Using a Flow Dynamics 2D Model to Develop Street Flooding Solutions in a Highly Transited Urban Area

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JANUARY 27 – 30
Boston Marriott Copley Place
Boston, Massachusetts

Outline

- Study Motivation
- Description of the Study Area
- Data Collection
- Design Criteria
- Model Setup
- Simulation Results
  - Existing and Proposed Conditions
- Conclusions

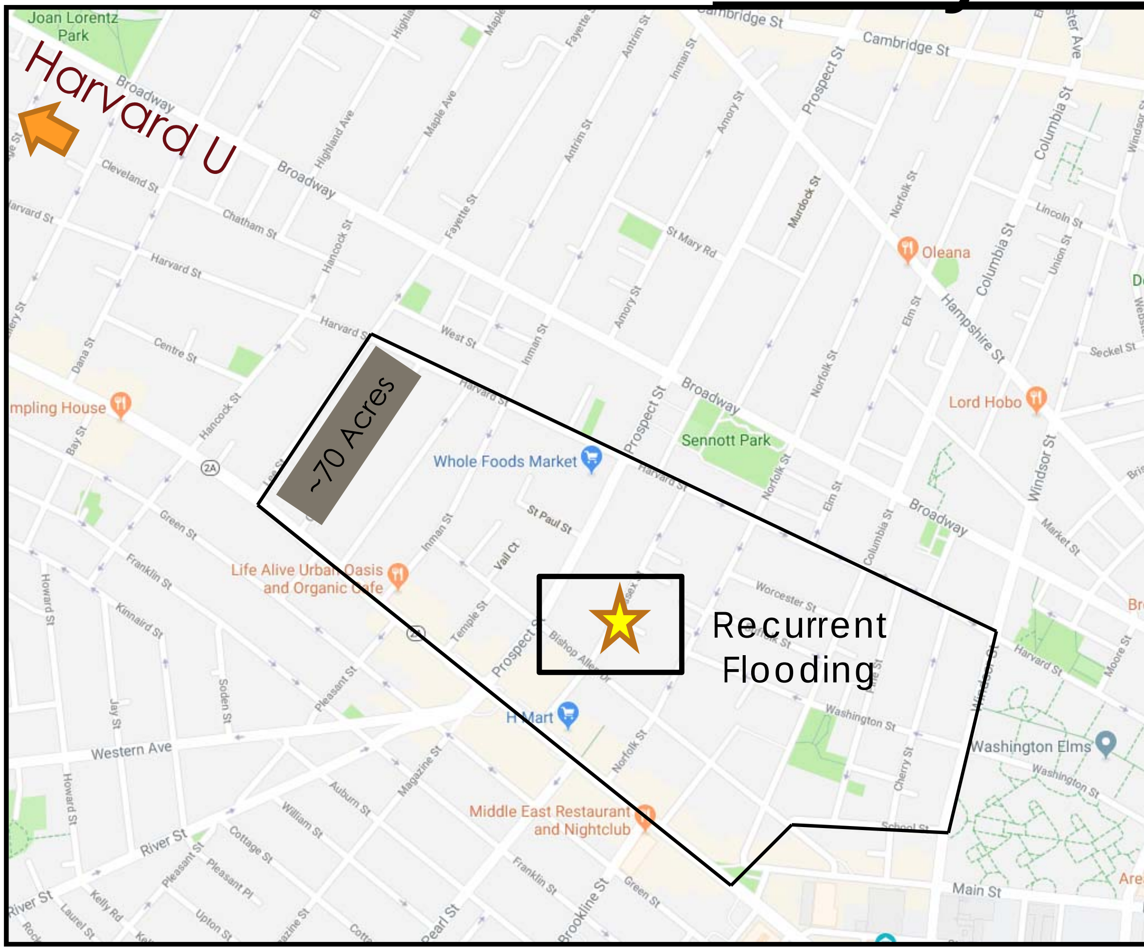
Study Motivation

- Recurrent street flooding in a highly transited area

➡ Need to evaluate flooding solution measures

- Use of 2D Overland Model over other approaches:
  - Traditional 1D Catchment Modeling not suited for analysis
  - Spread Analyses
    - Each CB requires calculation of its own tributary area => time consuming
    - Not direct visualization of flooding extents

Study Area



- LU: Residential/Commercial Area
- Pipe has leftover capacity, thus flooding induced by limited inlet capacity
- Low laying Area
- Low Curbs

Data Collection

- CB Field investigations:
    - Single & Double Grate
    - 10” Lead Pipes

- LiDAR terrain data, impervious, and soil type GIS layers:
    - Used to assign Zone roughness coefficients for pervious/impervious areas, and infiltration parameters

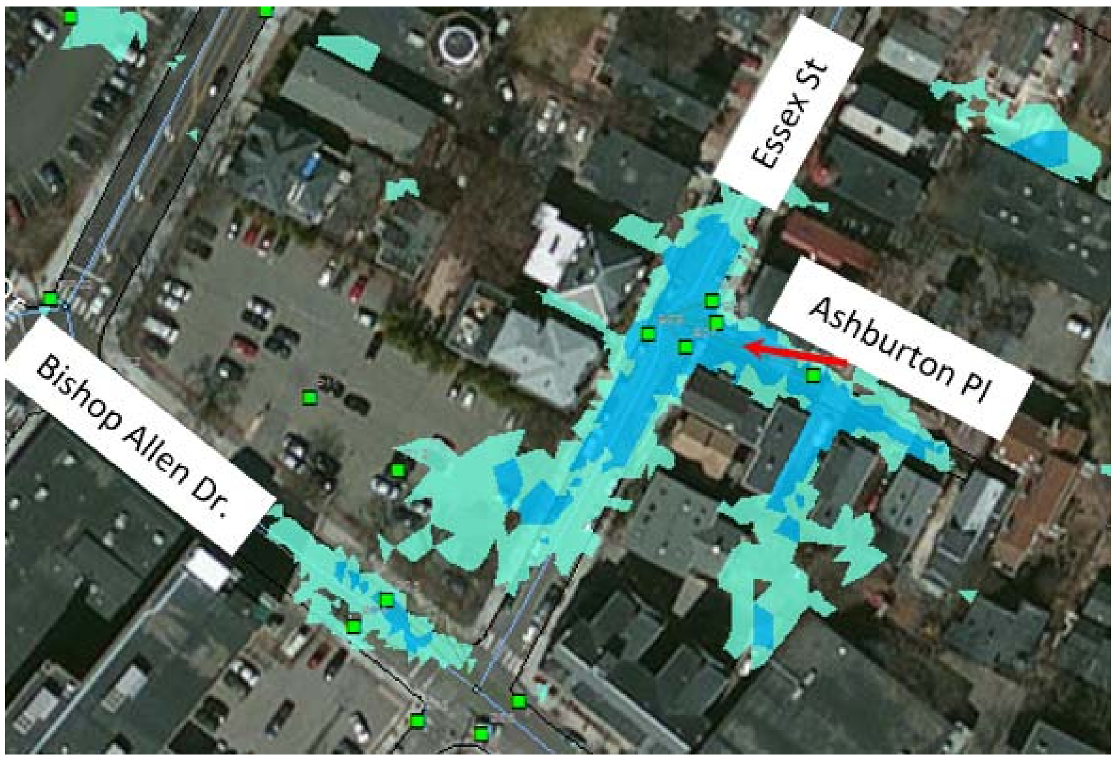
- Building Footprint, and Road GIS Layers

Design Criteria

Design Solution Scenarios to Limit Flooding to within Right-of-Way.

- Reduce Damaging Flooding into Private Property

Design 'short-burst' Storm: 1.5 in/hour, 1-hour



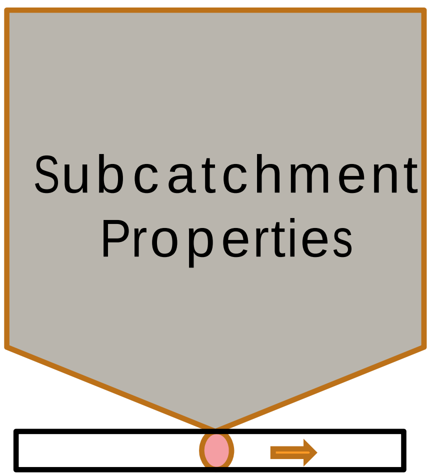
Numerical Model

- Existing Conditions Model
  - Citywide InfoWorks ICM Model
  - Underground sanitary and storm drain 1D model
  - Calibrated to Recent Metering Data

- Integrated 1D/2D Overland Flow Model
  - Covers ~70 Acres
  - Existing and Proposed Conditions
  - Uses HEC-22 (Urban Drainage Design Manual) Equations to model CB Hydraulics
  - Model Checks:
    - Against 1D model,
    - Mesh sensitivity

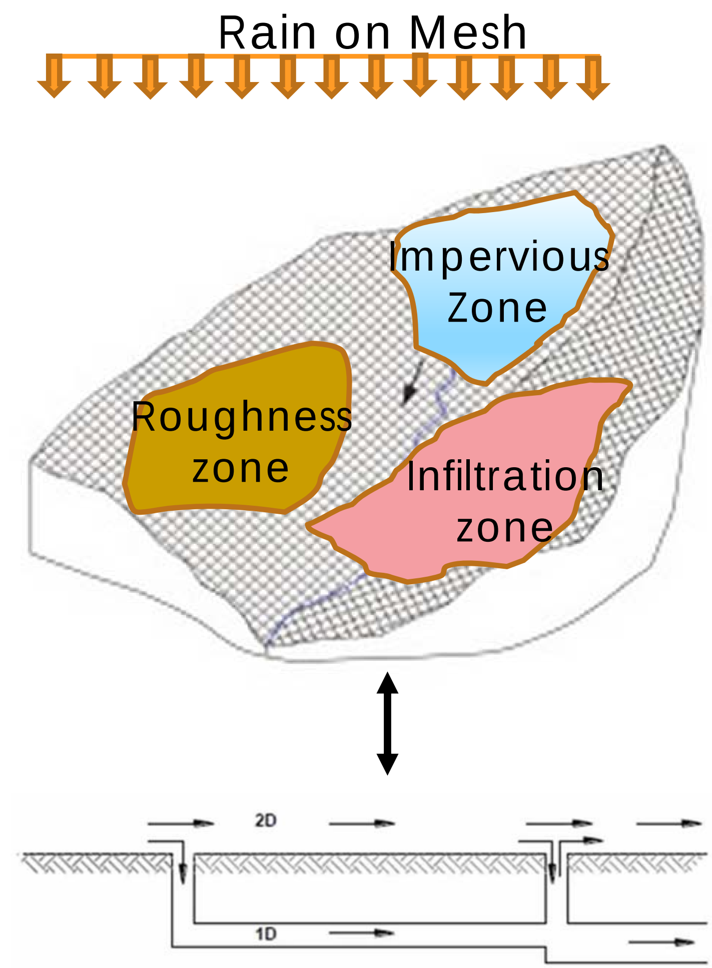
Numerical Model

1D Model



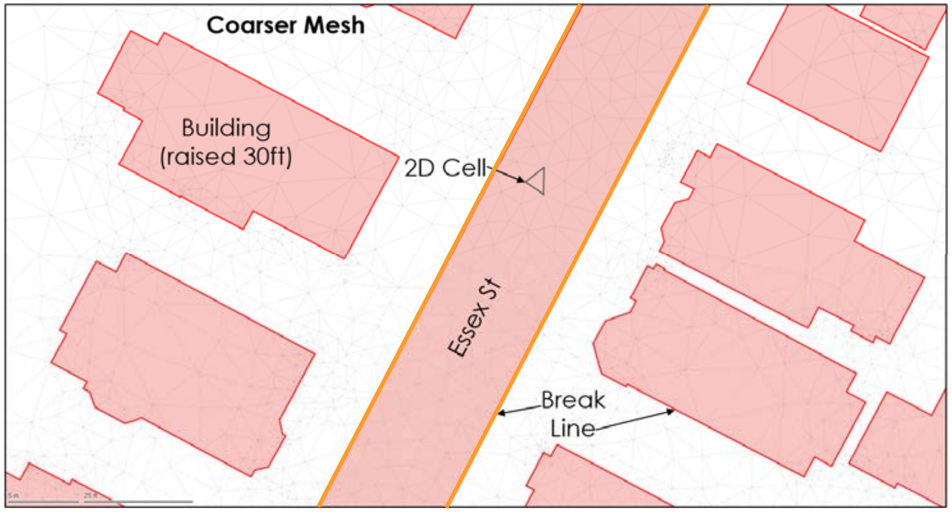
Infiltration,
Roughness,
Imperviousness

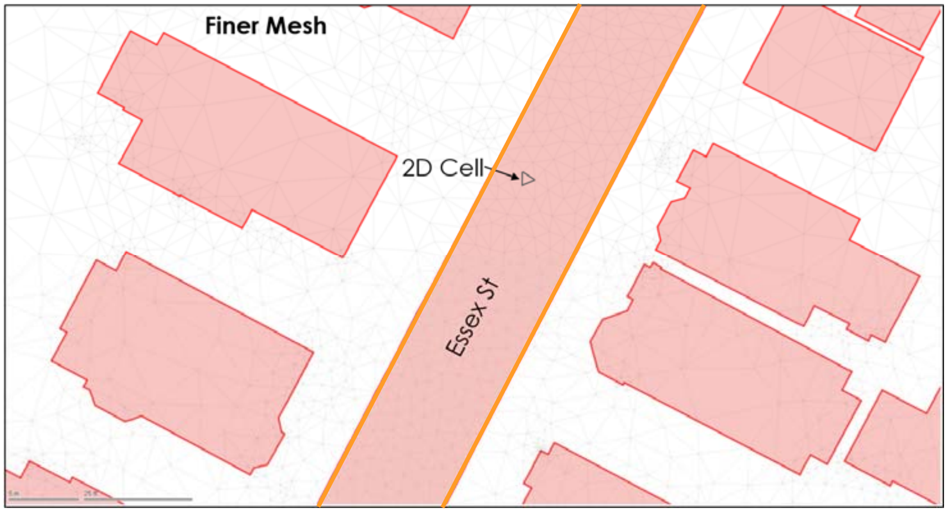
1D/2D Overland Model



Numerical Model

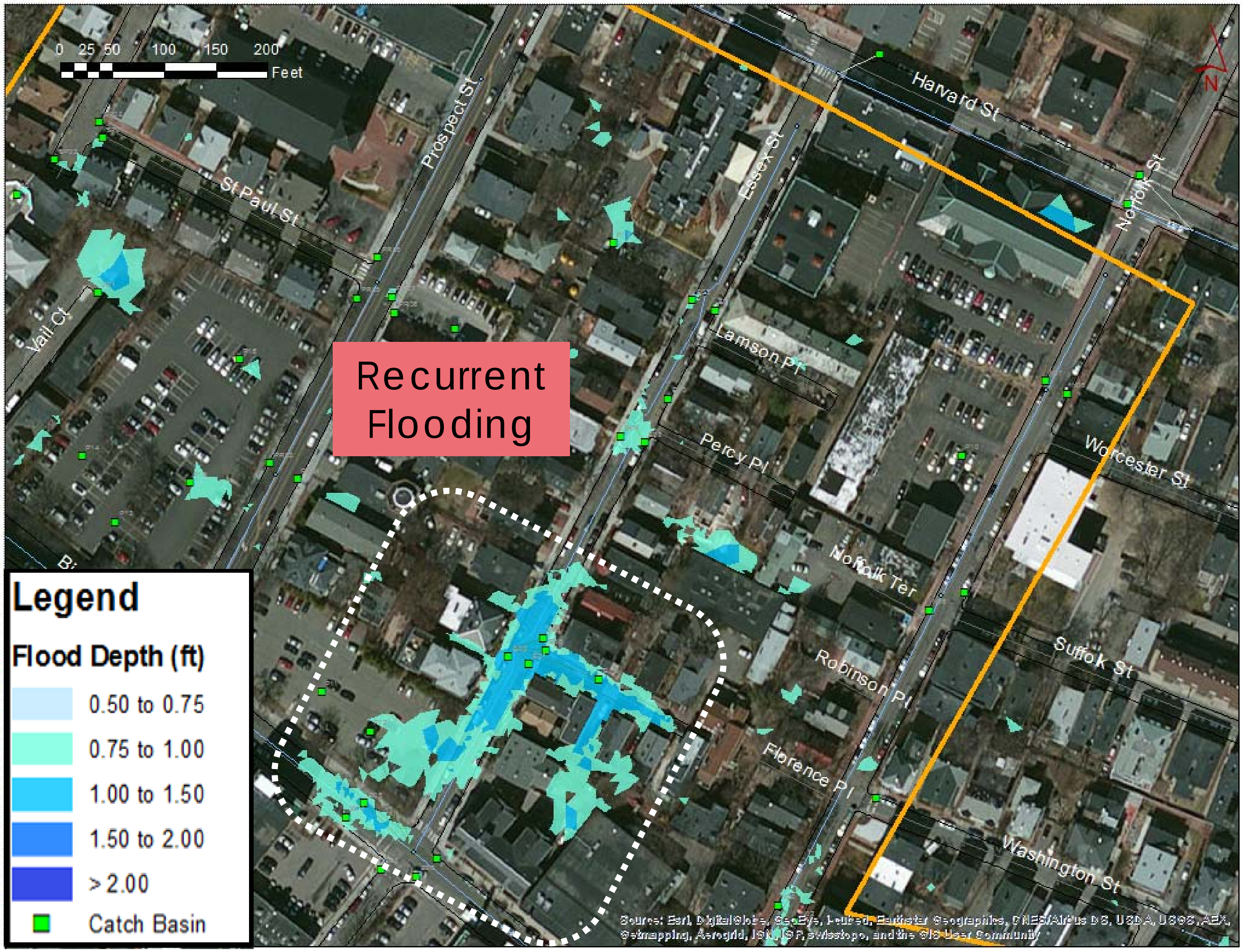
Mesh sensitivity analysis





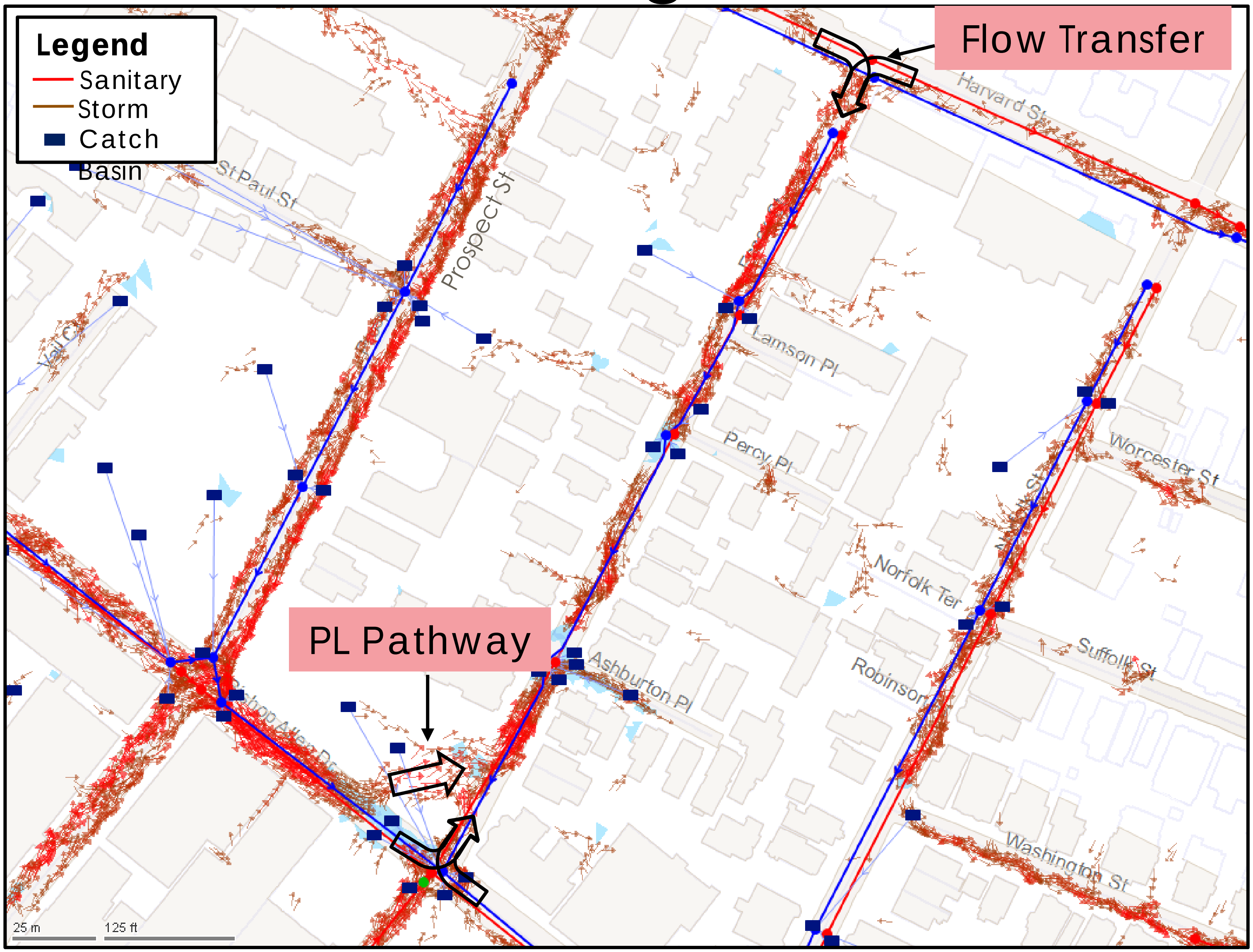
Evaluation of Existing Conditions

Results: Existing Conditions



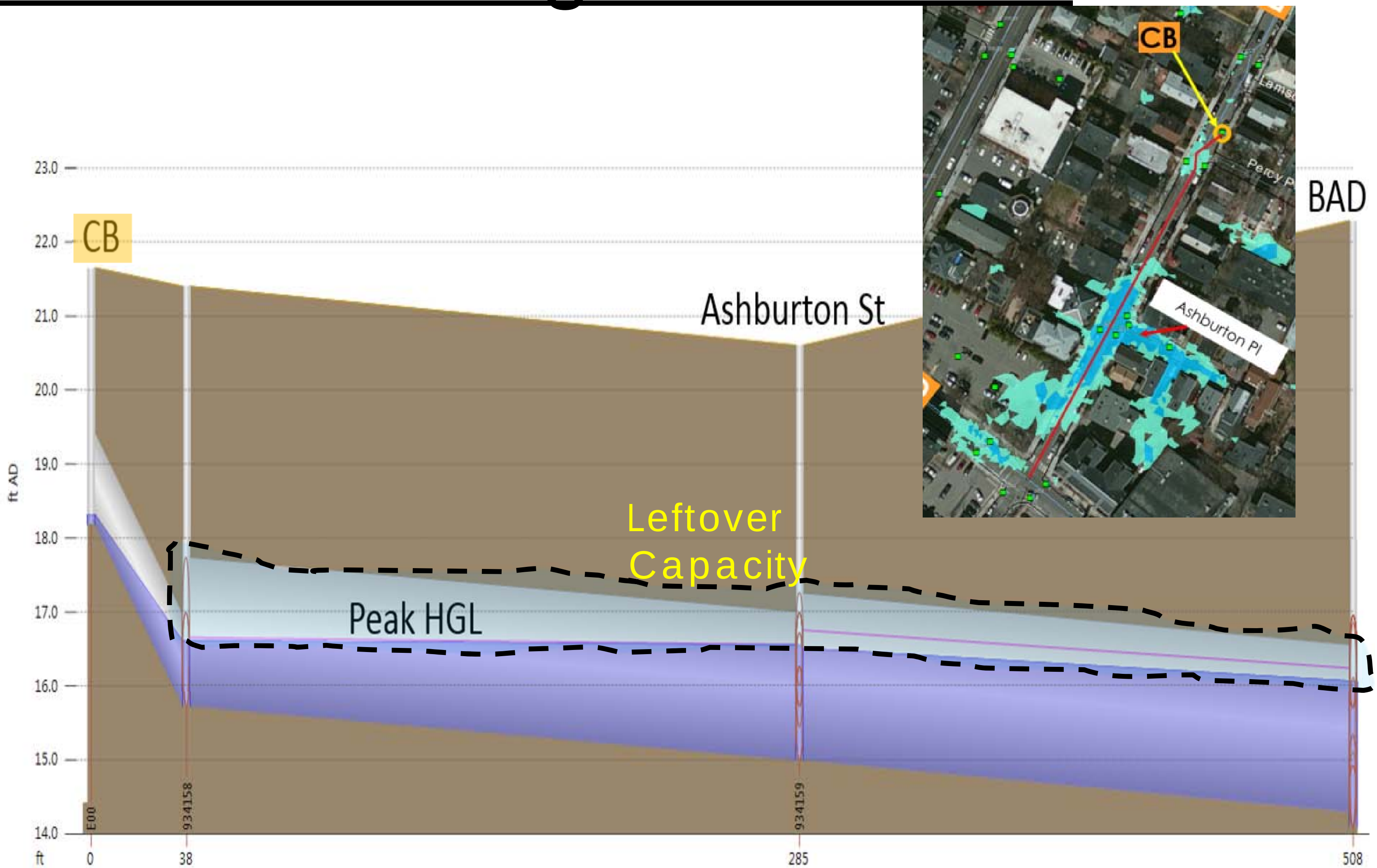
Simulated ground surface flooding during the 1.5 in/hour – 1 hour design storm under Existing Conditions.

Results: Existing Conditions



Simulated flow pathways into Ashburton Place during peak of the 1.5 in/hour – 1 hour design storm under Existing Conditions

Results: Existing Conditions



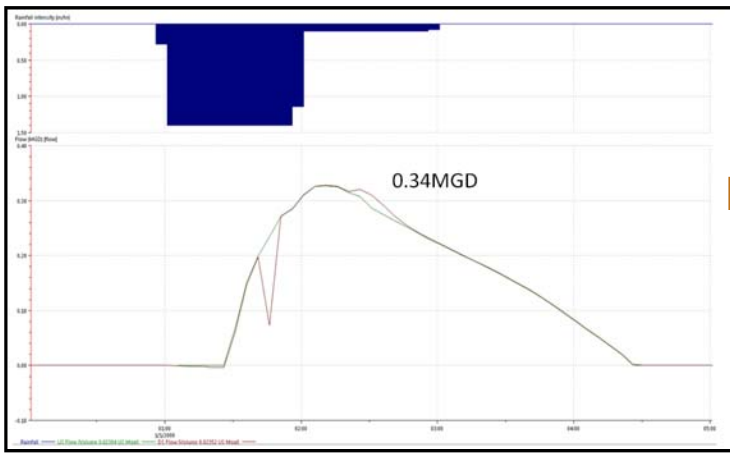
Simulated Peak HGL along Essex St. during the 1.5 in/hour – 1 hour design storm under existing conditions.

Evaluation of Flooding Solution Measures

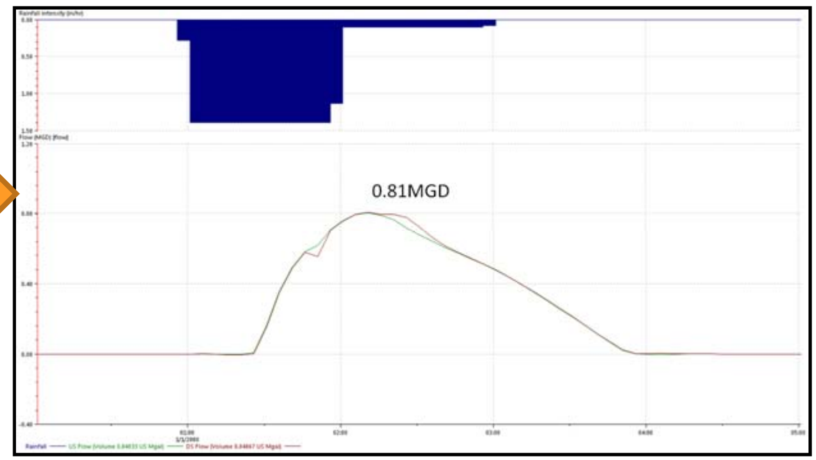
Results: Solution Scenario (Cont.)

Maximized CB Inflows

- New CBs were placed at lowest points



Added CB: Initial Location

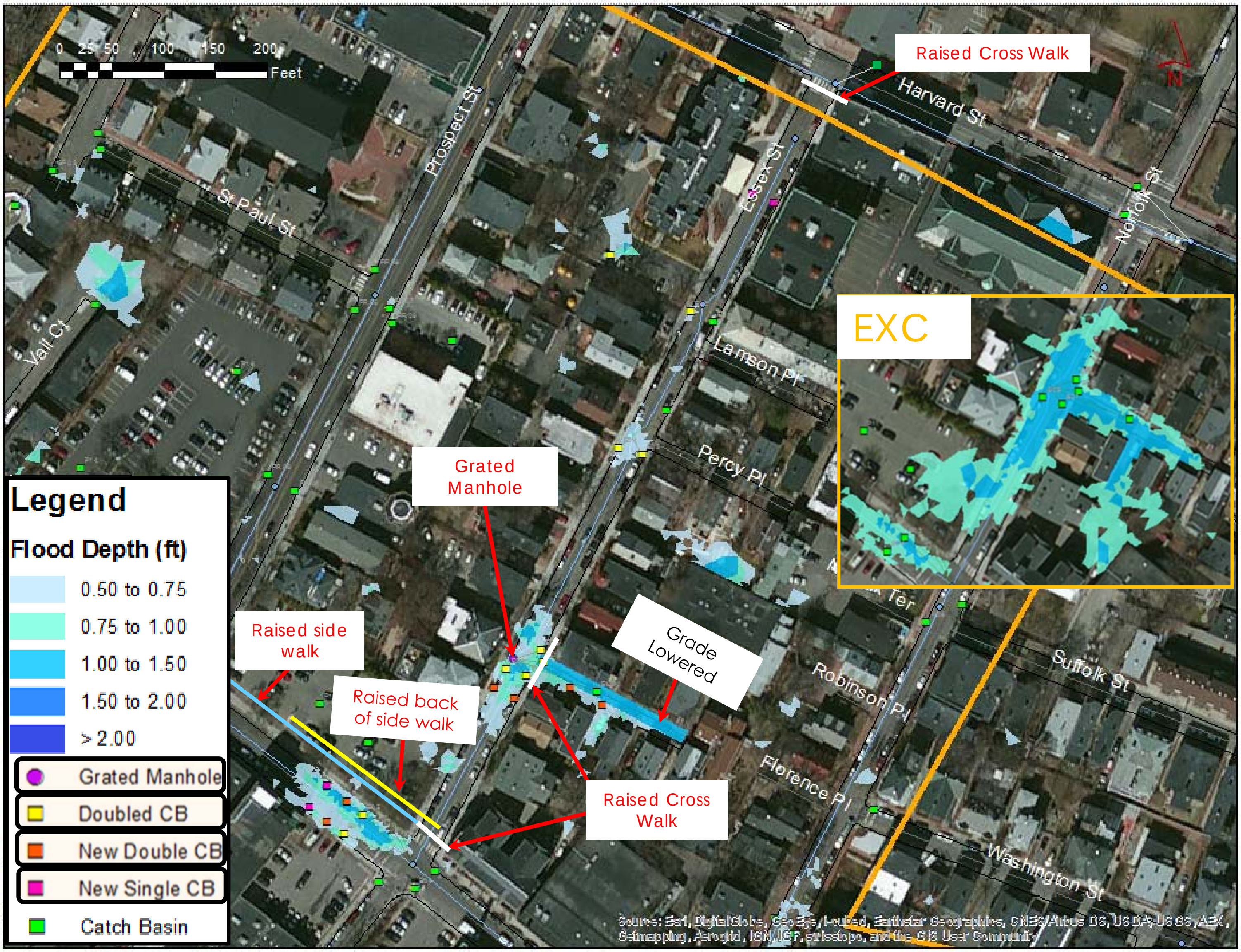


Added CB: Optimized Location

Results: Solution Scenario (Cont.)

Pavement Resurfacing

Results: Solution Scenario (Cont.)



Simulated ground surface flooding during the 1.5 in/hour – 1 hour design storm under Proposed Conditions

Results: Solution Scenario (Cont.)

Simulated ground surface flooding during the 2.5 in/hour – 30 min design storm under Proposed Conditions

Summary & Conclusions

- Under Existing Conditions,
  - Street flooding is primarily attributed to limited inlet capacity,
  - The simulated peak flood depths in the area of interest rise well above 6-in,
  - Flood waters reach into driveways, building fronts, and backyards, while
  - The underground drain system has leftover capacity,

Summary & Conclusions (Cont.)

- Under Solution Scenario, several flooding control measures were evaluated:
  - Double-grating of existing inlets,
  - Adding single and double grate inlets,
  - Upsizing lead pipes,
  - Grating of Manhole
  - Raising of cross-walks and back of sidewalks, and
  - Pavement resurfacing

Summary & Conclusions (Cont.)

- Advantages of the 1D/2D Integrated Model
  - Allows Identification/Visualization of flow pathways into area of interest
  - Allows evaluation of multiple control measures either separately or in combination in a fast and cost effective manner
- Recommend Maintenance (e.g., clogging)

Thank you

Questions?

Additional

Sample CB Spread Analysis

PROJECT: Essex STREET SEWER SEPARATION | DATE:

DESCRIPTION: CB SPREAD REV.#2 | BY: YAC

NEW CBs RESULTING FROM REV#1 | CHECKED/MODIFIED: YC 10/14/

Static Variables	Value	Units
Flow Analysis		
R = runnoff yeld	3.00	ft^3 / s * acre
Resultant Ponding		
n = Manning's coefficient	0.016	#
D_{MAX} = max allowable ponding depth	0.25	ft
T_{MAX} = max allowable ponding width	6.0	ft
Orifice Performance		
C_O = orifice constant	0.60	#
g = gravitational acceleration	32.20	ft^2 / s

Variables & Units

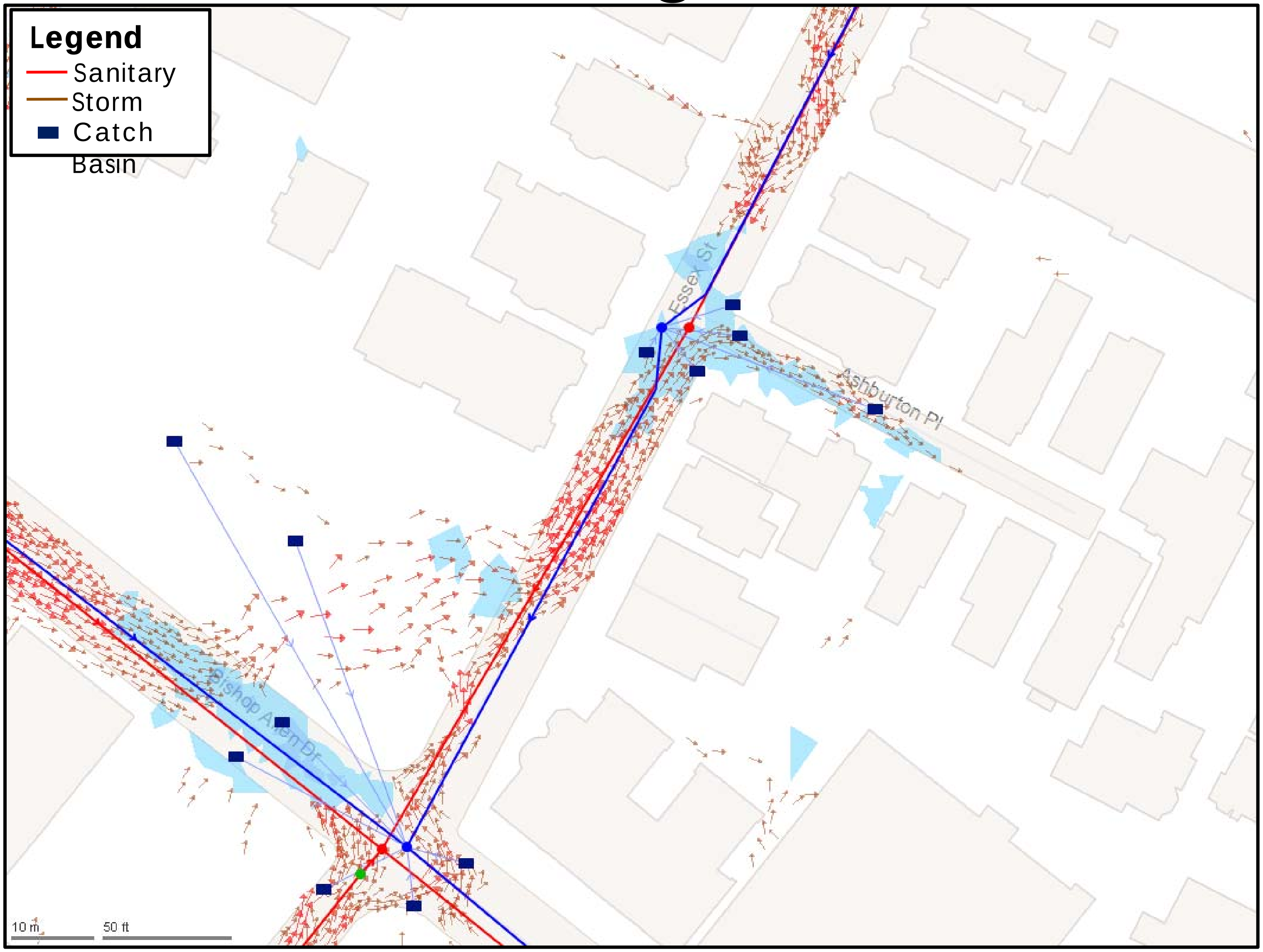
Site Conditions		Flow Analysis	
H_{gutter} = gutter height	ft	C = drainage coefficient	#
L_{gutter} = gutter length	ft	K_{GRATE} = grate minor loss coefficient	#
L_{curb} = curb length	ft	Q_{Rain} = rain flow	ft^3 / s
H_{crown} = crown height	ft	Q_{Total} = cumulative flow to CB	ft^3 / s
L_{crown} = crown length	ft	Q_{Grate} = max capacity through CB	ft^3 / s
L_{lane} = lane width	ft	Q_{Int} = flow actually intercepted by CB	ft^3 / s
A_T = total catch basin area	acres	Q_{Byp} = flow bypassing CB	ft^3 / s
S_L = longitudinal gutter slope	#	Q_{Avail} = remaining CB capacity	ft^3 / s
S_T = transverse gutter slope	#		
A = total catch basin area	ft^2	***Orifice Performance***	
		G_A = open area of grate	ft^2
Resultant Ponding		W = grate width	ft
D = depth of road ponding	ft	X = averaged head acting on CB orifices	ft
T = width of road ponding	ft	$Q_{Orifice}$ =cumulative flow through CB orifi	ft^3 / s

FORMULA BANK | ERROR | NEEHAH | "RECT. SLOT (TRADITIONAL)" | ERROR

This name convention does not apply any longer

Contibuting Area	CB Number	NEW CB	Street	Spread Flag	Manufacturer	Grate Type	SITE CONDITIONS: A_T	Gutter: H_{gutter}	Gutter: L_{gutter}	L_{curb}	Crown: H_{crown}	Crown: L_{crown}	L_{lane}
New-Northwest1	CB-1	CB-1	New	OK	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.5755	53.54	42.77	225	43	42.77	13
Larch-Northwest2	NA	CB-87	New	OK	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.0978	42.77	33.04	200	42.40	33.04	13
Larch-Northeast1	CB-2	CB-2	New	OK	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.202	53.34	42.16	200	42.40	42.16	13
Larch-Northeast2	NA	CB-88	New	FLOODED	NEEHAH	"RECT. SLOT (TRADITIONAL)"	1.0126	42.16	33.02	200	16.82	33.02	13
Larch-Sothwest1	CB-3	CB-3	New	OK	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.1002	52.81	46.61	100	46.87	46.61	13
Larch-Sothwest2	CB-4	CB-4	New	OK	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.1795	46.61	45.18	60	45.44	45.18	13
Larch-Sothwest3	CB-6	CB-6	New	FLOODED	NEEHAH	"RECT. SLOT (TRADITIONAL)"	2.1763	48.03	44.10	100	44.36	44.10	13
Larch-Sothwest4	CB-6.5	CB-8	New	FLOODED	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.3017	51.33	48.03	382	48.29	48.03	13
Larch-Sotheast1	CB-5	CB-5	New	OK	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.1167	52.42	44.87	150	45.13	44.87	13
Larch-Sotheast2	CB-7	CB-7	New	FLOODED	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.3127	51.17	44.47	506	44.73	44.47	13
Grozier-Northwest1	CB-8	CB-9	Grozier	OK	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.2243333	47.31	43.78	150	44.08	43.78	15
Grozier-Northeast1	CB-9	CB-10	Grozier	OK	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.1424	47.31	43.76	150	44.06	43.76	15
Grozier-Southwest1	CB-12	**CB-11**	Grozier	OK	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.1332417	48.62	48.56	40	48.86	48.56	15
Grozier-Southwest1	CB-12	CB-13	Grozier	OK	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.063225	48.62	48.56	40	48.86	48.56	15
Grozier-Southwest2	CB-13	CB-14	Grozier	OK	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.0784	48.56	47.88	75	48.18	47.88	15
Grozier-Southwest3	CB-15	CB-16	Grozier	FLOODED	NEEHAH	"RECT. SLOT (TRADITIONAL)"	0.4752	49.75	46.97	156	47.27	46.97	15

Results: Existing Conditions



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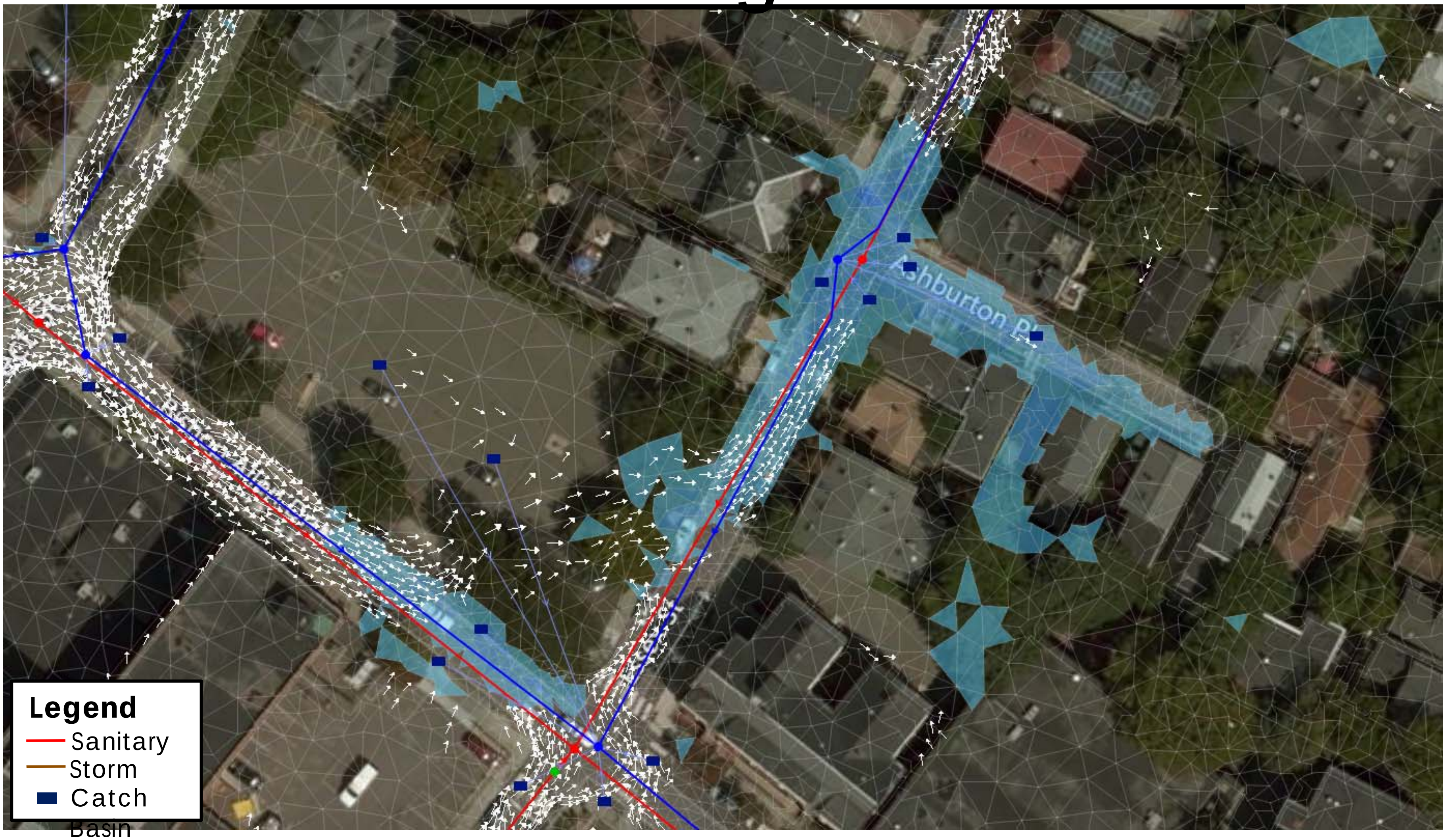
Results: Existing Conditions



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