Lake Champlain Basin Program

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City of Plattsburgh Stormwater Conveyance System & Green Infrastructure Planning

August 2015

Final Report

Prepared by:
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For:
The Lake Champlain Basin Program and
New England Interstate Water Pollution Control Commission

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City of Plattsburgh Stormwater Conveyance System & Green Infrastructure Planning

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Executive Summary

The City of Plattsburgh (City) is the most urbanized area within the New York State Lake Champlain Basin. Land-use varies from residential areas with small and large parks and schools to the industrial sections and the highly commercialized downtown. All of these areas contribute to the imperviousness of the land within the City, which creates a large amount of stormwater runoff that is conveyed through the City's sub-surface separate stormwater sewer system to 41 outfalls that discharge directly to Lake Champlain, the Saranac River and their tributaries within the City.

In an effort to fully understand the conveyance of stormwater within the City and identify vulnerabilities within the stormwater system, the City undertook an extensive mapping project that included identification and data collection for all stormwater trunklines. Information was digitized from existing paper maps, as well as collected by City staff throughout the summer of 2013, and includes data on storm sewer manholes, catch basins, storm sewer mains and combined sewer mains. This information was then utilized within the US EPA SWMM computer model to complete sub-sewershed mapping, which ultimately identified 54 principle sub-sewersheds within the City's system, and identify areas within the City that are or will be prone to flooding during 5-year, 10-year, 25-year, 50-year and 100-year design storm scenarios. Outcomes of the modeling include the identification of the manholes that surcharge above rim elevation and identification of the areas with an increase in flood volume throughout the City as the higher intense storms transpire.

Information obtained from the modeling was then used to identify 12 City or school district owned sites directly within or adjacent to flood prone areas that can be used as sites for green infrastructure retrofit project implementation. The sites were ranked based on a matrix created by the project partners that takes into consideration project achievability, stormwater volume reduction potential and stormwater quality impacts. Of the 12 projects, the US Oval parking lot was ranked as the highest for implementation, and use of green infrastructure practice ranking matrix indicated that a bioretention area would reduce water quantity while improving water quality at the site.

In the spring of 2015 the City constructed a bioswale and bioretention basin at the US Oval that was designed to collect stormwater from 2.5 acres, of which 1.5 acres is impervious surface. The bioswale was constructed to convey at least 4.6 cfs, and is connected to the bioretention basin via an underground pipe. A basin area of 1200 square feet with total volume of 9700 cubic feet was constructed to receive 8300 cubic feet of water quality volume. The basin also contains several New York native plant species, and two educational signs have been installed at the site.

On July 27, 2015, a ribbon cutting was held at the basin to mark the opening of the first green infrastructure project within the City of Plattsburgh. Members of the press, as well as residents, attended the event to learn about the project and become educated on the City's plans to continue addressing stormwater runoff in the future.

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1 Project Introduction

The City of Plattsburgh (City) is situated along the western shoreline of Lake Champlain, and is the most urbanized area on the New York side of the Champlain Basin. It is 6.6 square miles built along 5.5 miles of shoreline, encompassing over 60 miles of city streets. Plattsburgh is home to a variety of urban land uses including residential, industrial, manufacturing, business, and commercial. This urbanization has created significant impervious cover throughout the City, which increases stormwater runoff due to a lack of natural terrain for stormwater to infiltrate. All the stormwater runoff and potential pollutants from these impervious covers are funnelled into the City's 41 stormwater outfalls that discharge directly into the Saranac River, Lake Champlain and their tributaries. The City's stormwater collection system is almost entirely closed drainage (i.e. curbed streets, drain inlets and an underground network of storm collection pipe) with a total length of 108,000 lineal feet (20 miles). In addition, the sanitary sewer system includes another 267,000 feet (50 miles) of sanitary sewer pipe, much of which is a combined sewer collecting both sanitary sewage and stormwater.

In recent years the City of Plattsburgh, as well as the region, has been subjected to more intense and frequent rainfall events. These events have given anecdotal evidence of increasingly severe weather patterns, which have highlighted vulnerabilities within the City with respect to the ability for existing infrastructure to manage stormwater. Furthermore, phosphorus contained within the stormwater runoff from the urban land use in Plattsburgh is contributing to the total phosphorus loading from non-point source pollution into Lake Champlain. This major source of non-point source pollution only has the potential to increase with increased storm severities, if not properly addressed now.

As a result, the City, in cooperation with the Lake Champlain – Lake George Regional Planning Board (LCLGRPB), completed a stormwater mapping, infrastructure assessment and Green Infrastructure project location identification to;

- Inventory and map the stormwater infrastructure and catchment areas within the City's stormwater collection system to gain better knowledge of the City stormwater system,
- Assess stormwater system vulnerabilities to future high intensity storm events associated with anticipated climate change, and
- Identify and demonstrate appropriate green infrastructure retrofit technologies intended to reduce stormwater volume flow into the system, while also educating the public.

These goals were accomplished through work completed by City staff and staff of the LCLGRPB, as well as through a consulting contract with CDM Smith of Syracuse, NY. Tasks performed for project completion include; compilation of all existing records of the stormwater system; inventorying and mapping infrastructure and catchment areas within the urbanized collection system; calculating runoff, discharge and storage volumes; assessing vulnerabilities; identifying and prioritizing green infrastructure retrofits within the system on city property; implementing one green infrastructure technology on city property; and performing a public education workshop to demonstrate the benefits of the project.

The City of Plattsburgh Stormwater Conveyance System and Green Infrastructure Planning project demonstrates the City's and LCBP's shared goal to "reduce phosphorus inputs to Lake Champlain to promote a healthy and diverse ecosystem and provide for sustainable human use and enjoyment of the Lake," as outlined in Opportunities for Action: An Evolving Plan for the Future of the Lake Champlain Basin. Specifically, the City addressed Priority Actions 4.2; Reduce the non-point source phosphorus load that is being generated by runoff from developed land in the Basin and 4.5; Use education to empower the general public to reduce phosphorus contributions. Completion of this project has put the City in a better position to make decisions on stormwater conveyance system retrofitting in the urbanized area, and aiding the public in understanding their role in helping the City reduce stormwater pollution and runoff.

2 Tasks Completed

Several Tasks were completed for this project, resulting in the identification of publically owned parcels throughout the City that can be utilized as areas for green infrastructure implementation.

2.1 Compilation of Existing Stormwater Infrastructure Mapping

The City of Plattsburgh has an extensive stormwater network that includes over 100,000 lineal feet of stormwater conveyance infrastructure. Much of this infrastructure has previously been mapped, however the maps were created in a variety of methods including paper, autocad, survey grade construction as-built drawings and former United States Air Force Base military maps. Each of these maps have varying degrees of format, scale and accuracy, and it was determined that each should be converted to a GIS format to ensure that all the information was in a form useful to the project parameters. To achieve this, staff from the City Engineering and Planning Department digitized the existing maps and input the information into the City's GIS System. Positional discrepancies were orthorectified and field verified when necessary. The City then utilized this information to determine areas within the City that were lacking completed data and in need of additional infrastructure mapping.

2.2 Additional GIS Stormwater Infrastructure Mapping

Once all paper maps were digitized, the City completed a comprehensive separate stormwater system mapping and inventory of all of the City's trunklines. The following information was obtained for each part of the system;

1. Storm Sewer Manholes – rim elevation, invert elevation, what material the manhole is constructed of (brick, pre-cast, etc.), and frame type and size.

2. Catch Basins – rim elevation, invert elevation, bottom elevation, material that the basin is constructed of (block or pre-cast), and frame and grate information.

3. Storm Sewer Mains – pipe material, pipe diameter, pipe section length to next manhole (unless diameter or pipe type has changed between manholes) and installation date.

4. Combined Sewer Mains – pipe material, pipe diameter, pipe length and installation date.

Originally, the City intended to only compile information for trunklines 24" inches or greater, however, time and budget allowed for additional mapping of the entire system, creating a more useful database to be utilized for this project and in the future.

2.3 Delineation of Sub-Sewersheds

For this task the City contracted with CDM Smith (consultants), with a goal of identifying the stormwater runoff catchment areas that contribute flow to each City outfall. This was achieved by utilizing topographic information coupled with the City's stormwater sewer mapping to model the hydrologic flows within the City. The catchment areas also take into consideration flow from the Town of Plattsburgh into the City's stormwater sewer system in an effort to depict a more accurate representation of water volume, but areas within the Town were not assessed for this project, nor were projects locations outside of the City borders identified.

In total, 54 sub-watersheds were identified that ultimately flow to 41 outfalls that discharge into Lake Champlain, Saranac River, and smaller tributaries to these major surface waters. A more in depth discussion on the modeling process utilized to create the sub-sewersheds can be found in Section 3.1.2.

2.4 Calculate Runoff, Discharge, and Storage Volume for City Stormwater System and Identify Infrastructure Vulnerabilities

The consultants utilized an USEPA Storm Water Management Model (SWMM) to assess the City's closed and open channel separate stormwater conveyance system to calculate runoff, discharge, and storage volume of the City's system, as well as identify infrastructure vulnerabilities during 5-year, 10-year, 25-year, 50-year and 100-year storms. The EPA SWMM is used worldwide for planning, analysis and design of urban collection systems, and is a dynamic hydrology-hydraulic simulation model designed for single event and long-term simulations. The runoff component operates on a collection of sub-sewersheds that receive precipitation and generate runoff, typically at a time step of 15 minutes or less. The routing portion transports water through pipes, channels, and control structures, computing discharge and water levels at a time step of 15 seconds or less. The core functionality of EPA SWMM is incorporated into several commercial software packages, and this project was executed using both the EPA SWMM and the Computational Hydraulics International (CHI) PCSWMM. Specific methodology utilized for this Task can be found in Section 3.

2.5 Identification and Prioritization of Green Infrastructure Retrofit Projects

Utilizing the information obtained from the SWMM Model, ten (10) sites within the City were initially identified as potential areas for green infrastructure project implementation based on the results of the simulated 5-year design storm. Sites were chosen based on their proximity to flood prone areas as indicated by the model, and only on City and school district owned property for ease of installation. Two additional sites were added, Durkee Street Parking Lot (Site 11) and Cornelia Street (Site 12), in an effort to include areas within the City that may not be directly adjacent to a flood prone area, but contribute to flooding of an area downstream within the City's system separate stormwater sewer system, as well as show that municipal right-of-ways are a potential area for green infrastructure retrofit projects. Information for each individual site can be found in Table 2-1.

Once the sites were identified through the modeling, staff from the City, LCLGRPB and the consultants completed evaluations of each individual site to assess current conditions, feasibility of installation of a green infrastructure project at each site, and identify the most suitable green infrastructure projects for implementation. Additional information that was collected at each site included proximity to storm sewer inlet, land-use, overhead/underground utility assessments, and whether the project will enhance natural vegetation for urban habitat or improve aesthetics. This information, along with other information gathered from the SWMM model, was utilized in the creation of the Site Evaluation Ranking Matrix discussed in Section 2.6.

Pollutants of Concern (POC's) were also identified for each potential green infrastructure project site. In general, the major land-uses within the City includes;

- Residential/Schools which includes parks and recreational fields. POC's associated with this land use includes phosphorus and nitrogen from residential fertilizers and bacteria from pet waste.
- Commercial/Residential which includes much of the City. Specific POC's associated with this land use include phosphorus and nitrogen from residential fertilizers, sediment, floatables, and oil/grease.
- Commercial land use includes phosphorus from commercial wash water, floatables, oil/grease, and sediment and de-icing agents from private parking lots.
- Industrial/Commercial land-use has the most POC's, including phosphorus from commercial wash water, floatables, oil/grease, sediment and de-icing agents from private parking lots, and metal from industrial facilities.
- Industrial or densely populated land-use POC's include floatables, oil/grease, sediment and de-icing agents from private parking lots and metal from industrial facilities.

The major land-use categories for each site, as classified from USGS 2011 Landsat Satellite Imagery, and their associated pollutants can be found in Table 2-2.

Table 2-1. Project Site Identification and Information

Site ID	Owner	Property Address	Property Class	Total Acres	Outfall Discharge
1	City	1 Broadway Road	Playground	0.7	Wetland (Truman Ave.)
2	City	49 Flaglar Drive	Playground	0.7	Wetland (Truman Ave.)
3	City	139 Boynton Avenue	Park	25.5	Lake Champlain
4	School District	50 Bailey Avenue	School	6.8	Lake Champlain
5	School District	108 Oak Street	School	7.1	Lake Champlain
6	City	2 Dock Street	Pier/Wharf	11.9	Lake Champlain
7	City	51 US Oval	Parking Lot	4.5	Lake Champlain
8	School District	60 Monty Street	School	7.1	Saranac River
9	School District	1 Clifford Drive	School	47.3	Saranac River
10	City	Park Avenue West	Municipal Park	4.6	Saranac River
11	City	Durkee Street Parking Lot	Municipal Parking Lot	5.5	Saranac River
12	City	Cornelia Street	Right-of-Way	3.1	Saranac River

Table 2-2. Identified Pollutants for Project Sites based on Land Use

Site ID	Major Land-use	Potential Pollutants							
		Phosphorus	Nitrogen	Bacteria	Sediment	Floatables	Oil/ Grease	De-Icing agents	Metals
1	Residential/Schools	X	X	X					
2	Residential/Schools	X	X	X					
3	Residential/Schools	X	X	X					
4	Residential/Schools	X	X	X					
5	Residential/Schools	X	X	X					
6	Industrial/Dense Pop.				X	X	X	X	X
7	Commercial	X			X	X	X	X	
8	Residential/Schools	X	X	X					
9	Residential/Schools	X	X	X					
10	Commercial/ Residential	X	X		X	X	X	X	
11	Industrial/Dense Pop.				X	X	X	X	X
12	Commercial	X			X	X	X	X	

2.6 Prioritization of Green Infrastructure Project Sites

In an effort to prioritize the project sites, a Site Evaluation Ranking Matrix was developed by all the project partners to evaluate the water quantity reduction potential and benefits of the sites, as well as the potential pollutant reductions and achievability of the projects.

There are five major categories in the Site Evaluation Ranking Matrix; Subwatershed Assessment, Flood Reduction, Pollutant Reduction, Natural System Enhancement and Project Benefits, each with its own subset of ranking parameters used to identify sites that are priorities for retrofit project implementation (Table 2-3). Each parameter was chosen based on its association with reducing flooding and pollutant movement through the City's stormwater sewer system. Achievability of a project is gauged by whether the site is owned by the City, and if not, what is the level of cooperation needed from the property owner (for example permission from the City School District) to achieve implementation of a project. Parameters within the Subwatershed Assessment Category identify areas that have the highest amount of available open space for green infrastructure retrofit project installation, with a low slopes to promote velocity reduction and capture of stormwater runoff, and a hydrologic soil group that promotes infiltration. The Flood Reduction Category utilizes the information produced by the

Table 2-3. Site Evaluation Ranking Matrix Parameters and Ranking Criteria

SITE EVALUATION	POINT SCORING				
	5	4	3	2	1
Level of coordination necessary to implement GI project	Low		Moderate		High
Is the property City owned?	Yes		Easement/ROW		No
SUBWATERSHED ASSESSMENT					
Site Slope	0 to 4%	5 to 8%	9 to 12%	13 to 15%	16+%
Hydrologic Soil Group	A	B	C	C/D	D
Acreage available for siting GI projects	>5 acres	3 to 4 acres	2 to 3 acres	1 to 2 acres	< 1 acre
FLOOD REDUCTION					
Is the site within a flood prone area?	Directly		Bordering		No
For the 5 year design storm, are storm manholes surcharged above the ground surface?	Yes				No
For the 10-year design storm, what level of flooding occurs in in the site or manholes directly upstream of the site?	0.5 to 1.0 MG	0.1 to 0.5 MG	0.01 to 0.1 MG	<0.01 MG	
Does the site or the area immediately around the site contribute to flood problems downstream in the sub-sewershed?	Yes		Possibly		No
Number of Combined Sewer Overflow (CSO) events in the subwatershed over the past 5 years	10+	7 to 9	4 to 6	1 to 3	0
POLLUTANT REDUCTION					
Proximity to storm sewer system inlet	0 to 50 ft	51 to 100 ft	101 to 150 ft	151 to 200 ft	201 + ft
Existing stormwater treatment system?	No				Yes
Major land use within sub-watershed	Industrial or densely populated	Industrial/ Commercial	Commercial	Commercial/ Residential	Residential/ Schools
Imperviousness of sub-watershed	High	High – Moderate	Moderate	Low-Moderate	Low
Does this project address a direct discharge into:	Lake Champlain		Saranac River		Other
Will the project reduce stormwater flow into a CSO?	Yes		Possibly		No
NATURAL SYSTEM ENHANCEMENT					
Will a GI project enhance or preserve existing natural vegetation?	Yes		Possibly		No
PROJECT BENEFITS					
Will the project cultivate educational opportunities (base on location, accessibility, to public, amt. of foot traffic)?	Yes, highly visible	Yes, moderately visible	Moderate	Low to Moderate	No

SWMM to assess the severity of the flood prone areas that the project sites are either within or adjacent to. This includes looking at the 5-year, 10-year and 25-year design storm data to identify whether manholes are surcharged during rain events and to what level the flooding is occurring. These parameters also give the most amount of points to sites that will directly reduce flooding downstream of the system by reducing volume upstream, and will reduce the effects that stormwater has on the City's Combined Sewer System by addressing areas with a large number of Combined Sewer Overflow events. The Pollutant Reduction category assesses the sites ability to reduce pollutant movement into in the stormwater system by taking into account proximity to inlets, the land-use and imperviousness of the sub-sewershed, and whether a project would reduce direct discharges into surface waters, including Lake Champlain and the Saranac River. Also taken into consideration are the sites ability to enhance or preserve natural vegetation and cultivate public educational opportunities. Each ranking parameter was given a numerical value from one to five, with a maximum total of 90 points.

In an effort to identify which green infrastructure practices would benefit the most at the priority site identified through the Site Evaluation Ranking Matrix process above, a ranking matrix for green infrastructure practices was also created, based on the achievability of the installation and potential benefits on a site specific basis. This includes assessing the projects based on ease of installation, including whether utilities have to removed or replaced, as well as assessing future maintenance responsibilities and the specific practices ability to reduce stormwater quantity and increase stormwater quality, urban habitat potential and quality of life. The parameters for this matrix are illustrated in Table 2-4.

Table 2-4. Green Infrastructure Practice Ranking Matrix Parameters and Ranking Criteria

GI PRACTICE EVALUATION	5	4	3	2	1
PROJECT ACHIEVABILITY					
Compatibility with urban environment	High		Moderate		Low
Depth to groundwater necessary for installation	≤ 12 inches		~24 inches		≥ 36 inches
Will overhead or underground utilities need to be relocated for installation?	Not Likely		Possible		Most Likely
Drainage area GI practice can treat as it relates to impervious surface of the site.	Large		Moderate		Small
Cost for installation (per square foot)	Low	Moderately – Low	Moderate	Moderately – High	High
Maintenance requirements	Easy	Moderately-Easy	Moderate	Difficult	Very Difficult
PROJECT BENEFITS					
Reduction in effective imperviousness by GI practices	≥ 61 sq. ft.	46 to 60 sq. ft.	31 to 45 sq. ft.	16 to 30 sq. ft.	0 to 15 sq. ft.
Method of runoff retention	Infiltration and ponding		Infiltration, little ponding		Little infiltration/ attenuation
Does the project address phosphorus reduction?	Mostly infiltration, plant uptake and sediment removal	Plant uptake and sediment removal	Sediment removal	Runoff attenuation, some plant uptake	Runoff attenuation only
Will the project improve habitat for wildlife?	Yes		Moderately		No
Will the project improve aesthetics of the area?	Yes		Moderately		No

3 Methodology

3.1 Model Creation

Utilizing the information obtained during the City's stormwater mapping efforts, the consultants developed a US EPA SWMM for the City to; (1) delineate sub-sewersheds; (2) calculate runoff, discharge and storage volume of the system; and (3) identify vulnerabilities within the system during 5-year, 10-year, 25-year, 50-year and 100-year storms. The computer model was developed primarily for design storm analysis of flood vulnerability during intense rainfalls, although it can also be used for continuous simulation, however its present configuration does not represent baseflow variation or snow processes.

The model's hydraulic component was developed from the City's GIS, supplemented with information about open channel drainage from maps, drawings, and City staff, and United States Geological Survey (USGS) data for the Saranac River and Lake Champlain. It uses SWMM's dynamic wave solution, which solves the complete one-dimensional Saint Venant flow equations for continuity and momentum. Dynamic wave routing accounts for channel storage, backwater, entrance/exit losses, flow reversal, and pressurized flow. The hydraulic model simulates all flow in the City's storm sewer system, as well as flows entering the system from the Town of Plattsburgh, and represents water levels in the Saranac

River and Lake Champlain. Together, these flows and levels allow accurate representation of hydraulic grade lines and flow rates throughout the City. The hydraulic model component consists primarily of manholes and pipes, with each manhole assigned an invert and rim elevation, while each pipe is assigned a shape, length, and Manning's roughness coefficient (N value). Open channel segments are similarly specified, with junctions at open channel segment intersections specified in the same way as manholes.

The model's hydrologic component uses SWMM's non-linear reservoir model to simulate runoff from specified rainfall. Each drainage outfall's sewershed is subdivided into smaller sub-sewersheds so that flows can be allocated throughout the collection system. Each sub-sewershed is assigned an area, total and effective imperviousness, slope, characteristic width, roughness, as well as additional parameters. No flow measurements are available for model calibration, however the model's performance was validated by comparing its flows and levels with discharge estimates from the USGS National Streamflow Statistics (NSS) program and anecdotal reports from City staff. The model uses the New York State Plane East coordinate system (1983 datum, feet) and NAVD 88 vertical datum (0.48 feet above the older NGVD 29 datum at Plattsburgh).

3.1.1. Hydraulics

The hydraulic model consists of 970 pipe segments totaling 35 miles in length. Two hundred pipes smaller than 18 inch diameter are included where long runs of small pipe are prevalent, such as the 15 inch pipe on Sharron Avenue, and east of the US Oval, where six outfalls are connected to small pipes. The modeled hydraulic network is shown in Figure 3-1. Modeled pipes are shown in light blue, open channel segments are shown in thick dark blue, and small pipes omitted from the model are shown in grey.

The City's stormwater GIS project identified 118 outlets from the storm sewer system to receiving waters, most of which discharge to Lake Champlain, Saranac River, or the small stream that drains southward west of Sandra Avenue, through the SUNY athletic complex, and into the Saranac River. The hydraulic model incorporates most of these outfalls, omitting only those that serve a single catch basin, such as a 6-inch pipe from the intersection of Pine and White Streets to the Saranac River. To account for the impact of open channel water levels on Plattsburgh drains, the Sandra Avenue stream and the Saranac River downstream of the ditch beginning near Adirondack Lane are directly represented in the model. Many of the outlets identified in the GIS are thus modeled as conduits, as opposed to hydraulic outfalls, where the model terminates at receiving waters.

The hydraulic model incorporates 33 hydraulic outfalls, including,

- one at the downstream end of the Saranac River;
- 30 that discharge directly to Lake Champlain, Saranac River downstream of Bridge Street (where river stage is indistinguishable from lake stage), or Scomotion Creek;
- one at the intersection of Route 22 and Arizona Avenue that discharges to the Saranac River one mile upstream of Adirondack Lane; and
- one that discharges from Truman Lane north into a wooded area near Northway exit 38, which ultimately drains to Scomotion Creek via a small stream in the Town of Plattsburgh.

Manning's roughness coefficient (N) for most pipes was specified as 0.013, while 185 pipes identified in the City database as corrugated metal were assigned N=0.024.

Open channel characteristics were estimated from topographic data and cross-section data for a USGS gage on the Saranac River at the foot of Adirondack Lane. Most open channel segments other than the river were represented as trapezoidal sections with bottom widths of six feet and 2:1 side slopes.

The Sandra Avenue stream's 500-acre watershed in the City and in the Town of Plattsburgh is fully represented in the model. Average baseflow in the stream was estimated at 0.75 cubic feet per second (cfs). This flow is specified at node J1161 near the southeast corner of the Walmart property. The detention pond along the eastern edge of the Walmart site is represented as an 850-foot parabolic channel with a 5-foot long transverse weir offset 7 feet from the channel invert, which then connects to the Sandra Avenue stream via 400 feet of 18-inch pipe.

Lake Champlain water levels typically vary between 94 and 101 ft NAVD 88 based on USGS gage 04294500 at Burlington, Vermont. Average levels vary from 98 ft in April and May to 95 ft in September and October. For design storm simulations, Lake Champlain water level was fixed at 96.0 ft, its average level for 1970 to the present.

3.1.2. Hydrology

Figure 3-2 shows 54 principal sub-sewersheds delineated for the stormwater model. Other parts of the city either drain to the combined sewer system, such as most of Catherine Street, or are not served by drainage systems, such as various wooded areas. The model also includes portions of the Town of Plattsburgh, including drainage that contributes to the Sandra Avenue stream from Champlain Centre and Walmart, and part of the Plattsburgh Airbase. The model domain encompasses four square miles, with three-quarters of that area within the city limits.

The principal sub-sewersheds were defined during development of the City GIS. These sub-sewersheds were subsequently subdivided, primarily using Thiessen polygons, yielding 916 sub-sewersheds, approximately one per modeled junction in the hydraulic network. Sub-sewershed boundaries are shown as light grey lines in Figure 3-2.

Hydrologic modeling parameters were specified, including;

- Imperviousness of each sub-sewershed was determined based on the impervious cover data layer developed by the Lake Champlain Basin Program (LCBP). The 2006 US National Land Cover Database was used for sub-sewersheds on or outside of the city boundary for which LCBP estimates were not available. Weighted average imperviousness for the study area is 46%. Effective imperviousness was specified as 40% of total imperviousness, yielding a system-wide effective imperviousness of 18%.

- The sub-sewersheds width, catchment slope, and surface roughness parameters control hydrograph shape. SWMM lumps these three values into a single parameter, so the model is relatively insensitive to any one of them individually. Width was specified based on a regression equation fitted to calibrated Combined Sewer Overflow (CSO) model values that are within the City's previously completed CSO model. The equation used is Width (ft) = 464 x Acres$^{3/8}$. The specified widths have a median value of 380 feet per acre, or an equivalent median drainage length of 114 feet (i.e. the typical length of overland flow). Sub-sewershed slope was uniformly specified at 0.5 percent, as in the CSO model. Surface roughness (N) was specified at 0.05 for impervious areas and 0.1 for pervious surfaces, consistent with the City's CSO model.

- Initial abstraction was specified as 0.05 inches for impervious surfaces and 0.2 inches for pervious surfaces, as in the CSO model.

- The Green-Ampt soil infiltration model was used with all soils specified as well-drained silt with hydraulic conductivity of 0.86 inches per hour, as in the CSO model.

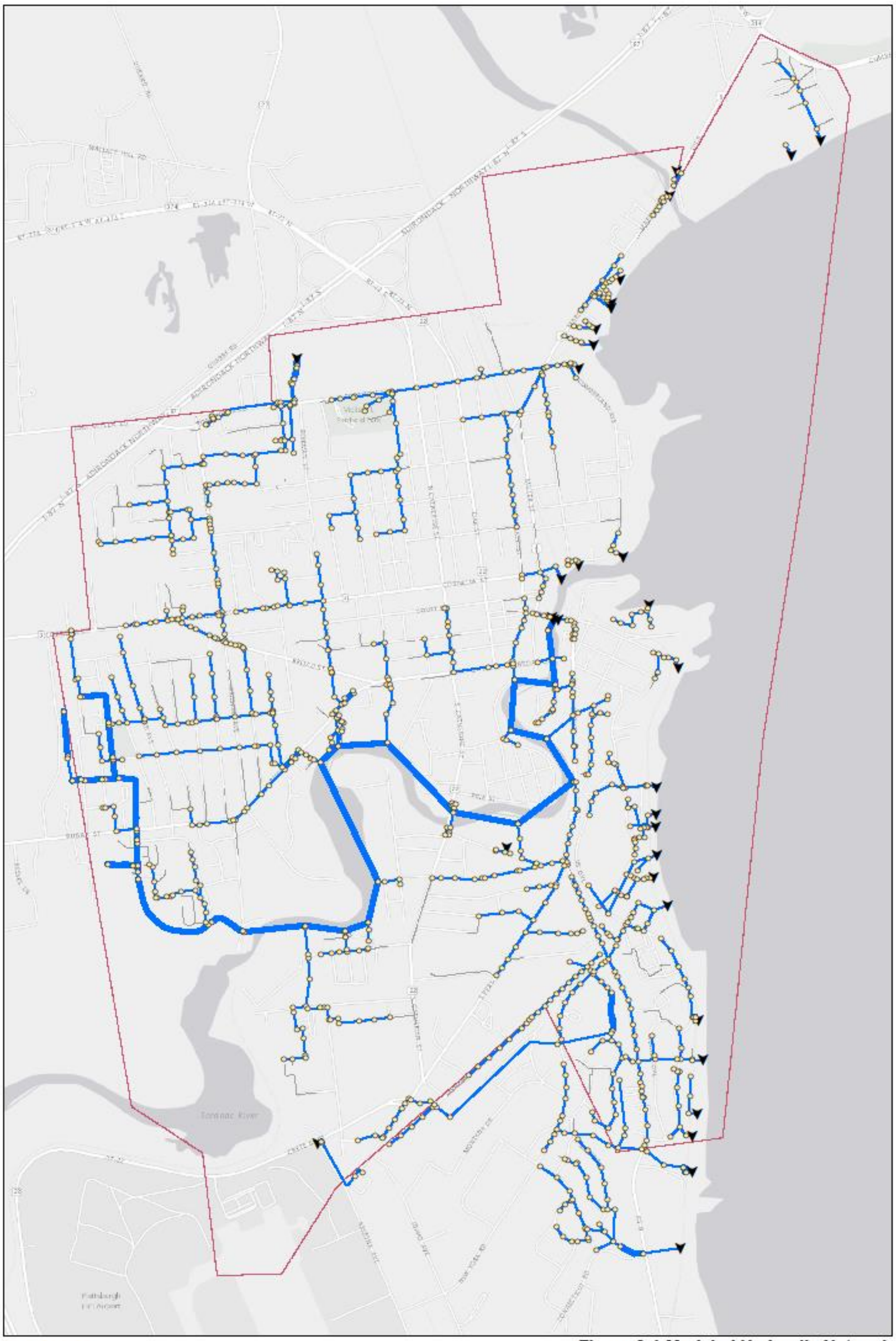
- Monthly evaporation rates match those in the CSO model. This parameter is of minor importance for flood assessment.

- A typical set of snow process parameters were specified. As the model is currently configured primarily to model design storm peak discharges, these parameters are of minimal importance.

- While the CSO model was configured to simulate baseflow as a function of continuously simulated groundwater levels, the drainage model omits groundwater processes, as these are of little importance for peak discharge analysis.

3.1.3. Saranac River Representation

The Saranac River drains a 600 mi² watershed. The greatest recorded streamflow for the Saranac River at Plattsburgh (USGS 04273500; in service since 1944) is 14,400 cfs measured November 9, 1996. This flow had a 100-year average recurrence interval based on USGS peak discharge analyses. Table 3-1 lists principal recent storm depths, associated river flows, and average recurrence intervals for rainfall and streamflow.



CDM Smith

Figure 3-1 Modeled Hydraulic Network
Plattsburgh, NY

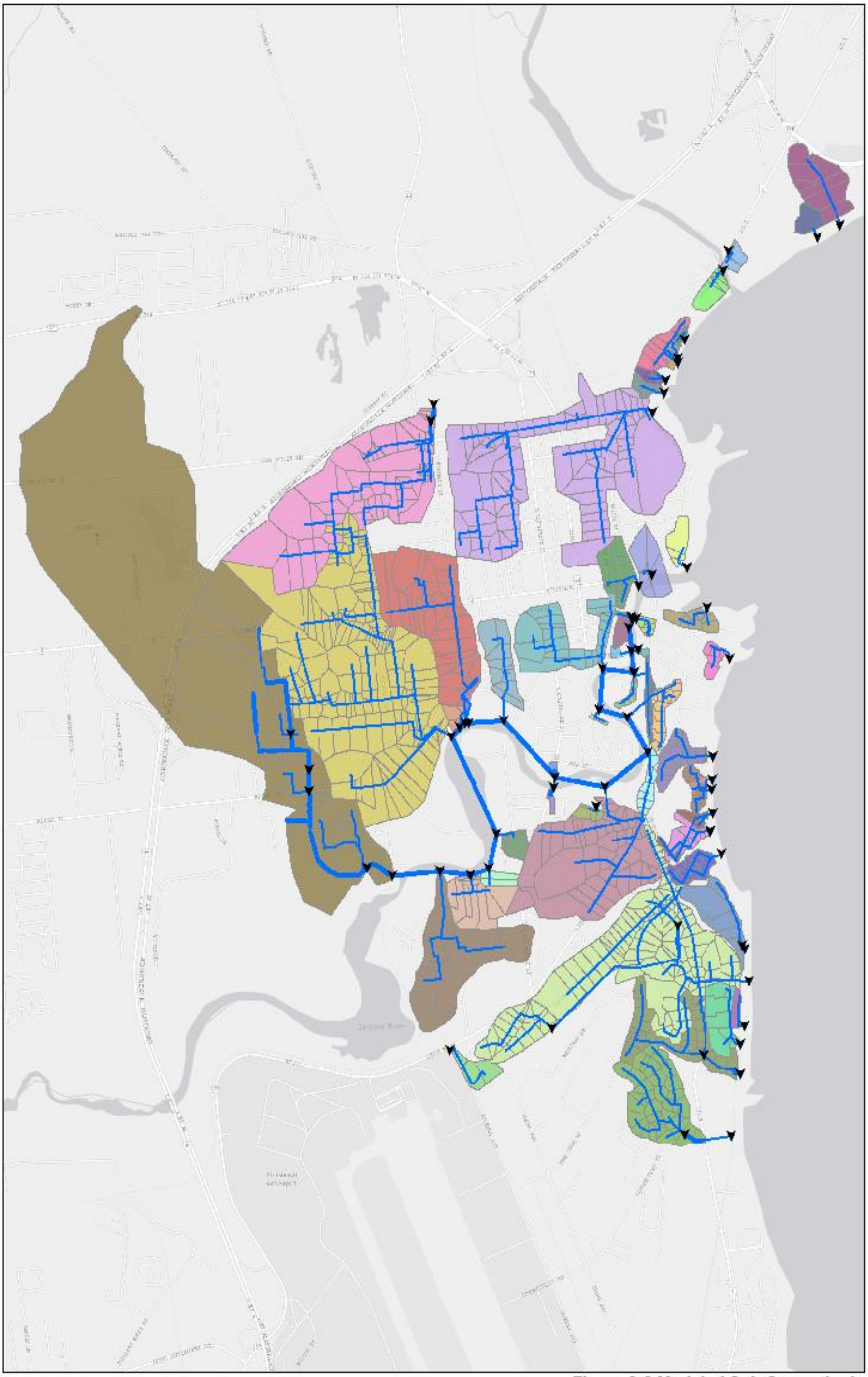


Figure 3-2 Modeled Sub-Sewersheds
Plattsburgh, NY

CDM Smith

The most recent high streamflow events were June 11-12, 2013, when discharge reached 9,430 cfs, and April 28, 2011, when discharge reached 8,760 cfs. These were 11-year and 8-year average recurrence interval events, respectively, based on USGS statistics. The June 2013 event was associated with a 2.08 inch rainfall at Plattsburgh Airport. This rainfall had a 1-year 24-hour average recurrence interval. While the April 2011 storm corresponded with only 1.4 inches of rain over one day, total precipitation for the month was 5.7 inches, the second wettest April on record for Plattsburgh. For the June 2013 storm, peak flow in the Saranac River occurred more than 12 hours after the peak of the rainfall, due to the difference in time of concentration between the city drain system's 4 square mile watershed and the river's 600 square mile basin. The rainfall hyetograph and discharge hydrograph for this storm are shown in Figure 3-3.

Peak discharge in the Saranac River associated with large storms occurs 12 hours or more after peak rainfall. Storms that cause high flows and potential flood problems in the City's drain system generally cause peak discharge in the drain system within 15 minutes of peak rainfall. As peak flows in the river occur well after drain system peaks, it is appropriate to use an average river tailwater condition for assessing peak stages in the drain system, except immediately adjacent to the river, where high river stage causes flooding regardless of drain system conditions. For typical uses of the City's drain system model, the river can thus be represented with its long-term average discharge of 880 cfs at Adirondack Lane (node OUTLET115), based on USGS data for 1944-2013.

Table 3-1. Storms with at least 1.7 inches 1-day Rainfall 2007-2014

	Rainfall (inches)				Saranac River
	1-hr	6-hr	24-hr	48-hr	Peak Discharge (cfs)
May 27, 2011	0.68	1.10	1.88	3.25	4,680
August 28, 2011	0.53	2.38	3.50	3.50	7,050
June 11, 2013	0.16	0.52	1.93	2.08	9,430
August 13, 2014	0.70	1.54	2.04	2.07	1,930
	Average Recurrence Interval				
May 27, 2011	6 mo	6 mo	1 y	8 y	1.5 y
August 28, 2011	3 mo	15 y	20 y	12 y	4 y
June 12, 2013	<1 mo	1 mo	1 y	1 y	11 y
August 13, 2014	6 mo	2 y	1 y	1 y	<1 y

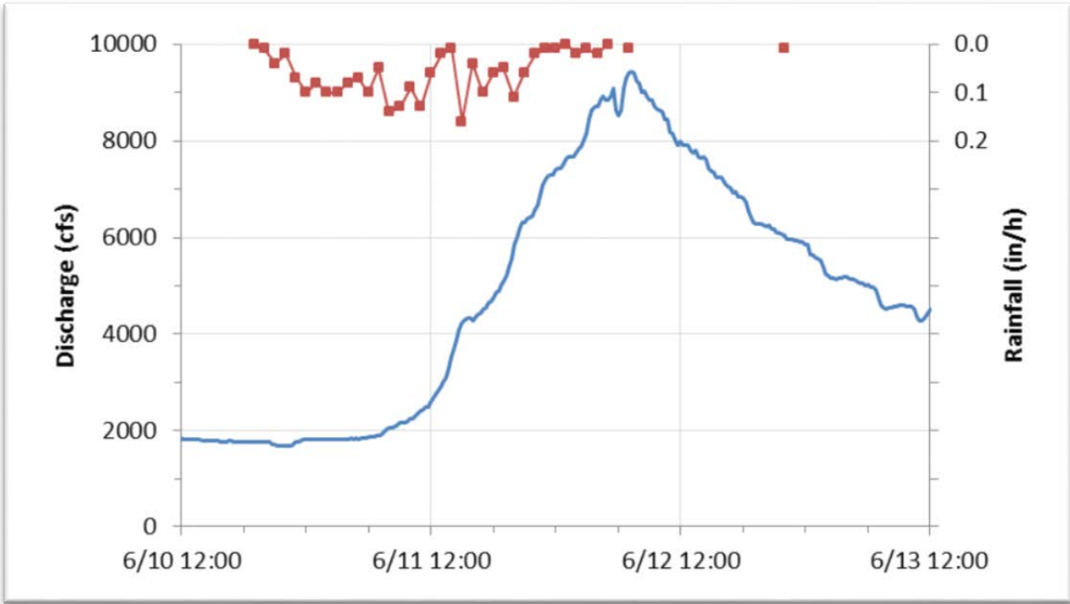


Figure 3-3. June 11-12, 2013 Rainfall and Saranac River Discharge

3.1.4. Design Storms

Design storm hyetographs were developed using the Natural Resources Conservation Service (NRCS) Type II distribution. Total 24-hour storm depths were determined using estimates from the Cornell Northeast Regional Climate Center (NRCC). Table 3-2 and Figure 3-4 show NRCC precipitation frequency estimates for Plattsburgh. The 5-year, 10-year, 25-year, and 50-year 24-hour rainfall depths are 2.62 inches, 3.04 inches, 3.71 inches, and 4.32 inches, respectively.

Table 3-2. Plattsburgh NY Precipitation Frequency Estimates (inches)

	Average Recurrence Interval (years)						
Duration	1	2	5	10	25	50	100
5 min	0.28	0.3	0.35	0.40	0.49	0.56	0.65
10 min	0.43	0.46	0.54	0.62	0.74	0.85	0.98
15 min	0.53	0.56	0.67	0.77	0.92	1.06	1.23
30 min	0.71	0.76	0.92	1.07	1.32	1.52	1.77
1 hour	0.87	0.94	1.17	1.39	1.73	2.05	2.43
2 hours	1.00	1.08	1.34	1.58	1.97	2.32	2.74
3 hours	1.11	1.20	1.48	1.74	2.17	2.56	3.03
6 hours	1.37	1.47	1.81	2.12	2.62	3.08	3.62
12 hours	1.66	1.78	2.18	2.55	3.13	3.65	4.28
1 day	1.87	2.15	2.62	3.04	3.71	4.32	5.02
2 days	2.11	2.42	2.93	3.39	4.10	4.74	5.49

Source: Cornell Northeast Regional Climate Center http://precip.eas.cornell.edu

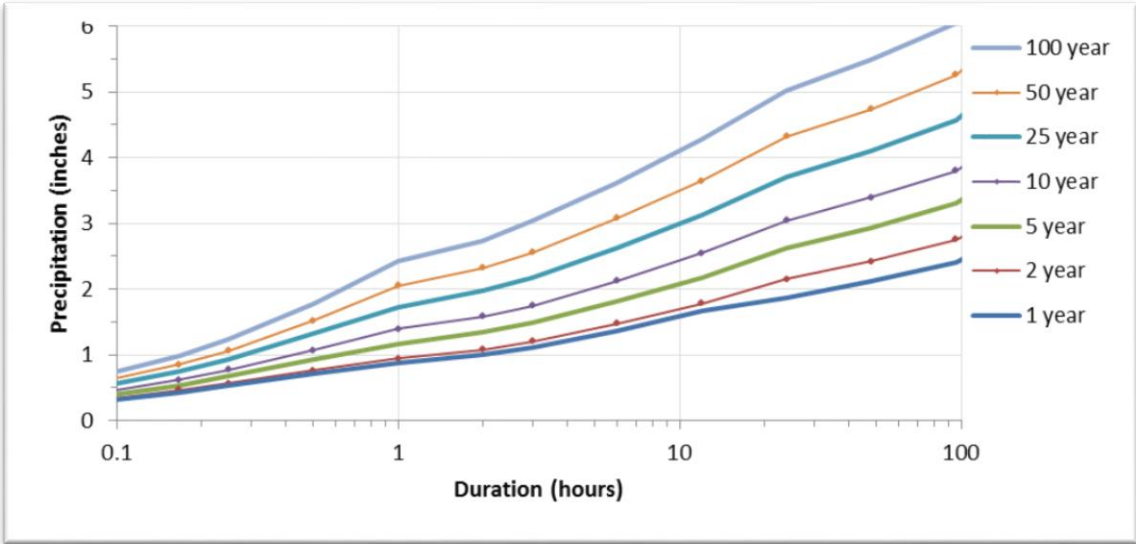


Figure 3-4. Plattsburgh NY Precipitation Depth-Duration-Frequency

3.1.4.1 Climate Change Impacts on Design Storm

Climate change impacts on design storm depths were assessed based in part on EPA's Climate Resilience Evaluation & Awareness Tool (CREAT) software. CREAT assists municipal utility owners in understanding potential climate change. It presents precipitation frequency estimates with a 2010 baseline, as well as for 2035 and 2060. Estimates for 2100 were obtained through regression analysis of values obtained from CREAT. Table 3-3 presents 5-year, 10-year, 25-year, 50-year, and 100-year 24-hour rainfall estimates for Plattsburgh for 2010, 2035, 2060, and 2100. The present case estimates differ from those presented above from NRCC, as EPA's methodology differs from that used in the NRCC analysis, and the EPA estimates are for Peru, NY, 12 miles southwest of Plattsburgh.

Table 3-3. 24-hour Precipitation Frequency Current Estimates and Projections

ARI (y)	NRCC / Plattsburgh	EPA CREAT / Peru NY			
		2010	2035	2060	2100
5	2.62	2.4	2.5	2.6	2.8
10	3.04	2.9	3.1	3.2	3.4
25	3.71	3.7	3.9	4.1	4.4
50	4.32	4.5	4.7	4.9	5.2
100	5.02	5.4	5.7	5.9	6.3

ARI: Average recurrence interval
Gray shading indicates values directly from CREAT; others interpolated or extrapolated

While the NRCC and EPA estimates in Table 3-3 are not consistent with each other, and the 2100 estimates extend beyond CREAT's planning horizon, the table offers a framework for using current precipitation frequency estimates to evaluate the impact of changing climate on extreme rainfall. The values from CREAT indicate that 2035 extreme rainfall can be expected to be about 5 percent higher than 2010 depths, and 2060 storms are expected to be 9 percent higher than 2010 depths. When extended to 2100, the projected extreme rainfall is 16% higher than present day values. Based on these assumptions, today's 50-year 24-hour rainfall will be approximately a 25-year event in 2100 (between 4.3 and 4.5 inches), while today's 10-year rainfall will become a 5-year event (between 2.8 and 3.0 inches). This simple paradigm offers a useful way of assessing climate change impacts on extreme rainfall without necessitating development of additional hyetographs that would necessarily be based on numerous assumptions.

3.2 Model Validation

3.2.1 Discharge Rates

Discharges computed by the model for the selected design storms were compared against estimates computed using USGS's NSS software. NSS estimates peak discharges for rural and urban streams across the US using state-specific regression equations based on drainage area, precipitation statistics, imperviousness, watershed slope, and other factors. For New York, the software includes both a drainage area-only method for estimating peak discharge on rural streams, as well as a detailed method. The detailed method estimates peak discharge as a function of drainage area, lag factor (relating main-channel length and slope), basin storage, percent forested, and annual precipitation using equations presented in a 2006 USGS report (Lumia, R., et al., USGS Scientific Investigations Report 2006–5112). The software also incorporates a New York-specific method for estimating peak runoff in urban waterways (Stedfast, D. A., 1986, USGS Water-Resources Investigations Report: 84-4350).

Peak discharge estimates were developed for the Sandra Avenue stream, which is the largest single drainage system within the study area, as well as for the system immediately to the east that drains to the Saranac River near the intersection of Rugar Street and Sanborn Avenue. The Sandra Avenue system drains 1.2 square miles (mi^2); the Rugar Street system drains 0.56 mi^2.

Table 3-4 shows peak discharges for the Sandra Avenue and Rugar Street systems obtained from NSS and from SWMM. Estimates obtained using SWMM for the Sandra Avenue stream ranged from 4% lower to 17% higher than NSS estimates for the 5- through 100-year design storms. SWMM estimates for the Rugar Street system were between 3% below and 10% above NSS estimates. Both these results indicate that SWMM simulates peak discharges well.

Table 3-4. SWMM and NSS Peak Discharge Estimate Comparison

ARI (y)	Rainfall (in)	Sandra Avenue			Rugar Street		
		NSS	SWMM	Difference	NSS	SWMM	Difference
5	2.6	240	230	-4%	200	220	10%
10	3.0	290	310	7%	240	240	0%
25	3.7	350	400	14%	290	280	-3%
50	4.3	410	480	17%	330	350	6%
100	5.0	470	540	15%	380	380	0%

NSS input parameters are shown in Table 3-5; some parameters were determined from GIS; others were estimated.

Table 3-5. NSS Input Parameters

	Sandra Ave	Rugar Street
Drainage area (mi^2)	1.18	0.56
Lag factor	1.16	1.16
Storage	0%	0%
Forest	10%	0%
Annual precipitation (in)	33	33
Imperviousness	40%	49%
2-y 2-h precipitation (in)	1.08	1.08
Development factor (0-12)	7	11
Slope (ft/mi)	60	65

3.2.2 Flood Locations

The City indicated that spring 2011 had high river stage conditions and reported flooding throughout the storm sewer system. Table 3-6 lists 3- and 24-hour maxima for events in April and May 2011 based on 5-minute rainfall data from Plattsburgh Airport's National Weather Service Automated Surface Observing System (ASOS) gage.

Table 3-6. Rainfall Maxima (3- and 24-hour) Spring 2011

Date	Inches
3-Hour Maxima	
05/27/2011 14:23	0.90
04/26/2011 19:56	0.74
04/20/2011 3:55	0.66
24-Hour Maxima	
05/26/2011 19:50	2.07
05/03/2011 10:35	1.96
04/25/2011 23:26	1.40

A model simulation was performed for April and May 2011 using 5-minute ASOS rainfall data, daily discharge for Saranac River at Plattsburgh, and daily stage data for Lake Champlain. Figure 3-5 shows simulated surface flooding locations, which include these flood-prone areas noted by the City:

- McKinley Avenue (Skyway Plaza)
- Park Avenue/Sanborn Avenue and Dennis Avenue
- Morrison Avenue, Grace Avenue, and Beekman Street

- Margaret Street from Cornelia Street to Riley Avenue

The model indicated surface flooding at other manhole locations, such as along Sharron Avenue and east of US Oval, but simulated flood volumes at these sites were mostly less than 0.1 MG. Invert and rim elevations for many manholes in these areas were estimated and not field verified. The locations with the largest simulated flood volumes (0.1 – 1.0 MG) were along North Margaret Street and the parking lot south of the Water Pollution Control Plant. Many invert and rim elevations in these areas were also estimated.

3.3 Vulnerability Assessment

Following model validation, the model was used to assess system deficiencies for various frequency storm events. Surface flooding locations and volumes were identified for each simulation. The model was also used to estimate future vulnerabilities of the system related to more intense storm events due to climate change.

3.3.1. Average Storm

An average rainfall event was selected from the Burlington, Vermont long-term hourly dataset, as Burlington is the nearest location with long-term hourly precipitation data. The selected storm occurred October 1, 1965 with 0.53 inches over 16 hours and a peak hour depth of 0.16 inches. Total simulated discharge from the system for this event was 7.0 million gallons (MG), with 3.3 MG discharging via outfalls to Lake Champlain or Scomotion Creek and 3.7 MG to Saranac River. No surface flooding was simulated for this event. Figure 3-6 shows the minimum depth to water below manhole rims. The peak hydraulic grade line was greater than 3 feet below rim throughout most of the system and between 1 to 3 feet below rim at other areas.

3.3.2. Design Storm

Model simulations were performed for the 5-year, 10-year, 25-year, and 50-year design storms, with total surface flooding and discharge volumes for each event are summarized in Table 3-7.

Table 3-7. Simulated Design Storm Flooding and Discharge Volume

		Discharge Volume (MG)	
Design Storm	Total Flood Volume (MG)	Lake Champlain/Dead Creek	Saranac River
5-yr	8	22	31
10-yr	13	27	39
25-yr	22	37	53
50-yr	33	46	66

Simulated surface flooding and minimum depth to water below manhole rims for each design storm are shown in Figures 5-1 to 5-4. At manholes that flooded during the 5-year storm, all flood volumes were less than 0.1 MG. Maximum flooding at a manhole during the 50-year storm was 0.4 MG.

As discussed in Section 3.1.4, climate change impacts on design storm depths were assessed using EPA's CREAT software. Projected extreme rainfall for 2100 is 16% higher than present day values. Therefore, the flooding and discharge results presented above for the 10-year, 25-year, and 50-year events also approximate the system performance for the 5-year, 10-year, and 25-year events in 2100, respectively. The present day 100-year event (5.02 inches over 24 hours) is reasonably comparable with the projected 50-year event in 2100. Total flood volume for this event is 45 MG. Discharge volumes to Lake Champlain/Scomotion Creek and Saranac River are 56 MG and 82 MG, respectively. Figure 5-6 indicates surface flooding volumes and minimum depth to water below manhole rims for the 100-year event. Maximum flooding at any manhole during the 100-year storm is 0.6 MG at the downstream end of the channel at the Walmart site.

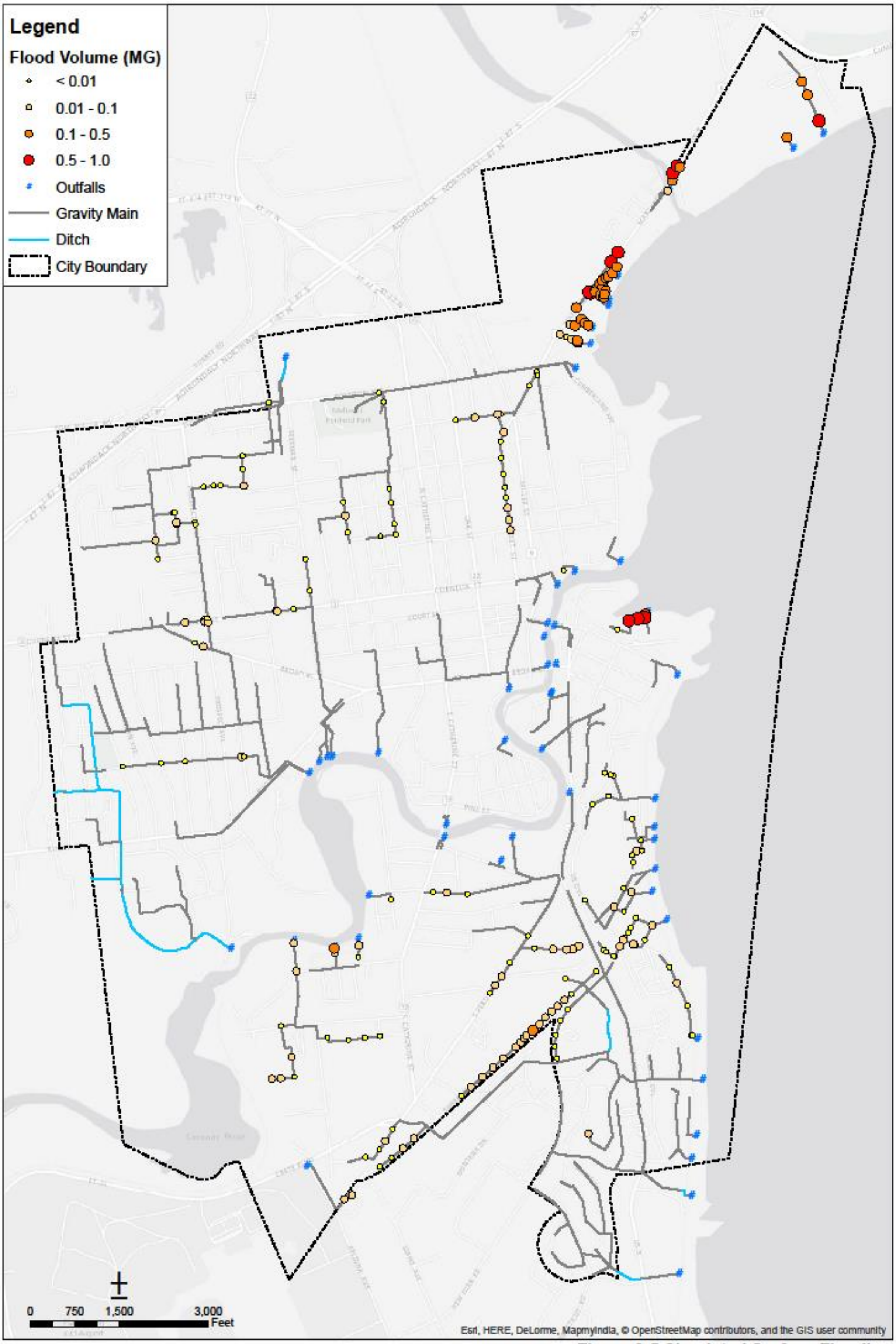


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Figure 3-5 Simulated Surface Flooding
Spring 2011 (April - May)
Plattsburgh, NY

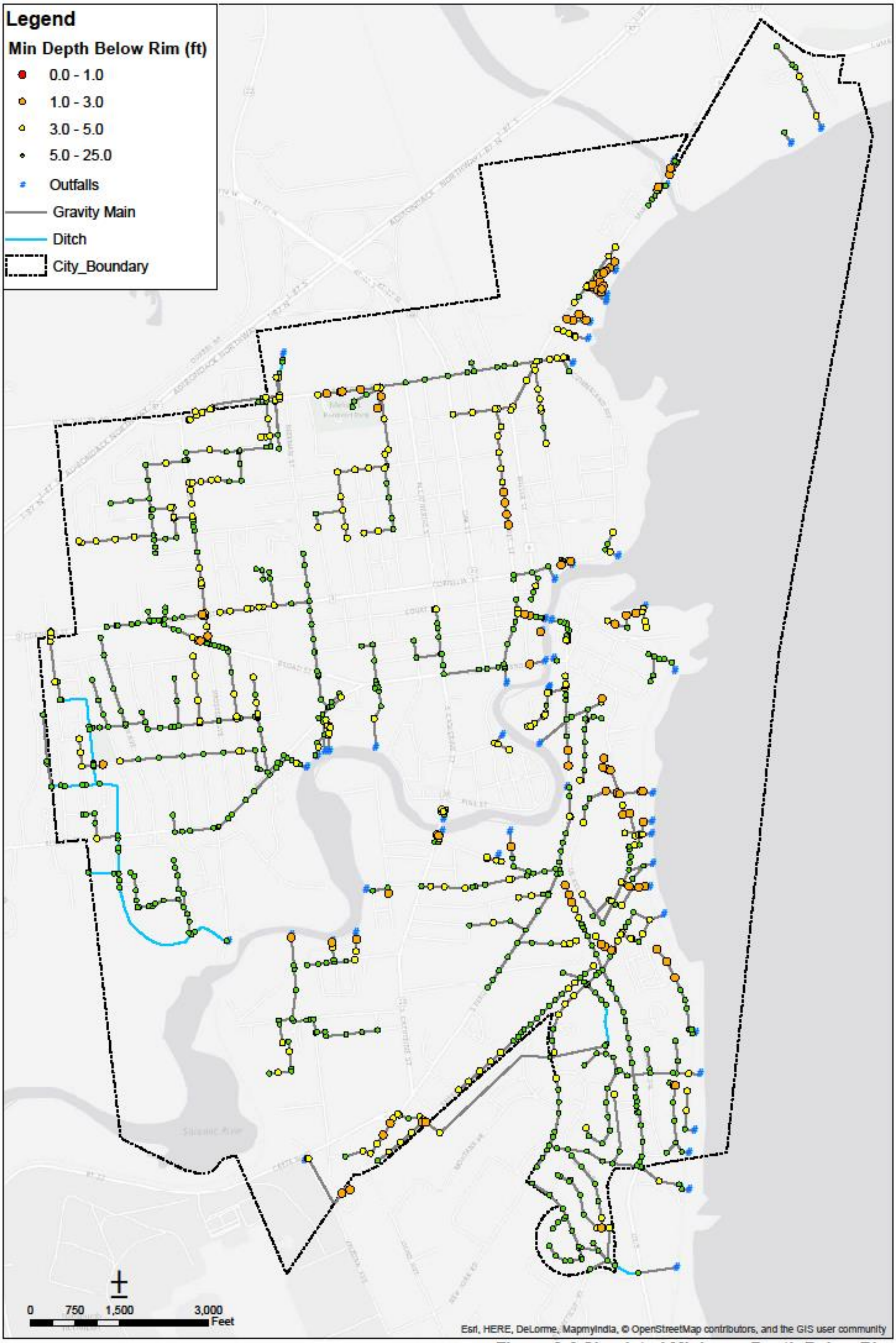

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Figure 3-6 Simulated Minimum Depth Below Rim
Average Storm Event
Plattsburgh, NY

4 Quality Assurance Tasks Completed

The project data-quality objective was to collect, provide, maintain, analyse, display, and document valid GIS data for existing stormwater infrastructure and to calculate runoff, discharge and storage volume for the existing system using a SWMM 5 model. The quality assurance objectives performed to measure accuracy, precision, representativeness and comparability of additional data collected to support the existing stormwater infrastructure mapping and identify areas for potential green infrastructure projects are outlined below.

4.1 Complete GIS Infrastructure Mapping & Database Creation

Utilizing existing record drawings, as-built drawings, and CAD data, City staff digitized the stormwater system into a GIS through orthorectification and on-screen digitizing in the ArcGIS Desktop 10.1 environment, with associated metadata meeting FGDC and NYS GIS standards in ArcGIS/XML. As part of the mapping process, record drawings were scanned and orthorectified and then digitized on screen into the GIS. Locational refinement of stormwater manholes and catch basins in the GIS was carried out by referencing high-resolution orthophotography and highly detailed oblique imagery (Pictometry high resolution geo-referenced imagery, 6” tiles flown in 2008). Further refinement and accuracy checks were performed through field verification and an asset inventory using a high-accuracy sub-foot GPS unit.

The City then completed additional stormwater infrastructure mapping for all trunklines with a Trimble R8Model 3 GNSS receiver, with a horizontal error of 0.1 –ft and a vertical error of 0.1 –ft. Both point (manholes) and line (stormwater mains) features were collected and real time kinematic (RTK) corrected via internet through the NYSDOT special reference network (NYSNET) of continuously operating Global Positioning System survey control Station in Plattsburgh. Calibration of the field equipment followed manufacturer instructions and procedures.

City staff then worked with the consultant to address the proper geodatabase schema, attribution, digitizing processes, and database standardization for the SWMM modeling. A 100% quality review of the database shell/schema was conducted by the consultant, and no issues were found that needed attention from the City. All data acquired and generated was documented as to original source, quality and history using FGDC Content Standard for Digital Geospatial Metadata (version 2.0). Positional accuracy for GIS layers created was then evaluated according to the FGDC Geospatial Positioning Accuracy Standard.

Once the field data collection was completed, a final stormwater GIS database was transferred from the City to the consultant for inclusion in the SWMM modeling. Before the model was created, the consultant conducted a 100% quality review of the GIS database, including location, attribute, topology, and database checks. For this process, all data went through a 100% visual QC process to compare source documents with converted data. The proper placement of features and their locations were checked against record drawings and existing aerial land-base mapping. Attributes on all features were reviewed to ensure data was as complete as possible and was normalized to provide consistent reporting of the system. Manual and automated data checks were used to ensure the data tables were complete and do not have any erroneous data. Topology checks were run on the system to ensure proper connectivity. The geometric network built into the data model was used to perform connectivity, flow, and snapping checks. Issues found during the quality review included certain data gaps, which were rectified by the City staff, and a completed database was transferred to the modeler for SWMM modeling.

4.2 SWMM Model and Vulnerability Assessment

Sub-sewersheds were delineated by the consultants utilizing existing Digital Elevation Models (DEMs) overlain with the completed stormwater infrastructure GIS layers created by the City. The DEM is from the National Elevation Data Set collected in 2009 by USGS at 10m x 10m grid spacing. The stormwater conveyance system information obtained in the infrastructure mapping and delineation of sub-sewersheds was coupled with meteorological data from Plattsburgh Airport and supplemented with data from South Hero and Burlington, Vermont as needed. From these data, the City’s stormwater runoff volumes, peak discharge rates and required storage volume for the average rainfall event were calculated using the EPA Stormwater Management Model (SWMM 5). Recent precipitation data is being used to estimate runoff rates and pollutant loads. This information was used to inform the prioritization of green infrastructure projects, discussed in Section 5.

4.3 QAPP Completion

Once all the data was compiled and the SWMM Model was created and utilized, the Project Manager reviewed the data quality and determined that it falls within acceptable limits per user requirements. Known limitations within the data were discussed amongst project partners are documented in Section 3 of this report. All electronic files are housed on the City's Centralized GIS Database, which is backed up on a daily basis to ensure no data is lost. Data that are in paper format is currently stored in the project files at the City Engineering and Planning Department office, and is available upon request. Copies of all the relevant information, project files and electric database will be provided to the LCBP upon approval of this report.

5 Deliverables Completed

5.1 Storm Sewer Mapping

As part of this project, the City mapped the entire separate storm sewer system with associated metadata, as discussed in Section 4. In total, 970 pipe segments totalling over 35 miles were mapped and assessed, resulting in 100% completion of the separate stormwater sewer system mapping (Figure 5-1). The separate storm sewer system can now be integrated with the mapping of the City's combined sewer system completed in a previous project that was part of the creation of the City's CSO Long Term Control Plan, and future planning for stormwater flow control can be performed, including the separation of storm sewers from sanitary sewer lines, which in many places will aid in quantity reductions. This information is available on the City's Centralized GIS Server and is available for access by all City employees and the public.

5.2 System Vulnerabilities Identified

The model created for the vulnerability assessment was utilized to simulate surface flooding in areas throughout the City based on a 5-year, 10-year, 25-year, 50-year and 100-year storm. Results, indicated as simulated flood volume, as well as rim elevation above surface level, can be found in Figure 5-2 through 5-11, respectively. In general, the results of the modeling indicate that the residential areas of the City are the most vulnerable to increased precipitation events, as they have the majority of the separated stormwater sewer system, and therefore the majority of green infrastructure projects should be located in residential areas. This is in line with the City owned sites that have been identified for retrofit projects, as most of the parks and schools are located within or adjacent to the flood prone areas. It is also worth noting that the majority of downtown is located on the combined sewer system, and therefore is also vulnerable to increased precipitation, but only the separate storm sewer system was taken into account in this modeling.

Figure 5-1. Portion of the City of Plattsburgh Completed Separate Stormwater Sewer System Map

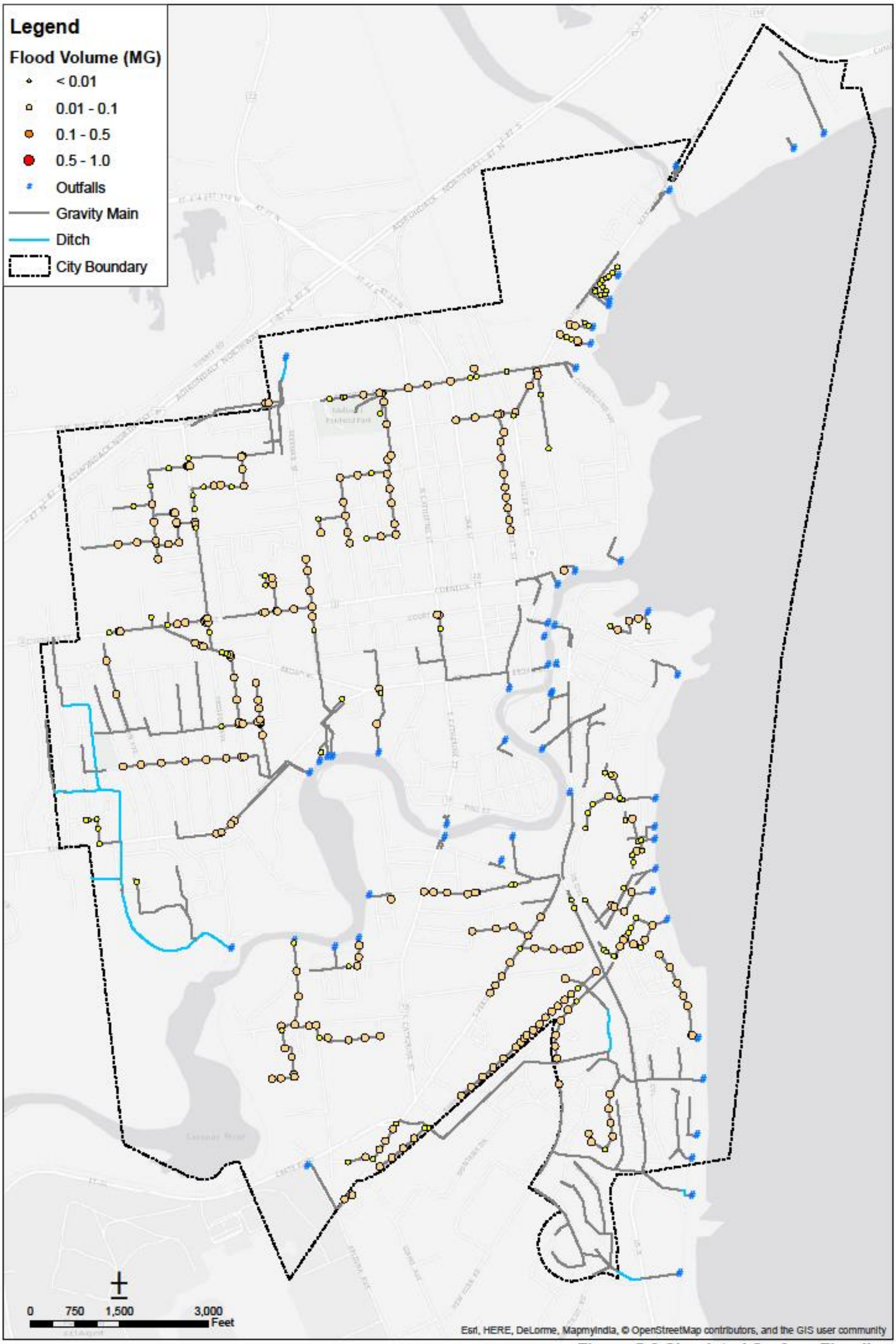

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Figure 5-2 Simulated Surface Flooding
5-year Design Storm
Plattsburgh, NY

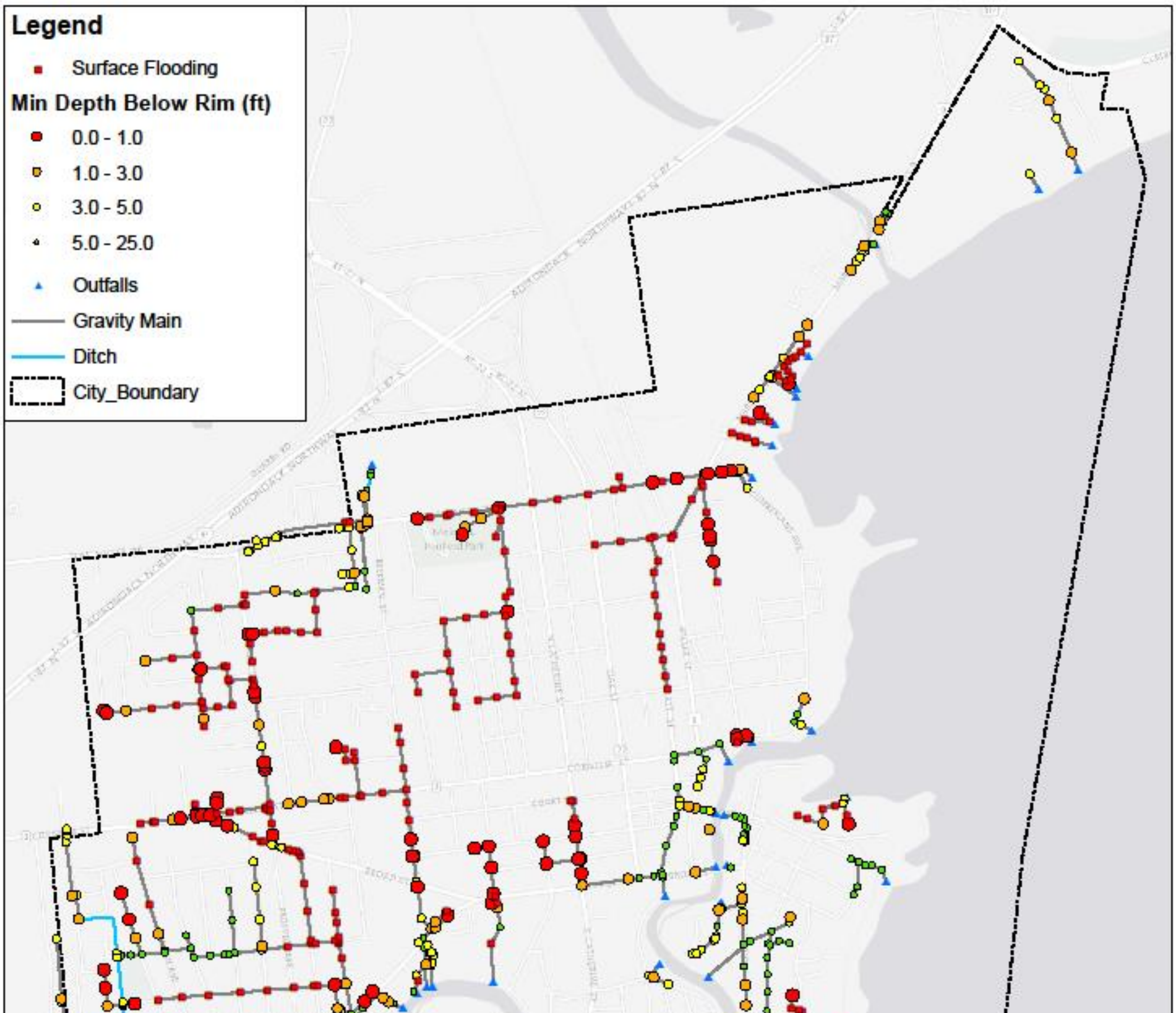

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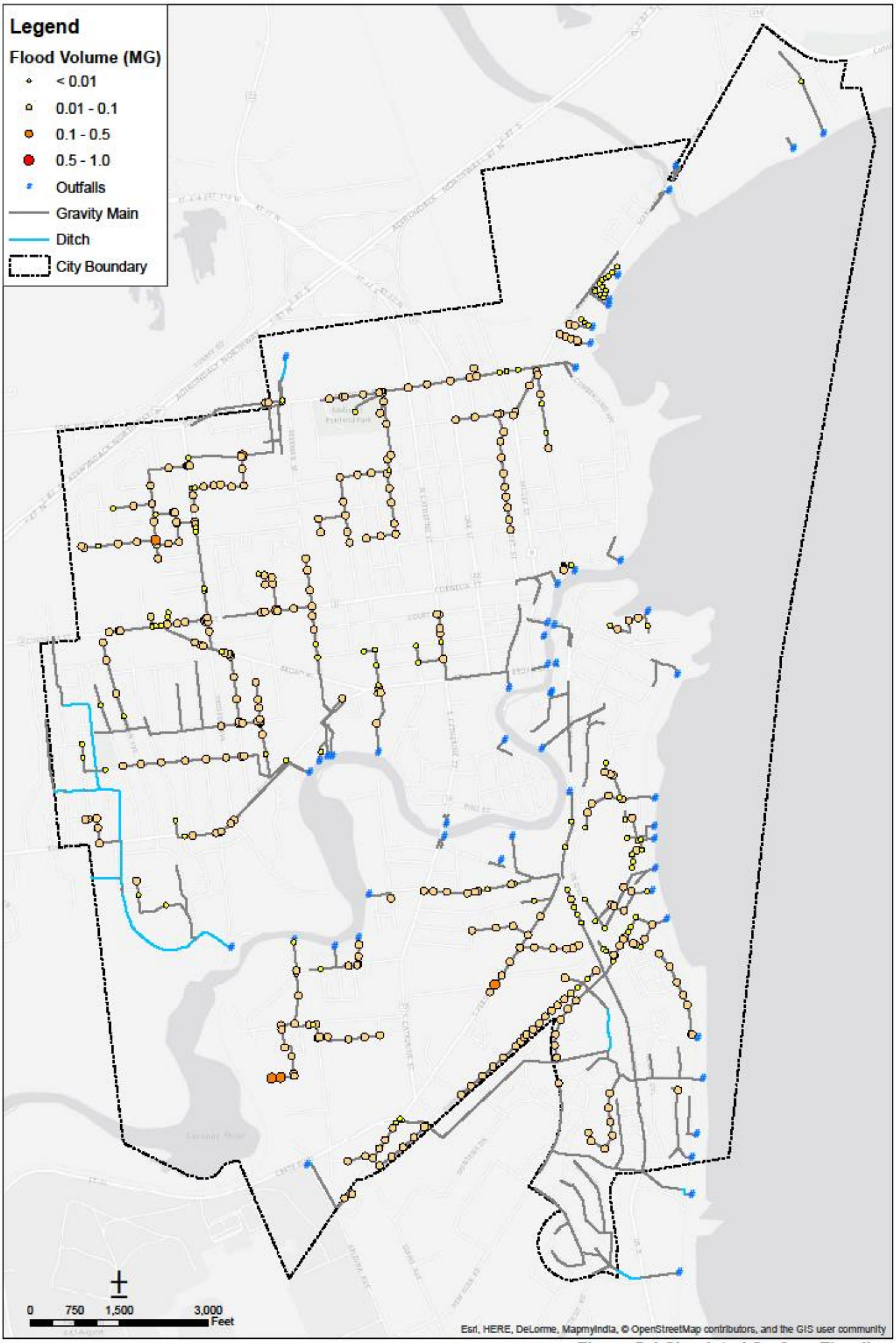
Figure 5-3 Simulated Flooding and Minimum Depth Below Rim
5-yr Design Storm
Plattsburgh, NY



CDM Smith

Figure 5-4 Simulated Surface Flooding
10-year Design Storm
Plattsburgh, NY

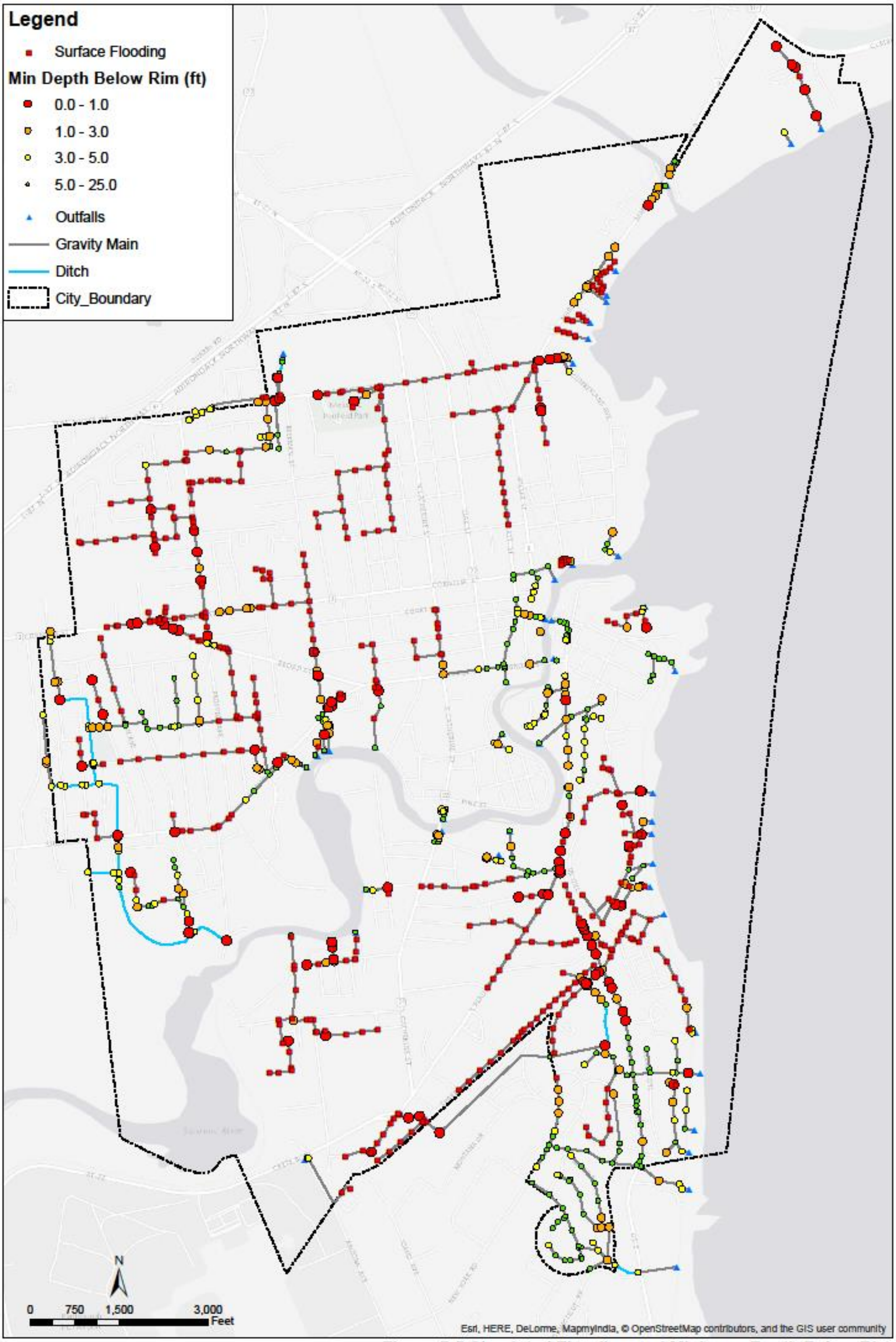


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Figure 5-5 Simulated Flooding and Minimum Depth Below Rim
10-yr Design Storm
Plattsburgh, NY

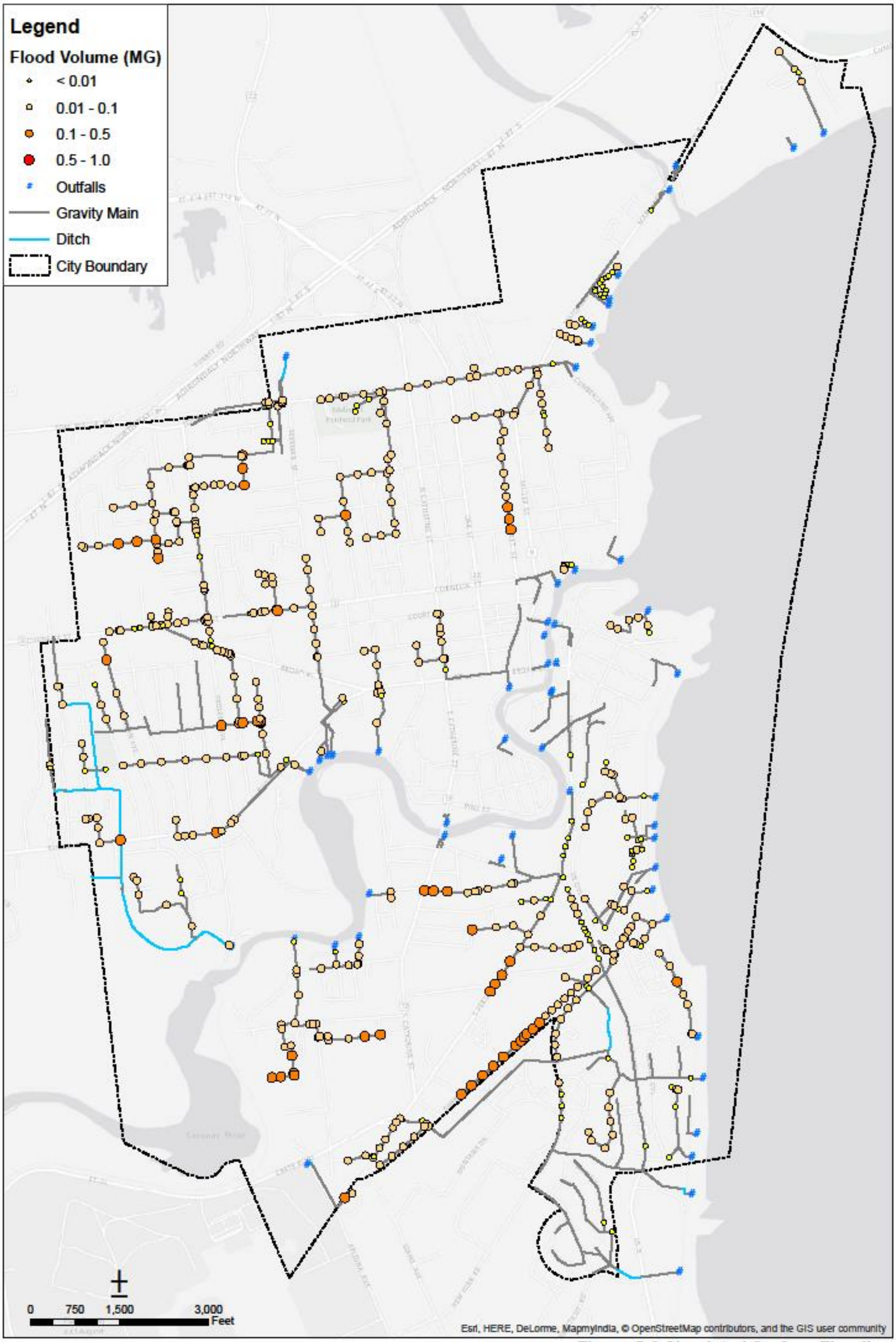

Figure 5-6 Simulated Surface Flooding
25-year Design Storm
Plattsburgh, NY

CDM Smith

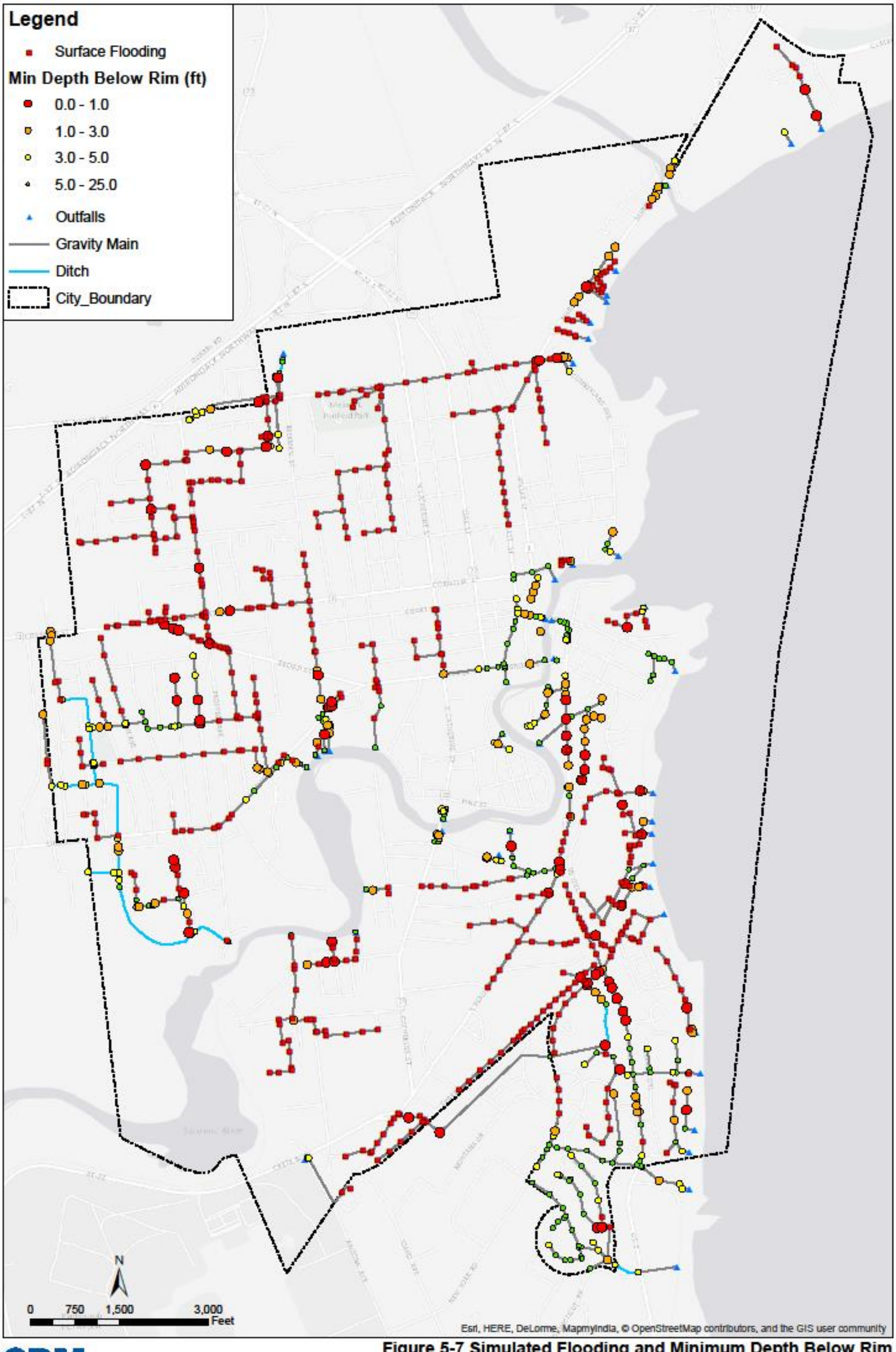

Figure 5-7 Simulated Flooding and Minimum Depth Below Rim
25-yr Design Storm
Plattsburgh, NY

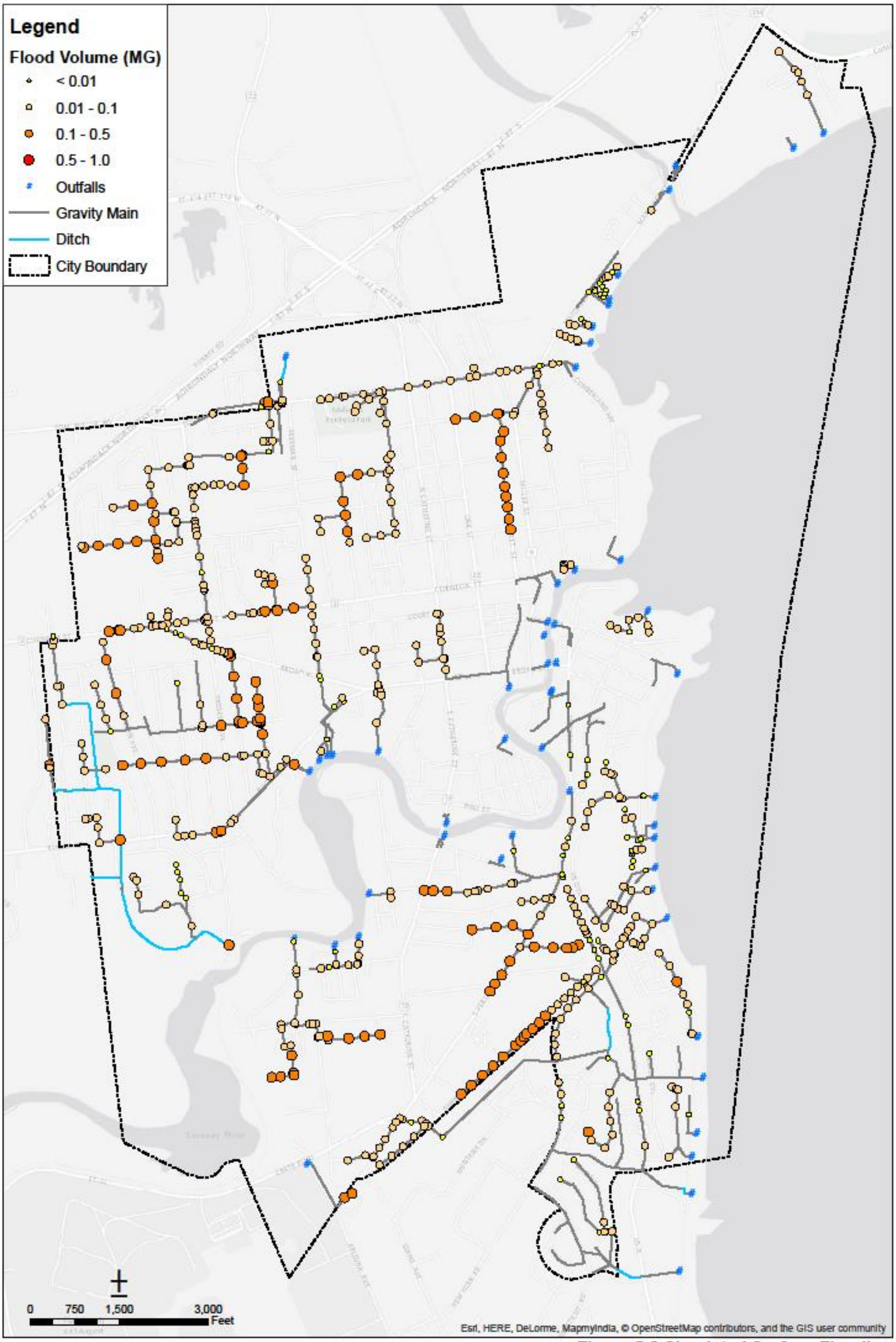

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Figure 5-8 Simulated Surface Flooding
50-year Design Storm
Plattsburgh, NY

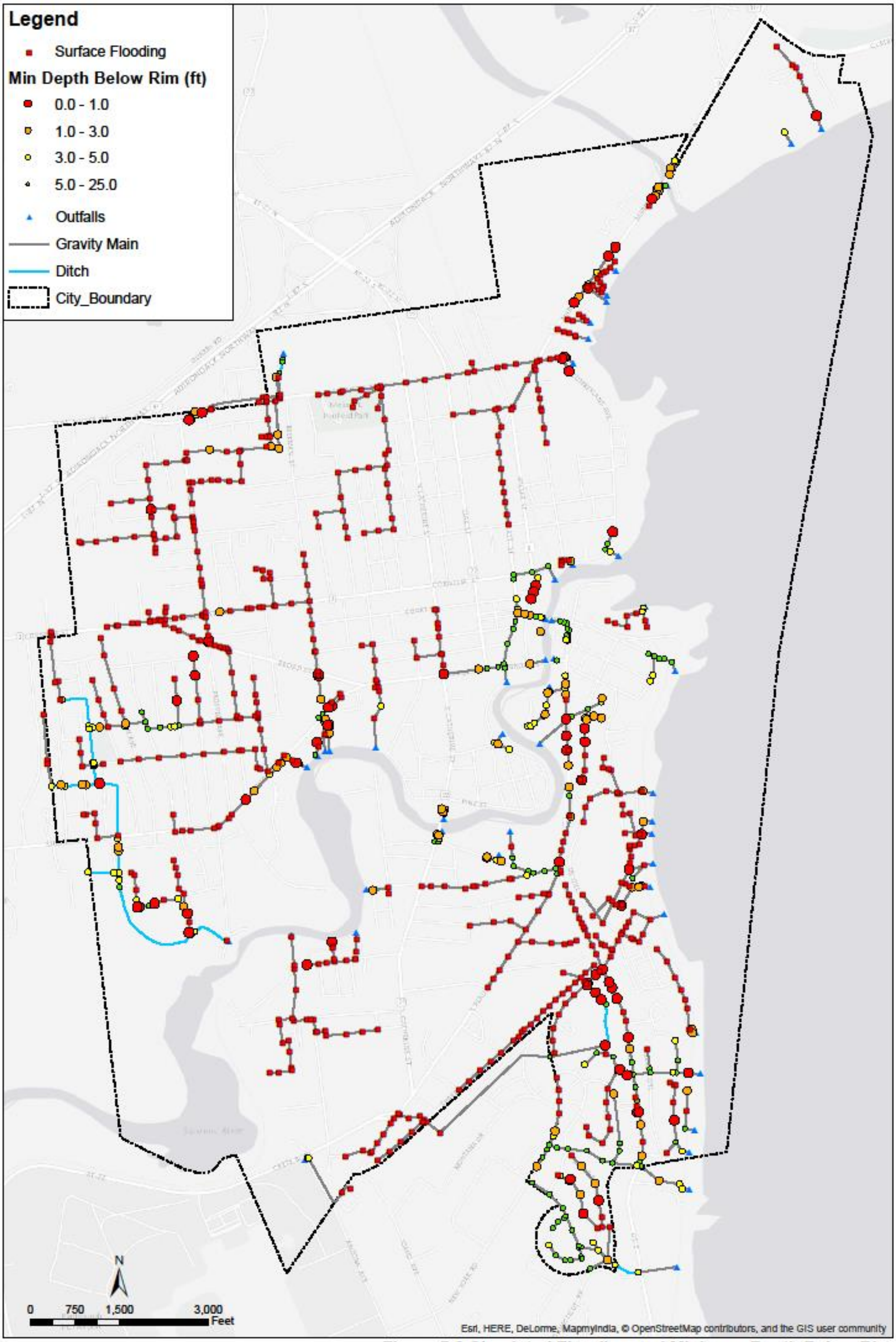

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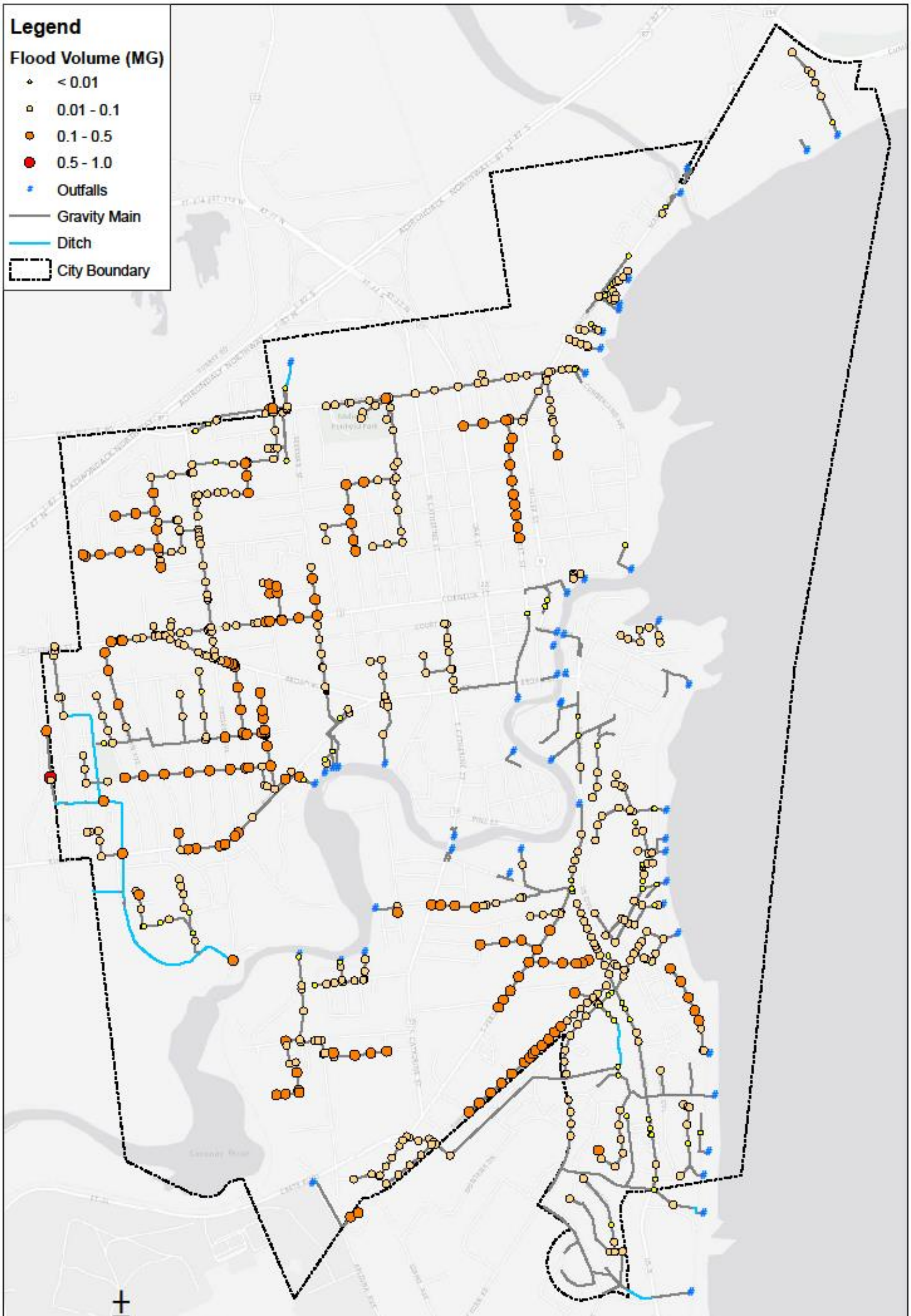
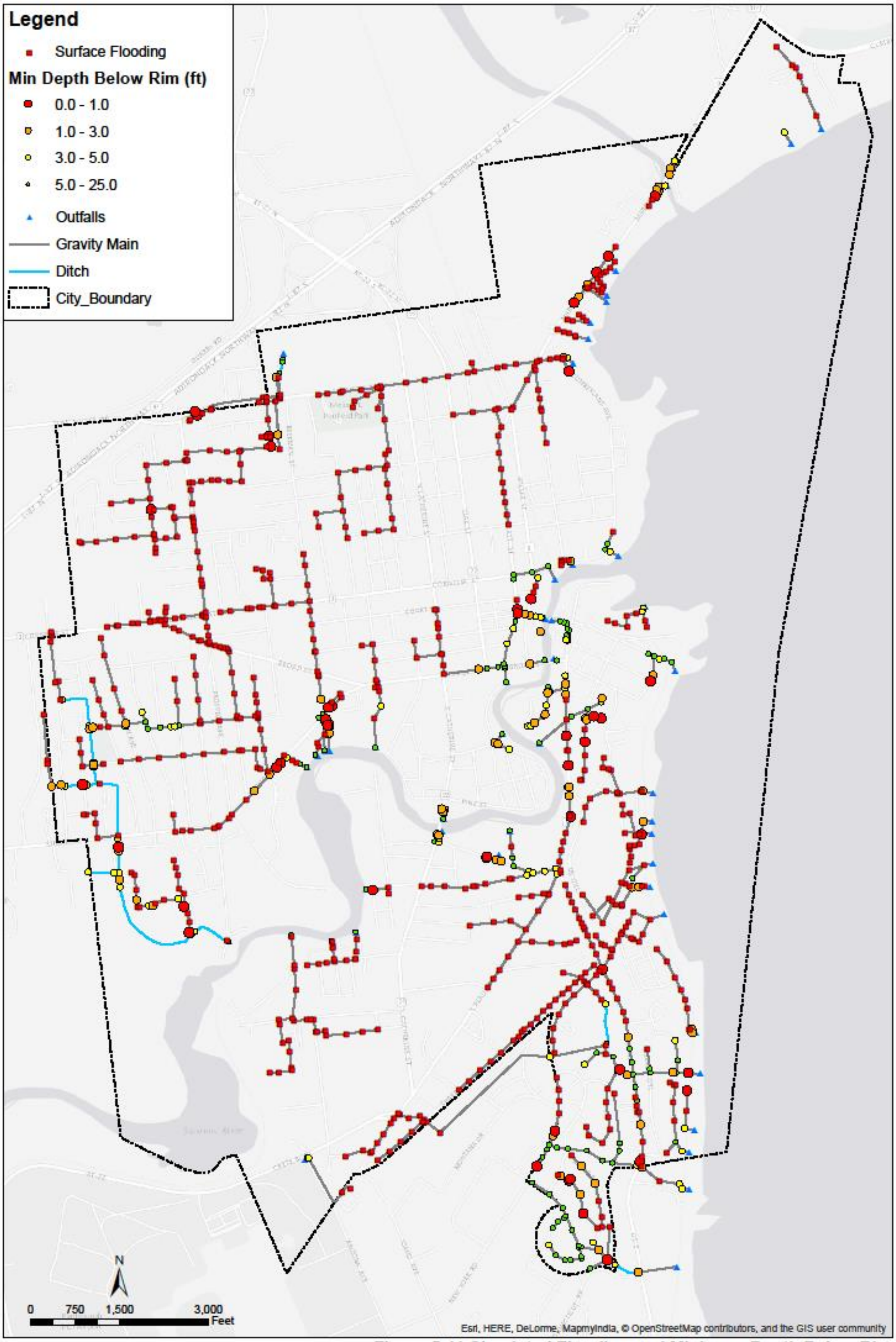
Figure 5-9 Simulated Flooding and Minimum Depth Below Rim
50-yr Design Storm
Plattsburgh, NY



CDM Smith

Figure 5-10 Simulated Surface Flooding
100-year Design Storm
Plattsburgh, NY



CDM Smith

Figure 5-11 Simulated Flooding and Minimum Depth Below Rim
100-yr Design Storm
Plattsburgh, NY

5.2 Project Prioritization

Utilizing the SWMM Model information, each site was ranked using the Site Evaluation Ranking Matrix to identify those that would aid in the greatest environmental benefit for stormwater quantity reduction and water quality improvements. The maximum achievable score is a 90, and sites with the highest numbers are deemed high priority for implementation.

Table 5-1. Site Evaluation Ranking Matrix Scores per Project Site

RANKING PARAMETERS	RANKED SCORES											
	Broadway Rd. Playground	Flaglar Drive Playground	Melissa L. Penfield Park	Bailey Avenue School	Oak Street School	City Pier/Wharf	US Oval Parking Lot	Monty Street School	Clifford Drive School	Park Avenue West Park	Durkee Street Parking Lot	Cornelia Ave. Right-of-Way
Level of Coordination necessary to implement GI project	5	5	5	1	1	5	5	1	1	5	5	3
Is the property City owned?	5	5	4	1	1	5	5	1	1	5	5	3
SUBWATERSHED ASSESSMENT												
Site Slope	5	5	5	5	5	4	5	5	4	5	4	5
Hydrologic Soil Group	3	2	5	5	5	5	5	5	5	4	5	5
Acreage available for siting GI projects	1	1	2	3	2	2	3	2	4	2	1	3
FLOOD REDUCTION												
Is the site within a flood prone area?	5	5	5	5	5	5	5	5	5	5	3	5
For the 5-year design storm, are storm manholes surcharged above the ground surface?	5	1	5	5	5	5	5	5	5	5	1	1
For the 10-year design storm, what level of flooding occurs in the site or manholes directly upstream of the site?	3	3	3	3	3	3	3	3	2	2	2	4
Does the site or area immediately around the site contribute to flood problems downstream in the sub-sewershed?	5	5	1	1	1	1	3	3	3	5	1	5
Number of CSO events in the subwatershed over the past 5 years	1	1	1	1	1	1	1	1	1	1	1	1
POLLUTANT REDUCTION												
Proximity to storm sewer inlet	4	3	5	4	4	4	5	4	1	3	5	5
Existing stormwater treatment system?	5	5	5	5	5	1	5	5	5	5	5	5
Major land-use within sub-sewershed	1	1	1	1	1	5	3	1	1	2	5	3
Imperviousness of sub-sewershed	1	1	2	2	2	4	4	2	2	2	5	5
Does the project address a direct discharge into: Lake Champlain (5 points) Saranac River (3 points) Other (1 point)	1	1	5	5	5	5	5	3	3	3	3	3
Will the project reduce stormwater flow into a CSO?	1	1	1	1	1	1	1	1	1	1	1	1
NATURAL SYSTEM ENHANCEMENT												
Will the project enhance/preserve natural vegetation?	5	5	3	3	3	1	5	3	3	5	3	3
PROJECT BENEFITS												
Will the project cultivate public education opportunities?	3	3	4	4	4	2	3	4	4	3	5	4
TOTAL POINTS	59	53	62	55	54	59	71	54	51	63	60	64

Based on the outcome of the Site Evaluation Ranking Matrix, the US Oval Parking Lot is the best project site to implement a green infrastructure practice to address water quantity reductions and water quality improvements, followed by the Cornelia Avenue Right-of-Way, Park Avenue West Municipal Park, Melissa L. Penfield Park, Durkee Street Parking Lot, Broadway Road Playground and the City Pier/Wharf, Bailey Avenue School, Oak Street and Monty Street Schools, Flaglar Drive Playground and

Clifford Drive School. It is important to note that the ranking matrix does not take into account actual feasibility of placing a green infrastructure project at the site, but indicates that sites with a higher score have the greatest potential to reduce water quantity and improve water quality.
The next step in the process was to determine which green infrastructure projects were the most likely to aid in achieving the City's goal at the US Oval site, which includes reducing water volume while improving water quality. To do this, seven types of green infrastructure practices were chosen and ranked. Results can be found in Table 5-2.

Table 5-2. Green Infrastructure Practice Ranking Matrix Scores for US Oval Project

GI PRACTICE RANKING PARAMETERS	RANKING SCORES						
	Vegetated Swale	Tree Plantings/ Tree Pits	Disconnection of rooftop runoff	Rain Garden/ Bioretention Area	Stormwater Planters	Rain Barrel/ Cisterns	Porous Pavers
PROJECT ACHIEVABILITY							
Compatibility with urban environment	1	5	5	3	3	5	3
Depth to groundwater necessary for installation	3	1	5	1	3	5	1
Will overhead or underground utilities need to be relocated for installation?	5	3	5	1	3	5	1
Drainage area GI practice can treat as it relates to impervious surface of the site.	3	1	1	5	1	1	5
Cost for installation	3	3	5	1	3	5	1
Maintenance requirements	4	3	5	3	1	3	1
PROJECT BENEFITS							
Reduction in effective imperviousness by GI practices	2	2	1	5	2	1	4
Method of runoff retention	1	3	1	5	3	1	3
Does the project address phosphorus reduction?	4	5	1	5	5	1	3
Will the project improve habitat for wildlife?	3	3	1	3	3	1	1
Will the project improve aesthetics of the area?	3	5	1	5	5	1	1
TOTAL POINTS	32	34	31	37	32	29	24

The Green Infrastructure Practice Matrix indicated that rain gardens and bioretention areas are the most practical and effective practice for installation at the US Oval due to its ability to retain water volume and reduce stormwater pollution through plant uptake and utilization.

5.3 Green Infrastructure Project Site Assessment

Utilizing the results from the Site Evaluation Ranking Matrix, project partners identified the top three project sites for consideration in implementing green infrastructure projects; (3) Park Avenue West Municipal Park; (2) Cornelia Street Right-of-Way and (1) US Oval, and created a generalized plan for green infrastructure project implementation for the top three sites.

5.3.1 #3: Park Avenue West Municipal Park

The Park Avenue West Municipal Park is a 4.6 acre park located on the western border of the City. The Park is a relatively open space, sans the location of a soccer field that would not be able to be utilized for stormwater retention. The site evaluation identified that although the Park itself does not create a large volume of stormwater, it has the potential to reduce volume from its surrounding streets by accepting redirected stormwater flow. This could be achieved through utilizing rain gardens and small bioretention areas throughout the Park to direct flow from the streets for retention and infiltration. This

would, however, include re-routing existing stormwater conveyance pipes within the streets, which will add to the cost of the project, as well as decrease its feasibility. However, the City has concluded that during any capital project work in the area, staff will assess the use of the park for green infrastructure project implementation.

Figure 5-12. Aerial Image of the Park Avenue West Municipal Park

5.3.2 #2. Cornelia Street Right-of-Way

The Cornelia Street Right-of-Way (ROW) was chosen as a project site to emphasize the importance of implementing green infrastructure practice along roadways. Urbanized areas, such as the City, do not possess a large amount of open land for retrofits, and ROWs can be utilized to quickly capture and infiltrate stormwater runoff from City streets. This particular ROW on Cornelia Street is the site of a large trunkline that accepts stormwater runoff from several surrounding streets. By collecting and infiltrating flow within this junction, flooding downstream in the City's stormwater system will be alleviated, and less polluted flow will enter into the Saranac River. This project, however, will include a major capital project with high costs and low achievability, but there is the potential for installation of stormwater planters, rain gardens or rain barrels at commercial buildings and homes to aid in attenuating some of the flow from the direct area, as well as in areas upstream of the system.

5.3.3 #1. US Oval

The US Oval is part of the United States Military Air Force Base that was closed in 1995. Since then, the City has purchased portions of the base for various uses, including a 30 acre recreation field, 4.5 acre lot for parking, and a building across the street from the field that now houses the City's recreational facilities. Although the parking lot is where the majority of the stormwater volume originates via sheet flow into the surrounding street, a site evaluation identified the potential for a bioretention area to be constructed adjacent to the recreational facility building. This is the project that was chosen by the City for the implementation portion of this funding.

Figure 5-13. Aerial Image of the US Oval Showing Location of the City Recreation Facility with Surrounding Street and Parking Lot

The building that houses the City's recreational facilities is situated on the lowest elevation point of the sewershed and receives sheet flow from the surrounding street and parking lot, as well as runoff from the building's large roof system. In high intensity storms, the front doors and lower windows of the building flood, as well as portions of the street. To combat this, a large bioretention area will be built in a field adjacent to the gym, and much of the runoff from the parking lot and road will be directed to the bioretention area. This project will not only decrease stormwater runoff and flooding from high intensity rain events, but also act as a demonstration project for local contractors and the public on the importance an applicability of green infrastructure projects. The site is also incredibly close to Lake Champlain, adding to its appeal and educational value.

5.4 US Oval Bioretention Project Implementation

The US Oval Bioretention Basin was completed in the summer of 2015. The overall goal of the project was to maximize the amount of stormwater runoff captured and infiltrate it into the ground, rather than allowing it to enter the normal stormwater system and be discharged to Lake Champlain.

5.4.1 Project Design

Preliminary data collection at the site was performed by staff at the City and included a soil permeability test, which indicated a highly permeable, sandy soil was present, and estimation of the depth to groundwater, which was determined to be below the required minimum based upon both historical observation and observations during the permeability tests. Thorough evaluation of the site showed that the site itself gently slopes away from the U.S. Oval road to the east toward Lake Champlain, and was mostly grass cover with one tree in fair condition. Utilities are present on the outer edges of the parcel, but the open space in middle of the parcel is free of utilities based upon the investigation of site utilities. The parking lot and adjacent roadway are up-gradient of the site, and there were storm drain inlets in the road which were at an elevation to allow redirection to the bioretention basin.

Figure 5-14. Aerial Image of the City's Recreational Facility and Bioretention Site

Based upon the space that was available, a basin area of 1200 square feet and total volume of 9700 cubic feet, along with a water quality volume of the drainage area calculated at 8300 cubic feet, were determined. This information was utilized in the water quality volume equation and filter bed area equation provided in the NYS DEC Stormwater Management Design Manual, to identify the volume of stormwater that could be treated. This lead to the identification of the area of parking lot and roadway that could be redirected to the bioretention basin. The existing drainage infrastructure within this area was evaluated and various methods of conveyance to the basin, including swales, pipe networks and sheet flow, were explored, taking into consideration impact, cost, and aesthetics. A preliminary layout of the basin was created and vetted, specifically considering aesthetics, handicap, public and maintenance crew access, and integration into the existing landscape, including shape, benches and signage. It was then determined that a vegetated swale on the opposite side of the road would be integrated into the project to capture additional stormwater from the parking lot, and a layout for that was created, taking into consideration vehicular circulation, parking and existing trees and utilities. Once the preliminary design was agreed upon, size conveyance calculations, which can be seen in Appendix A, were determined for each contributing area, including;

- time of concentration and rainfall intensity for 10 and 25 year storm events for a duration equal to the time of concentration,
- runoff coefficients based on drainage area characteristics,
- peak flow rates from the sub-sewersheds to each pipe and catch basin using the Rational Method,
- pipe sizing using the Manning Equation, and

- inlet capacity to pipes and for inlets to ensure flow can get into the pipes.

The peak flow to the bioretention basin, which is 5.3 cfs for 10-year storm event and 6.4 cfs for a 25-year storm event, and bottom elevation of 49.5 were finalized based on depth to bedrock or groundwater as described in the NYS DEC Stormwater Management Design Manual. It was determined unnecessary to remove the soil that was present at the area because of its high permeability. The basin was designed without an underdrain, as stormwater is expected to exfiltrate into the soil. For large storm events, flow will be conveyed through an elevated outlet located two feet above the basin, which was conservatively designed to convey the peak influent flow rate to the basin (6.3 cfs for a 25-year frequency, 15 minute duration storm). The pipe size is a 15-inch diameter which in consistent with the other pipe diameters used on the project.

A planting plan was developed for the basin taking into consideration the use of New York native species in an effort to not only better integrate the bioretention area into its surroundings, but to utilize plant material with deeps roots for maximum water and nutrient uptake, while decreasing the likelihood of having to replace dead plants. An appropriate seed mix that will be able to tolerate the extreme conditions of both drought and inundation was also identified for establishment on the basin floor.

5.4.2 Project Construction

Bids were accepted by the City for construction of the project, and the winning bid was delivered by Northern Snow and Dirt, Inc. The total project cost for the bioretention area and bioswale was $112,000. The bioswale was constructed to convey at least 4.6 cfs, and is connected to the bioretention basin via an underground pipe. Two catch basins located in the street will convey 1.8 cfs, and are also directly connected to the bioretention basin. All together, the project receives flow from 2.5 acres, of which 1.5 acres is impervious.

Figure 5-15. Photo of bioswale

Figure 5-16. Photo of bioretention basin

Figure 5-17. Photo of bioretention basin inlet

Figure 5-18. Photo of bioretention basin outlet

Photos provided by Fred Dunlap, NYS DEC

New York native plants species within the basin include Buttonbush, Gray Dogwood, Red Twig Dogwood, Eastern Ninebark, Big Bluestem, New England Aster, Joe Pye Weed, Blue Lobelia, and New York Ironweed.

5.4.3 Public Outreach and Education

Several public outreach and education components were incorporated into this project, including the creation of two signs located at the project site to describe the project components, as well as discuss the environmental benefits of the project and highlight how homeowners can achieve green infrastructure projects on their properties.

Figure 5-19. Bioretention Basin Signs

Figure 5-20. Photo of City Engineer Kevin Farrington at the ribbon cutting on July 27, 2015.

Figure 5-21. Photo of Councillor Rachelle Armstrong cutting the ribbon at the bioretention basin on July 27, 2015

An educational pamphlet entitled "*City of Plattsburgh: Introducing Homeowners to Green Infrastructure"* was also created as part of this project, and more specifically outlines how homeowners can help, including the basics of planting a rain garden, rain barrels, permeable pavers, and information on the NYS Dishwasher Detergent and Nutrient Runoff Law. Printed copies of the pamphlet are available at City Hall and electronic copies are available upon request.

The final public outreach component of the project was a ribbon cutting ceremony that was held at the bioretention basin location on July 27, 2015. City Councillor Rachelle Armstrong welcome the attendees… "I think we really have reason to celebrate," said at the event, "because this project represents a significant turning point in the way we regard our relationship to nature — a relationship that, as a result of climate change, we've been forced to re-evaluate." City Engineer Kevin Farrington discussed the technical aspects of the project at the hour long event, which was covered by reporters from the Press Republican, WPTZ News Channel 5, Vermont Public Television and Saranac Lakes' 106.3.

6 Conclusions

As a result of the work performed under this project, the City of Plattsburgh is now much more equipped to address stormwater volume reductions and stormwater quality improvements throughout the City, which will aid elected officials within the City in making important choices for the betterment of Lake Champlain as a whole. This will be achieved through utilizing the completed mapping system to identify areas for improvement within the City's sub-surface infrastructure, and utilizing the information obtained through the vulnerability analysis to pinpoint areas within the City that could become issues should be weather patterns continue as they have in recent years. The City is also open to the idea of working with green infrastructure technologies not only for the improvement of water quantity and quality, but also for the quality of life of the residents within the City.

NEW YORK STATE DEPARTMENT OF HEALTH
Bureau of Water Supply Protection

Percolation Test Data
(see instructions on reverse side)

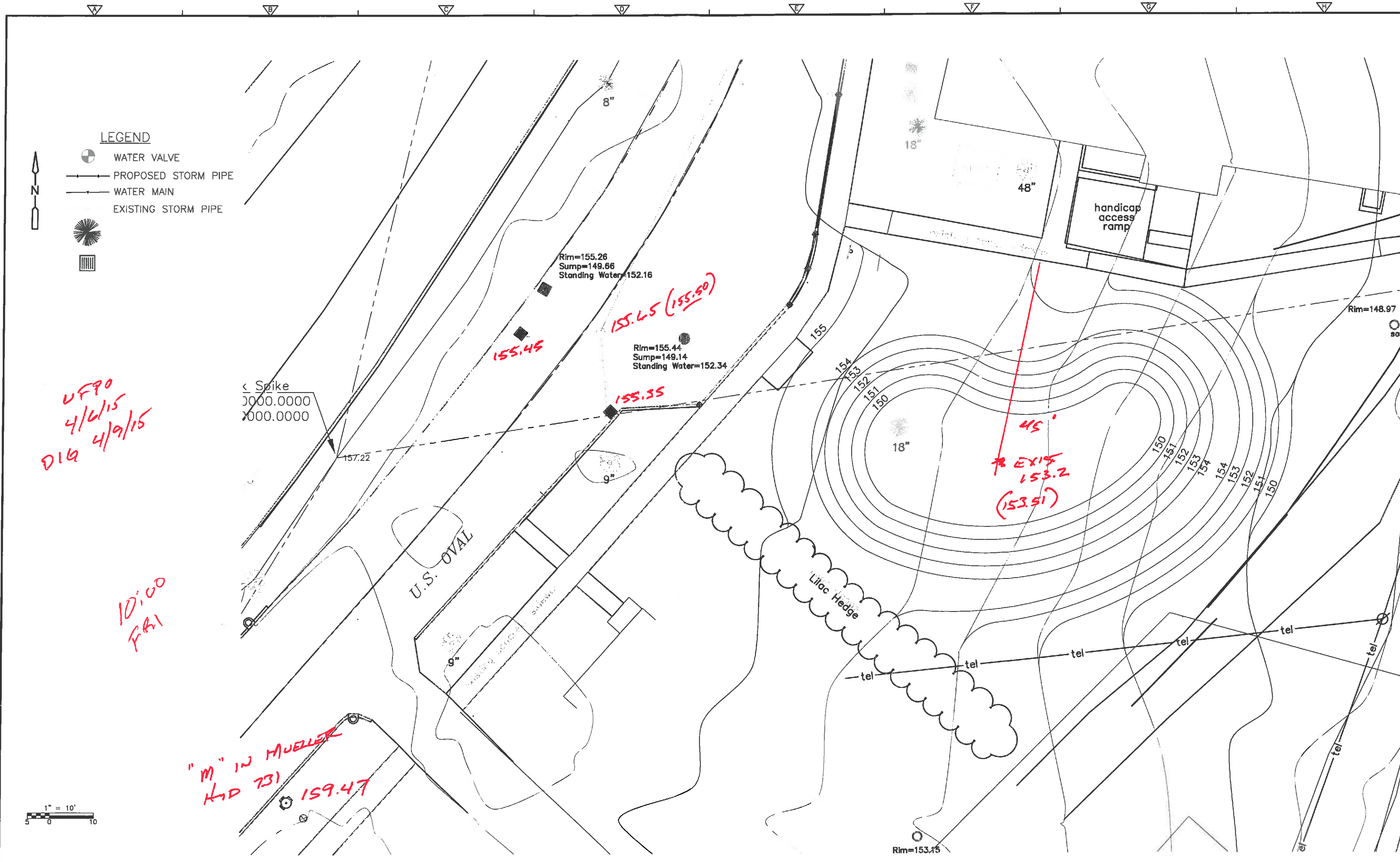
Development Site: REC. DEPT. BASE/GYM (T/V/C): ____ County: CLINTON

Date: 4/13/15 Tests Conducted By: ____

Weather Conditions: CLEAR 70° WINDY

Test Hole No.	Test Hole Depth (inches)	Lot No.	Soil Profile Description and Groundwater Depth (if identified)	Presoaking Date & Time	Time	Percolation Test (TIME) 1	2	3	4	5	6
#1	EXIST. GRND 153.50 TOP PERK HOLE 150.0 28"		0-8" TOPSOIL 8"-2'-10" SAND (BRICKS) 2'-10"-5'-2" SAND (PERC HOLE)	4/13/15 1 HR.	End						
					Begin						
					Result	38"	50"	1'-19"	1'-23"	1'-20"	1'-22"
			NOTES 1'-19" = 1 min 19 SECONDS		End						
					Begin						
					Result						
					End						
					Begin						
					Result						
					End						
					Begin						
					Result						
					End						
					Begin						
					Result						
					End						
					Begin						
					Result						

Begin time, end time, and result in minutes for a water elevation change from 6" to 5" above the bottom of the test hole.



REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY:
DRAWN BY:
SHEET CHK'D BY:
CROSS CHK'D BY:
APPROVED BY:
DATE:

CDM Smith
6800 Old Collamer Road Ext, Suite 3
East Syracuse, NY 13057
Tel: (315) 434-3200

CITY OF PLATTSBURGH, NY

CITY OF PLATTSBURGH STORMWATER AND GREEN INFRASTRUCTURE PLANNING PROJECT

U.S. OVAL GREEN INFRASTRUCTURE DEMONSTRATION PROJECT
BIORETENTION GRADING PLAN

PROJECT NO. XXXXX-XXXXX
FILE NAME: CSTPL101.dwg
SHEET NO.
C-2

Calculation Form (Excel)		Job #	20738-99849	Calc. By:	EWM
Client:	City of Plattsburgh	Checked By:	NOV	Date:	04/20/15
Project:	U.S. Oval Green Infrastructure	Date:	04/28/15	Calc. No.:	1
Detail:	Bioret. Basin Design	Reviewed By:	VR	Revision#:	
		Date:	04/28/15	Date:	

BIORETENTION BASIN DESIGN CALCULATIONS

Purpose: The purpose of this set of calculations is to determine the maximum catchment area that can contribute storm water flow to a bioretention basin with filter area constrained by location.

- ASSUMED
- FROM AUTOCAD PROJECTION
- FROM CALCULATIONS
- FROM NYS STORMWATER MANAGEMENT DESIGN MANUAL

Objective 1: Calculate Water Quality Volume (WQ_v) from required filter bed area formula, as the filter bed area is constrained by site location

Formula: $A_f = \frac{(WQ_v)(d_f)}{[(k)(h_f + d_f)(t_f)]}$ Rearranged for Water Quality Volume $WQ_v = \frac{(A_f)[(k)(h_f + d_f)(t_f)]}{d_f}$

Assumptions:

Total Available Filter Area =	1200.00	SF	*Filter bed area selected
% Dry Space in Filter Area =	0.00%		

Known:

Filter Bed Area =	A_f =	1200	SF	
Filter Bed Depth =	d_f =	2.75	ft	
Coeff. Permeability =	k =	3.5	ft/day	*From NYS Stormwater Management Design Manual, p. 6-52
Avg. Ponded Water =	h_f =	0.5	ft	*From NYS Stormwater Management Design Manual, 6" ponded depth
Design Drain Time =	t_f =	1.67	days	*From NYS Stormwater Management Design Manual, p. 6-52

Find: WQ_v

WQ_v = 8289.273 CF

Objective 2: Determine Maximum Catchment Area (A) that can contribute to the bioretention basin from WQv calculated in Objective 1
Calculate Catchment Area via Water Quality Volume formula

Formula: $WQ_v = \frac{(P)(R_v)(A)}{12}$ Rearranged for Catchment Area $A = \frac{12WQ_v}{(P)(R_v)}$

Assumptions: Impervious Catchment Area = I = 98.00 %

Known:

Water Quality Volume =	WQv =	8289.273	CF	*Determined from Objective 1
90% Rainfall Event Number =	P =	0.9		*NYS Stormwater Management Design Manual p. 4-2, Figure 4.1
0.05 + 0.009(I) =	Rv =	0.932		*NYS Stormwater Management Design Manual

Find: Maximum Catchment Area

A =	118588	SF	
A =	2.72	acres	< 10 acres maximum

Conclusions: Based on drainage area above, a bioretention basin with filter bed area of 1200 SF can have up to 2.7 acres of collective catchment area.

Calculation Form (Excel)		Job #	20738-99849	Calc. By:	EWM
Client:	City of Plattsburgh	Checked By:	NOV	Date:	04/28/15
Project:	U.S. Oval Green Infrastructure	Date:	04/28/15	Calc. No.:	1
Detail:	Conveyance Pipe Sizing	Reviewed By:	VR	Revision#:	
		Date:	04/28/15	Date:	

PIPE SIZING CALCULATIONS FROM SWALE TO BASIN

Purpose: The purpose of this set of calculations is to size conveyance piping from bioswale to manhole to bioretention basin.

ASSUMED
FROM AUTOCAD PROJECTION
FROM CALCULATIONS

Objective 1: Determine Drainage Area and Area of Bioretention Basin
Determine Rainfall Amounts for 10, 25-year storm

Parking Lot Catchment Area =	1	acres	
Park Catchment Area =	1	acres	
10-year Rainfall =	3.08	inch/hr	*Cornell Northeast Regional Climate Center (intensity for a 15 minute rainfall at an average recurrence interval of 10 years)
25-year Rainfall =	3.68	inch/hr	*Cornell Northeast Regional Climate Center (intensity for a 15 minute rainfall at an average recurrence interval of 25 years)

Objective 2: Size Each Section of Pipeline to Convey Stormwater to Bioretention Basin. Size for 10-year storm.

Objective 2a: Size Pipeline to Convey Stormwater From Bioswale to Bioretention Basin: Determine Flowrate (Q) for 10-year storm

Formula: Q =CIA Rational Method will be used to determine Q

Assumptions:	Park. Lot Runoff Coefficient =	C1 =	0.95	
	Park Runoff Coefficient =	C2 =	0.30	
Known:	10 Year Rainfall Intensity =	i =	3.08	in/hr
	Parking Lot Catchment Area =	A =	1	acres
	Park Catchment Area =	A =	1	acres

Find: Flow Rate

Qpark =	0.92	cfs	*This is flow from park area
Qlot =	2.93	cfs	*This is flow from parking lot area
Q =	3.85	cfs	*This is sum of flows from park and parking lot area

Objective 2b: Size Pipeline to Convey Stormwater From Bioswale to Bioretention Basin: Determine Minimum Pipe Size for 10-year storm

Formula: Manning's Equation

$$Q = \frac{1.49AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

Rearranged for Pipe Diameter

$$d = \left(\frac{4^{\frac{5}{3}}Qn}{1.49\pi S^{\frac{1}{2}}}\right)^{\frac{3}{8}}$$

Derivation of rearranged manning's equation shown under Attachment

Assumptions:	Friction factor =	n =	0.013	RCP pipe friction factor
Known:	Flow Rate =	Q =	3.85	cfs
	Length of Pipe =	L =	102.00	ft
	Starting Invert =	=	154.72	
	End Invert =	=	150.25	
	Slope =	S =	0.043824	ft/ft

Find: Minimum Required Pipe Diameter

d =	0.78	ft	
d =	9.36	inches	*For storm drain design, it is standard practice to use a minimum 12" diameter pipe

Pipe Selection: d = 12.00 inch RCP   Area = 0.79 SF

A 12" diameter pipe at conditions described above (slope, Mannings n) will convey:	7.48	cfs
Velocity in the 12" pipe at peak flow in a 10 year, 15 minute storm will be:	4.90	ft/s

Check inlet flow rate via Orifice Equation:

Formula: $Q = CA\sqrt{2gh}$ $H = H_1 - H_2$

Assumptions:	Coefficient of Discharge	C =	0.600	
Known:	Area =	A =	0.79	SF
	Gravity =	g =	32.20	ft/s^2
	Crown of Pipe =	H_1 =	155.85	ft
	Centerline of Pipe =	H_2 =	155.22	ft
	Head =	H =	0.63	ft

Q (12") =	2.99	cfs	is not >	3.85	cfs	Orifice Equation Does NOT Check - inlet is too small, try 15" diameter pipe
Q (15") =	4.68	cfs	>	3.85	cfs	Orifice Equation Checks

Conclusions: For a 10 year storm, a 15-inch diameter pipe is required

Objective 3: Size Sections of Pipeline to Convey Stormwater from Bioswale to Bioretention Basin. Size for 25-year storm.

Objective 3a: Size Pipeline to Convey Stormwater From Bioswale to Bioretention Basin: Determine Flowrate (Q) for 25-year storm

Rational Method will be used to determine Q

Formula: Q =CIA

Assumptions:

Park. Lot Runoff Coefficient =	C3 =	0.95	
Park Runoff Coefficient =	C4 =	0.30	

Known:

25-year Rainfall Intensity =	i =	3.68	in/hr
Parking Lot Catchment Area =	A =	1	acres
Park Catchment Area =	A =	1	acres

Find: Flow Rate

Qpark2 =	1.10	cfs	*This is flow from park area
Qlot2 =	3.50	cfs	*This is flow from parking lot area
Q =	4.60	cfs	*This is sum of flows from park and parking lot area

Objective 3b: Size Pipeline to Convey Stormwater From Bioswale to Bioretention: Determine Minimum Pipe Size for 25-year storm

Formula: Manning's Equation

$$Q = \frac{1.49AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

Rearranged for Pipe Diameter See Sheet1

$$d = \left(\frac{4^{\frac{5}{3}}Qn}{1.49\pi S^{\frac{1}{2}}}\right)^{\frac{3}{8}}$$

Assumptions:

Friction factor =	n =	0.013	RCP pipe friction factor

Known:

Flow Rate =	Q =	4.60	cfs
Length of Pipe =	L =	102.00	ft
Starting Invert =	=	154.72	
End Invert =	=	150.25	
Slope =	S =	0.043824	ft/ft

Find: Minimum Required Pipe Diameter

d =	0.83	ft	
d =	10.00	inches	*For storm drain design, it is standard practice to use a minimum 12" diameter pipe

Pipe Selection:

d =	15.00	inch RCP	Area =	1.23	SF

A 15" diameter pipe at conditions described above (slope, Mannings n) will convey: 13.56 cfs

Velocity in the 15" pipe at peak flow in a 25 year, 15 minute storm will be: 3.75 ft/s

Note that as part of the iterative process, after checking the orifice equation for a 12" and not having enough capacity, the pipe diam. was increased to 15"

Check via Orifice Equation:

Formula:

$$Q = CA\sqrt{2gh}$$
$$H = H_1 - H_2$$

Assumptions:

Coefficient of Discharge	C =	0.600	

Known:

Area =	A =	1.23	SF
Gravity =	g =	32.20	ft/s^2
Crown of Pipe =	H_1 =	155.85	ft
Centerline of Pipe =	H_2 =	155.22	ft
Head =	H =	0.63	ft

Check: Flow Rate

Q =	4.67	cfs	>	4.60	cfs	Orifice Equation Checks

Conclusions: For a 25 year storm, design criteria indicates a **15-inch** RCP pipe would convey the calculated flow rate from the drainage area described above.

Calculation Form (Excel)		Job #	20738-99849	Calc. By:	EWM
Client:	City of Plattsburgh	Checked By:	NOV	Date:	04/28/15
Project:	U.S. Oval Green Infrastructure	Date:	04/28/15	Calc. No.:	1
Detail:	Conveyance Pipe Sizing	Reviewed By:	VR	Revision#:	
		Date:	04/28/15	Date:	

CONVEYANCE PIPE SIZING CALCULATIONS - CB1 to CB2 to Basin

Purpose: The purpose of this set of calculations is to size conveyance piping from catch basin to 2nd catch basin to bioretention basin.

(yellow)	ASSUMED
(green)	FROM AUTOCAD/DRAWINGS
(purple)	FROM CALCULATIONS

Objective 1: Determine Catchment Area
Determine Rainfall Amounts for 10, 25-year storm

1st Catch Basin Catchment Area =	0.25	acres	*Assumed half of total catchment area contributes to first catch basin (CB1)
Total Catchment Area =	0.5	acres	
10-year Rainfall =	3.08	inch/hr	*Cornell Northeast Regional Climate Center (intensity for a 15 minute rainfall at an average recurrence interval of 10 years)
25-year Rainfall =	3.68	inch/hr	*Cornell Northeast Regional Climate Center (intensity for a 15 minute rainfall at an average recurrence interval of 25 years)

Objective 2: Size Each Section of Pipeline to Convey Stormwater to Bioretention Basin. Size for 10-year storm.

Objective 2a: Size Pipeline to Convey Stormwater From Catch Basin to Bioretention Basin: Determine Flowrate (Q) for 10-year storm

Formula: Q =CiA Rational Method will be used to determine Q

Assumptions: Runoff Coefficient = C = 0.95

Known:

10 Year Rainfall Intensity =	i =	3.08	in/hr
1st Catch Basin (CB1) Catchment Area =	A1 =	0.25	acres
Total Catchment Area =	A2 =	0.5	acres

Find: Flow Rate

Q1 =	0.73	cfs	this is flow into the 1st catch basin labeled CB 1 on drawing C-4
Q2 =	1.46	cfs	this is total flow into both catch basins (CB 1 and CB 2 on drawing C-4) that will be conveyed from CB2 to basin

Objective 2b: Size Pipeline to Convey Stormwater From Catch Basin CB 1 to CB 2: Determine Minimum Pipe Size for 10-year storm

Formula: Manning's Equation

$$Q = \frac{1.49AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

Rearranged for Pipe Diameter See Attachment

$$d = \left(\frac{4^{\frac{5}{3}}Qn}{1.49\pi S^{\frac{1}{2}}}\right)^{\frac{3}{8}}$$

Derivation of rearranged manning's equation shown under Attachment

Assumptions: Friction factor = n = 0.013 RCP pipe friction factor

Known:

Flow Rate =	Q1 =	0.73	cfs
Length of Pipe =	L =	25.00	ft
Starting Invert =	=	152.10	
End Invert =	=	151.85	
Slope =	S =	0.010	ft/ft

Find: Minimum Required Pipe Diameter

d =	0.55	ft	
d =	6.62	inches	*For storm drain design, it is standard practice to use a minimum 12" diameter

Pipe Selection: d = 12 inch RCP   Area = 0.785 sq ft

A 12" diameter pipe at conditions described above (slope, Mannings n) will convey:	3.57	cfs
Velocity in the 12" pipe at peak flow in a 10 year, 15 minute storm will be:	0.93	ft/sec

Check inlet flow rate via Orifice Equation:

Formula: $Q = CA\sqrt{2gh}$ $H = H_1 - H_2$

Assumptions: Coefficient of Discharge C = 0.600

Known:

Area =	A =	0.79	SF
Gravity =	g =	32.20	ft/s^2
Crown of Pipe =	H_1 =	152.10	ft
Centerline of Pipe =	H_2 =	151.60	ft
Head =	H =	0.50	ft

Q = 2.67 cfs > 0.73 cfs   Orifice Equation Checks

Conclusions: For a 10 year storm, design criteria indicates a **12-inch** RCP pipe will convey the calculated flow rate from the drainage area described above.

Objective 2c: Size Pipeline to Convey Stormwater From CB 2 to Bioretention basin: Determine Minimum Pipe Size for 10-year storm

Manning's Equation will be used to determine minimum pipe diameter (d)

Formula: $Q = \frac{1.49AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$ Rearranged for Pipe Diameter See Sheet1 $d = \left(\frac{4^{\frac{5}{3}}Qn}{1.49\pi S^{\frac{1}{2}}}\right)^{\frac{3}{8}}$

Assumptions: Friction factor = n = 0.013 RCP pipe friction factor

Known: Flow Rate =	Q2 =	1.46	cfs
Length of Pipe =	L =	63.00	ft
Starting Invert =	=	151.80	
End Invert =	=	150.25	
Slope =	S =	0.024603	ft/ft

Find: Minimum Required Pipe Diameter

d =	0.60	ft
d =	7.25	inches

*For storm drain design, it is standard practice to use at a minimum 12" diameter pipes

Pipe Selection: d = 12 inch RCP Area = 0.785 sq ft

A 12" diameter pipe at conditions described above (slope, Mannings n) will convey	5.60	cfs
Velocity in the 12" pipe at peak flow in a 10 year, 15 minute storm will be	1.9	ft/sec

Check inlet flow rate via Orifice Equation:

Formula: $Q = CA\sqrt{2gh}$ $H = H_1 - H_2$

Assumptions: Coefficient of Discharge C = 0.600

Known: Area =	A =	0.79	SF
Gravity =	g =	32.20	ft/s^2
Top Elevation of Water =	H_1 =	152.10	
Bottom Elevation of Basin =	H_2 =	151.60	
Head =	H =	0.50	ft

Q = 2.67 cfs > 1.46 cfs Orifice Equation Checks

Conclusions: For a 10 year storm, design criteria indicates a **12-inch** RCP pipe would convey the calculated flow rate from the drainage area described above.

Objective 3: Size Sections of Pipeline to Convey Stormwater to Bioretention Basin. Size for 25-year storm.

Objective 3a: Size Pipeline to Convey Stormwater From Catch Basin (CB2) to Bioretention Basin: Determine Flowrate (Q) for 25-year storm

Rational Method will be used to determine Q

Formula: $Q = CiA$

Assumptions:	Runoff Coefficient =	C =	0.95	
Known:	25-year Rainfall Intensity =	i =	3.68	in/hr
	1st Catch Basin Catchment Area =	A1 =	0.25	acres
	Catchment Area =	A2 =	0.5	acres

Find: Flow Rate

Q3 =	0.87	cfs
Q4 =	1.75	cfs

Objective 3b: Size Pipeline to Convey Stormwater From Catch Basin CB 2 to Basin: Determine Minimum Pipe Size for 25-year storm

Formula: Manning's Equation

$$Q = \frac{1.49AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

Rearranged for Pipe Diameter See Sheet1

$$d = \left(\frac{4^{\frac{5}{3}}Qn}{1.49\pi S^{\frac{1}{2}}}\right)^{\frac{3}{8}}$$

Assumptions:	Friction factor =	n =	0.013	RCP pipe friction factor
Known:	Flow Rate =	Q3 =	0.87	cfs
	Length of Pipe =	L =	25.00	ft
	Starting Invert =	=	152.10	
	End Invert =	=	151.85	
	Slope =	S =	0.010	ft/ft

Find: Minimum Required Pipe Diameter

d =	0.59	ft
d =	7.08	inches

*For storm drain design, it is standard practice to use a minimum 12" diameter

Pipe Selection: d = 12 inch RCP   Area = 0.785 sq ft

A 12" diameter pipe at conditions described above (slope, Mannings n) will convey	3.57	cfs
Velocity in the 12" pipe at peak flow in a 25 year, 15 minute storm will be	1.1	ft/sec

Check inlet flow rate via Orifice Equation:

Formula: $Q = CA\sqrt{2gh}$ $H = H_1 - H_2$

Assumptions:	Coefficient of Discharge	C =	0.600	
Known:	Area =	A =	0.79	SF
	Gravity =	g =	32.20	ft/s^2
	Top Elevation of Water =	H_1 =	152.10	
	Bottom Elevation of Basin =	H_2 =	151.60	
	Head =	H =	0.50	ft

Q = 2.67 cfs > 0.87 cfs   Orifice Equation Checks

Conclusions: For a 25 year storm, design criteria indicates a **12-inch** RCP pipe would convey the calculated flow rate from the drainage area described above.

Objective 3c: Size Pipeline to Convey Stormwater From Catch Basin CB 2 to Bioretention Basin: Determine Minimum Pipe Size for 25-year storm

Formula: Manning's Equation

$$Q = \frac{1.49AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

Rearranged for Pipe Diameter See Sheet1

$$d = \left(\frac{4^{\frac{5}{3}}Qn}{1.49\pi S^{\frac{1}{2}}}\right)^{\frac{3}{8}}$$

Assumptions:

Friction factor =	n =	0.013	RCP pipe friction factor

Known:

Flow Rate =	Q4 =	1.75	cfs
Length of Pipe =	L =	63.00	ft
Starting Invert =	=	151.80	
End Invert =	=	150.25	
Slope =	S =	0.024603	ft/ft

Find: Minimum Required Pipe Diameter

d =	0.65	ft
d =	7.75	inches

*For storm drain design, it is standard practice to use at a minimum 12" diameter pipes

Pipe Selection: d = 12 inch RCP   Area = 0.785 sq ft

A 12" diameter pipe at conditions described above (slope, Mannings n) will convey: 5.60 cfs

Velocity in the 12" pipe at peak flow in a 25 year, 5 minute storm will be 2.2 ft/sec

Check inlet flow rate via Orifice Equation:

Formula: $Q = CA\sqrt{2gh}$ $H = H_1 - H_2$

Assumptions:

Coefficient of Discharge	C =	0.600	

Known:

Area =	A =	0.79	SF
Gravity =	g =	32.20	ft/s^2
Top Elevation of Water =	H_1 =	152.10	
Bottom Elevation of Basin =	H_2 =	151.60	
Head =	H =	0.50	ft

Q = 2.67 cfs   >   1.75 cfs   Orifice Equation Checks

Conclusions: For a 25 year storm, design criteria indicates a **12-inch** RCP pipe would convey the calculated flow rate from the drainage area described above.

Calculation Form (Excel)		Job #	20738-99849	Calc. By:	EWM
Client:	City of Plattsburgh	Checked By:	NOV	Date:	04/28/15
Project:	U.S. Oval Green Infrastructure	Date:	04/28/15	Calc. No.:	1
Detail:	Conveyance Pipe Sizing	Reviewed By:	VR	Revision#:	
		Date:	04/28/15	Date:	

BASIN OUTLET PIPE SIZING CALCULATIONS

Purpose: The purpose of this set of calculations is to size overflow piping from bioretention basin to outlet

(yellow)	ASSUMED
(green)	FROM AUTOCAD PROJECTION
(purple)	FROM CALCULATIONS

Objective 1: Determine Maximum Flow Rate Through Overflow Pipe for 10, 25, 100 year storms

Catchment Area =	2.5	acres	
10-year Rainfall =	3.08	inch/hr	*Cornell Northeast Regional Climate Center (intensity for a 15 minute rainfall at an average recurrence interval of 10 years)
25-year Rainfall =	3.68	inch/hr	*Cornell Northeast Regional Climate Center (intensity for a 15 minute rainfall at an average recurrence interval of 25 years)
10-year Flowrate =	5.31	cfs	
25-year Flowrate =	6.35	cfs	

Objective 2: Size Overflow Pipeline to Convey Stormwater From Bioretention Basin to Outlet: Determine Minimum Pipe Size for 10-year storm

Manning's Equation will be used to determine minimum pipe diameter (d)

Formula: $Q = \frac{1.49AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$ Rearranged for Pipe Diameter See Sheet1 $d = \left(\frac{4^{\frac{5}{3}}Qn}{1.49\pi S^{\frac{1}{2}}}\right)^{\frac{3}{8}}$

Assumptions: Friction factor = n = 0.013 RCP pipe friction factor

Known:

Flow Rate =	Q =	5.31	cfs
Length of Pipe =	L =	66.67	ft
Starting Invert =	=	152.25	
End Invert =	=	143.00	
Slope =	S =	0.138743	ft/ft

Find: Minimum Required Pipe Diameter

d =	0.71	ft
d =	8.50	inches

*For storm drain design, it is standard practice to use at a minimum 12" diameter pipes

Pipe Selection: d = 15.00 inch RCP   Area = 1.23 SF

A 15" diameter pipe at conditions described above (slope, Mannings n) will convey: 24.13 cfs

Velocity in the 15" pipe at peak flow in a 10 year, 15 minute storm will be: 4.33 ft/s

Check inlet flow rate via Orifice Equation:

Formula: $Q = CA\sqrt{2gh}$ $H = H_1 - H_2$

Assumptions: Coefficient of Discharge C = 0.600

Known:

Area =	A =	1.23	SF
Gravity =	g =	32.20	ft/s^2
Top of Water Surface =	H_1 =	153.00	ft
Centerline of Pipe =	H_2 =	151.63	ft
Head =	H =	1.38	ft

Q = 6.93 cfs > 5.31 cfs   Orifice Equation Checks

Conclusions: For a 10 year storm, design criteria indicates a **15-inch** RCP pipe is required

Objective 3: Size Overflow Pipeline to Convey Stormwater From Bioretention Basin to Outlet: Determine Minimum Pipe Size for 25-year storm

Manning's Equation will be used to determine minimum pipe diameter (d)

Formula: $Q = \frac{1.49AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$ Rearranged for Pipe Diameter See Sheet1 $d = \left(\frac{4^{\frac{5}{3}}Qn}{1.49\pi S^{\frac{1}{2}}}\right)^{\frac{3}{8}}$

Assumptions: Friction factor = n = 0.013 RCP pipe friction factor

Known:			
Flow Rate =	Q =	6.35	cfs
Length of Pipe =	L =	66.67	ft
Starting Invert =	=	152.25	
End Invert =	=	143.00	
Slope =	S =	0.138743	ft/ft

Find: Minimum Required Pipe Diameter

d =	0.76	ft
d =	9.09	inches

*For storm drain design, it is standard practice to use at a minimum 12" diameter pipes

Although 12" appears to be the appropriate size based on Mannings Eqn, the inlet capacity is not sufficient, thus a 15" pipe is needed as determined by the orifice equation below.

Pipe Selection: d = 15.00 inch RCP Area = 1.23 SF

A 15" diameter pipe at conditions described above (slope, Mannings n) will convey: 24.13 cfs

Velocity in the 15" pipe at peak flow in a 10 year, 15 minute storm will be: 5.17 ft/s

Check inlet flow rate via Orifice Equation:

Formula: $Q = CA\sqrt{2gh}$ $H = H_1 - H_2$

Assumptions: Coefficient of Discharge C = 0.600

Known:				
Area =	A =	1.23	SF	
Gravity =	g =	32.20	ft/s^2	
Top Elevation of Water =	H_1 =	153.00	ft	151.25
Centerline of Pipe =	H_2 =	151.63	ft	151.63
Head =	H =	1.38	ft	

Q = 6.93 cfs > 6.35 cfs Orifice Equation Checks

Conclusions: For a 25 year storm, design criteria indicates a **15-inch** RCP pipe is required