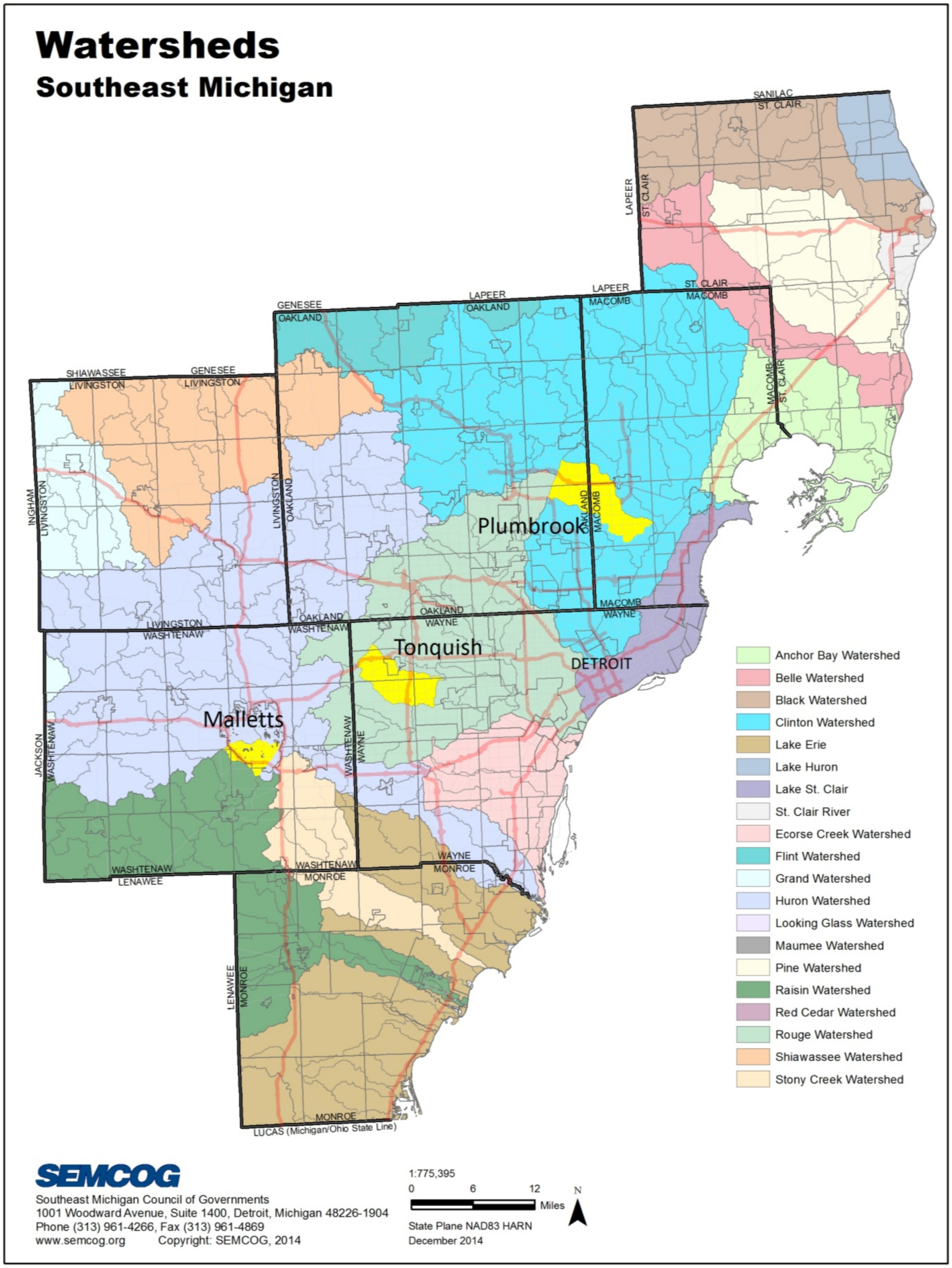


Figure 8. Final pilot subwatersheds selected.

2.3 Target Development

The concept of using hydrologic indicators associated with biological resources in southeast Michigan was initially precipitated by University of Michigan work in developing *Ecological Targets for Rehabilitation of the Rouge River* (Wiley et al. 1998). Recently, MDEQ examined the use of hydrologic indicators connected to bioassessment scores as part of a stormwater TMDL project. That aspect of the project involves reviewing both approaches and considers other options to establish runoff targets for the pilot subwatersheds.

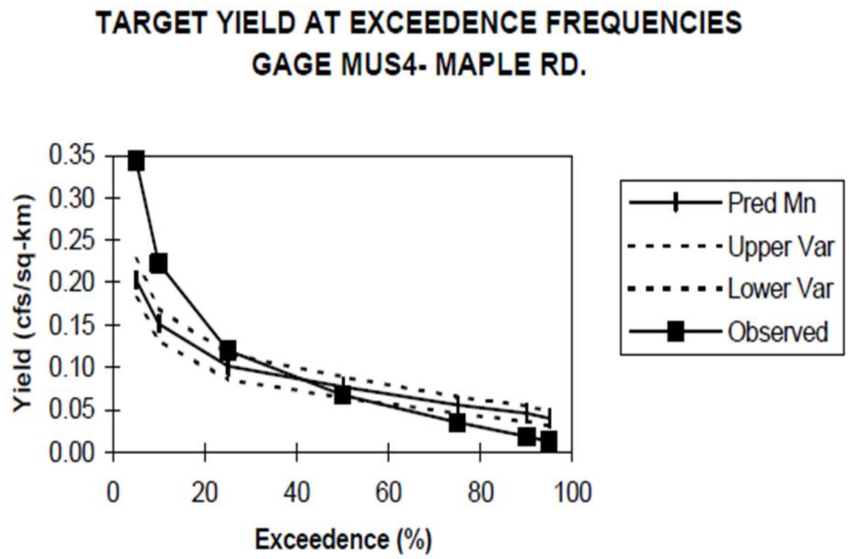
2.3.1 Previous Work in Southeast Michigan

The *Ecological Targets for Rehabilitation of the Rouge River* study (Wiley et al. 1998) provides an example framework for identifying approaches, indicators, and targets that reflect desired biological conditions as determined through Michigan's bioassessment protocol, the Procedure 51 Biological Community Assessment Protocol (P51) (MDEQ 1997). That effort focused on fisheries management and identified desirable discharge regimes using a duration curve framework. Ecologically based, target flow-duration curves were developed by summarizing pooled discharge from subsets of Michigan River Inventory (MRI) sites where selected target fishes were known to be abundant.

Discharge data in the MRI database included both gage data, where available, and synthetic exceedance discharges modeled from landscape variables for ungaged sites. Figure 9 provides an example target duration curve from the report. The flow-based targets were developed to protect fish communities and are expressed at intervals on the duration curve that range from the 5th percentile to the 95th percentile. In addition to annual average targets at each interval, the document defined upper and lower bounds. Table 5 summarizes those targets for small streams. Recognizing that geology exerts a major influence on local hydrology, targets were identified for very low base flow streams, low base flow streams, and moderate base flow streams (Wiley et al. 1998).

The Wiley study describes the relationship between flow exceedance frequencies and fish communities. The targets presented in Table 5 indicate that identifying a specific value is no simple task; physical factors at each site must be considered (notably base geology). Information from this study demonstrates a relationship between *exceedance flows* and fish communities. However, the highest flow condition target identified corresponds to a duration curve interval at the 5th percentile (Wiley et al. 1998).

Work in other states suggests that green infrastructure practices are most effective in addressing water quality and drainage problems between the 1st and the 10th to 20th percentiles on the flow-duration curve. For instance, Washington State uses 50 percent of the 2-year peak as the upper duration curve interval specified in the MS4 permit as a performance standard (i.e., approximately the 1st percentile for duration curves developed using daily average flow data). Other options for estimating runoff volume reduction targets are explored below.



from ""Ecological Targets for Rehabilitation of the Rouge River"
(Wiley et al, 1998)

Figure 9. Example Rouge basin draft target water yield.

Table 5. River Rouge ecological targets for fish protection based on duration curve framework

Stream Type	Flow-Duration Curve Target (inches per day)							Target Description
	High		Moist	Mid	Dry	Low		
	(5th %)	(10th %)	(25th %)	(50th %)	(75th %)	(90th %)	(95th %)	
Small stream *(Very low base flow)*	0.117	0.064	0.027	0.015	0.010	0.006	0.006	*Upper Range*
	0.104	0.059	0.022	0.010	0.005	0.003	0.003	*Average*
	0.092	0.054	0.017	0.004	0.000	0.000	0.000	*Lower Range*
Small stream *(Low base flow)*	0.073	0.046	0.026	0.015	0.011	0.008	0.006	*Upper Range*
	0.070	0.044	0.024	0.014	0.009	0.007	0.005	*Average*
	0.066	0.042	0.022	0.013	0.008	0.006	0.005	*Lower Range*
Small stream *(Moderate base flow)*	0.091	0.062	0.034	0.021	0.014	0.012	0.011	*Upper Range*
	0.086	0.060	0.031	0.018	0.012	0.010	0.008	*Average*
	0.081	0.057	0.027	0.014	0.009	0.007	0.005	*Lower Range*

2.3.2 Relationship to Macroinvertebrates

Hydrology can be a major factor affecting aquatic communities, thus influencing bioassessment scores (Figure 10). Stable flow regimes support the establishment of healthy macroinvertebrate populations. Flashy flows (e.g., caused by urban runoff) disrupt aquatic community structure and increase the transport of total suspended solids loads that cause downstream siltation problems. Flashiness is an indicator of the frequency and rapidity of short-term changes in stream flow, particularly during runoff events (Baker et al. 2004). Increased flashiness is typically associated with both unstable watersheds and degraded habitat, which can adversely affect aquatic life.

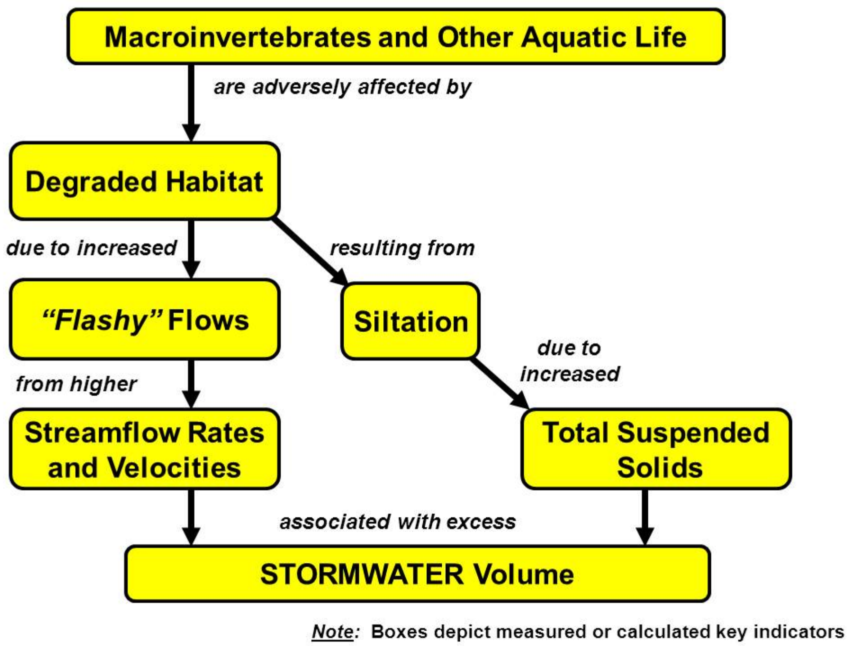


Figure 10. Relationship between key indicators in establishing stormwater volume targets.

A list was assembled of sites with a watershed area of less than 30 square miles based on the Fongers study (Fongers et al. 2007). The sites examined include a number of streams located in southeast Michigan. As an initial screening analysis, stream flashiness for the sites was compared to P51 bioassessment scores reported by MDEQ. In addition, the R-B Index was examined relative to two P51 component metrics: percent caddisflies and percent dominant taxa.

The purpose of this screening analysis was to determine, through an examination of general patterns, if there is (1) a relationship between stream flashiness and bioassessment metrics that will lead to improvement in MDEQ's P51 scores; or (2) a threshold flashiness value above which MDEQ's bioassessment metrics show consistently poor communities.

The results of the analysis are shown in Figure 11 through Figure 13. Vertical lines drawn from the x-axis represent the median R-B Index value for all sites in the Fongers study that are less than 30 square miles (Fongers et al. 2007). Vertical lines also are drawn at the 25th and 75th percentiles. As indicated, some general patterns start to appear at the 75th percentile (i.e., above an R-B Index value of 0.5).

One useful statistical measure is the coefficient of determination, or r^2. For purposes of this analysis, r^2 provides a measure of how useful the R-B Index might be in estimating the biological response for each metric considered (e.g., P51 score, percent mayflies, percent caddisflies, percent dominant taxa). In each case, the r^2 value was less than 0.3, indicating that any relationship between the R-B Index and biological response is not linear. The relationship between stream flashiness and biological response, however, could be a step function.

A step function relationship implies that there is a threshold value above which a bioassessment metric shows consistently poor communities. While that could be the case (particularly for R-B Index values above 0.5), the sample population size is too small to identify a specific threshold value. In addition, other site-specific stressors could be influencing the results of this preliminary screening analysis.

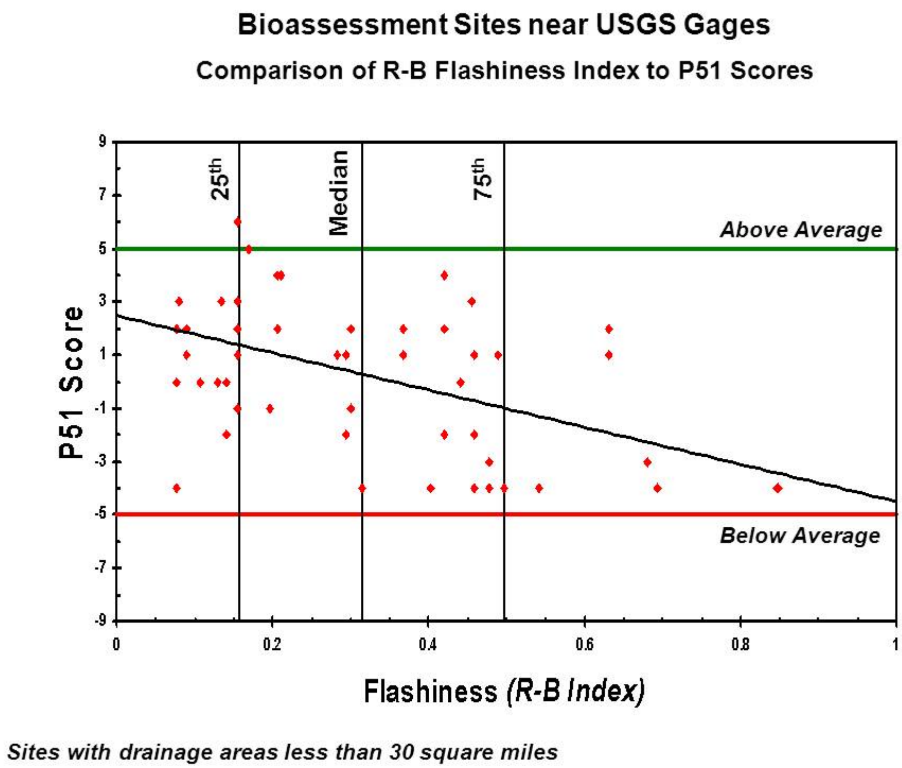


Figure 11. Comparison of R-B Index and P51 bioassessment scores.

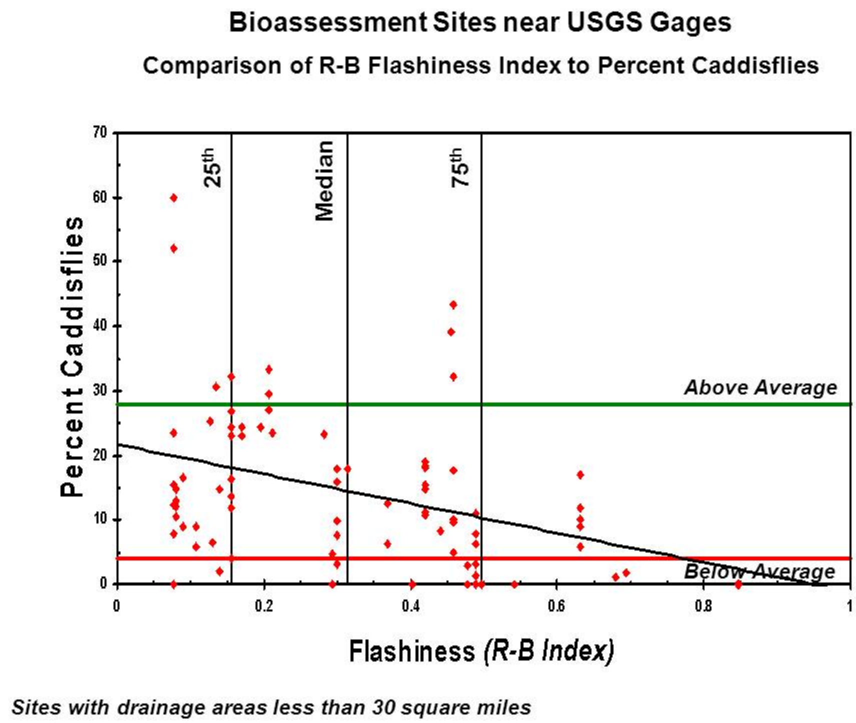


Figure 12. Comparison of R-B Index and percent caddisflies scores.

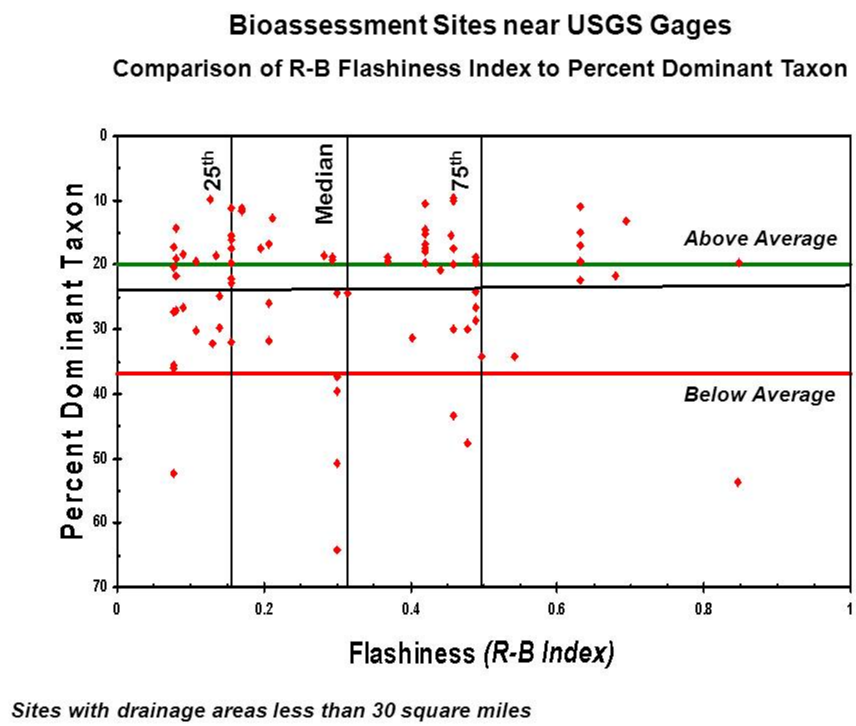


Figure 13. Comparison of R-B Index and dominant taxa scores.

Local organizations in the SEMCOG area are engaged in volunteer monitoring efforts to foster stewardship and encourage action. These organizations include the Clinton River Watershed Council, the Friends of the Rouge, and the Huron River Watershed Council. Several locations monitored by the groups coincide with streams where flow gaging data exists. Collectively, that information can be used to further examine the relationship between macroinvertebrates and stream flashiness (Figure 14). Patterns using the volunteer data are similar to those observed based on MDEQ bioassessment surveys; the condition of the macroinvertebrate community decreases with increased stream flashiness.

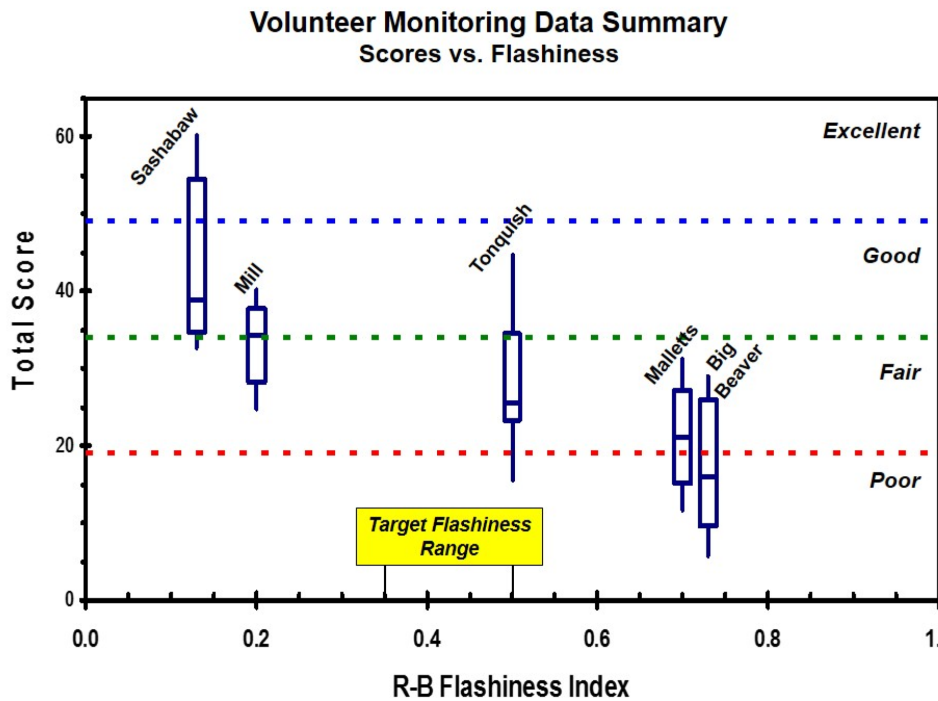


Figure 14. Comparison of R-B Index to several southeast Michigan volunteer monitoring sites.

2.3.3 Impervious Cover Analysis

In benchmarking the amount of green infrastructure needed in southeast Michigan, SEMCOG evaluated land cover information from 2010 aerial imagery and land use data. A portion of that analysis included a compilation of total impervious cover, estimated to be over 16,800 acres across the three pilot subwatersheds. One way to assess the benefits derived from green infrastructure is by looking at potential volumes of stormwater produced. For example, annual average precipitation at the Detroit Metropolitan Airport is just over 30 inches. Volume estimates used by the Detroit Water and Sewerage Department in developing their *Green Infrastructure Plan for the Upper Rouge Tunnel Area* indicate that this translates to about 680,000 gallons of stormwater annually per acre of impervious cover (Tetra Tech 2014).

Stormwater volume reduction targets for this project were identified based on the relationship between aquatic biology and hydrology. An assessment of macroinvertebrate data and stream flashiness shows a general range above which bioassessment scores reflect poor conditions for aquatic life. This range occurs somewhere between an R-B Index value of 0.35 and 0.50, which is used as the target for evaluating green infrastructure opportunities in the pilot subwatersheds.

The R-B Index was calculated using daily average flow values (as opposed to stormwater volume). A rainfall–runoff model, which generates daily average flow estimates, was used to examine green infrastructure practices relative to the effect on R-B Index values.

Models are particularly useful tools in evaluating the effect that different land uses could have on any particular receiving water. A basic watershed model allows consideration of unique features that affect local hydrology; both natural factors (e.g., soils, topography, vegetation) and alterations such as increased impervious cover. Principles behind the Loading Simulation Program C++ (LSPC) can be coupled with precipitation information to examine the effect of land use on runoff. Rainfall–runoff analysis in LSPC is based on algorithms from the Hydrologic Simulation Program FORTRAN (HSPF), a model widely used to support watershed analysis.

One major advantage of the modeling approach is that it provides a platform for consistent comparisons showing the relative effect of significant factors on key hydrologic indicators (e.g., increase in impervious cover associated with land use changes, infiltration rates dependent on soil types). An important focus of stormwater management is the effect of impervious cover on flow patterns. LSPC, for example, enables an analysis of the *relative* effect of changing impervious cover on hydrology when all other variables are held constant. For example, Figure 15 shows the relationship between the 1-day flow ($FDC_{1\text{-}day}$ in Table 2) and impervious cover using the LSPC model information. As indicated, increased impervious cover results in a higher 1-day flow.

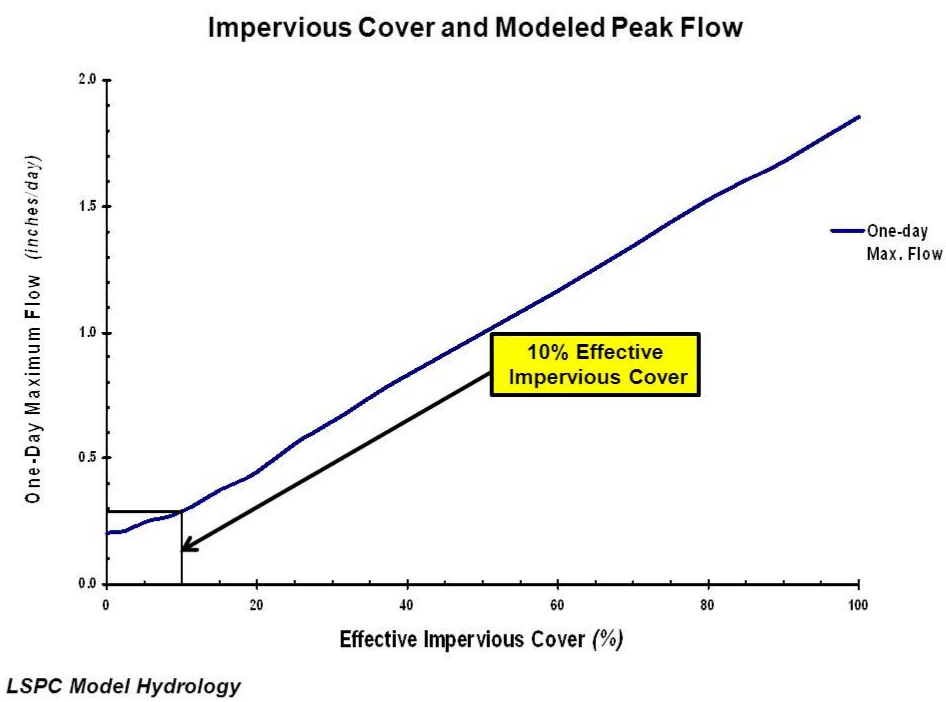


Figure 15. Relative effect of impervious cover on 1-day flow-duration interval.

One point worth noting is the increase in the slope of the line in Figure 15, which occurs at around 10-percent impervious cover. A number of studies have shown that streams can show signs of degradation and are considered stressed when the impervious cover exceeds 10–15 percent. A modeling analysis allows for a closer examination of the effect that increased effective impervious cover exerts on other flow-related parameters.

Table 6 summarizes modeled changes in several key hydrologic indicators as impervious cover increases. For reference purposes only, values associated with an effective impervious cover level of 10 percent are highlighted. Because of the effect of flashiness on aquatic organisms, the relationship between impervious cover and the R-B Index is shown in Figure 16. As indicated in Table 6 and Figure 16, the greatest increase in stream flashiness occurs at impervious cover levels between 10 and 15 percent.

Table 6. Modeled relative effect of impervious cover on key hydrologic indicators

Effective Impervious Cover *(%)*	**Hydrologic Indicator**[a]		
	FDC $_{1\text{-day}}$ *(in/day)*	**R-B Index**	**Average Annual Runoff Volume** *(inches)*
0	0.184	0.135	12.4
2.5	0.189	0.178	12.8
5	0.215	0.236	13.1
10	**0.266**	**0.353**	**13.7**
15	0.331	0.462	14.3
20	0.419	0.563	15.0
25	0.497	0.656	15.6
30	0.577	0.743	16.2
40	0.719	0.897	17.5
50	0.871	1.030	18.8
60	1.026	1.147	20.0
70	1.163	1.250	21.3
80	1.313	1.342	22.5
90	1.476	1.424	23.8
100	1.639	1.497	25.1

Note: a Hydrologic indicators are defined in Table 2.

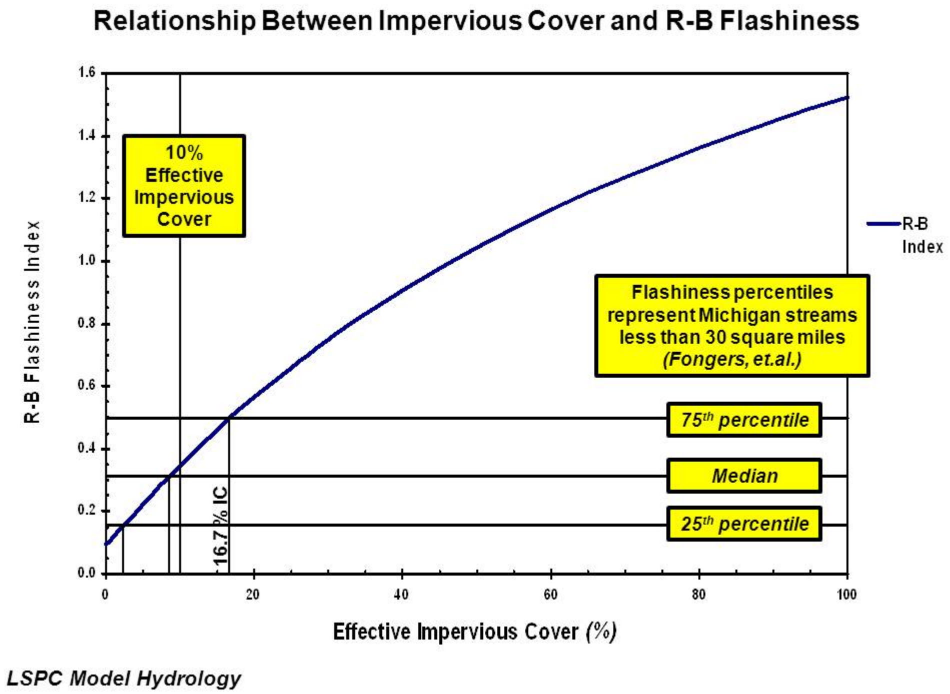


Figure 16. Relative effect of impervious cover on R-B Index.

2.3.4 Stormwater Volume Reduction Targets

The *Low Impact Development Manual for Michigan* describes a methodology for estimating the level of volume control needed to manage stormwater (SEMCOG 2008). The approach emphasizes BMPs designed to mimic presettlement hydrology—as defined by ground water recharge, stream channel stability, and flooding. It is an approach routinely used in other stormwater management guidance documents. This project extended the target development process to also consider aquatic biology.

The R-B Index can be a good indicator of the relationship between hydrology and its effect on macroinvertebrates (Figure 10 through Figure 14). In addition, the R-B Index is related to effective impervious cover (Figure 16), the reduction of which is a major focus of green infrastructure management areas. Unlike volume, however, stream flashiness is not particularly well suited for evaluating specific stormwater runoff mitigation practices, which are typically implemented at smaller scales (i.e., site or catchment level as opposed to the watershed scale).

MDEQ has suggested the 90-percent non-exceedance method for managing runoff from multiple sites or for watershedwide design (Fongers 2006). The 90-percent non-exceedance event is the storm in which 90 percent of the runoff-producing precipitation events are equal to or less than a specified value. The 90-percent method generally results in green infrastructure management strategies that will retain approximately a 1-inch, 24-hour storm volume and maintain release rates at predevelopment levels. The primary objective of the 90-percent method is channel protection, which in turn affects stream habitat and aquatic biology.

The result of the 90-percent non-exceedance analysis using Detroit Metro Airport precipitation data is 0.98 inches of rainfall, as shown in Figure 17. A stormwater runoff reduction target can be derived using the retention volume that corresponds to the 90-percent non-exceedance storm. Retention means that water from rainfall at or below that level is held on-site; it can leave only through infiltration or evapotranspiration. From Figure 17, a green infrastructure practice sized to retain the 90-percent rainfall event (0.98 inches) will reduce the annual average runoff volume by 85 percent.

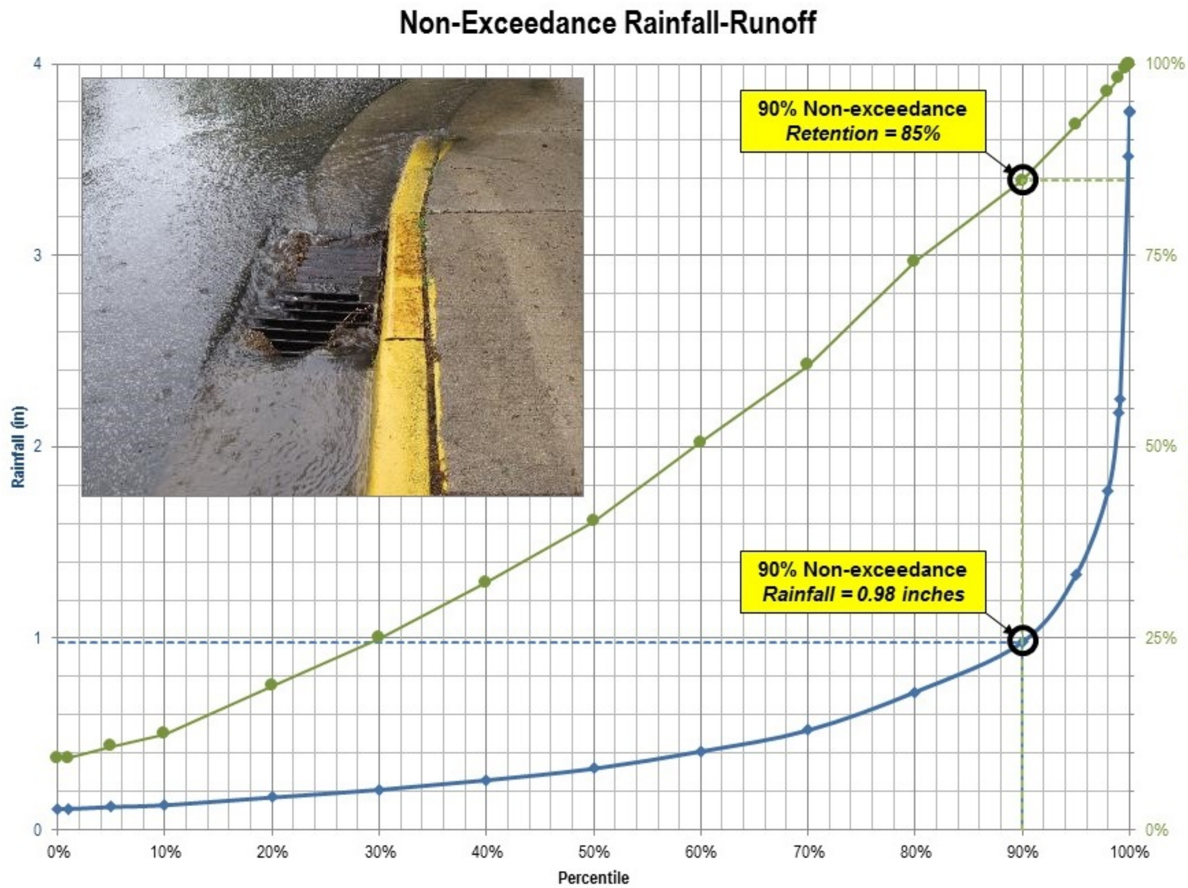


Figure 17. Non-exceedance rainfall-runoff—Detroit Metro airport.

The LSPC model analysis provides information that connects annual average runoff volumes to R-B Index values (see Table 6). Results from the analysis can be used to estimate R-B Index values that correspond to different annual average runoff reductions. In Table 6, the annual average runoff volume associated with no effective impervious cover (i.e., 12.4 inches) represents a baseline condition. The excess annual average runoff above the baseline condition is the volume that can be attributed to increased levels of impervious cover (i.e., the effective impervious area that needs to be managed for stormwater using green infrastructure). The difference between the annual average runoff resulting from 100-percent impervious cover (or 25.1 inches) and the baseline condition represents the total volume that could be reduced through green infrastructure practices (i.e., 25.1 minus 12.4, or 12.7 inches excess runoff volume).

The relationship between reductions in annual average runoff volume and R-B Index values is shown in Figure 18, which depicts how the relative infiltration benefit of pervious areas affects the R-B Index values for different reduction volumes. For example, catchments with low infiltration rates in pervious areas will require a higher level of volume reduction to achieve the same R-B Index value than those catchments with higher infiltration rates in pervious areas. That result illustrates the benefit of using multiple green infrastructure management strategies such as implementing grow zones or increased tree canopy to complement structural practices.

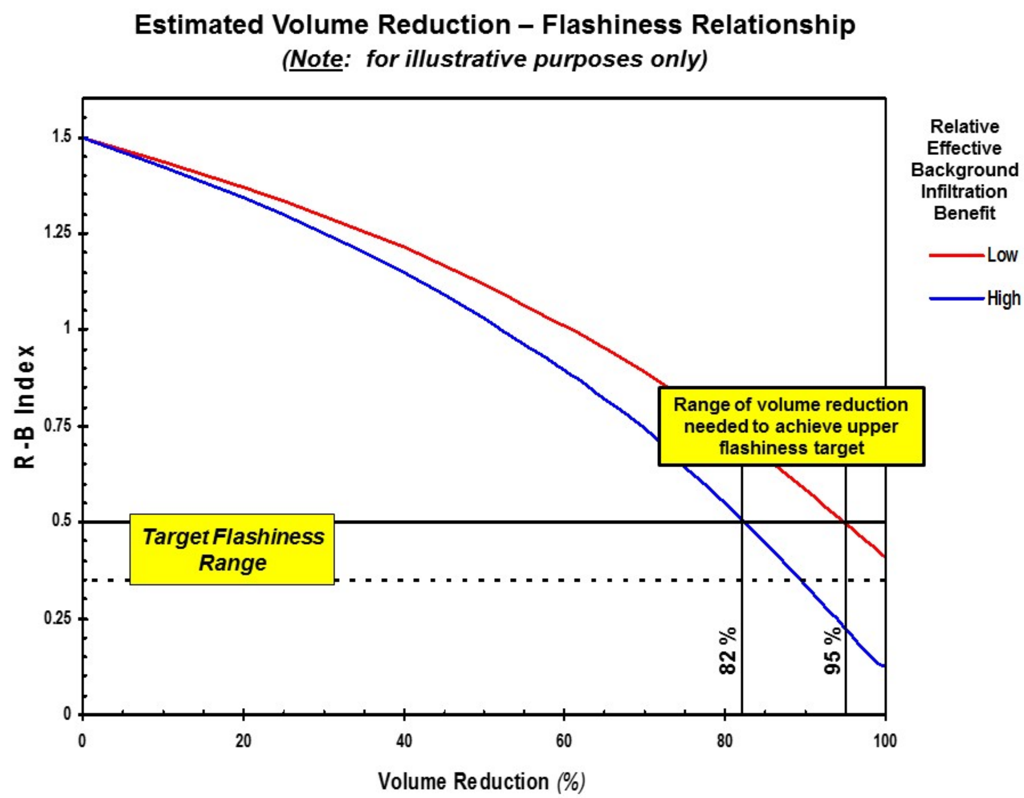


Figure 18. Relative response of R-B Index to reduction of annual average stormwater runoff volume.

3 Green Infrastructure Opportunities

For the purposes of this analysis, green infrastructure includes both natural areas and constructed management practices (e.g., bioswales, rain gardens, pervious pavement, green roofs). The outcome-based strategic planning framework recognizes the need to examine green infrastructure opportunities concurrently with target development. This approach minimizes potential confusion that could result from establishing reduction targets that have no clear connection to implementation options. For that reason, desktop screening analyses are developed to estimate the relative benefit of different green infrastructure strategies in the context of hydrologic targets (either R-B Index values or volume reduction).

The following sections describe major implementation activities highlighted in the *Green Infrastructure Vision for Southeast Michigan* that can significantly reduce stormwater runoff volume and improve water quality (SEMCOG 2014). Included are native plant grow zones, tree canopy, and constructed management practices. The desktop screening analyses illustrate the connection between each implementation option and the hydrologic targets. Green infrastructure opportunities within each pilot subwatershed are then examined.

3.1 Native Plant Grow Zones

Native vegetation has significant root systems that promote runoff infiltration and plant uptake. The term *grow zone* was coined by Wayne County as they began converting large-scale park areas to native planting areas to improve water quality and habitat and reduce the volume of stormwater runoff. Grow zones work best in adjacent roadside areas where roadway runoff is directed via sheet flow. Large open areas that have been traditionally managed as turf can be easily converted to native plant grow zones and can include large highway medians and cloverleaf areas around on- and off-ramps for highways. Grow zones also are feasible in linear vegetated areas adjacent to roadway impervious surfaces.

Photo credit: Wayne County Environmental Services Group

One way to illustrate the contribution of grow zones toward achieving hydrologic targets is through a screening analysis. A major benefit of grow zones is the increased ability of pervious areas to infiltrate precipitation. The relative effect of improved infiltration can be illustrated through continuous simulation of rainfall–runoff over an extended period of time. Figure 19 provides an example of the relative effect of increased infiltration on reducing R-B Index values. The screening analysis was developed using LSPC and hourly precipitation data over a 34-year period from a SEMCOG area climate station.

The range of target R-B Index values is included as a point of reference. As indicated, minor improvements in soil conditions resulting from green infrastructure practices (e.g., grow zones) provide the greatest relative benefit in pervious areas with lower relative infiltration benefit (e.g., hydrologic soil groups C and D or compacted urban soils found in developed portions of the SEMCOG region).

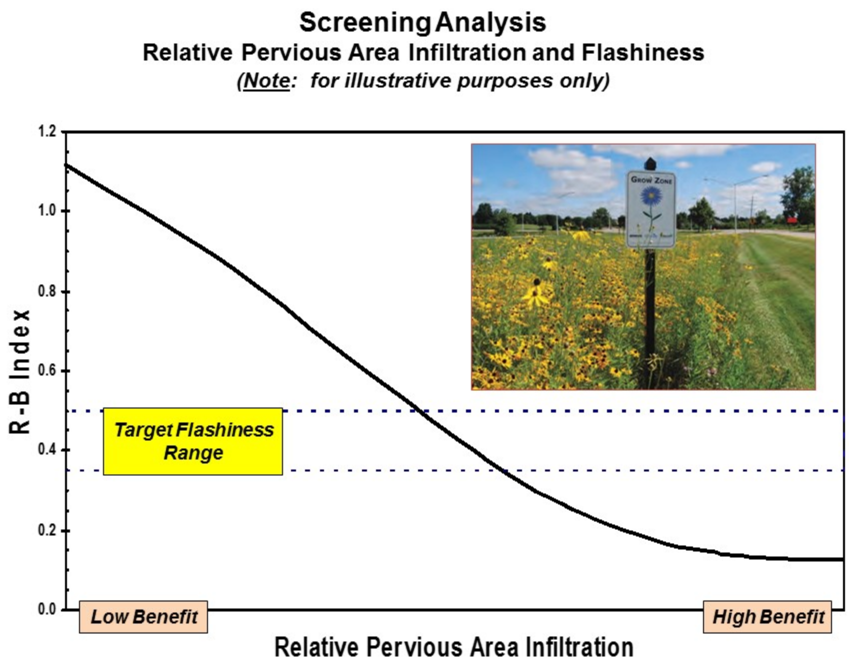


Figure 19. Relative effect of increased infiltration benefit on stream flashiness.

3.2 Tree Canopy

Tree canopy is another component of green infrastructure that has the potential to provide numerous benefits. In addition to improving aesthetics, trees provide water quality/hydrologic benefits by intercepting precipitation, improving soil conditions with increased infiltration, and reducing runoff volume through evapotranspiration. SEMCOG's *Green Infrastructure Vision for Southeast Michigan* indicates that southeast Michigan will strive to meet the standards developed by American Forests, including a 40-percent tree canopy for the region. It focuses on urban areas where tree canopy is below 20 percent and prioritizes specific land uses around industrial property and central business districts and along roadways and parking lots (SEMCOG 2014).

A screening analysis similar to the one used for grow zones can be used to illustrate the contribution of tree canopy towards achieving hydrologic targets. Figure 20 shows the benefits derived from increasing tree canopy by comparing R-B Index estimates across a range of impervious cover assumptions using LSPC. In this example, the upper flashiness target is reached in areas with no tree canopy when impervious cover is lower than when the remaining pervious area consists of a full tree canopy. For this particular situation, a full tree canopy mitigates the adverse effect of the additional impervious cover—an important consideration in areas in which options to reduce effective impervious cover are limited.

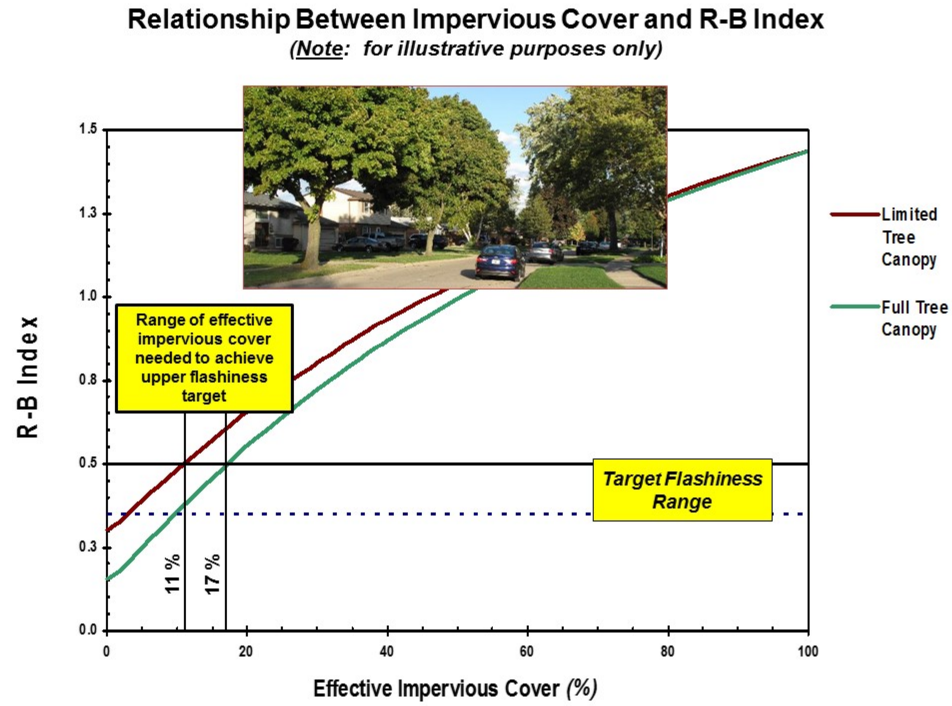


Figure 20. Relative effect of impervious cover and tree canopy on stream flashiness.

3.3 Constructed Management Practices

The integrated network of green infrastructure includes constructed practices (e.g., bioswales, permeable pavement, rain gardens). Constructed practices play an important role in developing green infrastructure strategies by providing ecological, environmental, economic, and social benefits. These techniques work primarily to improve water quality by reducing stormwater runoff entering surface waters. Their characteristics and designs can increase economic value of adjacent properties due to improved aesthetics and quality of life. The recommended amount of constructed green infrastructure is linked to the percentage of impervious surfaces. Priority areas for constructed practices in southeast Michigan include roadways, institutional properties, and both public and private parking lots.

A key part of SEMCOG's *Green Infrastructure Vision* is a focus on volume reduction through infiltration (SEMCOG 2014). The presumption is that decreased stormwater flows also result in lower stream flashiness and reduced pollutant loads. Roads and parking areas, for instance, are high-priority surfaces for treatment because they are the most likely to be directly connected to storm sewer systems that discharge to streams. They also represent a significant proportion of total impervious area in the pilot subwatersheds, as shown in Figure 21. The graph depicts the total impervious area and the impervious area for the primary land use categories (i.e., residential, commercial/industrial, road right-of-way [ROW], and institutional). Information in this form conveys the amount of constructed green infrastructure opportunity in each subwatershed. The percent impervious cover, also shown in Figure 21, reflects density.

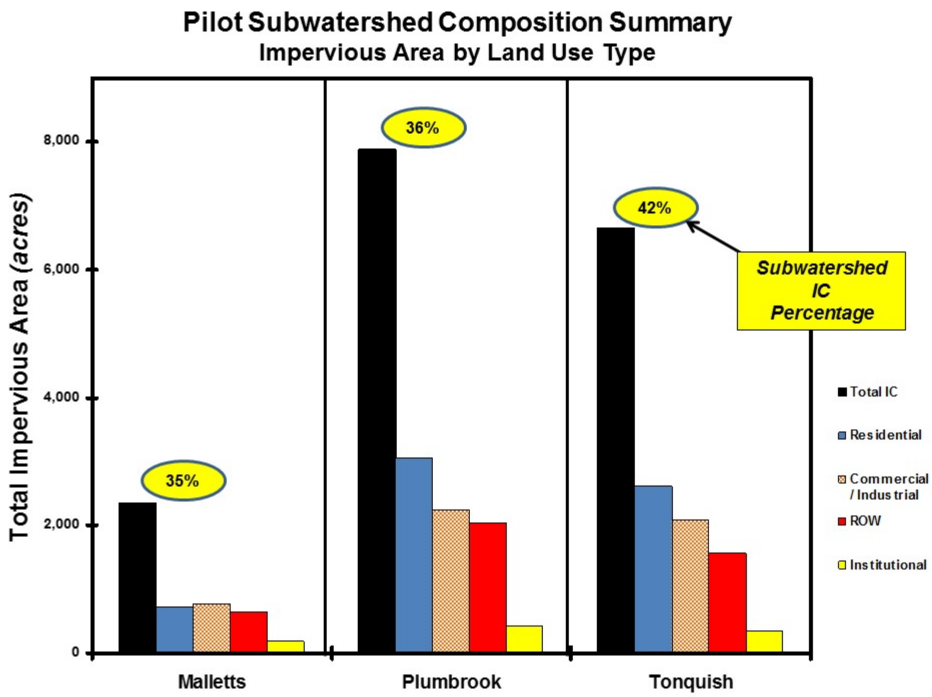


Figure 21. Pilot subwatershed impervious surface composition.

An important part of evaluating constructed green infrastructure opportunities is assessing options. Impervious area by land use category as shown in Figure 21 is one consideration. Figure 22 shows an example schematic for determining where certain types of constructed practices could actually be implemented. As indicated in Figure 22, bioretention and porous pavement are options for parking lots. Bioswales are a viable option for some roads and residential streets. These linear practices are designed to provide off-line retention for road runoff and surrounding areas. In addition to assessing individual practices, another option to consider could be the use of treatment trains (e.g., flow from porous pavement systems to bioretention).

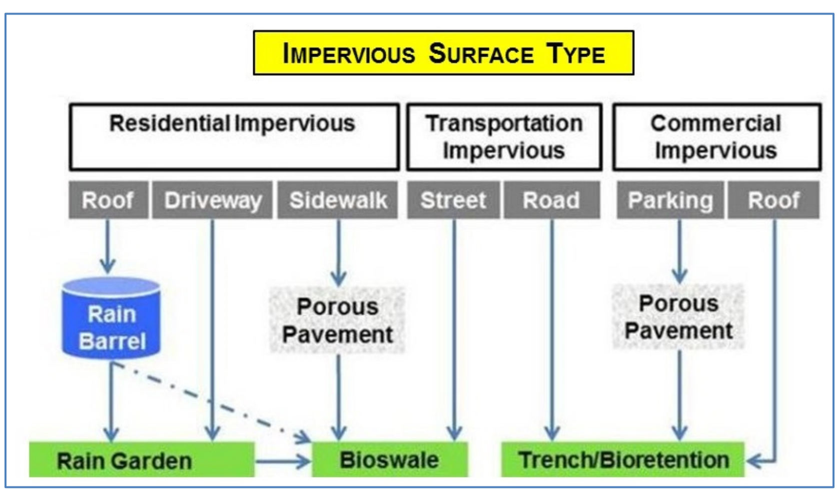


Figure 22. Constructed practice options by impervious surface type.

Another aspect of the opportunity assessment involves estimating the level of implementation that might be needed beyond the site scale (e.g., catchment or subwatershed level). Once areas of opportunity and potential BMPs are identified, desktop analyses can be used to evaluate constructed green infrastructure options. The screening analyses are designed to recognize and account for uncertainty associated with physical constraints and key design parameters. Specifically, screening analyses can be used to evaluate relative BMP performance given the array of sizing options (e.g., bioretention media depth, amount of area retrofitted, and so forth) and the range of design assumptions (e.g., native soil infiltration rates). An example of a constructed bioretention practice sized to retain the 90-percent non-exceedance storm under different relative infiltration assumptions is shown in Figure 23.

Determining the maximum extent to which impervious surface types could be converted to constructed practices is an important part of the opportunity assessment. That amount represents the percentage of impervious area managed for stormwater using green infrastructure. Figure 24 and Figure 25 provide examples for two constructed practices that show how volume reduction and the amount of area managed using green infrastructure vary with key assumptions (e.g., relative effective infiltration benefit). The curves shown in the examples were developed using the BMP assessment module of the System for Urban Stormwater Treatment and Analysis INtegration, or SUSTAIN (Shoemaker 2009).

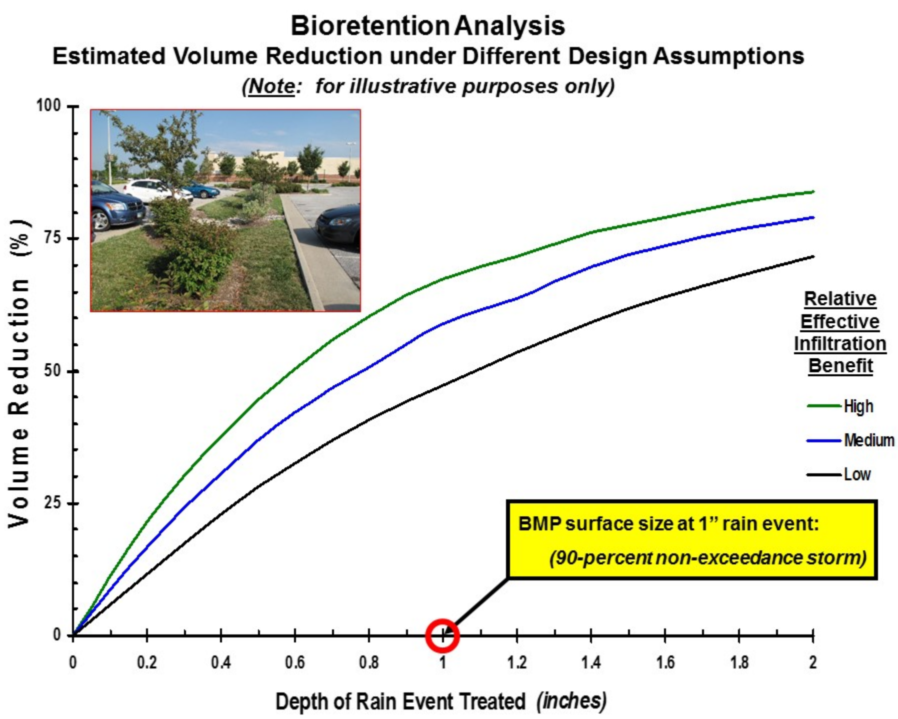


Figure 23. Bioswale screening analysis using different relative infiltration assumptions.

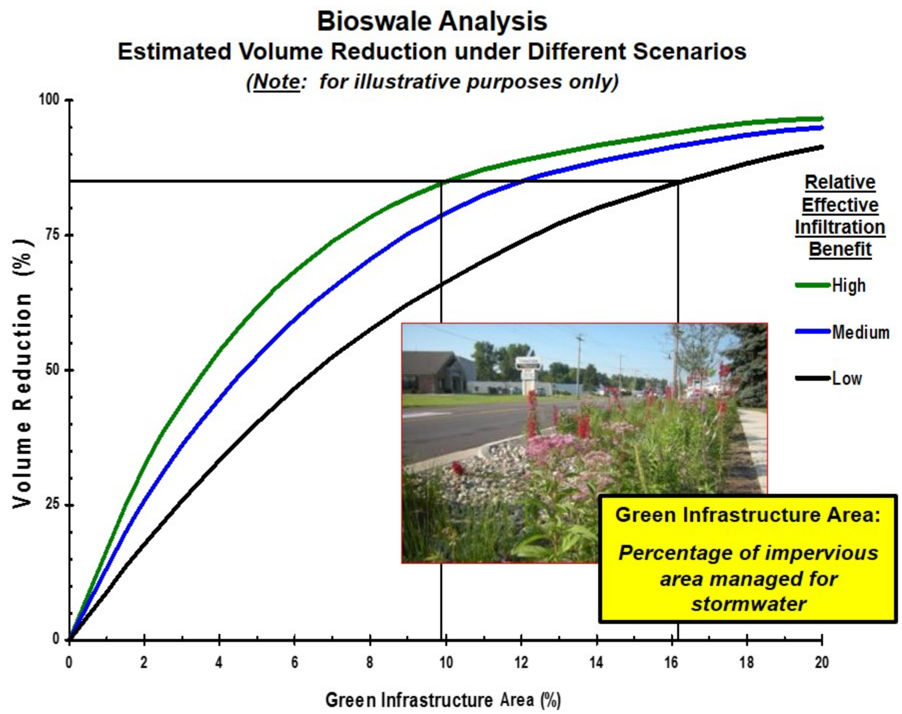


Figure 24. Bioswale volume reduction estimates at different infiltration rates.

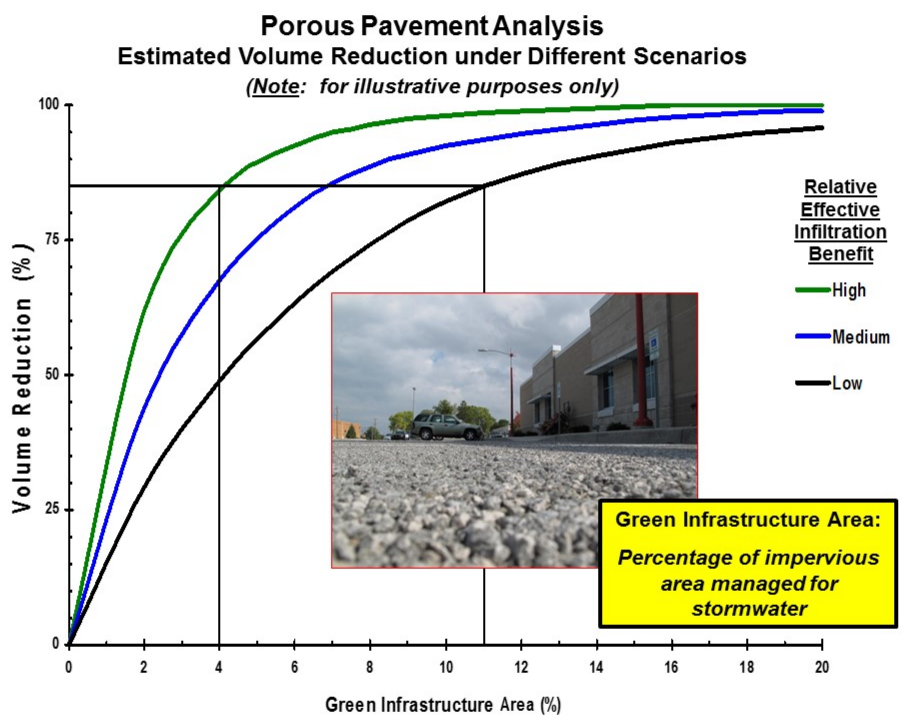


Figure 25. Porous pavement volume reduction estimates at different infiltration rates.

4 Pilot Subwatershed Assessment Results

SEMCOG's *Green Infrastructure Vision* is intended to highlight solutions that address hydrology and water quality challenges in surface waters across southeast Michigan (SEMCOG 2014). While solutions include the entire network of green infrastructure, focusing on urban areas and the extent of impervious cover is a priority. Consistent with the vision, the pilot subwatershed opportunity assessments focus on major areas of impervious surfaces and publicly owned properties. This approach emphasizes the following land use types:

Institutional properties include publicly owned property such as municipal facilities and complexes, libraries, parks, schools, and universities. The focus for those properties is to evaluate opportunities for managing runoff from paved surfaces and rooftops. In addition, large open spaces dominated by turf present options for increasing tree canopy or developing native plant grow zones.

Roadways are generally represented by major arterials, including local, county, and state roads. Southeast Michigan's transportation infrastructure (e.g., roads, bridges, nonmotorized pathways, transit routes, and facilities) along with the people and vehicles that use it affect the physical landscape. Transportation infrastructure can provide connectivity with natural areas and features for recreational enjoyment and represents the land use type with the highest levels of impervious cover directly impacting the region's water resources. Green infrastructure, both natural and constructed, can be strategically used along roadway corridors to provide recreational, social, and aesthetic amenities to surrounding communities in addition to providing local and regional environmental benefits.

Within the southeast Michigan region, there are over 23,400 miles of roadways with approximately 245 square miles of impervious cover, which comprises approximately 36 percent of all impervious cover in southeast Michigan. Roadway pavement, including residential streets, is nearly 40 percent of all impervious cover in the three pilot subwatersheds. Major roads comprise approximately 150 square miles in the region, with approximately 86 square miles of impervious cover and 64 square miles of open space and tree canopy.

Green infrastructure can be constructed within the ROW in existing open space or, where traffic data support it, as part of a road diet to reduce the number of travel lanes while adding other features. Local residential streets, although not emphasized in the vision, represent secondary opportunity areas.

Parking lots, both publicly and privately owned, represent a major opportunity category for green infrastructure implementation. Publicly owned parking lots are included as part of the impervious cover within the institutional properties. Privately owned parking lots represent the larger commercial areas in each pilot subwatershed. Bioretention areas, bioswales, and porous pavement are techniques that can significantly reduce stormwater runoff from paved surfaces. From a planning perspective, inverted parking lot islands can double as bioretention areas when coordinated with engineering design.

In benchmarking the amount of green infrastructure and identifying opportunities in the region, SEMCOG relied primarily on land cover information from 2010 aerial imagery and its own land use data. The *Green Infrastructure Vision* used impervious surface land cover data to estimate the annual stormwater runoff volume generated in the SEMCOG area (SEMCOG 2014). Information from SEMCOG's land cover database also includes estimates of impervious surface types (e.g., building, road, parking). Table 7 summarizes green infrastructure opportunities by land use category for each pilot subwatershed.

Table 7. Green infrastructure opportunities within the pilot subwatersheds

Subwatershed	Total Area (acres)	Institutional (publicly owned acres)			Roadways (publicly owned acres)		Other (privately owned acres)			Total Impervious Area (percent)
		Impervious Surface: Buildings	*Impervious Surface: Pavement*	*Open Space*	*Impervious Surface: Pavement*	*Open Space*	*Privately Owned Parking*	*Tree Canopy*	*Open Space*	
Malletts Creek	6,725	51	120	259	650	282	588	1,457	1,287	35%
Plumbrook Drain	21,625	100	294	639	2,050	1,234	1,642	4,104	5,219	36%
Tonquish Creek	15,952	84	223	435	1,558	675	1,584	3,283	3,227	42%

4.1 Malletts Creek Subwatershed

Malletts Creek drains approximately 11 square miles of land in the Huron River watershed (Figure 26). It is located in Washtenaw County and includes the City of Ann Arbor and Ann Arbor, Lodi, and Pittsfield townships. Portions of the University of Michigan also are located within this subwatershed. Malletts Creek is a designated county drain encompassing approximately 10 miles of open streams, many of which have been enclosed. The Washtenaw County Water Resources Commission has jurisdiction over Malletts Creek.

Substantial restoration efforts have been implemented across the subwatershed, including the Malletts Creek Library, the Mary Beth Doyle Park wetland complex, the Malletts Creek streambank restoration, the Buhr Park Children's Wet Meadow, and the Easy Street pavement rehabilitation. Challenges remain due to the urban nature of the stream, with stormwater runoff from impervious surfaces leading to increased stream flashiness, degraded water quality, and poor biological conditions.

To help address those concerns, Ann Arbor is currently refining their stormwater management model (SWMM) to develop a shared understanding with the local community of stormwater behavior in the city. A key aspect of the pilot subwatershed opportunity assessments was the use of a multiscale analysis framework to identify high-priority areas for BMP implementation. Ann Arbor's SWMM model units were examined as a starting point. For the Malletts Creek subwatershed, there are nearly 500 model units with an average size of nearly 14 acres per unit. Catchment delineations for the Malletts Creek subwatershed also were developed by MDEQ's Hydrologic Studies Unit. The MDEQ catchments provide a platform for clustering Ann Arbor's SWMM model units into a manageable number for purposes of conducting opportunity assessment screening analyses. Catchment boundaries used for the screening analyses are shown in Figure 27.

4.1.1 Land Use and Land Cover

Land use and land cover information inventoried by SEMCOG for each pilot subwatershed is an important part of the overall analysis. The data can be used to develop subwatershed-scale runoff estimates that reflect the mix of different land uses present across the Malletts Creek drainage. The SEMCOG inventory provides impervious cover estimates based on an evaluation of parcel-scale data, including building footprints, parking lot locations, and transportation corridors. The SEMCOG land use information for the Malletts Creek subwatershed is shown in Figure 28 and summarized by catchment in Table 8. This tabular summary highlights land use categories in each catchment that exceed the subwatershed average—a useful indicator in targeting priority areas for green infrastructure planning.

Another way to view SEMCOG's land use data is by examining land cover patterns for each category (Table 9). In addition to supporting development of subwatershed-scale runoff estimates, information presented in this manner helps identify implementation options (e.g., what percentage of road ROW is pavement that could be routed to grow zones or constructed bioretention, how much commercial land use is parking area potentially available for green infrastructure practices, and so forth).

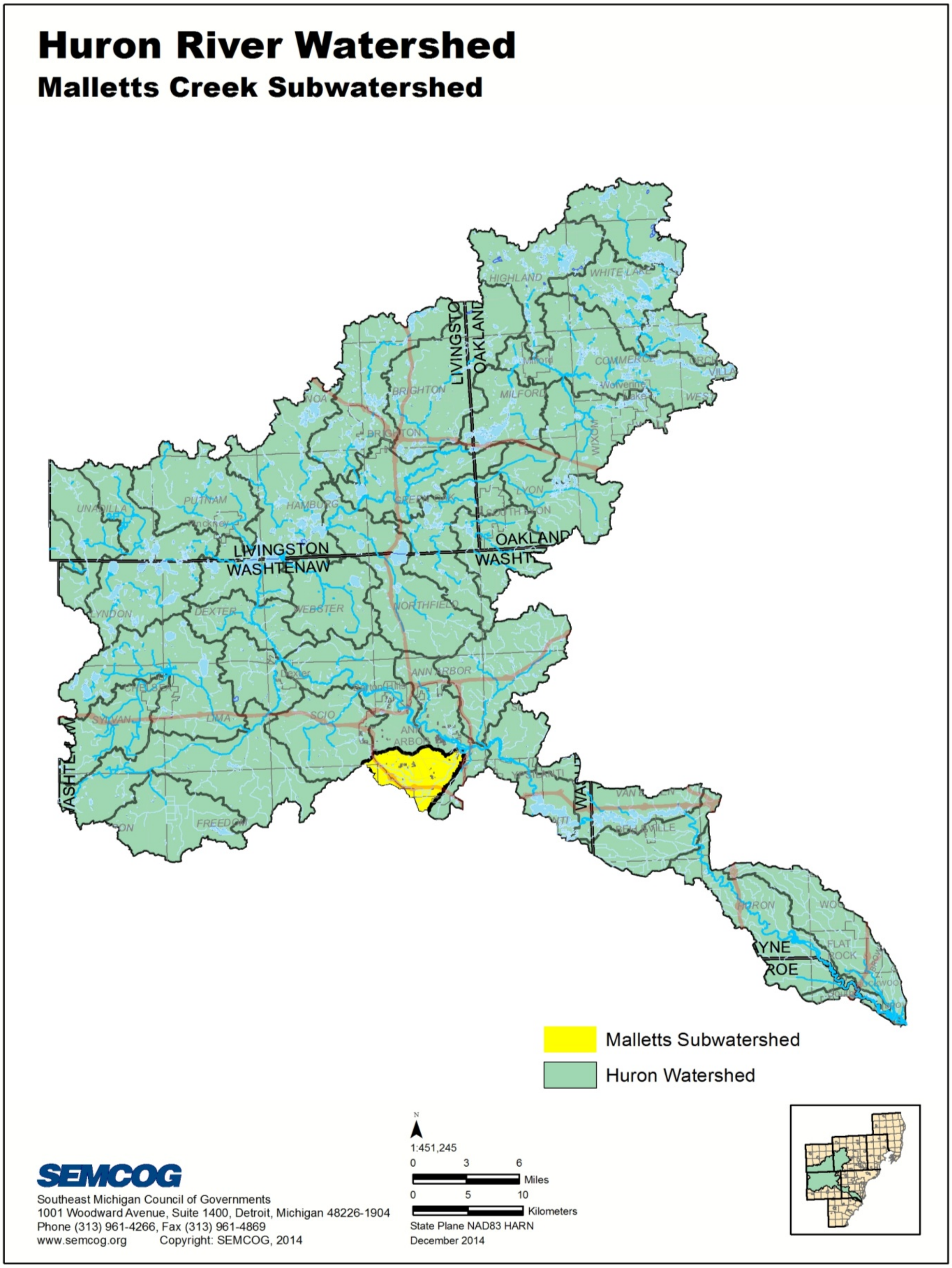


Figure 26. Location of Malletts Creek pilot subwatershed within Huron River watershed.

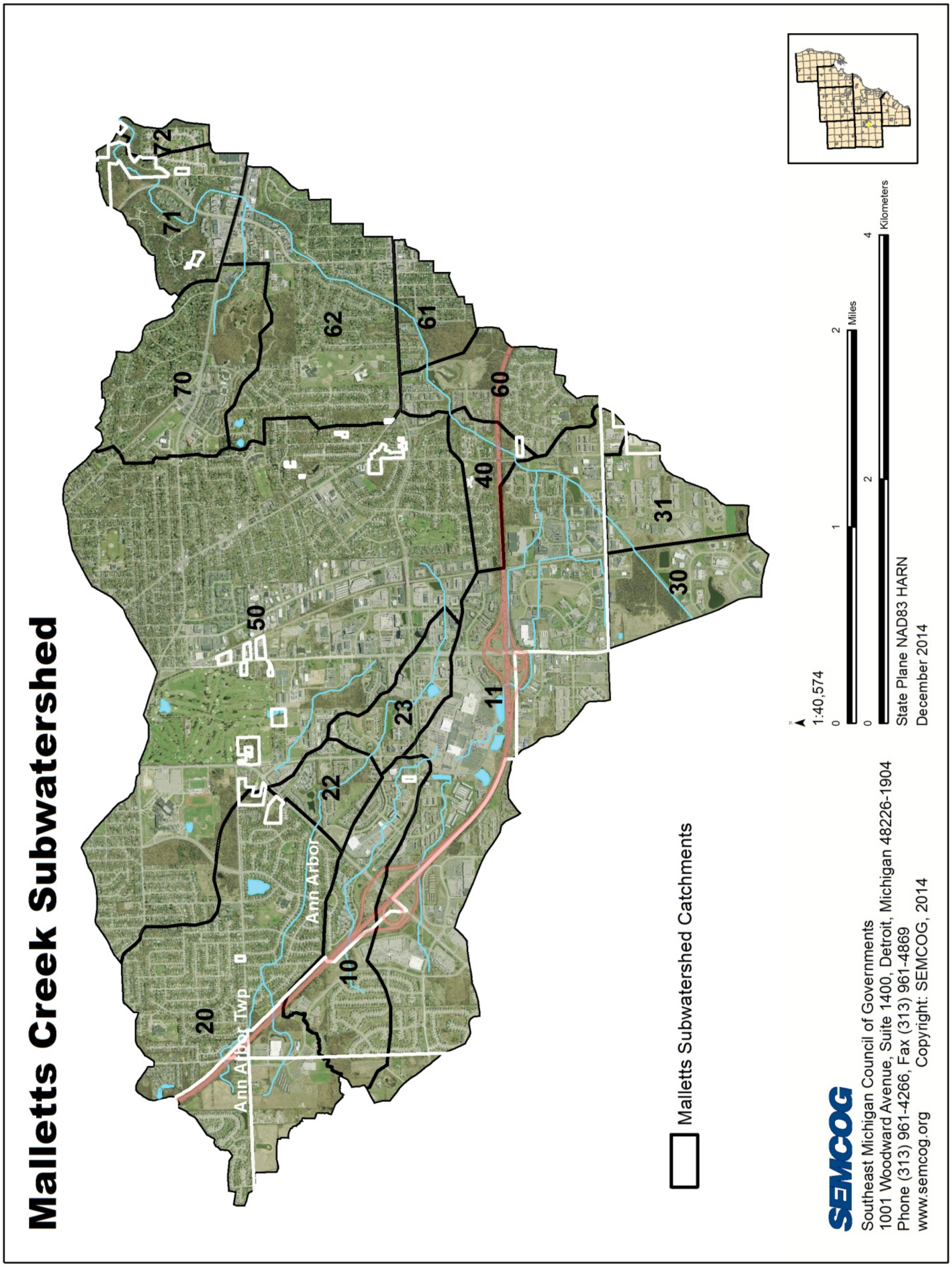


Figure 27. Aerial imagery of catchment boundaries—Malletts Creek subwatershed.

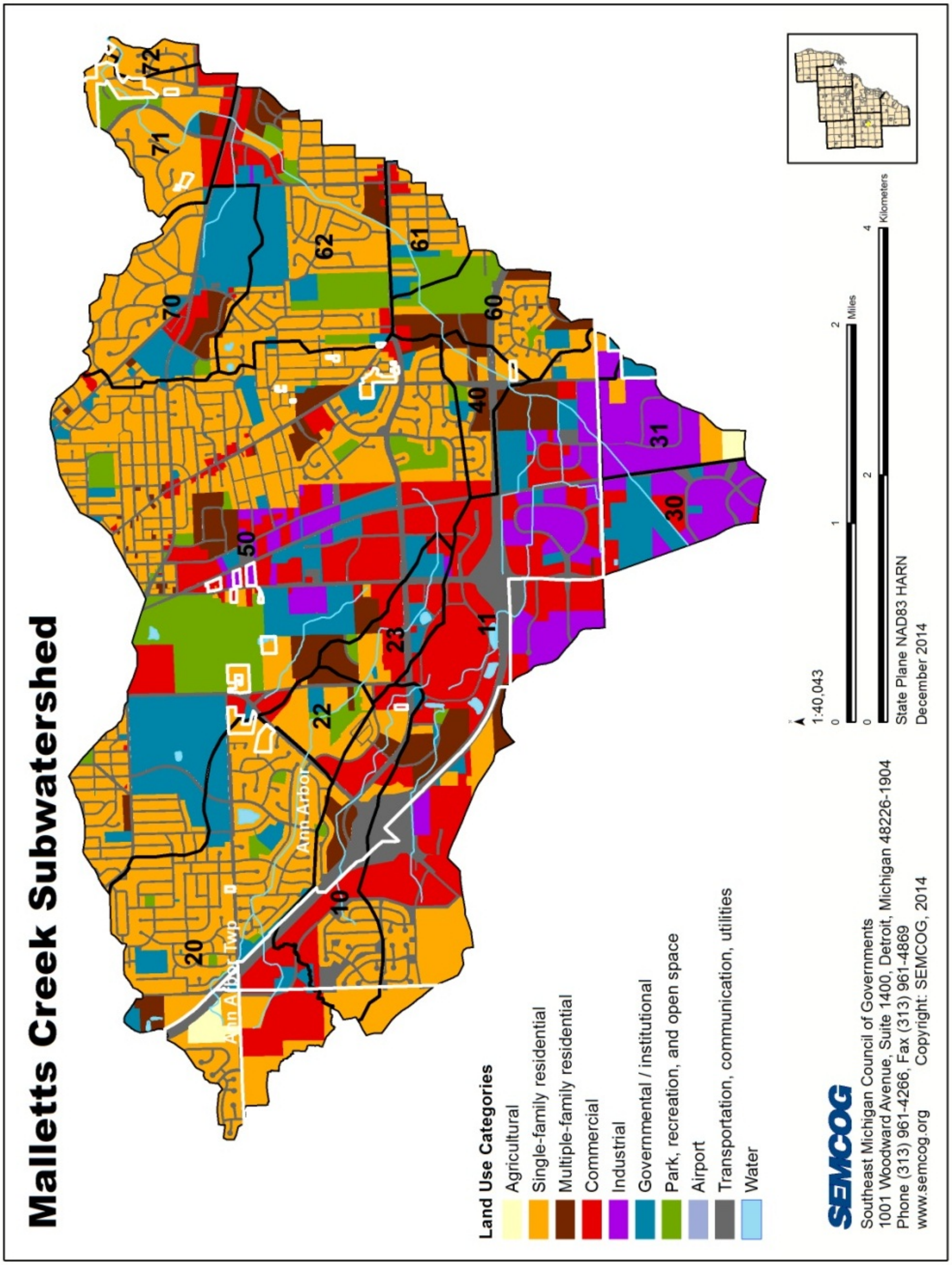


Figure 28. Land use—Malletts Creek subwatershed.

Table 8. Malletts Creek subwatershed land use

Catchment Group / Catchment ID		Area *(acres)*	Land Use *(percent)*								Total Impervious Area *(percent)*
			Single-family Residential	*Multifamily Residential*	*Commercial*	*Institutional*	*Industrial*	*Road ROWs*	*Parks, Open*	*Other*	
A	**10** – *Cranbrook Mall*	322	34%	8%	23%	2%	---	32%	1%	---	37%
	11 – *Briarwood/I-94 Corridor*	1,153	15%	8%	35%	5%	15%	22%	0.2%	1%	47%
B	**20** – *Upper Malletts*	873	55%	2%	10%	9%	---	19%	2%	3%	29%
	22 – *Cranbrook Park*	107	54%	10%	8%	6%	---	8%	15%	---	39%
	23 – *State & Eisenhower*	140	15%	13%	37%	15%	1%	16%	2%	1%	53%
C	**30** – *Upper South*	205	---	---	15%	33%	41%	11%	---	0.1%	22%
	31 – *Middle South*	172	12%	---	---	5%	69%	8%	---	6%	38%
D	**40** – *Junction Reach*	110	40%	21%	5%	3%	---	28%	3%	---	33%
E	**50** – *Upper State - Packard*	2,078	36%	5%	13%	14%	3%	18%	10%	0.1%	35%
F	**60** – *Doyle Park*	223	32%	22%	1%	4%	---	14%	26%	---	31%
	61 – *Packard*	121	46%	---	4%	11%	---	19%	19%	---	27%
	62 – *Scheffler Park*	558	45%	5%	7%	13%	0.2%	17%	11%	0.2%	29%
G	**70** – *County Farm Park*	371	40%	6%	5%	31%	---	16%	1%	---	28%
	71 – *Huron Parkway*	250	62%	2%	12%	1%	---	14%	7%	---	27%
	72 – *Malletts Outlet*	43	81%	---	2%	---	---	17%	0.1%	---	26%
TOTAL		**6,725**	**36%**	**6%**	**15%**	**11%**	**7%**	**18%**	**6%**	**1%**	35%

Note: **Yellow highlighted cells** identify land use categories in each catchment that exceed the subwatershed average.

Table 9. Malletts Creek subwatershed land cover by land use category

Land Use Category	Area *(acres)*	Impervious Surface Types (*percent*)		Pervious Area (*percent*)	
		Building	***Pavement*** *(road surface, parking, driveways, sidewalks)*	***Open***	***Tree Canopy***
Single-family residential	2,385	*12%*	*11%*	*28%*	*49%*
Multifamily residential	405	*18%*	*27%*	*28%*	*27%*
Commercial	1,036	*15%*	*41%*	*31%*	*13%*
Institutional	763	*7%*	*19%*	*34%*	*40%*
Industrial	443	*15%*	*30%*	*43%*	*12%*
Road ROWs	1,236	*0.1%*	*53%*	*23%*	*24%*
Parks, Open Space	409	*1%*	*7%*	*58%*	*34%*
Other	48	*1%*	*24%*	*49%*	*26%*
TOTAL	6,725	*10%*	*26%*	*31%*	*33%*

4.1.2 Existing Conditions Related to Flashiness

Flooding and water quality problems in Malletts Creek have been well documented (WCDC 2000). Existing flow conditions are best described as unstable and flashy in response to storm events (Wuycheck 2004). *Flashy streams* are characterized by rapid rates of change, high pulses, and frequent flow reversals as runoff quickly leaves the land in response to storms. Figure 29 shows daily average flows monitored over a 3-month period at two USGS gage locations in Malletts Creek, illustrating the rapid rise and fall in flow as Malletts Creek responds to different rain events (shown across the top of Figure 29).

Based on USGS data, R-B Index values in Malletts Creek currently exceed 0.7 (see Table 4). The focus of the pilot subwatershed opportunity assessment was to examine green infrastructure implementation opportunities that will work towards reducing stream flashiness in Malletts Creek to a target range between 0.35 and 0.50 as measured by the R-B Index.

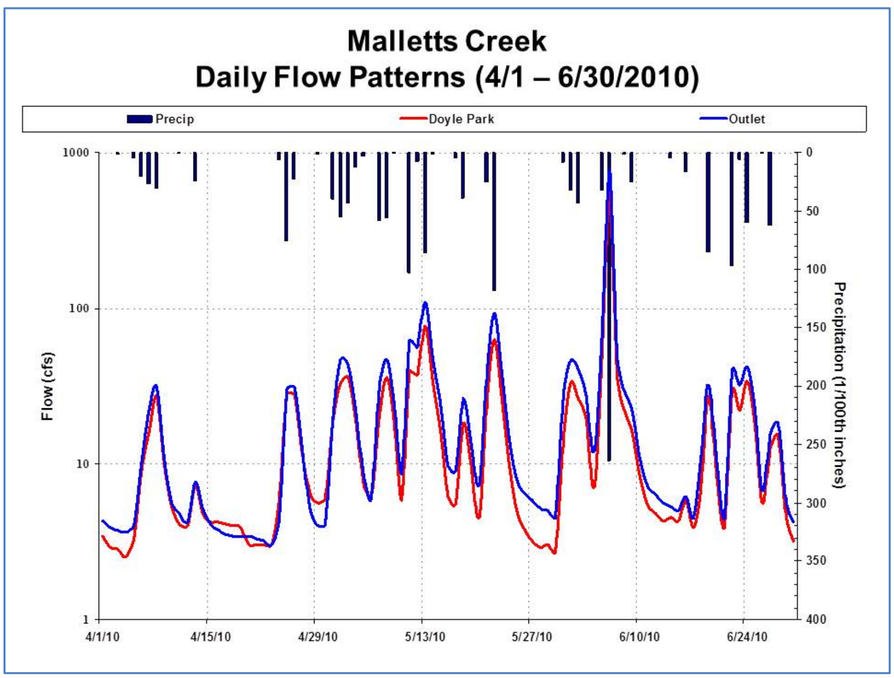


Figure 29. Daily average streamflow patterns in Malletts Creek (4/1–6/30/2010).

4.1.3 Stormwater Runoff Reduction Targets

The LSPC screening analysis offers a method to evaluate subwatershed-scale runoff patterns in the context of current land use information. R-B Index estimates based on local meteorological information and the SEMCOG land cover data were used to benchmark existing conditions for relative comparison with different implementation strategies, including identifying the percentage of effective impervious cover that would need to be managed for stormwater using green infrastructure to meet the target R-B Index range.

The results of the screening analysis are represented in Figure 30. The box in the upper left identifies the estimated baseline effective impervious cover that corresponds to the current Malletts Creek R-B Index value. It is important to note that the effective impervious cover is less than the total impervious area in Table 8. The effective amount acknowledges that not all impervious surface runoff reaches the stream. For example, a portion of storm runoff from residential roofs likely flows to yards, where it infiltrates into the ground. Similarly, some storm runoff from roads without curb and gutter or well-defined ditch systems could simply flow from pavement to pervious areas and infiltrate into the ground.

The screening analysis shown in Figure 30 used baseline assumptions to examine the change in R-B Index values as effective impervious cover is varied across the Malletts Creek subwatershed. Under those baseline scenario assumptions, effective impervious cover would need to be managed to approximately 11 percent to meet the upper R-B Index target (i.e., 0.50). This represents an ambitious goal from the current 24-percent estimated effective impervious cover, particularly in light of significant changes to the existing subwatershed land cover that might be needed.

Developing stormwater volume reduction targets using LSPC estimated an annual 12.7 inches of excess runoff from effective impervious surface areas. That translates into approximately 63 million cubic feet annually of excess stormwater runoff volume to be reduced to achieve the upper R-B Index flashiness goal (depending on background infiltration benefit assumptions). Another way to view this challenge, however, is to focus on simply estimating the percentage of effective impervious cover that would need to be managed for stormwater using green infrastructure.

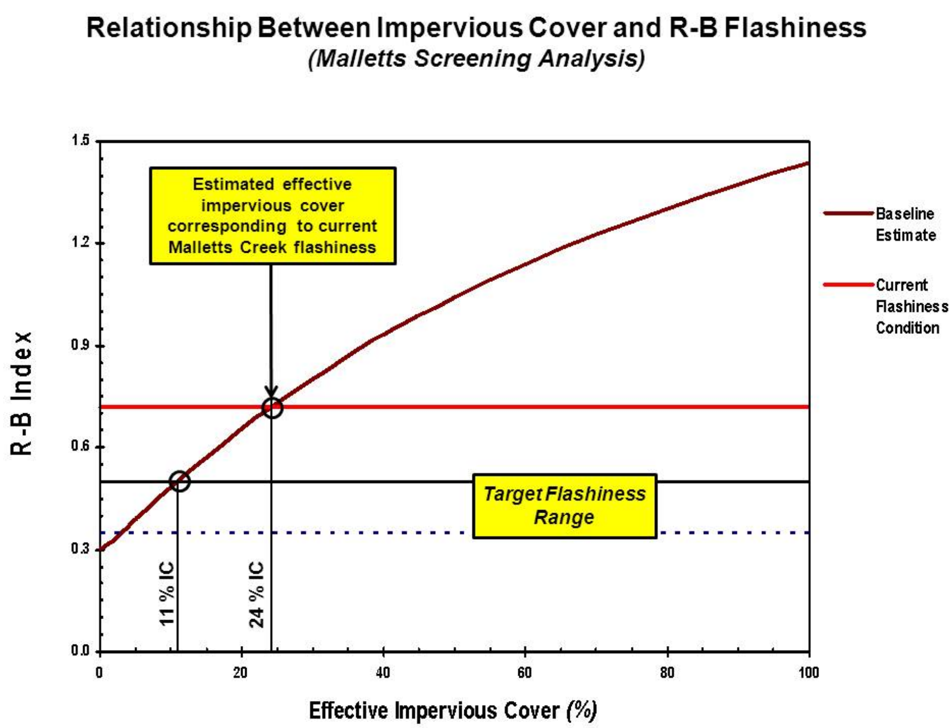


Figure 30. Malletts Creek subwatershed effective impervious cover and R-B flashiness screening analysis.

The current estimated effective impervious area in the Malletts Creek subwatershed is 24 percent, or approximately 1,600 acres. The screening analysis indicates that this effective impervious area should be reduced to 11 percent, or to approximately 740 acres. The difference of 860 acres represents an effective impervious cover target that should be prioritized for identifying areas that could be managed using green infrastructure.

In summary, the baseline curve shown in Figure 30 provides an initial frame of reference from which to examine green infrastructure implementation strategies. Options include the use of grow zones at key locations, increasing tree canopy across the subwatershed, and evaluating design alternatives for constructed BMPs intended to reduce effective impervious cover.

4.1.4 Areas of Opportunity and Priorities

SEMCOG's *Green Infrastructure Vision* sets a direction for southeast Michigan based on stakeholder input and identifies 10 primary regional policy recommendations on how to get there (SEMCOG 2014). Regional policies that relate directly to improving water quality include:

- Encouraging policies to integrate constructed green infrastructure in publicly funded projects, including institutional properties and major roadways. Focus implementation on roads, parking lots, and large managed turf areas.
- Minimizing mowing within riparian corridors, and seeking opportunities to increase tree canopy and native plant grow zones in open space areas.

Figure 31 shows the green infrastructure vision for the Malletts Creek subwatershed. The Current Green Infrastructure network is shown as the background on Figure 31, representing the larger green infrastructure network of tree canopy and open space based on the 2010 land cover analysis for southeast Michigan. The region's public parks and conservation lands are classified as Conservation and Recreation Lands. The Potential Conservation & Recreation Lands classification highlights areas that could be added to the network. The Potential Green Streets classification identifies major roads that have opportunities for improving infiltration through grow zones, enhancing tree canopy coverage, and implementing constructed practices. In addition, the top 10 percent by area of institutional properties is highlighted as an initial priority. Finally, the top 1 percent by area of private parking lots is identified.

The SEMCOG land cover data provide a starting point from which to describe opportunities (Figure 32). An important aspect is identifying potential impervious surface types that could be managed for stormwater using green infrastructure. Within the Malletts Creek pilot subwatershed, pavement (e.g., roads, parking lots, driveways, sidewalks, and so forth) represents nearly three-quarters of all impervious surface types (Table 10).

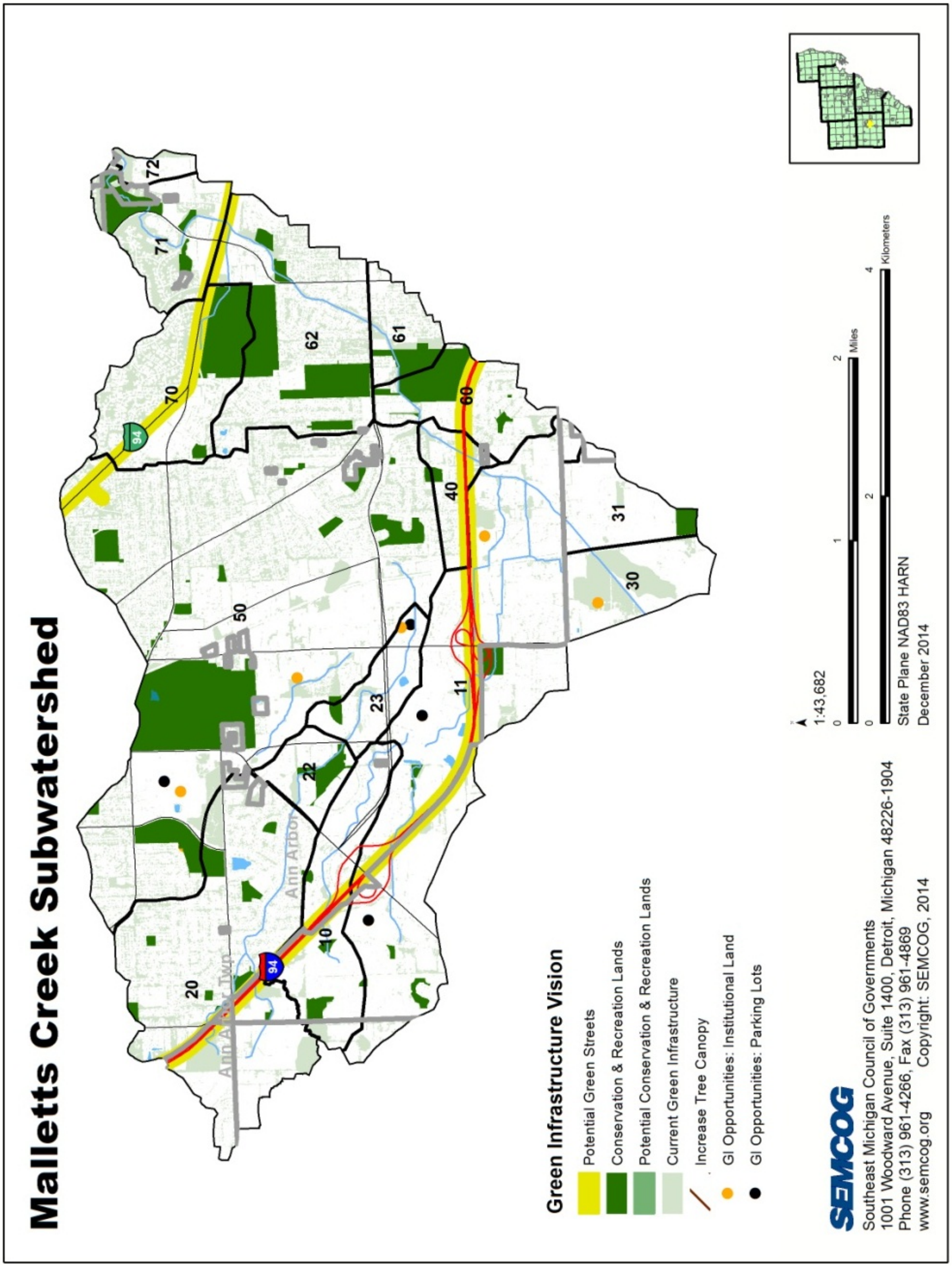


Figure 31. Green Infrastructure Vision—Malletts Creek subwatershed.

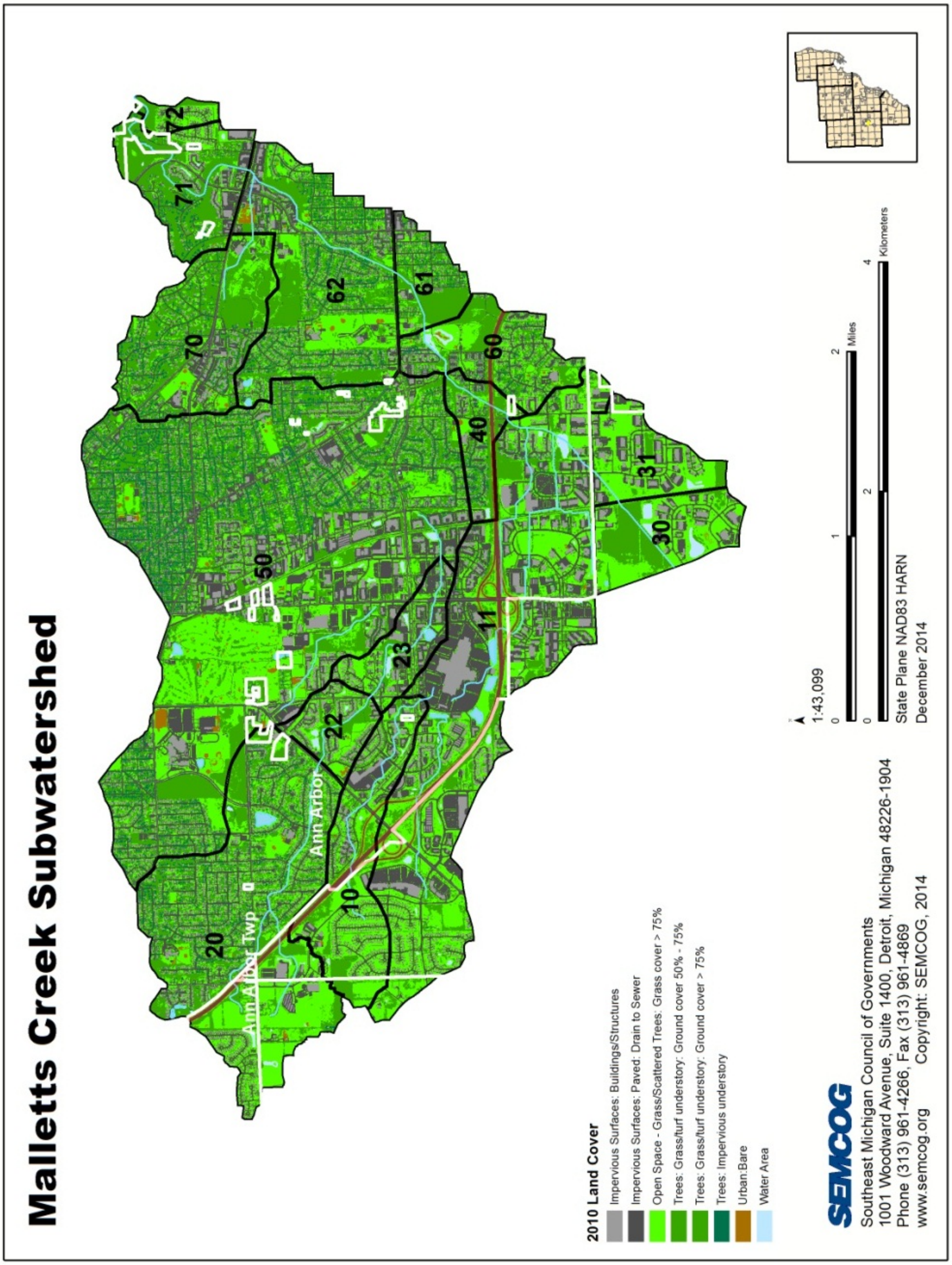


Figure 32. Land cover—Malletts Creek subwatershed.

Table 10. Malletts Creek subwatershed impervious cover estimates by surface type

Catchment Group / Catchment ID		Area *(acres)*	Total Impervious Area *(acres)*	Percent of Total Impervious Area (*percent*)			Tree Canopy *(percent)*
				Building	***Road***	***Other Pavement***	
A	**10** – *Cranbrook Mall*	322	121	*25%*	*37%*	*38%*	19%
	11 – *Briarwood/I-94 Corridor*	1,153	540	*25%*	*21%*	*54%*	15%
B	**20** – *Upper Malletts*	873	251	*31%*	*41%*	*28%*	35%
	22 – *Cranbrook Park*	107	42	*34%*	*14%*	*52%*	23%
	23 – *State & Eisenhower*	140	75	*22%*	*18%*	*60%*	14%
C	**30** – *Upper South*	205	45	*25%*	*20%*	*55%*	28%
	31 – *Middle South*	172	65	*27%*	*9%*	*64%*	11%
D	**40** – *Junction Reach*	110	37	*25%*	*39%*	*36%*	44%
E	**50** – *Upper State - Packard*	2,078	731	*28%*	*27%*	*45%*	37%
F	**60** – *Doyle Park*	223	69	*26%*	*28%*	*46%*	36%
	61 – *Packard*	121	33	*26%*	*41%*	*33%*	53%
	62 – *Scheffler Park*	558	164	*29%*	*34%*	*37%*	44%
G	**70** – *County Farm Park*	371	103	*26%*	*34%*	*40%*	51%
	71 – *Huron Parkway*	250	67	*31%*	*25%*	*44%*	59%
	72 – *Malletts Outlet*	43	11	*31%*	*36%*	*33%*	41%
TOTAL		6,725	2,351	*27%*	*28%*	*45%*	33%

The land use/land cover inventory data compiled by SEMCOG provide detailed information that can be used to identify priority areas. Figure 33 summarizes the impervious surface composition for catchment groups in the Malletts Creek subwatershed. The 15 catchments in Figure 27, Figure 28, and Table 8 are clustered into groups A through G, shown in Figure 33. The number behind each letter on the x-axis represents the first digit of those catchment identifiers, which have been clustered in that particular group (e.g., catchments 10 and 11 in group A; catchments 20, 22, and 23 in group B; and so forth).

This chart conveys two types of information useful for targeting green infrastructure implementation efforts: the quantity of impervious area and the density of impervious cover in each catchment group. The quantity aspect identifies the groups that contain higher amounts of total impervious area. In the Malletts Creek subwatershed, those are catchment groups A (Briarwood) and E (Upper State–Packard). The value in the oval for each group represents the percent impervious cover (or the density aspect). The combination of both aspects points to Briarwood as a high priority for targeting green infrastructure, which does not mean that green infrastructure in other groups is less important. Instead, it highlights the fact that managing impervious cover in the Briarwood catchment group must play a major role in reducing stream flashiness in the Malletts Creek subwatershed.

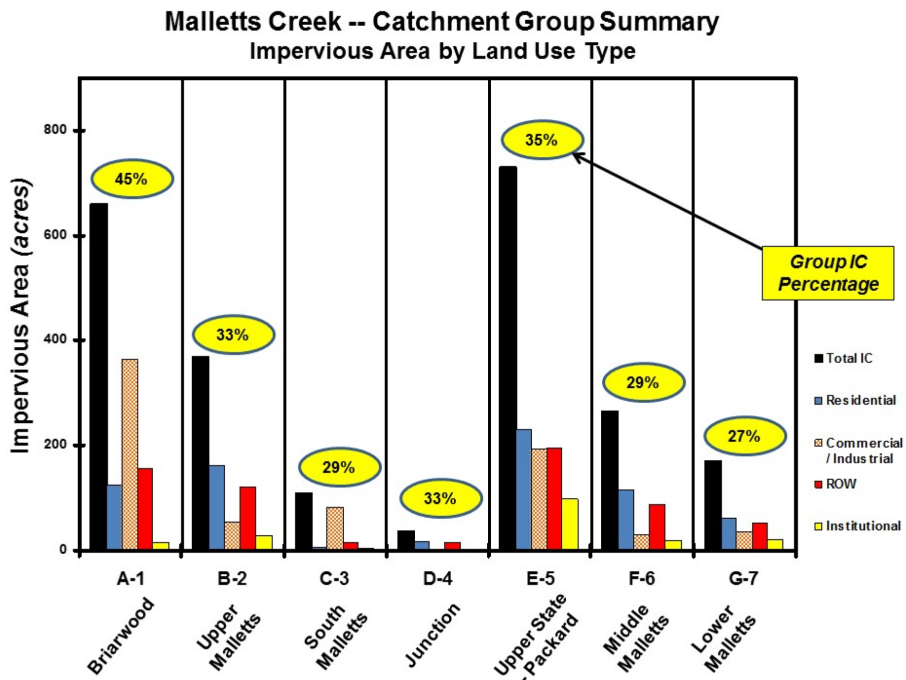


Figure 33. Impervious surface composition—Malletts Creek subwatershed.

The impervious surface composition shown in Figure 33 provides other useful information for targeting green infrastructure implementation. As indicated, Briarwood (A) is a high-priority group. The greatest amount of impervious area in group A catchments is associated with commercial land use followed by roads. The green infrastructure vision map identifies parking lot and green street opportunities (Figure 31). While the Upper State–Packard group (G) has high amounts of commercial land and road surfaces, targeting residential areas in that catchment should play an important role for green infrastructure, which is consistent with Ann Arbor projects in place (e.g., Easy Street, Miller Avenue). In addition, this group has the greatest amount of impervious area on institutional properties with opportunities noted in the vision (Figure 31).

4.1.5 Recommendations

Significant restoration efforts have already been implemented to address flooding and water quality problems in the Malletts Creek subwatershed. In addition, other efforts are either underway or have been suggested as potential opportunities, including:

- State Street—transportation corridor planning *(catchments 11, 23, 50)*
- Stone School Road—bioswales *(catchment 11)*
- Springwater subdivision—sand filter BMPs within ROW *(catchment 61)*
- Buhr Park—parking lot infiltration *(catchment 62)*
- Reimagine Washtenaw—integrated transportation opportunities *(catchments 62, 71)*

To complement these ongoing activities, several recommendations are offered based on an analysis of existing conditions related to flashiness and priorities identified using land use/land cover information. These recommendations follow key components of SEMCOG's *Green Infrastructure Vision* (SEMCOG 2014).

Institutional Properties

Green infrastructure on institutional properties offers several benefits, including a public display of the types of practices suitable for implementation in the local community. Based on SEMCOG's analysis of parcel-level information, more than 1,000 acres of the Malletts Creek subwatershed are publicly owned or institutional property, including parks and open space areas (Figure 34). Managing impervious surfaces on publicly owned property is another priority opportunity identified in the vision. Table 11 details the land cover breakdown of those properties by jursidiction.

Figure 35 highlights the extent of school district property in the Malletts Creek subwatershed. School districts can benefit from green infrastructure implementation through construction of schoolyard habitats and native plant grow zones. In addition to the educational value, green infrastructure on school properties can work to reduce long-term maintenance costs by improving drainage and replacing high-maintenance turf with lower maintenance trees, shrubs, and ornamental grasses.

Of the different types of impervious surfaces on publicly owned properties, pavement represents the largest proportion. The *Low Impact Development Manual for Michigan* provides detailed information on suitable practices for those surface types (SEMCOG 2008). Recommended BMPs include bioretention, infiltration trenches, pervious pavement, planter boxes, level spreaders, and vegetated swales. The manual also describes the range of design options available to accommodate site-specific situations. The Site Development Stormwater Tool, which has been applied in Michigan, can be used to guide more parcel-specific screening analyses (similar to that shown in Figure 23) to reflect design configurations appropriate for each location (Christian 2014).

The *level of implementation* curves shown in Figure 24 and Figure 25 are based on southeast Michigan climate data. The curves provide a general estimate of environmental benefits that could be derived from constructed green infrastructure on institutional properties across all catchments in the Malletts Creek subwatershed. A significant percentage of the soils in the subwatershed are in hydrologic soil group (HSG) D, which provide lower infiltration benefit. That local challenge can be addressed either with enhanced design for constructed practices (e.g., soil amendments, increased BMP treatment capture depth) or by improving the infiltration of pervious areas (e.g., grow zones, increased tree canopy).

Table 11. Malletts Creek subwatershed publicly owned property by jurisdiction

Jurisdiction	Area *(acres)*	Impervious Surface Types *(acres)*		Pervious Area *(acres)*	
		Building	*Pavement (parking, driving surfaces, sidewalks)*	*Open*	*Tree Canopy*
City of Ann Arbor	293	*7*	*22*	*119*	*145*
Washtenaw County	201	*3*	*20*	*56*	*123*
Pittsfield Township	4	*0*	*1*	*3*	*0*
State of Michigan	12	*0*	*2*	*5*	*5*
Federal Property	3	*1*	*1*	*1*	*0*
University of Michigan	262	*12*	*39*	*151*	*60*
School Property	266	*20*	*53*	*113*	*80*
TOTAL	**1,041**	***42***	***138***	***448***	***413***

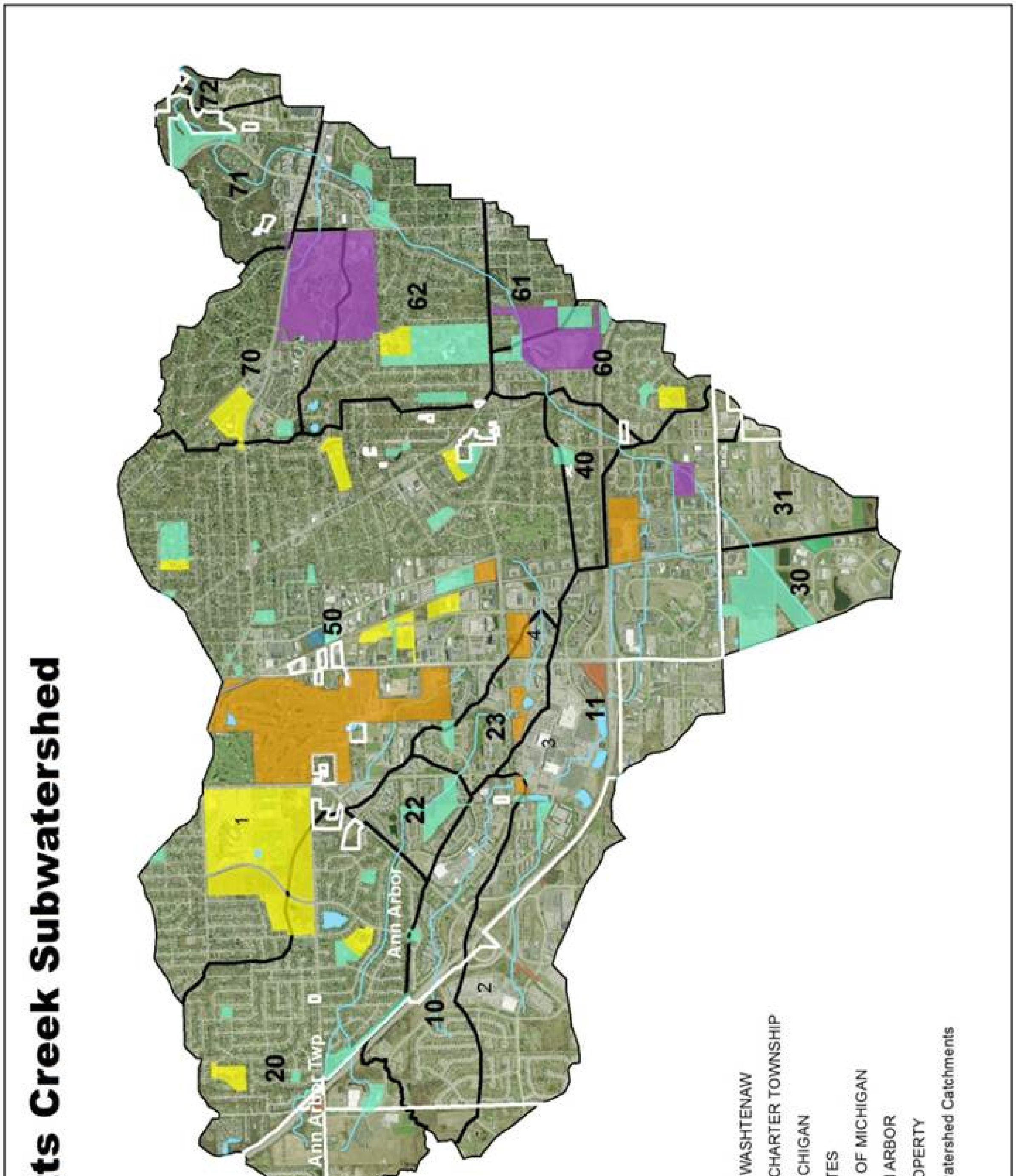


Figure 34. Public parcels—Malletts Creek subwatershed.

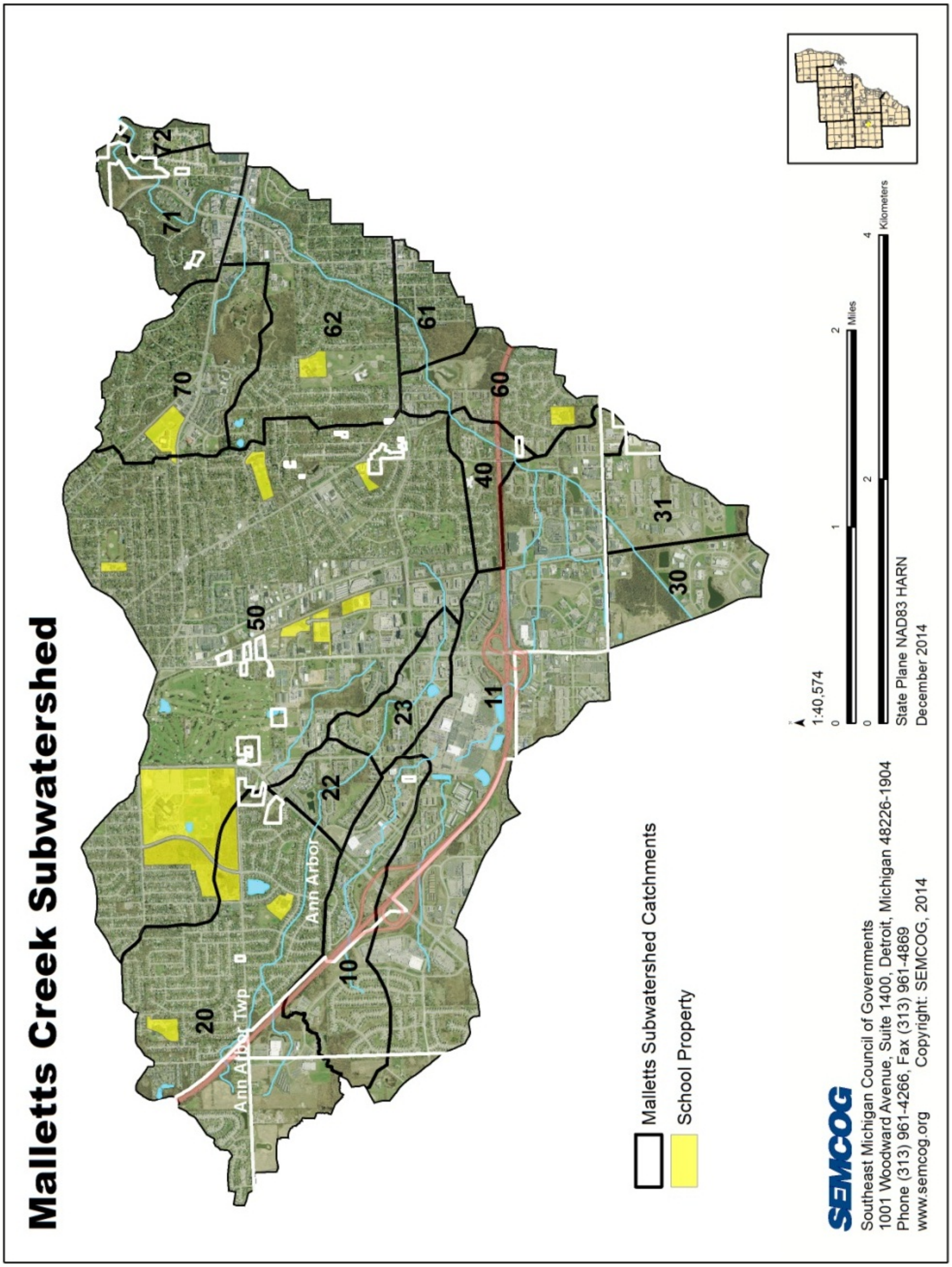


Figure 35. School properties—Malletts Creek subwatershed.

Roadways

The aerial imagery and land use displayed in Figure 27 and Figure 28 show the extent of the roadway network in the Malletts Creek subwatershed. That information is summarized in Table 12 by general jurisdictional ownership for the Malletts Creek subwatershed. As indicated, nearly 10 percent of the entire 6,725-acre land area is comprised of roadway impervious surfaces. The SEMCOG parcel data identify major roadways as potential opportunities for increasing green infrastructure in the Malletts Creek subwatershed (Figure 36).

Roadway type affects the applicability of different green infrastructure practices within the ROW. Within the Malletts Creek subwatershed, roadway types include interstates (e.g., I-94), arterial and collector roads (e.g., State Street, Ann Arbor–Saline Road, Eisenhower Parkway), local and residential streets, and alleys. Roads—including those under the jurisdiction of the City of Ann Arbor, the Washtenaw County Road Commission, and the Michigan Department of Transportation (MDOT)—represent 650 acres, or more than one-quarter, of the total impervious surface area of 2,351 acres in the Malletts Creek subwatershed.

Open spaces within the road ROW represent potential opportunities to increase green infrastructure, depending on the array of site-specific factors. In addition to the *Low Impact Development Manual for Michigan*, the *Green Streets Guidebook: A Compilation of Road Projects Using Green Infrastructure* also provides information on suitable practices for use on road ROWs (SEMCOG 2008, 2013). Recommended BMPs include bioretention, permeable pavement, bioswales, and native plant grow zones.

As with institutional properties, the benefits of green infrastructure across all catchments in the Malletts Creek subwatershed (both constructed practices and the use of grow zones) can be estimated using the level of implementation curves (see Figure 24 and Figure 25). The screening analysis guided by spreadsheet methods (e.g., the Site Development Stormwater Tool) can be used to account for site-specific design adjustments appropriate to each location (see Figure 23 for an example).

In addition to recognizing the significant percentage of HSG D soils in the Malletts Creek subwatershed, continuing to address local roads should be an integral part of green infrastructure implementation efforts in the subwatershed. Green infrastructure practices recommended for the roadways already have been successfully implemented in the Ann Arbor area (e.g., Miller Avenue).

Table 12. Malletts Creek subwatershed road ROW land cover

Jurisdiction	**Area** *(acres)*	**Pavement** *(acres)*	**Pervious Area** *(acres)*	
			Open	***Tree Canopy***
Local	871	*479*	*163*	*229*
Washtenaw County	137	*77*	*49*	*11*
MDOT	228	*94*	*71*	*63*
TOTAL	1,236	*650*	*283*	*303*

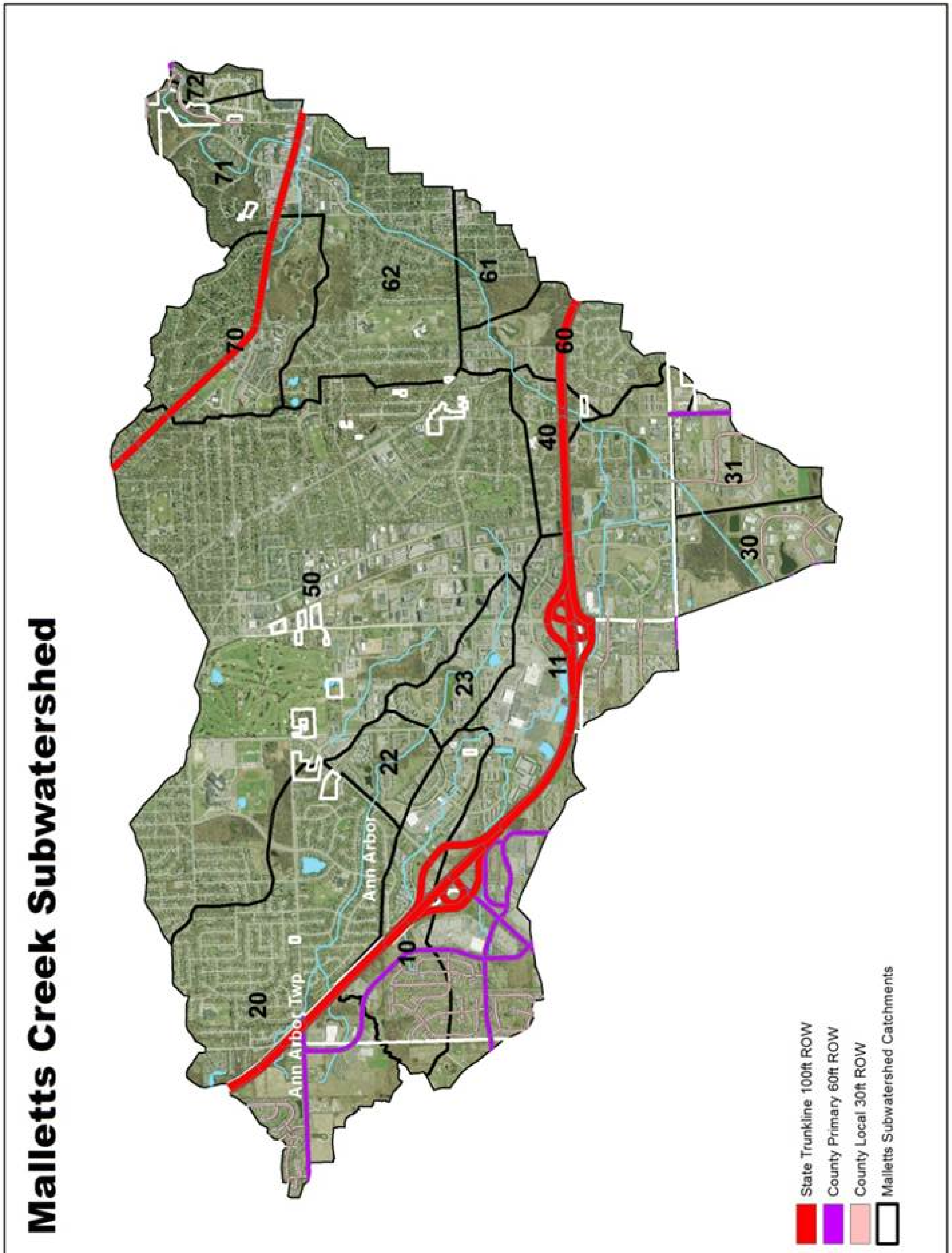


Figure 36. Road ROWs—Malletts Creek subwatershed.

Parking Lots

Publicly and privately owned parking lots comprise a significant percentage of all impervious surfaces in the Malletts Creek subwatershed. The SEMCOG parcel data identify priority parking lots for increasing green infrastructure in the subwatershed (Figure 37): one institutional parking lot (in catchment 50) and three privately owned parking lots (two in catchment 11 and one in catchment 23). Recommended BMPs include bioretention, infiltration trenches, pervious pavement, and increasing tree canopy.

As noted in Figure 33, catchment 11 is located in group A (Briarwood) and is a high-priority area for green infrastructure implementation to reduce stormwater volume in the Malletts Creek subwatershed. It is recommended as a high-priority area based on both the amount and density of impervious cover. Commercial land use dominates total impervious cover in the area and is one reason implementing green infrastructure for the two priority parking lots could be an important component in reducing stream flashiness in Malletts Creek. Incorporating stormwater volume reduction practices into the priority parking lots would represent a major step towards addressing the 860-acre target of effective impervious cover to be managed using green infrastructure in this pilot subwatershed.

Similar to the discussion of institutional properties earlier in this section, the benefits of green infrastructure across all catchments in the Malletts Creek subwatershed can be estimated using the level of implementation curves (Figure 24 and Figure 25) included in this report. The screening analysis (e.g., Figure 23) is based on spreadsheet methods (e.g., Site Development Stormwater Tool) and can be used to account for site-specific design adjustments appropriate for each location.

4.1.6 Pilot Watershed Summary

The Malletts Creek subwatershed assessment illustrates the value of the outcome-based strategic planning framework to determine the role green infrastructure can play in working towards WQS attainment by addressing documented stormwater problems. The pilot assessment describes overall existing conditions related to flashiness in the subwatershed (Figure 29). The amount of impervious cover that needs to be managed to achieve the stream flashiness goal is identified (Figure 30). Land use/land cover detail is provided in the form of maps (Figure 28 and Figure 32) and tables (Table 8, Table 9, and Table 10). Priority catchments are defined using impervious cover composition and density information (Figure 33). Recommendations are summarized based on areas emphasized in SEMCOG's *Green Infrastructure Vision for Southeast Michigan* (SEMCOG 2014).

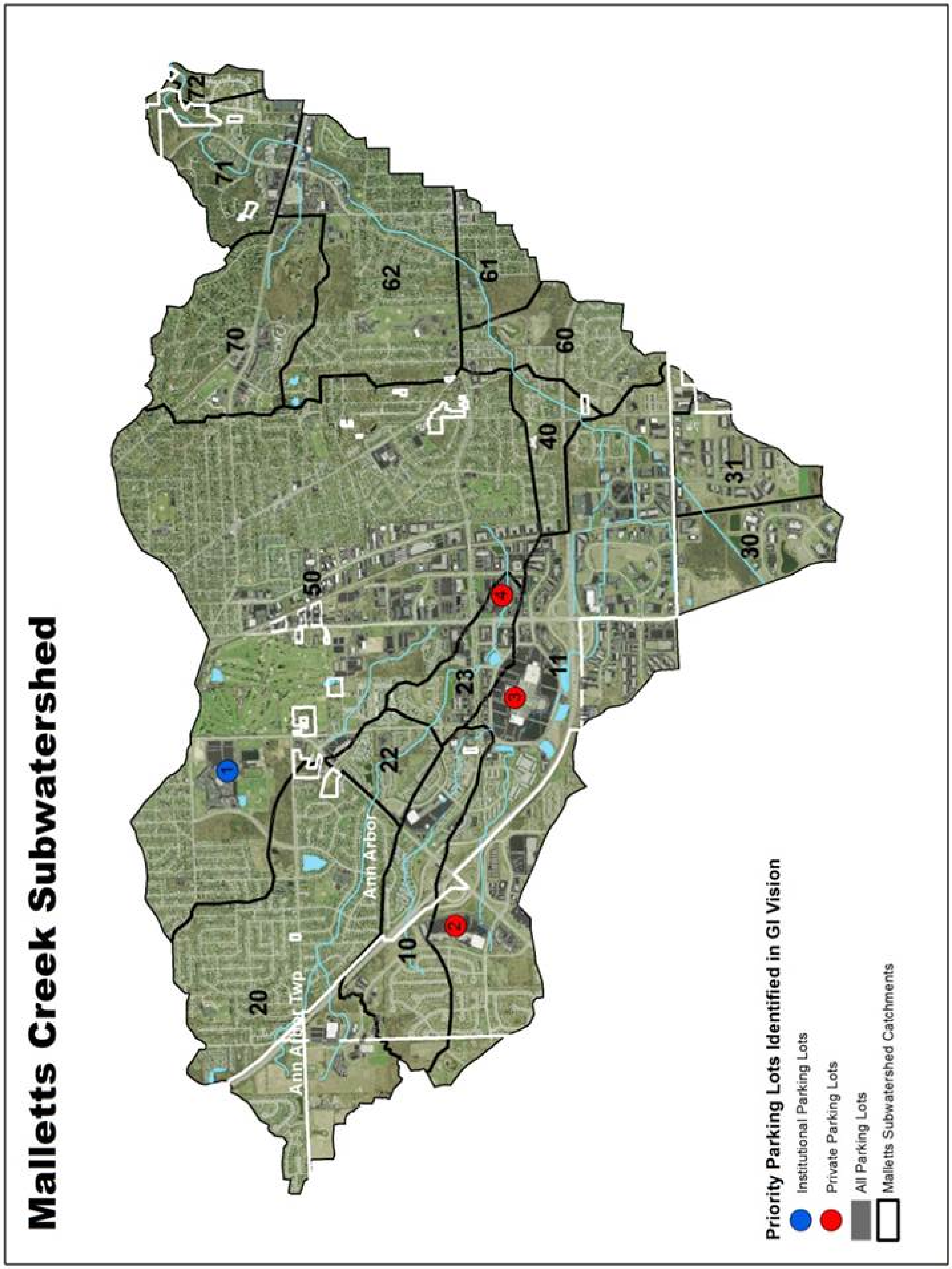


Figure 37. Priority parking lots in Green Infrastructure Vision—Malletts Creek subwatershed.

4.2 Plumbrook Drain Subwatershed

The Plumbrook Drain subwatershed is a tributary to Red Run, which flows into the Clinton River near Utica (Figure 38). It consists of two HUC-12s (04090003-1218 and 04090003-1219) for a combined drainage area of 23.8 square miles. SEMCOG communities located within the Plumbrook Drain subwatershed include the City of Sterling Heights and Shelby Township in Macomb County, and the cities of Rochester Hills and Troy in Oakland County.

Plumbrook Drain is a designated county drain in both Oakland and Macomb counties. Planning efforts in the Clinton River watershed are widespread with a goal of reducing "runoff impacts through sustainable stormwater management" (R2W SWAG 2006, p. xxi). Additionally, degradation of fish and wildlife populations and the habitats that support them are identified as beneficial use impairments within the Clinton River Area of Concern. More specifically, Plumbrook Drain was identified as one of the most impaired reaches for habitat and wildlife populations.

Given this high priority for addressing both habitat and fish and wildlife populations, an analysis of green infrastructure target setting and opportunities will help support strategic implementation. Green infrastructure implementation will reduce stormwater runoff and ultimately stream flashiness to work towards removing the habitat and wildlife population beneficial use impairments.

As a starting point, evaluating the extent of land use and land cover based on delineated catchments enabled the study to identify and prioritize areas of opportunity. Working with MDEQ, catchments were defined, as shown in Figure 39.

4.2.1 Land Use and Land Cover

Land use and land cover information inventoried by SEMCOG can be used to develop subwatershed-scale runoff estimates that reflect the mix of different land uses present across the Plumbrook drainage. The SEMCOG inventory provides impervious cover estimates based on an evaluation of parcel-scale data, including building footprints, parking lot locations, and transportation corridors.

The SEMCOG land use information for the Plumbrook Drain subwatershed is shown in Figure 40 and summarized by catchment in Table 13. The primary land use type in the Plumbrook Drain subwatershed is single-family residential housing, covering approximately 47 percent of the entire drainage. This subwatershed also is home to several large industrial facilities along the Van Dyke transportation corridor, including Chrysler and Ford assembly plants.

The Table 13 summary highlights land use categories in each catchment that exceed the subwatershed average, which is a useful indicator in targeting priority areas for green infrastructure planning. Another way to view SEMCOG's land use data is by examining land cover patterns for each category (Table 14). In addition to supporting development of subwatershed-scale runoff estimates, information presented in this manner helps identify implementation options.

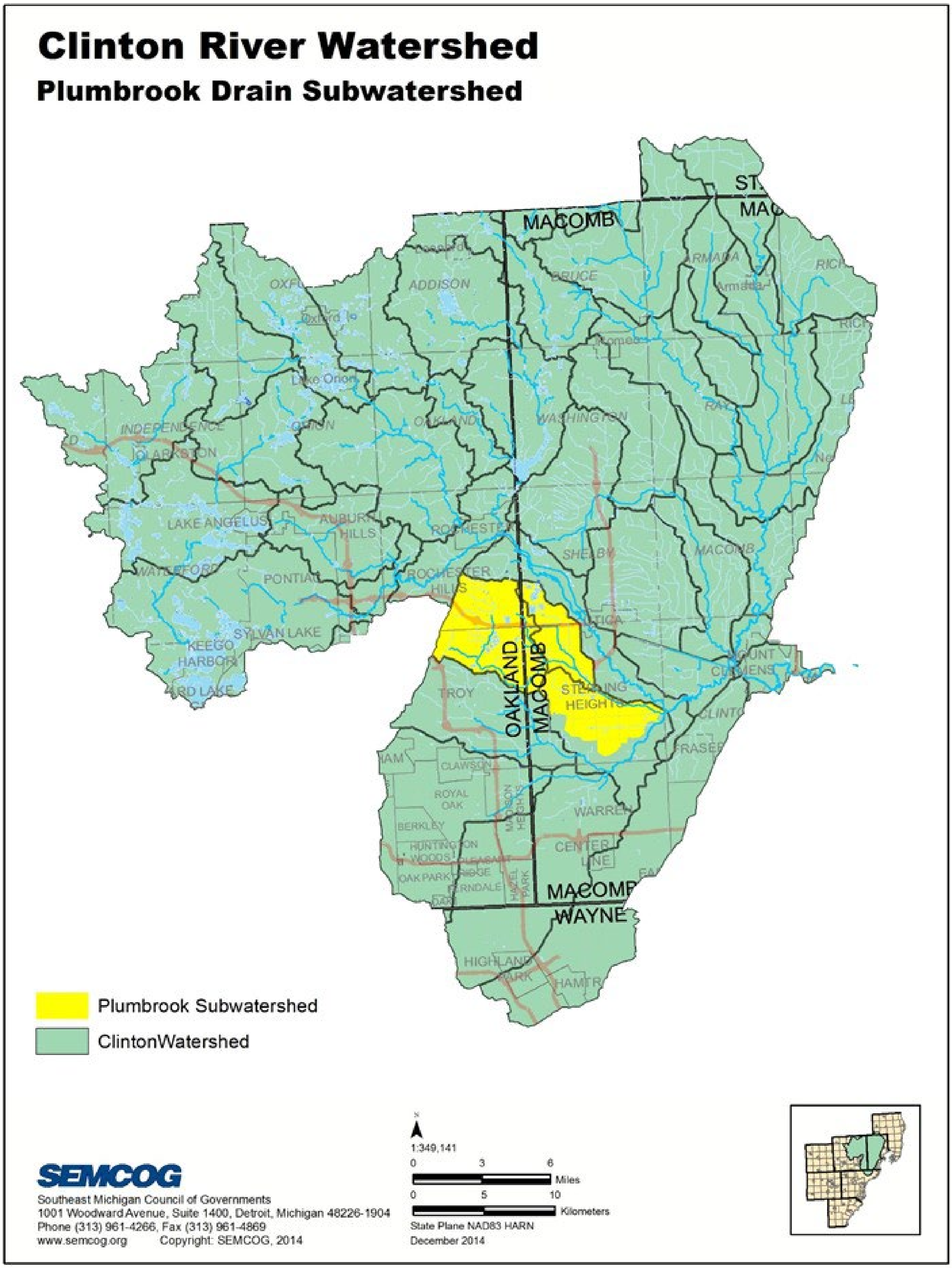


Figure 38. Location of Plumbrook Drain pilot subwatershed within Clinton River watershed.

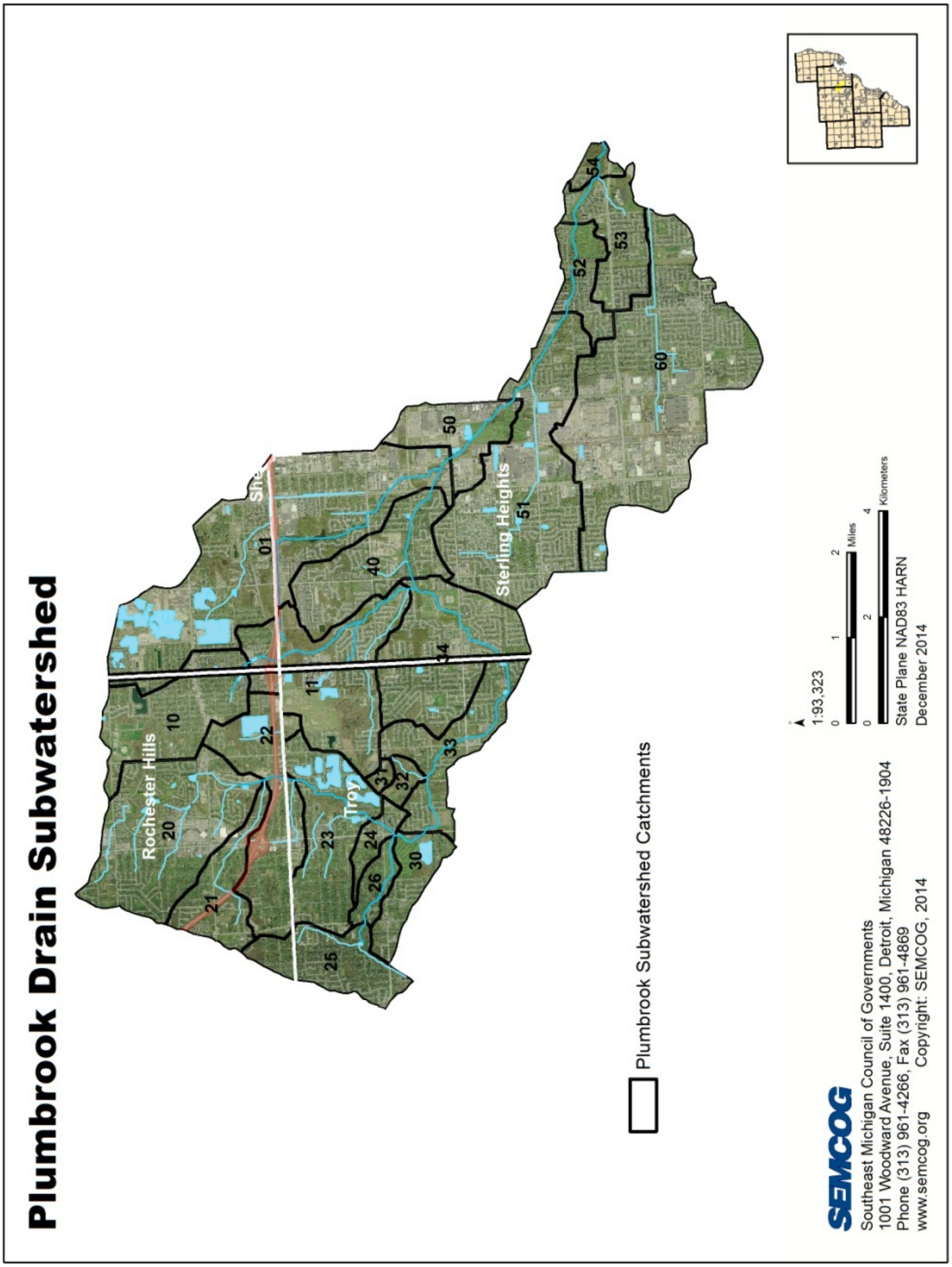


Figure 39. Aerial imagery of catchment boundaries—Plumbrook Drain subwatershed.

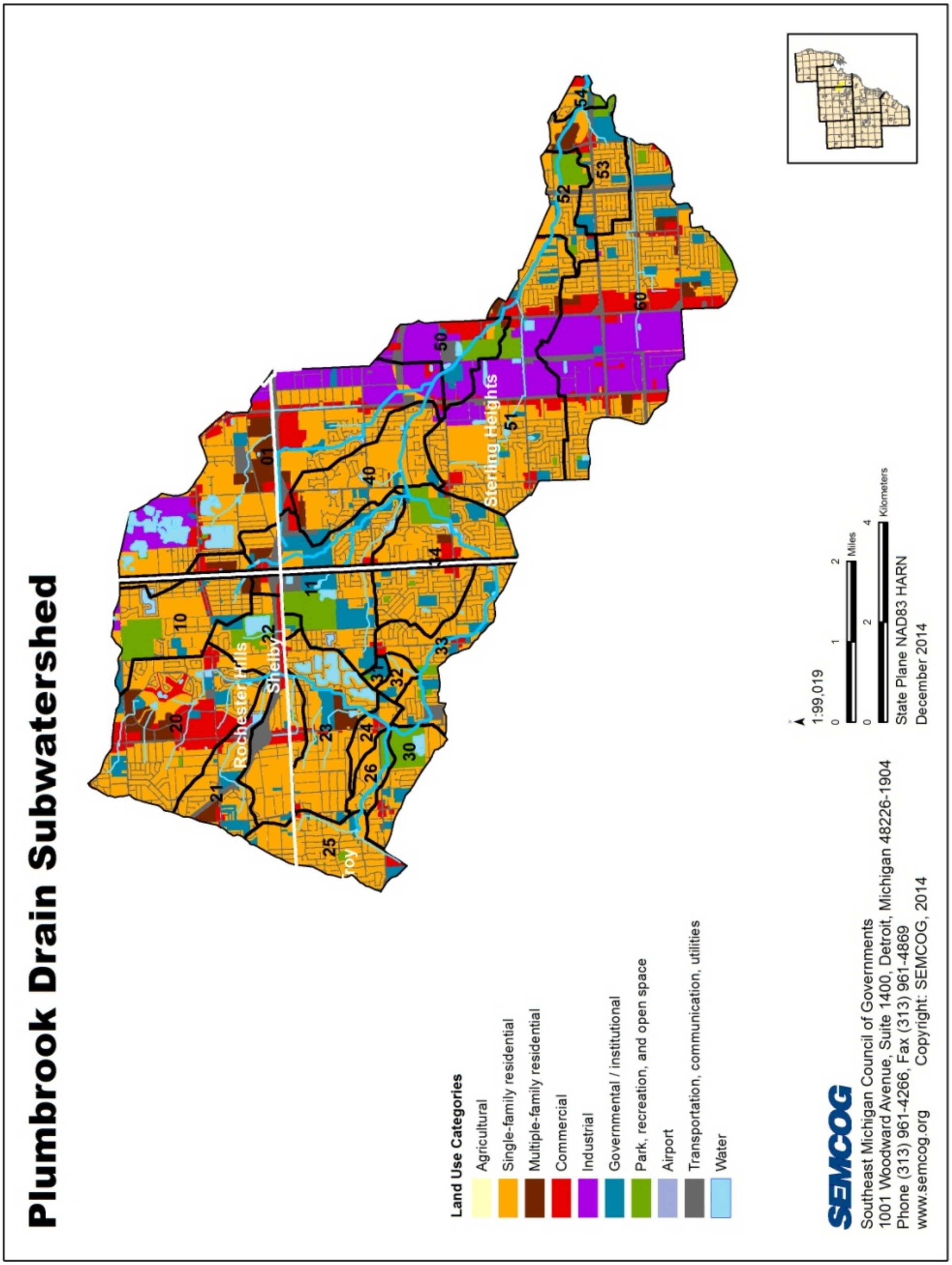


Figure 40. Land use—Plumbrook Drain subwatershed.

Table 13. Plumbrook Drain subwatershed land use

Catchment Group / Catchment ID		Area *(acres)*	Land Use *(percent)*								Total Impervious Area *(percent)*
			Single-family Residential	*Multifamily Residential*	*Commercial*	*Institutional*	*Industrial*	*Road ROW*	*Parks, Open*	*Other*	
A	**01** – *Chrissman Drain*	3,050	39%	6%	10%	2%	20%	16%	0%	7%	35%
B	**10/11** – *Dequindre*	2,494	43%	4%	4%	17%	1%	17%	13%	2%	29%
C	**20/21/22** – *Upper Gibson*	3,318	51%	5%	14%	6%	---	19%	3%	2%	34%
	23/24 – *Square Lake*	1,185	65%	5%	2%	7%	---	13%	0.3%	7%	27%
	25/26 – *Gibson Tributary*	885	71%	---	2%	6%	---	14%	6%	0.1%	27%
D	**30/31/32/33** – *Middle Gibson*	1,386	58%	---	2%	12%	---	15%	11%	2%	26%
	34 – *Lower Gibson*	1,343	60%	1%	4%	7%	---	16%	10%	2%	36%
E	**40** – *Plum below Gage*	970	72%	2%	1%	7%	1%	16%	---	1%	32%
F	**50** – *Plum/Van Dyke*	586	2%	1%	15%	7%	41%	17%	15%	1%	49%
	51 – *Plum/Dodge Park*	2,169	47%	1%	7%	4%	20%	17%	3%	1%	46%
	52/53/54 – *Lower Plum*	1,173	46%	4%	3%	13%	---	21%	12%	---	32%
G	**60** – *Canterbury*	3,066	32%	3%	11%	5%	27%	20%	1%	0.2%	51%
	TOTAL	**21,625**	**47%**	**3%**	**7%**	**7%**	**10%**	**17%**	**5%**	**2%**	36%

Note: **Yellow highlighted cells** identify land use categories in each catchment that exceed the subwatershed average.

Table 14. Plumbrook Drain subwatershed land cover by land use category

Land Use Category	Area *(acres)*	Impervious Surface Types		Pervious Area	
		Building	***Pavement*** *(road surface, parking, driveways, sidewalks)*	***Open***	***Tree Canopy***
Single-family residential	10,257	*13%*	*14%*	*38%*	*35%*
Multifamily residential	675	*17%*	*34%*	*26%*	*23%*
Commercial	1,620	*13%*	*46%*	*26%*	*15%*
Institutional	1,577	*6%*	*23%*	*41%*	*31%*
Industrial	2,157	*23%*	*37%*	*32%*	*8%*
Road ROWs	3,716	*0.4%*	*55%*	*33%*	*11%*
Parks, Open Space	1,125	*1%*	*9%*	*62%*	*28%*
Other	498	*1%*	*74%*	*19%*	*6%*
TOTAL	21,625	*11%*	*29%*	*36%*	*25%*

4.2.2 Existing Conditions Related to Flashiness

Flooding and water quality problems in the Plumbrook Drain subwatershed have been well documented (R2W SWAG 2006). Existing flow conditions are best described as unstable and flashy in response to storm events. Figure 41 shows daily average flows monitored over a 3-month period at the USGS gage on Plumbrook Drain. It illustrates the rapid rise and fall in flow as Plumbrook Drain responds to different rain events (shown across the top of Figure 41).

Based on USGS data, R-B Index values in Plumbrook Drain at the gage location currently exceed 0.56 (see Table 4). The focus of the pilot subwatershed opportunity assessment was to examine green infrastructure implementation options that could reduce stream flashiness in Plumbrook Drain to a target range of 0.35 to 0.50 as measured by the R-B Index.

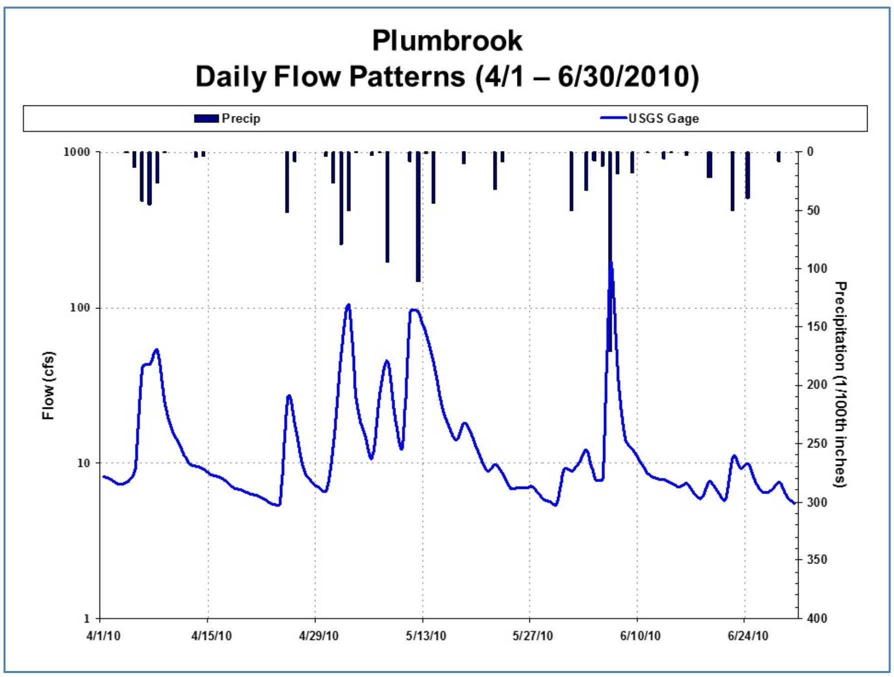


Figure 41. Daily average streamflow patterns Plumbrook Drain (4/1–6/30/2010).

4.2.3 Stormwater Runoff Reduction Targets

The LSPC screening analysis offers a method to evaluate subwatershed-scale runoff patterns in the context of current land use information. R-B Index estimates based on local meteorological information and the SEMCOG land cover data were used to benchmark existing conditions for relative comparison with different green infrastructure implementation strategies. This included identifying the impervious cover that would need to be managed to meet the target R-B Index range. Figure 42 presents the screening analysis results. The box in the upper left of the graph points to the estimated baseline effective impervious cover that corresponds to current Plumbrook Drain R-B Index values at the USGS gage site.

The screening analysis shown in Figure 42 assumed baseline conditions when examining the change in R-B Index values as effective impervious cover is varied across the Plumbrook Drain subwatershed. Again, *effective* impervious cover is less than the *total* impervious cover reported in Table 13, which acknowledges the fact that not all impervious surface runoff reaches the stream. The baseline curve assumes that no other green infrastructure opportunities are used. Under this scenario, effective impervious cover would need to be reduced to approximately 11 percent using green infrastructure to meet the upper R-B Index target (i.e., 0.50).

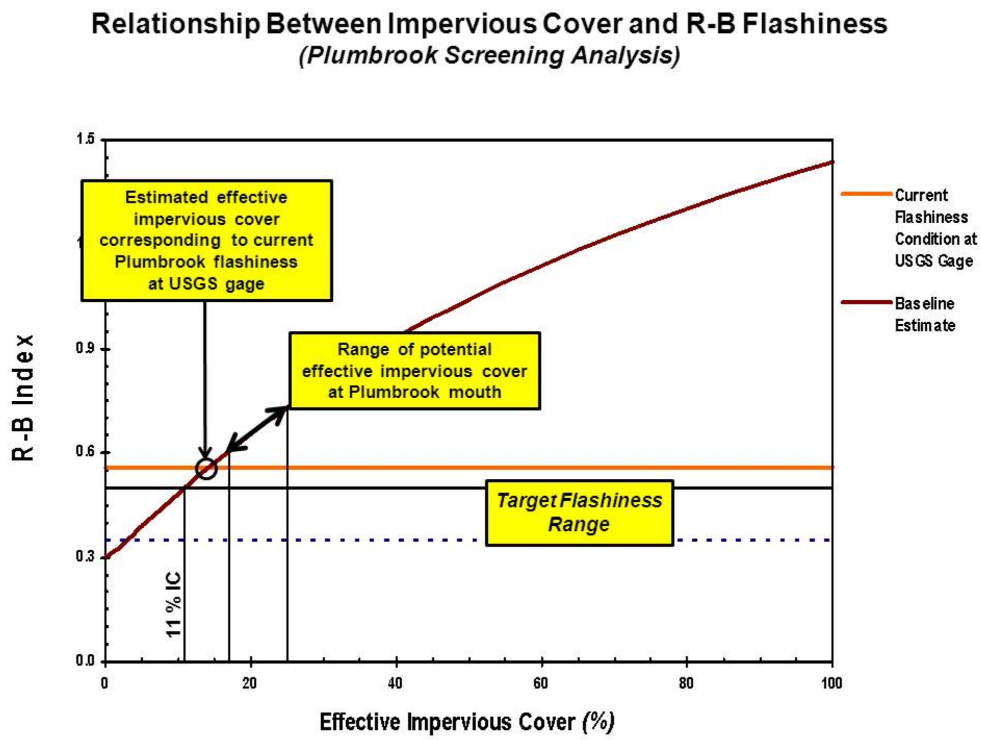


Figure 42. Plumbrook Drain subwatershed effective impervious cover and R-B flashiness screening analysis.

One item is important to note: The total impervious cover of the drainage area upstream of the USGS gage is less than the total impervious cover across the entire subwatershed; the latter would be reflected in R-B Index values at the mouth of Plumbrook Drain. In addition, the mix of land use and impervious surface types is different between the two locations. There is a higher percentage of residential land use above the USGS gage and more industrial/commercial land use with more parking lots below the gage.

An estimated range of potential effective impervious cover at the mouth of Plumbrook Drain is shown in Figure 42. This range is intended to address uncertainties associated with differences in land use/impervious surface types between the two locations. The range shown in Figure 42 is based on estimated ratios between effective impervious cover and total impervious cover derived from the SEMCOG land cover data and USGS flow data examined for this project.

To account for the array of uncertainties (e.g., differences in land use/impervious surface types, background infiltration rate assumptions), planners can estimate the amount of impervious area that needs to be managed for stormwater using green infrastructure in priority catchments (as shown below).

4.2.4 Areas of Opportunity and Priorities

The *Green Infrastructure Vision*, which sets out a direction for southeast Michigan based on regional policy recommendations and stakeholder input, was the basis for SEMCOG developing green infrastructure vision maps (SEMCOG 2014). The vision for the Plumbrook Drain subwatershed is shown in Figure 43. The map shows the following classifications: Potential Green Streets on state-owned roadways, Conservation & Recreation Lands (current and potential), Current Green Infrastructure, GI Opportunities: Institutional Land, and GI Opportunities: Parking Lots.

The SEMCOG land cover data provides a starting point from which to describe opportunities (Figure 44). An important aspect is identifying potential impervious surface types that could be managed for stormwater using green infrastructure. Within the Plumbrook Drain pilot subwatershed, pavement (e.g., roads, parking lots, driveways, and so forth) represents more than 70 percent of all impervious surface types (Table 15).

In terms of priority areas, in the catchment along Van Dyke (catchment 50), industrial land use comprises more than 40 percent of the area with at least 49 percent impervious cover. The extent of impervious cover in this industrial setting presents numerous opportunities for strategic partnerships to reduce runoff to the local stormwater infrastructure discharging to Plumbrook Drain. In addition, SEMCOG's *Green Infrastructure Vision* further highlights the numerous large parking lots as potential opportunities for green infrastructure implementation in addition to increasing tree canopy coverage within the City of Sterling Heights (SEMCOG 2014).

The land use/land cover inventory data compiled by SEMCOG provides detailed information that can be used to identify priority areas. Figure 45 summarizes the impervious surface composition for catchment groups in the Plumbrook Drain subwatershed. The 22 catchments in Figure 39, Figure 40, and Table 13 have been clustered into A through G, shown in Figure 45. The number behind each letter on the x-axis represents the first digit of those catchment identifiers, which have been clustered in that particular group (e.g., catchments 10 and 11 into group B, catchments 20 through 26 into group C, and so forth).

Table 15. Plumbrook Drain subwatershed impervious cover estimates by surface type

Catchment Group / Catchment ID		Area *(acres)*	Total Impervious Area *(acres)*	Percent of Total Impervious Area (*percent*)			Tree Canopy *(percent)*
				Building	***Road***	***Other Pavement***	
A	**01** – *Chrissman Drain*	3,050	1,081	*28%*	*24%*	*48%*	27%
B	**10/11** – *Dequindre*	2,494	734	*23%*	*29%*	*48%*	33%
C	**20/21/22** – *Upper Gibson*	3,318	1,143	*22%*	*30%*	*48%*	30%
	23/24 – *Square Lake*	1,185	316	*26%*	*30%*	*44%*	35%
	25/26 – *Gibson Tributary*	885	240	*23%*	*35%*	*42%*	38%
D	**30/31/32/33** – *Middle Gibson*	1,386	362	*24%*	*35%*	*41%*	38%
	34 – *Lower Gibson*	1,343	477	*32%*	*32%*	*46%*	24%
E	**40** – *Plum below Gage*	970	311	*36%*	*27%*	*37%*	19%
F	**50** – *Plum/Van Dyke*	586	289	*29%*	*15%*	*56%*	11%
	51 – *Plum/Dodge Park*	2,169	991	*33%*	*22%*	*45%*	14%
	52/53/54 – *Lower Plum*	1,173	370	*34%*	*31%*	*35%*	19%
G	**60** – *Canterbury*	3,066	1,560	*35%*	*20%*	*45%*	10%
	TOTAL	21,625	7,874	*29%*	*26%*	*45%*	25%

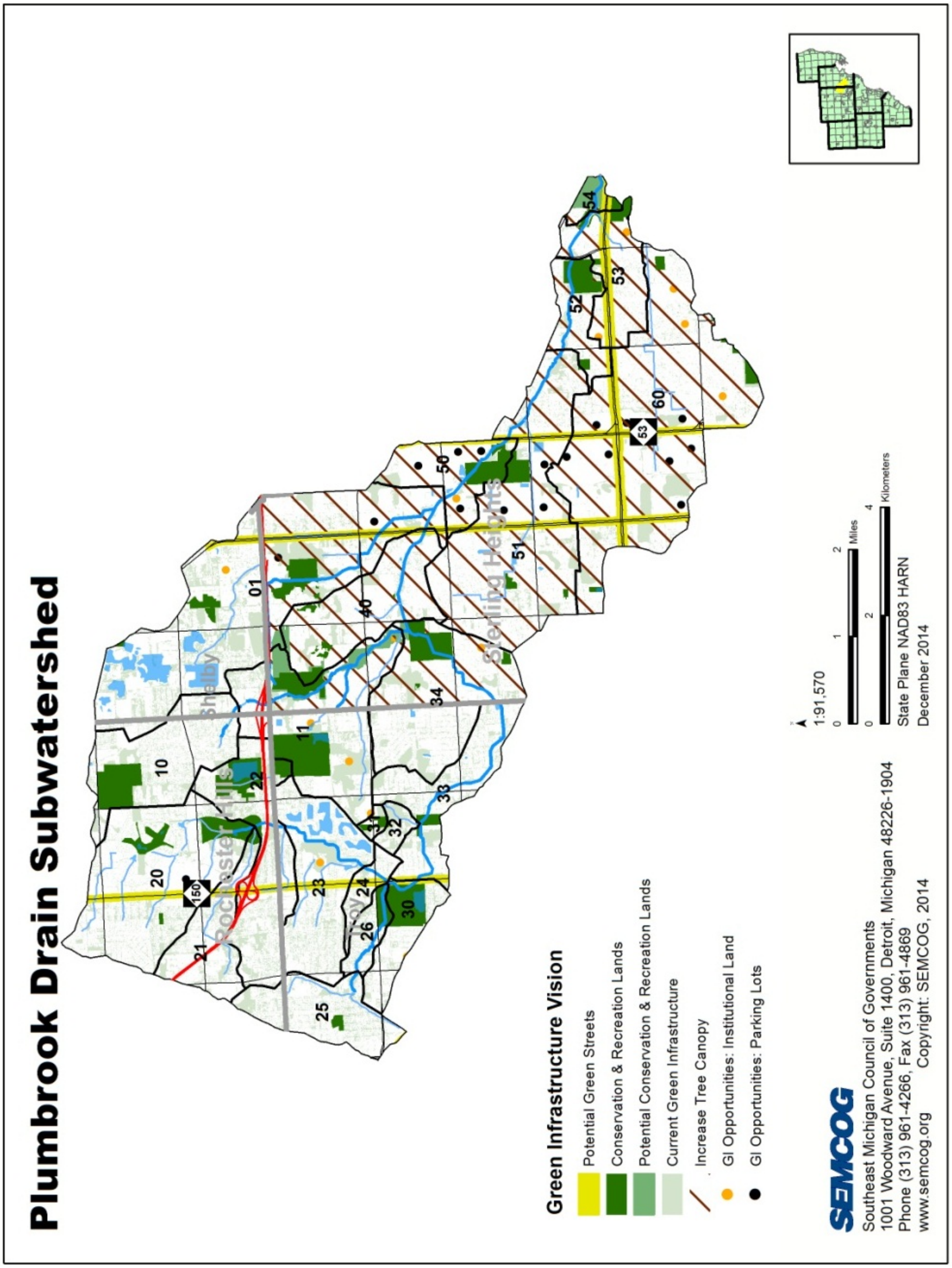


Figure 43. Green Infrastructure Vision—Plumbrook Drain subwatershed.

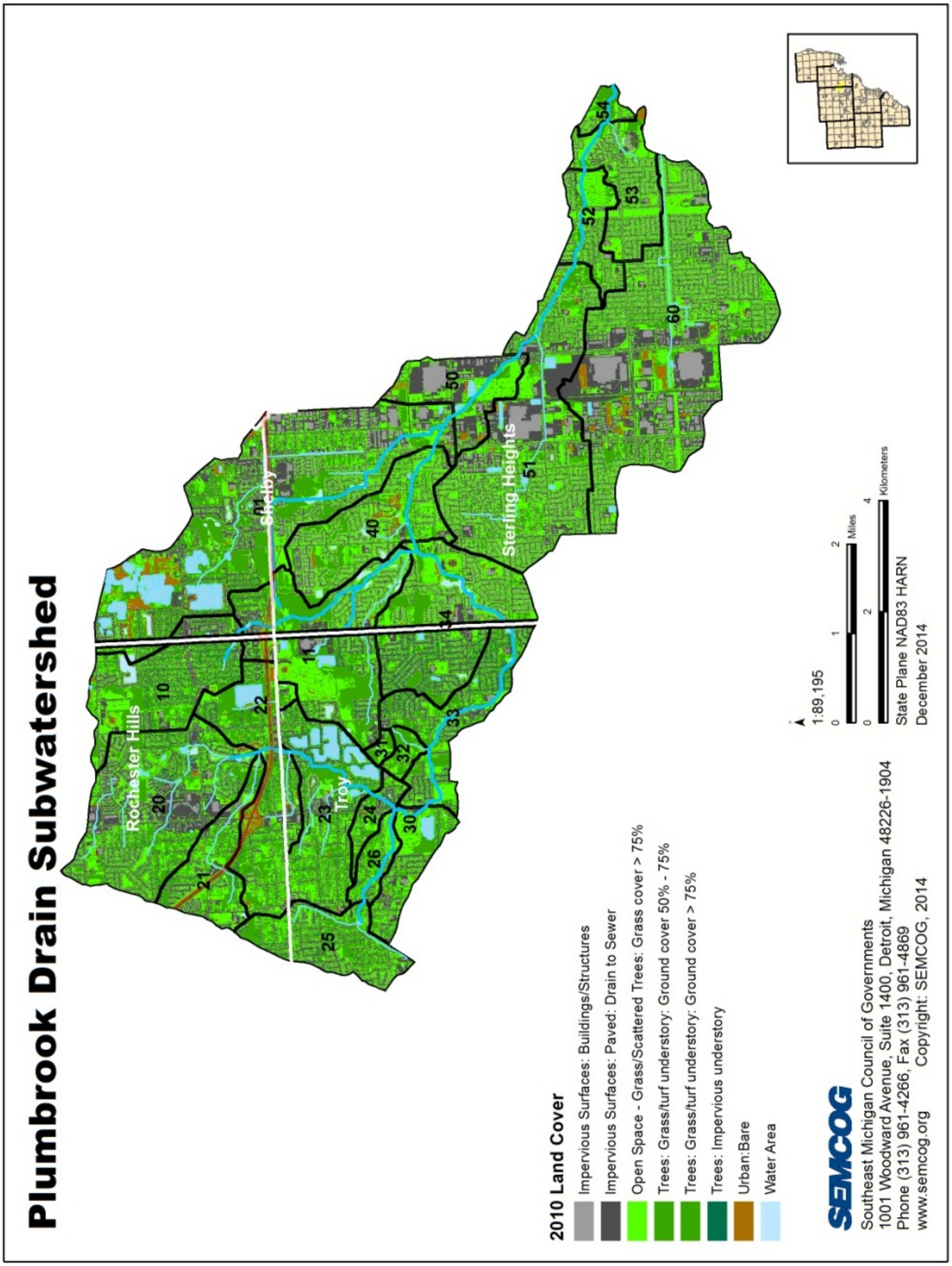


Figure 44. Land cover—Plumbrook Drain subwatershed.

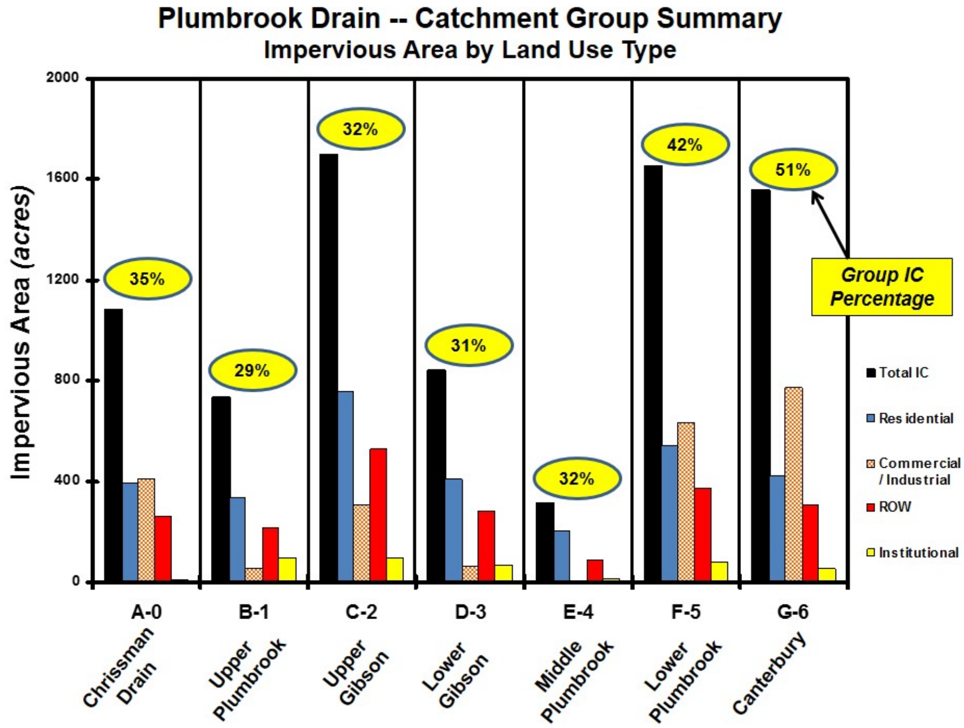


Figure 45. Impervious surface composition—Plumbrook Drain subwatershed.

Figure 45 conveys two types of information useful for targeting green infrastructure implementation efforts: the quantity of impervious area and the density of impervious cover in each catchment group. The quantity aspect identifies groups that contain the higher amounts of total impervious area. In the Plumbrook Drain subwatershed, those are catchment groups C (Upper Gibson), F (Lower Plumbrook), and G (Canterbury). The value in the oval for each group represents the percent impervious cover (or the density aspect). The combination of both aspects points to Lower Plumbrook and Canterbury as high priorities for targeting green infrastructure, which does not mean that green infrastructure in other groups is less important. Instead, it highlights the fact that managing impervious cover in these groups must play a major role in reducing stream flashiness in the Plumbrook Drain watershed.

The impervious surface composition shown in Figure 45 provides other useful information for targeting green infrastructure implementation. As indicated, Lower Plumbrook (F) and Canterbury (G) are high-priority groups. The greatest amount of impervious area in those catchments is associated with commercial/industrial land use. The *Green Infrastructure Vision* map (Figure 43) identifies parking lot and green street opportunities. While groups F and G have high amounts of commercial/industrial impervious surfaces, targeting residential areas in other catchments (e.g., Upper Gibson) should play an important role for green infrastructure.

4.2.5 Recommendations

Substantial restoration efforts already have been implemented to address flooding and water quality problems in the Plumbrook Drain subwatershed. To complement the ongoing activities, several recommendations are offered based on an analysis of existing conditions related to flashiness and priorities identified using land use/land cover information. These recommendations follow key components of SEMCOG's *Green Infrastructure Vision* (SEMCOG 2014).

Institutional Properties

Green infrastructure on institutional properties offers several benefits, including a public display of the types of practices suitable for implementation in the local community. Based on SEMCOG's analysis of parcel-level information, more than 1,550 acres of the Plumbrook Drain subwatershed are publicly owned or institutional property (Figure 46). Table 16 details the land cover breakdown of those properties by jursidiction.

Figure 47 highlights the extent of school district property in the Plumbrook Drain subwatershed. School districts can benefit from green infrastructure implementation through construction of schoolyard habitats and native plant grow zones. In addition to the educational value, green infrastructure on school properties can work to reduce long-term maintenance costs by improving drainage and replacing high-maintenance turf with lower-maintenance trees, shrubs, and ornamental grasses.

Pavement represents the highest percentage of impervious surface types on publicly owned properties. Recommended BMPs for these surface types include bioretention, infiltration trenches, pervious pavement, planter boxes, level spreaders, and vegetated swales. The *Low Impact Development Manual for Michigan* also describes the range of design options available to accommodate site-specific situations (SEMCOG 2008). The Site Development Stormwater Tool, which has been applied in Michigan, can be used to guide more parcel-specific screening analyses (similar to that shown in Figure 23) to reflect design configurations appropriate for each location (Christian 2014).

The level of implementation curves shown in Figure 24 and Figure 25 are based on southeast Michigan climate data. The curves provide a general estimate of environmental benefits that could be derived from constructed green infrastructure on institutional properties across all catchments in the Plumbrook Drain subwatershed. While individual opportunities might have unique site constraints, local challenges can be addressed either with enhanced design for constructed practices (e.g., soil amendments, increased BMP treatment capture depth) or by improving the infiltration benefit of pervious areas (e.g., grow zones, increased tree canopy).

Table 16. Plumbrook Drain subwatershed publicly owned property by jurisdiction

Jurisdiction	**Area** *(acres)*	**Impervious Surface Types** *(acres)*		**Pervious Area** *(acres)*	
		Building	***Pavement*** *(parking, driving surfaces, sidewalks)*	***Open***	***Tree Canopy***
City of Rochester Hills	267	*2*	*38*	*106*	*121*
City of Sterling Heights	456	*3*	*50*	*212*	*191*
City of Troy	449	*2*	*38*	*302*	*107*
Macomb County	111	*1*	*9*	*82*	*19*
Oakland County	43	*1*	*7*	*30*	*5*
State of Michigan	17	*0*	*1*	*8*	*8*
School Property	586	*59*	*133*	*312*	*82*
TOTAL	**1,929**	***68***	***276***	***1,052***	***533***

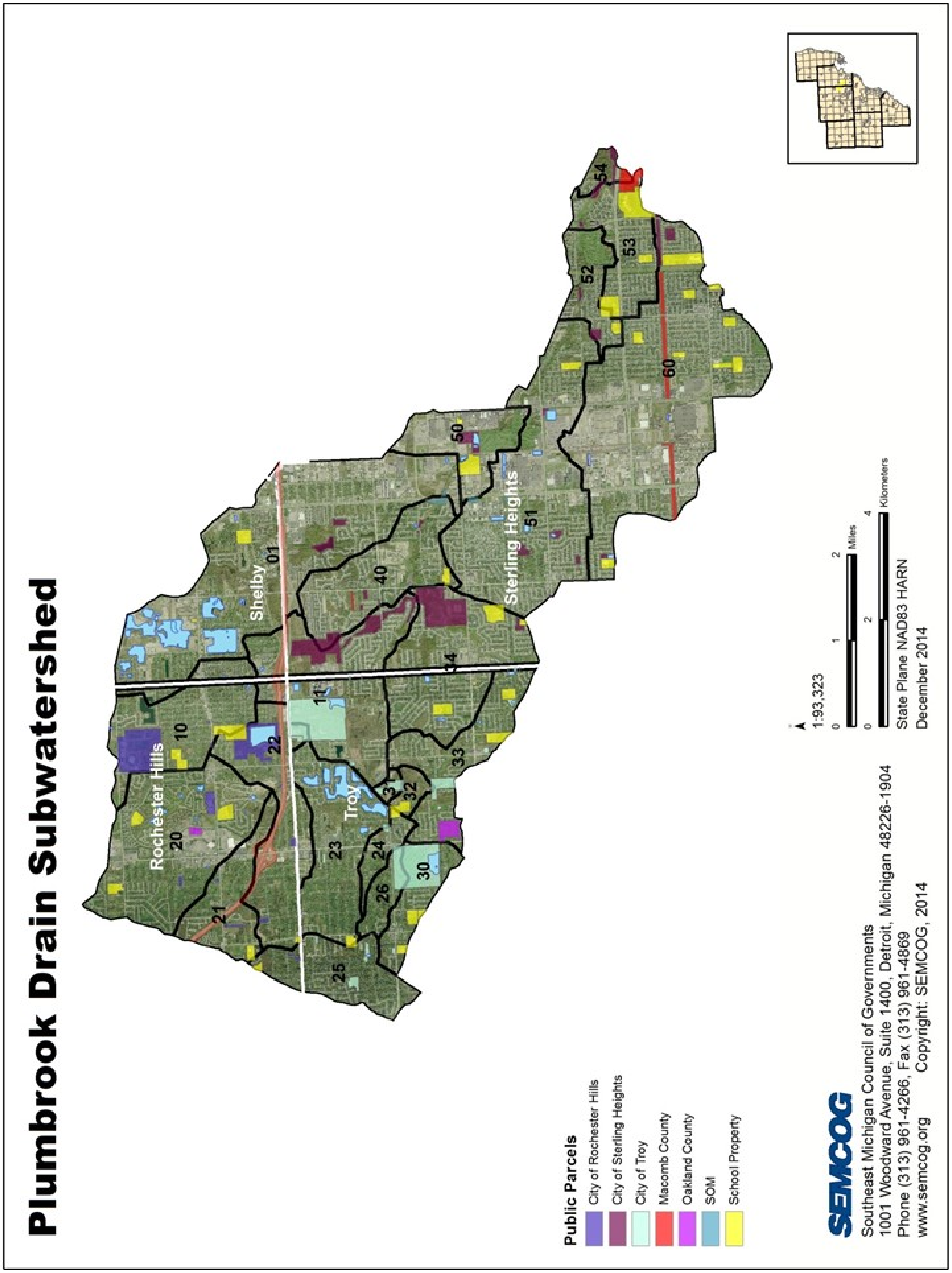


Figure 46. Public parcels—Plumbrook Drain subwatershed.

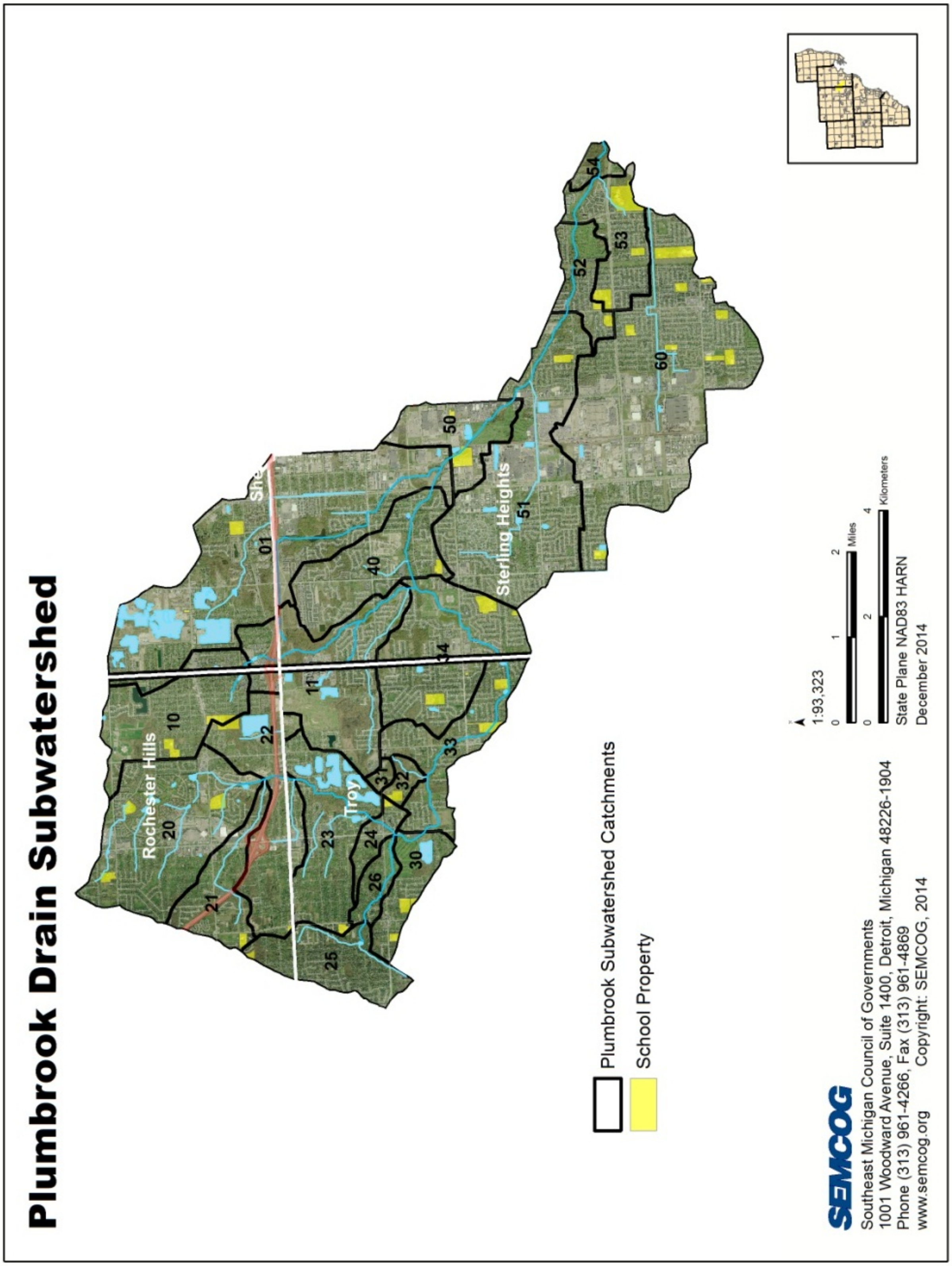


Figure 47. School properties—Plumbrook Drain subwatershed.

Roadways

The aerial imagery and land use displayed on Figure 39 and Figure 40 show the extent of the roadway network in the Plumbrook Drain subwatershed. This information is summarized in Table 17 by general jurisdictional ownership for the Plumbrook Drain subwatershed. As indicated, 10 percent of the entire 21,625-acre land area is comprised of roadway impervious surfaces. The SEMCOG parcel data identify major roadways as potential opportunities for increasing green infrastructure in the subwatershed (Figure 48).

Open spaces within the road ROWs represent potential opportunities to increase green infrastructure, depending on an array of site-specific factors. In addition to the *Low Impact Development Manual for Michigan*, the *Green Streets Guidebook: A Compilation of Road Projects Using Green Infrastructure* also provides information on suitable practices for use on road ROWs (SEMCOG 2008, 2013). Recommended BMPs include bioretention, permeable pavement, bioswales, and native plant grow zones.

Similar to the discussion of institutional properties, the benefits of green infrastructure (both constructed practices and the use of grow zones) across all catchments in the Plumbrook Drain subwatershed can be estimated using the level of implementation curves (Figure 24 and Figure 25). The screening analysis (e.g., Figure 23) guided by spreadsheet methods (e.g., Site Development Stormwater Tool) can be used to account for site-specific design adjustments appropriate for each location.

Table 17. Plumbrook Drain subwatershed road ROW land cover

Jurisdiction	**Area** *(acres)*	**Pavement** *(acres)*	**Pervious Area** *(acres)*	
			Open	***Tree Canopy***
Local	2,536	*1,404*	*820*	*315*
County (Oakland/Macomb)	688	*408*	*218*	*62*
MDOT	492	*238*	*210*	*41*
TOTAL	3,716	*2,050*	*1,248*	*418*

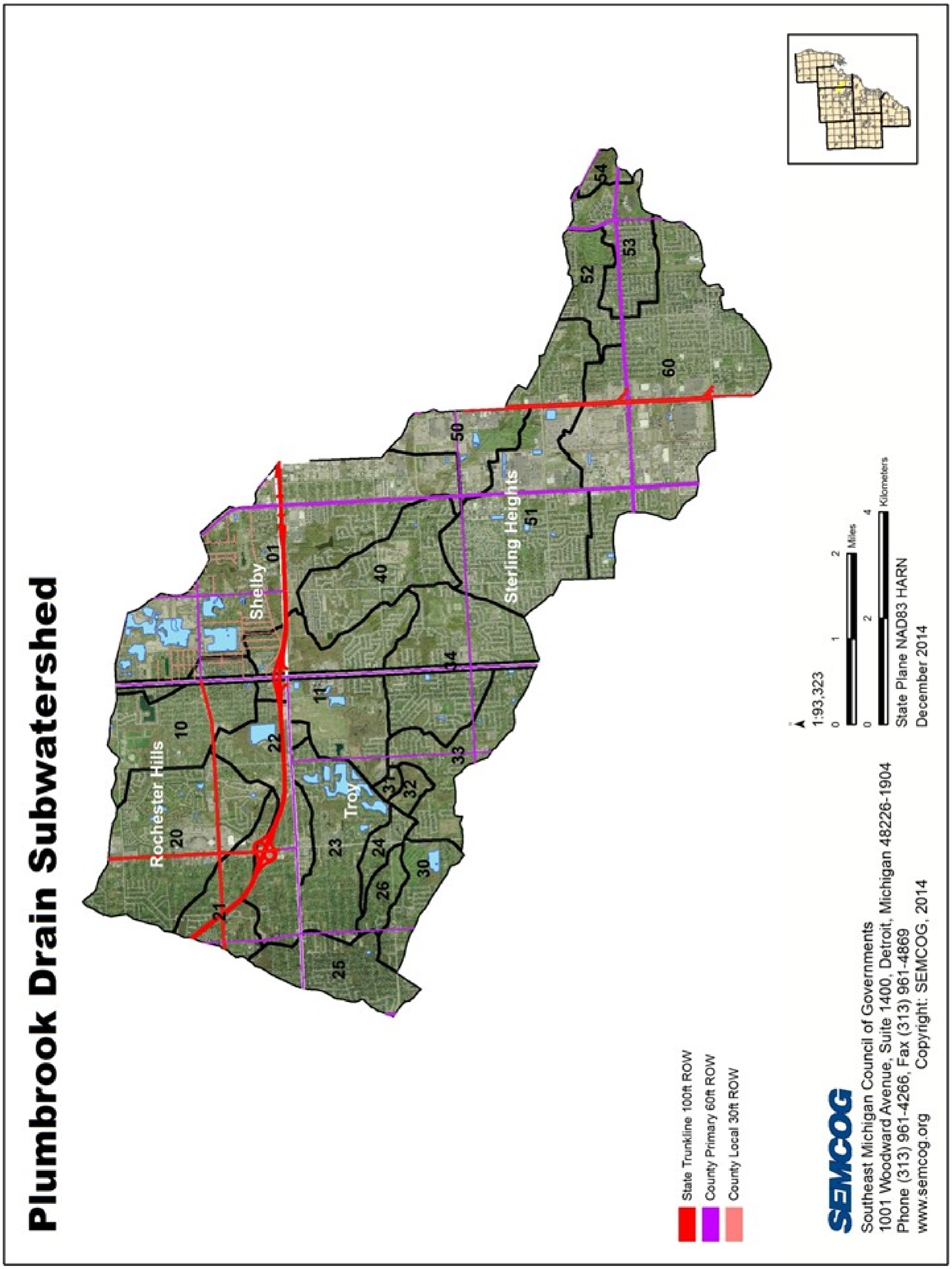


Figure 48. Road ROWs—Plumbrook Drain subwatershed.

Parking Lots

Publicly and privately owned parking lots comprise a significant portion of all impervious surfaces in the Plumbrook Drain subwatershed. The SEMCOG parcel data identify 15 privately owned parking lots that are high priorities for increasing green infrastructure in the Plumbrook Drain subwatershed (Figure 49); most of the privately owned parking lots are located in catchment groups F and G. Recommended BMPs include bioretention, infiltration trenches, pervious pavement, and increasing tree canopy.

As noted in Figure 45, catchment groups F and G are high-priority areas for green infrastructure implementation to reduce stormwater volume in the Plumbrook Drain subwatershed. Those recommended high-priority areas are based on both the amount and density of impervious cover. Commercial/industrial land use dominates total impervious cover in this area and is one reason that green infrastructure implementation for the priority parking lots will be an important component in reducing stream flashiness in Plumbrook Drain. Incorporating stormwater volume reduction practices into the priority parking lots would represent a major step towards reducing the amount of effective impervious cover that needs to be managed using green infrastructure in this pilot subwatershed.

Similar to the discussion of institutional properties earlier in this section, the benefits of green infrastructure across all catchments in the Plumbrook Drain subwatershed can be estimated using the level of implementation curves (Figure 24 and Figure 25) included in this report. The screening analysis (e.g., Figure 23) guided by spreadsheet methods (e.g., Site Development Stormwater Tool) can be used to account for site-specific design adjustments appropriate for each location.

4.2.6 Pilot Watershed Summary

The Plumbrook Drain subwatershed assessment illustrates the value of the outcome-based strategic planning framework to determine the role green infrastructure can play in working towards WQS attainment by addressing documented stormwater problems. The pilot assessment describes overall existing conditions related to flashiness in the subwatershed (Figure 41). The amount of impervious cover that needs to be managed to achieve the stream flashiness goal is identified (Figure 42). Land use/land cover detail is provided in the form of maps (Figure 40 and Figure 44) and tables (Table 13, Table 14, and Table 15). Priority catchments are defined using impervious cover composition and density information (Figure 45). Recommendations are summarized based on areas emphasized in SEMCOG's *Green Infrastructure Vision for Southeast Michigan* (SEMCOG 2014).

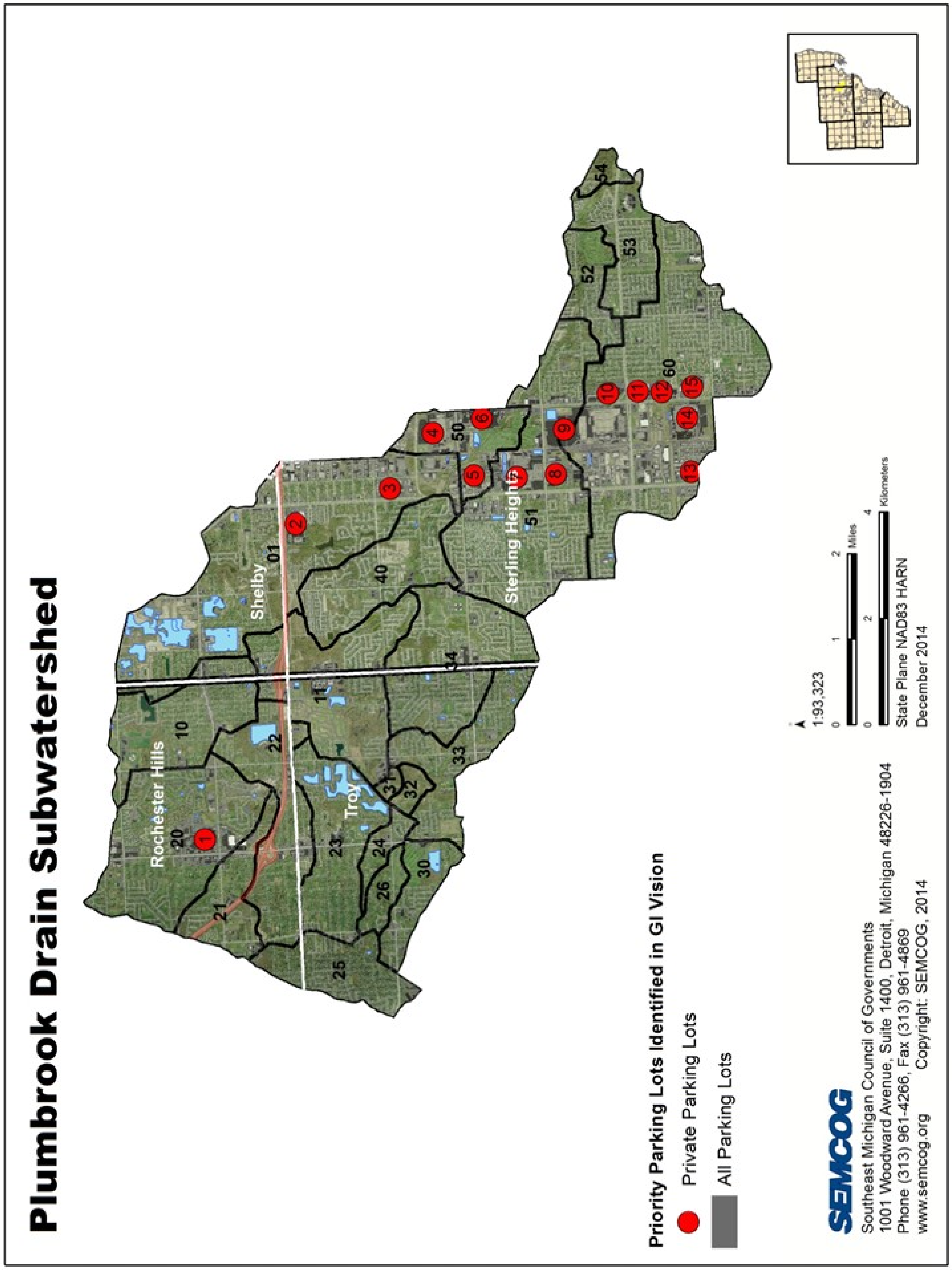


Figure 49. Priority parking lots in Green Infrastructure Vision—Plumbrook Drain subwatershed.

4.3 Tonquish Creek Subwatershed

The Tonquish Creek pilot subwatershed (HUC 04090004-0202), located in Wayne County, is a tributary to the Middle Rouge River, draining an area of approximately 25 square miles (Figure 50). Tonquish Creek and its tributaries flow through the communities of Canton Township, Plymouth Township, and the cities of Livonia, Plymouth, and Westland, entering the Middle Rouge below Nankin Lake.

Tonquish Creek is a headwater tributary of the Rouge River watershed. The dominant land use in the area is single-family residential housing, followed by commercial and industrial areas. The stream's lower reach makes up a large part of the Holliday Nature Preserve.

EPA has approved a TMDL for biota across the entire Rouge River watershed, including Tonquish Creek as an identified impaired stream. The biota target is the reestablishment of fish and macroinvertebrate communities that result in a consistent Acceptable or Excellent rating from P51 (ARC 2012).

Figure 51 shows the catchment boundaries within the Tonquish Creek subwatershed that were used for the green infrastructure screening analyses. Those catchments are used to examine potential stormwater source areas and evaluate BMP implementation opportunities.

4.3.1 Land Use and Land Cover

Land use and land cover information inventoried by SEMCOG can be used to develop runoff estimates that reflect the mix of different land uses present across the Tonquish Creek subwatershed. The SEMCOG inventory includes impervious cover estimates based on evaluation of parcel-scale data, including building footprints, parking lot locations, and transportation corridors.

The SEMCOG land use information for the Tonquish Creek subwatershed is shown in Figure 52 and summarized by catchment in Table 18. The primary land use in the subwatershed is single-family residential housing, which covers approximately 42 percent of the entire drainage area. The subwatershed also contains a number of high-density commercial areas, particularly in the Westland Mall vicinity, along the Ford Road corridor, and around Plymouth.

The Table 18 summary highlights land use categories in each catchment that exceed the subwatershed average, which is a useful indicator in targeting priority areas for green infrastructure planning. Another way to view SEMCOG's land use data is by examining land cover patterns for each category (Table 19). In addition to supporting development of subwatershed-scale runoff estimates, information presented in this manner helps identify implementation options.

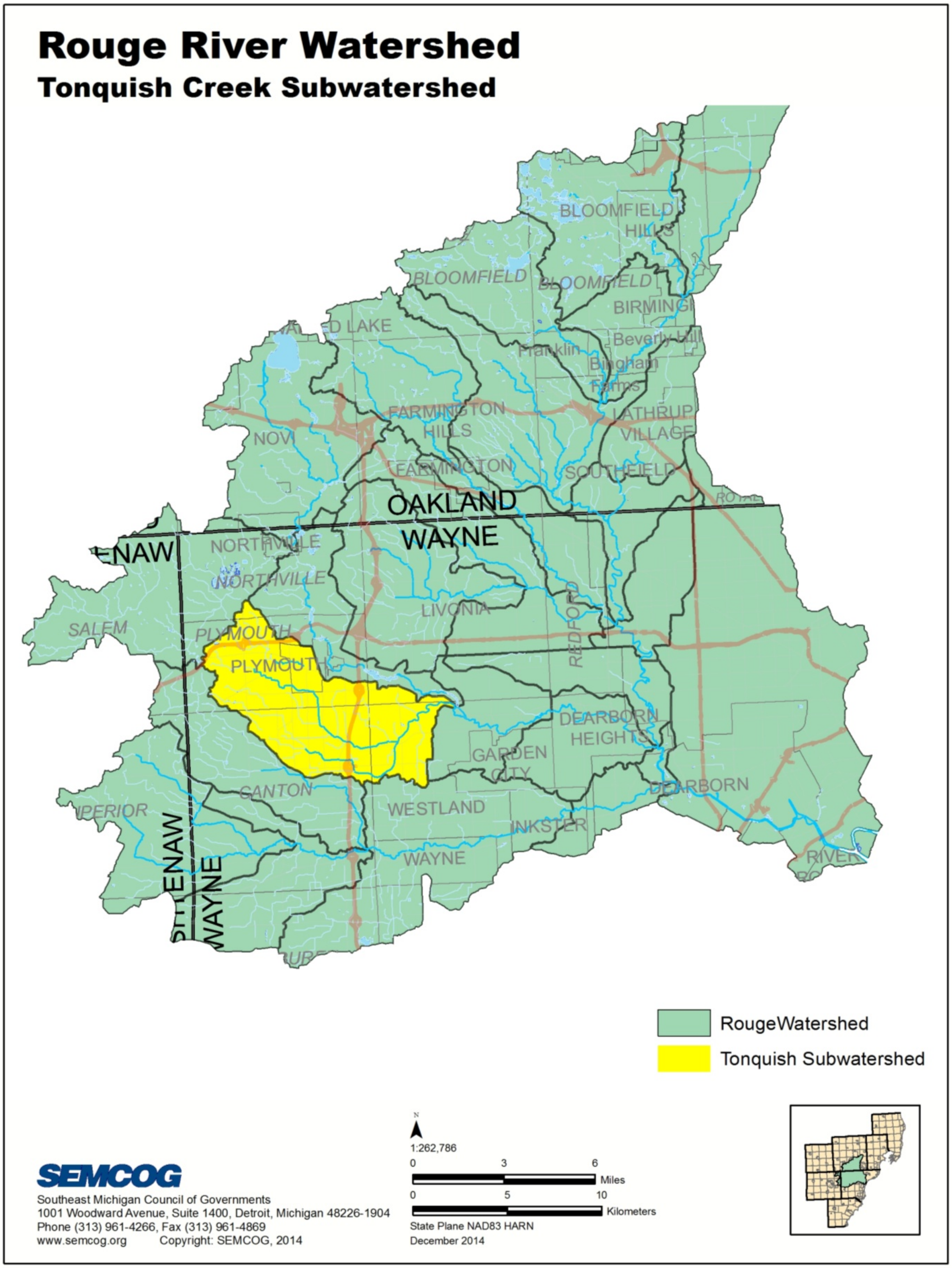


Figure 50. Location of Tonquish Creek pilot subwatershed within River Rouge watershed.

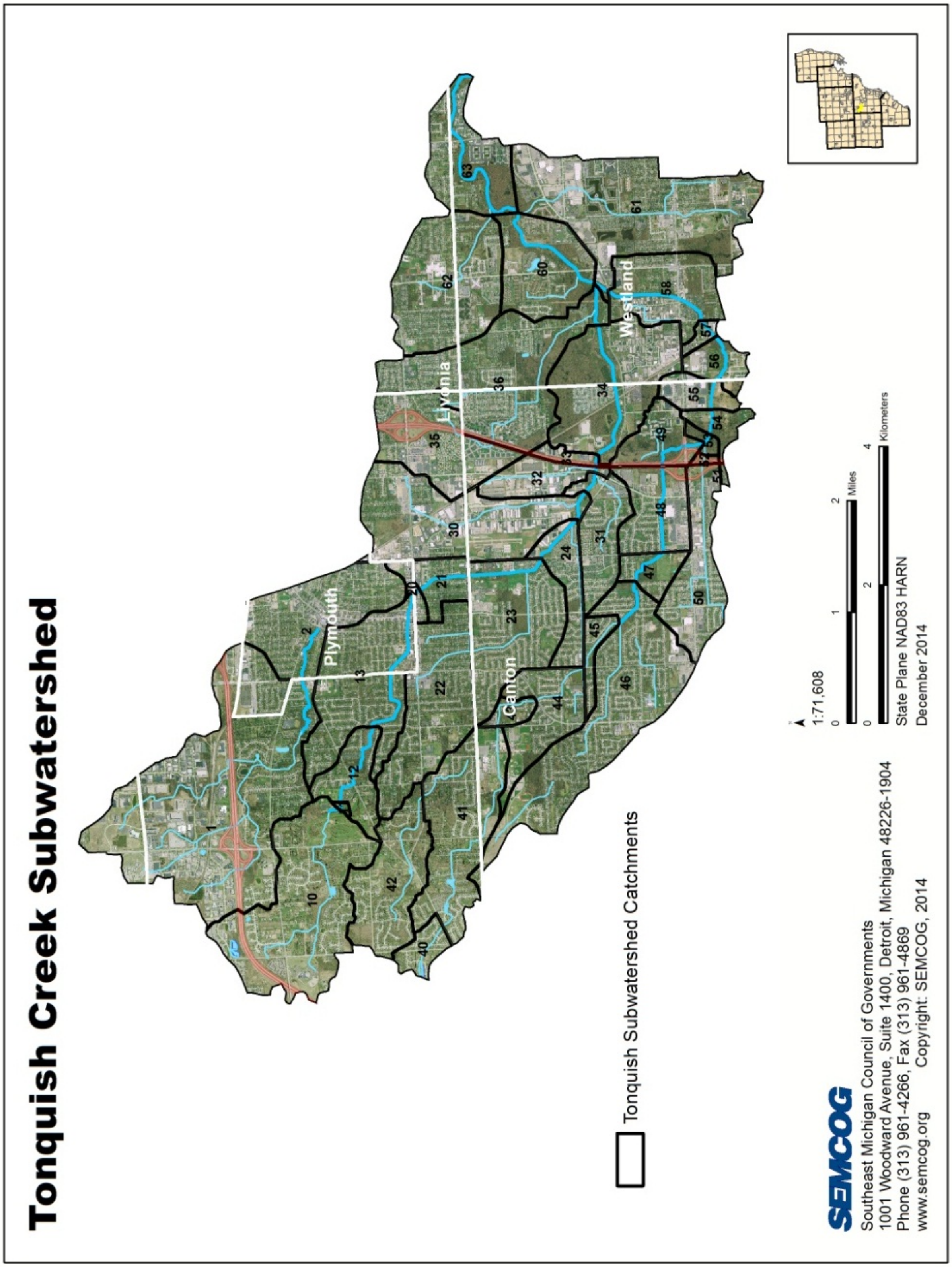


Figure 51. Aerial imagery of catchment boundaries—Tonquish Creek subwatershed.

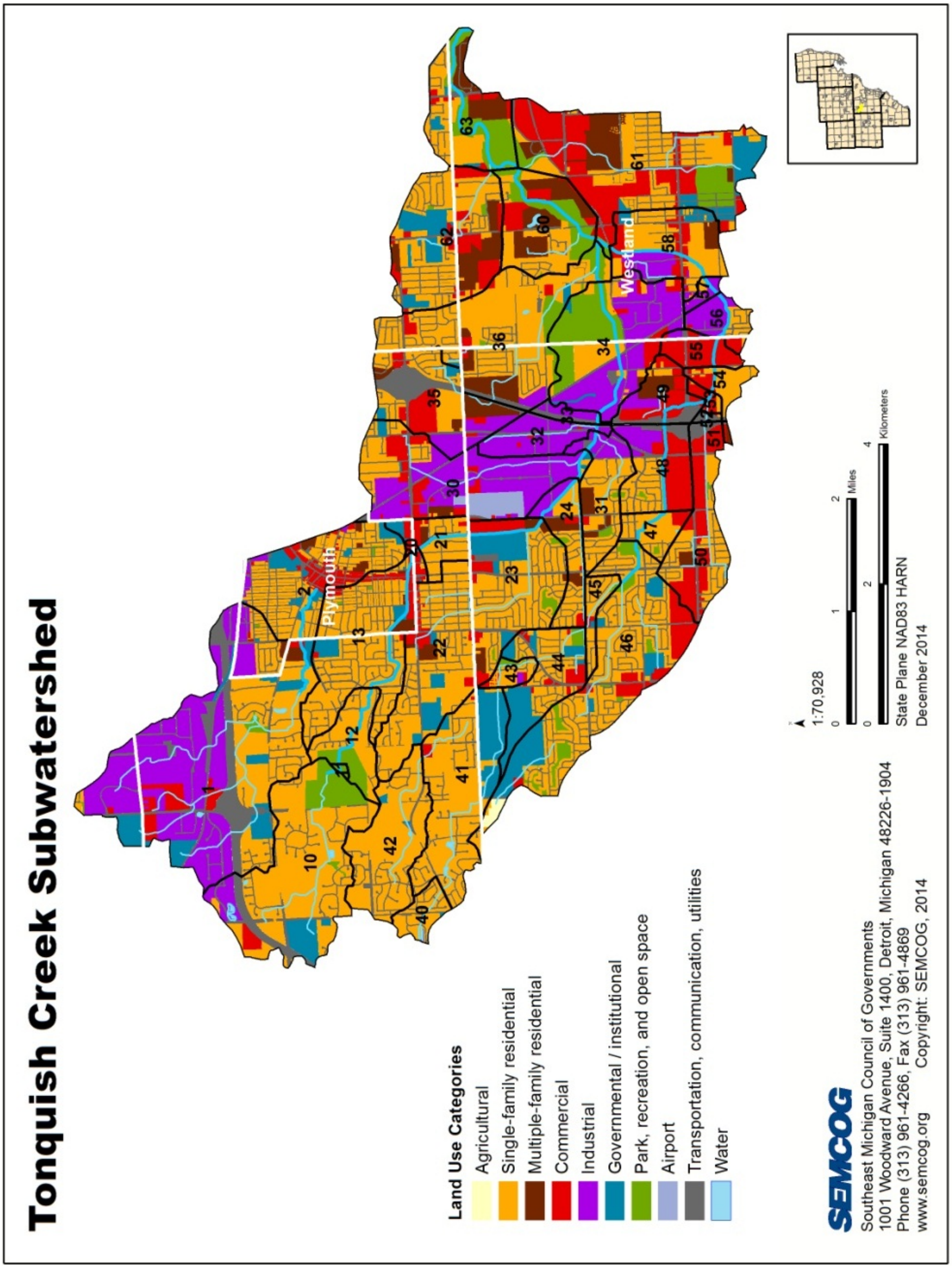


Figure 52. Land use—Tonquish Creek subwatershed.

Table 18. Tonquish Creek subwatershed land use

Catchment Group / Catchment ID		Area *(acres)*	Land Use *(percent)*								Total Impervious Area *(percent)*
			Single-family Residential	*Multifamily Residential*	*Commercial*	*Institutional*	*Industrial*	*Road ROW*	*Parks, Open*	*Other*	
A	**01/02** – *North Branch*	2,355	31%	2%	6%	9%	31%	21%	1%	0.1%	44%
B	**10/11/12/13** – *South Branch*	1,835	64%	1%	3%	5%	2%	16%	9%	0.3%	33%
C	**20/21** – *Ann Arbor/Joy Road*	179	53%	4%	20%	7%	---	15%	---	---	48%
	22/23/24 – *Upper Tonquish*	1,377	56%	5%	7%	9%	2%	18%	1%	---	44%
D	**30/31/32/33** – *Koppernick*	1,236	19%	3%	8%	1%	47%	15%	1%	6%	54%
	34/35/36 – *Middle Tonquish*	2,007	38%	6%	7%	2%	18%	16%	13%	---	39%
E	**40/41/42** – *Willow Headwaters*	1,189	75%	---	1%	11%	---	13%	---	0.4%	32%
	43/44/45 – *Upper Willow*	458	45%	---	8%	24%	1%	17%	5%	---	42%
	46/47/48/49 – *Willow/Travis*	1,558	41%	2%	19%	8%	4%	19%	5%	1%	43%
F	**50/51/52** – *Ford Tributary*	397	32%	4%	40%	0.1%	---	24%	1%	---	57%
	53/54/55 – *Willow/I-275*	235	30%	---	59%	---	3%	7%	---	---	30%
	56/57/58 – *Lower Willow*	543	39%	4%	13%	4%	27%	13%	0.1%	---	41%
G	**60** – *Lower Tonquish*	424	30%	28%	12%	---	---	5%	25%	1%	33%
	61 – *Morgan Creek*	1,057	27%	11%	33%	8%	---	13%	9%	---	50%
	62/63 – *Tonquish Outlet*	1,103	39%	15%	11%	9%	---	12%	14%	---	38%
	TOTAL	15,952	42%	5%	11%	7%	12%	16%	6%	1%	42%

Note: **Yellow highlighted cells** identify land use categories in each catchment that exceed the subwatershed average.

Table 19. Tonquish Creek subwatershed land cover by land use category

Land Use Category	Area *(acres)*	Impervious Surface Types (*percent*)		Pervious Area (*percent*)	
		Building	***Pavement*** *(road surface, parking, driveways, sidewalks)*	***Open***	***Tree Canopy***
Single-family residential	6,739	*14%*	*19%*	*31%*	*36%*
Multifamily residential	756	*18%*	*41%*	*24%*	*17%*
Commercial	1,811	*14%*	*44%*	*21%*	*20%*
Institutional	1,049	*8%*	*25%*	*41%*	*25%*
Industrial	1,978	*19%*	*34%*	*28%*	*19%*
Road ROWs	2,592	*0.2%*	*60%*	*26%*	*14%*
Parks, Open Space	910	*0%*	*5%*	*23%*	*72%*
Other	117	*4%*	*25%*	*62%*	*9%*
TOTAL	15,952	*11%*	*31%*	*29%*	*29%*

4.3.2 Existing Conditions Related to Flashiness

The *Rouge River Watershed Management Plan* describes an array of water quality concerns in Tonquish Creek subwatershed. Poor macroinvertebrate communities have been observed at several sites in the drainage through monitoring by both the Friends of the Rouge and MDEQ (ARC 2012; Goodwin 2009). The Rouge River plan noted that the developed area within the Tonquish Creek subwatershed continues to expand and that unmitigated stormwater inputs could continue to degrade the stream as a result of higher peak flows and decreased base flow. In addition, Tonquish Creek is a tributary to the section of the Middle Rouge River, which has degraded stream habitat caused by excessive flow instability and accompanying bank erosion.

Although streamflow records for the Tonquish Creek subwatershed are not available, two locations monitored by USGS on the Middle Rouge (one above and one below Tonquish) can be used to develop flow estimates for this pilot subwatershed. Figure 53 depicts estimated daily average flows for Tonquish Creek based on the difference in discharge between the two Middle Rouge gages. R-B Index values in Tonquish Creek currently exceed 0.5 based on those estimates.

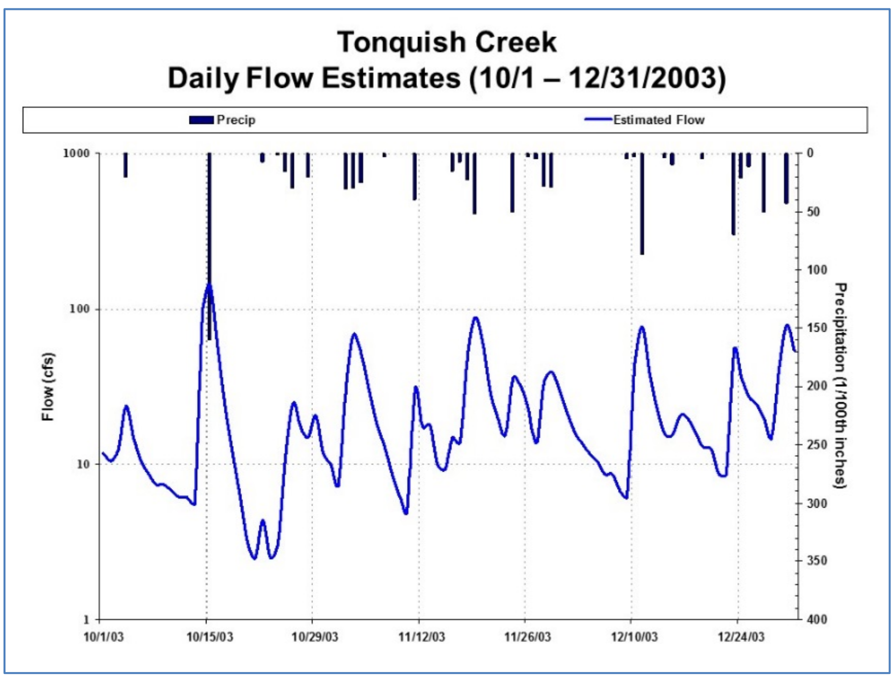


Figure 53. Estimated daily average Tonquish Creek streamflow patterns *(10/1–12/31/2003)*.

4.3.3 Stormwater Runoff Reduction Targets

The LSPC screening analysis offers a method to evaluate subwatershed-scale runoff patterns in the context of current land use information. R-B Index estimates based on local meteorological information and the SEMCOG land cover data were used to benchmark existing conditions for relative comparison with different green infrastructure implementation strategies. This included identifying the impervious cover that would need to be managed to meet the target R-B Index range.

Figure 54 presents the screening analysis results, which used baseline assumptions to examine the change in R-B Index values as effective impervious cover is varied across the Tonquish Creek subwatershed. The baseline curve assumes that no other green infrastructure opportunities are used. Under this scenario, effective impervious cover would need to be managed to 11 percent to meet the upper R-B Index target (i.e., 0.50). It is important to note that the *effective* impervious cover is less than the *total* impervious cover reported in Table 18.

An estimated range of potential effective impervious cover at the mouth of Tonquish Creek is shown in Figure 54. This range is intended to address uncertainties associated with differences in land use/impervious surface types in the Tonquish Creek subwatershed. The range shown in Figure 54 is based on estimated ratios between effective impervious cover and total impervious cover derived from the SEMCOG land cover data and USGS flow data examined for this project. To account for the array of uncertainties (e.g., differences in land use/impervious surface types, background infiltration rate assumptions), planners can estimate the amount of impervious area that needs to be managed for stormwater using green infrastructure in priority catchments (as shown below).

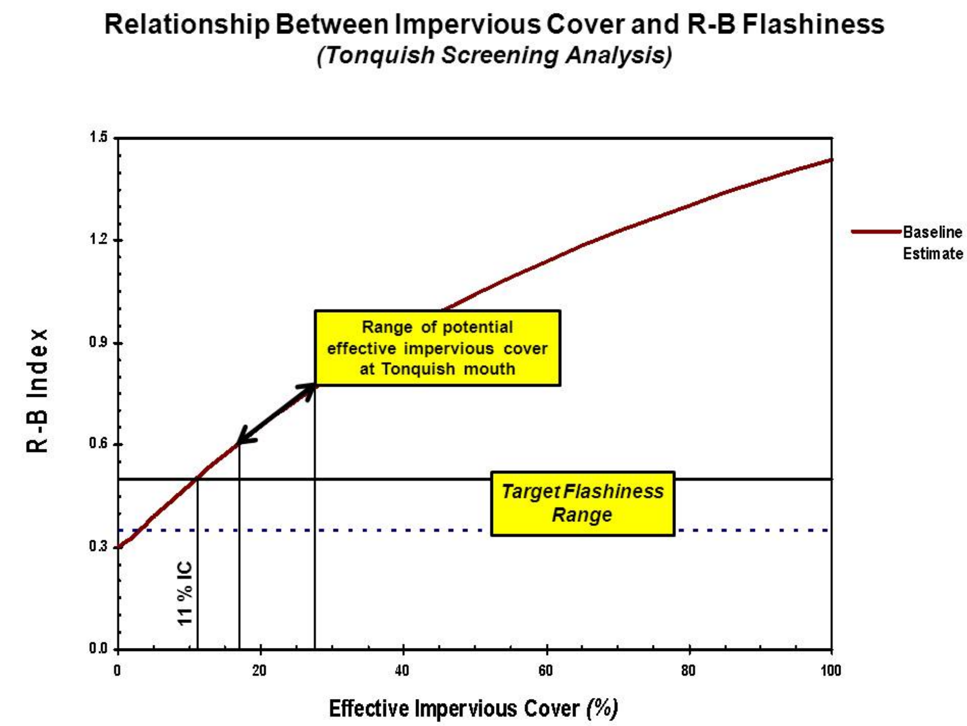


Figure 54. Tonquish Creek subwatershed effective impervious cover and R-B flashiness screening analysis.

4.3.4 Areas of Opportunity and Priorities

Figure 55 shows the *Green Infrastructure Vision* for the Tonquish Creek subwatershed. The Potential Conservation & Recreation Lands classification highlights areas that could be added to the network. Potential Green Streets identifies major roads that have opportunities for improving soil health through grow zones and/or implementing constructed practices. Finally, the top 10 percent by area of institutional properties is highlighted as an initial priority along with the top 1 percent by area of private parking lots. These opportunities are described in greater detail in the subsequent sections.

The SEMCOG land cover data provides a starting point from which to describe opportunities (Figure 56). An important aspect is identifying potential impervious surface types that could be managed for stormwater using green infrastructure. Within the Tonquish Creek pilot subwatershed, pavement (e.g., roads, parking lots, driveways, sidewalks, and so forth) represents nearly three-quarters of all impervious surface types (Table 20).

Table 20. Tonquish Creek subwatershed impervious cover estimates by surface type

Catchment Group / Catchment ID		Area *(acres)*	Total Impervious Area *(acres)*	Percent of Total Impervious Area			Tree Canopy *(percent)*
				Building	***Road***	***Other Pavement***	
A	**01/02** – *North Branch*	2,355	1,036	*27%*	*25%*	*48%*	25%
B	**10/11/12/13** – *South Branch*	1,835	613	*24%*	*29%*	*47%*	31%
C	**20/21** – *Ann Arbor/Joy Road*	179	86	*24%*	*20%*	*56%*	29%
	22/23/24 – *Upper Tonquish*	1,377	611	*29%*	*28%*	*43%*	24%
D	**30/31/32/33** – *Koppernick*	1,236	664	*31%*	*16%*	*53%*	14%
	34/35/36 – *Middle Tonquish*	2,007	784	*27%*	*21%*	*52%*	37%
E	**40/41/42** – *Willow Headwaters*	1,189	379	*24%*	*27%*	*49%*	36%
	43/44/45 – *Upper Willow*	458	193	*28%*	*29%*	*43%*	22%
	46/47/48/49 – *Willow/Travis*	1,558	672	*28%*	*29%*	*43%*	23%
F	**50/51/52** – *Ford Tributary*	397	225	*24%*	*25%*	*51%*	11%
	53/54/55 – *Willow/I-275*	235	70	*22%*	*14%*	*64%*	43%
	56/57/58 – *Lower Willow*	543	224	*25%*	*21%*	*54%*	34%
G	**60** – *Lower Tonquish*	424	140	*26%*	*12%*	*62%*	43%
	61 – *Morgan Creek*	1,057	531	*25%*	*16%*	*59%*	29%
	62/63 – *Tonquish Outlet*	1,103	421	*29%*	*21%*	*50%*	37%
TOTAL		15,952	6,652	*27%*	*23%*	*50%*	*26%*

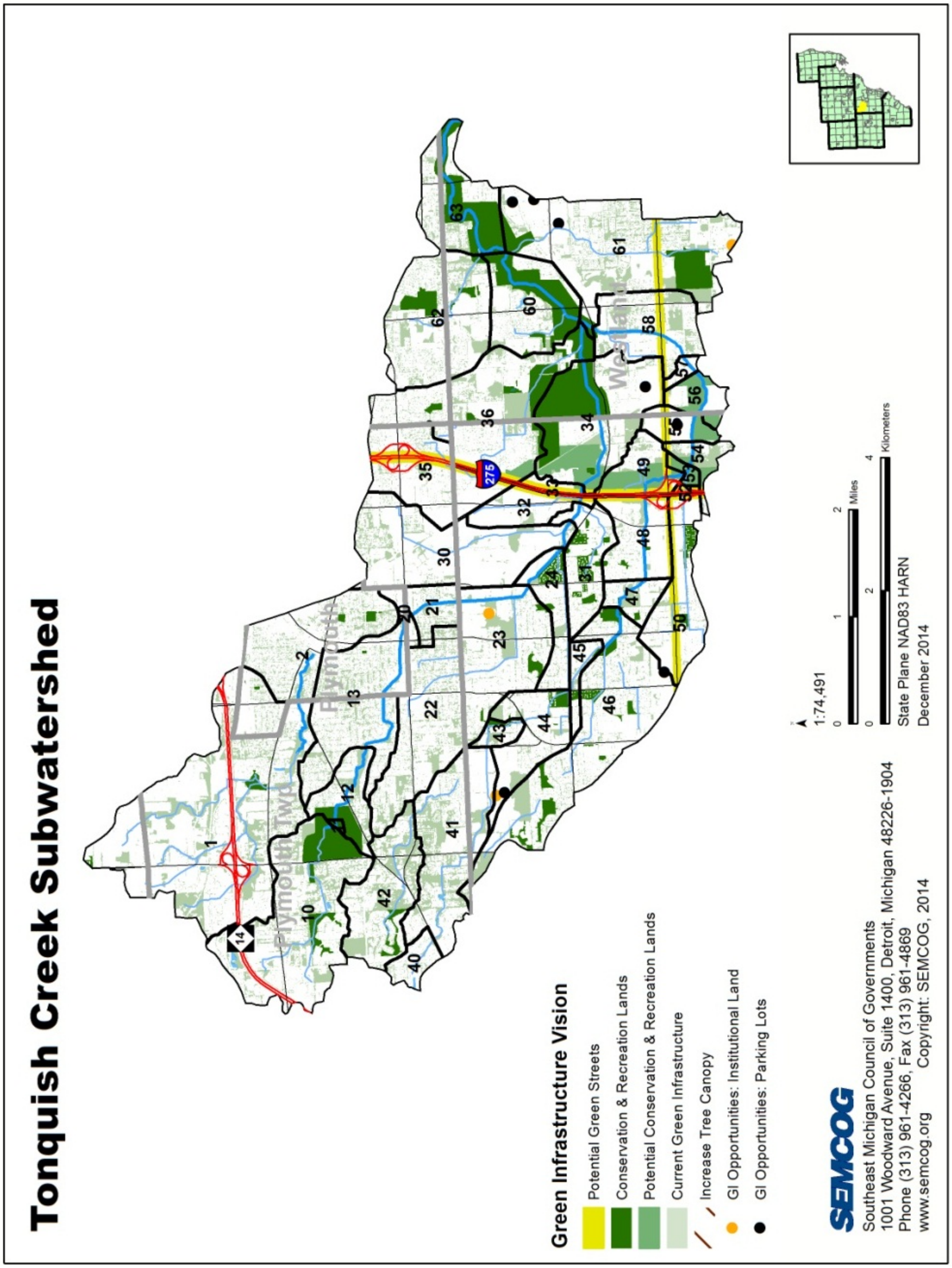


Figure 55. Green Infrastructure Vision—Tonquish Creek subwatershed.

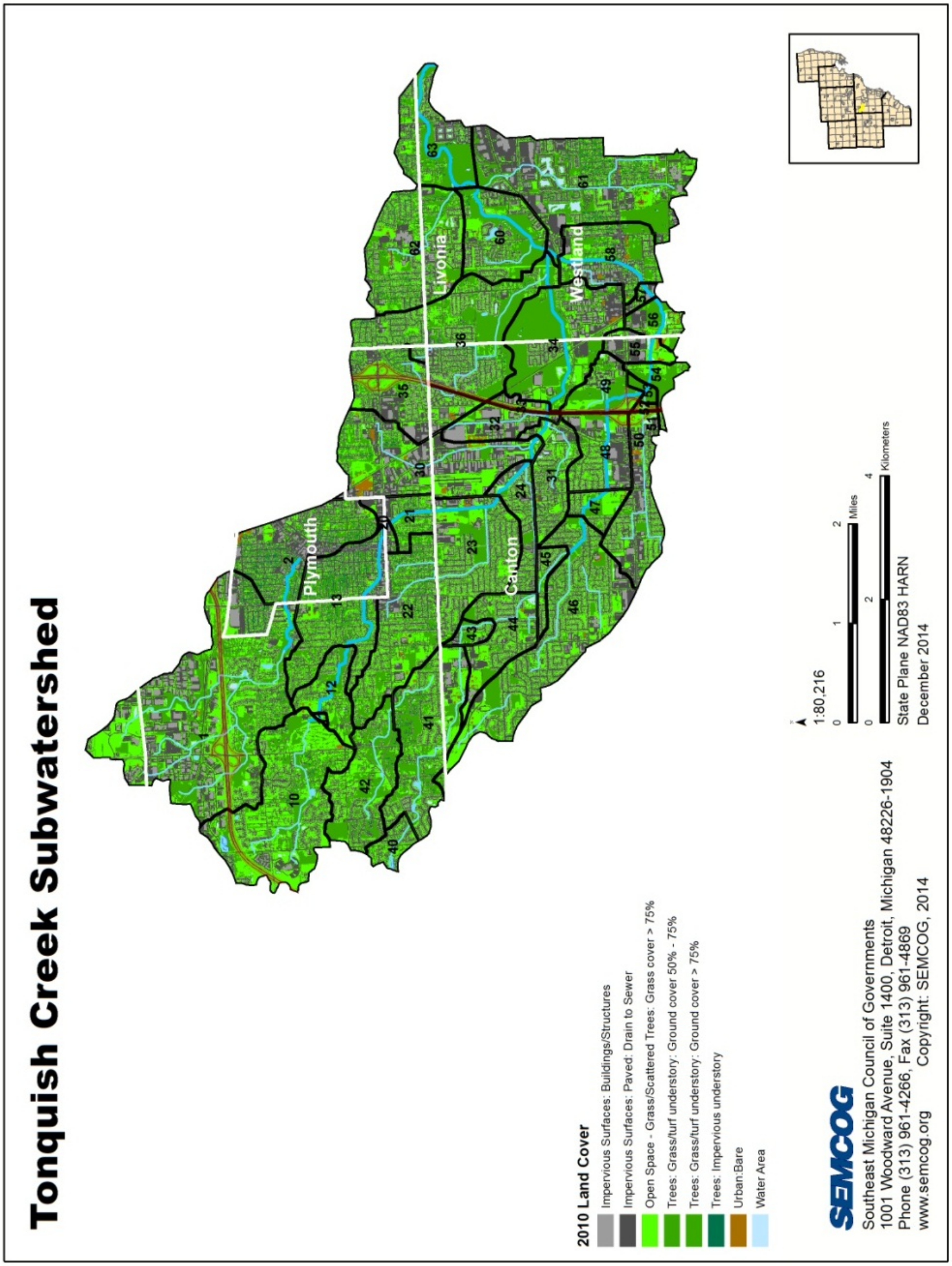


Figure 56. Land cover—Tonquish Creek subwatershed.

The land use/land cover inventory data compiled by SEMCOG provides detailed information that can be used to identify priority areas. Figure 57 summarizes the impervious surface composition for catchment groups in the Tonquish Creek subwatershed. This chart conveys two types of information useful for targeting green infrastructure implementation efforts: the quantity of impervious area and the density of impervious cover in each catchment group. The quantity aspect identifies groups that contain higher amounts of total impervious area. In the Tonquish Creek subwatershed, those are catchment groups A (North Branch), D (Middle Tonquish), E (Upper Willow), and G (Lower Tonquish). The value in the oval for each group represents the percent impervious cover (or the density aspect). The combination of both aspects points to North Branch, Middle Tonquish, and Lower Tonquish as high priorities for targeting green infrastructure, which does not mean that green infrastructure in other groups is less important. Instead, it highlights the fact that managing impervious cover in these catchment groups must play a major role in reducing stream flashiness in the Tonquish Creek subwatershed.

The impervious surface composition shown in Figure 57 provides other useful information for targeting green infrastructure implementation. As indicated, Middle Tonquish (group D) is a high-priority group. The greatest amount of impervious area in group D catchments is associated with commercial/industrial land use followed by roads.

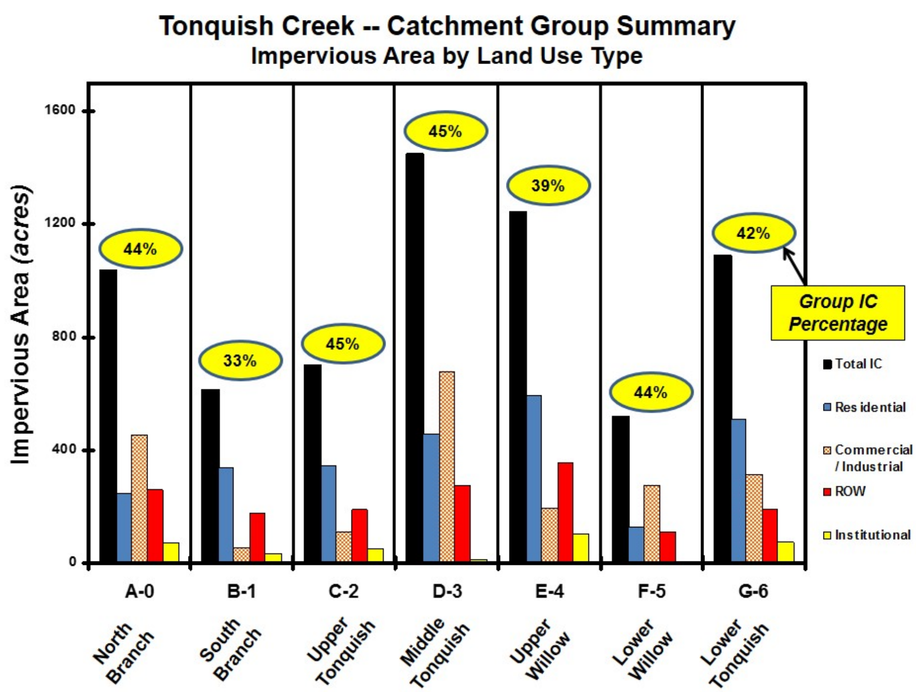


Figure 57. Impervious surface composition—Tonquish Creek subwatershed.

4.3.5 Recommendations

Substantial restoration efforts already have been implemented to address flooding and water quality problems in the Tonquish Creek subwatershed. To complement ongoing and planned activities, several recommendations are offered based on an analysis of existing conditions related to flashiness and priorities identified using land use/land cover information. These recommendations follow key components of SEMCOG's *Green Infrastructure Vision* (SEMCOG 2014).

Institutional Properties

Green infrastructure on institutional properties offers several benefits, including a public display of the types of practices suitable for implementation in the local community. Based on SEMCOG's analysis of parcel-level information, more than 1,400 acres of the Tonquish Creek subwatershed are either publicly owned or institutional property (Figure 58). Table 21 details the land cover breakdown by jursidiction.

Figure 59 highlights the extent of school district property in the Tonquish Creek subwatershed. School districts can benefit from green infrastructure implementation through construction of schoolyard habitats and native plant grow zones. In addition to the educational value, green infrastructure on school properties can work to reduce long-term maintenance costs by improving drainage and replacing high-maintenance turf with lower-maintenance trees, shrubs, and ornamental grasses.

Of the different types of impervious surfaces on publicly owned properties, pavement represents the largest proportion. Recommended BMPs include bioretention, infiltration trenches, pervious pavement, planter boxes, level spreaders, and vegetated swales. The *Low Impact Development Manual for Michigan* also describes the range of design options available to accommodate site-specific situations (SEMCOG 2008). The Site Development Stormwater Tool, which has been applied in Michigan, can be used to guide more parcel-specific screening analyses (similar to that shown in Figure 23) to reflect design configurations appropriate for each location (Christian 2014).

The level of implementation curves shown in Figure 24 and Figure 25 are based on southeast Michigan climate data. These curves provide a general estimate of environmental benefits that could be derived from constructed green infrastructure on institutional properties across all catchments in the Tonquish Creek subwatershed. While individual opportunities might have unique site constraints, local challenges can be addressed either with enhanced design for constructed practices (e.g., soil amendments, increased BMP treatment capture depth) or by improving the infiltration benefit of pervious areas (e.g., grow zones, increased tree canopy).

Table 21. Tonquish Creek subwatershed publicly owned property by jurisdiction

Jurisdiction	Area *(acres)*	Impervious Surface Types *(acres)*		Pervious Area *(acres)*	
		Building	***Pavement*** *(parking, driving surfaces, sidewalks)*	***Open***	***Tree Canopy***
City of Livonia	52	*2*	*5*	*17*	*28*
City of Plymouth	22	*3*	*5*	*4*	*10*
City of Westland	58	*0*	*2*	*2*	*54*
Canton Township	69	*0*	*8*	*14*	*47*
Plymouth Township	191	*2*	*23*	*102*	*64*
Detroit Metro Water Department	10	*0*	*2*	*6*	*2*
Wayne County	294	*0*	*9*	*11*	*274*
State of Michigan	67	*5*	*15*	*25*	*22*
School Property	647	*58*	*162*	*284*	*143*
TOTAL	**1,410**	***70***	***231***	***465***	***644***

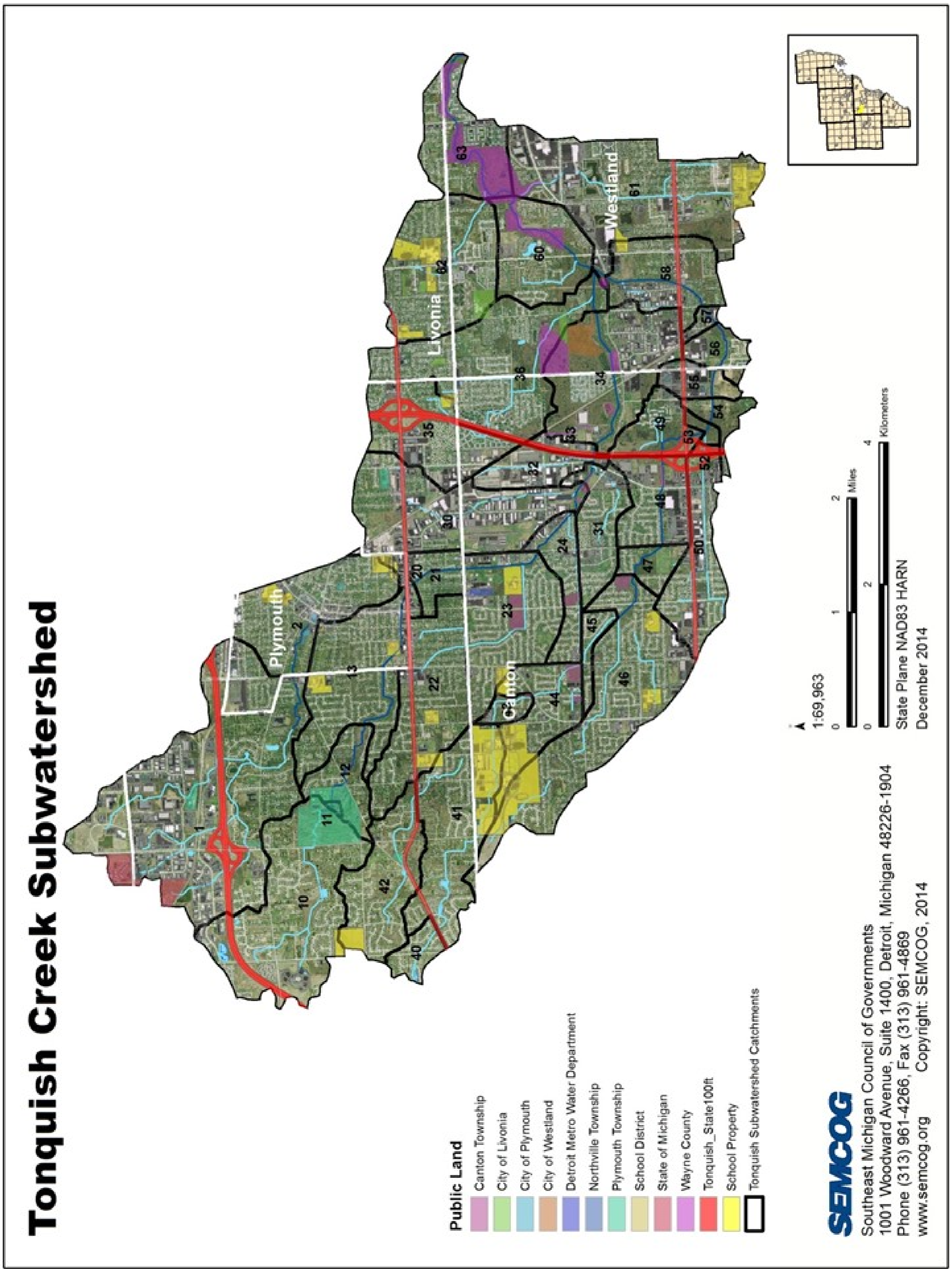


Figure 58. Public parcels—Tonquish Creek subwatershed.

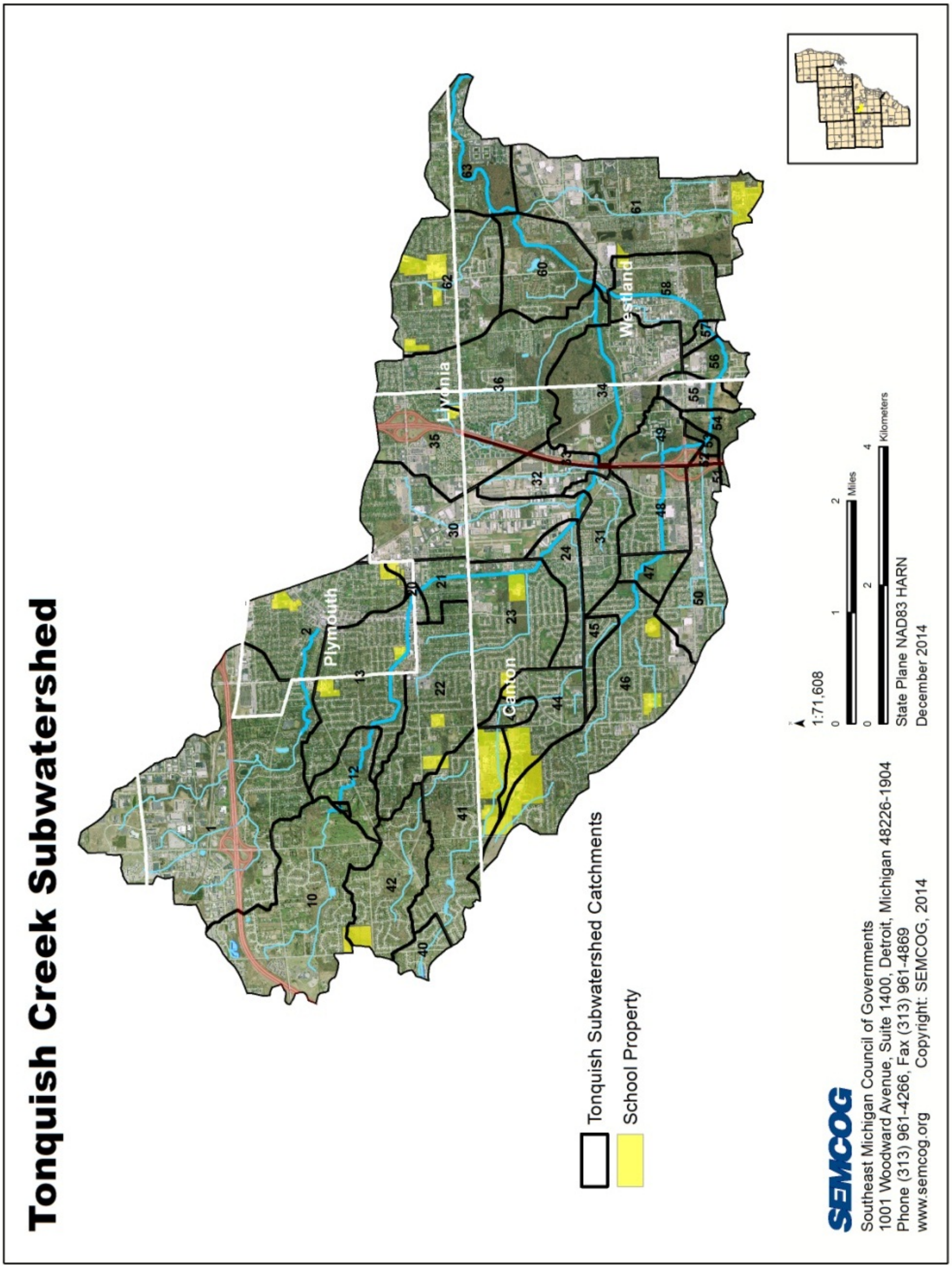


Figure 59. School properties—Tonquish Creek subwatershed.

Roadways

Green infrastructure, both natural and constructed, can be strategically used along roadway corridors to provide recreational, social, and aesthetic amenities to surrounding communities in addition to providing local and regional environmental benefits. Within the Tonquish Creek subwatershed, roadway types include freeways (e.g., I-275, M-14), arterial and collector roads (e.g., Ford Road, Warren Road), local and residential streets, and alleys.

Roads—including those under the jurisdiction of the local communities, Wayne County, and MDOT—represent 2,592 acres, or nearly 40 percent, of the total impervious surface area of 6,765 acres in the Tonquish Creek subwatershed. Open spaces within the road ROWs represent potential opportunities to increase green infrastructure, depending on the array of site-specific factors.

The aerial imagery and land use displayed on Figure 51 and Figure 52 shows the extent of the roadway network in the Tonquish Creek subwatershed. As indicated, nearly 10 percent of the entire 15,952-acre land area is comprised of roadway impervious surfaces. The SEMCOG parcel data identify major roadways as potential opportunities for increasing green infrastructure in the subwatershed (Figure 60). Table 22 summarizes the existing land cover and general jurisdictional ownership of the roadway network in subwatershed.

Open spaces within the road ROWs represent potential opportunities to increase green infrastructure, depending on the array of site-specific factors. In addition to the *Low Impact Development Manual for Michigan*, the *Green Streets Guidebook: A Compilation of Road Projects Using Green Infrastructure* also provides information on suitable practices for use in road ROWs (SEMCOG 2008, 2013). Recommended BMPs include bioretention, permeable pavement, bioswales, and native plant grow zones.

Similar to the discussion of institutional properties earlier in this section, the benefits of green infrastructure (both constructed practices and the use of grow zones) across all catchments in the Tonquish Creek subwatershed can be estimated using the level of implementation curves (Figure 24 and Figure 25). The screening analysis (e.g., Figure 23) guided by spreadsheet methods (e.g., Site Development Stormwater Tool) can be used to account for site-specific design adjustments appropriate for each location.

Table 22. Tonquish Creek subwatershed road ROW land cover

Jurisdiction	**Area** *(acres)*	**Pavement** *(acres)*	**Pervious Area** *(acres)*	
			Open	***Tree Canopy***
Wayne County & Local	2,031	*1,314*	*415*	*302*
MDOT	561	*250*	*260*	*51*
TOTAL	2,592	*1,564*	*675*	*353*

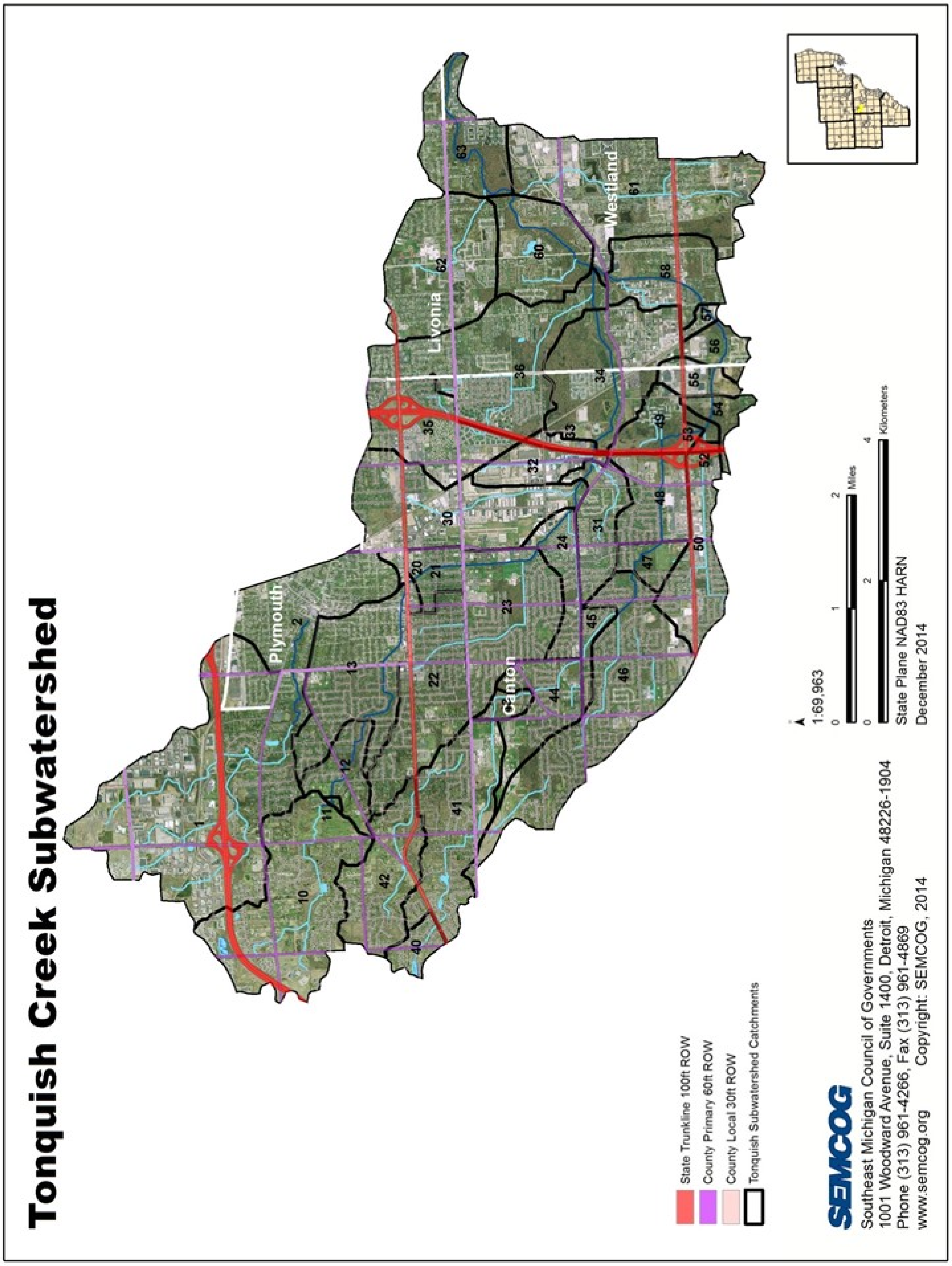


Figure 60. Road ROWs—Tonquish Creek subwatershed.

Parking Lots

Publicly and privately owned parking lots comprise a significant portion of impervious surface area in the Tonquish Creek subwatershed. The SEMCOG parcel data identify two institutional and six privately owned parking lots, which provide optimal opportunities for increasing green infrastructure in the subwatershed (Figure 61). Recommended BMPs include bioretention, infiltration trenches, pervious pavement, and increasing tree canopy.

As noted in Figure 61, groups F and G are high-priority areas for green infrastructure to reduce stormwater volume in the Tonquish Creek subwatershed. This recommended high-priority area is based on both the amount and density of impervious cover. Commercial land use dominates total impervious cover in this area and is one reason that green infrastructure implementation for the priority parking lots will be an important component to reduce stream flashiness in Tonquish Creek. Incorporating stormwater volume reduction practices into the priority parking lots would represent a major step towards reducing the amount of effective impervious cover that needs to be managed using green infrastructure in this pilot subwatershed.

Similar to the discussion of institutional properties earlier in this section, the benefits of green infrastructure across all catchments in the Tonquish Creek subwatershed can be estimated using the level of implementation curves (Figure 24 and Figure 25) included in this report. The screening analysis (e.g., Figure 23) guided by spreadsheet methods (e.g., Site Development Stormwater Tool) can be used to account for the site-specific design adjustments appropriate for each location.

4.3.6 Pilot Watershed Summary

The Tonquish Creek subwatershed assessment illustrates the value of the outcome-based strategic planning framework to determine the role green infrastructure can play in working towards WQS attainment by addressing documented stormwater problems. The pilot assessment describes overall existing conditions related to flashiness in the subwatershed (Figure 53). The approximate amount of impervious cover that needs to be managed to achieve the stream flashiness goal is identified (Figure 54). Land use/land cover detail is provided in the form of maps (Figure 52 and Figure 56) and tables (Table 18, Table 19, and Table 20). Priority catchments are defined using impervious cover composition and density information (Figure 57). Recommendations are summarized based on areas emphasized in SEMCOG's *Green Infrastructure Vision for Southeast Michigan* (SEMCOG 2014).

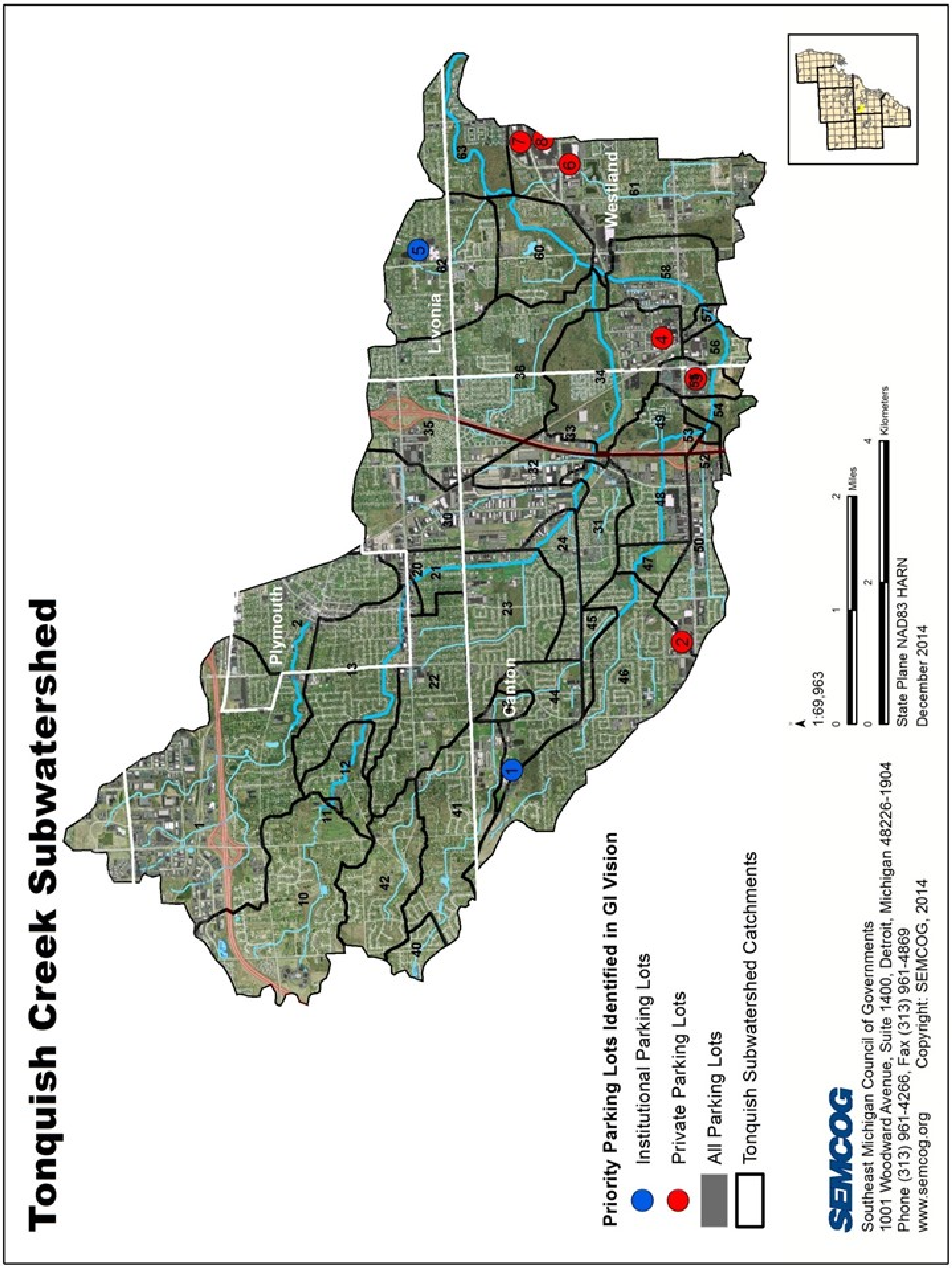


Figure 61. Priority parking lots in Green Infrastructure Vision—Tonquish Creek subwatershed.

5 Conclusions

The overall purpose of this project was to determine the role of green infrastructure in working towards meeting WQS in southeast Michigan and in protecting western Lake Erie. Stormwater runoff volume reduction targets were identified using stream flashiness to connect aquatic biology and stream channel concerns with TMDLs and stormwater management activities. Those targets were based on local monitoring data and provide a baseline from which to examine alternatives for green infrastructure techniques that achieve WQS and protect biological communities using an outcome-based strategic planning process.

The approach was applied to three pilot subwatersheds selected by SEMCOG staff and several members of the Southeast Michigan Green Infrastructure Partners. Each pilot subwatershed has land use/land cover characteristics representative of green infrastructure planning challenges and opportunities in southeast Michigan. The green infrastructure assessment for each pilot project described existing hydrologic conditions in the subwatershed. The amount of impervious cover needing green infrastructure improvements to achieve the stream flashiness goal was identified.

A detailed analysis of SEMCOG's land use/land cover data defined priority catchments within each pilot subwatershed based on impervious cover composition and density. Opportunities were examined using desktop screening analyses to estimate the relative benefit of different implementation strategies highlighted in SEMCOG's *Green Infrastructure Vision* (SEMCOG 2014). The green infrastructure options evaluated to achieve stream flashiness and stormwater reduction targets include native plant grow zones, increasing tree canopy, and the use of constructed practices (e.g., bioretention, pervious pavement, bioswales).

The green infrastructure target setting process for this project is transferable to other southeast Michigan watersheds. In a separate project, the framework is being extended to other Detroit-area subwatersheds in support of efforts to develop a water quality program strategy that aligns MDOT transportation infrastructure goals with watershed management plans. In addition, this framework will serve as a baseline from which to evaluate progress for urban watershed restoration across the region.

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