

Hydrogeological soil research for green stormwater infrastructure planning and design: *new methods for adapting urban coastal communities aka "Calumet Soils Design"*

Presenting today

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Kristine Ryan, NRCS

Numerous others who we thank immensely!

Calumet soils design: update

research premise *coordinated* Green Infrastructure is a better investment than *opportunistic* Green Infrastructure.

research steps

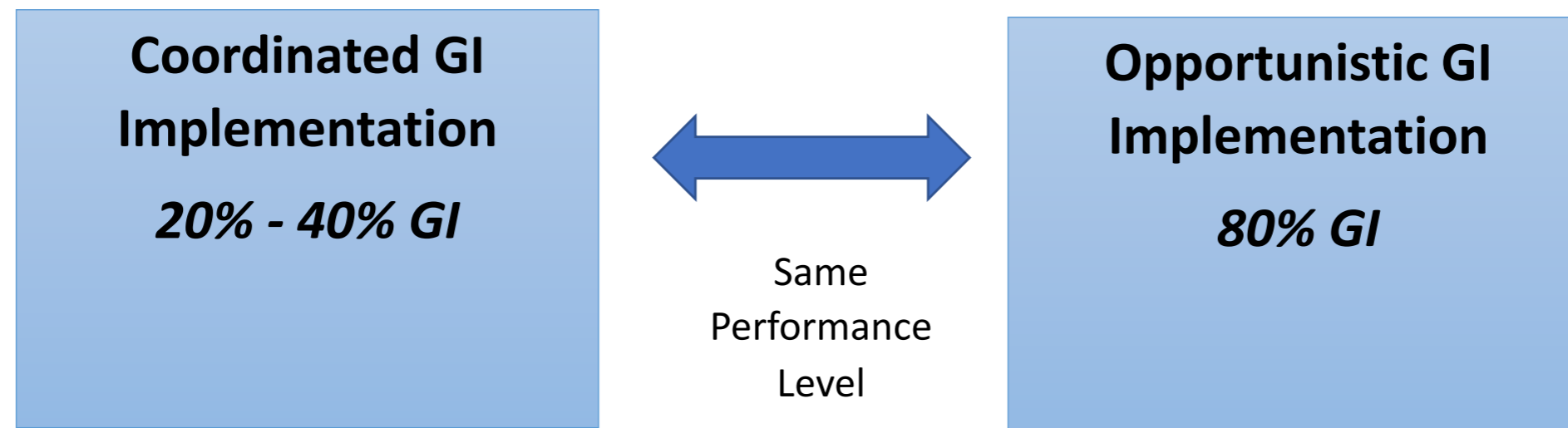
- ✓ soils research
- ✓ design/engineering
- ✓ optimized GI network in pilot communities
- ✓ process guide

where are we now? GI designs presented to pilot communities, working with communities on pilot projects and process guide.

Illinois-Indiana Sea Grant Program (NOAA) 2018-2019 # NA18OAR4170082 Hydrogeological soil research for green stormwater infrastructure planning and design: new methods for adapting coastal communities

Calumet soils design: research premise

soil properties are the foundation of GI design performance at a coordinated scale.



Illinois-Indiana Sea Grant Program (NOAA) 2018-2019 # NA18OAR4170082 Hydrogeological soil research for green stormwater infrastructure planning and design: new methods for adapting coastal communities

Calumet soils design: steps and status

Soils research	Design Engineering	Proof of concept Pilots	Process guide
1) Update publically-available data 2) Site-specific soils properties in pilot communities <i>Status: Complete, some work ongoing</i>	Model soils performance under differing rainfall volumes and GI types <i>Status: Complete</i>	Optimal green infrastructure network <i>Status: Complete, some work ongoing</i>	Sharable process toolkit to incorporate soils into GI planning <i>Status: In progress</i>
← Outreach →			

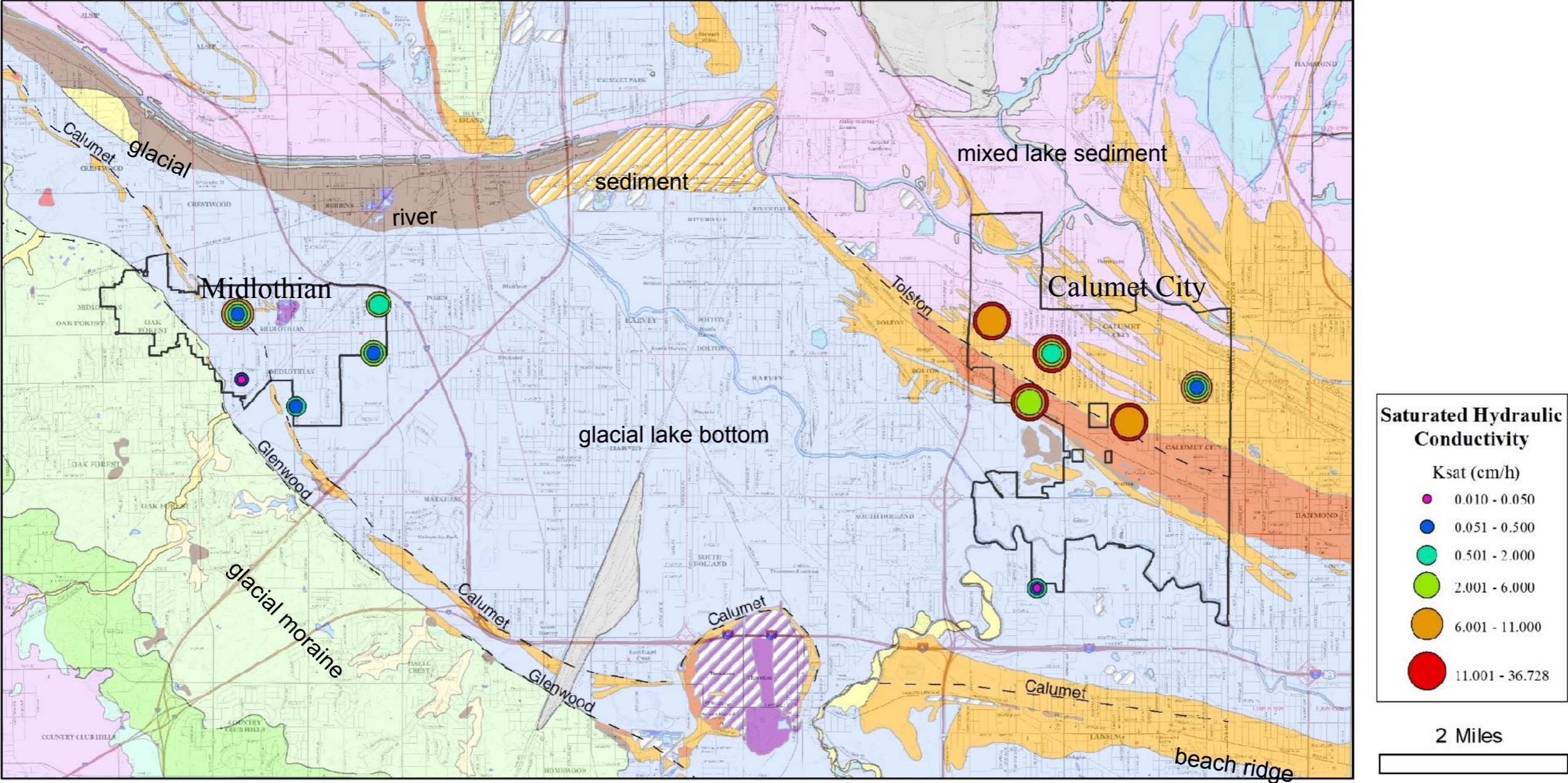
Illinois-Indiana Sea Grant Program (NOAA) 2018-2019 # NA18OAR4170082 Hydrogeological soil research for green stormwater infrastructure planning and design: new methods for adapting coastal communities

Calumet Soils Design: early findings and next steps

- Early research findings
 - for more permeable (coarser) soils, depth of installation does not matter
 - as the loading ratio (impervious drainage area to infiltration area) decreases, retrofitting not as effective
 - loading ratio is key determinant to GI Success (performance reliability)
 - placement is important, critical not to site GI at the end of a drainage surface or network
- Next steps
 - working with communities on pilot projects
 - developing sharable process toolkit to incorporate soils data into GI planning
 - peer reviewed publications

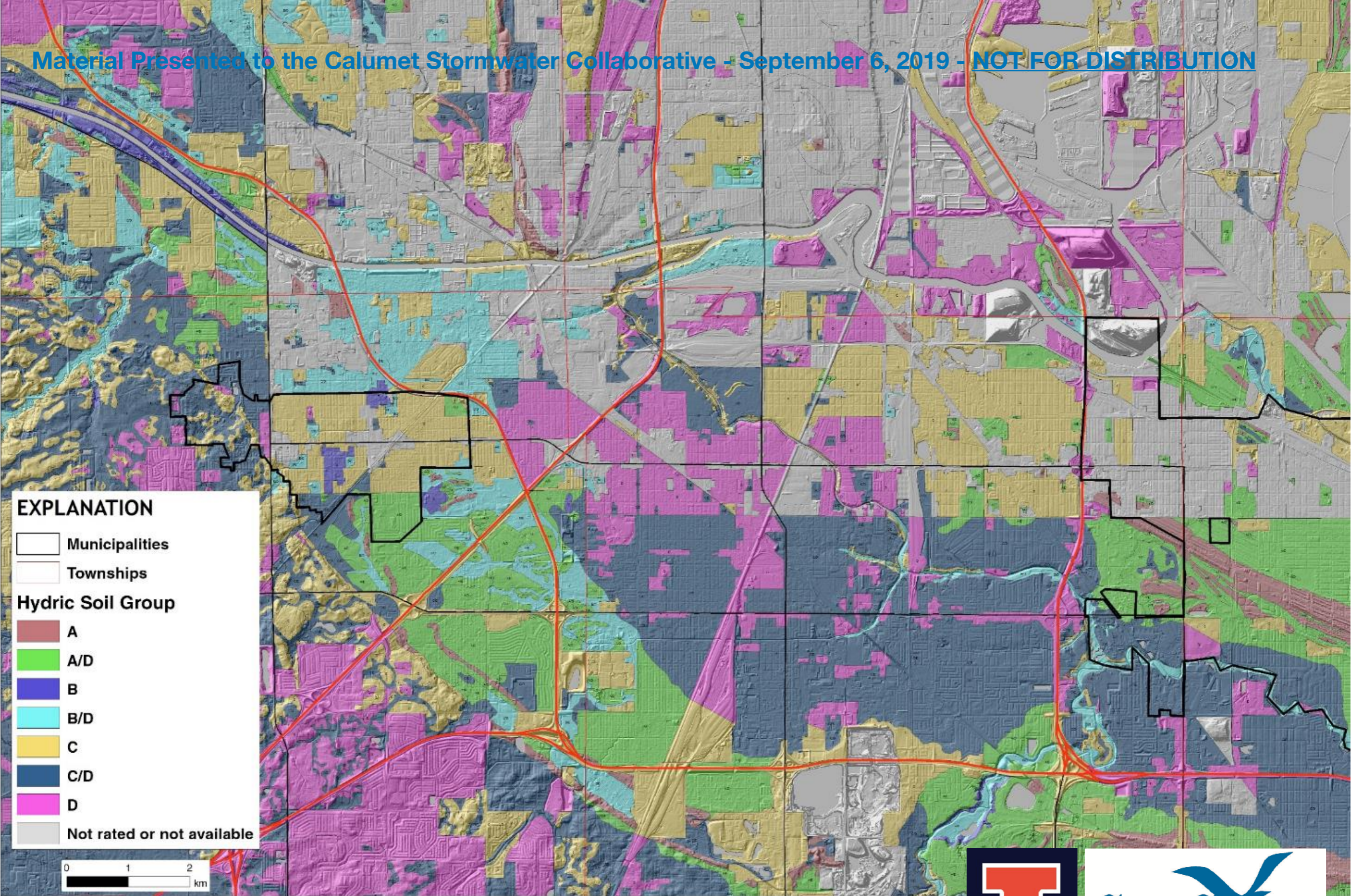
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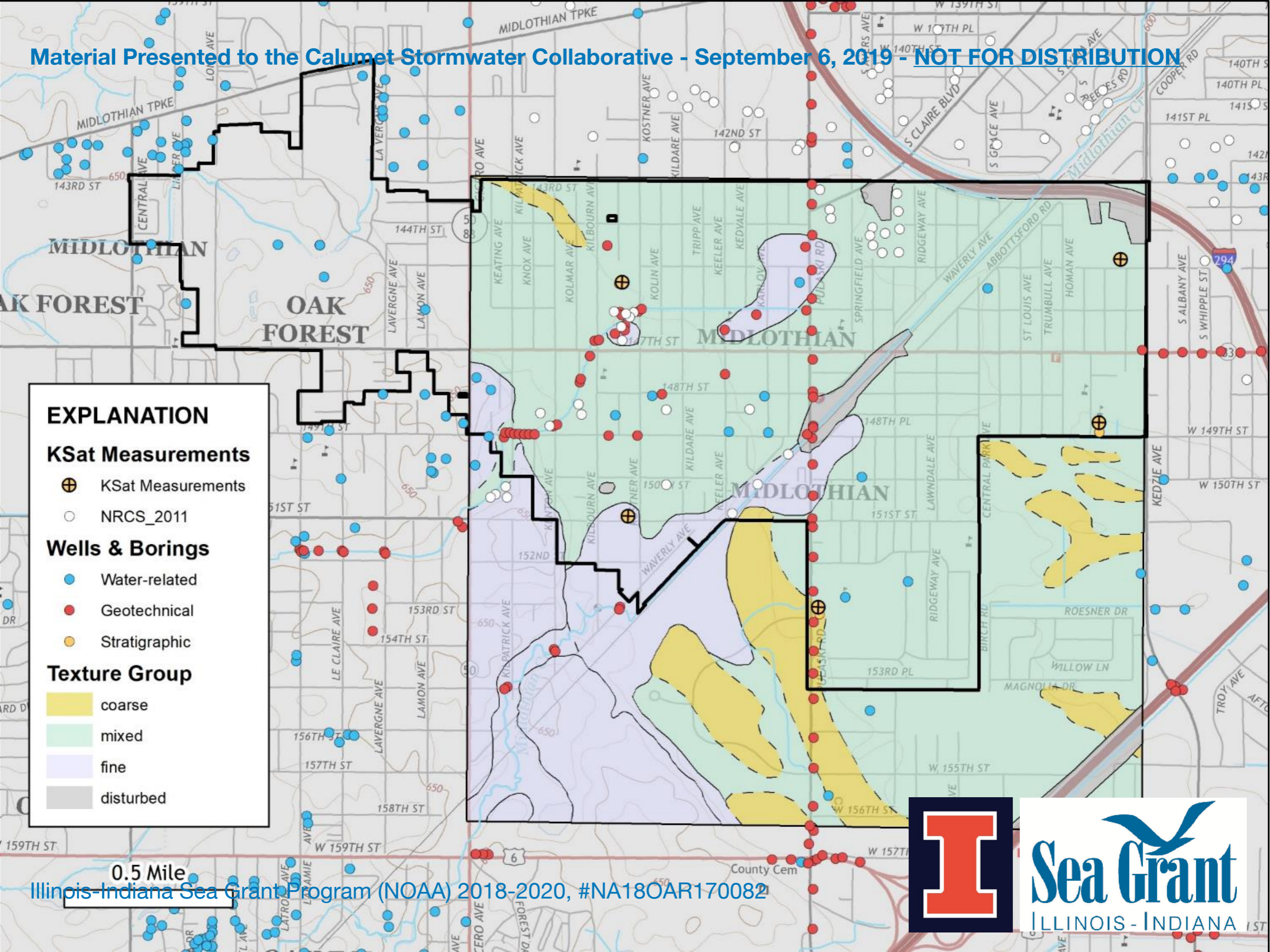
Soil Characteristics for Green Infrastructure Planning



Geology from J.H. Bretz (1948)







EXPLANATION

KSat Measurements

- ⊕ KSat Measurements
- NRCS_2011

Wells & Borings

- Water-related
- Geotechnical
- Stratigraphic

Texture Group

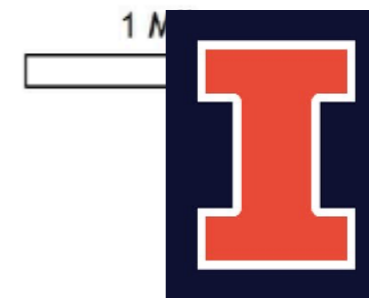
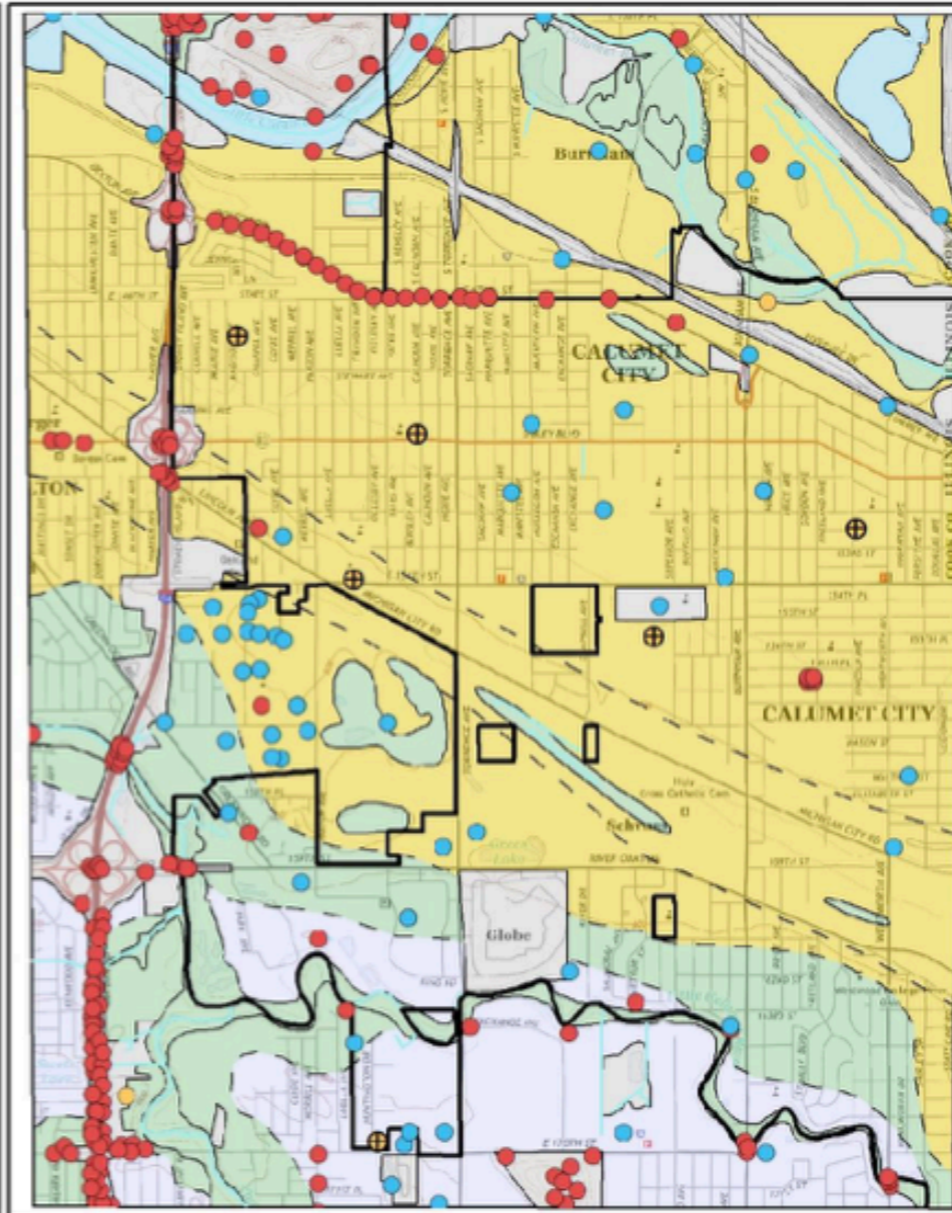
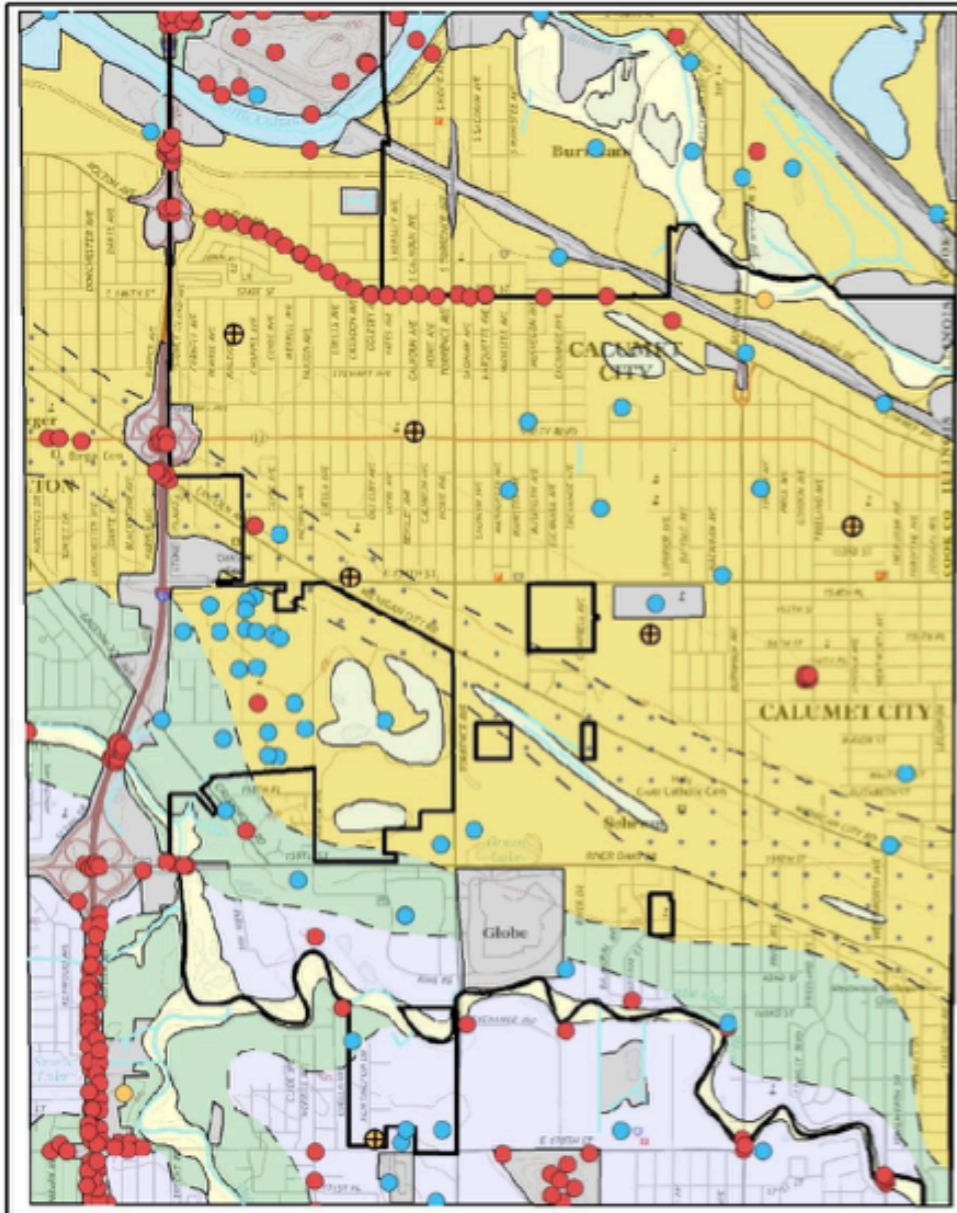
- coarse
- mixed
- fine
- disturbed

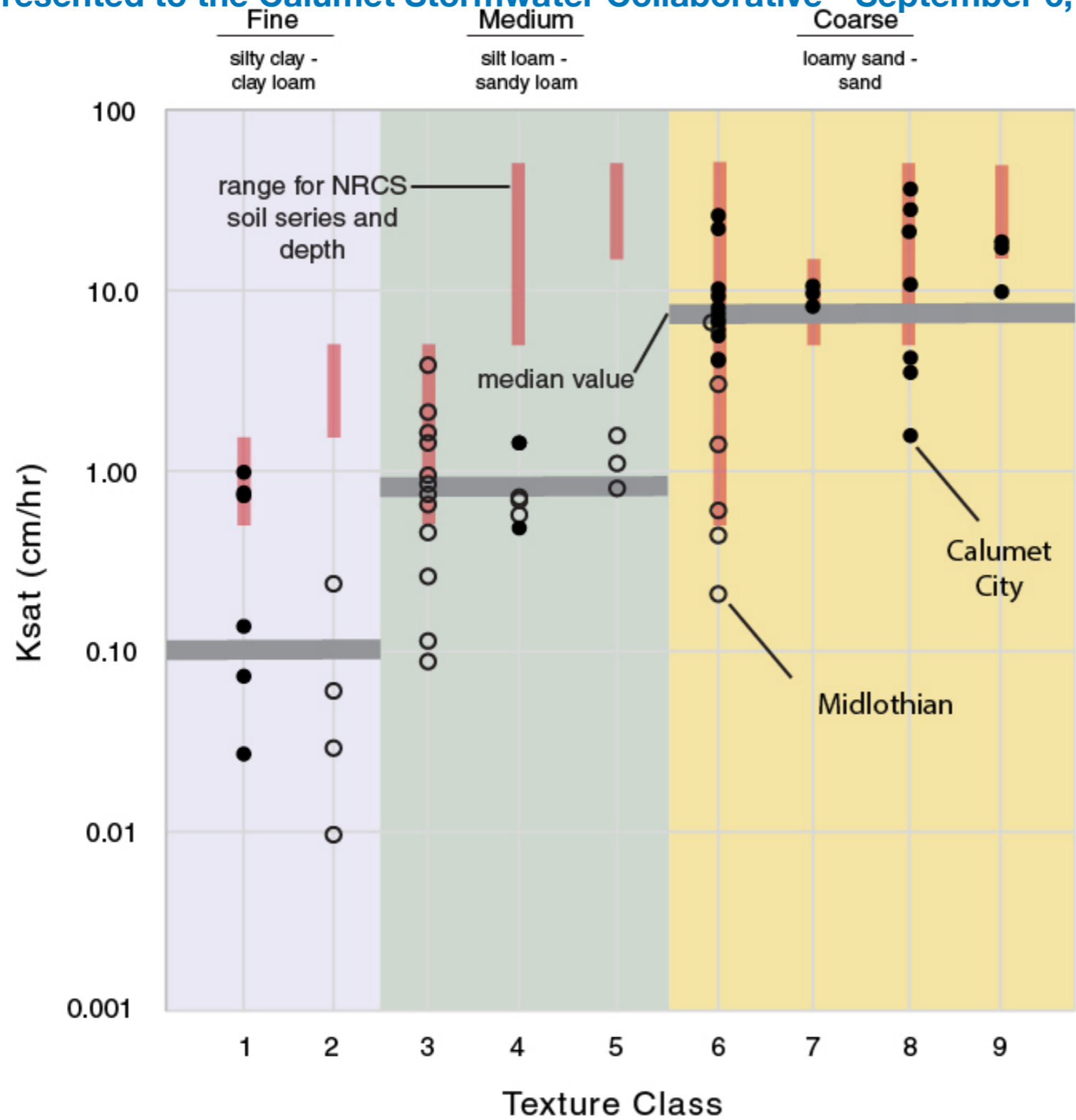
0.5 Mile



Surficial Geology

Texture Group

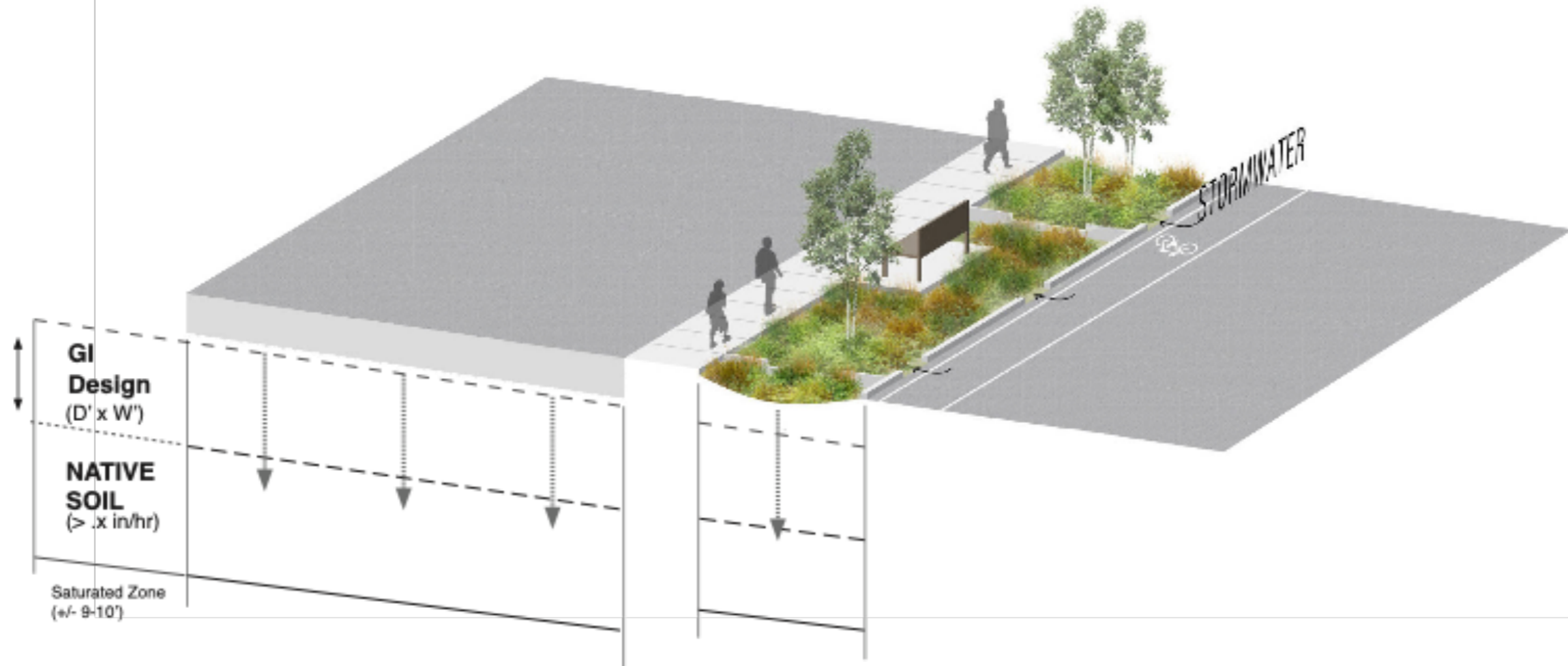




Green Stormwater Infrastructure Design, based on underlying soils

key principles:

- intercept water directly (or, as close as possible)
- create underlying layers of material (organic and/or open-graded) to further capture water
- reduce energy and erosion (make capture very direct)
- convey water downward through soils, through gravity and/or soil properties
- use planting to uptake (everywhere possible)



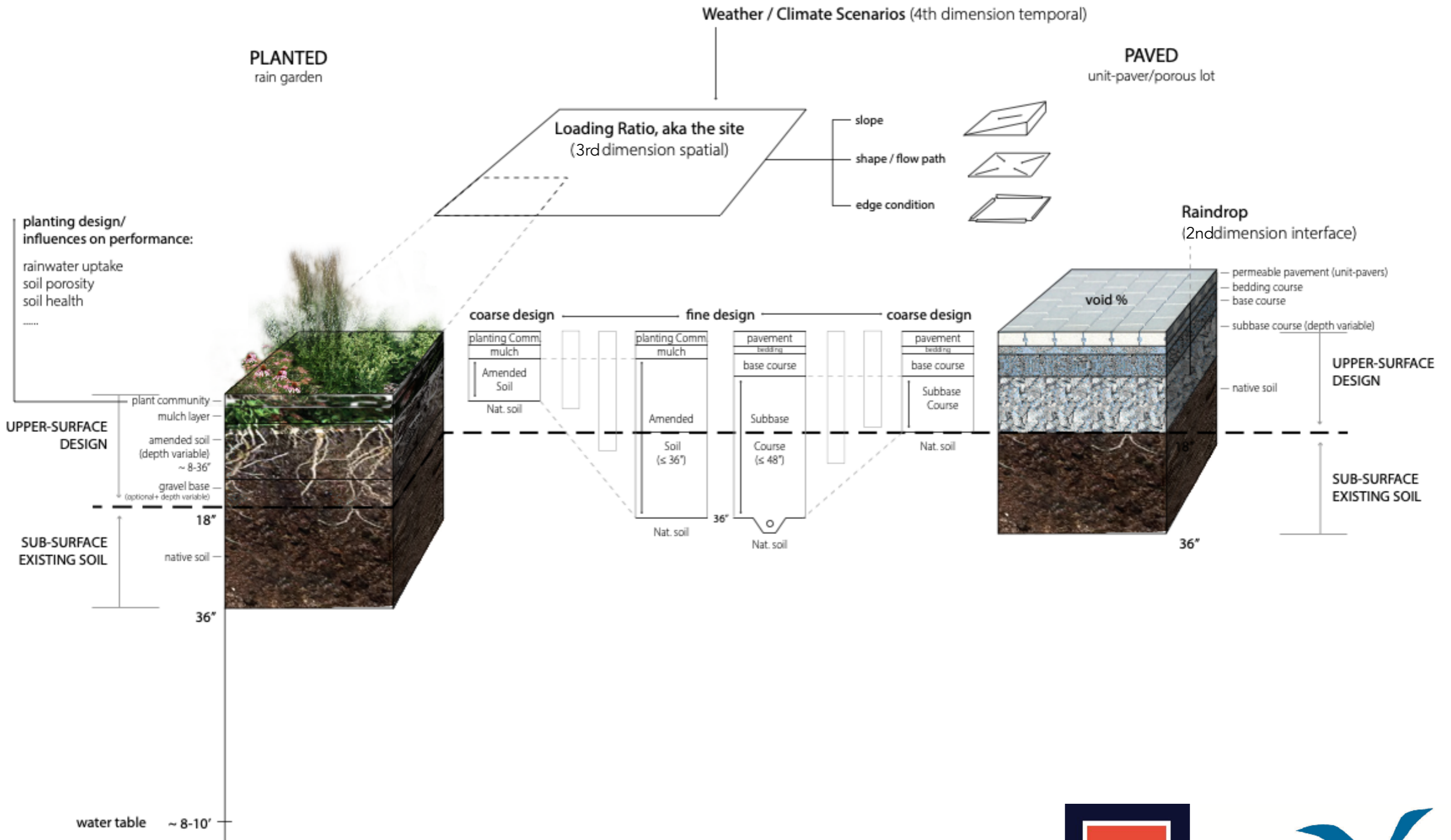
GI Surfaces
(e.g. parking lots)

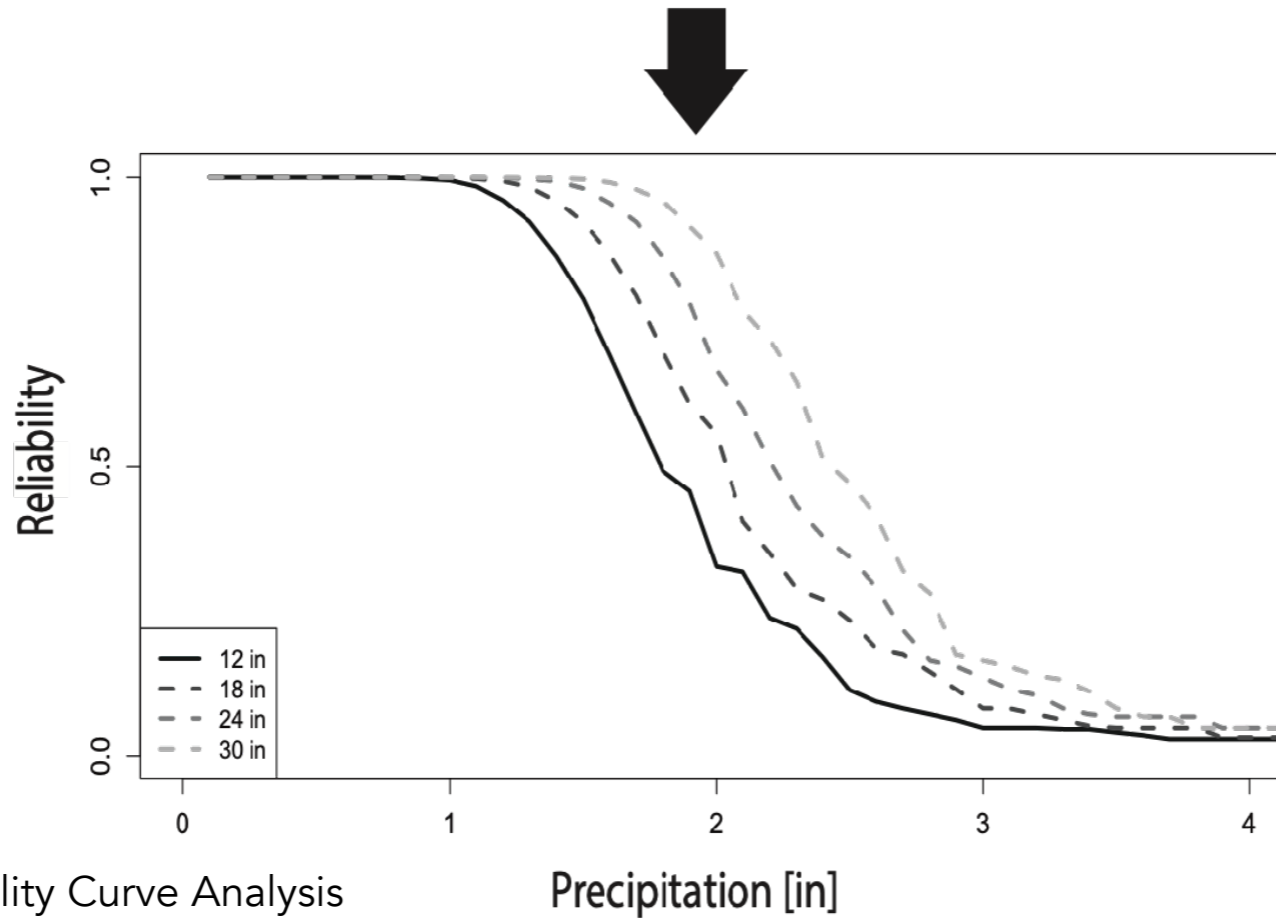
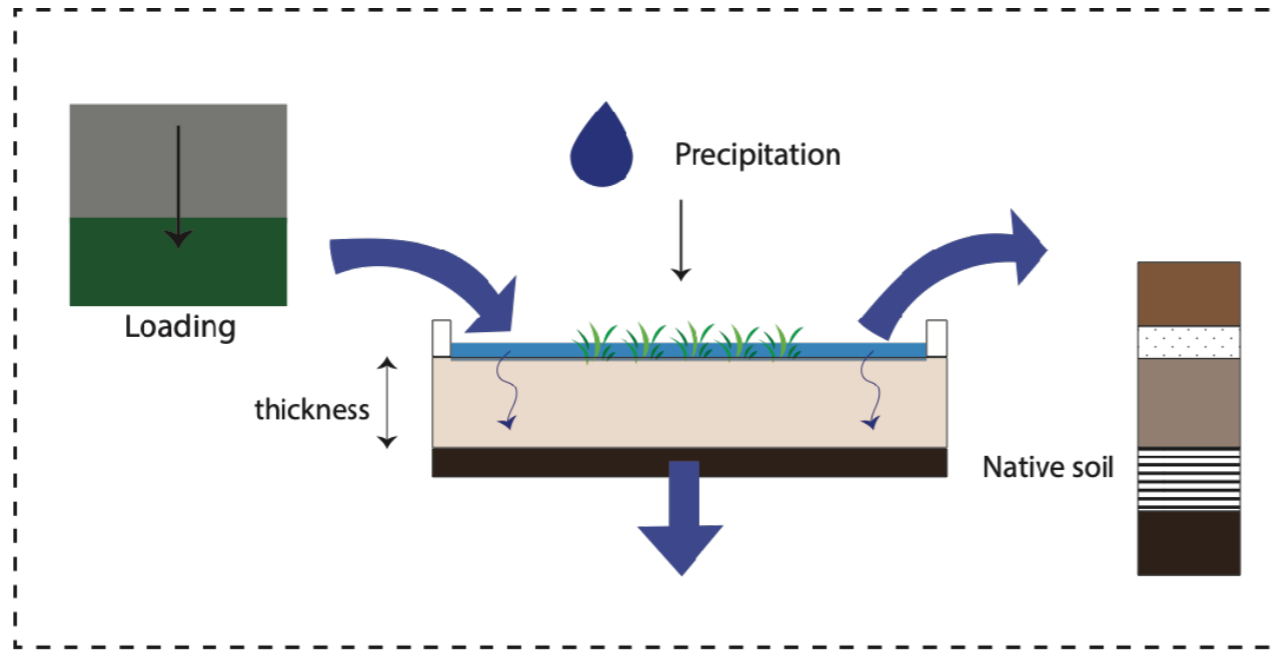
- designed to handle water directly through the surface
- optional to receive from adjacent surfaces
- lower loading ratio

GI Features
(e.g. bioswales)

- designed to receive water from adjacent surfaces
- higher loading ratio







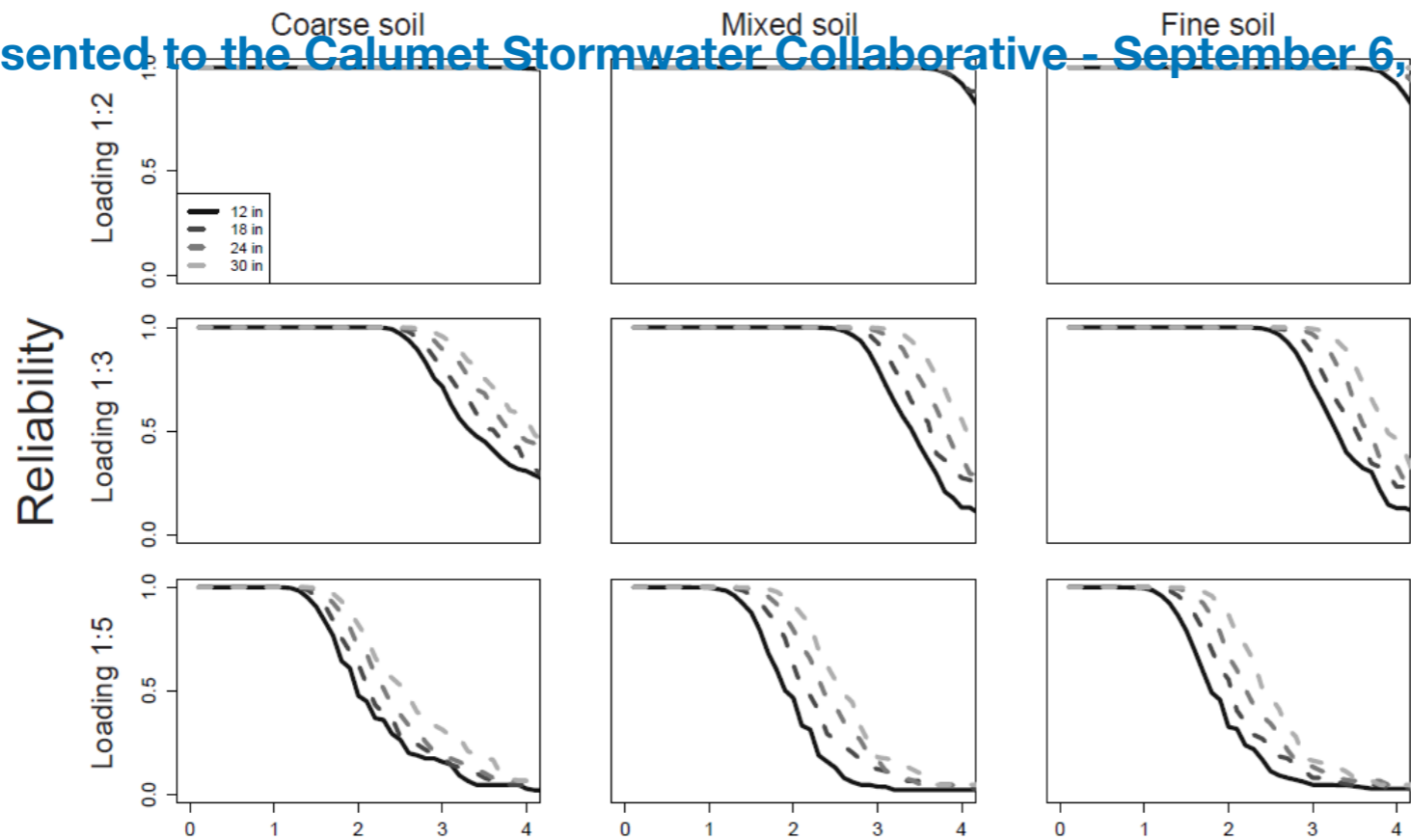
Variability and Fragility Curve Analysis

Illinois-Indiana Sea Grant Program (NOAA) 2018-2020, #NA18OAR170082

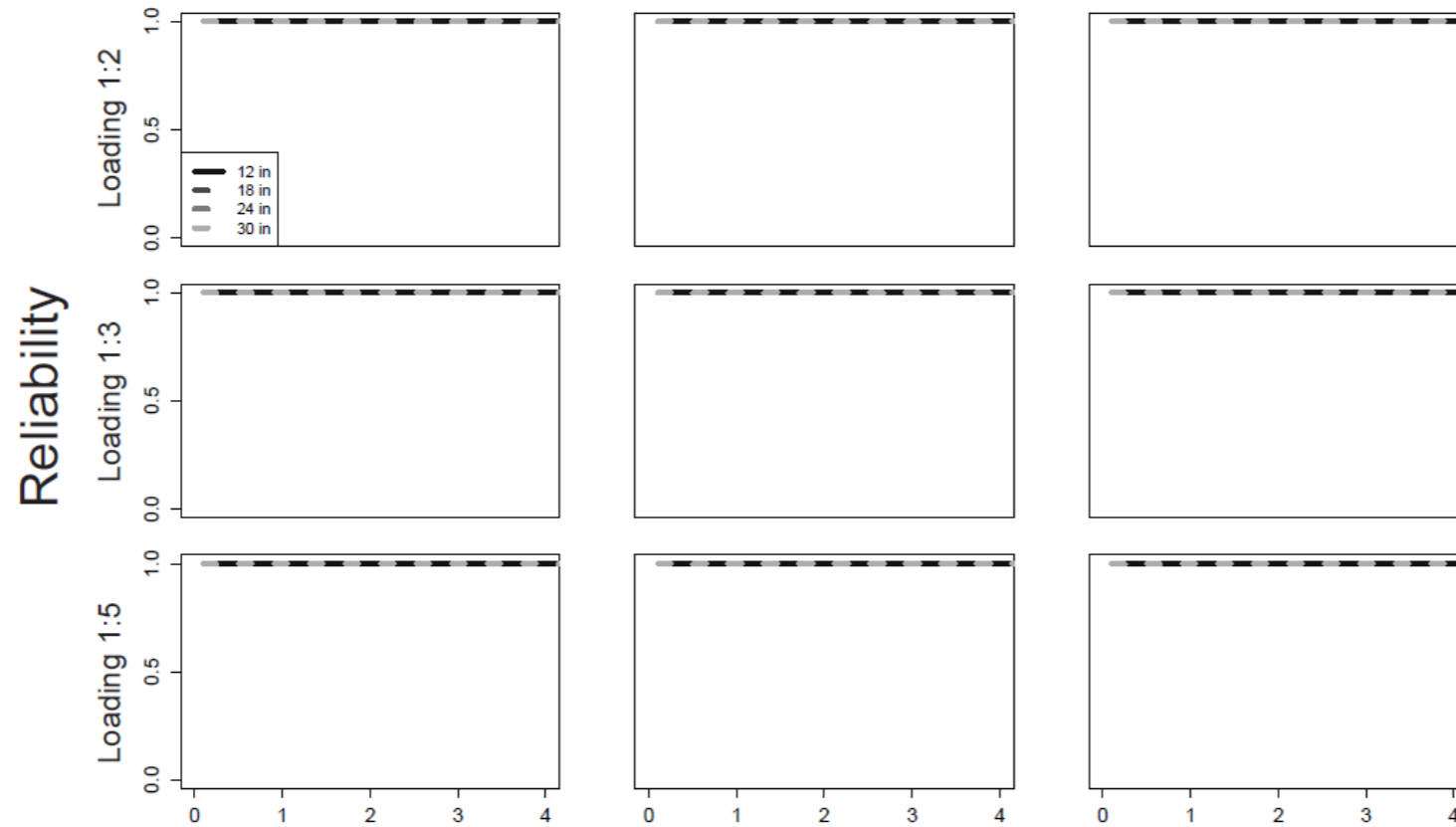


Planted

2 hour



24 hour

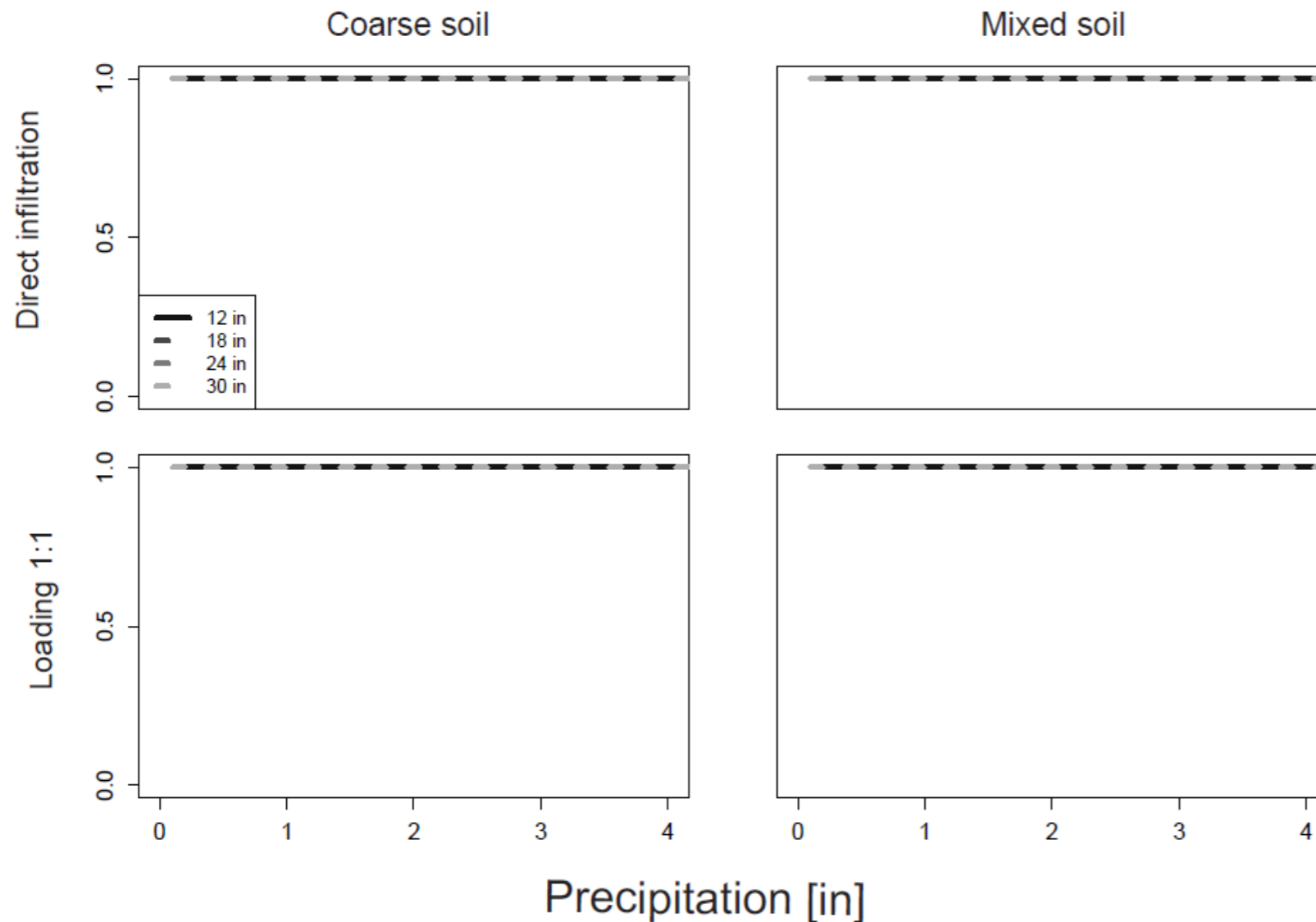


- Rain garden **performance variability** can be quantified.
- Rain gardens can effectively reduce runoff **even with fine native soils.**
- Rain gardens can effectively reduce runoff (~80% runoff reduction) **even with clayey native soils.**
- **Media thickness** is most important for mixed and fine native soils.
- **Loading ratio** is the most important design consideration for improved reliability

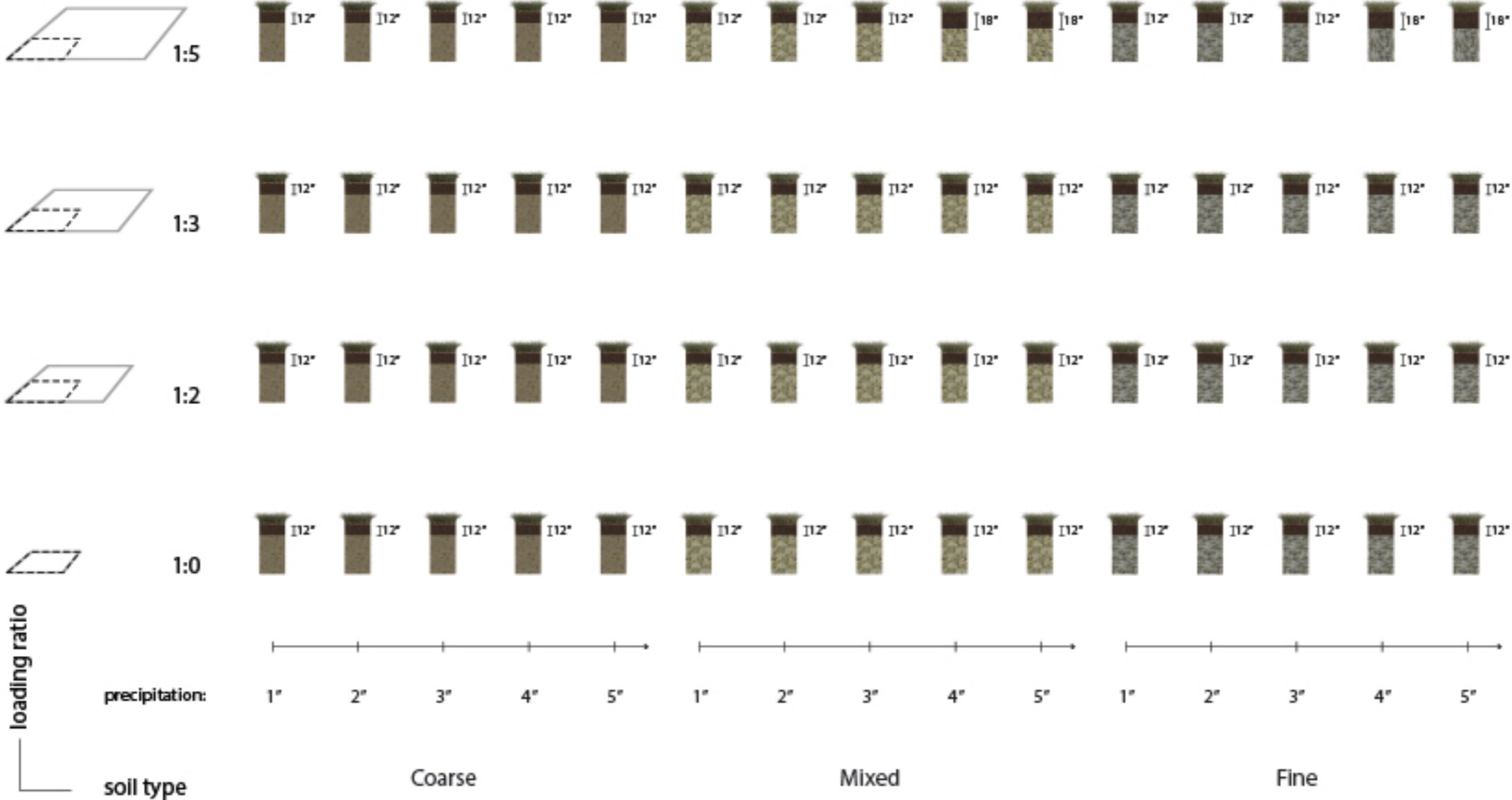
Paved

- To prevent clogging, a loading of no greater than 1:2 is recommended.
- Because of the low loading, permeable pavement is highly effective over a wider range of storms.
- Coarse and mixed soils do not require an underdrain.

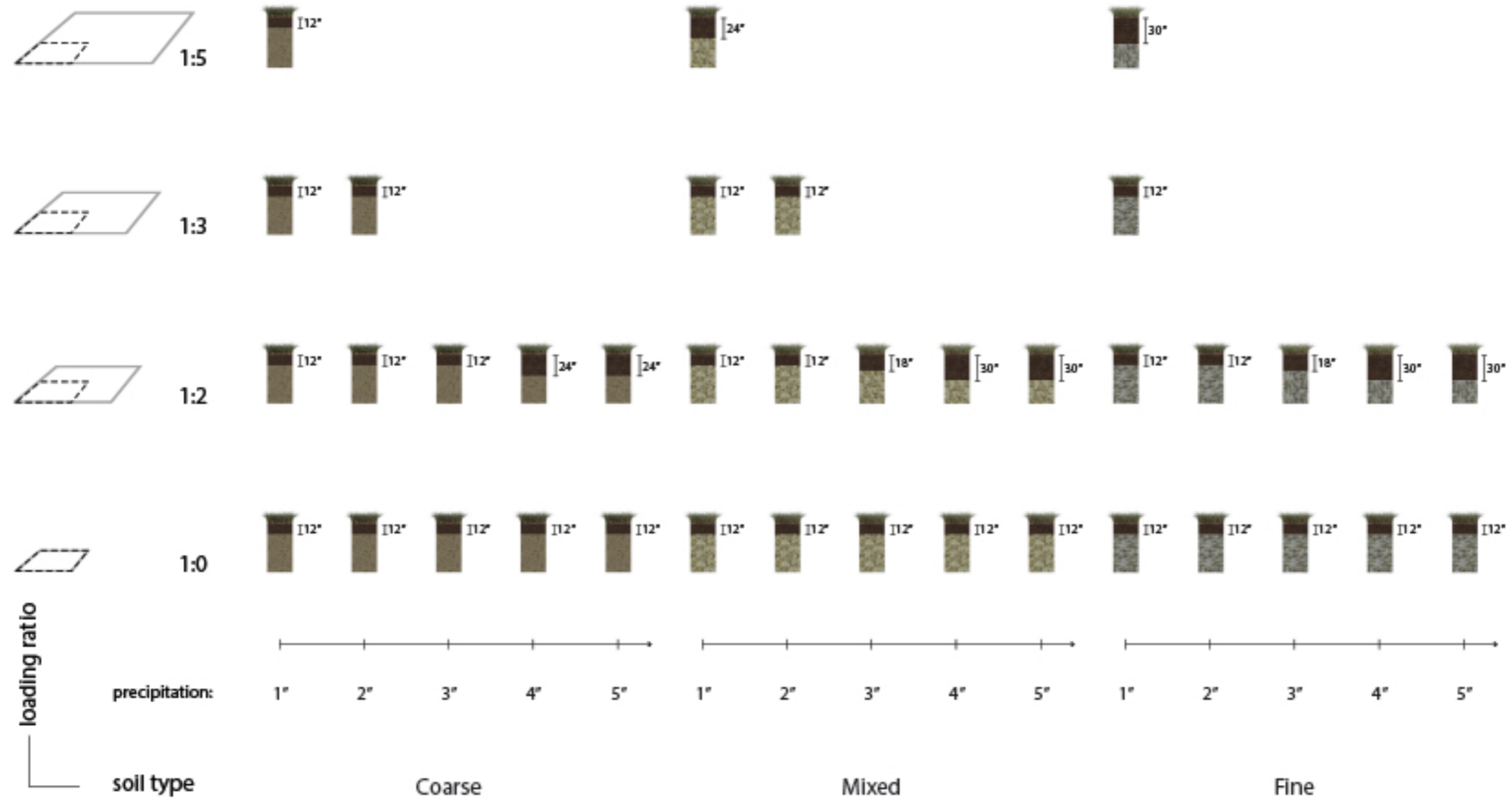
Reliability



Design Prototypes - sections for planted surface (80% peak reduction standard / 24-hour duration)



Design Prototypes - sections for planted surface (80% peak reduction standard / 2-hour duration)



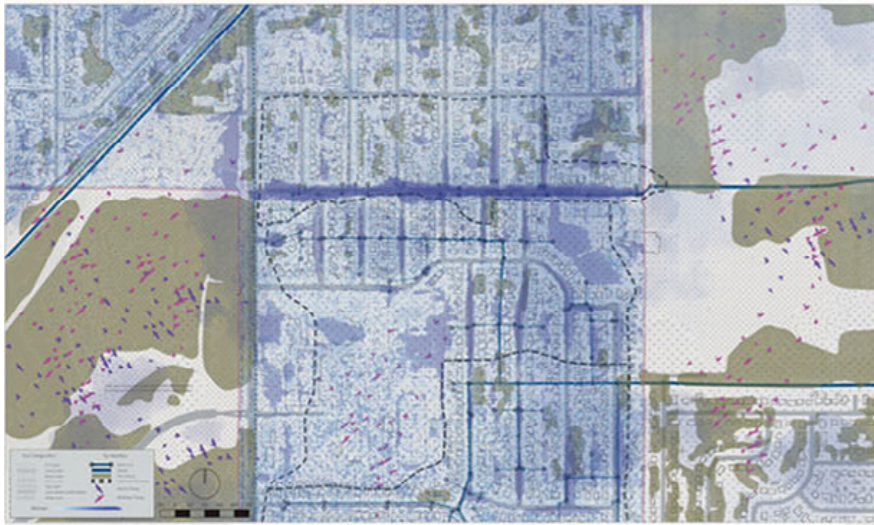
- **Loading ratio (ratio of green infrastructure surface area to directly connected impervious surface area) is an important design consideration for increasing reliability of green infrastructure runoff reduction.**

Village of Midlothian, IL: Green infrastructure design framework

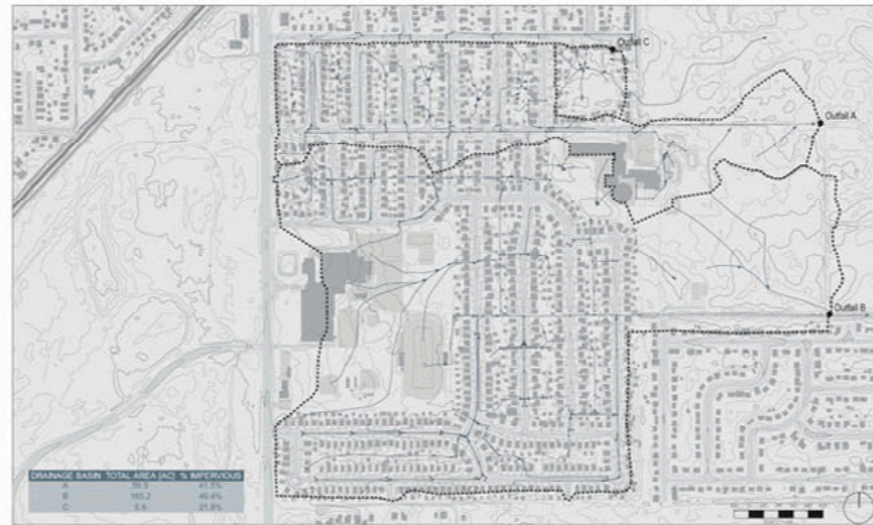


Village of Midlothian, IL: site observation and analysis

The wetness pattern highlights the 151 street as a key area of flooding.

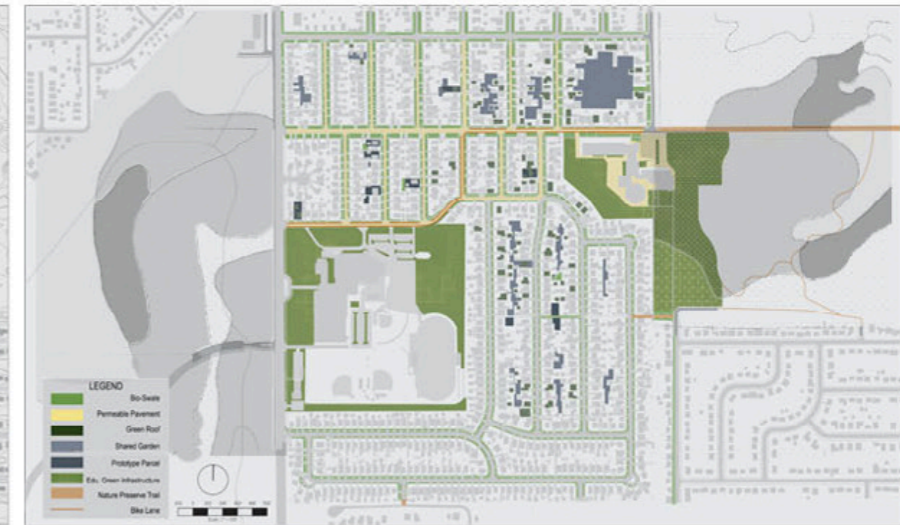


The catchment supports the study area as a unit for green infrastructure



Catchment Basin	Total Area (Ac)	% Impervious
B	162.2	46.4%
C	3.8	21.8%

The native soil pattern is seemingly cut-off by the urban fabric. Our intervention rebuilds that connection.



The ice in lawn surface depression pond.



The messy boundary between a nature preserve and the school yard.



The fenced nature preserve area.



The backup sewer stream.



Calumet Corridor: plants research

Plant Community Layer

Woody Plants

Woody plants have persistent above-ground wooden stems and branches. These plants are the backbones to the ecosystem due to their size. This layer provides the greatest impact on local microclimates, providing high levels of ecosystem services like water interception, movement, and storage, local cooling effects, and increased biodiversity (Carniero, 2011)(Solano, 2017).

There are three components to the woody plants layer:

- Canopy
- Understory
- Shrubs



There are three components to the herbaceous plants layer (Rainer, 2016):

- Living mulch
- Seasonal interest
- Structure



Herbaceous Plants Community

Living Mulch Layer

The living mulch layer should be established first. It is the foundational layer which each other plant community builds off of, and it is composed primarily of sedges (Hoffman Nursery, 2016).

This layer (Hoffman Nursery, 2016)

- Has dense, fairly shallow roots which stabilize soil and rebuild healthy soil ecologies
- Increases soil organic matter and water retention capability
- Covers open soil, decreasing weed colonization and guarding against washout and scouring



Plant Community Saturated Stage 1

These plants are capable of handling short periods of standing water. They can be placed in the lowest parts of the swales.

WOODY

CANOPY
 *American Sycamore
Platanus occidentalis

Black Maple
Acer saccharum subsp. nigrum

UNDERSTORY
 *Black Tupelo
Nyssa sylvatica

SHRUBS
 *Common Winterberry
Ilex verticillata

*Buttonbush
Cephalanthus occidentalis

HERBACEOUS

STRUCTURE
 *Swamp Milkweed
Asclepias incarnata

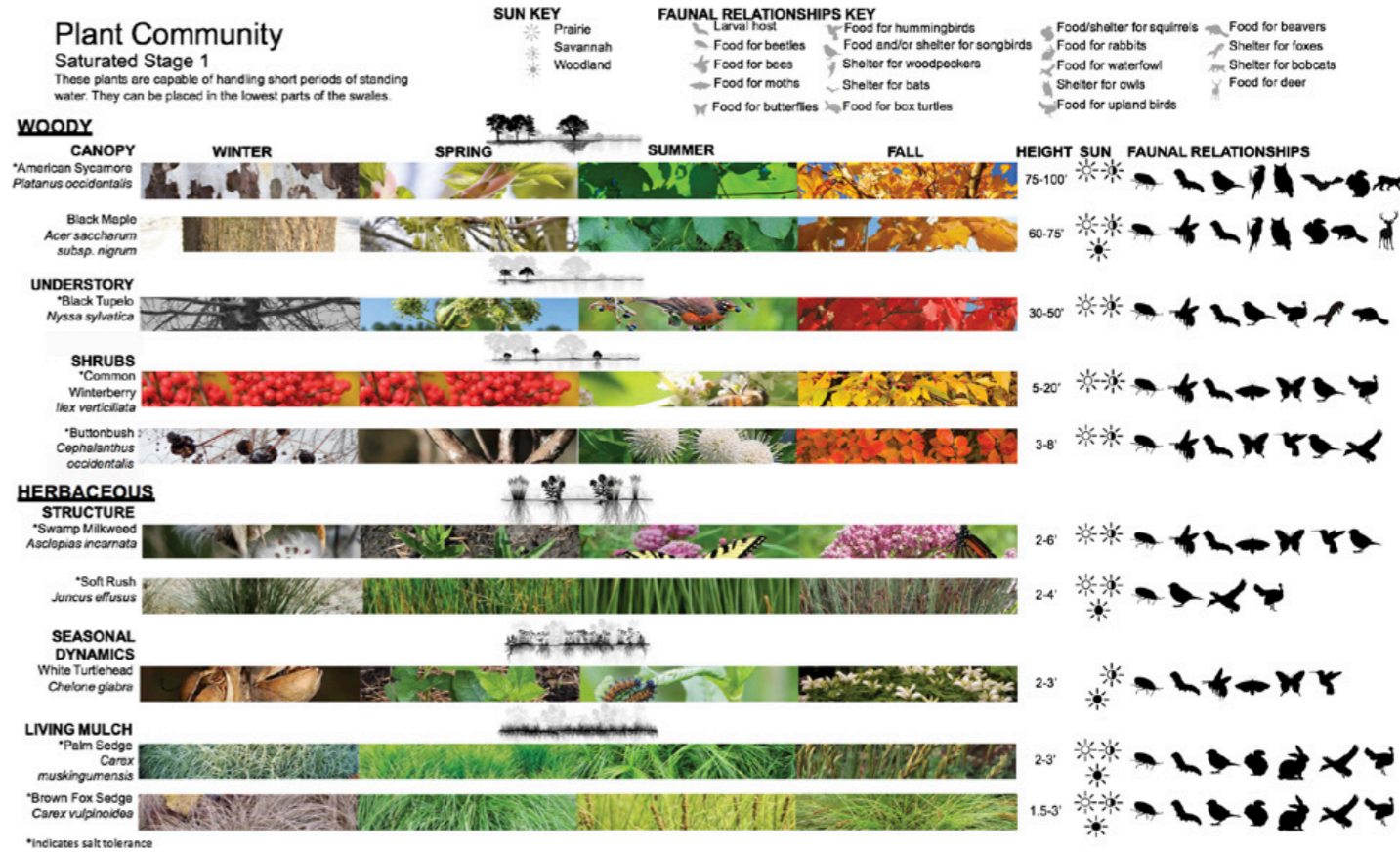
*Soft Rush
Juncus effusus

SEASONAL DYNAMICS
 White Turtlehead
Chelone glabra

LIVING MULCH
 *Palm Sedge
Carex muskingumensis

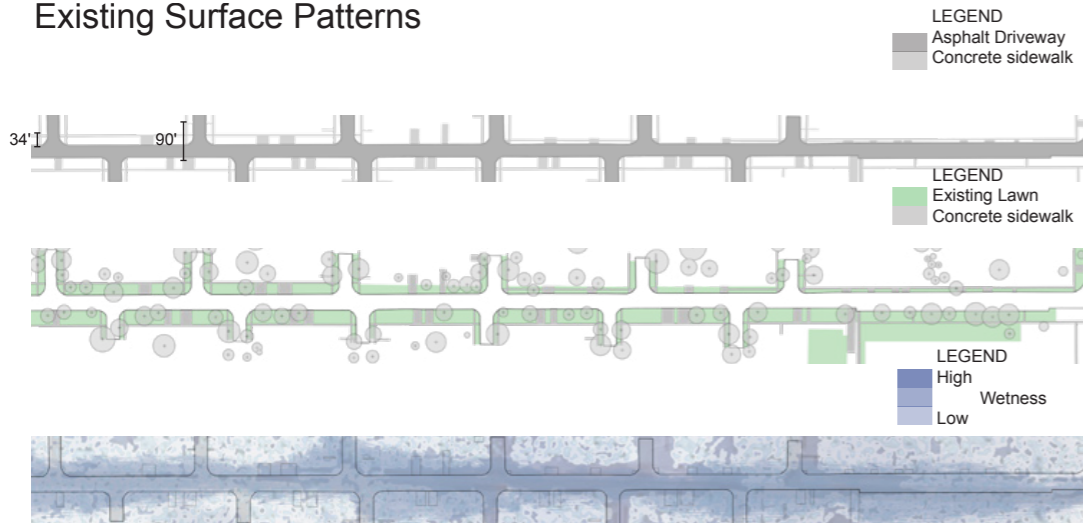
*Brown Fox Sedge
Carex vulpinoidea

*Indicates salt tolerance

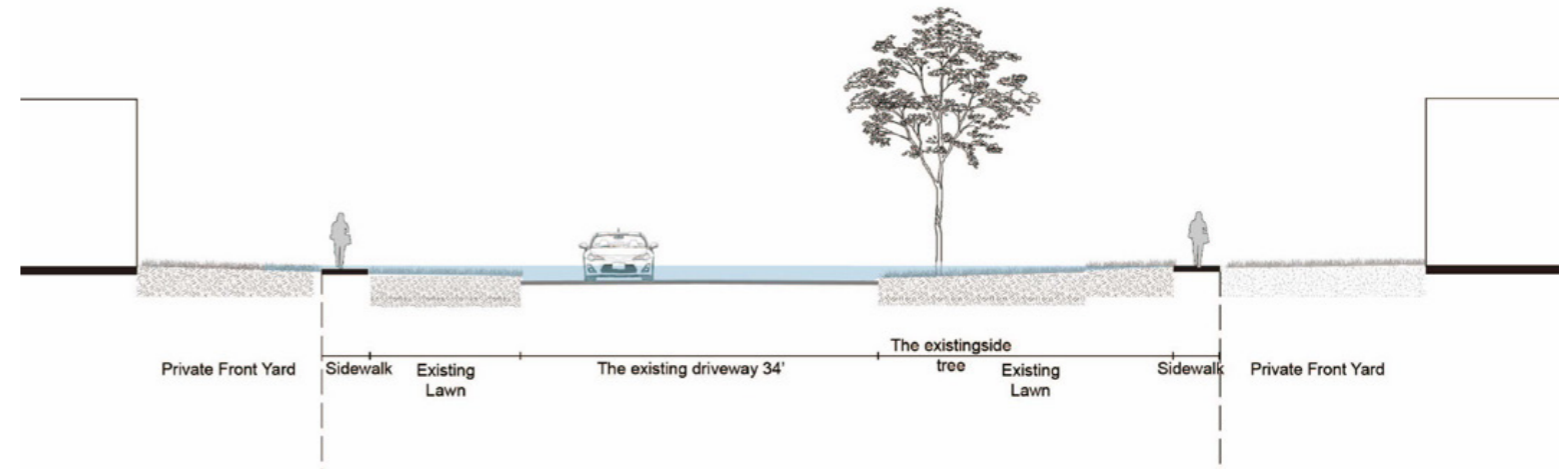


Village of Midlothian, IL: designing the ground for healthy rainwater

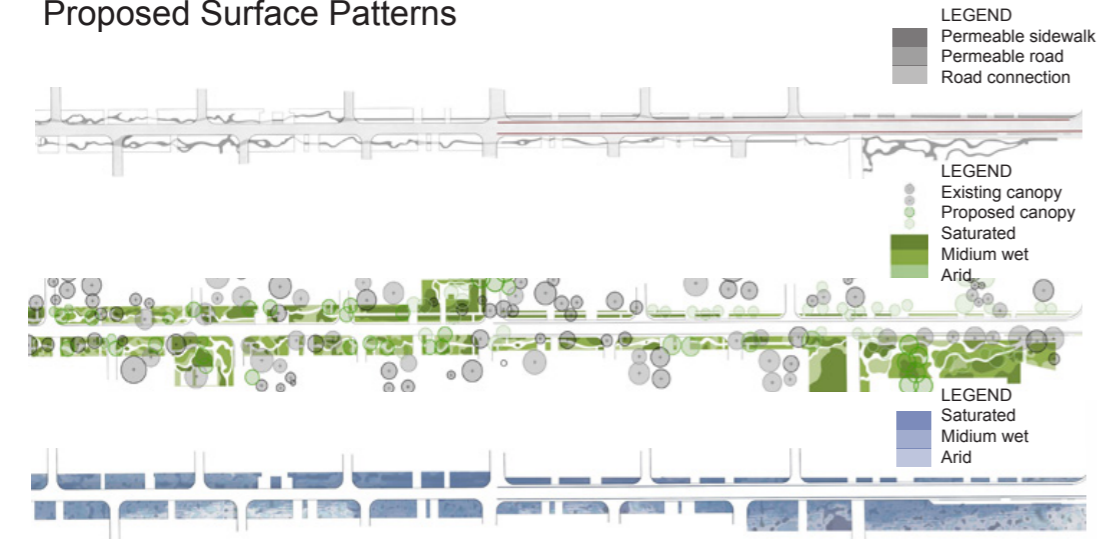
Existing Surface Patterns



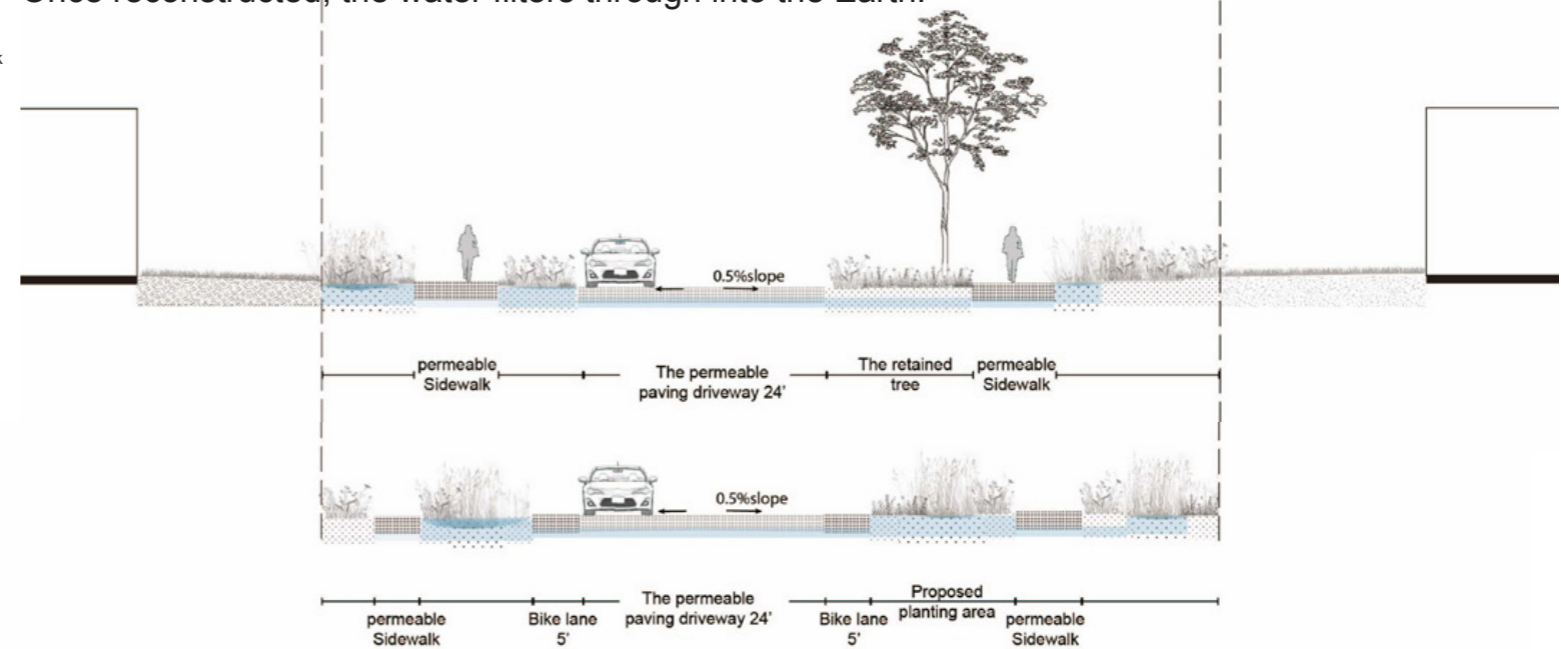
Rain water currently sits above the ground.



Proposed Surface Patterns



Once reconstructed, the water filters through into the Earth.



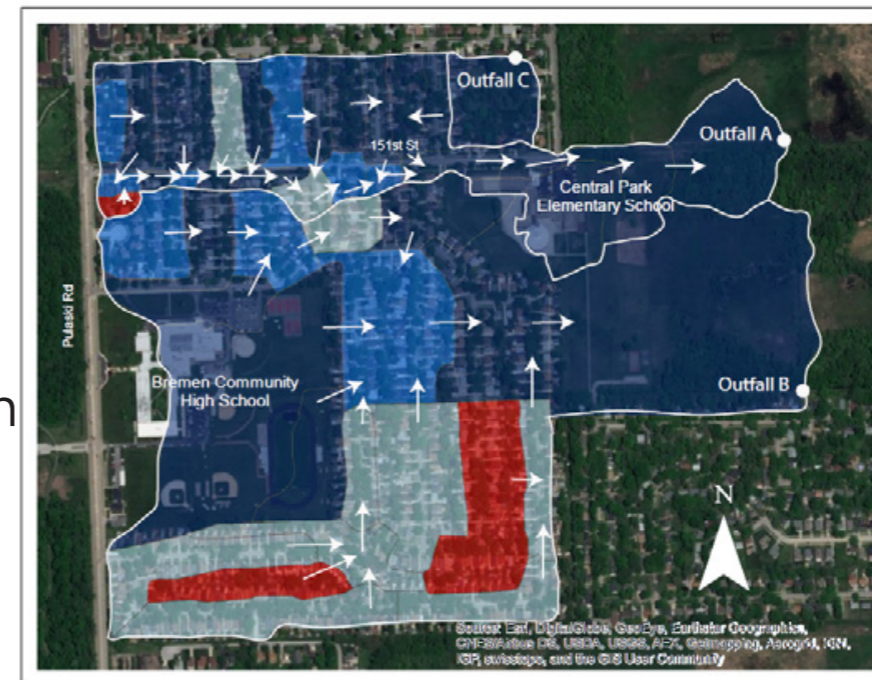
Village of Midlothian, IL : results for Jolly Homes



Maximum storm with 100% reliable reduction

- Minimal reduction
- 2.0 inch
- 3.5 inch
- 5.0 inch

5.0 inches
80% Reduction
24-hour storm



Maximum storm with 100% reliable reduction

- Minimal reduction
- 2.0 inch
- 3.5 inch
- 5.0 inch

1.9 inches
80% Reduction
2-hour storm



Calumet City, IL: Green infrastructure design framework



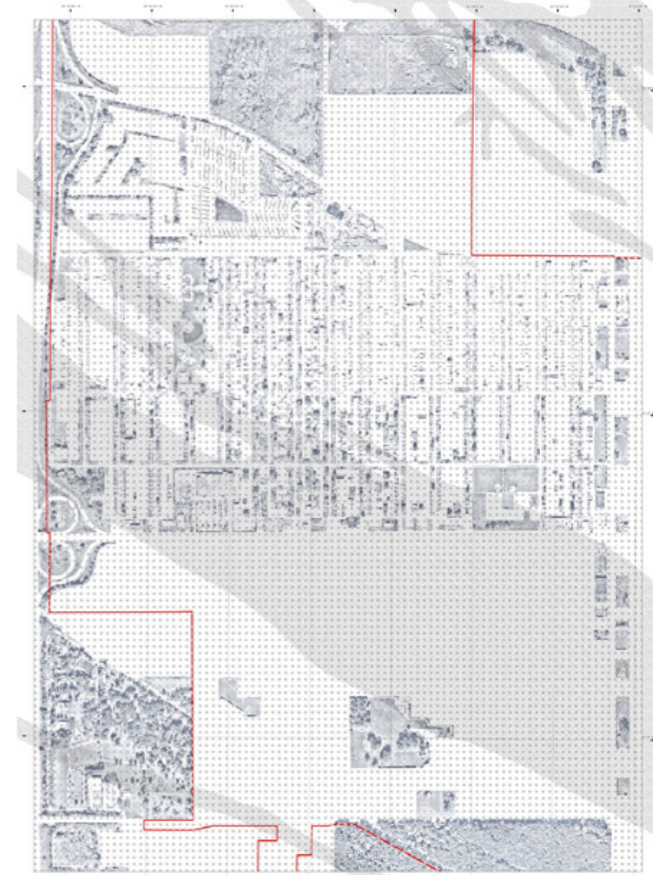
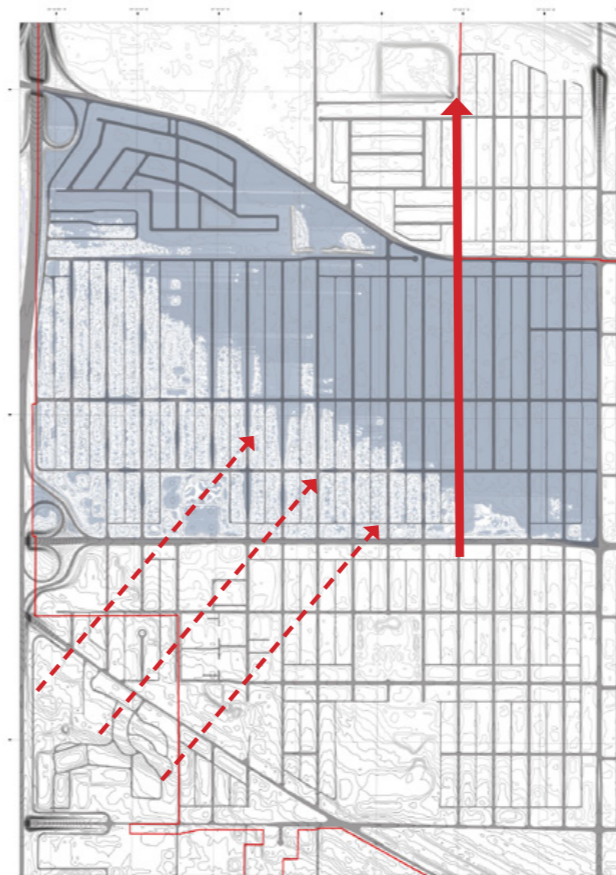
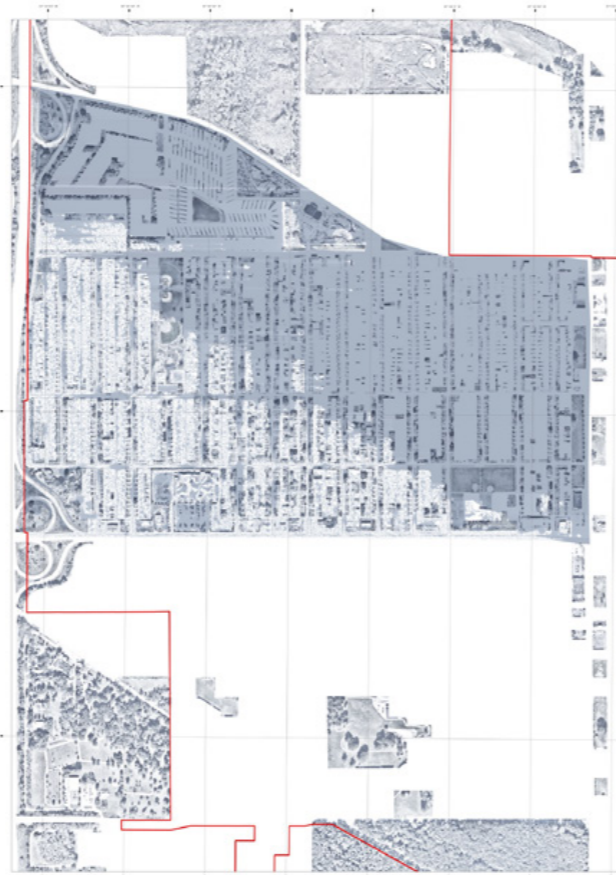
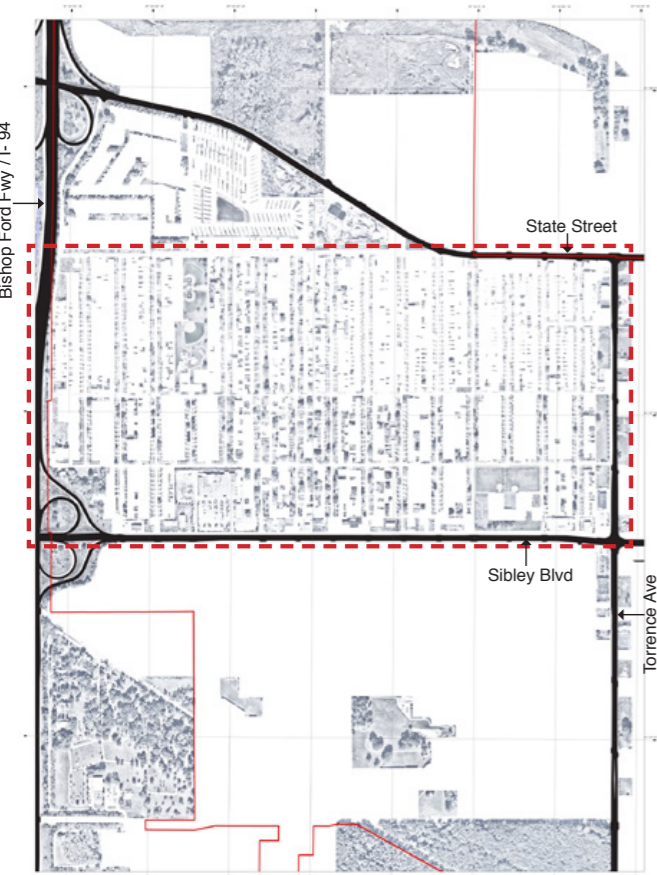
Calumet City, IL: site observation and analysis

Site Location


Flooding Pattern



Two Primary Causes of Flooding


Soil Data



 Calumet City Neighborhood Project Area (~250 acres)

 Flooding Pattern
Source: CMAP Chicago Metropolitan Area for Planning

 Bottleneck in the gray infrastructure system
 General Topographic Trend from Beach Ridge

 Qb, Beach Deposit
Source: U.S. Geological Survey, J Harlan Bretz, 1930's





Calumet City, IL: inventory of surfaces for redesign

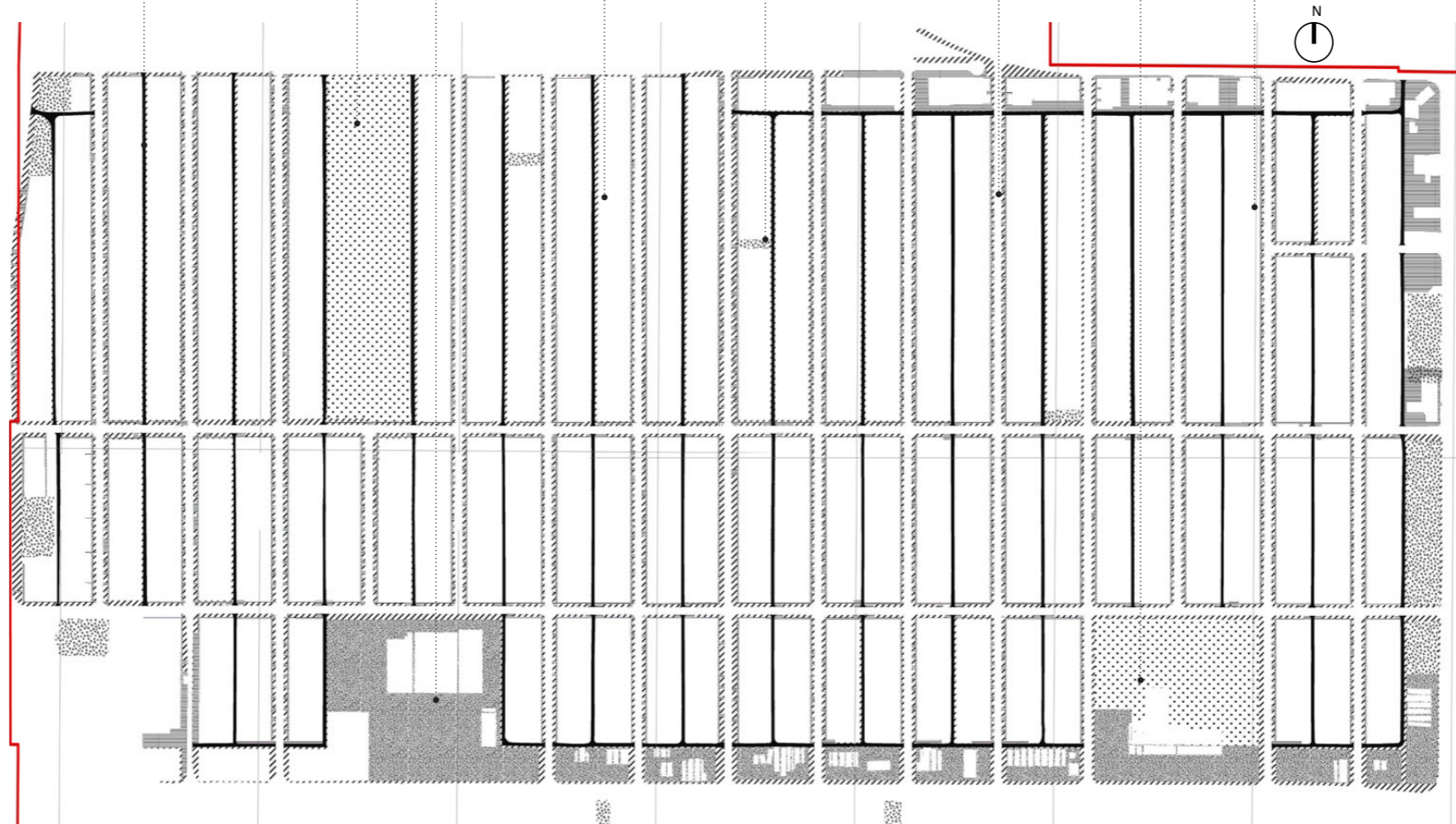


Neighborhood Area 410.97 acres
Impermeable Surface **149.14 acres, 36.3%**

-  Alley 10.4 acres, 2.5%
-  Sidewalk 58.89 acres, 14.3%
-  Street 61.6 acres, 15%
-  Vacant Land 7.7 acres, 1.9%
-  Parking 18.25 acres, 4.4%

Opportunity Surface **273.83 acres, 51.6%**

-  Alley 10.4 acres, 2.5%
-  Vacant Land 7.7 acres, 1.9%
-  Parking 18.25 acres, 4.4%
-  Park 18 acres, 4.4%
-  Sidewalk 58.89 acres, 14.3%



Impervious Asphalt Ground



Can we transform neighborhood streets for better rainwater collection and infiltration?

Neighborhood and its Residents



Can we create spaces in the neighborhood that provide rainwater management and socially beneficial spaces?



Calumet City, IL: linking GI to the regional soil ecology

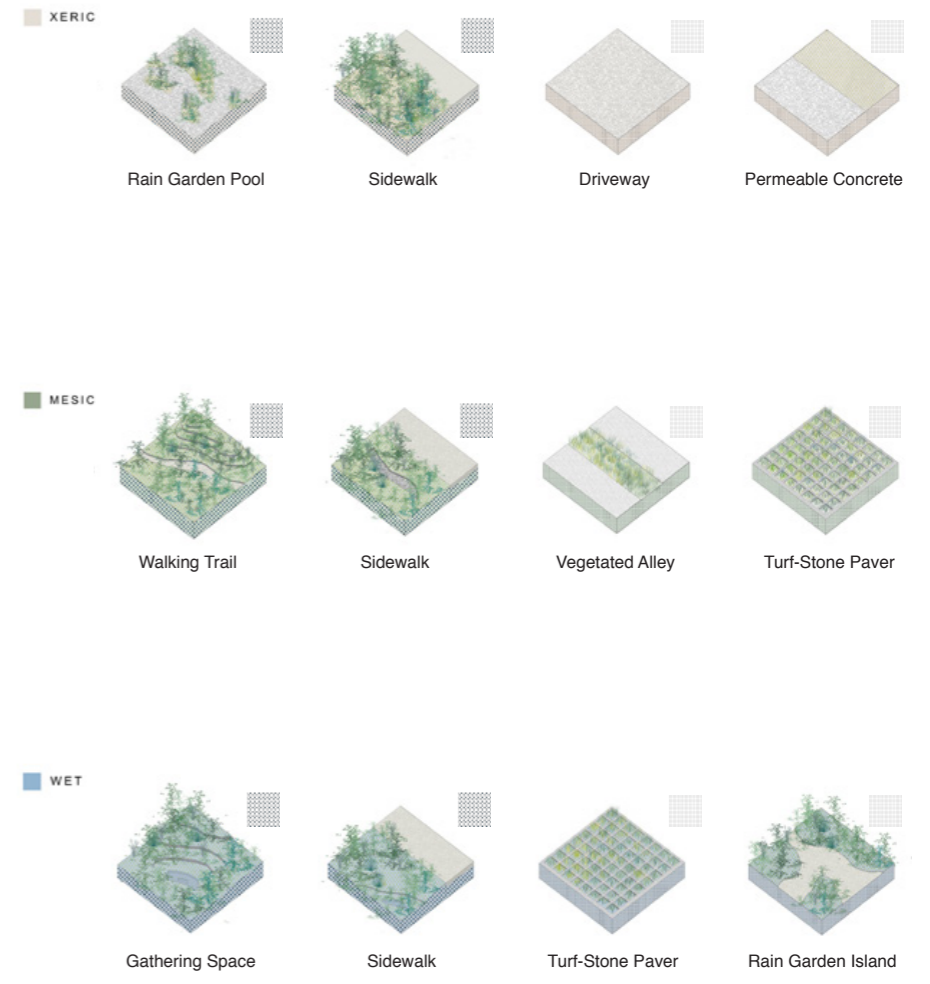
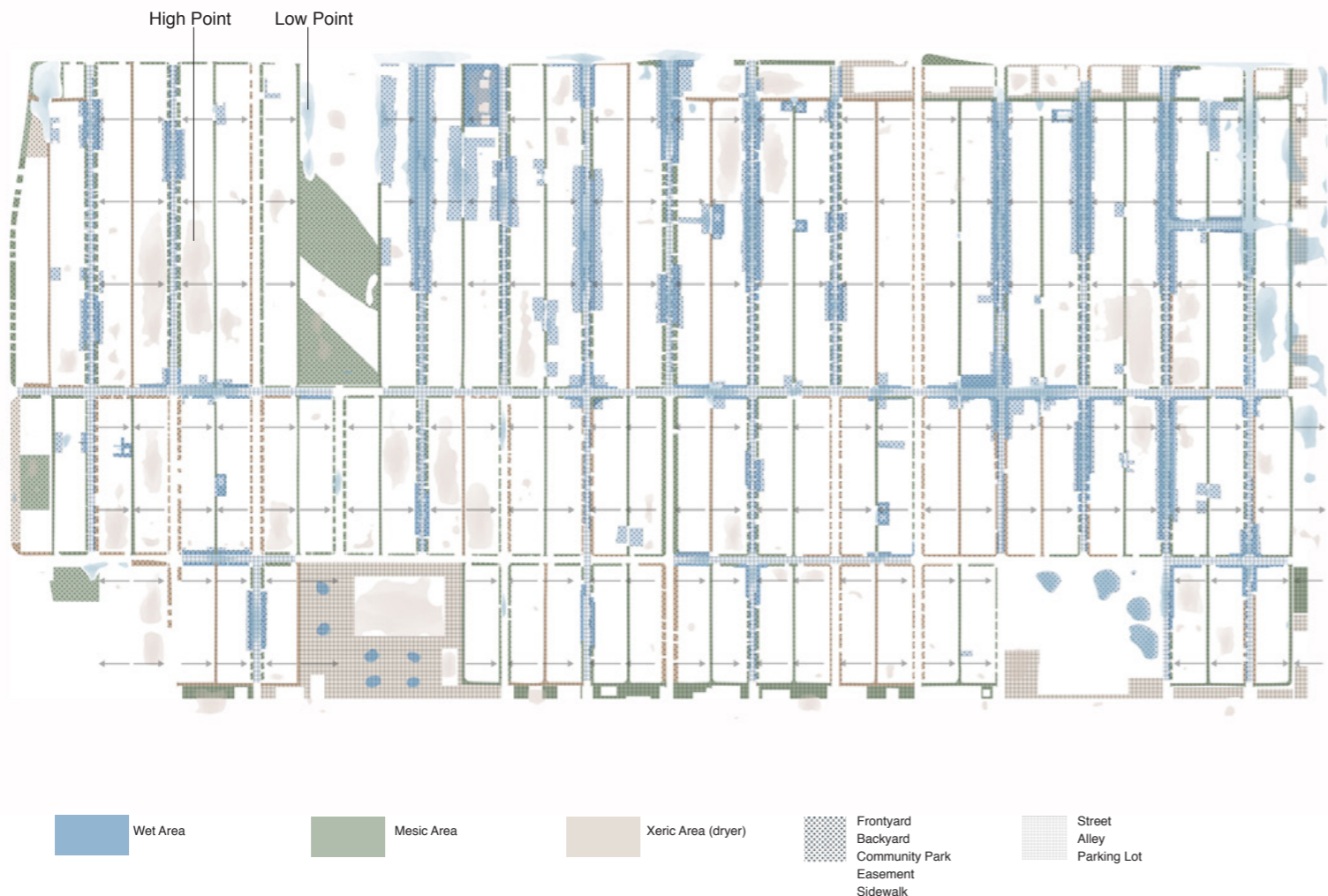
Soil Fieldwork in the Calumet



Dune-Swale



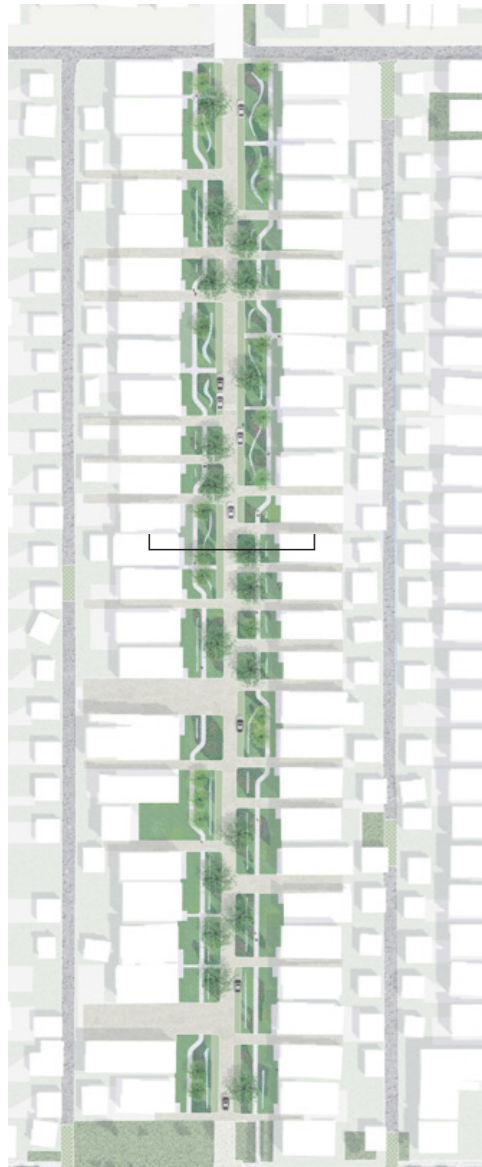
Calumet City, IL: collection of strategies



Calumet City, IL: wet street example

Wet Street a precedent for other “new swale streets”

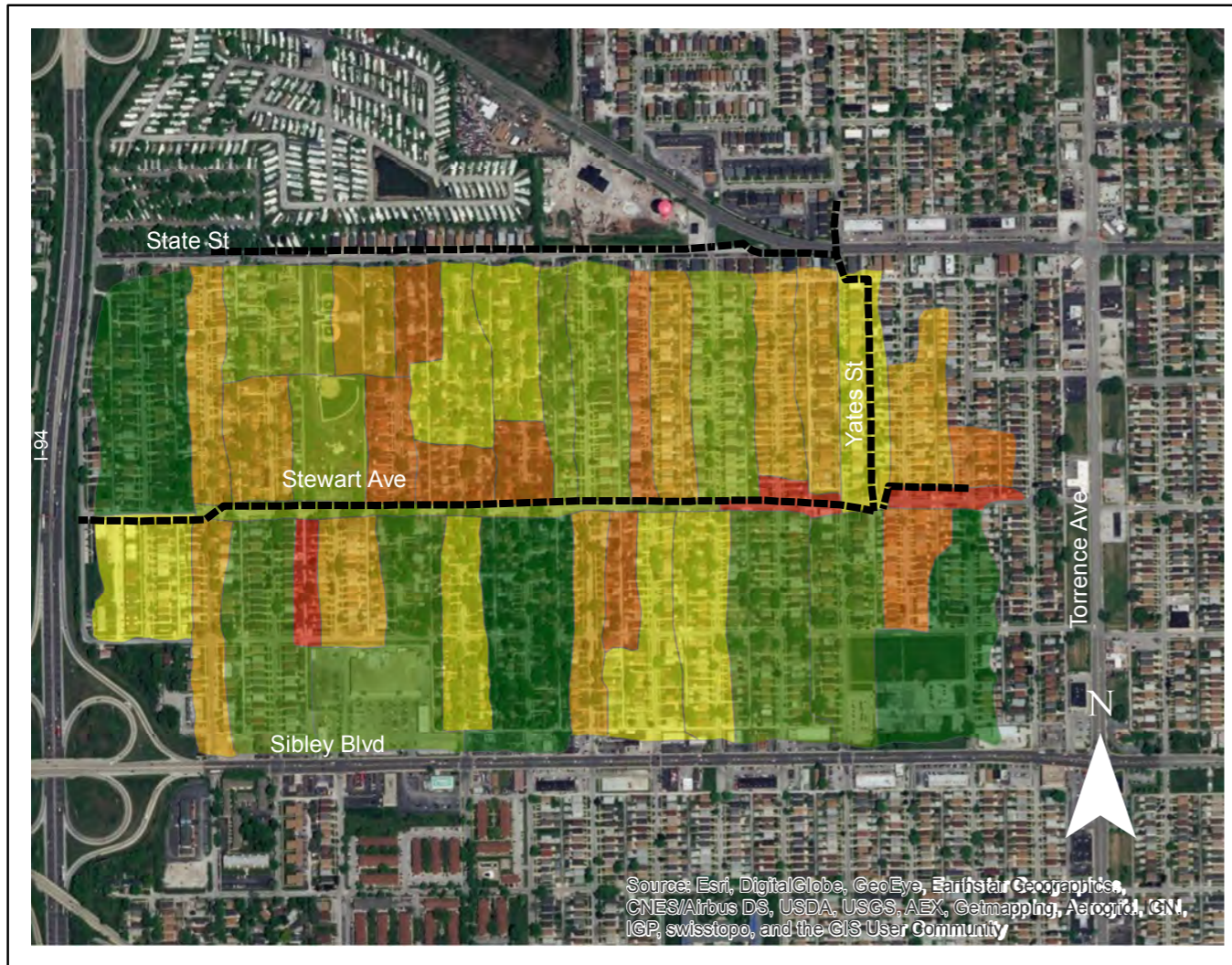
Swale Special Plants



Stable Plants



Calumet City, IL : stormwater volume reduction results



Gallons of water removed with GI for 2-inch, 2-hour storm

Water prevented from entering sewer system

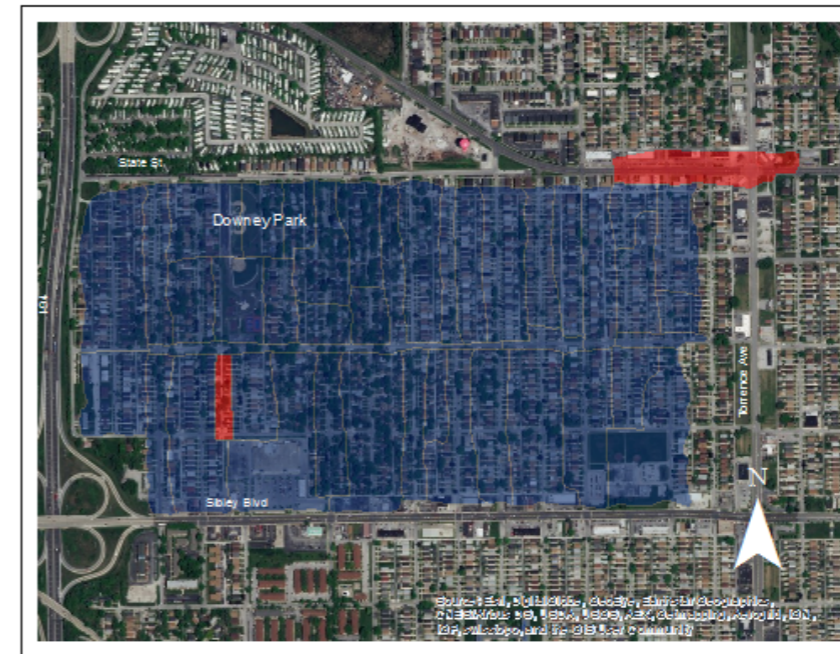
- 0- 50,000
- 50,000 - 100,000
- 100,000-150,000
- 150,000-200,000
- 200,000-250,000
- 250,000-300,000
- 300,000-400,000

The dashed line represents the existing combined/seperated storm sewer system, as inferred from the Calumet City sewer atlas.

The total amount of water removed using GI from each of the sewers in the network is as follows:

- Stewart: 3,350,000 gallons
- State: 1,720,000 gallons
- Yates: 1,430,000 gallons

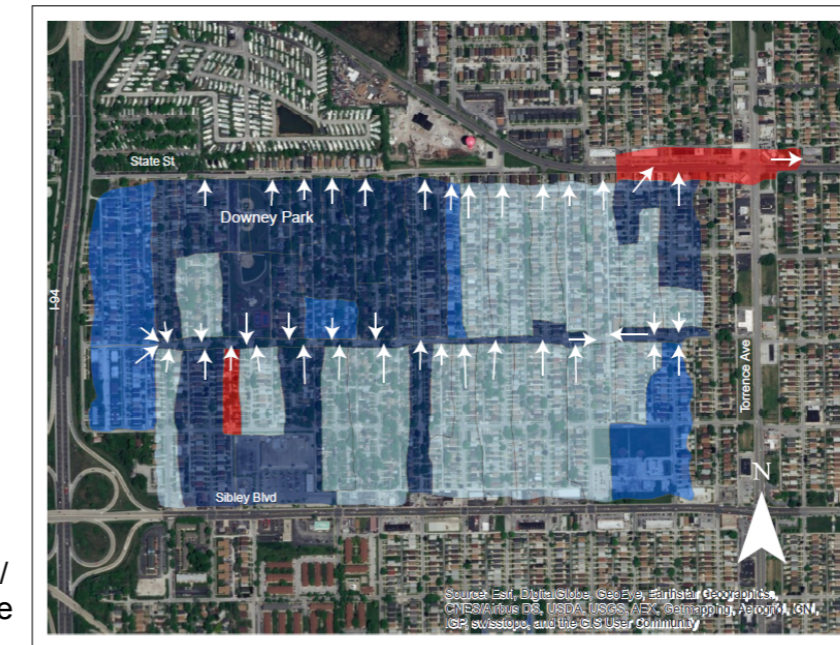
Map created by Reshmina William, PhD
June 18th 2019



Maximum storm with 100% reliable reduction

- Minimal reduction
- 2.0 inch
- 3.5 inch
- 5.0 inch

5.0 inches
80% Reduction
24-hour storm



Maximum storm with 100% reliable reduction

- Minimal reduction
- 2.0 inch
- 3.5 inch
- 5.0 inch

2.0 inches
80% Reduction
2-hour storm



Calumet soils design: steps and status

Current Phase



Soils research	Design Engineering	Proof of concept Pilots	Process guide
1) Update publically-available data 2) Site-specific soils properties in pilot communities <i>Status: Complete, some work ongoing</i>	Model soils performance under differing rainfall volumes and GI types <i>Status: Complete</i>	Optimal green infrastructure network <i>Status: Complete, some work ongoing</i>	Sharable process toolkit to incorporate soils into GI planning <i>Status: In progress</i>

← Outreach →

Q: we developed a process, but how should this be organized?

IL/IN Sea Grant
2019-2020

Decision Toolkit

STAGE	1 WILLINGNESS/SUPPORT	2 SITE ANALYSIS/SITE RESEARCH PROCESS	3 APPLY PROTOTYPE/MODEL	4 EVALUATION & VALUES ASSESSMENT	5 ADJUST/MODIFY	6 DECISION
	ESTABLISH COMMITMENT AND PROCESS: <ul style="list-style-type: none"> - capital planning - regional/municipal plan - leadership and staff - regional institutional support 	ESTABLISH GOALS + PRIORITIES <ul style="list-style-type: none"> - Performative - Economic - Qualitative - social, aesthetic 	UNDERSTAND THE PROTOTYPES - identify relevant charts/graphs/curves (<i>see diagrams</i>) <ul style="list-style-type: none"> - Review the variables (cakes + images) - Review performance data - compare against targets (Goals in #2) 	MEETING TARGETS: (objective/subjective targets; measurable targets, + public process for evaluation essential in this stage)	(RE)SET PRIORITIES, BASED ON OUTCOMES (above) and the condition and realities/potentials of: <ul style="list-style-type: none"> - Support (\$ and people - see #1) - Education and buy-in (engagement on the ground and in the public works staff) - Funding opportunities - Long-term care 	THE PLAN: What we will build + where we will build it When we will build it - phasing? Develop a plan for funding Hiring consultants Constituency/buy-in process Other
		INVENTORY AND EVALUATE EXISTING CONDITIONS (histories of the site, disconnections - where) Identify Potential (re)new(ed) Relationships/Identify Areas and Issues of Priority + Opportunity	APPLY THE LOGIC OF THE UNIT (<i>see diagrams</i>) <ul style="list-style-type: none"> - At parcel scale (both public and private sites) - At sub-catchment scale (private (+public) --- > public) - At catchment scale (public --- > public) 	QUANTITATIVE VALUES (modeling) <ul style="list-style-type: none"> - Run-Off reduction - Reduction in flooding (water in the wrong place to water in the right place) - Water quality improvement - Gray/green infrastructure design? - Cost evaluation - construction cost, and maintenance over time 	BIG OPPORTUNITY/HOPE <ul style="list-style-type: none"> - Can see/vision the site through time - Make a long-term decision and investment - History of the site, determines its future - The design tells a story and creates a new setting for people 	
		DATA/INPUTS Gather information (quantitative + qualitative) <ul style="list-style-type: none"> - Land-use - Surface (ground) conditions (land cover) - Flooding areas - Soil type - People, community organization and character - Gray infrastructure, network and condition Identify <ul style="list-style-type: none"> - Opportunities for social improvement, ecological connectivity, economic growth 	DEVELOP/EVALUATE SPATIAL DISTRIBUTION <ul style="list-style-type: none"> - by loading ratios - by soils - by topography, flow path - by culture and care (maintenance) 	OTHER VALUES/BENEFITS <ul style="list-style-type: none"> - Economic benefits - to the public, to private home/land/business owners - Ecological benefits - human health, biodiversity, other - Social benefits - human health, connectivity to each other and to nature, aesthetic 		
		CORRELATION MAPPING <ul style="list-style-type: none"> - Mapping overlays (by various units of analysis) - Conduct interviews (reports of conditions and patterns) - Conduct site visits (ground truth observations) 	RECORD AND ACCOUNT FOR OPTIONS/LIMITATIONS (site specific) <ul style="list-style-type: none"> - soil texture - public land versus private land participation - stormwater ordinance and goals - severity and patterns of flooding - cost and budget - education of public/community; buy-in 			
		VISUALIZATION/COMMUNICATION <ul style="list-style-type: none"> - Create maps and diagrams, photos and images - Look at relationships - Talk through patterns and opportunities - Build consensus about sites of interest 				

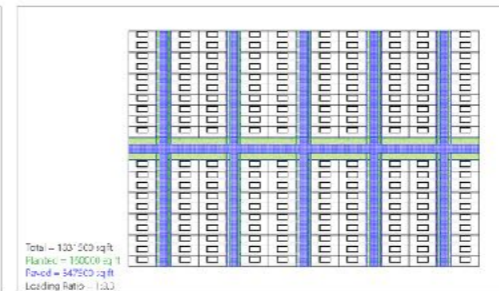
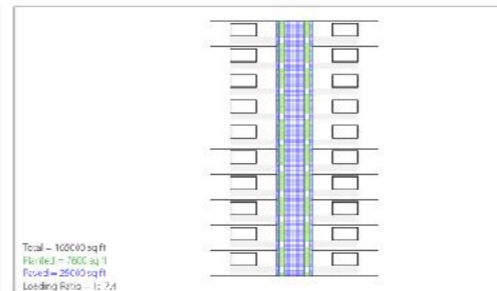
Q: we have modeled data, but how should this be shared?

Parcel - Subcatchment - Catchment Diagram

SCENARIO 1

All GI Surface in public:
 - bioretention on along street (planted)
 - sidewalk (paved)
 - street (paved)

No private GI Surface



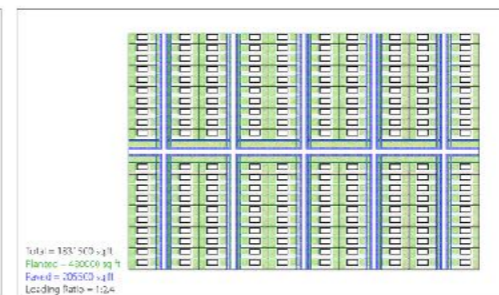
Existing Surface

- type1: Lawn
- type2: Roof
- type3: Pavement

SCENARIO 2

Public GI Surface:
 - bioretention on along street (planted)
 - sidewalk (paved)
 - parking area in street (paved)

Private GI Surface:
 - two bioretentions



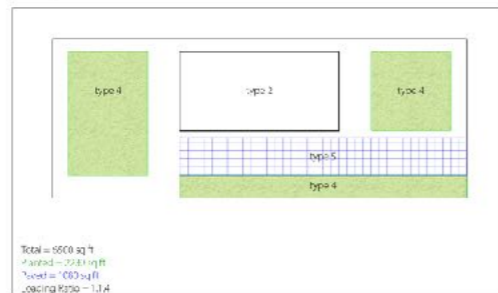
Proposed Surface

- type4: Bioretention
- type5: Permeable paver

SCENARIO 3

Public GI Surface:
 - bioretention on along street (planted)
 - sidewalk (paved)

Private GI Surface:
 - three bioretentions
 - private drive way (paved)



Residence

Parcel 1"=20'

Subcatchment 1"=125'

Catchment 1"=300'

All values in this table are based on calculations assuming a 30 inch deep rain garden layout, and a mixed soil profile for a 2 hour duration storm.

Parcel Subcatchment Catchment

1	N/A	N/A ¹	N/A ²
2	3.5 inch	3.6 inch	3.7 inch
3	5 inch	5 inch	5 inch

¹Routing excessive amounts of water to permeable pavement installations, especially across permeable (lawn) surfaces is not encouraged, since the excessive loading ratio means that the system will clog much more quickly than desired. We recommend that these paved areas be maintained as direct infiltration of stormwater rather than upstream runoff.

²At this loading ratio, a planted intervention would be able to deal with a 1.5 inch storm. See note [1] regarding paved interventions.

Examples of interactive toolkits

toolkit.climate.gov/steps-to-resilience/prioritize-plan

U.S. Climate Resilience Toolkit

Steps to Resilience Case Studies Tools Expertise Regions Topics

Prioritize & Plan

- Evaluate costs, benefits, and your team's capacity to accomplish each action.
- Rank the expected value of each action.
- Integrate the highest-value actions into a stepwise plan.

The result will be a comprehensive plan to implement your favored solutions.

Steps to Resilience

- Explore Hazards
- Assess Vulnerability & Risks
- Investigate Options
- Prioritize & Plan**
- Take Action

Case Studies

- Exploring Adaptation Options for Water Infrastructure at Sea Level >
- Extreme Rainfall Analyses Can Point to Right Size for Culverts >
- Looking to the Future on Alaska's North Slope >
- View all Step 4 Case Studies >

Tools

- Adaptation Workbook for Land Management and Conservation >
- Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans >
- Climate-Smart Conservation: Putting Adaptation Principles into Practice >
- Flood Resilience: A Basic Guide for Water and Wastewater Utilities >
- Hawaii Coastal Erosion Website >
- View all Step 4 Tools >

Relevant Reports

- Building National Capabilities for Long-Term Drought Resilience >
- Mapping the River Ahead: Priorities for Action Beyond the Colorado River Basin Study >
- A Blueprint for Action: Water Security for an Uncertain Future 2016-2018 >

Options	Resilience	Economics	Environmental Impact	Implementable
Option 1	●	●	●	●
Option 2	●	●	●	●
Option 3	●	●	●	●
Option 4	●	●	●	●
Option 3 & 4 combined	●	●	●	●

Consolidate actions into a cohesive plan

- Combine similar actions and sequence them to reduce risk across assets.

In this step, you'll raise the group's perspective from considering a subset of single assets to taking a look at the bigger picture. Examine your full list of actions from the previous step and look for patterns and similarities among the entries.

Consider how you might combine actions intended to increase resilience for single asset-threat pairs to protect several assets. Look for an efficient sequence of actions that could reduce risk across the full range of assets. Taking this larger view may help you find synergistic actions and cost savings; it can also help you recognize the potential for unintended consequences.

The goal of this step is identify a series of actions that all stakeholders will agree upon and support. The process also enables all stakeholders to represent the benefits of the plan to their own constituents.

Estimate the expected value of each action

- Assess whether investments will reduce risk.

Before you invest in an action, you'd like to have a good sense of if it will truly reduce risk. Recall that the concept of risk encompasses the probability of a loss as well as the magnitude of the loss. Effective actions need to reduce one or both of these elements. Addressing this type of risk is called an expected value analysis. As was the case with the Screenshots, some groups choose to engage risk management consultants to

Drinking Water 1 2 3

Drinking Water 1-2-3

A guide for local officials and community leaders.

Get started

Drinking Water 1 2 3

Guide contents

1

Meet your water: An introduction
Understanding Drinking water in northeast Illinois
Sources
Treatment
Infrastructure

2

Your water's keeper: Utilities and regulators
Understanding drinking water management and laws
Utility management
Regulation

3

Murky waters: The challenges we face
Understanding drinking water issues in our region
Supply constraints
Pollution
Crumbling infrastructure
Fragmented systems
Climate change

GO

Taking action: Your guide to important practices
Understanding the actions you need to take
Protect your source
Ensure you have enough
Maintain your infrastructure
Finance your system
Plan and coordinate with your neighbors
Engage your community

Glossary
Resource guide
Acknowledgements

Questions we have for you:

What information from this research is most useful for you at this point?

In what form is it most useful to receive this information?

What municipalities have interest in continuing soil studies (Kristine/NRCS)?

(Please fill out the handout - thank you for your feedback!)