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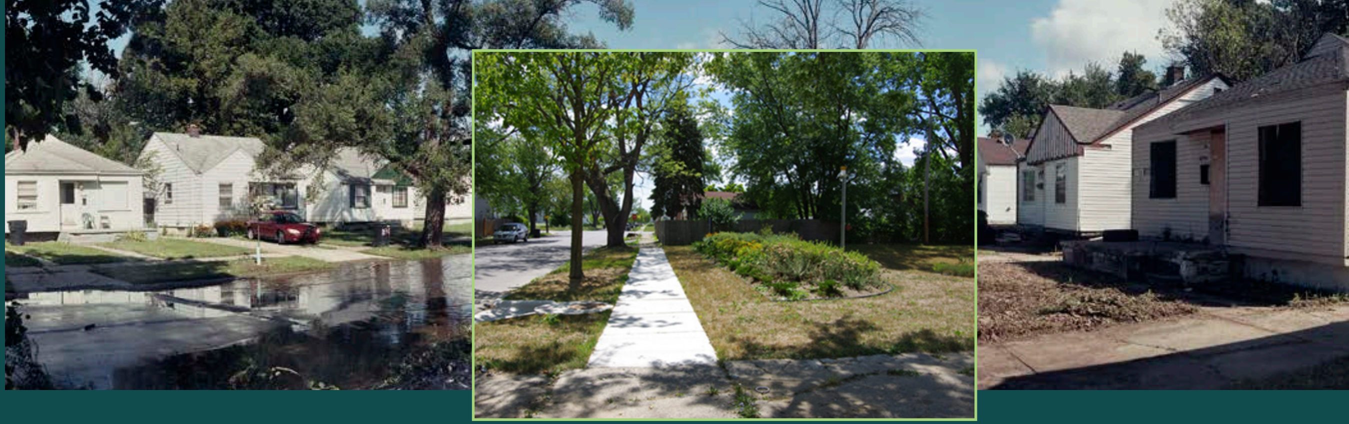

DIFFERENT CONTEXTS, DIFFERENT DESIGNS FOR GREEN STORMWATER INFRASTRUCTURE

JOAN IVERSON NASSAUER AND YUANQIU FENG

NEIGHBORHOOD, ENVIRONMENT AND WATER RESEARCH
COLLABORATIONS FOR GREEN INFRASTRUCTURE
NEW-GI TECHNICAL REPORT NO. 1 AUGUST 2018

NEW GI

ABOUT NEW-GI

PHOTO: DAVE BRENNER (2016)

NEW-GI (Neighborhood, Environment, and Water research collaborations for Green Infrastructure) contributes to knowledge about green infrastructure in legacy cities by integrating research about water quality, community well-being, governance and ecological design. Involving community, government and academic collaborators, it produces evidence-based guidance for sustainably managing stormwater in ways that enhance landscapes and the lives of residents in Detroit and other legacy cities.

NEW-GI ecological designs link Detroit's vacant property demolition process with new forms of green stormwater infrastructure (GSI) that aim to manage stormwater as well as increase nearby residents' well-being. This research uses a transdisciplinary design-in-science approach, in which researchers, practitioners and community members work together to contribute knowledge addressing social and ecological objectives. NEW-GI researchers assess the performance of different GSI designs and governance approaches. This assessment provides evidence for making decisions about how GSI can better achieve objectives.

Cover photos: Chris Faust (2014). Graphic design and visualization by Yuanqiu Feng.

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IMAGE CREDITS

Unless otherwise noted, all images and figures in this report are produced by the authors or members of the NEW-GI research team.

DATA SOURCES

The analytical maps and graphics produced in this report were created based on data provided by the following sources:

1. Hi-resolution satellite imagery, digital elevation model and catchment boundaries from the Detroit Water and Sewer Department.
2. Detroit vacancy data from Motor City Mapping's 2014 (last quarter) citywide property survey of Detroit. Accessible from: *https://motorcitymapping.org*.
3. Detroit urban soil data from USDA NRCS's web soil survey, based on information uploaded in December 2016. Accessible from: *https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm*
4. Hydrography data from the State of Michigan's GIS open data portal. Uploaded October 2017. Accessible from: *https://gis-michigan.opendata.arcgis.com/datasets/hydrography-polygons-v17a*
6. Road network data from Southeast Michigan Council of Goverments (SEMCOG) Open Data Portal. Accessible from: *http://maps-semcog.opendata.arcgis.com/datasets/roads*

CONTENTS

INTRODUCTION

The Neighborhood, Environment and Water research collaborations for Green Infrastructure (NEW-GI) project develops ecological designs that use vacant land to manage stormwater and enhance neighborhood landscapes. In 2015, the Detroit Water and Sewerage Department constructed NEW-GI pilot sites, four bioretention gardens, each on two vacant residential properties in the Warrendale neighborhood. This NEW-GI report draws on lessons from the pilot sites and the broader scientific literature to suggest how GSI might be employed across whole catchments for a more comprehensive effect on water quality and well-being.

Opening event for NEW-GI pilot sites.

PHOTO: DAVE BRENNER (2016)

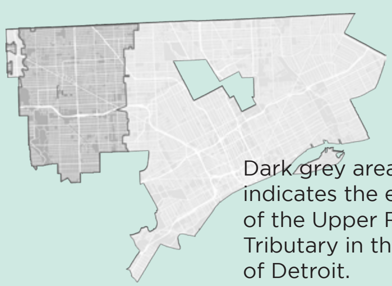
This NEW-GI report considers how different approaches to GSI might be employed across whole catchments to have a more comprehensive effect on water quality and well-being.

Where catchments differ in slope, soils, vacancy patterns, or existing grey infrastructure, different opportunities emerge for GSI designs. Looking at two catchments in Detroit, this report shows how different contexts suggest different GSI design approaches – with varying social and governance implications.

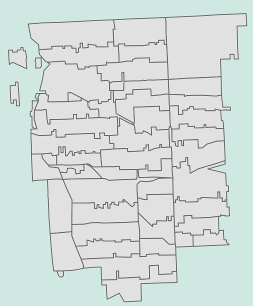
Designs for both catchments use land-based GSI (like retention ponds, bioretention gardens, and rainwater gardens) rather than structural GSI (like green roofs, permeable paving, rain barrels, and cisterns). Land-based GSI has many advantages for Detroit neighborhoods. Detroit's high proportion of publicly-owned vacant land, 25% of the city's area (Detroit Water and Sewerage Department, 2016), low land prices, and large area make the costs of using land to manage stormwater more affordable in Detroit than in many other cities. This is

'CATCHMENT' DEFINITION IN THIS REPORT

Stormwater from the houses, yards, and streets of Detroit flows into storm sewer pipes that combine with sanitary sewage pipes in each block. Water from many blocks, with total areas ranging from a few acres to more than 150 acres, flows into a single, larger sewer system pipe for each catchment. DWSD has grouped the 797 catchments in the Upper Rouge River service area into 46 catchment groups of adjacent networked, catchments. This report examines two of the catchment groups defined by DWSD. For the sake of simplicity, the report refers to the catchment groups, as "catchments".



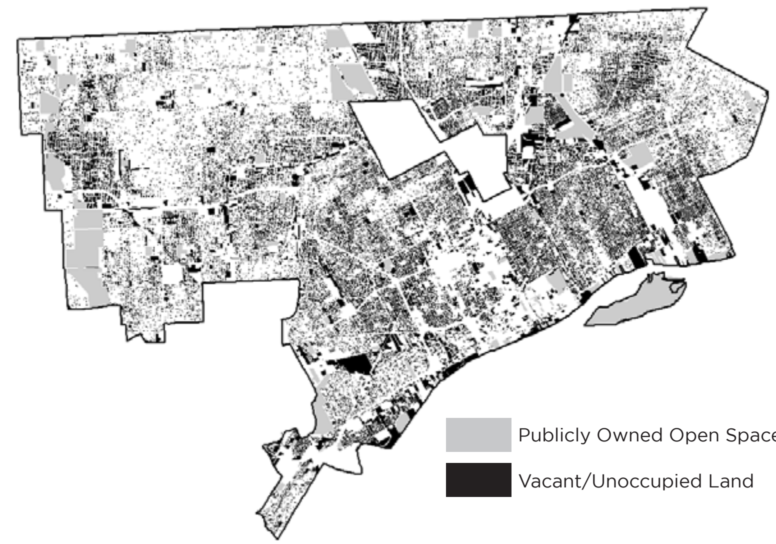
Dark grey area indicates the extent of the Upper Rouge Tributary in the city of Detroit.



The 46 catchments groups in the Upper Rouge Tributary service area in Detroit.

a big advantage for achieving climate-resilient, cost-effective GSI. Where enough land is available, land-based GSI can be designed to manage stormwater while minimizing property damage risks. Compared with structural systems, it can be designed to perform reliably over time with less frequent, less specialized, maintenance (Hufnagel and Rottle, 2014; City of New York, 2008; National Research Council, 2008).

The high proportion of vacant and public land in Detroit make the costs of using land-based GSI to manage stormwater more affordable in Detroit than in many other cities.



Vacant/unoccupied land, as well as publicly owned open spaces in the city of Detroit.

DATA FROM MOTOR CITY MAPPING SURVEY 2014.

Land-based GSI can be more cost-effective and resilient to extreme weather when it fits its context: the slope, soil, and grey stormwater infrastructure existing in a neighborhood. For example, where Detroit is flat with clay soils that limit the infiltration of stormwater, GSI should be designed for that context. The Warrendale pilot sites demonstrate a type of small GSI designed for just that context: a flat landscape with clay soils. Vacant residential sites in Warrendale made it possible to augment native clay soils with highly permeable engineered soils to greatly enhance the capacity for retaining

Bioretention garden pilot site in Warrendale, Detroit.

PHOTO: DAVE BRENNER (2016)

Land-based GSI can be more effective and resilient when it fits its context. This report contrasts GSI design approaches for two different catchments within the Upper Rouge Tributary area in Detroit.

stormwater. Each pilot site occupies two vacant lots and has the capacity to store 300,000 gallons of stormwater, roughly the amount of runoff from a city block during a 2 year 24-hour storm – far more than a conventional rain garden.

Since rolling hills or more permeable soils are not typical in much of Detroit, GSI designs that depend on those characteristics are less suitable in most of the city. However, where Detroit has rolling hills or more permeable soils, there may be special opportunities for GSI designs that work with nature at a broader scale than individual rainwater gardens or bioretention gardens. These may be focal opportunities for GSI innovation in the city.

This report contrasts GSI design approaches for different catchments within the Upper Rouge Tributary area in Detroit: 1) the Tireman Avenue catchment, which is flat with clay soils and evenly distributed vacant property, and 2) the Fenkell Avenue catchment, which has rolling hills and large areas of permeable soils. The Fenkell Avenue catchment has concentrated areas of vacancy in some neighborhoods, but also has areas with little vacancy. Because one part of the catchment has both highly permeable soils and high vacancy, and another part has low permeability soils and low vacancy, GSI could be designed to move stormwater from the low permeability, low vacancy context to the high permeability, high vacancy context.

IMPLICATIONS OF DIFFERENT DESIGN APPROACHES

Using these contrasting landscape contexts to demonstrate different approaches to the catchment-scale design of GSI, this report examines the implications for:

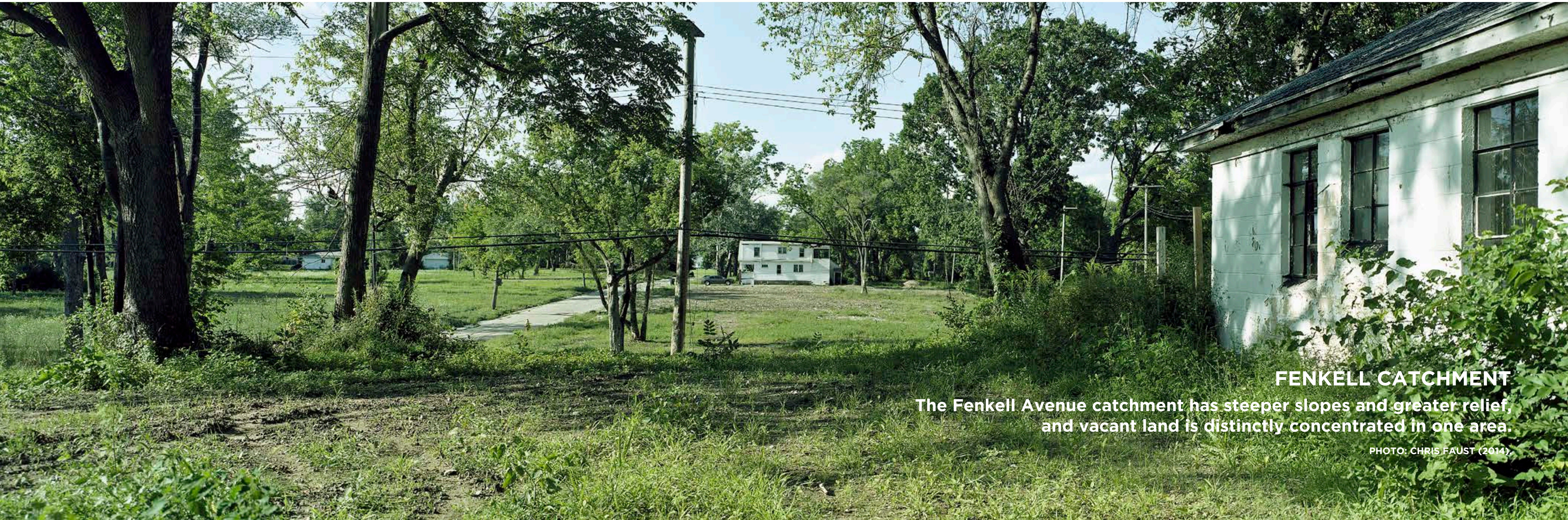
- integration with grey stormwater infrastructure,
- maintenance of stormwater systems,
- development patterns and real estate values, and
- the well-being of neighborhood residents.

It concludes that, in much of Detroit, where the landscape is flat with clay soils, there are social and hydraulic advantages to small GSI approaches, like block-scale bioretention gardens. In unusual contexts where patterns of vacancy, rolling hills and more permeable soils support large GSI approaches, there are opportunities to consider new patterns of GSI amenities that will be distinct from other neighborhoods in the city. A city-wide stormwater system that employs GSI to augment the existing grey infrastructure system could incorporate each of these approaches in different contexts.

TIREMAN CATCHMENT

The Tireman Avenue catchment is flat, and vacancy is evenly distributed in the catchment.

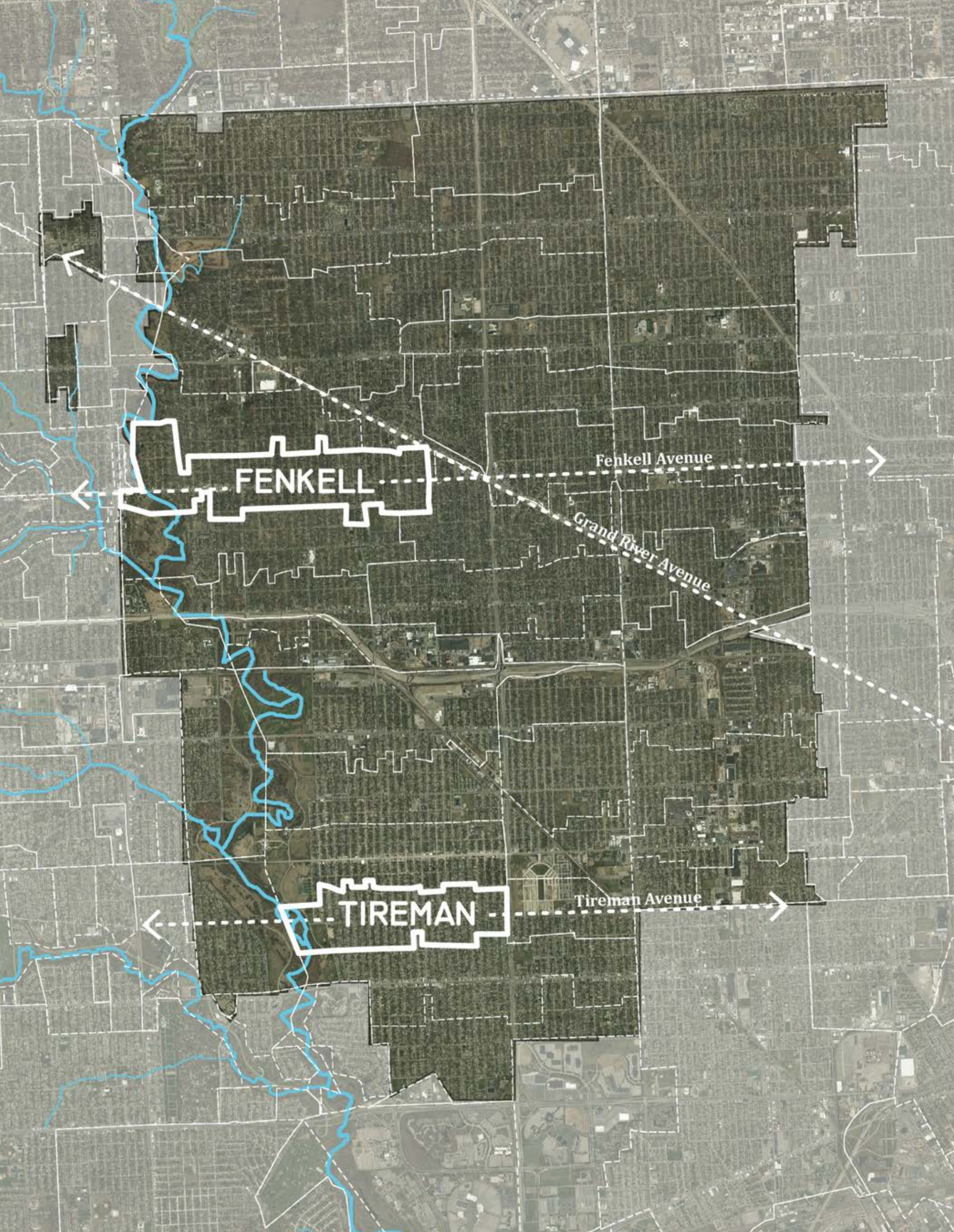
PHOTO: CHRIS FAUST (2014).



FENKELL CATCHMENT

The Fenkell Avenue catchment has steeper slopes and greater relief, and vacant land is distinctly concentrated in one area.

PHOTO: CHRIS FAUST (2014).



CONTEXT FOR GSI DESIGN: GREY INFRASTRUCTURE, SLOPE, SOILS AND PROPERTY VACANCY

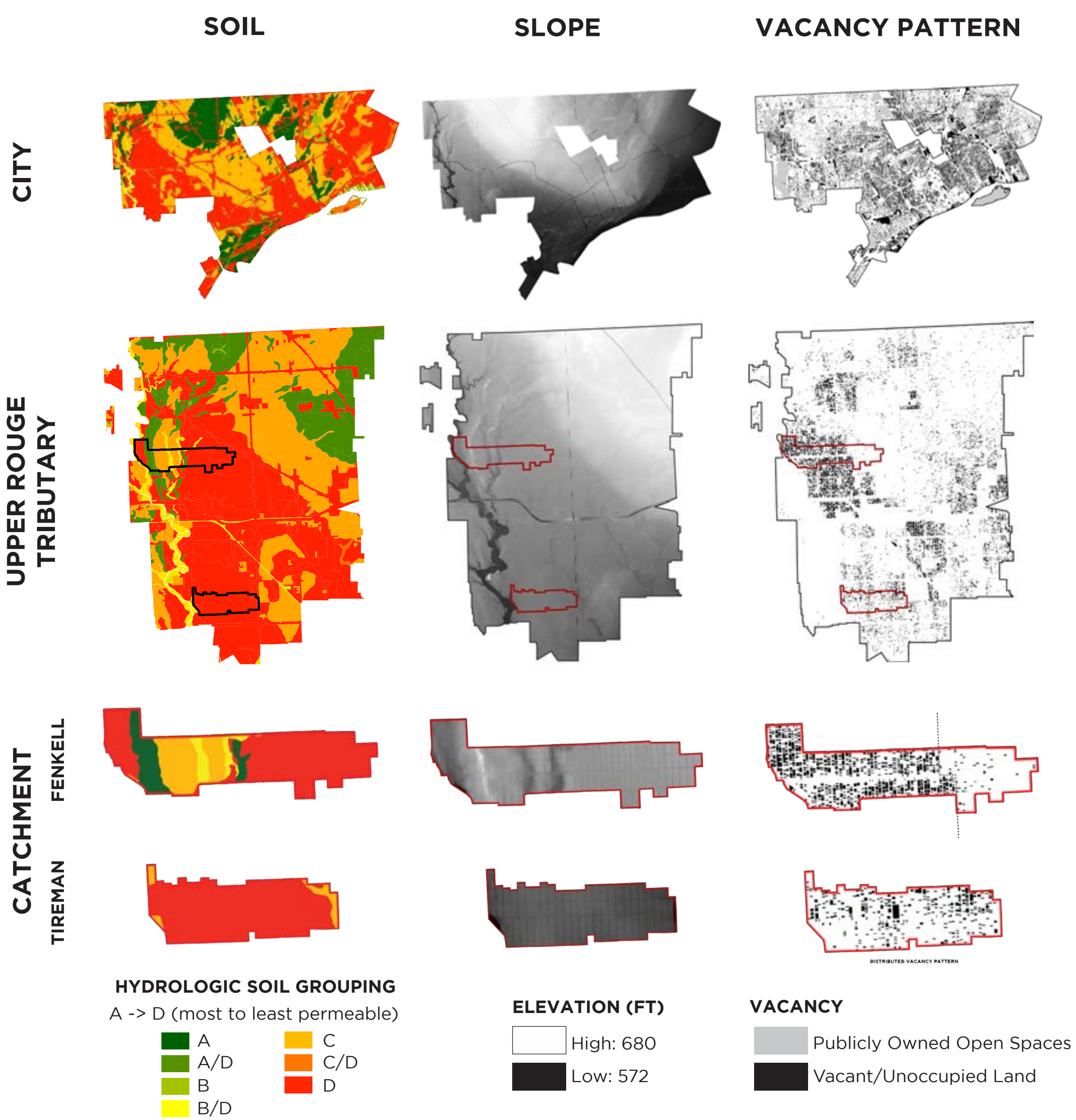
This study examines two contrasting catchments in the Upper Rouge Tributary (URT) area, where the Detroit Water and Sewerage Department (DWSD) has focused GSI implementation to date. The two catchments have different grey infrastructure, slopes, soils, and property vacancy characteristics (Table 1).

Table 1: Different landscape characteristics of the two catchments.

	TIREMAN	FENKELL
Soil	Clay - low infiltration capacity	Some areas of sand and loam - higher infiltration capacity
Slope	Flat	Some steeper slopes
Vacancy pattern	Vacancy widely distributed in a neighborhood with many occupied homes	Vacancy concentrated in a neighborhood with few occupied homes

Two different study catchments in the Upper Rouge Tributary in Detroit. Both catchments are immediately adjacent to the Rouge River.

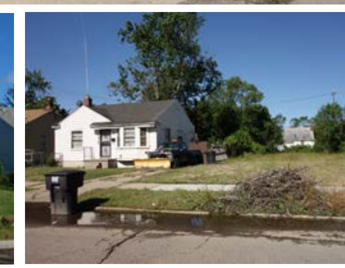
DATA LAYERS FROM DETROIT WATER AND SEWER DEPARTMENT (SATELLITE IMAGE) AND STATE OF MICHIGAN (HYDROGRAPHY).



Landscape variation in soil hydraulic conductivity, slope and vacancy patterns at three scales.

DATA LAYERS FROM USDA WEB SOIL SURVEY (SOIL DISTRIBUTION), DETROIT WATER AND SEWER DEPARTMENT (DIGITAL ELEVATION MODEL) & MOTOR CITY MAPPING (VACANCY DISTRIBUTION)

The Tireman catchment is dominated entirely by clayey soils on a flat landscape, and vacant property is relatively evenly distributed and interspersed with occupied homes. The Fenkell catchment includes large areas of permeable soil types and more steep slopes in a highly vacant neighborhood in the west, and a low vacancy neighborhood on clay soils in the eastern part of the catchment.

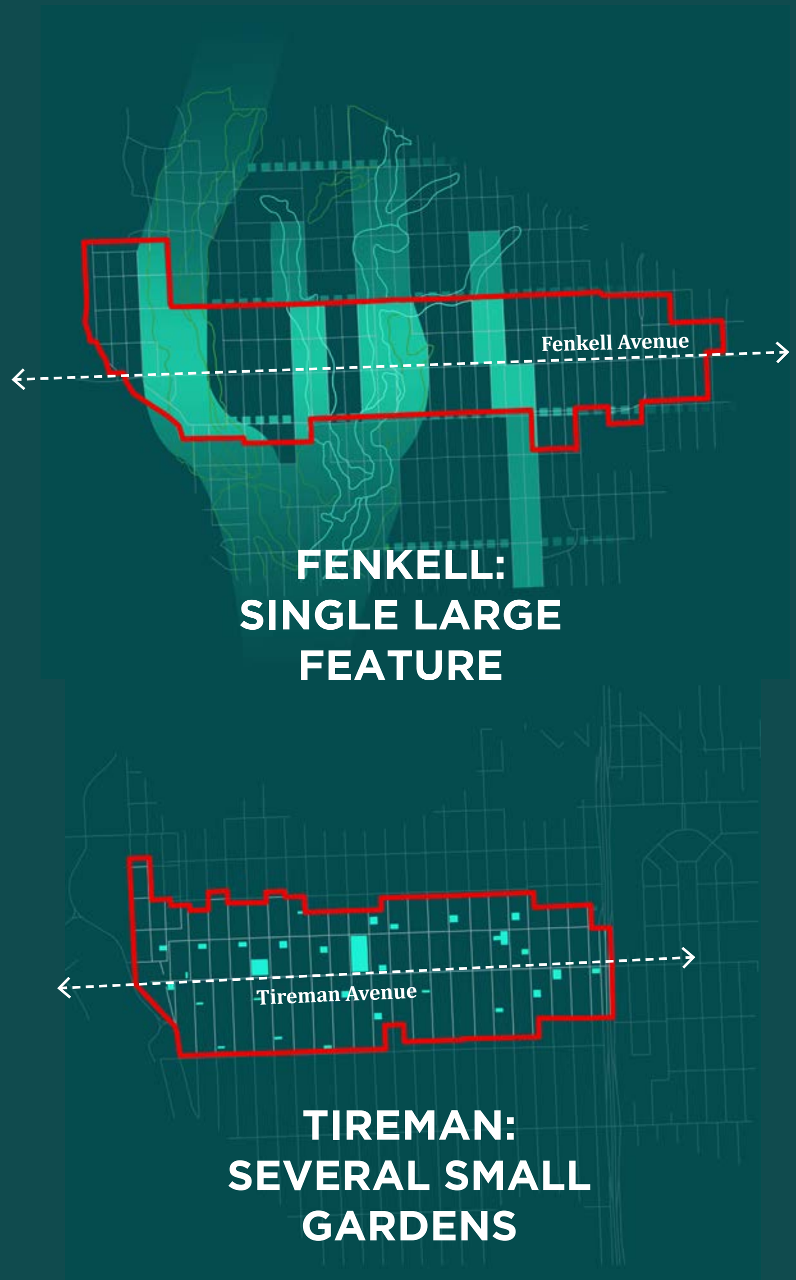


In the Fenkell catchment, steep slopes can be observed in the highly vacant neighbourhood to the west (bottom), while an attractive, low vacancy neighborhood can be found on the east (top).

These study catchments are indicative of some of the characteristics that create different contexts for GSI design across Detroit. Soil in the lowest elevation areas of the city is generally clayey; stormwater is likely to run-off quickly rather than to infiltrate. Neighborhoods at higher elevations generally have more permeable soils. Where more permeable soils are adjacent to relatively impermeable soils, there may be special opportunities for GSI to move stormwater to more permeable areas for land-based GSI.

Upper map indicates elevation (lighter is higher). Lower map indicates location of impermeable oils (hydrological soil group D). In Detroit, the lower-lying areas south of Grand River Avenue and Gratiot Avenue are dominated by clayey soils.

DATA LAYERS FROM USDA WEB SOIL SURVEY (SOIL DISTRIBUTION), DETROIT WATER AND SEWER DEPARTMENT (DIGITAL ELEVATION MODEL)



Two different design approaches for different landscape contexts.

GSI DESIGN APPROACHES FOR DIFFERENT CONTEXTS

Responding to these different contexts, two different approaches to GSI design are presented: 1) several small bioretention gardens distributed throughout the flat, clay soil Tireman catchment, where vacant property is interspersed among many occupied homes, and 2) a single large stormwater management feature that can be the focal area for a green space network in the Fenkell catchment. This single large feature is located in a low area with permeable soil, where the rolling hills are now largely vacant. It can receive stormwater from new development as well as from a nearby neighborhood on clay soil in the eastern part of the catchment, where there is little vacancy.

Single large stormwater management feature: In the Phalen Wetland Park (St. Paul, Minnesota), a single large GSI feature is used to help manage stormwater runoff from both existing and future developments.

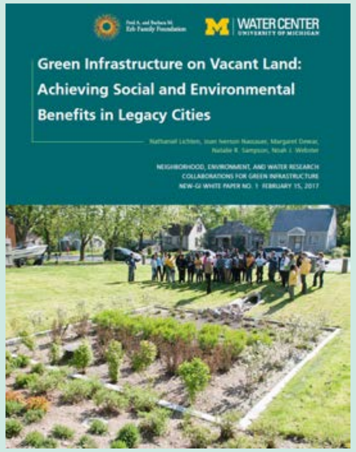
We describe how design characteristics of the two approaches respond to context. Then, using the peer-reviewed literature synthesized in NEW-GI White Paper No. 1, Green Infrastructure on Vacant Land: Achieving Social and Environmental Benefits in Legacy Cities (Lichten et al, 2017), as well as more recent literature forthcoming in White Paper No. 3, we examine the implications of each approach for installation and maintenance of GSI, for development patterns and future real estate values, and for the well-being of neighborhood residents.

For comparison of the two approaches, these characteristics are summarized in Table 2 in the following pages.

Several small bioretention gardens, each draining at least .5 acres, were constructed on vacant lots in the Tireman Catchment as pilot sites for NEW-GI's integrated assessment of GSI social and environmental functions.

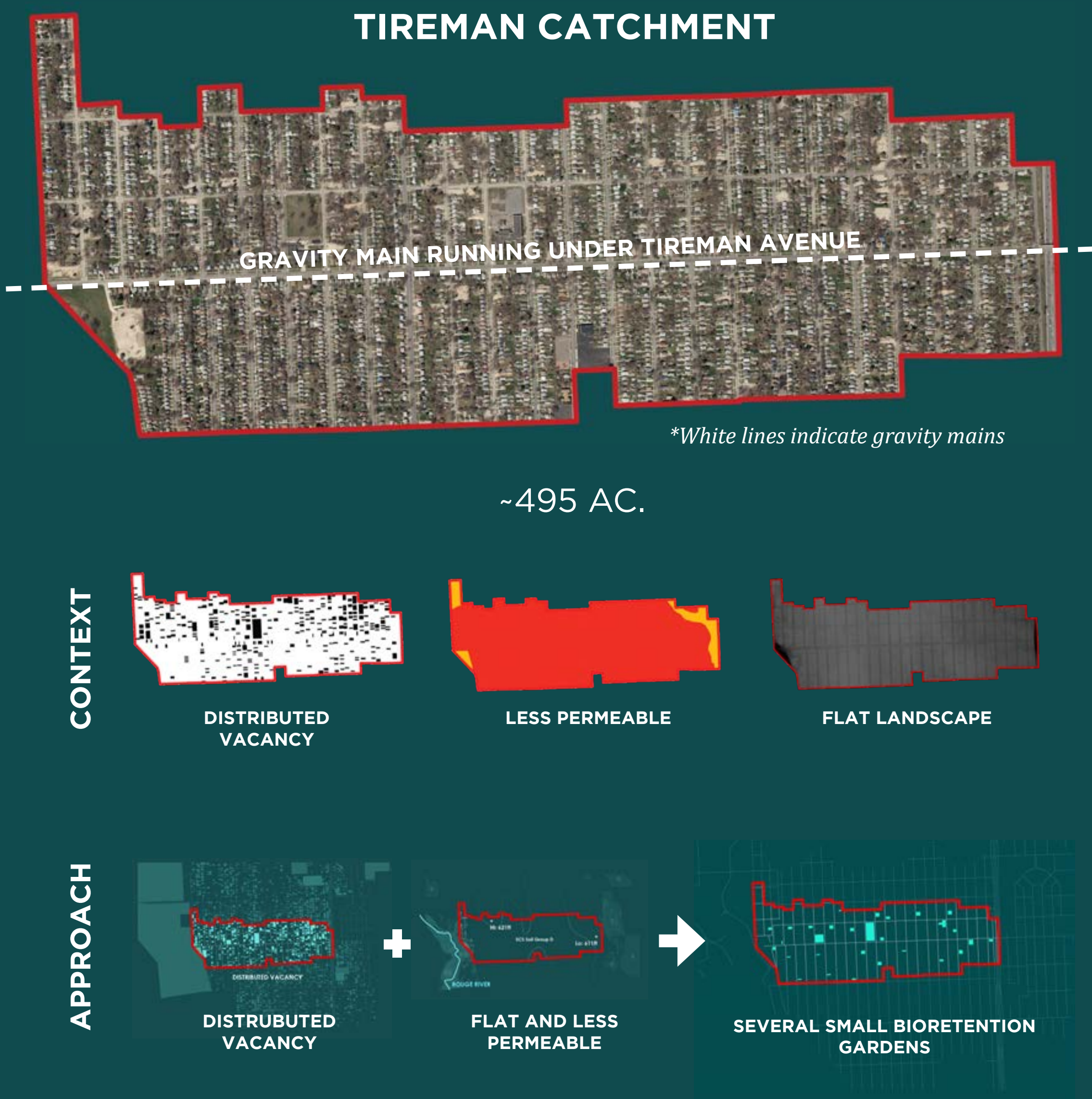
PHOTO: DAVE BRENNER (2016).

NEW-GI WHITE PAPER NO. 1



As a basis for understanding GSI and to support decision-making, this White Paper synthesizes relevant peer-reviewed literature through 2016 related to three key factors affecting GSI performance in legacy cities: 1) How governance affects planning and implementation of GSI on vacant property 2) How GSI in neighborhoods may affect residents , and 3) How residents and governance may affect the long-term success of GSI. It will be followed by White Paper No. 2 focusing on water quality in 2018, and a full synthesis of all of these topics with the most up-to-date literature in White Paper No. 3 in 2019.

		TIREMAN CATCHMENT: **SEVERAL SMALL GARDENS**	FENKELL CATCHMENT: **SINGLE LARGE OPEN SPACE FEATURE**
DEVELOPMENT	**Development pattern**	Existing pattern of low-density residential development will be reinforced by widely-distributed small amenity gardens.	Large stormwater management feature will act as a focal point for a neighborhood open space system that can host new development.
	Real estate values	Well-maintained GSI on most blocks will contribute to stabilizing real estate values.	Edges of the open space system will have higher real estate value and provide opportunities for new development on vacant land.
INSTALLATION & MAINTENANCE	**Gray infrastructure integration**	Bioretention areas are located where existing streets and grey infrastructure deliver stormwater to catch basins (local low points).	Where slopes or land development patterns limit surface conveyance, new grey infrastructure may be needed to move stormwater from source areas to focal management features.
	Maintenance	Street sediment and debris must be regularly removed to allow flows to enter bioretention areas; sites must be maintained as gardens with mowing and weeding, and kept free of dumped garbage.	Street sediment and debris must be regularly removed to allow flows to enter and move through grey or green infrastructure; focal stormwater management features and supporting GSI network must be maintained as gardens and kept free of dumped garbage.
	Governance	Maintaining many small retention areas requires attention to landscape maintenance and surface flows over a relatively large area.	Maintenance could focus on a single large stormwater feature if the system design effectively moves most sediment and debris to that feature; if the system design moves stormwater through a surface network, landscape appearance and stormwater flows across the entire network would also need maintenance.
HUMAN WELL-BEING	**Key design characteristics for social benefits**	Prominent mowing, colorful flowers, plants that maintain open views across the site, clearly defined edges to discourage public entry.	Prominent mowing where the large feature meets paths and streets, colorful flowers, plants that maintain open views across the site, legible integration with nearby paths, street systems, and public facilities to invite public use and enjoyment.
	Greater perceived safety	A well-maintained GSI landscape will enhance perceptions of a block as a safe place.	A well-maintained open space system will enhance perceptions that the immediate surroundings are safe; programming of the open space system to engage a diverse population will affect perceptions of safety.
	More physical activity outdoors	Blocks that feel safe and that provide a visual destination (something to see) will encourage people to be active outdoors.	A focal stormwater feature in an open space system will encourage people within a perceived safe travel distance to be active outdoors to reach the system and enjoy it, especially if programming of the system matches their capacities and interests.
	Increased satisfaction with the neighborhood	Residents will enjoy living near well-maintained GSI landscapes, building stronger social networks around these nearby green spaces.	Well-maintained focal stormwater features in an open space network will give residents within viewing distance more enjoyment of their block; neighborhood satisfaction may be unchanged for residents who cannot see the open space system from their home or block, or who do not use the open space frequently.
	Reduced risks of disease	Water-borne diseases, insect breeding sites, and household mold from basement flooding will be reduced.	Water-borne diseases, insect breeding sites, and household mold from basement flooding will be reduced.
	Reduced stress	Reduced exposure to localized flooding and related illness, greater perceived safety, increased satisfaction with the neighborhood, and more physical activity help to reduce stress and stress-related illness.	Reduced exposure to localized flooding and related illness, greater perceived safety, increased satisfaction with the neighborhood, and more physical activity help to reduce stress and stress-related illness.



TIREMAN CATCHMENT: SEVERAL SMALL BIORETENTION GARDENS

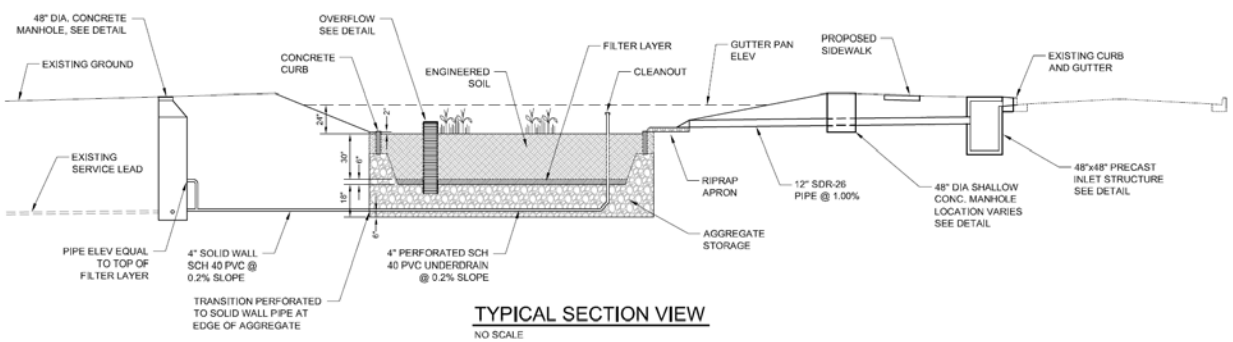
The GSI design strategy for the Tireman catchment is aimed at maximizing social and environmental benefits for residents by evenly distributing stormwater amenities in a neighborhood where property vacancy is interspersed with occupied homes. It employs the slopes of existing streets and driveways to deliver stormwater to nearby vacant lots, working within the limitations of low permeability soils and a flat landscape. The resulting design strategy of several small bioretention gardens, strategically distributed across the catchment, combines the opportunity for land-based GSI on vacant property with opportunities to enhance neighborhood well-being.

Small-scale, localized GSI is more appropriate where flat landscapes limit stormwater from traveling long distances.

Since stormwater cannot travel far over flat landscapes and is not easily infiltrated into clay soils, an effective GSI design for the Tireman catchment moves stormwater into bioretention areas within a city block, not far from where the rain fell. This catchment design uses a concept employed on four pilot sites in Warrendale, distributing variations on this design throughout the neighborhood. It uses the basement area of demolished houses to locate a depression below the flat landscape, then fills it with constructed, engineered "soil" that can hold water. Bioretention gardens are then built to move stormwater from the street into this engineered soil. These gardens connect to the street's grey infrastructure at low points, typically where catch basins are located, throughout the catchment. The gardens capture stormwater from nearby properties at these low points before it enters the storm sewer catch basins. Each small garden, built on two adjacent vacant properties, retains up to 300,000 gallons of stormwater – over twice as much as a traditional rainwater garden of the same surface area.

The drawing below shows a typical section through the pilot bioretention gardens.

DRAWING BY TETRA TECH, GSI CONTRACTOR OF DETROIT WATER AND SEWERAGE DEPARTMENT



To ensure continued function of bioretention gardens, regular maintenance is needed. This image shows maintenance being carried out on one of the NEW-GI pilot sites by DWSD's contractors.

Maintenance for both stormwater function and landscape appearance of a bioretention garden requires frequent attention. To keep it functioning properly, the entry point from the street must be kept free of debris, and sediment must be cleared periodically from pipes connecting the entry basin to the bioretention garden. The appearance of the bioretention garden is critical to its social benefits; mowing and weeding is essential. Beyond the two designs employed in the Warrendale pilot sites, the NEW-GI design team developed several related alternatives, each with different levels of required maintenance. Public preference for these alternatives is being assessed in the current NEW-GI survey of 500 households in the URT area.

To assess whether lower maintenance planting designs for bioretention gardens might be as well-received by residents as planting designs employed in the NEW-GI pilot sites, the NEW-GI team developed alternative designs to present as visual simulations in a current survey of 500 households within the URT. Each design option requires different levels of maintenance.

Image A: Mowed with bollards. In this alternative, established turf is kept well-mown. No additional flowers, shrubs, or trees are part of the planting design. The bollards and a concrete curb around the infiltration area signal appropriate use of the garden, discouraging dumping and compaction of bioretention soils.

Image B: Mowed with trees. Trees planted in rows are prominent near the front of the garden, but bollards are omitted. Established turf is kept well-mown. No additional flowers or shrubs are part of the planting design. A concrete curb around the infiltration area signals appropriate use of the garden.

Image C: Mowed with trees and bollards. In the study design, each alternative was presented with and without bollards. Here, bollards are shown in front of trees in rows. Established turf is kept well-mown. No additional flowers or shrubs are part of the planting design. The concrete curb is retained around the infiltration area.

Image D: Shrubs. Low-growing shrubs delineate the bioretention area and make a flowery display on its slopes. Shrubs alone may be easier to keep free of weeds than shrubs and flowers. Established turf is kept well-mown. No additional flowers or trees are part of the planting design. This illustration includes no bollards.

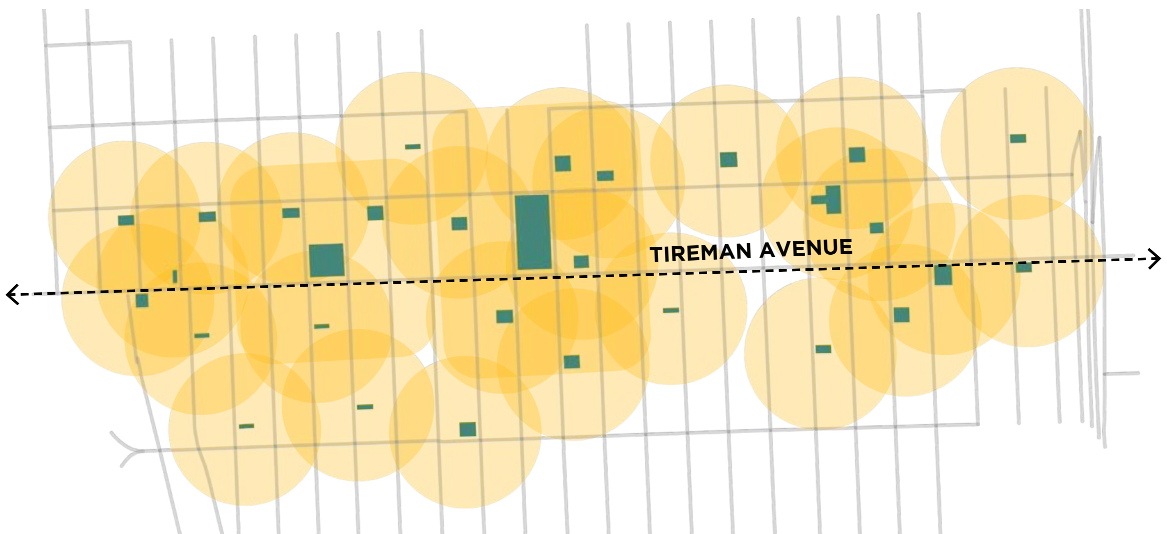
Image E: Flowering plants with bollards. The planting design for this alternative uses fewer flower and low-growing shrub species than in the original pilot sites, which may simplify weeding. The flowering herbaceous plants include ground-cover species that are likely to compete well against weeds over time, reducing maintenance needs. Established turf is kept well-mown. No additional trees are part of the planting design. This illustration includes bollards.

Image F: Infrequent maintenance. This alternative displays the appearance of the pilot sites' planting design if maintenance is reduced to an annual mowing to discourage incursion by volunteer shrubs and trees. Bollards remain, but the appearance of the amenity is severely compromised.

The "several small" design for the Tireman catchment widely distributes the benefits of living near well-maintained GSI.

The "several small" GSI design for the Tireman catchment widely distributes the benefits of living near well-maintained green infrastructure. The existing residential development pattern of the neighborhood is supported by the design. Installing a well-maintained garden on vacant property on each block maintains the current residential scale of the neighborhood and enhances neighborhood appearance. This contributes to elevating neighborhood real estate values over time.

Having a well-maintained garden within 150 yards of nearly every house in the neighborhood also enhances the well-being of residents in several ways. Familiar, valued design elements



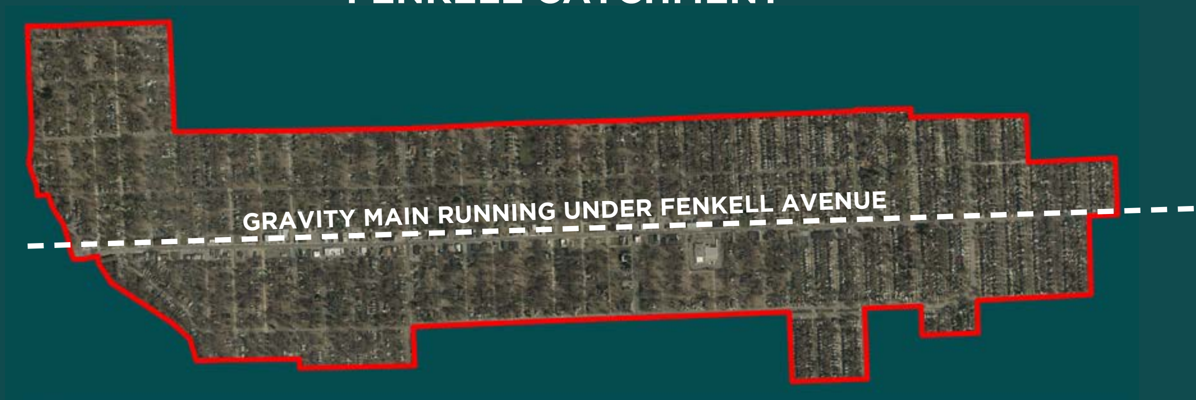
The "several small" design for the Tireman catchment locates bioretention gardens in a distribution that ensures access to an attractive flower garden for most residents within 150 yards of their homes (radius shown in orange).

PHOTO: DAVE BRENNER (2016).

like mown turf and colorful flowers, a design that maintains open views across the garden, clear boundaries to discourage public entry or dumping, and reliable maintenance – all contribute to making a place that residents enjoy and perceive as safe. These qualities may encourage people to spend more time outdoors, build stronger social networks on the block, and get more outdoor exercise. In addition, an efficient stormwater management system will help residents avoid health risks and safety concerns associated with localized flooding and ponded water. Together, all of the benefits contribute to reducing stress and building well-being for neighborhood residents.

Familiar, valued design cues (mown lawn and colorful flowers) in the bioretention gardens enhance perceptions of safety and care for residents living nearby.

FENKELL CATCHMENT



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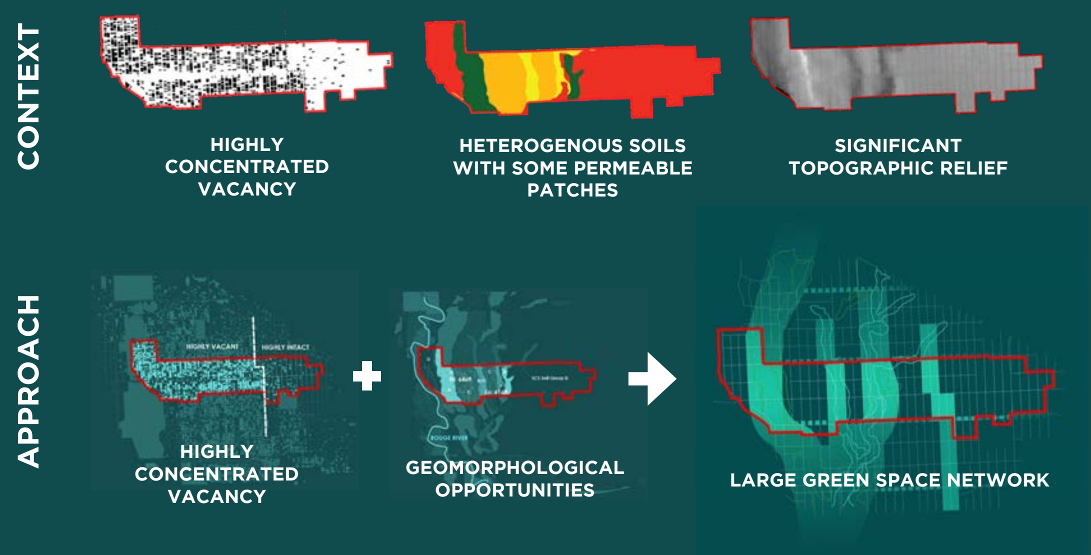
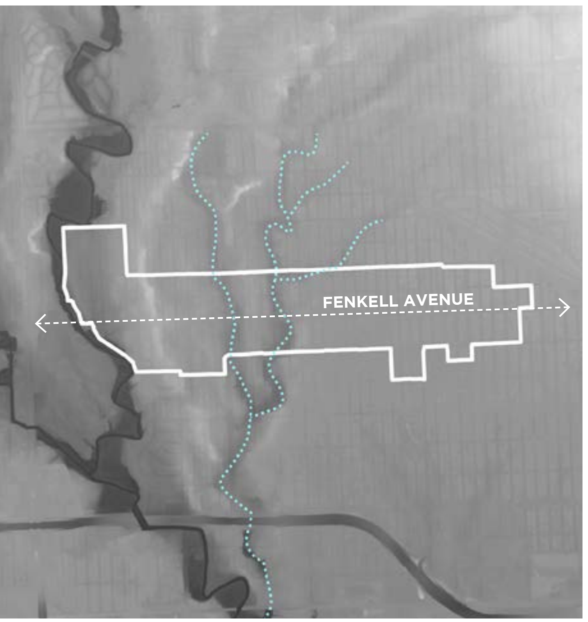


FENKELL CATCHMENT: A SINGLE LARGE STORMWATER MANAGEMENT FEATURE IN AN OPEN SPACE NETWORK

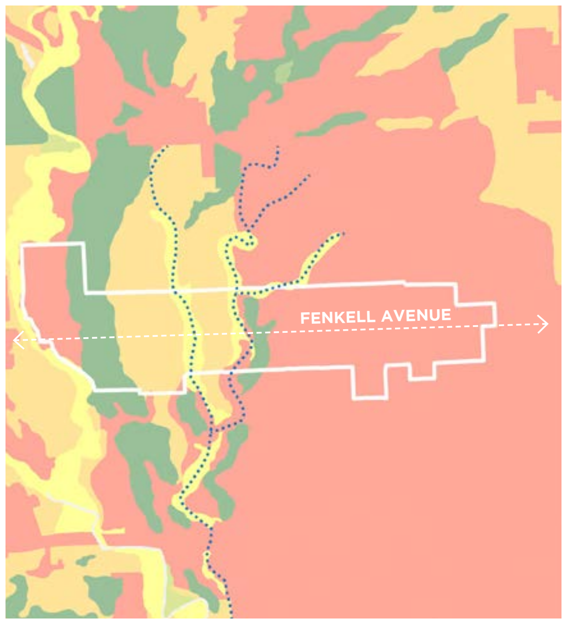
The GSI design strategy for the Fenkell catchment creates an attractive amenity stormwater management feature as the focus of a new green space network extending into nearby neighborhoods. The strategy employs large, low-lying areas of permeable soils among rolling hills in a highly vacant area to the west to manage stormwater for nearby intact neighborhoods on clay soils to the east. The focal stormwater feature could also manage stormwater from new development that could emerge in an attractive neighborhood organized around a large green space system.

An ancient stream presents unique geomorphic opportunities for GSI design in the Fenkell catchment.

The Fenkell catchment exemplifies the possibilities for GSI design to use adjacent soils conditions, where less permeable soils adjoin more permeable soils in Detroit. The catchment includes both clay soils and sandy soils, and more than 12 feet of relief within a distance of 200 feet at its steepest points. The lowest areas of the catchment have more permeable, sandy soils. The varied soils and rolling landscape result from the action of a glacial stream that flowed from north to south across the catchment toward the prehistoric Detroit River. The path of that ancient stream is apparent in the slopes and soils within the catchment and beyond. In the Fenkell catchment, the low area with sandy soils that it left behind is also an area of highly concentrated vacancy.



ELEVATION (FT)
High: 680
Low: 572



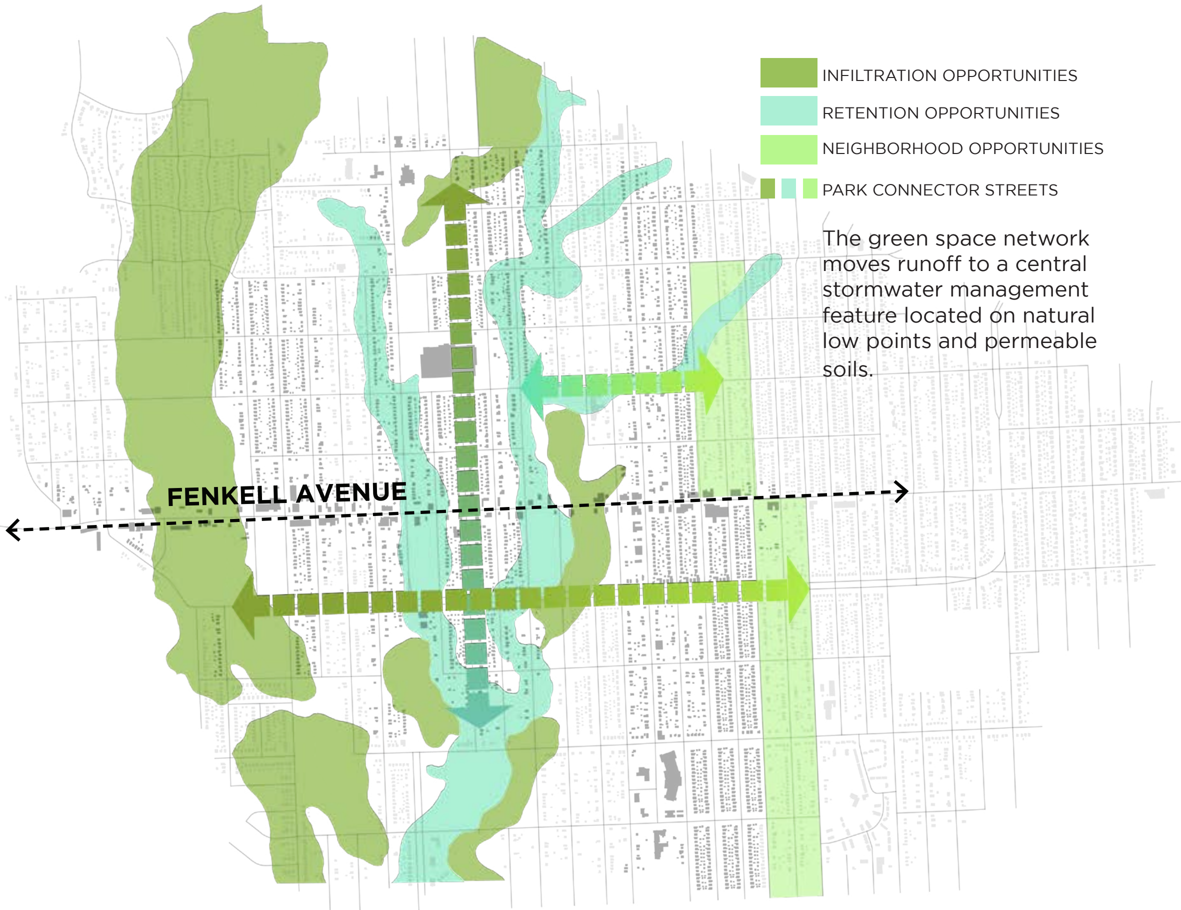
SCS HYDROLOGIC SOIL GROUPING
A -> D (most to least permeable)
A, B, C, D
A/D, B/D, C/D

This context creates an opportunity to design a single large stormwater management feature as the focus of an open space network that moves stormwater from neighborhoods elsewhere in the catchment to a focal open space on rolling hills with permeable soil.

The configuration of soil and slope left behind by the glacial stream could become a larger open space amenity system that retains and infiltrates stormwater from a large surrounding area, possibly extending beyond the catchment to the north and south. Such an open space system could be designed to invite new development along its edges to capitalize on its amenity value, and to penetrate the surrounding, intact neighborhoods with amenity streetscapes that signal the presence of a major open space amenity nearby. The stormwater performance of this GSI concept would depend on gravity flows of stormwater from surrounding areas; piped flows to the focal stormwater treatment features would allow drainage from a larger surrounding area than landscape surface flows alone.

A single large GSI feature may be more easily and reliably maintained than many small GSI features.

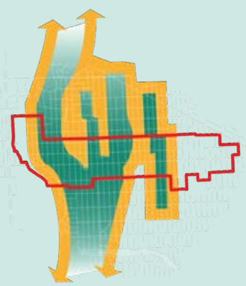
Construction of a single large stormwater management feature in an open space network would require investment to envision and implement an infrastructure open space plan that considers blue (open water), green, and grey infrastructure, as well as future development – all as parts of the same system. If future development is part of this plan, providing for maintenance of the open space network might be incorporated into development plans. If flows to the single large stormwater feature are designed to be easily maintained as part of regular street and property maintenance, sediment from upstream could collect in a few key locations that would



The green space network moves runoff to a central stormwater management feature located on natural low points and permeable soils.

REAL ESTATE DEVELOPMENT ALONG A HIGH AMENITY EDGE

The large open space network could attract new real estate development around its edges.



New development opportunities that could occur around the edges of the open space network could mix land uses in a way that contributes to the larger neighborhood by bringing more people to the open space and keeping it active. Activity on the edges of the open space and programming within it that invites a diversity of people of varying ages will further enhance perceived safety for residents.

be accessible for regular cleaning. As a result, maintenance of the single large focal stormwater management feature could be more efficient and reliable than maintenance of many small features.

Inviting neighborhood residents outdoors to use the open space network is fundamental to enhancing their well-being. Encouraging residents' outdoor physical activity and creating outdoor opportunities to build social networks with their neighbors contributes to reducing stress. While only some residents will live within sight of the open space network, the stormwater system design can promote the sense of a safe, well-maintained neighborhood even beyond the focal open space. For example, certain landscape elements of the open space network can be repeated in streetscapes throughout the neighborhood. These can define entry points for stormwater to flow into the conveyance system to the large focal stormwater feature, and they can link residents' homes to the path system that connects to the open space network.

Perhaps the most fundamental way in which neighborhood residents' well-being can be enhanced is by ensuring that GSI will control localized flooding of streets and homes, a benefit for residents throughout the catchment. This will reduce the health risks of water and insect-borne diseases and illness caused by mold in homes. It will also relieve the enormous stresses, including financial costs, of remediating and repairing flood damage to homes.

PHOTO: CHRIS FAUST (2014).

Design characteristics will further enhance perceived safety. Design of the open space landscape should create clear views across the space. Mown areas should be prominent throughout. Paths across the space should connect to the surrounding street pattern of the neighborhood.

Large bioretention feature at the the low point of the neighborhood; no standing water; planted with attractive wet meadow species in distinct bands.

Tree clusters with clear trunk height above eye level, to ensure open views across the neighborhood landscape.

New developments along the edges of the large open space system brings more people in and keeps it active, further enhancing perceived safety.

Paths across the open space connects to the surrounding street pattern of the neighborhood.

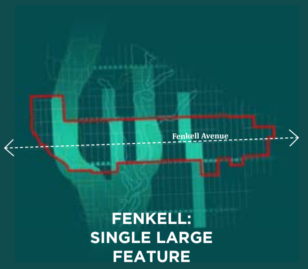
CONCLUSION

Detroit's neighborhood stormwater catchments present different contexts for the design of GSI, and the designs suggested by these contexts have different implications for supporting the well-being of neighborhood residents.

SUMMARY OF DESIGN APPROACHES

Two typical contexts examined in this study suggest two very different GSI design approaches. They are:

1. **Small bioretention gardens** – managing stormwater from a block or two. This design fits in neighborhoods that have scattered property vacancy with many occupied homes, and less permeable clay soils in flat landscapes. This form of small GSI (similar to the bioretention pilot sites in this study) can provide widely-distributed small, well-maintained amenity greenspaces that enhance the well-being and everyday experiences of residents.



2. **Large retention and infiltration basins** – managing stormwater from many blocks beyond the area of the basins. This design fits in neighborhoods that have concentrated property vacancy – several blocks where nearly all property is vacant, and more permeable soils in a rolling landscape. This form of large GSI can provide a focal amenity open space to draw people from a wider area of the city, give neighborhood residents a destination for nearby recreation, and create real estate development opportunities along its edges

Several small bioretention gardens (top), single large stormwater management feature (bottom).

PHOTO (TOP): DAVE BRENNER (2016)

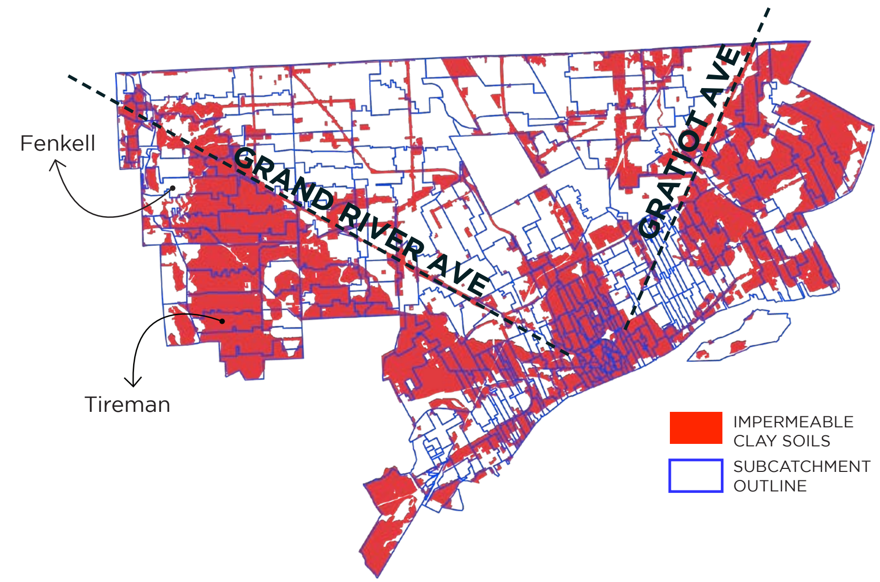
Not only are these design approaches different, they would be integrated with existing grey infrastructure differently, require somewhat different forms and routines for maintenance, and produce different opportunities for new development. Related to community benefits, key differences between these design approaches are:

- Smaller bioretention gardens, occurring every few blocks, more equally distribute access to amenity greenspace. To achieve these widespread greenspace benefits, greenspace maintenance also must be widespread and regular.
- Larger basins in focal greenspaces inherently concentrate everyday access to greenspaces among those who live most nearby. To more widely distribute greenspace benefits, the large basins might be designed as a pervasive, connected greenspace system that extends throughout the neighborhood served by the basins. While a focal greenspace may be more manageable to maintain than several small bioretention gardens, a greenspace system will also require maintenance.

For either design approach, maintenance is key to sustainable stormwater management and neighborhood well-being benefits.

The two different contexts explored in this report do not encompass all of the GSI design potentials of Detroit. They do help to demonstrate how differences in soils, slopes, and vacancy patterns across the city open up distinctly different opportunities for GSI to contribute to the green space experiences of city residents. Throughout the city, similar conditions may be amenable to similar solutions.

In other contexts, where different conditions of soils and slope are combined with varying concentrations of vacant property within a catchment, there will be different design opportunities for moving stormwater from contexts with limited permeability to contexts with more potential for stormwater management.



The clay soils in generally lower-lying areas south of Grand River Avenue in the west side of Detroit and south of Gratiot Avenue on the east side, occur within catchments that may be amenable to GSI approaches different from catchments to the north.

Considered together with flow characteristics of the existing grey infrastructure system and the extraordinary challenges of new weather patterns brought by climate change, soil and slope within Detroit's neighborhood stormwater catchments should inform the future landscape of the city. The clay soils in generally lower-lying areas south of Grand River Avenue in the west side of Detroit and south of Gratiot Avenue on the east side, occur within catchments that may be amenable to GSI approaches different from catchments to the north. To sustain new green space amenities over time in different neighborhoods of the city, different types of GSI with different functional characteristics should be tailored to local circumstances.

Guiding GSI design by attention to soils, slope, and vacancy patterns at the scale of catchments could help establish clear signature amenity identities for neighborhood landscapes in Detroit. GSI implementation at the catchment scale would allow for a more thorough assessment of the hydraulic, environmental, and social effects of different design approaches and contribute to the continuous adaptive improvement of GSI design for the city. This report aims to support a process that links Detroit's GSI innovations with continuous learning and assured benefits for the residents of Detroit.

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