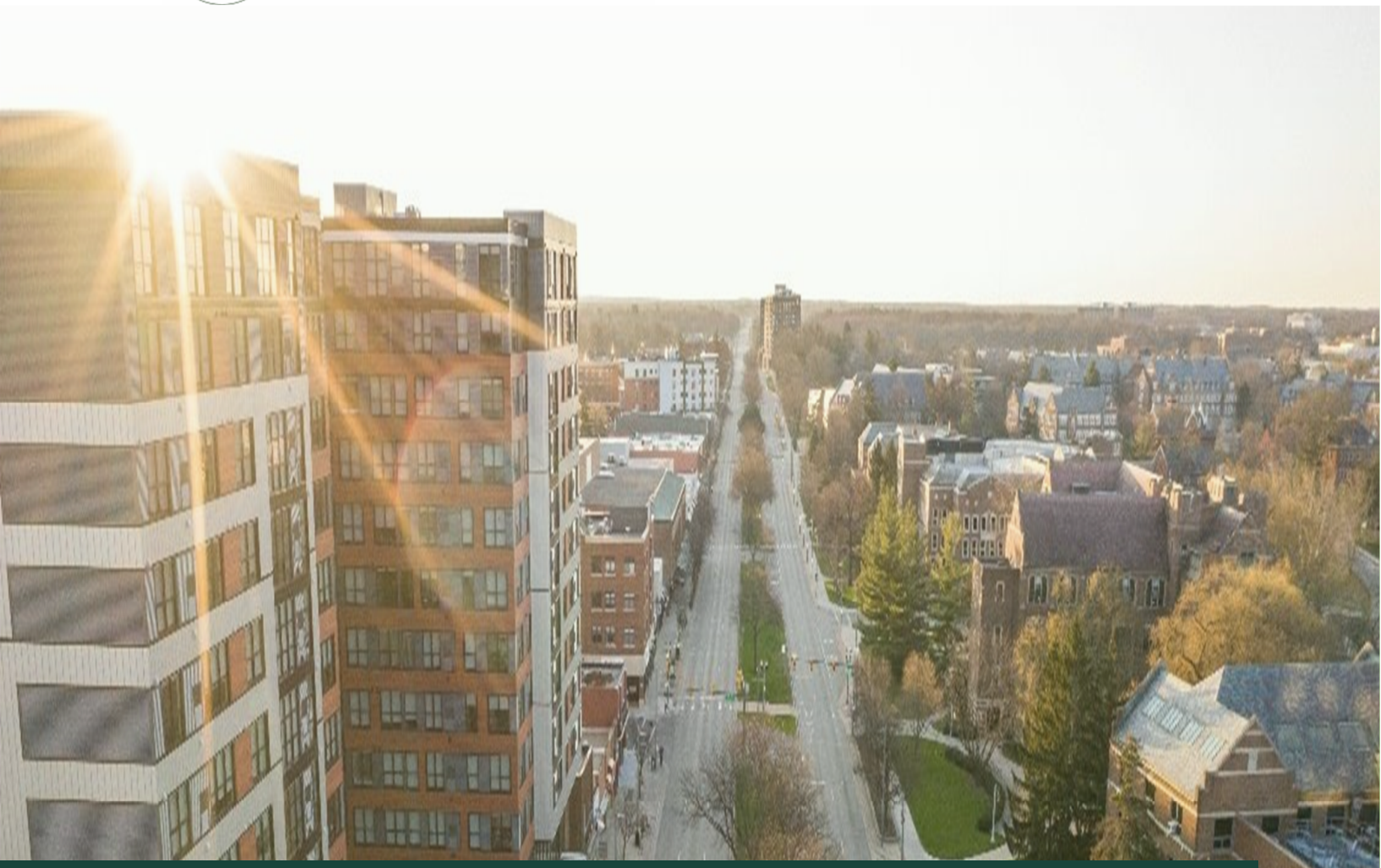
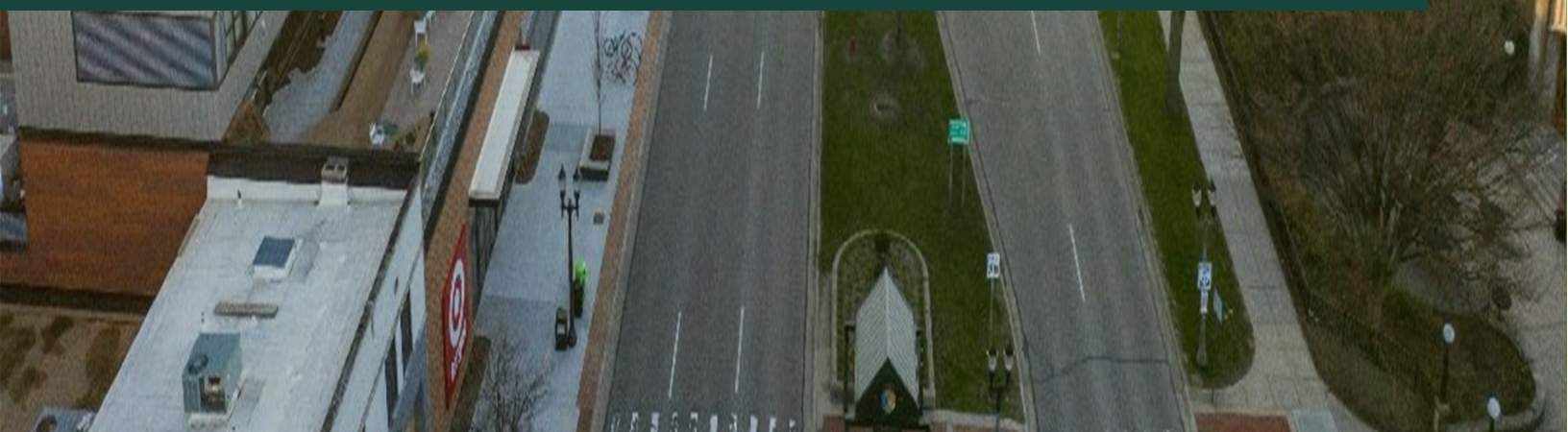
City of EAST LANSING
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City of East Lansing

Wet Weather Resiliency Plan

September 27, 2026



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Acknowledgements

The development of this Wet Weather Resiliency Plan (WWRP) was a team effort with many dedicated individuals across the City of East Lansing (City). The City team played an important role in the development of the WWRP by providing helpful insights, data, institutional knowledge, and decision-making criteria throughout the project. This collaboration, conducted via regular workshops, interviews, progress meetings, and check-in calls, was vital to the project.

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Appendix I. Open House Summary

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LIST OF ABBREVIATIONS

1D	one-dimensional
2D	two-dimensional
3DEP	Three-Dimensional Elevation Program
AACE	Association for the Advancement of Cost Engineering
ACS	American Community Survey
ADS	ADS Environmental
CA	concern area
CDC	Centers for Disease Control and Prevention
CIP	Capital Improvement Plan
City	City of East Lansing
CSO	combined sewer overflow
CSS	combined sewer system
CWSRF	Clean Water State Revolving Fund
DEI	diversity, equity, and inclusion
DEM	digital elevation model
DWF	dry weather flow
EGLE	(Michigan) Department of Environment, Great Lakes, and Energy
FY	fiscal year
GARR	Gauge-Adjusted Radar Rainfall
GCM	global climate model
GHG	greenhouse gas
GIS	geographic information system
GLISA	Great Lakes Integrated Sciences and Assessments Center
HDR	HDR Engineering, Inc.
H&H	hydraulic and hydrologic
HGL	hydraulic grade line
KLAN	Lansing Capital Region International Airport
LOS	level of service
MCDA	Multi-Criteria Decision Analysis
MDOT	Michigan Department of Transportation
mgd	million gallons per day
MS4	municipal separate storm sewer system
N/A	not applicable
NCEI	National Centers for Environmental Information
NEXRAD	Next Generation Weather Radar
NOAA	National Oceanic and Atmospheric Administration
SSP	Share Socioeconomic Pathways
SVI	Social Vulnerability Index
SWMM	Storm Water Management Model
USGS	United States Geological Survey
WaPUG	Wastewater Planning Users Group
WRD	Water Resources Division

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EXECUTIVE SUMMARY

The City of East Lansing (City) developed this Wet Weather Resiliency Plan (WWRP) to address flood risks posed by current and future rainfall events and address areas prone to flooding because of capacity limitations in the City's public drainage system. In recent years, several extreme storm events have resulted in flooding throughout many neighborhoods in the city. In August 2021, 7.22 inches of rainfall fell within the city in a span of 5 to 6 hours—an event deemed to be as rare as a 1,000-year storm. In 2024, two more severe rain events caused widespread flooding with approximately 470 incidents of overland flooding, sewage and seepage in basements, and private property flooding reported through a public survey conducted by the City. For the City, these events were reminders that rainfall patterns and intensity are changing and severe storms are happening more frequently. While no drainage infrastructure system can ever be designed and built to handle every possible extreme weather event, the frequency of flood impacts on the residents of East Lansing has been deemed intolerable to many and action is needed.

The purpose of this WWRP is to provide a future road map for reducing flood risk and creating a safer, more resilient city for its residents, businesses, and visitors. In this WWRP, a series of improvement projects and strategies are identified to mitigate both surface and basement flooding, with the goal of safeguarding the city's infrastructure and people. These improvement projects (structural) and programmatic efforts (non-structural) will increase the resiliency of public infrastructure and reduce private property flood risk, but they cannot address every extreme storm that the city may experience. The improvement projects will not address flooding caused by private property maintenance or on-site property drainage practices. Each strategy proposed is a culmination of City staff knowledge, community feedback, subject-matter expertise, and the hard work and collaboration of multiple stakeholders and project team members.

Understanding the root cause of flooding was vital to developing successful, lasting flood risk mitigation strategies. As part of the WWRP, 58 flooding concern areas (CAs) were identified across the entirety of the city using a state-of-the-art flood prediction model developed specifically for the WWRP. Of these 58 areas, 8 flooding CAs were prioritized for more detailed evaluation. A map of the areas selected for evaluation is shown in Figure ES-1. The remaining CAs not prioritized in this WWRP will be addressed in later phases as funding becomes available.

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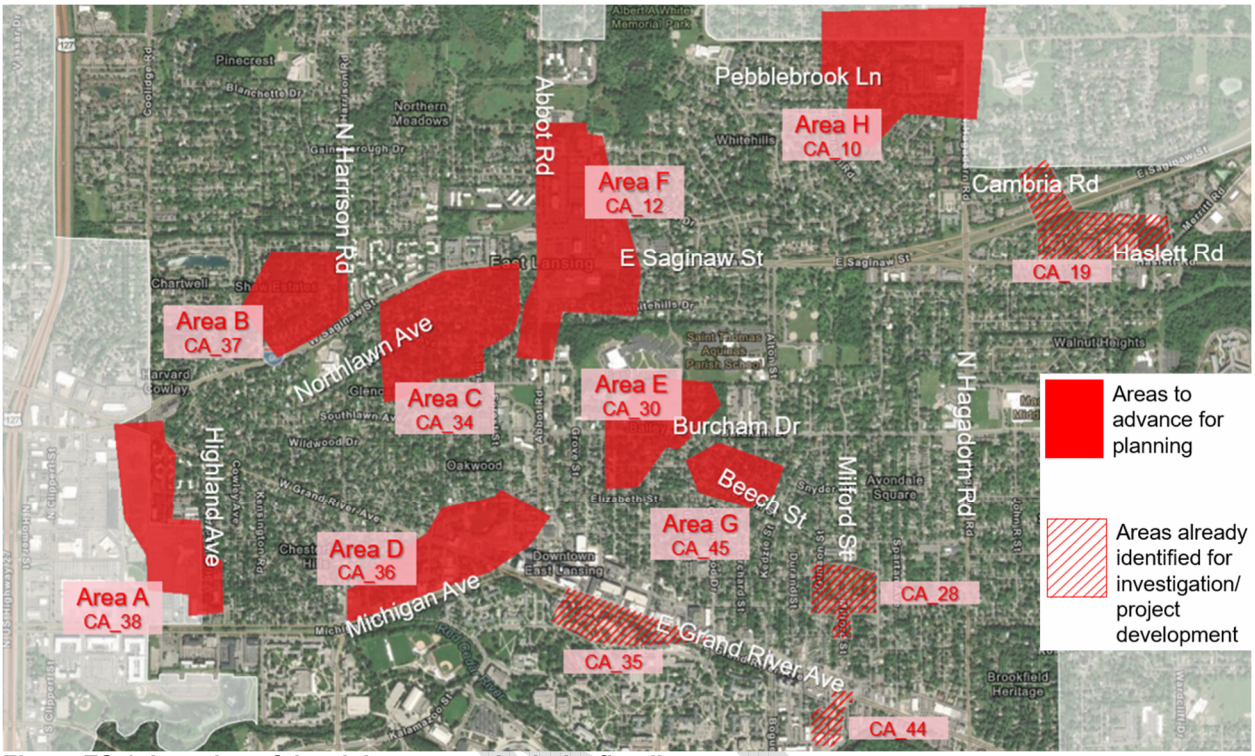


Figure ES-1. Location of the eight proposed priority flooding concern areas.

Results from the model indicate that the root cause of flooding in the eight CAs areas is due to a lack of capacity within the existing publicly owned sewers, which are not large enough to handle today's storms and impervious-surface conditions. At the time of construction, the City's design standard was for a 10-year design storm. However, climate change has now lowered the level of service (LOS), which is a common issue that older, similar communities are struggling with. Model results show that within the prioritized areas the City's existing sewers have the maximum LOS capacity for a current 5-year, 1-hour design storm or less, as shown in Table ES-1. Additionally, the results of a precipitation analysis indicate that the City's design storm (10-year, 1-hour) is outdated, based on current rainfall trends, and should be updated to incorporate impacts from climate change. Together, these findings show that the city's originally constructed drainage infrastructure is not adequate for current conditions and will be even less capable of meeting future demands.

Table ES-1. Existing maximum level of service for the top eight flooding concern areas.

Flooding CA	Existing maximum LOS (based on Huff and Angel)	Location	Sewer area
A	2-year, 1-hour	Highland Ave. and Westview Ave.	CSS
B	5-year, 1-hour	N Harrison Rd. and E Saginaw St.	CSS
C	2-year, 1-hour	Northlawn Ave.	CSS
D	<1-year, 1-hour	Michigan Ave. and W Grand River Ave.	CSS
E	1-year, 1-hour	Burcham Dr.	CSS
F	<1-year, 1-hour	Abbot Rd. and E Saginaw St.	MS4
G	<1-year, 1-hour	Beech St.	CSS
H	<1-year, 1-hour	Pebblebrook Ln.	MS4

CA = concern area; CSS = combined sewer system; LOS = level of service; MS4 = municipal separate storm sewer system.

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To increase system capacity, project alternatives were developed based on updated LOS targets that account for the effects of climate change. The Current LOS goal is defined as a 10-year, 1-hour design storm of 2.00 inches. The Enhanced LOS goal is defined as a 50-year, 1-hour design storm of 2.54 inches, which is equivalent to future 16-year, 1-hour design storm in the year 2100. As shown in Figure ES-2 below, these LOS goals are an increase compared to the previous LOS goal.

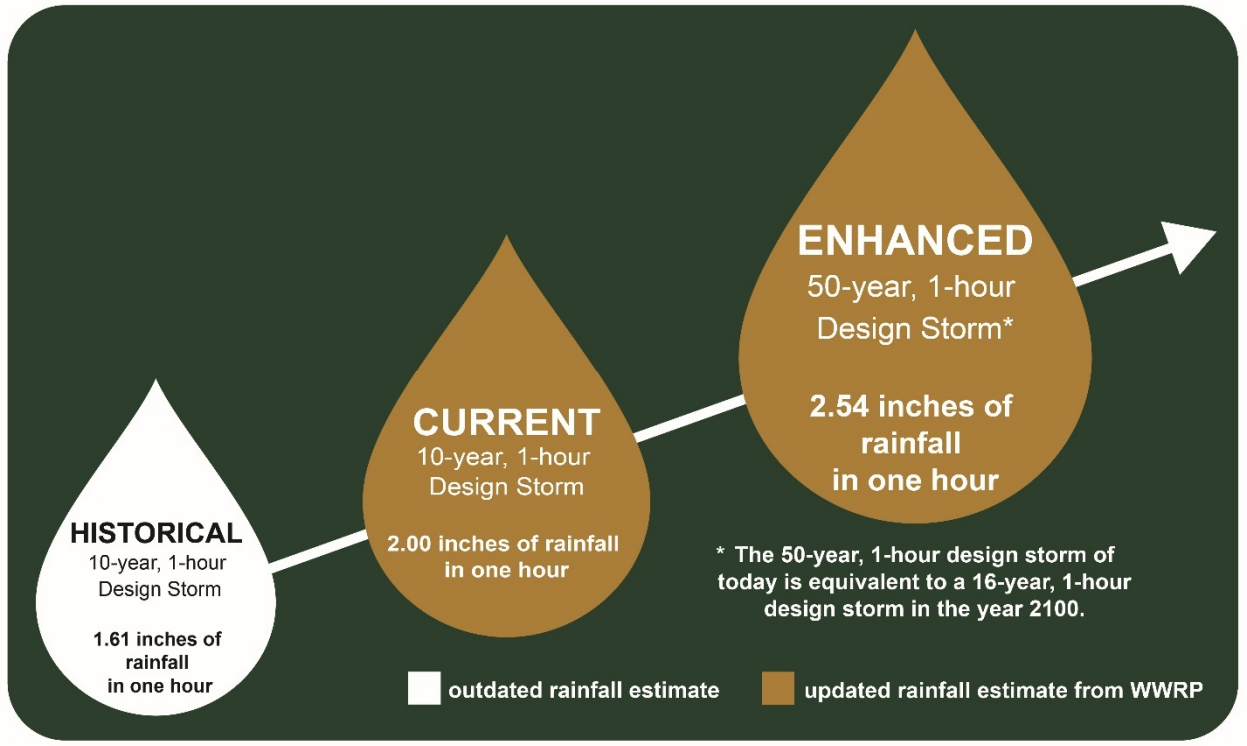


Figure ES-2. LOS goals and corresponding design storms.

Each alternative was comprised of multiple stormwater infrastructure improvement projects and flood risk mitigation strategies, listed below, to meet the current or enhanced LOS goals:

- Constructing new and upsized sanitary and storm sewers
- Separating combined sewers into separate sanitary and storm sewers
- Modifying or adding new structures that direct flow
- Identifying locations for stormwater detention storage and green infrastructure

A total of six alternatives were developed to reduce flooding risk in the eight flooding CAs that were deemed to be the most concerning flooding areas, based on the frequency and location of basement and roadway flooding, the location of critical facilities, and several other criteria. These alternatives comprise a group of smaller projects grouped into a larger alternative and are described below in Table ES-2.

Table ES-2. Summary of developed alternatives for evaluation.

Alternative	Description
Alternative 1: West Central Neighborhoods Combined Sewer Relief	This project would separate stormwater from the sewer mains and offload the stormwater to Ranney Park. This will require the construction of a storm main to convey the separated stormwater. Upsizing existing combined sewer lines along Glenmoor Road and Oakridge Avenue and adding new combined sewers will help to relieve remaining bottlenecks.
Alternative 2: Valley Court Corridor Combined Sewer Relief	This project would separate stormwater from the sewer mains and offload the stormwater to the Red Cedar River. This will require the construction of a storm main to convey the separated stormwater. Upsizing the existing combined sewer line along Valley Court, Hillcrest Avenue, Elm Place, and Elm Street and adding new combined sewers will help to relieve remaining bottlenecks.
Alternative 3: Downtown Neighborhoods Combined Sewer Relief (Harrison Road route)	This project would separate stormwater from the sewer mains and offload the stormwater to the Red Cedar River. It includes the upsizing of existing combined sewer lines to relieve remaining bottlenecks, and the construction of new combined mains. This project also includes the construction of underground stormwater storage facilities at Gordon Guyer Park and Glencairn Park.
Alternative 4: Downtown Neighborhoods Combined Sewer Relief (Sunset Avenue route)	This project would achieve all the same flood reduction benefits as Alternative 3. However, the proposed storm main is approximately 2x the length to route around a high-elevation area of the city.
Alternative 5: Abbot and Saginaw Storm Drainage Improvement	This project includes the upsizing of existing storm pipes to relieve bottlenecks in the area. It also includes stormwater storage opportunities at Harrison Meadows Park and in an open lot at the Fire Department.
Alternative 6: Whitehills Drainage Improvement	This project includes the upsizing of existing storm pipes to relieve bottlenecks in the area. It also includes stormwater storage opportunities at Albert A. White Memorial Park through the expansion of an existing fishing pond.

Alternative 4 was ultimately not selected for further evaluation during discussions with the City as this alternative provided the same benefit as Alternative 3 but with more technical implementation challenges such as increased new storm main lengths, more community disruptions from construction activities, and higher associated cost.

Each alternative was then right-sized for the Current LOS goal (referred to as “a” projects) and the Enhanced LOS goal (referred to as “b” projects). Each alternative was then simulated in the model for the two LOS design storm events and flood risk reduction benefits were quantified for reduced property and road flooding as shown in Table ES-3.

Table ES-3. Flood risk reduction results for the alternatives.

Alternative	Properties reduced for 10-year	Properties reduced for 16-year	Length of road reduced 10-year (ft)	Length of road reduced 16-year (ft)
1a	210	54	483	1,131
1b	210	55	483	1,242
2a	123	100	1,293	2,047
2b	123	148	1,293	2,302
3a	620	193	1,688	5,311
3b	620	796	1,688	6,853
5a	3	5	947	870
5b	3	5	947	1,062
6a	6	3	315	568
6b	6	6	315	1,275

It was important to the City that the WWRP be a community-informed plan, with several public outreach components to allow for input from several community members and stakeholders.

Through input by the City and the community, several prioritization criteria were developed and weights were applied, indicating the relative importance of each criterion. The prioritization criteria and their ranking are summarized below in Table ES-4.

Table ES-4. Project prioritization criteria for a community driven approach.

Criterion	Description	Weight	Rank
Flood risk reduction	The project's ability to: • Reduce property flood risk for basement backups in CSS • Reduce property flood risk from surface flooding in CSS and MS4 • Reduce roadway flood risk of 6 inches or greater	16.5%	1
Water quality	The project's alignment with the City's CSO elimination goals and/or ability to design with water quality treatment features consistent with the City's Stormwater Management Plan	15.5%	2
High impact	The total number of people served by the project or the visibility of the project to a total number people within a certain proximity	14.9%	3
City resiliency alignment	The project's alignment with identified priorities from the City's climate resiliency community meeting including green stormwater infrastructure that would provide community co-benefits (e.g., community improvements, green space, community gardens, shade and urban heat island mitigation, and/or air quality improvements)	13.0%	4
Impervious surface reduction	The project's ability to reduce unnecessary impervious surfaces	11.8%	5
Social and economic impacts	The project's ability to provide social or economic benefits to vulnerable populations because of the design, location, or nature of the project	11.0%	5
Level of maintenance	Type and/or extent of long-term maintenance required	9.4%	7
Ease of constructability	The level of ease to implement and build the project	7.9%	8

CSO = combined sewer overflow; CSS = combined sewer system; MS4 = municipal separate storm sewer system.

The selected alternatives, described in Table ES-2 and shown on Figure ES-2, were then scored using a Multi-Criteria Decision Analysis (MCDA) framework to understand and quantify how each alternative performed against the community-driven project prioritization criteria. Results from the MCDA prioritization analysis are shown in Table ES-5, with Alternative 3b in the combined sewer system (CSS) scoring the highest and Alternatives 6a and 5a in the municipal separate storm sewer system (MS4) area scoring the lowest. Figure ES-3 below shows the predicted benefits for all the selected alternatives

Table ES-5. Project prioritization ranking and overall score.

Alternative	Prioritization score	Prioritization ranking
3b + Storage: Downtown Neighborhoods CSS Relief (Harrison Rd. Route)	7.15	1
2b + Storage: Valley Court Corridor CSS Relief	6.16	2
1b: West Central Neighborhoods CSS Relief	5.55	3
6a: Whitehills Drainage Improvement	3.65	4
5a: Abbot and Saginaw Storm Drainage Improvement	3.64	5

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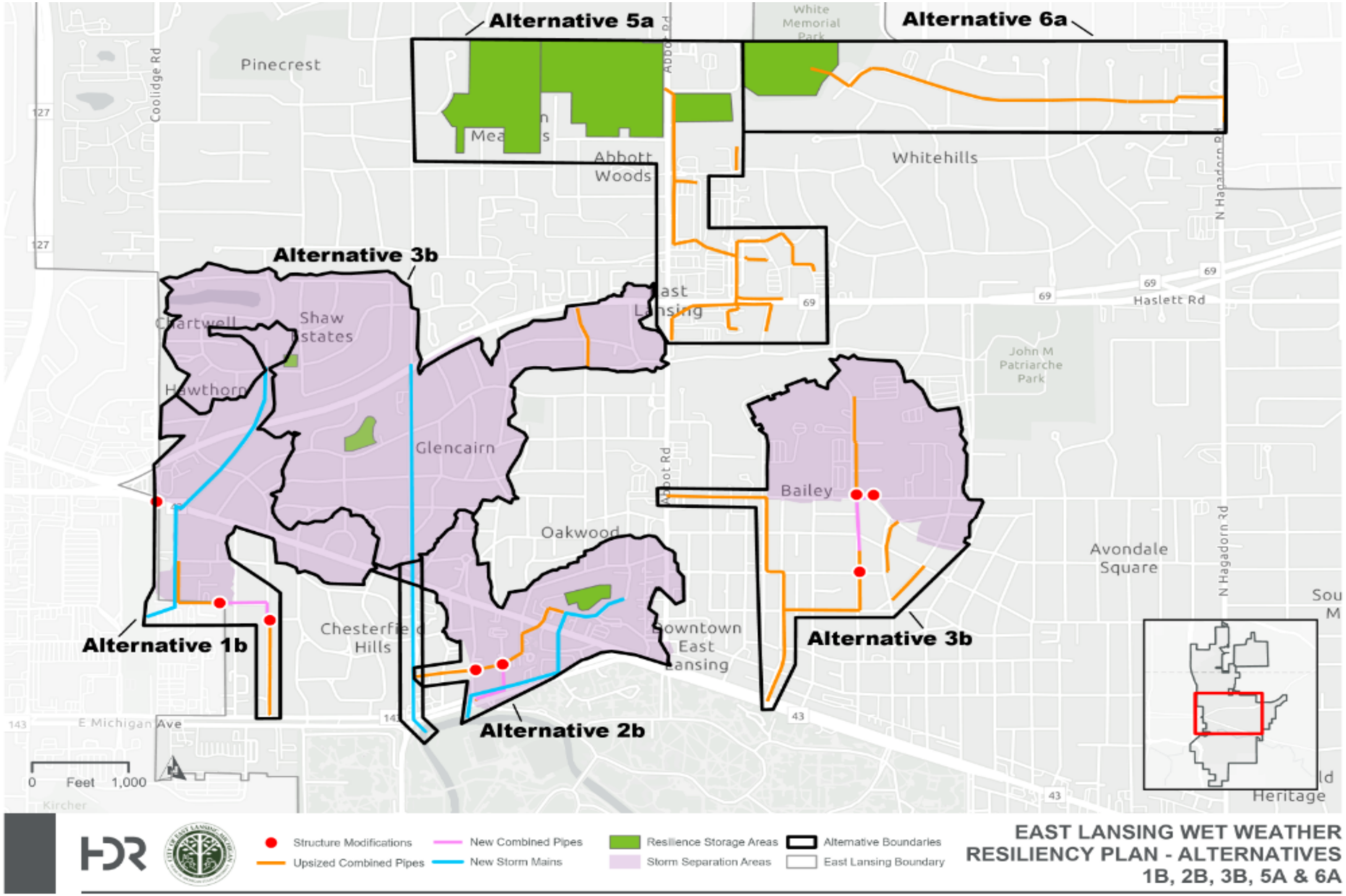


Figure ES-2. Selected alternatives for implementation.

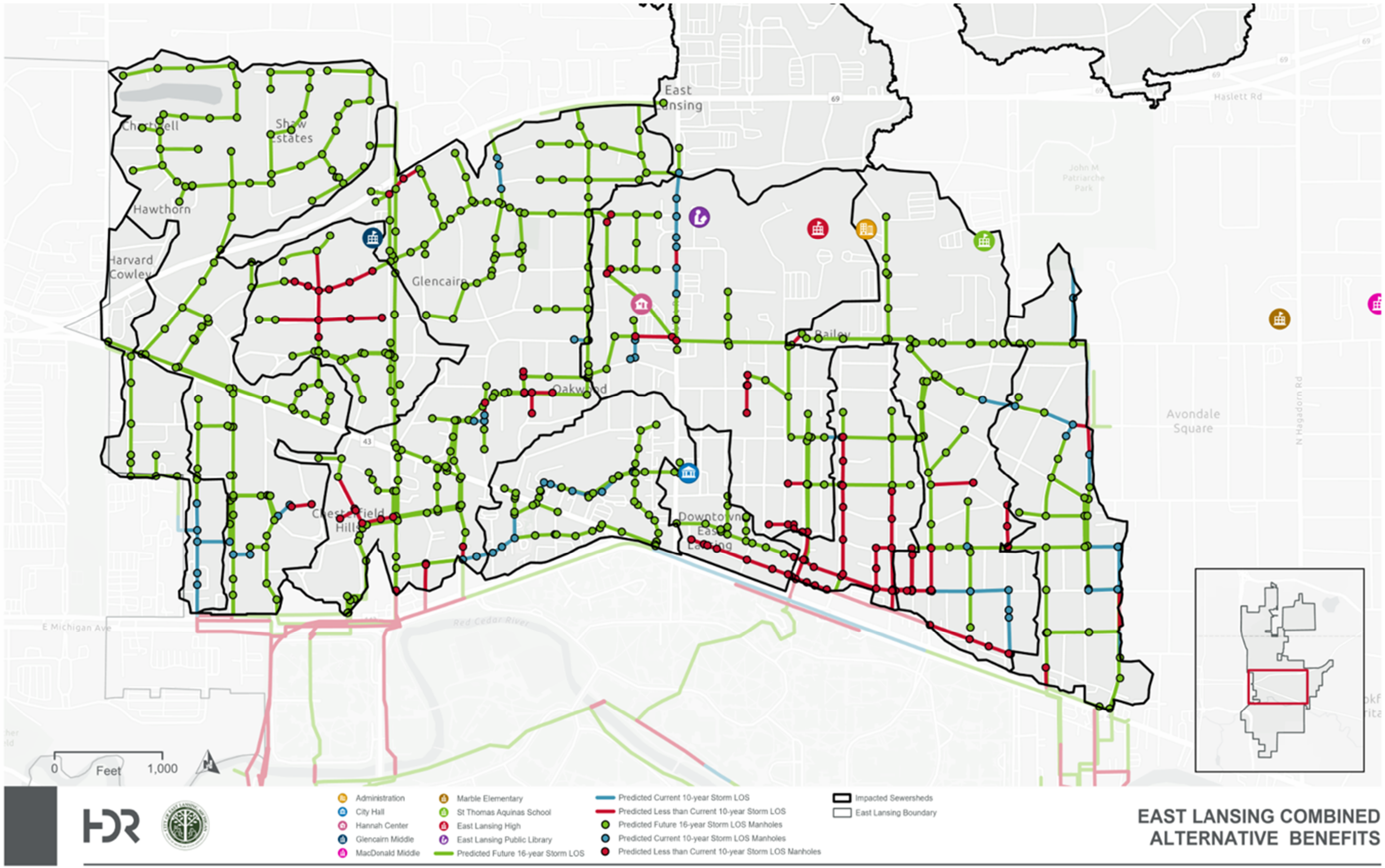


Figure ES-3 Predicted LOS benefits from all selected alternatives.

In addition to the prioritization score, planning-level (Association for the Advancement of Cost Engineering [AACE] Class 5) opinion of probable construction cost estimates for the alternatives were developed, which ultimately impacted the planned implementation and grouping of prioritized projects. Class 5 cost estimates are conceptual, rough order of magnitude, and are typically performed during the project planning phase and early in the design phase. The order of magnitude of the developed prices is based on cost data for similar types of projects that have been constructed in the same geographical area. Table ES-6 below provides an overview of the planning-level cost estimates for each selected alternative. Note that these are 2026 costs and have not been escalated to future years when the projects may be constructed.

Using the MCDA prioritization scores and the cost estimations, each selected alternative was divided into specific project bundles that can be implemented in a phased approach as part of the City's Capital Improvement Plan (CIP). The proposed implementation plan for the structural recommendations is presented below in Table ES-7 and Figure ES-4. It is important to note that for stormwater only projects to be eligible for SRF funding within Michigan, a dedicated stormwater funding repayment mechanism is required. Currently, the City does not have a dedicated funding source for stormwater and is unable to harness SRF for implementation of stormwater only projects. Therefore, due to the current lack of a dedicated funding mechanism for stormwater projects at the City, consideration for projects that rank lower in priority that have access to readily available funding may be needed. However, it is important to note that phase 1 of Alternative 2b and phase 3 of Alternative 1b is SRF funded through other projects.

In addition to the recommended structural strategies in the proposed implementation plan, several other nonstructural strategies (programs, policies, and studies) under consideration by the City would complement the structural strategies recommended in this WWRP. These strategies, described in Table ES-8, target primary needs such as funding and impervious-surface reduction, both of which were topics of discussion during the stakeholder focus groups. Each strategy also has additional benefits that are complementary to the recommended structural strategies.

The City of East Lansing's WWRP includes planning and conceptual project information that is subject to change. As the projects identified in the WWRP progress into detailed planning, design, and construction phases, project information may be updated to more accurately reflect updated climate data, field investigations, changed site conditions, and/or additional information.

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Table ES-6. Class 5 cost estimations for the selected alternatives.

Alternative 1b	
CSO upgrades and sewer upsizing	$2.95M
Storm separation	$21.60M
New storm trunk	$4.86M
Roadway, mobilization, other	$13.30M
Total Cost	$43M
Alternative 2b + storage	
CSO upgrades and sewer upsizing	$2.59M
Storm separation	$25.10M
New storm trunk	$4.17M
Roadway, mobilization, other	$16.11M
Underground Storage	$7.15M
Total Cost	$56M
Alternative 3b + storage	
CSO upgrades and sewer upsizing	$14.84M
Storm separation	$78.10M
New storm trunk	$13.30M
Roadway, mobilization, other	$46.10M
Underground storage	$6.70M
Total Cost	$160M
Alternative 5a + storage	
CSO upgrades and sewer upsizing	$23.70M
Aboveground storage	$1.51M
Roadway, mobilization, other	$12.80M
Total Cost	$39M
Alternative 6a + storage	
CSO upgrades and sewer upsizing	$5.50M
Aboveground storage	$0.30M
Roadway, mobilization, other	$4.40M
Total Cost	$11M

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Table ES-7. Proposed implementation plan for prioritized projects.

Priority	Alternative	Capital project	Proposed phase	Phasing justification	Cost
1	3b + storage	Construction of new storm trunkline sewer along Harrison Rd, including the outfall with treatment structure, combined sewer separation in areas north of Saginaw, and underground storage at Gordon Guyer.	1	Conducting storm separation first will reduce the likelihood of CSOs in subsequent phases. Storm trunkline is a necessary first step. Separate north of Saginaw as these areas will improve areas associated with Alternative 1b. Separating takes advantage of storage opportunity at Gordon Guyer Park to attenuate peak storm flow to river and improve resiliency.	$54.9M
		Combined sewer separation between Saginaw Hwy to Grand River, west of Harrison Rd, and underground storage at Glencairn Park.	2	Flows west of Harrison Rd can offload stormwater in the downstream combined system, east of Harrison Rd (existing flooding concern areas on Northlawn Ave and Sunset Ln). Also relieves water that flows toward flooding CAs on Charles St. Separating take advantage of storage opportunity at Glencairn Park to slow storm water flow to river and improve resiliency.	$25.8M
		Combined sewer separation east of Harrison Rd.	3	Flow monitoring and additional modeling after Phases 1 and 2 may reduce the amount of separation needed for this area depending on outcomes. This area should come last to understand the effectiveness of Phase 1 and 2.	$26.9M
		Upsizing combined sewer pipes and constructing new pipes along Charles St, including the structure modifications.	4	Cannot upsize without first completing combined sewer separation because of the potential for increased CSOs. Flow monitoring and additional modeling after Phase 2 may also reduce the required diameter of these pipes.	$21.3M
		Remaining storm separation required to address flooding CAs E and G.	5	Implementation of this remaining area is dependent upon upsizing of Charles Street and associated new pipes/modifications. Must do Phase 4 first for this project to be effective.	$30.3M
2	2b + storage	Construction of new storm trunkline sewer, including outfall with treatment structure, underground storage at Valley Court Park, and combined sewer separation north of Grand River Ave., around Valley Court Park.*	1	Conducting storm separation first would reduce the likelihood of CSO in subsequent phases. Storm trunkline sewer is necessary first step. Separating take advantage of storage opportunity at Valley Court park to attenuate peak storm flow to the river and increase resiliency. This storage is necessary prior to separating flow south of Saginaw in Phase 2. Currently part of a FY2028 plan.	$30.8M
		Combined sewer separation south of Grand River Ave. to Michigan Ave.	2	A natural ridgeline/separation within this watershed runs along Grand River Ave. Full separation south of Grand River Ave. should come second to not increasing peak flows to the river.	$15.6M
		Combined sewer separation north of Grand River Ave., in area of Ardson, Woodland, Marshall and Clifton streets.	3	This area should come last as there is potential for separated storm flow toward the Harrison trunkline in Alternative 3. As this alternative is in conjunction with Alternative 3, flow monitoring and modeling may reduce the area of separation needed depending on effectiveness of prior projects.	$4.9M
		New and upsized combined sewers, restrictor modification and new regulator.	4	Flow monitoring and modeling to confirm the effectiveness of prior phases may eliminate the need for these projects to relieve remaining combined sewer capacity, therefore, these projects should come last within this alternative.	$3.9M
3	1b	Construction of new storm trunkline sewer from the outfall at Ranney Park to Saginaw Hwy. Combined sewer separation of the area tributary to Phase 1 storm trunkline sewer.	1	Need to construct the storm trunkline and the separation of stormwater working from downstream to upstream. This ensures that the tributary areas realize incremental benefit as the trunkline is being constructed.	$11.7M
		Extension of the new storm trunkline sewer north of Saginaw Hwy. to Chartwell. Combined sewer separation of the area tributary to Phase 2 storm trunkline sewer.	2	Continue the construction of additional storm trunkline and connect into the Phase 1 system. Continue additional storm separation further upstream north of Saginaw Hwy.	$14.7M
		Construction of new storm trunkline sewer that runs along Grand River Ave. Combined sewer separation of the area tributary to the Phase 3 storm trunkline sewer. *	3	Continue third installment of additional storm trunkline and connect into Phases 1 and 2 system. Complete combined sewer separation along Grand River Ave. corridor.	$12.2M
		Upsized and new combined sewers with sewer bulkheads and the restrictor modification in the Highland and Cowley area.	4	Flow monitoring and additional modeling to confirm the effectiveness of prior phases may eliminate the need for these projects. Therefore, these projects should come last within this alternative.	$4.3M
4	6a	Expansion of the fishing pond at the Albert A. White Memorial Park for additional aboveground stormwater storage.	1	Construction of the storage facility is required prior to increasing the storm pipe capacity to ensure that downstream areas are not negatively impacted by increased flow from upsized pipes in Phase 2.	$0.5M
		Upsizing the storm sewers upstream from the aboveground storage along Pebblebrook Lane to Hagadorn Road.	2	Upsized pipes should come after storage to ensure that this alternative is not shifting flood risk to downstream areas.	$9.7M
5	5a	Construction of the aboveground storage at Harrison Meadows Park and at the Fire Department open lot.	1	Construction of the storage facility is required prior to upsizing the storm pipe capacity to ensure that downstream areas are not negatively impacted by increased flow from upsized pipes in Phase 2.	$13.5M
		Upsizing the storm pipes from the fire station to the commercial area to the south along Abbot Rd.	2	Upsized pipes should come after storage to ensure that this alternative is not shifting flood risk to downstream areas.	$24.4M

* SRF funded project

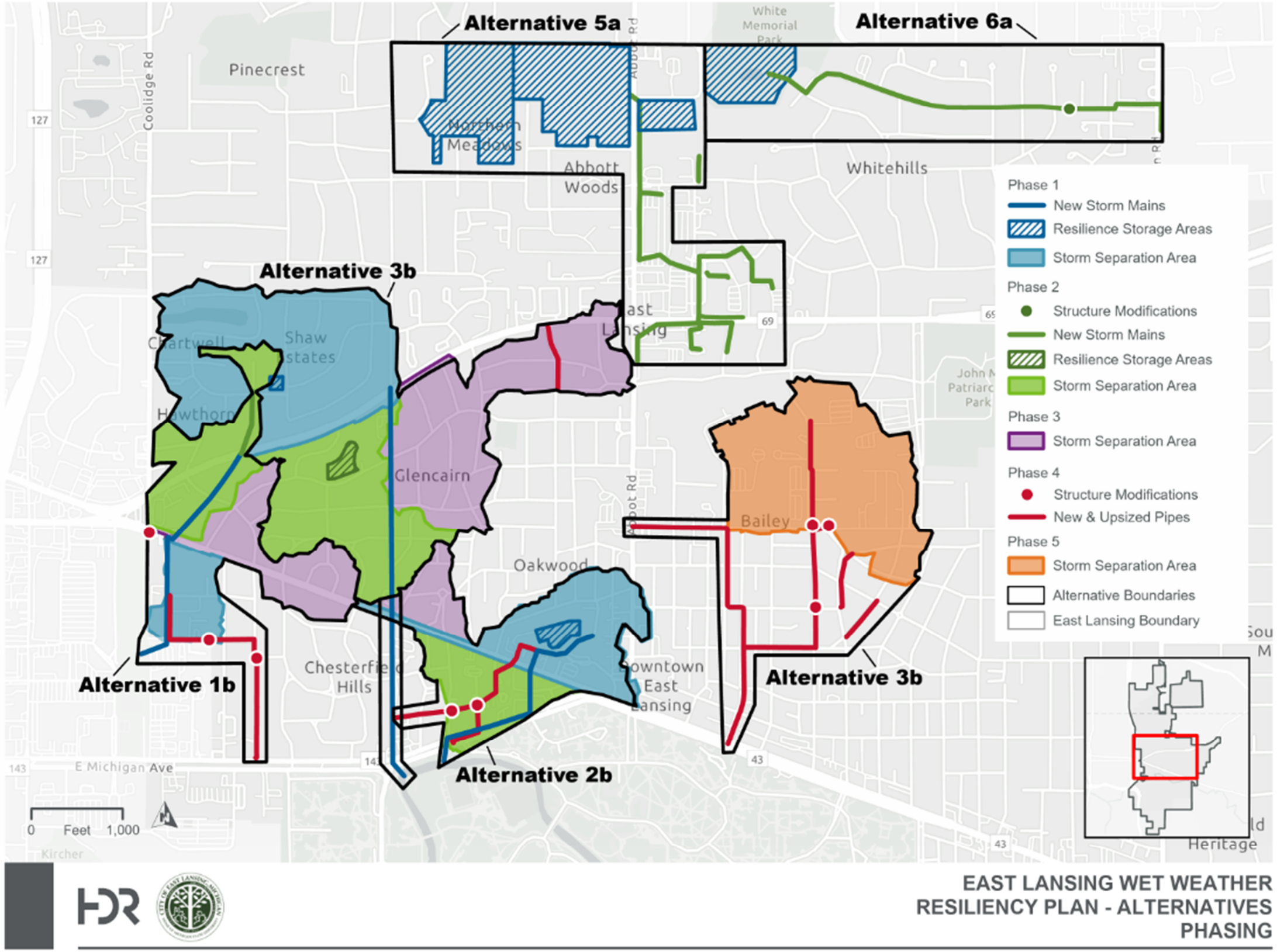


Figure ES-4. Overview of the phased implementation plan for the recommended structural strategies.

Table ES-8. Nonstructural strategies under consideration.

Nonstructural strategy	Description	Primary need addressed	Additional need addressed
Stormwater utility study	A stormwater utility study would explore creating a stormwater utility, which would support the implementation of both structural and nonstructural strategies. This directly addresses funding and has proved to be successful in other areas impacted by surface flooding. Inclusion of a stormwater credit program for property owner fee reductions should be considered to encourage stormwater management best practices to reduce runoff and/or improve water quality.	Funding	Asset management
Pay-in-lieu program study	A pay-in-lieu program allows developers to satisfy stormwater requirements through a fee payment when on-site compliance is impractical, while providing the City with a dedicated funding source for larger, watershed-scale stormwater improvements that can deliver equivalent or greater benefits.	Funding	New development and redevelopment
Updated post-construction standards	Updating post-construction standards (e.g., design storm, small site development, minimum requirements/credits) for resiliency.	Future climate	New development and redevelopment
Distributed green infrastructure program	This strategy would explore implementing a program specifically aimed at reducing the amount of impervious surfaces. More green infrastructure would improve drainage across the city.	Impervious-surface reduction	Widespread stormwater management, co-benefits
Consider expanded partnerships	Partnering with other City departments and nonprofit groups in the area would provide benefits across several areas, such as wetlands, trails, parks, etc.	Co-benefits (e.g., wetlands, trails and open space)	Funding, operations and maintenance support
Voluntary private property drainage audits	Providing additional staff and technical resources to residents and business owners on private property flood risk mitigation strategies.	Private property protection	Resiliency
Voluntary buy-out program	A voluntary program for City acquisition of flood-prone properties and structures that are not easily protected from flooding because of their specific location and surrounding topography. These areas would be turned into natural flood storage areas for additional flood risk reduction benefit.	Flood impact reduction	Additional stormwater storage opportunities
Basement backup protection program	Continue the City's existing Property Owner Assistance Program for Basement Backup Protection that provides financial reimbursement for installation of backflow preventers.	Private property protection	Resiliency
Enhanced GIS mapping	Develop enhanced GIS mapping of private drainage system infrastructure built by developers to document new systems and promote their active asset management and coordination with adjacent systems.	Private property protection	Infrastructure coordination
Stormwater management on City-controlled sites	Prioritize the proactive implementation of active stormwater management measures on City-controlled sites when other improvements are planned and implemented.	Runoff reduction and water quality	Additional green infrastructure
Impervious construction design standards	Review and modify current design and development standards for streets, bike lanes, sidewalks, and pathways that create additional impervious surfaces to incorporate current best practices for reducing hard-surface construction and incorporating green infrastructure.	Impervious-surface reduction	Additional green infrastructure

1.INTRODUCTION

The City of East Lansing (City) developed this Wet Weather Resiliency Plan (WWRP) to address flood risks posed by current and future rainfall events and address areas prone to flooding, based on comprehensive evaluations of East Lansing's existing drainage infrastructure. The following section outlines the purpose and need of the WWRP, the overarching goals for the project, and the overall planning process.

1.1. Purpose and Need

In recent years, several extreme storm events have resulted in flooding throughout many neighborhoods in the city. In August 2021, 7.22 inches of rainfall fell within the city in a span of 5 to 6 hours—an event deemed to be as rare as a 1,000-year storm. In 2024, two more severe rain events caused widespread flooding with approximately 470 incidents of overland flooding, sewage and seepage in basements, and private property flooding reported. See Figure 1-1. and Figure 1-2. for examples of the surface flooding experienced by the community. These events were only a few of the several short duration, extreme events the city has experienced recently. For the City, these events were reminders that rainfall patterns and intensity are changing and severe storms are happening more frequently. The drainage infrastructure intended to capture and convey stormwater runoff was built many decades ago and was based on design standards that are now outdated, given the changing nature of precipitation events. The continuous development of the city, involving the addition of new impervious area, over a prolonged period increases the rate and volume of stormwater runoff, compounding the impact of more intense rainfall.

Climate assessments performed specifically for the East Lansing region indicate that extreme rain events will likely become more frequent and intense in the coming decades. The increased frequency in extreme rain events will impact multiple facets of the community, including the City's built infrastructure and the properties, livelihoods, and mobility of local communities, especially vulnerable populations. As such, it is imperative that the City works to reduce the impacts of climate change and increase our community's resiliency to extreme wet weather and flooding events.

The purpose of this WWRP is to provide a future road map for reducing flood risk and creating a safer, more resilient city for its residents, businesses, and visitors. In this WWRP, a series of improvement projects and strategies are identified to mitigate surface and basement flooding, with the goal of safeguarding the City's infrastructure and people. These improvement projects will increase the resiliency of public infrastructure, but they cannot address every extreme storm that the city may experience. The improvement projects will not address flooding caused by private property maintenance or on-site property drainage practices. Each strategy proposed is a culmination of City staff knowledge, community feedback, subject-matter expertise, and the hard work and collaboration of multiple stakeholders and project team members.

The proposed projects included in the selected alternatives address flooding from capacity limitations associated with drainage infrastructure within the public rights-of-way consistent with the level-of-service (LOS) goals. The WWRP does not address flooding originating from individual properties because of deficient on-site drainage systems.

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Figure 1-1. Surface flooding at Applegate Lane following a high-intensity rainfall event in July 2024.



Figure 1-2. Flooding in a residential backyard at Foxcroft Road following a high-intensity rainfall event in July 2024.

1.2. Project Goals

Urban flooding is a significant concern for the residents of East Lansing. Therefore, the need for action by the City is urgent. This WWRP, as part of the High Water Infrastructure Grant Program, was envisioned by the City to be a foundational step toward helping the community become more resilient to current and future climate conditions. To develop a credible and actionable WWRP, the four key goals outlined in Figure 1-3 were identified to guide the project.

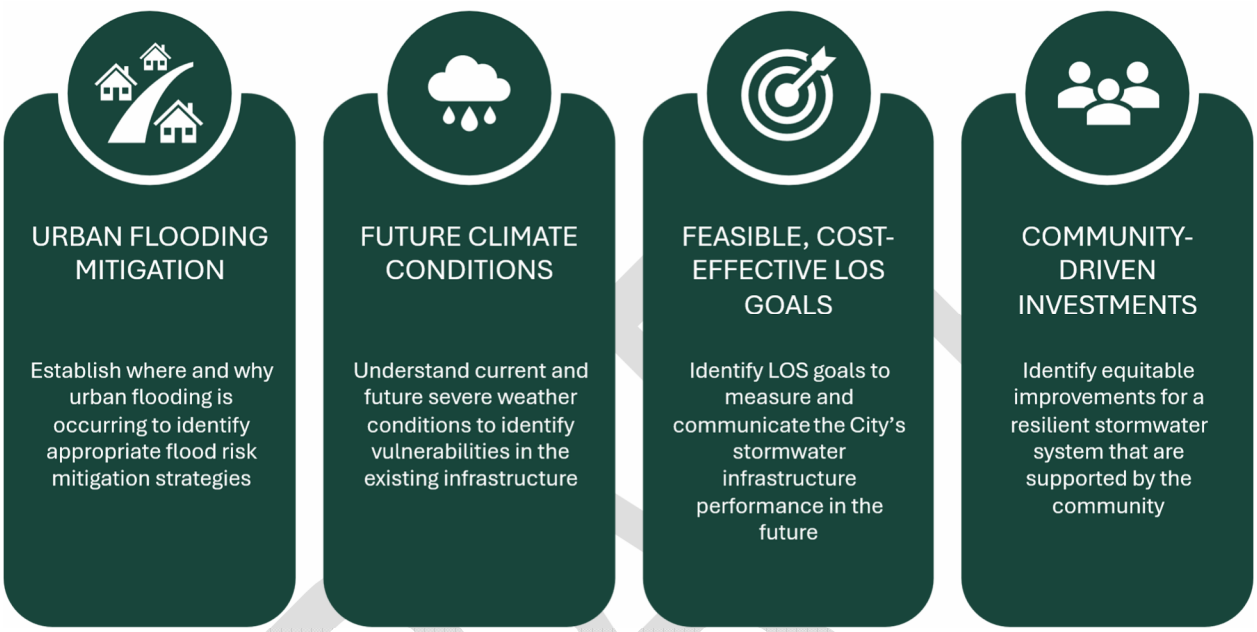


Figure 1-3. Four key goals for the Wet Weather Resiliency Plan.

The flooding in the city occurs during weather events when rainfall exceeds the available capacity in the storm sewers. When capacity is exceeded, the hydraulic grade line, or the elevation that water rises to within the vertical manhole pipes, increases. As shown below in Figure 1-4, when wet weather conditions raise the hydraulic grade line above manholes, surface flooding occurs.

Similar to public drainage systems, private drainage systems also have capacity limits and need to be updated. Though the improvement projects recommended in this WWRP do not directly address private property maintenance to reduce flooding, there are several recommendations for property owners to mitigate flood risk onsite, including upgrading sump pumps with an exceeded hydraulic capacity.

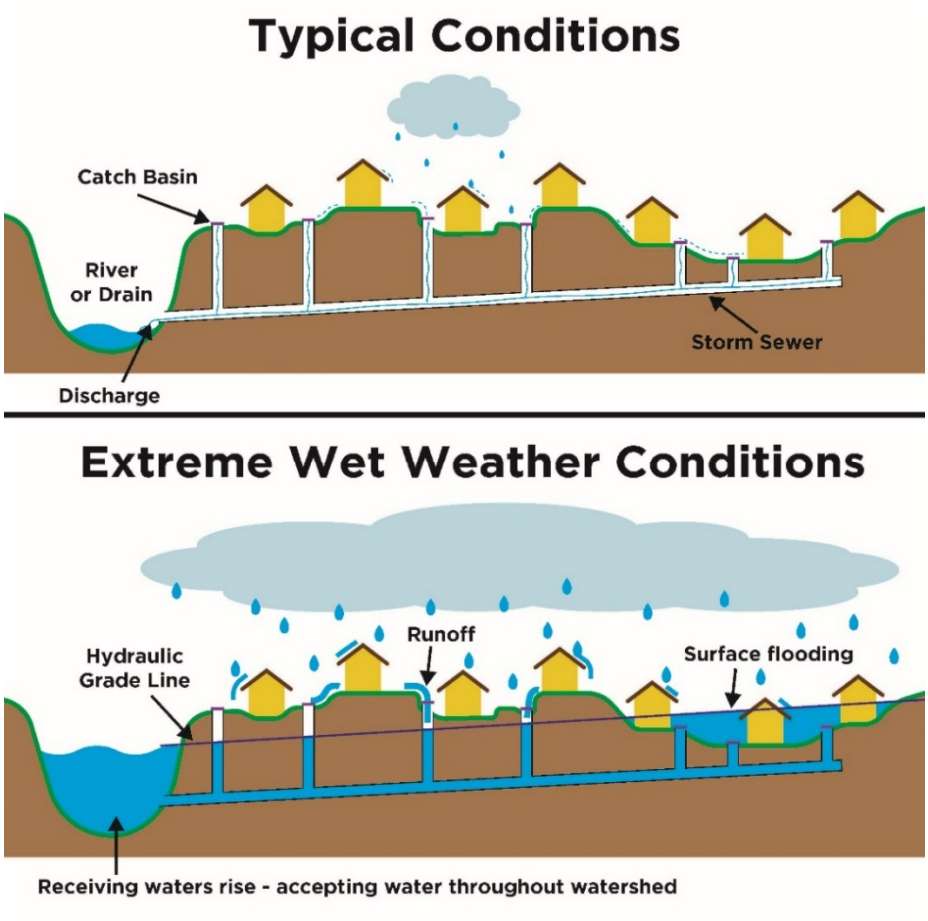


Figure 1-4. Schematic showing the movement of water through the storm sewers during typical and extreme wet weather conditions.

1.3. Key Stakeholders and Public Engagement

Following the June and July 2024 storms, a post-storm analysis was conducted to understand the magnitude of the storm and the impacts to the drainage system, and to incorporate the findings into the WWRP. On September 10, 2024, HDR Engineering, Inc. (HDR) presented the findings from the post-storm analysis to the East Lansing City Council. The post-storm analysis presented at this City Council meeting concluded that the current public drainage system could not be realistically designed to handle the magnitude of the storm events experienced in 2024. Some of the takeaways from this analysis included the following:

- It is not feasible or practical to size drainage infrastructure to convey every rain event.
- Flood resiliency needs to be a collaborative effort between the public and privately owned infrastructure.
- There is a clear need for private property actions such as backflow prevention and education on proper drainage practices.

The City hosted a listening session following storms in August 2024. The listening sessions provided the community with opportunities to share flooding concerns and complete a survey to further collect data to support the WWRP.

Because of the anticipated need for public and private collaboration for the successful implementation of the WWRP, the City built into the project a robust public engagement effort. In response, HDR developed a public engagement plan consisting of several workshops and focus group meetings throughout the development of the WWRP. The workshops with key stakeholders and consistent engagement with the public were critical to developing equitable, lasting flood mitigation strategies that were informed and driven by community needs.

A set of stakeholder focus group meetings were facilitated to share data collected and discuss the recent extreme storm events. At these focus group meetings, the City and HDR described the intended outcomes of the development process, including the shared responsibilities between the City's Public Works Department, County Drain Commissioners, and private property owners to meet existing and future level-of-service (LOS) goals. Stakeholders had the opportunity to provide feedback around project prioritization, messaging, and data needed to convey complex topics. The community stakeholders with representatives at these focus group meetings included the following:

- City of East Lansing staff
- Planning Commission
- Senior Commission
- Transportation Commission
- Michigan State University
- Commission on the Environment
- Watershed protection organizations
- Neighborhood and community associations
- Real estate companies
- Apartment managers
- Michigan Department of Environment, Great Lakes, and Energy (EGLE)

The first set of focus group meetings was held in November 2025. The key goal of these meetings was to describe LOS goals with the consideration of financial feasibility and other community priorities. Feedback was collected from the stakeholder representatives regarding project prioritization criteria, which were used in the development of the WWRP. Additional interest was shown for the consideration of detention and stormwater parks, balancing pervious and impervious areas, and education around private property flood prevention measures. Partnerships, education, and transparent communication with the community were key priorities for the stakeholders. Figure 1-5 shows an audience at one of the focus group meetings.

What is meant by "level of service"?

Level of service (LOS) refers to the performance target for new and upgraded public drainage systems. The LOS is commonly measured by the "design storm" conveyed, which considers the frequency (probability of occurrence each year) and the magnitude (inches of rain) of a storm event. For example, the LOS of a drainage system may be defined as a 10-year storm, which is a storm that has a 10 percent chance of occurring annually at a magnitude of 2.00 inches or more in 1 hour. This means that a system designed for a 10-year storm would be expected to experience problems during a 15-year event or greater.

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A second set of focus group meetings were held in June 2026. The purpose of these meetings was to present an overview of the project alternatives and how they were developed and scored for prioritization. Feedback regarding clarity, any missing information, and general input regarding communications needs before going to the public with open-house events was collected. General feedback included requests for information around personal property flooding mitigation education, additional detail regarding underground storage, and other visual or illustrative pieces to support project understanding.



Figure 1-5. The HDR and City of East Lansing Project Team members at the focus group meeting on November 6, 2025.

In addition to the focus group meetings, steps were taken to consistently engage the public through a series of online initiatives. Initially, a public survey was conducted at the outset of the project to seek input on where flooding was occurring, how frequently it was occurring, what types of flooding were occurring, and what the impacts were on property owners. Later, virtual public meetings were hosted to provide a space for the larger community to provide input on the development of the WWRP. The first virtual open house launched on March 9, 2026, with the purpose of collecting additional valuable feedback and understanding of known flood zones and impacts as identified using the mapping software (see Section 2). This virtual open house also aimed to understand stakeholder sentiments of priorities around mitigation solutions. The second virtual open house, launched in August 2026, was a similar format, providing a space for community members to read about the proposed flood risk mitigation projects, the next steps in the WWRP, and to provide feedback. This feedback was collected in preparation for the presentation of the WWRP to the City Council in September 2026. Following the City Council meeting, the WWRP will be finalized and published to the public.

Figure 1-6 provides a timeline overview of the key workshops with the City and the dates of stakeholder and public engagement meetings.

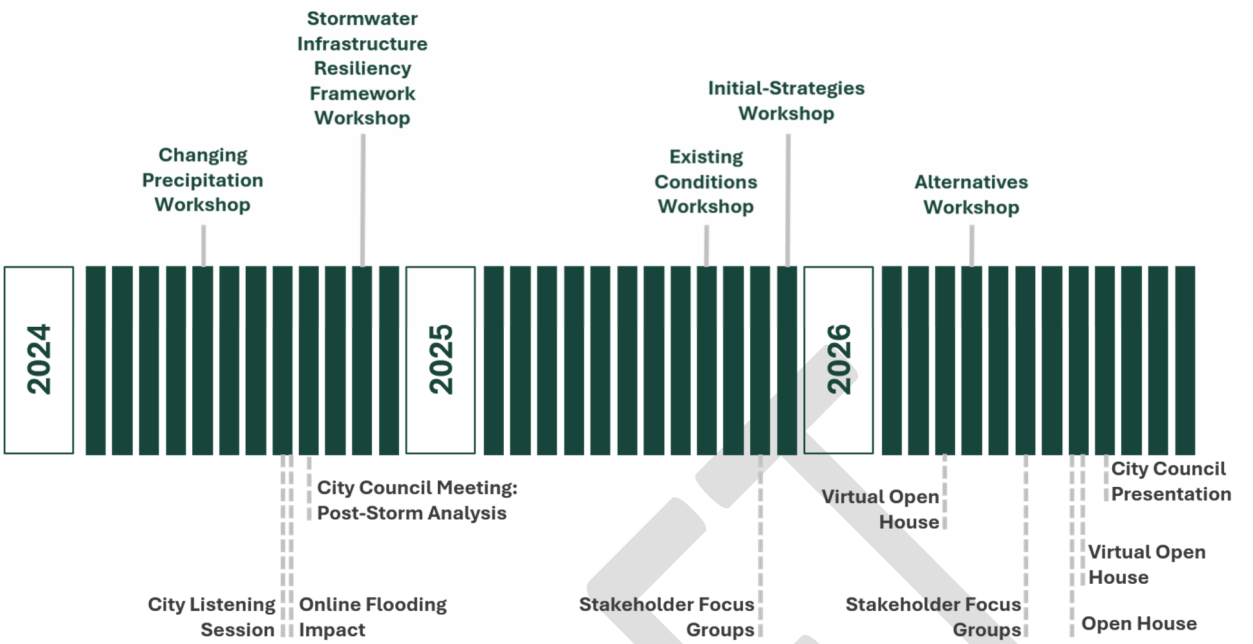


Figure 1-6. Timeline of key workshops with the City and public engagement.

1.4. Planning Process Overview

The WWRP planning process consisted of a series of defined technical tasks and targeted discussions with the City, key stakeholders, and the community. Each task and discussion was completed to advance progress toward a WWRP that addressed areas in the city determined to have a high risk of and impact from flooding. The planning process focused on data collection and analysis, development of modeling tools, and a comprehensive alternatives analysis to ultimately select flood risk mitigation strategies and projects for implementation, as illustrated in Figure 1-7.

Prior to the identification of the highest-priority flooding concern areas (CAs) and alternatives to address these areas, it was imperative to have a comprehensive understanding of historical and future precipitation trends in the city. This WWRP was scoped to identify the top eight highest-priority flooding CAs. The remaining flooding CAs not addressed as part of the WWRP will be addressed as part future planning phases as funding becomes available. A historical precipitation analysis was conducted with more than 60 years of rainfall data analyzed along with survey and complaint data from community members. Following the historical analysis, it was important to understand how future climate may impact different areas of the city, as current storm and combined sewers were sized based on historical design storms and urban development and related impervious surface coverage that no longer reflect current conditions. Future climate projections, as described in Section 2, were developed to assess the impact of future storms on existing stormwater infrastructure conditions.

For several years, the City has maintained a hydraulic and hydrologic (H&H) computer prediction model used for evaluating the performance of the existing combined sewer system (CSS) and sanitary sewer system. The model, although useful for these systems, did not include the City's

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stormwater infrastructure, namely pipes associated with the municipal separate storm sewer system (MS4), the open-channel drain system, or the street curb-and-gutter conveyance network. For the development of the WWRP, the City's existing H&H model was updated to include the stormwater infrastructure and ground-surface topography, allowing for the creation of a comprehensive combined, sanitary, and storm system model in one software using InfoWorks ICM. This model was ultimately used for an assessment of the existing condition of the stormwater infrastructure including where (surface flooding extents and basement backups), how much (water surface elevations or depths), and why flooding occurs. Section 3 outlines the model conversion to InfoWorks ICM 2024, the development of the storm drainage system, and the overall calibration process. Section 4 describes the qualitative and quantitative model results, including the analysis of flood risk areas based on flood risk and social vulnerability. Section 5 provides detailed information about the scoring methodology used to identify the top eight highest-priority flooding CAs. Section 5 also provides information regarding the social vulnerability overlay developed, the hydraulic connectivity between the top eight CAs, and the impact that this connectivity and other development and infrastructure limitations had on the development of alternatives.

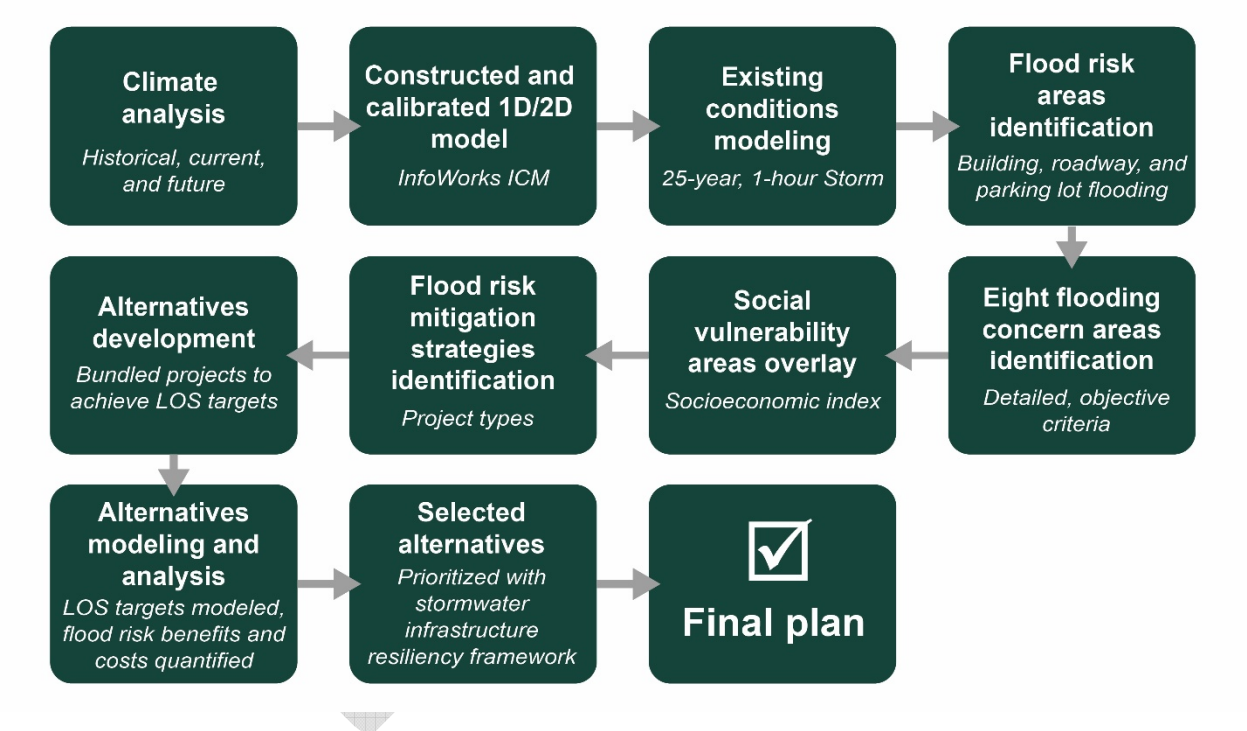


Figure 1-7. WWRP planning process overview.

To address the flooding in the top eight flooding CAs, flood risk mitigation strategies were bundled into project alternatives and assessed based on two different LOS goals: Current 10-year storm (Current) and Current 50-year/Future 16-year storm (Enhanced). Flood risk mitigation strategies included the following:

- Upsizing of existing sewers, the separation of the storm and sanitary sewers in CSS areas
- Construction of new storm sewer trunkline sewers and outfalls to the Red Cedar River or county drain systems
- Modification of flow restrictors and regulators to optimize use of existing infrastructure
- Green infrastructure and storage opportunities to reduce and treat runoff

Direct feedback from community stakeholders on their priorities for public investments within the city was sought to rank selected alternatives for implementation that would reduce flood risk and add other community benefits. Section 6 describes the flood risk mitigation strategies, the LOS they are evaluated on, and the community-focused prioritization of the alternative projects.

Based on findings throughout the development of the WWRP, complementary nonstructural strategies needed to address flood risk beyond the City's right-of-way and LOS goals were also identified for a layered approach to mitigating residual flood risks that cannot be solved through public infrastructure alone. Section 7 describes the resulting structural and nonstructural strategies to be implemented and further evaluated by the City in the implementation phase of the WWRP.

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2.PRECIPITATION ANALYSIS

A precipitation analysis specific to East Lansing was performed to inform the evaluation for proposed investments under current and future climate rainfall conditions. The following section provides a summary of the precipitation analysis. For additional information regarding the methods of analysis, the outcome, and the resulting impact on the WWRP, please refer to Task 1: *Changing Precipitation Conditions* technical memorandum in Appendix A.

2.1. Long-Term Precipitation Trends

To understand how rainfall patterns in the city have changed over time, historical precipitation data were collected to perform a historical trending analysis. Precipitation data from 1949 to 2023 were obtained from the Lansing Capital Region International Airport (KLAN) using the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) system. Though precipitation data from 1954 to 1959 were missing, the analysis still covered more than 60 years of consistent reporting. The data, provided in 1-hour and 24-hour increments, were reviewed for data quality assurance purposes prior to the historical trending analysis.

The trending analysis provided insight into the real observed changes in precipitation, specifically regarding precipitation intensity, over time. The annual precipitation in the East Lansing region increased by approximately 30 percent (from 27 to 35 inches of rain) from 1949 to 2023. This increase in annual precipitation is in line with other studies of precipitation over Michigan and the Midwest including the Great Lakes Integrated Sciences and Assessments Center (GLISA, n.d.). Additionally, the analysis showed that the maximum hourly precipitation intensity trends have increased by 70 percent from 1949–2023, as shown below in Figure 2-1.

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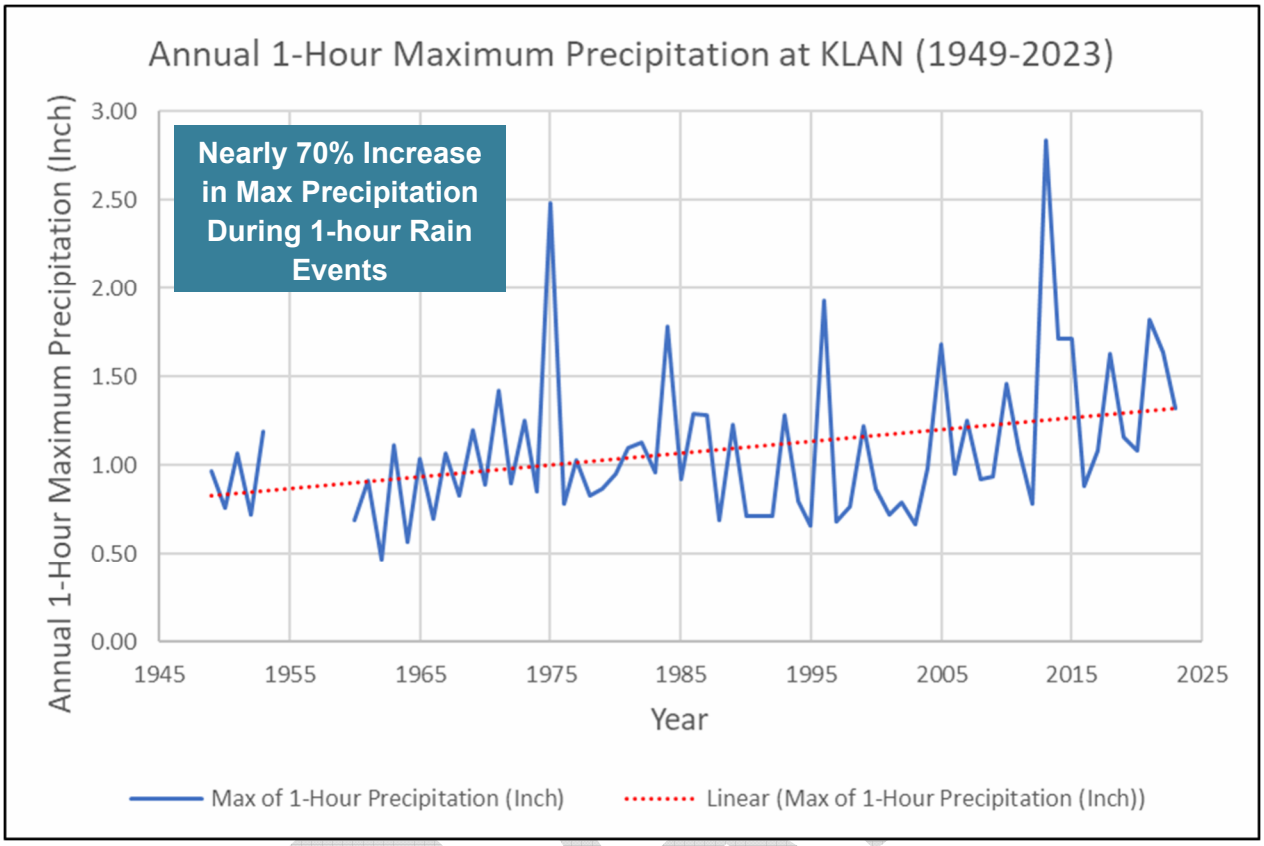


Figure 2-1. Annual 1-hour maximum precipitation observed for KLAN from 1949 to 2023.

2.2. Updated Precipitation Frequency Estimates

In 2016, the EGLE Water Resources Division (WRD) developed policy WRD-046, *Considering Climate Change in Water Resources Division Programs,* to consider climate change adaptation within the state programs (EGLE, 2023). The top requirement in this document states, "to use the most up-to-date precipitation estimates available for permitted design storms (i.e., National Oceanic and Atmospheric Administration [NOAA] Atlas 14 as of this publication)."

As part of the WWRP and in accordance with EGLE guidance, precipitation frequency estimates were updated using observed precipitation data from KLAN through 2023. Results from the updated estimates were then compared to NOAA Atlas-14, which was last updated in 2013 and does not include more recent precipitation as compared to the WWRP estimates. Results of this comparison are shown in Table 2-1. Results show that precipitation frequency estimates have increased for lower frequency design storms. Based on the findings of this analysis it is recommended that the updated precipitation frequency estimates that include more recent precipitation data be used as part of the WWRP.

Table 2-1. Historical and updated precipitation estimates.

Frequency	NOAA Atlas-14 (2013)	Updated estimates for WWRP	Percent increase
2-year, 6-hour	1.63	1.86	14%
5-year, 6-hour	2.21	2.49	13%
10-year, 6-hour	2.68	2.91	9%
25-year, 6-hour	3.37	3.44	2%
50-year, 6-hour	3.92	3.92	0%
100-year, 6-hour	4.52	4.52	0%

2.3. Representative Storm Analysis

Design storms play a vital role in the planning and design of stormwater infrastructure. A design storm is a statistically derived rainfall event that describes the likelihood of a depth of rainfall occurring over a given time duration. For example, designing stormwater infrastructure for a 10-year, 1-hour design storm means sizing infrastructure to manage the rainfall from a 1-hour duration storm that has a 10 percent chance of occurring annually. These design storms are typically derived at regional scales. However, as precipitation trends have increased at local levels, it is necessary to identify a representative design storm that is specifically tailored to the City's observed precipitation.

To develop a representative storm, HDR identified 12 of the largest historical storm events from the last 30 years that have caused flooding within the city. For each of these 12 storm events, Next Generation Weather Radar (NEXRAD) was obtained from NOAA. The NEXRAD radar data were used to develop gridded 5-minute Gauge-Adjusted Radar Rainfall (GARR) data, which were compared to local rain gauges from various sources to ensure that the GARR data were accurate.

Using the gridded GARR data from the 12 historical storms, a representative storm for the city was derived. This storm provides a statistical representation of a historical rainfall distribution pattern directly associated with flooding within the city. This pattern can then be used for planning and design purposes. A cumulative temporal distribution of the 6-hour representative storm shows that nearly 80 percent of the rainfall that caused flooding in the city occurred within the first 2 hours of the storm, as shown below in Figure 2-2. This indicates that the first few hours of a high-intensity storm may influence surface flooding the greatest.

In summary, analysis of the 12 historical storm events and the representative storm indicate that short-duration, high-intensity storms that are fewer than 6 hours in duration play a significant role in flooding in the city and form the basis for evaluating alternatives within the WWRP.

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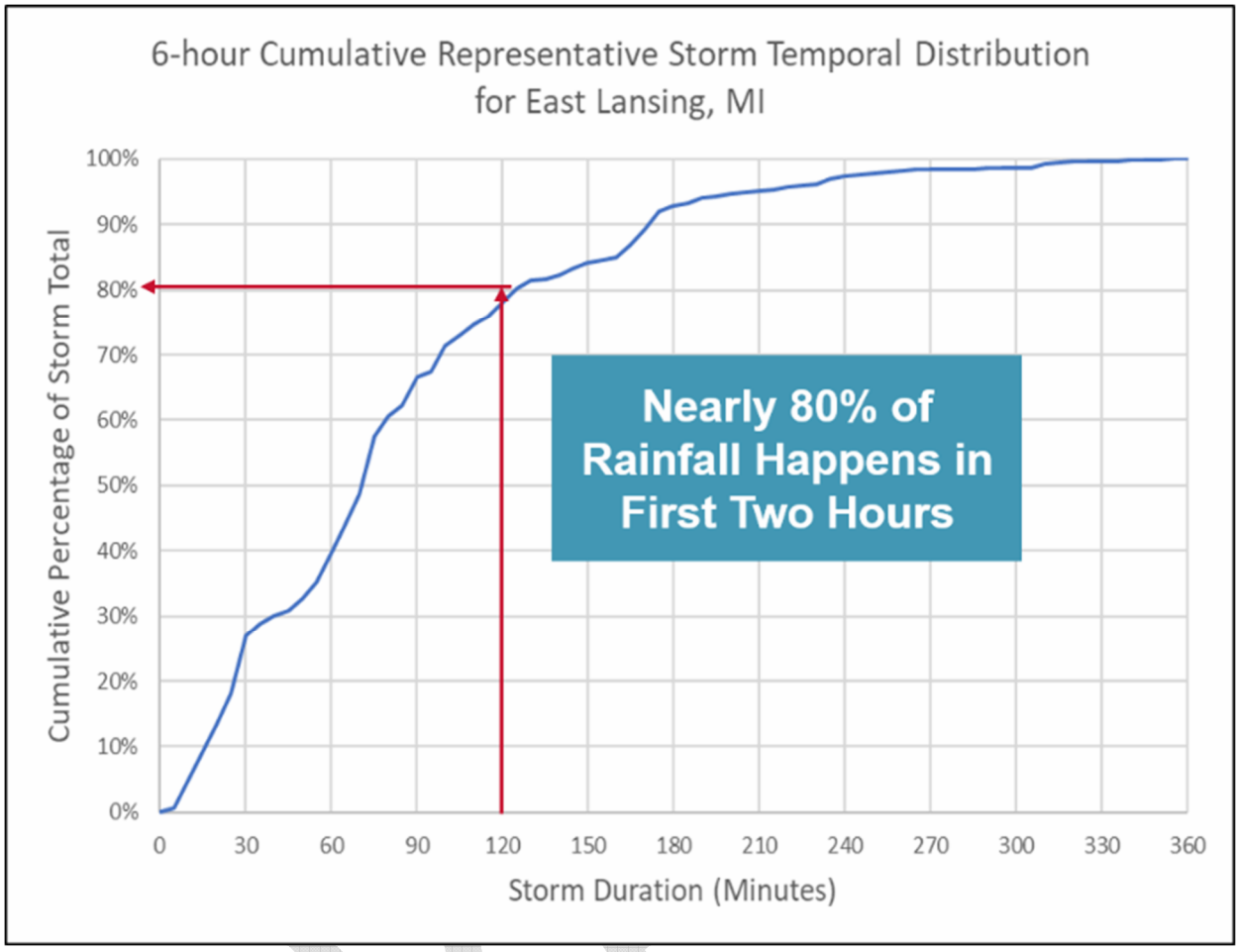


Figure 2-2. Cumulative temporal distribution for the 6-hour representative storm.

2.4. Future Precipitation Projections

Water management agencies, public-works departments, and stormwater utilities across the country are reviewing and updating regulatory guidance for the development of flood-resilient stormwater standards. The need to consider future climate when designing stormwater infrastructure is becoming more integral throughout the stormwater management sector to develop flood-resilient projects. The project team performed an analysis of future climate change precipitation projections specific to the city. The purpose of the analysis was to incorporate future precipitation increases into the evaluation of stormwater infrastructure upgrades as part of the WWRP.

To accomplish this task, an ensemble of global climate models (GCMs) specific to the state of Michigan were used. GCMs are computer programs that are designed to mimic the atmosphere on a global scale to determine the influence of the buildup of greenhouse gases (GHGs) within the atmosphere. Two climate change scenarios, SSP2-4.5 and SSP5-8.5, were used to represent a potential range of outcomes for precipitation in the future. SSP stands for Shared Socioeconomic Pathways, which represents the concentration of GHG that is expected to be released into the atmosphere in the future. The SSP2-4.5 scenario predicts that GHG emissions

will continue to increase at their current rate until the year 2050, when they begin to decrease for the remainder of the century. SSP5-8.5 is based on a scenario that sees emissions increase unabated through the end of the century. Each emissions scenario was then applied to the GCMs to determine the percent increase in precipitation under the medium-emissions scenario (SSP2-4.5) and the high-emissions scenario (SSP5-8.5). Table 2-2 below provides a summary of the projected percent increases in precipitation from 2035 to 2100.

Table 2-2. Potential percent increase in future precipitation because of climate change.

Year	Medium scenario (SSP2-4.5)	High scenario (SSP5-8.5)
2035	1.0%	2.7%
2050	2.6%	6.6%
2070	4.6%	12.0%
2100	7.8%	20.0%

The enhanced precipitation projections influence not only the development of the flood risk mitigation projects, but they also impact private development. As part of the WWRP, the High Scenario SSP5-8.5 for the year 2100 was selected for system evaluation.

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3. HYDROLOGIC AND HYDRAULIC MODEL DEVELOPMENT

Prior to the WWRP, the City invested in the development of its existing InfoSWMM model for the purposes of hydraulic characterization of its combined sewer and sanitary systems. However, Autodesk recently discontinued technical support of InfoSWMM. As a result, HDR was tasked with evaluating available modeling software to identify the most suitable platform for continuous hydraulic evaluations as well as two-dimensional (2D) surface flooding simulations. Converting the existing one-dimensional (1D) model to a 1D/2D model allows the City to conduct detailed evaluations of where, why, and how much surface flooding and basement backups may occur. With this modeling tool the City can be on the leading edge of citywide flood risk evaluations and project identification.

Once the software platform was selected, the existing model was converted to the new software and expanded to include the MS4 area, the open-channel storm drain system, and overland surface to characterize roadway drainage. The following section provides an overview of the software selection process and the steps taken to convert and expand the City's sanitary system model.

3.1. Software Selection

A model software discussion meeting between the City, Tetra Tech (the consultant that developed the current InfoSWMM model), and HDR was held on March 6, 2024, to better understand existing and future H&H modeling needs. A summary of the meeting is provided in the Task 5: *Model Software Evaluation and Recommendation* technical memorandum in Appendix D. Previously, Tetra Tech provided the City with a high-level summary of four modeling software platforms, including AquaTwin, SewerGEMS, PCSWMM, and InfoWorks ICM. It was decided that the software evaluation should be limited to PCSWMM and InfoWorks ICM, which were evaluated using 15 evaluation criteria (see Table 3-1).

Table 3-1. Model criteria evaluation results.

No.	Evaluation criterion	Importance	Advantage
1	InfoSWMM conversion capability	High	Equal
2	GIS integration	High	Equal
3	1D calculation engine and performance	High	InfoWorks ICM
4	2D overland flow	High	InfoWorks ICM
5	Model maintenance and scenario management	High	InfoWorks ICM
6	Hydrologic calculations	Medium	Equal
7	Managing model storage and delivery to consultants	Medium	InfoWorks ICM
8	Subscription cost	Medium	PCSWMM
9	Model troubleshooting capabilities	Medium	InfoWorks ICM
10	Technical support	Medium	PCSWMM
11	Level of complexity/learning curve for new users	Medium	PCSWMM
12	Customizable reports and outputs	Low	InfoWorks ICM
13	Advanced modeling tools	Low	InfoWorks ICM
14	FEMA floodplain mapping	Low	PCSWMM
15	Pump stations and force mains	Low	Equal

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Ultimately, InfoWorks ICM was the selected model software platform for the following two key reasons:

- The stability and speed of InfoWorks ICM 2D overland flow component is superior to PCSWMM.
- InfoWorks ICM has an advantage for model maintenance and excels at managing files, tracking changes, and sharing files across multiple firms.

3.2. Hydrologic Parameters

Hydrologic parameters are the essential variables that describe both the physical characteristics and the hydrological processes occurring within the modeled area. To remain consistent with the original InfoSWMM model, the hydrological parameters of the MS4 were calculated using the same methodology used for the CSS. This included using the Horton Infiltration method to determine the amount of runoff and the Storm Water Management Model (SWMM) method to convert the runoff to a hydrograph. Digital elevation model (DEM) data, land use data, and soils data were used to calculate the initial hydrologic parameters in the geographic information system (GIS). Descriptions of the key hydrologic parameters are described below in Table 3-2. These parameters were then adjusted during the model calibration process to better match observed flow and level data.

Table 3-2. Description of key hydrologic parameters in the model.

Hydrologic parameter	Description
Initial infiltration	The amount of water that enters the soil immediately after rainfall.
Limiting infiltration (inch/hour)	The maximum rate at which soil can absorb rainfall. When this rate is exceeded, runoff is experienced.
Decay factor ($hour^{-1}$)	A constant used to control the rate of decrease in the infiltration capacity of soil.
Drying time (day)	The amount of time it takes for conditions to be considered “dry” following a rainfall event.
Maximum infiltration volume (inch)	The available infiltration capacity divided by the surface area.

3.3. Subcatchment Delineation

Subcatchment delineation develops smaller, better-defined areas based on drainage patterns and critical infrastructure points that define the direction of flow. In addition to the infrastructure layout, 1-meter resolution DEM data from the United States Geological Survey (USGS) Three-Dimensional Elevation Program (3DEP) was used to provide additional accuracy to the subcatchment delineation.

The areas within the MS4 area and city limits were delineated into 361 separate subcatchments. The new MS4 and existing CSS subcatchments are used to refine how flow from rainfall events is loaded into the model and how flow travels through the drainage system. This approach provides a better understanding of possible flooding.

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3.4. Hydraulic System Model Building

Building the hydraulic system model in InfoWorks ICM can be divided into the following three key parts:

- Conversion of the existing InfoSWMM model for the CSS system
- Creation of the MS4
- Creation of a 2D surface for overland routing

3.4.1. CSS CONVERSION AND UPDATES

The original InfoSWMM model included only the CSS and sanitary system. The model was first converted to InfoWorks ICM SWMM. The model was then converted from the SWMM engine to InfoWorks ICM SIM, which has a 2D calculation engine that has proved to be accurate for modeling both 1D pipes and 2D overland flooding. Once the model was converted, an inventory of elements such as modeled nodes (manholes), links (pipes), outfalls, wet wells, and pump stations was validated to make sure that all elements were brought into InfoWorks ICM SIM correctly. Once the model was converted, the model was further updated to include four recently completed capital improvement projects that were not in the original model. These four capital improvement projects are provided in Table 3-3.

Table 3-3. CIP updates in the CSS/sanitary sewer area.

Capital improvement project name	Description of improvements
Kedzie and Sunrise	• Sanitary sewer upsizes, realignments, new catch basins primarily along Collingswood Dr. • New twin sewers on Kedzie St. • Combined sewer upsize on Sunrise Ct.
Michigan and Harrison	• New triple-barrel siphon sanitary sewer under Red Cedar River • New upstream sanitary sewers and reconfigurations • New upstream storm sewers on Michigan Ave. that discharge to the Red Cedar River
Oakhill and Evergreen	• New combined sewers • New orifice restrictor plate in Manhole SA#3 at the intersection of Valley Ct. and Evergreen Ave. • New storm sewers and catch basins (12 inches)
Northlawn	• Several sanitary sewer upsizes and new catch basins primarily on Northlawn Ave. • Improvements also on Southlawn Ave. and Glenhaven Ave.

Additional updates to the CSS and sanitary sewer model included changes to pipe alignments, pump curves, and the configuration of pump stations. All the updates to the CSS and sanitary sewer model help to improve the accuracy of the model for use in identifying surface flooding in the city.

3.4.2. MS4 DEVELOPMENT AND UPDATES

The original InfoSWMM model did not include the MS4. To develop a combined model that includes the sanitary system, CSS, and MS4, HDR developed a 1D/2D model for the MS4 area and then combined it with the converted CSS/sanitary system model.

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The City's geodatabase was used to identify the MS4 1D elements to be modeled. Storm drainage pipes, drains, junctions, and culverts of the MS4 were imported into the model from the geodatabase created by the City. Also included were survey data collected as part of the WWRP. The imported data were then reviewed to identify missing or potentially erroneous data based on a comparison between the City's geodatabase, available as-builts, and the newly collected survey data. These missing or conflicting locations were further investigated during several workshops with the City to resolve these question areas. In a few instances, pipe inverts and sizes were assumed in the model when the survey or the City data were nonexistent. For these locations best engineering judgment was used based on a combination of field investigations, arial imagery, street-view imagery, inference, and engineering judgment.

3.4.3. 2D SURFACE CREATION

A 2D surface was created to cover the entire extent of the MS4 and CSS area. This 2D surface is a mesh that reflects the ground surface, including small ditches and streams, to characterize overland flows across the surface. The purpose of the 2D surface is to understand where excess flows from the CSS or MS4 have the potential to exit the system and flow onto the surface. The 2D model can then predict depths of flows and the potential flood risk to roads, adjacent properties, and buildings. To develop the 2D mesh surface, defined boundaries were created around ditches and ponds. Roads within the mesh hydraulic parameters were assigned to accurately route the flows. For more information on the creation of the 2D surface mesh and associated properties please refer to the Tasks 5 and 6 Model Development and Existing Conditions Flood Assessment Report in Appendix E.

3.5. Flow and Rainfall Monitoring

ADS Environmental (ADS) installed and maintained a series of four rain gauges, five flow monitors, and three level-only sensors throughout the MS4 area to conduct a flow and rainfall monitoring study. The map in Figure 3-1 below shows the location of the flow monitors and rain gauges throughout the MS4 area. Five months of flow, level, and rainfall data were collected from July to November 2024. These data were analyzed to support the calibration of the H&H model in the MS4 area.

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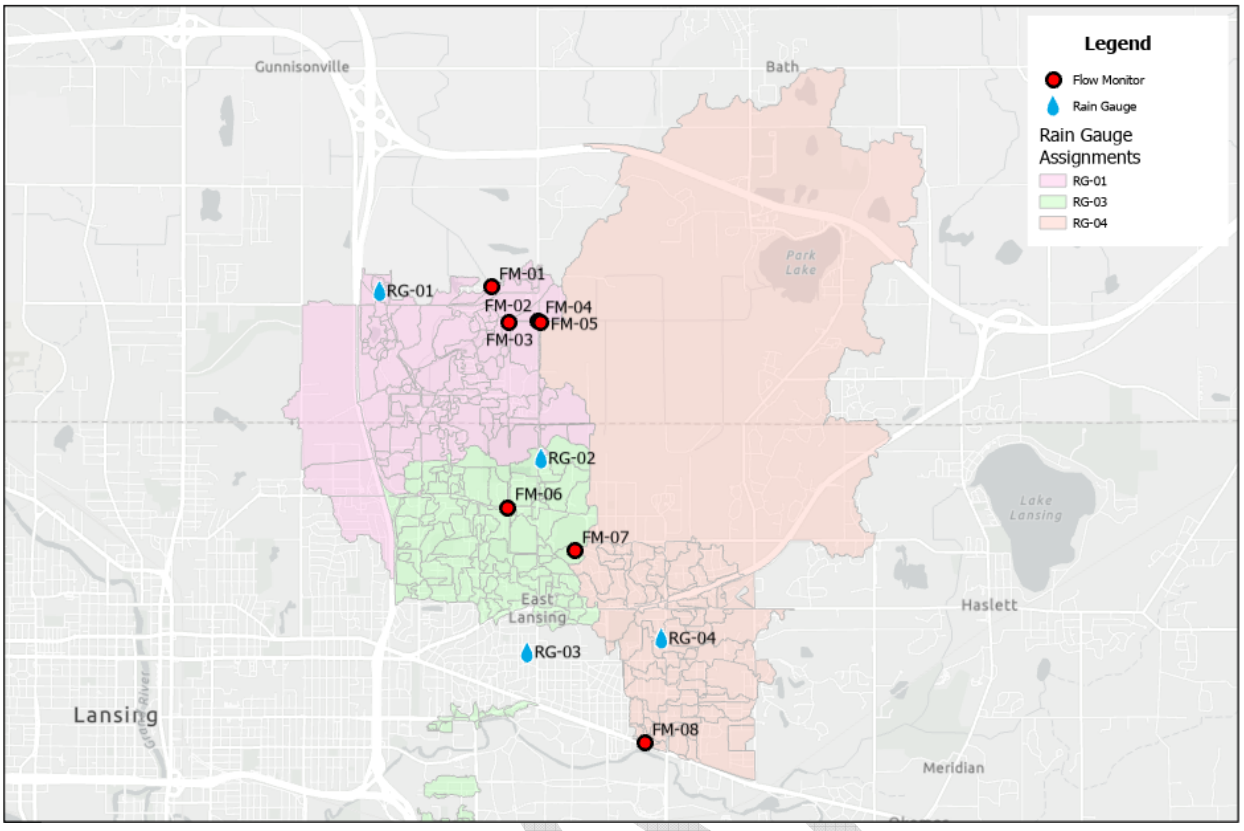


Figure 3-1. Flow monitor and rain gauge locations.

3.6. 2D Model Calibration and Validation

The calibration of the model consisted of two phases: the calibration of the MS4 model area using the storm events from the rainfall monitoring, and the calibration of the CSS model area using the dry weather flow (DWF) and wet weather flow (WWF) 2017 period previously used in the development of the InfoSWMM model. Following model calibration, the model was validated using the June and July storm events that resulted in significant flooding in 2024.

3.6.1. MS4 MODEL CALIBRATION

The purpose of the MS4 model calibration was to improve the model accuracy and to verify that the model can produce results similar to how flow realistically moves through the city during and after storm events. To perform this calibration, five storms from the collected rainfall data were selected for the model calibration. The model was run for each storm and the model output data were compared to the observed data from the meters for calibration.

Following Wastewater Planning Users Group (WaPUG)-recommended guidelines, a meter is considered calibrated if calibration criteria are met for 60 percent of the storm events. For more information on the calibration criteria refer to the Tasks 5 and 6 Model Development and Existing Conditions Flood Assessment Report in Appendix E. The calibration results for the MS4 area were deemed sufficient for the purpose of this model, meaning the development and identification of flooding CAs for the WWRP.

3.6.2. CSS CALIBRATION

The purpose of the CSS calibration process was to verify that the converted InfoWorks ICM SIM model produced results that were similar to the InfoSWMM model results during the 2017 calibration. Similar to the MS4, calibration criteria during dry and wet periods were used to confirm model accuracy. For more information on the calibration criteria refer to the Tasks 5 and 6 Model Development and Existing Conditions Flood Assessment Report in Appendix E. Results for the calibration process show that the updated InfoWorks ICM model produces similar values as the 2017 InfoSWMM model. The results demonstrate that the model was successfully converted to an InfoWorks ICM model and is sufficient for the purpose of evaluating flooding within the CSS.

3.6.3. MODEL VALIDATION FOR THE JUNE AND JULY 2024 FLOOD EVENTS

To validate the 2D calibrated model, rainfall from the June and July storm events in 2024 was simulated to identify flooding areas. These two events resulted in flooding complaints in areas throughout many portions of the city, with some areas seeing rainfall intensities that exceeded the 1,000-year storm.

To accurately model the June and July 2024 rain events, HDR used the rain gauge–collected data for these events and generated 5-minute GARR data using NEXRAD from KLAN. The GARR data for both storms were then input into the calibrated model and simulated to understand 2D surface flooding across the city.

Public survey complaint data of surface flooding, in addition to the City's recollection of the flooding areas from both storm events, were compared to the modeled 2D flooding results. Figure 3-2. and Figure 3-3. present the 2D model flooding results for the June and July 2024 flooding events, respectively. On these figures, the red dots represent street flooding survey complaints reported by the public in East Lansing. Generally, the model-simulated surface flooding agreed with reported known street flooding locations, especially within the Whitehills and Red Cedar neighborhoods. Results were reviewed with City staff to confirm model performance in known flooding areas. Based on feedback received during this workshop, additional minor model refinements were made to the model to better match flooding complaint areas. The model was subsequently considered calibrated and validated by HDR and City staff members after these additional refinements.

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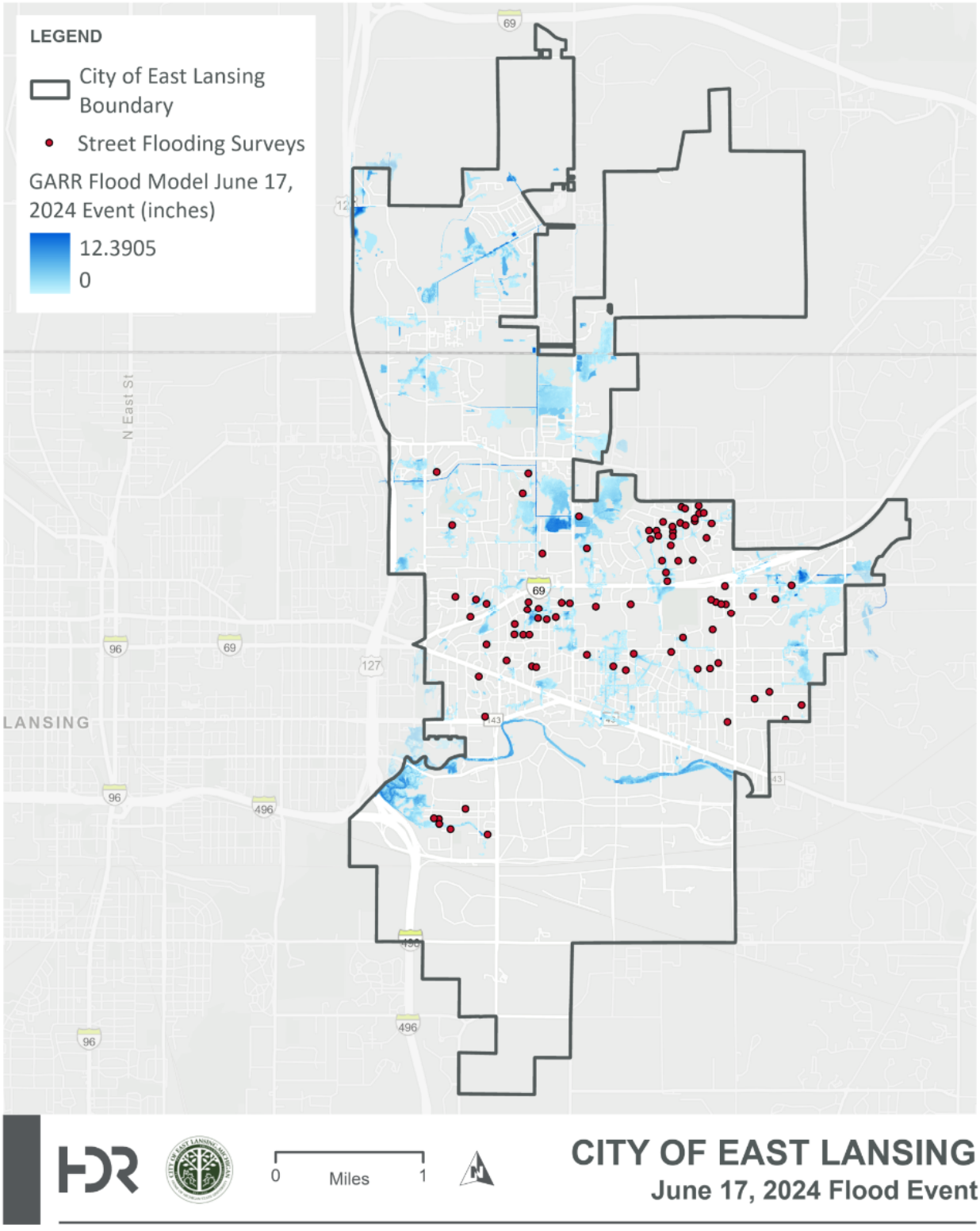


Figure 3-2. GARR model surface flooding results for the June 2024 rain event with flooding survey locations (red dots).

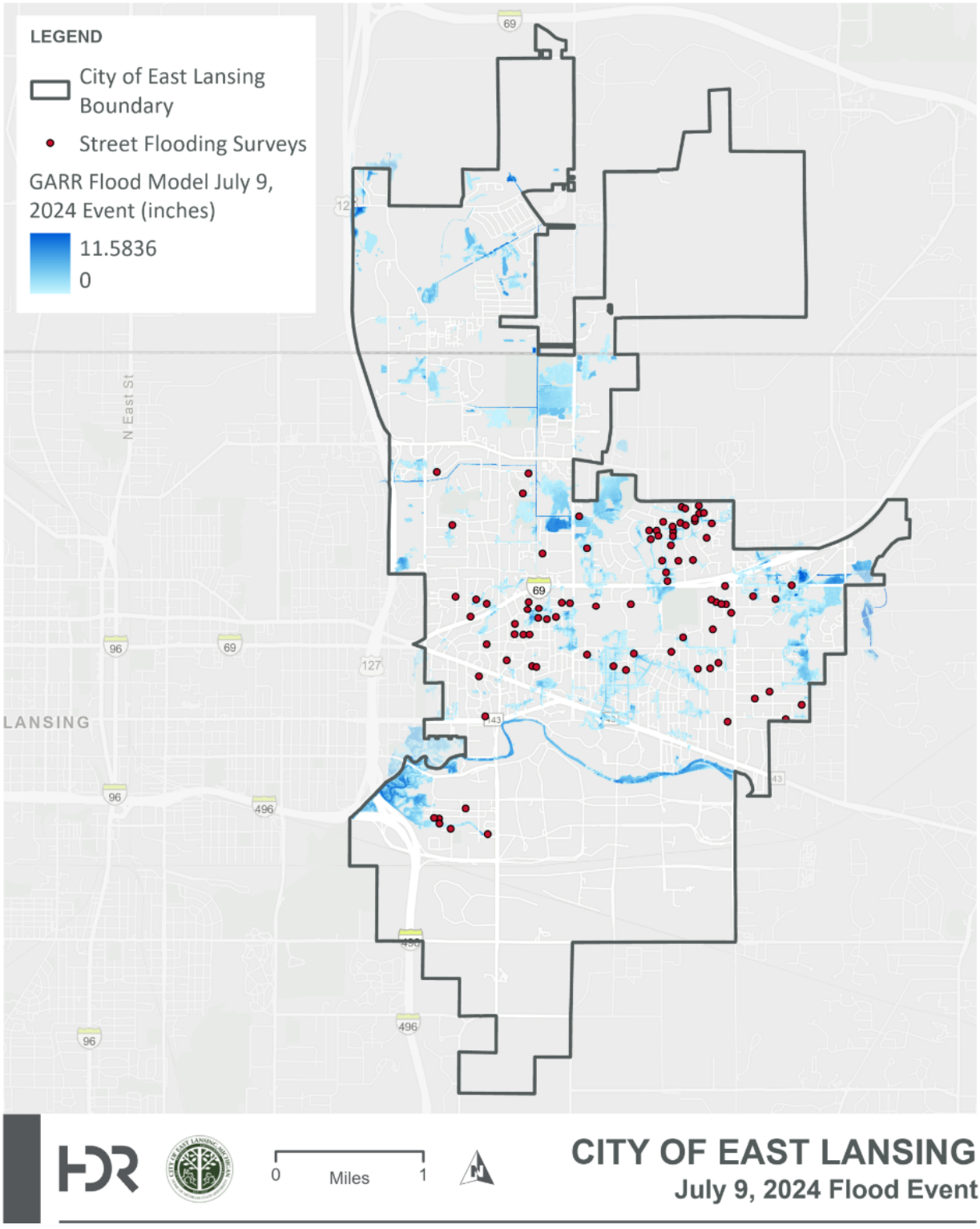


Figure 3-3. GARR model surface flooding results for the July 2024 rain event with flooding survey locations (red dots).

4.EXISTING-CONDITIONS ASSESSMENT

One of the primary goals of the WWRP is to understand where flooding is occurring because of limitations within the existing drainage infrastructure. Results extracted from the model inform the flooding extents (surface area) and depths (water surface elevations) in the City under present-day conditions. For East Lansing, it is especially important to consider both pipe surcharging and sewer backups from combined sewers as well as overland surface flooding.

The model developed by the project team was used to simulate a range of design storms so that flood-prone areas could be identified. This section provides an overview of the selected design storms, the modeled results, and the City's current and planned improvement projects in the area.

4.1. Selected Design Storms

For purposes of remaining consistent with the City's identified projects within the Combined Sewer System Modeling and Master Plan Report from 2020 and the City's stormwater regulations at the time of the analysis, rainfall estimates published from Huff and Angel (Huff and Angel, 1992) were used for the existing-conditions assessment. These are commonly used rainfall estimates used in stormwater evaluations throughout the Midwestern United States. The updated rainfall estimates in Task 2 were not used for this analysis as these rainfall estimates had not yet been formally adopted at the time of this analysis.

The model was stress-tested using the 2-, 5-, 10-, 25-, 50-, and 100-year design storms at durations of 1 hour, 6 hours, and 24 hours. Table 4-1 provides the total rainfall used for each design storm selected for climate region 9 within Huff and Angel.

Table 4-1. Rainfall (inches) for the selected design storms.

	Storm duration		
Recurrence interval	1 hour	6 hours	24 hours
2-year	1.14	1.82	2.42
5-year	1.40	2.24	2.98
10-year	1.61	2.57	3.43
25-year	1.92	3.07	4.09
50-year	2.18	3.47	4.63
100-year	2.44	3.90	5.20

The stress testing revealed that the flooding in the model was driven by short-duration, high-intensity rain events. This aligns with observations made during the representative storm analysis, which showed that rainfall events in the East Lansing area are trending toward shorter durations. More explicitly, the modeled flooding was more widespread and impacted more neighborhoods for the 1-hour event as compared to the 6- and 24-hour storm events.

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Ultimately, the 25-year, 1-hour design storm of 1.92 inches was selected to evaluate and identify flooding CAs in the city. This storm was selected for the following three primary reasons:

- The storm was large enough to generate enough flooded areas to adequately score and evaluate the model across both the CSS and MS4 areas.
- The temporal distribution of the Huff and Angel 1st quartile is similar to the Representative Storm temporal distribution.
- The current 25-year, 1-hour storm rainfall depth inherently takes into account future climate considerations. It is projected that the 10-year, 1-hour storm rainfall depth in 2035 will be approximately 2.02 inches, which is similar in magnitude to the 1.92 inches of rainfall for the current 25-year, 1-hour rainfall depth.

4.2. Modeling Results

The H&H model was used to identify locations that were at risk of experiencing surface flooding during the 25-year, 1-hour storm. In the H&H model, a location was at risk for surface flooding if at least one of the following three conditions were met:

- A roadway floods 6 inches or more
- A parking lot floods 6 inches or more
- A building floods

The above conditions for surface flooding were selected as roadway and parking lot flooding of 6 inches or greater has the potential to significantly impact the community as water exceeding this depth has the potential to impact vehicular traffic and to overtop street curbs into properties. Additionally, it was assumed that if a building experiences flooding from a storm event, there is a high likelihood that significant surface flooding is present.

The H&H modeling identified 58 locations at risk for surface flooding under the design storm. These 58 areas, which HDR defined as “flooding concern areas,” are shown in Figure 4-1. below. Of these, 28 of the flooding CAs were identified within the CSS area, and the other 30 were within the MS4 area. Section 5 describes how each of the flooding CAs were evaluated, based on a series of criteria, to identify the top eight flooding CAs for which the first phase of flood risk mitigation strategies would be developed to target. The top eight flooding CAs will be attached to watersheds.

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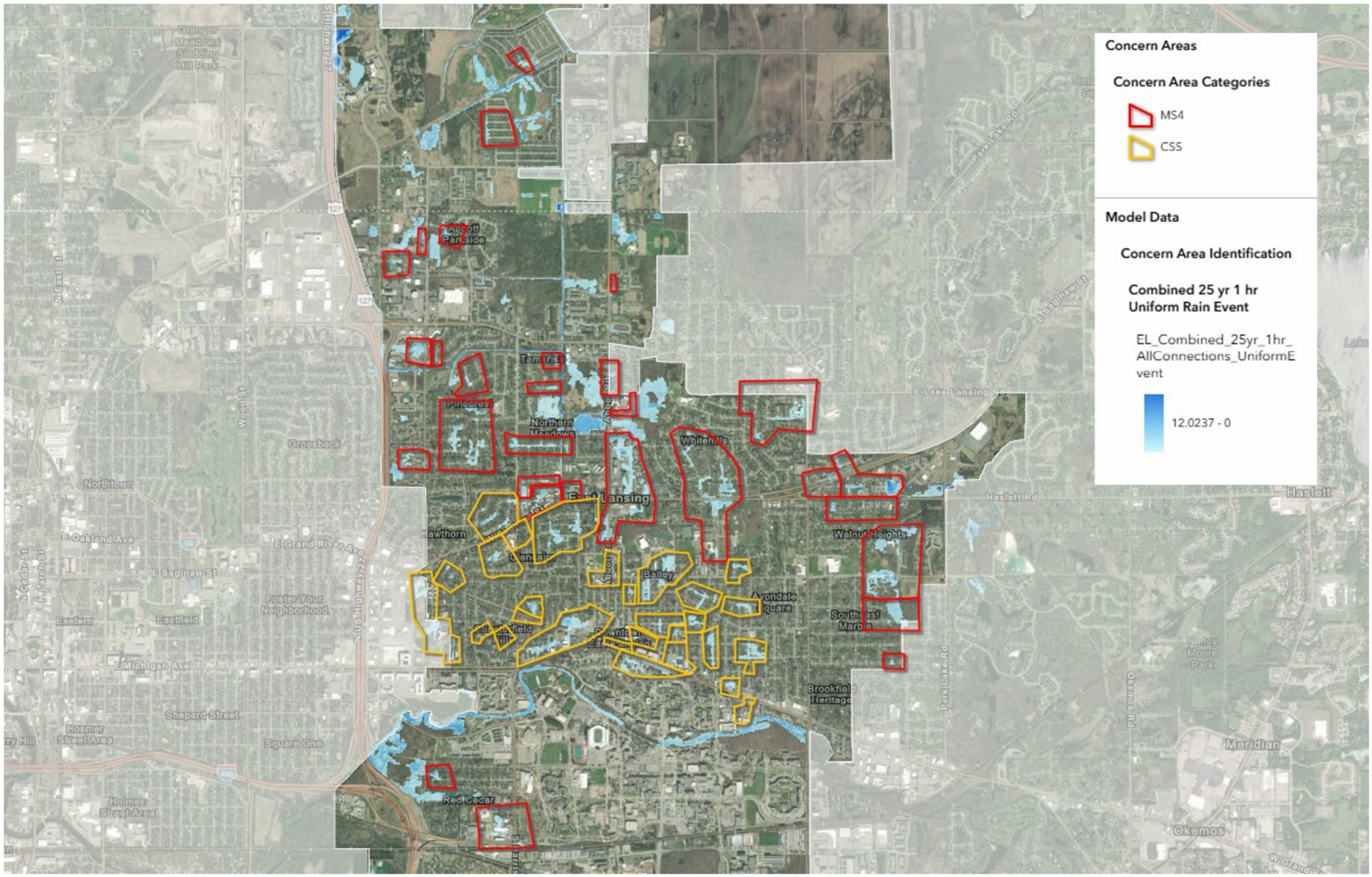


Figure 4-1. Flooding concern areas identified using 25-year, 1-hour design storm.

4.3. Current and Planned System Improvements

Separate from the WWRP, the City currently follows a Combined Sewer System Modeling and Master Plan Report from 2020 and a 2025 Clean Water State Revolving Fund (CWSRF) project planning document to manage and mitigate wet weather impacts on the CSS. The existing CSS master plan outlined several capital improvement projects for the CSS area, four of which have already been completed (see Table 3-3 in Section 3). Several of these projects overlap with CAs identified in the existing-conditions assessment. Table 4-2 provides a summary of the completed and planned improvements projects as part of the existing master plan and whether it overlaps with a CA.

Table 4-2. 2020 Master Plan completed and planned projects summary.

Project	Description	Completed? (Y/N)	Overlap with identified CA?
Project 1	Michigan Avenue and Harrison Road sewer improvements	Y	N/A
Kedzie Alternative 2	Kedzie Street storm sewer	Y	N/A
Sunrise Alternative 2	Sunrise Court storm sewer and Division/Linden connection	Y	N/A
Shaw Estates Alternative 1	Backflow prevention on service leads	Y	N/A
Project 10 Alternative 1 Segment 1	Portion of Northlawn Avenue sewer improvements between Harrison Road and Sunset Lane	Y	N/A
Project 2	Oakhill/Evergreen improvements	Y	N/A
Project 3 Alternative 4 Segment 1	Center and Beal regulator modifications	N	Y
Project 3 Alternative 4 Segment 2	Elm/Valley District storm sewer for upstream areas	N	Y
Project 13	Wilmarth-Woodmere relief	N	N
Project 4	Charles Street sewer replacement	N	Y
Project 6 Alternative 1	Chesterfield Hills Neighborhood sewer improvements	N	N
Project 7 Alternative 3	Separation and redirection of stormwater to Montgomery Drain	N	Y
Project 8	Bailey-Linden sewer	N	Y
Project 9 Alternative 1	Shaw Estates sewer separation with new sanitary sewers and a local pump station	N	Y
Project 10 Alternative 1 Segment 2	Remaining combined sewer improvements not constructed with Northlawn Avenue work	N	Y
Project 5 Alternative 1	Albert Alley sewer improvements	N	N
Project 11	Milford-Gunson sewer separation with new storm sewer	N	N
Local Improvements	Local sewer improvements to address local capacity restrictions	N	N/A

The location of the completed and planned CIP projects in the 2020 Master Plan were considered in the identification of the prioritized CAs, the development of alternatives, and the implementation plan for projects to avoid conflicts with scheduling and budget.

5.CONCERN AREA IDENTIFICATION

The model results from the existing-conditions assessment, which identified 58 flooding CAs, were used to identify and prioritize flooding CAs in the WWRP. The following section describes the methodology for selecting a certain number of flooding CAs (eight) for alternatives development and the identification of projects to mitigate flood risks in these high priority areas of the City.

5.1. Concern Area Scoring Methodology

Nine criteria (herein referred to as CA criteria) were defined to evaluate and score the 58 identified flooding CAs. CA criteria can be measured using the model results and objectively rank the areas by amount of impact, as opposed to a subjective selection of areas to focus the City's efforts on. The CA criteria used for this analysis, described in Table 5-1, were developed during the resiliency workshop held by the project team, where observed flooding problems were identified and defined.

Table 5-1. Flooding CA criteria.

Roadway flooding frequency	How frequently a roadway floods (For example, a road that frequently floods during 2-year event)
Roadway flooding location	Where roadway flooding occurs. For example, a heavily traveled road that floods.
Roadway flooding depth: critical facility	Flooding that occurs on a roadway near a critical facility such as a police or fire station.
Roadway flooding extent	The total area of roadway that floods 6 inches or greater within a flood-prone area.
Parking lot flooding	Flooding that occurs in parking lots.
Building flooding frequency	How frequently a building floods. For example, a building that frequently floods during a 2-year event.
Building flooding type	The type of building where flooding occurs. For example, a multi-residential apartment building.
Surface flooding: CSS area	Flooding on the surface within the combined sewer area.
Basement flooding: CSS area	Basement flooding within the combined sewer area.

A pairwise comparison was conducted to determine the relative importance of the CA criteria. A pairwise analysis involves the comparison of a set of objectives to each other to determine the relative importance of each objective. Participants in the analysis included representatives from multiple City departments including Public Works; Diversity, Equity, and Inclusion (DEI); Planning; and Emergency Services. The participants of the pairwise analysis compared the CA criteria against each other using a numerical score.Table 5-2 shows the results of the pairwise analysis, including the relative ranking for each criterion, its assigned weighted value, and the total possible "points" a flooding CA can be given based on the criterion. The total possible points is determined by multiplying weighting value by 5 to achieve a total numerical score of 100 possible points. For all flooding CAs, the objective criterion was scored between 0 and 5 based on the model results. For each criterion, the 0 to 5 flooding score result was then multiplied by the weight from the pairwise analysis to compute a total criteria score out of 100 in each flooding CA. For a more detailed description of the CA criteria and more details on the scoring methodology, please refer to the Tasks 5 and 6 Model Development and Existing Conditions Flood Assessment Report in Appendix E.

Table 5-2. Pairwise analysis results.

Objective criterion	Pairwise analysis rank	Criterion weighting value	Total possible points
Basement flooding: CSS surcharge	1	3.14	15.70
Roadway flooding depth critical facility	2	2.96	14.80
Building flooding type	3	2.69	13.45
Surface flooding: CSS area	4	2.34	11.70
Building flooding frequency	5	2.28	11.40
Roadway flooding location	6	2.06	10.30
Flooding extent	7	1.75	8.75
Roadway flooding frequency	8	1.69	8.45
Parking lot flooding	9	1.09	5.45
		Total	**100.00**

5.2. Concern Area Results and Descriptions

Using the weights and total possible points for each criterion, each of the 58 flooding CAs was scored to identify the top 8 flooding CAs to advance for flood risk mitigation project alternatives analysis.

The 58 flooding CAs were then ranked by their total flooding score. Table 5-3 below provides the total score, and whether the location is within the MS4 or CSS area for all flooding CAs. The top eight CAs, shown in Figure 5-1., are highlighted in red and represent the proposed priority flooding areas for flood risk mitigation alternatives analysis. The orange coloring indicates that these CAs will be considered in the second phase of projects, and the yellow coloring indicates that the areas will be prioritized in subsequent phases. CA 35, 28, 19, and 44 scored highly but were not advanced as one of the top eight locations for alternatives development because these areas are under the jurisdiction of MDOT or the Drain Commissioner (CA 35, 19, and 44) or the City is in the process of constructing a project to reduce flood risk in the area (CA 28).

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Table 5-3. Flood scoring results for all flood concern areas.

Concern area	Total score	Location		Concern area	Total score	Location
CA_36[a]	79.26	CSS		CA_56	36.05	MS4
CA_12[a]	64.95	MS4		CA_50	34.77	CSS
CA_38[a]	63.05	CSS		CA_09	34.62	MS4
CA_37[a]	60.81	CSS		CA_20	34.62	MS4
CA_35[b]	55.48	CSS		CA_05	33.94	MS4
CA_34[a]	51.44	CSS		CA_29	33.02	CSS
CA_28[c]	49.21	CSS		CA_01	31.58	MS4
CA_19[d]	49.05	MS4		CA_52	30.18	CSS
CA_45[a]	48.66	CSS		CA_24	28.06	MS4
CA_30[a]	48.20	CSS		CA_22	27.05	MS4
CA_44[c]	47.00	CSS		CA_51	26.05	CSS
CA_10[a]	46.01	MS4		CA_18	25.14	MS4
CA_49	45.40	CSS		CA_48	24.30	CSS
CA_33	45.16	CSS		CA_41	24.17	CSS
CA_31	45.08	CSS		CA_58	20.67	MS4
CA_13	44.46	MS4		CA_16	20.55	MS4
CA_08	43.97	MS4		CA_55	18.85	CSS
CA_43	43.91	CSS		CA_53	18.34	CSS
CA_14	43.59	MS4		CA_40	17.64	CSS
CA_11	42.66	MS4		CA_07	16.47	MS4
CA_42	41.74	CSS		CA_02	16.25	MS4
CA_46	41.74	CSS		CA_27	14.12	MS4
CA_47	41.74	CSS		CA_03	14.04	MS4
CA_21	41.58	MS4		CA_25	14.02	MS4
CA_15	41.02	MS4		CA_17	11.68	MS4
CA_54	40.37	CSS		CA_04	10.65	MS4
CA_23	38.08	MS4		CA_26	9.99	MS4
CA_39	36.84	CSS		CA_57	4.37	MS4
CA_32	36.58	CSS		CA_06	0.00	MS4
Highest-scoring flooding CA (first phase of project evaluations)						
Medium-scoring flooding CA (second phase of project evaluations)						
Lowest-scoring flooding CA (third phase of project evaluations)						

a. Top eight flooding CA selected for alternatives planning.
b. Not selected because area in MDOT jurisdiction and proximity to tunnel.
c. Not selected because City already in the process of constructing a project to reduce flooding in this area.
d. Not selected because area out of City jurisdiction with Ingham County Drain Commissioner.

Eight CAs were selected to remain within the project scope and align with available funding for the WWRP planning project. While the top eight CAs are prioritized for alternatives development, many of the lower-priority CAs will benefit from adjacent projects because of the interconnectivity of the drainage infrastructure. Additionally, the City intends to continue a phased approach for implementation of projects to address lower-priority areas as funding and resources allow. Lower priority CAs will be evaluated in future phases of the project when additional funding becomes available.

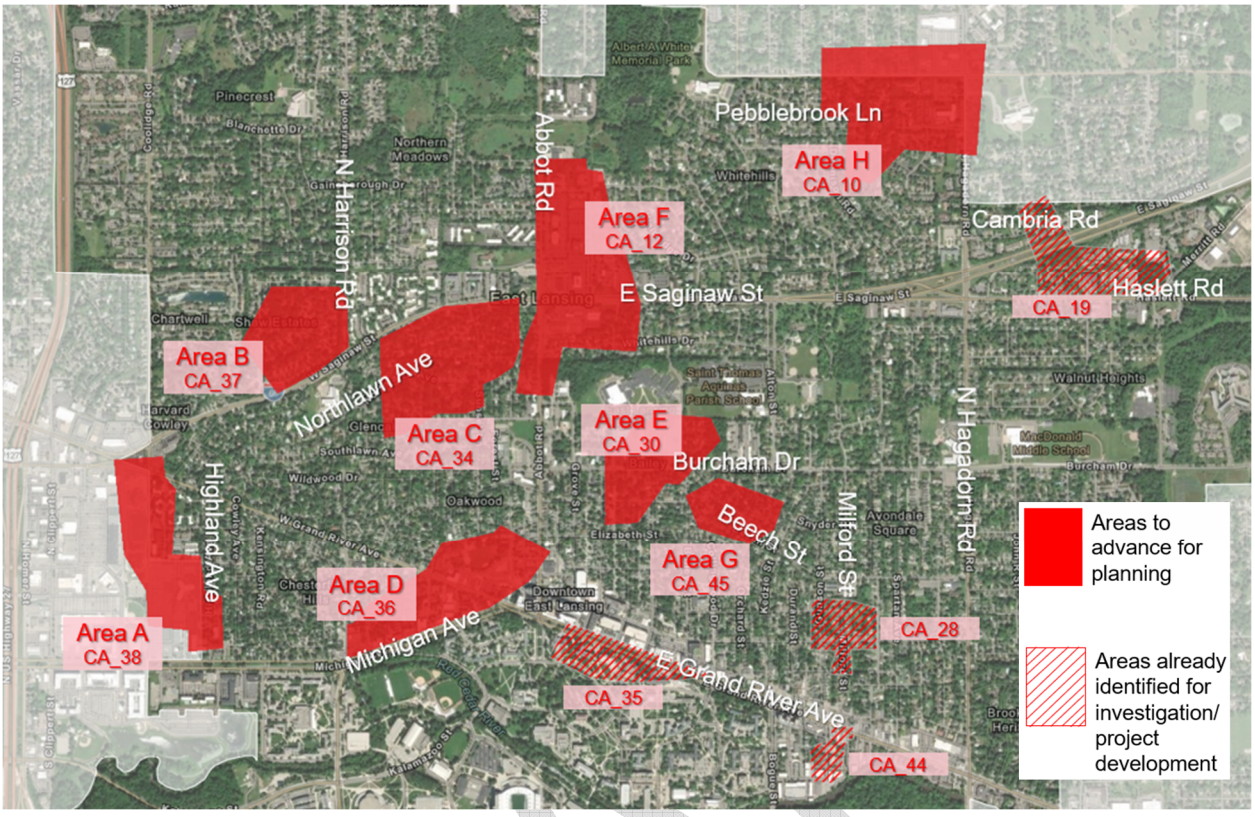


Figure 5-1. Location of the eight proposed priority flooding concern areas.

5.3. Level-of-Service Assessment

LOS provides a measure of performance for the City's stormwater infrastructure system. Various factors impact the LOS for a system including the following:

- Engineering standards at the time of design and construction
- Cost and community affordability
- Customer expectations
- Regulatory requirements
- Existing infrastructure

The existing stormwater conveyance systems in the city consist of combined and separate storm sewers and open-channel drains designed and constructed decades ago. As a result, the system was designed based on historical standards that were intended to address different storm events (i.e., less frequent, less intense events) and for different surface conditions with less impervious surface when the city was less developed. Table 5-4 below provides the existing maximum LOS rain event for each of the identified top eight flooding CAs. These values were determined by incrementally simulating the model for increasing rainfall amounts using the Huff and Angel rainfall estimates for the city (see Section 4.1). The City's historical LOS was based on the 10-year, 1-hour storm at the time of design and is currently being updated in the City's design manual. Because of the effects of climate change, the historical LOS goal in the top eight flooding CAs is

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not being met, as the H&H model indicates potential surface flooding and basement backups when the 10-year, 1-hour storm is simulated.

Table 5-4. Existing maximum level of service for the top eight flooding concern areas.

Flooding CA	Existing maximum LOS (based on Huff and Angel)	Location	Sewer area
A	2-year, 1-hour	Highland Ave. and Westview Ave.	CSS
B	5-year, 1-hour	N Harrison Rd. and E Saginaw St.	CSS
C	2-year, 1-hour	Northlawn Ave.	CSS
D	<1-year, 1-hour	Michigan Ave. and W Grand River Ave.	CSS
E	1-year, 1-hour	Burcham Dr.	CSS
F	<1-year, 1-hour	Abbot Rd. and E Saginaw St.	MS4
G	<1-year, 1-hour	Beech St.	CSS
H	<1-year, 1-hour	Pebblebrook Ln.	MS4

As it is not feasible to design and build a stormwater infrastructure system to manage and convey every storm, it is necessary to define LOS goals that balance design standards, affordability, and equity. Three LOS goals were identified for evaluating and modeling flood risk mitigation alternatives—**Current, Future Climate, and Enhanced**—and are further described in Table 5-5. Out of these three goals, two were selected by the City in the initial-strategies workshop for the purpose of sizing alternatives in the model. A conservative approach was selected for future conditions using the Enhanced LOS goal, as new infrastructure should be designed for many decades in the future. This approach establishes lower and upper LOS bounds, resulting in planning-level alternatives with a range of benefits and costs that will be refined during implementation as project funding and design limitations are better defined. The Enhanced LOS goal is an aggressive design standard that few communities provide.

Table 5-5. Evaluated and selected level-of-service scenarios for alternatives.

	LOS goal	Design storm	Rainfall depth (inches)	Selected for alternatives modeling
1	Current: upgrade localized drainage system consistent with current goal	Current 10-year, 1-hour	2.00	✓
2	Future Climate: upgrade localized drainage system consistent with current goal and based on climate anticipated in the future	2100 10-year, 1-hour (slightly bigger than today's 25-year design storm)	2.40	X
3	Enhanced: enhance localized drainage system to manage a larger design storm, where feasible	2100 16-year, 1-hour (equal to today's 50-year design storm)	2.54	✓

5.4. Social Vulnerability Review

To develop a comprehensive WWRP for the City, it was critical that environmental justice and equity were layered into the existing-conditions assessment and considered as part of the project prioritization. The inclusion of social vulnerability data ensures that economically disadvantaged and historically underinvested areas are considered early and confirms that future capital investments do not neglect these areas. To accomplish this, the Centers for Disease Control and

Prevention (CDC) Social Vulnerability Index (SVI) (CDC/ATSDR SVI, 2020) was used to identify and quantify social vulnerability variability across the city.

The CDC SVI methodology applies social factors centered around the following four core themes:

- Socioeconomic status
- Household composition and disability
- Racial composition and language
- Housing type and transportation

The specific variables across all core themes applied for the City's WWRP are identified in Table 5-6. Unique conditions within the city potentially impacting social vulnerability conditions were also identified and related data applied in the index analysis. As the city houses a large population of college-aged students, the additional variables listed in Table 5-6 below were added to the methodology to more effectively differentiate temporary versus permanent City residents in the analysis.

Table 5-6. SVI variables used for social vulnerability overlay.

CDC SVI variables used	
• Below 150% poverty • Unemployed • Housing cost burden • No high school diploma • No health insurance • Aged 65 and older • Aged 17 and younger • Aged 18 to 24 (positive attribute) • Civilian with disability • Mobile homes • Crowding	• Race: Black or African American alone • Race: American Indian and Alaska Native alone • Race: Native Hawaiian and other Pacific Islander alone • Race: some other race alone • Race: two or more races • Race: Hispanic or Latino • Single-parent households • English language proficiency • Multi-unit structures • No vehicle
Additional variables created	
• Group quarters: college student housing (positive attribute)	• Renter occupied: nonfamily households

The American Community Survey (ACS) 5-year estimates from 2019 to 2023 were applied for the SVI variables to create a numeric index or scores based on census tracts. These scores were normalized and scaled to a 0–100 range to allow for the scoring and ranking of different areas across the city. A social vulnerability map overlay was created to identify where vulnerable neighborhoods overlap with the identified flooding CAs. As shown in Figure 5-2, many of the flooding CAs identified in red overlap with neighborhoods that score high based on the SVI methodology customized for East Lansing. Four of the eight CAs are located within the most socially vulnerable areas of the city. Specifically, CAs B, D, E, and G, which are all CSS areas, are located within the more socially vulnerable areas.

There is also a high-scoring CA, located along Saginaw Highway on the east side of the city and within the Ingham County Drain Commissioner's jurisdiction. The City and the Ingham County Drain Commissioner will continue to discuss improvements in this area. This analysis is intended to not focus efforts of the project solely on flood risk, but rather to take steps to consider the needs of vulnerable and historically underserved populations to the extent feasible with infrastructure improvements.

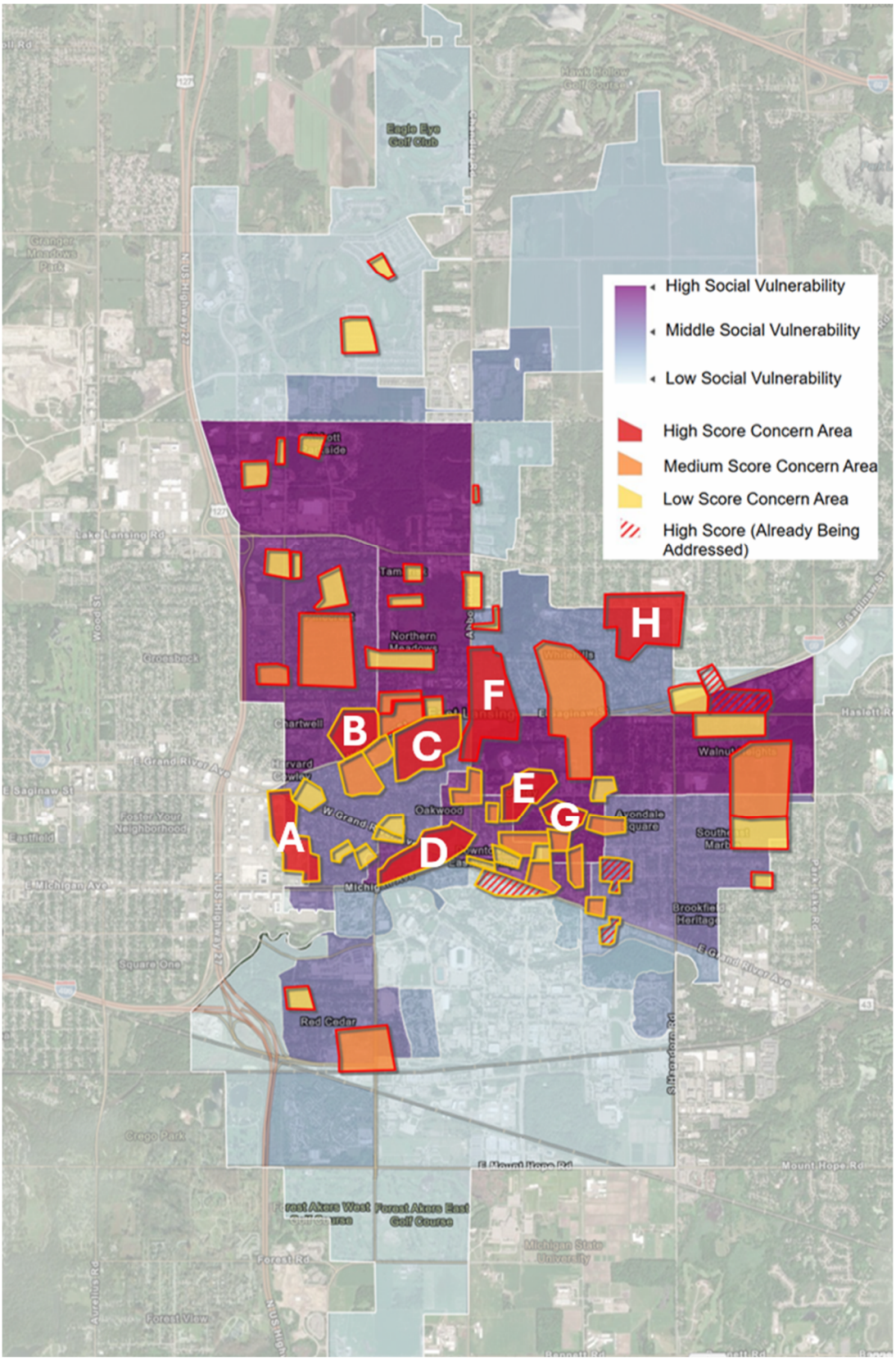


Figure 5-2. Social vulnerability overlay with top eight flooding concern areas.

5.5. Concern Areas and Hydraulic Connections between CSS Watersheds

Understanding how the six flooding CAs are hydraulically connected within the CSS is critical to the development of the flood risk mitigation alternatives, as it allows us to predict the movement of water during intense storm events. Because many of the CAs are within the same connected network, flood risk mitigation in one area will impact the surrounding upstream and downstream areas. Figure 5-3 below shows the primary direction of flow between the watersheds in the CSS model area. On the map, the star icons represent key hydraulic splits in the flow.

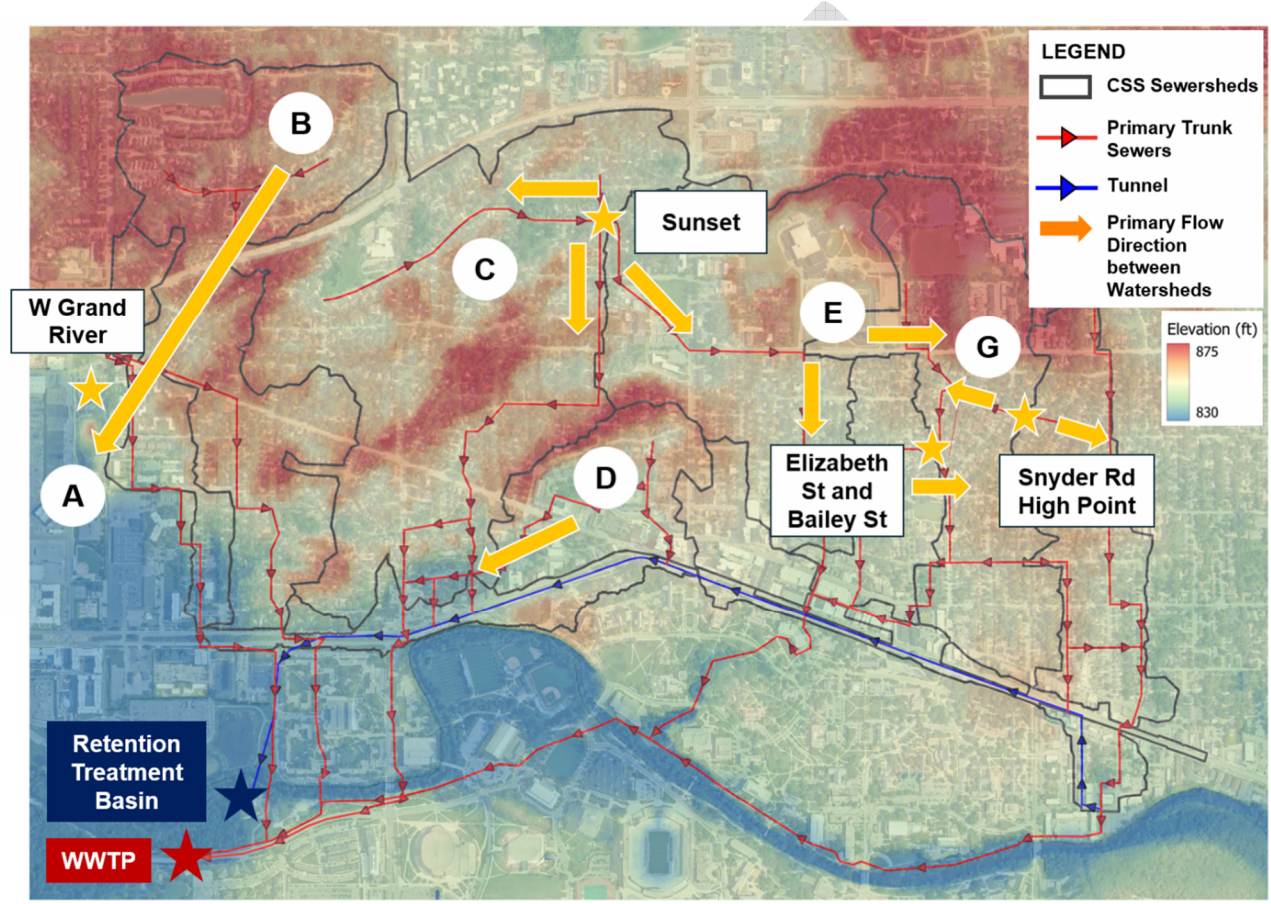


Figure 5-3. Hydraulic connectivity between concern area CSS watersheds.

As shown in the map above, the flooding CAs in the CSS area can be organized into hydraulically connected "systems" or groups:

- CAs A and B are connected
- CAs C, E, and G are connected
- CA D is independent

The hydraulic connections between these watersheds influenced the development of the flood risk mitigation alternatives, which are packages of projects aimed at reducing flooding in one or

more CAs. CAs F and H are not shown on Figure 5-3 as they are within the MS4 area, so they were considered as independent CAs.

5.6. Qualitative Analysis

The existing-conditions assessment quantified the severity within the flooding CAs by estimating flood risk to buildings and roadways using outputs from the model. In addition to the quantitative assessment, it is equally important to examine and understand the existing system qualitatively. Qualitative factors include the following:

- The existing CSS has significant interconnectivity between the identified CAs. This interconnectivity will allow for adjacent CAs to be improved by the flood risk mitigation strategies that target the top eight CAs.
- There are difficulties in the layout of the system in the downtown area of the city that limits the ability to separate stormwater from this portion of the system. The campus of Michigan State University blocks the connection to the Red Cedar River from the Charles Street area. This issue impacts CAs C, E, and G. Additionally, the model indicates that the existing storm trunk sewer along Charles Street and its connection to the tunnel is hydraulically limited during large storm events. During high-flow events, flows can reverse back into Sunset Avenue and surrounding areas. These issues are illustrated in Figure 5-4.

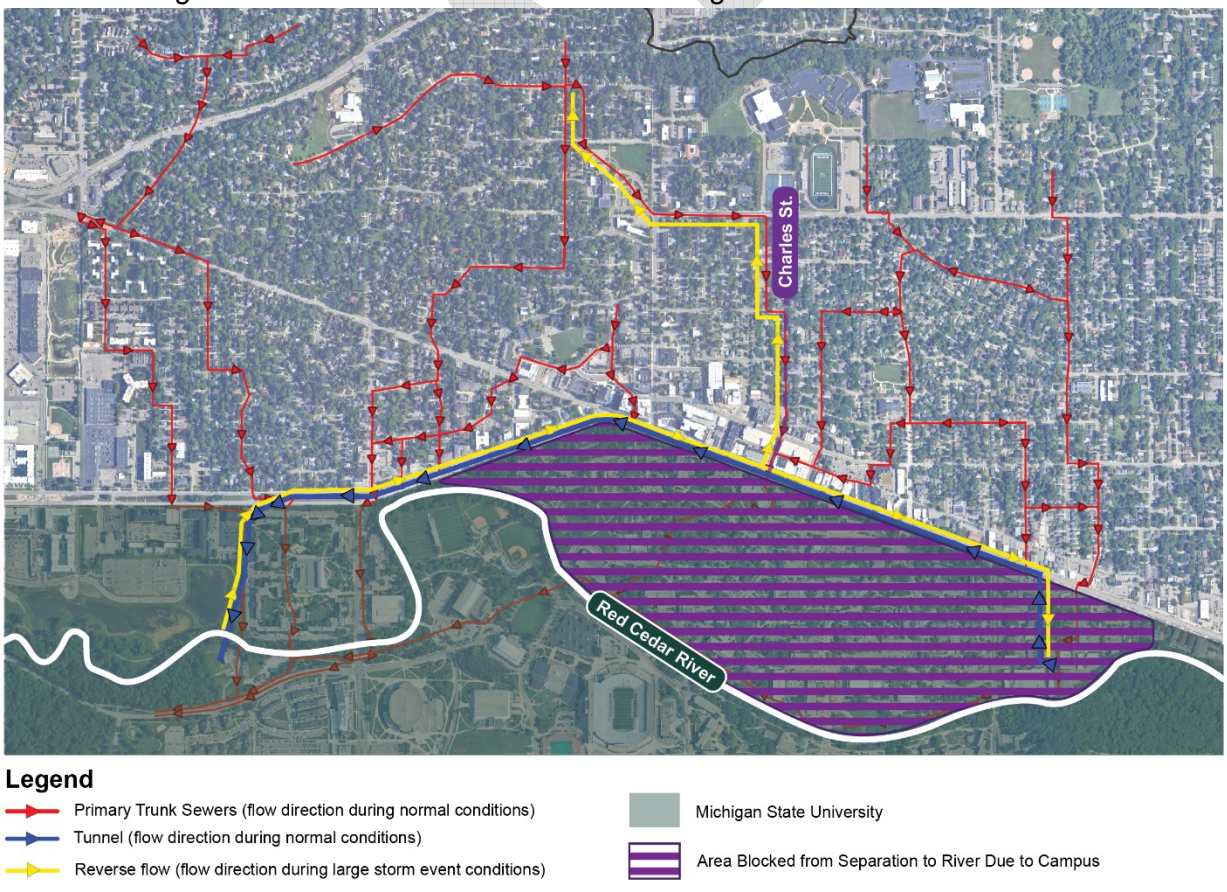


Figure 5-4. The layout of downtown East Lansing limits stormwater separation because the Michigan State University campus divides the Charles Street area from the Red Cedar River.

- Within CAs A and B, separated storm flow to Ranney Park is limited by existing Drain Commissioner agreements and existing infrastructure. These agreements are ongoing and the total volume of stormwater to be separated to Ranney Park will need to be finalized as part of future efforts outside the scope of the WWRP.
- The identification of stormwater storage locations, both above ground and underground, will help by reducing the required pipe size, providing greater LOS, and/or providing water quality benefits.
- The physical topography of the city contributes to difficulties in eliminating surface flooding. For example, low-lying bowl areas of the city, shown in Figure 5-5 may continue to be flood risk areas even after projects are implemented. However, the improvements in the overall system will help to reduce the overall risk of flooding.

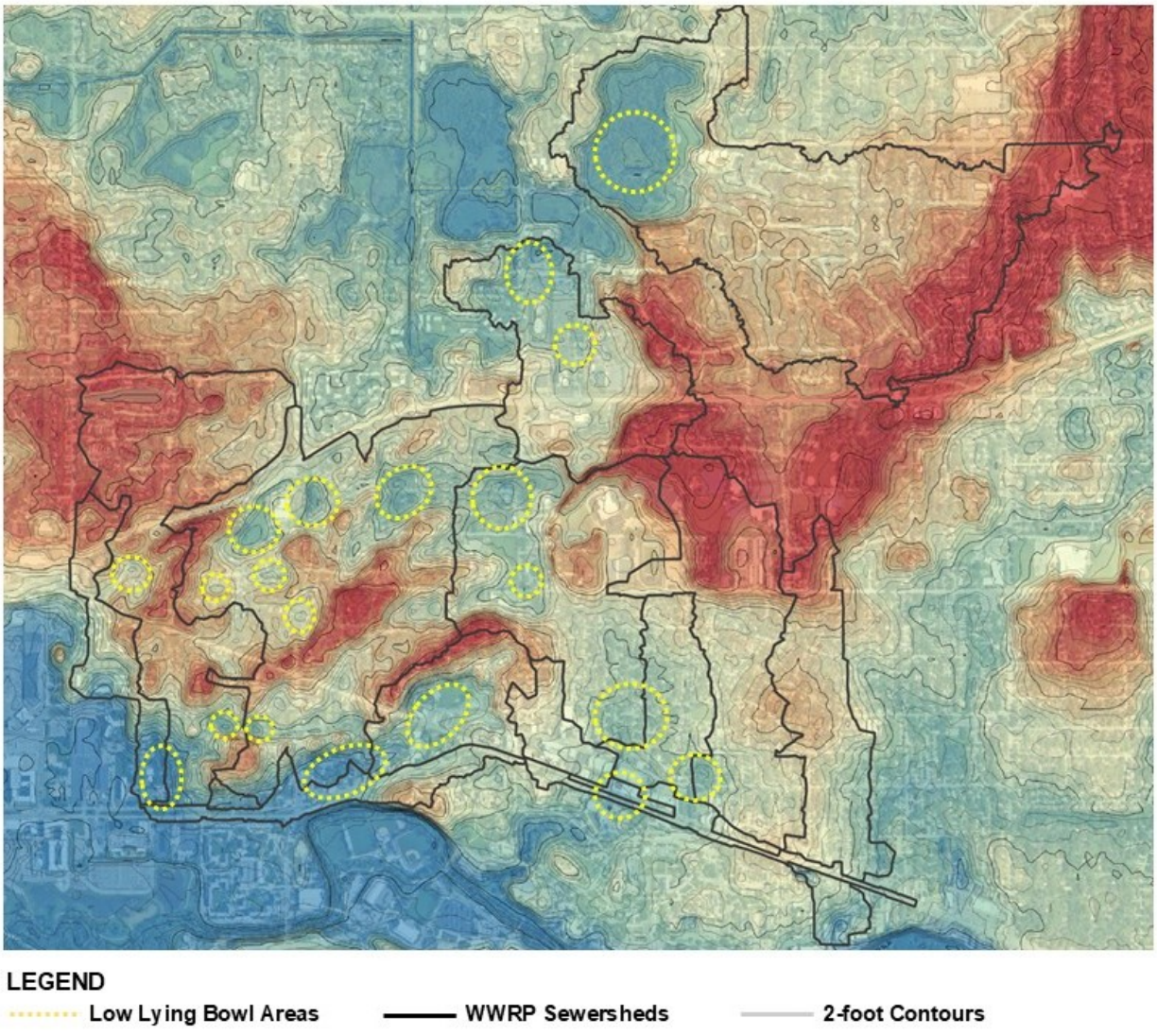


Figure 5-5. Topographic map of the City of East Lansing.

6. ALTERNATIVES DEVELOPMENT AND EVALUATION

The following section provides detailed information regarding the flood risk mitigation strategies that will be used to create alternatives to address the flooding problems in the CAs, the LOS goals for the alternatives, and the list of alternatives developed. The section then compares the increased LOS and the estimated flood risk reduction benefits for each alternative, which then determined the selected alternatives list. Finally, planning-level cost estimates for the selected alternatives are provided and the projects were prioritized based on a set of community-driven criteria.

6.1. Flood Risk Mitigation Strategies

Understanding the root cause of flooding in each of the top eight flooding CAs was vital to developing successful, lasting flood risk mitigation strategies. Unsurprisingly, the root cause of flooding in all eight flooding CAs was that the existing drainage infrastructure is undersized and unable to handle today's storms. Analysis shows that across the system, the existing sewers in the top eight flooding CAs have the capacity for a 2-year to 5-year design storm. This shows that the historical design standards by which the existing system was sized are not adequate for today's climate.

Since the drainage infrastructure is undersized, a mix of strategies is needed to increase the LOS performance in the developed areas of East Lansing to the current and enhanced LOS goals. Four key flood risk mitigation strategies were considered in the development of alternatives; Table 6-1 below provides an overview of each strategy. Within the CSS, sewer separation is the City's preferred strategy over combined sewer upsizing. The developed alternatives did not include in-kind rehabilitation of existing sewers as rehabilitation projects generally involve keeping the same diameter size pipe and maintaining existing capacity.

Table 6-1. Key strategies for flood risk mitigation alternatives.

Strategy	Description
Combined sewer separation	Constructing new storm sewer pipes that run parallel to the existing combined sewer to separate stormwater and sanitary flows. This reduces combined sewer overflows (CSOs) by providing a separate flow path for stormwater to outfall to the river or other receiving systems. This requires the construction of potentially large-diameter new storm trunkline sewers.
Upsizing of pipes	Upsizing of existing combined and separate storm sewer pipes. This is useful in areas where separation alone will not reduce flooding risk. This is also applicable in areas where there is no route to a nearby river for a separate storm sewer or where existing separate storm sewers are also undersized.
Flow diversions or regulator modifications	A modification to a flow regulator, such as the addition of a sewer bulkhead or the removal of a weir, to redirect water within the CSS in different directions. For the alternatives developed, this primarily included lowering weir elevations to increase the capacity of water sent to the CSO tunnel. This helps to optimize the use of existing infrastructure.
Green infrastructure and storage	Aboveground (e.g., stormwater wetlands and detention ponds) or underground storage for stormwater retention. The addition of green infrastructure and storage can provide additional resiliency, or it can reduce required pipe sizes. It also provides water quality benefits and attenuates peak flows to the river and open drain systems. Green Infrastructure is also a community priority and an educational opportunity.

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As shown below in Figure 6-1, extreme weather events fill undersized storm sewers, causing the water level to rise until the risk of surface flooding increases, especially in catch basins with lower elevations. The existing drainage infrastructure in the city, which is undersized, reacts in a similar way. As shown in Figure 6-2, which shows a modeled profile of sewers in the city and represents the actual elevation changes in the city, the existing storm sewer completely fills with water (the water level is shown by the red line, which represents the hydraulic grade line), causing stormwater to rise up the manholes (vertical lines). This causes surface flooding, especially in areas of the city at low elevations. The lack of available capacity in the drainage system not only increases the risk of surface flooding, but it also increases the risk of basement flooding in combined sewer areas. The flood risk mitigation strategies above aim to increase the available capacity in the storm sewers to reduce the risk of flooding.

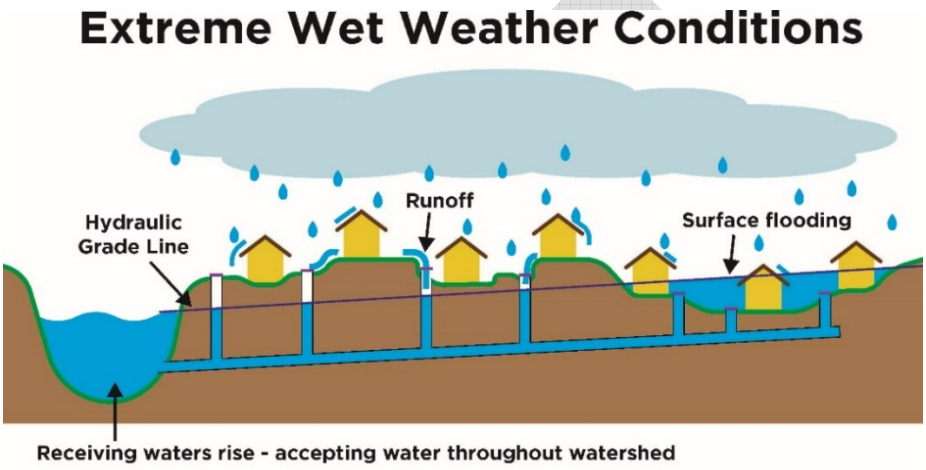


Figure 6-1. Example of surface flooding during extreme wet weather conditions.

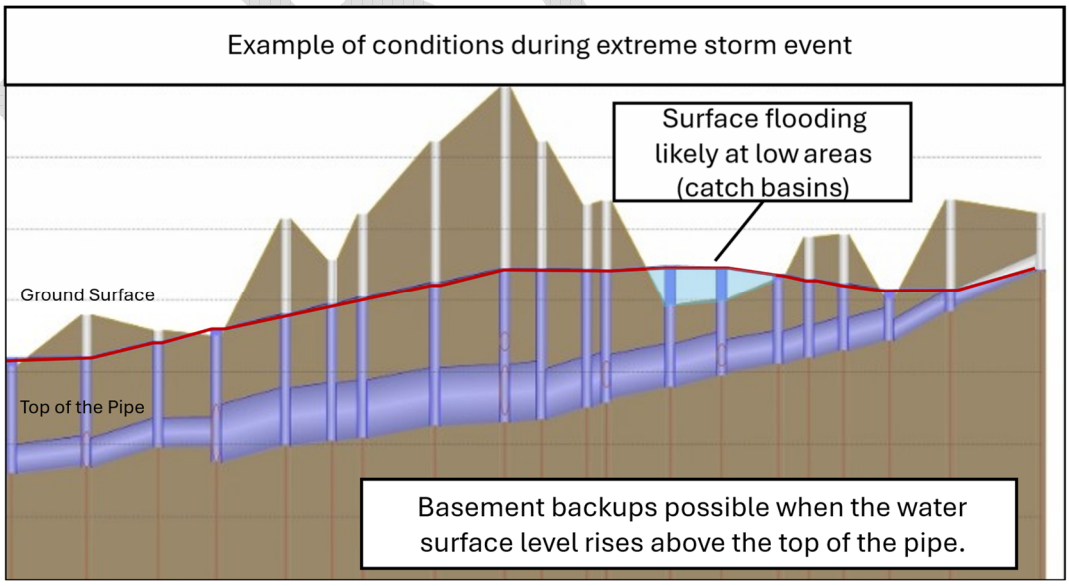


Figure 6-2. Hydraulic grade line (water level) profile showing the impacts of an undersized combined sewer during an extreme storm event.

Community representatives indicated a strong desire for green infrastructure to be incorporated into the alternatives. As a result, several opportunities for green infrastructure and storage facilities were identified, mainly from available City-controlled properties. In general, privately owned parcels were not studied extensively for green infrastructure and storage opportunities because of a lack of property control to easily implement projects. The one exception to this approach are the privately held commercial properties in the Saginaw/Abbot Commercial Area discussed below. This area has an extremely high level of impervious cover within large surface-level parking areas and generates a significant amount of runoff within the H&H model. Opportunities for impervious cover reduction and/or storage may exist in this area and should be explored further as redevelopment opportunities arise. This solution will reduce the amount of runoff in the system and will reduce the size and cost of the upsized sewers needed to provide a higher level of service to this area.

The potential green infrastructure and storage are shown in Figure 6-3 and are located at:

- Gordon Guyer Park
- Glencairn Park
- Valley Court Park
- Saginaw/Abbot Commercial Area
- Albert A. White Memorial Park
- Harrison Meadows Park and open areas west of Abbot Road
- The Fire Department
- Ranney Park

It should be noted that Ranney Park is currently constructed and owned and operated by the Ingham County Drain Commissioner (Montgomery Drainage District). Any stormwater management within Ranney Park would require an agreement to be in place before sending stormwater to this area. As part of the construction of Ranney Park, the City proactively worked with the Drain Commissioner to allow for future additional stormwater offloading into the park as part of the design. Final agreements must be formalized prior to using this park for the City's stormwater management goals.

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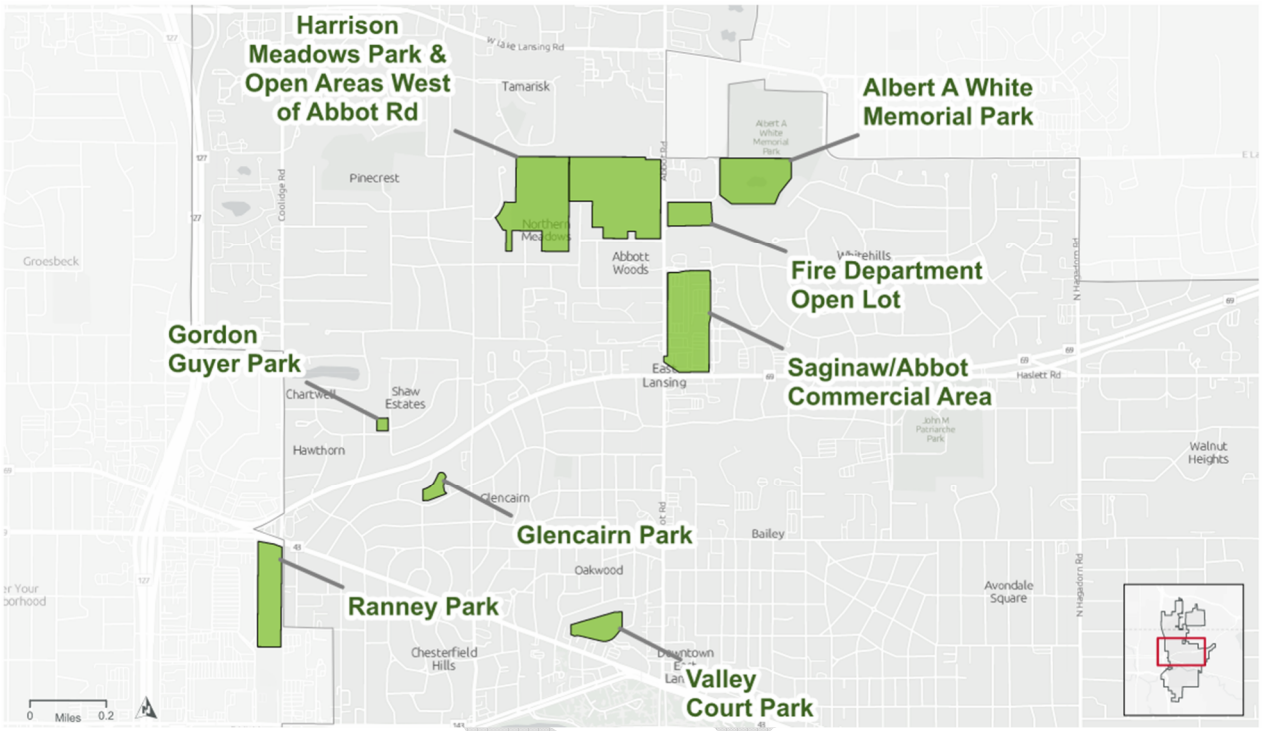


Figure 6-3. Map showing the location of identified opportunities for green infrastructure/storage opportunities.

6.2. Level-of-Service Goals for Evaluation

It is not feasible to build a drainage system to convey every storm or extreme storms. However, updated design storms that better reflect current and future climate conditions including more frequent design storms with impacts on the City allow for a detailed evaluation of different LOS goals and anticipated system performance. The Current LOS goal is defined as a 10-year, 1-hour design storm of 2.00 inches. The Enhanced LOS goal is defined as a 50-year, 1-hour design storm of 2.54 inches, which is equivalent to future 16-year, 1-hour design storm in the year 2100. As shown in Figure 6-4 below, these LOS goals are an increase compared to the previous LOS goal.

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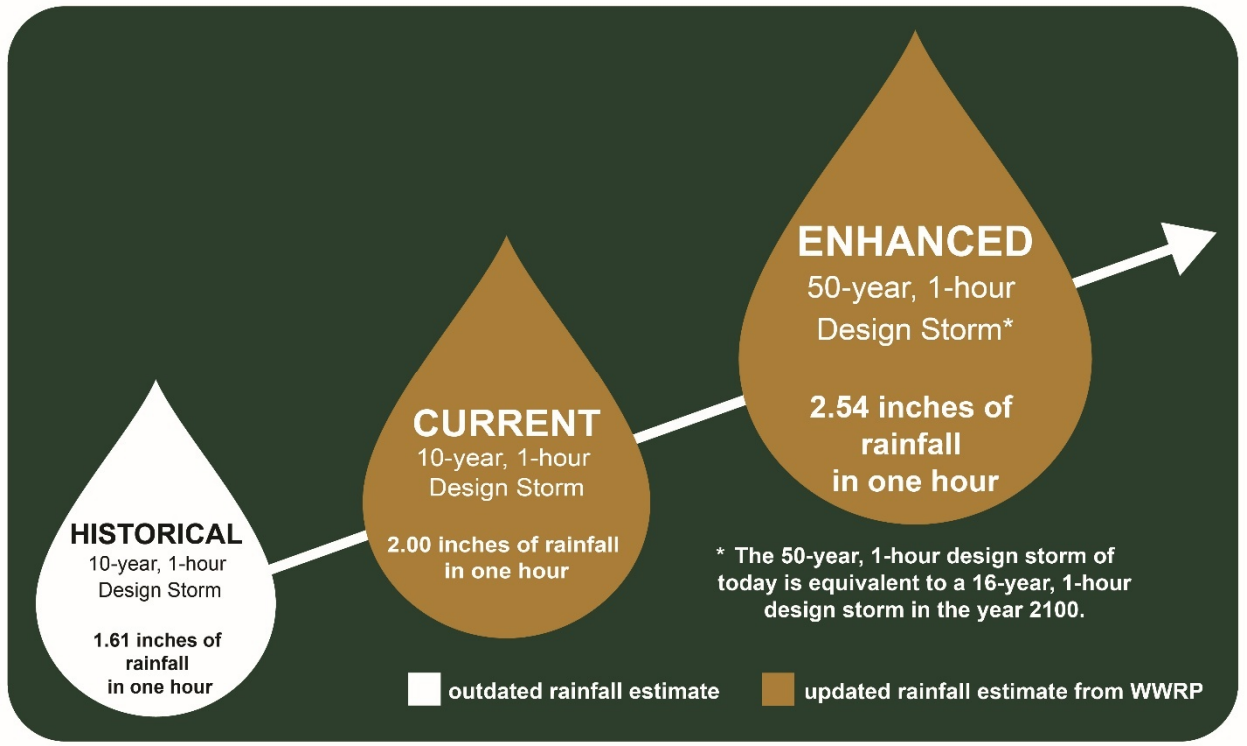


Figure 6-4. LOS goals and corresponding design storms.

The current 10-year, 1-hour storm is in the process of being adopted into the City's updated stormwater codes and ordinances. This design storm is representative of the storms that currently have the greatest impact on surface flooding in the City. The future 16-year, 1-hour storm, which is roughly equivalent to the current 50-year design storm, is intended to proactively account for climate change when considering making long-term capital investments in the City's drainage infrastructure.

Each alternative is then simulated within the H&H model for each design storm to evaluate the performance against the LOS goals. To identify whether an alternative meets the current or enhanced LOS goals, they must meet the following criteria:

- **Within the CSS:** The LOS goals are met if the hydraulic grade line (HGL) is 8.5 feet below ground at either or both ends of the pipe. Alternatively, the LOS goals are met if the surcharge in the pipe is less than 1.0 foot above the pipe crown.
    - This criterion is intended to keep water levels in the sewer below an elevation where basement flooding from sewer backup may pose a risk. Additionally, this criterion has been used in previous evaluations and planning efforts for the CSS.
- **Within the MS4:** The LOS goals are met if there is no manhole flooding onto the surface.

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6.3. Alternatives Developed for Evaluation

Based on the hydraulic connectivity of the top eight flooding CAs, locations for the four key flood risk reduction strategies, and opportunities for green infrastructure/storage, six alternatives were developed for analysis. These alternatives comprise a group of smaller projects grouped into a larger alternative and are described below in Table 6-2.

Table 6-2. Summary of developed alternatives for evaluation.

Alternative	Description
Alternative 1: West Central Neighborhoods Combined Sewer Relief	This project would separate stormwater from the sewer mains and offload the stormwater to Ranney Park. This will require the construction of a storm main to convey the separated stormwater. Upsizing existing combined sewer lines along Glenmoor Road and Oakridge Avenue and adding new combined sewers will help to relieve remaining bottlenecks.
Alternative 2: Valley Court Corridor Combined Sewer Relief	This project would separate stormwater from the sewer mains and offload the stormwater to the Red Cedar River. This will require the construction of a storm main to convey the separated stormwater. Upsizing the existing combined sewer line along Valley Court, Hillcrest Avenue, Elm Place, and Elm Street and adding new combined sewers will help to relieve remaining bottlenecks.
Alternative 3: Downtown Neighborhoods Combined Sewer Relief (Harrison Road route)	This project would separate stormwater from the sewer mains and offload the stormwater to the Red Cedar River. It includes the upsizing of existing combined sewer lines to relieve remaining bottlenecks, and the construction of new combined mains. This project also includes the construction of underground stormwater storage facilities at Gordon Guyer Park and Glencairn Park.
Alternative 4: Downtown Neighborhoods Combined Sewer Relief (Sunset Avenue route)	This project would achieve all the same flood reduction benefits as Alternative 3. However, the proposed storm main is approximately 2x the length to route around a high-elevation area of the city.
Alternative 5: Abbot and Saginaw Storm Drainage Improvement	This project includes the upsizing of existing storm pipes to relieve bottlenecks in the area. It also includes stormwater storage opportunities at Harrison Meadows Park and in an open lot at the Fire Department.
Alternative 6: Whitehills Drainage Improvement	This project includes the upsizing of existing storm pipes to relieve bottlenecks in the area. It also includes stormwater storage opportunities at Albert A. White Memorial Park through the expansion of an existing fishing pond.

For more detail on each developed alternative, refer to the following sections which provide descriptions of each alternative and the proposed bundled projects and key components. For a detailed methodology of the development of each alternative, refer to the Task 8: *Evaluation of Flood Mitigation Alternatives* technical memorandum in Appendix F.

The public infrastructure upgrades described in each alternative will not prevent private property flooding. These alternatives were developed to reduce flooding risk for public infrastructure – the area within the City's jurisdiction, sphere of influence, and legal spending authority. There are several flood risk reduction strategies that private-property owners can take, which are described in Section 7.2.

6.3.1. ALTERNATIVE 1

Alternative 1, the West Central Neighborhoods Combined Sewer Relief, was developed to mitigate flood risk in CAs A and B. These areas are located on the west side of the city, with CA A being south of W Grand River Avenue and CA B near the intersection of N Harrison Road and

W Saginaw Street. As CA B contributes flow to CA A, improvements within CA B also benefit CA A downstream.

A key component of Alternative 1 is the ability to offload separated stormwater from the CSS and convey this stormwater to a receiving waterway. CA A has four existing stormwater connections into Ranney Park, which is part of the Montgomery Drainage District, controlled by the Ingham County Drain Commissioner. The current agreement allows the City to convey up to 66 million gallons per day (mgd) via four stormwater connections into Ranney Park, where it ultimately flows to the Montgomery Drain and into the Red Cedar River. However, preliminary results show that the amount of stormwater separation required to meet the Current LOS may exceed 66 mgd. As a result, it is proposed to convey all or a portion of CA B's stormwater flows to the east, toward Harrison Road, via the proposed stormwater mains detailed in Alternatives 3 and 4. Therefore, Alternative 1 requires the implementation of either Alternative 3 or 4 to increase the LOS.

To meet the Current LOS, the following group of projects are proposed as **Alternative 1a**:

- **Stormwater separation:** Stormwater separation is proposed to convey stormwater to a new storm main, as opposed to relying on the existing combined system to convey all the flow. If paired with Alternative 3, this would require approximately 69 acres of separation. If paired with Alternative 4, this would require approximately 79 acres of separation.
- **New storm main:** 3,400 feet of new storm main is proposed to convey stormwater from CAs A and B to Ranney Park and the Montgomery Drain. A 36-inch-diameter storm main would extend from Chartwell Carriage Way S along Touraine Avenue and Glenmoor Road.
- **Upsized combined pipes:** Two segments of the existing combined sewers are proposed to be replaced with upsized combined pipes. A 30-inch-diameter sewer would replace the existing 24-inch-diameter combined sewer along Glenmoor Road and Oakridge Avenue, and the existing 15- and 18-inch-diameter combined sewer along Cowley Avenue would be replaced with a combination of 36- and 42-inch-diameter combined sewer.
- **New combined pipes:** 725 feet of new, 36-inch-diameter combined sewer is proposed to connect the upsized combined sewer on Oakridge Avenue to the upsized combined sewer on Cowley Avenue.
- **Structure modifications**: Three structure modifications are proposed in Alternative 1a to achieve the Current LOS. First, the removal of an existing flow restrictor at the intersection of Grand River Avenue and Coolidge Road is proposed. Additionally, two new bulkheads are required to connect the new combined sewers on Oakridge Avenue and Cowley Avenue to the upsized combined pipes.

For additional resiliency and to meet the Enhanced LOS (current 50-year/future 16-year, 1-hour design storm), Alternative 1a can be expanded to include the following as **Alternative 1b**:

- **Stormwater separation:** An additional 7.7 acres of stormwater separation with Alternative 3, or an additional 29.4 acres of separation with Alternative 4, can be included to convey additional flow to Ranney Park.
- **New storm main:** The storm main section from Chartwell Carriage Way S along Touraine Avenue and Glenmoor Road would be upsized to 54-inch-diameter storm main.

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6.3.2. ALTERNATIVE 2

Alternative 2, the Valley Court Corridor Combined Sewer Relief, was developed to mitigate flood risk in CA D. This area is located within the combined sewer area of East Lansing, west of downtown, on either side of Grand River Avenue. This area is an independent watershed, so it is not significantly impacted by other alternatives.

A key component of Alternative 2 is the ability to offload separated stormwater from the CSS and convey this stormwater to the receiving waterway. Near CA D there is opportunity to tie into an existing MS4 outfall to the Red Cedar River near Beal Street. The outfall currently serves the 18- and 24-inch-diameter storm sewer along Michigan Avenue and could be redesigned to avoid adding a second stormwater outfall in close proximity. Further detailed engineering beyond the scope of this study would be required.

To meet the Current LOS, the following group of projects are proposed as **Alternative 2a**:

- **Stormwater separation:** Approximately 78 acres of stormwater separation is proposed to convey stormwater to a new storm main.
- **New storm main:** 2,750 feet of new storm main is proposed to convey stormwater to the Red Cedar River. This includes 32- and 54-inch-diameter pipe along Valley Court, Delta Street, and Michigan Avenue.
- **Upsized combined pipes:** 1,970 feet of combined sewer upsizing is proposed. This would replace the existing 27-inch-diameter, 24-by-30-inch-diameter ellipse, and 36-inch-diameter combined sewer along Valley Court, Hillcrest Avenue, Elm Place, and Elm Street with a 36-inch-diameter sewer.
- **New combined pipes:** 630 feet of new 36-inch-diameter combined sewer along Louis Street and Michigan Ave would connect a proposed regulator at Louis Street to the combined sewer overflow (CSO) tunnel.
- **Structure modifications:** Two structure modifications are proposed in Alternative 2a to achieve the Current LOS. First, the removal of an existing flow restrictor at Beal Street is proposed. The removal of this weir would allow more flow from the overflow sewer to enter the CSO tunnel. Additionally, a regulator with a weir is proposed at Louis Street to control flow into the CSO tunnel.

For additional resiliency, Alternative 2a can be expanded to include the following as **Alternative 2b**:

- **Stormwater separation:** An additional 11.5 acres of stormwater separation to the northwest of CA D is proposed.
- **New storm main:** To achieve additional resiliency, the proposed storm main would be upsized to 36- and 60-inch-diameter pipe.

It should be noted that Alternative 2b would not fully achieve the Enhanced LOS (future 2100 16-year, 1-hour design) because of downstream hydraulic flow constraints that make achieving the Enhanced LOS technically infeasible. However, the LOS for Alternative 2b is predicted to be

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greater than the Current 10-year, 1-hour storm. This compares to a current estimated LOS of less than 1-year, 1-hour storm.

Within CA D, there is an opportunity for underground storage at Valley Court Park. The footprint of the park could provide an estimated storage volume of 2.4 million gallons.

6.3.3. ALTERNATIVE 3

Alternative 3, the Downtown Neighborhoods Combined Sewer Relief (Harrison Road route), was developed to mitigate flood risk within CAs B, C, E, and G, within the CSS. As CAs C, E, and G are hydraulically connected, improvements have the potential to benefit adjacent CAs. As discussed in Alternative 1, improvements in CA B would also benefit CA A.

A key component of Alternative 3 is the ability to offload separated stormwater from the CSS and convey this stormwater to a receiving waterway. Under Alternative 3, separated flows from CAs B and C are conveyed via a new storm main along N Harrison Road to the Red Cedar River. An existing CSO outfall to the Red Cedar River serves the storm sewer along Michigan Avenue and provides relief for the 60-inch-diameter combined sewer along Harrison Road. This outfall can potentially be redesigned to avoid adding another stormwater outfall in close proximity. Further detailed engineering beyond the scope of this study would be required.

Separation of stormwater flows tributary to Charles Street was not considered as part of the alternatives planning process because of a lack of a viable stormwater outfall, as it would require crossing the Michigan State University campus to reach the Red Cedar River. Instead, modifications to existing CSS infrastructure are proposed to maximize the use of existing assets.

To meet the Current LOS, the following group of projects are proposed as **Alternative 3a**:

- **Stormwater separation:** Approximately 92 acres of stormwater separation is proposed to convey stormwater to a new storm main.
- **New storm main:** 5,200 feet of new storm main is proposed to convey stormwater to the Red Cedar River. This includes 36-, 54-, and 60-inch-diameter storm main along N Harrison Road. As this route would go through a high-elevation area, the maximum bury depth of this pipe would be upwards of 35 to 40 feet. This would be a deep, costly main to install, but the benefits that it provides to offload stormwater from downstream CSS areas to the east would also be significant.
- **Upsized combined pipes:** 7,050 feet of combined sewer upsizing is proposed. This would replace the existing 48-, 54-, and 60-inch-diameter combined sewer along Charles Street with 72- and 84-inch-diameter sewer. This would also replace the 12-inch-diameter combined sewer along Bailey and Linden streets with 42- and 54-inch-diameter sewer.
- **New combined pipes:** 875 feet of new combined sewer is proposed. This includes 42-inch-diameter combined sewer along Bailey Street and 42-inch-diameter combined sewer along Burcham Drive.
- **Structure modifications:** Three structure modifications are proposed. This includes three new sewer bulkheads: one on Burcham Drive on the 36-inch-diameter combined sewer to redirect flow from the east to the new combined sewer along Bailey Street, one on Burcham

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Drive to redirect flow from the south to the new combined sewer along Bailey Street, and one on Elizabeth Street on the 24-inch-diameter combined sewer to remove the interconnection and keep flows within the upsized Bailey Street combined sewer.

For additional resiliency and to meet the Enhanced LOS (current 50-year/future 16-year, 1-hour design storm), Alternative 3a can be expanded to include the following as **Alternative 3b**:

- **Stormwater separation:** An additional 186.5 acres of stormwater separation is proposed. This additional separation would be near East Lansing High School along Burcham Drive and around Glencairn Elementary School.
- **New storm main:** To achieve additional resiliency, the proposed storm main would be upsized to 48-, 66-, and 84-inch-diameter storm main pipe.

Within CAs B and C, there is an opportunity for underground storage at Gordon Guyer Park and Glencairn Park. The footprint of the parks could potentially provide a combined storage volume of 2.2 million gallons and would reduce the required storm main diameter for the Enhanced LOS to 48, 60, and 66 inches.

Though this alternative does not include stormwater separation directly on Northlawn Avenue, which has experienced several instances of surface flooding in recent years, the hydraulic connectivity of this area means that the stormwater separation projects in this alternative will also reduce flooding risk on Northlawn Avenue. Figure 6-5 below shows the modeled flood risk reduction in the area with and without Alternative 3b. The red line represents the hydraulic grade line, or modeled water level during a 10-year, 1-hour design storm in the existing system. The green line represents the predicted water level following the implementation of Alternative 3b. As shown, despite there being no stormwater separation directly on Northlawn Ave, the H&H model shows a reduced flooding risk in the area.

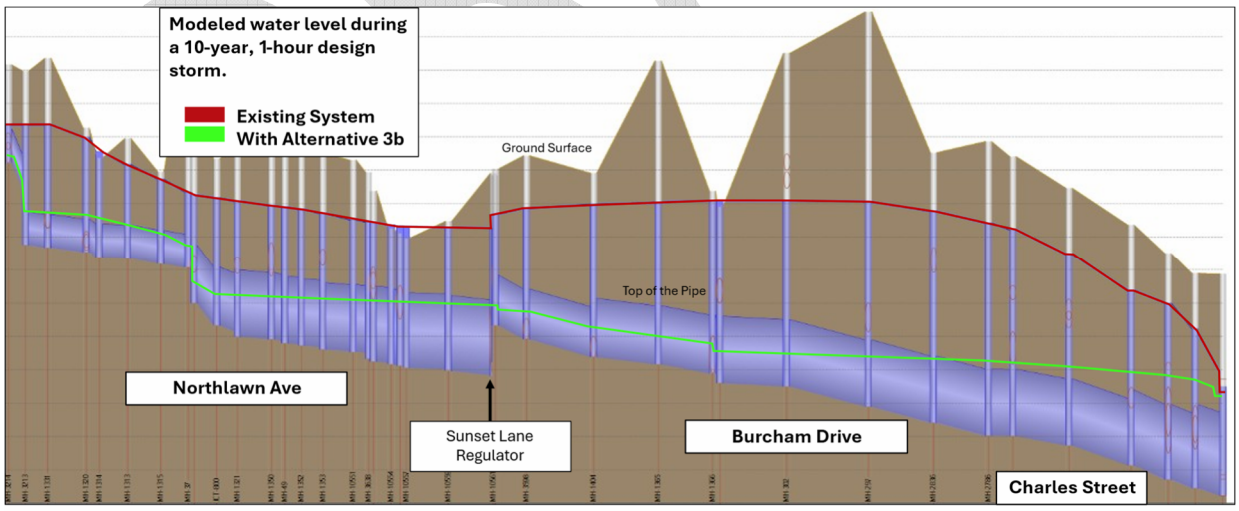


Figure 6-5. Comparison between the hydraulic grade line (water level) during a 10-year, 1-hour design storm in the existing combined sewer system (red) and the system with the improvements in Alternative 3b (green).

6.3.4. ALTERNATIVE 4

Alternative 4, the Downtown Neighborhoods Combined Sewer Relief (Sunset Avenue route), addresses the same CAs as Alternative 3. However, the major difference between the two alternatives is the route of the new storm main to the receiving water source at the Red Cedar River. As the two alternatives share similar projects, both Alternatives 3 and 4 would not be implemented. Rather, the recommended alternatives within the WWRP should select the best option between the two alternatives.

A key component of Alternative 4 is the ability to offload separated stormwater from the CSS and convey this stormwater to the receiving waterway. Separated flows from the north and east portions of CAs B and C can be conveyed via a new storm main following the existing route of the combined sewer from Longfellow Drive, Northlawn Avenue, Marshall Street, to Beal Street. An existing MS4 outfall to the Red Cedar River near Beal Street that serves the 18- and 24-inch-diameter storm sewer along Michigan Avenue can be redesigned to avoid adding another stormwater outfall in close proximity. This new stormwater outfall would also need to include capacity for stormwater flows from Alternative 2 (CA D) to avoid adding another stormwater outfall in close proximity. Further detailed engineering beyond the scope of this study would be required.

As discussed in Alternative 3, separation of stormwater flows to Charles Street was not considered as part of the alternatives planning process because of a lack of a viable stormwater outfall, as it would require crossing the Michigan State University campus to reach the Red Cedar River.

To meet the Current LOS, the following group of projects are proposed as **Alternative 4a**:

- **Stormwater separation:** Approximately 101 acres of stormwater separation is proposed to convey stormwater to a new storm main.
- **New storm main:** 10,500 feet of new storm main is proposed to convey stormwater to the Red Cedar River. This includes 48-, 54-, 72-, and 84-inch-diameter storm main along Longfellow Drive, Northlawn Avenue, and Marshall Street to Beal Street.
- **Upsized combined pipes:** 7,050 feet of combined sewer upsizing is proposed. This would replace the existing 48-, 54-, and 60-inch-diameter combined sewer along Charles Street with 72- and 84-inch-diameter sewer. This would also replace the 12-inch-diameter combined sewer along Bailey and Linden streets with 42- and 54-inch-diameter sewer. Additional upsizes would include upsizing the following combined sewer pipes to 24 inches: the 12- and 15-inch-diameter combined sewer along Old Hickory Lane, the 12- and 18-inch-diameter combined sewer along Sunset Lane, the 18-inch-diameter combined sewer along Collingwood Drive, and the 12-inch-diameter combined sewer along Butterfield Drive.
- **New combined pipes:** 875 feet of new combined sewer is proposed. This includes 42-inch-diameter combined sewer along Bailey Street and 42-inch-diameter combined sewer along Burcham Drive.
- **Structure modifications:** Three structure modifications are proposed. This includes three new sewer bulkheads: one on Burcham Drive on the 36-inch-diameter combined sewer to redirect flow from the east to the new combined sewer along Bailey Street, one on Burcham Drive to redirect flow from the south to the new combined sewer along Bailey Street, and one

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on Elizabeth Street on the 24-inch-diameter combined sewer to remove the interconnection and keep flows within the upsized Bailey Street combined sewer.

For additional resiliency and to meet the Enhanced LOS (current 50-year/future 16-year, 1-hour design storm), Alternative 4a can be expanded to include the following as **Alternative 4b**:

- **Stormwater separation:** An additional 165 acres of stormwater separation is proposed. This additional separation would be near East Lansing High School along Burcham Drive and around Glencairn Elementary School.
- **New storm main:** To achieve additional resiliency, the proposed storm main would be upsized to 54-, 84-, and 96-inch-diameter storm main pipe.

Within CA C, there is an opportunity for underground storage at Glencairn Park, Shaw Park, and the Hannah Community Center. The combined footprint of these areas could potentially provide 4.6 million gallons of storage and would reduce the required storm main diameter for the Enhanced LOS to 54, 60, and 80 inches.

The flood risk reduction benefits would be the same as Alternative 3. However, as shown in Figure 6-6 below, the pathway of the new storm main would be nearly twice the length to avoid the deep bury depth required in Alternative 3 to pass through an area of high elevation. This increase in required pipe length would greatly increase the cost for the alternative projects. Additionally, the pathway of the new storm main would pass through a residential area of the City and would be significantly more disruptive to the community. For these reasons, Alternative 4 was ultimately not selected for further evaluation during discussions with the City.

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Figure 6-6. Storm trunkline comparison between Alternative 3 (blue) and Alternative 4 (orange).

6.3.5. ALTERNATIVE 5

Alternative 5, Abbot and Saginaw Storm Drainage Improvement, was developed to mitigate flood risk in CA F, which is in the MS4 area of the City. CA F is a hydraulically independent watershed that contributes stormwater flow to the Taylor Drain, which then flows into the Sanderson Branch of the Remey-Chandler Drain.

A key component of Alternative 5 is its ability to store and detain stormwater during large rainfall events with nature-based approaches such as ponds and stormwater wetlands. Storage in these areas would allow for the ability to attenuate peak flows, enhance water quality, and provide potential recreational opportunities such as additional trail connections along the Northern Tier Trail. Downstream of CA F there are several aboveground natural stormwater storage opportunities including the open area north of the fire station, at Harrison Meadows Park, and within the open lots west of Abbot Road.

To meet the Current LOS, the following group of projects are proposed as **Alternative 5a**:

- **Upsized storm sewers:**
    - 7,860 feet of the existing storm sewer would be upsized. The existing 42-inch-diameter, 43-by-68-inch ellipse, 48-by-76-inch ellipse, and 58-by-91-inch ellipse storm sewer along Abbot Road to Kendale Boulevard would be replaced with a 60-by-144-inch box culvert and a 48-by-168-inch box culvert.
    - The existing 18-, 24-, 27-, 30-, 36-, 42-, 48-, and 54-inch-diameter storm sewers within the commercial areas north and south of E Saginaw Street would be replaced with 24-, 30-, 36-, 48-, and 54-inch-diameter storm sewer.
    - The existing 21-inch-diameter culvert along Woodland Pass at Kendale Boulevard would be replaced by 30-inch-diameter storm sewer.
- **Stormwater storage:** The open surface areas north of the fire station, Harrison Meadows Park, and open areas west of Abbot Road would provide approximately 1.2 million gallons of stormwater attenuation and offset increased peak flows from the upsized storm sewers.

For additional resiliency and to meet the Enhanced LOS (current 50-year/future 16-year, 1-hour design storm), Alternative 5a can be expanded to include the following as **Alternative 5b**:

- **Upsized storm sewers:** The storm sewer along Abbot Road to Kendale Boulevard would be increased to a 48-by-168-inch box culvert and a 60-by-240-inch box culvert. Additionally, the storm sewer in the commercial areas north and south of E Saginaw Street would be upsized to 30-, 36-, 42-, and 54-inch-diameter storm sewer.
- **Stormwater storage:** The open surface areas north of the fire station, Harrison Meadows Park, and open areas west of Abbot Road can be added for a total of 1.7 million gallons of storage to attenuate and offset increased peak flows from the upsized storm sewers.

There is an opportunity to potentially add 1.31 million gallons of underground stormwater storage beneath the parking lots in the surrounding commercial areas. However, this would require collaboration with the private property owners. See Section 7.2 for discussion of important considerations regarding voluntary private property stormwater programs that would need to be implemented for storage under privately owned parking lots.

6.3.6. ALTERNATIVE 6

Alternative 6, Whitehills Drainage Improvement, was developed to mitigate flood risk within CA H, located in the MS4 area of the City. CA H is a hydraulically independent watershed that contributes stormwater flow to the Taylor Drain, which then flows into the Sanderson Branch of the Remey-Chandler Drain.

A key component of Alternative 6 is its ability to store and detain stormwater during large rainfall events with nature-based approaches such as ponds and stormwater wetlands. Storage in these areas would allow for the ability to attenuate peak flows, enhance water quality, and provide potential recreational opportunities such as additional trail connections within Albert A. White Memorial Park. Downstream of CA H there is an opportunity for aboveground stormwater storage through the expansion of the Albert A. White Memorial Park fishing pond.

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To meet the Current LOS, the following group of projects are proposed as **Alternative 6a**:

- **Upsized storm sewer:** 4,601 feet of the existing storm sewer would be upsized. The existing 18-, 24-, 30-, 36-, 48-, and 54-inch-diameter storm sewer along N Hagadorn Road, Applegate Lane, and Pebblebrook Lane would be upsized to 24-, 36-, and 54-inch-diameter storm sewer.
- **Stormwater storage:** The open area surrounding the Albert A. White Memorial Park fishing pond would provide approximately 0.2 million gallons of storage to attenuate and offset increased peak flows from the upsized storm sewers.
- **Structure modifications:** It is proposed to remove the 7.5-inch flow restrictor along Applegate Lane near Wyngarden Lane.

For additional resiliency and to meet the Enhanced LOS (current 50-year/future 16-year, 1-hour design storm), Alternative 6a can be expanded to include the following as **Alternative 6b**:

- **Upsized storm sewer:** 4,610 feet of the existing storm sewer would be upsized. The existing 18-, 24-, 30-, 36-, 48-, and 54-inch-diameter storm sewer along N Hagadorn Road, Applegate Lane, and Pebblebrook Lane would be upsized to 24-, 42-, and 60-inch-diameter storm sewer.
- **Stormwater storage:** The open area surrounding the Albert A. White Memorial Park fishing pond would provide approximately 0.6 million gallons of storage to attenuate and offset increased peak flows from the upsized storm sewers.

6.4. Level of Service and Flood Risk Reduction Results

The proposed alternatives were analyzed using the H&H model to quantify the flood risk reduction benefits and the results for the Current LOS goal and Enhanced LOS goal. The alternatives were modeled as individual scenarios for prioritization purposes and together as single scenarios.

As shown below in Table 6-3, the H&H model predicted that the alternatives were all able to manage the Current 10-year, 1-hour LOS with the exception of Alternative 2a. Because of the complicated layout of the pipes in an area downstream, an area of pipes near the interceptor does not meet the 10-year, 1-hour LOS. The Current 50-year/Future 16-year, 1-hour (Enhanced) LOS was not achieved with all the alternatives evaluated.

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Table 6-3. Predicted LOS for each alternative.

CA	Alternative	Predicted LOS
A and B	1a	Current 10-year, 1-hour
A and B	1b	Current 50-year/Future 16-year, 1-hour
D	2a	Current 10-year, 1-hour (except near the interceptor)
D	2b	Between the Current 10-year, 1-hour and Current 50-year/Future 16-year, 1-hour
B, C, E, and G	3a	Current 10-year, 1-hour
B, C, E, and G	3b	Current 50-year/Future 16-year, 1-hour
F	5a	Current 10-year, 1-hour
F	5b	Current 50-year/Future 16-year, 1-hour
H	6a	Current 10-year, 1-hour
H	6b	Current 50-year/Future 16-year, 1-hour

Additional key takeaways regarding the LOS achieved by the alternatives are as follows:

- **Stormwater separation:** Large areas of stormwater separation are needed to increase LOS. This will significantly increase the cost of the alternatives. The stormwater separation will need to precede the upsizing of combined sewer pipes to offset potential CSO impacts.
- **New storm mains and upsized CSS/MS4 pipes:** Some of the pipe diameters and bury depth required to increase LOS are large and deep. This will require a feasibility assessment to determine impacts to existing utilities and other right-of-way impacts such as open-cut trenching widths during installation.
- **Green infrastructure/storage opportunities:** Storage opportunities have the benefit of potentially decreasing the required diameter for the new storm mains.

To quantify the flood risk reduction for the Current and Enhanced LOS goals, the number of properties with reduced flooding risk and the length of road with reduced flooding risk were counted. Table 6-4 summarizes the flood risk reduction results for all the alternatives except for Alternative 4 since it was removed from further consideration. Flood risk results were quantified by using predicted model outputs under each alternative for the two LOS design storm events. Properties removed from the risk of flooding areas were calculated from the model by comparing the total number of properties at risk during existing conditions to the total number of properties at risk with the alternative in place. Similarly, the amount of roadway experiencing flooding depth of 6 inches or more was identified by performing a comparison of roadway flooding with and without the alternatives in place. The flood risk reduction benefits for the additional aboveground and underground storage options were not quantified as they were not input to the H&H model. However, these storage options would provide an additional level of resiliency as a project benefit in the future.

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Table 6-4. Flood risk reduction results for the alternatives.

Alternative	Properties reduced for 10-year	Properties reduced for 16-year	Length of road reduced for 10-year (ft)	Length of road reduced for 16-year (ft)
1a	210	54	483	1,131
1b	210	55	483	1,242
2a	123	100	1,293	2,047
2b	123	148	1,293	2,302
3a	620	193	1,688	5,311
3b	620	796	1,688	6,853
5a	3	5	947	870
5b	3	5	947	1,062
6a	6	3	315	568
6b	6	6	315	1,275

6.5. Selected Alternatives and Conceptual Project Information

Through a series of workshops and discussions with the City, a set of alternatives was selected to be prioritized and implemented in the WWRP. Several factors impacted the selection of the alternatives, including the LOS goals and predicted performance of each alternative and the size and scope of the project, which directly influences the cost. This section provides a brief overview of the reasoning for selecting each alternative.

- To address flooding in CAs A and B, Alternative 1b was selected. Much of the discussion for Alternative 1 was based on minimizing the amount of flow that would be diverted to Ranney Park to keep flows within the pre-established agreement. As the decision was made early in the process to move forward with Alternative 3 rather than Alternative 4, the amount of flow to Ranney Park would be minimized by not including additional stormwater from the Chartwell and Shaw Estates neighborhoods. Separated stormwater from these neighborhoods would instead be directed to the east to the new storm main on Harrison Road as part of Alternative 3. Alternative 3 also reduced the required area for separation and the diameter and length for the new storm main. This allowed the City to move forward with Alternative 1b, which increases LOS to the current 50-year/future 16-year, 1-hour storm when combined with Alternative 3b.
- To address flooding in CA D, Alternative 2b was selected with underground storage at Valley Court Park. This alternative increases LOS to the current 10-year, 1-hour LOS by conveying separated stormwater to the Red Cedar River. It also increases LOS to the current 50-year/future 16-year LOS in some areas. Compared to Alternative 2a, the upsizing of some of the combined sewer mains will help to relieve some of the remaining bottlenecks currently experienced downstream but will not address the current 50-year/future 16-year because of model-predicted hydraulics of the existing CSO tunnel system and the shallow nature of the pipes within this area.
- To address flooding in CAs B, C, E, and G, Alternative 3b was selected with the storage options at Gordon Guyer and Glencairn Park included. This alternative increases LOS to the current 50-year/future 16-year LOS. Similar to Alternative 2b, the upsizing of combined sewers from this alternative will help to relieve some of the remaining bottlenecks downstream that are not currently in the top eight flooding CAs.

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- To address flooding in CAs F and H, both hydraulically independent watersheds in the MS4, Alternatives 5a and 6a were selected. This can be seen below in Figure 6-7, which shows the number of properties with reduced flooding risk and the total length of road flooding with 6 inches or greater of flood depth. The flood risk reduction benefits show a minimal increase for the added cost to provide an LOS from a current 10-year, 1-hour LOS to a current 50-year/future 16-year, 1-hour. Both alternatives increase LOS to the current 10-year, 1-hour LOS in their respective CAs. Alternative 5a includes aboveground storage at flexible open-surface areas near the fire station, Harrison Meadows Park, and open areas west of Abbot Road. Alternative 6a includes storage at Albert A. White Memorial Park in the open areas surrounding the fishing pond.

Table 6-5 provides a summary overview of the selected alternatives, the increased LOS, and the estimated flood risk reduction benefits. Figure 6-8 shows the location of all the selected alternatives. Figure 6-9 to Figure 6-18 provide alternating visual overviews of the components, including the location of new and upsized pipes, structure modifications, resiliency storage areas, and nearby key facilities, and the flood risk reduction benefits for each alternative.

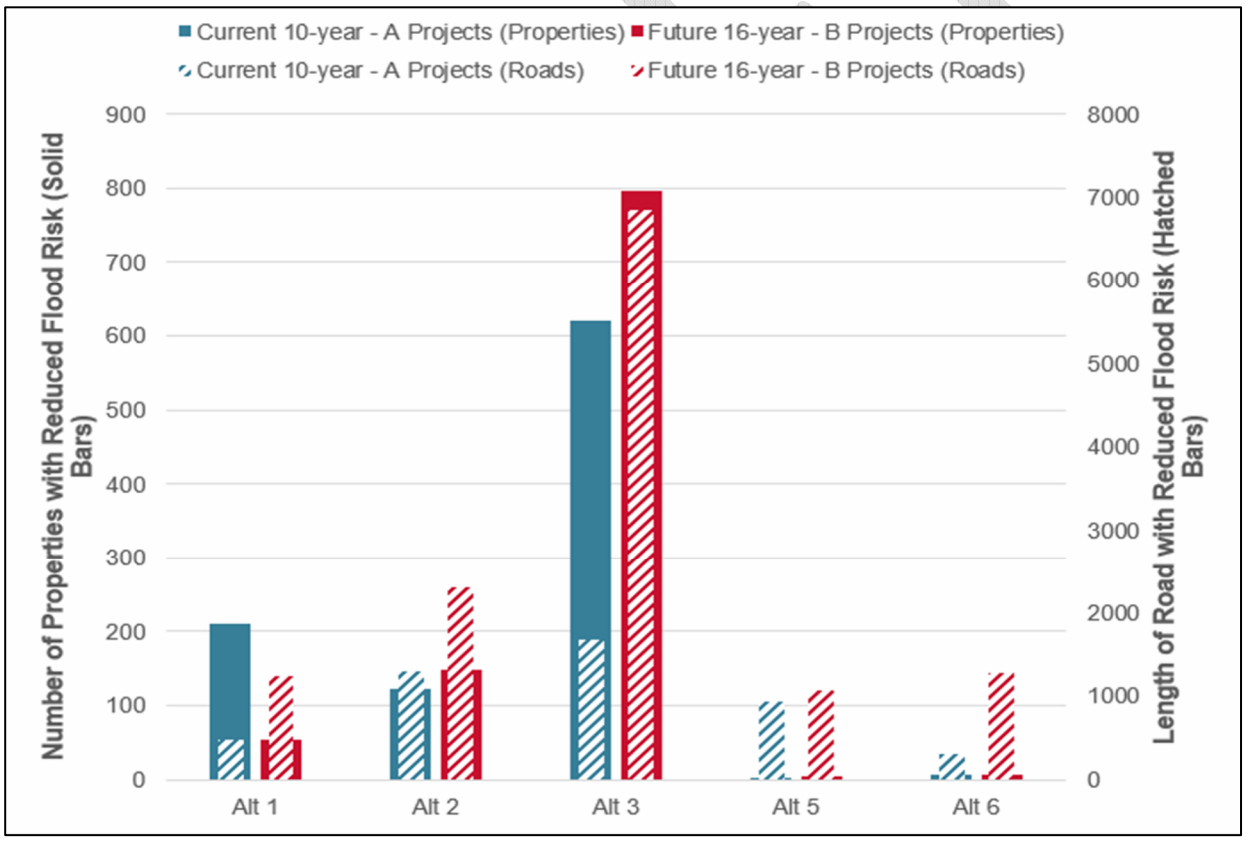


Figure 6-7. Comparison of reduced flood risk (number of properties and length of road) with each alternative evaluated for Current and Enhanced LOS goals.

Table 6-5. Selected alternatives LOS and flood risk reduction benefits.

Alternative	Predicted LOS	Estimated number of properties with reduced flood risk	Estimated feet of road with reduced flood risk
1b: West Central Neighborhoods CSS Relief	Current 50-year/Future 16-year	210	1,242
2b + Storage: Valley Court Corridor CSS Relief	Current 10-year	123	2,302
3b + Storage: Downtown Neighborhoods CSS Relief (Harrison St. Route)	Current 50-year/Future 16-year	620	6,853
5a: Abbot and Saginaw Storm Drainage Improvement	Current 10-year	3	947
6a: Whitehills Drainage Improvement	Current 10-year	6	315

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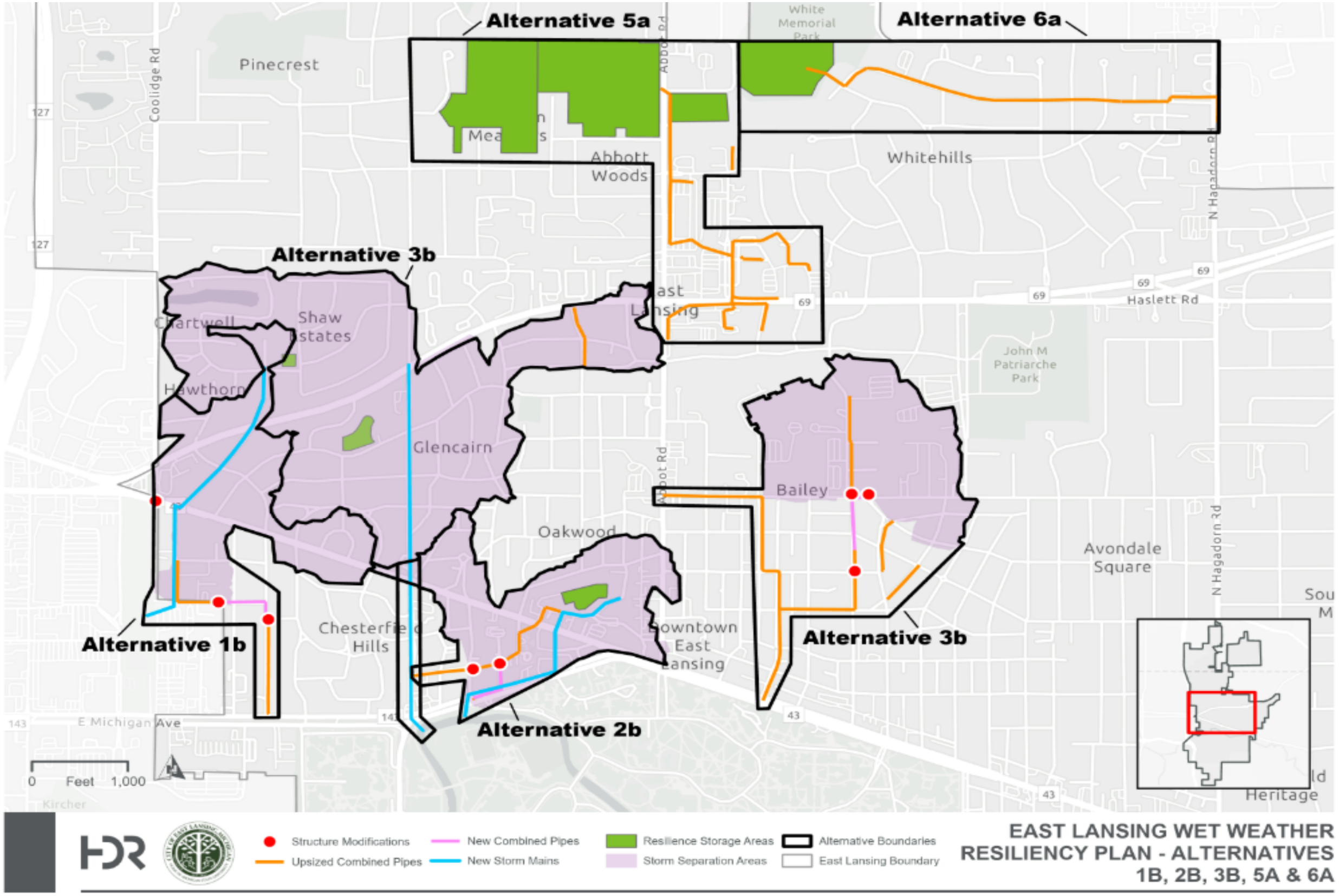


Figure 6-8. All selected alternatives.

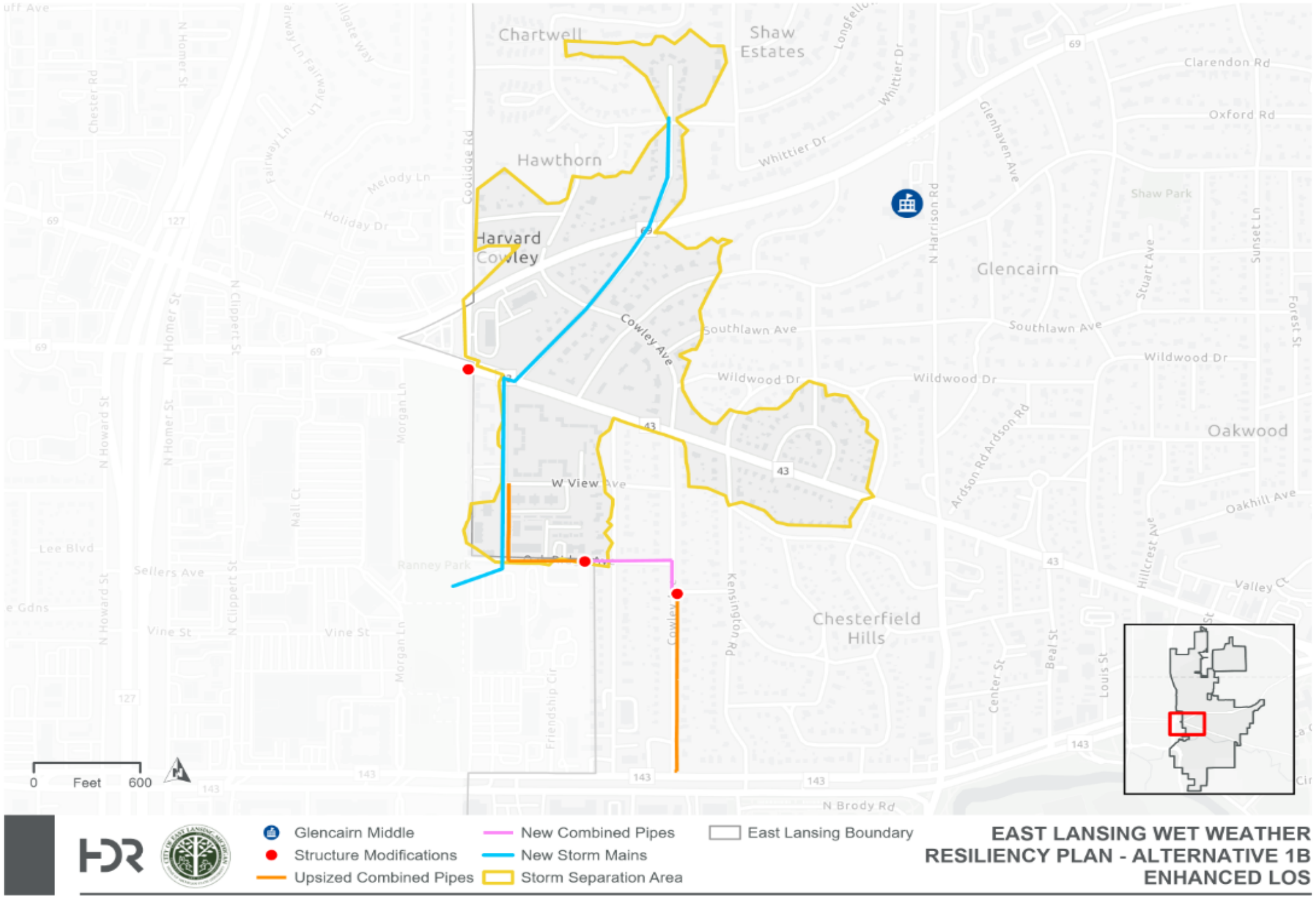


Figure 6-9. Conceptual map for Alternative 1b: West Central Neighborhoods CSS Relief.

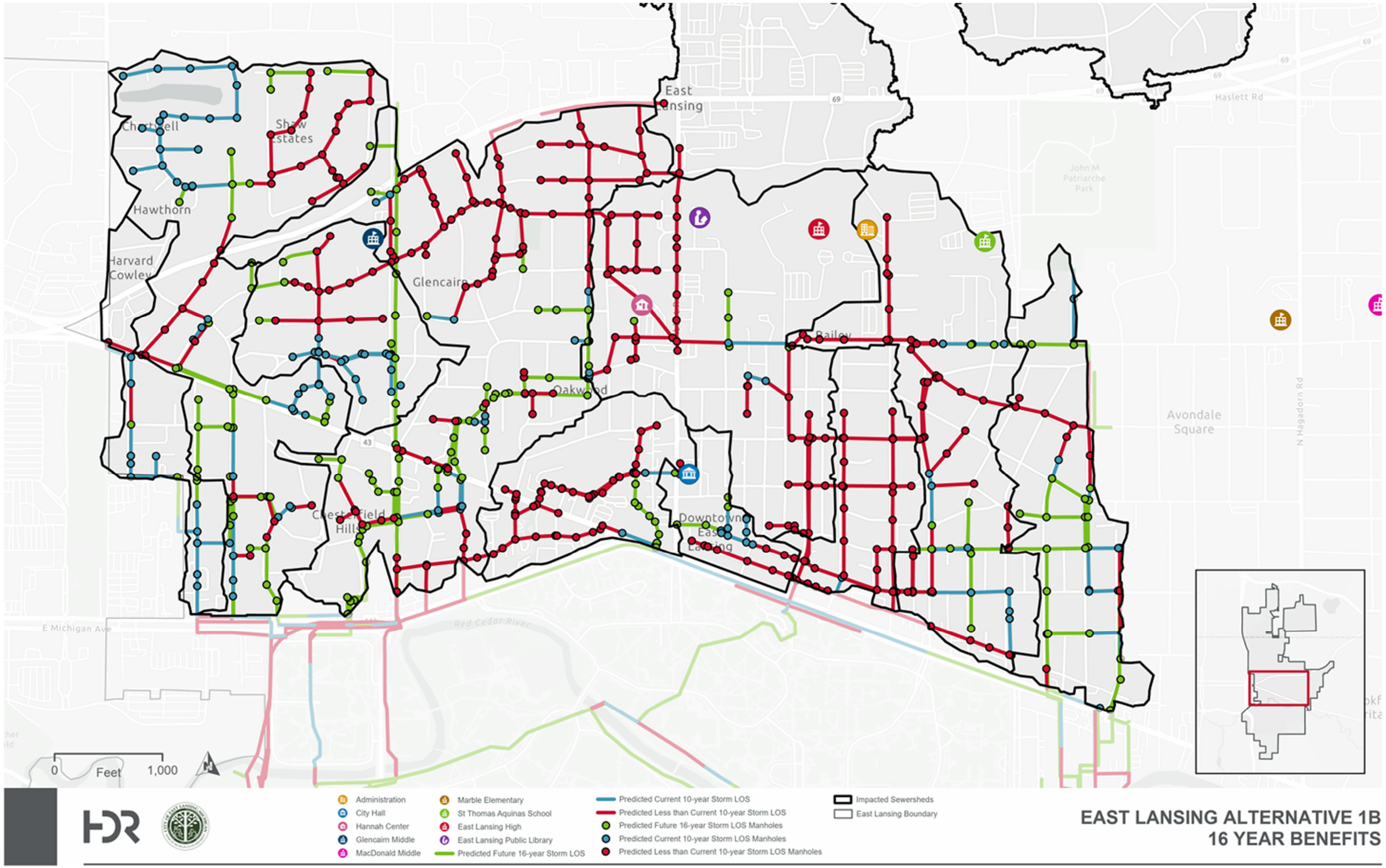


Figure 6-10. Predicted LOS performance for Alternative 1b.

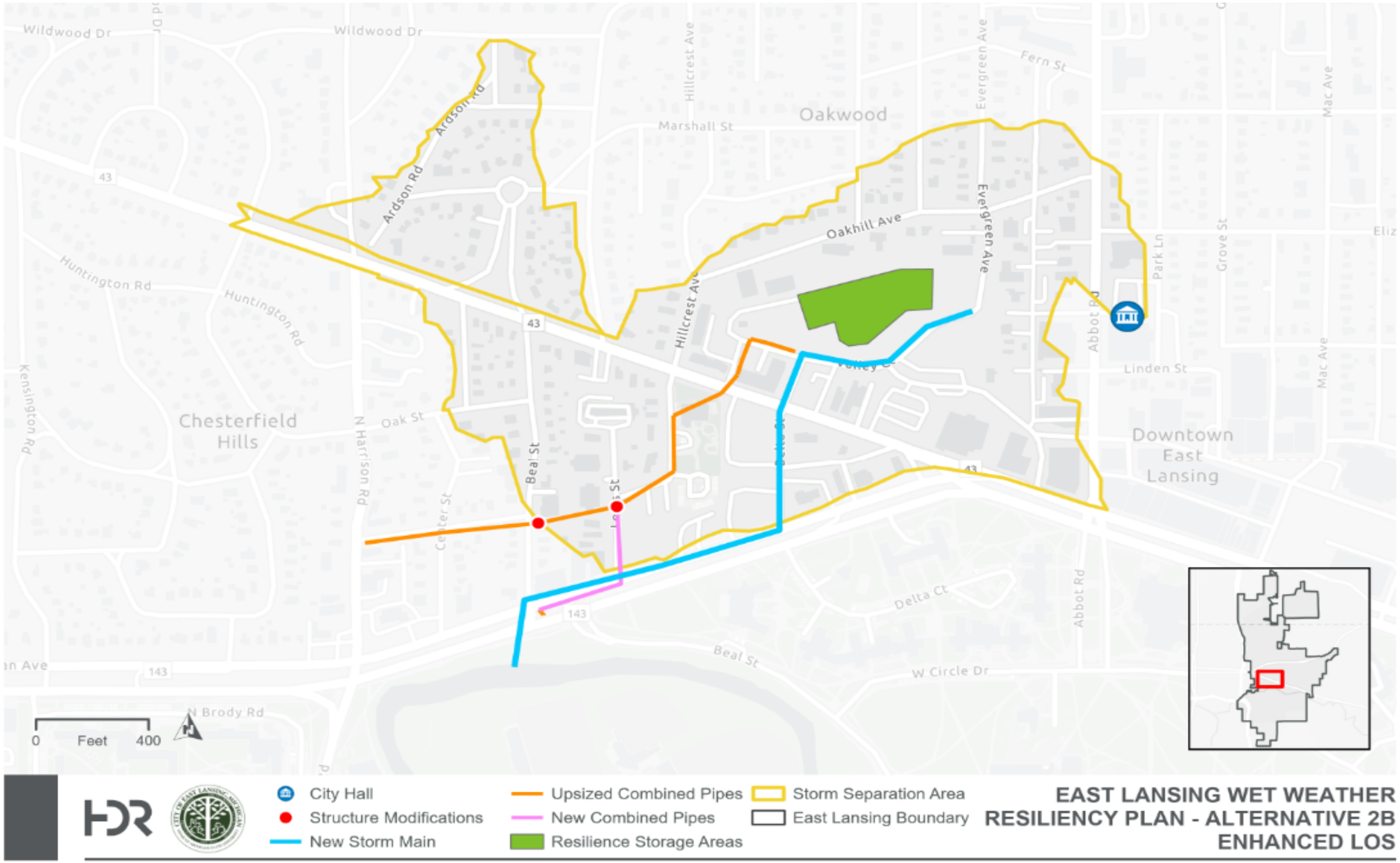


Figure 6-11. Conceptual map for Alternative 2b + Storage: Valley Court Corridor CSS Relief.

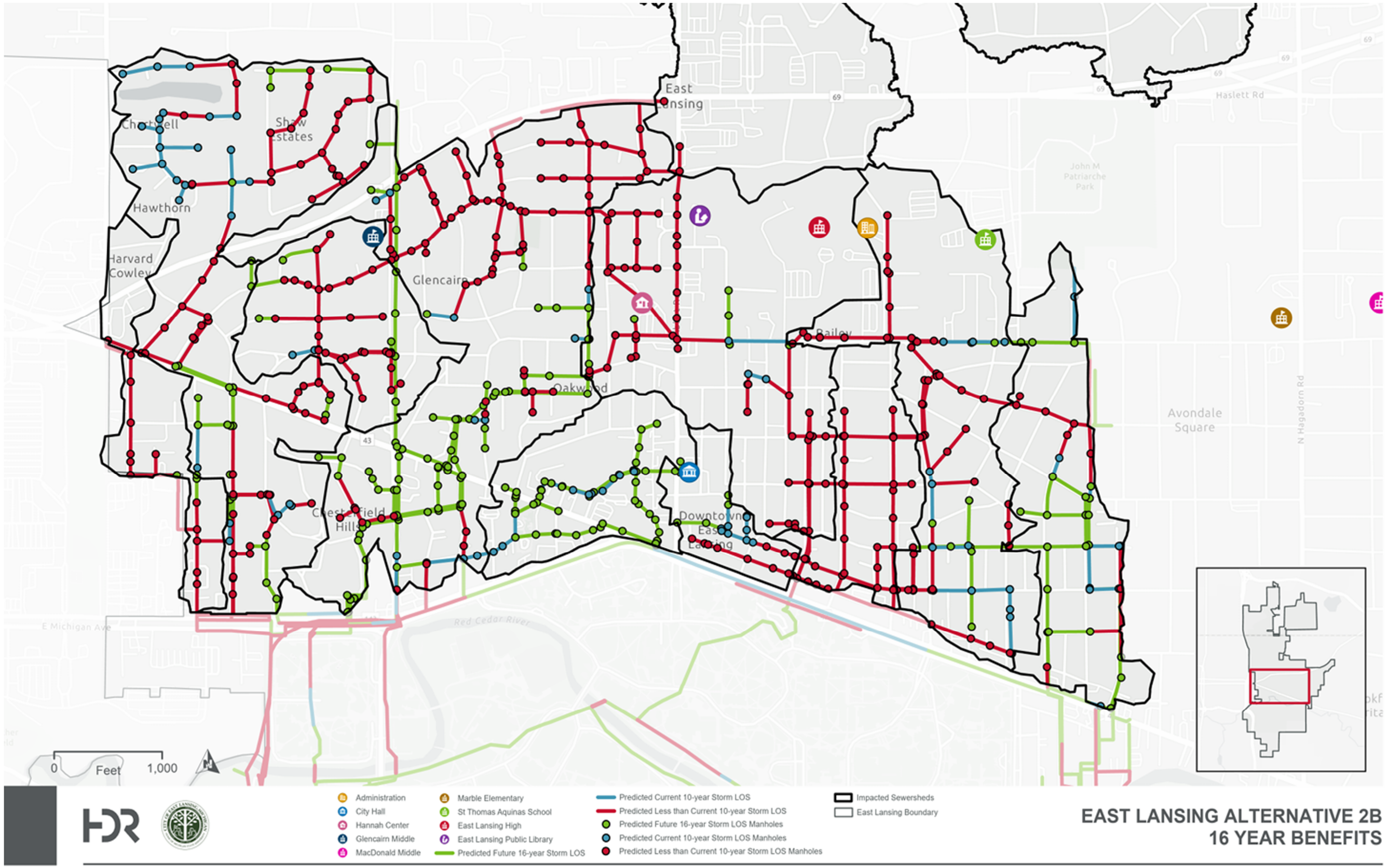


Figure 6-12. Predicted LOS performance for Alternative 2b + Storage.

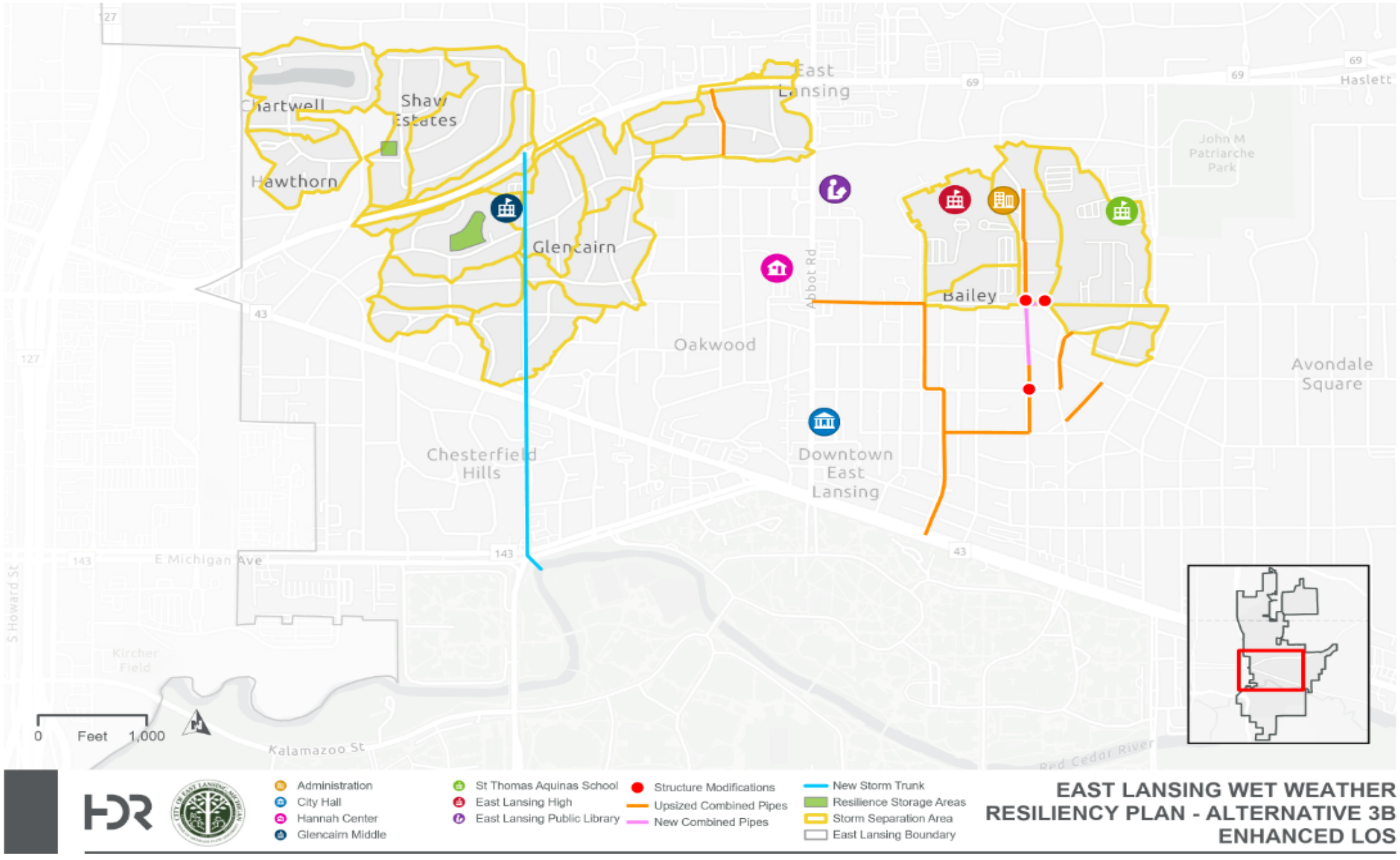


Figure 6-13. Conceptual map for Alternative 3b + Storage: Downtown Neighborhoods CSS Relief (Harrison Road Route).

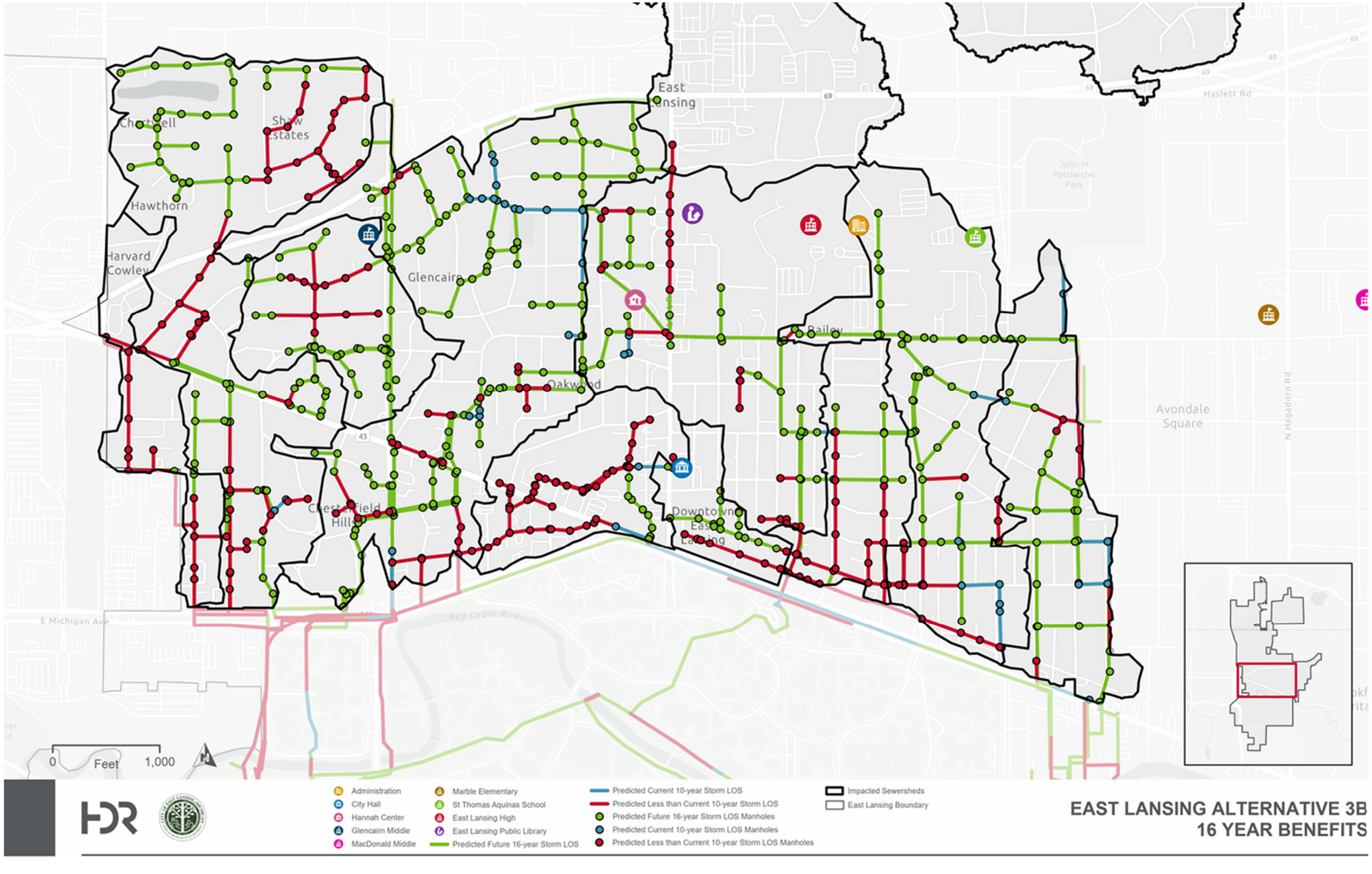


Figure 6-14. Predicted LOS performance for Alternative 3b + Storage.

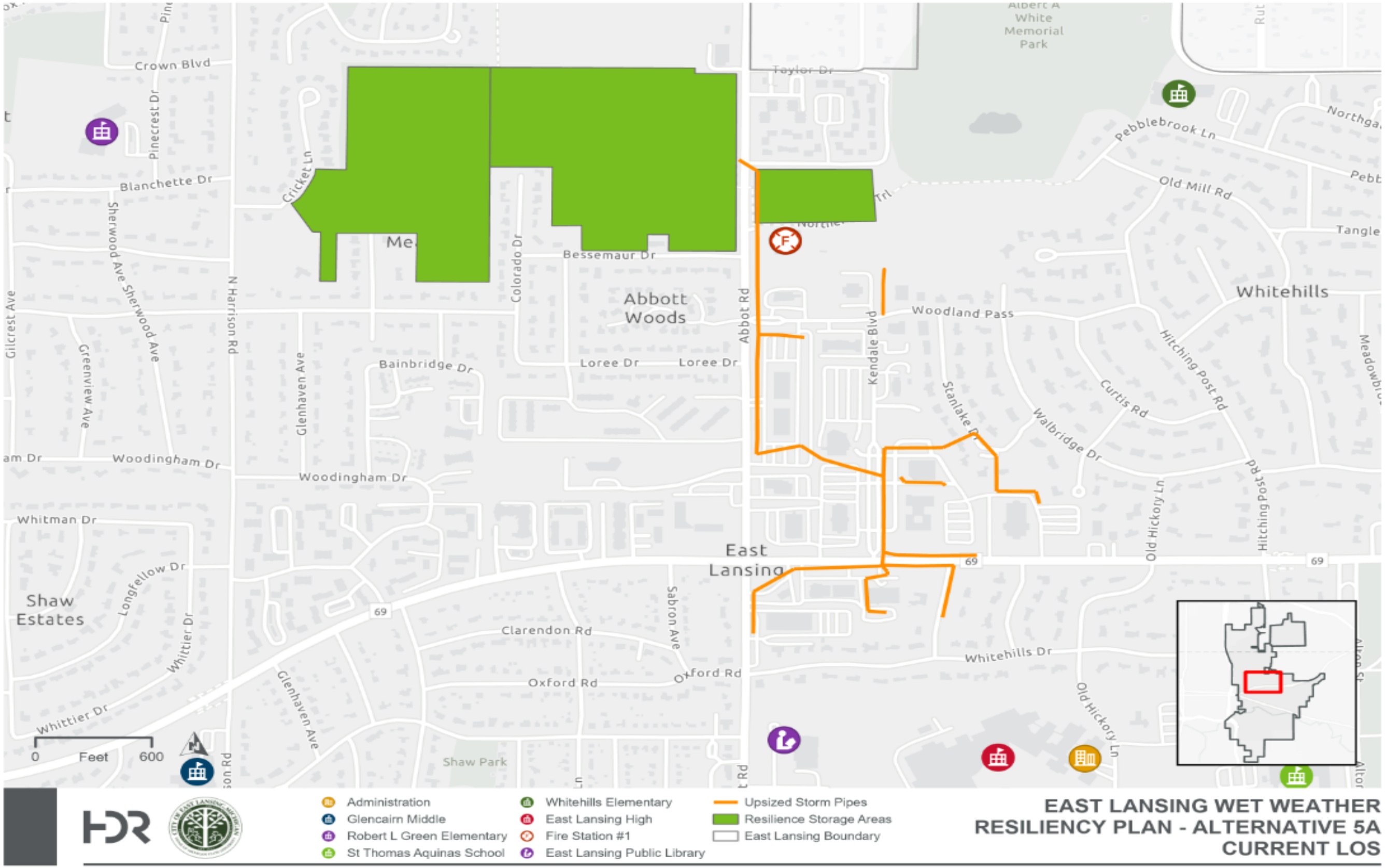


Figure 6-15. Conceptual map for Alternative 5a: Abbot and Saginaw Storm Drainage Improvement.

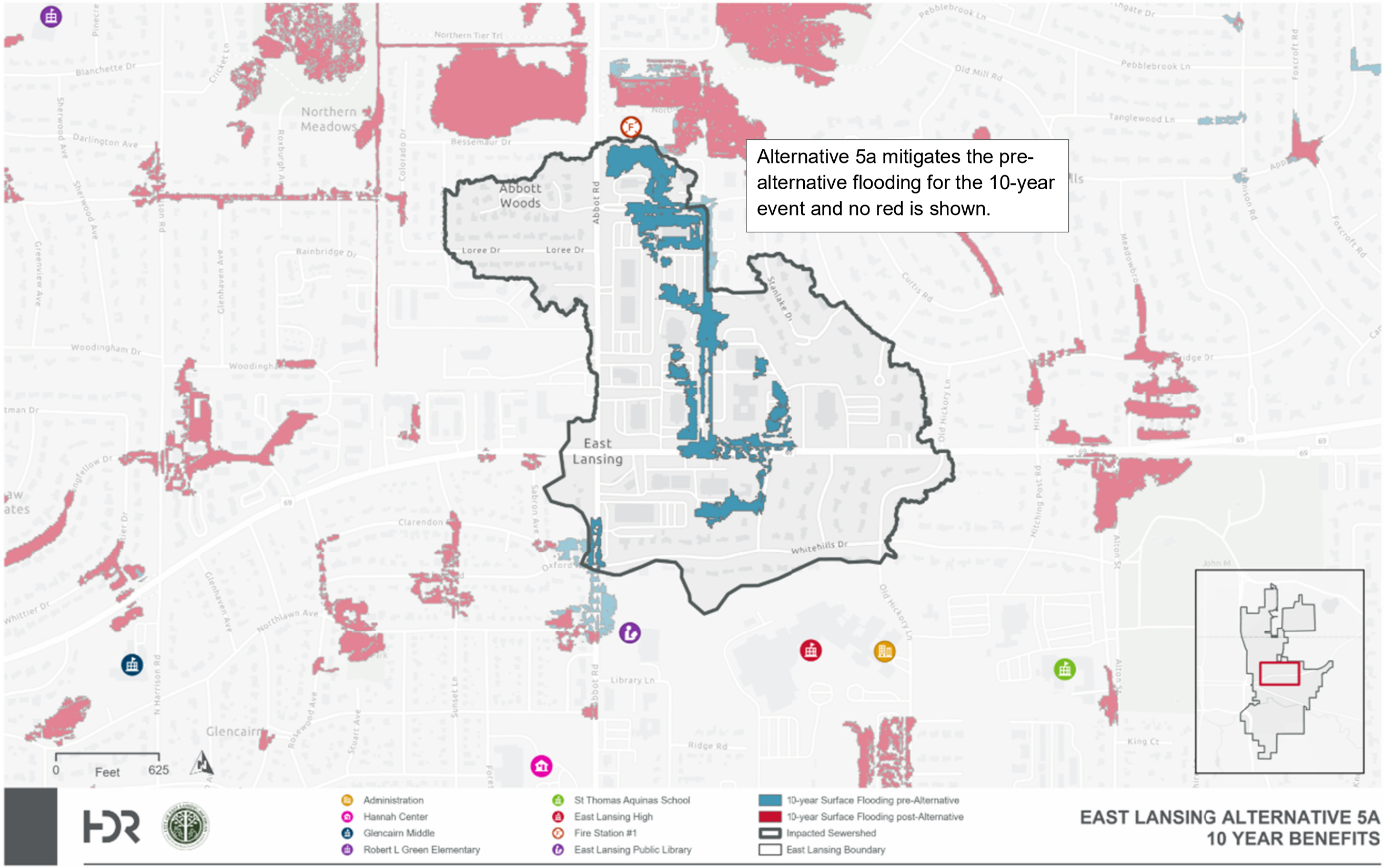


Figure 6-16. Predicted LOS performance for Alternative 5a.

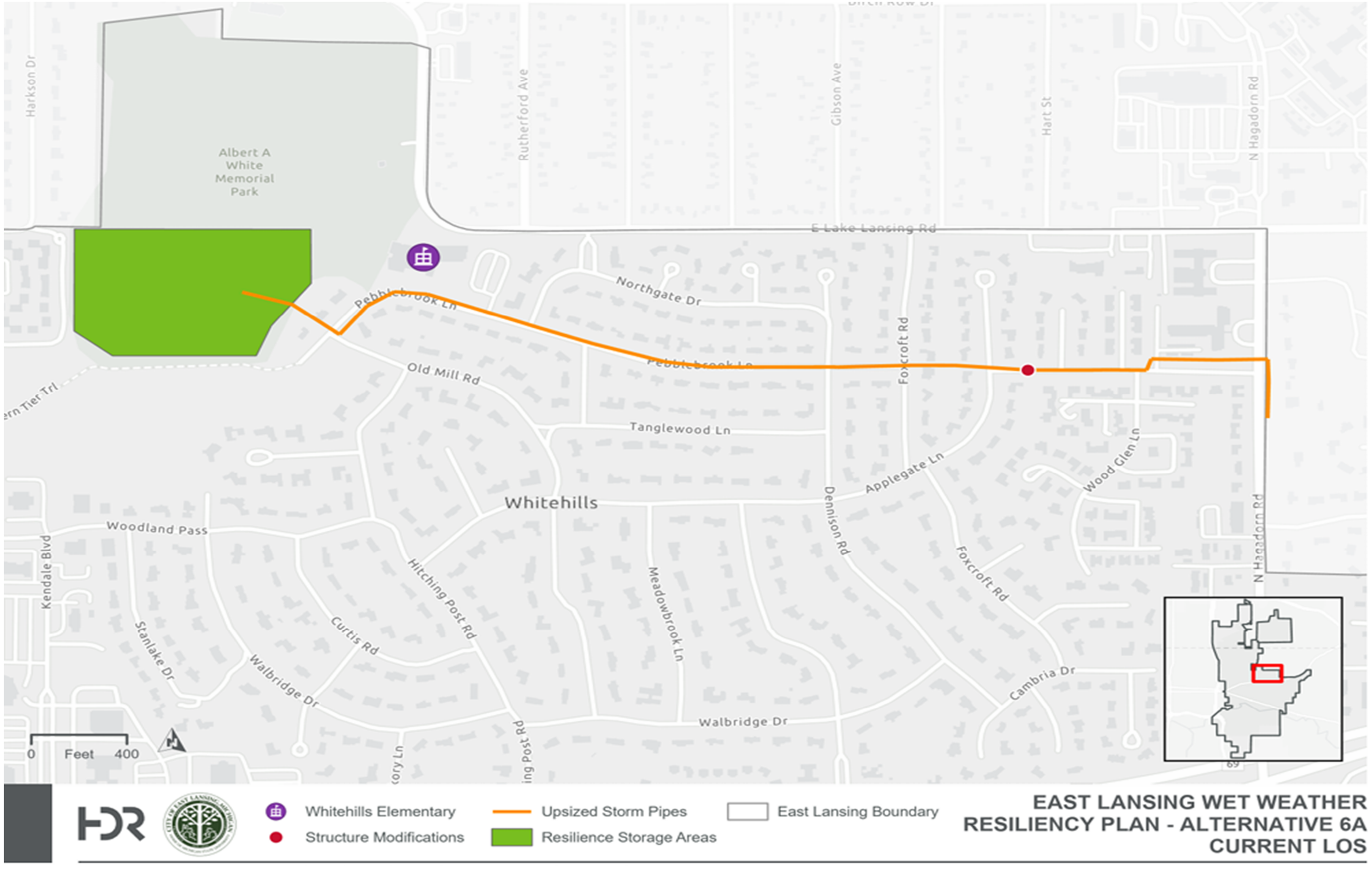


Figure 6-17. Conceptual map for Alternative 6a: Whitehills Drainage Improvement.

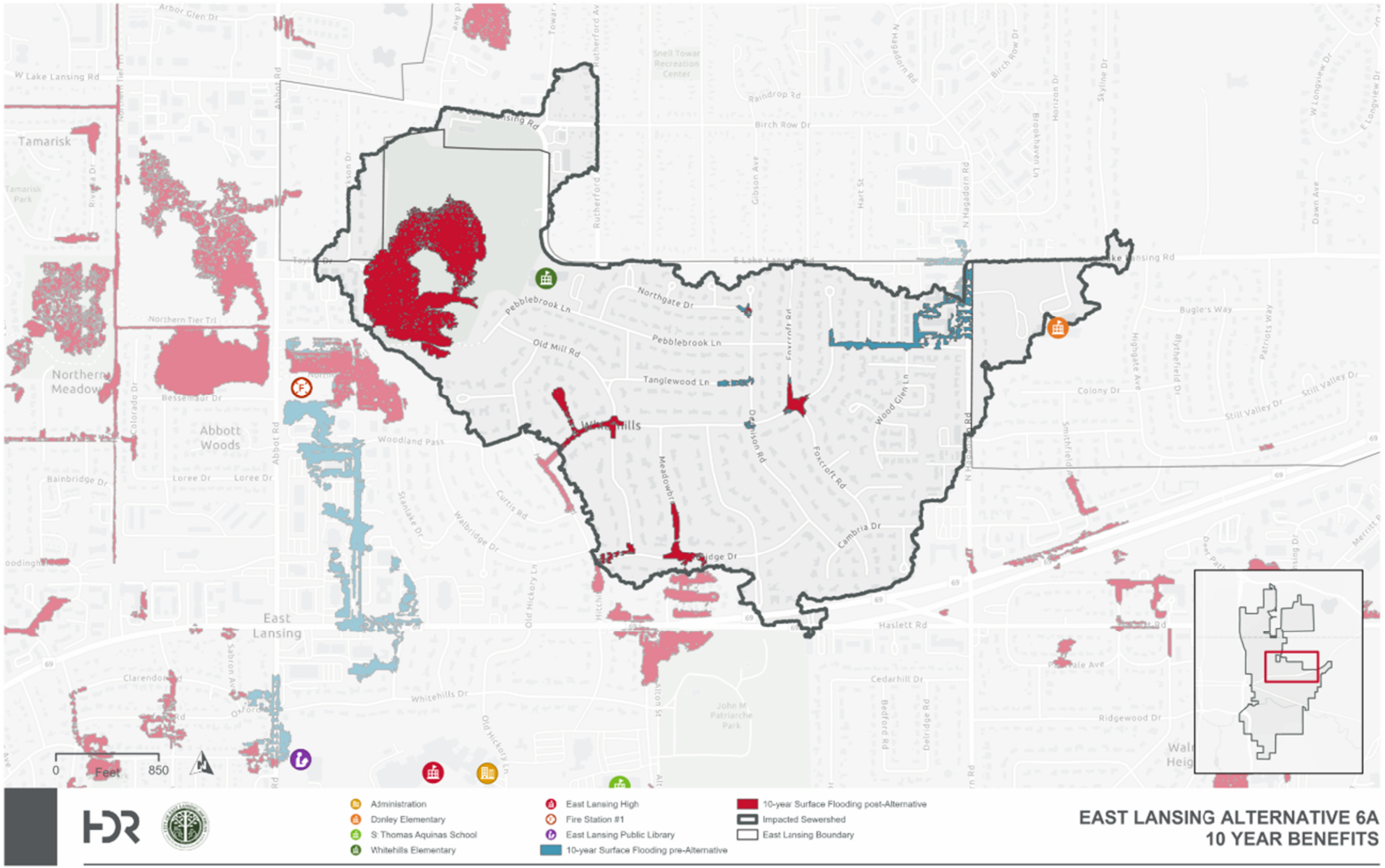


Figure 6-18. Predicted LOS performance for Alternative 6a.

6.6. Probable Construction Cost Estimates for Proposed Projects

Planning-level (Association for the Advancement of Cost Engineering [AACE] Class 5) opinion of probable construction cost estimates (henceforth referred to as “cost estimates”) were developed for each selected alternative. Class 5 cost estimates are conceptual, rough order of magnitude, and are typically performed during the project planning phase and early in the design phase. The order of magnitude of the developed prices is based on cost data for similar types of projects that have been constructed in the same geographical area.

The cost estimates developed for the alternatives include several components, including but not limited to the following:

- Linear footage of pipes of varying diameters and depths for the upsized and new combined sewers, upsized storm mains, and new storm mains
- Estimated number of manholes and other structures required on the new pipes
- Structure modifications
- Local storm pipes that connect into the new storm main required for the storm separation
- Materials required for the construction of aboveground and underground storage options

The unit costs used in the development of the cost estimates were based on multiple sources, including recent project tabulations provided by the City, a recently developed stormwater separation project in southeast Michigan, and industry experience. Costs were escalated to 2026 dollars using an annual inflation rate of 3.83 percent as necessary. As these are conceptual costs, several contingency cost multipliers and soft costs have been added, including but not limited to the following:

- Preliminary design costs (5 percent)
- Design and engineering services (10 percent)
- Administration legal costs (2 percent)
- Field engineering and inspection costs (5 percent)
- Mobilization (12 percent)
- Traffic control (2 percent)
- Adjustments to utility lines (20 percent)
- Undefined work contingency (35 percent)

Table 6-6 provides a summary of the Class 5 cost estimations developed for each of the selected alternatives. **Note that these are 2026 costs and are not inflated to future years when project construction may occur.**

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Table 6-6. Class 5 cost estimations for the selected alternatives.

Alternative 1b	
CSO upgrades and sewer upsizing	$2.95M
Storm separation	$21.60M
New storm trunk	$4.86M
Roadway, mobilization, other	$13.30M
Total Cost	$43M
Alternative 2b + storage	
CSO upgrades and sewer upsizing	$2.59M
Storm separation	$25.10M
New storm trunk	$4.17M
Roadway, mobilization, other	$16.11M
Underground Storage	$7.15M
Total Cost	$56M
Alternative 3b + storage	
CSO upgrades and sewer upsizing	$14.84M
Storm separation	$78.10M
New storm trunk	$13.30M
Roadway, mobilization, other	$46.10M
Underground storage	$6.70M
Total Cost	$160M
Alternative 5a + storage	
CSO upgrades and sewer upsizing	$23.70M
Aboveground storage	$1.51M
Roadway, mobilization, other	$12.80M
Total Cost	$39M
Alternative 6a + storage	
CSO upgrades and sewer upsizing	$5.50M
Aboveground storage	$0.30M
Roadway, mobilization, other	$4.40M
Total Cost	$11M

6.7. Prioritized Projects

This section presents the methodology by which the selected alternatives were prioritized based on City staff and community stakeholder input. It also provides the results of the prioritization, which ultimately impacted the proposed phased implementation plan.

6.7.1. PRIORITIZATION METHODOLOGY

To develop a framework for project prioritization that is community-driven, it was critical that City staff and impacted community members were afforded a common understanding of flood risk

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today and in the future, as well as clarity of the City's roles and responsibilities for managing rainfall events up to a certain intensity, duration, and frequency. For the purpose of the WWRP, this understanding helps to maintain a focus on higher-risk areas of the city, as identified by the existing-conditions modeling and the identification of projects with the greatest potential impact for the community. Direct feedback from community stakeholders on their priorities for public investments within the city was sought to rank projects for implementation that would reduce flood risk and also help to add additional community benefits.

Figure 6-19 provides an overview of this step-by-step process for providing the information necessary to engage City staff and impacted community members in the development of the framework. This information was shared via a series of meetings and workshops with City staff and stakeholders to help develop the framework for the development of the WWRP.

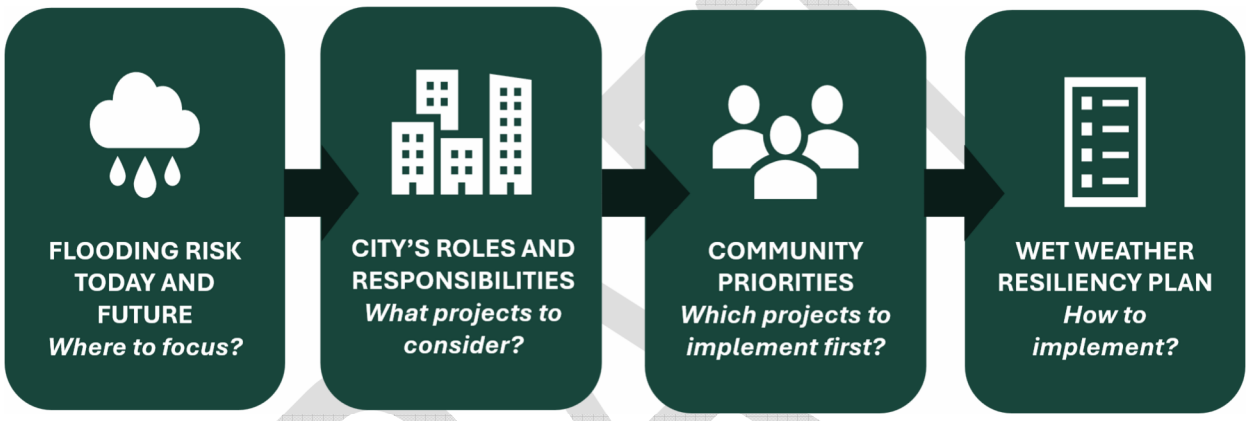


Figure 6-19. Stormwater infrastructure resiliency framework.

Using input from the City, HDR developed the project prioritization criteria presented in Table 6-7. To understand the relative importance of the prioritization criteria a pairwise analysis was conducted with City staff and community stakeholders. During the focus group meetings, each attendee was asked to complete a survey of 25 questions, in which survey respondents identified which of two prioritization criteria was "more important." This survey was conducted in a similar manner as the pairwise analysis for flooding criteria in Section 5. The exercise was done for all paired combinations of the criteria. Additionally, City staff were asked to complete the same survey to identify the City's priorities under each criterion. The results were then combined into an overall focus group and City staff pairwise analysis result. The combined focus group and City staff results of the pairwise analysis, including the weight and the overall rank, are provided in Table 6-7.

Table 6-7. Project prioritization criteria for a community driven approach.

Criterion	Description	Weight	Rank
Flood risk reduction	The project's ability to: • Reduce property flood risk for basement backups in CSS • Reduce property flood risk from surface flooding in CSS and MS4 • Reduce roadway flood risk of 6 inches or greater	16.5%	1
Water quality	The project's alignment with the City's CSO elimination goals and/or ability to design with water quality treatment features consistent with the City's Stormwater Management Plan	15.5%	2
High impact	The total number of people served by the project or the visibility of the project to a total number people within a certain proximity	14.9%	3
City resiliency alignment	The project's alignment with identified priorities from the City's climate resiliency community meeting including green stormwater infrastructure that would provide community co-benefits (e.g., community improvements, green space, community gardens, shade and urban heat island mitigation, and/or air quality improvements)	13.0%	4
Impervious surface reduction	The project's ability to reduce unnecessary impervious surfaces	11.8%	5
Social and economic impacts	The project's ability to provide social or economic benefits to vulnerable populations because of the design, location, or nature of the project	11.0%	5
Level of maintenance	Type and/or extent of long-term maintenance required	9.4%	7
Ease of constructability	The level of ease to implement and build the project	7.9%	8

These prioritization criteria were then implemented within a Multi-Criteria Decision Analysis (MCDA) tool to understand how each alternative performed against each criterion. MCDA is a means of semi-quantitatively comparing alternatives with similar outcomes based on a set of decision criteria. Typically, an MCDA has the following elements:

- A set of decision criteria
- Criteria weights established through pairwise analysis or another ranking process
- Scored projects against each criterion

Using the defined set of criteria and weighting described above, HDR worked with the City to compare each alternative based on the benefits associated with each project and how well they align with City and community stakeholders' priorities.

The general approach to applying the criteria and weights (using ArcGIS) is illustrated in Figure 6-20. First, the defined criteria and assigned weights, as determined by City staff and community stakeholders, are used as inputs into the tool. From there, the alternative is scored based on how the project contributes to each of the criteria. For example, an alternative that would positively impact a very densely populated neighborhood may score greater than an alternative impacting only a few residential homes under the "high impact" criterion. Finally, an alternative's benefits under each criterion are summed up to calculate a "total prioritization score." The total prioritization score is then compared against the other alternatives. The prioritization score is then used along with estimated cost information to rank and prioritize alternatives for implementation.

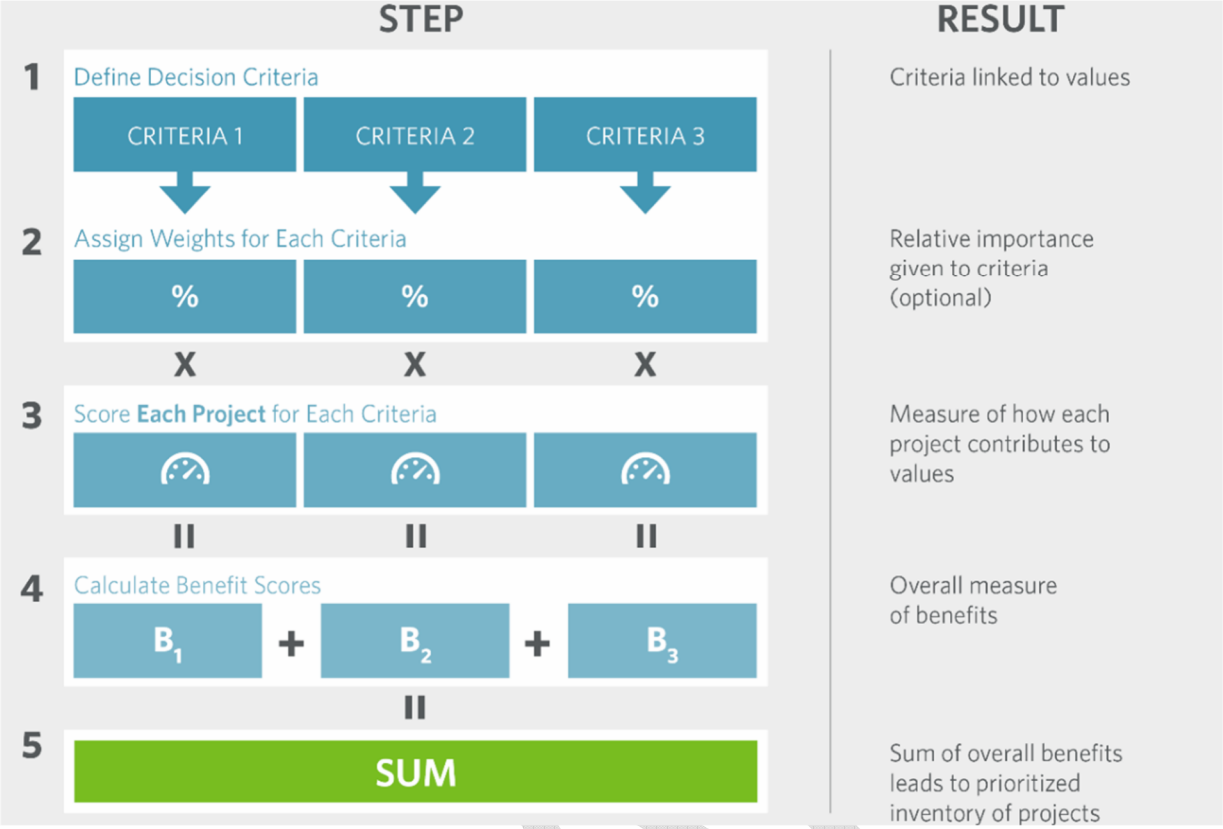


Figure 6-20. Multi-Criteria Decision Analysis approach.

6.7.2. PRIORITIZATION RESULTS

Using the results from the MCDA prioritization tool, the selected alternatives were ranked based on their total prioritization score. Table 6-8 provides the alternatives ranked by their total prioritization score, which reflects the needs and wants of the community using the MCDA tool as previously discussed.

Table 6-8. Project prioritization ranking and overall score.

Alternative	Prioritization score (out of 10)	Prioritization ranking
3b + Storage: Downtown Neighborhoods CSS Relief (Harrison Rd. Route)	7.15	1
2b + Storage: Valley Court Corridor CSS Relief	6.16	2
1b: West Central Neighborhoods CSS Relief	5.55	3
6a: Whitehills Drainage Improvement	3.65	4
5a: Abbot and Saginaw Storm Drainage Improvement	3.64	5

6.8. Impact on Adjacent Areas

Because of the interconnectivity between the CSS watersheds, the selected alternatives provide benefits to several flooding CAs that are adjacent to the top eight CAs. These areas are not predicted to meet the LOS of the target CA in most cases. However, the H&H model predicted

that these areas may experience flooding in fewer manholes in comparison to the existing conditions. Table 6-9 lists the CAs adjacent to the top eight, targeted CAs that will be positively impacted by the completion of the alternatives in the CSS. The H&H model predicted LOS for the Current 50-year/Future 16-year, 1-hour would be met for CA_52 and CA_53 with the implementation of Alternative 2b and CA_40 with the implementation of both Alternative 1b and Alternative 3b. Figure 6-21 provides a visual overview of the CAs that are not within the top eight flooding CAs that receive additional flood risk reduction benefits.

Table 6-9. Adjacent concern areas receiving flood risk reduction benefits from the selected alternatives.

Alternative	Predicted LOS	Other CAs that benefit
1b: West Central Neighborhoods CSS Relief	Current 50-year/Future 16-year	CA_40, CA_41
2b + Storage: Valley Court Corridor CSS Relief	Current 10-year	CA_52, CA_53
3b + Storage: Downtown Neighborhoods CSS Relief (Harrison St. Route)	Current 50-year/Future 16-year	CA_28, CA_31, CA_32, CA_33, CA_39, CA_40, CA_42, CA_46, CA_54

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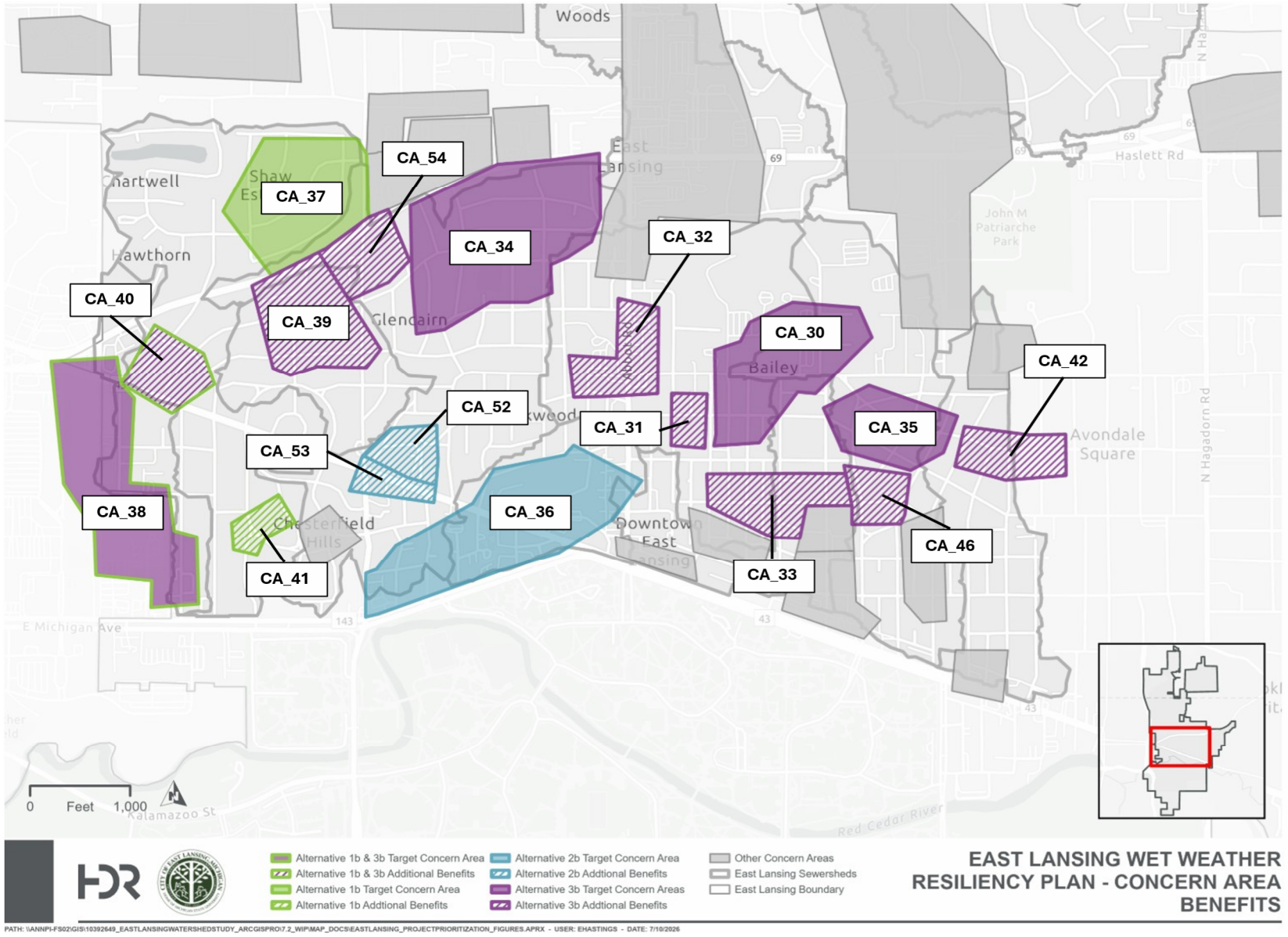


Figure 6-21. Adjacent concern areas that receive flood risk reduction benefits from Alternatives 2b and 3b.

7.RECOMMENDATIONS

Several structural and nonstructural flood risk reduction strategies are recommended under the WWRP. This section provides an overview of these recommended flood risk reduction strategies and an implementation plan for a phased approach to advance capital improvement projects by the City.

7.1. Structural Strategies

The structural strategies recommended for implementation are a culmination of the WWRP planning process and resultant alternatives selected, as described in Section 6. The proposed projects that comprise the selected and prioritized alternatives consist of the following structural strategies:

- Stormwater separation
- New storm sewer mains
- Combined sewer pipe upsizing
- New combined sewer pipes
- Regulator structures and weir modifications
- Aboveground storage
- Underground storage

The combinations of structural strategies in this WWRP target improved LOS for the City's drainage infrastructure in flood risk CAs given historical storms, future climate projections, and existing LOS below the City's historical standard. Alternatives were evaluated to determine the extent of LOS improvements possible within the City's right-of-way. While a significant enhancement in LOS (i.e., upgrading existing infrastructure that conveys less than a 1-year storm in several CAs to convey a current 10-year storm or a current 50-year/future 16-year storm) was evaluated, this was done for planning purposes. Lower and upper bounds for LOS goals were used to assess and compare the performance of different combinations of structural strategies and guide the continuous development of infrastructure improvements and related benefits that would be visible to the community.

The proposed projects are planning-level and will require detailed planning and design as part of the City's CIP. Additional information to support CIP planning is presented below in Section 7.3. Figure 7-1 shows the location of all of the selected alternatives in this WWRP. Figure 7-2 shows the predicted LOS performance with all the selected alternatives implemented.

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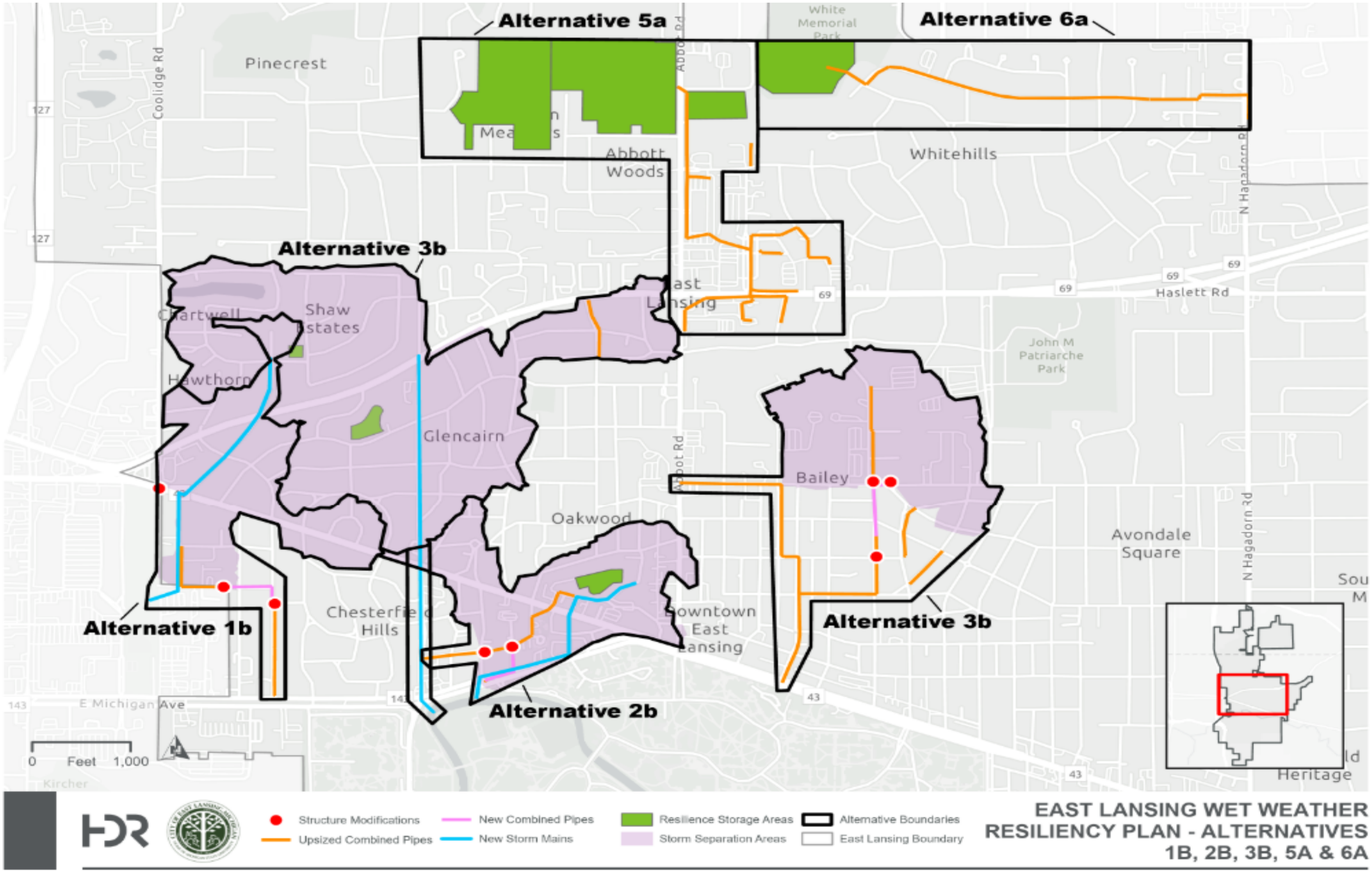


Figure 7-1. All selected alternatives.

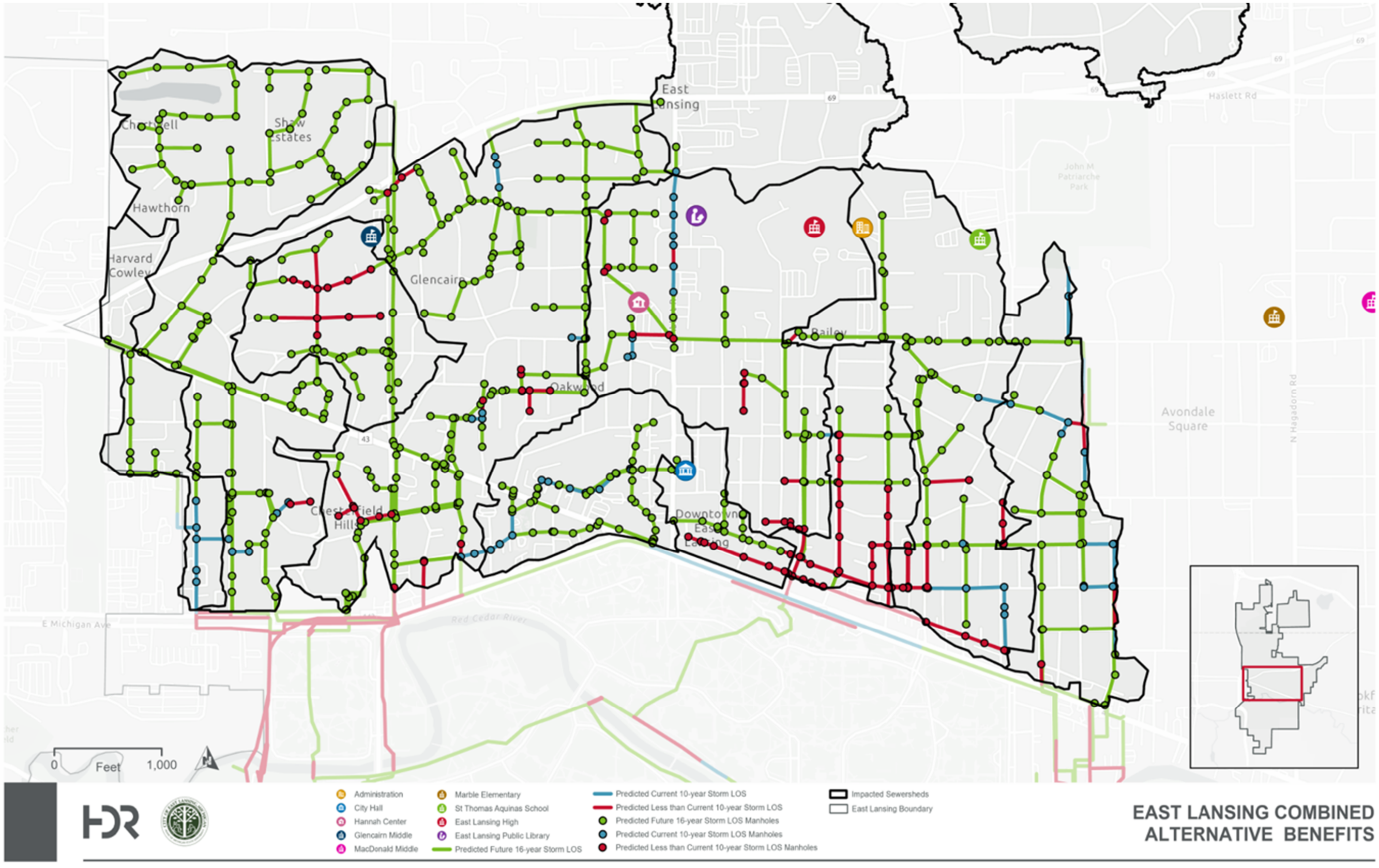


Figure 7-2. Predicted LOS benefits from all selected alternatives.

7.2. Non-structural Strategies under Consideration

Private property is both a contributor to the flooding problem and the primary victim of urban flooding. The structural strategies for public infrastructure improvements developed as part of this study are limited, on their own, in their ability to reduce flood risk to the community. The City recognizes that any plan to increase resiliency and reduce flood risk must include a holistic approach. Based on study findings, several complementary nonstructural strategies are needed to reduce the remaining flood risk that the selected alternatives do not address.

Drainage infrastructure on private property also has hydraulic capacity limits and need to be updated to meet the needs of increased rainfall during storm events. Basement flooding, shown below in Figure 7-3, has several causes including broken or undersized sump pumps, poor landscape grading or downspout design, and more. This is different from basement backups, which also occur during storm events.

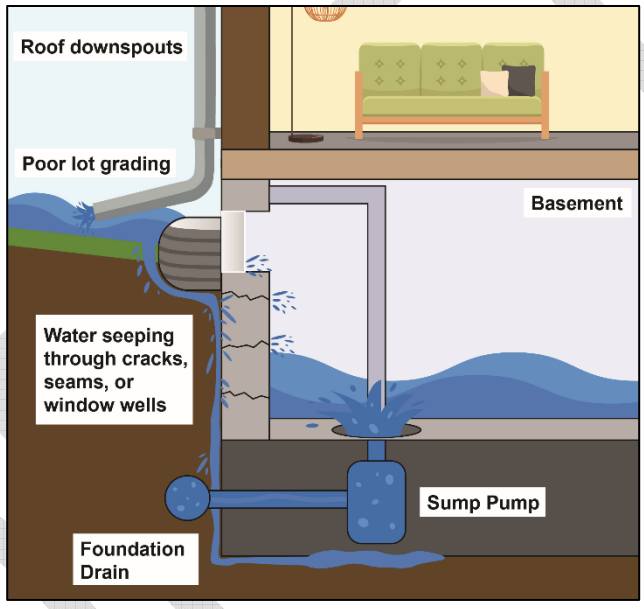


Figure 7-3. Additional causes of basement flooding that are not directly addressed in the WWRP.

The City currently provides information on several strategies for private property owners to help prevent basement flooding on its website, including the following:

- Checking gutters and downspouts for debris that accumulates over time. Removing the debris will reduce the likelihood of water spilling over the edge.
- Ensuring that downspout extensions are secure and functional. Downspouts should be at least 4 to 6 feet from the building to reduce the amount of water that saturates the ground near the building's foundation.
- Considering drainage areas when landscaping and grading. The ground should slope away from the foundation to encourage proper drainage. Adding patios, garden beds, and other hardscape can alter how water flows on the property.
- Testing sump pumps. The sump pump is the last line of defense against basement flooding, so residents should be sure to test that it is working before they need it.

While the above strategies can be implemented by private property owners, several other nonstructural strategies (programs, policies, and studies) under consideration by the City would complement the structural strategies recommended in this WWRP. These strategies, described in Table 7-1, target primary needs such as funding and impervious-surface reduction, both of which were topics of discussion during the stakeholder focus groups. Each strategy also has additional benefits that are complementary to the recommended structural strategies.

Implementation of these additional non-structural strategies would require additional City staff resources and funding. Some may be higher priority than others and should be vetted and discussed at the City leadership level to determine which strategies to implement and in what order of priority. A stormwater utility, which can provide the necessary funding for both structural and non-structural strategies and could serve as the repayment mechanism which, when combined with the plan, could open up low interest loans and grants for implementing the project. Efforts toward the creation of a stormwater utility should be considered foundational and made a high priority toward plan implementation.

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Table 7-1. Non-structural strategies under consideration.

Non-structural strategy	Description	Primary need addressed	Additional need addressed
Stormwater utility study	A stormwater utility study would explore creating a stormwater utility to support the implementation of both structural and nonstructural strategies. This directly addresses funding and has proved to be successful in other areas impacted by surface flooding. Inclusion of a stormwater credit program for property owner fee reductions should be considered to encourage stormwater management best practices to reduce runoff and/or improve water quality.	Funding	Asset management
Pay-in-lieu program study	A pay-in-lieu program allows developers to satisfy stormwater requirements through a fee payment when on-site compliance is impractical, while providing the City with a dedicated funding source for larger, watershed-scale stormwater improvements that can deliver equivalent or greater benefits.	Funding	New development and redevelopment
Updated post-construction standards	Updating post-construction standards (e.g., design storm, small site development, minimum requirements/credits) for resiliency.	Future climate	New development and redevelopment
Distributed green infrastructure program	This strategy would explore implementing a program specifically aimed at reducing the amount of impervious surfaces. More green infrastructure would improve drainage across the city.	Impervious-surface reduction	Widespread stormwater management, co-benefits
Consider expanded partnerships	Partnering with other City departments and nonprofit groups in the area would provide benefits across several areas, such as wetlands, trails, parks, etc.	Co-benefits (e.g., wetlands, trails and open space)	Funding, operations and maintenance support
Voluntary private property drainage audits	Providing additional staff and technical resources to residents and business owners on private property flood risk mitigation strategies.	Private property protection	Resiliency
Voluntary buy-out program	A voluntary program for City acquisition of flood-prone properties and structures that are not easily protected from flooding because of their specific location and surrounding topography. These areas would be turned into natural flood storage areas for additional flood risk reduction benefit.	Flood impact reduction	Additional stormwater storage opportunities
Basement backup protection program	Continue the City's existing Property Owner Assistance Program for Basement Backup Protection that provides financial reimbursement for installation of backflow preventers.	Private property protection	Resiliency
Enhanced GIS mapping	Develop enhanced GIS mapping of private drainage system infrastructure built by developers to document new systems and promote their active asset management and coordination with adjacent systems.	Private property protection	Infrastructure coordination
Stormwater management on City-controlled sites	Prioritize the proactive implementation of active stormwater management measures on City-controlled sites when other improvements are planned and implemented.	Runoff reduction and water quality	Additional green infrastructure
Impervious construction design standards	Review and modify current design and development standards for streets, bike lanes, sidewalks, and pathways that create additional impervious surfaces to incorporate current best practices for reducing hard-surface construction and incorporating green infrastructure.	Impervious-surface reduction	Additional green infrastructure

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7.3. Plan Implementation

The implementation of the recommended structural and non-structural strategies will be a long, iterative process. For each project or program, available funding must be identified to support the necessary capital, programmatic and operation and maintenance investments. Detailed planning, final design, and construction will occur for the recommended flood risk mitigation projects identified in the WWRP with capital funding identified and secured. The implementation of the WWRP and the recommended structural and non-structural strategies included will require ongoing collaboration between the City and neighborhood residents for open and inclusive stakeholder engagement during all phases of implementation.

The implementation of the recommended capital projects is impacted by several factors and must be carefully considered to develop a successful CIP. The selected alternatives will be implemented based on the results of the prioritization exercise described in Section 6.7. However, each selected alternative consists of several bundled projects which can be separated into phased projects to facilitate their completion. The size of the project bundles and the order in which they are implemented are influenced by the following factors:

- Available funding
- Existing City and State capital projects and construction
- Permitting requirements
- Potential utility investigations and relocations

As the projects bundled in each alternative specifically address flood risk reduction in the flooding CAs, it was also vital to consider the hydraulic connectivity between areas to minimize negative upstream and downstream impacts. Specifically, this typically necessitates the construction of outfalls to rivers, the main storm trunklines, storage facilities/green infrastructure and finally storm separation in the CSS area. Generally, the final phase of projects includes construction of upsized and new pipes. This is because following the implementation of the first phases of projects, additional flow monitoring and modeling should be conducted to inform the final design of CSS upgrades, with the potential to reduce the size and costs of future improvements. As part of the phasing process, permitting requirements will also require more detailed investigation as projects that impact regulated floodplains or protected wetlands will impact project implementation and schedule.

Table 7-2 provides an overview of the implementation plan for the selected and prioritized alternatives. Figure 7-4 provides a visual overview of the implementation plan. This implementation plan follows the order of prioritized alternatives and provides a brief justification for sequencing and phasing the capital projects that comprise each alternative for implementation. Currently, the City does not have a dedicated funding source for stormwater and is unable to harness SRF for implementation of stormwater only projects. Therefore, due to the current lack of a dedicated funding mechanism for stormwater projects at the City, consideration for projects that rank lower in priority that have access to readily available funding may be needed. However, it is important to note that phase 1 of Alternative 2b and phase 3 of Alternative 1b is SRF funded through other projects. The costs are provided in 2026 dollars and have not been escalated to a future year.

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Parallel to the implementation of the proposed capital projects, the City should work to add staff and technical resources needed to implement the non-structural programs that can help further mitigate climate change and assist property owners. Following the implementation of each new program and construction of each capital project, the implementation plan should be reviewed, modified and adapted based on new data, outcomes and newly identified strategies.

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Table 7-2. Proposed implementation plan for prioritized projects.

Priority	Alternative	Capital project	Proposed phase	Phasing justification	Cost
1	3b + storage	Construction of new storm trunkline sewer along Harrison Rd, including the outfall with treatment structure, combined sewer separation in areas north of Saginaw, and underground storage at Gordon Guyer.	1	Conducting storm separation first will reduce the likelihood of CSOs in subsequent phases. Storm trunkline is a necessary first step. Separate north of Saginaw as these areas will improve areas associated with Alternative 1b. Separating takes advantage of storage opportunity at Gordon Guyer Park to attenuate peak storm flow to river and improve resiliency.	$54.9M
		Combined sewer separation between Saginaw Hwy to Grand River, west of Harrison Rd, and underground storage at Glencairn Park.	2	Flows west of Harrison Rd can offload stormwater in the downstream combined system, east of Harrison Rd (existing flooding concern areas on Northlawn Ave and Sunset Ln). Also relieves water that flows toward flooding CAs on Charles St. Separating take advantage of storage opportunity at Glencairn Park to slow storm water flow to river and improve resiliency.	$25.8M
		Combined sewer separation east of Harrison Rd.	3	Flow monitoring and additional modeling after Phases 1 and 2 may reduce the amount of separation needed for this area depending on outcomes. This area should come last to understand the effectiveness of Phase 1 and 2.	$26.9M
		Upsizing combined sewer pipes and constructing new pipes along Charles St, including the structure modifications.	4	Cannot upsize without first completing combined sewer separation because of the potential for increased CSOs. Flow monitoring and additional modeling after Phase 2 may also reduce the required diameter of these pipes.	$21.3M
		Remaining storm separation required to address flooding CAs E and G.	5	Implementation of this remaining area is dependent upon upsizing of Charles Street and associated new pipes/modifications. Must do Phase 4 first for this project to be effective.	$30.3M
2	2b + storage	Construction of new storm trunkline sewer, including outfall with treatment structure, underground storage at Valley Court Park, and combined sewer separation north of Grand River Ave., around Valley Court Park.*	1	Conducting storm separation first would reduce the likelihood of CSO in subsequent phases. Storm trunkline sewer is necessary first step. Separating take advantage of storage opportunity at Valley Court park to attenuate peak storm flow to the river and increase resiliency. This storage is necessary prior to separating flow south of Saginaw in Phase 2. Currently part of a FY2028 plan.	$30.8M
		Combined sewer separation south of Grand River Ave. to Michigan Ave.	2	A natural ridgeline/separation within this watershed runs along Grand River Ave. Full separation south of Grand River Ave. should come second to not increasing peak flows to the river.	$15.6M
		Combined sewer separation north of Grand River Ave., in area of Ardson, Woodland, Marshall and Clifton streets.	3	This area should come last as there is potential for separated storm flow toward the Harrison trunkline in Alternative 3. As this alternative is in conjunction with Alternative 3, flow monitoring and modeling may reduce the area of separation needed depending on effectiveness of prior projects.	$4.9M
		New and upsized combined sewers, restrictor modification and new regulator.	4	Flow monitoring and modeling to confirm the effectiveness of prior phases may eliminate the need for these projects to relieve remaining combined sewer capacity, therefore, these projects should come last within this alternative.	$3.9M
3	1b	Construction of new storm trunkline sewer from the outfall at Ranney Park to Saginaw Hwy. Combined sewer separation of the area tributary to Phase 1 storm trunkline sewer.	1	Need to construct the storm trunkline and the separation of stormwater working from downstream to upstream. This ensures that the tributary areas realize incremental benefit as the trunkline is being constructed.	$11.7M
		Extension of the new storm trunkline sewer north of Saginaw Hwy. to Chartwell. Combined sewer separation of the area tributary to Phase 2 storm trunkline sewer.	2	Continue the construction of additional storm trunkline and connect into the Phase 1 system. Continue additional storm separation further upstream north of Saginaw Hwy.	$14.7M
		Construction of new storm trunkline sewer that runs along Grand River Ave. Combined sewer separation of the area tributary to the Phase 3 storm trunkline sewer. *	3	Continue third installment of additional storm trunkline and connect into Phases 1 and 2 system. Complete combined sewer separation along Grand River Ave. corridor.	$12.2M
		Upsized and new combined sewers with sewer bulkheads and the restrictor modification in the Highland and Cowley area.	4	Flow monitoring and additional modeling to confirm the effectiveness of prior phases may eliminate the need for these projects. Therefore, these projects should come last within this alternative.	$4.3M
4	6a	Expansion of the fishing pond at the Albert A. White Memorial Park for additional aboveground stormwater storage.	1	Construction of the storage facility is required prior to increasing the storm pipe capacity to ensure that downstream areas are not negatively impacted by increased flow from upsized pipes in Phase 2.	$0.5M
		Upsizing the storm sewers upstream from the aboveground storage along Pebblebrook Lane to Hagadorn Road.	2	Upsized pipes should come after storage to ensure that this alternative is not shifting flood risk to downstream areas.	$9.7M
5	5a	Construction of the above ground storage at Harrison Meadows Park and at the Fire Department open lot.	1	Construction of the storage facility is required prior to upsizing the storm pipe capacity to ensure that downstream areas are not negatively impacted by increased flow from upsized pipes in Phase 2.	$13.5M
		Upsizing the storm pipes from the fire station to the commercial area to the south along Abbot Rd.	2	Upsized pipes should come after storage to ensure that this alternative is not shifting flood risk to downstream areas.	$24.4M

* SRF funded project

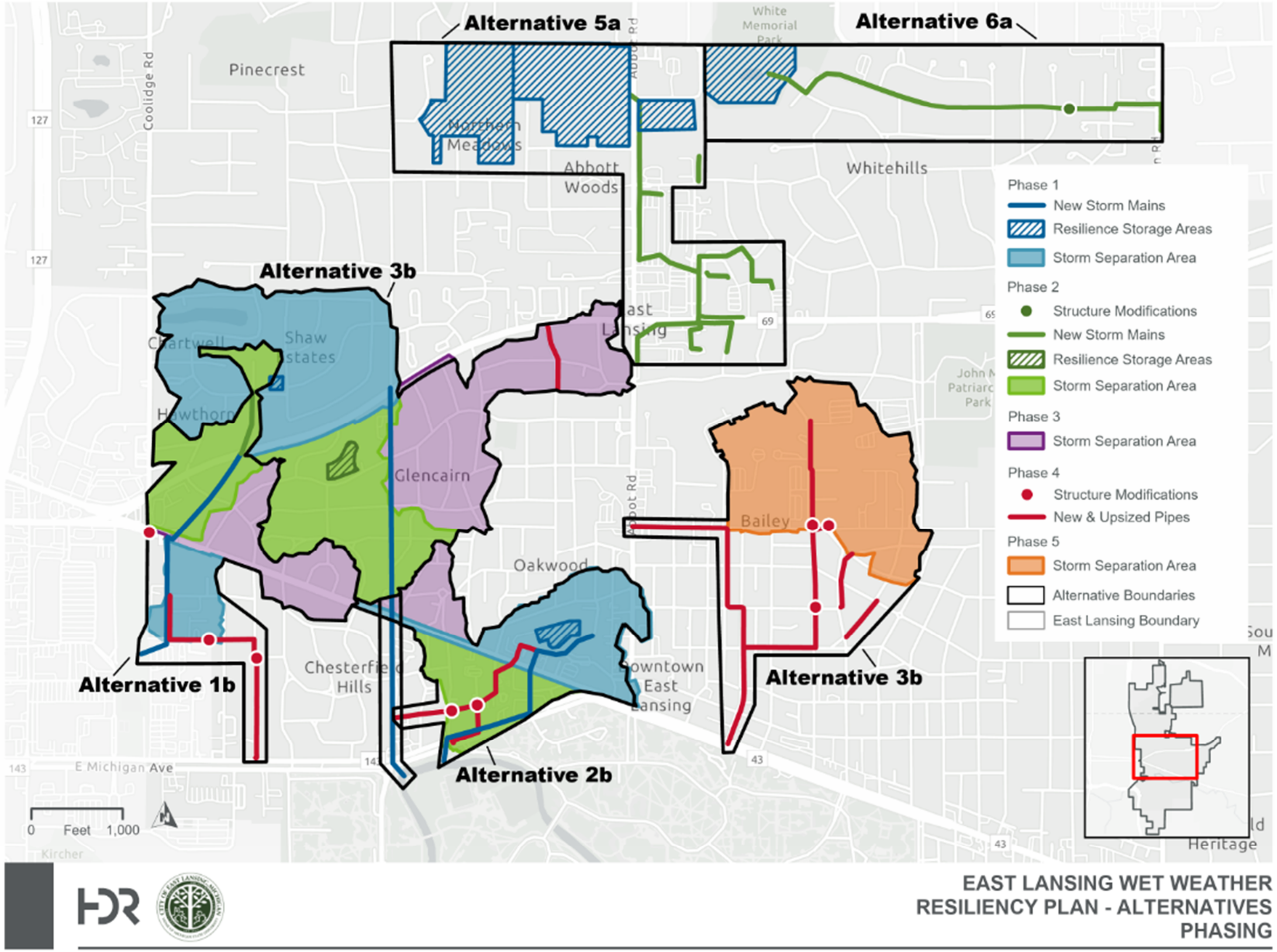


Figure 7-4. Overview of the phased implementation plan for the recommended structural strategies.

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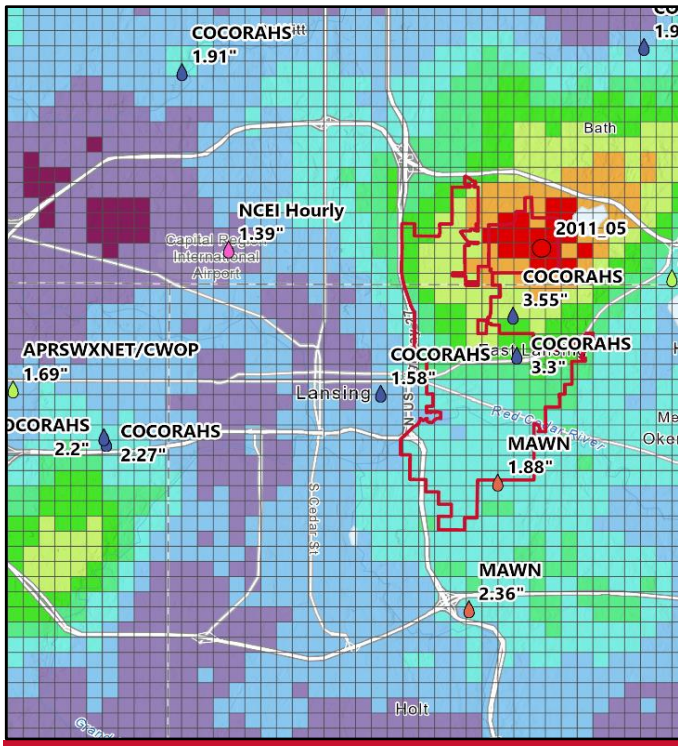
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Appendix A.

Task 1: *Changing Precipitation Conditions* Technical Memorandum



City of East Lansing Changing Precipitation Conditions Report

East Lansing Wet Weather Resiliency Plan

June 27, 2024

Prepared for

City of EAST LANSING
Home of Michigan State University

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Appendix A: GARR Methodology

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List of Acronyms and Abbreviations

AMS	Annual Maximum Series
City	City of East Lansing
CMIP	Coupled Model Intercomparison Project
DDF	Depth-Duration Frequency
EGLE	State of Michigan Department of Environment, Great Lakes, and Energy
GARR	Gauge-Adjusted Radar Rainfall
GCM	Global Climate Model
GHG	Greenhouse Gas
GLISA	Great Lakes Integrated Sciences and Assessments Center
KLAN	Lansing Capital Regional International Airport
LOCA 2	Localized Constructed Analog 2
MAWN	Michigan Automated Weather Network
MSU	Michigan State University
NCEI	National Centers for Environmental Information
NOAA	National Oceanic and Atmospheric Administration
PFE	Precipitation Frequency Estimate
POR	Period of Record
QA	Quality Assured
QC	Quality Controlled
SSP	Share Socioeconomic Pathway
WRD	Water Resources Division

Executive Summary

In August 2021, East Lansing (City) faced an unprecedented challenge when 7.22 inches of rainfall fell within the City in the span of 5-6 hours—an event deemed to be as rare as a 1,000-year storm. The event resulted in 227 reported incidents of flooding. Just a month later, in September 2021, the City saw 25 more reports of flooding, this time from a mere half-hour downpour of 1.25 inches. It was a stark reminder of the increasing frequency of short but intense storms hitting our community. These events are not unique to East Lansing as communities across the nation are grappling with the challenges of more frequent, high-intensity storms. In a proactive response, the City has initiated the development of a Wet Weather Resilience Plan (Plan) to find ways to mitigate flooding and safeguard its residents and visitors. As part of the Plan, the City and its consultant HDR have developed *The City of East Lansing Changing Precipitation Conditions Report* that incorporates the latest scientific analysis using historic and future climate change rainfall. The findings within the report will ensure that future investments as part of the Plan are functional and resilient to increasing rainfall patterns.

What type of analysis was performed?

Historical Trending Analysis. The report analyzed historical rainfall trends using rainfall data from 1949 to 2023 from the Lansing Airport. Over this period the trendline of annual precipitation in the East Lansing region increased approximately 30% (from 27 to 35 inches of rain). Likewise, the historical trends indicate that the intensity of rain events have also increased. For high intensity 1-hour duration rain events, historic trends indicate an almost 75% increase in rainfall from 1949 to 2023.

Engineering Design Storm Analysis. Engineers rely on prescribed engineering design storms to "right size" stormwater drainage systems. These events are the so called "10-year" or "100-year" rain events. Analysis within this report found that the engineering design storm estimates developed by the National Oceanic and Atmospheric Agency, commonly referred to as Atlas-14, are over 10 years out of date. The engineering design storms were updated for the City using more recent rainfall data. Analysis indicates that by including more recent rainfall data the engineering design storm for the 1 though 25 year rain events all increase, indicating that smaller, more intense, and more frequent rain events are increasing in size.

Representative Storm Analysis. Using radar rainfall data, twelve of the largest rain events that have impacted East Lansing in the past 30 years were analyzed. Analysis from these events indicate that storms that result in flooding in East Lansing are often 3 to 18 hours in duration. Most of the rainfall in these events happens in fewer than two to three hours. This indicates that short duration rain events should be a focus for the Plan.

Future Climate Change Analysis. The impact of future climate change was determined using state of the practice Global Climate Models specific to East Lansing. Climate change projections were determined for the years 2035, 2050, 2070, and 2100. Under a medium global climate change scenario, rainfall estimates are predicted to increase by eight percent by 2100. Under a high global climate change scenario, rainfall estimates are predicted to increase by 20 percent by 2100.

What are the key takeaways that you should know about changing precipitation in East Lansing?

1. **Using actual observed data from the Lansing Airport, annual rainfall volumes and single event intensities are both increasing. Engineering design standards should consider this increase by using more up to date engineering design storms determined as part of this analysis.**
2. **Analysis of twelve heavy rain events over the past 30 years indicate that rainfall patterns happen in a short intense burst of rain with most of the rainfall occurring in fewer than two to three hours. Engineering design standards should incorporate and account for short intensity rainfall by using a "representative storm" specific to East Lansing.**
3. **Future climate change results in an eight to 20 percent increase in rainfall for the year 2100. The percentage increase due to climate change should be considered as part of the Plan.**

1 Introduction

The City of East Lansing (City) is developing a Wet Weather Resilience Plan to mitigate surface and basement flooding across the City. As part of the plan, the City is looking to incorporate climatic analysis specific to East Lansing to ensure that future infrastructure investments are safe guarded against potential increases in future rainfall patterns. The City of East Lansing Changing Precipitation Conditions Report provides the following analysis in each section:

- Section 2: Climatic Precipitation Trends. This section provides historical trending analysis of historical rainfall data collected from the East Lansing Region. The purpose of this section is to understand how rainfall patterns have changed using nearby readily available historic rainfall data from weather stations.
- Section 3: Updated Precipitation Frequency Estimates. This section provides analysis for the development of updated precipitation duration frequency estimates for use by the City for stormwater design purposes. Recommendations are provided for consideration for design implementation.
- Section 4: Site Specific Representative Storm. This section analyzes historic rainfall events over the past 30 years that have impacted City stormwater infrastructure due to flooding. Gauge Adjusted Radar Rainfall (GARR) data were developed to scientifically understand how large rainfall events have historically moved (both temporally and spatially) across the City. Using the GARR data, a site-specific representative storm was developed for use in conjunction with the updated precipitation frequency estimates.
- Section 5: Climate Change Projections. This section provides future climate change projections specific to East Lansing using downscaled global climate models. The results of this analysis inform how rainfall patterns may increase into the future in the years 2035 and 2050.

A summary of findings is provided at the conclusion of the report that has a high-level discussion of the results from each section for consideration as part of the Wet Weather Resilience Plan.

2 Climatic Precipitation Trends

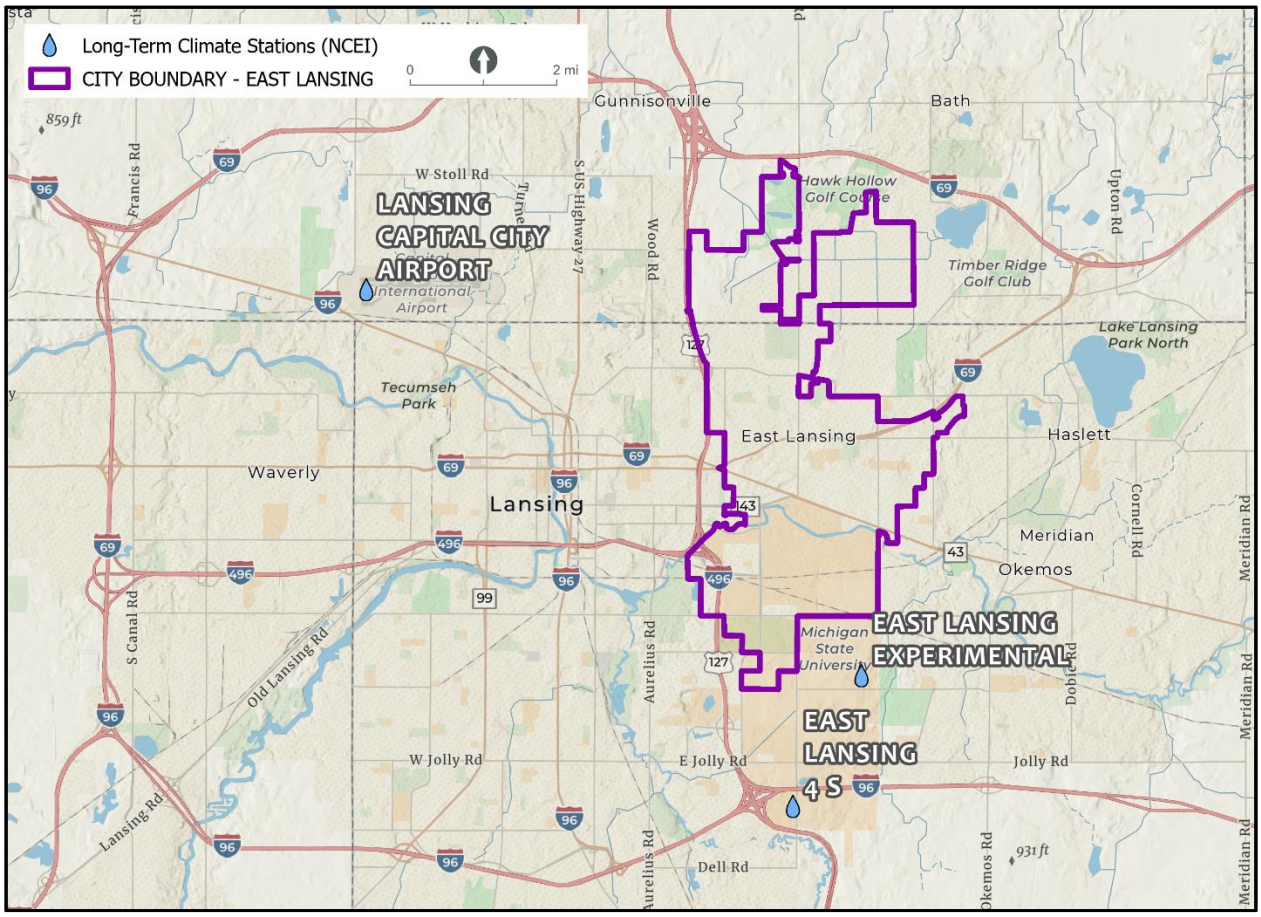
This section provides analysis of historical precipitation trends using long-term climate data.

2.1 Data Development

HDR was tasked with analyzing long-term climate data to understand how the historical observations of precipitation are trending in the City. The long-term climate station located at the Lansing Capital Regional International Airport (KLAN), approximately 4 to 8 miles west of the City, provided the project with a complete and very consistent dataset to analyze. These data were downloaded from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI). The precipitation data were provided in 1-hour and 24-hour increments from the source. The available period of record (POR) of precipitation data from KLAN was from 1949 to 2023, with precipitation data missing for the years of 1954 through 1959, which equates to over 60 years of consistent precipitation reporting. These hourly and daily precipitation data were quality assured (QA) and quality controlled (QC) prior to being made available in these data archives but were further QA/QC'd by HDR prior to being developed into a climatic precipitation trends and new precipitation frequency distribution for the City (Task 1.2).

HDR also analyzed data from two long-term climate stations closer to East Lansing that sat on the campus of Michigan State University (MSU). These climate stations are the East Lansing Experiment Farm (POR: 1911–2008) and East Lansing 4S (POR: 1957–2010) stations and only had 24-hour reporting intervals. These data were also provided by NOAA NCEI. Upon further investigation, while being fairly consistent in their reporting, both stations only averaged about 350 daily reports per year, meaning they were missing on average 15 days of precipitation reports per year. For comparison, KLAN averaged 365 daily reports of precipitation per year in its daily precipitation product. Also, the PORs of these stations were not as complete as would be required for an up-to-date climate trend analysis. The PORs of both stations fell off in 2008 and 2010, respectively, meaning approximately the last 15 years of observed data would not appropriately inform the climate trends of East Lansing. Error! Reference source not found. shows the locations of these NCEI long-term climate stations in the Lansing and East Lansing area.

Figure 1. NCEI Long-Term Climate Stations for the Lansing and East Lansing Area

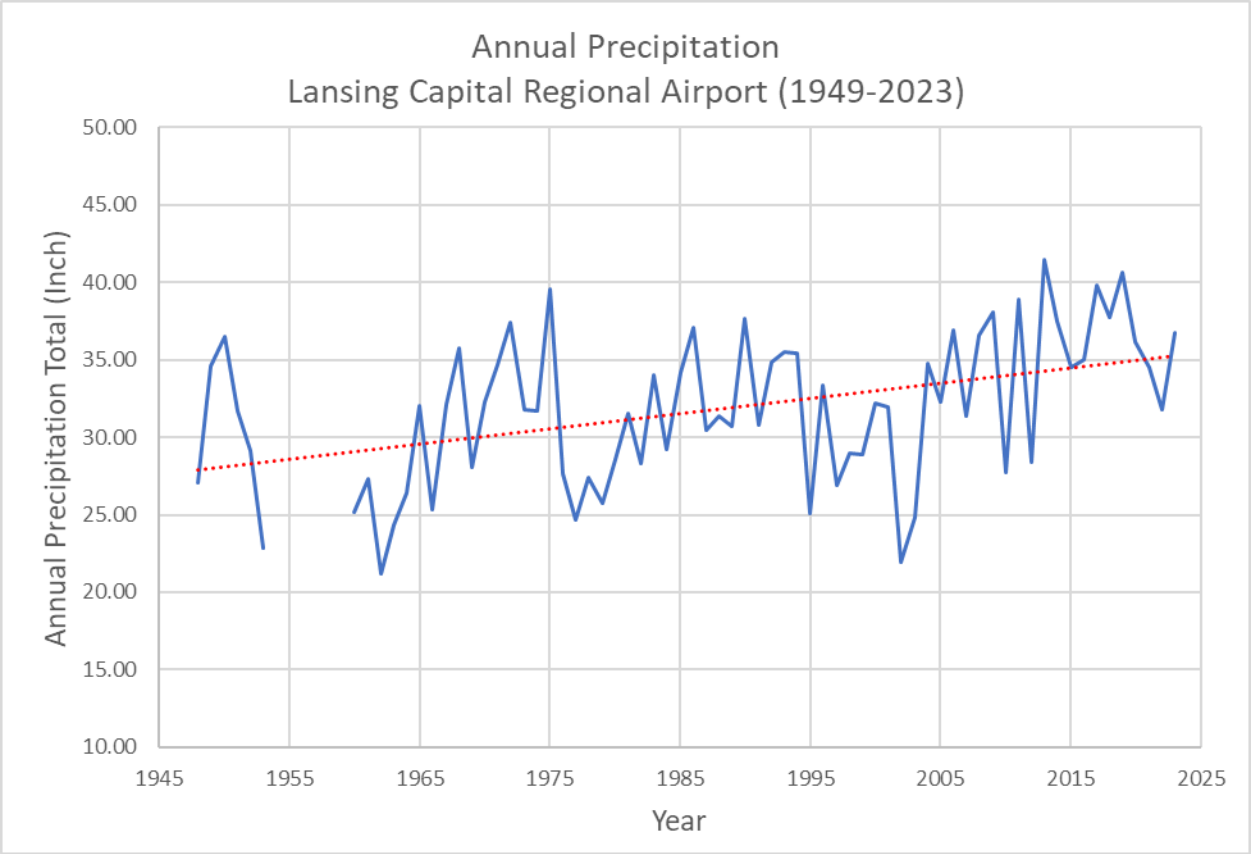


A historic precipitation trend analysis was performed on the annual precipitation data at the KLAN meteorological reporting station. These data, particularly as they pertain to precipitation intensities over various durations, provided insight into the changes that can be seen between the depth-duration frequency (DDF) curves that utilized data up until approximately the year 2010 (NOAA Atlas 14, Volume 8, Version 2.0[1]) as well as the updated curves and return frequency data that HDR has recently developed (Task 1.2).

Figure 2 shows the change in annual precipitation at KLAN during the POR 1948–2023. The long-term trend shows an increase of approximately 7 inches of annual precipitation at this site. This increase in annual precipitation is in line with other studies of precipitation over Michigan and the Midwest. The Great Lakes Integrated Sciences and Assessments Center (GLISA 2024)[2] found that since 1951, the total annual precipitation has increased by 14 percent in the U.S. Great Lakes Region.

[1] https://www.weather.gov/media/owp/oh/hdsc/docs/Atlas14_Volume8.pdf.
[2] https://glisa.umich.edu/resources-tools/climate-impacts/precipitation/.

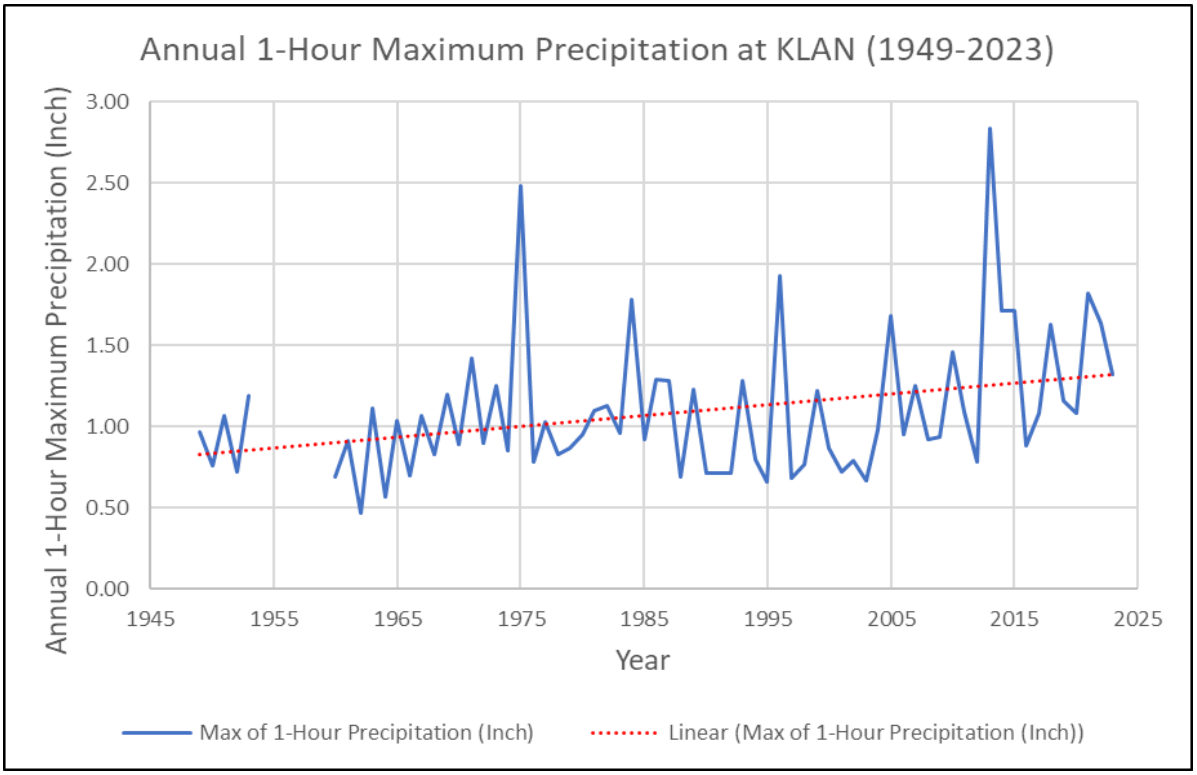
Figure 2. Annual Observed Precipitation Totals for KLAN from 1949–2023



Trendline in red.

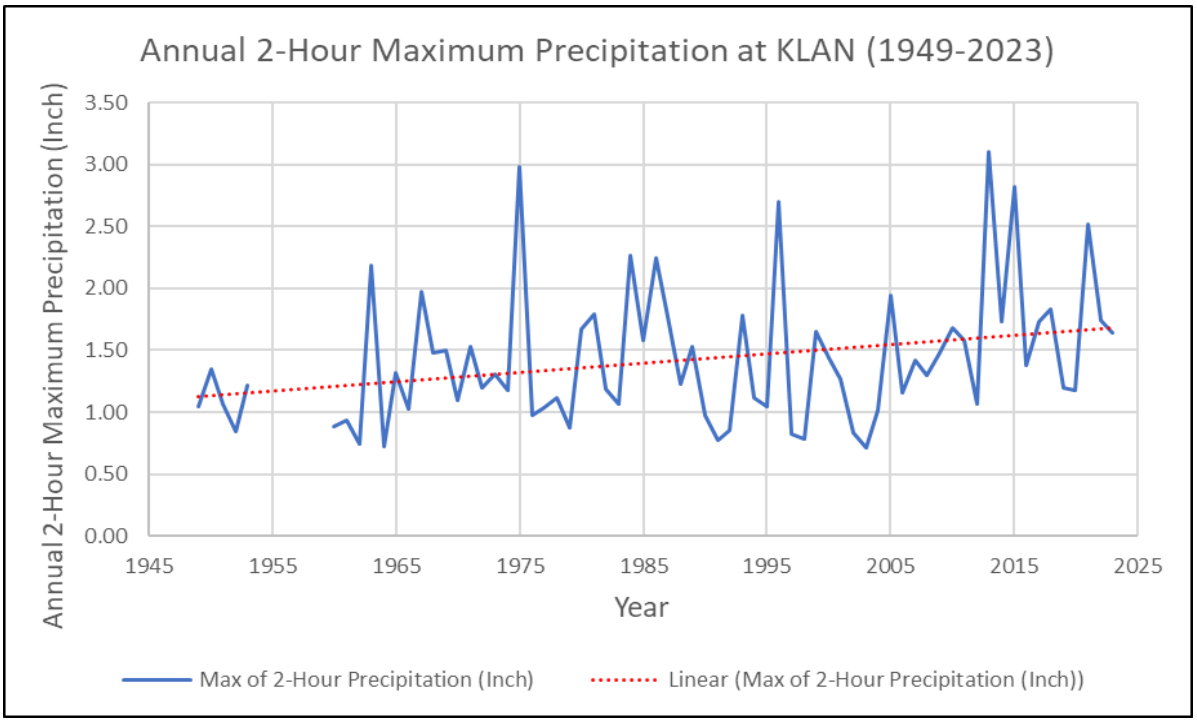
While tasked with looking at the 6-hour and 24-hour precipitation trends, HDR assessed the observed trends in the 1-hour, 2-hour, 6-hour, 12-hour, and 24-hour maximum precipitation intensities for the POR 1949–2023. These were analyzed using the hourly precipitation data from the KLAN meteorological reportion station. Figure 3 through Figure 7 show these observed trends. Much like the annual trend, the precipitation intensities at 1-hour, 2-hour, 6-hour, 12-hour, and 24-hour durations are increasing. Upon closer examination, precipitation intensities are also becoming more variable year-over-year at this location.

Figure 3. Annual 1-hour Maximum Precipitation at KLAN (1949–2023)



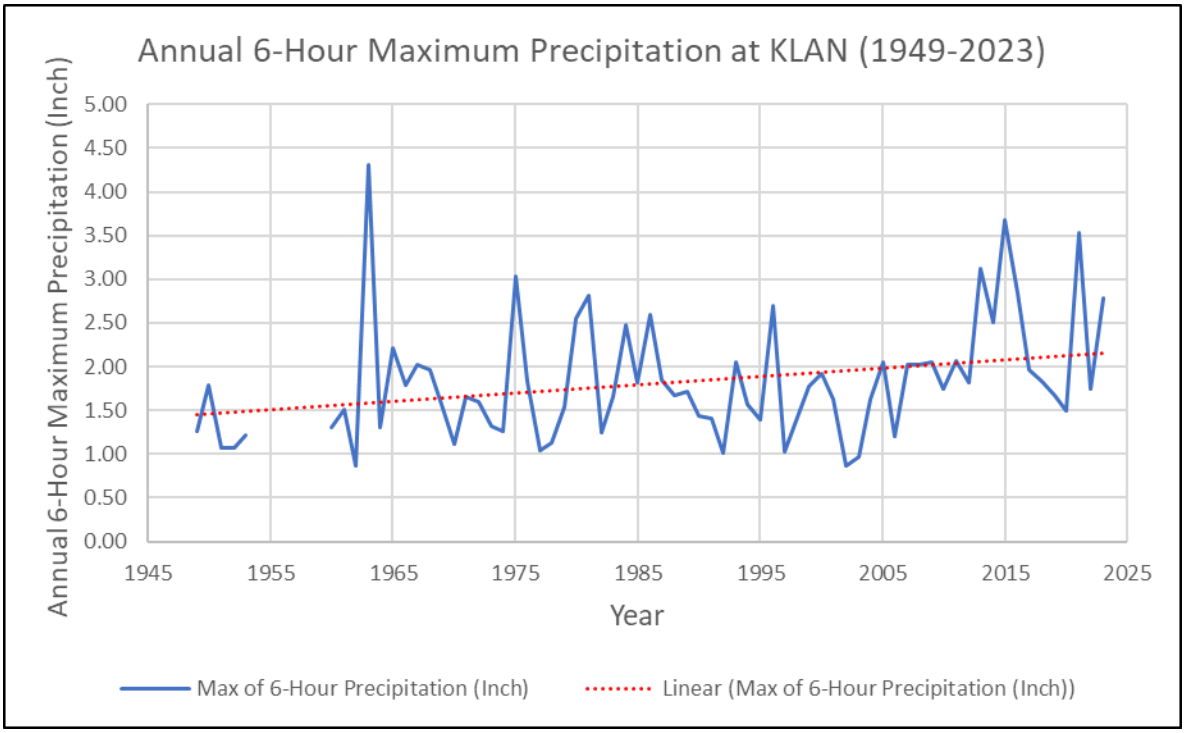
Trendline in red.

Figure 4. Annual 2-hour Maximum Precipitation at KLAN (1949–2023)



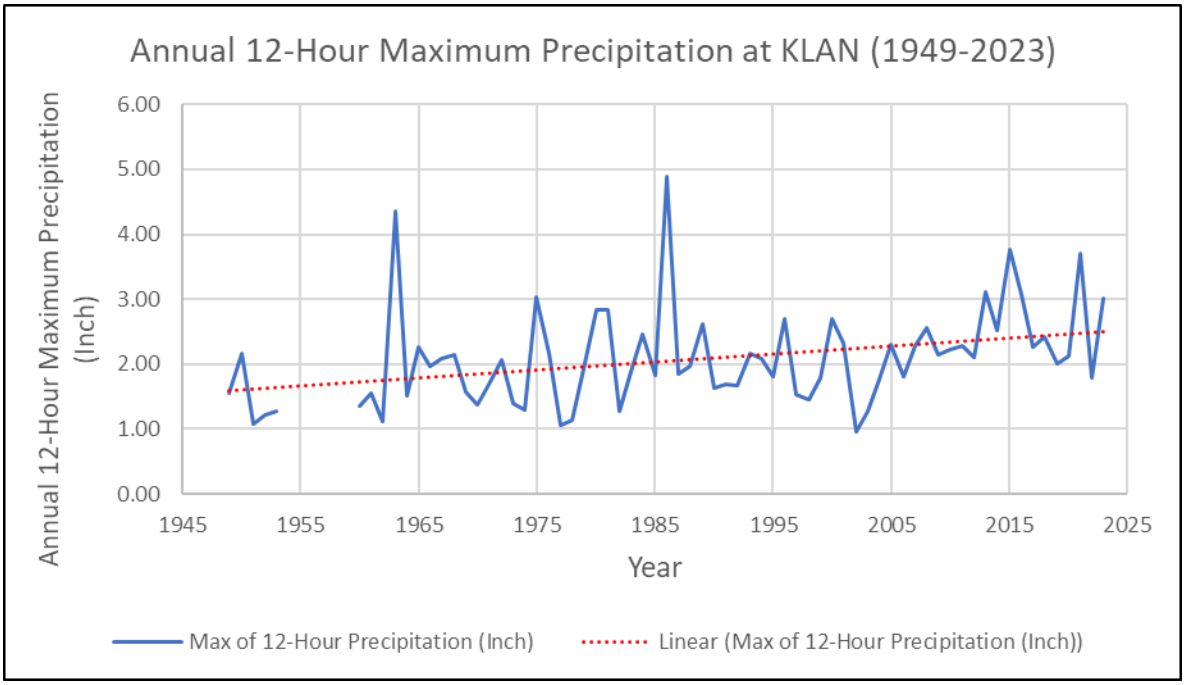
Trendline in red.

Figure 5. Annual 6-hour Maximum Precipitation at KLAN (1949–2023)



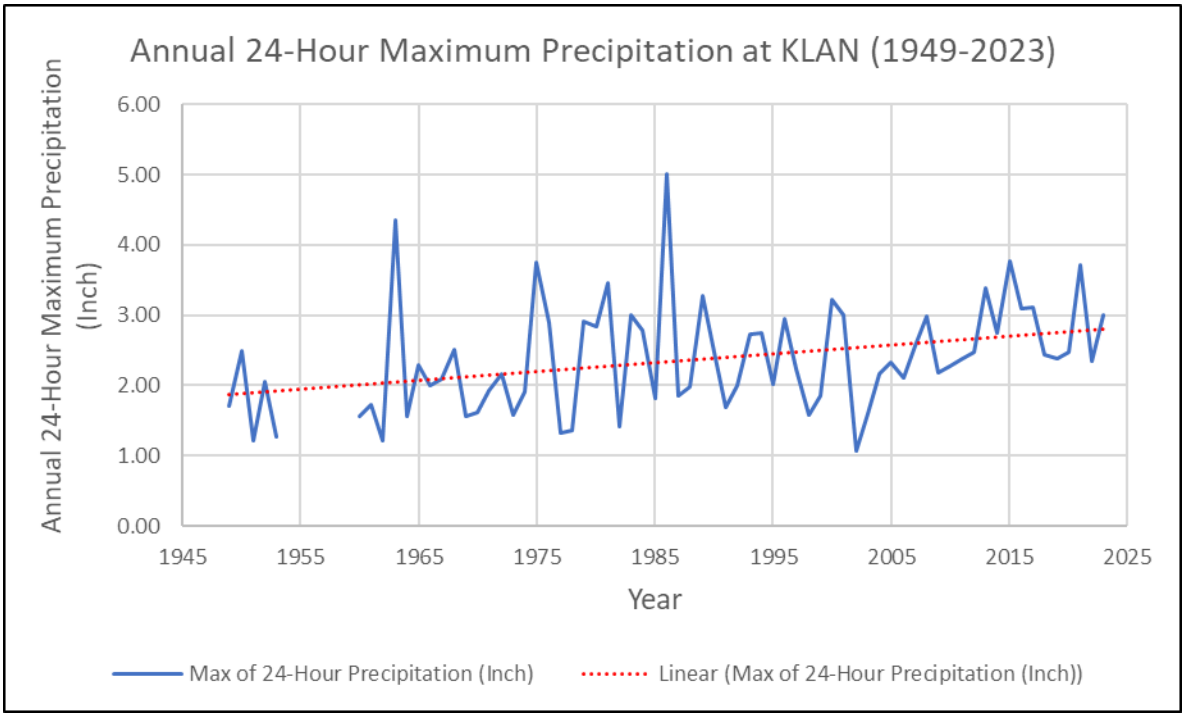
Trendline in red.

Figure 6. Annual 12-hour Maximum Precipitation at KLAN (1949–2023)



Trendline in red.

Figure 7. Annual 24-hour Maximum Precipitation at KLAN (1949–2023)



Trendline in red.

3 Updated Precipitation Frequency Estimates

The following section provides analysis for the development of updated precipitation frequency estimates for the City of East Lansing.

3.1 Background and Current Return Frequency Values

The current City of East Lansing Stormwater Design Manual (2016) utilizes the Huff and Angel 24-hour design storm event for Zone 9 developed from precipitation frequency data prior to 1992. Also, NOAA Atlas 14, Volume 8, Version 2.0 (annual maximum series [AMS]) for the Midwest states is available and was created in 2013 (NOAA, 2023); however, is over 10 years old for this region. The NOAA Atlas 14 data that are representative of the City as a whole can be seen in Table 1, which also provides the point estimates for the 1-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year durations as well as the 6-hour, 12-hour, and 24-hour durations at KLAN in addition to the City of East Lansing. These NOAA Atlas 14 values are also compared to Huff and Angel (1992) for Zone 9.

Table 1. Return Frequency Estimates for East Lansing

		PRECIPITATION FREQUENCY ESTIMATES						
Source	**Duration**	**1yr**	**2yr**	**5yr**	**10yr**	**25yr**	**50yr**	**100yr**
Huff and Angel (1992) Zone 9	6-hour	1.52	1.82	2.24	2.57	3.07	3.47	3.90
NOAA Atlas 14 Volume 8, Version 2.0 (KLAN)	6-hour	-	1.63	2.21	2.68	3.37	3.92	4.52
NOAA Atlas 14 Volume 8, Version 2.0 (East Lansing)	6-hour	-	1.62	2.20	2.68	3.37	3.94	4.54
Huff and Angel (1992) Zone 9	12-hour	1.77	2.11	2.59	2.98	3.56	4.03	4.52
NOAA Atlas 14 Volume 8, Version 2.0 (KLAN)	12-hour	-	1.95	2.50	2.98	3.69	4.29	4.95
NOAA Atlas 14 Volume 8, Version 2.0 (East Lansing)	12-hour	-	1.94	2.49	2.97	3.68	4.29	4.95
Huff and Angel (1992) Zone 9	24-hour	2.03	2.42	2.98	3.43	4.09	4.63	5.20
NOAA Atlas 14 Volume 8, Version 2.0 (KLAN)	24-hour	-	2.29	2.87	3.37	4.14	4.78	5.49
NOAA Atlas 14 Volume 8, Version 2.0 (East Lansing)	24-hour	-	2.28	2.85	3.35	4.11	4.76	5.47

NOTE: NOAA Atlas 14 does not calculate 1-year value in its annual maximum series (AMS) analysis.
Source: Huff and Angel (1992) and NOAA Atlas 14, Volume 8, Version 2.0 (2013)

As shown in Table 1, the Huff and Angel values for the 2-year and 5-year durations were generally greater when compared to NOAA Atlas 14 values but, conversely, the values for Huff and Angel were less than the NOAA Atlas 14 values for the 25-year, 50-year, and 100-year return frequencies. Comparing the NOAA Atlas 14 values at KLAN and East Lansing, there was less than a half of a percent difference between the values for all estimates and durations. Therefore, the NOAA Atlas 14 value for KLAN will be used for the rest of the study in order to compare directly to the updated return frequency analysis of KLAN data.

3.2 Updated Return Frequency Analysis and Results

To assess if there is need to reanalyze the Huff and Angel and NOAA Atlas 14 return frequency data using the last 10 to 30+ years of additional data, HDR performed a Gumbel Type-1 distribution analysis to create an updated determination of these return frequency estimates using the AMS from the entire POR (69 years) as well as the last 30 years of precipitation gauge data from the KLAN meteorological station. HDR looked to the last 30 years of data as a check to see if the increasing precipitation intensities due to climate change that have been observed in the past 30 years (Task 1.1) yielded different results.

The Gumbel distribution of the annual maximum series over the last 30 years from KLAN can be seen in

Figure 8 for the 6-hour duration, Figure 9 for the 12-hour duration, and Figure 10 for the 24-hour duration. This distribution provides an extrapolation of these trends out to 50 and 100-year return frequencies at this location.

Figure 8. Gumbel Type-I Statistical Distribution of 6-hour Annual Maximum Series Precipitation for KLAN for the Last 30 Years (1994–2023)

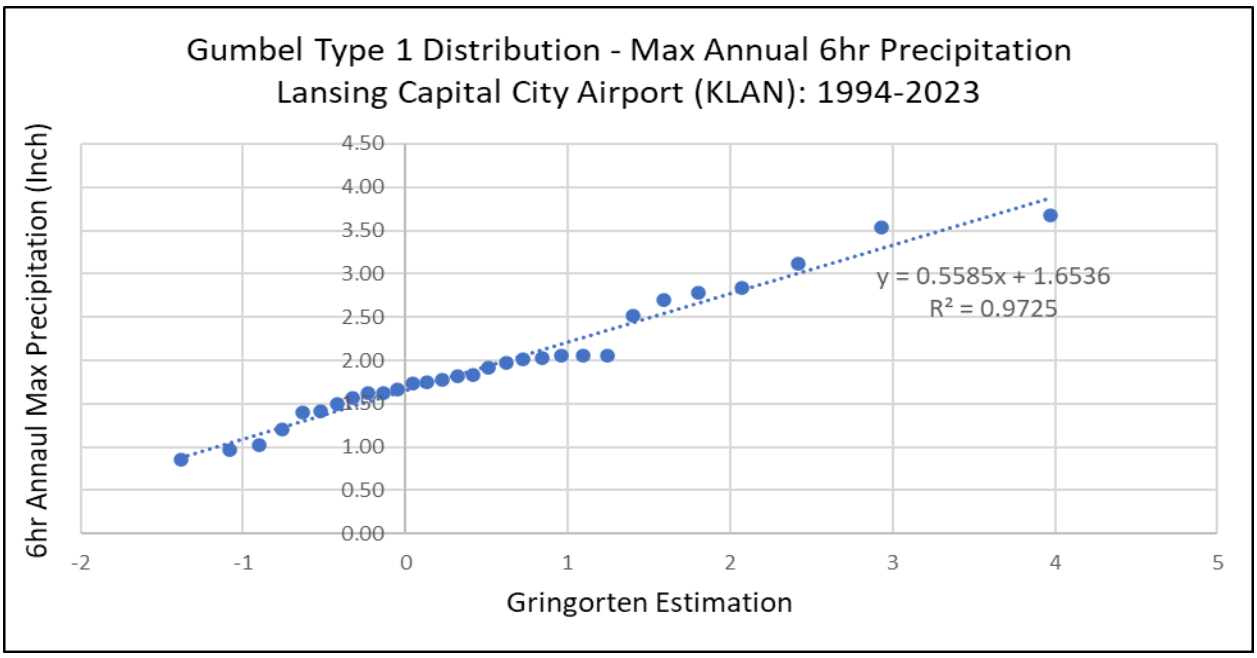


Figure 9. Gumbel Type-I Statistical Distribution of 12-hour Annual Maximum Series Precipitation for KLAN for the Last 30 Years (1994–2023)

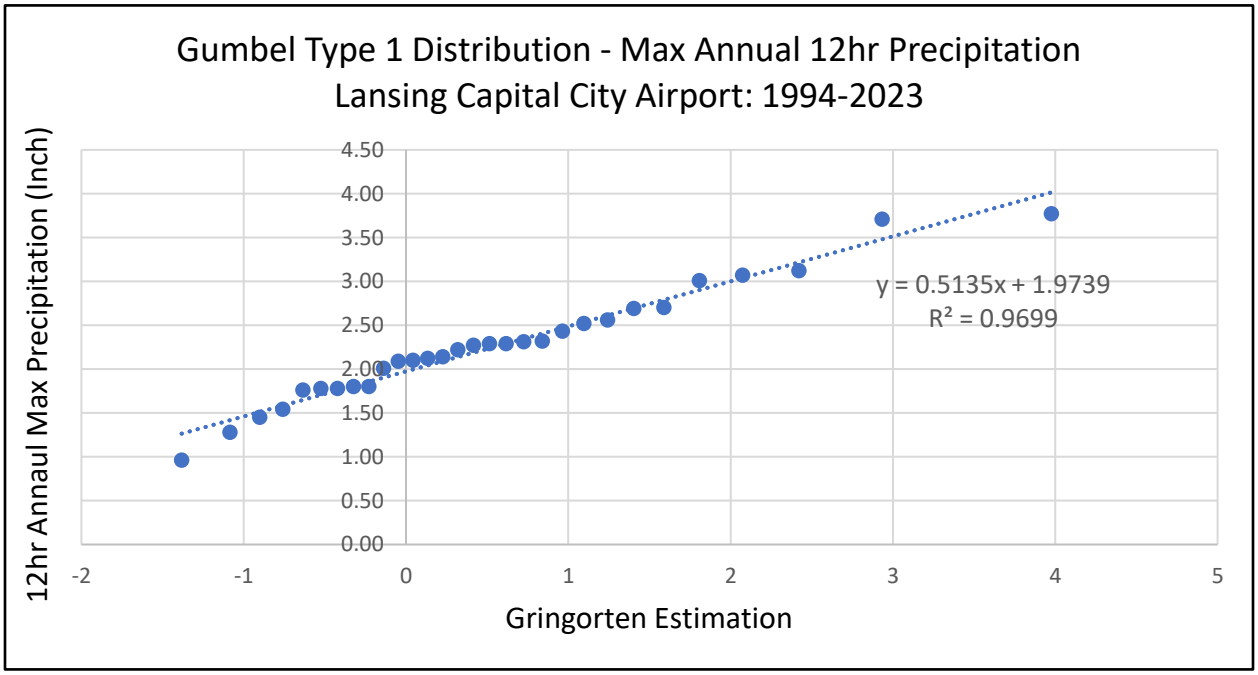


Figure 10. Gumbel Type-I Statistical Distribution of 24-hour Annual Maximum Series Precipitation for KLAN for the Last 30 Years (1994–2023)

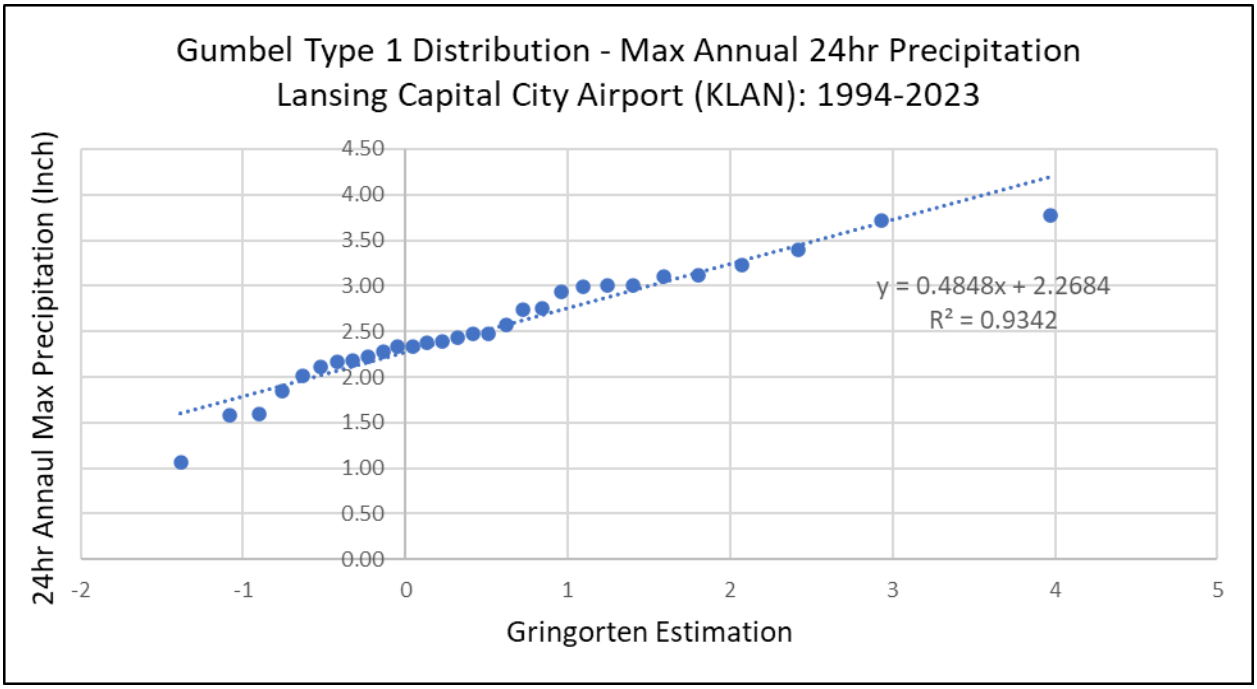


Table 2 shows the results of the analysis using the statistical distribution for the past 30 years of data in Figure 8, Figure 9, and Figure 10, as well as the results from the Gumbel Type-I analysis using the entire POR for KLAN. Table 2 also shows the calculated return frequency comparisons to NOAA Atlas 14 and Huff and Angel (1992).

Table 2. Return Frequency Comparisons of the Gumbel Type-1 Analysis (at KLAN), NOAA Atlas 14 (at KLAN), and Huff and Angel (Zone 9)

Analysis Type	Duration	Precipitation Frequency Estimates						
		1-year	2-year	5-year	10-year	25-year	50-year	100-year
Gumbel at KLAN (Entire POR)	6-hour	1.52	1.72	2.34	2.74	3.26	3.65	4.03
Gumbel at KLAN (Last 30-years)	6-hour	1.65	1.86	2.49	2.91	3.44	3.83	4.22
Huff and Angel (1992) Zone 9	6-hour	1.52	1.82	2.24	2.57	3.07	3.47	3.90
NOAA Atlas 14 (KLAN)	6-hour	-	1.64	2.21	2.68	3.36	3.92	4.52
Gumbel at KLAN (Entire POR)	12-hour	1.74	1.96	2.64	3.09	3.65	4.07	4.49
Gumbel at KLAN (Last 30-years)	12-hour	1.97	2.16	2.74	3.13	3.62	3.98	4.34
Huff and Angel (1992) Zone 9	12-hour	1.77	2.11	2.59	2.98	3.56	4.03	4.52
NOAA Atlas 14 (KLAN)	12-hour	—	1.95	2.50	2.98	3.69	4.29	4.95
Gumbel at KLAN (Entire POR)	24-hour	2.02	2.25	2.95	3.41	4.00	4.43	4.86
Gumbel at KLAN (Last 30-years)	24-hour	2.27	2.45	3.00	3.36	3.82	4.16	4.50
Huff and Angel (1992) Zone 9	24-hour	2.03	2.42	2.98	3.43	4.09	4.63	5.20
NOAA Atlas 14 (KLAN)	24-hour	—	2.29	2.87	3.38	4.14	4.79	5.50

Green indicates values calculated for the entire 69-year Period of Record (POR) at KLAN, blue indicates values calculated for the last 30-year POR at KLAN, yellow is the Huff and Angel (1992) Zone 9 values, and orange is NOAA Atlas 14, Volume 8, Version 2.0 values at KLAN.

As shown in Table 2 (and summarized in Table 3), the Gumbel Type-1 analysis for the last 30 years has the greatest return frequency values for the 2-year and 5-year periods in both the 6-hour and 24-hour durations. NOAA Atlas 14 (at KLAN) has the greatest return frequency for both durations at the 50-year and 100-year return frequencies. The 10-year and 25-year frequencies combine the three sources listed in Table 3 for both durations. Overall, the Gumbel Type-1 analysis for the last 30 years and the NOAA Atlas 14 analysis provided the greatest DDF values when looking at all sources for almost all return frequencies.

Table 3. Max Return Frequency Values and Analysis Method Summarized from Table 2

Analysis Type	Max-1-year	Max-2-year	Max-5-year	Max-10-year	Max-25-year	Max-50-year	Max-100-year
6-hour	1.65	1.86	2.49	2.91	3.44	3.92	4.52
Analysis	G-30	G-30	G-30	G-30	G-30	NA14	NA14
12-hour	1.97	2.16	2.74	3.13	3.69	4.29	4.95
Analysis	G-30	G-30	G-30	G-30	NA14	NA14	NA14
24-hour	2.27	2.45	3.00	3.43	4.14	4.79	5.50
Analysis	G-30	G-30	G-30	HA	NA14	NA14	NA14

G-30 = Gumbel Type-1 (30yrs); HA = Huff and Angel; NA14 = NOAA Atlas 14.

Blue indicates values calculated for the last 30-year Period of Record (POR) at KLAN, yellow is the Huff and Angel (1992) Zone 9 values, and orange is NOAA Atlas 14, Volume 8, Version 2.0 values at KLAN.

3.3 Frequency Analysis Recommendations

In 2016, The State of Michigan Department of Environment, Great Lakes, and Energy (EGLE) Water Resources Division (WRD) developed the policy WRD-046 "*Considering Climate Change in Water Resources Division Programs*" in order to consider climate change adaptation and mitigation measures in its purview.[3] The WRD set out a series of requirements and recommendations to begin planning for projected changes in wet weather patterns in Michigan. The top requirement in this document states "*to use the most up-to-date precipitation estimates available for permitted design storms (i.e., National Oceanic and Atmospheric Administration [NOAA] Atlas 14 as of this publication).*"

With this requirement in mind, HDR recommends that the City of East Lansing adopt the DDF values listed in Table 4, which represent the maximum values at each return frequency, regardless of analysis method, in Table 3. The maximum values selected for this recommendation allows for the most conservancy while including data and methodologies adopted over the last 10 to 30 years, especially within the requirements listed by the WRD.

Table 4. Recommended DDF values for East Lansing for the 6-hour, 12-hour, and 24-hour Duration

Duration	PRECIPITATION FREQUENCY ESTIMATES						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
6-hour	1.65	1.86	2.49	2.91	3.44	3.92	4.52
12-hour	1.97	2.16	2.74	3.13	3.69	4.29	4.95
24-hour	2.27	2.45	3.00	3.43	4.14	4.79	5.50

[3] https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Programs/WRD/NPDES/climate-change-plan.pdf.

4 Site-Specific Representative Storm

HDR was tasked with investigating the nature of storms and precipitation within the City service region. HDR identified 12 of the largest and most problematic historic storms from the approximately the last 30 years. Each storm was found within an approximate 15-mile by 15-mile box around East Lansing. The analysis used gauge adjusted Level 2 Doppler radar data. HDR analyzed spatial (gridded precipitation) and temporal (5-minute) characteristics of each storm event to understand the characteristics of extreme storm events specific to East Lansing. Gauge-Adjusted Radar Rainfall (GARR) using a 500-meter grid and 5-minute temporal increments was developed for each of the storms within this study to allow for development of a representative storm that is a scientifically derived representation of a rainfall specific to East Lansing for stormwater modeling and design purposes.

4.1 Storm Event Selection

Table 5 shows the complete list of the 12 storm events analyzed as part of this representative storm study. These storms were identified through various sources, including the flood complaint records provided to HDR from the City. HDR also searched rainfall records from KLAN as well as local rain gauges in and around East Lansing from the Michigan Automated Weather Network (MAWN) to help find the greatest events of the last 30 years. These rainfall sources helped identify the greatest 1-hour and 24-hour precipitation totals from the years 1995 through 2023. As can be seen in Table 5, the events varied in duration; however, a distinct grouping of events occurred in the 6-hour duration as well as the 12-hour duration. Two storm events were approximately 18 hours in duration but none of the storms identified lasted 24 hours or more.

Storms were analyzed using GARR methodologies from one hour prior to the start of the precipitation to one hour after the precipitation ended. Several of these precipitation events had more than one wave of precipitation, which was combined into a singular event. The storm of event of May 28, 2013 was a good example of a storm with four multiple waves of precipitation. The first wave of this event was approximately 3 hours in duration and maximized west of the City footprint near KLAN. The third wave was about 2 hours in duration and quite intense with almost 3.50 inches of rainfall at the storm total precipitation point in Dewitt, MI.

Table 5. Storms Analyzed

Storm Date	Duration (Hours)	Storm Total Depth (at Storm Center; Inch)
September 13, 2008	18.00	3.56
September 14, 2008	12.00	2.80
September 16, 2010	13.00	3.91
May 13, 2011	6.00	4.89
July 27–28, 2011	11.25	5.73
July 29, 2011	5.25	3.67
May 28, 2013	18.75	4.45
June 12–13, 2013	6.10	5.77
August 10, 2015	3.10	5.36
August 11–12, 2021	6.50	7.22
April 3–4, 2023	15.75	1.63
April 5, 2023	5.25	2.83

4.2 GARR Methodology and Analysis

Meteorological data, by nature, is neither consistent, nor of a quality that can be used without rigorous QC. It requires a consistent level of QC to ensure that no equipment malfunction, environmental impediment, or human error was allowed to corrupt the data. HDR endeavors to use only data that has gone through a rigorous QC process both from the data supplier and a second level of QC from HDR staff.

As previously stated, HDR used an approximately 15-mile by 15-mile area around the City from which to analyze GARR data for the 12 storms. This area was identified as being climatologically similar to East Lansing and, therefore, any of the 12 storms analyzed could have also occurred directly over the City center. For the 12 rainfall events, rain gauge data were recorded at 16 rain gauges within and just outside the analysis area. HDR utilized each of the 16 gauges in varying combinations for each rainfall event pursuant to their data availability and the level of data QC accuracy. Rain gauge data were collected from various sources as highlighted in Table 6, which also includes the minimum rainfall data reporting interval.

Table 6. Rain Gauge Networks/Sources Used for the GARR Analysis Portion of the Study

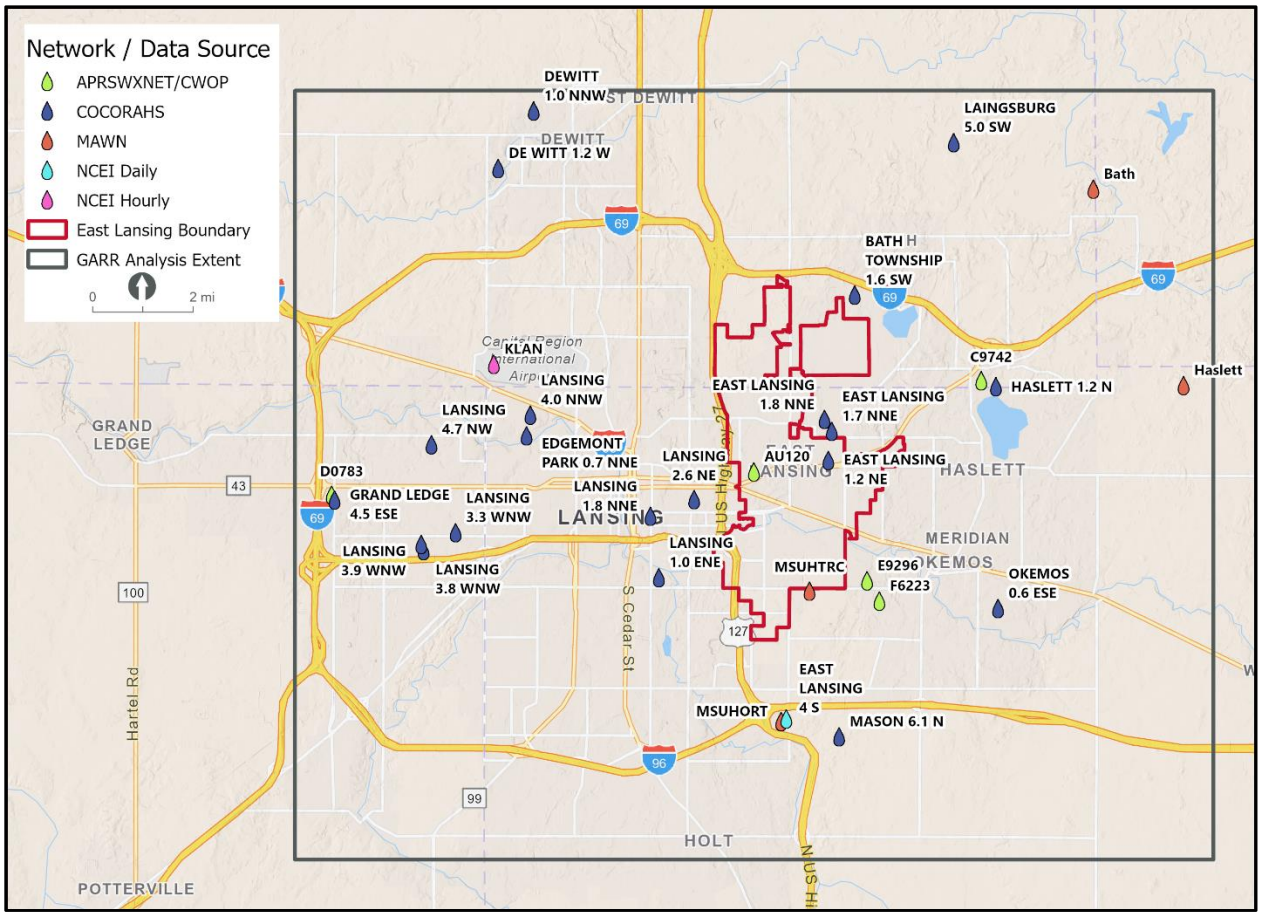
Precipitation Gauge Network/Source	Minimum Data Reporting Interval
APRSWXNET/CWOP (Automatic Position Reporting System Weather NETwork / Citizen Weather Observer Program)	5-min
CoCoRaHS (Community Collaborative Rain, Hail & Snow Network)	24-hour
Enviro-weather / MAWN (Michigan Automated Weather Network)	5-min
NCEI (National Centers for Environmental Information) Airport	1-hour
NCEI COOP	24-hour

The number of gauges used for each rainfall event varies based on a number of factors, including the POR, but a sufficient number of geographically spaced gauges was available to produce an accurate GARR for each event. Table 7 identifies the number of gauges used for each event and the meteorological data networks (source data) utilized. Figure 11 shows a map of the available locations of the precipitation gauge stations for the GARR analysis.

Table 7. List of Precipitation Gauges Used per Event

Storm Dates	Number of Gauges Used	APRSWXNET/CWOP	COCORAHS	MAWN	NCEI COOP	NCEI Hourly
Sept. 13, 2008	13		X	X	X	X
Sept. 14, 2008	12		X	X	X	X
Sept. 16, 2010	10		X	X		X
May 13, 2011	13	X	X	X		X
July 27–28, 2011	5	X		X		X
July 29, 2011	13		X	X		X
May 28, 2013	5	X		X		X
June 12–13, 2013	10	X	X	X		X
August 10, 2015	16	X	X	X		X
August 11–12, 2021	16		X	X		X
April 3–4, 2023	14	X	X	X		X
April 5, 2023	13	X	X	X		X

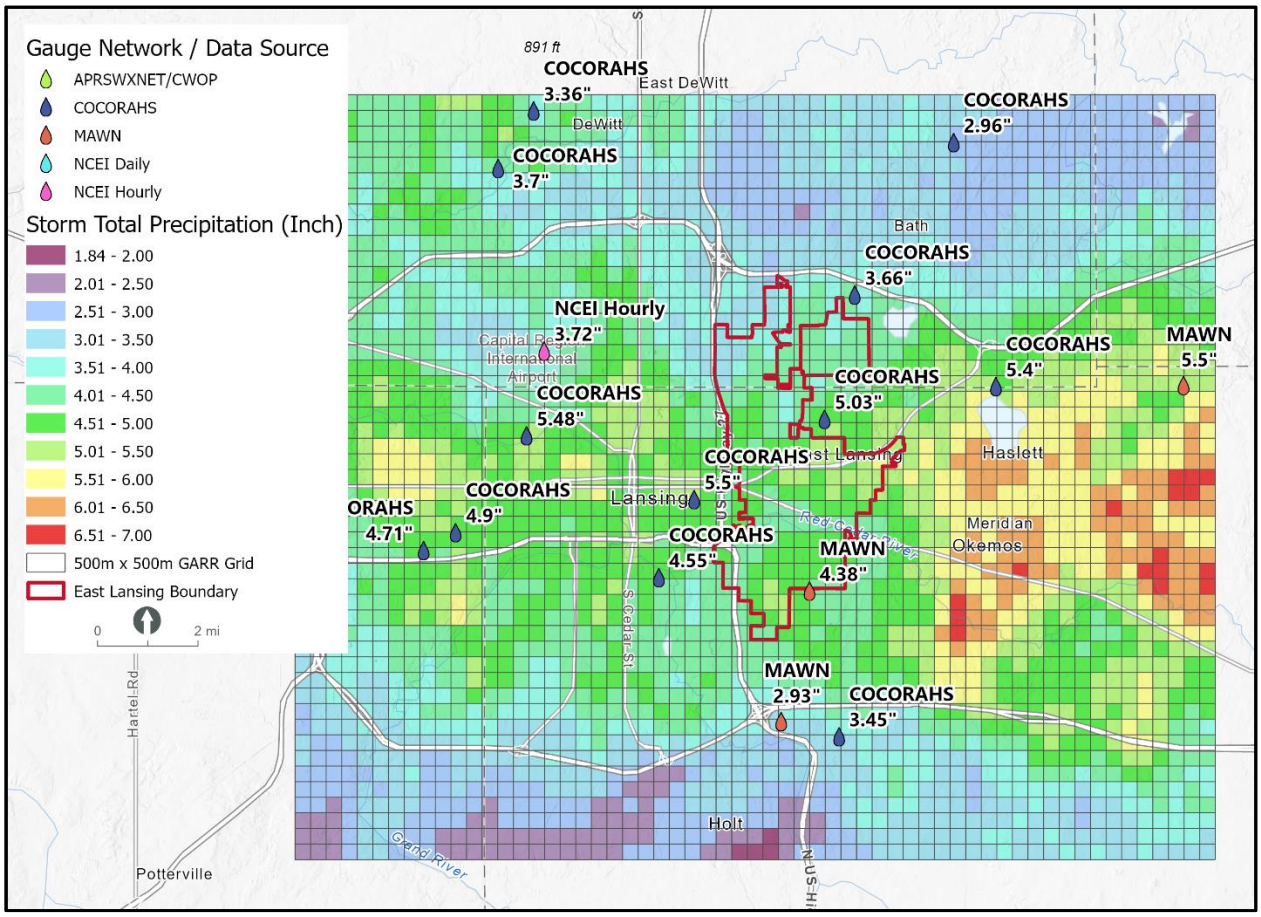
Figure 11. Locations of the Precipitation Gauges and Typology used for Gauge Adjusting the Radar Rainfall Data within the East Lansing study Area



Radar data utilized in the production of GARR are produced by the NWS NEXRAD Dual Pol Doppler Radar system. Radar data for this project came from the NCEI meteorological data archive online. The primary source of radar data for this study came from the Detroit, MI (KDTX) Radar located at latitude 42.70 N, longitude –83.47 W. This radar is located approximately 50 miles east of East Lansing. Rain gauges were consistently analyzed to determine whether they were in good agreement with radar data and surrounding rain gauges. A bias correction value was calculated for each rainfall event and the resultant correction value was then used to convert the raw radar reflectivity values to rainfall values for each 5-minute radar scan. For more information on the processing of GARR data, refer to Appendix A.

An example of the final product from this methodology for the August 11–12, 2021, event is shown in Figure 12. According to data obtained, this event created numerous complaints and issues across the City. Each one of the native radar grid squares in this image represent the accumulation from the 79 individual radar scans every 5 minutes over this domain. Appendix B provides GARR figures for all 12 storms.

Figure 12. Example of GARR Gridded Storm Total Precipitation from the Storm of August 11–12, 2021.



4.3 Representative Storm Development

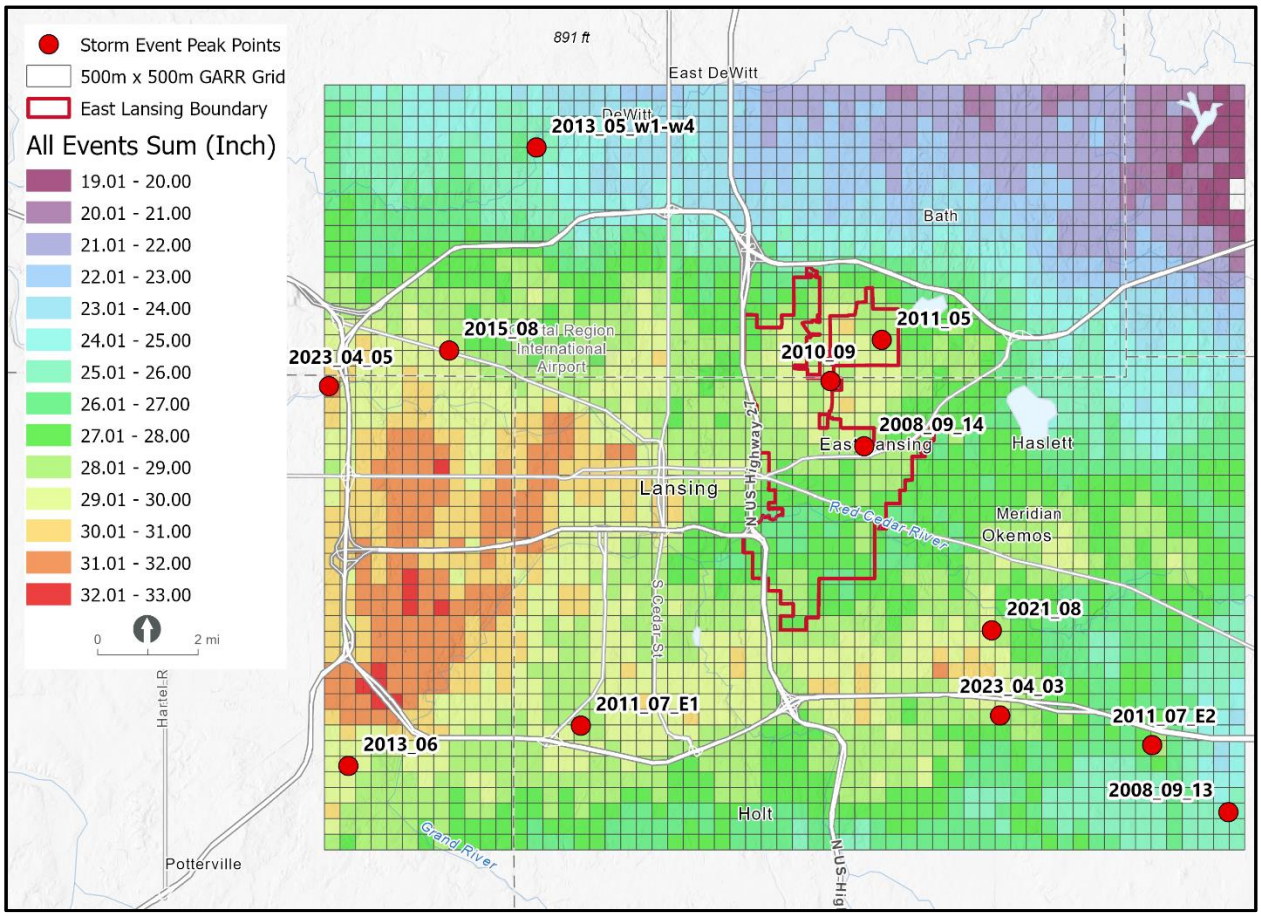
Design storms of the past were, typically, a one-size-fits-all proposition, which were developed using all precipitation data from the entire POR rather than using an understanding of the storms that are specifically significant to a given region. Using the one-size-fits-all methodology, design storms such as the NRCS Type II distribution were developed for large areas of the country and are a synthetic interpretation of storm events. Synthetic storms are not specifically tailored to the East Lansing region and do not account for how storms move spatially and temporal variation.

Analysis of the temporal variation of the 12 storms indicates that there were two distinct storm types with distinct storm durations. Six of the storms were convective, with short duration, high-intensity rainfall precipitation and six storms were longer in duration equal to or greater than 12 hours. Two events had durations of around 18 hours and no event analyzed had a duration lasting 24 hours or more. Thus, it was determined to analyze the 6- hour and 12-hour representative storm event distribution and the 10, 25, and 100-year recurrence interval gridded rainfall using the data. HDR utilized the 5-minute radar data for each event to develop the representative storms so that they move within the region as real 10-year, 25-year, or 100-year storms endemic to this region would. This level of detail has been shown in other studies to greatly aid the understanding of stormwater flows as a storm event moves over the area.

4.3.1 Spatial Distribution Analysis

The precipitation climatology of south-central Michigan is quite similar from north to south and east to west, at least within the 15-mile by 15-mile box for this study. However, central Michigan in general, has a general trend of increasing precipitation frequencies along the western edge of the state, likely due to the influence of the moisture from Lake Michigan in storm production. A sampling of NOAA Atlas 14 24-hour, 100-year return frequency estimates show a variance of approximately +/- 0.25 inch across the GARR extent footprint (Figure 12). Lower precipitation frequencies were found in the southern area of the GARR extent while the greater estimates were on the northern side of the study area. However, there are no significant geographical features, nor significant changes in latitude that have an impact on the magnitude and intensity of storms in this region. As a test of this finding, HDR utilized the storm total precipitation from each of the 12 storms within this study to create a GARR composite of all the storms. Figure 13 shows this cumulative map of all the significant storms in the region for this study from 2008 to 2023 with their storm centers highlighted in red. These cumulative storms show a consistent pattern of raining more over the western half of the GARR domain than the eastern half and raining more over the northern part of the East Lansing service region than over the southern half.

Figure 13. Storm Total Precipitation Compilation of all 12 Storms within the Analysis Area



Storm center points in red.

As noted at the beginning of this section, this analysis separated the 12 storms into two groups based on storm type and storm duration. The cumulative spatial distribution of all six short-duration, convective storms can be seen in Figure 14, while the cumulative spatial distribution of all six longer duration storm events can be seen in Figure 15.

Figure 14. Storm Total Compilation of all Six Convective, Short-Duration Storm Events with their Storm Centers

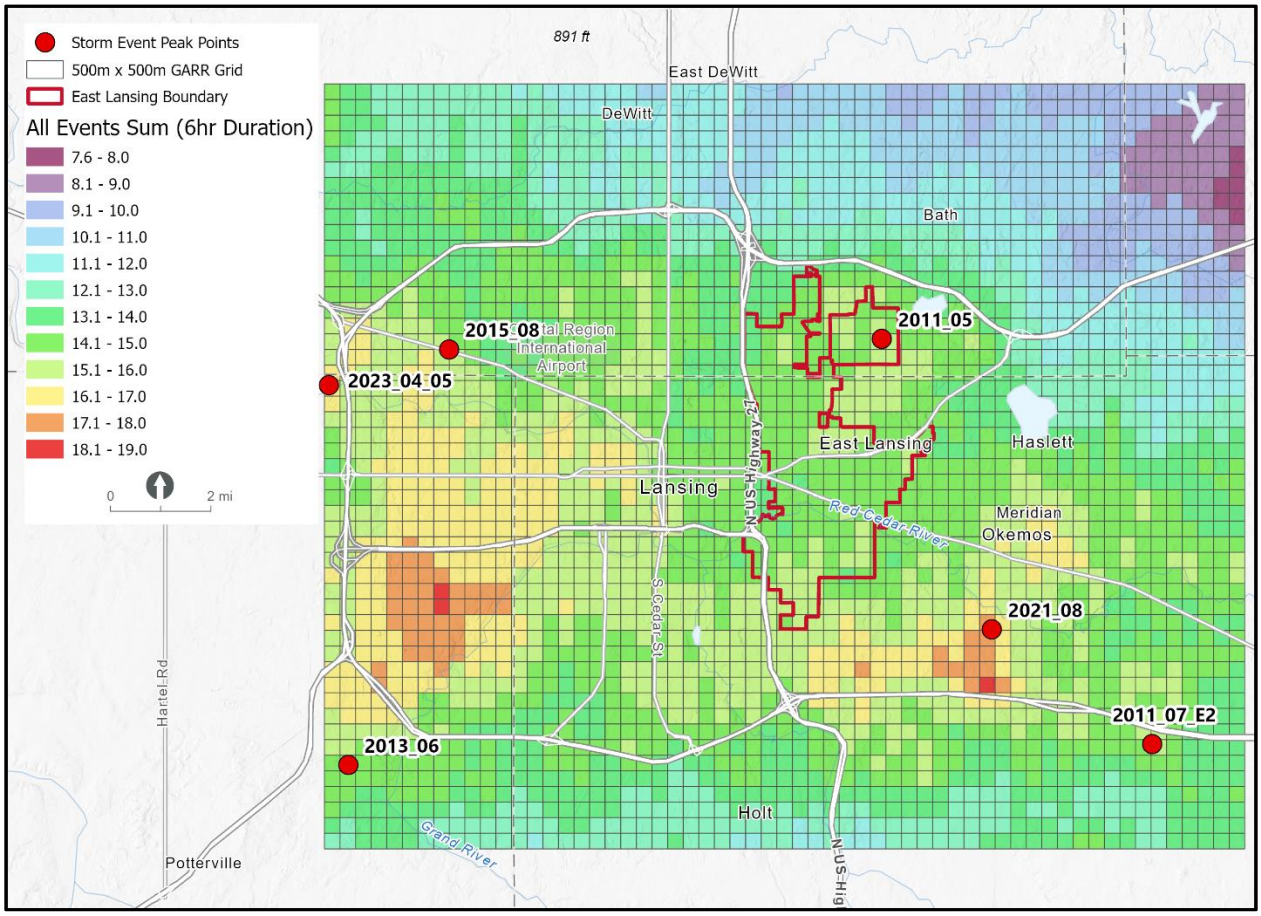


Figure 15. Storm Total Compilation of all Five Longer Duration, General Storm Events with their Storm Centers

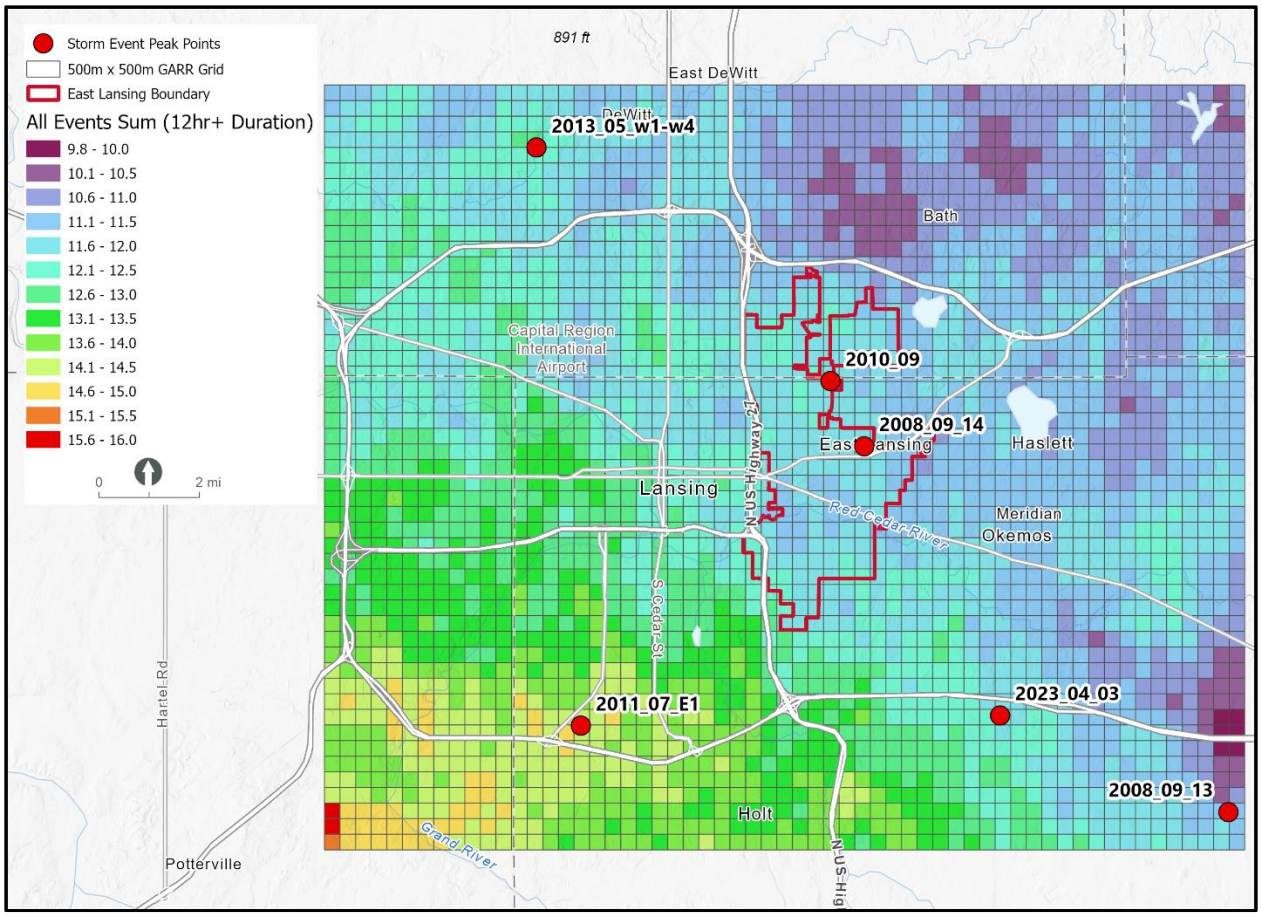


Figure 14 and Figure 15 both show a similar distribution to the 12-storm cumulative spatial distribution in Figure 13 in that the greater totals tend to be in the northern portions of the City of East Lansing GARR area. These spatial distributions were incorporated into the final representative storm events.

4.3.2 Temporal Distribution Analysis and Results

The analysis of the 12 largest storms found distinct temporal patterns for both the short-duration (6-hour) and longer duration (12 hours and greater) storm types. Each of the storms' temporal distributions were analyzed at the GARR grid point that represented the maximum peak precipitation that occurred during the event. The maximum peak grid points are shown in Figure 13. A graph of every 5-minute interval in the shorter duration, convective storms (6 hours) is shown in Figure 16, while the 5-minute incremental storm temporals for the longer-duration storms is shown in Figure 17. The short-duration storms (Figure 16) produced the greatest precipitation intensities with the majority of the total storm volume in the first three hours of the storm. The longer-duration storms exhibited a double peak in storm intensity, with the greatest volume of precipitation being strongly center weighted around the 6th and 10th hours of a 12-hour storm event. Similarly, the two events with approximately an 18-hour duration had a peak around 3 to 6 hours and another peak around 12 hours.

Figure 16. 5-minute Incremental Temporal Distributions of the Six Short-Duration, Convective Storm Events from the East Lansing GARR Analysis Area

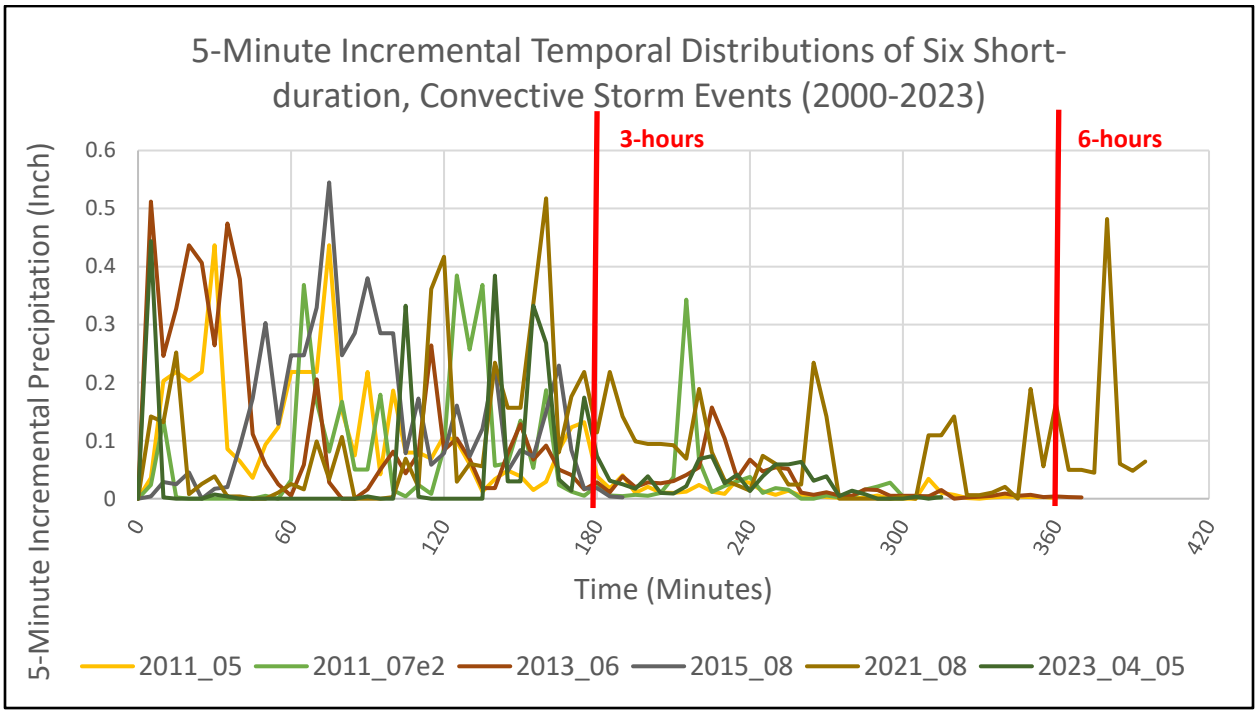
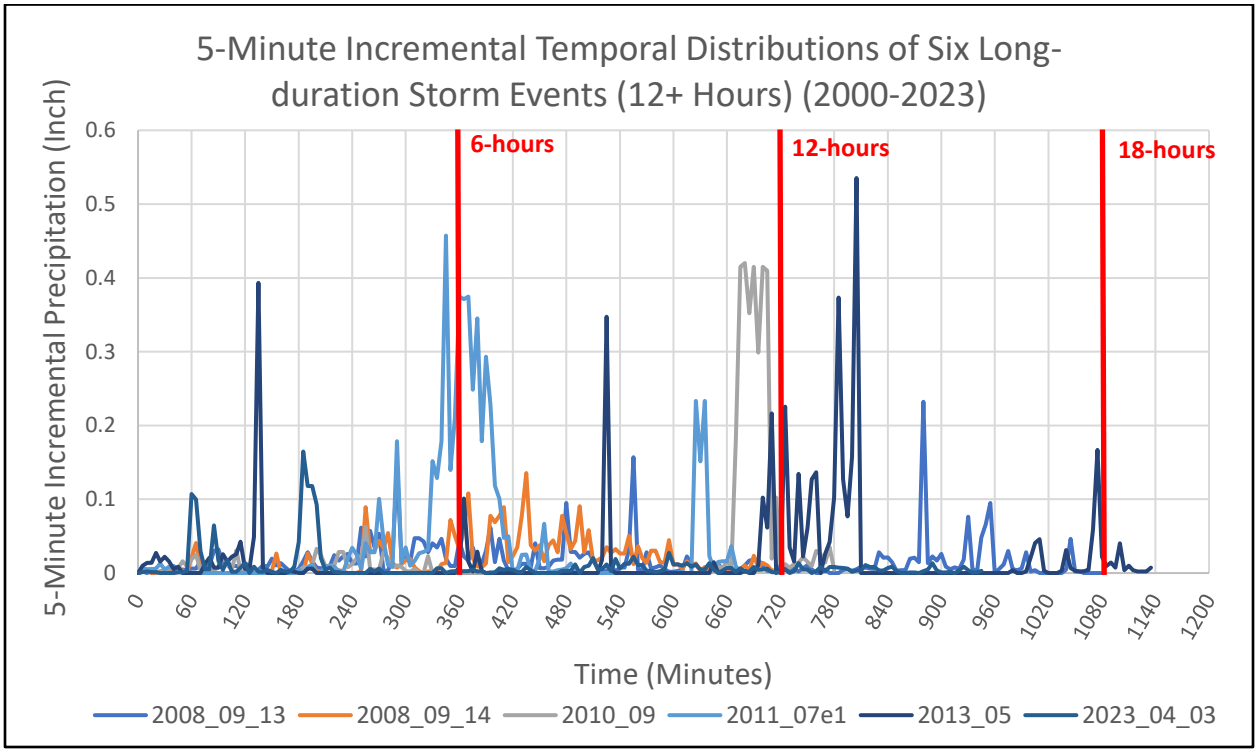


Figure 17. 5-minute Temporal Distributions of the Five Longer-Duration Storms Events from the East Lansing GARR Analysis Area



Additional analysis was performed to capture an understanding of the peak precipitation intensities in the storm temporals. A statistical analysis of the peak precipitation intensities for each storm events indicated that a significant percentage of the 6-hour storm total precipitation came in first half of the storm. In most instances, the 75–90 percent of total storm precipitation volume fell in the first three hours of the 6-hour duration storm. The longer-duration storm events indicate an early peak intensity in the first 3 to 6 hours and then a second more intense peak period between the 10th and 12th hours. Using the temporal patterns, two temporal distributions endemic to the East Lansing region were developed for the representative 6-hour and 12-hour storms. Figure 18 shows the cumulative representative storm temporal distribution of the 6-hour storm. Figure 19 shows the cumulative representative storm temporal distribution of the 12-hour storm.

Figure 18. 6-hour Cumulative Temporal Distribution of the Final Short-Duration Representative Storm Event

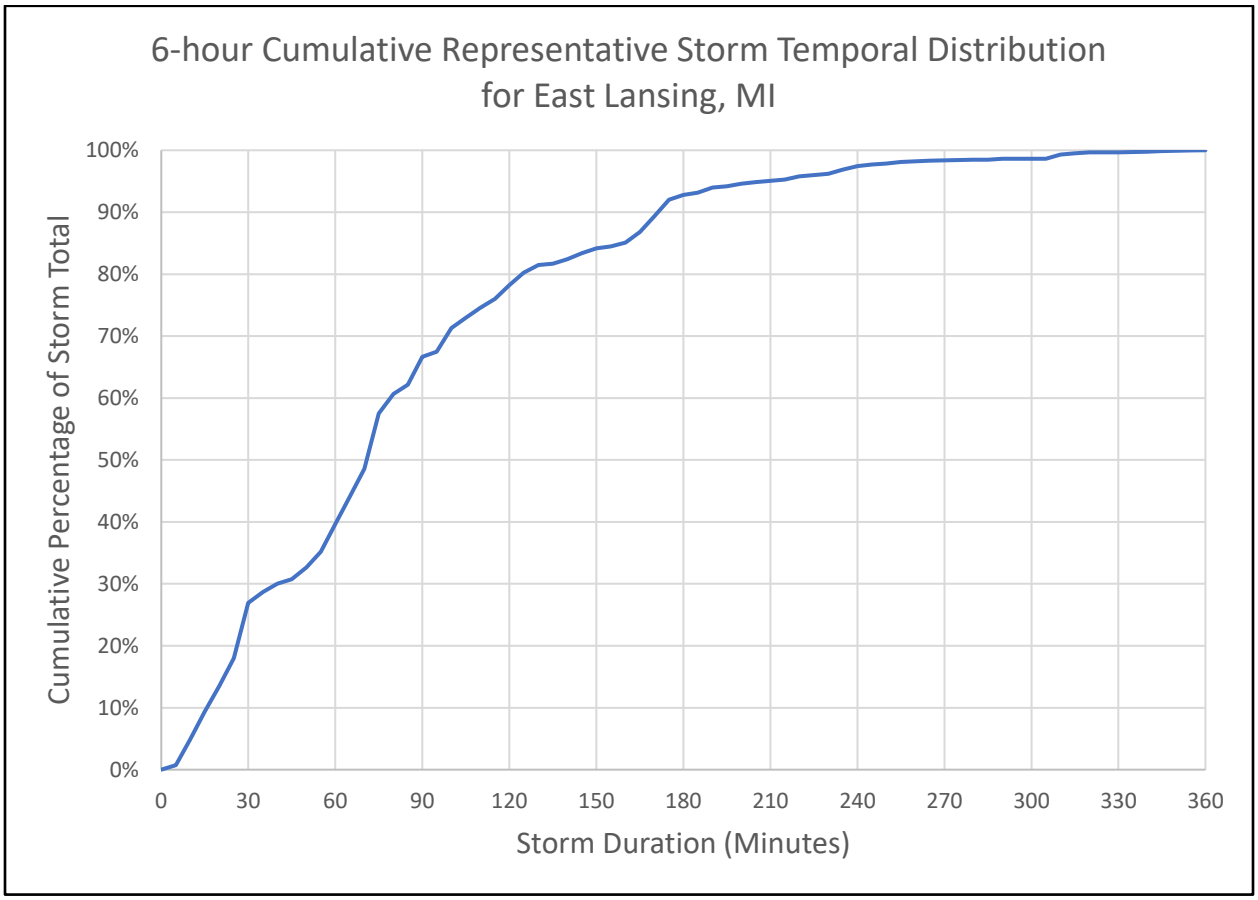
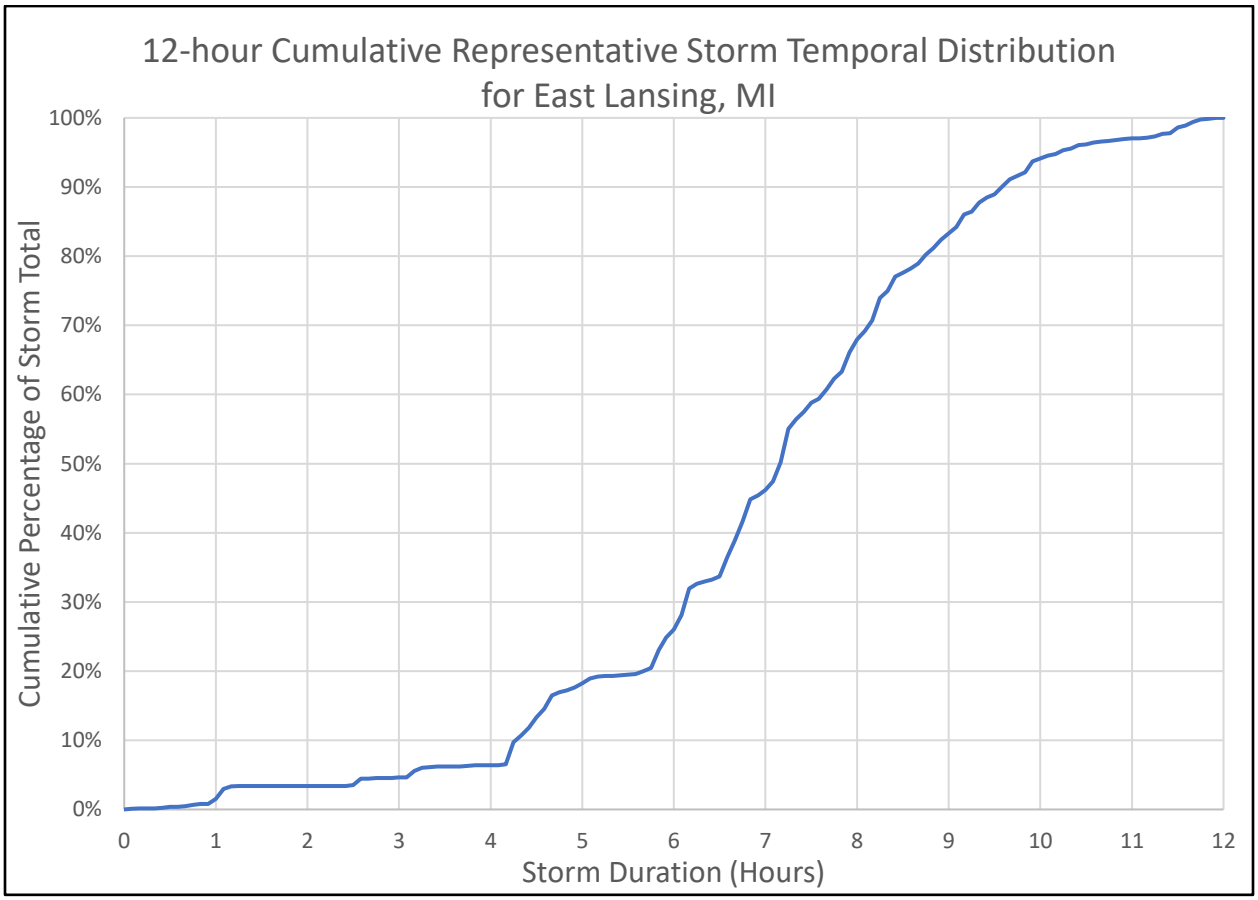


Figure 19. 12-hour Cumulative Temporal Distribution of the Final Longer Duration Representative Storm Event



4.3.3 Storm Movement Analysis

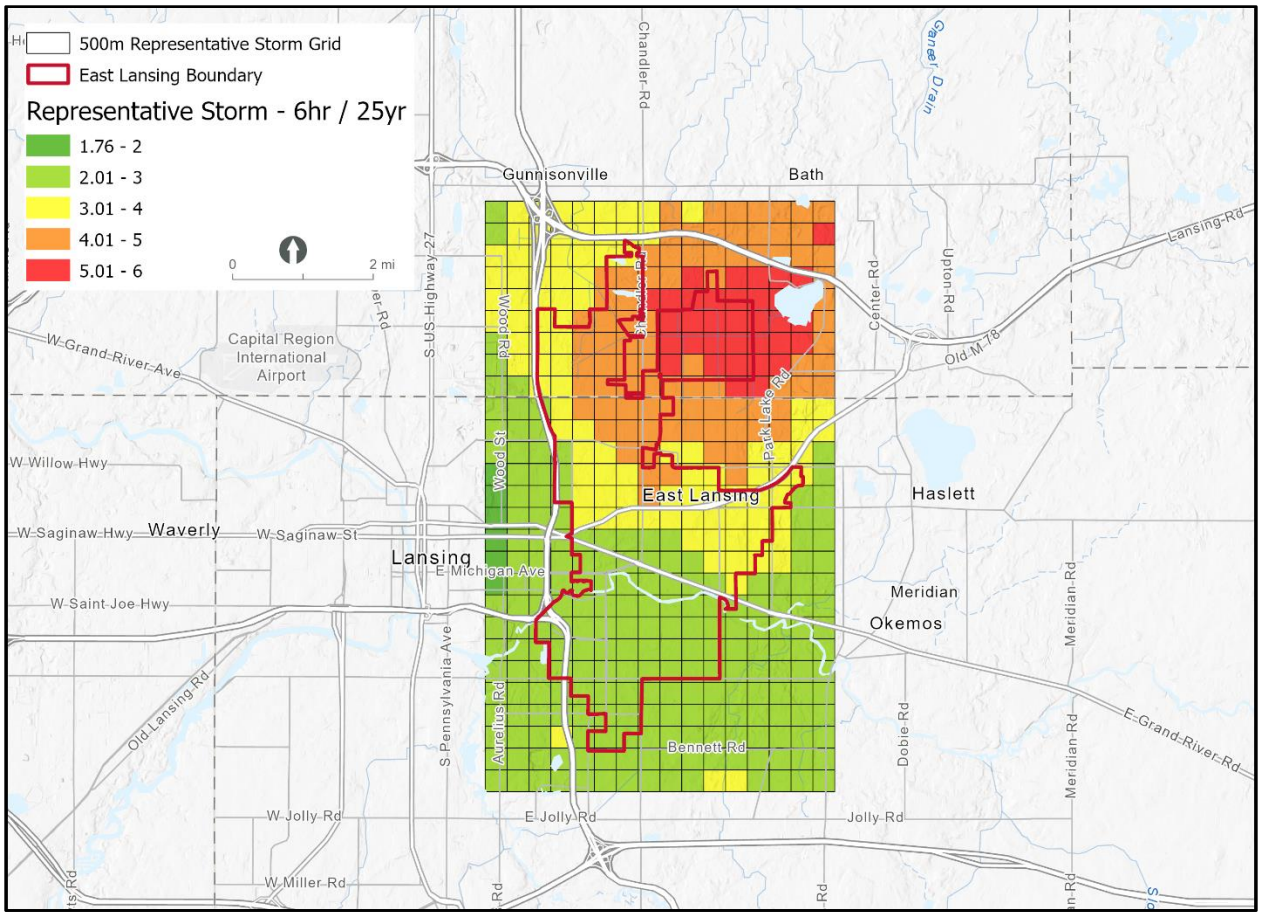
GARR animations for the storm reconstructions were developed for this study. The animations provide the means to better understand how large storm events move across the region and the GARR study area. The great majority of the storm events (10 out of 12) generally moved from west to east across the study area. A notable exception was the heavy rainfall event from May 2011. This storm formed along a stationary front where several strong cells sat nearly motionless across Central Michigan. One of the cells sat over the northern portions of East Lansing. This storm and motion is the type of storm that causes the most problems across North America, including East Lansing, as the lack of storm motion can cause flash flooding from heavy rainfall. The May 2011 storm motion was the primary driver for the 6-hour representative storm as it is the type of storm that can cause the most issues related to flooding. Storm movement plays a key role in runoff production, especially in situations where storm cells move in a line along a given stormwater catchment. The characteristic storm movement identified within this study was applied to the 6-hour and 12-hour representative storm events for 10-year, 25-year, 50-year and 100-year recurrence intervals.

4.4 Final Representative Storms

HDR developed the representative event in a model-ready spreadsheet format that represents every 5-minute period of the 6-hour and 12-hour basin average precipitation volumes associated with the 10, 25, and

100-year areal recurrence intervals as identified in Section 1.2. Figure 20 shows the coverage of the 500-meter × 500-meter precipitation grid that was used to create the final design storm events for the 6-hour 25-year representative storm. The remaining representative storm spatial patterns are provided in Appendix C.

Figure 20. 500-meter × 500-meter Representative Storm Grid and 6-hour Spatial Pattern for the 25-year Recurrence Interval



The final representative gridded storm events were spatially and temporally distributed according to the observed temporal signatures of the two types of significant storm events. The final representative gridded storm events also include storm movement and have precipitation volume as associated with the updated frequency estimates. The gridded representative storms are the type events that are historically endemic to East Lansing. The representative storms can also be transposed anywhere in the East Lansing service area so that the center of heavy precipitation changes as needed.

5 Climate Change Projections

Water management agencies across the country are dealing with the need of regulatory guidance for the development of flood-resilient stormwater standards. The need to consider future climate change when designing stormwater infrastructure is becoming more integral throughout the industry to achieve flood-resilient projects. This section describes analysis performed to incorporate the adjustment of the precipitation frequencies for future climate change.

5.1 Climate Projections: Impacts to Precipitation Frequencies

As with all studies of the potential impacts of climate change, there is a need to develop an understanding of what kind of changes are expected to occur with precipitation specific to a given location using Global Climate Models (GCM). GCM (GFDL, 2023)[4] are computer programs that are designed to mimic the atmosphere on a global scale to determine the influence of the buildup of greenhouse gases (GHGs) within the atmosphere. GCM calculate the interactions between the ocean, atmosphere, and land-using factors such as water vapor, GHG concentrations (e.g., carbon dioxide, methane, nitrous oxide), heat, and the earth's rotation as inputs. The output data from the GCM are then statistically downscaled (GFDL-2, 2023)[5] into a finer geographic scale (6 km) so that they become more meaningful for analyzing local and regional climate conditions. The output data were downscaled utilizing the Localized Constructed Analogs 2 (LOCA 2) methodology (LOCA, 2023).[6]

There are many different GCM and many different climate scenarios used to determine what the impact of climate change will be on precipitation for a given locations. Fortunately, every available GCM and every future climate scenario is created and publicly available for use by Lawrence Livermore Lab's supercomputers. The climate change datasets are called the Coupled Model Intercomparison Project (CMIP), which provides access to a very large range of climate projections (forecasts) through the year 2100. The current version of these climate projections is called CMIP6.[7]

5.2 Methodology for the Use of Climate Projections

There are four GCM that have been shown in previous studies to perform well in the development of climate projections specific to the State of Michigan. The GCM that were used represent a wide range of potential outcomes (i.e. warm/dry, cool/wet, etc.) so that when combined will form an ensemble (mean) of the trends in precipitation likely for the region. The GCM used in this study and their country of origin are as follows:

- HadGEM3-GC31-LL (warm/dry) – United Kingdom.

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[4] Geophysical Fluid Dynamics Laboratory (GFDL), 2023. Climate Modeling. Website: https://www.gfdl.noaa.gov/climate-modeling/#:~:text=of%20data%20storage.-,What%20is%20a%20Global%20Climate%20Model%3F,to%20long%2Dterm%20climate%20prediction.

[5] Geophysical Fluid Dynamics Laboratory (GFDL-2), 2023. Climate Model Downscaling. Website: https://www.gfdl.noaa.gov/climate-model-downscaling/.

[6] LOCA, 2023. LOCA Version 2 for North America (ca. Jan 2023). Website: LOCA version 2 for North America (ca. Jan 2023) - LOCA Statistical Downscaling (Localized Constructed Analogs) (ucsd.edu). University of California at San Diego. Scripps Institution of Oceanography, La Jolla, CA.

[7] Coupled Model Intercomparison Project 6 (CMIP6), 2023. Lawrence Livermore National Labs. Website: https://pcmdi.llnl.gov/CMIP6/.

- CNRM-CM6-1 (cool/wet) – France.
- CanESM5 (middle) – Canada.
- MIROC6 (complement) – Japan.

The most recent climate emissions scenarios, SSP2-4.5 and SSP5-8.5, were used to represent the range of outcomes for precipitation in the future. SSP stands for Share Socioeconomic Pathways, which are representative of the concentration of GHG that are expected to be released into the atmosphere in the future. The SSP2-4.5 is based on a scenario where GHG emissions continue to increase at their current rate until the year 2050, when they begin to decrease through the year 2070, at which point they begin to decline through the remainder of the century. SSP5-8.5 is an emissions scenario that sees emissions increase unabated through the end of the century. Each emissions scenario was used with each GCM for a total of eight forecasts of future precipitation. All the projections for future precipitation from each GCM were combined for each of the emissions scenarios. These combinations (ensembles) of GCM resulted in one future precipitation trend analysis for the lower emissions scenario (SSP2-4.5) and one future precipitation trend analysis for the higher emissions scenario (SSP5-8.5).

The future projections of daily rainfall were used to develop an understanding of the trend in annual maximum 24-hour precipitation, or AMS, under both climate scenarios. There was a very wide variety of outcomes from each model and each emissions scenario. Thus, an ensemble of the four models was developed to normalize the model output for both the SSP2-4.5 and the SSP5-8.5 climate emission scenarios. Analyses presented in Section 3 determined that the most significant storm systems that impact the East Lansing service region are of 6-hour and 12-hour durations. Since hourly GCM data are very difficult to develop and require dynamic downscaling using an atmospheric model (Weather Research and Forecasting model), this project utilized the projected change in the 24-hour AMS as a proxy for the change anticipated in the 6-hour and 12-hour duration storms.

5.3 Future Climate Change Results

The combinations of GCM and climate scenarios indicated that under the lower emissions scenario (SSP2-4.5) precipitation frequencies for the 6-hour and 12-hour storm events would be expected to increase 1 percent 2035, 2.6 percent by 2050, 4.6 percent by 2070, and 7.8 percent by 2100 (Figure 21). Under the higher emissions scenario (SSP5-8.5), these precipitation frequencies would be expected to increase 2.7 percent by 2035, 6.6 percent by 2050, 12 percent by 2070, and 20 percent by 2100 (Figure 22). The linear trendline in Figure 21 and Figure 22 represents the anticipated adjustment factor for a given year for the precipitation frequencies as estimated in Section 3. Applying adjustment factors to the precipitation frequencies, Table 8 and Table 9 show the future precipitation frequencies under the SSP2-4.5 emissions scenario for the years 2035 and 2050, respectively. Similarly, Table 10 and Table 11 show the future precipitation frequencies for the higher emissions scenario (SSP5-8.5) for 2035 and 2050, respectively. Additional tables for 2050 and 2070 are included in Appendix D.

Table 8. Future Return Frequency Values for East Lansing for the Year 2035 for SSP2-4.5

Duration	Precipitation Frequency Estimates (SSP2-4.5) - 2035						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
6-hour	1.67	1.88	2.51	2.94	3.47	3.96	4.57
12-hour	1.99	2.18	2.77	3.16	3.73	4.33	5.00

Table 9. Future Return Frequency Values for East Lansing for the Year 2050 for SSP2-4.5

Duration	Precipitation Frequency Estimates (SSP2-4.5) - 2050						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
6-hour	1.69	1.91	2.55	2.99	3.53	4.02	4.64
12-hour	2.02	2.22	2.81	3.21	3.79	4.40	5.08

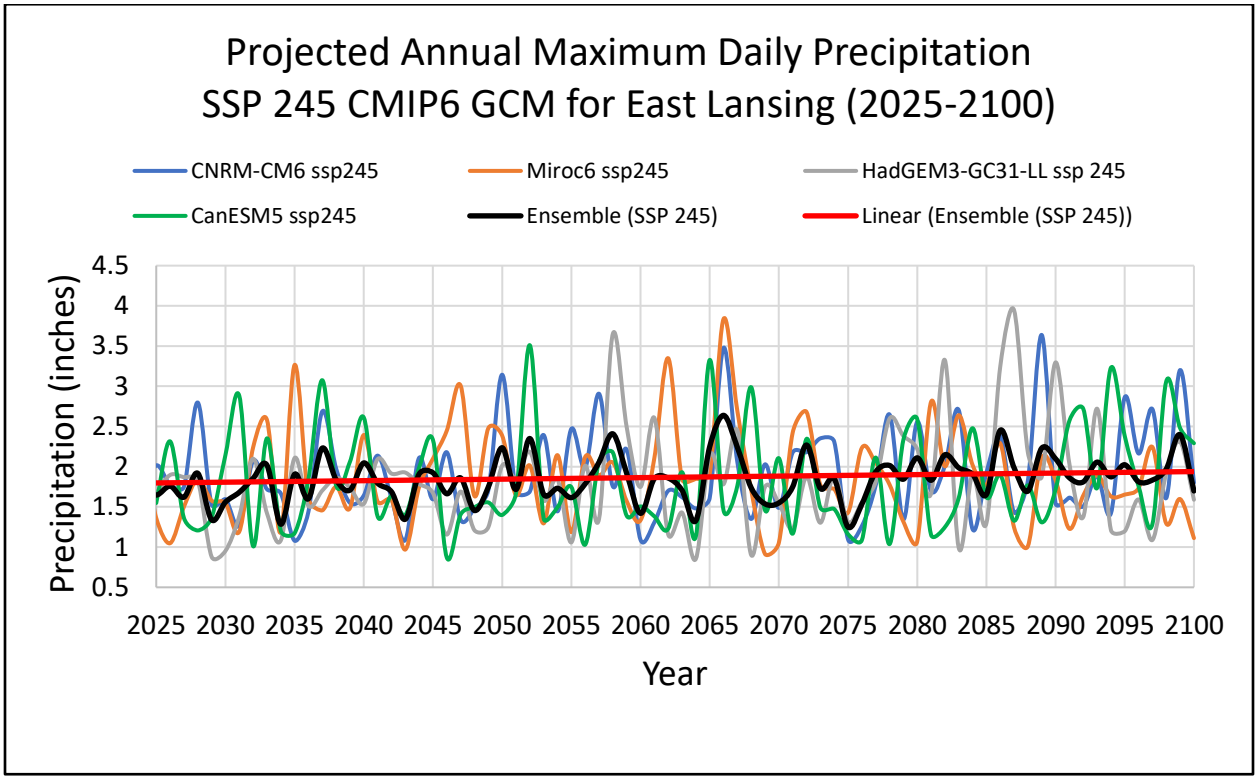
Table 10. Future Return Frequency Values for East Lansing for the Year 2035 for SSP5-8.5

Duration	Precipitation Frequency Estimates (SSP5-8.5) - 2035						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
6-hour	1.69	1.91	2.56	2.99	3.53	4.03	4.64
12-hour	2.02	2.22	2.81	3.21	3.79	4.41	5.08

Table 11. Future Return Frequency Values for East Lansing for the Year 2050 for SSP5-8.5

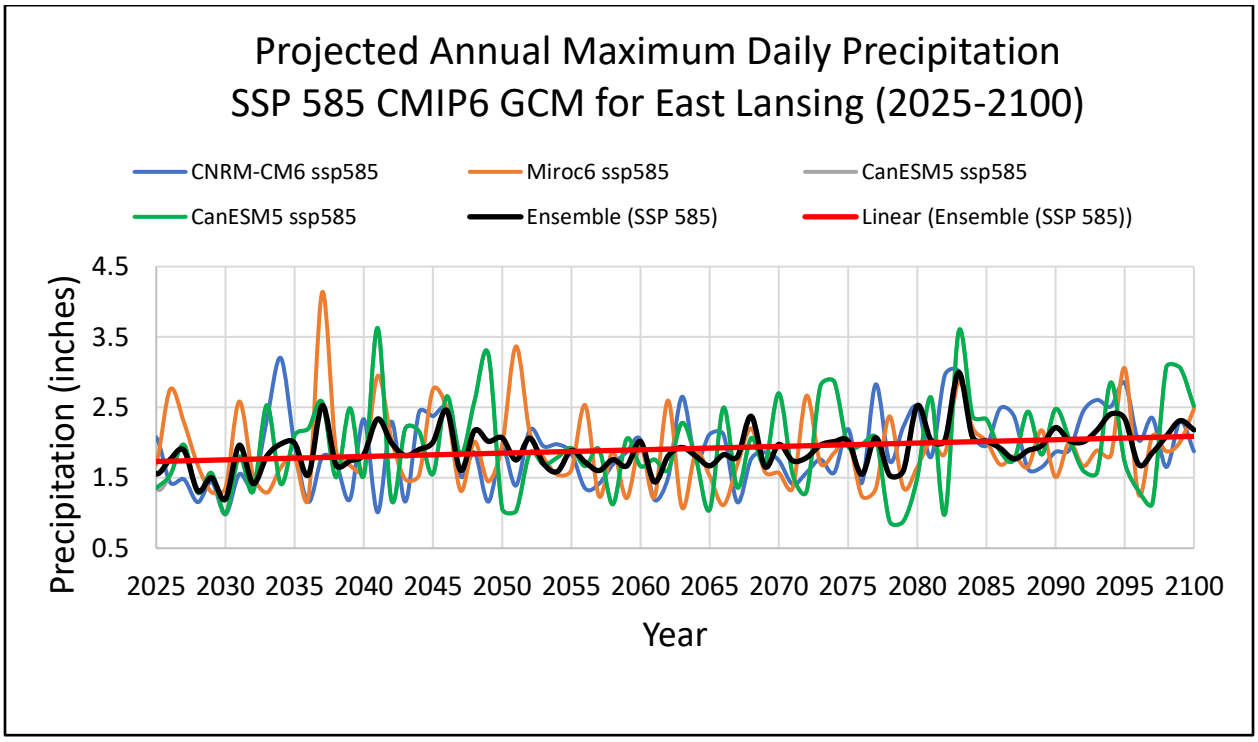
Duration	Precipitation Frequency Estimates (SSP5-8.5) - 2050						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
6-hour	1.76	1.98	2.65	3.10	3.67	4.18	4.82
12-hour	2.10	2.30	2.92	3.34	3.93	4.57	5.28

Figure 21. Projected Annual Maximum Daily Precipitation using the Lower SSP2-4.5 Emissions Scenario



Linear trend represents the ensemble (mean) of the 4 GCM used in this analysis.

Figure 22. Projected Annual Maximum Daily Precipitation using the Lower SSP5-8.5 Emissions Scenario



Linear trend represents the ensemble (mean) of the 4 GCM used in this analysis.

6 Summary of Findings

This report examined changing precipitation patterns in the City of East Lansing (City). The assessment's goal was to aid the City in considering future climate scenarios in stormwater infrastructure design for flood-resilient projects.

The analysis reveals a clear historic trend of increasing annual precipitation and precipitation intensities within the City (See Section 2). From 1949 to 2023 the trend of annual precipitation indicates approximately a 30% increase. Notably, precipitation intensities during short duration 1-hour, 2-hour, 6-hour, 12-hour, and 24-hour durations are observed to be on the rise, accompanied by increasing variability year over year. For high intensity cloudburst 1-hour rain events that are often problematic to stormwater drainage systems, historic trends indicate nearly a 75% increase from 1949 to 2023. These findings are consistent with broader studies of precipitation over Michigan and the Midwest. In light of the observed increases, the report underscores the necessity to update precipitation frequency estimates (PFEs) for storm design in the City. These new estimates (see Table 4), which previously had not been revised in over a decade, require attention to align with the changing precipitation patterns.

Section 4 highlights the development of a 6-hour and 12-hour representative storm based on the updated PFEs. This was accomplished through radar rainfall analysis of the largest 12 storms impacting the East Lansing region in the last 30 years. The analysis utilized gauge-adjusted Level 2 Doppler radar data to create a scientifically derived representation of rainfall specific to East Lansing, essential for stormwater modeling, planning, and design purposes. Results from the representative storm analysis indicate that the 12 storms have historically impacted the northeastern portions of the City to a greater extent in terms of total observed rainfall. This is primarily due to the May 13, 2011 event which northern portions of the City experienced nearly five inches of rain in just under 24 hours.

Section 5 provides analysis of future climate change green-house gas emissions scenarios using state of the practice Global Climate Models specifically downscaled to East Lansing. Under medium emissions scenario precipitation depths were determined to increase 1.0 percent 2035, 2.6 percent by 2050, 4.6 percent by 2070, and 7.8 percent by 2100. Under the higher global emissions scenario precipitation depths were determined to increase 2.7 percent by 2035, 6.6 percent by 2050, 12 percent by 2070, and 20 percent by 2100.

The analysis presented within the report stresses the need for East Lansing to consider historic rainfall data as well as future climate change when planning and designing stormwater infrastructure, essential for achieving flood-resilient projects.

Appendix A: GARR Methodology

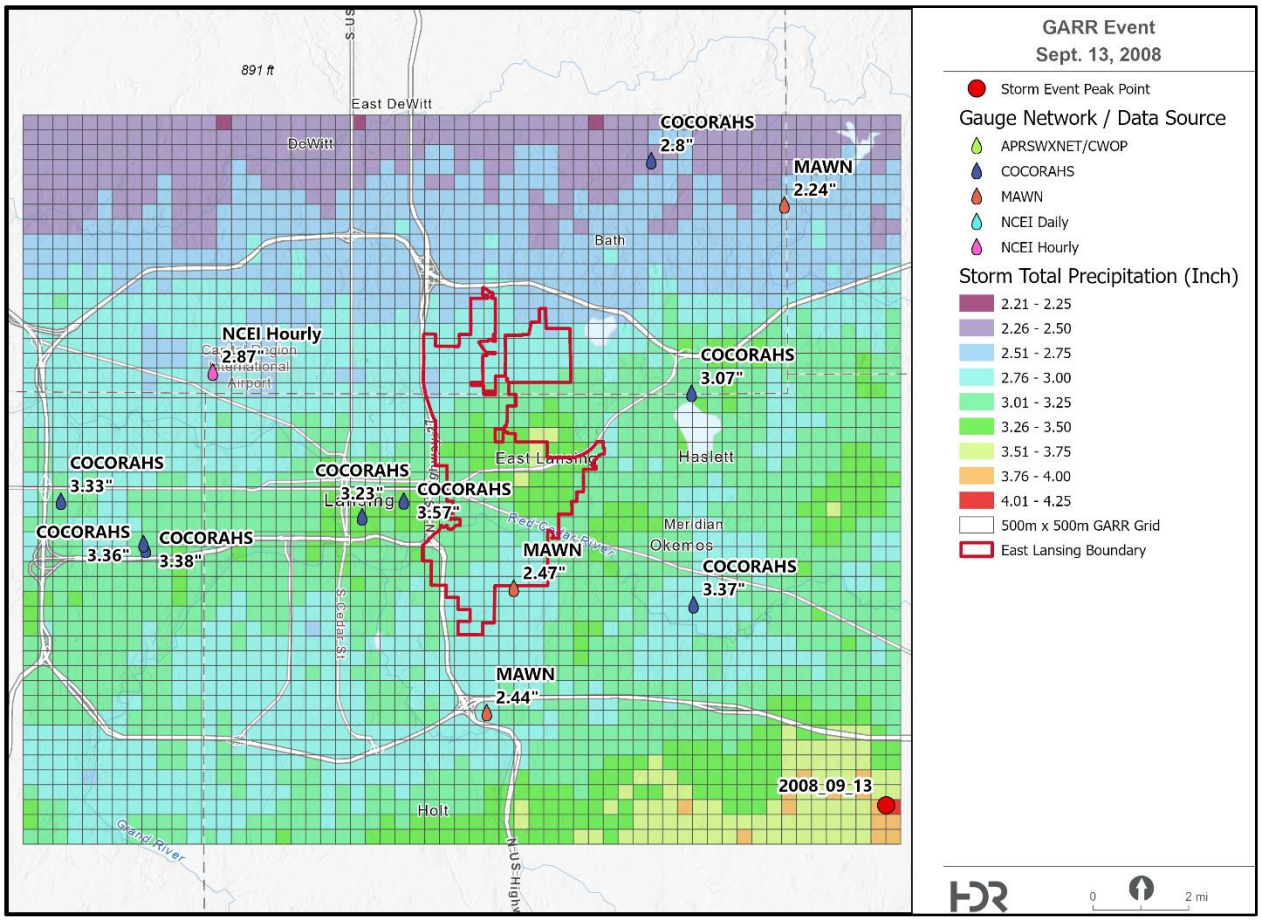
HDR utilizes the 0.5-degree elevation angle data from NEXRAD radars to provide the most accurate measure of rain that is hitting the ground. This radar elevation angle measures rainfall reflectivity at the lowest elevation possible in the atmosphere without encountering beam blockage. Radar reflectivity from information contained in the NEXRAD data is measured in polar coordinates starting at the radar site. Hence, the 1-degree azimuth of the beam increases in width as it moves downrange out to its effective range of 230 km unless curtailed by terrain. The GARR data are extracted, as an end product, into a Cartesian grid of 500-meter × 500-meter spatial resolution and for every 5 minutes of a given storm event.

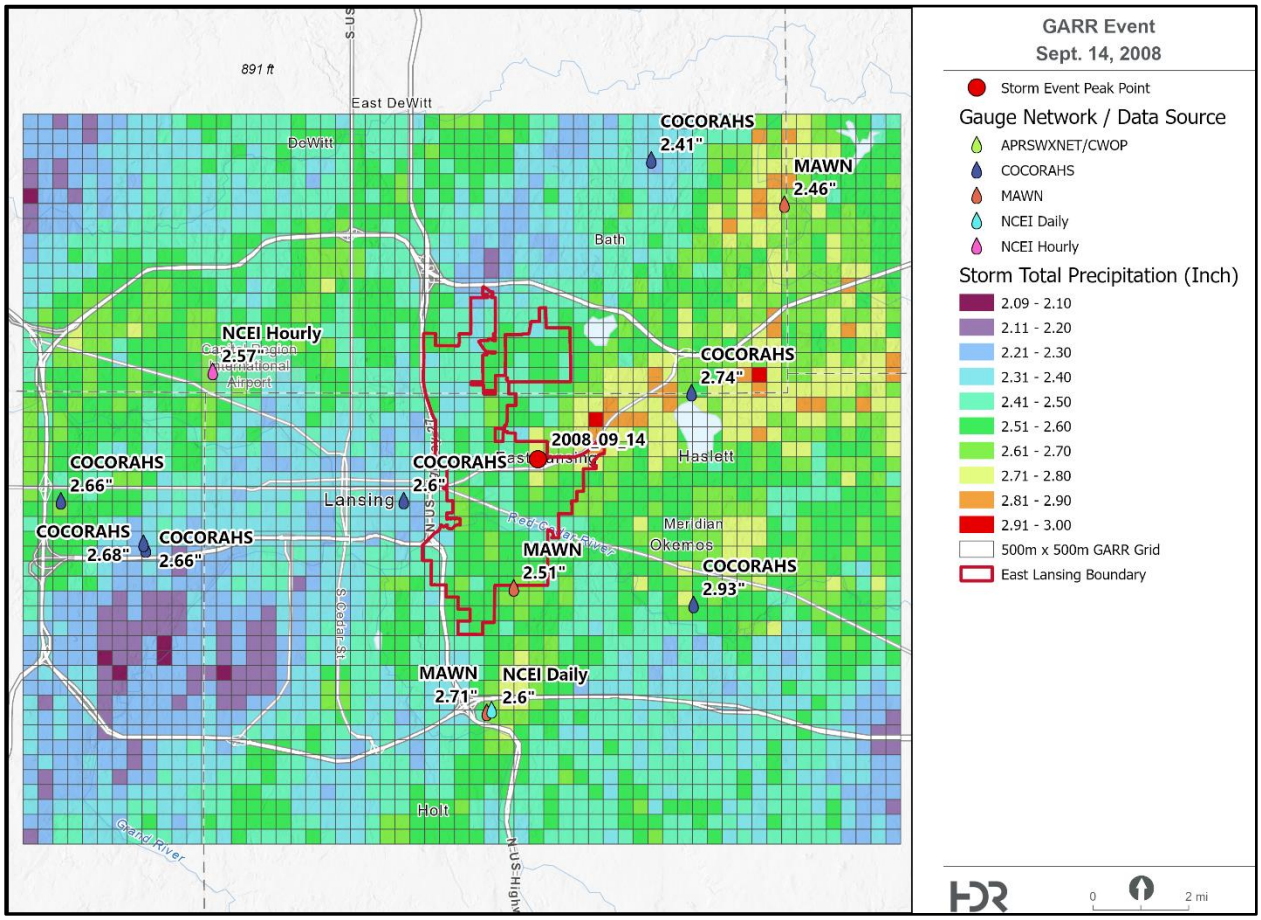
The accuracy of radar data (reflectivity data) varies considerably from day to day and storm to storm depending on atmospheric conditions and the type and intensity of precipitation. Light, moderate, and heavy rainfall have slightly different reflectivity values under different atmospheric conditions, as does the reflective signature of snow, hail, and other types of freezing precipitation. These differences were reduced with the advent of Dual Pol Doppler in 2012. Developing a statistical control of these data requires a customization of a combination of rainfall-to-reflectivity (ZR, Z=reflectivity, R=Rainfall) ratio and gauge adjustment to develop corrections to produce a refined evaluation of rainfall that either rain gauges or radar could produce by themselves.

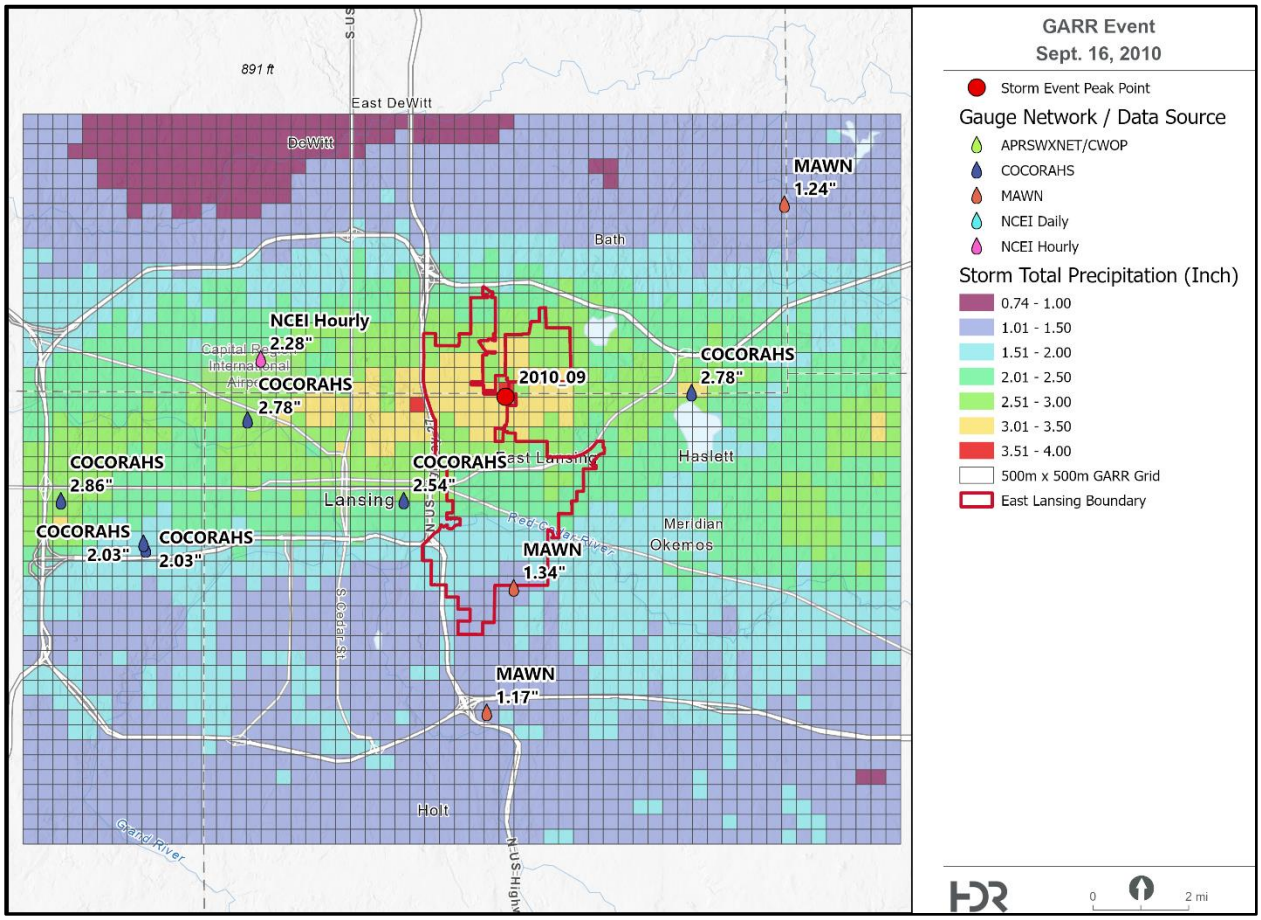
The process followed to develop these corrections begins with the application of the ZR relationship for convective atmospheric conditions (where Z=300R1.4) or the Marshall-Palmer mixed conditions (where Z=130R1.6), whichever provides the first best fit to gauge data. A GARR analysis spreadsheet is created for each event to compare the sum of the radar estimated precipitation total to the sum of the actual gauge report of rainfall for every gauge location. The difference between these 2 values is then calculated automatically in percent and inches. That is, the user can see the difference between the radar estimates and the actual gauge readings in total percent difference or the difference in depth (inches). This difference percentage is then averaged for every gauge location and reported at the top of the sheet and is labeled “Calibrated Adjusted Difference” (CAD).

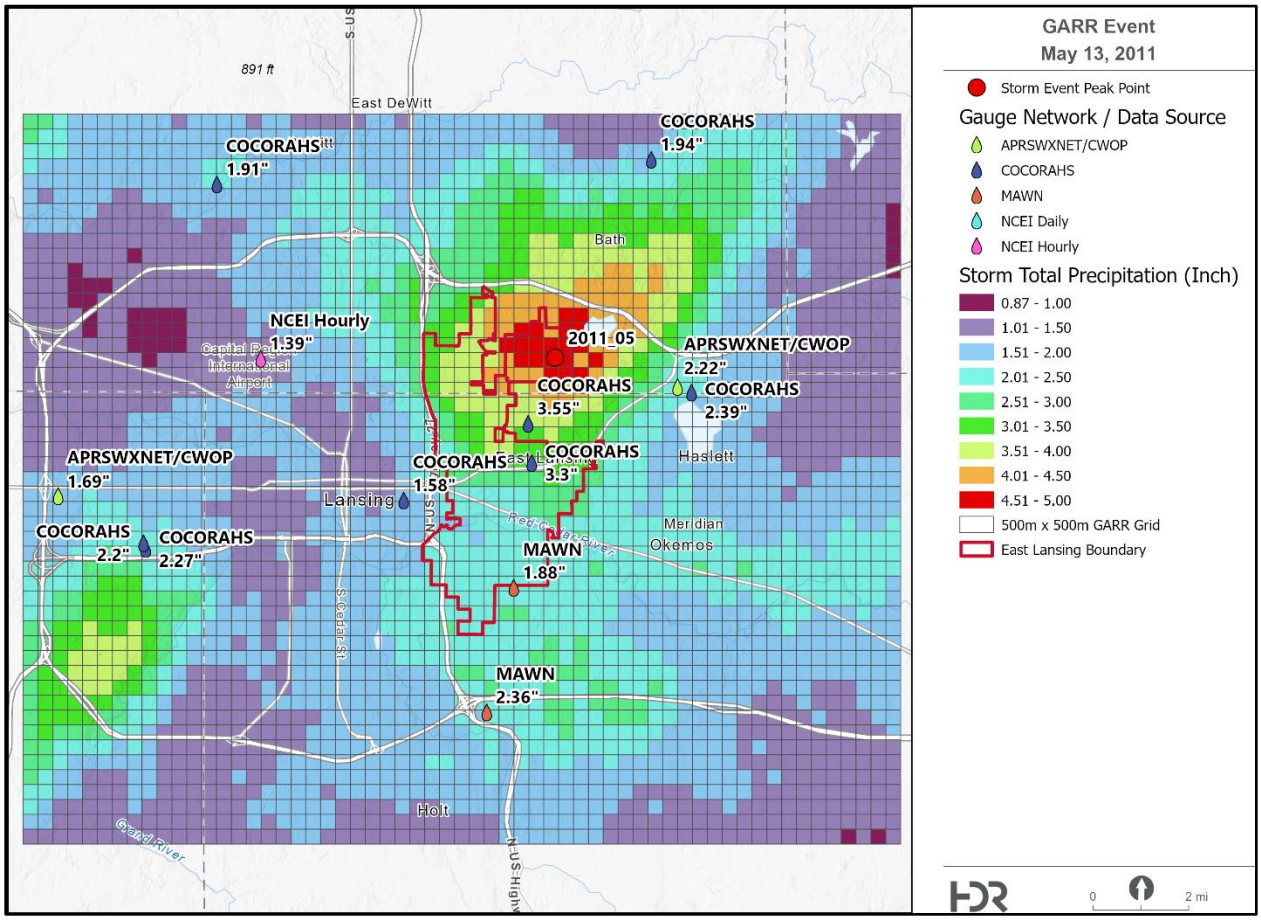
A CAD is determined that represents the most refined correlation between GARR and rain gauge values for all gauges used to adjust the radar. Generally speaking, the lower the CAD value, the greater statistical correlation between radar and rain gauge. A Bias Correction value is developed from the sum of the radar rainfall values divided by the sum of the gauges for each event. The goal of the GARR process is to get the Bias Correction value as close to 1 as possible while trying to get the lowest CAD value. This is obtained by using a calibration factor that simply adjusts the Z-R being used up or down by a certain percentage. Initially, the process begins with a 0-calibration factor and uses the default convective or Marshall-Palmer Z-R as is. Then the practitioner can adjust the calibration factor up or down depending on how far the Bias Correction is from 1. In the end and as a final GARR, adjusting the best fit Z-R up or down by a certain percentage for all events, the bias correction value was close to 1 and the CAD value is an average of 14 percent for all the events was achieved. The statistical analysis of these factors varies considerably from GARR analysis to GARR analysis depending on atmospheric conditions and the initial ZR relationship set by the NWS radar site. The factors for all of these storms are well within an acceptable range for use.

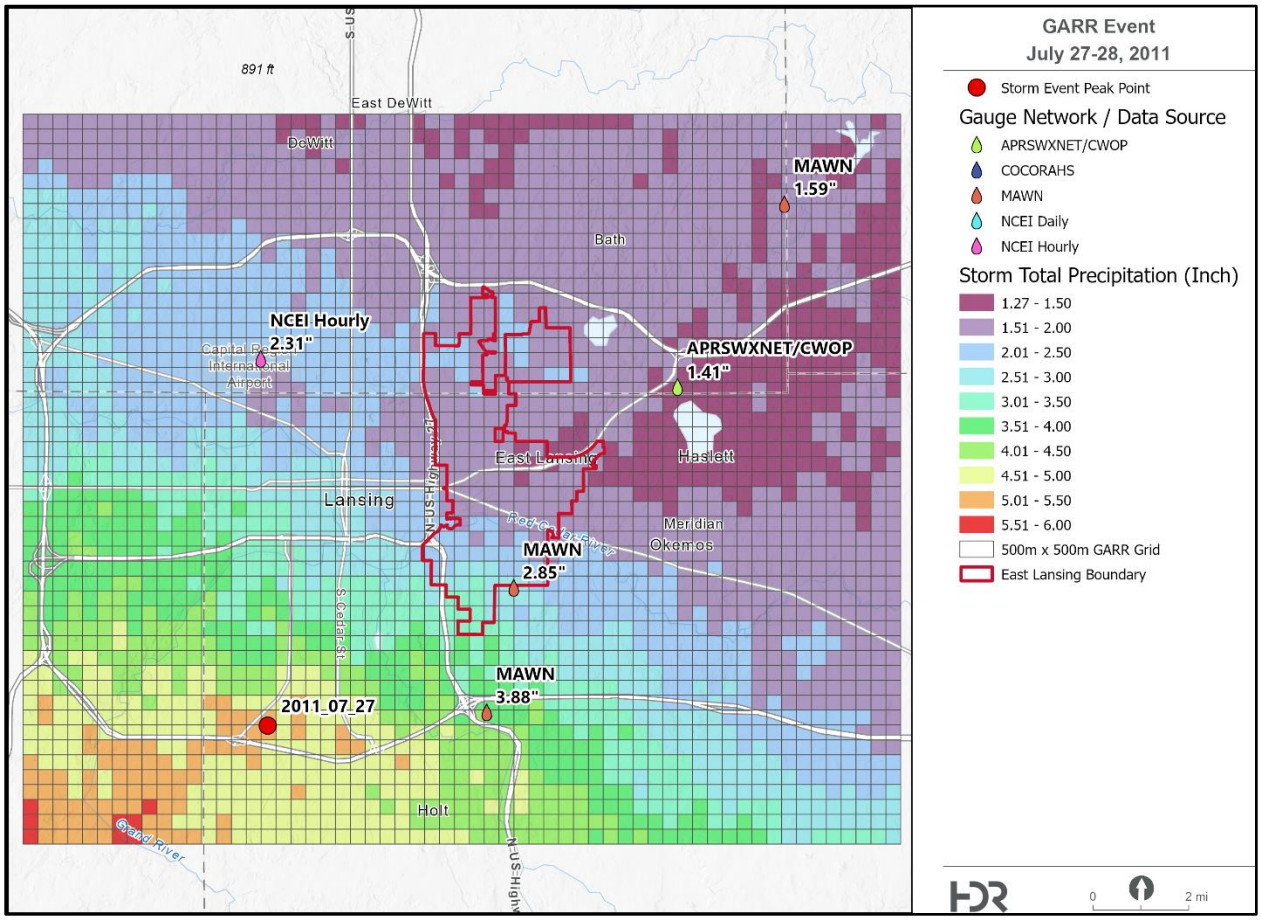
Appendix B: GARR Figures for Twelve Selected Storms

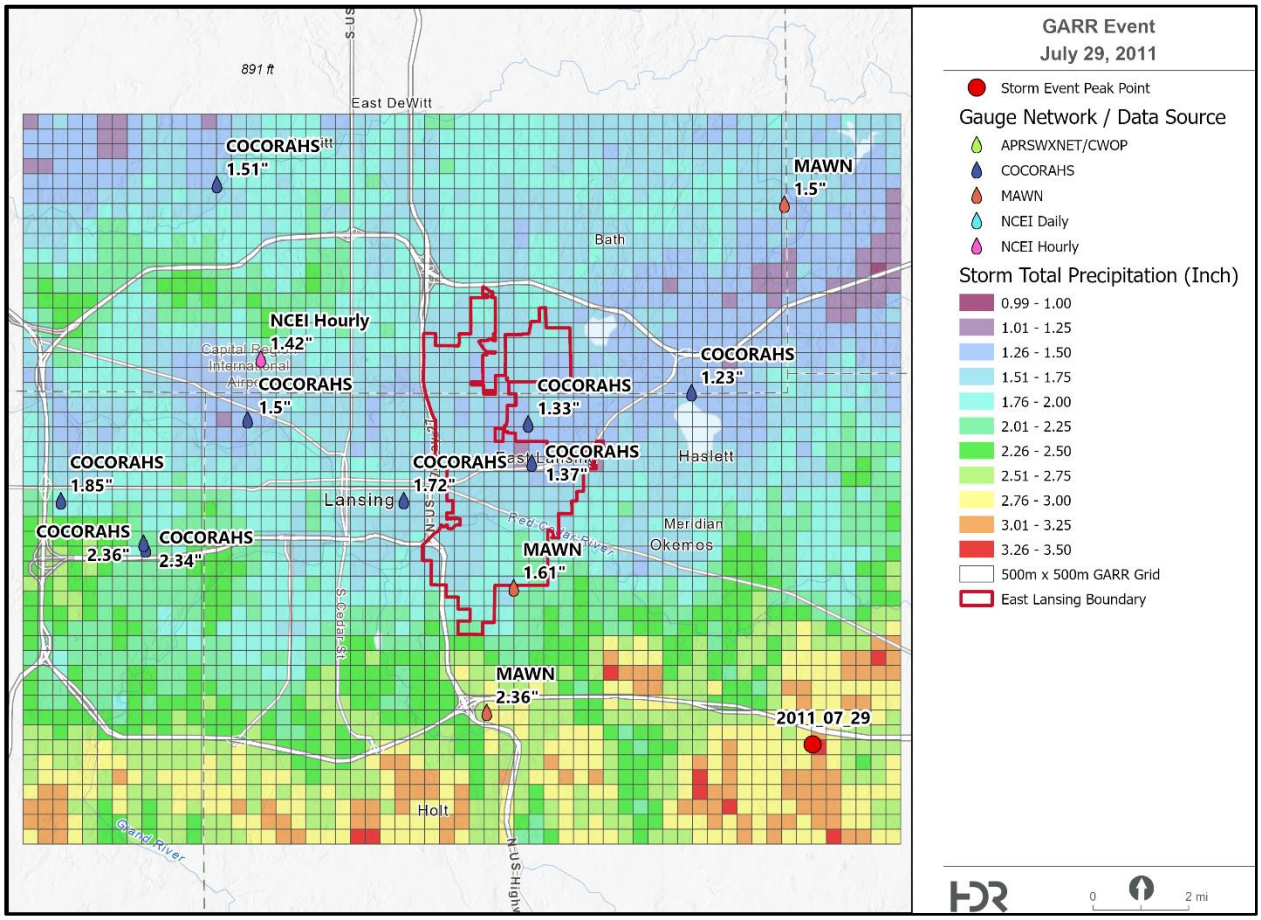


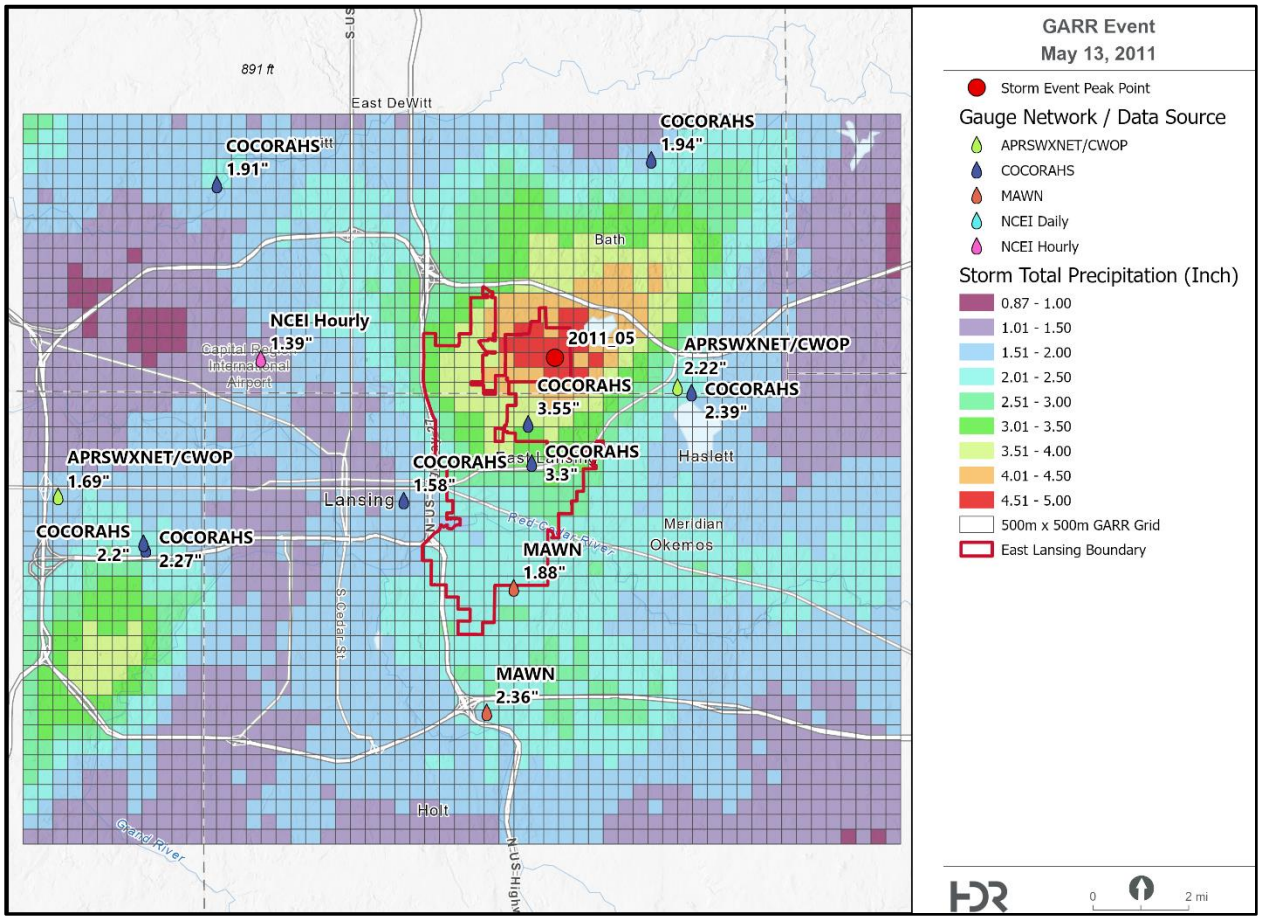

GARR Event
Sept. 14, 2008
Storm Event Peak Point
Gauge Network / Data Source
APRSWXNET/CWOP
COCORAHS
MAWN
NCEI Daily
NCEI Hourly
Storm Total Precipitation (Inch)
2.09 - 2.10
2.11 - 2.20
2.21 - 2.30
2.31 - 2.40
2.41 - 2.50
2.51 - 2.60
2.61 - 2.70
2.71 - 2.80
2.81 - 2.90
2.91 - 3.00
500m x 500m GARR Grid
East Lansing Boundary
East DeWitt
DeWitt
Bath
Haslett
Lansing
Meridian
Okemos
Holt
Grand River
COCORAHS 2.41"
MAWN 2.46"
NCEI Hourly 2.57"
COCORAHS 2.74"
2008_09_14
COCORAHS 2.66"
COCORAHS 2.6"
COCORAHS 2.68"
COCORAHS 2.66"
MAWN 2.51"
COCORAHS 2.93"
MAWN 2.71"
NCEI Daily 2.6"
0
2 mi

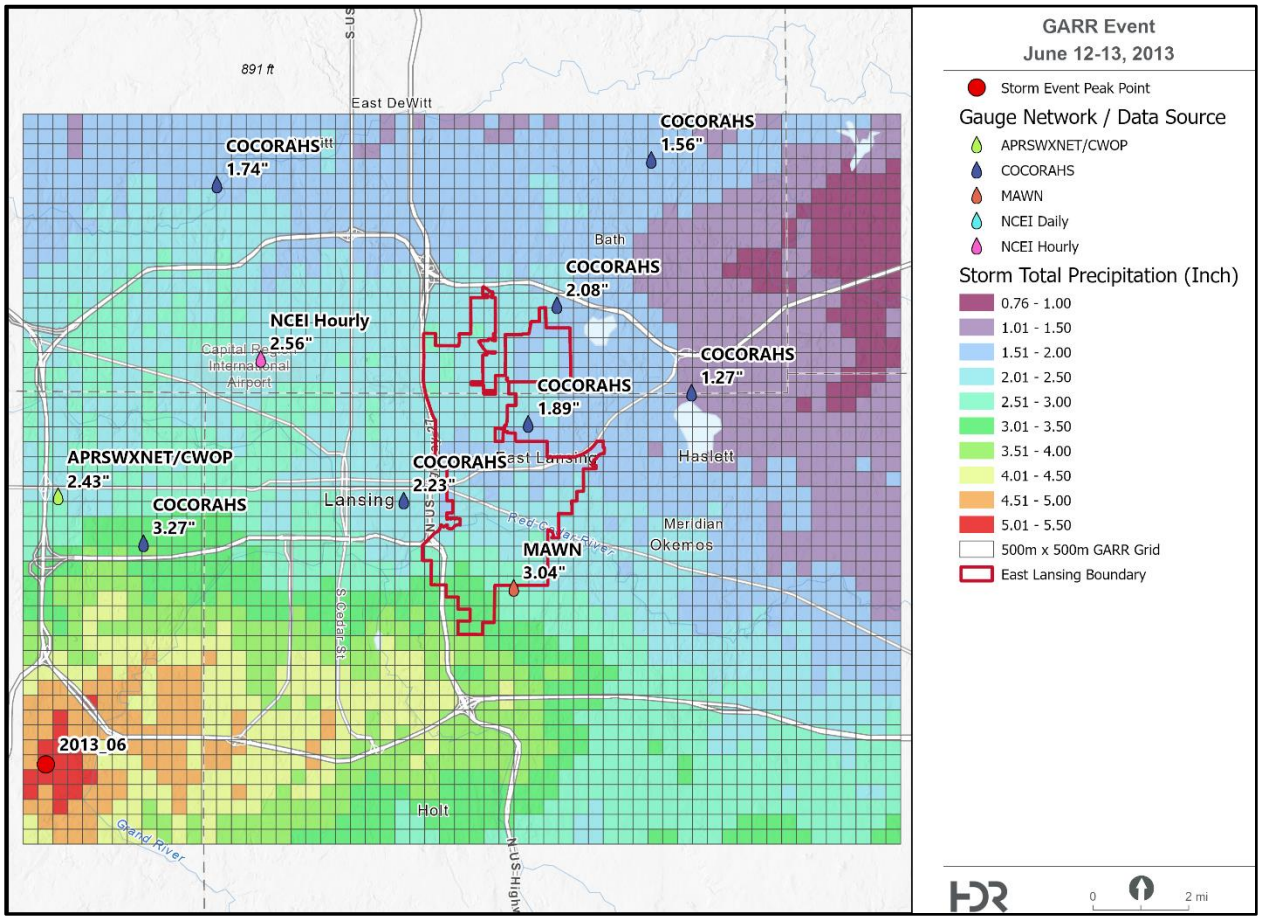

GARR Event
Sept. 16, 2010
Storm Event Peak Point
Gauge Network / Data Source
APRSWXNET/CWOP
COCORAHS
MAWN
NCEI Daily
NCEI Hourly
Storm Total Precipitation (Inch)
0.74 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
500m x 500m GARR Grid
East Lansing Boundary
0
2 mi
891 ft
East DeWitt
DeWitt
Bath
Haslett
Lansing
East Lansing
Meridian
Okemos
Holt
Grand River
Red Cedar River
S. US-127
N. US-127
S. Cedar St
MAWN
1.24"
NCEI Hourly
2.28"
COCORAHS
2.78"
2010_09
COCORAHS
2.78"
COCORAHS
2.86"
COCORAHS
2.54"
COCORAHS
2.03"
COCORAHS
2.03"
MAWN
1.34"
MAWN
1.17"

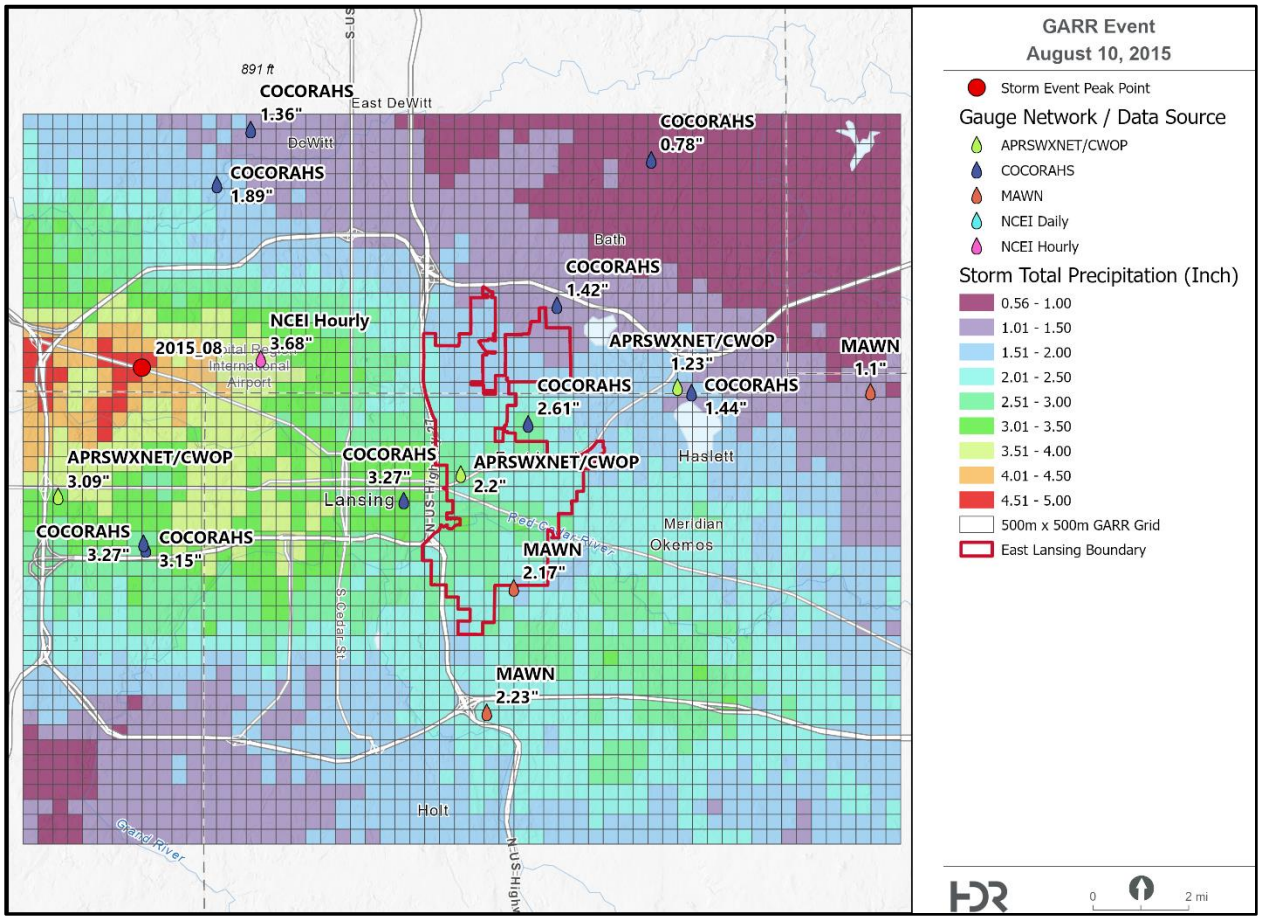

GARR Event
May 13, 2011
Storm Event Peak Point
Gauge Network / Data Source
APRSWXNET/CWOP
COCORAHS
MAWN
NCEI Daily
NCEI Hourly
Storm Total Precipitation (Inch)
0.87 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 4.50
4.51 - 5.00
500m x 500m GARR Grid
East Lansing Boundary
East DeWitt
Bath
Haslett
Lansing
Meridian
Okemos
Holt
COCORAHS 1.91"
COCORAHS 1.94"
NCEI Hourly 1.39"
2011_05
APRSWXNET/CWOP 2.22"
COCORAHS 3.55"
COCORAHS 2.39"
COCORAHS 3.3"
APRSWXNET/CWOP 1.69"
COCORAHS 1.58"
COCORAHS 2.2"
COCORAHS 2.27"
MAWN 1.88"
MAWN 2.36"
0
2 mi

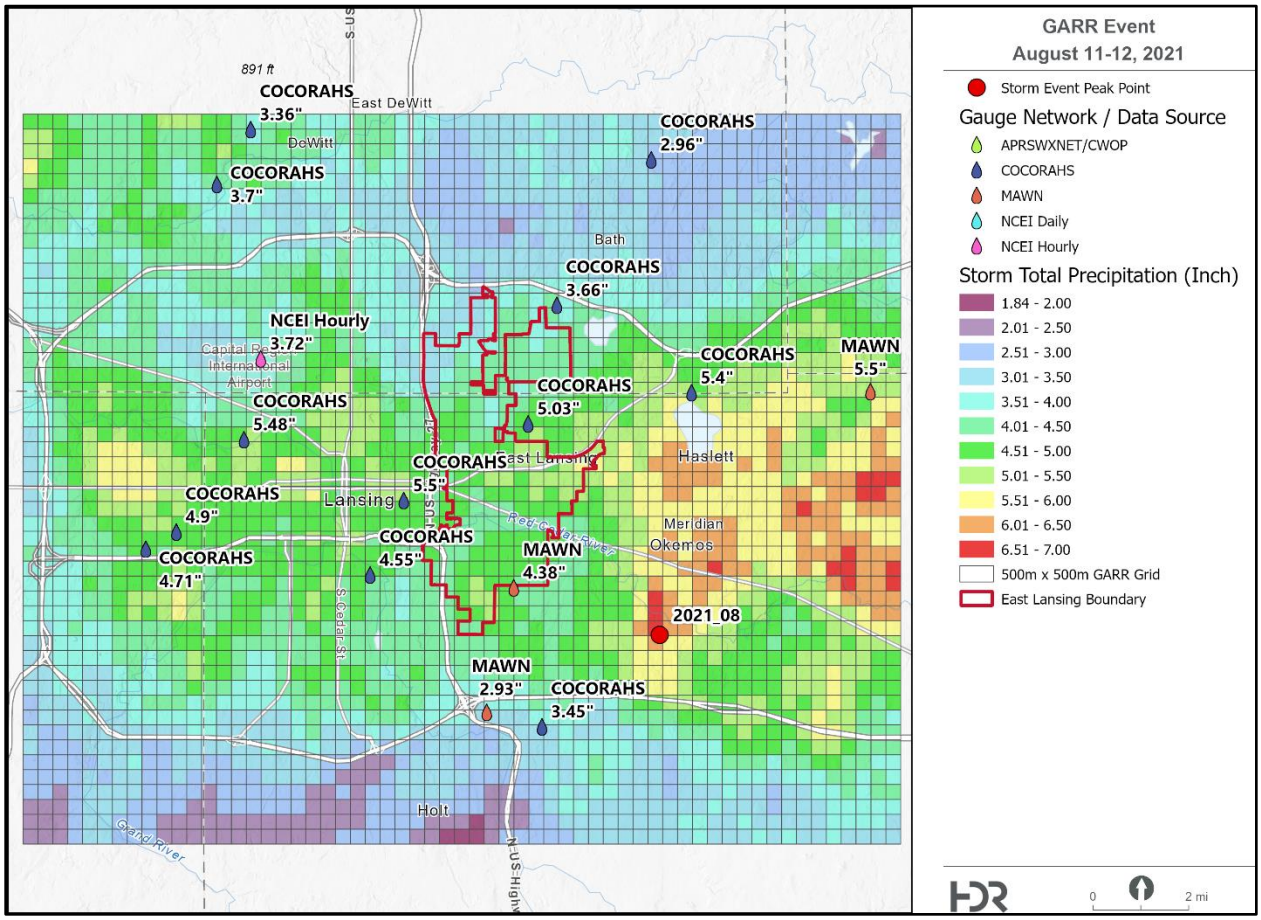

GARR Event
July 27-28, 2011
Storm Event Peak Point
Gauge Network / Data Source
APRSWXNET/CWOP
COCORAHS
MAWN
NCEI Daily
NCEI Hourly
Storm Total Precipitation (Inch)
1.27 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 4.50
4.51 - 5.00
5.01 - 5.50
5.51 - 6.00
500m x 500m GARR Grid
East Lansing Boundary
891 ft
East DeWitt
DeWitt
Bath
MAWN
1.59"
NCEI Hourly
2.31"
APRSWXNET/CWOP
1.41"
Haslett
East Lansing
Lansing
Meridian
Okemos
MAWN
2.85"
MAWN
3.88"
2011_07_27
Holt
0
2 mi

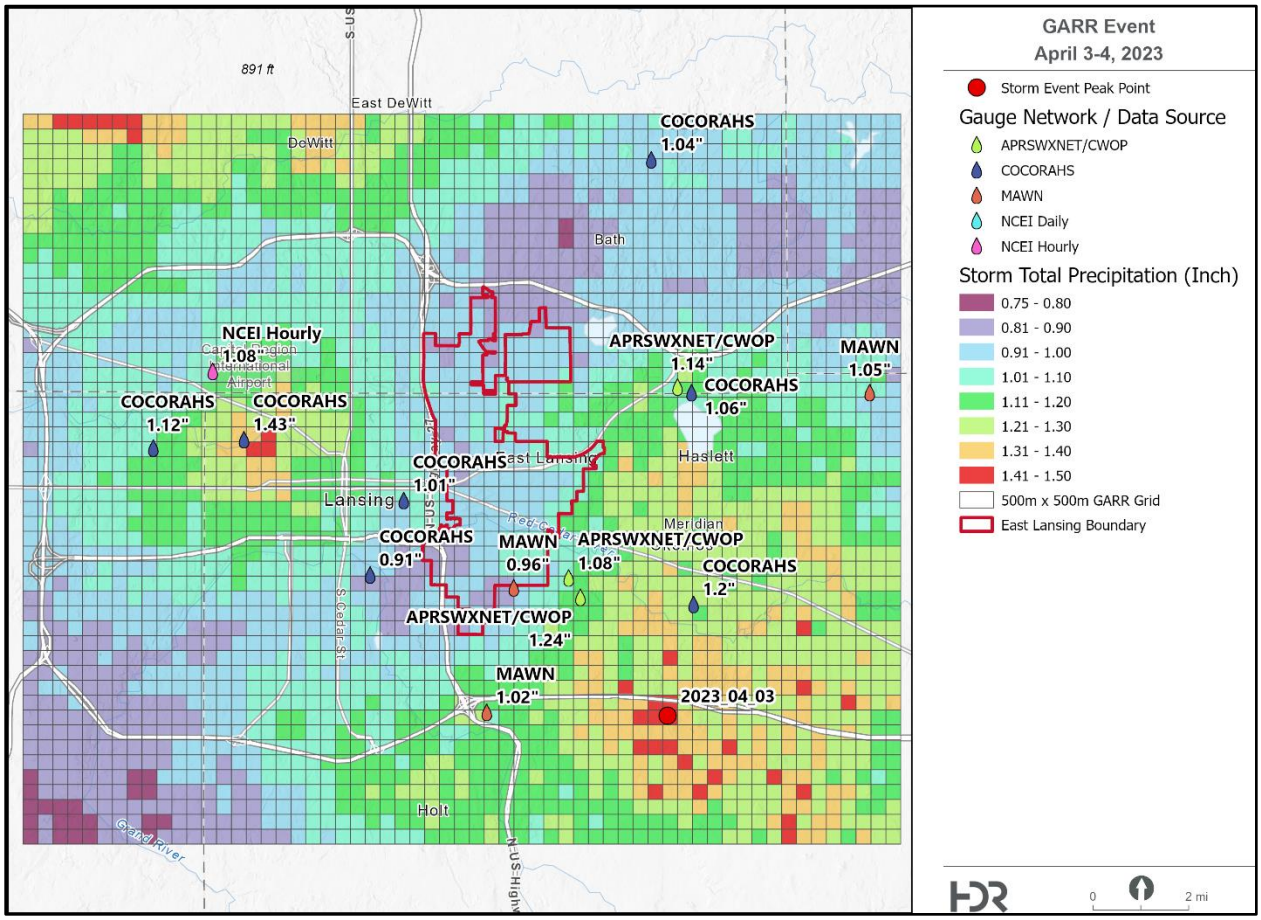

GARR Event
July 29, 2011
Storm Event Peak Point
Gauge Network / Data Source
APRSWXNET/CWOP
COCORAHS
MAWN
NCEI Daily
NCEI Hourly
Storm Total Precipitation (Inch)
0.99 - 1.00
1.01 - 1.25
1.26 - 1.50
1.51 - 1.75
1.76 - 2.00
2.01 - 2.25
2.26 - 2.50
2.51 - 2.75
2.76 - 3.00
3.01 - 3.25
3.26 - 3.50
500m x 500m GARR Grid
East Lansing Boundary
0
2 mi
891 ft
East DeWitt
Bath
Haslett
Lansing
Meridian
Okemos
Holt
COCORAHS 1.51"
MAWN 1.5"
NCEI Hourly 1.42"
COCORAHS 1.5"
COCORAHS 1.23"
COCORAHS 1.33"
COCORAHS 1.37"
COCORAHS 1.72"
COCORAHS 1.85"
COCORAHS 2.36"
COCORAHS 2.34"
MAWN 1.61"
MAWN 2.36"
2011_07_29

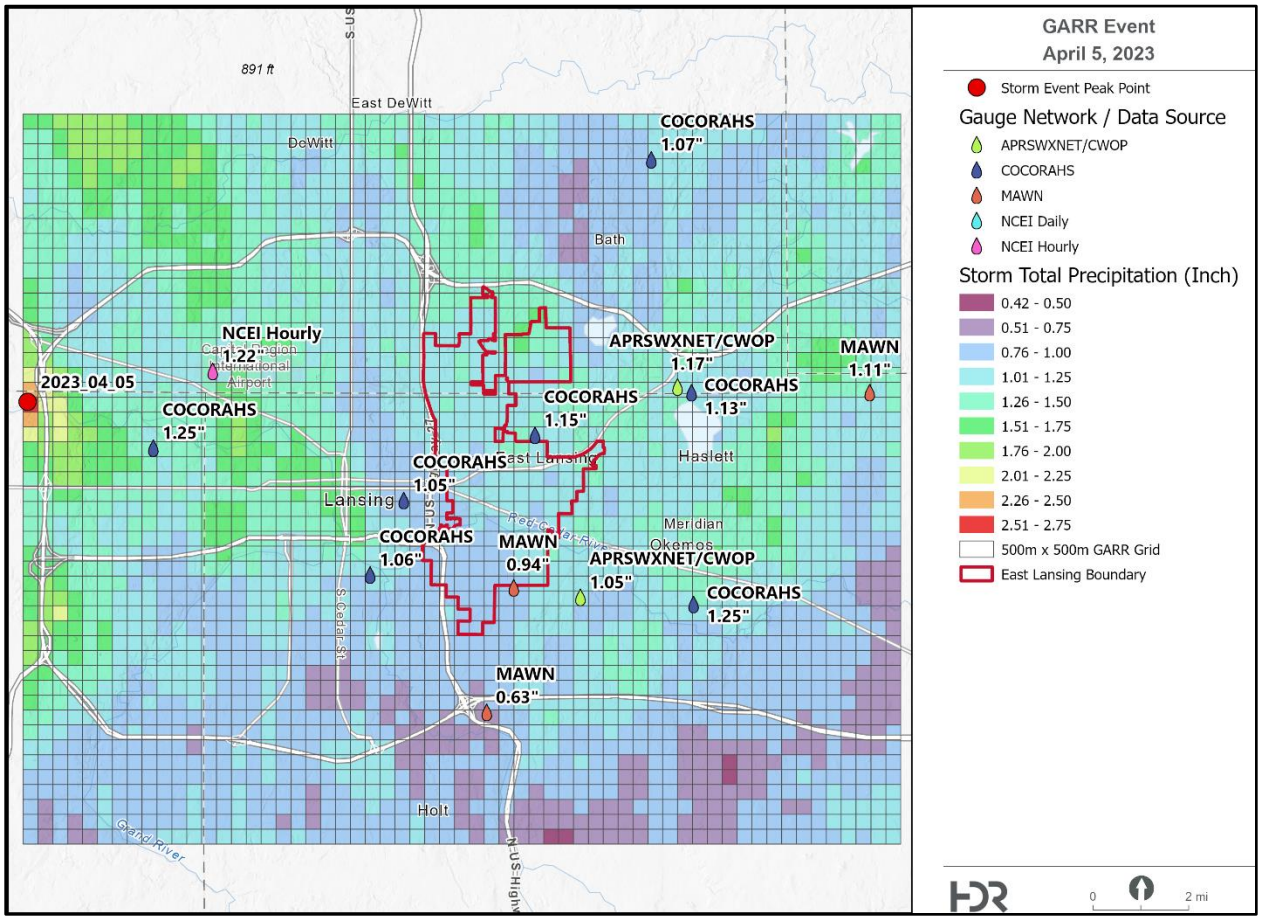

GARR Event
May 13, 2011
Storm Event Peak Point
Gauge Network / Data Source
APRSWXNET/CWOP
COCORAHS
MAWN
NCEI Daily
NCEI Hourly
Storm Total Precipitation (Inch)
0.87 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 4.50
4.51 - 5.00
500m x 500m GARR Grid
East Lansing Boundary
East DeWitt
Bath
Haslett
Lansing
Meridian
Okemos
Holt
COCORAHS 1.91"
COCORAHS 1.94"
NCEI Hourly 1.39"
2011_05
APRSWXNET/CWOP 2.22"
COCORAHS 2.39"
COCORAHS 3.55"
COCORAHS 3.3"
COCORAHS 1.58"
APRSWXNET/CWOP 1.69"
COCORAHS 2.2"
COCORAHS 2.27"
MAWN 1.88"
MAWN 2.36"
0
2 mi


GARR Event
June 12-13, 2013
Storm Event Peak Point
Gauge Network / Data Source
APRSWXNET/CWOP
COCORAHS
MAWN
NCEI Daily
NCEI Hourly
Storm Total Precipitation (Inch)
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 4.50
4.51 - 5.00
5.01 - 5.50
500m x 500m GARR Grid
East Lansing Boundary
0
2 mi
COCORAHS 1.74"
COCORAHS 1.56"
COCORAHS 2.08"
NCEI Hourly 2.56"
COCORAHS 1.27"
COCORAHS 1.89"
APRSWXNET/CWOP 2.43"
COCORAHS 2.23"
COCORAHS 3.27"
MAWN 3.04"
2013_06
East DeWitt
Bath
Lansing
East Lansing
Haslett
Meridian
Okemos
Holt
Grand River
Red Cedar River
S. Cedar St.
N. US Highway
891 ft

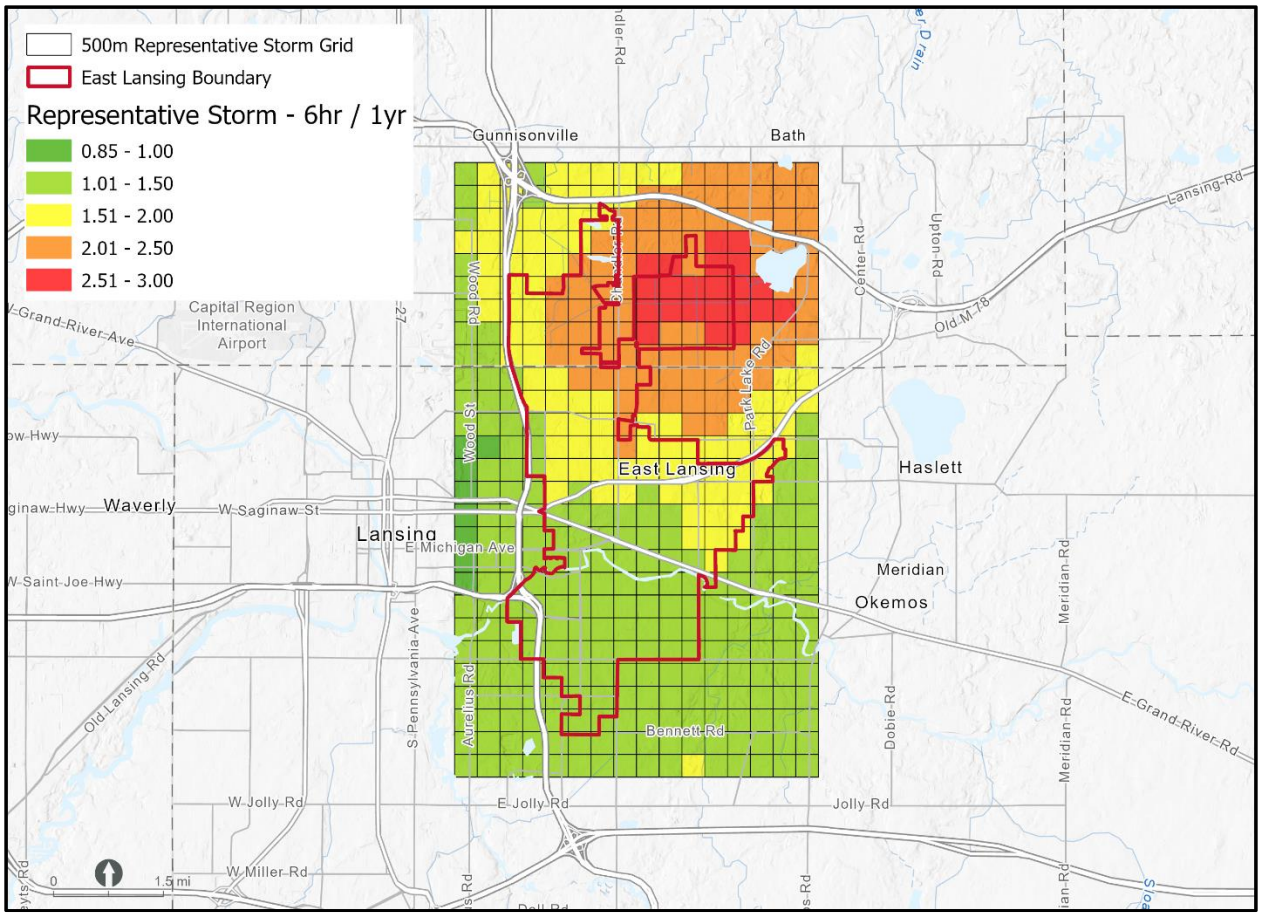

GARR Event
August 10, 2015
Storm Event Peak Point
Gauge Network / Data Source
APRSWXNET/CWOP
COCORAHS
MAWN
NCEI Daily
NCEI Hourly
Storm Total Precipitation (Inch)
0.56 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 4.50
4.51 - 5.00
500m x 500m GARR Grid
East Lansing Boundary
0
2 mi
891 ft
COCORAHS 1.36"
East DeWitt
DeWitt
COCORAHS 1.89"
COCORAHS 0.78"
Bath
COCORAHS 1.42"
NCEI Hourly 3.68"
2015_08
Capital Region International Airport
APRSWXNET/CWOP 1.23"
MAWN 1.1"
COCORAHS 2.61"
COCORAHS 1.44"
APRSWXNET/CWOP 3.09"
COCORAHS 3.27"
APRSWXNET/CWOP 2.2"
Haslett
Lansing
Red Cedar River
Meridian
Okemos
COCORAHS 3.27"
COCORAHS 3.15"
MAWN 2.17"
S Cedar St
MAWN 2.23"
Holt
Grand River
N US Highway

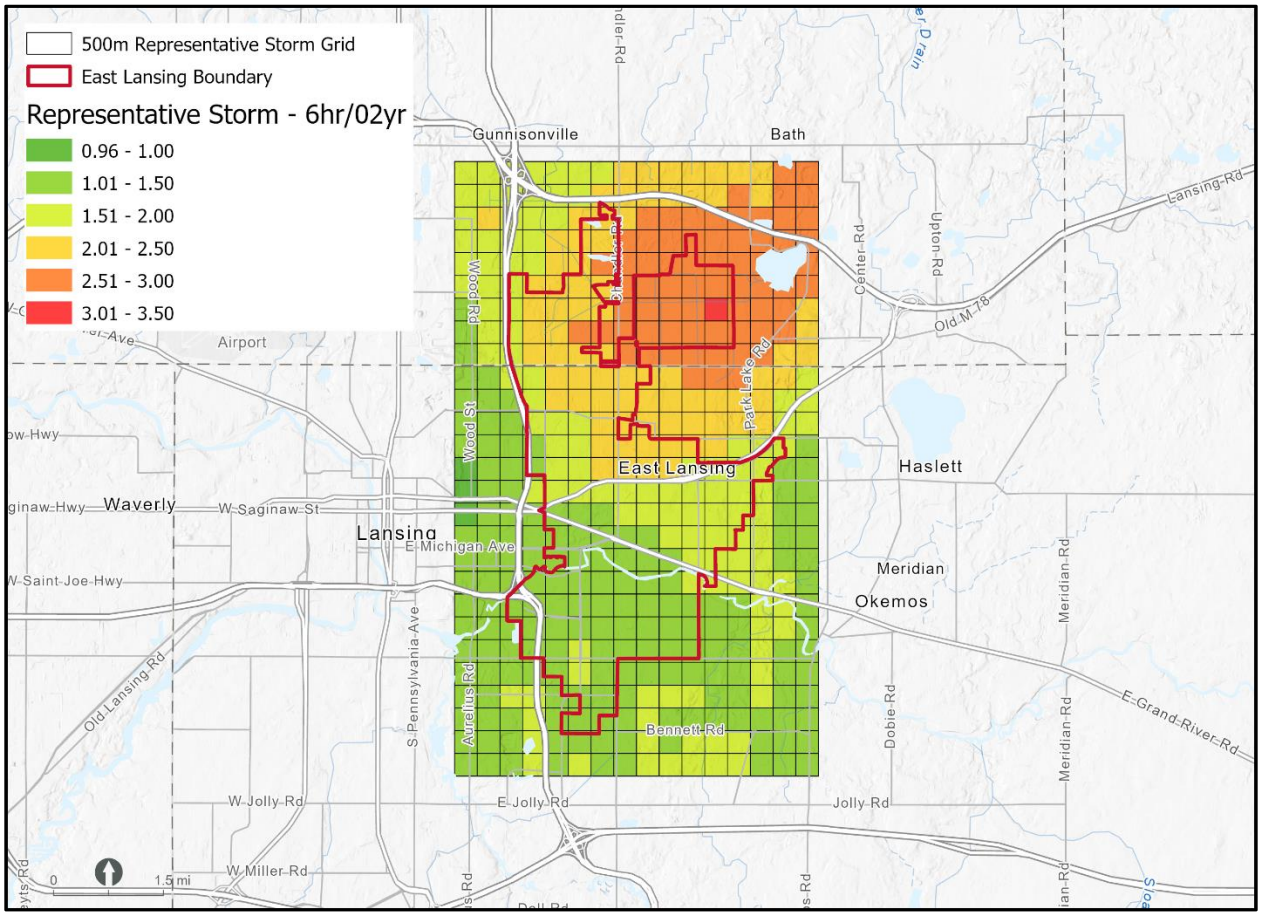

GARR Event
August 11-12, 2021
Storm Event Peak Point
Gauge Network / Data Source
APRSWXNET/CWOP
COCORAHS
MAWN
NCEI Daily
NCEI Hourly
Storm Total Precipitation (Inch)
1.84 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 4.50
4.51 - 5.00
5.01 - 5.50
5.51 - 6.00
6.01 - 6.50
6.51 - 7.00
500m x 500m GARR Grid
East Lansing Boundary
0
2 mi
COCORAHS 3.36"
COCORAHS 3.7"
COCORAHS 2.96"
COCORAHS 3.66"
NCEI Hourly 3.72"
COCORAHS 5.48"
COCORAHS 5.03"
COCORAHS 5.4"
MAWN 5.5"
COCORAHS 5.5"
COCORAHS 4.9"
COCORAHS 4.71"
COCORAHS 4.55"
MAWN 4.38"
2021_08
MAWN 2.93"
COCORAHS 3.45"
East DeWitt
DeWitt
Bath
Capital Region International Airport
East Lansing
Haslett
Lansing
Meridian
Okemos
Holt
Grand River
Red Cedar River
S. US-127
S. Grand St.
N. U.S. Highway

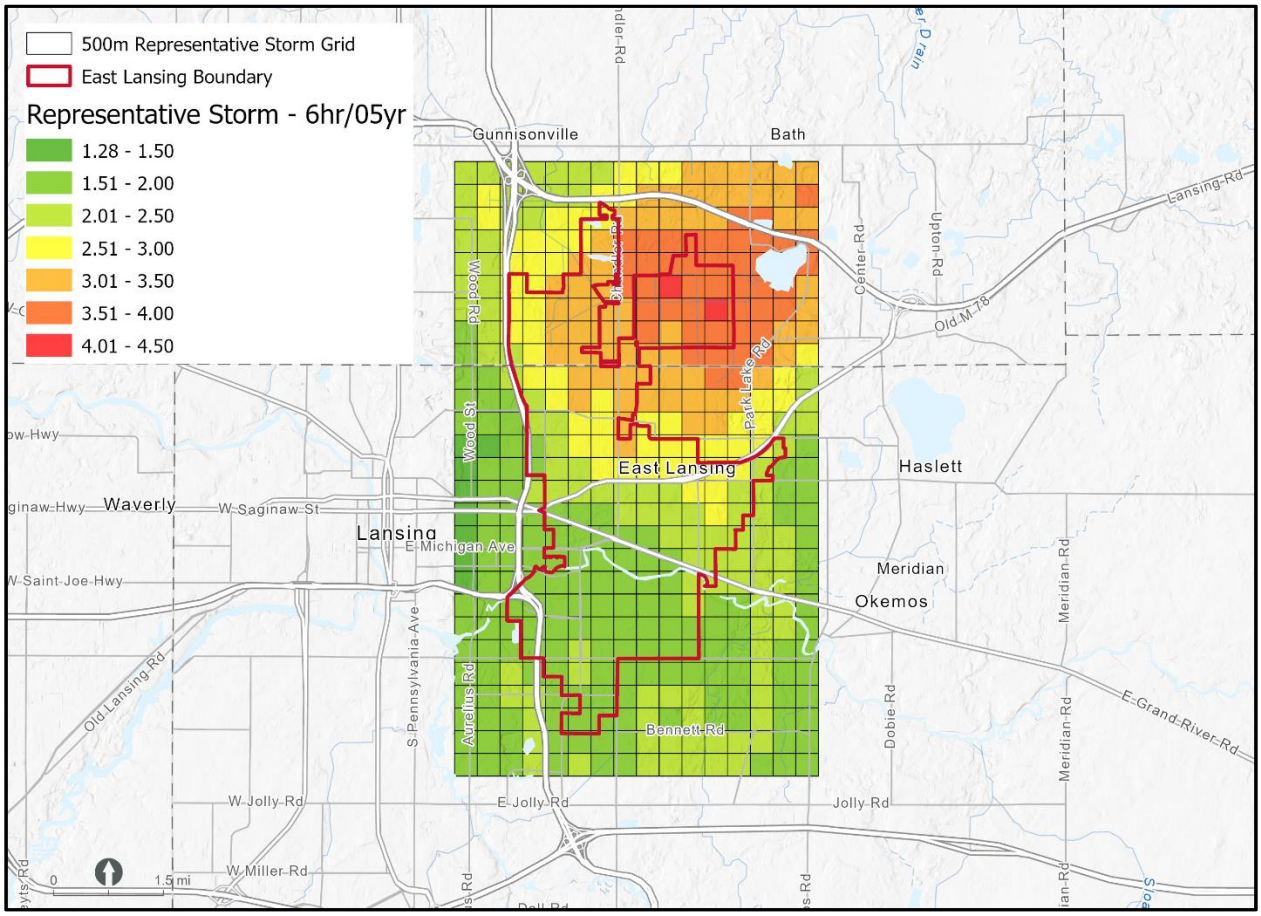

GARR Event
April 3-4, 2023
Storm Event Peak Point
Gauge Network / Data Source
APRSWXNET/CWOP
COCORAHS
MAWN
NCEI Daily
NCEI Hourly
Storm Total Precipitation (Inch)
0.75 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.10
1.11 - 1.20
1.21 - 1.30
1.31 - 1.40
1.41 - 1.50
500m x 500m GARR Grid
East Lansing Boundary
East DeWitt
DeWitt
Bath
Haslett
Lansing
East Lansing
Meridian
Holt
COCORAHS 1.04"
NCEI Hourly 1.08"
APRSWXNET/CWOP 1.14"
MAWN 1.05"
COCORAHS 1.06"
COCORAHS 1.12"
COCORAHS 1.43"
COCORAHS 1.01"
COCORAHS 0.91"
MAWN 0.96"
APRSWXNET/CWOP 1.08"
COCORAHS 1.2"
APRSWXNET/CWOP 1.24"
MAWN 1.02"
2023 04 03
0
2 mi

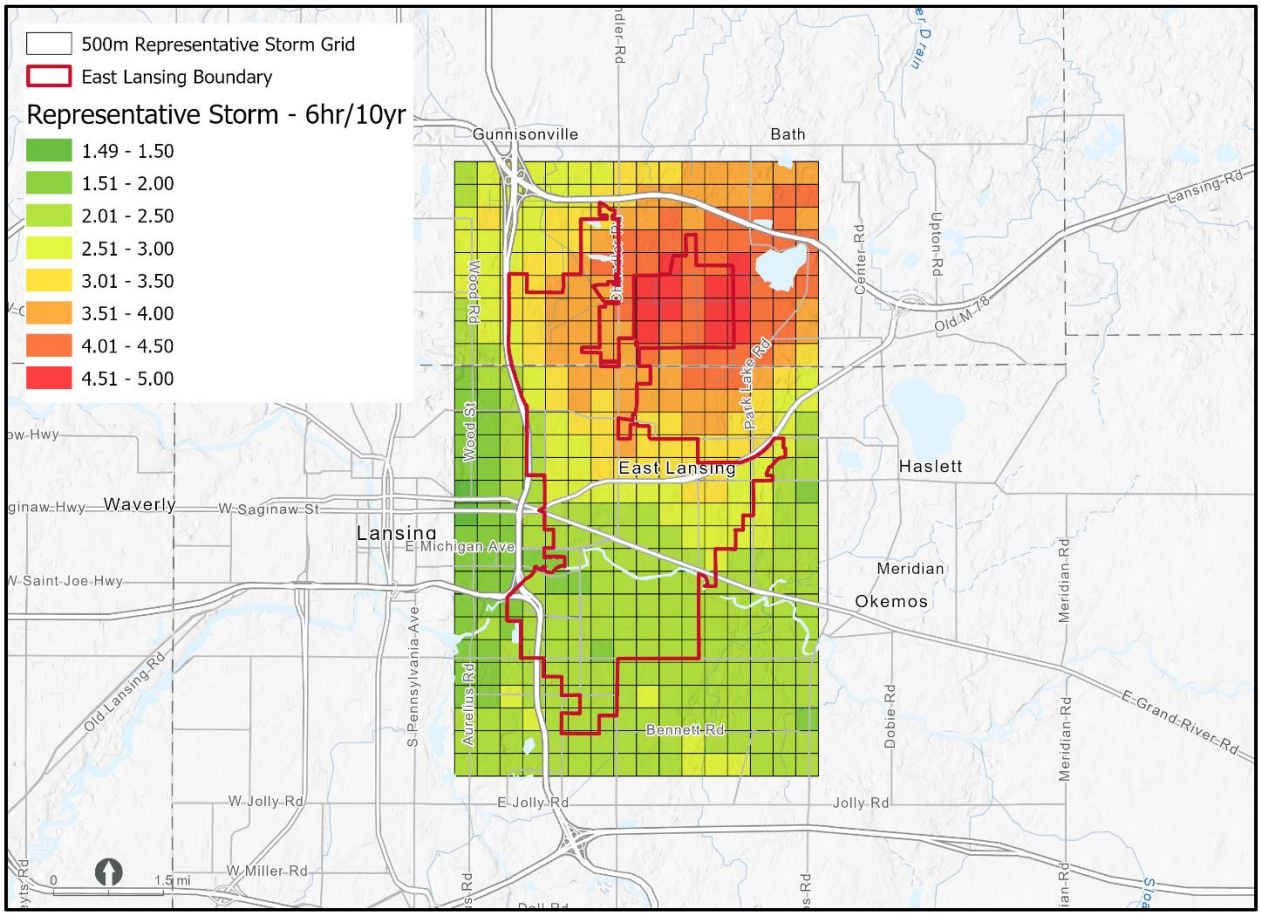

GARR Event
April 5, 2023
Storm Event Peak Point
Gauge Network / Data Source
APRSWXNET/CWOP
COCORAHS
MAWN
NCEI Daily
NCEI Hourly
Storm Total Precipitation (Inch)
0.42 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.25
1.26 - 1.50
1.51 - 1.75
1.76 - 2.00
2.01 - 2.25
2.26 - 2.50
2.51 - 2.75
500m x 500m GARR Grid
East Lansing Boundary
0
2 mi
891 ft
East DeWitt
DeWitt
Bath
Haslett
East Lansing
Lansing
Meridian
Okemos
Holt
Grand River
2023_04_05
NCEI Hourly
1.22"
COCORAHS
1.25"
COCORAHS
1.07"
APRSWXNET/CWOP
1.17"
COCORAHS
1.13"
MAWN
1.11"
COCORAHS
1.15"
COCORAHS
1.05"
COCORAHS
1.06"
MAWN
0.94"
APRSWXNET/CWOP
1.05"
COCORAHS
1.25"
MAWN
0.63"

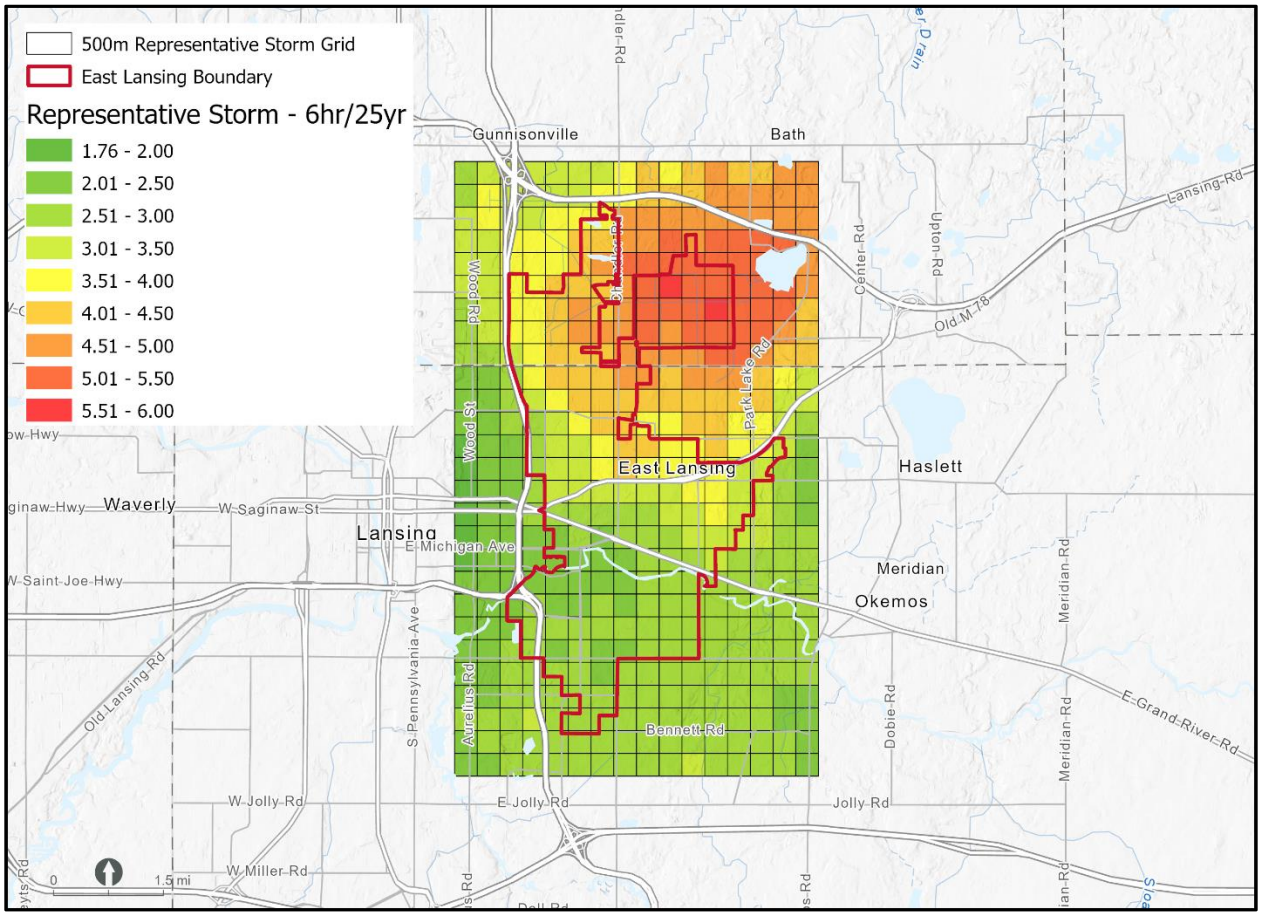
Appendix C: Representative Storms Figures

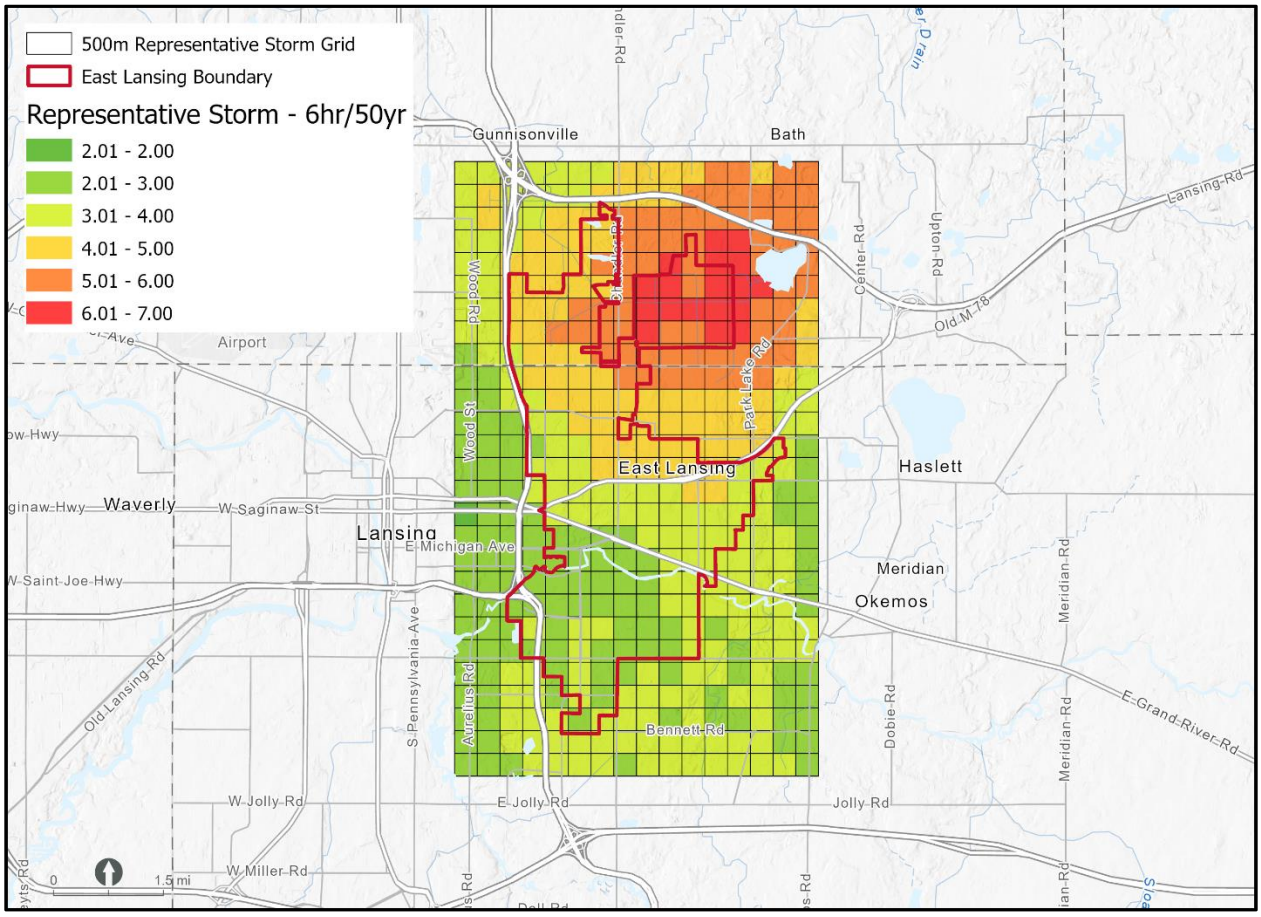


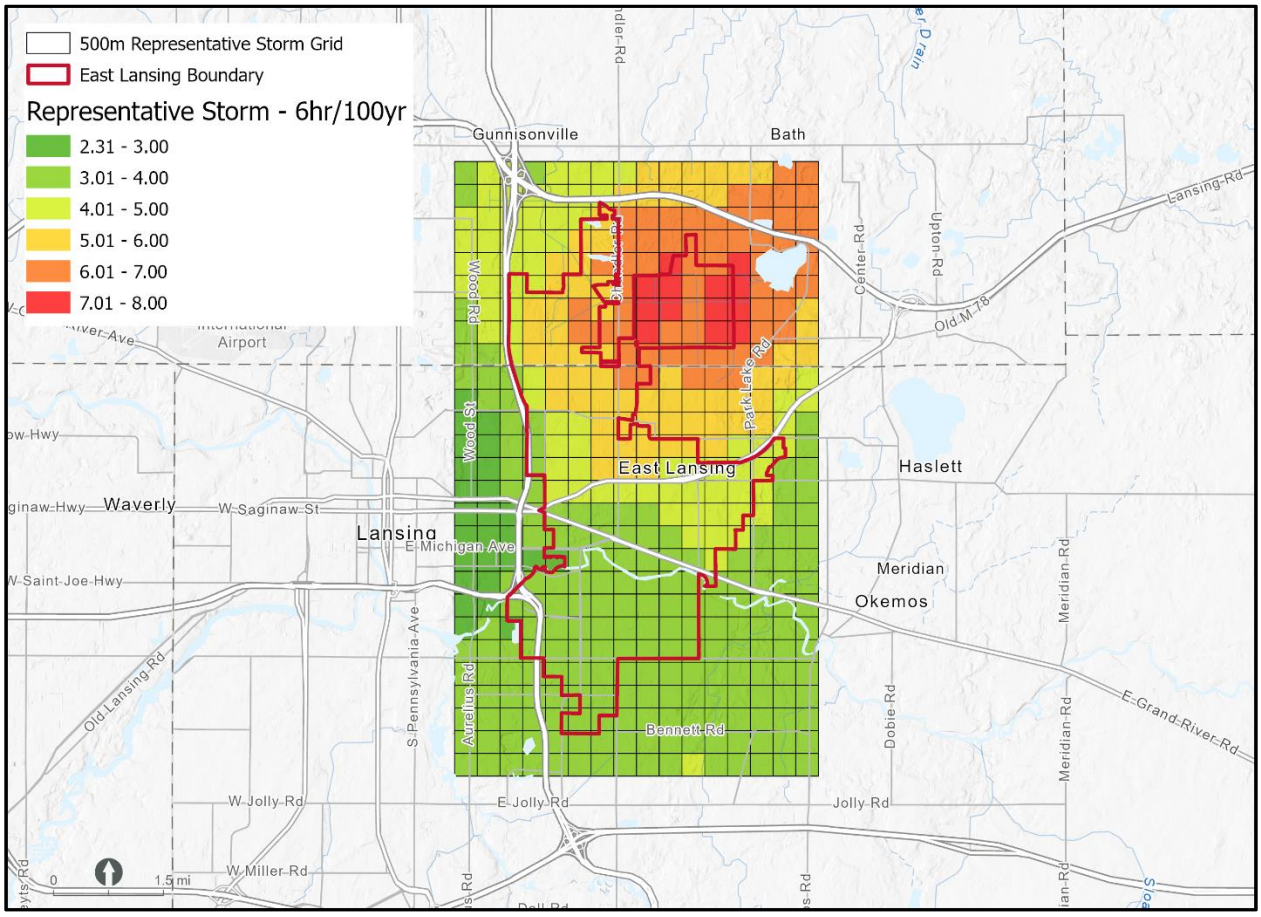

500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 6hr/02yr
0.96 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
Gunnisonville
Bath
Lansing Rd
Center Rd
Upton Rd
Old M-78
Airport
Wood Rd
Wood St
Park Lake Rd
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
Meridian
Okemos
Meridian Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
Old Lansing Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi

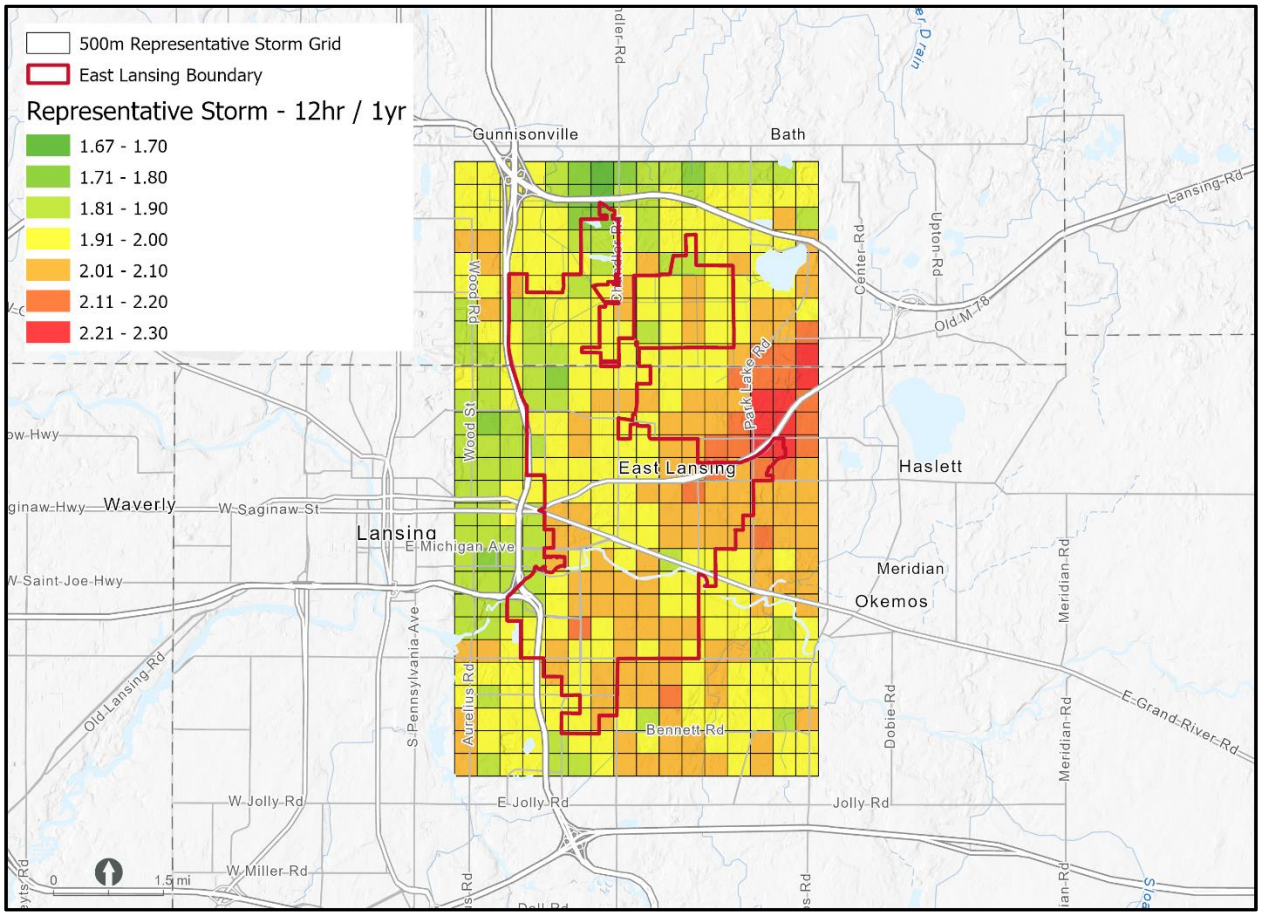

500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 6hr/05yr
1.28 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 4.50
Gunnisonville
Bath
Lansing Rd
Center Rd
Upton Rd
Old M-78
Wood Rd
Wood St
Park Lake Rd
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
Meridian
Okemos
Meridian Rd
W Saint Joe Hwy
Old Lansing Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi

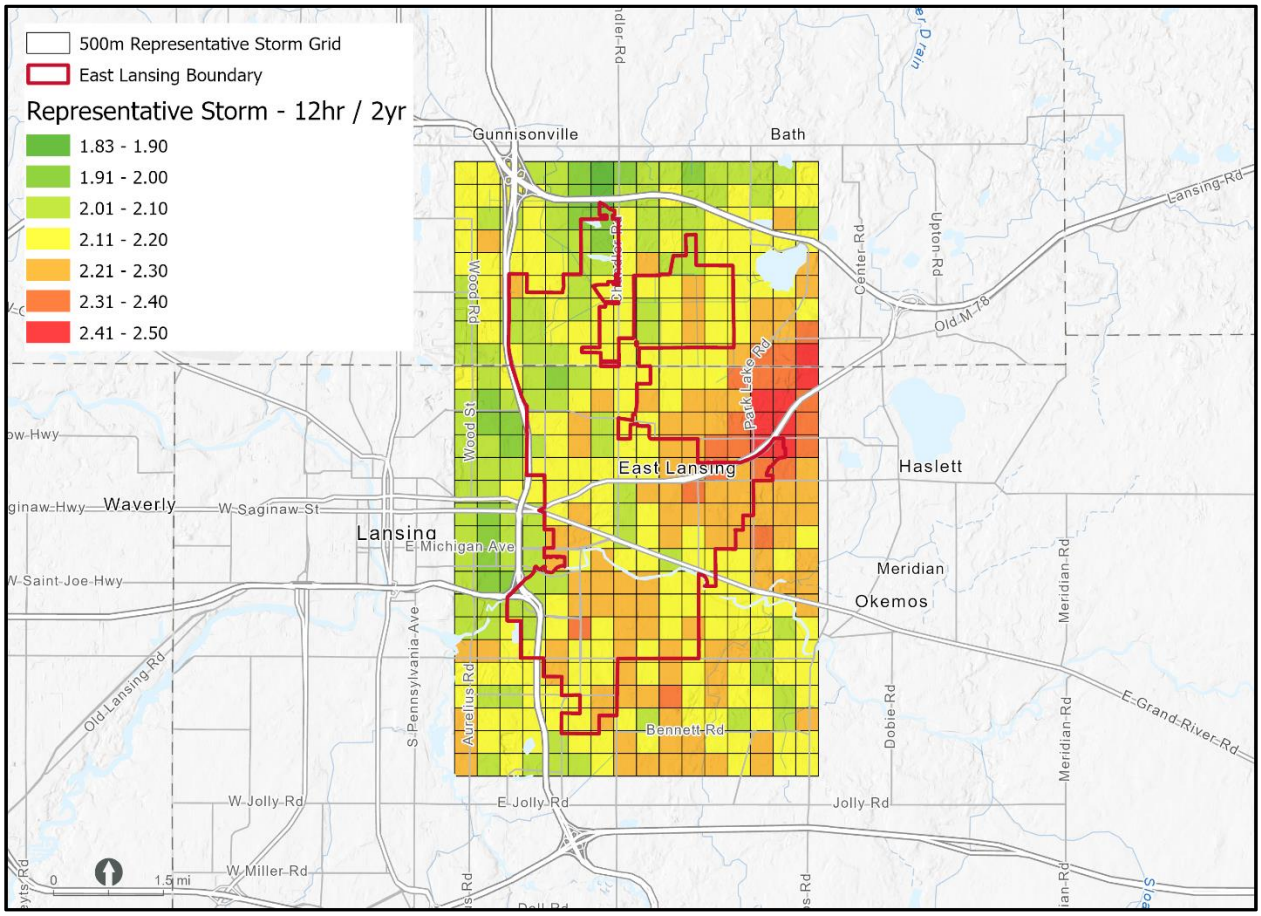

500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 6hr/10yr
1.49 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 4.50
4.51 - 5.00
Gunnisonville
Bath
Lansing Rd
Center Rd
Upton Rd
Old M-78
Wood Rd
Wood St
Park Lake Rd
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
Meridian
Okemos
Meridian Rd
W Saint Joe Hwy
Old Lansing Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi

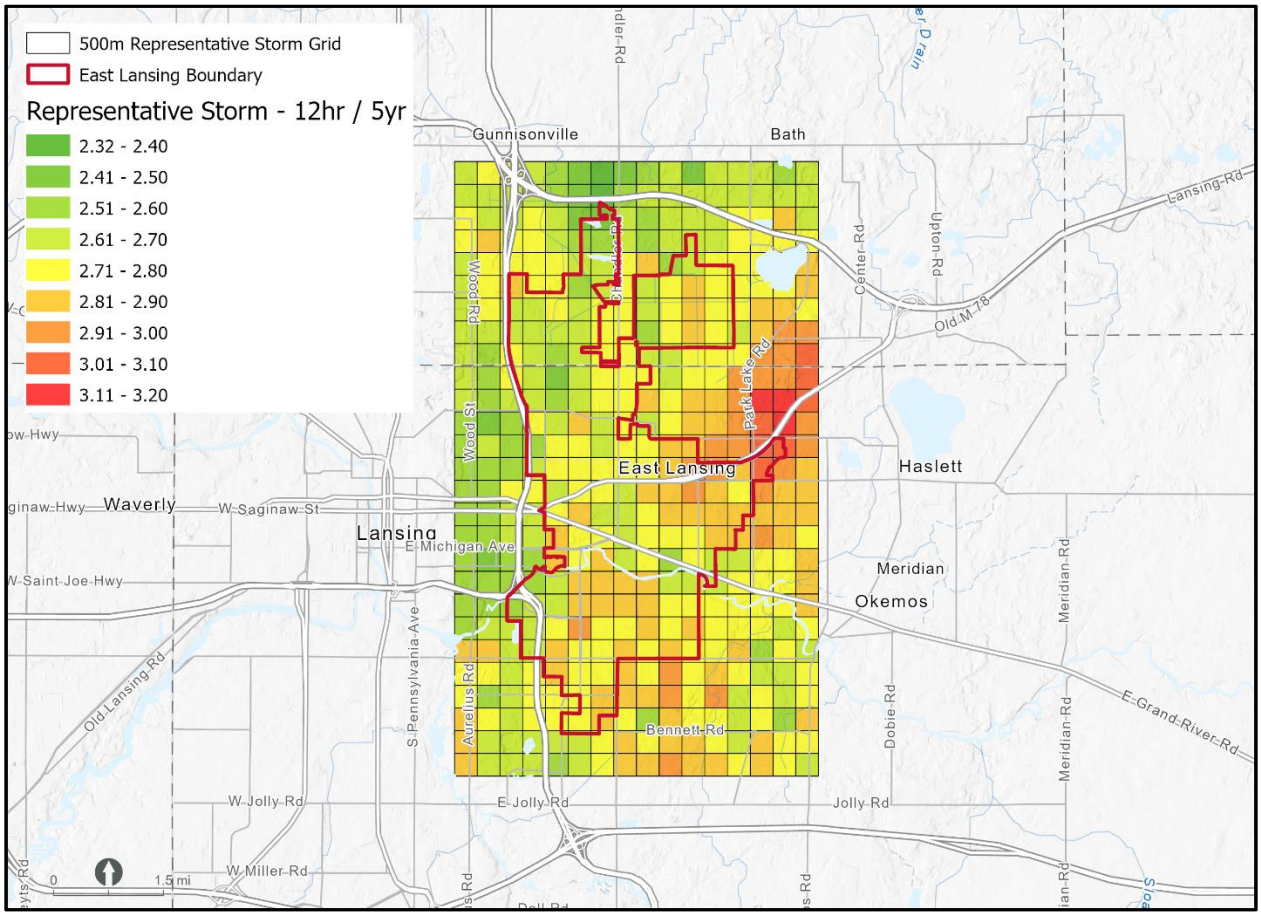

500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 6hr/25yr
1.76 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 4.50
4.51 - 5.00
5.01 - 5.50
5.51 - 6.00
Gunnisonville
Bath
Lansing Rd
Center Rd
Upton Rd
Old M-78
Wood Rd
Wood St
Park Lake Rd
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
Meridian
Okemos
Meridian Rd
W Saint Joe Hwy
Old Lansing Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi

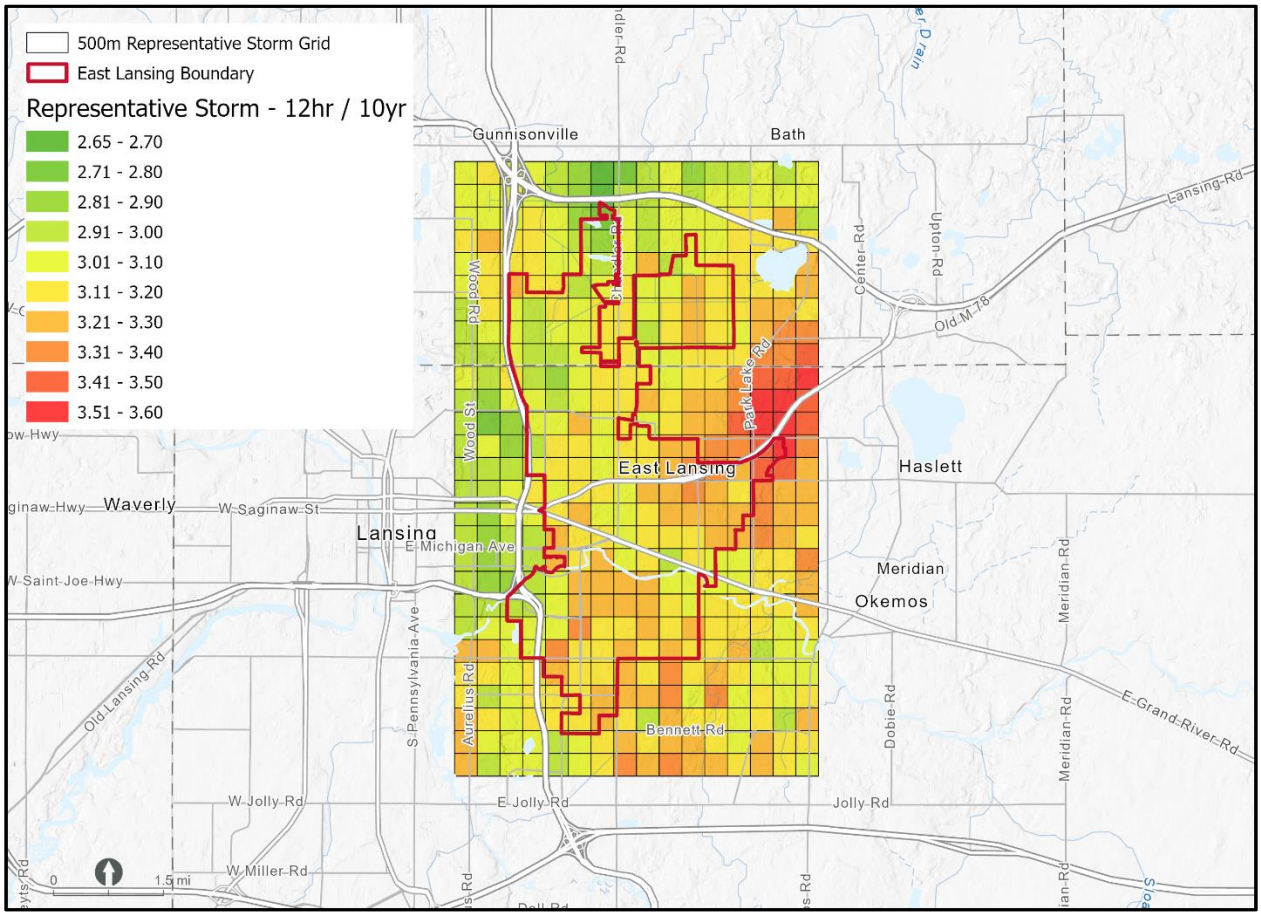

500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 6hr/50yr
2.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
Gunnisonville
Bath
Lansing Rd
Center Rd
Upton Rd
Old M-78
Airport
Wood Rd
Wood St
Park Lake Rd
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
Meridian
Okemos
Meridian Rd
W Saint Joe Hwy
Old Lansing Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi

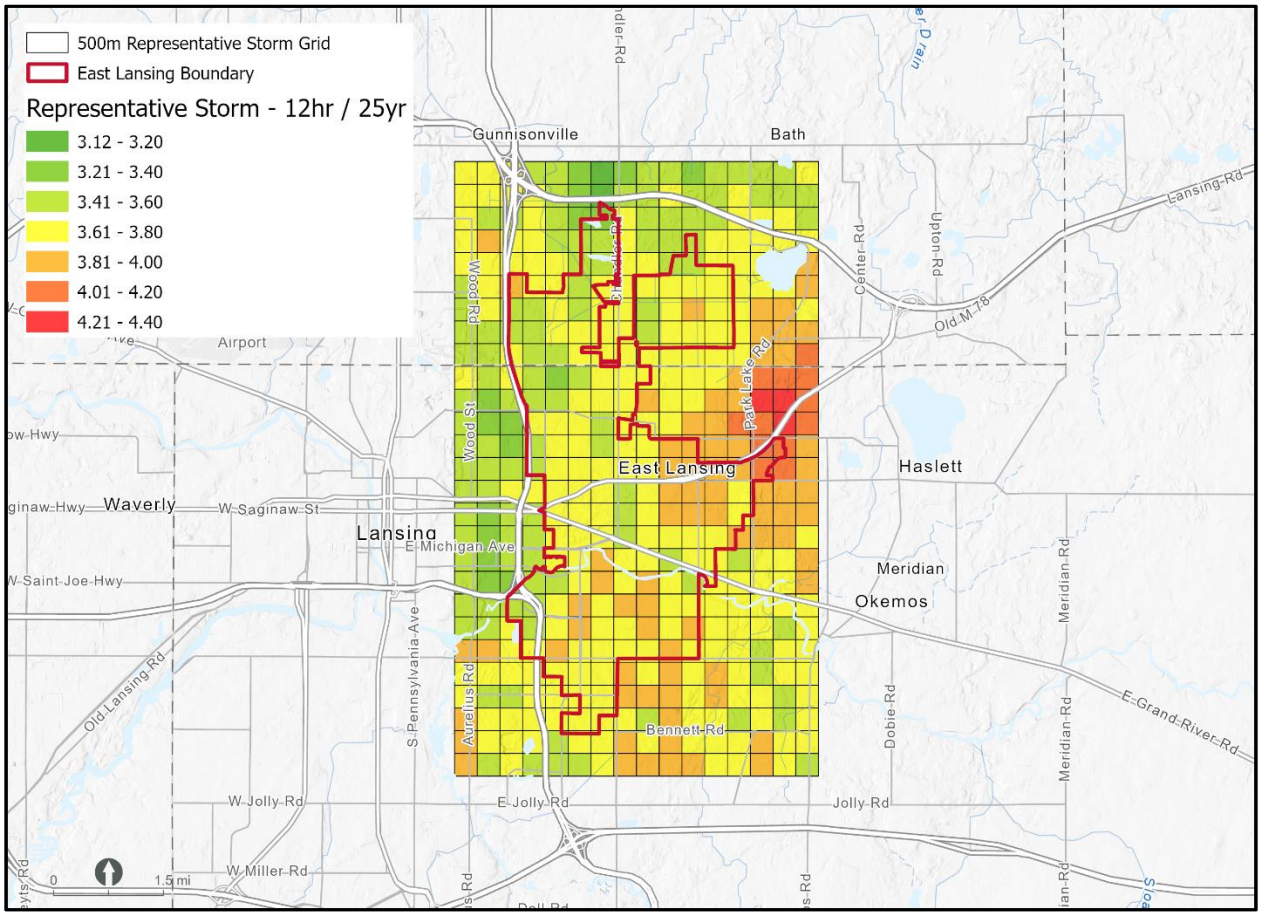

500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 6hr/100yr
2.31 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
Gunnisonville
Bath
Lansing Rd
Center Rd
Upton Rd
Old M-78
Wood Rd
Park Lake Rd
Wood St
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
Meridian
Okemos
Meridian Rd
W Saint Joe Hwy
Old Lansing Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi

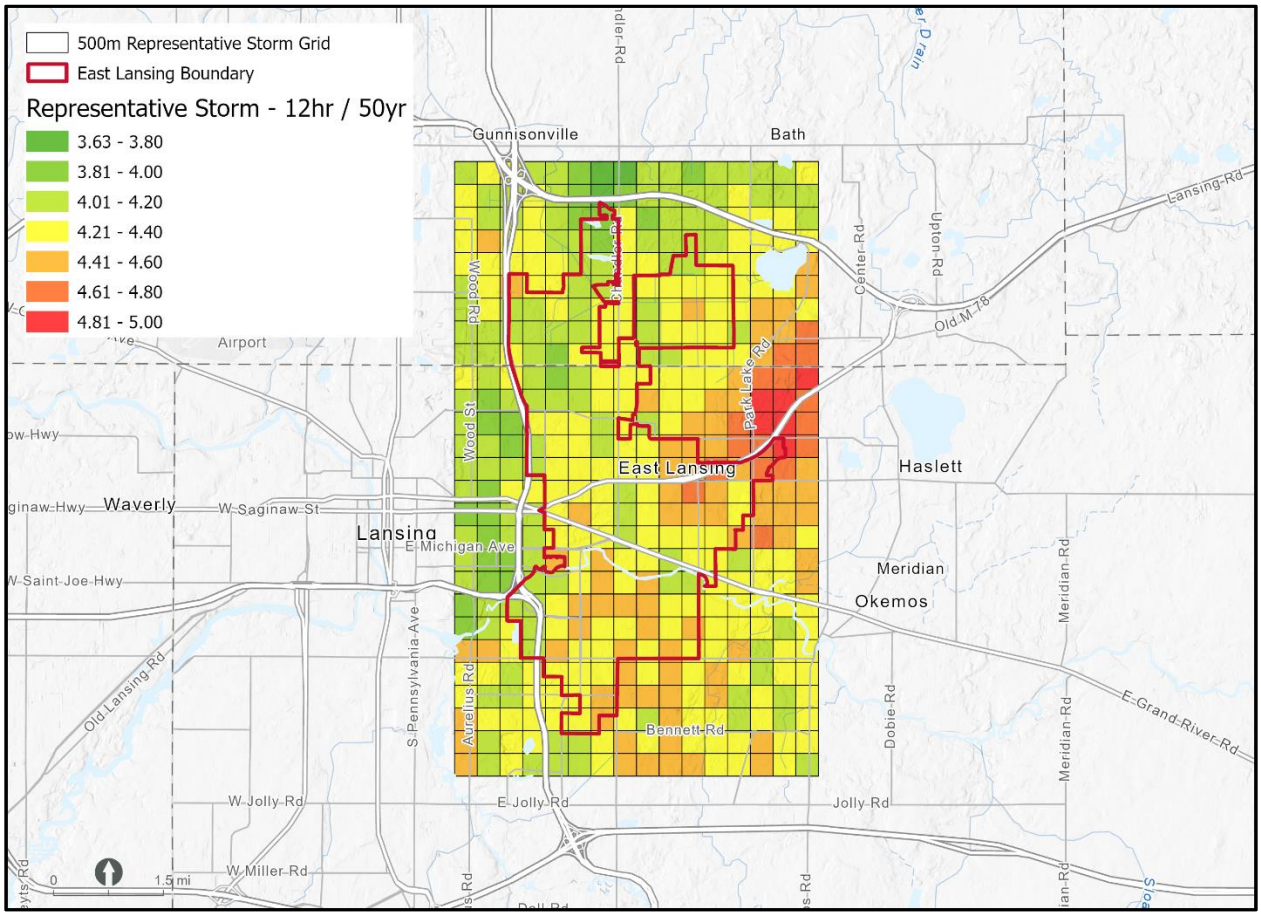

500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 12hr / 1yr
1.67 - 1.70
1.71 - 1.80
1.81 - 1.90
1.91 - 2.00
2.01 - 2.10
2.11 - 2.20
2.21 - 2.30
Gunnisonville
Bath
Lansing Rd
Center Rd
Upton Rd
Old M-78
Wood Rd
Wood St
Park Lake Rd
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
Meridian
Okemos
Meridian Rd
W Saint Joe Hwy
Old Lansing Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi

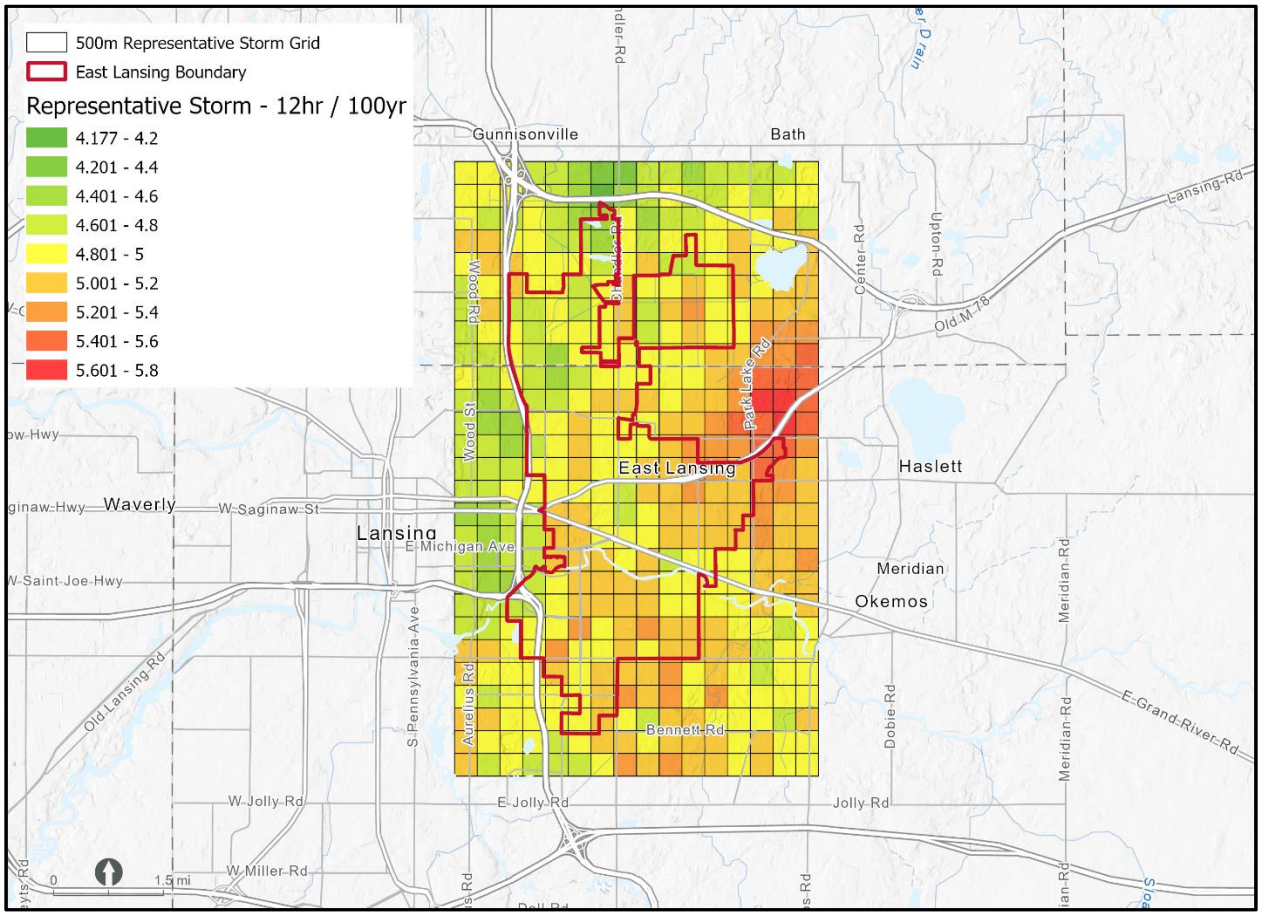

500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 12hr / 2yr
1.83 - 1.90
1.91 - 2.00
2.01 - 2.10
2.11 - 2.20
2.21 - 2.30
2.31 - 2.40
2.41 - 2.50
Gunnisonville
Bath
Lansing Rd
Center Rd
Upton Rd
Old M-78
Wood Rd
Wood St
Park Lake Rd
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
Meridian
Okemos
Meridian Rd
W Saint Joe Hwy
Old Lansing Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi


500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 12hr / 5yr
2.32 - 2.40
2.41 - 2.50
2.51 - 2.60
2.61 - 2.70
2.71 - 2.80
2.81 - 2.90
2.91 - 3.00
3.01 - 3.10
3.11 - 3.20
Gunnisonville
Bath
Lansing Rd
Upton Rd
Center Rd
Old M-78
Wood Rd
Wood St
Park Lake Rd
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
Meridian
Okemos
Meridian Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
Old Lansing Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi


500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 12hr / 10yr
2.65 - 2.70
2.71 - 2.80
2.81 - 2.90
2.91 - 3.00
3.01 - 3.10
3.11 - 3.20
3.21 - 3.30
3.31 - 3.40
3.41 - 3.50
3.51 - 3.60
Gunnisonville
Bath
Lansing Rd
Center Rd
Upton Rd
Old M-78
Wood Rd
Wood St
Park Lake Rd
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
W Saint Joe Hwy
Meridian
Okemos
Meridian Rd
Old Lansing Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi


500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 12hr / 25yr
3.12 - 3.20
3.21 - 3.40
3.41 - 3.60
3.61 - 3.80
3.81 - 4.00
4.01 - 4.20
4.21 - 4.40
Gunnisonville
Bath
Lansing Rd
Center Rd
Upton Rd
Old M-78
Airport
Wood Rd
Wood St
Park Lake Rd
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
Meridian
Okemos
Meridian Rd
W Saint Joe Hwy
Old Lansing Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi


500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 12hr / 50yr
3.63 - 3.80
3.81 - 4.00
4.01 - 4.20
4.21 - 4.40
4.41 - 4.60
4.61 - 4.80
4.81 - 5.00
Gunnisonville
Bath
Lansing Rd
Center Rd
Upton Rd
Old M-78
Airport
Wood Rd
Wood St
Park Lake Rd
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
Meridian
Okemos
Meridian Rd
W Saint Joe Hwy
Old Lansing Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi


500m Representative Storm Grid
East Lansing Boundary
Representative Storm - 12hr / 100yr
4.177 - 4.2
4.201 - 4.4
4.401 - 4.6
4.601 - 4.8
4.801 - 5
5.001 - 5.2
5.201 - 5.4
5.401 - 5.6
5.601 - 5.8
Gunnisonville
Bath
Lansing Rd
Center Rd
Upton Rd
Old M-78
Wood Rd
Wood St
Park Lake Rd
East Lansing
Haslett
Waverly
W Saginaw St
Lansing
E Michigan Ave
Meridian
Okemos
Meridian Rd
W Saint Joe Hwy
Old Lansing Rd
S Pennsylvania Ave
Aurelius Rd
Bennett Rd
Dobie Rd
E Grand River Rd
W Jolly Rd
E Jolly Rd
Jolly Rd
W Miller Rd
0
1.5 mi

Appendix D: Future Climate Frequency Estimates

	PRECIPITATION FREQUENCY ESTIMATES (SSP2-4.5) - 2035						
Duration	**1yr**	**2yr**	**5yr**	**10yr**	**25yr**	**50yr**	**100yr**
6-hour	1.67	1.88	2.51	2.94	3.47	3.96	4.57
12-hour	1.99	2.18	2.77	3.16	3.73	4.33	5.00

	PRECIPITATION FREQUENCY ESTIMATES (SSP2-4.5) - 2050						
Duration	**1yr**	**2yr**	**5yr**	**10yr**	**25yr**	**50yr**	**100yr**
6-hour	1.69	1.91	2.55	2.99	3.53	4.02	4.64
12-hour	2.02	2.22	2.81	3.21	3.79	4.40	5.08

	PRECIPITATION FREQUENCY ESTIMATES (SSP2-4.5) - 2070						
Duration	**1yr**	**2yr**	**5yr**	**10yr**	**25yr**	**50yr**	**100yr**
6-hour	1.73	1.95	2.60	3.04	3.60	4.10	4.73
12-hour	2.06	2.26	2.87	3.27	3.86	4.49	5.18

	PRECIPITATION FREQUENCY ESTIMATES (SSP2-4.5) - 2100						
Duration	**1yr**	**2yr**	**5yr**	**10yr**	**25yr**	**50yr**	**100yr**
6-hour	1.78	2.01	2.68	3.14	3.71	4.23	4.87
12-hour	2.12	2.33	2.95	3.37	3.98	4.62	5.34

	PRECIPITATION FREQUENCY ESTIMATES (SSP5-8.5) - 2035						
Duration	**1yr**	**2yr**	**5yr**	**10yr**	**25yr**	**50yr**	**100yr**
6-hour	1.69	1.91	2.56	2.99	3.53	4.03	4.64
12-hour	2.02	2.22	2.81	3.21	3.79	4.41	5.08

	PRECIPITATION FREQUENCY ESTIMATES (SSP5-8.5) - 2050						
Duration	**1yr**	**2yr**	**5yr**	**10yr**	**25yr**	**50yr**	**100yr**
6-hour	1.76	1.98	2.65	3.10	3.67	4.18	4.82
12-hour	2.10	2.30	2.92	3.34	3.93	4.57	5.28

	PRECIPITATION FREQUENCY ESTIMATES (SSP5-8.5) - 2070						
Duration	**1yr**	**2yr**	**5yr**	**10yr**	**25yr**	**50yr**	**100yr**
6-hour	1.85	2.08	2.79	3.26	3.85	4.39	5.06
12-hour	2.21	2.42	3.07	3.51	4.13	4.80	5.54

	PRECIPITATION FREQUENCY ESTIMATES (SSP5-8.5) - 2100						
Duration	**1yr**	**2yr**	**5yr**	**10yr**	**25yr**	**50yr**	**100yr**
6-hour	1.98	2.23	2.99	3.49	4.13	4.70	5.42
12-hour	2.36	2.59	3.29	3.76	4.43	5.15	5.94

Appendix B.

Task 2: *Stormwater Infrastructure Resilience Framework* Technical Memorandum

Technical Memo

Date:	Tuesday, December 23, 2025
Project:	City of East Lansing Wet Weather Resiliency Plan
To:	Cliff Walls, City of East Lansing
From:	Ernie West Julie Stein Tom Batroney Anna Kilts
Subject:	Task 2: Stormwater Infrastructure Resiliency Framework

1 Introduction

The City of East Lansing (City) is developing a Wet Weather Resiliency Plan (WWRP) to mitigate surface and basement flooding in the city. In December 2023, the City of East Lansing (City) retained HDR Michigan, Inc. (HDR) to support the implementation of Environment, Great Lakes, and Energy's (EGLE) High Water Infrastructure Grant Program for the development of the WWRP. The primary goals of the WWRP are to:

- Establish where and why urban flooding is occurring
- Identify existing and future severe weather vulnerabilities
- Determine equitable, community-driven capital investments.

The current development of the WWRP is based on:

- Extensive review of existing data
- Detailed analysis of historic and projected future rainfall events
- Development of a 1D-2D hydraulic model of the City's drainage systems
- Identification of flooding concern areas based on existing conditions and various storm events
- Focus group workshops with stakeholders to gather community input.

In order to define the problem and identify potential solutions, HDR worked with City staff and community stakeholders to review and understand the existing conditions that are most impactful and problematic to the Community. HDR also compiled stakeholder input about City and community priorities, to inform future capital investments for the City's drainage systems.

This technical memorandum summarizes the Stormwater Infrastructure Resilience Framework (Framework) developed in Task 2 – Stormwater Resilience Framework, to assess, rank and prioritize flood risk mitigation strategies to be included in the WWRP. The Framework describes a Multi-Criteria Decision Analysis (MCDA) tool including project prioritization criteria identified by City staff and community stakeholders to be applied in subsequent tasks for the development of

the WWRP. This Task 2 effort will form the basis of an actionable WWRP that is reflective of the East Lansing Community's priorities.

2 Framework Overview and Objective

The purpose of Task 2 is to develop a comprehensive framework for selecting capital projects that balance stormwater management and level of service (LOS) with costs and community priorities. This framework is meant to support decision-making for identifying and evaluating flood risk reduction alternatives during Task 8 – Flood Mitigation Alternatives for the eight (8) flooding concern areas identified in Task 6 – Execute Existing Conditions Model. The Framework will also support the ranking and prioritization of evaluated alternatives in Task 10 – Project Prioritization. The final WWRP will include descriptions and cost estimates for the highest priority public infrastructure projects, based on the Framework, to guide the City's future capital improvement program and overall project implementation.

To develop a framework for project prioritization that is community driven, it is critical that City staff and impacted community members are afforded a common understanding of flood risk today and in the future, as well as clarity of the City's roles and responsibilities for managing rainfall events up to a certain intensity, duration, and frequency. For the purposes of the WWRP, this understanding helps to maintain a focus on higher risk areas of the City, as identified by the existing conditions modeling (Task 6) and the identification of projects with the greatest potential impact for the Community (Task 8). Direct feedback from community stakeholders on their priorities for public investments within the City was sought to rank projects for implementation that would reduce flood risk and help to achieve other community benefits (Task 10).

Figure 2-1 provides an overview of this step-by-step process for engaging City staff and impacted community members in key discussions about flood risk, roles and responsibilities, priorities, and plan implementation. This information was shared via a series of meetings and workshops with City staff and stakeholders to develop the Framework for deciding projects to be designed and constructed for flood risk mitigation in East Lansing.

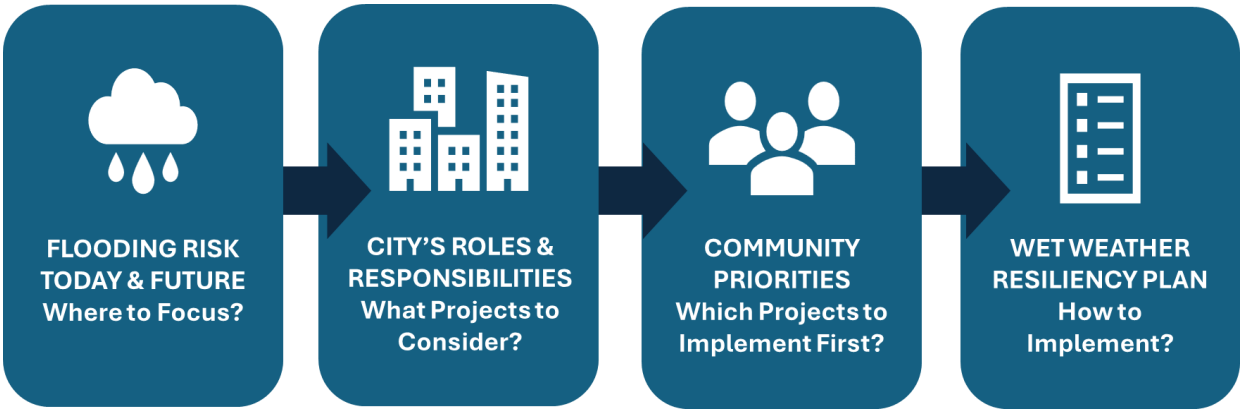


Figure 2-1. Stormwater Infrastructure Resilience Framework

3 City Workshop and Stakeholder Meetings

On November 7, 2024, HDR facilitated a workshop with City staff to discuss the approach for developing the WWRP and specifically for deciding which capital improvement projects may be evaluated, selected and prioritized based on City and community needs balanced with costs[1]. At the workshop, City representatives from the Planning and Zoning, Community and Economic Development, Engineering, and Administrative departments, as well as the City Police, were present. From this workshop, the City described the desired resiliency planning process outcomes and identified community stakeholders to participate in a series of focus group meetings.

The workshop also involved a discussion of project prioritization criteria that City staff would want to consider when evaluating and prioritizing projects. These criteria include drainage and LOS improvements, ease of maintenance, and constructability. City staff also suggested that the City's sustainability-related priorities identified at the City's Climate Resiliency Community Meeting, held on August 19, 2024, should be considered for the development of the WWRP. These criteria include:

- Green stormwater management and infrastructure
- Green buildings and building elements
- Increased transit and bicycle infrastructure access
- Housing near shops, jobs, and transit
- Commercial recycling and organics management
- More shade, trees, and green spaces
- Reduce vehicle parking zoning requirements
- Small-scale renewable energy.

On November 6, 2025, the City hosted two focus group meetings (one during the day and one in the evening) with community stakeholders including representatives from:

- City of East Lansing staff
- Planning Commission
- Senior Commission
- Transportation Commission
- Commission on the Environment
- Neighborhood and community associations
- Real estate companies
- Apartment managers.

Between both meetings, a total of 18 community members were present. HDR facilitated discussions with attendees about recent extreme storm events, historic precipitation trends and

[1] For a full summary of the Task 2 Workshop with the City, please refer to the *City of East Lansing Wet Weather Resiliency Plan – Task 2: Stormwater Infrastructure Framework Workshop* summary.

future precipitation projections, and existing flooding concerns[2]. The City and HDR described the intended outcomes of the WWRP development process including shared responsibilities between the City's Public Works Department, County drain commissions, and private property owners to meet existing and future LOS goals.

A key goal of the stakeholder focus group meetings was to describe LOS goals with consideration of financial feasibility and other community priorities. Unfortunately, the WWRP will be limited in that the City cannot afford to build a stormwater system that will provide a LOS for every storm event such as the extreme storm events on June 17 and July 9, 2024. The implementation of the WWRP will ideally lead to the design and construction of projects that best serve the community and balance hydraulic benefits for existing flooding and future LOS goals with costs. The focus group meetings also provided a forum to obtain feedback on project prioritization criteria to be applied in the MCDA tool for the development of the City's WWRP.

4 Proposed Criteria Selection for MCDA

4.1 Proposed Criteria

Following the November 2024 workshop with City staff, HDR developed the project prioritization criteria in Table 4-1 for the City's review and comment. The City commented that while the criteria are appropriate and applicable, they want to make sure that equity-related considerations were also prioritized earlier in the development of the WWRP. Based on this feedback, equity is being considered at two steps in the development of the WWRP; first, at the "where to focus" or flooding concern area identification step in Task 6 and, second, during the MCDA tool buildout and project prioritization step in Task 10, using the "Social and Economic Impacts" criterion shown in Table 4-1.

Table 4-1. Project Prioritization Criteria for a Community Driven Approach

Criteria	Description
Improved Drainage	The project's ability to enhance level of service to reduce flood risk.
City Resiliency Alignment	The project's alignment with the City's resiliency initiatives related to green stormwater management and infrastructure.
Water Quality	The project's alignment with the City's CSO reduction goals and/or ability to design with water quality treatment features consistent with the City's Stormwater Management Plan.
Impervious Surface Reduction	The project's ability to reduce unnecessary impervious surfaces.
Social and Economic Impacts	The project's ability to provide social or economic benefits to vulnerable populations due to the design, location, or nature of the project.
High Impact	The total number of people served by the project or being high visibility.
Ease of Constructability	The level of ease to build and implement the project.
Level of Maintenance	How easy the project is to maintain.

[2] For a full summary of the focus group workshops, please refer to the *Focus Group Summary* meeting minutes.

To first address equity within the WWRP, social vulnerability data was incorporated into Task 6 existing conditions assessment. This approach ensures that economically disadvantaged and historically underinvested areas are considered early in the process and confirms priority flooding concern zones for future capital investment do not neglect these areas. To accomplish this, the Centers for Disease Control and Prevention (CDC) Social Vulnerability Index (SVI) methodology[3] was used to identify and quantify social vulnerability variability across the City.

The CDC SVI methodology applies social factors centered around four core themes: 1) socioeconomic status, 2) household composition and disability, 3) racial composition and language, and 4) housing type and transportation. The specific variables across all core themes applied for the City's WWRP are identified in Table 4-2. Unique conditions within the City potentially impacting social vulnerability conditions were also identified and related data applied in the analysis. As the City houses a large population of college-aged students, additional variables were applied to capture community factors that are not fully visible in standard population metrics.

Table 4-2. SVI Variables for East Lansing

CDC SVI Variables Used	New Variables Created
• Below 150% Poverty • Unemployed • Housing Cost Burden • No High School Diploma • No Health Insurance • Aged 65 & Older • Aged 17 & Younger • Aged 18 to 24 (positive attribute) • Civilian with Disability • Race: Black or African American Alone • Race: American Indian & Alaska Native Alone • Race: Native Hawaiian and Other Pacific Islander Alone • Race: Some other Race Alone • Race: Two or More Races • Race: Hispanic or Latino • Single Parent Households • English Language Proficiency • Multi-Unit Structures • Mobile Homes • Crowding • No Vehicle	• Group Quarters – College Student Housing (positive attribute) • Renter Occupied – Nonfamily Households

The American Community Survey (ACS) 5-year estimates from 2019 to 2023 were applied for the above variables to create numeric index values or scores based on census tracts. Following review with the City, the SVI methodology applied to East Lansing was updated so that only the proportion of the census tract that fell within the City limits was used. This was done to ensure

[3] *CDC/ATSDR SVI 2020 documentation*. Agency for Toxic Substances and Disease Registry. (2022, August 5). https://www.atsdr.cdc.gov/place-health/media/pdfs/2024/08/SVI2020Documentation_08.05.22.pdf

that the scores were representative of the Community within the East Lansing boundary and not impacted by the data from neighboring municipalities.

To calculate the SVI score for an area, each variable identified in 4-2 was normalized to a scale of 0 to 1. All variables were then averaged together to create a composite SVI score, which was then adjusted based on the proportion of the tract within the City limits. Equation 1, shown below, provides the breakdown of this calculation and the variables used.

Equation 1. Min-Max Normalized SVI Score Equation

$$\boldsymbol{SVI_{final}} = \frac{\left(\left(\frac{\mathbf{1}}{\boldsymbol{n}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}\frac{\boldsymbol{x_i - x_{i,min}}}{\boldsymbol{x_{i,max} - x_{i,min}}}\right) \times \boldsymbol{p}\right) - \boldsymbol{SVI_{min}}}{\boldsymbol{SVI_{max} - SVI_{min}}} \times \mathbf{100}$$

n= number of variables
x_i= value of variable i for the tract
$x_{i,min}$, $x_{i,max}$ = min and max for variable i across all tracts
p= proportion of tract within city limits
SVI_{min}, SVI_{max}= min and max of the intermediate scores across all tracts

An example of the SVI scoring for the most socially vulnerable areas of the City is provided below in Figure 4-1. The dark purple regions represent the highest SVI scores, and the light blue regions represent the lowest SVI scores. Notably, neighborhoods such as Walnut Heights, Pinecrest, Northern Meadows, and Downtown East Lansing received SVI scores of 100, 89.96, 97.94, and 87.05, respectively, which are comparatively the highest SVI scores in the City. City staff confirmed that high SVI scores in these neighborhoods made sense.

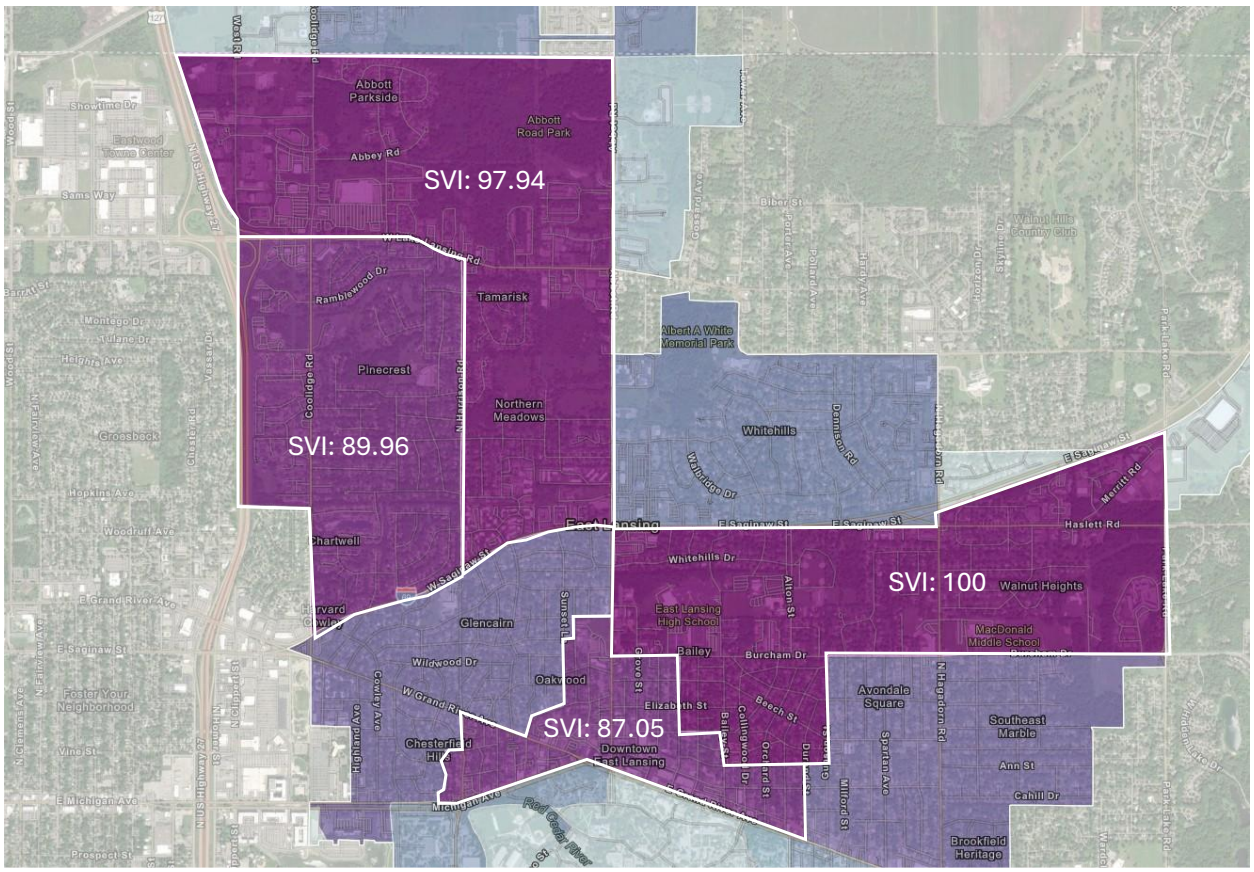


Figure 4-1. Highest Scoring Neighborhoods based on the Social Vulnerability Index Assessment

The social vulnerability map overlay created was used to identify where vulnerable neighborhoods overlap with the identified flooding concern areas in Task 6. As shown below in Figure 4-2, many of the flooding concern areas identified in red and labeled A-H overlap with neighborhoods that score high based on the SVI methodology customized for East Lansing. Four (4) of the eight (8) concern areas are located within the most socially vulnerable areas of the City. Specifically, concern areas B, D, E, and G, which are all combined sewer system (CSS) areas, are located within the more socially vulnerable areas.

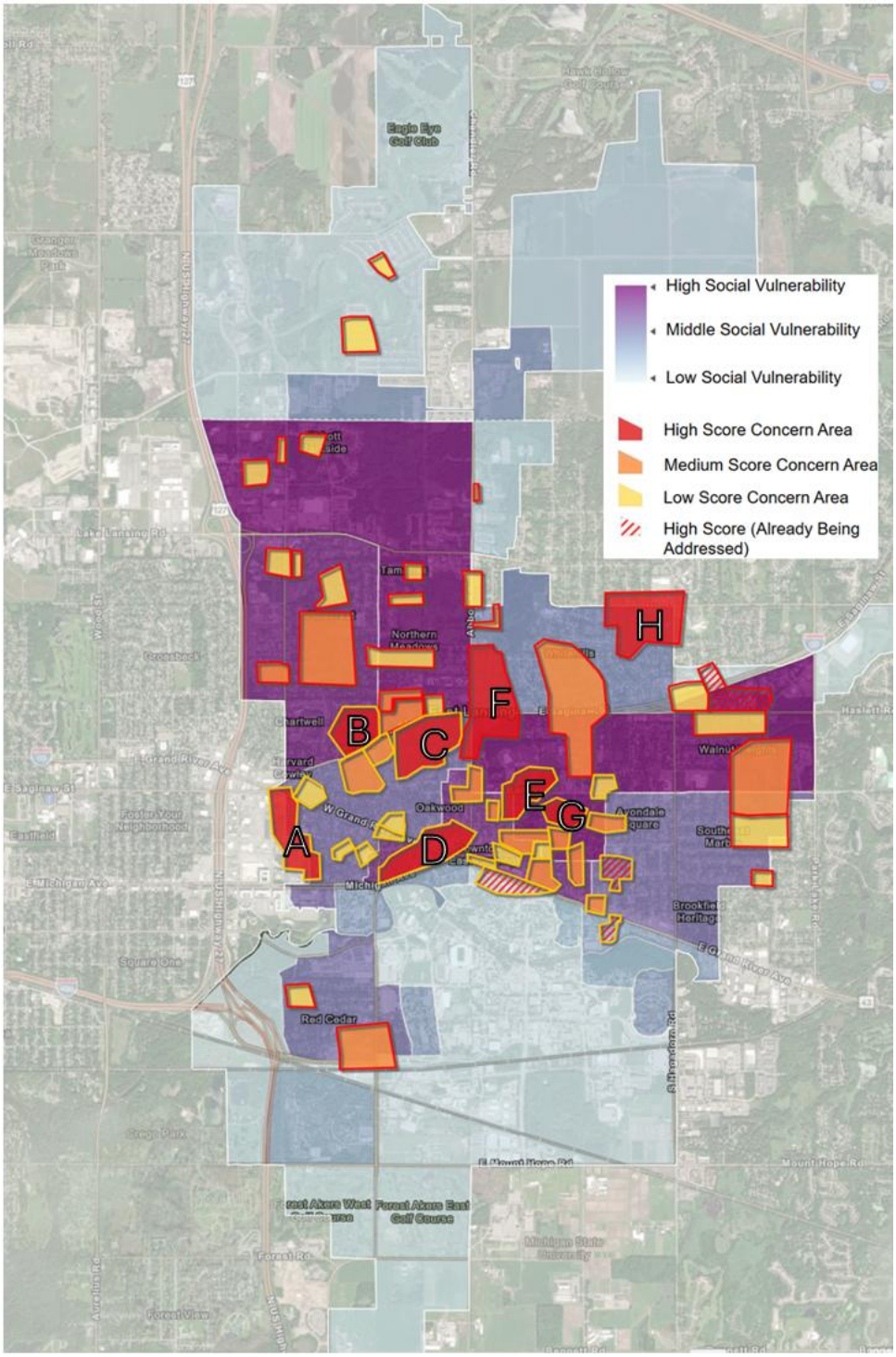


Figure 4-2. Social Vulnerability Overlay with Flooding Concern Areas

After confirming the areas of the City to focus on for the development of flood mitigation alternatives in Task 8, the proposed criteria in Table 4-1 were presented to community stakeholders during the Focus Group meetings for review, concurrence and weighting (described in Section 4.2 below).

4.2 Recommended Criteria Weighting

A pairwise analysis was performed to identify whether the prioritization criteria should be considered equal, or if they were better suited to be weighted based on City staff and community stakeholders' input. A pairwise analysis is an exercise that compares two variables or criteria and applies objective scores to find the relative importance of each criterion. During the focus group meetings, each attendee was asked to complete a survey of 25 questions, in which survey respondents identified which of two prioritization criteria was "more important." Additionally, City staff were asked to complete the same survey to identify the City's priorities for deciding improvement projects for implementation. Table 4-3 below provides the combined, summarized results from the pairwise analysis completed by City staff and focus group attendees.

Table 4-3. Combined Pairwise Analysis Results from City Staff and Community Stakeholders

Criteria	Weight	Rank
Improved Drainage	16.5%	1
Water Quality	15.5%	2
High Impact	14.9%	3
City Resiliency Alignment	13.0%	4
Impervious Surface Reduction	11.8%	5
Social & Economic Impacts	11.0%	5
Level of Maintenance	9.4%	7
Ease of Constructability	7.9%	8
Total	100%	

While the above criteria weighting for the MCDA is recommended as it reflects City staff and community stakeholders' input, HDR recognizes that the alternatives analysis and project selection to occur next for the development of the WWRP may require weighting to be adjusted, e.g., Level of Maintenance may need to be ranked higher based on life cycle cost estimate and long term funding considerations.

5 Applying MCDA for Projection Prioritization

An MCDA tool will be developed to integrate City and community stakeholders' priorities into alternatives analysis and project prioritization decision-making for the WWRP. The output of the tool itself allows for a streamlined assessment process for comparing potential projects against weighted criteria that are tailored to WWRP goals.

MCDA is a means of semi-quantitatively comparing alternatives with similar outcomes based on a set of decision criteria. Typically, an MCDA has the following elements:

1. A set of decision criteria
2. Criteria weights established through pairwise analysis or another ranking process
3. Scored projects against each criterion.

Using the defined set of criteria and weighting described in Section 4, HDR will support the City to identify improvement projects in flooding concern areas and effectively describe the benefits

associated with each project based on how well they align with City and community stakeholders' priorities.

Ultimately, the MCDA tool will be used to compare and rank project alternatives identified. The general approach to applying the criteria and weights (using ArcGIS) is illustrated in Figure 5-1. First, the defined criteria and the assigned weights shown in Table 4-3 are inputs into the tool. From there, a project is scored based on how the project contributes to each of the criteria. For example, a project that would positively impact a very densely populated neighborhood may score greater than a project impacting only a few residential homes consistent with the High Impact criterion. Finally, a project's benefits are totaled and compared to other projects, along with estimated cost information, to rank and prioritize projects across the flooding concern areas for the final WWRP and future implementation by the City (based on funding and schedule development).

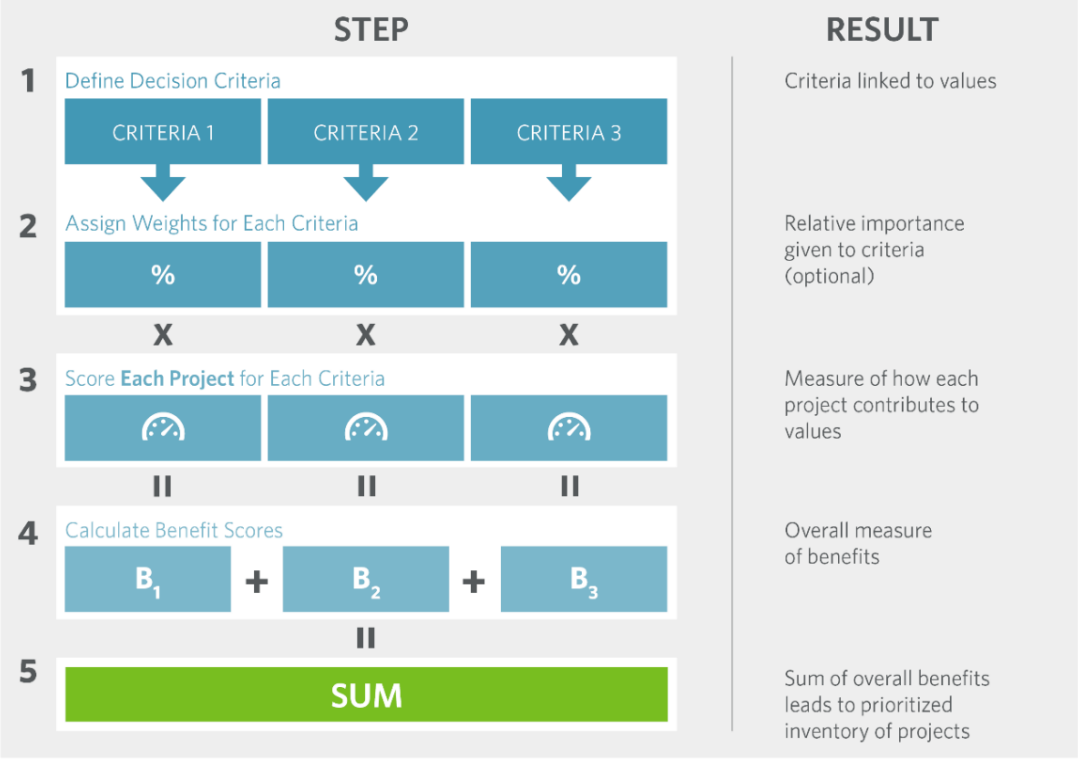


Figure 5-1. Multi-Criteria Decision Analysis Approach

The tool developed for the City will utilize the criteria and scoring weights, as identified in Table 4-3, to score proposed projects. The cumulative, weighted score will then be used to prioritize projects for implementation. For example, of the two following projects, Project A would be prioritized:

- Project A: A sewer separation project, aimed at reducing CSOs in a densely populated neighborhood. This project, as it reduces CSOs, will help improve local water quality and drainage.
- Project B: A sewer upsizing project alongside a low-traffic road in a municipal separate storm sewer (MS4) area.

6 Assessing Level of Service

Generally, LOS provides a measure of performance for the City's stormwater infrastructure system. However, there are various factors that impact the LOS for a system including:

- Engineering standards at the time of design and construction
- Cost and community affordability
- Customer expectations
- Regulatory requirements
- Existing infrastructure.

The current stormwater conveyance systems in East Lansing consist of combined and separate storm sewers and open channel drains mostly designed and constructed decades ago. As a result, the system was designed based on historic standards that were intended to address different storm events (i.e., less frequent, less intense events) and for surface conditions that were less paved or more pervious than those that exist today, due to continual development within the City. The existing conditions hydraulic model determined that the LOS in each flooding concern area shown in red in Figure 6-1 is less than a 5-year storm. This equates to a greater than 20% chance of flooding occurring in any given year.

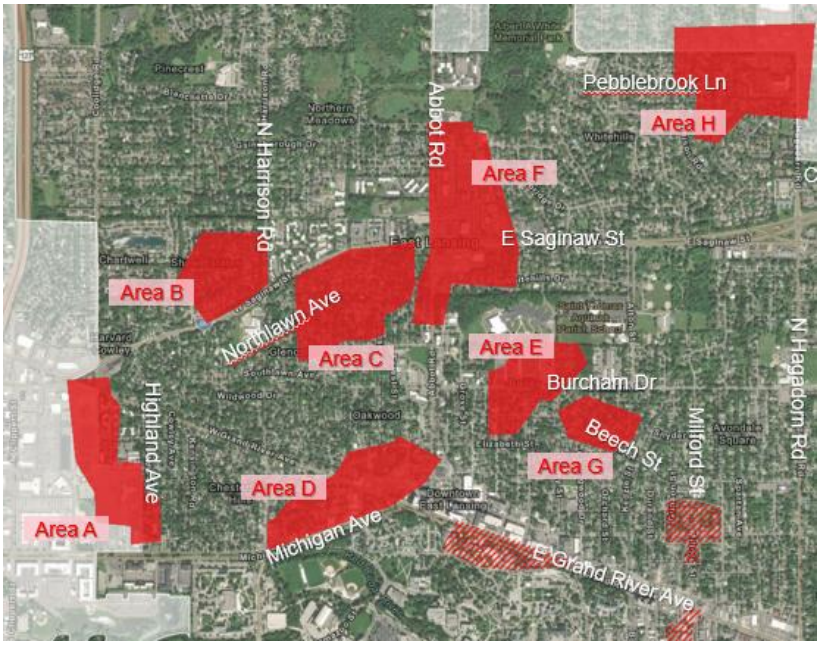


Figure 6-1. Identified Flooding Concern Areas

Table 6-1 below provides the identified LOS design standards for each of the identified flooding concern areas. The LOS criteria for the MS4 area were based on modeled flooding with the 2D mesh applied within each concern area; if flooding occurred, the area does not meet the LOS for the design storm. Alternatively, the LOS criteria for the CSS areas were based on surcharged sewers; if there are surcharged sewers within the concern area, the LOS for the design storm are not met.

Table 6-1. Level of Service Design Standards for Flooding Concern Areas

Flooding Concern Area	Current Level of Service	Location	Level of Service Category
A	2-year, 1-hour	Highland Ave. and Westview Ave.	CSS
B	5-year, 1-hour	N Harrison Rd. and E Saginaw St.	CSS
C	2-year, 1-hour	Northlawn Ave.	CSS
D	<1-year, 1-hour	Michigan Ave. and W Grand River Ave.	CSS
E	1-year, 1-hour	Burcham Dr.	CSS
F	<1-year, 1-hour	Abbot Rd. and E Saginaw St.	MS4
G	<1-year, 1-hour	Beech St.	CSS
H	<1-year, 1-hour	Pebblebrook Ln.	MS4

As it is not practical to build a stormwater infrastructure system to manage and convey every storm, it is necessary to define LOS goals that balance affordability and equity. Based on the existing conditions assessment, it was determined that short duration, high intensity 1-hour storm events are the types of events that most impact flooding in the City. This finding also aligns with analysis of twelve historic flooding events dating back to 2008 using gauge adjusted radar rainfall data performed under Task 1 – Changing Precipitation Conditions. Analysis of the past historic flooding events developed a “representative storm” that demonstrated flooding in the City is a result of short duration “cloudburst” rain events. These events deliver rain in 6 hours or less with upwards of 80% of the rainfall falling in a 2-hour duration.

Various 1-hour duration storm events under current and future rainfall conditions were also evaluated in Task 1 – Changing Precipitation Conditions, to assess potential enhanced LOS goals in Task 8. The 2050 and 2100 future climate rainfall estimates were developed using an ensemble of global climate models specific to the State of Michigan for two Shared Socioeconomic Pathways (SSP) greenhouse gas (GHG) emissions scenarios:

- Lower GHG Emissions SSP2-4.5, and
- Higher GHG Emissions SSP5-8.5

The higher emissions scenario (SSP5-8.5) was chosen for conservative purposes and for assessing different potential LOS goals as shown in Table 6-2.

Table 6-2 Evaluated Design Storms for Assessing Increased Level of Service

Event	Climate Condition	Rainfall Depth (Inches)	Rainfall Source
10-year, 1-hour	Current	2.00	Updated T2 IDF Estimates
25-year, 1-hour	Current	2.31	Updated T2 IDF Estimates
50-year, 1-hour	Current	2.54	Updated T2 IDF Estimates
100-year, 1-hour	Current	2.77	Updated T2 IDF Estimates
10-year, 1-hour	2050 Future Climate	2.13	SSP5-8.5 Emission Scenario
25-year, 1-hour	2050 Future Climate	2.46	SSP5-8.5 Emission Scenario
50-year, 1-hour	2050 Future Climate	2.71	SSP5-8.5 Emission Scenario
100-year, 1-hour	2050 Future Climate	2.95	SSP5-8.5 Emission Scenario
10-year, 1-hour	2100 Future Climate	2.40	SSP5-8.5 Emission Scenario
25-year, 1-hour	2100 Future Climate	2.77	SSP5-8.5 Emission Scenario
50-year, 1-hour	2100 Future Climate	3.05	SSP5-8.5 Emission Scenario
100-year, 1-hour	2100 Future Climate	3.32	SSP5-8.5 Emission Scenario

For discussions with the City and community stakeholders, three LOS goals or scenarios for flood mitigation alternatives evaluations − Current Standard, Future Climate, and Enhanced − were chosen and are further described in Table 6-3. HDR recommends 2100 as the representative future conditions LOS target as well as the SSP5-8.5 climate scenario given that the life span of future mitigation projects and new infrastructure are for many decades into the future. For the CSS area, there is an additional LOS goal to prevent and minimize surcharged sewers within the flooding concern areas that may result in basement backups.

Table 6-3. Selected Level of Service Scenarios for Alternatives Evaluations

	LOS Goal	Design Storm	Rainfall Depth (Inches)
1	Current Standard: Upgrade localized drainage system consistent with current standard.	Current 10-year, 1-hour	2.00
2	Future Climate: Upgrade localized drainage system consistent with current standard and based on climate anticipated in the future.	2100 10-year, 1-hour (slightly bigger than today's 25-year design storm)	2.40
3	Enhanced: Enhance localized drainage system to manage a larger design storm, where feasible.	2100 16-year, 1-hour storm (equal to today's 50-year design storm)	2.54

7 Conclusions and Next Steps

To develop a framework for project prioritization that is community driven and equitable, it is critical that impacted community members are given the space to understand urban flooding, the need for balanced LOS goals for the City's stormwater system, and co-benefits possible with capital investments. An MCDA tool will be created to reflect discussions with City staff and community stakeholders about these overall WWRP goals and the Sustainable Infrastructure

Resilience Framework developed in Task 2, and ultimately to prioritize capital investments for implementation.

With the City's review and acceptance of this technical memorandum, the MCDA tool will be built in ArcGIS. Concurrently, HDR will continue to work with the City to identify flood mitigation projects including sewer upgrades, detention or retention storage, and green infrastructure for alternatives development in flooding concern areas. The alternatives analysis will include modeling, conceptual plan layouts, and cost estimating. Based on the flood risk reduction modeling results, LOS benefits and community co-benefits, and costs of the different alternatives, recommended projects will advance to prioritization for the final WWRP.

Appendix C.

Task 3: *Data Sources* Technical Memorandum

Technical Memo

Date:	Friday, June 14, 2024
Project:	City of East Lansing Wet Weather Resiliency Plan
To:	Cliff Walls (City of East Lansing)
From:	Ernie West, Tom Batroney, and Lukas Vander Linden (HDR)
Subject:	Data Inventory and Data Gap Assessment – Existing Data Status Update and Next Steps

1.0 Introduction

HDR submitted the "Data Inventory and Data Gap Assessment" memo on March 11, 2024 which provided an assessment of data provided by the City and remaining data gaps for the development of stormwater system hydrologic and hydraulic model. The purpose of this memo is to provide a status update with respect to the previously identified data gaps.

2.0 Newly Obtained Data

Hydrologic Data

Detailed Land Use

The City has provided a detailed land use shapefile that contains land use classification based on parcel zoning information within the City.

Hydrologic Data Status Update:

Based on hydrologic data gathered, HDR has enough data to adequately characterize critical hydrologic elements for the development of the stormwater hydrologic model and overland 2D hydraulic mesh. No further action is needed by the City at this time.

Hydraulic Data

HRC Survey GIS Dataset

HDR reviewed manhole survey inspection GIS data collected by the City's consultant, HRC. This layer contains surveyed manhole locations and inverts for the CSO and sanitary portions of the City's sewer system. Within this dataset, no information pertaining to stormwater manholes is provided. Therefore, the HRC data will not be used for the development of the stormwater hydraulic model for the project.

Stormwater As-Built Drawings

The City has provided additional as-built drawings in pdf format that contain information covering various locations of the stormwater system. Locations of the reviewed as-built drawings are highlighted in Figure 1. As shown in Figure 1, HDR has obtained as-built drawings

concentrated east and northwest of the CSO portion of the City up to the West Lake Lansing Road. These drawings contain necessary pipe size and invert information for many stormwater pipe systems in these areas and will be utilized for model construction as applicable.

FEMA Flood Insurance Study Model

The Federal Emergency Management Agency (FEMA) as part of its Flood Insurance Study (FIS) developed a HEC-RAS model (version 3.1.3) for the Remey Chandler Drain. HDR reviewed the model and confirmed that the model contains cross sectional data of the channel and invert elevation for the Remey Chandler Drain as well as elevations and dimensions of roadway culverts between West Lake Lansing Road and Interstate-69. According to the FIS report all channel cross sectional data, bridges, and culverts along the Remy Chander Drain were obtained from field surveys conducted between January and July of 2006. Normal depth is assumed at the furthest downstream reach of the model downstream of the Interstate 69 crossing. Drains and culverts included in the obtained FEMA FIS HEC-RAS model are shown in Figure 1.

In addition to hydraulic elements, the FEMA FIS HEC-RAS model also includes flood event flows for the 10, 50, 100, and 500-year recurrence intervals. According to the FIS report, discharges for these events were calculated using HEC-HMS 3.0.1 with SCS methodology and drainage areas delineated from USGS topographic quadrangle maps from various dates. Precipitation values used to estimate the discharges were taken from the Illinois State Water Survey publication, Bulletin 71 otherwise known as Huff and Angel.

Hydraulic Data Status Update:

Upon HDR review of the HRC inspection data, City as-built drawings, and the FEMA FIS Model, there are several remaining areas where stormwater pipes, drains, and culverts are missing to be able to adequately construct the stormwater model. Areas with remaining data gaps are indicated on Figure 1. Missing information in these areas will either needs to be surveyed or needs to be assumed if the allocated budget for survey cannot capture all these areas.

3.0 Next Steps

Based on the areas with missing data in Figure 1, HDR will develop survey and field inspection work plan to prioritize field data collection efforts. Based on Task 3.4 of the scope of work, HDR has budgeted for two (2) days of a two (2) person crew for HDR staff field inspections as well as ten (10) field crew days for survey grade data collection by HDR's subconsultant, Geodetic Designs. Based on the budgeted time allocation, HDR will prioritize areas for field investigation and detailed surveys to fill in data gaps identified. Work will be described in a Field Inspection and Survey Work Plan for delivery and review by the City.

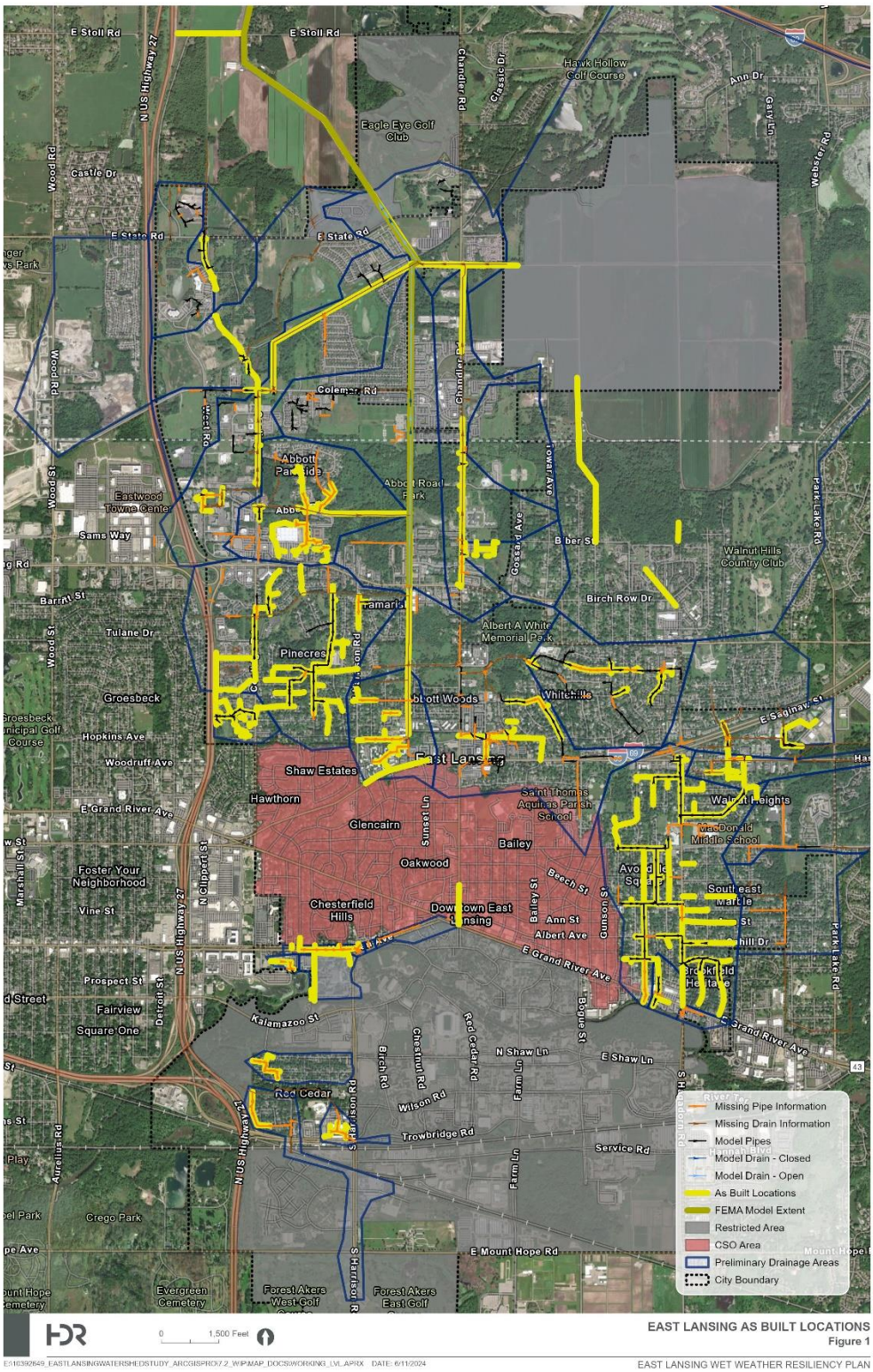


Figure 1: East Lansing As Built Locations

Appendix D.

Task 5: *Model Evaluation* Technical Memorandum

Technical Memo

Date:	Friday, March 29, 2024
Project:	City of East Lansing Wet Weather Resiliency Plan
To:	Cliff Walls (City of East Lansing)
From:	Ernie West, Tom Batroney, and Ken Trefzger (HDR)
Subject:	Model Software Evaluation and Recommendation

1.0 Introduction

The City of East Lansing (City) has heavily invested in the development of its existing InfoSWMM model for the purposes of hydraulic characterization of its sanitary system of which a portion is a combined sanitary and storm sewer system. However, it is anticipated that technical support and model software updates for InfoSWMM will soon be discontinued by Autodesk (formerly Innovyze). HDR is tasked with utilizing the existing InfoSWMM model and incorporating the City's stormwater drainage system greater than 18-inches into a comprehensive model that includes both the combined system and separate stormwater drainage system. Prior to the development of the comprehensive model, HDR is tasked with performing a vendor-agnostic model software evaluation and recommendation. The contents of this technical memo summarize the results of the evaluation.

2.0 Required Model Features and Capabilities

A model software discussion meeting between the City, Tetra Tech (the consultant that developed the current InfoSWMM model), and HDR was held on March 6, 2024 to better understand existing and future hydrologic and hydraulic modeling needs. Details pertaining to the items discussed during this meeting are provided in Appendix A. The following is a summary of the key outcomes from the meeting:

- The City does not have plans of simulating the models in-house. City staff envisions the model only being used by consultants.
- The City would like the model to be able to integrate with the City's GIS system.
- The model shall be able to perform the sanitary and combined sewer system analysis currently being performed in the InfoSWMM model as well as include areas of the City that drain to a separate stormwater drainage system. The separate stormwater drainage system includes the closed storm sewer system, open channels, culverts, streams, ponds, and stormwater control measures.
- The model shall be able to perform a two dimensional (2D) overland flow analysis to determine overland flooding extents, depth, and velocity when the closed system surcharges and in the open channels and streams.
- The model shall be able use the same hydrologic method used to determine the stormwater runoff in current InfoSWMM model.

- The model will not be used for individual developer projects.
- The model will not be used for the purposes of updating FEMA regulatory mapping products.

3.0 Modeling Software Evaluation

Separately from this project Tetra Tech provided the City with a high level summary of four (4) modeling software that included AquaTwin, SewerGEMS, PCSWMM, and InfoWorks ICM. Each of these models were briefly discussed during the March 6, 2024 meeting along with the minimum criteria that should be inlcuded in the software evaluation. Below is a summary of this discussion.

- Aqua Twin is a new software on the market and there may be some risk with going with an unestablished product. It was decided not to include Aqua Twin as part of HDR's evaluation.
- SewerGEMs while it has 2D capability, has traditionally been used more for 1D models. It was decided not to include SewerGEMs as part of HDR's evaluation.
- PCSWMM is widely used by smaller firms and uses the same EPASWMM engine that is used in InfoSWMM.
- InfoWorks ICM is the model software that Autodesk is recommending to be used to replace InfoSWMM models.

It was decided that the HDR evaluation of modeling software should be narrowed down to an evaluation between PCSWMM and InfoWorks ICM. The Model Evaluation Memo should include, at a minimum, a discussion of pros and cons of the following items:

1. Cost to purchase/annual subscription.
2. Effort involved in converting the existing InfoSWMM model.
3. Level of effort/ease in maintaining the model. Overall cost benefit of each software factoring in periodic updates and maintenance updates. Consider long-term maintenance.
4. Ease of use by City consultants and ability for use on future design of City capital projects.

Based on the required features described in Section 2.0 above and the minimum items identified above, the PCSWMM and InfoWorks ICM were evaluated using fifteen (15) separate model evaluation criteria. Each individual criterion was categorized in terms of importance using a High, Medium, and Low designation. For each criteria the advantage was given to either PCSWMM or InfoWorks ICM in terms of their respective capabilities. A score of 3 points was given for High criteria, 2 points for Medium, and 1 point for Low to consider weighting points of more important modeling criteria factors. For each criteria points are awarded on a winner take all basis. If the softwares are deemed equal, both are awarded zero points. Table 1 presents the evaluation criteria for each model, criteria notes, level of importance and the model with the advantage for each criterion. Table 2 shows the total scoring results for each criteria in Table 1.

Table 1. Model Evaluation Criteria and Results

Evaluation Criteria		Infoworks ICM (Autodesk)	PCSWMM (CHI)	Criteria Notes	Level of Importance	Advantage
1	InfoSWMM Conversion Capability	InfoWorks ICM has developed tools for importing of InfoSWMM modeling files into InfoWorks ICM SWMM Network. Only one scenario can be imported at a time. May require some copying of information tables.	Capable of importing SWMM5 files, which are the basis of InfoSWMM models. Only one scenario can be imported at a time. May require some copying of information tables.	Both models can import the City's existing InfoSWMM model. Both models will need to be troubleshooted during the conversion effort. Since Autodesk owns both InfoSWMM and InfoWorks ICM several features have been added to InfoWorks ICM making the model conversion less time consuming. However, since the ICM SWMM Network has recently been added there remain some issues with the conversion.	High	Equal
2	GIS Integration	Does not directly connect to an ESRI GIS geodatabase. Has GIS integration capabilities but requires scripting. A separate model database is used to perform the analysis.	Does not directly connect to an ESRI GIS geodatabase. Has GIS integration capabilities but requires scripting. A separate model database is used to perform the analysis.	Both models can import GIS files and have automated scripting for periodic model updates directly from GIS. Both models can export model results in GIS which will be required to generate exhibits to present to the public as well as populate the results geodatabase(s) which will be required for the Dynamic Master Plan.	High	Equal

Table 1. Model Evaluation Criteria and Results

Evaluation Criteria		Infoworks ICM (Autodesk)	PCSWMM (CHI)	Criteria Notes	Level of Importance	Advantage
3	1D Calculation Engine and Performance	ICM Wallingford Engine (Implicit Solver) or SWMM Engine (Explicit Solver)	SWMM Engine (Explicit Solver Only)	The current InfoSWMM model uses the SWMM Engine. Therefore, both models can be used to duplicate the current model. The InfoWorks ICM model also includes the ICM Wallingford calculation engine which is well known in the industry for faster calculation speeds and greater stability due to its proprietary implicit solver and automated time step halving functionality. As the model expands, the use of the ICM solver may be assessed to improve model run times.	High	InfoWorks ICM
4	2D Overland Flow	Irregular triangle mesh 2D shallow water equations 3D visualization tools	Hexagonal mesh 1D shallow water equations	The InfoWorks ICM solves the 2D shallow water equations whereas the PCSWMM model applies the 1D shallow water equations to each cell within 2D overland flow area. The 2D shallow water equations are more accurate when the overland flow is complex in nature. The InfoWorks ICM 2D runs faster and is generally more stable than PCSWMM allowing for larger meshes with smaller cell sizes in key areas.	High	InfoWorks ICM

Table 1. Model Evaluation Criteria and Results

Evaluation Criteria		Infoworks ICM (Autodesk)	PCSWMM (CHI)	Criteria Notes	Level of Importance	Advantage
5	Model Maintenance and Scenario Management	Has a centralized database system allowing models to be organized into one singular file. Also provides model versioning, track changes log files, and understand model maintenance activities over time. Has data flagging capabilities to identify sources of data (i.e. survey data, GIS data, etc.) that is useful for understanding model source data. The model has a robust scenario management process that allows quick access and tracking of alternative scenarios.	Model file storage structure is simplistic and uses stand alone files. Tracking of model changes needs to be done with internal notes field or externally within a change management document log. No flagging capabilities to identify data sources. The model scenario management is cumbersome.	InfoworksICM central database provides a file structure that allows for more seamless and better model maintenance and scenario management than PCSWMM. This provides more efficient model upkeep and maintenance over its lifecycle.	High	InfoWorks ICM
6	Hydrologic Calculations	SWMM method available in the SWMM network. Multiple other methods available in the ICM network.	SWMM method is standard. Alternative Runoff Methods available.	The current InfoSWMM model uses the SWMM hydrology method to generate the stormwater runoff and hydrograph. This is the standard method in PCSWMM. The InfoWorks ICM model SWMM network can use this hydrology method.	Medium	Equal

Table 1. Model Evaluation Criteria and Results

Evaluation Criteria		Infoworks ICM (Autodesk)	PCSWMM (CHI)	Criteria Notes	Level of Importance	Advantage
7	Managing Model Storage and Delivery to Consultants.	The model can be stored and delivered in a transportable database. This includes all associated files required to reproduce the model on another computer.	The model can be stored and delivered as a packaged project file. This includes all associated files required to reproduce the model on another computer.	The InfoWorks ICM model database has more tools to track changes and data sources when being modified by different consultants. InfoWorks ICM also has cloud computing options which provides access control to multiple users.	Medium	InfoWorks ICM
8	Subscription Cost	$18,000 per year or $54,000 for 3 years (2D unlimited nodes single user) Has a more affordable token based system to allow limited model use for less frequent users. Tokens are generally not cost effective for frequent users.	$2,400 per year (2D unlimited nodes single user)	PCSWMM is more affordable than InfoWorks ICM on an annual per user basis. It should be noted that costs have come down in recent years for InfoWorks ICM since they have been purchased by Autodesk.	Medium	PCSWMM
9	Model Troubleshooting Capabilities	Detailed model performance log files, model element diagnostics, and job progress window allows detailed investigation of model performance improvements and identification of calculation instabilities.	Provides diagnostics where model improvements are necessary and flow balance errors can be reviewed anywhere in the model.	Resolving model instabilities is a critical component in the development of 1D-2D models which are computationally intensive. InfoWorks ICM provides several ways to trouble shoot model stability. PCSWMM is limited on providing diagnostics for where modeling improvements are necessary.	Medium	InfoWorks ICM

Table 1. Model Evaluation Criteria and Results

Evaluation Criteria		Infoworks ICM (Autodesk)	PCSWMM (CHI)	Criteria Notes	Level of Importance	Advantage
10	Technical Support	Technical support is primarily conducted via Autodesk help system.	CHI provides professional technical support and has an extensive free online community.	Due to the open source nature of EPASWMM, SWMM based products such as PCSWMM have a larger user base. Technical support and online support community is broader for PCSWMM as compared to InfoWorks ICM.	Medium	PCSWMM
11	Level of Complexity/Learning Curve for New Users	InfoWorks ICM has more complexity. The graphical user interface has more windows and options that new users will need to understand before becoming familiar with the models. The file management is unique and is best learned by formal or hands-on training.	PCSWMM while still complex and requires training for new users, its graphical user interface is simpler and offers less functionality, tools, and windows for new users to understand. Free Online training videos are available and sufficient for new users to edit and run the models.	More hands-on training is required for new users of InfoWorks ICM as compared to PCSWMM.	Medium	PCSWMM
12	Customizable Reports and Outputs	Has ability to create customizable reports based on saved model element selection sets allowing for quick data reporting and exporting to Excel.	PCSWMM is more time consuming for creating automated reports. Does have the ability to save graphing output formats.	InfoWorks ICM provides faster methods for generating custom reports and being more time efficient with extracting results.	Low	InfoWorks ICM

Table 1. Model Evaluation Criteria and Results

Evaluation Criteria		Infoworks ICM (Autodesk)	PCSWMM (CHI)	Criteria Notes	Level of Importance	Advantage
13	Advanced Modeling Tools	InfoWorks ICM provides ICMLive subscription service for additional cost which allows the model to hosted in the cloud and viewed via an external website. ICMLive allows for model versus real-world comparisons of system performance and future forecasting. Can provide customizable text based alerts to inform system operations. InfoWorks ICM has Probability Distributed Model (PDM) calibration tool which provides semi-automated calibration of parameters.	PCSWMM Real Time allows for real time and future forecast flood modeling for additional cost. PCSWMM Real Time is desktop based. Allows for user developed Python scripting for external programming capabilities providing greater functionality of programming tools. PCSWMM has Sensitivity-based Radio Tuning Calibration (SRTC) tool which provides semi-automated calibration of parameters.	InfoWorks ICM Live cloud-based modeling functionality and web integration are powerful tools not offered in PCSWMM Real Time. A custom website is needed for PCSWMM. Both ICM Live and PCSWMM Real Time can be time consuming setting up from a system IT standpoint, but once functioning both can be useful future tools for system owners. Both tools have semi-automated tools for streamlining model calibration efforts.	Low	InfoWorks ICM
14	FEMA Approved for Floodplain Mapping	Not approved by FEMA.	EPASWMM approved by FEMA.	PCSWMM is a SWMM based product and therefore is approved for FEMA Mapping purposes.	Low	PCSWMM

Table 1. Model Evaluation Criteria and Results

Evaluation Criteria		Infoworks ICM (Autodesk)	PCSWMM (CHI)	Criteria Notes	Level of Importance	Advantage
15	Pump Stations and Force Mains	Can model pump station wet well storages, pump curves, pump settings, variable frequency drives, and head losses in pressurized force mains.	Can model pump station wet well storages, pump curves, pump settings, variable frequency drives, and head losses in pressurized force mains.	Both InfoWorks ICM and PCSWMM can model force mains, but long force mains in SWMM can be problematic for calculation stabilities. The ICM Wallingford engine is typically more stable for long force mains due to its solver. SWMM force main instabilities can typically be rectified by breaking up the force main into smaller segments.	Low	Equal

Table 2. Model Criteria Evaluation Scores.

No.	Evaluation Criteria	Importance	Advantage	Score	
				InfoWorks ICM	PCSWMM
1	InfoSWMM Conversion Capability	High	Equal	0	0
2	GIS Integration	High	Equal	0	0
3	1D Calculation Engine and Performance	High	InfoWorks ICM	3	0
4	2D Overland Flow	High	InfoWorks ICM	3	0
5	Model Maintenance and Scenario Management	High	InfoWorks ICM	3	0
6	Hydrologic Calculations	Medium	Equal	0	0
7	Managing Model Storage and Delivery to Consultants.	Medium	InfoWorks ICM	2	0
8	Subscription Cost	Medium	PCSWMM	0	2
9	Model Troubleshooting Capabilities	Medium	InfoWorks ICM	2	0
10	Technical Support	Medium	PCSWMM	0	2
11	Level of Complexity/Learning Curve for New Users	Medium	PCSWMM	0	2
12	Customizable Reports and Outputs	Low	InfoWorks ICM	1	0
13	Advanced Modeling Tools	Low	InfoWorks ICM	1	0
14	FEMA Floodplain Mapping	Low	PCSWMM	0	1
15	Pump Stations and Force Mains	Low	Equal	0	0
			TOTAL	15	7

Scoring is winner take all for each category.
High = 3 points
Medium = 2 points
Low = 1 point
Equal = 0 points

4.0 Model Recommendation

Based on the analysis presented in Table 1, InfoWorks ICM held an advantage of 7 out of the 15 criteria and scored a total of 15 points as compared to 4 criteria and 7 points for PCSWMM.

The 2D overland flow, model maintenance and scenario management, and model storage and delivery to consultants criteria are the key differentiators between the InfoWorks ICM and PCSWMM models. The more robust InfoWorks ICM 2D overland flow analysis will be important to East Lansing given the goal is to model overland flow within the City and the more robust InfoWorks ICM file management capabilities will provide better tracking of the model changes as the model is updated by multiple consultants.

Two limitations of InfoWorks ICM are the subscription cost, especially for smaller firms, and the model learning curve. This can be overcome for isolated projects as InfoWorks ICM can readily create a subset of the overall model that is hydrologically and hydraulically independent. The smaller model can then be exported as a SWMM format model that can then be imported into a PCSWMM or EPASWMM model for use by smaller firms that do not have a subscription to InfoWorks ICM. All SWMM work products and model changes within the isolated portion of the model can then be imported back into the overall InfoWorks ICM model and tracked within the file manager.

In terms overall industry costs InfoWorks ICM is comparable to other high end modeling softwares such as SewerGEMs ($15,000 for a single annual subscription with unlimited nodes) and AquaTwin ($23,000 for a single annual subscription with unlimited nodes and maintenance). It should also be noted that based on discussions with Autodesk they have realized that many small to mid-size firms struggle with paying InfoWorks ICM's annual subscription costs and have provided more flexibility using their token based system to allow for daily usage. This allows smaller consulting firms to essentially "rent" the software based on project-by-project needs. Tokens work for 24-hours of unlimited usage and cost 75 tokens for 1 day of usage for InfoworksICM 2D. The cost to purchase 500 tokens is $1,500 dollars on Autodesk's website.

Given the results of the analysis and the discussion points above, it is recommended that the City approve InfoWorks ICM for use on the Wet Weather Resiliency Plan project. This recommendation is based on the following:

- The stability and speed of InfoWorks ICM 2D overland flow component is superior to PCSWMM.
- InfoWorks ICM has an advantage for model maintenance and excels at managing files, tracking changes, and sharing files across multiple firms.

Appendix A – March 6, 2024 Model Discussion Meeting Minutes

hdrinc.com

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Meeting Minutes

Project: City of East Lansing

Implementation of EGLE's State High Water Infrastructure Grant Program

Subject: Model Software Discussion

Date: Wednesday, March 06, 2024

Location: DPW Conference Room and Microsoft Teams meeting

Attendees	Organization
Scott House	City of East Lansing
Dena Fitzgerald	City of East Lansing
Ronald Lacasse	City of East Lansing
Robert Scheuerman	City of East Lansing
Stephen Clayton	City of East Lansing
Cliff Walls	City of East Lansing
Justin Voss	Tetra Tech
Ernie West	HDR
Tom Batroney	HDR
Ken Trefzger	HDR

1) HDR Scope of Work

a) City's existing InfoSWMM model software will no longer be supported by Autodesk.

b) Autodesk pushing users to transfer InfoSWMM models to InfoworksICM.

c) HDR scoped to evaluate up to five modeling software platforms as part of the High Water Infrastructure Scope of Work.

d) Purpose of meeting is to understand the needs of the City for selecting a software platform for the High Water Infrastructure project, considering additional water, sanitary and combined sewer model needs also.

2) On-Going Model Evaluations by Tetra Tech

a) Tetra Tech (Justin Voss) provided some modeling software platforms via email to the City for their combined and sanitary sewer system.

b) Model software platforms in email included InfoworksICM, PCSWMM, AquaTwin, SewerGEMS.

c) Focus was primarily on InfoworksICM or PCSWMM.

3) General Discussion of Modeling Software

a) Model selection does not need to consider water distribution modeling needs (modeling by LBWL).

b) City does not plan to use the storm water model directly or simulating the model in-house. Envision only being used by consultants.

c) Model not being used for individual developer projects. Developer consultants typically simplified models to adhere to stormwater codes and ordinances. (i.e. first flush, 100-year event peak flow requirements, 2-year channel protection, etc.)

d) Aqua Twin is a new software on the market and there may be some risk with going with an unestablished product. It was decided not to include Aqua Twin as part of HDR's evaluation.

e) SewerGEMs while has 2D capability, has traditionally been used more for 1D models. Decided not to include SewerGEMs as part of HDR evaluation.

3) Pros and Cons of InfoworksICM and PCSWMM

a) Both capable of GIS integration and modeling combined and sanitary systems.

b) InfoworksICM more advanced modeling with more tools and steeper learning curve.

c) HDR experience is that the 2D capabilities are stronger in InfoworksICM (faster computation speeds, computations/results more stable)

d) PCSWMM more widely used by smaller consulting firms. Cost of software is low to purchase.

e) InfoworksICM more expensive.

f) Both models capable of simulating sewer separation projects that City is in the process of implementing. Both capable of GIS integration and consuming rainfall data from external sources.

g) FEMA Floodplain Modeling

i) PCSWMM approved by FEMA for floodplain mapping while InfoworksICM is not.

ii) The models developed for the City are likely to be used for smaller event capital projects and not meant for regulatory FEMA floodplain mapping purposes. Will likely be areas in the new model that will show flooding where FEMA does not.

iii) OK to have separate models for each purpose.

iv) HDR has submitted a request to FEMA for the flood insurance models.

v) Cliff Walls has contacts at EGLE (Christine Alwin) and will forward contact information to HDR for potential discussions related to FEMA flood mapping.

h) Existing model future flows in sanitary system are potentially conservative and an overestimate. Assumed full buildout in sanitary system based on land use zoning assumptions. Combined system had minor increases since it is already built up.

i) HDR to consider how future flow estimates impact the modeling results.

ii) City is working on a Clean Water State Revolving Fund project plan for additional sewer separation projects that will need to be updated in the model

i) No hardware restrictions on the City's end as they do not plan on simulating in-house.

j) Memo will include evaluation between PCSWMM and InfoworksICM.

k) Items to consider within the memo to include, at minimum:

i) Life cycle cost benefit including cost to purchase/annual subscription.

ii) Effort involved in converting the existing InfoSWMM model.

iii) Level of effort/ease in maintaining the model. Overall cost benefit of each software factoring in periodic updates and maintenance updates. Consider long-term maintenance. Where the model will "live" and protocols for how it will be periodically updated.

iv) Ease of use by city consultants and ability for use on future design of City capital projects.

(1) Explore InfoworksICM export capability to SWMM file.

4) Next Steps

a) Model Software Evaluation and Recommendation Memo

i) Anticipated Delivery Date: March 29, 2024.

5) Action Items

i) Cliff Walls to forward EGLE contacts related to the FEMA floodplain mapping to HDR.

Appendix E.

Tasks 5 and 6: Model Development and Existing Conditions Flood Assessment Report

Model Development and Existing Conditions Flood Assessment

Wet Weather Resilience Plan

City of East Lansing, Michigan

February 20, 2026

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Executive Summary

The City of East Lansing (City) Combined Sewer System (CSS) and sanitary system model was created by Tetra Tech in 2017 using InfoSWMM software. Because the InfoSWMM software is being phased out by Autodesk support within the next two years, it was decided to convert the model to a new software platform. Ultimately, InfoWorks ICM was the software selected for the model conversion. In addition to the model conversion of the CSS and sanitary sewer model, the InfoWorks ICM model was expanded for the Municipal Separate Storm Sewer System (MS4) area for the purposes of modeling and predicting flooding issues related to basement backups in the CSS and surface flooding due to City sewer infrastructure.

As part of the model MS4 expansion effort, a flow, level, and rainfall monitoring program was conducted to calibrate and verify model performance in the MS4 area. This program was conducted from July to November 2024. Data was collected at five (5) flow monitors, three (3) level sensors, and four (4) rain gauges, and was transmitted to the ADS Cloud data viewer, PRISM, so that the HDR team could perform weekly QA/QC of the data. From this data, five (5) wet weather events were selected for use with the MS4 model calibration.

The MS4 model was calibrated according to model calibration best practice guidelines to ensure the model would be sufficient for the purpose of assessing existing conditions and identifying flooding concern areas. As the calibration results overall were within the defined criteria, and the modeled hydrographs generally matched well with the observed hydrographs, the MS4 portion of the model was deemed sufficiently validated. Within the CSS area, the converted Infoworks ICM model was calibrated for dry and wet weather periods using the same observed data used to calibrate the Tetra Tech InfoSWMM Model. For locations that did not meet the calibration standards, the model was adjusted to closely match the Tetra Tech InfoSWMM model. The converted Infoworks ICM model sufficiently matched previous model performance of the Tetra Tech InfoSWMM model.

To validate the Infoworks ICM model, gridded rainfall data from the June and July 2024 storm events, both of which resulted in surface flooding within the City, were input to the model to simulate the event and determine the overland flooding results. During a workshop with City staff, the simulated flooding results for both events were compared to street flooding public complaint survey data. Overall, the areas with recorded street flooding matched the predicted flooding results from the model. Based on the workshop and discussions with the City, this model was considered validated and suitable for the purposes of the Wet Weather Resilience Plan (WWRP).

The primary purpose of the newly created Infoworks ICM model is to use the model to help identify and prioritize the top eight flooding concern areas throughout the City, and within these eight areas, identify and prioritize flood mitigation projects. The existing condition assessment, which used the 25-Year, 1-hour design storm, identified 58 flooding concern areas that met the following criteria:

- A roadway floods 6-inches or more,
- A parking lot floods 6-inches or more, or

- A building floods.

The scope of the WWRP is to identify eight (8) priority areas for evaluating flood mitigation projects. To identify these eight priority areas out of the 58 flooding concern areas, nine (9) flood related criteria were defined to measure, and ultimately develop a total flood score for each concern area. A pairwise analysis was conducted to determine the relative importance of each of the nine criteria. The following criteria (presented in order of importance based on the pairwise results) were used to determine a numerical score for the 58 flooding concern areas:

1. Basement Flooding in the CSS Area - number of manholes within the CSS area that surcharge and risk basement flooding.
2. Roadway Flooding Depth Critical Facility – depth and frequency of flooding in the vicinity of a critical facility.
3. Building Flooding Type – type of buildings that flood.
4. Surface Flooding in the CSS Area – frequency of surface flooding in the CSS area.
5. Building Flooding Frequency – number and frequency of building flooding.
6. Roadway Flooding Location – location and roadway speed.
7. Flooding Extent – number of acres of roadway flooding.
8. Roadway Flooding Frequency – frequency of roadway flooding.
9. Parking Lot Flooding – depth and frequency of parking lot flooding.

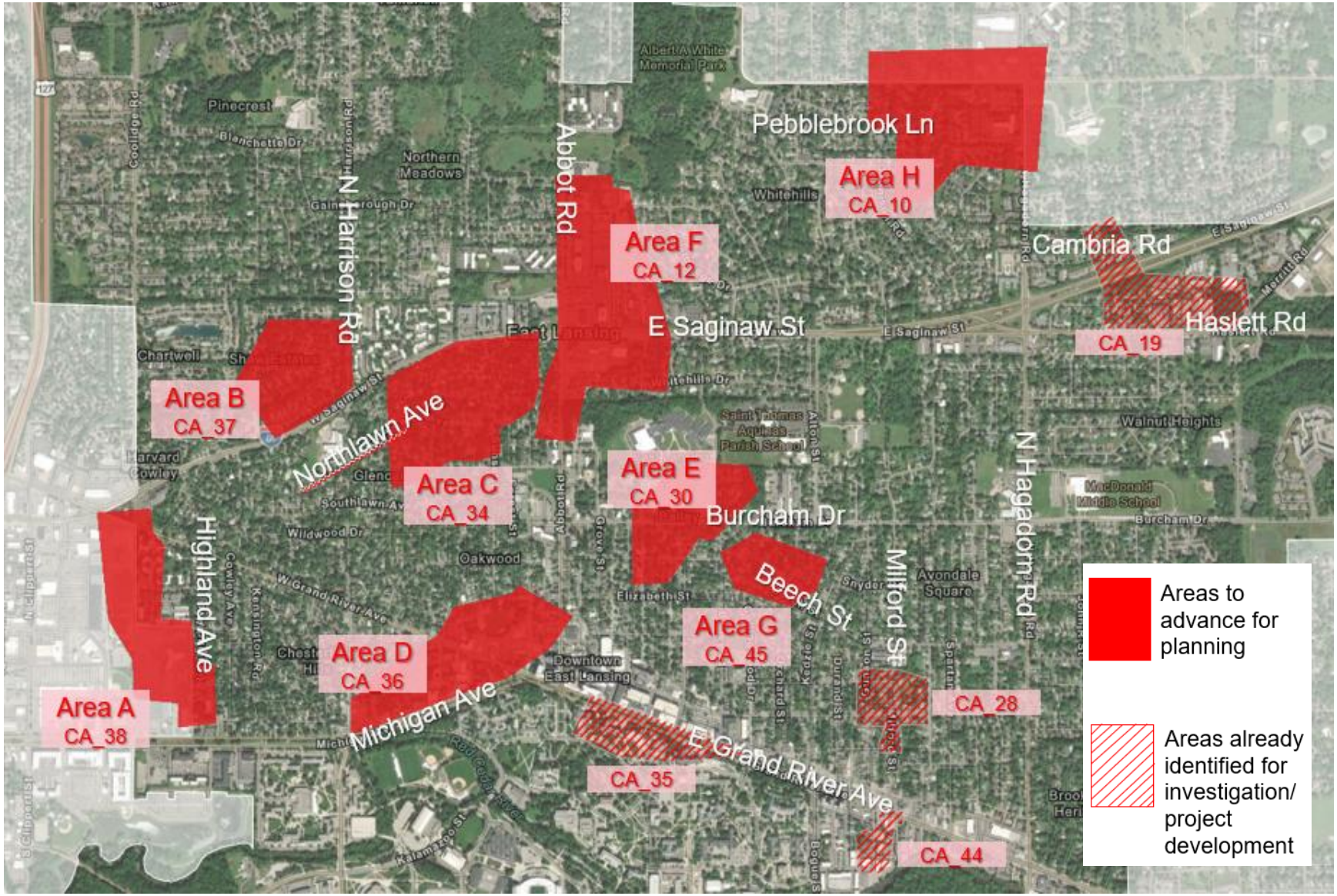
The top eight (8) highest scoring flooding concern areas for advancing as a first phase of the WWRP project prioritization are as follows:

Top 8 Flooding Concern Areas.

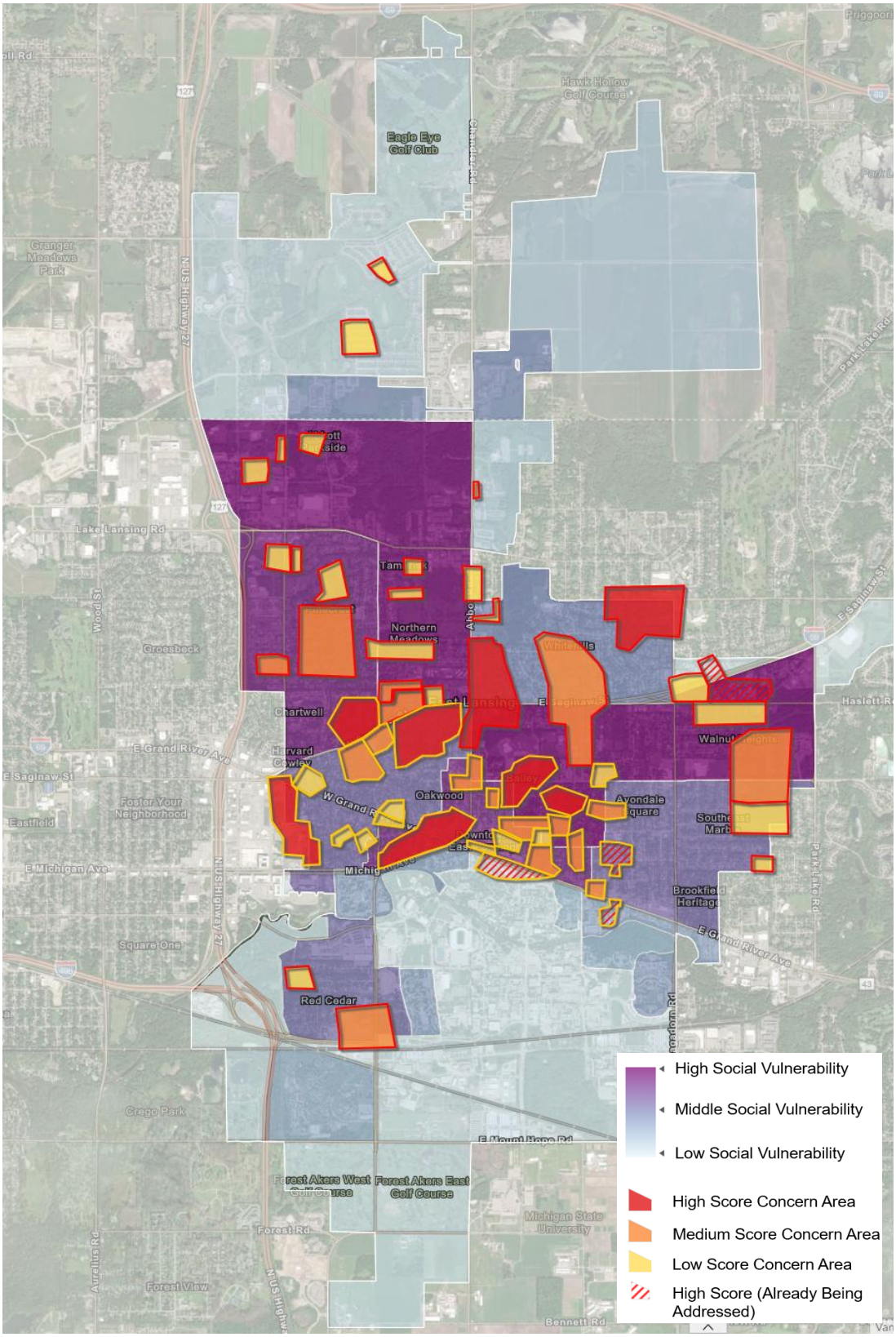
Flooding Concern Area	Location
A	Highland Ave and Westview Ave
B	North Harrison and E Saginaw
C	Northlawn Ave
D	Michigan Ave and W Grand River Ave
E	Burcham Drive
F	Abbot Rd and E Saginaw
G	Beech St
H	Pebblebrook Lane

The top 8 scoring areas were then compared to a social vulnerability overlay, which was developed using the CDC Social Vulnerability Index (SVI). This comparison was critical to ensure that economical and socially vulnerable communities and neighborhoods were

thoroughly considered for project prioritization. Maps showing the top 8 flooding concern areas and the social vulnerability overlay are shown on the following pages.



Location of the Eight (8) Proposed Priority Flooding Concern Areas.



Social Vulnerability Overlay with Flooding Concern Areas

1 Background and Purpose

In December 2023, the City of East Lansing (City) contracted HDR Michigan, Inc. (HDR) to support the implementation of the State of Michigan Environment, Great Lakes, and Energy (EGLE) High Water Infrastructure Grant Program by developing a Wet Weather Resiliency Plan (WWRP). The ultimate goal of the WWRP is to:

- Establish where and why urban flooding is occurring,
- Identify existing and future severe weather vulnerabilities, and
- Determine an equitable, community-driven approach to climate-resilient stormwater management.

In August 2021, the City experienced a rare 1,000-year storm, in which 7.22 inches of rainfall fell in the span of 5-6 hours. This event resulted in 227 reported incidents of flooding in the community. One month later, the City experienced a short-duration, intense storm that resulted in 25 additional flooding reports. These frequent, high-intensity storm events have prompted the City to initiate the development of the WWRP and to be proactive in the development of strategies to mitigate flooding and minimize community impacts.

To aid in the development of the WWRP, HDR has been scoped to develop a hydrologic and hydraulic model of the City's systems that convey stormwater, to better understand the system level of service (LOS) and identify areas that are vulnerable to flooding. Prior to HDR's work, a hydraulic model of the City's sanitary system was developed in 2017 using InfoSWMM by Tetra Tech, Inc. (Tetra Tech). This model contained the combined sewer system (CSS) and separate sanitary sewer system and utilized 1D subsurface pipe system only. Its primary usage was to support combined sewer overflow (CSO) and basement backup mitigation planning within the CSS area. Since the model was limited to the 1D pipe system, the model was unable to characterize overland flooding. Additionally, the InfoSWMM model did not include the Municipal Separate Storm Sewer (MS4) areas.

To provide a comprehensive assessment of flooding the extent and depth of the surface flooding needed to be defined. The most accurate method of defining surface flooding is using the overland 2D method. Although the InfoSWMM model includes a 2D overland method, it was decided to convert the InfoSWMM model to another software because Autodesk, who owns the InfoSWMM model, has decided to phase out support for the InfoSWMM model in the near future. After looking at few different softwares that supports the 1D and 2D modeling, it was decided to use the InfoWorks ICM model which is also owned by Autodesk. Figure 1-1 provides an overview map of the project area.

The purpose of this report is to provide an overview of the existing InfoSWMM to Infoworks ICM model conversion, the creation of the MS4 model, and the calibration and validation of the newly created combined CSS/Sanitary/MS4 model. Additionally, this report summarizes how areas of concern were identified using the updated model results and provides an assessment of the eight (8) most flooding concern areas to be evaluated for flood mitigation alternatives.

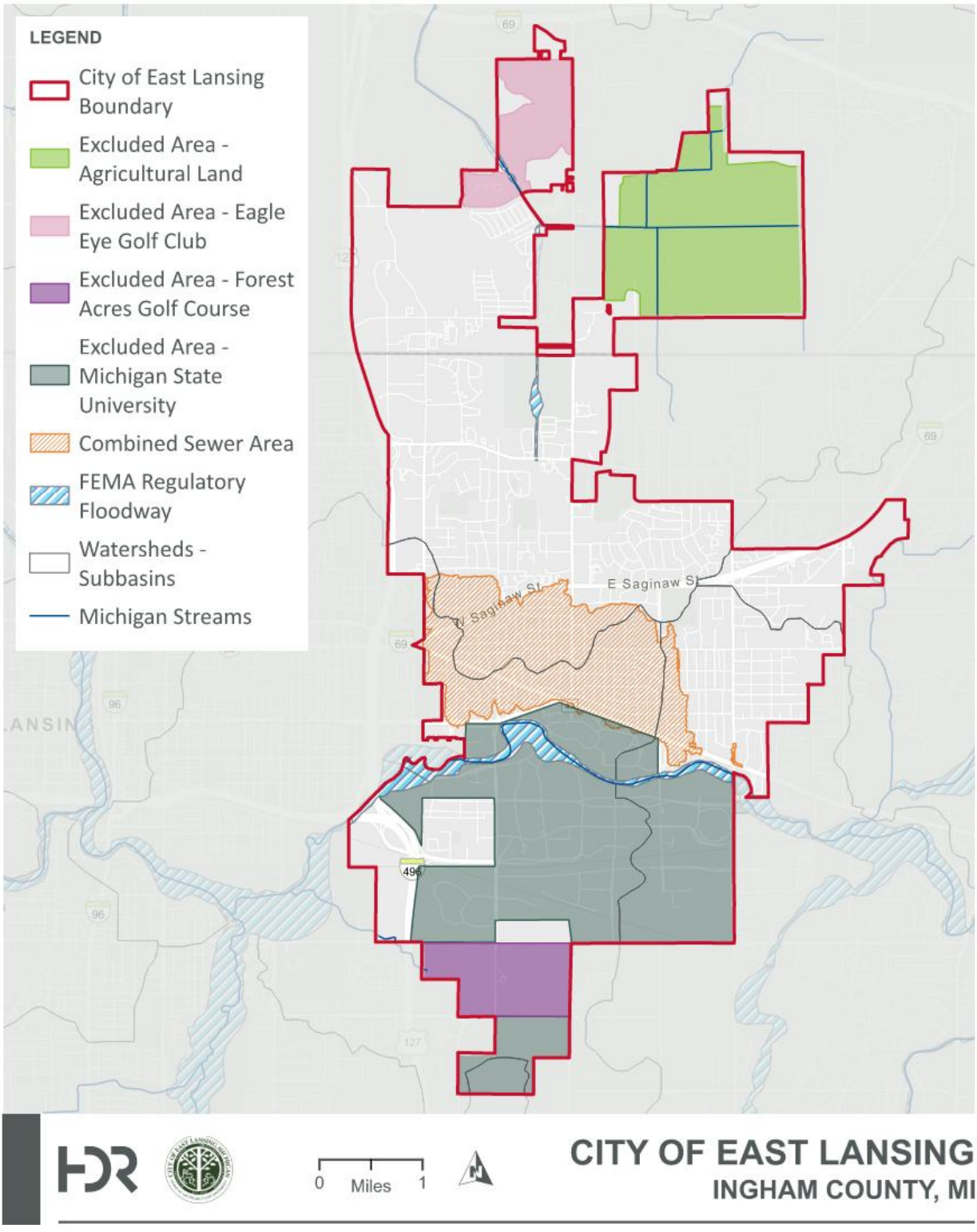


Figure 1-1. Project Area Model Conversion and Updates

2 Model Conversion and Updates

2.1 Conversion to InfoWorks ICM

The City's CSS and sanitary system model was created by Tetra Tech in 2017 using InfoSWMM software. Because the InfoSWMM software is being phased out by Autodesk support within the next two years, it was decided to convert the model to a new software platform. HDR originally recommended InfoWorks ICM SWMM to be able to use the SWMM calculation engine for the 1D pipe system and SWMM hydrology for runoff. However, it was discovered during the model conversion process that InfoWorks ICM SWMM has calculation errors at the 1D-2D connections, particularly at larger culverts. This error was unknown to HDR and Autodesk at the time of model selection and later acknowledged by Autodesk as a fatal flaw for using InfoWorks ICM SWMM for flood evaluations. To overcome the InfoWorks ICM SWMM 2D calculation error, Autodesk recommended that the model be converted to the InfoWorks ICM SIM, which has a different 2D calculation engine and has proven to be accurate for modeling both 1D pipes and 2D overland flooding. Through discussions with the City, it was decided that the entire model (CSS and MS4) be fully converted into InfoWorks ICM SIM.

Generally, the following activities were performed to convert the InfoSWMM model to InfoWorks ICM before the calibration recheck:

The original InfoSWMM model went through a two-step conversion. First it was imported into the InfoWorks ICM SWMM model. Next, the ICM SWMM model was converted into an InfoWorks ICM SIM model, due to the issues previously discussed. Once the model was imported, it was validated, and a log of the validation errors were documented for future comparison. An inventory of validation tracking elements (e.g., the modeled nodes, links, outfalls, wet wells, and pump stations, etc.) were compared to make sure that all the model elements were brought in correctly to the InfoWorks ICM SIM software.

The initial InfoSWMM model had four (4) hydraulic scenarios that were ultimately converted to InfoWorks ICM:

- 2017-FM-PERIOD
- DESIGNSTORM-010YR01HR-2019
- DESIGNSTORM-010YR01HR-HA-2019
- LTS-EXISTING

The 2017-FM-PERIOD scenario was imported as the Base, as it was representative of the pipe system during the flow monitoring period Tetra Tech had used for the previous calibration. Because the InfoSWMM and InfoWorks ICM software use different simulation engines and have different hydrology and hydraulics methodologies, it was necessary to check that the converted InfoWorks ICM model produced similar results to the original InfoSWMM model. Further details of this calibration check, and the results, are provided in Section 4.2.

Following the calibration check, HDR made additional changes to the base system (CSS model area) to reflect completed Capital Improvement Projects (CIPs) and updated pump controls

since 2017. An overview of all changes made to the base system is provided below in Section 2.2.

The new ICM base system was reviewed for any InfoSWMM attributes that may not have been imported correctly. The following general updates were made to update the model so that it could be run in InfoWorks ICM:

- "Outfall manholes" were changed to outfalls from manholes,
- Pipes with lengths below the minimum length of 3.3 feet were updated to the minimum length needed for InfoWorks ICM-SIM, and
- Objects created during the import that had non-existent reference nodes were deleted.

2.2 CSS/Sanitary Sewer Updates

The original InfoSWMM model included only the CSS and sanitary system. Following the model conversion to InfoWorks ICM the model was updated with four (4) recently completed sanitary sewer system CIPs. Additionally, the City provided HDR with updated pump curves and controls to ensure that pump stations within the CSS and sanitary system model were accurately reflecting current operations. The following sections describe these changes in greater detail.

2.2.1 Four CIP Projects Updates

Four (4) CIP projects were incorporated into the existing condition model within the CSS area of the InfoWorks ICM model. These four (4) CIP projects have been summarized below in Table 2-1.

Table 2-1. CIP Updates in the CSS/Sanitary Sewer Area.

CIP Name	Description of Improvements
Kedzie & Sunrise	• Sanitary sewer upsizes, realignments, new catch basins primarily along Collingswood Dr. • New twin sewers on Kedzie St. • Combined Sewer upsize on Sunrise Ct.
Michigan & Harrison	• New triple barrel siphon combined sanitary sewer under Red Cedar River. • New upstream sanitary sewers and reconfigurations • New upstream storm sewers in Michigan that discharge to the Red Cedar River.
Oakhill & Evergreen	• New combined sewers. • New orifice restrictor plate in Manhole SA#3 at intersection of Valley Ct. and Evergreen Ave. • New storm sewers and catch basins (12 inches)
Northlawn	• Several sanitary sewer upsizes and new catch basins primarily on Northlawn Ave. • Improvements also on Southlawn Ave. and Glenhaven Ave.

2.2.2 Pump Station Review and Updates

Additional updates to the CSS/sanitary sewer model include changes to pipe alignments, pump curves, and the configuration of pump stations.

In the original InfoSWMM model there were six (6) pump stations, all modeled as ideal pumps. To model the pump operations more accurately, all six (6) pump stations were updated with specific pump control parameters based on supporting documentation, such as pump curves, controls (on/off settings), and product sheets provided by the City. As part of the model updates, Rotodynamic pump controls were used in the model. At each of the pump stations, the wet well geometry was also reviewed and updated based on the as-builts provided by the City.

The Woodingham Pump Station required additional changes. In the original model, the two dry weather flow pumps were set to be on by default. To update the model, Real Time Control (RTC) was set to automatically turn the pumps off when the wet weather flow pumps turned on. According to the documentation provided, the Woodingham Pump Station is restricted to a capacity of 10.2 MGD due to the downstream forcemain. To reflect this restriction, HDR applied headloss to the forcemain and adjusted the pump curve.

2.3 MS4 Updates

The original InfoSWMM model did not include the MS4 system. To develop a combined model that includes the sanitary system, the CSS, and the MS4, HDR developed a 1D/2D model for the MS4 area and then combined it with the converted CSS/sanitary system model. This section summarizes the model building process of the MS4 model.

2.3.1 Survey Data/As-built Data Review and Import

The City's geodatabase was used to identify the MS4 system 1D elements to be modeled. Missing information was then updated, where possible, based on the as-builts provided by the City. The 1D elements of the MS4 system were imported into the model from the geodatabase created by the City and from newly collected survey data collected by HDR using the Open Data Import Centre (ODIC) functionality of ICM. The 1D elements included the storm drainage pipes, drains, junctions and culverts.

The imported data was then reviewed to identify missing or potentially erroneous data based on a comparison with terrain data and provided as-built drawings. In some cases, the imported data showed downstream invert elevations of conduits that were slightly higher than upstream invert elevations, these locations were not changed in the model, and it was assumed the surveyed elevations are correct. However, some imported data indicated steep negative slopes, pipes above the roadway, or conflicts between the City's geodatabase and the newly collected survey data. In these instances, the areas were revisited using as-built information along with several workshops with the City to resolve question areas. In some instances, pipes inverts and sizes were assumed in the model when the survey or the City data was non-existent. These assumptions were made based on field investigations, areal imagery, street-view imagery, inference, and engineering judgement. Using the InfoWorks ICM data flag feature, the following flags were used to identify the parameter source:

GIS – The data was provided in the City geodatabase.

AB-The data from as-builts.

SV – The data was obtained from survey.

AS – The data was assumed based on engineering judgement when no other data source is available.

DEM – The ground elevation was obtained from the Digital Elevation Model (DEM) data.

ECIP – The data from existing CIP since 2017.

EL – The data provided by city of East Lansing.

FEMA – The data from FEMA model.

The MS4 model includes several outfalls that discharge to a surface drainage feature such as the drain system. The tailwater conditions for these outfalls were assumed to be a free outfall.

2.3.2 Subcatchment Delineation

The subcatchments within the MS4 area were delineated using 1 meter resolution DEM file downloaded from the United States Geological Survey (USGS) 3D Elevation Program. The DEM was used to determine the overland flow direction. Survey of the existing infrastructure was used to determine sub-surface flow direction and provide additional accuracy to the subcatchment delineation. The number of subcatchments delineated were determined by identifying the locations of critical infrastructure points where explicitly defining the flow to a point would provide a better understanding of possible flooding or attenuation of flow. The areas within the MS4 area and the city limits were delineated into 361 separate subcatchments and were named based on the hydraulic node that the subcatchment flow loading is applied.

2.3.3 Hydrologic Parameter Development

To remain consistent with the hydrologic method used in the original InfoSWMM model, the hydrology of the MS4 subcatchments used the Horton Infiltration method to determine the amount of runoff and SWMM method to convert the runoff to a hydrograph. Initial parameterization of the MS4 subcatchments, including the subcatchment width, slope, longest flow path, infiltration parameters were calculated in GIS using DEM data, land use data, and soils data. During the calibration process, these hydrological parameters were further adjusted as needed to match observed flow and level data. Table 2-2 below provides a summary of the parameters used for the model development and their source.

Table 2-2. Hydrologic Parameters and Sources.

Parameter	Description	Source
Land Use	Contained a field indicating grass, woods, or impervious.	The City and NOAA Coastal Change Analysis (C-CAP) Land Cover
Soil Type	A GIS layer that was prepopulated with the soil texture, and with Rawls Ksat, Rawls Effective Porosity and the Max infiltration. Calculated based on soil texture data.	Soil Survey Geographic Database (SSURGO)
Available Water Storage	A GIS layer with available water storage data.	Soil Survey Geographic Database (SSURGO)
Subcatchment Width	The width of the flow path for subcatchment runoff.	Calculated using subcatchment area divided by longest flow length for a subcatchment

The limiting infiltration, a key hydrologic parameter, was calculated using the K_{sat} parameter in the soil layer. To calculate this, the built-in "Tabulate Intersection" tool in GIS was utilized.

Using the above GIS datasets, a parameterized subcatchments layer was generated with the following fields:

- Initial Infiltration – Used values from the Hortons Infiltration Parameters for dry soils.
- Limiting Infiltration (in/hr) – The hydraulic conductivity based on Rawls Infiltration Parameters[1] values applied to SSURGO soil texture types.
- Decay Factor (1/hr) – Used the suggested value from Innovyze.
- Drying Time (day) – Used the suggested value from Innovyze.
- Maximum Infiltration Volume (in) – Used the available water storage from SSURGO and are area weighted.

2.4 2D Surface Creation

A 2D surface was created to cover the entire extent of the MS4 and CSS area. This 2D surface is a mesh that reflects the ground surface, including small ditches and streams. Stormwater runoff that does not flow into the storm drainage pipes or flows out of the storm drainage pipes and onto the 2D mesh, where it is conveyed until it eventually reaches a storm drainage pipe or an outfall.

In the 2D model areas, the 2D mesh used the parameters shown in Table 2-3 below, to determine the meshing properties. A maximum triangle area of 5000 square feet was used for the 2D zones. Breaklines and mesh level zones were added to further define ditches, ponds, and roads. Default Manning's "n" values in each 2D zone was set as 0.15 which represents the

[1] Rawls W., Brakensiek D., and Miller N. Green-ampt Infiltration Parameters from Soils Data. Journal of Hydraulic Engineering, Volume 109, Issue 1. 1983.

low-density residential areas that represents most of the modeled MS4 area. Roughness zones were applied to the mesh where the 2D zone default was not applicable, and buildings were incorporated into the mesh as porous polygons with zero porosity. Typical manning's N values for the various roughness zones added in the model are shown in Table 2-4.

Table 2-3. Typical Meshing Properties for 2D Areas in ICM Model.

Polygon Property	
ID	2D_zone
Area (acre)	7246.839
Maximum Triangle Area (ft2)	5000.000
Minimum Element Area (ft2)	1000.000
Mesh Generation	Clip Meshing
Boundary Type	Normal Condition
Terrain-Sensitive Meshing	Yes
Maximum Height Variation (ft)	1.000
Minimum Angle (degree)	25.000
Roughness (Manning's n)	0.150

Table 2-4. Manning's N Values for Different Roughness Zones.

Roughness Zone	Manning's n
Road	0.0130
Woods	0.4000
Paved	0.0130
Channel	0.0350
Smooth Channel	0.0150
Rough Channel	0.0600

The manholes within the CSS area were converted to 2D nodes so that flooding from pipe surcharging to the surface would flow on the 2D mesh. Several sanitary sewer manholes within the MS4 area were located near a stream or conveyance channel. It was assumed that these manholes are sealed. to ensure that flow from the normal stormwater conveyance feature in the MS4 area would not be able to get into the sanitary system.

3 Flow and Rainfall Monitoring

ADS Environmental (ADS) installed and maintained a series of four (4) rain gauges, five (5) flow monitors, and three (3) level only sensors throughout the MS4 area to conduct a flow and rainfall monitoring study. Figure 3-1 provides an overview map displaying the locations of the monitors. Five (5) months of flow and rainfall data were collected and analyzed to support the calibration of the hydraulic model in the MS4 area. The monitoring study was conducted from July to November 2024. Data was collected and transmitted to the ADS Cloud data viewer, PRISM, so that the HDR team could perform a QA/QC of the data weekly.

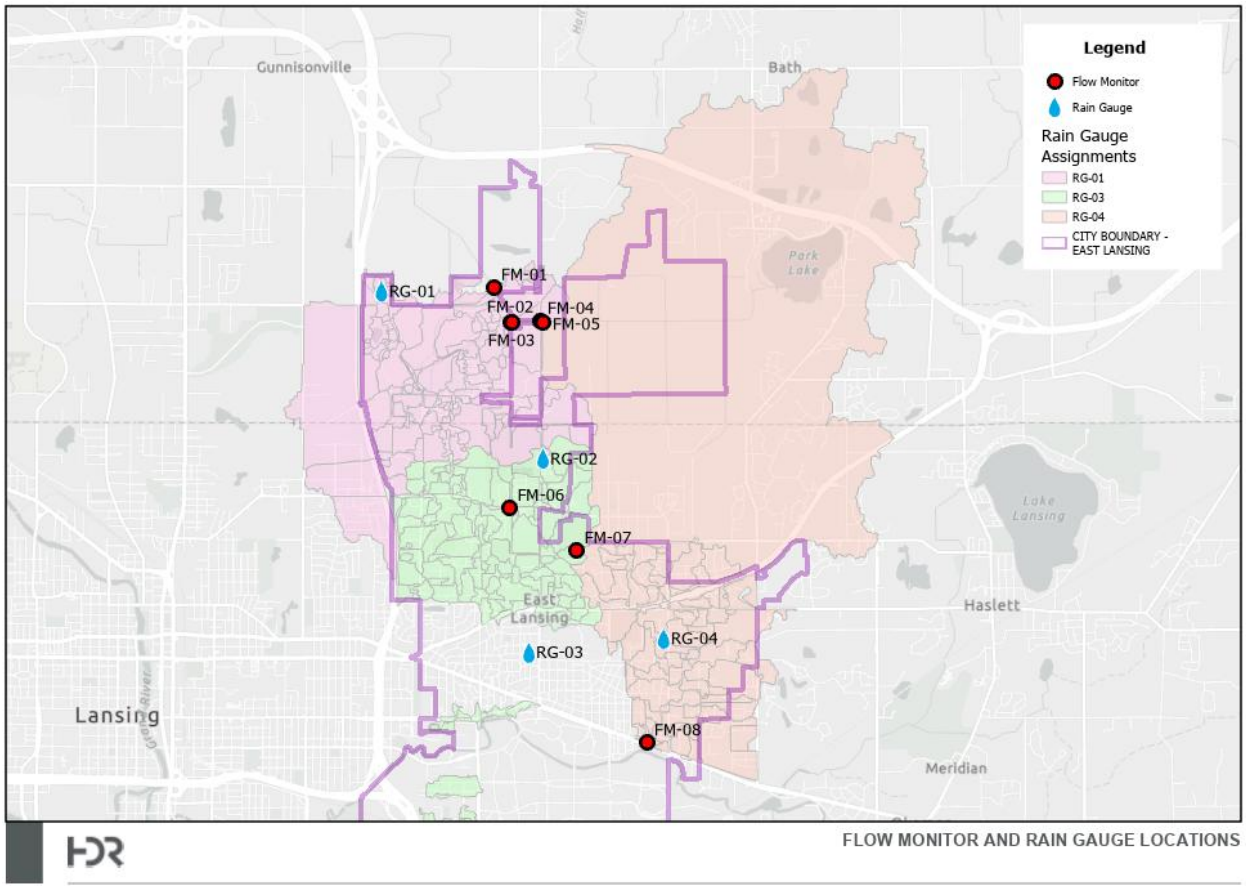


Figure 3-1. Flow Monitor and Rain Gauge Locations.

3.1 Flow and Level Monitoring

A series of flow and level monitors were installed throughout the City's stormwater system, with considerations such as flooding complaints and system connectivity were incorporated when deciding the locations. Table 3-1 provides a summary of each flow monitor, including the location and the size, type, material of the location, and the type of data collected at each monitor.

Table 3-1. Summary of Flow Monitors.

Meter ID	Location Description	Data Type	Type	Size	Material	Jurisdiction
FM-01	Under golf path; N of E State Rd.	Depth Only	Culvert	140.25" x 213"	Corrugated Metal Pipe	Clinton County
FM-02	S of 3922 Palomino Dr.	Depth, Flow	Culvert	62" x 60"	Corrugated Metal Pipe	Clinton County
FM-03	S of 3922 Palomino Dr.	Depth, Flow	Culvert	59.63" x 58.88"	Concrete	Clinton County
FM-04	E of Chandler Rd., S of Springer Way.	Depth Only	Culvert	119.5" x 253.5"	Corrugated Metal Pipe	Clinton County
FM-05	E of Chandler Rd., S of Springer Way.	Depth, Flow, Velocity	Culvert	54" x 54"	Corrugated Metal Pipe	Clinton County
FM-06	N Tier Trail on W Lake Lansing Rd.	Depth Only	Culvert	75" x 115.5"	Corrugated Metal Pipe	Clinton County
FM-07	Intersection of Old Mill Rd. and Pebblebrook Ln.	Depth, Flow	Pipe	54"	Reinforced Concrete Pipe	City of East Lansing
FM-08	In Crosswalk of Spartan Ave, near the Grand River Ave Intersection.	Depth, Flow	Pipe	84"	Concrete	City of East Lansing

Weekly, the collected flow monitor data underwent engineering analysis to identify inconsistencies, gaps in the data due to technology issues, and "noise" in the data.

The flowmeter installation reports provided by ADS are in Appendix A. These installation reports provide the information in Table 3-1, along with GPS coordinates, maps and photographs of the installation location, and other installation field notes.

3.2 Rainfall Monitoring

Four (4) rain gauges were installed throughout the MS4 area. Rainfall data were reviewed throughout the monitoring period to identify a series of storm events for the MS4 model calibration and the validation purposes. Figure 3-1 shows the rain gauge assignment for each subcatchment in the model.

4 Model Calibration and Validation

The calibration of the model consisted of two phases: the calibration of the MS4 model area using the storm events from the rainfall monitoring, and the calibration of the CSS model area using the dry weather flow (DWF) and wet weather flow (WWF) 2017 period that Tetra Tech had used in the InfoSWMM model. Following the model calibration, the model was validated using the June and July storm events that resulted in significant flooding in 2024.

The following section of the report outlines both calibration methods, their respective results, and the model validation results.

4.1 MS4 Calibration

4.1.1 MS4 Calibration Events

Five (5) storms, summarized below in Table 4-1, were selected for model calibration purposes. However, as RG-02 experienced outages during the selected WWF period, only RG-01, RG-03, and RG-04 were used for modeling purposes.

Table 4-1. Storm Event Statistics.

	Rain Event Start	Rain Event End	Total Rainfall (inches)		
			RG-01	RG-03	RG-04
Event 1	7/29/2024 17:50	7/30/2024 6:50	0.81	0.72	0.64
Event 2	8/1/2024 17:40	8/2/2024 15:50	0.39	0.93	0.89
Event 3	8/5/2024 9:55	8/6/2024 14:50	1.15	1.28	1.03
Event 4	8/15/2024 20:00	8/18/2024 15:30	1.89	1.46	1.33
Event 5	8/27/2024 6:00	8/27/2024 16:20	0.82	0.93	0.95

It should be noted that for Rain Gauge 1, the time between Event 1 and Event 2 is relatively short, resulting in the flow being unable to return to antecedent conditions. As such, Event 2 has not been included in the calibration for flow meters receiving rainfall data from Rain Gauge 1. This includes the following flow meters FM1, FM2, and FM3.

4.1.2 MS4 Calibration Criteria

As defined by best practice, the following model calibration guidelines were applied during the WWF calibration process:

- Observed and model-predicted WWF hydrographs shall closely follow each other both in shape and in magnitude, until the flow has substantially returned to dry-weather flow rates.
- Model-calculated hydrographs shall meet the following criteria for at least 60% of the rainfall events observed during the WWF monitoring program.
    - Timing of the peaks and troughs shall be similar to observed.
    - Peak flows at each significant peak shall be in the range – 15 % to + 25% of the observed peaks.
    - Volume of flow should be in the range -10% to 20% of the observed depths.
    - Surcharged flow depth shall be in the range -0.32 feet to +1.64 feet.

- Unsurcharged flow depth shall be within the range of ±0.33 feet of observed depths.

For monitor locations with low flows, the model can often be difficult to calibrate within the percentage standards, since even a small difference between the numerical model result and observed data can result in a large percentage difference. Therefore, it is common practice to use numerical criteria in lieu of the percentage criteria for monitors exhibiting low flows. The following guidelines were used for locations where low flow was observed:

- Volume of flow should be in the range of ±0.1 MG of observed flow volume when observed flow volume is less than 1 MG.
- Peak flow should be in the range of ±0.1 MGD of observed peak flow when observed peak flow is less than 1 MGD.

4.1.3 MS4 Calibration Results

Scatterplot comparisons of modeled and monitored data with the criteria bound lines were used to evaluate calibration performance. The Figure 4-1 shows an example graphic, where the points represent the model peak depths versus the monitored for individual storm events. For comparison to the calibration criteria, the line of equality was drawn in the graphic, as well as the envelope representing the model calibration upper and lower guidelines ranges. Similar graphics for peak flow and volume were developed for the flow monitors when data for each respective storm event was available. Additionally, the hydrograph comparisons of modeled and monitored data were plotted to evaluate the timing and shape of the RDII responses. The graphs for all flow monitors are provided in Appendix B.

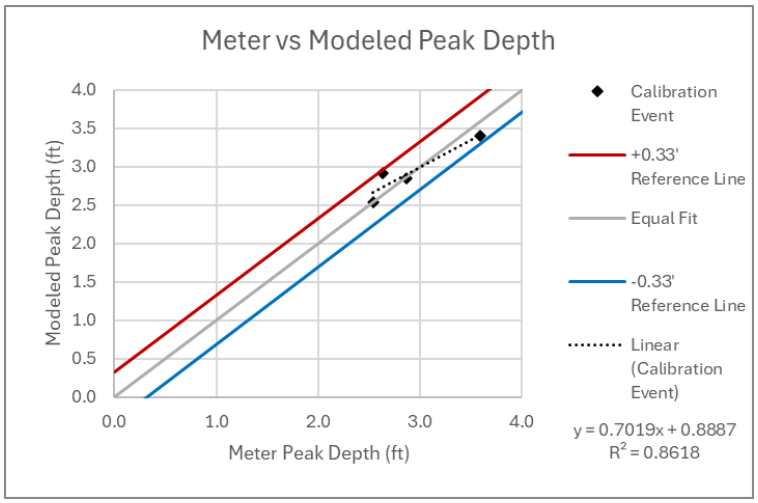


Figure 4-1. Meter vs Modeled Peak Depth for FM1.

Following typical model calibration best practice guidelines, a meter is considered calibrated if calibration criteria are met for 60% of the storm events. Table 4-2 below provides an overview summary of the MS4 model calibration results. The calibration results for the MS4 area were deemed sufficient for the development and identification of flooding concern areas for the WWRP.

Table 4-2. Calibration Results for MS4 Area.

Meter	Number of Events	% Events Meeting Calibration Criteria at Flow Meter		
		Peak Flow (MGD)	Storm Volume (MG)	Peak Depth (ft)
FM1	4	N/A	N/A	100%
FM2	4	33% [a]	60%	40%
FM3	3	66%	66%	100%
FM4	5	N/A	N/A	100%
FM5	4	33% [a]	60%	100%
FM6	5	N/A	N/A	40%
FM7	4	33% [a]	60%	60%
FM8	5	80%	100%	60%

[a] These locations are considered calibrated based on engineering analysis.

For most meters not meeting the calibration goals, the model and meter hydrographs matched well. Generally, the model slightly overpredicted the peak flow, which is the preferred result as opposed to under predicting as it keeps the model results conservative. Meters FM2, FM5, and FM7 do not meet the peak flow calibration criteria for at least 60% of the events. However, after performing an engineering analysis and reviewing the model results, it has been determined that the meters are still considered calibrated as the hydrographs are similar in shape and they did not over predict by a relatively great amount. The amount by which the model is over predicting peak flow is not considered to decrease the confidence in the model's ability to be used to assess existing conditions or to identify flooding concern areas.

Observing the hydrographs for FM3, it appears that a shift in the observed flow data occurred, where the observed increase in depth data occurs before the storm event begins for events two and three. As a result, storms 2 and 3 were disregarded from the calibration from FM3.

4.2 CSS Calibration

The purpose of the CSS calibration process was to verify that the converted InfoWorks ICM SIM model produced results that were similar to the InfoSWMM model results during the calibration periods identified by Tetra Tech. The following section outlines the calibration period and criteria for DWF and WWF and summarizes the calibration results. This calibration was performed by Autodesk following the conversion process and was verified by HDR.

4.2.1 CSS Dry Weather Calibration

For dry weather calibration Tetra Tech had identified a 7-day period from June 5, 2017, to June 12, 2017, during which there was no measured rainfall. Tetra Tech used the following calibration criteria:

- The modeled dry weather volume (represented by the average dry weather flow rate) is +20 to -10 percent or within ±0.5 MGD of the measured dry weather volume, whichever is greater.
- The modeled average of the daily peak and minimum hour dry weather flow rates are +25 to -15 percent or within ±0.5 MGD of the measured average of the daily peak and minim hour dry weather flow rates, respectively, whichever is greater.
- The modeled diurnal pattern is quantitatively similar to the measured pattern.

For consistency, HDR used the same criteria at the 19 flow meters used by Tetra Tech. For the CSS dry weather calibration, the converted InfoWorks ICM SIM model was run during the calibration period and the results were compared to the original measured data provided by Tetra Tech. Table 4-3 below provides a summary of the number of meters and the percentage of meters that meet the calibration criteria for the average dry weather flow, the daily peak flow, and the minim hour flow. More detailed information at each flow meter location is provided in Appendix C.

Table 4-3. CSS Dry Weather Flow Results Summary.

	Average Weather Flow	Daily Peak Flow	Minimum Hour Flow
Number of Meters Meeting Calibration	18	17	19
% Of Meters Meeting Calibration – Updated Model	95%	89%	100%
% of Meters Meeting Calibration – Tetra Tech Model	100%	95%	100%

4.2.2 CSS Wet Weather Calibration

For wet weather calibration Tetra Tech identified 16 storm events from April 3, 2017, to August 17, 2017, that were used for calibration. For the CSS wet weather calibration process, the measured peak flow and volume for each storm event was compared to the modeled output results from the converted InfoWorks ICM model.

The calibration criteria used by Tetra Tech, and subsequently used by HDR for model performance evaluation, are outlined below:

- The modeled wet weather volume is +20 to -10 percent or within ±0.1 MG of the measured wet weather volume, whichever is greater.
- The modeled peak wet weather flow rate is +25 to -15 percent or within ±0.1 MGD of the measured wet weather flow, whichever is greater.
- The timing of the modeled peak matches the timing of the measured peaks.

Scatter plots with the modeled results on the X-Axis and the measured results on the Y-Axis were generated, with a trendline showing the general calibration of the meter. These scatterplot summaries are provided in Appendix D, along with the calibration results. Table 4-4 below provides a summary of the WWF calibration results.

Table 4-4. WWF Calibration Results Summary.

Meter	Number of Events	% Meeting Calibration Criteria – Updated Model		% Meeting Calibration Criteria – Tetra Tech Model	
		Peak Flow	Total Volume	Peak Flow	Total Volume
Beal-24	16	38%	88%	31%	88%
Charles-24E	12	42%	92%	33%	92%
Charles-27W	15	58%	100%	47%	100%
Charles-54N	9	56%	67%	44%	56%
Collingwood-30S [a]	5	66%	-	60%	100%
Collingwood-54N	15	53%	60%	47%	53%
Durand-78	16	25%	38%	38%	38%
Kensington-60	16	50%	50%	44%	38%
Louis-36	16	50%	19%	44%	57%
Michigan-36	16	50%	19%	57%	63%
Michigan-72	16	25%	44%	25%	44%
Northlawn-36	16	44%	56%	38%	50%
Oak-15	16	50%	81%	44%	88%
River-42	14	43%	50%	50%	50%
Snyder-36	16	31%	75%	31%	81%
Sunset-27 [b]	16	40%	50%	38%	75%
Touraine-48	14	43%	64%	50%	64%
Valley-12 [c]	10	33%	60%	20%	100%
Valley-18	16	50%	94%	31%	94%

[a] The monitor values for Coolingwood-30S were exported from the model, rather than the Tetra Tech report.

As the goal of the CSS wet weather calibration was to match the Tetra Tech calibration results, as shown in previous tables this was successfully performed and the converted ICM model was determined be sufficient for the purposes for evaluating flooding within the CSS.

4.3 Model Validation for June and July 2024 Flood Events

To validate the calibrated model, rainfall from the June and July storm events in 2024 were simulated to identify flooding areas. These two events resulted in flooding complaints in areas throughout many portions of the City, with some areas seeing rainfall intensities that exceeded the 1000-year storm.

To model the June and July 2024 rain events, HDR utilized the rain gauge collected data for these events and generated 5-minute Gauge-Adjusted Radar Rainfall (GARR) data using Next Generation Weather Radar (NEXRAD) from the Lansing airport. The GARR data provides localized rainfall data at 1 kilometer grid resolution and allows highly spatially variable rainfall to be simulated across the model area. The GARR data for both storms were then input into the calibrated model and simulated to understand 2D surface flooding across the City.

Public survey complaint data of surface flooding, in addition to the City's recollection of the flooding areas from both storm events, were compared to the modeled 2D flooding results. Figure 4-2 and Figure 4-3 present the 2D model flooding results for the June and July 2024 flooding events, respectively. On these figures, the red dots represent street flooding survey complaints received by the public in East Lansing. Generally, the model simulated surface flooding agreed with reported known street flooding locations, especially within the Whitehills and Red Cedar neighborhoods. Results were reviewed with City staff to confirm model

performance in known flooding areas. Based on feedback received during this workshop, additional minor model refinements were made to better match known flooding areas. These refinements included splitting subcatchments to better distribute stormwater flow loadings, adding a restrictor to a storm sewer near the vicinity of Beechlawn Court, and adding additional model detail with small runs of pipe to better represent localized drainage patterns near flooding areas. After these adjustments, the model was subsequently considered calibrated and validated by HDR and City staff members.

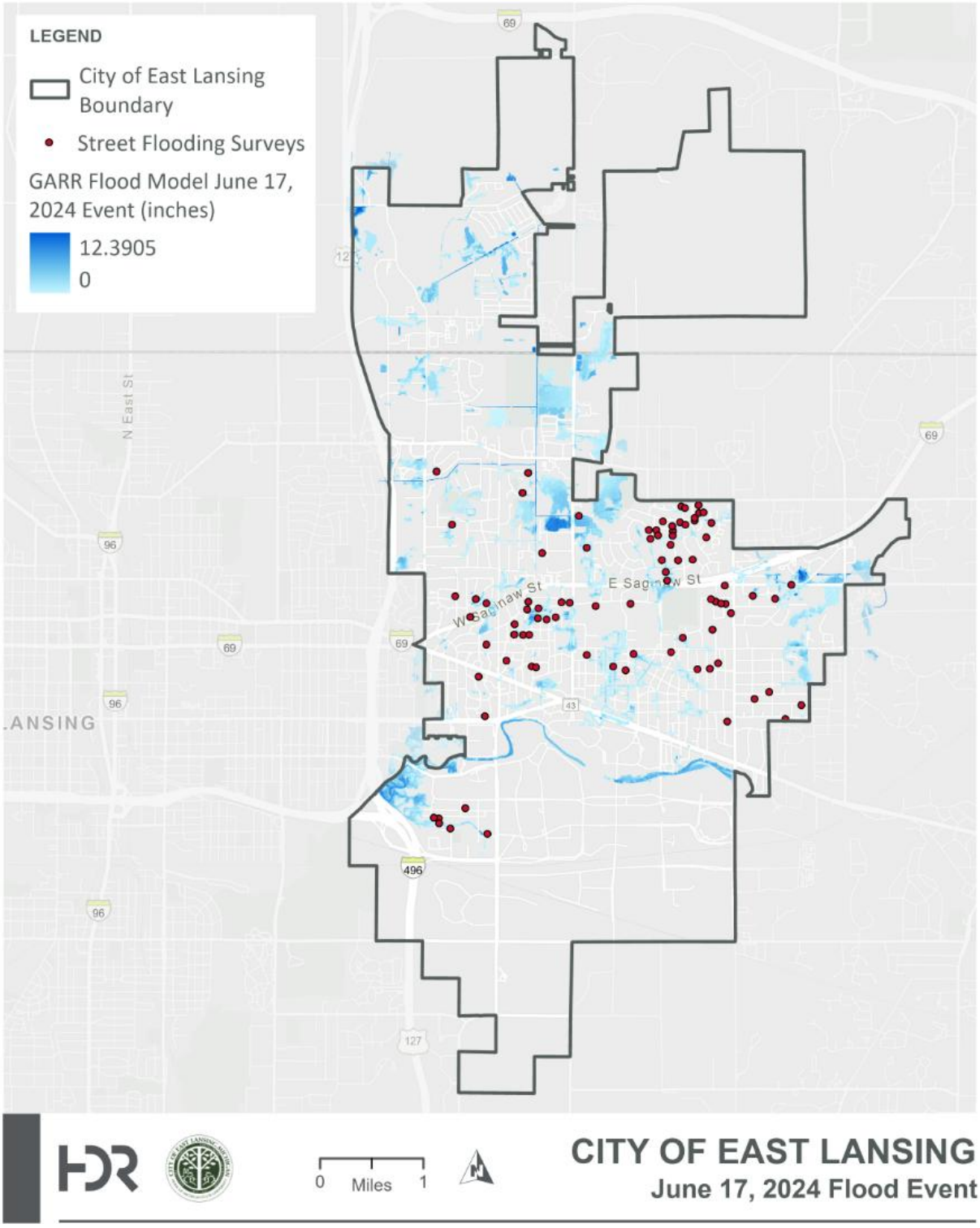


Figure 4-2. GARR Model Surface Flooding Results for the June 2024 Rain Event with Flooding Survey Locations (Red Dots).

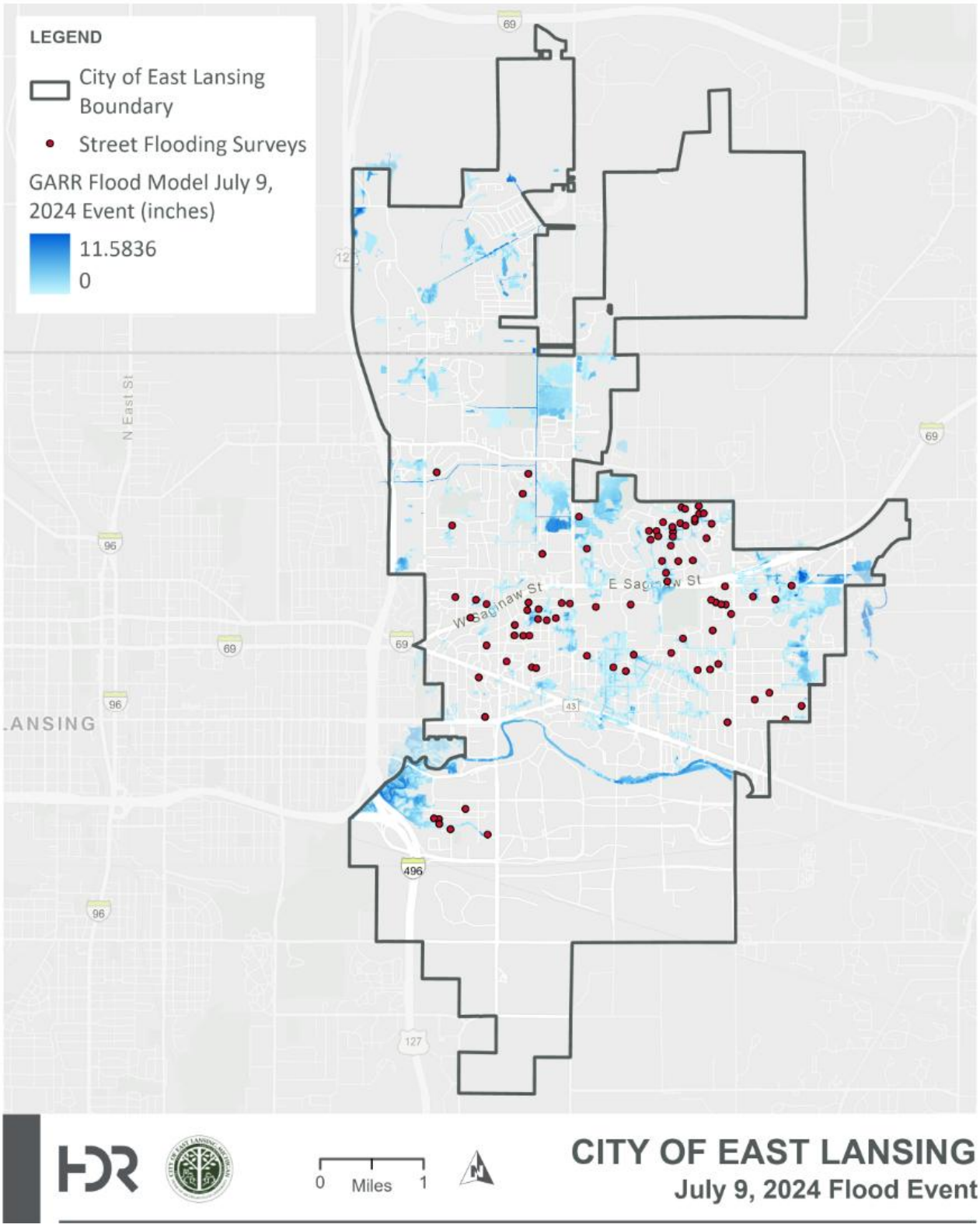


Figure 4-3. GARR Model Surface Flooding Results for the July 2024 Rain Event with Flooding Survey Locations (Red Dots).

5 Existing Condition Assessment

The calibrated and validated 1D-2D model was used to simulate a range of design storms, to identify and numerically score flooding concern areas. The following section provides an overview of the flood scoring methodology, including descriptions of the design storms simulated, the model results, and scoring results.

5.1 Flood Scoring Methodology

5.1.1 Selected Design Storms

As part of previous tasks under the WWRP, HDR developed a Changing Precipitation Conditions Report, which used historical and future climate change rainfall data to ensure that the WWRP will take into consideration increasing rainfall patterns local to the City. As part of this work, an analysis was performed to develop a representative storm based on the actual temporal distribution of storms in the City. Overall, it was found that the distribution of the representative storm analysis closely matched the Huff and Angel estimates for storms in the Midwest for a 6-hour rain event as shown in Figure 5-1. Since both the representative storm and Huff and Angel distributions were similar, to remain consistent with the CSS masterplan and current City stormwater regulations, the Huff and Angel design storms were used for the Existing Conditions assessment.

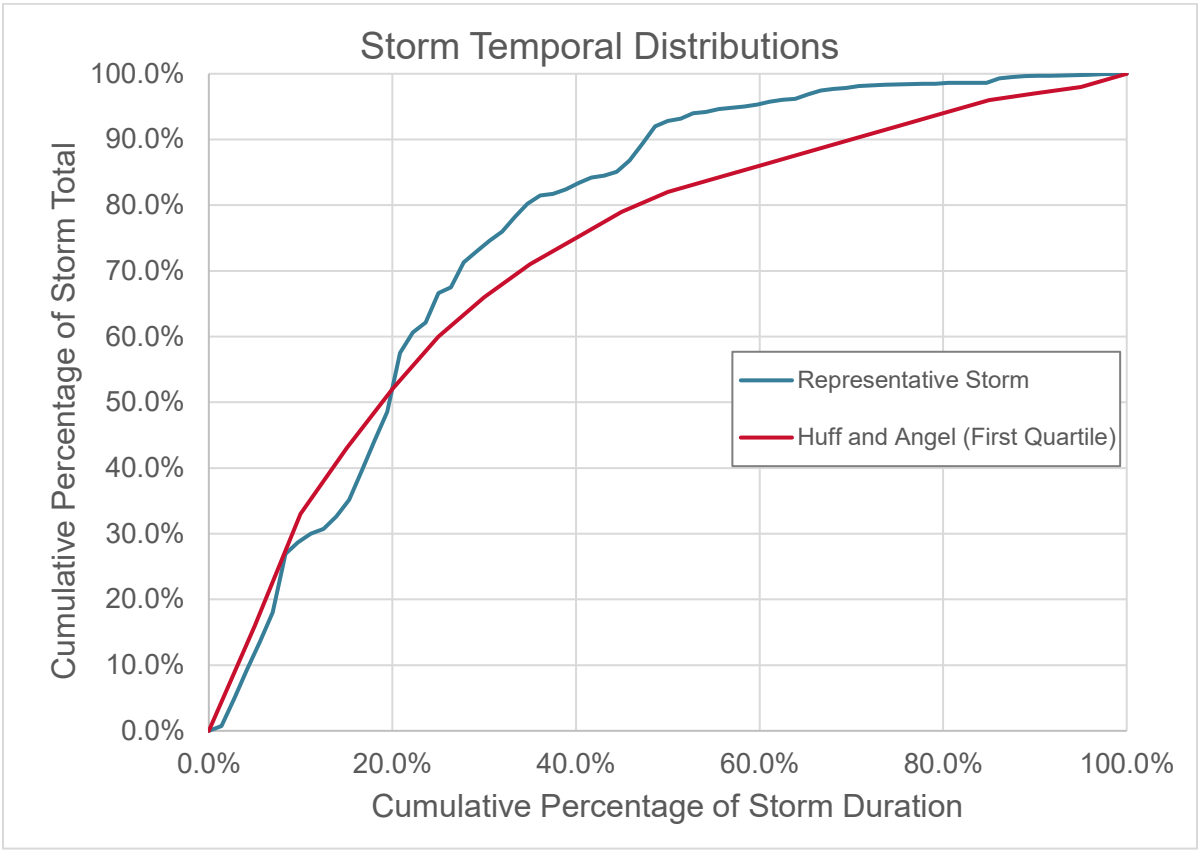


Figure 5-1 Comparison of Representative and Huff and Angel Storm Distributions.

The Huff and Angel[2] estimates for storms in the Midwest examined rainfall frequency throughout the Midwest including all of Michigan. As part of the Huff and Angel survey time distributions and rainfall depth-frequency statistics for storms up to 10-days in duration were developed, both of which have been used by the City for stormwater regulation purposes. As such, the model was stress tested using 2, 5, 10, 25, 50, and 100-year storm events at storm durations of 1-hour, 6-hours, and 24-hours. Table 5-1 below provides the total rainfall for each design storm selected for climate region 9 within Huff and Angel.

Table 5-1. Rainfall (inches) for the Selected Design Storms.

	Storm Duration		
Recurrence Interval	1-Hour	6-Hour	24-Hour
2-Year	1.14	1.82	2.42
5-Year	1.40	2.24	2.98
10-Year	1.61	2.57	3.43
25-Year	1.92	3.07	4.09
50-Year	2.18	3.47	4.63
100-Year	2.44	3.90	5.20

Upon simulating each of these events it was determined that the flooding within the model is more driven by short duration, high intensity rain events. Flooding is more widespread and impacts more neighborhoods for a 1-hour event as compared to a 6-hour or 24-hour event.

5.1.2 Inundation Mapping for 25-year, 1-hour Storm

Following a workshop with the City, the 25-year, 1-hour design storm of 1.92 inches using a Huff and Angel 1st Quartile temporal distribution was selected to evaluate and identify flooding concern areas across the City. This storm was selected for three primary reasons:

1. The storm was large enough to generate enough flooded areas to adequately score and evaluate the model across both the CSS and MS4 areas,
2. The temporal distribution of the Huff and Angel 1st Quartile is similar to the Representative Storm temporal distribution (as previously shown in Figure 5-1), and
3. The 25-year, 1-hour storm rainfall depth inherently takes into account future climate considerations. It is projected that the 10-year, 1-hour storm rainfall depth in 2035 will be approximately 1.97 inches, which is similar in magnitude to the 1.92 inches of rainfall for the current 25-year, 1-hour rainfall depth.

The inundation flooding map from the current 25-year, 1-hour design storm using the Huff and Angel 1st Quartile temporal distribution was considered suitable for evaluating existing flooding conditions within the City and was therefore used to identify flooding concern areas.

5.1.3 Identification of Flooding Concern Areas

The primary purpose of the updated model was to use modeling results to identify flooding concern areas and to prioritize the first phase of projects as part of the WWRP. HDR has

[2] Huff, Floyd A., Angel, James R. Rainfall Frequency Atlas of the Midwest. Illinois State Water Survey, Champaign, Bulletin 71, 1992.

defined a “Flooding Concern Area” as anywhere where one of the three conditions are met during the 25-year, 1-hour storm:

1. A roadway floods 6-inches or more,
2. A parking lot floods 6-inches or more, or
3. A building floods.

Figure 5-2 below shows the identified areas of concern identified during the 25-year, 1-hour design storm. In total, 58 flooding concern areas were identified between the CSS and MS4 areas.

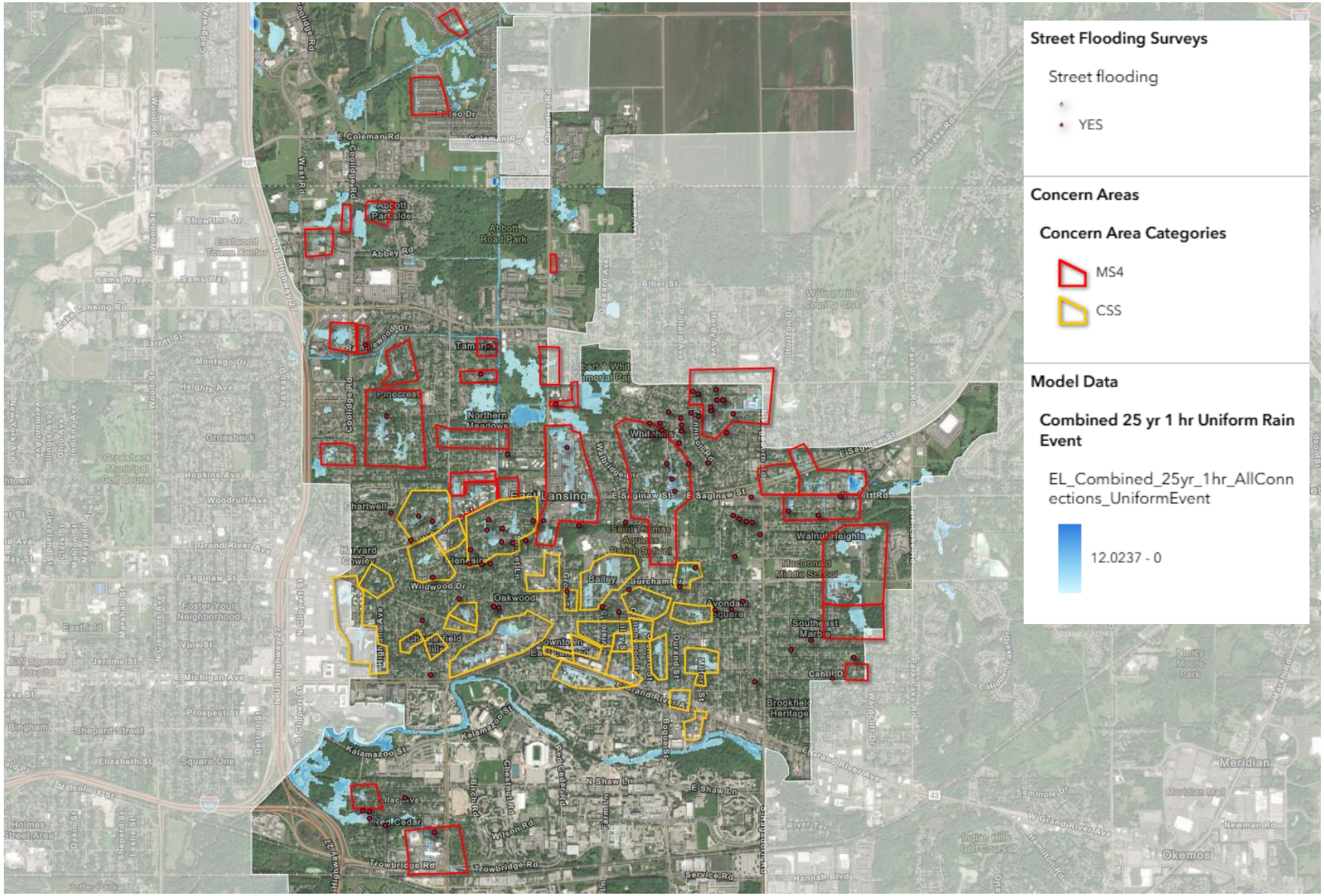


Figure 5-2. Concern Areas Identified using 25-Year, 1-hour Design Storm.

5.1.4 Scoring Criteria

Nine (9) objective flooding criteria (herein referred to as objective criteria) were defined to evaluate and score the 58 identified flooding concern areas. Flooding objective criteria can be measured using the model results and do not include any subjectivity. The objective criteria used for this analysis, described below in Table 5-2, were developed from the Resilience Workshop (Task 2) held between HDR and the City, where observed flooding problems were identified and defined by the City.

Table 5-2. Flooding Concern Area Objective Criteria.

Objective Criteria	Description
Roadway Flooding Frequency	How frequently a roadway floods. For example, a road that floods during a 2-year event, floods frequently.
Roadway Flooding Location	Where roadway flooding occurs. For example, a road that floods on heavily traveled road.
Roadway Flooding Depth - Critical Facility	Flooding greater than 12-inches that occurs on a roadway near a critical facility such as a police or fire station.
Roadway Flooding Extent	The total area of roadway that floods 6-inches or greater within the flooding concern area.
Parking Lot Flooding	Flooding frequency and depth in a parking lot can impact vehicle access and flooding.
Building Flooding Frequency	How frequently a building floods. For example, a building that floods during a 2-year event, floods frequently.
Building Flooding Type	The type of building where flooding occurs. For example, a multi-residential apartment building.
Surface Flooding - CSS Area	Flooding on the surface within the combined sewer area.
Basement Flooding - CSS Area	Basement flooding within the combined sewer area is likely to occur when the pipe system surcharges.

5.1.5 Pairwise Analysis of the Objective Criteria

The purpose of pairwise analysis is to determine the relative importance of a set of variables against each other. A pairwise analysis generally involves comparing a set of variables, in this case the objective criteria from Table 5-2, one at a time to determine the relative importance of each. HDR provided a pairwise analysis template to the City. City staff, which included representatives from the departments of public works DEI, planning, and emergency services, then conducted a pairwise analysis to determine numerical weighting for each flooding objective criterion. The objective criteria were compared against each other using a ranking between 0 and 5:

- Criteria A is much less important than Criteria B = 1
- Criteria A is less important than Item Criteria B = 2
- Criteria A is the same importance as Item Criteria B = 3
- Criteria A is more important than Item Criteria B = 4
- Criteria A is much more important than Item Criteria B = 5

The numerical weighting was then used to distribute the 100 possible points for each flooding concern area as part of the scoring. As shown below in Table 5-3, the pairwise analysis results ranked basement flooding from CSS surcharge to be the most important objective criteria with a relative weight of 3.1 and 15.7 possible points. Parking lot flooding was found to be the least important objective criteria with respect to the others. Appendix E contains the full description of the scoring criteria and measurements for the criteria explored in the pairwise analysis.

Table 5-3. Pairwise Analysis Results.

Objective Criteria	Pairwise Analysis Rank	Criteria Weighting Value	Total Possible Points
Roadway Flooding Frequency	8	1.694	8.47
Roadway Flooding Location	6	2.064	10.32
Roadway Flooding Depth Critical Facility	2	2.962	14.81
Flooding Extent	7	1.750	8.75
Parking Lot Flooding	9	1.092	5.46
Building Flooding Frequency	5	2.276	11.38
Building Flooding Type	3	2.686	13.43
Surface Flooding - CSS Area	4	2.340	11.70
Basement Flooding - CSS Surcharge	1	3.136	15.68
		Sum =	100.00

5.1.6 Flood Scoring

Using the criteria weights and total possible points for each category as shown in Table 5-3, each of the 58 identified concern areas were scored to identify the top eight (8) concern areas to advance for flood mitigation project alternatives analysis. For all of the flooding concern areas, the objective criteria was scored between 0 and 5 based on the model results. Table 5-4 below provides an example of the 0 to 5 scoring for the Roadway Flooding Frequency objective criteria. The full list of 0 to 5 criteria scores are provided in Appendix E.

Table 5-4. Scoring Criteria for Roadway Flooding Frequency.

Roadway Flooding Frequency		
Score	Measurement	Scoring Criteria
0	No Flooding	
1	6-inches or greater in flood depth in a road	100-year, 1-hour
2	6-inches or greater in flood depth in a road	50-year, 1-hour
3	6-inches or greater in flood depth in a road	25-year, 1-hour
4	6-inches or greater in flood depth in a road	10-year, 1-hour
5	6-inches or greater in flood depth in a road	2-year, 1-hour

For each criterion, the 0 to 5 flooding score result was then multiplied by the weight from the pairwise analysis in Table 5-3 to get total criteria score in each flooding concern area. For example, if a flooding concern area experienced 6-inches or greater of flooding in the road for 2-year, 1-hour the flooding concern area would receive score of 5. The score of 5 would then be multiplied by the pairwise weight of 1.694 and would receive the maximum total possible points in this criteria of 8.47 points. This process was performed for all criteria to calculate a total flooding score out of 100 for each of the 58 flooding concern areas. To streamline the scoring process an automated script in ArcGIS was created to analyze exported model flooding results for each of the nine (9) objective criteria.

The 58 flooding concern areas were then ranked by their total flooding score. Table 5-5 provides the total score, and whether the location is within the MS4 or CSS area for all flooding concern areas. The top eight (8) concern areas, shown in Figure 5-3, are highlighted in red and represent the proposed priority flooding areas for flood mitigation alternatives analysis. The orange coloring indicates that these concern areas will be considered in the second phase of projects, and the yellow coloring indicates that the areas will be prioritized in the third phase.

Table 5-5. Flood Scoring Results for All Concern Areas.

Concern Area	Total Score	Location		Concern Area	Total Score	Location
CA_36*	79.26	CSS		CA_56	36.05	MS4
CA_12*	64.95	MS4		CA_50	34.77	CSS
CA_38*	63.05	CSS		CA_09	34.62	MS4
CA_37*	60.81	CSS		CA_20	34.62	MS4
CA_35[a]	55.48	CSS		CA_05	33.94	MS4
CA_34*	51.44	CSS		CA_29	33.02	CSS
CA_28[b]	49.21	CSS		CA_01	31.58	MS4
CA_19[c]	49.05	MS4		CA_52	30.18	CSS
CA_45*	48.66	CSS		CA_24	28.06	MS4
CA_30*	48.20	CSS		CA_22	27.05	MS4
CA_44[b]	47.00	CSS		CA_51	26.05	CSS
CA_10*	46.01	MS4		CA_18	25.14	MS4
CA_49	45.40	CSS		CA_48	24.30	CSS
CA_33	45.16	CSS		CA_41	24.17	CSS
CA_31	45.08	CSS		CA_58	20.67	MS4
CA_13	44.46	MS4		CA_16	20.55	MS4
CA_08	43.97	MS4		CA_55	18.85	CSS
CA_43	43.91	CSS		CA_53	18.34	CSS
CA_14	43.59	MS4		CA_40	17.64	CSS
CA_11	42.66	MS4		CA_07	16.47	MS4
CA_42	41.74	CSS		CA_02	16.25	MS4
CA_46	41.74	CSS		CA_27	14.12	MS4
CA_47	41.74	CSS		CA_03	14.04	MS4
CA_21	41.58	MS4		CA_25	14.02	MS4
CA_15	41.02	MS4		CA_17	11.68	MS4
CA_54	40.37	CSS		CA_04	10.65	MS4
CA_23	38.08	MS4		CA_26	9.99	MS4
CA_39	36.84	CSS		CA_57	4.37	MS4
CA_32	36.58	CSS		CA_06	0.00	MS4

Highest Scoring Flooding Concern Area (First Phase of Project Evaluations)

Medium Scoring Flooding Concern Area (Second Phase of Project Evaluations)

Lowest Scoring Flooding Concern Area (Third Phase of Project Evaluations)

Footnotes:
* = Top 8 Flooding Concern Area Selected for Alternatives Planning
a = Not selected due to area in MDOT jurisdiction and proximity to tunnel.
b = Not selected due to City already in the process of constructing a project to reduce flooding in this area.
c = Not selected due to being out of City jurisdiction with Ingham County Drain Commission.

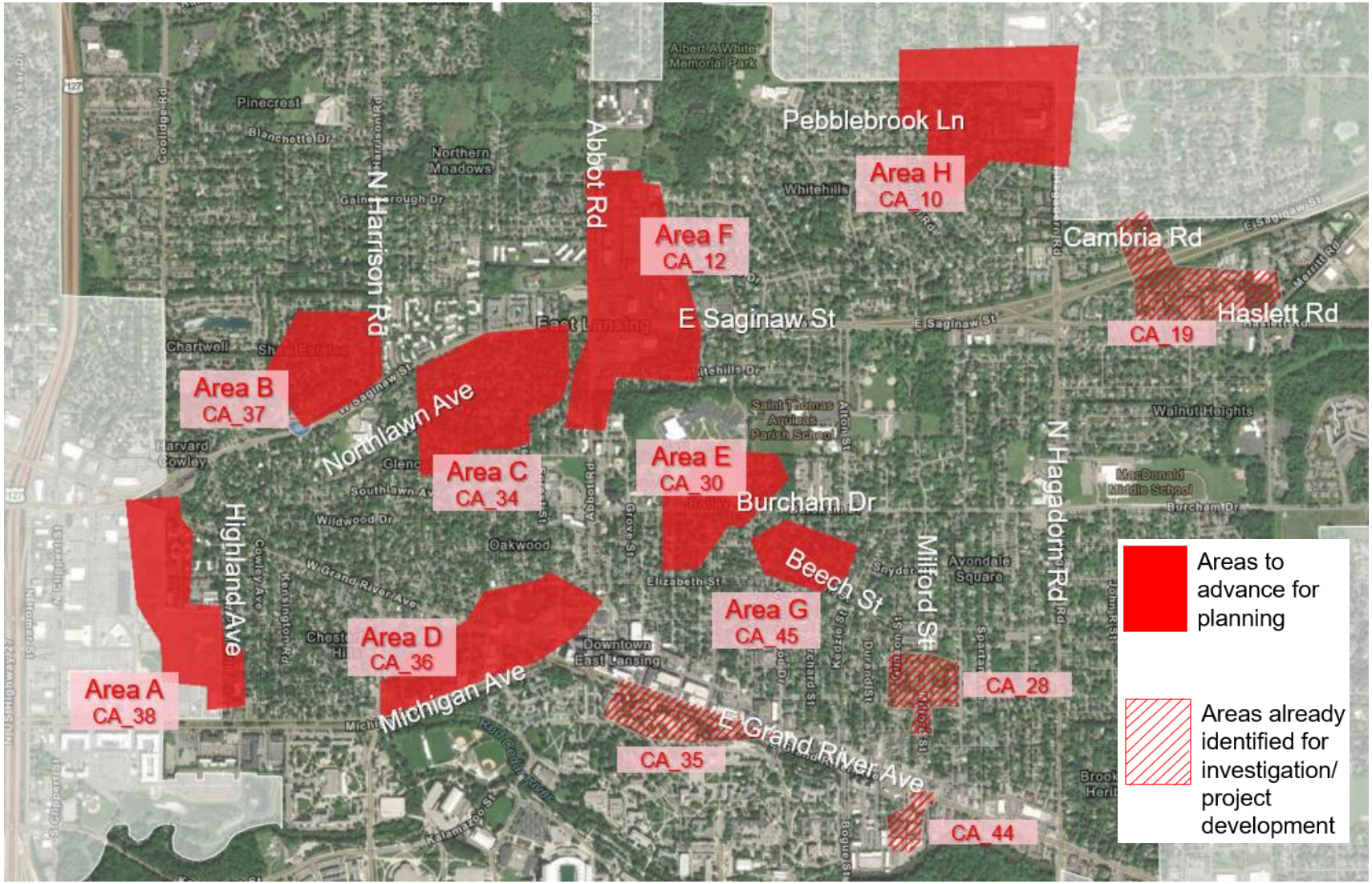


Figure 5-3. Location of the Eight (8) Proposed Priority Flooding Concern Areas.

A workshop, hosted by HDR, provided time to discuss the top eight (8) scoring flood concern areas with the City to gain their input on the results. The next step is to solicit public feedback during focus group meetings with invited stakeholders. During the meetings the City along with HDR staff will present the methodology and the proposed areas for project planning as part of the WWRP.

5.1.7 Social Vulnerability Overlay

To develop a comprehensive WWRP for the City, it is critical that environmental justice and equity are layered into the existing conditions assessment and considered as part of the project prioritization. To accomplish this a social vulnerability index (SVI) overlay was developed from the two-part social vulnerability analysis conducted as part of the Task 2 Stormwater Resilience Framework report. For information on how this layer was developed refer to the Stormwater Infrastructure Resilience Framework Report. Figure 5-4 below provides an overview of the SVI overlay results onto flooding concern areas.

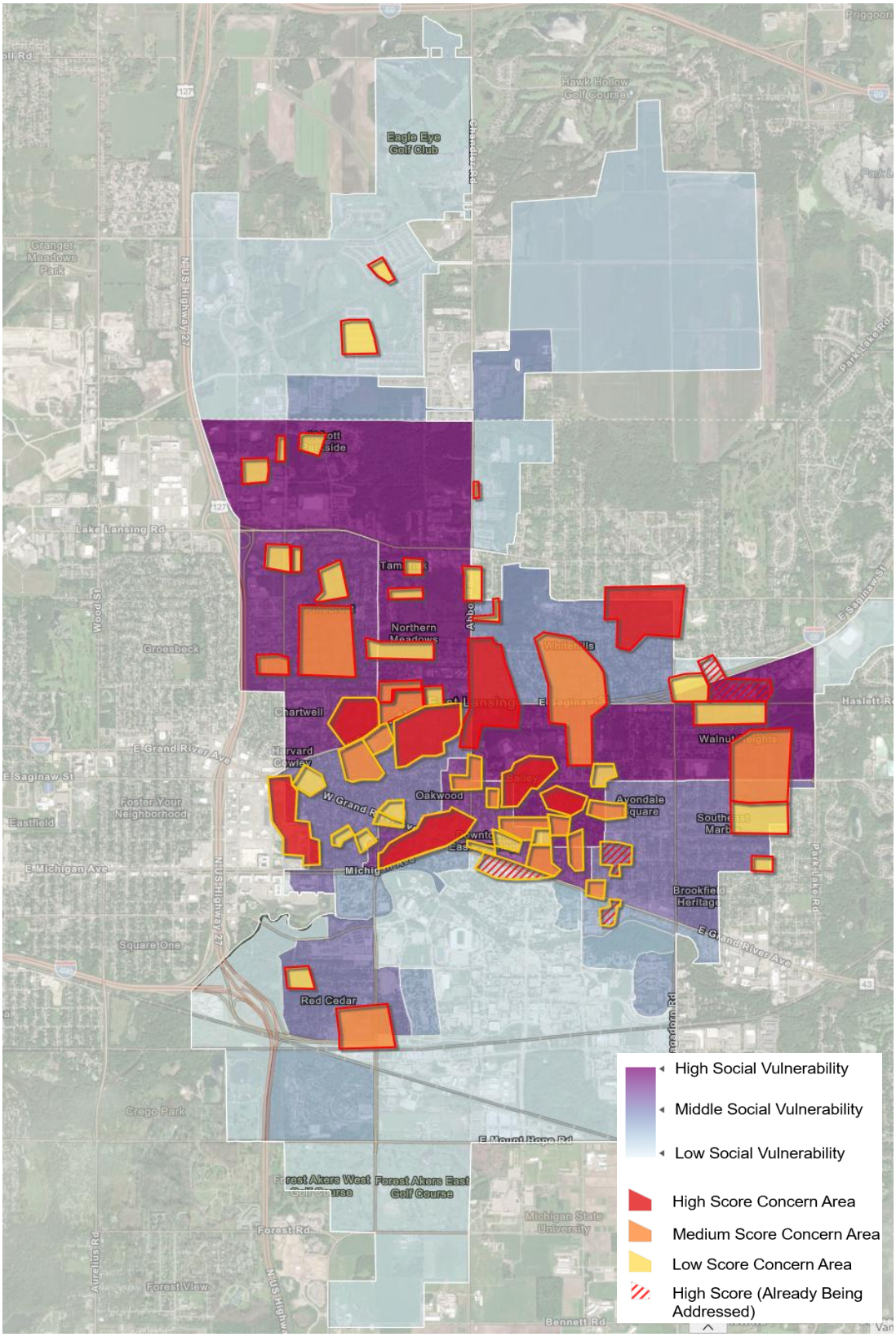


Figure 5-4. SVI Overlay with Scored Flooding Concern Areas.

6 Summary and Conclusions

The East Lansing CSS model was most recently updated by Tetra Tech in 2017 using InfoSWMM software. Because the InfoSWMM software is being phased out within the next two years, it was necessary to convert the model to a new software platform. Ultimately, InfoWorks ICMSIM was the software selected for the model conversion. In addition to the model conversion, the model was expanded to include the MS4 area and a 2D surface was developed to model overland flooding and surface drainage patterns.

As part of the model conversion effort, a flow and rainfall monitoring survey was conducted. This survey was conducted from July to November 2024. Data was collected at five (5) flow monitors, three (3) level sensors, and four (4) rain gauges. From this data, five (5) wet weather events were selected for use with the MS4 model calibration.

The MS4 model was calibrated according to model calibration best practice guidelines to ensure the model would be sufficient for the purpose of assessing existing conditions and identifying flooding concern areas. As the calibration results overall were within the defined criteria, and the modeled hydrographs generally matched well with the observed hydrographs, the MS4 model area was deemed sufficiently calibrated. The CSS model was calibrated for dry and wet weather with the purpose of matching the converted InfoWorks ICM model to the Tetra Tech calibration results from 2017.

To validate the combined model, rainfall data from the June and July 2024 storm events, which resulted in severe flooding in the City, were input to the model and used to simulate 2D surface flooding. During a workshop with the City, flooding results were compared to street flooding public complaint data and City staff observations to verify that the model captured the flooding from these events. Overall, the areas of the City with recorded street flooding generally matched the flooding results from the model. From the workshop and discussions with the City, this model was considered validated for the purposes of assessing existing conditions.

The primary purpose of the updated MS4 and CSS model was to identify flooding concern areas throughout the city, and to identify the areas to prioritize in the first phase of projects. The existing condition assessment, which used the current 25-Year, 1-hour design storm, identified 58 flooding concern areas.

To prioritize the flooding concern areas, nine (9) objective criteria were defined to measure, and ultimately score each concern area. A pairwise analysis was conducted to determine the relative importance of each of the nine (9) objective criteria. Through this analysis, in order of relative importance, the following objective criteria were determined and used to assign a numerical weighting to each concern area score:

1. Basement Flooding – CSS Surcharge
2. Roadway Flooding Depth Critical Facility
3. Building Flooding Type
4. Surface Flooding – CSS Area
5. Building Flooding Frequency
6. Roadway Flooding Location
7. Flooding Extent
8. Roadway Flooding Frequency
9. Parking Lot Flooding

The resulting flooding score was then compared to a social vulnerability overlay, which was developed using the CDC SVI. This comparison was critical to ensure that economical and socially vulnerable communities and neighborhoods were thoroughly considered for project prioritization.

Following the existing conditions assessment, the 58 concern areas were ranked and grouped into three phases of projects, with the first phase containing the top eight (8). These areas are shown below in Table 6-1.

Table 6-1. Top 8 Flooding Concern Areas.

Flooding Concern Area	Location
A	Highland Ave. and Westview Ave.
B	N Harrison Rd. and E Saginaw St.
C	Northlawn Ave.
D	Michigan Ave. and W Grand River Ave.
E	Burcham Dr.
F	Abbot Rd. and E Saginaw St.
G	Beech St.
H	Pebblebrook Ln.

Appendix A. Flow Monitor Installation Reports

EAST LANSING

Flow Monitoring
Site Installation Report

ADS ENVIRONMENTAL SERVICES®

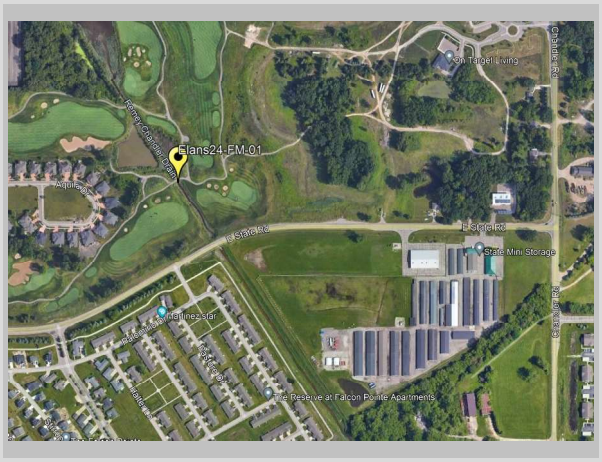
SITE I.D.

ELANS24-FM-01

Site Address / Location:	Under golf path, N of E State Rd. Between E State, and Thoroughbred
Site Access:	Drive

Monitor Series	Location Type
Foresite- UL	Temporary
GPS Coordinates	**Pipe Shape**
42.78628, -84.491455	Elliptical

Manhole #	System Characteristics
N/A	Other
Access	**Traffic**
Walk (Commercial)	None









ADS Crew Leader:	Jimmy Hinton
ADS Field Manager:	Tom Pientak

Installation Information

Installation Date:	Installation Type:
Friday July 12 2024	Level Only
Monitoring Location (Sensors):	**Monitor Location:**
Drainage ditch	On pipe
Sensors / Devices:	**Pressure Sensor Range (psi)**
Foresite Depth	N/A

Installation Confirmation:

Confirmation Time:	Pipe Size (HxW) (in)
11:18 am	140.25 x 213
Depth of Flow (Wet DOF) (in)	**Range (Air DOF) (in)**
52.5	80.91
Downlooker Physical Offset (in)	**Measurement Confidence (in)**
N/A	N/A
Peak Velocity (fps)	**Velocity Sensor Offset (in)**
N/A	N/A
Silt (in)	**Silt Type**
N/A	N/A

Hydraulic Comments:
Slow, smooth flow

Manhole / Pipe Information:

Manhole Depth (Approx. FT):	Manhole Configuration
N/A	N/A
Manhole Material:	**Manhole Condition:**
-N/A	N/A
Manhole Opening Diameter (in)	**Manhole Diameter (Approx.):**
N/A	-N/A
Manhole Cover	**Manhole Frame**
N/A	N/A
Active Drop Connections	**Air Quality (O2, LEL, H2S, CO):**
N/A	20.8, 0, 0, 0
Pipe Material	**Pipe Condition:**
Corrugated Metal Pipe	Good

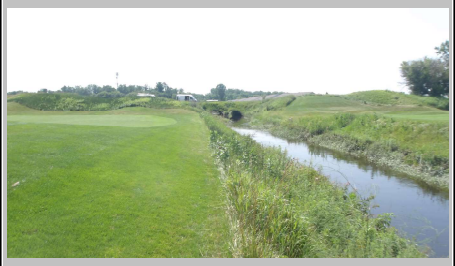
Communication Information:

Communication Type	Antenna Location
Wireless	On pipe

Additional Site Info. / Comments:

S/N: 20130

Additional Photos

Drive Access (E State Rd)	Drive Access/ Location	Location
		
Recon Down	Recon Location	

EAST LANSING

Flow Monitoring
Site Installation Report

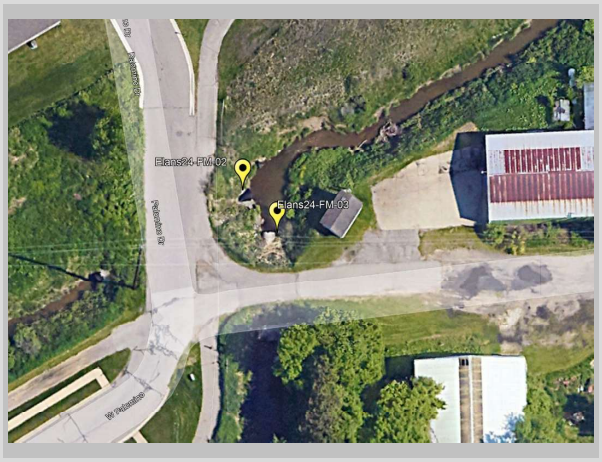
SITE I.D.

ELANS24-FM-02

Site Address / Location:	S of 3922 Palomino Dr
Site Access:	Drive

Monitor Series	Location Type
Triton+	Temporary
GPS Coordinates	**Pipe Shape**
42.782095, -84.48845	Elliptical

Manhole #	System Characteristics
N/A	Other
Access	**Traffic**
Drive	Light









ADS Crew Leader:	Jimmy Hinton
ADS Field Manager:	Tom Pientak

Installation Information

Installation Date:	Installation Type:
Wednesday July 17 2024	Doppler Standard Ring and Crank
Monitoring Location (Sensors):	**Monitor Location:**
Upstream 0-5 FT	On pipe
Sensors / Devices:	**Pressure Sensor Range (psi)**
AV/Max (CS9) & Paradepth (CS8)	0 - 10 psi

Installation Confirmation:

Confirmation Time:	Pipe Size (HxW) (in)
12:16 pm	62x60
Depth of Flow (Wet DOF) (in)	**Range (Air DOF) (in)**
12.21	46.15
Downlooker Physical Offset (in)	**Measurement Confidence (in)**
3.63	0.38"
Peak Velocity (fps)	**Velocity Sensor Offset (in)**
0.58	-
Silt (in)	**Silt Type**
0	-

Hydraulic Comments:
Slow, smooth flow

Manhole / Pipe Information:

Manhole Depth (Approx. FT):	Manhole Configuration
N/A	N/A
Manhole Material:	**Manhole Condition:**
-N/A	N/A
Manhole Opening Diameter (in)	**Manhole Diameter (Approx.):**
N/A	-N/A
Manhole Cover	**Manhole Frame**
N/A	N/A
Active Drop Connections	**Air Quality (O2, LEL, H2S, CO):**
N/A	20.8, 0, 0, 0
Pipe Material	**Pipe Condition:**
Corrugated Metal Pipe	Good

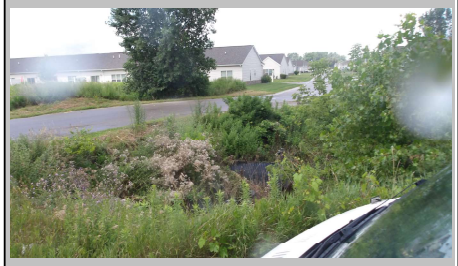
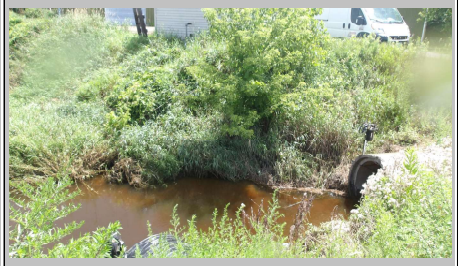
Communication Information:

Communication Type	Antenna Location
Wireless	On meter

Additional Site Info. / Comments:

SN: 40515
Flow from the West, next to Elans24-FM-03.

Additional Photos

Drive Access (Palomino Dr)	Location	Drive Access (service drive)
		
Location		
		
Recon Down	**Recon Location**	

EAST LANSING

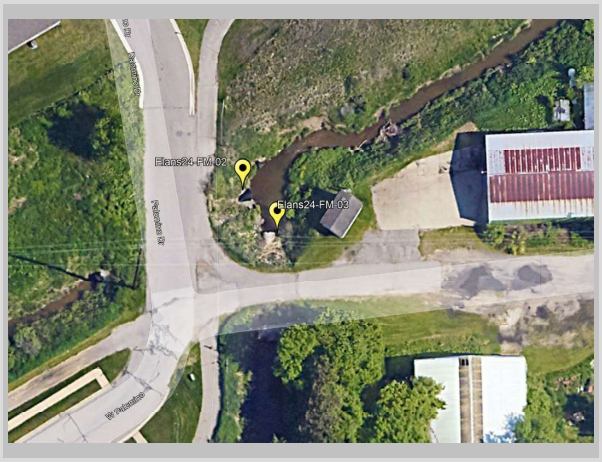
Flow Monitoring
Site Installation Report

SITE I.D.

ELANS24-FM-03

Site Address / Location:	S of 3922 Palomino Dr
Site Access:	Drive

Monitor Series	Location Type
Triton+	Temporary
GPS Coordinates	**Pipe Shape**
42.782047, -84.488411	Elliptical



Manhole #	System Characteristics
N/A	Other
Access	**Traffic**
Drive	Light







ADS Crew Leader:	Jimmy Hinton
ADS Field Manager:	Tom Pientak

Installation Information

Installation Date:	Installation Type:
Wednesday July 17 2024	Doppler Special Installation
Monitoring Location (Sensors):	**Monitor Location:**
Upstream 0-5 FT	In drainage pipe
Sensors / Devices:	**Pressure Sensor Range (psi)**
AV/Max (CS9) & Paradepth (CS8)	0 - 10 psi

Installation Confirmation:

Confirmation Time:	Pipe Size (HxW) (in)
12:36 pm	59.63x58.88
Depth of Flow (Wet DOF) (in)	**Range (Air DOF) (in)**
12.74	44
Downlooker Physical Offset (in)	**Measurement Confidence (in)**
2.88	0.38"
Peak Velocity (fps)	**Velocity Sensor Offset (in)**
1.27	-
Silt (in)	**Silt Type**
0	-

Hydraulic Comments:
Slow, smooth flow

Manhole / Pipe Information:

Manhole Depth (Approx. FT):	Manhole Configuration
N/A	N/A
Manhole Material:	**Manhole Condition:**
N/A	N/A
Manhole Opening Diameter (in)	**Manhole Diameter (Approx.):**
N/A	N/A
Manhole Cover	**Manhole Frame**
N/A	N/A
Active Drop Connections	**Air Quality (O2, LEL, H2S, CO):**
N/A	20.8, 0, 0, 0
Pipe Material	**Pipe Condition:**
Concrete	Good

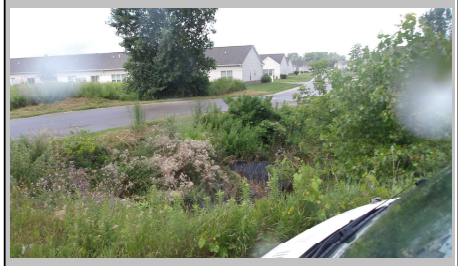
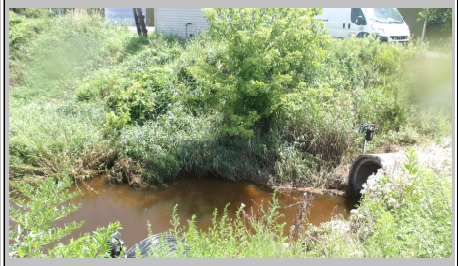
Communication Information:

Communication Type	Antenna Location
Wireless	On meter

Additional Site Info. / Comments:

SN: 49536
Flow from the South, next to Elans24-FM-02.

Additional Photos

Drive Access (Palomino Dr)	Location	Drive Access (service drive)
		
Location		
		
Recon Down	**Recon Location**	

EAST LANSING

Flow Monitoring
Site Installation Report

ADS ENVIRONMENTAL SERVICES®

SITE I.D.

ELANS24-FM-04

Site Address / Location:	E of Chandler Rd, S of Springer Way
Site Access:	Drive

Monitor Series	Location Type
Foresite- UL	Temporary
GPS Coordinates	**Pipe Shape**
42.782215, -84.483536	Basket Handle



Manhole #	System Characteristics
N/A	Other
Access	**Traffic**
Drive	Light







ADS Crew Leader:	Jimmy Hinton
ADS Field Manager:	Tom Pientak

Installation Information

Installation Date:	Installation Type:
Thursday July 11 2024	Level Only
Monitoring Location (Sensors):	**Monitor Location:**
Drainage ditch	On pipe
Sensors / Devices:	**Pressure Sensor Range (psi)**
Foresite Depth	N/A

Installation Confirmation:

Confirmation Time:	Pipe Size (HxW) (in)
2:00 pm	119.5x254.5
Depth of Flow (Wet DOF) (in)	**Range (Air DOF) (in)**
28	118.5
Downlooker Physical Offset (in)	**Measurement Confidence (in)**
N/A	N/A
Peak Velocity (fps)	**Velocity Sensor Offset (in)**
N/A	N/A
Silt (in)	**Silt Type**
N/A	N/A

Hydraulic Comments:

Drainage flow

Manhole / Pipe Information:

Manhole Depth (Approx. FT):	Manhole Configuration
N/A	N/A
Manhole Material:	**Manhole Condition:**
N/A	N/A
Manhole Opening Diameter (in)	**Manhole Diameter (Approx.):**
N/A	N/A
Manhole Cover	**Manhole Frame**
N/A	N/A
Active Drop Connections	**Air Quality (O2, LEL, H2S, CO):**
N/A	20.8, 0, 0, 0
Pipe Material	**Pipe Condition:**
Corrugated Metal Pipe	Good

Communication Information:

Communication Type	Antenna Location
Wireless	On sensor

Additional Site Info. / Comments:

S/N: 20147

Additional Photos

Location	Drive Access (Chandler Rd)	
		
Recon Down	Recon Location	

EAST LANSING

Flow Monitoring
Site Installation Report

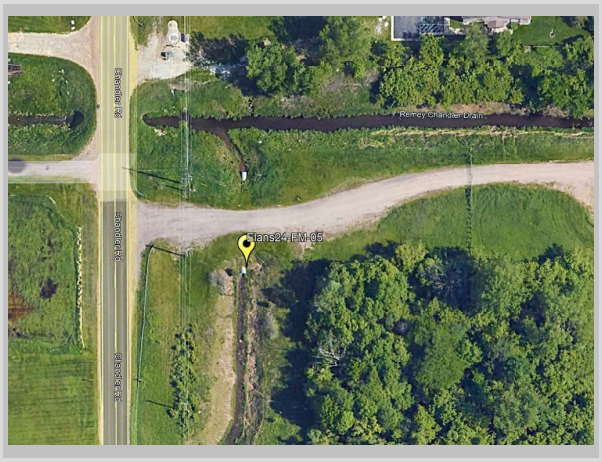
ADS ENVIRONMENTAL SERVICES®

SITE I.D.

ELANS24-FM-05

Site Address / Location:	E of Chandler Rd, S of Springer Way, SE of Elans24-FM-04
Site Access:	Drive

Monitor Series	Location Type
Triton+	Temporary
GPS Coordinates	**Pipe Shape**
42.781876, -84.483234	Circular



Manhole #	System Characteristics
N/A	Other
Access	**Traffic**
Drive	Light







ADS Crew Leader:	Jimmy Hinton
ADS Field Manager:	Tom Pientak

Installation Information

Installation Date:	Installation Type:
Thursday July 11 2024	Doppler Standard Ring and Crank
Monitoring Location (Sensors):	**Monitor Location:**
Downstream 0-5 FT	In drainage pipe
Sensors / Devices:	**Pressure Sensor Range (psi)**
AV/Max (CS9) & Paradepth (CS8)	0 - 10 psi

Installation Confirmation:

Confirmation Time:	Pipe Size (HxW) (in)
1:00 pm	54x54
Depth of Flow (Wet DOF) (in)	**Range (Air DOF) (in)**
27.52	22.85
Downlooker Physical Offset (in)	**Measurement Confidence (in)**
	0.38"
Peak Velocity (fps)	**Velocity Sensor Offset (in)**
2.01	-
Silt (in)	**Silt Type**
1.5	Soft / Loose

Hydraulic Comments:

Drainage flow

Manhole / Pipe Information:

Manhole Depth (Approx. FT):	Manhole Configuration
N/A	N/A
Manhole Material:	**Manhole Condition:**
N/A	N/A
Manhole Opening Diameter (in)	**Manhole Diameter (Approx.):**
N/A	N/A
Manhole Cover	**Manhole Frame**
N/A	N/A
Active Drop Connections	**Air Quality (O2, LEL, H2S, CO):**
N/A	20.8, 0, 0, 0
Pipe Material	**Pipe Condition:**
Corrugated Metal Pipe	Good

Communication Information:

Communication Type	Antenna Location
Wireless	On meter

Additional Site Info. / Comments:

SN: 20919

Additional Photos

Location	Drive Access (service drive)	Drive Access (Chandler Rd)
		
Recon Down	Recon Location	

EAST LANSING

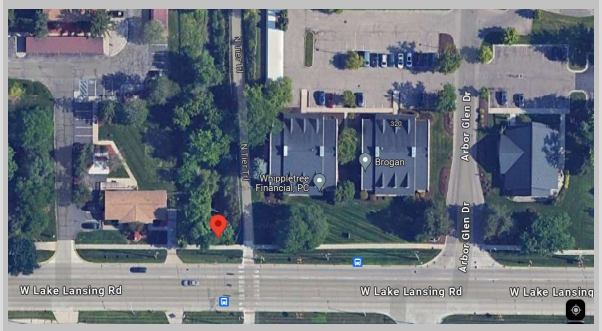
Flow Monitoring
Site Installation Report

SITE I.D.

ELANS24-FM-06

Site Address / Location:	N Tier Trail on W Lake Lansing Rd
Site Access:	Drive

Monitor Series	Location Type
Foresite- UL	Temporary
GPS Coordinates	Pipe Shape
42.759502, -84.488594	Basket Handle



Manhole #	System Characteristics
N/A	Other
Access	Traffic
Walk (Wooded)	None







ADS Crew Leader:	Jimmy Hinton
ADS Field Manager:	Tom Pientak

Installation Information

Installation Date:	Installation Type:
Friday July 12 2024	Level Only
Monitoring Location (Sensors):	Monitor Location:
Drainage Ditch	On Pipe
Sensors / Devices:	Pressure Sensor Range (psi)
Foresite Depth	N/A

Installation Confirmation:

Confirmation Time:	Pipe Size (HxW) (in)
3:09 pm	75x115.5
Depth of Flow (Wet DOF) (in)	Range (Air DOF) (in)
25.5	52.88
Downlooker Physical Offset (in)	Measurement Confidence (in)
N/A	0.38"
Peak Velocity (fps)	Velocity Sensor Offset (in)
N/A	-
Silt (in)	Silt Type
N/A	-

Hydraulic Comments:

Drainage flow

Manhole / Pipe Information:

Manhole Depth (Approx. FT):	Manhole Configuration
N/A	-N/A
Manhole Material:	Manhole Condition:
-N/A	-N/A
Manhole Opening Diameter (in)	Manhole Diameter (Approx.):
N/A	N/A
Manhole Cover	Manhole Frame
N/A	N/A
Active Drop Connections	Air Quality (O2, LEL, H2S, CO):
N/A	20.8, 0, 0, 0
Pipe Material	Pipe Condition:
Corrugated Metal Pipe	Good

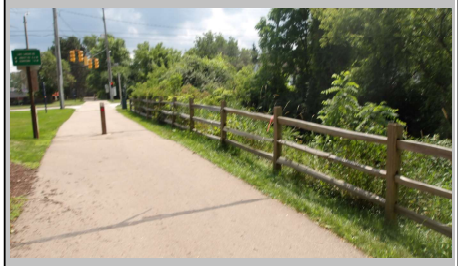
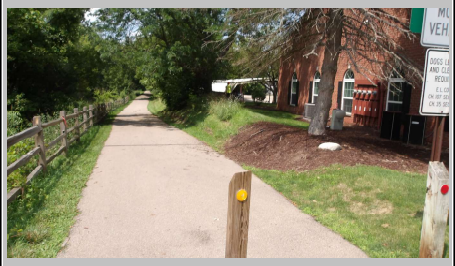
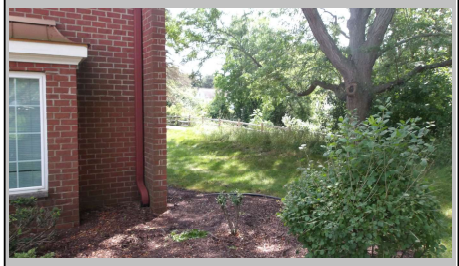
Communication Information:

Communication Type	Antenna Location
Wireless	-On sensor

Additional Site Info. / Comments:

S/N: 20144

Additional Photos

Walk Access (N Tier Trail)	Site Access (stream)	Walk Access (N Tier Trail)
		
Walk Access (trail)	**Drive Access (330 W Lake Lansing Rd)**	
		
Recon Down	**Recon Location**	

EAST LANSING

Flow Monitoring
Site Installation Report

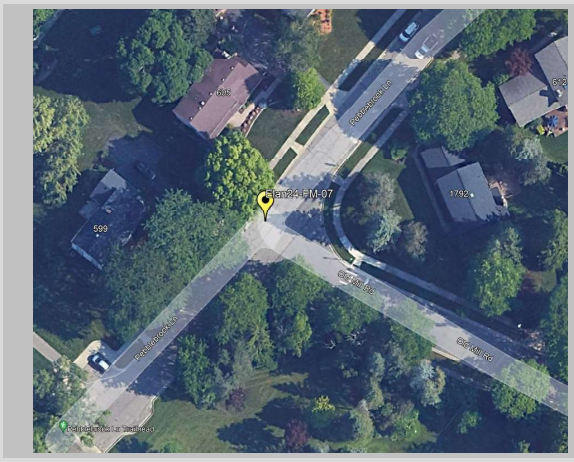
ADS ENVIRONMENTAL SERVICES®

SITE I.D.

ELANS24-FM-07

Site Address / Location:	Intersection of Old Mill Rd and Pebblebrook Ln
Site Access:	Drive

Monitor Series	Location Type
Triton+	Temporary
GPS Coordinates	**Pipe Shape**
42.753762, -84.476804	Elliptical



Manhole #	System Characteristics
N/A	Other
Access	**Traffic**
Drive	Light







ADS Crew Leader:	Jimmy Hinton
ADS Field Manager:	Tom Pientak

Installation Information

Installation Date:	Installation Type:
Thursday July 11 2024	Doppler Special Installation
Monitoring Location (Sensors):	**Monitor Location:**
Downstream 0-5 FT	Manhole
Sensors / Devices:	**Pressure Sensor Range (psi)**
AV/Max (CS9) & Paradepth (CS8)	0 - 10 psi

Installation Confirmation:

Confirmation Time:	Pipe Size (HxW) (in)
2:52 pm	53.13x54
Depth of Flow (Wet DOF) (in)	**Range (Air DOF) (in)**
17.11	33.27
Downlooker Physical Offset (in)	**Measurement Confidence (in)**
2.75	0.38"
Peak Velocity (fps)	**Velocity Sensor Offset (in)**
0.45	-
Silt (in)	**Silt Type**
0	-

Hydraulic Comments:
Slow, smooth flow

Manhole / Pipe Information:

Manhole Depth (Approx. FT):	Manhole Configuration
7.41	Single
Manhole Material:	**Manhole Condition:**
Brick	Fair
Manhole Opening Diameter (in)	**Manhole Diameter (Approx.):**
24	24
Manhole Cover	**Manhole Frame**
Unbolted	Offset
Active Drop Connections	**Air Quality (O2, LEL, H2S, CO):**
No	20.8, 0, 0, 0
Pipe Material	**Pipe Condition:**
Concrete	Good

Communication Information:

Communication Type	Antenna Location
Wireless	Drilled Pavement / Concrete

Additional Site Info. / Comments:

Additional Photos

Incoming connection 1 (48")	Incoming connection 2 (42")	Incoming connection 3 (18")
		
Manhole	**Location**	**Location**
		
Location		
		

EAST LANSING

Flow Monitoring
Site Installation Report

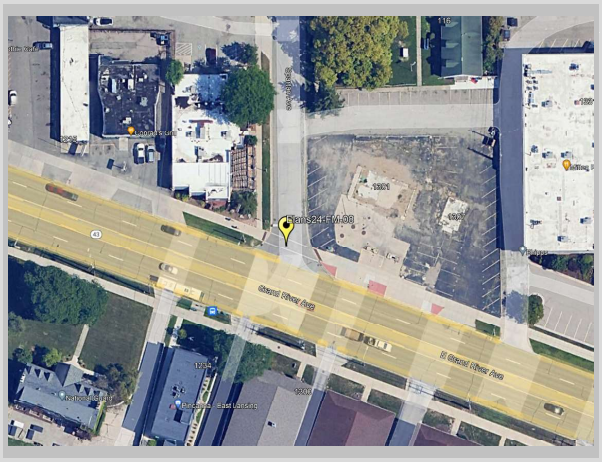
ADS ENVIRONMENTAL SERVICES®

SITE I.D.

ELANS24-FM-08

Site Address / Location:	In crosswalk of Spartan Ave, near the Grand River Ave intersection.
Site Access:	Drive

Monitor Series	Location Type
Triton+	Temporary
GPS Coordinates	**Pipe Shape**
42.730496, -84.465792	Circular



Manhole #	System Characteristics
N/A	Other
Access	**Traffic**
Drive	Light



Installation Information

Installation Date:	Installation Type:
Thursday July 11 2024	Doppler Special Installation
Monitoring Location (Sensors):	**Monitor Location:**
Upstream 0-5 FT	Manhole
Sensors / Devices:	**Pressure Sensor Range (psi)**
AV/Max (CS9) & Paradepth (CS8)	0 - 10 psi

Installation Confirmation:

Confirmation Time:	Pipe Size (HxW) (in)
3:23 pm	84x84
Depth of Flow (Wet DOF) (in)	**Range (Air DOF) (in)**
14	67.75
Downlooker Physical Offset (in)	**Measurement Confidence (in)**
2.63	0.38"
Peak Velocity (fps)	**Velocity Sensor Offset (in)**
0	-
Silt (in)	**Silt Type**
0	-

Hydraulic Comments:

Drainage flow



ADS Crew Leader:	Jimmy Hinton
ADS Field Manager:	Tom Pientak

Manhole / Pipe Information:

Manhole Depth (Approx. FT):	Manhole Configuration
	Single
Manhole Material:	**Manhole Condition:**
-	Good
Manhole Opening Diameter (in)	**Manhole Diameter (Approx.):**
24	-
Manhole Cover	**Manhole Frame**
Vented	Normal
Active Drop Connections	**Air Quality (O2, LEL, H2S, CO):**
No	20.8, 0, 0, 0
Pipe Material	**Pipe Condition:**
Concrete	Good

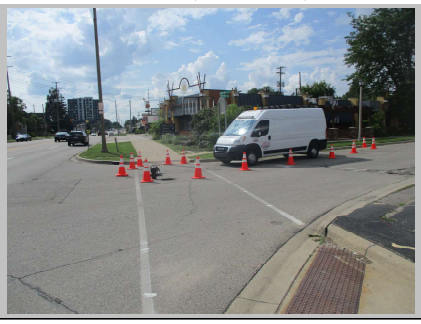
Communication Information:

Communication Type	Antenna Location
Wireless	Drilled Pavement / Concrete

Additional Site Info. / Comments:

SN: 49533

Additional Photos

Location (Spartan Ave)	Location	Location (Grand River)
		
Outgoing		
		

East Lansing, MI

Flow Monitoring
Site Installation Report

SITE I.D.

Elans24-RG-01

Site Address / Location:	East Lansing Public Works Dept., 1800 E State Rd
Site Access:	Drive

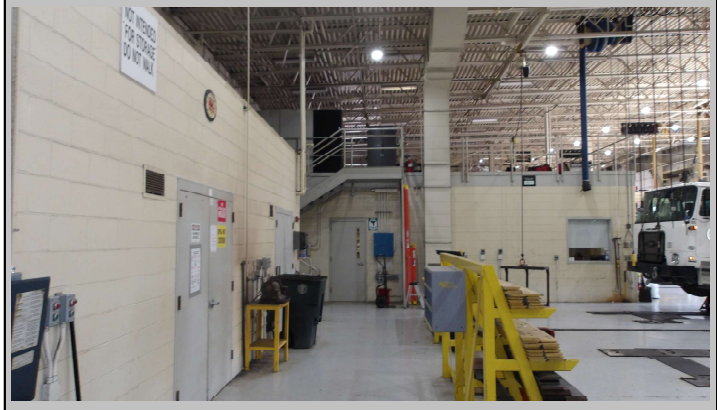
Monitor Series	Location Type
Rain Alert III	Temporary
GPS Coordinates	**Pipe Shape**
42.78608239612891, -84.510414	N/A

Manhole #	System Characteristics
N/A	Other
Access	**Traffic**
Drive	None









ADS Crew Leader:	Jimmie Hinton
ADS Field Manager:	Thomas Pientak

Installation Information

Installation Date:	Installation Type:
Thursday July 11 2024	Rain Gauge
Monitoring Location (Sensors):	**Monitor Location:**
Rooftop	Building
Sensors / Devices:	**Pressure Sensor Range (psi)**
Rain Gauge Tipping Bucket	N/A

Installation Confirmation:

Confirmation Time:	Pipe Size (HxW) (in)
	N/A
Depth of Flow (Wet DOF) (in)	**Range (Air DOF) (in)**
N/A	N/A
Downlooker Physical Offset (in)	**Measurement Confidence (in)**
N/A	N/A
Peak Velocity (fps)	**Velocity Sensor Offset (in)**
N/A	N/A
Silt (in)	**Silt Type**
N/A	N/A

Hydraulic Comments:

N/A

Manhole / Pipe Information:

Manhole Depth (Approx. FT):	Manhole Configuration
N/A	N/A
Manhole Material:	**Manhole Condition:**
N/A	N/A
Manhole Opening Diameter (in)	**Manhole Diameter (Approx.):**
N/A	N/A
Manhole Cover	**Manhole Frame**
N/A	N/A
Active Drop Connections	**Air Quality (O2, LEL, H2S, CO):**
N/A	O2=20.9, LEL=0, H2S=0, CO=0
Pipe Material	**Pipe Condition:**
N/A	N/A

Communication Information:

Communication Type	Antenna Location
Wireless	Internal

Additional Site Info. / Comments:

Additional Photos

East Lansing, MI

Flow Monitoring
Site Installation Report

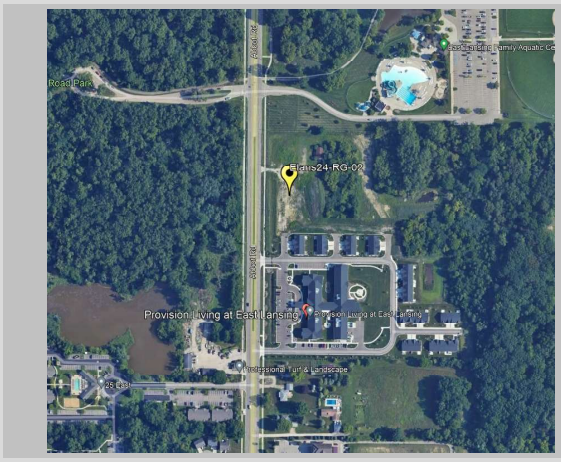
ADS ENVIRONMENTAL SERVICES®

SITE I.D.

Elans24-RG-02

Site Address / Location:	In field N of Provision Living at East Lansing, 6300 Abbot Rd.
Site Access:	Drive

Monitor Series	Location Type
Rain Alert III	Temporary
GPS Coordinates	**Pipe Shape**
42.765484109078514, -84.48307	N/A



Manhole #	System Characteristics
N/A	Other
Access	**Traffic**
Drive	None







ADS Crew Leader:	Jimmie Hinton
ADS Field Manager:	Thomas Pientak

Installation Information

Installation Date:	Installation Type:
Friday July 12 2024	Rain Gauge
Monitoring Location (Sensors):	**Monitor Location:**
Field	Field
Sensors / Devices:	**Pressure Sensor Range (psi)**
Rain Gauge Tipping Bucket	N/A

Installation Confirmation:

Confirmation Time:	Pipe Size (HxW) (in)
	N/A
Depth of Flow (Wet DOF) (in)	**Range (Air DOF) (in)**
N/A	N/A
Downlooker Physical Offset (in)	**Measurement Confidence (in)**
N/A	N/A
Peak Velocity (fps)	**Velocity Sensor Offset (in)**
N/A	N/A
Silt (in)	**Silt Type**
N/A	N/A

Hydraulic Comments:
N/A

Manhole / Pipe Information:

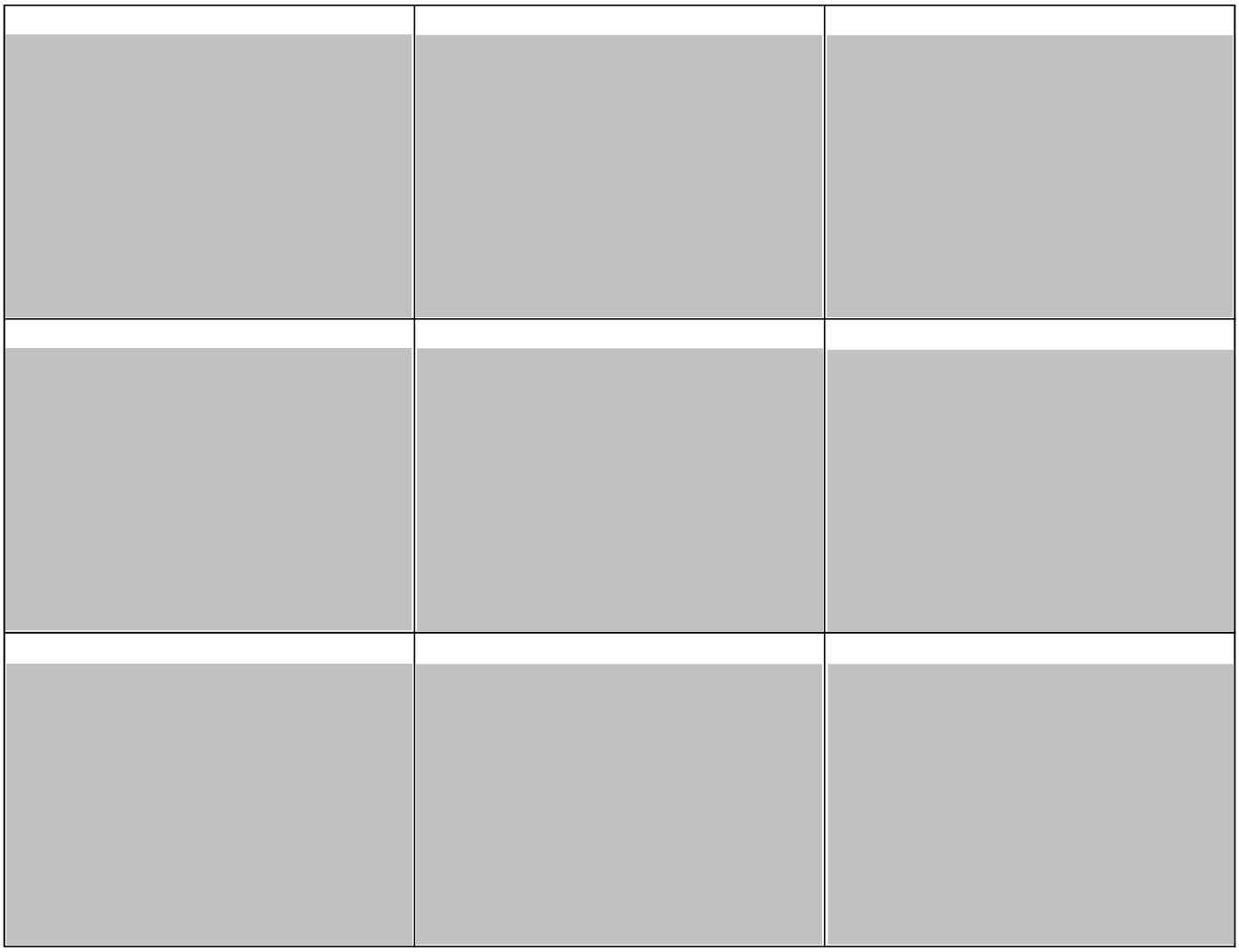
Manhole Depth (Approx. FT):	Manhole Configuration
N/A	N/A
Manhole Material:	**Manhole Condition:**
N/A	N/A
Manhole Opening Diameter (in)	**Manhole Diameter (Approx.):**
N/A	N/A
Manhole Cover	**Manhole Frame**
N/A	N/A
Active Drop Connections	**Air Quality (O2, LEL, H2S, CO):**
N/A	O2=20.9, LEL=0, H2S=0, CO=0
Pipe Material	**Pipe Condition:**
N/A	N/A

Communication Information:

Communication Type	Antenna Location
Wireless	Internal

Additional Site Info. / Comments:

Additional Photos



East Lansing, MI

Flow Monitoring
Site Installation Report

SITE I.D.

Elans24-RG-03

Site Address / Location:	East Lansing Hannah Community Center, 819 Abbot Rd
Site Access:	Drive

Monitor Series	Location Type
Rain Alert III	Temporary
GPS Coordinates	Pipe Shape
42.741554, -84.485577	N/A

Manhole #	System Characteristics
N/A	Other
Access	Traffic
Drive	None









ADS Crew Leader:	Jimmie Hinton
ADS Field Manager:	Thomas Pientak

Installation Information

Installation Date:	Installation Type:
Thursday July 11 2024	Rain Gauge
Monitoring Location (Sensors):	Monitor Location:
Rooftop	Building
Sensors / Devices:	Pressure Sensor Range (psi)
Rain Gauge Tipping Bucket	N/A

Installation Confirmation:

Confirmation Time:	Pipe Size (HxW) (in)
	N/A
Depth of Flow (Wet DOF) (in)	Range (Air DOF) (in)
N/A	N/A
Downlooker Physical Offset (in)	Measurement Confidence (in)
N/A	N/A
Peak Velocity (fps)	Velocity Sensor Offset (in)
N/A	N/A
Silt (in)	Silt Type
N/A	N/A
Hydraulic Comments:	
N/A	

Manhole / Pipe Information:

Manhole Depth (Approx. FT):	Manhole Configuration
N/A	N/A
Manhole Material:	Manhole Condition:
N/A	N/A
Manhole Opening Diameter (in)	Manhole Diameter (Approx.):
N/A	N/A
Manhole Cover	Manhole Frame
N/A	N/A
Active Drop Connections	Air Quality (O2, LEL, H2S, CO):
N/A	O2=20.9, LEL=0, H2S=0, CO=0
Pipe Material	Pipe Condition:
N/A	N/A

Communication Information:

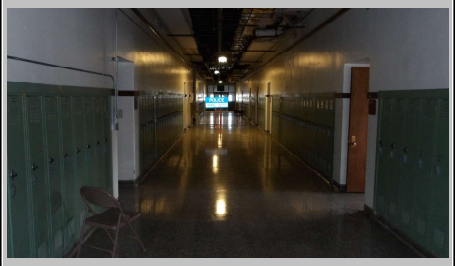
Communication Type	Antenna Location
Wireless	Internal

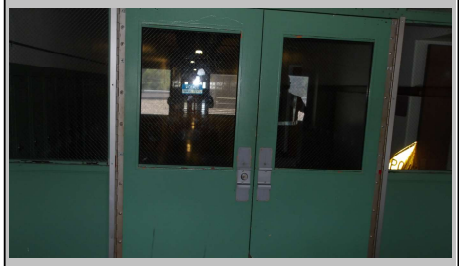
Additional Site Info. / Comments:

Additional Photos











East Lansing, MI

Flow Monitoring
Site Installation Report

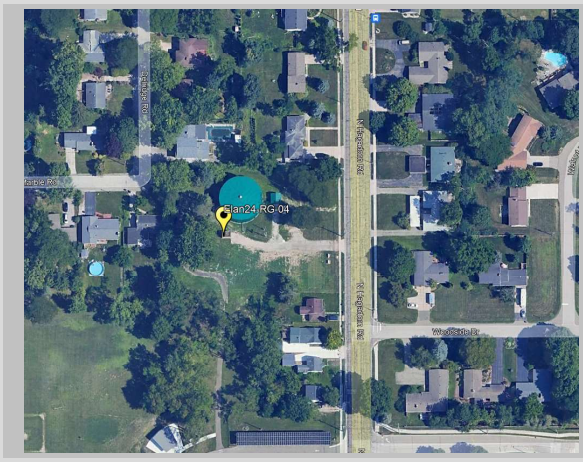
ADS ENVIRONMENTAL SERVICES®

SITE I.D.

Elans24-RG-04

Site Address / Location:	Water tower, NW of the intersection of N. Hagadorn and Woodside
Site Access:	Drive

Monitor Series	Location Type
Rain Alert III	Temporary
GPS Coordinates	Pipe Shape
42.743395787785715, -84.463116	N/A



Manhole #	System Characteristics
N/A	Other
Access	Traffic
Drive	None







ADS Crew Leader:	Jimmie Hinton
ADS Field Manager:	Thomas Pientak

Installation Information

Installation Date:	Installation Type:
Friday July 12 2024	Rain Gauge
Monitoring Location (Sensors):	Monitor Location:
Field	Field
Sensors / Devices:	Pressure Sensor Range (psi)
Rain Gauge Tipping Bucket	N/A

Installation Confirmation:

Confirmation Time:	Pipe Size (HxW) (in)
	N/A
Depth of Flow (Wet DOF) (in)	Range (Air DOF) (in)
N/A	N/A
Downlooker Physical Offset (in)	Measurement Confidence (in)
N/A	N/A
Peak Velocity (fps)	Velocity Sensor Offset (in)
N/A	N/A
Silt (in)	Silt Type
N/A	N/A
Hydraulic Comments:	
N/A	

Manhole / Pipe Information:

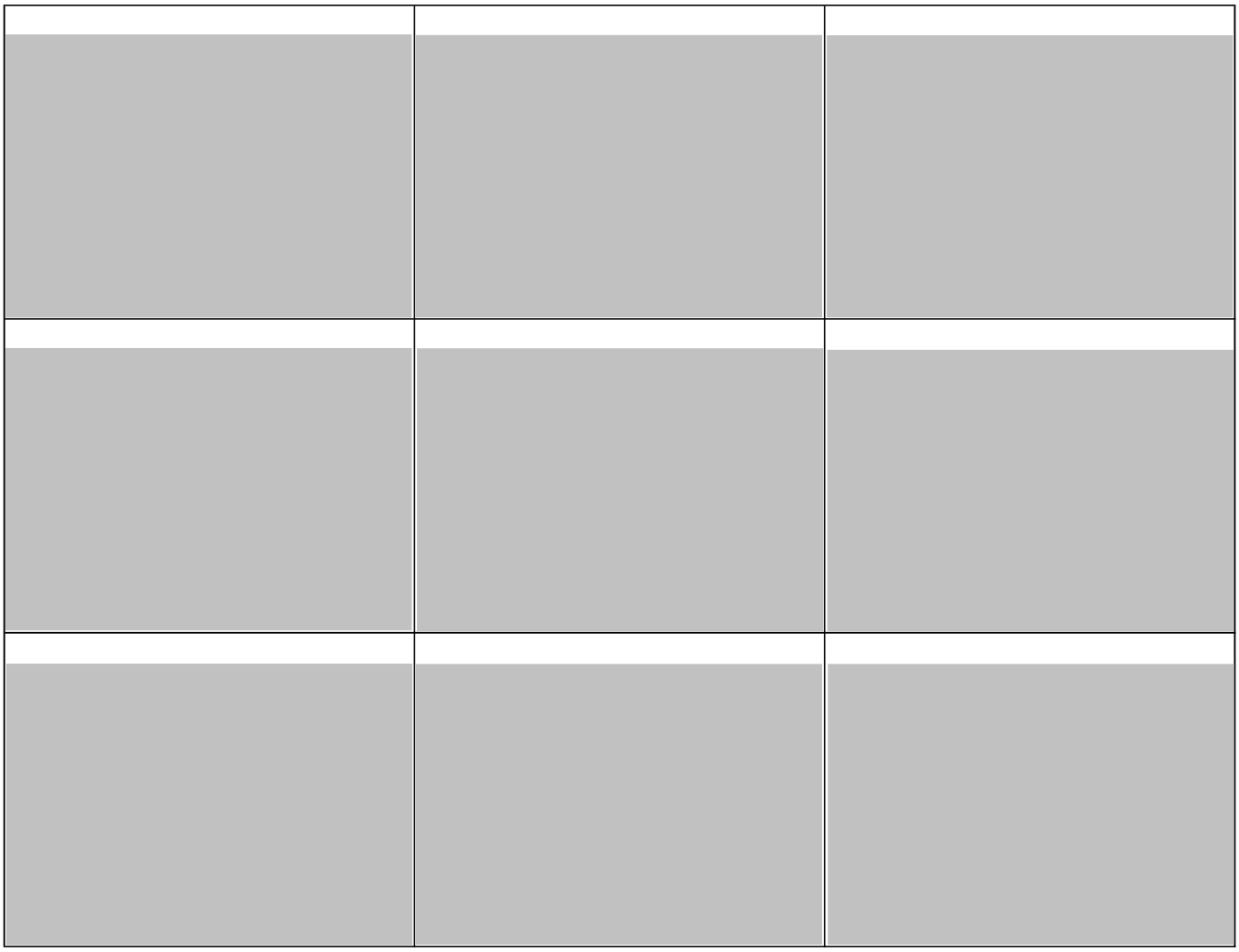
Manhole Depth (Approx. FT):	Manhole Configuration
N/A	N/A
Manhole Material:	Manhole Condition:
N/A	N/A
Manhole Opening Diameter (in)	Manhole Diameter (Approx.):
N/A	N/A
Manhole Cover	Manhole Frame
N/A	N/A
Active Drop Connections	Air Quality (O2, LEL, H2S, CO):
N/A	O2=20.9, LEL=0, H2S=0, CO=0
Pipe Material	Pipe Condition:
N/A	N/A

Communication Information:

Communication Type	Antenna Location
Wireless	Internal

Additional Site Info. / Comments:

Additional Photos

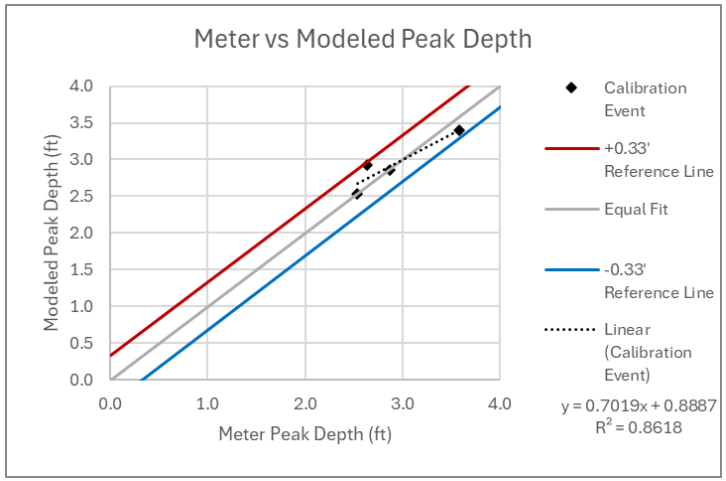


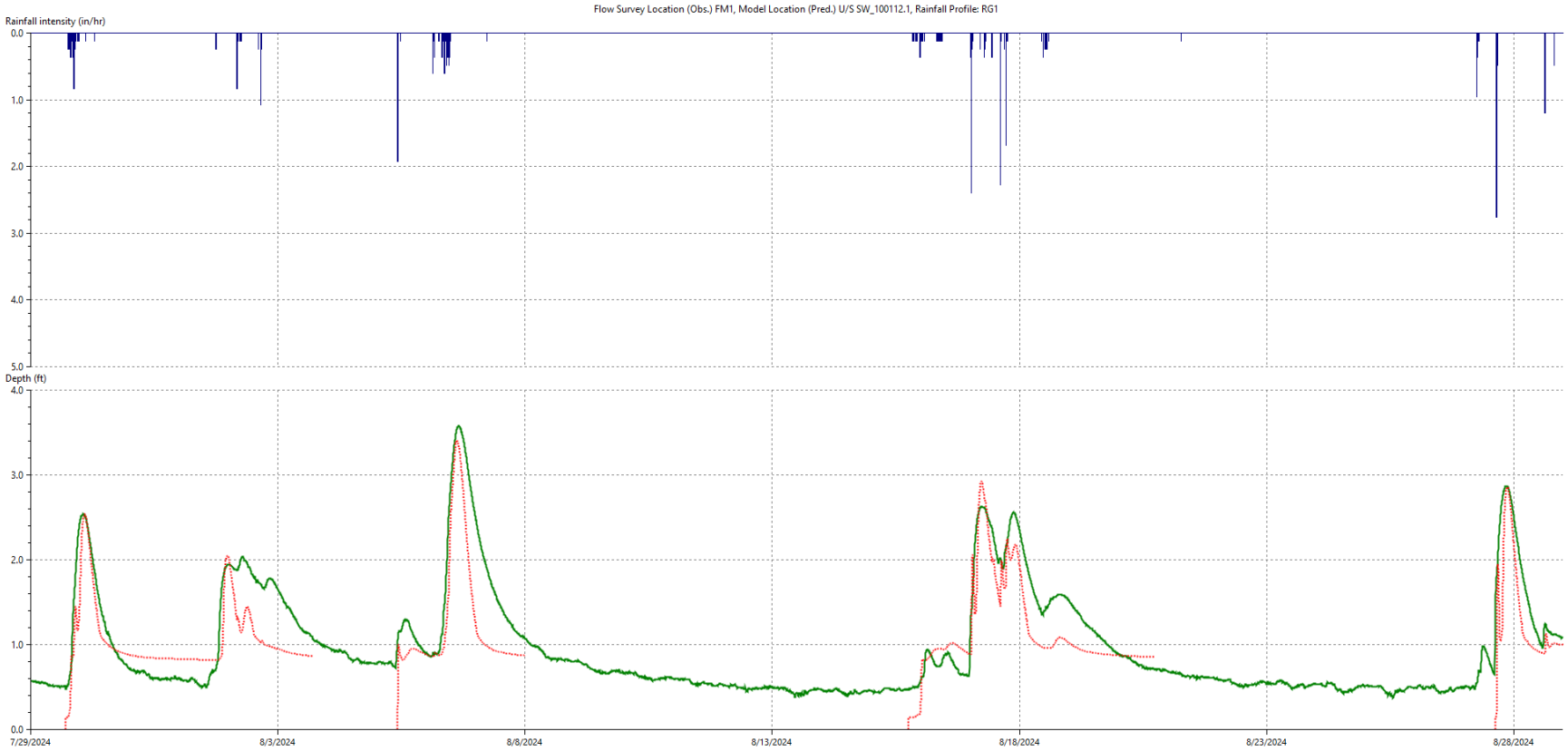
Appendix B. MS4 Calibration Results

Calibration Summary for FM1

Monitor Type: Depth

Model Assessment Summary for FM1													
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)			Peak Depth (Ft)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error	Meter	Model	Error
1	7/29/2024 17:00	13.0	0.81	0.84							2.54	2.54	0.00
3	8/5/2024 10:00	28.9	1.16	1.92							3.59	3.41	-0.18
4	8/15/2024 18:00	67.5	1.89	2.4							2.63	2.92	0.29
5	8/27/2024 15:00	10.3	1.03	2.76							2.87	2.85	-0.01

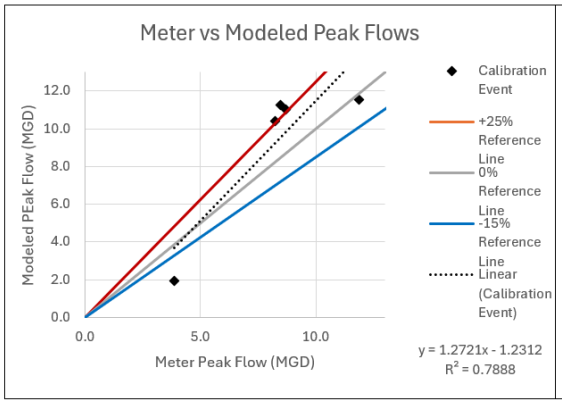


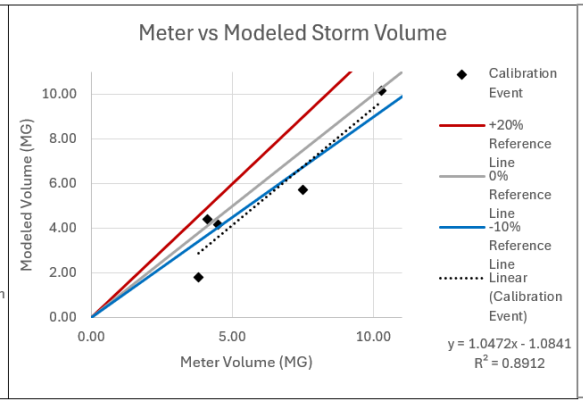

Flow Survey Location (Obs.) FM1, Model Location (Pred.) U/S SW_100112.1, Rainfall Profile: RG1
Rainfall intensity (in/hr)
0.0
1.0
2.0
3.0
4.0
5.0
Depth (ft)
4.0
3.0
2.0
1.0
0.0
7/29/2024
8/3/2024
8/8/2024
8/13/2024
8/18/2024
8/23/2024
8/28/2024

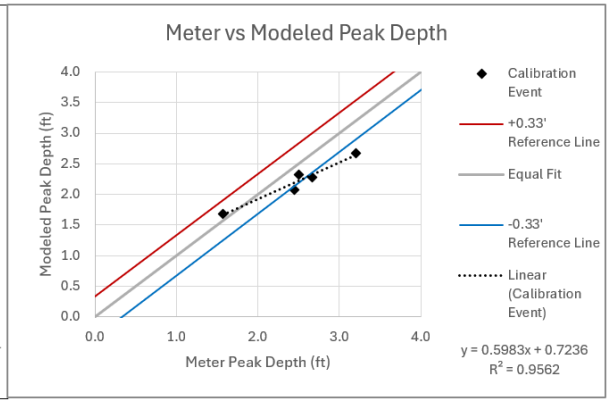
Calibration Summary for FM2

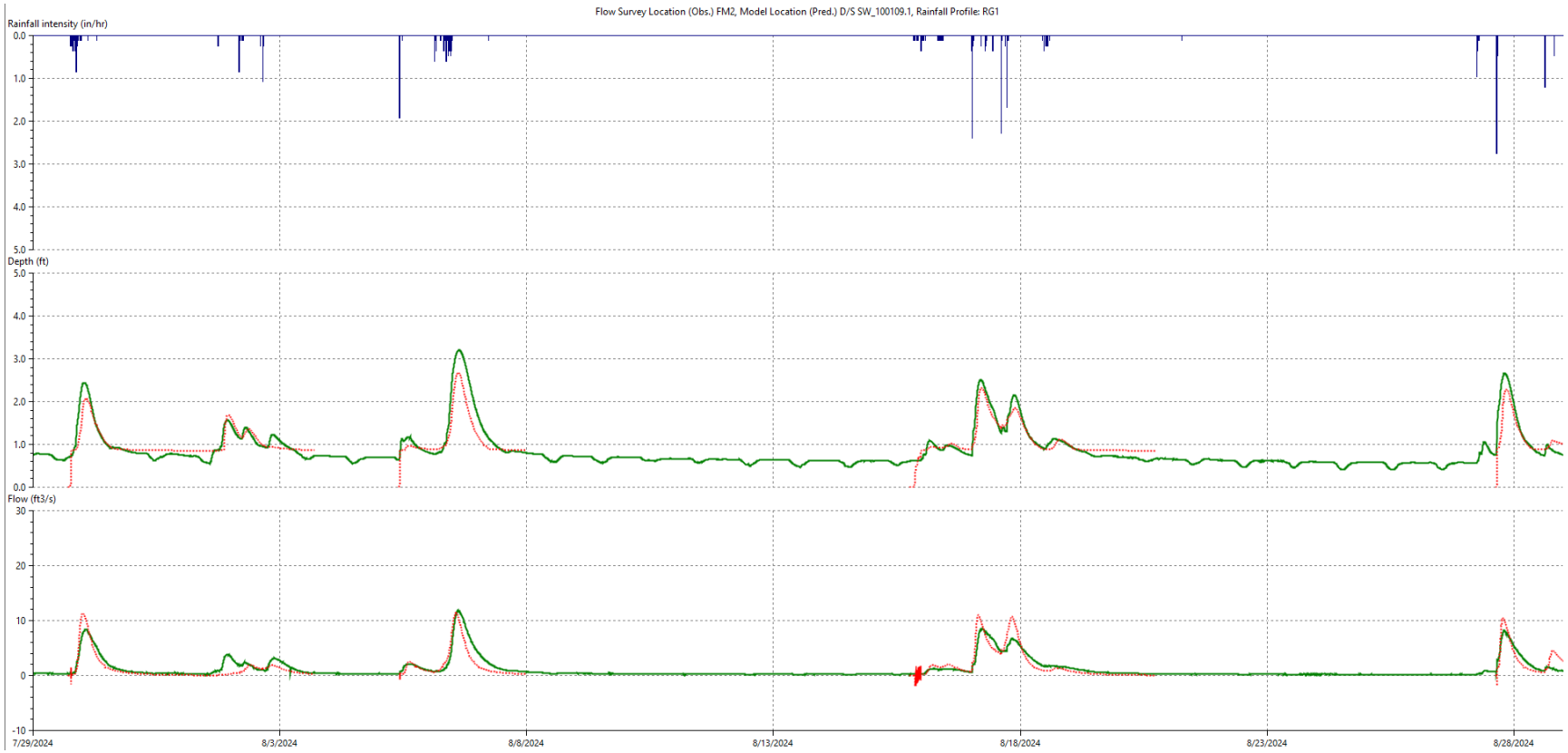
Monitor Type: Flow and Depth

Model Assessment Summary for FM2													
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)			Peak Depth (Ft)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error	Meter	Model	% Error
1	7/29/2024 17:00	13.0	0.81	0.84	8.47	11.25	33%	4.50	4.14	-8%	2.44	2.08	-0.36
2	8/1/2024 17:40	22.2	0.39	1.08	3.85	1.94	-50%	3.80	1.79	-53%	1.57	1.69	0.11
3	8/5/2024 10:00	28.9	1.16	1.92	11.89	11.55	-3%	7.51	5.71	-24%	3.21	2.67	-0.54
4	8/15/2024 18:00	67.5	1.89	2.4	8.70	11.03	27%	10.29	10.18	-1%	2.50	2.32	-0.19
5	8/27/2024 15:00	10.3	1.3	2.76	8.24	10.42	26%	4.13	4.40	7%	2.67	2.28	-0.39





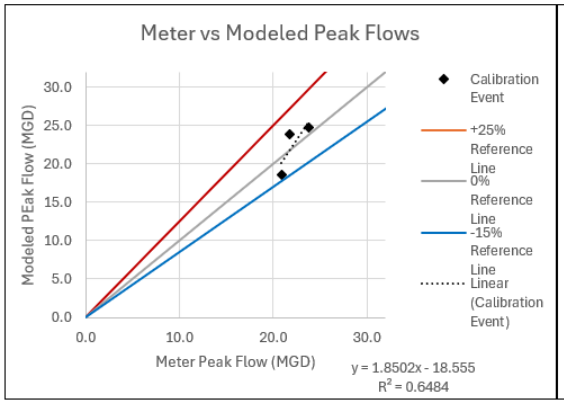


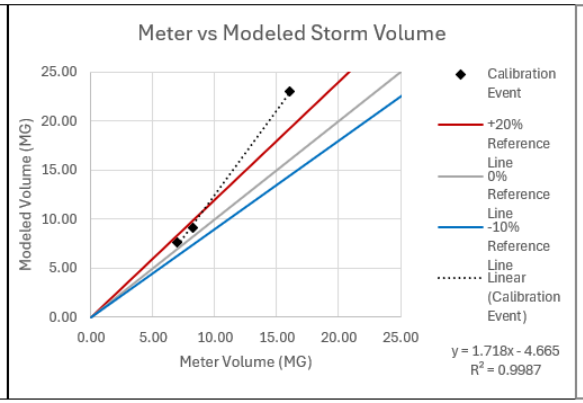

Flow Survey Location (Obs.) FM2, Model Location (Pred.) D/S SW_100109.1, Rainfall Profile: RG1
Rainfall intensity (in/hr)
0.0
1.0
2.0
3.0
4.0
5.0
Depth (ft)
5.0
4.0
3.0
2.0
1.0
0.0
Flow (ft3/s)
30
20
10
0
-10
7/29/2024
8/3/2024
8/8/2024
8/13/2024
8/18/2024
8/23/2024
8/28/2024

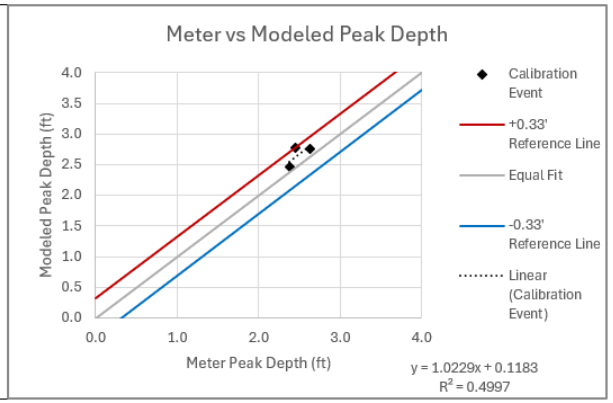
Calibration Summary for FM3

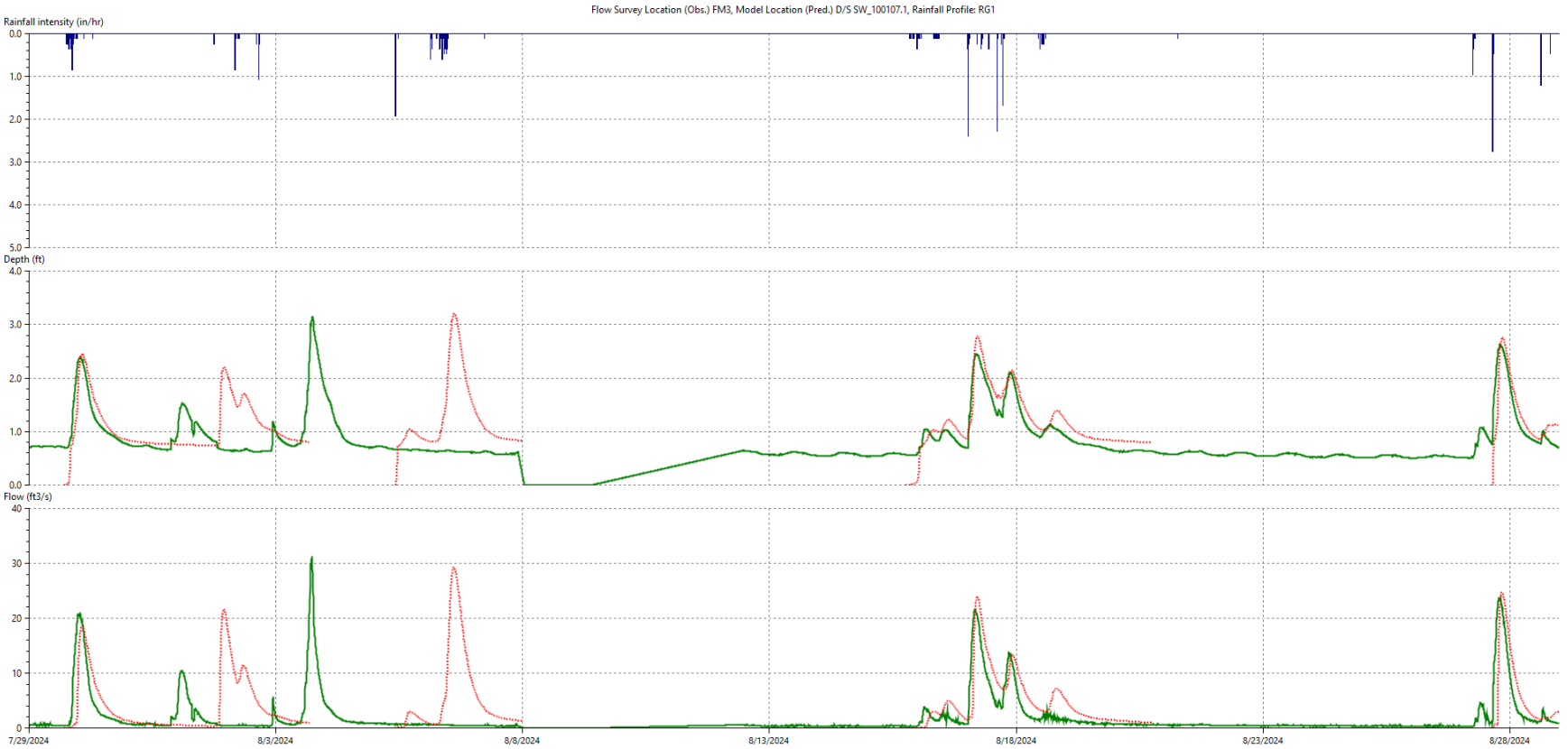
Model Type: Flow and Depth

Model Assessment Summary for FM3													
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)			Peak Depth (Ft)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error	Meter	Model	Error
1	7/29/2024 17:00	13.0	0.81	0.84	20.93	18.59	-11%	7.00	7.64	9%	2.38	2.45	0.07
4	8/15/2024 18:00	67.5	1.89	2.4	21.75	23.92	10%	16.07	22.99	43%	2.46	2.78	0.32
5	8/27/2024 15:00	10.3	1.03	2.76	23.76	24.75	4%	8.25	9.18	11%	2.63	2.76	0.13





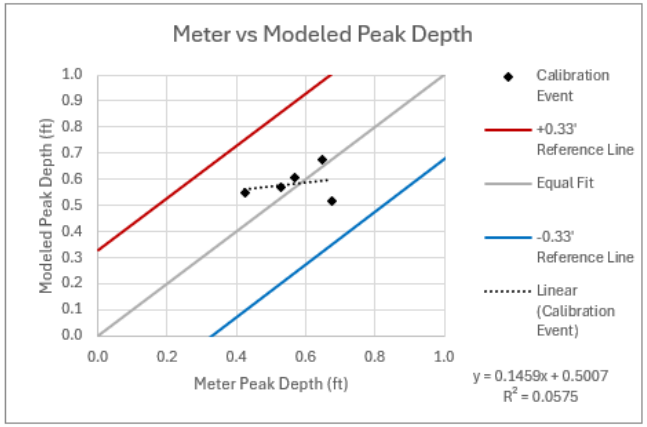


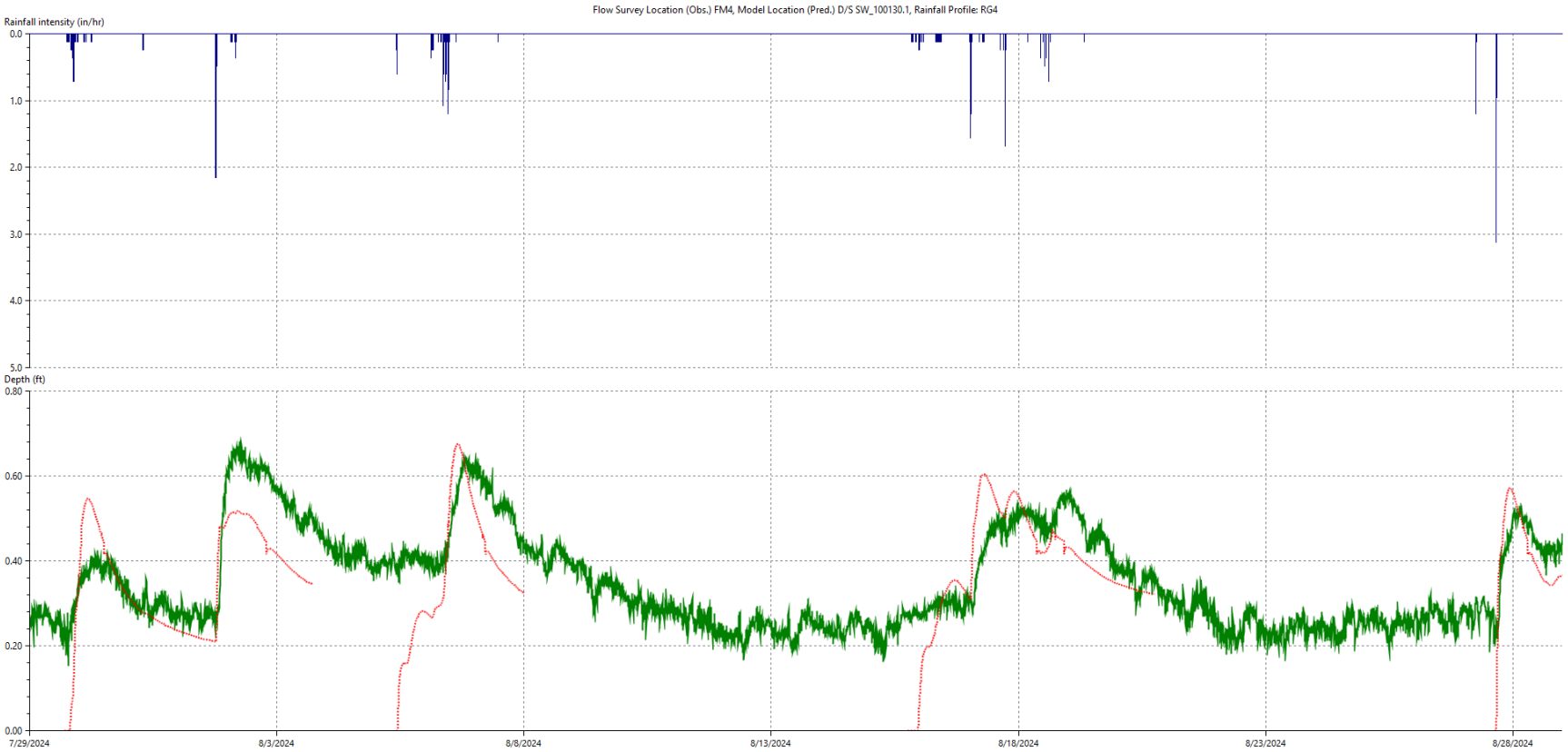

Flow Survey Location (Obs.) FM3, Model Location (Pred.) D/S SW_100107.1, Rainfall Profile: RG1
Rainfall intensity (in/hr)
0.0
1.0
2.0
3.0
4.0
5.0
Depth (ft)
4.0
3.0
2.0
1.0
0.0
Flow (ft3/s)
40
30
20
10
0
7/29/2024
8/3/2024
8/8/2024
8/13/2024
8/18/2024
8/23/2024
8/28/2024

Calibration Summary for FM4

Monitor Type: Depth

Model Assessment Summary for FM4													
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)			Peak Depth (Ft)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error	Meter	Model	Error
1	7/29/2024 17:00	13.0	0.66	0.72							0.42	0.55	0.12
2	8/1/2024 17:40	22.2	0.89	2.16							0.68	0.52	-0.16
3	8/5/2024 10:00	28.9	1.16	1.2							0.65	0.68	0.03
4	8/15/2024 18:00	67.5	1.61	1.68							0.57	0.61	0.04
5	8/27/2024 15:00	10.3	0.74	3.12							0.53	0.57	0.04

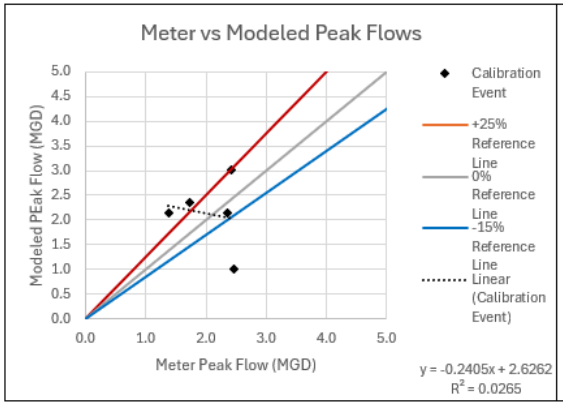


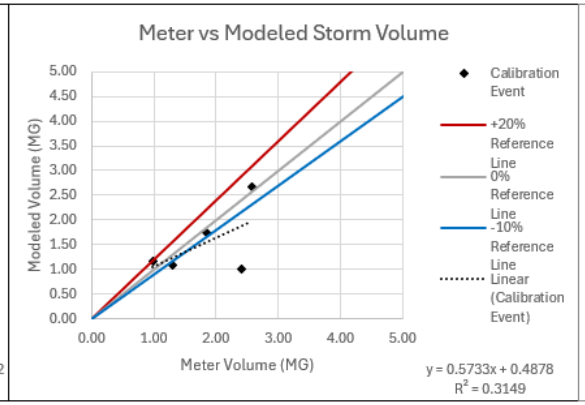

Flow Survey Location (Obs.) FM4, Model Location (Pred.) D/S SW_100130.1, Rainfall Profile: RG4
Rainfall intensity (in/hr)
0.0
1.0
2.0
3.0
4.0
5.0
Depth (ft)
0.80
0.60
0.40
0.20
0.00
7/29/2024
8/3/2024
8/8/2024
8/13/2024
8/18/2024
8/23/2024
8/28/2024

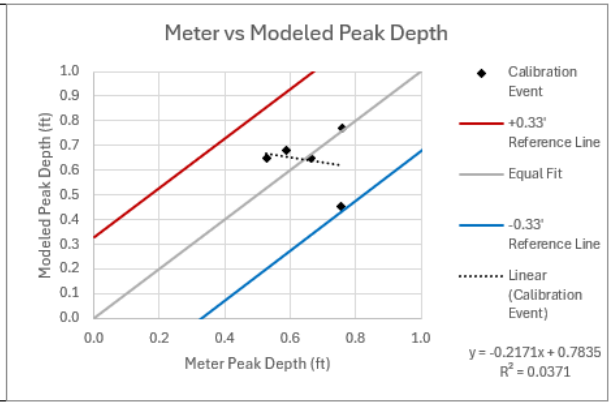
Calibration Summary for FM5

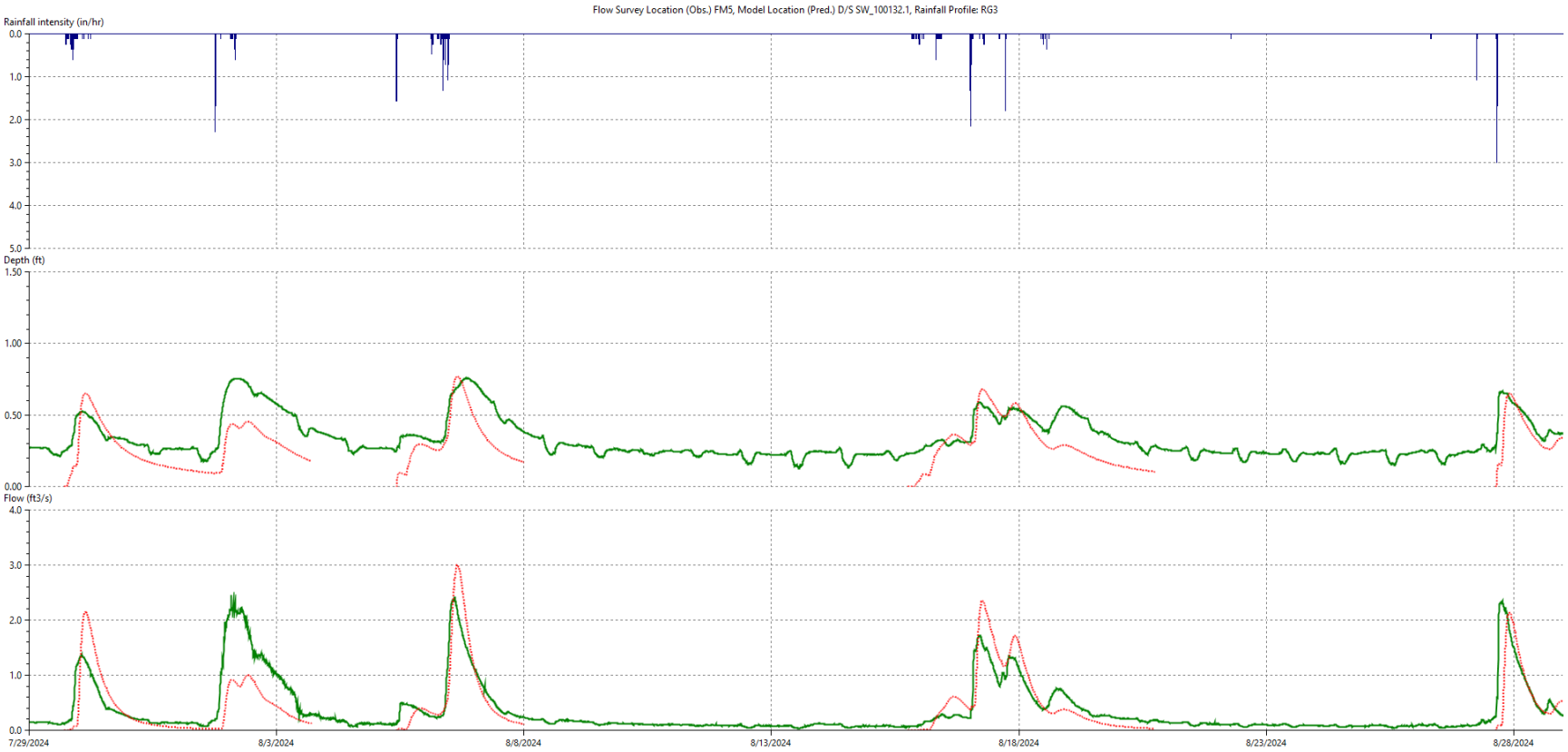
Monitor Type: FM5

Model Assessment Summary for FM5													
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)			Peak Depth (Ft)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error	Meter	Model	Error
1	7/29/2024 17:00	13.0	0.72	0.6	1.38	2.15	56%	0.99	1.16	17%	0.53	0.65	0.12
2	8/1/2024 17:40	22.2	0.93	2.28	2.46	1.00	-59%	2.42	1.00	-59%	0.76	0.46	-0.30
3	8/5/2024 10:00	28.9	1.28	1.56	2.42	3.00	24%	1.84	1.75	-5%	0.76	0.77	0.01
4	8/15/2024 18:00	67.5	1.46	2.16	1.72	2.35	37%	2.57	2.67	4%	0.59	0.68	0.09
5	8/27/2024 15:00	10.3	0.77	3	2.35	2.14	-9%	1.31	1.09	-17%	0.67	0.65	-0.02





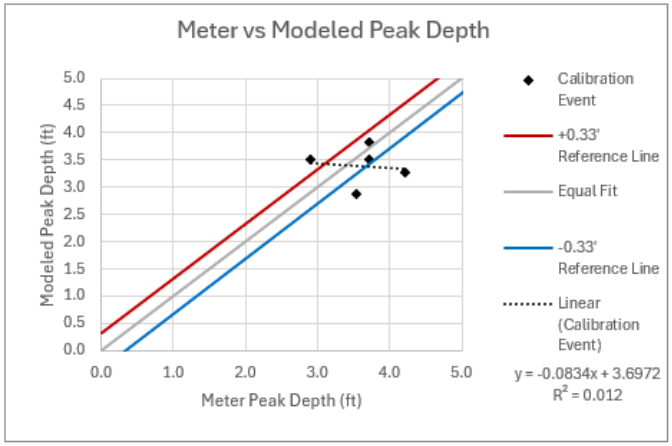


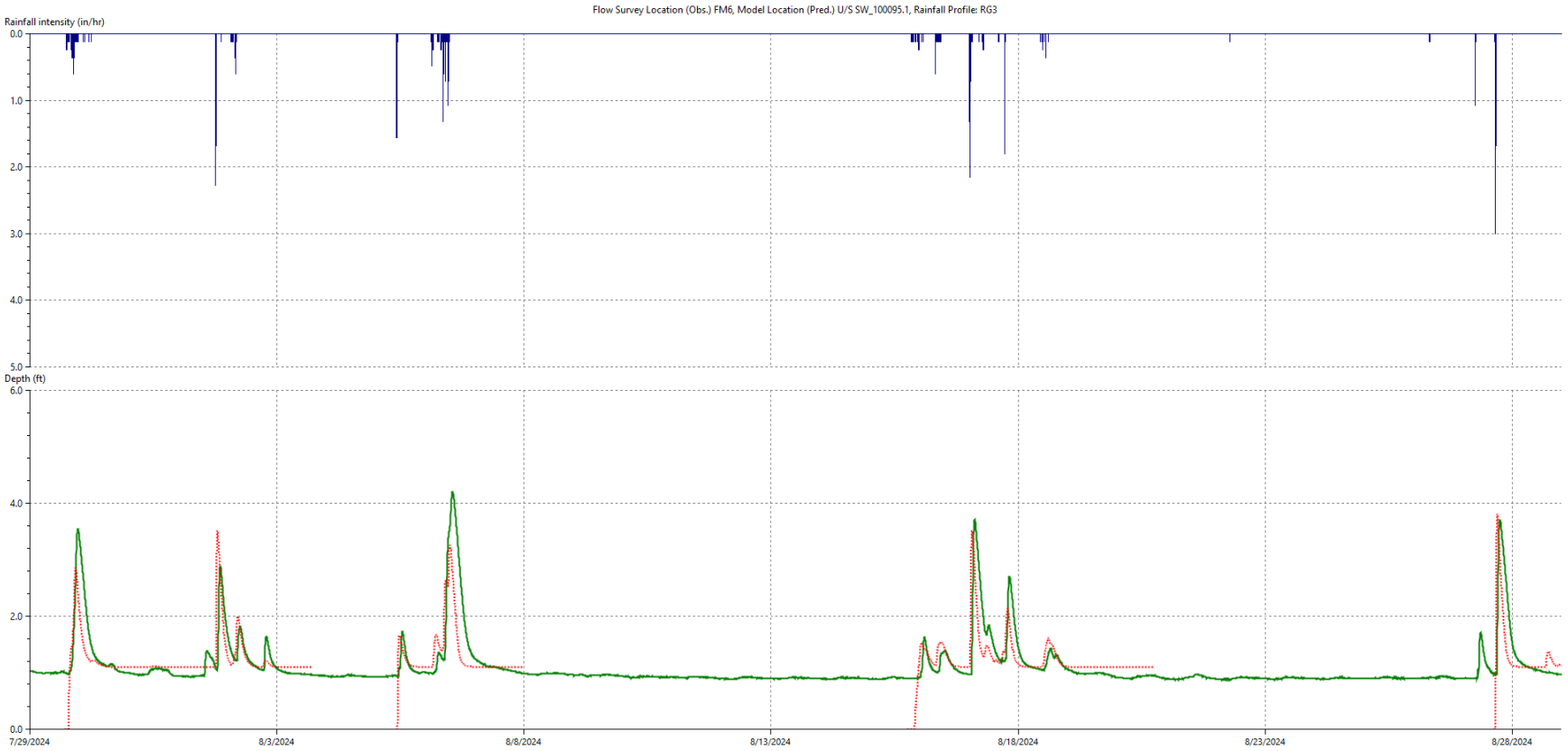

Flow Survey Location (Obs.) FM5, Model Location (Pred.) D/S SW_100132.1, Rainfall Profile: RG3
Rainfall intensity (in/hr)
0.0
1.0
2.0
3.0
4.0
5.0
Depth (ft)
1.50
1.00
0.50
0.00
Flow (ft3/s)
4.0
3.0
2.0
1.0
0.0
7/29/2024
8/3/2024
8/8/2024
8/13/2024
8/18/2024
8/23/2024
8/28/2024

Calibration Summary for FM6

Monitor Type:

Model Assessment Summary for FM6													
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)			Peak Depth (Ft)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error	Meter	Model	Error
1	7/29/2024 17:00	13.0	0.72	0.6							3.55	2.86	-0.68
2	8/1/2024 17:40	22.2	0.93	2.28							2.90	3.52	0.61
3	8/5/2024 10:00	28.9	1.28	1.56							4.21	3.26	-0.94
4	8/15/2024 18:00	67.5	1.46	2.16							3.72	3.52	-0.20
5	8/27/2024 15:00	10.3	0.77	3							3.71	3.82	0.10

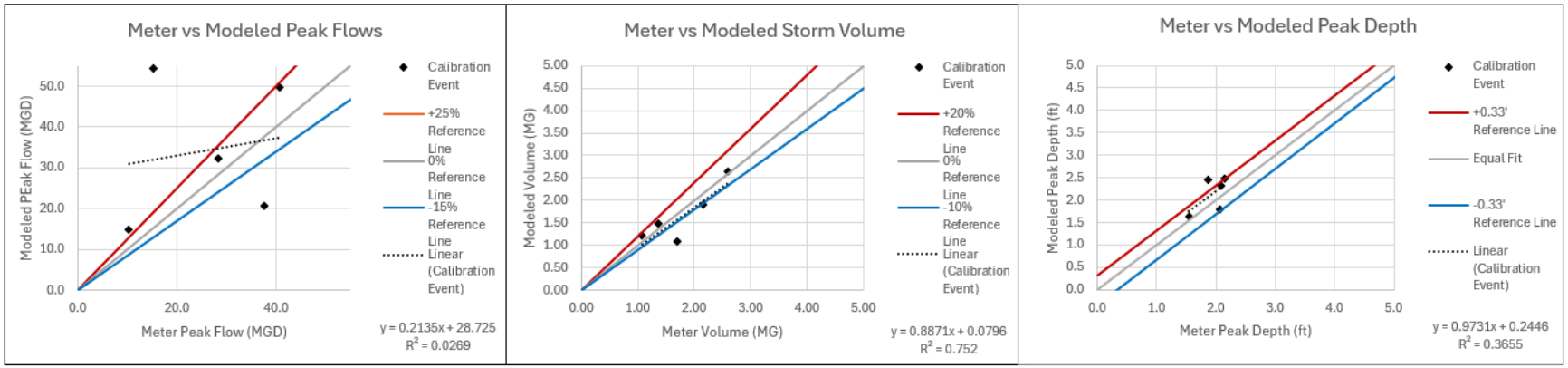


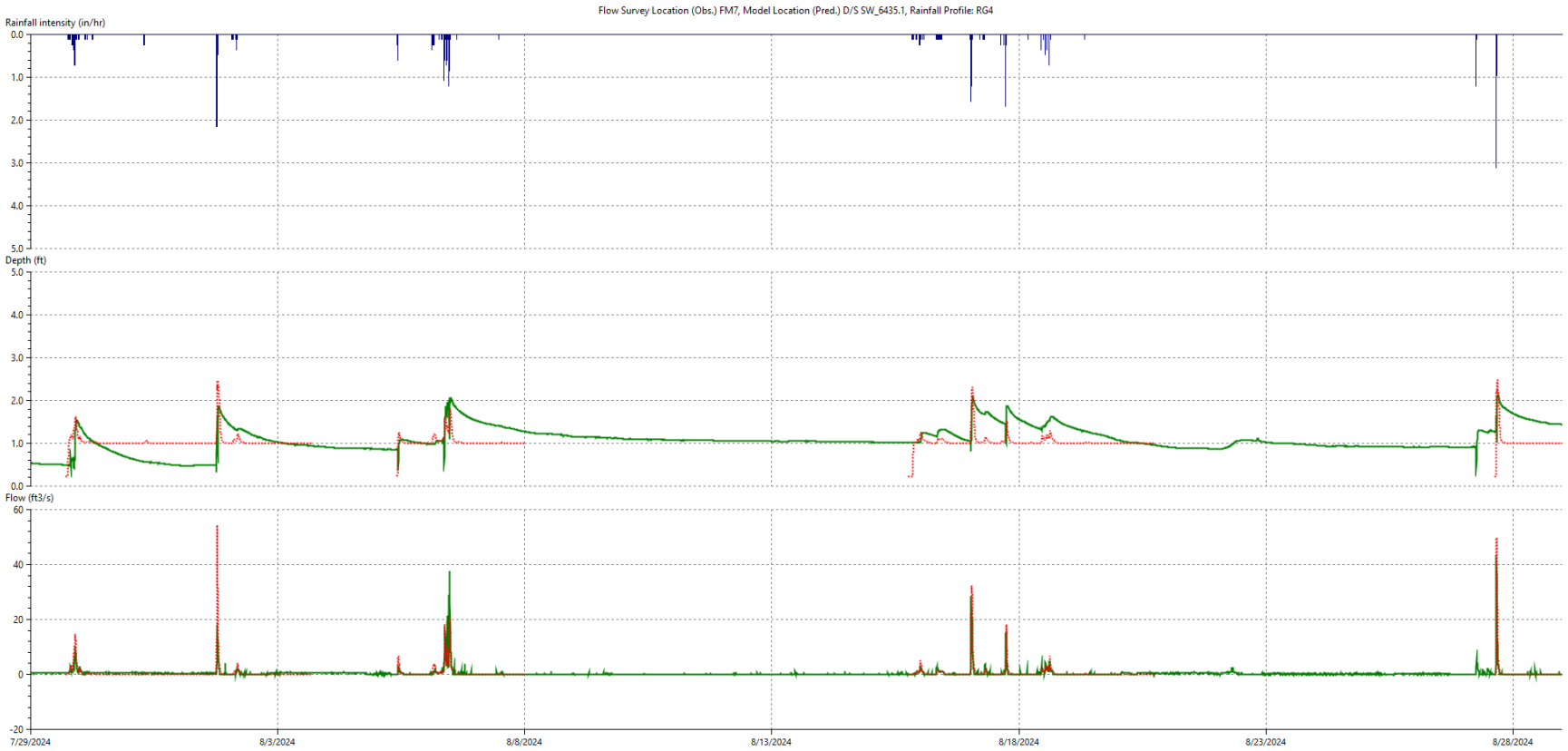

Flow Survey Location (Obs.) FM6, Model Location (Pred.) U/S SW_100095.1, Rainfall Profile: RG3
Rainfall intensity (in/hr)
0.0
1.0
2.0
3.0
4.0
5.0
Depth (ft)
6.0
4.0
2.0
0.0
7/29/2024
8/3/2024
8/8/2024
8/13/2024
8/18/2024
8/23/2024
8/28/2024

Calibration Summary for FM7

Monitor Type: Flow and Depth

Model Assessment Summary for FM7													
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)			Peak Depth (Ft)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error	Meter	Model	Error
1	7/29/2024 17:00	13.0	0.66	0.72	10.29	14.77	44%	1.69	1.07	-37%	1.54	1.63	0.08
2	8/1/2024 17:40	22.2	0.89	2.16	15.23	54.37	257%	1.36	1.48	9%	1.88	2.46	0.59
3	8/5/2024 10:00	28.9	1.16	1.2	37.65	20.71	-45%	2.15	1.89	-12%	2.07	1.80	-0.27
4	8/15/2024 18:00	67.5	1.61	1.68	28.40	32.23	13%	2.61	2.63	1%	2.10	2.31	0.22
5	8/27/2024 15:00	10.3	0.74	3.12	40.60	49.76	23%	1.07	1.20	12%	2.14	2.48	0.34

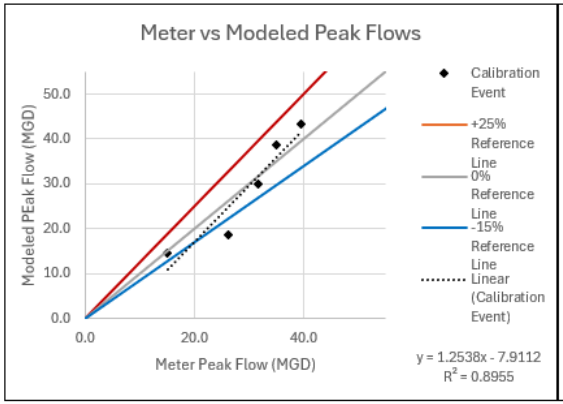


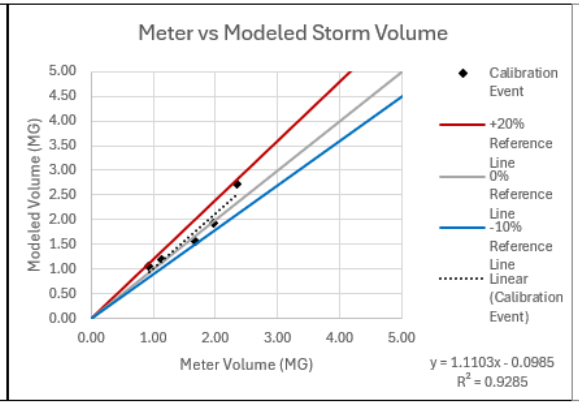

Flow Survey Location (Obs.) FM7, Model Location (Pred.) D/S SW_6435.1, Rainfall Profile: RG4
Rainfall intensity (in/hr)
0.0
1.0
2.0
3.0
4.0
5.0
Depth (ft)
5.0
4.0
3.0
2.0
1.0
0.0
Flow (ft3/s)
60
40
20
0
-20
7/29/2024
8/3/2024
8/8/2024
8/13/2024
8/18/2024
8/23/2024
8/28/2024

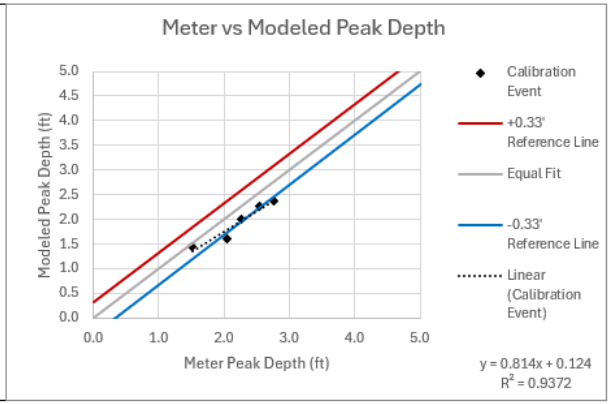
Calibration Summary for FM8

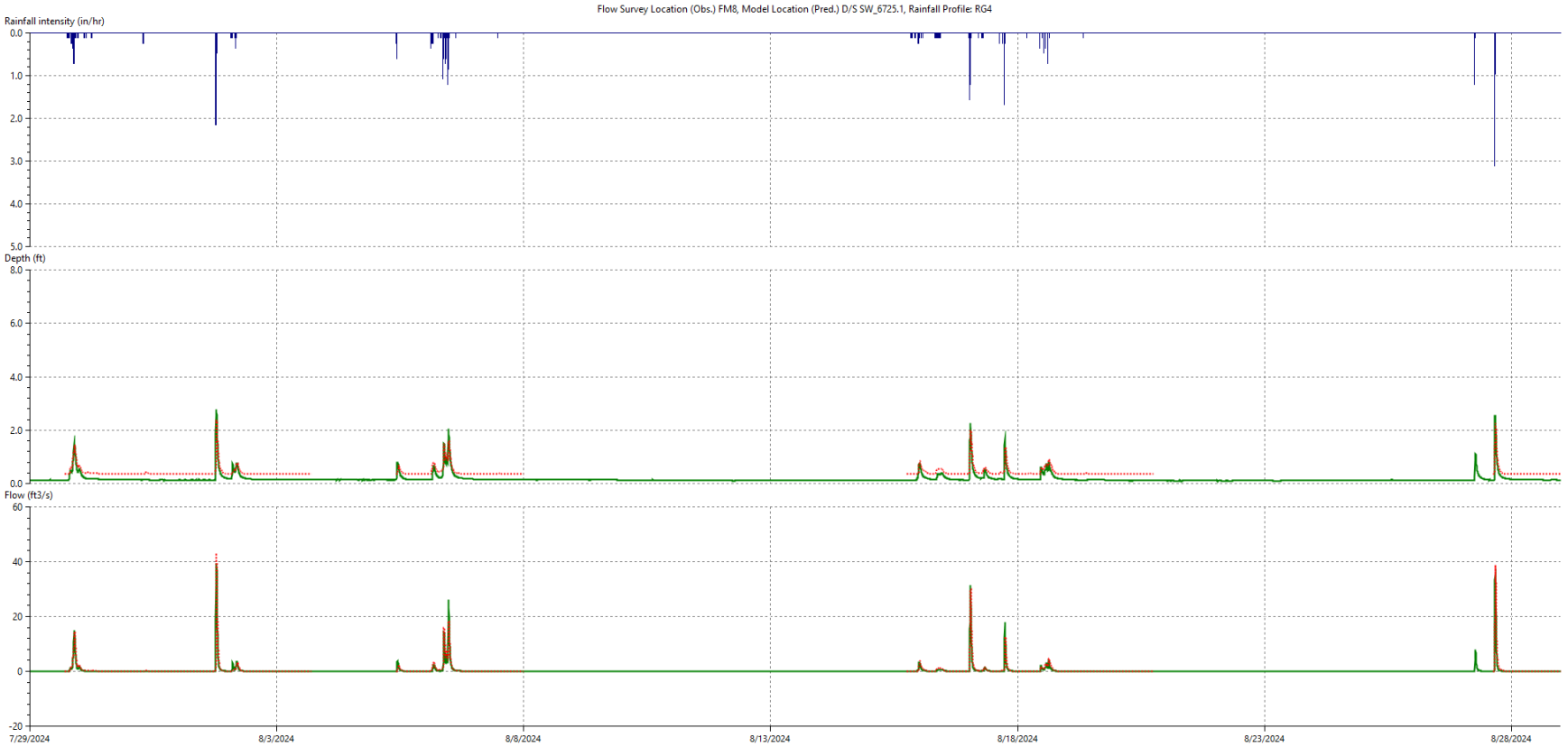
Monitor Type: Flow and Depth

Model Assessment Summary for FM8													
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)			Peak Depth (Ft)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error	Meter	Model	Error
1	7/29/2024 17:00	13.0	0.66	0.71	15.09	14.45	-4%	0.93	1.05	12%	1.52	1.44	-0.08
2	8/1/2024 17:40	22.2	0.89	2.16	39.56	43.33	10%	1.69	1.57	-7%	2.77	2.38	-0.39
3	8/5/2024 10:00	28.9	1.16	1.2	26.17	18.63	-29%	1.97	1.93	-2%	2.04	1.61	-0.43
4	8/15/2024 18:00	67.5	1.61	1.68	31.53	29.94	-5%	2.34	2.72	16%	2.26	2.00	-0.26
5	8/27/2024 15:00	10.3	0.74	3.12	34.96	38.79	11%	1.13	1.19	5%	2.55	2.26	-0.29







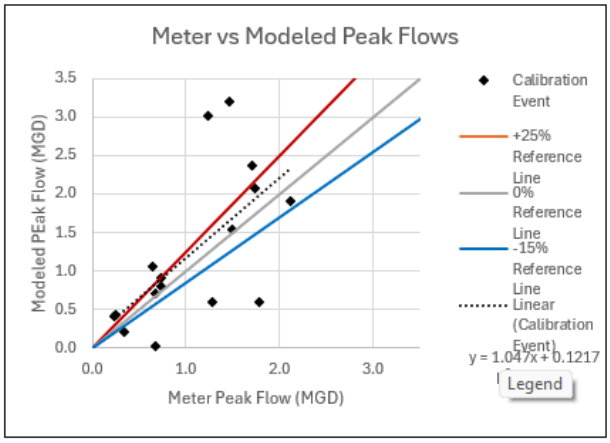

Flow Survey Location (Obs.) FM8, Model Location (Pred.) D/S SW_6725.1, Rainfall Profile: RG4
Rainfall intensity (in/hr)
0.0
1.0
2.0
3.0
4.0
5.0
Depth (ft)
8.0
6.0
4.0
2.0
0.0
Flow (ft3/s)
60
40
20
0
-20
7/29/2024
8/3/2024
8/8/2024
8/13/2024
8/18/2024
8/23/2024
8/28/2024

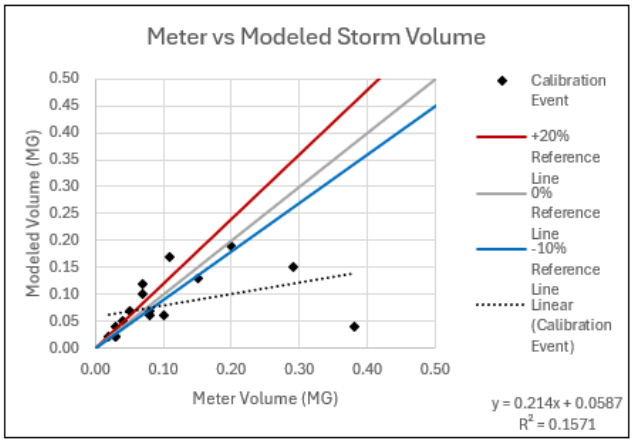
Appendix C. CSS Dry Weather Calibration

Model Node Name	Meter	Average Weather Flow, MGD				Average Daily Peak Hour Flow, MGD				Average of Daily Minimum Hour Flow, MGD			
		Measured	Modeled	% Difference	Within Calibration Criteria?	Measured	Modeled	% Difference	Within Calibration Criteria?	Measured	Modeled	% Difference	Within Calibration Criteria?
MH-5733	Beal-24	0.010	0.01	-25%	yes	0.01	0.01	13%	yes	0.01	0.00	-0.71	yes
A0043	Charles-24E	0.040	0.04	9%	yes	0.07	0.06	-8%	yes	0.02	0.01	-0.40	yes
A0043	Charles-27W	0.140	0.12	-11%	yes	0.22	0.18	-17%	yes	0.04	0.04	0.11	yes
A0043	Charles-54N	0.180	0.18	-2%	yes	0.27	0.24	-13%	yes	0.09	0.07	-0.26	yes
MH-258	Collingwood-30S	0.010	0.00	-69%	yes	0.01	0.00	-53%	yes	0.01	0.00	-0.85	yes
MH-257	Collingwood-54N	0.040	0.04	7%	yes	0.06	0.06	5%	yes	0.02	0.02	-0.12	yes
A0033	Durand-78	0.090	0.10	7%	yes	0.13	0.13	3%	yes	0.04	0.05	0.29	yes
MH-519	Kensington-60	0.140	0.16	11%	yes	0.21	0.21	0%	yes	0.08	0.11	0.32	yes
MH-417	Louis-36	0.300	0.27	-9%	yes	0.39	0.31	-19%	no	0.21	0.20	-0.03	yes
MH-5497	Michigan-36	0.100	0.16	57%	no	0.13	0.23	74%	no	0.06	0.08	0.31	yes
A0500	Michigan-72	0.080	0.09	10%	yes	0.13	0.14	9%	yes	0.04	0.04	0.08	yes
MH-367	Northlawn-36	0.040	0.04	-8%	yes	0.05	0.06	19%	yes	0.02	0.02	0.01	yes
MH-460	Oak-15	0.020	0.01	-48%	yes	0.03	0.02	-35%	yes	0.01	0.00	-0.60	yes
A0040	River-42	0.150	0.16	7%	yes	0.17	0.20	20%	yes	0.08	0.11	0.43	yes
MH-2964	Snyder-36	0.010	0.01	3%	yes	0.03	0.01	-53%	yes	0.01	0.01	-0.28	yes
MH-368	Sunset-27	0.030	0.03	-11%	yes	0.05	0.04	-28%	yes	0.01	0.01	0.48	yes
MH-3430	Touraine-48	0.070	0.07	2%	yes	0.09	0.09	2%	yes	0.05	0.05	0.09	yes
MH-1381	Valley-12	0.020	0.02	-3%	yes	0.03	0.03	-16%	yes	0.01	0.02	0.53	yes
MH-1382	Valley-18	0.030	0.03	-8%	yes	0.05	0.04	-16%	yes	0.02	0.01	-0.40	yes

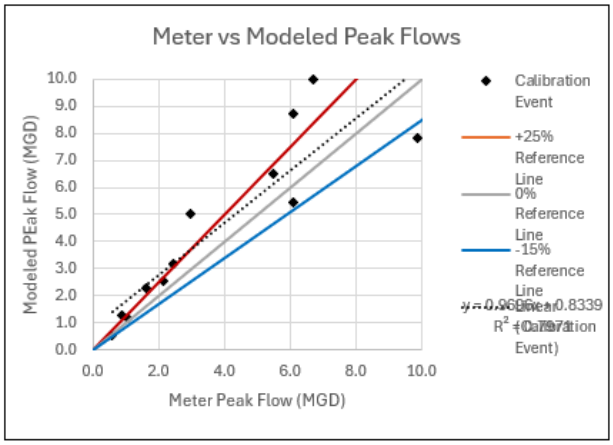
Appendix D. CSS Wet Weather Calibration Results

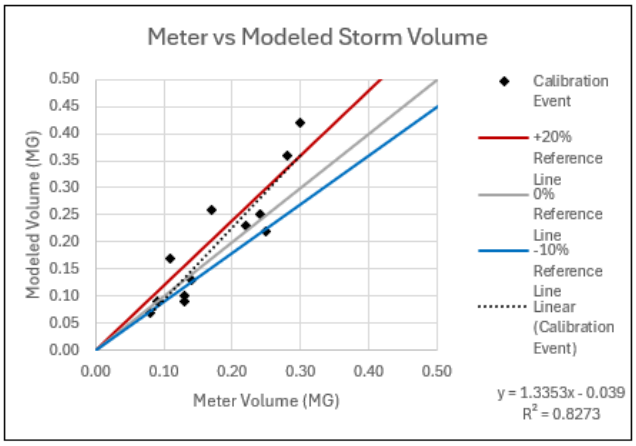
Model Assessment Summary for Beal-24										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	40.5	1.28	0.42	1.78	0.60	-66%	0.29	0.15	-48%
2	4/5/2017	40.5	0.92	0.13	0.68	0.02	-97%	0.38	0.04	-89%
3	4/20/2017	29	0.98	0.58	2.11	1.90	-10%	0.15	0.13	-13%
4	4/29/2017	75.5	1.2	0.22	0.67	0.70	4%	0.20	0.19	-5%
5	5/20/2017	44.25	0.73	0.38	0.64	1.06	66%	0.07	0.12	71%
6	5/24/2017	16.25	0.56	0.34	0.73	0.80	10%	0.05	0.07	40%
7	6/17/2017	36	1.24	0.53	1.24	3.02	144%	0.11	0.17	55%
8	6/22/2017	22.25	0.75	0.52	1.73	2.08	20%	0.08	0.07	-13%
9	7/7/2017	16	0.78	0.6	1.49	1.54	3%	0.08	0.06	-25%
10	7/10/2017	17	0.71	0.58	1.46	3.20	119%	0.07	0.10	43%
11	7/11/2017	10.25	0.29	0.29	1.28	0.60	-53%	0.03	0.02	-33%
12	7/13/2017	30.5	0.64	0.57	1.71	2.37	39%	0.10	0.06	-40%
13	8/3/2017	33.25	0.36	0.17	0.25	0.43	72%	0.03	0.04	33%
14	8/11/2017	10.75	0.24	0.18	0.24	0.41	71%	0.02	0.02	0%
15	8/15/2017	21.75	0.38	0.3	0.74	0.90	22%	0.04	0.05	25%
16	8/17/2017	29	0.24	0.09	0.34	0.21	-38%	0.03	0.02	-33%



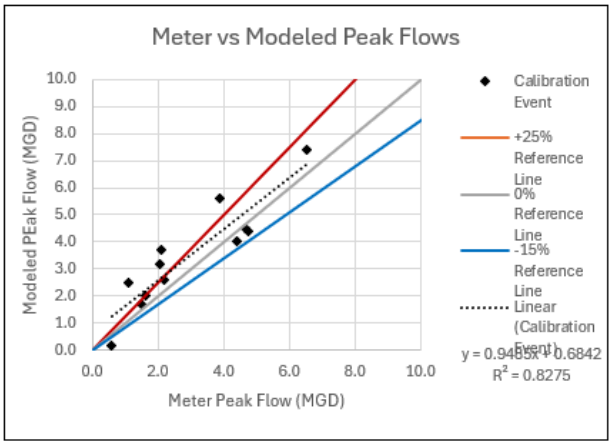


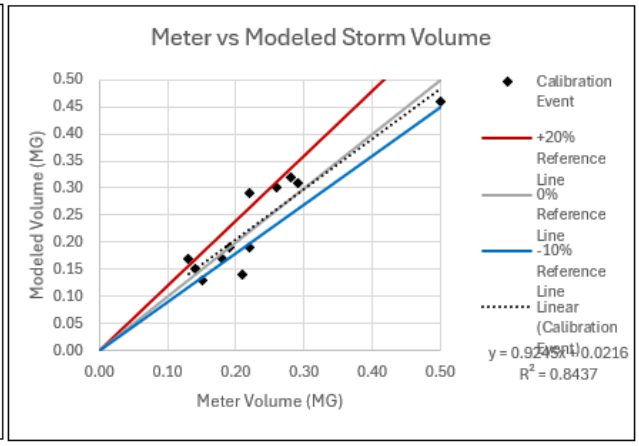
Model Assessment Summary for Charles-24E										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
5	5/20/2017	40	0.75	0.47	2.43	3.16	30%	0.22	0.23	5%
6	5/24/2017	13	0.46	0.32	1.62	2.30	42%	0.11	0.17	55%
7	6/17/2017	25.25	1.53	0.66	6.10	8.73	43%	0.30	0.42	40%
8	6/22/2017	36.5	0.8	0.61	5.50	6.50	18%	0.24	0.25	4%
9	7/7/2017	16	0.9	0.68	2.95	5.02	70%	0.17	0.26	53%
10	7/10/2017	35	0.86	0.67	6.69	10.00	49%	0.28	0.36	29%
11	7/11/2017	8.5	0.32	0.32	6.08	5.46	-10%	0.13	0.10	-23%
12	7/13/2017	13.25	0.69	0.6	9.87	7.83	-21%	0.25	0.22	-12%
13	8/4/2017	13.75	0.09	0.21	1.04	1.18	13%	0.09	0.09	0%
14	8/11/2017	10.25	0.25	0.23	0.88	1.25	42%	0.08	0.07	-13%
15	8/15/2017	15.5	0.44	0.41	2.14	2.53	18%	0.14	0.13	-7%
16	8/17/2017	19.75	0.22	0.11	0.60	0.55	-8%	0.13	0.09	-31%



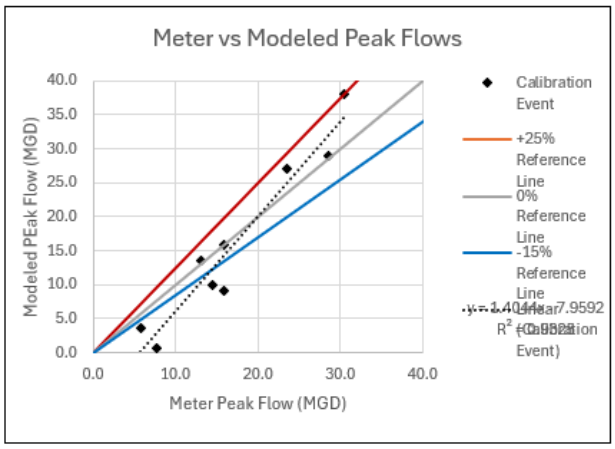


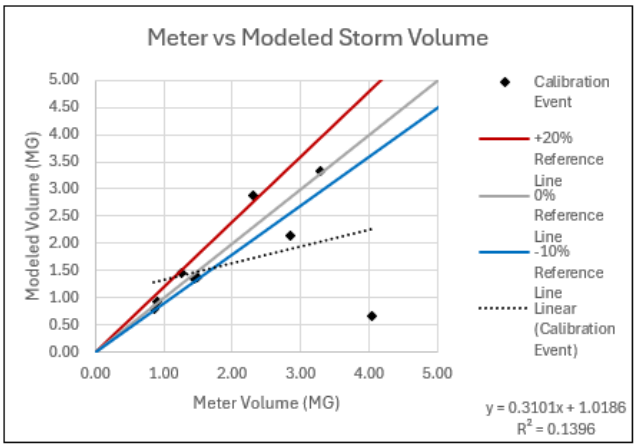
Model Assessment Summary for Charles-27W										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	41	1.28	0.42	1.49	1.72	15%	0.28	0.32	14%
2	4/5/2017	41	0.92	0.13	0.59	0.14	-76%	0.21	0.14	-33%
3	4/20/2017	23.75	0.98	0.58	2.07	3.16	53%	0.22	0.29	32%
4	4/30/2017	60.5	1.18	0.22	1.09	2.50	129%	0.50	0.46	-8%
5	5/20/2017	24.5	0.73	0.38	2.17	2.61	20%	0.29	0.31	7%
6	5/24/2017	8.5	0.56	0.34	1.62	2.04	26%	0.15	0.13	-13%
7	6/17/2017	11	1.23	0.53	3.88	5.60	44%	0.26	0.30	15%
8	6/22/2017	15.75	0.75	0.52	4.74	4.38	-8%	0.22	0.19	-14%
9	7/7/2017	6	0.78	0.6	2.10	3.70	76%	0.13	0.17	31%
10	7/10/2017	6.5	0.71	0.58	6.52	7.40	13%	0.19	0.19	0%
11	7/11/2017	19.25	0.48	0.29	4.42	4.00	-10%	0.18	0.17	-6%
12	7/13/2017	9	0.64	0.57	4.66	4.49	-4%	0.14	0.15	7%
13	8/3/2017	15.25	0.32	0.17	0.99	1.01	2%	0.13	0.10	-23%
14	8/11/2017	4.5	0.24	0.18	0.62	1.02	65%	0.05	0.05	0%
15	8/15/2017	7.5	0.38	0.3	1.69	2.16	28%	0.11	0.11	0%



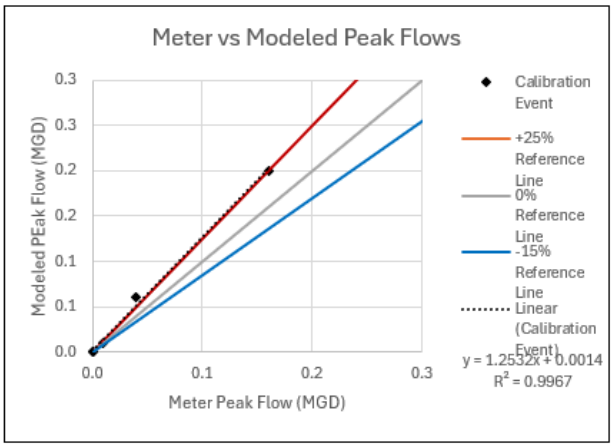


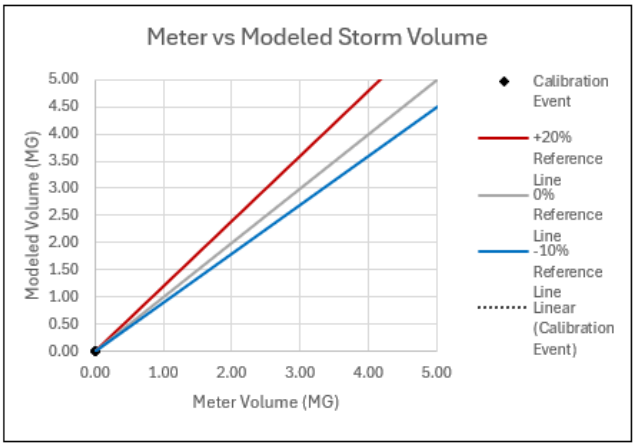
Model Assessment Summary for Charles-54N										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	38.25	1.28	0.42	14.49	10.00	-31%	2.84	2.14	-25%
2	4/5/2017	38.25	0.92	0.13	7.75	0.58	-93%	4.03	0.65	-84%
4	4/29/2017	104.25	1.21	0.22	15.82	9.17	-42%	3.29	3.33	1%
5	5/20/2017	47.75	0.73	0.38	15.92	15.78	-1%	1.45	1.35	-7%
6	5/24/2017	28.5	0.58	0.34	13.11	13.49	3%	0.90	0.92	2%
7	6/17/2017	62.75	1.24	0.53	30.49	38.08	25%	2.31	2.87	24%
8	6/22/2017	38.75	0.75	0.52	28.54	28.90	1%	1.48	1.38	-7%
9	7/7/2017	20.75	0.79	0.6	23.55	27.04	15%	1.26	1.45	15%
16	8/17/2017	41.5	0.24	0.09	5.73	3.57	-38%	0.86	0.79	-8%



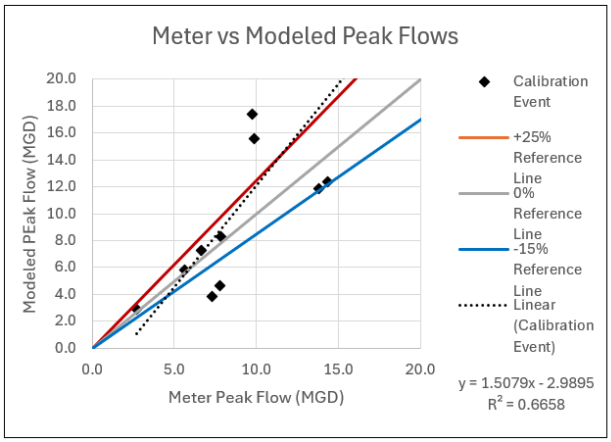


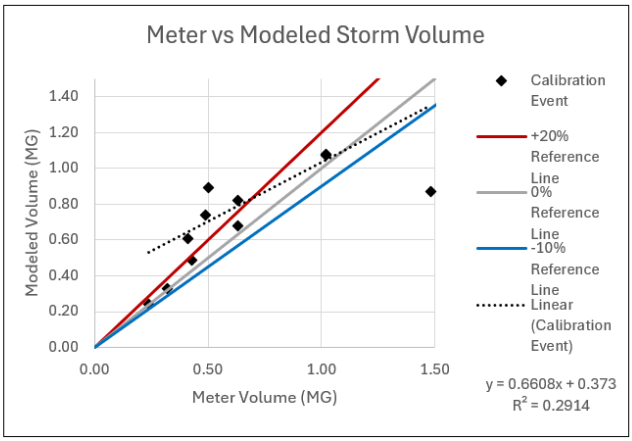
Model Assessment Summary for Collingwood-30S										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	36.75	1.28	0.42	0.01	0.01	0%	0.00	0.00	#DIV/0!
2	4/5/2017	60.75	0.93	0.13	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
3	4/20/2017	34.75	0.98	0.58	0.16	0.20	25%	0.00	0.00	#DIV/0!
4	4/29/2017	97	1.21	0.22	0.04	0.06	50%	0.00	0.00	#DIV/0!
5	5/4/2017	21.75	0.24	0.04	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!



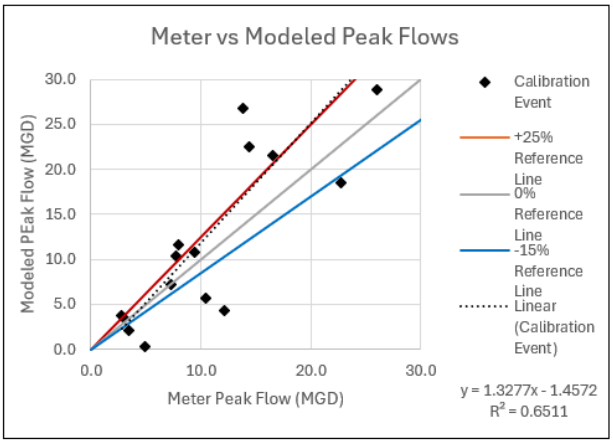


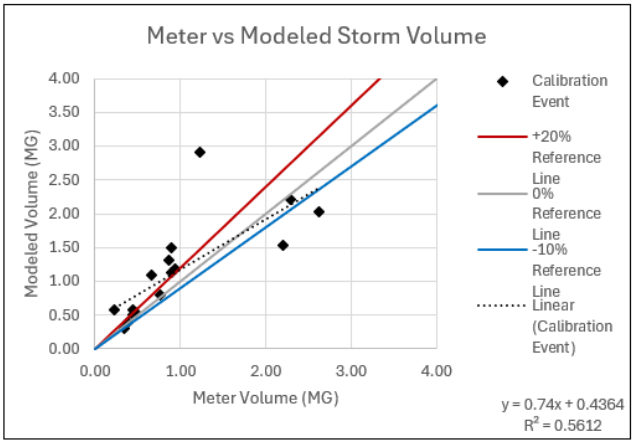
Model Assessment Summary for Coolingwood-54N										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	38.5	1.04	0.26	7.80	4.68	-40%	1.48	0.87	-41%
3	4/20/2017	74.5	0.98	0.58	14.35	12.40	-14%	1.02	1.08	6%
4	4/29/2017	99.25	1.21	0.22	7.29	3.85	-47%	1.02	1.07	5%
5	5/20/2017	83.25	0.77	0.47	6.66	7.31	10%	0.63	0.68	8%
6	5/24/2017	56.5	0.53	0.32	5.62	5.79	3%	0.43	0.49	14%
7	6/17/2017	51.75	1.53	0.66	16.03	27.18	70%	0.81	1.93	138%
8	6/22/2017	68	0.87	0.61	9.73	17.40	79%	0.49	0.74	51%
9	7/7/2017	46.5	0.9	0.68	9.84	15.55	58%	0.50	0.89	78%
10	7/10/2017	36.25	0.86	0.67	13.82	11.90	-14%	0.41	0.61	49%
11	7/11/2017	29.5	0.55	0.32	7.86	8.30	6%	0.32	0.33	3%
12	7/13/2017	76.25	0.69	0.6	13.29	20.20	52%	0.63	0.82	30%
13	8/4/2017	40.25	0.25	0.21	2.68	2.93	9%	0.24	0.24	0%
14	8/11/2017	24.25	0.28	0.23	2.54	3.00	18%	0.20	0.24	20%
15	8/15/2017	39	0.44	0.41	5.50	7.64	39%	0.28	0.37	32%
16	8/17/2017	39	0.3	0.11	2.47	2.47	0%	0.19	0.16	-16%



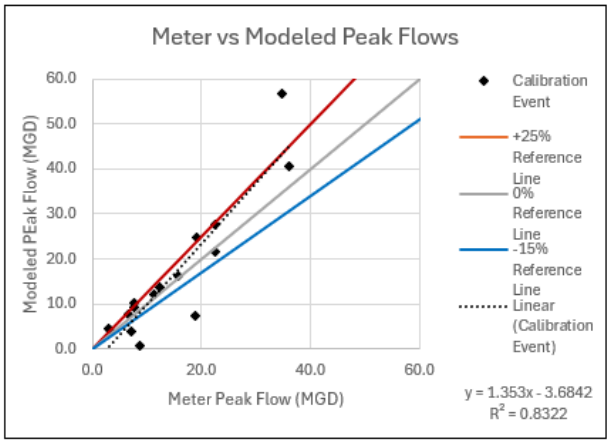


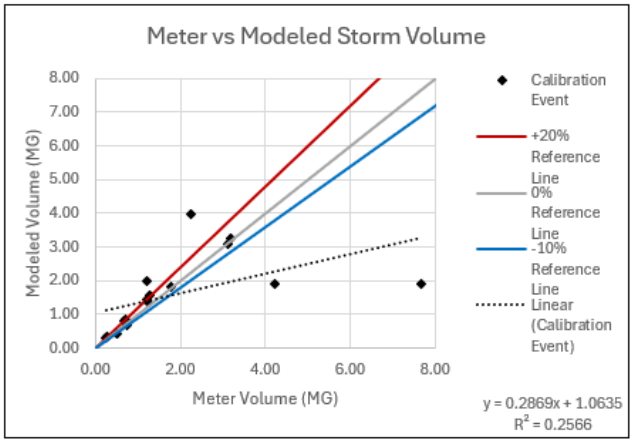
Model Assessment Summary for Durand-78										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	46.25	1.29	0.42	10.40	5.70	-45%	2.21	1.53	-31%
2	4/5/2017	46.25	0.93	0.13	4.90	0.36	-93%	0.23	0.58	152%
3	4/20/2017	96.25	0.98	0.58	22.77	18.47	-19%	2.29	2.22	-3%
4	4/29/2017	102.75	1.21	0.22	12.15	4.32	-64%	2.63	2.03	-23%
5	5/20/2017	75	0.74	0.38	8.00	11.64	46%	0.94	1.18	26%
6	5/24/2017	67.75	0.58	0.34	7.24	7.19	-1%	0.76	0.79	4%
7	6/17/2017	53.75	1.24	0.53	19.17	40.30	110%	1.23	2.91	137%
8	6/22/2017	78.5	0.75	0.52	13.85	26.79	93%	0.87	1.31	51%
9	7/7/2017	66.25	0.79	0.6	16.52	21.60	31%	0.89	1.49	67%
10	7/10/2017	34.75	0.71	0.58	14.40	22.54	57%	0.66	1.10	67%
11	7/11/2017	29.5	0.48	0.29	9.48	10.80	14%	0.48	0.54	13%
12	7/13/2017	44.5	0.64	0.57	26.00	28.81	11%	0.89	1.12	26%
13	8/3/2017	40.25	0.36	0.17	3.01	3.45	15%	0.38	0.40	5%
14	8/11/2017	71.25	0.28	0.18	2.81	3.71	32%	0.44	0.51	16%
15	8/15/2017	39.25	0.38	0.3	7.69	10.38	35%	0.45	0.58	29%
16	8/17/2017	39.25	0.24	0.09	3.50	2.12	-39%	0.35	0.31	-11%



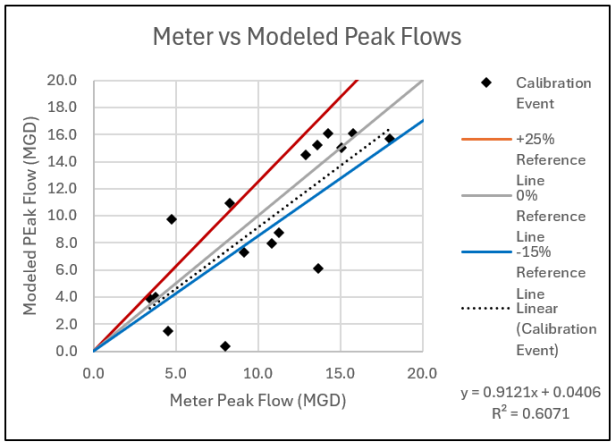


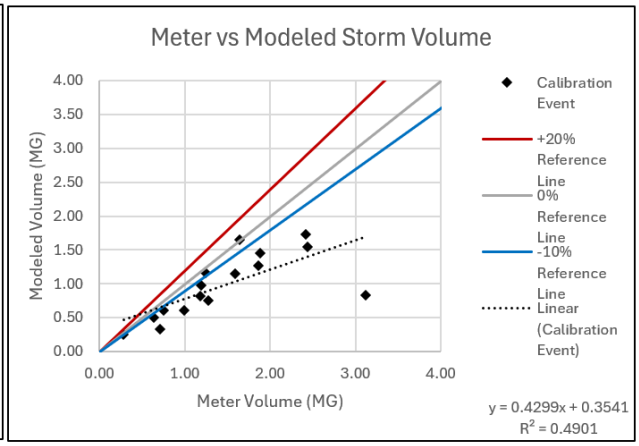
Model Assessment Summary for Kensington-60										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	40	0.97	0.26	18.96	7.20	-62%	4.22	1.89	-55%
2	4/5/2017	94.5	0.93	0.13	8.75	0.64	-93%	7.68	1.90	-75%
3	4/20/2017	119.75	0.98	0.54	22.43	21.60	-4%	3.20	3.26	2%
4	4/29/2017	106.5	1.42	0.24	6.60	7.70	17%	3.13	3.09	-1%
5	5/20/2017	81.25	0.75	0.38	7.57	10.19	35%	1.20	1.45	21%
6	5/24/2017	91	0.58	0.34	7.53	9.25	23%	1.24	1.36	10%
7	6/17/2017	95.75	1.86	0.96	34.67	56.84	64%	2.24	3.99	78%
8	6/22/2017	88	0.86	0.63	19.02	24.90	31%	1.27	1.55	22%
9	7/7/2017	74	1.01	0.8	22.55	27.77	23%	1.21	2.00	65%
10	7/10/2017	35	0.61	0.45	12.30	13.61	11%	0.70	0.85	21%
11	7/11/2017	29.25	0.59	0.37	15.75	16.13	2%	0.74	0.68	-8%
12	7/13/2017	99.75	0.79	0.7	35.98	40.72	13%	1.78	1.80	1%
13	8/4/2017	35.75	0.23	0.19	3.04	4.45	46%	0.29	0.36	24%
14	8/11/2017	18	0.27	0.21	3.19	4.18	31%	0.25	0.30	20%
15	8/15/2017	42	0.5	0.42	11.21	12.18	9%	0.68	0.82	21%
16	8/17/2017	37	0.32	0.15	7.04	3.81	-46%	0.51	0.42	-18%



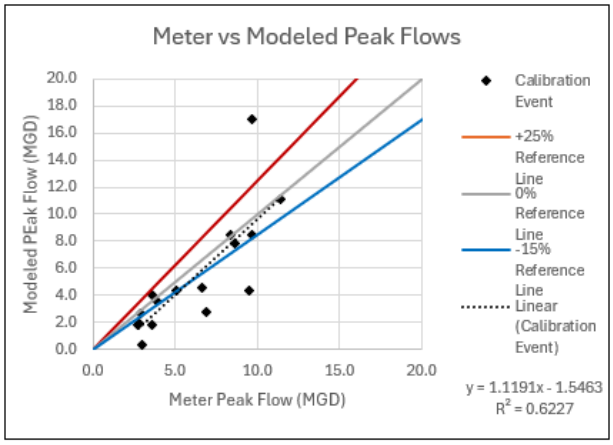


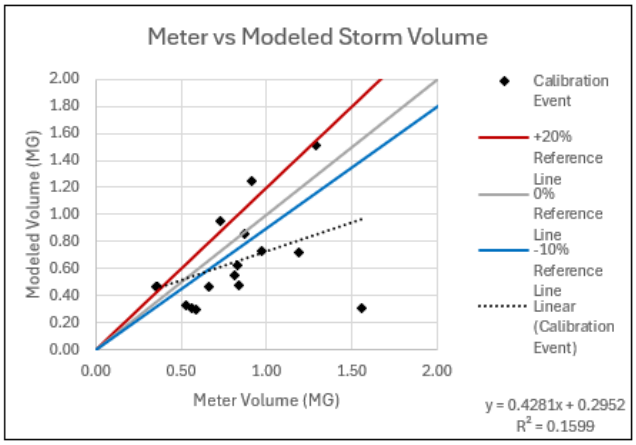
Model Assessment Summary for Louis-36										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	40.5	1.28	0.42	13.66	6.12	-55%	2.44	1.54	-37%
2	4/5/2017	57.25	0.93	0.13	8.00	0.39	-95%	3.12	0.83	-73%
3	4/20/2017	38.75	0.98	0.58	15.06	15.02	0%	1.88	1.45	-23%
4	4/29/2017	72	1.2	0.22	9.16	7.30	-20%	2.42	1.73	-29%
5	5/20/2017	52.75	0.73	0.38	8.26	10.93	32%	1.86	1.27	-32%
6	5/24/2017	35.5	0.57	0.34	10.81	7.95	-26%	1.27	0.76	-40%
7	6/17/2017	37.5	1.24	0.53	14.25	16.06	13%	1.64	1.65	1%
8	6/22/2017	48.75	0.75	0.52	13.59	15.20	12%	1.59	1.15	-28%
9	7/7/2017	33.75	0.79	0.6	12.92	14.48	12%	1.24	1.16	-6%
10	7/10/2017	33.75	0.71	0.58	18.02	15.72	-13%	1.19	0.98	-18%
11	7/11/2017	31	0.48	0.29	4.74	9.75	106%	0.75	0.61	-19%
12	7/13/2017	32.75	0.6	0.57	15.80	16.11	2%	1.18	0.82	-31%
13	8/3/2017	39.5	0.36	0.17	3.76	4.02	7%	0.64	0.50	-22%
14	8/11/2017	10.25	0.24	0.18	3.41	3.95	16%	0.28	0.25	-11%
15	8/15/2017	33.25	0.38	0.3	11.29	8.73	-23%	0.99	0.61	-38%
16	8/17/2017	33.25	0.24	0.09	4.56	1.50	-67%	0.71	0.33	-54%



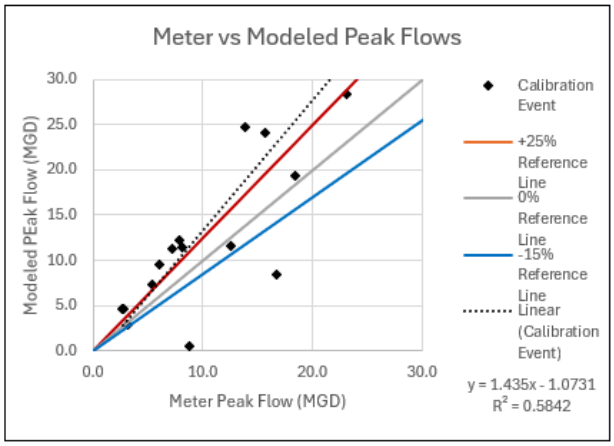


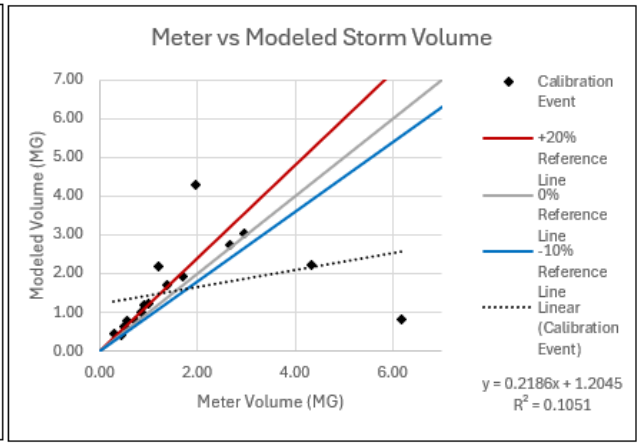
Model Assessment Summary for Michigan-36										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	32.25	0.92	0.26	6.93	2.78	-60%	1.19	0.72	-39%
2	4/5/2017	35.5	0.92	0.13	2.97	0.37	-88%	1.56	0.31	-80%
3	4/20/2017	52.25	0.98	0.54	8.66	7.84	-9%	0.73	0.95	30%
4	4/29/2017	83.75	1.42	0.24	2.93	2.66	-9%	0.91	1.25	37%
5	5/21/2017	36.5	0.6	0.38	3.56	4.08	15%	0.36	0.46	28%
6	5/24/2017	31.75	0.58	0.34	3.84	3.62	-6%	0.35	0.47	34%
7	6/17/2017	39.5	1.85	0.96	9.63	17.02	77%	1.29	1.51	17%
8	6/23/2017	33.75	0.73	0.63	9.67	8.51	-12%	0.83	0.62	-25%
9	7/7/2017	27.75	1.01	0.8	8.38	8.51	2%	0.87	0.86	-1%
10	7/10/2017	28.25	0.61	0.45	9.46	4.30	-55%	0.81	0.55	-32%
11	7/11/2017	30.5	0.59	0.37	6.66	4.60	-31%	0.84	0.48	-43%
12	7/13/2017	26.75	0.79	0.7	11.39	11.07	-3%	0.97	0.73	-25%
13	8/4/2017	26.25	0.27	0.19	2.80	1.90	-32%	0.56	0.31	-45%
14	8/11/2017	25	0.27	0.21	2.74	1.86	-32%	0.53	0.33	-38%
15	8/15/2017	25.25	0.5	0.42	5.07	4.36	-14%	0.66	0.46	-30%
16	8/17/2017	25.25	0.32	0.15	3.60	1.78	-51%	0.59	0.30	-49%



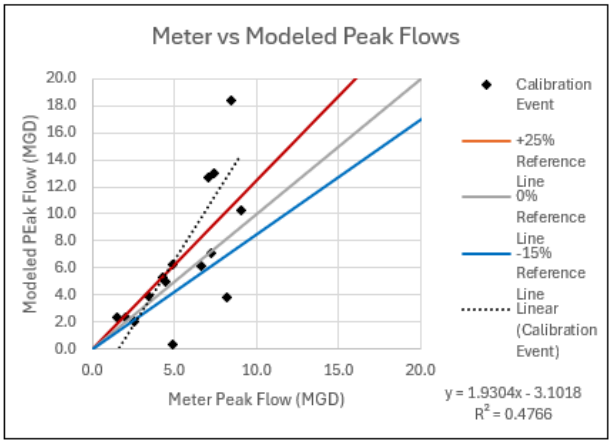


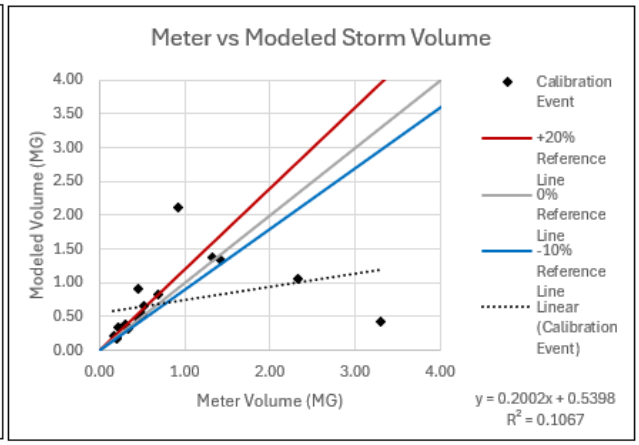
Model Assessment Summary for Michigan-36										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	42	0.97	0.26	16.70	8.37	-50%	4.35	2.22	-49%
2	4/5/2017	42	0.92	0.13	8.75	0.56	-94%	6.18	0.81	-87%
3	4/20/2017	127.75	0.98	0.54	18.43	19.28	5%	2.96	3.04	3%
4	4/29/2017	101.25	1.42	0.24	5.38	7.35	37%	2.68	2.73	2%
5	5/20/2017	99.75	0.76	0.38	7.16	11.24	57%	1.01	1.21	20%
6	5/24/2017	120.25	0.57	0.34	6.03	9.51	58%	0.90	1.19	32%
7	6/17/2017	107.5	1.86	0.96	19.50	48.17	147%	1.97	4.30	118%
8	6/22/2017	119.5	0.86	0.63	15.68	24.13	54%	1.38	1.70	23%
9	7/7/2017	73.5	1.01	0.8	13.89	24.77	78%	1.20	2.17	81%
10	7/10/2017	36.75	0.61	0.45	12.57	11.62	-8%	0.85	1.01	19%
11	7/11/2017	29.25	0.59	0.37	8.07	11.42	42%	0.74	0.77	4%
12	7/13/2017	79.75	0.79	0.7	23.07	28.44	23%	1.69	1.91	13%
13	8/3/2017	24.25	0.27	0.19	2.81	4.61	64%	0.29	0.44	52%
14	8/11/2017	69.75	0.29	0.21	2.68	4.60	72%	0.50	0.63	26%
15	8/15/2017	38.25	0.5	0.42	7.91	12.30	55%	0.56	0.78	39%
16	8/17/2017	44.25	0.32	0.15	3.14	2.95	-6%	0.45	0.42	-7%



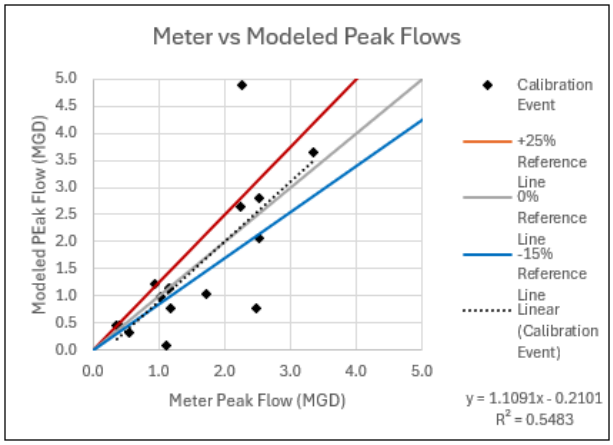


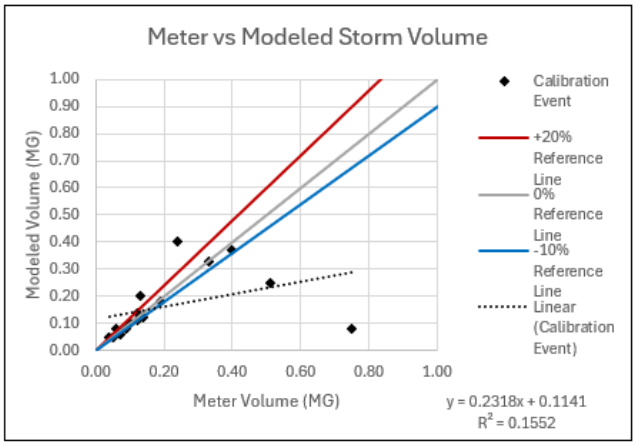
Model Assessment Summary for Northlawn-36										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	42.5	0.97	0.26	8.16	3.85	-53%	2.33	1.06	-55%
2	4/5/2017	42.5	0.92	0.13	4.93	0.30	-94%	3.30	0.43	-87%
3	4/20/2017	113.75	0.98	0.54	9.02	10.27	14%	1.33	1.37	3%
4	4/29/2017	100.25	1.42	0.24	3.44	3.91	14%	1.42	1.33	-6%
5	5/20/2017	98	0.75	0.38	4.31	5.29	23%	0.51	0.52	2%
6	5/24/2017	77.25	0.57	0.34	4.43	4.96	12%	0.45	0.46	2%
7	6/17/2017	105.75	1.86	0.96	8.44	26.26	211%	0.92	2.12	130%
8	6/22/2017	87.25	0.86	0.63	7.39	12.97	76%	0.52	0.65	25%
9	7/7/2017	73	1.01	0.8	7.05	12.68	80%	0.46	0.91	98%
10	7/10/2017	36	0.61	0.45	6.61	6.13	-7%	0.30	0.39	30%
11	7/11/2017	29.25	0.59	0.37	7.21	7.08	-2%	0.33	0.31	-6%
12	7/13/2017	75.25	0.79	0.7	8.48	18.41	117%	0.69	0.83	20%
13	8/3/2017	45.75	0.36	0.19	2.03	2.38	17%	0.20	0.20	0%
14	8/11/2017	58.25	0.29	0.21	1.49	2.29	54%	0.17	0.22	29%
15	8/15/2017	46.75	0.5	0.42	4.88	6.22	27%	0.22	0.33	50%
16	8/17/2017	60	0.32	0.15	2.58	1.98	-23%	0.20	0.18	-10%



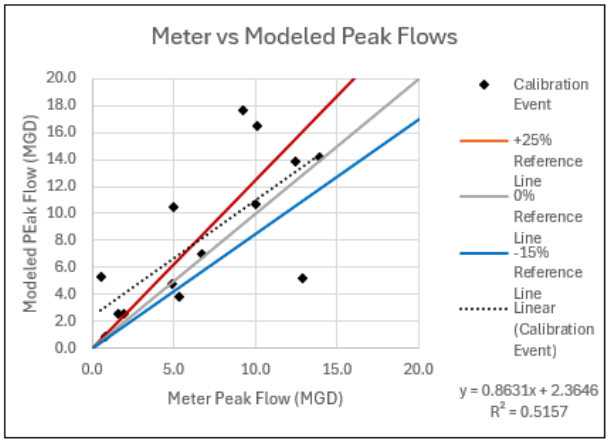


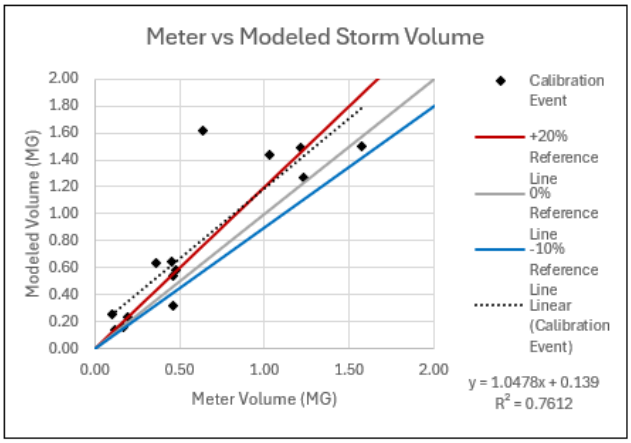
Model Assessment Summary for Oak-15										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	42.5	0.97	0.26	2.49	0.76	-69%	0.51	0.25	-51%
2	4/5/2017	42.5	0.92	0.13	1.12	0.07	-94%	0.75	0.08	-89%
3	4/20/2017	82.25	0.98	0.54	2.52	2.06	-18%	0.33	0.33	0%
4	4/29/2017	102.75	1.42	0.24	1.19	0.76	-36%	0.40	0.37	-8%
5	5/20/2017	75.25	0.74	0.38	1.16	1.13	-3%	0.14	0.12	-14%
6	5/24/2017	72	0.57	0.34	1.03	0.99	-4%	0.12	0.11	-8%
7	6/17/2017	98.25	1.86	0.96	2.26	4.89	116%	0.24	0.40	67%
8	6/22/2017	46	0.86	0.63	2.25	2.65	18%	0.12	0.14	17%
9	7/7/2017	53.75	1.01	0.8	2.52	2.79	11%	0.13	0.20	54%
10	7/10/2017	34.25	0.61	0.45	1.73	1.04	-40%	0.10	0.10	0%
11	7/11/2017	30.5	0.59	0.37	0.94	1.23	31%	0.09	0.08	-11%
12	7/13/2017	74.75	0.79	0.7	3.35	3.66	9%	0.19	0.18	-5%
13	8/4/2017	35	0.27	0.19	0.40	0.45	13%	0.04	0.05	25%
14	8/11/2017	40.25	0.27	0.21	0.36	0.44	22%	0.05	0.05	0%
15	8/15/2017	34.5	0.5	0.42	1.16	1.15	-1%	0.06	0.08	33%
16	8/17/2017	54.75	0.32	0.15	0.55	0.33	-40%	0.07	0.06	-14%



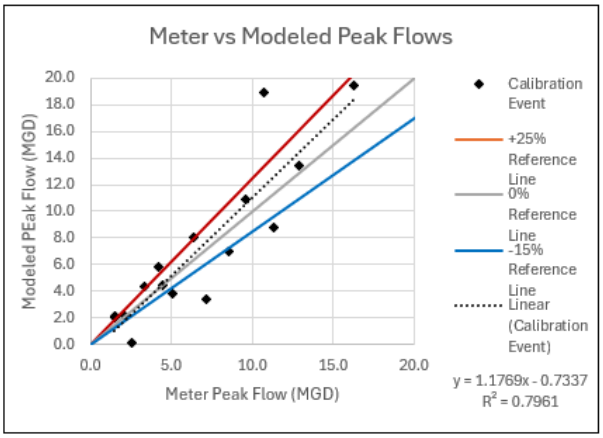


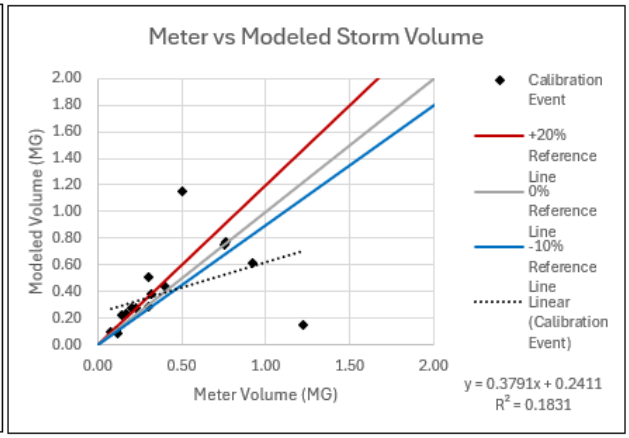
Model Assessment Summary for River-42										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
3	4/20/2017	52.5	0.98	0.58	9.99	10.73	7%	1.23	1.27	3%
4	4/30/2017	103	1.2	0.22	5.33	3.85	-28%	1.57	1.50	-4%
5	5/20/2017	71.25	0.74	0.38	6.71	7.03	5%	1.03	1.44	40%
6	5/24/2017	22.5	0.56	0.34	4.91	4.76	-3%	0.46	0.54	17%
7	6/17/2017	26.5	1.24	0.53	9.21	17.65	92%	0.64	1.62	153%
8	6/22/2017	79.25	0.75	0.52	12.45	13.85	11%	1.21	1.49	23%
9	7/7/2017	19.5	0.79	0.6	5.01	10.52	110%	0.36	0.63	75%
10	7/10/2017	26.75	0.71	0.58	13.90	14.20	2%	0.45	0.65	44%
11	7/11/2017	30.75	0.48	0.29	12.88	5.16	-60%	0.46	0.32	-30%
12	7/13/2017	31.75	0.64	0.57	10.08	16.48	63%	0.48	0.58	21%
13	8/3/2017	32	0.36	0.17	1.97	2.58	31%	0.19	0.23	21%
14	8/11/2017	14.75	0.18	0.18	1.61	2.50	55%	0.12	0.14	17%
15	8/15/2017	21	0.38	0.3	0.51	5.25	929%	0.10	0.25	150%
16	8/17/2017	29	0.24	0.09	0.77	0.82	6%	0.17	0.16	-6%



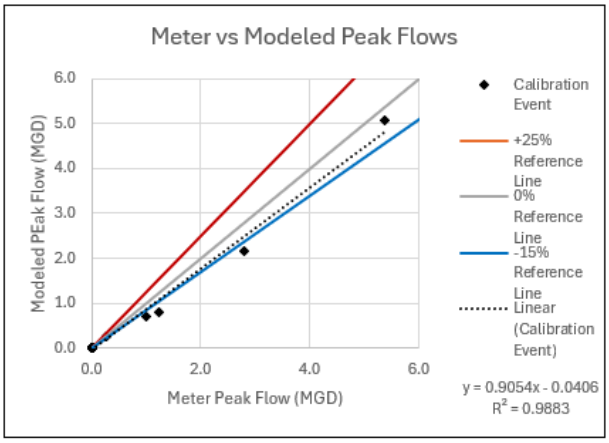


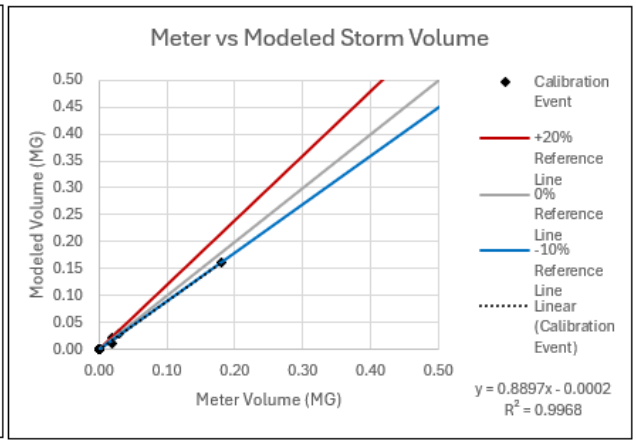
Model Assessment Summary for Snyder-36										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	42.75	0.97	0.26	7.12	3.42	-52%	0.92	0.61	-34%
2	4/5/2017	42.75	0.93	0.13	2.56	0.11	-96%	1.22	0.15	-88%
3	4/20/2017	123.5	0.98	0.54	11.31	8.75	-23%	0.75	0.75	0%
4	4/29/2017	105.5	1.42	0.24	5.04	3.80	-25%	0.76	0.77	1%
5	5/20/2017	60	0.73	0.38	4.48	4.47	0%	0.30	0.29	-3%
6	5/24/2017	59	0.58	0.34	3.36	4.33	29%	0.23	0.27	17%
7	6/17/2017	58.75	1.85	0.96	10.73	18.97	77%	0.50	1.15	130%
8	6/22/2017	51	0.86	0.63	9.56	10.94	14%	0.32	0.38	19%
9	7/7/2017	14	1	0.8	12.87	13.46	5%	0.30	0.51	70%
10	7/10/2017	35.75	0.61	0.45	8.58	6.94	-19%	0.20	0.28	40%
11	7/11/2017	29.75	0.59	0.37	6.35	8.08	27%	0.17	0.23	35%
12	7/13/2017	54.5	0.79	0.7	16.27	19.41	19%	0.40	0.43	7%
13	8/4/2017	32.75	0.36	0.19	1.49	2.11	42%	0.11	0.11	0%
14	8/11/2017	24.25	0.27	0.21	1.52	1.97	30%	0.08	0.10	25%
15	8/15/2017	45	0.5	0.42	4.17	5.86	41%	0.14	0.22	57%
16	8/17/2017	39	0.32	0.15	2.10	2.17	3%	0.12	0.08	-33%



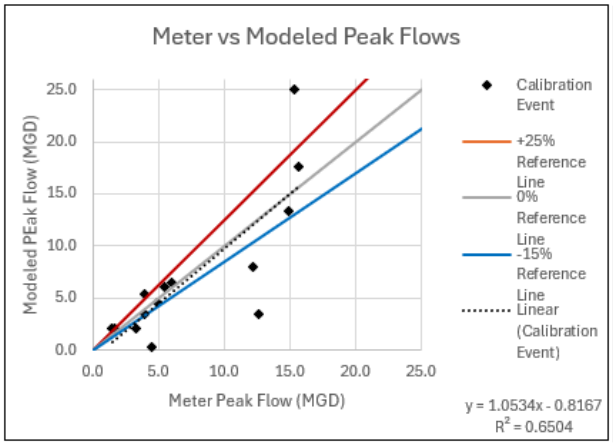


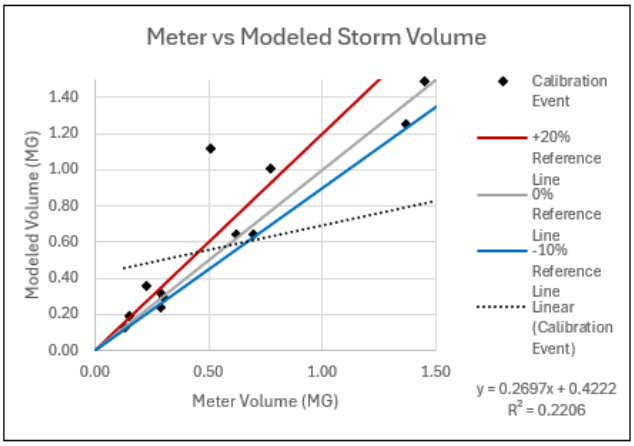
Model Assessment Summary for Sunset-27										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	42.25	0.97	0.26	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
2	4/5/2017	42.25	0.92	0.13	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
3	4/20/2017	118.5	0.98	0.54	0.28	0.26	-7%	0.00	0.00	#DIV/0!
4	4/29/2017	98.75	1.42	0.24	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
5	5/20/2017	92.5	0.75	0.38	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
6	5/24/2017	77	0.57	0.34	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
7	6/17/2017	70.75	1.85	0.96	5.37	5.09	-5%	0.18	0.16	-11%
8	6/22/2017	67	0.86	0.63	1.00	0.71	-29%	0.02	0.01	-50%
9	7/7/2017	57	1.01	0.8	1.23	0.80	-35%	0.02	0.02	0%
10	7/10/2017	34	0.61	0.45	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
11	7/11/2017	31.25	0.59	0.37	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
12	7/13/2017	76.75	0.79	0.7	2.80	2.15	-23%	0.03	0.03	0%
13	8/3/2017	34	0.36	0.19	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
14	8/11/2017	49	0.29	0.21	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
15	8/15/2017	46.75	0.5	0.42	0.00	0.01	#DIV/0!	0.00	0.00	#DIV/0!
16	8/17/2017	48.5	0.32	0.15	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!



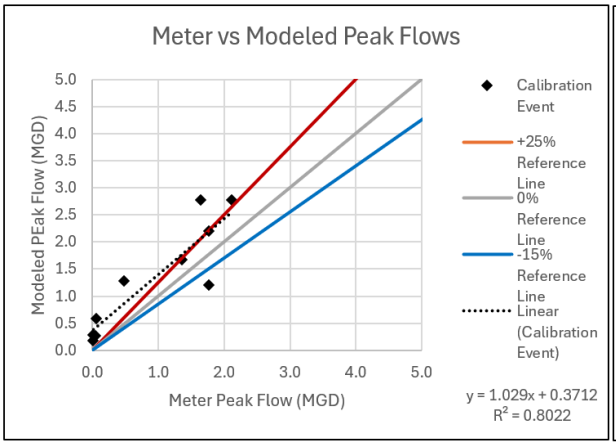


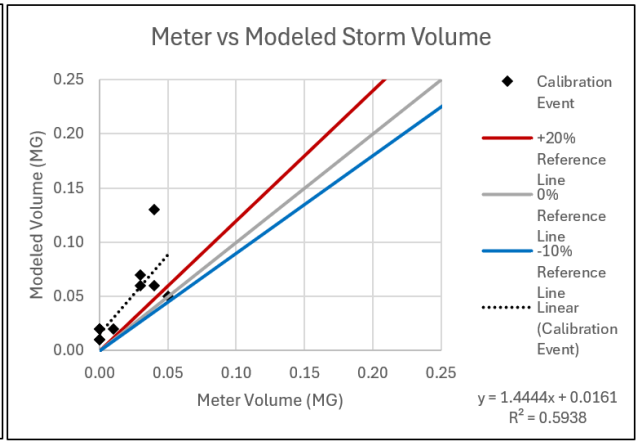
Model Assessment Summary for Touraine-48										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	42.5	0.97	0.26	12.64	3.47	-73%	2.09	0.89	-57%
2	4/5/2017	42.5	0.92	0.13	4.52	0.27	-94%	2.55	0.43	-83%
3	4/20/2017	119	0.98	0.54	14.87	13.31	-10%	1.45	1.49	3%
4	4/29/2017	106.25	1.42	0.24	3.90	3.49	-11%	1.37	1.25	-9%
5	5/20/2017	85	0.75	0.38	3.90	5.37	38%	0.62	0.64	3%
6	5/24/2017	107.5	0.58	0.34	4.94	4.57	-7%	0.70	0.64	-9%
9	7/7/2017	75	1.01	0.8	15.68	17.56	12%	0.51	1.12	120%
10	7/10/2017	35.75	0.61	0.45	5.99	6.42	7%	0.23	0.36	57%
11	7/11/2017	29.25	0.59	0.37	12.15	8.04	-34%	0.30	0.29	-3%
12	7/13/2017	99.75	0.79	0.7	15.37	25.01	63%	0.77	1.01	31%
13	8/4/2017	39.5	0.27	0.19	1.62	2.14	32%	0.13	0.13	0%
14	8/11/2017	71.75	0.29	0.21	1.45	2.06	42%	0.15	0.19	27%
15	8/15/2017	47.75	0.5	0.42	5.44	6.11	12%	0.29	0.32	10%
16	8/17/2017	92.5	0.32	0.15	3.27	2.13	-35%	0.29	0.24	-17%



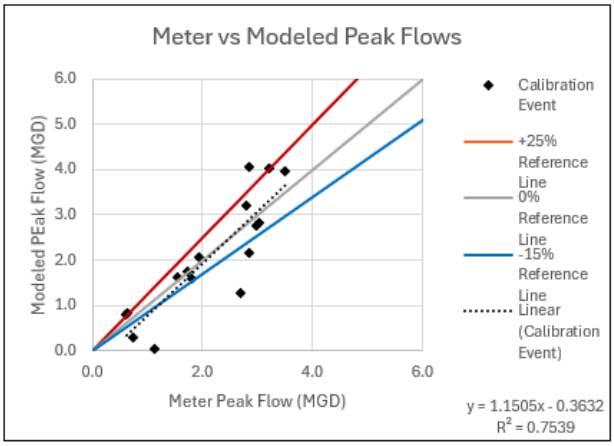


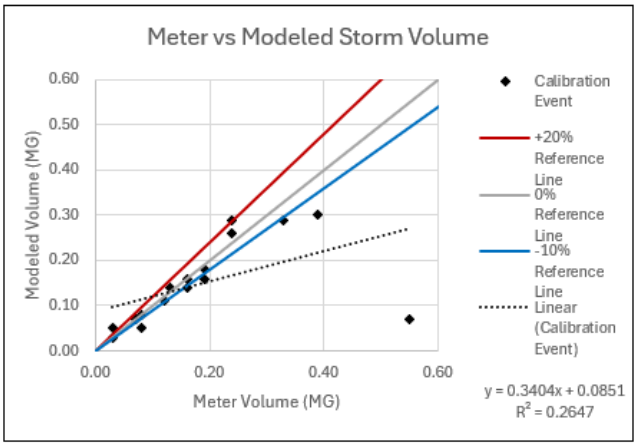
Model Assessment Summary for Valley-12										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
7	6/17/2017	6.25	1.15	0.53	1.64	2.78	70%	0.04	0.13	225%
8	6/22/2017	28.5	0.75	0.52	1.36	1.67	23%	0.03	0.06	100%
9	7/7/2017	20.75	0.79	0.6	1.77	1.21	-32%	0.03	0.07	133%
10	7/10/2017	35.25	0.71	0.58	2.11	2.77	31%	0.04	0.06	50%
11	7/11/2017	29	0.48	0.29	0.48	1.28	167%	0.01	0.02	100%
12	7/13/2017	15.5	0.64	0.57	1.77	2.20	24%	0.05	0.05	0%
13	8/3/2017	45.25	0.36	0.17	0.04	0.27	575%	0.00	0.02	#DIV/0!
14	8/11/2017	15.25	0.24	0.18	0.01	0.29	2800%	0.00	0.01	#DIV/0!
15	8/15/2017	13.75	0.38	0.3	0.06	0.58	867%	0.00	0.02	#DIV/0!
16	8/17/2017	26.75	0.24	0.09	0.01	0.18	1700%	0.00	0.01	#DIV/0!





Model Assessment Summary for Valley-18										
Event ID	Storm Statistics				Peak Flow Rate (MGD)			Storm Volume (MG)		
	Start Date	Duration (hr)	Total Rain (in)	Peak 1-Hr Intensity (in/hr)	Meter	Model	% Error	Meter	Model	% Error
1	4/3/2017	42.75	1.28	0.42	2.69	1.27	-53%	0.39	0.30	-23%
2	4/5/2017	42.75	0.93	0.13	1.13	0.05	-96%	0.55	0.07	-87%
3	4/20/2017	28.5	0.98	0.58	2.97	2.76	-7%	0.24	0.26	8%
4	4/30/2017	58.25	1.17	0.22	1.81	1.59	-12%	0.33	0.29	-12%
5	5/20/2017	71.75	0.74	0.38	1.93	2.06	7%	0.19	0.16	-16%
6	5/24/2017	40.5	0.58	0.34	1.54	1.62	5%	0.12	0.11	-8%
7	6/17/2017	38.75	1.24	0.53	2.84	4.05	43%	0.24	0.29	21%
8	6/22/2017	51	0.75	0.52	2.79	3.22	15%	0.19	0.18	-5%
9	7/7/2017	24	0.79	0.6	3.02	2.83	-6%	0.16	0.16	0%
10	7/10/2017	10.75	0.71	0.58	3.20	4.02	26%	0.13	0.14	8%
11	7/11/2017	28.5	0.48	0.29	2.84	2.17	-24%	0.08	0.08	0%
12	7/13/2017	35.5	0.64	0.57	3.51	3.98	13%	0.16	0.14	-13%
13	8/3/2017	19.25	0.32	0.17	0.63	0.82	30%	0.03	0.05	67%
14	8/11/2017	4.5	0.24	0.18	0.62	0.81	31%	0.03	0.03	0%
15	8/15/2017	12.75	0.38	0.3	1.72	1.74	1%	0.07	0.07	0%
16	8/17/2017	29	0.24	0.09	0.73	0.28	-62%	0.08	0.05	-38%





Appendix E. Pairwise Analysis Spreadsheets and Results

Flooding Concern Area Identification

A flooding concern area were identified if any of the following three conditions were met.

1. A roadway floods 6-inches or more during a 25-year, 1-hour event.
2. A parking lot floods 6-inches or more during a 25-year, 1-hour event
3. A building floods during a 25-year, 1-hour event.

Once the flooding concern area is identified, the concern area will be scored using all of the criteria.

Roadway Flooding Frequency

If any part of a roadway is flooded more than 6-inches during a given fequency event.

Score	Measurement	Scoring Criteria
0		
1	6-inches or greater in flood depth in a road	100-year, 1-hr
2	6-inches or greater in flood depth in a road	50-year, 1-hr
3	6-inches or greater in flood depth in a road	25-year, 1-hr
4	6-inches or greater in flood depth in a road	10-year, 1-hr
5	6-inches or greater in flood depth in a road	2-year, 1-hr

Roadway Flooding Location

Higher speed roadway flooding increase hydroplaining, residential intersection flooding is more important than other areas of residential roadway flooding.

Score	Measurement	Scoring Criteria
0		
1	6-inches or greater of flooding on a local roadway (25 mph or less)	25-year, 1-hr
2		
3	6-inches or greater of flooding on a local roadway intersection (25 mph or l	25-year, 1-hr
4		
5	6-inches or greater of flooding on a high speed roadway (35 mph or greate	25-year, 1-hr

Roadway Flooding Depth - Critical Facility

The roadway depth of flooding may prevent emergency vehicle access to a critical facility.

Score	Measurement	Scoring Criteria
0		
1	12-inches or greater of road flooding within 500 ft of a Crtical Facility	50-year, 1-hr
2		
3	18-inches or greater of road flooding within 500 ft of a Critical Facility	100 year, 1-hr
4		
5	18-inches or greater of road flooding within 500 ft of a Critical Facility	50-year, 1-hr

Parking Lot Flooding

6-inches of flooding hinders vehicle access, 12-inches risks car flooding.

Score	Measurement	Scoring Criteria
0		
1	6-inches or greater in flood depth in a parking lot	25-year, 1-hr
2	6- inches or greater in flood depth in a parking lot	10-year, 1-hr
3	6-inches or greater in flood depth in a parking lot	2-year, 1-hr
4	12-inches or greater in flood depth in a parking lot	100-year, 1-hr
5	12-inches or greater in flood depth in a parking lot	50-year, 1-hr

Roadway Flooding Extent

The amount of roadway area flooded 6-inches or more during the 25-year, 1-hour event

Score	Measurement	Scoring Criteria
0	less than 0.02 acres of flooded road area	
1	greater than 0.02 acres but less than 0.1 acres of flooded road area	25-year, 1-hr
2	greater than 0.1 acres but less than 0.2 acres of flooded road area	25-year, 1-hr
3	greater than 0.2 acres but less than 0.4 acres of flooded road area	25-year, 1-hr
4	greater than 0.4 acres but less than 1.0 acres of flooded road area	25-year, 1-hr
5	greater than 1.0 acres of flooded road area	25-year, 1-hr

Building Surface Flooding Frequency

A building that floods during a fequent rain event is more important than multiple buidlings flooding during a less frequent event. Buildings <500 square feet are excluded from the analysis as these were assumed to be smaller structures such as garages or sheds.

Score	Measurement	Scoring Criteria
0		none
1	1 to 5 buildings flooded	100-year, 1-hr
2	greater than 5 buildings	100-year, 1-hr
3	1 to 5 buildings flooded	25-year, 1-hr
4	greater than 5 buildings	25-year, 1-hr
5	1 or more buildings	2-year, 1-hr

Building Flooding Type

Mulitple residential building flooding is more important than office/commercial building flooding. Buildings <500 square feet are excluded from the analysis as these were assumed to be smaller structures such as garages or sheds.

Score	Measurement	Scoring Criteria
0		
3	Only a Office, Commercial, Other building floods	25-year, 1-hr
4	At least 1 Single Family Residential building floods	25-year, 1-hr
5	At least 1 Multiple Residential building floods	25-year, 1-hr

Surface Flooding - CSS Area

Surface flooding within a CSS area has a higher health risk than flooding in an MS4 area.

Score	Measurement	Scoring Criteria
0		
1	More than 1-inch of surface flooding during the 25-year, 1-hr	25-year, 1-hr
2		
3	More than 1-inch of surface flooding during the 10-year, 1-hr	10-year, 1-hr
4		
5	More than 1-inch of surface flooding during the 2-year, 1-hr	2-year, 1-hr

Basement Flooding - CSS Surcharge

If the HGL at a node is less than 8 feet below the rim or if the node invert is less than 8 feet below the rim and the node is surcharged during the 10-year, 1-hour storm the basments connected near the node is at risk of flooding.

Score	Measurement	Scoring Criteria
0		
1	1 to 5 basement flooding nodes	10-year, 1-hr
2		
3	6 to 10 basement flodding nodes	10-year, 1-hr
4		
5	11 or more basement flooding nodes	10-year, 1-hr

Exhibit 3
City of Fayetteville
Bonnie Doone Drainage Improvements
Criteria Pairwise Ranking

City Staff - March 11, 2009

		ITEM 2									RESULTS		
	Criteria	Roadway Flooding Frequency	Roadway Flooding Location	Roadway Flooding Depth - Critical Facility	Roadway Flooding Extent	Parking Lot Flooding	Building Flooding Frequency	Building Flooding Type	Surface Flooding - CSS Area	Basement Flooding - CSS Area	SUM	Rank	%
ITEM 1	Roadway Flooding Frequency		2	2.2	2.9	4.0	2.0	1.7	2.0	1.2	18.3	8	0.08
	Roadway Flooding Location	3.7		1.6	3.7	4.3	2.8	2.0	2.6	1.6	22.3	6	0.10
	Roadway Flooding Depth - Critical Facility	3.8	4.4		4.3	4.9	4.0	3.3	4.2	3.2	32.0	2	0.15
	Roadway Flooding Extent	3.1	2.3	1.7		4.1	2.1	1.9	2.3	1.4	18.9	7	0.09
	Parking Lot Flooding	2.0	1.7	1.1	1.9		2.0	1.1	1.0	1.0	11.8	9	0.05
	Building Flooding Frequency	4.0	3.2	2.0	3.9	4.0		2.5	2.8	2.2	24.6	5	0.11
	Building Flooding Type	4.3	4.0	2.7	4.1	4.9	3.5		3.2	2.3	29.0	3	0.13
	Surface Flooding - CSS Area	4.0	3.4	1.8	3.7	5.0	3.2	2.8		1.4	25.3	4	0.12
	Basement Flooding - CSS Area	4.8	4.4	2.8	4.6	5.0	3.8	3.7	4.6		33.8	1	0.16

Item

Item 1 is MUCH LESS important than Item 2 = 1

Item 1 is LESS important than Item 2 = 2

Item 1 has the SAME importance as Item 2 = 3

Item 1 is MORE important than Item 2 = 4

Item 1 is MUCH MORE important than Item 2 = 5

Criteria	Description
Roadway Flooding Frequency	How frequently a roadway floods. For example, a road that frequently floods during 2-year event.
Roadway Flooding Location	Where roadway flooding occurs. For example, a road that floods on heavily traveled road.
Roadway Flooding Depth - Critical Facility	Flooding that occurs on a roadway near a critical facility such as a police or fire station.
Roadway Flooding Extent	The total area of roadway that floods 6-inches or greater within an flood prone area.
Parking Lot Flooding	Flooding that occurs in parking lots.
Building Flooding Frequency	How frequently a building floods. For example, a building that frequently floods during a 2-year event.
Building Flooding Type	The type of building where flooding occurs. For example, a multi-residential apartment building.
Surface Flooding - CSS Area	Flooding on the surface within the combined sewer area.
Basement Flooding - CSS Area	Basement flooding within the combined sewer area.

Appendix F.

Task 8: *Alternatives Analysis* Technical Memorandum

Technical Memo

Date:	Friday, July 24, 2026
Project:	City of East Lansing Wet Weather Resiliency Plan
To:	Cliff Walls, City of East Lansing
From:	Ernie West Julie Stein Tom Batroney Kaylee Johnson Anna Kilts
Subject:	Task 8: Evaluation of Flood Mitigation Alternatives

1 Introduction

The City of East Lansing (City) is developing a Wet Weather Resiliency Plan (WWRP) to mitigate surface and basement flooding in the city. In December 2023, the City of East Lansing (City) retained HDR Michigan, Inc. (HDR) to support the implementation of Environment, Great Lakes, and Energy's (EGLE) High Water Infrastructure Grant Program for the development of the WWRP. The primary goals of the WWRP are to:

- Establish where and why urban flooding is occurring
- Identify existing and future severe weather vulnerabilities
- Determine equitable, community-driven capital investments

This technical memorandum summarizes the identification, evaluation, and recommendations for flood mitigation alternatives under Task 8 – Evaluate Flood Mitigation Alternatives to be included as part of the WWRP.

2 Establishment of Approach

The goal of this task is to identify, evaluate, and prioritize potential alternatives to mitigate flood risk within the City. Several meetings and workshops were held with the City throughout the alternative development process. Key meetings are summarized in Table 2-1. Available meeting minutes and presentation slides are also included as Appendix A.

Table 2-1. Task 8 Meetings and Workshops Summary

Date	Meeting or Workshop	Primary Discussion Topics
12/10/25	Planned CIP Projects	• Existing City CIP projects that overlap with the Top 8 Concern Areas (CAs)
12/19/25	Initial Strategies Workshop	• Flooding CAs screening analysis & potential flood mitigation strategies • Alternatives for modeling
2/20/26	Phase 1 Modeling Results Workshop #1	• First round of model results for CAs A, B, C, D, F, and H • Stormwater separation sensitivity analysis
4/30/26	Alternatives Modeling Results Workshop #2	• Second round of model results for CAs, A, B, C, D, E, G, F, and H • Preliminary stormwater trunk sizing
5/29/26	Alternatives Modeling Results Workshop #2 Follow Up	• Third round of model results incorporating feedback from the previous Workshop #2

The following subsections establish the general approach and important considerations for the development of the flood mitigation alternatives discussed in Section 5:

- Identification of Top 8 Flooding Concern Areas
- Selected Level of Service Goals for Alternative Evaluation
- Review of Current and Planned System Improvements
- Screening of Flood Mitigation Strategies
- Review of Concern Areas and Hydraulic Connections Between CSS Watersheds

2.1 Identification of Top 8 Flooding Concern Areas

Alternatives were developed for the top 8 flooding concerns areas (CAs) shown in Figure 2-1. Flooding CAs were previously identified and prioritized as part of the Existing Conditions Flood Assessment Report (February 2026). The assessment used the 25-year, 1-hour design storm to identify a total of 58 areas at risk of flooding. Flooding CAs were defined as anywhere the model predicts one of the three conditions are met:

1. A roadway floods 6-inches or more
2. A parking lot floods 6-inches or more, or
3. A building floods

The top 8 flooding CAs were selected through a weighted scoring of objective flooding criterion developed during the resiliency workshop held by the project team. Of the top flooding CAs, 6 are located in the CSS (combined sewer system) and 2 are located in the MS4 (stormwater system).

The reason for limiting the alternatives development to the top 8 flooding CAs is based on available funding for the project. While the top 8 flooding CAs are prioritized for alternatives development, it is anticipated many of the lower-priority CAs will benefit from adjacent projects because of the interconnectivity of the drainage infrastructure. The analysis, identification, and

implementation of alternatives to address the remaining CAs will occur as additional funding becomes available.

The existing conditions maximum level of service (LOS) rain event for each of the top 8 flooding CAs is summarized in Table 2-2. For the purposes of this evaluation, LOS is considered to be met if the majority of sewers within the CA are not surcharged above pipe crown. These values were determined by incrementally simulating the model for increasing rainfall amounts using the Huff and Angel rainfall estimates for consistency with the City's current stormwater regulations and Combined Sewer System Modeling and Master Plan Report from 2020. These are commonly used rainfall estimates in stormwater evaluations throughout the Midwestern United States. The updated rainfall estimates in the Task 1 Changing Precipitations Conditions Report were not used for this analysis as these rainfall estimates had not yet been formally adopted at the time of this analysis.

Currently, the City's LOS standard for analyzing existing combined sewer capacity (10-year, 1-hour Assessment Storm, 1.61 inches) is not being met in the top 8 flooding concern areas, as the H&H model indicates potential flooding risk in the form of surface flooding and basement backups. Analysis shows that the existing sewers only have the capacity for a 5-year design storm or less, with most concern areas only meeting a capacity of a 1-year design storm or less.

Table 2-2. Current level of service for the top 8 flooding concern areas

Flooding CA	Current Maximum LOS (based on Huff and Angel)	Location	Sewer Area
A	2-year, 1-hour	Highland Ave. and Westview Ave.	CSS
B	5-year, 1-hour	N Harrison Rd. and E Saginaw St.	CSS
C	2-year, 1-hour	Northlawn Ave.	CSS
D	<1-year, 1-hour	Michigan Ave. and W Grand River Ave.	CSS
E	1-year, 1-hour	Burcham Dr.	CSS
F	<1-year, 1-hour	Abbot Rd. and E Saginaw St.	MS4
G	<1-year, 1-hour	Beech St.	CSS
H	<1-year, 1-hour	Pebblebrook Ln.	MS4

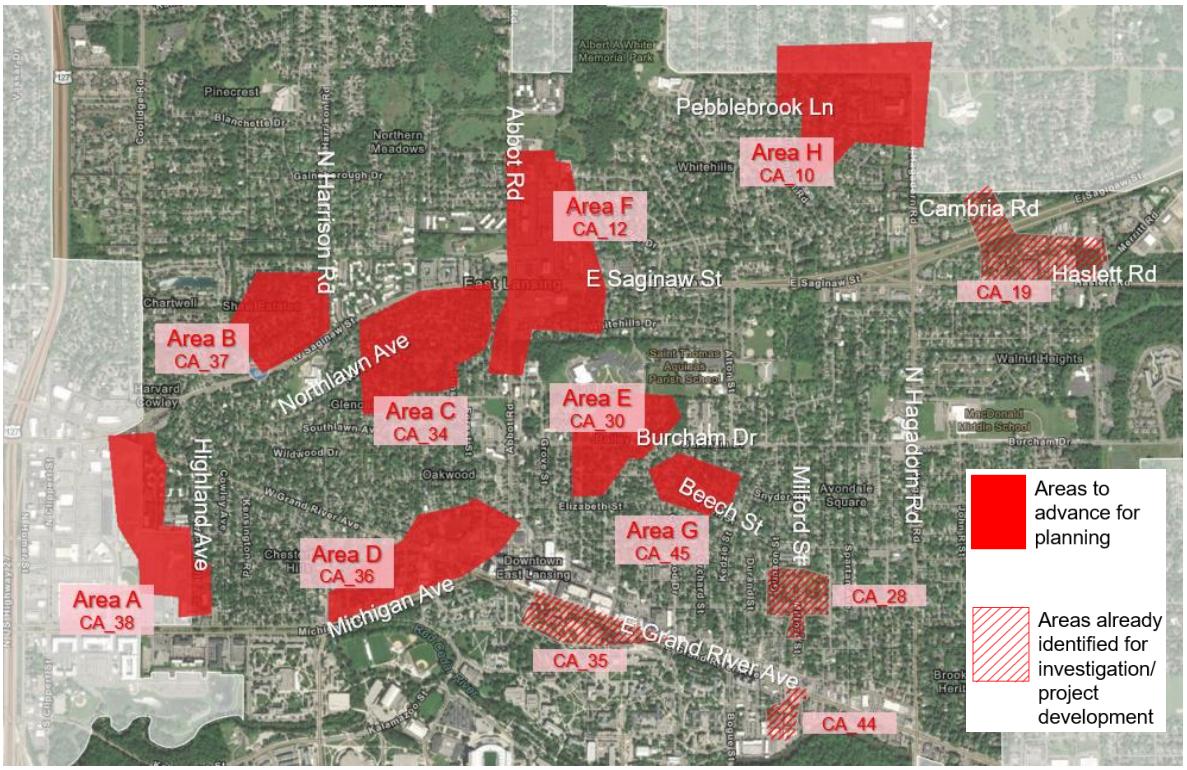


Figure 2-1. Location of the Top 8 Flooding Concern Areas

2.2 Selected Level of Service Goals for Alternative Evaluation

As it is not feasible to design and build a stormwater infrastructure system to manage and convey every storm, it is necessary to define LOS goals that balance design standards, affordability, and equity. Two LOS storm events were selected by the City during the Initial Strategies Workshop (December 2025) for the purpose of sizing alternatives in the model. The LOS storm events for alternatives evaluation are further described in Table 2-3. Similar to the existing conditions assessment, Huff and Angel rainfall distributions were assumed.

This approach establishes lower and upper bounds, resulting in planning-level alternatives with a range of benefits and costs. The current 10-year, 1-hour storm is City's current LOS standard and was previously used as part of the Combined Sewer System Modeling and Master Plan Report from 2020. The future 2100 16-year, 1-hour storm, which is roughly equivalent to the current 50-year design storm, is intended to proactively account for climate change and inform decision making related to long-term capital investments for the City's drainage infrastructure.

Table 2-3. Evaluated LOS Scenarios for Alternatives

LOS Goal	Design Storm	Rainfall Depth (inches)
Current Standard: upgrade localized drainage system consistent with current standard	Current 10-year, 1-hour	2.00
Enhanced: enhance localized drainage system to manage a larger design storm, where feasible	2100 16-year, 1-hour (equal to today's 50-year design storm)	2.54

To evaluate the performance of alternatives the H&H model is simulated and compared against LOS goals. To identify whether an alternative meets the current or enhanced LOS goals, they must meet the following criteria:

- **Within the CSS:** The LOS goals are met if the hydraulic grade line (HGL) is 8.5 feet below ground at both ends of the pipe. Alternatively, the LOS goals are met if the surcharge in the pipe is less than 1.0 foot above the pipe crown.
    - This criterion is intended to keep water levels in the sewer below an elevation where basement flooding from sewer backup may pose a risk. Additionally, this criterion has been used in previous evaluations and planning efforts for the CSS.
- **Within the MS4:** The LOS goals are met if there is no manhole flooding onto the surface.

2.3 Review of Current and Planned System Improvements

To identify potential flood risk mitigation alternatives, it is important to consider current and planned system improvements previously developed by the City. Separate from the WWRP, the City currently follows a Combined Sewer System Modeling and Master Plan Report from 2020 and a 2025 Clean Water State Revolving Fund (CWSRF) project planning document to manage and mitigate wet weather impacts on the CSS. The existing CSS master plan outlined several capital improvement projects for the CSS area, four of which have already been completed and included in the updated H&H model. Several other planned projects overlap with top 8 flooding CAs. Table 2-4 provides a summary of the completed and planned improvements projects as part of the existing master plan and whether it overlaps with a CA.

Table 2-4. 2020 Master Plan completed and planned projects summary.

Project	Description	Completed? (Y/N)	Overlap with identified CA?
Project 1	Michigan Avenue and Harrison Road sewer improvements	Y	N/A
Kedzie Alternative 2	Kedzie Street storm sewer	Y	N/A
Sunrise Alternative 2	Sunrise Court storm sewer and Division/Linden connection	Y	N/A
Shaw Estates Alternative 1	Backflow prevention on service leads	Y	N/A
Project 10 Alternative 1 Segment 1	Portion of Northlawn Avenue sewer improvements between Harrison Road and Sunset Lane	Y	N/A
Project 2	Oakhill/Evergreen improvements	Y	N/A

Table 2-4. 2020 Master Plan completed and planned projects summary.

Project	Description	Completed? (Y/N)	Overlap with identified CA?
Project 3 Alternative 4 Segment 1	Center and Beal regulator modifications	N	Y
Project 3 Alternative 4 Segment 2	Elm/Valley District storm sewer for upstream areas	N	Y
Project 13	Wilmarth-Woodmere relief	N	N
Project 4	Charles Street sewer replacement	N	Y
Project 6 Alternative 1	Chesterfield Hills Neighborhood sewer improvements	N	N
Project 7 Alternative 3	Separation and redirection of stormwater to Montgomery Drain	N	Y
Project 8	Bailey-Linden sewer	N	Y
Project 9 Alternative 1	Shaw Estates sewer separation with new sanitary sewers and a local pump station	N	Y
Project 10 Alternative 1 Segment 2	Remaining combined sewer improvements not constructed with Northlawn Avenue work	N	Y
Project 5 Alternative 1	Albert Alley sewer improvements	N	N
Project 11	Milford-Gunson sewer separation with new storm sewer	N	N
Local Improvements	Local sewer improvements to address local capacity restrictions	N	N/A

The following CIP projects in the 2020 Master Plan have not yet been completed and overlap with one or more of the top 8 floodings CAs. The developed flood mitigation alternatives consider these projects and several concepts were modified to meet the updated LOS goals for the alternatives analysis.

- Project 3 – overlaps CA-36 (D)
- Project 4 – downstream of CAs 34, 30, 45 (C, E, G)
- Project 7 – overlaps CA-38 (A) and downstream of CA-37 (B)
- Project 8 – downstream of CAs 30, 45 (E and G)
- Project 9 – overlaps CA-37 (B)
- Project 10 – overlaps CA-34 (C)

Due to proximity to CA G and potential impacts on the CSO tunnel, the Milford Gunson Street sewer separation project (Project 11) was incorporated into the existing conditions model as it is currently under construction. Sewer separation extents and combined sewer upsizing were included for this project based on the PCSWMM model developed by Fishbeck to inform the design.

2.4 Screening of Flood Mitigation Strategies

To mitigate flood risk within the top 8 flooding CAs, several mitigation strategies were considered to create alternative projects. Since the drainage infrastructure does not have capacity for today's climate, a mix of strategies is needed to increase the LOS performance in the developed areas of the City to the current and enhanced LOS goals. As part of the Initial Strategies Workshop (December 2015) four key flood risk mitigation strategies were identified

for use as part of the development of alternatives. Table 2-5 provides an overview of each strategy.

Table 2-5. Key strategies for flood risk mitigation alternatives

Strategy	Description
Combined sewer separation	Constructing new storm sewer pipes that run parallel to the existing combined sewer to separate stormwater and sanitary flows. This reduces combined sewer overflows (CSOs) by providing a separate flow path for stormwater to outfall to the river or other receiving systems. This requires the construction of potentially large-diameter new storm trunkline sewers.
Upsizing of pipes	Upsizing of existing combined and separate storm sewer pipes. This is useful in areas where separation alone will not reduce flooding risk. This is also applicable in areas where there is no route to a nearby river for a separate storm sewer or where existing separate storm sewers are also undersized.
Flow diversions or regulator modifications	A modification to a flow regulator, such as the addition of a sewer bulkhead or the removal of a weir, to redirect water within the CSS in different directions. For the alternatives developed, this primarily included lowering weir elevations to increase the capacity of water sent to the CSO tunnel. This helps to optimize the use of existing infrastructure.
Green infrastructure and storage	Aboveground (e.g., stormwater wetlands and detention ponds) or underground storage for stormwater retention. The addition of green infrastructure and storage can provide additional resiliency, or it can reduce required pipe sizes. It also provides water quality benefits and attenuates peak flows to the river and open drain systems.

Within the CSS, sewer separation is the City's preferred strategy over combined sewer upsizing. Preliminary results show that upsizing may still be required at some locations to meet LOS goals after sewer separation is complete and should be confirmed by post construction flow monitoring and re-evaluated. The developed alternatives did not include in-kind rehabilitation of existing sewers as rehabilitation projects generally involve keeping the same diameter size pipe and maintaining existing capacity.

Community representatives indicated a strong desire for green infrastructure to be incorporated into the alternatives. As a result, several opportunities for green infrastructure and storage facilities were identified, mainly from available City-controlled properties. In general, privately owned parcels were not studied extensively for green infrastructure and storage opportunities because of a lack of property control to easily implement projects. The one exception to this approach are the privately held commercial properties in the Saginaw/Abbot Commercial Area discussed below. This area has an extremely high level of impervious cover within large surface-level parking areas and generates a significant amount of runoff within the H&H model. Opportunities for impervious cover reduction and/or storage may exist in this area and should be explored further as redevelopment opportunities arise. This solution will reduce the amount of runoff in the system and will reduce the size and cost of the upsized sewers needed to provide a higher level of service to this area.

The potential green infrastructure and storage are shown in Figure 2-2 and are located at:

- Gordon Guyer Park
- Glencairn Elementary School
- Valley Court Park
- Saginaw/Abbot Commercial Area
- Albert A. White Memorial Park
- Harrison Meadows Park and open areas west of Abbot Road
- The Fire Department
- Ranney Park

It should be noted that Ranney Park is currently constructed, owned, and operated by the Ingham County Drain Commissioner (Montgomery Drainage District). Any stormwater management within Ranney Park would require an agreement to be in place before sending stormwater to this area. As part of the construction of Ranney Park, the City proactively worked with the Drain Commissioner to allow for future additional stormwater offloading into the park as part of the design. Final agreements must be formalized prior to using this park for the City's stormwater management goals.

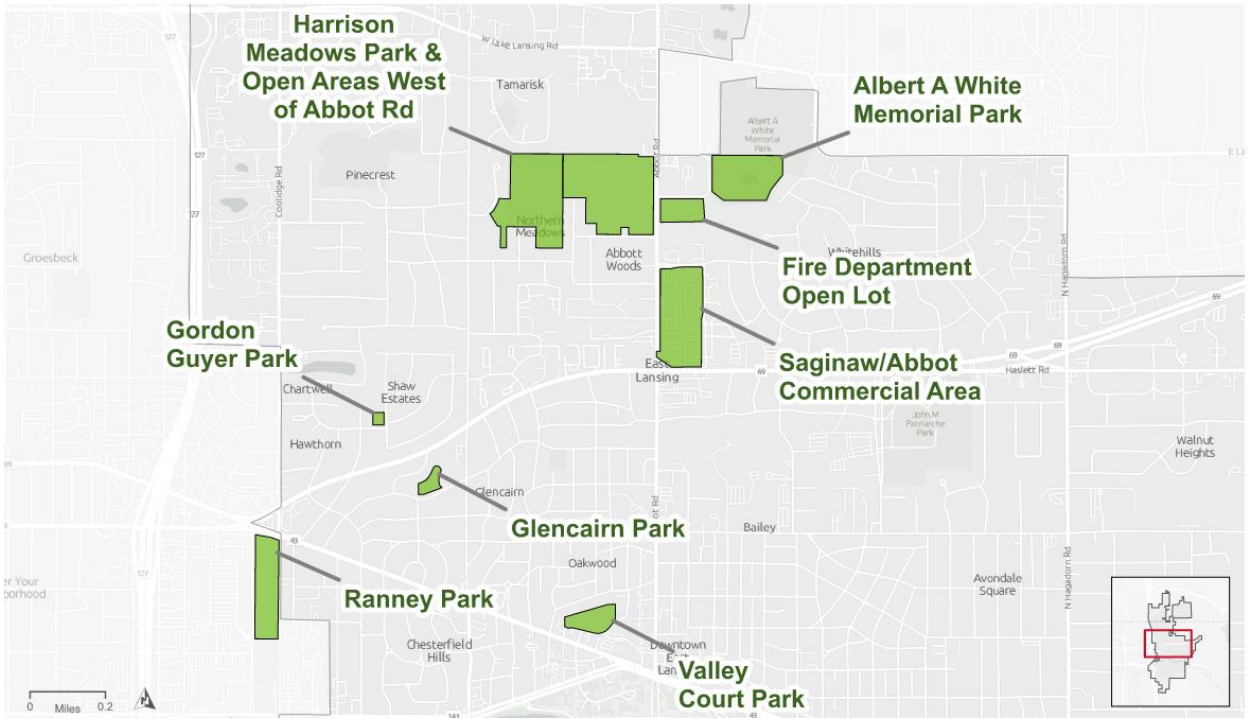


Figure 2-2. Map showing the location of identified opportunities for green infrastructure/storage opportunities.

2.5 Review of Concern Areas and Hydraulic Connections Between CSS Watersheds

Understanding how the 6 flooding CAs are hydraulically connected within the CSS is critical to the development of the flood risk mitigation alternatives and the overall approach. This understanding allows us to predict the movement of water within the subsurface drainage system during intense storm events. Because many of the CAs are within the same connected network, flood risk mitigation in one area will impact the surrounding upstream and downstream areas. Figure 2-3 below shows a map of the primary direction of combined sewer flows between the watersheds in the CSS model area. On the map, the star icons represent key hydraulic splits in the flow. During the current 10-year, 1-hour storm the model predicts a hydraulic backup occurs at the Sunset regulator along Northlawn Avenue and reverses flow into CA C, and is further discussed in Section 3.2.

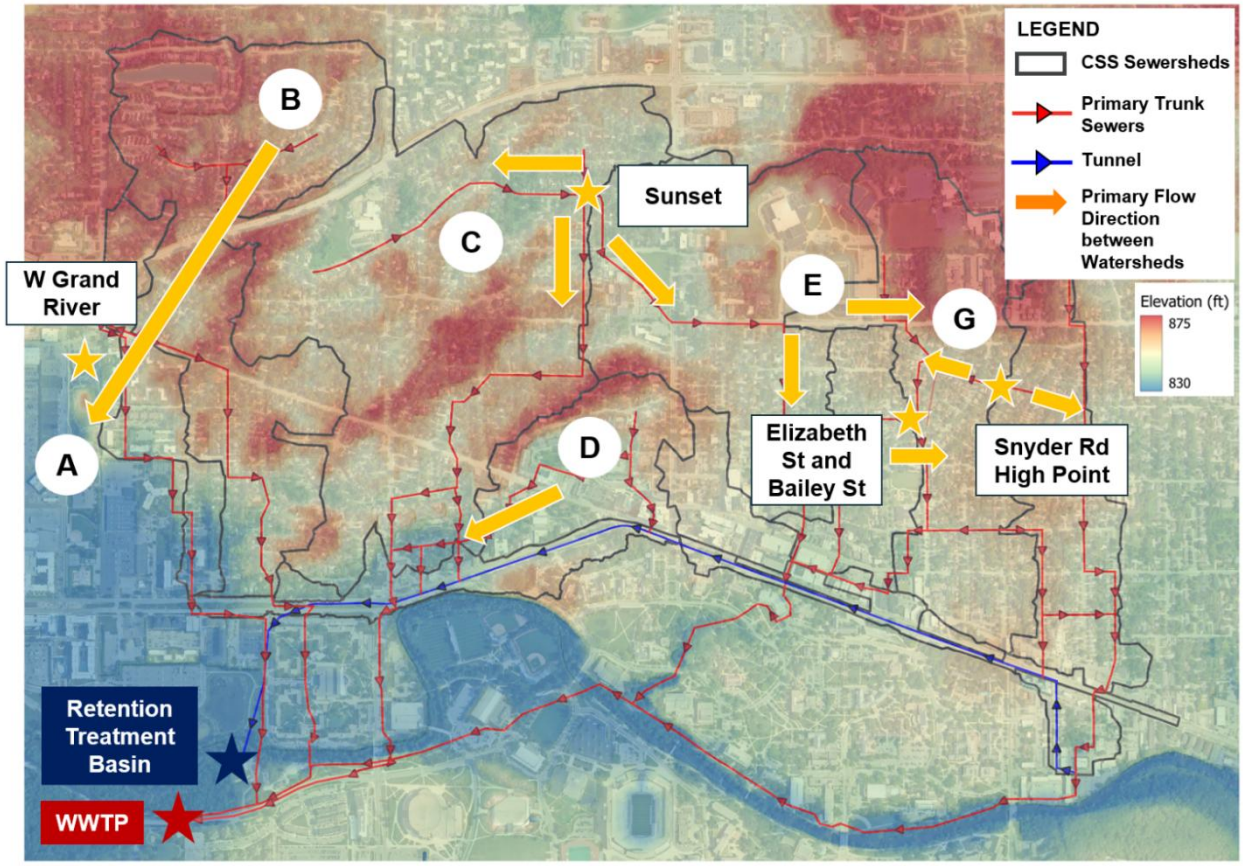


Figure 2-3. Hydraulic connectivity between concern area CSS watersheds

As shown in the map above, the flooding CAs in the CSS area can be organized into hydraulically connected "systems" or groups:

- CAs A and B are connected
- CAs C, E, and G are connected
- CA D is independent

Additionally, hydraulic conditions within the downstream interceptor and CSO tunnel have the potential to impact upstream CAs as capacity is exceeded. The hydraulic connections influenced the development of the flood risk mitigation alternatives, which are packages of projects aimed at reducing flooding in one or more CAs. CAs F and H are not sown in Figure 2-3 as they are located within the MS4 area, and were considered as independent CAs for alternatives analysis.

3 Initial Storm Separation and Charles Street Modeling

To assess the viability of sewer separation to address flood risk within the CSS, the H&H model was updated to account for sewer separation, simulated for the current 10-year 1-hour storm, and evaluated against LOS criteria. Results were presented and discussed with the City during the Phase 1 Modeling Results Workshop #1 (February 2026.)

3.1 CSS Storm Separation Sensitivity Analysis

Phase 1 of the alternatives modeling focused on separation within CAs A, B, C, and D. Separation within CAs E and G was not modeled at this time to determine whether these areas benefit from separation in CA C. Sewer separation was initially modeled assuming a stormwater separation effectiveness of 100%, where only sanitary flows would remain tributary to the existing combined sewer system and all stormwater from public and private sources would be separated into a new storm sewer. Modeling was completed in three iterations by expanding the separation area in each consecutive simulation to best meet LOS goals. The targeted separation areas for the sensitivity analysis are shown in Figure 3-1. The targeted separation areas were preliminary to test model LOS benefits to increased separation area and do not necessarily match the identified alternatives. To meet LOS goals the model predicts sewer separation extents of Run 3 would be required for the current 10-year, 1-hour design storm, including all 3 colored boundaries. Results of the Phase 1 modeling showed that separation in CA C does not benefit CAs E or G downstream.

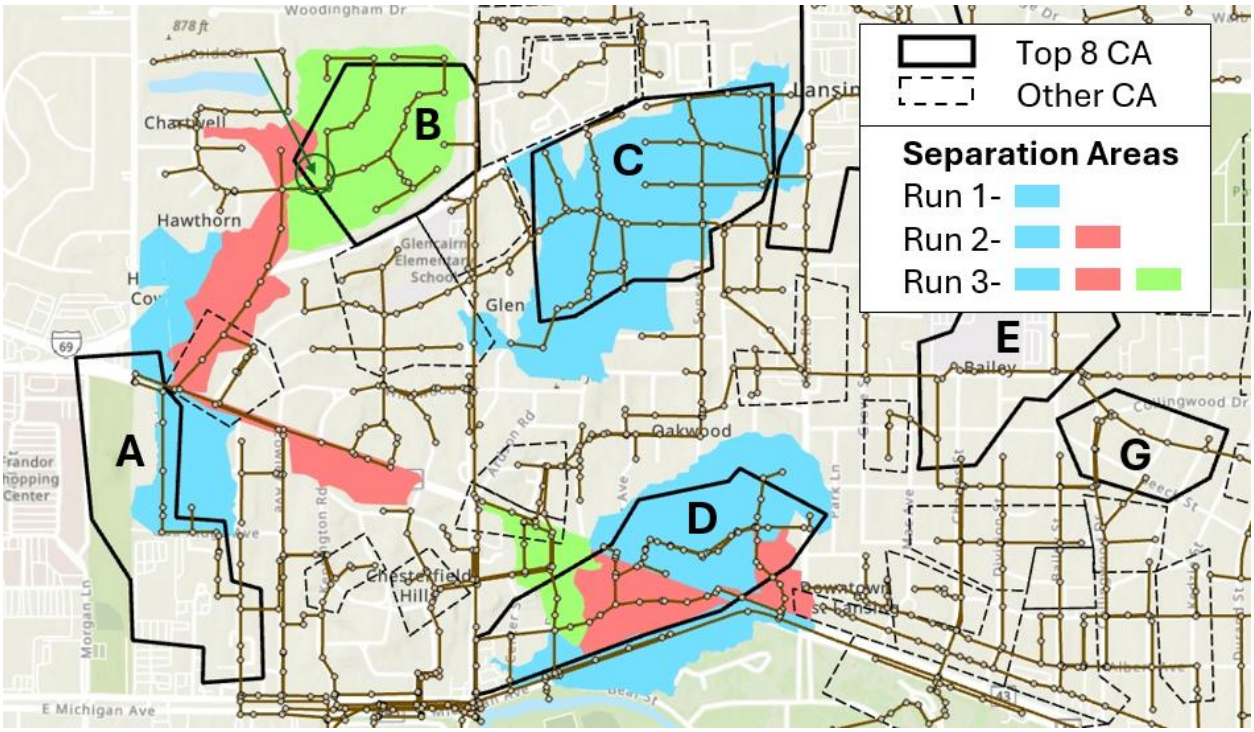


Figure 3-1. Storm Separation Areas for Sensitivity Analysis

As achieving a 100% stormwater effectiveness is typically considered unrealistic for sewer separation projects, an additional sensitivity analysis was completed in the H&H model to determine the required separation effectiveness to meet LOS goals. Using the Run 3 separation areas the model was updated assuming a separation effectiveness of 90% and 80%. Sewer separation was modeled by reducing the subcatchment contributing area to 10% and 20%, respectively, to account for the fraction of stormwater that would remain within the existing combined sewer system. The H&H model predicts that additional improvements would be needed if a separation effectiveness lower than 100% is assumed. Model predicted LOS results for the sensitivity analysis considering the 80% and 90% stormwater separation effectiveness

assumptions for separation of the Run 3 areas are shown in Figure 3-2. Sewers shown in red do not meet LOS goals and manholes shown in yellow are flooding to surface. Based on discussions during the Phase I Modeling Results Workshop #1 it was ultimately decided to proceed with the 80% stormwater separation effectiveness assumption as a planning level estimate for the development of alternatives based on conversations with the City.

Results of the sensitivity analysis indicate that additional flood mitigation strategies aside from sewer separation will likely be needed to mitigate flood risk within the combined sewer system.

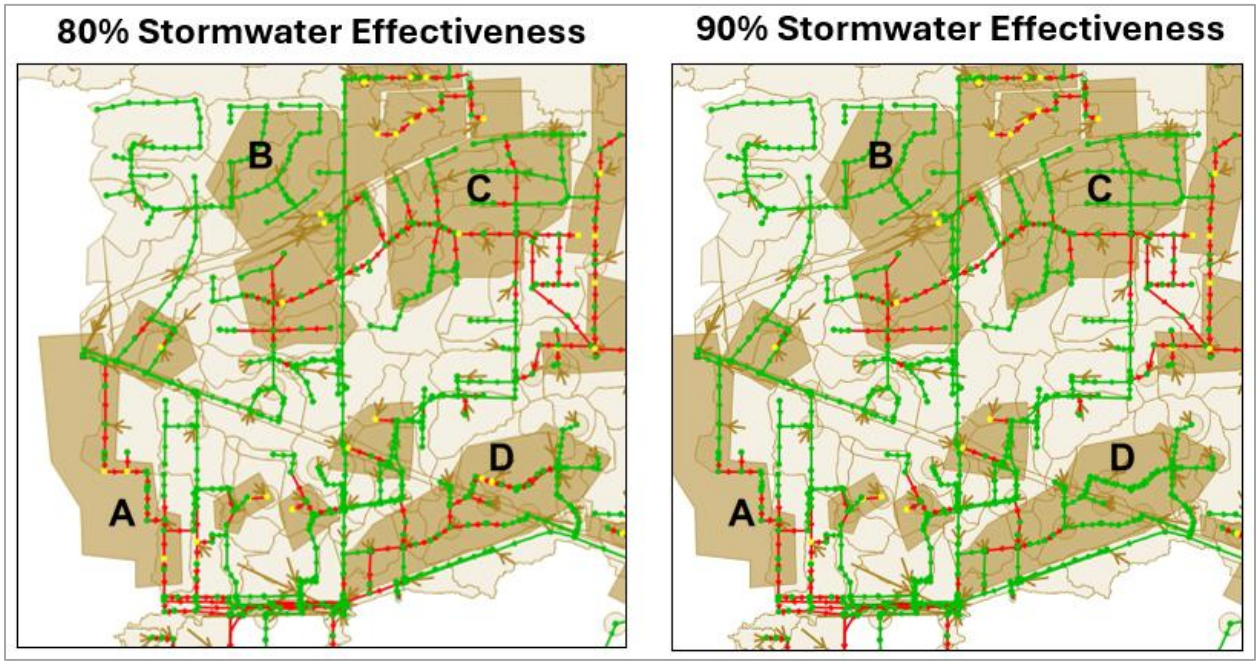


Figure 3-2. LOS Results – Sensitivity Analysis – Run 3 Areas at 80% & 90% Separation Effectiveness- Current 10-year, 1-hour Design Storm

3.2 Charles Steet CIP

During Phase 1 it was also discovered that the Charles Street trunk sewer contributes to flood risk in CA C for the current 10-year, 1-hour design storm. The existing 48-inch and 54-inch combined sewer along Charles Street is under capacity to convey the design storm. As capacity is exceeded a hydraulic backup occurs reaching the low-lying manhole at the intersection of Abbot Road and Burcham Drive (MH-336) and further upstream to Northlawn Avenue. The hydraulic backup also reverses flow over the diversion weir at the intersection of Northlawn Avenue and Sunset Lane. A hydrograph of the reverse flow over the weir is shown in Figure 3-3 for the current 10-year, 1-hour design storm.

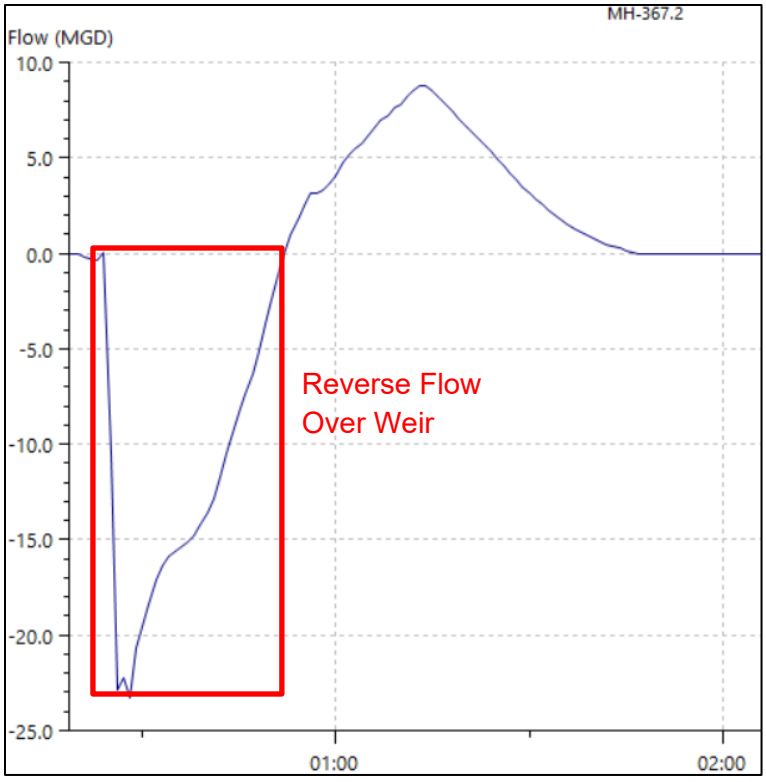


Figure 3-3. Sunset Diversion Weir Hydraulic Backup from Charles Street During Current 10-year, 1-hour Design Storm

While stormwater separation decreases the hydraulic grade line (HGL) of the combined sewer by approximately 1 ft at the Sunset diversion structure, storm separation on its own is not enough achieve the LOS goals as reversal of flow over the Sunset diversion continues to occur due to limited hydraulic capacity on Charles Street. Based on the need to increase capacity of the Charles Street trunk sewer to mitigate flood risk in CA C, the H&H model was updated to include the Charles Street combined sewer upsizing CIP (MP Project 4).

A hydraulic profile of the existing combined sewer system extending from CA-39 at the upstream end of the profile through Northlawn Avenue (CA C) and downstream to Charles Street tunnel connection at Grand River Avenue is shown in Figure 3-4. Within Figure 3-4 the red line represents the HGL for existing conditions, the black line represents Run 3 with 80% stormwater separation effectiveness, and the green line represents Run 3 with 80% stormwater separation effectiveness and the Charles Street upsizing CIP. As shown in the Figure, LOS is met within CA C for the current 10-year, 1-hour design storm if the Charles Street CIP is included along with upstream separation. Based on conversations with the City during the Phase 1 Modeling Results Workshop #1 the importance of the Charles Steet project was discussed. At the conclusion of the workshop, it was determined to include the Charles Street upsizing project in all alternatives developed for CA C.

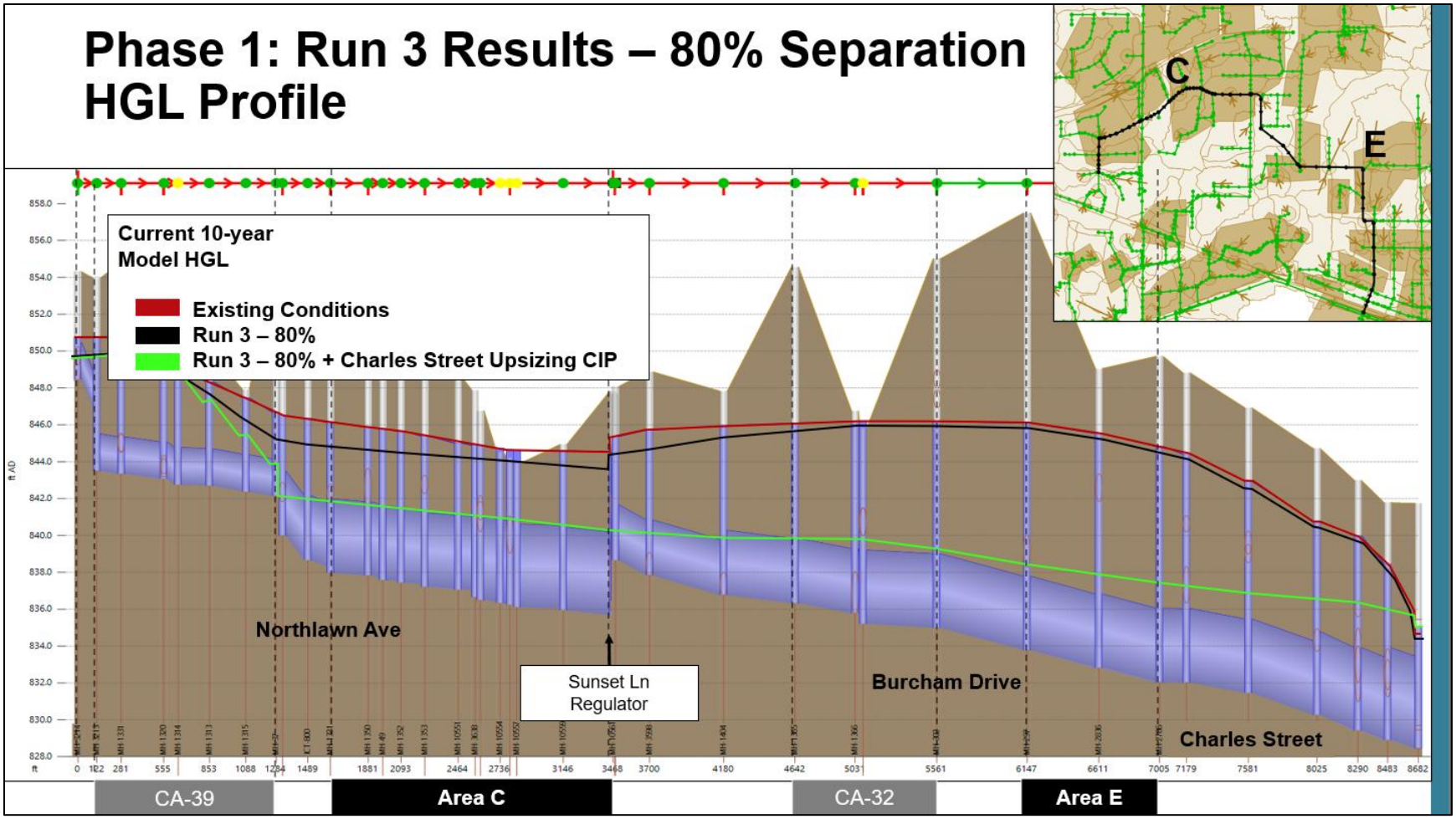


Figure 3-4. Hydraulic Profile – Run 3 Results – CA C, Current 10-year, 1-hour Design Storm

4 Modeling Methodology & Assumptions for Alternatives Scenarios

Potential flood mitigation alternatives were developed and modeled based on the following assumptions and methodology:

4.1 Methodology

The following is a summary of the general methodology applied for the development of the alternatives:

1. Alternatives were developed for each of the top 8 flooding CAs in the following groupings:
    - Alternatives CAs A and B within the CSS were bundled together due to the hydraulic connectivity and shared benefit between these sets of CAs.
    - Alternative projects for CAs C, E, and G were bundled together due to the hydraulic connectivity and shared benefit between these sets of CAs.
    - Alternatives for the two MS4 CAs (F, H) were modeled together as both are independent watersheds and not hydraulically connected.
2. Alternatives within each grouping of alternatives were developed to achieve each LOS goal.
3. Within the CSS areas combined sewer separation was modeled first to prioritize the benefits of separation. If separation alone did not achieve the LOS goals, sewer capacity improvements such as combined sewer upsizing and structure modifications were then modeled as needed to meet the LOS goals.
4. The following strategies were not modeled for this planning level study:
    - Green infrastructure (GI) storage areas. These were conceptually sized and estimated for performance using spreadsheet analysis.
    - Storm sewers and mains for the storm separation areas in the CSS. Sizing of storm mains included in this TM is based on spreadsheet analysis looking at capacity based on the approximate slope along the conceptual alignments.

4.2 Modeling Assumptions

The following is a summary of assumptions that were applied to the alternatives analysis.

Stormwater Separation in CSS Areas:

Combined sewer separation was modeled assuming a stormwater separation effectiveness of 80% as previously discussed. This was selected as a conservative planning level assumption by the City for alternatives evaluation. Sewer separation was modeled by reducing the subcatchment contributing area to account for the 20% fraction of stormwater that would remain within the existing combined sewer system.

The stormwater separation effectiveness of 80% was applied to the Milford Gunson Street sewer separation project (Project 11 in Table 2-4) to be consistent with how sewer separation is

modeled for the development of alternatives. As part of the Gunson Street project design, a PCSWMM model of the project was provided by the City to HDR for review and inclusion within alternatives analysis. Upon HDR review it was discovered that the PCSWMM model assumes 100% stormwater separation effectiveness as part of this design which could potentially overestimate potential project benefits in the CSS associated with the design of the project. Further monitoring of this project is recommended when it is complete.

Charles Street Upsizing Project:

The Charles Street and Bailey-Linden upsizing CIP projects were included in all alternatives for CAs C, E, and G. The CIP projects (MP Projects 4&8 in Table 2-4) were modified and expanded to meet the updated LOS goals for the alternatives evaluation. For MP Project 4: Charles Street sewer replacement, approximately 1,030 LF of the combined sewer replacement identified in the MP was increased from 60-inch to 72-inch as shown in Figure 4-1.Two sizing options were developed for the Charles Street upsizing project based on each LOS design storm. For MP Project 8: Bailey – Linden Sewer, approximately 1,230 LF of the combined sewer replacement the MP was increased from 42-inch and 48-inch to 54-inch as shown in Figure 4-2. One sizing option was developed for Bailey Street and was determined sufficient for both LOS design storms.

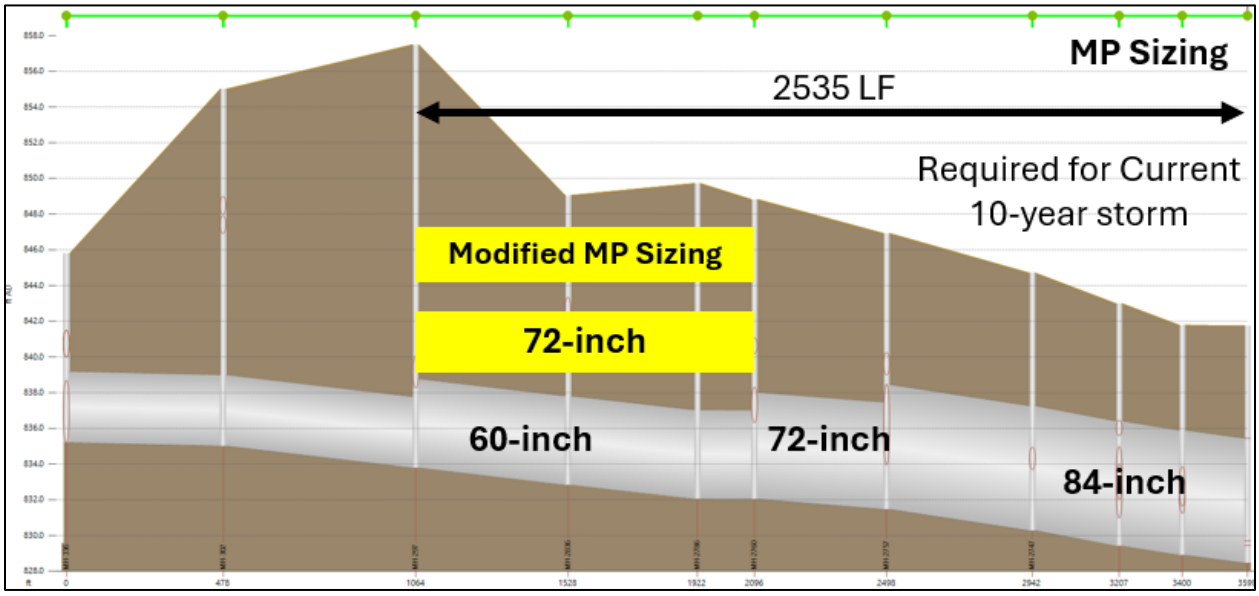


Figure 4-1. Profile – Modified Charles Street Upsizing Project, Current 10-year, 1-hour Design Storm

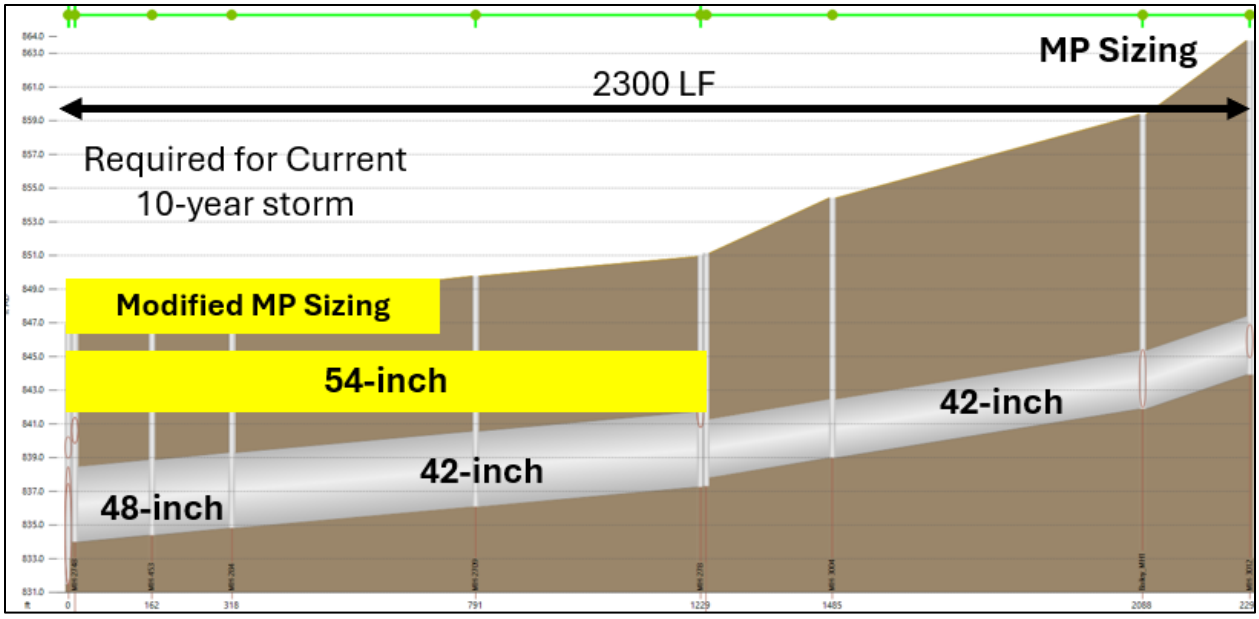


Figure 4-2. Profile – Modified Bailey Street Upsizing Project, Current 10-year, 1-hour Design Storm

Charles Street Regulator Modification:

The Charles Street regulator was modified in all alternatives to maximize flow to the CSO tunnel and to further reduce surcharge along Charles Street. Modifications included increasing the overflow weir length to the tunnel to 8.5 ft. The model representation of the Charles Street regulator was reviewed during alternatives development for potential improvements and compared to as-built drawings shown in Figure 4-3 (Contract No. 2 CSO Control Facilities (1994) reference drawing. Based on our review of the drawing the following was determined:

- The influent weir length is approximately 5.75 ft, offset approximately 1.3 ft above the 5 ft diameter concrete pipe channel.
- There is a 3x4 ft drop opening into the 120-inch CSO tunnel.
- The chamber is divided by a concrete wall and 12-inch orifice.

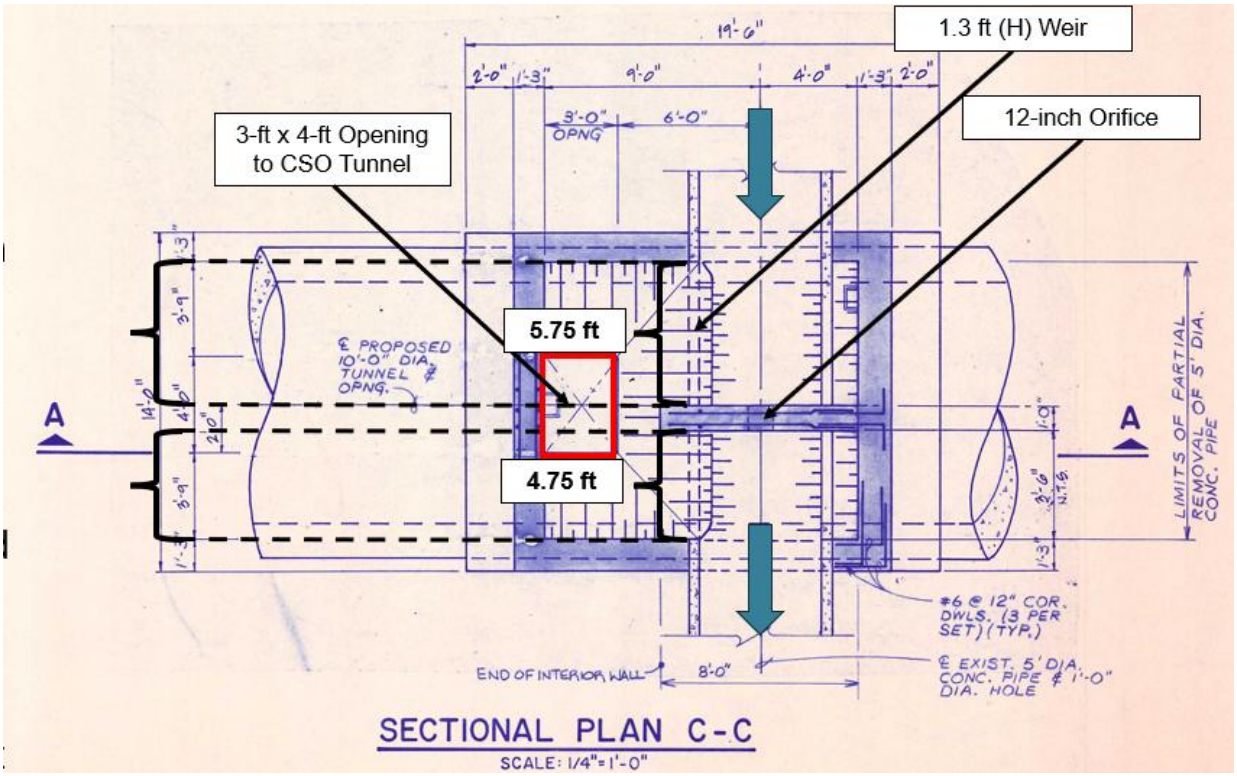


Figure 4-3. Charles Street Regulator Contract No. 2 CSO Control Facilities (1994) reference drawing (Markup)

The as-built drawing was used to confirm the model representation. It was found that the weir lengths were approximately 1 ft different than shown on the reference drawing. The weirs in the existing conditions H&H model were updated from 6.75 ft to 5.75 ft and 3.75 ft to 4.75 ft. The drop opening is not modeled. However, desktop analysis using the orifice equation and model predicted flow rates under both design storms indicate the opening dimension may not be sufficient to convey the increased weir flows. A preliminary concept for increasing the weir length and enlarging the drop opening is provided in Figure 4-4, which would require the demolition and relocation of the concrete wall dividing the chamber as well as increasing the drop opening.

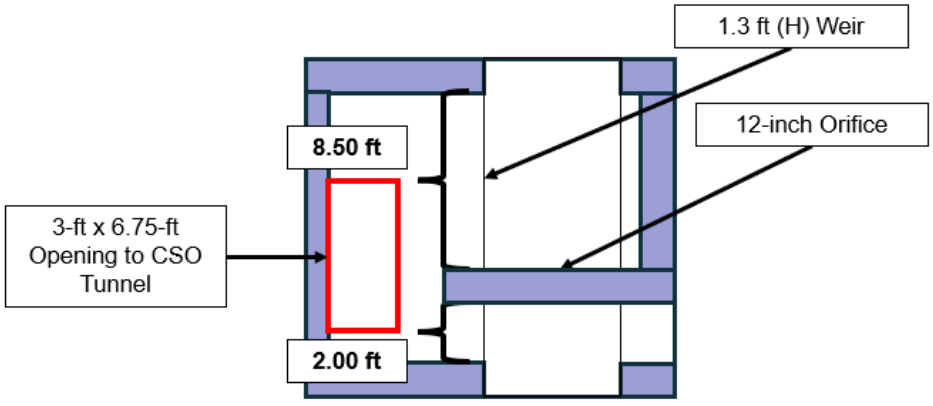


Figure 4-4. Charles Street Regulator Concept - Weir Modification & Enlarged Drop to CSO tunnel

By increasing the influent weir length to 8.5 ft, the model predicts the HGL along Charles Street can be reduced by approximately 3-4 ft with the alternatives in place for both design storms evaluated. Based on modeling, it was determined that LOS goals cannot be met for CA C for the current 50-year/future 16-year, 1-hour storm without including modifications to the Charles Street regulator structure.

A hydraulic profile of the existing combined sewer system extending from CA-39 at the upstream end of the profile through Northlawn Avenue (CA C) and downstream to Charles Street tunnel connection at Grand River Avenue is shown in Figure 4-5. The HGL for the existing conditions is shown by the red line and the black line shows the result of Alternative 3b (See Section 5.3) for the current 50-year/future 16-year, 1-hour storm design storm. As shown by the dashed line, the HGL improves with the Charles Street regulator structure modification by decreasing headloss.

Based on the findings of the results, it was determined to include the Charles Street regulator modification as part of the alternative evaluations for CAs C, E, and G.

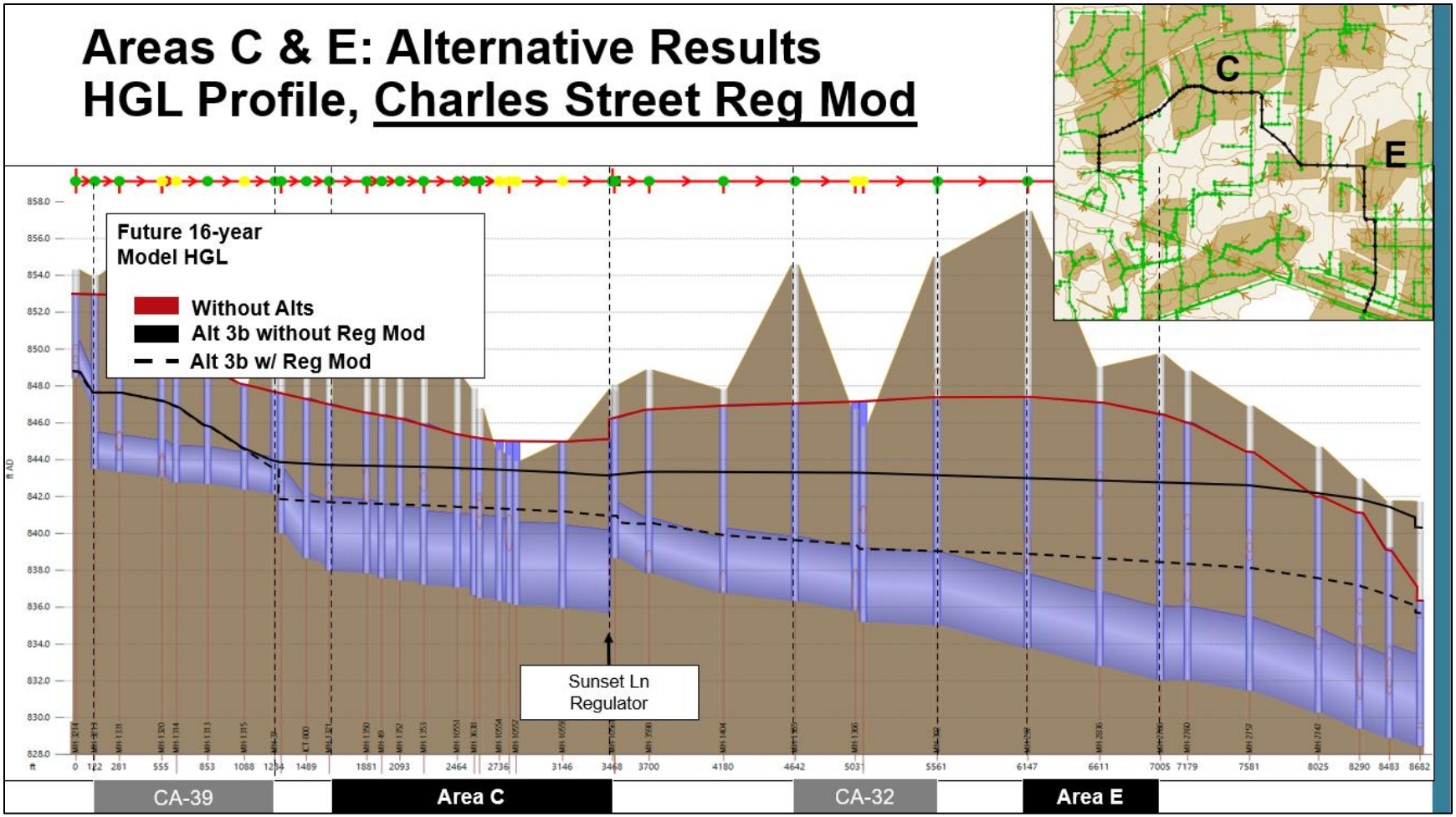


Figure 4-5. Hydraulic Profile – Alternative 3b Results – Charles Street Regulator Modification, current 50-year/future 16-year, 1-hour storm

5 Alternatives Development

Based on the hydraulic connectivity of the top 8 flooding CAs, locations for the four key flood risk reduction strategies, and opportunities for green infrastructure/storage, six alternatives were developed for analysis. These alternatives comprise a group of smaller projects grouped into a larger alternative and are described below in Table 5-1.

The alternatives were sized for both design storm LOS. Alternatives follow the naming convention of “Alternative #a” or “Alternative #b” where,

- # - is the alternative number based on CA or CA grouping
- a – is sized for the current 10-year, 1-hour storm of 2.00 inches
- b – is sized for the current 50-year/2100 future 16-year, 1-hour storm of 2.54 inches

For more detail on each developed alternative, refer to the following subsections which provide descriptions of each alternative and the proposed bundled projects and key components.

Table 5-1. Summary of developed alternatives for evaluation.

Alternative	Description
Alternative 1: West Central Neighborhoods Combined Sewer Relief	This project would separate stormwater from the sewer mains and offload the stormwater to Ranney Park. This will require the construction of a storm main to convey the separated stormwater. Upsizing existing combined sewer lines along Glenmoor Road and Oakridge Avenue and adding new combined sewers will help to relieve remaining bottlenecks.
Alternative 2: Valley Court Corridor Combined Sewer Relief	This project would separate stormwater from the sewer mains and offload the stormwater to the Red Cedar River. This will require the construction of a storm main to convey the separated stormwater. Upsizing the existing combined sewer line along Valley Court, Hillcrest Avenue, Elm Place, and Elm Street and adding new combined sewers will help to relieve remaining bottlenecks.
Alternative 3: Downtown Neighborhoods Combined Sewer Relief (Harrison Street route)	This project would separate stormwater from the sewer mains and offload the stormwater to the Red Cedar River. It includes the upsizing of existing combined sewer lines to relieve remaining bottlenecks, and the construction of new combined mains. This project also includes the construction of underground stormwater storage facilities at Gordon Guyer Park and Glencairn Park.
Alternative 4: Downtown Neighborhoods Combined Sewer Relief (Sunset Avenue route	This project would achieve all the same flood reduction benefits as Alterative 3. However, the proposed storm main is approximately 2x the length to route around a high-elevation area of the city.
Alternative 5: Abbot and Saginaw Storm Drainage Improvement	This project includes the upsizing of existing storm pipes to relieve bottlenecks in the area. It also includes stormwater storage opportunities at Harrison Meadow Park and in an open lot at the Fire Department.
Alternative 6: Whitehills Drainage Improvement	This project includes the upsizing of existing storm pipes to relieve bottlenecks in the area. It also includes stormwater storage opportunities at Albert A. White Memorial Park through the expansion of an existing fishing pond.

5.1 Alternative 1 – CAs A&B

Alternative 1, the West Central Neighborhoods Combined Sewer Relief, was developed to mitigate flood risk in CAs A and B. These areas are located on the west side of the city, with CA A being south of W Grand River Avenue and CA B near the intersection of N Harrison Road and W Saginaw Street. As CA B contributes flow to CA A, improvements within CA B also benefit CA A downstream.

A key component of Alternative 1 is the ability to offload separated stormwater from the CSS and convey this stormwater to a receiving waterway. CA A has four existing stormwater connections into Ranney Park, which is part of the Montgomery Drainage District, controlled by the Ingham County Drain Commissioner. The current agreement allows the City to convey up to 66 million gallons per day (mgd) via four stormwater connections into Ranney Park, where it ultimately flows to the Montogomery Drain and into the Red Cedar River. However, preliminary results show that the amount of stormwater separation required to meet the Current LOS may exceed 66 mgd. As a result, it is proposed to convey all or a portion of CA B's stormwater flows to the east, toward Harrison Road, via the proposed stormwater mains detailed in Alternatives 3 and 4. Therefore, Alternative 1 requires the implementation of either Alternative 3 or 4 to increase the LOS.

The four currently constructed stormwater connections to Ranney Park into the City are listed below for future consideration. Stormwater to be separated into Ranney Park will need to be finalized with a formal agreement with the Ingham County Drain Commissioner (Montgomery Drainage District) as part of future efforts outside the scope of the WWRP.

- Harvard (18")
- Saginaw (24")
- Grand River (30")
- Oak Ridge (54")

To meet the Current LOS, the following group of projects are proposed as **Alternative 1a**:

- Stormwater Separation
    - Stormwater separation is proposed to convey stormwater to a new storm main, as opposed to relying on the existing combined system to convey all the flow. If paired with Alternative 3, this would require approximately 69 acres of separation. If paired with Alternative 4, this would require approximately 79 acres of separation.
- New Storm Main
    - 3,400 feet of new storm main is proposed to convey stormwater from CAs A and B to Ranney Park and the Montgomery Drain. A 36-inch-diameter storm main would extend from Chartwell Carriage Way S along Touraine Avenue and Glenmoor Road.
- Upsized Combined Pipes
    - 2,060 feet of combined sewer upsizing is proposed. Two segments of the existing combined sewers are proposed to be replaced with upsized combined pipes.
        - A 30-inch-diameter sewer would replace the existing 24-inch-diameter combined sewer along Glenmoor Road and Oakridge Avenue (920 LF).
        - The existing 15- and 18-inch-diameter combined sewer along Crowley Avenue would be replaced with a combination of 36- and 42-inch-diameter combined sewer (1,140 LF).
- New Combined Pipes
    - 725 feet of new, 36-inch-diameter combined sewer is proposed to connect the upsized combined sewer on Oakridge Avenue to the upsized combined sewer on Cowley Avenue.

- Structure Modifications
    - Three structure modifications are proposed in Alternative 1a to achieve the Current LOS. First, the removal of an existing flow restrictor at the intersection of Grand River Avenue and Coolidge Road is proposed. Additionally, two new bulkheads are required to connect the new combined sewers on Oakridge Avenue and Cowley Avenue to the upsized combined pipes.
        - MH-3092 – remove 8-inch orifice plate at Grand River Avenue
        - MH-1348 – install bulkhead on 24-inch combined sewer flowing south
        - MH-3048 – install bulkhead and abandon/remove combined sewer flowing south along Cowley Avenue

For additional resiliency and to meet the Enhanced LOS (current 50-year/future 16-year, 1-hour design storm), Alternative 1a can be expanded to include the following as **Alternative 1b**:

- Stormwater Separation
    - An additional 7.7 acres of stormwater separation with Alternative 3, or an additional 29.4 acres of separation with Alternative 4, can be included to convey additional flow to Ranney Park.
- New Storm Main
    - The storm main section from Chartwell Carriage Way S along Touraine Avenue and Glenmoor Road would be upsized to 54-inch-diameter storm main.

Concept maps for Alternative 1a and Alternative 1b are shown in Figure 5-1 and Figure 5-2 are taken from the Wet Weather Resiliency Plan Web Map (ARCGIS Online). Separation extents shown for Alternative 1 are to be paired with Alternative 3.

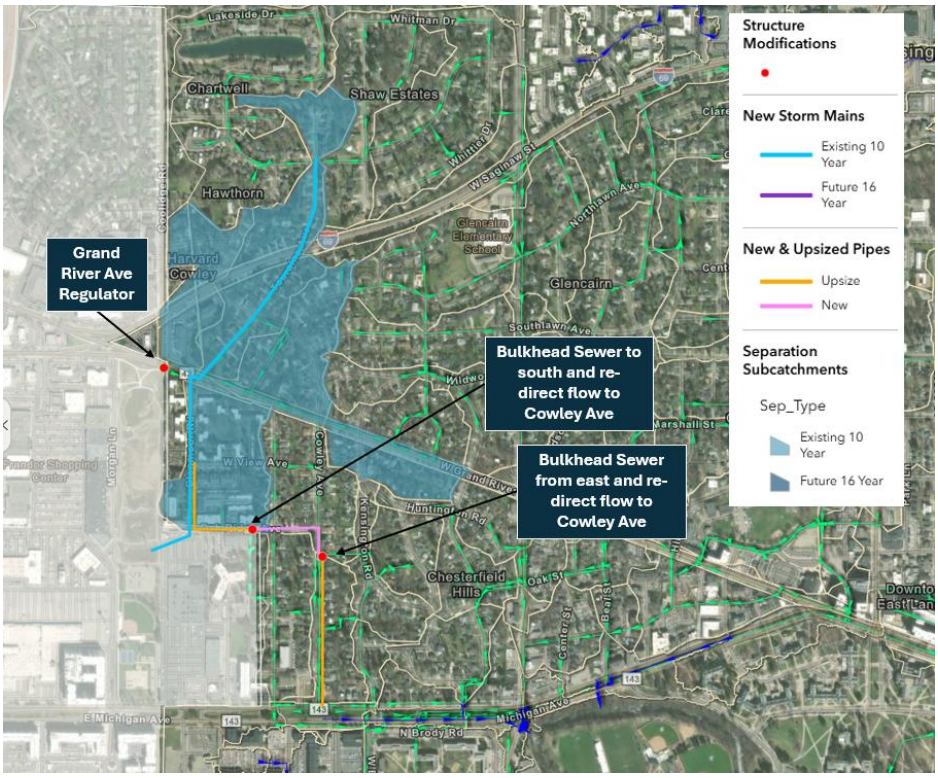


Figure 5-1. Conceptual Map - Alternative 1a (Web Map)

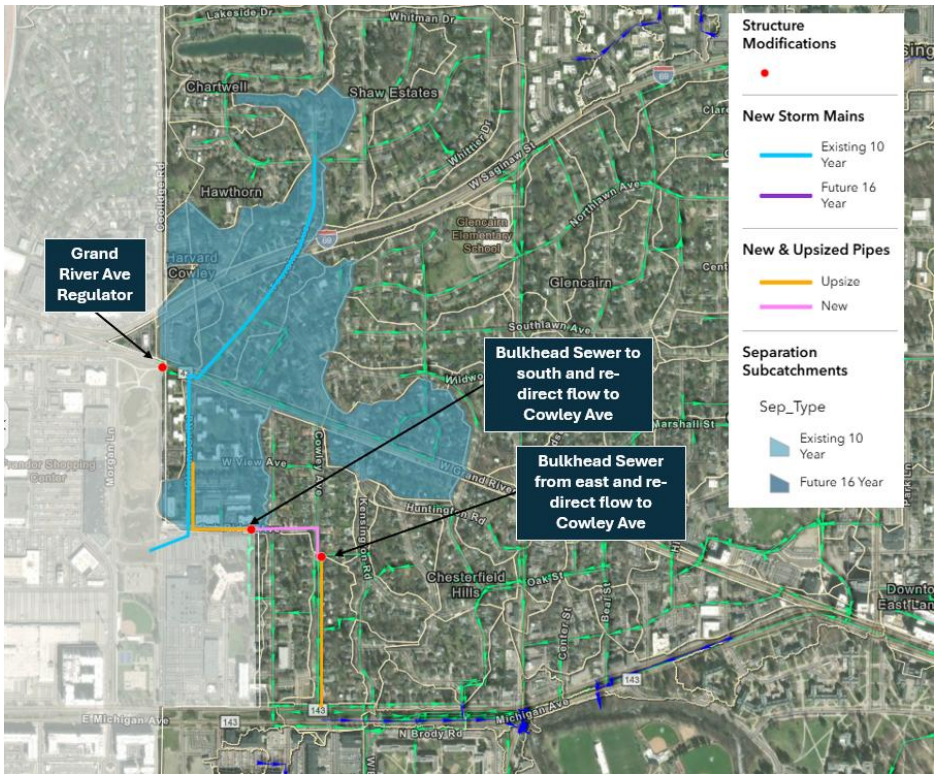


Figure 5-2. Conceptual Map - Alternative 1b (Web Map)

5.2 Alternative 2 – CA D

Alternative 2, the Valley Court Corridor Combined Sewer Relief, was developed to mitigate flood risk in CA D. This area is located within the combined sewer area of East Lansing, west of downtown, on either side of Grand River Avenue. This area is an independent watershed, so it is not significantly impacted by other alternatives.

A key component of Alternative 2 is the ability to offload separated stormwater from the CSS and convey this stormwater to the receiving waterway. Near CA D there is opportunity to tie into an existing MS4 outfall to the Red Cedar River near Beal Street. The outfall currently serves the 18- and 24-inch-diameter storm sewer along Michigan Avenue and could be redesigned to avoid adding a second stormwater outfall in close proximity. Further detailed engineering beyond the scope of this study would be required.

To meet the Current LOS, the following group of projects are proposed as **Alternative 2a**:

- Stormwater Separation
    - Approximately 78 acres of stormwater separation is proposed to convey stormwater to a new storm main.
- New Storm Main
    - 2,750 feet of new storm main is proposed to convey stormwater to the Red Cedar River. This includes 32- and 54-inch-diameter pipe along Valley Court, Delta Street, and Michigan Avenue.
- Upsized Combined Pipes
    - 1,970 feet of combined sewer upsizing is proposed. This would replace the existing 27-inch-diameter, 24-by-30-inch-diameter ellipse, and 36-inch-diameter combined sewer along Valley Court, Hillcrest Avenue, Elm Place, and Elm Street with a 36-inch-diameter sewer.
- New Combined Pipes
    - 630 feet of new 36-inch-diameter combined sewer along Louis Street and Michigan Ave would connect a proposed regulator at Louis Steet to the combined sewer overflow (CSO) tunnel.
        - The 36-inch sewer is recommended to tie into MH-A0061C to utilize the existing connection to the CSO tunnel at Beal Street. Alternatively, a new connection to the CSO tunnel could be made at Louis Street.
- Structure Modifications
    - Two structure modifications are proposed in Alternative 2a to achieve the Current LOS. First, the removal of an existing flow restrictor at Beal Street is proposed. The removal of this weir would allow more flow from the overflow sewer to enter the CSO tunnel. Additionally, a regulator with a weir is proposed at Louis Street to control flow into the CSO tunnel.
        - MH-A0061 – remove weir to invert of 30-inch overflow sewer to CSO tunnel
        - MH-417 – replace manhole with regulator structure. Add weir to new combined 36-inch sewer with crest elevation 832.04 and width of 3.0 feet.

For additional resiliency, Alternative 2a can be expanded to include the following as **Alternative 2b**:

- Stormwater Separation
    - An additional 11.5 acres of stormwater separation to the northwest of CA D is proposed.
- New Storm Main
    - To achieve additional resiliency, the proposed storm main would be upsized to 36- and 60-inch-diameter pipe.

It should be noted that Alternative 2b would not fully achieve the Enhanced LOS (future 2100 16-year, 1-hour design) because of downstream hydraulic flow constraints that make achieving the Enhanced LOS technically infeasible. However, the LOS for Alternative 2b is predicted to be greater than the Current 10-year, 1-hour storm. This compares to a current estimated LOS of less than 1-year, 1-hour storm.

Within CA D, there is an opportunity for underground storage at Valley Court Park. The footprint of the park could provide an estimated storage volume of 2.4 million gallons and would reduce the required storm main diameter for the Enhanced LOS to 36-inch.

Concept maps for Alternative 2a and Alternative 2b are shown in Figure 5-3 and Figure 5-4 are taken from the Wet Weather Resiliency Plan Web Map (ARCGIS Online).

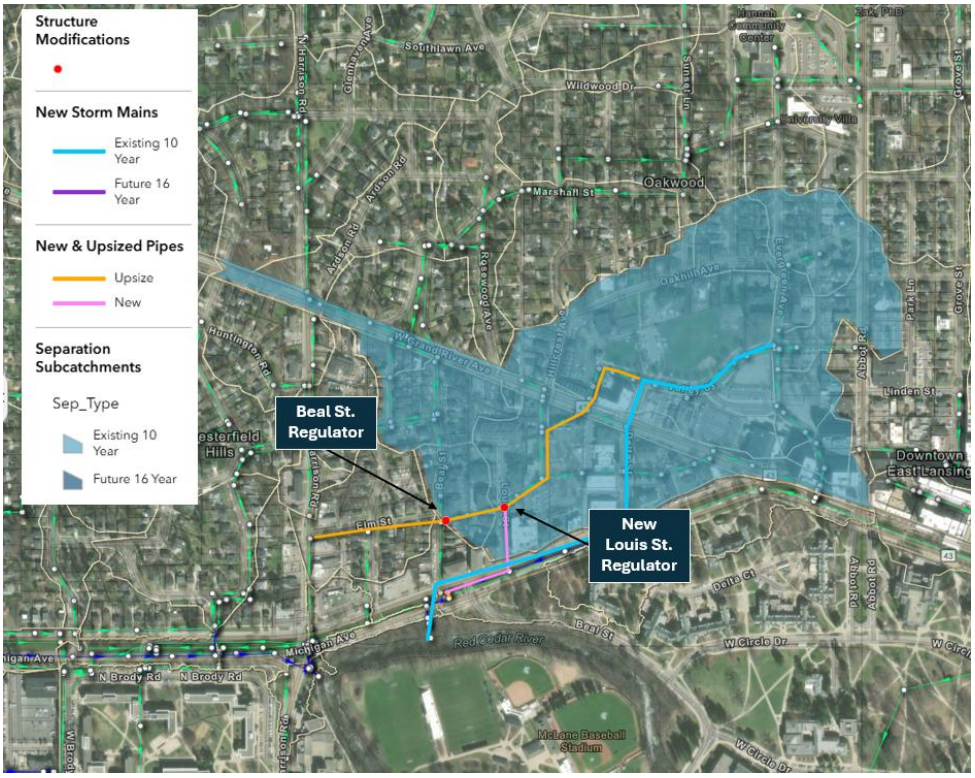


Figure 5-3. Conceptual Map - Alternative 2a (Web Map)

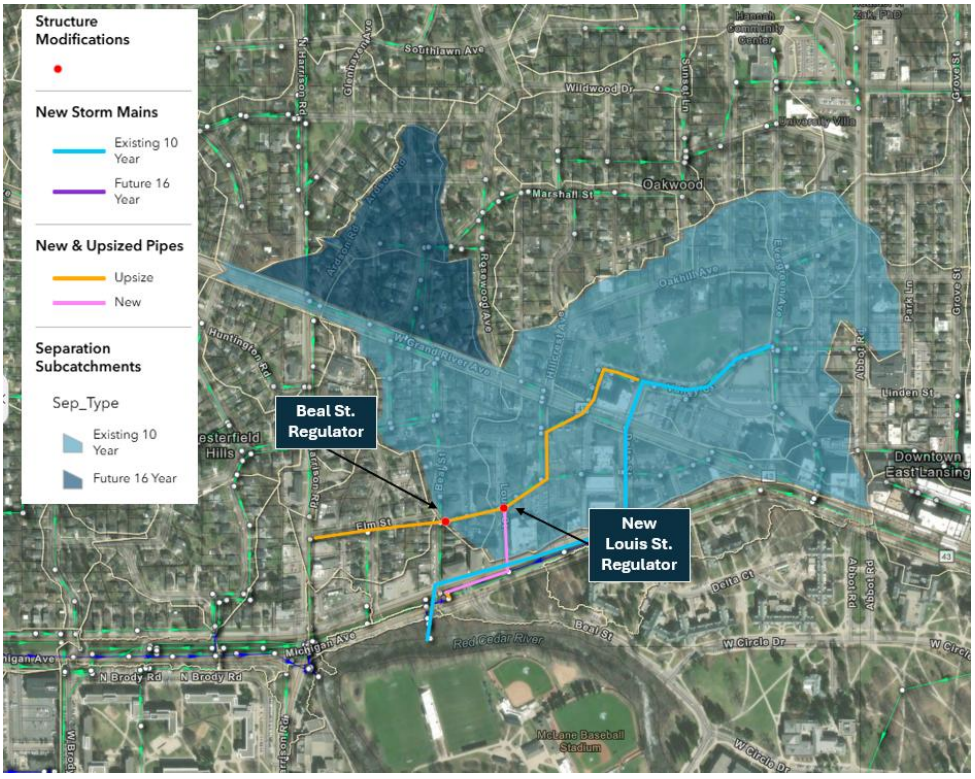


Figure 5-4. Conceptual Map - Alternative 2b (Web Map)

5.3 Alternative 3 – CAs B, C, E, & G

Alternative 3, the Downtown Neighborhoods Combined Sewer Relief (Harrison Street route), was developed to mitigate flood risk within CAs B, C, E, and G, within the CSS. As CAs C, E, and G are hydraulically connected, improvements have the potential to benefit adjacent CAs. As discussed in Alternative 1, improvements in CA B would also benefit CA A.

A key component of Alternative 3 is the ability to offload separated stormwater from the CSS and convey this stormwater to a receiving waterway. Under Alternative 3, separated flows from CAs B and C are conveyed via a new storm main along N Harrison Road to the Red Cedar River. An existing CSO outfall to the Red Cedar River serves the storm sewer along Michigan Avenue and provides relief for the 60-inch-diameter combined sewer along Harrison Road. This outfall can potentially be redesigned to avoid adding another stormwater outfall in close proximity. Further detailed engineering beyond the scope of this study would be required.

Separation of stormwater flows tributary to Charles Street was not considered as part of the alternatives planning process because of a lack of a viable stormwater outfall, as it would require crossing the Michigan State University campus to reach the Red Cedar River. Instead, modifications to existing CSS infrastructure are proposed to maximize the use of existing assets.

To meet the Current LOS, the following group of projects are proposed as **Alternative 3a**:

- Stormwater Separation
    - Approximately 92 acres of stormwater separation is proposed to convey stormwater to a new storm main.
- New Storm Main
    - 5,200 feet of new storm main is proposed to convey stormwater to the Red Cedar River. This includes 36-, 54-, and 60-inch-diameter storm main along N Harrison Road. As this route would go through a high-elevation area, the maximum bury depth of this pipe would be upwards of 35 to 40 feet. This would be a deep, costly main to install, but the benefits that it provides to offload stormwater from downstream CSS areas to the east would also be significant.
- Upsized Combined Pipes
    - 7,050 feet of combined sewer upsizing is proposed. Multiple segments of the existing combined sewers are proposed to be replaced by upsized combined pipes.
        - This would replace the existing 48-, 54-, and 60-inch-diameter combined sewer along Charles Street with 72- and 84-inch-diameter sewer (2,535 LF).
        - This would also replace the 12-inch-diameter combined sewer along Bailey and Linden streets with 42- and 54-inch-diameter sewer (1,475 LF).
        - Additional upsizes would include upsizing the following combined sewer pipes to 24-inches: the 12- and 15-inch-diameter combined sewer along Old Hickory Lane (1,150 LF), the 12- and 18-inch-diameter combined sewer along Sunset Lane (710 LF), the 18-inch-diameter combined sewer

along Collingwood Drive (660 LF), and the 12-inch-diameter combined sewer along Butterfield Drive (520 LF).

- New Combined Pipes
  - 875 feet of new combined sewer is proposed. This includes 42-inch combined sewer along Bailey Street (667 LF) and 42-inch combined sewer along Burcham Drive (208 LF).
- Structure Modifications
  - Three structure modifications are proposed. This includes three new sewer bulkheads: one on Burcham Drive on the 36-inch-diameter combined sewer to redirect flow from the east to the new combined sewer along Bailey Street, one on Burcham Drive to redirect flow from the south to the new combined sewer along Bailey Street, and one on Elizabeth Street on the 24-inch-diameter combined sewer to remove the interconnection and keep flows within the upsized Bailey Street combined sewer.
    - MH-2634 – install bulkhead on 36-inch combined sewer flowing east
    - MH-3012 – install bulkhead on 36-inch combined sewer flowing south
    - MH-277 – install bulkhead on 24-inch combined sewer flowing east to Collingwood Drive

For additional resiliency and to meet the Enhanced LOS (current 50-year/future 16-year, 1-hour design storm), Alternative 3a can be expanded to include the following as **Alternative 3b**:

- Stormwater Separation
  - An additional 186.5 acres of stormwater separation is proposed. This additional separation would be near East Lansing High School along Burcham Drive and around Glencairn Elementary School.
- New Storm Main
  - To achieve additional resiliency, the proposed storm main would be upsized to 48-inch, 66-inch, and 84-inch-diameter storm main pipe.
- Upsized Combined Pipes
  - A key consideration to providing additional resiliency is the sizing of Charles Street combined sewer project, which would need to be enlarged if the higher LOS is selected.
  - To achieve additional resilience, the Charles street upsizing would need expanded to replace the existing 48-inch, 54-inch, and 60-inch combined sewer with 72-inch and 84-inch sewer (3,600 LF).

Within CAs B and C, there is an opportunity for underground storage at Gordon Guyer Park and Glencairn Park. The footprint of the parks could potentially provide a combined storage volume of 2.2 million gallons and would reduce the required storm main diameter for the Enhanced LOS to 48, 60, and 66 inches.

Concept maps for Alternative 3a and Alternative 3b are shown in Figure 5-5 and Figure 5-6 are taken from the Wet Weather Resiliency Plan Web Map (ARCGIS Online).

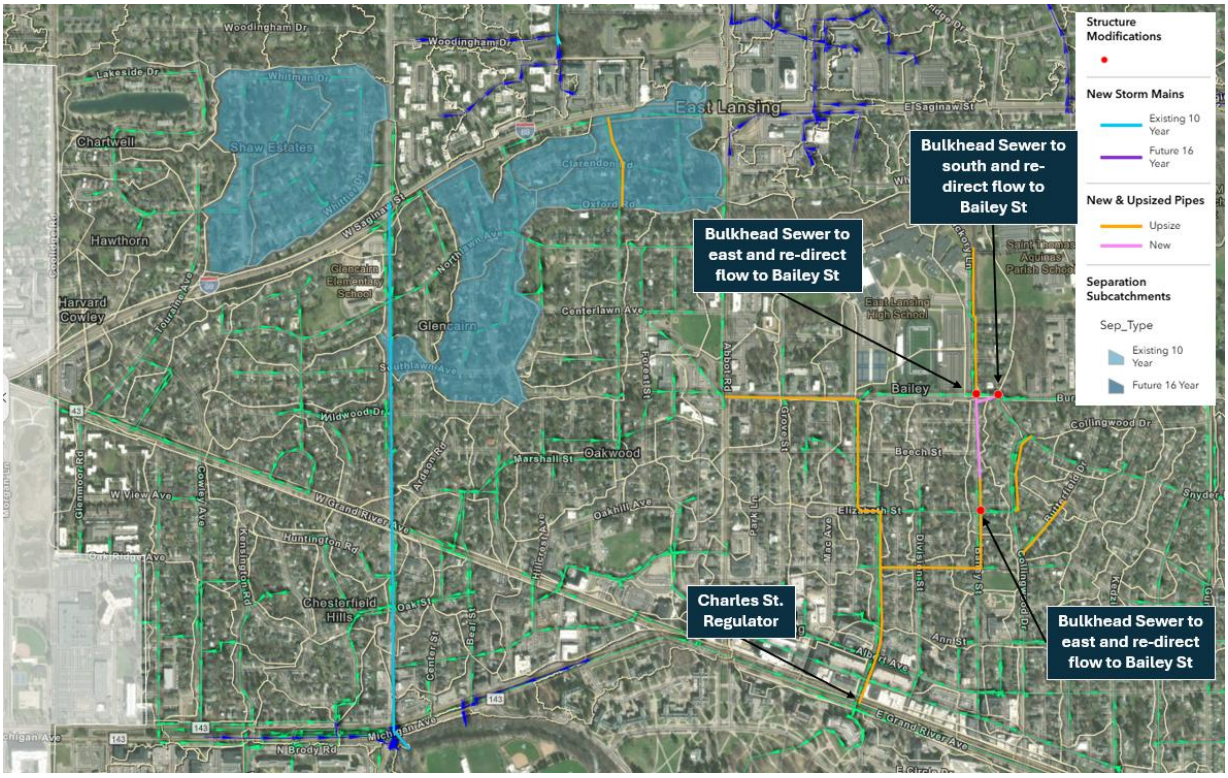


Figure 5-5. Conceptual Map - Alternative 3a (Web Map)

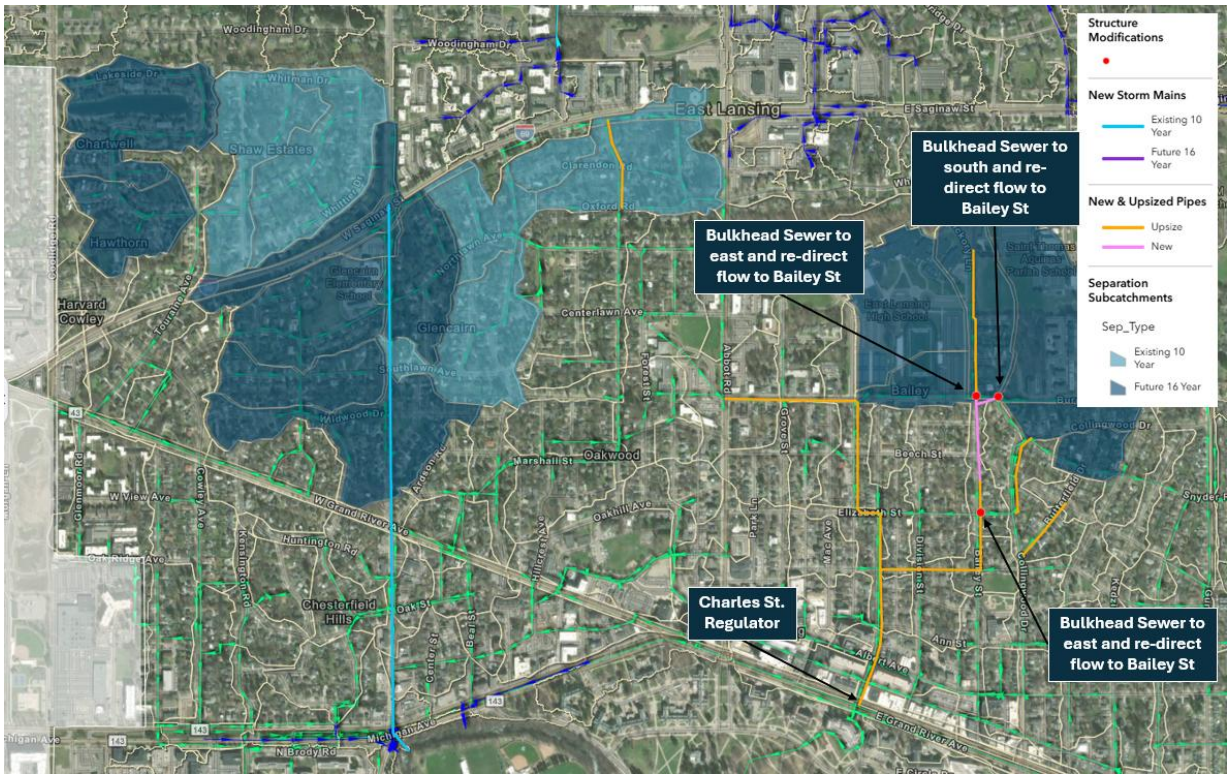


Figure 5-6. Conceptual Map - Alternative 3b (Web Map)

5.4 Alternative 4 - CAs B, C, E, & G

Alternative 4, the Downtown Neighborhoods Combined Sewer Relief (Sunset Avenue route), addresses the same CAs as Alternative 3. However, the major difference between the two alternatives is the route of the new storm main to the receiving water source at the Red Cedar River. As the two alternatives share similar projects, both Alternatives 3 and 4 would not be implemented. Rather, the recommended alternatives within the WWRP should select the best option between the two alternatives.

A key component of Alternative 4 is the ability to offload separated stormwater from the CSS and convey this stormwater to the receiving waterway. Separated flows from the north and east portions of CAs B and C can be conveyed via a new storm main following the existing route of the combined sewer from Longfellow Drive, Northlawn Avenue, Marshall Street, to Beal Street. An existing MS4 outfall to the Red Cedar River near Beal Street that serves the 18- and 24-inch-diameter storm sewer along Michigan Avenue can be redesigned to avoid adding another stormwater outfall in close proximity. This new stormwater outfall would also need to include capacity for stormwater flows from Alternative 2 (CA D) to avoid adding another stormwater outfall in close proximity. Further detailed engineering beyond the scope of this study would be required.

As discussed in Alternative 3, separation of stormwater flows to Charles Street was not considered as part of the Alternatives planning process due to a lack of a viable stormwater outfall, as it would require crossing the Michigan State University campus to reach the Red Cedar River.

To meet the Current LOS, the following group of projects are proposed as **Alternative 4a**:

- Stormwater Separation
    - Approximately 101 acres of stormwater separation is proposed to convey stormwater to a new storm main.
- New Storm Main
    - 10,500 feet of new storm main is proposed to convey stormwater to the Red Cedar River. This includes 48-, 54-, 72-, and 84-inch-diameter storm main along Longfellow Drive, Northlawn Avenue, and Marshall Street to Beal Street.
- Upsized Combined Pipes
    - 7,050 feet of combined sewer upsizing is proposed. Multiple segments of combined sewers are proposed to be replaced by upsized combined pipes.
        - This would replace the existing 48-, 54-, and 60-inch-diameter combined sewer along Charles Street with 72- and 84-inch-diameter sewer (2,535 LF).
        - This would also replace the 12-inch-diameter combined sewer along Bailey and Linden streets with 42- and 54-inch-diameter sewer (1,475 LF).
        - Additional upsizes would include upsizing the following combined sewer pipes to 24-inches: the 12- and 15-inch-diameter combined sewer along Old Hickory Lane (1,150 LF), the 12- and 18-inch-diameter combined sewer along Sunset Lane (710 LF), the 18-inch-diameter combined sewer along Collingwood Drive (660 LF), and the 12-inch-diameter combined sewer along Butterfield Drive (520 LF).

- New Combined Pipes
    - 875 feet of new combined sewer is proposed. This includes 42-inch diameter combined sewer along Bailey Street (667 LF) and 42-inch diameter combined sewer along Burcham Drive (208 LF).
- Structure Modifications
    - Three structure modifications are proposed. This includes three new sewer bulkheads: one on Burcham Drive on the 36-inch-diameter combined sewer to redirect flow from the east to the new combined sewer along Bailey Street, one on Burcham Drive to redirect flow from the south to the new combined sewer along Bailey Street, and one on Elizabeth Street on the 24-inch-diameter combined sewer to remove the interconnection and keep flows within the upsized Bailey Street combined sewer.
        - MH-2634 – install bulkhead on 36-inch combined sewer flowing east
        - MH-3012 – install bulkhead on 36-inch combined sewer flowing south
        - MH-277 – install bulkhead on 24-inch combined sewer flowing east to Collingwood Drive

For additional resiliency and to meet the Enhanced LOS (current 50-year/future 16-year, 1-hour design storm), Alternative 4a can be expanded to include the following as **Alternative 4b**:

- Stormwater Separation
    - An additional 165 acres of stormwater separation is proposed. This additional separation would be near East Lansing High School along Burcham Drive and around Glencairn Elementary School.
- New Storm Main
    - To achieve additional resiliency, the proposed storm main would be upsized to 54-inch, 84-inch, and 96-inch-diameter storm main pipe.
- Upsized Combined Pipes
    - A key consideration to providing additional resiliency is the sizing of Charles Street combined sewer project, which would need to be enlarged if the higher LOS is selected.
    - To achieve additional resilience, the Charles street upsizing would need expanded to replace the existing 48-inch, 54-inch, and 60-inch combined sewer with 72-inch and 84-inch sewer (3,600 LF).

Within CA C, there is an opportunity for underground storage at Glencairn Park, Shaw Park, and the Hannah Community Center. The combined footprint of these areas could potentially provide 4.6 million gallons of storage and would reduce the required storm main diameter for the Enhanced LOS to 54, 60, and 80 inches.

Concept maps for Alternative 4a and Alternative 4b are shown in Figure 5-7 and Figure 5-8 are taken from the Wet Weather Resiliency Plan Web Map (ARCGIS Online). The flood risk reduction benefits would be the same as Alternative 3. However, as shown below, the pathway of the new storm main would be nearly twice the length to avoid the deep bury depth required in Alternative 3 to pass through an area of high elevation. This increase in required pipe length

would greatly increase the cost for the alternative projects. Additionally, the pathway of the new storm main would pass through a residential area of the City and would be significantly more disruptive to the community. For these reasons, Alternative 4 was ultimately not selected for further evaluation during discussions with the City.

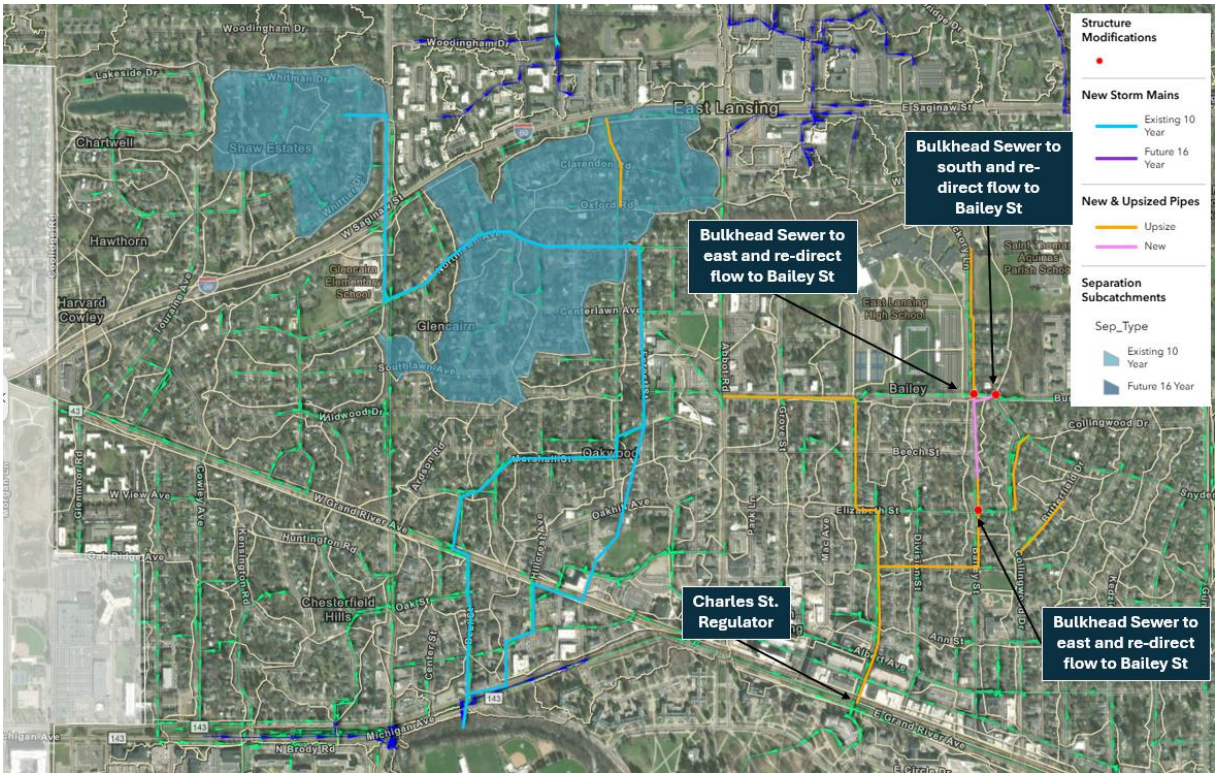


Figure 5-7. Conceptual Map - Alternative 4a (Web Map)

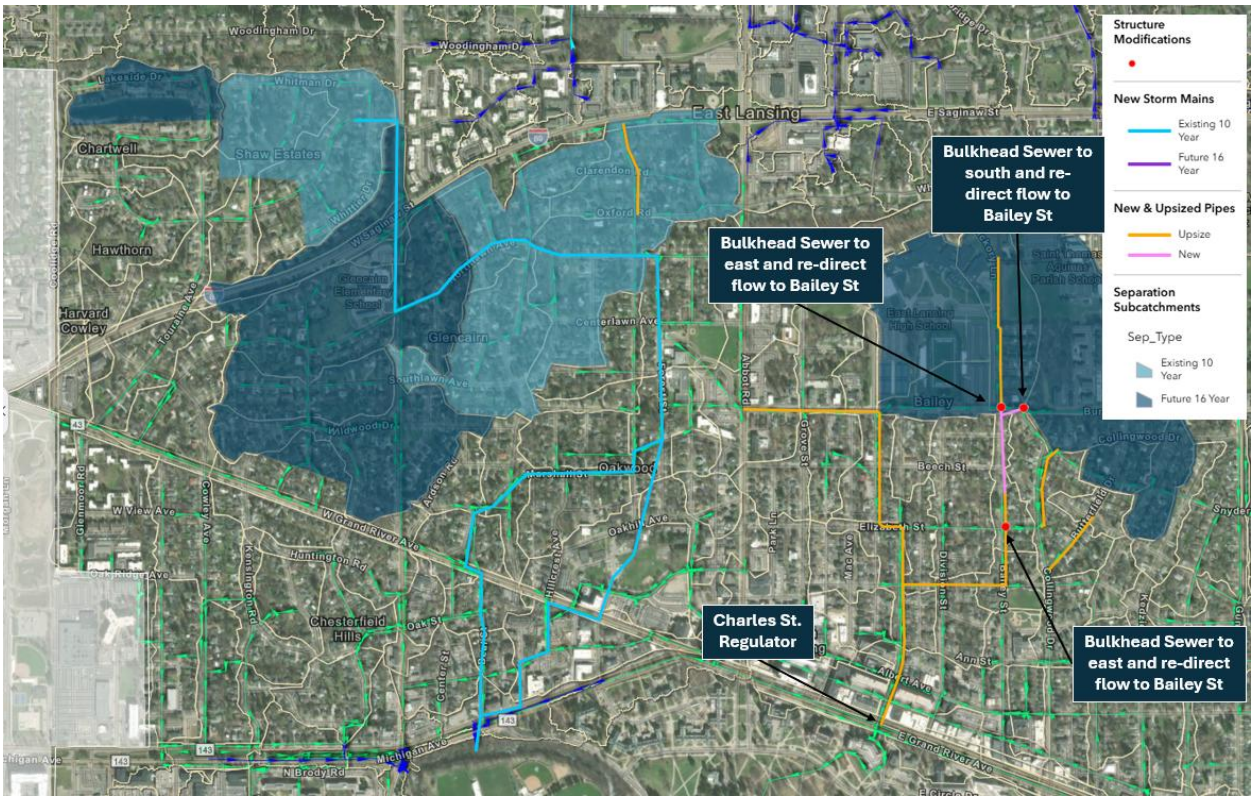


Figure 5-8. Conceptual Map - Alternative 4b (Web Map)

5.5 Alternative 5 – CA F

Alternative 5, Abbot and Saginaw Storm Drainage Improvement, was developed to mitigate flood risk in CA F, which is in the MS4 area of the City. CA F is a hydraulically independent watershed that contributes stormwater flow to the Taylor Drain, which then flows into the Sanderson Branch of the Remey-Chandler Drain.

A key component of Alternative 5 is its ability to store and detain stormwater during large rainfall events with nature-based approaches such as ponds and stormwater wetlands. Storage in these areas would allow for the ability to attenuate peak flows, enhance water quality, and provide potential recreational opportunities such as additional trail connections along the Northern Tier Trail. Downstream of CA F there are several aboveground natural stormwater storage opportunities including the open area north of the fire station, at Harrison Meadows Park, and within the open lots west of Abbot Road.

To meet the Current LOS, the following group of projects are proposed as **Alternative 5a:**

- Upsized Storm Sewers:
    - 7,860 ft of combined sewer upsizing is proposed. Multiple segments of the existing storm sewers are proposed to be replaced by upsized storm pipes.
        - This would replace the existing 42-inch diameter, 43-inch H x 68-inch W ellipse, 48-inch H x 76-inch W ellipse, and 58-inch H x 91-inch W ellipse storm sewers along Abbot Road to Kendale Boulevard with a 60-inch H x 144-inch box culvert and a 48-inch H x 168-inch box culvert (2,560 LF).
        - This would also replace the existing 18-inch, 24-inch, 27-inch, 30-inch, 36-inch, 42-inch, 48-inch, and 54-inch diameter storm sewers within the commercial areas north and south of E. Saginaw Street with 24-inch, 30-inch, 36-inch, 48-inch, 54-inch diameter storm sewers (5,020 LF).
        - Additional upsizes would include upsizing the existing 21-inch storm culvert along Woodland Pass at Kendale Boulevard to 30-inch (275 LF).
- Stormwater Storage:
    - The open surface areas north of the fire station, Harrison Meadow Park, and open areas west of Abbot Road can be added for a total of 1.7 million gallons of storage to attenuate and offset increased peak flows from the upsized storm sewers.
        - For Alternative 5a, the model predicts approximately 1.15 MG or 3.53 ac-ft is required to attenuate peak flows. This storage volume was estimated by taking the difference in the downstream peak flow hydrographs for the existing and upsized conditions during the peak event window, as shown in Figure 5-9.

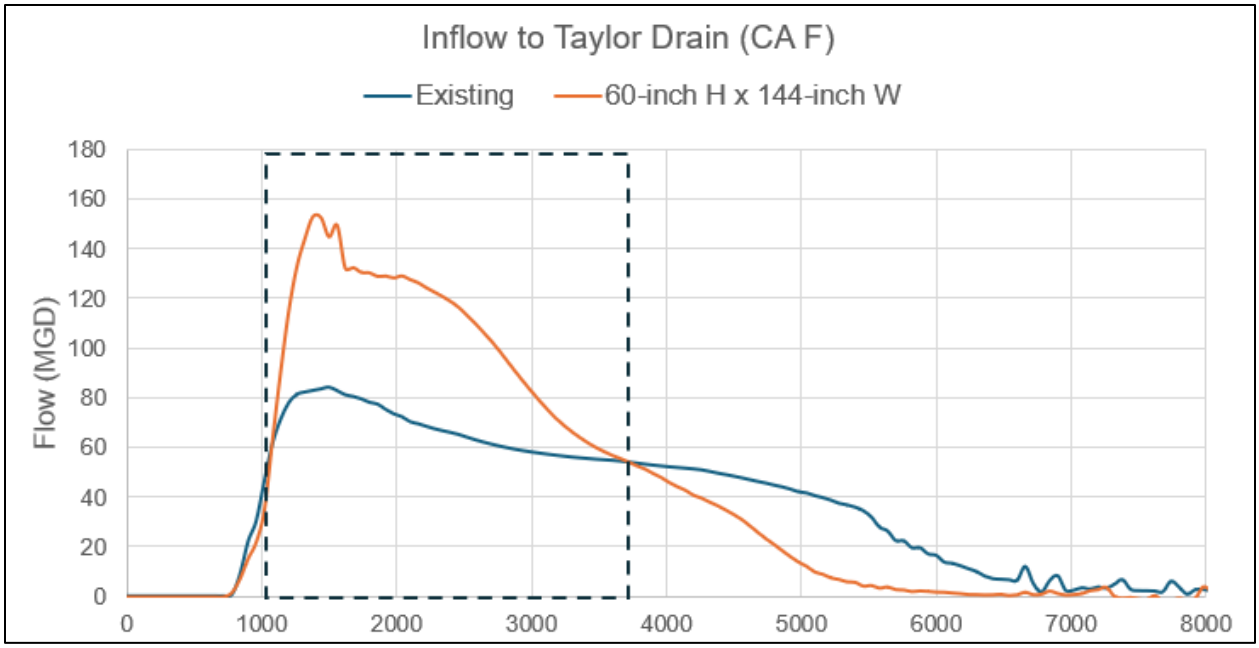


Figure 5-9. Alternative 5a – Estimated Storage Volume – Peak Flow Hydrograph

- There is also an opportunity to potentially add 1.31 million gallons of underground stormwater storage beneath the parking lots in the surrounding commercial areas. However, this would require collaboration with the private property owners.
  - If storage is added upstream, the required storm sewer upsizes projects could potentially be reduced significantly pending further study.

For additional resiliency and to meet the Enhanced LOS (current 50-year/future 16-year, 1-hour design storm), Alternative 5a can be expanded to include the following as **Alternative 5b**:

- Upsized Storm Sewers:
  - To achieve additional resilience, the following upsizing projects would need expanded:
    - Increase the diameter of storm sewer upsizing along Abbot Road to Kendale Boulevard from 60-inch H x 144-inch box culvert and 48-inch H x 168-inch box culvert (2,560 LF).
    - Increase diameter of storm sewer upsizing within the commercial areas north and south of E. Saginaw Street from 24-inch, 30-inch, 36-inch, 48-inch, and 60-inch H x 144-inch W box culvert (Alternative 6a) to 30-inch, 36-inch, 42-inch, 54-inch, and 60-inch H x 240-inch W box culvert (3,610 LF).
- Stormwater Storage:
  - An additional 0.5 million gallons of stormwater storage is proposed.
    - For Alternative 5b, the model predicts approximately 1.67 MG or 5.12 ac-ft is required to attenuate peak flows. This storage volume was estimated by taking the difference in the downstream peak flow hydrographs for the

existing and upsized conditions during the peak event window, as shown in Figure 5-10.

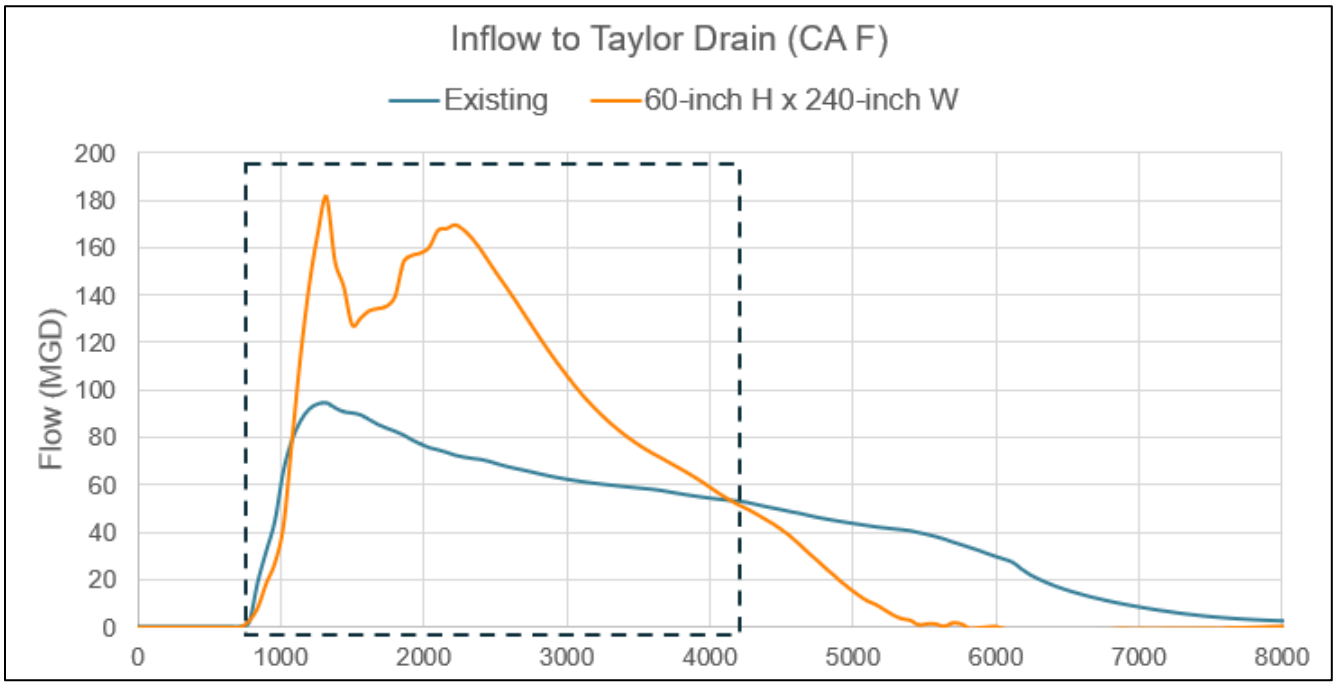


Figure 5-10. Alternative 5b – Estimated Storage Volume – Peak Flow Hydrograph

Concept maps for Alternative 5a and Alternative 5b are shown in Figure 5-11 are taken from the Wet Weather Resiliency Plan Web Map (ARCGIS Online). Only one concept map is provided as the project extents are the same, with the main difference being sizing.



Figure 5-11. Conceptual Map - Alternative 5a & 5b (Web Map)

5.6 Alternative 6 – CA H

Alternative 6, Whitehills Drainage Improvement, was developed to mitigate flood risk within CA H, located in the MS4 area of the City. CA H is a hydraulically independent watershed that contributes stormwater flow to the Taylor Drain, which then flows into the Sanderson Branch of the Remey-Chandler Drain.

A key component of Alternative 6 is its ability to store and detain stormwater during large rainfall events with nature-based approaches such as ponds and stormwater wetlands. Storage in these areas would allow for the ability to attenuate peak flows, enhance water quality, and provide potential recreational opportunities such as additional trail connections within Albert A. White Memorial Park. Downstream of CA H there is an opportunity for aboveground stormwater storage through the expansion of the Albert A. White Memorial City Park fishing pond.

To meet the Current LOS, the following group of projects are proposed as **Alternative 6a**:

- Upsized Storm Sewers:
    - 4,601 feet of the existing storm sewer would be upsized. The existing 18-inch, 24-inch, 30-inch, 36-inch, 48-inch, and 54-inch-diameter storm sewer along N Hagadorn Road, Applegate Lane, and Pebblebrook Lane would be upsized to 24-inch, 36-inch, and 54-inch-diameter storm sewer.
- Stormwater Storage:

- The open area surrounding the Albert A. White Memorial City Park fishing pond would provide approximately storage to attenuate and offset increased peak flows from the upsized storm sewers.
    - For Alternative 6a, the model predicts approximately 0.20 MG or 0.61 ac-ft is required to attenuate peak flows. This storage volume was estimated by taking the difference in the downstream peak flow hydrographs at the outfall into the pond near Pebblebrook Lane for the existing and upsized conditions during the peak flow event window, as shown in Figure 5-12.

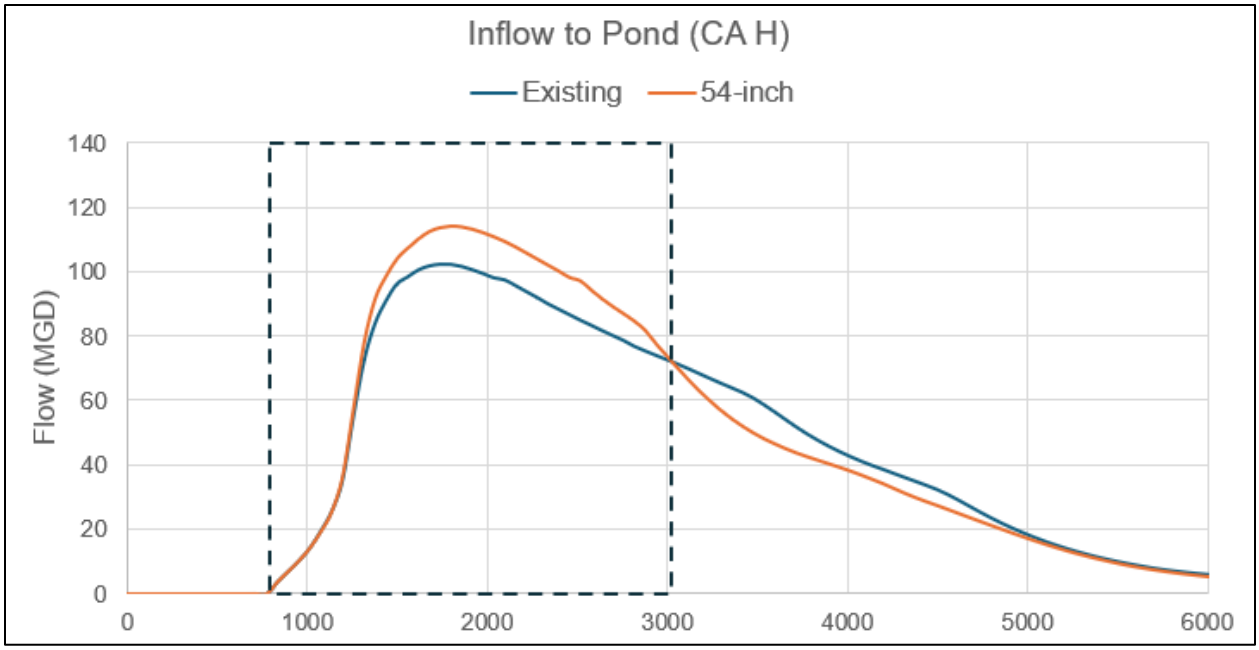


Figure 5-12. Alternative 6a – Estimated Storage Volume – Peak Flow Hydrograph

- Structure Modifications:
    - It is proposed to remove the 7.5-inch flow restrictor along Applegate Lane near Wyngarden Lane (SW-4310).

For additional resiliency and to meet the Enhanced LOS (current 50-year/future 16-year, 1-hour design storm), Alternative 6a can be expanded to include the following as **Alternative 6b:**

- Upsized Storm Sewers:
    - To achieve additional resilience, the following projects would need expanded:
        - Increase diameter of the sewer upsizing along Applegate Lane and Pebblebrook Lane from 36-inch, and 54-inch-diameter (Alternative 6a) to 42-inch and 54-inch diameter storm sewer (3,880 LF).
- Stormwater Storage:
    - An additional 0.4 million gallons of stormwater storage is proposed.
        - For Alternative 6b, the model predicts, the model predicts approximately 0.6 MG or 1.73 ac-ft is required to attenuate peak flows. This storage volume was estimated by taking the difference in the downstream peak

flow hydrographs for the existing and upsized conditions during the peak event window, as shown in Figure 5-13.

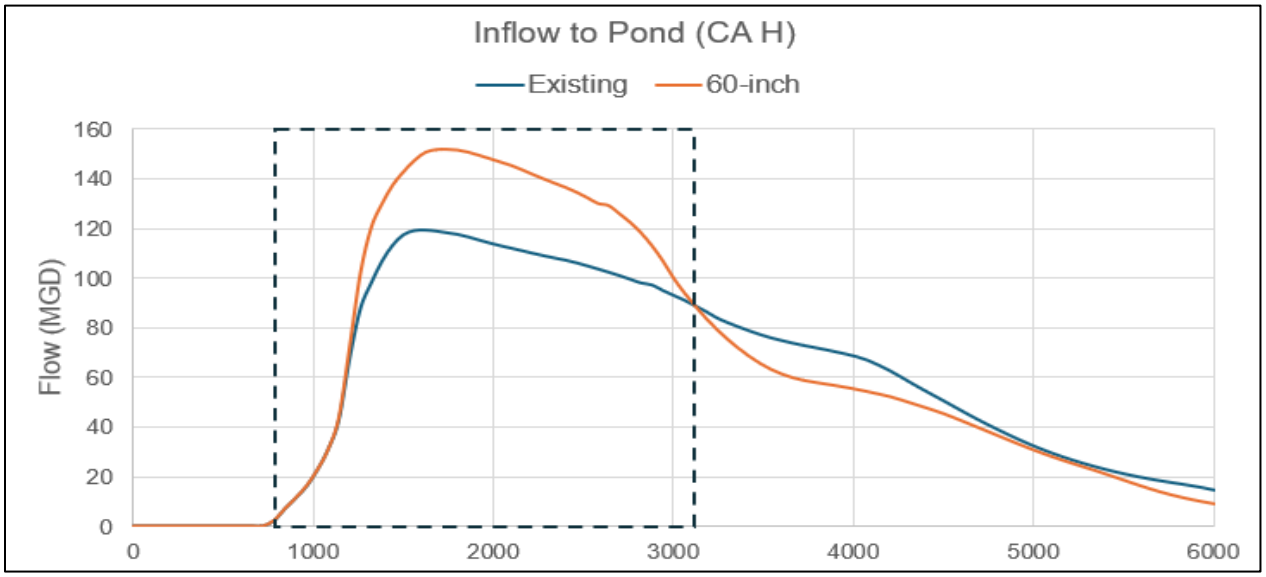


Figure 5-13. Alternative 6b – Estimated Storage Volume – Peak Flow Hydrograph

Concept maps for Alternative 6a and Alternative 6b are shown in Figure 5-14 are taken from the Wet Weather Resiliency Plan Web Map (ARCGIS Online). Only one concept map is provided as the project extents are the same, with the main difference being sizing.

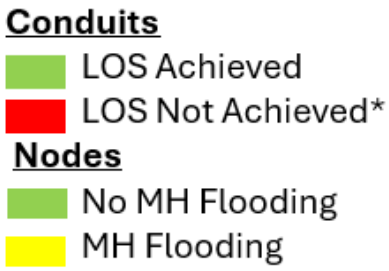


Figure 5-14. Conceptual Map - Alternative 6a & 6b (Web Map)

6 Alternative LOS Results

The developed alternatives were analyzed using the H&H model to quantify the flood risk reduction benefits and the results for the Current Standard and Enhanced LOS goals. The alternatives were modeled as individual scenarios and together as single scenarios for evaluation. This section summarizes the LOS results.

Color-coded symbology was created in the H&H model environment to quickly identify sewers and manholes that do not meet the established LOS criteria for alternatives evaluation. The color-coded symbology is shown in Figure 6-1 for the CSS and Figure 6-2 for the MS4.



*Note: Previous iterations used “Exceeds LOS” and terminology was later updated to “LOS Not Achieved”

Figure 6-1. Model Symbology Theme – CSS LOS

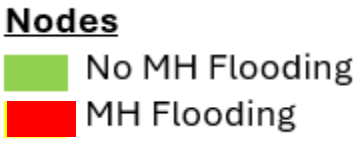


Figure 6-2. Model Symbology Theme – MS4 LOS

The model predicted LOS results for each alternative modeled independently is provided in the following subsections to show what LOS could be expected with only that alternative in place. As discussed below, LOS is not met at some locations if adjacent alternatives are not in place resulting in a lower predicted LOS. Due to interconnected behavior of the system, in order to achieve the target LOS goals within the CAs, the full implementation of alternatives across the CSS is required. See Section 9 for LOS results with the full implementation of selected alternatives.

6.1 Alternative 1 – CAs A&B

Results for Alternative 1a and 1b for the current 10-year, 1-hour and future 16-year, 1-hour events are shown Figure 6-3 and Figure 6-4, respectively. As shown in the figures, the current 10-year and future 16-year LOS goals are not met in CA A without improvements in CA B included as Alternative 3. Although manhole flooding within CA A is mitigated with Alternative 1, several pipes are shown to not meet LOS. A few pipes do not meet LOS as described below:

- Current 10-year, 1-hour LOS:

- Sewer along Glenmoor Road
- Future 16-year, 1-hour LOS:
  - Sewers along Glenmoor Road to Highland Avenue

To meet LOS goals in CAs A and B, both Alternative 1 and Alternative 3 projects implemented together are needed. For LOS results with both alternatives modeled together, see Section 9.

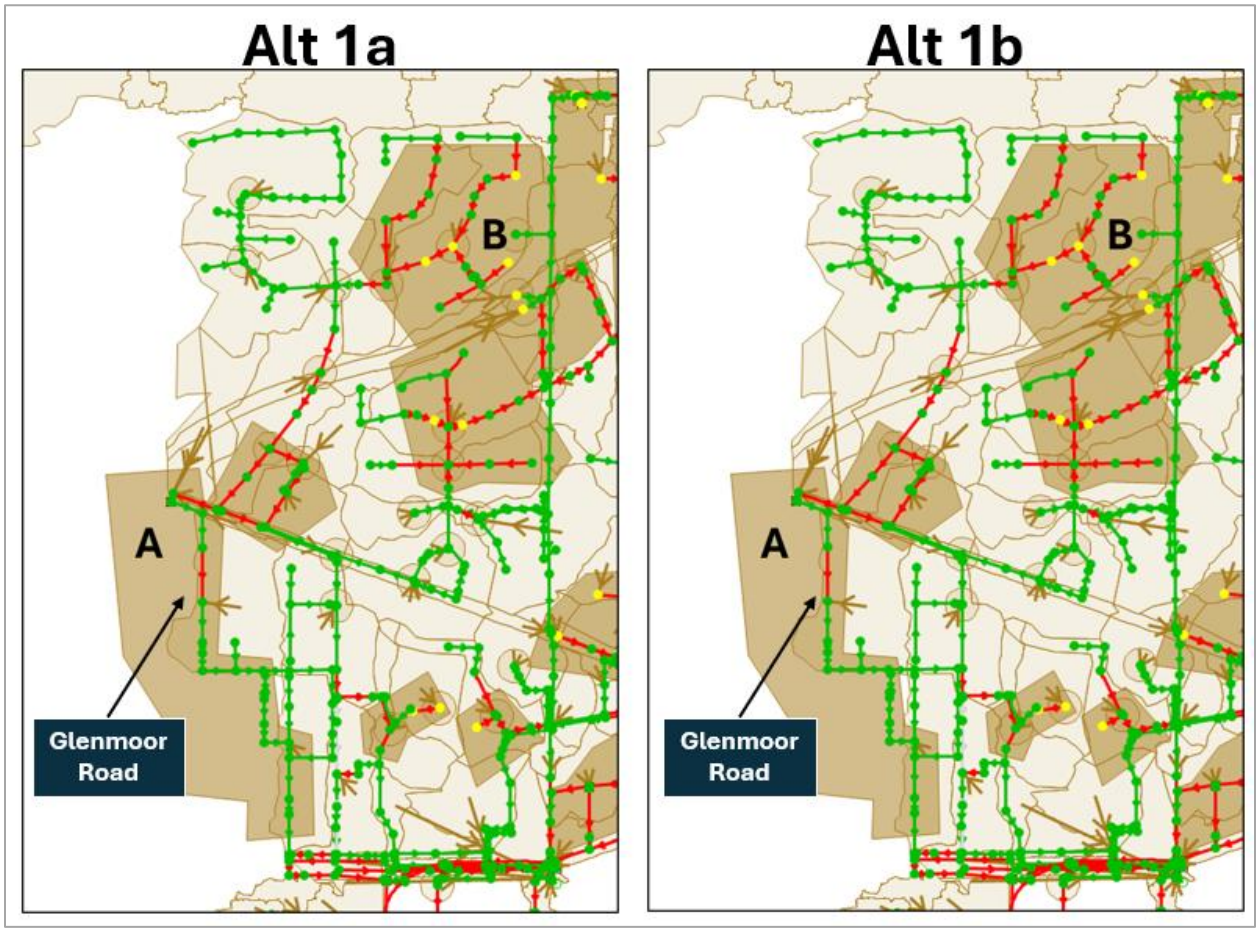


Figure 6-3. LOS Results – Alternative 1 Only (Model) - Current 10-year, 1-hour Design Storm

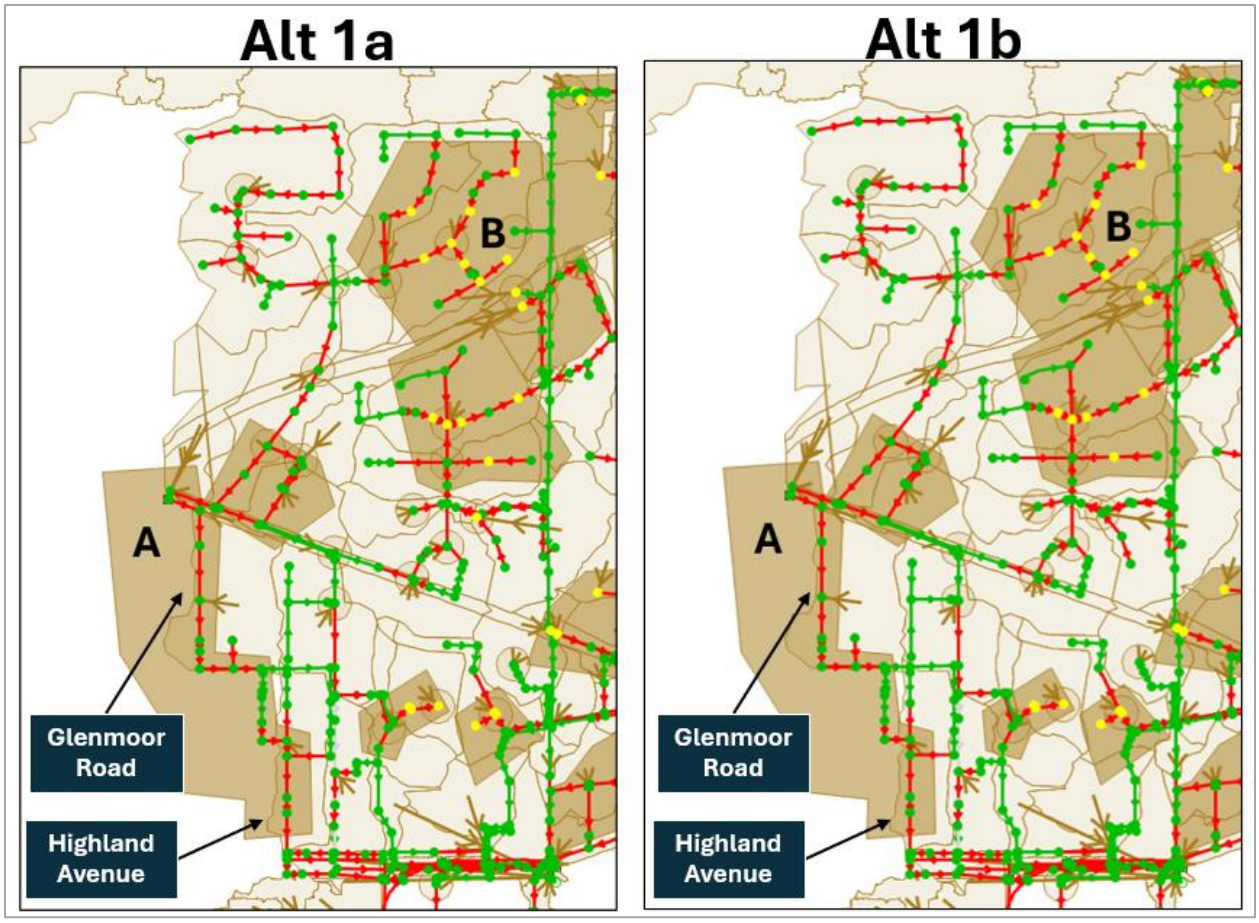


Figure 6-4. LOS Results – Alternative 1 Only (Model) - Future 16-year, 1-hour Design Storm

6.2 Alternative 2 – CA D

Alternative 2 is not dependent on other alternatives to meet LOS goals as this area of the CSS is hydraulically independent. As shown in Figure 6-5 and Figure 6-6, the current 10-year, 1-hour and future 16-year, 1-hour LOS goals are generally met in CA D. Manhole flooding within CA D is mitigated with Alternative 2. A few shallow pipes in low lying areas do not meet LOS as described below:

- Current 10-year, 1-hour LOS:
  - Sewers near interceptor, sewers along Beal Street
- Future 16-year, 1-hour LOS:
  - Sewers near interceptor, sewers along Beal Street, shallow sewers along Valley Court, Elm Place, and Elm Street

For Alternative 2 the mainline sewer was upsized to 36-inch to match the diameter of the existing combine sewer downstream of CA D. Since the mainline sewer cannot be upsized further to meet the required capacity due lack of cover within the shallow area, as well as potential downstream impacts, LOS goals are not able to be met for the future 16-year, 1-hour design storm. Therefore, the predicted LOS for Alternative 2b is between the current 10-year and future 16-year design storms. As with all combined sewer upsizing projects, project need

and sizing requirements should be re-evaluated after performing flow monitoring after sewer separation is implemented.

6.3 Alternative 3 – CAs B, C, E, & G

Results for Alternative 3a and 3b for the current 10-year, 1-hour and future 16-year, 1-hour events are shown in Figure 6-7 and Figure 6-8, respectively. As shown in Figure 6-7, the current 10-year, 1-hour LOS goals are met in CAs B, C, E, and G with Alternative 3. However, for CA B to meet LOS goals separation must either be expanded to Chartwell (under Alternative 3b) or include separation areas from Alternative 1. As shown in Figure 6-8, a few pipes do not meet Enhanced LOS goals as described below:

- Future 16-year, 1-hour LOS:
  - Shallow sewers along Northlawn Avenue, Sunset Lane
  - Sewer along Synder Road

Within CA C LOS goals are not met for the shallow sewers along Northlawn Avenue and along Sunset Lane. With Alternative 3b, the HGL along Northlawn is predicted to reach within 2.0 ft of ground at the low-point at MH-10557. With the addition of Alternative 2b downstream, as shown in Section 9, the HGL along Northlawn is predicted to decrease by approximately 6-inches, and becomes within the 1 ft above pipe crown criteria to meet LOS goals in CA C. Pipes not meeting LOS along Rosewood Avenue are expected to remain, however the HGL is not expected to reach above the pipe crown of the upstream sewer segment and is considered minimal.

Within CA G the surcharged pipe along Synder Road occurs at the high-point of the sewer where flow splits directions at MH-2953. The HGL does not reach the invert of the 12-inch pipe coming from the north. While the HGL does not meet LOS goals, surcharged is considered minimal and reaches a maximum of 8.2 ft below ground which is close to the 8.5 ft threshold.

To meet Enhanced LOS goals in CAs B, C, E, and G the model predicts Alternative 1 and Alternative 2 will be required. LOS in CA C should be re-evaluated after performing flow monitoring after sewer separation is implemented. See Section 9 for the selected alternatives.

6.4 Alternatives 5 & 6 – CAs F&H

As shown in Figure 6-9 and Figure 6-10, the current 10-year and future 16-year LOS goals are generally met in CAs F and H with Alternatives 5 and 6. The alternatives are not dependent on each other to meet LOS goals.

A few manholes do not meet LOS as described below, and flooding should be verified following the construction of the alternative projects. Additional localized projects may be needed to address minor surface flooding that remains.

- Current 10-year, 1-hour LOS:
  - CA H: Minor surface flooding from manholes SW-4435 and SW-4261. It should be noted that SW-4435 flooding is mitigated for Alternative 5b.

- CA F: MH-207 and MH-208 are located in the CSS and were not considered in the alternatives development for CA H, which focused on the MS4 system.

- Future 16-year, 1-hour LOS:
  - CA H: Minor surface flooding from manholes SW-4435 and SW-4261. Note SW-4435 flooding is mitigated for Alternative 5b.

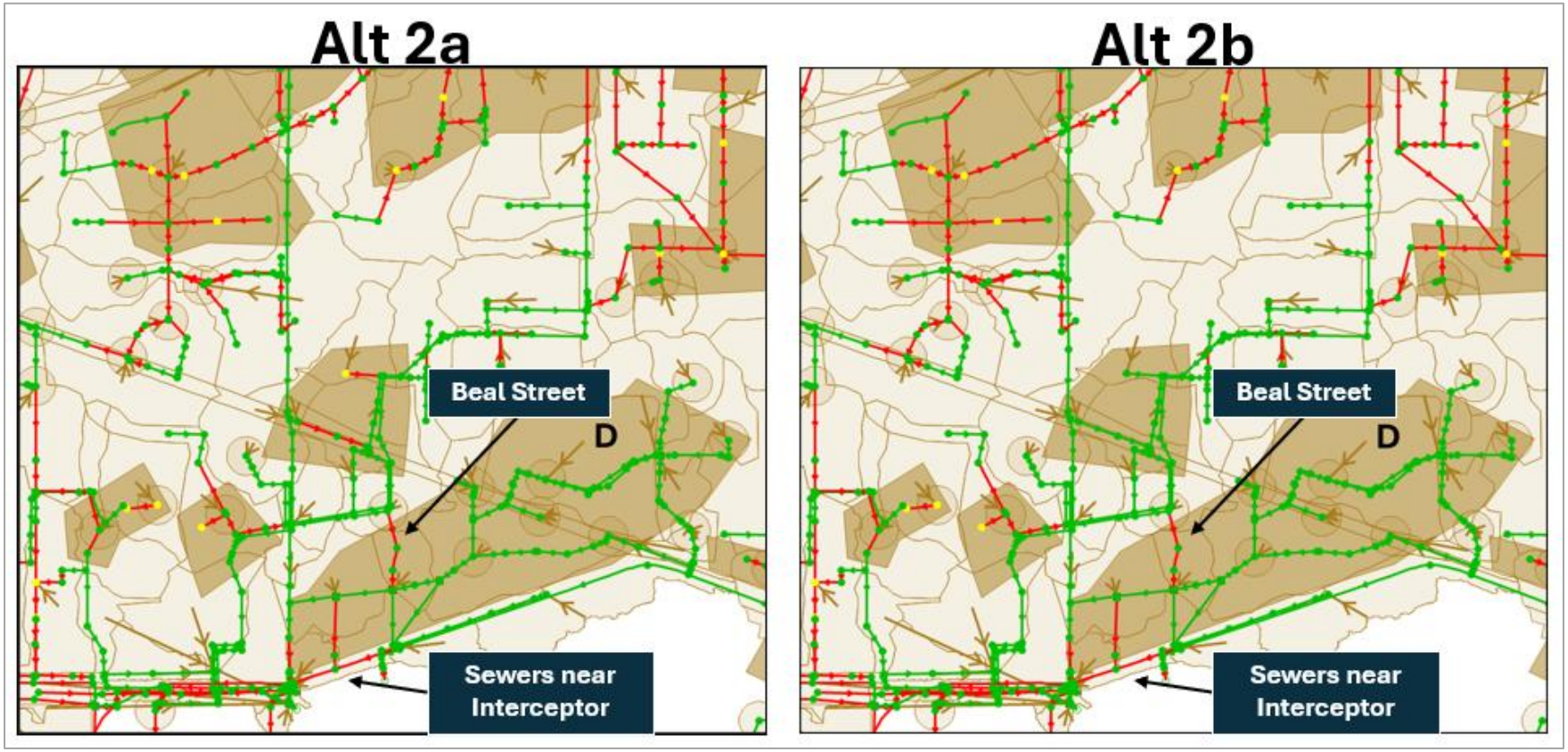


Figure 6-5. LOS Results – Alternative 2 Only (Model) - Current 10-year, 1-hour Design Storm

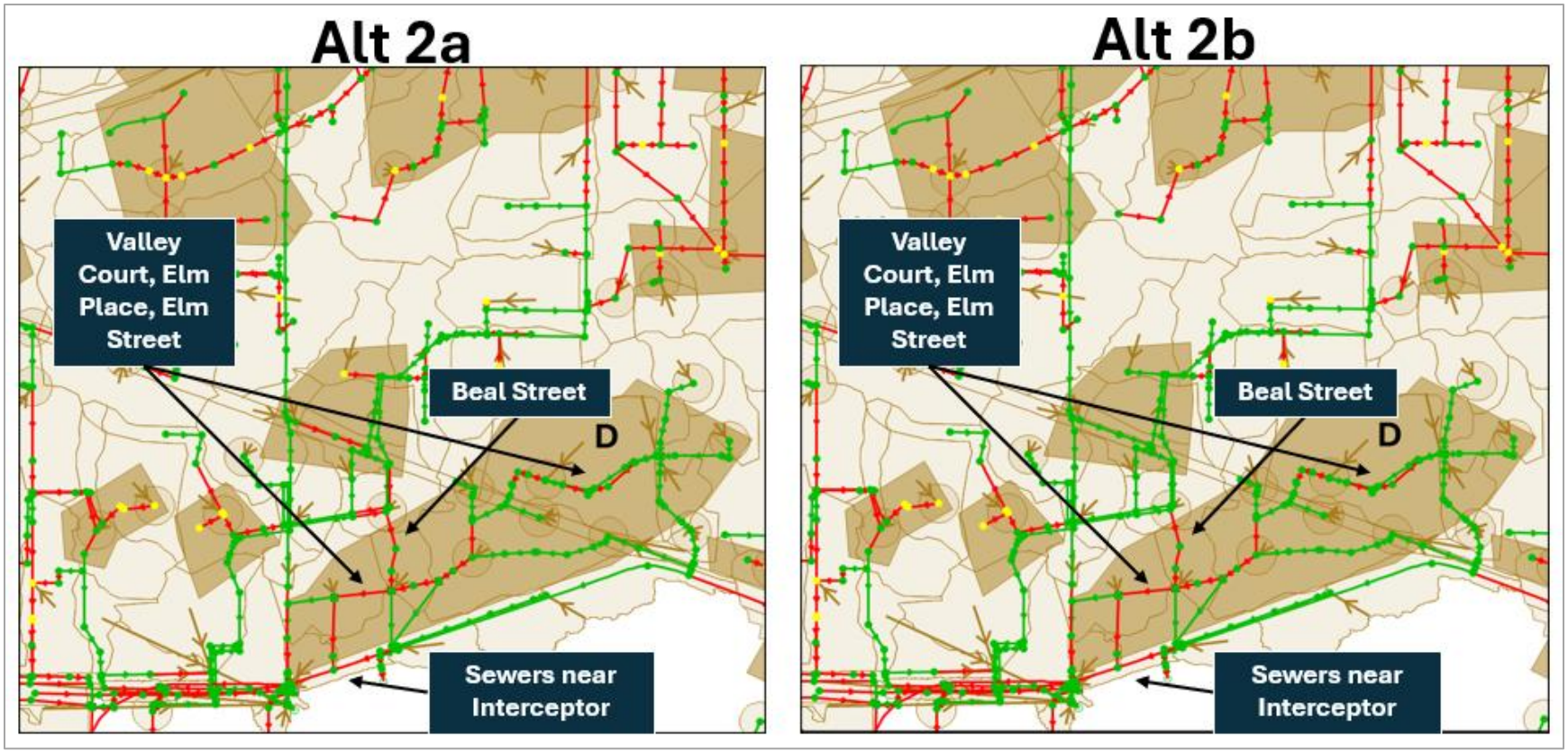


Figure 6-6. LOS Results – Alternative 2 Only (Model) - Future 16-year, 1-hour Design Storm

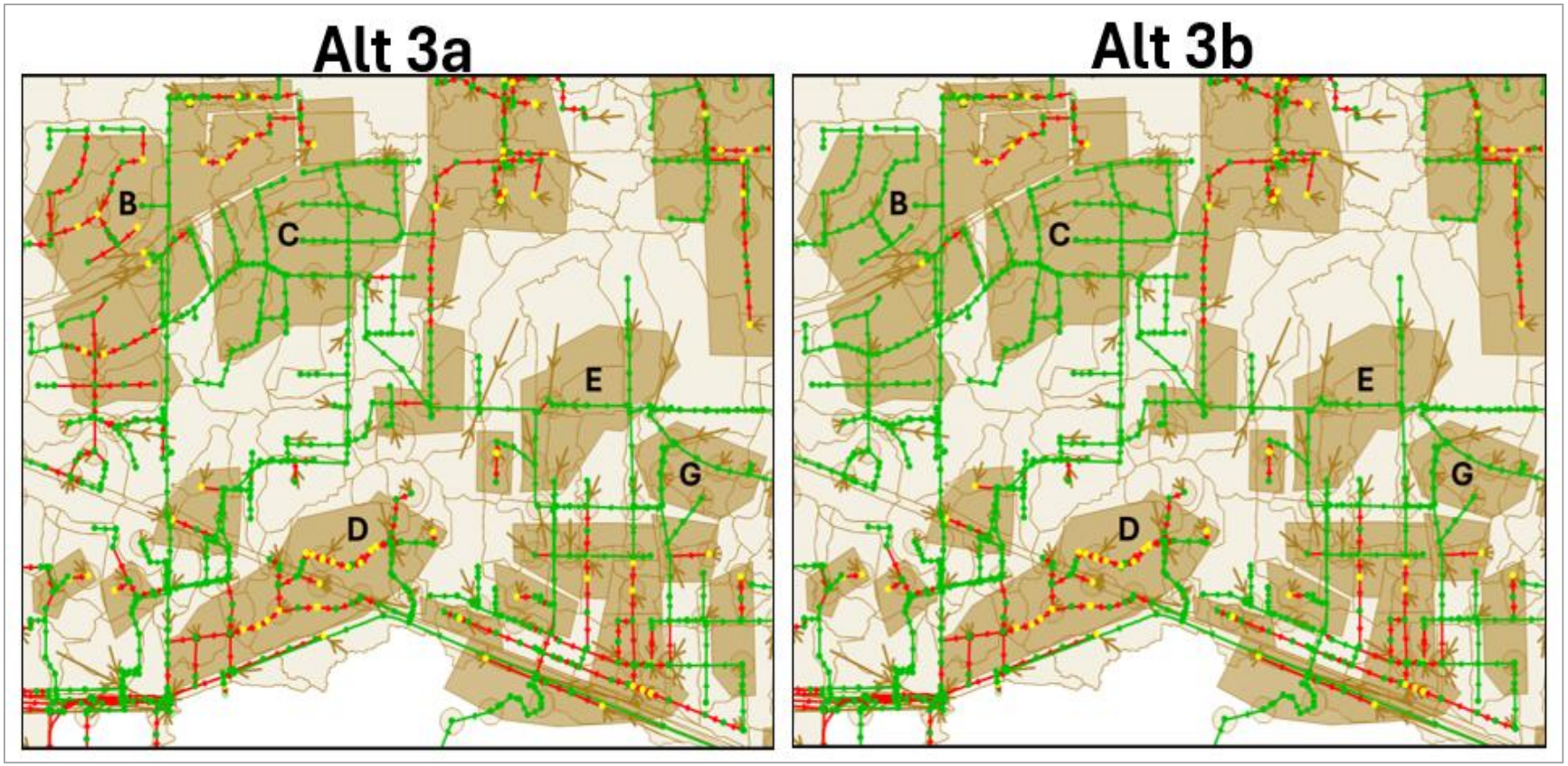


Figure 6-7. LOS Results – Alternative 3 Only (Model) - Current 10-year, 1-hour Design Storm

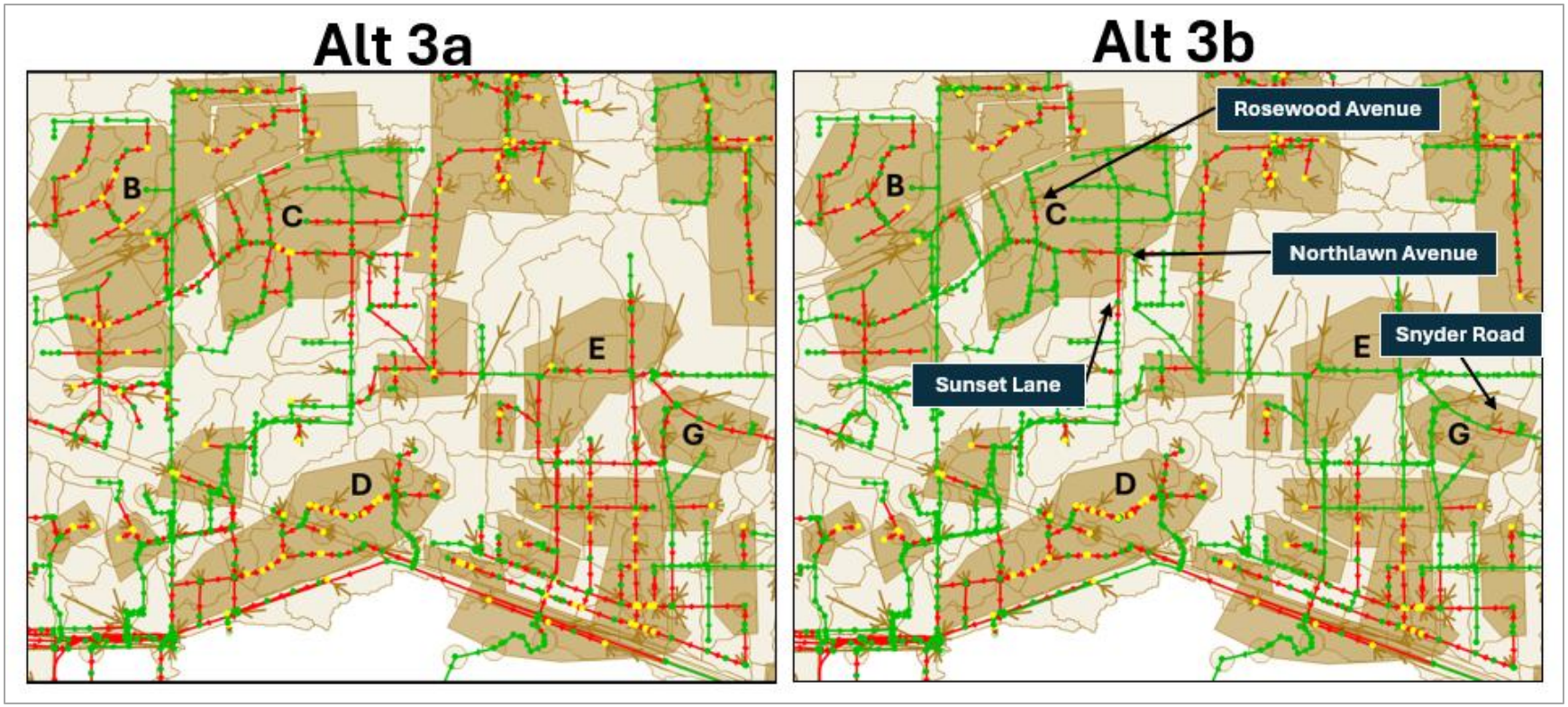


Figure 6-8. LOS Results – Alternative 3 Only (Model) - Future 16-year, 1-hour Design Storm

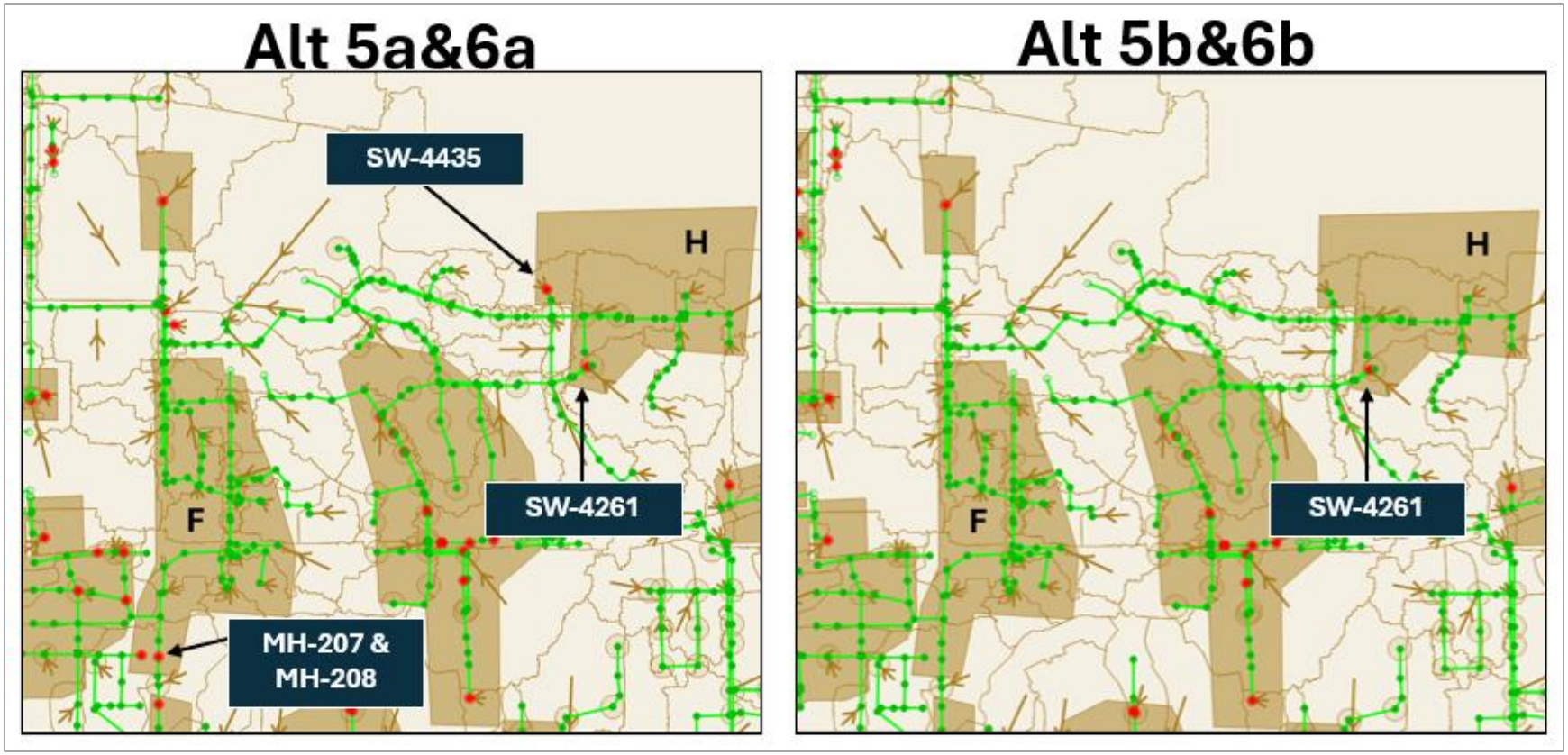


Figure 6-9. LOS Results – Alternative 5&6 (Model) - Current 10-year, 1-hour Design Storm

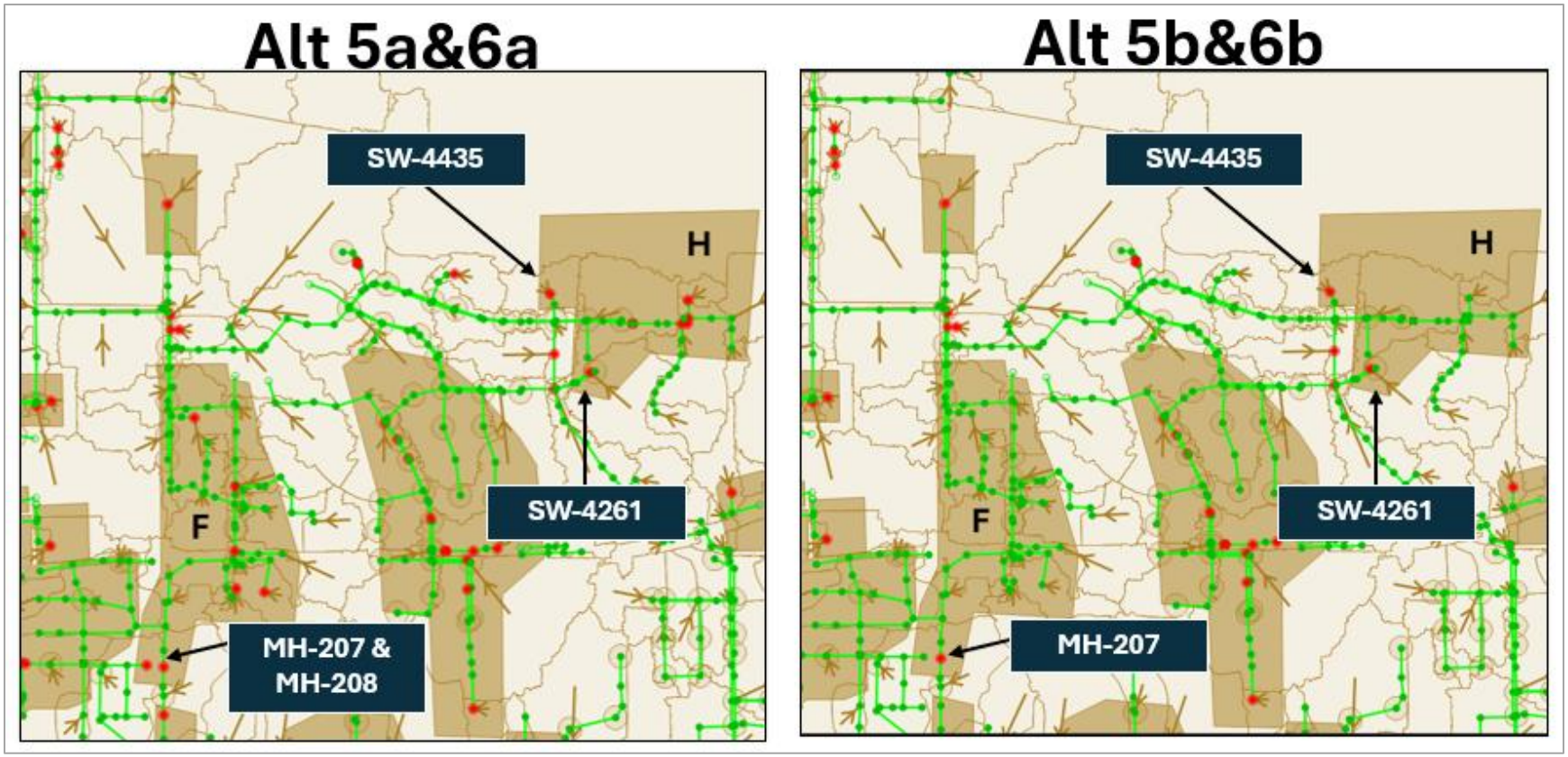


Figure 6-10. LOS Results – Alternative 5&6 (Model) - Future 16-year, 1-hour Design Storm

7 Alternative Flood Reduction Benefits

For each alternative, the flood risk reduction benefit for the current 10-year, 1-hour and future 16-year, 1-hour LOS goals were quantified by evaluating the number of properties with reduced flooding risk and the length of road with reduced flooding risk.

Flood risk results were quantified by using predicted model outputs under each alternative for the two LOS design events. Properties reduced from the risk of flooding were calculated by comparing the total number of properties at risk with and without the alternative in place. Similarly, the reduction in the length of roadway was estimated by comparing the length of flooding depth of 6 inches with and without the alternative in place. The flood risk reduction benefits for the additional aboveground and underground storage options were not quantified as they were not input to the H&H model. However, these storage options would provide an additional level of resiliency as a project benefit in the future.

Table 7-1 summarizes the flood risk reduction results for all the alternatives except for Alternative 4 since it was removed from further consideration. Results are presented graphically in Figure 7-1.

Table 7-1. Flood Risk Reduction Results for the Alternatives

Alternative	Properties reduced for 10-year	Properties reduced for 16-year	Length of road reduced for 10-year (ft)	Length of road reduced for 16-year (ft)
1a	210	54	483	1,131
1b	210	55	483	1,242
2a	123	100	1,293	2,047
2b	123	148	1,293	2,302
3a	620	193	1,688	5,311
3b	620	796	1,688	6,853
5a	3	5	947	870
5b	3	5	947	1,062
6a	6	3	315	568
6b	6	6	315	1,275

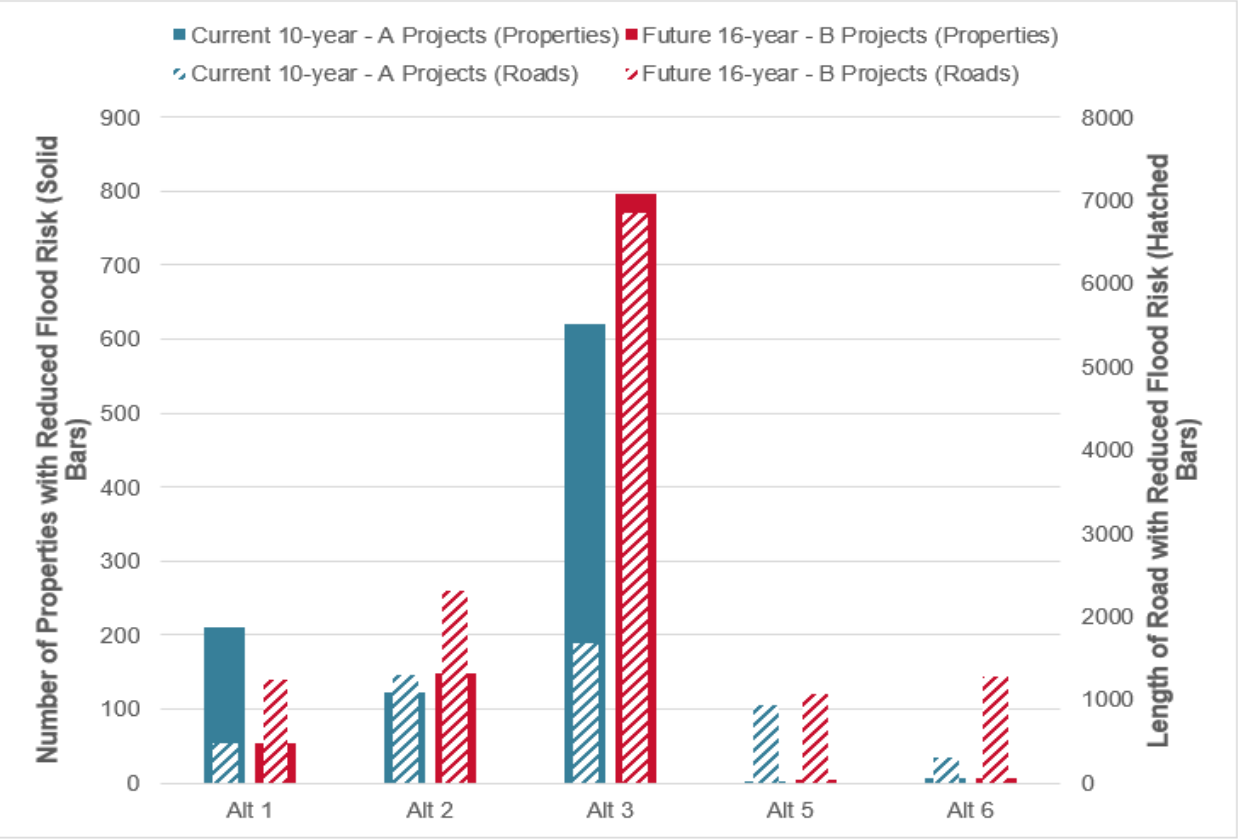


Figure 7-1. Comparison of reduced flood risk (number of properties and length of road) with each alternative evaluated for Current Standard and Enhanced LOS goals.

8 Alternative CSO Statistics

The City of East Lansing's wastewater collection system model has two combined sewer overflow (CSO) outfalls that discharge flow to the Red Cedar River during large rainfall events when the sewer capacity is exceeded. The State of Michigan regulates overflows from the system through the City's National Pollutant Discharge Elimination System (NPDES) Permit MI0022853. The two CSO outfalls are located at the following locations:

- Michigan Avenue & S. Harrison Road
- Kalamazoo Street & W. Brody Road

Modeled sewers tributary to each outfall is shown in Figure 8-1 and Figure 8-2. The outfall at Michigan Avenue is downstream of CA C and the outfall at Kalamazoo Street is located near the City's retention treatment basin. The combined and sanitary system is tributary to the Kalamazoo outfall and includes the 6 CSS CAs A, B, C, D, E, and G.

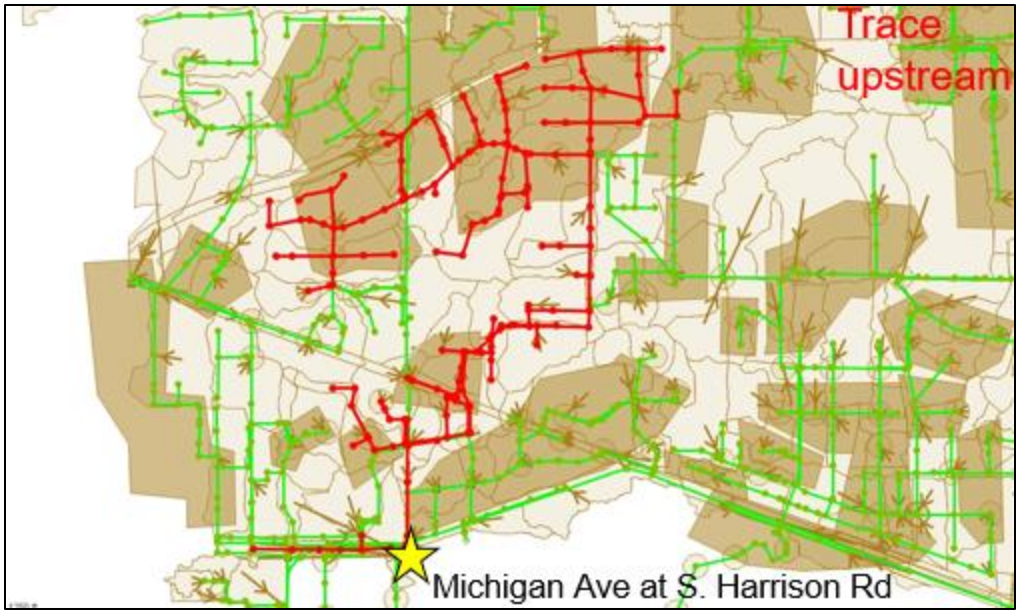


Figure 8-1. Model Sewers Tributary to CSO Outfall at Michigan Avenue



Figure 8-2. Model Sewers Tributary to CSO Outfall at Kalamazoo Street

To ensure compliance with CSO discharge requirements it is important that the alternative projects do not increase CSO volume. Potential flow increases from sewer upsizing must be offset by the removal of stormwater accomplished through combined sewer separation. To determine potential CSO impacts the H&H model was simulated for the current 10-year, 1-hour and future 16-year, 1-hour design storm under existing conditions and with the proposed alternatives. Additionally, an upsizing only scenario was created which incorporated all combined sewer upsizing projects with no combined sewer separation. The upsizing only scenario provides insight on the worse case outcome if the combined sewer separation projects are not performed first. For each model scenario the model predicted peak flow and CSO

volume were compared against the existing conditions to determine potential for increased CSO discharge.

Results from the analysis are provided in the following subsections.

8.1 CSO Results – Current 10-year Storm

Peak flow and volume results are provided in Table 8-1 and Table 8-2 for the current 10-year, 1-hour storm. The model predicts the peak flow at Kalamazoo will exceed the existing conditions peak flow of 309 mgd by approximately 47 mgd if only upsizing projects are completed without combined sewer separation. Similarly, the model predicts the peak flow at Kalamazoo will also be exceeded by approximately 13 mgd if only Alternative 3a is implemented, however the model predicts that the volume of CSO will be decreased by approximately 0.7 MG. As shown in Table 8-2 and Figure 8-3 the volume of CSO is only exceeded for the current 10-year, 1-hour storm if the combined sewer upsizing alternative projects are implemented before sewer separation. Under this condition, CSO volume is predicted to increase by approximately 1.3 MG.

Table 8-1. CSO Statistics – Peak Flow (mgd) - Current 10-year Storm

CSO Outfall	Existing Conditions	Upsizing Projects Only (1a, 2a, 3a)	With Alt 1a, 2a, 3a	With Alt 1b, 2, 3b	Alt 1a Only	Alt 2a Only	Alt 3a Only
Michigan	78.2	71.9	57.3	43.6	74.7	71.7	67.0
Kalamazoo	308.8	356.3	275.3	139.6	302.4	282.1	321.6
	Peak flow exceeds existing conditions						

Table 8-2. CSO Statistics – Volume – Current (mg) 10-year Storm

CSO Outfall	Existing Conditions	Upsizing Projects Only (1a, 2a, 3a)	With Alt 1a, 2a, 3a	With Alt 1b, 2, 3b	Alt 1a Only	Alt 2a Only	Alt 3a Only
Michigan	2.9	2.7	1.8	1.2	2.6	2.7	2.3
Kalamazoo	8.2	9.5	5.1	1.9	7.4	6.7	7.5
	CSO volume exceeds existing conditions						

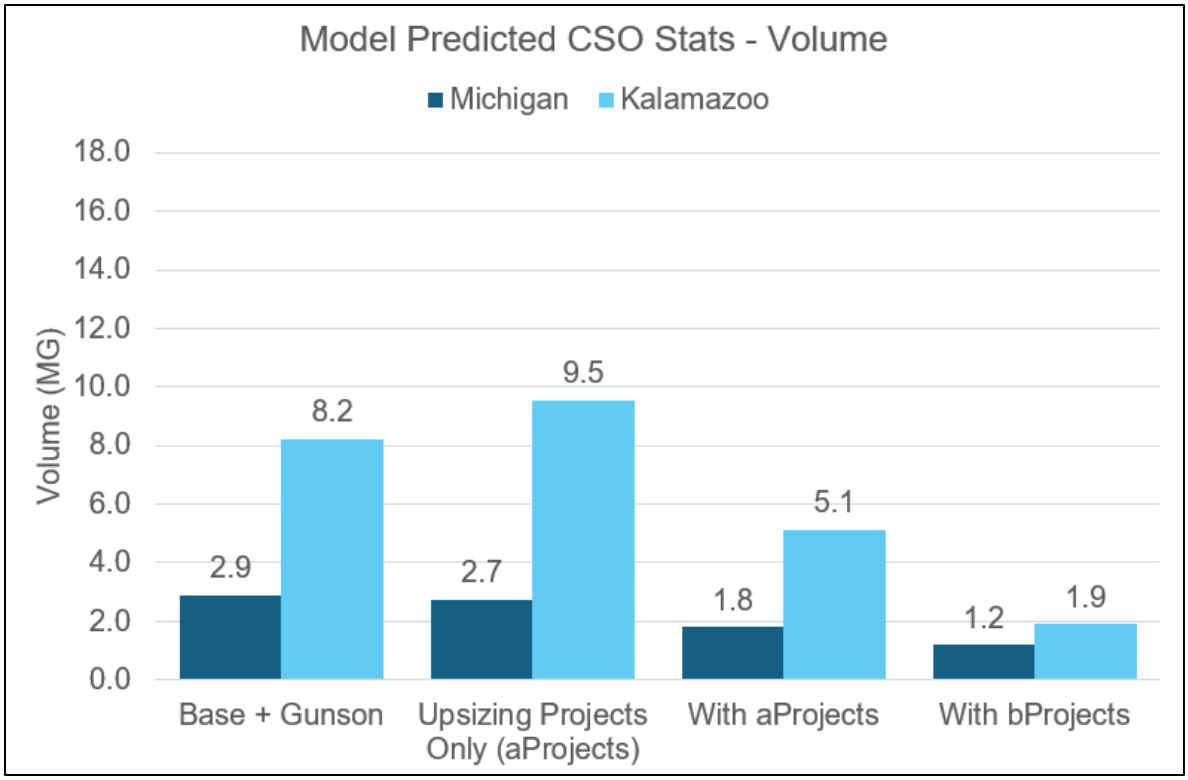


Figure 8-3. CSO Statistics – Volume - Current 10-year Storm

8.2 CSO Results – Future 16-year Storm

Peak flow and volume results are provided in Table 8-3 and Table 9-1 for the future 16-year, 1-hour storm. The model predicts the peak flow at Kalamazoo will exceed the existing conditions peak flow of 374 mgd by approximately 64 mgd if only upsizing projects are completed without combined sewer separation. The model also predicts that the peak flow at Kalamazoo will be exceeded for the future 16-year, 1-hour design storm by approximately 16 mgd if Alternative 1a, 2a, and 3a are implemented. Additionally, the model predicts the peak flow at Kalamazoo will be exceeded if only Alternative 1b or Alternative 3b are implemented. As shown in Table 8-4 and Figure 8-4 the volume of CSO is only exceeded for the future 16-year, 1-hour storm if the combined sewer upsizing alternative projects are implemented before sewer separation. Under this condition, CSO volume is predicted to increase by approximately 1.7 MG.

Table 8-3. CSO Statistics – Peak Flow (mgd) - Future 16-year Storm

CSO Outfall	Existing Conditions	Upsizing Projects Only (1a, 2a, 3a)	With Alt 1a, 2a, 3a	With Alt 1b, 2, 3b	Alt 1a Only	Alt 2a Only	Alt 3a Only
Michigan	99.7	96.6	85.4	66.6	97.0	86.4	83.2
Kalamazoo	374.1	437.8	390.2	318.5	376.3	344.1	375.8
	Peak flow exceeds existing conditions						

Table 8-4. CSO Statistics – Volume (mg) – Future 16-year Storm

CSO Outfall	Existing Conditions	Upsizing Projects Only (1a, 2a, 3a)	With Alt 1a, 2a, 3a	With Alt 1b, 2, 3b	Alt 1a Only	Alt 2a Only	Alt 3a Only
Michigan	4.3	4.2	3.1	2.0	4.0	3.9	2.9
Kalamazoo	14.5	16.2	11.0	6.9	13.8	12.2	10.1
	CSO volume exceeds existing conditions						

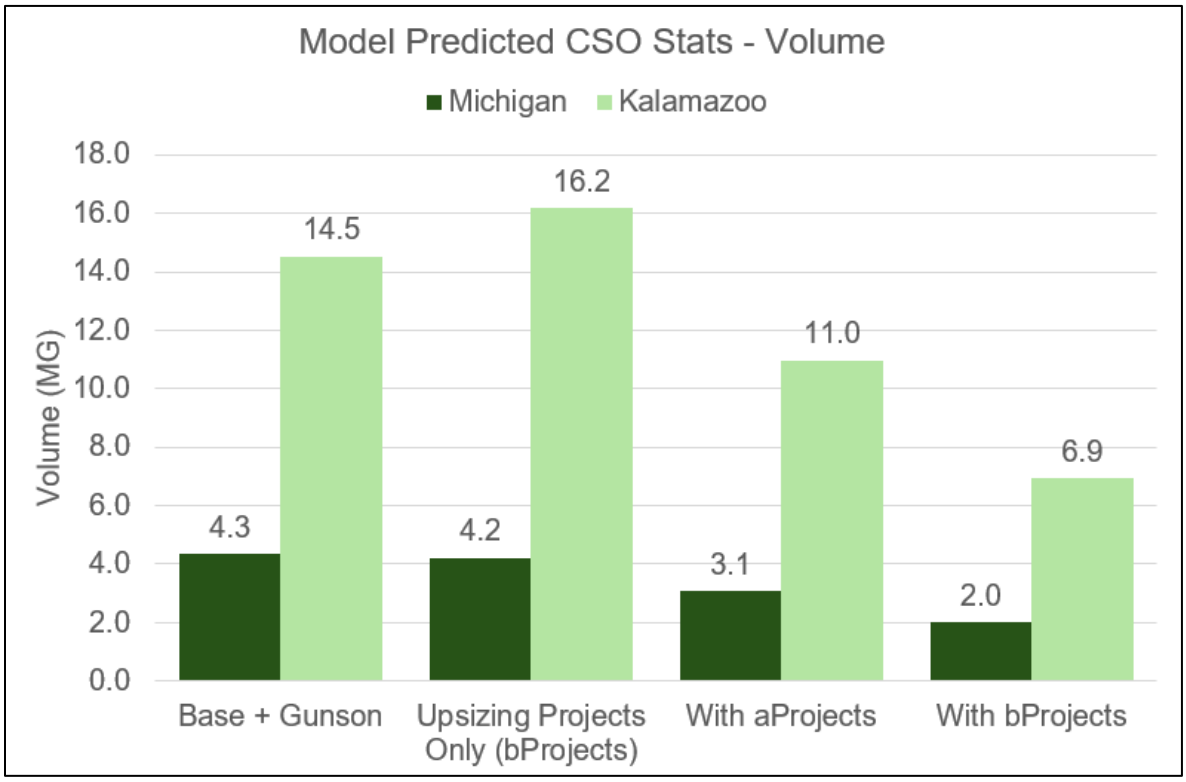


Figure 8-4. CSO Statistics – Volume – Future 16-year Storm

8.3 Summary of CSO Results

Results indicate that CSO volumes may increase for both design storms evaluated if combined sewer upsizing is performed before combined sewer separation. Potential impact to CSOs should be considered in a phased implementation of alternatives projects where a targeted combined sewer separation project is performed before upsizing of sewers in the CSS.

9 Selected Alternatives

Through a series of workshops and discussions with the City, a set of alternatives was selected to be prioritized and implemented in the WWRP. Several factors impacted the selection of the alternatives, including the LOS goals and predicted performance of each alternative and the size and scope of the project, which directly influences the cost. For each flooding CA, or grouping of CAs based on hydraulic connectivity, the City identified one modeled alternative to be advanced as conceptual layout and cost estimating, i.e., Association for the Advancement of

Cost Engineering (AACE) Level Class 5. This section provides a brief overview of the reasoning for selecting each alternative.

- To address flooding in CAs A and B, **Alternative 1b was selected**. Much of the discussion for Alternative 1 was based on minimizing the amount of flow that would be diverted to Ranney Park to keep flows within the pre-established agreement. As the decision was made early in the process to move forward with Alternative 3 rather than Alternative 4, the amount of flow to Ranney Park would be minimized by not including additional stormwater from the Chartwell and Shaw Estates neighborhoods. Separated stormwater from these neighborhoods would instead be directed to the east to the new storm main on Harrison Road as part of Alternative 3. Alternative 3 also reduced the required area for separation and the diameter and length for the new storm main. This allowed the City to move forward with Alternative 1b, which increases LOS to the future 16-year, 1-hour storm when combined with Alternative 3b.
- To address flooding in CA D, **Alternative 2b was selected with underground storage at Valley Court Park**. This alternative increases LOS to the current 10-year, 1-hour LOS by conveying separated stormwater to the Red Cedar River. It also increases LOS to the current future 16-year LOS in some areas. Compared to Alternative 2a, the upsizing of some of the combined sewer mains will help to relieve some of the remaining bottlenecks currently experienced downstream but will not address the current future 16-year because of model-predicted hydraulics of the existing CSO tunnel system and the shallow nature of the pipes within this area.
- To address flooding in CAs B, C, E, and G, **Alternative 3b was selected with the storage options at Gordon Guyer and Glencairn Park** included. This alternative increases LOS to the current future 16-year LOS. Similar to Alternative 2b, the upsizing of combined sewers from this alternative will help to relieve some of the remaining bottlenecks downstream that are not currently in the top eight flooding CAs.
- To address flooding in CAs F and H, both hydraulically independent watersheds in the MS4, **Alternatives 5a and 6a were selected**. The flood risk reduction benefits show a minimal increase for the added cost to provide an LOS from a current 10-year, 1-hour LOS to a current future 16-year, 1-hour. Both alternatives increase LOS to the current 10-year, 1-hour LOS in their respective CAs. Alternative 5a includes aboveground storage at flexible open-surface areas near the fire station, Harrison Meadow Park, and open areas west of Abbot Road. Alternative 6a includes storage at Albert A. White Memorial Park in the open areas surrounding the fishing pond.

As shown below in Table 9-1, the H&H model predicted that implementation of the identified alternatives were all able to manage the current 10-year, 1-hour LOS with the exception of Alternative 2a. Because of the complicated layout of the pipes in an area downstream, an area of pipes near the interceptor does not meet the current 10-year, 1-hour LOS. The future 16-year, 1-hour (Enhanced) LOS was not able to be managed everywhere with the alternatives evaluated.

Table 9-1. Predicted LOS for each alternative.

CA	Alternative	Predicted LOS
A and B	1a	Current 10-year, 1-hour
A and B	1b	Current 50-year/Future 16-year, 1-hour (except near the interceptor)
D	2a	Current 10-year, 1-hour (except near the interceptor)
D	2b	Between the Current 10-year, 1-hour and Current 50-year/Future 16-year, 1-hour
B, C, E, and G	3a	Current 10-year, 1-hour
B, C, E, and G	3b	Current 50-year/Future 16-year, 1-hour
F	5a	Current 10-year, 1-hour
F	5b	Current 50-year/Future 16-year, 1-hour
H	6a	Current 10-year, 1-hour
H	6b	Current 50-year/Future 16-year, 1-hour

Table 9-2 provides a summary overview of the selected alternatives, the increased LOS, and the estimated flood risk reduction benefits. Figure 9-1 shows the location of all of the selected alternatives. Systemwide existing conditions model LOS results for the Current 50-year/Future 16-year, 1-hour event is provided in Figure 9-2. LOS results for the selected alternatives are shown in Figure 9-3 and Figure 9-4 for the current 10-year, 1-hour and future 16-year, 1-hour design storms, respectively. Profiles through the CAs are provided in Appendix B.

Table 9-2. Selected alternatives LOS and flood risk reduction benefits.

Alternative	Predicted LOS	Estimated number of properties with reduced flood risk	Estimated feet of road with reduced flood risk
1b: West Central Neighborhoods CSS Relief	Current 50-year/Future 16-year	210	1,242
2b + Storage: Valley Court Corridor CSS Relief	Between Current 10-year and Current 50-year/Future 16-year	123	2,302
3b + Storage: Downtown Neighborhoods CSS Relief (Harrison St. Route)	Current 50-year/Future 16-year	620	6,853
5a: Abbot and Saginaw Storm Drainage Improvement	Current 10-year	3	947
6a: Whitehills Drainage Improvement	Current 10-year	6	315

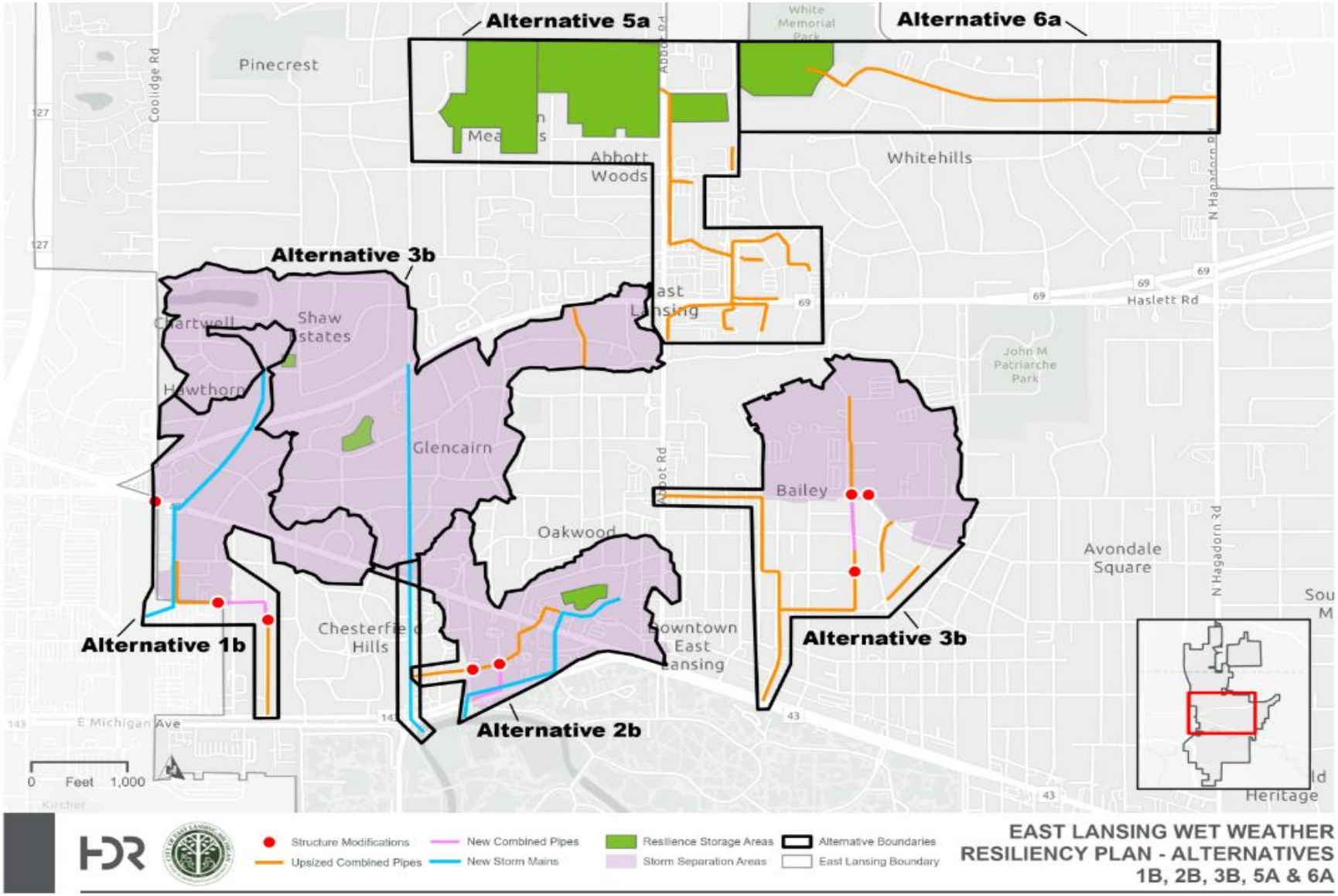


Figure 9-1. All Selected Alternatives

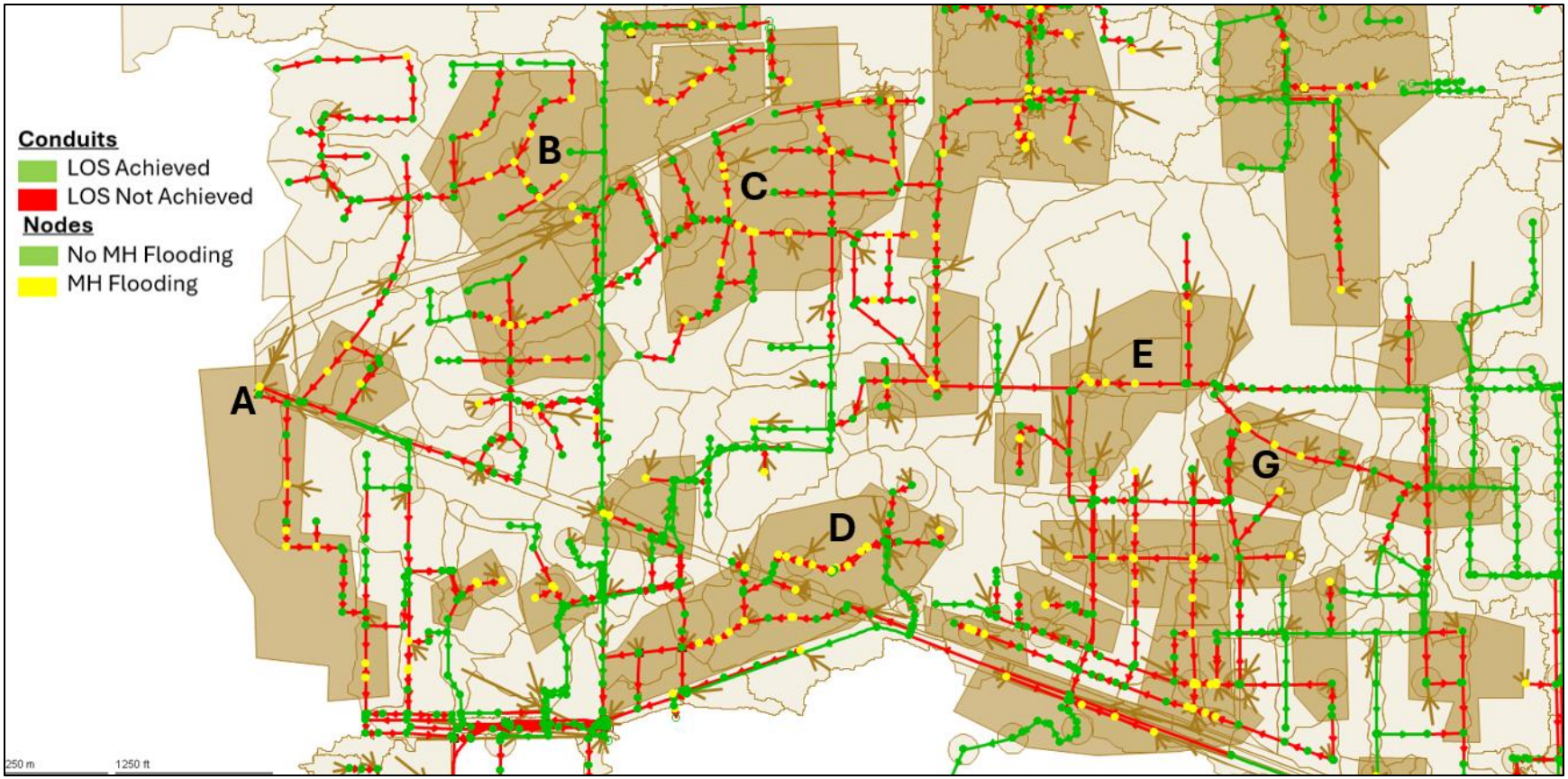


Figure 9-2. LOS Results – Existing Conditions – Future 16-year, 1-hour Design Storm

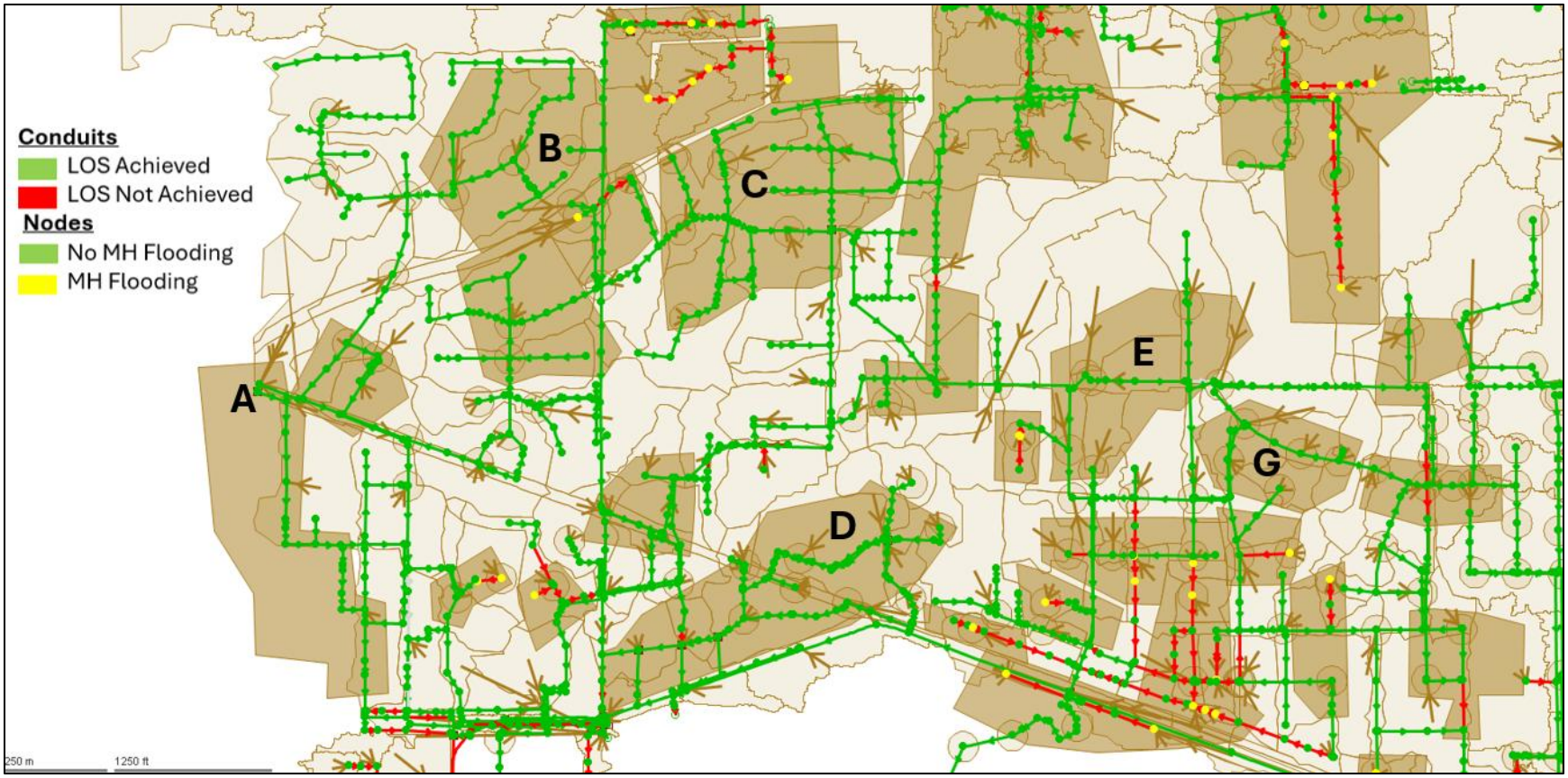


Figure 9-3. LOS Results – All Selected Alternatives – Current 10-year, 1-hour Design Storm

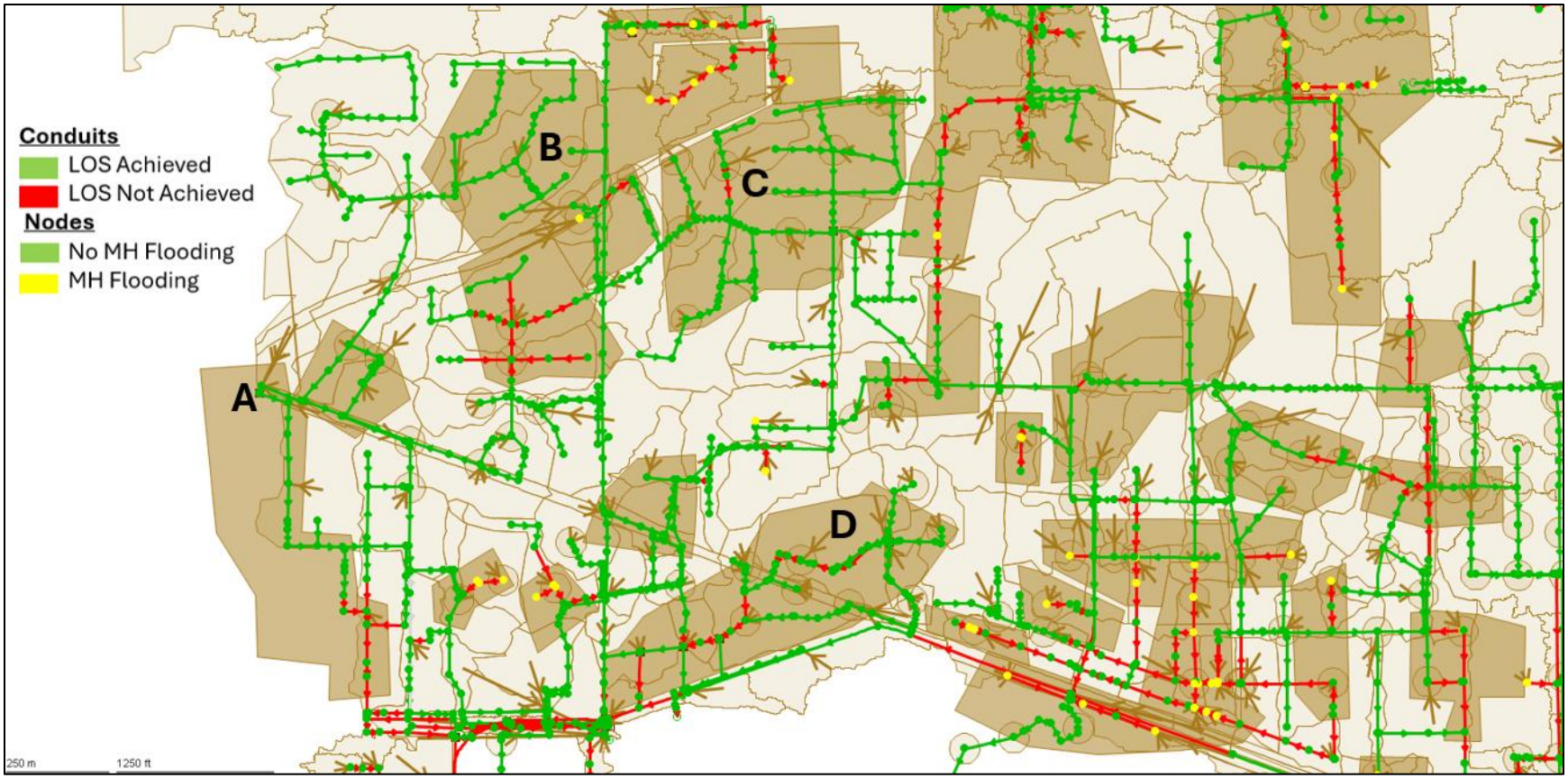


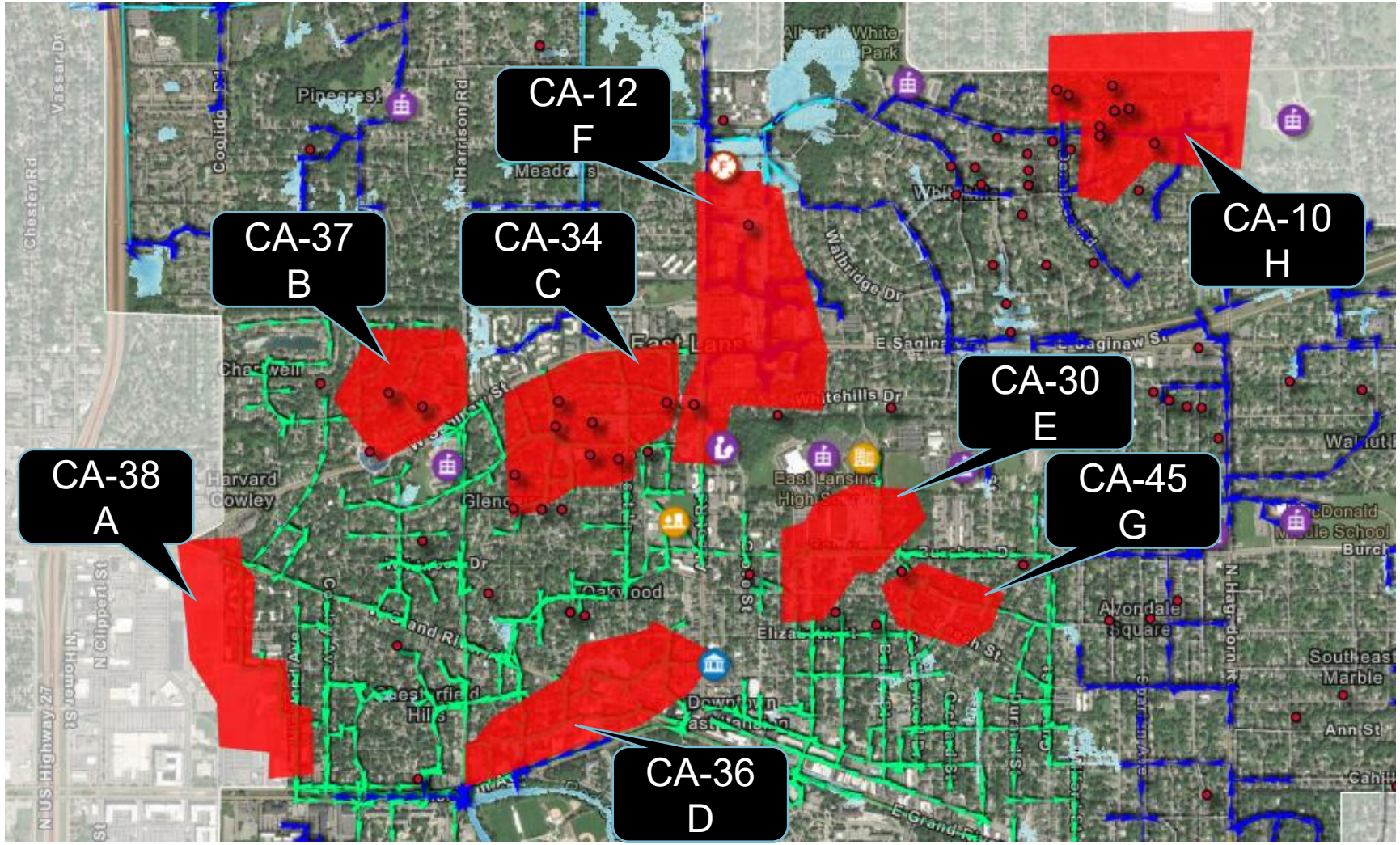
Figure 9-4. LOS Results – All Selected Alternatives – Future 16-year, 1-hour Design Storm

Appendix A. Workshop Slides & Meeting Minutes

Appendix A.1 – Planned CIP Projects (December 10th 2025)

Top 8 Concern Areas

Overview Map

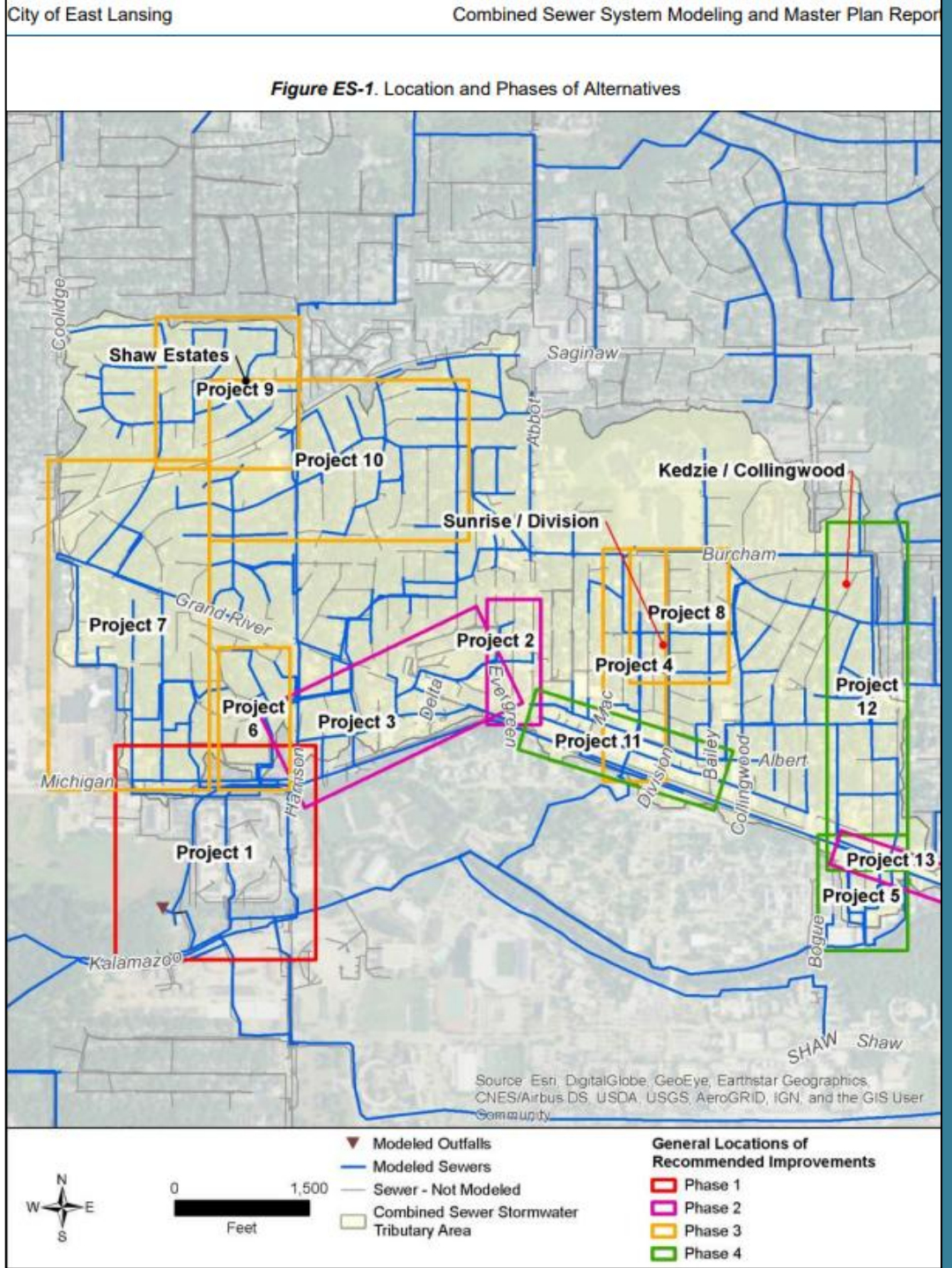


Document Review

Report List

- Combined Sewer System Modeling and Master Plan Report (2020)
- 2025 Clean Water State Revolving Funds Project Planning Document Submittal Form (CWSRF/ SWQIF)
- Separate Sewer Study

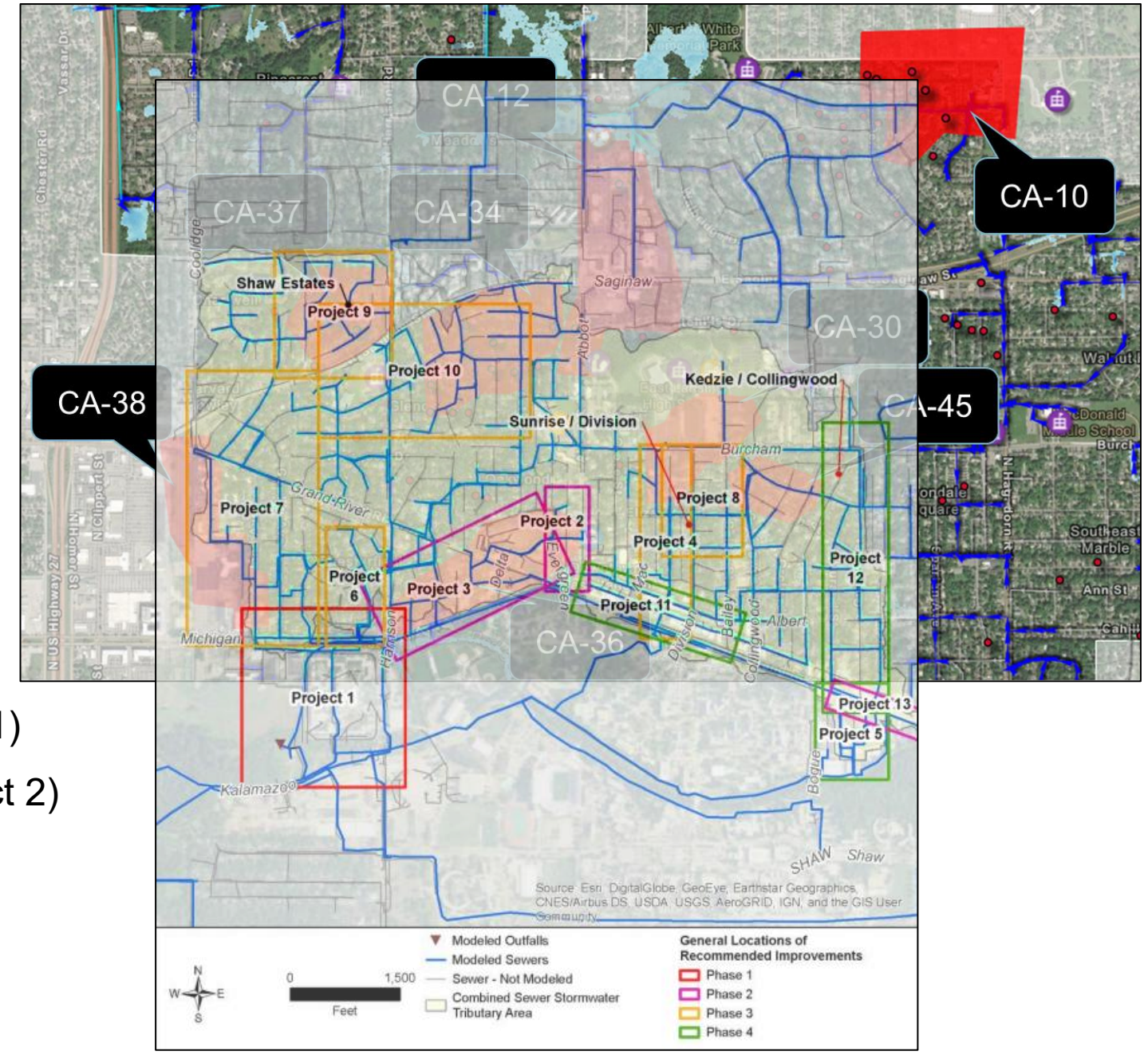




Master Plan

Projects Locations

- Overlay graphics
- Projects overlap 5 CAs
- Already Constructed:
  - 4 CIP Projects:
    - Kedzie / Collingwood
    - Sunrise / Division
    - Michigan and Harris (Project 1)
    - Oakhill and Evergreen (Project 2)



Master Plan

Recommended Plan and Project Phasing

- Constructed
- ☆ Overlaps Top 8 CAs

★ 2025 CWSRF alternative
★ Not funded under 2025 CWSRF

Project	Description	Opinion of Cost	Projected Phasing
~~Project 1~~	~~Michigan Avenue and Harrison Road Sewer Improvements~~	~~$9,381,374†~~	~~2019 Construction~~
~~Kedzie Alternative 2~~	~~Kedzie Street storm sewer~~	~~$340,000~~	~~Fiscal Year 2020~~
~~Sunrise Alternative 2~~	~~Sunrise Court storm sewer and Division / Linden connection~~	~~$250,000~~	~~Fiscal Year 2020~~
~~Shaw Estates Alt. 1~~	~~Backflow prevention on service leads~~	~~$160,000~~	~~Fiscal Year 2020~~
~~Project 10 Alternative 1 Segment 1~~	~~Portion of Northlawn Avenue sewer improvements between Harrison Road and Sunset Lane~~	~~$2,950,000~~	~~Fiscal Year 2020~~
~~Project 2~~	~~Oakhill / Evergreen Improvements~~	~~$4,250,000~~	~~Phase 1~~
★ Project 3 Alternative 4 Segment 1	Center and Beal regulator modifications	$920,000	Phase 1
★ Project 3 Alternative 4 Segment 2	Elm / Valley District storm sewer for upstream areas	$6,250,000	Phase 1
Project 13	Wilmarth-Woodmere Relief	$3,260,000	Phase 1
★ Project 4	Charles Street sewer replacement	$4,750,000	Phase 2
Project 6 Alternative 1	Chesterfield Hills Neighborhood Sewer Improvements	$1,920,000	Phase 2
★ Project 7 Alternative 3	Separation and redirection of stormwater to Montgomery Drain	$2,740,000	Phase 2
★ Project 8	Bailey - Linden Sewer	$3,560,000	Phase 2
★ Project 9 Alternative 1	Shaw Estates sewer separation with new sanitary sewers and local pump station	$5,480,000	Phase 2
★ Project 10 Alternative 1 Segment 2	Remaining combined sewer improvements not constructed with Northlawn Avenue work	$2,580,000	Phase 2
Project 5 Alternative 1	River / Waters Edge District sewer separation	$3,090,000	Phase 3
Project 11	Albert Alley Sewer Improvements	$1,780,000	Phase 3
Project 12 Alternative 1	Milford - Gunson sewer separation with new storm sewer	$6,840,000	Phase 3
Local Improvements	Local sewer improvements to address local capacity restrictions	-	with street and water projects

† Contractor bid.

Table ES-6. Estimated SRF Eligibility

	Estimated Portion of Construction Cost Eligible for SRF, %
Project 2	32
Project 3 Alternative 4	44
Project 5 Alternative 1	62
Project 7 Alternative 3	38
Project 9 Alternative 1	100
Project 12 Alternative 1	48
Project 13	100

Brookfield Relief Sewer

Top 8 Concern Areas

Planned Project Summary

				General Project Category				
Concern Area	Type	Overlapping MP Project ID	MP Project Alternatives (Ea.)	Combined Sewer Replacement	New Combined Sewer	Sewer Separation, New Storm Sewer	2025 CWSRF Alternatives (Ea.)	2025 CWSRF Project Category
CA-10	MS4	-	-	-	-	-	-	-
CA-12	MS4	-	-	-	-	-	-	-
CA-30	CSS	4 & 8	1 (2 projects)	X	X	-	-	Combined Sewer Replacement; New Combined Sewer
CA-34	CSS	10	2	X	-	X	-	-
CA-36	CSS	3	4	X	-	X	2	Sewer Separation, New Storm Sewer
CA-37	CSS	9	3	X	-	X	2	Sewer Separation, New Storm Sewer
CA-38	CSS	7	3	X	-	X	2	Combined Sewer Replacement; Sewer Separation
CA-45	CSS	-	-	-	-	-	-	-

Top 8 Concern Areas

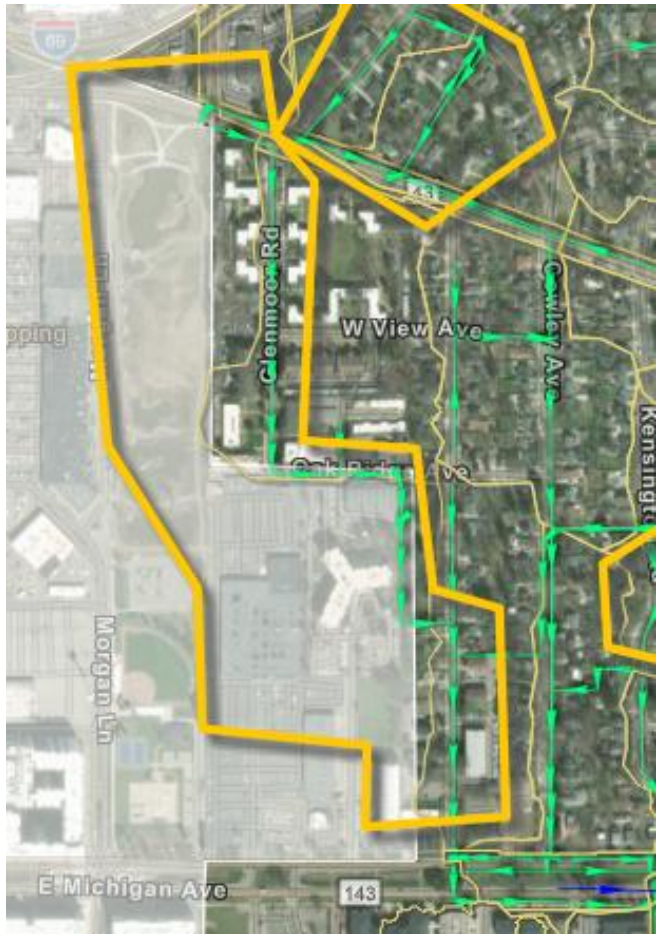
Planned Project Summary Notes

Concern Area	Type	Notes / observations for Alternatives Modeling
CA-10	**MS4**	Modeled storm sewers do not extend to catch basins along Wyngarden Ln. There are 3 reported flooding locations at the upstream end of the cul-de-sac. Wyngarden Ln is just downstream of the existing flow restrictor along Applegate Ln. Improvements should not increase HGL along Appleton Ln. Consider extending model to include catch basins along Wyngarden Ln.
CA-12	**MS4**	-
CA-30	**CSS**	MP determined there was no viable storm sewer outlet nearby.
CA-34	**CSS**	MP Project 10 Alt 2 requires downstream storm sewer from Project 9 Alt 3 (CA-37).
CA-36	**CSS**	MP determined storage was not a viable option in Valley Court Park due to potential impacts to the park and maintenance needs. Perhaps clarify maintenance concerns to get a better understanding of how willing the City is to consider storage options through out the CAs (i.e., pump maintenance, debris, inline vs tank etc.) CA-34 is upstream CA-36.
CA-37	**CSS**	-
CA-38	**CSS**	The Montgomery Drain, proposed outlet of new storm sewers, is outside of the model extents. CA-37 is upstream CA-38.
CA-45	**CSS**	CA-30 is upstream CA-45.

Area A (CA-38)

CSS Area

- MP Alternatives:
  - Project 7:
    - Alternatives 1 – 3
- MP Recommendation:
  - Project 7:
    - Alternative 3
- 2025 CWSRF Projects:
  - C-3 (Project 7)
    - Alternative A – Montgomery Drain Storm Sewer
    - Alternative B – Combined Sewer Replacement



ArcGIS

Area A (CA-38)

MP Alternatives

Table 3-5. Summary of Project 7 Alternatives

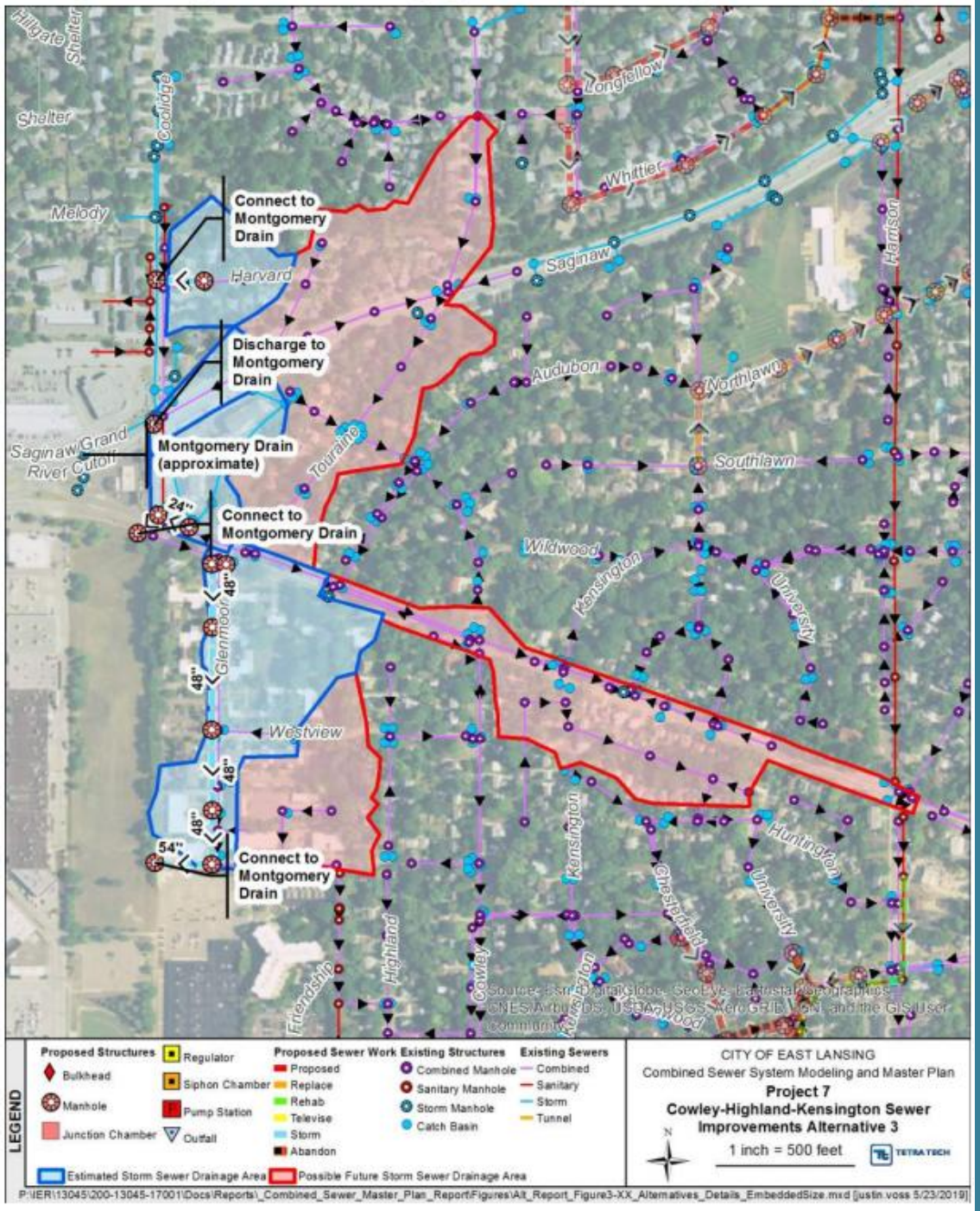
Alter-native	Project Description	Proposed Level of Service	Reduced Basement Flooding†	Reduced Surface Flooding†	Reduced CSO to River†	Opinion of Cost
1	Combined Sewer Replacement Glenmoor and Oak Ridge	10-year, 1-hour	Yes	Yes	No	$4,430,000
2	Combined Sewer Replacement Westview and Highland	10-year, 1-hour	Yes	Yes	No	$4,070,000
3	Sewer Separation	Combined: 10-year, 1-hour Storm: 10-year, 1-hour	Yes	Yes	Yes	$2,740,000

† Relative to the Year 2017 conditions during the 10-year, 1-hour Design Storm.

Area A (CA-38)

MP Alternative 3 (Recommended)

Figure 3-17. Project 7 Alternative 3 Cowley-Highland-Kensington Sewer Improvements Concept Map



Area A (CA-38)

CWSRF Alternatives

- Alternative A – Montgomery Drain Storm Sewer
- Alternative B – Combined Sewer Replacement

Table 4-3. Project C-3, Alternatives A and B Present Worth

Cost Category	Alternative A	Alternative B
Capital Cost	$2,870,000	$4,819,000
Present Worth of Salvage Value	($785,000)	($1,464,000)
Present Worth of Annual OM&R	$15,000	$91,000
Total Present Worth	**$2,100,000**	**$3,466,000**

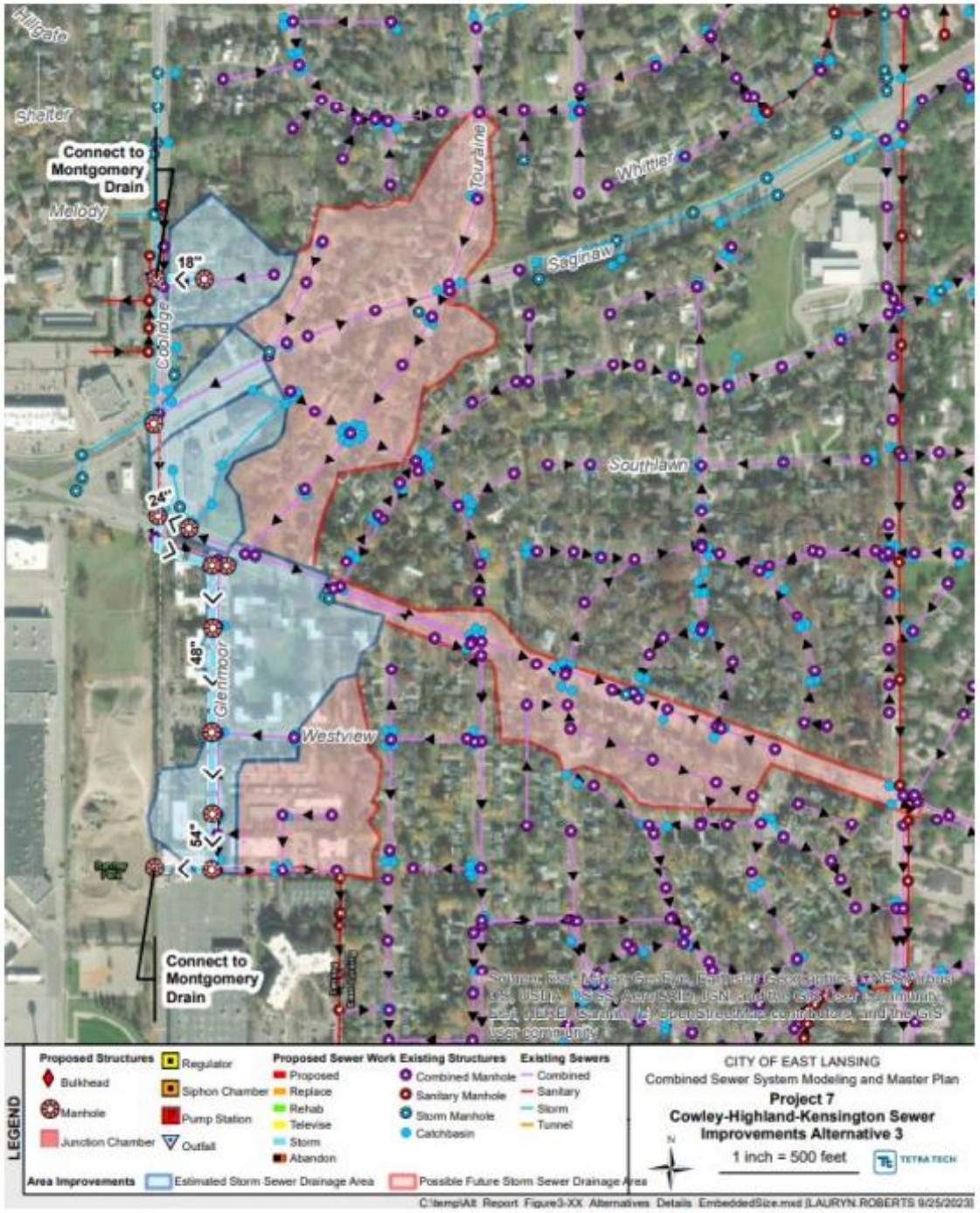
Area A (CA-38)

CWSRF Alternative A

Selected

- Similar to MP Alternative 3
- Tie into Ranney Park, already accounted for in the design of the park. City agreed to the connection with Drain Commission. Needs to use the outfall in the southwest corner. Alignments not set stone. Need to get an easement if sewer went through Ranney Park.
- Timeline 2029 construction or later, need to confirm with next budget cycle
- Connection fee still up for negotiation

Figure 4-4. Project C-3, Alternative A



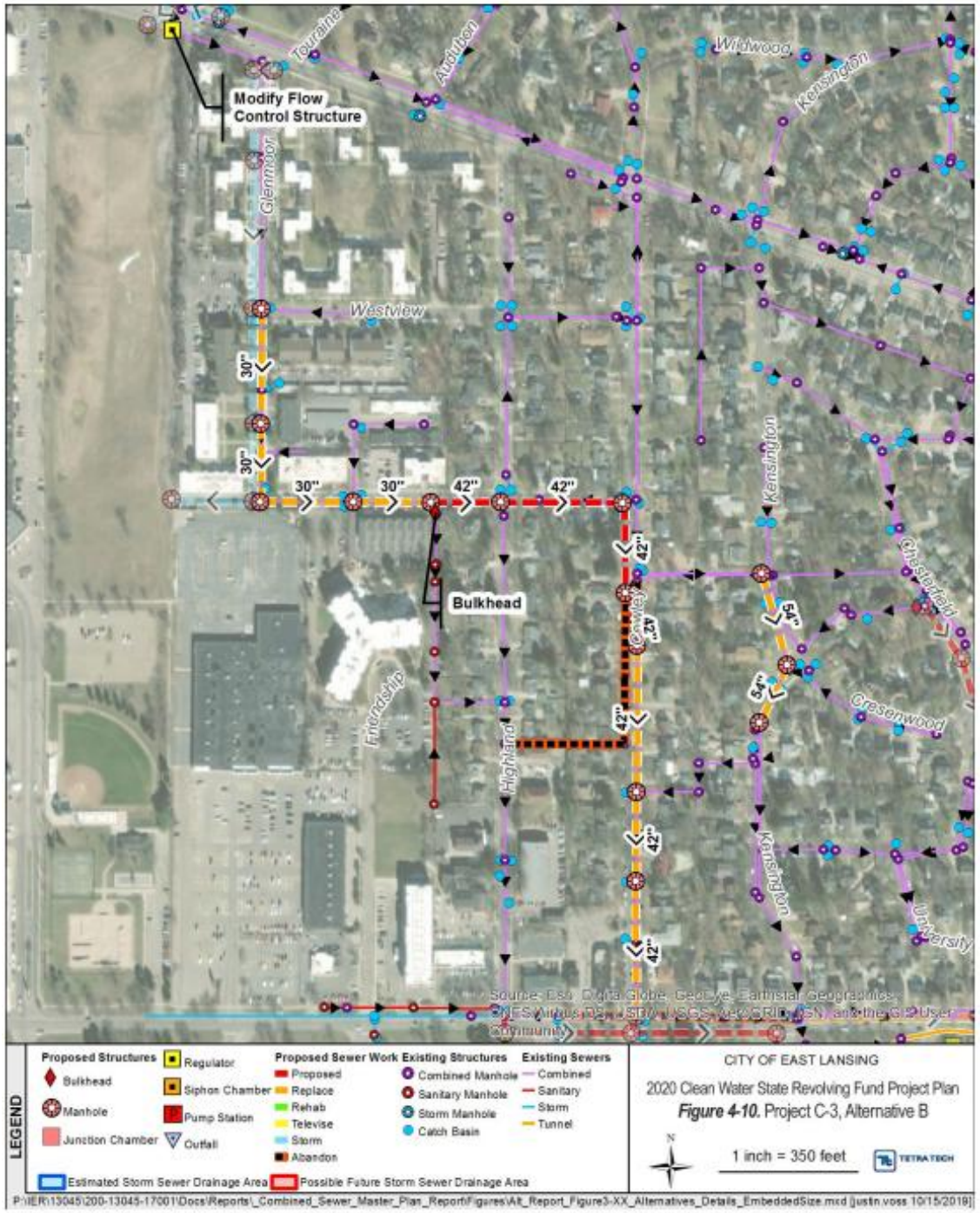
Area A (CA-38)

CWSRF Alternative B

Not Selected

- Similar to MP Alternative 1
- Could potentially come back on the table depending on discussions with County Drain on Alt 1. Preference is Alt 1 to fully separate rather than put in tunnel.

Figure 4-5. Projet C-3, Alternative B



Area B (CA-37)

CSS Area

- MP Alternatives:
  - Project 9:
    - Alternatives 1 - 3
- MP Recommendation:
  - Project 9:
    - Alternative 1
- 2025 CWSRF Projects: none
  - C-4 (Project 9)
    - Alternative A - New Sanitary Sewer with Pump Station
    - Alternative B – Harrison Road Storm Sewer



ArcGIS

Area B (CA-37)

MP Alternatives

Table 3-6. Summary of Project 9 Alternatives

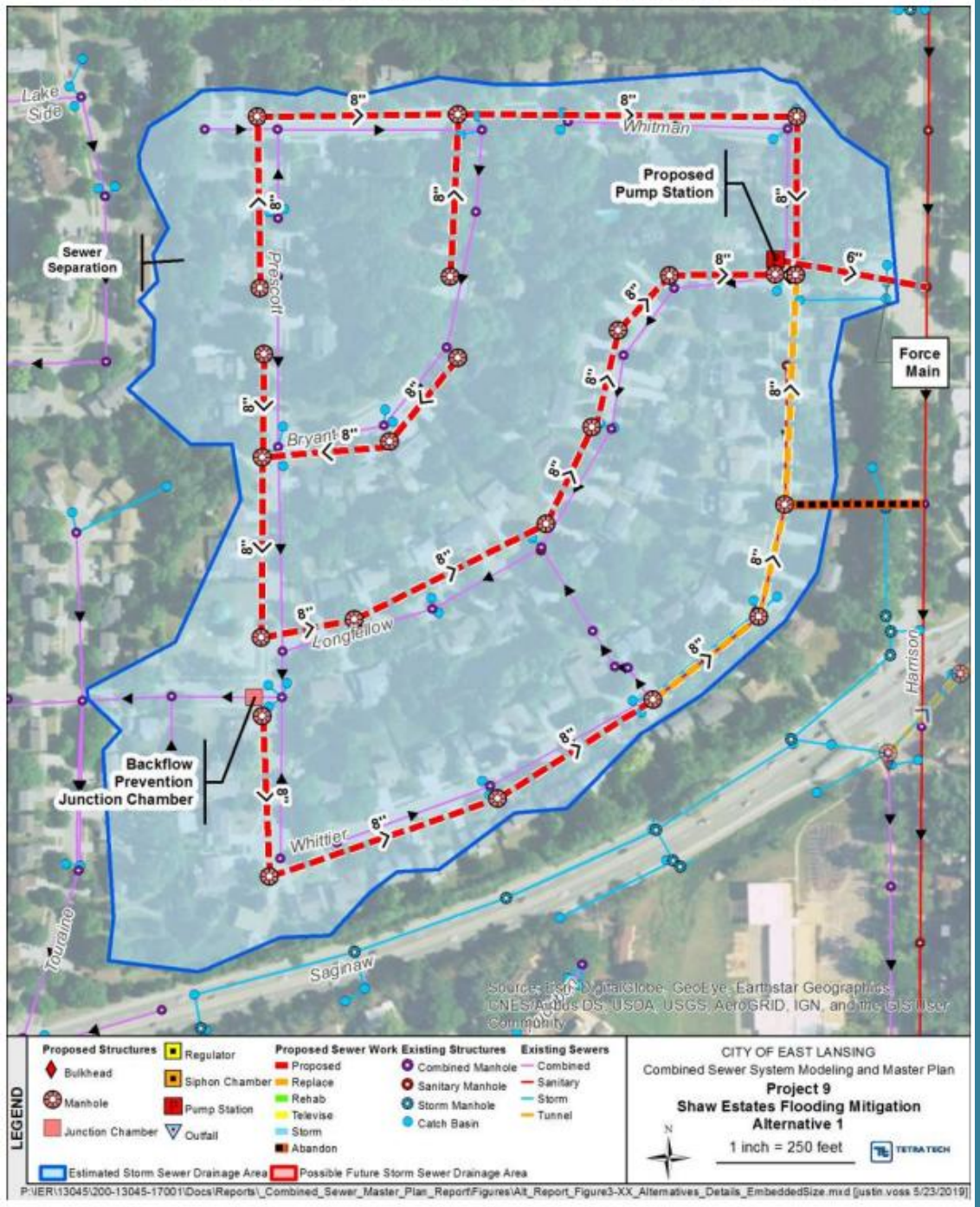
Alter-native	Project Description	Proposed Level of Service	Reduced Basement Flooding†	Reduced Surface Flooding†	Reduced CSO to River†	Opinion of Cost
1	Sewer Separation: New Sanitary Sewer with Pump Station	Sanitary: 25-year, 24-hour Combined: <10-year, 1-hour	Yes	No	No	$5,480,000
2	Larger sewers along and downstream of Touraine Avenue	Combined: 10-year, 1-hour	Yes	Yes	No	$6,420,000
3	Harrison Road Storm Sewer	Combined: 10-year, 1-hour Storm: 10-year, 1-hour	Yes	Yes	Yes	$14,460,000

† Relative to the Year 2017 conditions during the 10-year, 1-hour Design Storm.

Area B (CA-37)

MP Alternative 1 (Recommended)

Figure 3-19. Project 9 Alternative 1 Shaw Estates Flooding Mitigation Concept Map



Area B (CA-37)

CWSRF Alternatives

- Alternative A - New Sanitary Sewer with Pump Station
- Alternative B – Harrison Road Storm Sewer

Table 4-4. Project C-4, Alternatives A and B Present Worth

Cost Category	Alternative A	Alternative B
Capital Cost	$6,510,000	$16,609,000
Present Worth of Salvage Value	($1,787,000)	($5,002,000)
Present Worth of Annual OM&R	$203,000	$163,000
Total Present Worth	$4,926,000	$11,770,000

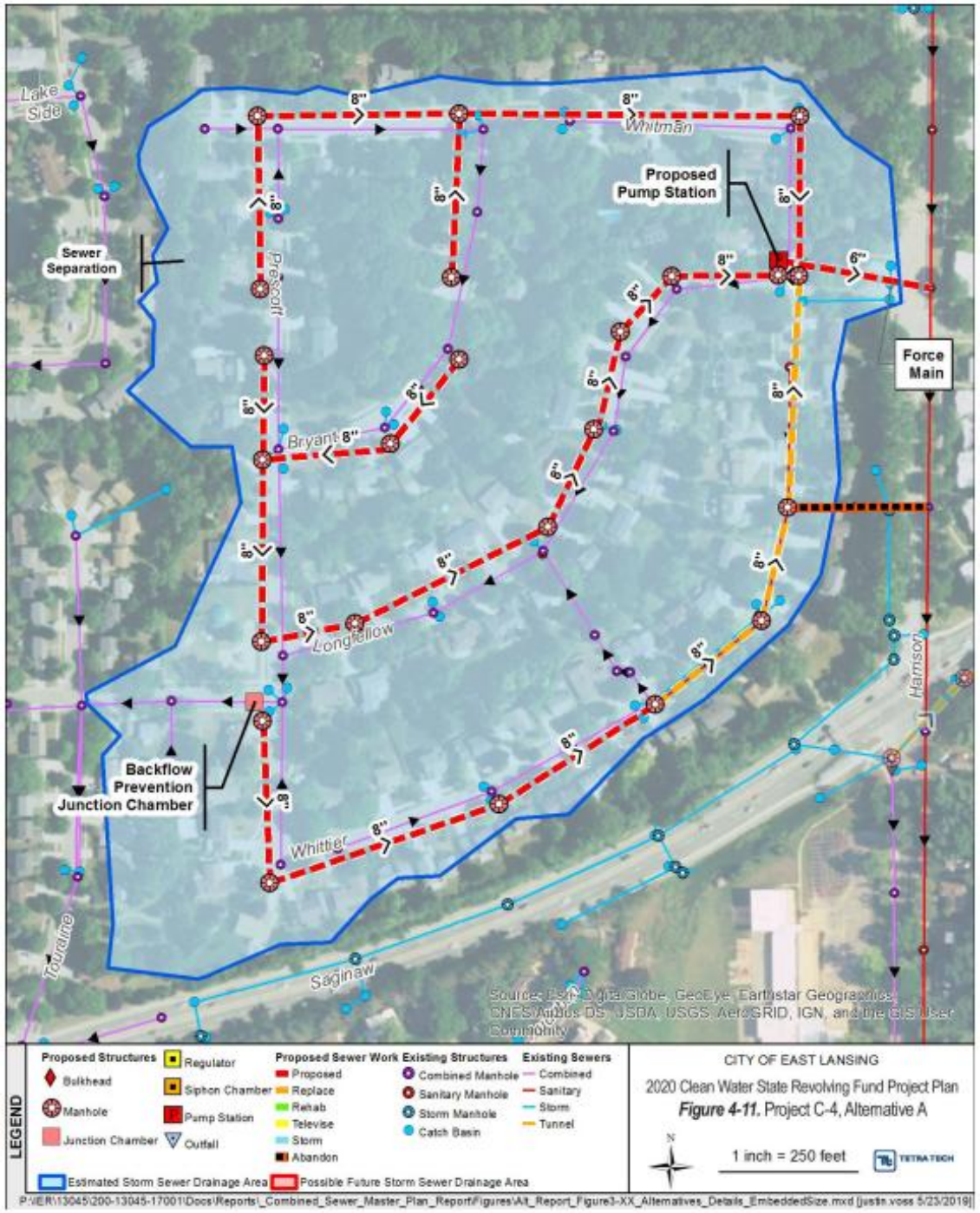
Area B (CA-37)

CWSRF Alternative A

Selected

- Identical to MP Alternative 1
- Convert combined sewer into storm only
- Timeline 2029 construction or later, need to confirm with next budget cycle
- Discharge sewer is gravity currently, future intent is to turn it into a forcemain and line the system including sewers through manholes. Cost for forcemain conversion is included in this alternative.

Figure 4-6. Project C-4, Alternative A



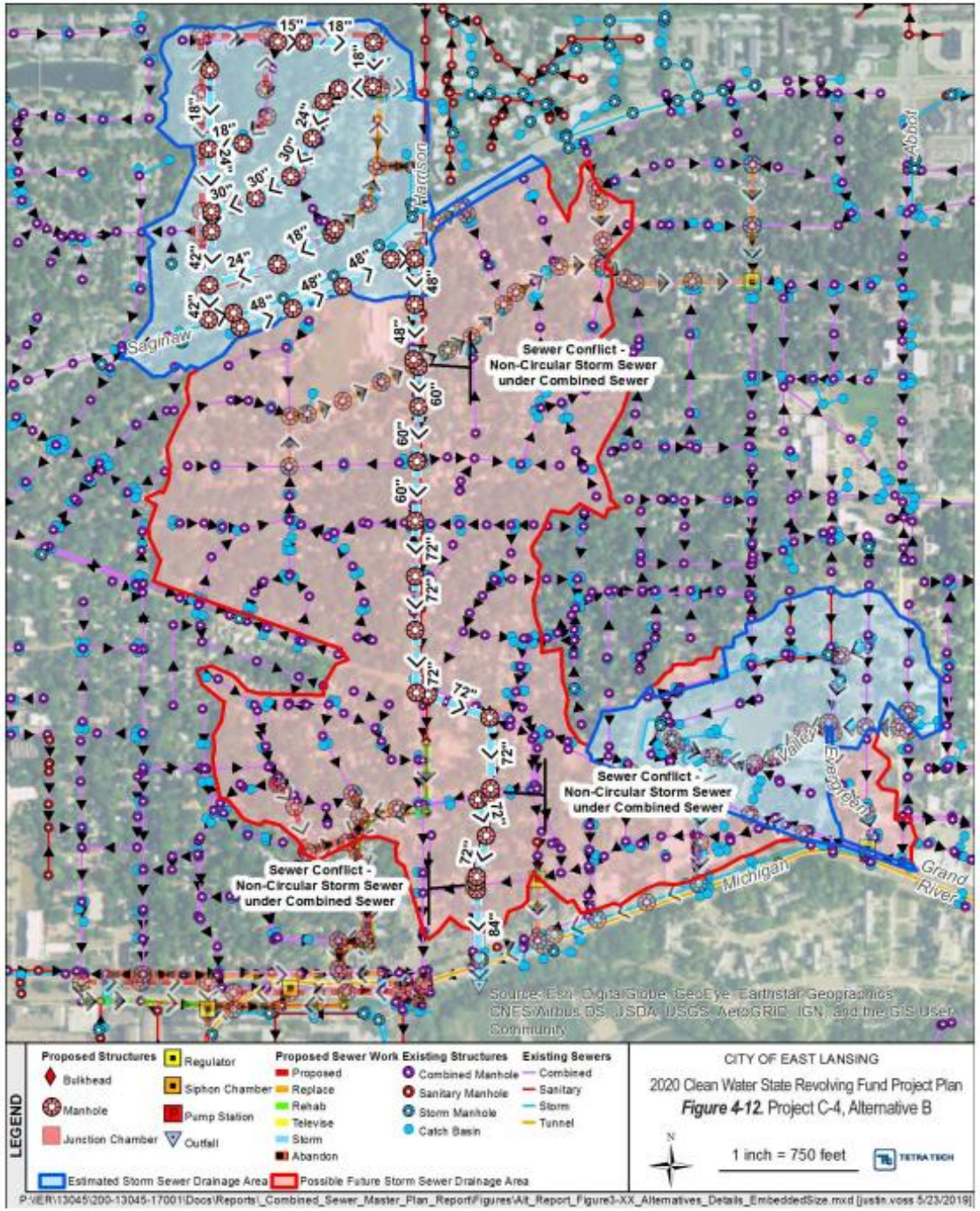
Area B (CA-37)

CWSRF Alternative B

Not Selected

- Similar to MP Alternative 3
- Would allow for separation of red area, but financially it would potentially be unaffordable.
- Alternate A is preferred and B is no longer on the table.

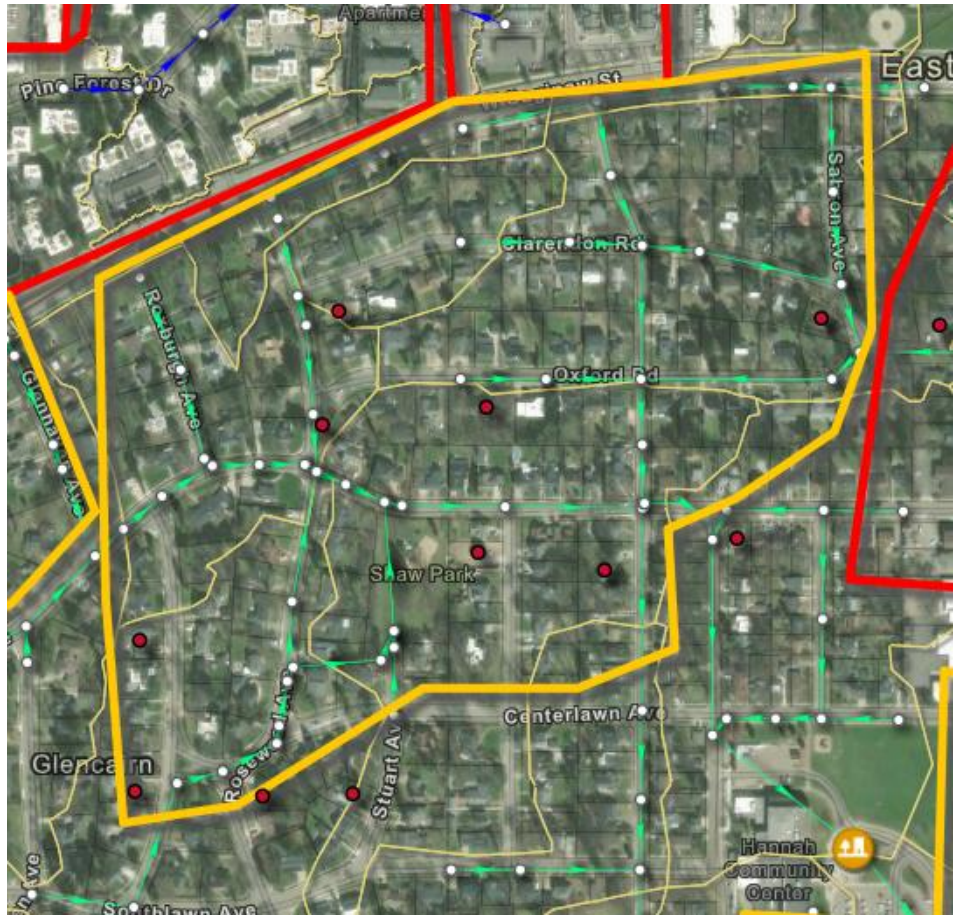
Figure 4-7. Project C-4, Alternative B



Area C (CA-34)

CSS Area

- MP Alternatives:
  - Project 10:
    - Alternatives 1 - 2
- MP Recommendation:
  - Project 10
    - Alternative 1
- 2025 CWSRF Projects: none



ArcGIS

Area C (CA-34)

MP Alternatives

Table 3-7. Summary of Project 10 Alternatives

Alter-native	Project Description	Proposed Level of Service	Reduced Basement Flooding†	Reduced Surface Flooding†	Reduced CSO to River†	Opinion of Cost
1	Combined Sewer Replacement	Combined: 10-year, 1-hour	Yes	Yes	No	$5,530,000
2	Storm Sewer	Combined: 10-year, 1-hour Storm: 10-year, 1-hour	Yes	Yes	Yes	$3,810,000

† Relative to the Year 2017 conditions during the 10-year, 1-hour Design Storm.

Selected and constructed

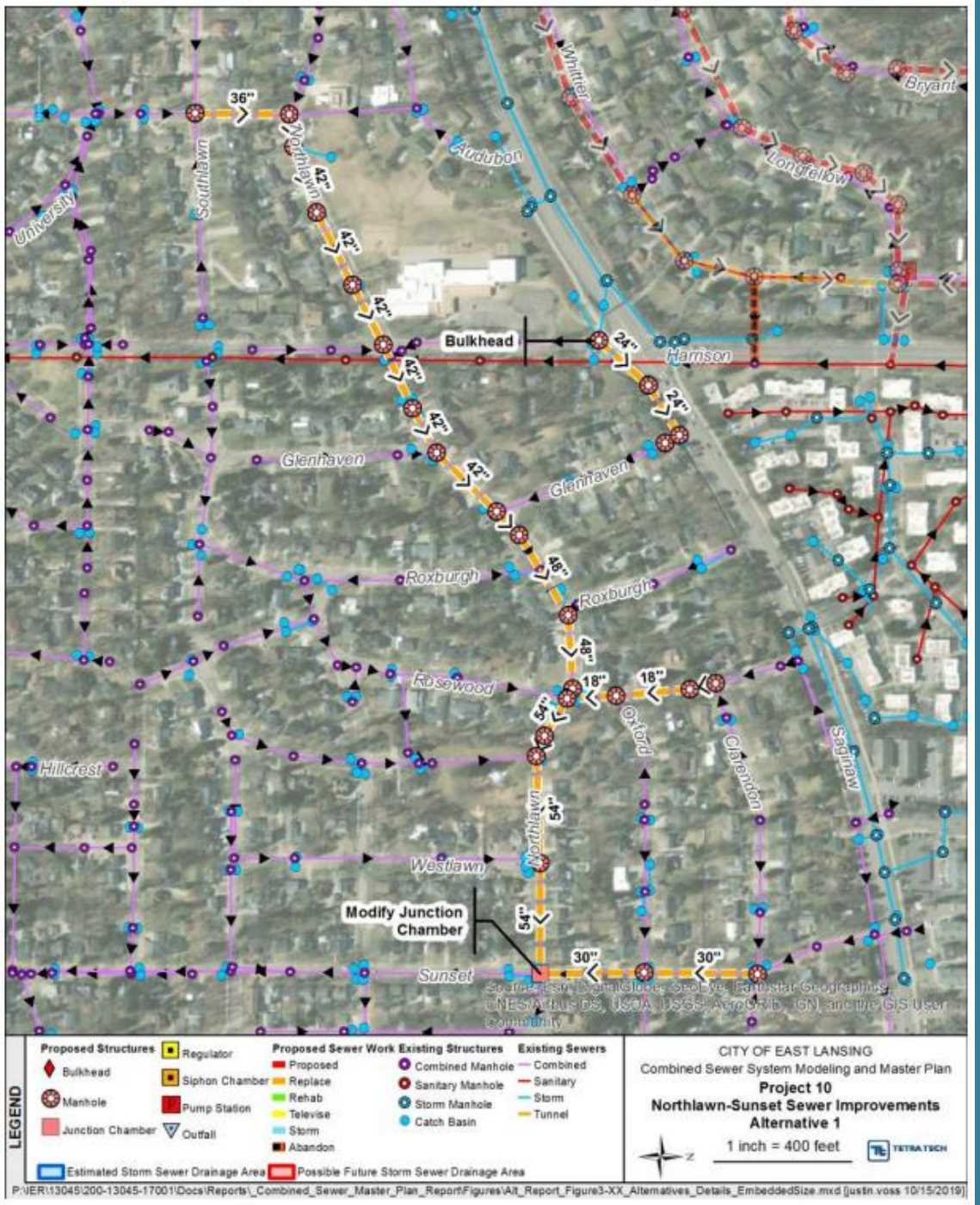
Area C (CA-34)

MP Alternative 1 (Recommended)

Selected and constructed (included as part of WWRP updated model)

- Flows going south on Sunset can't handle all the flow, so there's a flow diversion to send flows to Charles and Grove which tie into CA_30. Contributes to known flooding at Abbot and Burcham.

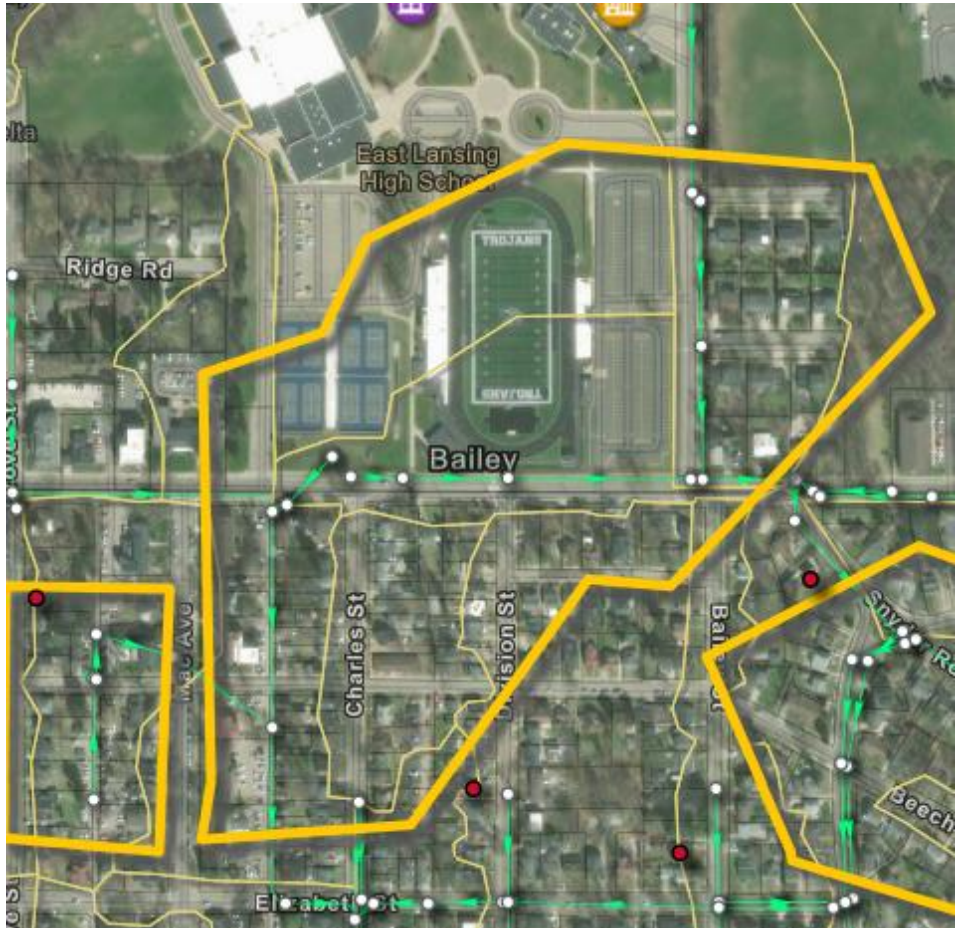
Figure 3-22. Project 10 Alternative 1 Northlawn-Sunset Sewer Improvements Concept Map



Area E (CA-30)

CSS Area

- MP Alternatives:
  - Project 4 – Sewer Replacement
  - Project 8 – New Combined Sewer
- MP Recommendation:
  - Project 4
  - Project 8
- 2025 CWSRF Projects: none



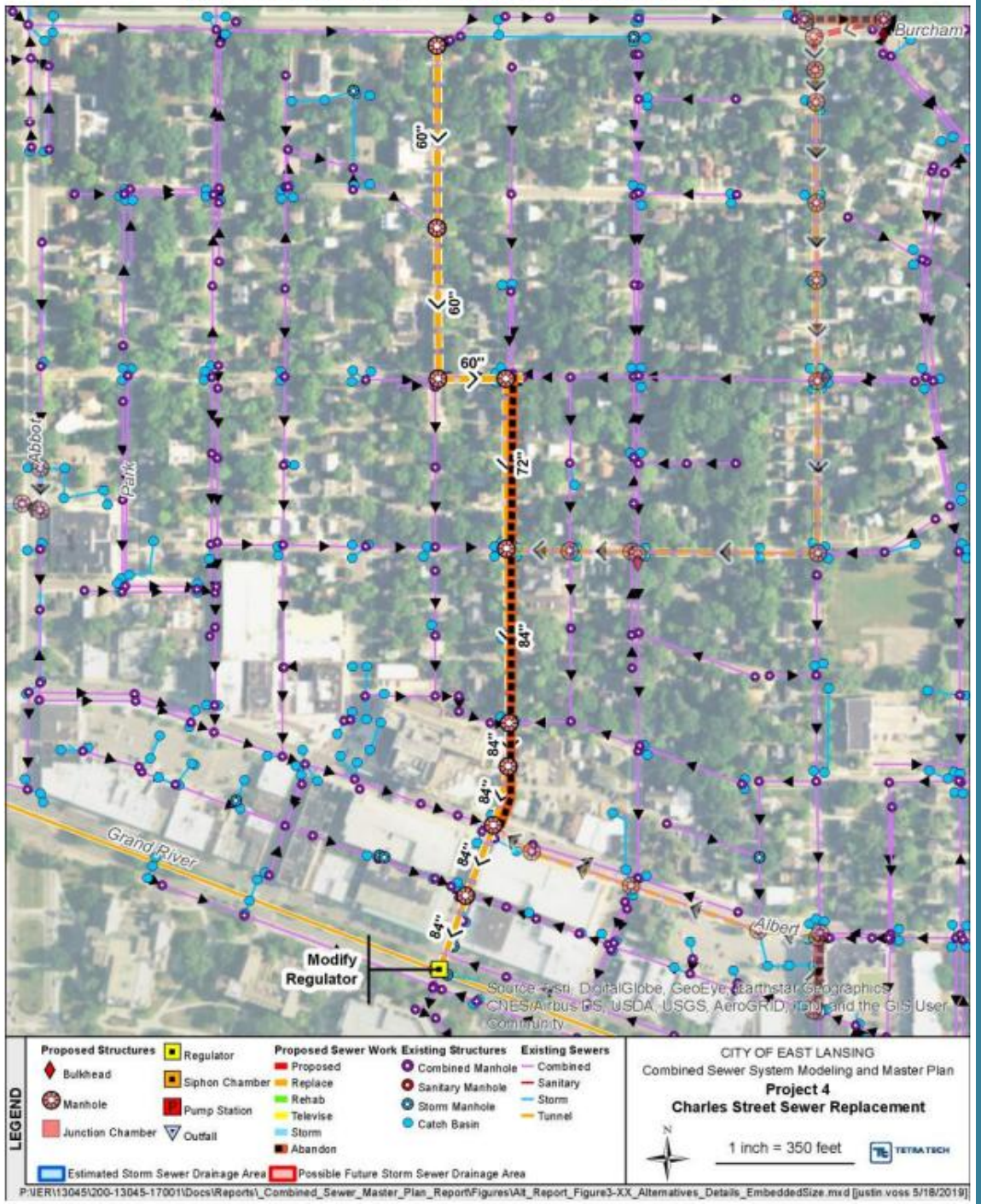
ArcGIS

Area E (CA-30)

MP Project 4 (Recommended)

- This project is needed to address upstream flooding for CA-30 and CA-34. Can have hydraulic impact at both areas.
- The diversion at Sunset TT model showed that the existing pipes can handle the flows, need to confirm this finding in updated model.
- Modification of regulator at Grand River is to increase flows to the tunnel.
- TBD on construction timeframe not included in 2025 CIP

Figure 3-10. Project 4 Charles Street Sewer Replacement Concept Map

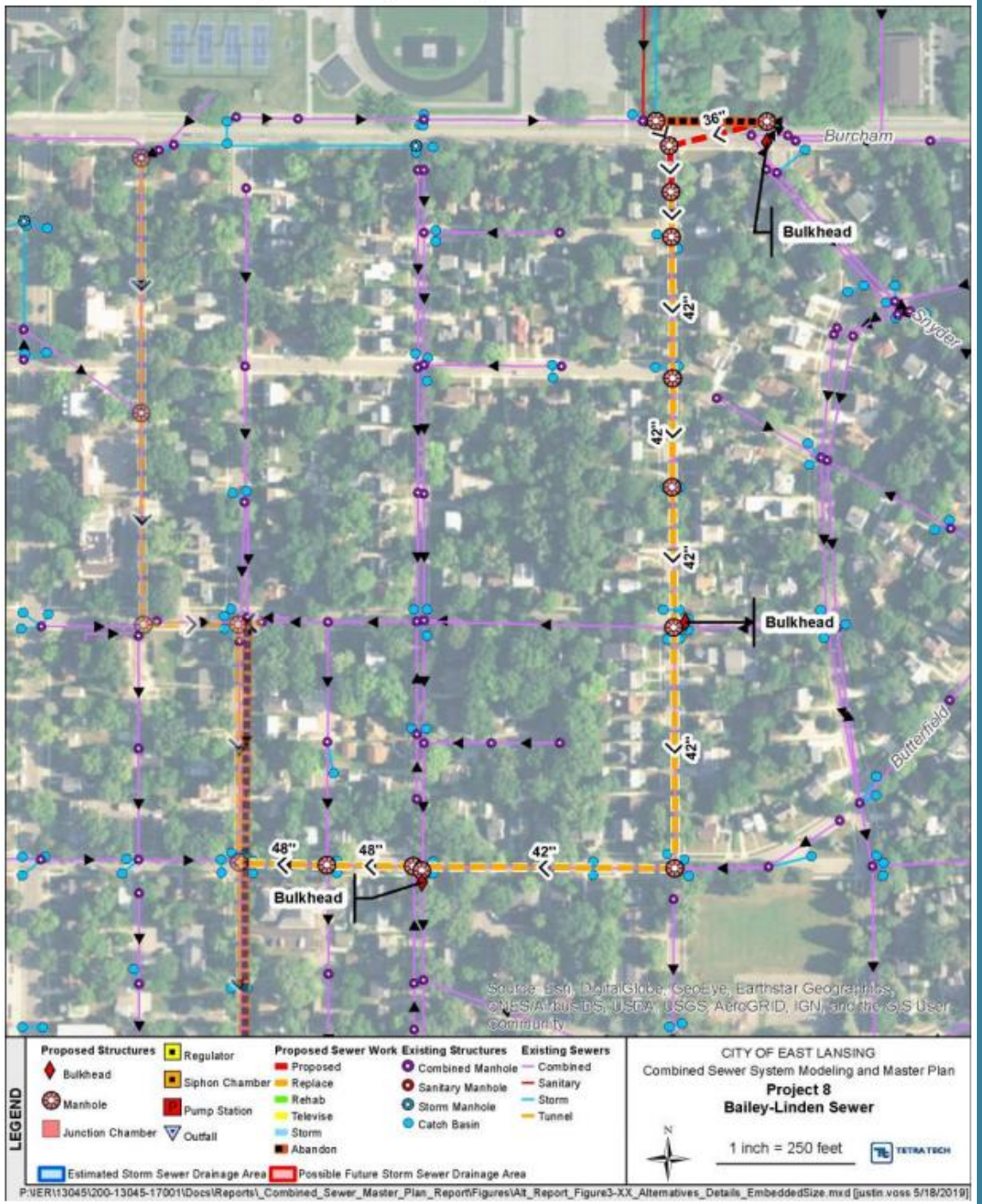


Area E (CA-30)

MP Project 8 (Not Recommended)

- This project could go away if CA-45 is constructed.
- There is discussion that this alternative could help CA-45 if there is enough upstream drainage to redirect to MP Project 4.
- TBD on construction timeframe not included in 2025 CIP

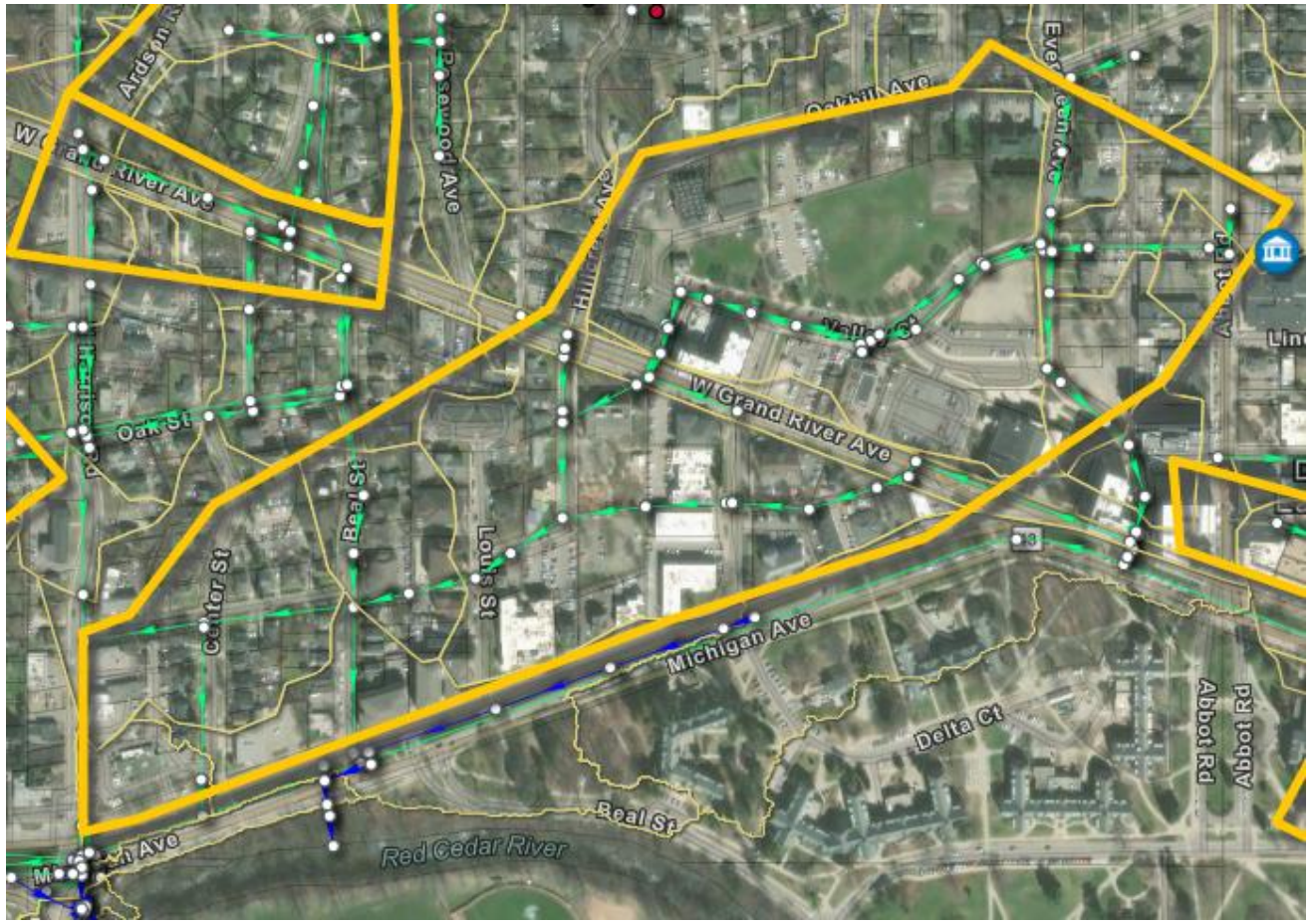
Figure 3-18. Project 8 Bailey-Linden Sewer Concept Map



Area D (CA-36)

CSS Area

- MP Alternatives:
  - Project 3:
    - Alternatives 1 - 4
- MP Recommendation:
  - Project 3:
    - Alternative 4
- 2025 CWSRF Projects:
  - C-1 (Project 3)
    - Alternative A – New Storm Sewer for Upstream Areas
    - Alternative B – Partial Sewer Separation



ArcGIS

Area D (CA-36)

MP Alternatives

Table 3-2. Summary of Project 3 Alternatives

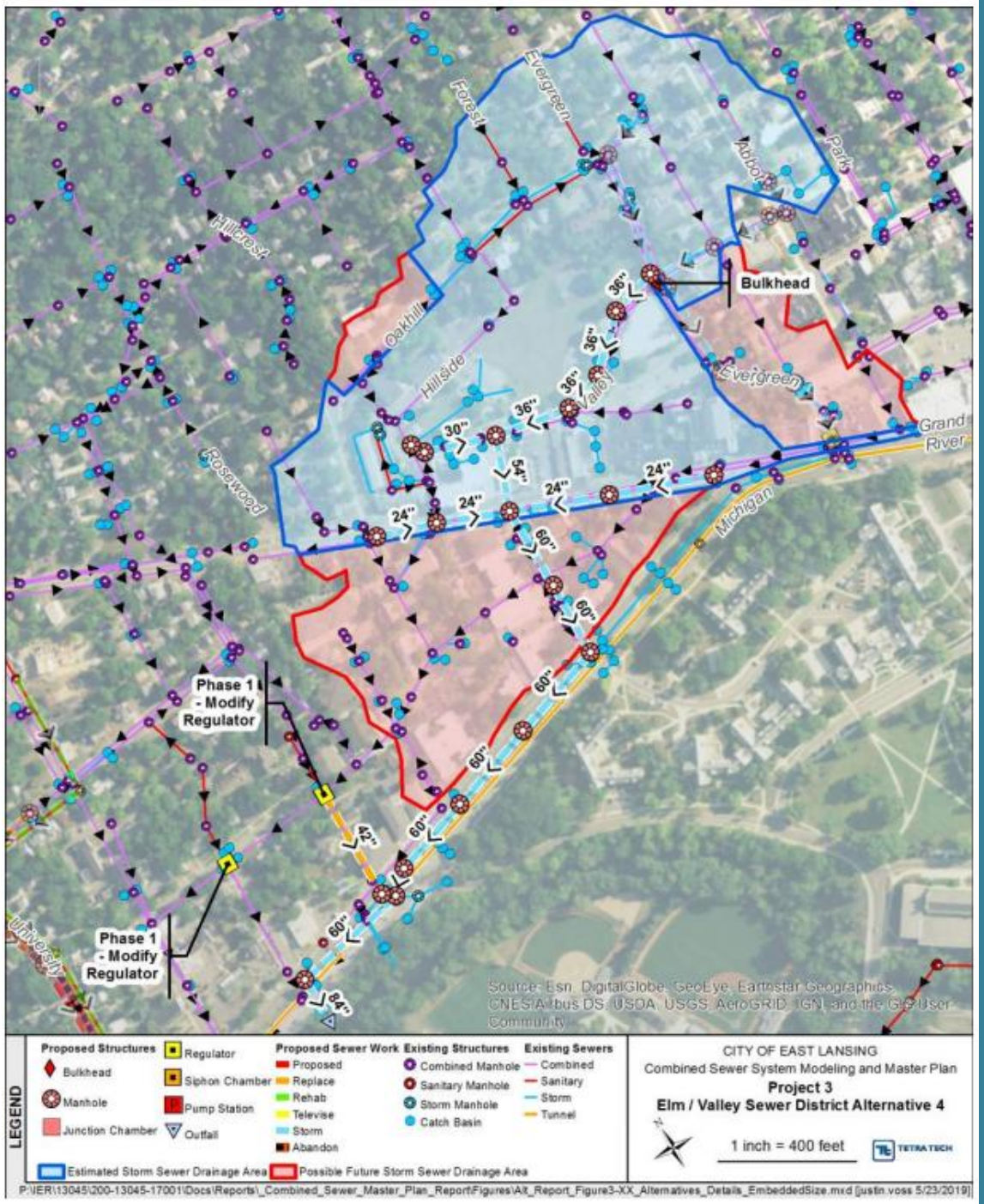
Alter-native	Project Description	Proposed Level of Service	Reduced Basement Flooding†	Reduced Surface Flooding†	Reduced CSO to River†	Opinion of Cost
1	Segment 1 – Regulator Modifications	10-year, 1-hour	Yes	Yes	No	$920,000
	Segment 2 – Combined Sewer Replacement		Yes	Yes	No	$2,230,000
2	Sewer Separation; New Sanitary, Existing Combined Converted to Storm Sewer	Sanitary: 25-year, 24-hour Storm: <10-year, 1-hour	Yes	No	Yes	$6,670,000
3	Sewer Separation; New Sanitary and Storm Sewer	Sanitary: 25-year, 24-hour Storm: 10-year, 1-hour	Yes	Yes	Yes	$8,700,000
4	Segment 1 – Regulator Modifications	Combined: 10-year, 1-hour Storm: 10-year, 1-hour	Yes	Yes	No	$920,000
	Segment 2 – Combined Sewer remains with new Storm Sewer for Upstream Areas		Yes	Yes	Yes	$6,250,00

† Relative to the Year 2017 conditions during the 10-year, 1-hour Design Storm.

Area D (CA-36)

MP Alternative 4 (Recommended)

Figure 3-9. Project 3 Alternative 4 Elm / Valley District Sewer District Improvements Concept Map



Area D (CA-36)

CWSRF Alternatives

- Alternative A – New Storm Sewer for Upstream Areas
- Alternative B – Partial Sewer Separation

Table 4-1. Project C-1, Alternatives A and B Present Worth

Cost Component	Alternative A	Alternative B
Capital Cost	$7,870,000	$10,260,000
Present Worth of Salvage Value	($2,393,000)	($3,205,000)
Present Worth of Annual OM&R	$68,000	$145,000
Total Present Worth	$5,545,000	$7,200,000

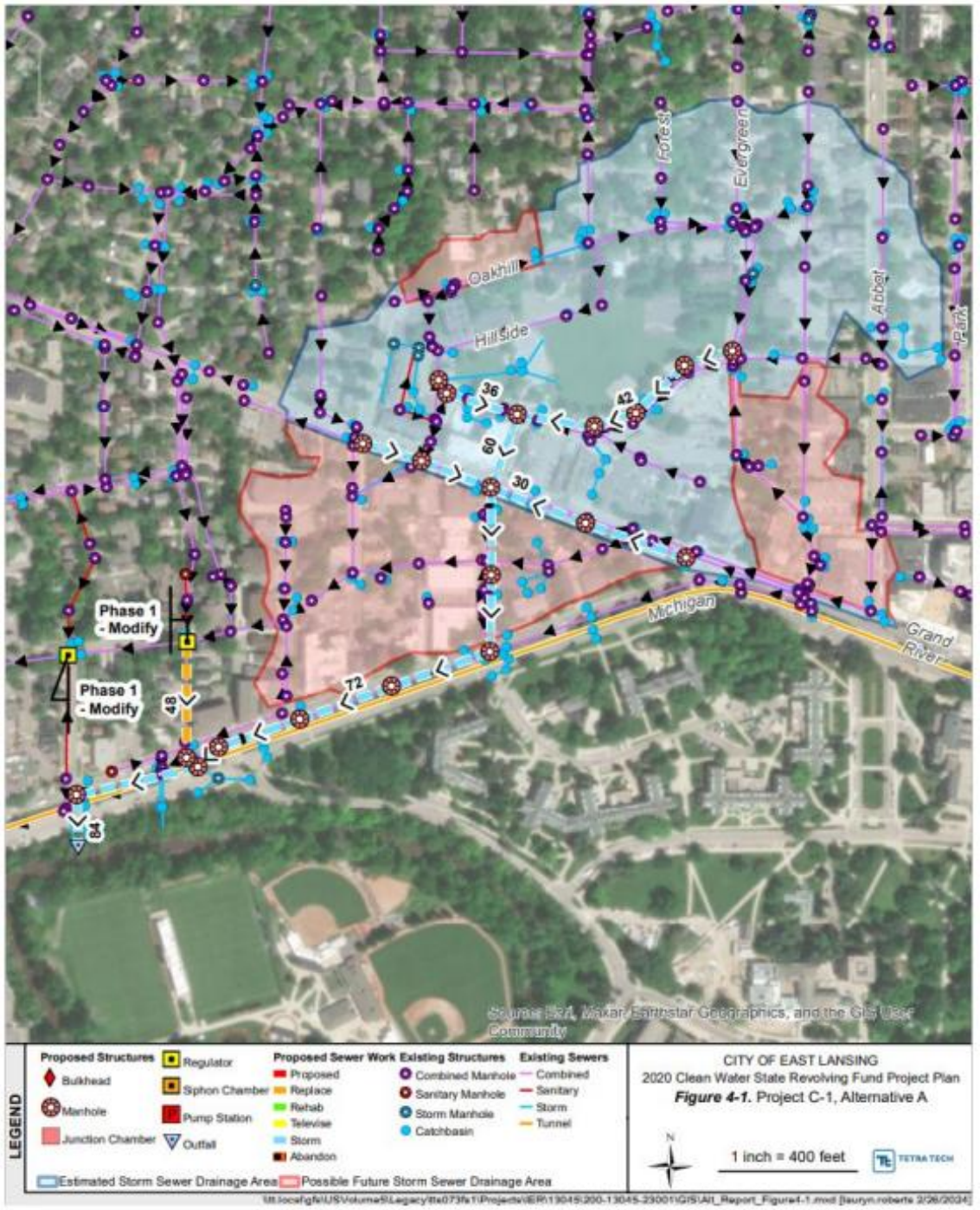
Area D (CA-36)

CWSRF Alternative A

Selected

- Similar to MP Alternative 4. Changed slightly around Evergreen.
- Timeline 2029 construction or later, need to confirm with next budget cycle
- Regulators have already been designed. Intention is to get more water to tunnel.
- Storm sewers would discharge directly into Red Cedar. Stormceptor to be included for WQ. EGLE has approved this strategy in the past for EL projects.

Figure 4-1. Project C-1, Alternative A



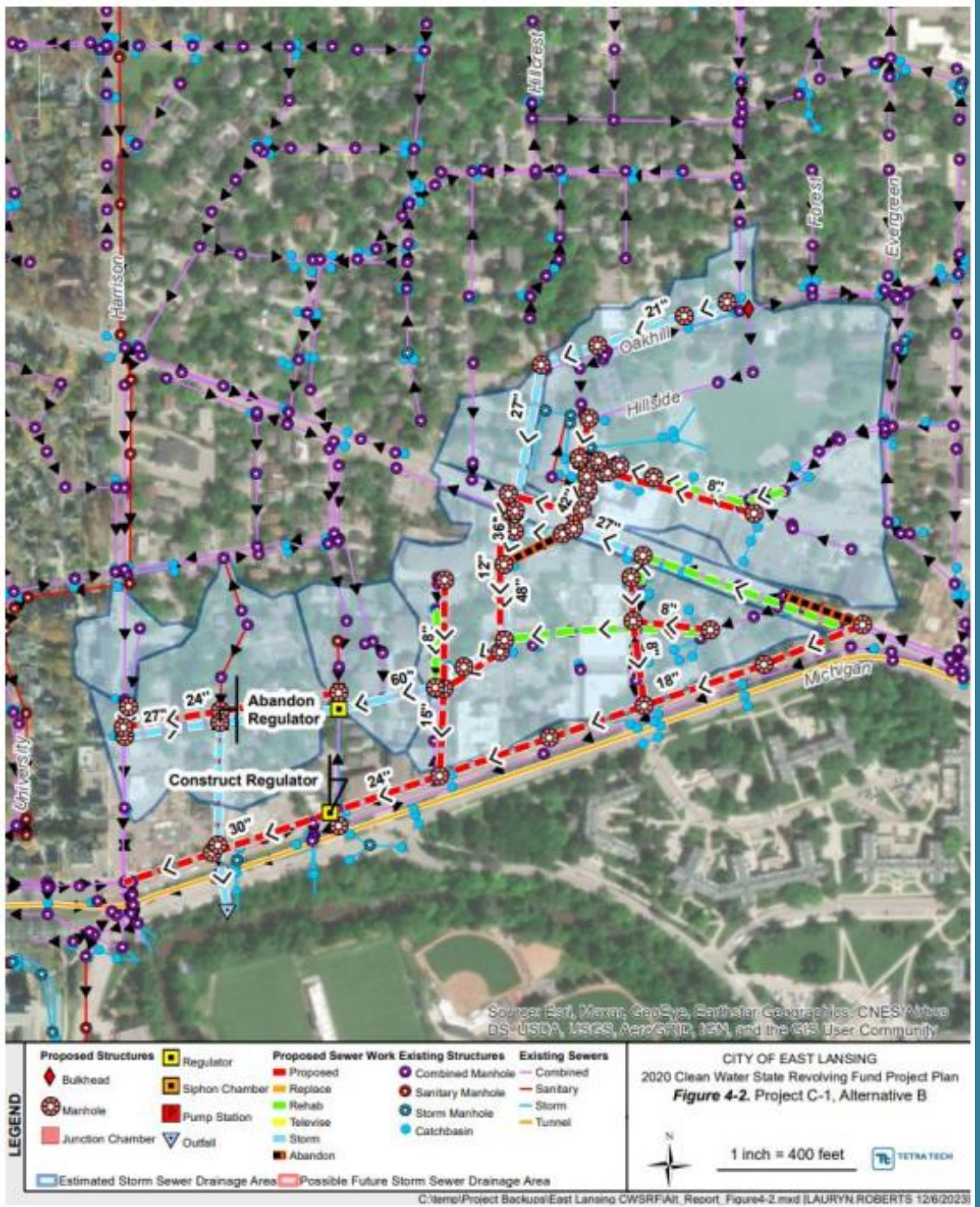
Area D (CA-36)

CWSRF Alternative B

Not Selected

- Similar to MP Alternative 3
- No longer under consideration, going with Alternative A

Figure 4-2. Project C-1, Alternative B



Area F (CA-12)

MS4 Area

- MP Alternatives: none
- MP Recommendation: none
- 2025 CWSRF Projects: none
- Blank slate to evaluate, no projects identified

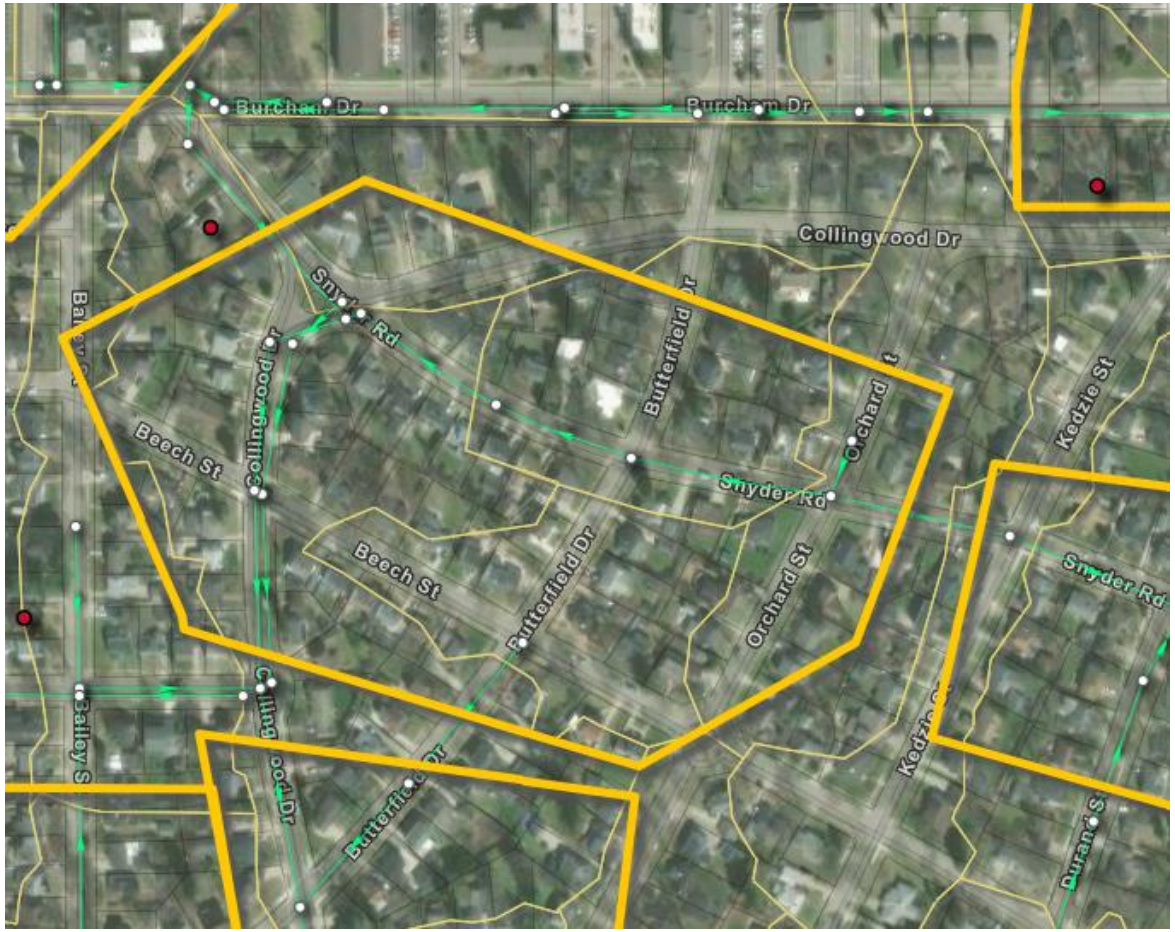


ArcGIS

Area G (CA-45)

CSS Area

- MP Alternatives: none
- MP Recommendation: none
- 2025 CWSRF Projects: none
- MP Project 8 (Recommended)
- Separating sewers here to common outlet not possible.
- There is some pipe upsizing downstream as part of Kedzie and Collingwood.

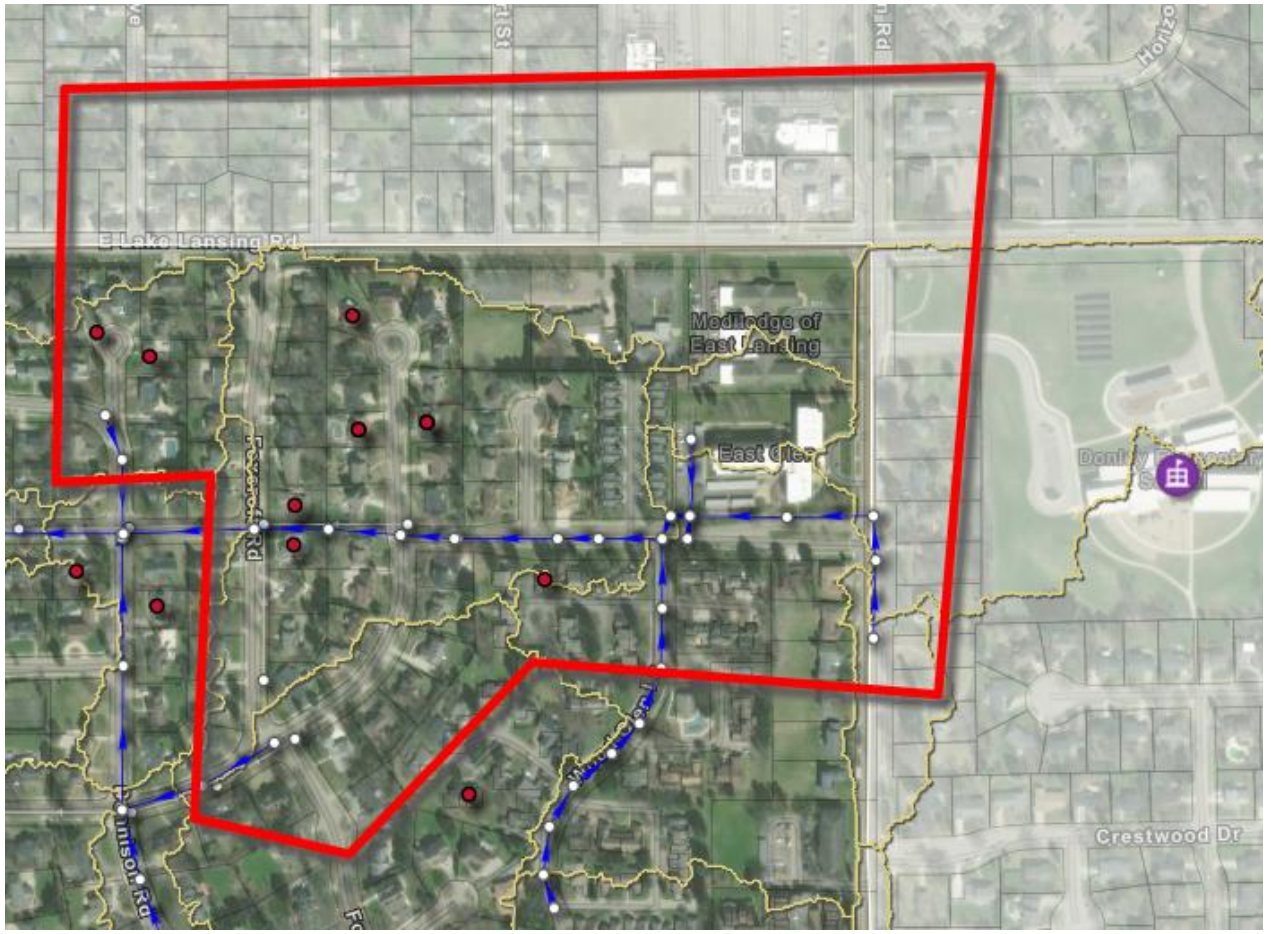


ArcGIS

Area H CA-10

MS4 Area

- MP Alternatives: none
- MP Recommendation: none
- 2025 CWSRF Projects: none
- Separate Sanitary Model, 2008 Masterplan area shows capacity constraints. SSES project recommendations. Stephen to send file – District F project in report. I&I issues.



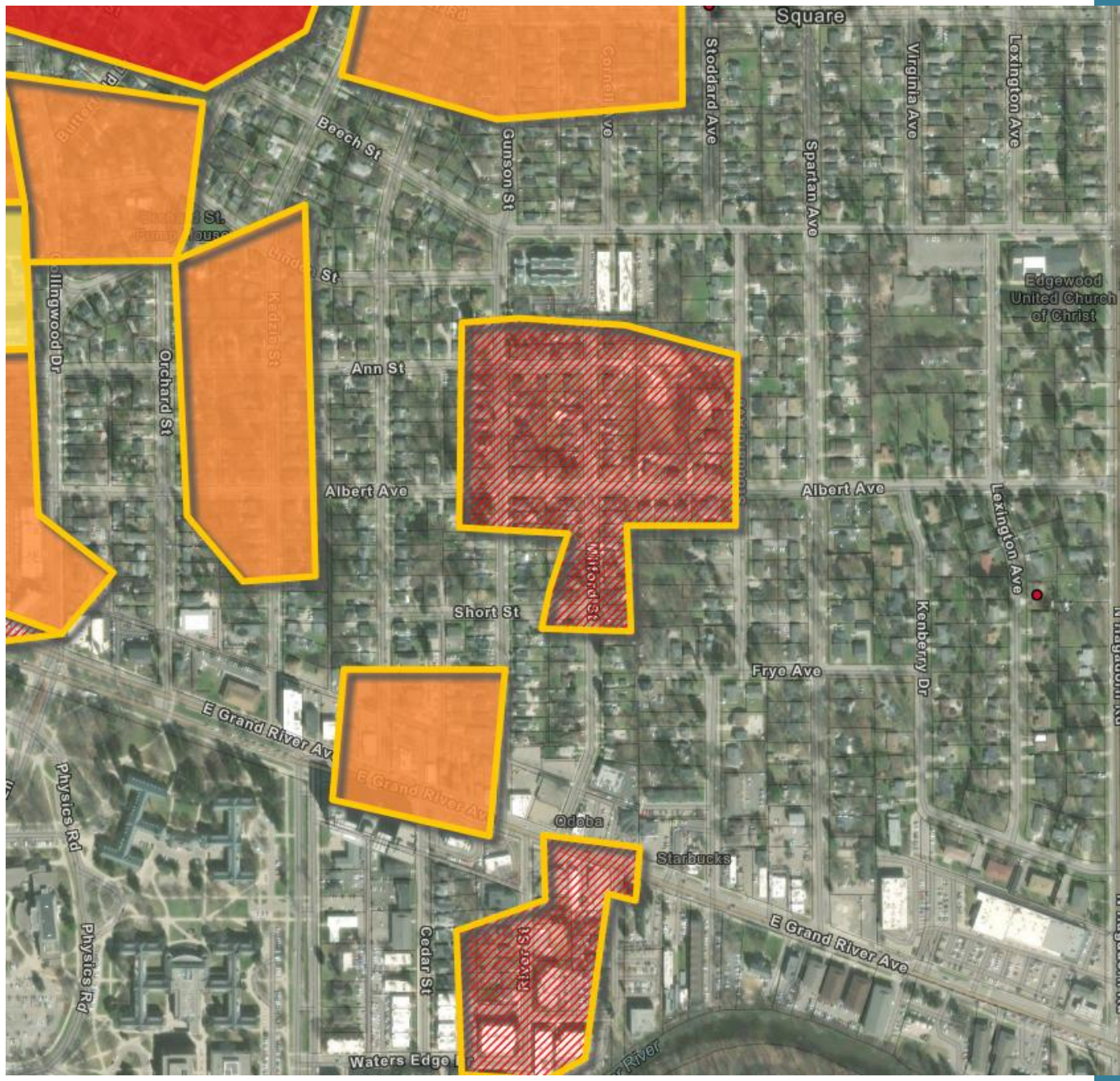
ArcGIS

CA_28 (Top Ranking)

CSS Area

Project advancing

- 2025 CWSRF Project: Project C-2 Alternative A
- Only one alternative available – no other feasible alternatives

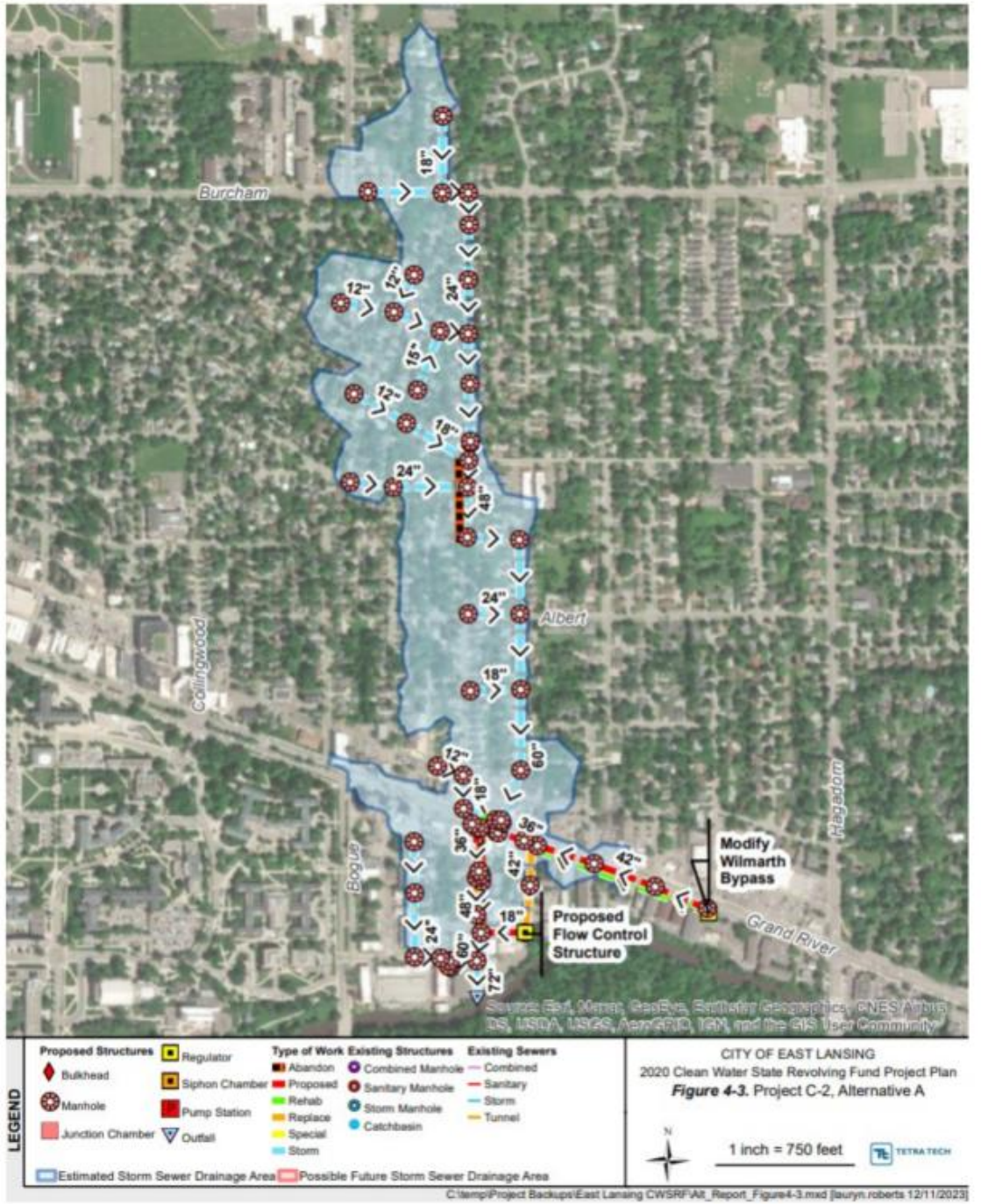


CA_28

CSS Area

- Sewer Separation
- New flow control structure
- Could potentially impact CA-45 if included in the model.
- Design is done and under construction and schedule to be complete end of 2027
- Designed for the 10-year, 1-hour Assessment Storm (1.61 inches)
- Fishbeck (design engineer) has their own model (Stephen to request model and cc Tom), design slightly tweaked from shown on map.

Figure 4-3. Project C-2, Alternative A



Appendix A.2 – Initial Strategies Workshop (December 19th 2025)

Meeting Minutes

Project:	East Lansing Wet Weather Resiliency Plan
Subject:	Flooding Concern Areas Strategies Workshop
Date:	Friday, December 19, 2025
Location:	In-person / MS Teams
Attendees:	Ernie West (HDR) Tom Batroney (HDR) Brendan Ward (HDR) Kaylee Johnson (HDR) Ron Lacasse (City) Bob Scheuerman (City) Cliff Walls (City) Stephen Clayton (City)

1. **HDR presented Workshop Goals & Objectives**
    a. HDR reviewed MCDA criteria for alternatives evaluation, and weighting as developed and presented in the Task 2 memo for future use in project prioritization in Task 9.
        i. City commented that level of maintenance and maintenance concerns (money, time, to keep infrastructure functioning/ useable) is an important consideration for the City. The current ranking of 7 might be low.
        ii. HDR commented rankings could be revisited, however the weights have similar percentages and outcome may not be that different. Also, maintenance will be inherently improved as a result of these projects.
        iii. City commented that council's mindset on the rankings may not be that different. City will put additional thought into whether rankings should be revisited. Proceed for now.
        iv. City to complete Task 2 memo review and provide feedback prior to HDR finalizing.

2. **HDR presented Flooding Concern Areas Screening Analysis**
    a. HDR provided summaries of Top 8 concern areas and existing CIP projects within each of the concern areas.
        i. Noted that Area H has been previously studied as far as separate sanitary sewer system study and related recommendations regarding removing I/I in this area. Bob to review status of illegal storm connections being removed from sanitary and re-routed to storm system. Any re-routed storm discharge that was done after summer 2024 would not show up in the flow metering that was used for storm model calibration and this flow would need to be added into the storm system model.
    b. HDR provided detailed summaries of each concern area including existing level-of-service (LOS), flooding drivers, model results and HGL for 10yr1hr assessment storm, and potential strategies.
        i. **Area A:**
            1. Strategy 1: City commented that separation area shown in the CIP as red is future separation, while the blue may solve the immediate capacity issue. Both the blue and red area has guaranteed capacity within the county drain design for Ranney Park. City commented the sewer alignment could be revisited to go through the walking trail to avoid the roadway. City commented the existing connection to the south, and possibly north may not be the correct size. Need to verify connections (2 existing vs 3 planned) and re-visit pipe sizing. Cost to serve the blue and/or red areas is unknown and subject to negotiation that will affect the cost effectiveness of this option.

2. Strategy 4: City commented street narrowing is unlikely to be accepted by the road agency (MDOT), but other GI improvements are possible. City commented that stormwater runoff charges may incentivize support for projects.

ii. **Area B:**
1. Strategy 2: City commented Strat 2 is preferred over Strat 3, as sending water east of Harrison changes the watershed and likely causes downstream flooding. HDR commented the storm could be connected from B to A as part of full separation. City commented that are in favor of that concept since the Shaw project alone does not address stormwater. City previously looked at 72-inch storm sewer south on Harrison to river, but cost was much higher. The 48-inch pipes crossing Harrison were a conflict and grade issues required multiple siphons. City commented if separation of B addresses C or possibly D, the cost may make more sense. HDR will confirm with modeling the impact of C on downstream areas.
2. Strategy 3: City commented expanding MS4 area is complicated due to intercounty agreements with changing the watershed drainage (county culverts, floodplain elevations, Hawksnest flooding). City commented Strat 2 is preferred over Strat 3.
3. Strategy 4: City commented that visible solutions are good politically and community awareness. City commented the water tower on Chartwell Carriage Way S is close to end of life and there is potential to expand GI. GI solutions should be layered on other infrastructure upgrade projects.
4. Area B solutions have potential to benefit A. HDR will confirm with modeling the impact of B on A.

iii. **Area C:**
1. Strategy 1: City commented the potential storage locations are popular and public may support improvement projects. City commented challenging soils in the area as a concern from other project experience.
2. Strategy 2: City commented that the identified parcel is owned by the City and has already been identified by the community as a location for a project.
3. Strategy 3: Potential to combine strategies with D.
4. HDR will explore potential for regional solutions in CSS. Area C solutions have potential to benefit multiple concern areas. HDR will confirm with modeling the impact of C on D, and C on B, and C on E.
5. HDR will approach modeling solutions from west to east and north to south to understand impact to downstream areas.
6. City commented that previous MP studies looked at concern areas independently which was a disconnect and they like HDR's approach for regional projects.

iv. **Area D:**
1. Strategy 3: City commented that potential solutions at Valley Court Park would likely need to be mostly underground with limited surface features. The loss of greenspace (with large surface GI footprints, etc.) for children's sporting activities is a main concern. Location is popular and requires public support and acceptance.

v. **Area E&G:**
1. Area E solutions have potential to benefit G. HDR will confirm with modeling the impact of E on G (and F,C,E,G).
2. Upstream solutions may negate need for Charles St CIP project (Strategy 3). HDR will confirm with modeling the impact of upstream solutions on Charles St. project area.

vi. **Area F:**

1. City confirmed that Kendale MH surcharges during intense storm events (as shown in HGL plot). Pressure was enough to blow out pavement around bolted down casting on lid and since has been changed to a grated lid.
2. City commented that Taylor Drain experiences backup and a restriction west of Abbot Rd. The culvert was sized for 10yr. Previous consultants looked at dredging. City might have additional modeling for this.
3. Strategy 1: HDR commented de-paving may be an incentive to business/ property owners to mitigate flooding and potential stormwater runoff charges.

vii. **Area H:**

1. Strategy 4: City commented that speeding in residential areas is a concern for residents. Circles at intersections to slow traffic with infiltration basins underneath would likely be well received, and likely better received than ROW GI.
2. HDR commented any future storm disconnections or re-routing of illegal connects may impact model calibration (completed with 2024 flow data). City will check for changes to sanitary flow routing since calibration and will notify HDR of any future disconnections that could increase stormwater flows to the MS4 system.

3. Flow Diversions/splits within Concern Areas:

a. The City provided the following information post-meeting (email dated 12/23/2025) and clarified there are no flow restrictions, but rather flow diversion as follows:
b. At the manhole in the intersection of Touraine and Cowley the flow splits as follows:
   i. 48" NE on Touraine I.E. 844.76
   ii. 48" SE on Cowley I.E. 844.76
   iii. 24" SW on Touraine I.E. 845.86
   iv. This allows dry weather flow to go down Cowley and then wet weather flow to go down Touraine as well as Cowley
c. The flow in Cowley from Touraine continues in a 48" to Audubon then SW in Audubon in a 48" to Grand River and a manhole as follows:
   i. 48" NE on Audubon I.E. 842.83
   ii. 48" SE on Grand River I.E. 842.63
   iii. 30" NW on Grand River I.E. 842.63
   iv. The flow in Grand River then flows SE to the 54" Cowley sewer south of Grand River and ultimately to Michigan Avenue.
d. The flow in Touraine south of Cowley continues in a 24" to Grand River and a manhole:
   i. 24" NE on Touraine I.E. 844.42
   ii. 24" SW on Grand River I,E. 844.56
   iii. 30" SE on Grand River I.E. 844.40
   iv. This allows the wet weather flow to go both ways in Grand River as the downstream capacities allow.

4. Post-presentation Discussion:

a. **Design storm rainfall and LOS:** City commented that rainfall options 1&3 provide a good comparisons for understanding current and future climate impacts. HDR commented that the existing 10yr1hr assessment storm has a total rainfall of 1.61 inches and is less than option 1 that is based on the climate analysis in Task 1. Through discussions during the meeting City directed HDR to proceed with option 1 (2.0 inches) and option 3 (2.54 inches) for the target LOS options, and future conditions evaluation respectively.
b. **What makes an alternative?:** HDR commented that a single alternative can be a combination of multiple strategies, and HDR expects multiple strategies will be needed within a concern area.

c. **Schedule:** City commented grant is due the end of June. City expressed modeling the right solutions is of most concern and that an extension could be requested if needed. Need to get to the right answers given this plan will be millions of dollars and many years to complete.

5. Next Steps:

a. City to internally discuss up to two (2) alternatives each for Area F and H (MS4 areas) and provide direction to HDR.
b. HDR to discuss initial modeling strategy for modeling CSS alternatives to allow for a system wide analysis that informs downstream impacts and provide outline to City for feedback.
c. After reaching agreement on modeling strategy with City, HDR will complete first round of CSS modeling and present to City for feedback before proceeding to connected areas downstream. Target mid to late January for results of first round of CSS modeling.



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City of East Lansing Wet Weather Resiliency Plan

Task 8: Initial Strategies Workshop

12.19.2025

Agenda

01 Workshop Goals & Objectives

02 Flooding Concern Areas Screening Analysis

03 Discussion of Recommended Alternatives for Modeling

04 Next Steps



01

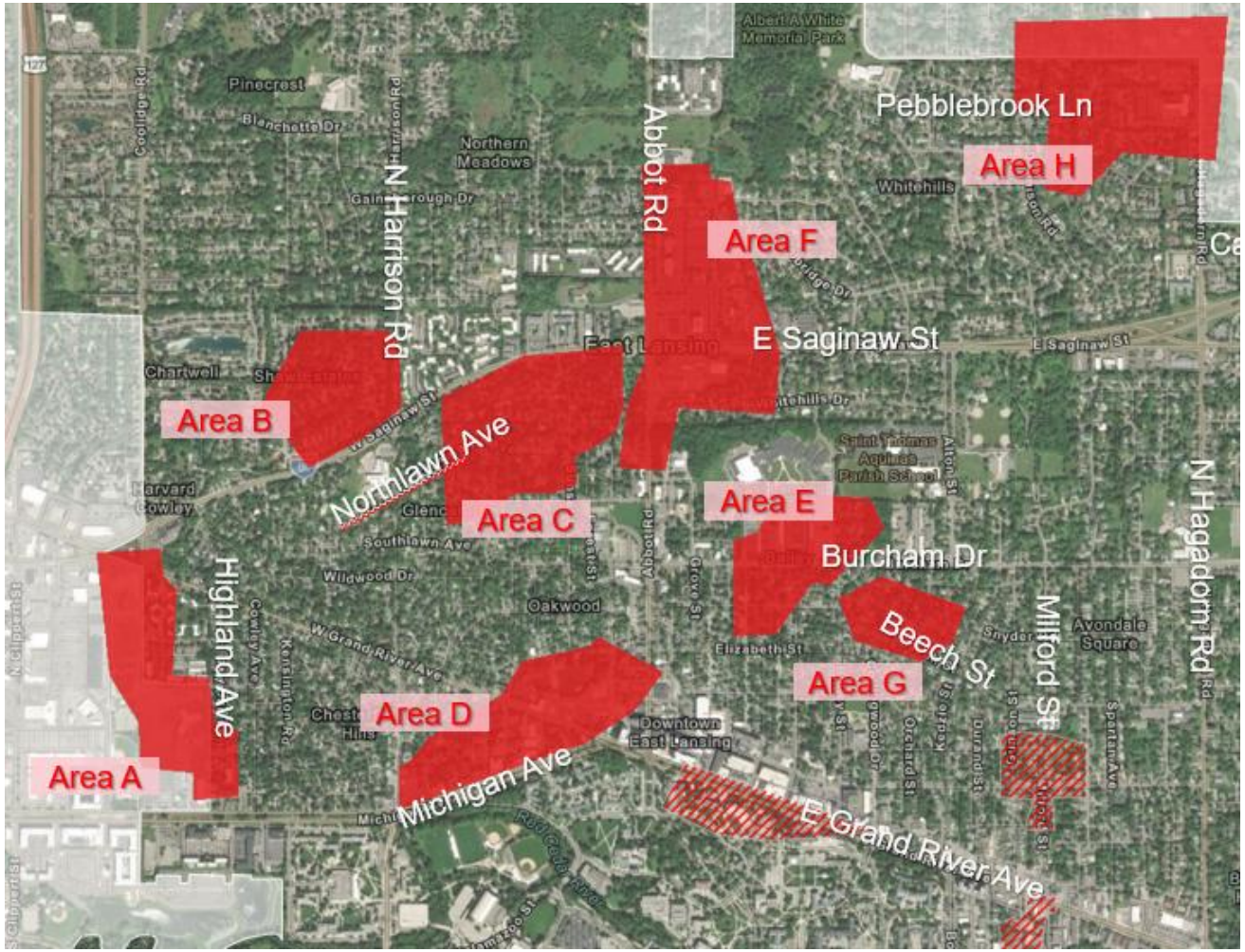
Workshop Goals

Workshop Goals

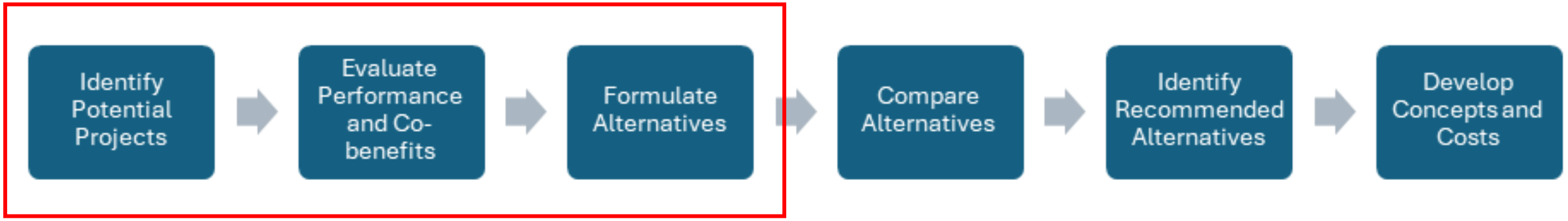
1. Understand drivers (root cause) of flooding within each flooding concern area

2. Identify suite of potential flood risk reduction strategies tailored to East Lansing system

3. Select two alternatives within each area to advance for detailed hydraulic modeling



Task 8 – Evaluate Flood Mitigation Alternatives



Task	Task Summary
Task 8.1 Establishment of Approach	• Identify potential alternatives using MCDA framework*. • Up to four (4) unique types (i.e storage, conveyance, levees, green infrastructure). • "Alternative" may be a combination of types. • HDR to review model results and propose initial solutions with City.
Task 8.2 Alternatives Development	• Identify up to (2) alternatives within each area • Model up to (2) alternatives within each area • Review model results in workshop
Task 8.3 Alternatives Analysis	• Select one (1) alternative within each area for conceptual layout and evaluate against MCDA framework weights* • Conceptual opinion of probable cost • Review concepts in a workshop
Deliverable:	• Technical memo describing improvement types, alternatives modeling, and preliminary solutions

Today's Workshop

MCDA Criteria for Alternatives Evaluation

Evaluate the alternatives through the lens of each of the established criteria.

Criteria	Description
Improved Drainage	The project's ability to enhance level of service to reduce flood risk.
City Resiliency Alignment	The project's alignment with the City's resiliency initiatives related to green stormwater management and infrastructure.
Water Quality	The project's alignment with the City's CSO elimination goals and/or ability to design with water quality treatment features consistent with the City's Stormwater Management Plan.
Impervious Surface Reduction	The project's ability to reduce unnecessary impervious surfaces.
Social and Economic Impacts	The project's ability to provide social or economic benefits to vulnerable populations due to the design, location, or nature of the project.
High Impact	The total number of people served by the project or being high visibility.
Ease of Constructability	The level of ease to build and implement the project.
Level of Maintenance	How easy the project is to maintain.

MCDA Criteria Weights for Project Prioritization (Task 9)

- Criteria weights will be applied to each alternative for prioritization
- Developed from Focus Groups and Staff per recommendation in T2 Memo

Criteria	Weight	Rank
Improved Drainage	16.5%	1
Water Quality	15.5%	2
High Impact	14.9%	3
City Resiliency Alignment	13.0%	4
Impervious Surface Reduction	11.8%	5
Social & Economic Impacts	11.0%	5
Level of Maintenance	9.4%	7
Ease of Constructability	7.9%	8
Total	100%	

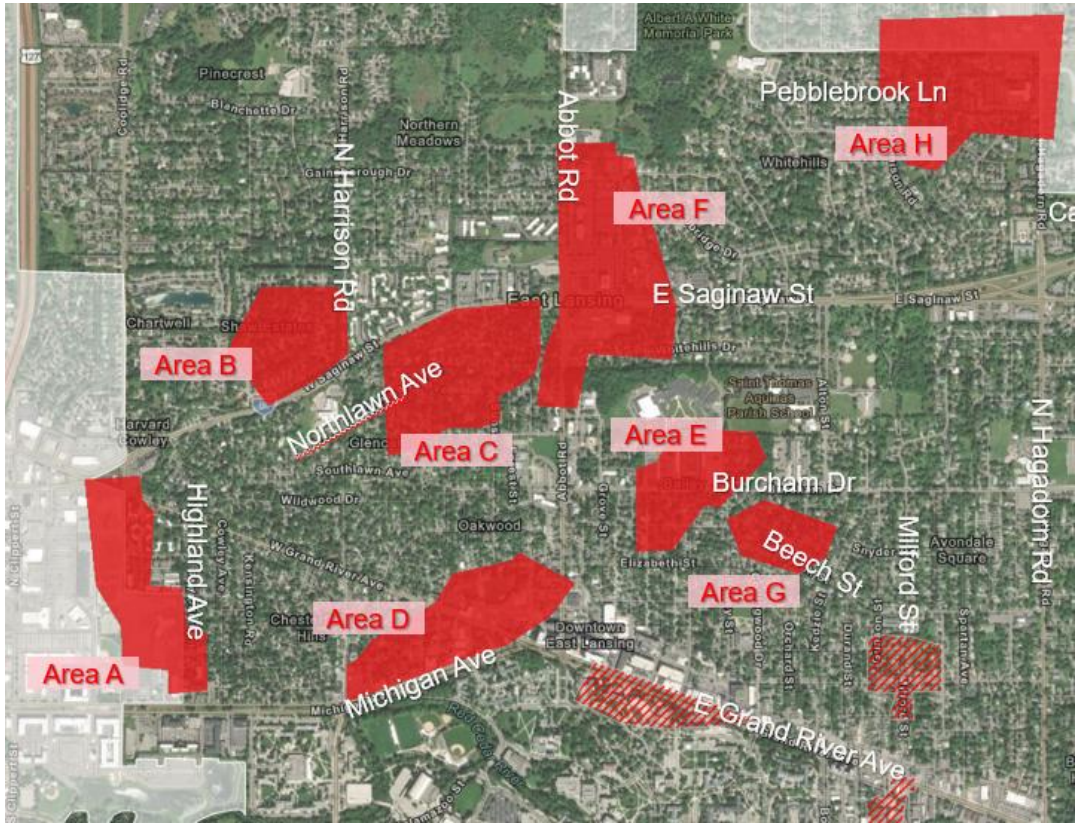


02

Flooding Concern Areas Screening Analysis

Existing Level of Service in Flooding Concern Areas

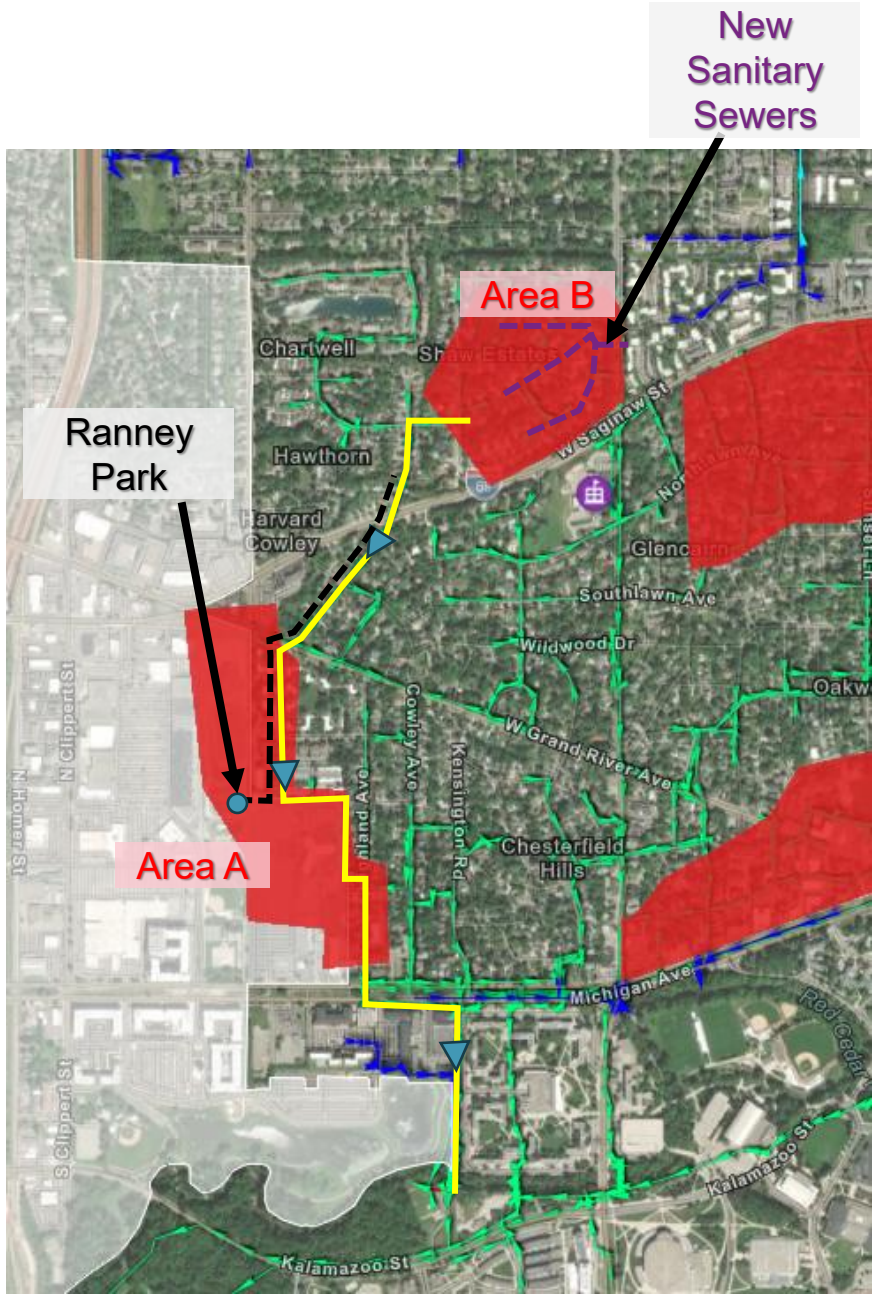
Flooding Concern Area	Location
A - CSS	**Highland Ave and Oak Ridge Ave**
B - CSS	**North Harrison Rd and Longfellow Dr**
C - CSS	**Northlawn Ave and Sunset Ln**
D - CSS	**Michigan Ave and W Grand River Ave**
E - CSS	**Burcham Drive**
F – MS4	Abbot Rd and E Saginaw
G - CSS	**Beech St and Collingwood Dr**
H – MS4	Pebblebrook Lane



All concern areas have a level of service less than a 5-year event, which is greater than a 20% chance storm.
These systems were built decades ago for a lower level of service (less intense storms and less impervious surface).

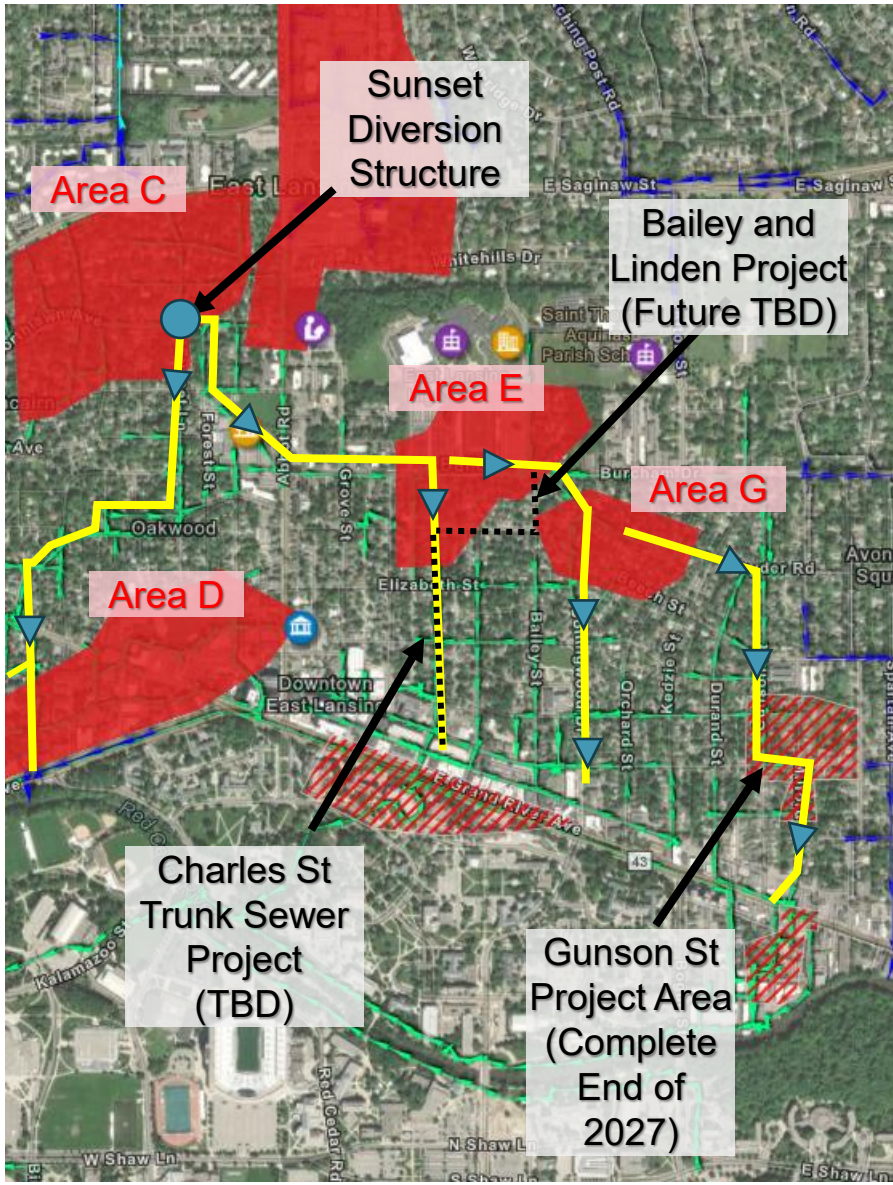
East Lansing Existing CIP Projects

Area	Type	Strategy	Timeline	Cost Estimate	Hydraulic Connectivity	Project Description/Notes
A	**CSS**	Sewer Separation (New Storm)	2029 or later	$2.1M (to Ranney Park) $3.5M (to Red Cedar River)	Connected with Area B	• Build new storm sewers and separate to Montgomery Drain/Ranney Park. • Separation is dependent upon agreement with Drain Commission.
B	**CSS**	Sewer Separation (New Sanitary)	2029 or later	$4.9M	Connected with Area A	• Build new sanitary sewers and convert existing CSS to storm only.



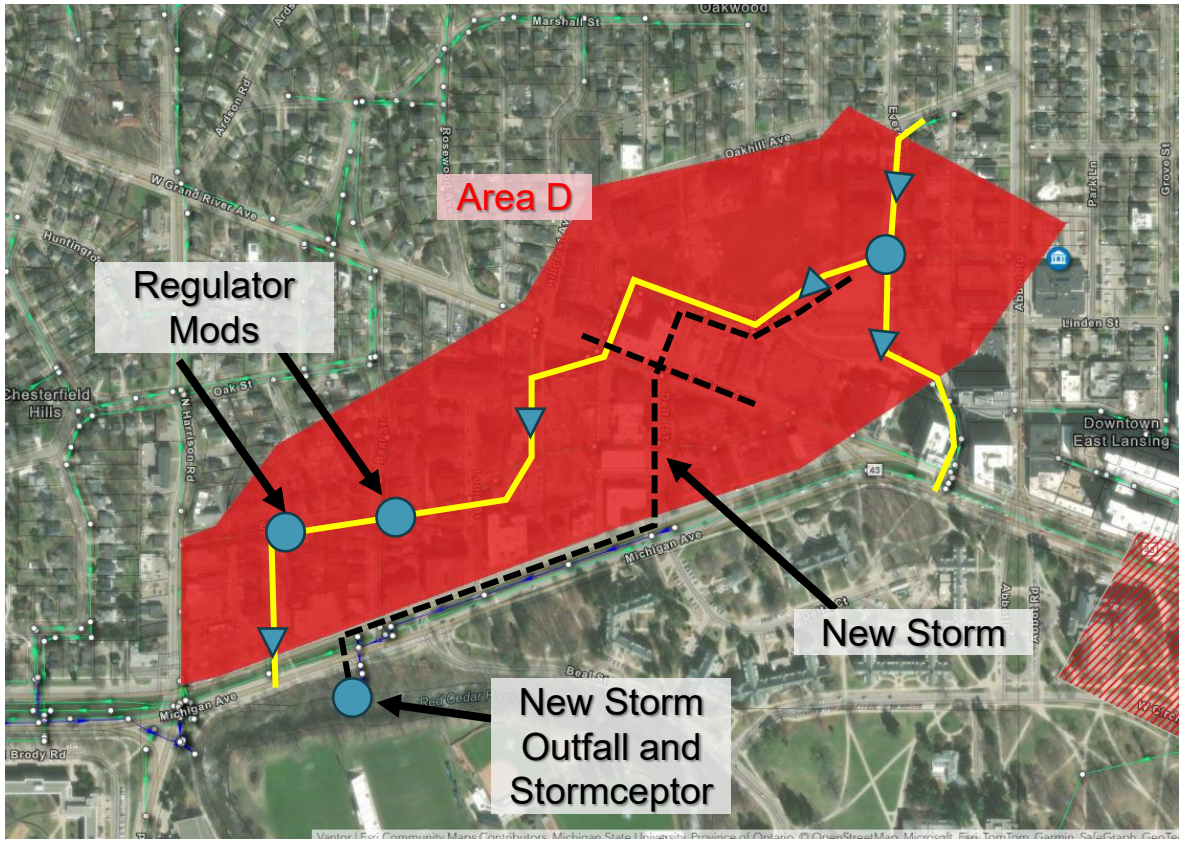
East Lansing Existing CIP Projects

Area	Type	Strategy	Timeline	Cost Estimate	Hydraulic Connectivity	Project Description/Notes
C	**CSS**	Sewer Upsizing	Project Already Constructed in Area		Connected with Area E via Diversion at Sunset and Northlawn Connected with Area D	• Level of service is impacted by downstream hydraulic constriction on Sunset and Charles St. • Sunset hydraulically connected to Area E via diversion structure at Sunset and Northlawn
E	**CSS**	Sewer Upsizing and Bulkheading	TBD not included in CIP		Connected with Area C and G	• Upsize trunk sewer on Charles St • Divert flows along new upsized sewer along Bailey St and Linden St • Hydraulically connected to Area C
G	**CSS**	No Projects Identified			Connected with E and Gunson St Project	• Gunson Street project needs to be included in model as part of alternatives evaluations.



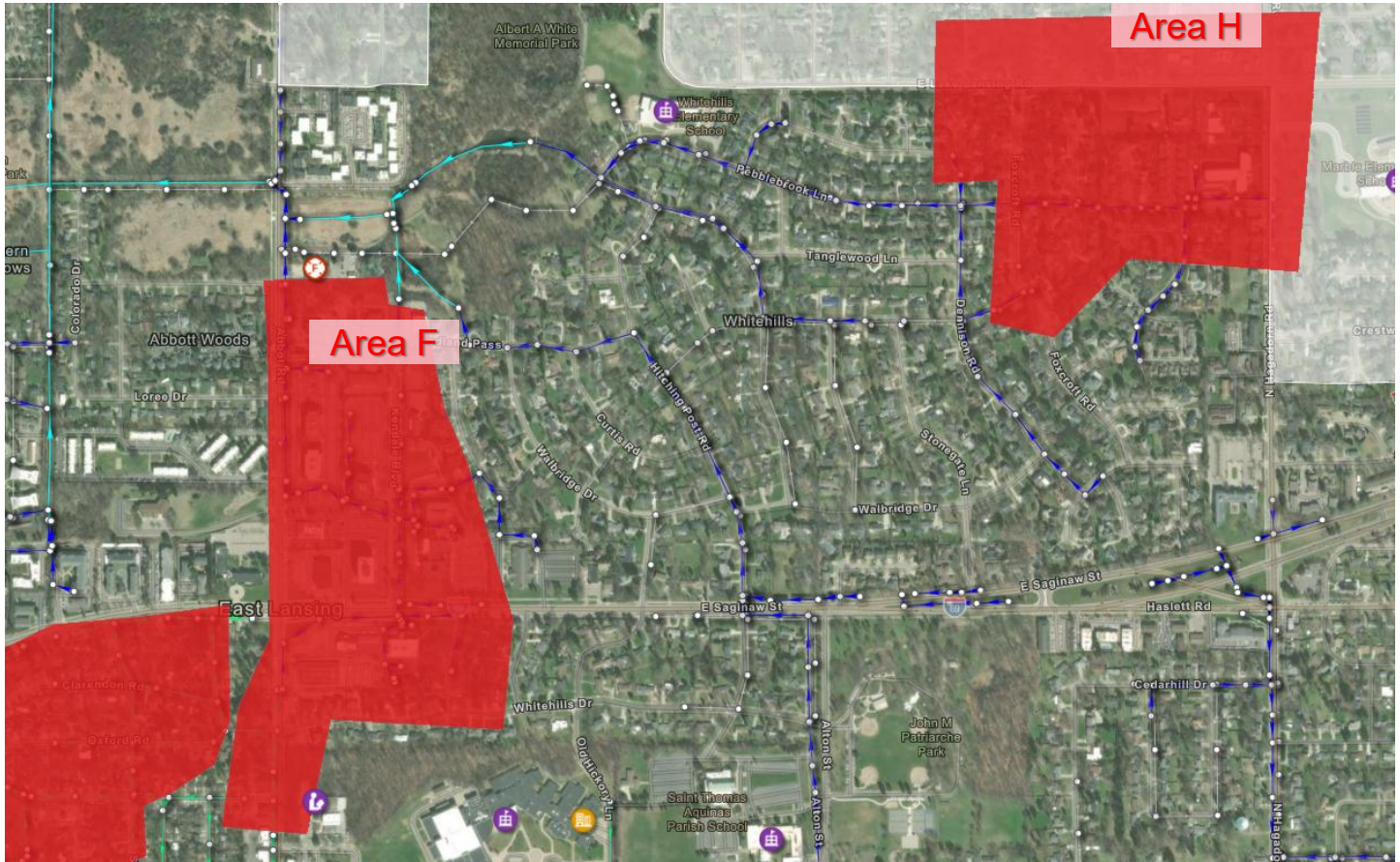
East Lansing Existing CIP Projects

Area	Type	Strategy	Timeline	Cost Estimate	Hydraulic Connectivity	Project Description/Notes
D	**CSS**	Sewer Separation (New Storm) Regulator Modifications Bulkheading	2029 or later	$5.5M	Own subshed	• New storm sewers to Red Cedar River • New stormceptor at outfall for WQ (EGLE has approved in past) • Modify regulators to increase flows to tunnel



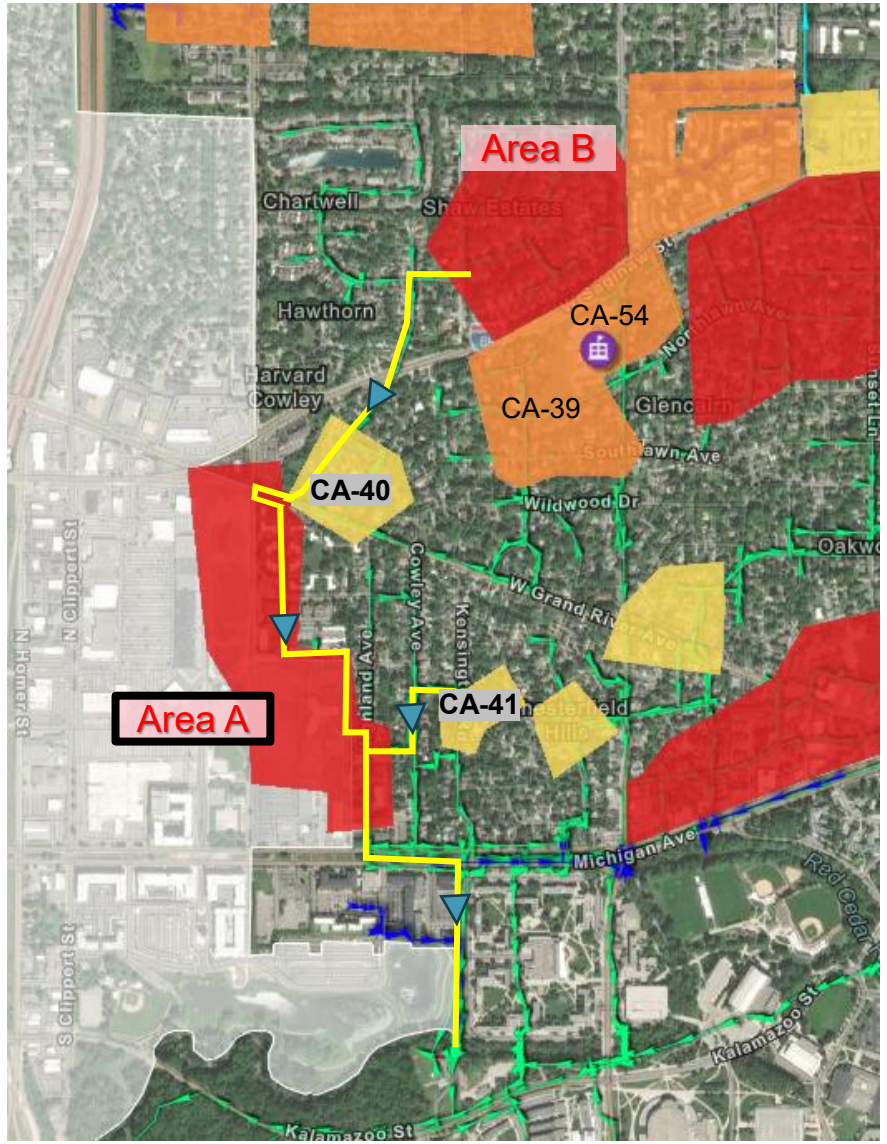
East Lansing Existing CIP Projects

Area	Type	Strategy	Construction Timeline	Cost Estimate	Hydraulic Connectivity	Project Description/Notes
F	**MS4**	No Projects Identified				
H	**MS4**	No Projects Identified				Project F in the 2008 sanitary sewer masterplan identified the area as need for additional evaluation for I&I source reduction. Suspected surface drains connected into the sanitary system. No MS4 capacity projects included.



Area A – Highland Ave and Oak Ridge Ave

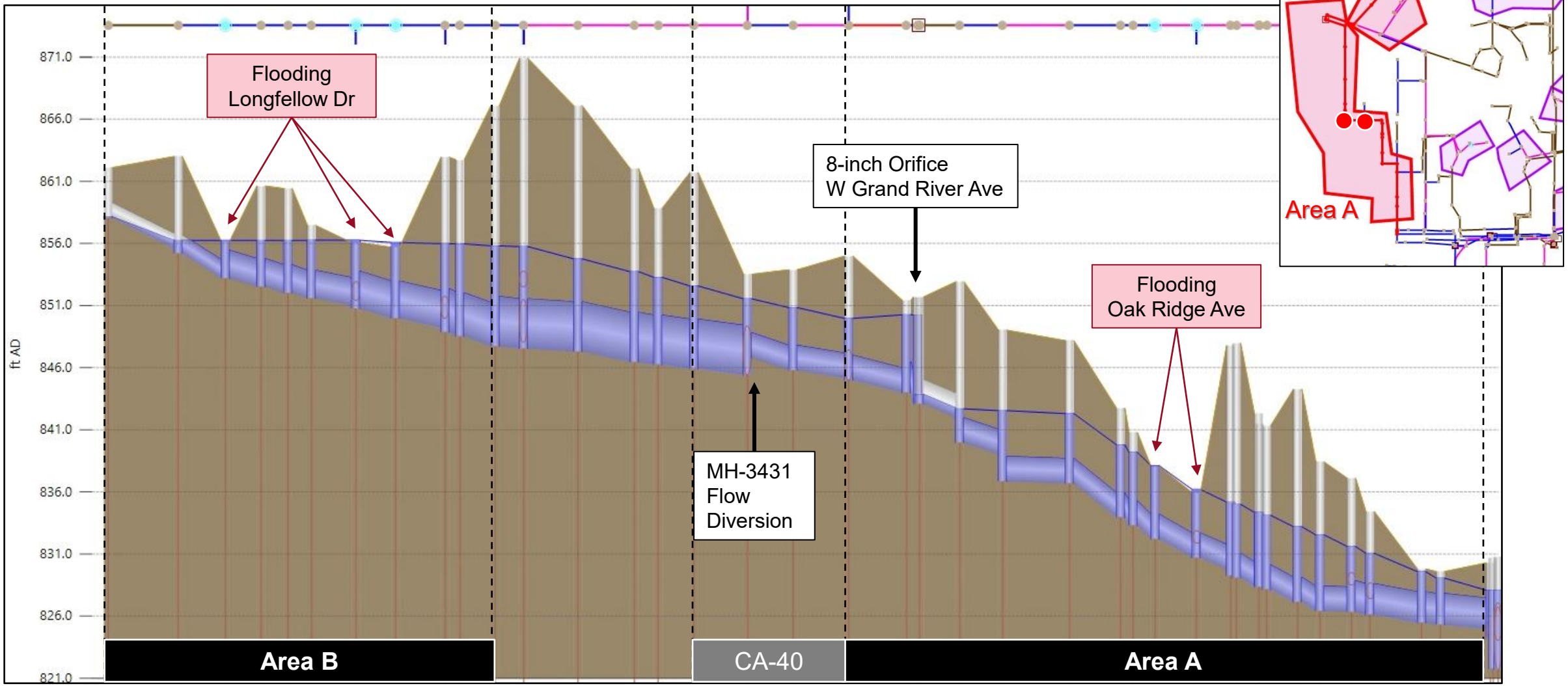
Criteria	
System (MS4/CSS)	CSS
Description of Problem	Surface Flooding; Sewer Surcharge for 10yr1hr Design Storm
Streets Impacted	Highland Ave, Oak Ridge Ave, W Grandview Ave
Existing LOS from Model	2-year
Root Cause	Sewer Capacity
Area Previously Identified for MP/CIP Project by City?	Yes
Hydraulically Connected to Other Flooding Concern Area?	Yes Area B is upstream and delivers flow into Area A
Other Adjacent Non-Top 8 Areas	CA_39, CA_40, CA_41, CA_54



Area A & B - Model HGL Results

Longfellow Dr to Highland Ave

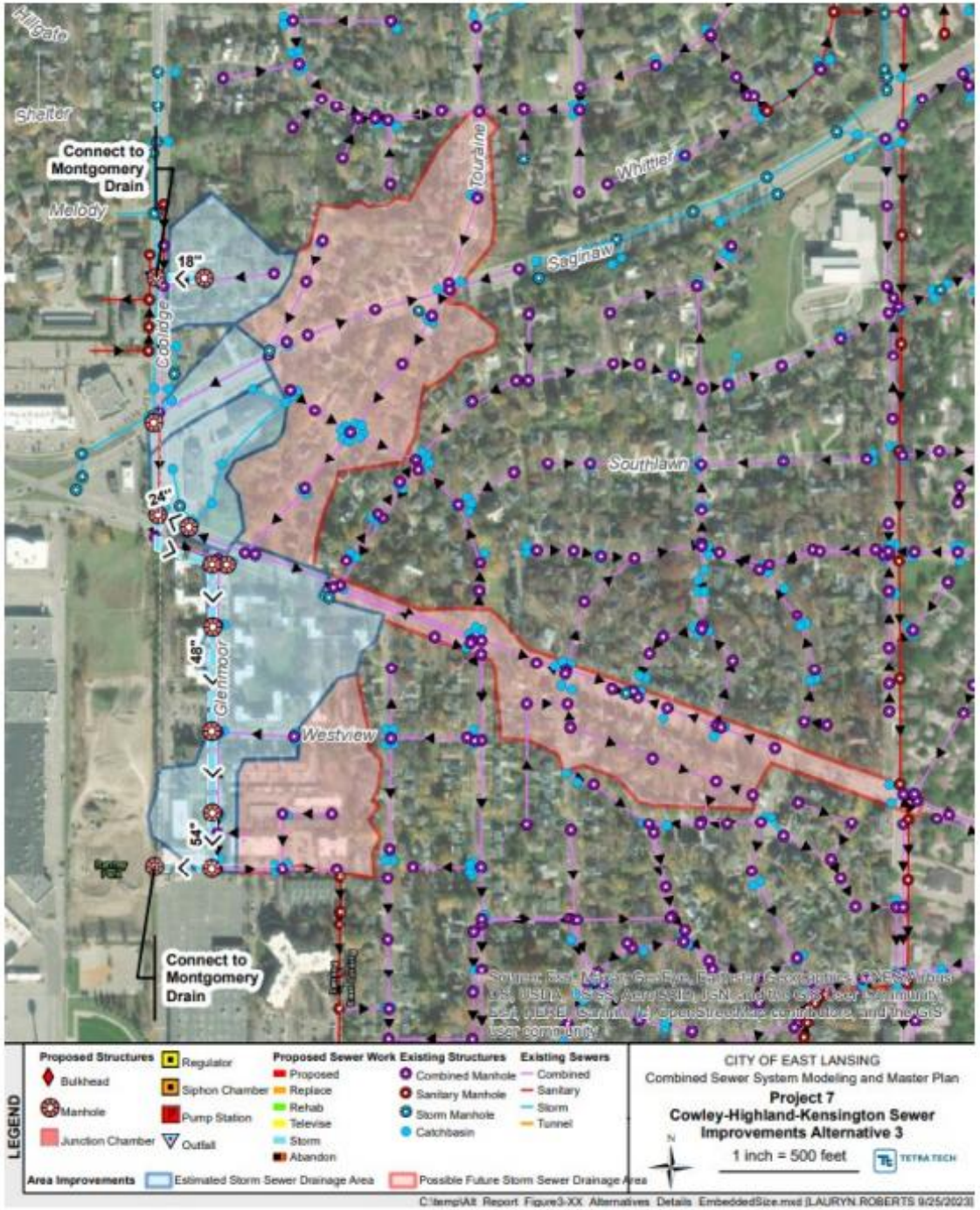
10yr, 1hr Design Storm



Strategy 1 – Separation to Ranney Park

- City CIP Project
- Target subsheds adjacent to Ranney Park for sewer separation
- Storm must connect in Southeast corner of the park as per agreement with Drain Commission
- Agreement for flow contributions are pending and will require negotiation

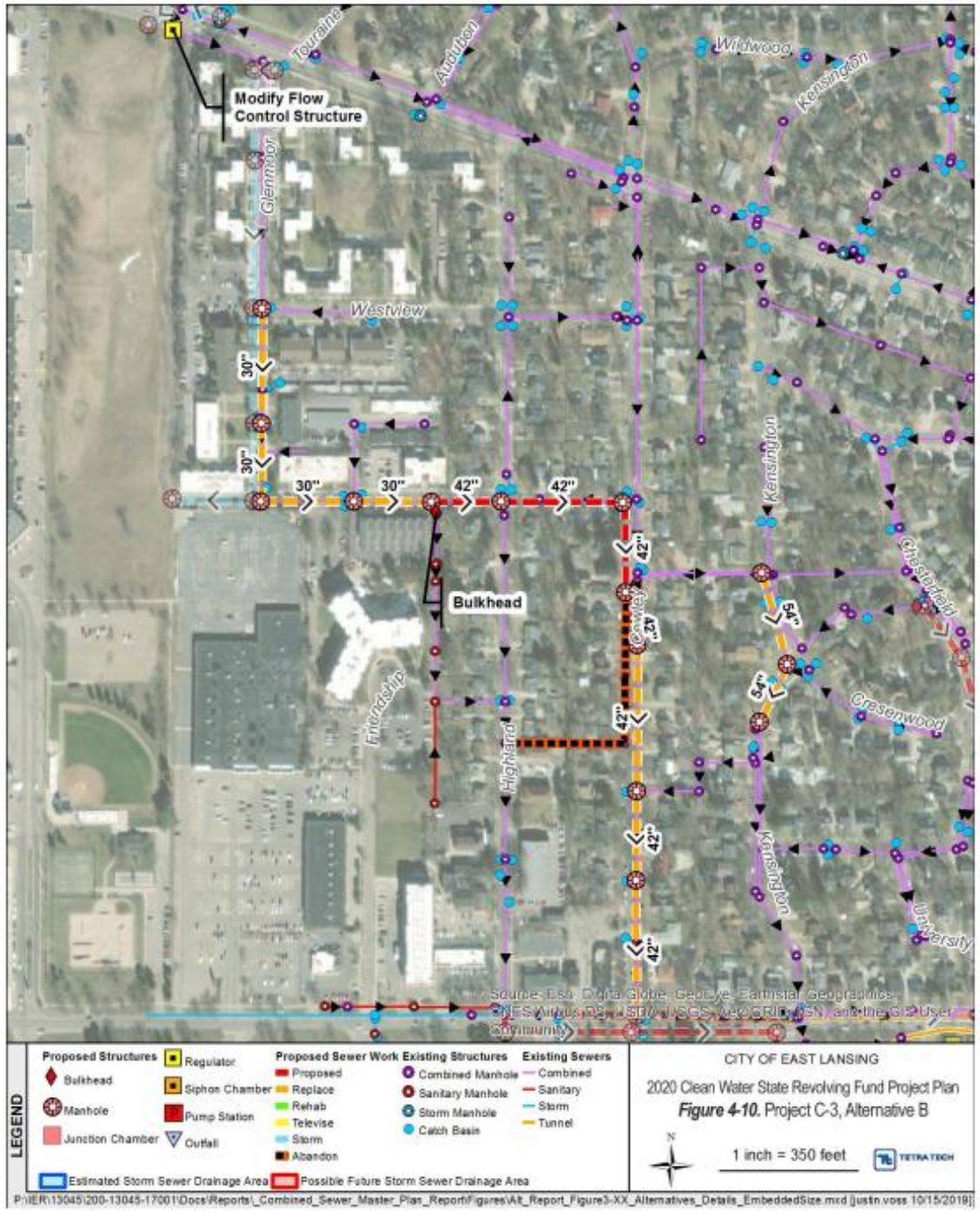
Figure 4-4. Project C-3, Alternative A



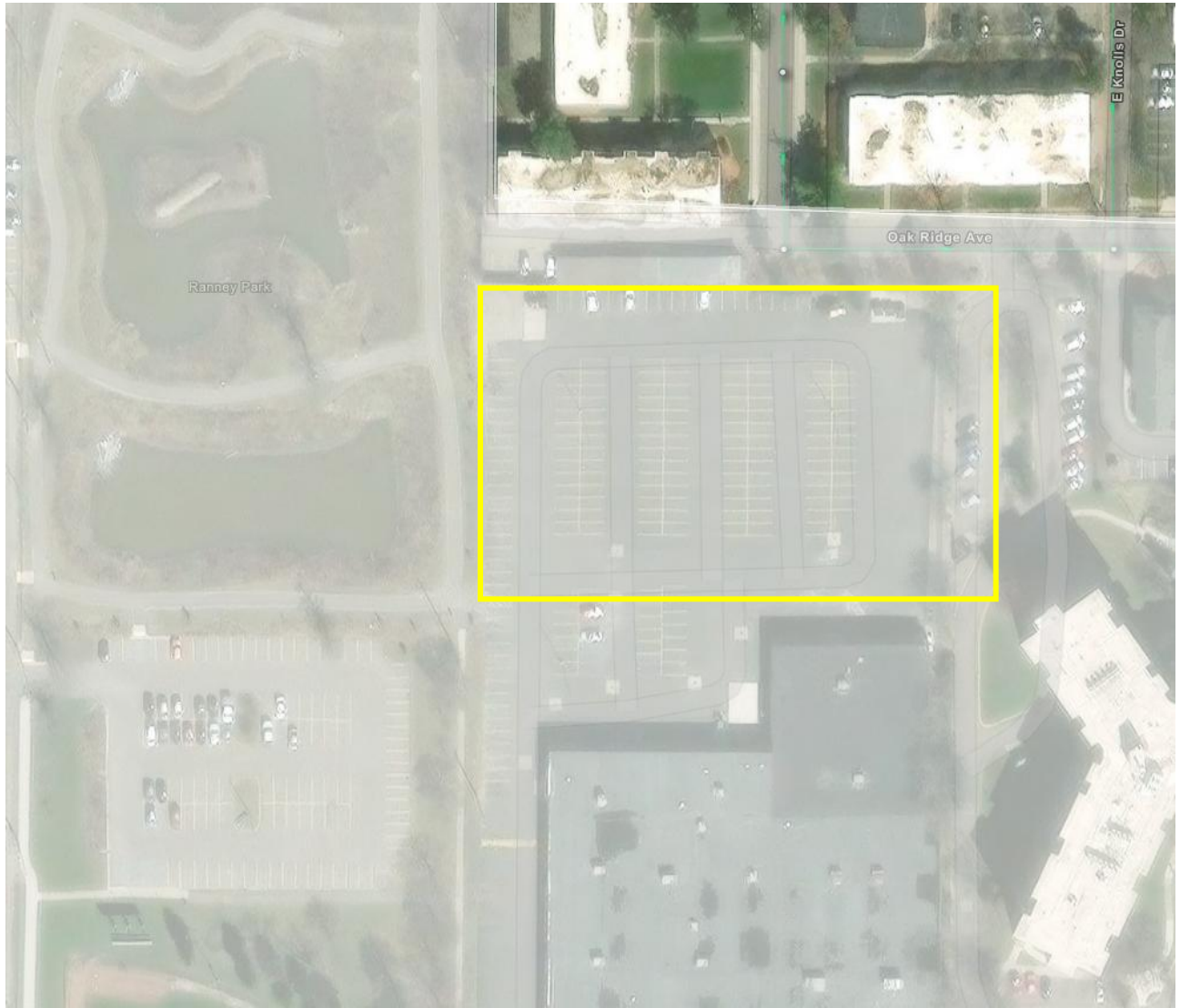
Strategy 2 – Separation to River

- City CIP Project
- Target separation of same subsheds
- Rather than connect into Ranney Park

Figure 4-5. Projet C-3, Alternative B



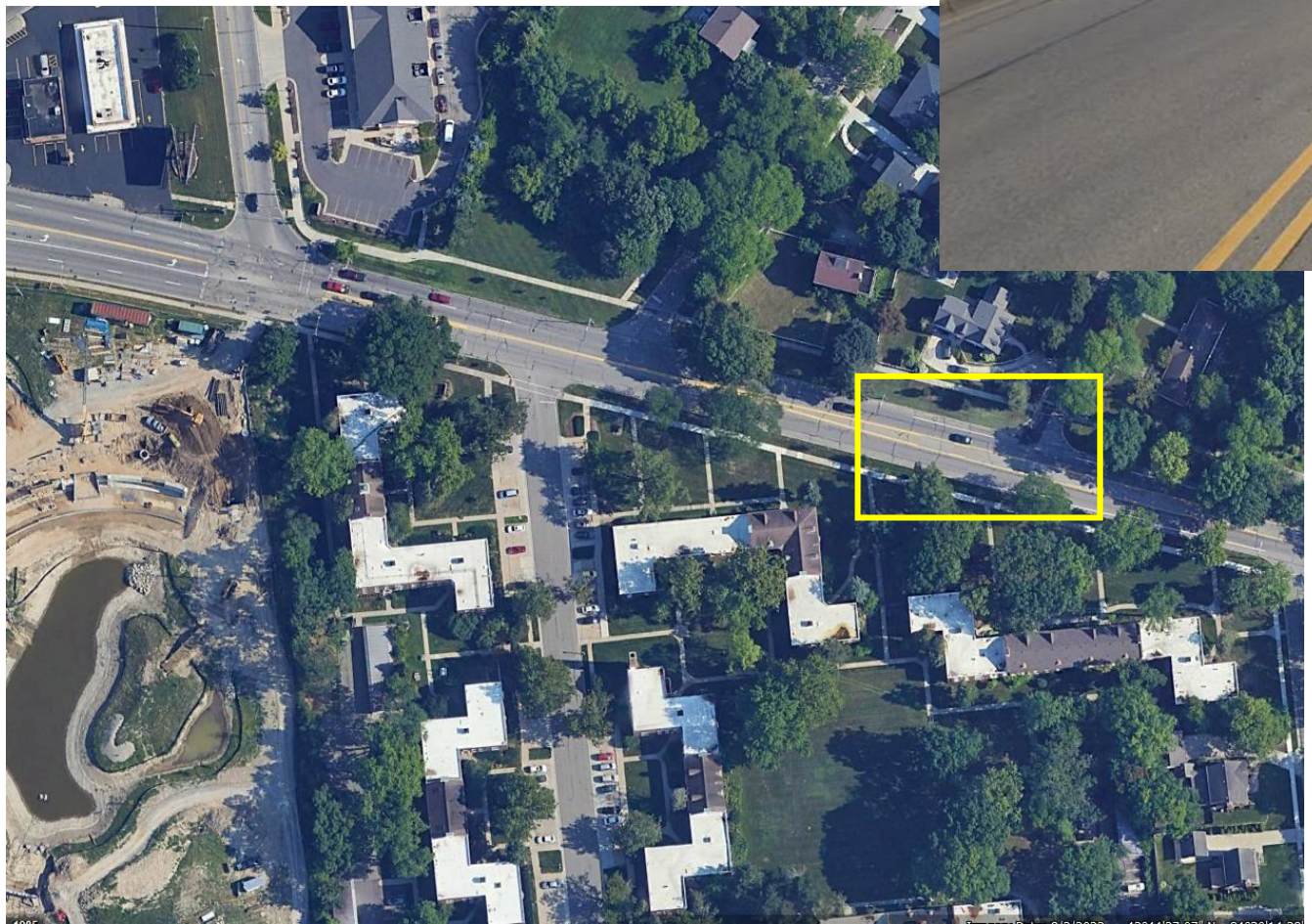
Strategy 3 – Local Storage Detention

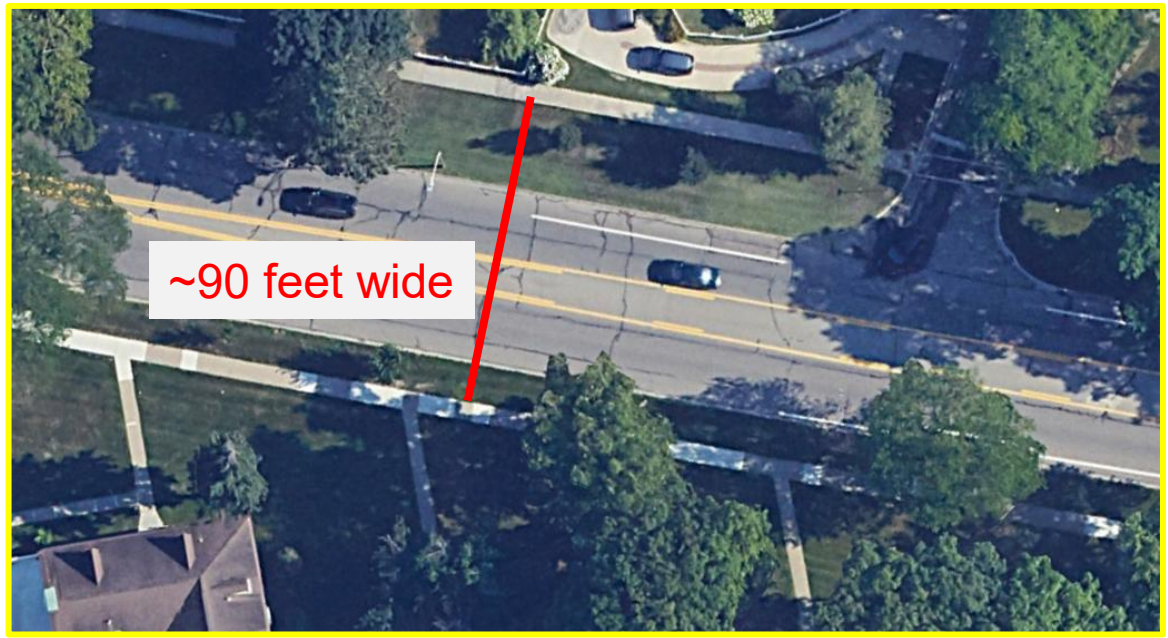




Strategy 4 – ROW Green Infrastructure





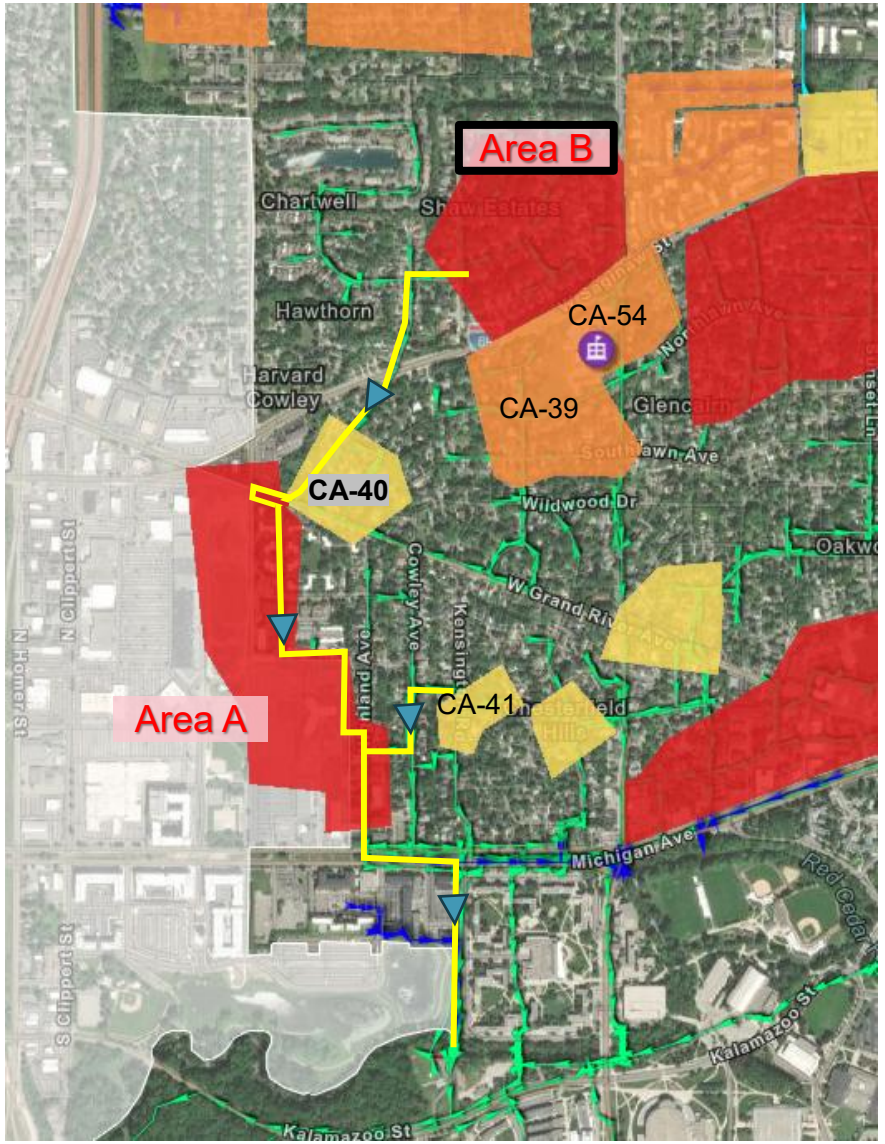


Area A – Potential Strategies

Strategy	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Description	Sewer Separation to Ranney Park	Sewer Separation to River	Local Storage	Green Infrastructure/ Depaving
Location	Ranney Park Neighborhood	Ranney Park Neighborhood	Private Lots	W Grand River
Function	Conveyance & Treat	Conveyance	Detention	Detain & Treat
MCDA Criteria				
Improved Drainage	High	High	Low	Med
City Resiliency Alignment	High	Low	Med	High
Water Quality	High	Low	Med	High
Impervious Surface Reduction	Low	Low	Low	High
Social and Econ Impacts	Low	Low	Low	Med
High Impact	High	High	Med	Low
Ease of Constructability	Med	Low	High	Low
Level of Maintenance	Low	Low	Med	High
LOS Impact	High	High	Med	Low

Area B – Highland Ave and Longfellow Dr

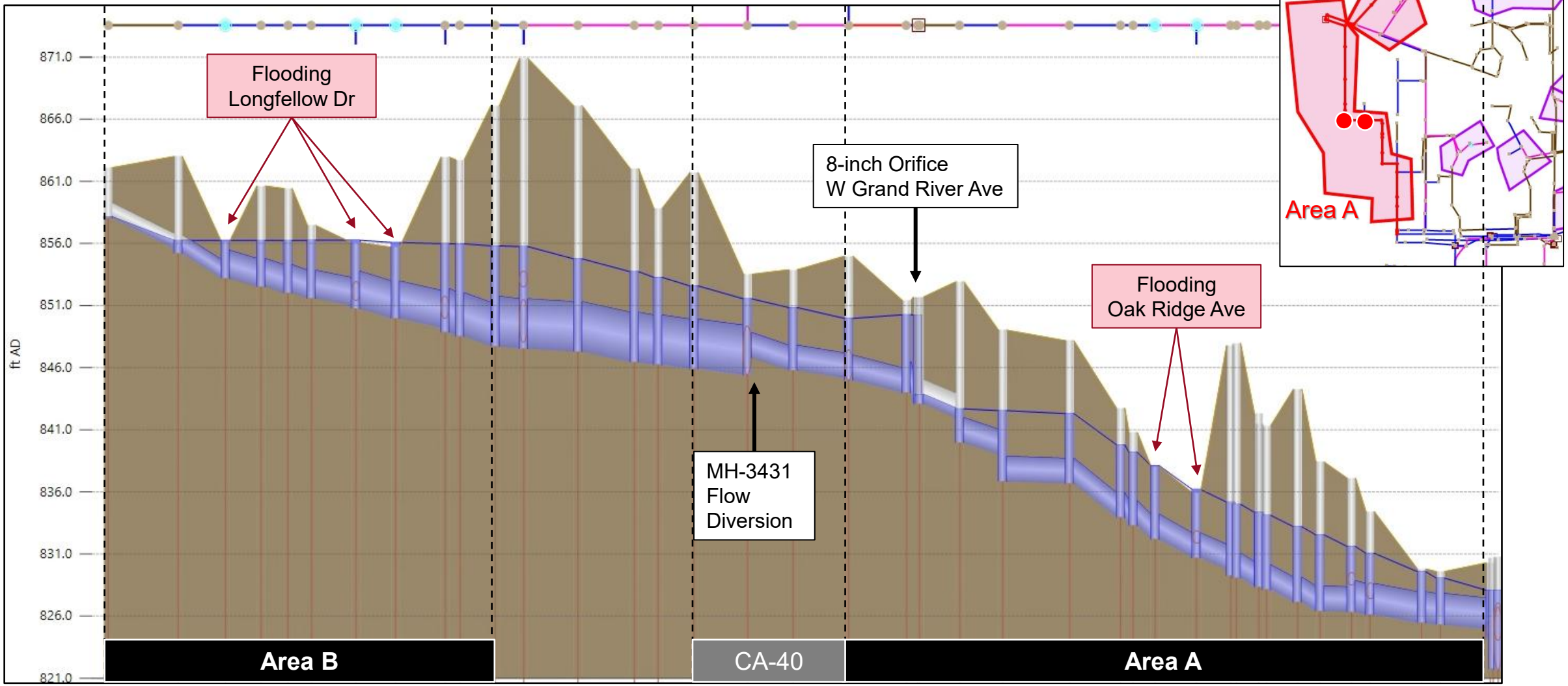
Criteria	
System (MS4/CSS)	CSS
Description of Problem	Surface Flooding; Sewer Surcharge for 10yr1hr Design Storm
Streets Impacted	Longfellow Dr, Whittier Dr, Bryant Dr
Existing LOS from Model	5yr
Root Cause	Sewer Capacity
Area Previously Identified for MP/CIP Project by City?	Yes
Hydraulically Connected to Other Flooding Concern Area?	Yes Area A is downstream of Area B
Other Adjacent Non-Top 8 Areas	CA_39, CA_40, CA_41, CA_54



Area A & B - Model HGL Results

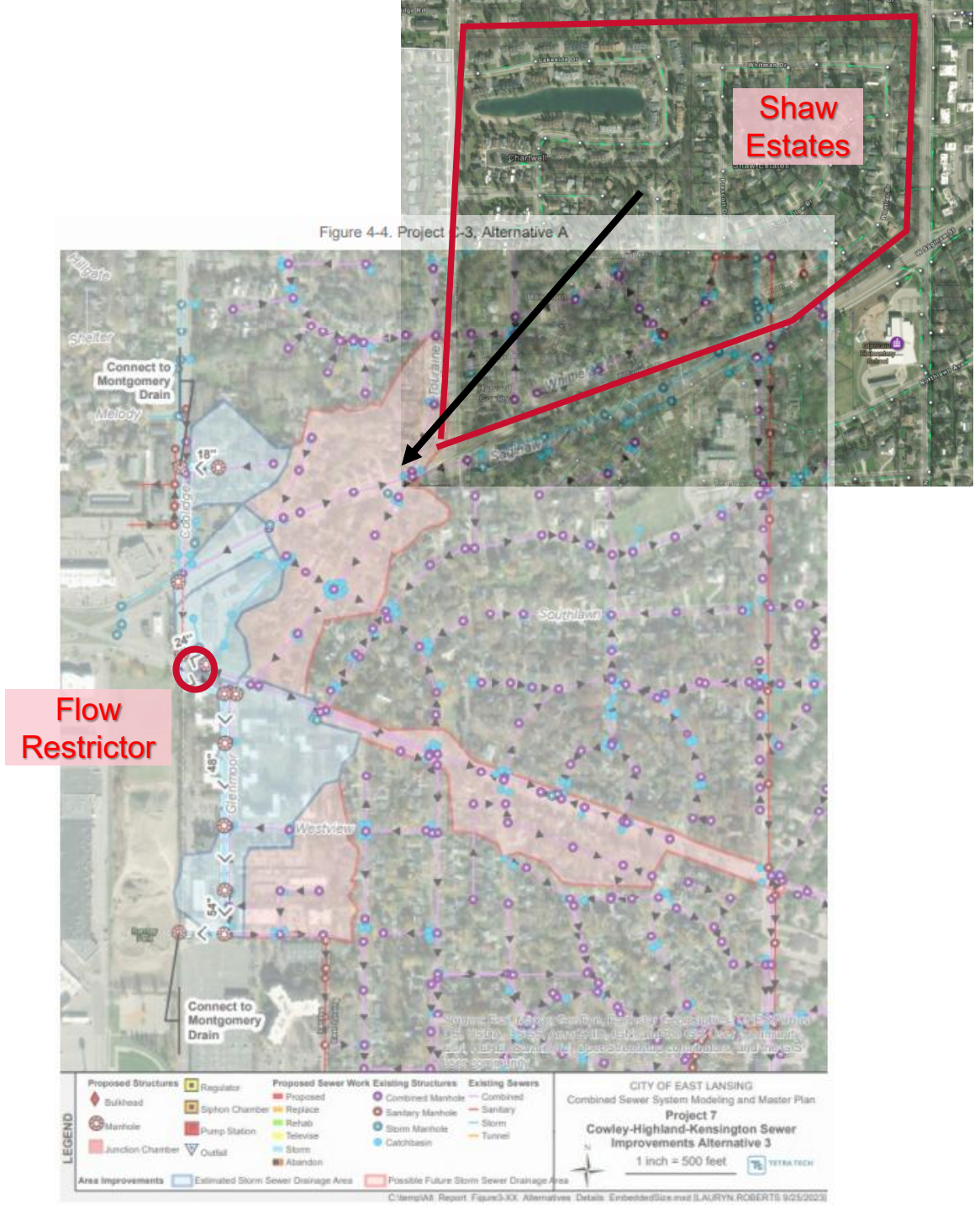
Longfellow Dr to Highland Ave

10yr, 1hr Design Storm



Strategy 1 – Separation & Flow Restrictor Modification Expand Area A to Include Area B

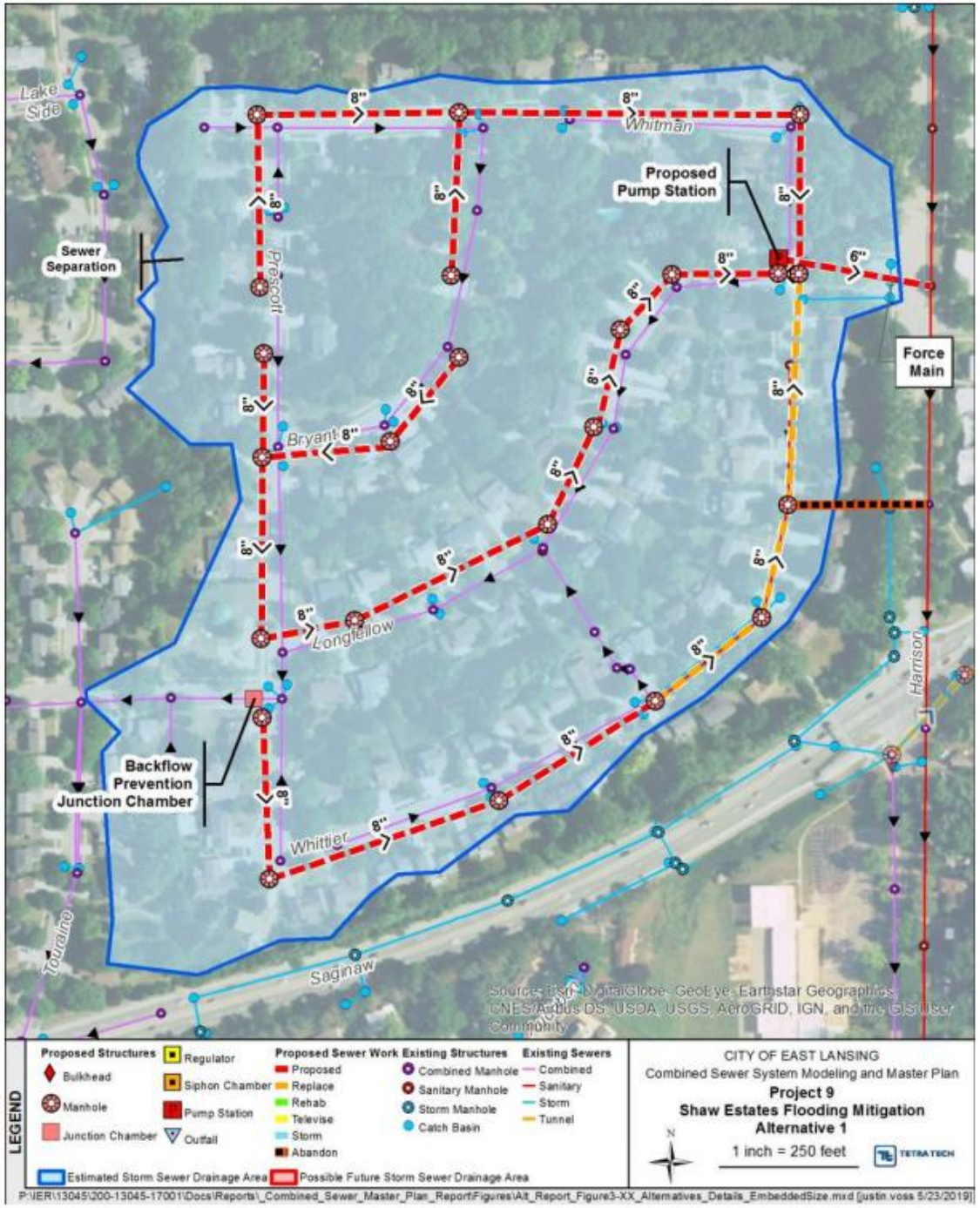
- Target more subsheds up into Shaw Estates for sewer separation to Ranney Park
- May need to combine with flow restrictor modifications to allow more flow downstream
- Agreement for flow contributions with Drain Commission are pending and will require negotiation



Strategy 2 – Separation New Sanitary Sewers

- City CIP Project
- Build new sanitary system
- Convert CSS into storm only

Figure 3-19. Project 9 Alternative 1 Shaw Estates Flooding Mitigation Concept Map



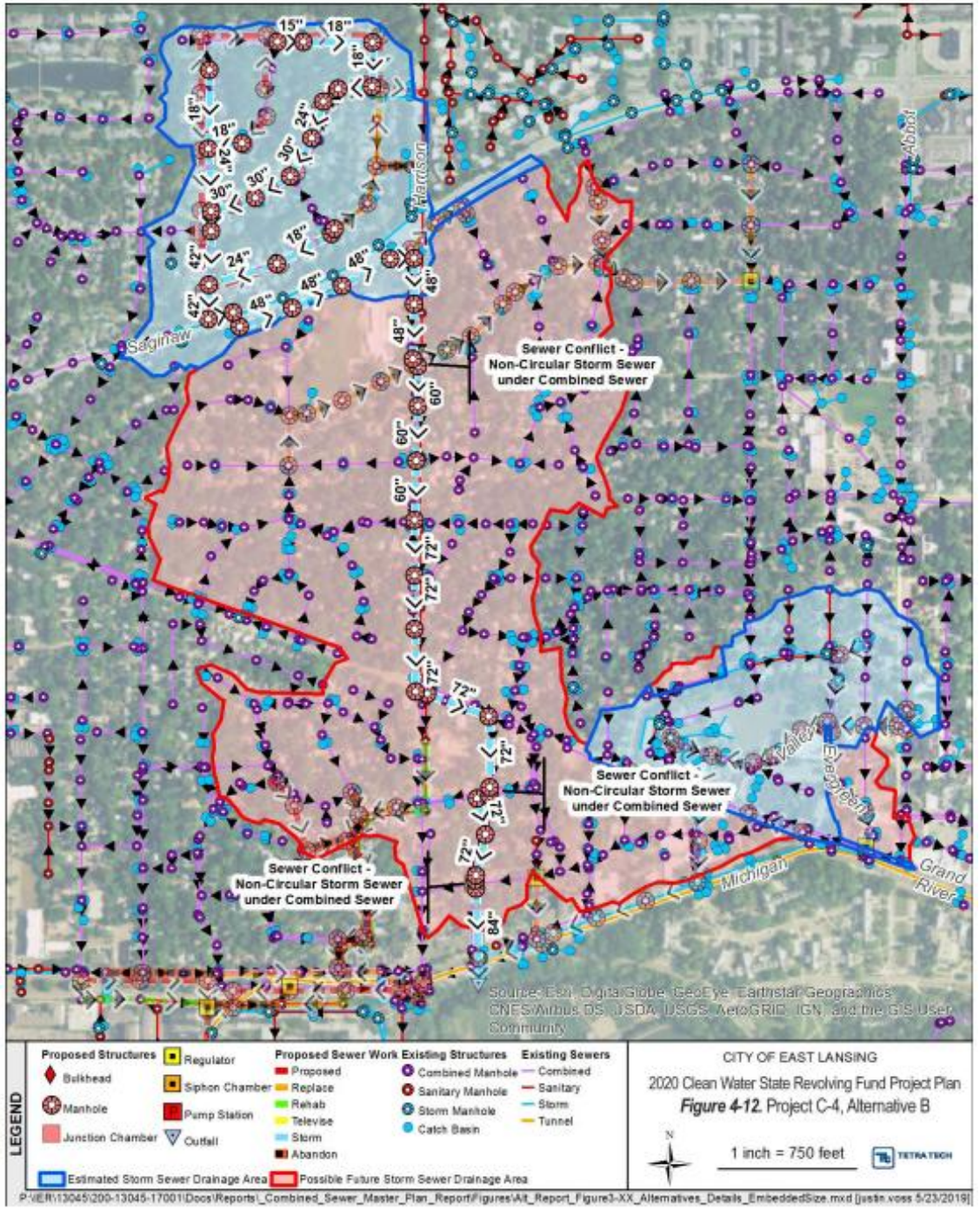
Area B (CA-37)

CWSRF Alternative B

Not Selected

- Similar to MP Alternative 3
- Would allow for separation of red area, but financially it would potentially be unaffordable.
- Alternate A is preferred and B is no longer on the table.

Figure 4-7. Project C-4, Alternative B



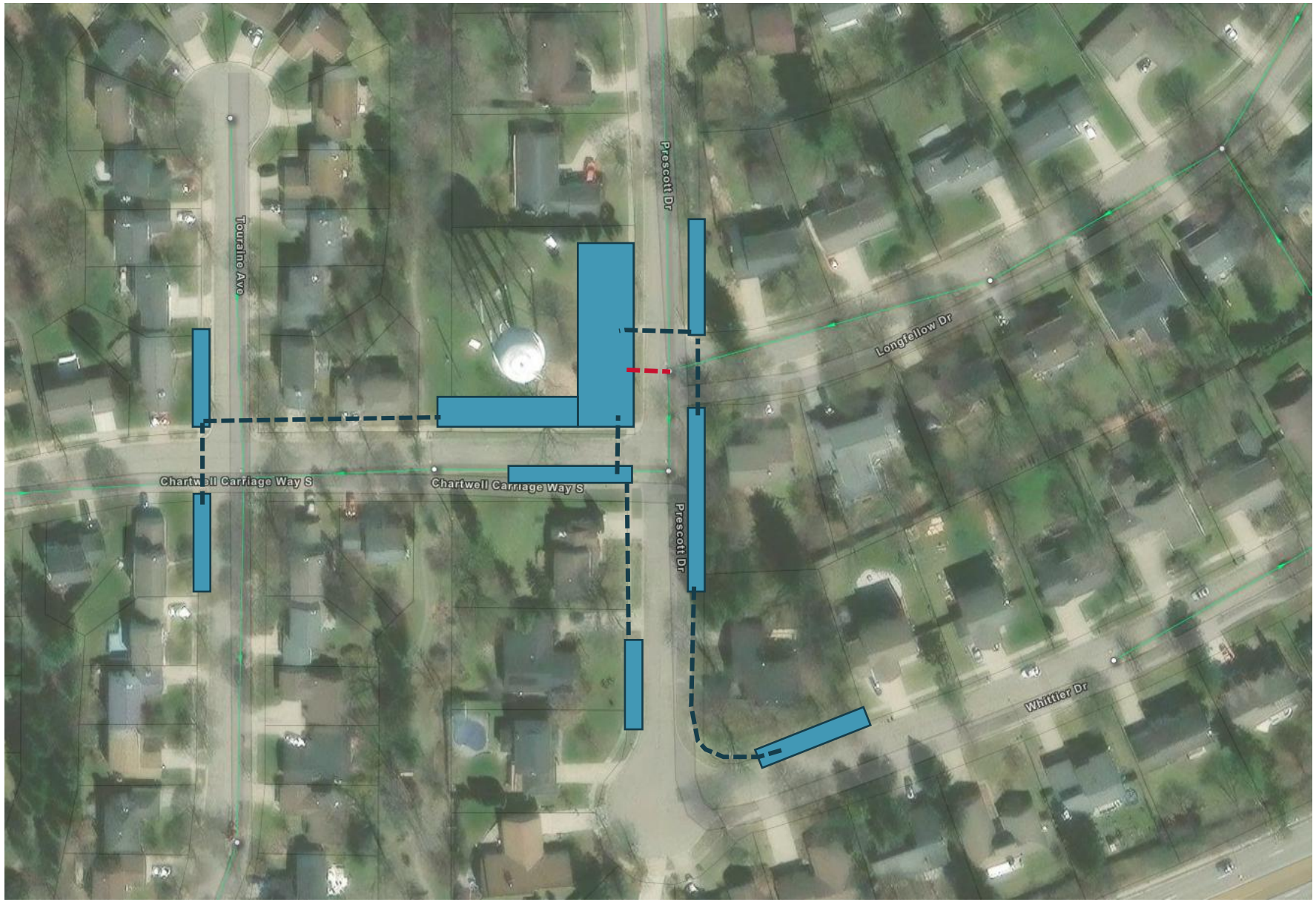
Strategy 3 – Separation Expand MS4

- Build new storm system and convey to nearby MS4
- May need PS depending on grade



Strategy 4 – ROW Green Infrastructure

- Distributed in ROW
- Bioswales, Tree Pits and Subsurface Storage
- Neighborhood Scale
- Utilize Gordon Guyer Park as main area and build out network of connected GI cells

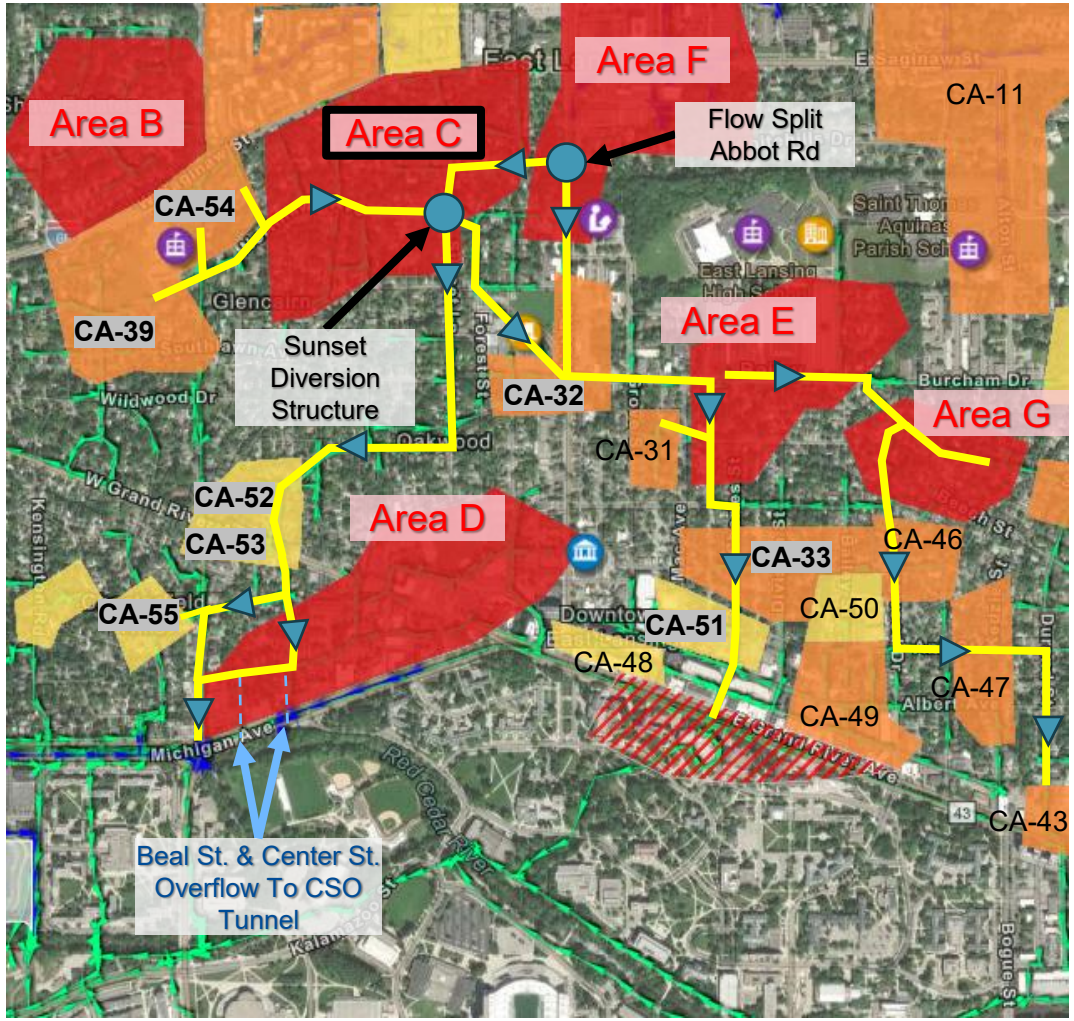


Area B – Potential Strategies

Strategy	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Description	Separation Expand Ranney Area A	Separation CSS Conversion	Separation Expand MS4	ROW Green Infrastructure
Location	Shaw Estates	Shaw Estates	Shaw Estates	Gordon Guyer Park
Function	Conveyance & Treat	Conveyance	Conveyance	Detain & Treat
MCDA Criteria				
Improved Drainage	High	High	High	Low
City Resiliency Alignment	Med	Low	Low	High
Water Quality	Med	Low	Low	High
Impervious Surface Reduction	Low	Low	Low	Med
Social and Econ Impacts	Med	Med	Med	Med
High Impact	High	High	High	Med
Ease of Constructability	Med	Med	Med	Low
Level of Maintenance	Low	Low	Med	High
LOS Impact	High	High	High	Low

Area C – Northlawn Ave and Sunset Ln

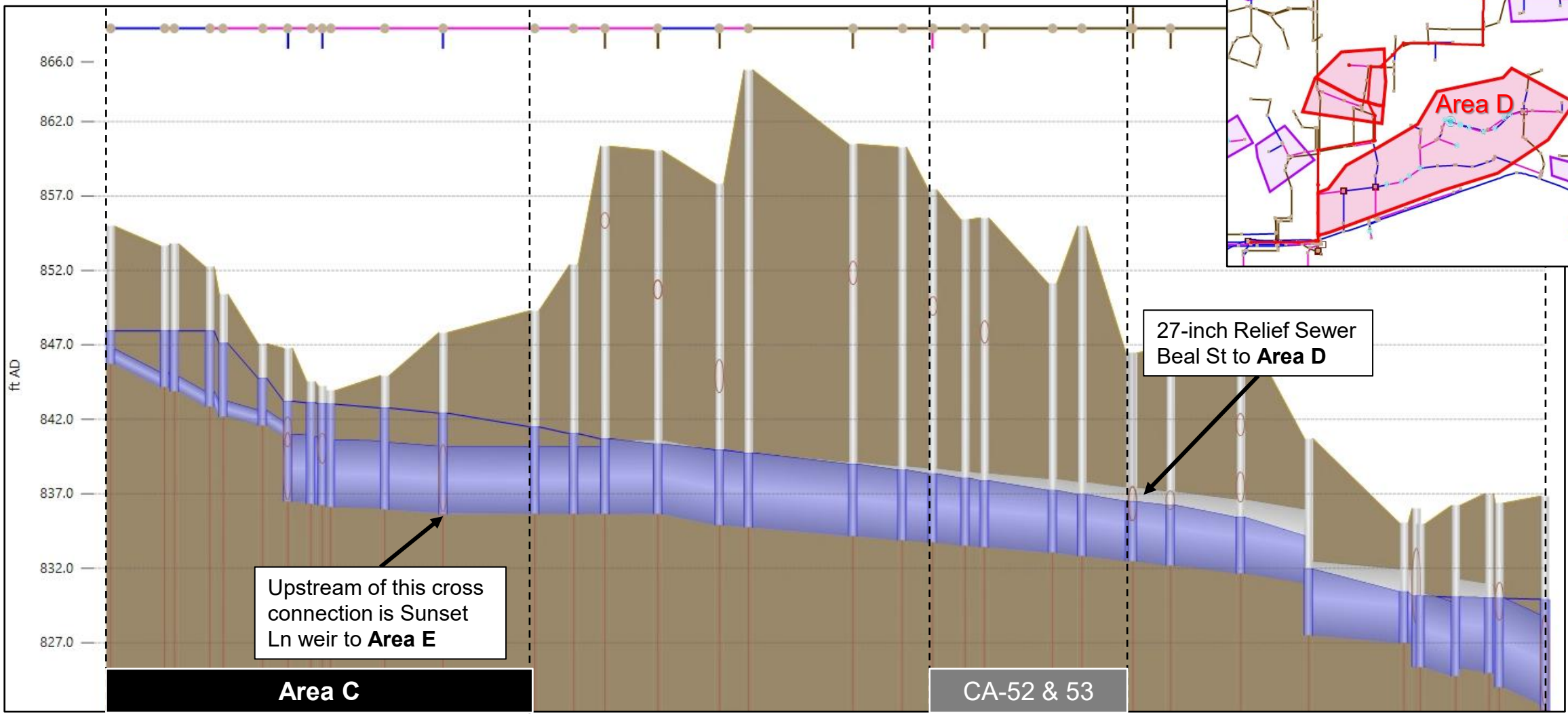
Criteria	
System (MS4/CSS)	CSS
Description of Problem	Sewer Surcharge for 10yr1hr Design Storm
Streets Impacted	Northlawn Ave, Rosewood Ave, Oxford Rd, Sunset Ln
Existing LOS from Model	2-year
Root Cause	Sewer Capacity
Area Previously Identified for MP/CIP Project by City?	Yes
Hydraulically Connected to Other Flooding Concern Area?	Yes Area C is upstream and delivers flow into Area D and Area E via relief sewer. Area C is downstream of Area F (relief sewer)
Other Adjacent Non-Top 8 Areas	CA_32, CA_33, CA_39, CA_51, CA_52, CA_53, CA_54, CA_55

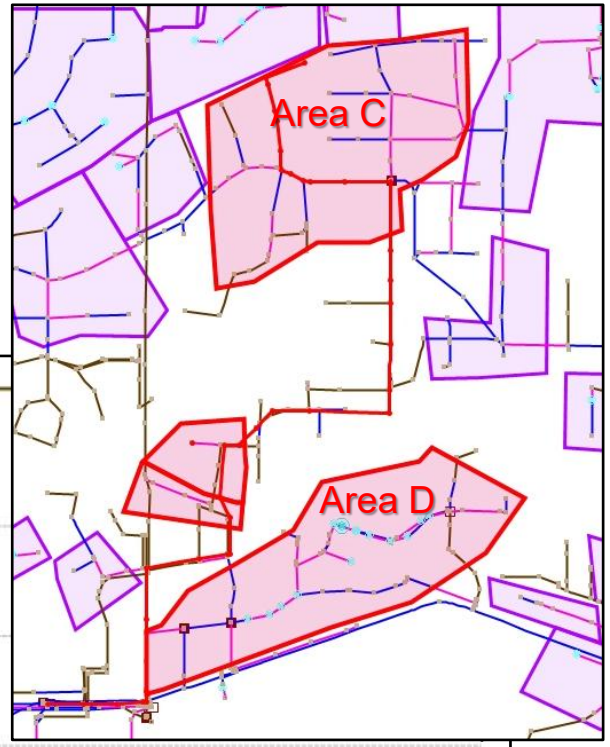


Area C - Model HGL Results

Rosewood Ave to Michigan Ave

10yr, 1hr Design Storm

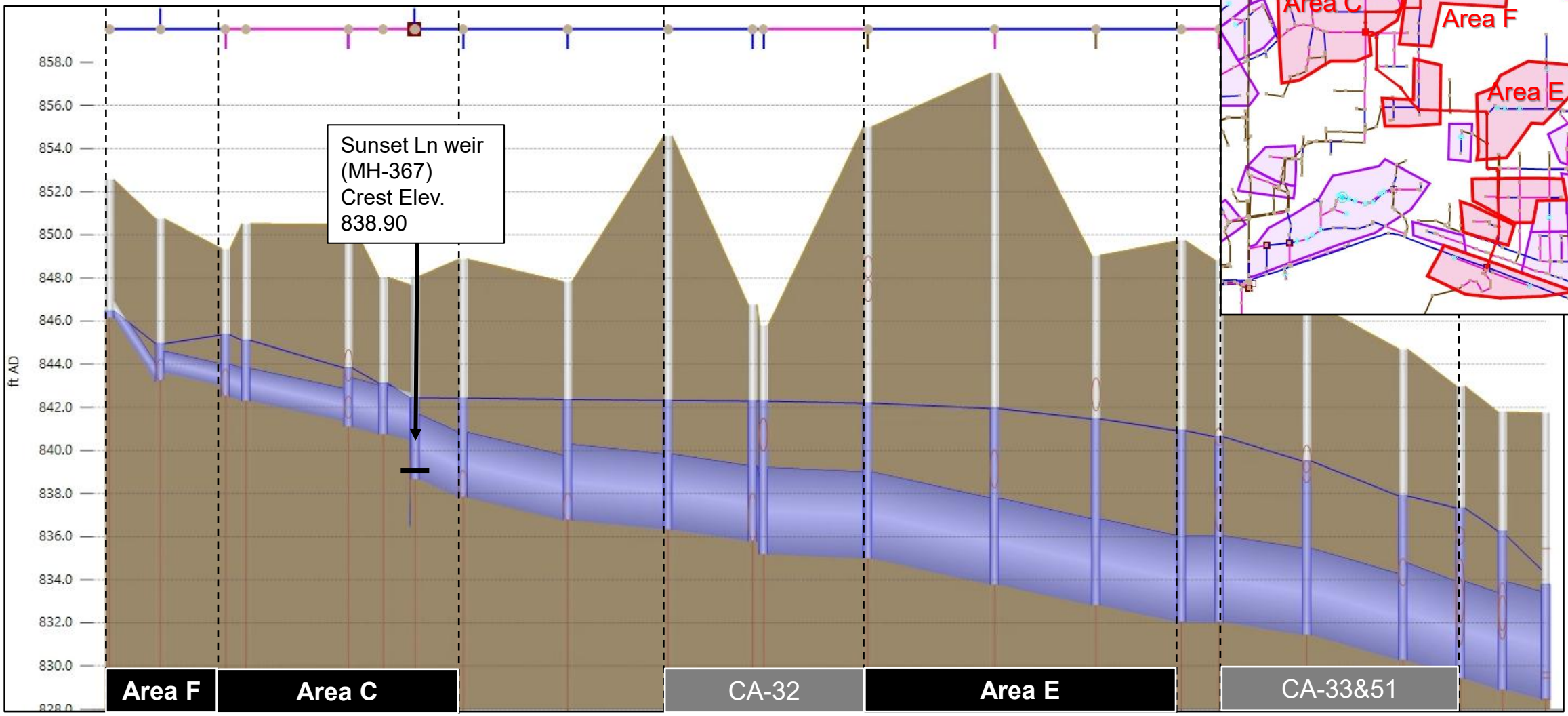


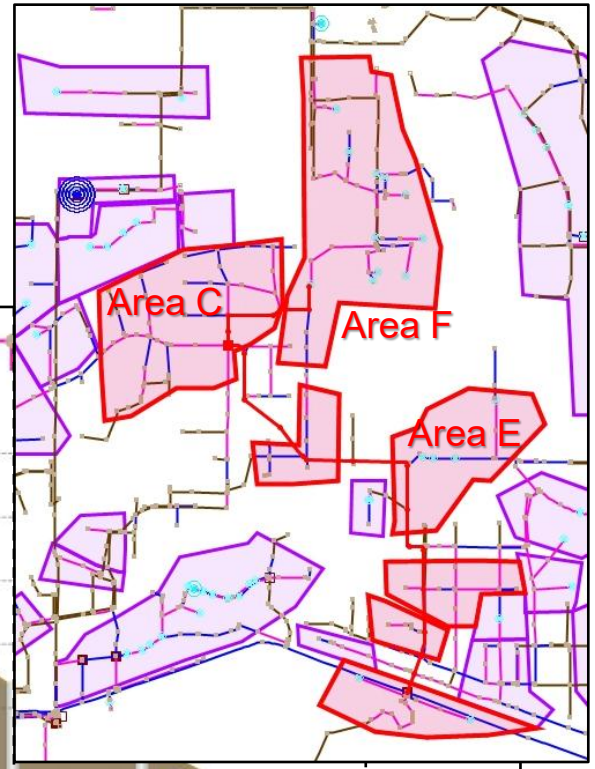


Area F,C, &E - Model HGL Results

Abbot Rd to E. Grand River Ave

10yr, 1hr Design Storm





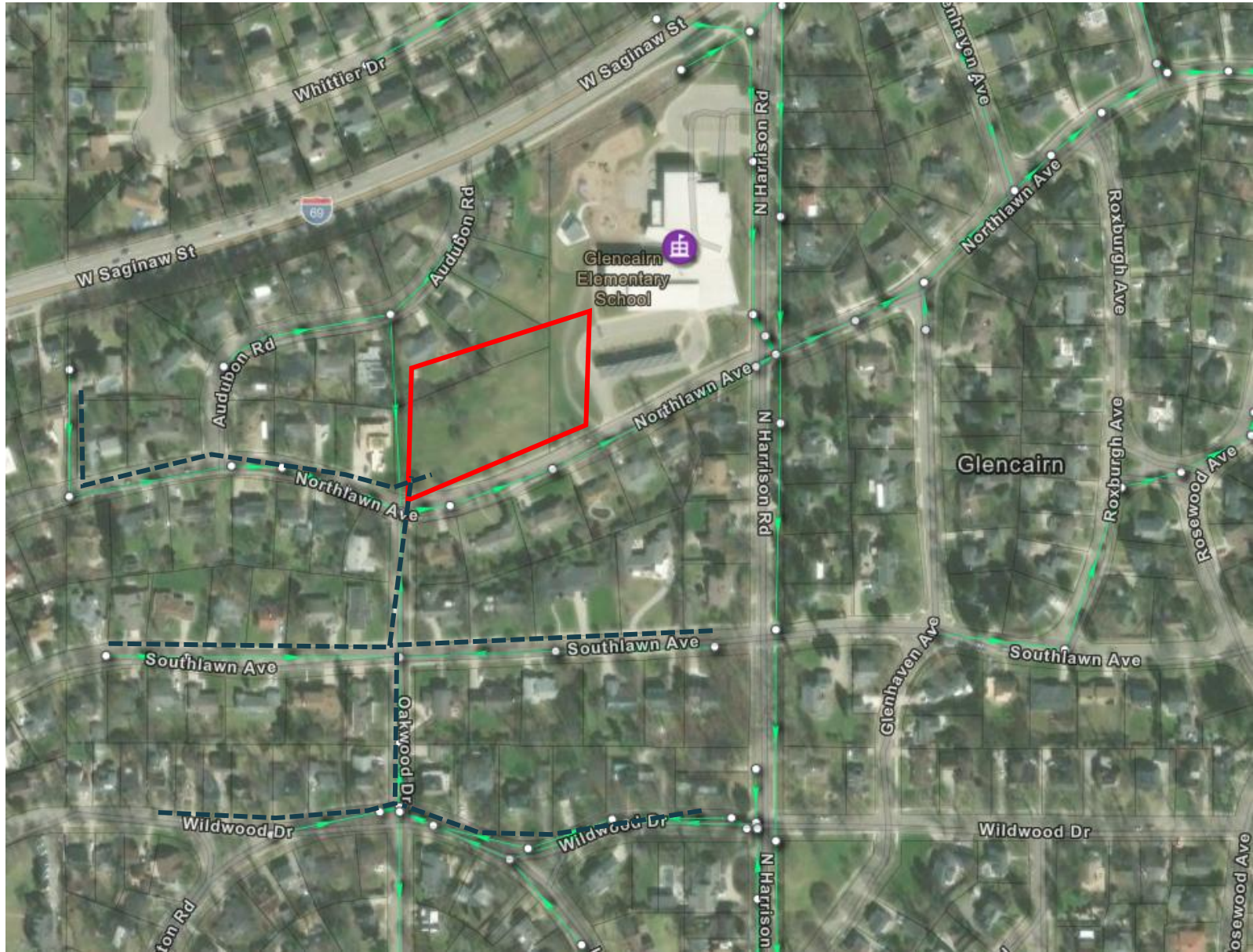
Strategy 1 – Downstream Local Storage

- Construct new high level storm sewers
- Detain, infiltrate (if feasible), and slow release in potential storage areas at Shaw Park, Hannah Community Center, Public Library
- Could be a combination of surface and subsurface storage



Strategy 2 – Upstream Local Storage

- Construct new high level storm sewers
- Detain, infiltrate (if feasible), and slow release in potential storage areas at Glencairn Elementary School
- Could be a combination of surface and subsurface storage



Strategy 3 – Separation (Combine with Area D Strategies)

- Construct High Level Separate Storm
  - Likely will require micro tunnel due to grade change at Oakhill Ave
- Convey to Area D for either:
  - Detention in Valley Court
  - Tie into Area D storm separation project

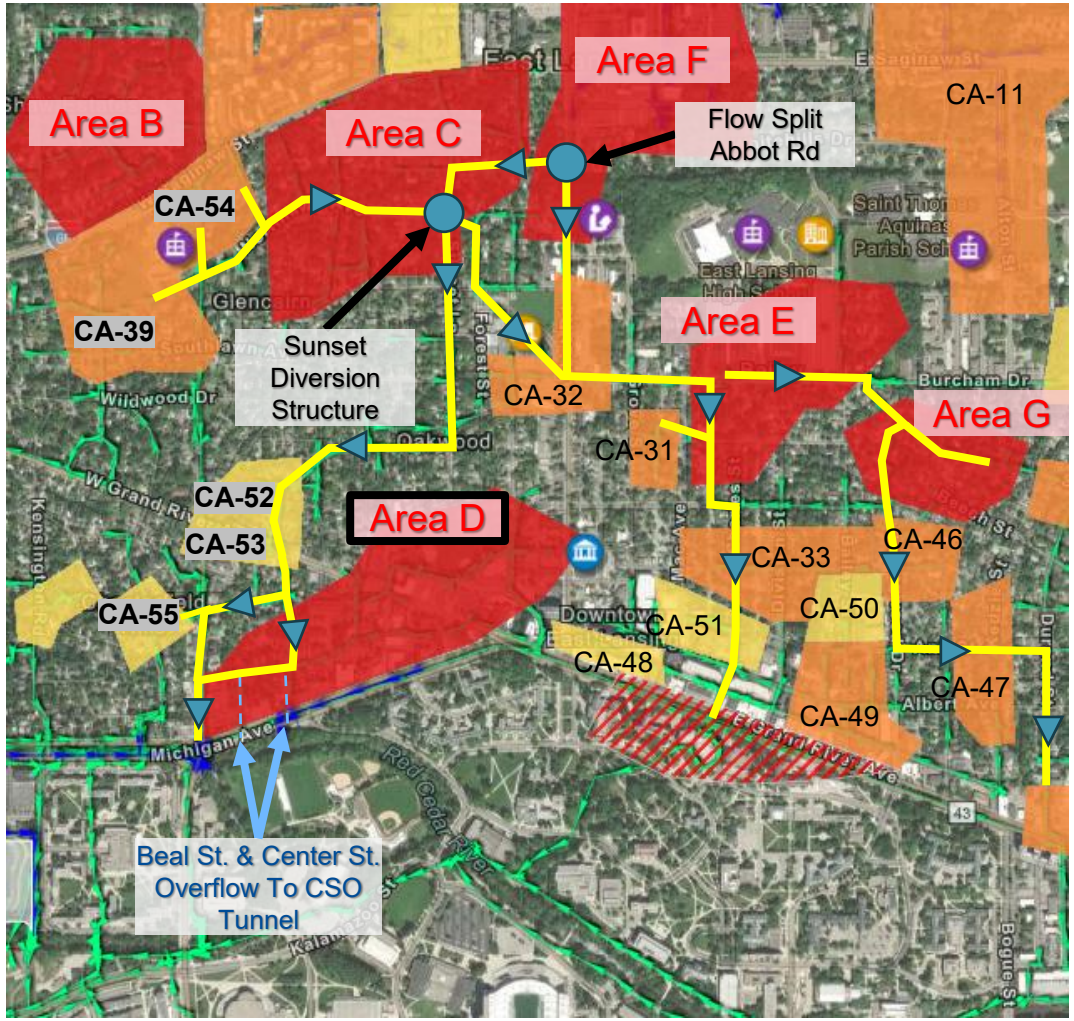


Area C – Potential Strategies

Strategy	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Description	Downstream Storage	Upstream Storage	Sewer Separation to Area D	None Identified
Location	Shaw Park, Library, Hannah CC	Glencairn Elementary	Sunset Ln	
Function	Detain & Treat	Detain & Treat	Conveyance	
MCDA Criteria				
Improved Drainage	High	Med	High	
City Resiliency Alignment	High	High	Low	
Water Quality	High	Med	Med	
Impervious Surface Reduction	Low	Low	Low	
Social and Econ Impacts	Med	Med	Med	
High Impact	High	Med	High	
Ease of Constructability	Med	Med	Low	
Level of Maintenance	High	Med	Low	
LOS Impact	Med	Low	High	

Area D – Michigan Ave and W Grand River Ave

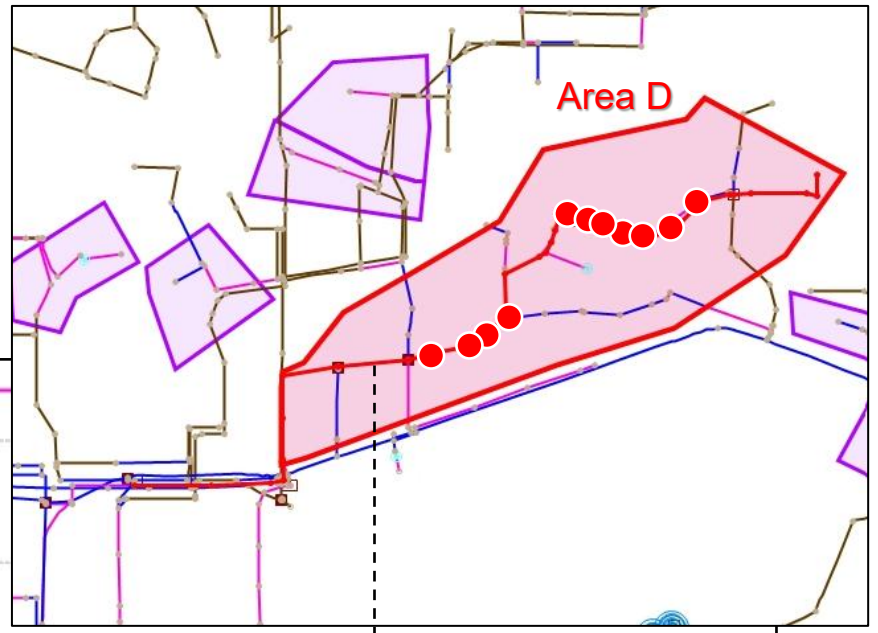
Criteria	
System (MS4/CSS)	CSS
Description of Problem	Surface Flooding; Sewer Surcharge for 10yr1hr Design Storm
Streets Impacted	Valley Ct, Elm Pl, W Grandview Ave
Existing LOS from Model	< 1-year
Root Cause	Sewer Capacity
Area Previously Identified for MP/CIP Project by City?	Yes
Hydraulically Connected to Other Flooding Concern Area?	Yes Area D is downstream of Area C (relief sewer)
Other Adjacent Non-Top 8 Areas	CA_39, CA_52, CA_53, CA_54, CA_55

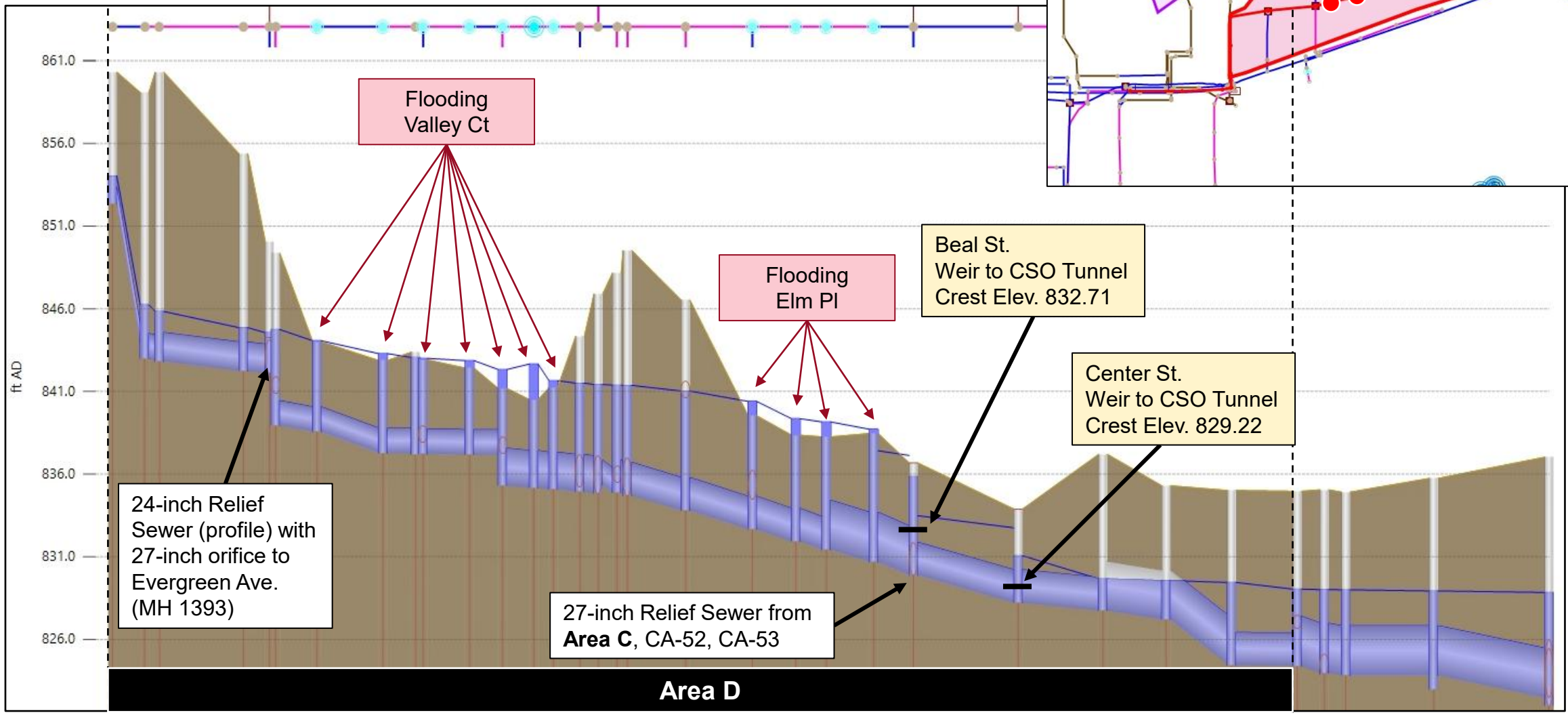


Area D - Model HGL Results

Valley Ct to E. Michigan Ave

10yr, 1hr Design Storm

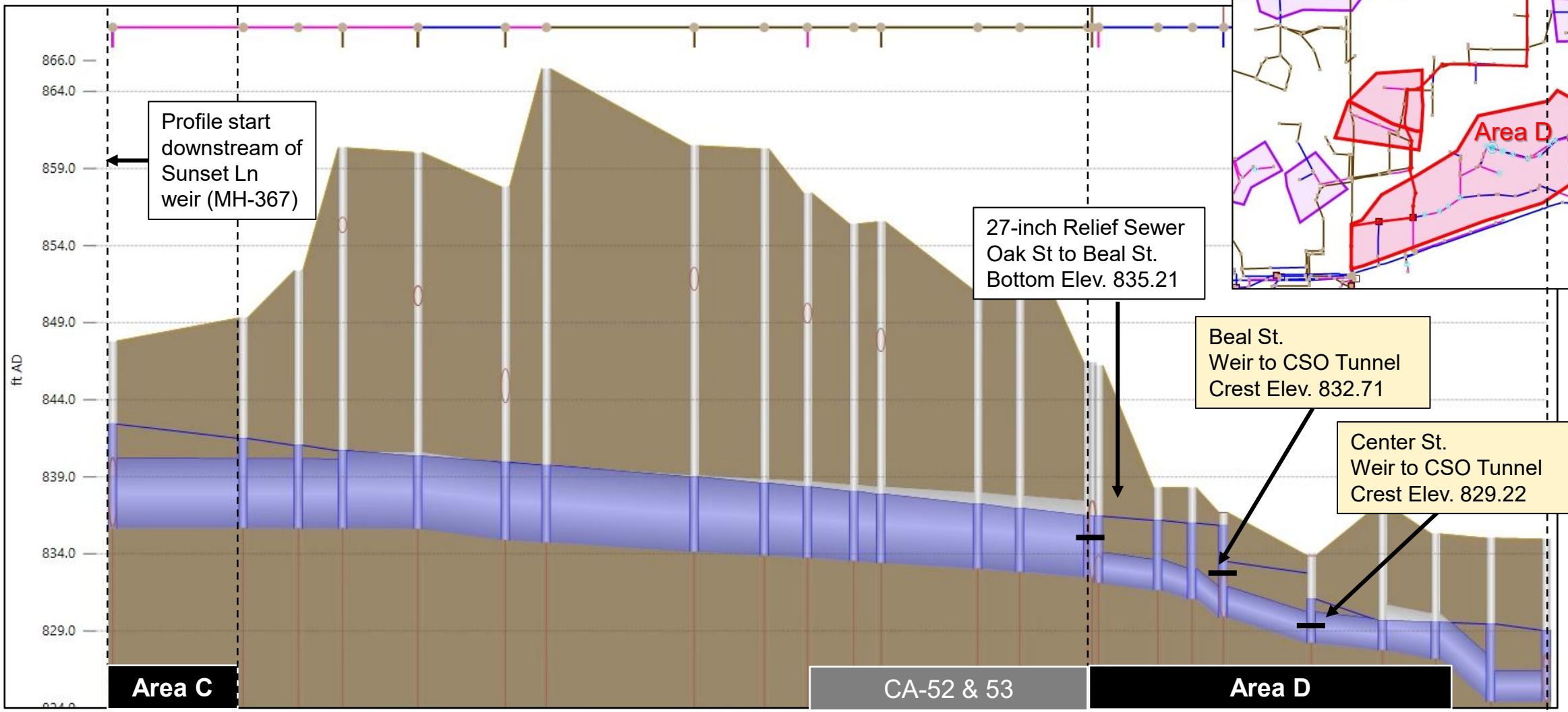


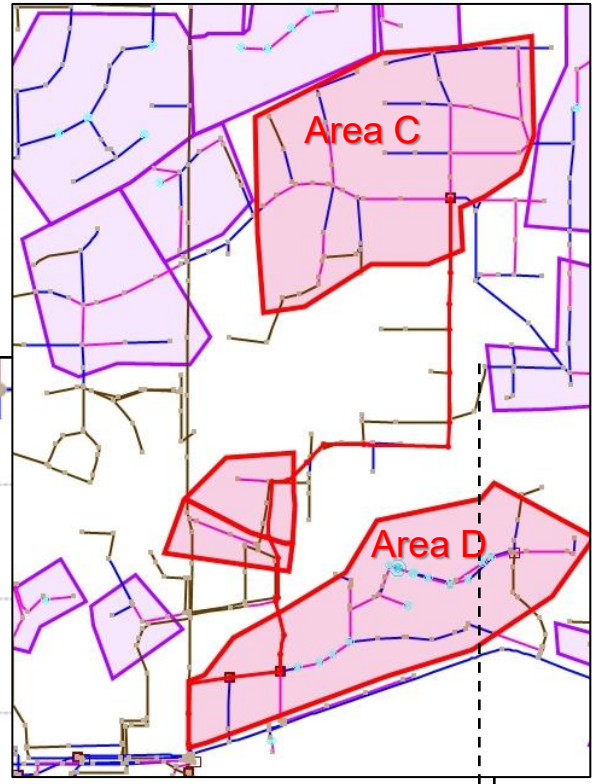


Area C&D - Model HGL Results

Sunset Ln to Michigan Ave

10yr, 1hr Design Storm

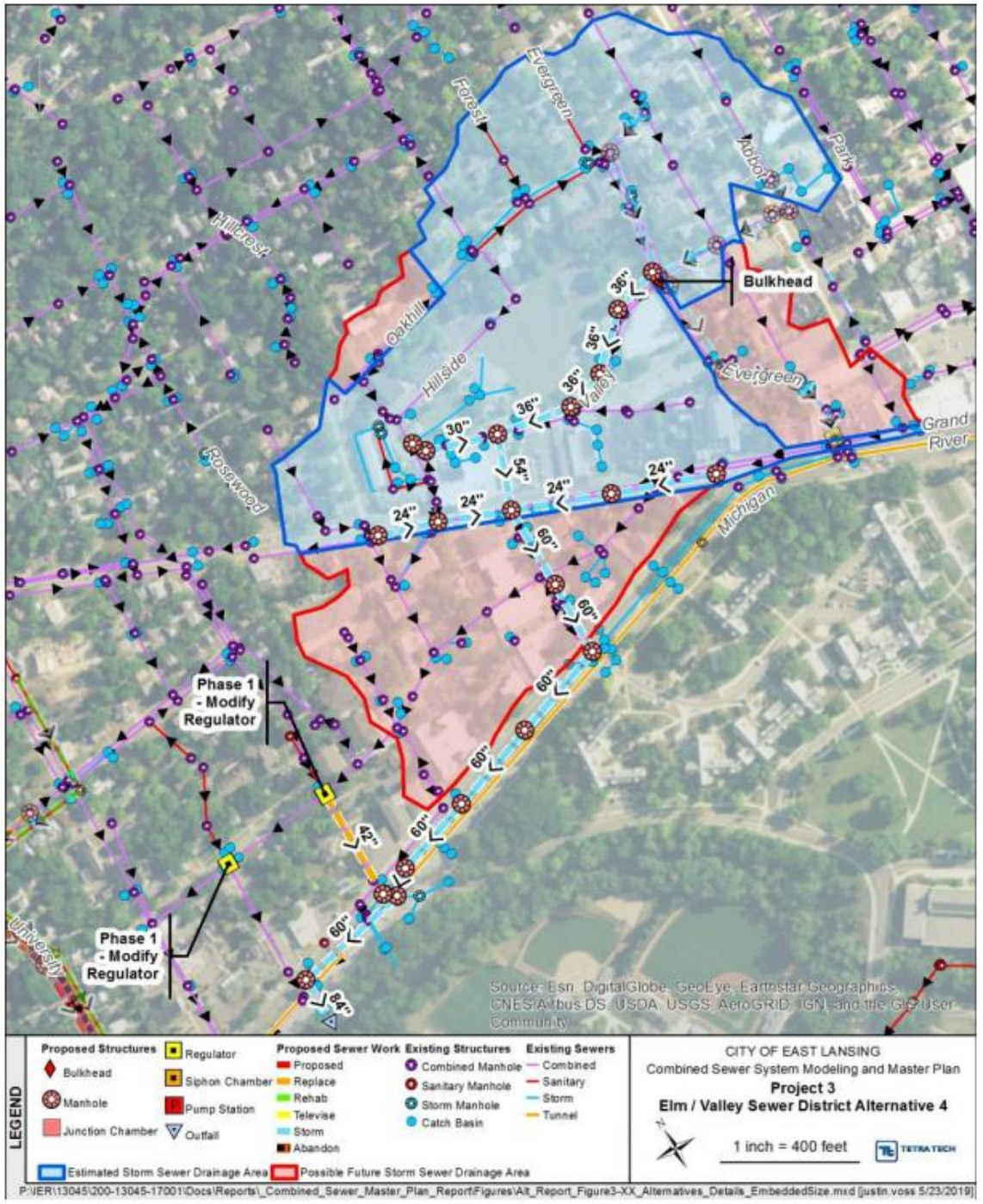




Strategy 1 – Sewer Separation

- City CIP Project
- New storm sewers and outfall to Red Cedar River
- New Stormceptor for water quality
- Regulator modifications to increase flow capacity to tunnel

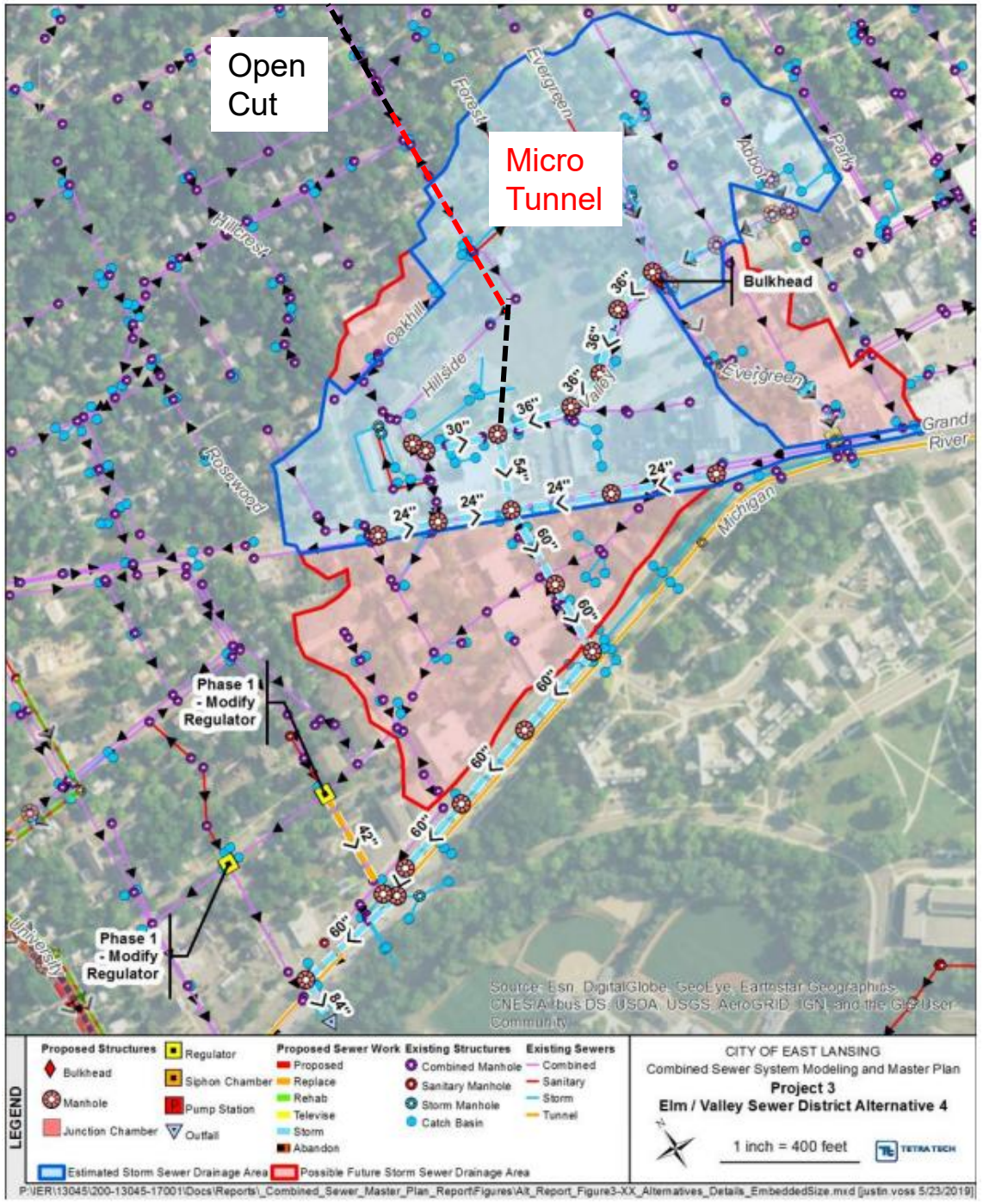
Figure 3-9. Project 3 Alternative 4 Elm / Valley District Sewer District Improvements Concept Map



Strategy 2 – Sewer Separation Expanded

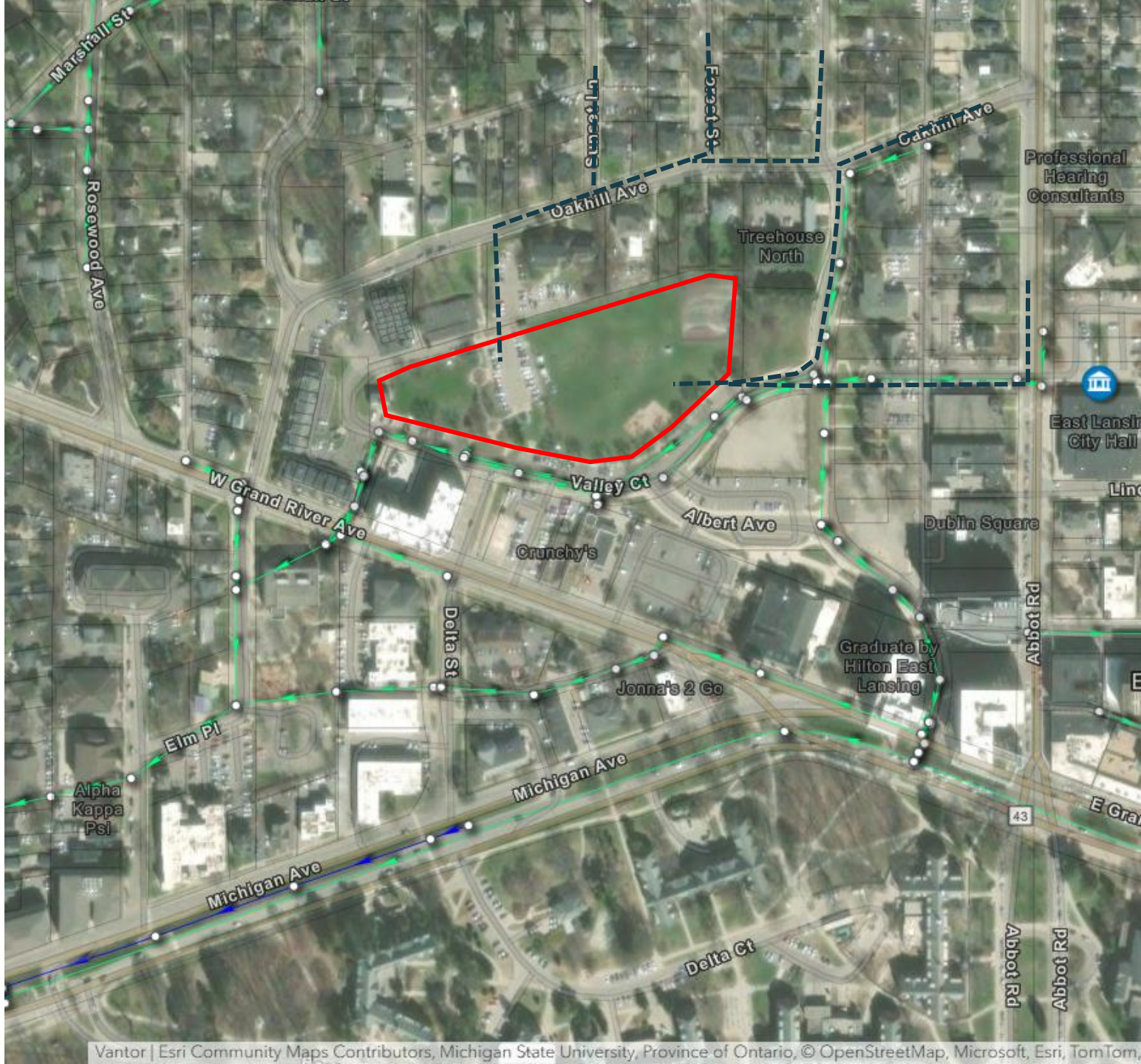
- Same as Strategy 1 but combine with Area C separation
- Likely will increase size of pipes shown in CIP Project

Figure 3-9. Project 3 Alternative 4 Elm / Valley District Sewer District Improvements Concept Map



Strategy 3 – Storage in Valley Court Park

- Construct new high level storm sewers
- Detain, infiltrate (if feasible), and slow release in potential storage area at Valley Court Park
- Could be a combination of surface and subsurface storage



Strategy 4 – Storage in Valley Court Park Expanded

- Same as Strategy 3 but combine with Area C separation
- Will increase size of storage needed

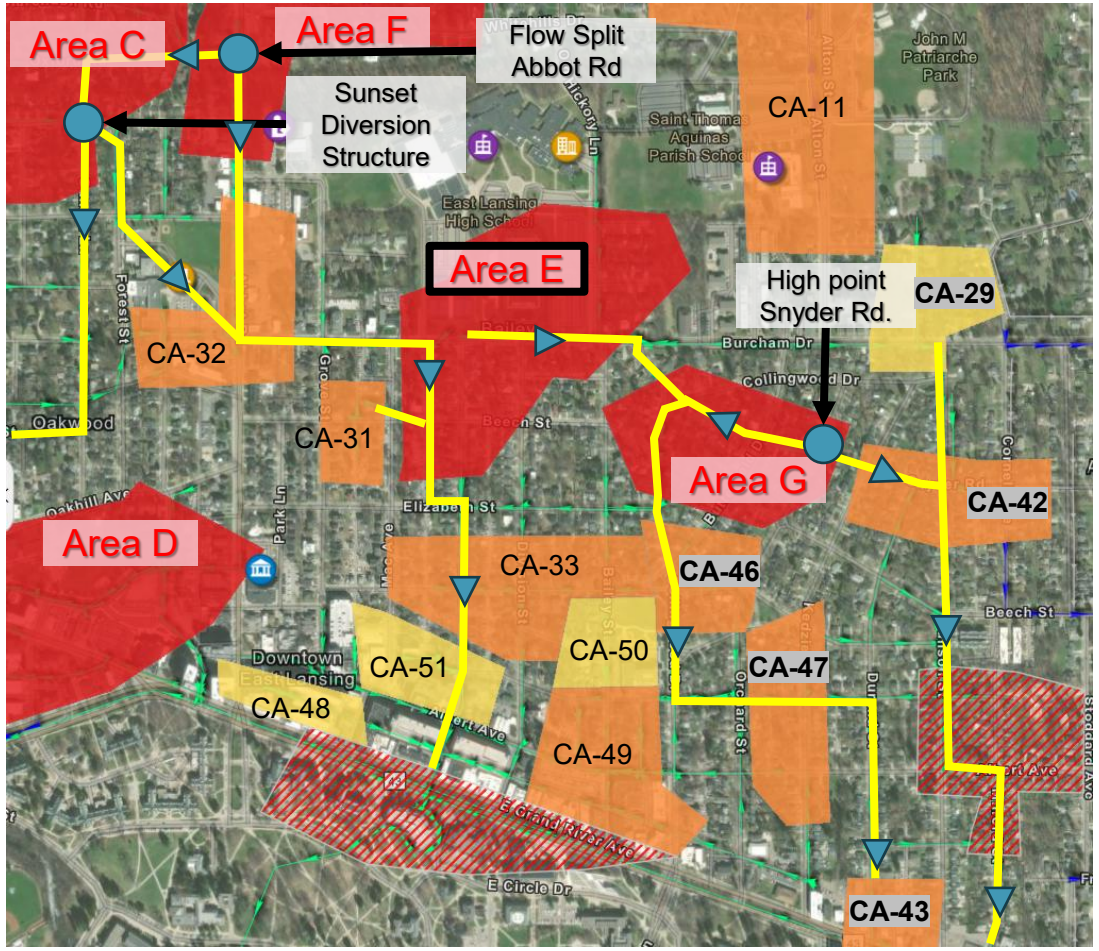


Area D – Potential Strategies

Strategy	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Description	Separation (City CIP)	Separation Expanded	Valley Court Storage	Valley Court Storage Expanded
Location	Michigan & Grand River	Michigan & Grand River	Valley Court Park	Valley Court Park
Function	Conveyance	Conveyance	Detain & Treat	Conveyance + Detain & Treat
MCDA Criteria				
Improved Drainage	High	High	High	High
City Resiliency Alignment	Low	Low	High	High
Water Quality	Low	Low	High	High
Impervious Surface Reduction	Low	Low	Low	Low
Social and Econ Impacts	Med	Med	High	High
High Impact	Med	High	High	High
Ease of Constructability	Med	Low	Low	Low
Level of Maintenance	Low	Low	High	High
LOS Impact	Med	High	Med	High

Area E – Burcham Dr

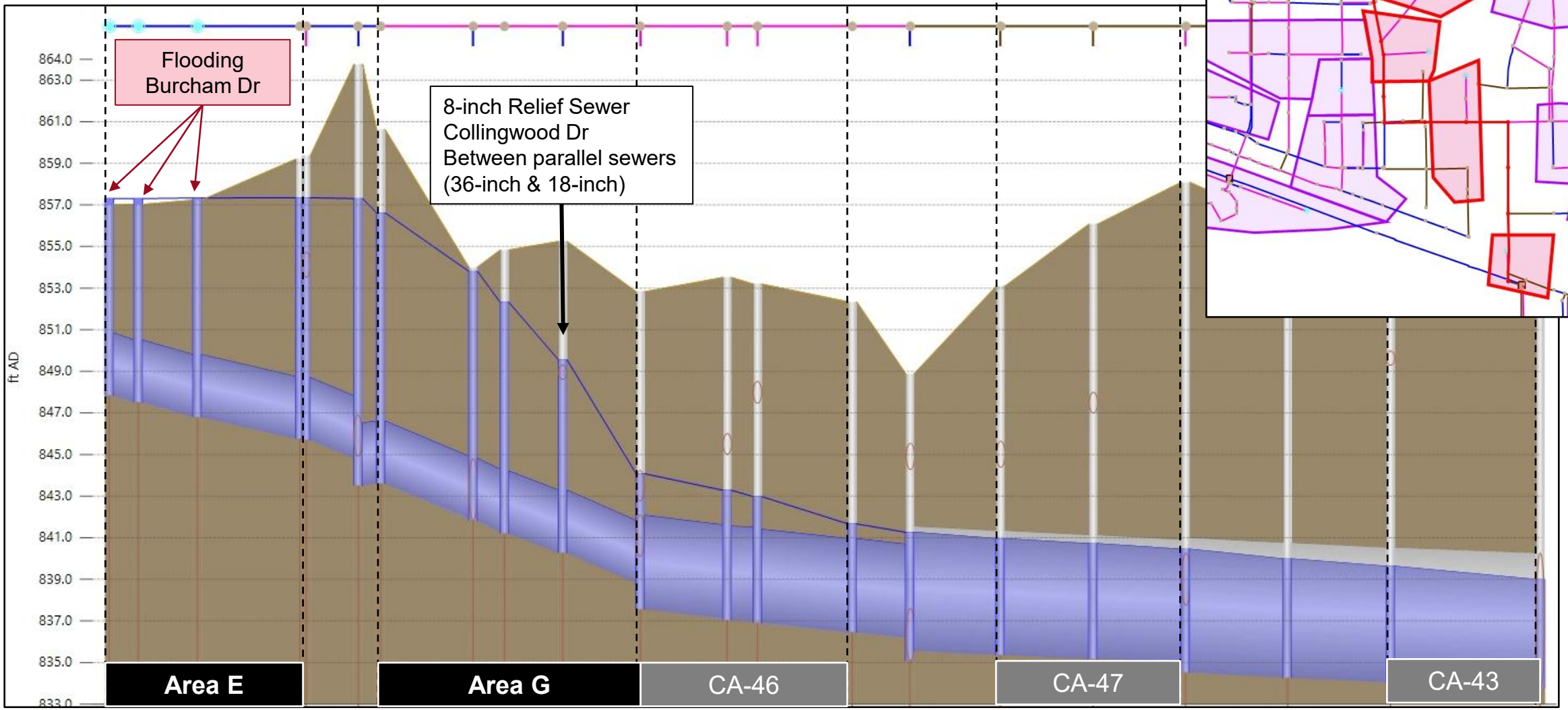
Criteria	
System (MS4/CSS)	CSS
Description of Problem	Surface Flooding; Sewer Surcharge for 10yr1hr Design Storm
Streets Impacted	Burcham Dr, Old Hickory Ln, Charles St, Division St
Existing LOS from Model	1-year
Root Cause	Sewer Capacity
Area Previously Identified for MP/CIP Project by City?	Yes
Hydraulically Connected to Other Flooding Concern Area?	Yes Area E is upstream and delivers flow into Area G
Other Adjacent Non-Top 8 Areas	CA_29, CA_42, CA_43, CA_46, CA_47

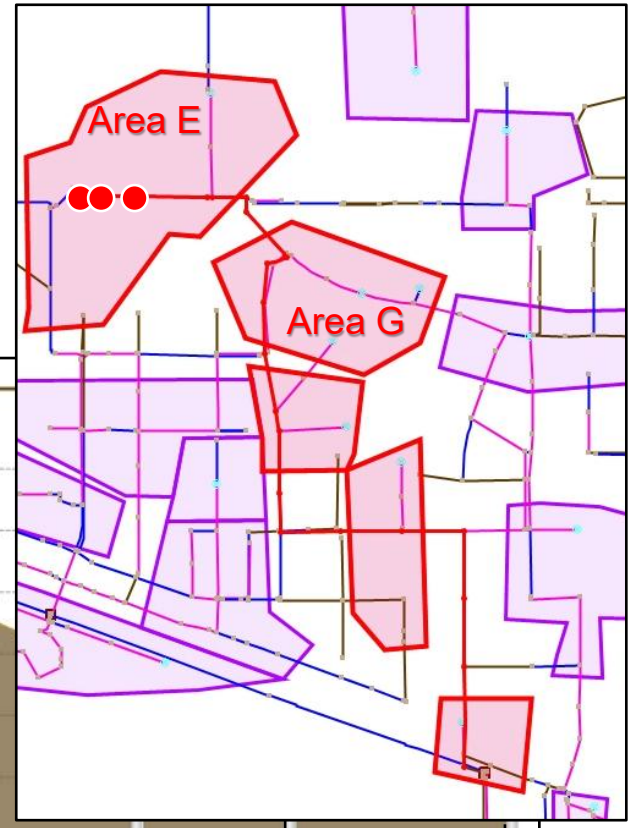


Area E&G - Model HGL Results

Burcham Dr to E Grand River Ave

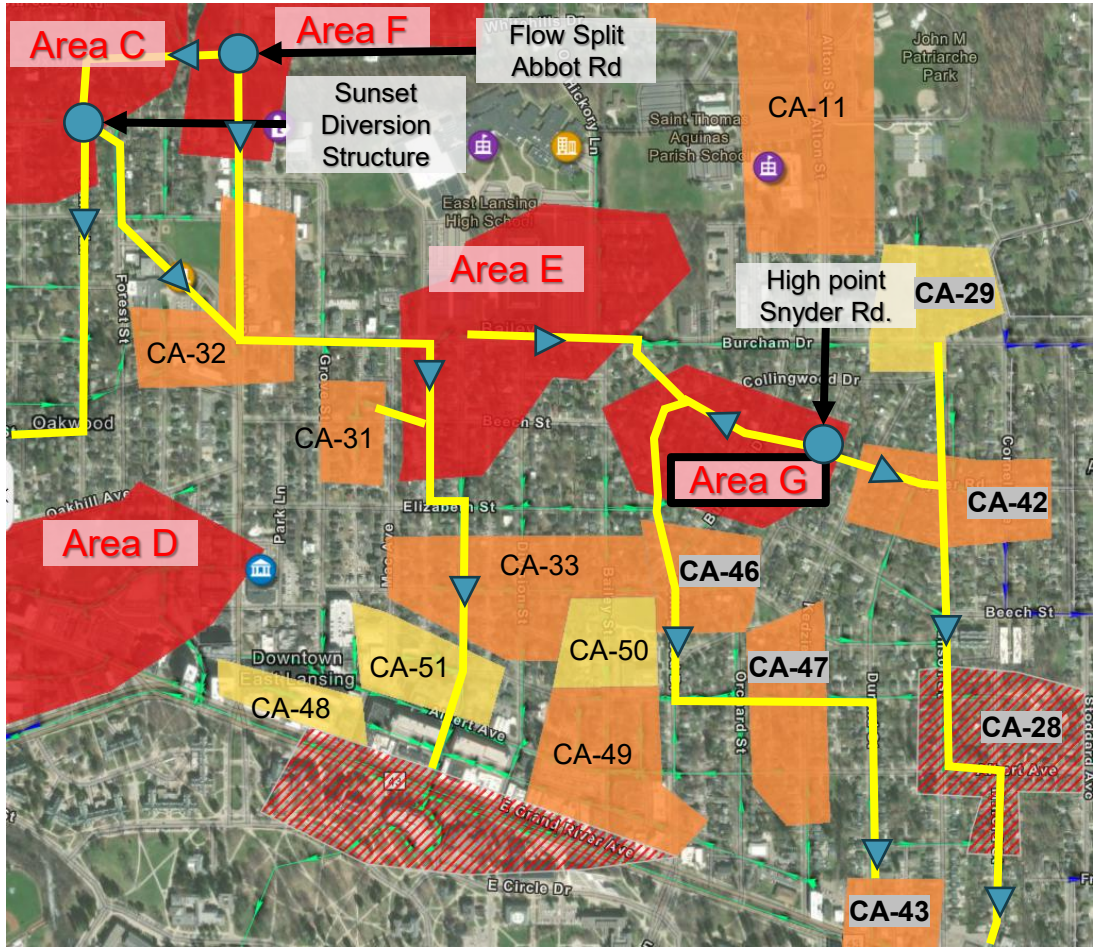
10yr, 1hr Design Storm





Area G – Beech St and Collingwood Dr

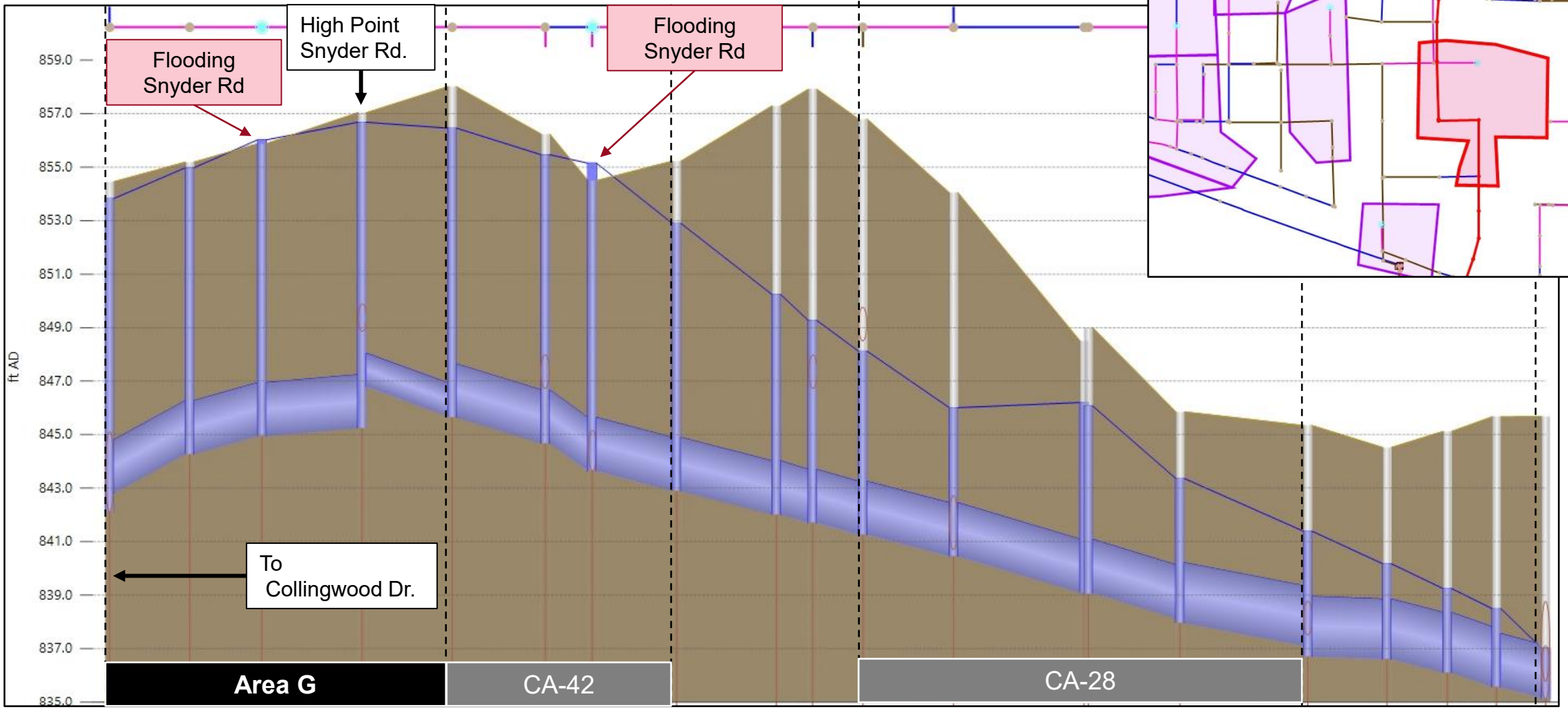
Criteria	
System (MS4/CSS)	CSS
Description of Problem	Surface Flooding; Sewer Surcharge for 10yr1hr Design Storm
Streets Impacted	Snyder Rd, Beech St, Butterfield Dr
Existing LOS from Model	1-year
Root Cause	Sewer Capacity
Area Previously Identified for MP/CIP Project by City?	No
Hydraulically Connected to Other Flooding Concern Area?	Yes Area G is downstream of Area E
Other Adjacent Non-Top 8 Areas	CA_28, CA_29, CA_42, CA_43, CA_46, CA_47

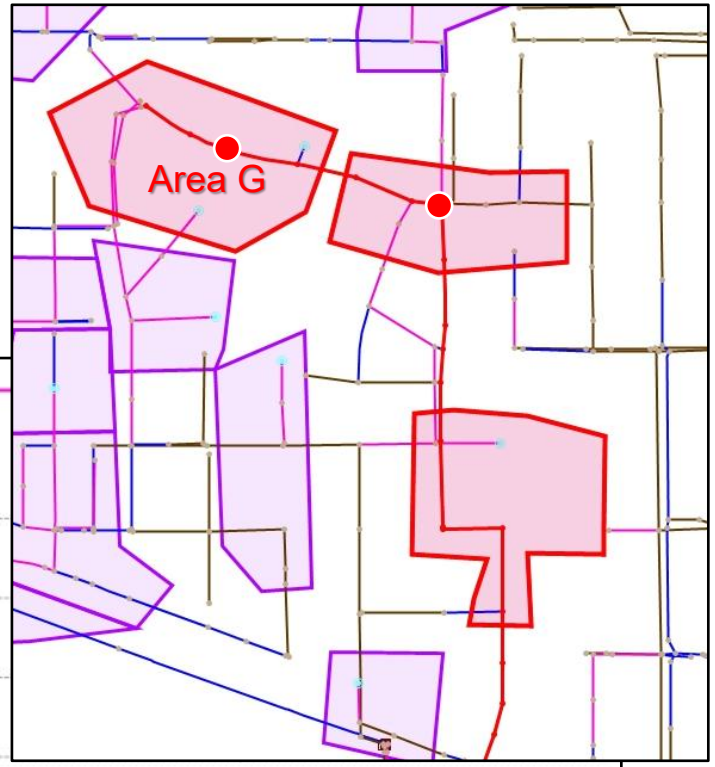


Area G - Model HGL Results

Snyder Rd to E Grand River Ave

10yr, 1hr Design Storm





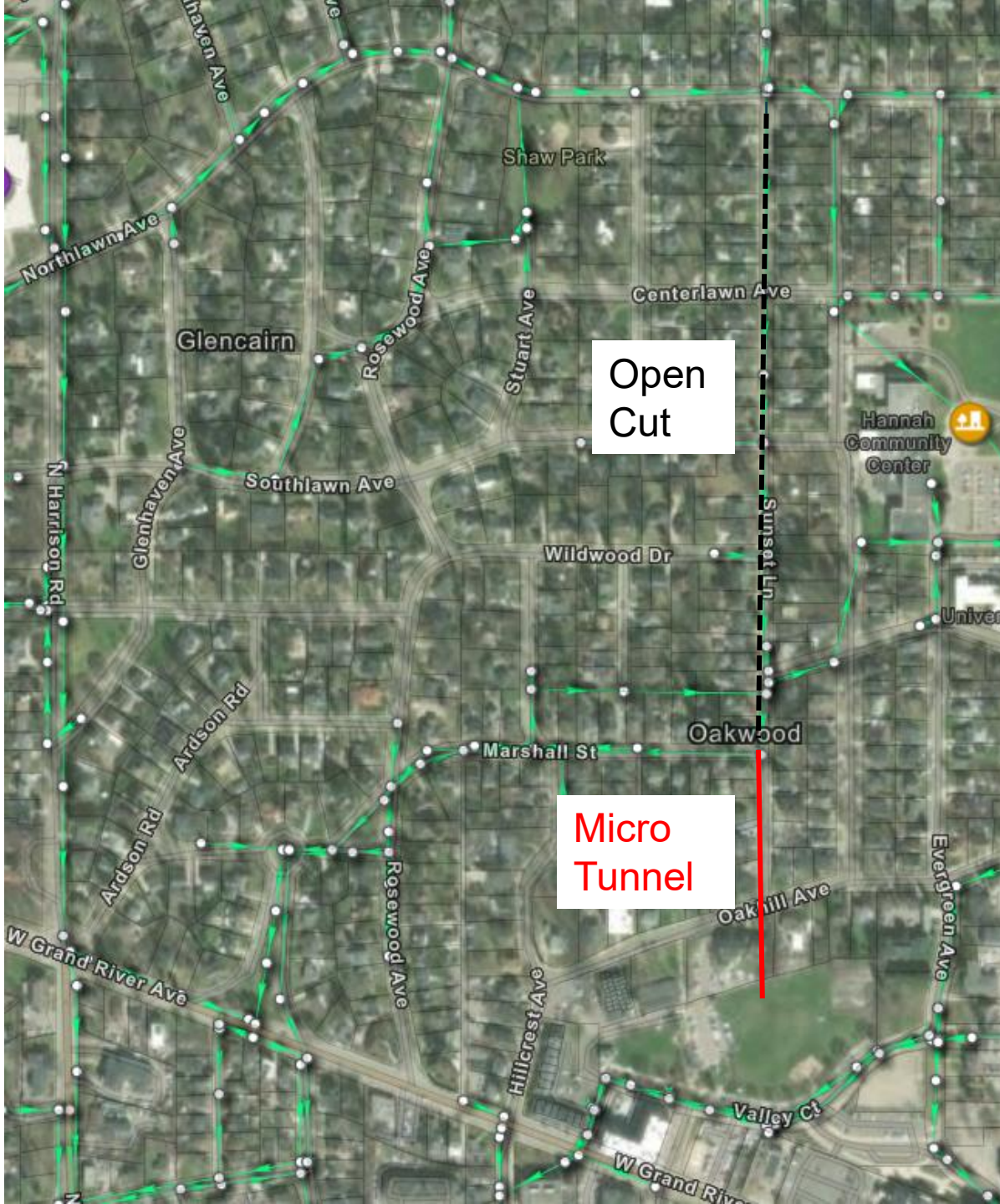
Strategy 1 – Upstream Local Storage

- Investigate benefits of upstream storage as part of Area C strategy
- Likely to have beneficial impacts on Areas E and G



Strategy 2 – Upstream Separation

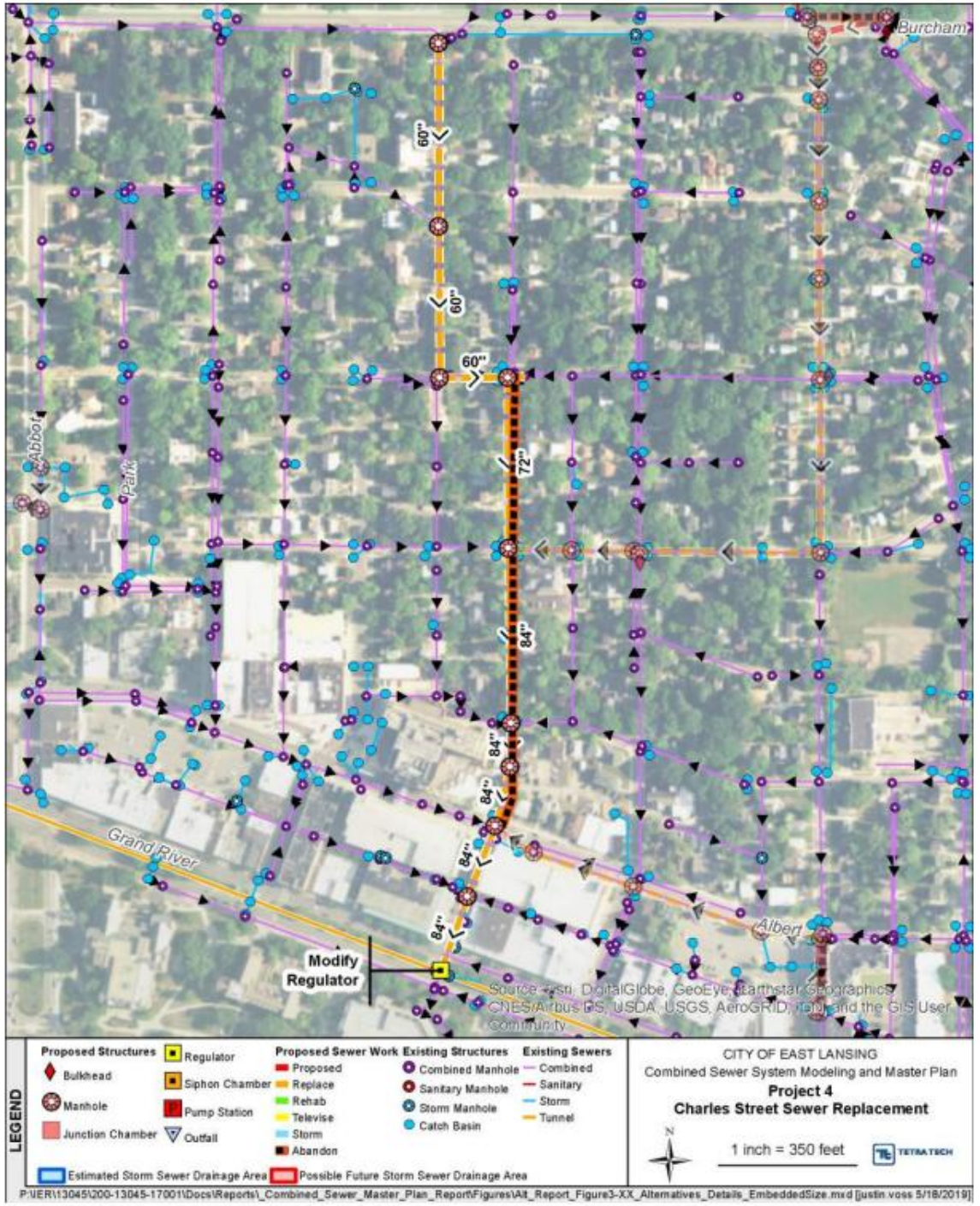
- Investigate benefits of improvements upstream separation as part of combined Area C and D strategy
- Likely to have beneficial impacts on Areas E and G



Strategy 3 – Downstream Sewer Upsizing

- City CIP Project
- Upsize existing CSS trunk sewer along Charles Street
- Modification of regulator at Grand River is to increase flows to the tunnel.

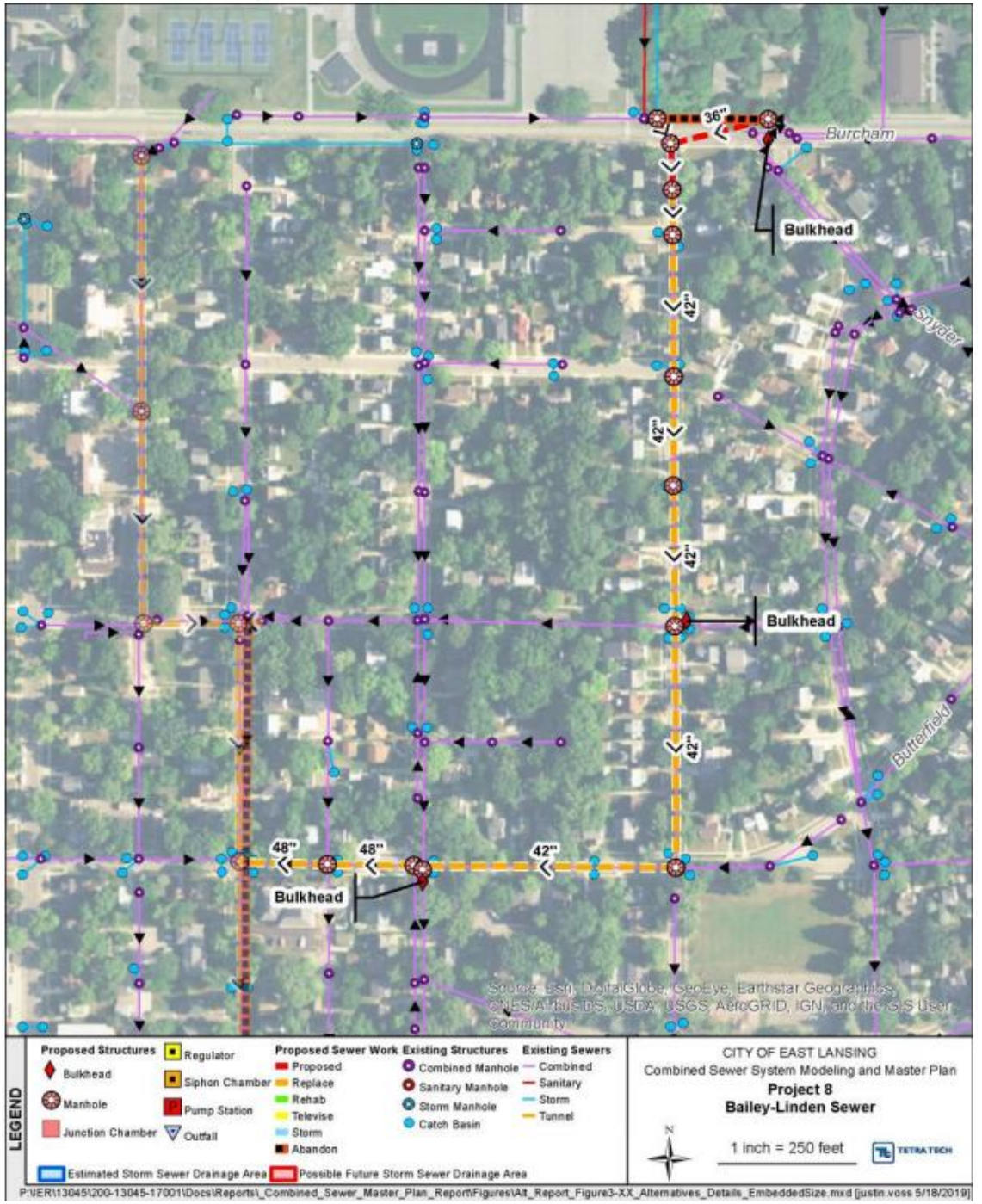
Figure 3-10. Project 4 Charles Street Sewer Replacement Concept Map



Strategy 4 – Sewer Diversion

- City CIP Project
- Bulkhead sewer and divert flows away from Area G.
- Construct new CSS sewer on Bailey St and Linden St and utilize upsized Charles Street sewer.

Figure 3-18. Project 8 Bailey-Linden Sewer Concept Map

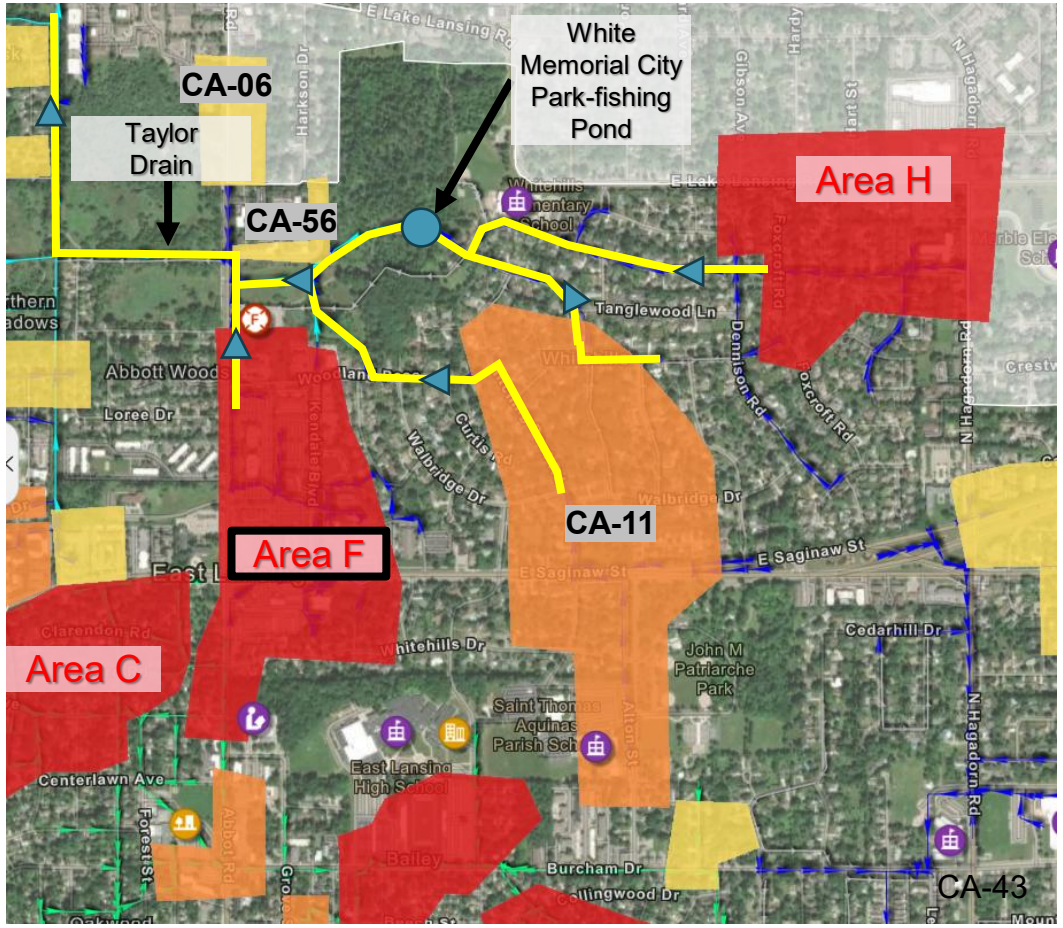


Area E & G – Potential Strategies

Strategy	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Description	Upstream Storage	Upstream Separation	Downstream Upsizing	Sewer Diversion
Location	Shaw Park, Library, Hannah CC	Sunset Ln	Charles St	Bailey St & Linden St
Function	Detain & Treat	Conveyance	Conveyance	Conveyance
MCDA Criteria				
Improved Drainage	High	High	High	Med
City Resiliency Alignment	High	Low	Low	Low
Water Quality	High	Med	Low	Low
Impervious Surface Reduction	Low	Low	Low	Low
Social and Econ Impacts	High	Med	Med	Med
High Impact	High	High		
Ease of Constructability	Med	Med	Med	Med
Level of Maintenance	High	Low	Low	Low
LOS Impact	Med	High	High	Med

Area F – Abbot Rd and E. Saginaw

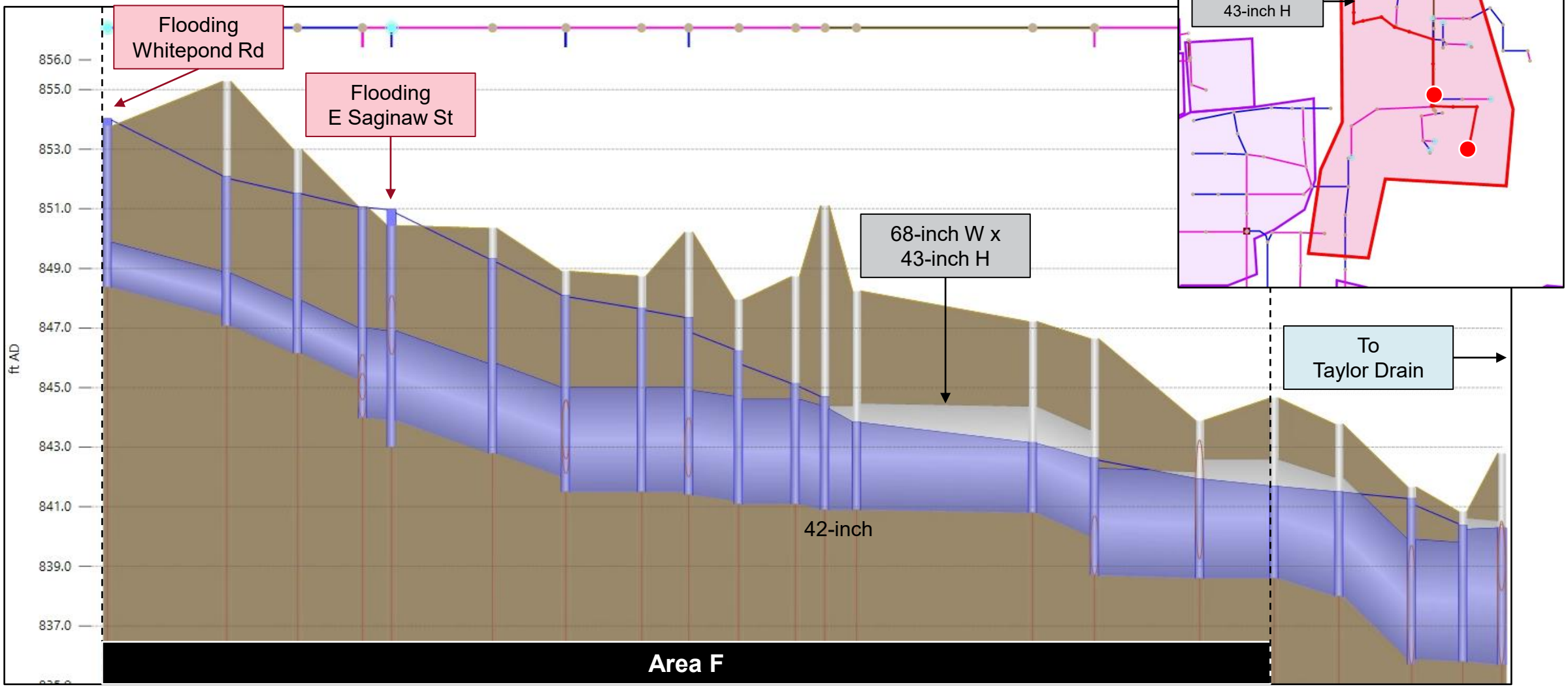
Criteria	
System (MS4/CSS)	MS4 / CSS
Description of Problem	Surface Flooding; Sewer Surcharge for 10yr1hr Design Storm
Streets Impacted	Woodland Pass, Kendale Blvd, E. Saginaw Rd, Abbot Rd (CSS)
Existing LOS from Model	<1-year (MS4) 5yr (CSS)
Root Cause	Sewer Capacity
Area Previously Identified for MP/CIP Project by City?	No
Hydraulically Connected to Other Flooding Concern Area?	Yes Area F and Area H hydraulically connected to Taylor Drain
Other Adjacent Non-Top 8 Areas	CA_06, CA_11, CA_56

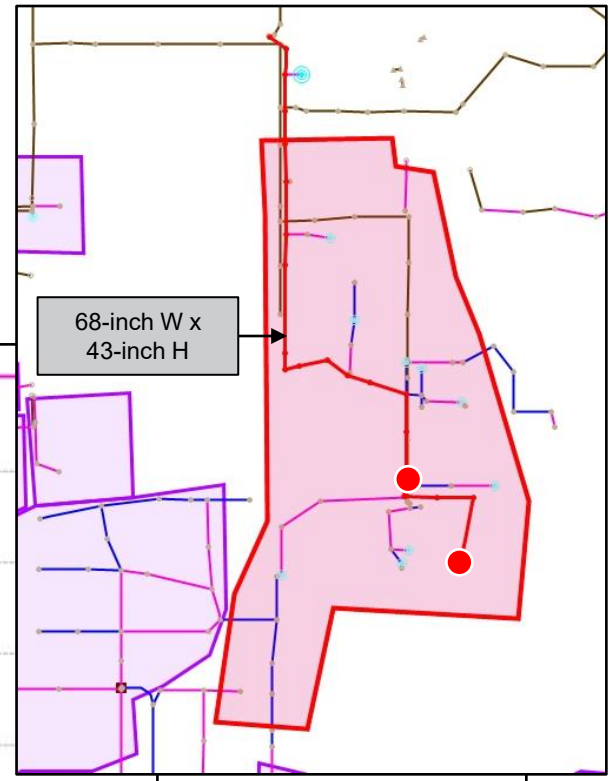


Area F - Model HGL Results (MS4)

E Saginaw St to Taylor Drain

10yr, 1hr Design Storm

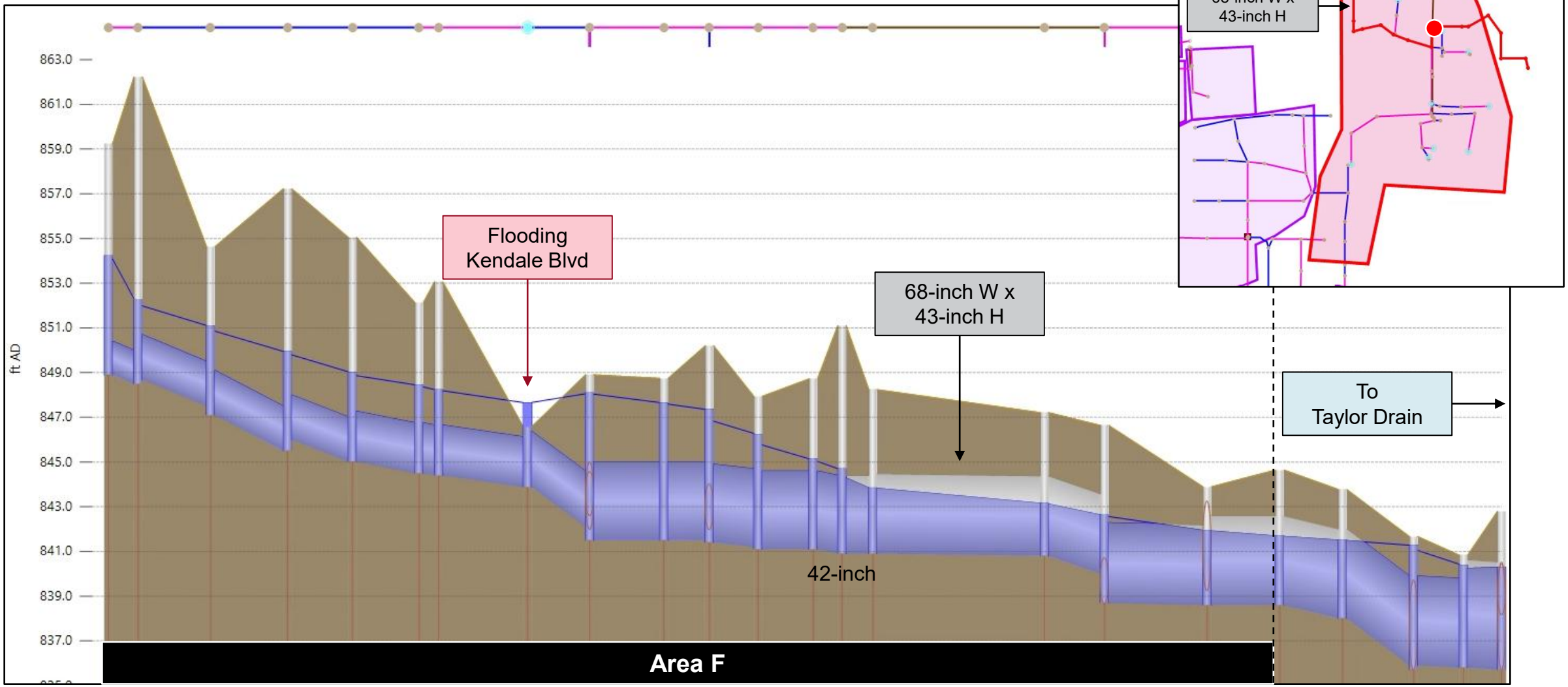


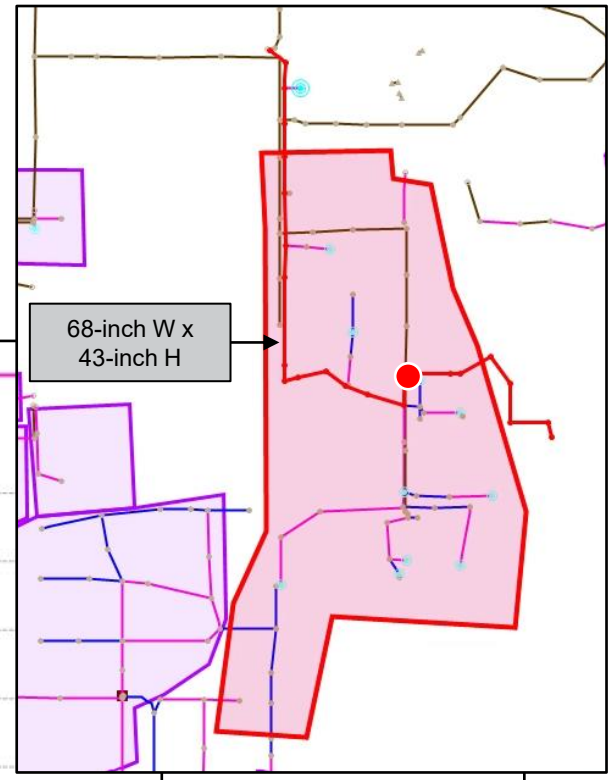


Area F - Model HGL Results (MS4)

Stanlake Dr to Taylor Drain

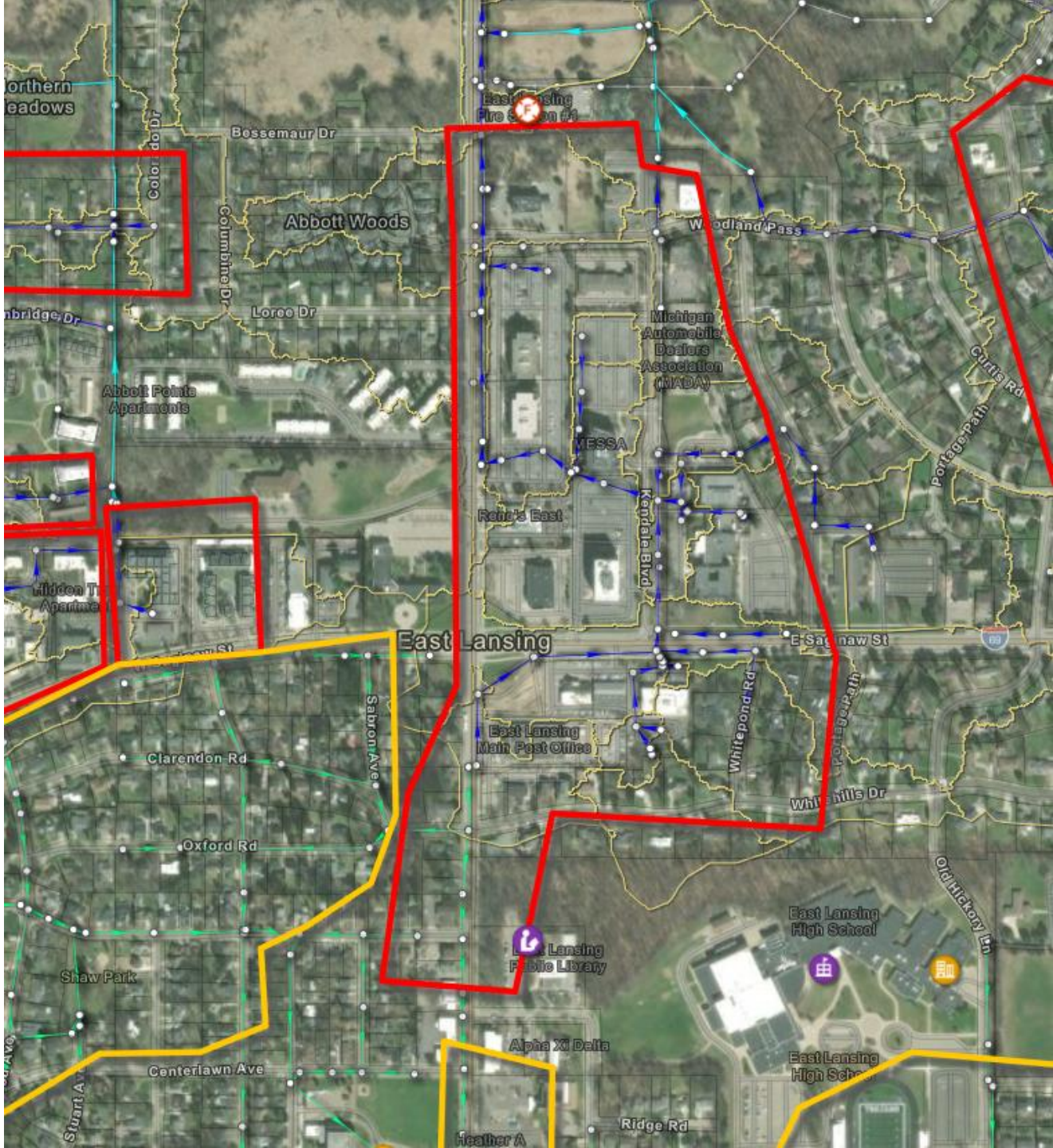
10yr, 1hr Design Storm





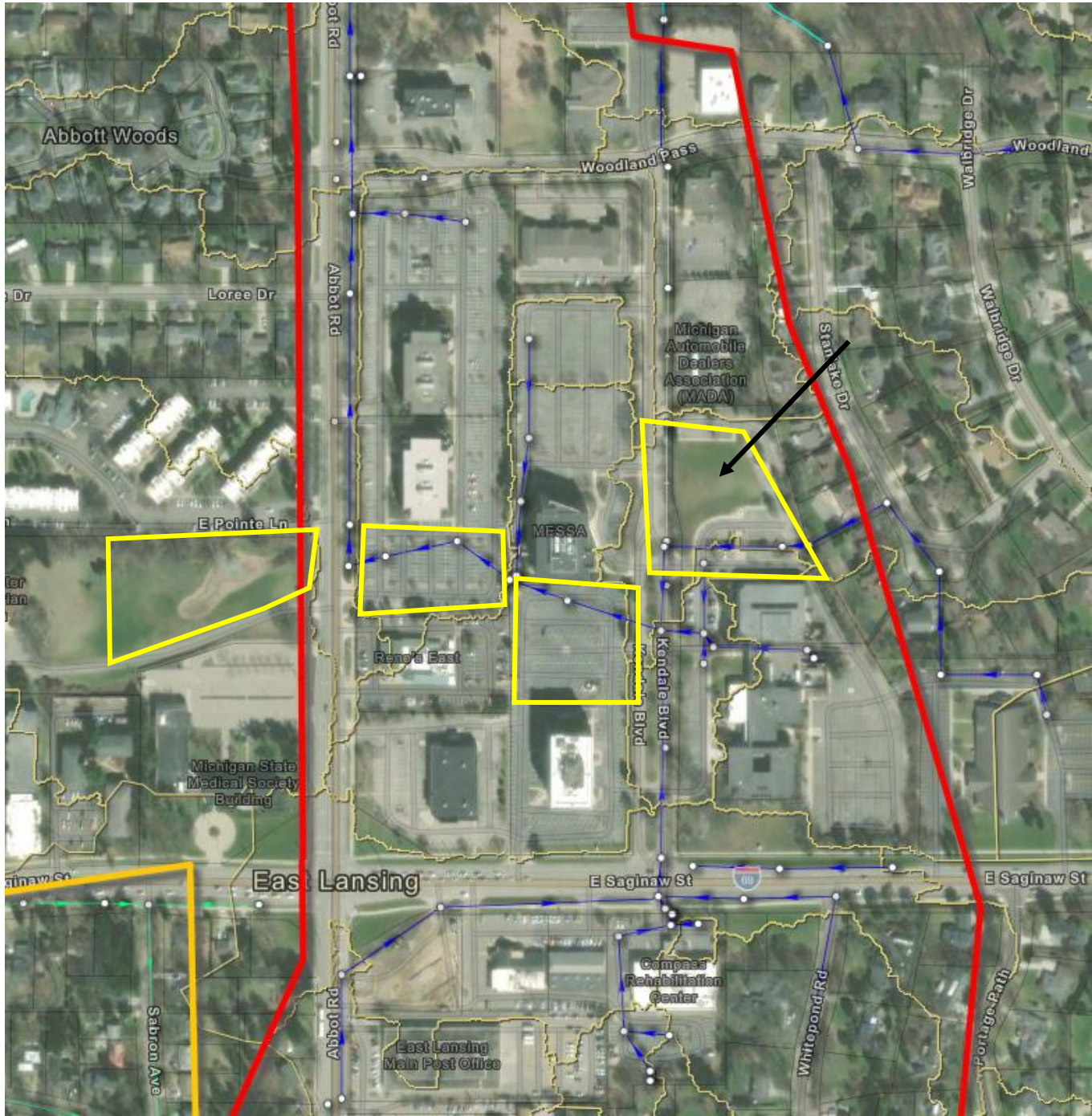
Strategy 1 – De-paving

- There are many large parking lots contributing runoff.
- Look for opportunities to work with private owners to reduce parking lots and create new green space.



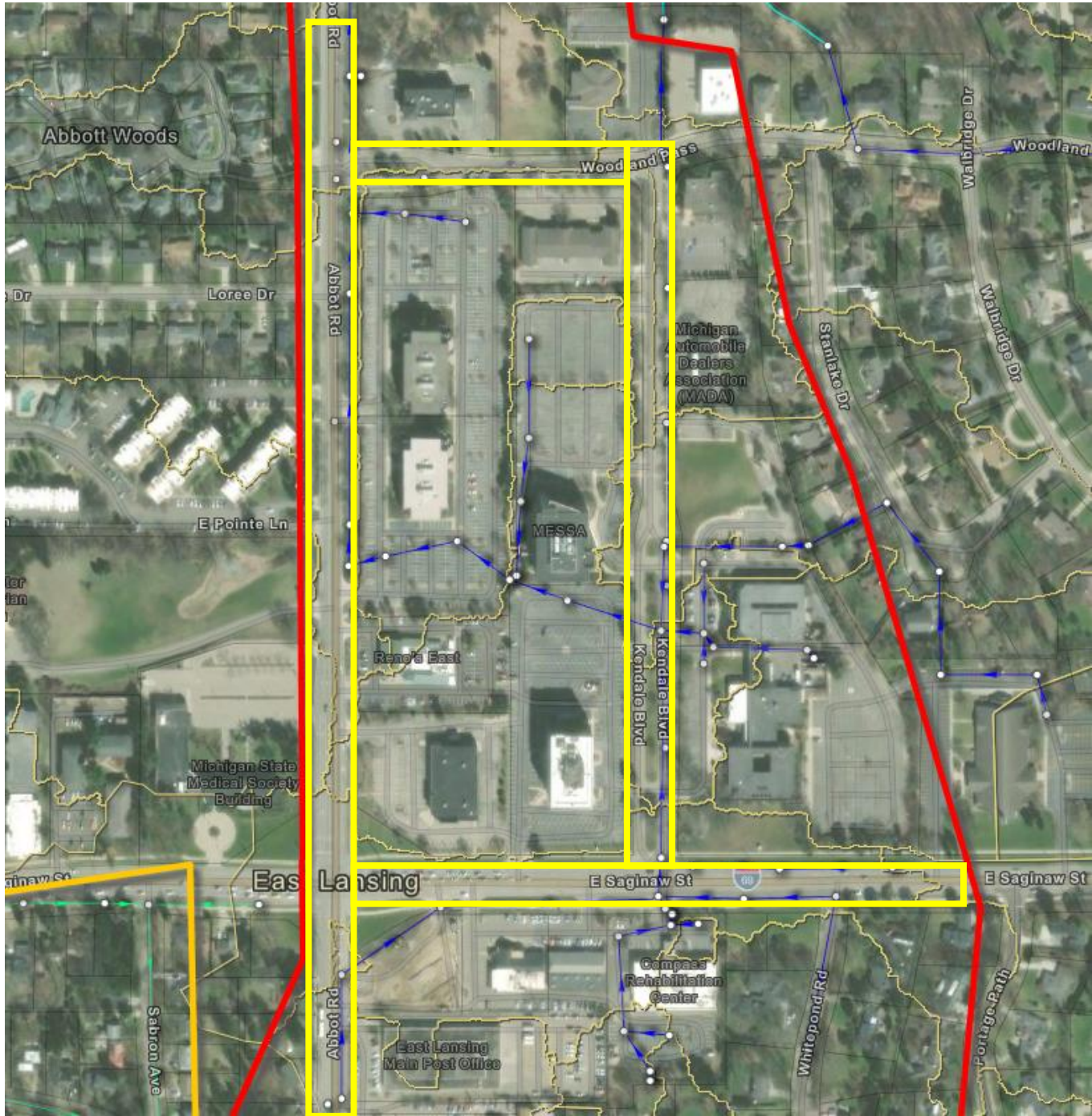
Strategy 2 – Storage

- Open area near Eastminster Presbyterian Church
- Various underground storage below parking lots
- Would require land purchase/agreements



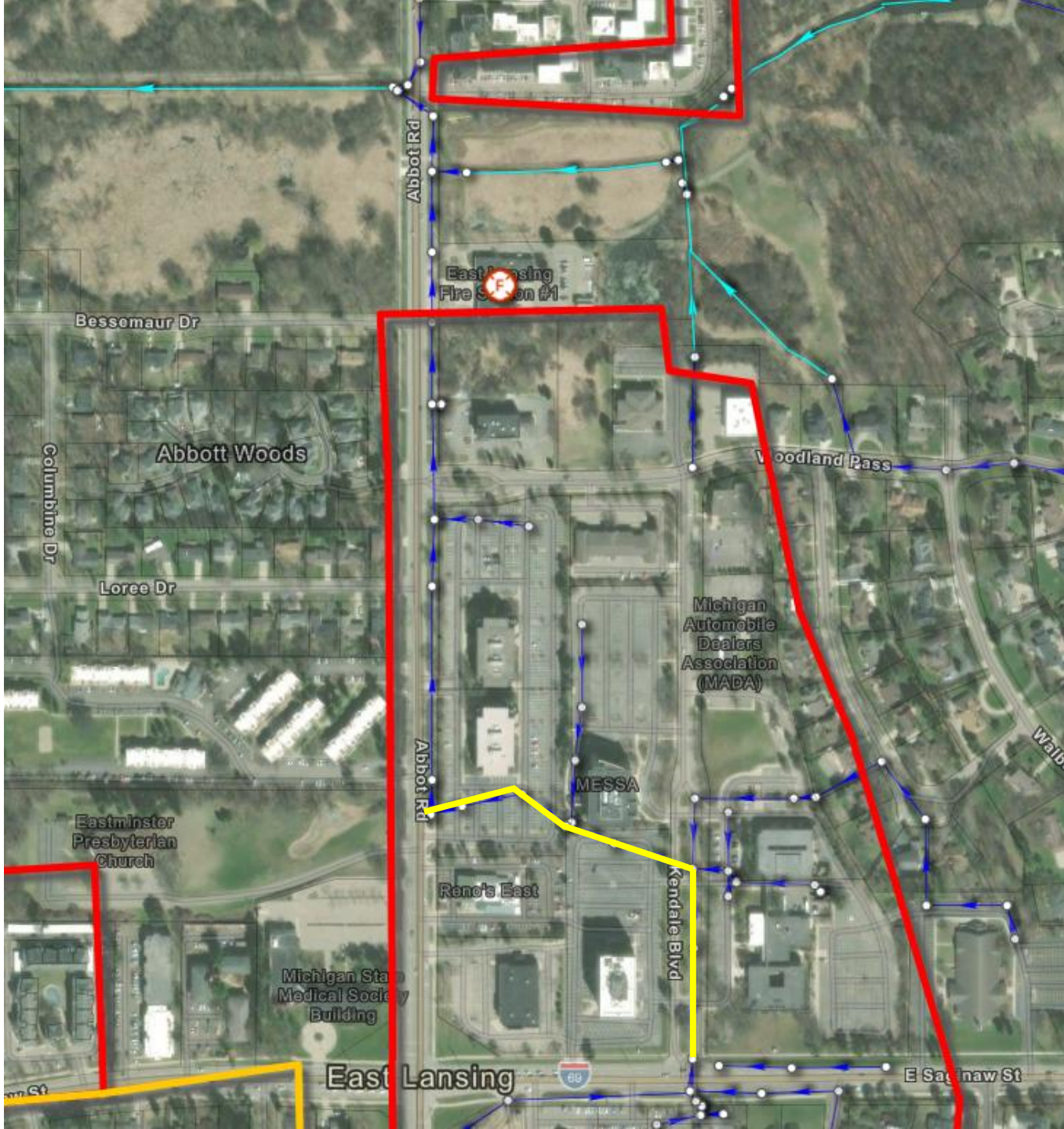
Strategy 3 – ROW Green Infrastructure

- Several wide roads in this area that could be utilized for distributed ROW green infrastructure
  - Kendale Boulevard
  - Abbot Road
  - Woodland Pass
  - E Saginaw St



Strategy 4 – Sewer Upsizing

- Increase diameters to deliver more flow downstream
- Would need to assess downstream impacts
  - The Quarters
  - County drain capacity and culverts
- Likely need storage to offset increase in peak flow

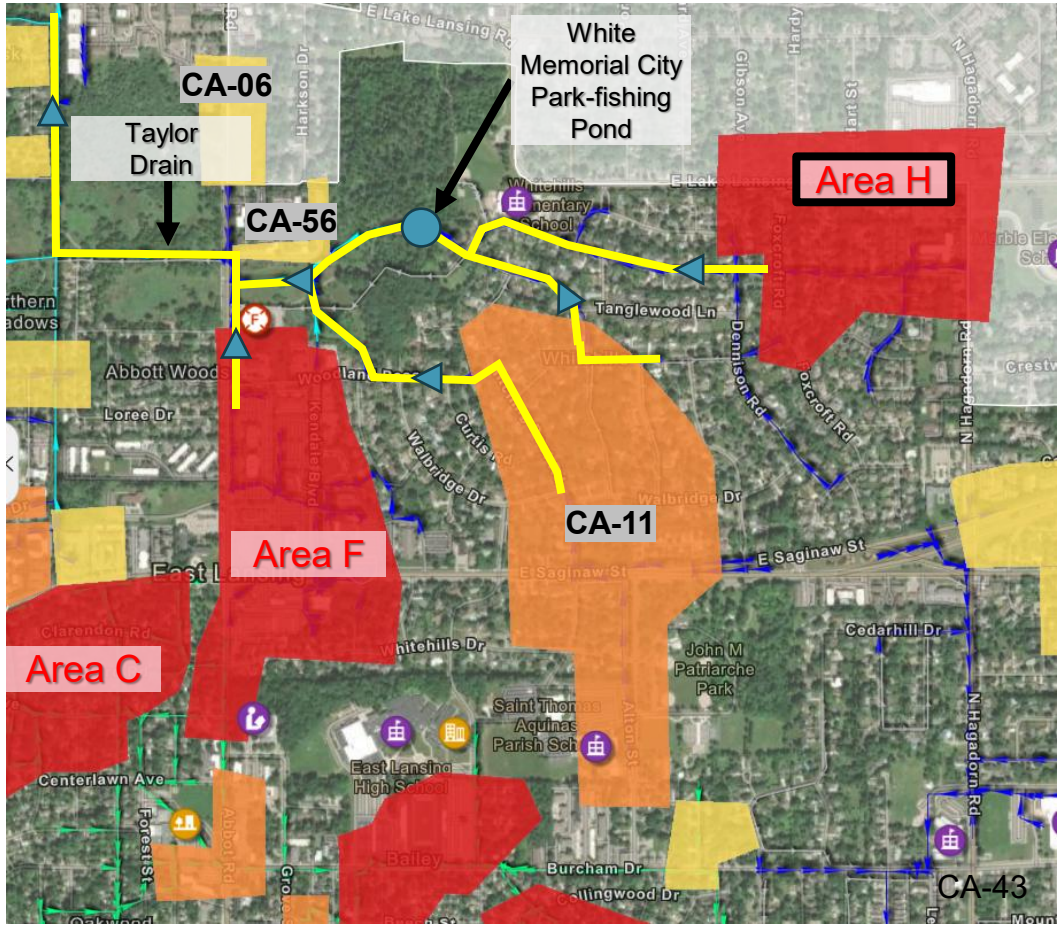


Area F– Potential Strategies

Strategy	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Description	Parking Lot Depaving	Storage	ROW Green Infrastructure	Sewer Upsizing
Location	Multiple Locations	Multiple Locations	Multiple Locations	U/S of Abott Road
Function	Flow Reduction	Detain & Treat	Detain & Treat	Conveyance
MCDA Criteria				
Improved Drainage	Med	Med	Med	High
City Resiliency Alignment	High	High	High	Med
Water Quality	High	Med	High	Low
Impervious Surface Reduction	High	Low	Med	Low
Social and Econ Impacts	Med	Low	Med	Low
High Impact	Low	Med	Med	Med
Ease of Constructability	Low	Low	Low	Med
Level of Maintenance	Low	High	High	Low
LOS Impact	Low	Med	Med	High

Area H – Pebblebrook Ln

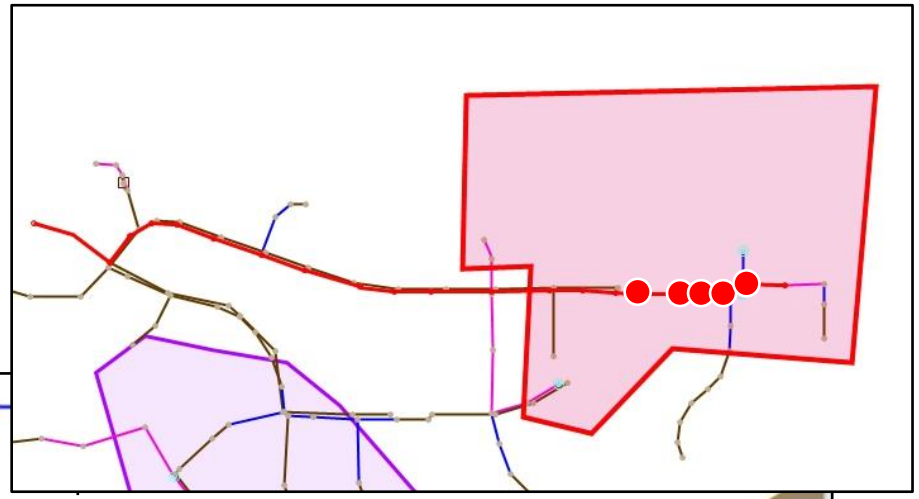
Criteria	
System (MS4/CSS)	MS4
Description of Problem	Surface Flooding; Sewer Surcharge for 10yr1hr Design Storm
Streets Impacted	Applegate Ln, Pebblebrook Ln, Wyngarden Ln
Existing LOS from Model	<1-year
Root Cause	Sewer Capacity
Area Previously Identified for MP/CIP Project by City?	No
Hydraulically Connected to Other Flooding Concern Area?	Yes Area F and Area H hydraulically connected to Taylor Drain
Other Adjacent Non-Top 8 Areas	CA_06, CA_11, CA_56

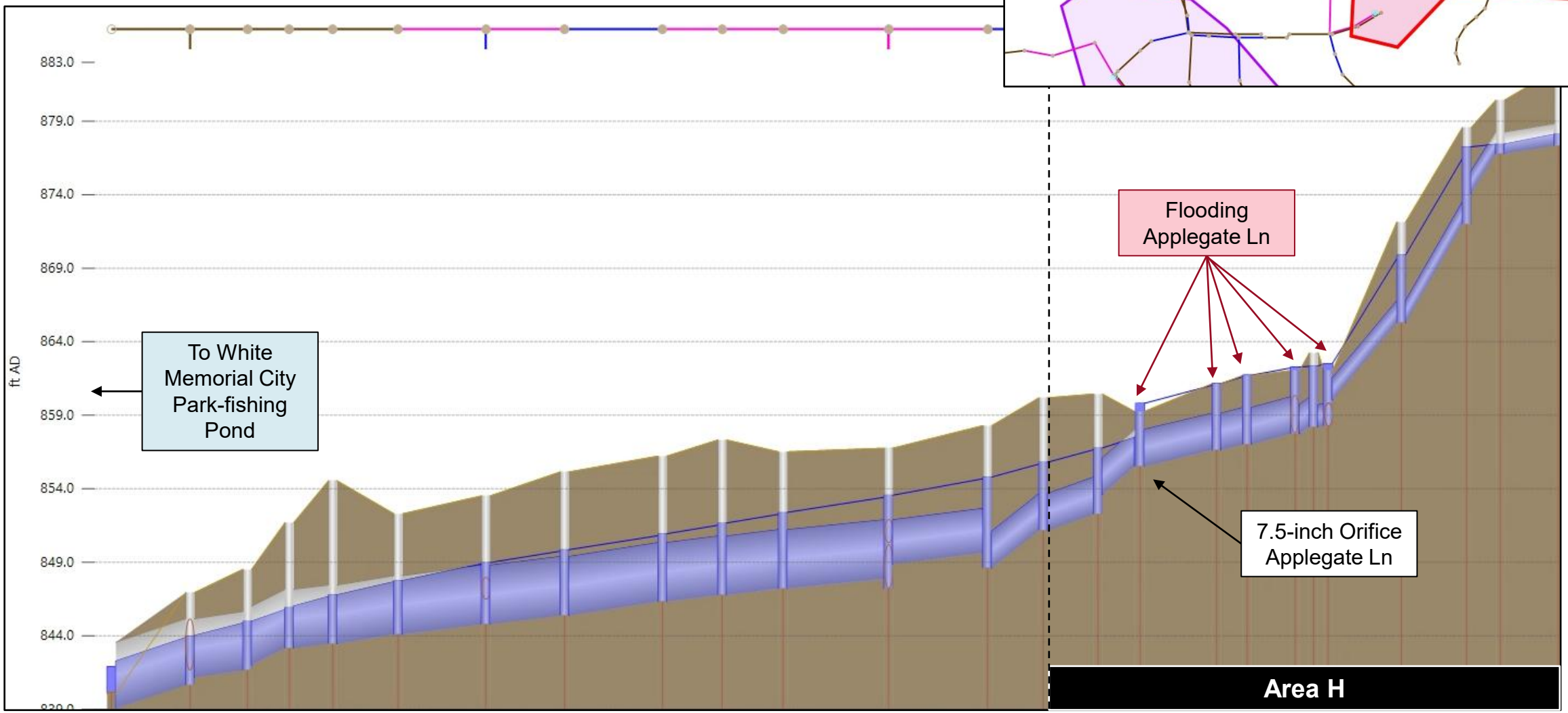


Area H - Model HGL Results

Applegate Ln to White Park Pond

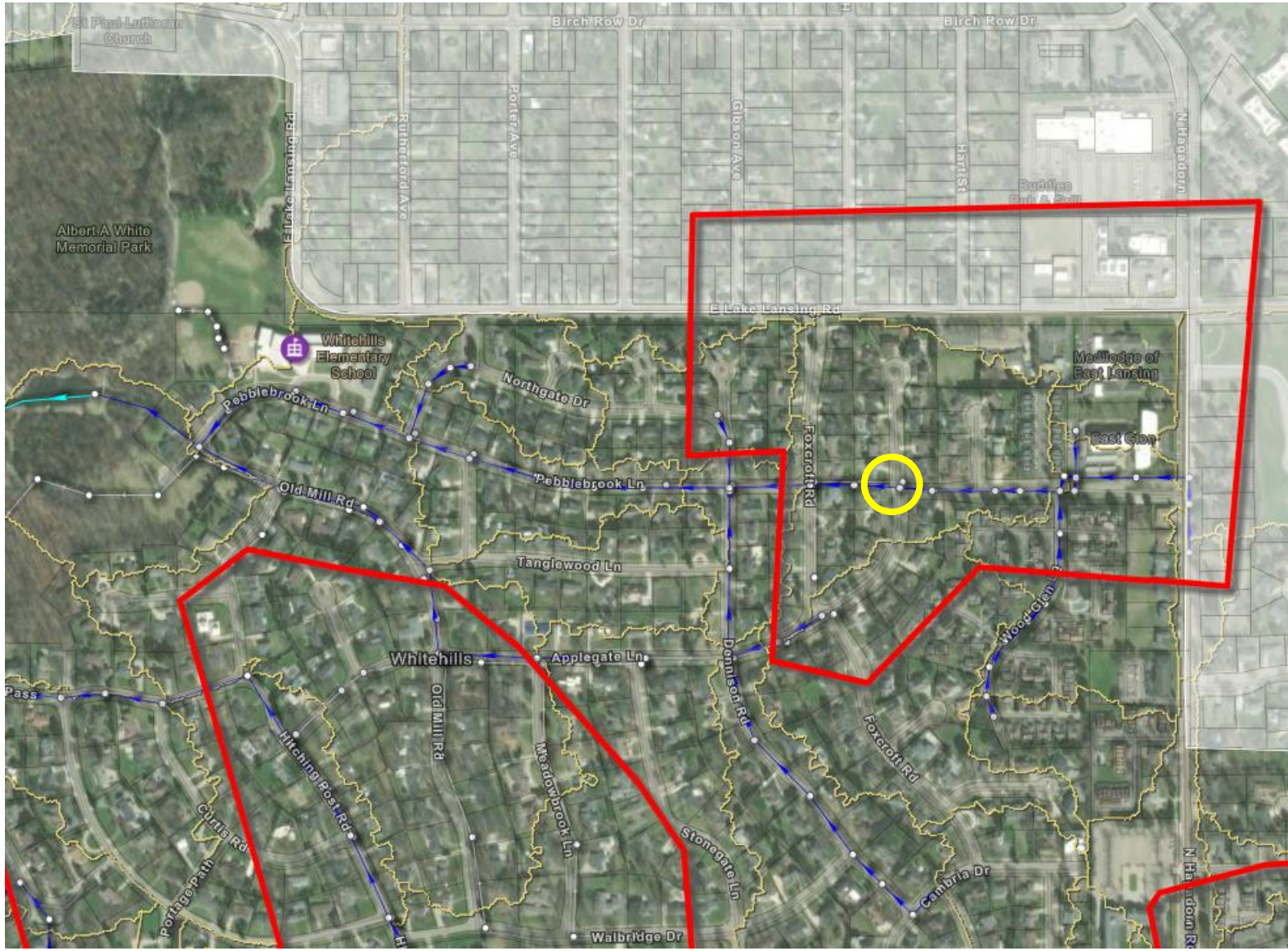
10yr, 1hr Design Storm





Strategy 1 – Flow Restrictor Modifications

- Increase flow restrictor orifice size to not cause backup during design event
- Orifice Opening = 7.5”
- Sewer Diameter = 30”



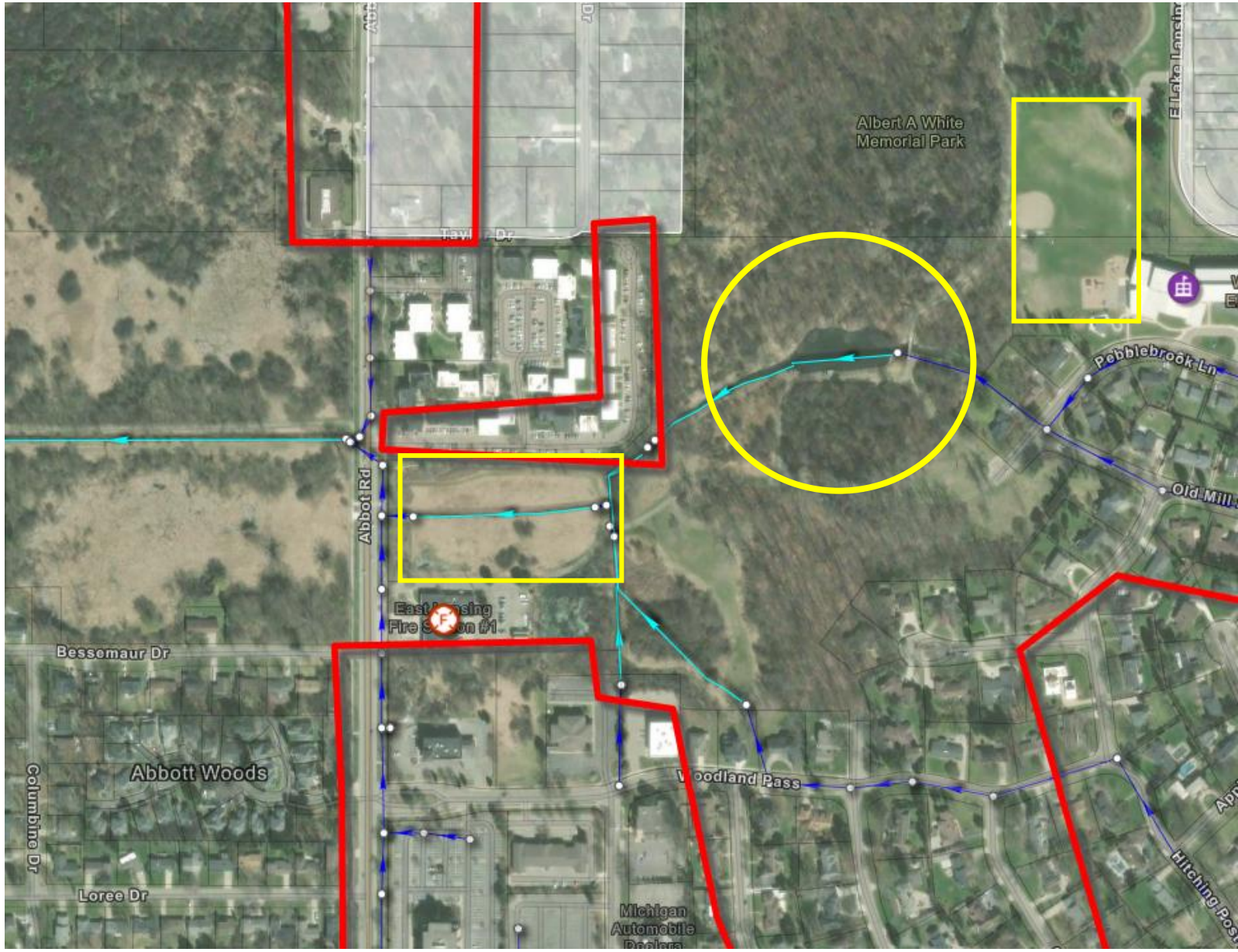
Strategy 2 – Upsize Sewer

- Increase capacity of local sewers
- Would need to assess downstream impacts
  - The Quarters
  - Taylor Drain capacity and culverts
- Likely need storage to offset increase in peak flow



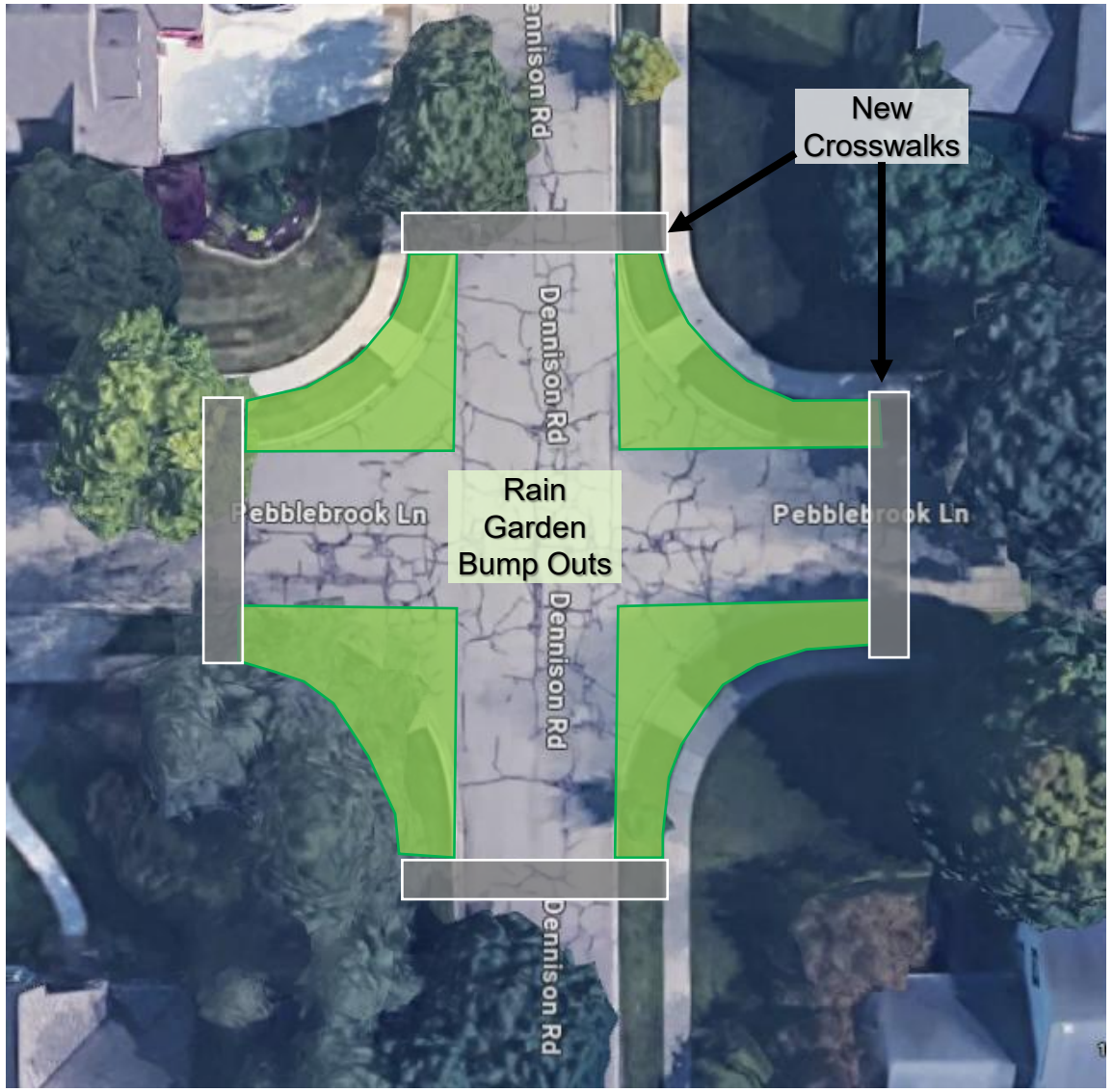
Strategy 3 – Storage

- Utilize Albert A White Park for storage and detention
  - Area is in Zone A FEMA flood mapped zone
- Underground storage under ball fields at Whitehills Elementary School
  - Not in mapped FEMA flood zone
- North Lot Above Fire Station



Strategy 4 – ROW Green Infrastructure

- Utilize wide intersections for traffic calming and green infrastructure “bump outs”
- Improve pedestrian safety by shifting crosswalks before turn radius



Area H – Potential Strategies

Strategy	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Description	Restrictor Plate Modifications	Sewer Upsizing	Downstream Storage	ROW Green Infrastructure
Location	Applegate Ln	Pebblebrook Ln	Albert A White Park & Surrounding Area	Multiple Intersections
Function	Conveyance	Conveyance	Detain & Treat	Detain & Treat
MCDA Criteria				
Improved Drainage	Med	High	Low	Med
City Resiliency Alignment	Low	Low	High	High
Water Quality	Low	Low	High	High
Impervious Surface Reduction	Low	Low	Low	Med
Social and Econ Impacts	Low	Low	Med	Med
High Impact	Med	Med	High	Med
Ease of Constructability	High	Med	Med	Low
Level of Maintenance	Low	Low	Med	High
LOS Impact	Med	High	Needs to coupled with conveyance	Low



03

Discussion of Recommended Alternatives for Modeling

Open Discussion for Two Alternatives for Modeling - CSS Areas

- Area A
  -
  -
- Area B
  -
  -
- Area C
  -
  -
- Area D
  -
  -
- Area E
  -
  -
- Area G
  -
  -

Open Discussion for Two Alternatives for Modeling – MS4 Areas

- Area F
  -
  -
- Area H
  -
  -

Evaluate Flood Benefits Against LOS Goals for Flooding

LOS Goal		Design Storm	Rainfall Depth (Inches)
1	Current Standard: Upgrade localized drainage system consistent with current standard.	Current 10-year, 1-hour	2.00
2	Future Climate: Upgrade localized drainage system consistent with current standard and based on climate anticipated in the future.	2100 10-year, 1-hour (slightly bigger than today's 25-year design storm)	2.40
3	Enhanced: Enhance localized drainage system to manage a larger design storm, where feasible.	Between 2100 10- and 25-year, 1-hour (equal to today's 50-year design storm)	2.54

Note: Flood mitigation projects under the City's CSS Masterplan and 2025 CIP use the 10-year, 1-hour "Assessment Storm" of 1.61 inches.



04

Next Steps and Schedule

Next Steps & Schedule

- Identify and agree on two modeling alternatives for each concern area (today's workshop)
- Alternatives Modeling (January)
- Alternatives Results Workshop (Mid February)
  - Review alternatives results and select preferred alternative
- Conceptual Layouts and Cost Estimates (Immediately Following Workshop)
- Alternatives Tech Memorandum (Early-Mid March)
- Begin Task 9 - Project Prioritization (April)



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Appendix A.3 – Phase 1 Modeling Results Workshop #1 (February 20th 2026)

Meeting Minutes

Project:	East Lansing Wet Weather Resiliency Plan
Subject:	Phase 1 Modeling Results Discussion
Date:	Friday, February 20, 2026
Location:	In-person / MS Teams
Attendees:	Tom Batroney (HDR) Kaylee Johnson (HDR) Ron Lacasse (City) Bob Scheuerman (City) Cliff Walls (City) Stephen Clayton (City)

1. **Goals & Objectives**
    a. HDR presented initial meeting goals and objectives. Meeting intent is for HDR to share preliminary modeling results, provide opportunities for City to give feedback, and review/ develop next steps.
    b. City commented that the Slide 1 graphic may not be suitable for the public. HDR will avoid sensitive images going forward, especially on documents could be shared with others. It was clarified that the meetings slides were not intended to be shared publicly.
2. **CSS & MS4 Modeling Results**
    a. **<u>CSS modeling results (Areas A,B,C,D)</u>**
        i. HDR presented preliminary model results for Combined Sewer System (CSS) Phase 1 Areas.
        ii. HDR reviewed CSS Level-of-Service (LOS) goals, adopting hydraulic grade line (HGL) criteria used in the 2020 Master Plan.
            1. LOS is met if: HGL is 8.5 ft below ground at either or both ends of pipe; or surcharge less than 1.0 ft above pipe crown.
        iii. HDR provided an overview of the previously discussed modeling approach which included: First determining the extent of sewer separation needed to meet LOS for the 10-year, 1-hour (2.00 inches) storm. Next, the amount of Green Stormwater Infrastructure (GSI) storage volume required to provide future resilience for the 2100 10-year, 1-hour (2.54 inch) event.
            1. HDR clarified the required volume of GSI storage was determined by taking the difference in subcatchment runoff generated between the current 10-year, 1-hour and future 10-year, 1-hour 2100 storm, for the identified separation areas.
            2. HDR reviewed GSI sites were identified in the CSS area in the prior Workshop on 12/19/2025.
            3. HDR acknowledged that Valley Court storage in Area D needs added to map graphic on Slide 5.
            4. City provided feedback that the methodology appears reasonable.
        iv. HDR determined “Run 3” separation areas are needed to meet LOS goals. See extents on Slide 5.
            1. <u>HDR noted that the preliminary results assumed a separation effectiveness of 100%. Additional sensitivity runs were completed, assuming 80%, 90% as well.</u>
        v. HDR and City held discussion to determine an appropriate separation effectiveness assumption:
            1. HDR acknowledged an assumed separation effectiveness of 100% may be aggressive, or unachievable as it requires all storm flow to be conveyed to the new storm sewer and include sources within both public and private property.

2. HDR asked if the City has any separation data, or past studies pertaining to what level of separation has been able to be achieved for similar projects, such as the recent project on Gunson St.
    a. HDR commented 50-80% separation effectiveness is commonly used but is dependent upon the location and local ordinances related to the ability to lawfully disconnect private downspouts. East Lansing may be able to achieve higher levels since many private homes actively disconnect house downspouts from the sewer system.
3. The City commented that is not something that was evaluated as part of previous projects and that 100% private property removal may be difficult to achieve since the removal of house drains, footing tiles, sump pumps, etc. has never been mandated before.
    a. After City inquired how the model representation accounts for sources of inflow, HDR clarified that the model representation does not include specific contributions from individual houses, but flow contribution from private sources is determined at the subcatchment level (roughly city block size) through previous calibration of the hydraulic model via flow metering.
4. The City commented that 90% may be achievable, while a more conservative assumption would likely work better to ensure the project is successful from a public perspective.
5. HDR commented that community ordinance and enforcement could become a large factor. With high enforcement, it is possible to achieve more capture and see more benefit.
6. <u>It was determined 80% would be the assumed separation effectiveness assumption to proceed with subsequent modeling. Going forward sewer separation within the CSS will assume 80% of existing storm flows are re-routed to the new storm system and the remaining 20% (+ sanitary DWFs) would remain connected to the existing combined sewer system.</u>
    a. HDR acknowledged that additional improvements will be needed to meet the LOS with a lower separation effectiveness assumption which could include sewer upsizing, storage, or expanding the separation areas further. However, this separation effectiveness value should be determined before proceeding with further modeling. The City understood and agreed with this approach.

vi. City reiterated Area B solution from previous Workshop to re-direct sanitary flows. City noted additional opportunity within the CSS to change direction of flows which could benefit the system downstream.
    1. Area B is tributary to Area A, where the sanitary flow from Area B could be re-directed to the sanitary sewer along N. Harrison Rd. Additionally sanitary flow west of Area C (CA-39) could be re-directed to N. Harrison Rd.
    2. City is curious what impact this would have on the future upsizing project along Charles St. and/or if it would still be needed. City commented Harrison cost is ~$5M.
    3. HDR stated that at this current stage of modeling the specific design of piping and alignments is still on-going. The modeling analysis as part of this phase is to understand the amount of stormwater separation that would need to be managed to achieve the LOS goals.
    4. HDR will remove sanitary flows from Area B to see what impact it has on remaining pipes in Area A that do not meet LOS with 80% assumption as another consideration.
vii. Key finding: Area E reverses flow to Area C via the diversion weir on Sunset Lane.

1. HDR presented a hydraulic grade profile from Northlawn Ave to Burcham Dr. showing the backup condition as it passes over the diversion weir (slide 8).
2. City commented they were unaware the backup from Charles St. extended farther upstream than Abbott Rd.
3. City commented that although it is not in the current project plan, the Charles St. upsizing needs to be constructed given the hydraulic impact to many parts of the system.
4. It was determined to include the Charles St. upsizing project in the model as we evaluate alternatives since it is a high impact project affecting many parts of the system.

b. **CSS modeling results future resilience (Areas A,B,C,D)**
   i. HDR presented required volumes needed to provide future resilience and provided a summary comparing the required storage volume to the available space within the identified site areas.
      1. Required footprints for the GSI storage assumed a storage depth of 4.0 ft.
   ii. HDR commented that within Area C, the sites at Glencairn Elementary and Taylor Park appear advantageous to capture storm flow along the normal route of the main sewer. City agreed that upper storage locations such as these two locations would be preferred compared to those downstream the Concern Areas in part due to likely lower maintenance requirements.
   iii. City commented they would be interested in comparing the cost of upsizing (potentially 1 or 2 pipe sizes) within the combined system vs. the cost of GSI storage for achieving the future 10-year storm. City mentioned that knowing what additional resilience/increased LOS beyond the 10-year the GSI systems could provide would also be of importance to the Plan.
   iv. HDR will look at the cost of upsizing vs. storage for future resiliency.

c. **MS4 modeling results (Areas F,H)**
   i. HDR reviewed LOS goals for the MS4 area and modeling approach.
      1. LOS is met in MS4 if: No flooding out of manhole is achieved.
   ii. HDR presented upsizing for Area F (Alternative F1) and downstream storage needed to offset peak flows to the Taylor Drain which cannot be increased to ensure downstream flood protection.
      1. HDR commented large pipe size is needed due to large amounts of impervious area and watershed size.
      2. City commented that Lot 2 would preferred over Lot 1 as a potential storage site for downstream detention, since Lot 1 is a regulated wetland.
      3. City clarified that the Taylor Drain is owned by the City and includes extents to the Sanderson Drain. City stated ongoing flooding issues occur near Taylor Drain. Sanderson cannot be resized due to downstream flooding impacts and there are flow restrictions in place to prevent these impacts.
      4. HDR commented that piping alignment of the upsized pipe follows the current alignment and would be a replace in-kind with bigger sized pipe. The design concept and potential alignment(s) would be reviewed in further detail, but preliminary modeling gives order of magnitude size of potential storage required and pipe upsizing needed to alleviate flooding.
      5. City commented about downstream boundary impacts during large events such as the 100-year in the CSS. River stage is not included in the model, but it is not anticipated that the 100-year river would significantly impact results in the CSS since this is a rare event and the RTB can handle most events.

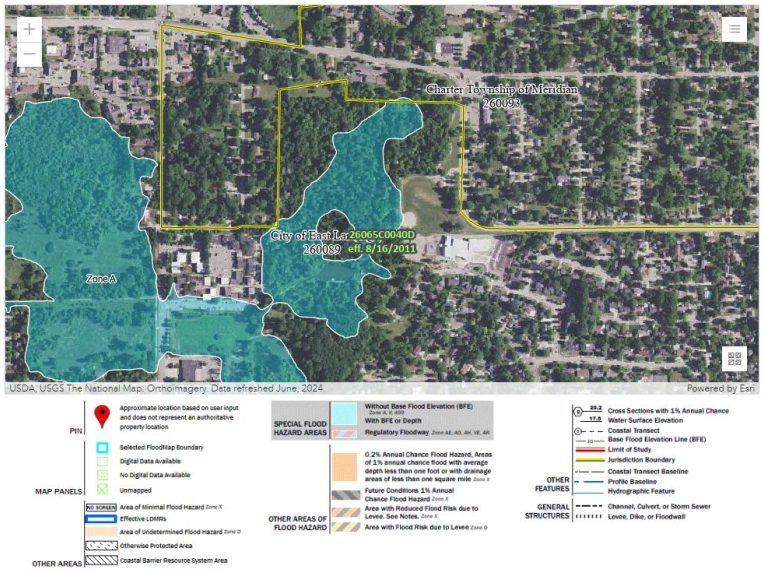
d. **MS4 modeling results future resilience (Areas F,H)**
   i. HDR presented findings for additional storage sites in Area F for future resilience.

ii. City and HDR discussed opportunities within the identified locations. City commented on possibility of getting permanent easement for storage within designated parking lots. It was acknowledged that buy-in from private property owners may be difficult, but some may be willing to work with City due to history of local flooding. HDR commented that incentivizing de-pavement as part of future stormwater utility fee may be a potential pathway that would open up space for storage.

iii. City reiterated maintenance concerns associated with GSI storage. It was noted that understanding how GSI storage can provide additional increases in future LOS is of interest to the City.

iv. HDR presented upsizing in Area H with downstream storage needed to offset peak flows to White City Memorial Fishing Pond.

1. City commented that the hydraulic profiles are reversed, but find them informative. HDR with correct profile orientation going forward.
2. HDR commented that the identified areas are FEMA zones (Zone A) which would likely require map revisions, H&H effort, etc. to ensure no adverse impacts. Adjacent ball field at Whitehills Elementary could be used to avoid FEMA, but requires more maintenance with underground systems.



3. City commented that the ballpark contains flow meter chamber and other sewer assets, and indicated space is limited for storage in this area.
4. City commented that the pond was recently expanded (within last 5 years or so). Pond was made deeper, and footprint was not believed to have been expanded, possibly just dredging of material.
5. City commented that expanding downstream storage capacity in White Memorial Park could be a great opportunity to enhance recreation and/or park appearance to make an interesting green feature, fishing, etc.

v. HDR presented findings for additional storage sites in Area H for future resilience.

1. HDR found no potential storage opportunities upstream within the Area H concern area, indicating potential storage would need to be sited downstream. (Unlike Area F which has upstream opportunity).
2. HDR presented additional upsizing and downstream storage required for the future storm.

3. Post Presentation Discussion

a. HDR recommended to meet with City once more to finalize alternative projects after modeling is complete (including Areas E&G which were not included in Phase 1). City encouraged touch points with as many or as few persons as needed as task proceeds. Appreciated the ability to provide feedback on results as things progress.
b. City commented that the slide presentation was very informative and are interested in how we can best relay this information to council, impacted property owners, and/or the public. City is interested in potentially elevating this information and making it understandable to the general public. Communication of results will be of great importance to the success of the Plan.

4. Next Steps

a. HDR to continue modeling of CSS alternatives assuming a separation effectiveness of 80%.
b. HDR to implement Charles Street upsizing project into the baseline condition of the alternatives modeling due to high project need.
c. HDR to reconvene internally and will update City of any additional next steps.

City of East Lansing Wet Weather Resiliency Plan

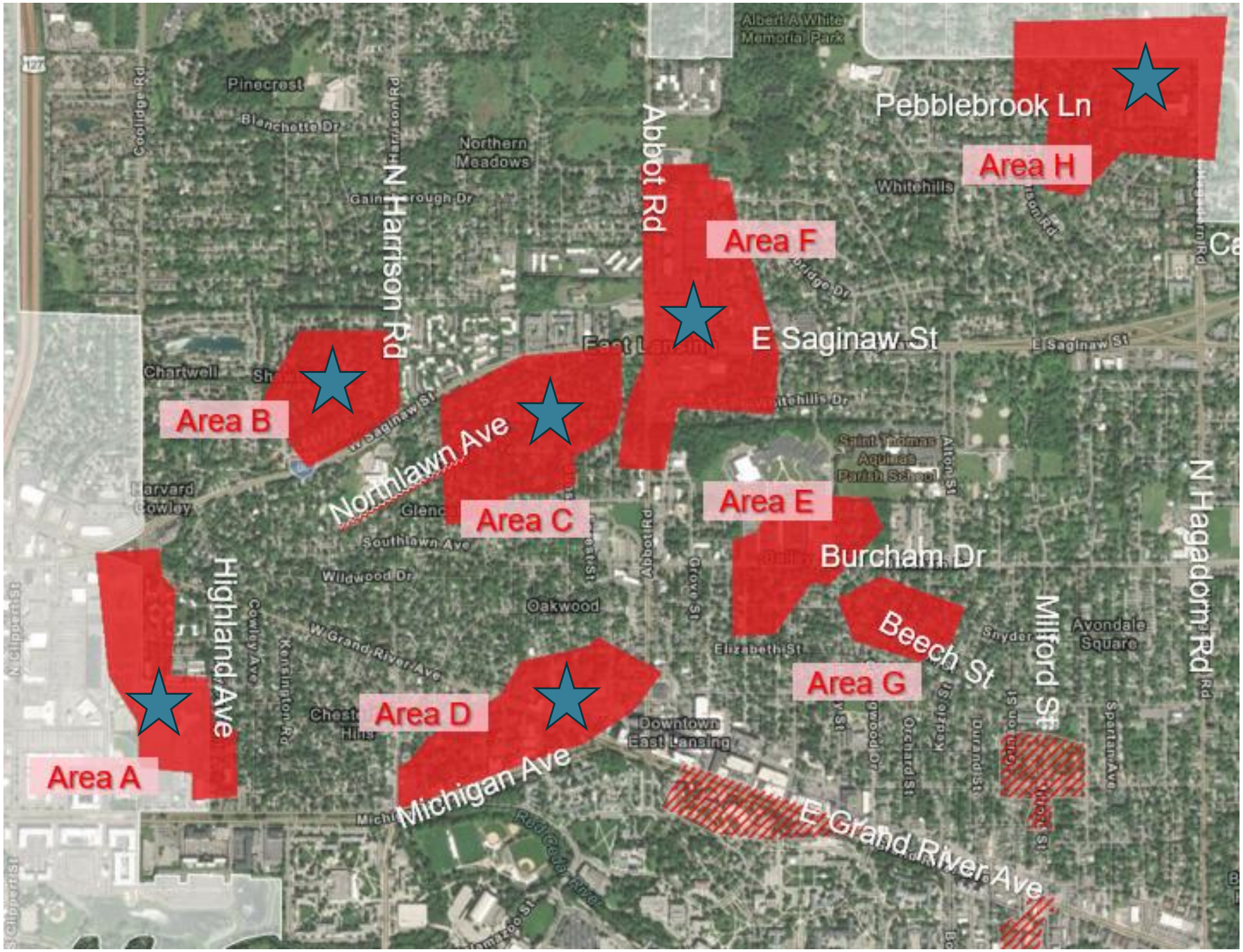
Task 8: Phase 1 Modeling Results

02.20.2026



Task 8 – Alternatives Modeling

Phase 1 Model Areas ★





01

CSS Modeling (Areas A, B, C, and D)

CSS Level of Service Modeling Approach

- LOS goal in CSS = HGL is 8.5 ft below ground at either or both ends of pipe; Or surcharge less than 1.0 ft above pipe crown.
- Step 1: Determine the optimum area of separation needed to achieve LOS goal in Areas A, B, C, and D for the current 10-year, 1-hour storm (2.00 inches)
- Step 2: Determine the amount of GSI storage volume needed to capture the runoff difference between the current 10-year, 1-hour storm (2.00 inches) and the future 2100 10-year, 1-hour storm (2.54 inches)

CSS Phase 1 – Methodology (Runs 1 – 4)
Area A,B,C&D

Expand separation as needed to meet LOS goal.

Separation Areas

Run 1-

Run 2-

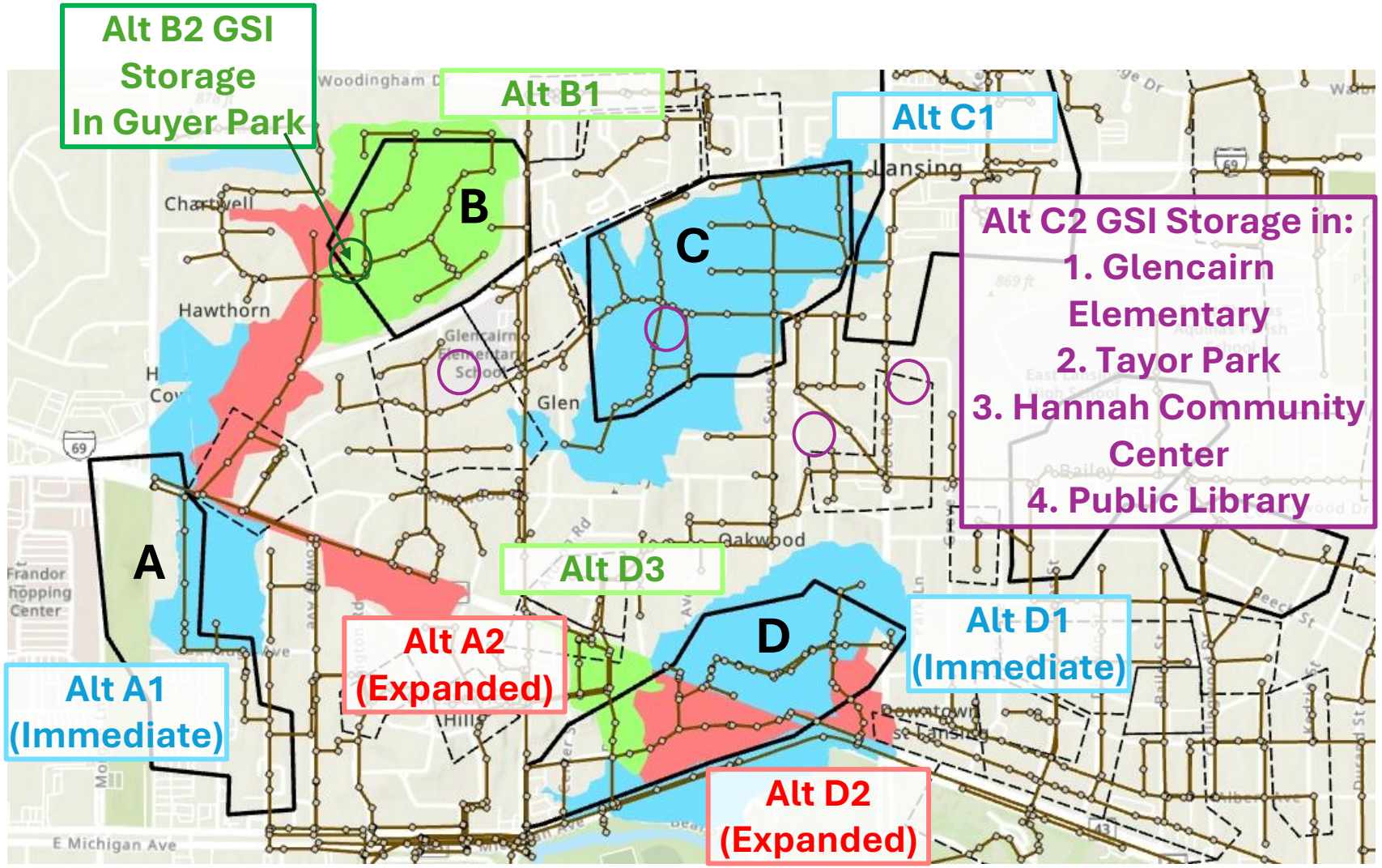
Run 3-

Separation Plus GSI

Run 4 - Optimum Separation from 1, 2, and 3 to Meet LOS with Added GSI Storage (B2 and C2) for Resilience

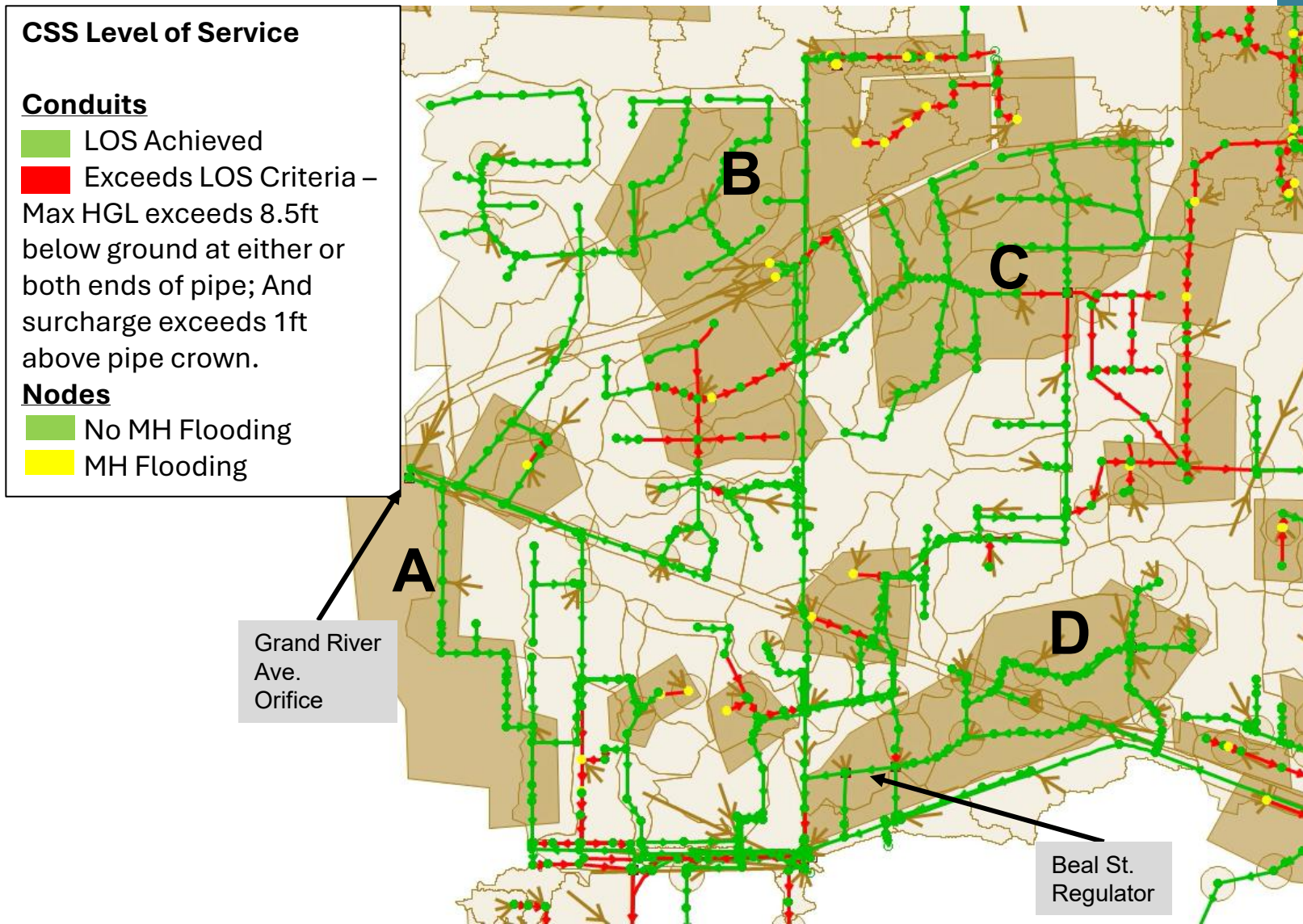
Top 8 Concern Area

Other Concern Area



Step 1 Results
To achieve LOS, Run 3 is required

- To achieve the a current 10-year, 1-hour LOS, separation of the area represented in Run 3 is required.
- These results are based on an assumption of 100% stormwater separation effectiveness. (i.e. all stormwater from public and private areas are captured and separated into new storm sewer)
- Additional improvements required:
  - Remove 8-inch orifice on Grand River in Area A
  - Lower Beal St Regulator Weir by 1.60 feet in Area D



Step 1 Results (Separation Effectiveness Sensitivity)

- A sensitivity assuming 80% and 90% stormwater separation effectiveness on Run 3.

CSS Level of Service

Conduits

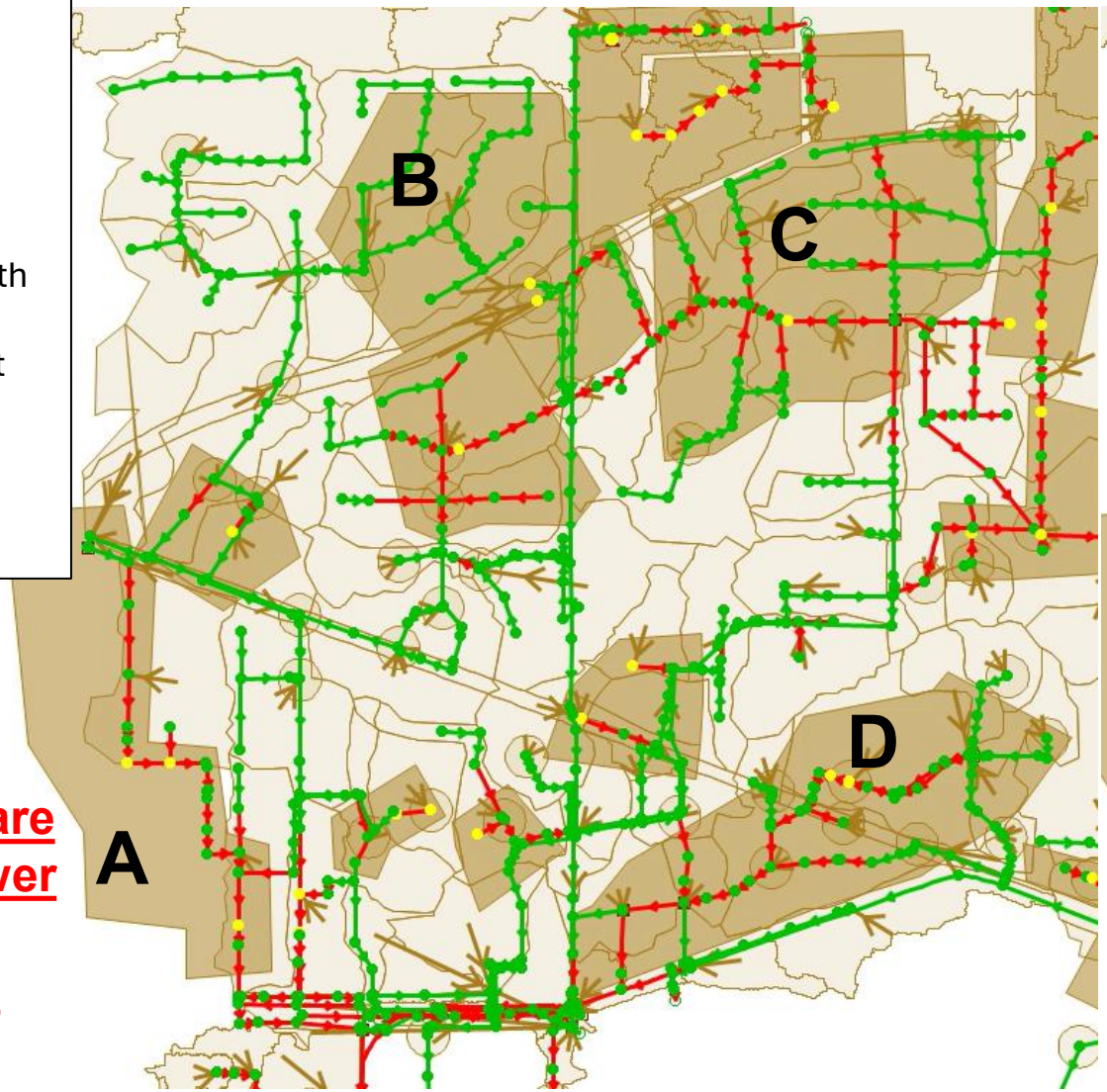
- LOS Achieved
- Exceeds LOS Criteria – Max HGL exceeds 8.5ft below ground at either or both ends of pipe; And surcharge exceeds 1ft above pipe crown.

Nodes

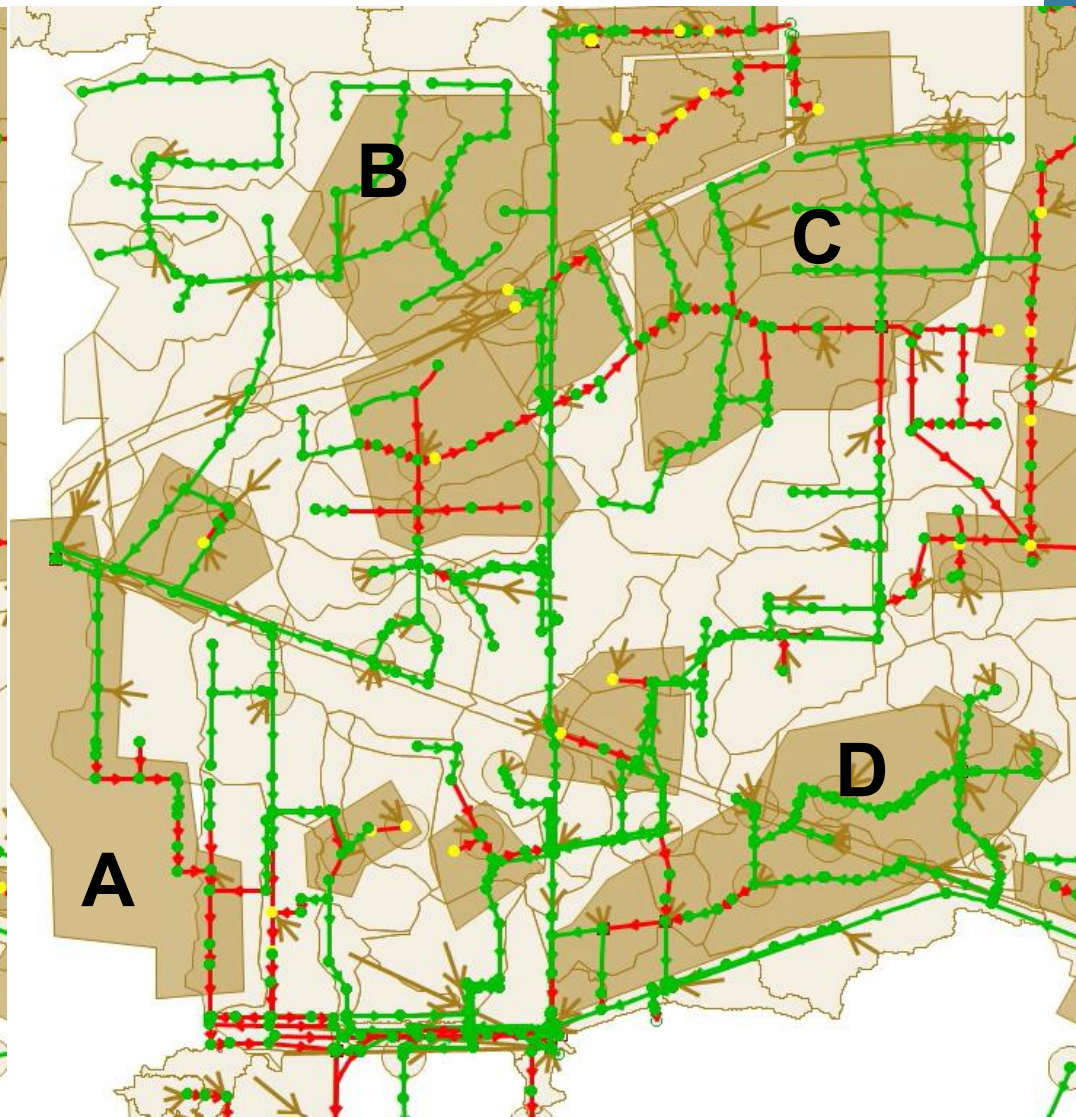
- No MH Flooding
- MH Flooding

Key Finding: Additional improvements are needed with lower separation effectiveness assumption

80% Stormwater Separation Effectiveness

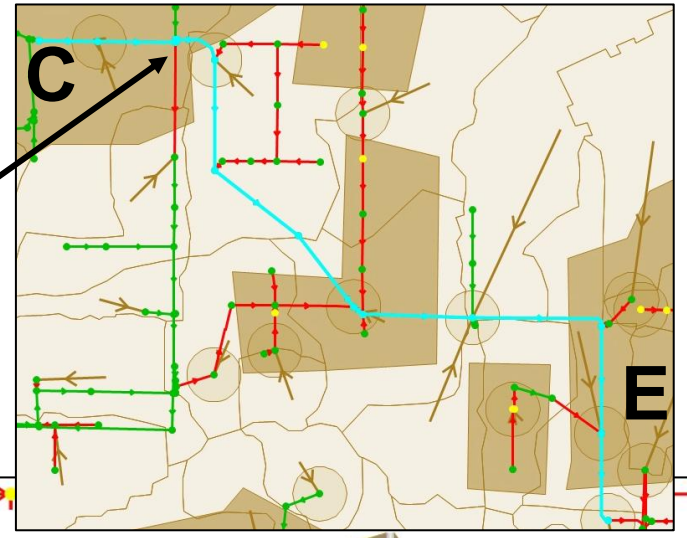


90% Stormwater Separation Effectiveness

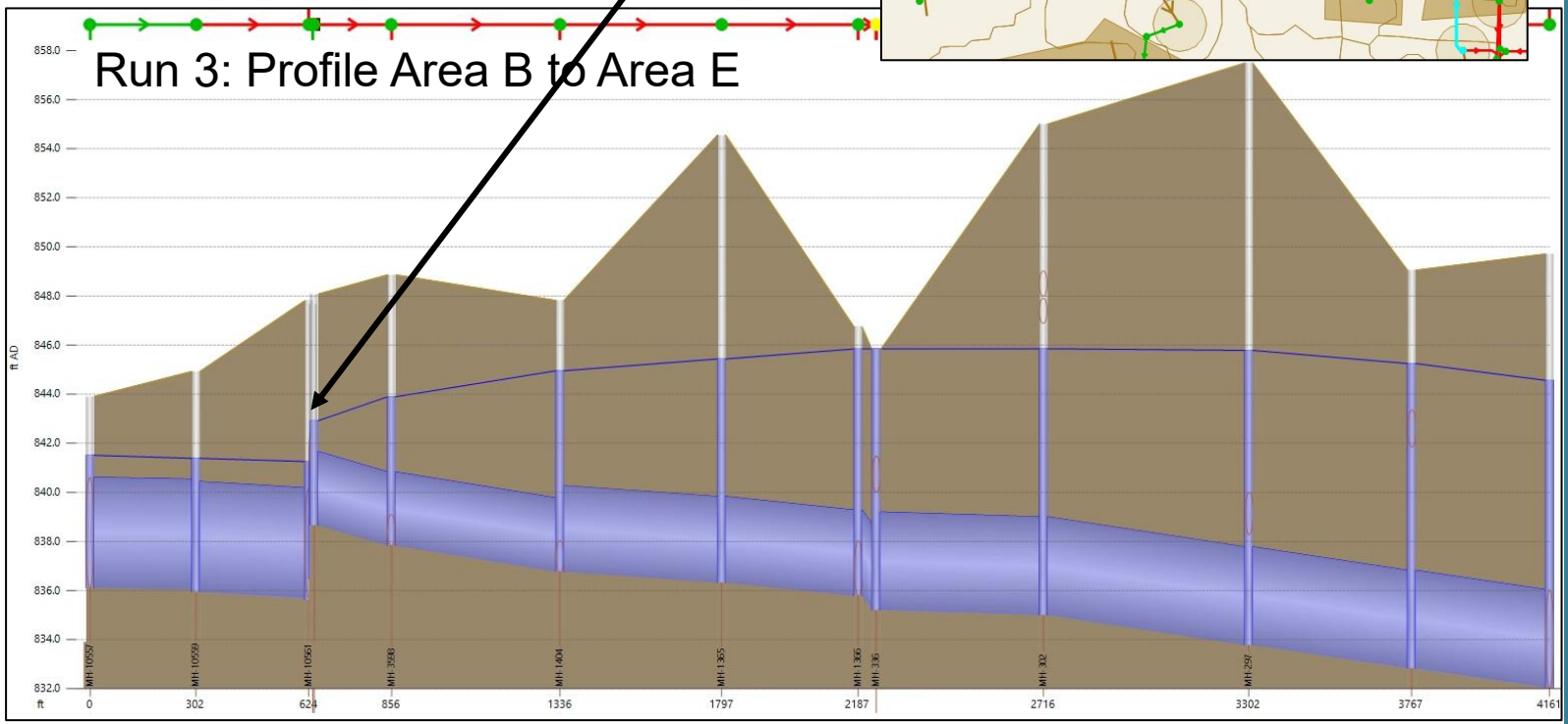


What if we add in Charles Street Upsizing from CIP?

Key finding: Based on 1st round of modeling we found that Charles Street trunk sewer in Area E backs up and reverse flows into Area C via the Sunset Diversion structure.



Sunset Diversion

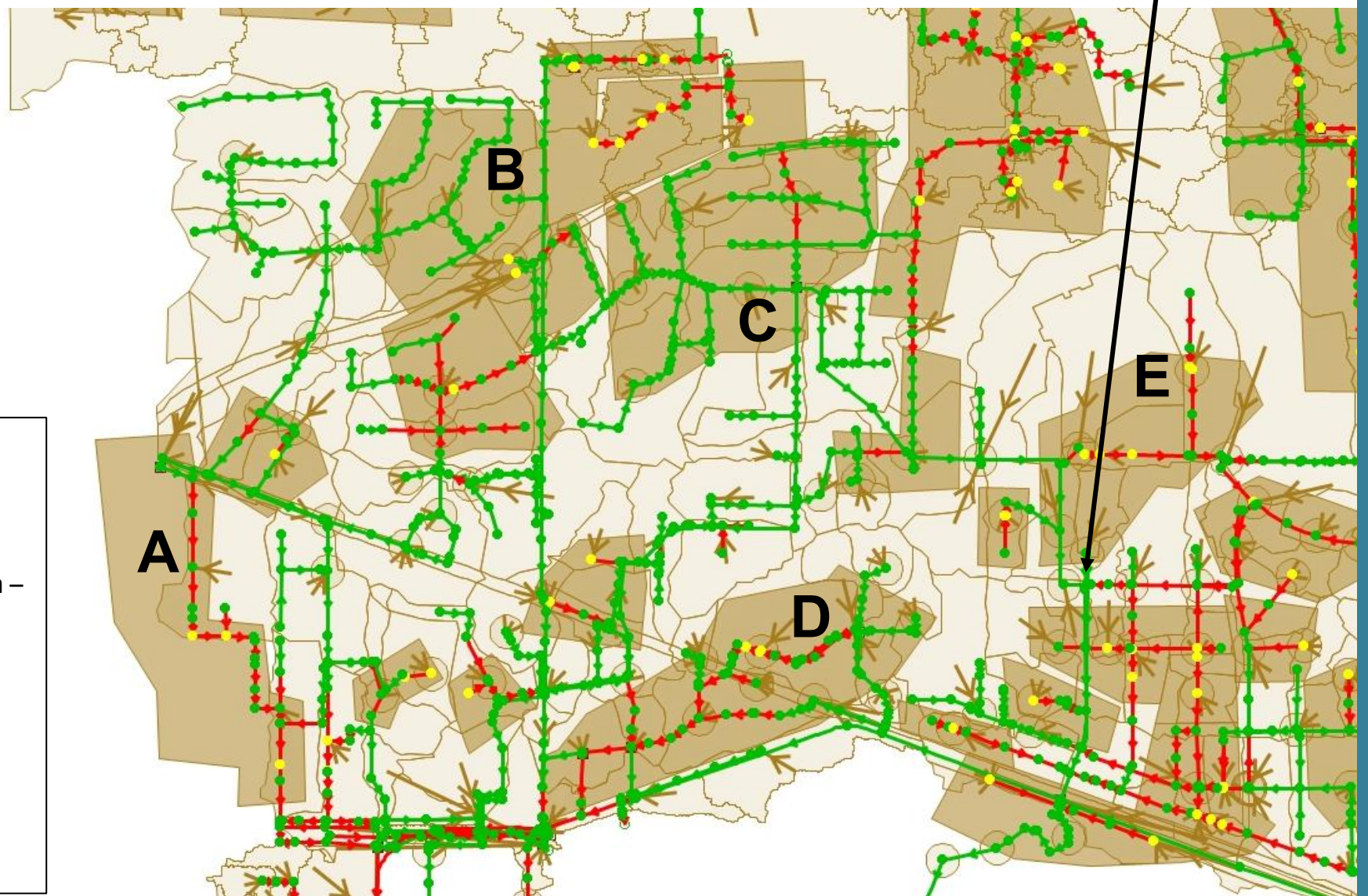


Scenario	Peak WSE (ft) @ MH-367	Difference from Existing (ft)
Existing	844.513	-
Run 1	841.253	-3.26
Run 2	841.227	-3.29
Run 3	841.214	-3.30

Charles Street Upsizing Results

By upsizing Charles St the LOS goal in Area C is mostly achieved under 80% stormwater separation effectiveness

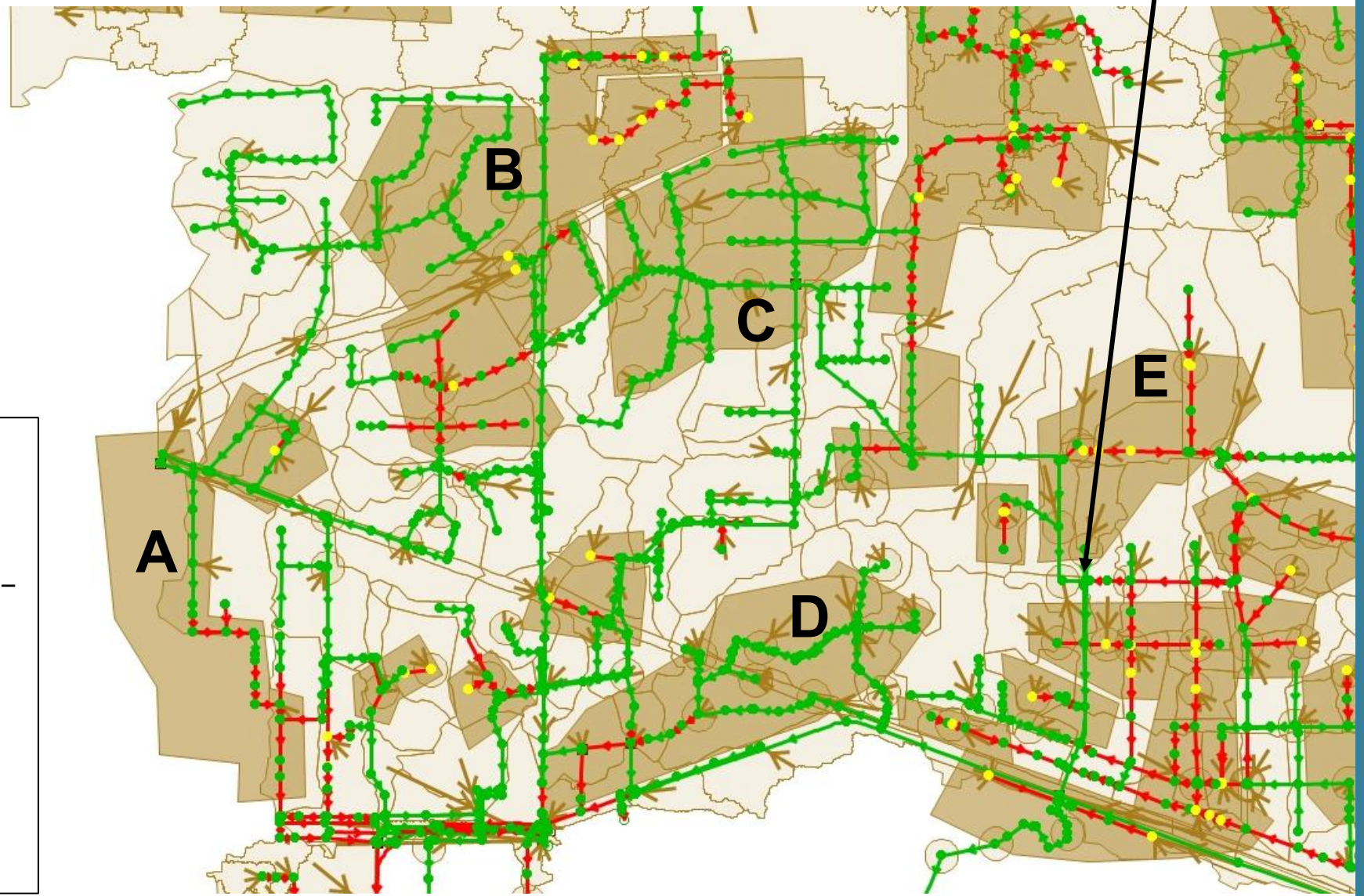
Run 3 with 80% Stormwater Separation Effectiveness



Charles Street Upsizing Results

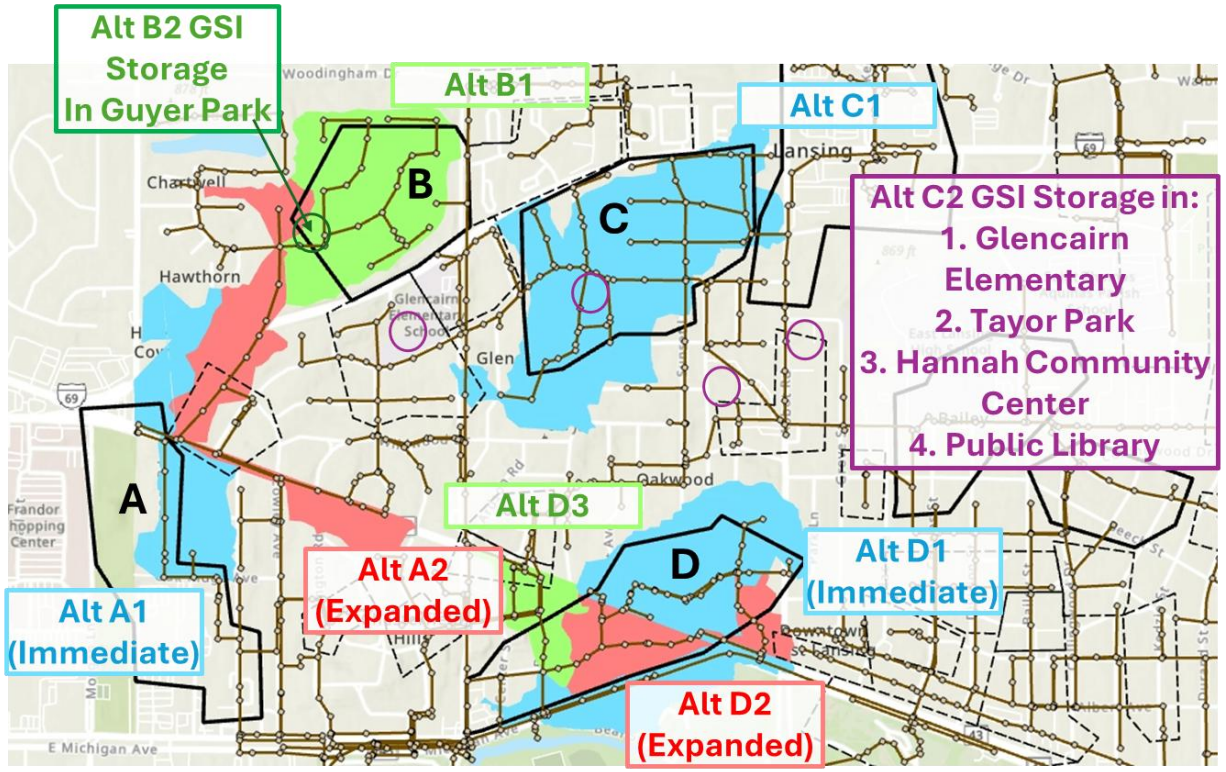
By upsizing Charles St the LOS goal in Area C is achieved by assuming 90% effectiveness

Run 3 with 90% Stormwater Separation Effectiveness



Step 2: GSI Storage Volume for Resilience

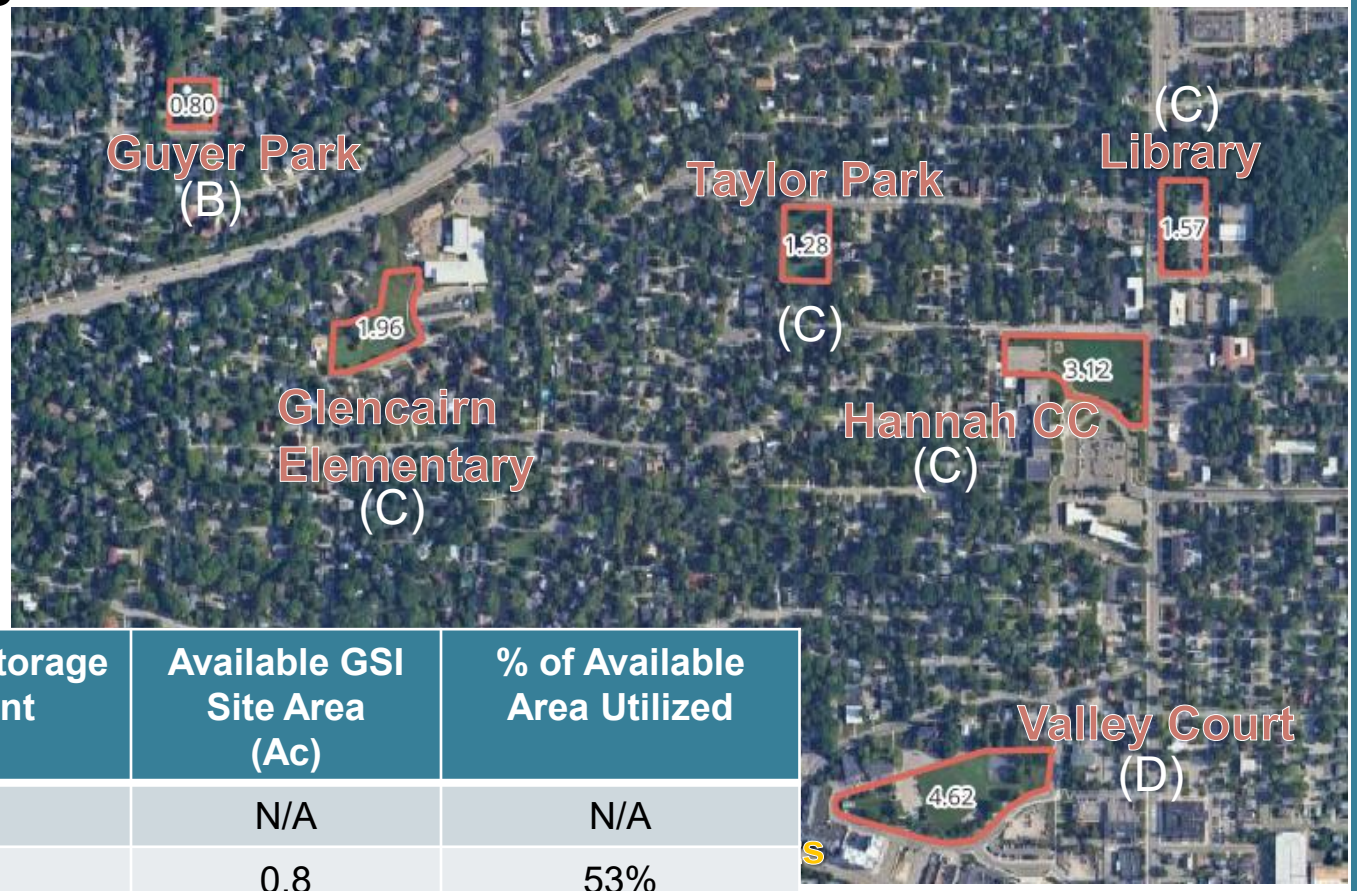
- Determine the difference in subcatchment runoff from the current 10-year, 1-hour storm (2.00 inches) and future 2100 10-year, 1-hour storm (2.54 inches) for each area A, B, C, and D
- The difference in runoff (shown in blue) is the approximate volume of GSI storage needed to provide future resilience
  - A1+A2: +0.7 MG (2.3 Ac-Ft)
  - B1: (Guyer Park): +0.6 MG (1.7 Ac-Ft)
  - C1: (Locations): +1.0 MG (2.9 Ac-Ft)
  - D1+D2+D3: +1.1 MG (3.3 Ac-Ft)



Storage Opportunity Analysis

Future Resilience

- Comparison of the potential GSI storage sites with the required storage footprints indicate the selected locations could be utilized to provide future resilience
  - The required storage footprint is calculated assuming a storage depth of 4.0 ft
  - Note: Total required storage for Area C is 2.9 Ac-ft. Table below shows multiple potential storage locations for this volume.



Separation Area	Storage Location	Storage Volume Required (Ac-ft)	Required Storage Footprint (Ac)	Available GSI Site Area (Ac)	% of Available Area Utilized
A	N/A	2.3	0.6	N/A	N/A
B	Guyer Park	1.7	0.4	0.8	53%
C	Glencairn Elem.	2.9	0.7	2.0	38%
C	Taylor Park	See Above	See Above	1.3	58%
C	Hannah CC	See Above	See Above	3.1	24%
C	Library	See Above	See Above	1.6	47%
D	Valley Court	3.3	0.8	4.6	18%

Area C Storage could be divided into multiple locations

CSS Phase I – Summary of Results

- Stormwater separation to the levels shown in Run 3 is needed to achieve current 10-year, 1-hour storm event (2.00 inches)
- Stormwater effectiveness assumption needs to be defined as a team
  - Results indicate separation effectiveness of 80%, 90%, or higher is needed to meet LOS
  - If a lower separation effectiveness is assumed, additional improvements are required in some areas. Does the City have data/ experience with prior separation work?
- The Sunset Diversion and downstream surcharging on Charles Street hydraulically impacts Area C from reverse flows
- Upsizing Charles Street prevents reverse flows from Area E into Area C
  - And allows LOS for Area C to be met with 80% separation effectiveness

CSS Phase I – Summary of Results

- Phase I modeling analysis results do not improve Areas E and G
- GSI storage needed for future resilience appears achievable within available footprints.
  - Analysis assumes storage depth of 4.0 ft.
  - Footprints could be further reduced by assuming a larger depth.

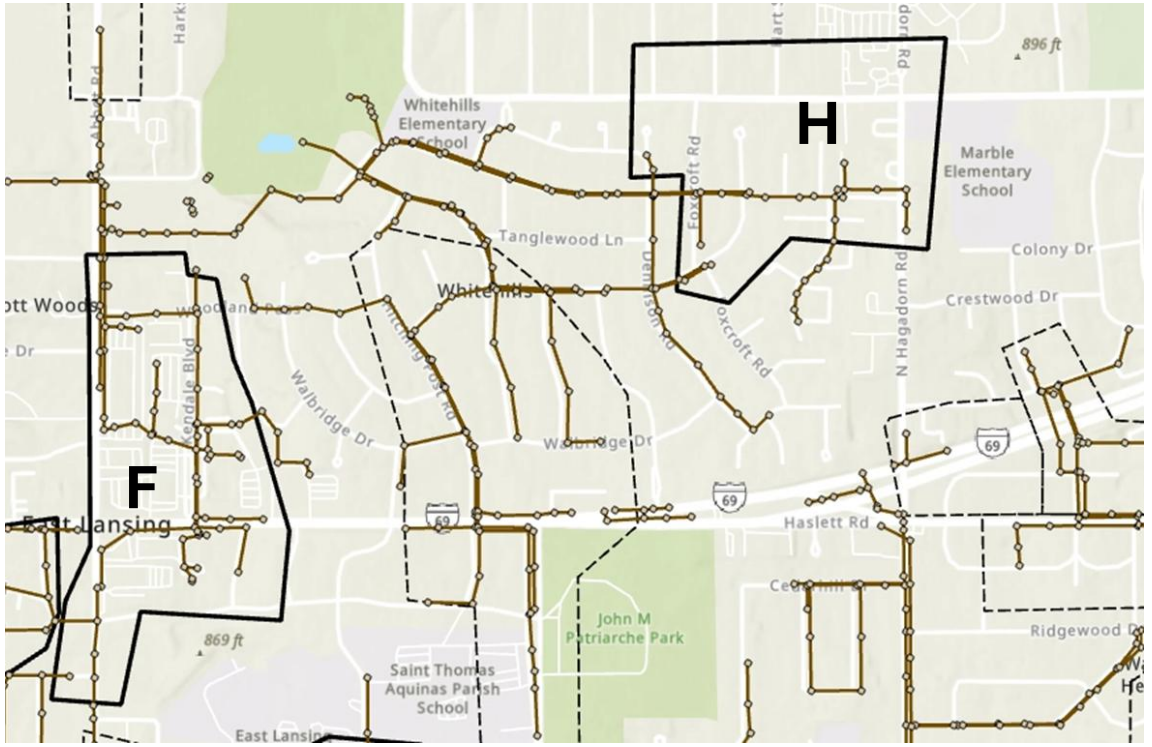


02

MS4 Modeling (Areas F and H)

MS4 Modeling Approach (Areas F and H)

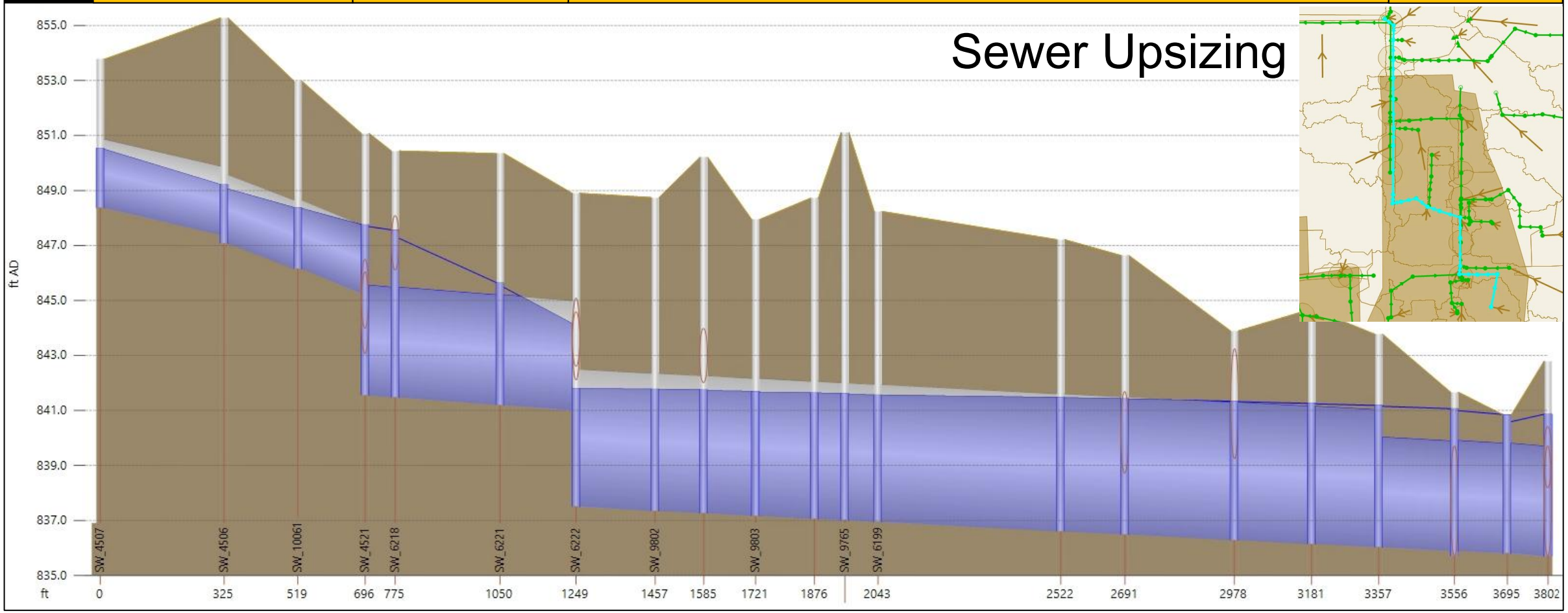
- LOS goal in MS4 = No manhole flooding onto the surface
- Alternatives to model:
  - Area F:
    - Alternative F1: Sewer Upsizing Alone
    - Alternative F2: Sewer Upsizing with a Combination of Storage & ROW Infrastructure
  - Area H:
    - Alternative H1: Restrictor Plate Modifications & Sewer Upsizing
    - Alternative H2: Downstream Storage



MS4 Area F – Alternative F1 Pipe Upsize

Required upsizes for the current 10-year, 1-hour, 2.00 inches

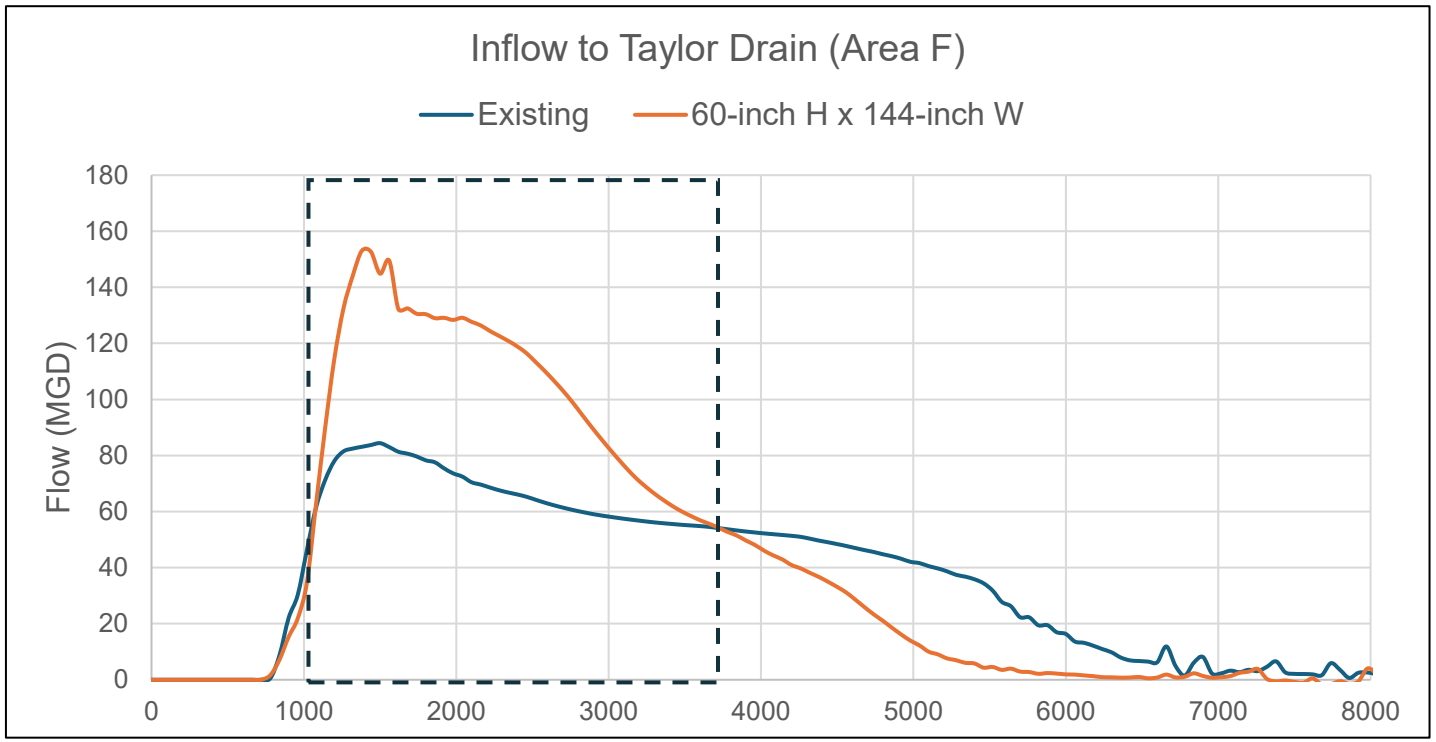
	Ex. 21-inch Upsize to 30-inch	Ex. 36-inch Upsize to 48-inch	Ex. 42-inch, 43-inch H x 68-inch W Upsize to 60-inch H x 144-inch W	Ex. 48-inch H x 76-inch W Upsize to 48-inch H x 168-inch W



MS4 Area F – Alternative F1 Downstream Increased Flow

Taylor Drain near East Lansing Fire Station

Required peak attenuation for the current 10-year, 1-hour, 2.00 inches



Peak Flow

Scenario	Peak Flow (MGD)	Difference from Existing (MGD)
Existing	84.40	-
Alt F1	153.00	68.60

Peak Volume

Scenario	Volume (Ac-Ft)	Difference from Existing (Ac-Ft)
Existing	6.75	-
Alt F1	10.31	**3.53**

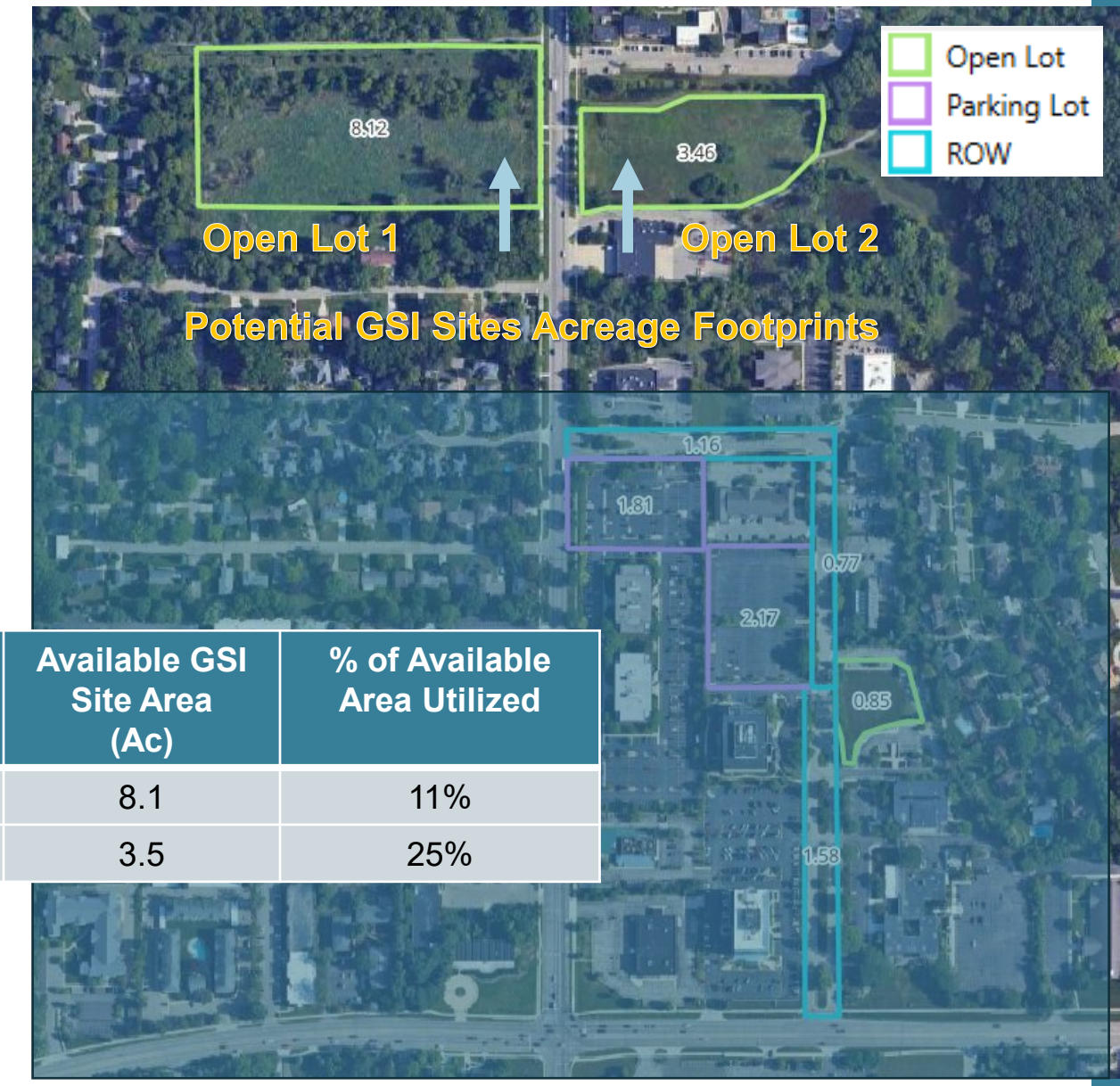
From 780 to 3780 simulation seconds

- Area F existing capacity: 84 MGD (130 cfs)
- Area F required capacity for current 10-year, 1-hour: 153 MGD (236 cfs)
- Approximate storage needed to offset peaks for current 10-year, 1-hour: 1.15 MG (3.53 Ac-Ft)

Storage Opportunity Analysis

Area F Upsizing

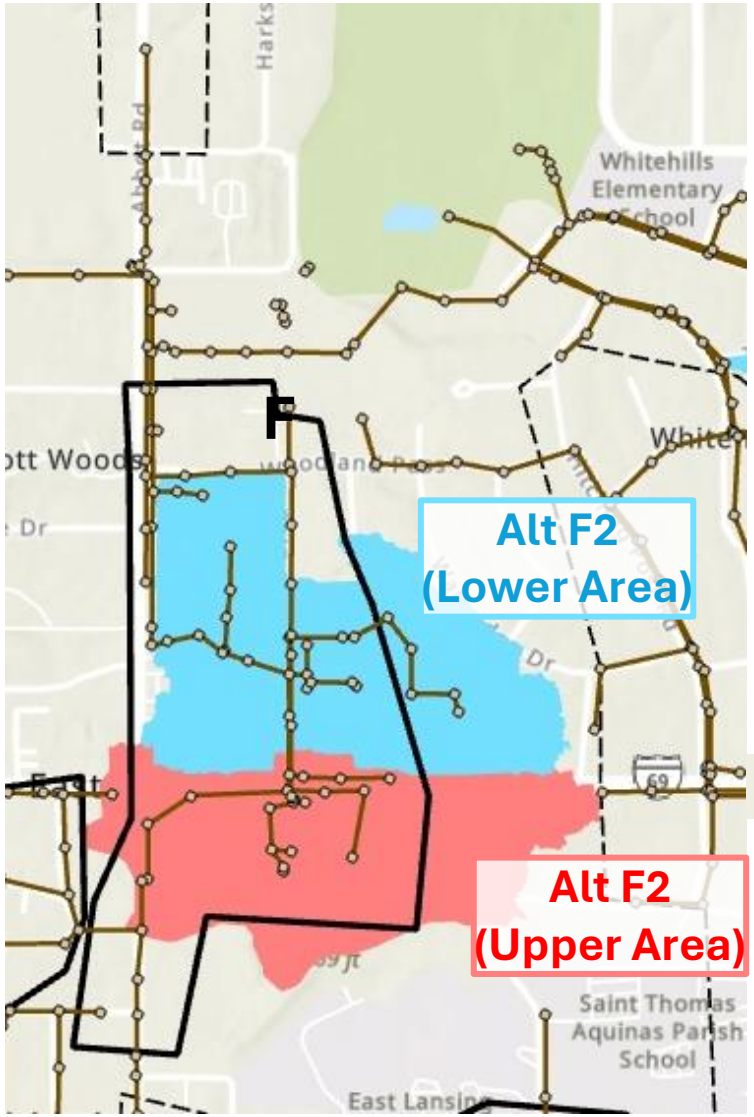
- Comparison of the potential GSI storage sites with the required storage footprints indicate the selected locations could be utilized to offset peak to Taylor Drain from sewer upsizing
  - The required storage footprint is calculated assuming a storage depth of 4.0 ft
  - Note: Total required storage for Area F is 3.5 Ac-ft. Table below shows two potential storage locations for this volume.
    - Storage could be divided into multiple locations



Separation Area	Storage Location	Storage Volume Required (Ac-ft)	Required Storage Footprint (Ac)	Available GSI Site Area (Ac)	% of Available Area Utilized
F	Open Lot 1	3.5	0.9	8.1	11%
F	Open Lot 2	See Above	See Above	3.5	25%

MS4 Area F – Alt F2 GSI Storage Future Resilience

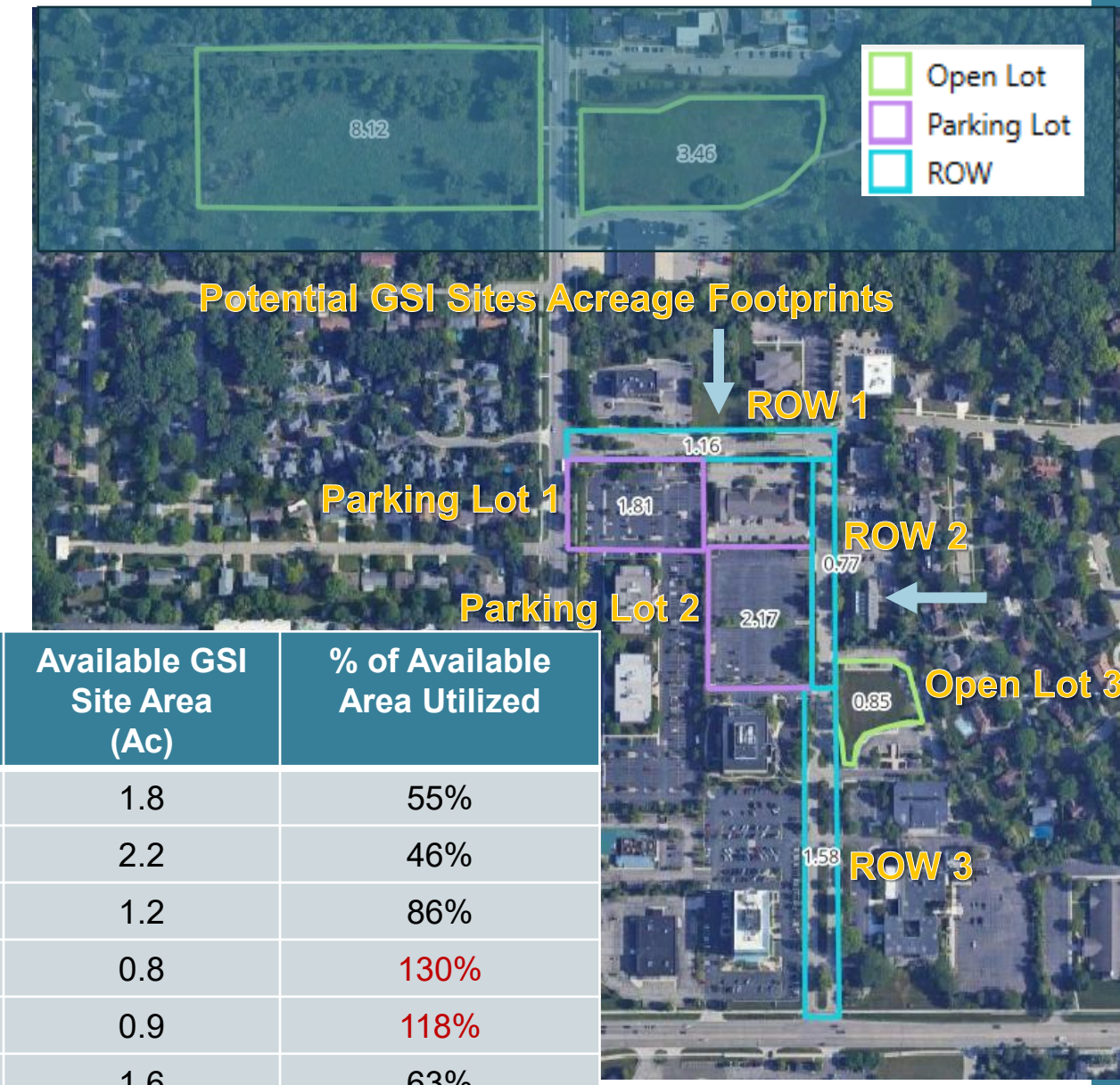
- Determine the difference in subcatchment runoff from the current 10-year, 1-hour storm (2.00 inches) and future 2100 10-year, 1-hour storm (2.54 inches) for each area
- The difference in runoff (shown in blue) is the approximate volume of GSI storage needed to provide future resilience
  - Lower Area (North of E. Saginaw St.):
    - +0.7 MG (2.1 Ac-Ft)
  - Upper Area (South of E. Saginaw St.):
    - +0.6 MG (1.8 Ac-Ft)



Storage Opportunity Analysis

Future Resilience

- Comparison of the potential GSI storage sites with the required storage footprints indicate the selected locations could be utilized to provide future resilience
  - The required storage footprint is calculated assuming a storage depth of 4.0 ft
  - Note: Total required storage for Area F is 4.00 Ac-ft. Table below shows four potential storage locations for this volume.
    - Storage could be divided into multiple locations

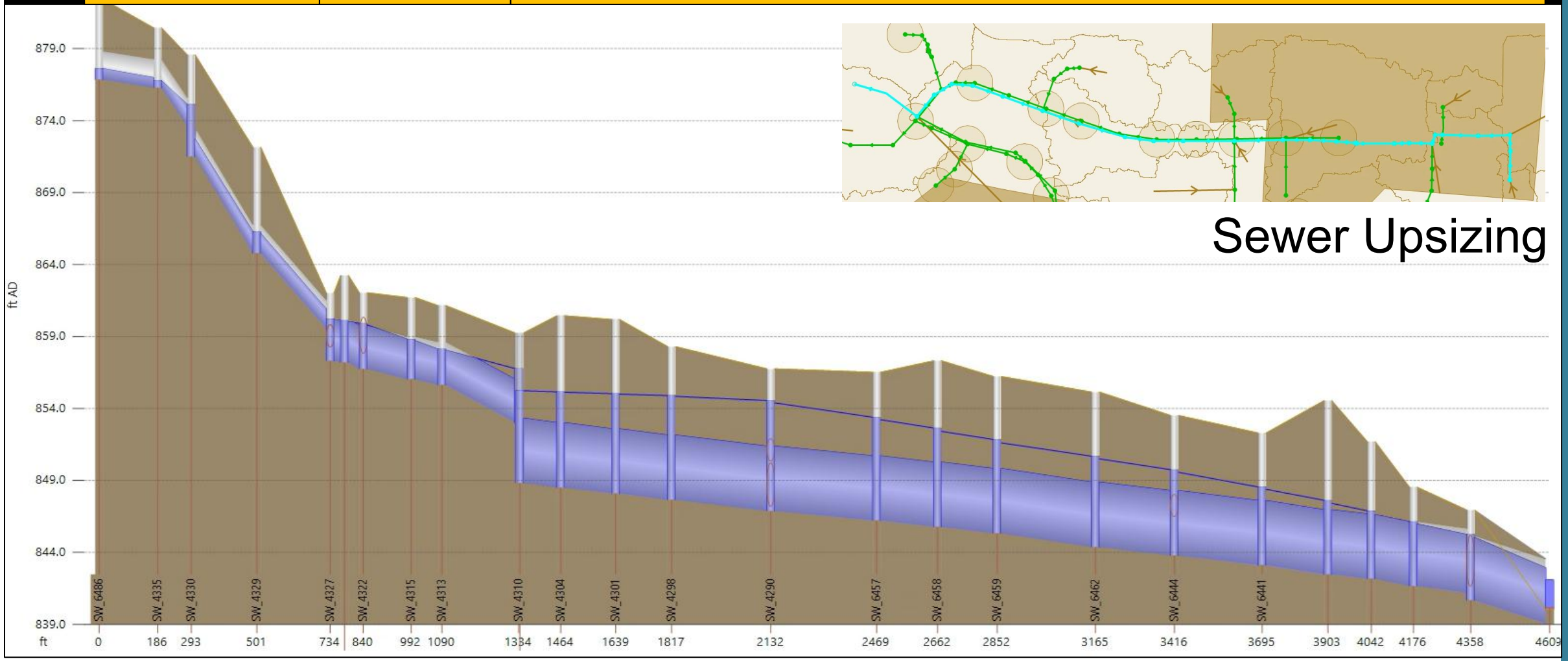


Separation Area	Storage Location	Storage Volume Required (Ac-ft)	Required Storage Footprint (Ac)	Available GSI Site Area (Ac)	% of Available Area Utilized
F	Parking Lot 1	4.0	1.0	1.8	55%
F	Parking Lot 2	See Above	See Above	2.2	46%
F	ROW 1	See Above	See Above	1.2	86%
F	ROW 2	See Above	See Above	0.8	130%
F	Open Lot 3	See Above	See Above	0.9	118%
F	ROW 3	See Above	See Above	1.6	63%

MS4 Area H – Alternative H1 Pipe Upsize and Restrictor

Required upsizes for the current 10-year, 1-hour, 2.00 inches

	Ex. 18 Upsize to 24-inch	Ex. 18, 30 Upsize to 36-inch	Ex. 30, 36, 48, 54 Upsize to 54-inch

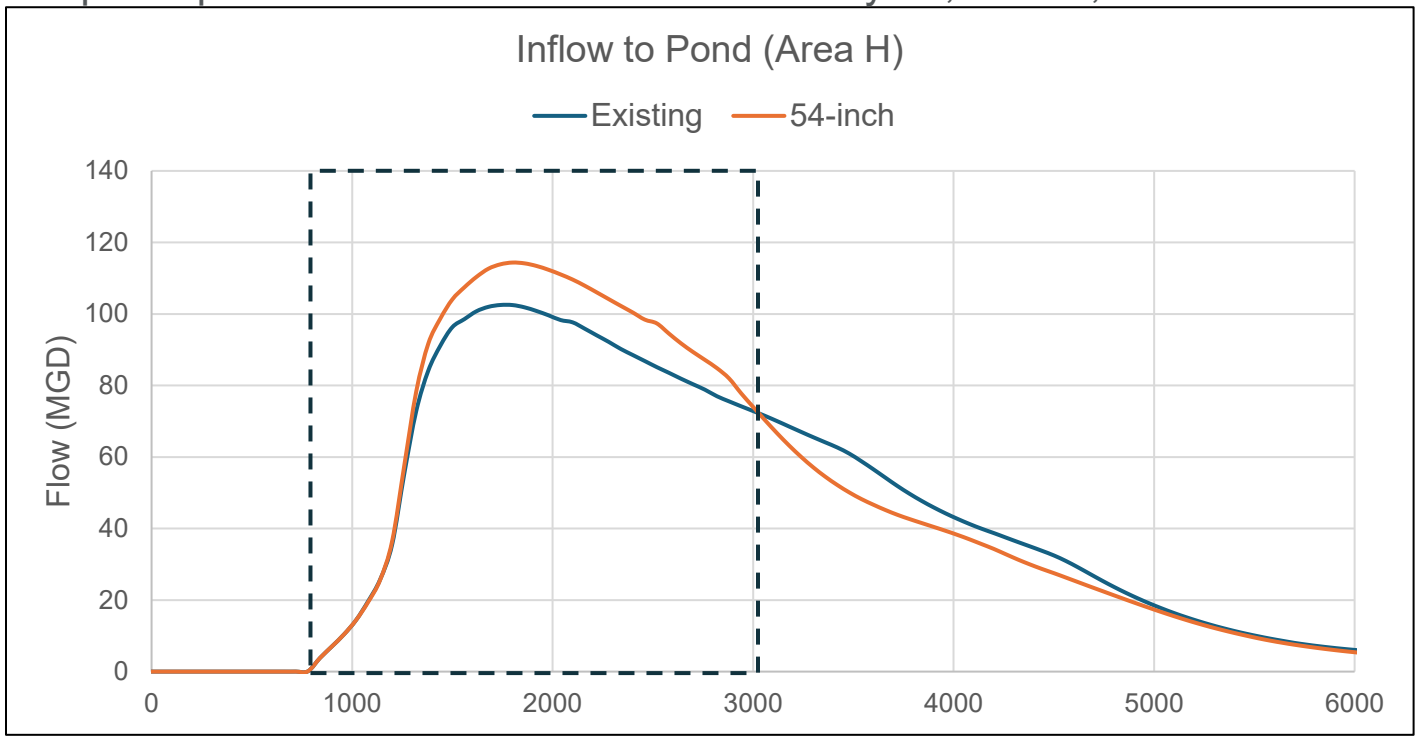


Sewer Upsizing

MS4 Area H – Alternative H1 Downstream Increased Flow

To White Memorial City Park-fishing Pond

Required peak attenuation for the current 10-year, 1-hour, 2.00 inches



Peak Flow

Scenario	Peak Flow (MGD)	Difference from Existing (MGD)
Existing	102.52	-
Run 1	114.37	11.86

Peak Volume

Scenario	Volume (Ac-Ft)	Difference from Existing (Ac-Ft)
Existing	6.07	-
Run 1	6.68	**0.61**

From 780 to 3060 simulation seconds

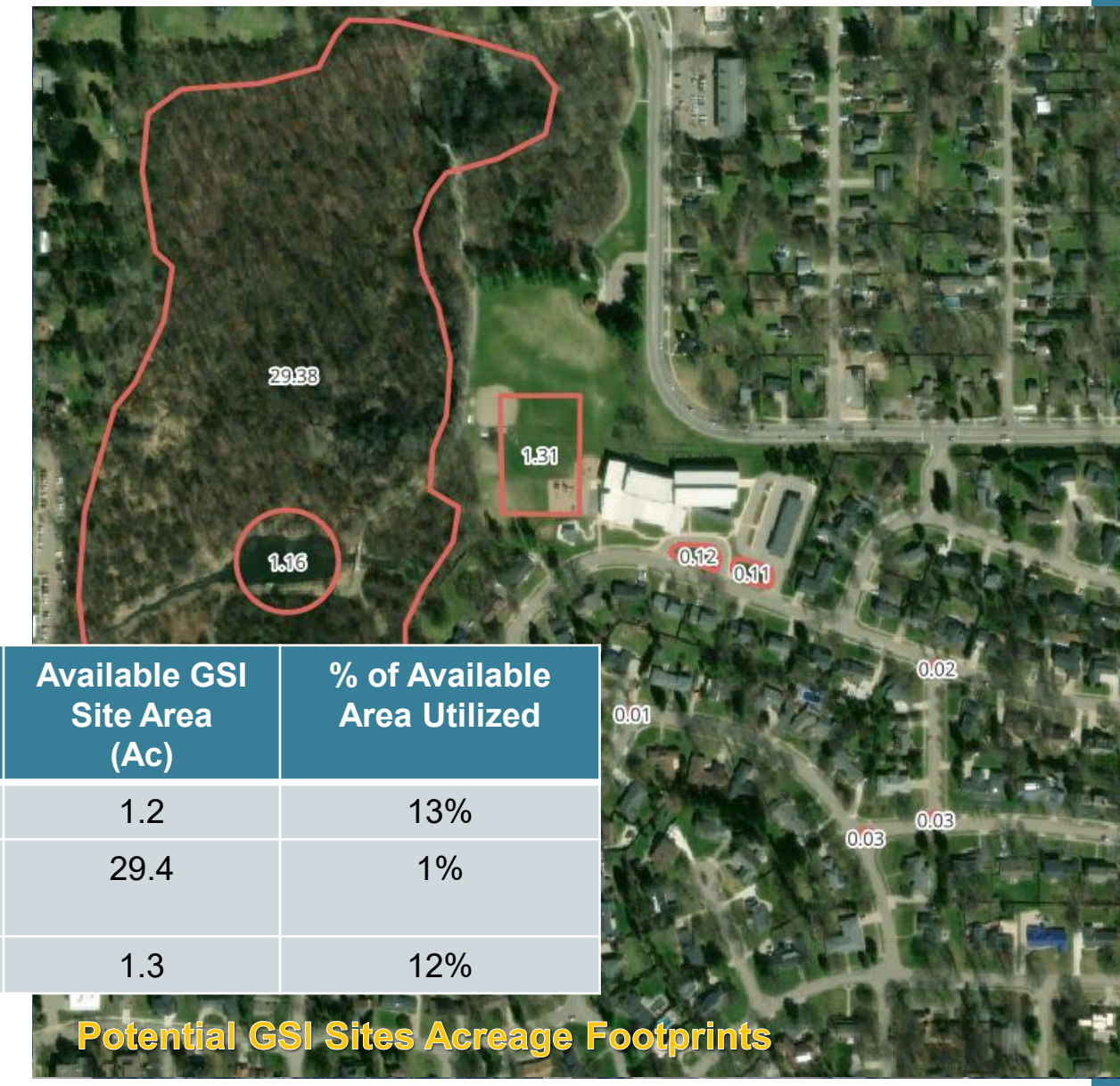
- Area H existing capacity: 102 MGD (158 cfs)
- Area H required capacity for current 10-year, 1-hour: 127 MGD (177 cfs)
- Approximate storage needed to offset peaks for current 10-year, 1-hour: 0.20 MG (0.61 Ac-Ft)

Storage Opportunity Analysis

Area H Upsizing

- Comparison of the potential GSI storage sites with the required storage footprints indicate the selected locations could be utilized to offset peak to White Memorial City Park-fishing Pond from sewer upsizing
  - The required storage footprint is calculated assuming a storage depth of 4.0 ft
  - Note: Total required storage for Area H is 0.61 Ac-ft. Table below shows three potential storage locations for this volume.
    - Storage could be divided into multiple locations

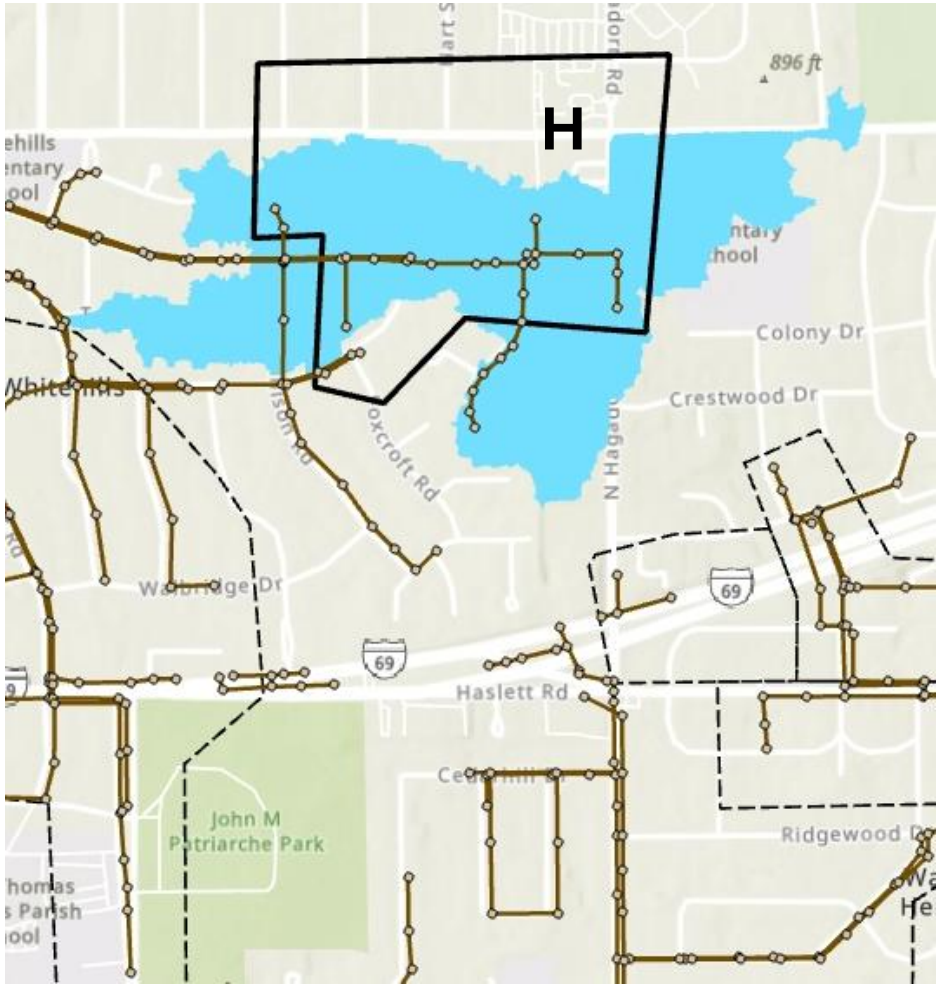
Separation Area	Storage Location	Storage Volume Required (Ac-ft)	Required Storage Footprint (Ac)	Available GSI Site Area (Ac)	% of Available Area Utilized
H	Pond	0.6	0.2	1.2	13%
H	Surrounding Park	See Above	See Above	29.4	1%
H	Ballpark	See Above	See Above	1.3	12%



Potential GSI Sites Acreage Footprints

MS4 Area H – Alt H2 GSI Storage Future Resilience

- Determine the difference in subcatchment runoff from the current 10-year, 1-hour storm (2.00 inches) and future 2100 10-year, 1-hour storm (2.54 inches)
- The difference in runoff (shown in blue) is the approximate volume of GSI storage needed to provide future resilience
  - Area H: +0.4 MG (1.3 Ac-Ft)



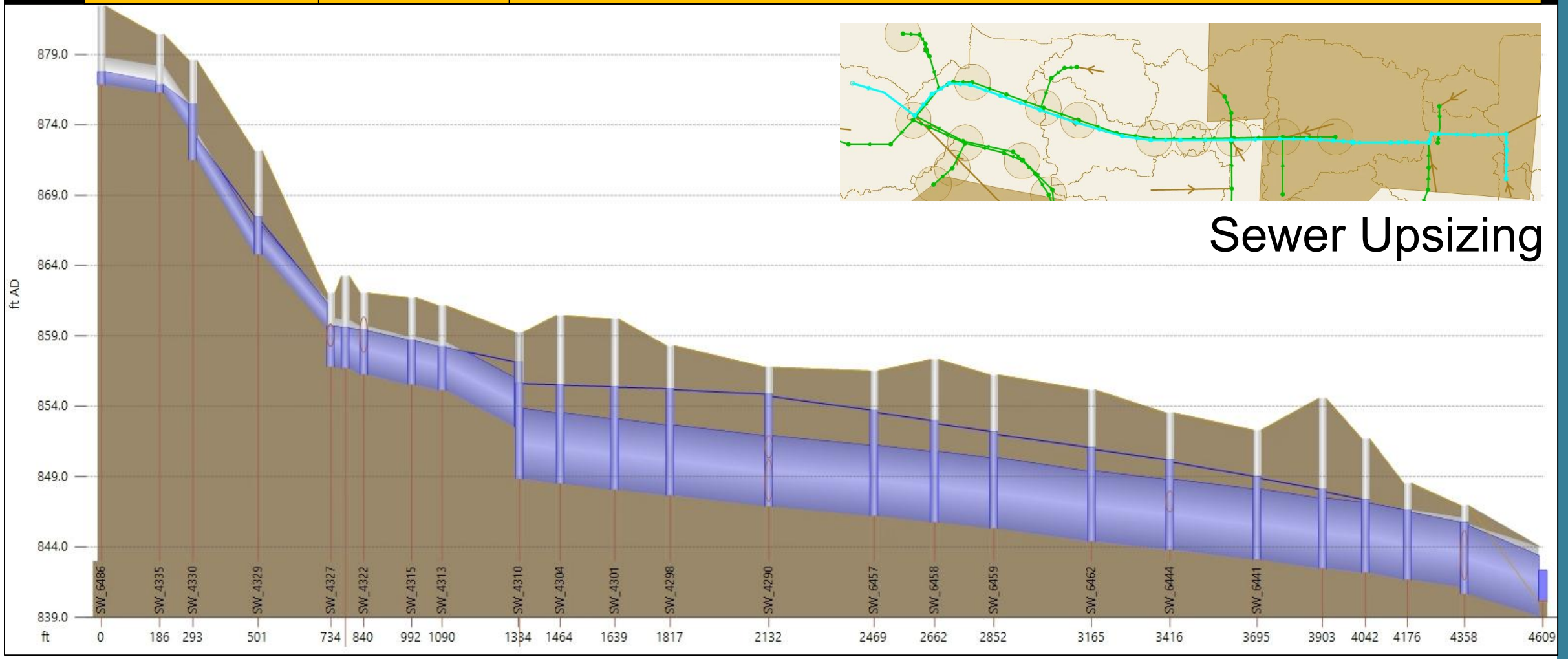
Area H – Alt H2 GSI Storage Sites

- Approximate volume to achieve future storm resilience
  - 0.4 MG (1.23 Ac-Ft)
- No available local storage to achieve future resilience storage target
  - Traffic islands do not provide enough volume required.
- To manage future storm will need a bigger pipe.



MS4 Area H – Alternative H2 Pipe Upsize and Restrictor

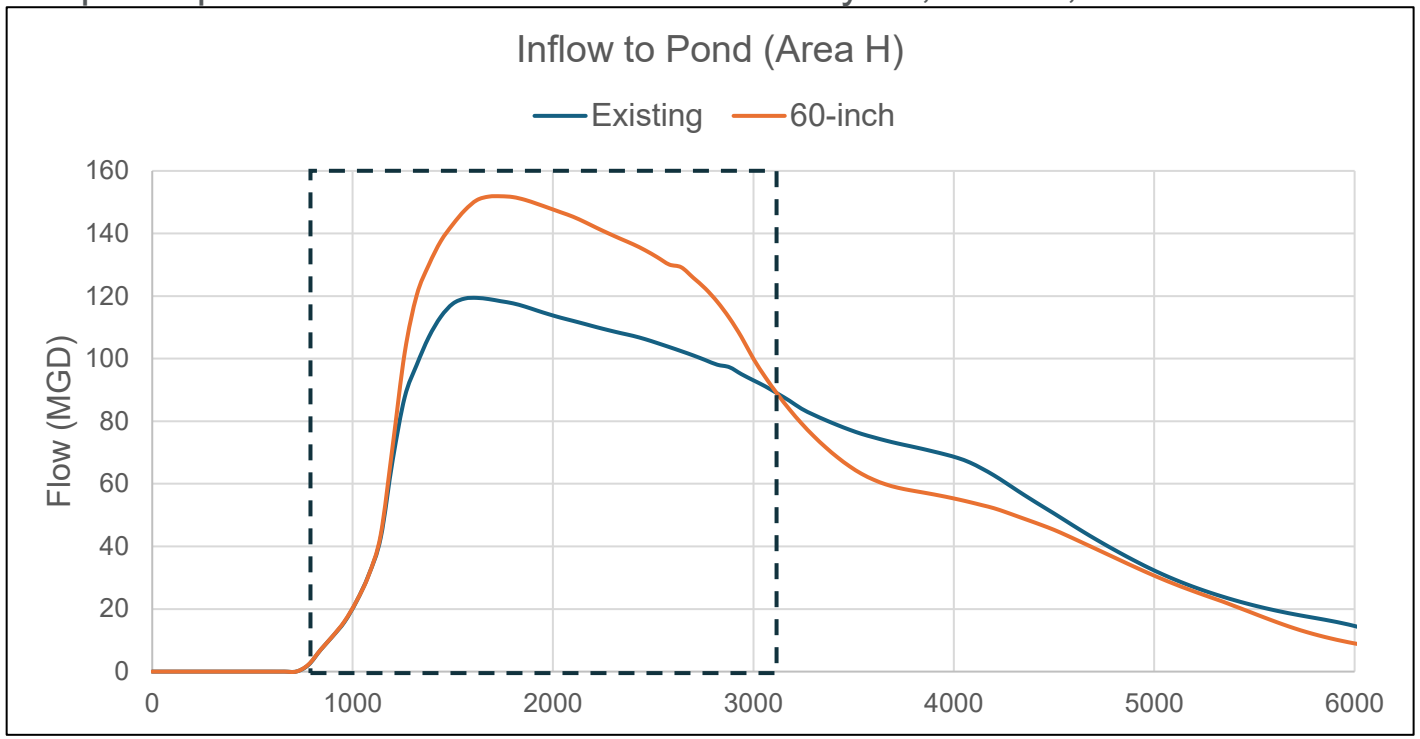
Required upsizes for the 2100 10-year, 1-hour, 2.54 inches



MS4 Area H – Alternative H2 Downstream Increased Flow

To White Memorial City Park-fishing Pond

Required peak attenuation for the future 10-year, 1-hour, 2.54 inches



Peak Flow

Scenario	Peak Flow (MGD)	Difference from Existing (MGD)
Existing	119.41	-
Run 1	151.89	32.47

Peak Volume

Scenario	Volume (Ac-Ft)	Difference from Existing (Ac-Ft)
Existing	7.71	-
Run 1	9.44	**1.73**

From 780 to 3120 simulation seconds

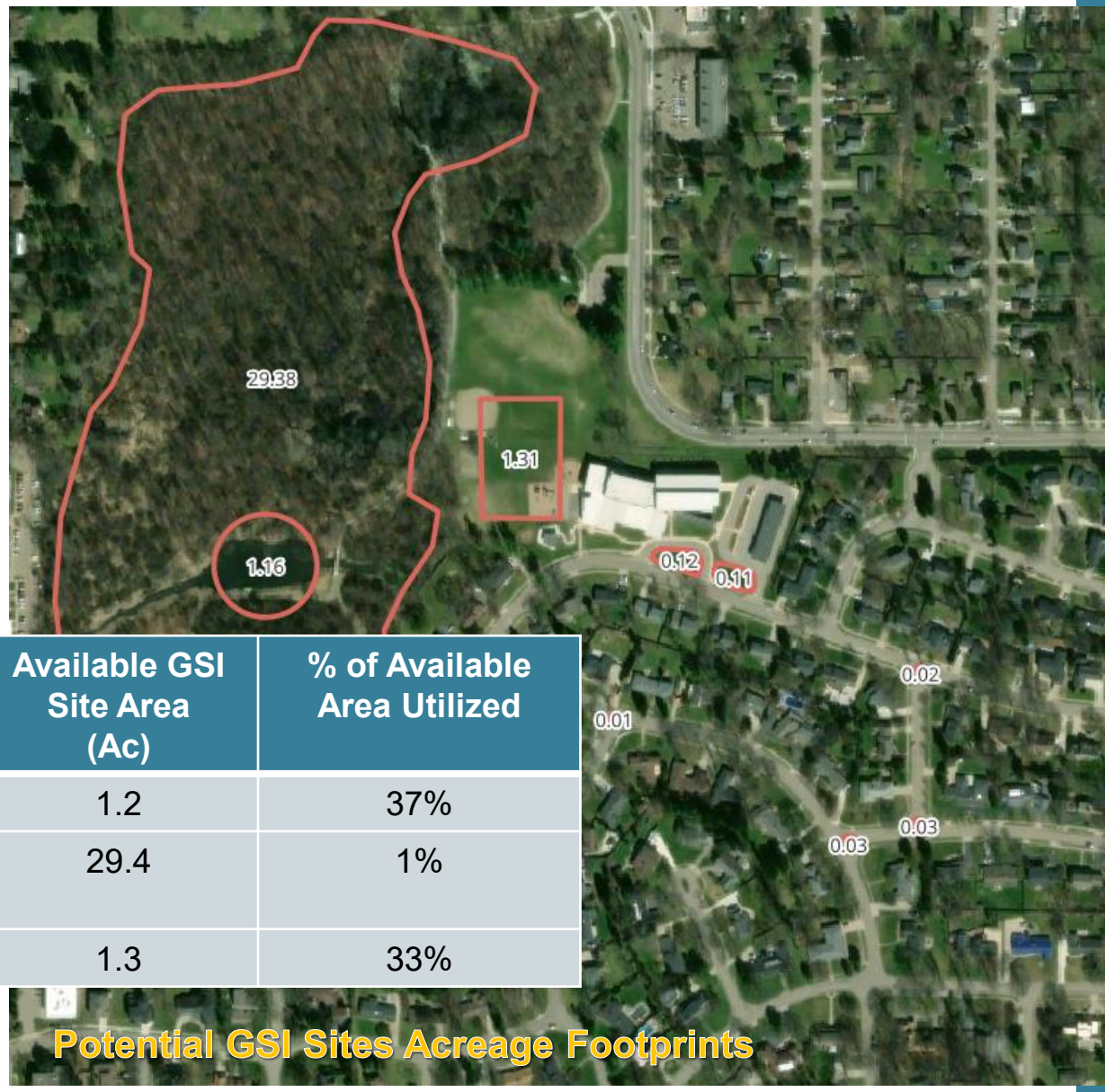
- Area H existing capacity: 120 MGD (186 cfs)
- Area H required capacity for future 10-year, 1-hour: 152 MGD (235 cfs)
- Approximate storage needed to offset peaks for future 10-year, 1-hour: 0.56 MG (1.73 Ac-Ft)

Storage Opportunity Analysis

Future Resilience

- Comparison of the potential GSI storage sites with the required storage footprints indicate the selected locations could be utilized to offset peak to White Memorial City Park-fishing Pond from sewer upsizing
  - The required storage footprint is calculated assuming a storage depth of 4.0 ft
  - Note: Total required storage for Area H is 1.73 Ac-ft. Table below shows three potential storage locations for this volume.
    - Storage could be divided into multiple locations

Separation Area	Storage Location	Storage Volume Required (Ac-ft)	Required Storage Footprint (Ac)	Available GSI Site Area (Ac)	% of Available Area Utilized
H	Pond	1.7	0.4	1.2	37%
H	Surrounding Park	See Above	See Above	29.4	1%
H	Ballpark	See Above	See Above	1.3	33%



Potential GSI Sites Acreage Footprints

MS4 – Summary of Results

- Area F
  - Requires ~7,000 feet of upsizing with largest pipe at the bottom with a size of 60”H x 144”W
  - Need downstream detention pond of 3.53 Ac-Ft for peak flow offset to protect county drain system
  - Need local storage of 4.00 Ac-Ft for future resilience, many opportunities but may require coordination with private property owners (parking lots)

MS4 – Summary of Results

- Area H
  - Requires ~4,600 feet of upsizing with largest pipe at the bottom with a size of 54” to matching size of existing outfall
  - Need downstream detention pond of 0.61 Ac-Ft for peak flow offset to protect county drain system
  - Upstream storage for future resilience not possible with available footprints. Requires upsizing with largest pipe at the bottom with a size of 60”
  - Using future storm need 1.73 Ac-Ft for peak flow offset to protect county drain system

Appendix A.4 – Alternatives

Modeling Results Workshop #2 (April 30th 2026)

City of East Lansing Wet Weather Resiliency Plan

East Lansing Wet Weather Resiliency Plan

Task 8: Alternatives Modeling Workshop #2

City of East Lansing
April 30, 2026

City of East Lansing Wet Weather Resiliency Plan

Task 8: Alternatives Modeling Workshop #2

April 30, 2026

Attendees

The City of East Lansing
Cliff Walls
Ron Lacasse
Bob Scheurman
Danielle Stahlin
Stephen Clayton

HDR
Ernie West
Tom Batroney (virtual)
Kaylee Johnson (virtual)
Julie Stein (virtual)

Slide Deck

The PowerPoint slides that were presented at the workshop are attached to the end of this workshop summary. The summary notes included hereafter are intended to document specific discussions, decisions and action items arising from the workshop. **Action items are noted in bold.**

Workshop Goals and Schedule Update

Project schedule to complete is tight, and the Project Team will need to be focused to achieve WWRP presentation at Council Meeting on September 15. Schedule drivers include the last Focus Group meeting to review and prioritize projects, and public open houses (virtual and in-person) to share the draft plan before City Council presentation.

Recap of Task 8 Work To-Date

The analysis in Task 8 is focused on LOS targets for two storms and the difference between current and enhanced LOS targets that were previously selected by the City.

Key assumptions that were identified at the December 2025 and February 2026 workshops were reviewed:

- Sewer separation effectiveness of 80% (20% remaining in the CSS)
- Need to keep Charles St project in the analysis because of the interconnectivity to several concern areas and that it is a bottleneck impacting many portions of the CSS

- Storm separation down Harrison St should be considered for Area B to offload flows from Area C and other areas downstream

City agreed that the previous workshop conclusions were accurately reflected.

HDR explained the 2.54 in/hr is based on 2100 global climate model projections, and represents the high end of projections in Task 1, and is being used to test the upper bound and account for the life expectancy of infrastructure upgrades being planned today.

Overview of alternatives and proposed projects

For the proposed projects summary table, HDR confirmed if the concern area type is CSS, than sewer upsizing is referencing upsizing of existing combined sewers and for MS4 areas, sewer upsizing is referencing upsizing of existing storm sewers.

For areas where additional separation is proposed, new storm sewers are proposed.

HDR explained that “a” projects are for the current 10-year storm, “b” projects include additional separation for the future 16-year storm, and “c” projects provide additional resiliency through GSI/storage.

Additional resiliency can involve higher LOS storm events and, in some cases, smaller pipelines.

City Staff mentioned discussions at the recent City Council meeting questioning the past decision to build an RTB and that full system separation should have been pursued instead. This needs to be considered when proposing/discussing alternatives that involve upsizing CSO lines and maintaining CSO infrastructure.

Project alternatives can be viewed in the Wet Weather Resiliency Plan Web Map at this link: East Lansing Wet Weather Resiliency Plan Web App. Alternatives can be toggled on and off in the Alternatives section of the Layers drop down menu.

CSS Alternatives Analysis Results

Challenges of CSS include diversions and interconnections. HDR provided a CSS watershed map that illustrates the interconnectivity. Due to the interconnectivity, the CSS concern areas were analyzed in groupings.

Areas A & B

Alt 1a & 1b

Alternatives involve separating CSS areas in Concern Area A and B, installing new trunkline storm mains routed to Ranney Park, upsizing and adding some existing combined sewer and redirecting some flow to Cowley Avenue.

City questioned if separating Shaw Estates and routing storm sewer trunkline down Harrison St was reviewed. For this alternative it was not. It was reviewed in a combined alternative for Areas B, C and D.

Alt 1a&1b includes stormwater separation effectiveness of 80% for areas shown in blue with storm only flowing going to Ranney Park and Montgomery St; there are backwater effects due to 20% of flow remaining within the existing combined sewer system, and requires additional projects to meet LOS for the current 10-year storm; upsizing is similar to the prior master plan project at Cowley Avenue and modified to account for separation.

City mentioned ongoing issues such as manhole and culvert for low lying property, plus Abbot Road.

Discussed assumptions for tying into the Montgomery St drain. Tie into existing drain, assumed normal pool elevation at Ranney Park of ~825 ft; showed profile of proposed storm trunk main and sizing for both design storms.

City to review and provide the drain commission agreement for how much flow can be sent to the 3 connections that exist today. HDR to look at limiting flow routed to Ranney Park to previously agreed to amounts.

HDR can look at peak flow and volume for flow going to Ranney Park, and provide these numbers and forward what we will convey. Showed storm sewer main sizes and peak flow for current 10-year and 16-year; may need to negotiate with drain commission.

The City was supposed to get a larger connection and more connections to Montgomery St. Northwest corner of Saginaw and Coolidge; another 24 at Harvard; and then south end of Glenmore. Need to confirm these connections and locations and refine Alt 1a and 1b. (*Sketch was developed by the City and provided at end of meeting*).

For the storm sewer trunk mains, discussed potential alignments and noted drop in elevation and concern about bank and coming up hill by mall area to connect to Glenmore and then to pond; if separated areas upstream are conveyed to Harrison Street or to closer drain connections, potential to lop off contributing flows and reduce size of pipe and volume to the downstream.

LOS results mapping (green, red, yellow) from the hydraulic model were provided for the current 10-year and future 16-year design storms, with and without alternative projects. City suggested adding the graphic for the 16-year LOS results without projects.

HGL profiles of the existing combined sewer were also provided for the current 10-year and future 16-year design storms, with and without alternative projects. City suggested

where showing HGLs, consistently label a few reference points like larger streets and/or match up labels on profiles to the maps. Also, add concern area A, B, Cs to DEM maps. **HDR will add in references to the profiles.**

Gordon Guyer Park Resilience Opportunity

This opportunity does not reduce size of the stormwater trunk main but would provide enhanced LOS.

Area D

Alts 2a, 2b, 2c

Alternatives involve separating CSS areas in Concern Area D, installing new trunkline storm mains routed to the Red Cedar River, upsizing and adding some existing combined sewer, creating a new CSS regulator at Louis Street and lowering the weir at the Beal Street regulator.

The shallow depth of the existing combined sewer within Area D increases the difficulty of achieving LOS. For sewers less than 8.5 ft deep, the surcharge must not exceed 1 ft above pipe crown. Depending on the actual elevation of basements within this area, additional surcharge may be OK, but basement elevations would need to be confirmed.

On the first HGL profile, the Red line is close with current 10-year and future 16-year; need to see what this increase is and look/comment.

- *(There is increased manhole flooding at during the larger design storm. The sewer capacity is well exceeded for both storms under existing conditions. Since flow is lost to the surface, the HGLs appear similar).*

On the second HGL profile, LOS is improved upstream of the Beal St. regulator for Alt 2b (Green line) for the future 16-year storm.

Route of stormwater trunk main, City questioned why the alignment did not extend further northeast down Michigan Avenue; HDR explained challenge with elevations and distances to come through the bowl at Valley Ct., and either route will require chasing grade; City requested to revise/ relook at alignments and proposed pipe routes leaving neighborhoods, prefer to have flooding on Michigan Avenue. Biggest bang for the buck may be the existing separate storm sewer and potentially upsizes; HDR confirmed that the pipe sizes of the stormwater trunk may not change since the same amount will be offloaded, but the alignment needs to be further evaluated to consider the depth of cover with sags. **HDR to review alignment down Delta St and Michigan Avenue.**

MDOT will have to participate in funding storm sewer upgrades in Michigan Ave.

Valley Court Park

Will require more detailed modeling for design but this location has the ability to lop off a significant portion of drainage area – almost 80% of watershed – for storage and peak flow control. Potential to reduce the required stormwater pipe size by a few sizes.

Areas B, C & D

Alt 3

Alternative involves Alternate 2a, which includes separating CSS areas in Concern Area D, installing new trunkline storm mains routed to the Red Cedar River, upsizing and adding some existing combined sewer, creating a new CSS regulator at Louis Street and lowering the weir at the Beal Street regulator, plus the addition of more CSS separation in Concern Area B and in areas either side of Harrison Street, plus a new storm water trunkline sewer running down Harrison.

As analyzed, this alternative did not solve flooding/surcharging in Concern Areas B and C, but significantly improve other concern areas along Harrison St. Really challenging project because of major ridgeline on Harrison St, really deep pipe and elevations. The City is very aware.

City questioned why separation of Shaw Estates, did not solve Area B. HDR explained that Alt 3 did not include offloading water to Ranney Park via the alternative projects for Area A. **City would like to analyze the Harrison Rd project in combination with offloading water from Area B through Area A and Ranney Park. HDR to review.**

Key takeaways: reinforcing need to offload Harrison due to the number of other concern areas that benefit; reinforcing need for the Charles St project since it has so much impact on HGL and Area C.

Areas C, E & G

Alts 4a, 4b & 4c

Alternative involves separating CSS areas in Concern Areas C, E and G. Additionally, west of Abbot Rd, new storm sewer trunklines would be required to be extended from Area D (or down Harrison Rd) to route separated storm water to the Red Cedar River. East of Abbot Rd, existing CSS mains would require upsizing upstream of the CSO tunnel due to lack of available outfall for separated storm water, with the exception of possible offloading of stormwater to storm sewers on Gunson Street. Finally, two bulkheads would be added to re-direct flow to Bailey Street.

One key assumption the Project Team made was that we can tie into the Gunson St project currently being built and potentially with storage e.g., at the High School, to meet LOS for the future 16-year storm for Area E and Area G. This concept would require

detailed modeling of Gunson St project, to verify if the storm sewer has capacity to accept additional flows.

Could expand sewer separation for Area C for additional benefits but has limited benefit downstream at Charles Street. All turns back to Red with future 16-year storm. Conduits in the area cannot handle 2.54 in/hr because of the volume of water and lack of capacity in Gunson and Charles Streets. Lack of nearby stormwater outfall from Charles Street limits the type of projects that can be considered for Area C.

HGL profile is through Charles St and up through Area C with Sunset Diversion and Abbot and Merchant. Alt 4a achieves LOS for current 10-year (with exception of downstream at Charles Street nearing the regulator), but Alt 4b does better. Tested with increase in weir regulator length from 6.75 to 10 feet, and shows HGL decreases.

City questioned how the Charles St sewer discharge into the CSO tunnel is modeled. City indicated that the 78” pipe, goes into chamber and takes pipe thru 12” orifice to restrict flow through campus; this shouldn’t change. City commented the weir does not restrict anything going to tunnel, it will be free discharge. Hopefully some of the issues upstream could be mitigated, orifice coefficient and velocity impact model results. **HDR will review the representation of the structure in the model and confirm with City.**

4a also includes the previous master plan project down Bailey St. and connecting into Charles Street. Bulkheading will help for 10-year design storm, future 16-year design storm may send more flow downstream; but will help Area G.

West side of the CSS has the most amount of separation required. Topological challenges of a storm sewer trunk main include bucking grade and going 30+ ft deep and with Harrison St ridgeline.

Even with resiliency opportunities at Glencairn Park, Shaw Park, and Hannah Community Center the stormwater trunk sewer main remains deep, and large especially for the 16-year design storm with Alt 4b.

CSO Impacts

HDR shared preliminary results of a completed CSO peak flow and volume analysis, so to not lose sight on CSO regulatory compliance. Analysis shows that proposed alternatives will reduce overall CSO volume with phasing to include sewer separation first. Model predicts combined sewers upsizing projects alone would increase CSO at Kalamazoo Street if separation projects are not completed first or concurrently.

Overarching Thoughts for CSS

City would like to know the number of basement backups before and after the projects are implemented, ie.

- What does including additional ft of pipe or acre of separation achieve?
- Would other solutions be more cost effective, such as backflow preventers, purchasing problematic properties, etc.?
- Consider low cost and non-structural strategies like reducing paving or underground storage at private property.

HDR confirmed that Area B, Area C, and Area D Alt 3 projects do not include improvements in Area A; Alt 3 was modeled based on sewer separation identified in the previous master plan project.

Separation of Area B does not achieve 10-year LOS without separation in Area A downstream.

City beginning to think about funding for projects, ie, BRIC grant application for Charles St.

City expressed that it seems a lot of areas are still unsolved, even with all the alternatives proposed. There may be a belief in the community and within the City Council that all flooding can be solved. Need to communicate large effort and large amount of funding needed, the inability to solve for every storm event and lack of funding available. Communication should include describing risk avoidance as opposed to never flooding again.

Be prepared to address questions around fully separating the CSO system.

HDR will include LOS results mapping for the 2100 (16-year) results without projects.

MS4 Alternatives Analysis Results

Area F

Alternatives involve upsizing existing storm sewer trunkline and storage at the downstream end to control peak flow rates into downstream county drain.

Reviewed surface flooding at the location where Kendale and Woodland pass intersect south of fire station. Manhole flooding is an issue for lower property at the southwest corner of Woodland Pass; isolated culvert restrictions flow, culvert size can be increased to push flow down to drain. **HDR to include culvert upsizing.**

Wet weather runoff in the model is highest in Area F due to large amounts of impervious area from buildings and parking lots. A large stormwater pipe is required to convey this flow downstream. Pipe sizes required for current and future storms is much larger than CSS pipe upsizes. HDR questioned if 240-inch W box culvert is wider than Abbot Road. Storage at the downstream fire station, or surrounding areas, would be needed to offset the increase in peak flows to the drain with upsizing. Locations are prone to flooding

already and feasibility will need to be reviewed. City frequently observes flooding north of Bessemaur Dr. during large rainfall events. Need to investigate storage upstream, City will need to help identify any private property options. Also need to verify that additional conveyance capacity to the Fire Station area will no make existing conditions worse, or even the perception of making it worse (Quarters area).

The City has observed combined sewer flooding along Abbot and Northlawn CSO spews out of system at the bottom of Area F, which was confirmed by the model results. The City and HDR agree that it would be good to redraw the concern area boundary so southern part of Area F is in CSS (Area C) and can be addressed by alternatives in Area C. **HDR to modify Area F boundary and include this area in Area C.**

Area H

Alternatives involve upsizing existing storm sewer trunkline, removing existing flow restrictor and storage at the downstream end to control peak flow rates into downstream county drain.

Apart from upsizing the storm sewer along Pebblebrook Ln to White Memorial City Park fishing pond, Dennison Road may benefit from surface storage or green infrastructure to address remaining surface flooding not solved by trunline storm sewer upsizing and restrictor removal.

The storm sewer upsizing for Area H is a more reasonable pipe size because runoff is not as great, as compared with Area F. In addition, there are good opportunities at the park to incorporate a peak flow detention strategy to mitigate impacts further downstream.

Alternatives Results Summary and Key Takeaways

See the key takeaways slide and next steps slides.

Need to finalize analysis and confirm alternatives to price and prioritize (Task 10).

Prepare for focus group meeting to convey solutions to public in June.

Identified feasibility and implementation considerations to continue to discuss:

- Alignments, especially Area D storm outfall routing down Michigan Ave
- Connections and flow rates to Ranney Park
- Overall Feasibility
- Potential Utility or Other Conflicts
- Construction Impacts
- Need for Phasing of Projects

The City to send pictures/drawings of Charles Street sewer drop into CSO tunnel.

City would like to have the combination of offloading water from Shaw Estates through the A/B alternative, limited to flow that Ranney Park can accept, combined with the Harrison Road storm main and associate separation analyzed. **HDR to review.**

City would like confirmed that the analysis for Area F considers the restriction caused by the existing culvert at Lake Lansing Road. **HDR to review.**

City is putting in a BRIC grant for the Charles Street project.

City noted that sewers that are part of the alternatives for Area D are part of the current SRF project plan and has been targeted for SRF funding and that proposed alternatives should be aligned, as able, with previous plans.

City will provide bid tab for the Gunson Separation project, or other current cost info from City sewer/separation projects.

Action Items Summary

- Resend link to webmapper (HDR, *See below*)
    - Project alternatives can be viewed in the Wet Weather Resiliency Plan Web Map at this link: East Lansing Wet Weather Resiliency Plan Web App. Alternatives can be toggled on and off in the Alternatives section of the Layers drop down menu
- Add a few reference points (i.e., streets) on HGL profiles, and match up labels on profiles to the maps. Add concern area identifiers (A, B, etc.) to DEM maps (HDR).
- Send manhole and culvert for low lying property and Abbot existing conditions info (City)
- Provide and review the drain commission agreement for how much flow can be sent to the 3 connections that exist today to Ranney Park (City)
- Look at limiting flow routed to Ranney Park to previously agreed to amounts (HDR)
- Review alignment of new storm trunkline down Delta Street and Michigan Avenue (HDR)
- Analyze the Harrison Rd project in combination with offloading water from Area B through Area A and Ranney Park (HDR)
- Review model representation and tunnel drawings, with elevation offset (HDR)
- Refine Area C and F, to ensure the CSS issues are part of Area C, since everything ends up in Charles St. (HDR)
- Include culvert upsizing to solve localized flooding in north end of Area F (HDR)
- Review culvert restriction at Lake Lansing Road for Area F impact

- Include LOS results mapping for the 2100 (16-year) results without projects (HDR)
- Review proposed pipe routes (HDR/City)
- Send pictures of system challenges discusses (overflows, etc.) (City)
- Send Gunson bid costs or other current cost info (City)



City of East Lansing Wet Weather Resiliency Plan

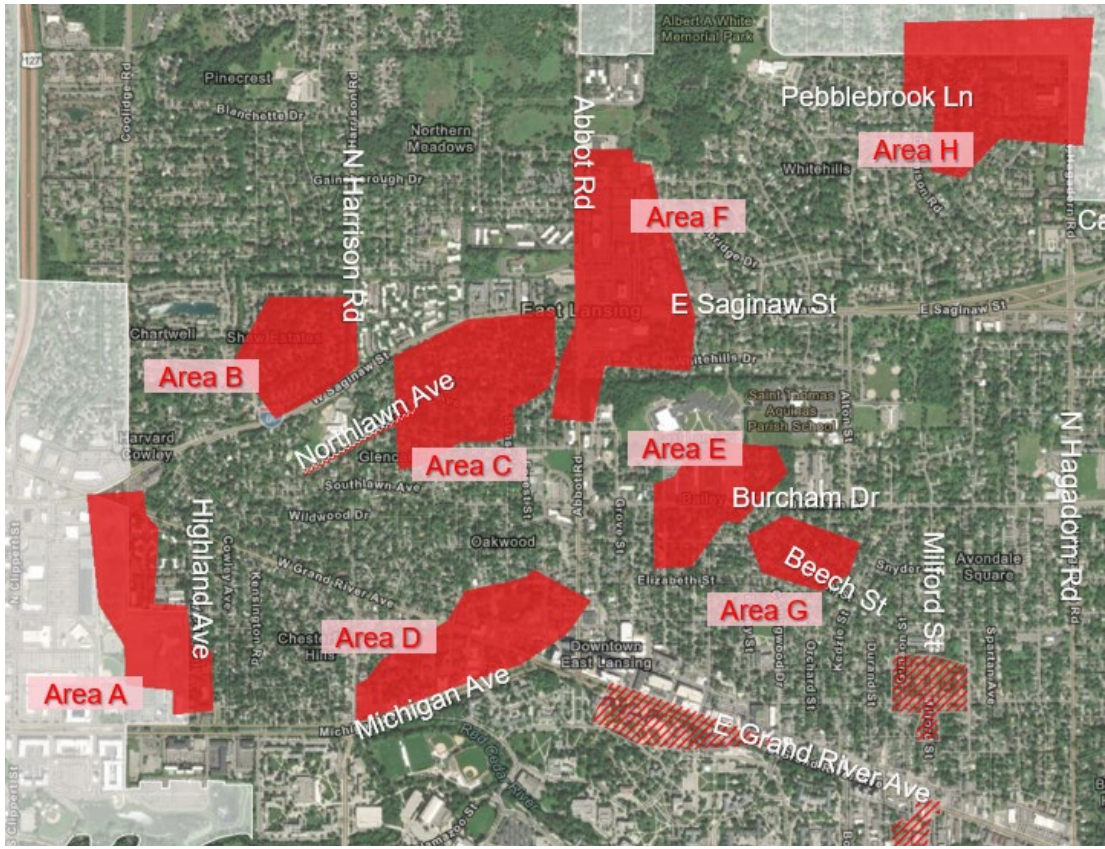
Task 8: Alternatives Modeling Workshop #2

04.30.2026



Today's Agenda

1. Workshop Goals and Schedule Update
2. Recap of Task 8 Work To-Date
3. CSS Alternatives Analysis Results
4. MS4 Alternatives Analysis Results
5. Alternatives Results Summary, Key Takeaways and Next Steps



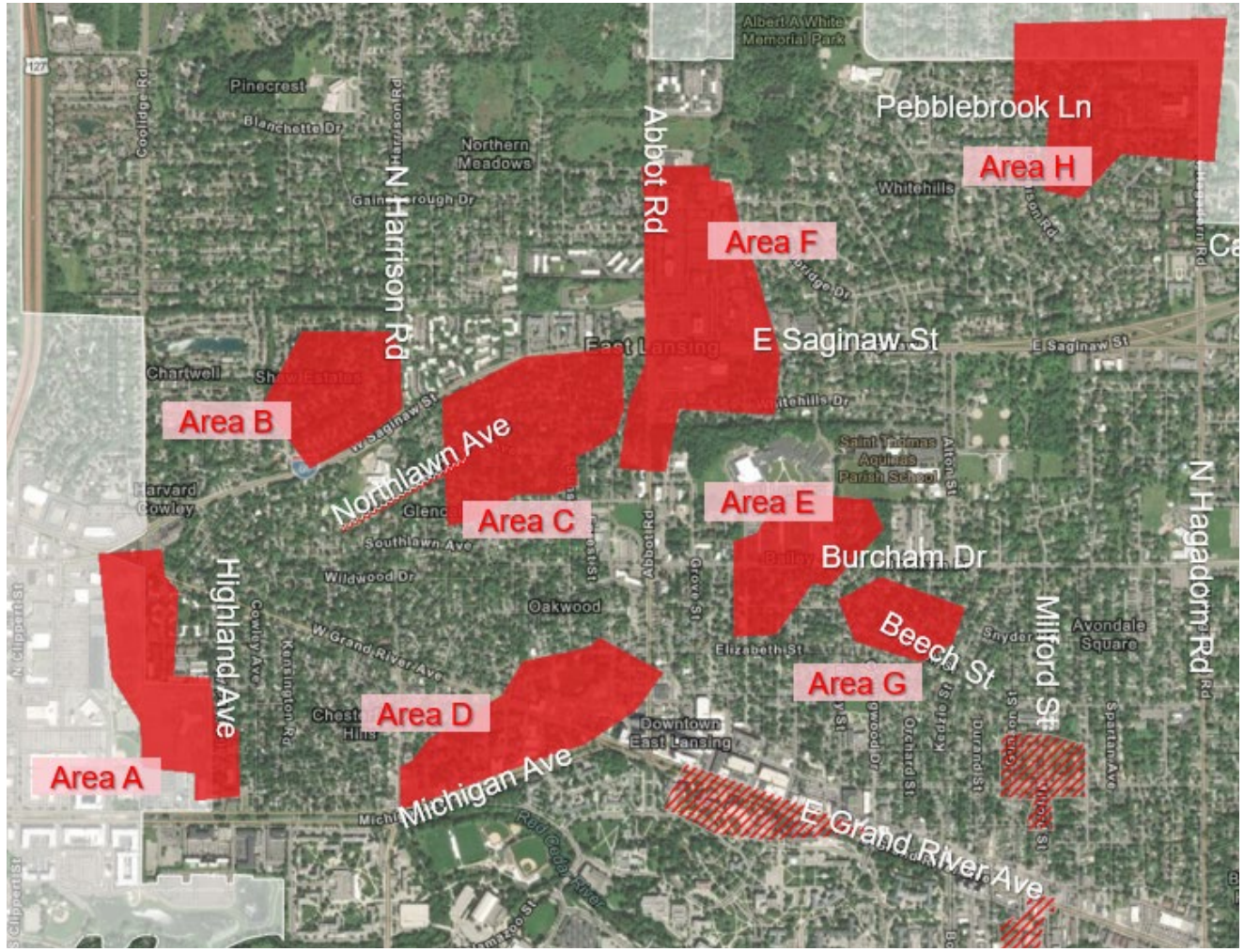


01

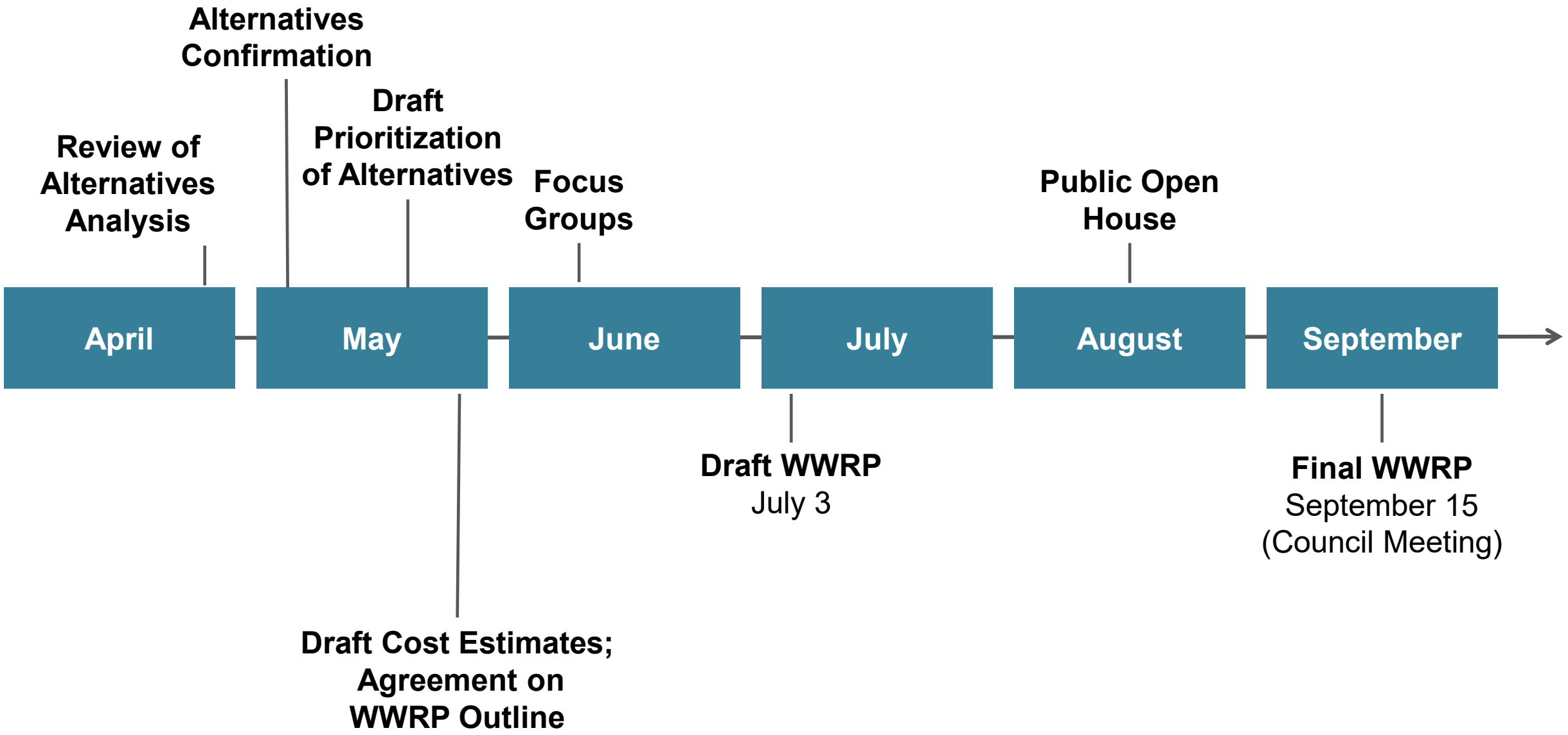
Workshop Goals and Schedule Update

Workshop Goals

1. Discuss alternatives analysis results
2. Gather City feedback related to feasibility and implementation of alternatives
3. Confirm direction for advancing project prioritization and costing



Next Steps


Review of Alternatives Analysis
Alternatives Confirmation
Draft Prioritization of Alternatives
Focus Groups
Public Open House
April
May
June
July
August
September
Draft Cost Estimates; Agreement on WWRP Outline
Draft WWRP
July 3
Final WWRP
September 15
(Council Meeting)



02

Recap of Task 8 Work To-Date

Key Outcomes: Initial Strategies Workshop (Dec 2025)

- Established existing level of service (LOS), root cause, and potential flood risk mitigation strategies in concern areas

Concern Area	System	Existing LOS	Root Cause	Identified Alternatives				
				Storm Separation	Pipe Upsizing	Sewer Diversion	Regulator/ Restrictor Modification	Opportunities for Green Infrastructure
A	CSS	2-year, 1-hour	Sewer Capacity	x	x		x	
B	CSS	5-year, 1-hour	Sewer Capacity	x		x		Gordon Guyer Park
C	CSS	2-year, 1-hour	Sewer Capacity	x	x			Glencairn Elementary, Shaw Park, and Hannah Community Center
D	CSS	<1-year, 1-hour	Sewer Capacity	x			x	Valley Court
E G	CSS	1-year, 1-hour	Sewer Capacity		x	x	x	
F	MS4	<1-year, 1-hour	Sewer Capacity		x			Underground Storage Parking Lot, *Fire Dept Open Lot**
H	MS4	<1-year, 1-hour	Sewer Capacity		x		x	*Albert A White Memorial Park**

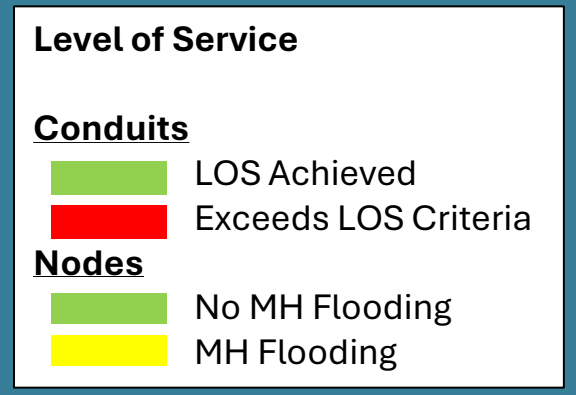
* Opportunities are downstream of concern area identified but can be used to mitigate peak flow increases resulting from pipe upsizes.

Key Outcomes: Initial Strategies Workshop (Dec 2025)

- Selected LOS evaluation storms for modeling:
  - Current 10-year, 1-hour of 2.00 inches (Current)
  - 2100 Future 16-year, 1-hour of 2.54 inches (Enhanced)

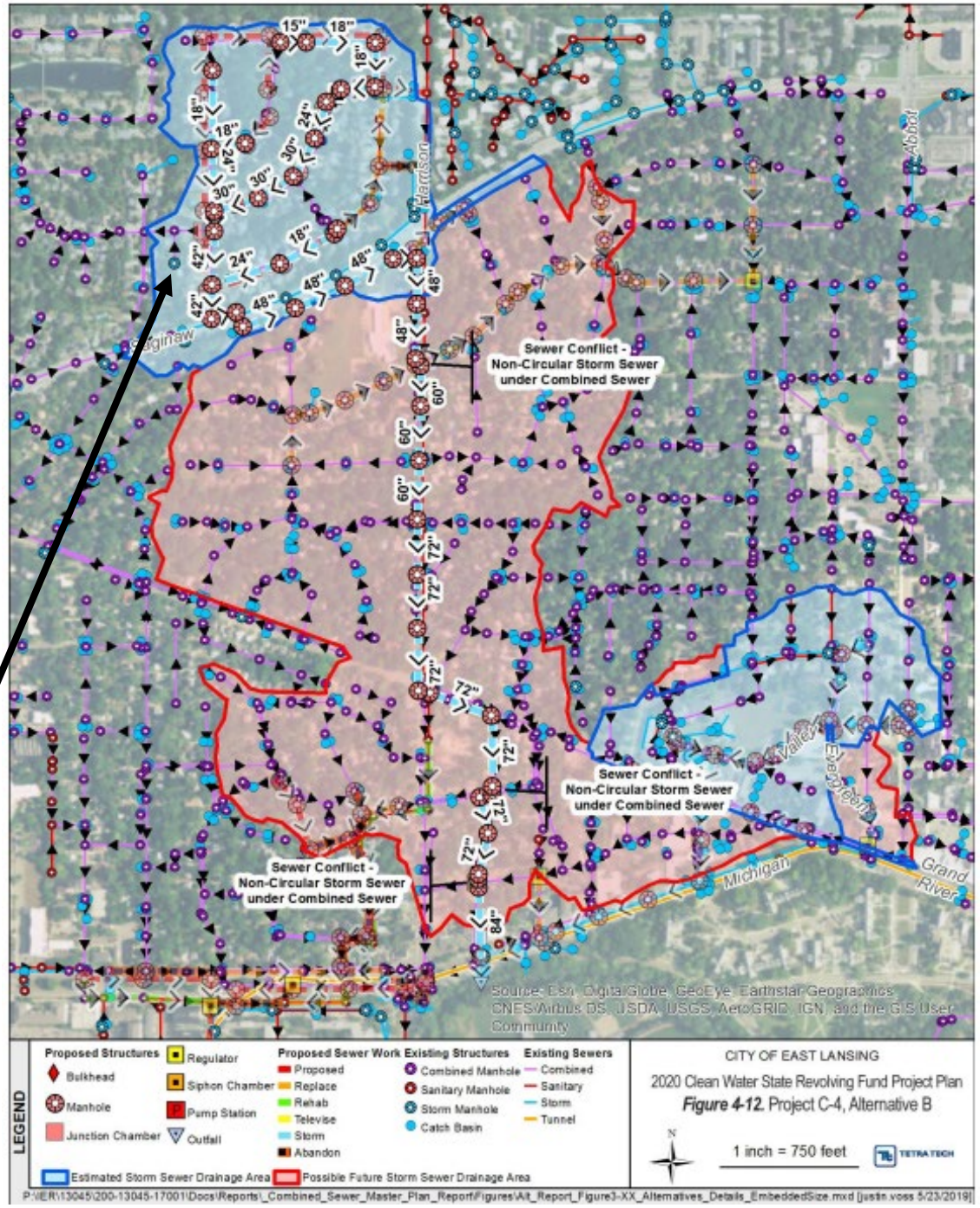
LOS goal in CSS = HGL is 8.5 ft below ground at either or both ends of pipe; Or surcharge less than 1.0 ft above pipe crown

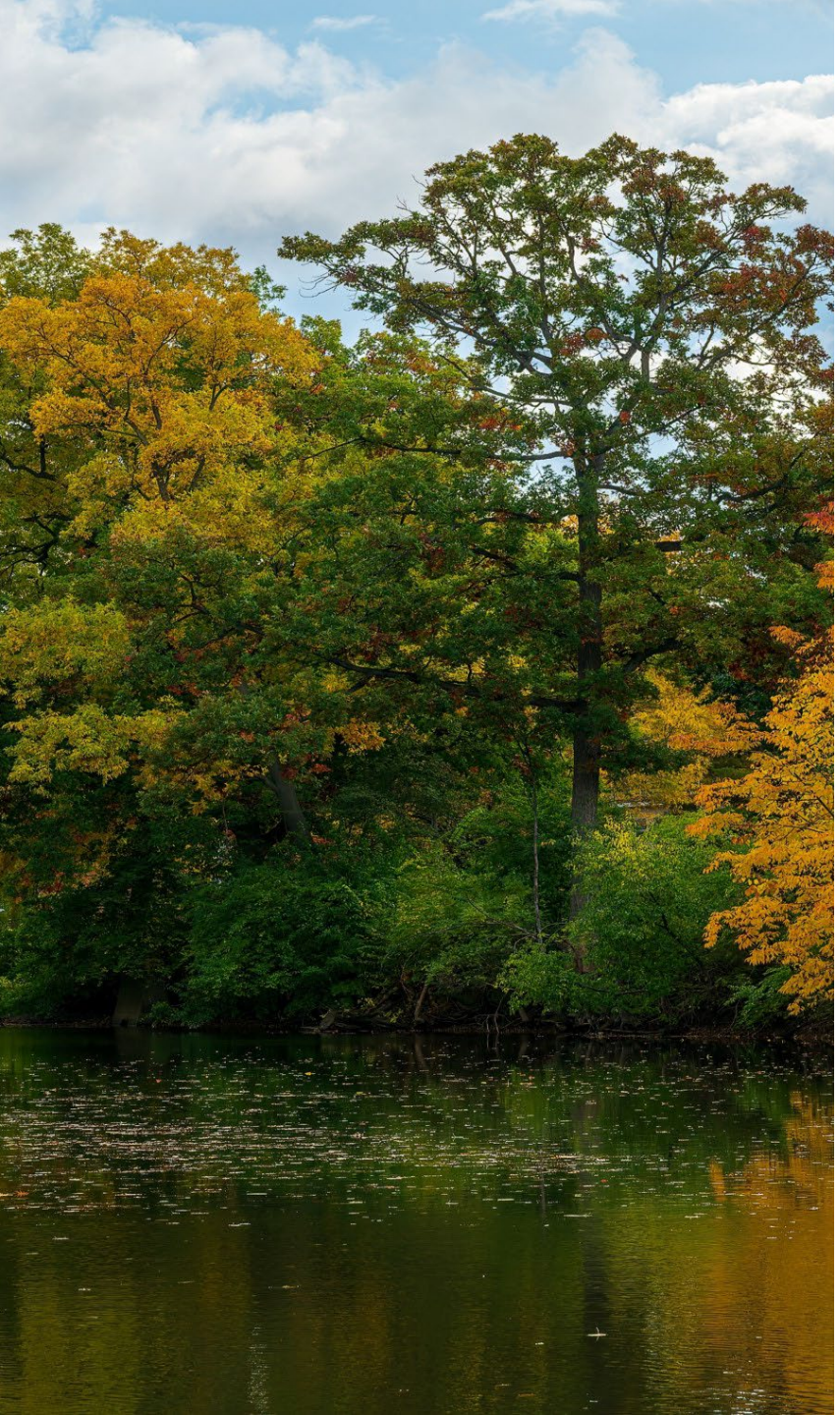
LOS goal in MS4 = No manhole flooding onto the surface



Key Outcomes: Ph I Modeling Results Meeting (Feb 2026)

- Established storm separation effectiveness:
  - 80% is captured in new storm pipes, 20% remains in existing combined pipes
- Charles St causes reverse flows over the Sunset Diversion upstream into Area C
  - Charles St sewer is a bottleneck impacting many portions of the CSS
  - The City decided to keep the Charles St upsize in all CSS model alternatives given the impact to the system
- Area B alternative should consider storm separation down Harrison St to offload flows from Area C and multiple concern areas downstream





Key Outcomes: Ph I Modeling Results Meeting (Feb 2026) (cont.)

For Top 8 concern areas, the City expressed the need to understand:

1. The increase in project size between current 10-year storm (2.00-in/hr) and future 2100 16-year enhanced storm (2.54 in/hr).
2. Can LOS be increased by implementing storage/green infrastructure? Can resilience projects achieve a higher LOS or reduce pipe size?
3. Are there other adjacent concern areas that can benefit from projects in the Top 8?

Alternatives and Proposed Projects Evaluated

Concern Area	Alt	Proposed Project(s)
A & B	**1a**	• 107.3 ac of storm separation • Restrictor modification – remove flow restrictor • 2,100 ft of sewer upsizing • 725 ft of new combined sewer • 2 sewer bulkheads
	1b	• 1a plus additional 68.7 ac of stormwater separation (total 176.0 ac)
	1c	• 1a or 1b plus Gordon Guyer Park storage
D	**2a**	• 77.6 ac of storm separation • Restrictor modification – lower weir at Beal St to invert of overflow sewer • New regulator at Louis St • 2,000 ft of sewer upsizing • 600 ft of new combined sewer
	2b	• 2a plus additional 14.6 ac of storm separation (total 92.2 ac)
	2c	• 2a or 2b plus Valley Court Park Storage
B, C & D	**3**	• 2a plus additional 122.5 ac of storm separation at Harrison St (total 200.1 ac)

Alternatives and Proposed Projects Evaluated (cont.)

Concern Area	Alt	Proposed Project(s)
C, E & G	**4a**	• 71.5 ac of storm separation • 8,100 ft of pipe upsizing • 900 ft of new combined sewer • 2 sewer bulkheads
	4b	• 4a plus additional 128.4 ac of storm separation (total 199.9 ac)
	4c	• 4a or 4b plus Glencairn Park, Shaw Park, Hannah Community Center storage
F	**5a**	• 7,600 ft of main storm sewer upsizing • 3.53 ac-ft of storage at Fire Department
	5b	• 5a plus additional 1.59 ac-ft of storage at Fire Department or upstream detention (total 5.12 ac-ft)
	5c	• 5a or 5b plus storage under parking lots
H	**6a**	• 4,600 ft of main storm sewer upsizing • Restrictor modification – remove flow restrictor • 0.61 ac-ft of storage at White Memorial City Park-fishing Pond
	6b	• 6a plus additional 1.12 ac-ft of storage at White Memorial City Park-fishing Pond (total 1.73 ac-ft)



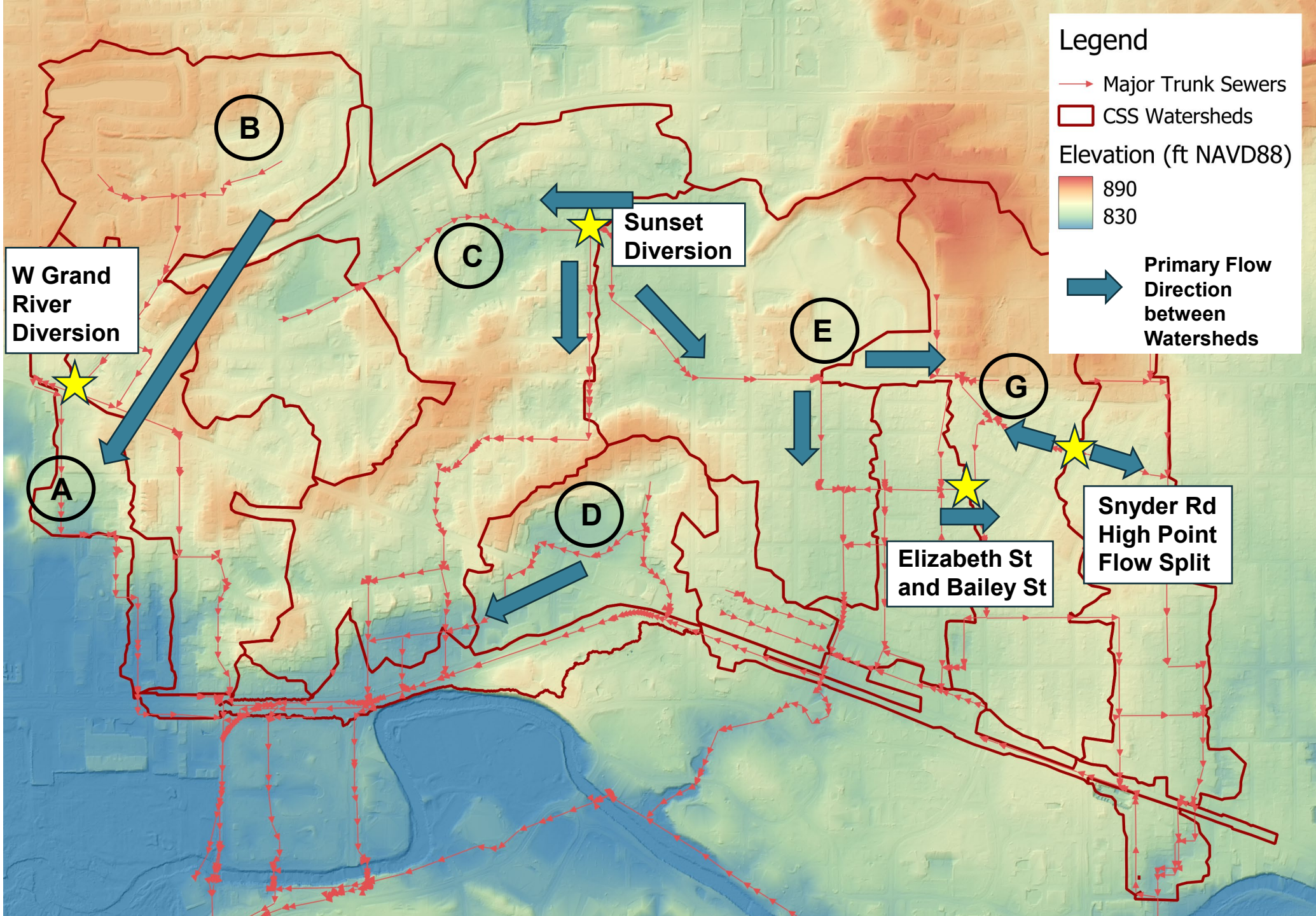
03

CSS Alternatives Analysis Results

CSS Watersheds

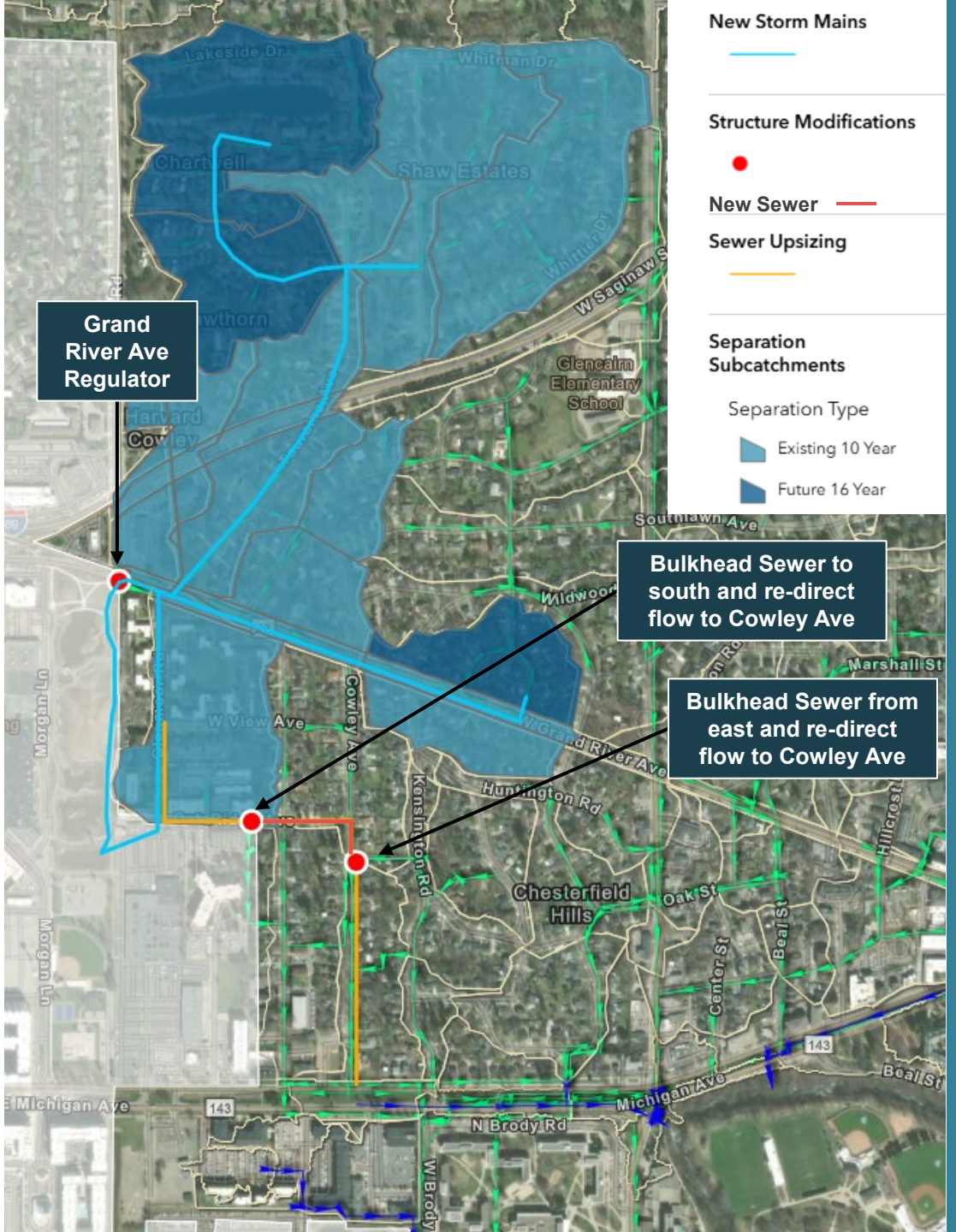
Watersheds and concern areas are hydraulically connected

- B impacts A
- E impacts C
- E impacts G
- D is independent
- Key Hydraulic Flow Splits



Areas A & B Alternatives

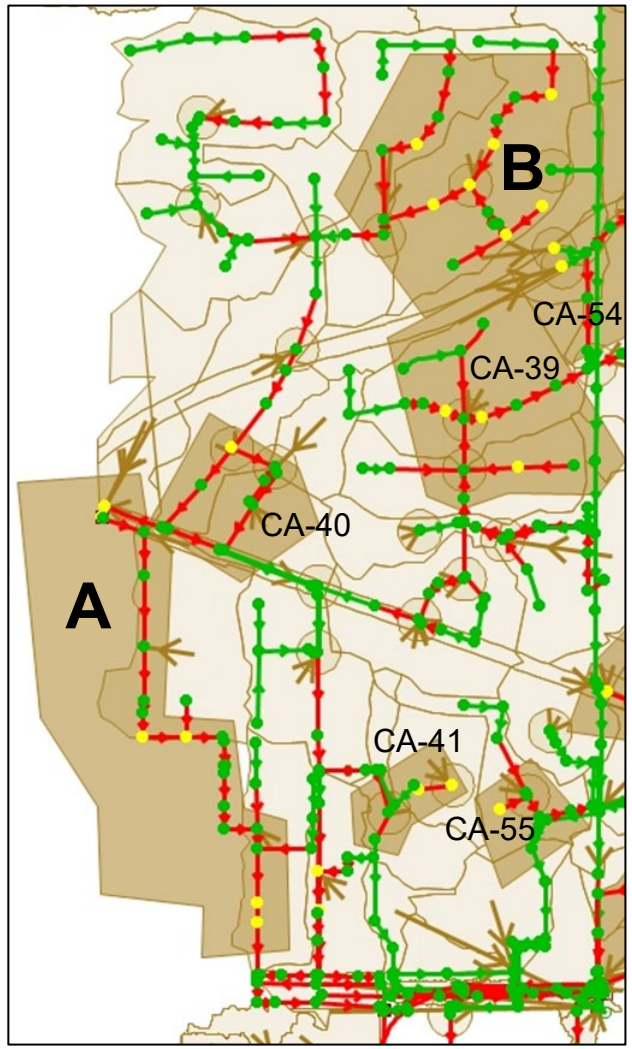
Concern Area	Alt	Proposed Project(s)
A & B	**1a**	• 107.3 ac of storm separation • Restrictor modification – remove flow restrictor • 2,100 ft of sewer upsizing • 725 ft of new combined sewer • 2 sewer bulkheads
	1b	• 1a plus additional 68.7 ac of stormwater separation (total 176.0 ac)
	1c	• 1a or 1b plus Gordon Guyer Park storage



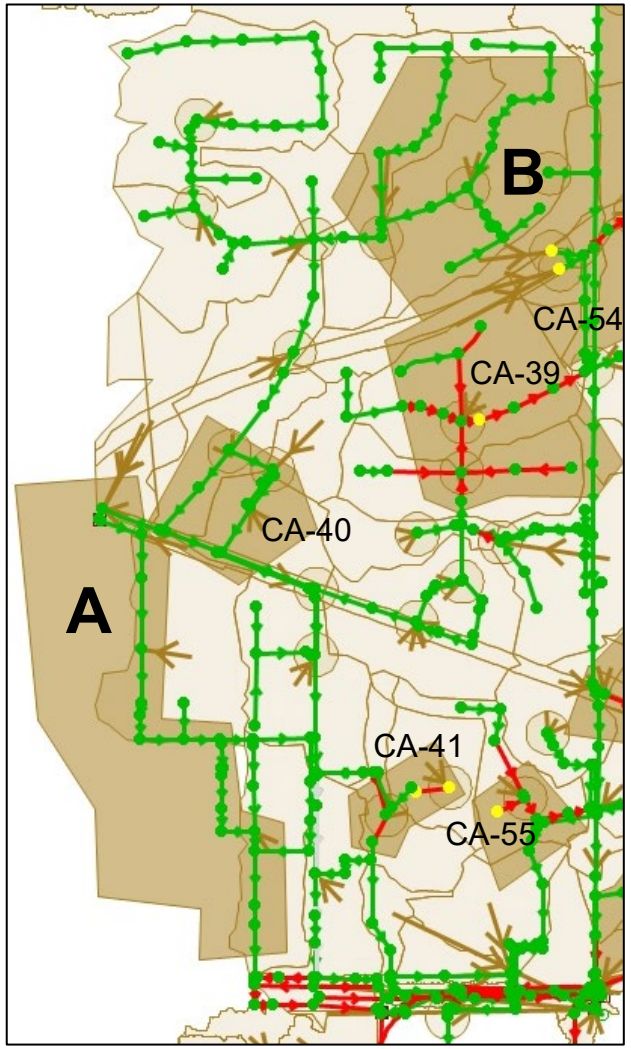
Areas A & B: Alt 1a

LOS Results for Current 10-year, 1-hour Storm

Without Alt



With Alt 1a



CSS Level of Service

Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

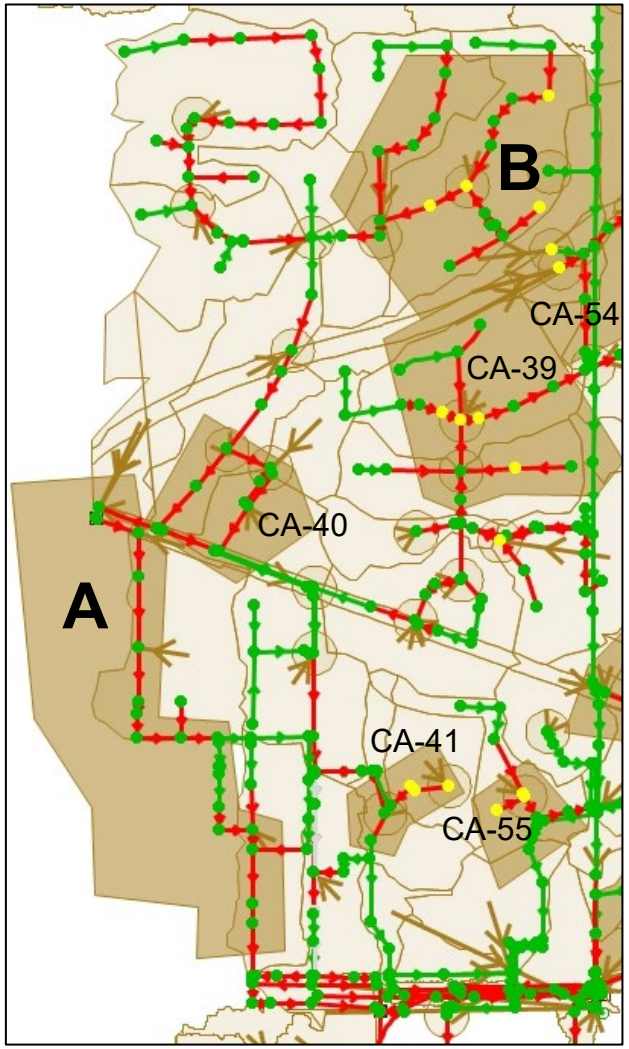
Key Takeaways:

- Alt 1a achieves Current 10-year LOS in Areas A and B.
- Alt 1a also benefits CA-40, CA-41.

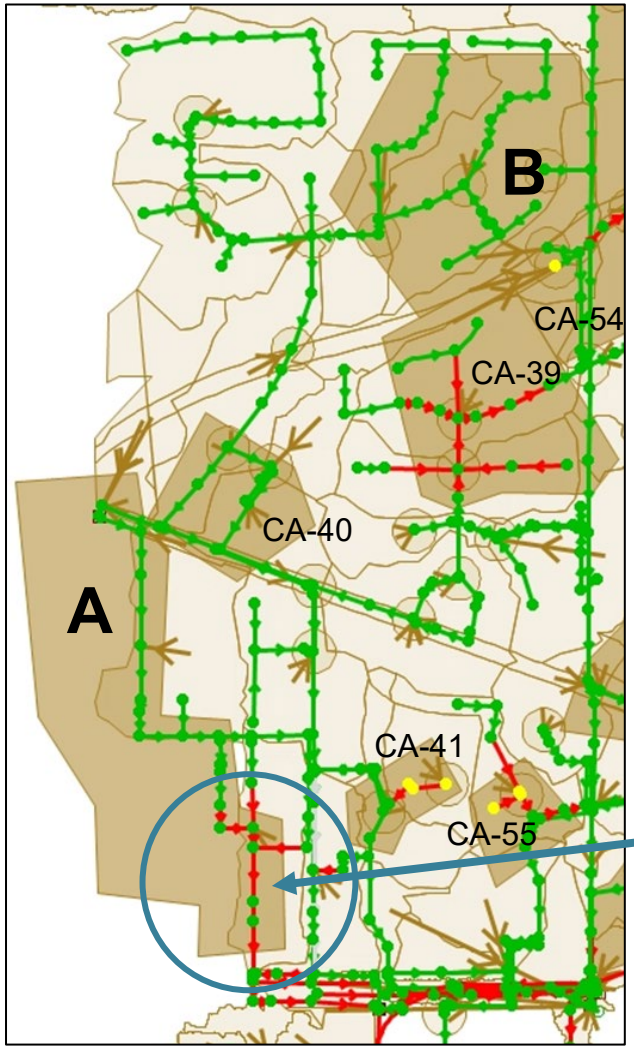
Areas A & B: Alts 1a & 1b

LOS Results for Future 16-year, 1-hour Storm

With Alt 1a



With Alt 1b



CSS Level of Service

Conduits

- LOS Achieved
- Exceeds LOS

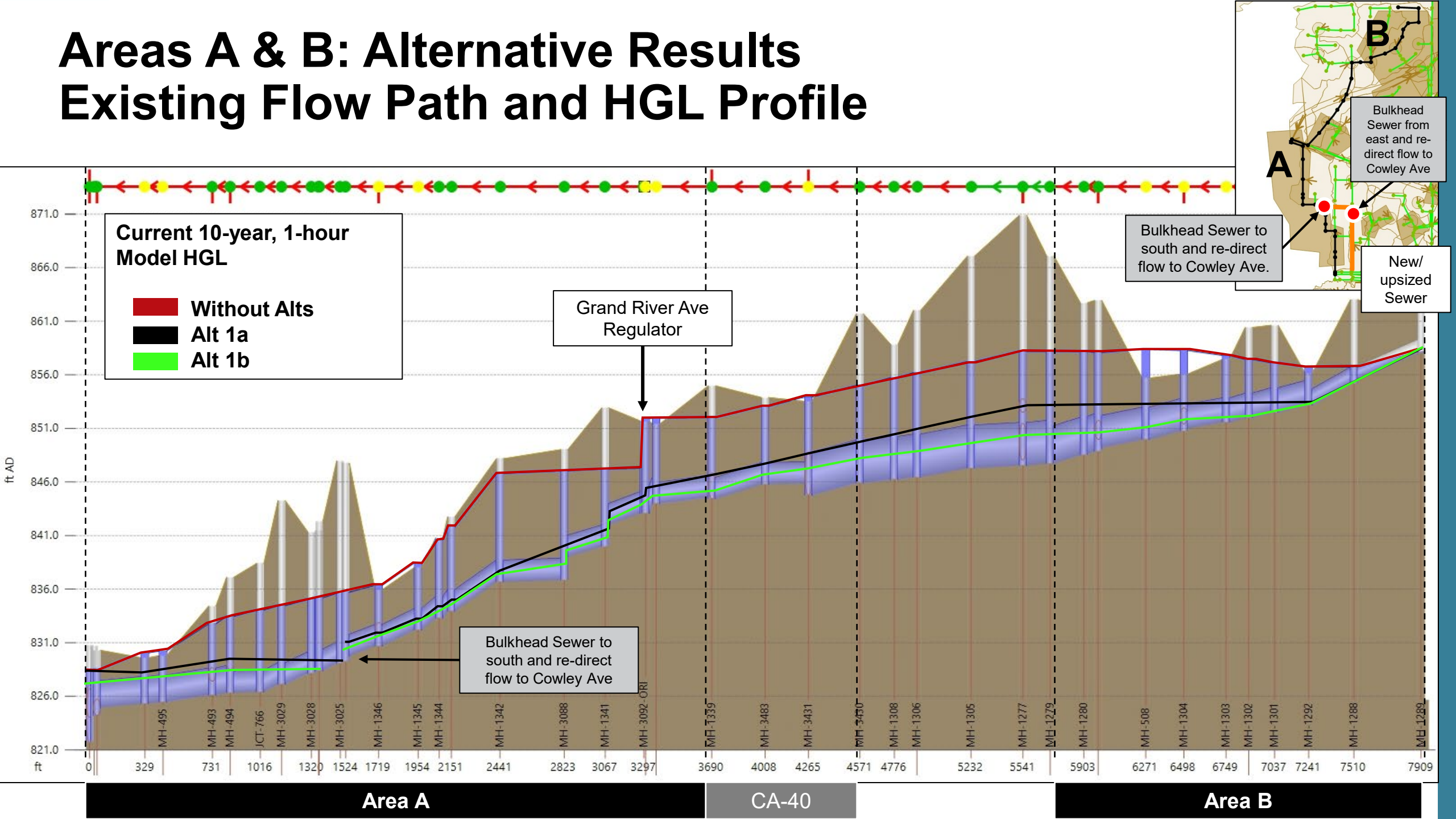
Nodes

- No MH Flooding
- MH Flooding

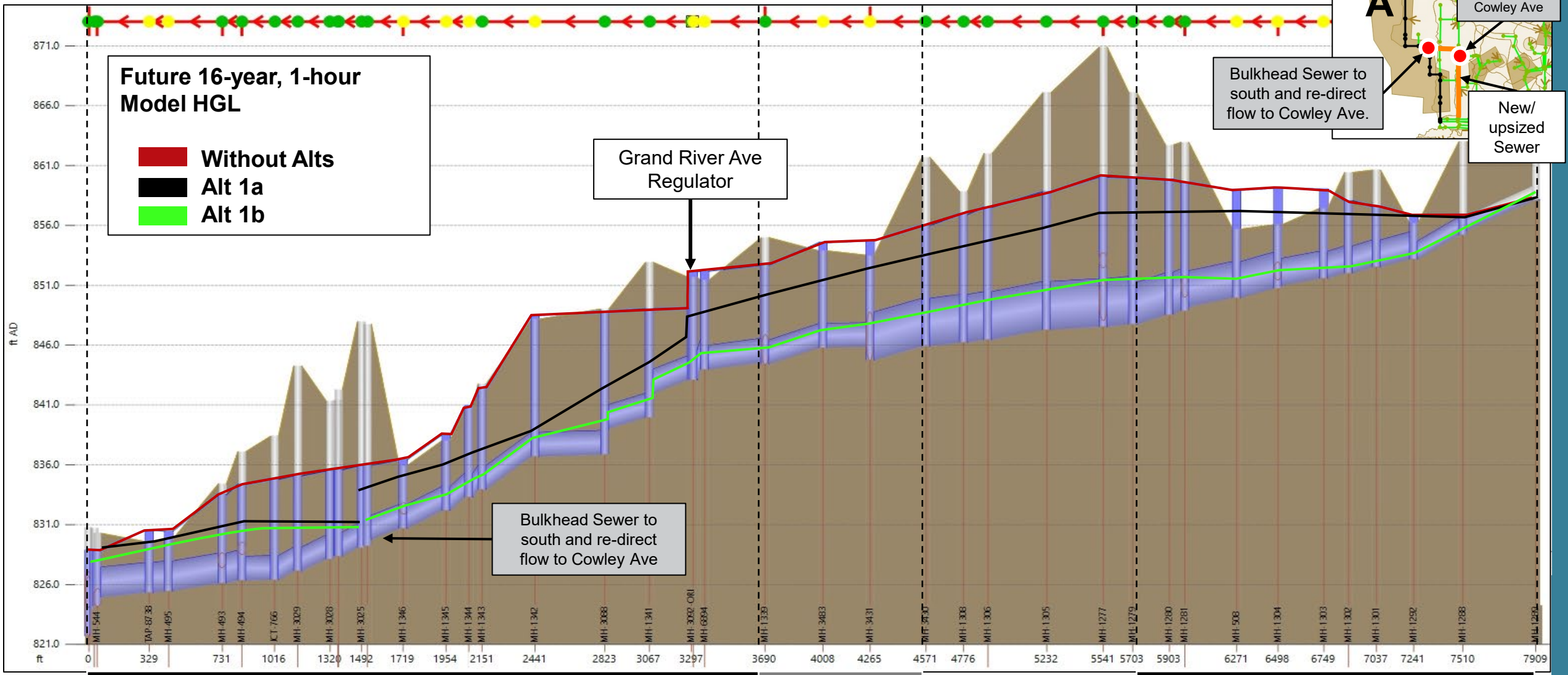
Key Takeaways:

- Alt 1a does not achieve Future 16-year LOS for Areas A and B.
- Alt 1b achieves Future 16-year LOS for Areas A and B
  - Conduits not meeting LOS in Area A are caused by downstream backup.
- Alt 1b also benefits CA-40, CA-41.

Areas A & B: Alternative Results
Existing Flow Path and HGL Profile



Areas A & B: Alternative Results
Existing Flow Path and HGL Profile



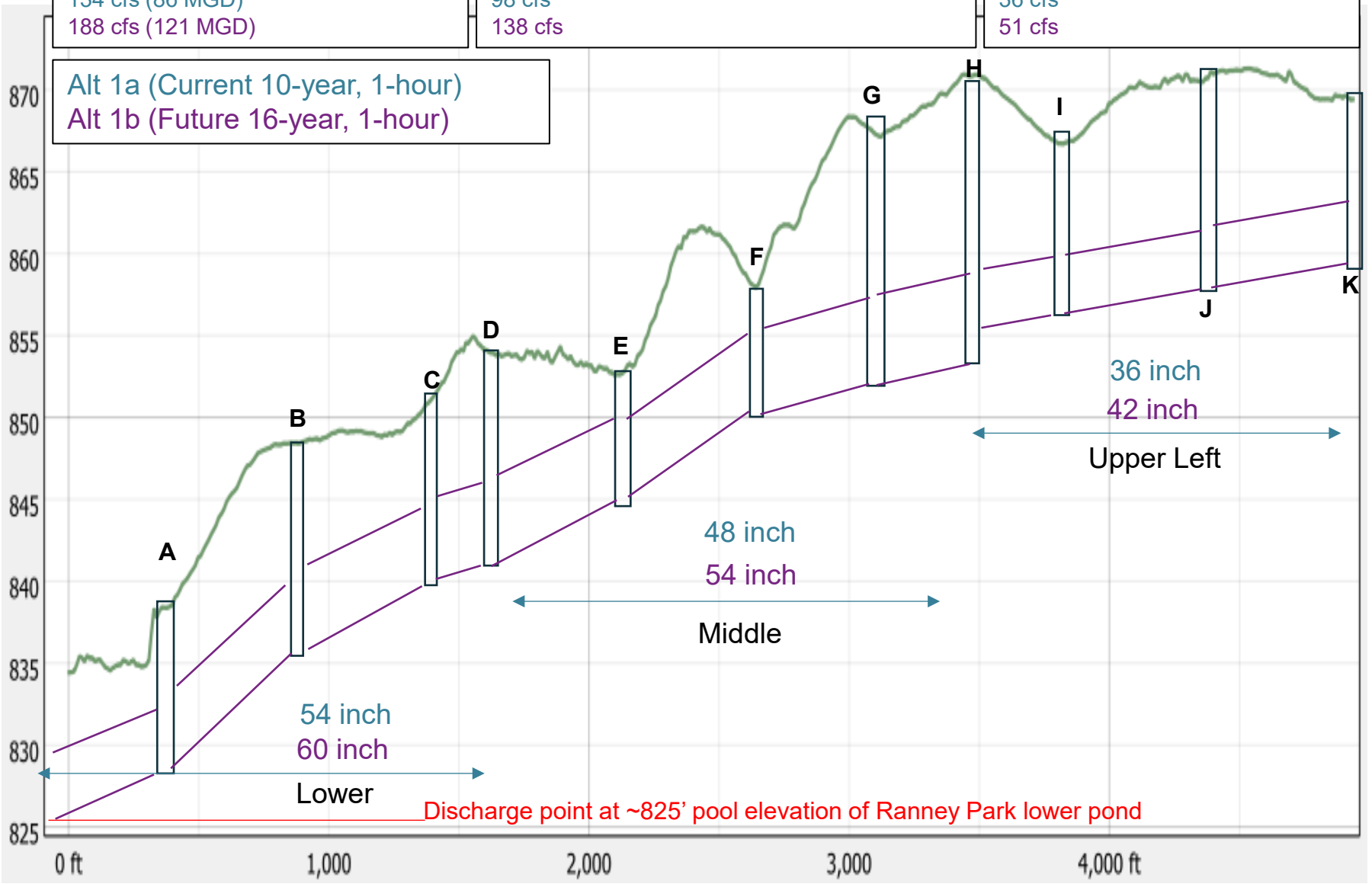
Alts 1a & 1b: Required Storm Sewer Main Sizes

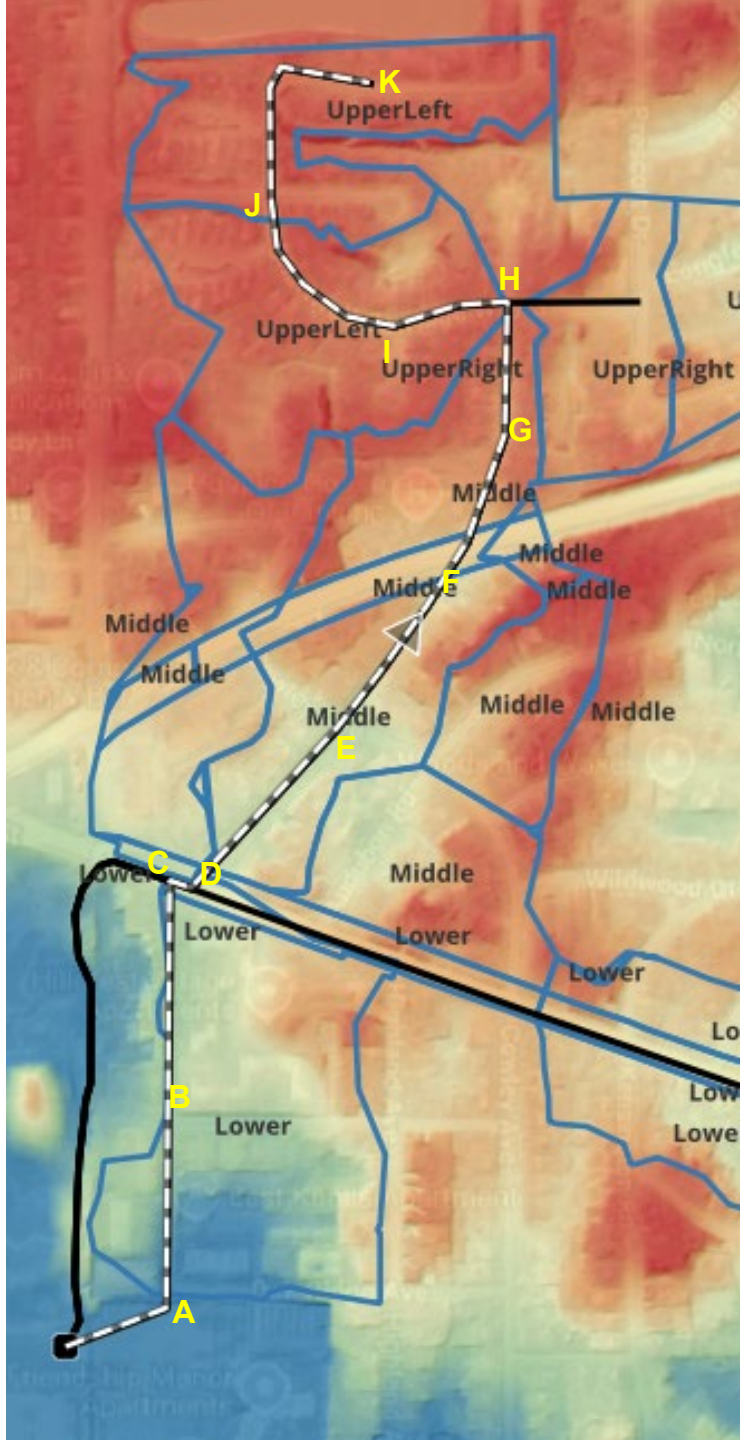
Lower
(D to Pond) =
134 cfs (86 MGD)
188 cfs (121 MGD)

Middle
(H to D) =
98 cfs
138 cfs

Upper Left
(K to H) =
36 cfs
51 cfs

Alt 1a (Current 10-year, 1-hour)
Alt 1b (Future 16-year, 1-hour)

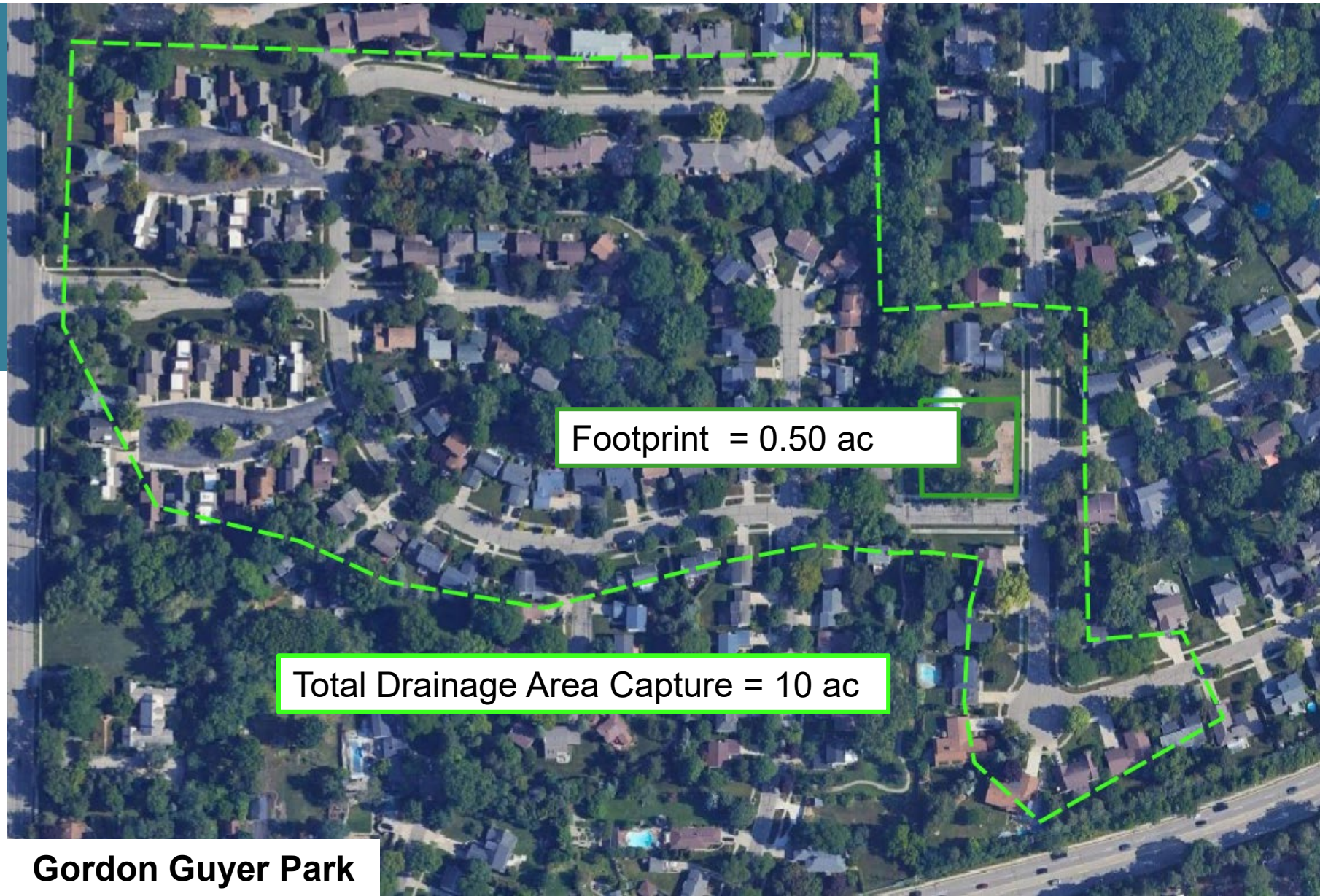




Area B: Alt 1c Gordon Guyer Park Resilience Opportunity

Calculated Peak Flow Reduction for Future 16-year Storm =

17 cfs



Gordon Guyer Park

Increased LOS with Alt 1c Resilience Opportunity

- ~17 cfs benefit to downstream system with Gordon Guyer Park Storage
  - Increase LOS from current 10-year to ~17-year
  - Increase LOS from future 16-year to ~22-year

Rainfall (inches)	Return Period (Years)		Peak Flow CFS		
	Current Day	2100 High Emissions	Area A B Total	With Gordon Guyer Park	
1.40	2	1	81		
1.61	3	1	99		
1.92	8	3	127		
2.00	10	3	134	151	+17 cfs
2.18	17	5	152		
2.44	38	10	178		
2.54	50	16	188	205	+17 cfs
2.77	100	22	213		
3.05	228	43	243		

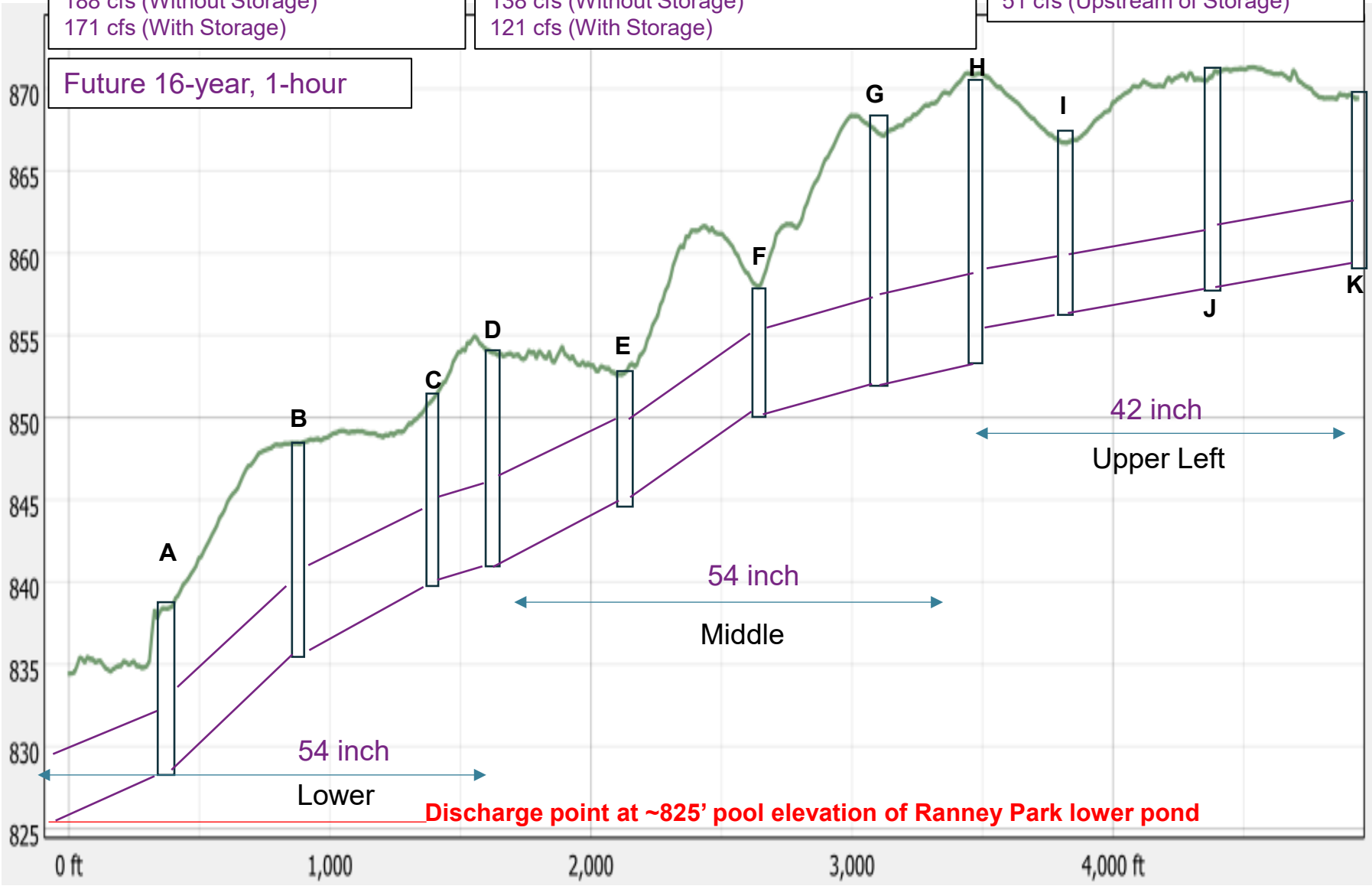
Alts 1b & 1c: Required Storm Sewer Main Sizes

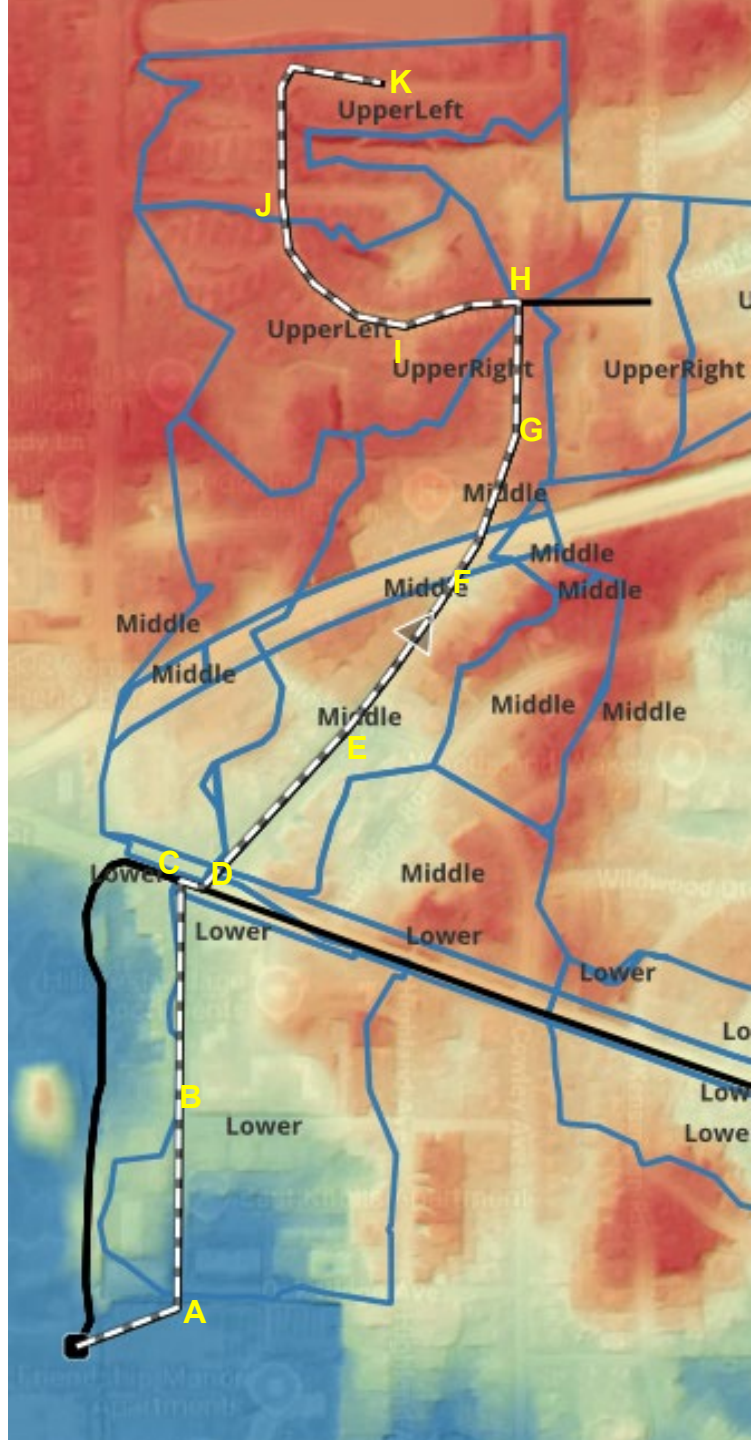
Lower
(D to Pond) =
188 cfs (Without Storage)
171 cfs (With Storage)

Middle
(H to D) =
138 cfs (Without Storage)
121 cfs (With Storage)

Upper Left
(K to H) =
51 cfs (Upstream of Storage)

Future 16-year, 1-hour





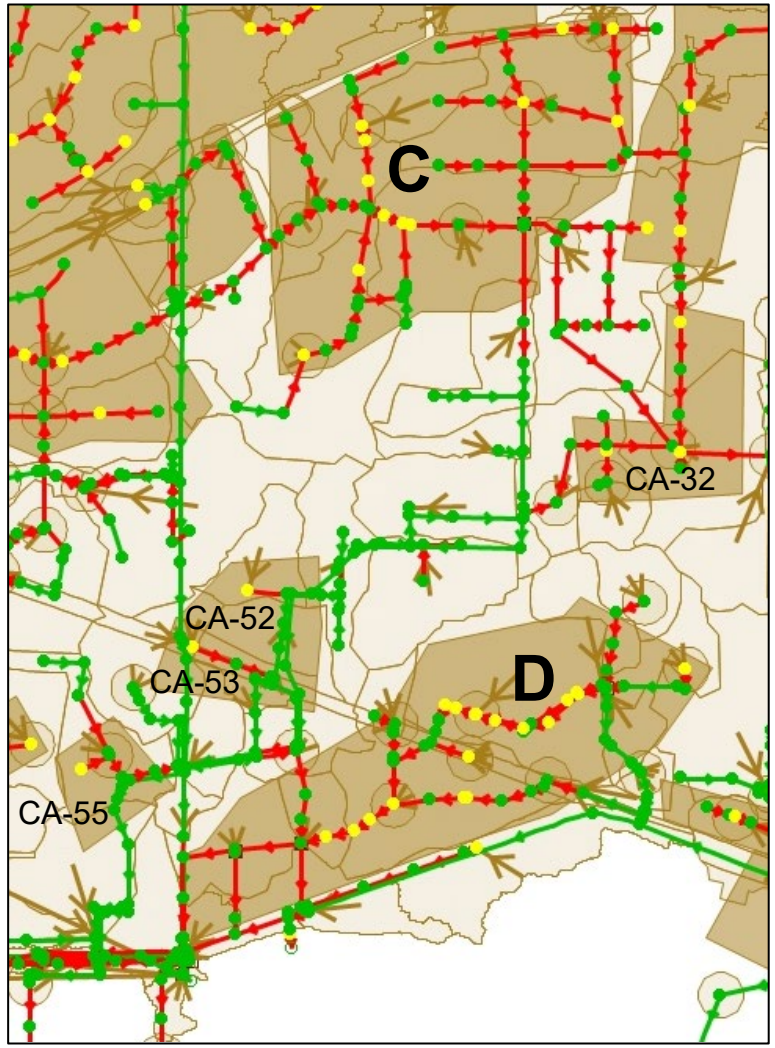
Area D Alternatives

Concern Area	Alt	Proposed Project(s)
D	**2a**	• 77.6 ac of storm separation • Restrictor modification – lower weir at Beal St to invert of overflow sewer • New regulator at Louis St • 2,000 ft of sewer upsizing • 600 ft of new combined sewer
	2b	• 2a plus additional 14.6 ac of storm separation (total 92.2 ac)
	2c	• 2a or 2b plus Valley Court Park Storage

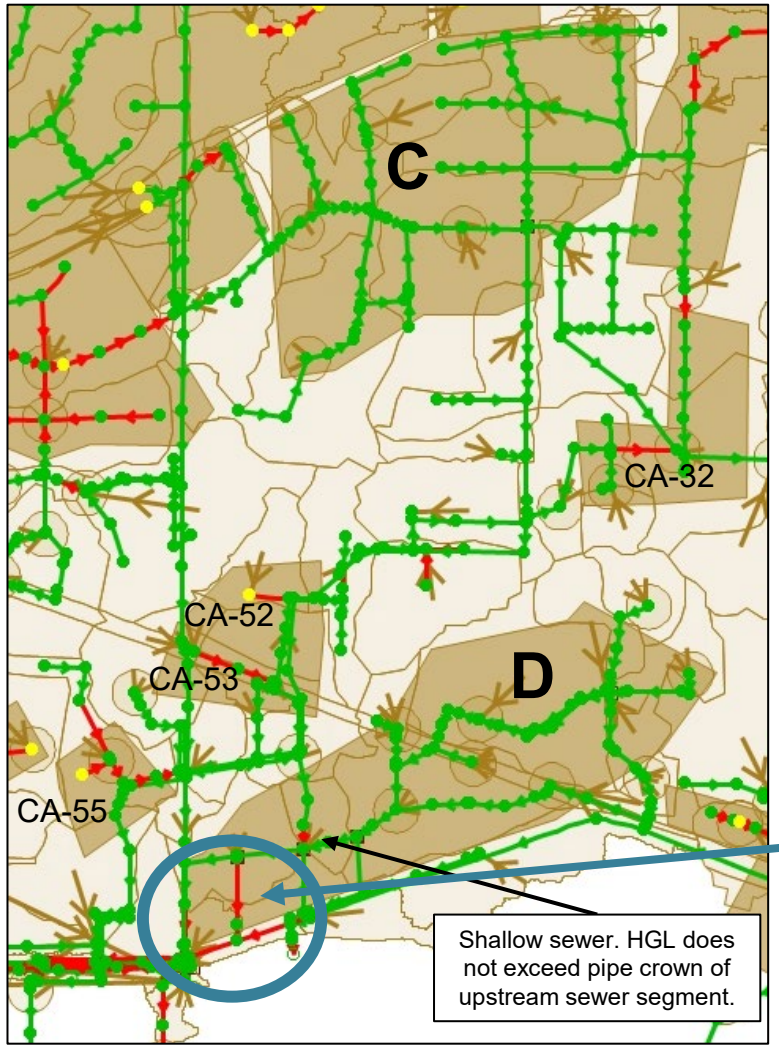


Area D: Alt 2a
LOS Results for Current 10-year, 1-hour Storm

Without Alt



With Alt 2a



CSS Level of Service

Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

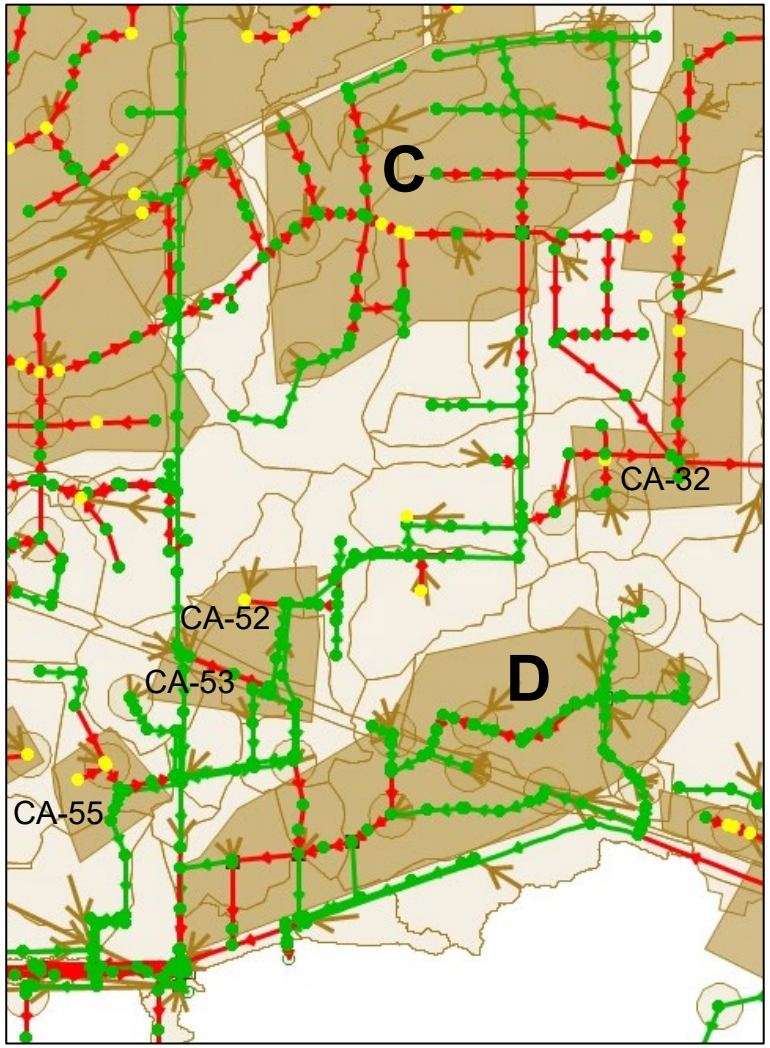
Key Takeaways:

- Alt 2a achieves Current 10-year LOS in Area D.
  - Conduits not achieving LOS in Area D due to downstream backup, with exception of shallow sewer along Beal St as noted.

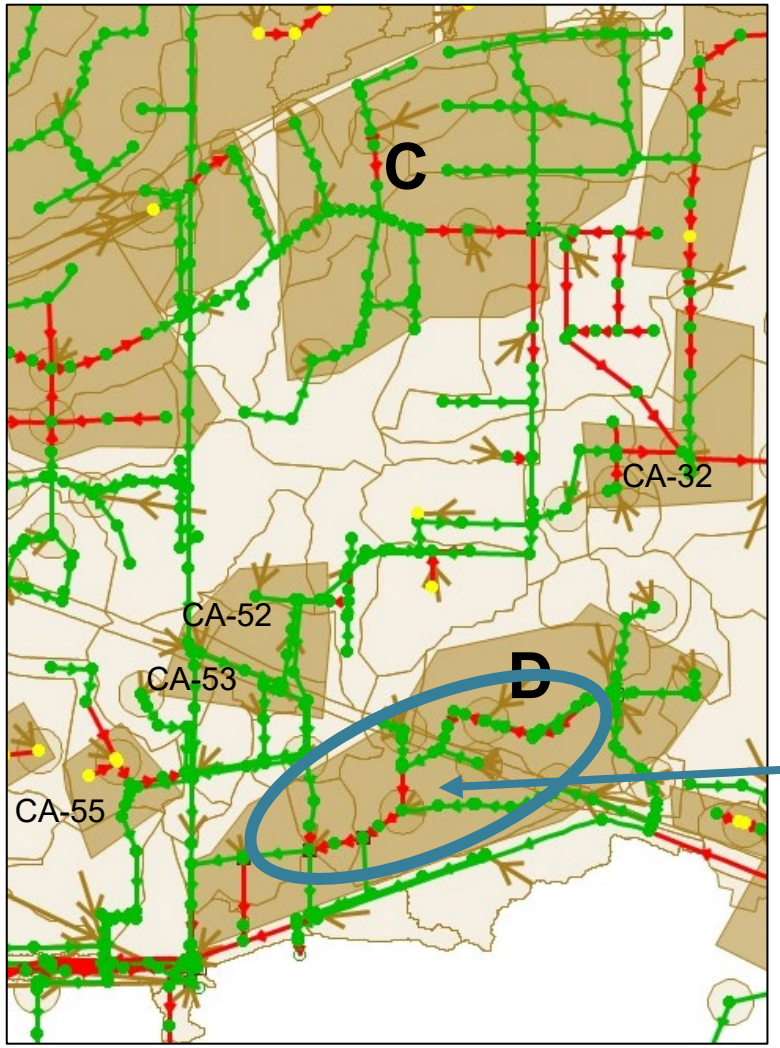
Area D: Alts 2a & 2b

LOS Results for Future 16-year, 1-hour Storm

With Alt 2a



With Alt 2b



CSS Level of Service

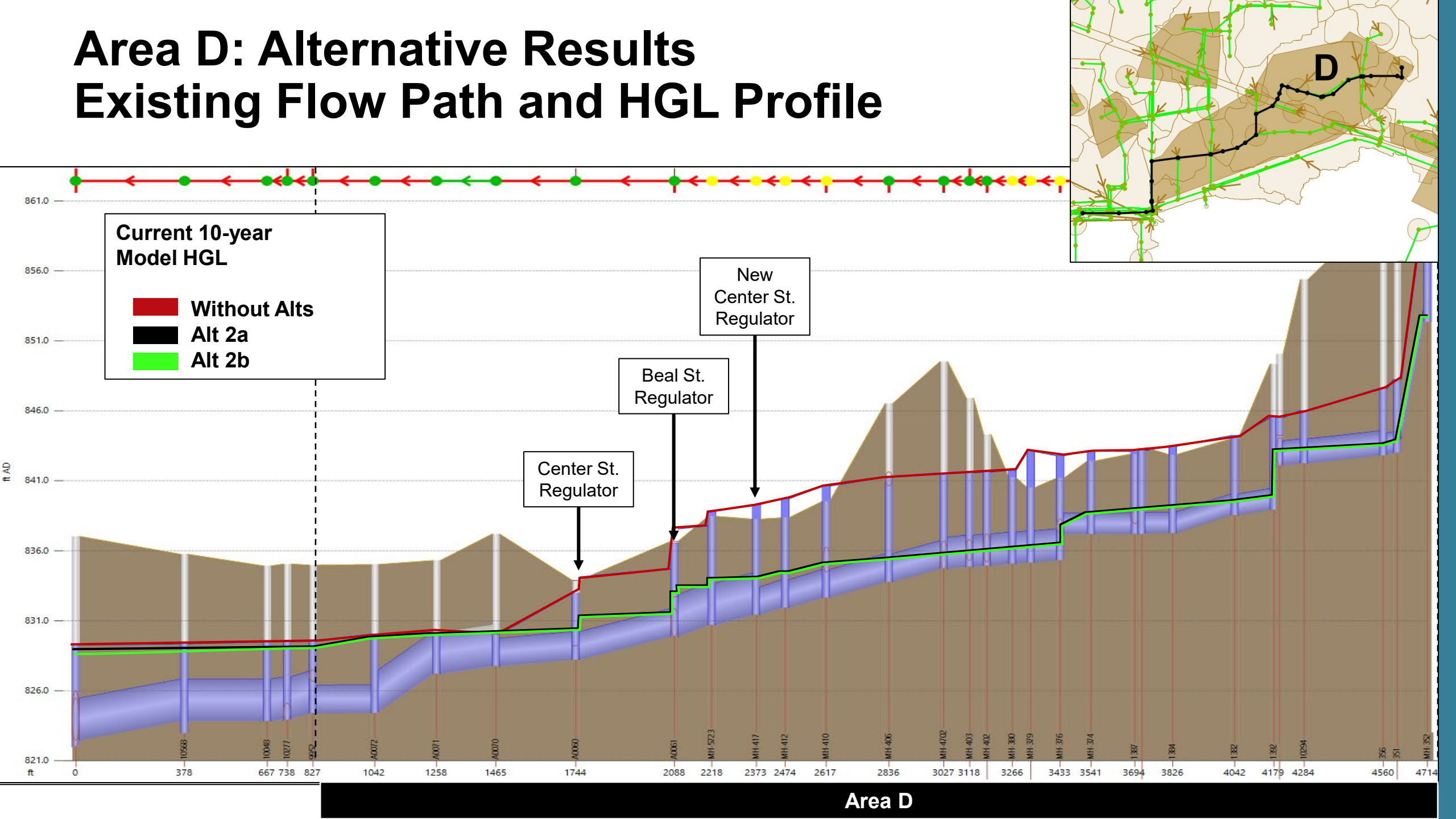
Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

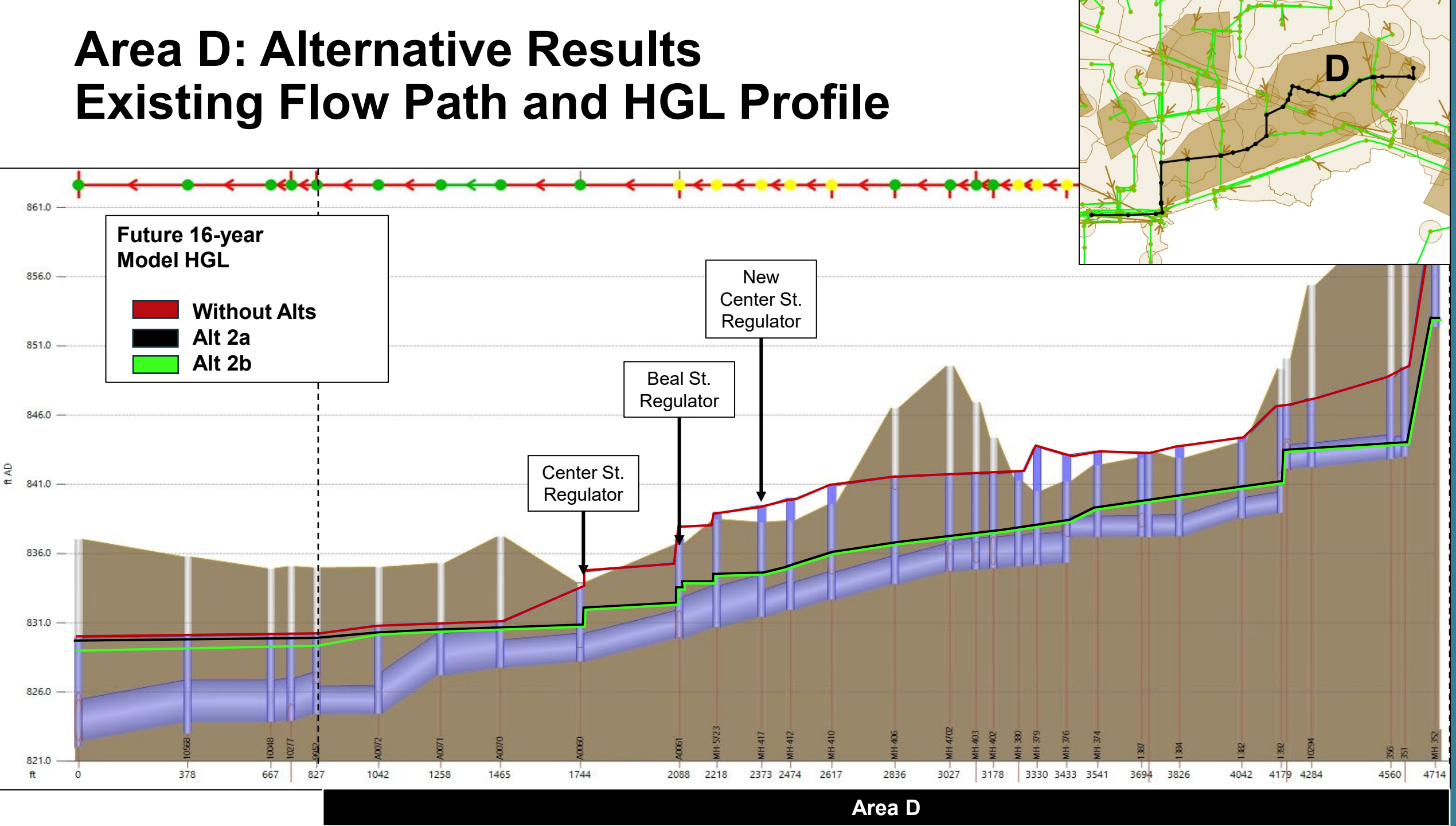
Key Takeaways:

- Alt 2a does not achieve Future 16-year LOS in Area D.
- Alt 2b does not achieve Future 16-year LOS in Area D.
  - Conduits not meeting LOS in Area D due to lack of capacity within mainline sewer.
  - Sewers were upsized to match downstream pipe diameter.
- Alt 2b benefits CA-52, CA-53.

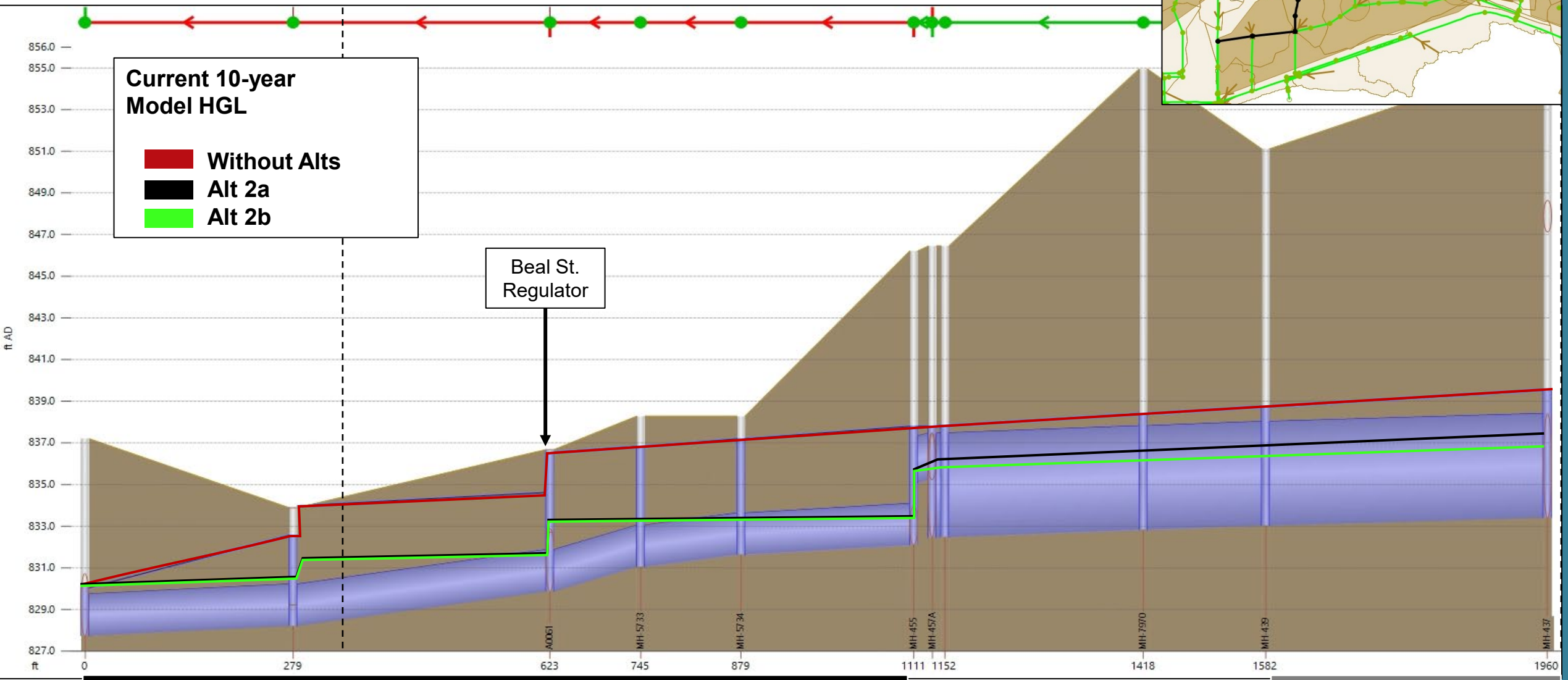
Area D: Alternative Results
Existing Flow Path and HGL Profile

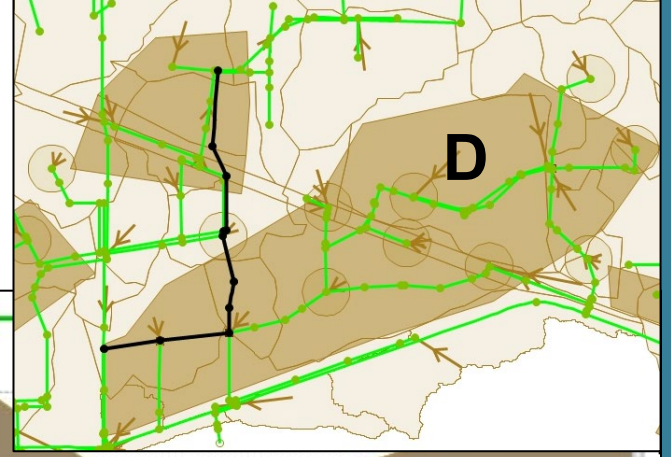


Area D: Alternative Results
Existing Flow Path and HGL Profile

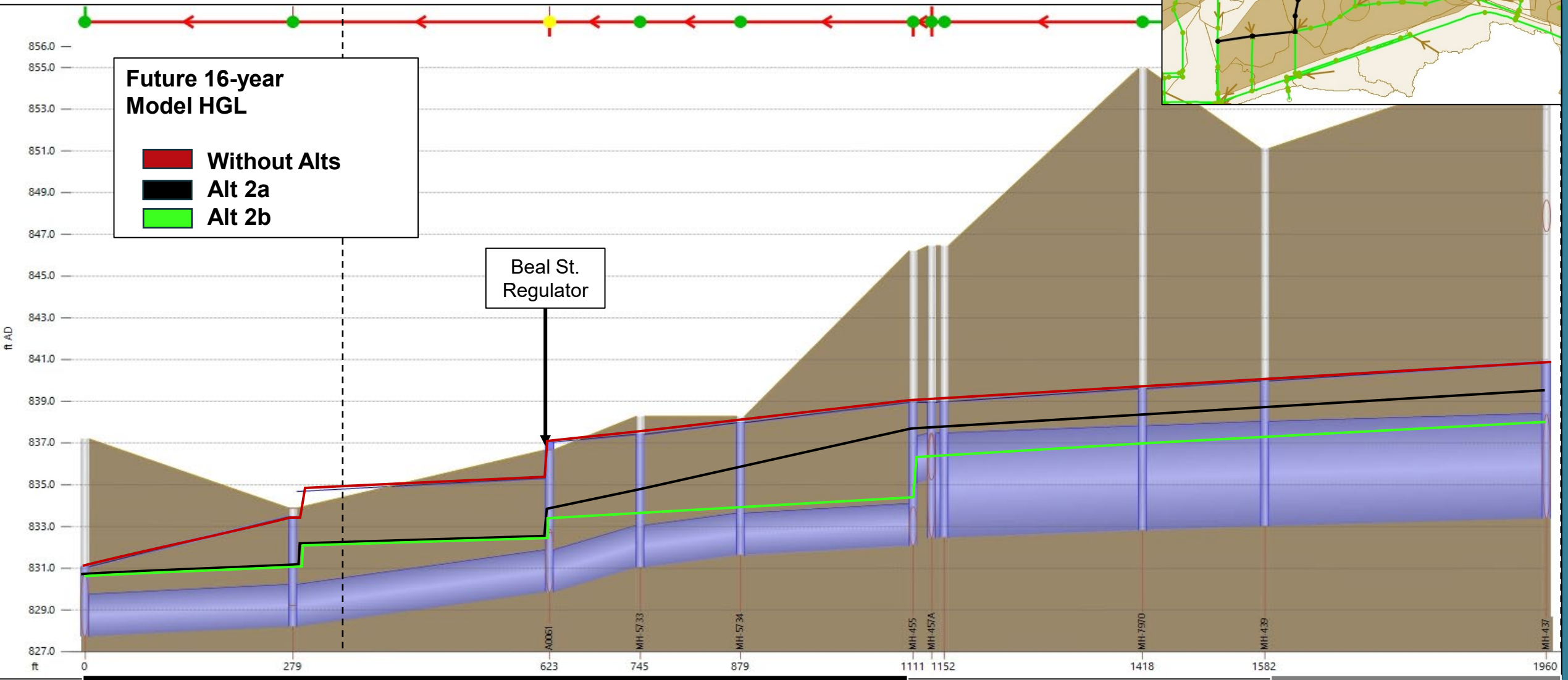


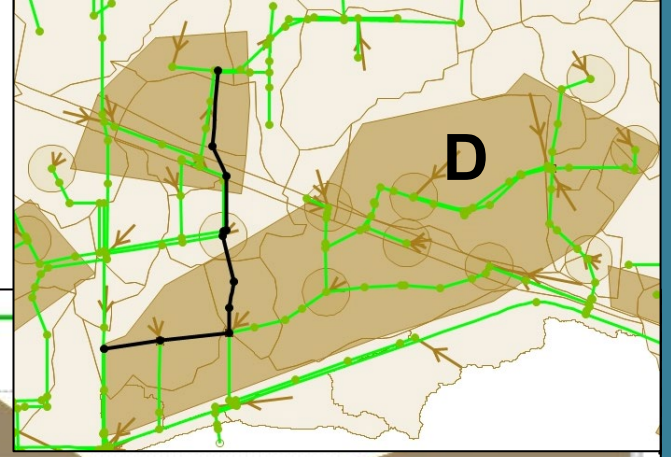
Area D: Alternative Results
Existing Flow Path and HGL Profile





Area D: Alternative Results
Existing Flow Path and HGL Profile





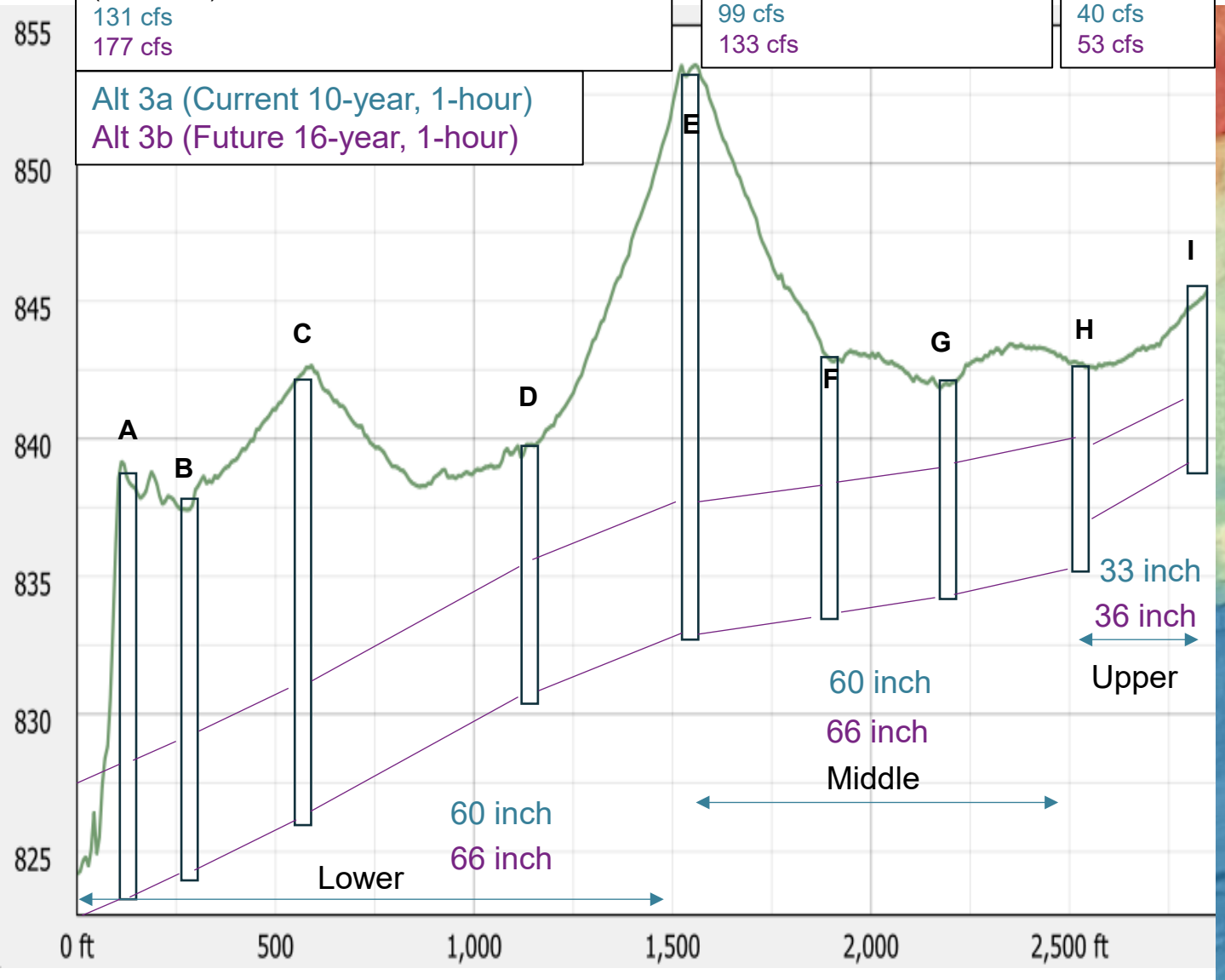
Alts 2a & Alt 2b: Required Storm Sewer Main Sizes

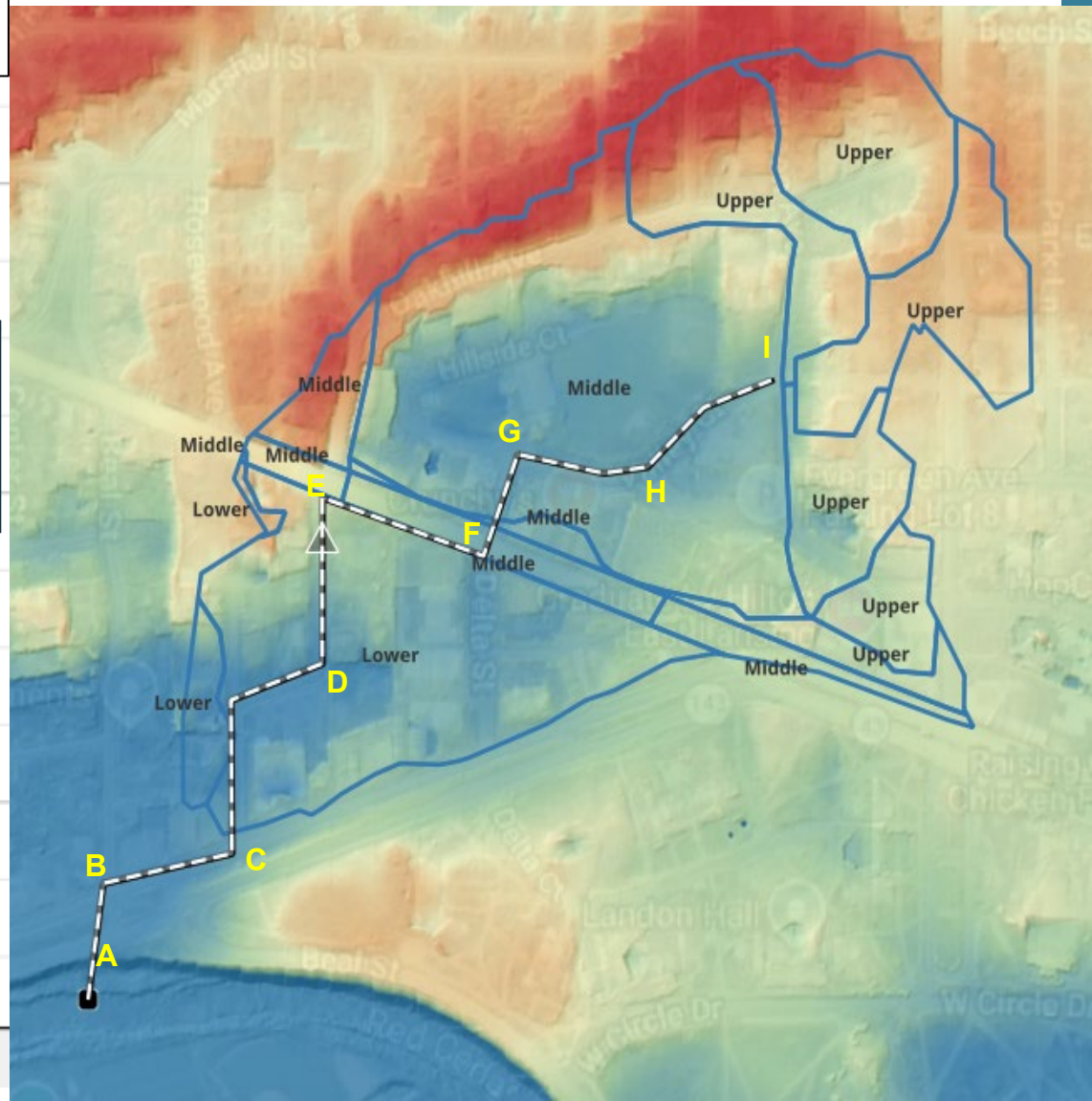
Lower
(E to River) =
131 cfs
177 cfs

Middle
(H to E) =
99 cfs
133 cfs

Upper
(I to H) =
40 cfs
53 cfs

Alt 3a (Current 10-year, 1-hour)
Alt 3b (Future 16-year, 1-hour)

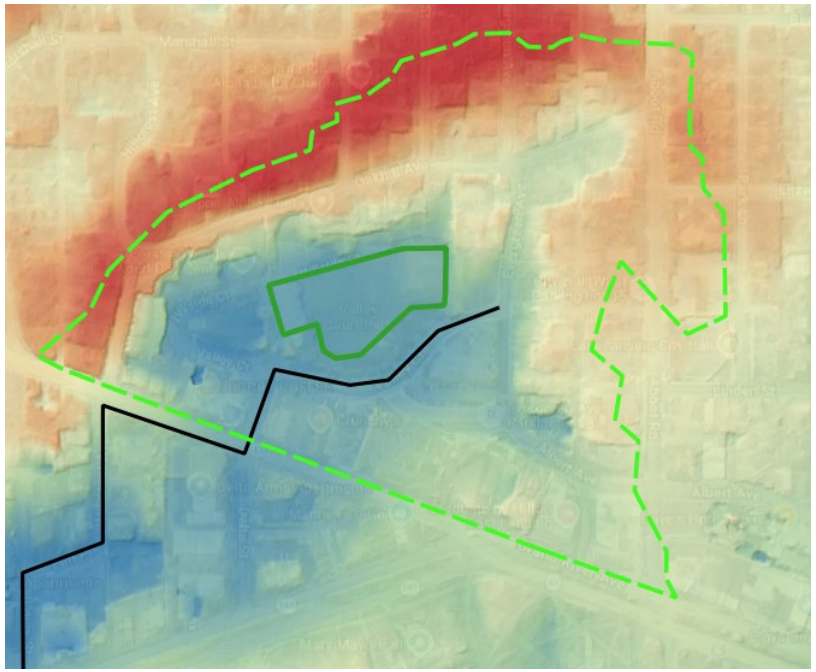


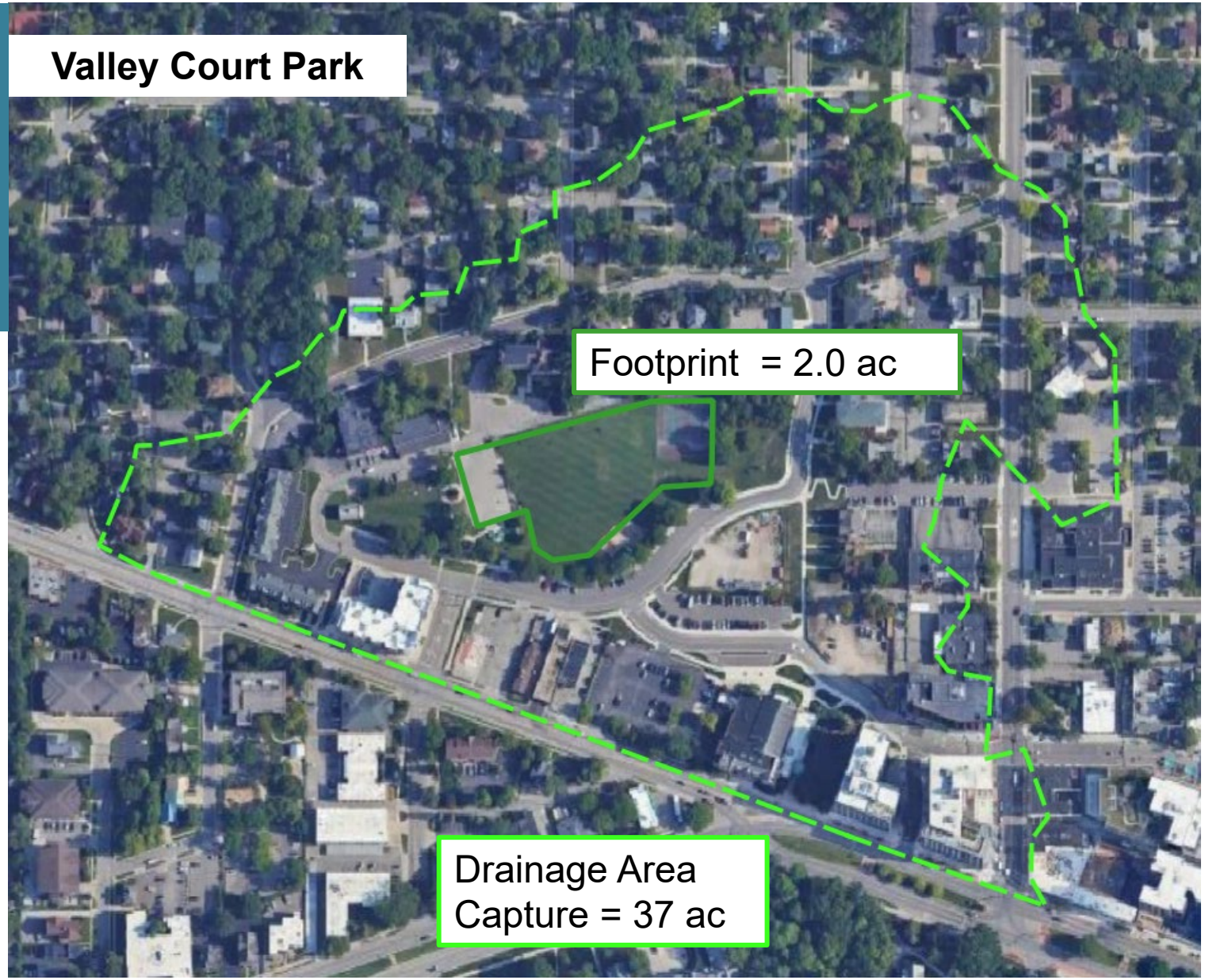


Area D: Alt 2c Valley Court Park Resilience Opportunity

Calculated Peak Flow Reduction for Future 16-year Storm =

132 cfs





Increased LOS with Alt 2c Resilience Opportunity

- ~132 cfs benefit to downstream system with Valley Court Park Storage
  - Increase LOS from current 10-year to ~500-year
  - Increase LOS from future 16-year to ~100-year

Rainfall (inches)	Return Period (Years)		Peak Flow CFS		
	Current Day	2100 High Emissions	Area D Total	With Valley Court Park	
1.40	2	1	83		
1.61	3	1	100		
1.92	8	3	124		
2.00	10	3	131	263	+132 cfs
2.18	17	5	146		
2.44	38	10	169		
2.54	50	16	177	309	+132 cfs
2.77	100	25	198		
3.05	200	50	223		
3.32	500	100	248		

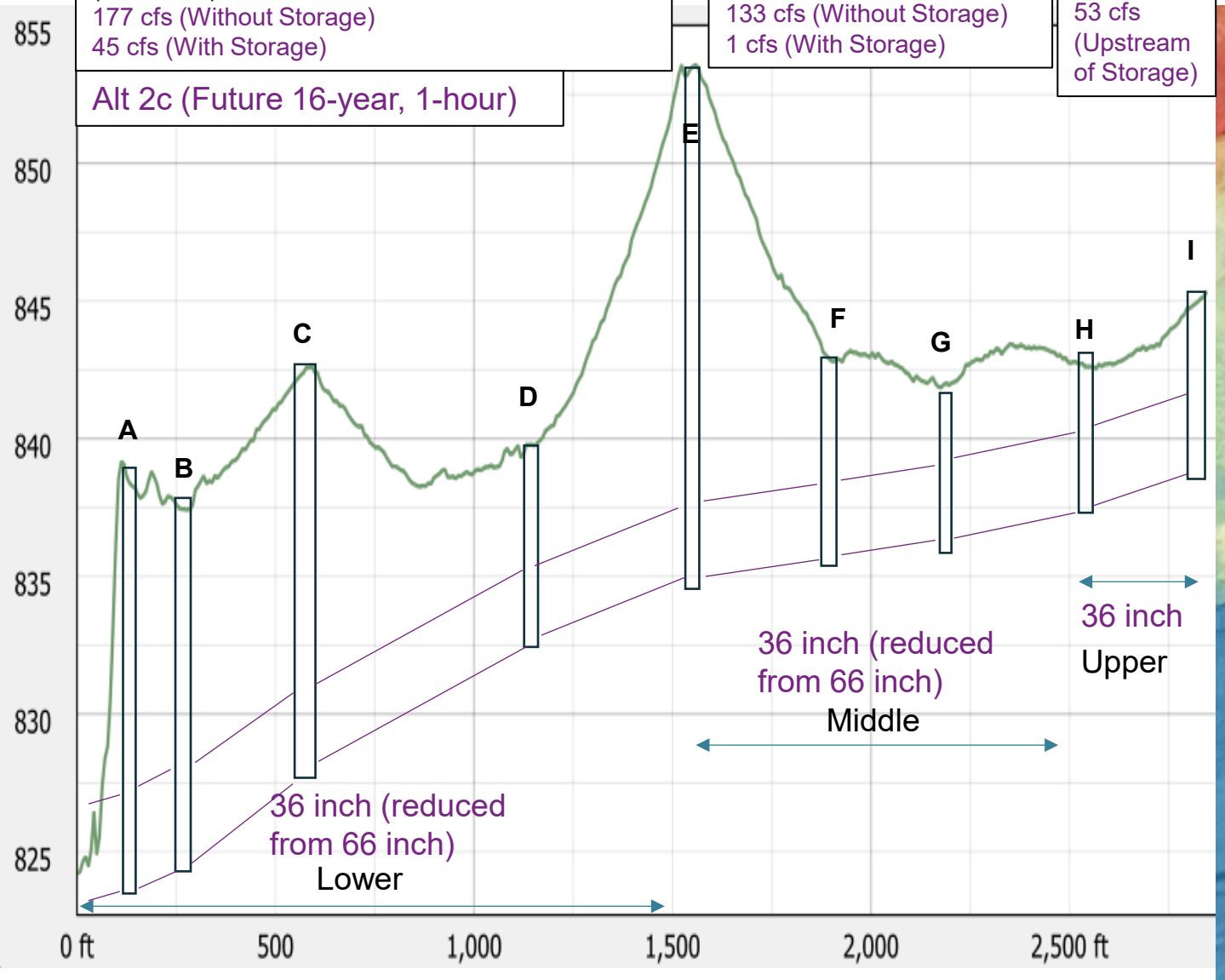
Alts 2b & 2c: Required Storm Sewer Main Sizes (Reduced)

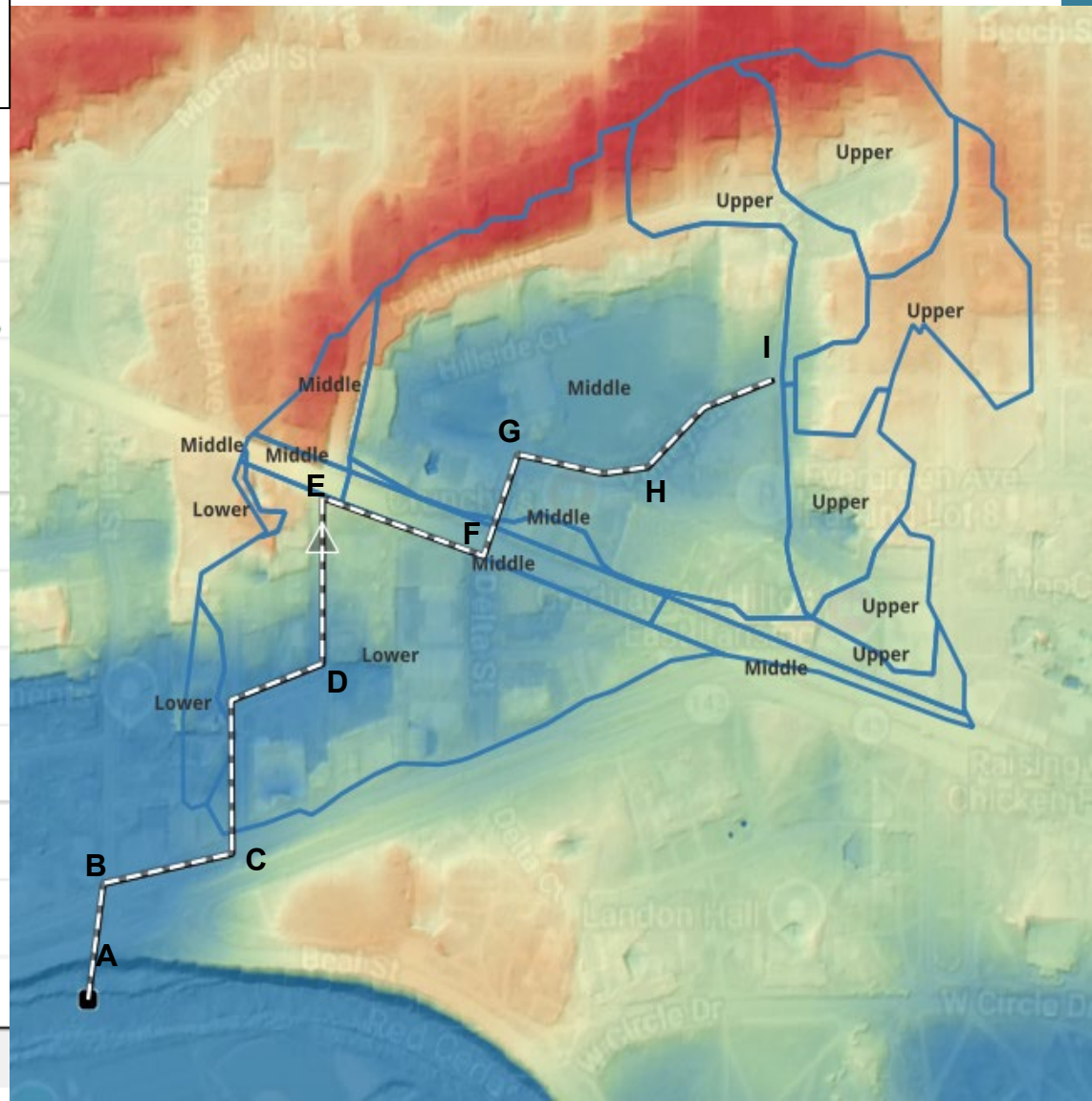
Lower
(E to River) =
177 cfs (Without Storage)
45 cfs (With Storage)

Middle
(H to E) =
133 cfs (Without Storage)
1 cfs (With Storage)

Upper
(I to H) =
53 cfs (Upstream of Storage)

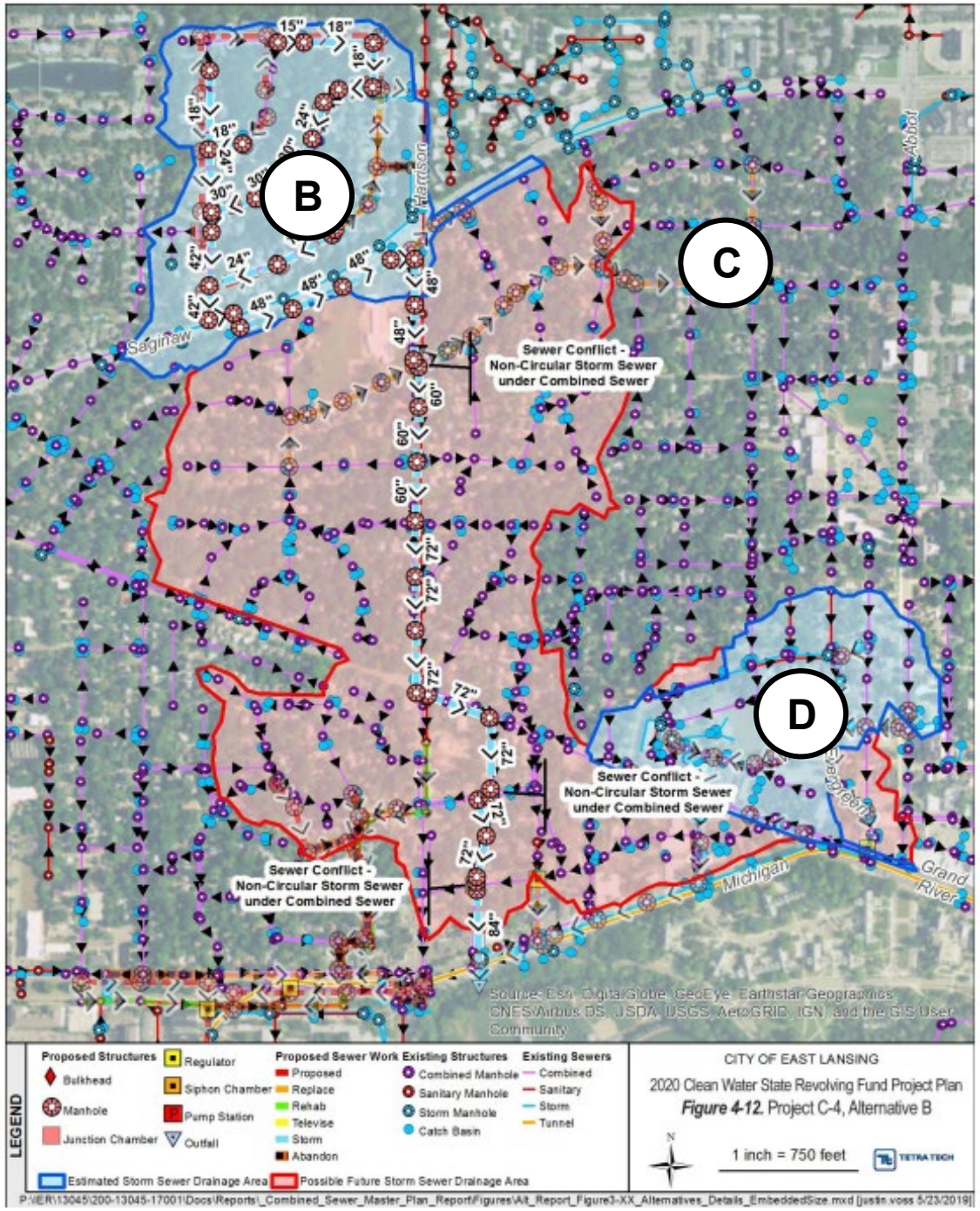
Alt 2c (Future 16-year, 1-hour)





Areas B, C & D Alternative

Concern Area	Alt	Proposed Project(s)
B, C & D	**3**	• 2a plus additional 122.5 ac of storm separation at Harrison St (total 200.1 ac)



Areas B, C & D: Alt 3

LOS Results for Current 10-year, 1-hour Storm

CSS Level of Service

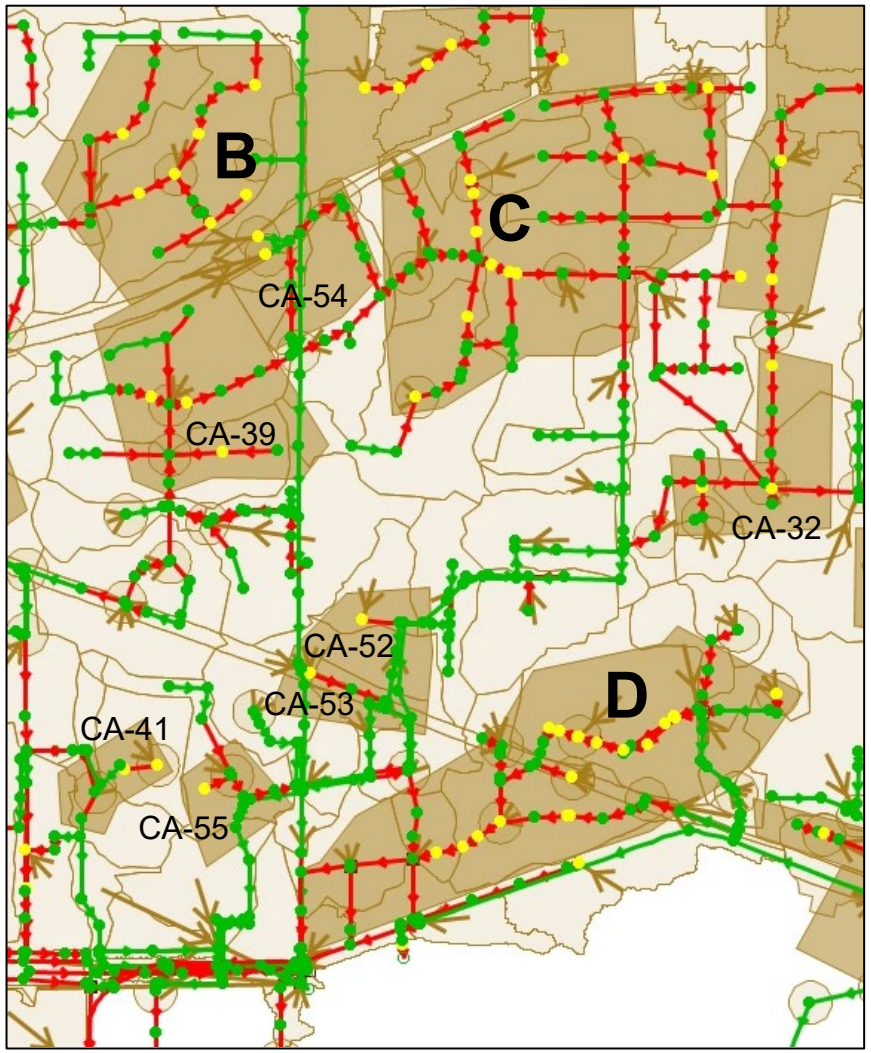
Conduits

- LOS Achieved
- Exceeds LOS

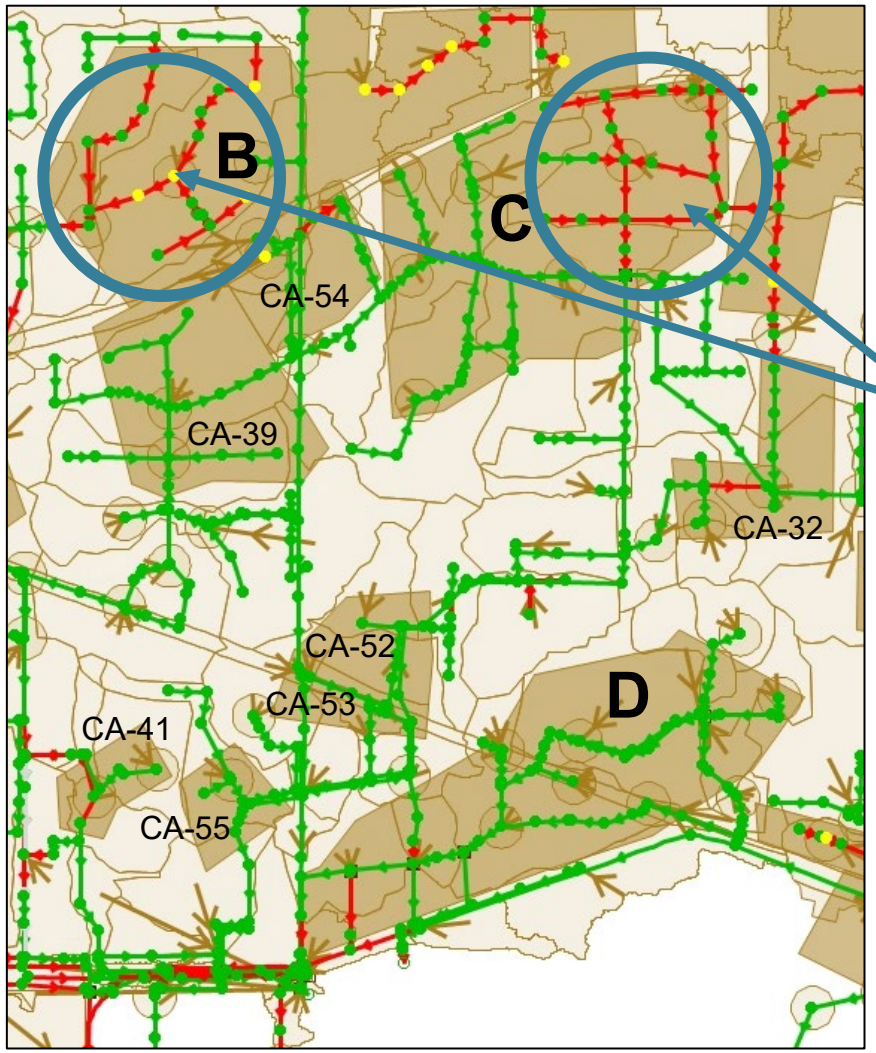
Nodes

- No MH Flooding
- MH Flooding

Without Alt



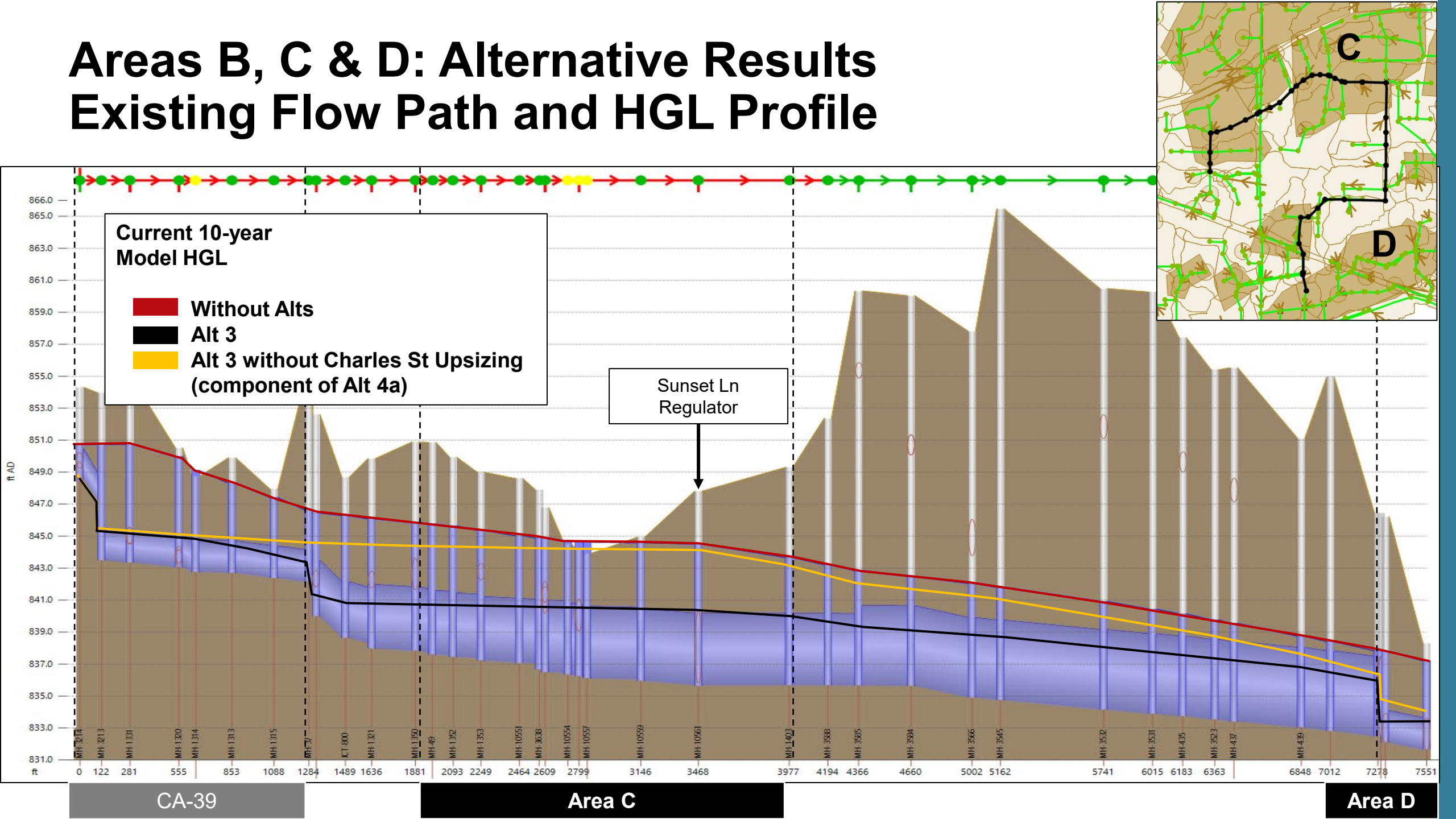
With Alt 3



Key Takeaways:

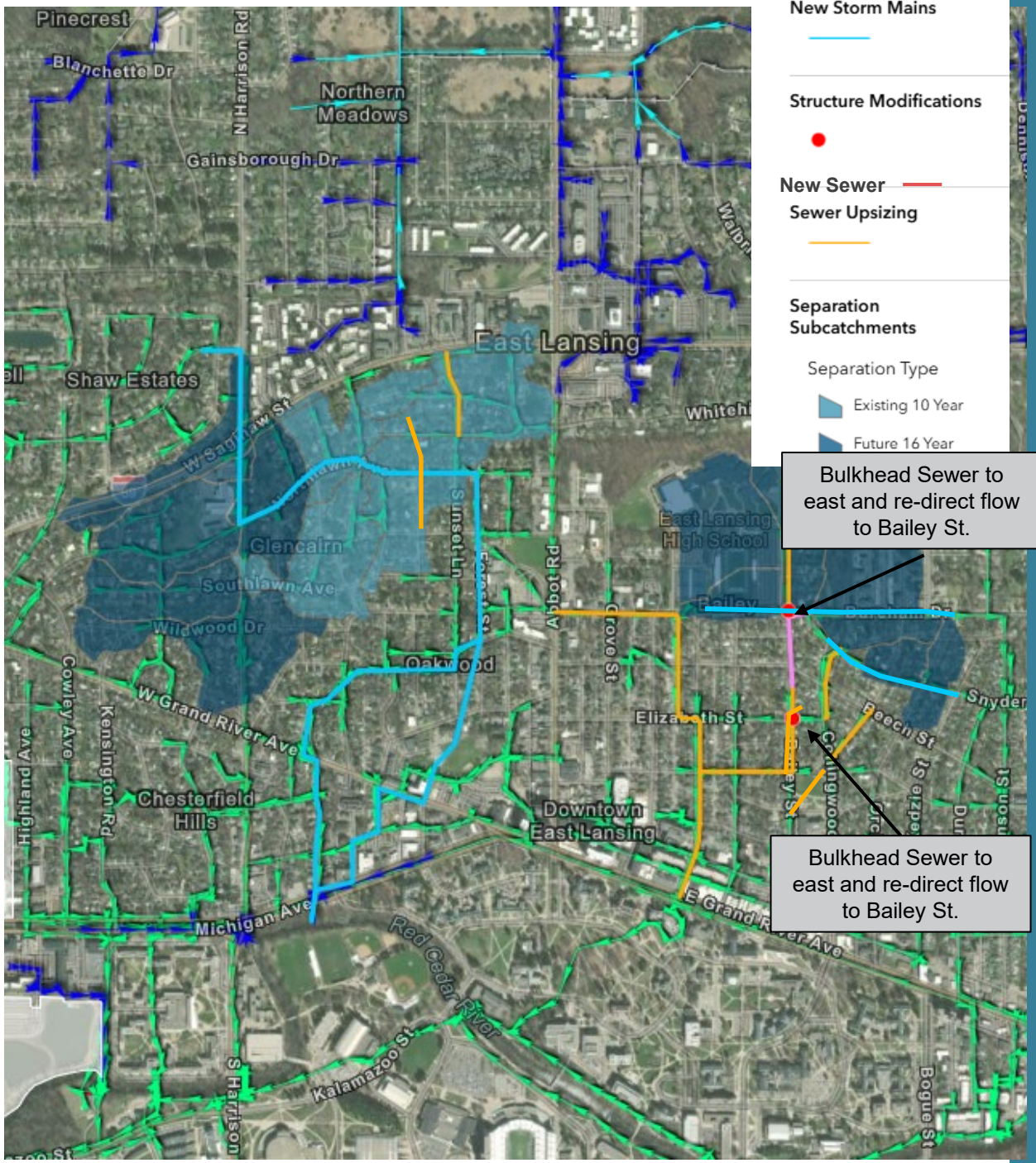
- Alt 3 does <u>not</u> achieve Current 10-year LOS in Areas B and C
  - Conduits not achieving LOS in Areas B and C due to lack of capacity within mainline and local sewers.
  - Alt 3 was not progressed for enhanced LOS.
- Alt 3 benefits CA-54, CA-39, CA-32, CA-52, CA-53, CA-55, and CA-41.

Areas B, C & D: Alternative Results
Existing Flow Path and HGL Profile

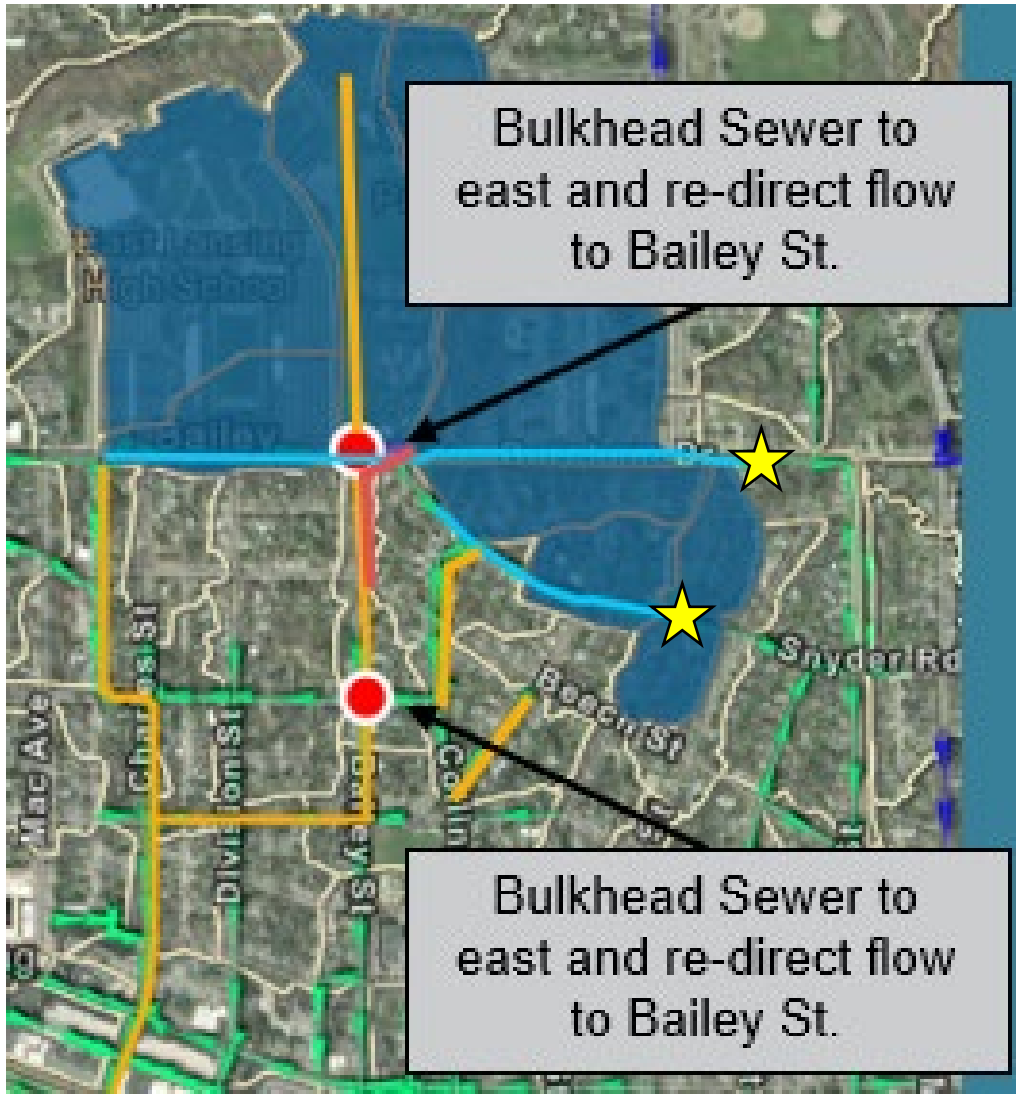


Areas C, E & G Alternatives

Concern Area	Alt	Proposed Project(s)
E, C & G	**4a**	• 71.5 ac of storm separation • 8,100 ft of pipe upsizing • 900 ft of new combined sewer • 2 sewer bulkheads
	4b	• 4a plus additional 128.4 ac of storm separation (total 199.9 ac)
	4c	• 4a or 4b plus Glencairn Park, Shaw Park, Hannah Community Center storage



Areas E & G: Alt 4b Storm Pipe (Tie into Gunson St Storm Sewer)



Alt 4b Future 16-year Separation Project:

★ Connect with existing Gunson St. Storm Sewer:

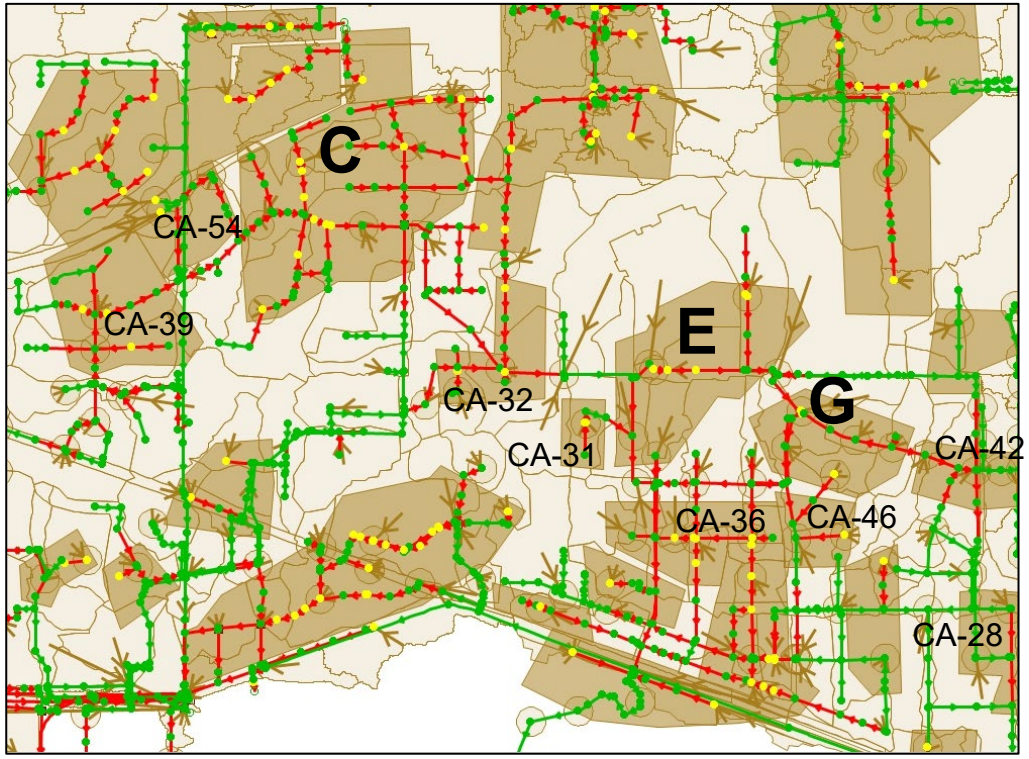
- Burcham Dr. 24-inch storm
- Snyder Rd. 15-inch storm (becomes 24-inch at Kedzie St.)

Available capacity within Gunson St. storm sewer needs to be verified to see if it can accept additional flows.

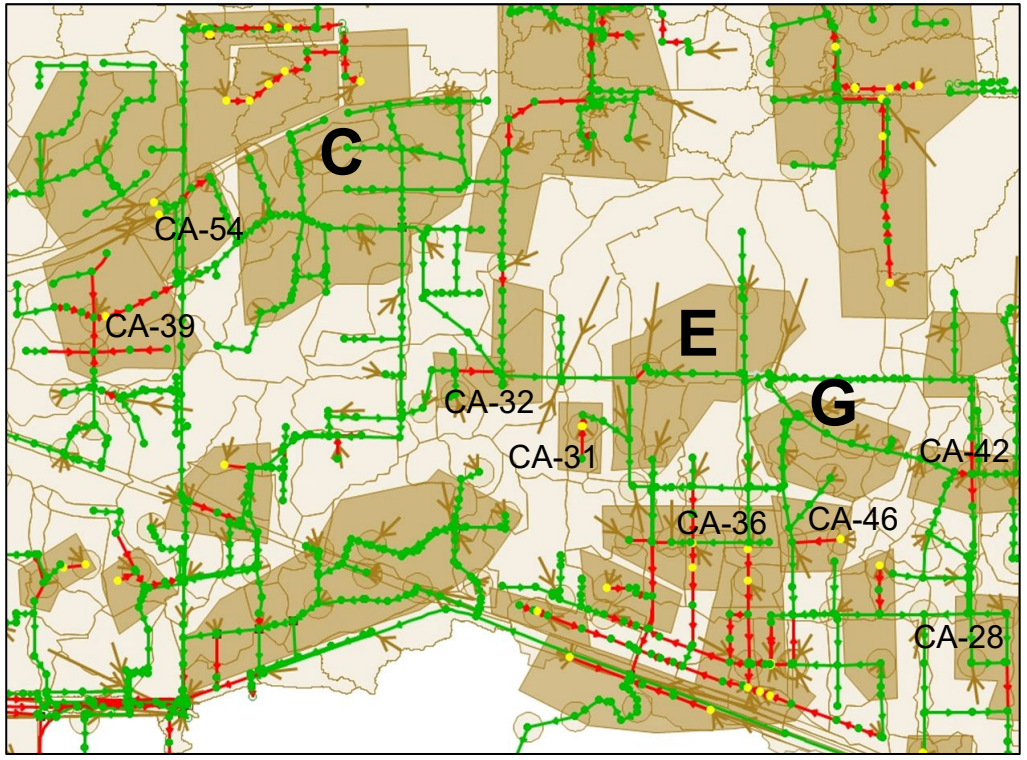
Area C, E & G: Alt 4a

LOS Results for Current 10-year, 1-hour Storm

Without Alt



With Alt 4a



CSS Level of Service

Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

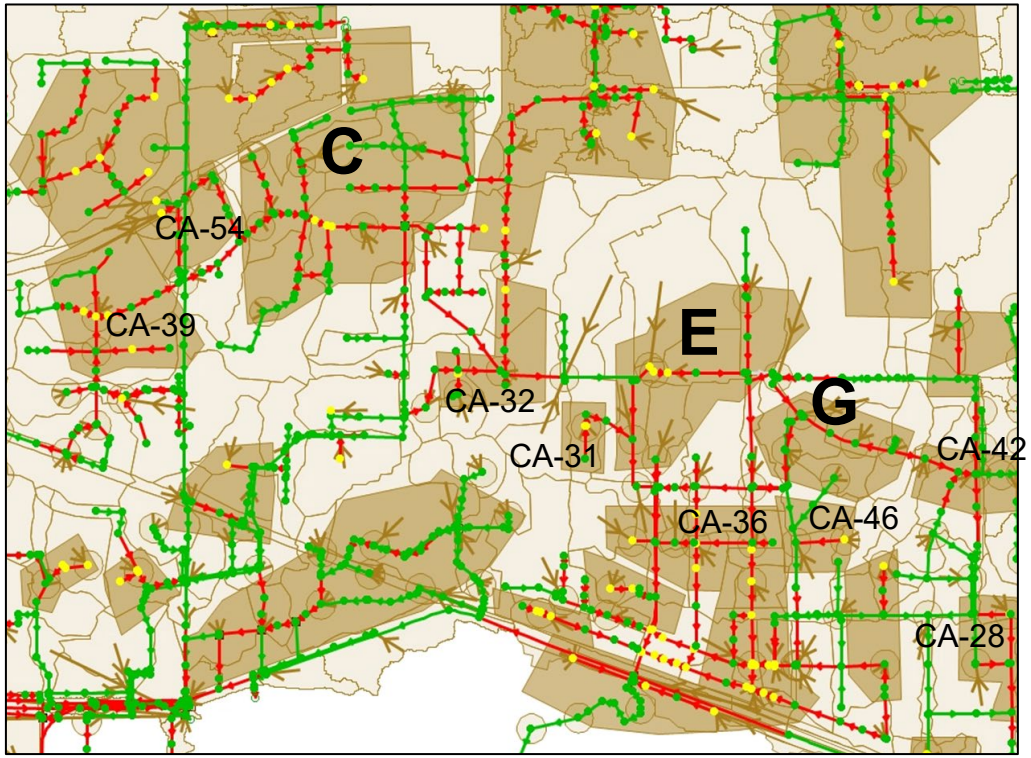
Key Takeaways:

- Alt 4a achieves Current 10-year LOS in Areas C, E and G.
- Alt 4a also benefits CA-54, CA-39, CA-32, CA-31, CA-36, CA-42, CA-46, and CA-28.

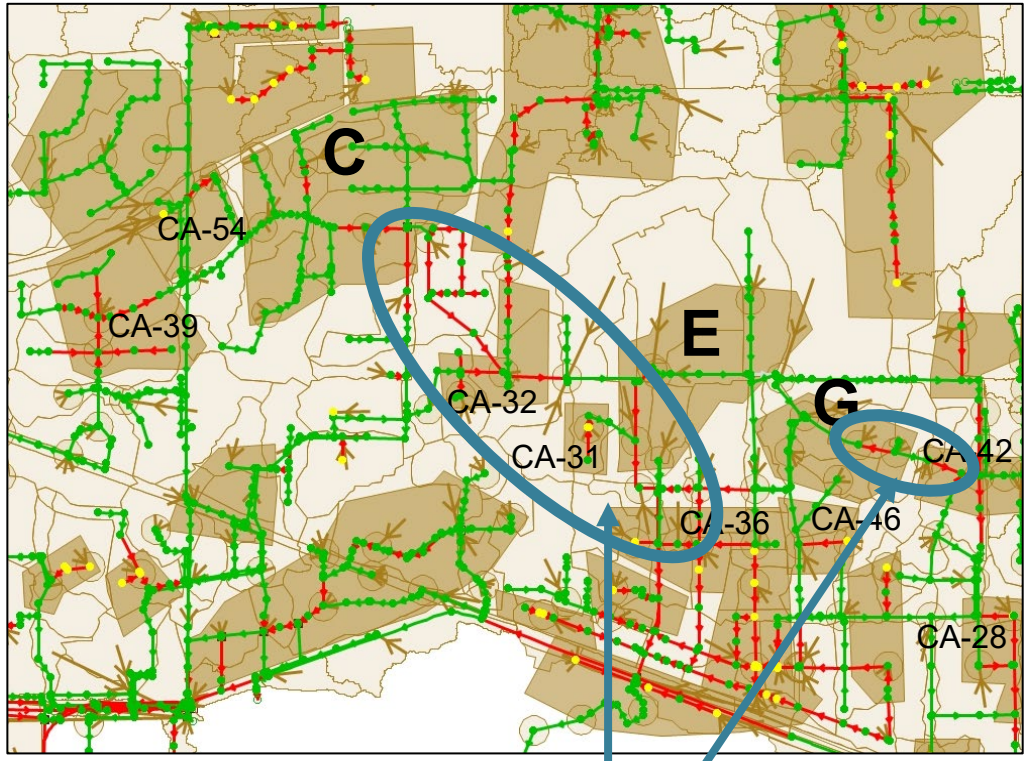
Area C, E & G: Alts 4a & 4b

LOS Results for Future 16-year, 1-hour Storm

With Alt 4a



With Alt 4b



CSS Level of Service

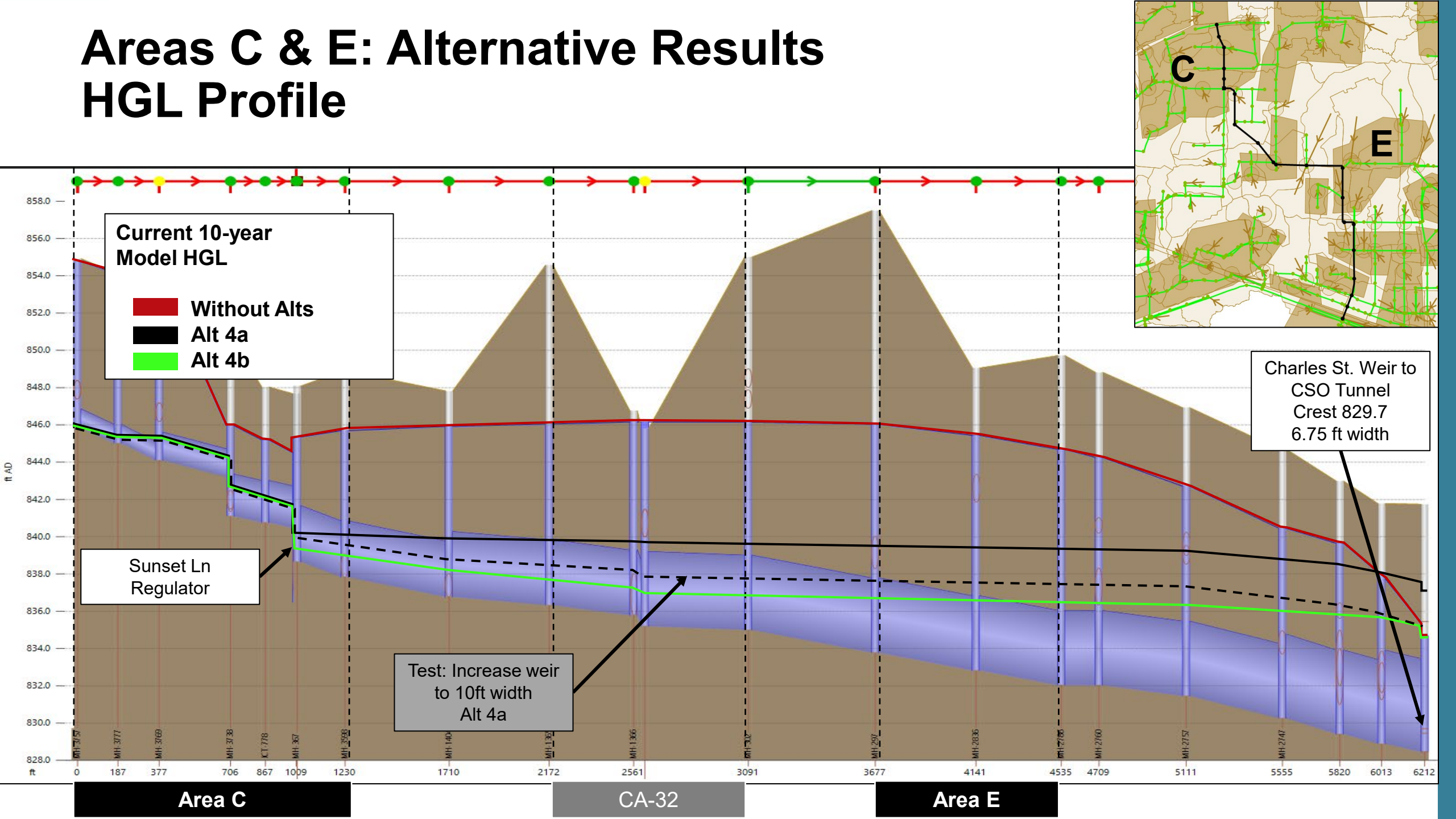
Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

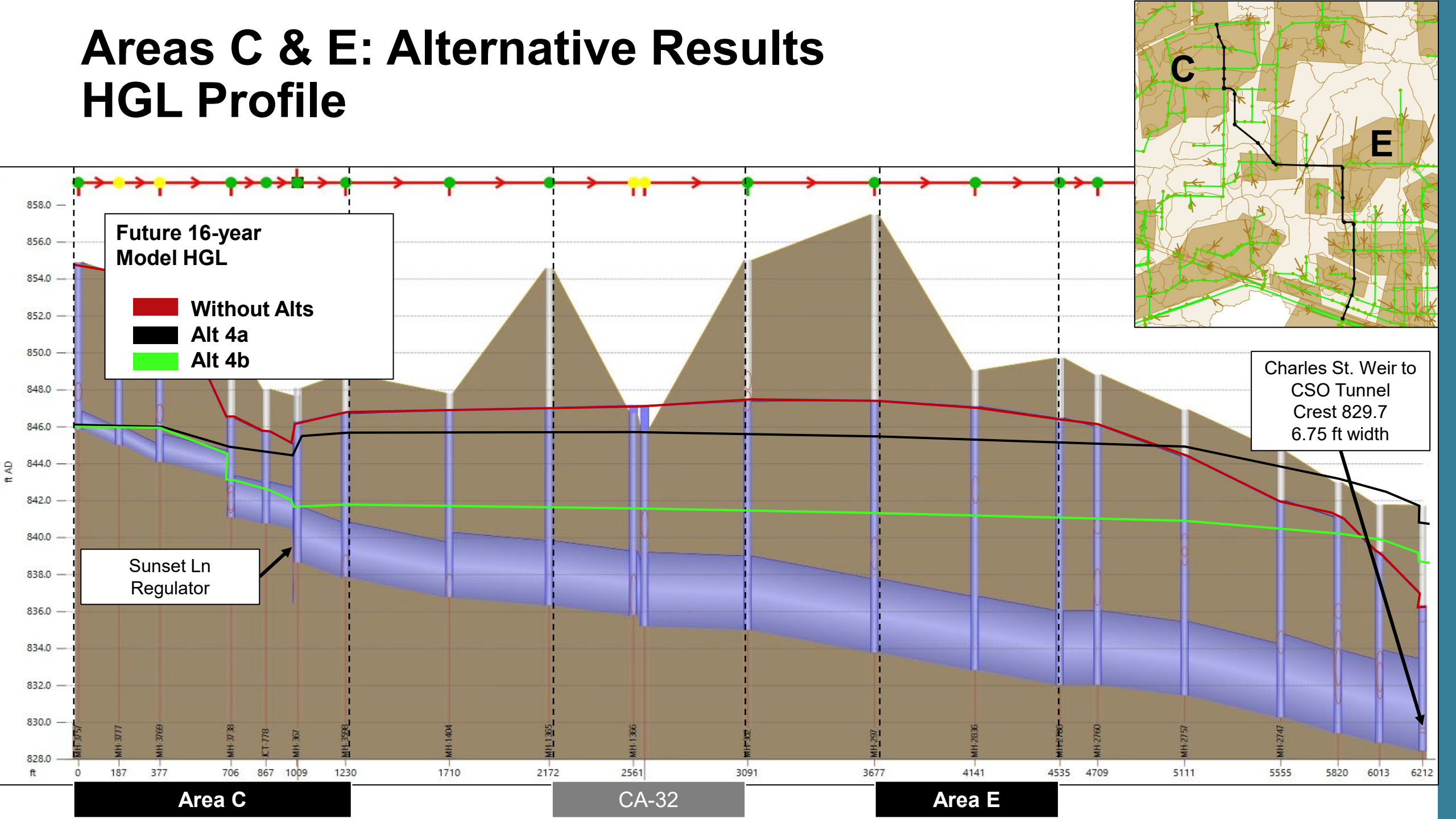
Key Takeaways:

- Alt 4a does not achieve Future 16-year LOS in Areas C, E and G.
- Alt 4b does not achieve Future 16-year LOS in Areas C, E and G
  - Conduits not achieving LOS in Areas C, E, and G due to lack of capacity within mainline sewer on Charles St and Gunson St.
- Alt 4b benefits CA-54, CA-39, CA-32, CA-31, CA-36, CA-42, and CA-46.

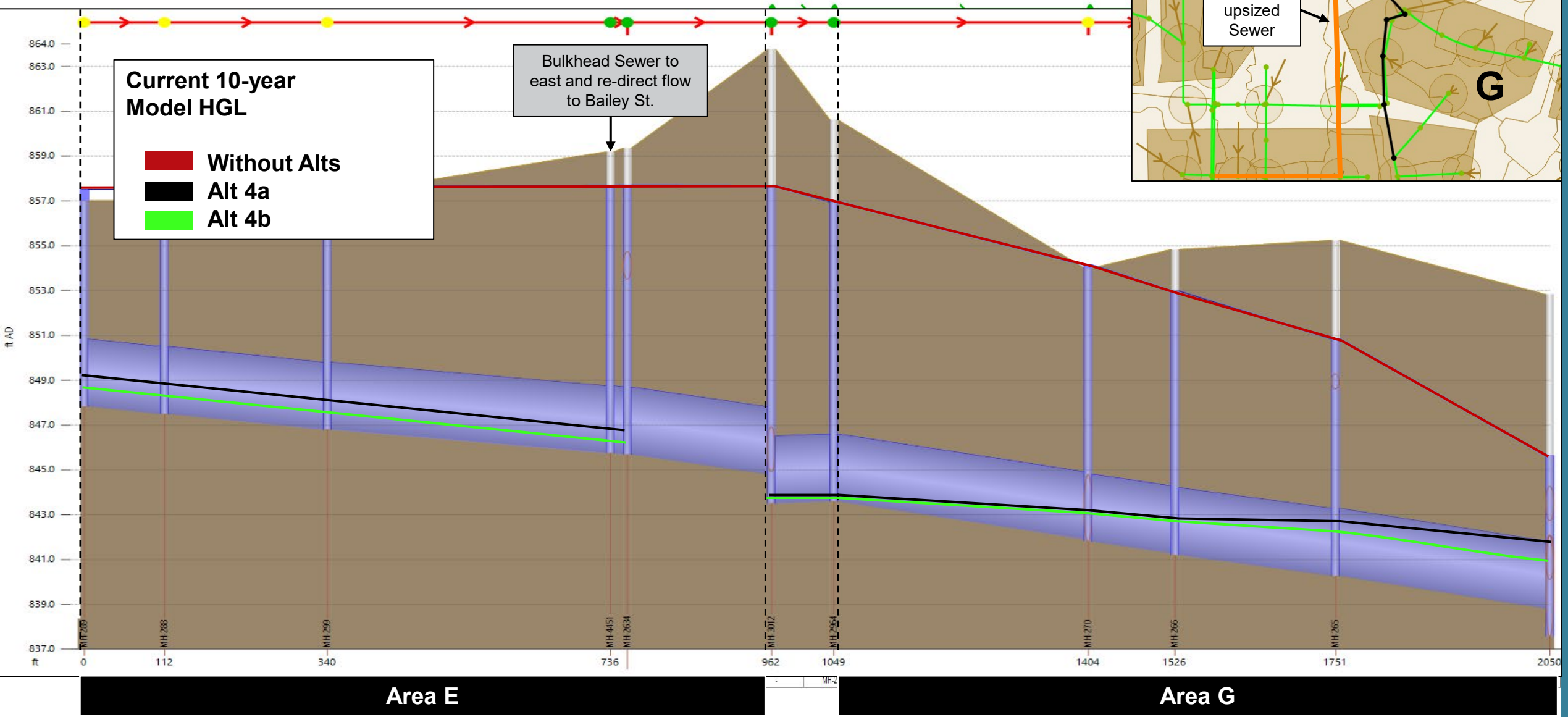
Areas C & E: Alternative Results
HGL Profile

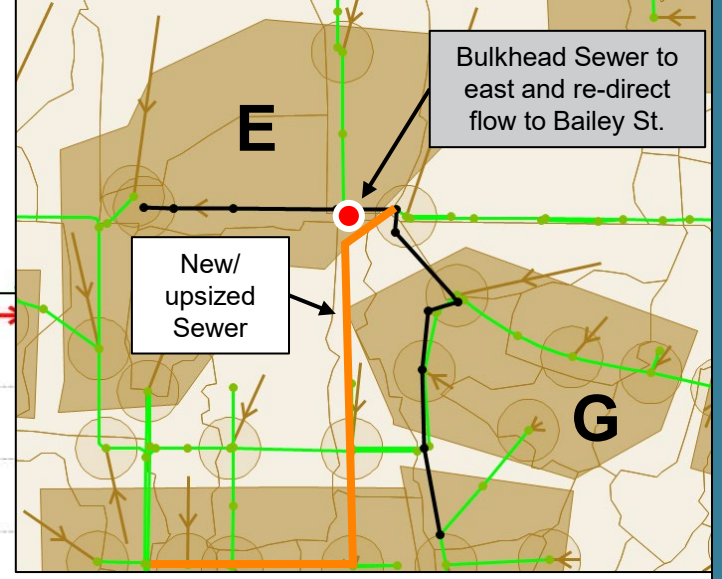


Areas C & E: Alternative Results
HGL Profile

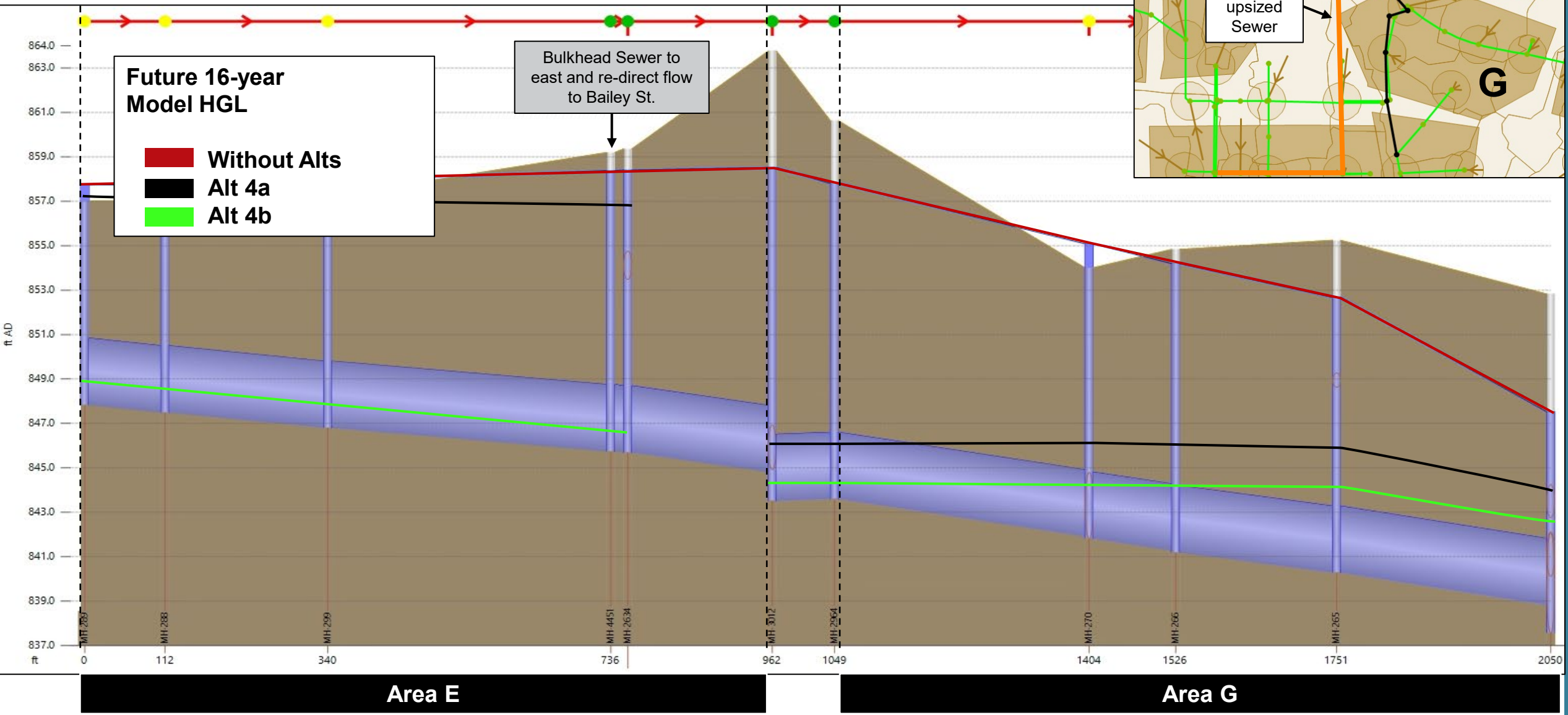


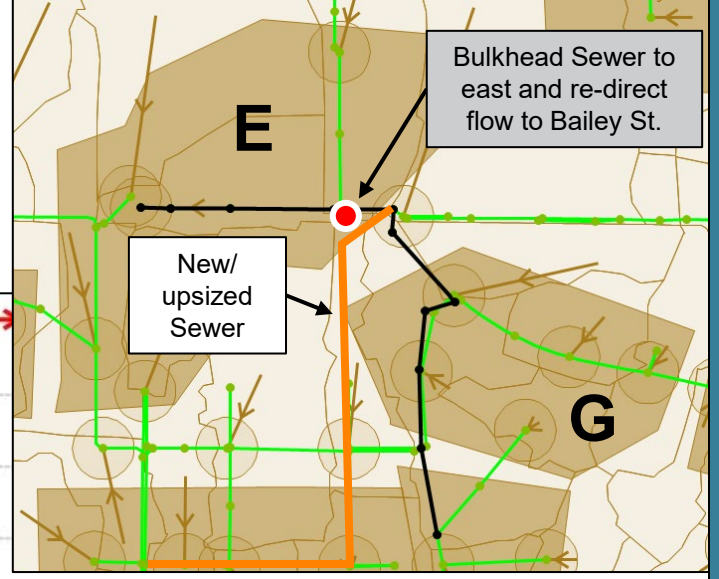
Areas E & G: Alternative Results HGL Profile



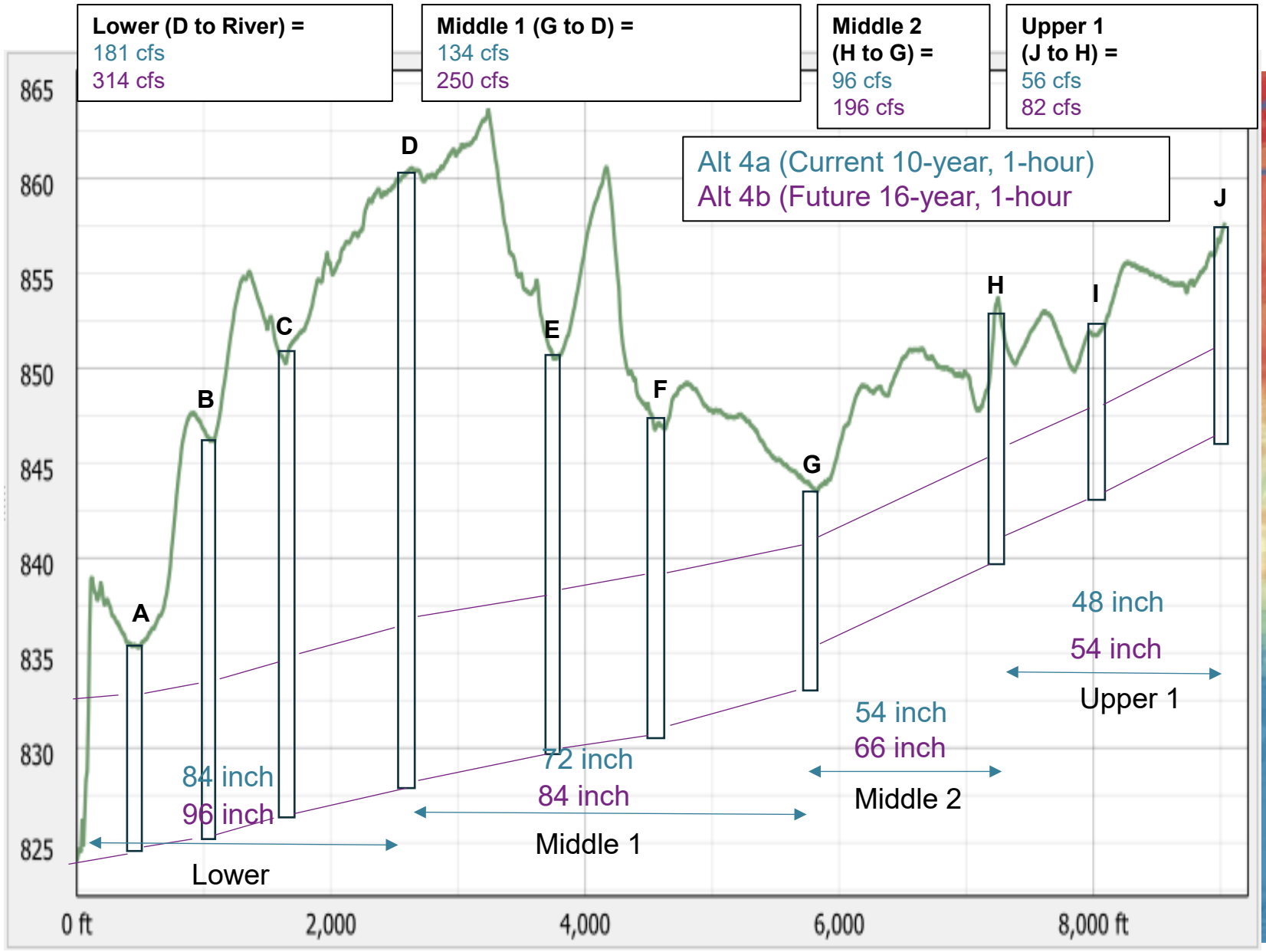


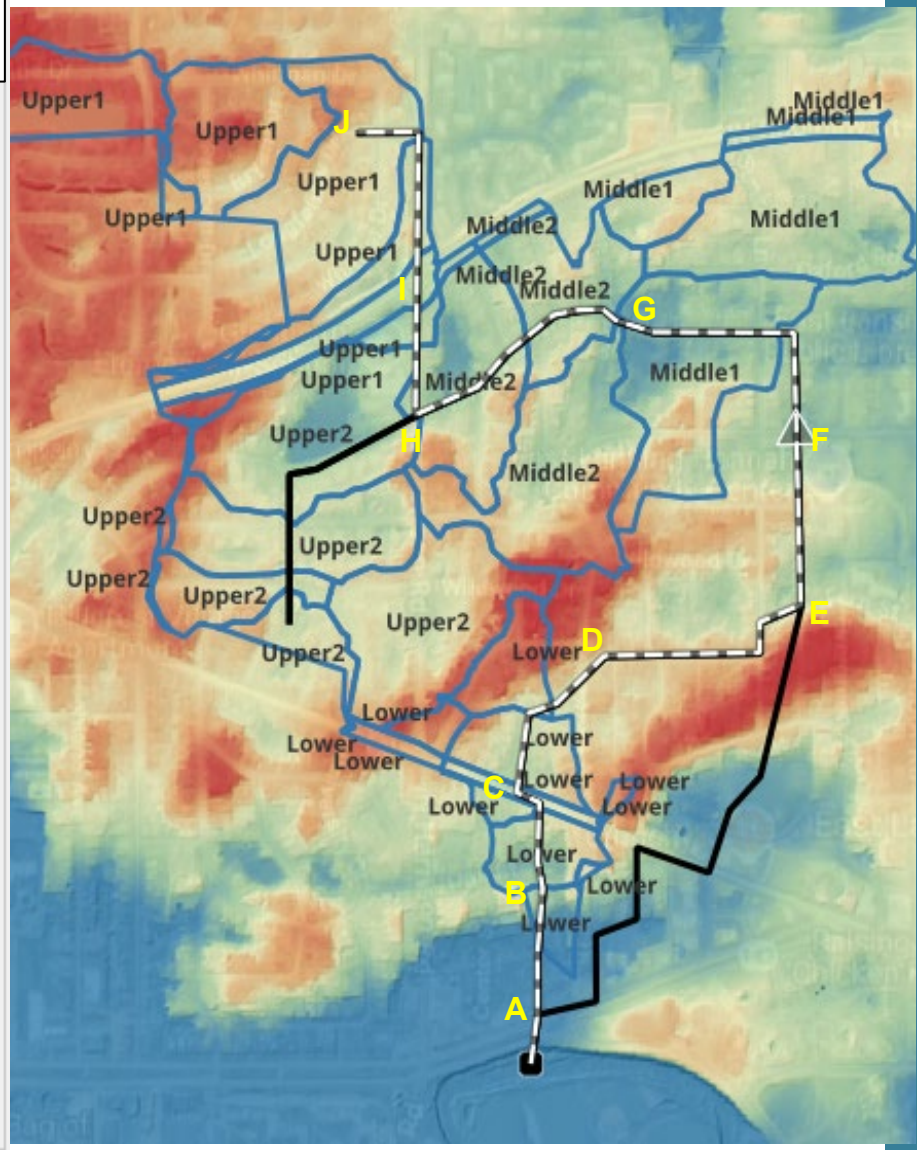
Areas E & G: Alternative Results HGL Profile





Alts 4a & 4b: Required Storm Sewer Main Sizes (Option 1)

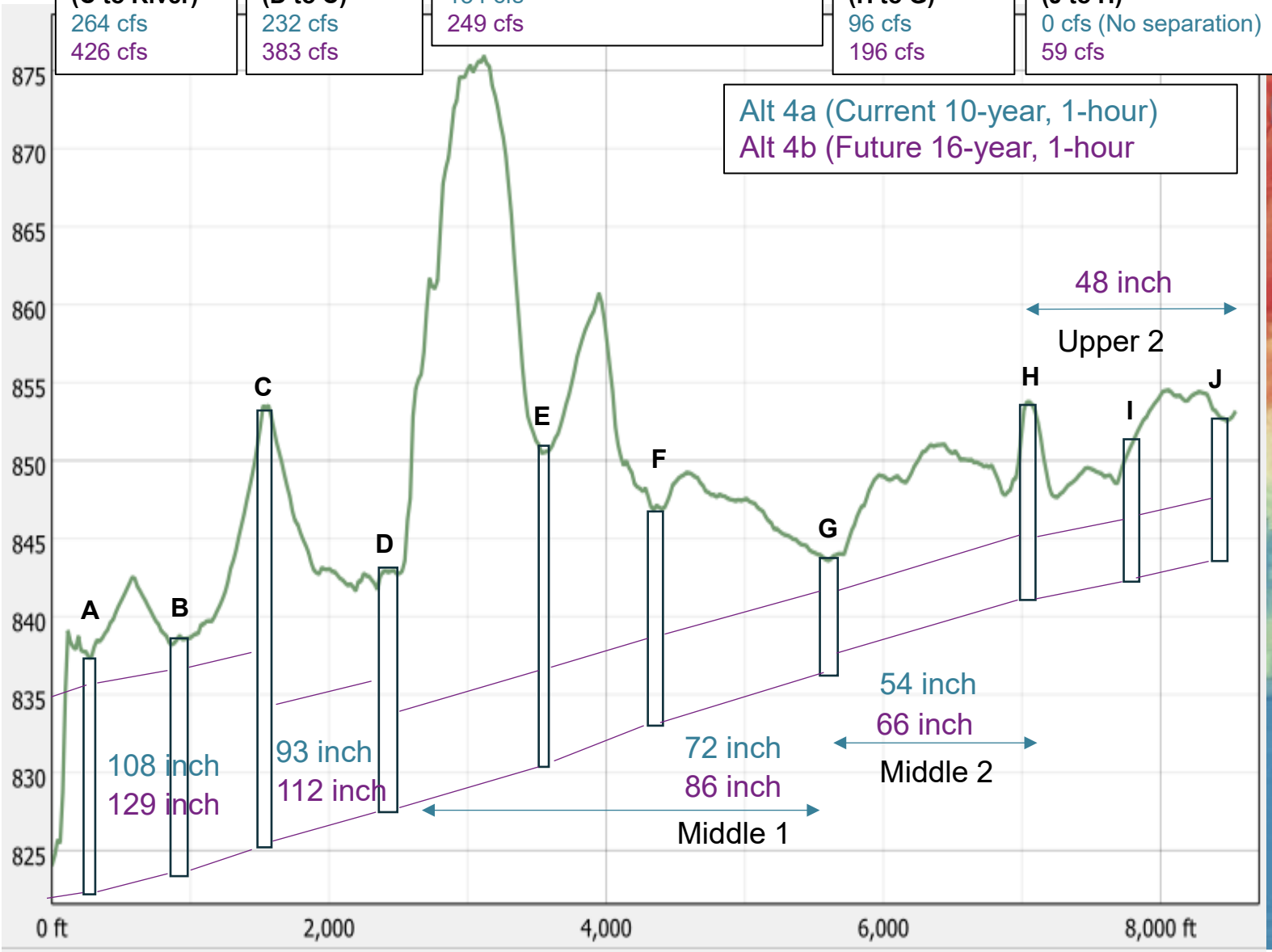


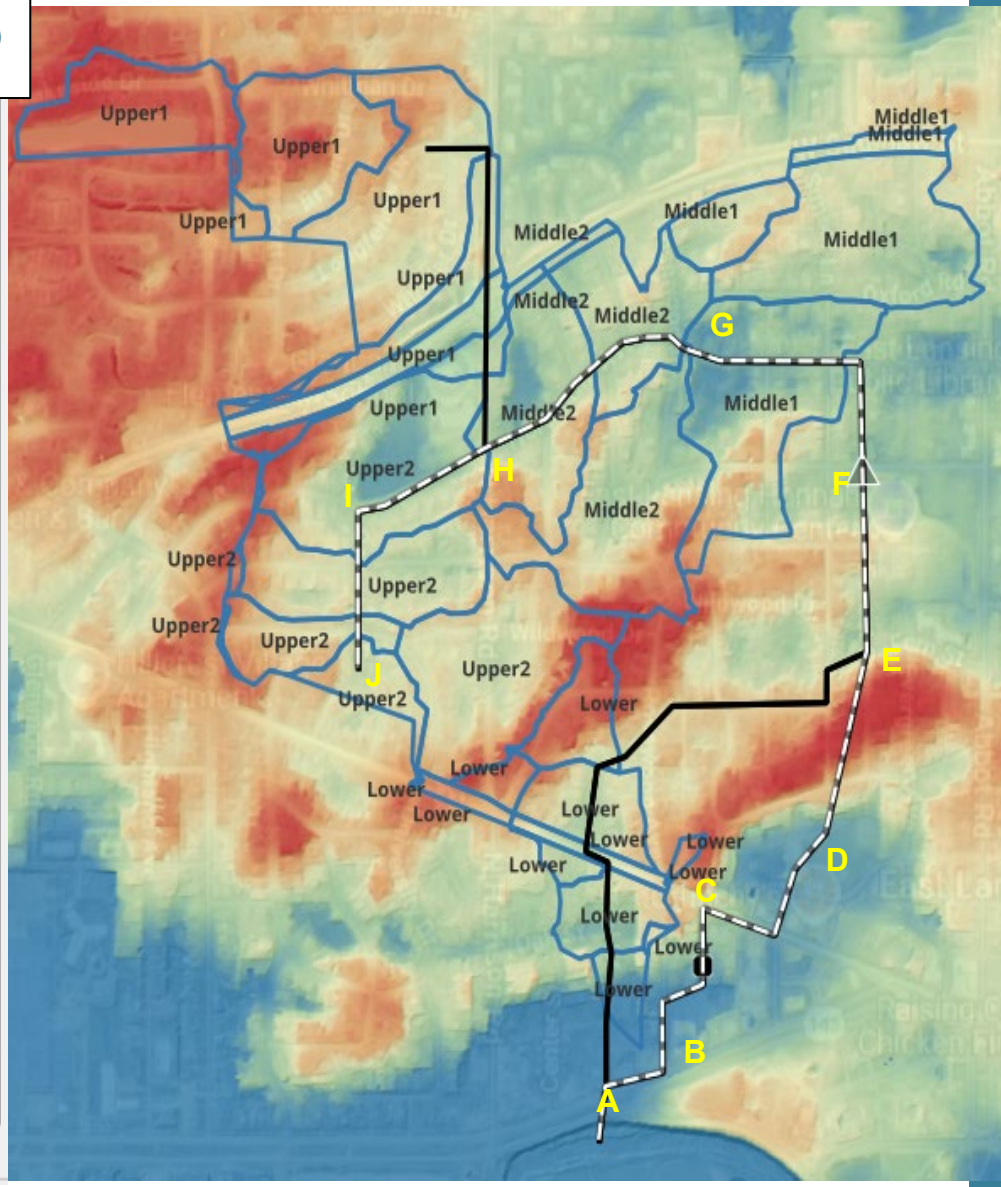


Alts 4a & 4b: Required Storm Sewer Main Sizes (Option 2 - Tie into Area D)

Lower 2 (C to River) =	Lower 1 (D to C) =	Middle 1 (G to D) =	Middle 2 (H to G) =	Upper 2 (J to H) =
264 cfs	232 cfs	134 cfs	96 cfs	0 cfs (No separation)
426 cfs	383 cfs	249 cfs	196 cfs	59 cfs

Alt 4a (Current 10-year, 1-hour)
Alt 4b (Future 16-year, 1-hour





Area C: Alt 4c Storage at Glencairn Park, Shaw Park, and Hannah Community Center Resilience Opportunities

1. **Glencairn Park**
   - Footprint = 1.68 ac
   - Drainage Area Captured = 34 ac
   - CFS Reduction = 50 cfs
2. **Shaw Park**
   - Footprint = 1.06 ac
   - Drainage Area = 22 ac
   - CFS Reduction = 31 cfs
3. **Hannah Community Center**
   - Footprint = 1.59 ac
   - Drainage Area = 32 ac
   - CFS Reduction = 47 cfs



Increased LOS with the Alt 4c Resilience Opportunity

- ~129 cfs benefit to downstream system with three storage locations
  - Increase LOS from current 10-year to ~100-year
  - Increase LOS from future 16-year to ~50-year

Rainfall (inches)	Return Period (Years)		Peak Flow CFS		
	Current Day	2100 High Emissions	Area D	With Glencairn, Shaw, Hannah Storage	
1.40	2	1	129		
1.61	3	1	160		
1.92	8	3	209		
2.00	10	3	221	350	+129 cfs
2.18	17	5	252		
2.44	38	10	298		
2.54	50	16	315	443	+129 cfs
2.77	100	25	358		
3.05	200	50	411		
3.23	500	100	465		

Area C: Alt 4c Storm Pipe Profile With Storage

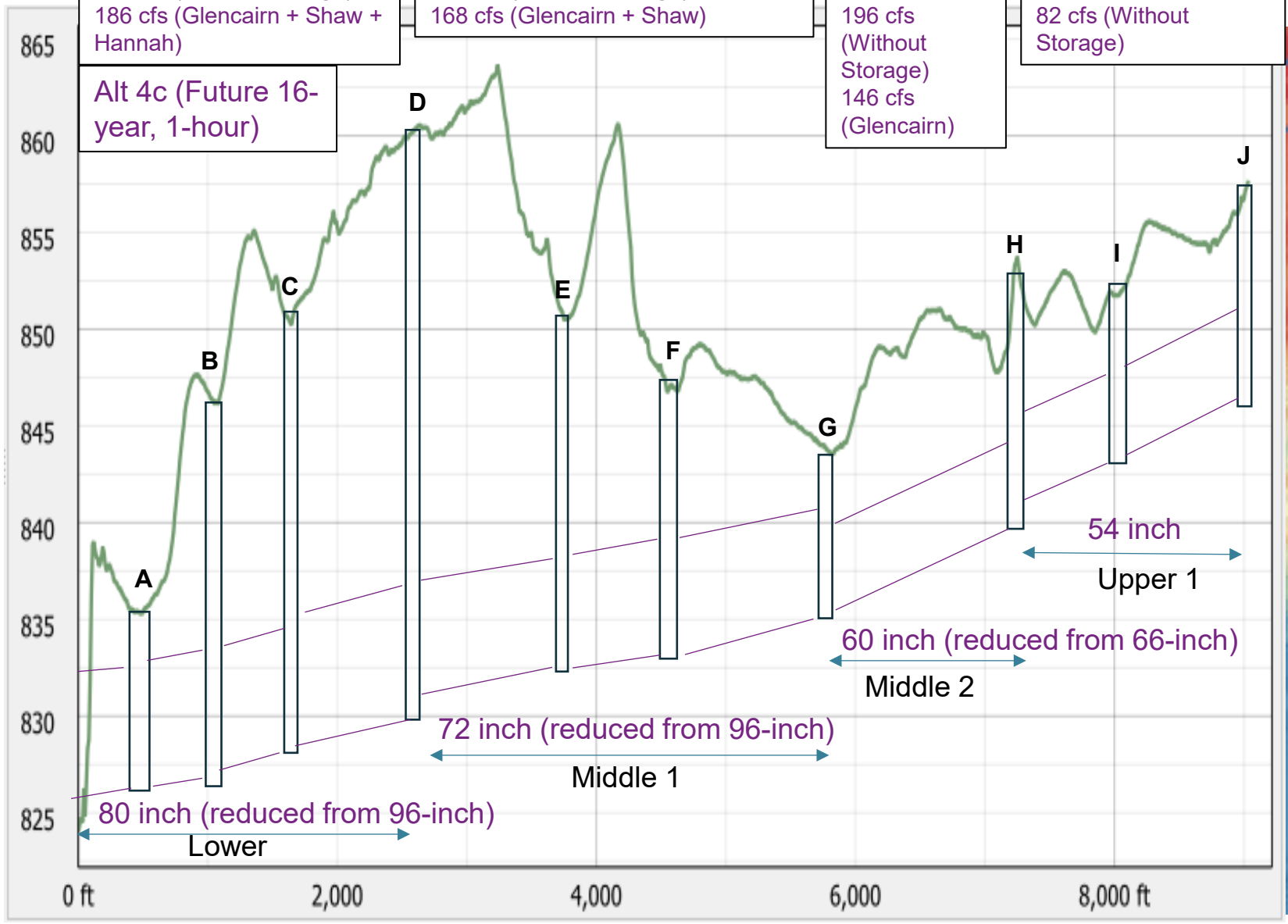
Lower (D to River) =
314 cfs (Without Storage)
186 cfs (Glencairn + Shaw + Hannah)

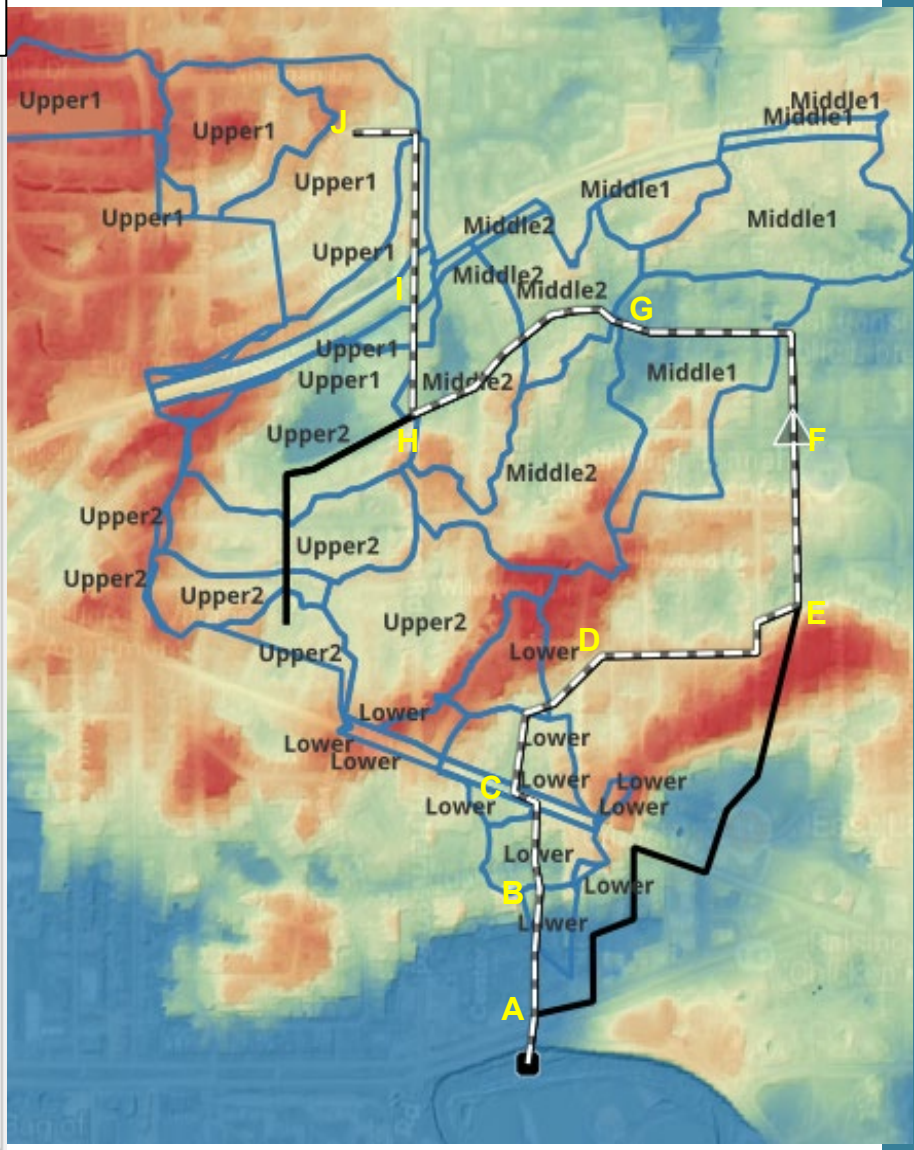
Middle 1 (G to D) =
250 cfs (Without Storage)
168 cfs (Glencairn + Shaw)

Middle 2 (H to G) =
196 cfs (Without Storage)
146 cfs (Glencairn)

Upper 1 (J to H) =
82 cfs (Without Storage)

Alt 4c (Future 16-year, 1-hour)

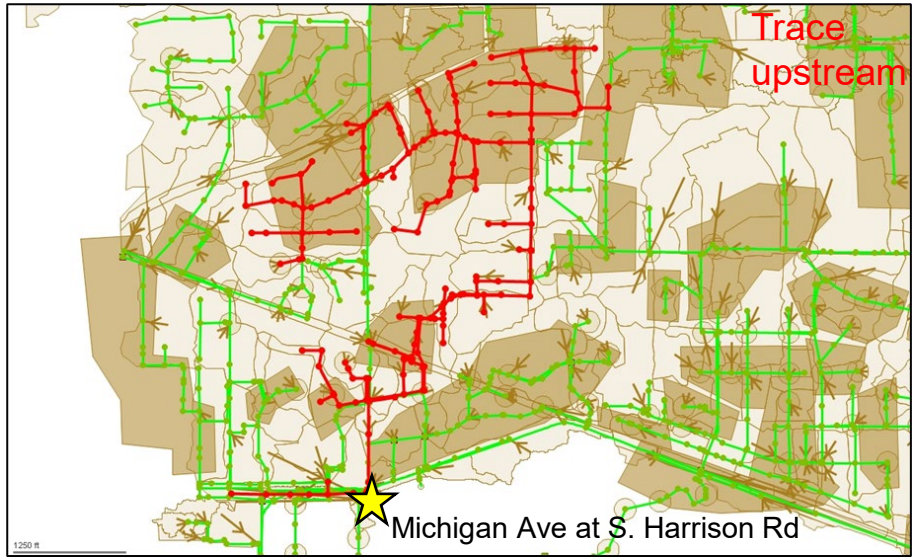


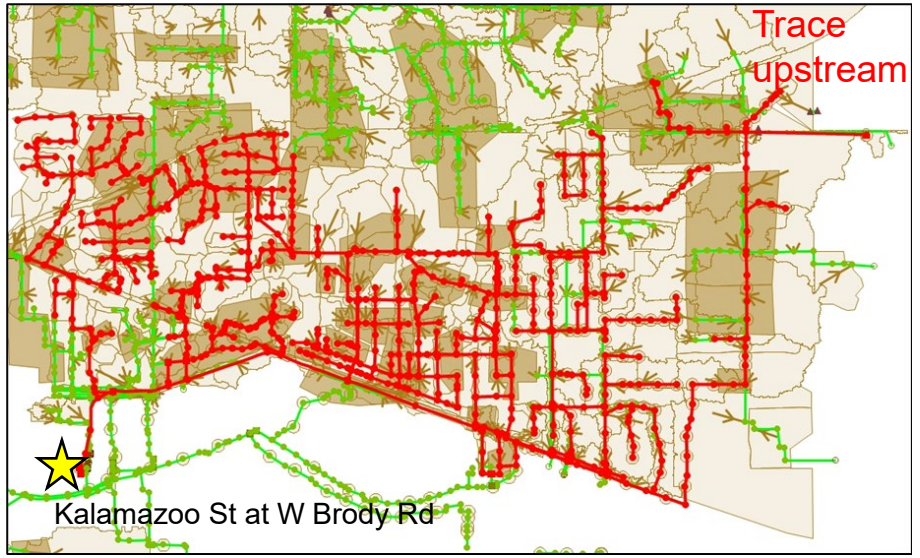


Potential CSO Impacts

- Upsizing CSO pipes without sewer separation may increase CSO.
- Phasing project implementation is important.
- Model was checked with alternatives in place to ensure projects are not increasing overall system CSO.

Outfall Locations	Discharges to
Michigan	Red Cedar River
Kalamazoo	Red Cedar River





Preliminary CSO Analysis Results (Current 10-year)

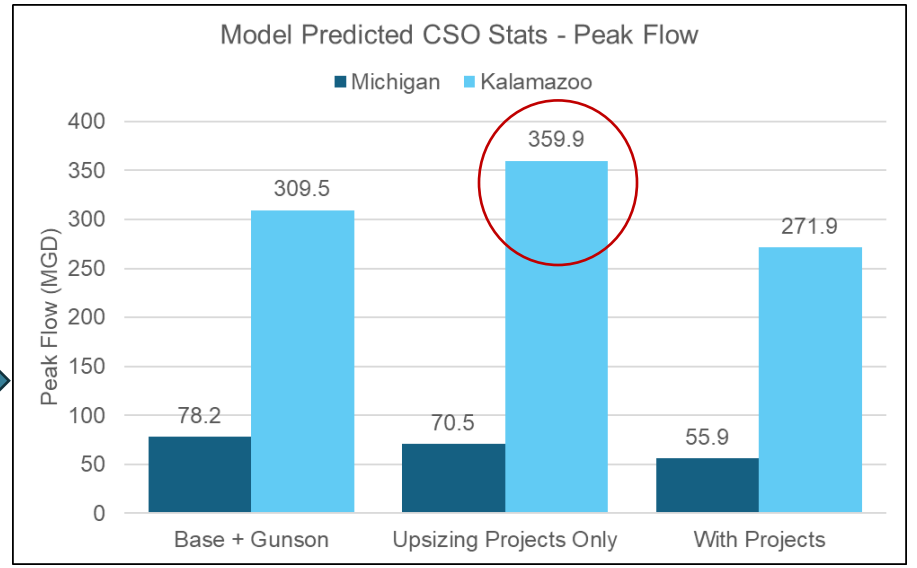
Peak Flow (MGD)

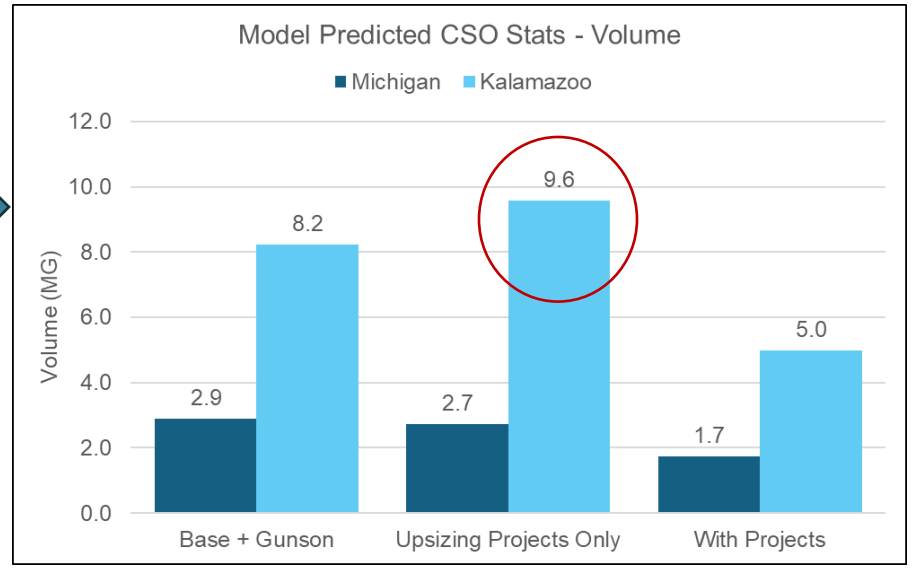
Outfall Location	Current Condition + Gunson	Upsizing Projects Only	With Alternative 1a, 3a, 4a
Michigan	78.2	70.5	55.9
Kalamazoo	309.5	359.9	271.9

Volume (MG)

Outfall Location	Current Condition + Gunson	Upsizing Projects Only	With Alternative 1a, 3a, 4a
Michigan	2.9	2.7	1.7
Kalamazoo	8.2	9.6	5.0

If upsizing projects are implemented before separation occurs, CSOs will increase at Kalamazoo outfall for the current 10-year storm.





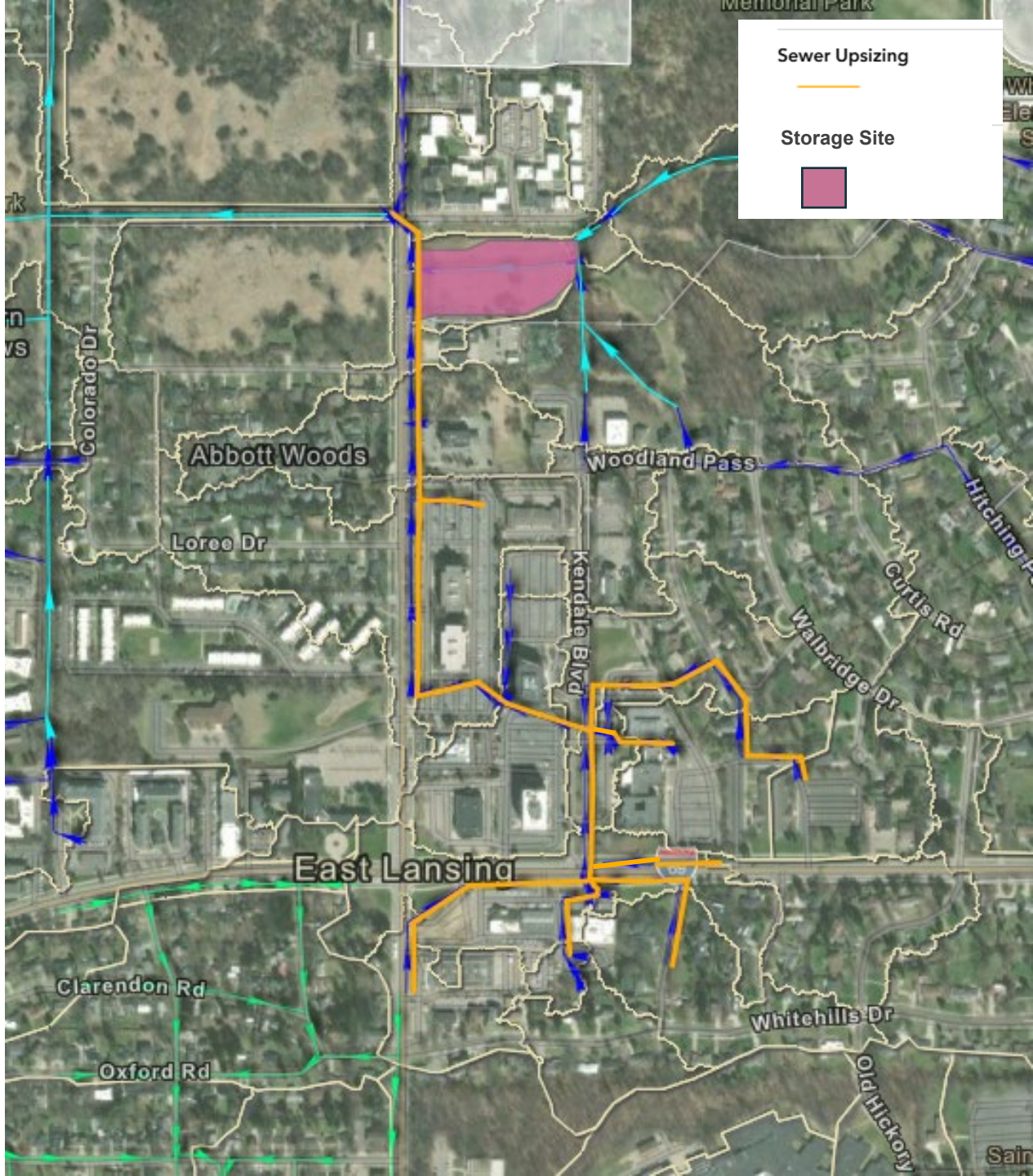


04

MS4 Alternatives Analysis Results

Area F Alternatives

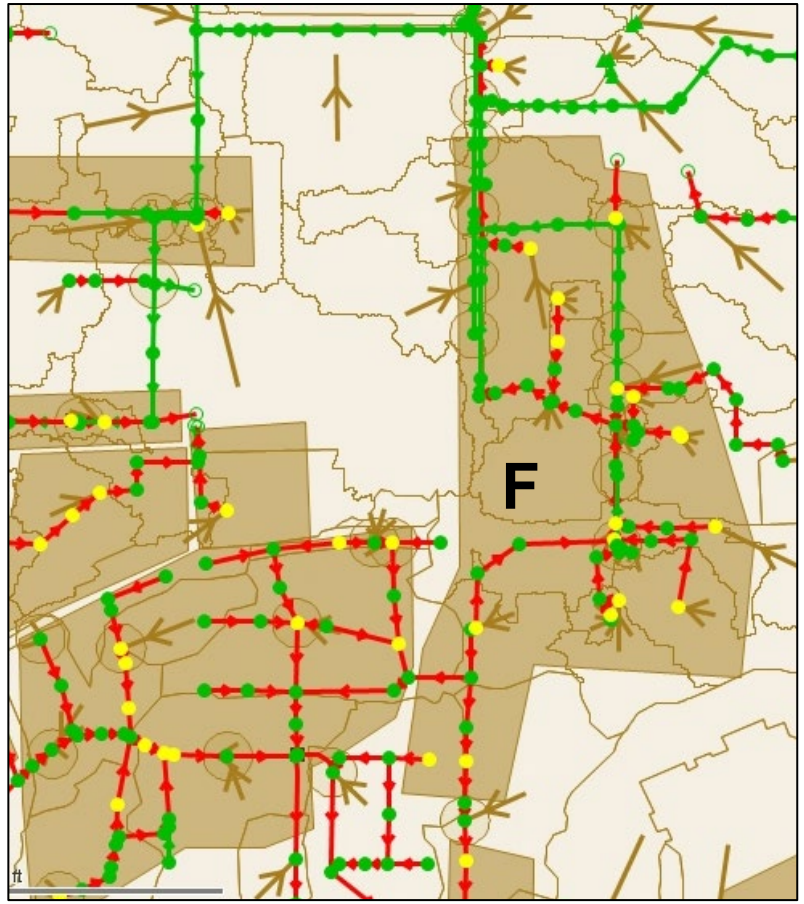
Concern Area	Alt	Proposed Project(s)
F	**5a**	• 7,600 feet of main storm sewer upsizing • 3.53 ac-ft of storage at Fire Department
	5b	• 5a plus additional 1.59 ac-ft of storage at Fire Department or upstream detention (total 5.12 ac-ft)
	5c	• 5a or 5b plus storage under parking lots



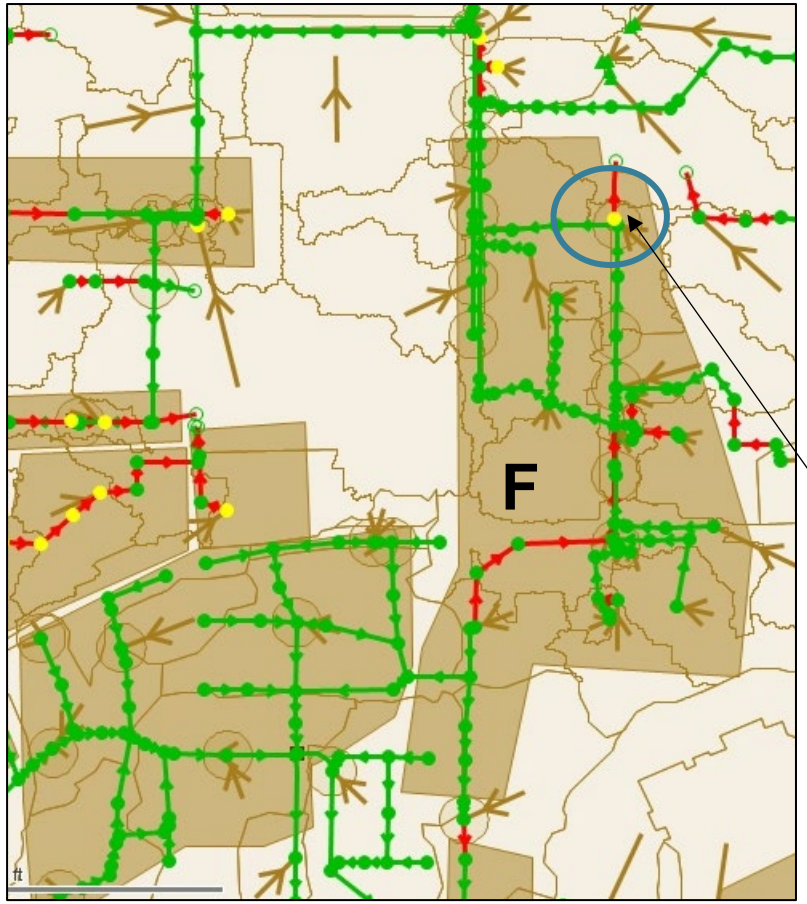
Area F: Alt 5a

LOS Results for Current 10-year, 1-hour Storm

Without Alt



With Alt 5a



MS4 Level of Service

Nodes

- No MH Flooding
- MH Flooding

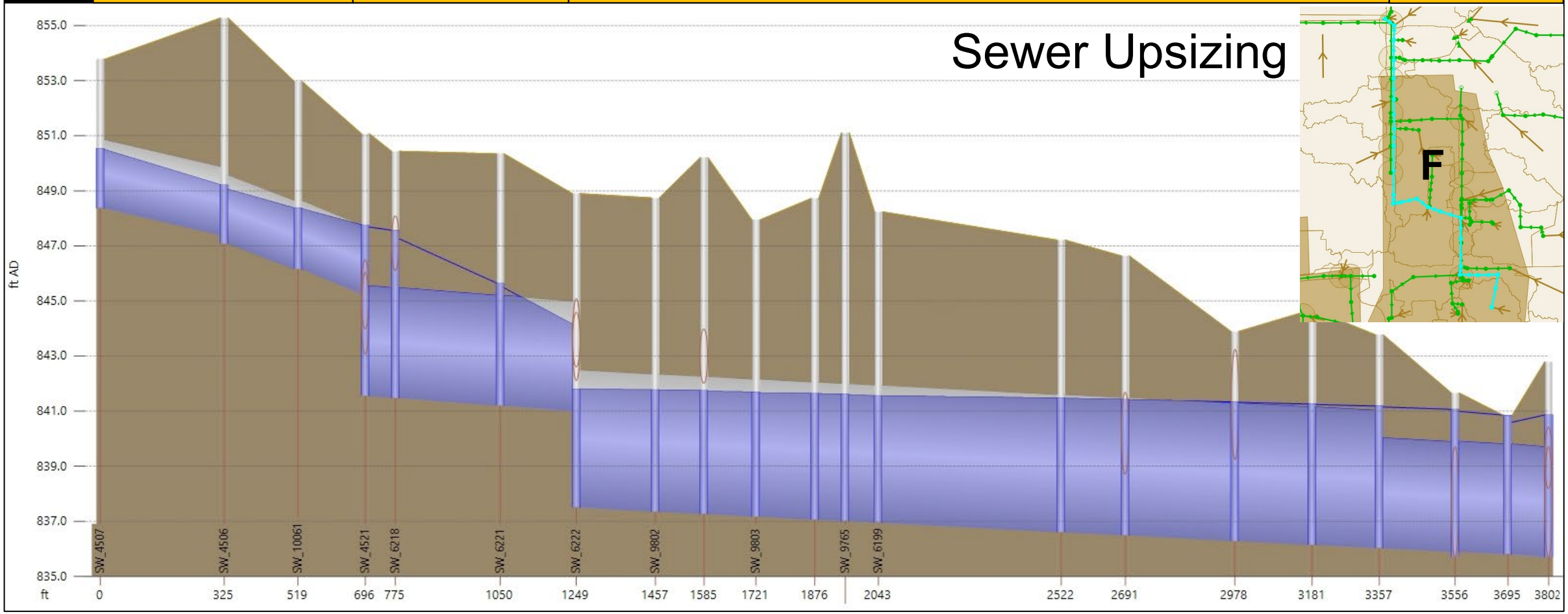
Key Takeaways:

- Alt 5a achieves Current 10-year LOS in Area F.
  - Node with flooding is an independent culvert and not hydraulically connected to other sewers in Area F.
  - Can upsize additional 275.5 LF culvert to achieve LOS.

Area F: Alt 5a Main Trunk Sewer Pipe Upsize

Required upsizes for the current 10-year, 1-hour, 2.00 inches

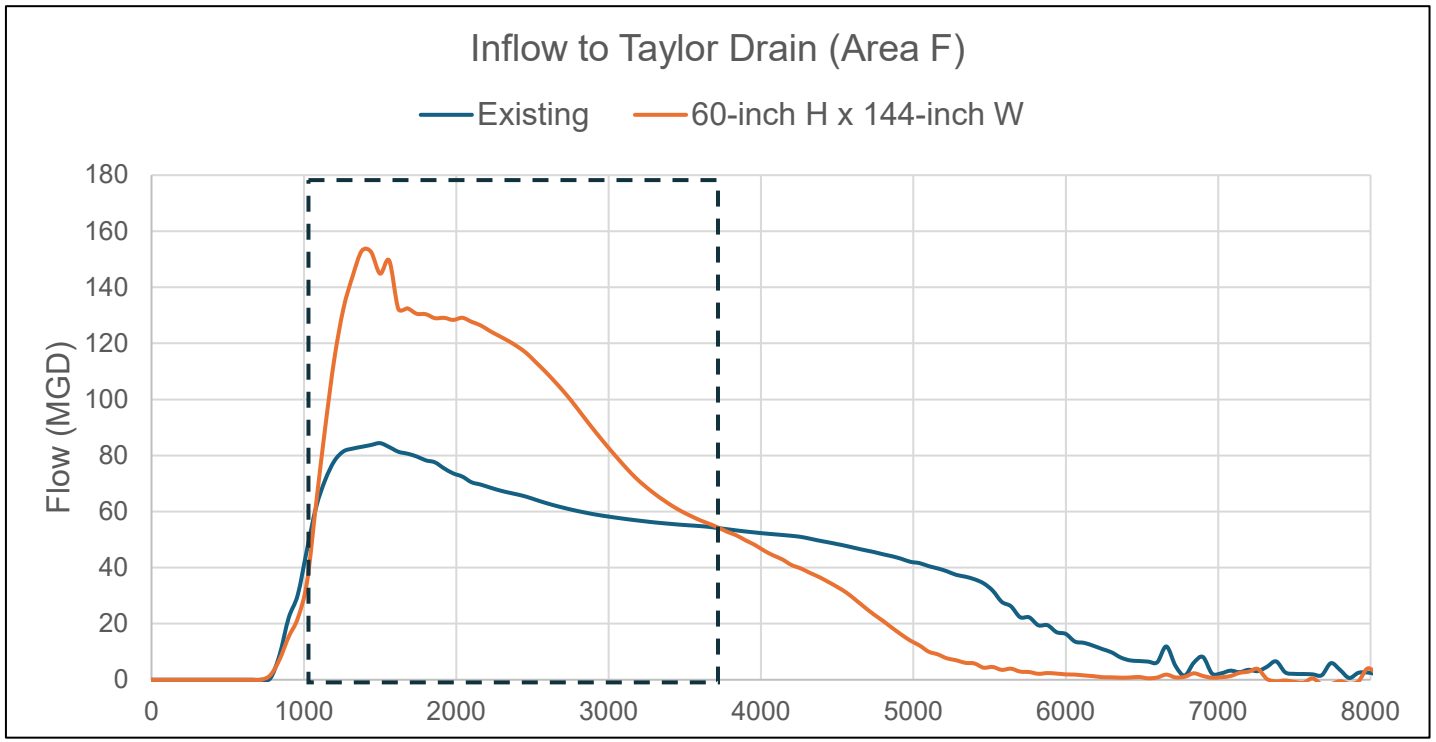
	Ex. 21-inch Upsize to 30-inch	Ex. 36-inch Upsize to 48-inch	Ex. 42-inch, 43-inch H x 68-inch W Upsize to 60-inch H x 144-inch W	Ex. 48-inch H x 76-inch W Upsize to 48-inch H x 168-inch W



Area F: Alt 5a Downstream Increased Flow

Taylor Drain near East Lansing Fire Station

Required peak attenuation for the current 10-year, 1-hour, 2.00 inches



Peak Flow

Scenario	Peak Flow (MGD)	Difference from Existing (MGD)
Existing	84.40	-
Alt 5a	153.00	68.60

Peak Volume

Scenario	Volume (ac-ft)	Difference from Existing (ac-ft)
Existing	6.75	-
Alt 5a	10.31	**3.53**

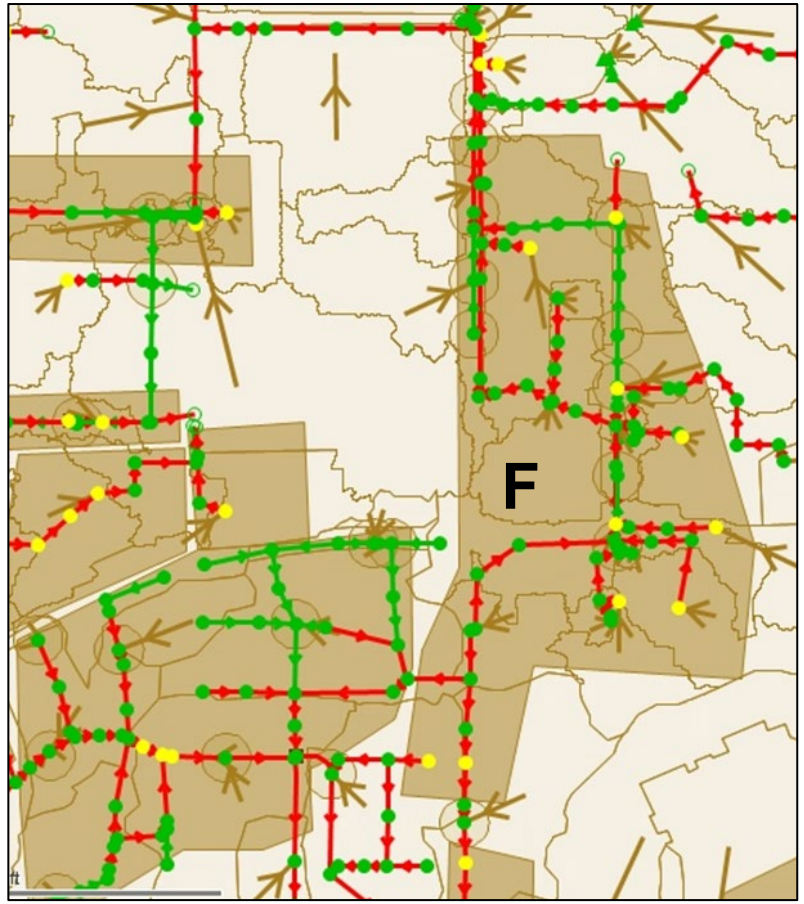
From 780 to 3780 simulation seconds

- Area F existing capacity: 84 MGD (130 cfs)
- Area F required capacity for current 10-year, 1-hour: 153 MGD (236 cfs)
- Approximate storage needed to offset peaks for current 10-year, 1-hour: 1.15 MG (3.53 ac-ft)

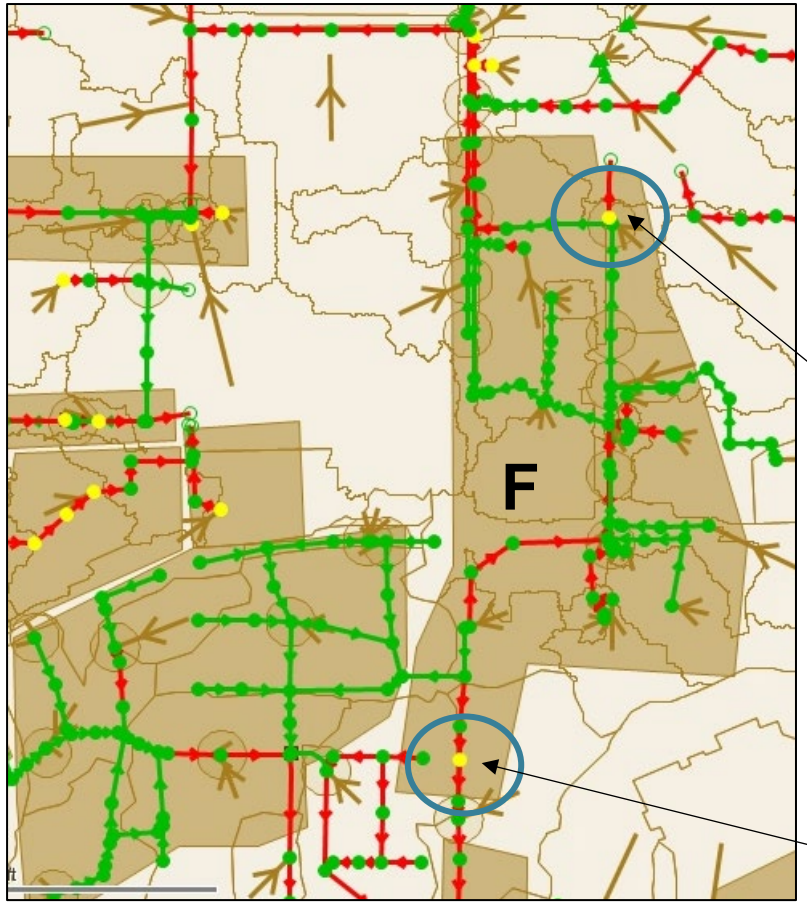
Area F: Alts 5a & 5b

LOS Results for Future 16-year, 1-hour Storm

Alt 5a



Alt 5b



MS4 Level of Service

Nodes

- No MH Flooding
- MH Flooding

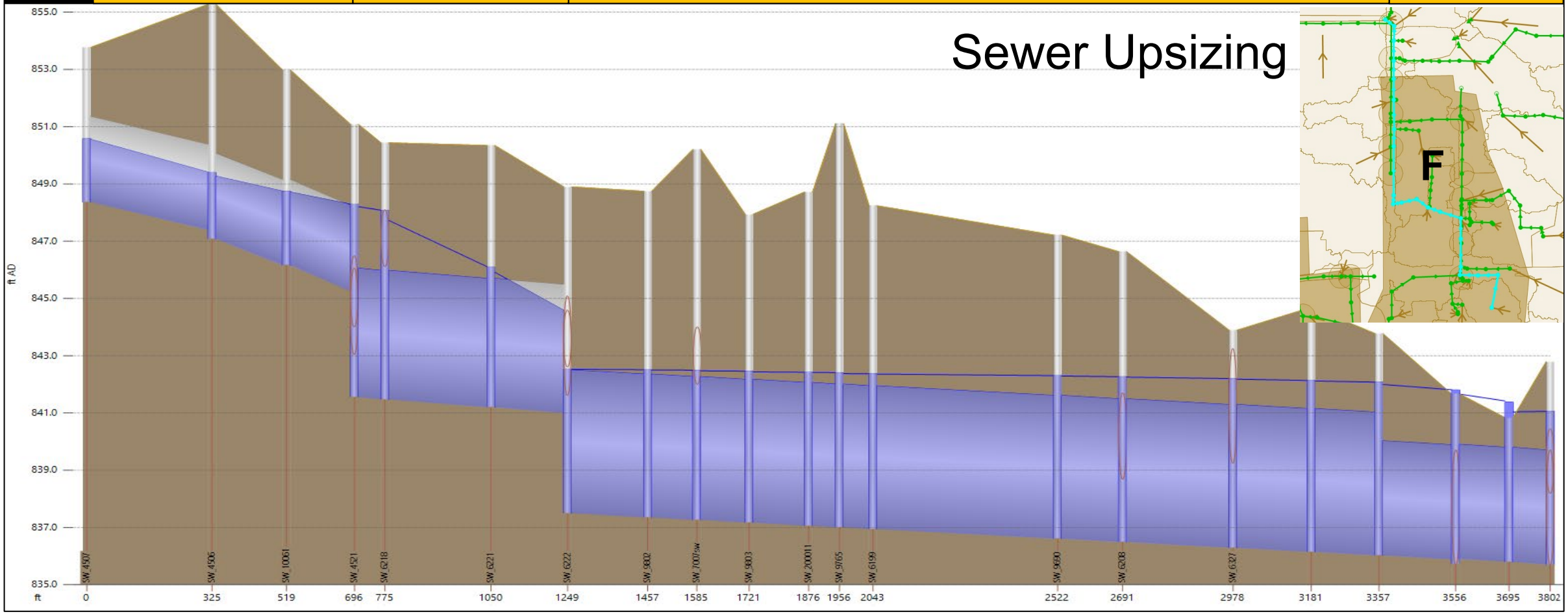
Key Takeaways:

- Alt 5a does not achieve Future 16-year LOS in Area F.
- Alt 5b achieves Future 16-year LOS in Area F.
  - Node with flooding is an independent culvert and not hydraulically connected to other sewers in Area F.
  - Can upsize additional 275.5 LF culvert to achieve LOS.
  - Flooded manhole is in CSS area and LOS cannot be achieved by MS4 projects alone.

Area F: Alt 5b Main Trunk Sewer Pipe Upsize

Required upsizes for the future 16-year, 1-hour, 2.54 inches

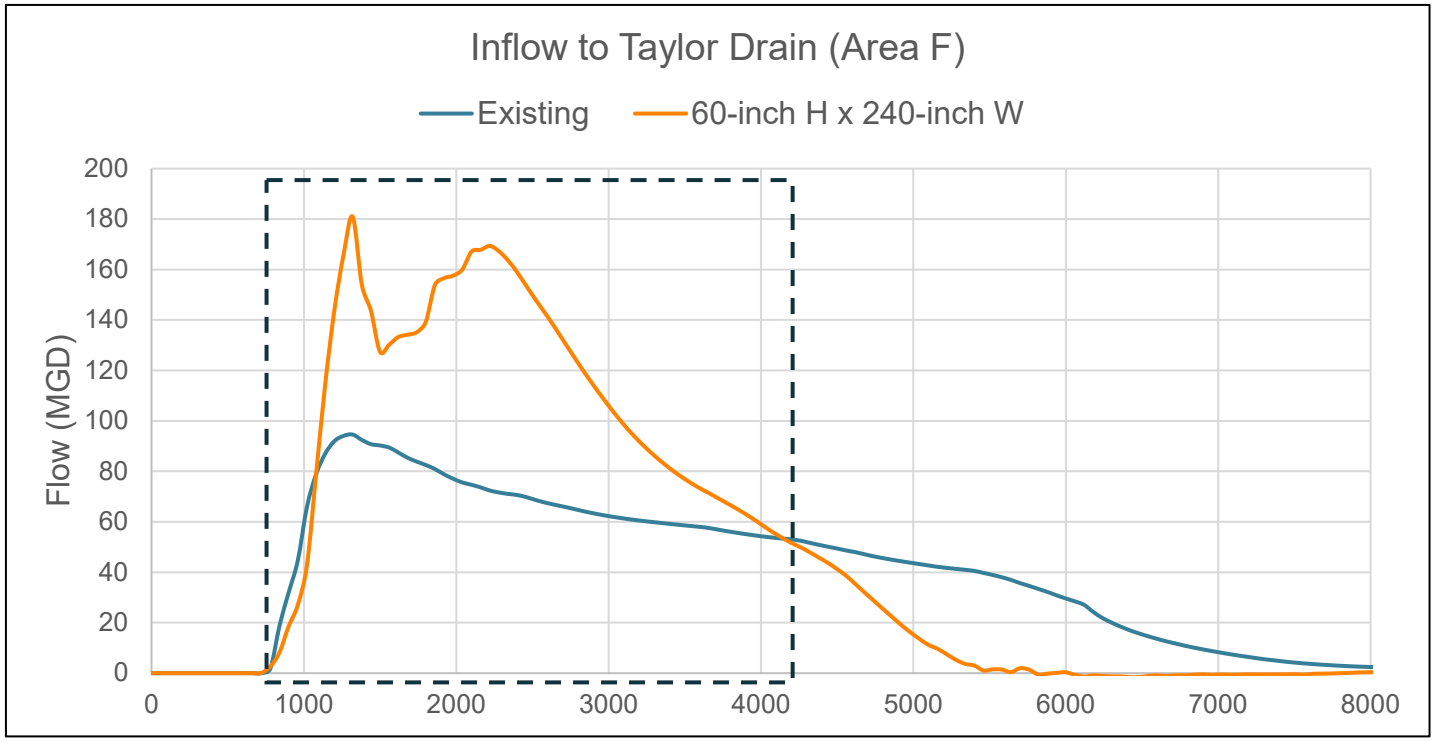
	Ex. 21-inch Upsize to 36-inch	Ex. 36-inch Upsize to 54-inch	Ex. 42-inch, 43-inch H x 68-inch W Upsize to 60-inch H x 240-inch W	Ex. 48-inch H x 76-inch W Upsize to 48-inch H x 168-inch W



Area F: Alt 5b Downstream Increased Flow

Taylor Drain near East Lansing Fire Station

Required peak attenuation for the future 16-year, 1-hour, 2.54 inches



Peak Flow

Scenario	Peak Flow (MGD)	Difference from Existing (MGD)
Existing	94.58	-
Alt 5b	180.93	86.36

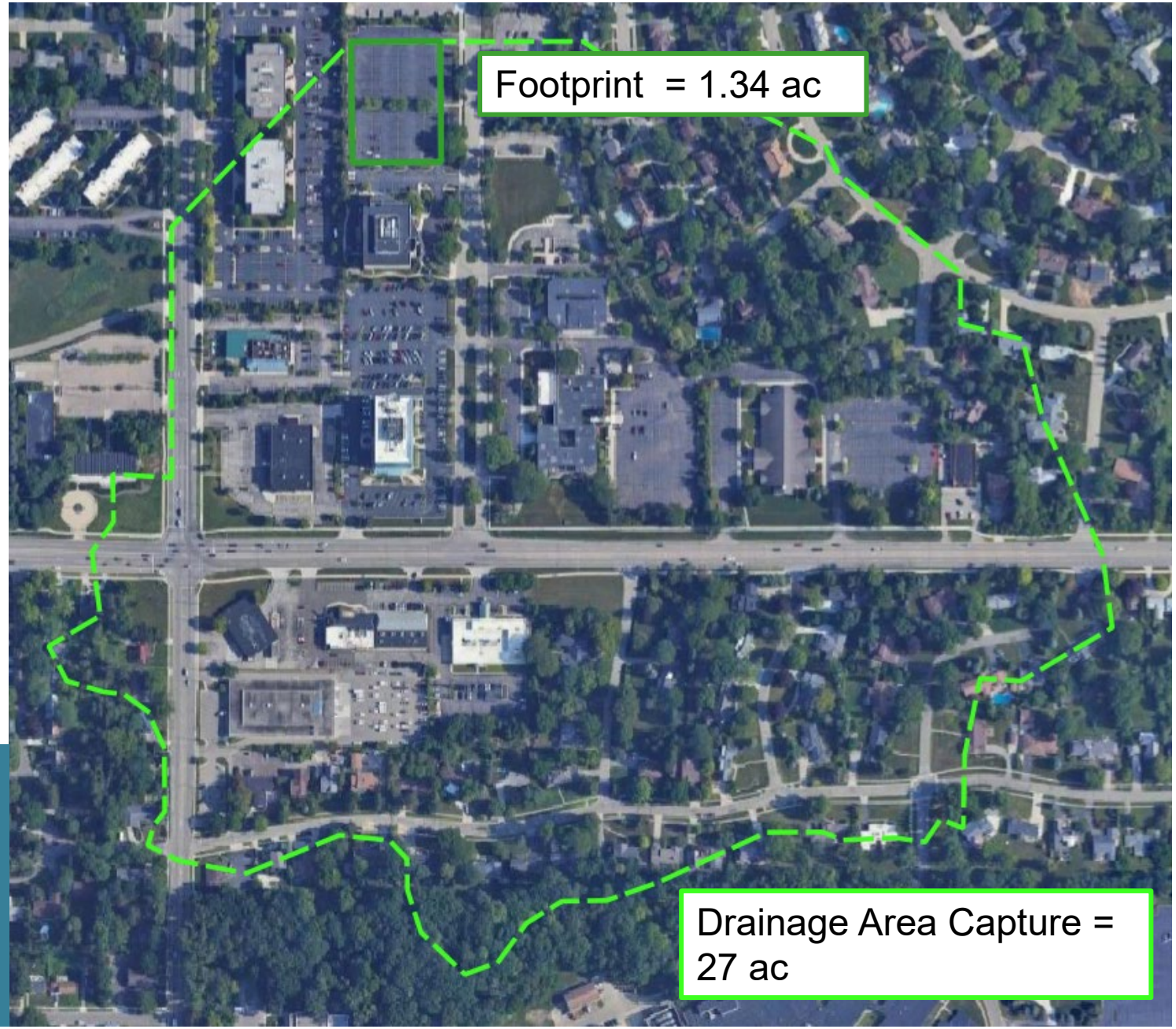
Peak Volume

Scenario	Volume (ac-ft)	Difference from Existing (ac-ft)
Existing	8.34	-
Alt 5b	13.47	**5.12**

From 780 to 4260 simulation seconds

- Area F existing capacity: 94 MGD (146 cfs)
- Area F required capacity for future 16-year, 1-hour: 181 MGD (280 cfs)
- Approximate storage needed to offset peaks for future 16-year, 1-hour: 1.67 MG (5.12 ac-ft)

Area F: Alt 5c Parking Lot Subsurface Storage Resilience Opportunity



Calculated Peak Flow Reduction for Future 16-year Storm =

68 cfs

Or, Increased LOS with the Alt 5c Resilience Opportunity

- ~68 cfs benefit to downstream system with three storage locations
  - Increase LOS from current 10-year to ~20-year
  - Increase LOS from future 16-year to ~25-year

Rainfall (inches)	Return Period (Years)		Peak Flow CFS		
	Current Day	2100 High Emissions	Area F	With Parking Lot Storage	
1.40	2	1	231		
1.61	3	1	276		
1.92	8	3	346		
2.00	10	3	364	432	+68 cfs
2.18	17	5	406		
2.44	38	10	467		
2.54	50	16	492	560	+68 cfs
2.77	100	25	549		
3.05	200	50	620		
3.32	500	100	691		

Area H Alternatives

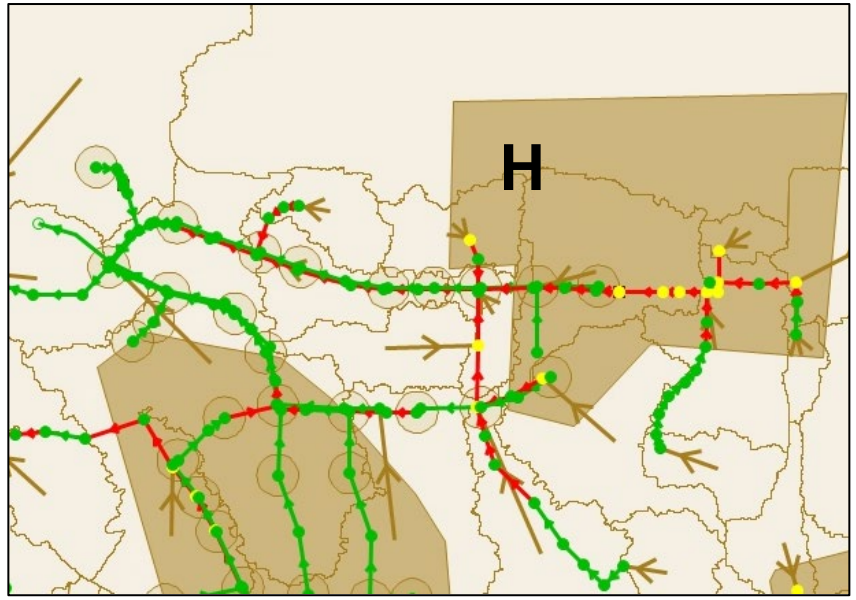
Concern Area	Alt	Proposed Project(s)
H	**6a**	• 4,600 feet of main storm sewer upsizing • Restrictor modification – remove flow restrictor • 0.61 Ac-ft of storage at White Memorial City Park-fishing Pond
	6b	• 6a plus additional 1.12 ac-ft of storage at White Memorial City Park-fishing Pond (total 1.73 ac-ft)



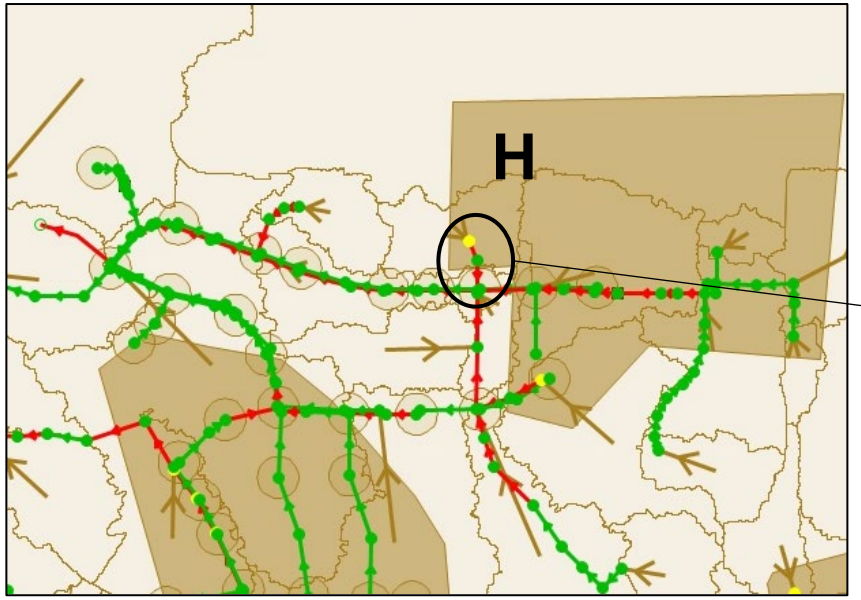
Area H: Alt 6a

LOS Results for Current 10-year, 1-hour Storm

Without Alt



With Alt 6a



MS4 Level of Service

Nodes

- No MH Flooding
- MH Flooding

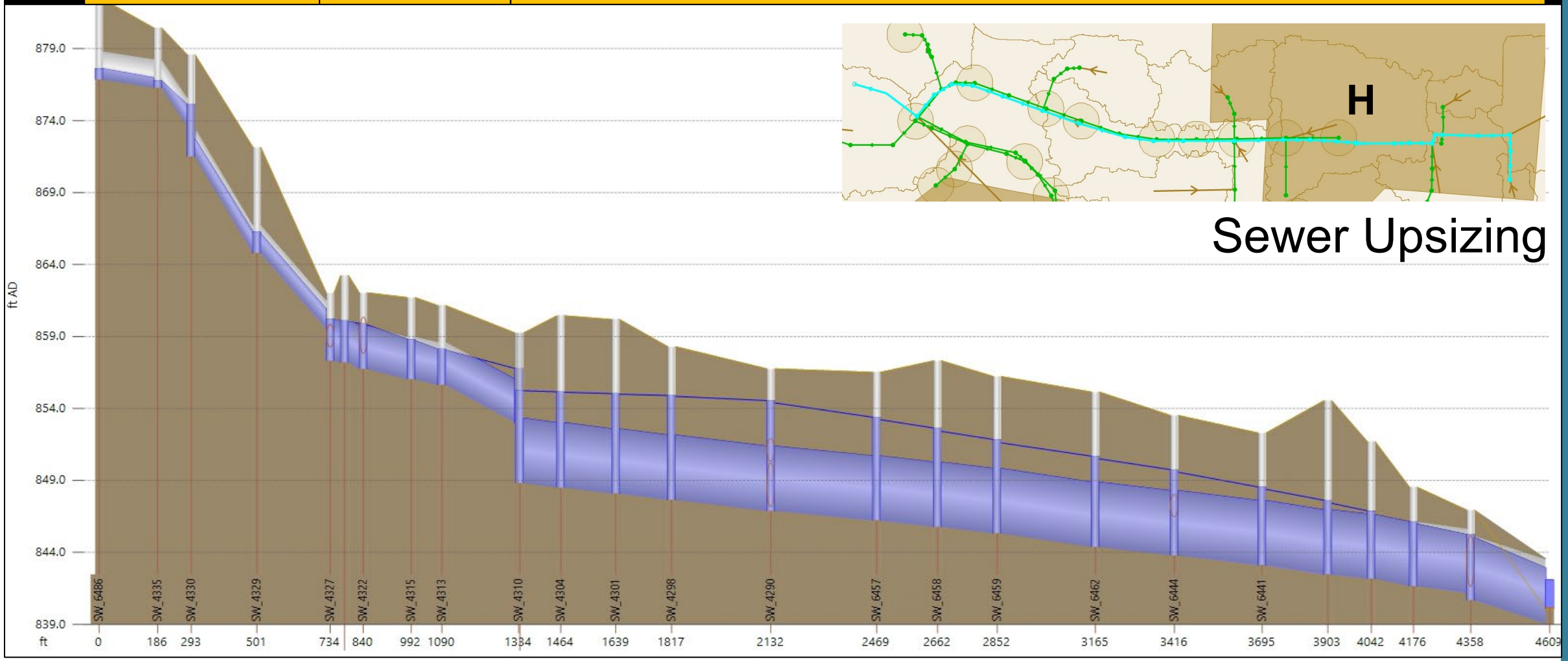


Key Takeaways:

- Alt 6a achieves Current 10-year LOS is Area H
  - Remaining nodes with flooding is due to lack of available sewer capacity along Dennison Rd
  - Street may benefit from green infrastructure to capture peak flows.
- Flooded volume from 2 locations above: ~ 10,000 gallons.

Area H: Alt 6a Main Trunk Sewer Pipe Upsize

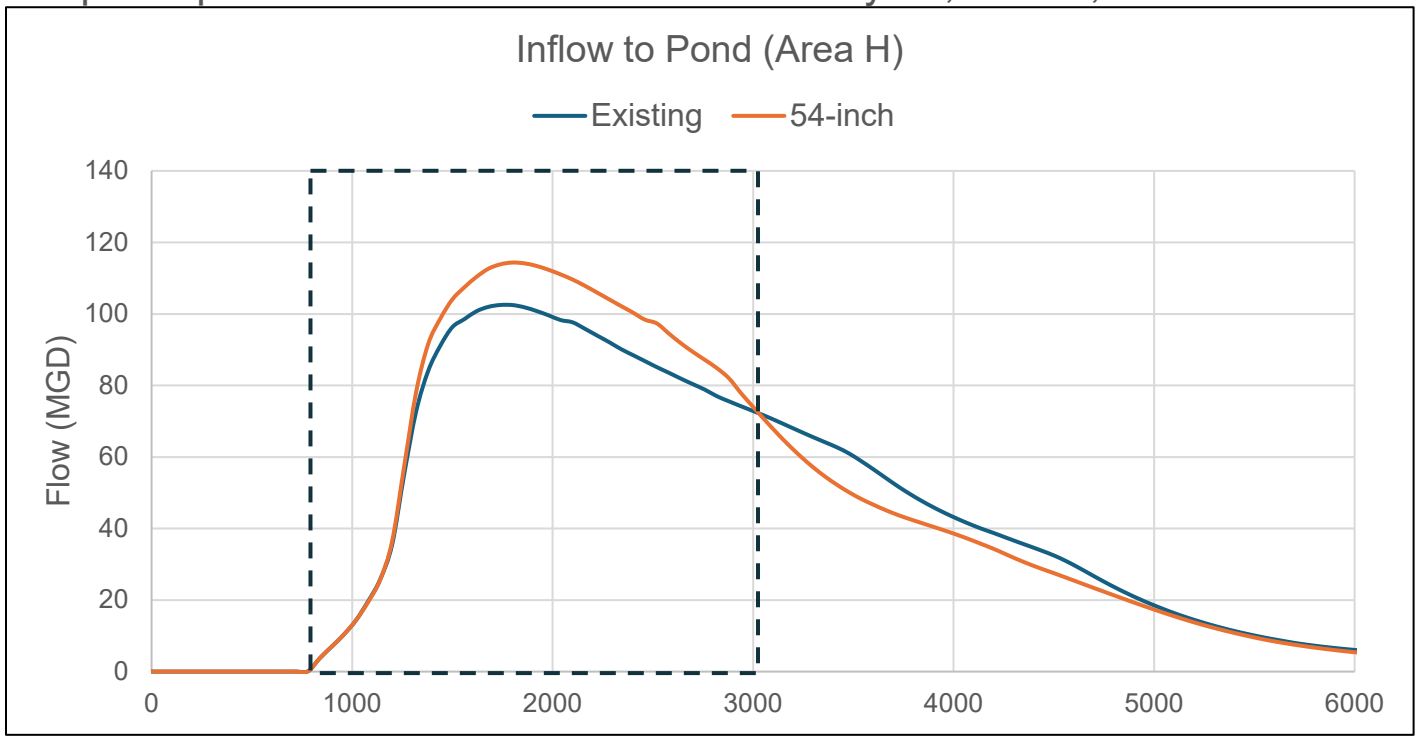
Required upsizes for the current 10-year, 1-hour, 2.00 inches



Area H: Alt 5a Downstream Increased Flow

To White Memorial City Park-fishing Pond

Required peak attenuation for the current 10-year, 1-hour, 2.00 inches



Peak Flow

Scenario	Peak Flow (MGD)	Difference from Existing (MGD)
Existing	102.52	-
Run 1	114.37	11.86

Peak Volume

Scenario	Volume (ac-ft)	Difference from Existing (ac-ft)
Existing	6.07	-
Run 1	6.68	**0.61**

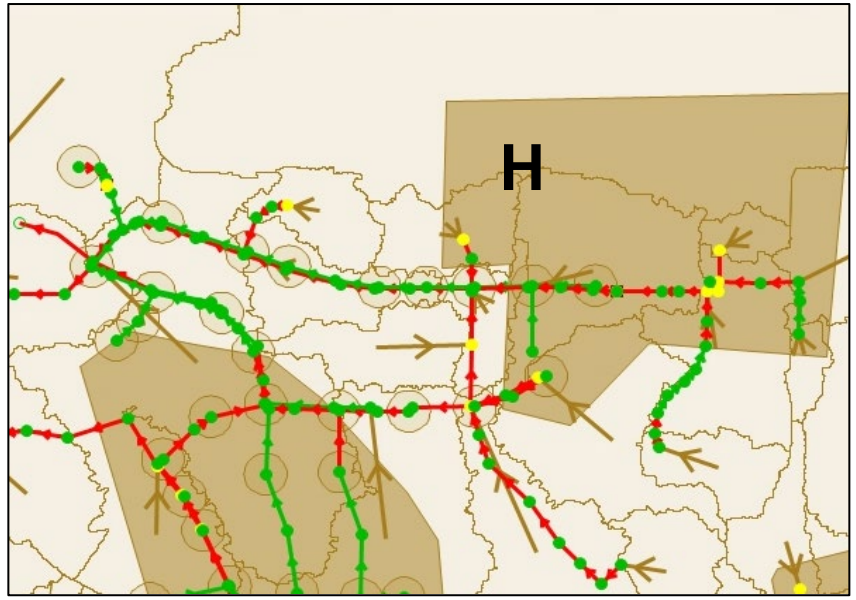
From 780 to 3060 simulation seconds

- Area H existing capacity: 102 MGD (158 cfs)
- Area H required capacity for current 10-year, 1-hour: 127 MGD (177 cfs)
- Approximate storage needed to offset peaks for current 10-year, 1-hour: 0.20 MG (0.61 ac-ft)

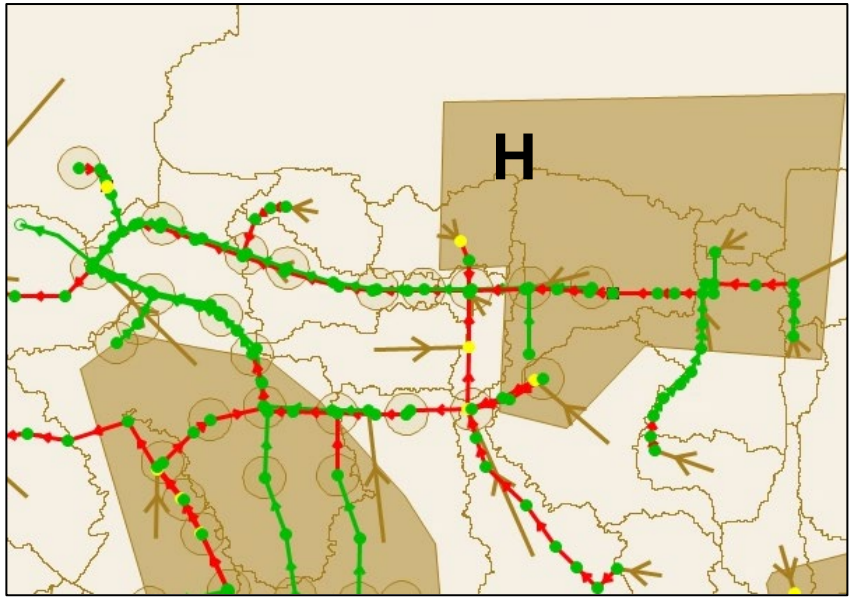
Area H: Alts 6a & 6b

LOS Results for Future 16-year, 1-hour Storm

With Alt 6a



With Alt 6b



MS4 Level of Service

Nodes

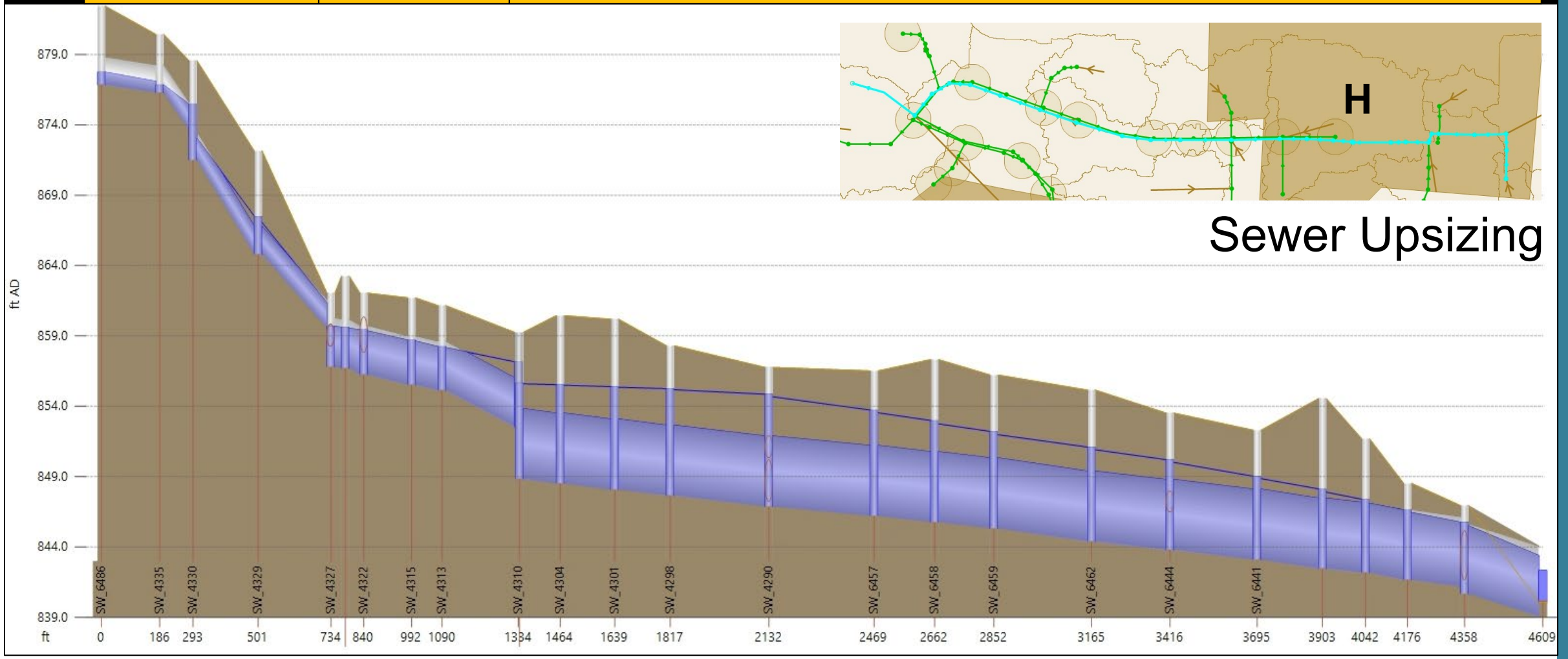
- No MH Flooding
- MH Flooding

Key Takeaways:

- Alt 6a does not achieve Future 16-year LOS in Area H.
- Alt 6b does achieve Future 16-year LOS in Area H
  - Nodes with flooding due to lack of available sewer capacity along Dennison Rd.
  - Street may benefit from green infrastructure to capture peak flows.
- Flooded volume from 4 locations above: ~ 27,500 gallons.
- Flooded volume from 2 locations within Area H only: ~10,500 gallons.

Area H: Alt 6b Main Trunk Sewer Pipe Upsize

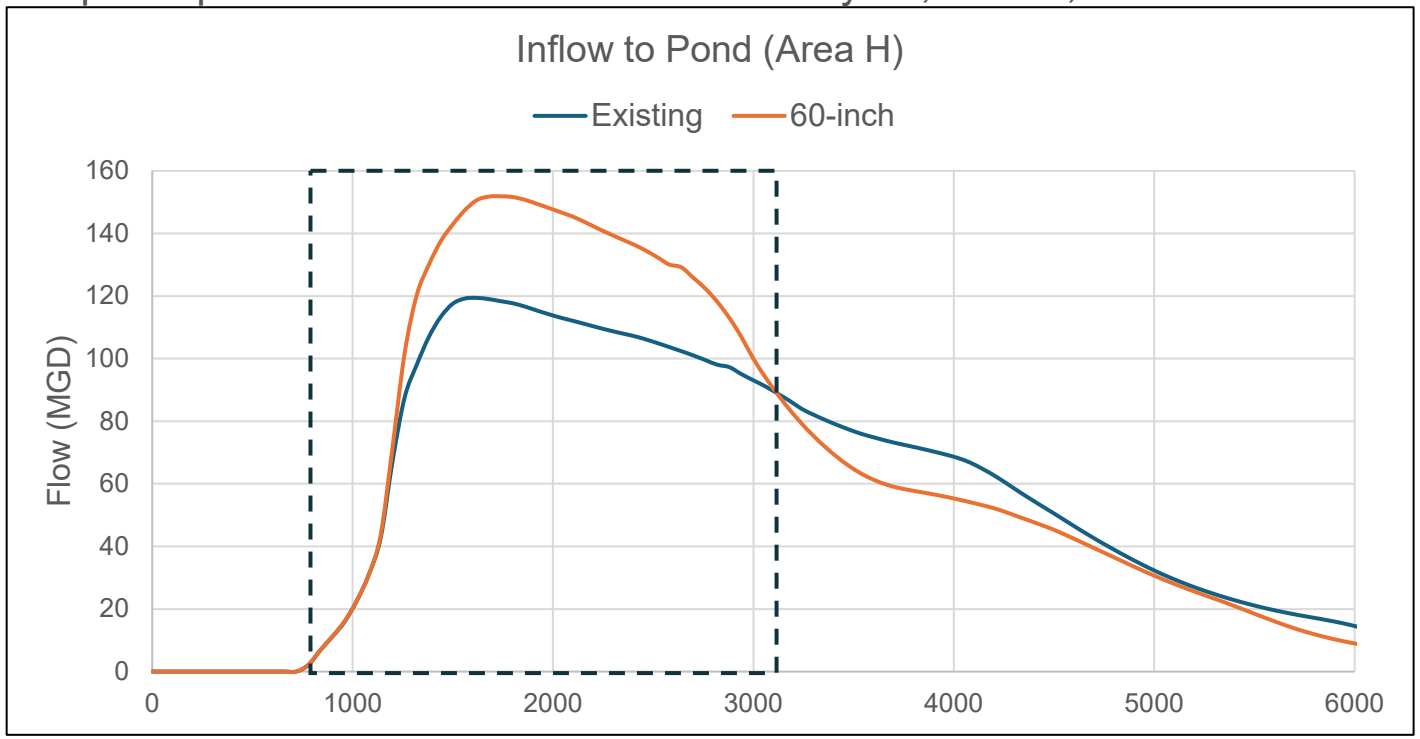
Required upsizes for the 2100 16-year, 1-hour, 2.54 inches



Area H: Alt 6b Downstream Increased Flows

To White Memorial City Park-fishing Pond

Required peak attenuation for the future 10-year, 1-hour, 2.54 inches



Peak Flow

Scenario	Peak Flow (MGD)	Difference from Existing (MGD)
Existing	119.41	-
Run 1	151.89	32.47

Peak Volume

Scenario	Volume (ac-ft)	Difference from Existing (ac-ft)
Existing	7.71	-
Run 1	9.44	**1.73**

From 780 to 3120 simulation seconds

- Area H existing capacity: 120 MGD (186 cfs)
- Area H required capacity for future 10-year, 1-hour: 152 MGD (235 cfs)
- Approximate storage needed to offset peaks for future 10-year, 1-hour: 0.56 MG (1.73 ac-ft)



05

Alternatives Results Summary, Key Takeaways and Next Steps

Alternatives and Proposed Projects Results Summary

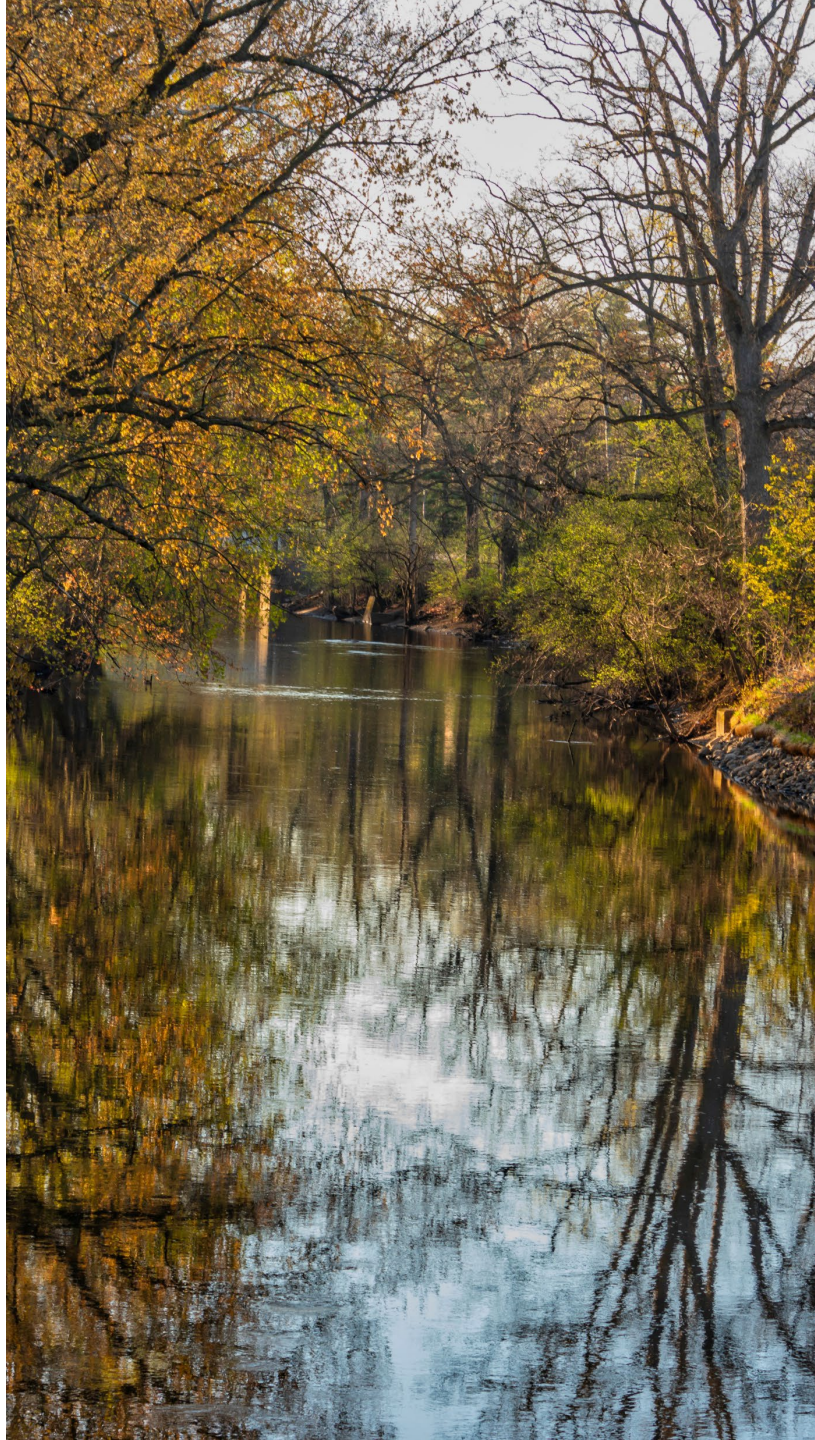
Concern Area	Alt	Proposed Project(s)	LOS Achieved
A & B	**1a**	• 107.3 ac of storm separation • Restrictor modification – remove flow restrictor • 2,100 ft of sewer upsizing • 700 ft of new combined sewer • 2 sewer bulkheads	Current 10-year, 1-hour
	1b	• 1a plus additional 68.7 ac of stormwater separation (total 176.0 ac)	Future 16-year, 1-hour
	1c	• 1a or 1b plus Gordon Guyer Park storage	Current 17-year, 1-hour (with 1a) Future 21-year, 1-hour (with 1b)
D	**2a**	• 77.6 ac of storm separation • Restrictor modification – lower weir at Beal St to invert of overflow sewer • New regulator at Louis St • 2,000 ft of sewer upsizing • 600 ft of new combined sewer	Current 10-year, 1-hour (except near interceptor)
	2b	• 3a plus additional 14.6 ac of storm separation (total 92.2 ac)	Between the Current 10-year, 1-hour and Future 16-year, 1-hour
	2c	• 3a or 3b plus Valley Court Park Storage	Current 500-year, 1-hour (with 2a) Future 100-year, 1-hour (with 2b)
B, C & D	**3**	• 2a plus 122.5 ac of storm separation at Harrison St (total 200.1 ac)	Less than Current 10-year, 1-hour

Alternatives and Proposed Projects Results Summary (cont.)

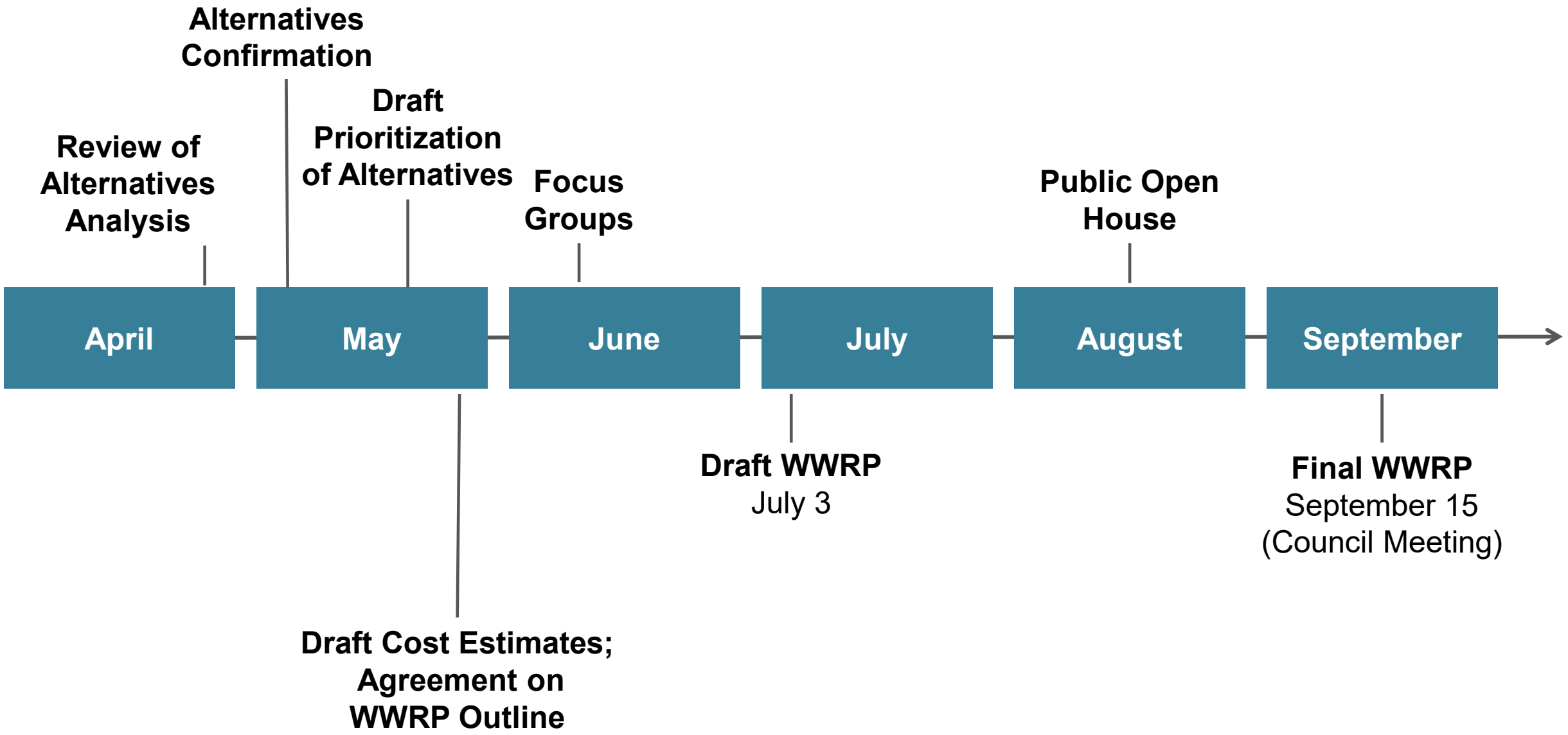
Concern Area	Alt	Proposed Project(s)	LOS Achieved
C, E & G	**4a**	• 71.5 ac of storm separation • 7,000 ft of pipe upsizing • 900 ft of new combined sewer • 2 sewer bulkheads	Current 10-year, 1-hour
	4b	• 4a plus additional 128.4 ac of storm separation (total 199.9 ac)	Between the Current 10-year, 1-hour and Future 16-year, 1-hour
	4c	• 4a or 4b plus Glencairn Park, Shaw Park, Hannah Community Center storage	Current 100-year, 1-hour (with 4a); Future 50-year, 1-hour (with 4b)
F	**5a**	• 7,200 ft of main storm sewer upsizing • 3.53 ac-ft of storage at Fire Department	Current 10-year, 1-hour
	5b	• 5a plus additional 1.59 ac-ft of storage at Fire Department or upstream detention (total 5.12 ac-ft)	Future 16-year, 1-hour
	5c	• 5a or 5b plus storage under parking lots	Current 20-year, 1-hour (with 5a); Future 25-year, 1-hour (with 5b)
H	**6a**	• 4,600 ft of main storm sewer upsizing • Restrictor modification – remove flow restrictor • 0.61 ac-ft of storage at White Memorial City Park-fishing Pond (total 5.12 ac-ft)	Current 10-year, 1-hour
	6b	• 6a plus additional 1.12 ac-ft of storage at White Memorial City Park-fishing Pond (total 1.73 ac-ft)	Future 16-year, 1-hour

Key Takeaways

- Alternatives achieve Current 10-year, 1-hour LOS (except Alt 3)
- Future 16-year, 1-hour LOS cannot be achieved everywhere with alternatives evaluated
- Remaining concerns for Areas C and D for enhanced LOS
  - Area C is regulator weir impacts
  - Area D is tunnel backwater impacts
- Feasibility needs to be addressed for large size pipes and depths of cover for both LOS scenarios
- Large acreages of separation are needed to achieve LOS targets
  - Will come with large price tags
  - Separation will need to be minimum 80% effective
- Planned Charles St project is assumed in all alternatives.
  - There is no nearby stormwater separation outfall available
  - Upsizing opportunity is limited
- The benefits of storage are potentially significant for both pipe sizing and achieving enhanced LOS
  - Particularly for MS4 Area F that is highly impervious
- Separation will need to be concurrent with upsizing to offset CSO impacts



Next Steps


Review of Alternatives Analysis
Alternatives Confirmation
Draft Prioritization of Alternatives
Focus Groups
Public Open House
April
May
June
July
August
September
Draft Cost Estimates; Agreement on WWRP Outline
Draft WWRP
July 3
Final WWRP
September 15
(Council Meeting)



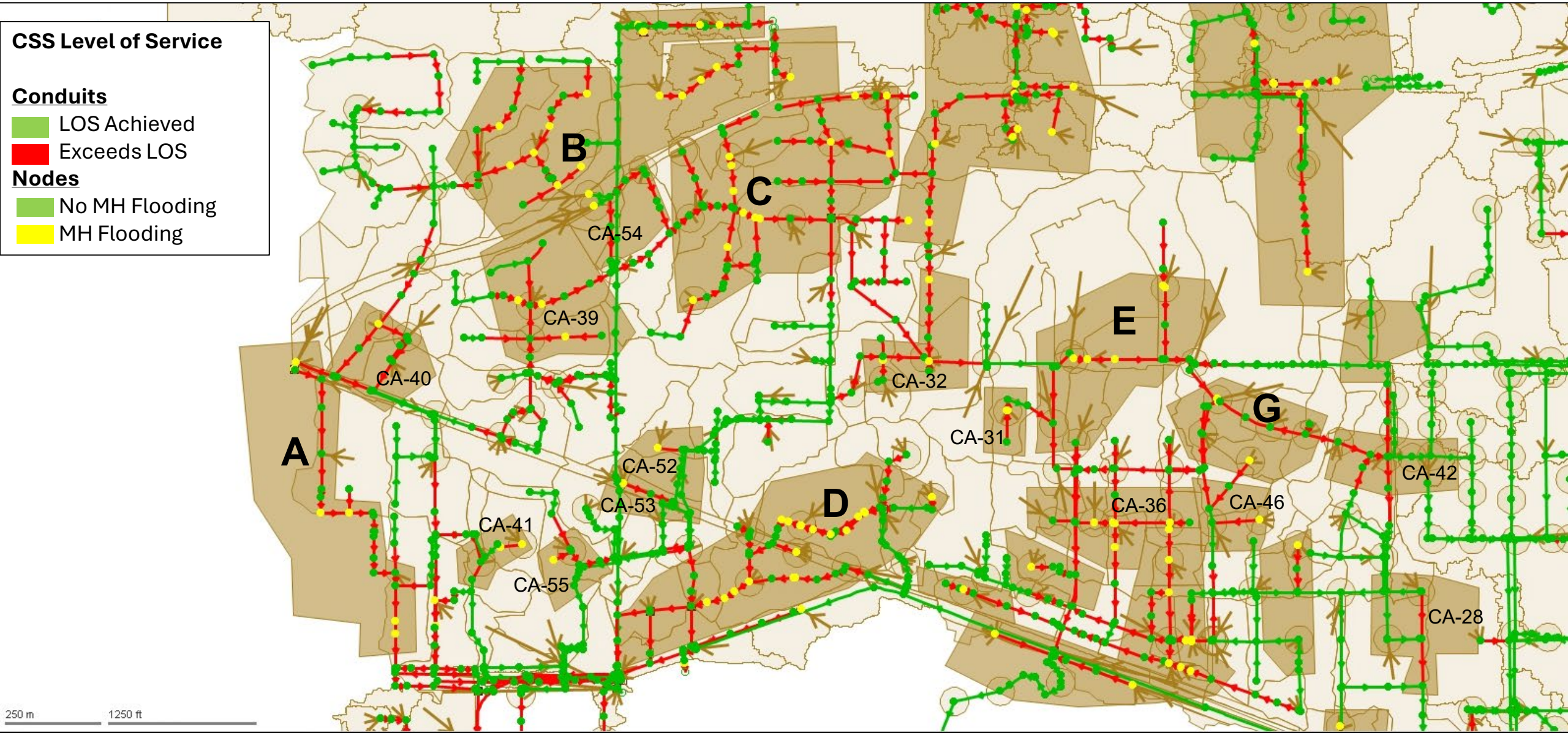
City of East Lansing Wet Weather Resiliency Plan

Task 8: Alternatives Modeling Workshop #2

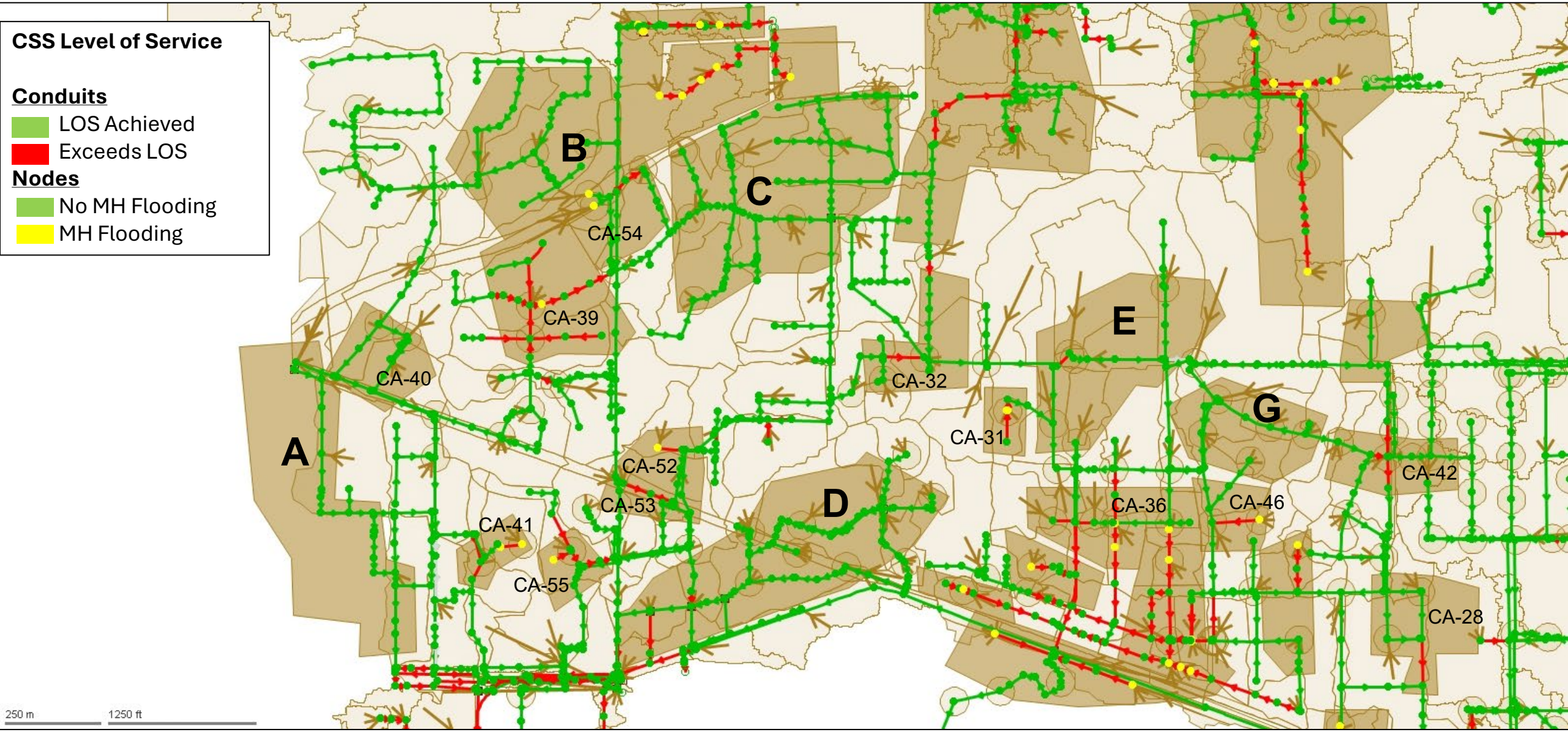
04.30.2026



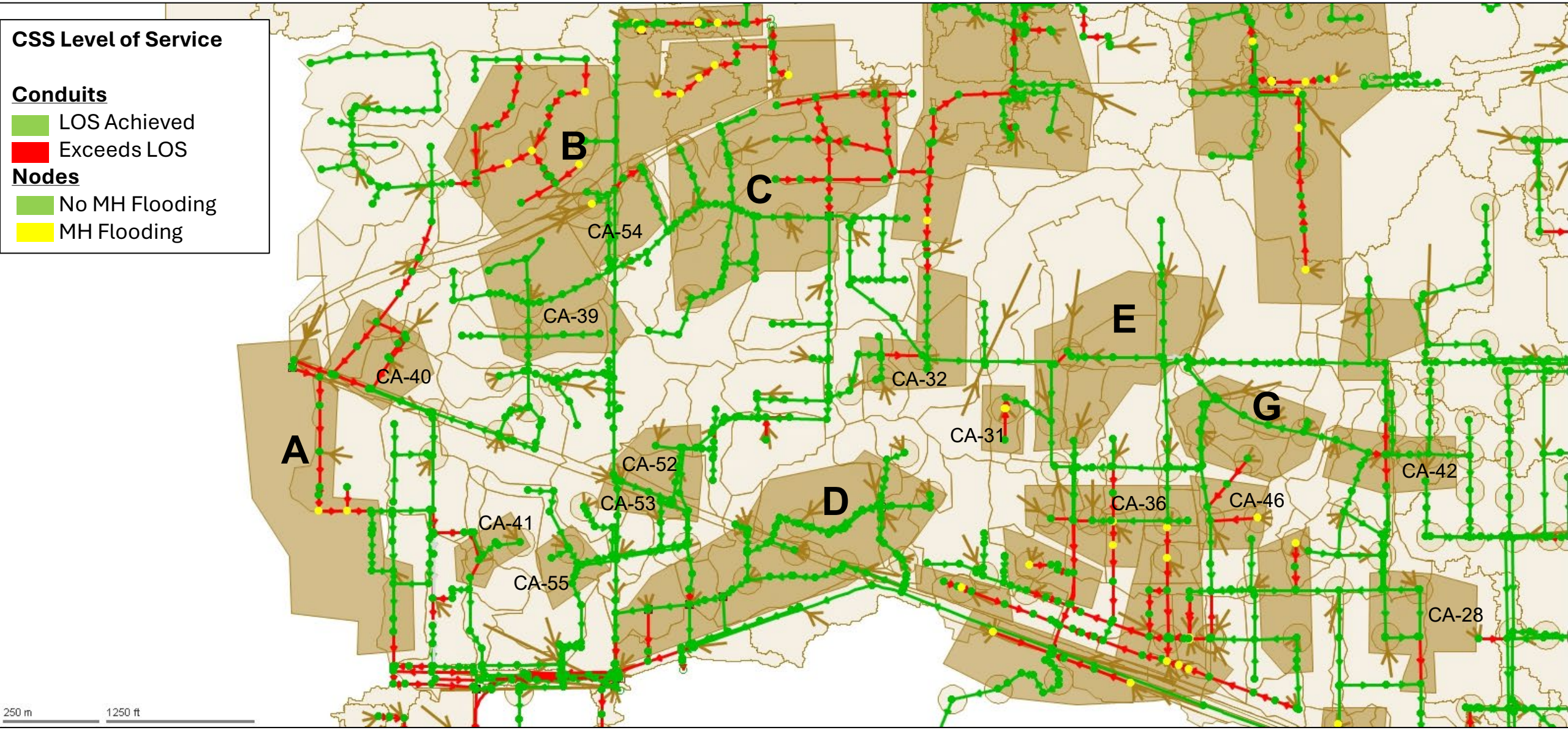
Model Results: Base + Gunson – Current 10-year



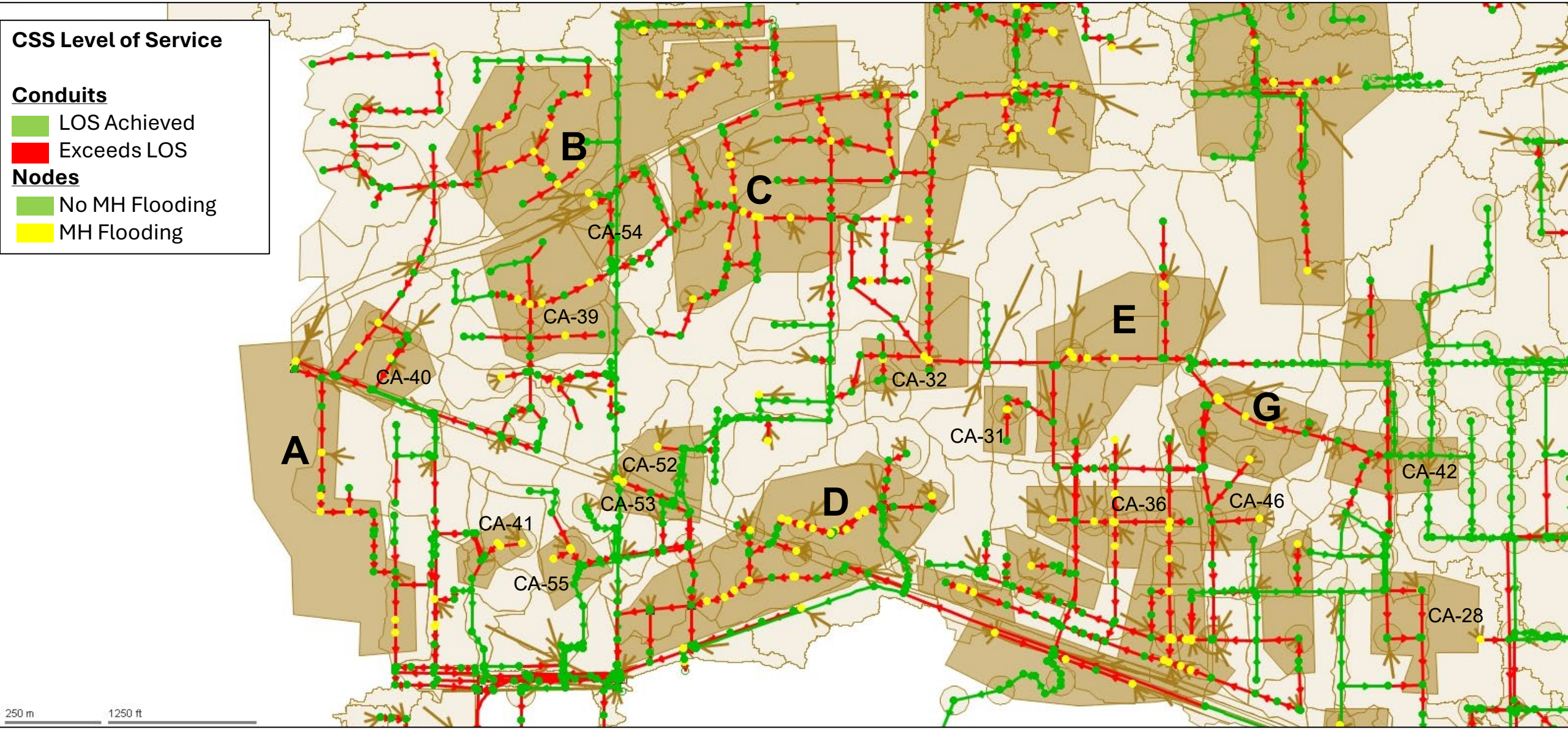
Model Results: Alternative 1a, 2a, 4a, 5a, 6a – Current 10-year



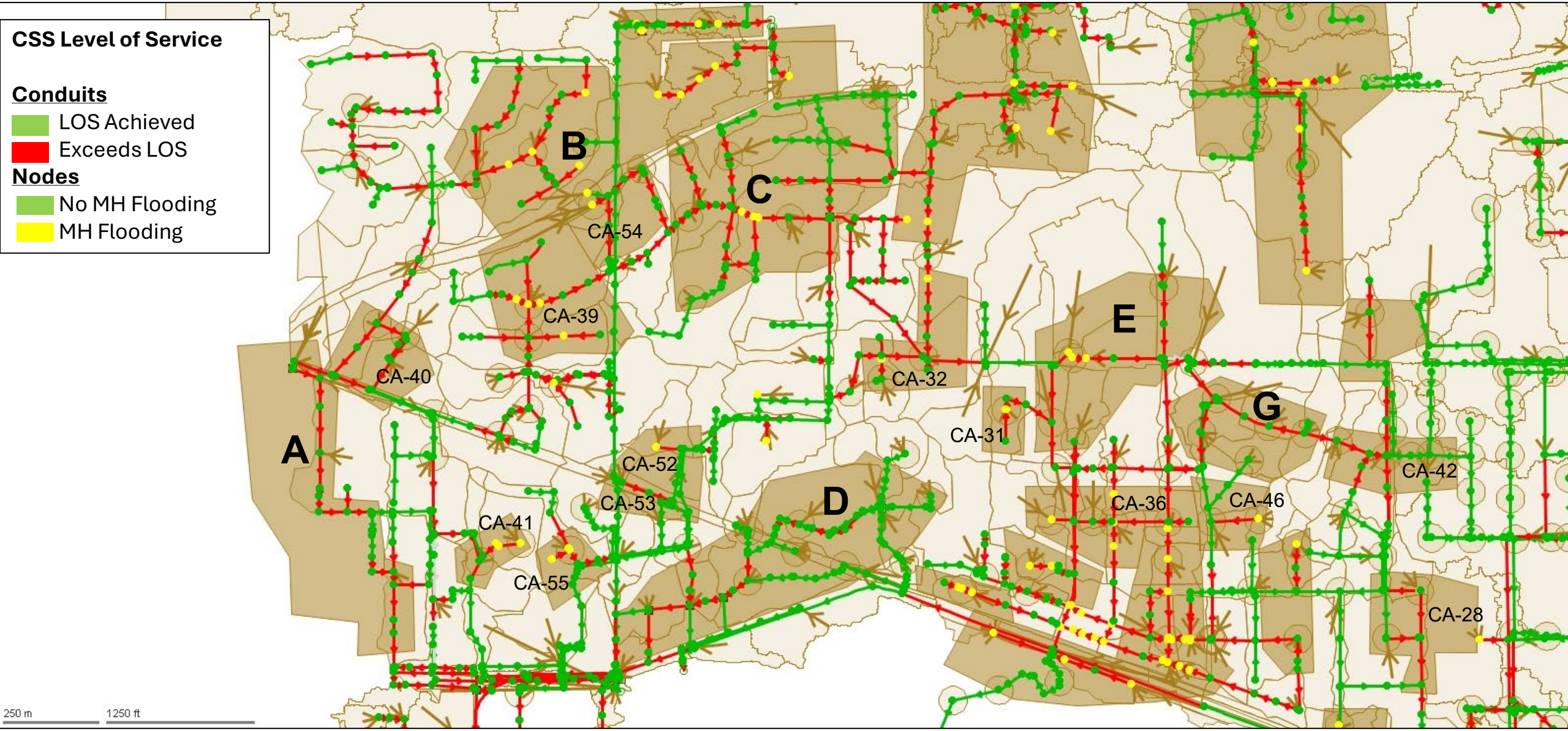
Model Results: Alternative 2a, 3 (Harrison), 4a, 5a, 6a – Current 10-year



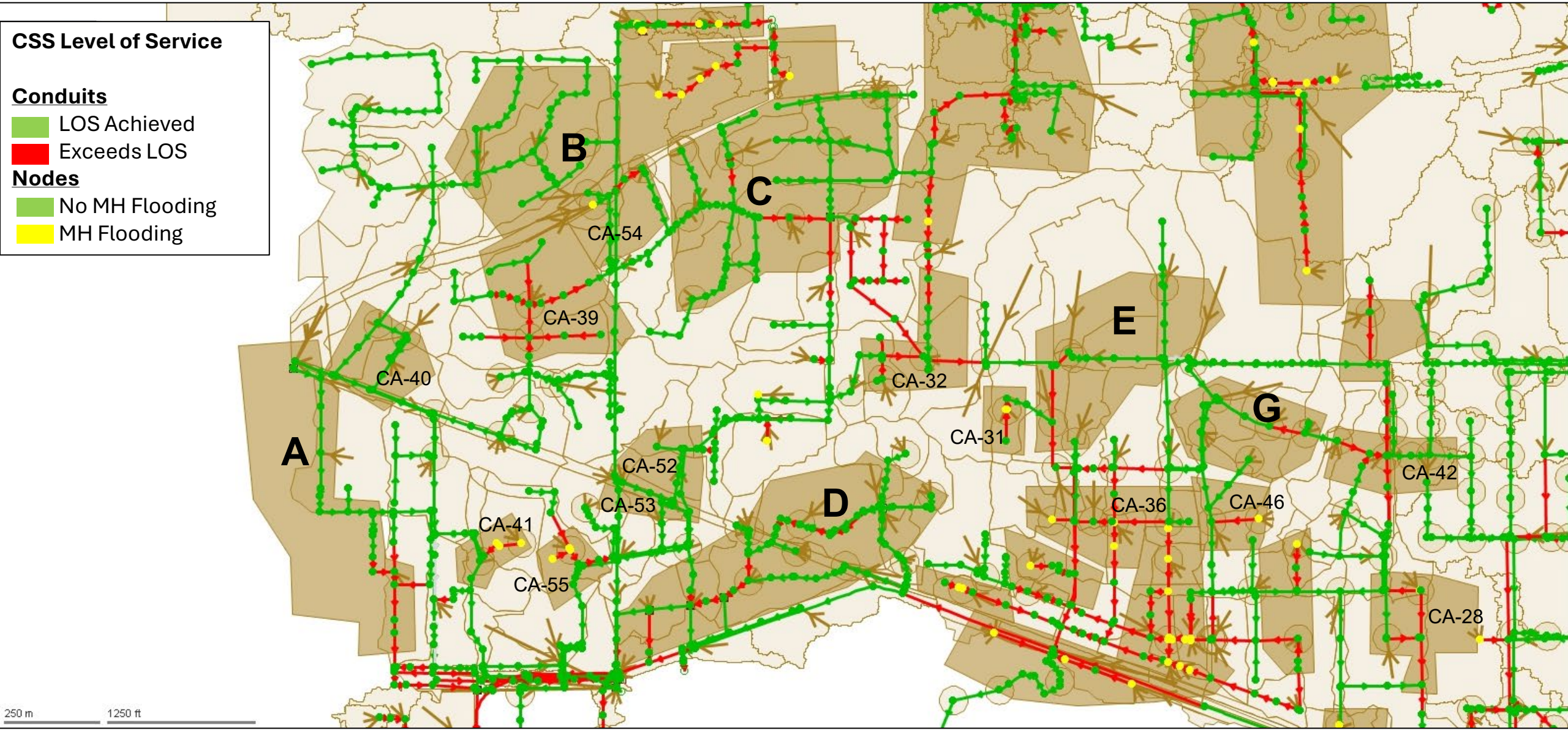
Model Results: Base + Gunson – Future 16-year



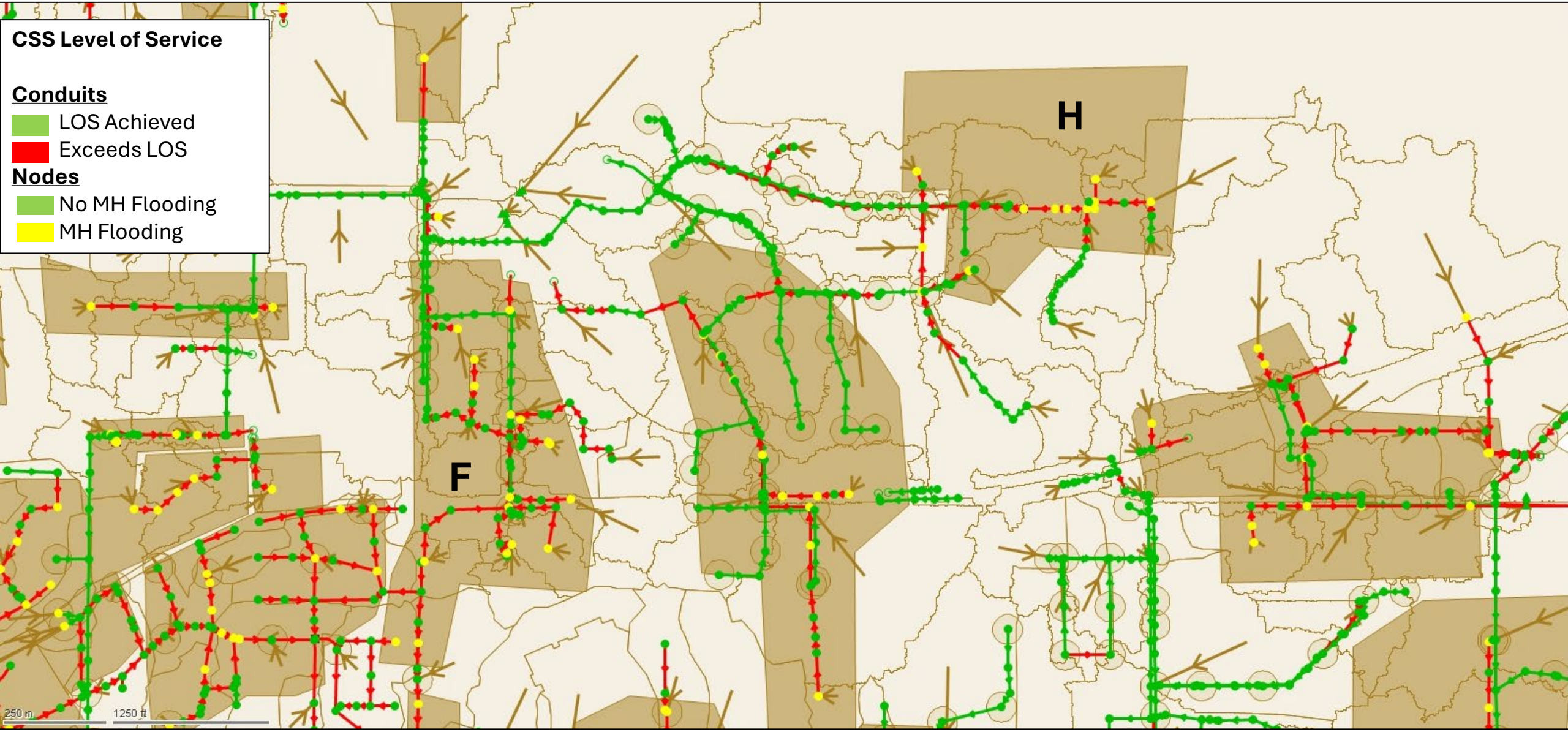
Model Results: Alternative 1a, 2a, 4a, 5a, 6a – Future 16-year



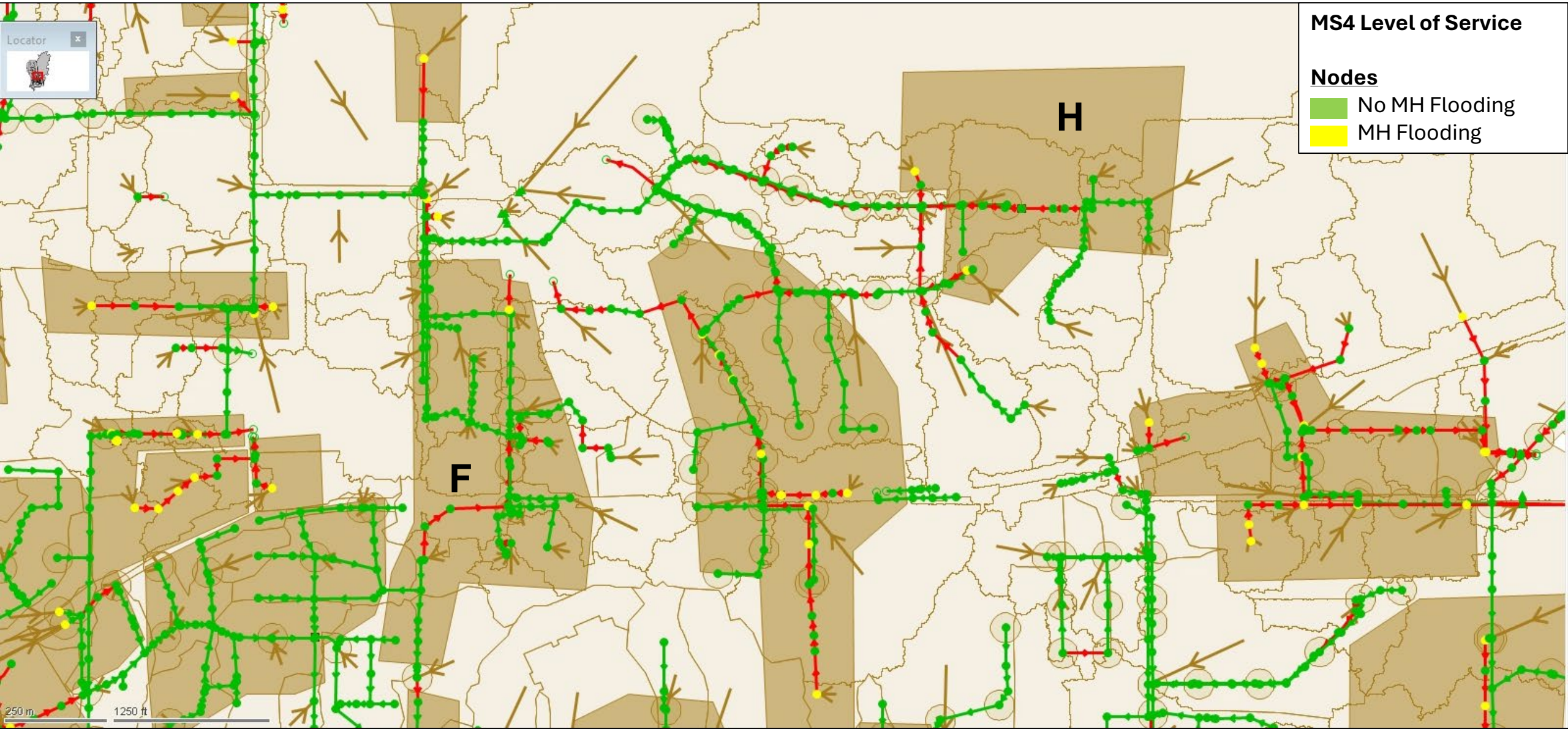
Model Results: Alternative 1b, 2b, 4b, 5b, 6b – Future 16-year



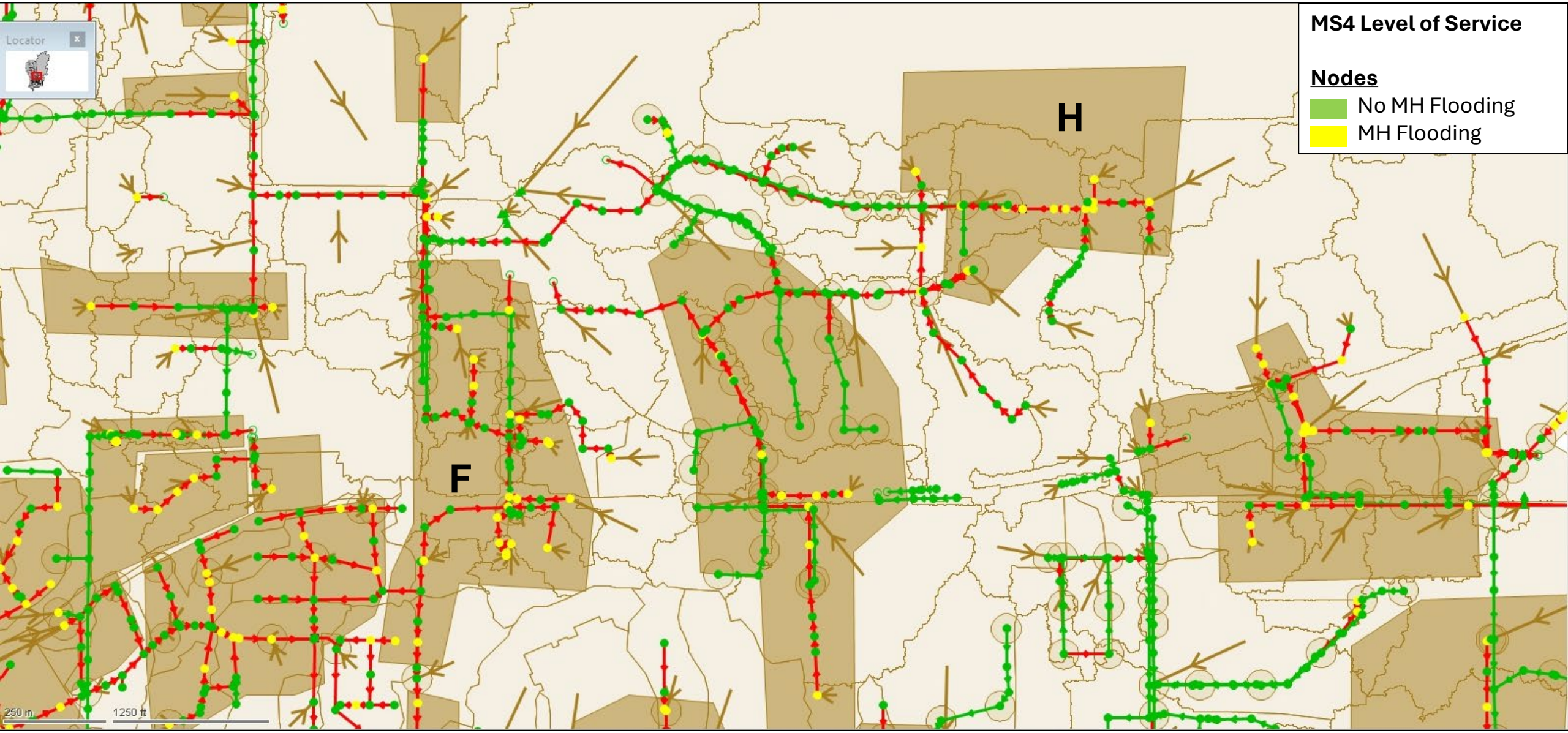
Model Results: Base – Current 10-year



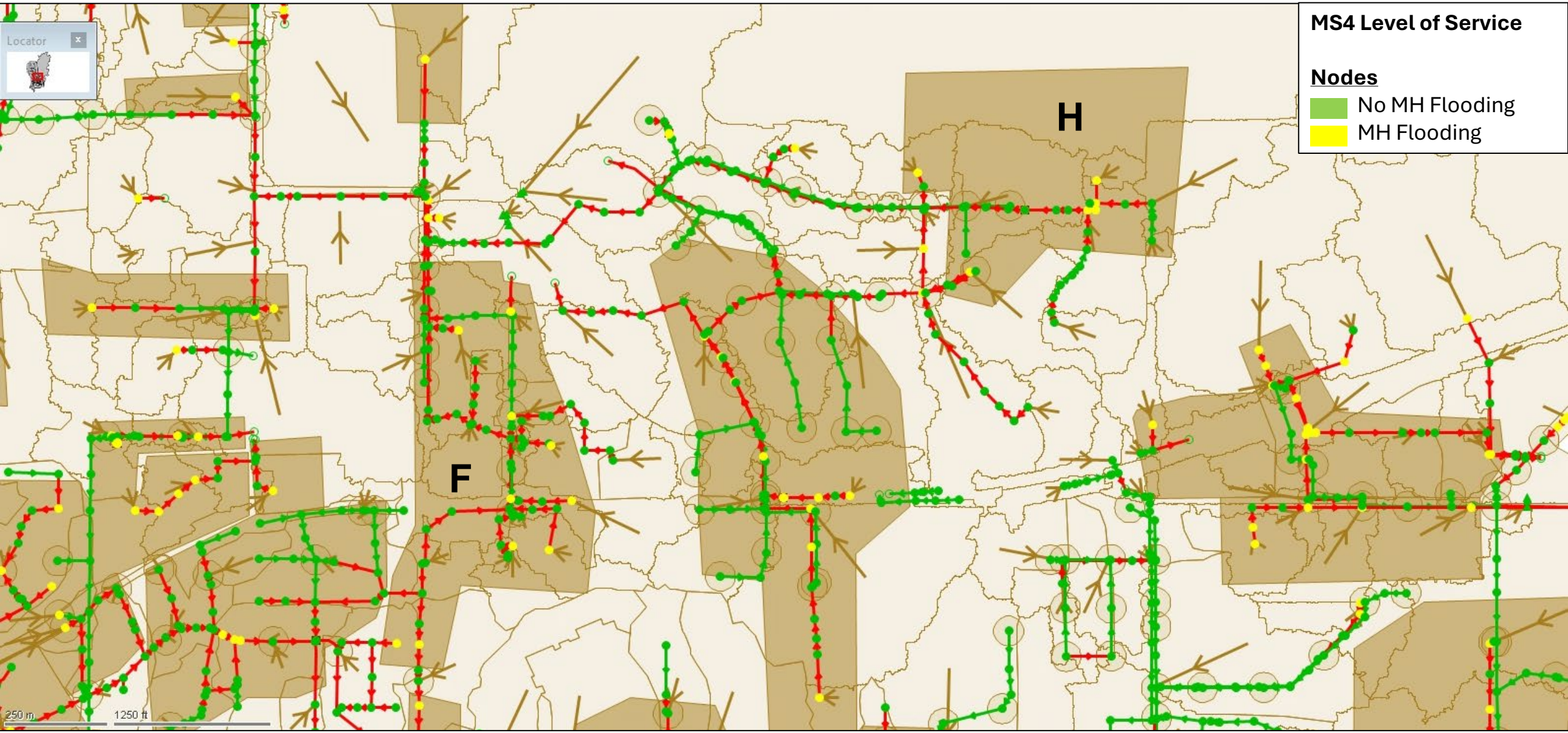
Model Results: Alternative 1a, 2a, 4a, 5a, 6a – Current 10-year



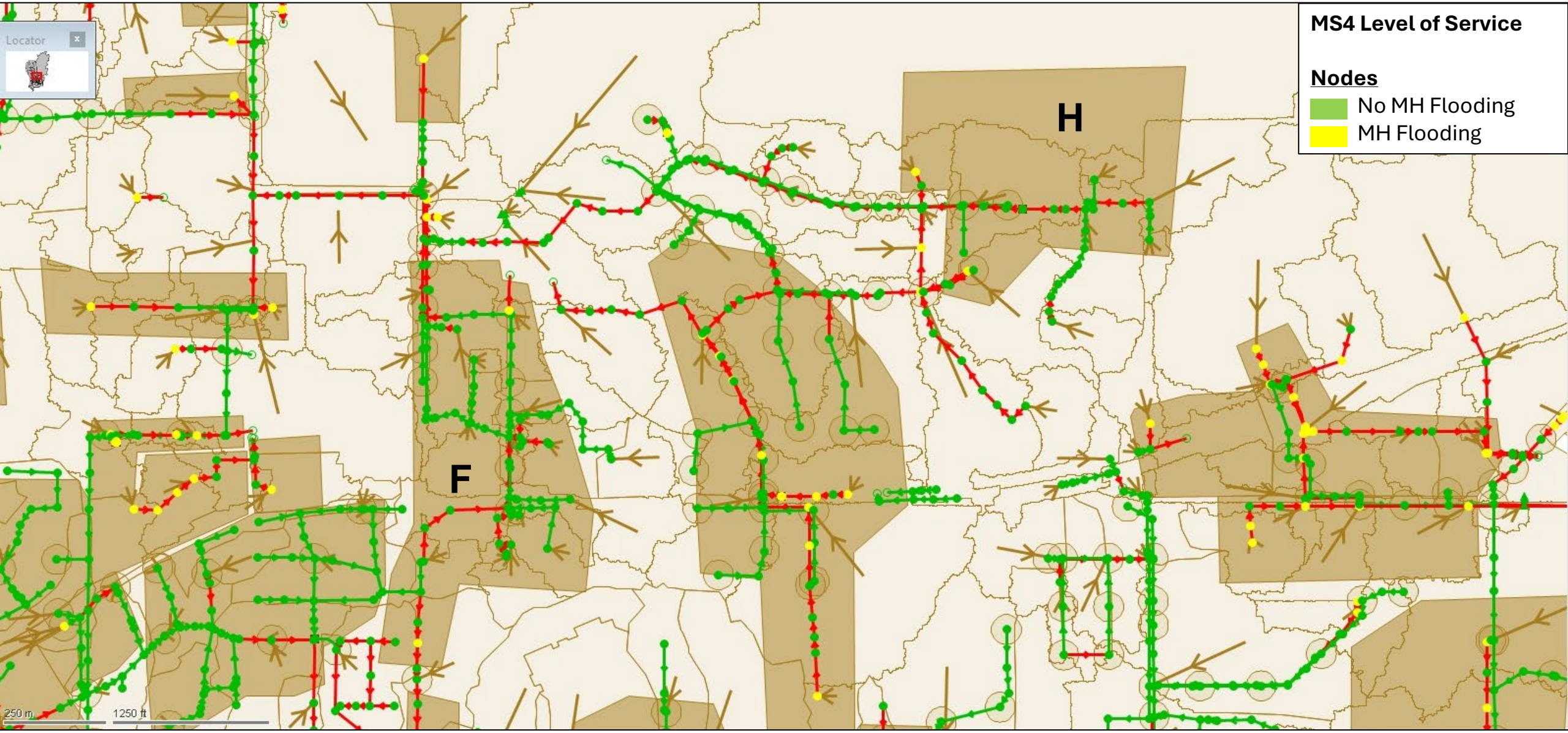
Model Results: Base – Future 16-year



Model Results: Alternative 1a, 2a, 4a, 5a, 6a – Future 16-year



Model Results: Alternative 1b, 2b, 4b, 5b, 6b – Future 16-year



Appendix A.5 – Alternatives

Modeling Results Workshop #2 Follow Up (May 29th 2026)

Meeting Minutes

Project:	East Lansing High Water Infrastructure Plan
Subject:	Progress Meeting
Date:	Tuesday, June 09, 2026
Location:	Teams & East Lansing DPW

Attendees:		
	Tom Batroney (HDR)	Cliff Walls (City)
	Julie Stein (HDR)	Ron Lacasse (City)
	Ernie West (HDR)	Stephen Clayton (City)
	Anne Cron (HDR)	Bob Scheuerman (City)
	Kaylee Johnson	Dani Stahlin (City)

1) City Feedback on Revised Alternatives Slides
   a) East Lansing High Water T8 Alternatives Workshop #2_20260601 Final.pdf
   b) Alt 1
      i) Ranney Park
         (1) No follow up yet from ICDC on their review of hydrographs.
         (2) Decision by City to minimize flow to Ranney Park, based upon likely assessment that will be charged to the City
      ii) Assume Chartwell and Shaw Estates flow to east, not to Ranney Park
      iii) ***City decision to proceed with Alt 3 with lower flow to Ranney Park***
      iv) Bob provided summary of pipe drop configuration into tunnel in the Highland-Cowley area. Questioning whether the new and upsized CSO pipe in this area is needed with the tunnel inlet configuration and storm flow offloaded to Ranney Park. If it's needed, should be a future phase. **HDR to review.**
   c) Alt 2
      i) ***City decision to proceed with Alt 2b. Size pipes to handle flow. Include recommendation for below grade storage at Valley Court Park, but do not reduce pipe size. Possibility of future development of property may impact storage volume in the future.***
   d) Alt 3
      i) Charles St regulator mods are a big impact, but sewer upsizing required to lower HGL under larger events.
      ii) Consider looking at separating CA-39 as a future phase to help Sunset/Northlawn area.
      iii) **Decision by City to choose Alt 3 over Alt 4. Set Alt 4 aside and dial in Alt 3.**
      iv) Plan pipe size to maximize ability to separate sewers along Harrison
      v) **HDR to review impact of separation of areas west of Harrison on achieving LOS on Northlawn in Area C for Alt 3a. Will remove storm flow and see if the**

light blue area as part of Alt 3a is no longer needed since this area was recently impacted by construction. Can the LOS analysis in Area C be achieved by separating stormwater west of Harrison?

vi) Alt 3a separation area, east of Harrison, if needed, should be a future phase due to previous project along Northlawn

e) Alt 4
   i) ***City decision to drop Alt 4 based upon 2x longer length of storm trunkline***
f) Alt 5
   i) HDR confirmed culvert at Lake Lansing Road is accurate in model.
   ii) Concept remains valid to solve flooding at Saginaw/Abbott, must push water to the north and mitigate with downstream storage
   iii) **City ok with concept.**
   iv) Look at expansion of wetland area associated with Harrison Meadows Park property
   v) Push water west across Abbott and manage on west side of road
   vi) Possibility for wetland improvement funding? Watershed stormwater mitigation credits? Good opportunity to make a beneficial environmental impact along existing pathways.
   vii) Above ground storage.
g) Alt 6
   i) **City ok with concept**.
   ii) Above ground storage.

2) Prioritization
   a) Reviewed the prioritization analysis and scoring approach
   b) Review example scoring for Alternative 2
   c) **HDR will submit first draft after scoring is completed, likely next week**

3) Cost Estimating
   a) Reviewed the approach & assumptions for cost estimating
   b) CSO extension/upsizing, main trunkline sewers, per acre of separation approach
   c) City provided bid tab/project. City to provide previous breakout of separation only costs. Using to check HDR cost/acre.
   d) State year of pricing on the cost estimates.

4) Focus Group 2 Update
   a) Scheduled for June 25th
   b) **Invitations going out tomorrow. HDR providing email. Include slides from first focus group meeting.**
   c) Draft Agenda
      i) Project Overview, Status and Recap
      ii) Approach to Developing Alternatives
      iii) Significant Findings from Analysis
      iv) Proposed Alternatives & Potential Projects
      v) Selected Projects & Prioritization

vi) Other Flood Risk Mitigation Strategies & Considerations
vii) Next Steps

d) Slide deck content in development. **HDR to provide to City for review on 6/19 +/-.**
e) Thoughts on public messaging
   i) Use profiles to show changing elevations
   ii) Describe limitations of the study, i.e., risk reduction, not a fix everywhere or for all future conditions and climate events
   iii) Lead with separation and the benefits it provides, i.e., back ups are not raw sewage in basements
   iv) Modeling is of an fully functioning system and can't predict things that get plugged up
   v) City wet weather planning efforts are ahead of most communities, especially those the size of East Lansing
   vi) Costs will inform how big a problem this is
   vii) What does the 2100 16-yr storm mean, i.e., current 50-yr storm? How aggressive is this approach?
   viii) Confirm that NOAA Atlas 15 isn't likely to be higher than what we are using

f) On-going tasks
   i) Benefits analysis
   ii) Cost estimating
   iii) Prioritization
   iv) Focus group slides
   v) Wet Weather Resiliency Plan development

g) Next steps
   i) Submit draft cost estimates
   ii) Submit alternatives summary with benefits and cost
   iii) Submit draft prioritization
   iv) Submit draft focus group slides
   v) Submit draft WWRP



City of East Lansing Wet Weather Resiliency Plan

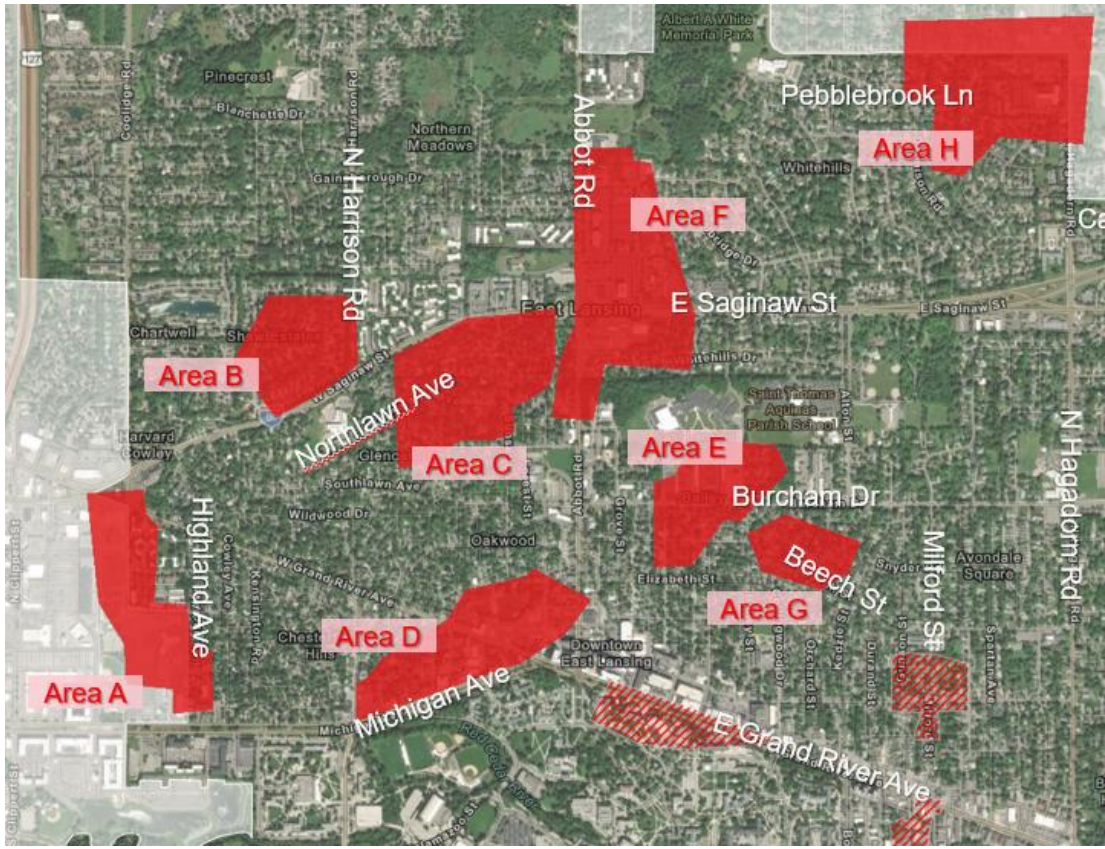
Task 8: Alternatives Modeling Workshop #2

04.30.2026 and 05.29.2026



Today's Agenda

1. Workshop Goals and Schedule Update
2. Recap of Task 8 Work To-Date
3. CSS Alternatives Analysis Results
4. MS4 Alternatives Analysis Results
5. Alternatives Results Summary, Key Takeaways and Next Steps



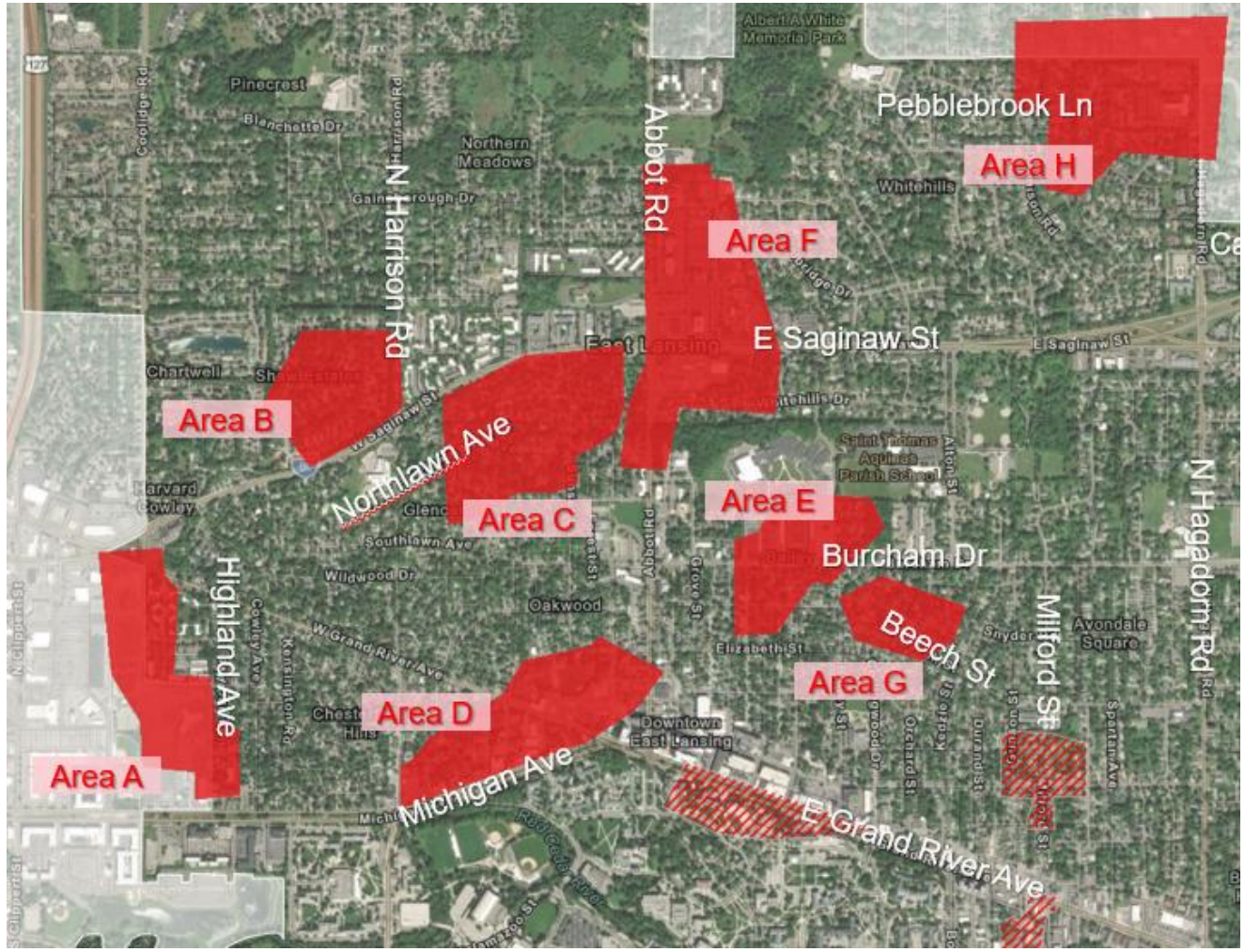


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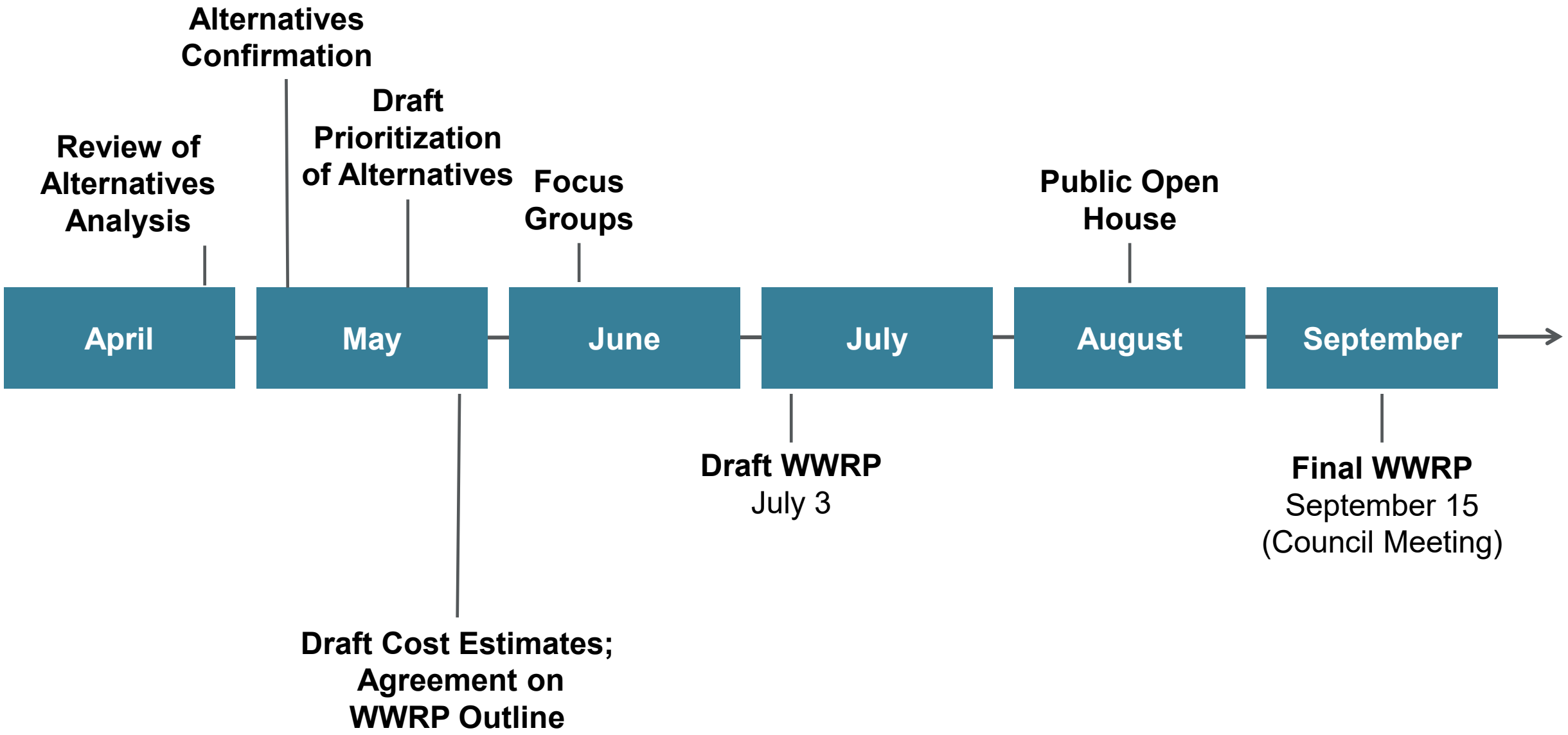
Workshop Goals and Schedule Update

Workshop Goals

1. Discuss alternatives analysis results
2. Gather City feedback related to feasibility and implementation of alternatives
3. Confirm direction for advancing project prioritization and costing



Next Steps


Review of Alternatives Analysis
Alternatives Confirmation
Draft Prioritization of Alternatives
Focus Groups
Public Open House
April
May
June
July
August
September
Draft Cost Estimates; Agreement on WWRP Outline
Draft WWRP
July 3
Final WWRP
September 15
(Council Meeting)



02

Recap of Task 8 Work To-Date

Key Outcomes: Initial Strategies Workshop (Dec 2025)

- Established existing level of service (LOS), root cause, and potential flood risk mitigation strategies in concern areas

Concern Area	System	Existing LOS	Root Cause	Identified Alternatives				
				Storm Separation	Pipe Upsizing	Sewer Diversion	Regulator/ Restrictor Modification	Opportunities for Green Infrastructure
A	CSS	2-year, 1-hour	Sewer Capacity	x	x		x	
B	CSS	5-year, 1-hour	Sewer Capacity	x		x		Gordon Guyer Park
C	CSS	2-year, 1-hour	Sewer Capacity	x	x			Glencairn Elementary, Shaw Park, and Hannah Community Center
D	CSS	<1-year, 1-hour	Sewer Capacity	x			x	Valley Court
E G	CSS	1-year, 1-hour	Sewer Capacity		x	x	x	
F	MS4	<1-year, 1-hour	Sewer Capacity		x			Underground Storage Parking Lot, *Fire Dept Open Lot**
H	MS4	<1-year, 1-hour	Sewer Capacity		x		x	*Albert A White Memorial Park**

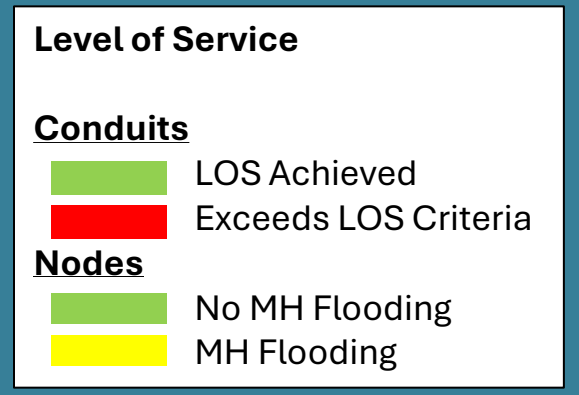
* Opportunities are downstream of concern area identified but can be used to mitigate peak flow increases resulting from pipe upsizes.

Key Outcomes: Initial Strategies Workshop (Dec 2025)

- Selected LOS evaluation storms for modeling:
  - Current 10-year, 1-hour of 2.00 inches (Current)
  - 2100 Future 16-year, 1-hour of 2.54 inches (Enhanced)

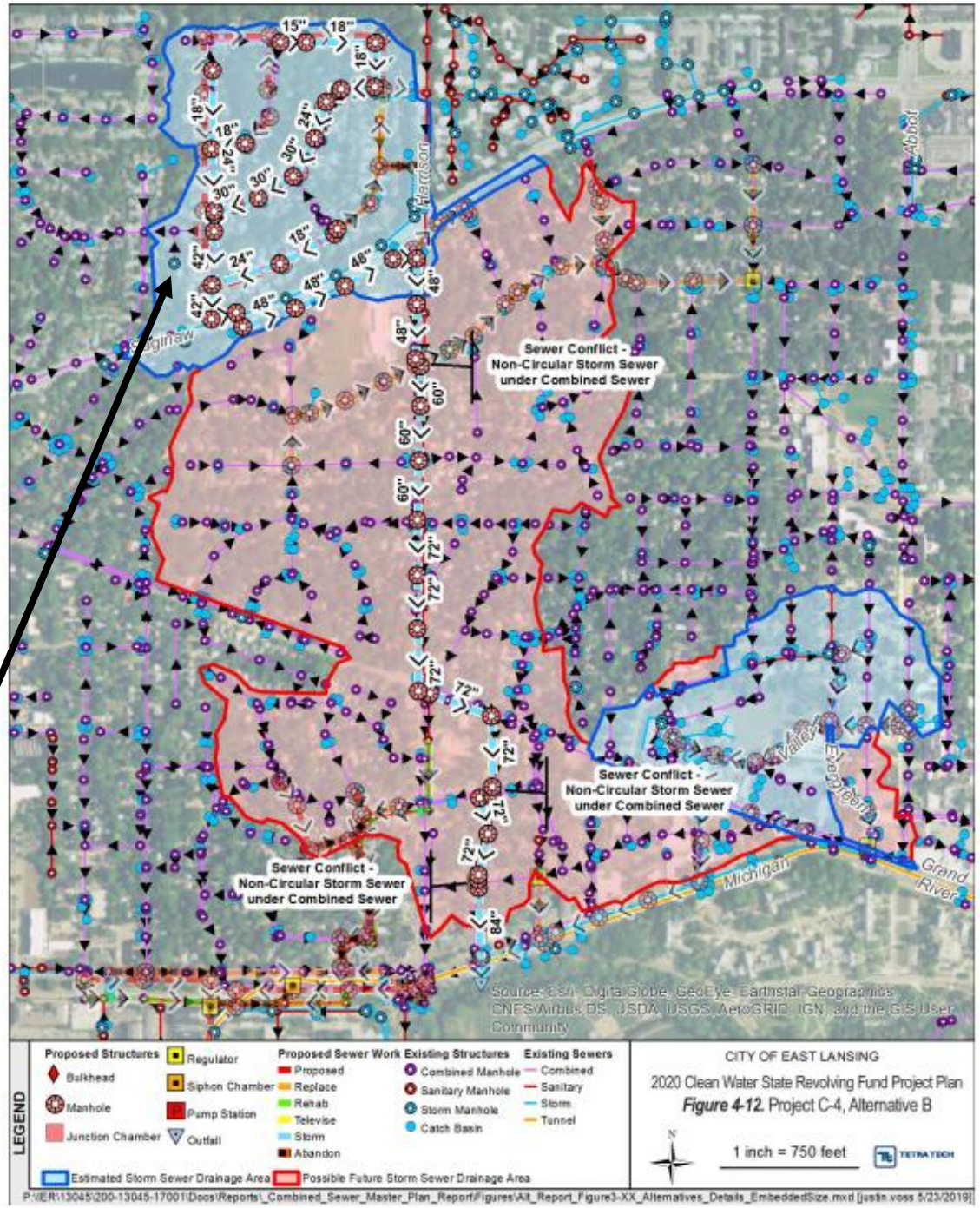
LOS goal in CSS = HGL is 8.5 ft below ground at either or both ends of pipe; Or surcharge less than 1.0 ft above pipe crown

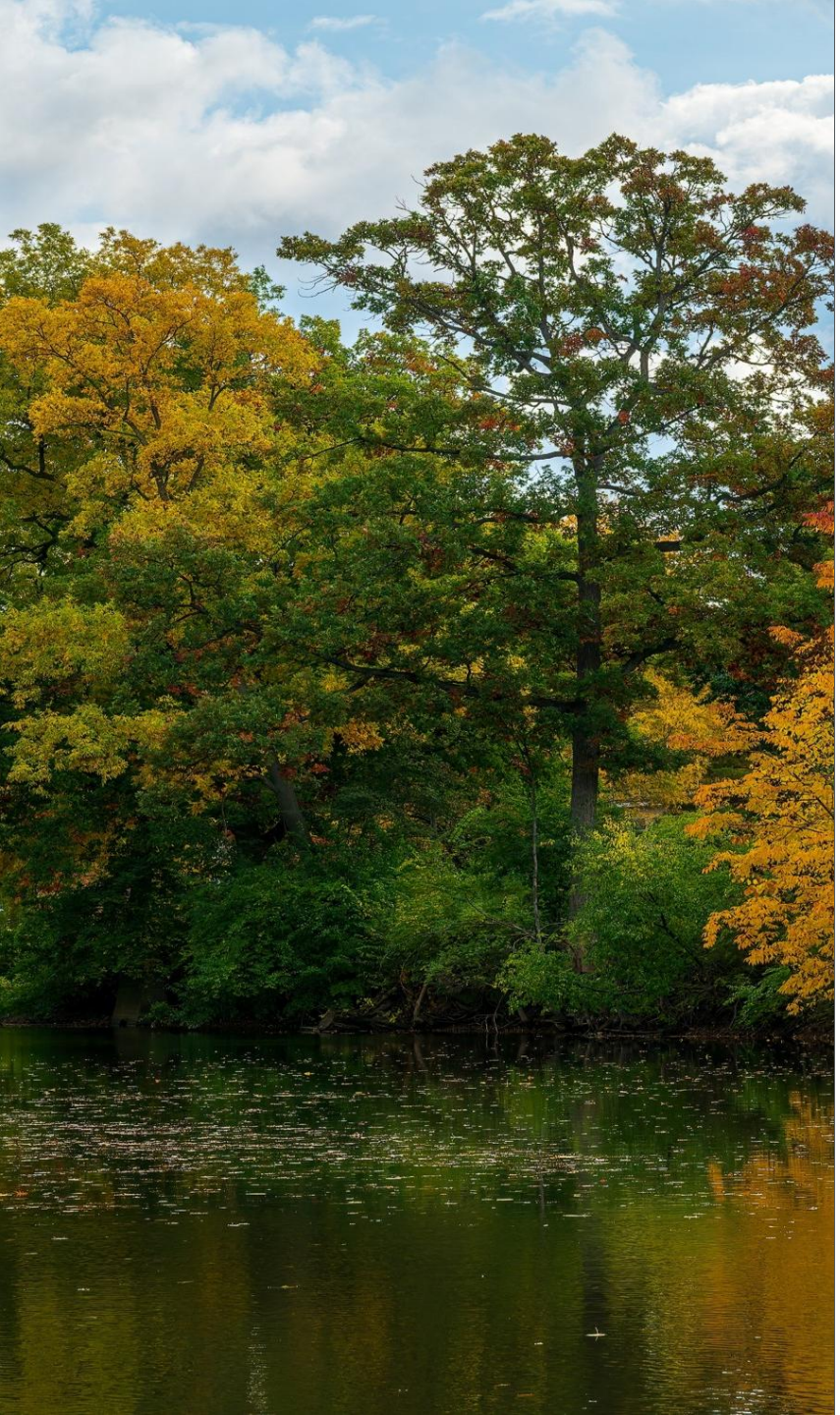
LOS goal in MS4 = No manhole flooding onto the surface



Key Outcomes: Ph I Modeling Results Meeting (Feb 2026)

- Established storm separation effectiveness:
  - 80% is captured in new storm pipes, 20% remains in existing combined pipes
- Charles St causes reverse flows over the Sunset Diversion upstream into Area C
  - Charles St sewer is a bottleneck impacting many portions of the CSS
  - The City decided to keep the Charles St upsize in all CSS model alternatives given the impact to the system
- Area B alternative should consider storm separation down Harrison St to offload flows from Area C and multiple concern areas downstream





Key Outcomes: Ph I Modeling Results Meeting (Feb 2026) (cont.)

For Top 8 concern areas, the City expressed the need to understand:

1. The increase in project size between current 10-year storm (2.00-in/hr) and future 2100 16-year enhanced storm (2.54 in/hr).
2. Can LOS be increased by implementing storage/green infrastructure? Can resilience projects achieve a higher LOS or reduce pipe size?
3. Are there other adjacent concern areas that can benefit from projects in the Top 8?

Alternatives and Proposed Projects Evaluated

Concern Area	Alt	Proposed Project(s)
A & B	**1a**	• 107.3 ac of storm separation • 7,200 ft of new storm main (max depth ~10-15 ft) • Restrictor modification – remove flow restrictor • 2,100 ft of combined sewer upsizing • 725 ft of new combined sewer • 2 sewer bulkheads
	1b	• 1a plus additional 40.9 ac of stormwater separation (total 148.2 ac) • Increased storm main sizing
	1c	• 1a or 1b plus Gordon Guyer Park storage
D	**2a**	• 77.6 ac of storm separation • 3,100 ft of new storm main (max depth ~15-20 ft) • Restrictor modification – lower weir at Beal St to invert of overflow sewer • New regulator at Louis St • 2,000 ft of sewer upsizing • 600 ft of new combined sewer
	2b	• 2a plus additional 11.5 ac of storm separation (total 89.1 ac) • Increased storm main sizing
	2c	• 2a or 2b plus Valley Court Park Storage

Alternatives and Proposed Projects Evaluated (cont.)

Concern Area	Alt	Proposed Project(s)
B, C, E & G – Harrison Storm	**3a**	• 91.7 ac of storm separation • 5,200 ft of new storm main (max depth ~35-40 ft) • 7,100 ft of combined sewer upsizing (includes Charles St) • 875 ft of new combined sewer • 2 sewer bulkheads • Charles St regulator modification – increase weir length to 8.5 ft
	3b	• 3a plus additional 192.5 ac of storm separation (total 284.2 ac) • Plus an additional 3,300 ft of new storm main (max depth ~10-15 ft) • Increased storm main sizing • Increased diameter of upsized Charles St combined sewer, and additional 1065 ft of upsizing.
	3c	• 3a or 3b plus Gordon Guyer Park and Glencairn Park
B, C, E & G – Sunset Storm	**4a**	• 110.0 ac of storm separation • 10,500 ft of new storm main (max depth ~25-30 ft) • 7,100 ft of pipe upsizing (includes Charles St) • 875 ft of new combined sewer • 2 sewer bulkheads • Charles St regulator modification – increase weir length to 8.5 ft
	4b	• 4a plus additional 192.5 ac of storm separation (total 302.5 ac) • Plus an additional 3,300 ft of new storm main (max depth ~10-15 ft) • Increased storm main sizing • Increased diameter of upsized Charles St combined sewer, and additional 1065 ft of upsizing.
	4c	• 4a or 4b plus Glencairn Park, Shaw Park, Hannah Community Center storage

Alternatives and Proposed Projects Evaluated (cont.)

Concern Area	Alt	Proposed Project(s)
F	**5a**	• 7,600 ft of main storm sewer upsizing • 3.53 ac-ft of storage at Fire Department
	5b	• 5a plus additional 1.59 ac-ft of storage at Fire Department or upstream detention (total 5.12 ac-ft)
	5c	• 5a or 5b plus storage under parking lots
H	**6a**	• 4,600 ft of main storm sewer upsizing • Restrictor modification – remove flow restrictor • 0.61 ac-ft of storage at White Memorial City Park-fishing Pond
	6b	• 6a plus additional 1.12 ac-ft of storage at White Memorial City Park-fishing Pond (total 1.73 ac-ft)



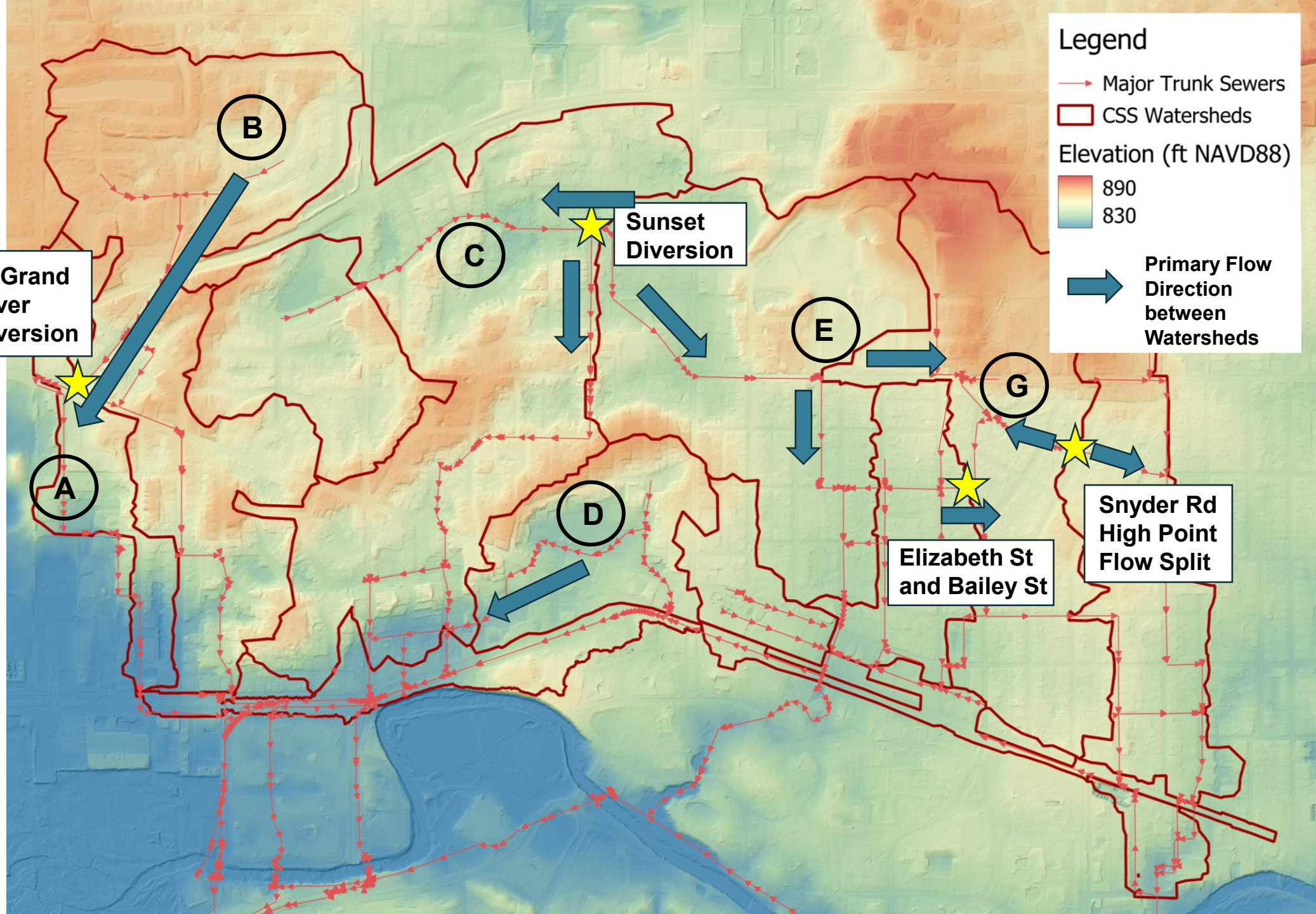
03

CSS Alternatives Analysis Results

CSS Watersheds

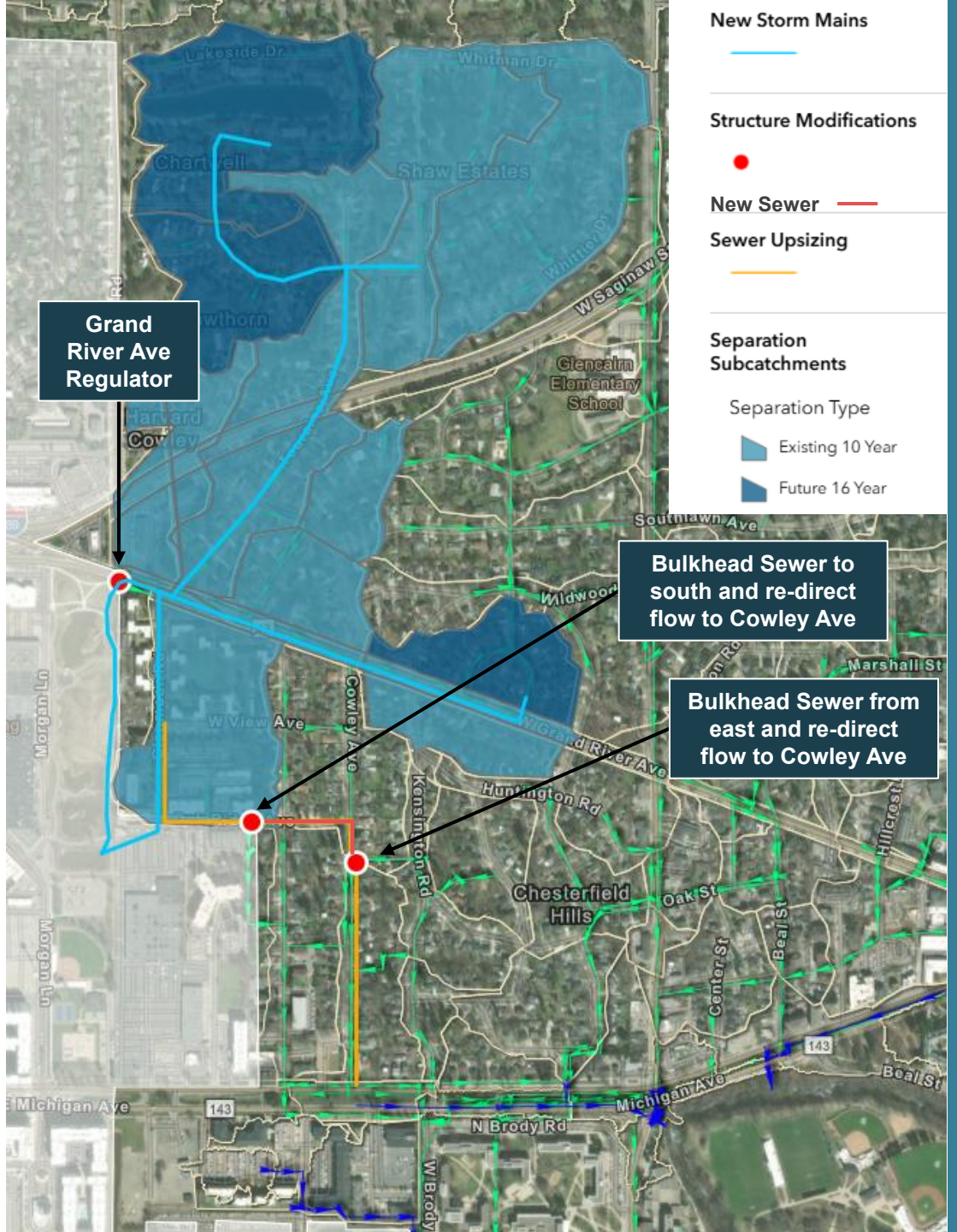
Watersheds and concern areas are hydraulically connected

- B impacts A
- E impacts C
- E impacts G
- D is independent
- Key Hydraulic Flow Splits



Areas A & B Alternatives

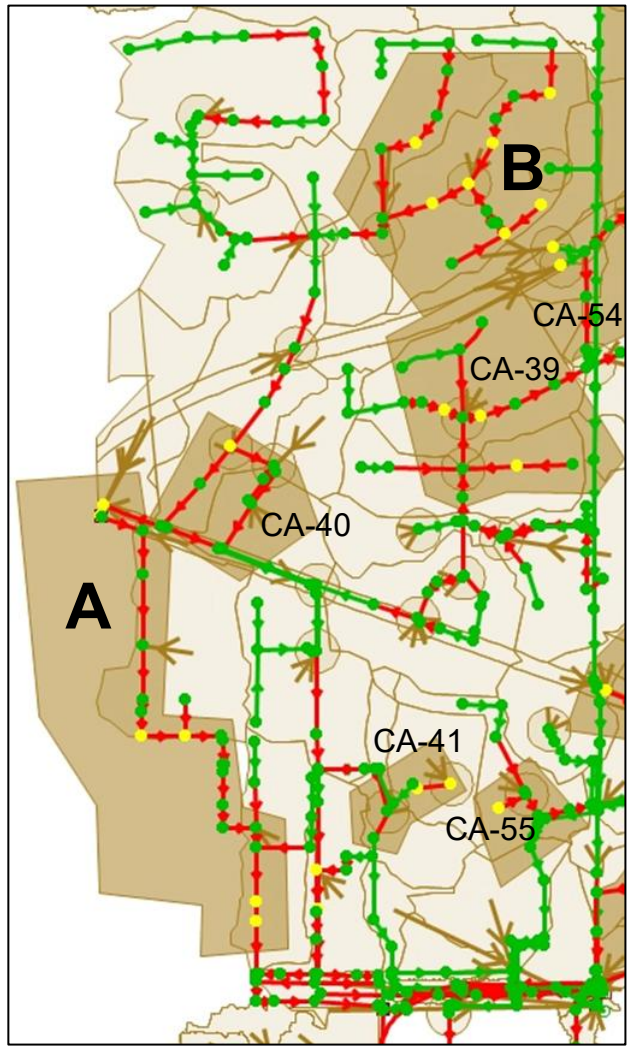
Concern Area	Alt	Proposed Project(s)
A & B	**1a**	• 107.3 ac of storm separation • 7,200 ft of new storm main (max depth ~10-15 ft) • Restrictor modification – remove flow restrictor • 2,100 ft of combined sewer upsizing • 725 ft of new combined sewer • 2 sewer bulkheads
	1b	• 1a plus additional 40.9 ac of stormwater separation (total 148.2 ac) • Increased storm main sizing
	1c	• 1a or 1b plus Gordon Guyer Park storage



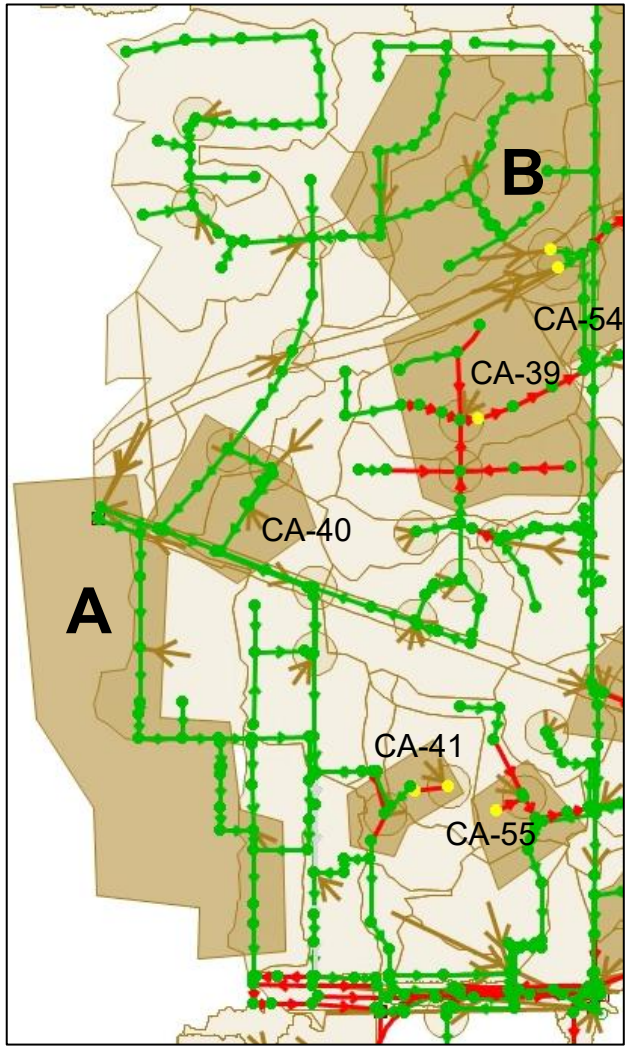
Areas A & B: Alt 1a

LOS Results for Current 10-year, 1-hour Storm

Without Alt



With Alt 1a



CSS Level of Service

Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

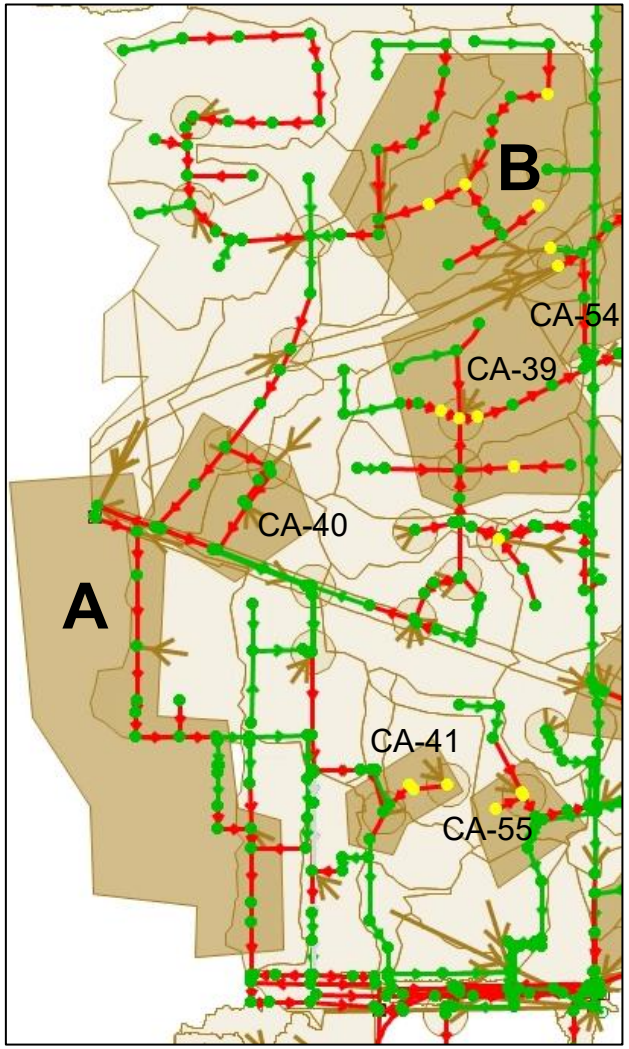
Key Takeaways:

- Alt 1a achieves Current 10-year LOS in Areas A and B.
- Alt 1a also benefits CA-40, CA-41.

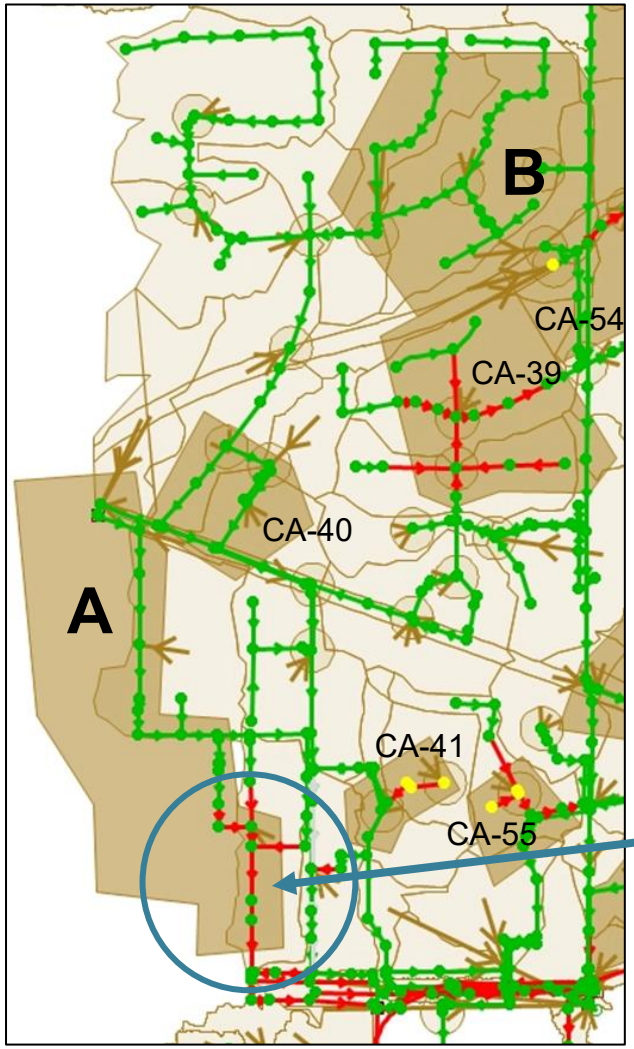
Areas A & B: Alts 1a & 1b

LOS Results for Future 16-year, 1-hour Storm

With Alt 1a



With Alt 1b



CSS Level of Service

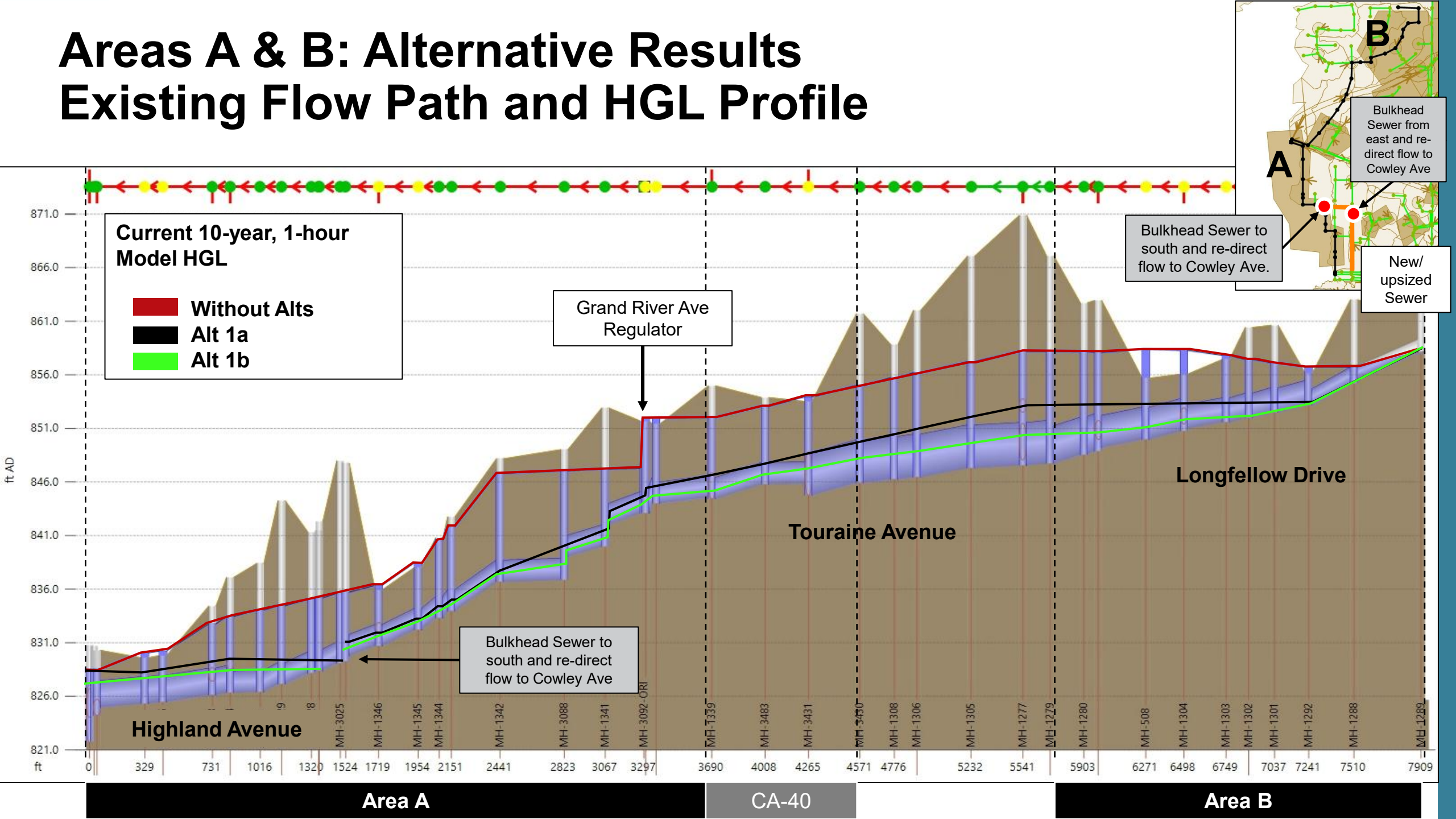
Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

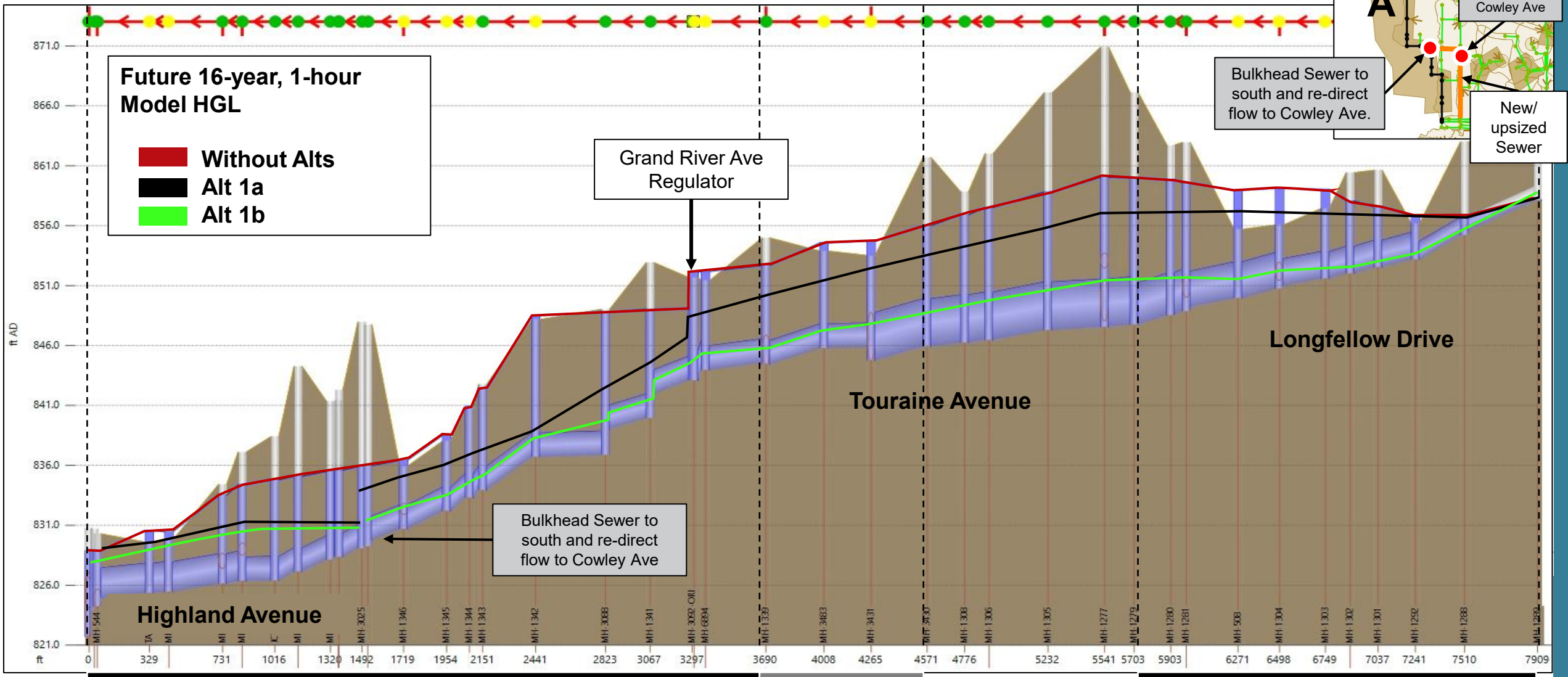
Key Takeaways:

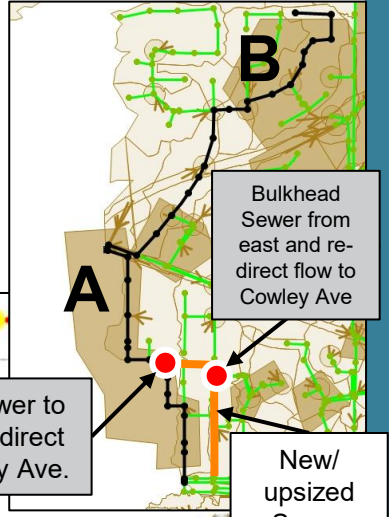
- Alt 1a does not achieve Future 16-year LOS for Areas A and B.
- Alt 1b achieves Future 16-year LOS for Areas A and B
  - Conduits not meeting LOS in Area A are caused by downstream backup.
- Alt 1b also benefits CA-40, CA-41.

Areas A & B: Alternative Results
Existing Flow Path and HGL Profile



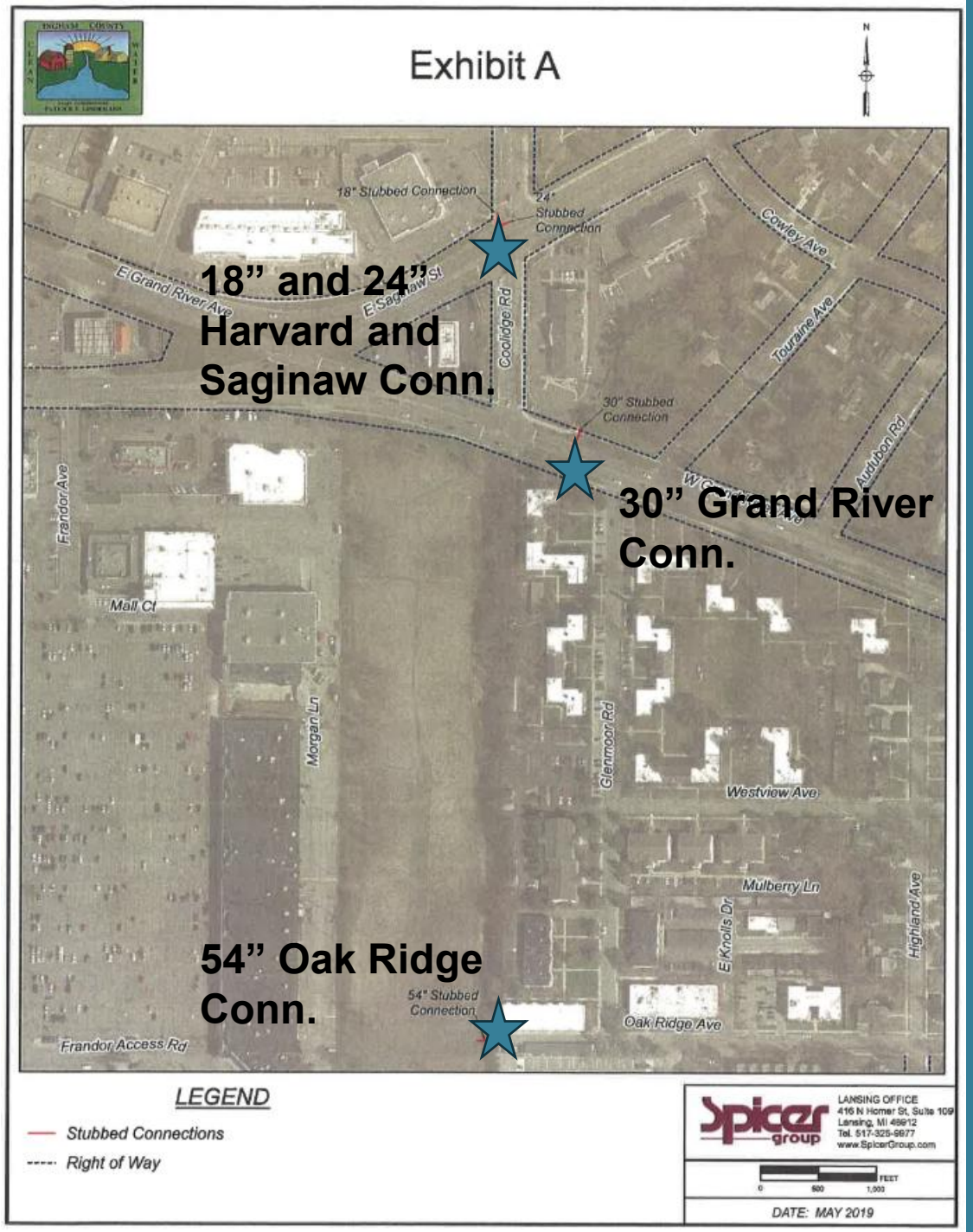
Areas A & B: Alternative Results
Existing Flow Path and HGL Profile





Storm Separation Connections to Ranney Park

- City entered into a signed agreement with Ingham County Drain Commissioner to establish four connections into Ranney Park. Connections are:
  - Harvard (18”)
  - Saginaw (24”)
  - Grand River (30”)
  - Oak Ridge (54”)



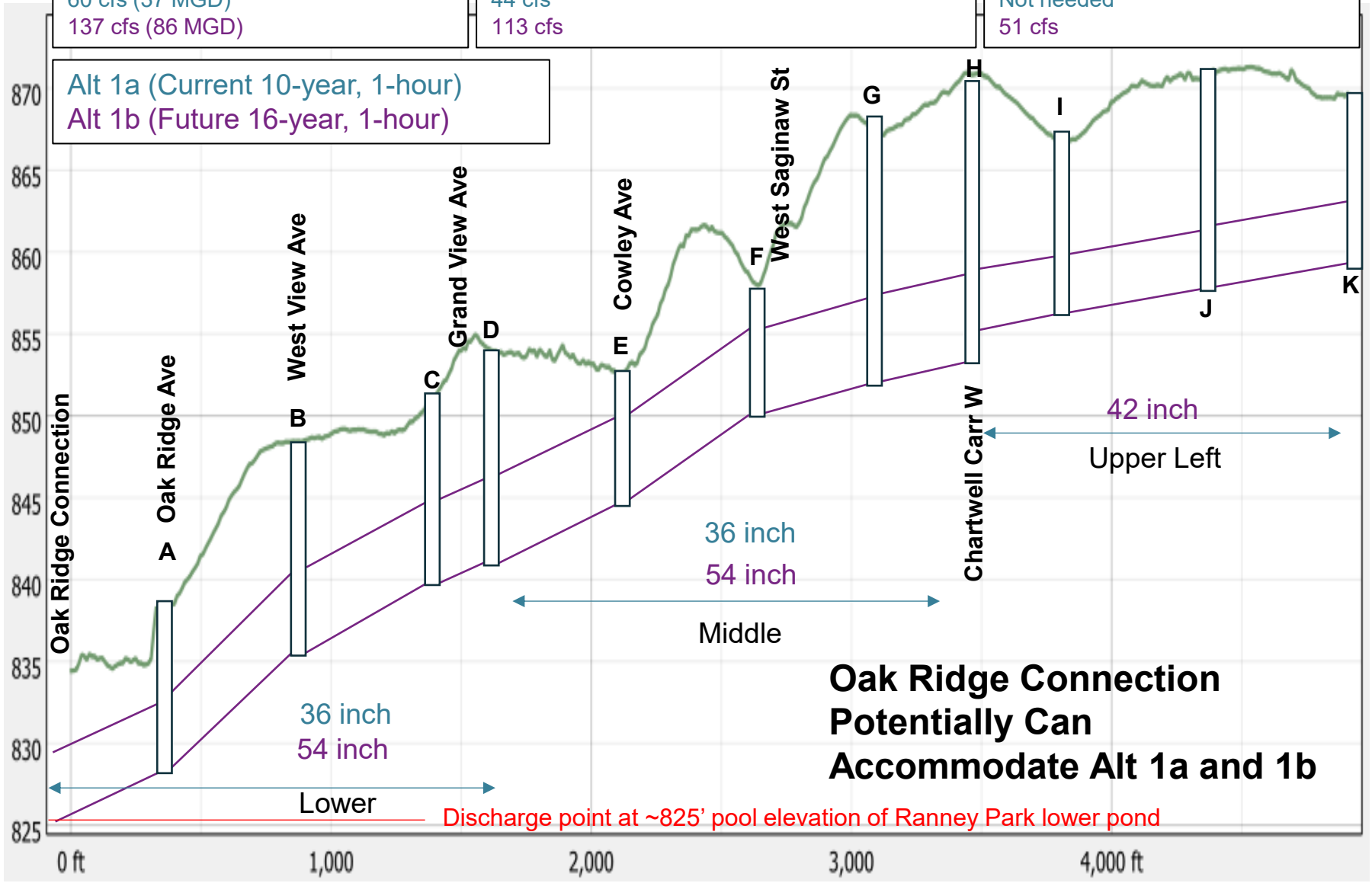
Alts 1a & 1b: Required Storm Sewer Main Sizes

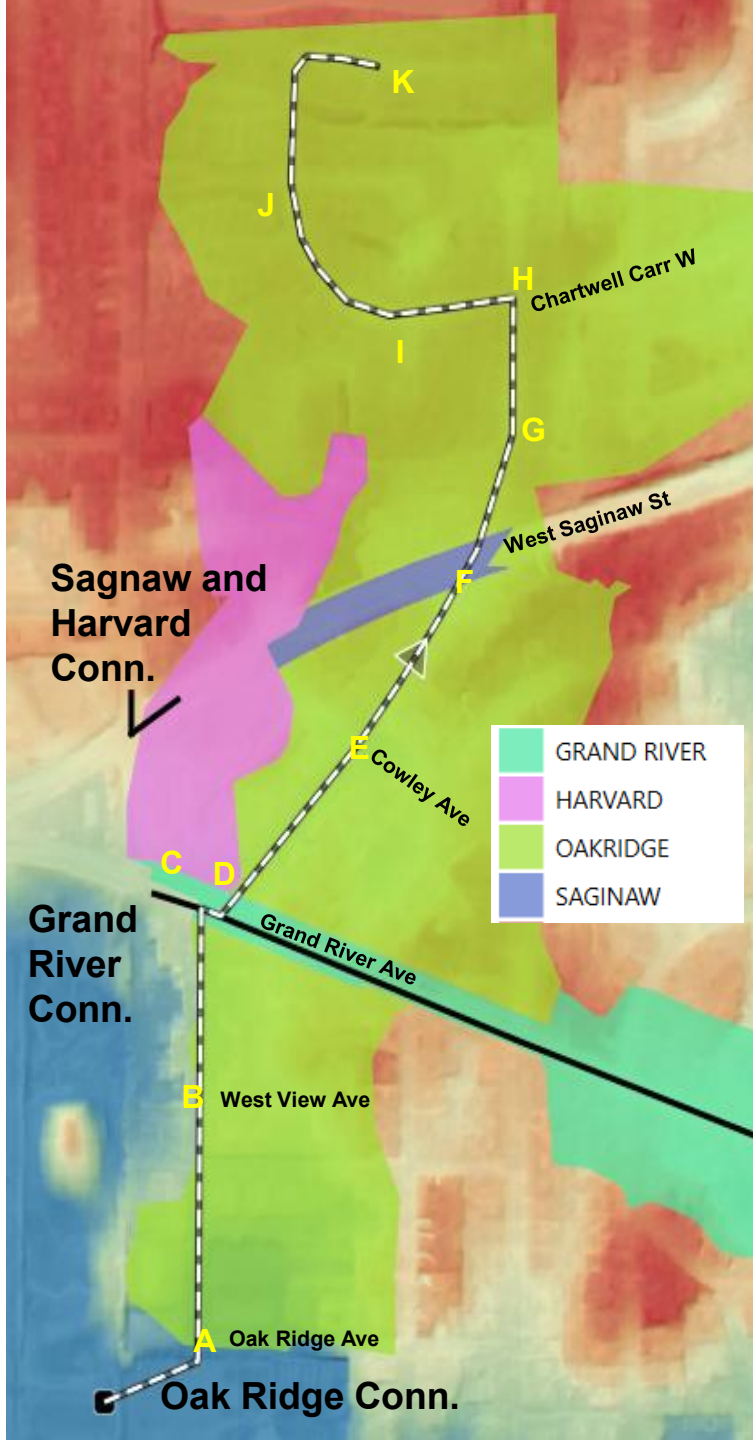
Lower
(D to Pond) =
60 cfs (37 MGD)
137 cfs (86 MGD)

Middle
(H to D) =
44 cfs
113 cfs

Upper Left
(K to H) =
Not needed
51 cfs

Alt 1a (Current 10-year, 1-hour)
Alt 1b (Future 16-year, 1-hour)





Storm Separation Results 1a

	Peak Flow (MGD)		Volume (MG)	
Connection	Current 10-year, 1-hour	2100 16-year, 1-hour	Current 10-year, 1-hour	2100 16-year, 1-hour
Harvard	8	10	0.31	0.42
Saginaw	4	5	0.07	0.09
Grand River	10	13	0.22	0.30
Oak Ridge	37	54	1.36	1.92
Totals	59	83	1.96	2.72

Storm Separation Results 1b

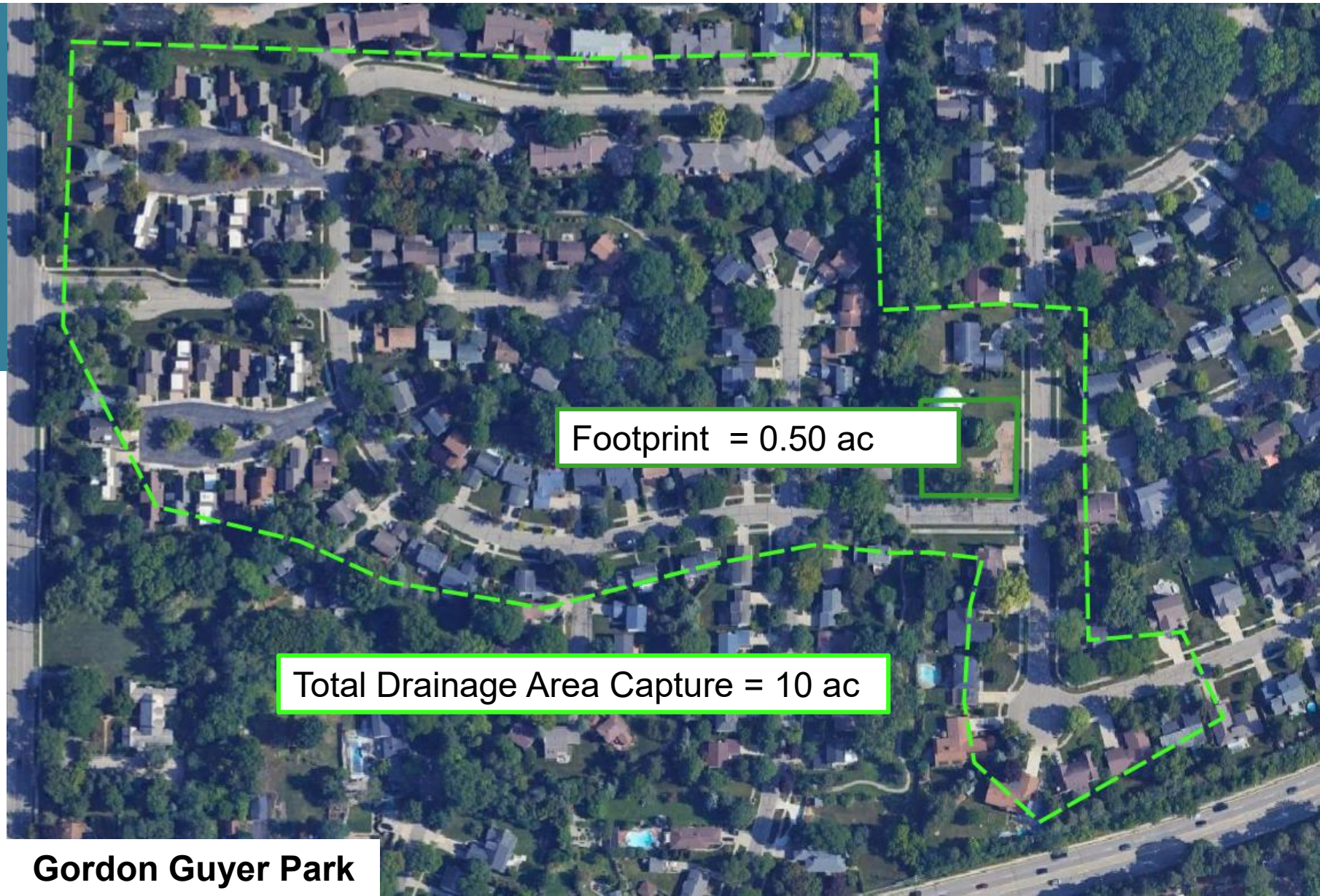
	Peak Flow (MGD)		Volume (MG)	
Connection	Current 10-year, 1-hour	2100 16-year, 1-hour	Current 10-year, 1-hour	2100 16-year, 1-hour
Harvard	8	10	0.31	0.42
Saginaw	4	5	0.07	0.09
Grand River	12	16	0.27	0.38
Oak Ridge	60	86	2.08	2.89
Totals	84	118	2.73	3.77

Note: Total flow contributions were revisited and were determined to be lower than previously calculated. This is due to the topography of Area B (Shaw Estates) which likely can not convey the full flow from this area to Ranney Park via gravity. This portion of Area B would need to be separated as part of Area C (Alt 3 - Harrison or Alt 4 – Sunset)

Area B: Alt 1c Gordon Guyer Park Resilience Opportunity

Calculated Peak Flow Reduction for Future 16-year Storm =

17 cfs



Gordon Guyer Park

Increased LOS with Alt 1c Resilience Opportunity

- ~17 cfs benefit to downstream system with Gordon Guyer Park Storage
  - Increase LOS from current 10-year to ~17-year
  - Increase LOS from future 16-year to ~22-year

Rainfall (inches)	Return Period (Years)		Peak Flow CFS		
	Current Day	2100 High Emissions	Area A B Total	With Gordon Guyer Park	
1.40	2	1	81		
1.61	3	1	99		
1.92	8	3	127		
2.00	10	3	134	151	+17 cfs
2.18	17	5	152		
2.44	38	10	178		
2.54	50	16	188	205	+17 cfs
2.77	100	22	213		
3.05	228	43	243		

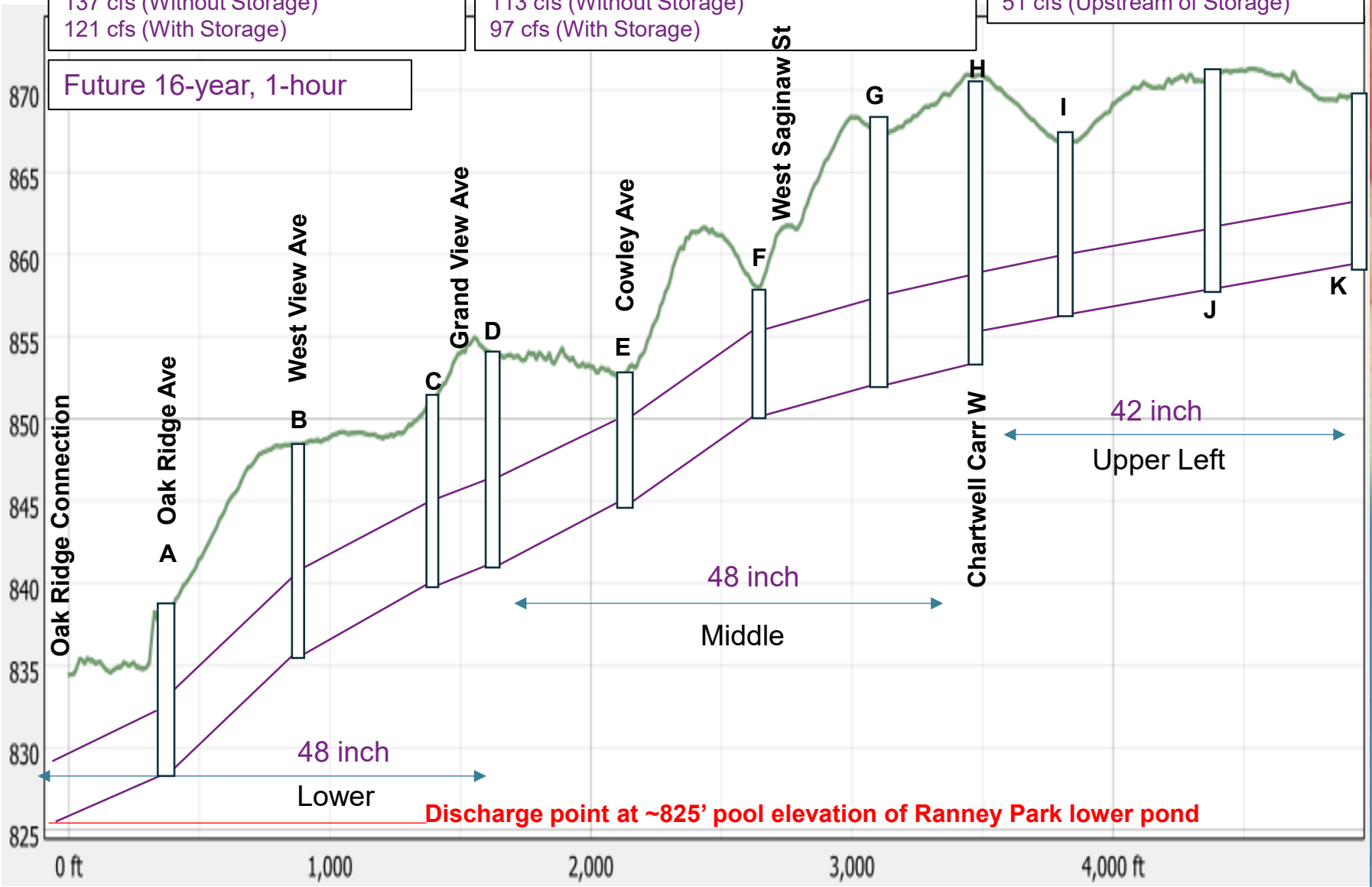
Alts 1c: Required Storm Sewer Main Sizes

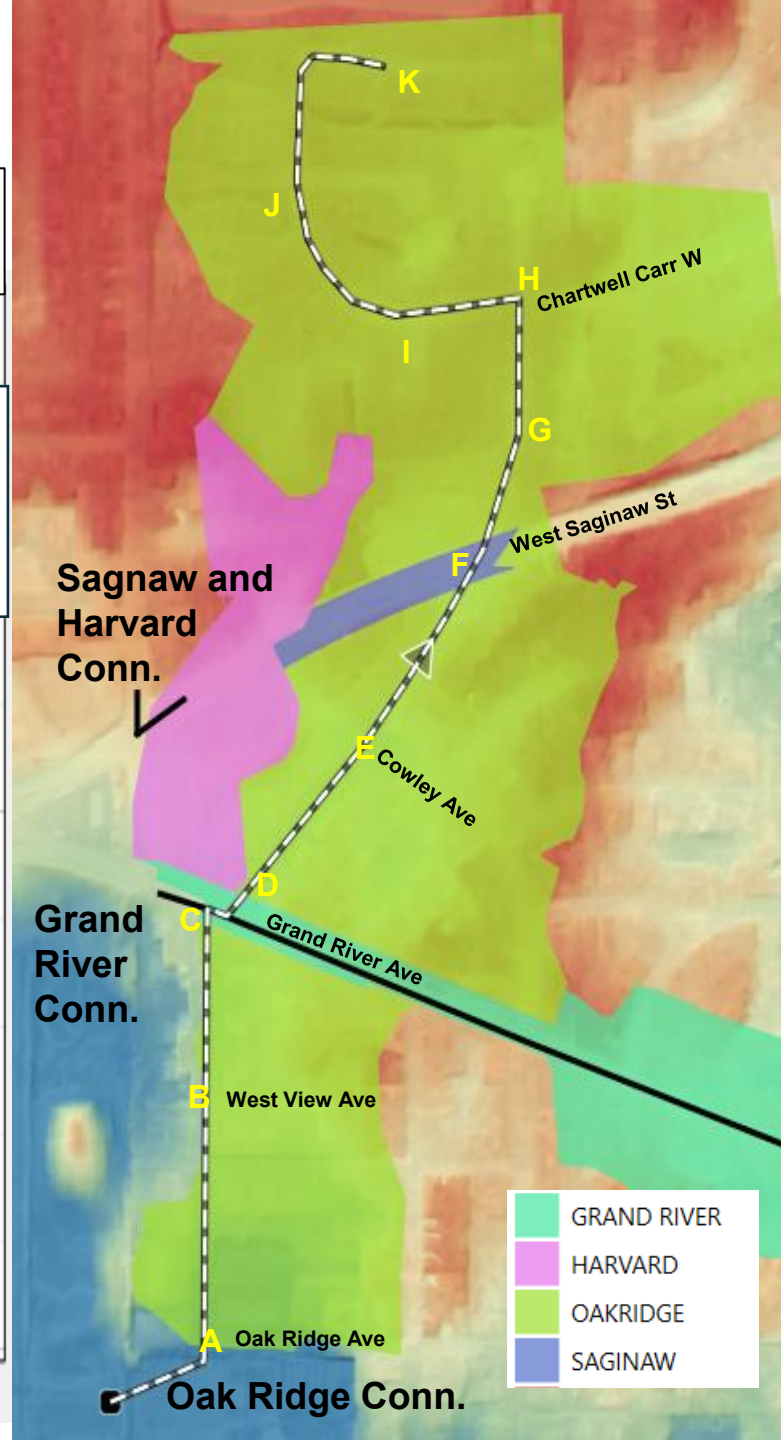
Lower
(D to Pond) =
137 cfs (Without Storage)
121 cfs (With Storage)

Middle
(H to D) =
113 cfs (Without Storage)
97 cfs (With Storage)

Upper Left
(K to H) =
51 cfs (Upstream of Storage)

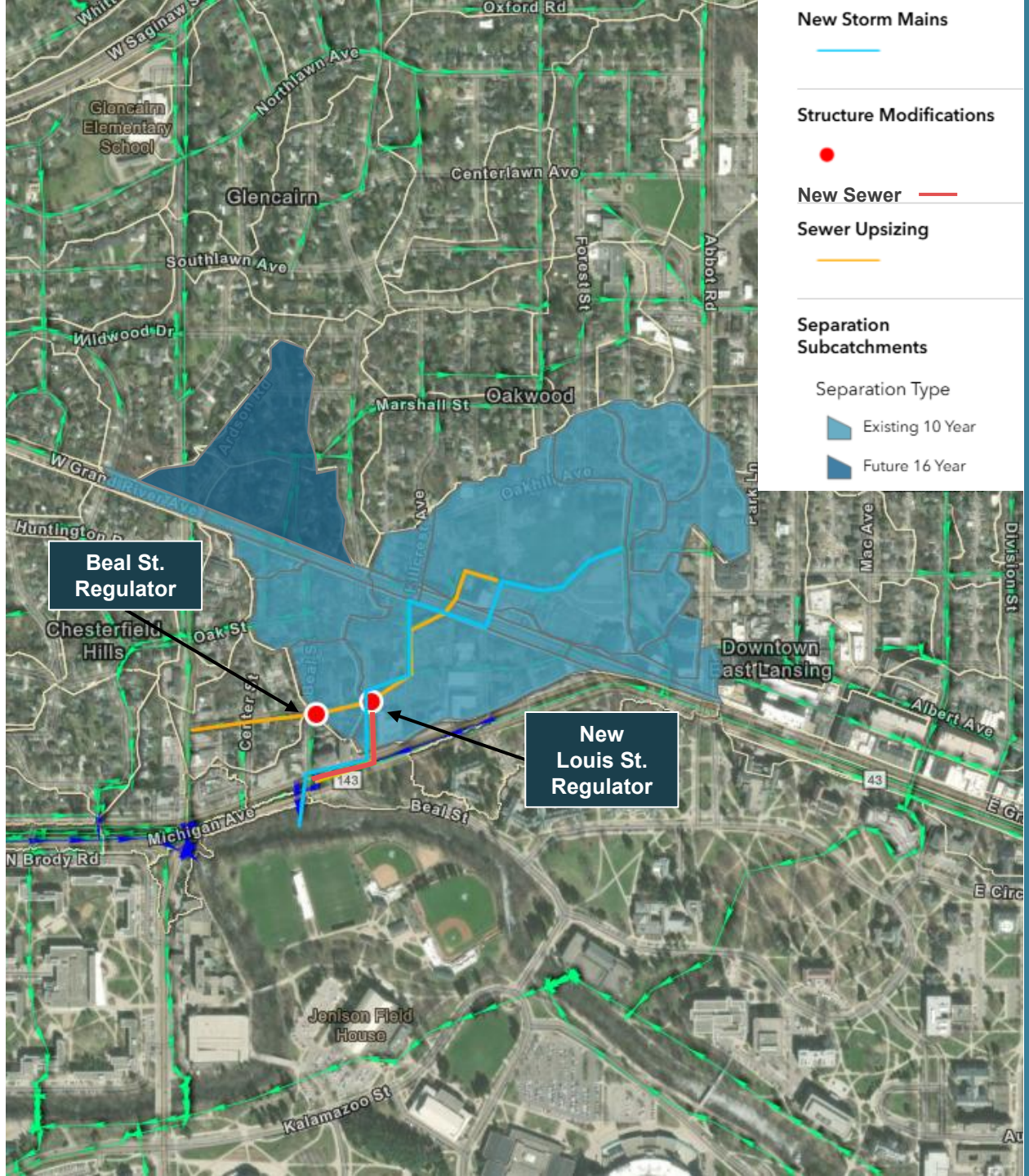
Future 16-year, 1-hour





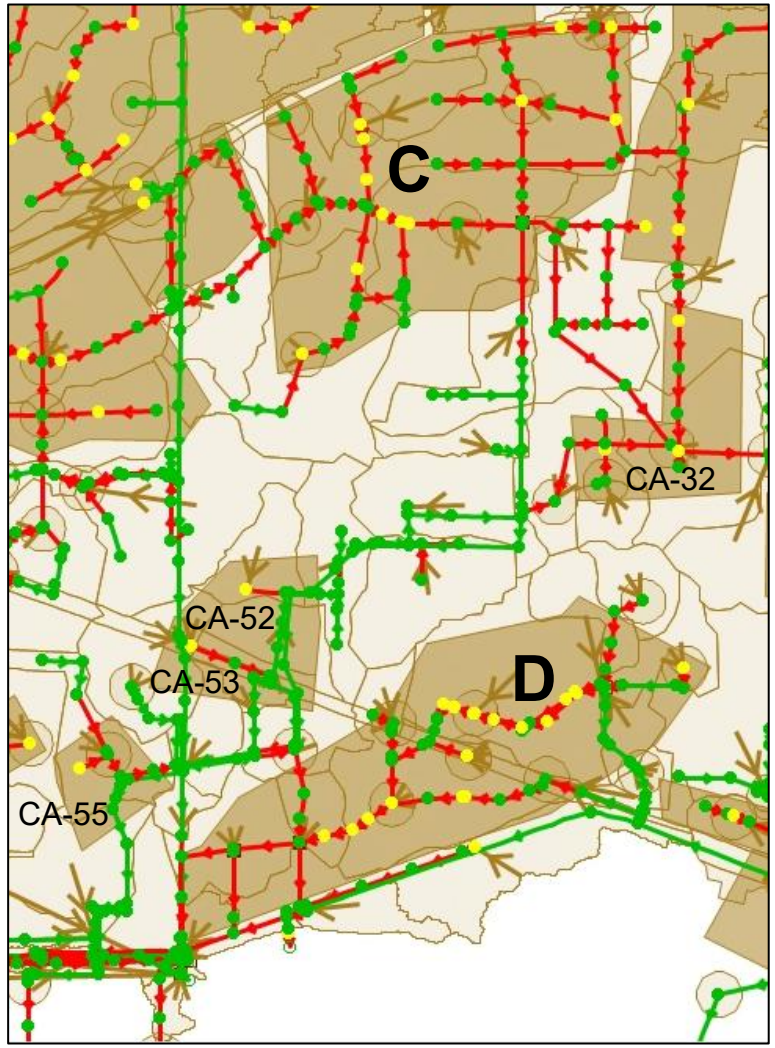
Area D Alternatives

Concern Area	Alt	Proposed Project(s)
D	**2a**	• 77.6 ac of storm separation • 3,100 ft of new storm main (max depth ~15-20 ft) • Restrictor modification – lower weir at Beal St to invert of overflow sewer • New regulator at Louis St • 2,000 ft of combined sewer upsizing • 600 ft of new combined sewer
	2b	• 2a plus additional 11.5 ac of storm separation (total 89.1 ac) • Increased storm main sizing
	2c	• 2a or 2b plus Valley Court Park Storage

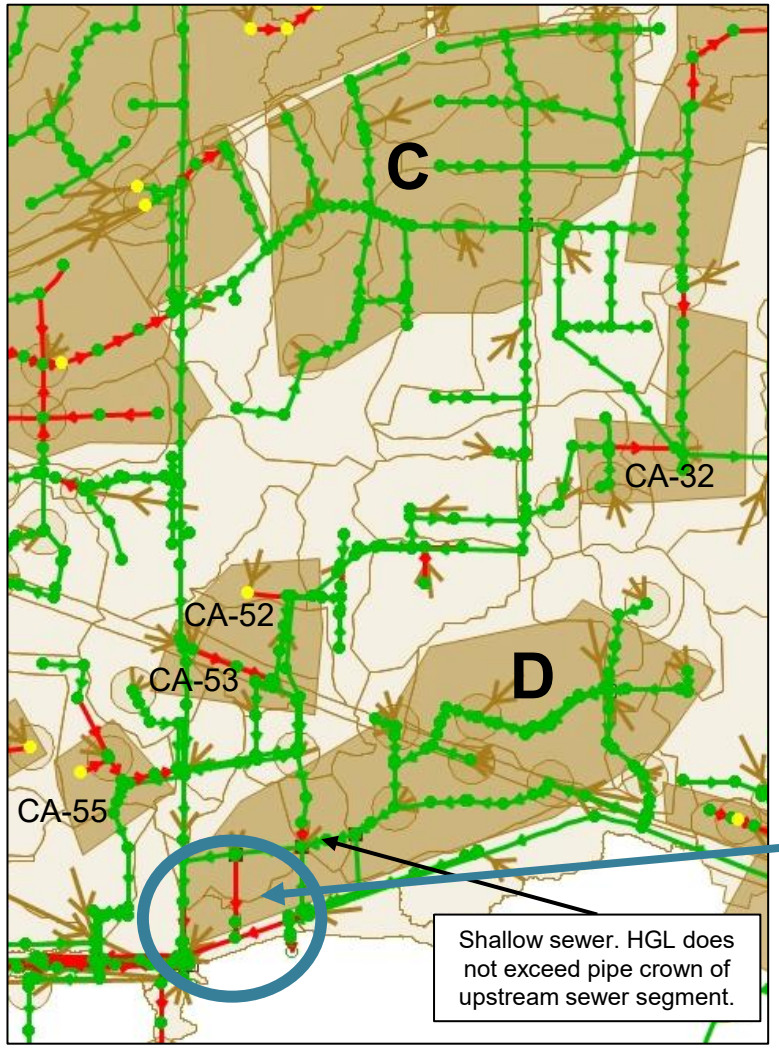


Area D: Alt 2a
LOS Results for Current 10-year, 1-hour Storm

Without Alt



With Alt 2a



CSS Level of Service

Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

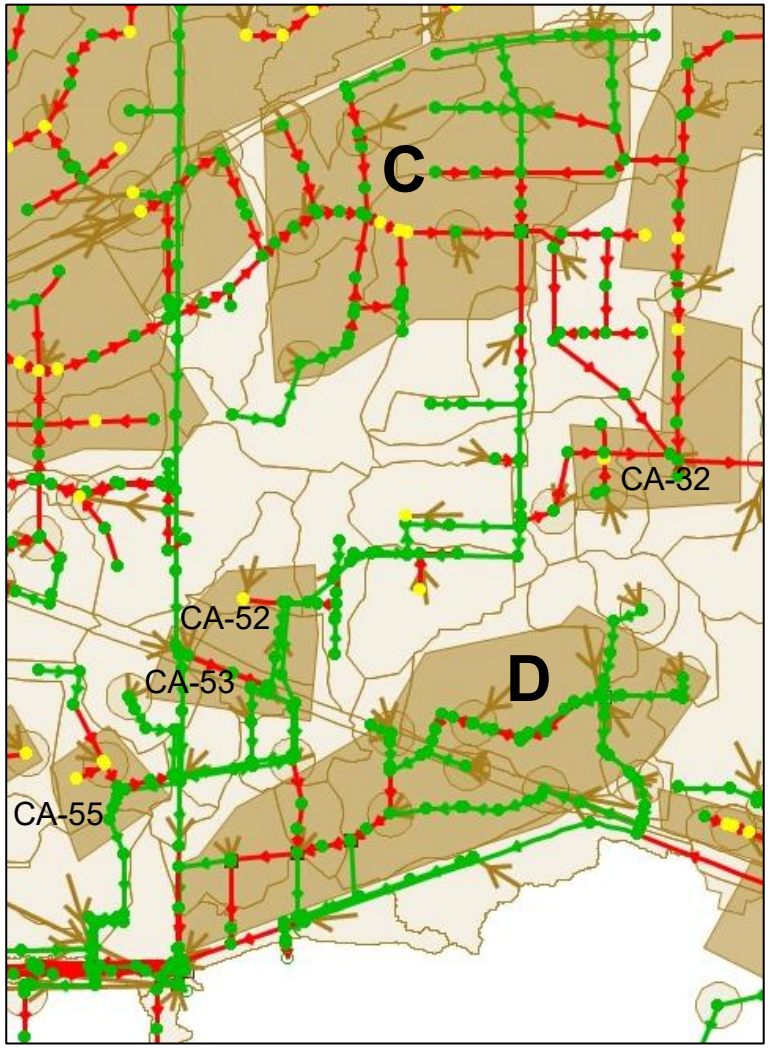
Key Takeaways:

- Alt 2a achieves Current 10-year LOS in Area D.
  - Conduits not achieving LOS in Area D due to downstream backup, with exception of shallow sewer along Beal St as noted.

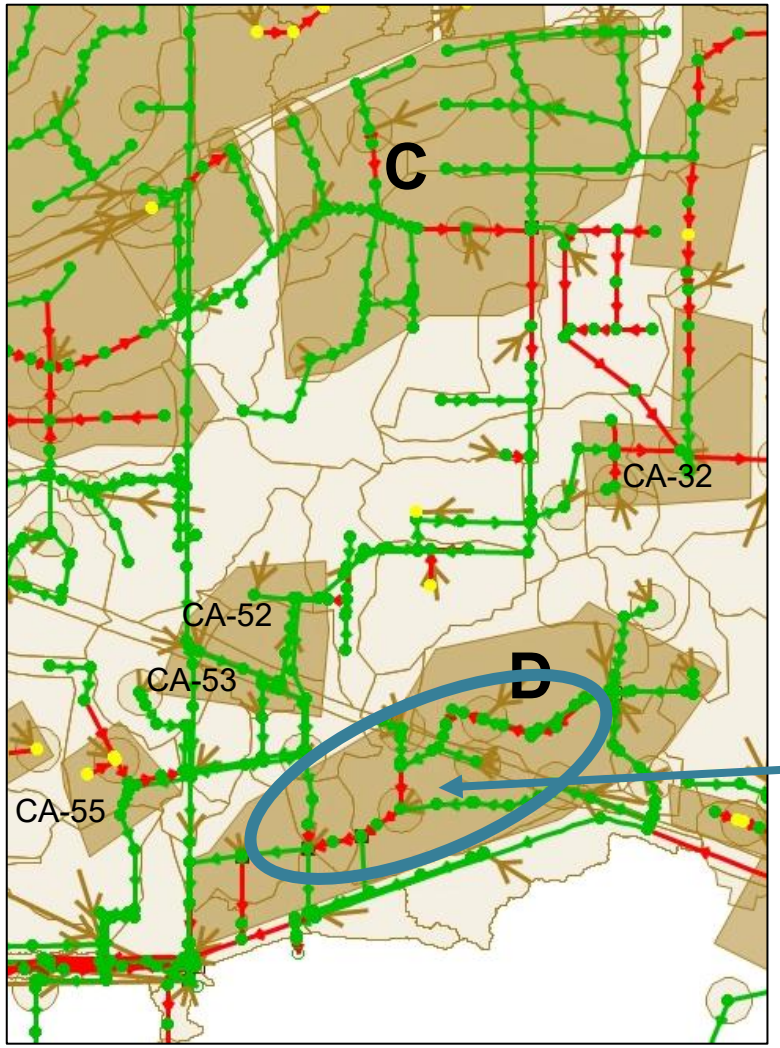
Area D: Alts 2a & 2b

LOS Results for Future 16-year, 1-hour Storm

With Alt 2a



With Alt 2b



CSS Level of Service

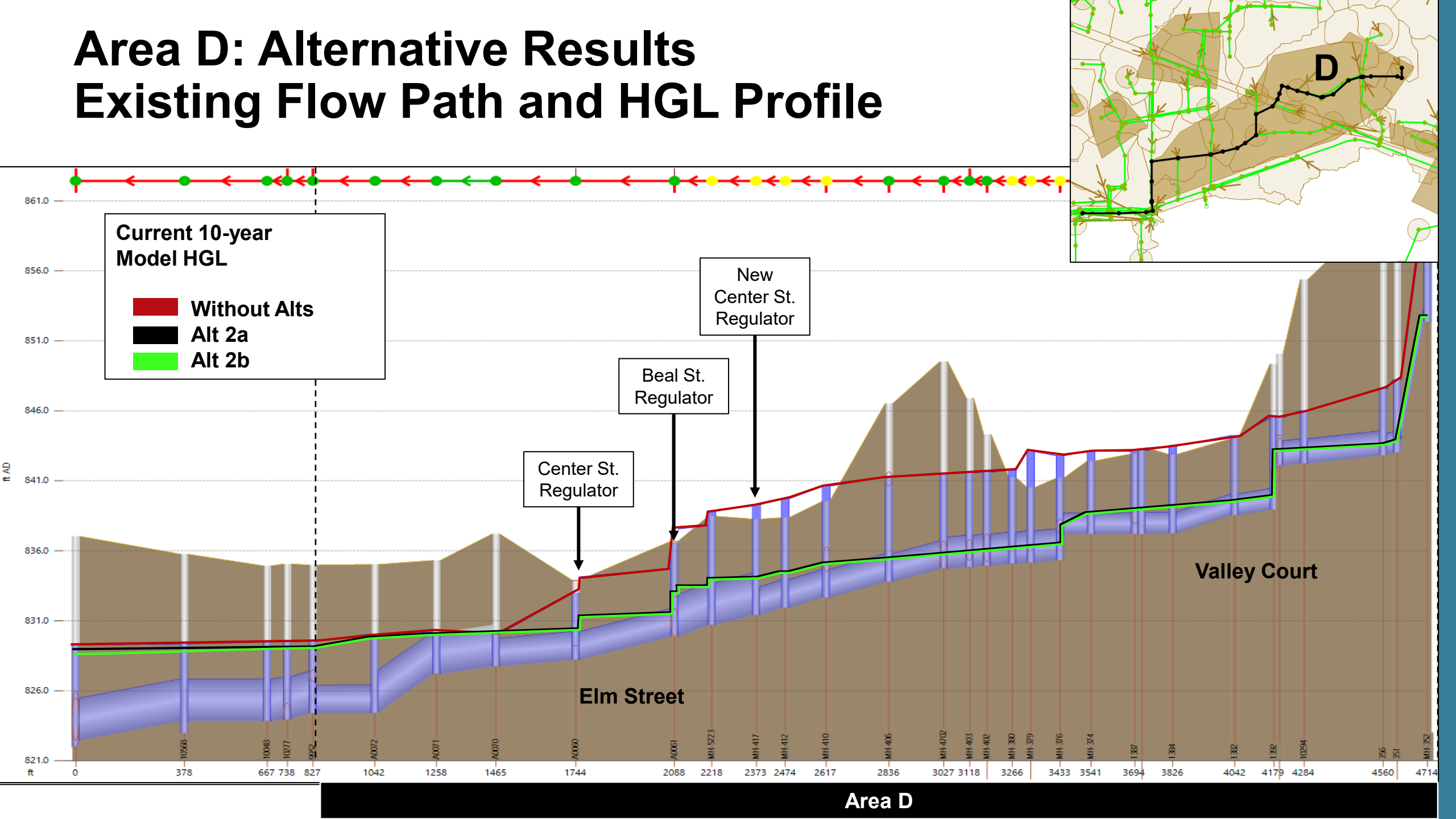
Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

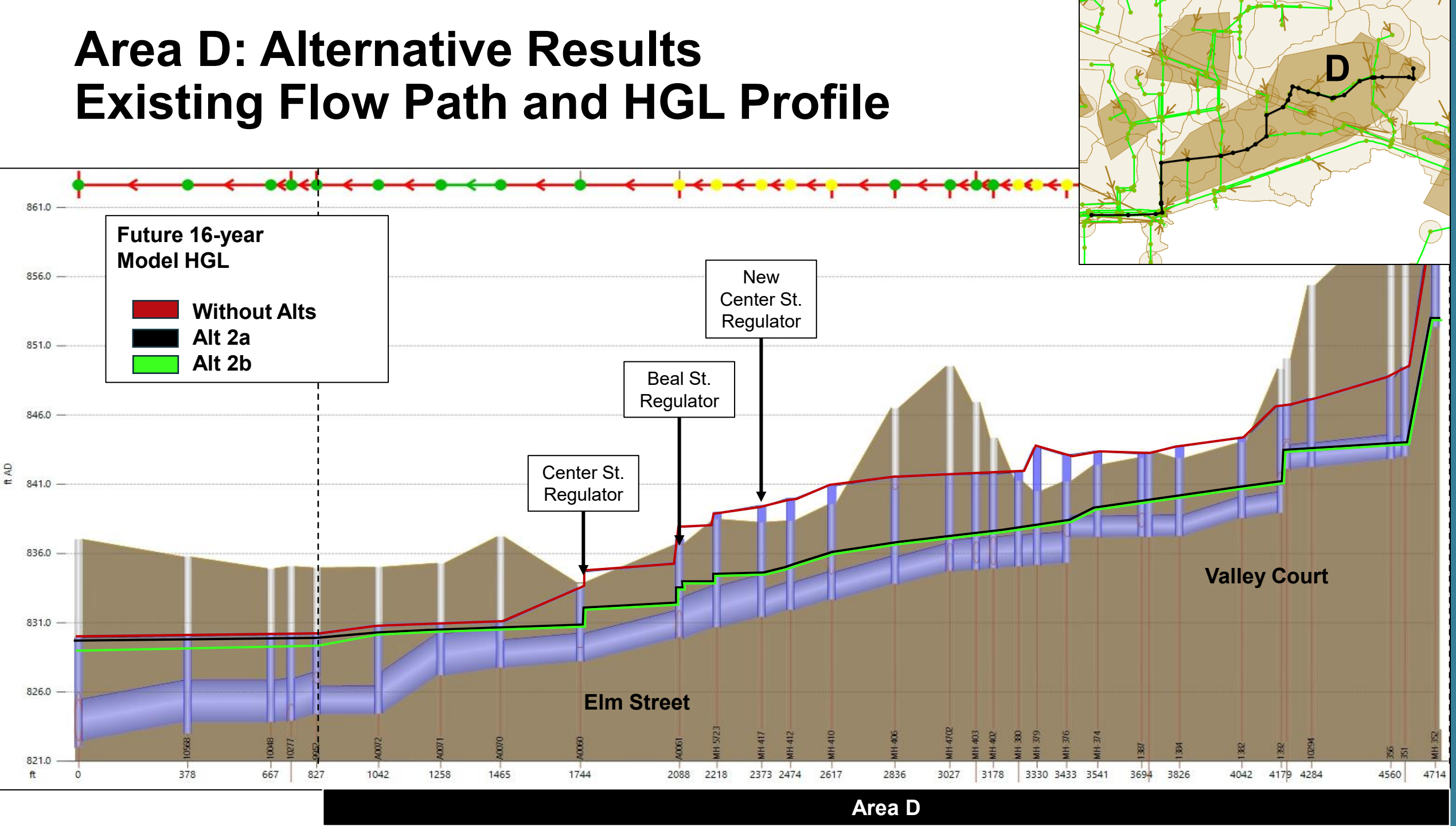
Key Takeaways:

- Alt 2a does not achieve Future 16-year LOS in Area D.
- Alt 2b does not achieve Future 16-year LOS in Area D.
  - Conduits not meeting LOS in Area D due to lack of capacity within mainline sewer.
  - Sewers were upsized to match downstream pipe diameter.
- Alt 2b benefits CA-52, CA-53.

Area D: Alternative Results
Existing Flow Path and HGL Profile

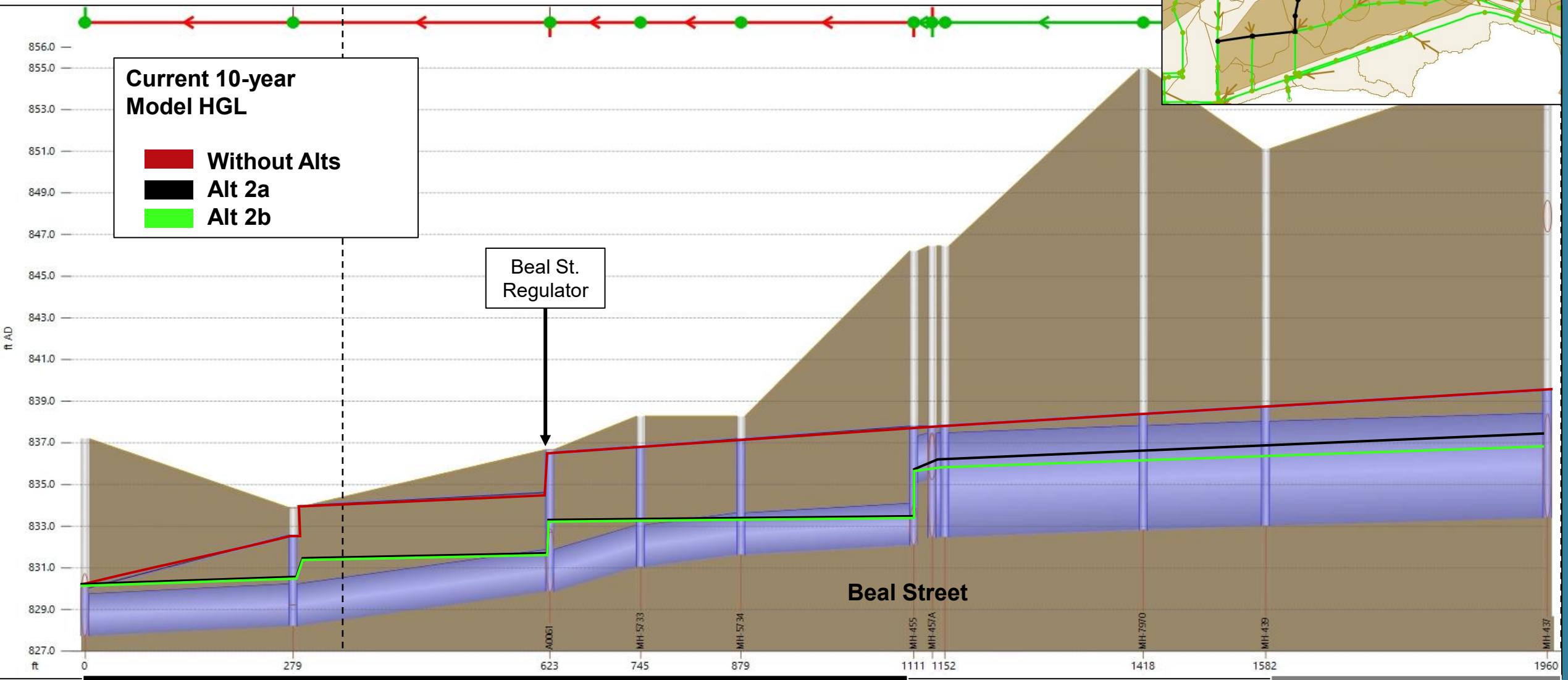


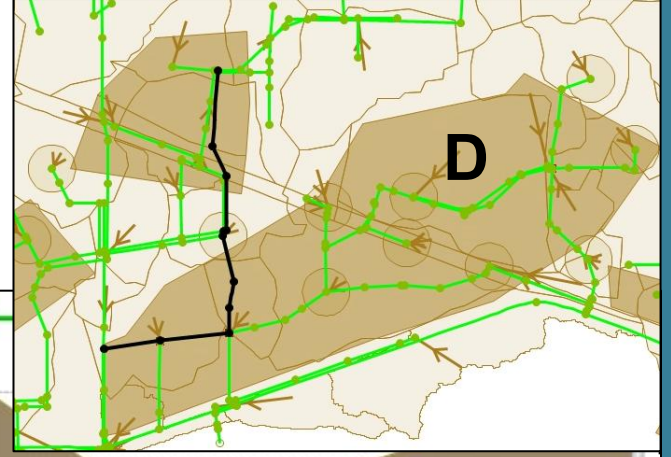
Area D: Alternative Results
Existing Flow Path and HGL Profile



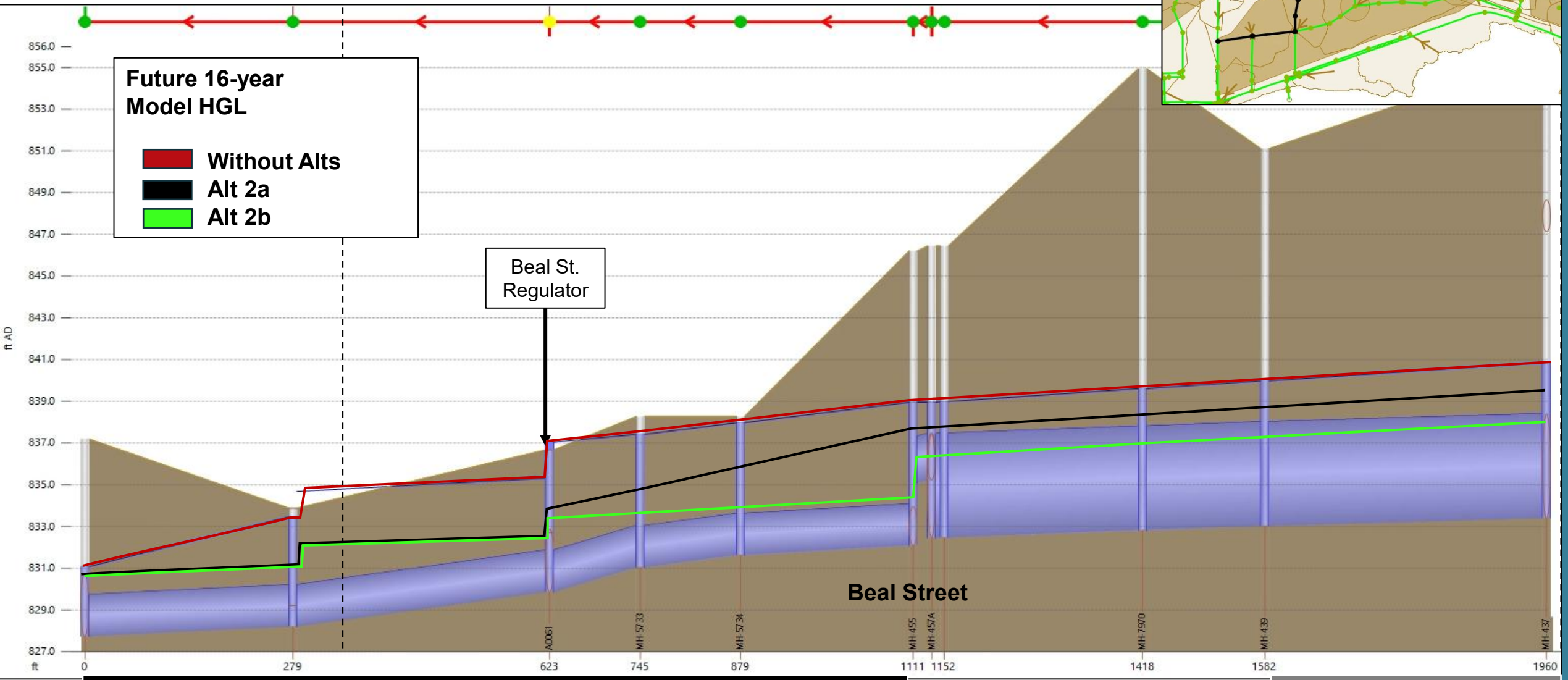
Area D

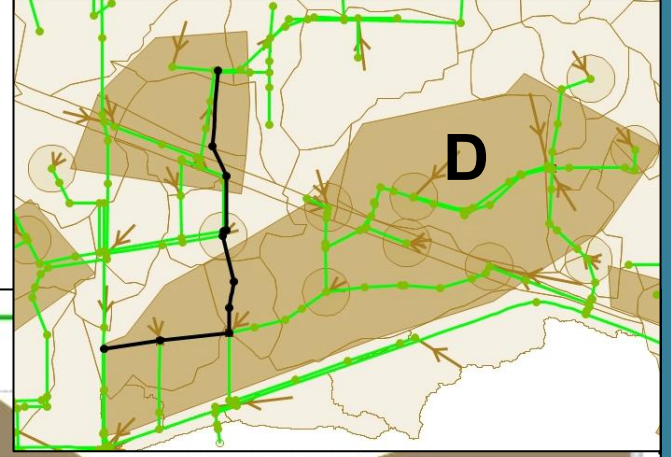
Area D: Alternative Results
Existing Flow Path and HGL Profile





Area D: Alternative Results
Existing Flow Path and HGL Profile





Area D

CA-52, CA-53

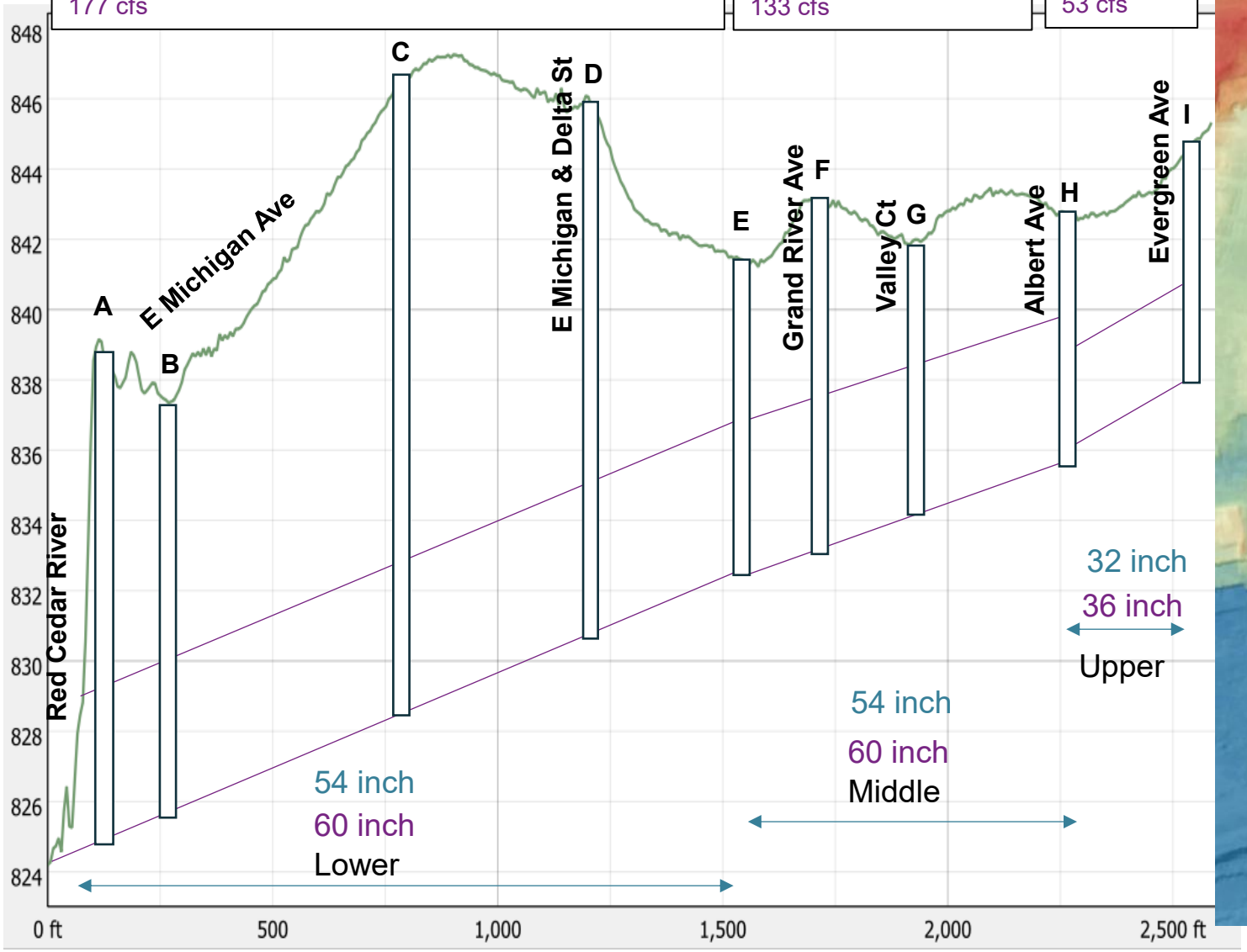
Alts 2a & Alt 2b: Required Storm Sewer Main Sizes

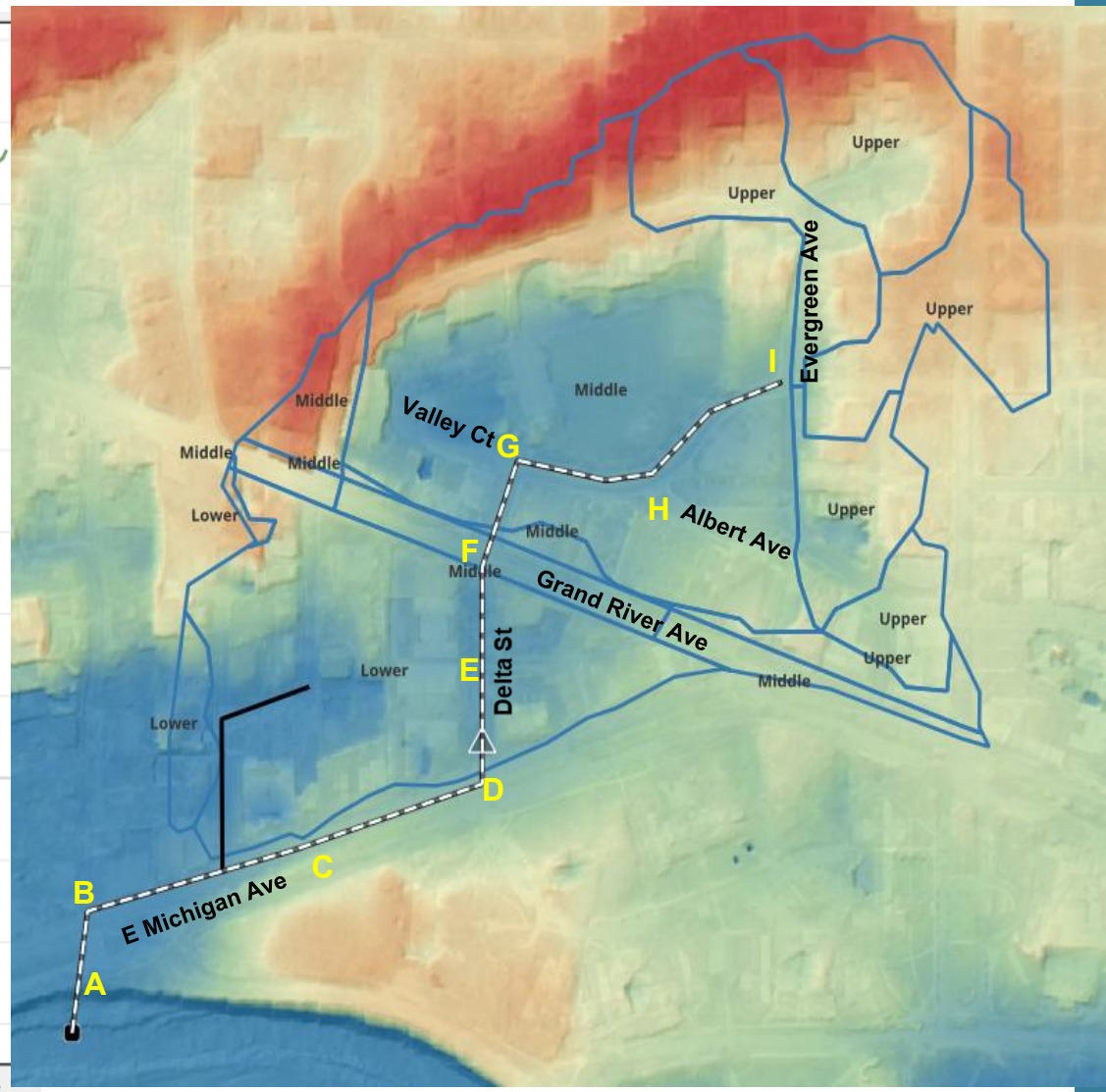
Lower
(E to River) =
131 cfs
177 cfs

Middle
(H to E) =
99 cfs
133 cfs

Upper
(I to H) =
40 cfs
53 cfs

Alt 2a (Current 10-year, 1-hour)
Alt 2b (Future 16-year, 1-hour)

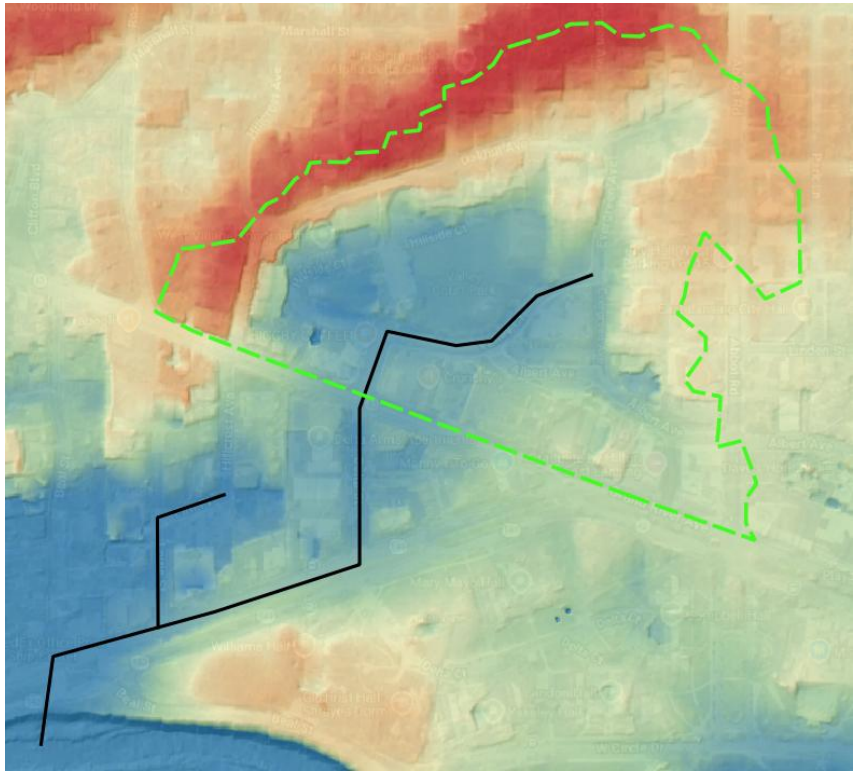


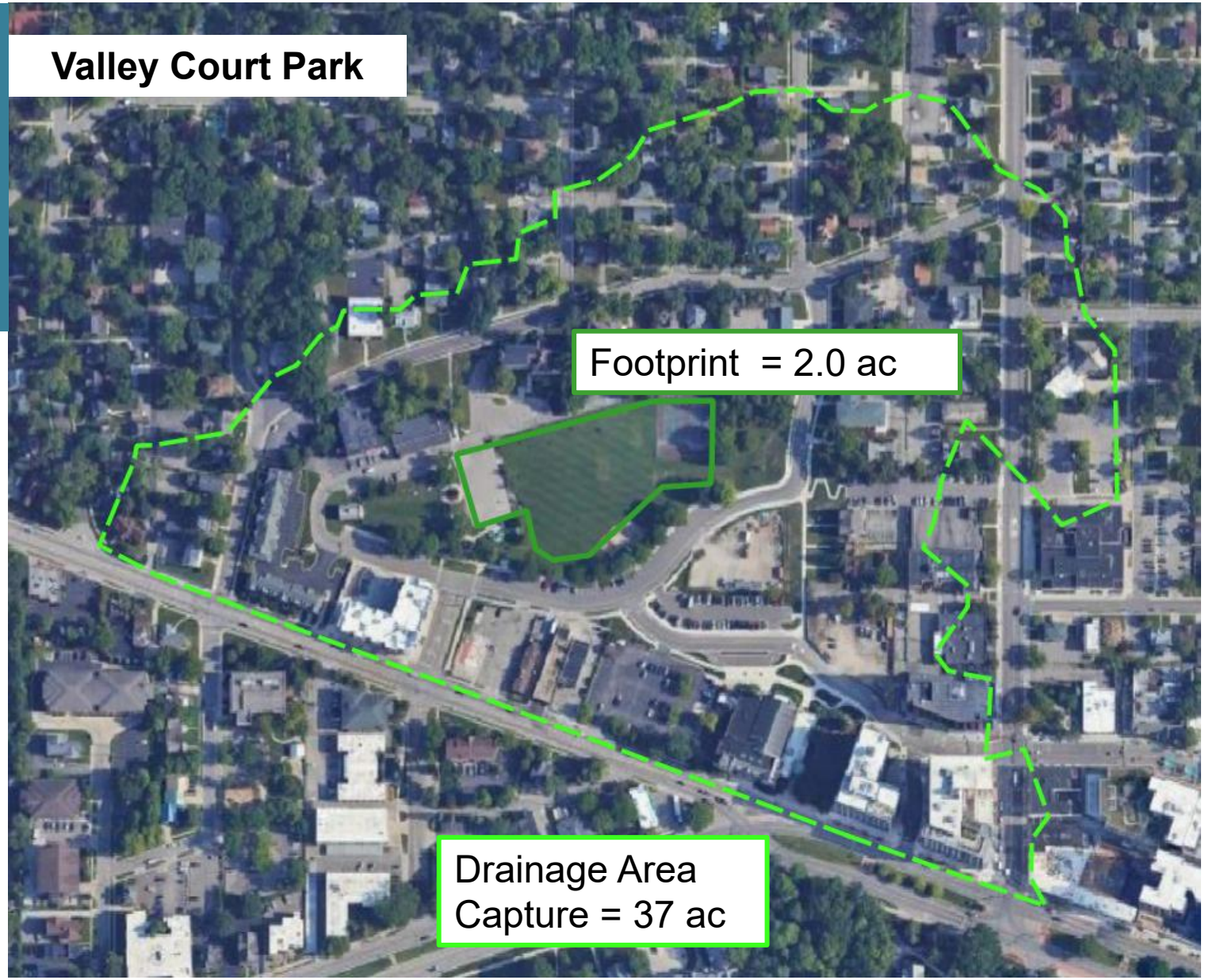


Area D: Alt 2c Valley Court Park Resilience Opportunity

Calculated Peak Flow Reduction for Future 16-year Storm =

132 cfs





Increased LOS with Alt 2c Resilience Opportunity

- ~132 cfs benefit to downstream system with Valley Court Park Storage
  - Increase LOS from current 10-year to ~500-year
  - Increase LOS from future 16-year to ~100-year

Rainfall (inches)	Return Period (Years)		Peak Flow CFS		
	Current Day	2100 High Emissions	Area D Total	With Valley Court Park	
1.40	2	1	83		
1.61	3	1	100		
1.92	8	3	124		
2.00	10	3	131	263	+132 cfs
2.18	17	5	146		
2.44	38	10	169		
2.54	50	16	177	309	+132 cfs
2.77	100	25	198		
3.05	200	50	223		
3.32	500	100	248		

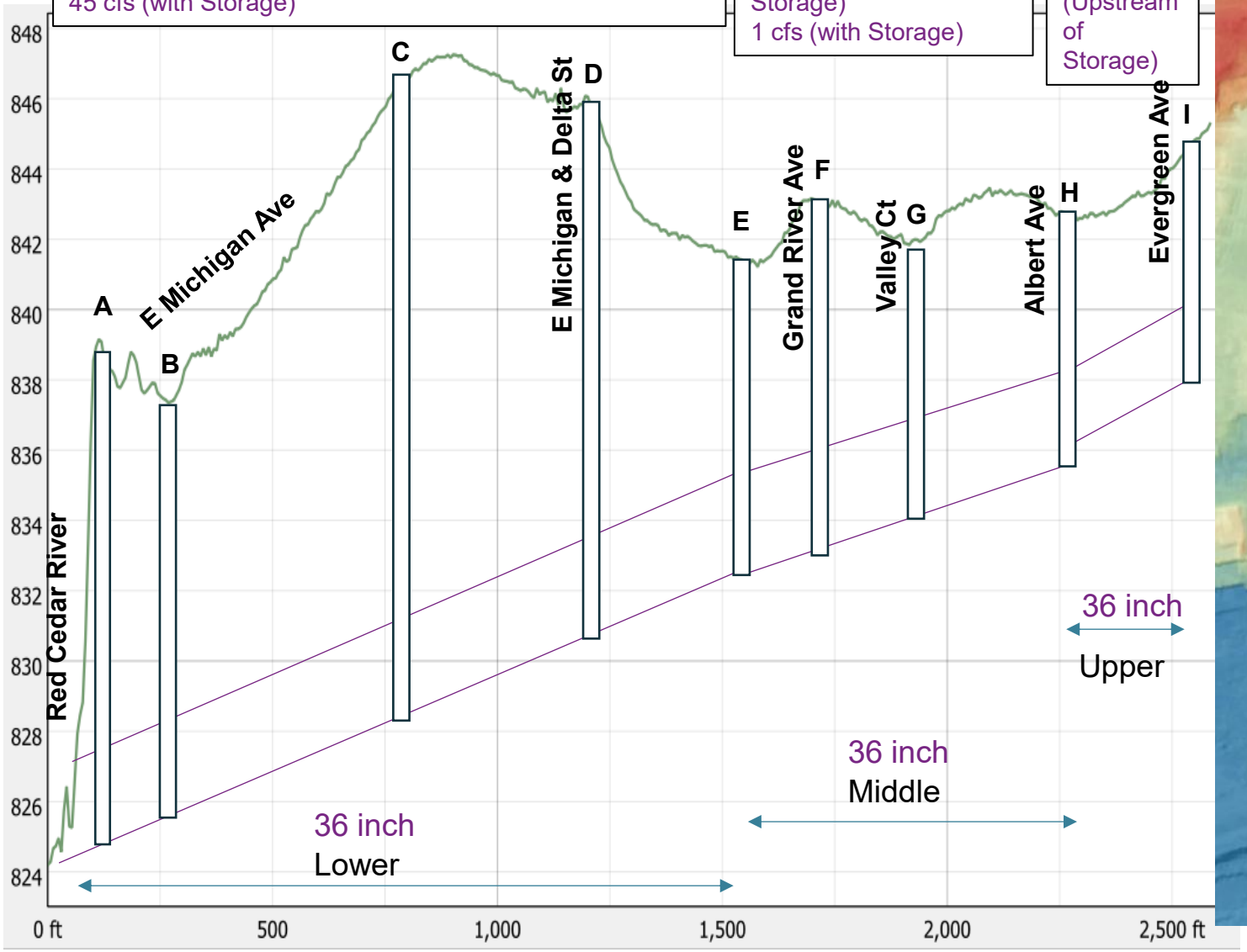
Alt 2c: Required Storm Sewer Main Sizes (with Storage)

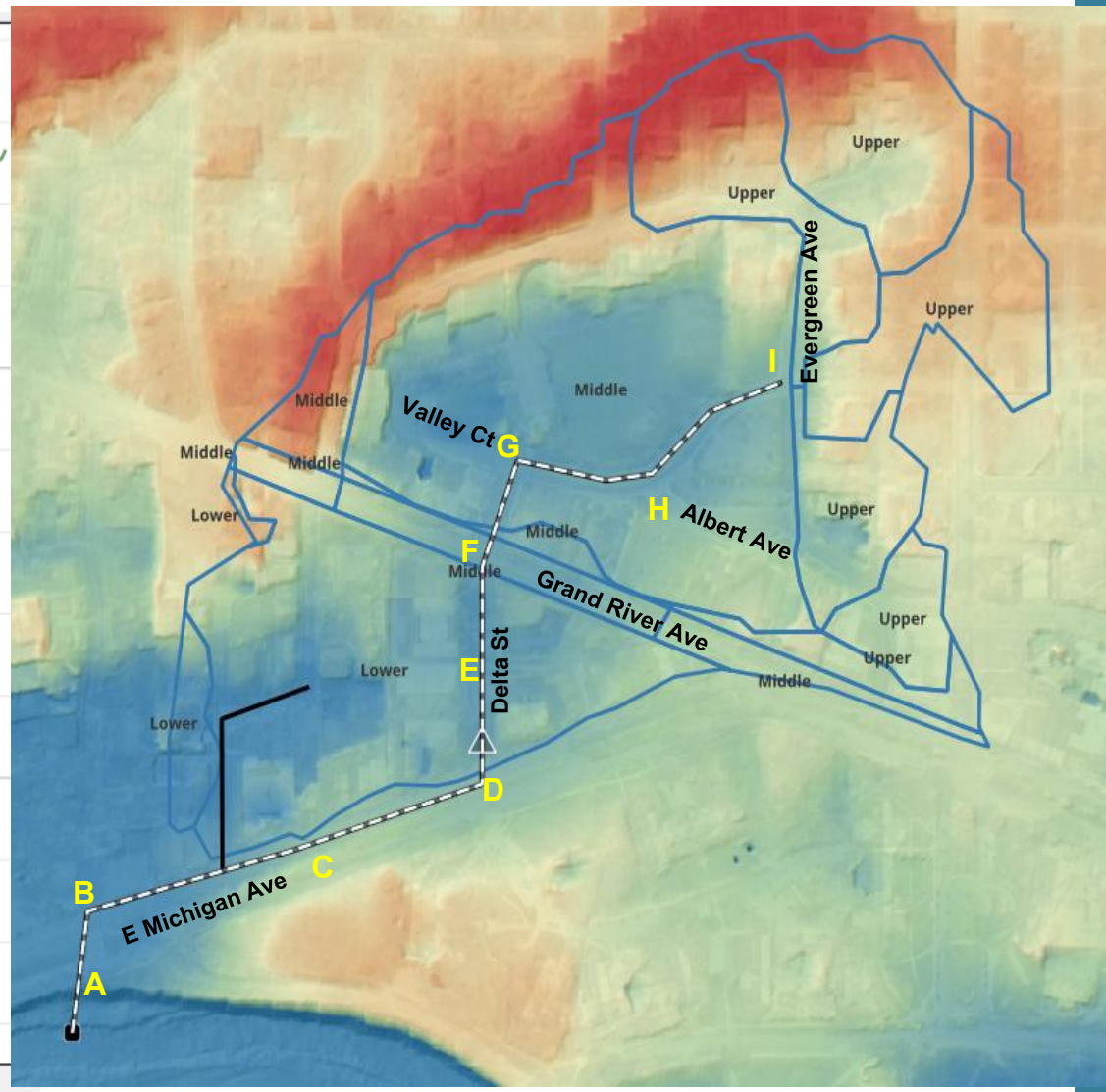
Lower
(E to River) =
177 cfs (without Storage)
45 cfs (with Storage)

Middle
(H to E) =
133 cfs (without Storage)
1 cfs (with Storage)

Upper
(I to H) =
53 cfs (Upstream of Storage)

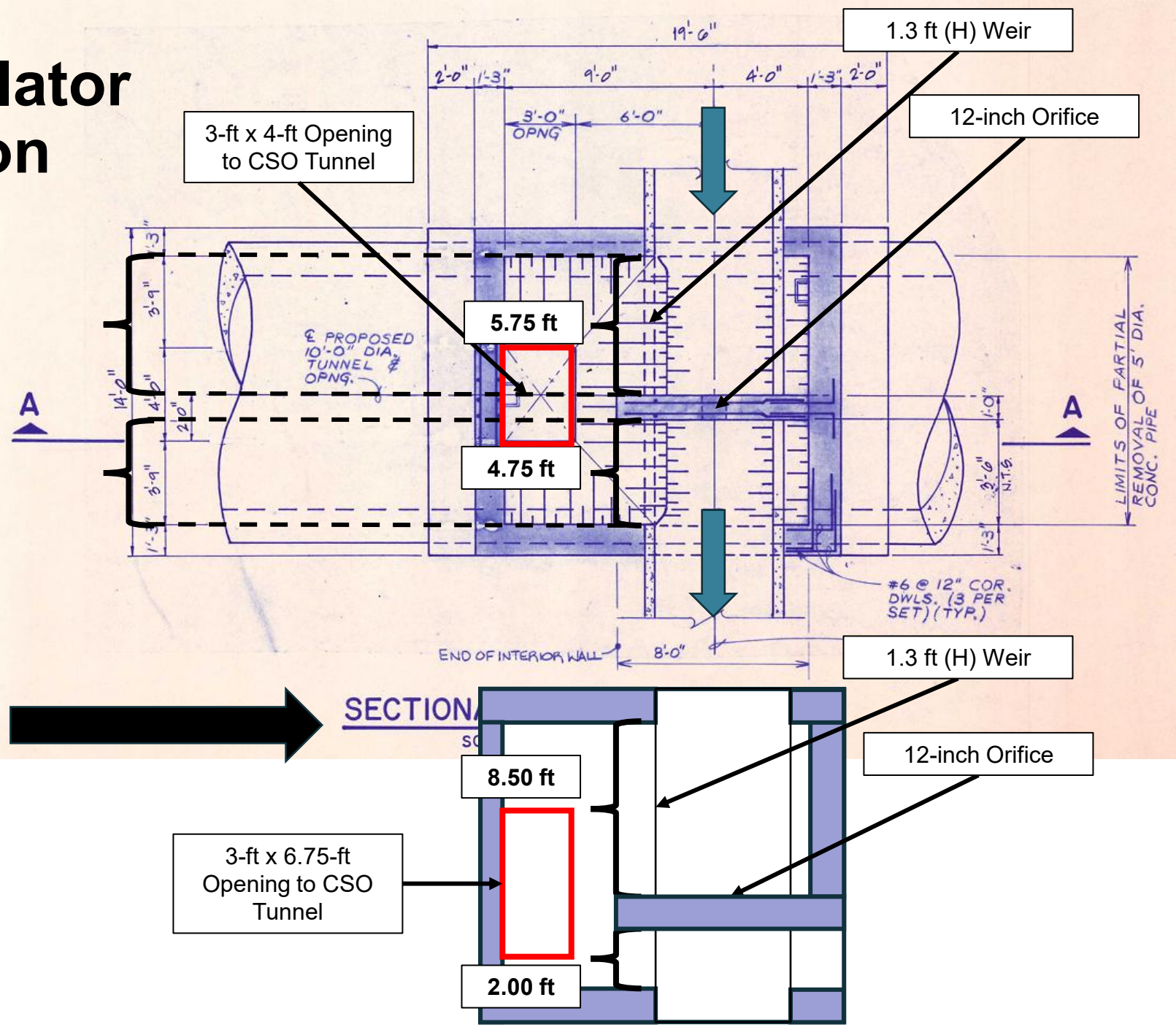
Alt 2b (Future 16-year, 1-hour)





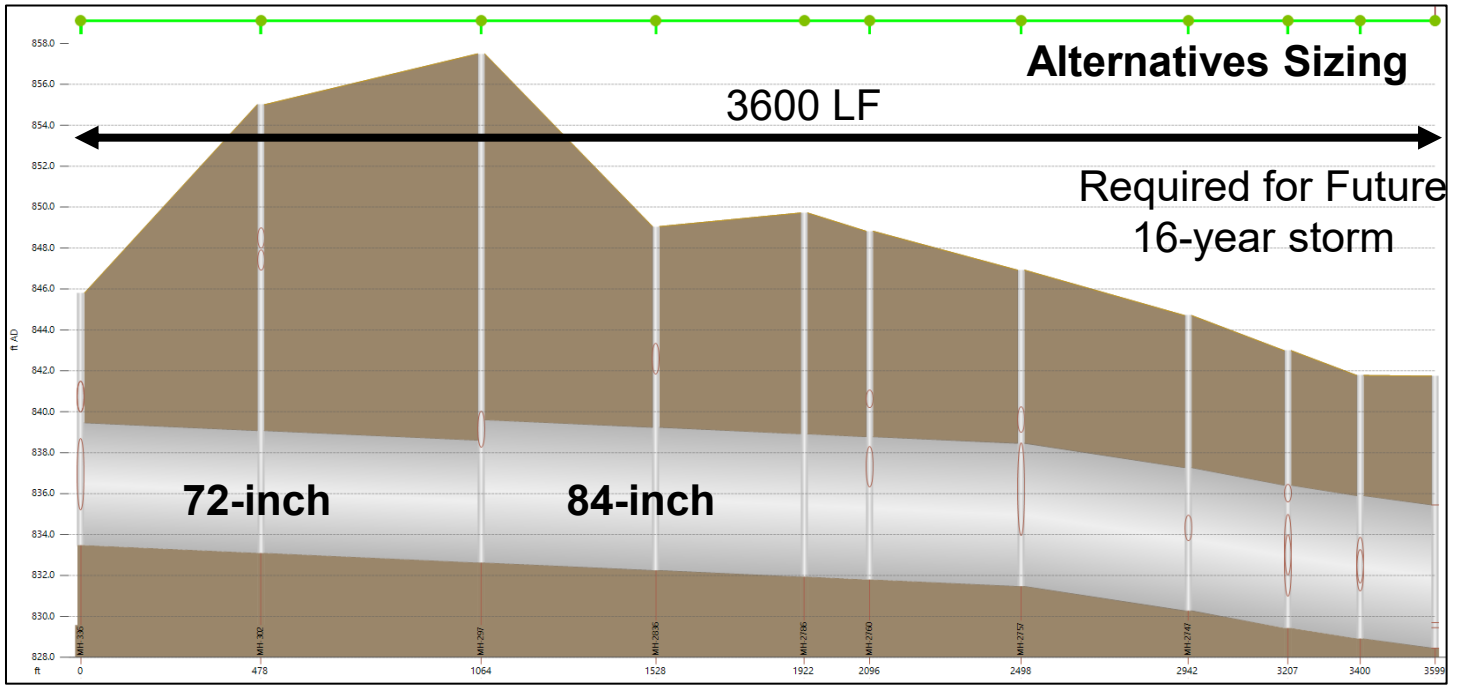
Charles Street Regulator Model Representation

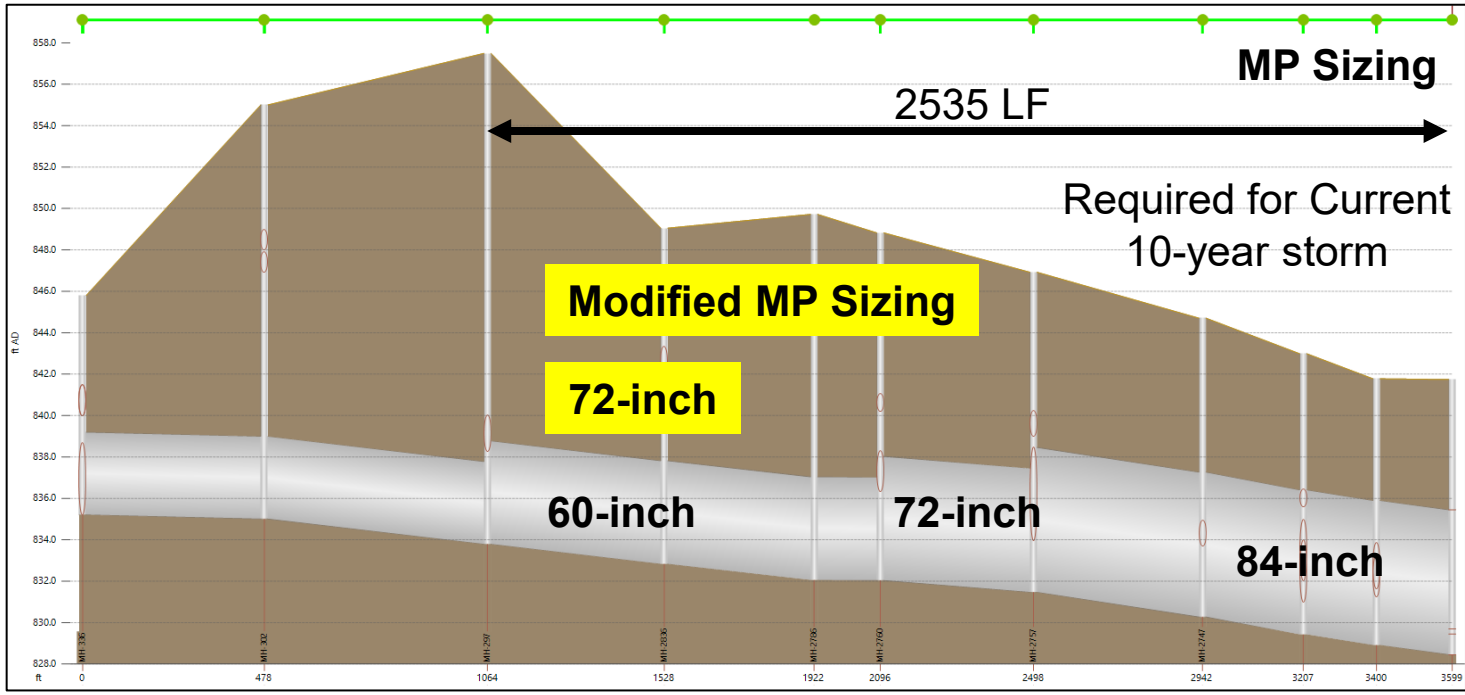
- Reviewed model representation against reference drawing information – Contract No. 2 CSO Control Facilities 1994 Sheet T-15
- Base Condition: Updated weir length from 6.75 ft to 5.75 ft and 3.75 ft to 4.75 ft respectively to match reference drawing.
- Alternative Condition: Structure Modification to increase influent weir length to 8.50 ft and increase drop opening to CSO tunnel, as needed, to accommodate increased weir flow. (Orifice equation).



Charles Street Upsizing Project

- By increasing the weir length at the Charles Street Regulator, Alt 3b & 4b achieves LOS for the Future 16-year design storm along Charles Street.
  - Alt 3 - Areas B, C, E & G Alternatives – Harrison Storm
  - Alt 4 - Areas B, C, E & G Alternatives – Sunset Storm
- Can the Charles Street Upsizing Projects be decreased to the original MP sizing and still meet LOS for the 10-year with regulator modifications under Alt 3a & 4a?
- If 60-inch is upsized to 72-inch, can achieve 10-year, 1-hour LOS. (Modified MP Sizing).





Charles Street Regulator
HGL Impact Summary

- Below summary table compares HGL at the Charles Street Regulator under several conditions.

Alt 3 Projects 10-year

Scenario	Storm	HGL at A0041 (Charles Street Regulator)	
Base	10-year	834.71	
Base (Updated respresentation)	10-year	834.97	Diff from Updated Base
Alternative 3a - Harrison	10-year	839.10	4.1
Alternative 3b - Harrison	10-year	835.30	0.3
Alternative 3a - Harrison + Reg Mod	10-year	834.81	-0.2
Alternative 3b - Harrison + Reg Mod	10-year	833.44	-1.5

Alt 4 Projects 10-year

Scenario	Storm	HGL at A0041 (Charles Street Regulator)	
Base	10-year	834.71	
Base (Updated respresentation)	10-year	834.97	Diff from Updated Base
Alternative 4a - Sunset	10-year	838.96	4.0
Alternative 4b - Sunset	10-year	835.30	0.3
Alternative 4a - Sunset + Reg Mod	10-year	834.80	-0.2
Alternative 4b - Sunset + Reg Mod	10-year	834.19	-0.8

Alt 3 Projects Future 16-year

Scenario	Storm	HGL at A0041 (Charles Street Regulator)	
Base	16-year	836.36	
Base (Updated respresentation)	16-year	836.97	Diff from Updated Base
Alternative 3a - Harrison	16-year	841.69	4.7
Alternative 3b - Harrison	16-year	840.38	3.4
Alternative 3a - Harrison + Reg Mod	16-year	839.32	2.4
Alternative 3b - Harrison + Reg Mod	16-year	835.61	-1.4

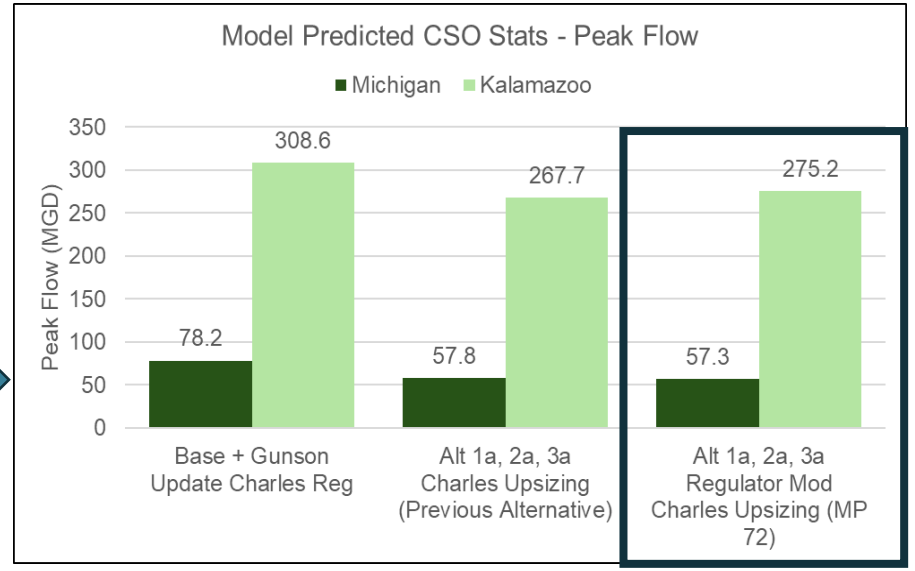
Alt 4 Projects Future 16-year

Scenario	Storm	HGL at A0041 (Charles Street Regulator)	
Base	16-year	836.36	
Base (Updated respresentation)	16-year	836.97	Diff from Updated Base
Alternative 4a - Sunset	16-year	841.68	4.7
Alternative 4b - Sunset	16-year	840.20	3.2
Alternative 4a - Sunset + Reg Mod	16-year	839.23	2.3
Alternative 4b - Sunset + Reg Mod	16-year	835.77	-1.2

Preliminary CSO Analysis Results (Current 10-year) Charles Regulator

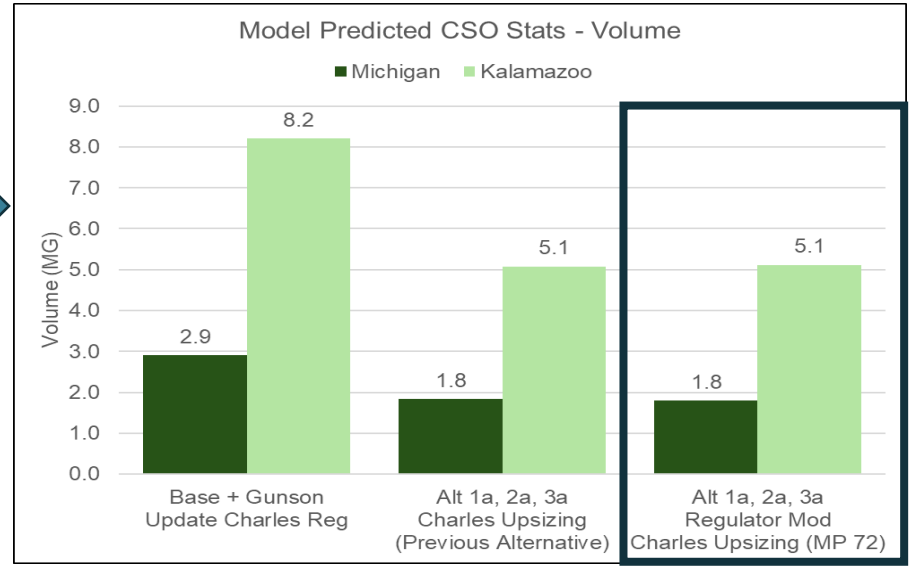
Peak Flow (MGD)

Outfall Location	Current Condition + Gunson	With CSS Alternatives 1a, 2a, 3a	With Alternative 1a, 2a, 3a + Charles Reg Mod
Michigan	78.2	57.8	57.3
Kalamazoo	308.6	267.7	275.2



Volume (MG)

Outfall Location	Current Condition + Gunson	With CSS Alternatives 1a, 2a, 3a	With Alternative 1a, 2a, 3a + Charles Reg Mod
Michigan	2.9	1.8	1.8
Kalamazoo	8.2	5.1	5.1

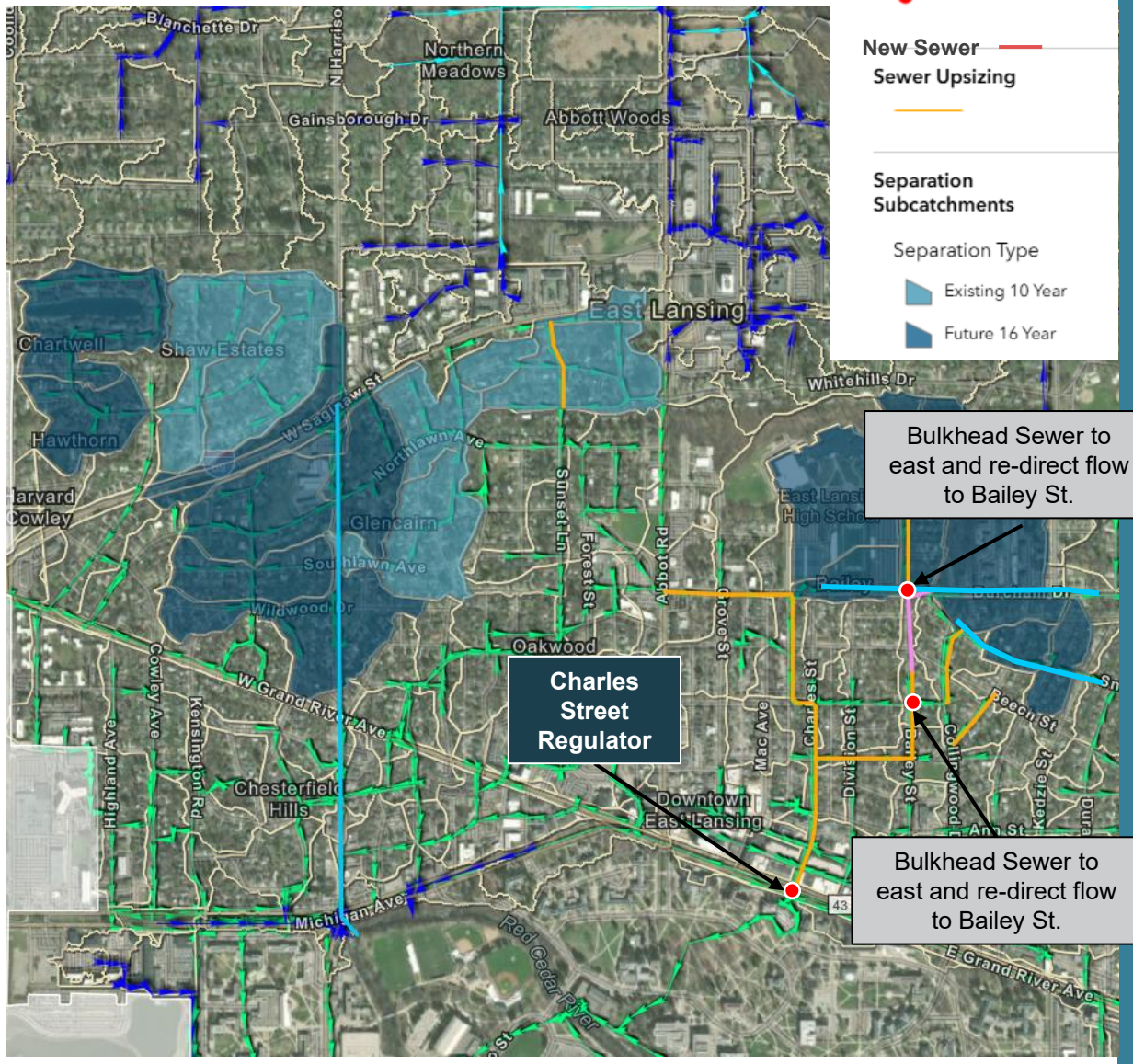


If the Charles Street Regulator weir length is increased to 8.5 ft with Alternative Projects, CSO peak flow and volume remain decreased compared to the base condition.

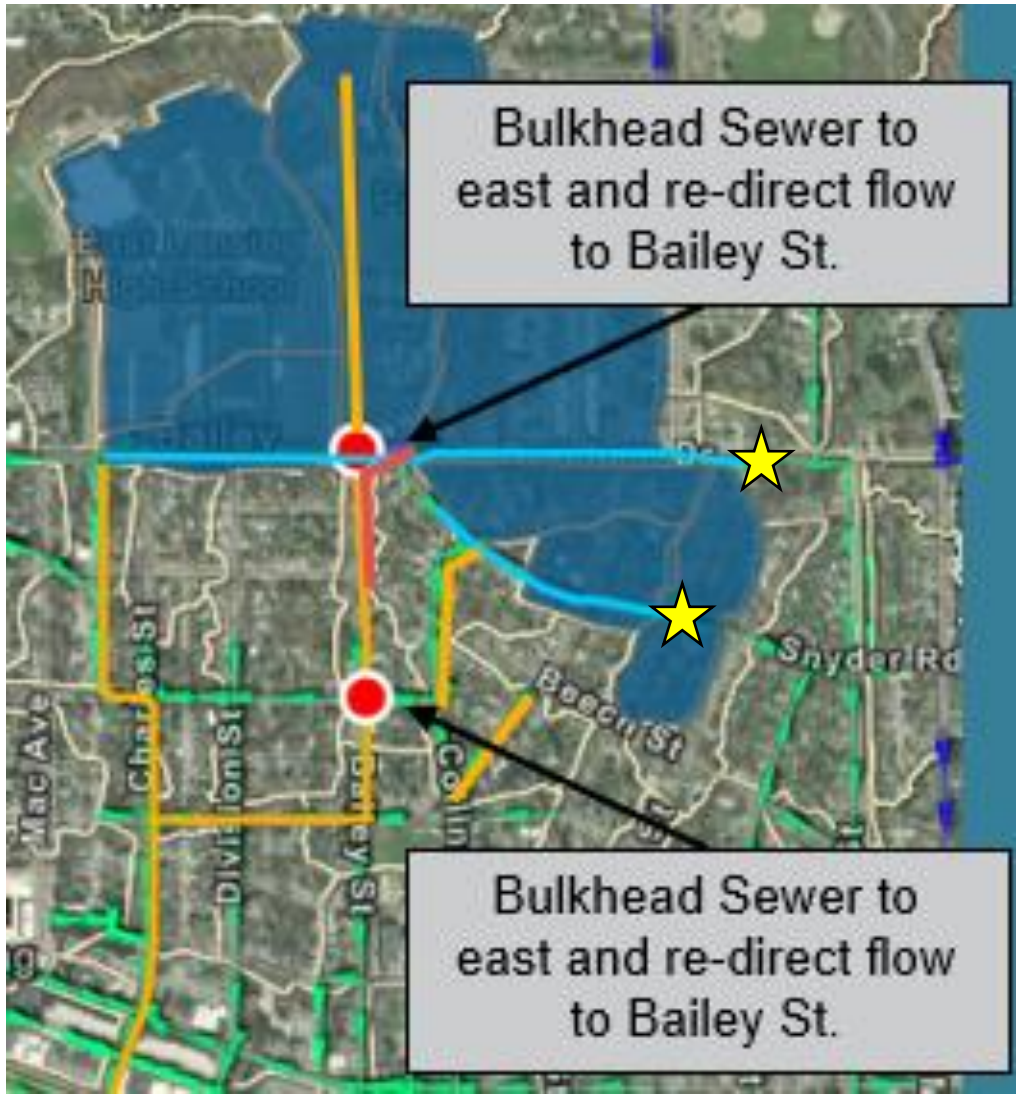
Areas B, C, E & G Alternatives – Harrison Storm

Concern Area	Alt	Proposed Project(s)
B, C, E & G – Harrison Storm	**3a**	• 91.7 ac of storm separation • 5,200 ft of new storm main (max depth ~35-40 ft) • 7,100 ft of combined sewer upsizing (includes Charles Street with modified MP sizing) • 875 ft of new combined sewer • 2 sewer bulkheads • 1 Regulator modification – increase weir length to 8.5 ft
	3b	• 3a plus additional 192.5 ac of storm separation (total 284.2 ac) • Plus an additional 3,300 ft of new storm main (max depth ~10-15 ft) • Increased storm main sizing • Increased Charles St upsize, and additional 1065 ft of upsizing
	3c	• 3a or 3b plus Gordon Guyer and Glencairn Park storage

Results assume Area A improvements downstream of Area B



Areas E & G: Alt 3b Storm Pipe (Tie into Gunson St Storm Sewer)



Alt 3b Future 16-year Separation Project:

★ Connect with existing Gunson St. Storm Sewer:

- Burcham Dr. 24-inch storm
- Snyder Rd. 15-inch storm (becomes 24-inch at Kedzie St.)

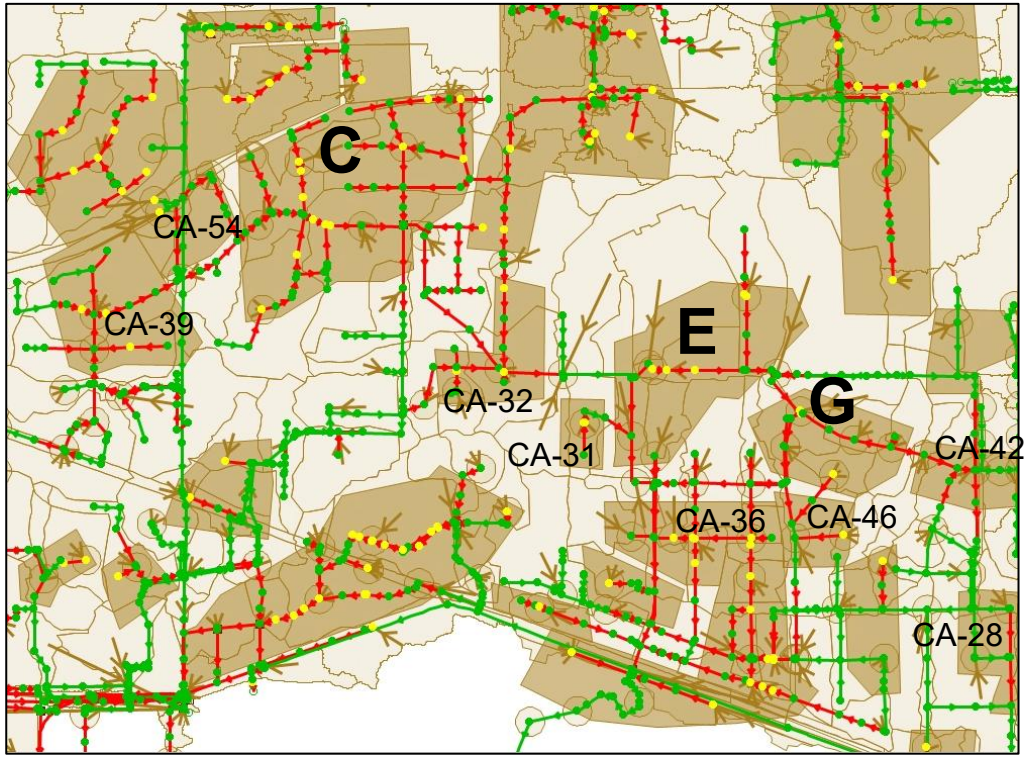
Available capacity within Gunson St. storm sewer needs to be verified to see if it can accept additional flows.

Same as Alt 4b Future 16-year Separation Project, next alternative.

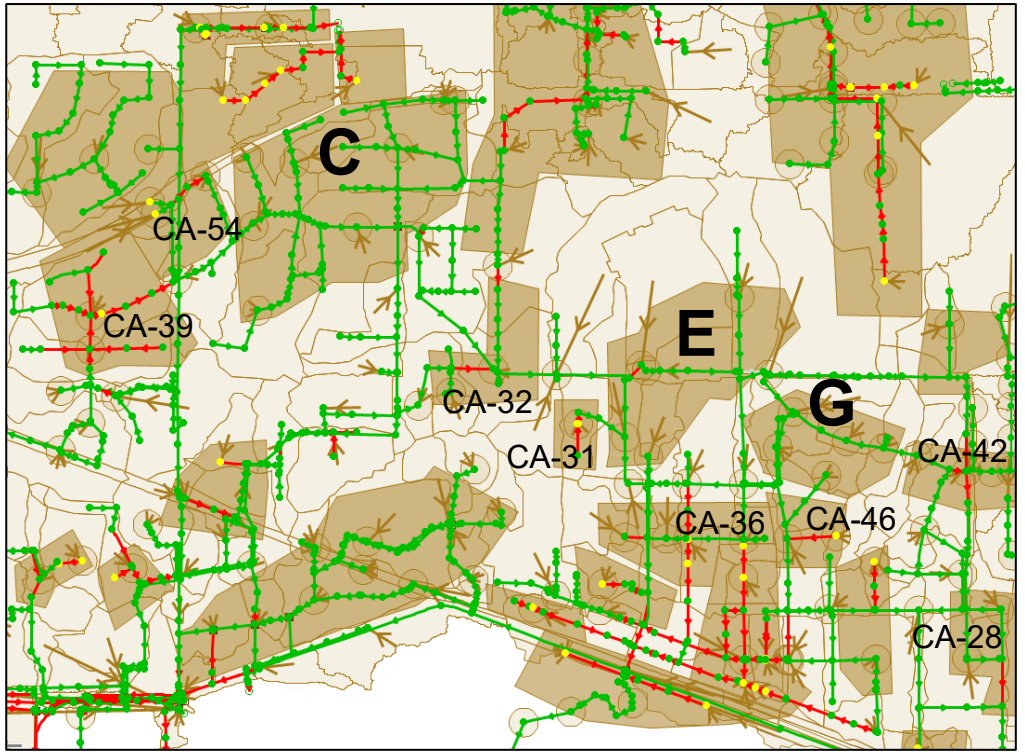
Area B, C, E & G: Alt 3a – Harrison Storm

LOS Results for Current 10-year, 1-hour Storm

Without Alt



With Alt 3a



CSS Level of Service

Conduits

- LOS Achieved
- Exceeds LOS

Nodes

- No MH Flooding
- MH Flooding

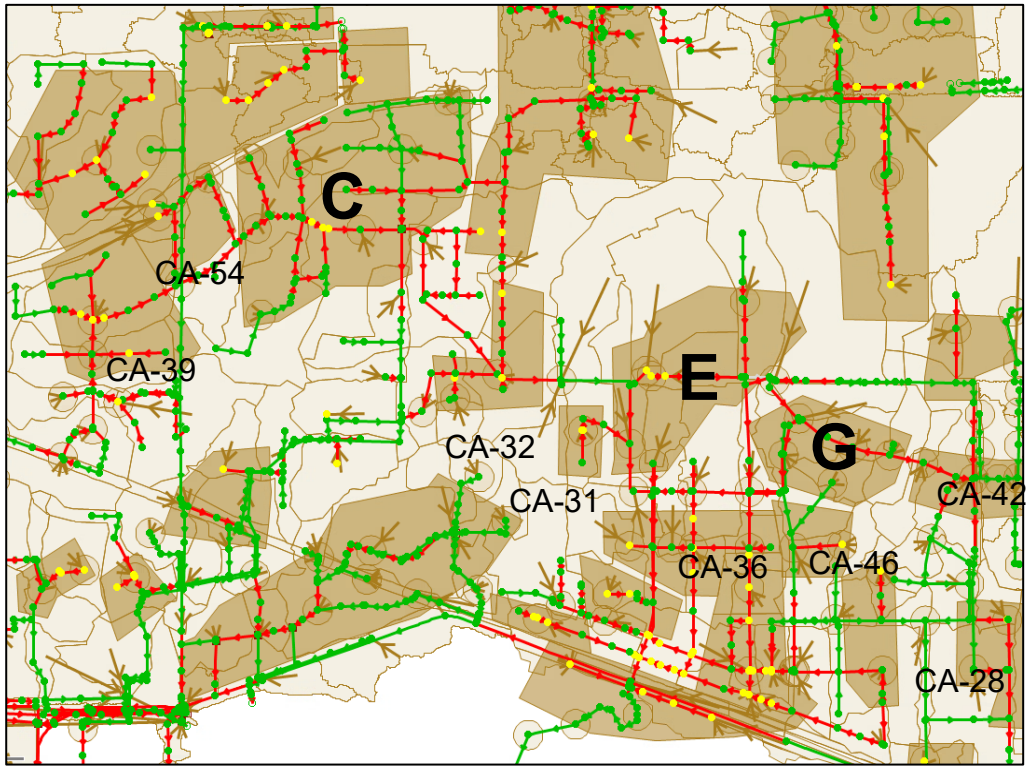
Key Takeaways:

- Alt 3a achieves Current 10-year LOS in Areas C, E and G.
- Alt 3a also benefits CA-54, CA-39, CA-32, CA-31, CA-36, CA-42, CA-46, and CA-28.

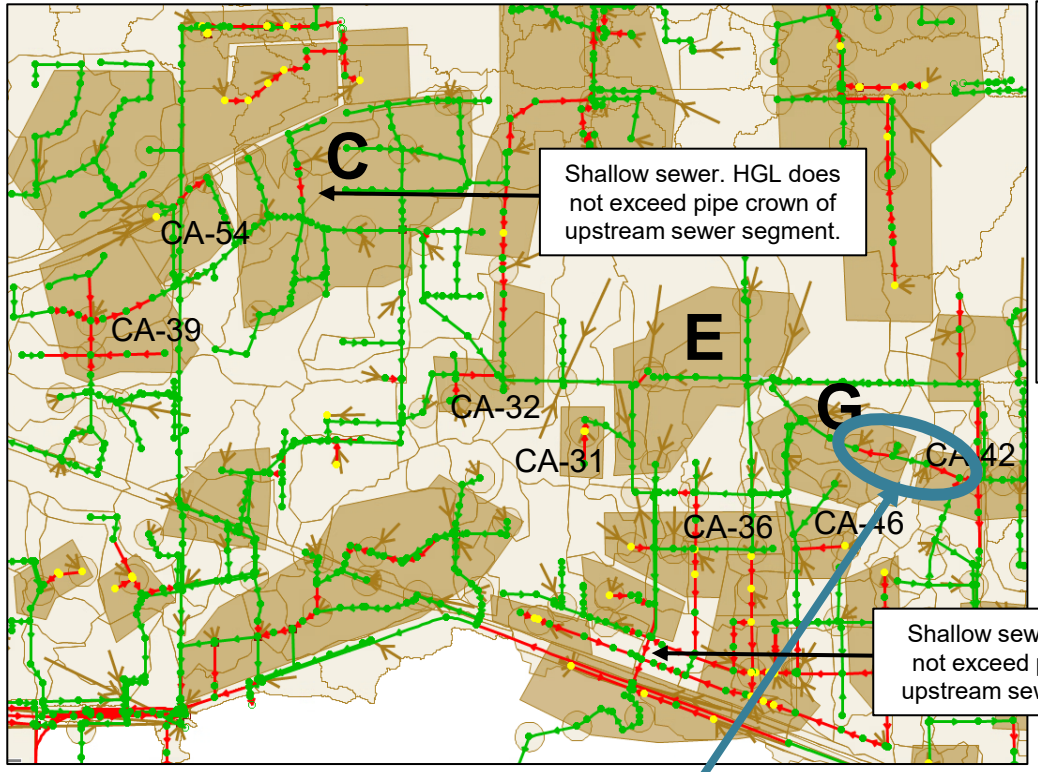
Area B, C, E & G: Alts 3a & 3b – Harrison Storm

LOS Results for Future 16-year, 1-hour Storm

With Alt 3a



With Alt 3b



CSS Level of Service

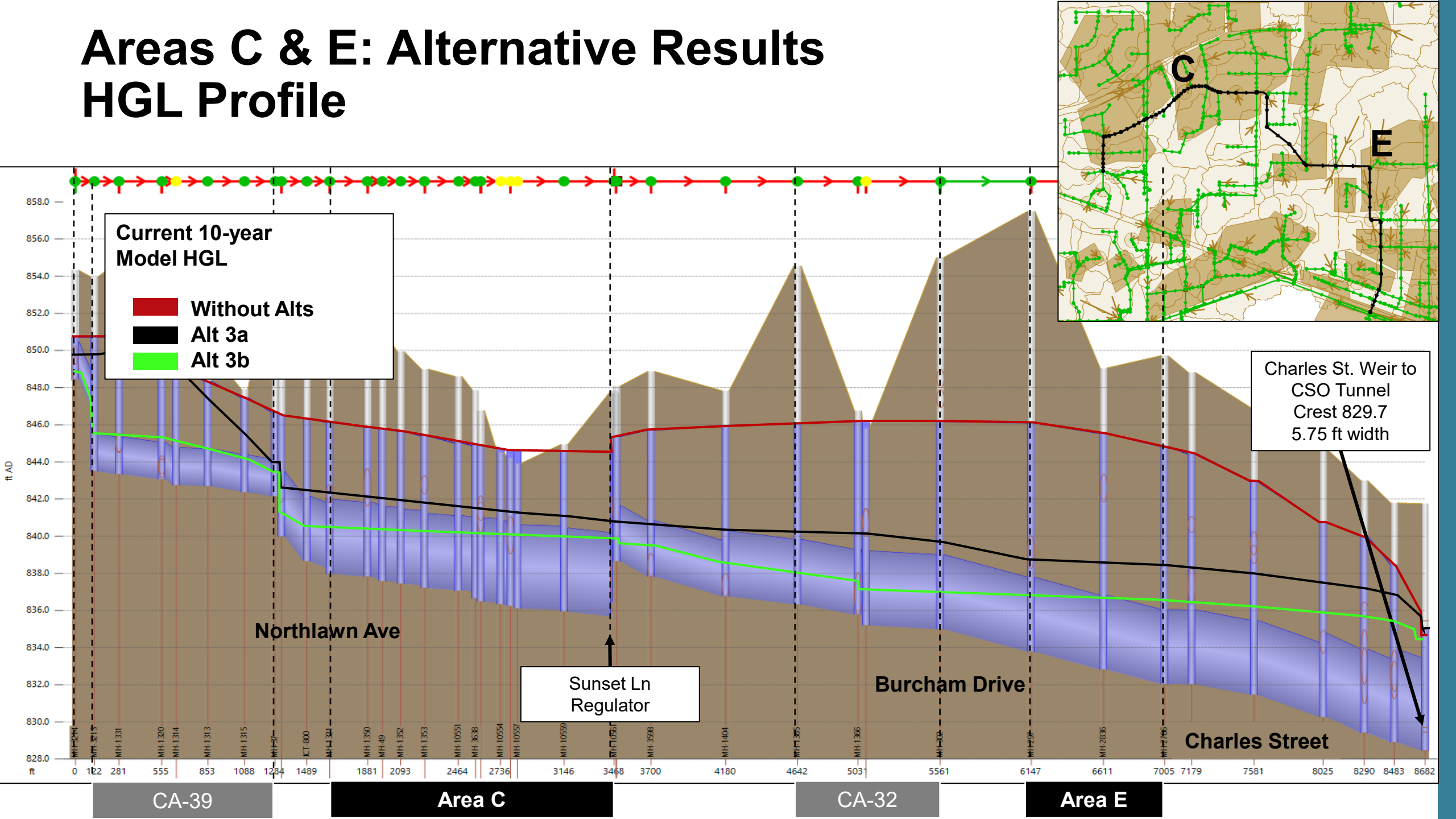
Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

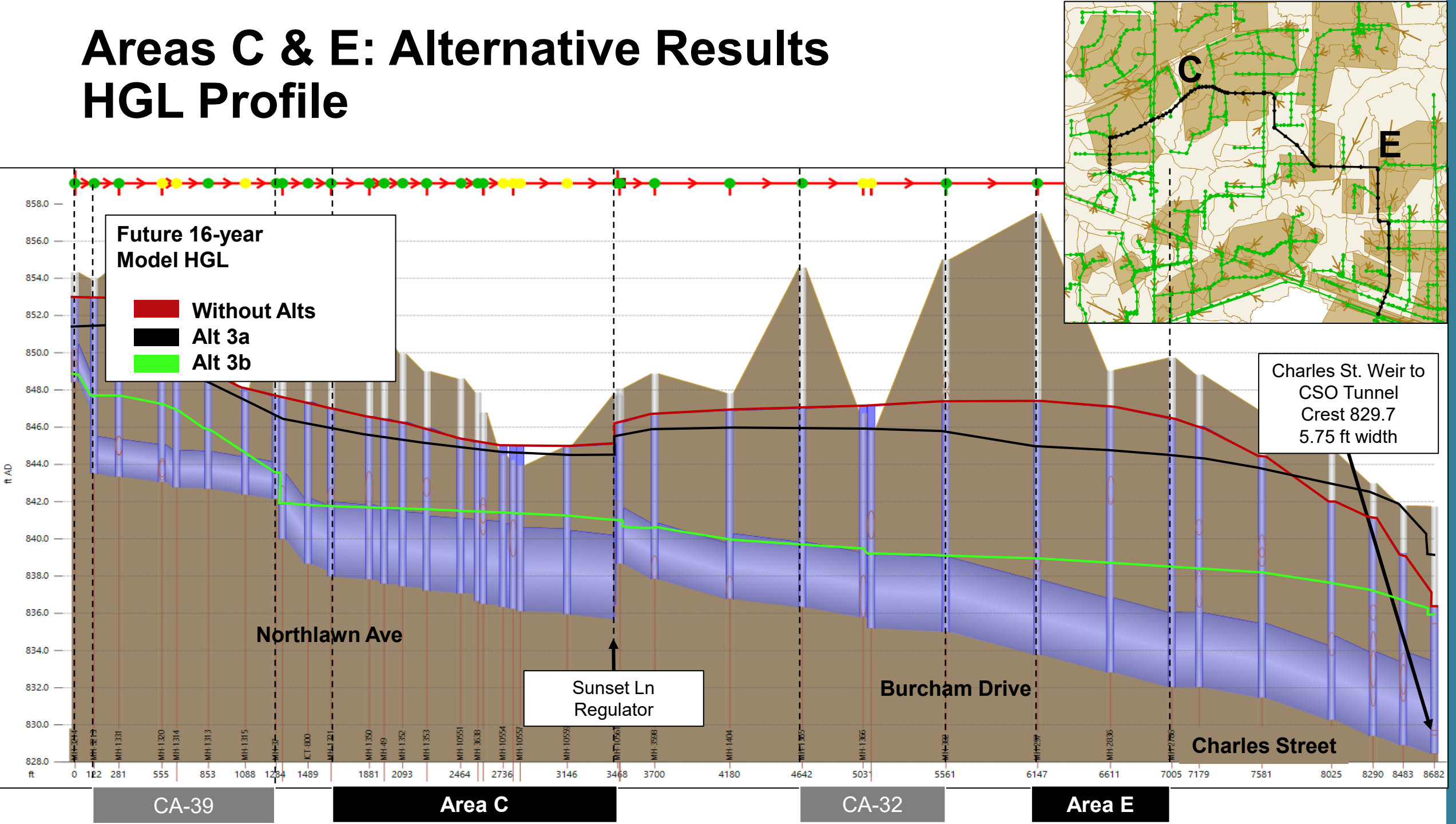
Key Takeaways:

- Alt 3a does not achieve Future 16-year LOS in Areas C, E and G.
- Alt 3b achieves Future 16-year LOS in Areas C and E
  - Conduits not achieving LOS in Area G is due to lack of capacity within mainline sewer on Gunson St.
- Alt 3b benefits CA-54, CA-39, CA-32, CA-31, CA-36, CA-42, and CA-46.

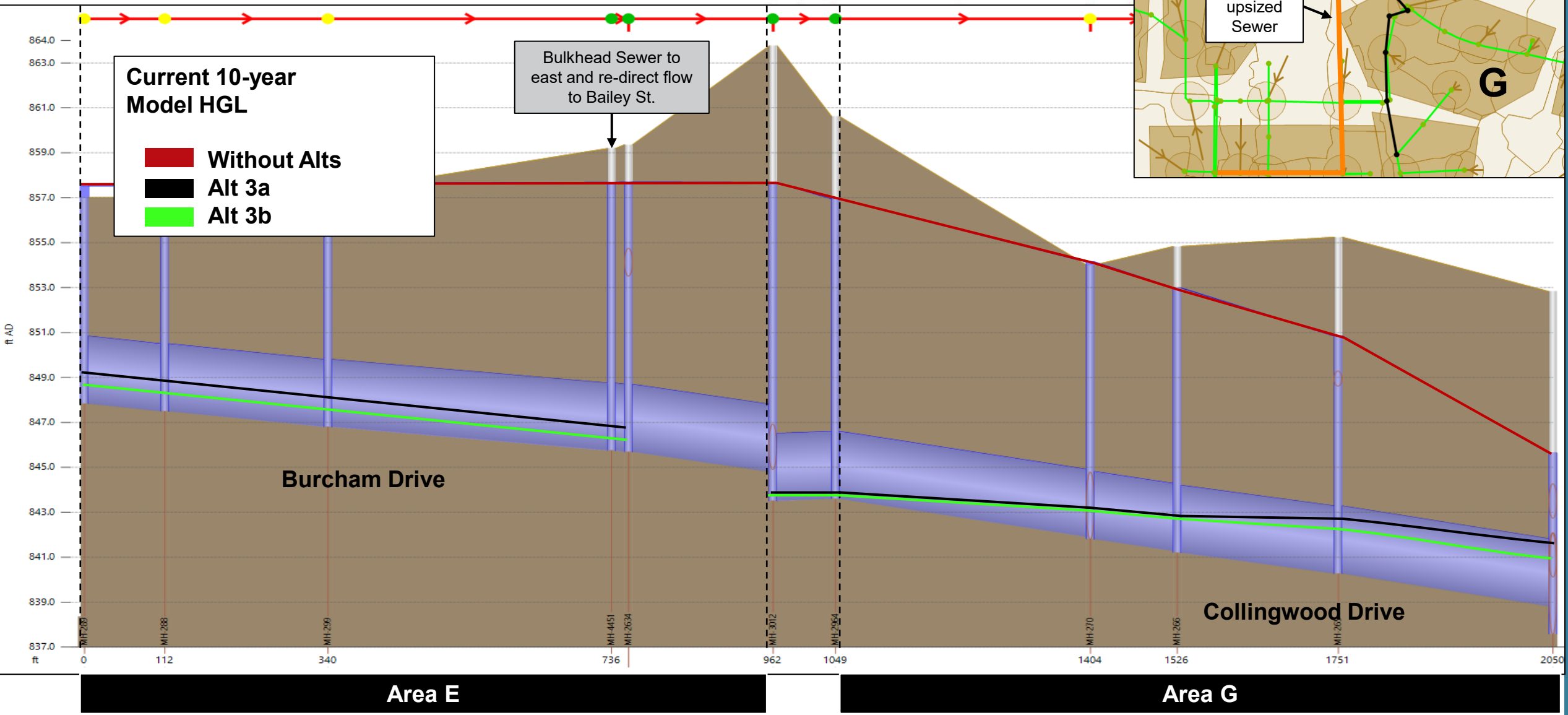
Areas C & E: Alternative Results
HGL Profile

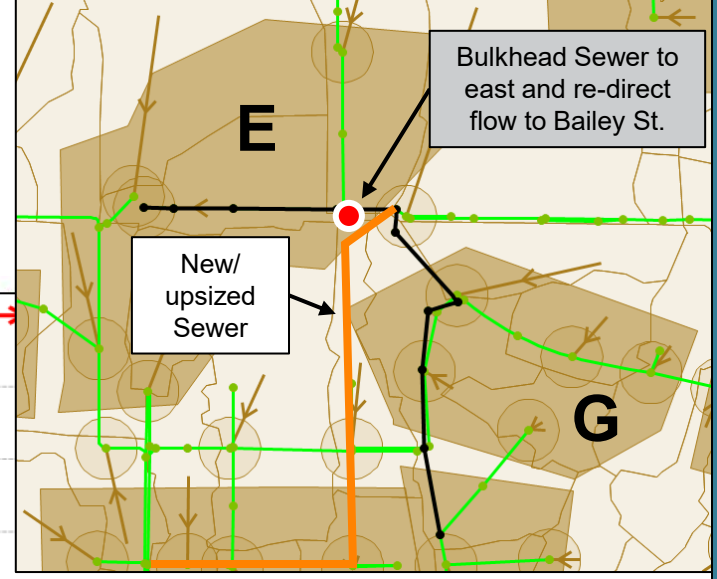


Areas C & E: Alternative Results
HGL Profile

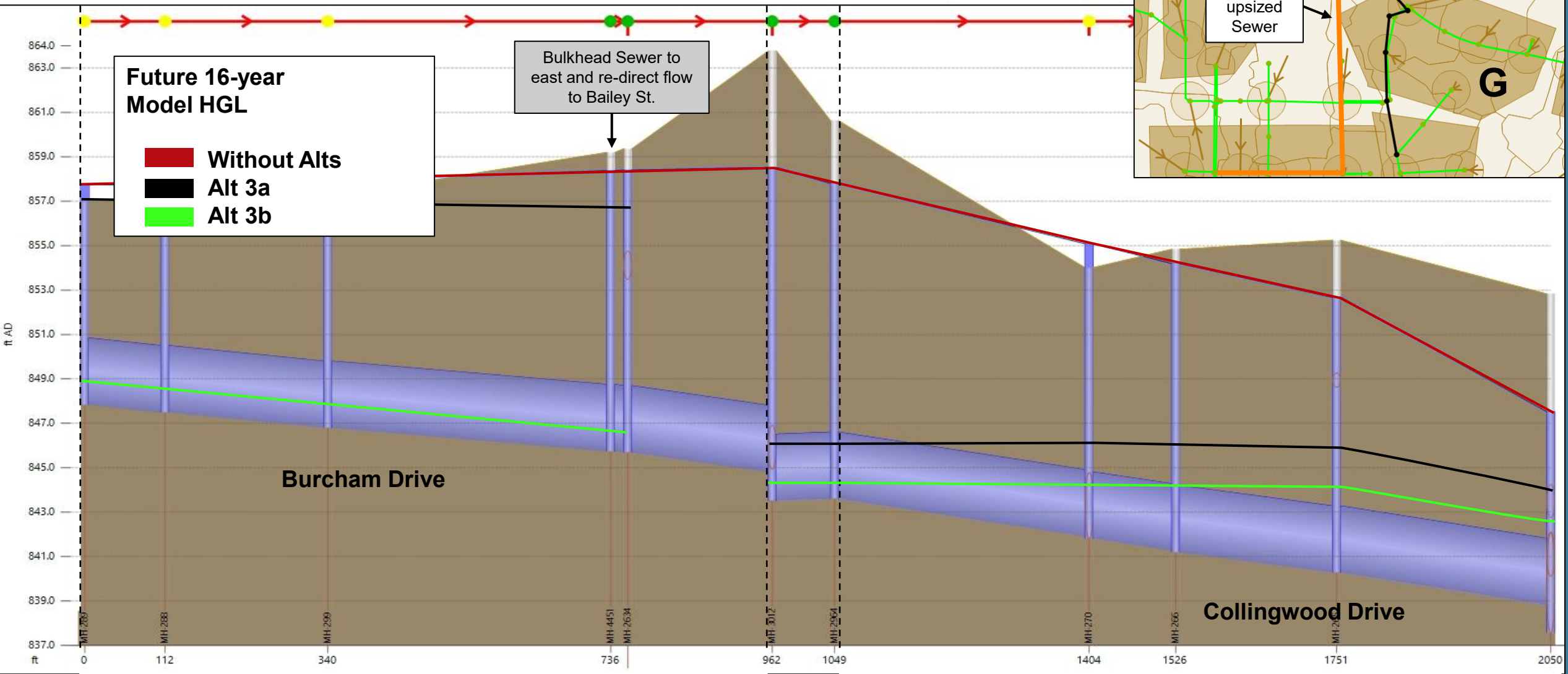


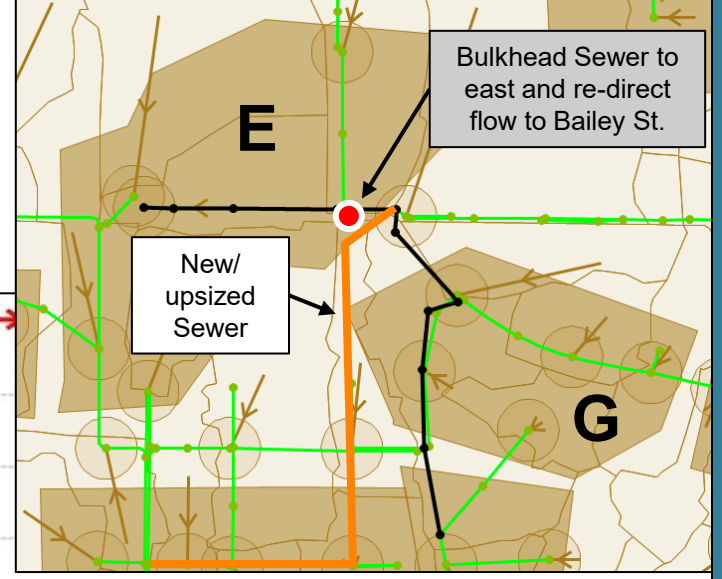
Areas E & G: Alternative Results HGL Profile





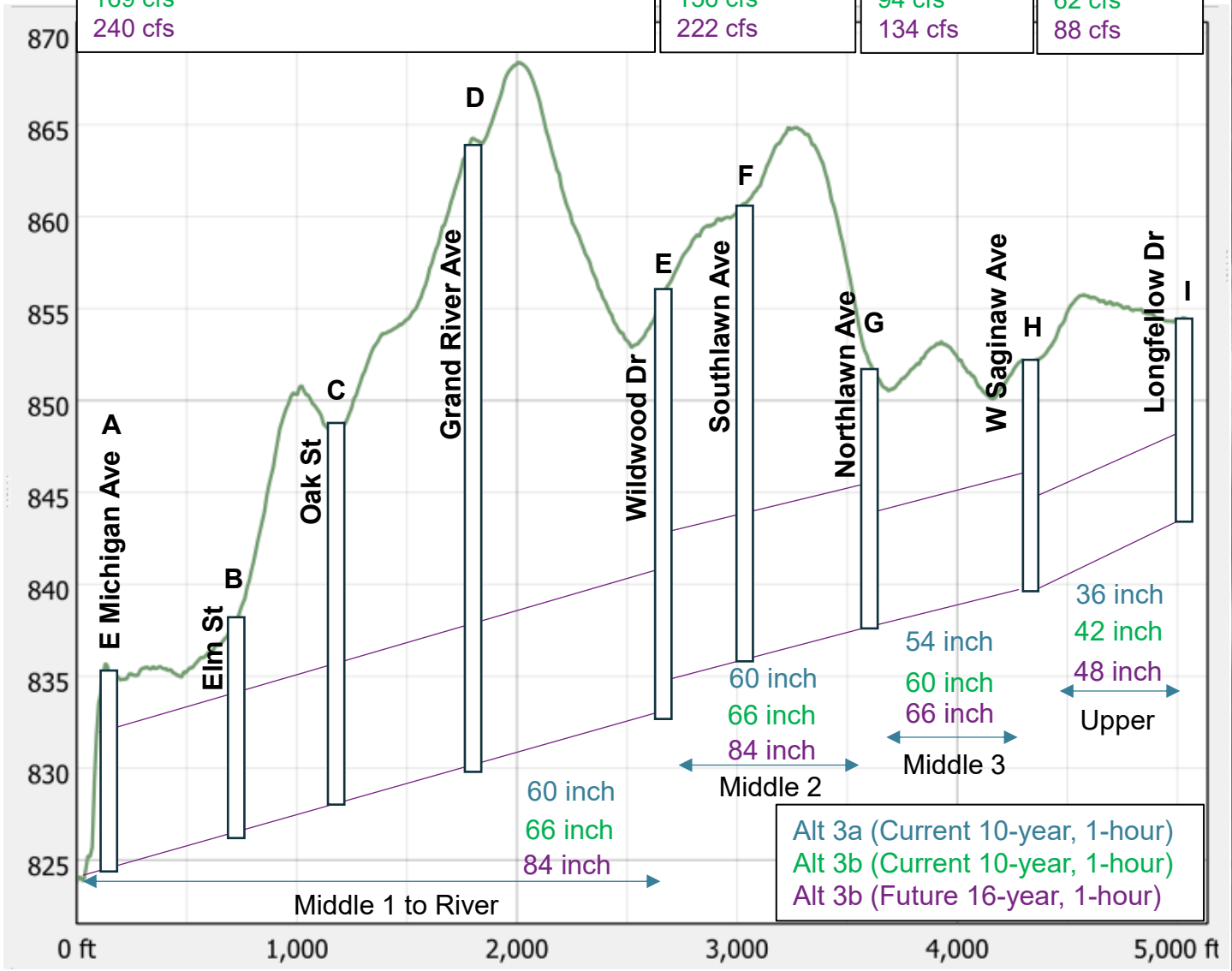
Areas E & G: Alternative Results HGL Profile

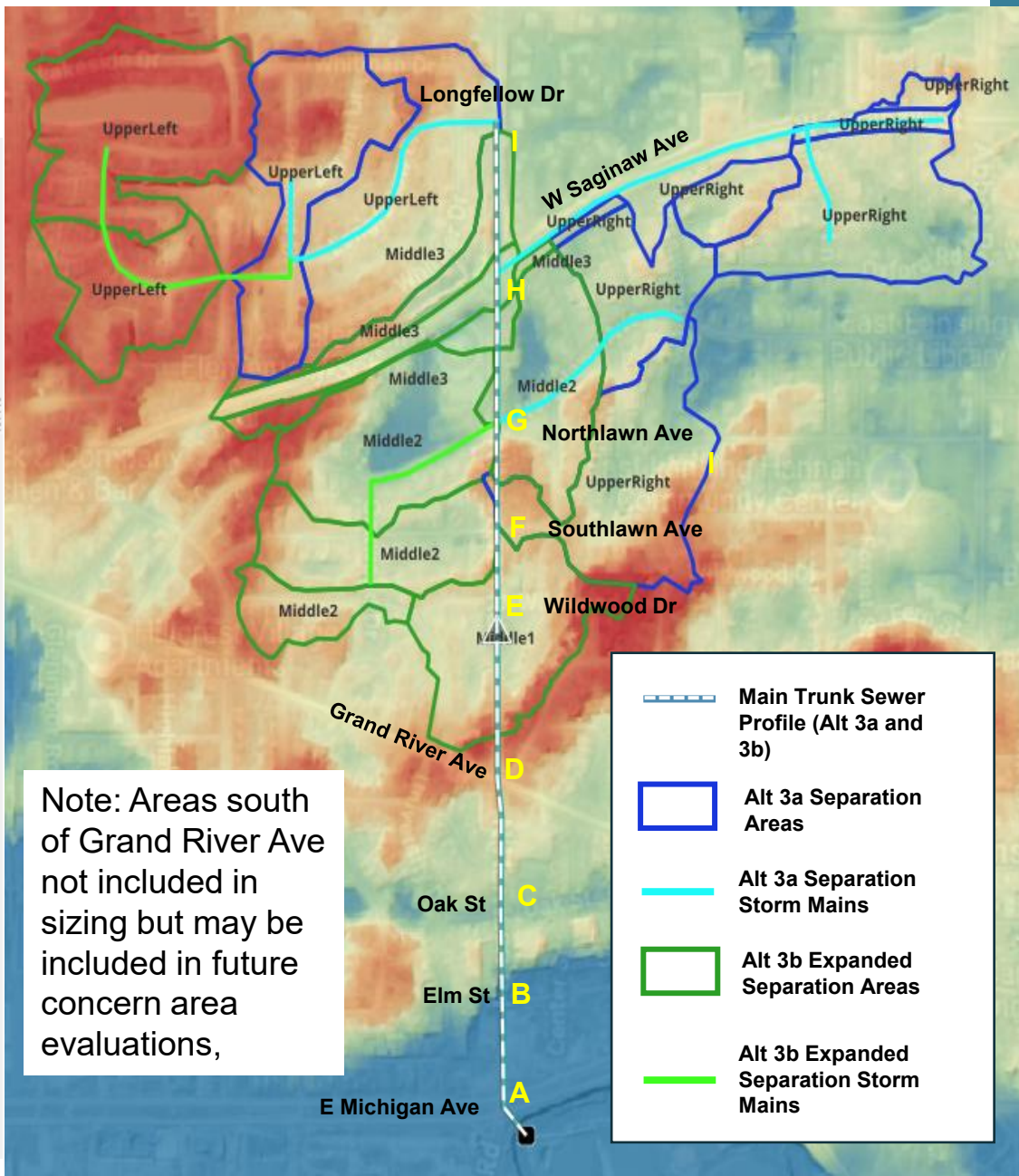




Alts 3a & Alt 3b: Required Storm Sewer Main Sizes

Middle1 to River (E to River) =	Middle2 (G to E) =	Middle3 (H to G) =	Upper (I to H) =
100 cfs	100 cfs	75 cfs	42 cfs
169 cfs	156 cfs	94 cfs	62 cfs
240 cfs	222 cfs	134 cfs	88 cfs

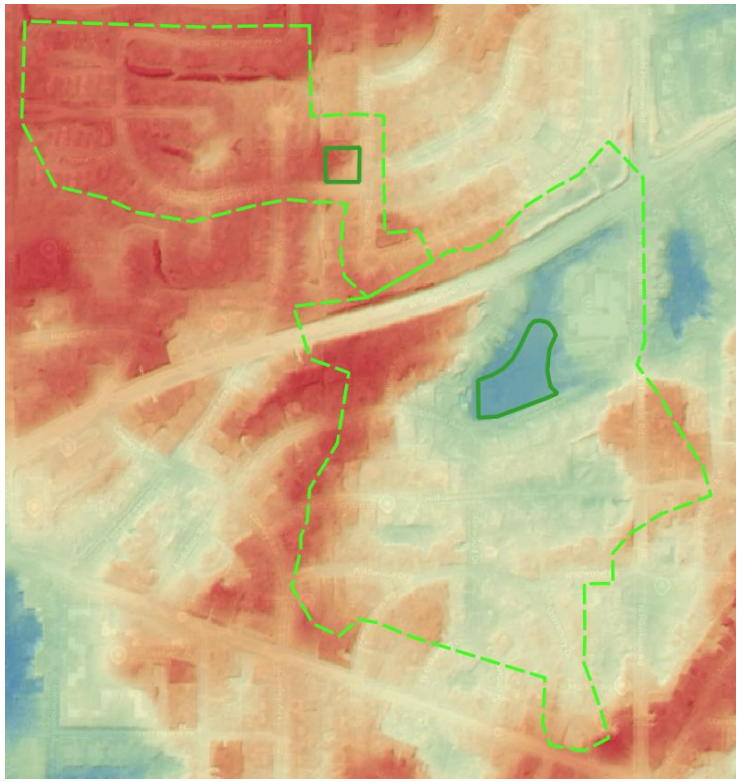




Area B, C, G, E: Alt 3c Resilience Opportunities

Total Calculated Peak Flow Reduction for Future 16-year Storm from Both Parks =

66 cfs





Increased LOS with the Alt 3c Resilience Opportunity

- ~66 cfs benefit to downstream system with storage at Gordon Guyer Park and Glencairn Park
  - Increase LOS from current 10-year to ~35-year
  - Increase LOS from future 16-year to ~37-year

Rainfall (inches)	Return Period (Years)		Peak Flow CFS		
	Current Day	2100 High Emissions	Area D	With Glencairn, Shaw, Hannah Storage	
1.40	2	1	150		
1.61	3	1	186		
1.92	8	3	244		
2.00	10	3	212	278	+66 cfs
2.18	17	5	242		
2.44	38	10	286		
2.54	50	16	303	369	+66 cfs
2.77	100	25	345		
3.05	200	50	396		
3.23	500	100	448		

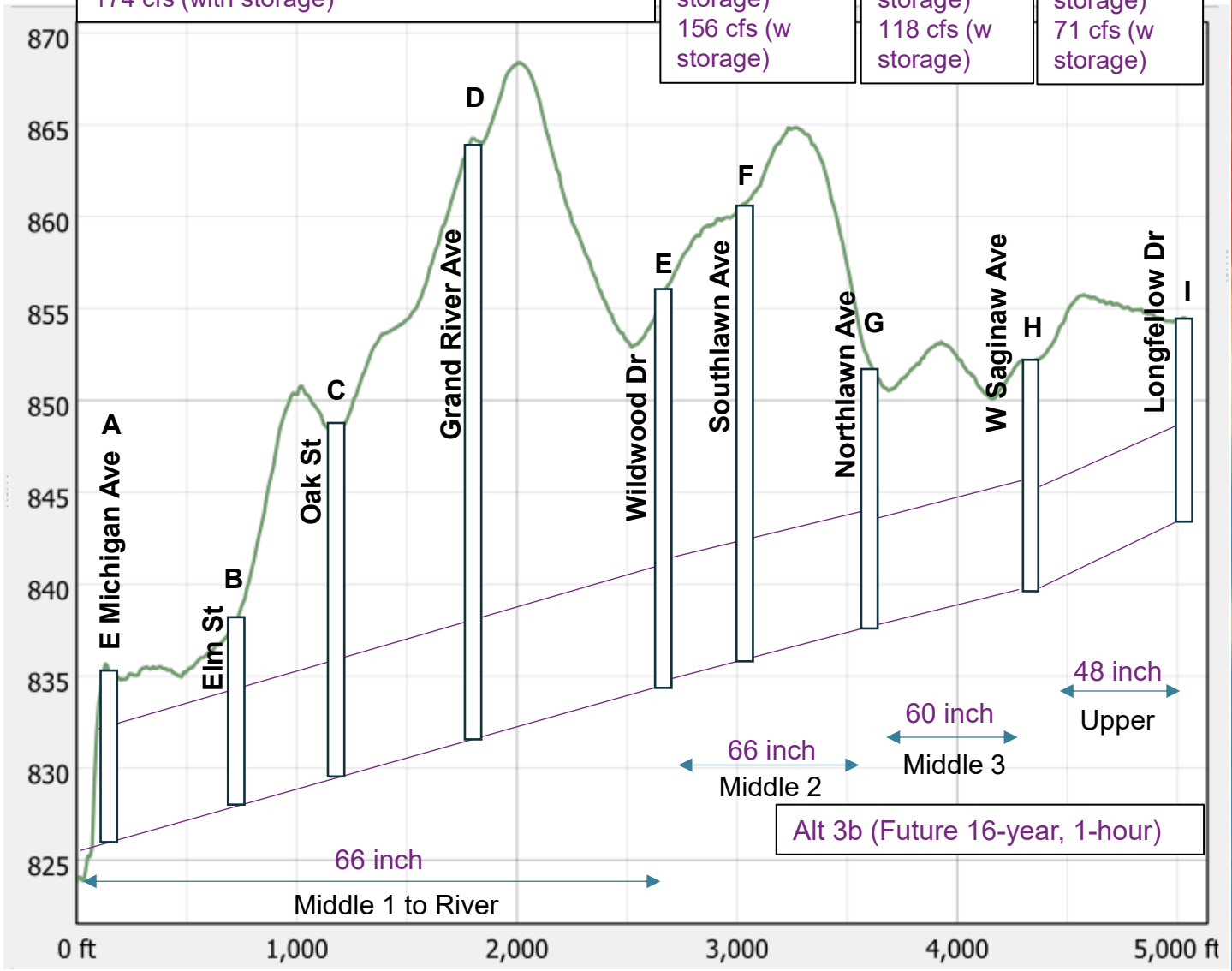
Alt 3c: Required Storm Sewer Main Sizes

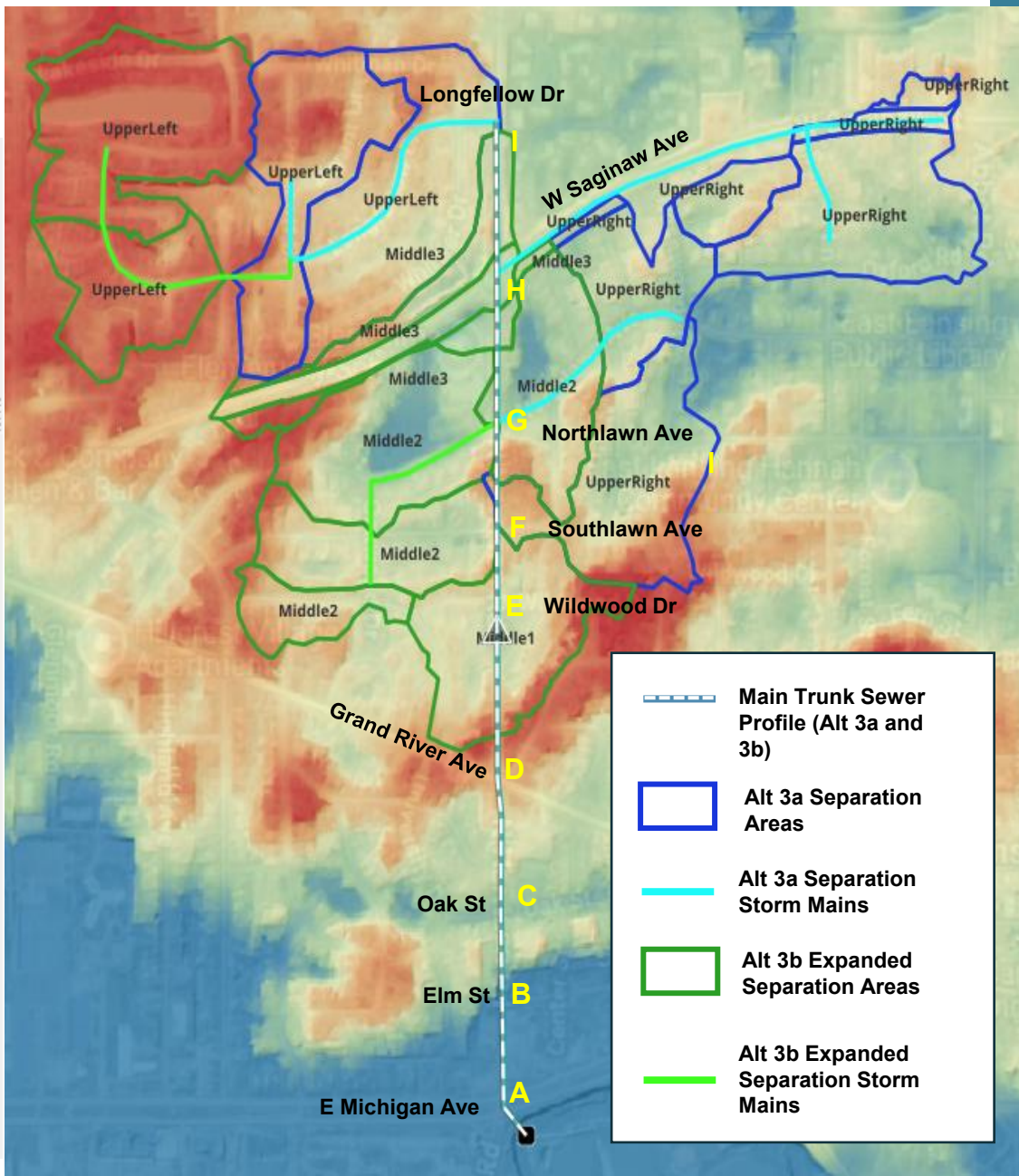
Middle1 to River
(E to River) =
240 cfs (without storage)
174 cfs (with storage)

Middle2
(G to E) =
222 cfs (w/o storage)
156 cfs (w storage)

Middle3
(H to G) =
134 cfs (w/o storage)
118 cfs (w storage)

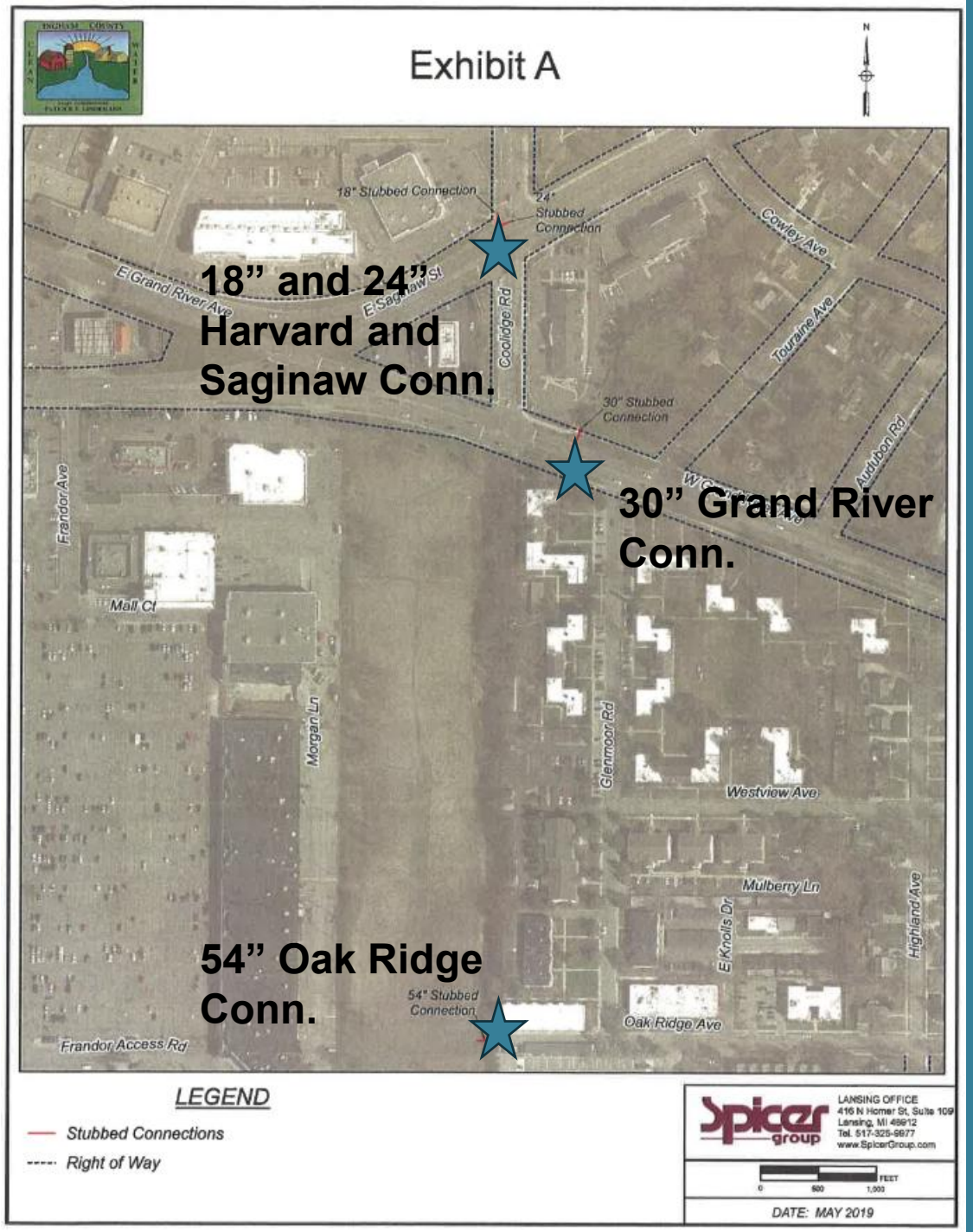
Upper
(I to H) =
88 cfs (w/o storage)
71 cfs (w storage)





Storm Separation Connections to Ranney Park

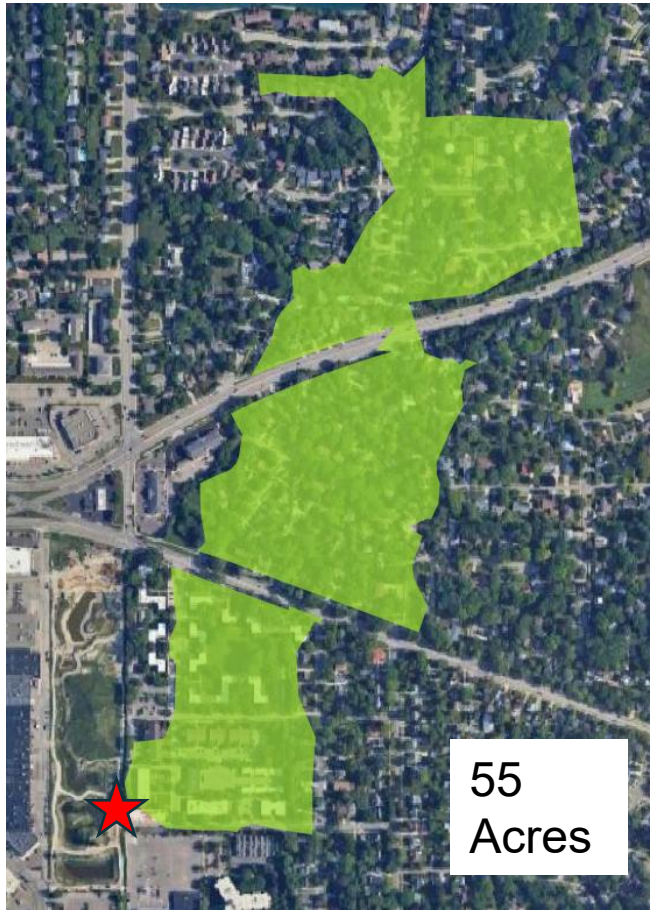
- City entered into a signed agreement with Ingham County Drain Commissioner to establish four connections into Ranney Park. Connections are:
  - Harvard (18”)
  - Saginaw (24”)
  - Grand River (30”)
  - Oak Ridge (54”)



Storm Separation Areas to Ranney Park (Storm Main to Oak Ridge)

Alt 1a

Alt	Storm Event	Peak Flow (MGD)	Volume (MG)
1a	Current 10-year, 1-hour	37	1.37
1a	Future 16-year, 1-hour	54	1.94



Alt 1b

Alt	Storm Event	Peak Flow (MGD)	Volume (MG)
1b	Current 10-year, 1-hour	60	2.08
1b	Future 16-year, 1-hour	86	2.89



Alt 3a and 3b

Alt	Storm Event	Peak Flow (MGD)	Volume (MG)
3a	Current 10-year, 1-hour	32	1.10
3a	Future 16-year, 1-hour	46	1.56
3b	Current 10-year, 1-hour	32	1.10
3b	Future 16-year, 1-hour	46	1.56



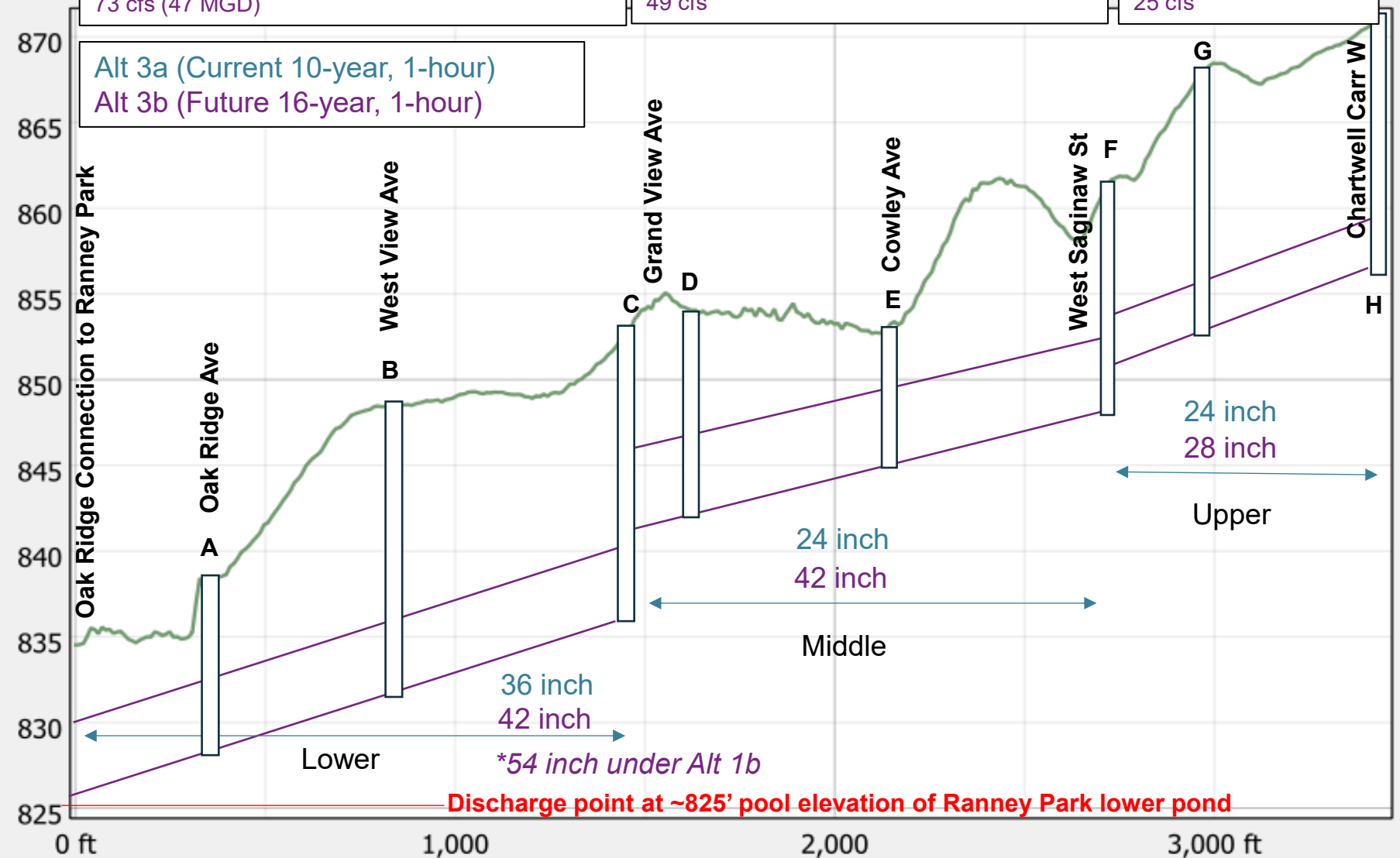
Alts 3a & 3b: Area A/B Storm Main is Reduced with Harrison St Project

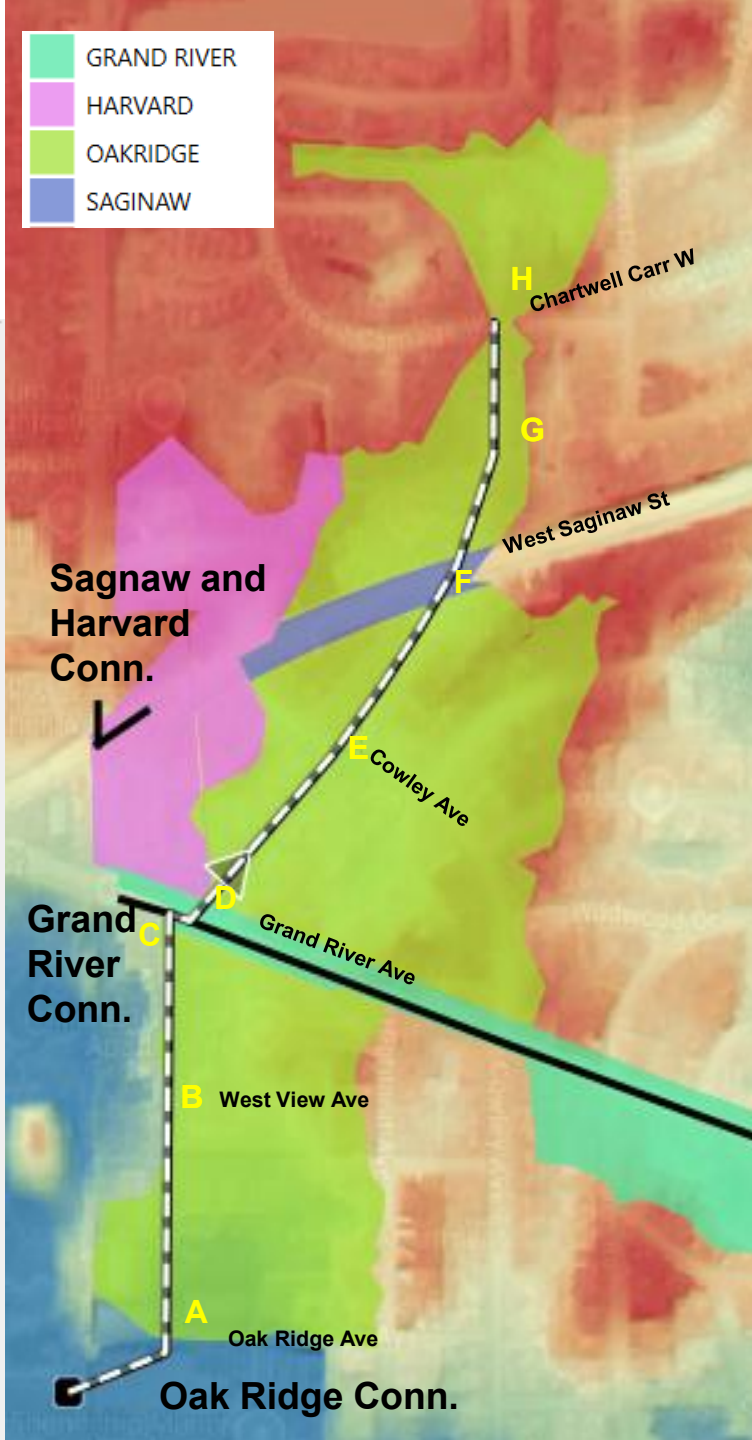
Lower
(C to Ranney) =
52 cfs (33 MGD)
73 cfs (47 MGD)

Middle
(F to C) =
34 cfs
49 cfs

Upper
(H to F) =
17 cfs
25 cfs

Alt 3a (Current 10-year, 1-hour)
Alt 3b (Future 16-year, 1-hour)





Storm Separation Results 3a

	Peak Flow (MGD)		Volume (MG)	
Connection	Current 10-year, 1-hour	2100 16-year, 1-hour	Current 10-year, 1-hour	2100 16-year, 1-hour
Harvard	9	12	0.36	0.48
Saginaw	4	5	0.07	0.09
Grand River	10	13	0.23	0.30
Oak Ridge	32	46	1.10	1.56
Totals	55	77	1.75	2.44

Storm Separation Results 3b

	Peak Flow (MGD)		Volume (MG)	
Connection	Current 10-year, 1-hour	2100 16-year, 1-hour	Current 10-year, 1-hour	2100 16-year, 1-hour
Harvard	9	12	0.36	0.48
Saginaw	4	5	0.07	0.09
Grand River	14	19	0.31	0.45
Oak Ridge	32	46	1.10	1.56
Totals	58	82	1.84	2.58

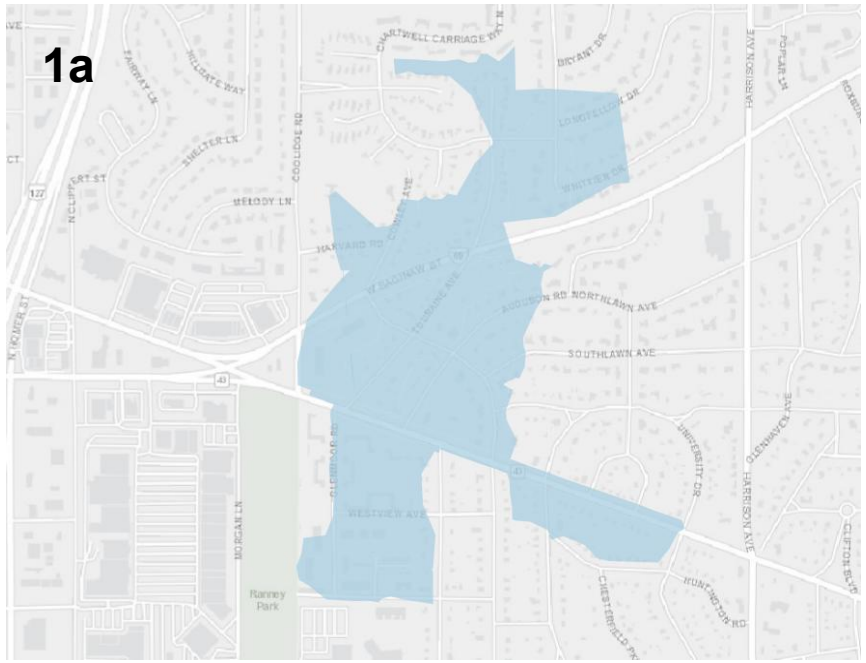
Total Separation Acres

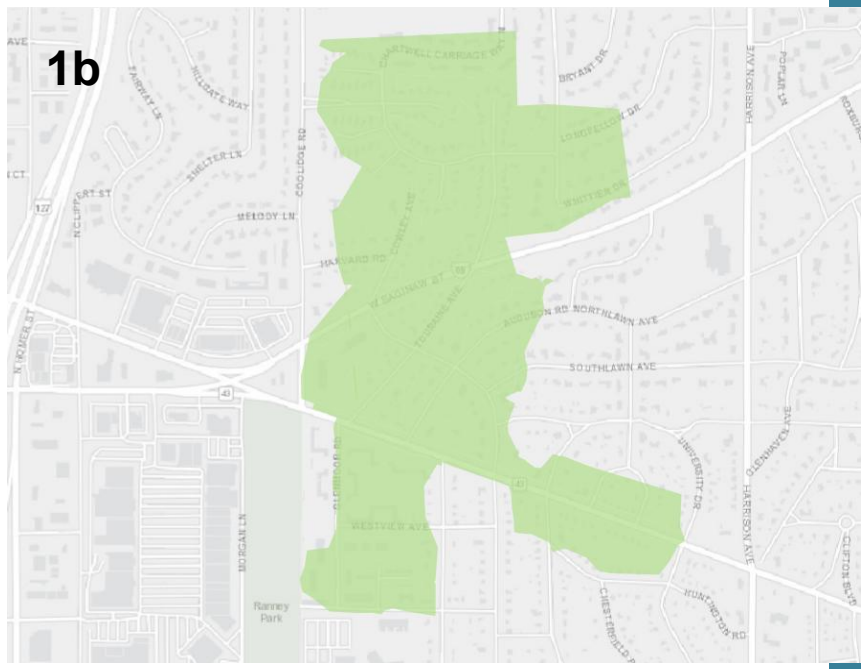
1a = 76 ac

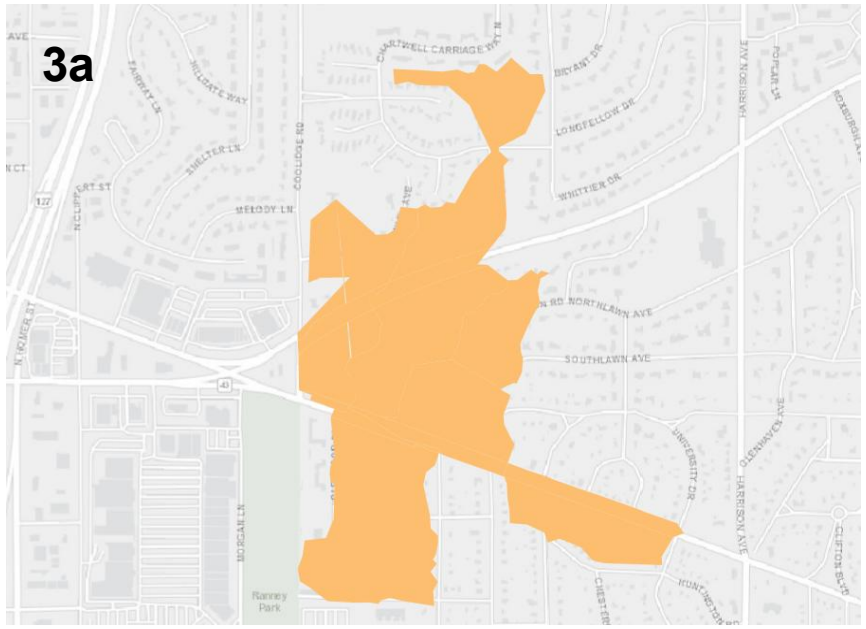
1b = 102 ac

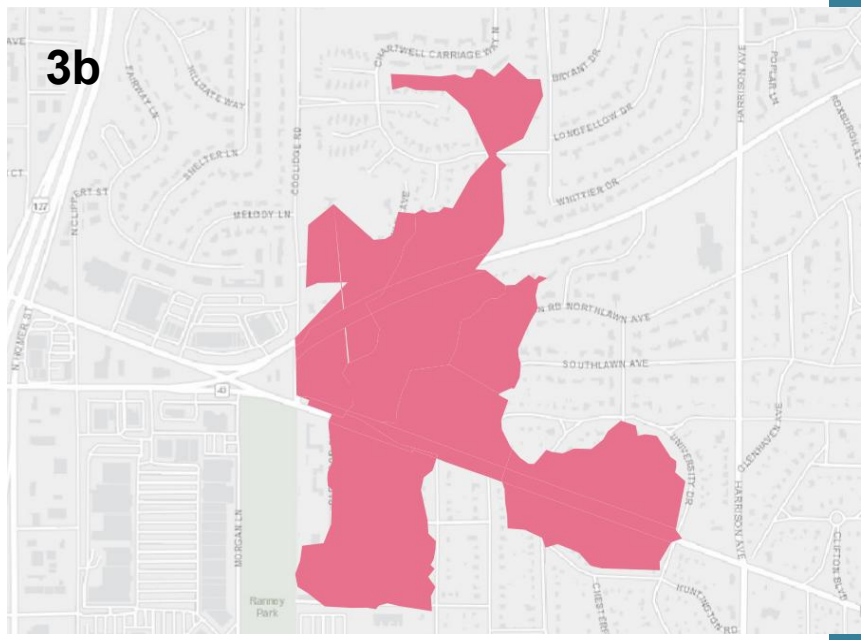
3a = 69 ac

3a = 77 ac





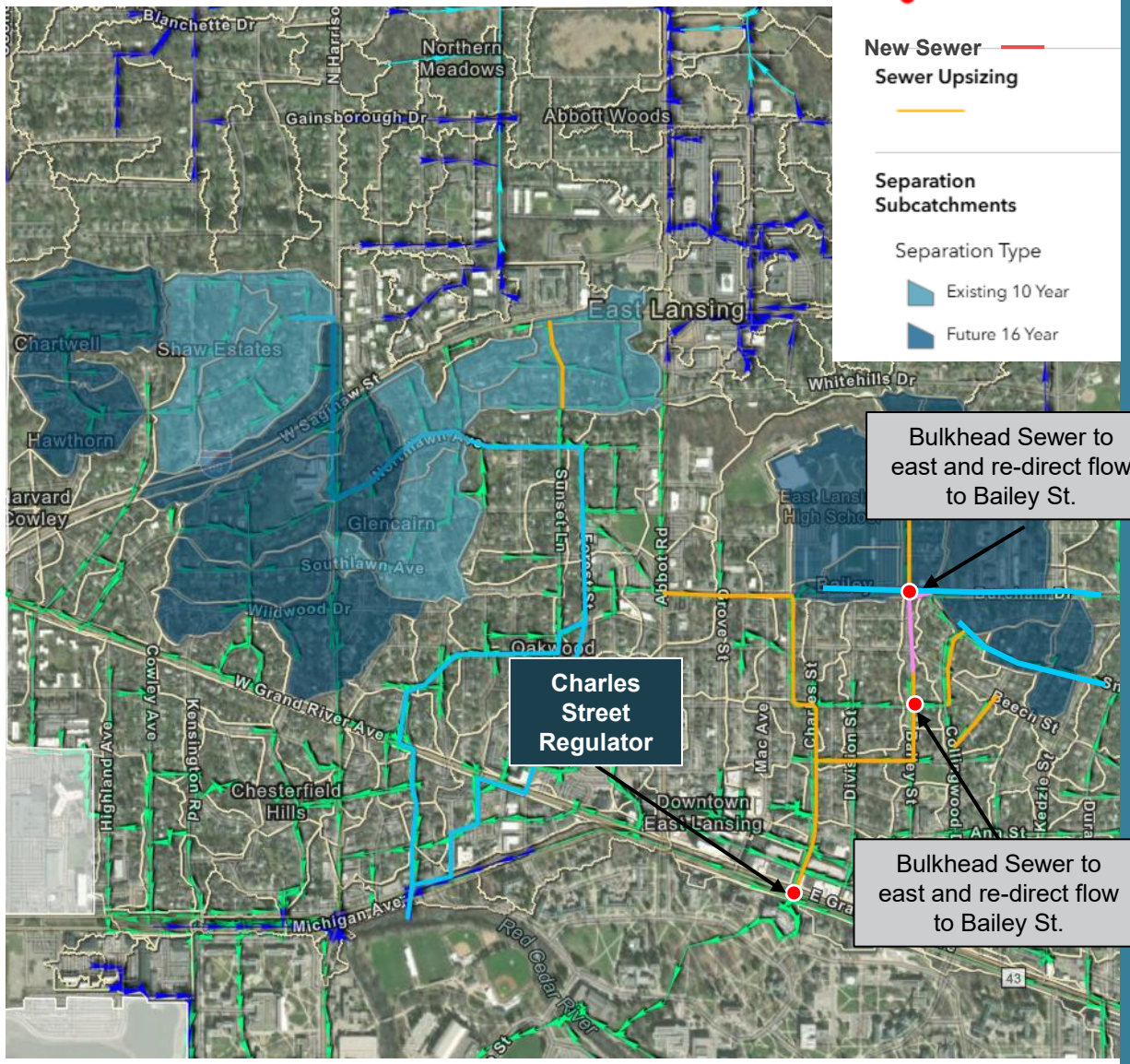




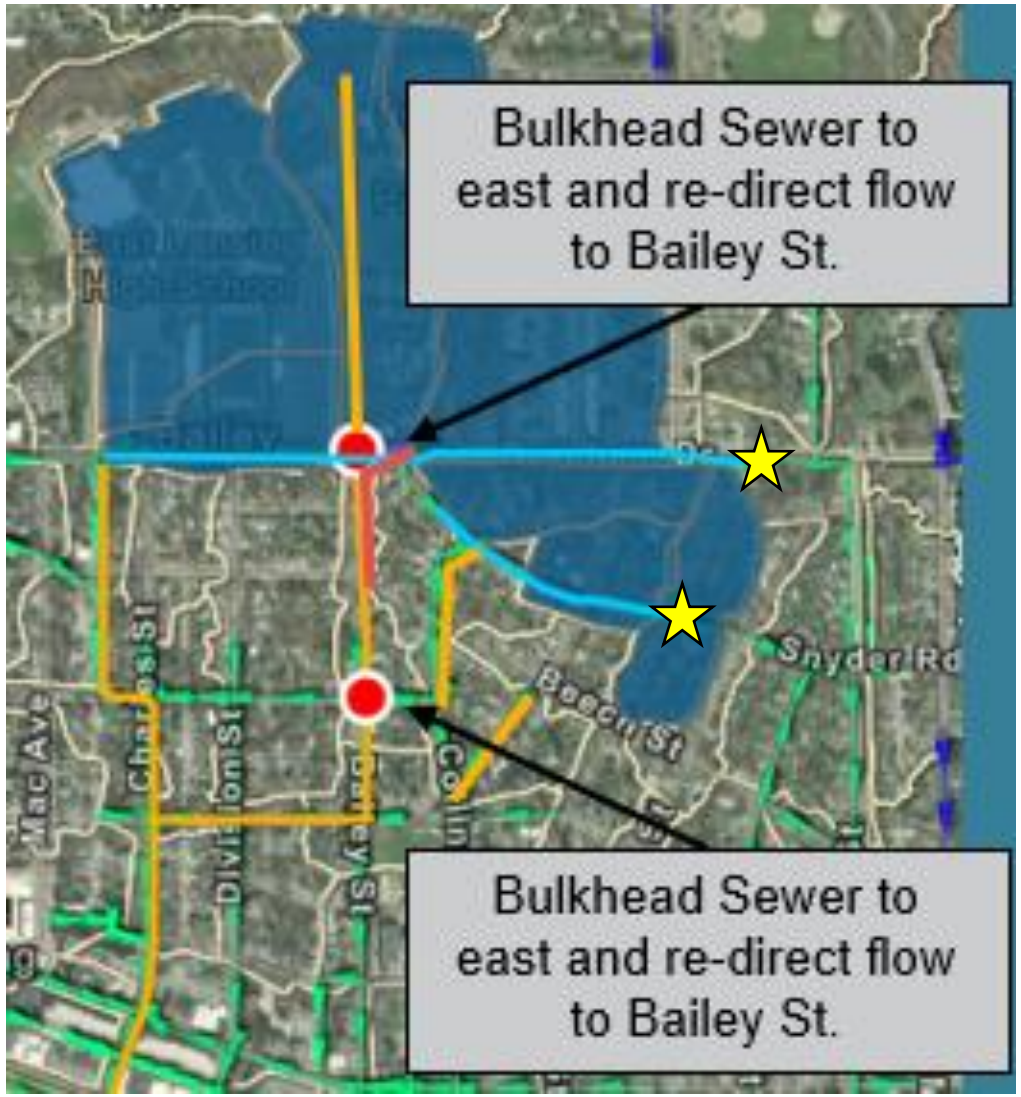
Areas B, C, E & G Alternatives – Sunset Storm

Concern Area	Alt	Proposed Project(s)
B, C, E & G – Sunset Storm	**4a**	• 110.0 ac of storm separation • 10,500 ft of new storm main (max depth ~25-30 ft) • 7,100 ft of combined sewer upsizing (includes Charles Street with modified MP sizing) • 875 ft of new combined sewer • 2 sewer bulkheads • 1 Regulator modification – increase weir length to 8.5 ft
	4b	• 4a plus additional 192.5 ac of storm separation (total 302.5 ac) • Plus an additional 3,300 ft of new storm main (max depth ~10-15 ft) • Increased storm main sizing • Increased Charles St upsize, and additional 1065 ft of upsizing
	4c	• 4a or 4b plus Glencairn Park, Shaw Park, Hannah Community Center storage

Results assume Area A improvements downstream of Area B



Areas E & G: Alt 4b Storm Pipe (Tie into Gunson St Storm Sewer)



Alt 4b Future 16-year Separation Project:

★ Connect with existing Gunson St. Storm Sewer:

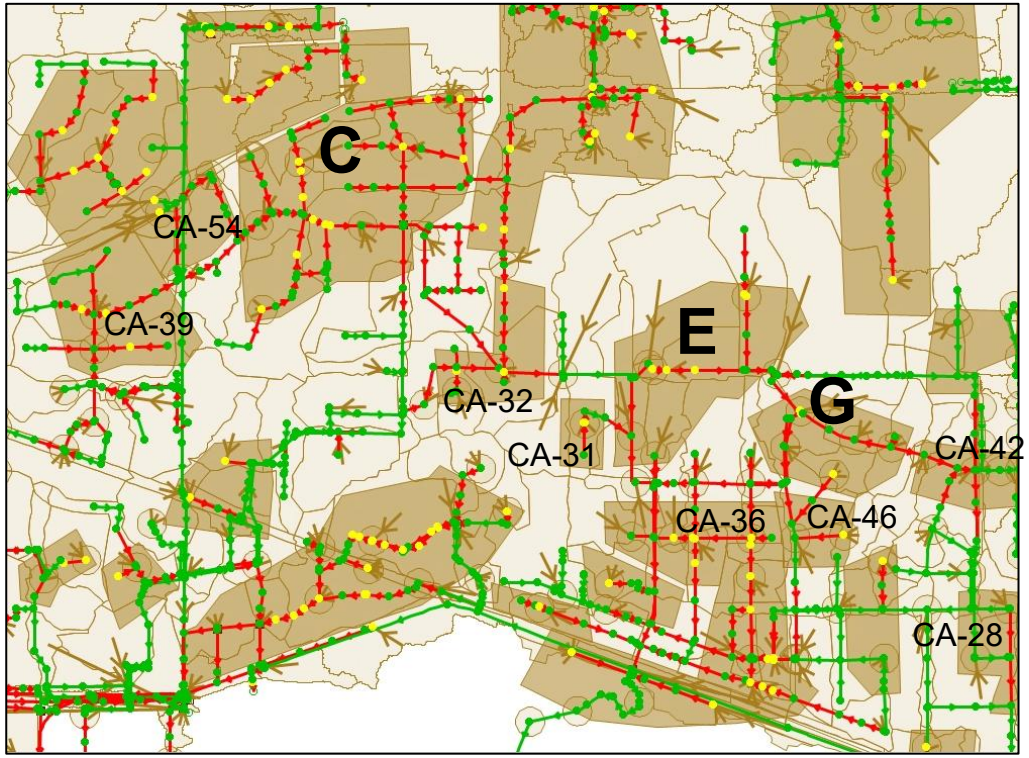
- Burcham Dr. 24-inch storm
- Snyder Rd. 15-inch storm (becomes 24-inch at Kedzie St.)

Available capacity within Gunson St. storm sewer needs to be verified to see if it can accept additional flows.

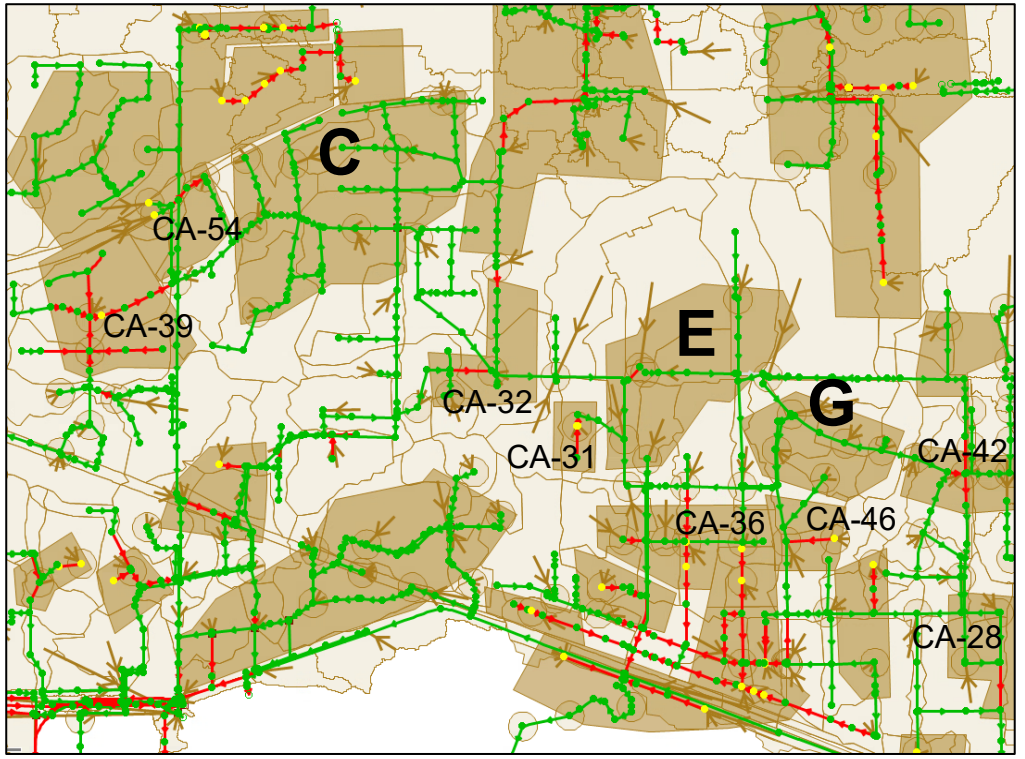
Area B, C, E & G: Alt 4a – Sunset Storm

LOS Results for Current 10-year, 1-hour Storm

Without Alt



With Alt 4a



CSS Level of Service

Conduits
- LOS Achieved
- Exceeds LOS

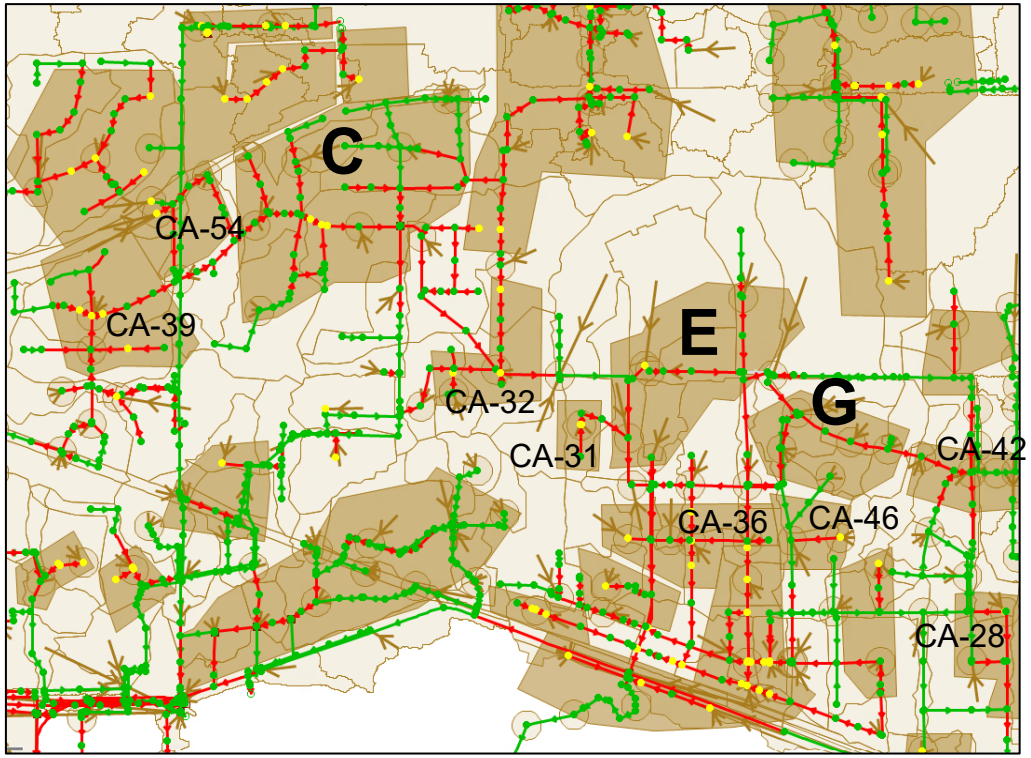
Nodes
- No MH Flooding
- MH Flooding

Key Takeaways:
- Alt 4a achieves Current 10-year LOS in Areas C, E and G.
- Alt 4a also benefits CA-54, CA-39, CA-32, CA-31, CA-36, CA-42, CA-46, and CA-28.

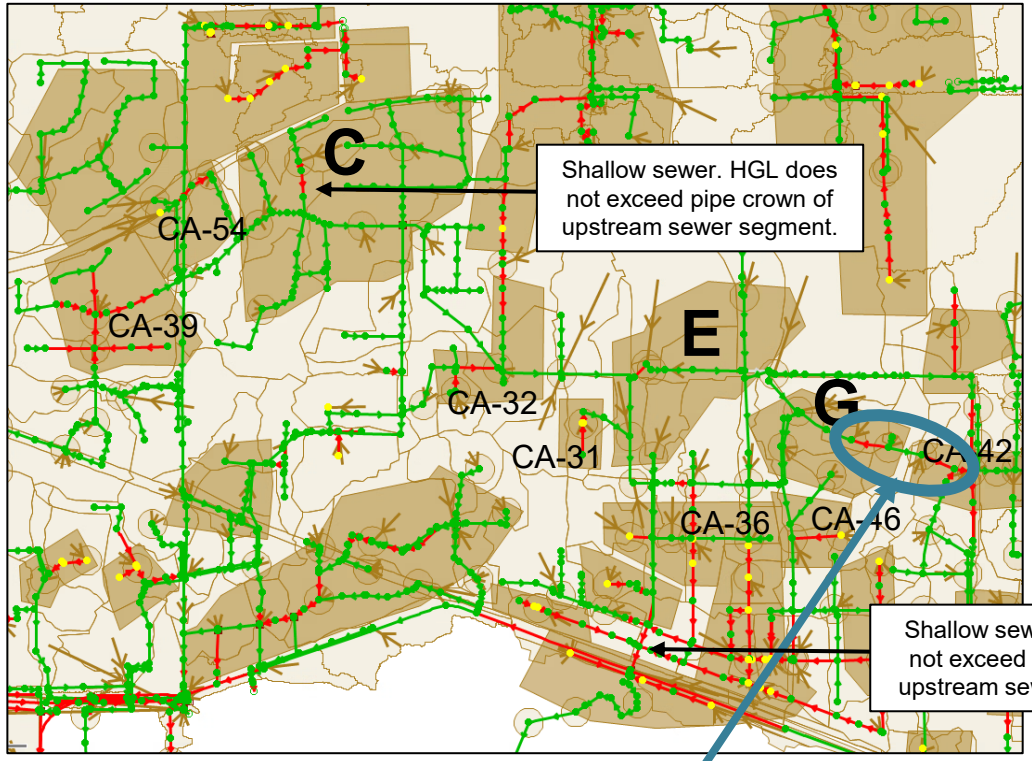
Area B, C, E & G: Alts 4a & 4b – Sunset Storm

LOS Results for Future 16-year, 1-hour Storm

With Alt 4a



With Alt 4b



CSS Level of Service

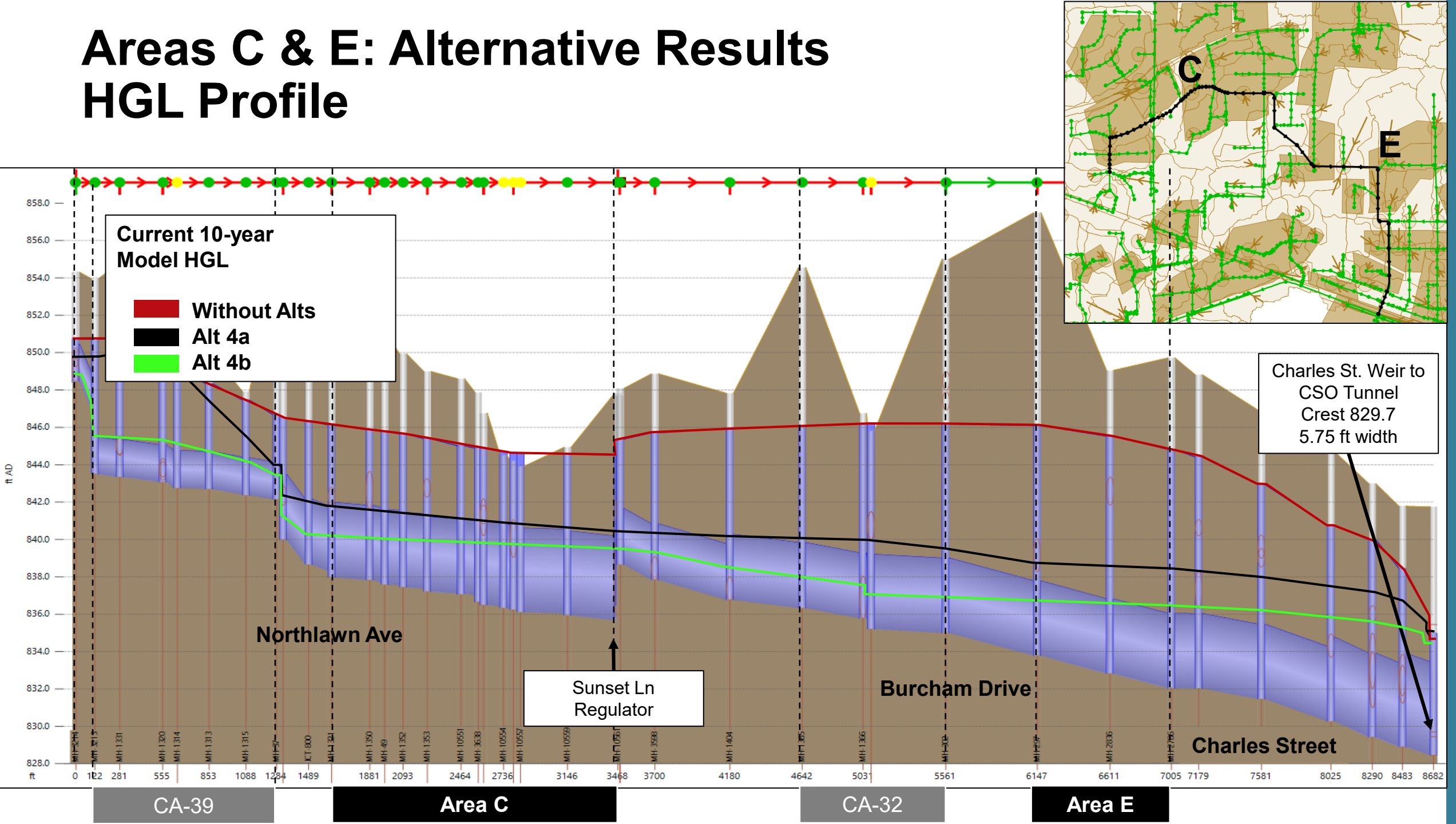
Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

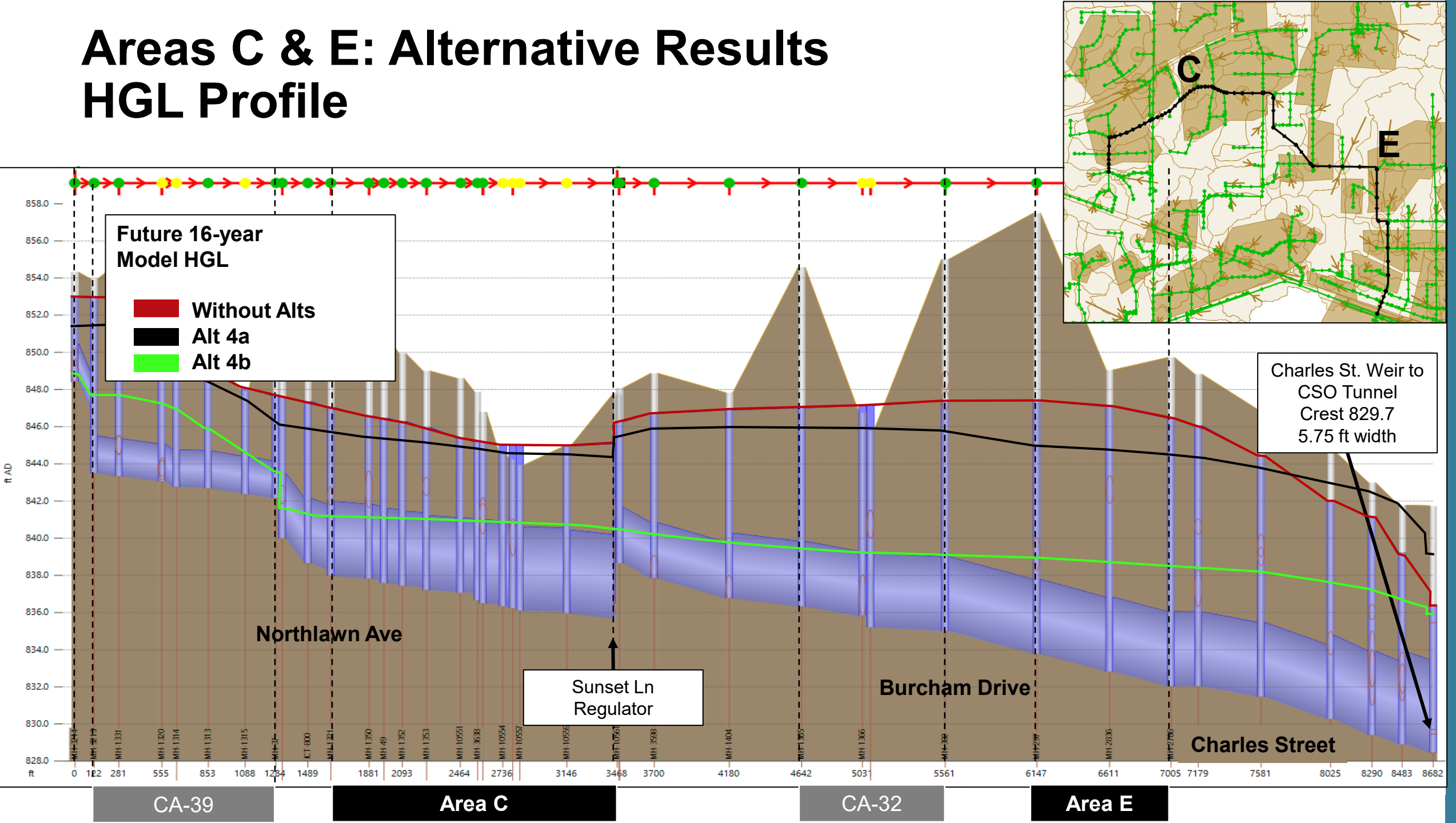
Key Takeaways:

- Alt 4a does not achieve Future 16-year LOS in Areas C, E and G.
- Alt 4b achieves Future 16-year LOS in Areas C and E
  - Conduits not achieving LOS in Area G is due to lack of capacity within mainline sewer on Gunson St.
- Alt 4b benefits CA-54, CA-39, CA-32, CA-31, CA-36, CA-42, and CA-46.

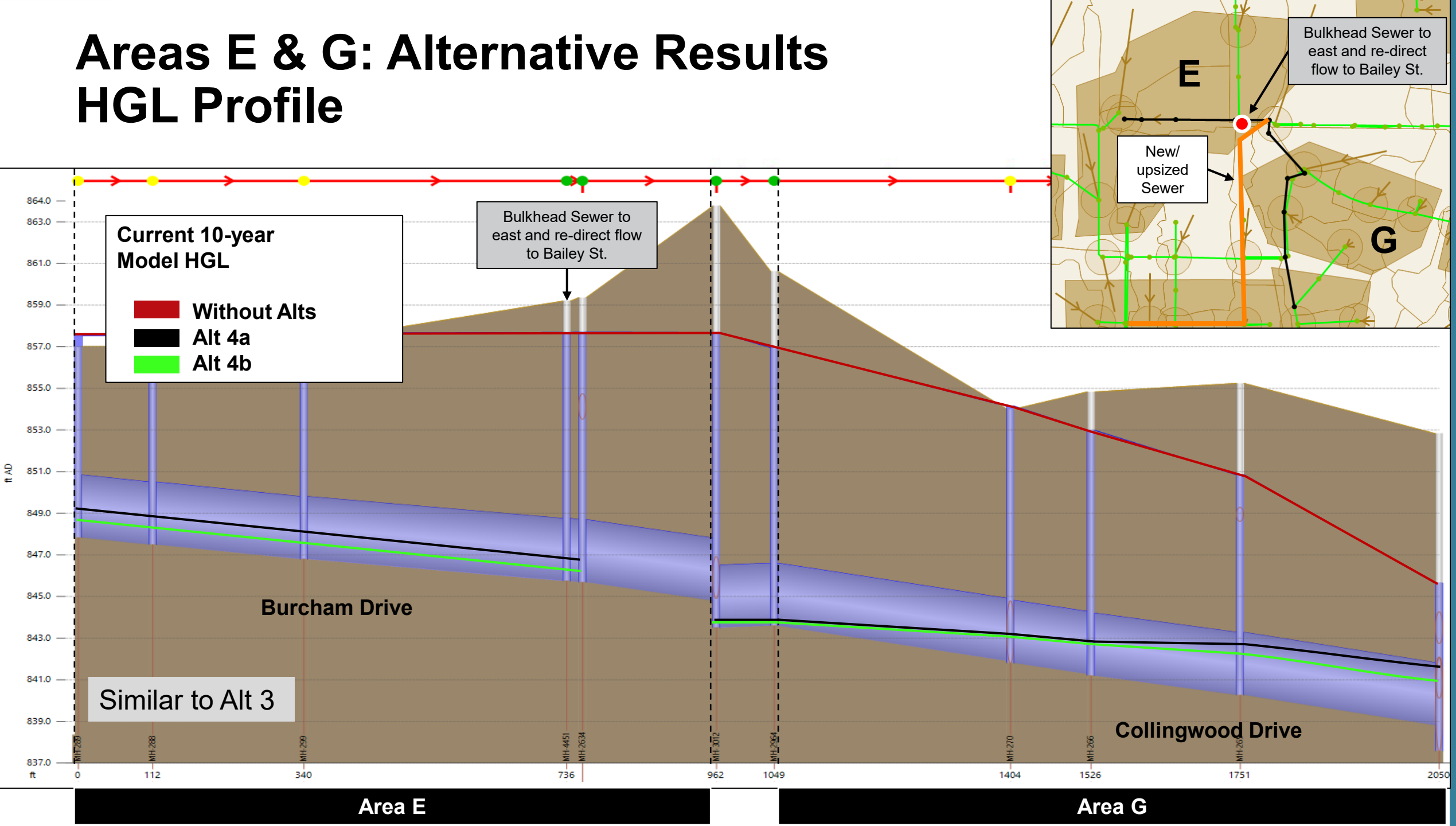
Areas C & E: Alternative Results
HGL Profile



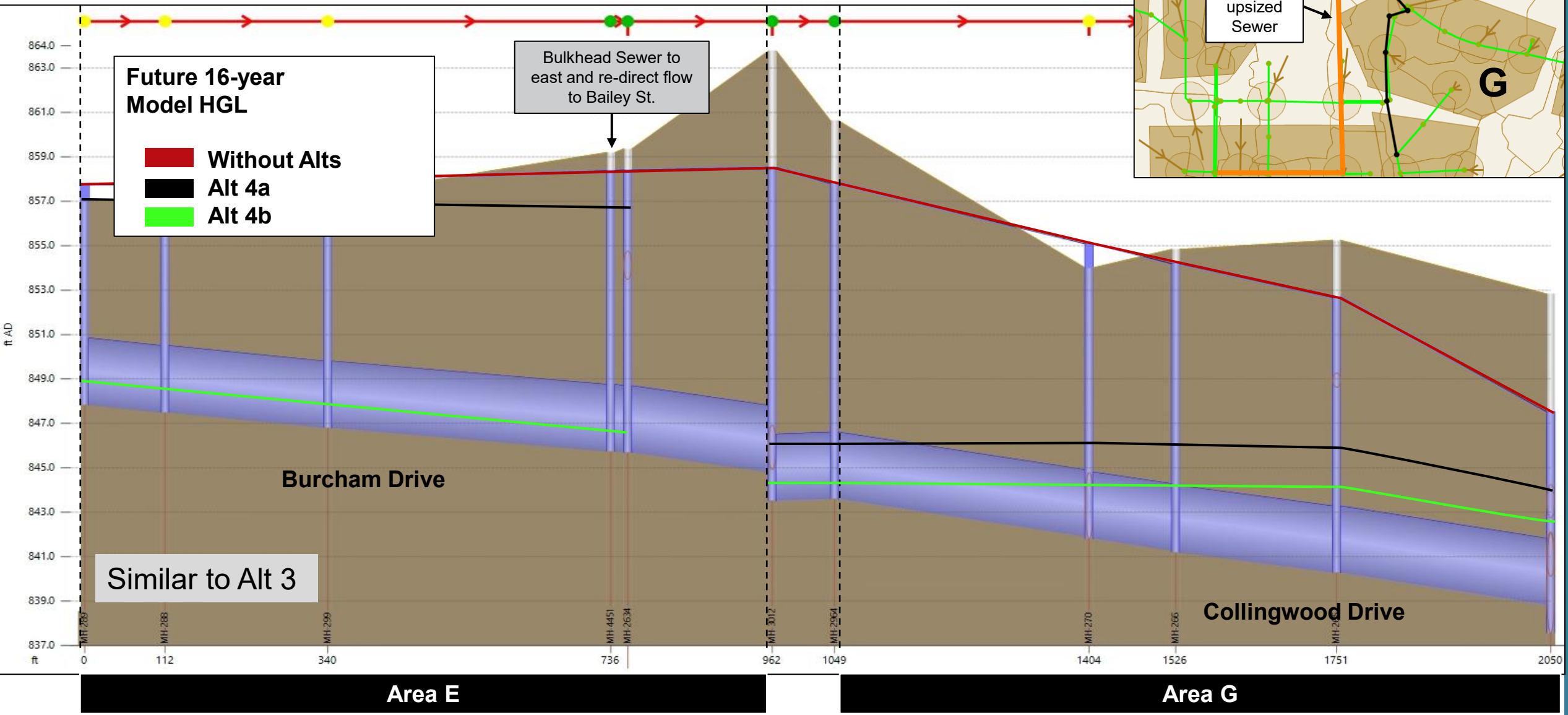
Areas C & E: Alternative Results
HGL Profile

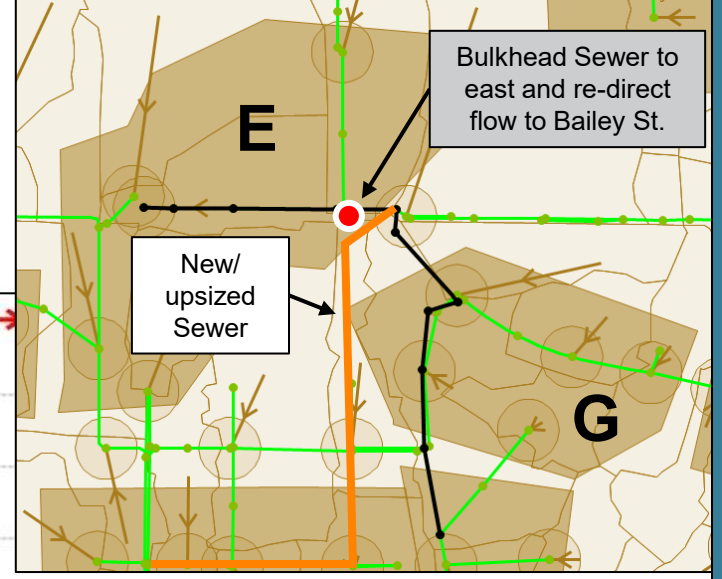


Areas E & G: Alternative Results HGL Profile

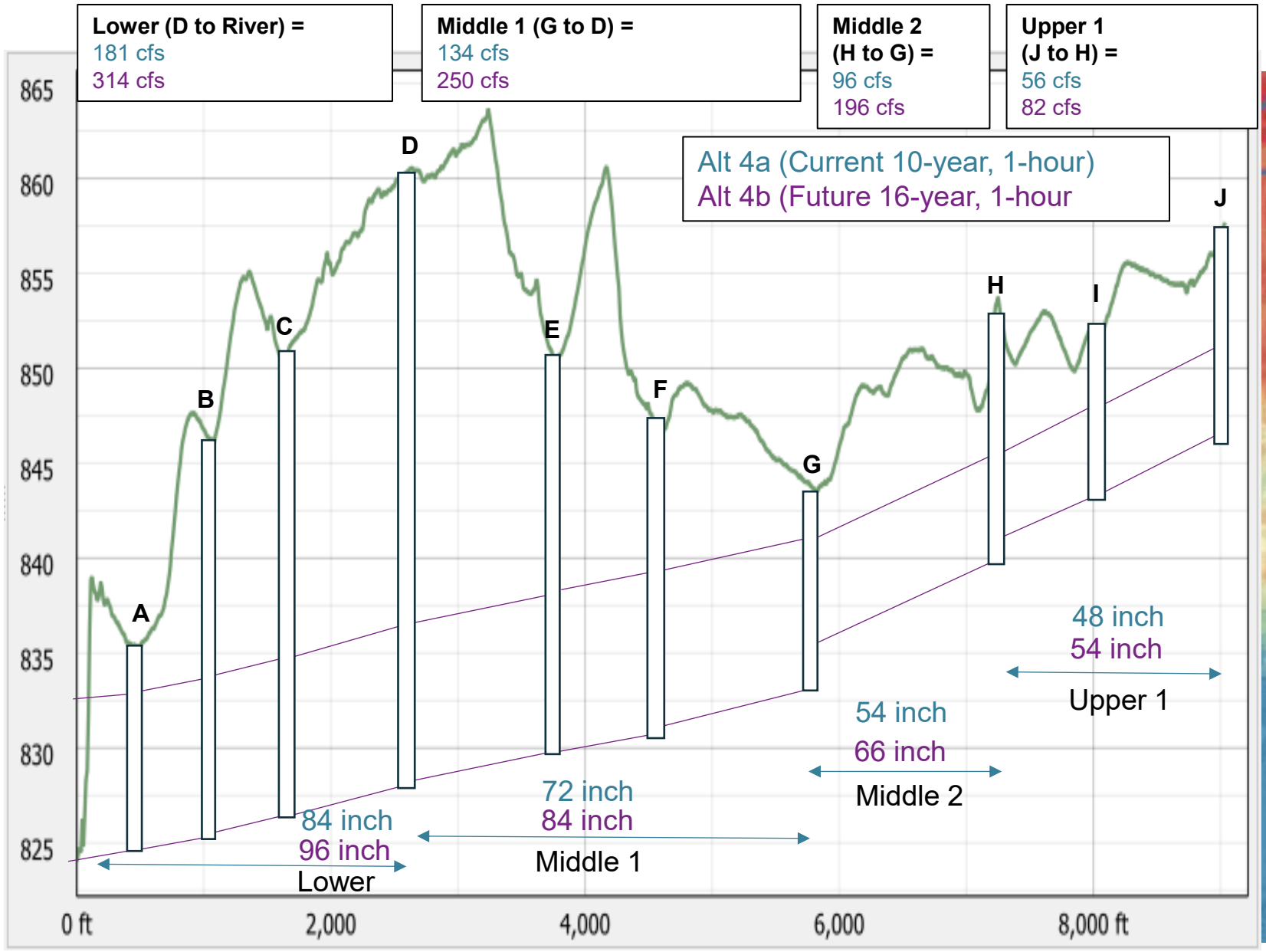


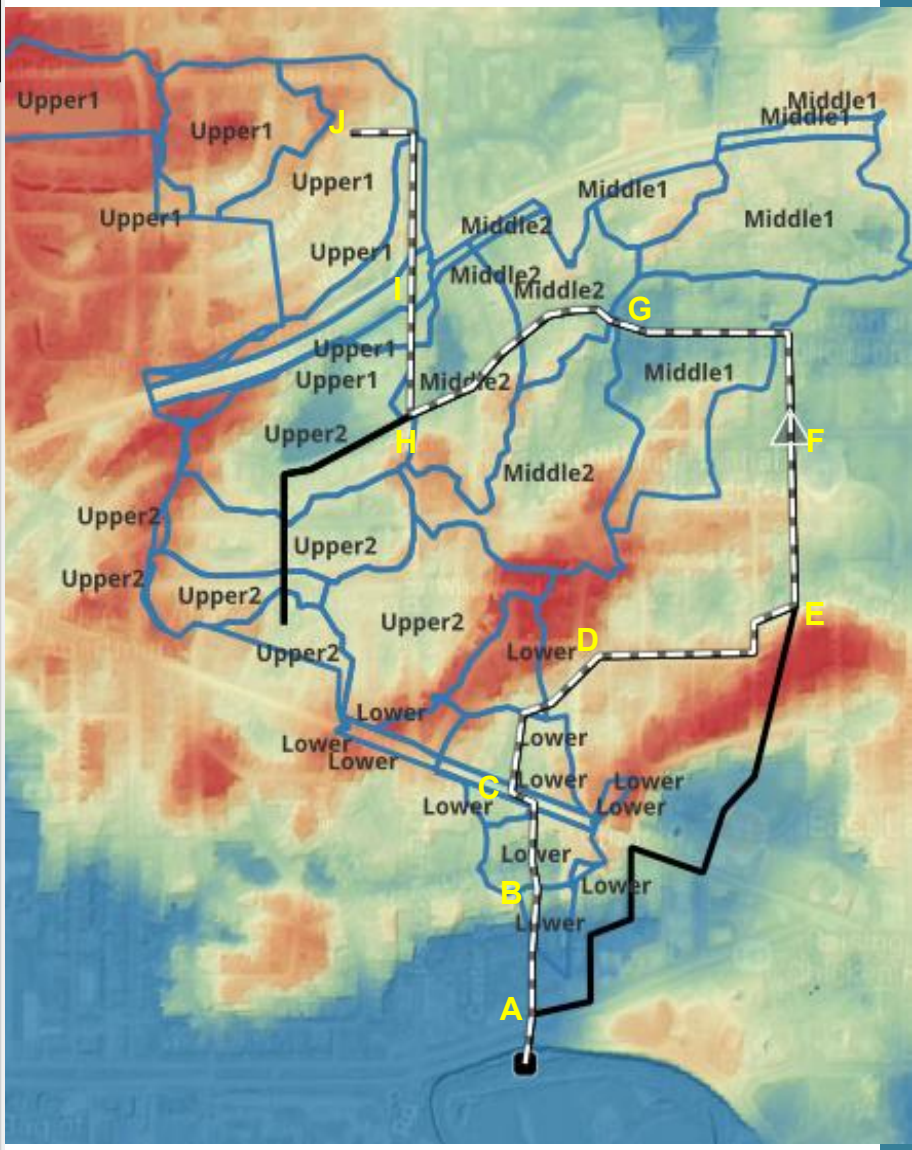
Areas E & G: Alternative Results HGL Profile





Alts 4a & 4b: Required Storm Sewer Main Sizes (Option 1)

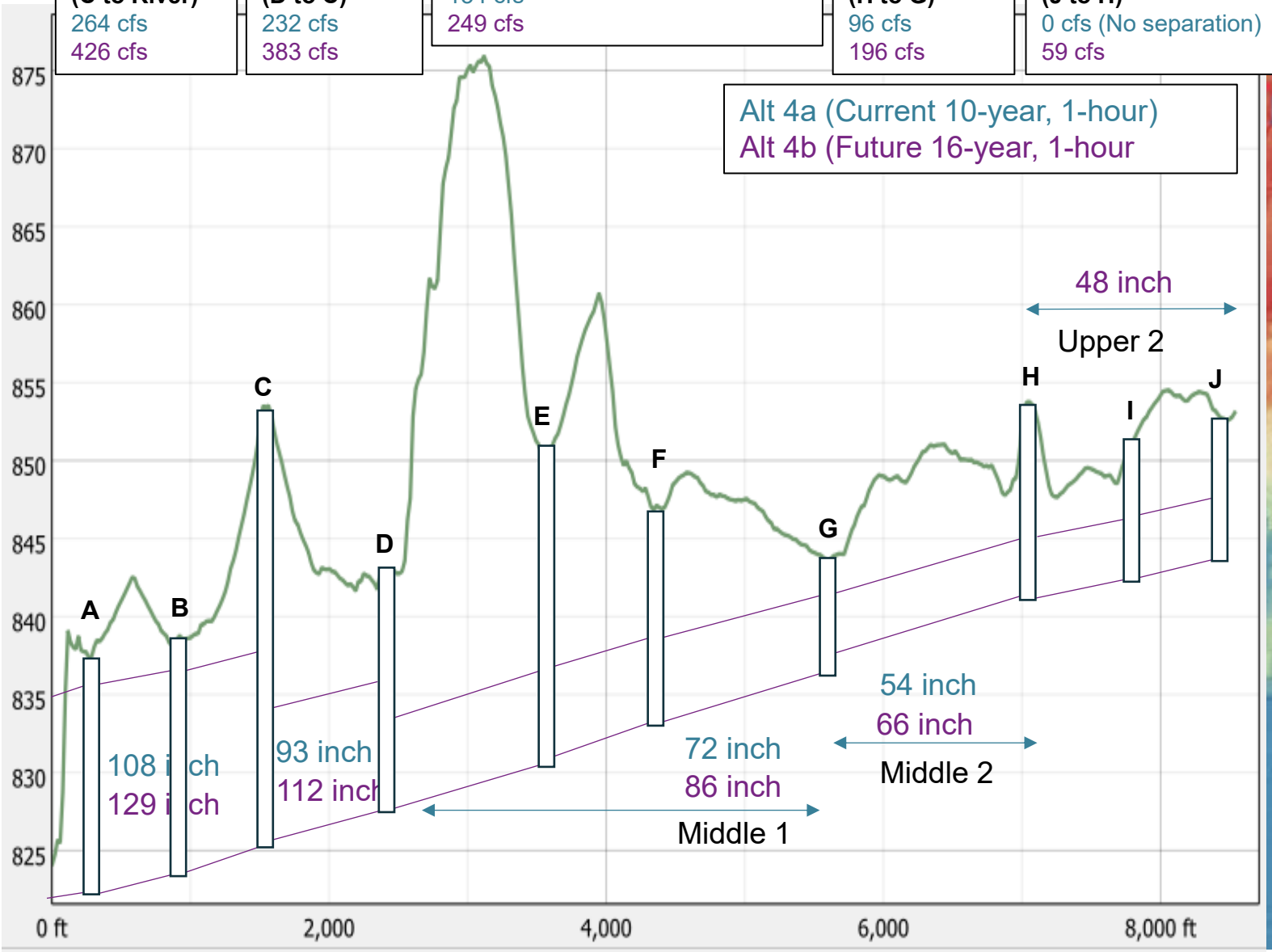


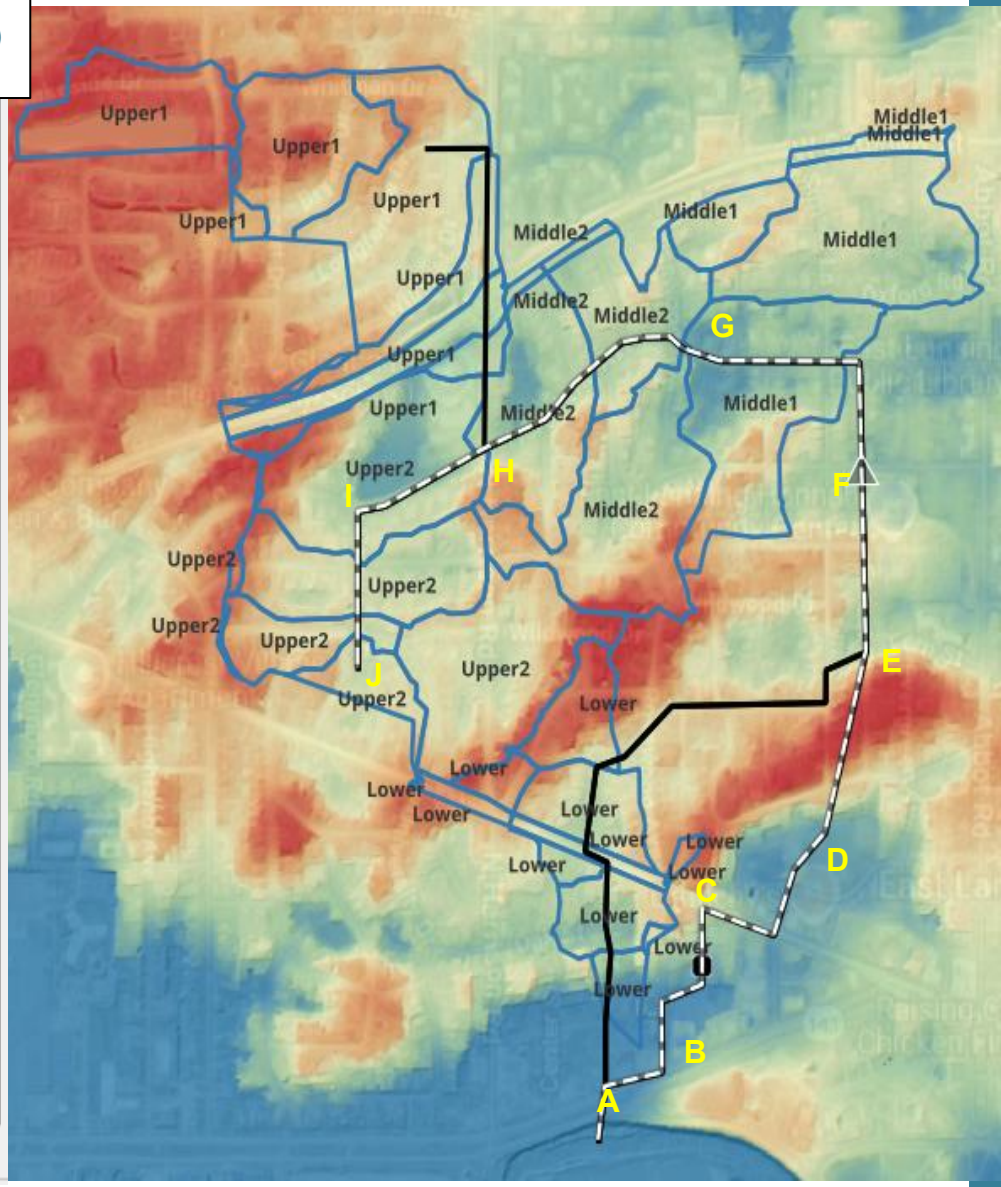


Alts 4a & 4b: Required Storm Sewer Main Sizes (Option 2 - Tie into Area D)

Lower 2 (C to River) =	Lower 1 (D to C) =	Middle 1 (G to D) =	Middle 2 (H to G) =	Upper 2 (J to H) =
264 cfs 426 cfs	232 cfs 383 cfs	134 cfs 249 cfs	96 cfs 196 cfs	0 cfs (No separation) 59 cfs

Alt 4a (Current 10-year, 1-hour)
Alt 4b (Future 16-year, 1-hour





Area C: Alt 4c Storage at Glencairn Park, Shaw Park, and Hannah Community Center Resilience Opportunities

1. **Glencairn Park**
   - Footprint = 1.68 ac
   - Drainage Area Captured = 34 ac
   - CFS Reduction = 50 cfs
2. **Shaw Park**
   - Footprint = 1.06 ac
   - Drainage Area = 22 ac
   - CFS Reduction = 31 cfs
3. **Hannah Community Center**
   - Footprint = 1.59 ac
   - Drainage Area = 32 ac
   - CFS Reduction = 47 cfs



Increased LOS with the Alt 4c Resilience Opportunity

- ~129 cfs benefit to downstream system with three storage locations
  - Increase LOS from current 10-year to ~100-year
  - Increase LOS from future 16-year to ~50-year

Rainfall (inches)	Return Period (Years)		Peak Flow CFS		
	Current Day	2100 High Emissions	Area D	With Glencairn, Shaw, Hannah Storage	
1.40	2	1	129		
1.61	3	1	160		
1.92	8	3	209		
2.00	10	3	221	350	+129 cfs
2.18	17	5	252		
2.44	38	10	298		
2.54	50	16	315	443	+129 cfs
2.77	100	25	358		
3.05	200	50	411		
3.23	500	100	465		

Area C: Alt 4c Storm Pipe Profile With Storage

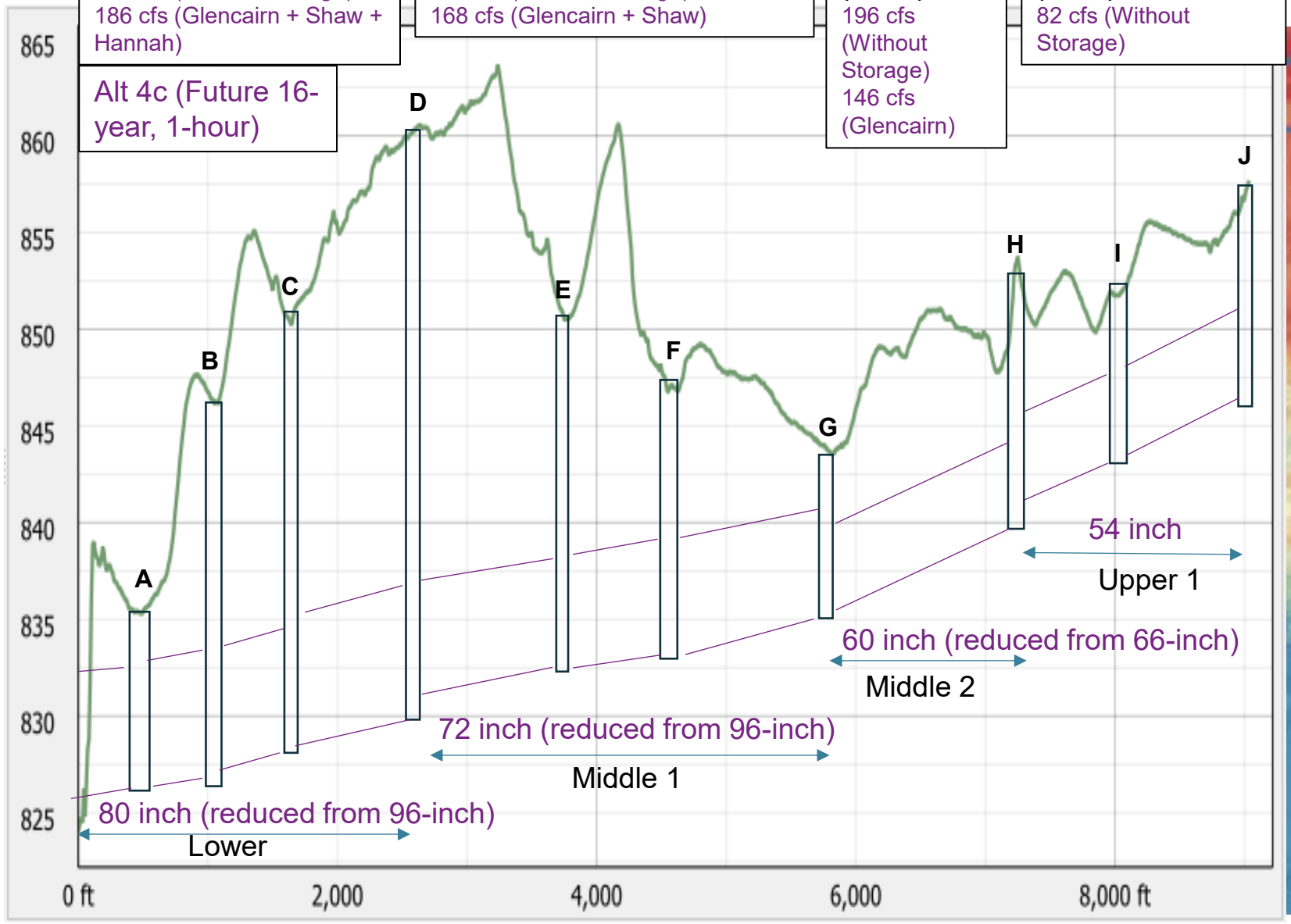
Lower (D to River) =
314 cfs (Without Storage)
186 cfs (Glencairn + Shaw + Hannah)

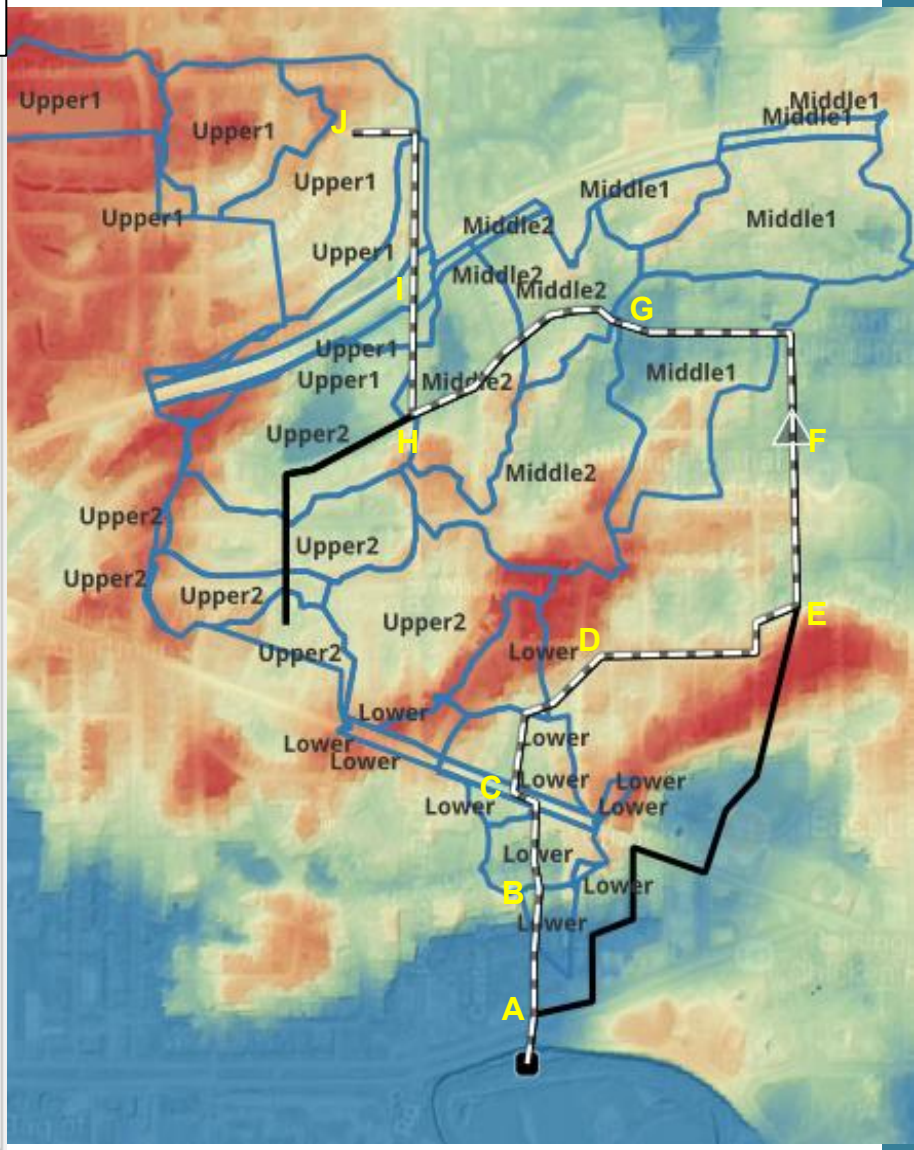
Middle 1 (G to D) =
250 cfs (Without Storage)
168 cfs (Glencairn + Shaw)

Middle 2 (H to G) =
196 cfs (Without Storage)
146 cfs (Glencairn)

Upper 1 (J to H) =
82 cfs (Without Storage)

Alt 4c (Future 16-year, 1-hour)

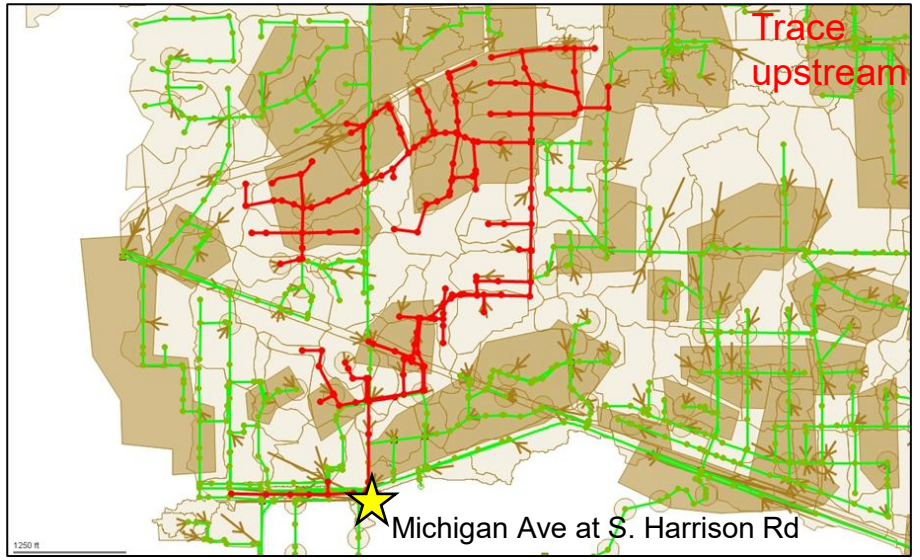


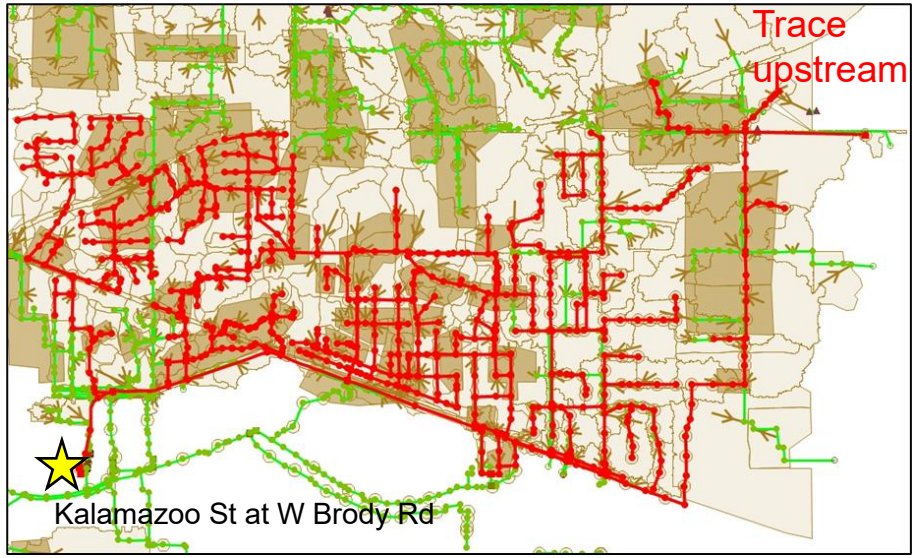


Potential CSO Impacts

- Upsizing CSO pipes without sewer separation may increase CSO.
- Phasing project implementation is important.
- Model was checked with alternatives in place to ensure projects are not increasing overall system CSO.

Outfall Locations	Discharges to
Michigan	Red Cedar River
Kalamazoo	Red Cedar River

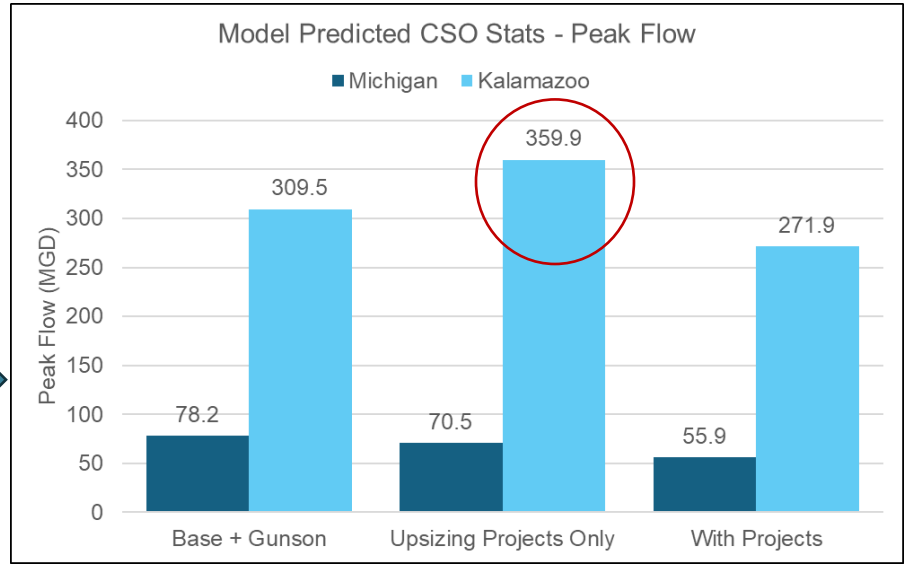




Preliminary CSO Analysis Results (Current 10-year)

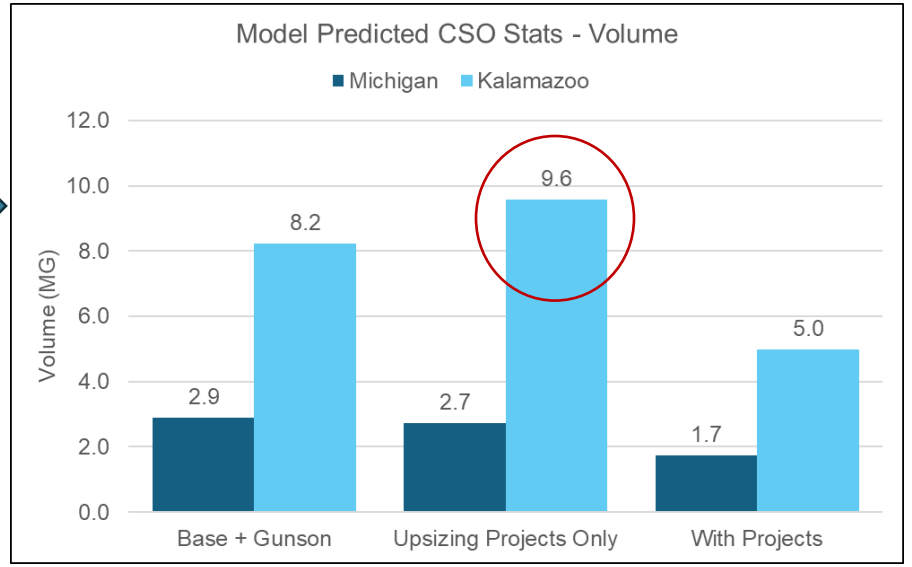
Peak Flow (MGD)

Outfall Location	Current Condition + Gunson	Upsizing Projects Only	With Alternative 1a, 2a, 4a
Michigan	78.2	70.5	55.9
Kalamazoo	309.5	359.9	271.9



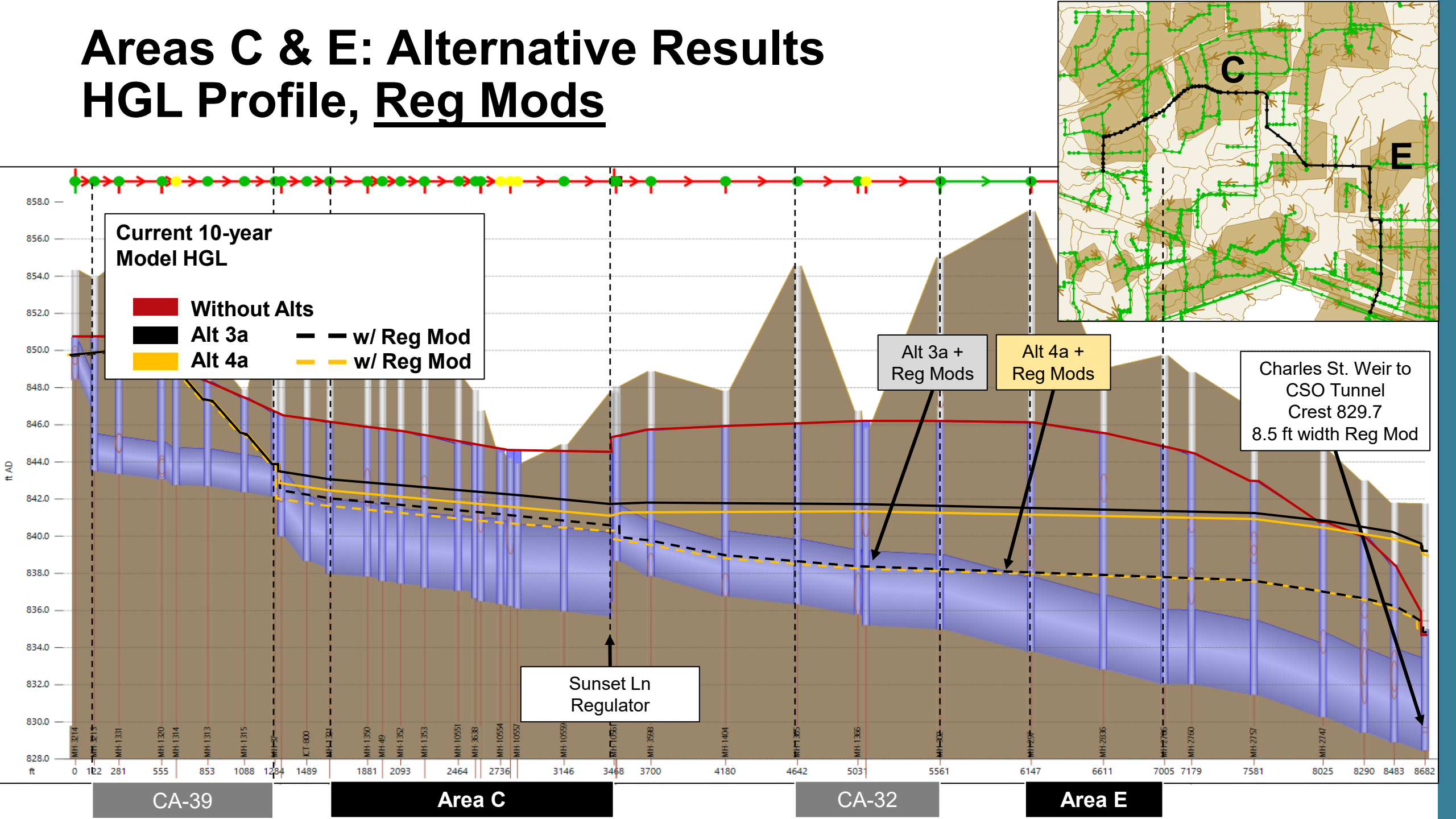
Volume (MG)

Outfall Location	Current Condition + Gunson	Upsizing Projects Only	With Alternative 1a, 2a, 4a
Michigan	2.9	2.7	1.7
Kalamazoo	8.2	9.6	5.0

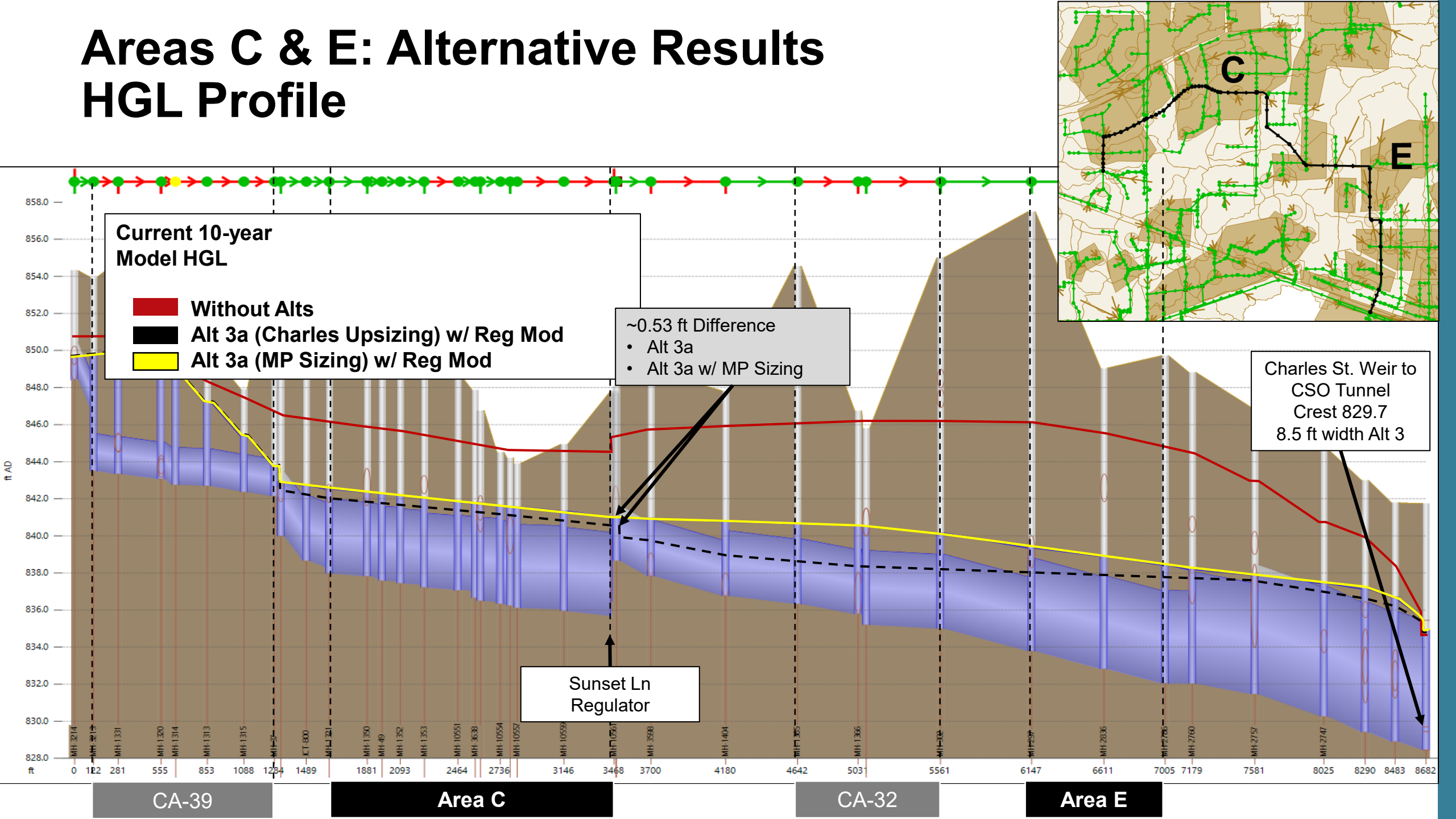


If upsizing projects are implemented before separation occurs, CSOs will increase at Kalamazoo outfall for the current 10-year storm.

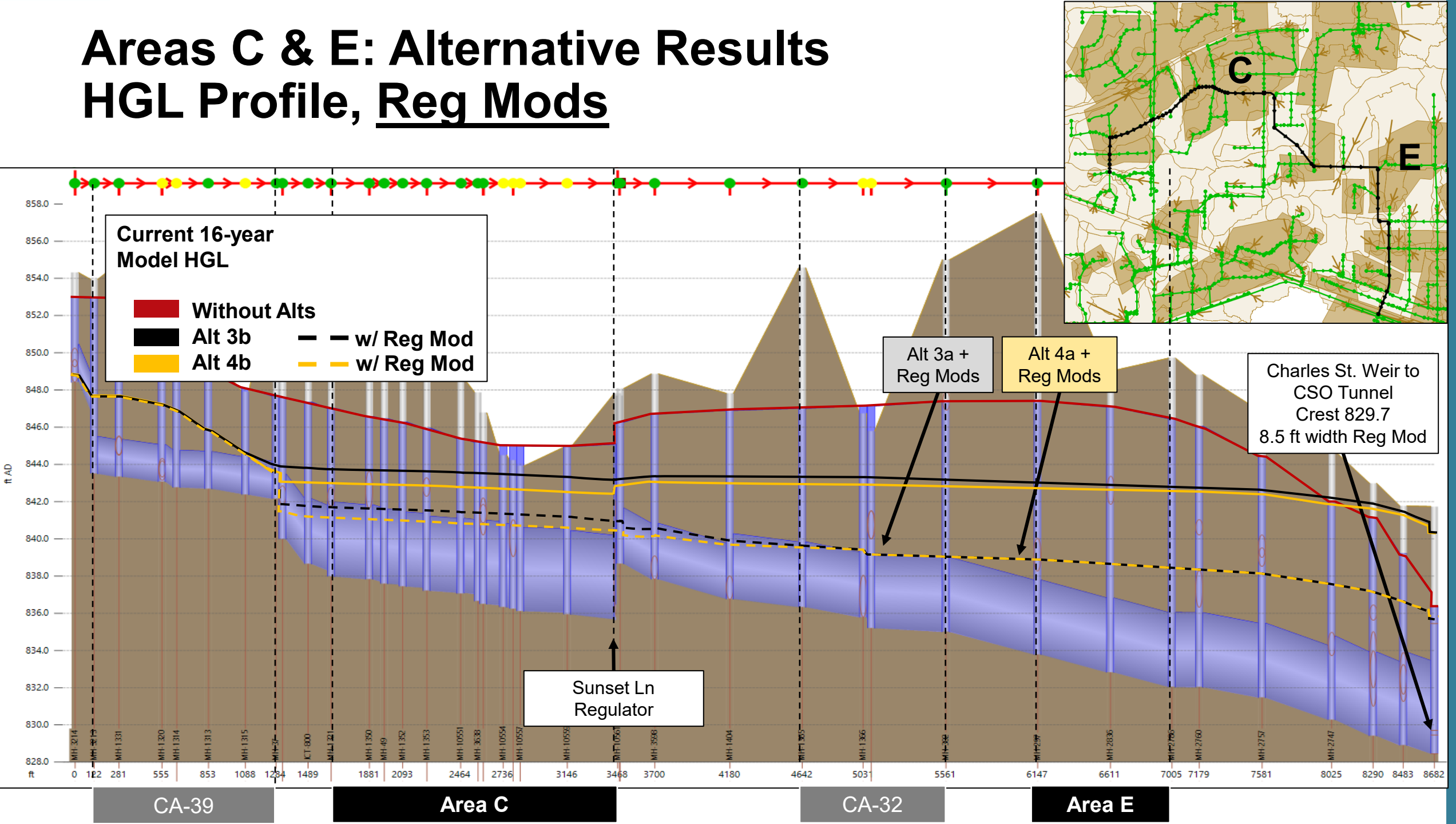
Areas C & E: Alternative Results
HGL Profile, Reg Mods



Areas C & E: Alternative Results
HGL Profile



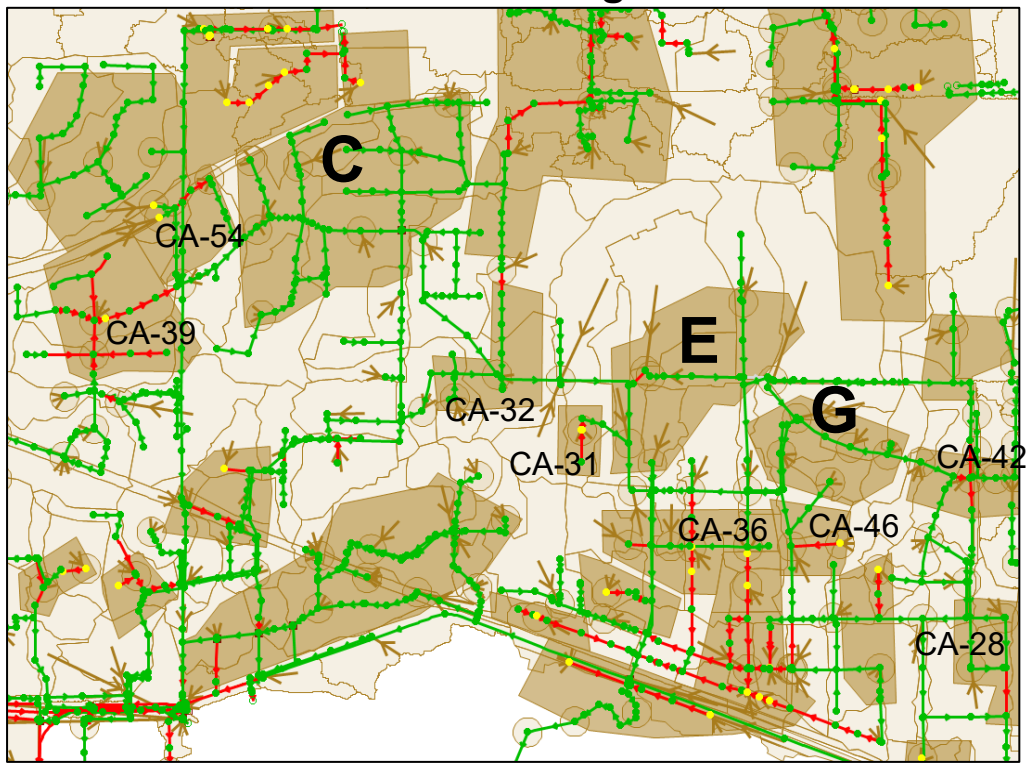
Areas C & E: Alternative Results
HGL Profile, Reg Mods



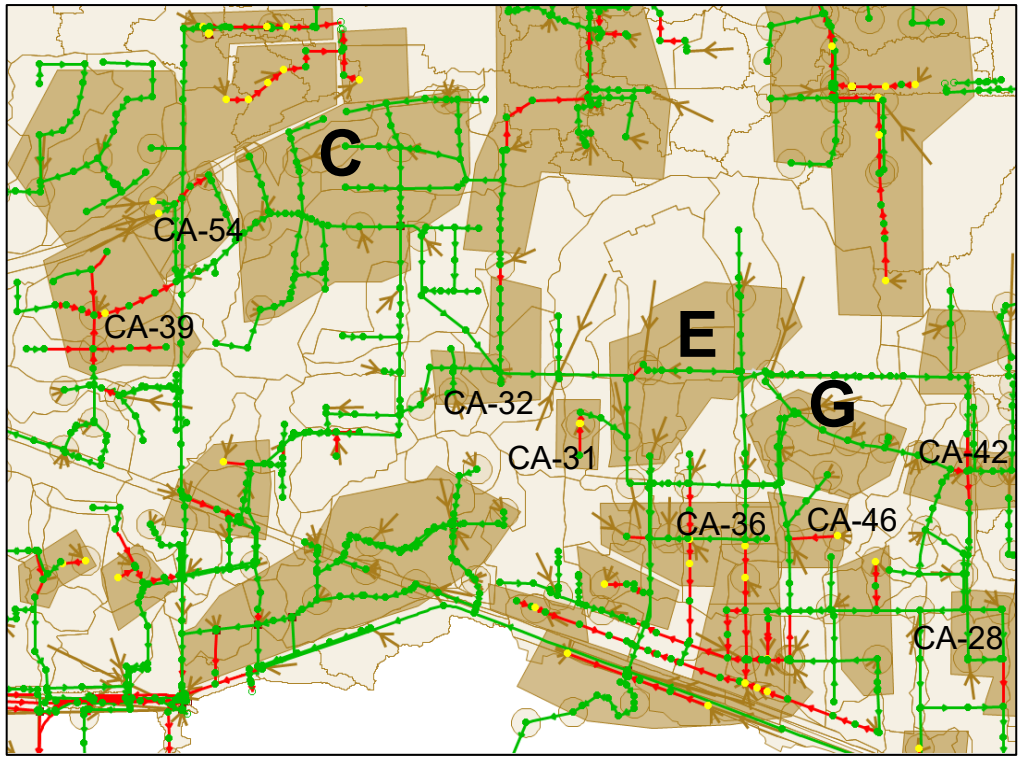
Area C, E & G: Alt 3a & 4a Reg Mods

LOS Results for Current 10-year, 1-hour Storm

With Alt 3a + Reg Mods



With Alt 4a + Reg Mods



CSS Level of Service

Conduits
- LOS Achieved
- Exceeds LOS

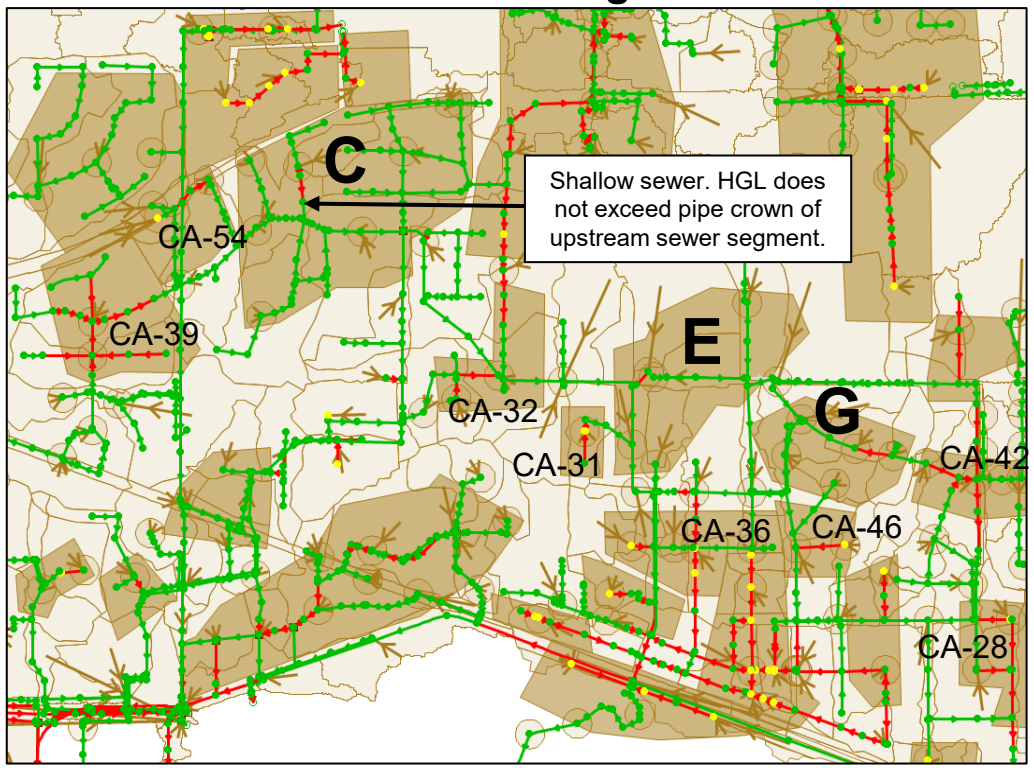
Nodes
- No MH Flooding
- MH Flooding

Key Takeaways:
- Alt 3a & 4a achieves Current 10-year LOS in Areas C, E and G.
- Alt 3a & 4a also benefits CA-54, CA-39, CA-32, CA-31, CA-36, CA-42, CA-46, and CA-28.

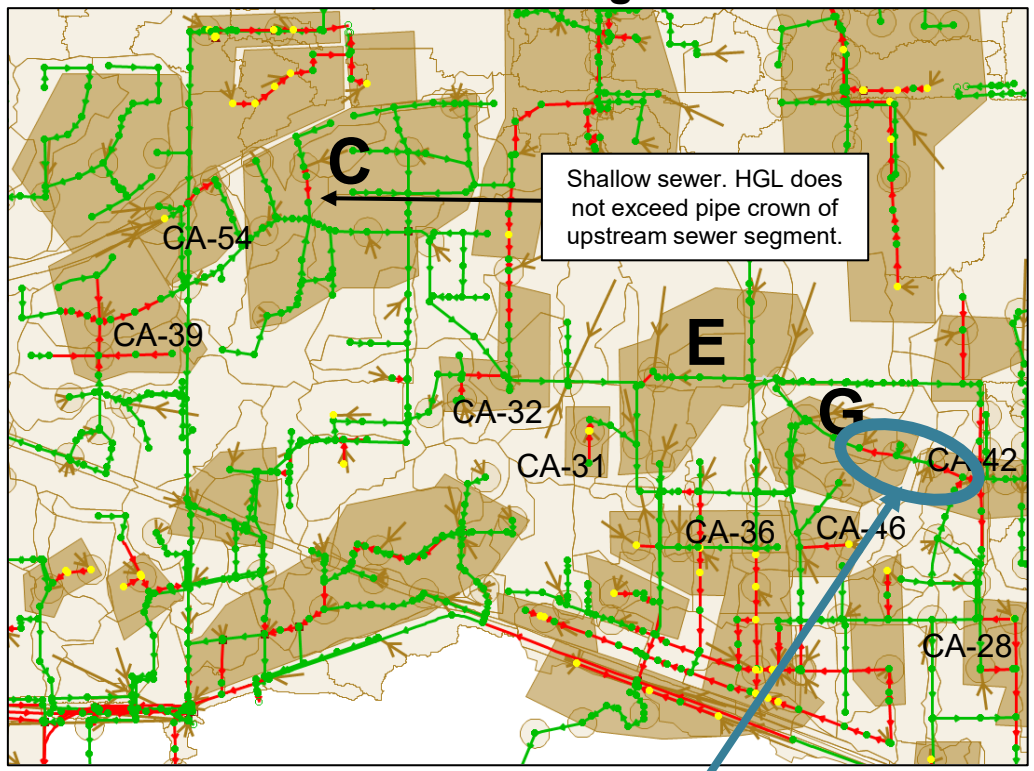
Area C, E & G: Alt 3b & 4b Reg Mods

LOS Results for Future 16-year, 1-hour Storm

With Alt 3b + Reg Mods



With Alt 4b + Reg Mods



CSS Level of Service

Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

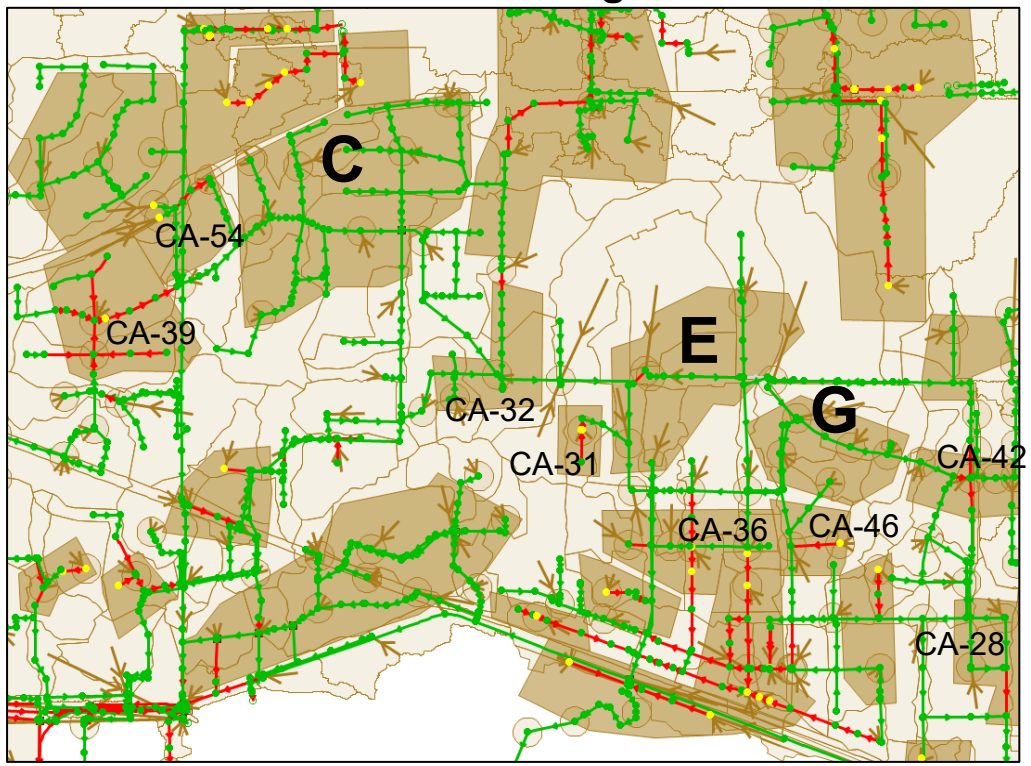
Key Takeaways:

- Alt 3b & 4b achieves Future 16-year LOS in Areas C and E.
- Alt 3b & 4b does not achieve Future 16-year LOS in Area G
  - Conduits not achieving LOS in Area G due to lack of capacity within mainline sewer on Gunson St.
- Alt 3b & 4b benefits CA-54, CA-39, CA-32, CA-31, CA-36, CA-42, and CA-46.

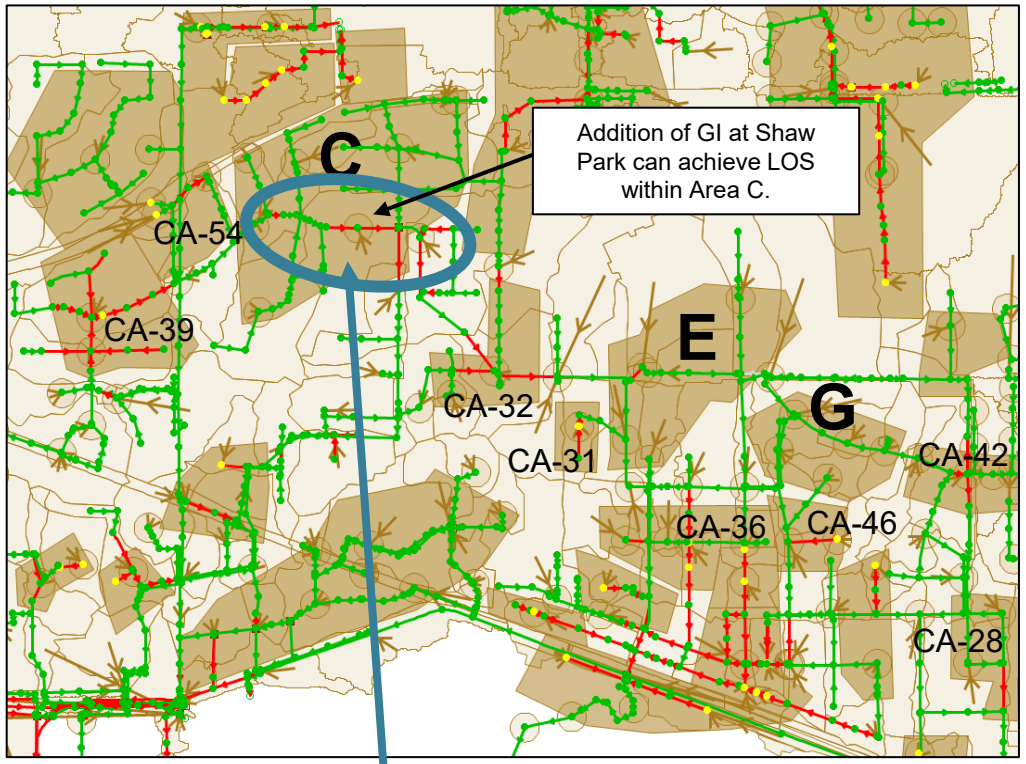
Area B, C, E & G: Alt 3a – MP Sizing

LOS Results for Current 10-year, 1-hour Storm

With Alt 3a + Reg Mods



With Alt 3a + Reg Mods - MP Sizing



CSS Level of Service

Conduits
- LOS Achieved
- Exceeds LOS

Nodes
- No MH Flooding
- MH Flooding

Key Takeaways:

- Alt 3a achieves Current 10-year LOS in Areas C, E and G.
- Alt 3a (with MP sizing) does not achieve Current 10-year LOS in Area C
- Alt 3a & 4a also benefits CA-54, CA-39, CA-32, CA-31, CA-36, CA-42, CA-46, and CA-28.

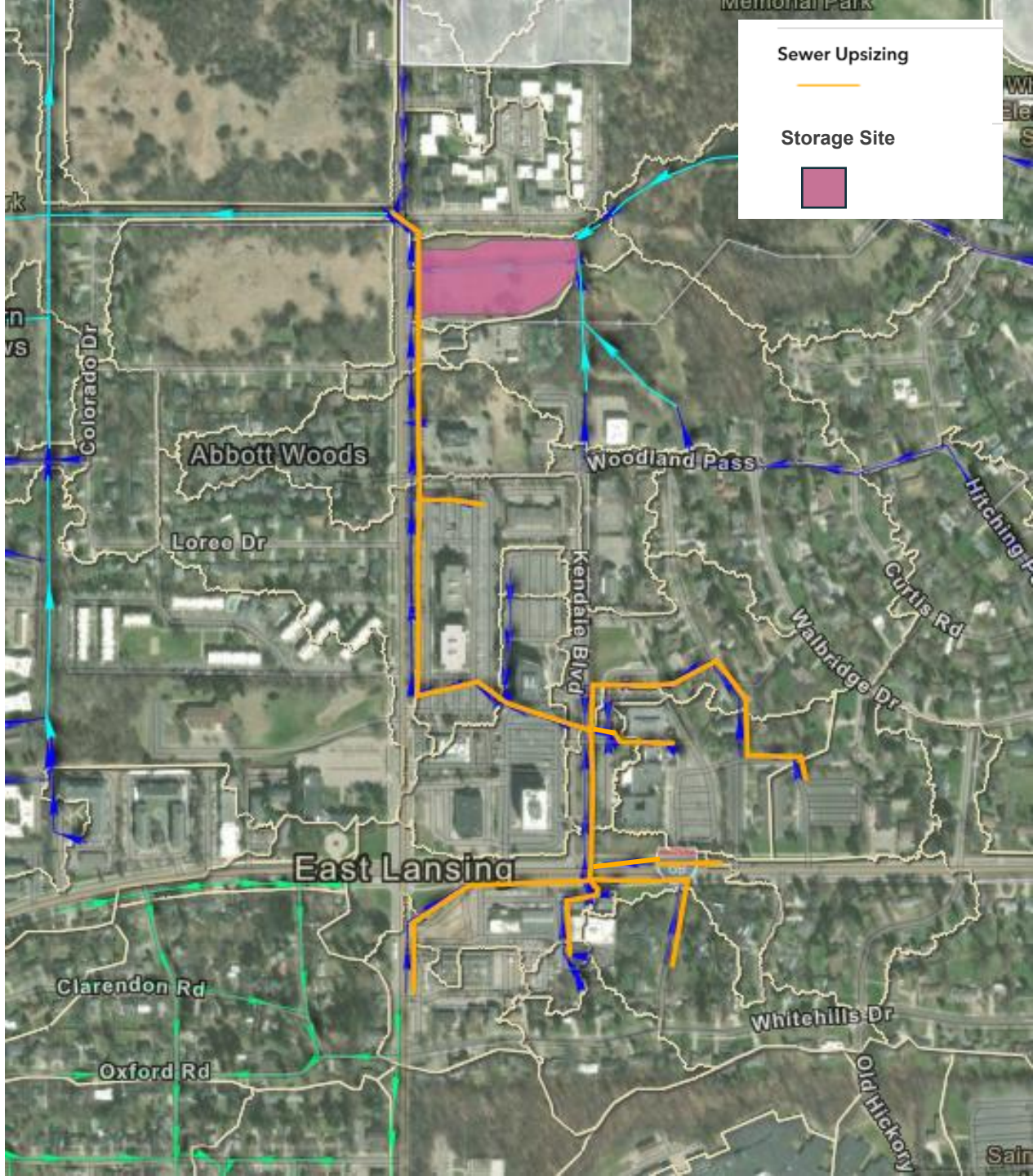


04

MS4 Alternatives Analysis Results

Area F Alternatives

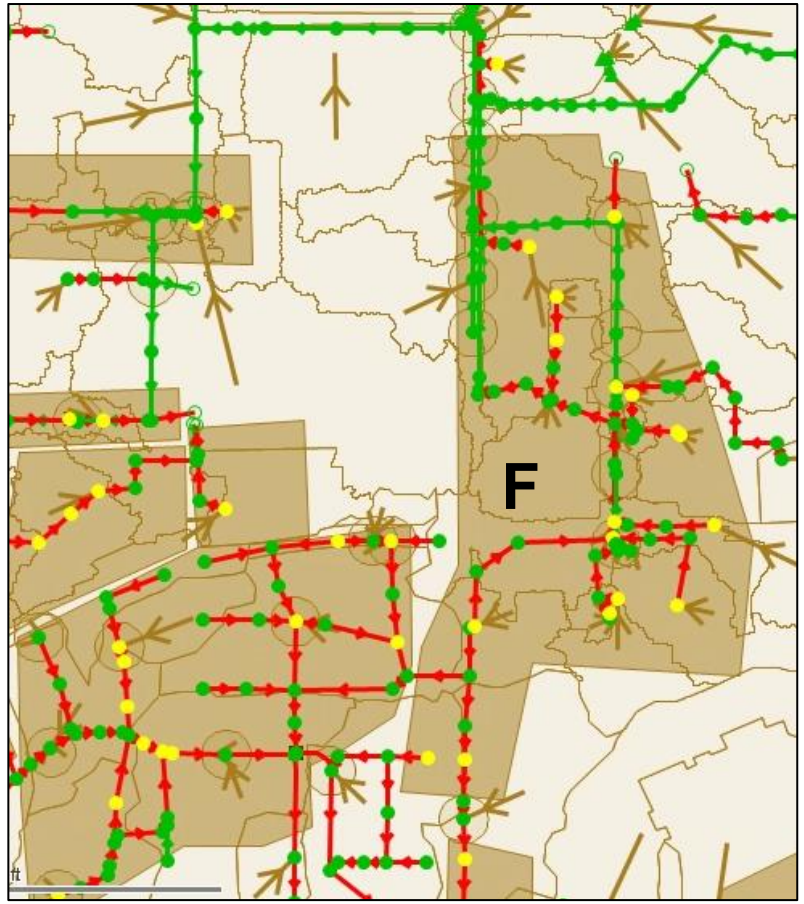
Concern Area	Alt	Proposed Project(s)
F	**5a**	• 7,600 feet of main storm sewer upsizing • 3.53 ac-ft of storage at Fire Department
	5b	• 5a plus additional 1.59 ac-ft of storage at Fire Department or upstream detention (total 5.12 ac-ft)
	5c	• 5a or 5b plus storage under parking lots



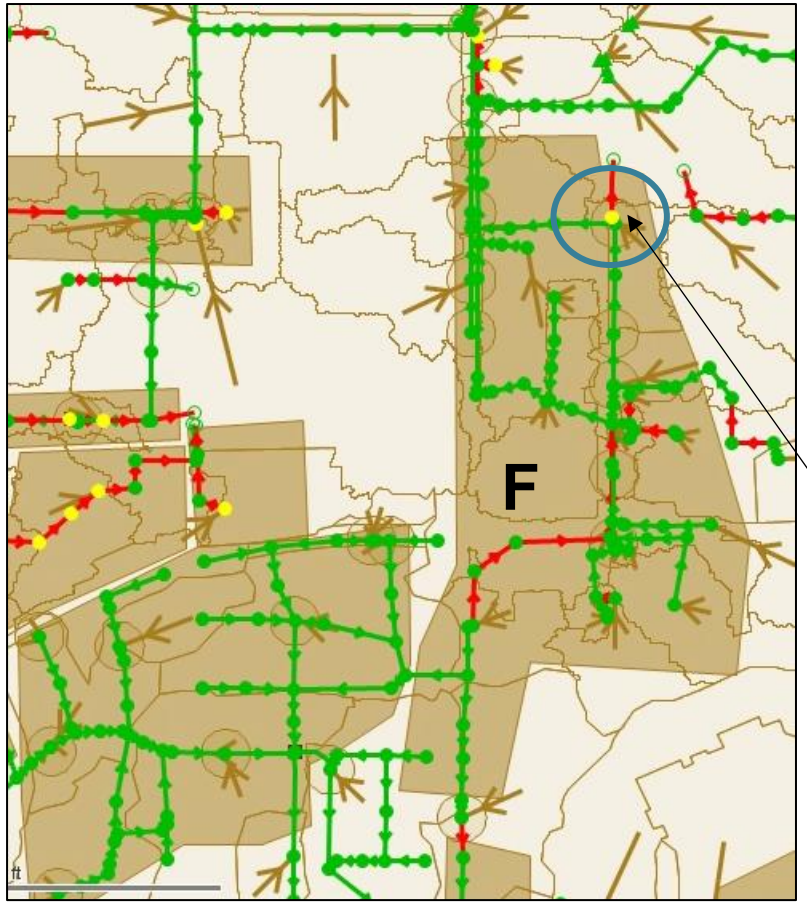
Area F: Alt 5a

LOS Results for Current 10-year, 1-hour Storm

Without Alt



With Alt 5a



MS4 Level of Service

Nodes

- No MH Flooding
- MH Flooding

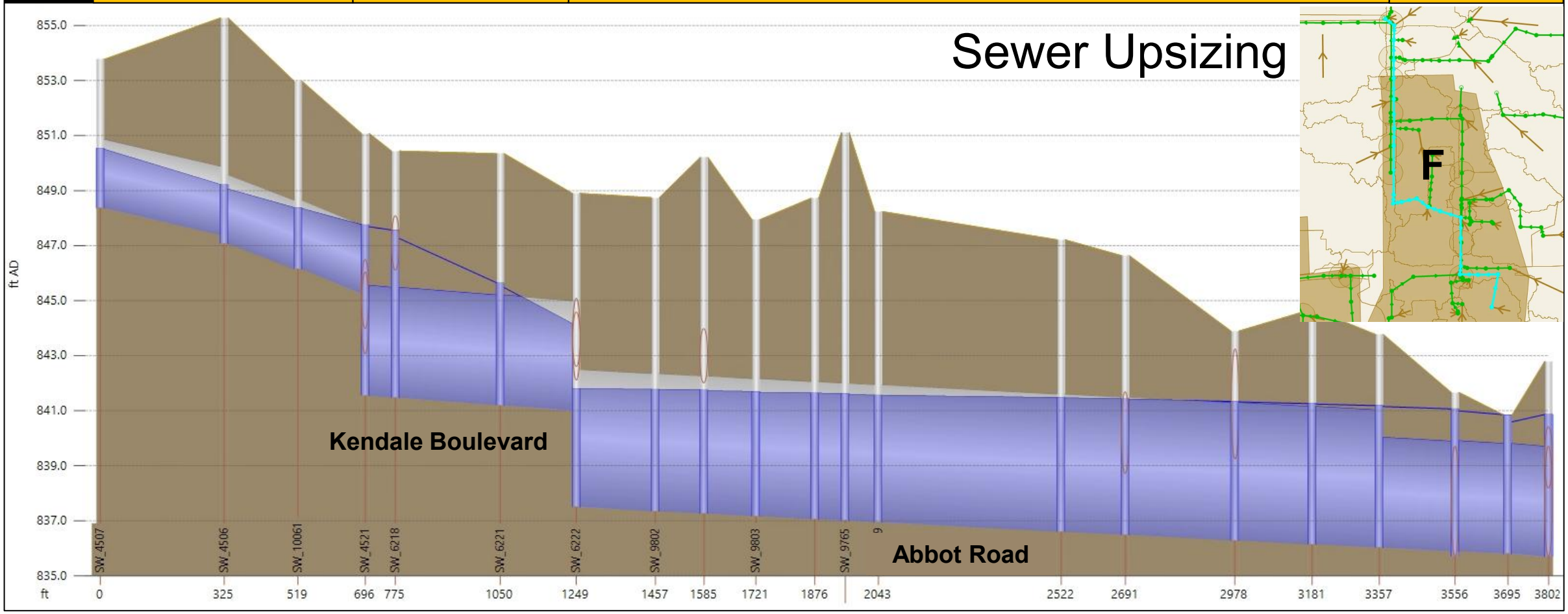
Key Takeaways:

- Alt 5a achieves Current 10-year LOS in Area F.
  - Node with flooding is an independent culvert and not hydraulically connected to other sewers in Area F.
  - Can upsize additional 275.5 LF culvert to achieve LOS.

Area F: Alt 5a Main Trunk Sewer Pipe Upsize

Required upsizes for the current 10-year, 1-hour, 2.00 inches

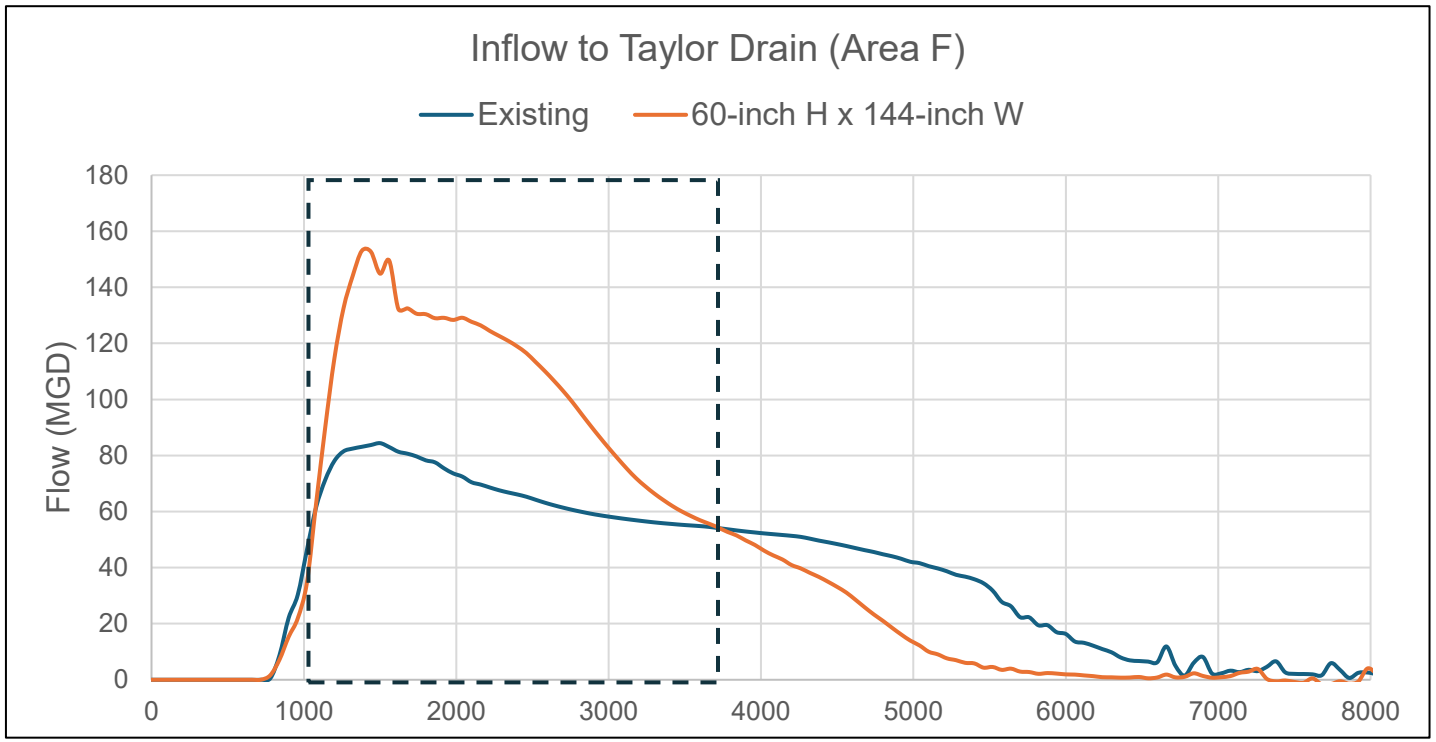
	Ex. 21-inch Upsize to 30-inch	Ex. 36-inch Upsize to 48-inch	Ex. 42-inch, 43-inch H x 68-inch W Upsize to 60-inch H x 144-inch W	Ex. 48-inch H x 76-inch W Upsize to 48-inch H x 168-inch W



Area F: Alt 5a Downstream Increased Flow

Taylor Drain near East Lansing Fire Station

Required peak attenuation for the current 10-year, 1-hour, 2.00 inches



Peak Flow

Scenario	Peak Flow (MGD)	Difference from Existing (MGD)
Existing	84.40	-
Alt 5a	153.00	68.60

Peak Volume

Scenario	Volume (ac-ft)	Difference from Existing (ac-ft)
Existing	6.75	-
Alt 5a	10.31	**3.53**

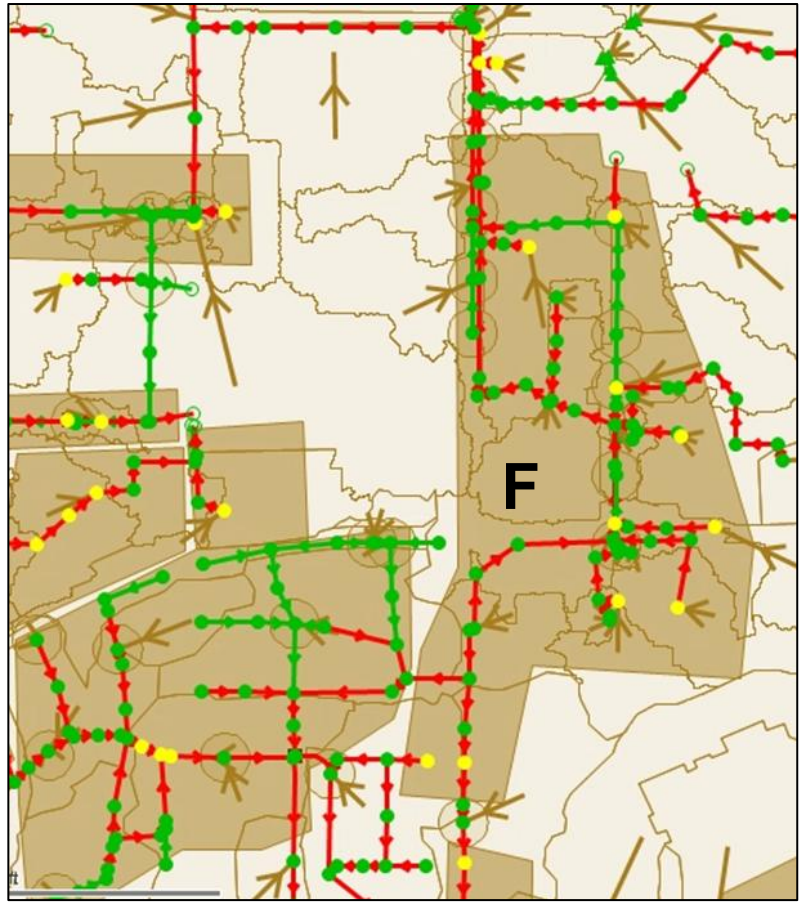
From 780 to 3780 simulation seconds

- Area F existing capacity: 84 MGD (130 cfs)
- Area F required capacity for current 10-year, 1-hour: 153 MGD (236 cfs)
- Approximate storage needed to offset peaks for current 10-year, 1-hour: 1.15 MG (3.53 ac-ft)

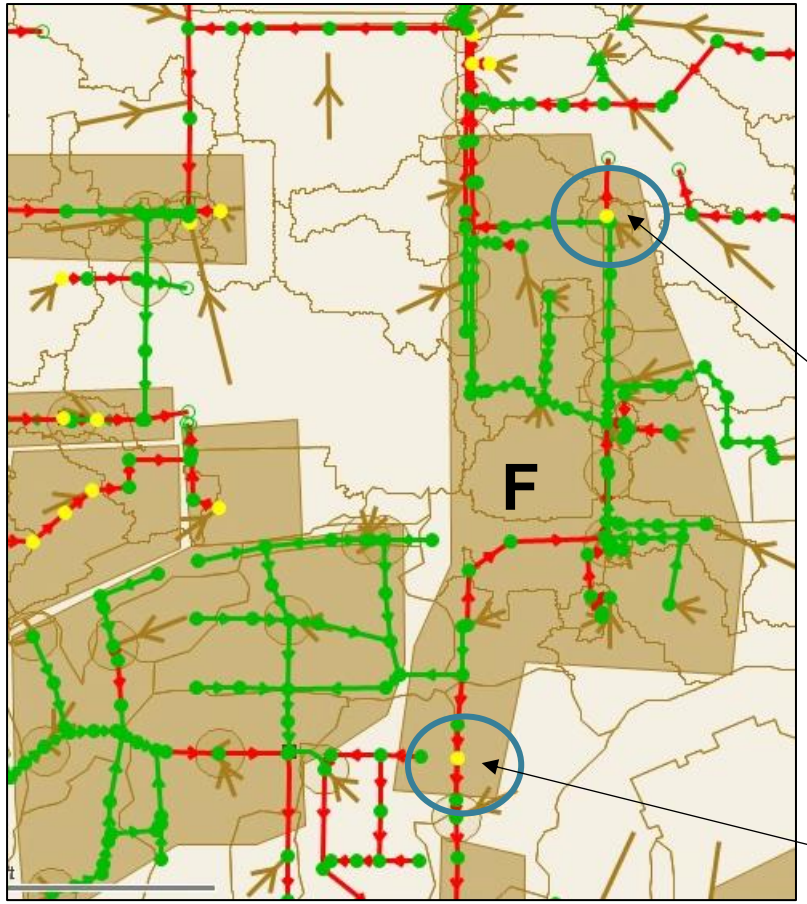
Area F: Alts 5a & 5b

LOS Results for Future 16-year, 1-hour Storm

Alt 5a



Alt 5b



MS4 Level of Service

Nodes

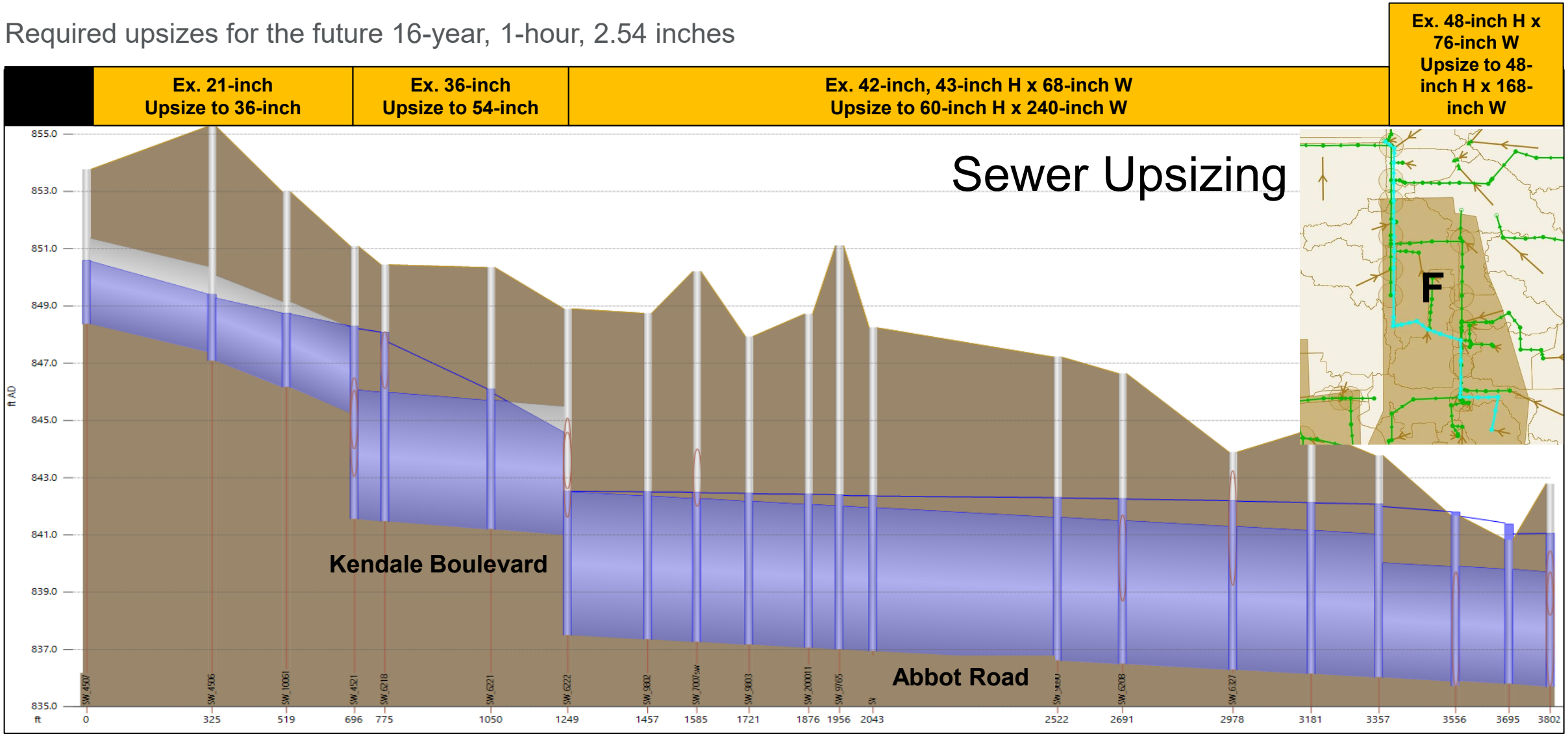
- No MH Flooding
- MH Flooding

Key Takeaways:

- Alt 5a does not achieve Future 16-year LOS in Area F.
- Alt 5b achieves Future 16-year LOS in Area F.
  - Node with flooding is an independent culvert and not hydraulically connected to other sewers in Area F.
  - Can upsize additional 275.5 LF culvert to achieve LOS.
  - Flooded manhole is in CSS area and LOS cannot be achieved by MS4 projects alone.

Area F: Alt 5b Main Trunk Sewer Pipe Upsize

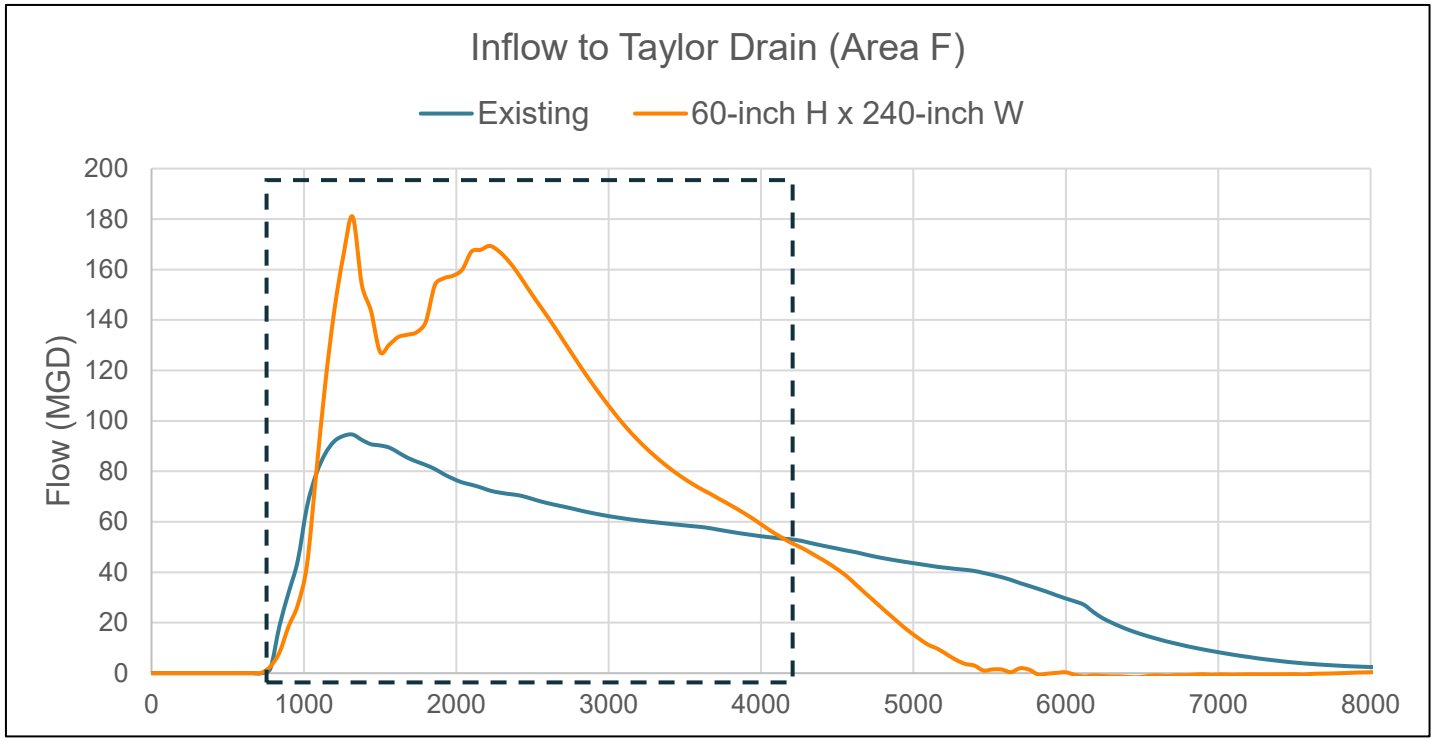
Required upsizes for the future 16-year, 1-hour, 2.54 inches



Area F: Alt 5b Downstream Increased Flow

Taylor Drain near East Lansing Fire Station

Required peak attenuation for the future 16-year, 1-hour, 2.54 inches



Peak Flow

Scenario	Peak Flow (MGD)	Difference from Existing (MGD)
Existing	94.58	-
Alt 5b	180.93	86.36

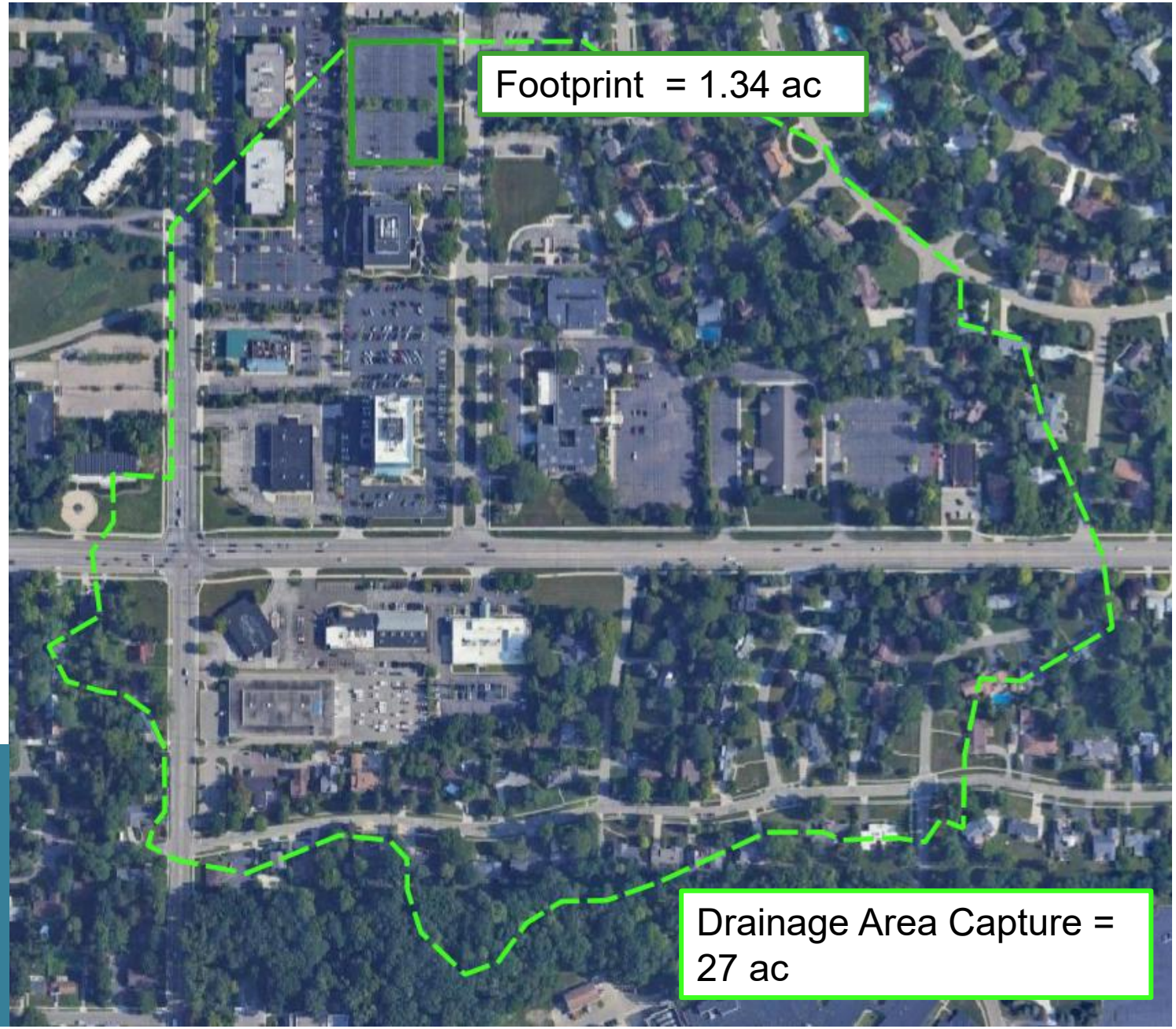
Peak Volume

Scenario	Volume (ac-ft)	Difference from Existing (ac-ft)
Existing	8.34	-
Alt 5b	13.47	**5.12**

From 780 to 4260 simulation seconds

- Area F existing capacity: 94 MGD (146 cfs)
- Area F required capacity for future 16-year, 1-hour: 181 MGD (280 cfs)
- Approximate storage needed to offset peaks for future 16-year, 1-hour: 1.67 MG (5.12 ac-ft)

Area F: Alt 5c Parking Lot Subsurface Storage Resilience Opportunity



Calculated Peak Flow Reduction for Future 16-year Storm =

68 cfs

Or, Increased LOS with the Alt 5c Resilience Opportunity

- ~68 cfs benefit to downstream system with three storage locations
  - Increase LOS from current 10-year to ~20-year
  - Increase LOS from future 16-year to ~25-year

Rainfall (inches)	Return Period (Years)		Peak Flow CFS		
	Current Day	2100 High Emissions	Area F	With Parking Lot Storage	
1.40	2	1	231		
1.61	3	1	276		
1.92	8	3	346		
2.00	10	3	364	432	+68 cfs
2.18	17	5	406		
2.44	38	10	467		
2.54	50	16	492	560	+68 cfs
2.77	100	25	549		
3.05	200	50	620		
3.32	500	100	691		

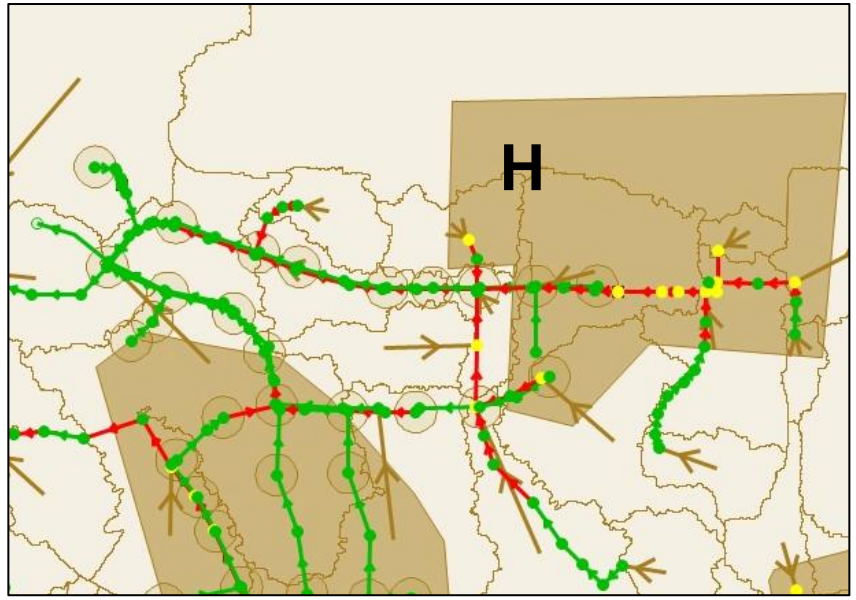
Area H Alternatives

Concern Area	Alt	Proposed Project(s)
H	**6a**	• 4,600 feet of main storm sewer upsizing • Restrictor modification – remove flow restrictor • 0.61 Ac-ft of storage at White Memorial City Park-fishing Pond
	6b	• 6a plus additional 1.12 ac-ft of storage at White Memorial City Park-fishing Pond (total 1.73 ac-ft)

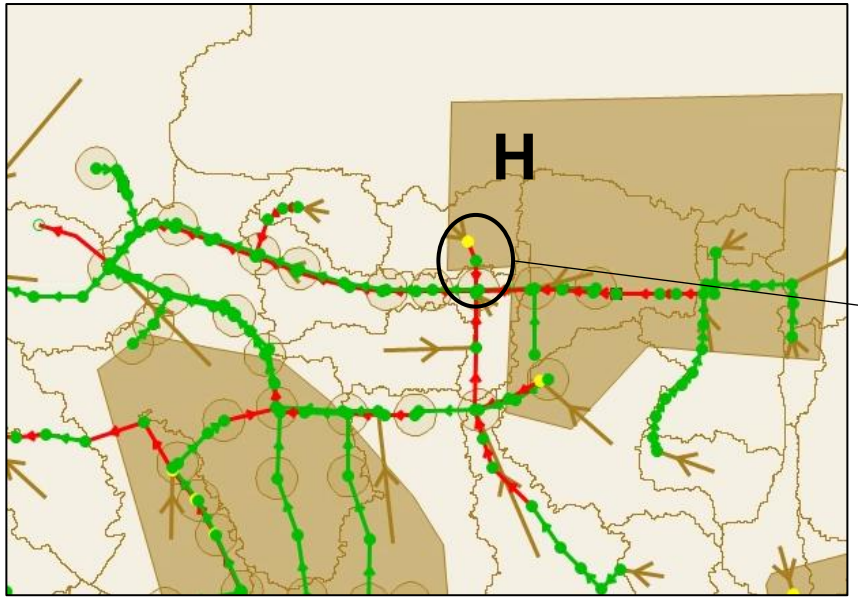


Area H: Alt 6a
LOS Results for Current 10-year, 1-hour Storm

Without Alt



With Alt 6a



MS4 Level of Service

Nodes

- No MH Flooding
- MH Flooding



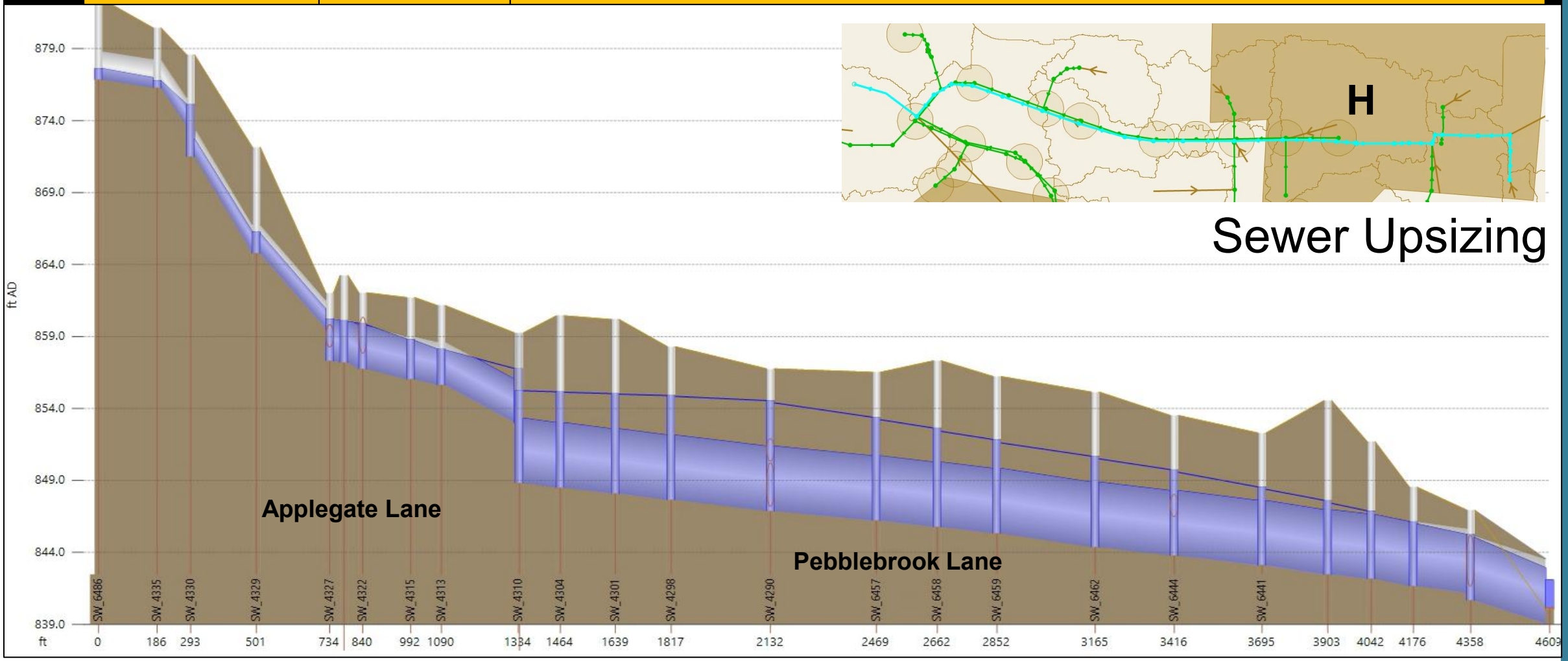
Key Takeaways:

- Alt 6a achieves Current 10-year LOS is Area H
  - Remaining nodes with flooding is due to lack of available sewer capacity along Dennison Rd
  - Street may benefit from green infrastructure to capture peak flows.
- Flooded volume from 2 locations above: ~ 10,000 gallons.

Area H: Alt 6a Main Trunk Sewer Pipe Upsize

Required upsizes for the current 10-year, 1-hour, 2.00 inches

	Ex. 18 Upsize to 24-inch	Ex. 18, 30 Upsize to 36-inch	Ex. 30, 36, 48, 54 Upsize to 54-inch

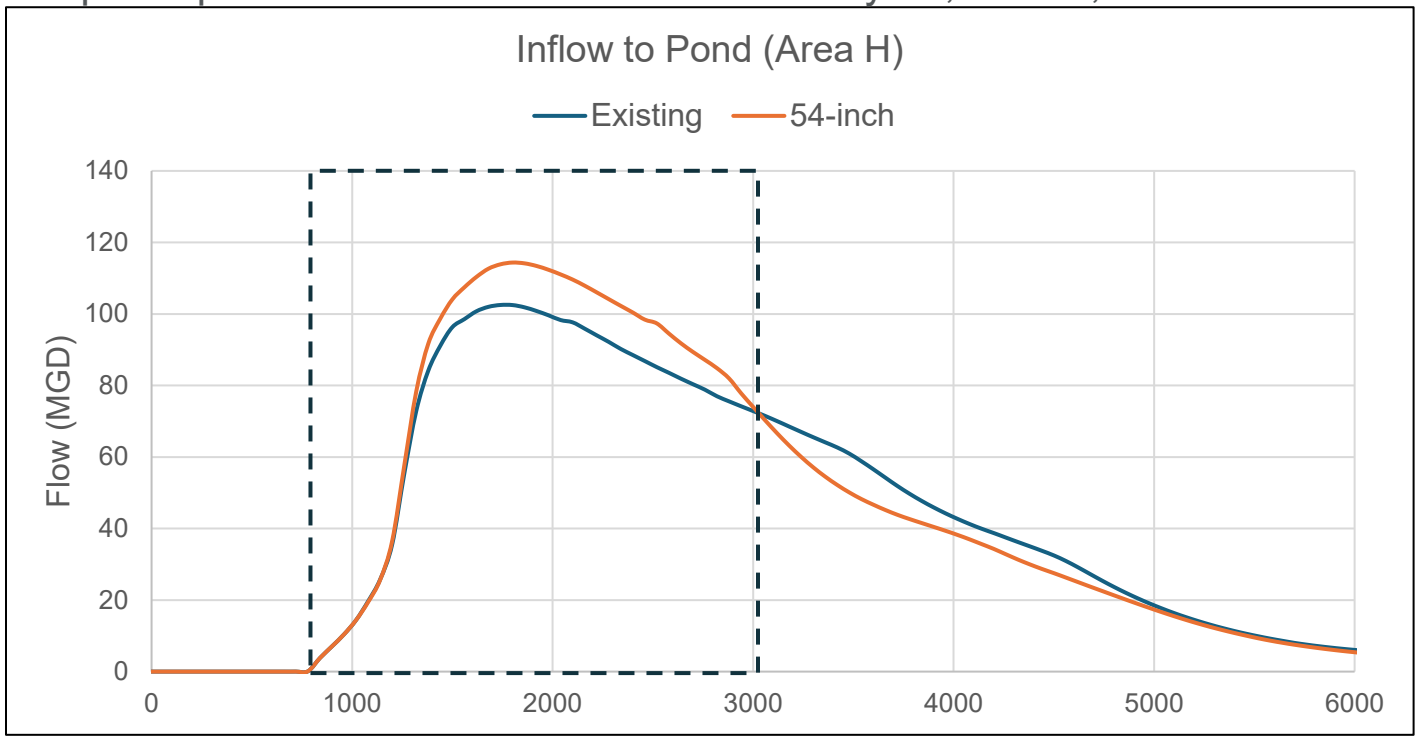


Sewer Upsizing

Area H: Alt 5a Downstream Increased Flow

To White Memorial City Park-fishing Pond

Required peak attenuation for the current 10-year, 1-hour, 2.00 inches



Peak Flow

Scenario	Peak Flow (MGD)	Difference from Existing (MGD)
Existing	102.52	-
Run 1	114.37	11.86

Peak Volume

Scenario	Volume (ac-ft)	Difference from Existing (ac-ft)
Existing	6.07	-
Run 1	6.68	**0.61**

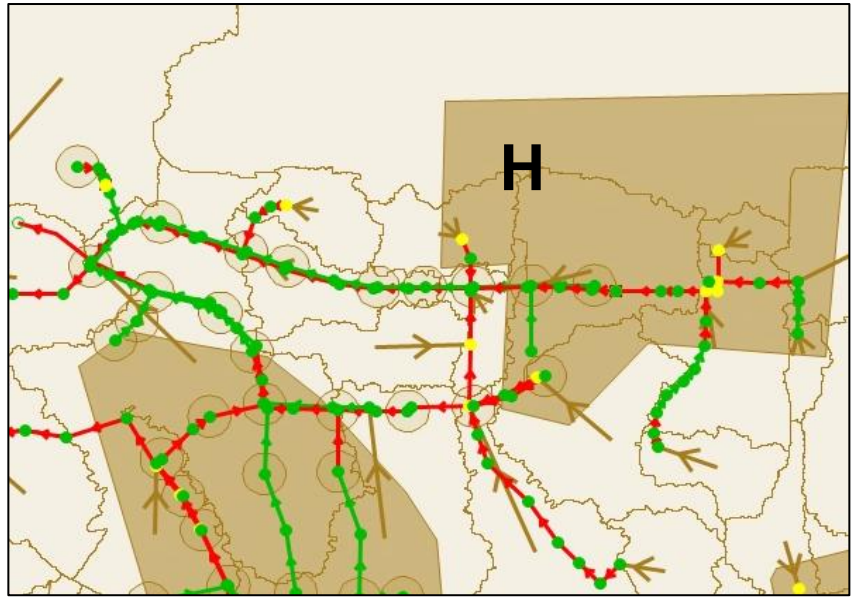
From 780 to 3060 simulation seconds

- Area H existing capacity: 102 MGD (158 cfs)
- Area H required capacity for current 10-year, 1-hour: 127 MGD (177 cfs)
- Approximate storage needed to offset peaks for current 10-year, 1-hour: 0.20 MG (0.61 ac-ft)

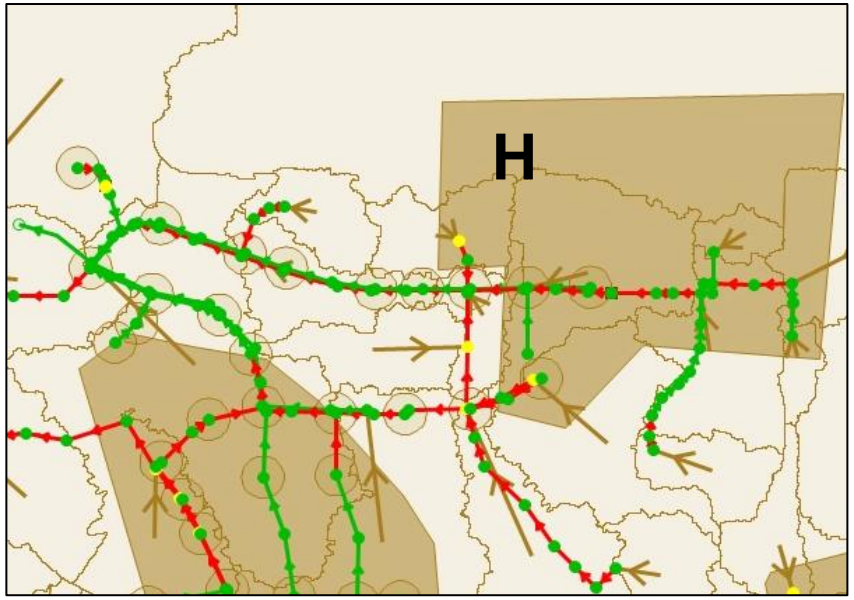
Area H: Alts 6a & 6b

LOS Results for Future 16-year, 1-hour Storm

With Alt 6a



With Alt 6b



MS4 Level of Service

Nodes

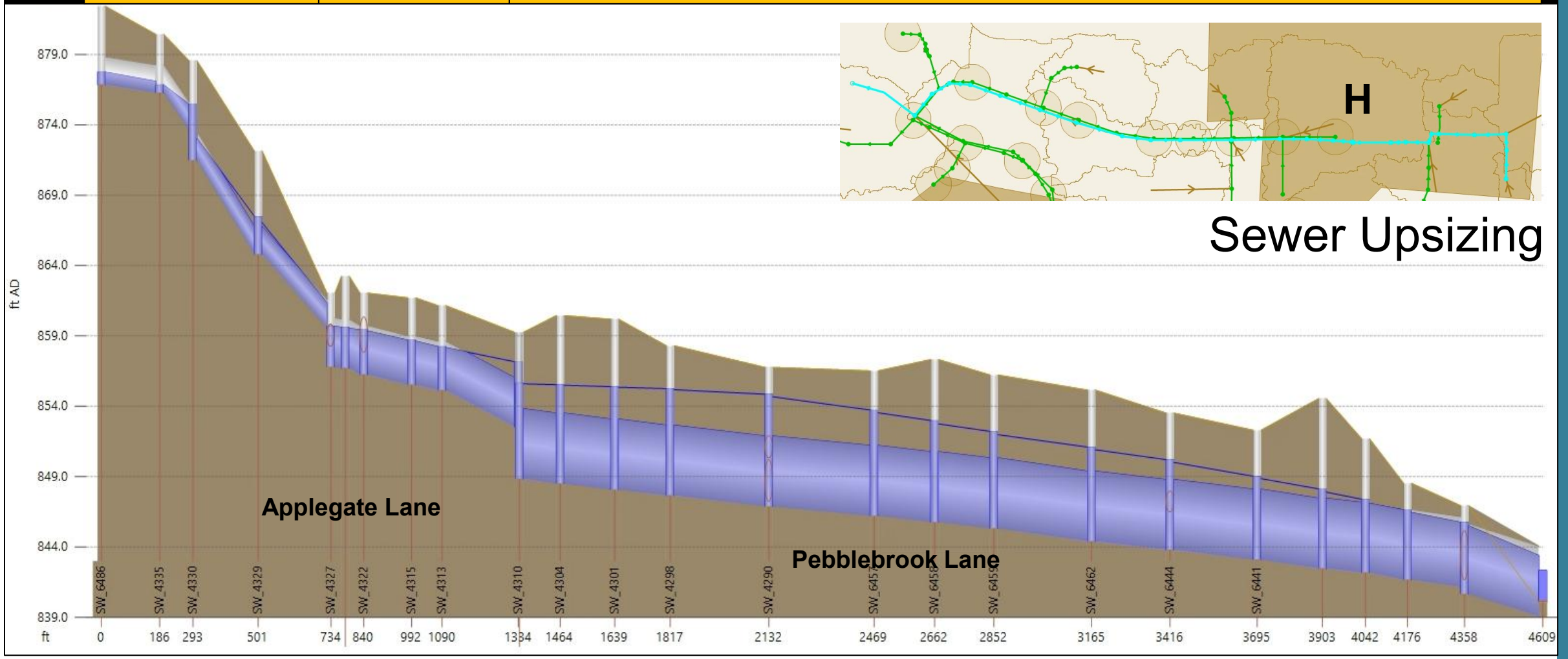
- No MH Flooding
- MH Flooding

Key Takeaways:

- Alt 6a does not achieve Future 16-year LOS in Area H.
- Alt 6b does achieve Future 16-year LOS in Area H
  - Nodes with flooding due to lack of available sewer capacity along Dennison Rd.
  - Street may benefit from green infrastructure to capture peak flows.
- Flooded volume from 4 locations above: ~ 27,500 gallons.
- Flooded volume from 2 locations within Area H only: ~10,500 gallons.

Area H: Alt 6b Main Trunk Sewer Pipe Upsize

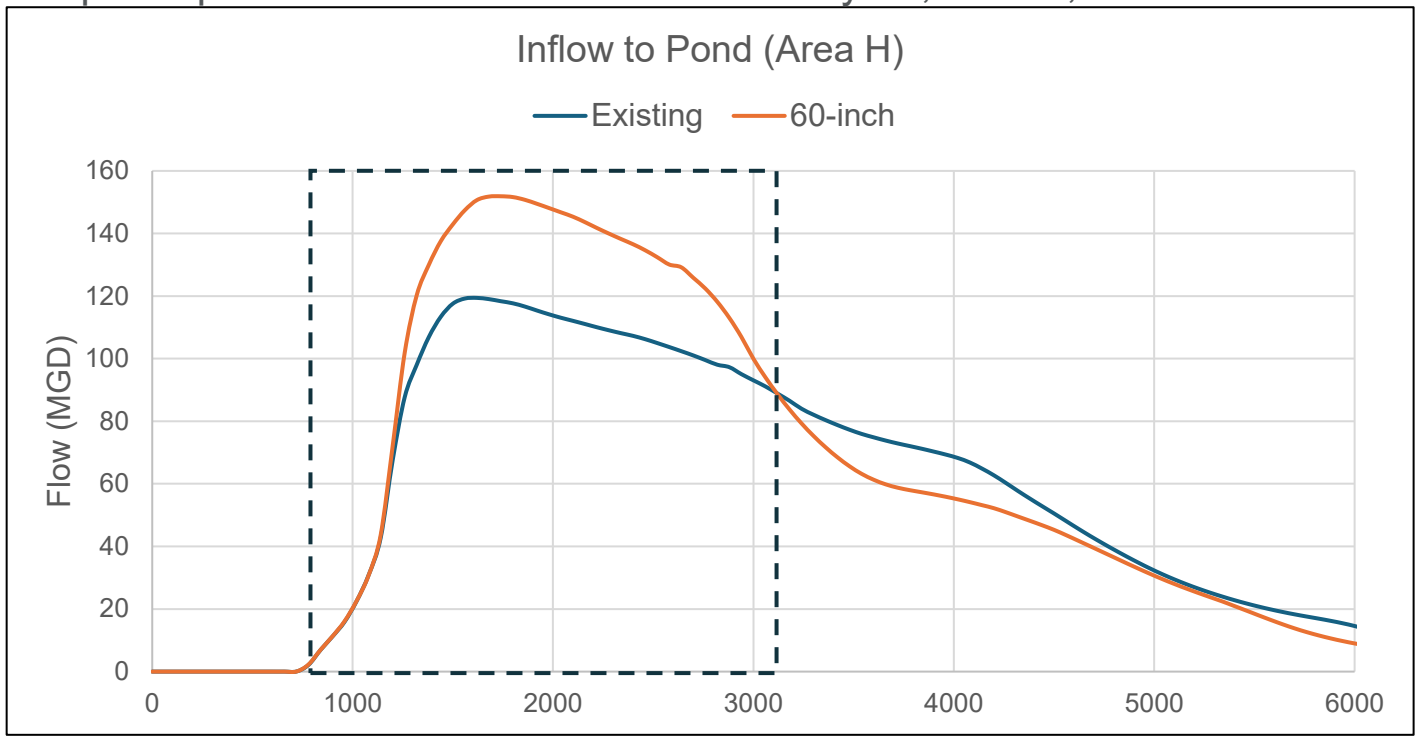
Required upsizes for the 2100 16-year, 1-hour, 2.54 inches



Area H: Alt 6b Downstream Increased Flows

To White Memorial City Park-fishing Pond

Required peak attenuation for the future 10-year, 1-hour, 2.54 inches



Peak Flow

Scenario	Peak Flow (MGD)	Difference from Existing (MGD)
Existing	119.41	-
Run 1	151.89	32.47

Peak Volume

Scenario	Volume (ac-ft)	Difference from Existing (ac-ft)
Existing	7.71	-
Run 1	9.44	**1.73**

From 780 to 3120 simulation seconds

- Area H existing capacity: 120 MGD (186 cfs)
- Area H required capacity for future 10-year, 1-hour: 152 MGD (235 cfs)
- Approximate storage needed to offset peaks for future 10-year, 1-hour: 0.56 MG (1.73 ac-ft)



05

Alternatives Results Summary, Key Takeaways and Next Steps

Alternatives and Proposed Projects Results Summary

Concern Area	Alt	Proposed Project(s)	LOS Achieved	Benefits	Note
A & B	1a	• 107.3 ac of storm separation • 7,200 ft of new storm main (max depth ~10-15 ft) • Restrictor modification – remove flow restrictor • 2,100 ft of combined sewer upsizing • 725 ft of new combined sewer • 2 sewer bulkheads	Current 10-year, 1-hour	Ability to offload of stormwater into Ranney Park (Agreement with County required), Increased CSS capacity	Alt 1 separation area extents and storm main size are reduced if Alt 3 is selected
	1b	• 1a plus additional 40.9 ac of stormwater separation (total 148.2 ac) • Increased storm main sizing	Future 16-year, 1-hour	Increased ability to offload of stormwater into Ranney Park (Agreement with County required)	
	1c	• 1a or 1b plus Gordon Guyer Park storage	Current 17-year, 1-hour (with 1a) Future 21-year, 1-hour (with 1b)	WQ Treatment, Low Added Resilience	
D	2a	• 77.6 ac of storm separation • 3,100 ft of new storm main (max depth ~15-20 ft) • Restrictor modification – lower weir at Beal St to invert of overflow sewer • New regulator at Louis St • 2,000 ft of combined sewer upsizing • 600 ft of new combined sewer	Current 10-year, 1-hour (except near interceptor)	New storm outfall into Red Cedar River	Alt 2 is an independent sewershed and does not impact other alternatives
	2b	• 2a plus additional 11.5 ac of storm separation (total 89.1 ac) • Increased storm main sizing	Between the Current 10-year, 1-hour and Future 16-year, 1-hour	Increased offload of stormwater into Red Cedar River	
	2c	• 2a or 2b plus Valley Court Park Storage	Current 500-year, 1-hour (with 2a) Future 100-year, 1-hour (with 2b)	Large capture area relative to drainage area. WQ treatment potential, High added resilience.	

Alternatives and Proposed Projects Results Summary

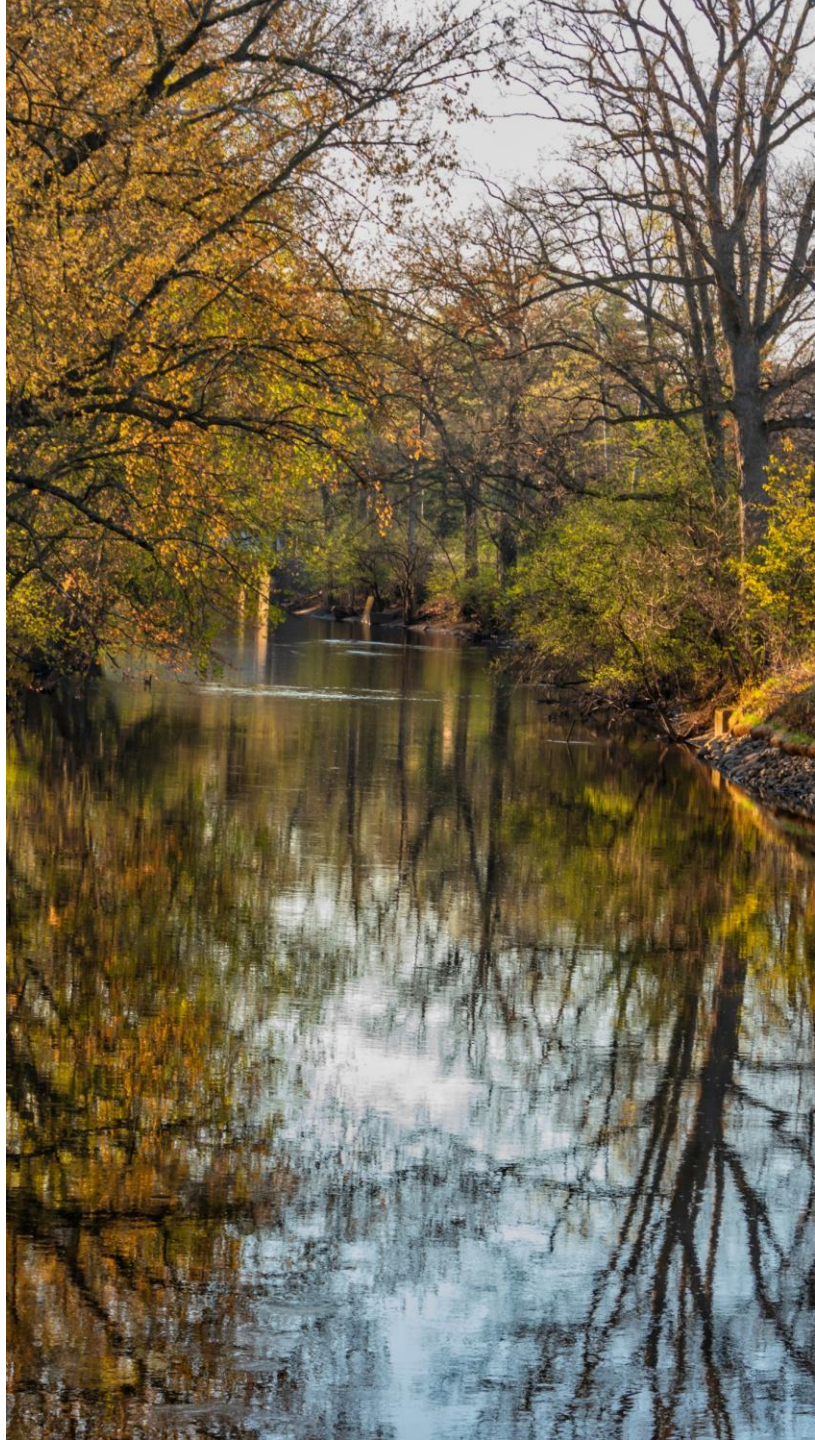
Concern Area	Alt	Proposed Project(s)	LOS Achieved	Benefits	Note
B, C, E & G – Harrison Storm	**3a**	• 91.7 ac of storm separation • 5,200 ft of new storm main (max depth ~35-40 ft) • 7,100 ft of combined sewer upsizing (Includes Charles St) • 875 ft of new combined sewer • 2 sewer bulkheads • Charles St regulator modification– increase weir length to 8.5 ft	Current 10-year, 1-hour	New storm outfall into Red Cedar River (shorther path down Harrison St.), reduces flow to Charles St., reduces flows from Area A B to Ranney Park (Agreement with County required)	Alt 3 projects will reduce size of Alt 1 projects. Alt 3 not needed if Alt 4 selected
	3b	• 3a plus additional 192.5 ac of storm separation (total 284.2 ac) • Plus an additional 3,300 ft of new storm main (max depth ~10-15 ft) • Increased storm main sizing • Increased Charles St upsize, and additional 1065 ft of upsizing	Future 16-year, 1-hour	New storm outfall into Red Cedar River, reduces flow to Charles St., reduces flows from Area A B to Ranney Park (Agreement with County required)	
	3c	• 3a or 3b plus Gordon Guyer Park and Glencairn Park storage	Current 35-year, 1-hour (with 1a) Future 37-year, 1-hour (with 1b)	WQ Treatment, Medium Added Resilience	
B, C, E & G – Sunset Storm	**4a**	• 110.0 ac of storm separation • 10,500 ft of new storm main (max depth ~25-30 ft) • 7,100 ft of combined sewer upsizing (Includes Charles St) • 875 ft of new combined sewer • 2 sewer bulkheads • Charles St regulator modification– increase weir length to 8.5 ft	Current 10-year, 1-hour	New storm outfall into Red Cedar River (longer path), reduces flow to Charles St about the same as Alt 3	Alt 3 not needed if Alt 4 selected.
	4b	• 4a plus additional 192.5 ac of storm separation (total 302.5 ac) • Plus an additional 3,300 ft of new storm main (max depth ~10-15 ft) Increased storm main sizing • Increased Charles St upsize, and additional 1065 ft of upsizing	Future 16-year, 1-hour	New storm outfall into Red Cedar River (longer path), reduces flow to Charles St about the same as Alt 3	
	4c	• 4a or 4b plus Glencairn Park, Shaw Park, Hannah Community Center storage	Current 100-year, 1-hour (with 4a); Future 50-year, 1-hour (with 4b)	Large capture area relative to drainage area. WQ treatment potential, High added resilience.	

Alternatives and Proposed Projects Results Summary

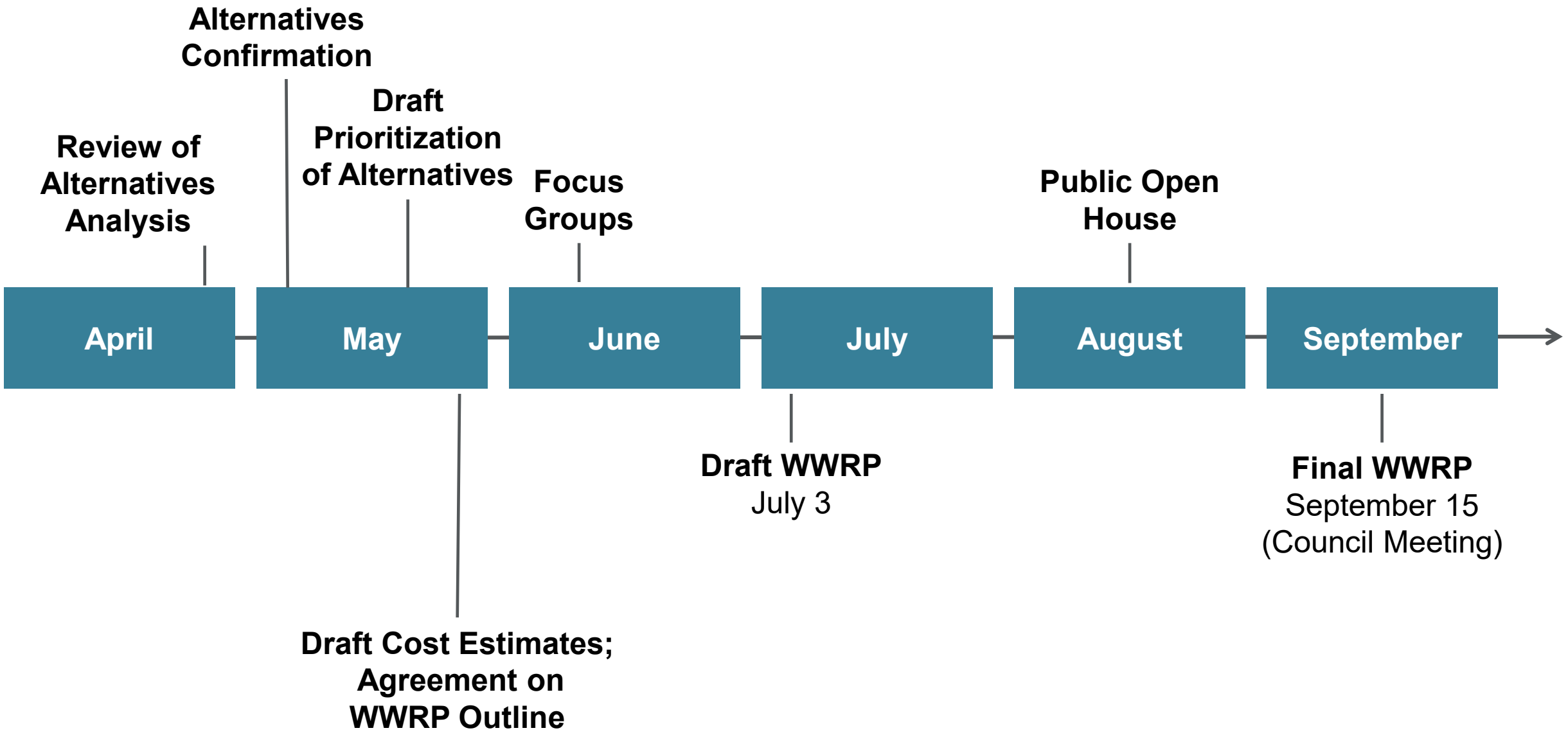
Concern Area	Alt	Proposed Project(s)	LOS Achieved	Benefits	Note
F	**5a**	• 7,600 ft of main storm sewer upsizing • 3.53 ac-ft of storage at Fire Department	Current 10-year, 1-hour	Reduced surface flooding, harness open floodplains for offset storage, WQ treatment	Downstream flow impacts will require more detailed analysis.
	5b	• 5a plus additional 1.59 ac-ft of storage at Fire Department or upstream detention (total 5.12 ac-ft)	Future 16-year, 1-hour	Harness additional open floodplains for offset storage, WQ treatment	
	5c	• 5a or 5b plus storage under parking lots	Current 20-year, 1-hour	WQ Treatment, Medium Added Resilience	
H	**6a**	• 4,600 ft of main storm sewer upsizing • Restrictor modification – remove flow restrictor • 0.61 ac-ft of storage at White Memorial City Park-fishing Pond	Current 10-year, 1-hour	Reduced surface flooding, recreational opportunities for offset storage, WQ treatment	Area H is upstream of Area F. Downstream flow impacts may be coupled with Area F to optimize increased flows due to upsizing.
	6b	• 6a plus additional 1.12 ac-ft of storage at White Memorial City Park-fishing Pond (total 1.73 ac-ft)	Future 16-year, 1-hour	Additional offset storage, WQ treatment	

Key Takeaways

- Alternatives achieve Current 10-year, 1-hour LOS (except Alt 3)
- Future 16-year, 1-hour LOS cannot be achieved everywhere with alternatives evaluated
- Remaining concerns for Areas C and D for enhanced LOS
  - Area C is regulator weir impacts
  - Area D is tunnel backwater impacts
- Feasibility needs to be addressed for large size pipes and depths of cover for both LOS scenarios
- Large acreages of separation are needed to achieve LOS targets
  - Will come with large price tags
  - Separation will need to be minimum 80% effective
- Planned Charles St project is assumed in all alternatives.
  - There is no nearby stormwater separation outfall available
  - Upsizing opportunity is limited
- The benefits of storage are potentially significant for both pipe sizing and achieving enhanced LOS
  - Particularly for MS4 Area F that is highly impervious
- Separation will need to be concurrent with upsizing to offset CSO impacts



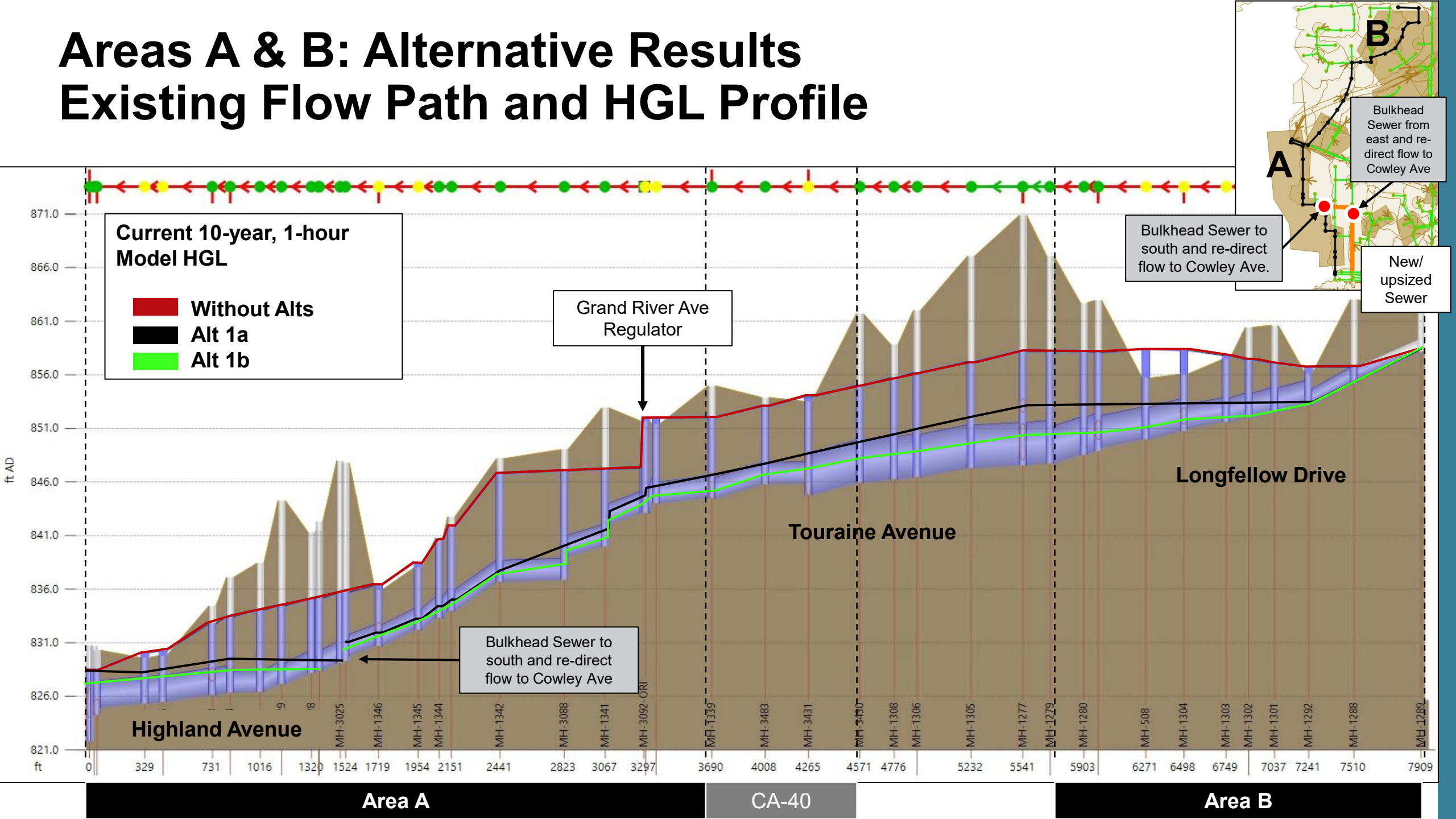
Next Steps


Review of Alternatives Analysis
Alternatives Confirmation
Draft Prioritization of Alternatives
Focus Groups
Public Open House
April
May
June
July
August
September
Draft Cost Estimates; Agreement on WWRP Outline
Draft WWRP
July 3
Final WWRP
September 15
(Council Meeting)

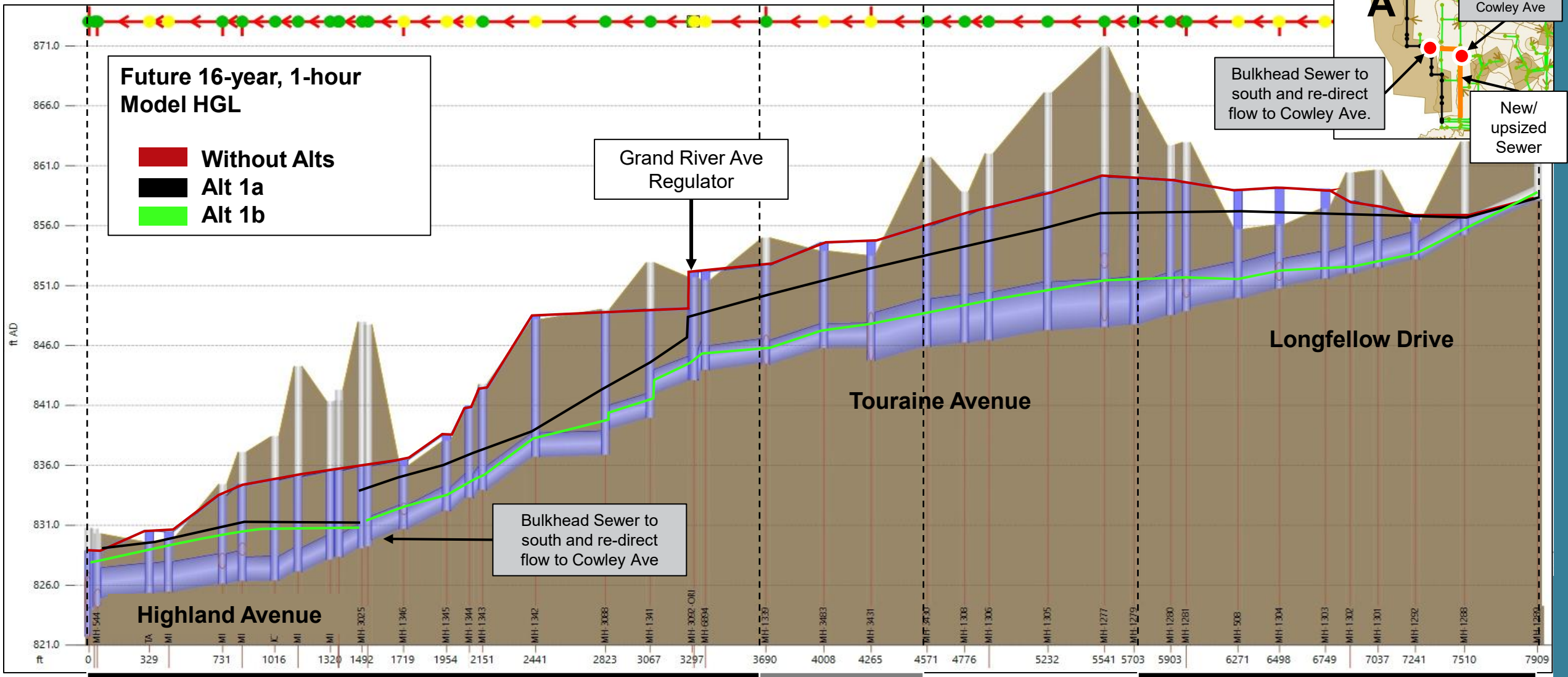
Appendix B. Model Hydraulic Profiles

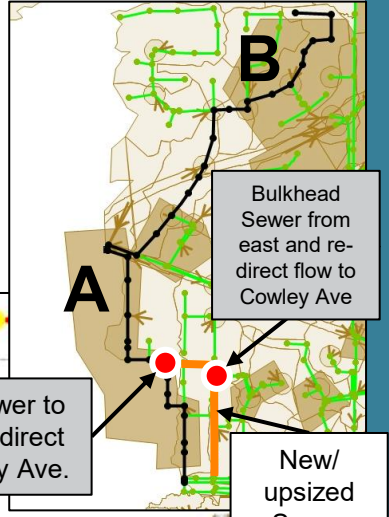
Hydraulic Profiles –
Alternative 1

Areas A & B: Alternative Results
Existing Flow Path and HGL Profile



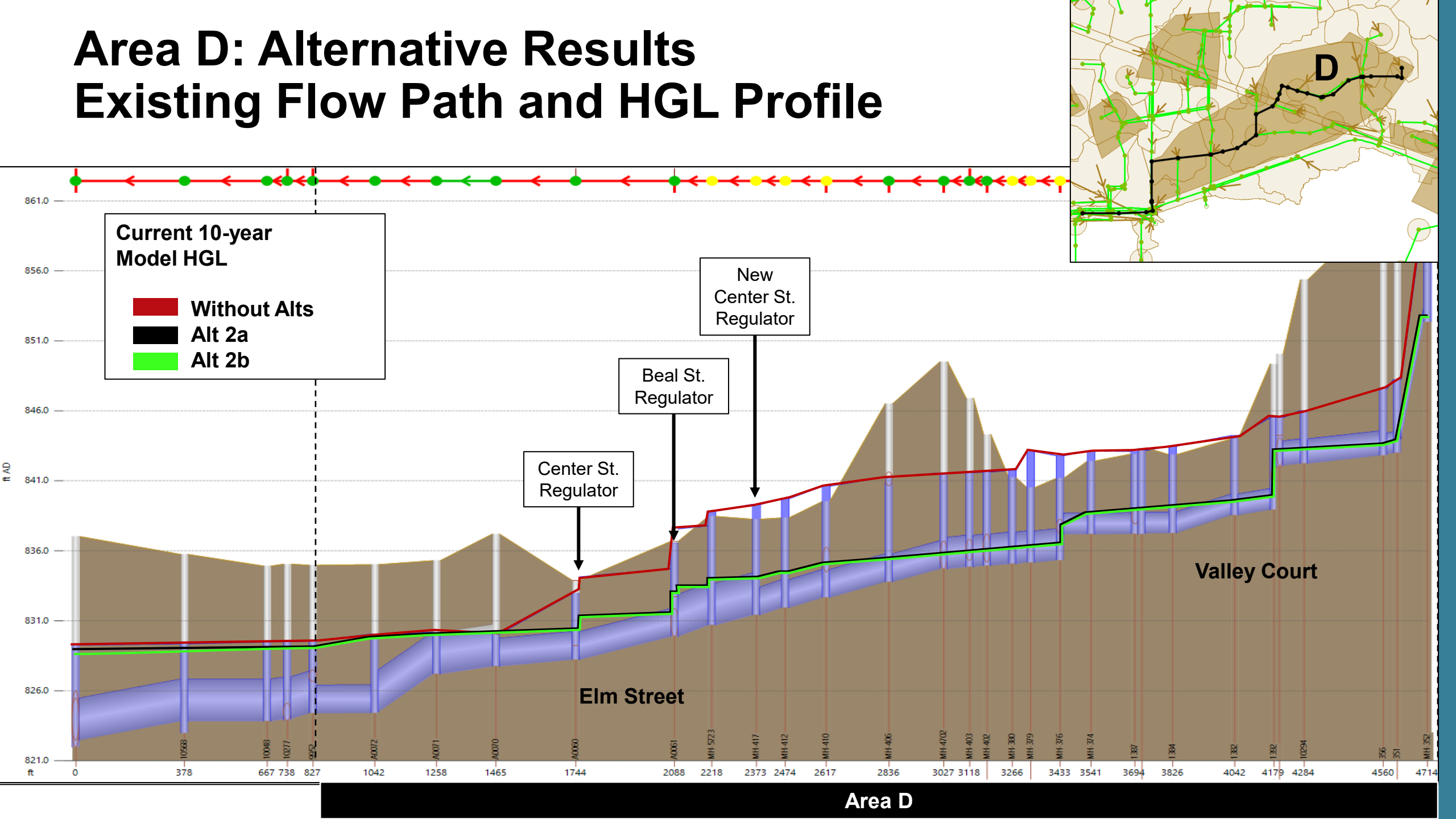
Areas A & B: Alternative Results
Existing Flow Path and HGL Profile



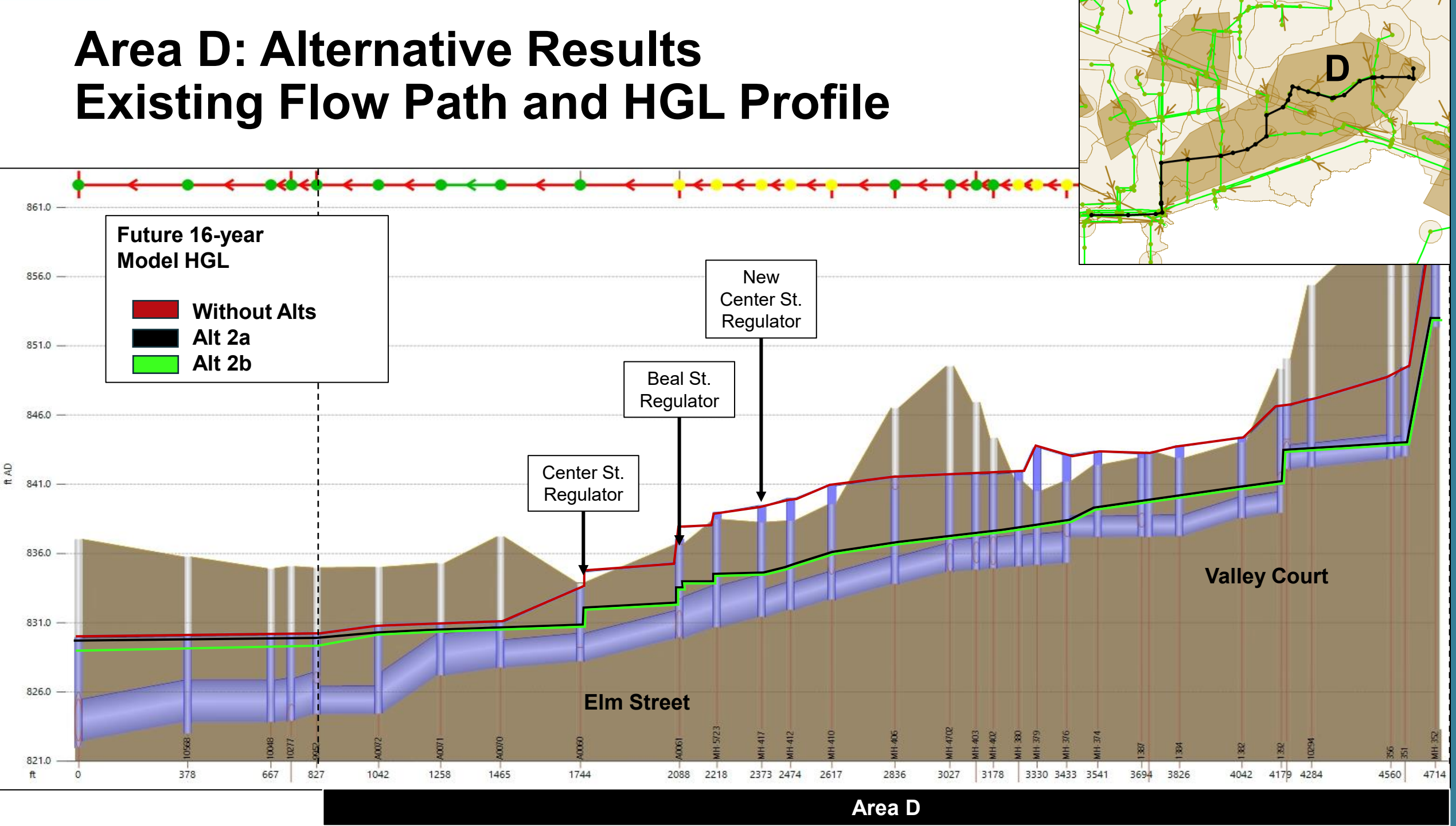


Hydraulic Profiles –
Alternative 2

Area D: Alternative Results
Existing Flow Path and HGL Profile

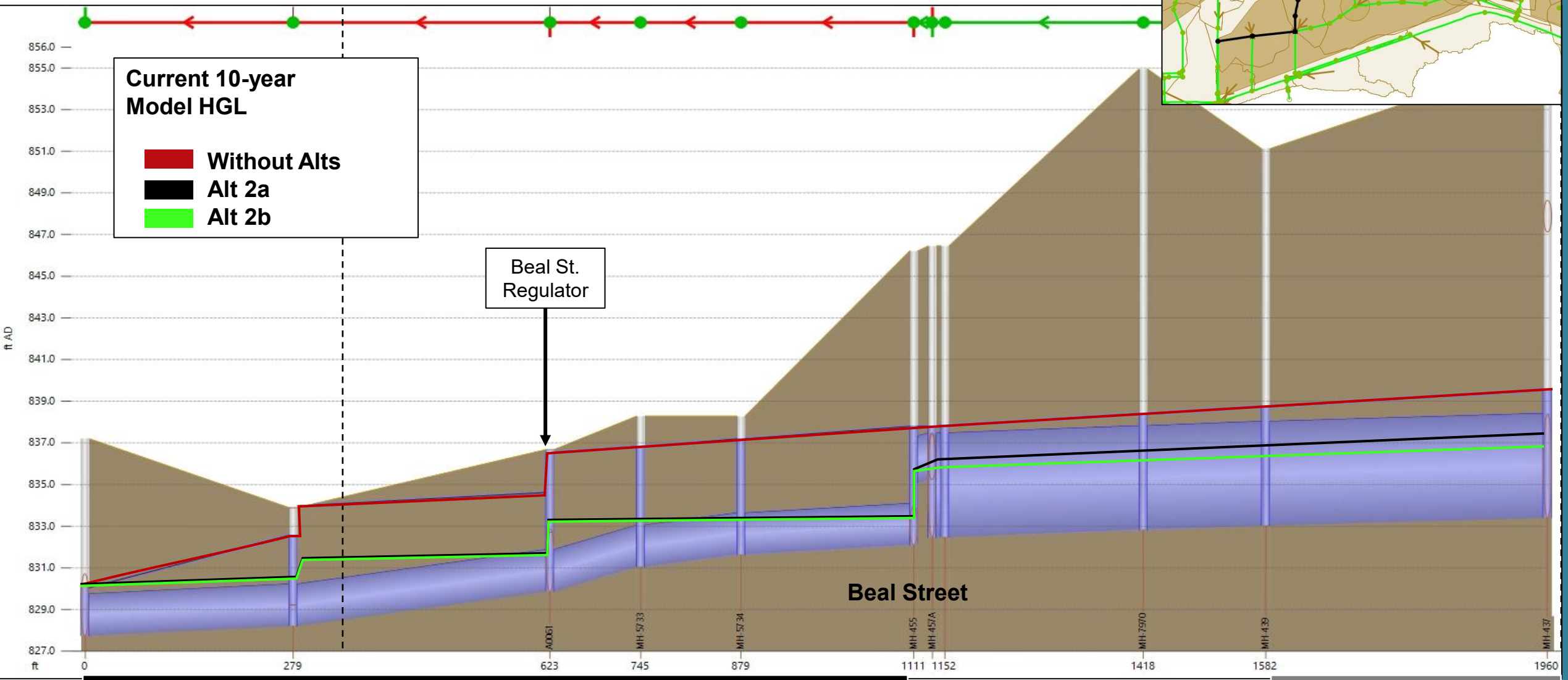


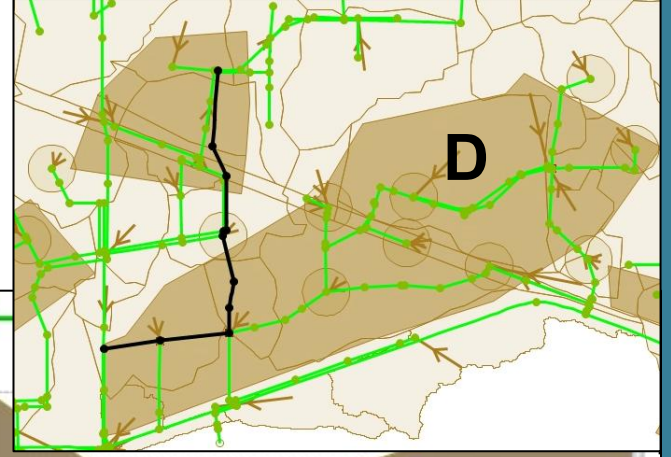
Area D: Alternative Results
Existing Flow Path and HGL Profile



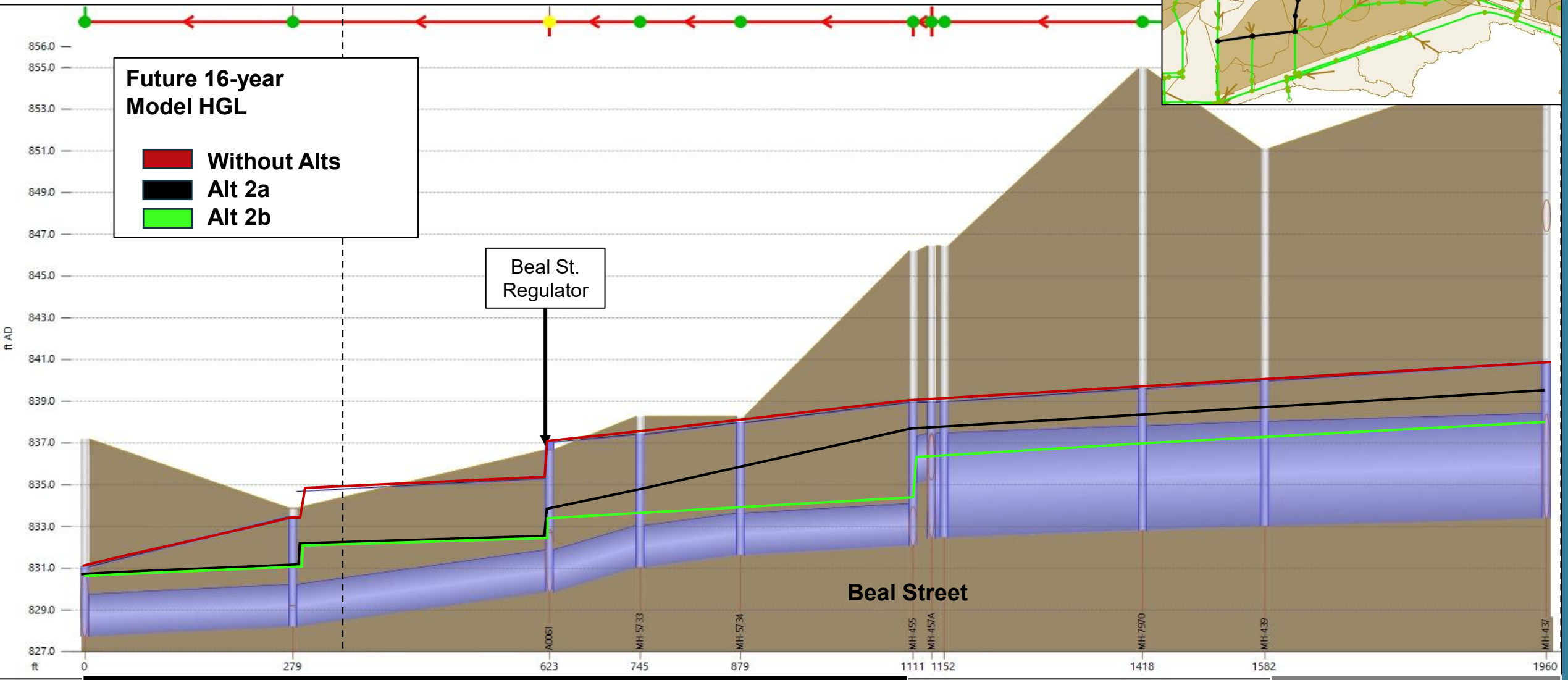
Area D

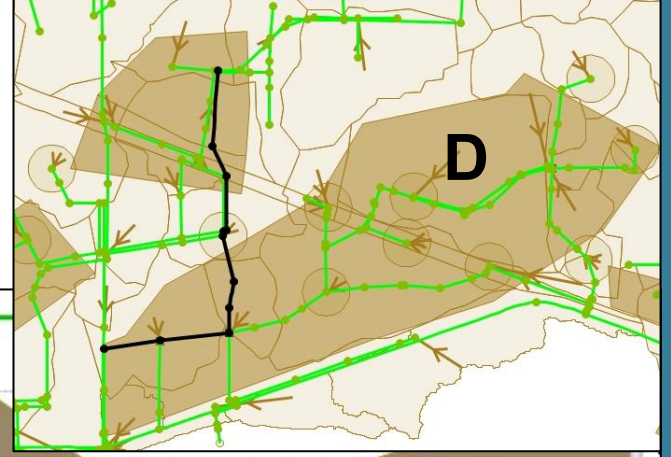
Area D: Alternative Results
Existing Flow Path and HGL Profile





Area D: Alternative Results
Existing Flow Path and HGL Profile



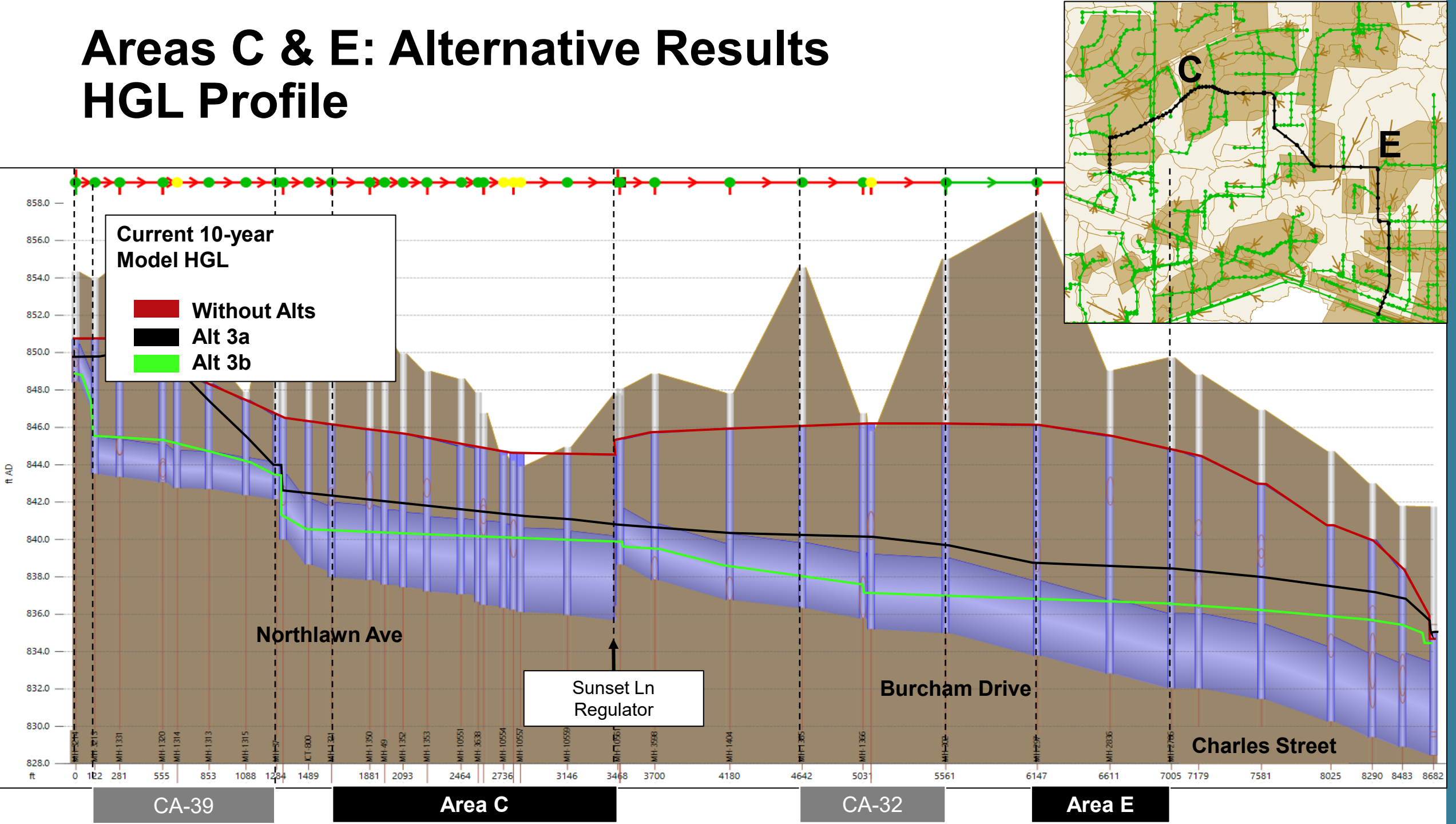


Area D

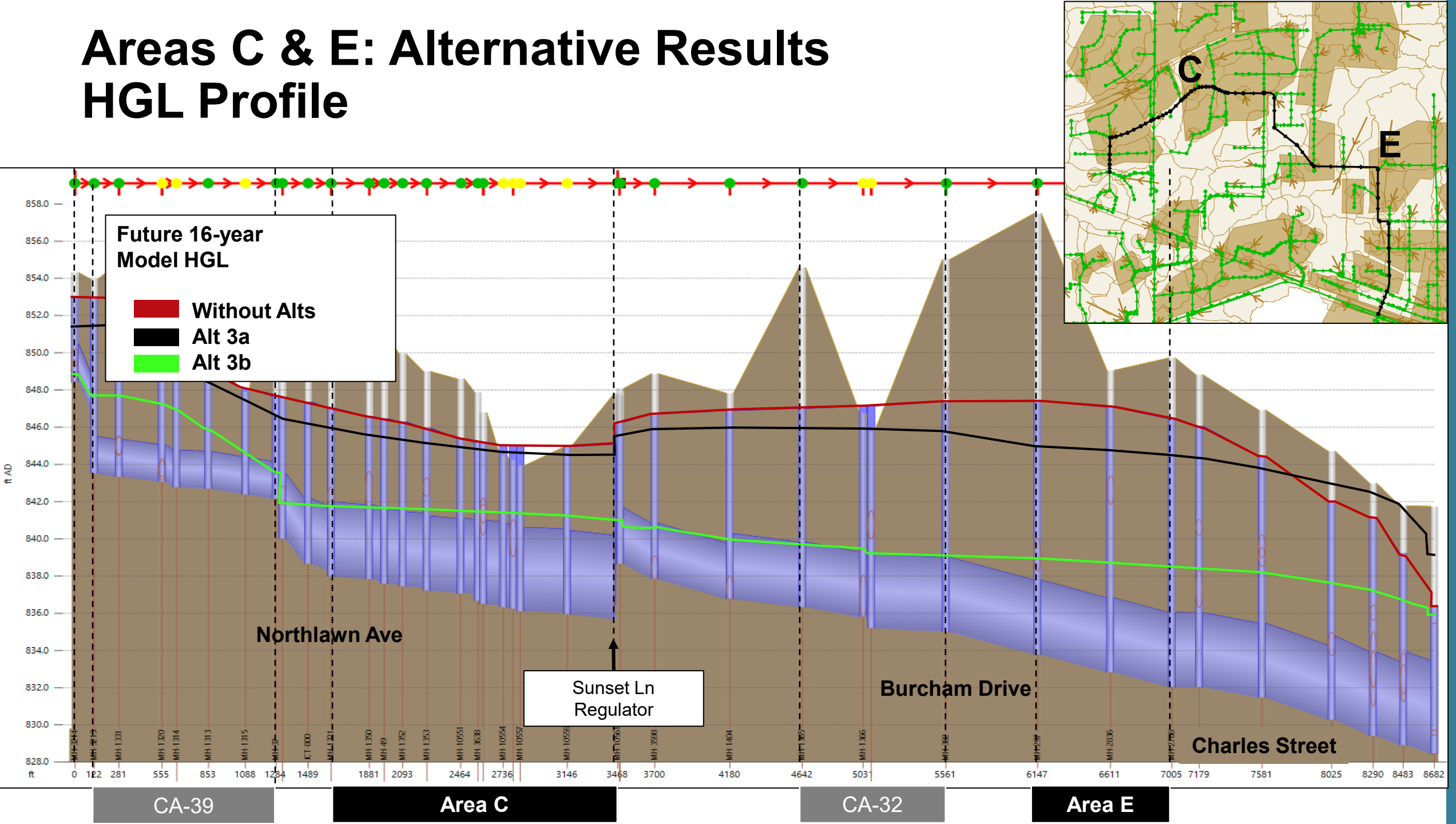
CA-52, CA-53

Hydraulic Profiles –
Alternative 3

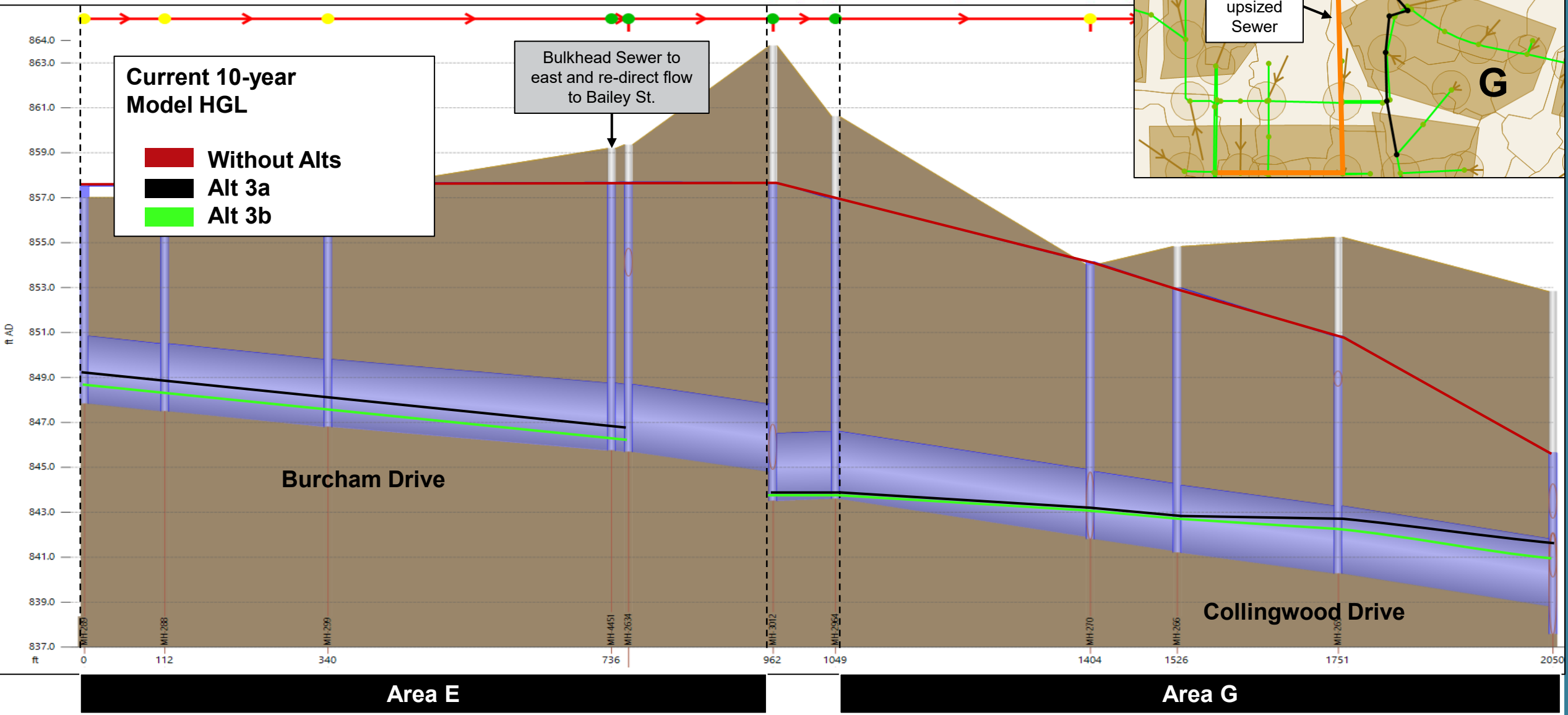
Areas C & E: Alternative Results
HGL Profile

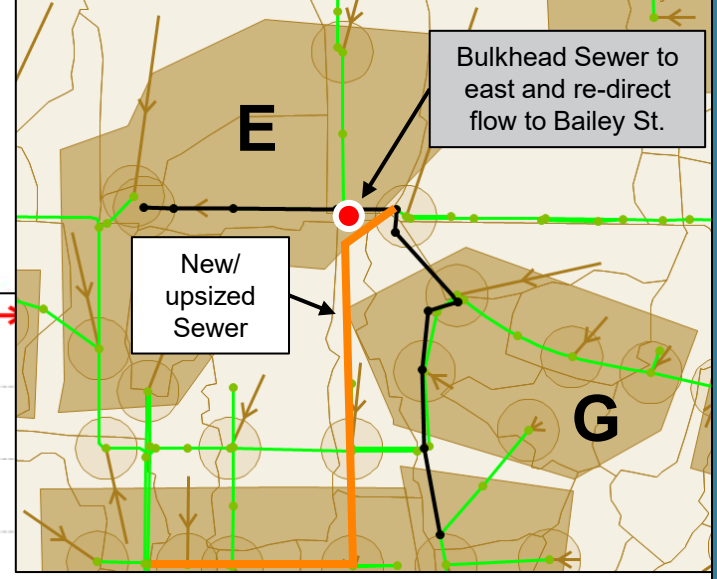


Areas C & E: Alternative Results
HGL Profile

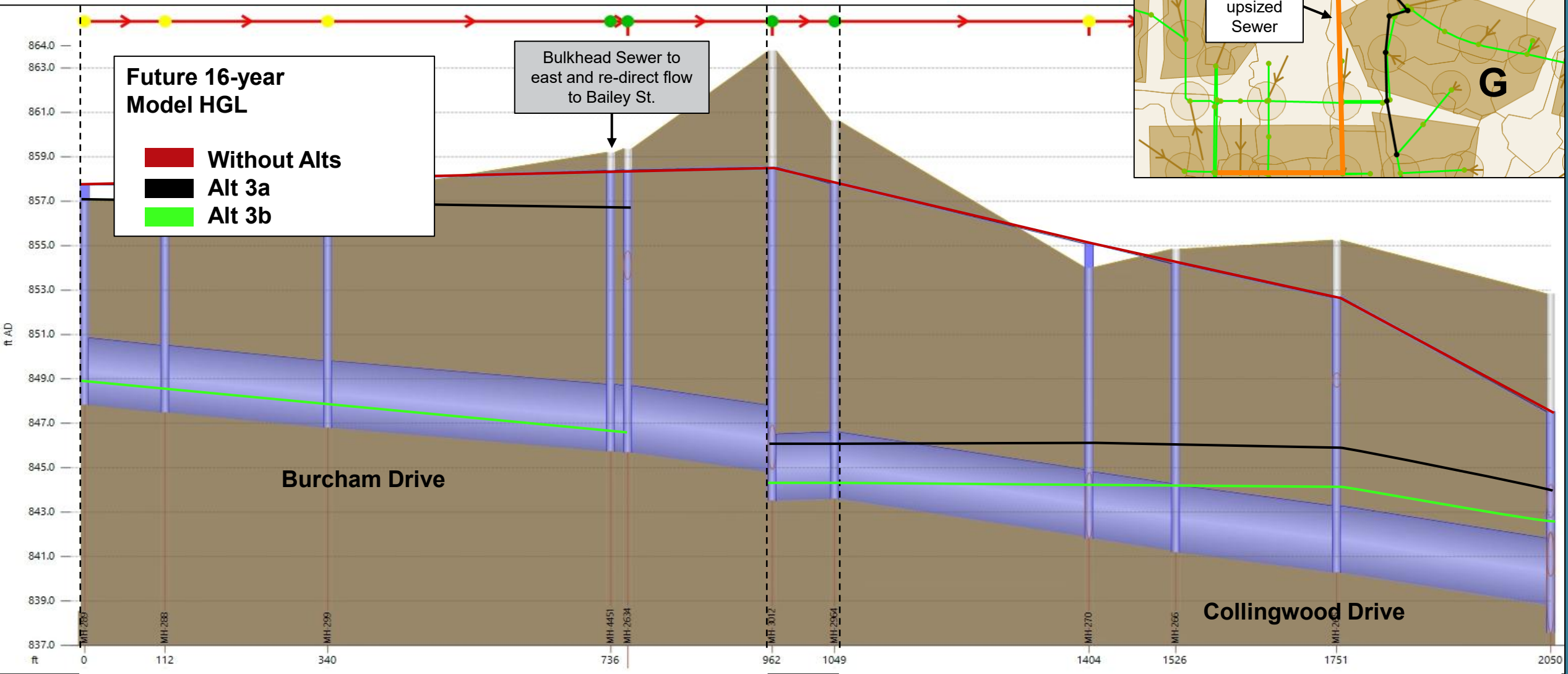


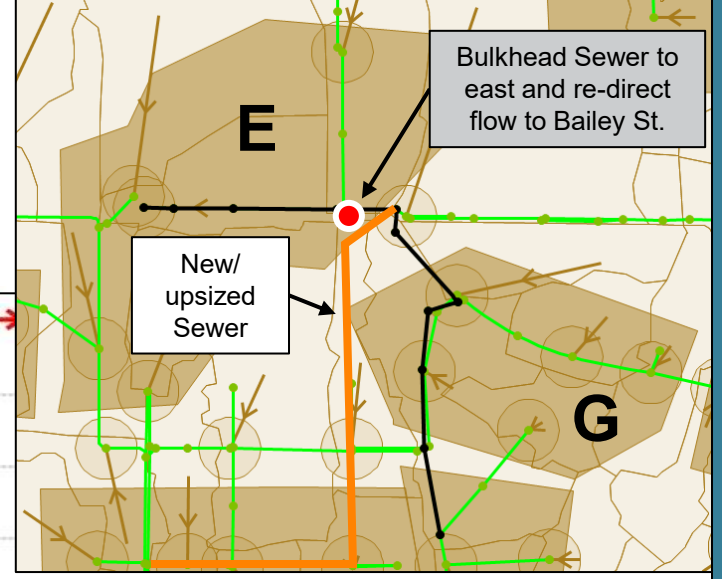
Areas E & G: Alternative Results HGL Profile





Areas E & G: Alternative Results HGL Profile

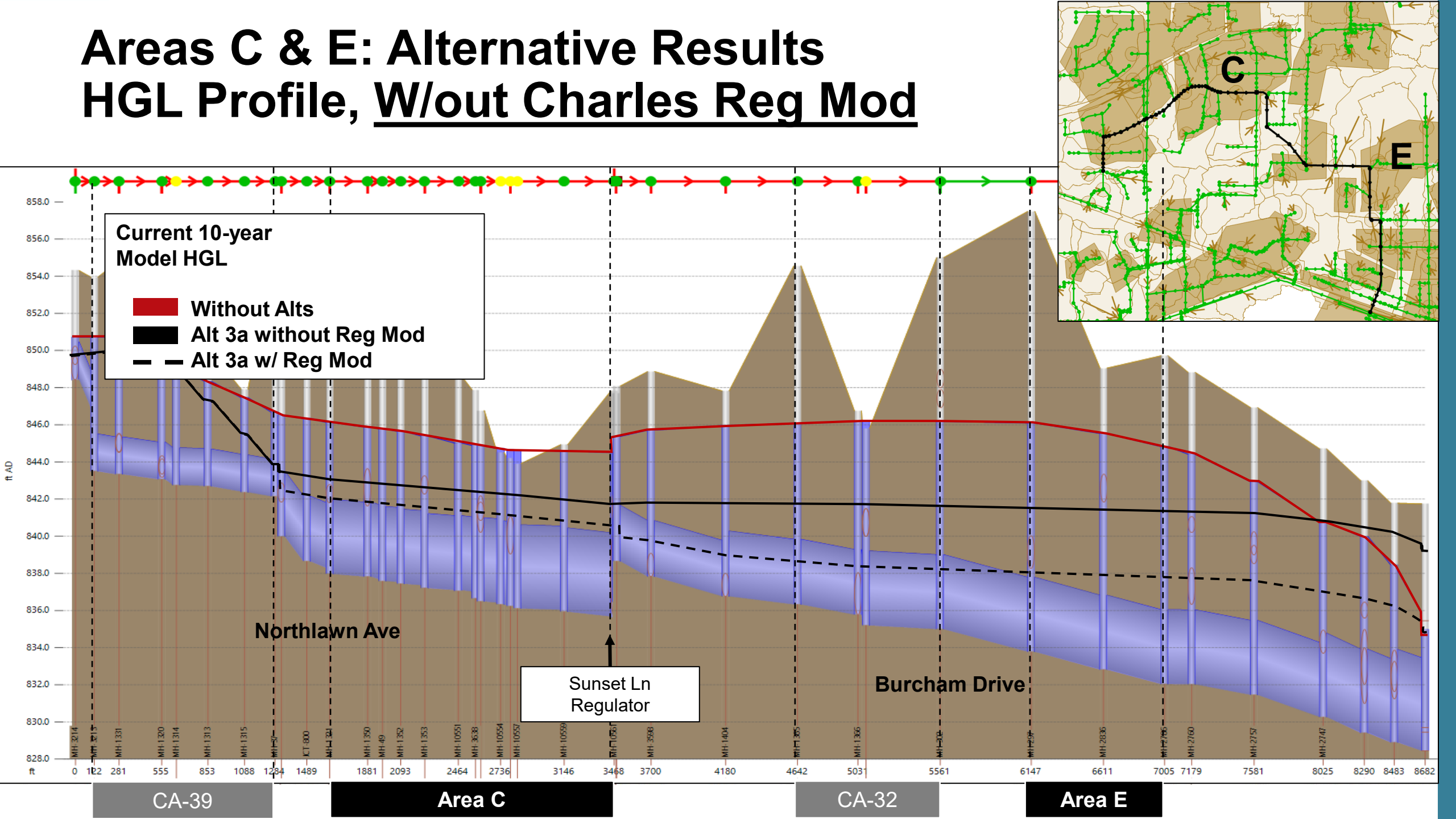




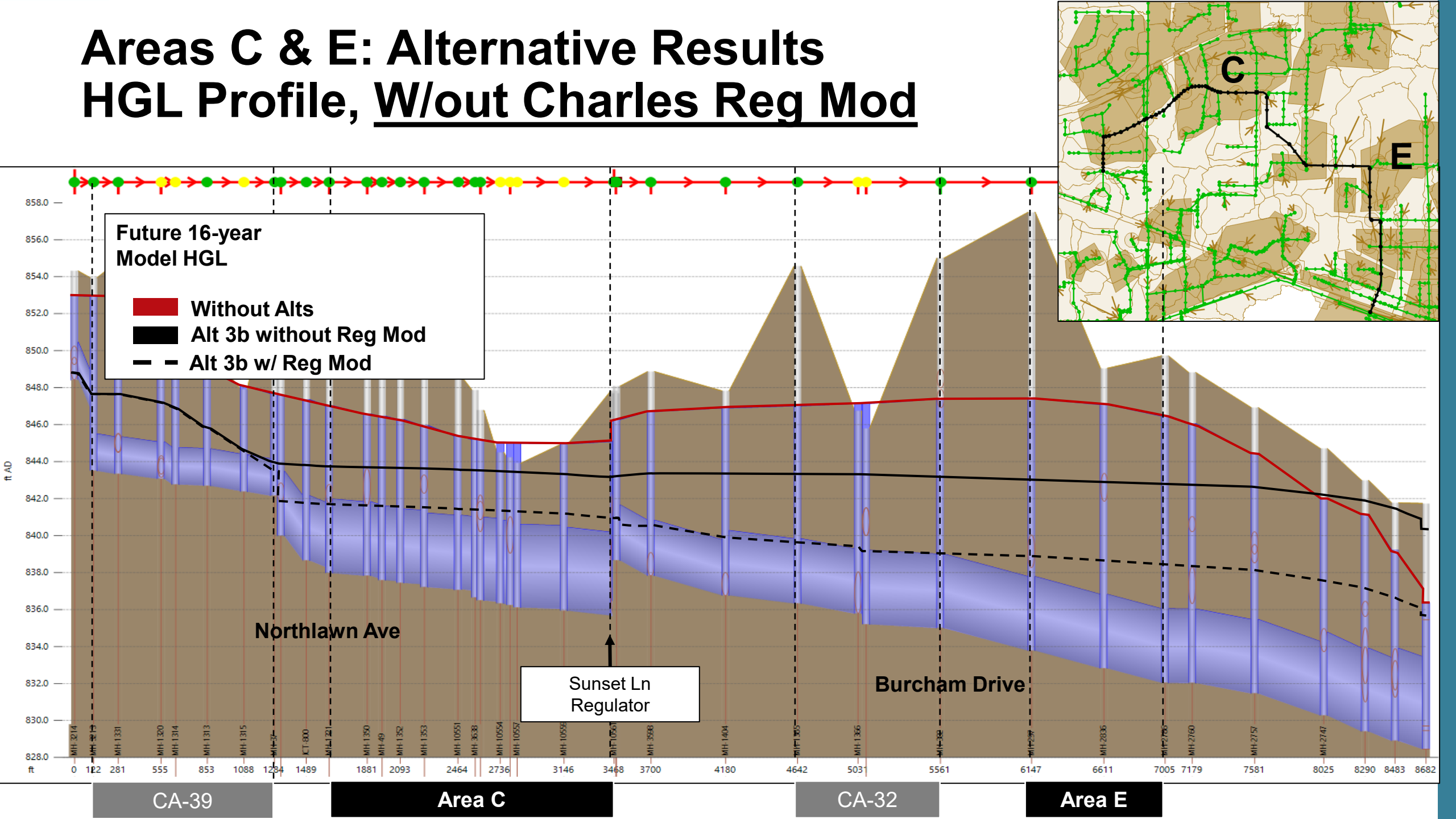
Hydraulic Profile – Charles Street Regulator Modification Comparison

Alternative 3

Areas C & E: Alternative Results
HGL Profile, W/out Charles Reg Mod



Areas C & E: Alternative Results
HGL Profile, W/out Charles Reg Mod

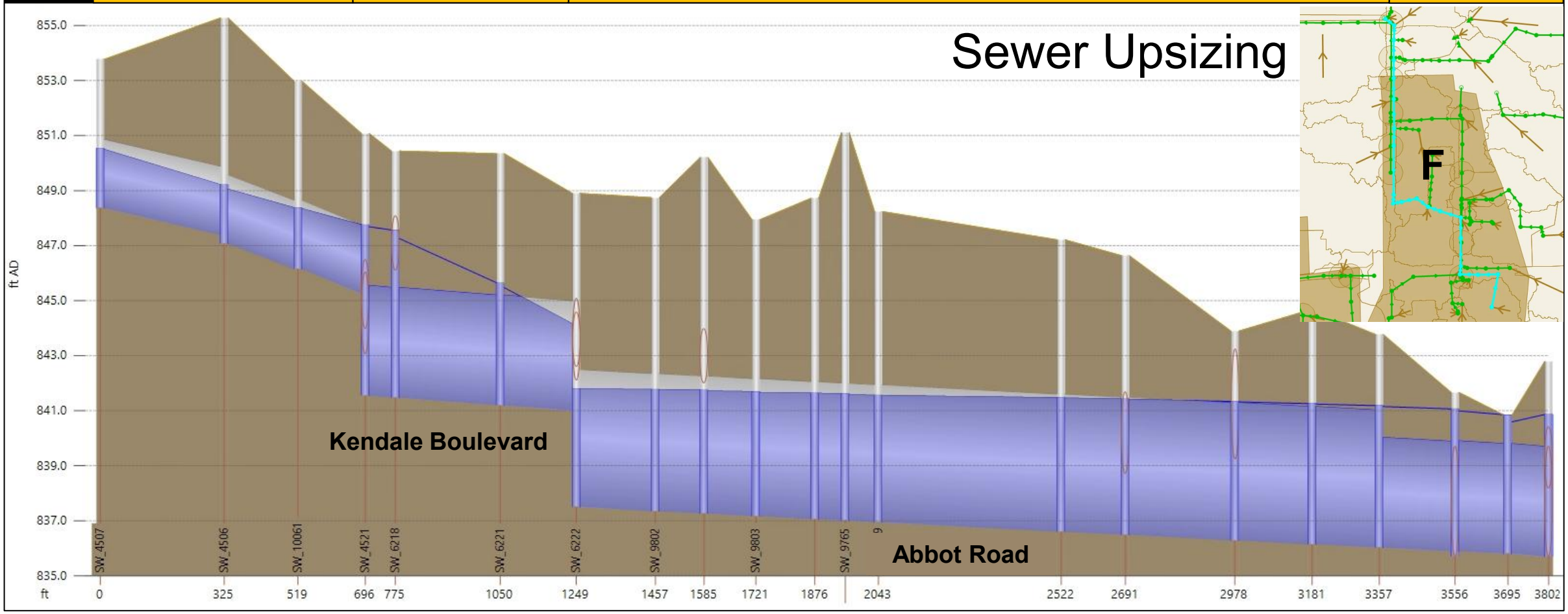


Hydraulic Profiles w/ Pipe Upsizing
Alternative 5

Area F: Alt 5a Main Trunk Sewer Pipe Upsize

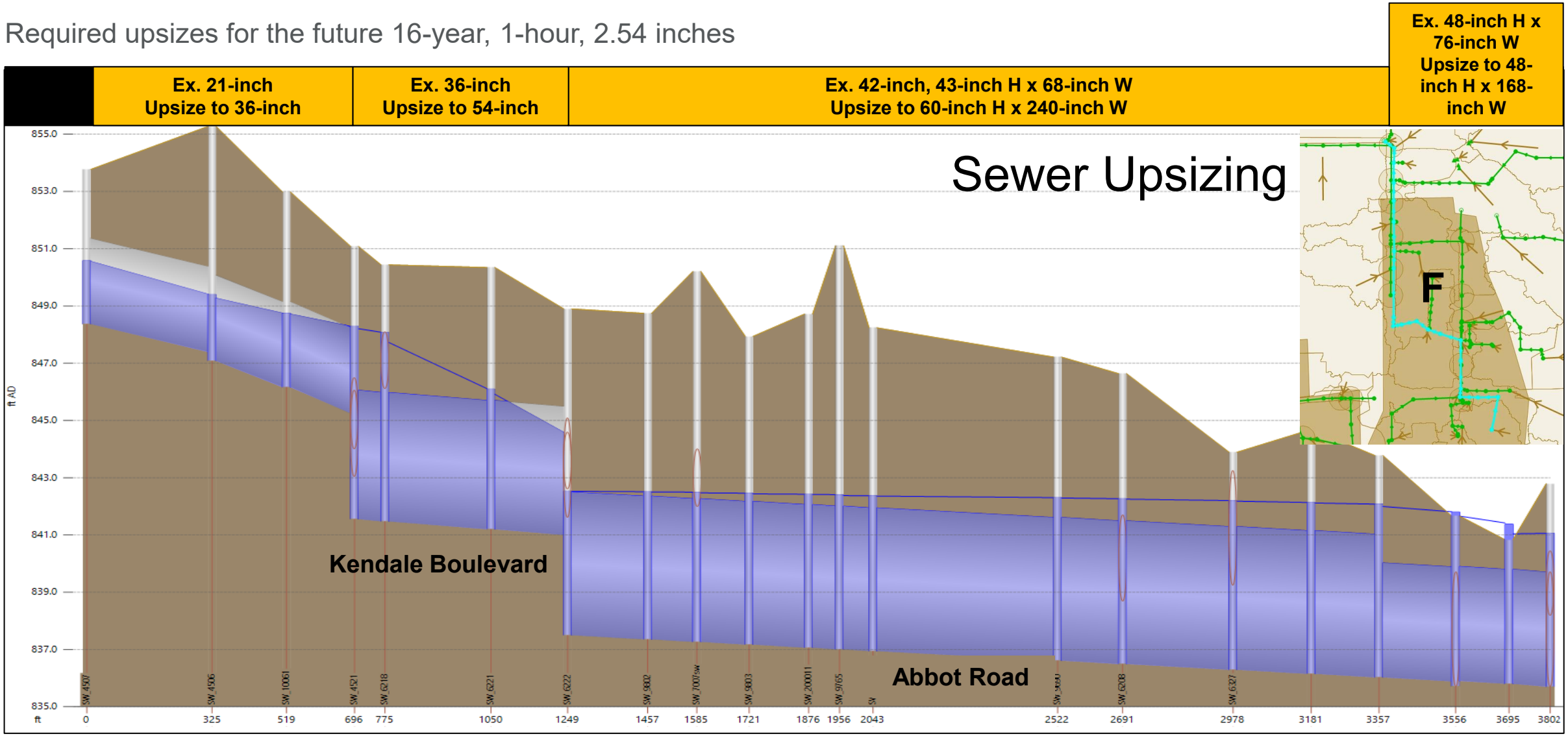
Required upsizes for the current 10-year, 1-hour, 2.00 inches

	Ex. 21-inch Upsize to 30-inch	Ex. 36-inch Upsize to 48-inch	Ex. 42-inch, 43-inch H x 68-inch W Upsize to 60-inch H x 144-inch W	Ex. 48-inch H x 76-inch W Upsize to 48-inch H x 168-inch W



Area F: Alt 5b Main Trunk Sewer Pipe Upsize

Required upsizes for the future 16-year, 1-hour, 2.54 inches

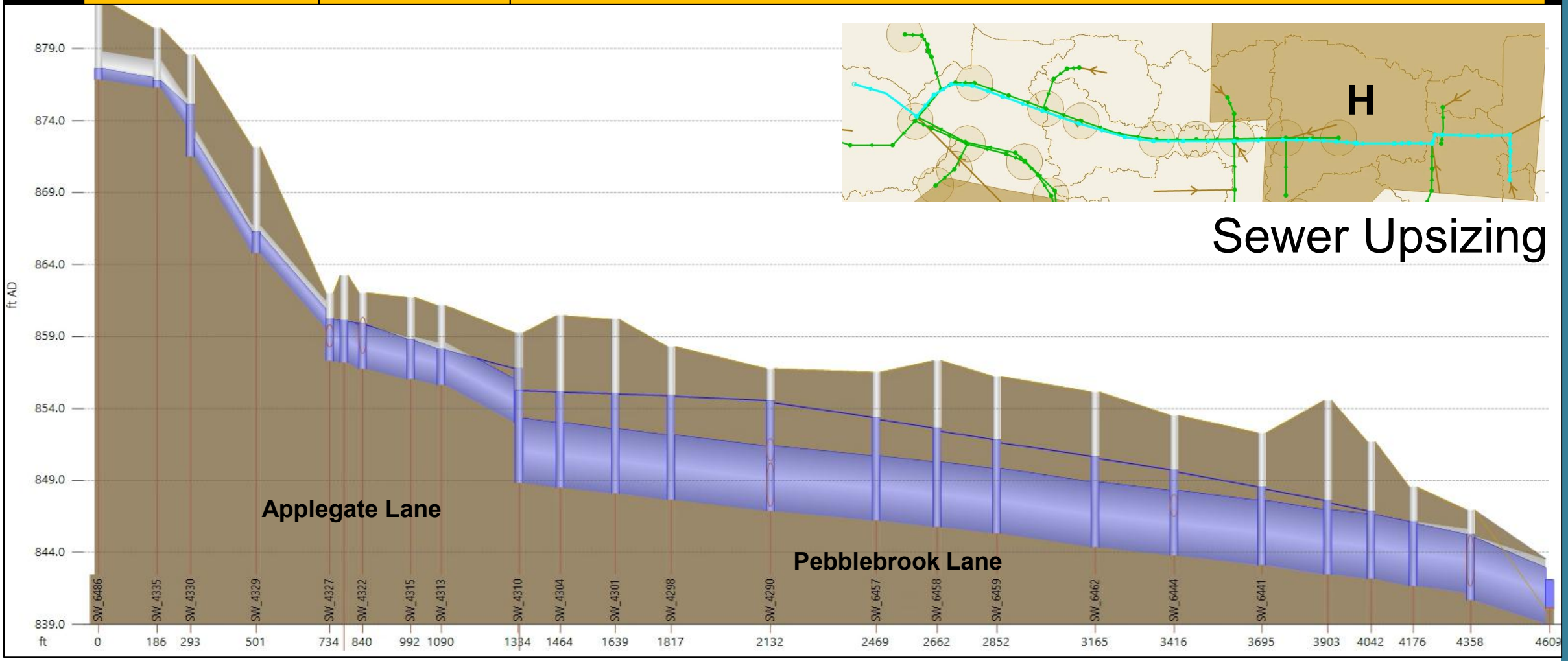


Hydraulic Profiles w/ Pipe Upsizing
Alternative 6

Area H: Alt 6a Main Trunk Sewer Pipe Upsize

Required upsizes for the current 10-year, 1-hour, 2.00 inches

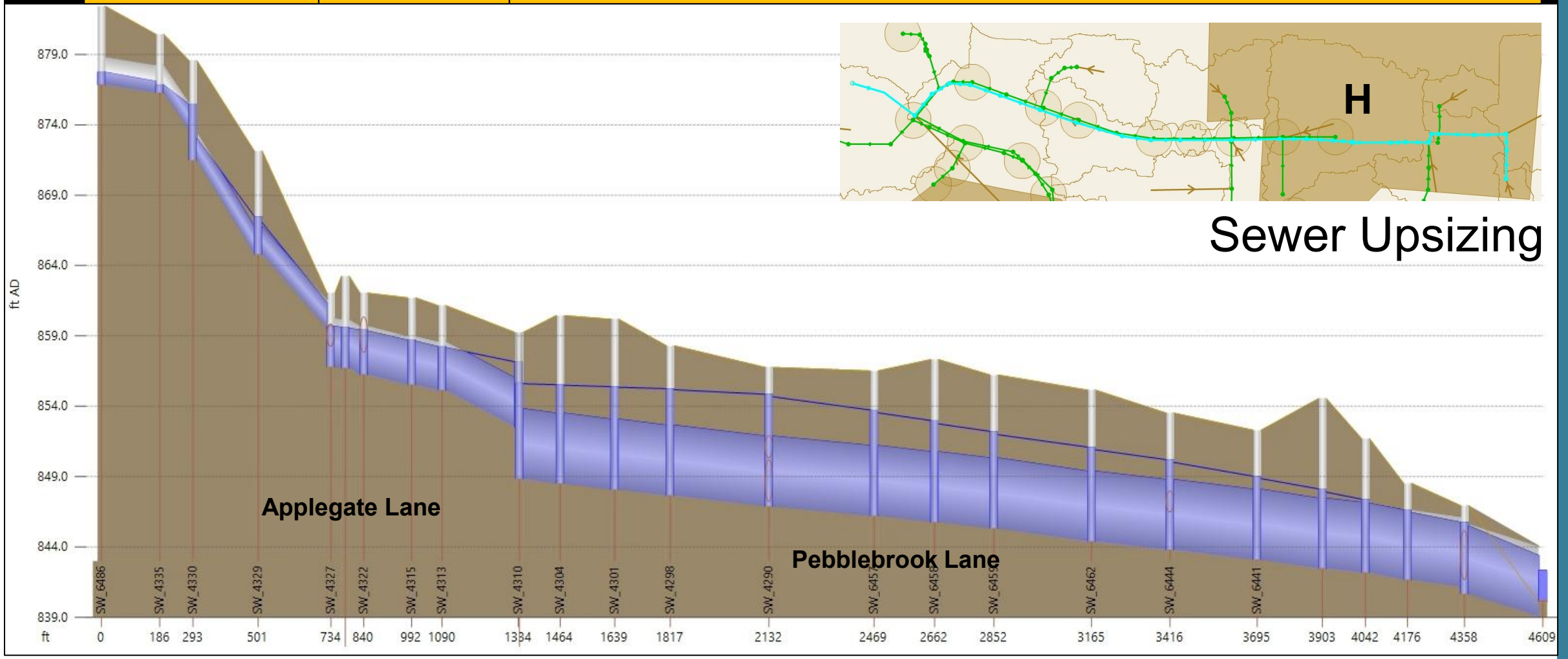
	Ex. 18 Upsize to 24-inch	Ex. 18, 30 Upsize to 36-inch	Ex. 30, 36, 48, 54 Upsize to 54-inch



Sewer Upsizing

Area H: Alt 6b Main Trunk Sewer Pipe Upsize

Required upsizes for the 2100 16-year, 1-hour, 2.54 inches



Appendix G.

Selected Alternatives/Projects Cost Estimates

Project: East Lansing Wet Weather Resiliency Plan
Subject: Alternatives Analysis
Class 5 Accuracy of Estimate (-35% to + 65%)
Assumptions

ASSUMPTIONS	
1	Northern Concrete (NCP) is a company based in the Midwest, so pipe unit costs were based on their pricing. The cost for the pipe is assumed to include excavation, backfill, and trench restoration.
2	The unit cost per acre for stormwater separation is assumed to include the material cost of the new storm sewers, including the excavation, backfill, and trench restoration. The cost for the construction of the storm trunk is a separate cost and is not included.
3	Subsurface (underground) storage unit cost is assumed to include the cost of materials, excavation, the construction of the facility, and all required underdrains.
4	Aboveground storage unit cost is assumed to include excavation, the outlet structure, and costs associated with the pretreatment cells.
5	Mobilization is assumed to include General Contractor costs associated with the overall contract, including: general conditions, office overhead, bond, market volatility adjustments, and construction escalation.
6	Access points to the box culverts were assumed to be every 600 feet, per HEC-22 recommendations for storm drain structures (AASHTO).
7	All work will be completed within existing r/w or on public property. No easement costs are included.
8	Manholes were assigned a diameter of 4, 5, 6, 7, 8, or 10-feet based on the pipe diameter as described in Table 7-4 below. The number of manholes are an estimate and are subject to change. Currently, it is assumed 1 manhole every 300 feet and additional manholes at pipe diameter changes.
9	No costs for combined sewer rehab/replacement is included.
10	Park restoration for aboveground storage assumes that 20% of the storage surface area will be restored. Includes sod, tree, and shrub replacement.
11	Park restoration for underground storage assumes that 20% of the storage surface area will be restored with trees and shrubs. It is assumed that 100% of the area will need sod replacement.

Table 7-4 Manhole Maximum Pipe Size

Manhole Diameter Inch	K Inch/Degree	Maximum Pipe Size Inch
48	0.42	30
60	0.52	42
72	0.63	54
84	0.73	66
96	0.84	72
108	0.94	84

Project: East Lansing Wet Weather Resiliency Plan
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Class 5 Accuracy of Estimate (-35% to + 65%)
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Alternative 1A					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
CSO Upgrades and Sewer Upsizing - Orange and Red Sewers					
Manhole, 4-foot Diameter	EA	6	$ 7,000	$ 42,000	Assumes a 4-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 5-foot Diameter	EA	11	$ 9,000	$ 99,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
30-inch RCP, Depth < 15ft	LF	722	$ 457	$ 331,000	
30-inch RCP, Depth > 15ft, <25ft	LF	196	$ 535	$ 105,000	
36-inch RCP, Depth < 15ft	LF	567	$ 539	$ 306,000	
36-inch RCP, Depth > 15ft, <25ft	LF	572	$ 630	$ 361,000	
36-inch RCP, Depth >25ft	LF	725	$ 716	$ 520,000	
42-inch RCP, Depth < 15ft	LF	12	$ 631	$ 8,000	
Storm Separation					
Storm Separation	AC	68.8	$ 170,328	$ 11,723,000	
New Storm Trunk					
Manhole, 5-foot Diameter	EA	16	$ 9,000	$ 144,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
36-inch RCP, Depth < 15ft	LF	2800	$ 539	$ 1,509,000	Estimated based on profile.
36-inch RCP, Depth > 15ft, <25ft	LF	600	$ 630	$ 379,000	Estimated based on profile.
Outlet Structure w/Treatment Device	EA	1	$ 140,000	$ 140,000	One outlet structure is needed at the end of the storm trunk.
Additional Costs					
Restrictor Modification	EA	1	$ 10,000	$ 10,000	Removing the flow restrictor at Grand River Ave.
New sewer bulkheads	EA	2	$ 3,000	$ 6,000	36-inch Sewer Bulkheads. Price is for a 42-inch sewer bulkhead.
Roadway Restoration	SF	74,332	$ 20.00	$ 1,490,000	Two major road crossings at West Saginaw and Grand River. Two lane roads for entire length of the storm trunk.

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Mobilization	%	12%	$	2,070,000	Includes site clearing.
Traffic Control	%	2%	$	344,000	
Utility Adjustments	%	20%	$	3,440,000	Relocation of utility lines
Contingency Costs					
Undefined Work Contingency	%	35%	$	8,060,000	
Construction Total			$	31,100,000	
Soft Costs					
Planning and Preliminary Design	%	5%	$	1,560,000	
Design and Engineering Services	%	10%	$	3,110,000	
Administration costs-Design, legal fees, and construction	%	2%	$	622,000	
Field Engineering and Inspection	%	5%	$	1,560,000	
Total Soft Cost for Alternative 1A			$	6,860,000	
Total Cost for Alternative 1A			$	38,000,000	
Total Cost for Alternative 1A (High Range)		65%	$	62,700,000	
Total Cost for Alternative 1A (Low Range)		-35%	$	24,700,000	

$ 12,121,920.00

Project: East Lansing Wet Weather Resiliency Plan
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Task: 8

Alternative 1B					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
CSO Upgrades and Sewer Upsizing - Orange and Red Sewers					
Manhole, 4-foot Diameter	EA	6	$ 7,000	$ 42,000	Assumes a 4-foot diameter manhole every 350-feet and at diameter changes.
Manhole, 5-foot Diameter	EA	11	$ 9,000	$ 99,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
30-inch RCP, Depth < 15ft	LF	722	$ 457	$ 331,000	
30-inch RCP, Depth > 15ft, <25ft	LF	196	$ 535	$ 105,000	
36-inch RCP, Depth < 15ft	LF	567	$ 539	$ 306,000	
36-inch RCP, Depth > 15ft, <25ft	LF	572	$ 630	$ 361,000	
36-inch RCP, Depth >25ft	LF	725	$ 716	$ 520,000	
42-inch RCP, Depth < 15ft	LF	12	$ 631	$ 8,000	
Storm Separation					
Storm Separation	AC	76.6	$ 170,328	$ 13,100,000	
New Storm Trunk					
Manhole, 6-foot Diameter	EA	16	$ 13,000	$ 208,000	Assumes a 6-foot diameter manhole every 300 feet and at diameter changes.
54-inch RCP, Depth < 15ft	LF	2800	$ 757	$ 2,120,000	Estimated based on profile.
54-inch RCP, Depth > 15ft, <25ft	LF	600	$ 800	$ 480,000	Estimated based on profile.
Outlet Structure w/Treatment Device	EA	1	$ 140,000	$ 140,000	One outlet structure is needed at the end of the storm trunk.
Additional Costs					
Restrictor Modification	EA	1	$ 10,000	$ 10,000	
New sewer bulkheads	EA	2	$ 3,000	$ 6,000	36-inch Sewer Bulkheads. Price is for a 42-inch sewer bulkhead.
Roadway Restoration	SF	74,332	$ 20.00	$ 1,490,000	Unit cost for backfilling the trench and new pavement

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Class 5 Accuracy of Estimate (-35% to + 65%)
Task: 8

Mobilization	%	12%	$ 2,320,000	Includes site clearing
Traffic Control	%	2%	$ 387,000	Two major road crossings at West Saginaw and Grand River. Two lane roads for entire length of the storm trunk.
Utility Adjustments	%	20%	$ 3,870,000	Relocation of utility lines
Contingency Costs				
Undefined Work Contingency	%	35%	$ 9,100,000	
Construction Total, High			$ 35,100,000	
Soft Costs				
Planning and Preliminary Design	%	5%	$ 1,760,000	
Design and Engineering Services	%	10%	$ 3,510,000	
Administration costs-Design, legal fees, and construction	%	2%	$ 702,000	
Field Engineering and Inspection	%	5%	$ 1,760,000	
Total Soft Cost for Alternative 1B			$ 7,740,000	
Total Cost for Alternative 1B			$ 42,900,000	
Total Cost for Alternative 1B (High Range)		65%	$ 70,800,000	
Total Cost for Alternative 1B (Low Range)		-35%	$ 27,900,000	

Project: East Lansing Wet Weather Resiliency Plan
Subject: Alternatives Analysis
Class 5 Accuracy of Estimate (-35% to + 65%)
Task: 8

Alternative 2A					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
CSO Upgrades and Sewer Upsizing - Orange and Red Sewers					
Manhole, 5-foot Diameter	EA	11	$ 9,000	$ 99,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
36-inch RCP, Depth < 15ft	LF	2321	$ 539	$ 1,250,000	
36-inch RCP, Depth > 15ft, <25ft	LF	282	$ 630	$ 178,000	
Storm Separation					
Storm Separation	AC	77.6	$ 170,328	$ 13,300,000	
New Storm Trunk					
Manhole, 5-foot Diameter	EA	5	$ 9,000	$ 45,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 6-foot Diameter	EA	11	$ 13,000	$ 143,000	Assumes a 6-foot diameter manhole every 300 feet and at diameter changes.
32-inch RCP, Depth < 15ft	LF	250	$ 535	$ 134,000	Estimated based on profile.
54-inch RCP, Depth < 15ft	LF	1870	$ 757	$ 1,420,000	Estimated based on profile.
54-inch RCP, Depth > 15ft, <25ft	LF	630	$ 800	$ 504,000	Estimated based on profile.
Outlet Structure w/Treatment Device	EA	1	$ 140,000	$ 140,000	One outlet structure is needed at the end of the storm trunk.
Additional Costs					
Restrictor Modification	EA	1	$ 10,000.00	$ 10,000	Modification to lower the weir at Beat Street to the invert of the overflow sewer.
New Regulator	EA	1	$ 15,000.00	$ 15,000	Regulator at Louis Street.

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Roadway Restoration	SF	64,228	$ 20.00	$ 1,290,000	One major road crossing at Grand River. Distance from B to D is along a high traffic road with 4-lanes and a grass median in between. Assume one lane closed. Section A to B is along a 5-lane road.
Mobilization	%		12%	$ 2,230,000	Includes site clearing.
Traffic Control	%		2%	$ 371,000	
Utility Adjustments	%		20%	$ 3,710,000	Relocation of utility lines.
Contingency Costs					
Undefined Work Contingency	%		35%	$ 13,400,000	
Construction Total				$ 38,300,000	
Soft Costs					
Planning and Preliminary Design	%		5%	$ 1,920,000	
Design and Engineering Services	%		10%	$ 3,830,000	
Administration costs-Design, legal fees, and construction	%		2%	$ 770,000	
Field Engineering and Inspection	%		5%	$ 1,920,000	
Total Soft Cost for Alternative 2A				$ 8,440,000	
Total Cost for Alternative 2A				$ 46,800,000	
Total Cost for Alternative 2A (High Range)			65%	$ 77,300,000	
Total Cost for Alternative 2A (Low Range)			-35%	$ 30,500,000	

Project: East Lansing Wet Weather Resiliency Plan
Subject: Alternatives Analysis
Class 5 Accuracy of Estimate (-35% to + 65%)
Task: 8

Alternative 2B					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
CSO Upgrades and Sewer Upsizing - Orange and Red Sewers					
Manhole, 5-foot Diameter	EA	11	$ 9,000	$ 99,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
36-inch RCP, Depth < 15ft	LF	2321	$ 539	$ 1,250,000	
36-inch RCP, Depth > 15ft, <25ft	LF	282	$ 630	$ 178,000	
Storm Separation					
Storm Separation, Sunset Option	AC	89.1	$ 170,328	$ 15,200,000	
New Storm Trunk					
Manhole, 5-foot Diameter	EA	3	$ 9,000	$ 27,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 7-foot Diameter	EA	11	$ 15,000	$ 165,000	Assumes a 7-foot diameter manhole every 300 feet and at diameter changes.
36-inch RCP, Depth < 15ft	LF	250	$ 539	$ 135,000	Estimated based on profile.
60-inch RCP, Depth < 15ft	LF	1870	$ 791	$ 1,480,000	Estimated based on profile.
60-inch RCP, Depth > 15ft, <25ft	LF	630	$ 925	$ 583,000	Estimated based on profile.
Outlet Structure w/Treatment Device	EA	1	$ 140,000	$ 140,000	One outlet structure is needed at the end of the storm trunk.
Additional Costs					
Restrictor Modification	EA	1	$ 10,000	$ 10,000	Modification to lower the weir at Beat Street to the invert of the overflow sewer.
New Regulator	EA	2	$ 15,000	$ 30,000	Regulator at Louis Street.

Project: East Lansing Wet Weather Resiliency Plan
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Task: 8

Roadway Restoration	SF	64,228	$ 20.00	$ 1,290,000	One major road crossing at Grand River. Distance from B to D is along a high traffic road with 4-lanes and a grass median in between. Assume one lane closed. Section A to B is along a 5-lane road.
Mobilization	%		12%	$ 2,480,000	Includes site clearing.
Traffic Control	%		2%	$ 412,000	
Utility Adjustments	%		20%	$ 4,120,000	Relocation of utility lines
Contingency Costs					
Undefined Work Contingency	%		35%	$ 9,660,000	
Construction Total				$ 37,300,000	
Soft Costs					
Planning and Preliminary Design	%		5%	$ 1,870,000	
Design and Engineering Services	%		10%	$ 3,730,000	
Administration costs-Design, legal fees, and construction	%		2%	$ 750,000	
Field Engineering and Inspection	%		5%	$ 1,870,000	
Total Soft Cost for Alternative 2B				$ 8,220,000	
Total Cost for Alternative 2B				$ 45,600,000	
Total Cost for Alternative 2B (High Range)			65%	$ 75,300,000	
Total Cost for Alternative 2B (Low Range)			-35%	$ 29,700,000	

Project: East Lansing Wet Weather Resiliency Plan
Subject: Alternatives Analysis
Class 5 Accuracy of Estimate (-35% to + 65%)
Task: 8

Alternative 2C (Storage Only)					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
Underground Storage					
Underground Storage	Mgal	2.4	$1,615,000	$ 3,950,000	Valley Court Park storage. Storm separation costs are included as part of Alternative 2A/2B. Cost includes all underdrains and materials for construction of facility.
Park Restoration - Trees and Shrubs	SF	17,424	$8	$ 144,000	Includes site restoration of trees and shrubs, consistent with the park's pre-construction condition.
Park Restoration - Sod Replacement	SF	87,120	$3	$ 218,000	Includes sod replacement, consistent with the park's pre-construction condition.
Outlet Structure	EA	1	$30,000	$ 30,000	
Additional Costs					
Mobilization	%		12%	$ 522,000	Includes site clearing.
Traffic Control	%		2%	$ 87,000	
Utility Adjustments	%		20%	$ 869,000	Relocation of utility lines.
Contingency Costs					
Undefined Work Contingency	%		35%	$ 2,040,000	
Construction Total				$ 7,860,000	
Soft Costs					
Planning and Preliminary Design	%		5%	$ 393,000	
Design and Engineering Services	%		10%	$ 786,000	
Administration costs-Design, legal fees, and construction	%		2%	$ 158,000	

Project: East Lansing Wet Weather Resiliency Plan
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Field Engineering and Inspection	%	5%	$	400,000	
Total Soft Cost for Alternative 2C			$	1,740,000	
Total Cost for Alternative 2C			$	9,600,000	
Total Cost for Alternative 2C (High Range)		65%	$	15,900,000	
Total Cost for Alternative 2C (Low Range)		-35%	$	6,240,000	

Project: East Lansing Wet Weather Resiliency Plan
Subject: Alternatives Analysis
Class 5 Accuracy of Estimate (-35% to + 65%)
Task: 8

Alternative 3A (Harrison)					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
CSO Upgrades and Sewer Upsizing - Orange and Red Sewers					
Manhole, 4-foot Diameter	EA	14	$ 7,000	$ 98,000	Assumes a 4-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 5-foot Diameter	EA	5	$ 9,000	$ 45,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 6-foot Diameter	EA	6	$ 13,000	$ 78,000	Assumes a 6-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 8-foot Diameter	EA	5	$ 20,000	$ 100,000	Assumes a 8-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 10-foot Diameter	EA	10	$ 35,000	$ 350,000	Assumes a 10-foot diameter manhole every 300 feet and at diameter changes.
24-inch RCP, Depth < 15ft	LF	3030	$ 362	$ 1,100,000	
42-inch RCP, Depth > 15ft, <25ft	LF	1121	$ 738	$ 828,000	
54-inch RCP, Depth < 15ft	LF	1239	$ 757	$ 938,000	
72-inch RCP, Depth > 15ft, <25ft	LF	1064	$ 1,362	$ 1,450,000	
84-inch RCP, Depth <15ft	LF	656	$ 1,401	$ 920,000	
84-inch RCP, Depth >15ft, <25ft	LF	1879	$ 1,635	$ 3,080,000	
Storm Separation					
Storm Separation	AC	91.7	$ 170,328	$ 15,700,000	
New Storm Trunk					
Manhole, 5-foot Diameter	EA	6	$ 9,000	$ 54,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 6-foot Diameter	EA	6	$ 13,000	$ 78,000	Assumes a 6-foot diameter manhole every 300 feet and at diameter changes.

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Manhole, 7-foot Diameter	EA	14	$ 15,000	$ 210,000	Assumes a 7-foot diameter manhole every 300 feet and at diameter changes.
36-inch RCP, Depth < 15ft	LF	800	$ 539	$ 431,000	Estimated based on profile.
54-inch RCP, Depth < 15ft	LF	800	$ 757	$ 606,000	Estimated based on profile.
60-inch RCP, Depth <15ft	LF	820	$ 791	$ 649,000	Estimated based on profile.
60-inch RCP, Depth > 15ft, <25ft	LF	1446	$ 925	$ 1,340,000	Estimated based on profile.
60-inch RCP, Depth >25ft	LF	1334	$ 1,052	$ 1,410,000	Estimated based on profile.
Outlet Structure w/Treatment Device	EA	1	$ 140,000	$ 140,000	
Additional Costs					
Regulator Modification	EA	1	$ 10,000	$ 10,000	Increase weir length of the Charles Street regulator to 8.5 ft.
New sewer bulkheads	EA	3	$ 3,000	$ 9,000	
Roadway Restoration	SF	170,263	$ 20.00	$ 3,410,000	Majorty of the road is 2-lanes, with a short section of N Harrison north of W Saginaw being 3-lanes. Major road crossing at W Saginaw.
Mobilization	%		12%	$ 3,970,000	Includes site clearing.
Traffic Control	%		2%	$ 661,000	
Utility Adjustments	%		20%	$ 6,610,000	Relocation of utility lines.
Contingency Costs					
Undefined Work Contingency	%		35%	$ 15,500,000	
Construction Total				$ 59,800,000	
Soft Costs					
Planning and Preliminary Design	%		5%	$ 2,990,000	
Design and Engineering Services	%		10%	$ 5,980,000	
Administration costs-Design, legal fees, and construction	%		2%	$ 1,200,000	
Field Engineering and Inspection	%		5%	$ 2,990,000	
Total Soft Cost for Alternative 3A				$ 13,200,000	
Total Cost for Alternative 3A				$ 73,000,000	
Total Cost for Alternative 3A (High Range)			65%	$ 121,000,000	
Total Cost for Alternative 3A (Low Range)			-35%	$ 47,500,000	

Project: East Lansing Wet Weather Resiliency Plan
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Alternative 3B					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
CSO Upgrades and Sewer Upsizing - Orange and Red Sewers					
Manhole, 4-foot Diameter	EA	14	$ 7,000	$ 98,000	Assumes a 4-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 5-foot Diameter	EA	5	$ 9,000	$ 45,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 6-foot Diameter	EA	6	$ 13,000	$ 78,000	Assumes a 6-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 8-foot Diameter	EA	5	$ 20,000	$ 100,000	Assumes a 8-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 10-foot Diameter	EA	10	$ 35,000	$ 350,000	Assumes a 10-foot diameter manhole every 300 feet and at diameter changes.
24-inch RCP, Depth < 15ft	LF	3030	$ 362	$ 1,100,000	
42-inch RCP, Depth > 15ft, <25ft	LF	1121	$ 738	$ 828,000	
54-inch RCP, Depth < 15ft	LF	1239	$ 757	$ 938,000	
72-inch RCP, Depth > 15ft, <25ft	LF	1064	$ 1,362	$ 1,450,000	
84-inch RCP, Depth <15ft	LF	656	$ 1,401	$ 920,000	
84-inch RCP, Depth >15ft, <25ft	LF	1879	$ 1,635	$ 3,080,000	
Storm Separation					
Storm Separation	AC	278.2	$ 170,328	$ 47,400,000	
New Storm Trunk					
Manhole, 6-foot Diameter	EA	5	$ 13,000	$ 65,000	Assumes a 6-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 7-foot Diameter	EA	4	$ 15,000	$ 60,000	Assumes a 7-foot diameter manhole every 300 feet and at diameter changes.

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Manhole, 10-foot Diameter	EA	13	$ 35,000	$ 455,000	Assumes a 10-foot diameter manhole every 300 feet and at diameter changes.
48-inch RCP, Depth < 15ft	LF	800	$ 723	$ 579,000	Estimated based on profile.
66-inch RCP, Depth < 15ft	LF	800	$ 945	$ 756,000	Estimated based on profile.
84-inch RCP, Depth <15ft	LF	820	$ 1,401	$ 1,150,000	Estimated based on profile.
84-inch RCP, Depth > 15ft, <25ft	LF	1446	$ 1,635	$ 2,370,000	Estimated based on profile.
84-inch RCP, Depth >25ft	LF	1334	$ 1,868	$ 2,500,000	Estimated based on profile.
Outlet Structure w/Treatment Device	EA	1	$ 140,000	$ 140,000	
Additional Costs					
Regulator Modification	EA	1	$ 10,000	$ 10,000	Increase weir length of the Charles Street regulator to 8.5 ft.
New sewer bulkheads	EA	3	$ 3,000	$ 9,000	
Roadway Restoration	SF	170,263	$ 20.00	$ 3,410,000	Majorty of the road is 2-lanes, with a short section of N Harrison north of W Saginaw being 3-lanes. Major road crossing at W Saginaw.
Mobilization	%		12%	$ 8,200,000	Includes site clearing.
Traffic Control	%		2%	$ 1,360,000	
Utility Adjustments	%		20%	$ 13,600,000	Relocation of utility lines.
Contingency Costs					
Undefined Work Contingency	%		35%	$ 31,900,000	
Construction Total				$ 123,000,000	
Soft Costs					
Planning and Preliminary Design	%		5%	$ 6,150,000	
Design and Engineering Services	%		10%	$ 12,300,000	
Administration costs-Design, legal fees, and construction	%		2%	$ 2,460,000	
Field Engineering and Inspection	%		5%	$ 6,150,000	
Total Soft Cost for Alternative 3B				$ 27,100,000	
Total Cost for Alternative 3B				$ 151,000,000	
Total Cost for Alternative 3B (High Range)			65%	$ 250,000,000	
Total Cost for Alternative 3B (Low Range)			-35%	$ 98,200,000	

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Task: 8

Alternative 3C (Storage Only)					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
Underground Storage					
Underground Storage	Mgal	2.2	$ 1,615,000	$ 3,620,000	Gordon Guyer Park and Glencairn Park storage. Storm separation costs are included as part of Alternative 3A/3B. Cost includes all underdrains and materials for construction of facility.
Park Restoration - Trees and Shrubs	SF	18,644	$8	$ 154,000	Includes site restoration of trees and shrubs, consistent with the park's pre-construction condition.
Park Restoration - Sod Replacement	SF	93,219	$3	$ 234,000	Includes sod replacement, consistent with the park's pre-construction condition.
Outlet Structure	EA	2	$30,000	$ 60,000	
Additional Costs					
Mobilization	%		12%	$ 489,000	Includes site clearing.
Traffic Control	%		2%	$ 82,000	
Utility Adjustments	%		20%	$ 814,000	Relocation of utility lines.
Contingency Costs					
Undefined Work Contingency	%		35%	$ 1,910,000	
Construction Total				$ 7,370,000	
Soft Costs					
Planning and Preliminary Design	%		5%	$ 370,000	
Design and Engineering Services	%		10%	$ 740,000	
Administration costs-Design, legal fees, and construction	%		2%	$ 150,000	
Field Engineering and Inspection	%		5%	$ 370,000	

Project: East Lansing Wet Weather Resiliency Plan
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Class 5 Accuracy of Estimate (-35% to + 65%)
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Total Soft Cost for Alternative 3C		$	1,630,000	
Total Cost for Alternative 3C		$	9,000,000	
Total Cost for Alternative 3C (High Range)	65%	$	14,900,000	
Total Cost for Alternative 3C (Low Range)	-35%	$	5,900,000	

Project: East Lansing Wet Weather Resiliency Plan
Subject: Alternatives Analysis
Class 5 Accuracy of Estimate (-35% to + 65%)
Task: 8

Alternative 5A					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
Storm Sewer Upsizing - Orange Sewers					
Manhole, 4-foot Diameter	EA	13	$ 7,000	$ 91,000	Assumes a 4-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 5-foot Diameter	EA	14	$ 9,000	$ 126,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 6-foot Diameter	EA	7	$ 13,000	$ 91,000	Assumes a 6-foot diameter manhole every 300 feet and at diameter changes.
Access Point	EA	5	$ 10,000	$ 50,000	Assumes 1 access every 600 feet. The access hole dimensions are assumed to be approximately 2.5-3 feet in diameter.
24-inch RCP, Depth < 15ft	LF	587	$ 362	$ 213,000	
30-inch RCP, Depth < 15ft	LF	1602	$ 457	$ 733,000	
36-inch RCP, Depth < 15ft	LF	2265	$ 539	$ 1,230,000	
36-inch RCP, Depth > 15ft, <25ft	LF	286	$ 630	$ 181,000	
48-inch RCP, Depth <15ft	LF	554	$ 723	$ 401,000	
60" x 144" Rectangular	LF	454	$ 4,500	$ 2,050,000	
48" x 168" Rectangular	LF	2108	$ 4,350	$ 9,170,000	
Additional Costs					
Aboveground Storage	Mgal	1.2	$ 695,000	$ 800,000	Storage at the Fire Department and Harrison Meadow Park. It is assumed that this storage provides water quality treatment.
Park Restoration	SF	10,251	$ 11	$ 111,000	Includes site restoration and park ammenities consistent with the park's pre-construction condition.
Roadway Restoration	SF	94,277	$ 20.00	$ 1,890,000	

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Mobilization	%	12%	$ 2,060,000	Includes site clearing.
Traffic Control	%	2%	$ 343,000	
Utility Adjustments	%	20%	$ 3,430,000	Relocation of utility lines.
Contingency Costs				
Undefined Work Contingency	%	35%	$ 8,040,000	
Construction Total			$ 31,100,000	
Soft Costs				
Planning and Preliminary Design	%	5%	$ 1,560,000	
Design and Engineering Services	%	10%	$ 3,110,000	
Administration costs-Design, legal fees, and construction	%	2%	$ 630,000	
Field Engineering and Inspection	%	5%	$ 1,560,000	
Total Soft Cost for Alternative 5A			$ 6,860,000	
Total Cost for Alternative 5A			$ 38,000,000	
Total Cost for Alternative 5A (High Range)		65%	$ 62,700,000	
Total Cost for Alternative 5A (Low Range)		-35%	$ 24,700,000	

Project: East Lansing Wet Weather Resiliency Plan
Subject: Alternatives Analysis
Class 5 Accuracy of Estimate (-35% to + 65%)
Task: 8

Alternative 5B					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
Storm Sewer Upsizing - Orange Sewers					
Manhole, 4-foot Diameter	EA	7	$ 7,000	$ 49,000	Assumes a 4-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 5-foot Diameter	EA	13	$ 9,000	$ 117,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 6-foot Diameter	EA	3	$ 13,000	$ 39,000	Assumes a 6-foot diameter manhole every 300 feet and at diameter changes.
Access Point	EA	5	$ 10,000	$ 50,000	Assumes 1 access every 600 feet. The access hole dimensions are assumed to be approximately 2.5-3 feet in diameter.
24-inch RCP, Depth < 15ft	LF	351	$ 362	$ 127,000	
30-inch RCP, Depth < 15ft	LF	1143	$ 457	$ 523,000	
36-inch RCP, Depth < 15ft	LF	1900	$ 539	$ 1,030,000	
42-inch RCP, Depth < 15ft	LF	1061	$ 631	$ 670,000	
42-inch RCP, Depth > 15ft, <25ft	LF	286	$ 738	$ 212,000	
54-inch RCP, Depth <15ft	LF	554	$ 757	$ 420,000	
48" x 168" Rectangular	LF	454	$ 4,350	$ 1,980,000	
60" x 240" Rectangular	LF	2108	$ 6,000	$ 12,650,000	
Aboveground Storage					
Aboveground Storage	Mgal	1.7	$ 695,000	$ 1,170,000	Additional storage at the Fire Department or upstream detention storage. It is assumed that this storage provides water quality treatment.
Park Restoration	SF	14,869	$ 11	$ 160,000	Includes site restoration and park ammenities consistent with the park's pre-construction condition.

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Roadway Restoration	SF	94,277	$ 20.00	$ 1,890,000	Cost for backfilling the trench and new pavement for CSO upgrades.
Mobilization	%		12%	$ 2,540,000	Includes site clearing.
Traffic Control	%		2%	$ 422,000	
Utility Adjustments	%		20%	$ 4,220,000	Includes the relocation of utility lines.
Contingency Costs					
Undefined Work Contingency	%		35%	$ 9,900,000	
Construction Total				$ 38,200,000	
Soft Costs					
Planning and Preliminary Design	%		5%	$ 1,910,000	
Design and Engineering Services	%		10%	$ 3,820,000	
Administration costs-Design, legal fees, and construction	%		2%	$ 770,000	
Field Engineering and Inspection	%		5%	$ 1,910,000	
Total Soft Cost for Alternative 5B				$ 8,410,000	
Total Cost for Alternative 5B				$ 46,700,000	
Total Cost for Alternative 5B (High Range)			65%	$ 77,100,000	
Total Cost for Alternative 5B (Low Range)			-35%	$ 30,400,000	

Project: East Lansing Wet Weather Resiliency Plan
Subject: Alternatives Analysis
Class 5 Accuracy of Estimate (-35% to + 65%)
Task: 8

Alternative 5C (Storage Only)					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
Underground Storage					
Underground Storage	Mgal	1.31	$ 1,615,000	$ 2,120,000	Additional storage under parking lots. It is assumed that water quality treatment is provided by the aboveground storage in alternatives 5A and 5B.
Park Restoration - Trees and Shrubs	SF	11,674	$8	$ 97,000	Includes site restoration of trees and shrubs, consistent with the park's pre-construction condition.
Park Restoration - Sod Replacement	SF	58,371	$3	$ 146,000	Includes sod replacement, consistent with the park's pre-construction condition.
Outlet Structure	EA	1	$30,000	$ 30,000	
Additional Costs					
Mobilization	%		12%	$ 288,000	Includes site clearing.
Traffic Control	%		2%	$ 48,000	
Utility Adjustments	%		20%	$ 479,000	Relocation of utility lines.
Contingency Costs					
Undefined Work Contingency	%		35%	$ 1,130,000	
Construction Total				$ 4,340,000	
Soft Costs					
Planning and Preliminary Design	%		5%	$ 220,000	
Design and Engineering Services	%		10%	$ 440,000	
Administration costs-Design, legal fees, and construction	%		2%	$ 90,000	

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Field Engineering and Inspection	%	5%	$ 220,000	
Total Soft Cost for Alternative 5C			$ 970,000	
Total Cost for Alternative 5C			$ 5,310,000	
Total Cost for Alternative 5C (High Range)		65%	$ 8,770,000	
Total Cost for Alternative 5C (Low Range)		-35%	$ 3,460,000	

Project: East Lansing Wet Weather Resiliency Plan
Subject: Alternatives Analysis
Class 5 Accuracy of Estimate (-35% to + 65%)
Task: 8

Alternative 6A					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
Storm Sewer Upsizing - Orange Sewers					
Manhole, 4-foot Diameter	EA	4	$ 7,000	$ 28,000	Assumes a 4-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 5-foot Diameter	EA	3	$ 9,000	$ 27,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 6-foot Diameter	EA	12	$ 13,000	$ 156,000	Assumes a 6-foot diameter manhole every 300 feet and at diameter changes.
24-inch RCP, Depth < 15ft	LF	734	$ 362	$ 267,000	
36-inch RCP, Depth < 15ft	LF	600	$ 539	$ 324,000	
54-inch RCP, Depth < 15ft	LF	3275	$ 757	$ 2,480,000	
Aboveground Storage					
Aboveground Storage	Mgal	0.2	$ 695,000	$ 139,000	White Memorial City Park fishing pond storage. It is assumed that this storage provides water quality treatment.
Park Restoration	SF	1771	$ 11	$ 20,000	Includes site restoration and park ammenities consistent with the park's pre-construction condition.
Additional Costs					
Restrictor Modification	EA	1	$ 10,000	$ 10,000	Removing the existing flow restrictor.
Roadway Restoration	SF	55,304	$ 20.00	$ 1,110,000	Cost for backfilling the trench and new pavement for CSO upgrades.
Mobilization	%		12%	$ 548,000	Includes site clearing.
Traffic Control	%		2%	$ 92,000	
Utility Adjustments	%		20%	$ 913,000	Includes the relocation of utility lines.
Contingency Costs					
Undefined Work Contingency	%		35%	$ 2,140,000	
Construction Total				$ 8,260,000	

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Task: 8

Soft Costs				
Planning and Preliminary Design	%	5%	$ 420,000	
Design and Engineering Services	%	10%	$ 830,000	
Administration costs-Design, legal fees, and construction	%	2%	$ 170,000	
Field Engineering and Inspection	%	5%	$ 420,000	
Total Soft Cost for Alternative 6A			$ 1,840,000	
Total Cost for Alternative 6A			$ 10,100,000	
Total Cost for Alternative 6A (High Range)		65%	$ 16,700,000	
Total Cost for Alternative 6A (Low Range)		-35%	$ 6,570,000	

Project: East Lansing Wet Weather Resiliency Plan
Subject: Alternatives Analysis
Class 5 Accuracy of Estimate (-35% to + 65%)
Task: 8

Alternative 6B					
Item	**Unit**	**Total Quantity**	**Unit Price**	**Total Cost**	**Comment**
Storm Sewer Upsizing - Orange Sewers					
Manhole, 4-foot Diameter	EA	4	$ 7,000	$ 28,000	Assumes a 4-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 5-foot Diameter	EA	3	$ 9,000	$ 27,000	Assumes a 5-foot diameter manhole every 300 feet and at diameter changes.
Manhole, 7-foot Diameter	EA	12	$ 15,000	$ 180,000	Assumes a 7-foot diameter manhole every 300 feet and at diameter changes.
24-inch RCP, Depth < 15ft	LF	734	$ 362	$ 267,000	
42-inch RCP, Depth < 15ft	LF	600	$ 631	$ 379,000	
60-inch RCP, Depth < 15ft	LF	3275	$ 791	$ 2,590,000	
Aboveground Storage					
Aboveground Storage	Mgal	0.6	$ 695,000	$ 392,000	Additional storage for the White Memorial City Park fishing pond storage. It is assumed that this storage provides water quality treatment.
Park Restoration	SF	5024	$ 11	$ 55,000	Includes site restoration and park ammenities consistent with the park's pre-construction condition.
Additional Costs					
Restrictor Modification	EA	1	$ 10,000	$ 10,000	Removing the existing flow restrictor.
Roadway Restoration	SF	55,304	$ 20.00	$ 1,110,000	Cost for backfilling the trench and new pavement for CSO upgrades.
Mobilization	%		12%	$ 605,000	Includes site clearing.
Traffic Control	%		2%	$ 101,000	
Utility Adjustments	%		20%	$ 1,010,000	Includes the relocation of utility lines.
Contingency Costs					
Undefined Work Contingency	%		35%	$ 2,370,000	
Construction Total				$ 9,130,000	

Project: East Lansing Wet Weather Resiliency Plan
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Class 5 Accuracy of Estimate (-35% to + 65%)
Task: 8

Soft Costs				
Planning and Preliminary Design	%	5%	$ 420,000	
Design and Engineering Services	%	10%	$ 830,000	
Administration costs-Design, legal fees, and construction	%	2%	$ 170,000	
Field Engineering and Inspection	%	5%	$ 420,000	
Total Soft Cost for Alternative 6B			$ 1,840,000	
Total Cost for Alternative 6B			$ 11,000,000	
Total Cost for Alternative 6B (High Range)		65%	$ 18,200,000	
Total Cost for Alternative 6B (Low Range)		-35%	$ 7,150,000	

Appendix H.

Stakeholder Focus Group Meeting Summaries

Summary Notes

Focus Group 2

Project:	East Lansing Wet Weather Resiliency Study
Subject:	Focus Group 2 Summary Notes
Date:	Thursday, June 25, 2026
Location:	Hannah Community Center
East Lansing and HDR Staff Attendees:	Cliff Walls, City of East Lansing Ron Lacasse, City of East Lansing Dani Stahlin, City of East Lansing Stephen Clayton, City of East Lansing Anne Cron, HDR Tom Batroney, HDR Ernie West, HDR
3:30 p.m. Focus Group Attendees:	Kathy Bouchard-Wyant – East Lansing Senior Commission Carolyn Boger – Glens of Whitehills Carol Garling – Glens of Whitehills Lynn Richardson – Pinecrest Neighborhood Association Andrew Kraft – DTN Management Company Matt Hagan – Hagan Realty Inc. Fred Cowles – Middle Grand River Organization of Watersheds Helana Nelson – Commission on the Environment Christie Alwin – EGLE-WRD
6 p.m. Focus Group Attendees:	Caroline Cookgaard – Homeowner Charles Cookergard – Homeowner Nathan Werner – Commission on the Environment, Transportation Commission Kathy Jacobs – St. Vincent de Paul. MidMEAC, Red Cedar Neighborhood Charlotte Mayworm – Montie House / EGLE Adam Rice – Montie House Ted Benca – Whitehills Neighborhood Association Erik Altmann – Mayor, City of East Lansing

Focus Group Discussion Themes

- Flooding Data and Problem Identification
- Equity and Mapping
- MSU and Regional Coordination
- Private Property Issues
- Funding and Implementation
- Neighborhood Flooding Concerns
- System Function and Hydrology
- Project Momentum and Communication
- Green Infrastructure and Property-Level Solutions
- Funding Opportunities
- Stormwater Utility Questions

3:30 p.m. Focus Group
Discussion Themes and Questions

Flooding Data and Problem Identification

- Asked whether project goals specifically address basement flooding.
- Requested clarification on whether basement backups are occurring only within the Combined Sewer Overflow (CSO) service area.
- Asked whether the City can determine how much debris or blockage exists within drainage pipes.
- Resident shared flooding experience on Applegate, noting water backup entering an egress window.
- Suggested clarifying the distinction between:
    - River/floodplain flooding
    - Collection system flooding

Equity and Mapping

- Christie Alwin asked how disadvantaged areas are being incorporated into project prioritization and evaluation matrices.
- Participants requested overlay maps to improve understanding of flooding patterns and proposed solutions.
- Asked why neighborhoods west of campus, including the “Flower Pot” area, are not more prominently included in analysis and communications.

Michigan State University and Regional Coordination

- Asked how Michigan State University impacts the City's ability to manage stormwater.
- Asked whether Lansing has been informed of plans that may result in moving stormwater to the river more quickly.

Private Property Issues

- Discussion regarding apartment management company being required to remove downspouts.
- Asked:
    - What other City departments have been consulted?
    - What level of effort and funding will be available to help move water from private property into public drainage systems?
- Requested clarification regarding underground versus aboveground storage options.
- Asked whether additional green space and green infrastructure opportunities are being considered.
- Suggested integrating information from homeowner education presentations into the overall communications strategy.
- Discussion on:
    - Small-site stormwater policies
    - Development standards

Funding and Implementation

- Asked about project implementation timelines, including how long it may take to construct major infrastructure (10–20 years).
- Requested information regarding funding opportunities, including:
    - Stormwater utility fees
    - Grants

Additional Comments

- Participant stated that recurring apartment flooding causes costs that significantly outweigh benefits and that DTN undertaking certain mitigation projects independently is not a practical solution.
- Suggested emphasizing that East Lansing is taking a leadership role in addressing flooding issues.

6:00 p.m. Focus Group
Discussion Themes and Questions

Neighborhood Flooding Concerns

- Flooding concerns raised regarding:
    - Montie House Cooperative
    - Red Cedar Neighborhood
    - Whitehills
    - Shaw Estates

System Function and Hydrology

- Asked whether Michigan State University operates a combined or separate sewer system.
    - Discussion noted that East Lansing has an interceptor associated with MSU.
- Asked whether water storage “bladder” systems are used beneath buildings in flood-prone areas.
- Asked whether the primary strategy is moving stormwater to the river more quickly.
- Asked whether additional drain tiles ultimately increase flows to the river.
- Asked where Shaw Estates drains.
- Asked how snowmelt combined with rainfall affects flooding conditions.

Project Momentum and Communication

- Multiple participants expressed that action should begin as soon as possible and that funding opportunities may follow once a clear plan is established.
- Suggested providing visual illustrations of existing site conditions compared to potential future improvements.
- Recommended messaging about how flooding impacts emergency services and public safety.

Green Infrastructure and Property-Level Solutions

- Suggested strengthening green infrastructure components.
- Participants were surprised that greater emphasis had not been placed on individual property solutions.
- Participants recommended:
    - Community outreach and education.
    - Support programs for on-site mitigation.
    - Water conservation and keeping rainfall on-site where possible.
- Asked whether a stormwater utility could provide:
    - Drainage audits.
    - Technical assistance specialists.
    - Educational resources for property owners.

Funding Opportunities

- Asked about costs and feasibility of purchasing homes for demolition to increase storage capacity and reduce impervious surfaces.
- Requested information on additional funding sources, including:
    - FEMA
    - EGLE
    - State Revolving Fund (SRF)
    - Building Resilient Infrastructure and Communities (BRIC)

Stormwater Utility Questions

- Asked how a stormwater utility could support private-property drainage improvements.
- Asked what a typical stormwater fee might be and how a fee structure would affect properties located at low points that receive runoff from surrounding areas.

Additional Comments

- Asked whether the City has considered a broader “porous city” concept that emphasizes infiltration and distributed stormwater management.

Key Takeaways Across Both Focus Groups

- Strong interest in addressing basement flooding and recurring neighborhood flooding issues.
- Significant interest in private-property solutions, homeowner education, and technical assistance.
- Desire for clearer mapping, visualizations, and communication materials.
- Questions regarding regional coordination with MSU and neighboring jurisdictions.
- Interest in green infrastructure, stormwater storage, and distributed solutions.
- Numerous questions about funding mechanisms, particularly stormwater utility fees and grant opportunities.
- Strong support for moving forward with implementation while continuing public engagement and education.

Focus Group Summary

Project:	East Lansing Wet Weather Resiliency Project
Subject:	Focus Groups
Date:	Wednesday, November 05, 2025
Location:	Hannah Community Center

Attendees:

Cliff Walls, EL
Ronald Lacasse, EL
Dani Stahlin, EL
Stephen Darling, EL
Elaine Hardy, EL
Carrie Sampson, EL
Lita Johnson, EL
Ernie West, HDR
Tom Batroney, HDR
Anne Cron, HDR

Reuben Levinsohn, afternoon participant
Fred Cowles, afternoon participant
Theodore Benca, afternoon participant
Dave Grummon, afternoon participant
Dave Chapin, afternoon participant
Mario McFaddon, afternoon participant
Matt Hagan, afternoon participant
Kathy Bouchard-Wyant, afternoon participant
Lynn Richardson, afternoon participant
Mark Sarvis , afternoon participant
Peter Dewan, afternoon participant
Charles Overbey, evening participant
Helana Nelson, evening participant
Mitch Moore, evening participant
Diane Wing, evening participant
Justin Booth, evening participant
Jeff Friedle, evening participant
Patrick Cline, evening participant

Agenda (same for each session)

	Topic	*Facilitator*
1	Welcome and Introductions	Anne Cron
2	Presentation	Cliff Walls, Ernie West, Tom Batroney, Anne Cron
3	Mentimeter Activity	Anne Cron
4	Conclusion and next steps	Anne Cron

Presentation Summary

Below captures summaries to provide context for slides shown to participants.

Slide 5
Increase in frequency of very intense rain events that are routinely overcoming the city's drainage system in recent years has caused the City to pursue development of a Wet Weather Resiliency Plan. Flooding that occurs in the system may be do to the downstream system being overwhelmed and not by a lack of sufficient local drainage infrastructure.

Slide 6
Defining a storm is done by the chance of it occurring in any given year and is based on historical data, which is why we are seeing more frequent "100-year storms" because the climate is changing but the definitions have not.

Slide 7
Just in the last 13 years, East Lansing has seen 6 storms events greater than a "200 year" event.

Slide 8
At the beginning of this study, we looked at 75 years of data to understand the historical trends, which validate the frequency of short duration, high intensity events, which are driving flooding in the City. We are also looking forward by reviewing available climate projection models to form a bracket of additional increase that we may see and need to plan for in the future.

Slide 9
The study has 11 tasks and we've nearly completed 6 of them so far. Thus far, we've been gathering data to understand the changing climate, understand what defines a flooding concern, what might be important in developing solutions, collecting data to build a functional system model, validating the model and identifying concern areas. We are now seeking feedback to confirm we are going in the right direction and don't have any serious blind spots. As we move forward into development of solutions, we'll be back to share those detail with you and get feedback as we begin to wrap up everything into a plan by middle of next year.

Slide 10
The plan will result in tangible outcomes that will form the basis of moving forward with solutions. This plan is needed in order to obtain grant/loan funding, similar to what the City has had to do on the CSO system to utilize the SRF funding program.

Slide 11
It's important to remember that public infrastructure projects will only address flooding caused by those systems. These projects won't address flooding on private property caused by particular limitation of those properties. Those issues will likely need to be address through a more educational, programmatic approach that the City may consider.

Slide 12
The model is a highly advanced tool that simulates flooding in the storm sewers and on the surface. This tool puts the City ahead of the curve when it comes to flood preparedness, especially for a city of its size. Usually, only models of this nature are for bigger Cities with more resources such as Houston or New York City. The model was demonstrated live in a webmapping tool for participants. The project team has used the webmap to verify flooding complaints from the June and July 2024 storms. During the demonstration, results from the model were shown for a more typical storm (25-year) and how this storm was used to identify 44 flooding concern areas.

Slide 13
The Flooding Concern Areas were scored and ranked High, Medium, and Low based on points accumulated in each area. Examples were provided regarding the scoring criteria to the audience of how flooding in the road of 6 inches or more was used to score the flooding concern areas. For example, flood concern areas with flooding depth of 6-inches or more for small events score higher points than areas that flood only during a 100-year event. Points were awarded for various other factors listed on the slide.

Slide 14
The top 8 scoring areas were selected for purposes of project planning under the WWRP as a first phase of projects. Other areas scored high (shown in dashed areas) are being pursued under other initiatives either by the City or County.

Slide 17
The definition of Level-of-Service with respect to flooding was discussed and how it is important for evaluating the performance of the system. The Level-of-Service of the system is dependent on various factors including engineering standards at the time, the affordability of the community, and existing infrastructure such as culverts under interstates versus local roads.

Slide 18
It was shown that the Level-of-Service for the Highest Scoring Flooding Concern Areas are all below a 5-year storm (i.e. a 20% chance of flooding any given year). Many of these areas are in the older part of the City that have combined sewers and were designed under

different climate conditions and with less development. Storms have gotten stronger over the years and there are now more impervious surfaces that have reduced the performance of these areas.

Slide 19
The plan will be evaluating 3 Increased Level-of-Service Scenarios that include future climate considerations. However, as these Level-of-Service scenarios increase, so do costs to the City of East Lansing taxpayers. The cost of increased Level of Service will need to consider affordability.

Slide 22
The Plan will focus on various public works infrastructure projects. Projects such as increased pipe sizes, underground storage holding tanks, increased channels and berms, and green infrastructure were presented and discussed as options for East Lansing.

Slide 23
As part of the Plan we have developed a four-step framework. The third step in the process is understanding community priorities when it comes to the type of projects that you would most like to see in your neighborhood.

Slide 24
To inform the selection of the potential projects the City has identified 8 criteria for evaluating projects as part of the plan. Each of the criteria on the slide were explained to the audience with examples for each.

Slide 25
The City has also stressed the importance of Environmental Justice and Equity as part of the development of the Plan. The Plan has assessed Social Vulnerability of Census Tracts in East Lansing using publicly available Census metrics. This data was analyzed to understand where the most vulnerable areas in the City are located.

Slide 26
The results of the Social Vulnerability analysis were presented and compared to the scoring of the flooding concern areas. It was noted that several of the highest scoring flood areas overlapped with the most vulnerable Census tracts. It was stressed that the areas selected for the plan were only the first phase of planning work, and the other areas identified would likely be part of future phases of work. It was stressed that this work would likely take decades to complete and it will be many years before projects are built.

Slide 27
The Project Criteria was re-introduced and the Pairwise scoring exercise was conducted to gauge the importance of each criteria to the participants.

Slide 30

There are limitations to this planning effort that need to be acknowledged in order to set expectations that solutions will not come overnight. This problem has been 100 years in the making and will take time to fix.

Slide 31

The implementation of this plan will be a long game of seeking funding, developing projects, adapting policy/programs and modifying the plan to keep it a living roadmap for achieving wet weather resilience over the long term.

Mentimeter Results

City Results Only

Pairwise	Improved Drainage	City Resiliency Alignment	Water Quality	Impervious Surface Reduction	Social & Economic Impacts	High Impact	Ease of Constructibility	Level of Maintenance	TOTAL	WEIGHT	RANK
Improved Drainage	-	3	4	4	4	3	4	2	24	20.0%	1
City Resiliency Alignment	2	-	2	2	0	1	3	2	12	10.0%	6
Water Quality	1	3	-	3	1	1	4	1	14	11.7%	5
Impervious Surface Reduction	1	2	1	-	0	2	1	1	8	6.7%	7
Social & Economic Impacts	1	4	3	4	-	2	4	1	19	15.8%	3
High Impact	2	3	3	2	2	-	3	0	15	12.5%	4
Ease of Constructibility	1	1	0	3	0	1	-	0	6	5.0%	8
Level of Maintenance	3	2	3	3	3	4	4		22	18.3%	2
					Total Check				120	100%	

Focus Group 1 Results Only

Pairwise	Improved Drainage	City Resiliency Alignment	Water Quality	Impervious Surface Reduction	Social & Economic Impacts	High Impact	Ease of Constructibility	Level of Maintenance	TOTAL	WEIGHT	RANK
Improved Drainage	-	9	7	6	9	7	8	8	54	18.4%	2
City Resiliency Alignment	1	-	3	10	2	6	7	6	35	11.9%	3
Water Quality	4	8	-	10	9	10	10	10	61	20.7%	1
Impervious Surface Reduction	4	1	1	-	5	6	6	6	29	9.9%	6
Social & Economic Impacts	2	9	2	5	-	6	4	5	33	11.2%	5
High Impact	3	5	1	5	4	-	8	9	35	11.9%	3
Ease of Constructibility	2	4	1	4	6	2	-	5	24	8.2%	7
Level of Maintenance	2	4	1	5	5	1	5		23	7.8%	8
					Total Check				294	100%	

Focus Group 2 Results Only

Pairwise	Improved Drainage	City Resiliency Alignment	Water Quality	Impervious Surface Reduction	Social & Economic Impacts	High Impact	Ease of Constructibility	Level of Maintenance	TOTAL	WEIGHT	RANK
Improved Drainage	-	4	5	4	4	2	4	4	27	13.8%	4
City Resiliency Alignment	3	-	6	2	4	3	6	5	29	14.8%	2
Water Quality	2	1	-	2	4	1	4	1	15	7.7%	7
Impervious Surface Reduction	3	5	5	-	4	2	5	5	29	14.8%	2
Social & Economic Impacts	3	3	3	3	-	2	3	4	21	10.7%	6
High Impact	5	4	6	5	5	-	7	6	38	19.4%	1
Ease of Constructibility	3	1	3	2	4	0	-	2	15	7.7%	7
Level of Maintenance	3	2	6	2	3	1	5		22	11.2%	5
					Total Check				196	100%	

Focus Group 1 and 2 Combined Results

Pairwise	Improved Drainage	City Resiliency Alignment	Water Quality	Impervious Surface	Social & Economic	High Impact	Ease of Constructibility	Level of Maintenance	TOTAL	WEIGHT	RANK
Improved Drainage	-	13	12	10	13	9	12	12	81	16.5%	1
City Resiliency Alignment	4	-	9	12	6	9	13	11	64	13.0%	4
Water Quality	6	9	-	12	13	11	14	11	76	15.5%	2
Impervious Surface Reduction	7	6	6	-	9	8	11	11	58	11.8%	5
Social & Economic Impacts	5	12	5	8	-	8	7	9	54	11.0%	6
High Impact	8	9	7	10	9	-	15	15	73	14.9%	3
Ease of Constructibility	5	5	4	6	10	2	-	7	39	7.9%	8
Level of Maintenance	5	6	7	7	8	3	10		46	9.4%	7
					Total Check				491	100%	

All Groups (City and Focus Groups) Combined Results

Pairwise	Improved Drainage	City Resiliency Alignment	Water Quality	Impervious Surface Reduction	Social & Economic Impacts	High Impact	Ease of Constructibility	Level of Maintenance	TOTAL	WEIGHT	RANK
Improved Drainage	-	16	16	14	17	12	16	14	105	17.5%	1
City Resiliency Alignment	6	-	11	14	6	10	16	13	76	12.7%	4
Water Quality	7	12	-	15	14	12	18	12	90	15.0%	2
Impervious Surface Reduction	8	8	7	-	9	10	12	12	66	11.0%	5
Social & Economic Impacts	6	16	8	12	-	8	7	9	66	11.0%	5
High Impact	10	12	10	12	9	-	18	15	86	14.4%	3
Ease of Constructibility	6	6	4	9	10	3	-	7	45	7.5%	8
Level of Maintenance	8	8	10	10	8	7	14		65	10.9%	7
					Total Check				599	100%	

Participant Questions/Comments

What is the general status of separating storm and sewer lines?

Will drainage issues on culverts be resolved?

Are only pavement issues being considered? What about places like parks? (Henry Fine Park/Pinecrest)

How will the City consider balancing green space with future plans for building growth?

Will the City consider health risks posed by mosquitos or muskrats drawn to standing water? (Pinecrest)

Could there be a deduction on income tax to support good stormwater practices for building owners?

Has analysis been given to changes to impervious areas over time?

City should consider the role they've played in building/growth planning over the years that have contributed to the problem.

Does this address new infrastructure to solve problems?

What partnerships has the City entered into or considered? (MSU?)

Education is needed to help residents understand things they can do and how things like leaf collection contributes to problem. Using communications tools like City Dialogues and social media are recommended.

Consider power lines and the access to those in an emergency as well as the risk of power outages caused by flooding.

Is the City considering scenarios that combine addressing concerns as well as acquiring properties and taking them out of circulation?

What kind of grant money is there out there for projects like these?

Consider the Kentucky University survey regarding money and the costs to homeowners because of these issues.

Is there a way to take a holistic approach? Consider ways to take the water to places away from homes (like a park) and collect and hold it until it can be dispersed? (Raney Park, example.)

Appendix I.

Open House Summary

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Summary Notes
Open House

Project:	East Lansing Wet Weather Resiliency Study
Subject:	In-Person Open House Summary Notes
Date:	Wednesday, August 12, 2026
Location:	East Lansing Hannah Community Center
East Lansing and HDR Staff Attendees:	Cliff Walls, City of East Lansing Ron Lacasse, City of East Lansing Stephen Clayton, City of East Lansing Anne Cron, HDR Tom Batroney, HDR Ernie West, HDR Anna Kilts, HDR Francisco Arce, HDR
Stakeholder attendees	See attached sign in sheet

Public Attendance

Approximately 20-30 community members attended the open house throughout the event. Participants reviewed project information boards and technical data, engaged project team members, and provided input regarding project priorities and potential resiliency solutions. A sign-in sheet documenting attendance was collected and will be provided to the City as part of the engagement record.

Media Attendance and Coverage

WLNS Channel 6 attended the open house and interviewed project representatives regarding the East Lansing Wet Weather Resiliency Study. Coverage included:

- **East Lansing invites residents to learn about flood resiliency plan**
- **Aug. 12 open house on East Lansing flood resilience plan - NewsBreak**

Open House Materials

For the in-person open house, 9 display boards were created along with a handout, comment cards and a sign in sheet. The 9 display boards included:

- About the Project
- Focus Areas
- Social Vulnerability
- Timeline
- Root Cause of Flooding
- Flood Mitigation
- Developed Projects
- Projects and Phasing
- Non-Structural Strategies

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Open House Discussion Themes

Project Priorities

Participants sought additional information regarding how flood resiliency projects were prioritized throughout the City. Questions focused on how potential projects were evaluated and how community concerns were incorporated into decision-making.

Project Schedule and Implementation

Community members expressed interest in understanding the anticipated timeline for project development and implementation. Discussions included near-term versus long-term improvements, planning milestones, phasing, and next steps following completion of the study.

Project Costs and Funding

Attendees asked questions regarding potential project costs, funding opportunities, and how recommended improvements would be implemented over time. Discussions focused on balancing project effectiveness with available funding resources.

Community Support

In general, community members expressed support for the study and the City's efforts to proactively address flooding and stormwater management challenges. Stakeholders appreciated the opportunity to review information, engage directly with project team members, and provide feedback.

Written Comment Received

One written comment was submitted during the open house:

> "I am in favor of the city buying the 4 rental properties along Northlawn as you approach Abbot Rd. Then those properties can be made into park land with native plants."
> Barb Anderson, Ph.D.

Online Engagement

The project's Online Meeting launched on August 14, 2026, and will remain available for approximately three weeks. The Online Meeting content follows what was displayed at the in-person open house. Additional comments are being collected through the online engagement platform and will be summarized at the conclusion of the engagement period to incorporate as much public feedback into the City Council presentation.

- **East Lansing Wet Weather Resiliency Plan Virtual Open House**

Key Takeaways

- Strong public participation with approximately 20-30 attendees throughout the open house.
- Stakeholders generally expressed support for the project and its goals.
- Most questions focused on project priorities, study area boundaries, alternatives analysis, phasing, implementation schedule, and project costs.

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- Participants valued the opportunity to discuss flood resiliency challenges directly with project team members.
- Local media coverage helped increase community awareness of the study and engagement opportunities.
- Additional public feedback is being gathered through the Online Meeting to be incorporated into future project communications and presentations.

Next Steps

- Continue collecting stakeholder input through the Virtual Open House.
- Compile and analyze all public comments received through both in-person and online engagement activities.
- Incorporate public feedback into project recommendations and materials being developed for City Council consideration.
- Provide a complete engagement summary, including attendance records and online engagement results, following closure of the Virtual Open House.

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