City of Dearborn
Sewer System Study Report

Prepared by **OHM Project Team**

Prepared for **City of Dearborn**

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FINAL REPORT

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Executive Summary

Purpose and Overview

The purpose of this study was to evaluate the recurring flooding issues within the City of Dearborn (City), and to develop alternatives to mitigate the basement backup effects of future flood events through identification of an overarching and prioritized sewer system plan. The study included a review of existing conditions, collection of system data, development of calibrated and validated hydrologic and hydraulic models, and completion of an in-depth analysis to identify the root causes of flooding. Several infrastructure control technologies were evaluated for multiple design storm conditions to identify solutions that would result in the most cost-effective options to mitigate flooding.

Through these analyses, the City will have a roadmap, with order of magnitude costs, to implement projects to reduce the risk of future flooding events.

Project Background

Most of the City's sewer system was built as a combined sewer system (storm and sanitary in the same pipe) until the 1960s when the federal government prohibited the discharge of raw sewage into waters of the state. Following the establishment of the federal Clean Water Act in 1972, the State of Michigan began incorporating Combined Sewer Overflow (CSO) control requirements into National Pollutant Discharge Elimination System (NPDES) permits. The City has since invested in and implemented projects to separate the combined sewer system and/or to control CSO discharges.

The City's existing sewer collection system service area is comprised of separate storm and sanitary sewer service areas, combined sewer system areas, and hybrid two-pipe systems combining stormwater sewers with combined sewers. The collection system discharges wastewater (combined and sanitary) to the Great Lakes Water Authority's (GLWA) collection system for treatment at the Water Resource Recovery Facility (WRRF) or to CSO discharge locations that discharge directly to the Rouge River during wet weather events that exceed the system's capacity. Separated stormwater is discharged to the lower and main branches of the Rouge River. **Figure 1** presents a map of the existing collection system.

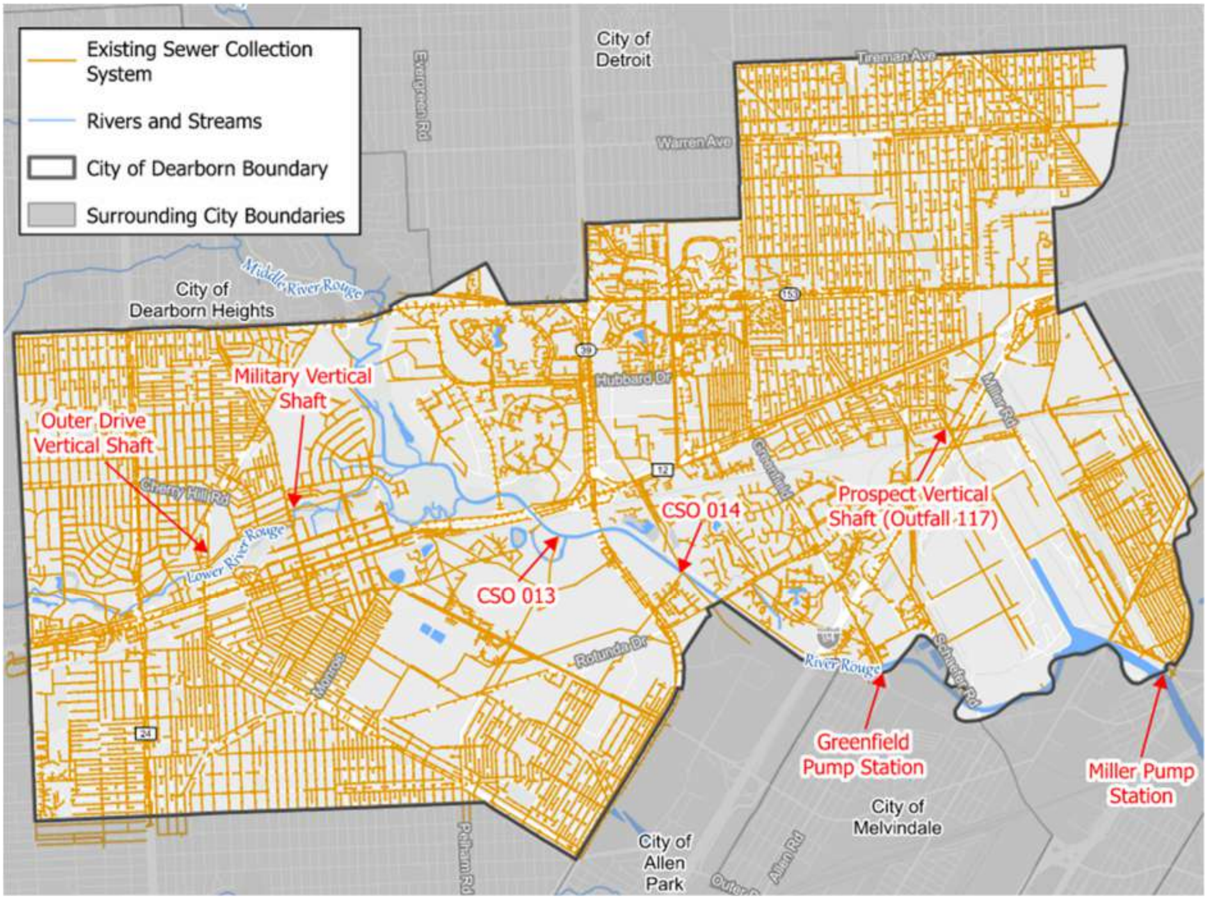


Figure 1. Existing Sewer Collection System

An increase in the frequency of high-intensity wet weather events, resulting in residential home flooding, has raised concern in the City to identify alternatives to mitigate future impacts. On August 11, 2014, an estimated 5.6-inches of rainfall occurred resulting in expansive flooding and basement backups that impacted approximately 10,000 homes. In 2021, the City experienced three additional large wet weather events on June 25-26, July 16, and July 24. During the June 25-26 storm event, the City received approximately 6.8-inches of rainfall, mostly occurring within a 7-hour period. The events in 2021 caused significant flooding and basement backups, impacting more than 20,000 homes. The basement backups reported for the June 25-26, 2021, event are displayed in Figure 2. Note that the existing separated sewer system (blue areas in Figure 2) performed well even with these extreme wet weather conditions, especially as compared to the areas that remain combined.

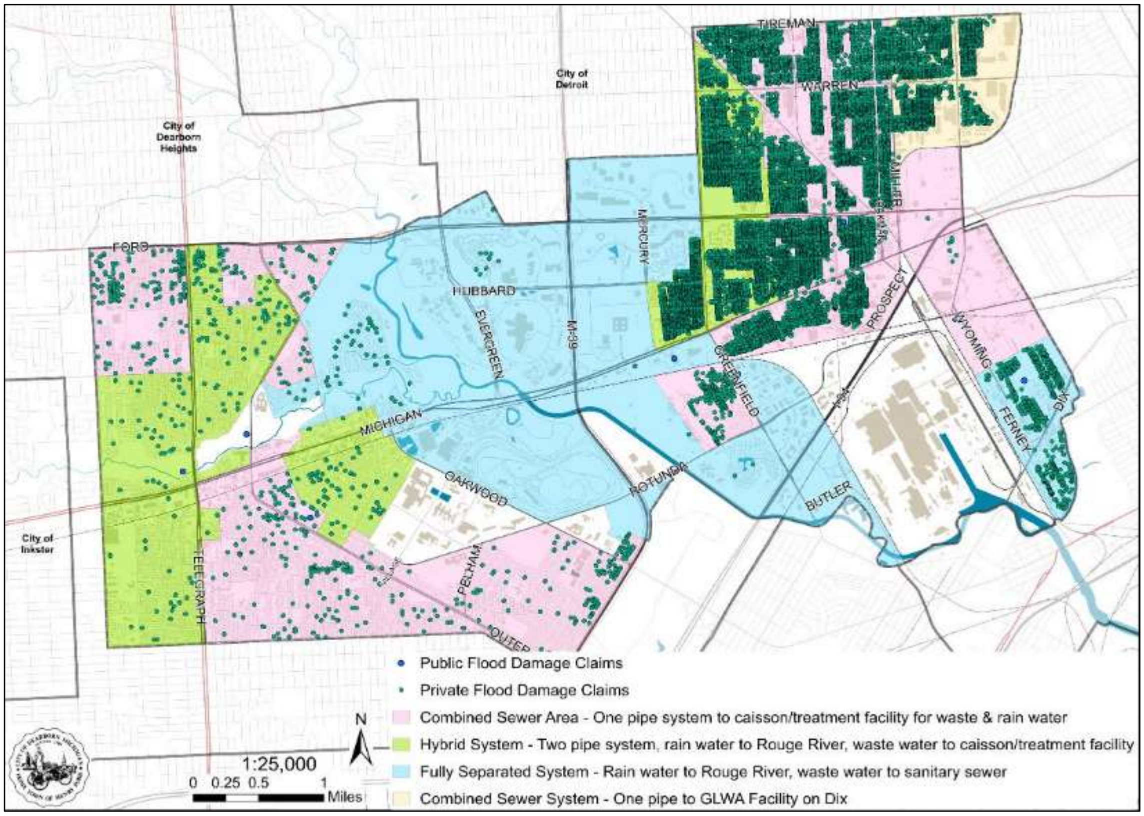


Figure 2. Dearborn June 25-26, 2021 Flood Claims

The City's sewer infrastructure was originally designed with a conveyance capacity between a 5-year, 24-hour (2.8-inch rainfall) and 10-year, 24-hour (3.3-inch rainfall) storm event, which was consistent with typical design standards at the time. As the population of the City and the surrounding area has grown and the intensity of the rain events has increased, the collection system has insufficient capacity to adequately convey these larger wet weather events.

The City commissioned this project for the development of a sewer collection system model as the first step towards determining the best approach to protect its residents from future flooding. This collection system model was used to evaluate the performance of the City's collection system for the 2021 event. The modeling predicted a similar response to this event and identified the CSO overflows from the City's permitted CSO discharge locations (CSO 013 and CSO 014) and significant backups into basements/basement flooding. The root cause of the flooding and CSOs in the system is multifaceted:

- Population growth (and consequently an increase in impervious surfaces), since the system was originally built in 1920-1950 and increased rainfall intensity have outgrown the current sewer collection system capacity.
- The elevation of the outfalls in the separated areas are lower than the current elevation of the Rouge River, making it hydraulically difficult for wet weather event flows to exit the system.

- The City discharges the sanitary and combined sewers to the GLWA system, and the set permitted flow rate that GLWA accepts from the City is significantly lower than the volume of flow produced from wet weather events. Currently the GLWA system lacks the capacity to handle an increased flow from the City's system.

System Description

The City, approximately 25 square miles, is relatively flat and lacks significant topographical relief. The City is traversed by the main and lower branch of the Rouge River, which lie in the shallow valleys. The ground slopes gently from the City's outer edges towards the rivers crossing its center. The City's collection system has a total of 456 miles of sewer, most of it constructed before 1940. The City's sewer system is divided into six drainage districts that collectively capture and convey wastewater and stormwater from the City. Drainage District 1, often referred to as the Chase District, is located in the northeast corner of the City and distinguishes itself with some of the lowest ground elevations in the City and has experienced some of the most widespread basement backups.

There are two pump stations, identified in Figure 1, in Dearborn that discharge most of the City's sewage to the GLWA system. Greenfield Road Pumping Station has five submersible pumps and a total station capacity of 68 cfs (44 MGD). Miller Road Pumping Station has four pumps, providing a firm capacity of 60-80 cfs (42-52 MGD).

Approximately forty percent of the City is served by combined sewers. During dry weather conditions, sanitary flows are conveyed to the GLWA WRRF where full treatment is provided prior to discharge to the environment. During wet weather conditions, combined sanitary and stormwater flows are conveyed to one of the three large vertical treatment shafts (caissons), where the flows are treated before being discharged to the Rouge River or to GLWA's system.

Another thirty percent of the City is served by a separated sewer system where stormwater runoff is collected in a separate pipe and conveyed to the Rouge River. Sanitary flows are collected in a separate sanitary main and conveyed to the GLWA WRRF. The remaining thirty percent of the City is served by a hybrid system where much of the stormwater is discharged to a separate storm sewer, but the combined/sanitary sewer still has some stormwater volume sources. The combined, separated, and hybrid sewer areas are shown above in **Figure 2**.

Design Criteria

Design criteria were established to develop an understanding of the level of service and level of performance for the different alternatives explored. The design criteria were established with input from the City and is inclusive of the extreme wet weather events that have occurred more recently due to climate change. The criteria are summarized in **Table 1** and described further below.

The targeted design storm was developed by the City and the OHM project team to establish a more robust level of service criteria. The robust nature of the design storm reflects the City's intent to reduce the number of flooding occurrences during wet weather events.

The design storm is based on the recurrence period of flows within the collection system in response to rainfall events. The suggested level of service is proposed to be the 25-year recurrence interval flow plus an additional 30% flow (which is equivalent to the peak flow from a 4.55-inch rainfall event) to accommodate effects of climate change and create a more resilient system. Applying a level of service based on ("in-system") collection system flows that produce flooding more directly ties the level of service to the recurrence period for flooding. It is worth noting that a 25-year plus 30% design criteria is a significantly larger storm event than what nearly every municipality has historically designed around and represents a large investment by the City in flood resiliency.

The manhole flooding criteria was established to minimize the volume of water that has exceeded the system's carrying capacity during the design storm. Reducing this criteria to zero would mean that the system is adequately sized to convey or store the design storm event. Combined sewer overflow volumes were included as a criteria to limit discharges to the Rouge River. Further consideration was given to the amount of freeboard available during the design storm event. Minimizing freeboard violations during the design storm means minimizing basement backups.

Table 1. Design Criteria for Evaluation

Criteria	Goal	Summary
Design Storm	System resiliency	25-year plus design criteria (25-year recurrence interval in-system peak flow + 30% flow). Sensitivity analysis performed for smaller design storms.
Manhole Flooding	Reduce surface flooding	Minimize MH flooding during the design storm.
Combined Sewer Overflows	Water quality improvements/regulatory compliance	Minimize CSOs during the design storm.
Freeboard	Reduce basement flooding	Minimize freeboard (ground elevation – maximum HGL) violations < 8 feet during the design storm.

Flood Control Technologies and Cost Development

Several flood control technologies were identified to develop alternatives and optimize the sewer system to effectively manage the system capacity. These system improvements are typically included to help manage stormwater, sanitary, and combined sewer systems and mitigate the peak flows associated with the design storm event.

The flood control technologies considered for the City of Dearborn are illustrated in Figure 3 and include the following technologies. These technologies have previously been implemented in the City in various locations and to varying levels of implementation.

- Dewatering pump options including wet weather treatment consisting of screening and disinfection. The treatment identified is consistent with the CSO treatment controls typical in the Rouge River watershed with 5-10 minutes of contact time for disinfection for the base assumption.
- Storage facility options. Storage facility options included tanks and storage shafts to detain water temporarily until system capacity is available; however larger facilities would require inclusion of drop shafts and storage tunnels to satisfy volume demand.
- Gravity sewer construction. Gravity sewers are conveyance options to increase system capacities at select locations. Larger diameter conveyance requires shallow tunnels in specific locations.
- Implementation of cross connection options on the existing system. This option includes creation of cross connections to convey flow from portions of the collection system under surcharge to portions of the collection system where excess capacity exists.
- Stormwater sewer separation. Stormwater sewer separation includes capturing stormwater flow prior to entering the combined sewer system. Stormwater separation of varying efficiencies was evaluated.

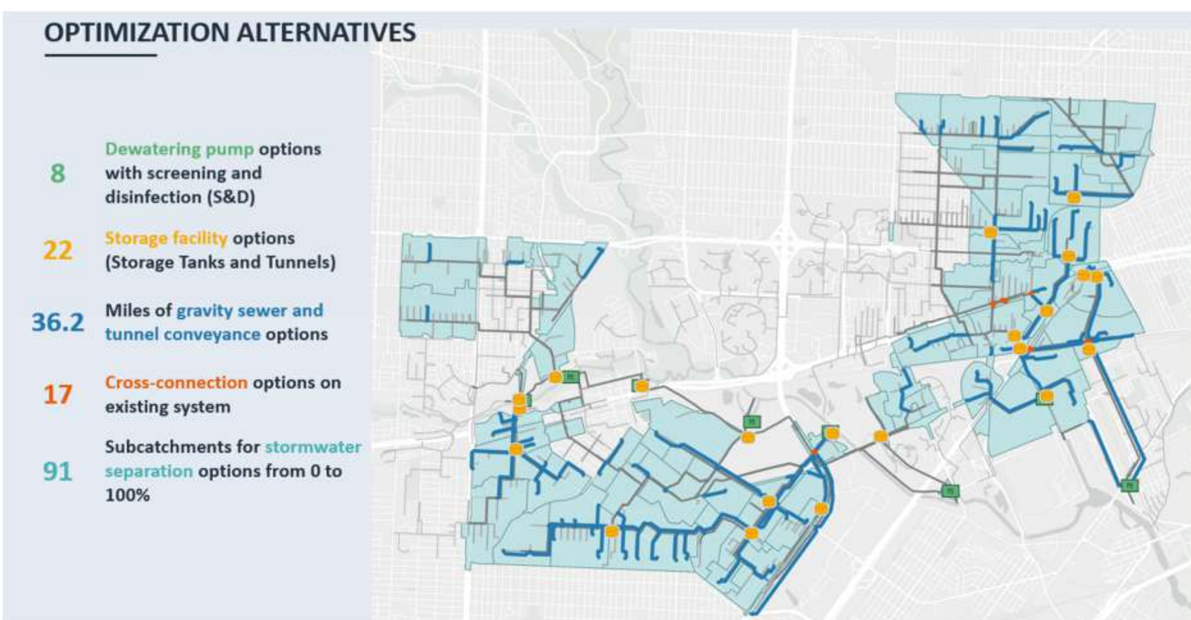


Figure 3. Optimization Technologies and Preliminary Locations

Green stormwater infrastructure (GSI) alternatives were considered subsidiary to stormwater sewer separation and other alternatives. The level of flooding identified in the City of Dearborn is much larger than the typical scale GSI would be designed for. However, layering distributed GSI on top of the existing and proposed gray infrastructure can improve the performance and resilience of the gray infrastructure, particularly in light of increases in rainfall intensity and frequency. This is in addition to the social and environmental benefits associated with introducing GSI landscapes throughout the community. Green stormwater infrastructure, including regional detention, will be further considered as part of the development and refinement of sewer separation projects.

Construction, capital, operations & maintenance (i.e. life cycle) costs were developed for each flood control technology listed above. The construction costs are Class V (rough order of magnitude) for comparative purposes and are very-high level preliminary costs with a range of -50%/+100%.

The life cycle costs include the total cost of implementing the flood control technologies over the entire lifespan of the project. The flood control technologies that are focused primarily on conveyance improvements (gravity sewers and sewer separation) have the longest asset life and lowest operations and maintenance costs.

Optimization Process

The optimization process utilized Optimizer software that evaluated 100,000+ options to identify the most cost-effective combination of technologies that meet the outlined design criteria from Table 1. **Figure 4** identifies the key activities included in the three-step evaluation process which are further defined below.

1. Develop a hydraulic model and identify flood control technologies and the associated costs.
2. Input the hydraulic model, control technologies, and design criteria to the Optimizer model to identify the most cost-effective solution.
3. Apply prioritization to identify the sequence of improvements to address flooding.

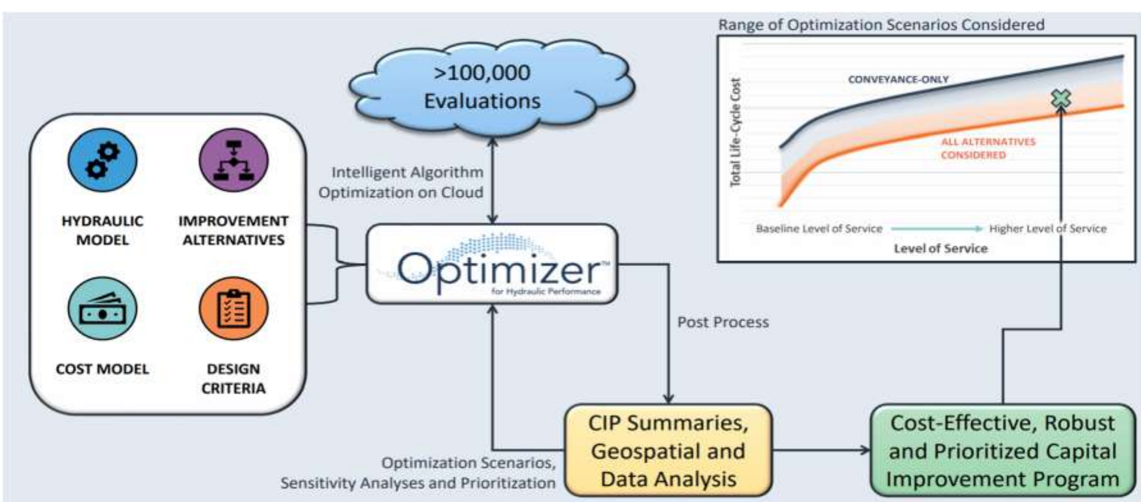


Figure 4. Optimization Process

Level of Service Options

The City's current level of service ranges from a 5-year to a 10-year storm. However, with climate change impacting the frequency and magnitude of wet weather events, as occurred in 2021, the City of Dearborn is taking a proactive approach to look beyond the typical design storm and is evaluating larger events.

Figure 5 illustrates the existing system performance for the 25-year plus 30% (25-year plus) recurrence interval flow. The figure identifies 181 million gallons of combined sewer surcharge at approximately 430 locations in the system which includes basement backup volumes. The separated stormwater system has 71 million gallons of separated stormwater surcharge at approximately 460 locations.

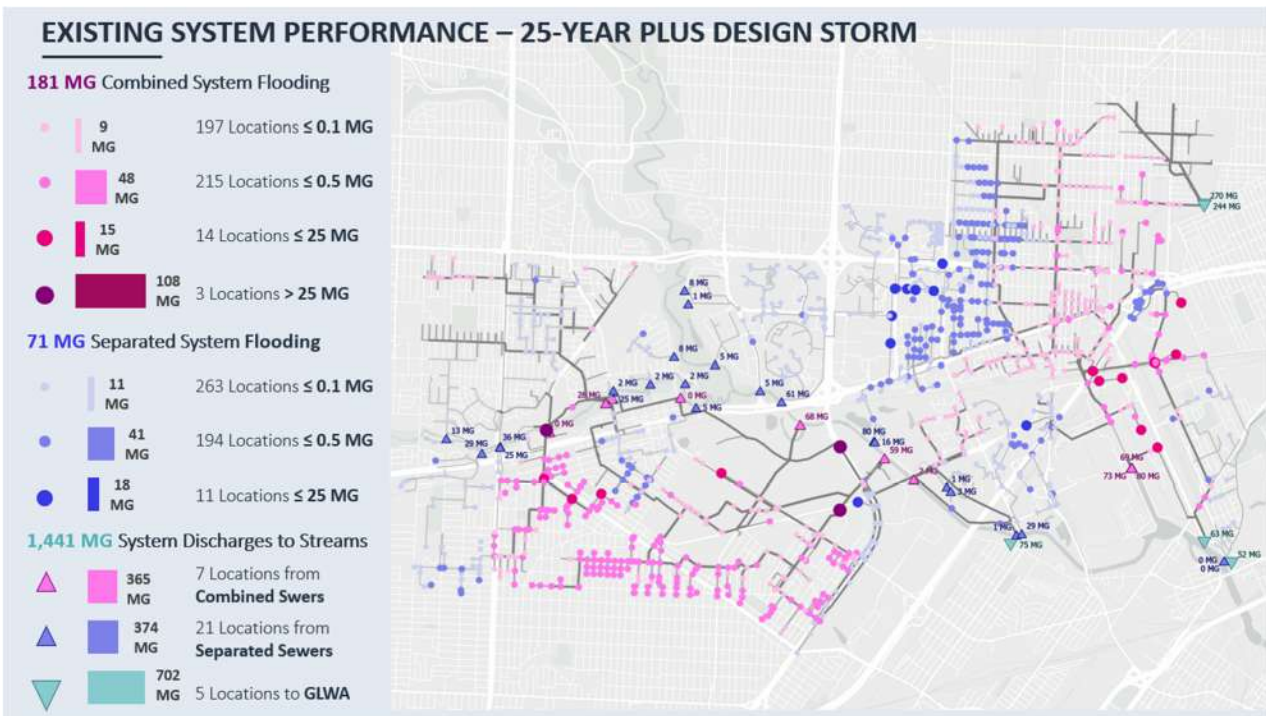


Figure 5. Existing System Performance - 25-Year (Plus) Design Storm

Alternatives Description and Evaluation

The optimization evaluation identified alternatives that include combinations of gravity sewers, cross connections, storage facilities (storage tanks or tunnels), dewatering pump stations, treatment (screening and disinfection), and stormwater separation. The capital construction costs were calculated and added to operation & maintenance and replacement costs to identify total life cycle costs. The evaluation also incorporated baseline improvement projects, which include projects that can provide obvious system performance benefits and can be committed to now by the City. These projects include, but are not limited to, sewer separation or inflow reduction projects in areas that have known backup issues, areas near stormwater lines with adequate capacity, and projects the City has already committed to for design and construction. The preliminary optimization from the Optimizer model for the 25-year plus design criteria identified five primary solution sets summarized below with (capital / life cycle) costs:

- 1A - Conveyance Only ($2,742 M / $4,070 M)
- 2A – Dewatering Limited to 200 MGD (storage and treatment options with pump stations) ($2,239 M / $3,435 M)
- 2B – Dewatering Limited to 100 MGD (storage and treatment options with pump stations) ($2,560 M / $3,972 M)
- 1D - Stormwater Separation Only Solution (separation to achieve conveyance capacity for the design storm) ($1,487M / $1,658M)
- 1E – Full Stormwater Separation (separation of the entire combined sewer system) ($1,898 M / $2,115M)

The results of the evaluation indicate a significant preference for stormwater sewer separation alternatives which have a much higher service life and much lower life cycle cost and don't require chemicals, electricity for pump stations, or additional operators for facilities. A stormwater separation alternative will have the added long-term benefit of reducing the amount of combined sewage treated through the GLWA system and would free up/reduce conveyance and treatment costs through that system while creating a more resilient sewer network.

With the downstream end of the collection system locked into a limited (fixed) flow rate, the most cost-effective option for flood mitigation is to invest in sewer separation and stormwater interceptors to remove storm event flow from the system and safely convey it to an outlet at the river. Sewer separation and stormwater interceptors can be paired with detention storage facilities and when possible, stormwater infiltration to further reduce the risk of flooding. By pursuing projects to separate the system and remove storm flows, the City will decrease basement flooding as well as overflows at CSO 013 and CSO 014 and create a more resilient sewer system.

The OHM project team further evaluated the stormwater separation solution and calculated the incremental capital cost vs flood reduction ratio. Figure 6 summarizes the flood reduction benefit for the corresponding capital investment in sewer separation. As more dollars are invested in projects aimed at flood reduction, the achieved benefits decrease, requiring larger investments to achieve similar results. There is a point along this curve where the diminished return on the investments may no longer be worth the investment for the benefits gained. This point will need to be decided by the City in charting a path forward to an acceptable and achievable flood reduction goal.

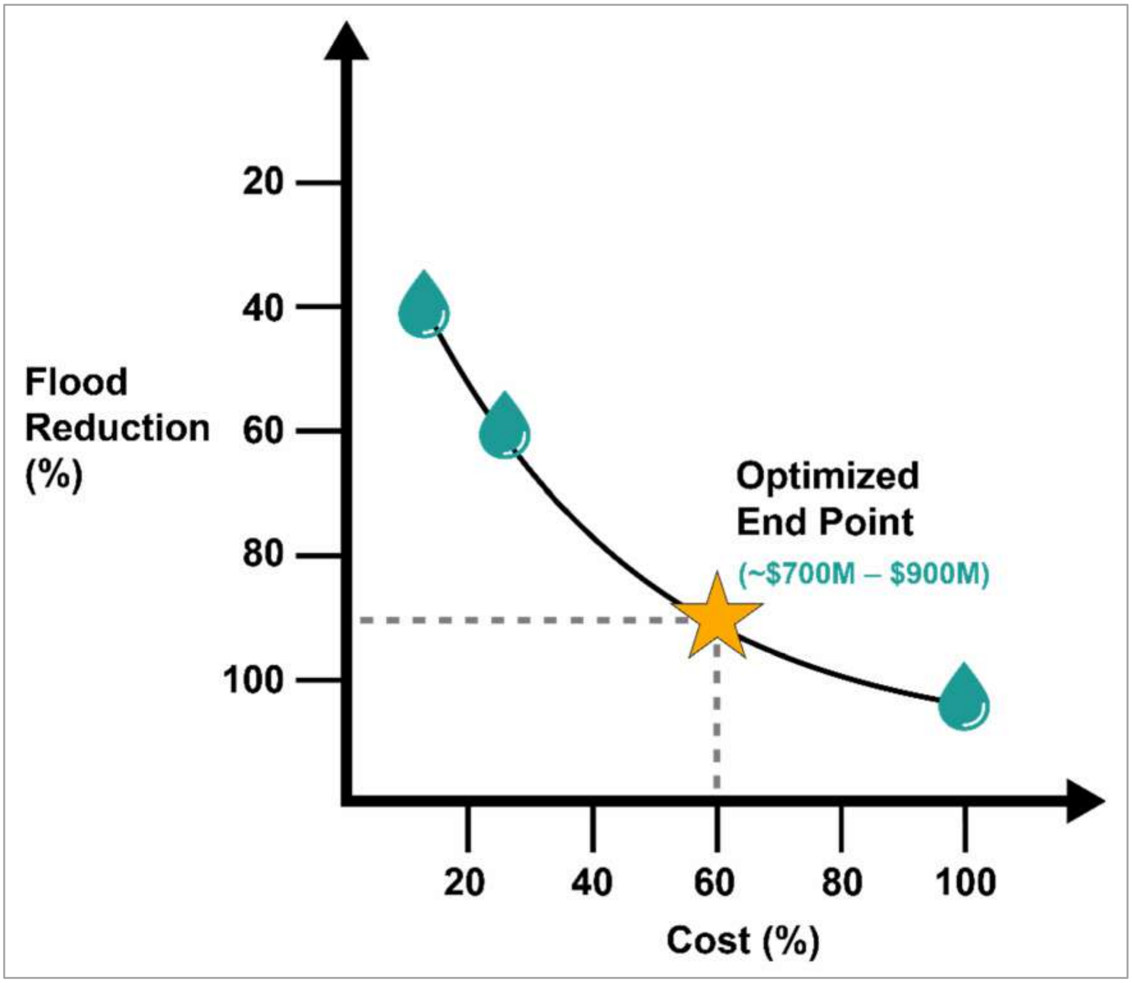


Figure 6. Optimized Investment for Flood Reduction Benefit

Prioritization

The Optimizer model ran a prioritization analysis of the optimized solution (stormwater sewer separation) to help identify priority projects for implementation. Priority projects are generally determined as the largest system performance improvement (reduced performance deficiency) for the least cost.

Figure 7 illustrates the Performance Deficiency versus Cost. As the City implements the sewer separation alternative projects, continued evaluation of the performance of the system is recommended through additional sewer monitoring (flow meters) and model updates to align projects and performance and determine the optimal time to conclude improvements when system performance goals are achieved to a sufficient level. This careful monitoring of system performance will identify the correct end-point for implementing projects and potentially save the City tens- to hundreds-of millions of dollars.

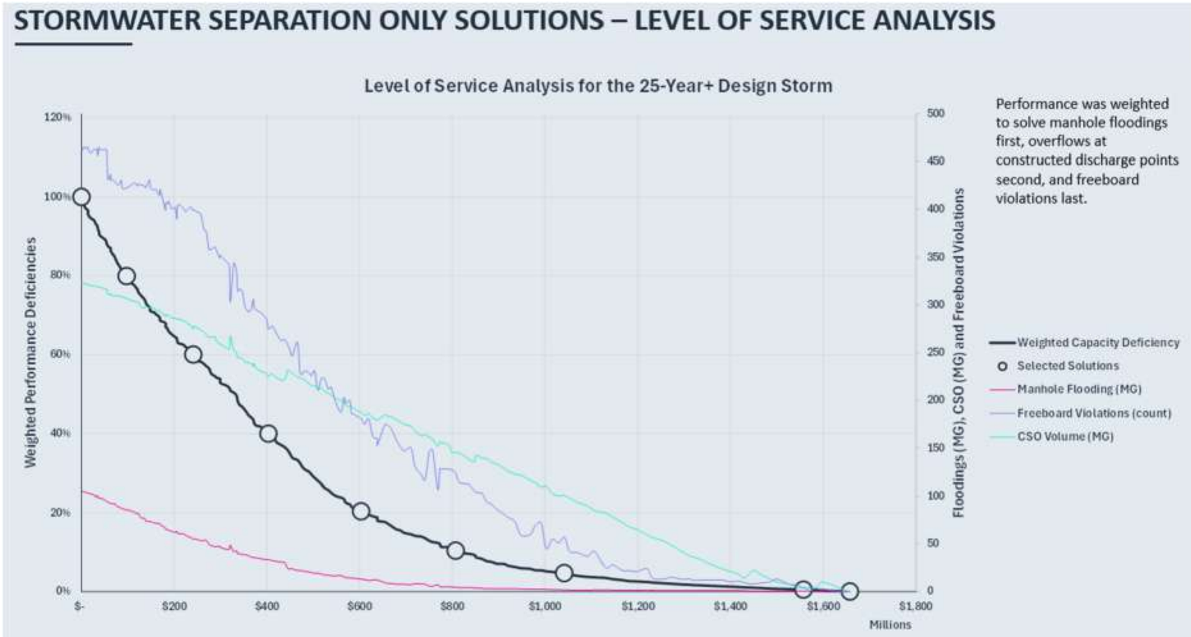


Figure 7. Performance Deficiency versus Cost

Dearborn is an urbanized community experiencing redevelopment that will continue to change the cityscape. As redevelopment occurs, the City's post-construction stormwater management standards will trigger on-site stormwater management and result in reduced stormwater runoff currently contributing to the stormwater and combined sewer system infrastructure. Consequently, it will be important for the City to evaluate system performance as sewer separation projects are implemented and redevelopment occurs to plan future separation projects and expenditures to meet the system design criteria. In addition to meeting the current selected Level of Service criteria (25-year plus), two key factors to consider prioritizing in the decision-making process are: 1) future local development/re-development and 2) impact on equity in the community. Additionally, after the first project phase has been implemented, the City should evaluate and compare the actual project costs to the projected costs, changes in the sewer collection system, effective capture efficiency from the separated sewers, population, and rainfall intensity, and reflect on any lessons learned.

Putting the needs and safety of the Dearborn community first is the driving force behind the flood mitigation study. Considering equity when reevaluating the impact of the first set of sewer system improvements ensures a community-first approach.

Key Findings and Next Steps

The study's alternatives optimization effort calculated that sewer separation is the most cost-effective solution to address the City's flooding issues. Sewer separation achieves the largest system benefit (reduction in flooding) at the lowest cost (capital and life cycle). Based on the high-level comparative alternatives analysis that was completed for this study, it is estimated that sewer separation implementation costs are on the order of a $1.5-billion-dollar investment to achieve 100% of all the City's goals (system resiliency, reduced surface flooding, reduced basement flooding, water quality improvements /regulatory compliance). However, it should be noted that significant success (70-80%) can be achieved with an investment of approximately 40-60% of the overall investment calculated. Figure 7 reflects this as the "knee" of the cost/performance curve.

The highest priority projects identified through the Optimizer model include sewer separation in South Dearborn and Northeast Dearborn. A key element of successfully achieving sewer separation in South Dearborn is implementation of a stormwater outfall conveying newly separated stormwater flows directly to the Rouge River. A feasibility study for outfall solutions from separated areas in South Dearborn is needed to evaluate route alternatives that take right-of-way and property impacts, capital and operation and maintenance costs, utility conflicts and constructability issues into consideration.

It is recommended that the City consider current and future sewer rates and develop a cost-constrained 10-year sewer system capital improvement program that defines annual investment proposed over the next 10 years (and beyond). Once a target level of investment to achieve reduced flooding has been identified, the next step is to begin preliminary engineering for the first group of prioritized sewer separation projects where sewer sizes, hydraulics, and capture areas are refined.

Continued coordination with development/re-development, public works projects, and equity to the community will allow for an adaptive approach that best meets the goals and needs of the community of Dearborn to reduce the risk of future flooding impacts.

Introduction

In the face of significant flooding, ever-increasing development in the upstream reaches of the Rouge River watershed, and the uncertainty of future heavy precipitation events brought on by climate change, the City of Dearborn commenced a strategic study of the existing combined, and stormwater conveyance systems.

An estimated 5-inches of rain fell on the City of Dearborn on August 11, 2014, which resulted in expansive flooding and basement backups. Residents and business owners felt the devastation with widespread reported flooding. Mother nature struck the City again with three large storms on June 25-26, 2021, July 16, 2021, and July 24, 2021. During the June 25-26 storm event, Dearborn received approximately 6.8 inches of rainfall mostly occurring within a 7-hour period.

In recent years the City of Dearborn has invested significant resources to improve sewer system operations and to comply with the federally mandated CSO control program. Since the CSO program's inception, the City has spent over $450 million with design and implementation of the CSO mitigation projects. The City installed more than 210,000 feet of new storm and sanitary sewers and three large vertical treatment caissons.

The goal of this strategic study is to make an informed decision concerning potential short-term and long-term improvements to the City's sewer system and to mitigate associated risks. The OHM project team, together with the City of Dearborn's project team, developed a level of service criteria which outlines the expectations for the sewer system response to rainfall events after the implementation of improvement recommendations. To reach this goal, the OHM project team has developed a hydrologic and hydraulic model to evaluate the combined, and storm sewers within the City, performed an Optimization review of the sewer system, and developed prioritized recommendations to mitigate street and basement flooding.

Background

Founded in 1786 and incorporated as a city in 1929, Dearborn stands as the second-largest city in Wayne County, boasting a rich history and vibrant multicultural heritage. Over the years, waves of immigrants seeking a better life, many through employment opportunities in Henry Ford's pioneering automotive industry, have shaped the city's unique character. Henry Ford himself held extensive land, utilized for experimental farms, his sprawling estate, and The Henry Ford estate (also known as Greenfield Village). This land division essentially demarcates the City into West and East Dearborn. With the transformation of dense deciduous forests into a burgeoning suburban center, investments in water and sanitation infrastructure paralleled the City's development.

Today, Dearborn is home to Ford World Headquarters, a thriving business community, and thousands of residences, collectively placing substantial demands on the City's infrastructure. The City's sewer system, originally constructed as a combined sewer system for the majority of the City, evolved over the years to accommodate changing regulations. Notably, federal mandates, introduced with the Clean Water Act, compelled the State of Michigan to incorporate Combined Sewer Overflow (CSO) control requirements into National Pollutant Discharge Elimination System (NPDES) permits. This regulation change marked a pivotal moment in the City's watershed management.

Dearborn's sewer system is divided into six drainage districts (Figure 8), each playing a unique role in capturing and conveying wastewater and stormwater across the City's approximately 25 square miles. However, it's important to note that not all neighborhoods and sewer districts within Dearborn share the same experiences of flooding in terms of quantity, severity, or type. For instance, Northeast Dearborn, often referred to as Drainage District 1 or the Chase District, distinguishes itself with some of the lowest ground elevations in the City. It utilizes a mix of sewer systems, including combined sewers that transport flows to vertical treatment caissons, hybrid two-pipe systems combining stormwater discharge with wastewater conveyance, and traditional combined sewer systems that pump and route flows directly to a Great Lakes Water Authority (GLWA) facility. This intricate system posed unique challenges, especially during severe weather events, such as the June 25, 2021, storm, when high wet weather flows combined with high Rouge River levels and inundated outlets, contributing to widespread basement backups.

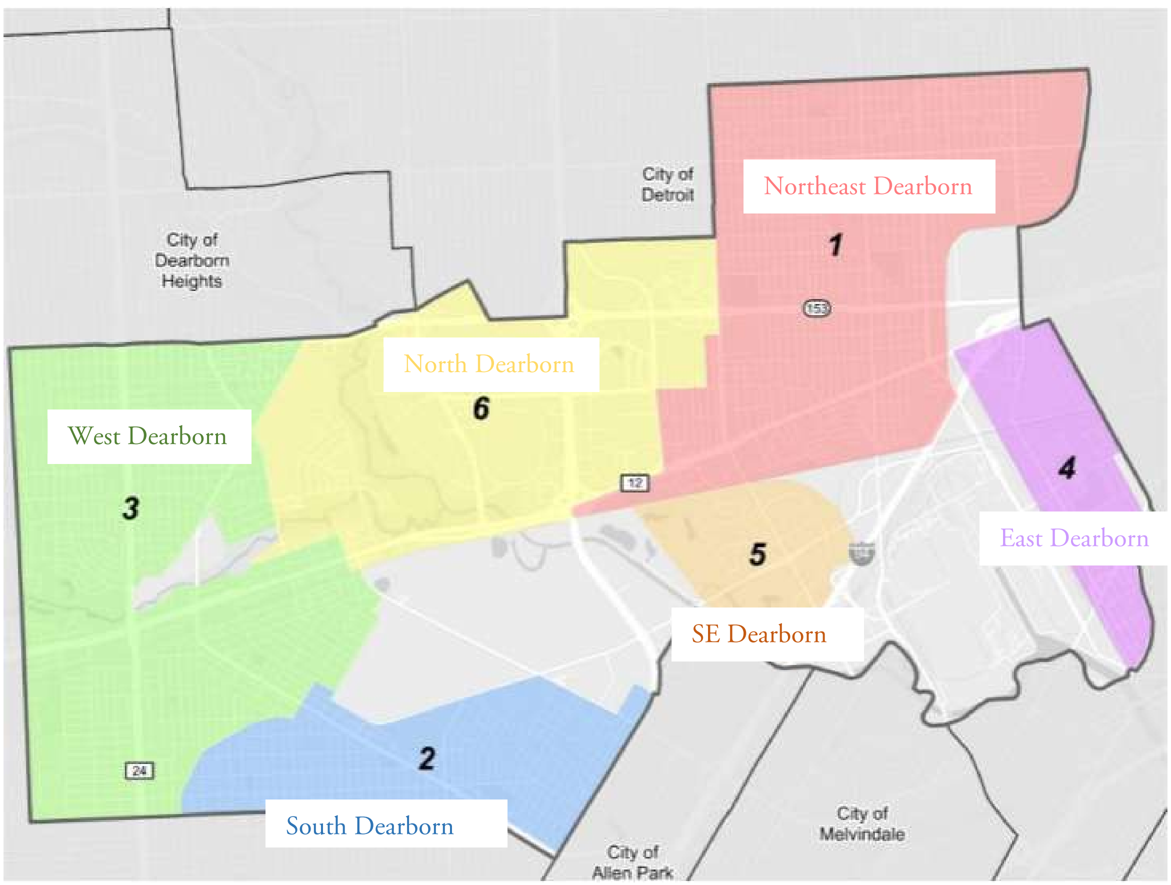


Figure 8. City of Dearborn Sewer District Areas

Despite its resilience, Dearborn's infrastructure has faced growing demands, exacerbated by upstream development in the Rouge River watershed and increasingly unpredictable precipitation patterns. Consequently, the City has witnessed an uptick in basement and street flooding incidents over the past eight years, marking some of the most significant flooding events in its history.

Objectives of the Study

The primary goal of this project was to evaluate the recurring flooding issues within the City of Dearborn, particularly in response to significant storm events, and to use information learned to educate the flood mitigations strategies moving forward. By closely examining existing conditions, collecting accurate data, developing hydrologic and hydraulic models, and conducting in-depth analysis, this project aimed to provide valuable insights into the root causes of flooding. Effectively utilizing the insights gained to inform decisions on infrastructure improvements to enhance flood resilience, the goal of these improvements, and the standard against which we measure their success, must be established. This standard is termed a “level of service criteria”. Establishment of a level of service criteria requires an economic balance between cost of investment and the level of protection against flooding.

The secondary goal of this project was to work with the City to find the economic balance and develop an expected level of service critical for the sewer collection system. This level of service outlines the expected performance and flood resiliency of the system in response to rainfall events and acts as a guide to compare proposed flood mitigation strategies against. By establishing a clear level of service criteria, City officials can use insights gained through the modeling and analysis of the physical collection system to inform their decisions on the appropriate system improvements that will best serve the community’s goals.

Level of Service Criteria

A clear level of service target must be established to achieve the primary goal of this project of developing flood mitigation strategies for the City and to evaluate and make informed decisions about which strategies to implement. The infrastructure must meet regulatory standards; however, these standards are often insufficient to provide level of protection against flooding associated with higher intensity design storms desired by the community. The Level of Service Criteria is a formal way of clarifying the desired goals the community wishes to establish for how their collection system performs during rainfall events. It defines the agreed upon balance between the maximum flood protection and available community funding to implement the flood mitigation strategies. The greater the protection provided by a flood mitigation strategy, the larger the financial burden on the City.

The Northeast and East Dearborn sewer district was designed based on the 1920’s combined sewer standards of conveying rainfall from an event that lasts 24 hours and statically occurs once every 5-years; a 5-yr, 24-hour storm event. This equates to a storm of approximately 2.8 inches over a 24-hour period. The West Dearborn sewer district was designed based on the 1950’s standard of a 10-yr, 24-hr storm event which is approximately 3.3 inches of rain in a 24-hour period of time. The Michigan Department of Environment, Great Lakes, and Energy (EGLE) requires combined sewers to capture and convey a 10-yr, 1-hour storm (1.7-inches in an hour) and uses the 25-yr, 24-hr storm (3.98 inches in 24 hours) when evaluating sanitary sewer capacity. In August of 2014, the City was hit with an event which dropped over 6.5 inches of rain, and in July of 2021 the City experienced an event in which over 4 inches of rain fell in under 24 hours. Both of these events, along with the June 2021 event, were in excess of the design standards of the system and brought about the realization that these currently established standards are insufficient for the flood resiliency desired by the City of Dearborn.

To establish a more robust level of serve criteria for the City of Dearborn, the OHM project team suggested a level of service criteria which is based on the recurrence period of flows within the collection system in response to rainfall events rather than the recurrence period of the rainfall event itself. More specifically, the City is concerned with reducing the occurrence of flooding caused by collection system backups, not specifically concerned with the rain event itself. Therefore, by establishing a level of service of the collection system in terms of recurrence of flows that produce flooding, the level of service is more directly tied to the recurrence period of flooding. To this end, the OHM project team suggested a level of service criteria of the collection system of a 25-yr, plus 30% system flow. In other words, the collection system will be designed to accommodate flow that is 30 percent higher than a flow that statistically occurs in the system once every 25 years. The additional 30% flow will allow the system to accommodate effects of climate change moving forward into the future.

To develop this 25-yr plus 30% flow, a statistic frequency analysis was developed by routing a long period of rainfall and temperature data through an antecedent moisture model (AMM) of the system and performing statistical analysis on the resulting model output.

Antecedent Moisture Model (AMM)

Rainfall-runoff dynamics of surface water, combined sewer, and separate sewer systems can be highly impacted by antecedent moisture conditions, i.e. the relative wetness or dryness of the system. Simulating these dynamics with a reasonable degree of accuracy is critical to the development of a predictive model of a system's sensitivity to antecedent moisture that can be used for risk management, planning, and design of upgrades. The H2O Metrics AMM model can accurately predict the system flow response to rainfall by incorporating the statistical variations of rainfall and temperature from the long-term record and the antecedent moisture conditions. Localized rain data from two Great Lakes Water Authority (GLWA) gages were used for the site-specific AMM model. The collection system flow data required to calibrate the AMM model to the Dearborn system was collected from two flow meters deployed in the collection system for a period of 11 months, beginning November 2022 and ending October 2023. Refer to **Figure 10** for the location of these meters within the collection system.

The statistical analysis of the flow responses to the long-term record of rainfall produced from the Dearborn AMM model indicates a flow of 158 cfs at the location of the Gould flow meter as a return frequency of 25-yrs. Increasing this flow by 30% results in the Level of Service Criteria flow of 226 cfs at the Gould meter location.

To apply this flow to the Dearborn system as a whole, a design storm with a duration of 24-hours is applied to the calibrated SWMM system model (detailed below). The peak rainfall intensity of this design storm is adjusted until the model results produce the Level of Service Criteria flow of 226 cfs at the Gould metering location. The resulting design event which produced the criteria flow is a 4.55-inch storm event. This event is roughly equivalent to the 50-yr, 24-hr storm. **Table 2** below contains system flows produced by this design storm at select key locations in the collection system as shown on **Figure 10**.

Table 2. System Flows produced by the 25-yr plus 30% in-system Level of Service Criteria

Metering Location	Peak Flow Rate (cfs)
1 – Dix Ave & Dale Pl	658
2 - Maple Rd & Barclay Ave	981
3 – Schaefer Rd & John Nagy Dr	626
4 – Rotunda Dr & Beaumont Dr	69
5 – Outer Dr & Michigan Ave	152
6 – Dearborn Hills Golf Course	443
AMM 1 – Lawrence Ave	193
AMM 2 – Gould Ave	226

Collection System Model Development

To evaluate the functionality of the existing collection system and identify potential root causes of system deficiencies contributing to flooding, a hydrologic and hydraulic model was developed for simulating the combined and stormwater collection system. Dearborn's sewer system is divided into six drainage districts (West, South, Central, SE, NE and East), each playing a unique role in capturing and conveying wastewater and stormwater across the City's approximately 25 square miles. However, due to the interconnected nature of these six drainage districts, a unified modeling approach was adopted. This unified approach allows for a single model encompassing all six districts to be developed. This strategic decision enables the interactions and dynamics experienced by these districts sewers during storm events to be more accurately reflected by the model.

Model Selection

The modeling framework for this system was selected through a thorough exploration of available modeling platforms, leading to the choice of PC SWMM—a software package rooted in EPA SWMM 5 that is widely recognized and has been applied worldwide for stormwater runoff planning, analysis, and design. Its capabilities include the modeling of rainfall, runoff, pipe flow, and various control structures and pumps, all of which are essential components of this modeling effort. While PC SWMM is a proprietary software that requires a paid license to access, PC SWMM is interchangeable with EPA SWMM (free software platform) which makes access and future use of the model versatile.

Model Parameters and Boundary Conditions

The most critical element in the successful modeling of a sewer system is the accurate representation of the system itself within the model framework. This representation consists of two parts: 1) the physical attributes of the system components (i.e. pipes characteristics, connectivity, land use, and soil parameters); and 2) the influence of the surrounding environment on the sewer system (i.e. rainfall, river elevations, and populations served by the system).

- **Physical System Attributes**

  The physical system attributes in the hydrologic and hydraulic model consists of sub-basins (drainage areas), pipes (conduits), manholes (junctions), and storage basins. These layers play essential roles in determining the behavior of the hydrologic and hydraulic model. The details of the physical parameters of the sewer collection system were provided to us from the City in the form of a GIS database, digitized construction section maps, as-builts and various CSO and sewer separation plan drawings as well as through in person meetings and email exchanges. Various physical model parameters, such as roughness coefficients of the overland surface and pipe interior, soil infiltration rates, percentages of impervious surfaces within the drainage areas, and others, are essential for calculating flows through the collection system but were not directly measured. In the absence of specific measurements, generalized regional values were initially selected as a starting point. These starting point attributes acted as calibration parameters, undergoing adjustments through multiple model iterations to achieve the observed system flow characteristics. For detailed information on how this data was used to build the system within the model, refer to the Dearborn Data Gap Analysis memo included in Appendix A.

- **Environmental Attributes**

  The environmental attributes in the hydrologic and hydraulic model consists of the external influences on the model such as the elevation of the Rouge River and the downstream end of the collection system, the magnitude and duration of the rainfall events that contribute flow into the system and the sanitary volume introduced to the system from the population served by it. River level information was collected from the United States Geological Survey (USGS) "Lower River Rouge at Dearborn, Mi gage (ID 04168400) to build the downstream boundary conditions of the model where the collection system connects to the river. Rainfall data was collected from the Great Lakes Water Authority (GLWA) Systems Analytics & Meter Operations (SA&MO), and the Greater Detroit Regional Sewer System (GDRSS) web portal. Based on locations and consistency of data, gages PG010, PG015, and PG036 were selected for use as the source of rainfall introduced into the model. To represent the sanitary flows in the system the US Census Data was used as the source of the current population and an area weighted flow was applied to the combined and sanitary pipes modeled within the system. For detailed information on this data, and any relevant limitations that may pertain to it refer to the Dearborn Data Gap Analysis memo included in Appendix A.

These comprehensive model parameters collectively form the foundation of the hydrologic and hydraulic model, enabling the evaluation of the City of Dearborn's collection system and the identification of root causes contributing to flooding.

The model developed for the Dearborn collection system encompasses approximately 20 square miles of area and 175 miles of storm and combined sewer pipes. Sanitary sewers and sewers with a diameter smaller than 24 inches were not included the Dearborn collection system model as the focus of this study is large scale flooding due to the effects of rainfall events on the larger trunk sewers in the City's storm and combined systems. **Figure 9** shows an illustrated view of the model extents. Each trunk sewer in the system has been color coded for ease of drainage area identification. Additionally, the separated stormwater drainage areas are shaded in blue, while the combined sewer areas are shaded in yellow.

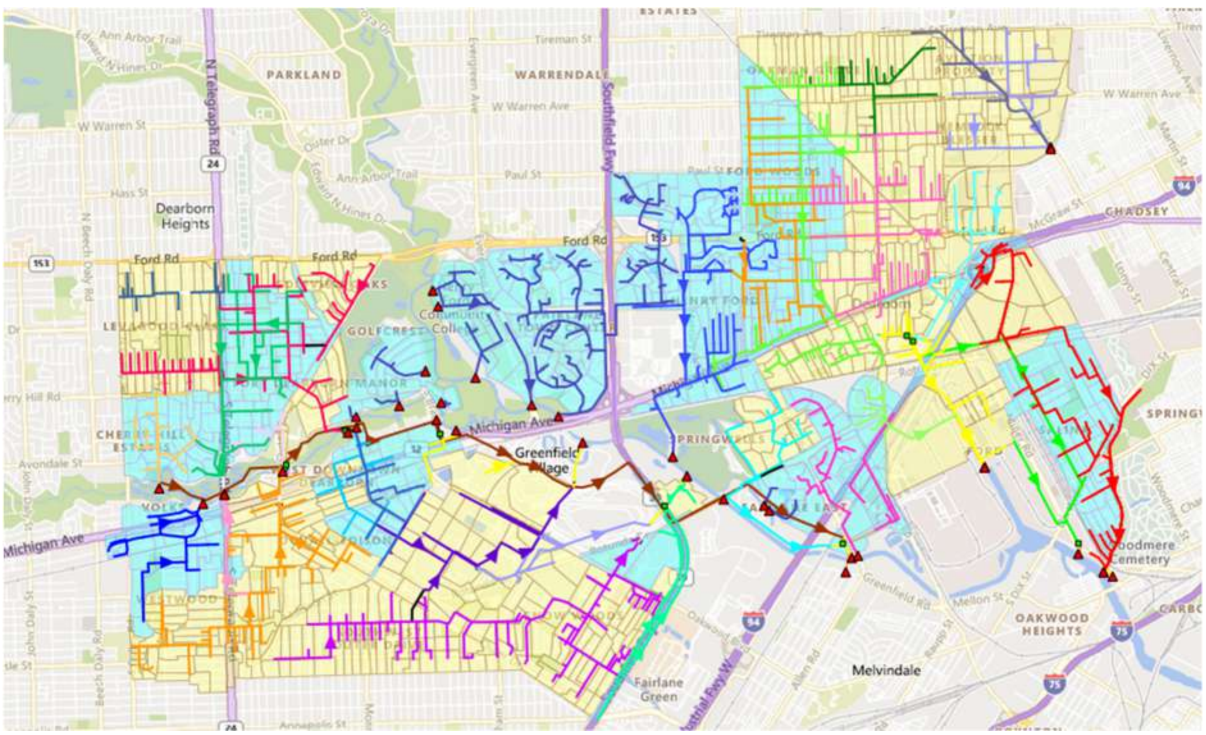


Figure 9. Dearborn Collection System Model Extents

Model Calibration

Model calibration is performed to tune model performance to more accurately reflect system behavior. Measured data in the system is used as the base data set and the model is adjusted iteratively until it can accurately predict the system's performance under a range of environmental conditions including rainfall and river elevations. For this effort, six ISCO flow monitoring devices were installed for a four (4) month period from April 25, 2023, through August 25, 2023. These six flow meters were placed in key locations within the system to characterize wet weather flows generated during rainfall events and were used as model calibration points. The data collected from these meters was compared against model flows for the same rainfall event to evaluate performance. **Figure 10** shows the location of these six meters, along with the additional two meters installed for the AMM effort discussed in a previous section. For a more detailed description of the locations of the meters refer to the Data Gap Analysis Memo in Appendix A.

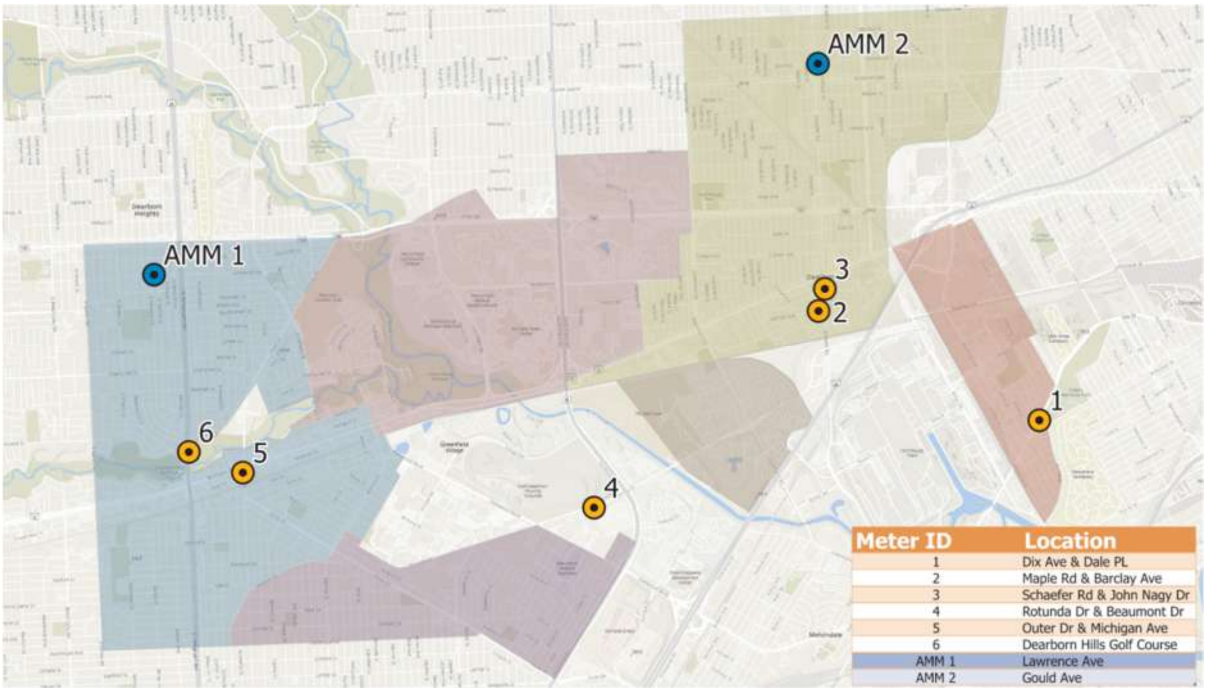


Figure 10. Flow monitoring locations in the City of Dearborn for the Antecedent Moisture Model (blue) and the collection system model (Orange)

The calibration process used rainfall data from the Great Lakes Water Authority (GLWA) which was collected for the period from April 25, 2023, through August 25, 2023, the same period in which the flow meter data was collected and applied to the model. The City was divided into three rainfall zones based on the location of three GLWA gages located in close proximity to Dearborn. These gages were used to apply the most accurate representation of the observed rainfall events to the model. The 5-minute data from these three rain gages was applied in a spatially varied manner such that the areas closest to each individual gage were assigned the rainfall data from that gage. **Figure 11** shows the location of the three rain gages used and the color-coded corresponding areas of the model to which each rain gage was applied.

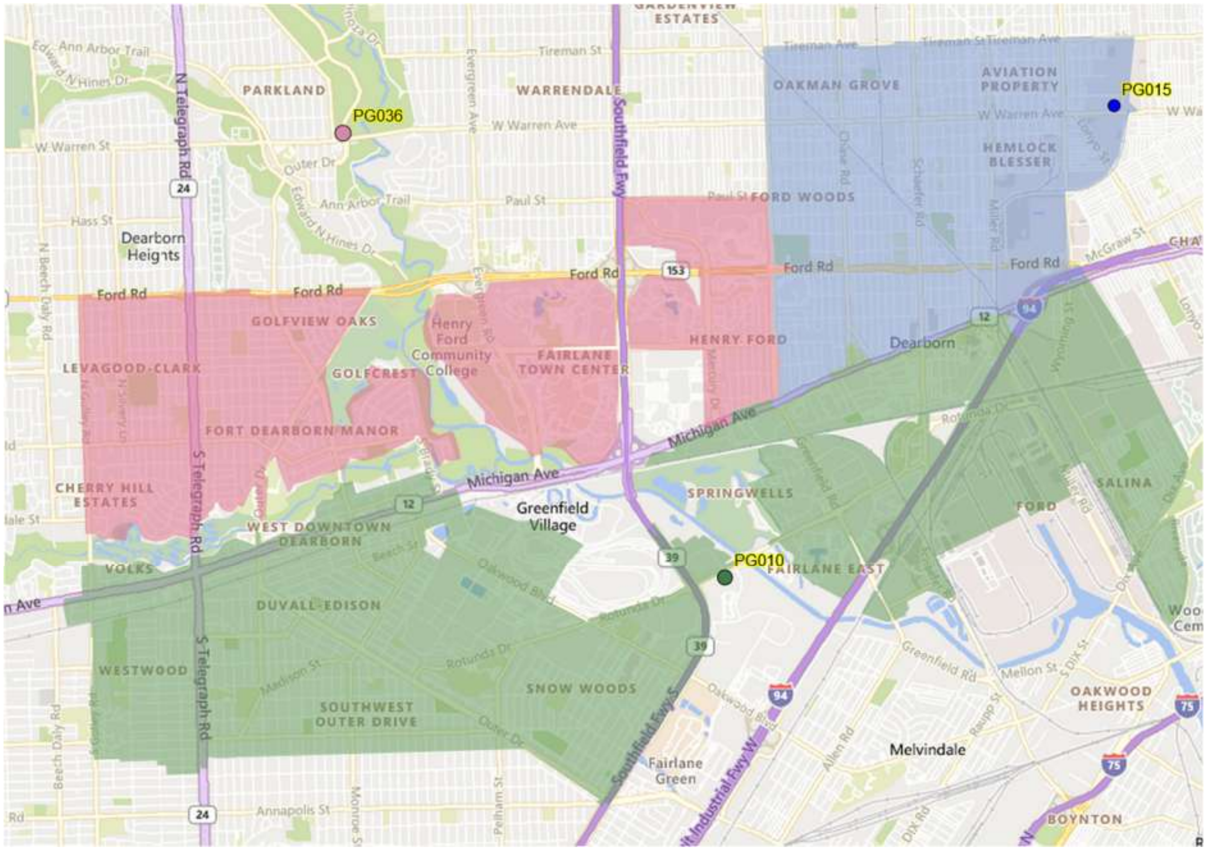


Figure 11. GLWA rain gage locations and associated model areas

Six rainfall events with measured total rainfall of over half an inch occurred during the period in which the flow meters were installed. These six events were used as calibration events for the model. **Table 3** contains the details of these events, which is located at the intersection of Schaefer Road and John Nagy Drive (Figure 10) and has the largest tributary area of all six meters. It measures flows coming from the heavily impacted Northeast area (Chase District) and measures a large fraction of the flows that empty into the Prospect caisson. The largest difference in total volume observed between the calibrated modeled and metered flows was –26% during event 5. The majority of the other events had errors closer to 10%, suggesting that the model is predicting the total volume entering the system well. Sources of error in these values can mostly be attributed to spatially varied rainfall patterns that can't be picked up by rain gages, but things like pipe blockages or preceding ground wetness can also significantly impact total volumes.

Table 3. Model Calibration Rainfall Event Results for Schaefer Road Meter (Meter 3)

Event	Date	Max Rainfall intensity (in/hr)	Total Rainfall (in)	Metered Volume / Peak Flow	Modeled Volume / Peak Flow	Total Volume % Error
1	July 2, 2023	0.6	1.4	97 MG / 168 cfs	87 MG / 113 cfs	-10%
2	July 15, 2023	0.6	0.6	38 MG / 111 cfs	43 MG / 182 cfs	13%
3	July 20, 2023	0.5	0.5	40 MG / 122 cfs	35 MG / 106 cfs	-13%
4	July 26, 2023	0.4	0.9	48 MG / 102 cfs	56 MG / 105 cfs	17%
5	August 6, 2023	0.3	0.6	76 MG / 161 cfs	56 MG / 134 cfs	-26%
6	August 14, 2023	0.4	1.0	51 MG / 137 cfs	56 MG / 113 cfs	10%

To calibrate the model to these events, modeling parameters were adjusted to provide the best fit to the observed data. These included runoff characteristics which are defined by site specific soil properties, the percentage of impervious area within each drainage basin, and the length of the flow path for the runoff in each basin. **Figure 12** plots the observed total volumes for these six-calibration events against the modeled total volumes for each of the six meters. The closer these points fall to the one-to-one line shown in the figure, the more closely the model is replicating the flow totals observed by the flow meters. As seen in the figure below, most of the points follow the one-to-one line with a reasonable degree of accuracy, suggesting a strong correlation to measured data.

In addition to total volume, time series plots were created for each of the six meters during events to evaluate the model's response time, time of concentration, and flow durations. The model's predicted time series data was shown to match well with metered data, suggesting that the model is connected properly and accurately reflecting system hydraulics. The detailed statistical results and time series plots from this analysis for each meter and event are shown in more detail in Appendix B.

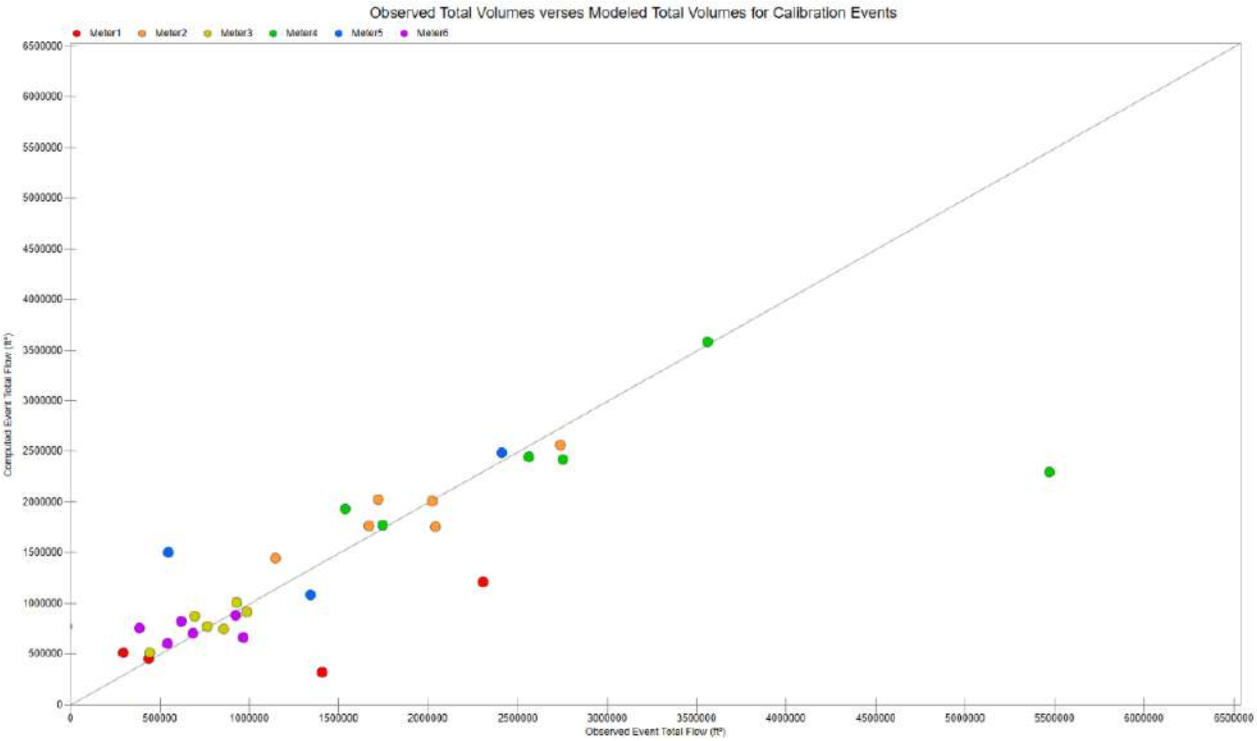


Figure 12. Observed total volumes vs. modeled total volumes for calibration events

Model Validation

To validate the model, the three rainfall events in 2021 that resulted in flooding within the City were simulated in the calibrated model. The resulting flood areas calculated by the model were compared to the flooding that occurred in the City as reported by flood insurance claim mapping. The rainfall amounts at each of the rainfall gages used in the model are detailed for these three events in **Table 4**. Also included in the table below is the historic flooding event which occurred in August 2014. This 2014 event, along with the June 2021 event, are the only events for which detailed flooding maps were available for validation comparison. Since the 2014 event, extensive system upgrades that include sewer separation have been performed on the City's collection system. Because of these upgrades, the current calibrated model would not provide an accurate representation of the flooding that occurred during the 2014 event. The model developed for this study represents the current connectivity of the system and will be used for planning and to support further proposed system improvements. Because of the significant differences between the 2014 system and the current system, the 2014 event was not used to validate the model's performance. However, by comparing the similarities in rainfall by location, generalizations can be made about the locations of observed flooding in the 2014 event and the locations of flooding in the 2021 events for certain locations in the system.

Table 4. Model validation rainfall events

Date	Rain at Gage PG015	Rain at Gage PG010	Rain at Gage PG036
August 11-12, 2014	5.6	3.5	4.9*
June 25-26, 2021	6.8	0.2	5.7
July 16, 2021	3.8	3.9	4.1
July 24, 2021	1.6	2.1	1.8

*Measured at PG034 gage in the same vicinity of PG036

- **June 25–26, 2021**

  Comparing the flooding maps from the model simulation and the City's flooding map for the June 2021 event, the general areas of flooding are similar with two notable exceptions. The model indicates little to no flooding in the area south of the river and in the far northeast corner of the City. The reason for these discrepancies will be discussed in further detail below but the simplified reasoning is two-fold. One, the spatial variance of the rainfall and the data collected at the rain gages, and two, flows and pipe conditions from GLWA existing outside of the model domain that are undefined and are not simulated in the model. **Figure 13** and Error! Reference source not found. show the flooding response for the model and as reported by the City, respectively.

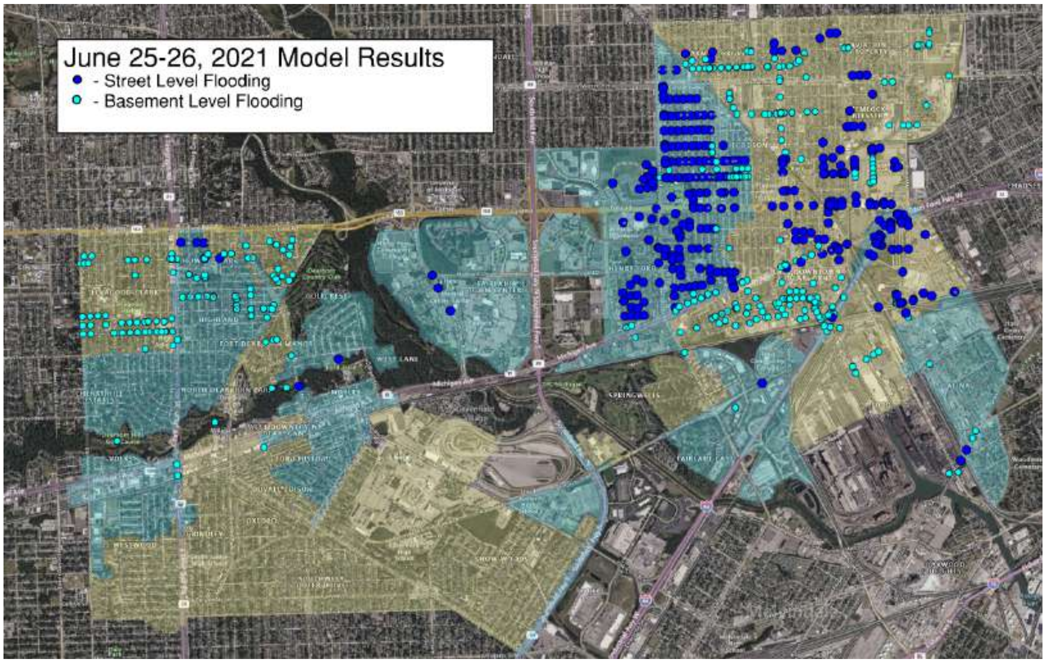


Figure 13. June 25–26, 2021, modeled flooding response

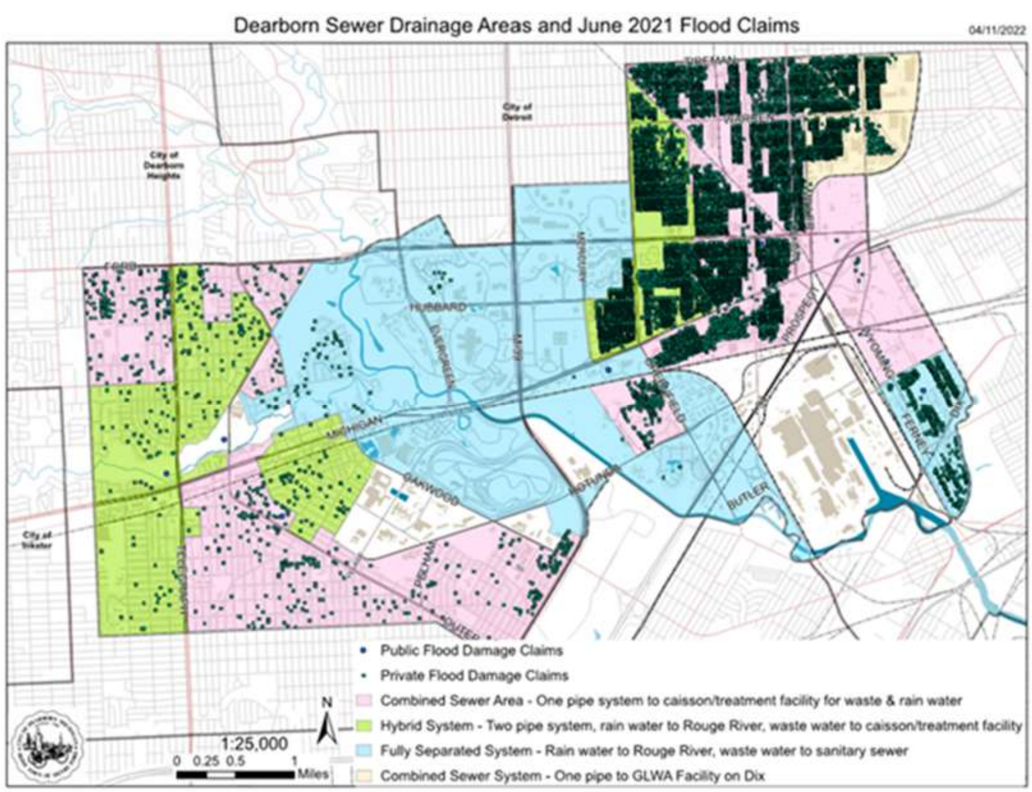


Figure 14. June 25–26, 2021, flooding claims as reported by the City

Referring to **Table 4**, rain gage PG010 only recorded 0.2 inches of rain for this event. This gage covered the majority of the southern half of the model and as a result, the model does not indicate flooding in this region of the model. In the absence of a rain gage in this region that accurately characterizes the rain that fell on this area of the City, the model is not able to capture the flooding observed in this area. However, we can make a generalization that uses a uniform rainfall assumption across the entire model to visualize what flooding would look like under this scenario. Applying the rainfall that occurred at gage PG036 (5.7 inches) to the entire model produces the flooding map shown in **Figure 15.** As can be seen, widespread flooding that closely mimics the flooding claims map from **Figure** 14 is the result. This suggests that the rain gage PG010 inaccurately measured rainfall during this event or was not reflective of total rainfall across this district, resulting in underreporting of the total observed rainfall. Given the close match in spatial extent of flooding across Dearborn from this analysis, the model is reasonably reflecting the spatial extent of flooding during large recent storm events.

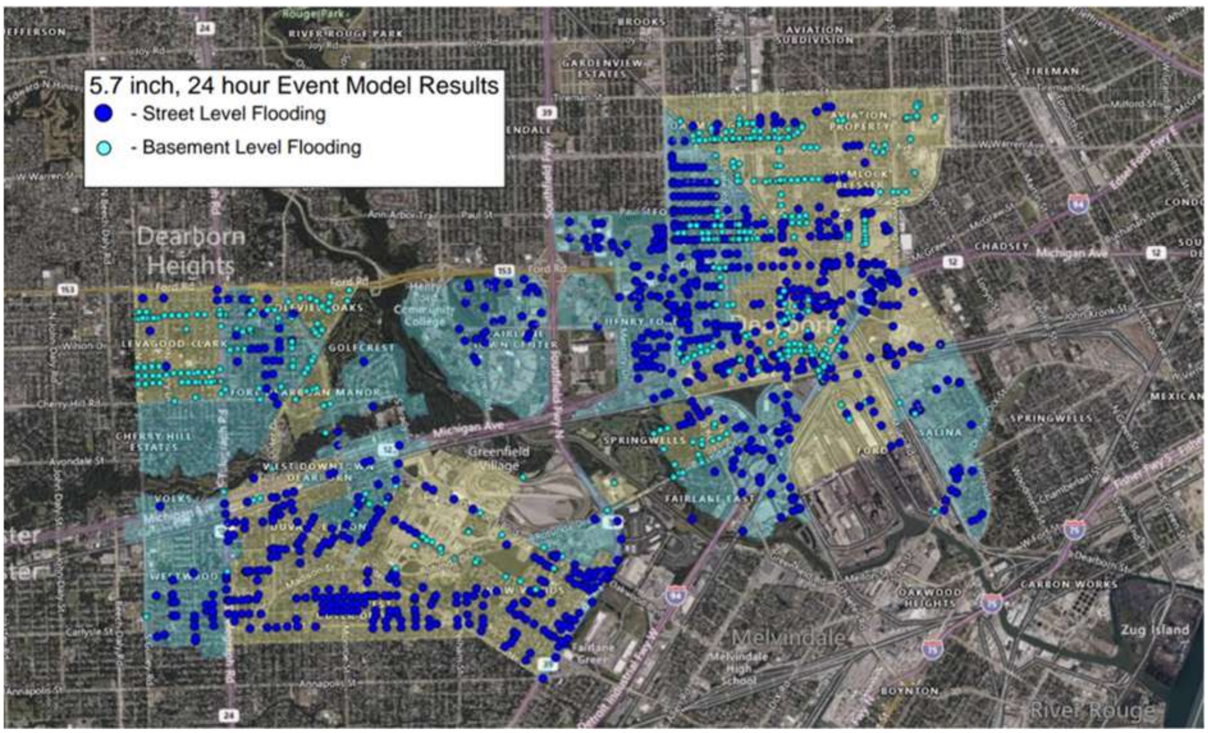


Figure 15. June 25–26, 2021, modeled flooding response using a 5.7-inch rain event distributed across the entire model

July 16, 2021, and July 24, 2021

The model was also used to simulate flooding during the July 16 and July 24, 2021, rainfall events that resulted in flooding. Detailed flood claim maps were not available for these events so a direct comparison cannot be made. It is useful, however, to draw on similarities between reported rainfall amounts at each rain gage used in the model for these events and the amount recorded during the August 2014 event for which a flood claims map is available. Note that exact correlation to location and amount of flooding cannot be made between the 2021 events and the 2014 event due to improvements in the collections system over the last decade. However, most of the system improvements that took place between the 2014 event and the current configuration of the system occurred in the areas north of the river. For the events on July 16 and 24, 2021, the majority of the flooding occurred south of the river where the system is mostly unchanged. The discussion comparing the resulting flooding for these two July 2021 events to that of the 2014 event will focus solely on the area south of the river. Figure 16 through Error! Reference source not found. contain the modeled flooding results for the July 16, 202l, July 24, 2021, and the City's flood claims map for the August 11–12, 2014, event.

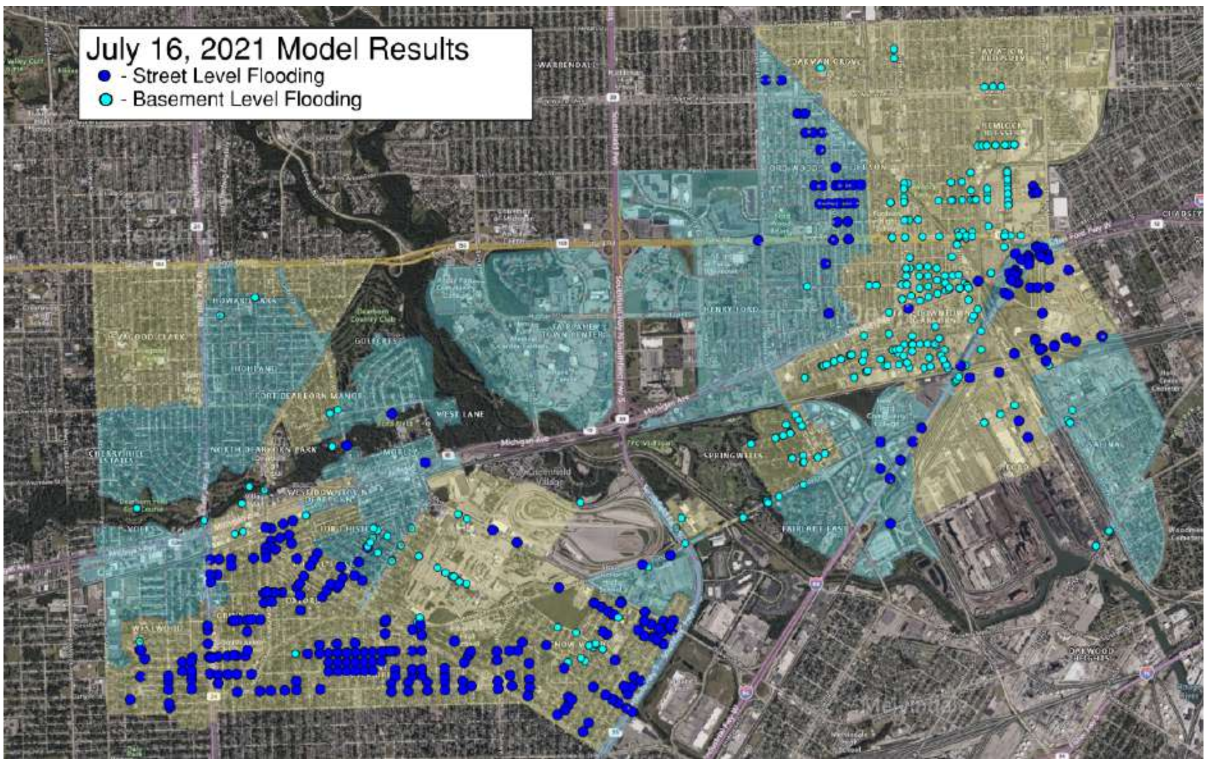


Figure 16. July 16, 2021, modeled flooding response

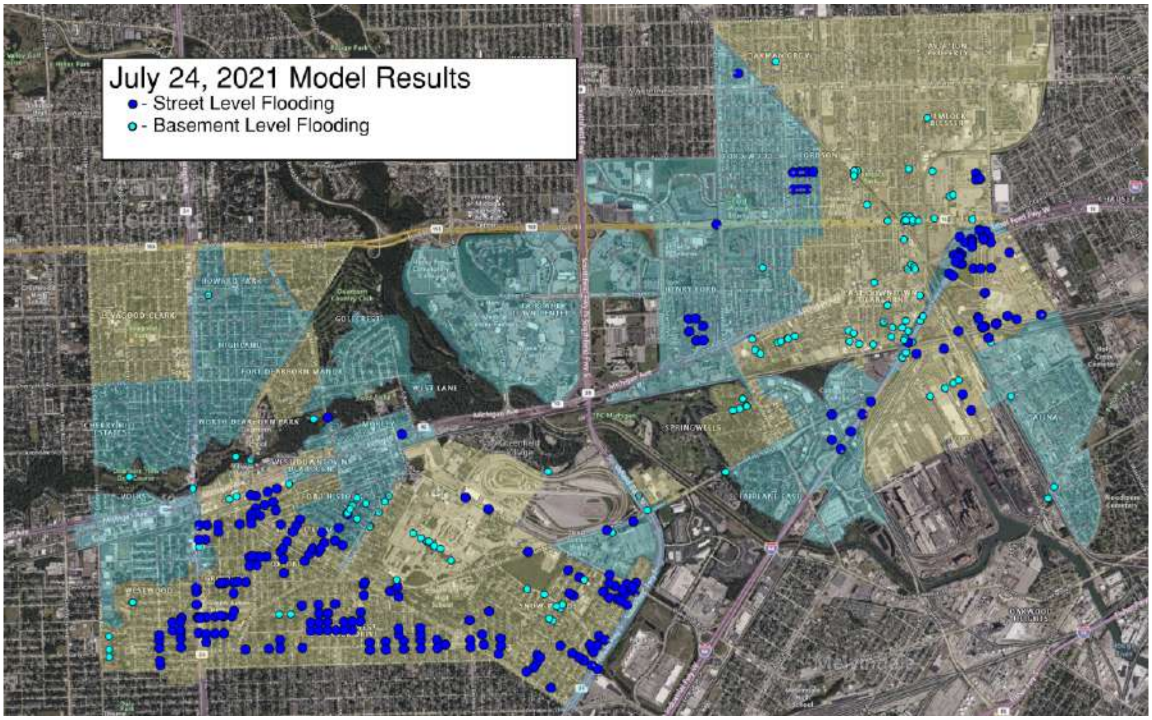


Figure 17. July 24, 2021, modeled flooding response

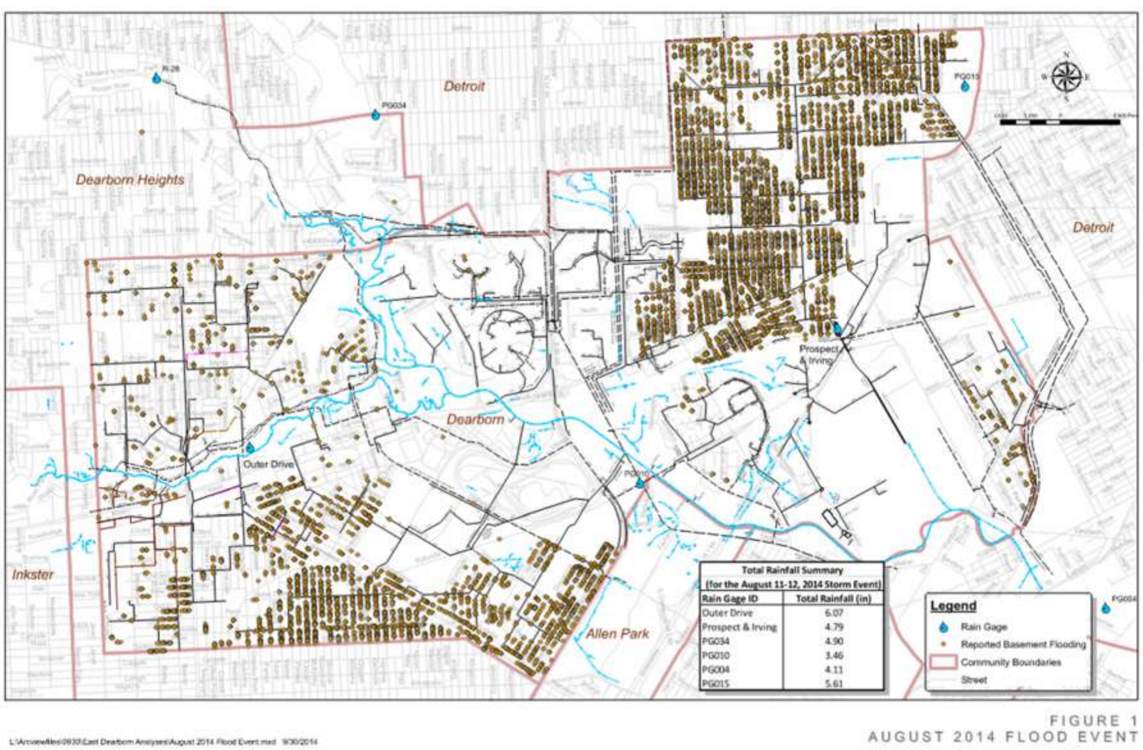


Figure 18. August 11–12, 2014, flooding claims as reported from the City

The majority of the flooding for the simulated events on July 16 and July 24, 2021, occurred in the south region of the City both south and west of the Rouge River. The rain gage that drives the flows and potential flooding response in this area of the model is gage PG010. As referenced in Error! Reference source not found., the rainfall recorded at gage PG010 for the July 16, 2021, event of 3.9-inches was very similar to the rainfall recorded during the August 11–12, 2014, event of 3.5-inches. The flooding response shown on the flood maps for these two events is similar and occurs along the same trunk lines for both. The rainfall recorded at PG010 for the July 24, 2021, event was smaller at 2.1-inches, but the flooding for this event also occurred along the same trunk lines. Both of these events show an area of extent of flooding that closely matches the similarly sized August 11, 2014, rainfall event. The areas south of the river that were impacted directly overlap what was observed in 2014, lending further credibility to the model's predictive capabilities.

With the data presented above, the model calibrated well and is able to predict with reasonable accuracy the system's response to a rain event. When compared against flooding claim maps in the validation analysis, the model was also able to accurately predict the areas of extent over which flooding occurred in response to historic large storm events. Given the results of these analyses, the model is well suited to evaluate flood mitigation alternatives to help alleviate Dearborn's recurring flooding issues. A more detailed analysis of system hydraulic grade lines in specific critical junctures with regard to the validation storm events is discussed in further detail in Appendix B.

Existing Conditions

Through evaluating the model behavior during the simulated validation storm events, a general understanding of the current system performance and hydraulic grade lines during rainfall events can be characterized.

To test the resilience of the system to rainfall volumes and gain an understanding of the volume of rainfall the system can convey before flooding occurs, three design storm scenarios were conducted. These three design storm scenarios were conducted assuming average June 2021 river elevations and upstream flow conditions from the Baby Creek facility. The design storms consisted of a 1-yr, 5-yr, and 10-yr, 24-hr event with total rainfall volumes of 2.06 inches, 3.3 inches and 3.98 inches, respectively. The system experienced flooding during even the smallest design storm event, (2.06 inches) in the southwest region of the City (tributary to the Dearborn interceptor), the northeast region (tributary to the Miller pump station interceptor), and in the southeast region (tributary to the Miller pump station interceptor). The northwest area tributary to the Dearborn interceptor was able to convey all three design storm events without experiencing flooding. **Figure 19** and **Figure 20** show the profiles of the Dearborn interceptor and the interceptor to the Miller pump station during the 1-yr, 24-hr event. Neither interceptor can adequately convey the peak flows produced from this event and the system experiences flooding along both interceptors.

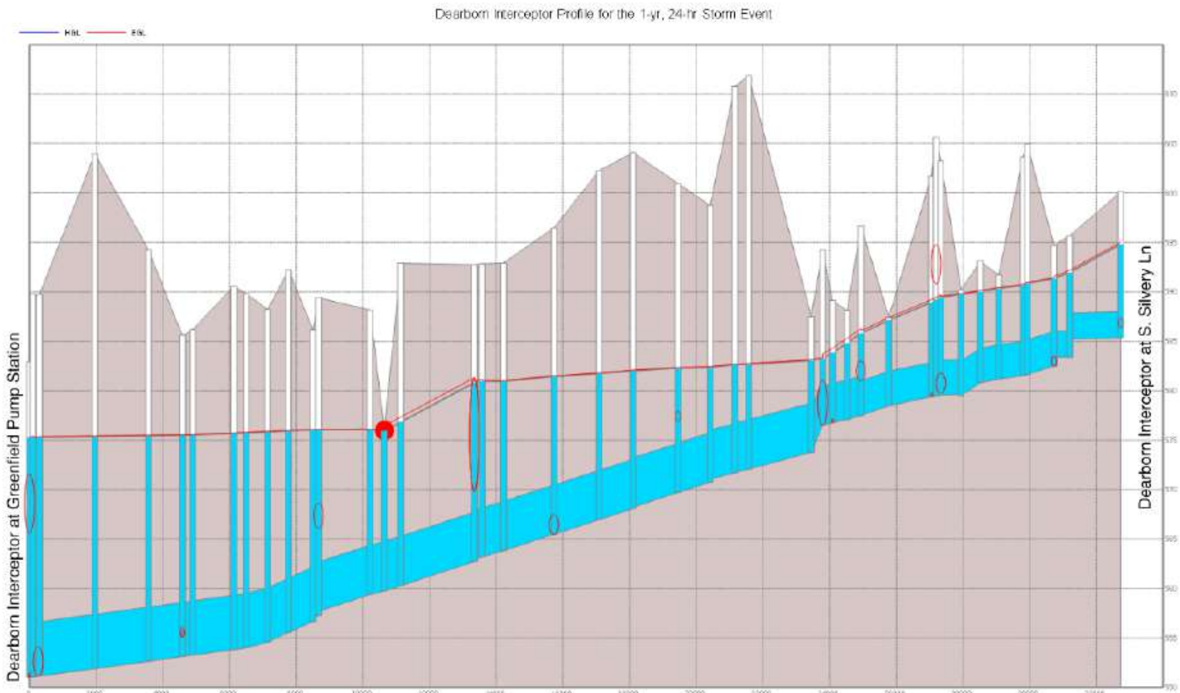


Figure 19. Dearborn Interceptor Profile during the 1-yr, 24-hr design storm

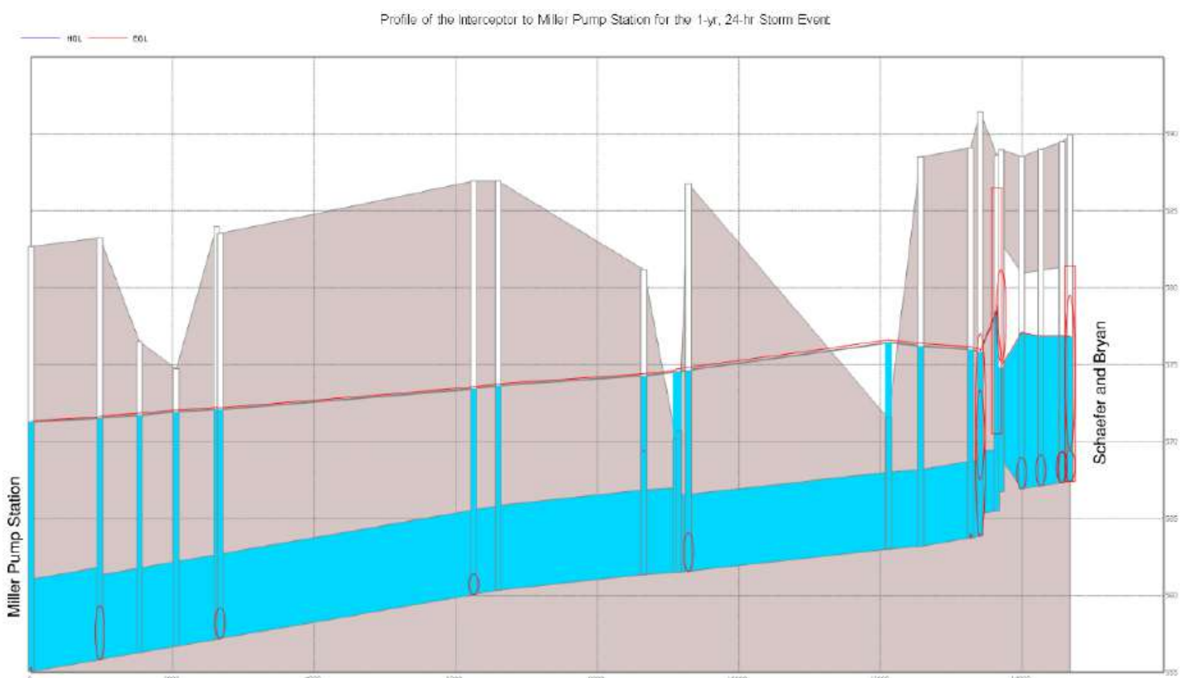


Figure 20. Profile of the interceptor to the Miller pump station during the 1-yr, 24-hr design storm

Approximate Cause of Flooding

The root causes of flooding vary by region and are broken down by drainage area. Figure 21 presents five color coded regions each with different primary root causes for flooding. Each of these five root causes are discussed in further detail below.

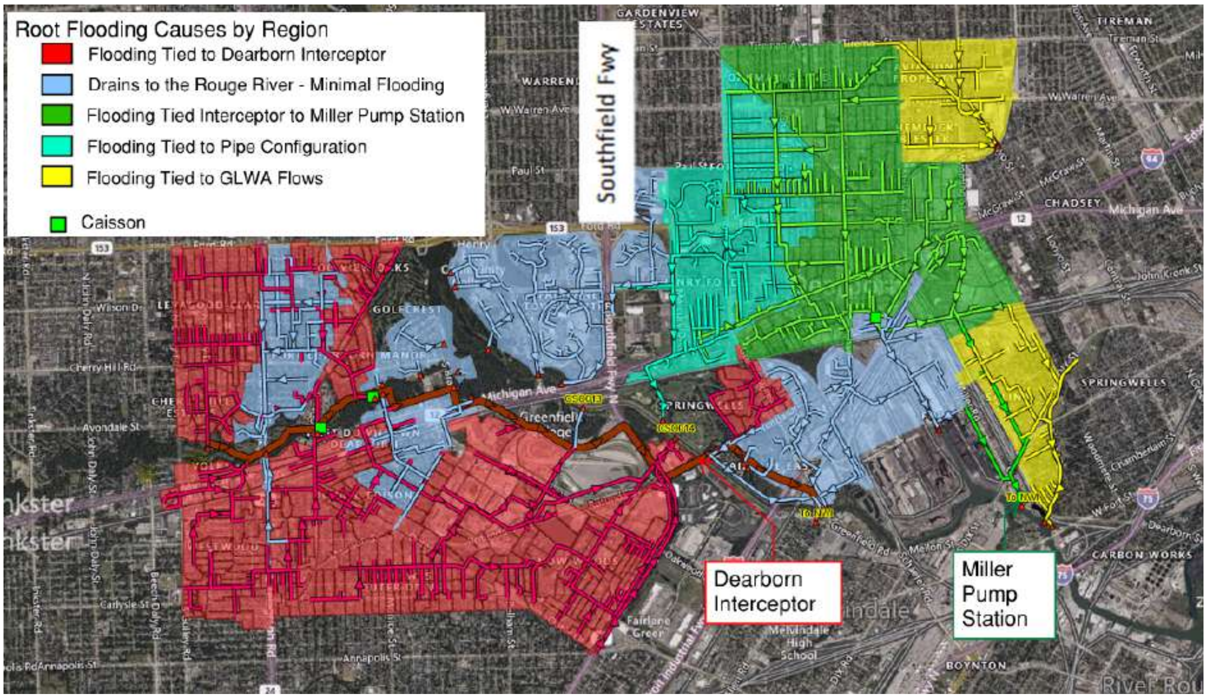


Figure 21. Root cause of flooding by region

Flooding Tied to the Dearborn Interceptor

The majority of the City west of the Southfield Freeway drains to the Dearborn interceptor. These areas tributary to the Dearborn interceptor are shaded in red in Figure 21, with the interceptor shown in red traversing along the Rouge River. As shown during the validation events and the 1-yr, 24-hr event profiled in Figure 19, the Dearborn interceptor is under sized (over capacity) and is unable to convey the flows generated from storm events as small as a 2.06-inch rainfall event.

Though the size of the interceptor is the root cause of flooding in the red shaded areas of Figure 19, there are contributing factors that affect the timing and severity of the flooding for any given storm event. First, the elevation of the Rouge River during a storm event has an effect on the ability of the system to effectively overflow to the river and relieve the system. Second, there are suspected system blockages in the sewers south of the river leading to additional flooding during rainfall events. To determine the extent to which these factors affect the occurrence of flooding, the July 16, 2021, validation event was re-run with the river "removed" from the model to simulate "free flows" out all the outfalls along the Rouge. Additionally, the suspected blockages were removed from the pipes in the southwest tributary area. Figure 22 presents model results of flooding locations from the pipe blockage and river elevation validation run and Figure 23 presents model results of flooding locations from the run without the effects of the river and with the pipe blockages removed. The results suggest flooding is less severe with the river and pipe blockages removed but is still present. This further reinforces that the size of the Dearborn interceptor is the root cause of the flooding in the (red) areas tributary to the interceptor.

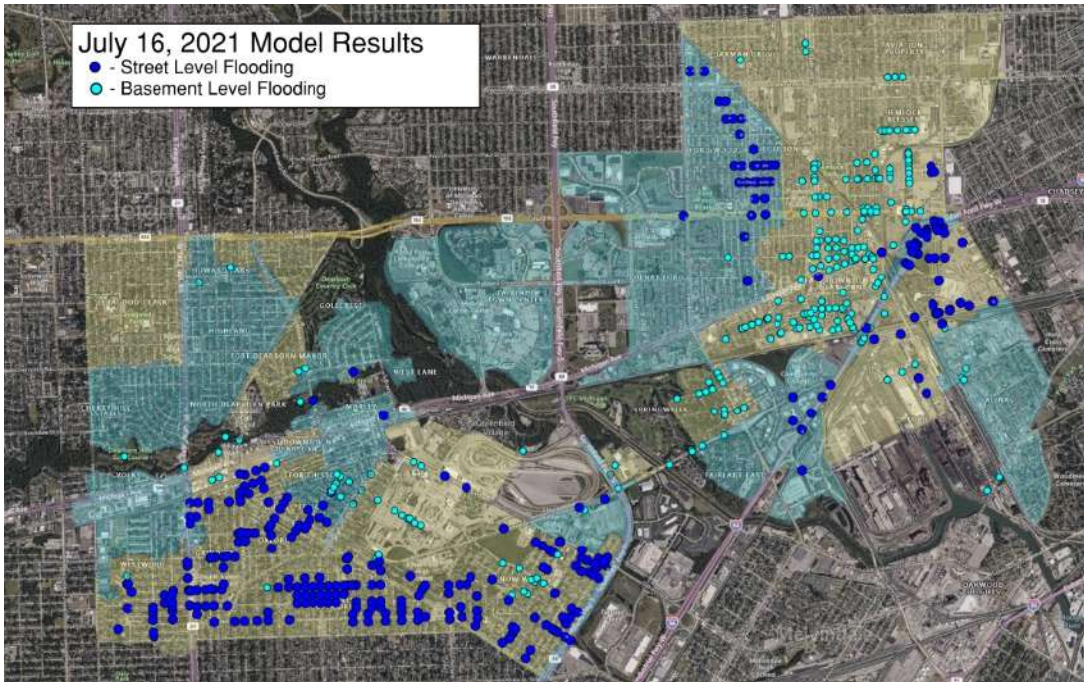


Figure 22. Model projected flooding from July 16, 2021, event for the current system

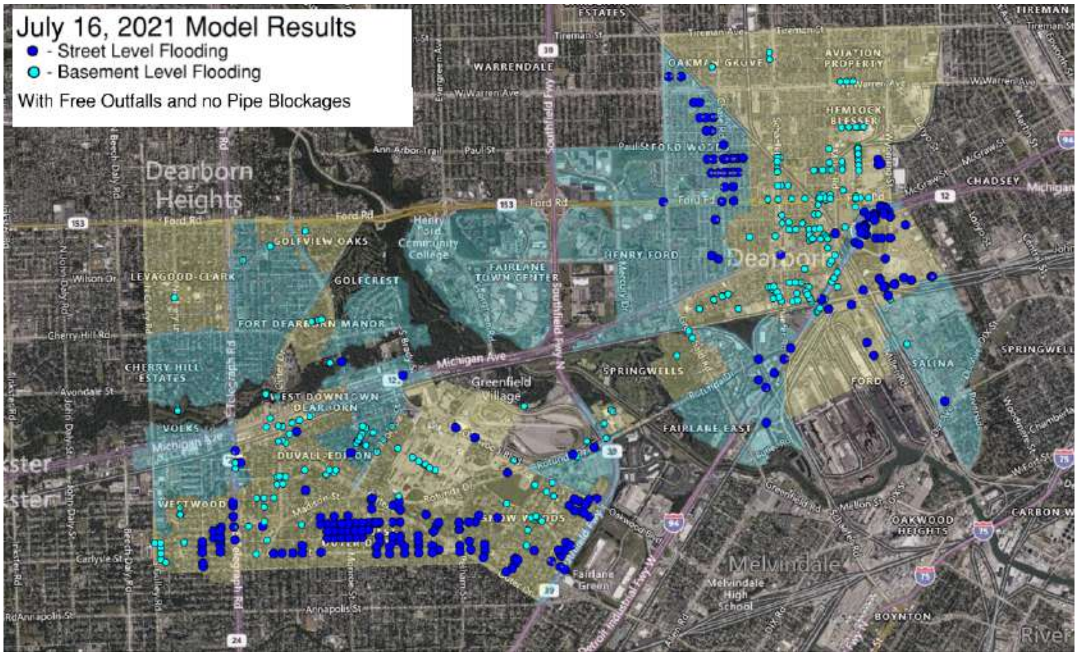


Figure 23. Model projected flooding from July 16, 2021, event without river influences and with blockages removed

A secondary contributing factor to the severity of flooding in the areas tributary to the Dearborn interceptor is the pumping rates at the Greenfield pump station that control flow downstream of the interceptor. In other words, the pump capacity at the Greenfield pump station contributed to flooding. To determine if increased pumping rates would eliminate flooding in the interceptor a model simulation of the June 2021 event was conducted with the pumping rates in the Greenfield (and the Miller) pump station increased to 300 cfs from the typical (contractual) 65 cfs. The model results indicate that the Greenfield pump station wet well maintains depths under 1-foot for the duration of the event and the maximum flows tributary to the pump was 110 cfs. To state this more simply, the Dearborn interceptor was restricting the flow to the pump, rather than the pumping rate restricting the flow out of the interceptor. Figure 24 shows the profile of the Dearborn interceptor from Greenfield pump station to the most upstream segment of the interceptor at Colburn and N. Gulley. Notice that the pipe at the downstream end of the interceptor maintains capacity at the pump station with flow levels below the crest of the pipe. Moving upstream to the middle section of the interceptor, the hydraulic grade line (blue) has a slope steeper than that of the pipe indicating the capacity of the pipe has been exceeded by the current flows and the pipe is unable to convey the volume to the more downstream pipe even though the pipe downstream has additional capacity. This flow restriction is the cause, and flooding occurring in this scenario further emphasizes the root cause of flooding in this area is due to the inadequate capacity of the Dearborn interceptor.

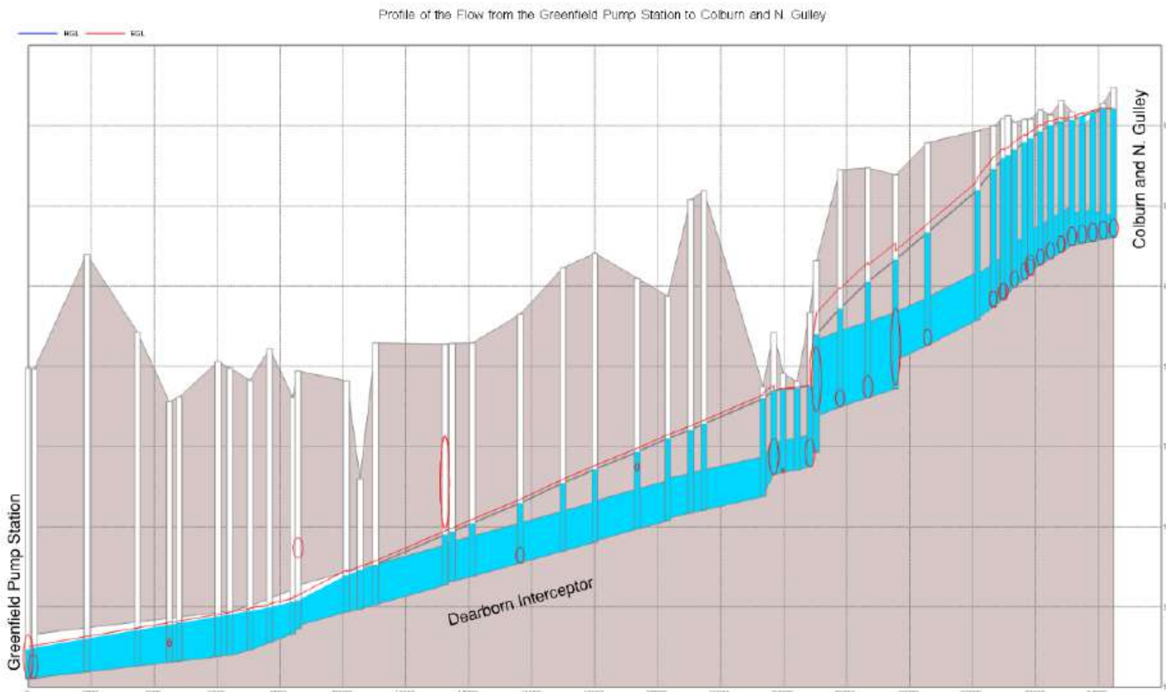


Figure 24. Dearborn Interceptor Profile with 300 cfs pump rate at Greenfield Pump Station

It must be noted that the Dearborn interceptor is not the only pipe in this area of the system that experiences capacity issues. Figure 25 is the profile of one of the trunk sewer connections to the Dearborn interceptor. The larger trunk sewer on the right of the profile is draining a tributary area into the Dearborn interceptor on the left. Notice the steep hydraulic grade line associated with the smaller diameter connecting sewer. This small diameter connecting pipe is significantly undersized for the volume of flow occurring during rainfall events. Undersized connecting pipes such as this exist at multiple locations in the system. These restrictions further increase the flooding experienced in tributaries connected to the Dearborn interceptor with small diameter pipes.

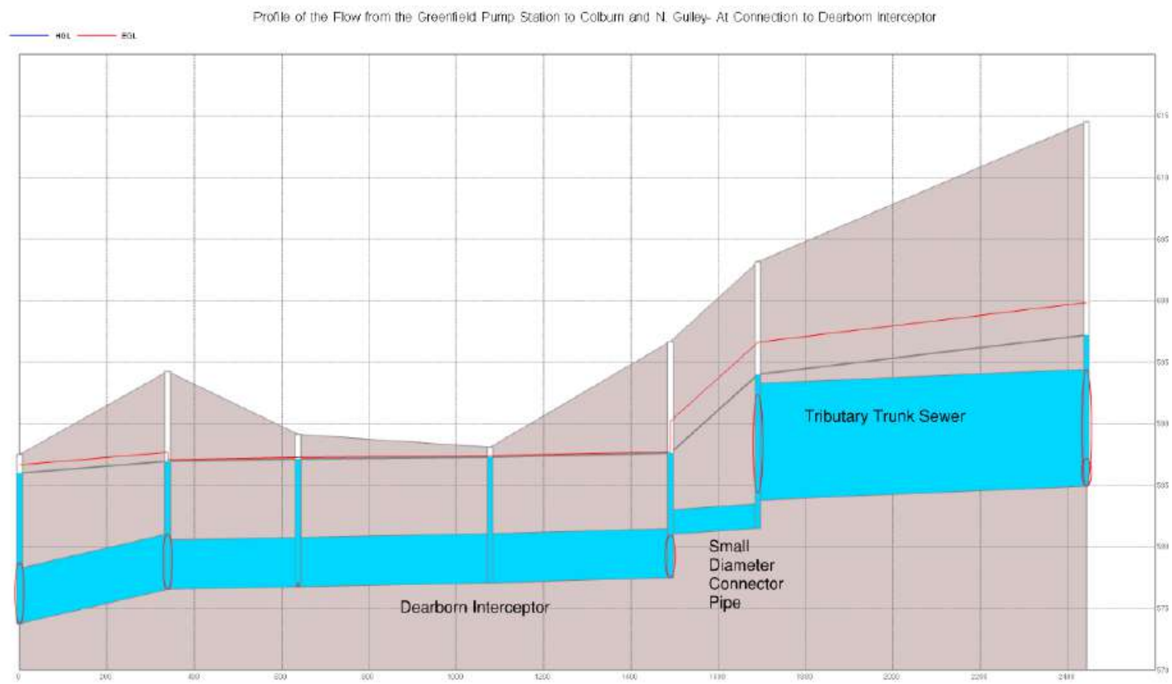


Figure 25. Example of small diameter trunk connections to the Dearborn Interceptor

Areas Draining Directly to the Rouge River

The portion of the City that drains directly into the Rouge River is shaded in blue in Figure 21. These are separated areas that are not tributary to either the Dearborn interceptor or the Miller pump station. These areas experience minimal flooding during the validation events as reported by the City in flood claims mapping and the model did not predict widespread flooding in these areas.

Flooding Tied to the Interceptor to Miller Pump Station

The northeast region of the City, known as the Chase District, drains through two trunk sewers to the Miller pump station. This region is shaded in green in Figure 21. As was shown during the validation events, as well as the 1-yr, 24-hr event profiled in Figure 20, the interceptor conveying flows to the Miller pump station is under sized and is unable of convey the flows generated from these events, resulting in flooding in the areas which drain to it.

Similar to the discussion above on the Dearborn interceptor, though the size of the interceptor is the root cause of flooding in green shaded areas of Figure 21, there are contributing factors that affect the timing and severity of the flooding from a given event. The elevations of the Rouge River, as well as the pumping rate in the Miller pump station at the downstream end of the interceptor were evaluated to determine the magnitude of the effect each has on the flooding in these areas.

Figure 22 and Figure 23 show the flood projections for the July 16, 2021, validation event for the current system both with and without the influence of the river levels on the system. Similar to the analysis for the area tributary to the Dearborn interceptor, the removal of the effect of the river did slightly lessen the flooding in the area tributary to the Miller pump station but did not eliminate the flooding.

The pumping rate at the Miller pump station was also evaluated to determine if a higher pumping rate could have a significant impact on flooding. Figure 26 contains a profile of the interceptor to the Miller pump station during a model simulation with the pumping rates at Miller pump station set to 300 cfs. The profile below shows that the pipes at the downstream end at the pump station are pumped down such that they have capacity. Beyond the first couple pipe segments upstream of the pump station, the flow exceeds the capacity of those upstream pipes and therefore flow is restricted resulting in flooding. This point is demonstrated by the fact that the slope of the hydraulic grade line (blue) is steeper than the slope of the pipe in the interceptor upstream of the pump station. Because of the flow restrictions from insufficient pipe capacity, the flooding cannot be completely alleviated by increasing the pump capacity alone. However, increasing pumping capacity could potentially minimize flooding in the tributary area immediately upstream of the Miller pump station.

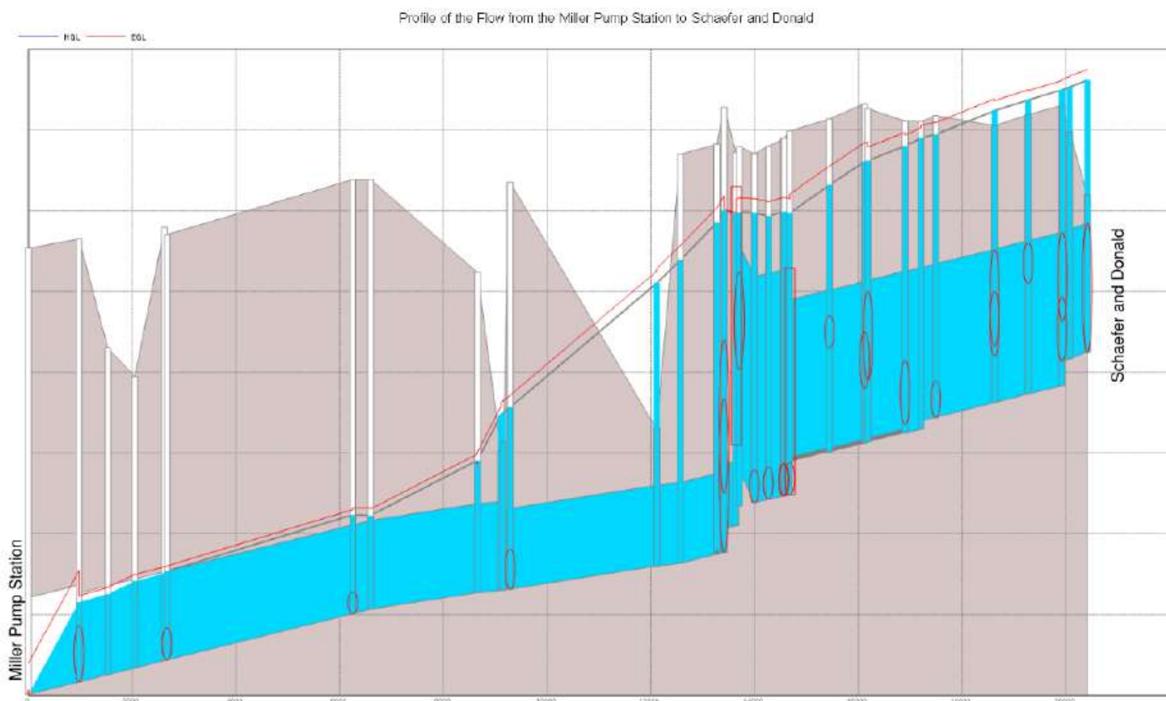


Figure 26. Profile of the interceptor to the Miller Pump Station with 300cfs pump rate at the station

Flooding Tied Pipe Configuration

Between the areas directly tributary to the river and the areas tributary to the Miller pump station is the area shaded teal in Figure 21. This is an area that had been part of the combined system in the Northeast District (Chase District) draining east to the Miller pump station. This area was then separated, and the drainage redirected to the west to the Rouge River outfall at Southfield. As part of the redirection of this area to the west, a section of pipe that used to drain east, was re-purposed and used to convey a portion of the flow to the west. In using the existing pipe, this new flow path forces flow upward and against the slope of the pipe until it overtops the high point in the drainage pathway on its westerly route to the Rouge River. Figure 27 is a duplicate of the profile included in the validation section above but is repeated here for ease of use and contains the profile of this flow path with inverted slope and illustrates the effect this slope has on the flow elevations.

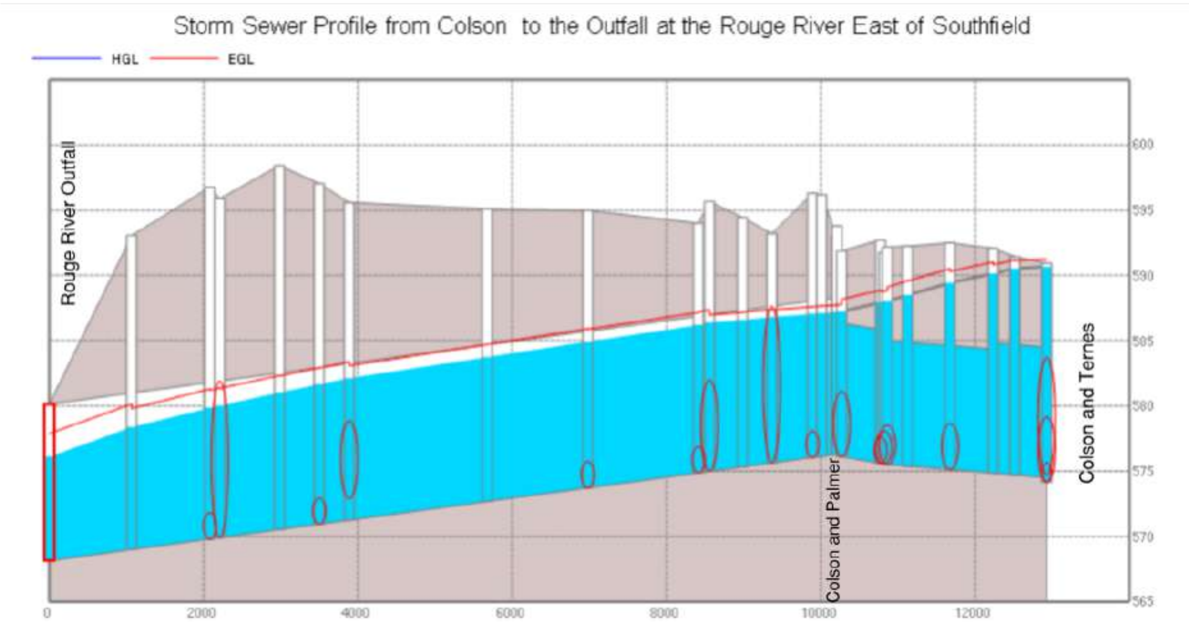


Figure 27. Profile of storm sewer from Colson and Ternes to the Rouge River Outfall

As illustrated in the figure above, the pipes on the downstream portion of the flow path still have some remaining capacity, but the configuration of the pipes upstream of Colson and Palmer force the flow to backup so that it can overtop the high point at Colson and Palmer, resulting in upstream flooding. To the east at Colson and Ternes, an 18-inch connection still exists to allows flow to drain east into the combined sewers tributary to the Miller pump station. As discussed in the previous paragraph, the interceptor to the Miller pump station experiences capacity limitations so the flow from this area is restricted from flowing to this direction as well. The root cause of flooding in this area is, due to pipe configurations and pipe capacity limitations in the flow path.

Flooding Tied to GLWA Flows

The last of the five regions in the City's sewer system is the area in Figure 21 which is shaded yellow. Flooding in the two yellow shaded regions is controlled by flows in the GLWA system outside of the domain of the Dearborn system and the Dearborn system model.

In the northeast corner of the City, flow enters the area in two trunk sewers, one 11.5-feet and one 15-feet in diameter. Less than one mile south of the point of entry, the flows exit the system in the same two 11.5-feet and 15-feet diameter trunk sewers. Any rainfall event induced spikes in flow that occur in these two trunk sewers upstream of where they enter the Dearborn system have not been quantified and could be a root cause of the flooding observed in this area. Additionally, flow restrictions that occur in these two trunk sewers downstream of where they exit the Dearborn system could cause flows to backup into the Dearborn system and serve as the root cause of flooding in this area.

To quantify the Dearborn contribution to the flow in these two trunk sewers, the June 2021 validation event was analyzed. From the June 25, 2021, validation event the peak flows generated within the Dearborn system account for 45% of the available capacity of the 11.5-feet diameter trunk and were collected from a 477-acres drainage area. Peak flows generated in the Dearborn system tributary to the 15-feet diameter trunk account for 17% of the pipe capacity and were collected from a 121-acre drainage area. Based on the required pipe capacity to convey flows generated in the Dearborn tributary area, the trunk sewers would need to flowing at less than 45% capacity to adequately convey Dearborn's flow contribution. If the trunk sewers are already flowing at greater than 55% capacity before Dearborn's contribution, the trunk sewers will not have the capacity to convey flows out of the system and will lead to flooding in this area of the City.

The second yellow shaded area is in the southeast portion of the City and is referred to as the Baby Creek area. The flooding in this area had two root causes, first, the flows in the effluent trunk sewer from the Baby Creek facility, and second, flooding caused by the lack of capacity in the interceptor to the Miller pump station.

First, the effluent pipe from the Baby Creek facility enters the Dearborn system as two 17.5-feet by 14.5-feet elliptical pipes. Flow metering conducted as part of this modeling study showed that flows though these two effluent sewers back up and is forced up into the tributary stormwater pipes connected which are draining to them. These backups into the storm pipes from the flows in the effluent Baby Creek facility trunks is one cause of surface flooding in this lower yellow shaded area.

The second cause of flooding in this area is attributed to the capacity issues in the interceptor to the Miller pump station. This is a separated area with sanitary pipes connecting to the combined interceptor draining to the Miller pump station. As discussed previously, this interceptor is undersized for many rainfall events including the validation events and a 1-yr, 24-hour event. Backups in the interceptor to the Miller pump station would lead to the connected sanitary pipes flooding into connected basements and the root cause of basement flooding in this separated area of the collection system. As discussed previously, the current model that is the focus of this report is a stormwater and combined sewer system model and as such, only included pipes that convey stormwater only or combined stormwater/sanitary flows. Since the interceptor to the Miller pump station drains a combined area, which included stormwater flows, it is included in this model. Individual sanitary pipes that experience flooding because of being connected to the Miller pump station interceptor are not included in the model and any resulting flooding is not indicated on projected flooding maps generated from the model.

Future Climate Change

Rainfall statistics vary across cities and regions and are developed based on a look back to historic rainfall records. The current state of the art rainfall data comes from the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) and is published in Atlas 14 for Michigan. For the Detroit region, rainfall records date back to the mid- to late 1800's.

The Southeast Michigan Council of Governments (SEMCOG) commissioned a study that was published in 2020 that calculated future precipitation estimates for Southeast Michigan. The study evaluated data from eight NOAA weather stations using six regional climate projection models for two future time periods; mid-century (2040-2059) and end of the century (2080-2099). Projections of future rainfall for a range of design storm events and recurrence intervals were calculated for each weather station. The results indicate future rainfall amounts vary widely depending on the climate projection model used. For example, predicted future mid-century rainfall depths for a 25-year, 24-hour storm event for the Detroit Metro Airport weather station range between 3.35-10.20 inches of rainfall with the current NOAA Atlas 14 rainfall depth being 3.98 inches. This indicates that future predicted rainfall for this weather station ranges from -18% to 200%.

The results of the future precipitation estimate study suggests, generally, that the intensity of storms of a given duration and frequency is likely to continue to increase in the future. Still unknown is by how much the rainfall will increase and when the region will see that increased rainfall occur.

The City has selected a very progressive level of service design criteria of 25-year plus 30% volumes. The alternatives analysis section of this sewer study report, discussed below, outlines a range of potential alternatives to achieve system benefits in Dearborn, including a sensitivity analysis of if the "preferred alternative" changes depending on the rainfall amount. Regardless of the design storm event (rainfall depth), the most cost-effective solution to achieve 100% of the City's design criteria, is sewer separation. As the City begins to implement sewer separation projects, further decision-making is recommended to determine if local conveyance sewers should be further upsized to address the more aggressive predictions of future rainfall or what level of surface (road) flooding may be acceptable for storm events that exceed the design criteria in future separated sewer areas. This of course, comes at an additional cost for the flood mitigation implementation strategy.

Alternatives Analysis & Improvement Options

The alternatives analysis and identification of improvement options are described in the following sections. The design criteria established for the project of a 25-year plus 30% volume design storm was paired with performance requirements criteria for the sewer system. Various flood control technologies were established to increase the performance of the collection system and optimization technologies were utilized to develop and compare alternatives using a cost model.

The optimization process allowed for identification of bookend solutions (stormwater separation, conveyance and treatment, and storage solutions). These solutions were refined to include sensitivity analyses in order to better understand performance of the system and associated costs. The optimization process identified the relationship between the different storm events, optimized solutions presented and comparative costs developed.

Optimization

Design criteria were established to ensure that there is an understanding of the level of service and performance for the development of alternatives. The design criteria were established based upon input from the City of Dearborn based on the extreme wet weather events that have occurred more recently, in part, because of climate change. The criteria are summarized in **Table 5** and described further below.

The targeted design storm was developed by the City of Dearborn and the OHM project team to establish a more robust level of service criteria. The robust nature of the design storm reflects the City's concern with reducing the number of flooding occurrences caused by collection system backups into basements both now and into the future. The design storm is based on the recurrence period of flows within the collection system in response to rainfall events. The suggested level of service was proposed to be the 25-year statistical sewer flow plus an additional 30% flow to accommodate effects of climate change. A sensitivity analysis was then performed by also considering the 25-year, 10-year, 5-year, 2-year, and 1-year design storms. The value of considering sensitivity for the wide variety of design storms is to determine if the primary identified alternatives to mitigate flooding changed between design storms. For example, would sewer separation be the primary control technology for larger design storms and then pumping and treatment control technologies be the primary control for smaller design storms.

Manhole flooding was identified as a design criterion with the intent to minimize the flooding during the design storm. The flooding includes inundation of the manhole with stormwater resulting in surcharge causing localized flooding. Manhole flooding is also a precursor to a combined sewer backup into basements. Combined sewer backups into basements was identified as key design criteria, including reducing the discharge of combined sewage to the receiving streams.

Finally, a strong focus was given to the freeboard in the collection system. The focus includes an understanding of the need to keep the hydraulic grade line eight feet below the surface elevation for the design storm. Eight feet below the surface elevations coincides with the typical basement floor elevation and the necessary freeboard to limit basement backups.

Table 5. Design Criteria for Evaluation

Criteria	Goal	Summary
Design Storm	System resiliency	25-year plus design storm (25-year in-system peak flow + 30% flow) Sensitivity analysis for 1-Year, 2-Year, 5-Year, 10-Year and 25-year design storms
Manhole Flooding	Reduce surface flooding	Minimize MH flooding during the design storm.
Combined Sewer Overflows	Water quality improvements/regulatory compliance	Minimize CSOs during the design storm.
Freeboard	Reduce basement flooding	Minimize freeboard (ground elevation – maximum HGL) violations < 8 feet during the design storm

Flood Control Technologies and Cost Development

Several flood control technologies and alternatives were identified to develop and optimize the sewer system to effectively manage system capacity increases. These system improvements were considered to help manage stormwater, sanitary, combined sewer systems, and mitigate the peak flows associated with design storm events.

The flood control technologies include the following, as illustrated in Figure 28.

- Dewatering pump options with treatment consisting of screening and disinfection (8 options). The treatment identified is consistent with the CSO treatment controls typical in the Rouge River watershed with 5-10 minutes of contact time for disinfection for the base assumption. Failure of several of the designed and existing built caissons eliminated that technology from consideration in the evaluation.
- Storage facility options (22 options). Storage included tanks primarily; however larger tank options would require inclusion of drop shafts and storage tunnels.
- Gravity sewer construction (36.2 miles of gravity sewer and tunnel options). The gravity sewers are conveyance options to increase system capacities at select locations. Larger diameter conveyance requires shallow tunnels in specific locations.

- Cross connection options on the existing system (17 options). Cross connections included options to convey (redirect) flows in portions of the collection system where excess capacity exists.
- Stormwater sewer separation (91 subcatchment options for stormwater separation). The assumptions for sewer separation, included separation of the subcatchment from 25%, 50%, 75% and 100% of the separated stormwater.

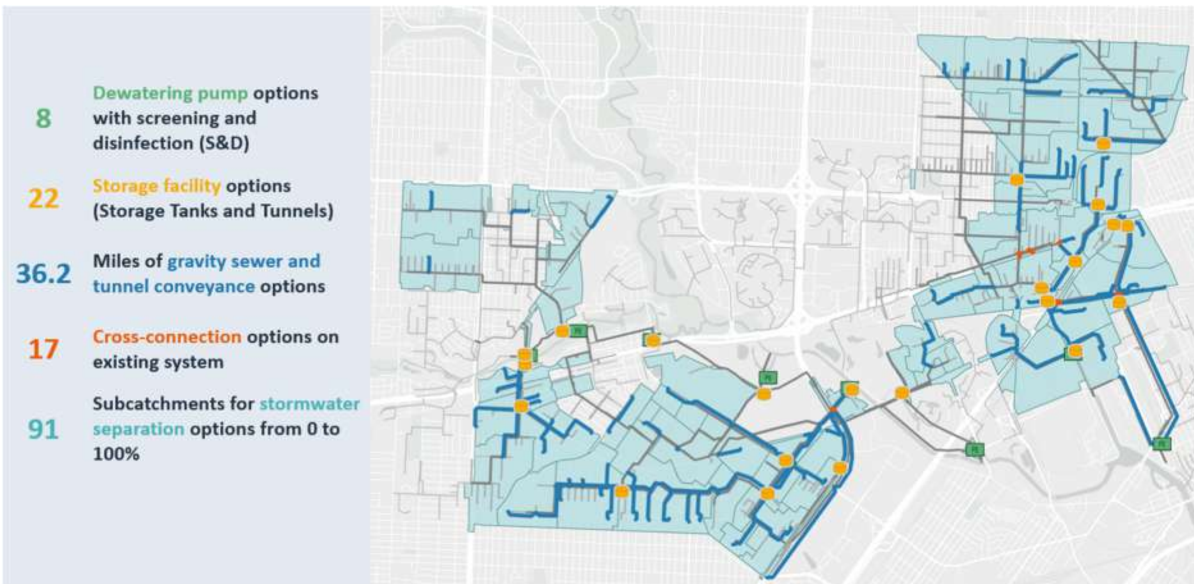


Figure 28. Optimization technologies and locations

Figure 28 illustrates 22 locations for storage facilities. Refinement of the storage facilities by combining stored volumes and converting the sites into drop shafts and a common tunnel would be a means to develop storage tunnel alternatives if that were a technology the City would determine appropriate in subsequent evaluations.

Construction, capital, operations & maintenance (i.e. life cycle costs) were developed for each control technology listed above. The costs are fully presented in Appendix C. The construction costs are Class V (rough order of magnitude) for comparative purposes and are very-high level preliminary costs with a range of -50%/+100%.

The life cycle costs include the total cost of implementing the flood control technologies over the entire lifespan of the project. The flood control technologies that are focused primarily on conveyance improvements (gravity sewers and sewer separation) have the longest asset life and lowest operations and maintenance costs.

Baseline Improvements

Baseline improvement projects for the Dearborn Sewer Study are projects that provide system performance benefits that have already been committed to by the City. These projects are at various stages of completion. These baseline improvement projects were incorporated into the hydraulic model used for the evaluation. The known baseline improvement projects that were incorporated to the baseline model include:

- Completion of the stormwater separation project at stormwater outfall 20 (SWOF20) north of the Rouge River at the west edge of Dearborn. The combined sewer separation effort at this location has already been completed and the project is just waiting to pass water quality testing to fully disconnect from the Dearborn west arm interceptor. A one-foot diameter pipe still remains connected to the Dearborn west arm interceptor and will contribute share flow during storm events. Full completion of this project will eliminate a source of stormwater to the west arm interceptor.
- Completion of the stormwater separation project at stormwater outfall 29 (SWOF29) south of the Rouge River at the west end of Dearborn. The combined sewer separation effort at this location has also already been completed and the project is just waiting on passing water quality testing to fully disconnect from the Dearborn west arm interceptor. Similar to above, a one-foot diameter pipe still remains connected to the interceptor and once eliminated, will reduce a source of stormwater to the interceptor.
- Implementing the proposed weir wall and dewatering pump project at the mouth of SWOF01 that discharges to the Rouge River adjacent to the Hubbell Southfield CSO facility. This stormwater line conveys a large volume of stormwater from the Chase district in northern Dearborn to the Rouge River. Conceptual drawings have been completed for a project to build a weir wall at the mouth of SWOF01 to keep the Rouge River out during high water conditions and prevent the pipe from sitting partially full. On the city side of the weir wall, a dewatering pump will be installed to drain the line following storm events to free up conveyance capacity. This project will reduce the Rouge River's influence on the stormwater system and provide resilience against high river levels.

  Two additional projects were identified through flow metering and modeling that were not incorporated into the baseline model but could provide system benefits pending further investigation. These projects include:

- Investigate the hydraulic anomaly on the primary CSO trunk line south of the intersection of Rotunda Drive and Oakwood Dearborn Medical Park. Flow metering at meter four from Figure 10 showed that water is not being conveyed through this branch of the system as quickly as should be expected given the slope and pipe size. Water is being held back somewhere upstream due to an unknown hydraulic anomaly that could be a blockage, collapsed pipe, or irregular structure. This should be investigated further through an investigation and pipe televising to identify the source of the restriction. This has the potential to increase pipe conveyance and limit a restriction that is contributing to basement backups upstream.

- Investigate the hydraulic anomaly on the primary CSO trunk line south of the Outer Drive and Michigan Ave intersection. Similar to above, flow metering at meter five from Figure 10 showed that water is not being conveyed through this branch of the system as quickly as should be expected given the slope and pipe size. This should also be investigated further through pipe televising and inspections to identify the source of the restriction. This area is less heavily impacted by basement backups, but freeing up additional capacity will provide additional system resilience in the event of a large storm.

Green Stormwater Infrastructure

Green stormwater infrastructure (GSI) is a generalized term used to define landscape-based practices used to reduce the rate and volume of stormwater reaching the sewer system. Rather than being composed of large facilities managing large volumes of runoff, GSI systems are typically composed of many small GSI features distributed throughout the drainage area with each GSI feature managing smaller volumes of water. Larger flood control facilities typically relieve the pressure from stormwater already in the sewer whereas GSI, reduces the volume and rate of runoff that the sewer receives.

The term green stormwater infrastructure can also be used to indicate measures that help more traditional flood control facilities provide a greater range of benefits. This can be in the form of naturalizing flood control facilities by introducing wetlands in the bottom and using native vegetation on the sides of the facilities. With these green infrastructure modifications, facilities can provide water quality and habitat benefits in addition to flood control. In some cases, basins may also be designed with park amenities such as trails, gathering areas, and other features that may be used by the larger community when the basins aren't flooded with runoff.

There are many types of the smaller distributed GSI practices that can be thought of as a GSI toolkit. The toolkit includes green (vegetated) roofs, permeable paving and other surfaces, and many forms of bioretention (rain gardens, bioswales, street planters, etc). Distribution of stormwater management features throughout a watershed or drainage area benefits the overall stormwater system in the area by reducing flows and runoff volumes that must be managed by any one component of the system. One way to conceptualize where distributed GSI fits into an existing stormwater management system is to see the distributed GSI as being a "top of sewer-shed" approach, and traditional gray infrastructure as a "bottom" of sewer-shed approach. Distributed GSI is installed within the sewershed at numerous points where the stormwater falls, gathering stormwater from areas as small as a sidewalk or yard to as large as a few blocks of a street. Gathering, treating, evaporating, and infiltrating or temporarily storing stormwater in numerous locations at the top of the sewershed reduces or removes the need to increase the size of downstream sewer systems. Reducing the stormwater burden on aging gray infrastructure has many benefits including:

- Avoiding the need to increase the size of downstream sewer systems.
- Mitigating the need to increase capacity of the receiving treatment plant (for combined sewer systems).
- Reducing discharge rates and volumes to local waterways and thereby reducing erosion and flooding.
- Improving water quality by reducing temperature and capturing sediment, metals, nutrient overflows, which reduces the pressure to treat stormwater at the treatment plant or improves the quality of the stormwater released into rivers and streams.
- Improving the resiliency of existing stormwater infrastructure due to increases in the intensity and frequency of rain events due to climate change.

In the context of Dearborn and the level of flooding defined in the previous section, the typical scale of GSI would be insufficient to meet the desired level of service and protection. However, layering distributed GSI on top of the existing and proposed gray infrastructure (especially sewer separation projects) can improve the performance and resilience of the gray infrastructure, particularly in light of increases in rainfall intensity and frequency as a result of climate change. This is in addition to the social and environmental benefits associated with introducing GSI landscapes throughout the community. See Appendix D for further discussion of distributed GSI, including a discussion of Philadelphia's Green City Clean Waters Program to use exclusively GSI to achieve compliance with their Long-Term Control Plan and design alternatives for the three potential Dearborn reservoir (regional detention) projects with two case studies of flood control reservoir projects in other cities.

Alternatives Description and Evaluation

Preliminary optimization runs were completed for 5 alternative scenarios with subsequent sensitivity analyses performed with multiple solutions extracted and reviewed for each multi-objective optimization analysis.

The following solutions were selected for presentation to demonstrate the key trends observed in the preliminary optimization. Unless otherwise stated, each scenario satisfies the design criteria listed in Table 5 for the 25-year plus 30% volume design storm. The alternatives are described in full detail later in this section.

1. **Bookend Optimization**
   a. Conveyance-only (1A). Alternative focused on conveying flows with gravity sewers to the receiving streams with lift (pump) stations followed by screening and disinfection.

b. Dewatering limited to 200 MGD (1B). Alternative decreased the pumping capacity of lift stations and screening/disinfection to force the inclusion of storage facilities.

c. Dewatering limited to 100 MGD (1C). Alternative further decreased the pumping capacity of lift stations and screening/disinfection to force the inclusion of storage facilities.

d. Stormwater separation only (1D). Stormwater sewer separation to achieve the design criteria, but also use the existing combined sewer system to convey flows from the areas not separated.

e. Full stormwater separation (1E). Stormwater sewer separation for the entire tributary area within the City of Dearborn.

2. **Preliminary Optimization with All Alternatives Considered**

   a. Optimized solution (2A). Optimization of the stormwater separation from Alternative 1D with the inclusion of additional gravity sewers for conveyance.

   b. Reduced stormwater separation (2B). Optimization of the stormwater separation from Alternative 1D with the inclusion of additional gravity sewers for conveyance, a storage tank and a lift station/treatment facility.

   c. Manhole flooding limited to 0.5 MG (2C). Optimization of the stormwater separation from Alternative 1D by relaxing the design criteria for manhole flooding to 0.5 MG.

   d. Manhole flooding limited to 1.5 MG (2D). Optimization of the stormwater separation from Alternative 1D by relaxing the design criteria for manhole flooding to 1.5 MG.

   e. Manhole Flooding limited to 10 MG (2E). Optimization of the stormwater separation from Alternative 1D by relaxing the design criteria for manhole flooding to 10.0 MG.

3. **Design Storm Sensitivity Analysis**

   a. 25-year design storm (3A). Optimization refinement for a 25-year design storm.

   b. 10-year design storm (3B). Optimization refinement for a 10-year design storm.

   c. 5-year design storm (3C). Optimization refinement for a 5-year design storm.

   d. 2-year design storm (3D). Optimization refinement for a 2-year design storm.

   e. 1-year design storm (3E). Optimization refinement for a 1-year design storm.

The results of the Optimization evaluation identified several alternatives that included combinations of gravity sewers, cross connections, storage facilities (storage tanks or tunnels), dewatering pumps stations, treatment (screening and disinfection), stormwater separation and then added operations & maintenance and replacement costs to identify total life-cycle costs. **Figure 29** through **Figure 40** provide a comparative cost summary and overview of each preliminary optimization solution. The breakdown in costs for each alternative is included in Appendix E.

Bookend Optimization Solutions

Initial bookend optimization solutions were identified to understand how the design criteria (see Table 5) can be met by focusing on individual alternatives. **Figure 29** provides a summary of the preliminary capital and operation and maintenance costs for each solution. Observing key trends in this set of solutions, stormwater separation presents lower total costs largely due to the lack of operation and maintenance costs that are associated with lift stations/treatment facilities. Additional details on the solutions and their associated costs are provided in the following section of the report.

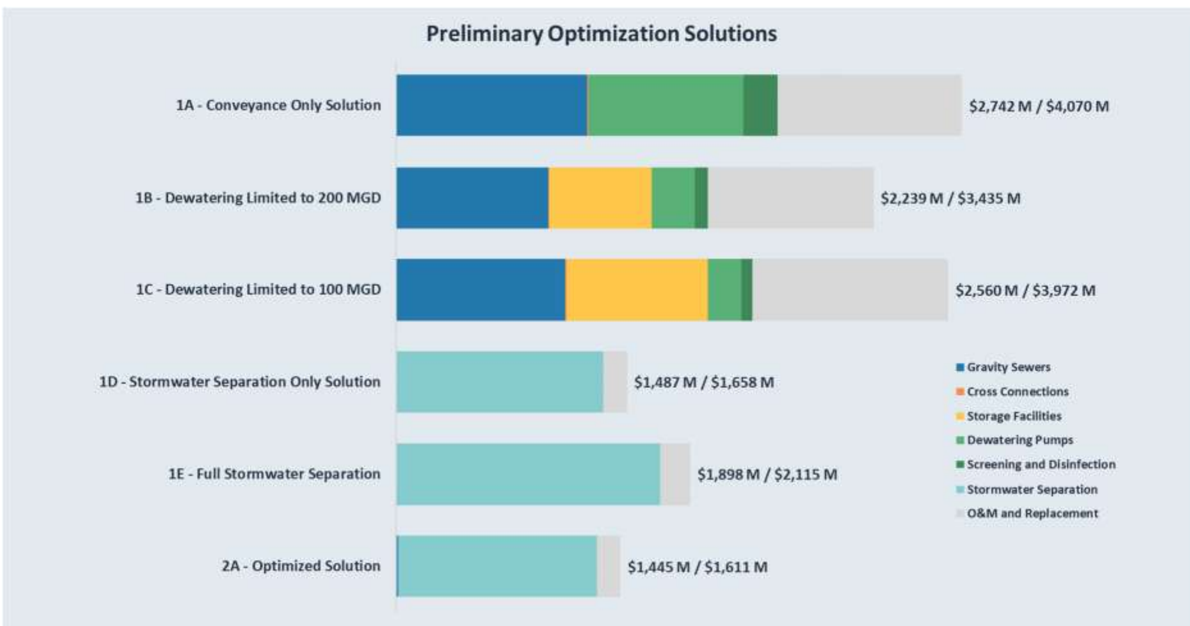


Figure 29. Bookend Optimization Solutions Summary

The following figures provide the technical details for each alternative solution. The cost summary is included on the top left of the figure illustrating the breakdown of costs in capital, present worth operations & maintenance, and present value replacement. The breakdown of assets, number of projects, size, and units are included beneath the cost summary. The total capital and lift cycle costs are presented at bottom left of the figure. The aerial figure to the right illustrates the locations the Optimizer™ identified for conveyance, stormwater separation, pump stations/screening & disinfection facilities, storage facilities, and cross connections. These locations are based on model output only and will need to be individually investigated for site viability.

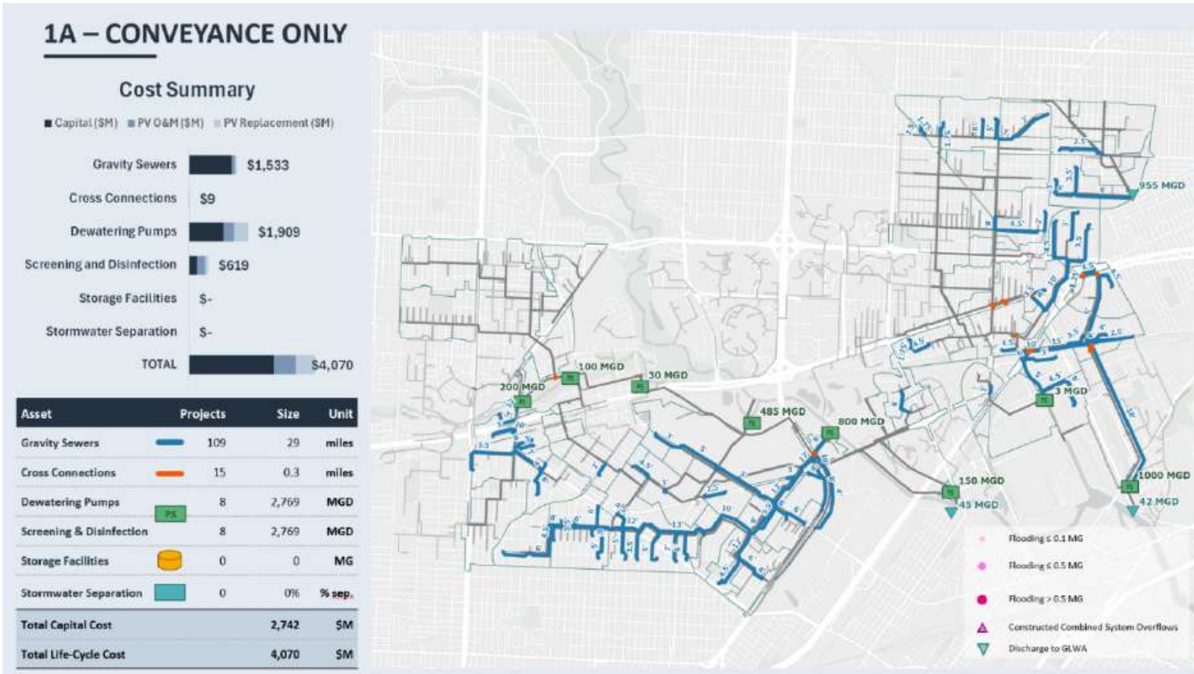


Figure 30. Alternative 1A – Conveyance Only with WRRF Upgrade

Alternative 1A considers a conveyance only solution. The conveyance only solution includes 29 miles of gravity sewers to maximize conveyance of flows away from the areas with the most prevalent capacity issues. In addition, there are 15 cross connection changes required to maximize the use of existing and new infrastructure for conveyance, and eight dewatering pumps associated with screening & disinfection treatment. The screening, pumping and disinfection facilities would be capable of pumping and treating 2,769 MGD (4,284 cfs).

This alternative is predicated on the assumption that the collection system downstream of the pumping stations can receive the substantial increase in flows. This would require major upgrades beyond the City's control to achieve.

The addition of eight lift stations/treatment facilities will require the staffing of additional operators, electrical, chemicals, and other elements that impact lift cycle costs. The siting of the pumping/treatment facilities (and associated property acquisition, connecting sewers, land acquisition costs) are not included with the evaluation. The routing of the sewers used existing streets and collection system alignments.

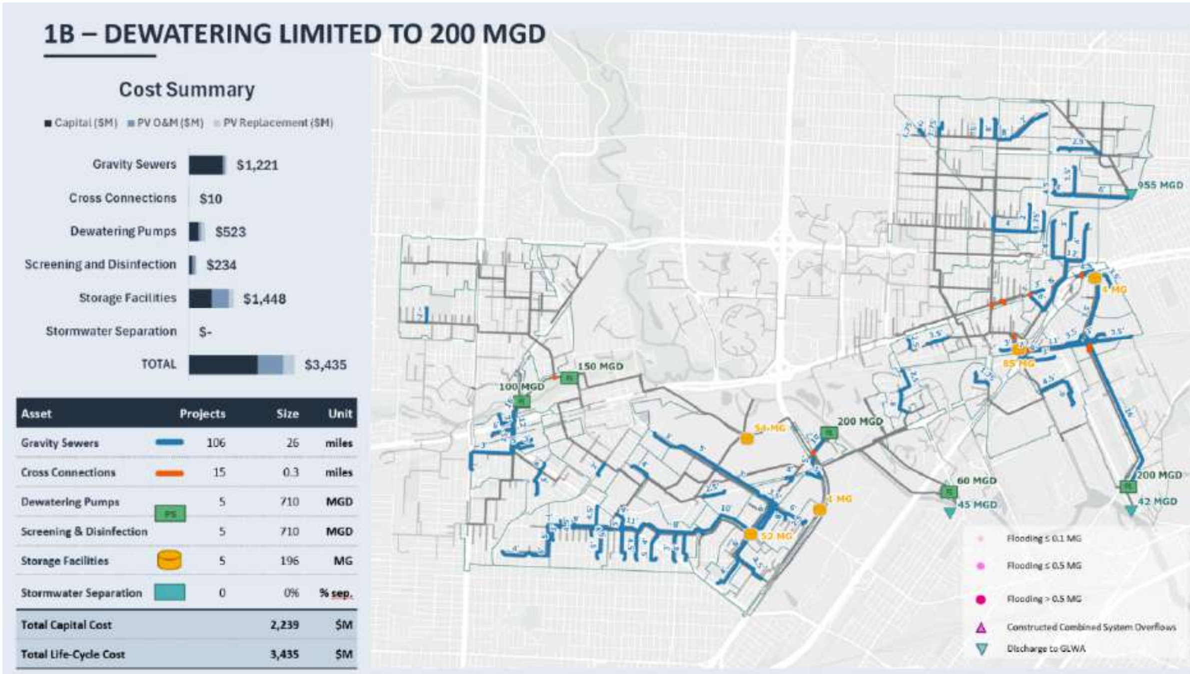


Figure 31. Alternative 1B – Dewatering Limited to 200 MGD

Alternative 1B includes 26 miles of gravity sewers to maximize conveyance of flows away from the areas with the most prevalent capacity issues, 15 cross connection changes to maximize the use of existing and new infrastructure, and dewatering pumps associated with screening & disinfection treatment facilities. The screening, pumping and disinfection facilities would be capable of pumping and treating 710 MGD (1,099 cfs), and 196 MG (303 cfs) of additional storage capacity throughout the City.

The addition of eight lift stations/treatment facilities will require the staffing of additional operators, electrical, chemicals, and other elements that impact lift cycle costs. The siting of the pumping/treatment facilities (and associated property acquisition, connecting sewers, land acquisition costs) are not included with the evaluation. The routing of the sewers used existing streets and collection system alignments.

The Optimizer™ solution identified five ideal locations for storage facilities, ranging in size from 1 MG to 85 MG, based on the needs in each area. However, as the locations were not identified using current site/City landuse information, it is unlikely that storage facilities, especially those of a larger capacity, could feasibly be constructed. Rather, it would be recommended that the City explores options for a tunnel-system under the City which can be used to convey flows to larger storage facilities.

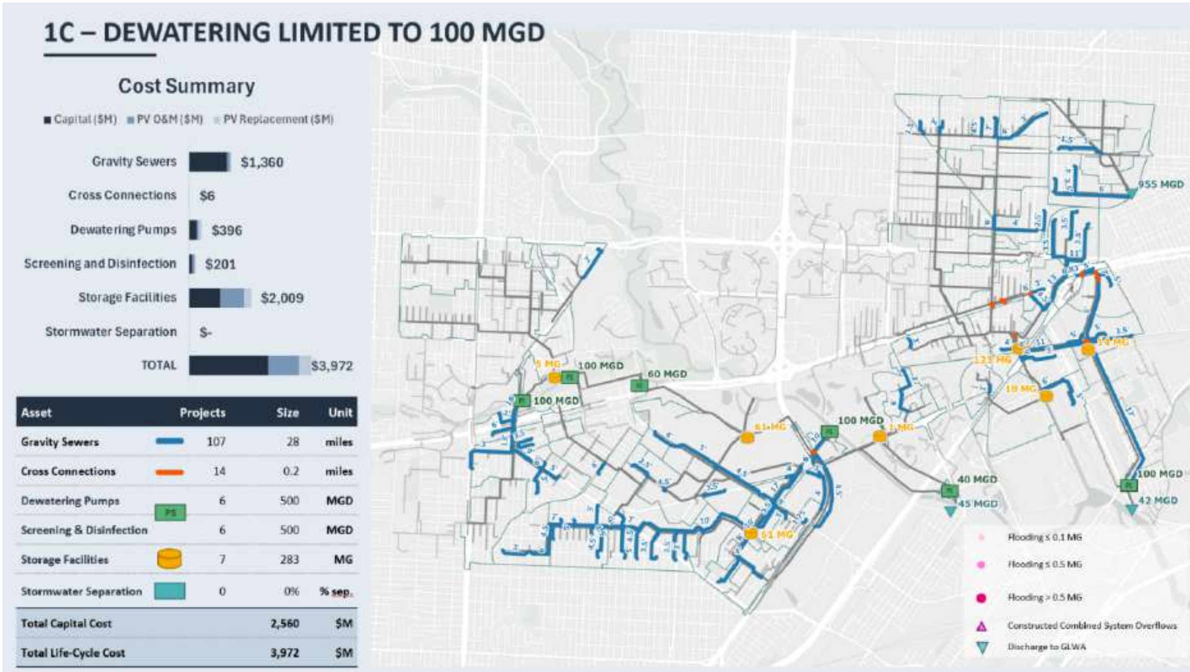


Figure 32. Alternative 1C – Dewatering Limited to 100 MGD

Alternative 1C is similar to the previous, but the capacity of the dewatering pumps was limited to 100 MGD (155 cfs). At this decreased dewatering capacity, the alternative solution includes 28 miles of gravity sewers to maximize conveyance of flows away from the areas with the most prevalent capacity issues.

In addition, 14 cross connection changes are required to maximize the use of existing and new infrastructure along with dewatering pumps. The dewatering pumps and associated screening & disinfection treatment facilities would be capable of pumping and treating 500 MGD (774 cfs), with 283 MG of additional storage capacity throughout the City.

The addition of eight lift stations/treatment facilities will require the staffing of additional operators, electrical, chemicals, and other elements that impact lift cycle costs. The siting of the pumping/treatment facilities (and associated property acquisition, connecting sewers, land acquisition costs) are not included with the evaluation. The routing of the sewers used existing streets and collection system alignments.

The Optimizer™ solution identified seven ideal locations for storage facilities, ranging in size from 5 MG to 123 MG, based on the needs in each area. Reducing dewatering to 100 MGD (155 cfs) increased the systems need for additional storage facilities. Similar to Alternative 1B, the construction of these large storage facilities may not be feasible, so tunnel facilities should be considered to meet the storage needs required to mitigate the impact of future large storm events.

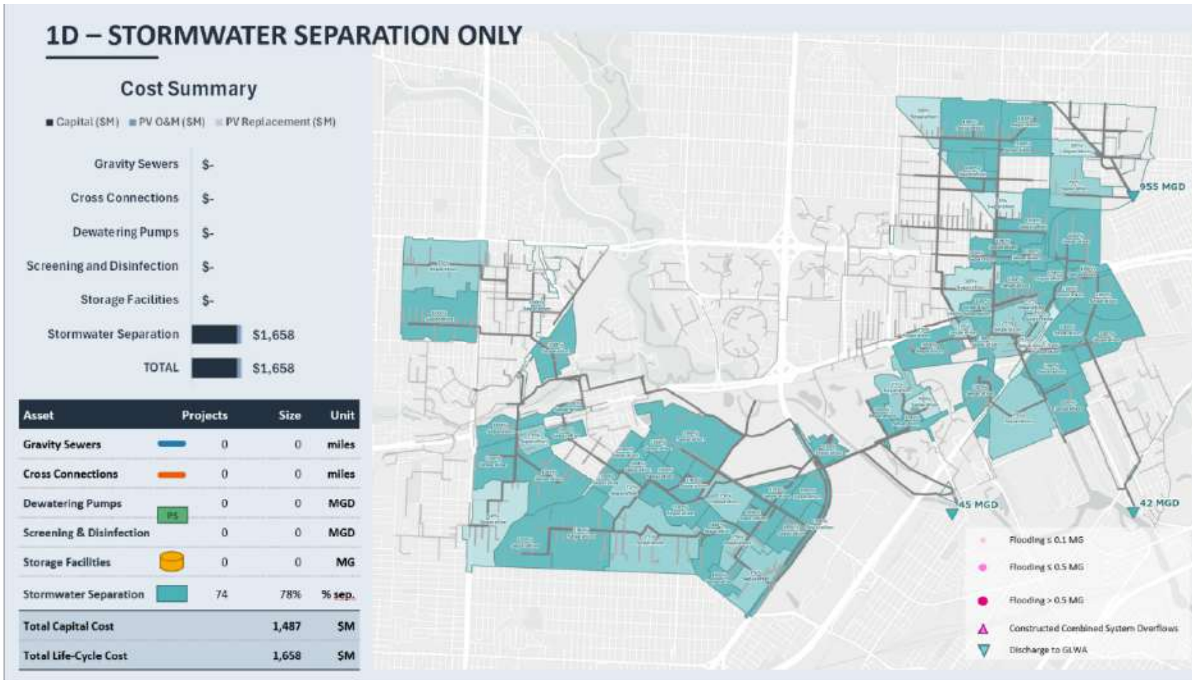


Figure 33. Alternative 1D – Stormwater Separation Only

Alternative 1D considers a stormwater separation only solution which includes 74 projects that, cumulatively, will result in 78% separation of the current sewer system. The 74 projects represent subcatchments, of which there are 91 total in the system, that are modified such that stormwater is separated from sewage flows.

The percent separation for each of the subcatchments in this solution is shown in the above figure. The proposed separation ranges from 50-100% and is calculated as a ratio of the total subcatchments area. The lighter colored areas represent 50% separation and the darker 100%. This solution has met all the design criteria so the impacts stormwater on flooding have been mitigated, but there remains a large portion of flow being diverted to GLWA.

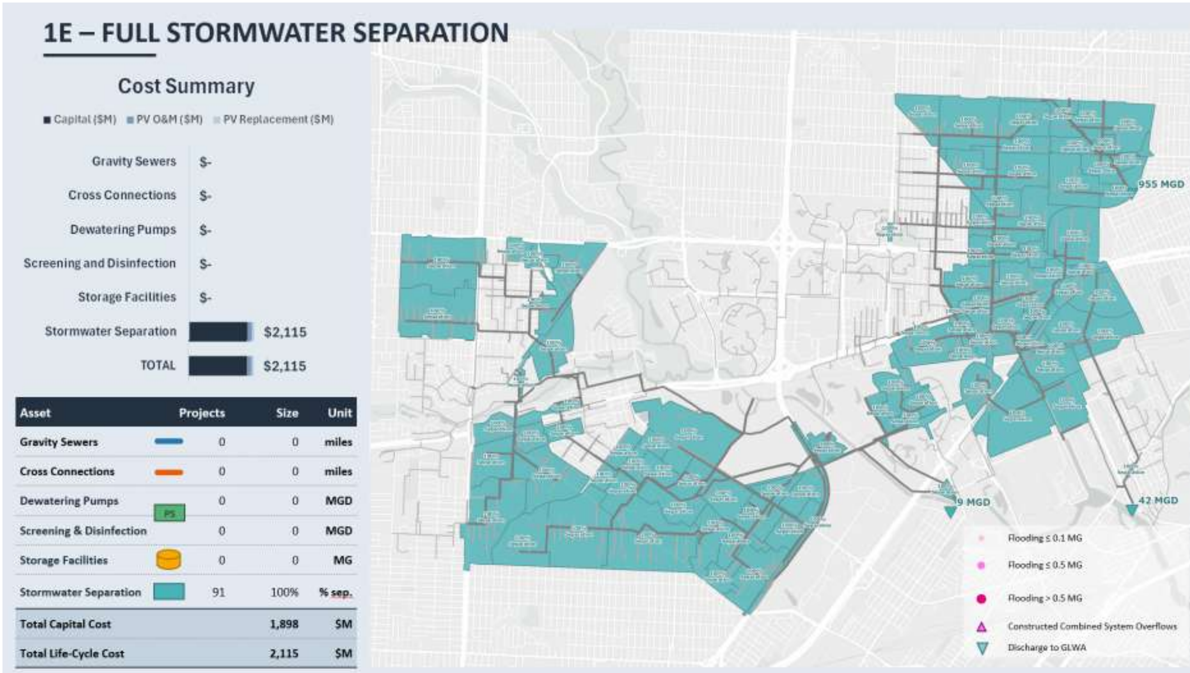


Figure 34. Alternative 1E – Full Stormwater Separation

Alternative 1E includes full stormwater separation within select subcatchments including 91 stormwater separation projects. The stormwater separation projects under this alternative include the construction of stormwater piping to complete the separation. The location of the subcatchments to be separated are represented in the darker teal shading in the figure above and represent 100% separation of the system. Areas not indicated for separation including the midsections of the City have been previously separated.

This solution has met all the design criteria to mitigate the impacts of stormwater flooding on the sanitary sewer collection system. However, there remains a large amount of flow being diverted to GLWA for treatment. The overall amount for diversion to GLWA under this alternative is reduced in comparison to alternative 1D (reduction of 33 MGD).

Optimized Solutions – Sensitivity Analysis of All Alternatives

Building off the bookend optimization solutions, the following optimized solutions were considered utilizing all of the flood control technologies available. These solutions use combinations of the different control technologies to meet the design criteria described in **Table 5**, as well as meeting relaxed versions of the design criteria. **Figure** 35. provides a summary of each solution, how the design criteria was relaxed, and the capital and operation and maintenance costs.

Additional details for each of the five solutions are provided in the following section of the report. These flood control technologies are directly comparable to Alternative 2A, which is the optimized sewer separation alternative. For each of the alternatives below which rely on stormwater separation, additional costs for stormwater conveyance need to be included through a separate costing evaluation.

Figure 35. Optimized Solutions with All Alternatives Considered Summary

All five of the optimized solutions summarized above largely meet the design criteria using stormwater separation as the main flood control technology alternative. As expected, relaxing the design criteria for manhole flooding lowered the total cost of the solution, with solution 2E having a capital cost that are approximately 34% of the optimized solution (2A). However, relaxing the design criteria decreases the flood mitigation impact for residents, especially those in areas with the most prevalent capacity issues during large storm events.

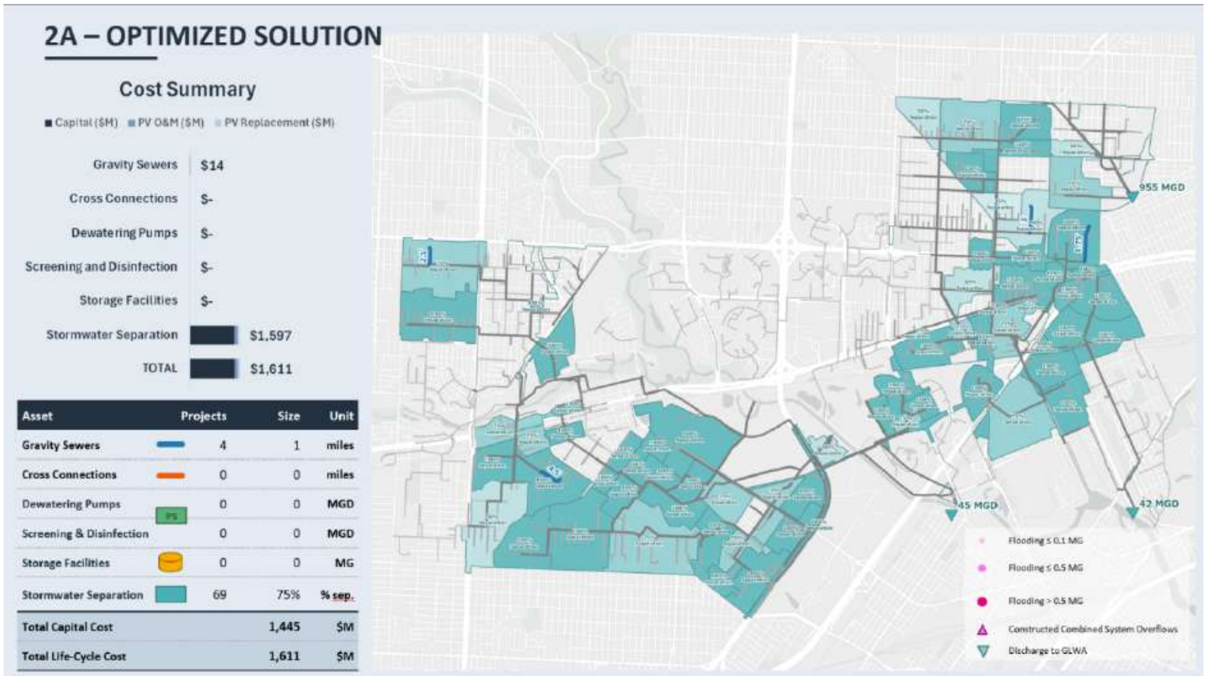


Figure 36. Alternative 2A – Optimized Solution

Alternative 2A presents the optimized solution which maximizes the reduction in system deficiencies and meets all the design criteria while minimizing project cost. This solution includes one mile of gravity sewer to maximize the conveyance of flows away from areas with the most prevalent capacity issues, and 69 projects that will provide a cumulative 75% stormwater separation.

Of the 69 subcatchments that will undergo changes to separate stormwater from the sewer flows, the percent separation ranges from 25-100%. In this optimized solution, 100% separation is included in east and south Dearborn, which have shown themselves to be areas with significant capacity issues.

With this optimized solution, the costs do not include estimates for the conveyance of separated stormwater flows to nearby receiving streams. Additionally, the flows being conveyed to GLWA for treatment are still large, which may pose future challenges due to the fixed flow allowable by GLWA. However, the solution is projected to meet the design criteria for a 25-year plus 30% storm, which alleviates the immediate impacts of large storm events on residential flooding.

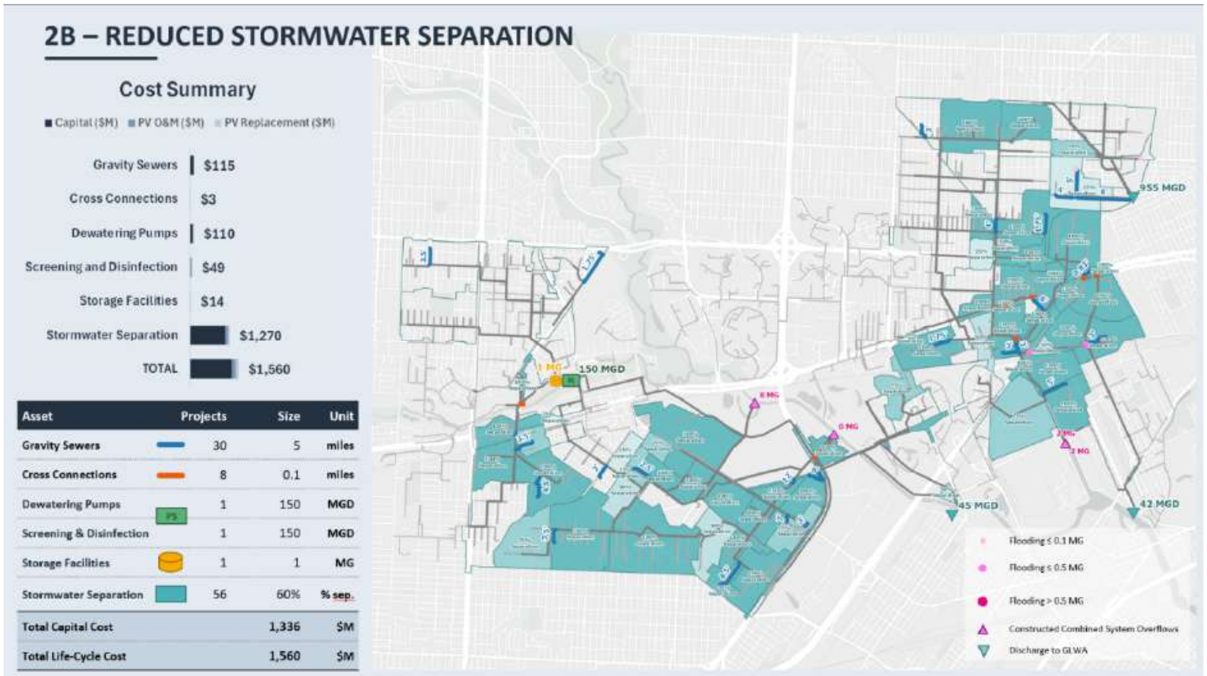


Figure 37. Alternative 2B– Reduced Stormwater Separation

Alternative 2B includes five miles of gravity sewer main to convey flows away from areas with the most prevalent capacity issues. The alternative includes 8 cross connection changes to maximize the use of new and existing infrastructure capacity. Additional dewatering includes one new dewatering pump and associated screening & disinfection. The additional screening, dewatering and treatment capacity is 150 MGD (279 cfs). The additional needed storage capacity is 1 MG, and the alternative includes 56 projects that will cumulatively provide 60% stormwater separation in the system.

The addition of one lift station/treatment facility will require the staffing of additional operators, electrical, chemicals, and other elements that impact lift cycle costs. The siting of the pumping/treatment facility and the storage facility (and associated property acquisition, connecting sewers, land acquisition costs) are not included with the evaluation. The routing of the sewers used existing streets and collection system alignments.

By reducing the amount of stormwater separation, this solution no longer meets all the design criteria at 100% and includes CSO's. The location of the CSO's is denoted by the pink and red point markers on the above figure. This solution has multiple areas where flooding will occur during a 25-year plus storm event. Most of this flooding is projected to occur in south and east Dearborn despite the 100% stormwater separation in the area.

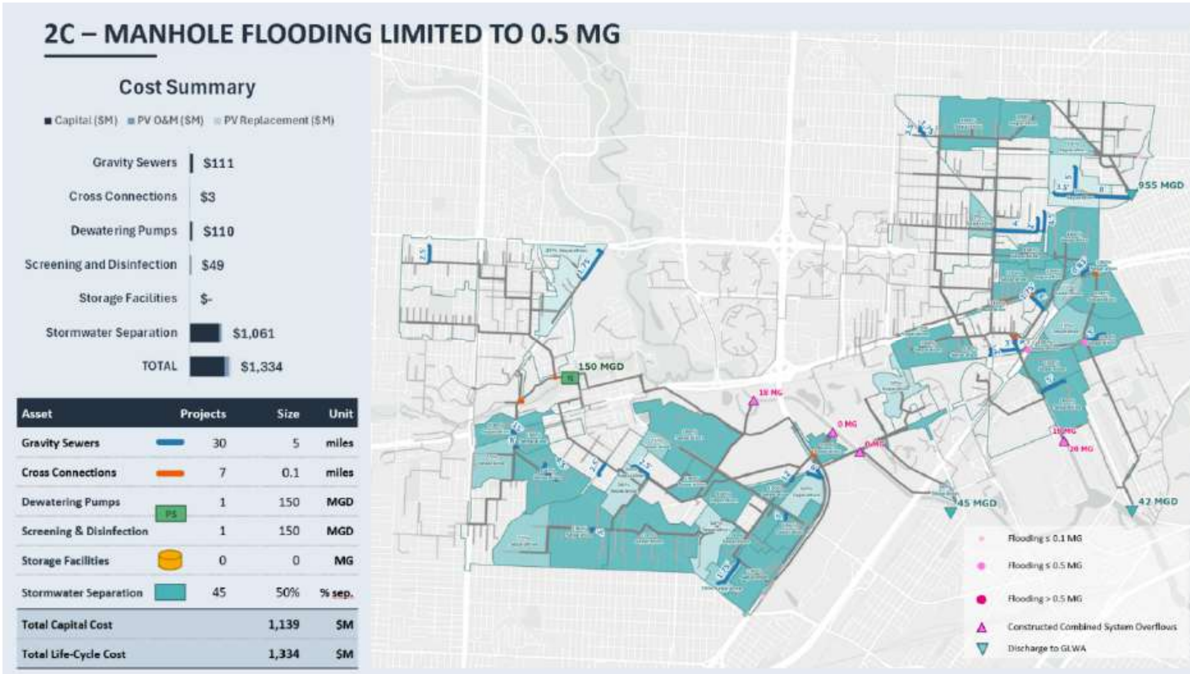


Figure 38. Alternative 2C– Manhole Flooding Limited to 0.5 MG

Alternative 2C introduces relaxed design criteria, in which the allowable manhole flooding was limited to 0.5 MG. This solution includes five miles of gravity sewer to maximize flow away from areas with the most prevalent capacity issues. There are seven cross connection changes to utilize existing and new infrastructure capacity. In addition, there is one dewatering pump associated with screening & disinfection that has a treatment capacity of 150 MGD (278 cfs), and 45 projects that will cumulatively provide 50% stormwater separation of the sewer system.

The addition of one lift station/treatment facility will require the staffing of additional operators, electrical, chemicals, and other elements that impact lift cycle costs. The siting of the pumping/treatment facility and the storage facility (and associated property acquisition, connecting sewers, land acquisition costs) are not included with the evaluation. The routing of the sewers used existing streets and collection system alignments.

By reducing the stormwater separation, this solution no longer meets all the design criteria at 100%. Denoted by the pink and red point markers on the above figure, this solution has multiple areas where flooding will occur during a 25-year plus storm event. Most of this flooding is projected to occur in east and south Dearborn despite near 100% stormwater separation in the areas. In addition, there are five locations where combined system overflows are projected to occur. Given that manhole flooding is tied closely with CSOs, it is no surprise that relaxing the design criteria to limit manhole flooding to 0.5 MG increased the projected overflows under this solution.

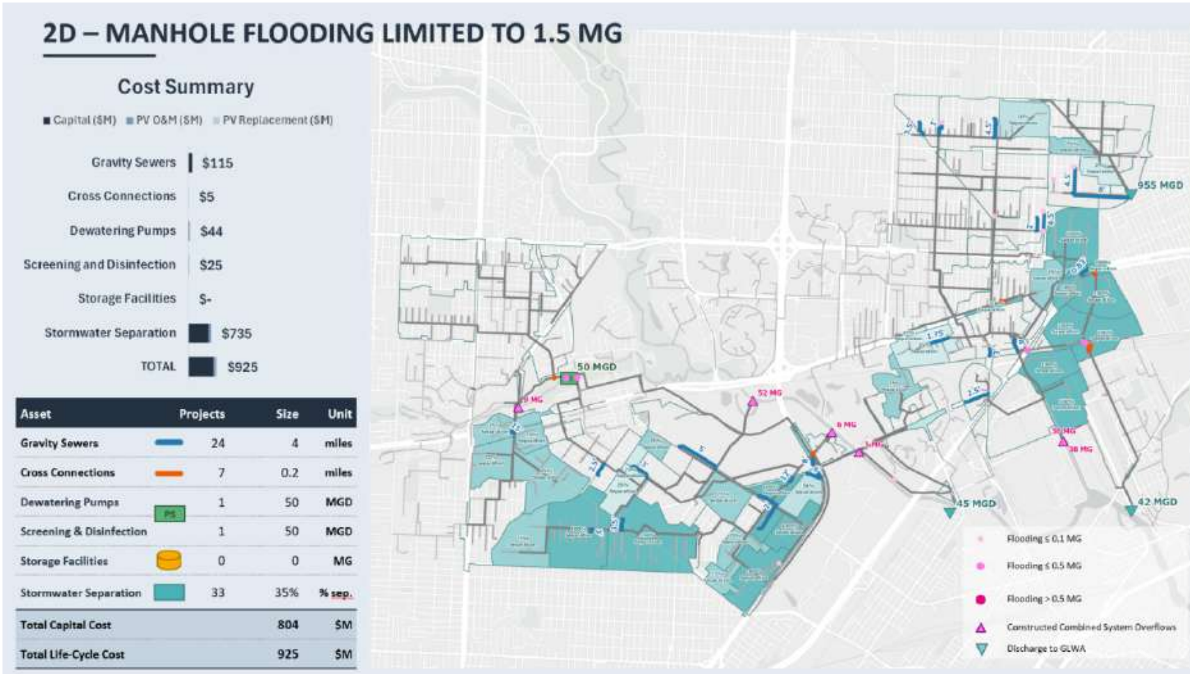


Figure 39. Alternative 2D– Manhole Flooding Limited to 1.5 MG

Alternative 2D introduces relaxed design criteria, in which the allowable manhole flooding was limited to 1.5 MG. This solution includes four miles of gravity sewer to maximize flow away from areas with the most prevalent capacity issues. There are seven cross connection changes to utilize existing and new infrastructure capacity. In addition, there is one dewatering pump proposed with the associated screening & disinfection. The dewatering pump would have the treatment capacity of 150 MGD (278 cfs), and 33 projects that will cumulatively provide 35% stormwater separation of the sewer system.

The addition of one lift station/treatment facility will require the staffing of additional operators, electrical, chemicals, and other elements that impact lift cycle costs. The siting of the pumping/treatment facility and the storage facility (and associated property acquisition, connecting sewers, land acquisition costs) are not included with the evaluation. The routing of the sewers used existing streets and collection system alignments.

By reducing the stormwater separation, this solution no longer meets all the design criteria at 100%. As denoted by the pink and red point markers on the above figure, this solution has multiple areas where flooding will occur during a 25-year plus storm event. Most of this flooding is projected to occur in east and south Dearborn. In addition, there are six locations where combined system overflows are projected to occur, with the largest overflow being projected at 52 MG. Given that manhole flooding is tied closely with CSOs, it is no surprise that relaxing the design criteria to limit manhole flooding to 1.5 MG increased the projected overflows under this solution.

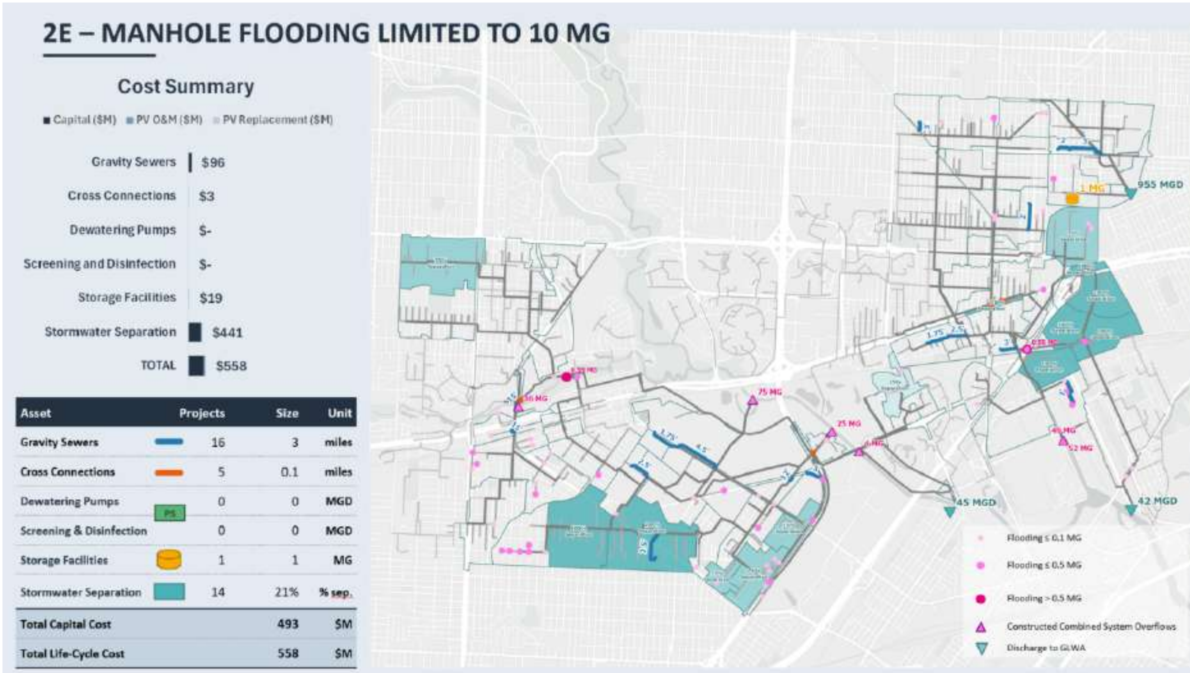


Figure 40. Alternative 2E– Manhole Flooding Limited to 10 MG

Alternative 2E introduces relaxed design criteria, in which the allowable manhole flooding was limited to 10 MG. This solution includes three miles of gravity sewer to maximize flow away from areas with the most prevalent capacity issues. The alternative includes five cross connection changes. The cross-connection changes utilize existing and new infrastructures capacity. The alternate also includes the addition of one storage facility with a capacity of 1 MG, and 33 projects that will cumulatively provide 35% stormwater separation of the sewer system. The siting of the storage facility (and associated property acquisition, connecting sewers, land acquisition costs) are not included with the evaluation. The routing of the sewers used existing streets and collection system alignments.

By reducing the stormwater separation, this solution no longer meets all the design criteria. Areas not meeting the design criteria are denoted by the pink and red point markers on the above figure, this solution has many areas where flooding will occur during a 25-year plus storm event. Most of this flooding is projected to occur in east and south Dearborn, but the flooding is generally projected to impact residents throughout the City. In addition, there are six locations where combined system overflows are projected to occur, with the largest overflow being projected at 52 MG. Given that manhole flooding is tied closely with CSOs, it is no surprise that relaxing the design criteria to limit manhole flooding to 10 MG resulted in little mitigation of the impact from large stormwater events. This solution also results in large flows continuing to be diverted to GLWA for treatment.

Optimized Solutions – Sensitivity Analysis of Design Storms

In addition to understanding the sensitivity of the design criteria and control technologies, a sensitivity analysis of different design storms can identify insightful trends in the solutions. Namely, large design storms of 25-years and 25-years plus 30% volume will impact most of the City, but smaller design storms of 1-, 2-, and 5-years can identify areas with limited capacity that are being impacted regularly by storm events. Figure 41 provides a summary of the solutions and their associated capital and operation and maintenance costs for five different design storms in comparison to the optimized solution for a 25-year plus 30% volume design storm (Alternative 2A).

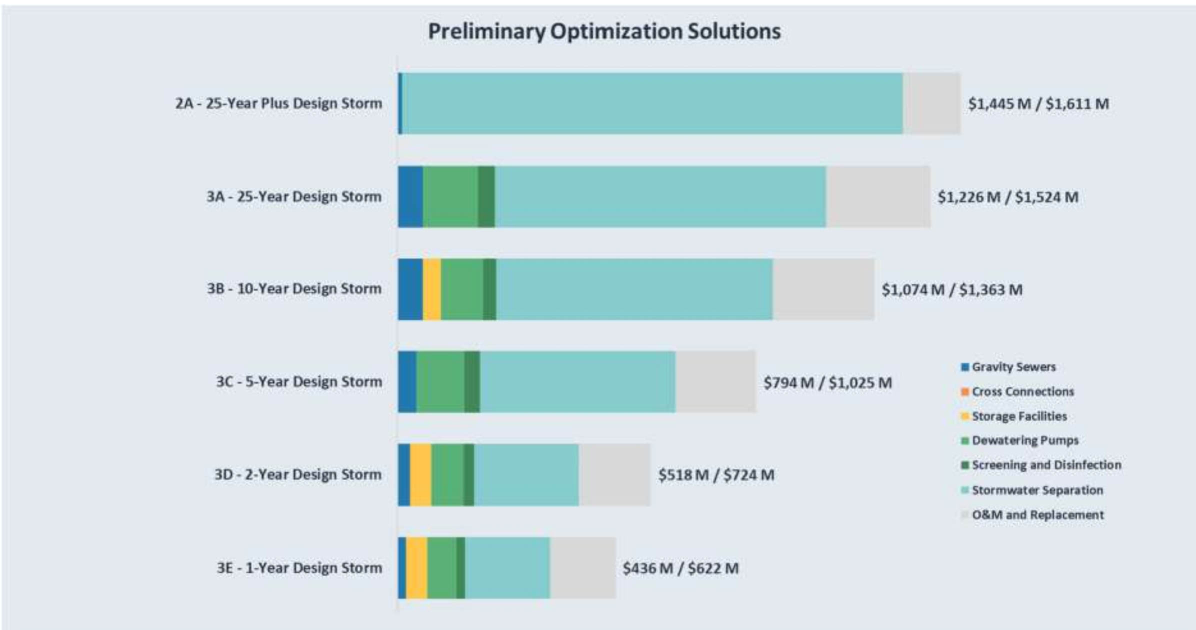


Figure 41. Optimized Solutions with Varied Design Storms Summary

The purpose of this sensitivity analysis was not to provide a solution to implement, as it is not recommended that the City implement a solution for a design storm less than 10-years. Rather, the analysis of the small design storms was done to highlight the fact that flood control technologies are required to meet the design criteria for small storm events that are occurring on a regular basis.

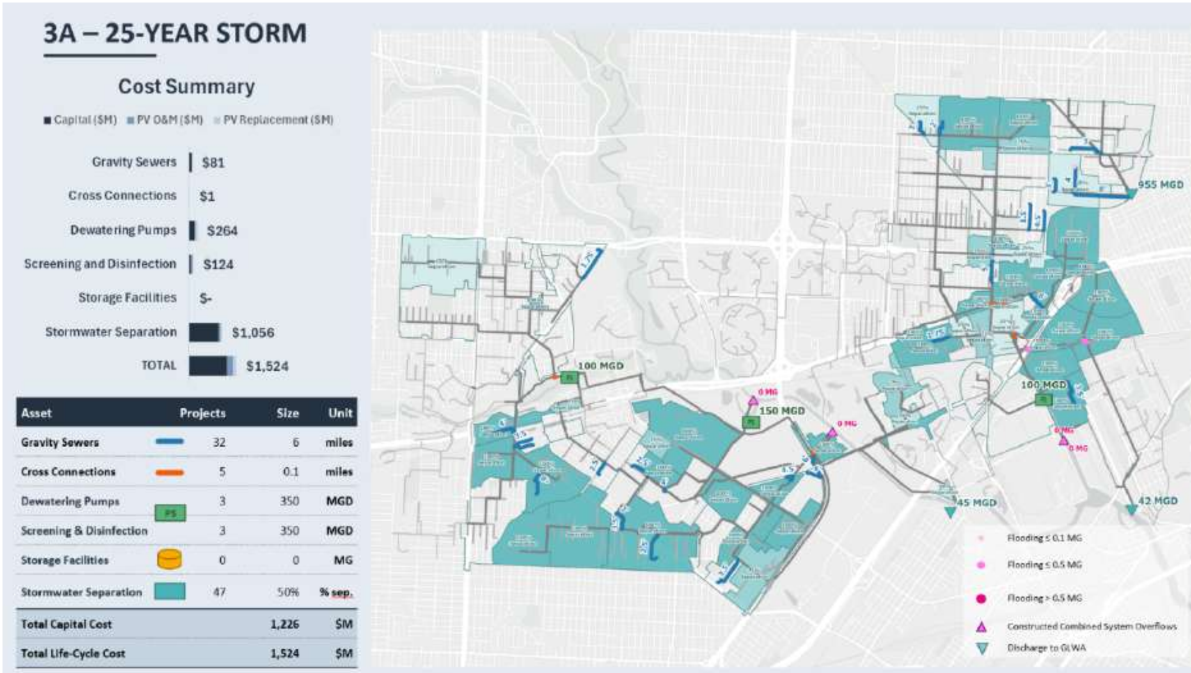


Figure 42. Alternative 3A – 25-Year Storm

Alternative 3A presents a solution to meet the criteria of a 25-year storm, rather than a 25-year plus design storm. This adjusted design criteria led to a solution that includes six miles of gravity sewer to convey flows away from areas with the most prevalent capacity issues. The alternative includes five cross connection changes to maximize the use of new and existing infrastructure capacity. In addition, the alternative includes three new pump stations associated with screening & disinfection to provide a total treatment capacity of 350 MGD (650 cfs), and 47 projects that will cumulatively provide 50% stormwater separation of the existing system. The siting of the pumping/treatment facility (and associated property acquisition, connecting sewers, land acquisition costs) are not included with the evaluation. The routing of the sewers used existing streets and collection system alignments.

This solution comes at a lower total estimated cost in comparison to the 25-year plus optimized solution, but with the trade-off of not meeting all the design criteria at 100%. As seen in **Figure** 42, designing to a 25-year storm resulted in multiple areas of flooding, largely in east Dearborn. As a general trend, the decrease in design storm intensity has increased the system deficiencies in comparison to the optimized solution 2A for a 25-year plus design storm.

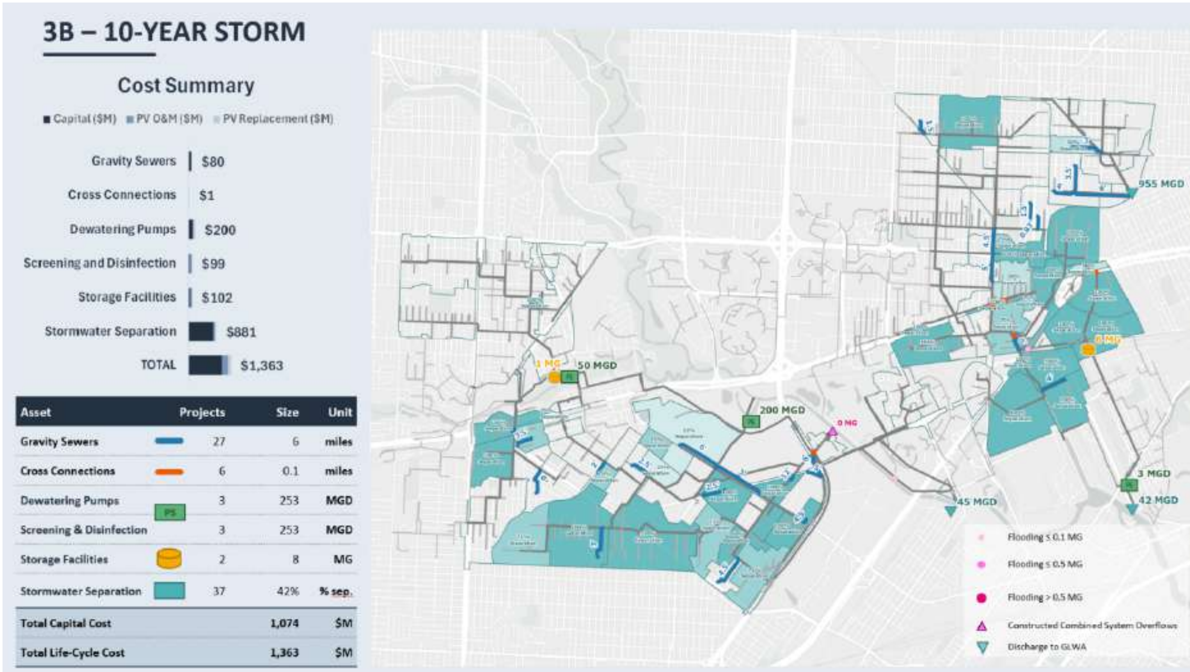


Figure 43. Alternative 3B – 10-Year Storm

Alternative 3B presents a solution to meet the criteria of a 10-year storm. This adjusted design criteria led to a solution that includes six miles of gravity sewer to convey flows away from areas with the most prevalent capacity issues, six cross connection changes to maximize the use of new and existing infrastructure, three new pump stations associated with screening & disinfection to provide a total treatment capacity of 253 MGD (470 cfs), two storage facilities with a combined capacity of 8 MG, and 37 projects that will cumulatively provide 42% stormwater separation of the existing system. The siting of the pumping/treatment facility (and associated property acquisition, connecting sewers, land acquisition costs) are not included with the evaluation. The routing of the sewers used existing streets and collection system alignments.

Designing around a 10-year storm provides a total estimated cost that is lower than the optimized solution 2A, but it comes at the tradeoff of increased system deficiencies. In **Figure** 43, the pink and red point markers indicate that areas in and around east Dearborn will continue to experience flooding during storm events despite the recommended improvement projects. The 10-year storm represents the smallest storm event that the OHM project team would recommend designing for. As storm event intensity and frequency increases due to climate change and the need to create more resilient systems, it is important to note that solutions optimized for a 10-year storm will have the risk of producing a system that will be under capacity and less resilient.

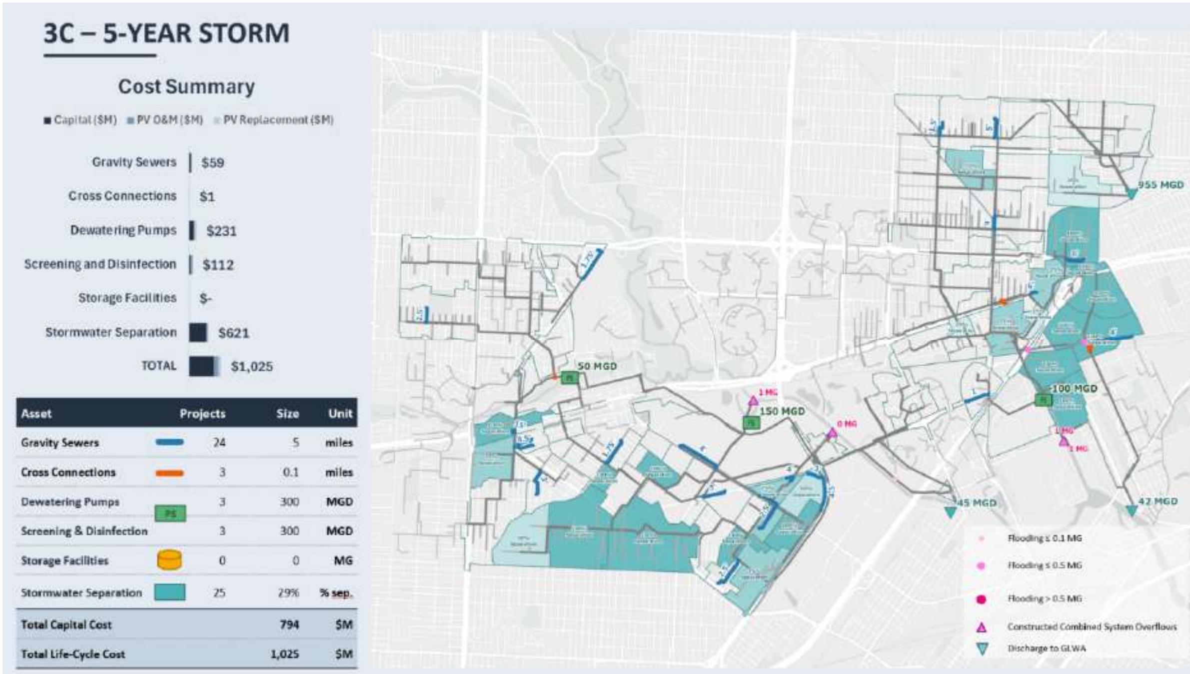


Figure 44. Alternative 3C – 5-Year Storm

Alternative 3C presents a solution to meet the criteria of a 5-year storm. This adjusted design criteria led to a solution that includes five miles of gravity sewer to convey flows away from areas with the most prevalent capacity issues. The alternate includes three cross connection changes to maximize the use of new and existing infrastructure. There are three new pump stations with screening & disinfection to provide a total treatment capacity of 300 MGD (557 cfs). Stormwater separation projects include 25 projects that will cumulatively provide 29% stormwater separation of the existing system. The siting of the pumping/treatment facility (and associated property acquisition, connecting sewers, land acquisition costs) are not included with the evaluation. The routing of the sewers used existing streets and collection system alignments.

With the design optimized for a 5-year storm, the presence of system deficiencies become more clear and well defined. As seen above in **Figure** 44, the City is predicted to experience flooding greater than 0.5 MG in and around east Dearborn, flooding events throughout the rest of the City, and numerous combined sewer system overflows. Alternative 3C is not a recommended solution; rather, it highlights the system deficiencies in areas that are particularly impacted by storm events. Approximately $1,025M in life-cycle costs are presented in alternative 3C, and yet it does not meet the design criteria for a 5-year storm.

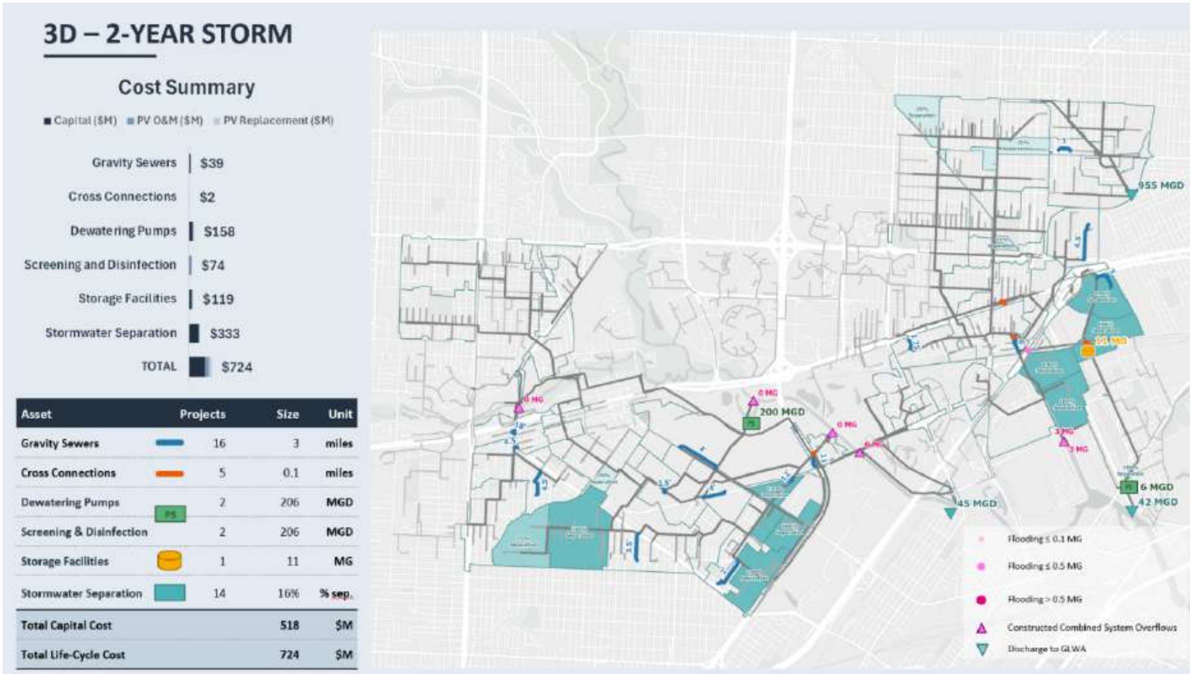


Figure 45. Alternative 3D – 2-Year Storm

Alternative 3D presents a solution to meet the criteria of a 2-year storm. This adjusted design criteria led to a solution that includes three miles of gravity sewer to convey flows away from areas with the most prevalent capacity issues. There are five cross connection changes to maximize the use of new and existing infrastructure capacity. In addition, there are two new pump stations with associated screening & disinfection to provide a total treatment capacity of 206 MGD (383 cfs). Stormwater separation includes 14 projects that will cumulatively provide 16% stormwater separation of the existing system. The siting of the pumping/treatment facility and the storage facility (and associated property acquisition, connecting sewers, land acquisition costs) are not included with the evaluation. The routing of the sewers used existing streets and collection system alignments.

With the design optimized for a 2-year storm, the presence of system deficiencies become more clear and well defined. As seen above in **Figure** 45, the City is predicted to experience flooding greater than 0.5 MG in and around east Dearborn, flooding events throughout the rest of the City, and numerous combined sewer system overflows. Alternative 3D is not a recommended solution; rather, it highlights the system deficiencies in areas that are particularly impacted by storm events. Approximately $724M in life-cycle costs are presented in alternative 3D, and yet it does not meet the design criteria for a 2-year storm.

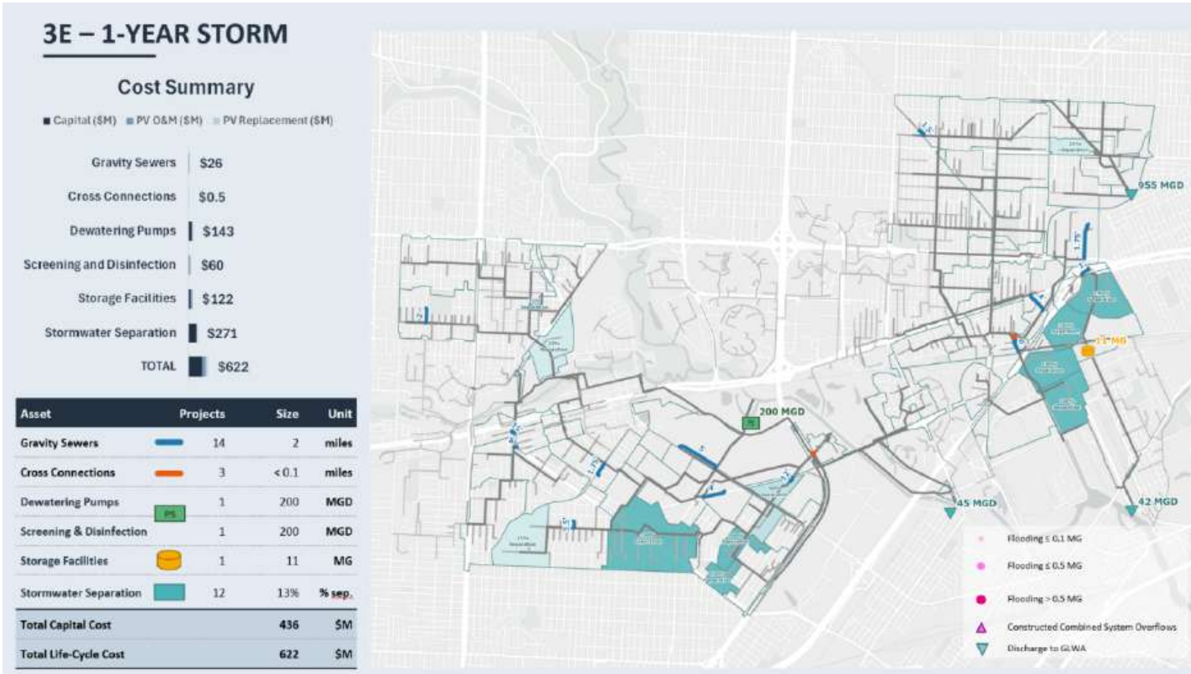


Figure 46. Alternative 3E – 1-Year Storm

Alternative 3E presents a solution to meet the criteria of a 1-year storm. This adjusted design criteria led to a solution that includes two miles of gravity sewer to convey flows away from areas with the most prevalent capacity issues. The alternate includes three cross connection changes to maximize the use of new and existing infrastructure capacity. In addition, one new pump station associated with screening & disinfection is included to provide a total treatment capacity of 200 MGD (371 cfs). Stormwater separation projects include 12 projects that will cumulatively provide 13% stormwater separation of the existing system. The siting of the pumping/treatment facility and the storage facility (and associated property acquisition, connecting sewers, land acquisition costs) are not included with the evaluation. The routing of the sewers used existing streets and collection system alignments.

With the design optimized for a 1-year storm, the presence of system deficiencies become more clear and well defined. As seen above in Figure **46**, the City is predicted to experience flooding greater than 0.5 MG. Alternative 3E is not a recommended solution; rather, it highlights the system deficiencies in areas that are particularly impacted by storm events. The solution to mitigate the flooding impacts from a 1-year storm highlight the system need to additional capacity in east and south Dearborn specifically. Approximately $622M in life-cycle costs are presented in alternative 3E, and yet it does not meet the design criteria for a 1-year storm.

A summary comparison of the key optimization solutions is presented in Table 6 (showing quantities of selected alternatives) and Table 7 (showing capital costs for selected alternatives).

Table 6. Summary of Key Preliminary Optimization Solutions – Quantities

Scenario Group	SC Ref.	Description	Selected Alternatives (Quantities)						Total Cost ($M)	
			Gravity (miles)	Dewatering (MGD)	Treatment (MGD)	Connects (miles)	Storage (MG)	Separation (%)	Capital	Life Cycle
Bookend Optimization	1A	Conveyance Only	29	2,769	2,769	0.3	-	-	2,742	4,070
	1B	Dewatering Limited to 200 MGD	26	710	710	0.3	196	-	2,239	3,435
	1C	Dewatering Limited to 100 MGD	28	500	500	0.3	283	-	2,560	3,972
	1D	Stormwater Separation Only	-	-	-	-	-	78	1,487	1,658
	1E	Full Stormwater Separation	-	-	-	-	-	100	1,898	2,115
All Alternatives	2A	Optimized Solution	1	-	-	-	-	75	1,445	1,611
	2B	Reduced Stormwater Separation	5	150	150	0.1	1	60	1,336	1,560
	2C	Manhole Flooding Limited to 0.5 MG	5	150	150	0.1	-	50	1,139	1,334
	2D	Manhole Flooding Limited to 1.5 MG	4	50	50	0.2	-	35	804	925
	2E	Manhole Flooding Limited to 10 MG	3	-	-	0.1	1	21	493	558
Design Storm Sensitivity	3A	25-year Design Storm	6	350	350	0.1	-	50	1,226	1,524
	3B	10-year Design Storm	6	253	253	0.1	8	42	1,074	1,363
	3C	5-year Design Storm	5	300	300	0.1	-	29	794	1,025
	3D	2-year Design Storm	3	206	206	0.1	11	16	518	724
	3E	1-year Design Storm	2	200	200	< 0.1	11	13	436	622

Table 7. Summary of Key Preliminary Optimization Solutions – Costs

Scenario Group	SC Ref.	Description	Selected Alternatives (Quantities)						Total Cost ($M)	
			Gravity ($M)	Dewatering ($M)	Screening & Disinfect ($M)	Connects ($M)	Storage ($M)	Separation ($M)	Capital	Life Cycle
Bookend Optimization	1A	Conveyance Only	1,533	1,909	619	9	-	-	2,742	4,070
	1B	Dewatering Limited to 200 MGD	1,221	523	234	10	1,448	-	2,239	3,435
	1C	Dewatering Limited to 100 MGD	1,360	396	201	6	2,009	-	2,560	3,972
	1D	Stormwater Separation Only	-	-	-	-	-	1,658	1,487	1,658
	1E	Full Stormwater Separation	-	-	-	-	-	2,115	1,898	2,115
All Alternatives	2A	Optimized Solution	14	-	-	-	-	1,597	1,445	1,611
	2B	Reduced Stormwater Separation	115	110	49	3	14	1,270	1,336	1,560
	2C	Manhole Flooding Limited to 0.5 MG	111	110	49	3	-	1,061	1,139	1,334
	2D	Manhole Flooding Limited to 1.5 MG	115	44	25	5	-	735	804	925
	2E	Manhole Flooding Limited to 10 MG	96	-	-	3	19	441	493	558
Design Storm Sensitivity	3A	25-year Design Storm	81	264	124	1	-	1,056	1,226	1,524
	3B	10-year Design Storm	80	200	99	1	102	881	1,074	1,363
	3C	5-year Design Storm	59	231	112	1	-	621	794	1,025
	3D	2-year Design Storm	39	158	74	2	119	333	518	724
	3E	1-year Design Storm	26	143	60	0.5	122	271	436	622

Capital Improvement Project Prioritization

The Optimizer model was also used to develop a prioritization sequence that is aligned with improving the system performance (reducing performance deficiency from 100% to 0%) by way of implementing stormwater separation projects. The project prioritization and aligns the performance with cost expenditures.

Figure 47 illustrates the Performance Deficiency versus Cost. As the City implements the Sewer Separation Alternative projects, continued evaluation of the performance of the system is required through sewer monitoring (flow meters) and model updates to align projects and performance and determine the optimal time to conclude improvements when system performance goals are achieved.

Program improvements inevitably have a greater impact at the beginning when more impactful projects are completed. As projects are implemented a knee-of-the curve analysis needs to be conducted to determine the optimal time to conclude efforts when the sewer performance is close to or meeting the design criteria of the 25-year plus 30% volume design storm. As can be seen below as the weighted capacity deficiency line becomes horizonal you begin to see diminishing returns for the invested dollar. The cost for achieving the last 10% of performance is close to the costs for mitigating the first 90% of the improvements.

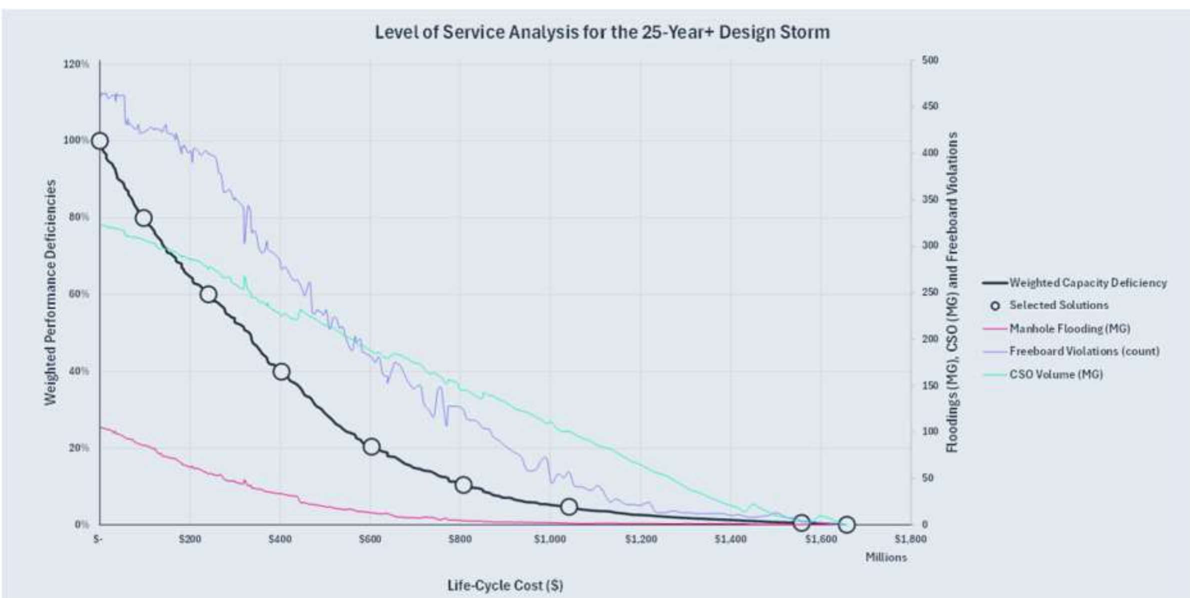


Figure 47. Performance deficiency versus cost

Storm	MH Flooding count	MH Flooding MG	CSOs count	CSOs MG	FB violations
1-Year	95	11.6	4	70.5	312
2-Year	152	18.6	4	96.9	365
5-Year	209	34.8	6	151.5	490
10-Year	523	48.4	6	198.9	588
25-Year	291	71.8	6	267.6	760
25-Year+	352	95.6	6	321.2	872

Project	Subcatchments	Total % separation
Stormwater Separation	0	0%
Total Capital Cost		0 $M
Total Life-Cycle Cost		0 $M

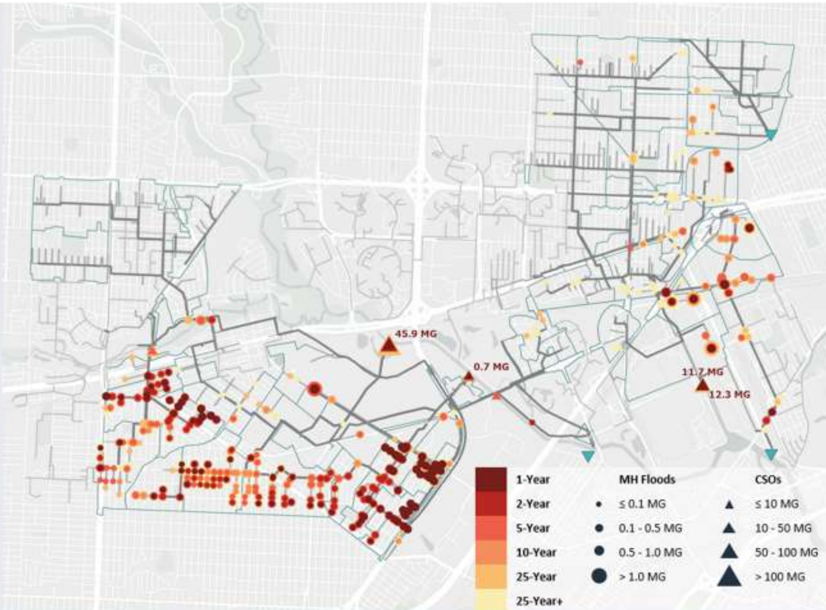


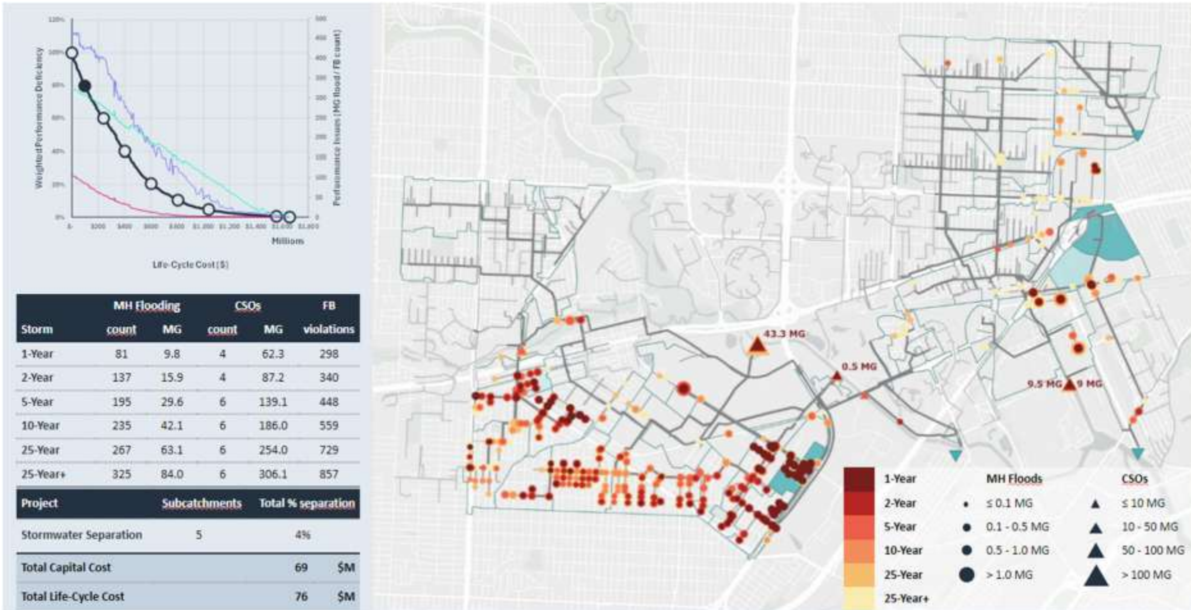
Figure 48. Existing system performance (25-year plus design storm)

Figure 48 identifies the performance of the existing system including manhole flooding, combined sewer overflows and freeboard violations in the system for the range of design storms prior to implementing any stormwater separation projects.

The range of the design storm includes the 1-year storm up to and including the design 25-year plus design storm. As noted earlier in **Figure** 2, system deficiencies are less prevalent in the mid-section of town where the existing system has been separated.

The graphic in the top left of **Figure 49** through **Figure 56** illustrates the cost versus performance value as alternative projects are implemented from the optimized (stormwater separation) solution.

The map on the right side of the page shows a decreasing level of manhole flooding and combined sewer overflows as the performance deficiencies decrease. The table in the left-hand corner of the figure depicts the level of service along with the capital costs and total life cycle costs.



	MH Flooding		CSOs		FB
Storm	count	MG	count	MG	violations
1-Year	81	9.8	4	62.3	298
2-Year	137	15.9	4	87.2	340
5-Year	195	29.6	6	139.1	448
10-Year	235	42.1	6	186.0	559
25-Year	267	63.1	6	254.0	729
25-Year+	325	84.0	6	306.1	857

Project	Subcatchments	Total % separation
Stormwater Separation	5	4%
Total Capital Cost		69 $M
Total Life-Cycle Cost		76 $M

Figure 49. 80% performance deficiency

Figure 49 identifies the initial recommended areas for sewer separation projects in east and southwest Dearborn to meet the 80% performance deficiency. These projects are aligned with historical data noting the most prevalent areas of sewer issues during larger wet weather events.

To achieve 80% performance deficiency stormwater separation projects of 100% and 75% are included in the east along with a section on the south side that is targeted for 100% separation. The area in the southwest is part of south Dearborn and an area characterized by private flood damage claims. These separation areas are high priority areas.

Capital costs to achieve an 80% performance deficiency include $69M in capital cost and $76M in life cycle costs. Modeling indicates several system deficiencies even at the 1-year rainfall event for the 80% performance deficiency. The 80% performance deficiency is characterized by numerous freeboard violations even at the 1-year storm event. Manhole flooding and CSO's are also consistently prevalent down to the 1-year storm event. The 80% performance deficiency does not meet the goals of the City and is presented for comparative purposes.

Storm	MH Flooding count	MH Flooding MG	CSOs count	CSOs MG	FB violations
1-Year	23	3.5	4	44.1	220
2-Year	46	5.7	4	65.1	272
5-Year	106	12.8	6	110.6	423
10-Year	136	21.0	6	153.9	538
25-Year	189	36.3	6	220.5	705
25-Year+	252	52.9	6	272.9	853

Project	Subcatchments	Total % separation	
Stormwater Separation	9	11%	
Total Capital Cost		214	$M
Total Life-Cycle Cost		238	$M

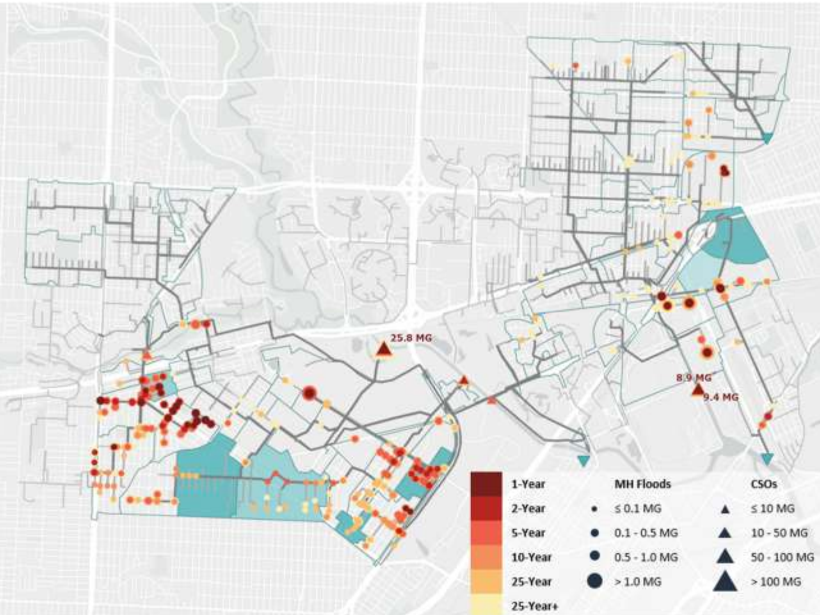


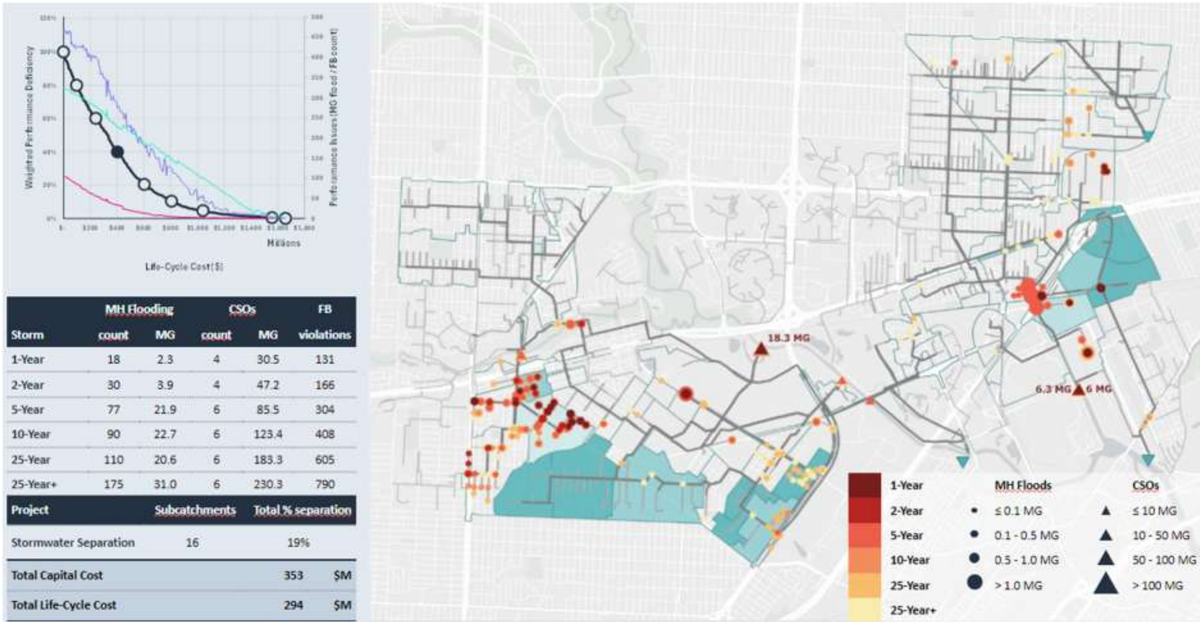
Figure 50. 60% performance deficiency

Figure 50 identifies the recommended areas for sewer separation projects to meet the 60% performance deficiency. The figure does not include the conveyance sewer in the southwest area, which is fundamental to this alternative and increases the capital and life-cycle costs.

To achieve a 60% performance deficiency the improvements, include those identified within **Figure** 50 with additional areas in the southwest. The additional areas include sections that are proposed to be 100% separated along with areas to be separated to a lesser degree of 75%. To achieve a 60% performance deficiency 9 subcatchments are separated totaling 11% separation.

Total capital costs for stormwater separation to achieve 60% performance deficiency are $214M with a total life cycle cost of $238M.

System performance increases substantially from 80% performance deficiency to 60% performance deficiency, however, as can be seen in **Figure** 50 there are still service issue even at the 1-year storm event. The 60% performance deficiency is characterized by freeboard violations even at the 1-year storm event. Manhole flooding and CSO's are also consistently prevalent down to the 1-year storm event. While improvement is noticeable from the 80% performance deficiency the 60% performance deficiency does not meet the goals of the City.



	MH Flooding		CSOs		FB
Storm	count	MG	count	MG	violations
1-Year	18	2.3	4	30.5	131
2-Year	30	3.9	4	47.2	166
5-Year	77	21.9	6	85.5	304
10-Year	90	22.7	6	123.4	408
25-Year	110	20.6	6	183.3	605
25-Year+	175	31.0	6	230.3	790
Project		Subcatchments		Total % separation	
Stormwater Separation		16		19%	
Total Capital Cost				353	$M
Total Life-Cycle Cost				294	$M

Figure 51. 40% performance deficiency

Figure 51 identifies the recommended areas for sewer separation projects to meet the 40% performance deficiency. Additional separation projects are identified north of Madison Street and east of Telegraph (US-24). This additional separation area is characterized by intense manhole flooding and identified by the modeling as requiring 50% separation.

In addition, to achieve a 40% percent performance deficiency separation the northeast separation area would be expanded to include more area. The expanded separation area targets one additional section for 100% separation and an additional section of 50% separation. To achieve a 40% performance deficiency 16 subcatchments are separated totaling 19% separation.

Total capital costs for stormwater separation to achieve 40% performance deficiency are $353M with a total life cycle cost of $294M. Similar to the previous performance deficiency improvements of 60% the 40% Performance Deficiency includes areas that are substantially affected by the 1-year storm. Most notable of this can be seen in south Dearborn. The 40% performance deficiency is characterized by freeboard violations even at the 1-year storm event. Manhole flooding and CSO's are also consistently prevalent down to the 1-year storm event.

Storm	MH Flooding count	MH Flooding MG	CSOs count	CSOs MG	FB violations
1-Year	6	1.3	4	19.8	45
2-Year	7	1.7	4	34.0	75
5-Year	30	15.6	5	66.1	245
10-Year	48	16.9	6	97.0	354
25-Year	64	9.5	6	152.1	547
25-Year+	120	15.4	6	196.0	722

Project	Subcatchments	Total % separation
Stormwater Separation	26	26%
Total Capital Cost		496 $M
Total Life-Cycle Cost		553 $M

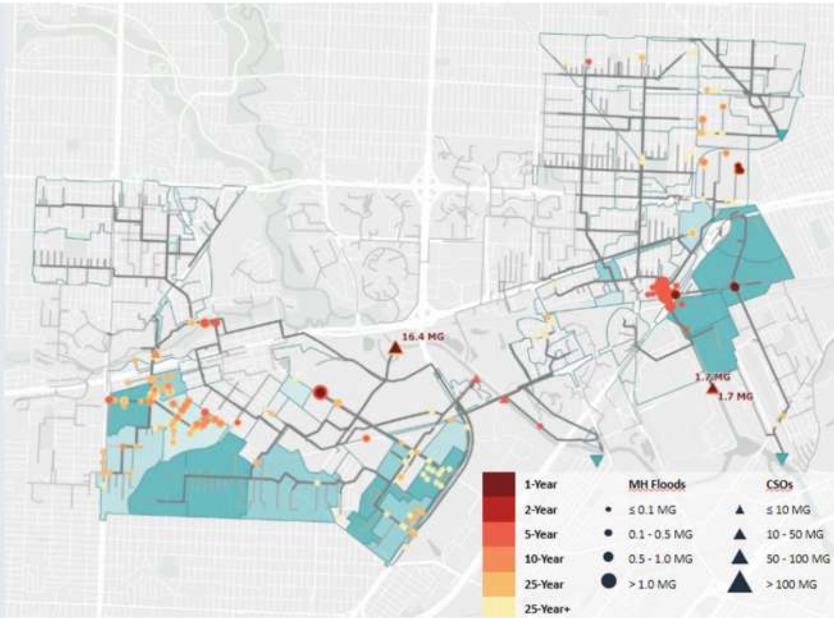
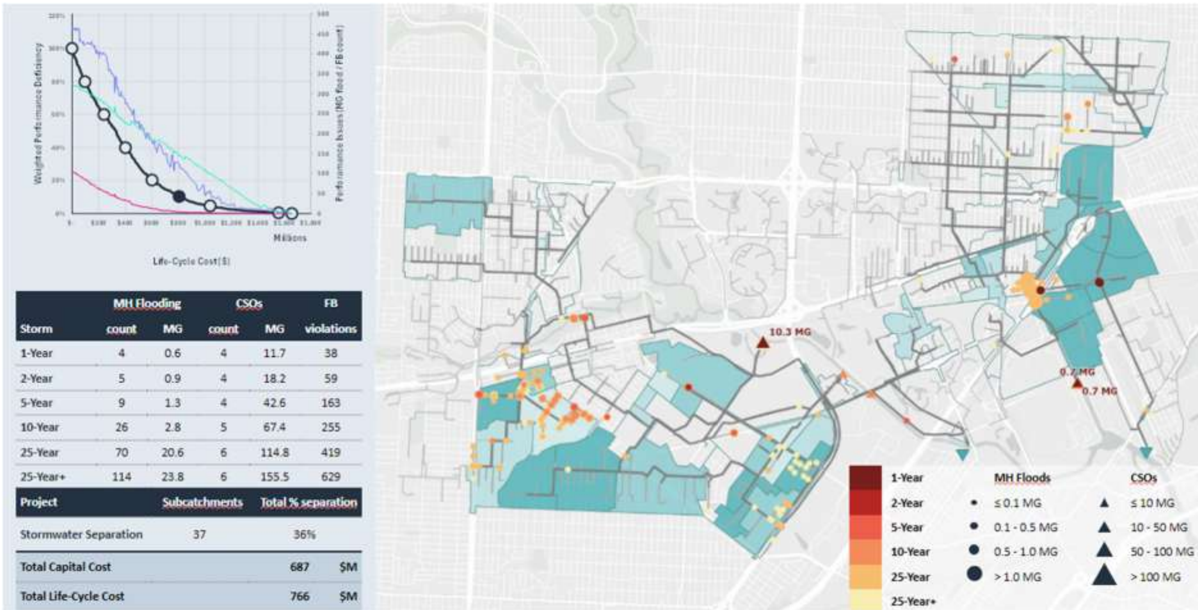


Figure 52. 20% performance deficiency

Figure 52 identifies the initial recommended areas for sewer separation projects to meet the 20% performance deficiency. Additional separation projects include 75% separation of areas located east of Telegraph (US-24) and north of Dartmouth Street in south Dearborn.

This separation area begins to address issues identified above as areas having problems with the 1-year storm. Additional sections to be separated are included in east and south Dearborn. To achieve a 20% performance deficiency 26 subcatchments are separated totaling 26% separation.

Total capital costs for stormwater separation to achieve 20% performance deficiency are $496M with a total life cycle cost of $553M. The 20% Performance Deficiency continues to show marked improvement with the most obvious and noticeable improvement occurring in South Dearborn where manhole flooding has diminished to the 5-year event. The 20% performance deficiency is characterized by freeboard violations even at the 1-year storm event. Manhole flooding and CSO's are also consistently prevalent down to the 1-year storm event.



Storm	MH Flooding count	MH Flooding MG	CSOs count	CSOs MG	FB violations
1-Year	4	0.6	4	11.7	38
2-Year	5	0.9	4	18.2	59
5-Year	9	1.3	4	42.6	163
10-Year	26	2.8	5	67.4	255
25-Year	70	20.6	6	114.8	419
25-Year+	114	23.8	6	155.5	629

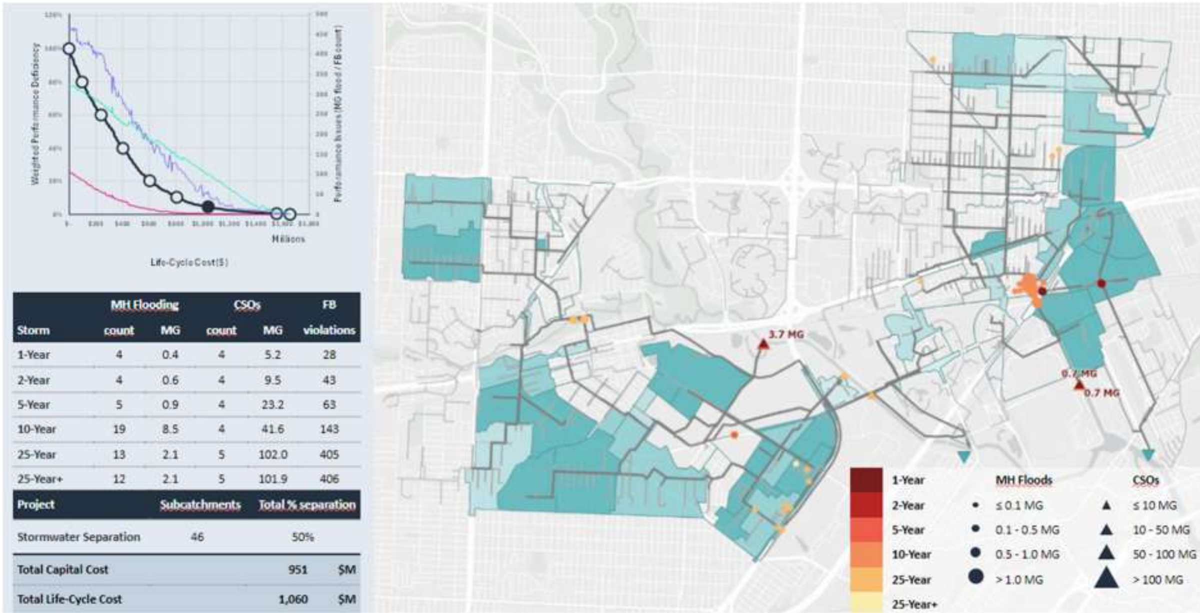
Project	Subcatchments	Total % separation
Stormwater Separation	37	36%
Total Capital Cost	687	$M
Total Life-Cycle Cost	766	$M

Figure 53. 10% performance deficiency

Figure 53 identifies the initial recommended areas for sewer separation projects to meet the 10% performance deficiency. The additional areas continue to address stormwater separation in east and south Dearborn with separation projects that are less impactful but require less separation. To achieve a 10% performance deficiency 37 subcatchments are separated totaling 36% separation.

Total capital costs for stormwater separation to achieve 10% performance deficiency are $687M with a total life cycle cost of $766M. The 10% Performance Deficiency continues to see gains with reduction in manhole flooding and combined sewer overflow volumes. Reduction in freeboard violations show a more modest reduction.

The 10% performance deficiency is characterized by freeboard violations even at the 1-year storm event. Manhole flooding and CSO’s are still prevalent as well but still trending downward.



	MH Flooding		CSOs		FB
Storm	count	MG	count	MG	violations
1-Year	4	0.4	4	5.2	28
2-Year	4	0.6	4	9.5	43
5-Year	5	0.9	4	23.2	63
10-Year	19	8.5	4	41.6	143
25-Year	13	2.1	5	102.0	405
25-Year+	12	2.1	5	101.9	406

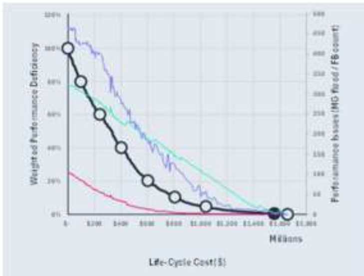
Project	Subcatchments	Total % separation
Stormwater Separation	46	50%
Total Capital Cost	951	$M
Total Life-Cycle Cost	1,060	$M

Figure 54. 5% performance deficiency

Figure 54 identifies the initial recommended areas for sewer separation projects to meet the 5% performance deficiency. Addition separation projects achieving the 5% performance deficiency include areas the northeast section of the City within north and south Dearborn.

Total capital costs for stormwater separation to achieve 5% performance deficiency are $951M with a total life cycle cost of $1,060M. To achieve a 5% performance deficiency 46 subcatchments are separated totaling 50% separation.

The 5% Performance Deficiency limits manhole flooding to the 5-year event with much of the manhole flooding eliminated throughout the City. Combine sewer overflow volumes are also reduce significantly with most overflow volume occurring at CSO 014 outfall. There are still freeboard violations down to the 1-year event with reduction continuing on a linear path.



Storm	MH Flooding count	MH Flooding MG	CSOs count	CSOs MG	FB violations
1-Year	0	0	0	0	0
2-Year	0	0	0	0	0
5-Year	0	0	0	0	1
10-Year	2	< 0.1	0	0	12
25-Year	4	0.4	1	0.8	41
25-Year+	4	0.7	3	3.1	78

Project	Subcatchments	Total % separation
Stormwater Separation	70	74%
Total Capital Cost	1,400	$M
Total Life-Cycle Cost	1,560	$M

Figure 55. Near 0% design deficiency

Figure 55 identifies the initial recommended areas for sewer separation project to meet the near 0% performance deficiency. Separation projects proposed to reach a near 0% performance level are included in all the Sewer District Areas with many of the proposed projects increasing separation in areas that were previously included but to a lesser degree of separation.

Total capital costs for stormwater separation to achieve near 0% performance deficiency are $1,400M with a total life cycle cost of $1,560M. To achieve a near 0% performance deficiency 70 subcatchments are separated totaling 74% separation.

The Near 0% Performance Deficiency eliminates all but two locations for manhole flooding that are limited to the most extreme storm events of 25-year and 25-year plus storm events. Under this design deficiency all combined sewer overflows are eliminated with the exception of CSO 014 outfall which is limited to the 25-year plus storm event. Free board violations still exist down to the 5-year storm event but are eliminated for the 2-year and 1-year event.

Storm	MH Flooding count	MH Flooding MG	CSOs count	CSOs MG	FB violations
1-Year	0	0	0	0	0
2-Year	0	0	0	0	0
5-Year	0	0	0	0	0
10-Year	0	0	0	0	6
25-Year	0	0	0	0	26
25-Year+	0	0	0	0	52

Project	Subcatchments	Total % separation
Stormwater Separation	76	80%
Total Capital Cost		1,516 $M
Total Life-Cycle Cost		1,690 $M

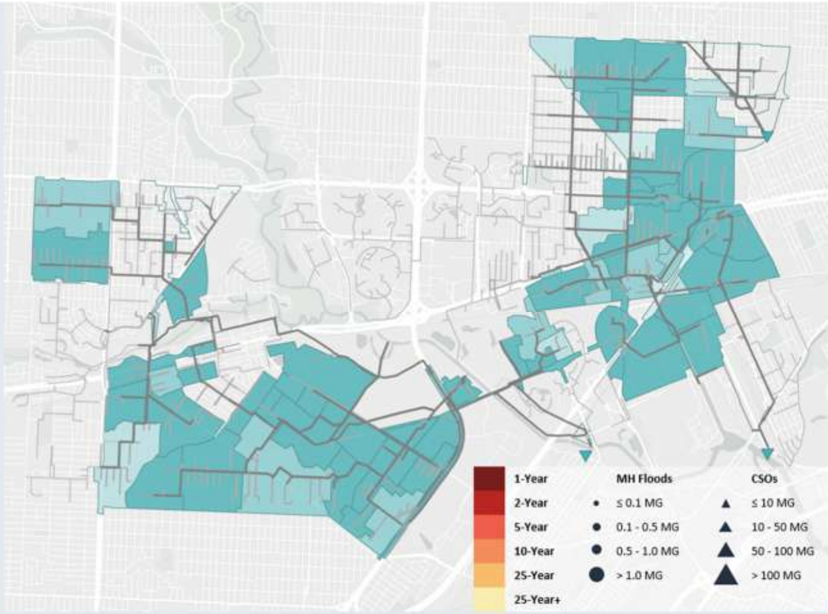


Figure 56. Optimized Solution – 0% design deficiency

Figure 56 identifies the completed stormwater sewer separation to reach a 0% design deficiency. The addition separation to reach 0% includes areas within east Dearborn. As can be seen in **Figure** 56 there is no indication of manhole flooding or combined sewer overflows for the 25-year plus design storm. Freeboard violations are limited to the 25-year and 25-year plus storm event. To achieve a 0% performance deficiency 76 subcatchments are separated totaling 80% separation. It is important to note that it is not necessary to fully separate the entire combined sewer service area to achieve the goals of the design storm.

Total capital costs for stormwater separation to achieve near 0% performance deficiency are $1,516M with a total life cycle cost of $1,690M.

Optimization Refinement

- Basic assumption for screening and disinfection was to treat flows for the design storm modeled. The assumptions for screening and disinfection could be further refined to identify a specific design storm and set that for all alternatives.

- Pumping, Screening/Disinfection, and Storage technologies don't include costs for conveyance to the facilities, property acquisition, or confirmation that property exists for the facilities.

- Detailed planning and feasibility assessments are recommended to further refine the planning level cost estimates presented in this report. Specific capital improvement recommendations, identified in this report as being sensitive to cost rate assumptions, may also be refined based on the outcome of detailed planning and feasibility assessments. Rerunning the optimization model based on revised cost estimates should be contemplated if differences are found to exceed the range of sensitivities considered.

Funding Programs

This section identifies potential funding sources for the City of Dearborn's sewer system improvements. This section reviews some of the funding options from state and federal sources. No opinions or recommendations on debt or financing structures are provided. These decisions will need to be made in the context of the City's financial situation, long-term financial plans, project costs, and funding available during the respective application period(s).

The U.S. Congress passed the Infrastructure Investment and Jobs Act (also known as Bipartisan Infrastructure Law or BIL) in 2021. BIL is significant and provides additional funding opportunities under many water-based infrastructure funding programs. Additional funding through BIL must be allocated by 2027 but can be used for projects costs past the 2027 allocation deadline when awarded.

Most direct water and wastewater infrastructure funding through BIL is dispersed through the EPA State Revolving Fund (SRF). The influx of BIL funding into state SRF funds has raised grant and funding levels in each state to record highs. Once BIL money is allocated, the level of funding available through SRF programs will significantly decline and will not increase without the passage of another funding bill through Congress. If the City wishes to fund initial project design or early project component costs with SRF funding, applications should be submitted in 2025 or 2026 while SRF funding availability is still high.

With the influx of BIL money into the SRF funds, there has been an escalating trend of water and clean water funds being allocated through earmarks. Earmarks are direct congressional funding for a specific local project. Earmarks are administered through federal agencies and projects must qualify based on established program requirements. Earmarks are not merit based and circumvent the traditional grant application process. Earmarked projects are selected for funding and then follow an application process to ensure projects meet agency/program guidelines. If the City has a relationship with a congressional representative who understands the value of the sewer system projects, it could attempt to secure some of the project funding through earmarks.

Water Infrastructure Finance and Innovation Act

The Water Infrastructure Finance and Innovation Act (WIFIA) created a federal loan program at the EPA to accelerate investment in our nation's water infrastructure. The program provides long-term, low-cost supplemental financing for water and wastewater infrastructure projects of national or regional significance. The WIFIA programs offers financial assistance that can help borrowers implement water capital improvement projects to help build climate resilience.

Following its annual appropriation, the WIFIA program opens a new selection round and announces the funding available in a Notice of Funding Availability. Each year, the Administrator establishes how projects will be prioritized based on the EPA's assessment of the critical immediate water risks facing water and wastewater service providers. These priorities, the amount of funding available, and the application process are communicated to the public in the annual notice. Eligible borrowers include local, state, Tribal, and federal government entities; partnerships and joint ventures; corporations and trusts; and the Clean Water State Revolving Fund (CWSRF) and Drinking Water State Revolving Fund (DWSRF) programs.

WIFIA financing can fund development and implementation activities for several project categories to address climate mitigation and resilience. Projects eligible for the CWSRF, such as projects to construct and rehabilitate wastewater treatment plants and conveyances, implement state nonpoint source management programs, manage stormwater, reuse or recycle wastewater, and improve security and energy efficiency at treatment plants, are appliable for the loan program.

WIFIA loans cover 49% of the eligible project costs and SRF loans can be used to make up the balance of the costs. The interest rate is based on U.S. Treasury Securities. WIFIA interest rates are currently at 4.12% but in 2020 reached lows of 1.45%. Borrowers can customize their repayments to match their anticipated revenues and expenses for the life of the loan. This flexibility provides borrowers with time they may need to phase-in rate increases to generate revenue to repay the loan. The WIFIA program offers repayment terms of up to 35 years after project completion. Borrowers may also defer repayments for up to 5 years after project completion and make interest-only payments for additional years.

When the project reaches the 10% design milestone, the City could develop and submit a (WIFIA) Letter of Intent (LOI) for loan funding through the EPA. The submittal of an LOI is not binding and does not require any fees at this stage. If the City is successful with the LOI, the U.S. EPA will formally invite the City to submit a full application within one year of the letter. The City can evaluate WIFIA and Bond interest rates to determine which funding mechanism would be most cost effective. If the City decides to move forward to submit a WIFIA Application, the $100,000 application fee would be required at submission.

Building Resilient Infrastructure and Communities Funding

Federal Emergency Management Agency (FEMA) Building Resilient Infrastructure and Communities (BRIC) funding may be applicable to portions of the sewer improvement projects. The BRIC program is intended to proactively shift federal funding away from reactive disaster spending towards projects that create communities more resilient to natural disasters. To be eligible for BRIC funding, the City would have to demonstrate that the project has long term flood reduction benefits. The project would also have to undergo a benefit-cost analysis, a project is considered cost-effective when the benefit-cost ratio is greater than one. BRIC grants have a 75% Federal/25% non-Federal match requirement with applications occurring once per year. BRIC grants do require a high level of effort for the applications.

Clean Water State Revolving Fund

If the City wishes to pursue additional low interest loans for the project through the Michigan Clean Water State Revolving Fund (CWSRF) it should apply for funding in 2025 and 2026 while BIL money is still available. Funding levels and principal forgiveness is likely to significantly decline after all BIL money is fully allocated in 2027. CWSRF loans are low interest for 20-year maturity. The amount of funding is likely to decline after 2026. The sewer improvement projects have broad eligibility and should be a high priority.

Programmatic Approach

The City should take a programmatic approach for funding the sewer system improvement projects. Evaluate the list of grant and loan programs and identify project components that closely align with grant eligibility requirements. Also, identify which grants could provide funding for different stages of project development including design, environmental review, and construction. Consideration should also be given to required federal cost shares for each program. For example, WIFIA can only cover 49% of project costs and additional funding must come from other sources, including SRF loans.

Conclusions and Recommendations

The study's alternatives optimization effort proved that sewer separation is the most cost-effective solution to address the City's flooding issues. Sewer separation achieves the largest system benefit (reduction in flooding) at the lowest cost (capital and life cycle). For sewer separation, an estimated $1.5 billion dollar investment will be needed to achieve 100% of all the City's goals (system resiliency, reduced surface flooding, reduced basement flooding, water quality improvements /regulatory compliance). However, it should be noted that significant success (70-80%) can be achieved with an investment of approximately 40-50% ($500-$700M) of the overall $1.5B investment calculated. Figure 7 reflects this as the "knee" of the cost/performance curve.

The highest priority project areas identified through the Optimizer model include sewer separation in South Dearborn and Northeast Dearborn. A key element of successfully achieving sewer separation in South Dearborn is implementation of a stormwater outfall conveying newly separated stormwater flows directly to the Rouge River. A feasibility study for outfall solutions from separated areas in South Dearborn is needed to evaluate route alternatives that consider right-of-way and property impacts, capital and operation and maintenance costs, utility conflicts and constructability issues.

The optimized solutions for the 1-year, 2-year, 5-year, 10-year, and 25-year design storms provide an indication of priority investments to progressively improve the level-of-service of the sewer system. At a 1-year storm intensity, the cost to impede manhole flooding and CSO discharge in the highest priority areas was estimated at $436M in capital costs. This analysis has highlighted prevalent capacity issues in the existing system and confirmed the need for improvement projects to meet the needs of the Dearborn community.

It is recommended that the City consider current and future sewer rates and develop a cost-constrained 10-year sewer system capital improvement program that defines annual investment proposed over the next 10 years (and beyond).

Once the City has identified a target level of investment to achieve reduced flooding, the next step is to begin preliminary engineering for the first group of prioritized sewer separation projects.

Continued coordination with development/re-development, public works projects, and equity to the community will allow for an adaptive approach that best meets the goals and needs of the community of Dearborn.

The objective of this report was to present a comparative evaluation to guide the City in the next steps of project development, complete with high-level indications of least-cost improvement strategies to decrease system deficiencies and limit the impact of flooding. The recommended next step to reduce the sewer system deficiencies would be to do a full GIS layout, with elevations, for the entire collection system. This planning level model would help to generate better cost estimates for the improvement projects and would refine the Optimizer solution locations and layout for the control technologies being implemented. Additional optimization analyses and prioritization could be undertaken to evaluate hybrids of the level of service targets and to prioritize investments to maximize the return on investment.

Appendix A: Dearborn Data Gap Analysis Memorandum

Appendix B: Model Calibration and Validation Memorandum

Appendix C: Cost Tool Assumptions

Appendix D: Green Stormwater Infrastructure Evaluations and Case Studies

Appendix E: Cost Summaries

Appendix F: Alternatives PowerPoint Presentation

Appendix G: City Council Briefing Presentation