Metropolitan Water Reclamation District of Greater Chicago

MWRD Phase II Study

Session #2C: Optimizing Solutions to Urban Flooding

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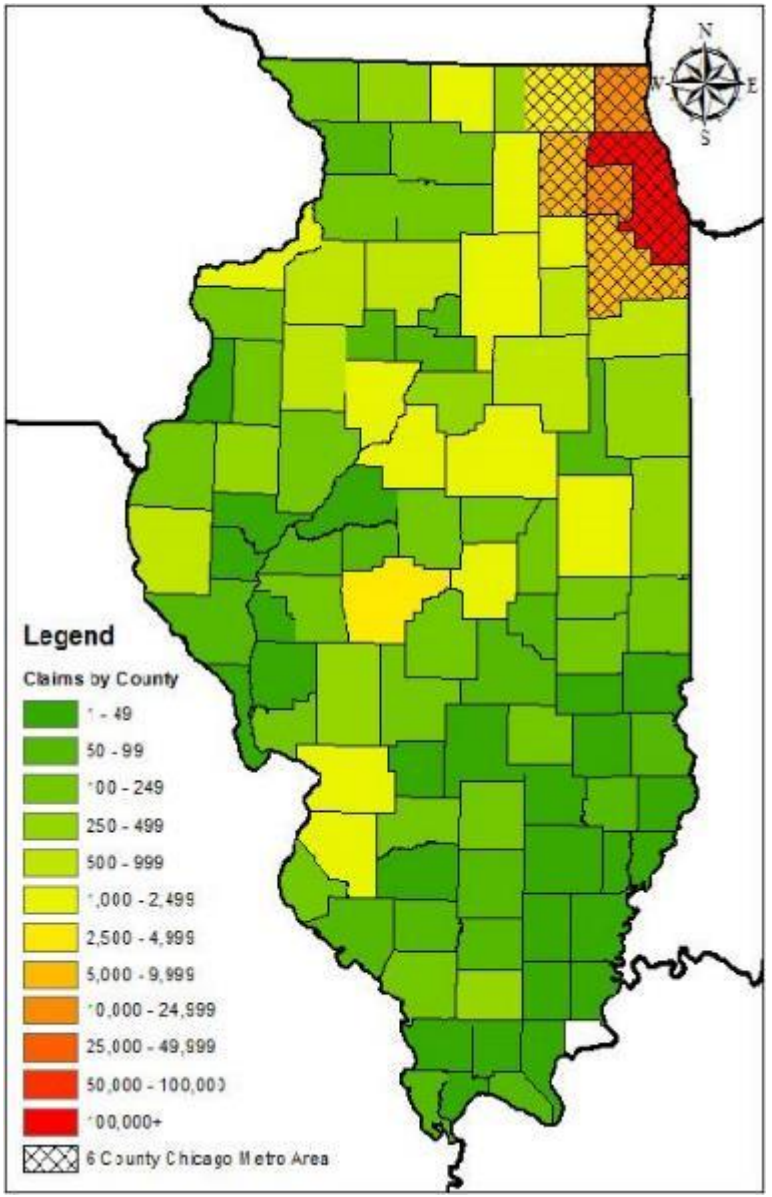
Geosyntec consultants
engineers | scientists | innovators

Overview:
MWRD Phase II Projects

- Stormwater Master Plans of Urbanized Areas
- $2.32 billion in documented urban flooding damages (2007-2014)
- 90% of claims were from outside mapped floodplain



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Information and Graphic provided by: IDNR Report for the Urban Flooding Awareness Act

Overview:
MWRD Phase II Projects

Stormwater Master Plans

5 Pilot Study Areas:

- Little Calumet River/Calumet-Sag Channel
- Village of Northbrook
- Roberts Road
- Village of Harwood Heights
- City of Chicago (southeast side)

3 Areas Using Optimizer Software:

- City of Chicago (Geosyntec)
- Village of Northbrook (ERA)
- Village of Harwood Heights

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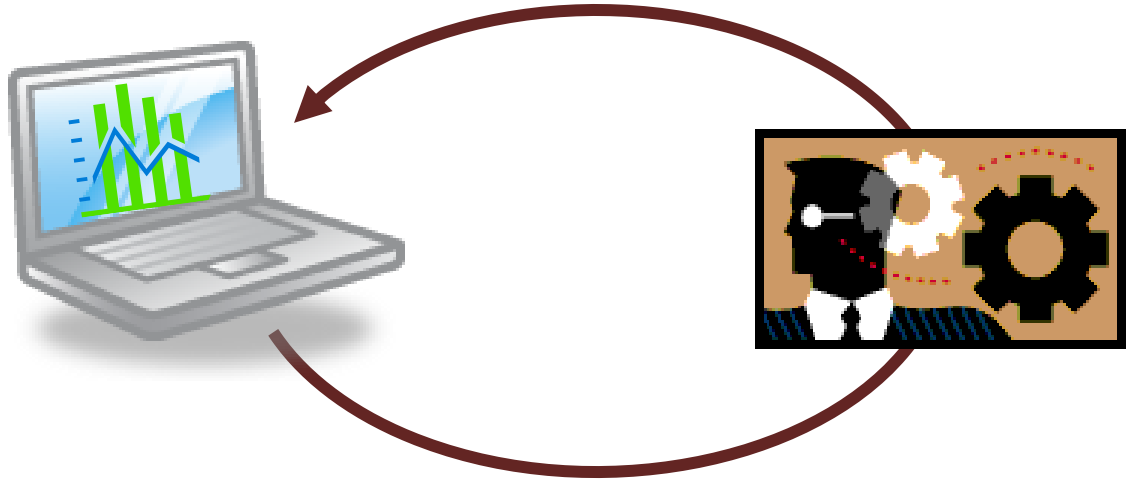
Traditional Planning

optimatics.com

Planner interacts with simulation model using iterative, trial and error process



Planner inputs simulation data, but is unable to consider both the life-cycle costs and the hydraulic performance of alternative designs necessary to identify the best solutions

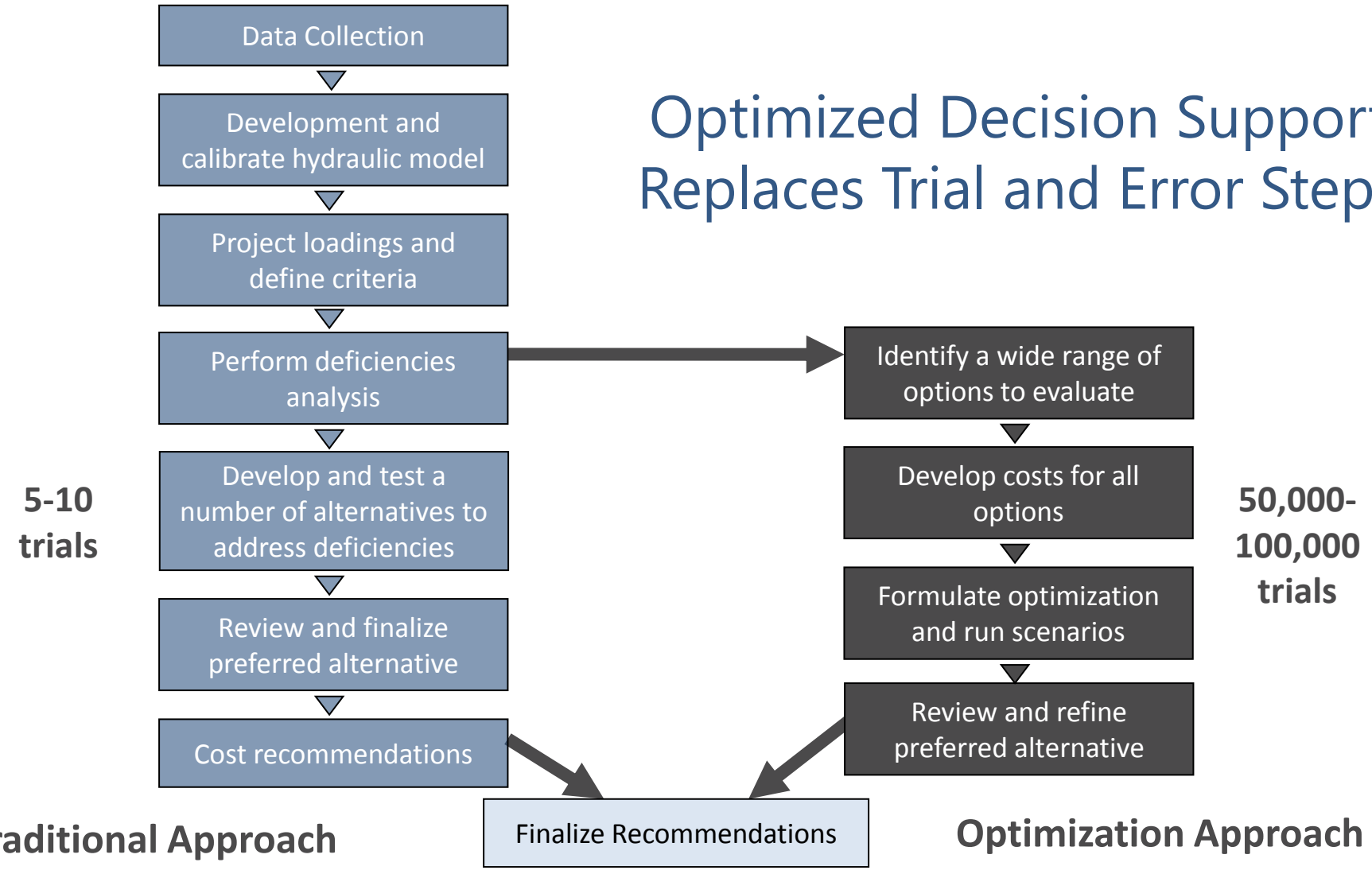
Optimization Approach

optimatics.com

Planner inputs all allowable improvement options as well as the required performance standards to be met

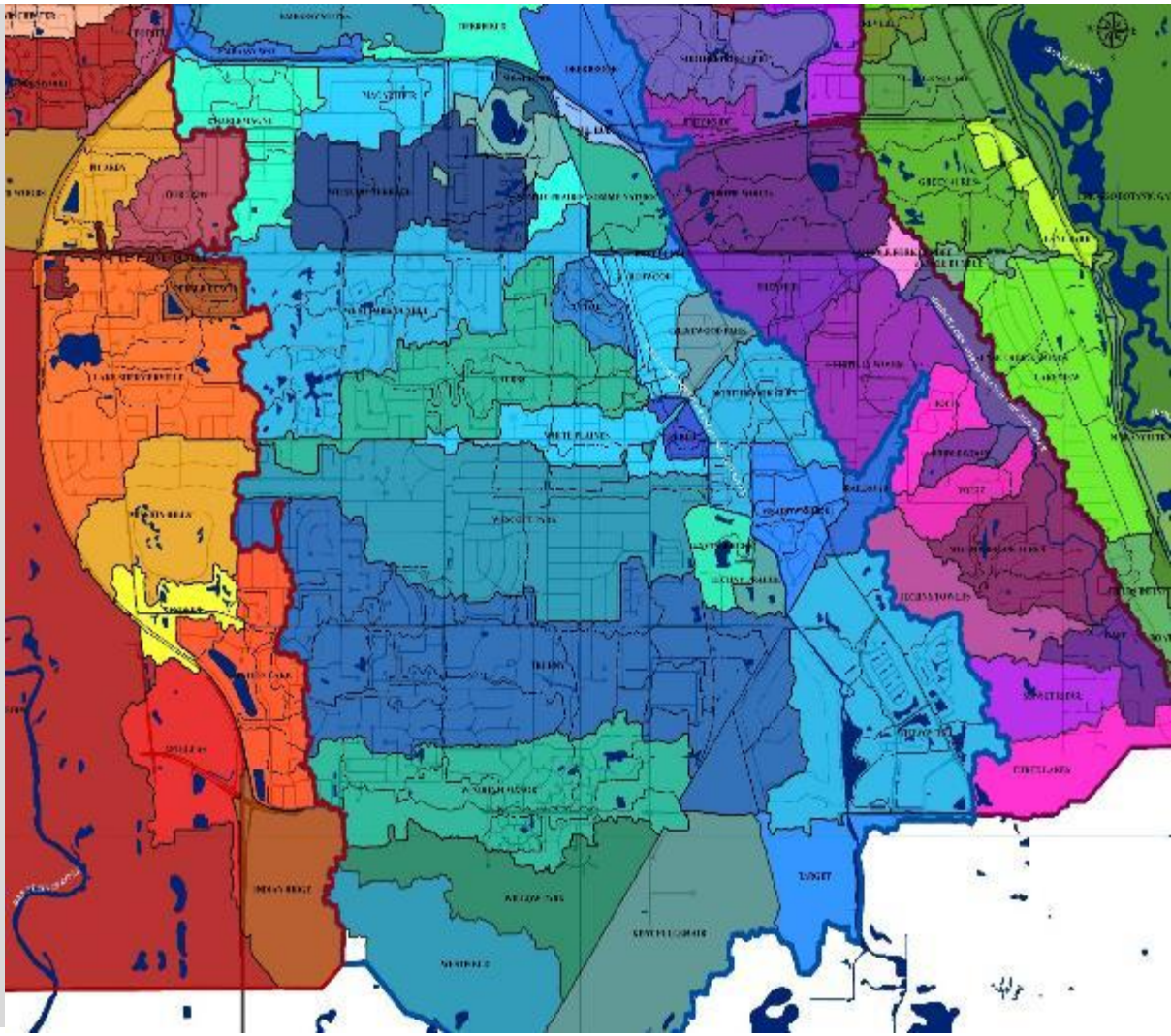
Optimizer automates the iterative process by creating thousands of solutions, simulating each one to evaluate its cost and performance while converging on lowest cost strategy

Optimized Decision Support Replaces Trial and Error Steps



Overview:
Village of Northbrook

- Incorporated Village of Northbrook
- Unincorporated Northfield Township
- 14 square miles tributary
- Tributary to 4 major watersheds



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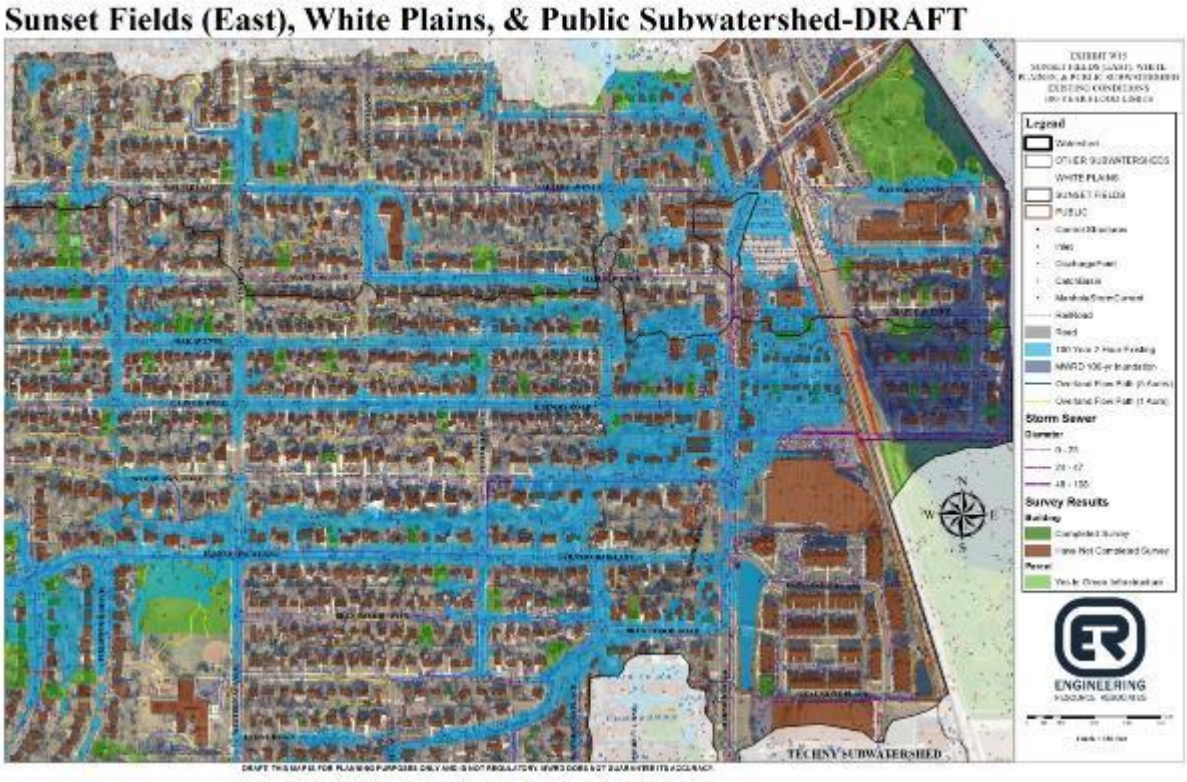
Overview:
Village of Northbrook

- 78 sub-watersheds
- 275 storm sewer miles
- 13,000 storm structures
- 1,400 at risk buildings



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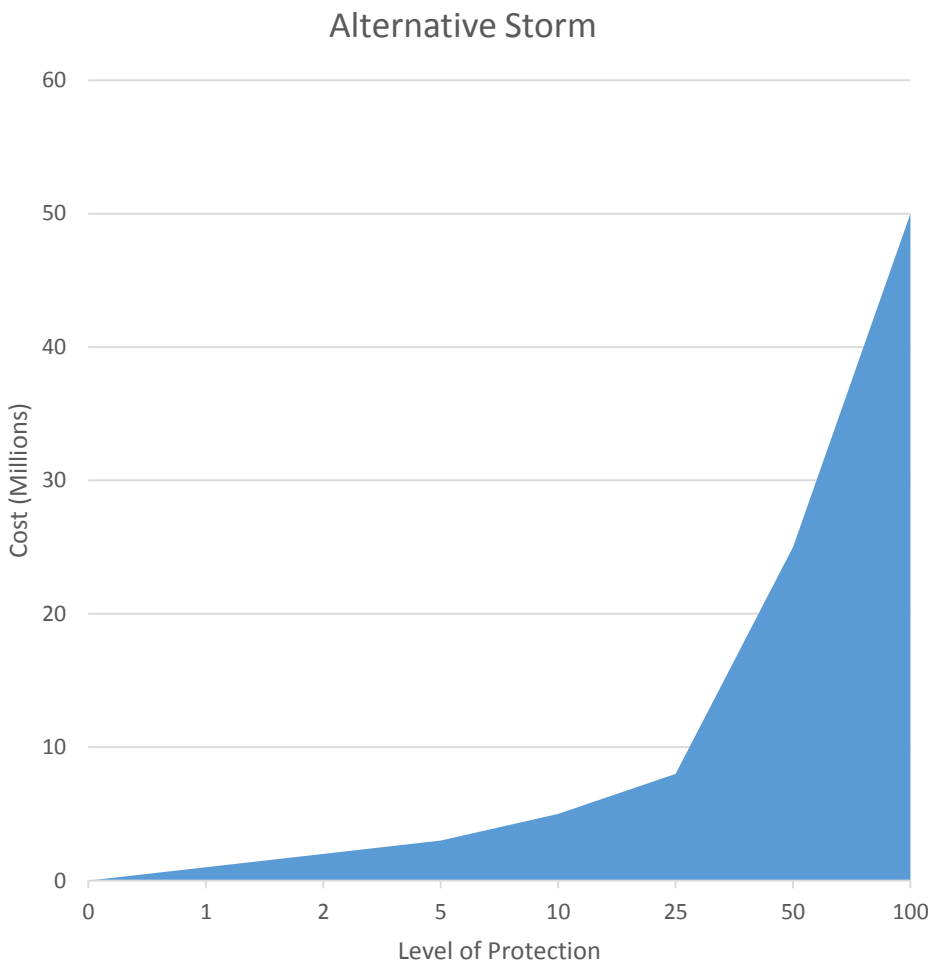
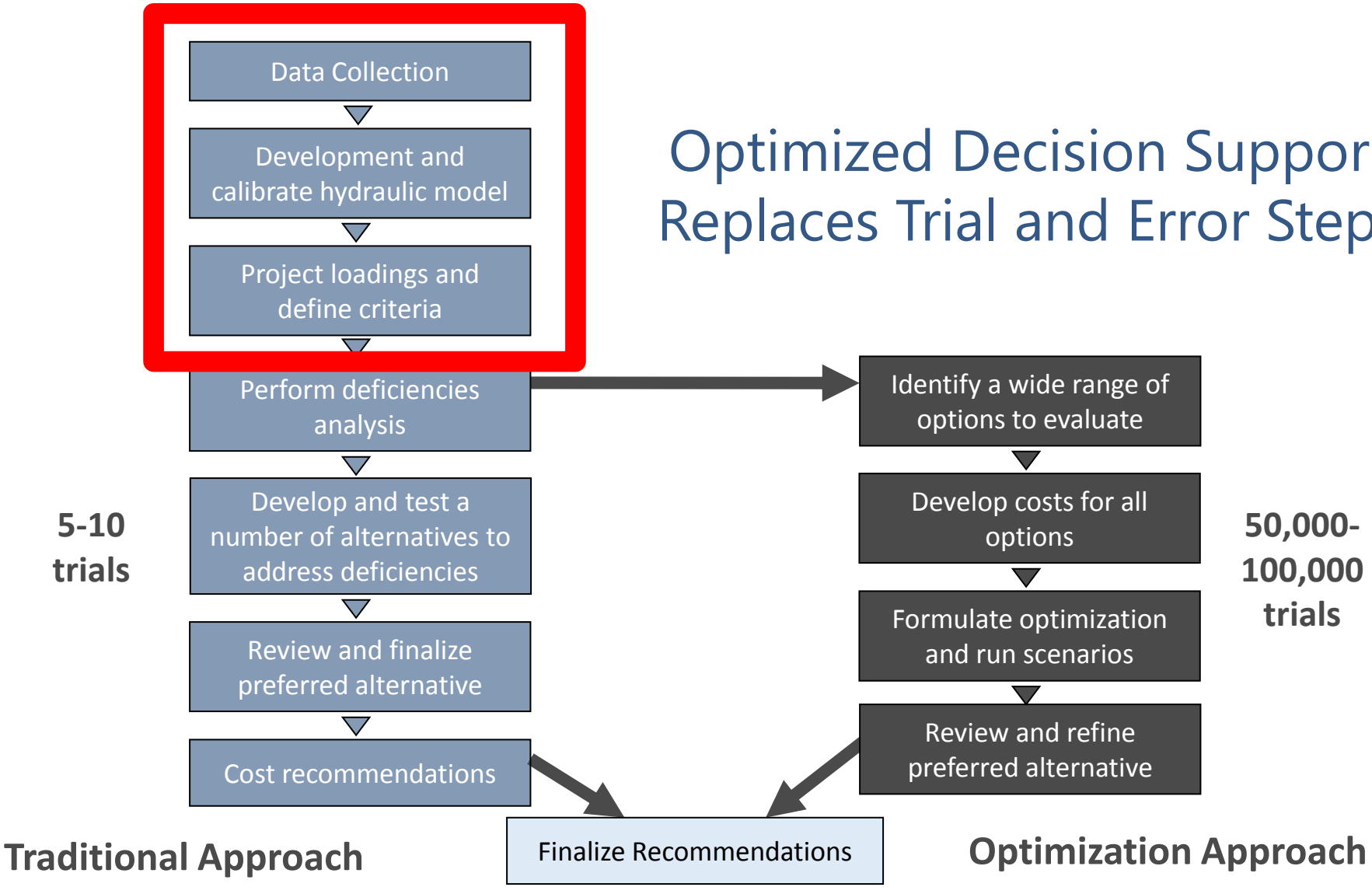
Goals of the Project: Village of Northbrook

- Identify public/private, grey/green infrastructure improvements that will reduce flooding for the 1% and alternative storm event



Optimized Decision Support Replaces Trial and Error Steps



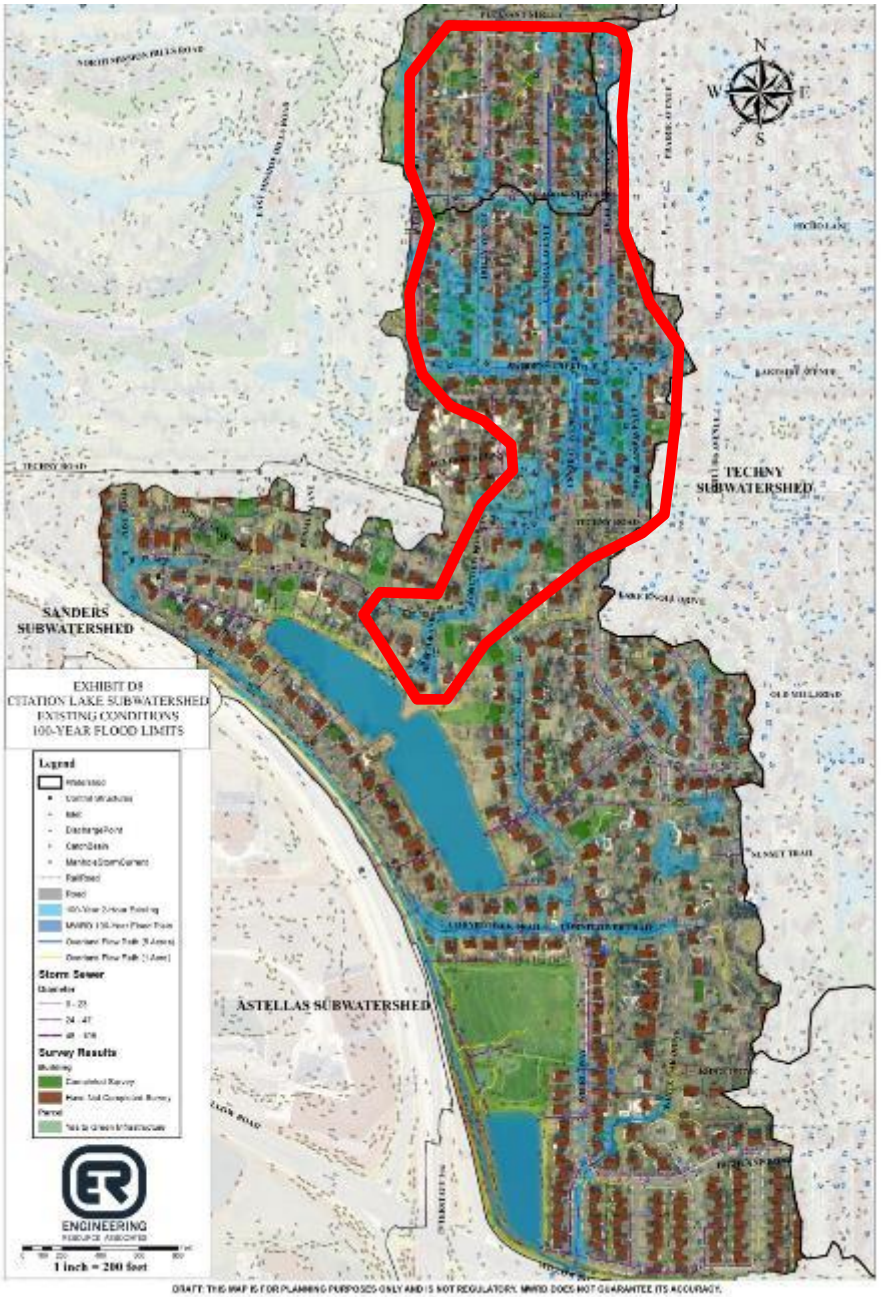
Optimatics
PLAN SMARTER

Optimizer Workflow

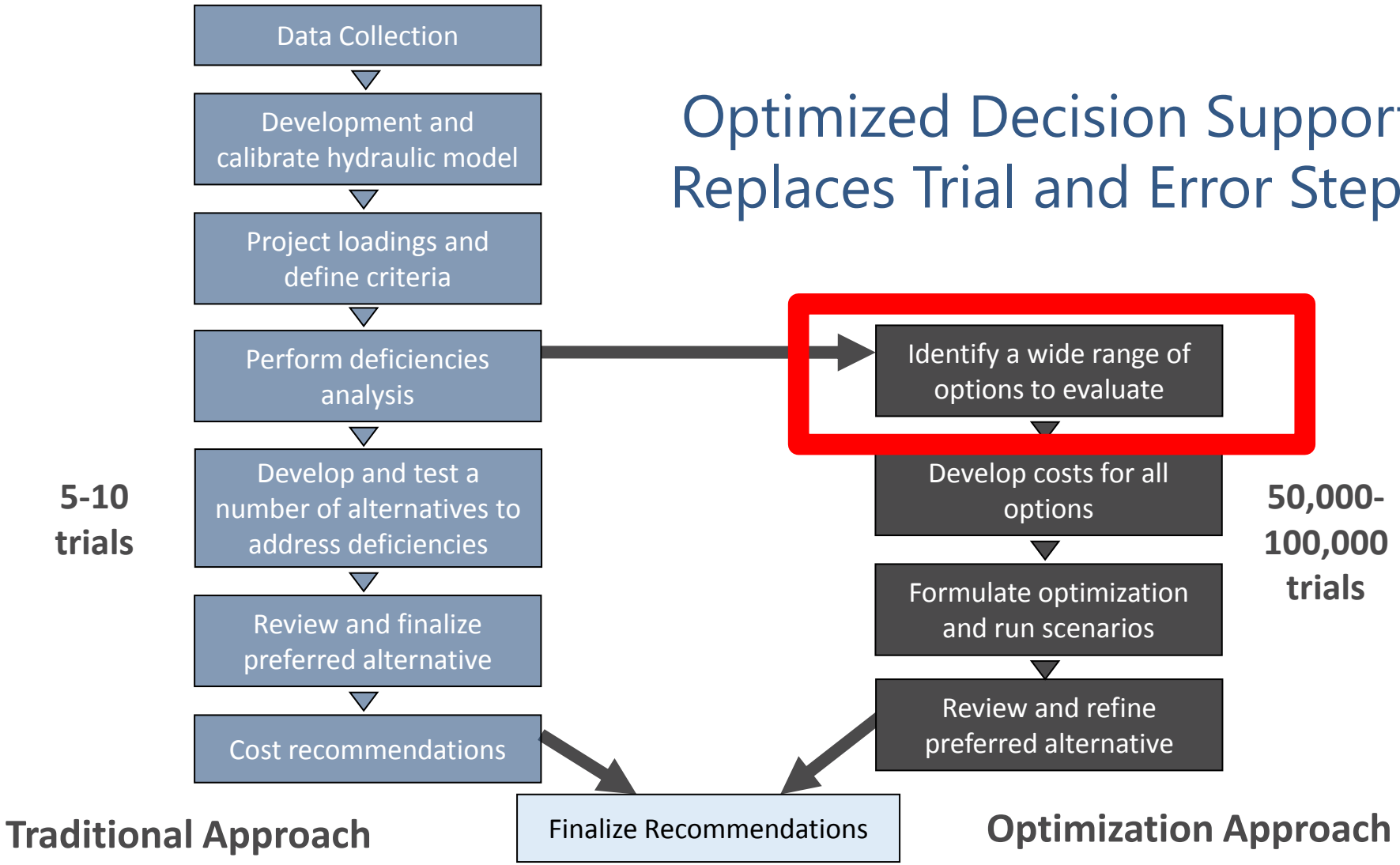
Identify Problem

- Existing conditions EPA-SWMM models
  - 100-year critical duration

- Quickly limit solution space based on criteria



Optimized Decision Support Replaces Trial and Error Steps



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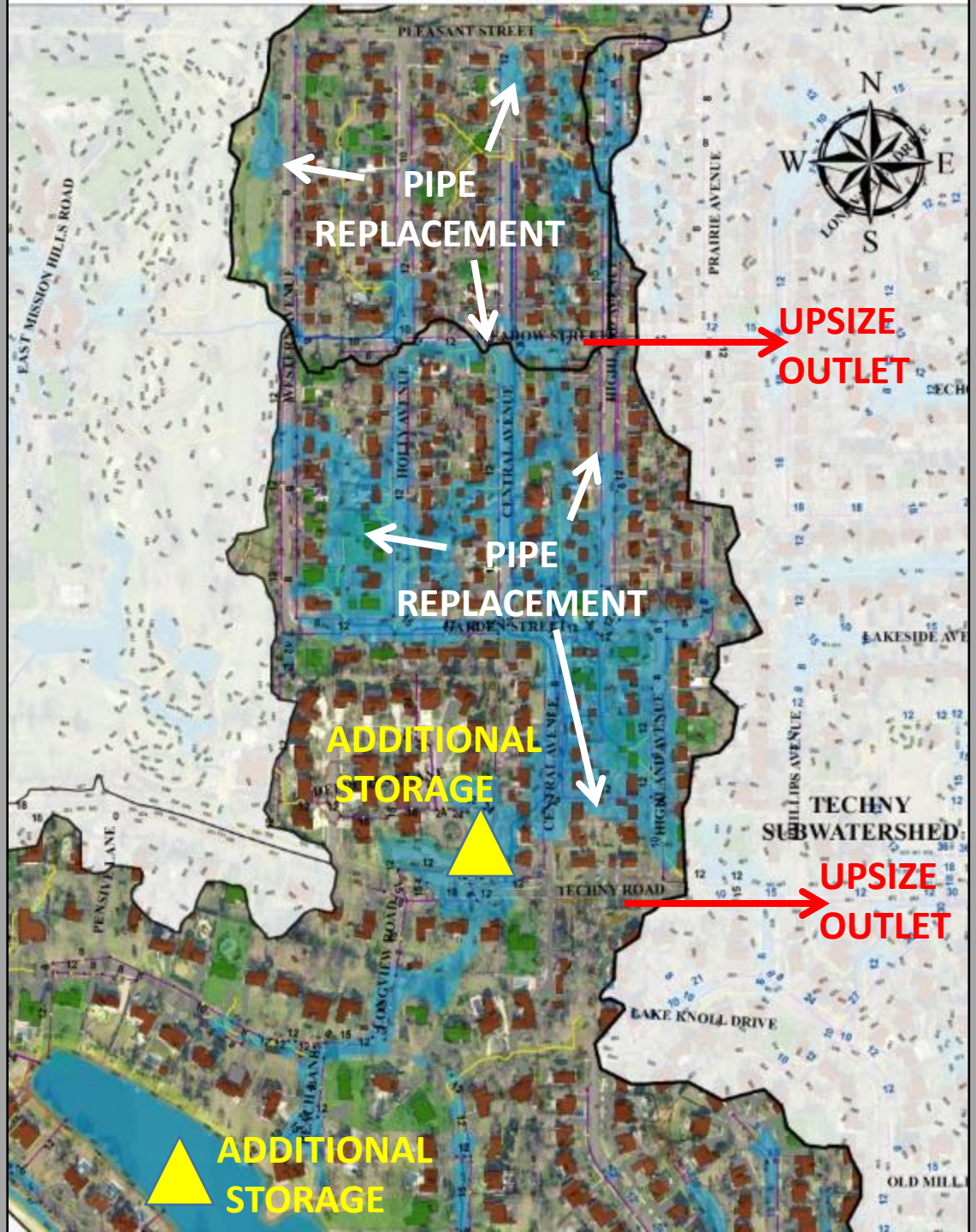

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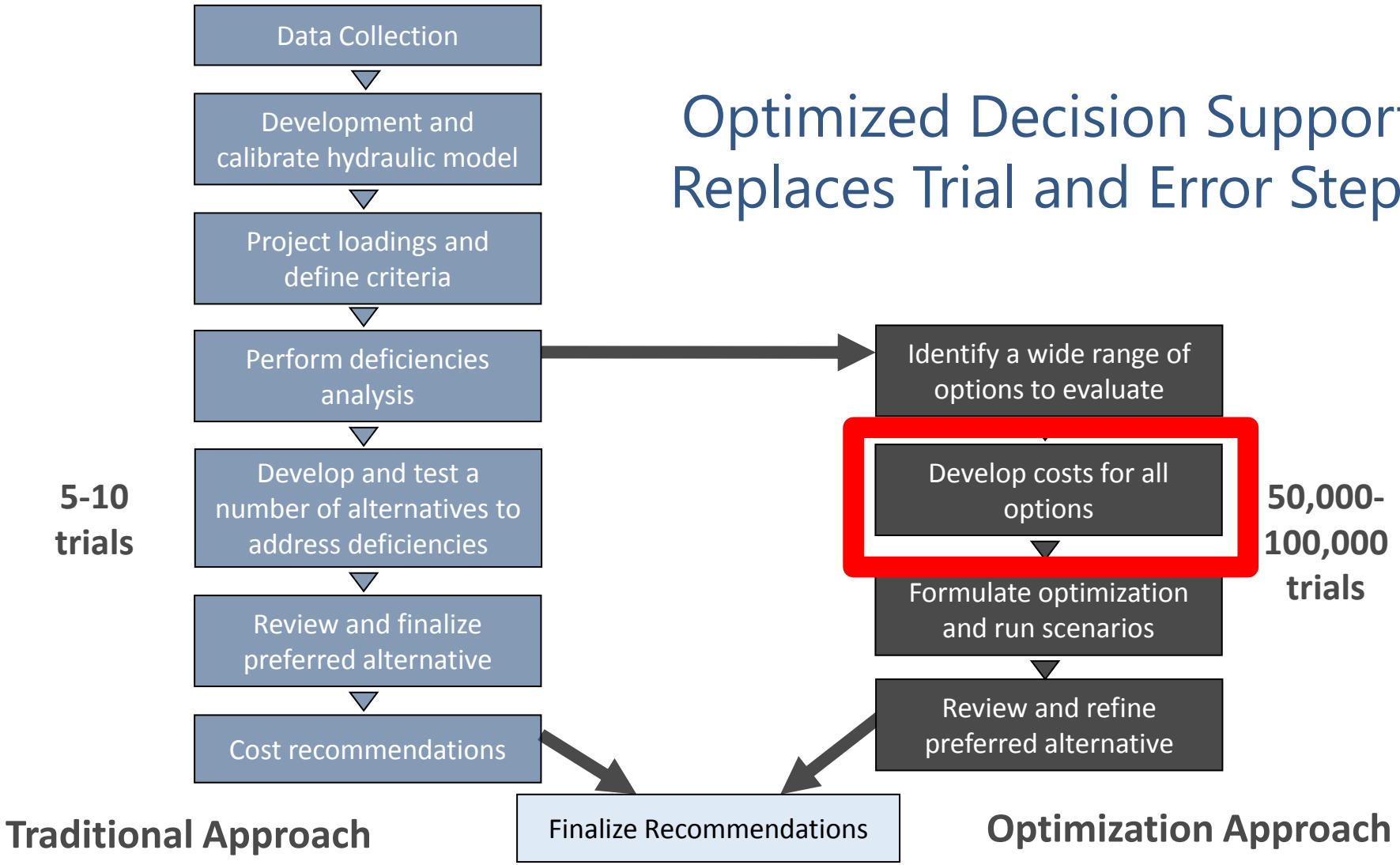
ADDITIONAL STORAGE
NEW STORAGE
ADDITIONAL STORAGE
GREEN INFRASTRUCTURE
WATERSHED
OLD MILL ROAD
SUNSET TRAIL
CORNFLOWER TRAIL
CORNFLOWER TRAIL
WHIRLAWAY
WHITE OAK DRIVE
RIDGE DRIVE
HIGHLAND ROAD
INTERSTATE 294
WILLOW

Optimized Decision Support Replaces Trial and Error Steps



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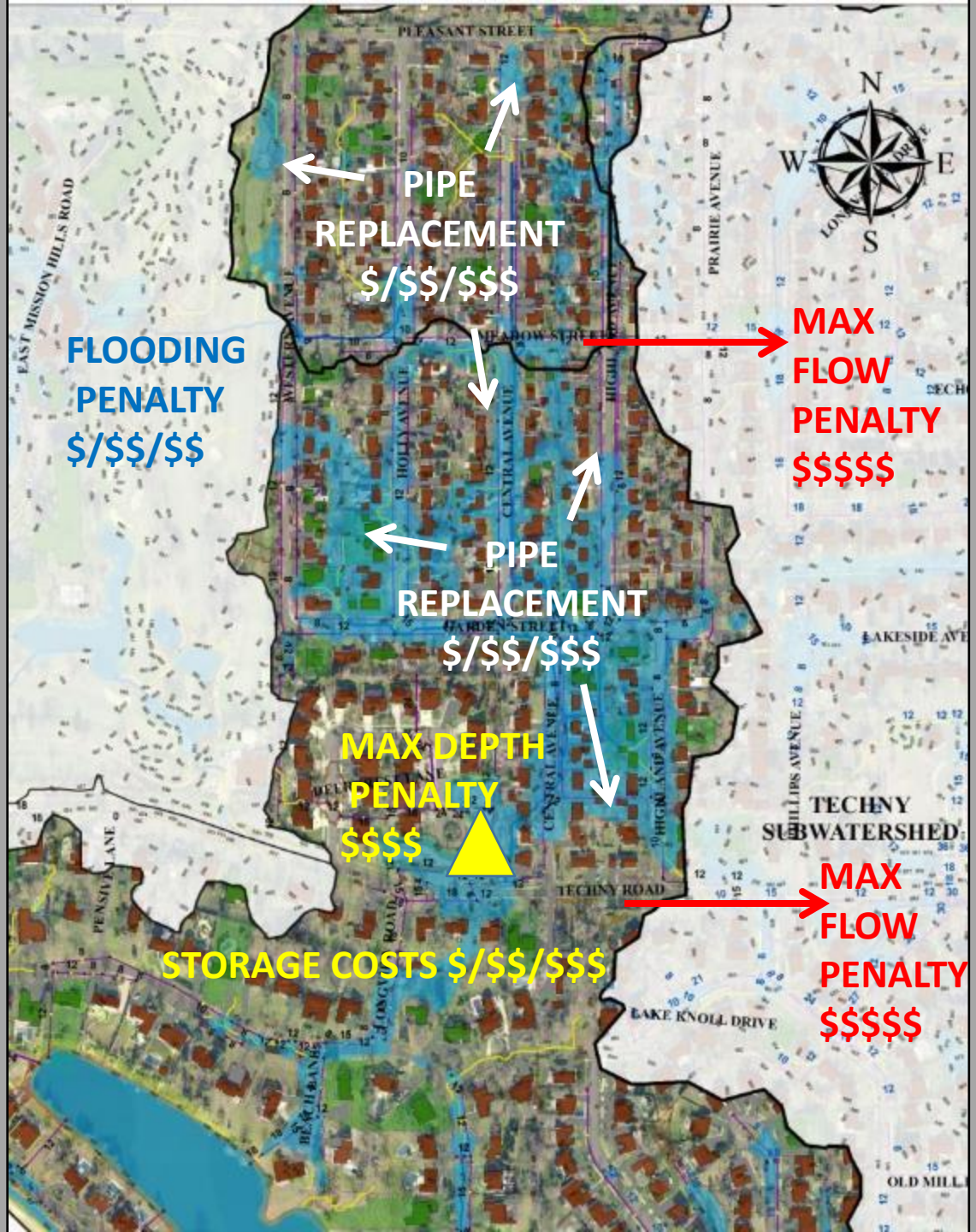
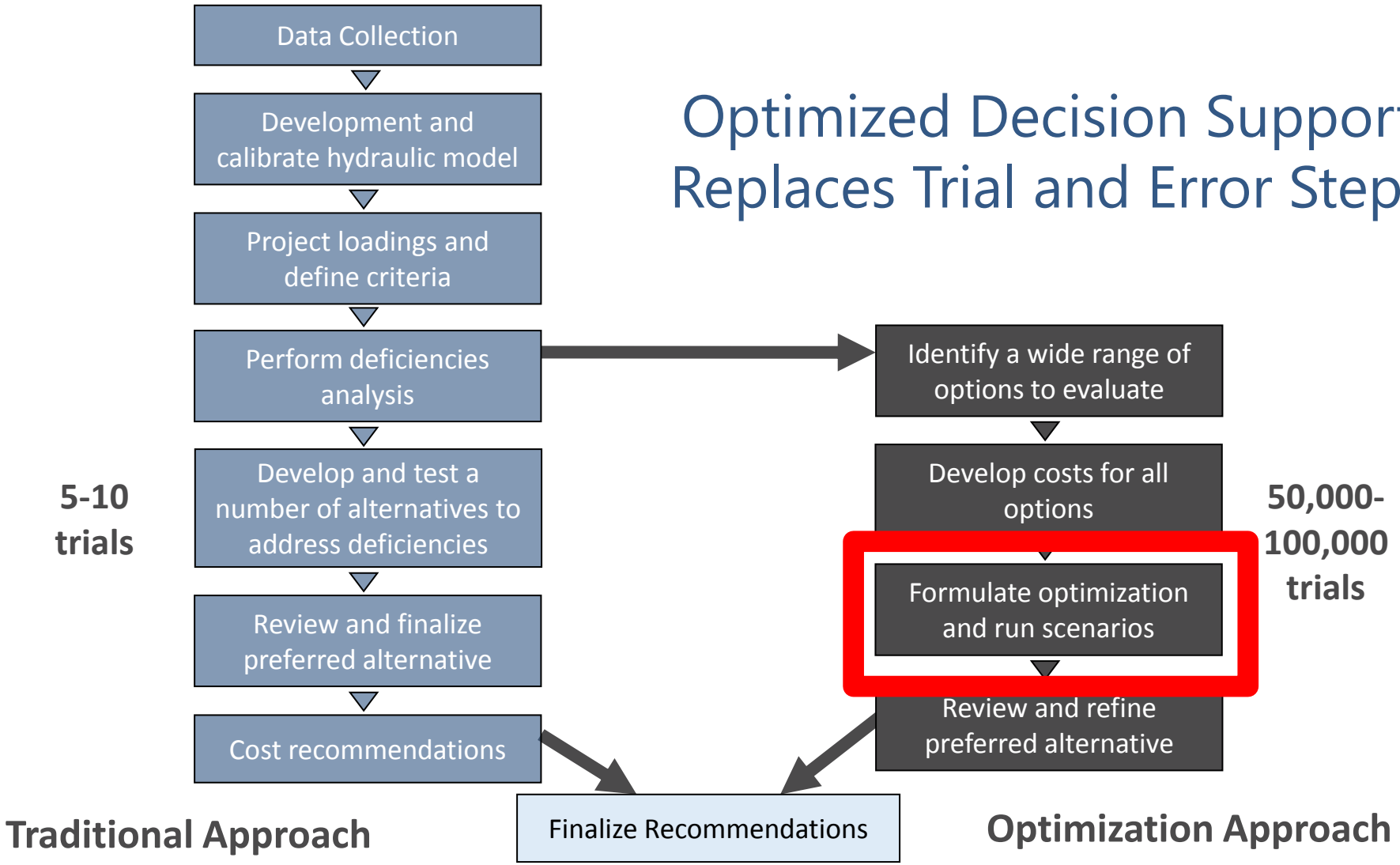

PLEASANT STREET
PIPE REPLACEMENT $/$$/$$$
FLOODING PENALTY $/$$/$$
MAX FLOW PENALTY $$$$$
PIPE REPLACEMENT $/$$/$$$
MAX DEPTH PENALTY $$$$
STORAGE COSTS $/$$/$$$
MAX FLOW PENALTY $$$$$
TECHNY SUBWATERSHED
TECHNY ROAD
LAKE KNOLL DRIVE
EAST MISSION HILLS ROAD
PRAIRIE AVENUE
HOLLY AVENUE
CENTRAL AVENUE
HIGHLAND AVENUE
PHILLIPS AVENUE
LAKESIDE AVE
OLD MILL
N
S
E
W

ENGINEERING

Optimized Decision Support Replaces Trial and Error Steps



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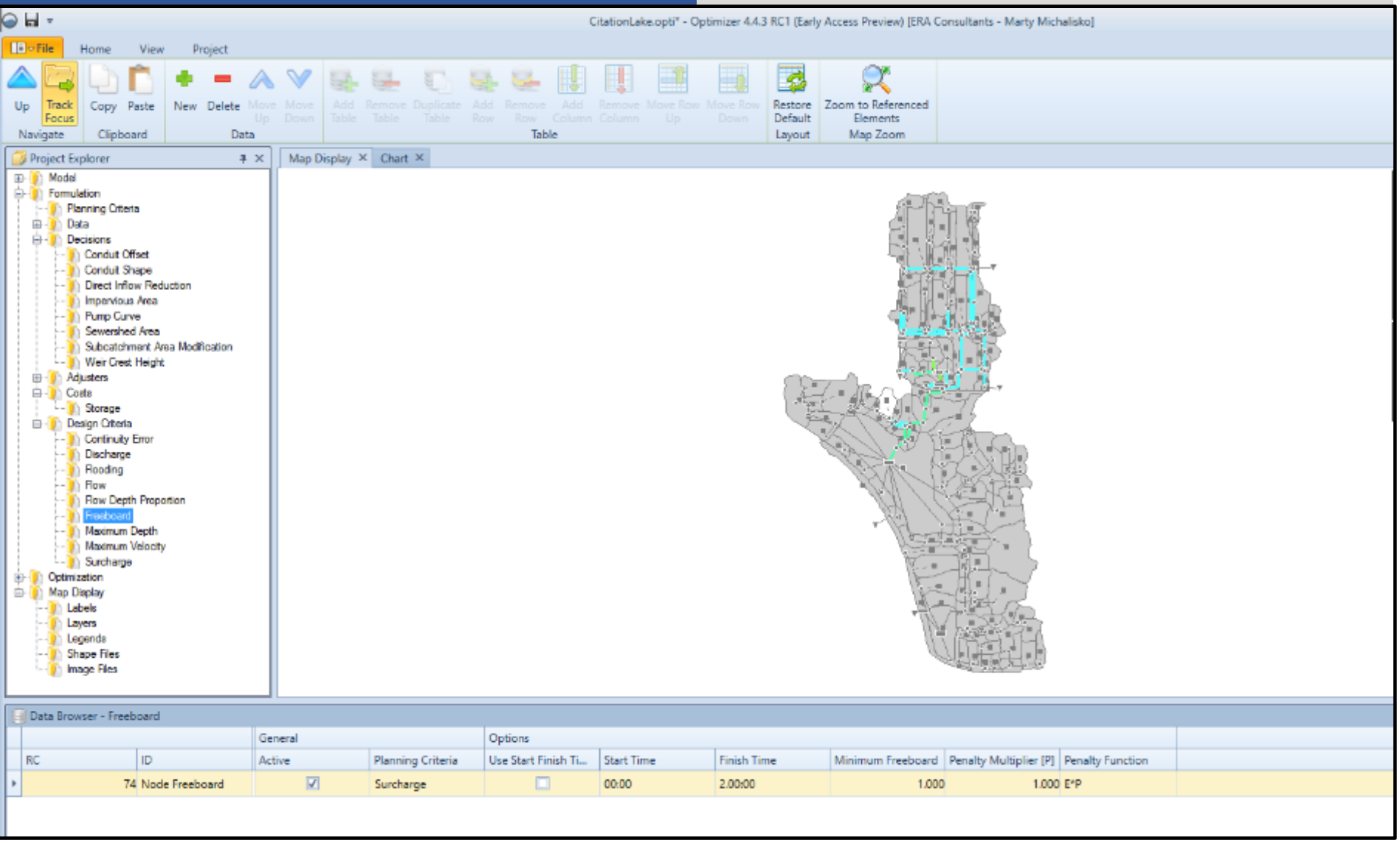
Optimizer Workflow

Formulate Optimization



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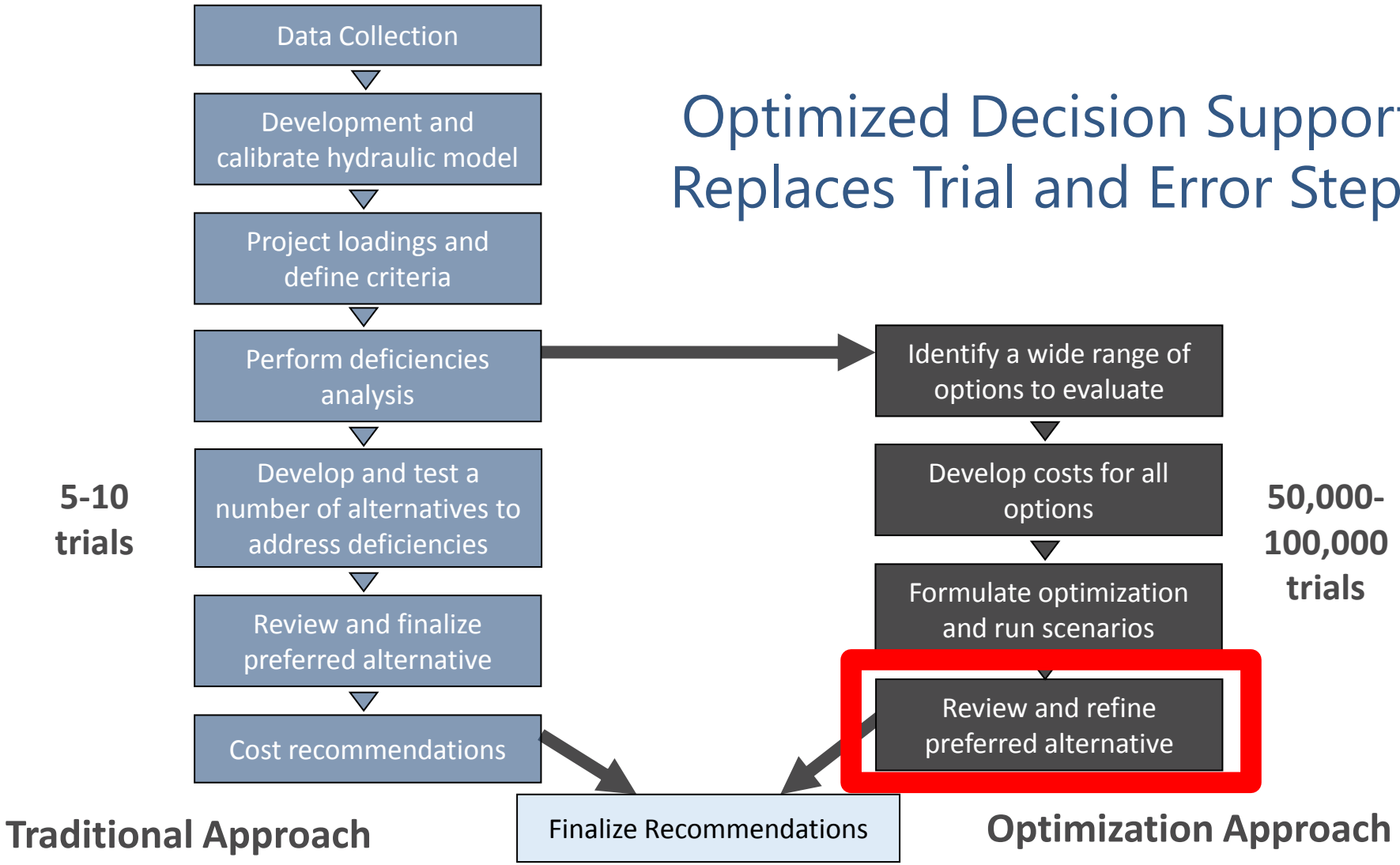

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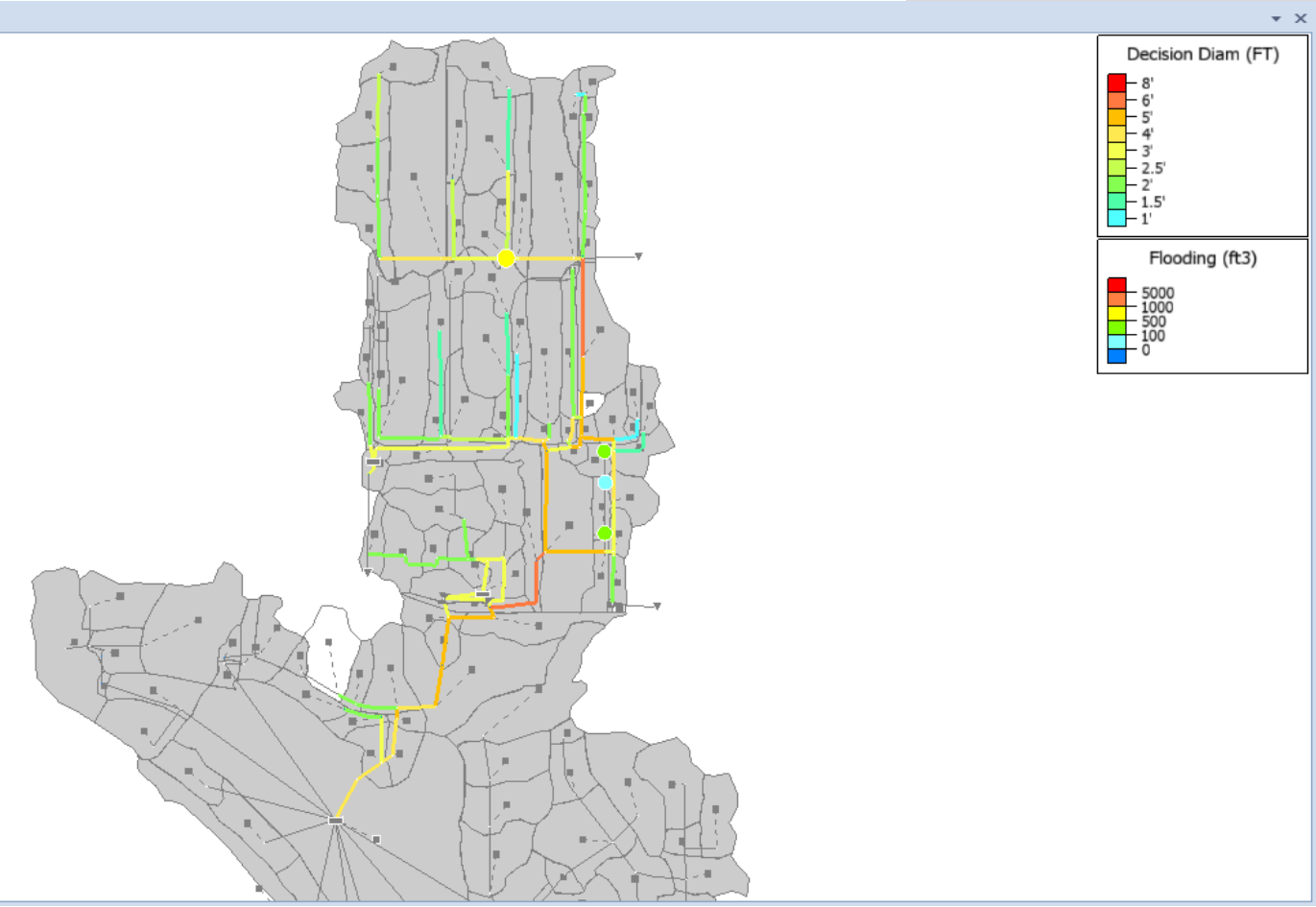
Optimizer Workflow

Review and Refine Optimization



Plan Editor

	Input Model	Best
PC: Conduit ($)	5,219,958.67	8,584,183.12
PC: Flooding ($)	31,786,106.63	2,637,580.98
PC: Surcharge ($)	302.21	14.29
O: Fitness ($)	37,006,367.51	11,221,778.38
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Replacement Level 2	CIRCULAR, 1, 2, 0...	CIRCULAR, 1, 3, 0..
Replacement Level 2	CIRCULAR, 1, 2, 0...	CIRCULAR, 1, 3, 0..
Replacement Level 2	CIRCULAR, 1, 2, 0...	CIRCULAR, 1, 4, 0..
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Replacement Level 2	CIRCULAR, 1, 2, 0...	CIRCULAR, 1, 2.5,..
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Properties Editor - Junctions | Plan Editor

Approach Advantages

- Don’t have to limit design alternatives
- Builds public and stakeholder confidence
- Finds costs savings otherwise not discovered
- Compares grey vs. green vs. combination
- Provides value to the properties, structures, and easements

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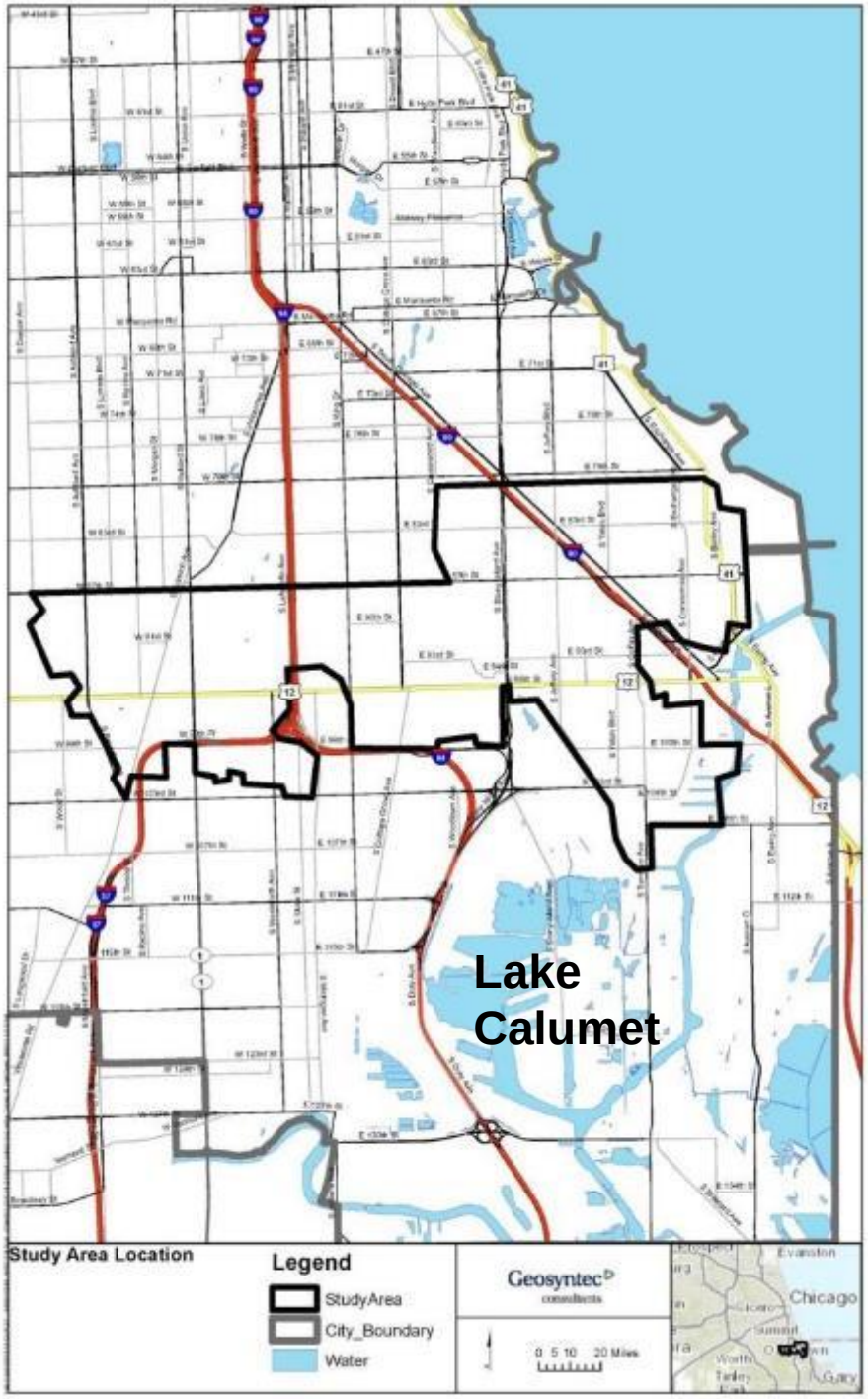
Project Overview

City of Chicago – MWRD Pilot Study

Initial Study Area



- 13 Square Miles
- Within Chicago limits & MWRD service area
- 7 Wards (7,8,9,10,21, 34, & 19)
- Densely urbanized
- Prior & ongoing studies
- Chronic urban flooding
  - Basement backups
  - Surface flooding

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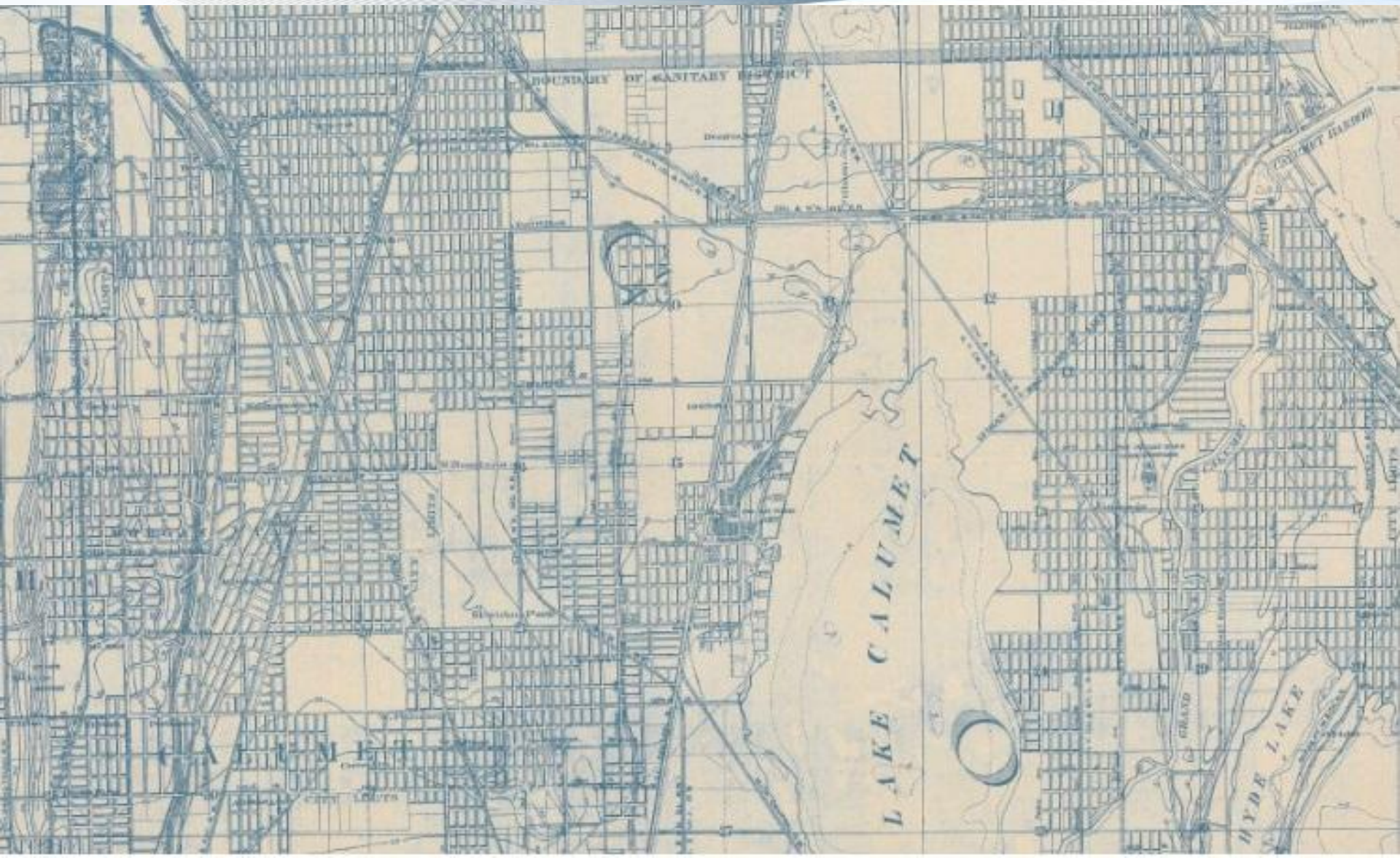
Sanitary District of Chicago Map c1895



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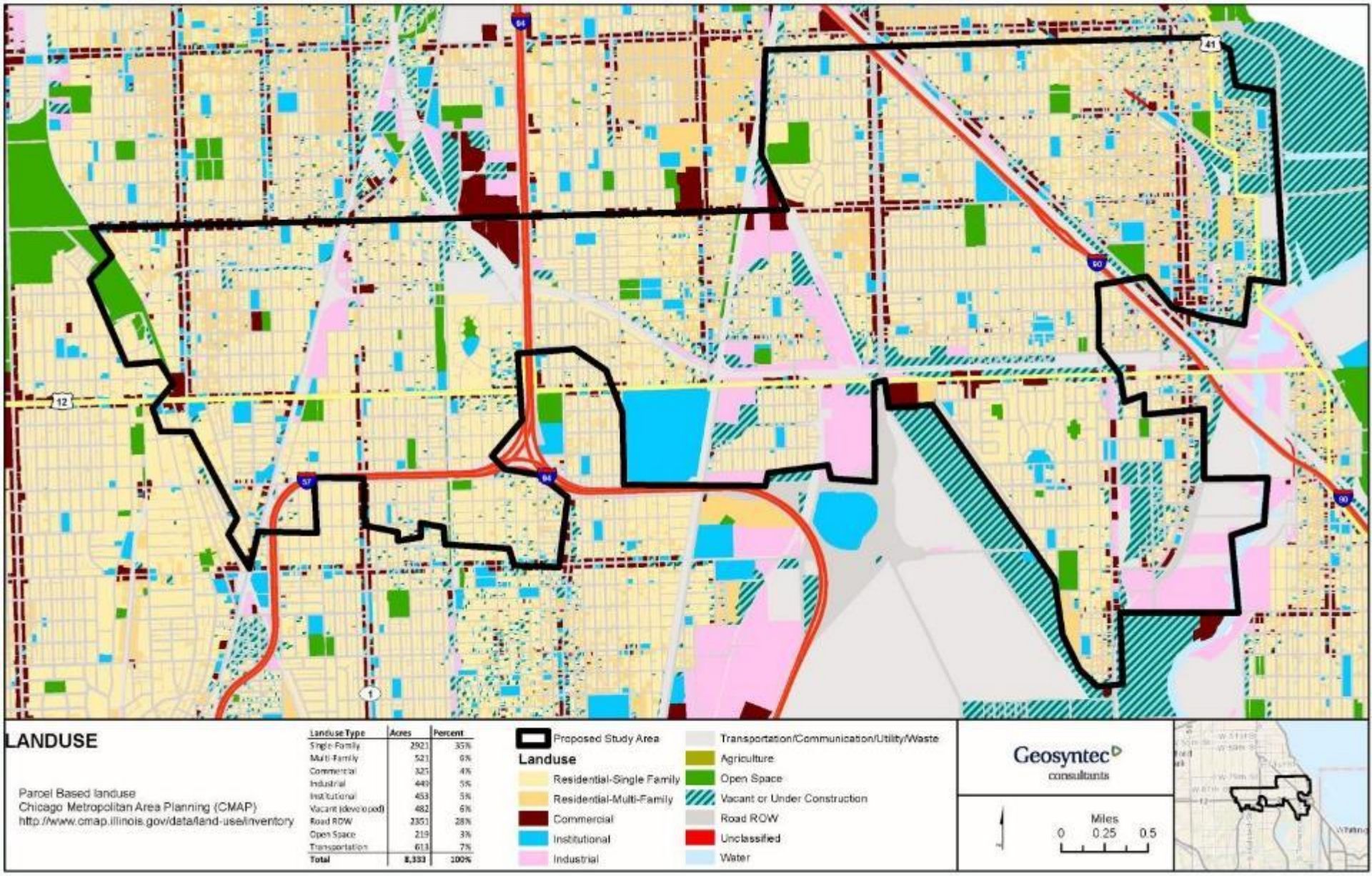
Land Use



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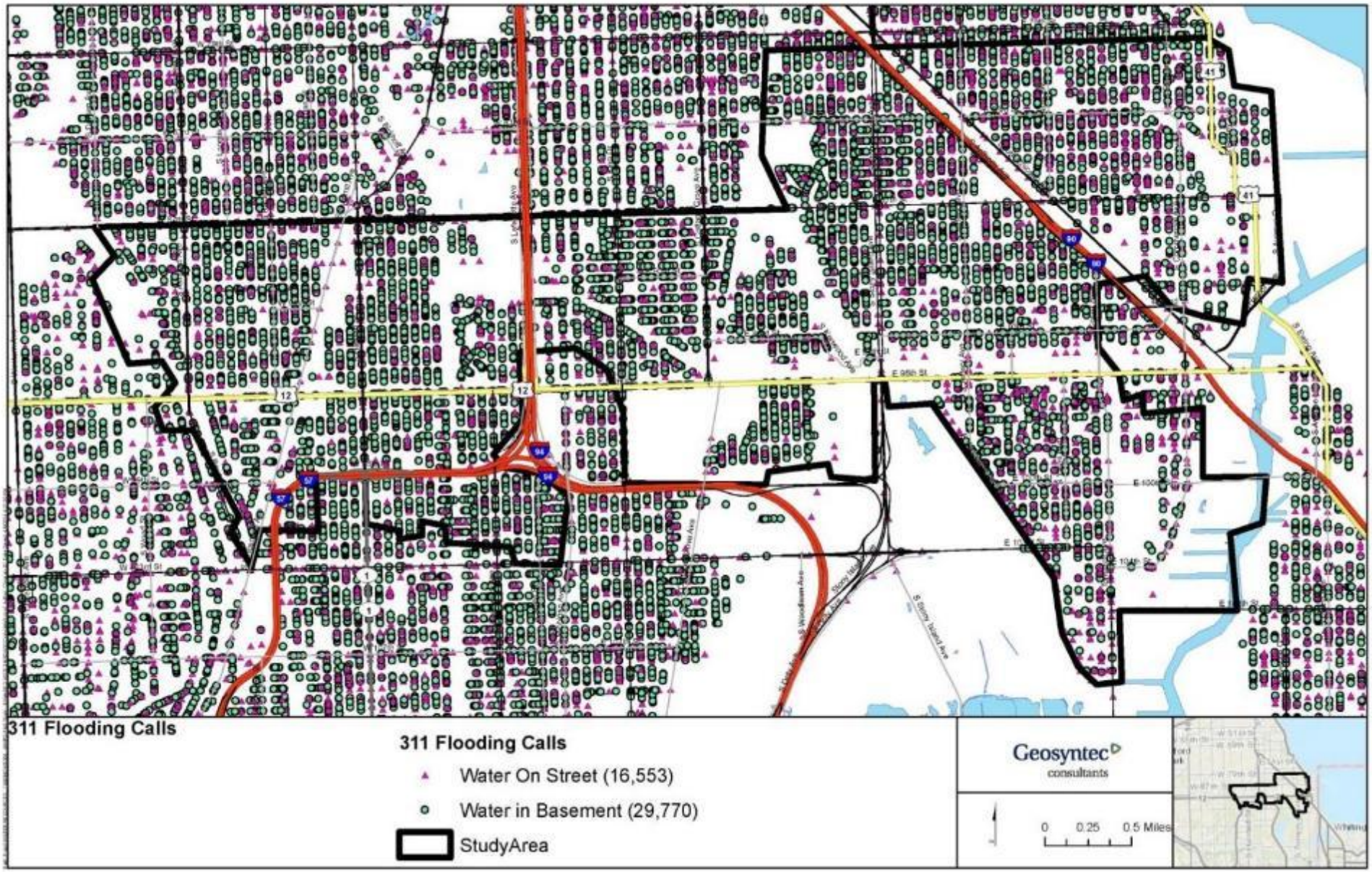
311 Flooding Calls
(2010-2014)



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Understanding the Study Area

- Highly Urbanized Combined Sewer Network
  - Basement backups of primary concern (elevated HGL)
  - Local & regional sewer capacity issues
  - Significant efforts to increase roof disconnection
  - Installed flow restrictors in catch basins

- Category of Identified Improvements
  - Regional – conveyance or storage tunnel (primary focus)
  - Connecting – problem areas that rely on regional outlets
  - Isolated – not directly associated with regional or connecting

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Project Approach & Work Plan

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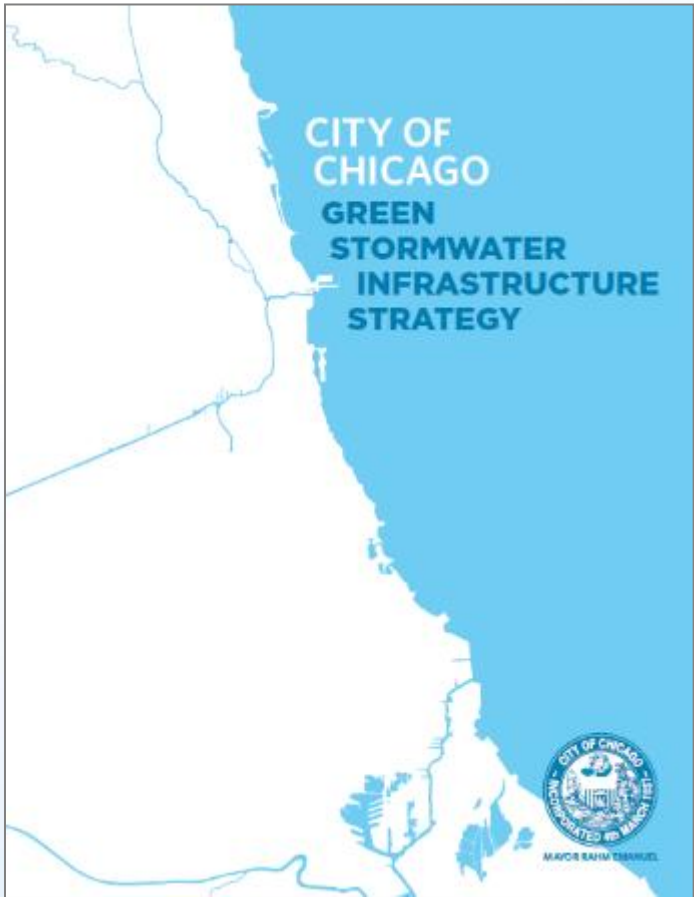
Project Approach & Work Plan

- Foundation of Project Approach: **Green Stormwater Infrastructure Strategy**
- Holistic Vision by MWRD & City
- Progressive evaluation of integrating both green and gray solutions
- Identifies the Need to:
  - Quantify costs & benefits of green
  - Seek to integrate green & gray
  - Evaluate scaling up green solutions



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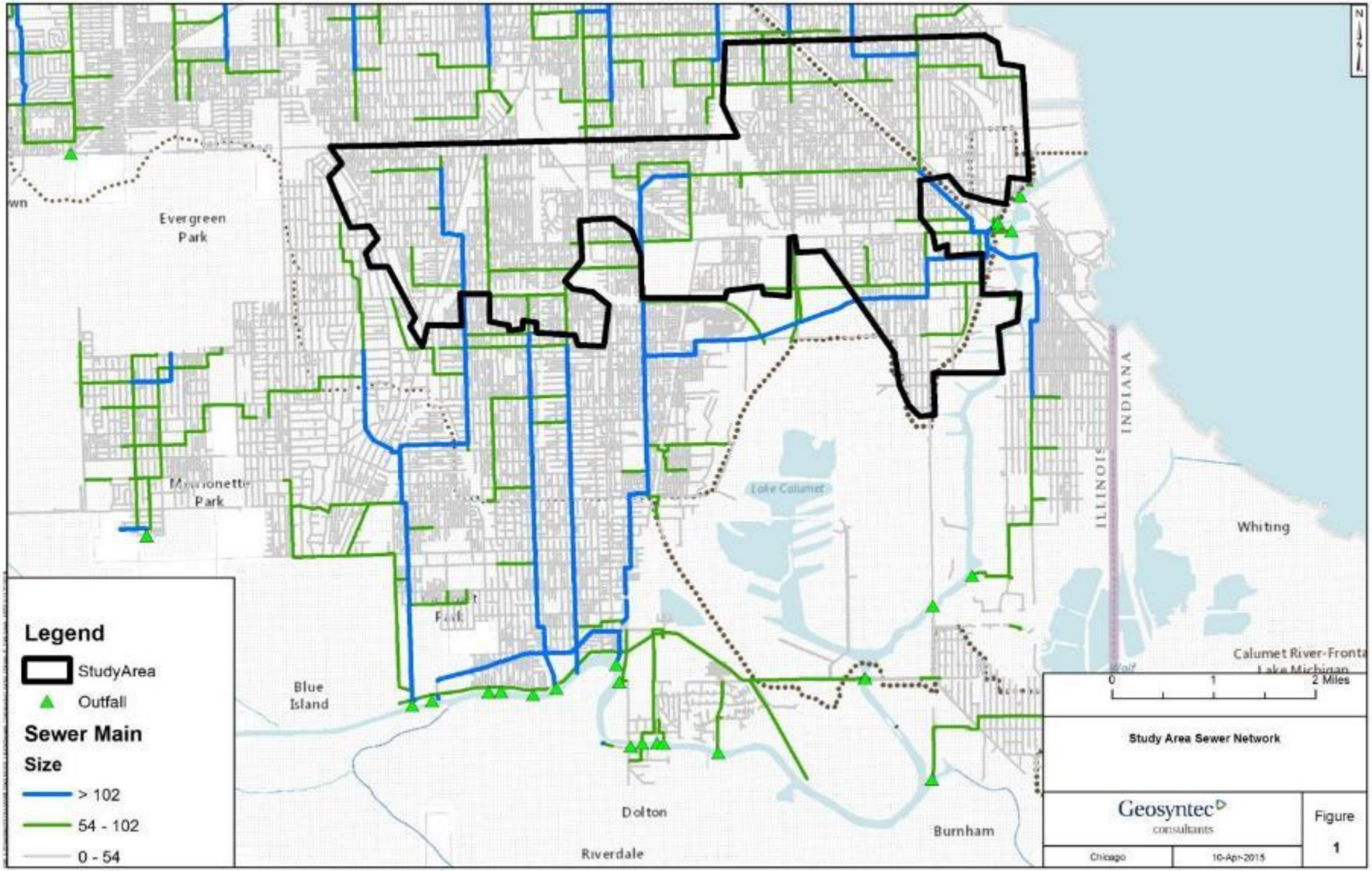
Original Target Study Area



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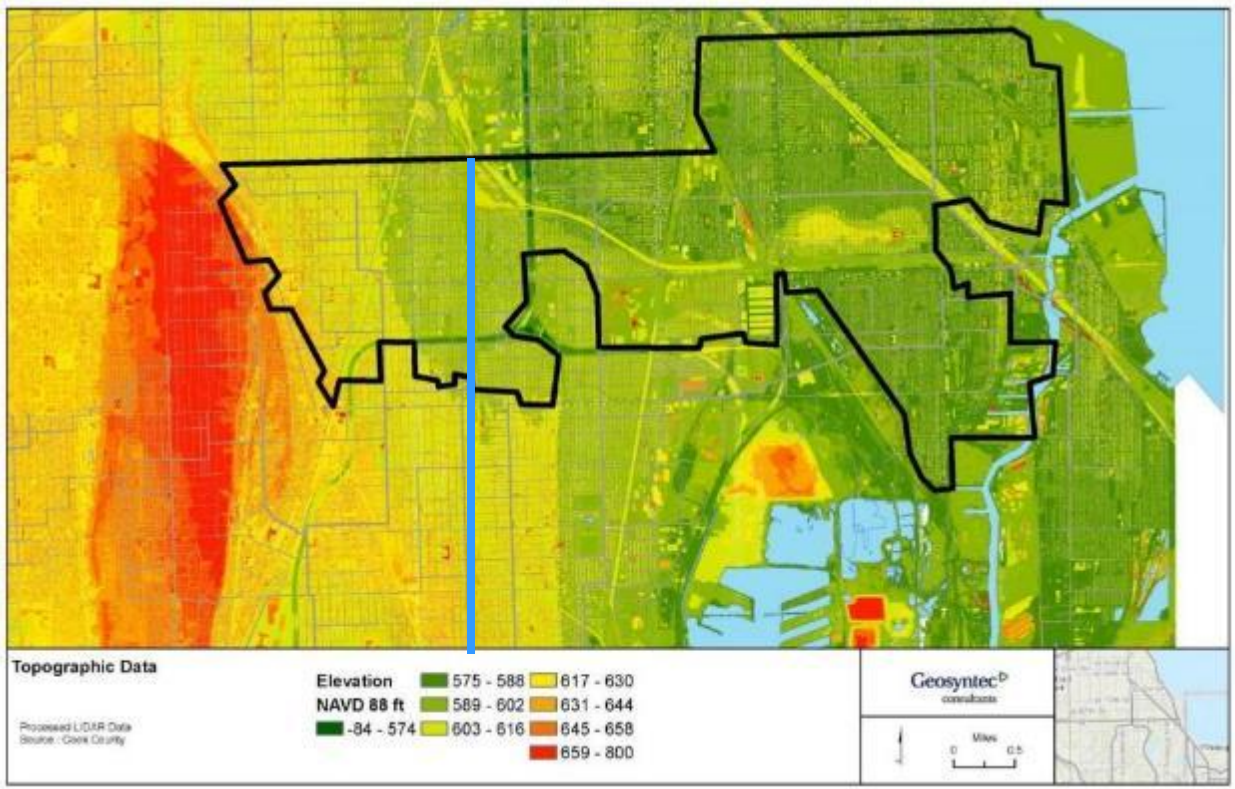
Looking for Solutions

- Flooding Solutions are a Balance of:
  - Conveyance
  - Volume

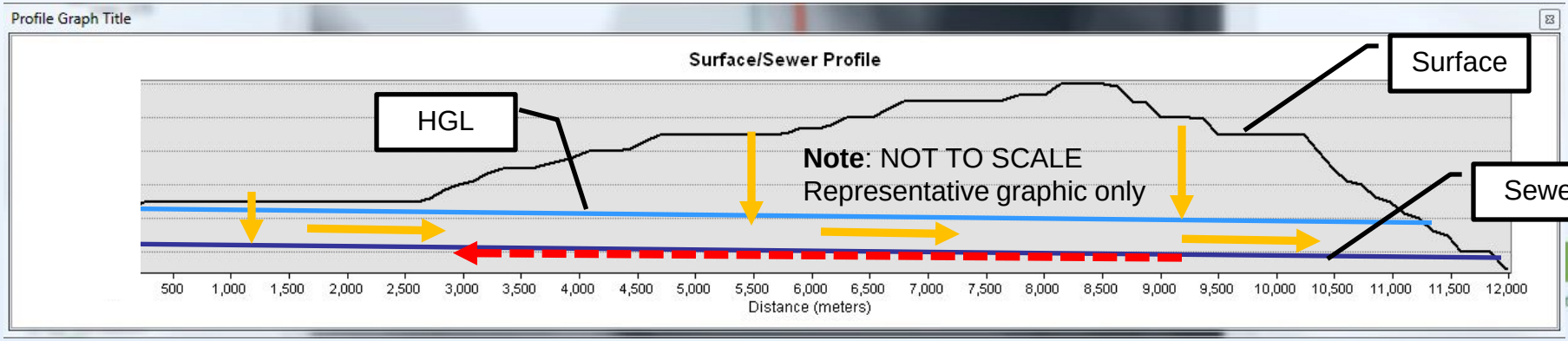
- Ensure the Question Being Asked is Framed Properly
  - Define baseline conditions
  - Define target condition
  - Evaluate level of service
  - Identify source of problem(s)
  - Identify potential suite of solutions

Baseline Conditions

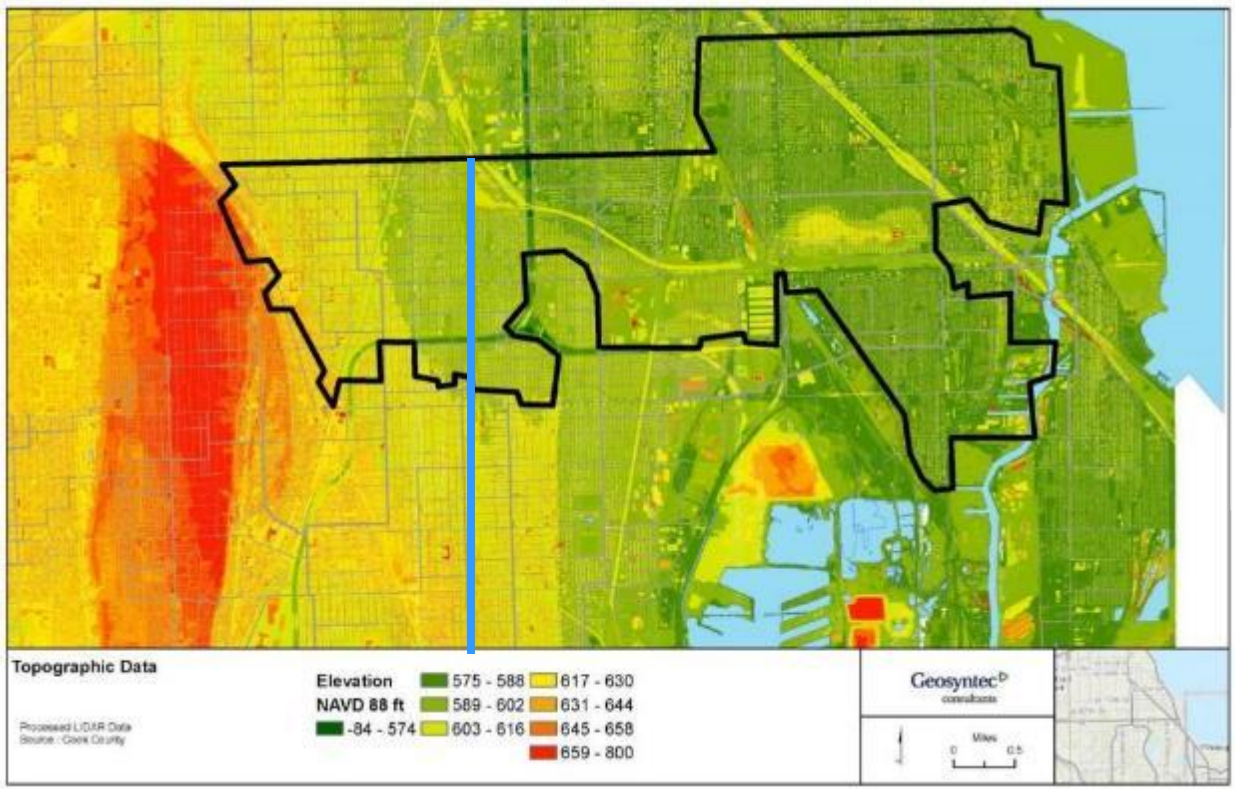


Source of problem?

- Conveyance
- Lack of storage volume
- Topography

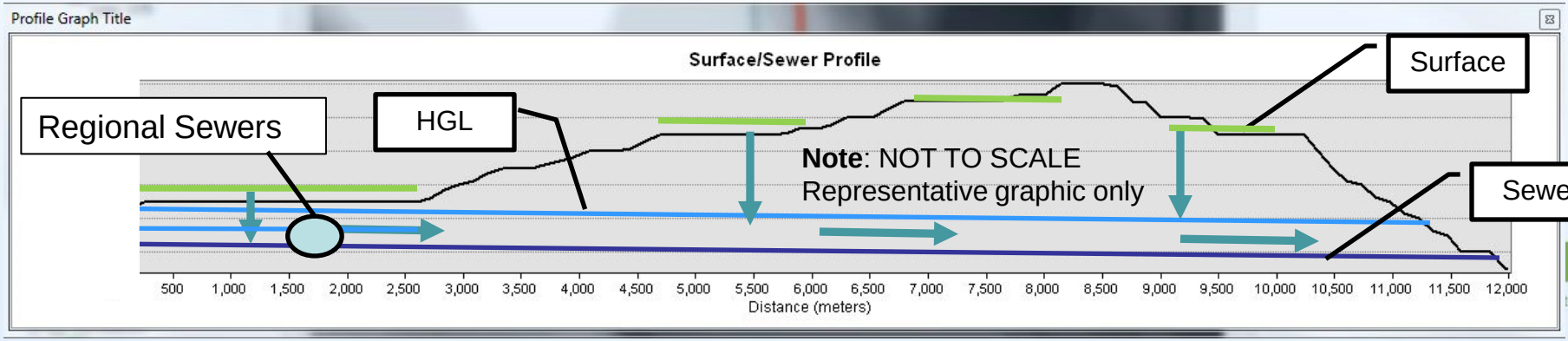


Potential Solutions



What is the solution?

- Conveyance
- Volume
  - Green Infrastructure
  - Gray storage



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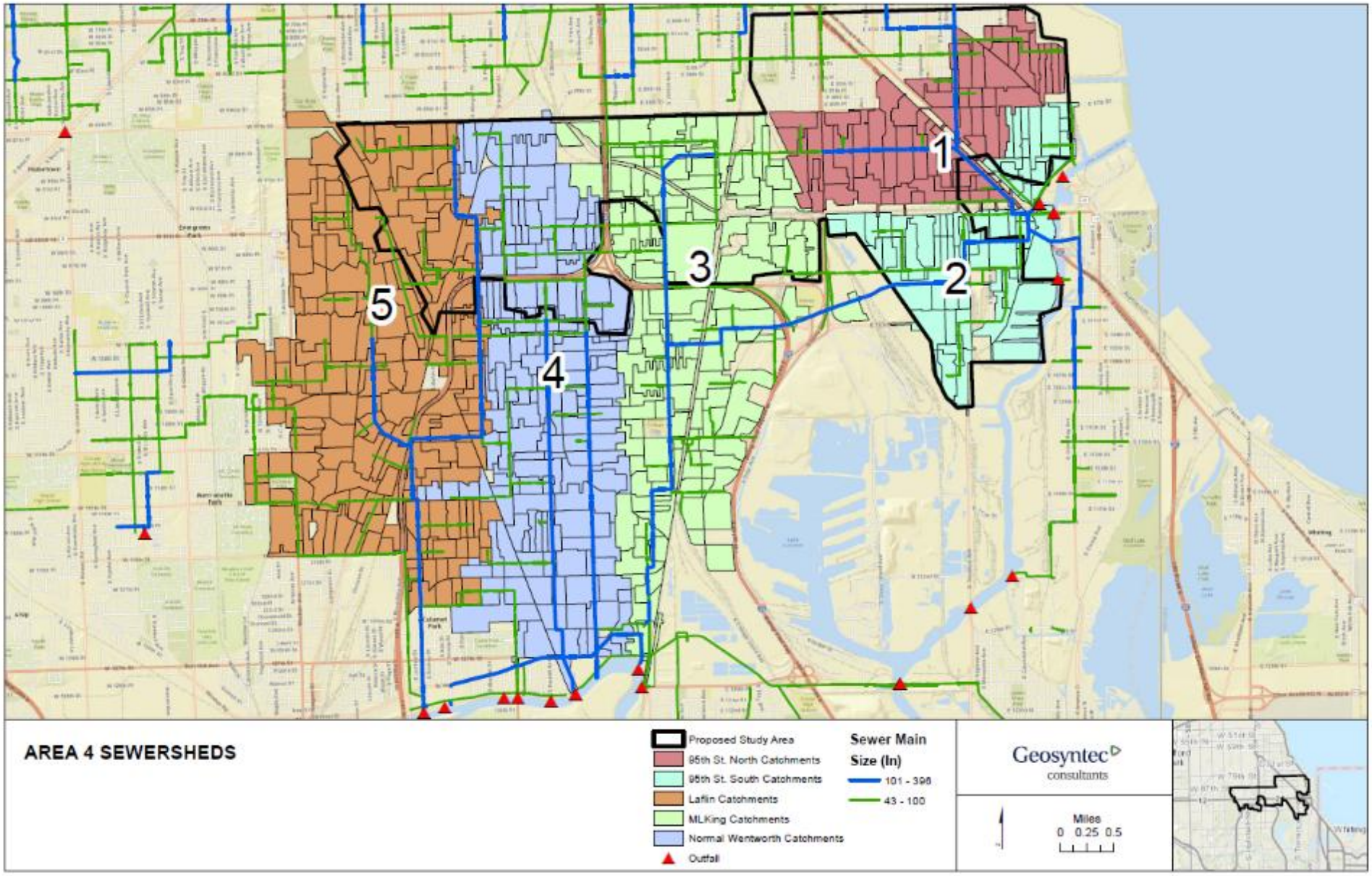
Re-Defining the Study Areas
(Reframing the question)



Refined Approach

- Original Target Study Area Limited to Location Experiencing the Worst Flooding
  - Hydraulically dependent on areas beyond study area
  - GI performance highly dependent on regional gray solutions (could not evaluate GI only scenario)
- Proposed Study Area Expanded to Full Southside Sewershed
  - Modified study area considers downstream influences
  - Subdivided sewersheds into hydraulically independent zones
  - Able to analyze sewersheds individually
  - Evaluate conveyance and volume based solutions

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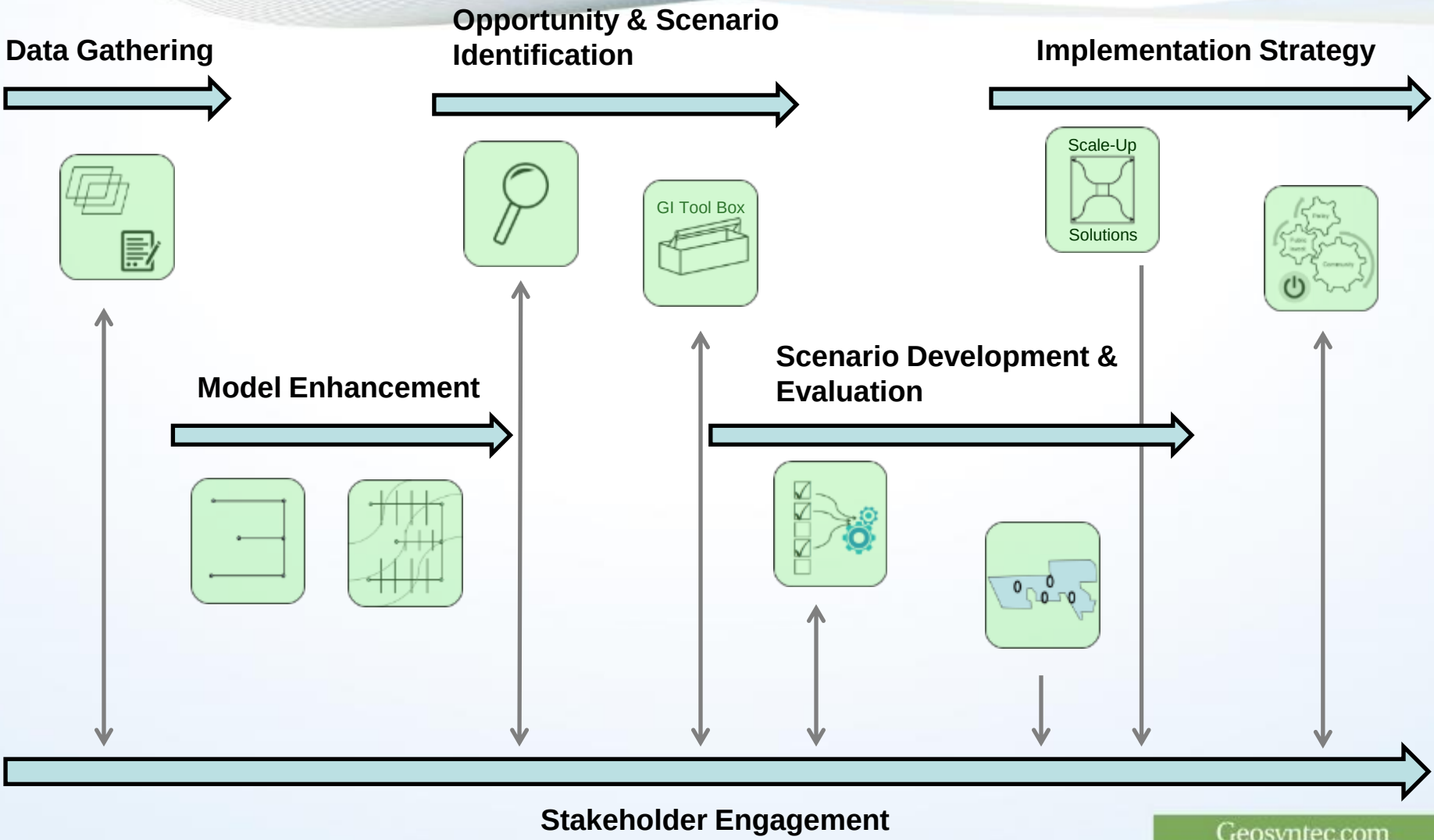
Work Flow



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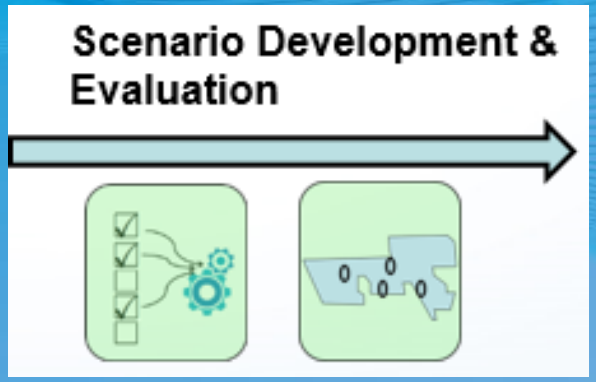
Scenario Development & Evaluation

Modeling Approach



Modeling Approach

- Direct representation of GI in combined sewer model
  - Explicit representation of GI in Chicago model has never been done
  - Integration with existing model network allows direct comparison of green vs gray performance
- Leverages power of optimization analysis
  - Optimizes 100,000+ combinations (performance & cost)
  - Evaluates targeted scenarios (implementation strategies)

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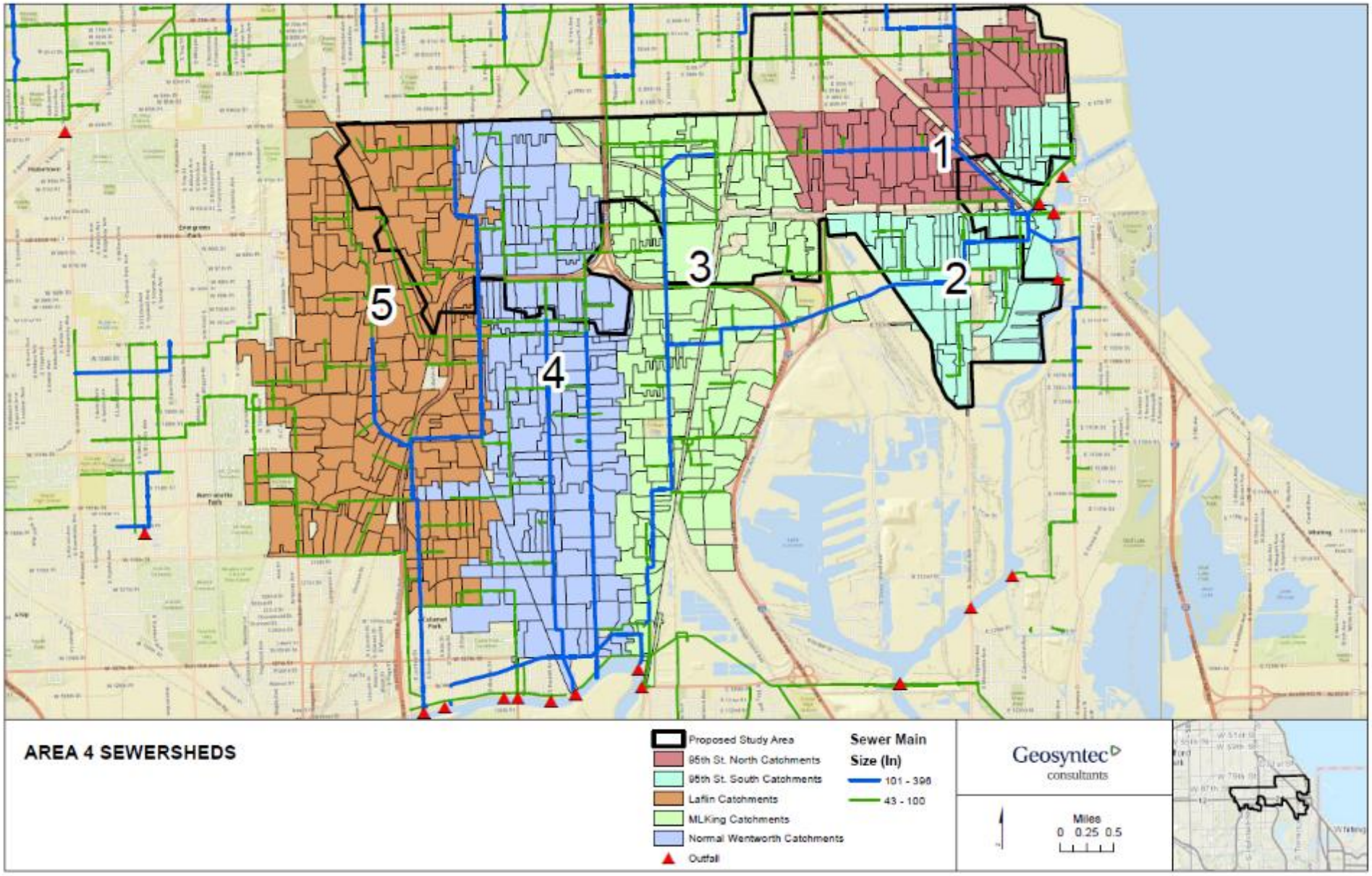
Defined Study Areas



Scenario Based Analysis

- **GI Only**
  - Quantify performance and cost for levels of GI Implementation
  - Question: Can planned gray infrastructure projects be replaced?
- **GI & Regional Gray Projects**
  - Quantify performance and cost for levels of GI Implementation
  - Question: What is the max level of service?
- **GI & Regional Gray Projects with Supplemental Solutions**
  - Regional conveyance is maxed (are there local conveyance issues – “connecting projects”?)
  - Typical GI volume is maxed (what larger green/gray volume can we achieve?)

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Model Framework Development

GI Scenario Management

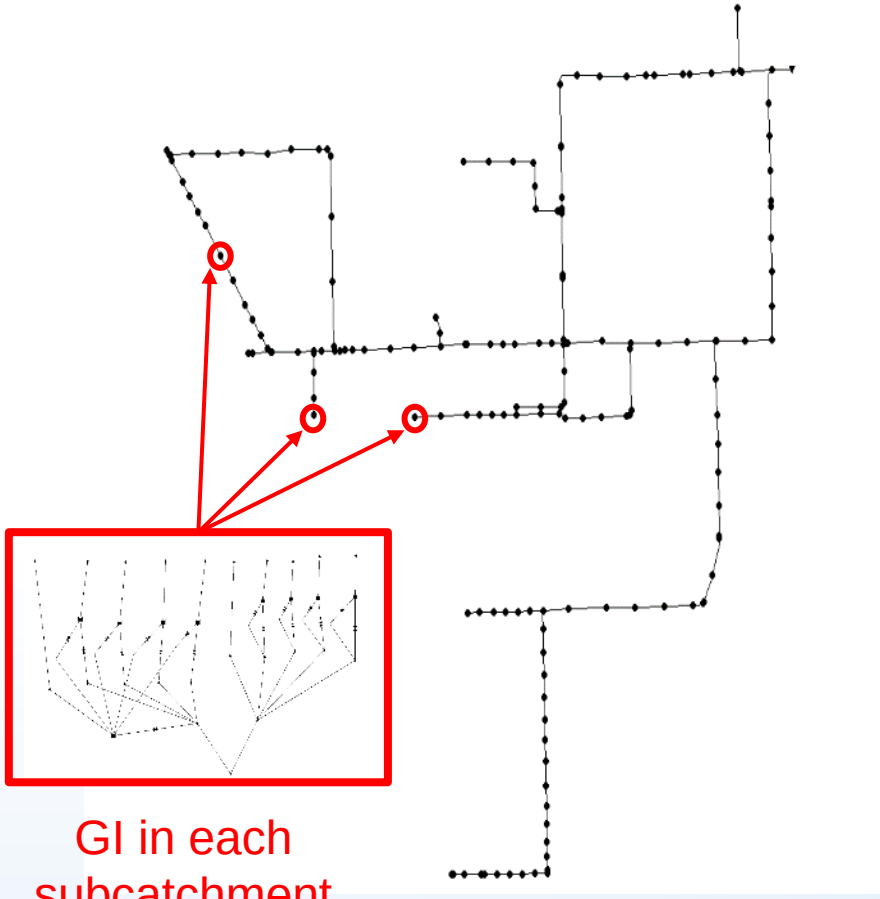
GI Scenario Manager Summary

- Green Infrastructure Practices
  - 5 Unique GI Practices
  - 9 Unique GI Applications
  - Established GI Design Basis
  - Established Practical Implementation Ranges
- Unit Construction Cost Estimate
- Landuse Categories
  - 83 Separate Landuse Categories
  - 23 Aggregated Categories

Land Use	GI Type	LandUse_GI
Commercial, Industrial, and Institutional	Pervious Pavement	Com, Ind, and Inst_PerPave
Roadway ROW and Alleys	Pervious Pavement	Road ROW and Alleys_PerPave
Roadway ROW	Bioretention	Road ROW_Bio
Commercial, Industrial, and Institutional	Bioretention	Com, Ind, and Inst_Bio
Residential	Above Ground Cistern	Residential_Cistern
Commercial, Industrial, and Institutional	Above Ground Cistern	Com, Ind, and Inst_Cistern
Commercial, Industrial, and Institutional	Green Roof or Blue Roof	Com, Ind, and Inst_Green Roof

Optimizer Application to Sub-Areas

- Optimization of GI infrastructure for all subcatchments in sub-area
- Decisions: % Implementation of five GI practices (Cistern, Green Roof, Permeable Pavement, and Bioretention)
- Design Criteria: Maintain 6ft Freeboard
- Objective: Minimize Cost of GI



GI in each subcatchment is modelled explicitly

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Strength of Optimization Protocol:
Sewershed 2 Modeling Stats

- 82 model catchments
- 9 land use based GI types
- 738 GI implementation decisions per optimization iteration
- 3 ½ hour simulation at 2 second time step

~50 seconds per run in real time on laptop

- 40,000 runs would take over 550 hours to complete, but on cloud is less than 6 hours
- Optimization protocol replaces effort of manual trial & error set up

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Strength of Optimization Protocol:
Sewershed 4 Modeling Stats

- 294 model catchments
- 9 land use based GI types
- 2646 GI implementation decisions per optimization iteration
- 10 ½ hour simulation at 10 second time step

~10 minutes per run in real time on laptop

- 40,000 runs would take over 6,660 hours to complete, but on cloud is less than 36 hours
- Optimization protocol replaces effort of manual trial & error set up

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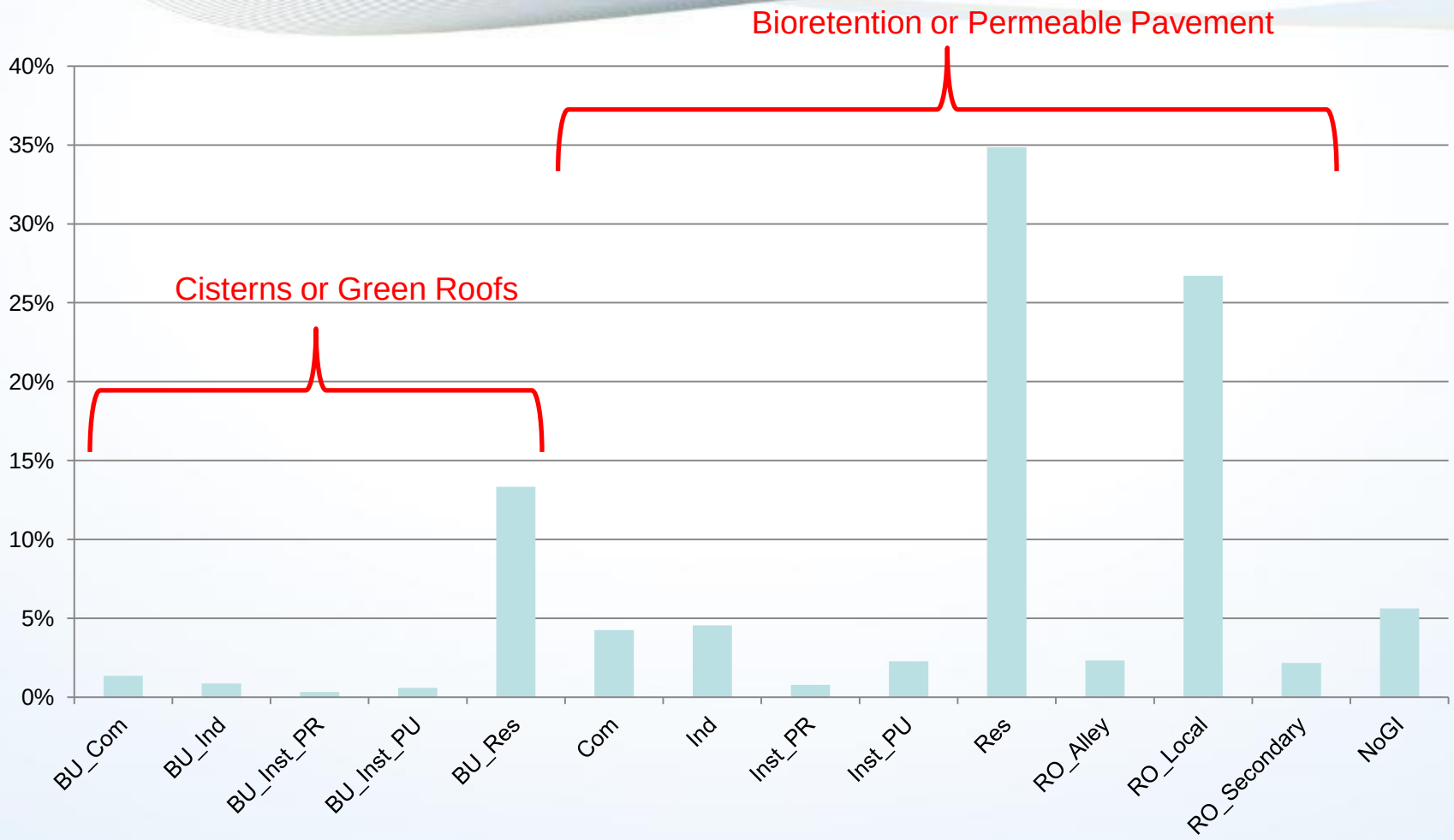
Preliminary Sewershed 2 Results

Draft Optimized GI Simulation Results for Sewershed 2

Sewershed 2 - Land Use Distribution



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Sewershed 2 Results

Scenario A: without Regional Gray Solution

5-yr, 2-hr Storm

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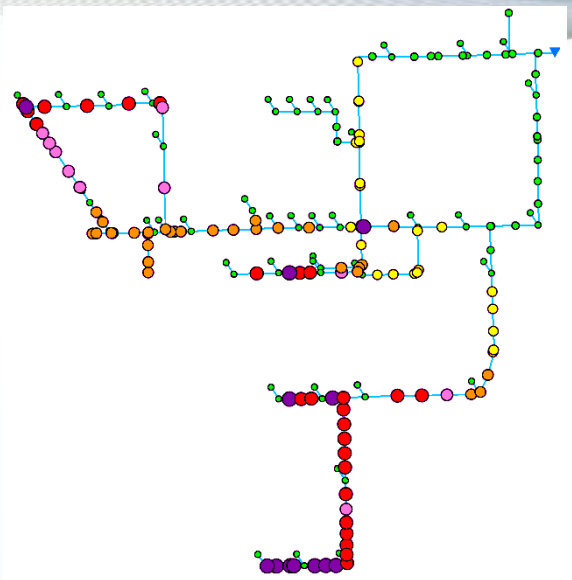
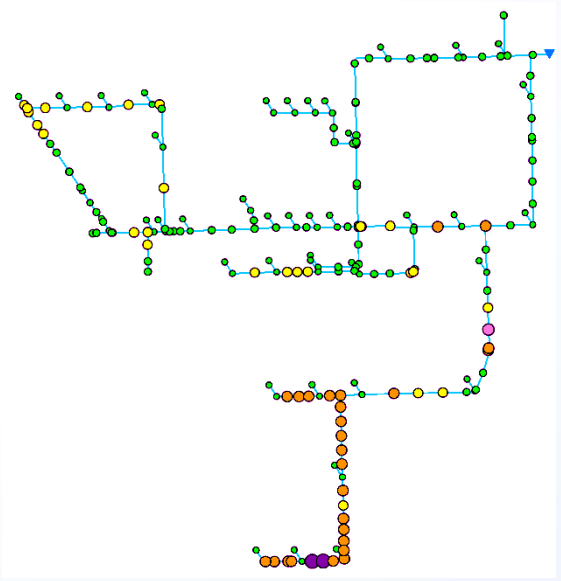
Results Comparison

5-yr, 2-hr Storm / GI5

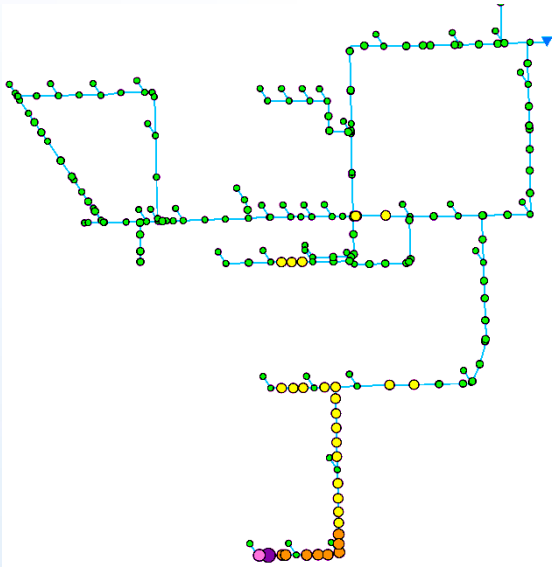
Baseline

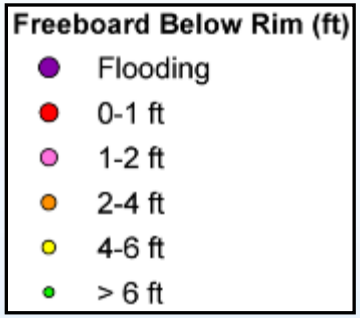


Optimized GI



Max GI

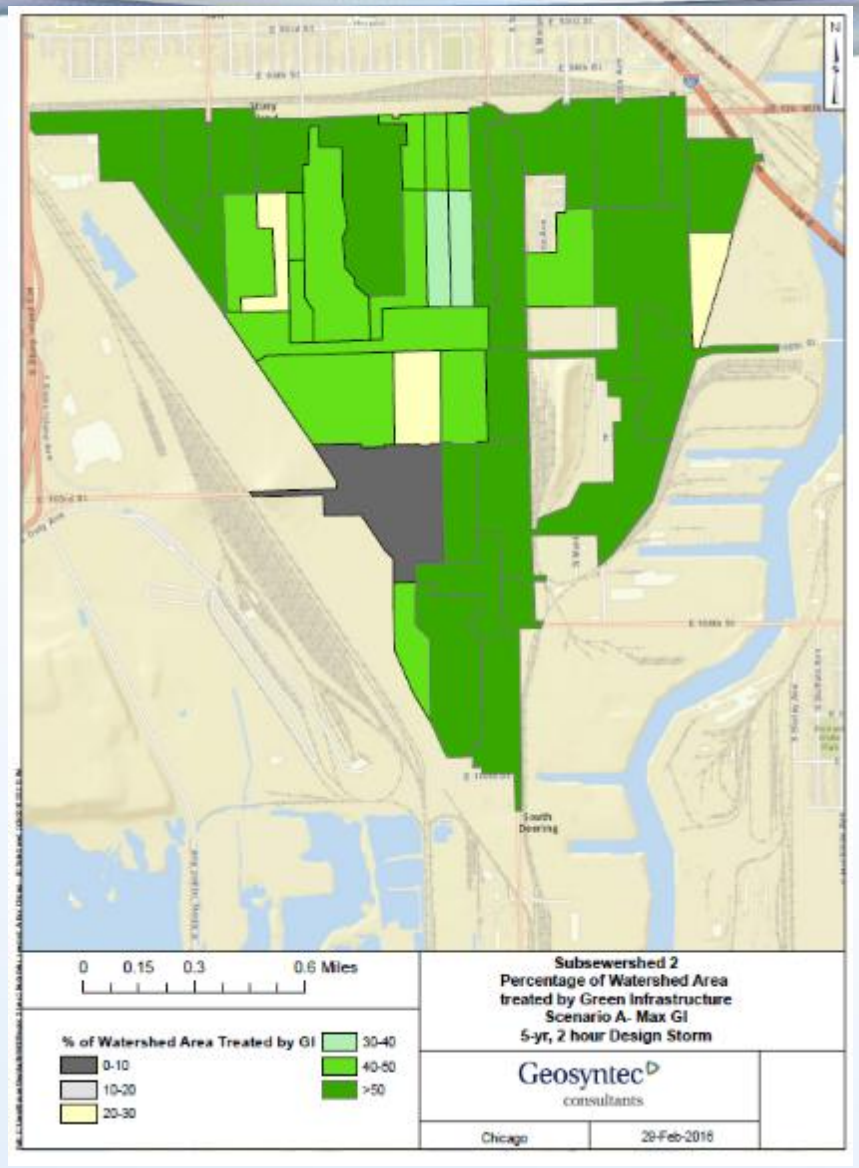




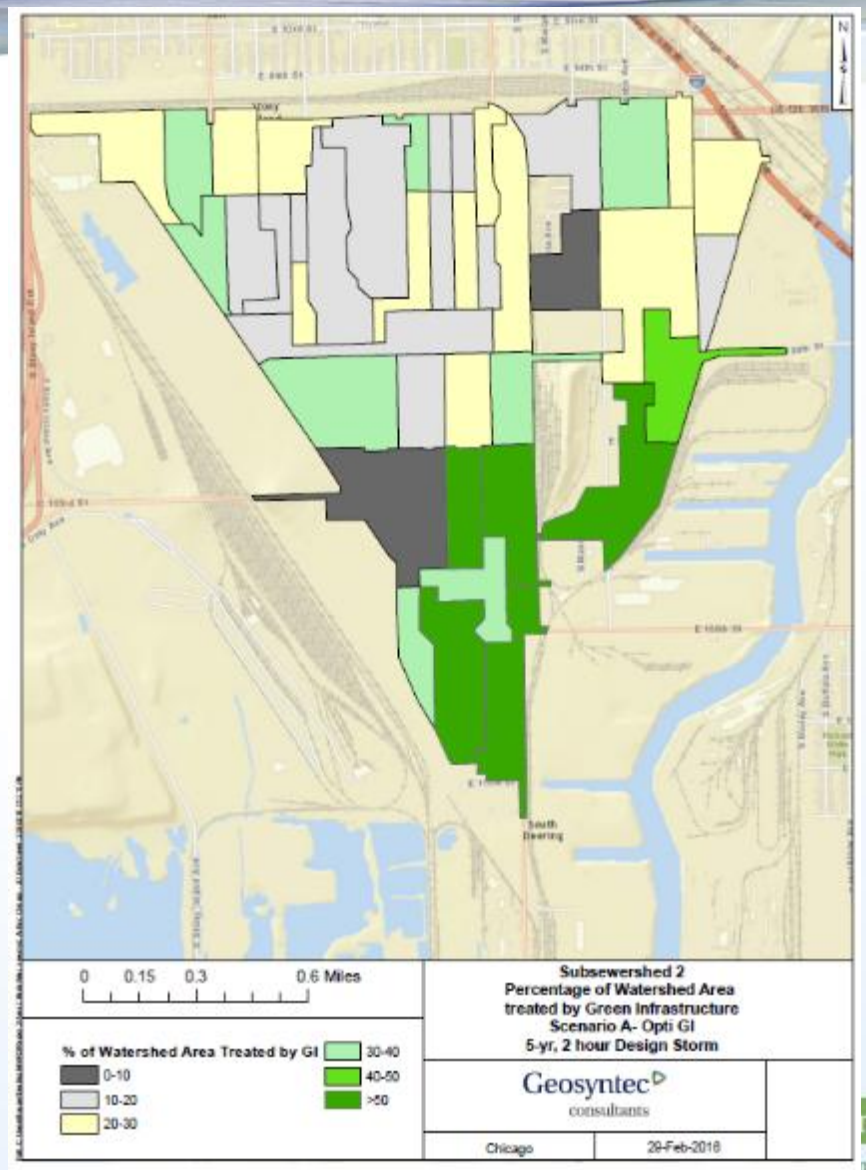
GI Distribution

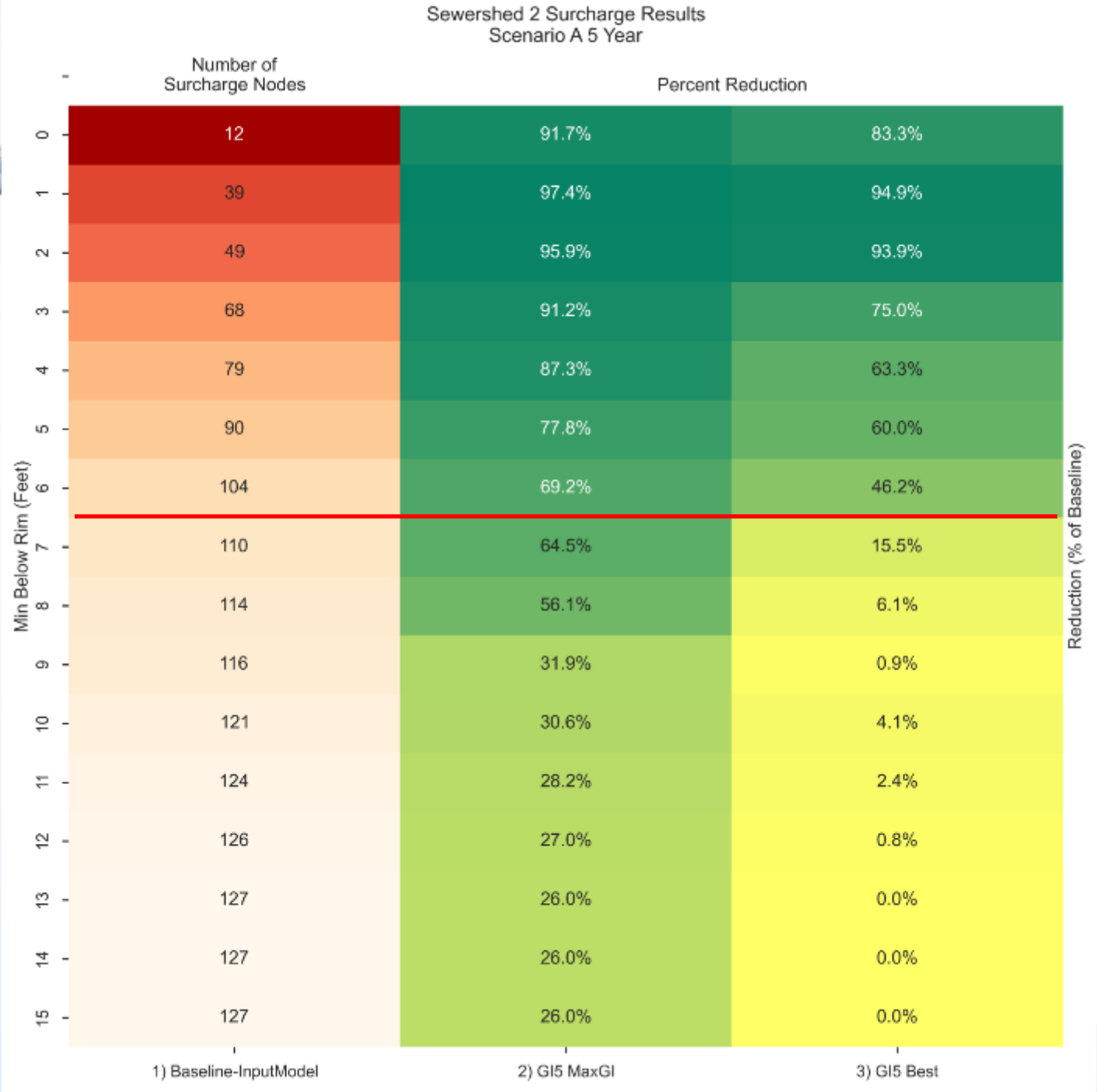
5-yr, 2-hr Storm / GI5

Max GI



Optimized GI





Node Surcharge Summary

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Sewershed 2 Results

Scenario B: with Regional Gray Solution

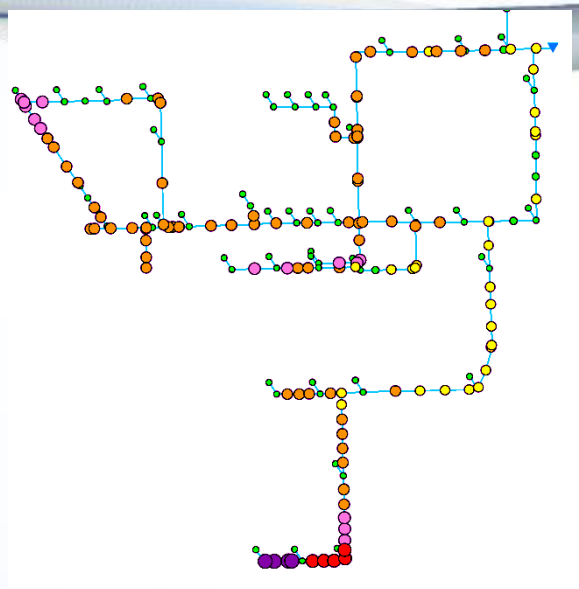
25-yr, 2-hr Storm

Geosyntec consultants

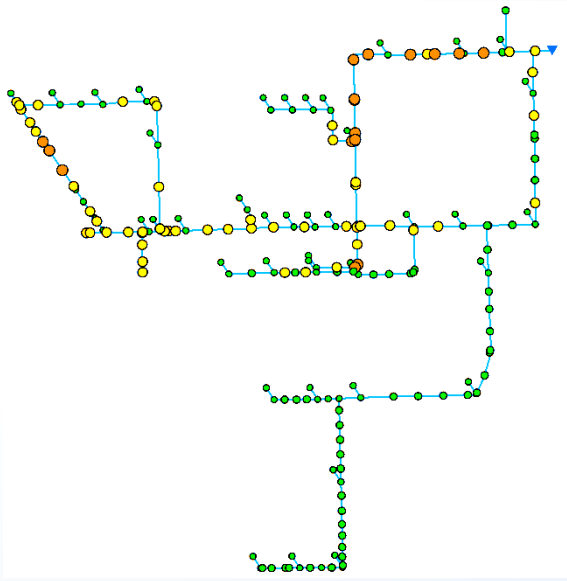
Results Comparison

25-yr, 2-hr Storm / GI25

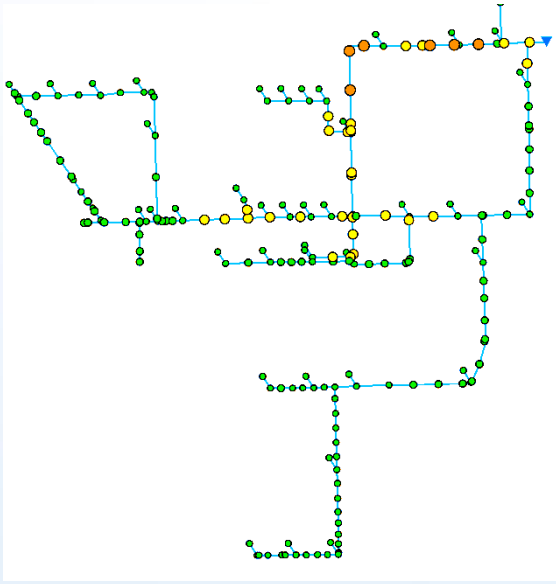
Baseline

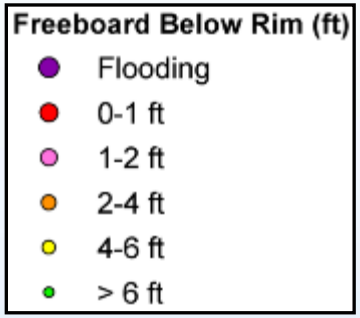


Optimized GI



Max GI





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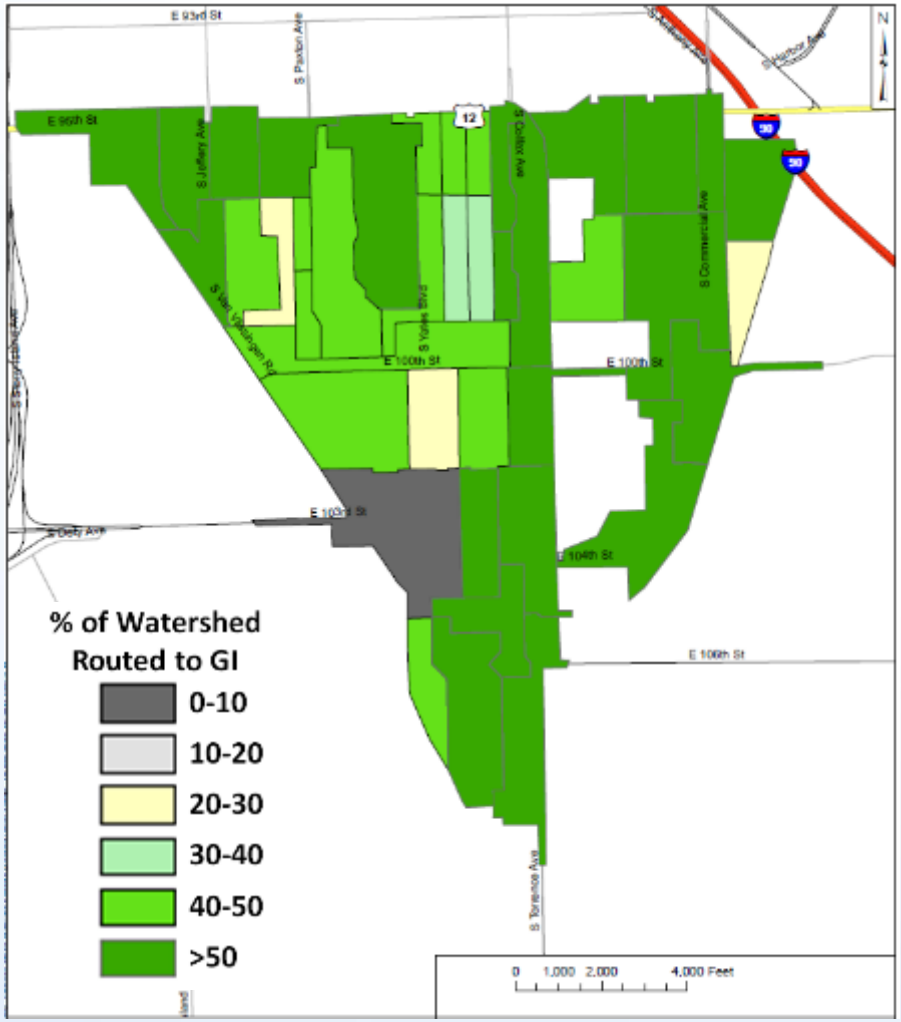
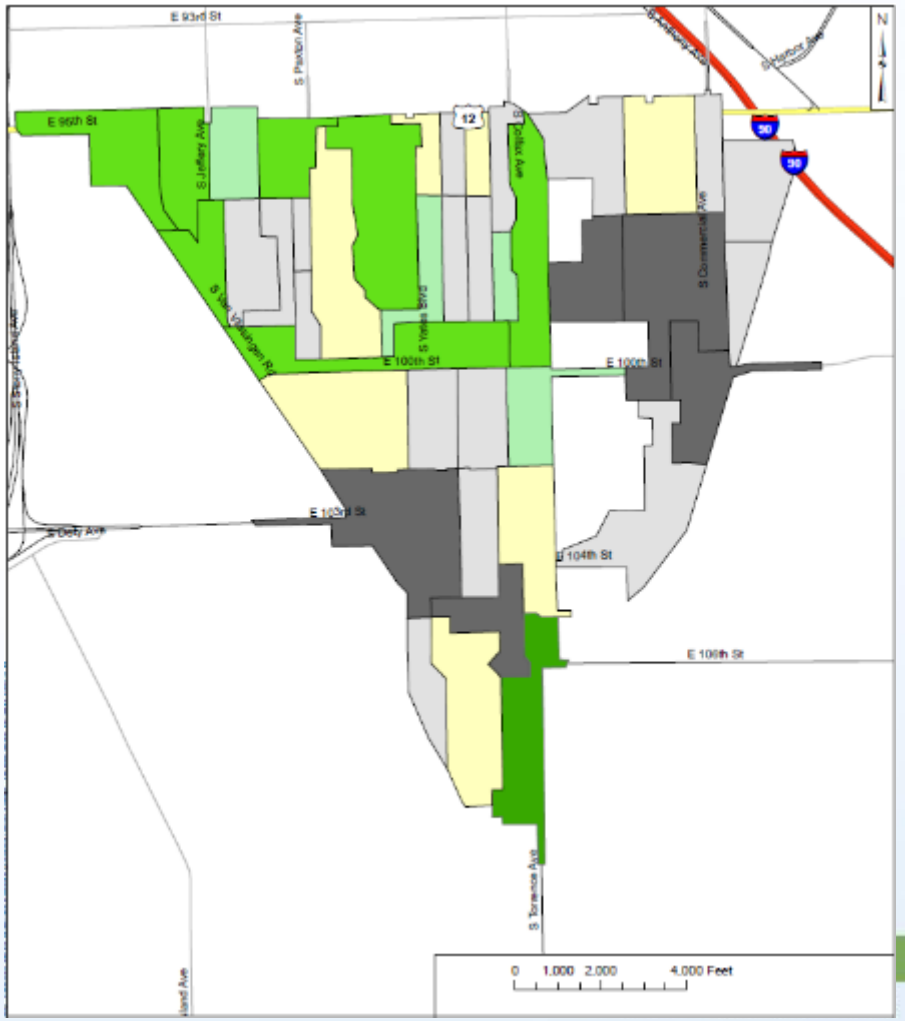
GI Distribution

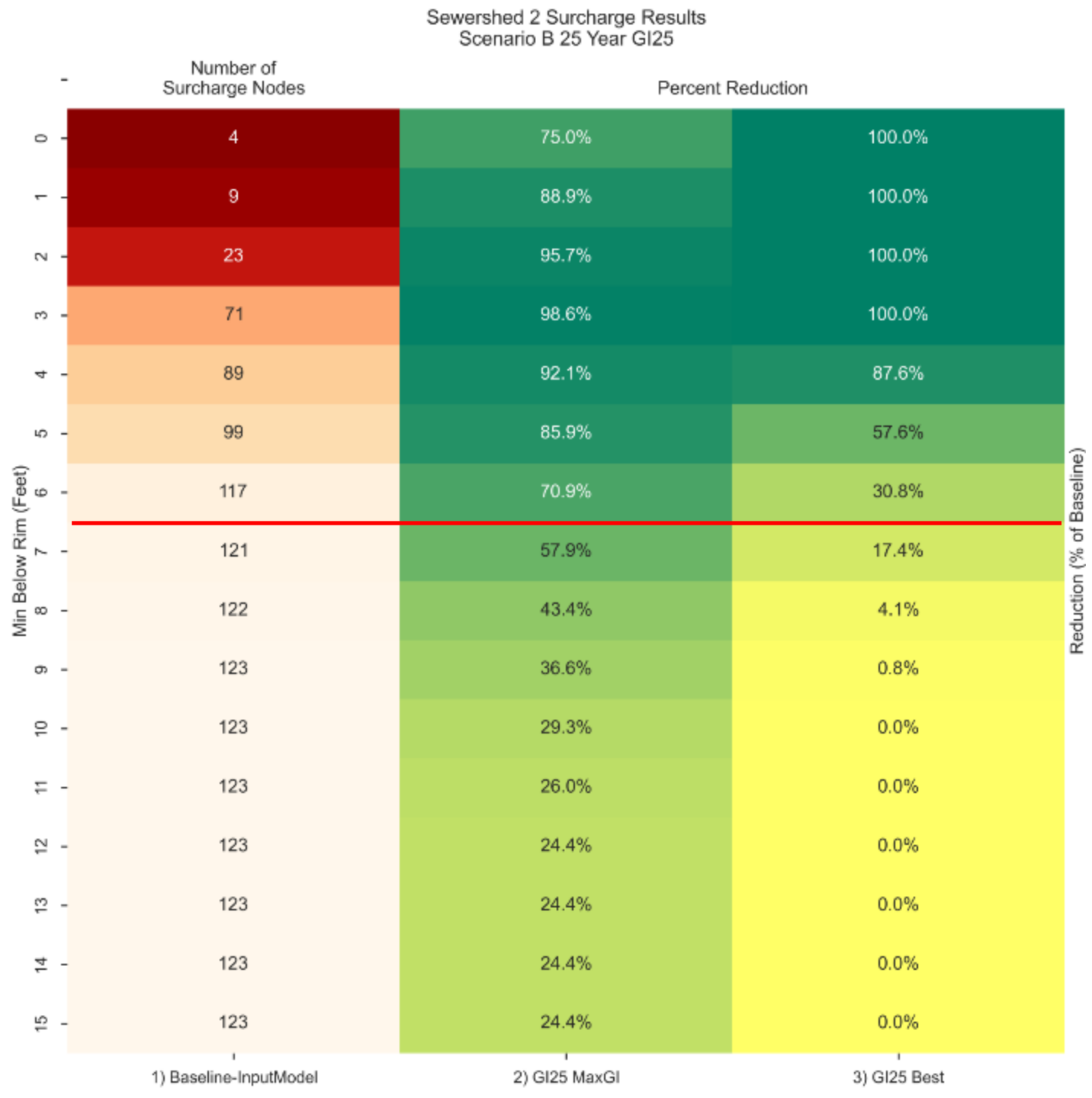
25-yr, 2-hr Storm / GI25

Max GI



Optimized GI





Node Surcharge Summary

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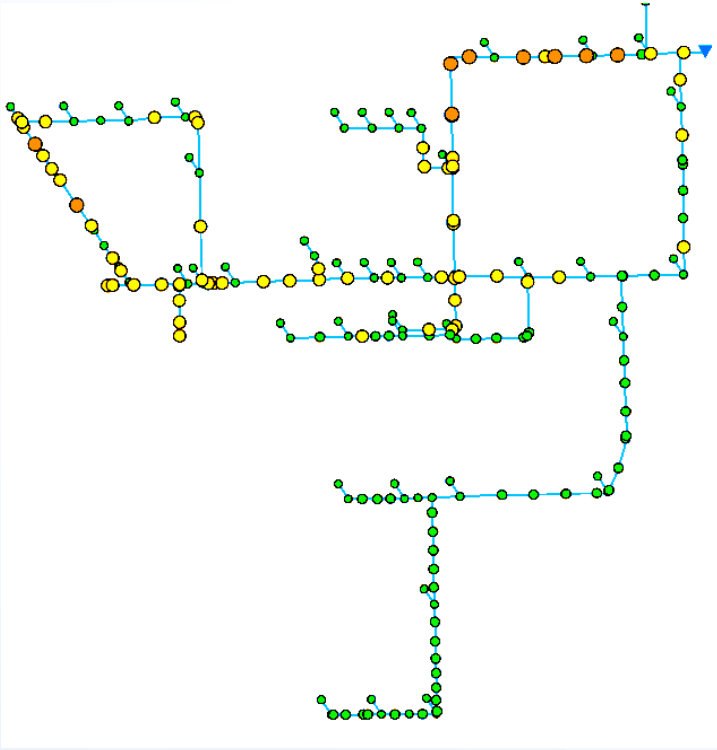
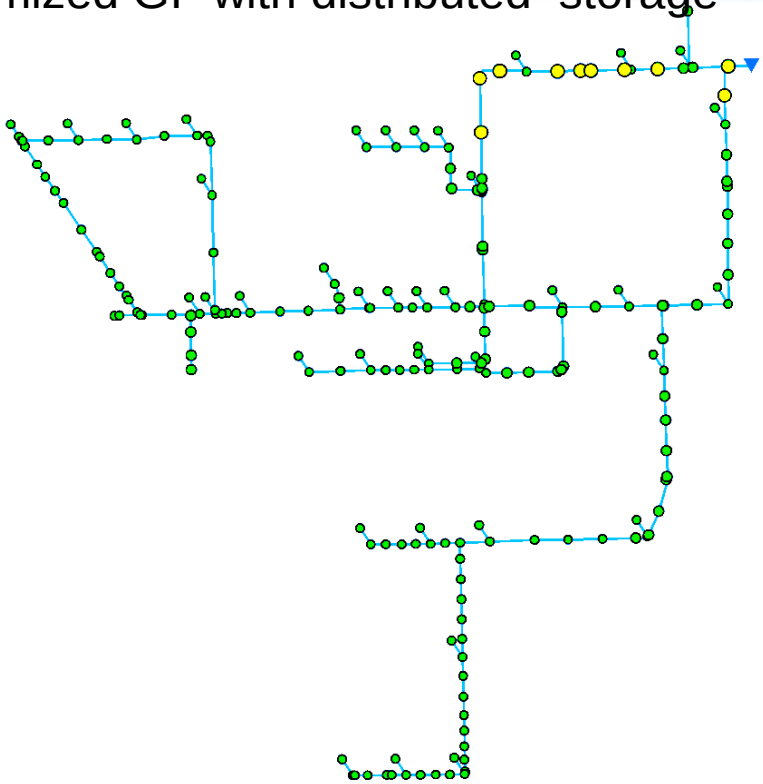
Additional Storage Needed

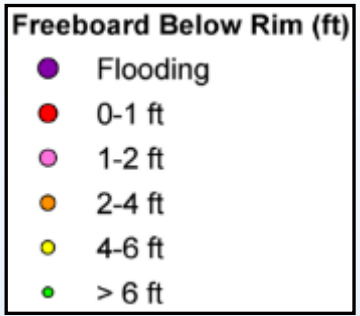
25-yr, 2-hr Storm / GI25

Optimized GI



Optimized GI- with distributed storage





Manhole Surcharging Results after **59 ac-ft** of Additional Distributed Storage

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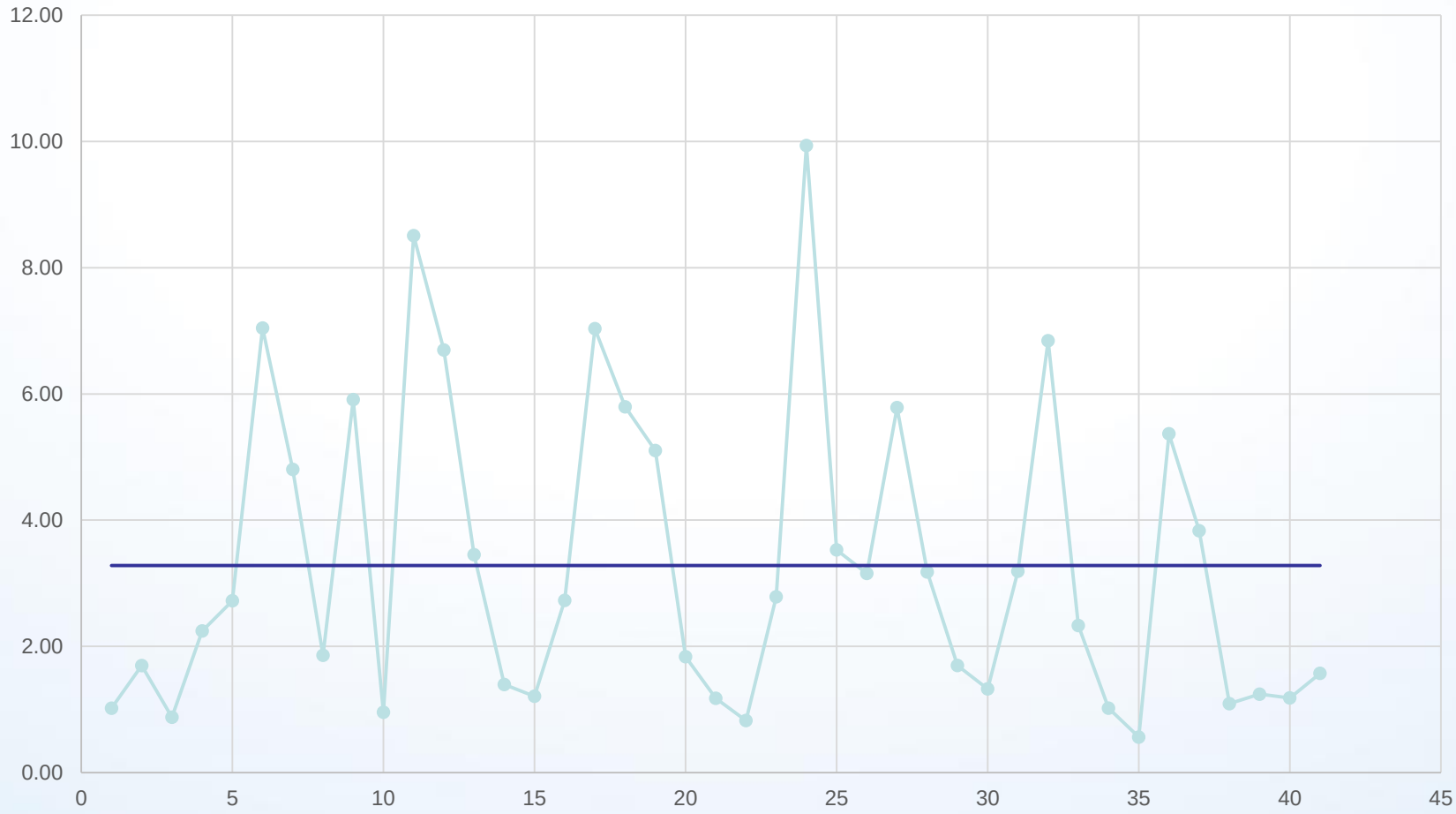
Additional Storage Distribution



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Preliminary Sewershed 4 Results

Draft Optimized GI Simulation Results for Sewershed 4

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Sewershed 4 Results

Scenario A: without Regional Gray Solution
5-yr, 2-hr Storm

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Results Comparison

5-yr, 2-hr Storm / GI5

Freeboard Below Rim (ft)
- Flooding
- 0-1 ft
- 1-2 ft
- 2-4 ft
- 4-6 ft
- > 6 ft

Baseline

Max GI

Optimized GI

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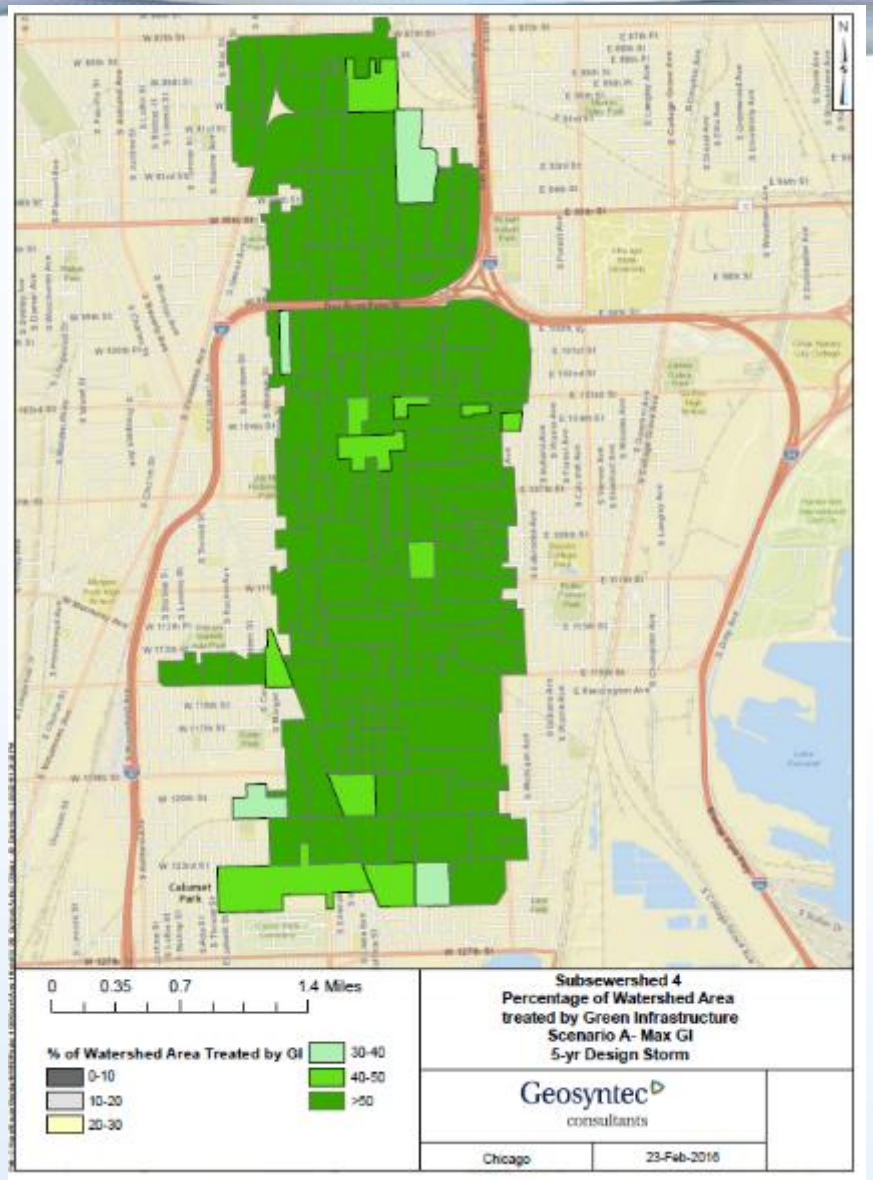
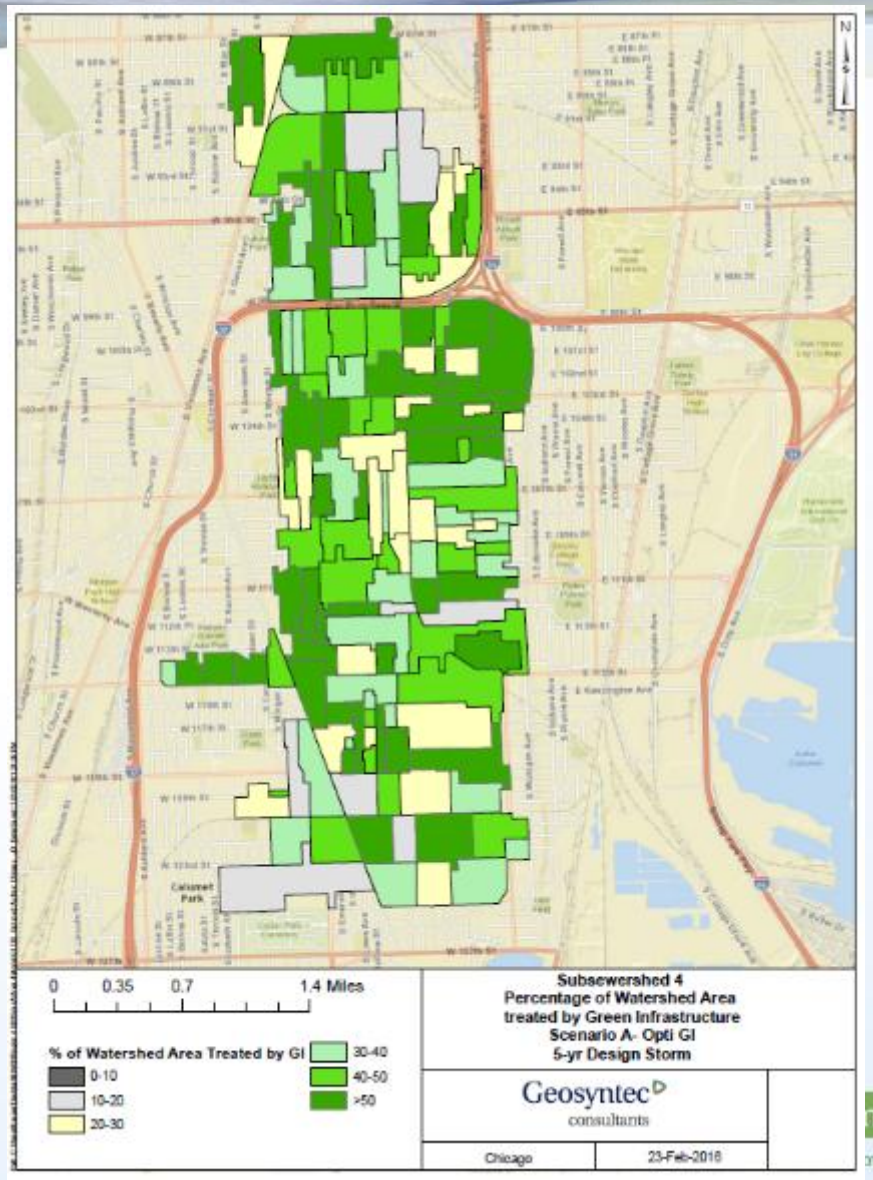
GI Distribution

5-yr, 2-hr Storm / GI5

Max GI



Optimized GI



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Sewershed 4 Results

Scenario B: with Regional Gray Solution
25-yr, 2-hr Storm

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Results Comparison

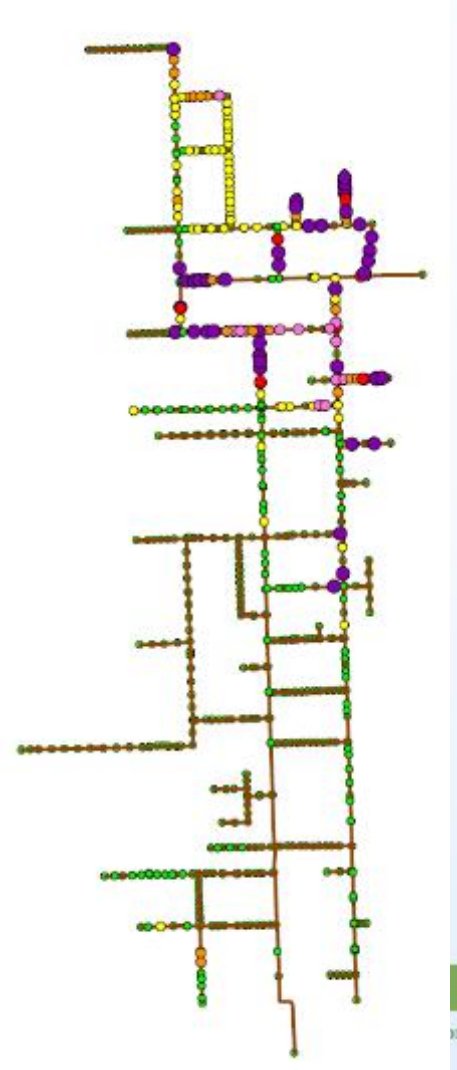
25-yr, 2-hr Storm / GI25

Freeboard Below Rim (ft)
- Flooding
- 0-1 ft
- 1-2 ft
- 2-4 ft
- 4-6 ft
- > 6 ft

Baseline

Max GI

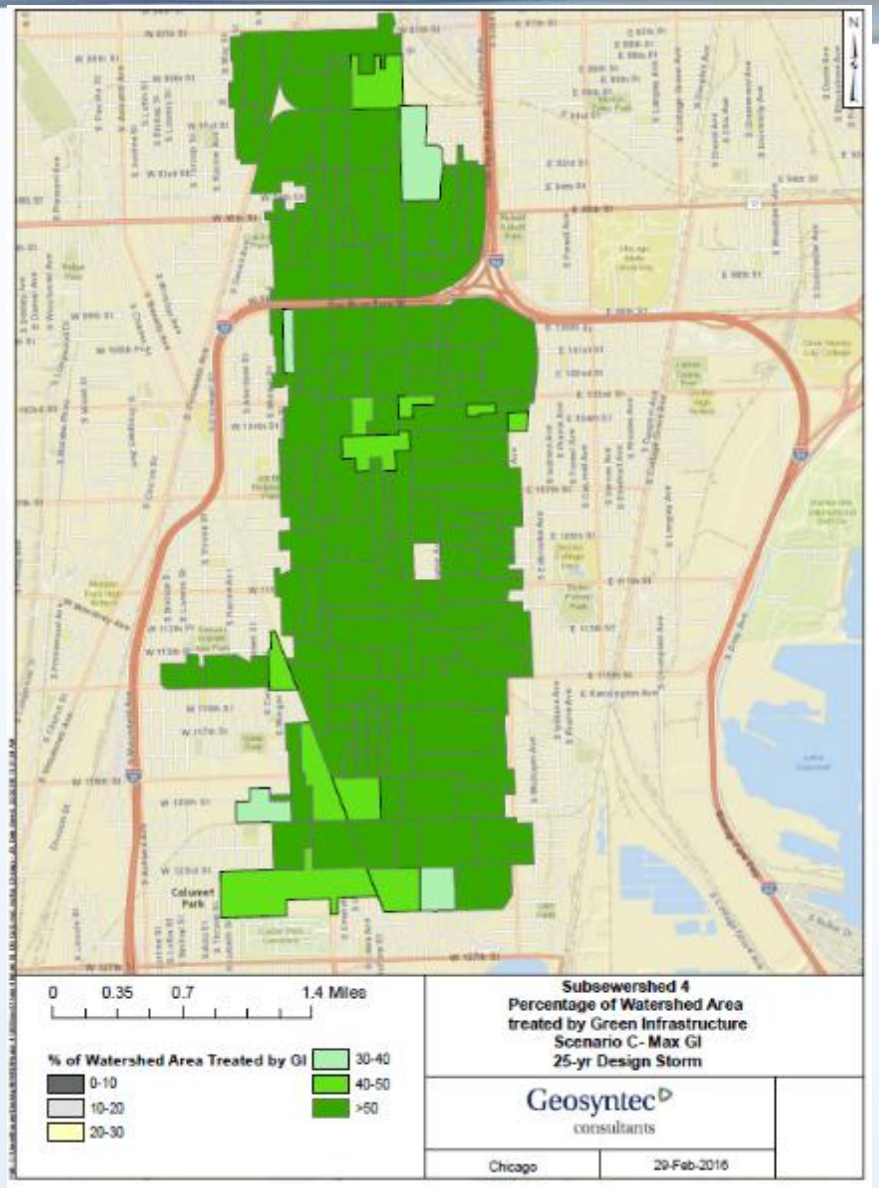
Optimized GI



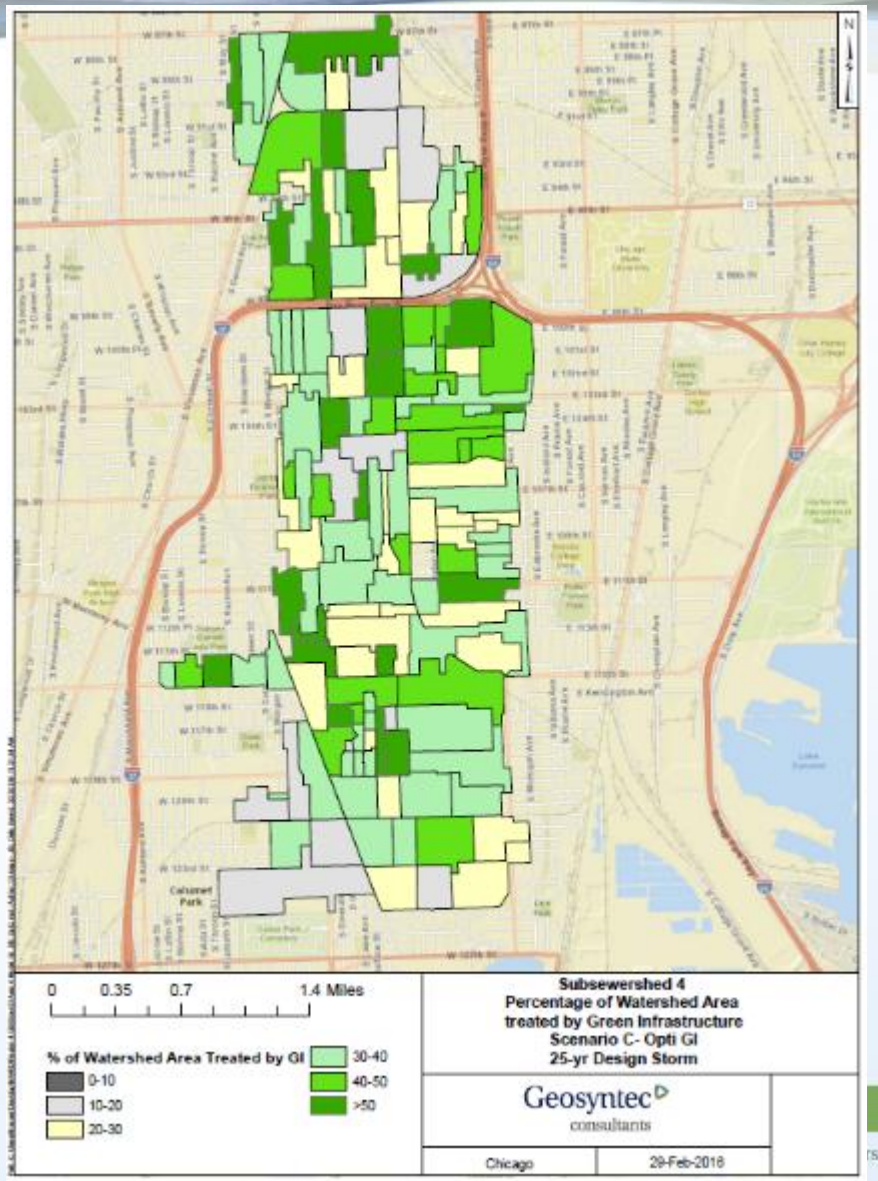
GI Distribution

25-yr, 2-hr Storm / GI25

Max GI



Optimized GI



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ENGINEERING RESOURCE ASSOCIATES

Questions?

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