City of Manhattan Downtown East & West Basins Watershed Study

August, 2016

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1. Executive Summary

The City of Manhattan retained the services of Amec Foster Wheeler to complete a watershed study for the Downtown East and Downtown West Watersheds. The Scope of Work included completing a comprehensive stormwater model to predict flooding and the stormwater system's performance for multiple frequency storm events. Once completed, the model was then be utilized to evaluate potential improvements to the system that would increase performance and reduce flood risk. Working closely with City staff, the consultant was to develop approximately five capital improvement projects for each watershed that would have the largest impact in increasing system performance and reducing flood risk. Concepts and budget level cost estimates were be developed for each capital improvement project, which could be used as the basis for future design projects.

These watersheds have a number of known flooding issues, which prompted this project. Major known flooding issues include:

1. Water flowing from Campus Creek and rainfall falling on the Downtown West Watershed cannot be contained within the existing stormwater system; causing surcharging, which begins at approximately a 2-year event. Water generally runs to the east where it ponds against Tuttle Creek Boulevard. Street flooding on Manhattan Avenue, Bluemont Avenue and other major streets is a significant concern.

2. Water falling in the Southern half of the Downtown East Watershed flows to the east, causing flooding concerns for a portion of the downtown areas. This typically begins around a 10-year event and includes significant street flooding along Poyntz Avenue and Houston Avenue.

3. A number of commercial and residential areas experience street flooding and property flooding at a number of locations throughout the watershed.

A stormwater model was developed for the watersheds to predict flooding conditions. The model was calibrated to the May 4, 2015 flooding event, which was between a 25-yr and 50-yr flooding event, depending on the duration considered. Once the model predicted the results of the May 4, 2015 event, a number of potential alternatives were developed for consideration to reduce flooding. Working closely with City staff, alternatives that maximized benefits and were most practical were selected for evaluation. Improvements for these projects were sized based upon flooding up to the 100-yr flood event, with efforts to completely contain 100-yr flooding on City right-of-way whenever possible, and contain the 50-yr flooding event within the City stormwater infrastructure at locations of major arterials.

As a result of modeling efforts of the selected alternatives, 14 Capital Improvement Projects (CIPs) were selected for the two watersheds to be included in the City's planning. Budget level costs were developed for each concept to be used for City planning purposes moving forward. It is important to note that the overall goal of this project was to identify systemic capacity deficiencies in the existing stormwater system within the two watersheds, then develop solutions to those issues. Recommended solutions are intended to address significant infrastructure needs, which have the ability to substantially reduce flooding. However, it was not the intent of this study, nor is it practical or feasible, to evaluate and reduce the flood risk to every home or business within the watersheds, and provide solutions for each of these flooding issues. The recommended improvements from this study address large scale improvements which, if implemented, will provide an overall reduction to the flood risk within the watersheds.

The major CIP projects can be summarized as follows. Note that several of these projects have been broken into multiple CIP projects based on a number of considerations.

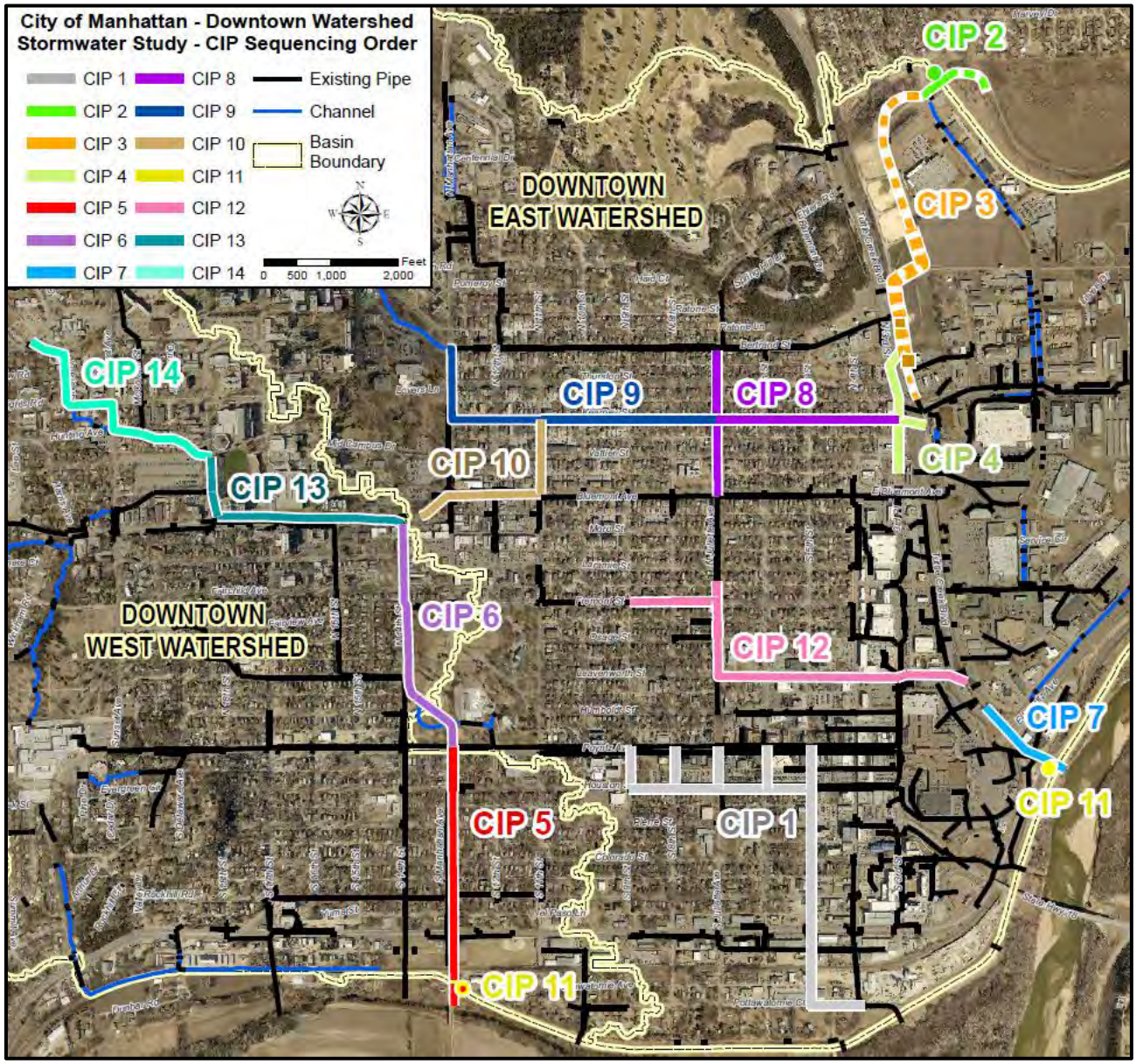
- A new storm sewer is proposed to be constructed along Kearney Street, beginning at Manhattan Avenue and extending through Tuttle Creek Boulevard to the open channel east of Tuttle Creek Boulevard. This system will carry overflows from Campus Creek, relieving flooding on Manhattan Avenue between Pomeroy Street and Bluemont Avenue east to Tuttle Creek Boulevard.
- Storm sewer improvements are proposed for Poyntz Avenue and Houston Street near the downtown area to reducing flooding potential to the downtown area.
- The existing storm sewer along North 14th Street and Manhattan Avenue, south of Bluemont is proposed to be increased in size, to capture overflows from Anderson Avenue onto Bluemont Avenue at the Manhattan Avenue intersection, and route them to the south. This project will substantially reduce overflow from the Downtown West Watershed into the Downtown East Watershed, which will significantly relieve flooding along Bluemont Ave. An increase in the capacity of the South Manhattan Pump station is proposed in addition to this project, which will increase the City's ability to flood fight in the event of a significant rainfall event in the City when the Kansas River is experiencing a flooding event.
- Tuttle Creek Boulevard Channel improvements are proposed to handle increased flows from the proposed Kearney Line as well as an additional CIP proposed along Leavenworth Street, to prevent increased flooding to businesses along Tuttle Creek Boulevard. These improvements consist of channel improvements beginning at McCall Road and running north to and through the existing levee system, construction of a new pump station and increasing outlet structure sizes at the levee and just to the west at Hayes Drive. Improvements to the Poyntz Pump station and to the levee outfall structure at this location are also proposed. These improvements will not only prevent increased flooding to businesses east of Tuttle Creek Boulevard due to the construction of the other CIP projects, but will increase the City's ability to flood fight in the event of a significant rainfall event in the City when the Kansas River is experiencing a flooding event.

Projects were phased and sequenced based on a number of factors. In general, Phase I projects address flooding issues for a variety of flood frequencies on a larger scale, and have broader based benefits. Phase II projects are either for higher frequency flooding events, or address identified flooding issues on a smaller more localized scale. Project sequencing was developed working closely with City Staff, and considers prerequisite projects as well as a number of other factors. Projects were sequenced generally from downstream to upstream, to ensure that no improvement would increase flooding at another location once it was constructed. Project sequencing may be changed as dictated by opportunities to pair with other projects and reduce overall cost, so long as prerequisite projects are constructed first as discussed in the report.

The following table provides a summary and budget level cost estimate of the fourteen proposed projects in the recommended order of construction, based upon the considerations discussed above.

Downtown Watersheds Stormwater CIP Cost Estimates				
CIP #	Project Name	Estimated Construction Cost	Design / Construction Oversight Cost	Total Cost
Phase I Projects				
1	Poyntz Avenue / Houston Street Interceptor	$3,037,870	$607,574	$3,645,444
2	Tuttle Creek North Channel Improvements - Phase 1	$3,271,304	$654,261	$3,925,565
3	Tuttle Creek North Channel Improvements - Phase 2	$2,427,767	$485,553	$2,913,320
4	Lower Kearney Street Collector	$4,450,993	$890,199	$5,341,192
5	South Manhattan Interceptor (1st Half - Levee to Poyntz)	$7,311,485	$1,462,297	$8,773,782
6	14th Street Interceptor (2nd Half - Poyntz to Anderson)	$3,213,199	$642,640	$3,855,839
7	Tuttle Creek South Outlet Improvements	$2,355,141	$471,028	$2,826,169
8	Middle Kearney Street Collector	$5,742,260	$1,148,452	$6,890,711
9	Upper Kearney Street Collector	$7,346,425	$1,469,285	$8,815,710
10	Bluemont Avenue Collector	$1,944,468	$388,894	$2,333,362
	Subtotals	**$41,100,911**	**$8,220,182**	**$49,321,093**
Phase 2 Projects				
11	Poyntz / South Manhattan Pump Station Improvements	$4,420,000	$884,000	$5,304,000
12	Leavenworth Street Collector	$3,199,330	$639,866	$3,839,197
13	Anderson-Tecumseh-Quivera Collector - Phase 1	$6,951,400	$1,390,280	$8,341,680
14	Anderson-Tecumseh-Quivera Collector - Phase 2	$3,279,085	$655,817	$3,934,902
	Subtotals	**$17,849,816**	**$3,569,963**	**$21,419,779**
	Totals	**$58,951,000**	**$11,790,000**	**$70,741,000**

The following figure provides an overview of the locations of the fourteen proposed projects.



2. Overview

To achieve the goal for the development of an urban watershed study and proposed improvements for downtown Manhattan, the City of Manhattan retained the services of Amec Foster Wheeler, a global environmental and civil engineering firm with expertise in municipal storm water management programs. Amec Foster Wheeler evaluated the performance of the City's existing stormwater system throughout the Downtown East and West Watersheds. Following this assessment, recommendations and budget level cost estimates for addressing specific system deficiencies through capital improvement projects were provided.

To evaluate the existing stormwater system, new hydrologic and hydraulic analyses were performed for the Downtown East and West Watersheds. The goal of the analysis was to develop a global model for these basins to determine system performance and to assist in identifying systemic deficiencies with the existing stormwater infrastructure. Available data for the downtown watersheds was assessed and incorporated into the modeling effort. By performing this analysis, we can provide the City an overall understanding of the system function and deficiencies of the City's current storm water infrastructure.

To evaluate potential improvements to the stormwater system, several alternatives analyses were performed based on the modeling as well as input from City staff. From these analyses, multiple Capital Improvement Projects (CIPs) were developed for the Downtown East and West Watersheds. For each of these projects, Amec Foster Wheeler developed conceptual designs, including a general description, a schematic of the proposed alternative, a list of design considerations, and a budget level cost estimate.

2.1 System Overview

Downtown Manhattan's East and West Watersheds are highly urbanized and much of the area is protected by the City's levee system. West of Tuttle Creek Boulevard, the general slope of the terrain drains water primarily toward the east through Tuttle Creek Boulevard, and to the south through a gravity outfall in the levee system along with the South Manhattan Pump Station. East of Tuttle Creek Boulevard, water drains to the north through a gravity structure in the levee system, or to the southeast through a gravity structure in the levee system and through the Poyntz Pump Station. The watersheds discharge through the levee into the Kansas River, which borders the city to the south, and Big Blue River, which borders the city to the northeast. The City's stormwater systems are dependent on the water's ability to exit through the levee control structures, which are in turn impacted by the tail water condition of the two rivers. Figure 2-1 provides an overview of the Downtown Manhattan East and West Watersheds.

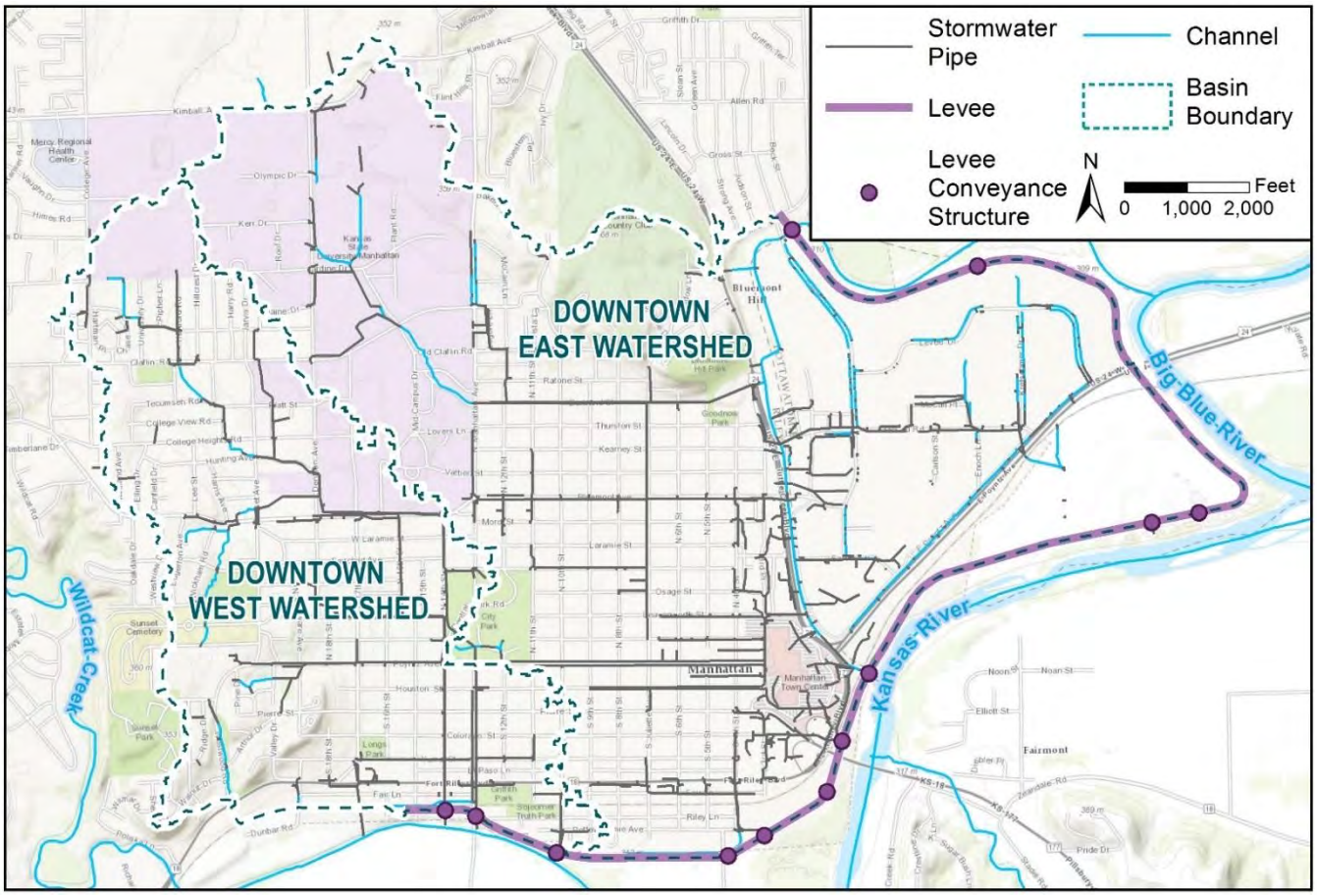


Figure 2-1: Overview of Downtown East and West Watersheds in Manhattan, KS

2.2 Known Flooding Issues

On May 4, 2015, the City of Manhattan was impacted by a significant flooding event. The area experienced approximately five inches of rainfall within approximately three hours during the evening of May 4th, 2015. Flooding issues occurred in many locations across the downtown Manhattan study area. The fact that this flood event occurred during the course of this study provided a unique opportunity to assess specific needs within the watershed and accurately calibrate the Stormwater model for existing conditions. Rainfall data, field visit information, and input from City staff was utilized to determine the extent of flooding within the downtown watersheds.

While only a 25-yr to 50-yr rainfall event, the May 4th event caused significant street flooding beyond City right-of-way, and flooding to a number of businesses. Ground moisture and available detention storage conditions were normal leading up to the event. Just as significant as the flood damages that did occur, were the flood damages that were narrowly avoided which could have potentially been an order of magnitude worse with just a little more rainfall. Witnesses reported that downtown businesses along Poyntz Ave. had water lapping at their front doors. The same could be said along Moro Street and in the Aggieville area.

Flooding of businesses and homes did occur just to the west of Tuttle Creek Blvd. between Bluemont and Bertrand. This flooding was due in part to two major storm water issues that have been well documented and understood by City staff for a long time. The first issue is that the storm sewer system is drastically undersized to handle water flowing off the Kansas State University Campus through Campus Creek. Campus Creek overflows onto Manhattan Ave, causing flooding issues to the east from Manhattan Ave. all the way to Tuttle Creek Blvd. The second issue is that storm water surcharges occurring west of Manhattan Ave. along the curbs of Anderson Ave. have the potential to break out of the Downtown West Watershed into the Downtown East Watershed near Manhattan Ave. This causes increased flooding to Manhattan Ave. and Bluemont Ave, ultimately causing flooding issues all the way east on Bluemont to Tuttle Creek Blvd. The combination of these two issues are the major factors in all the documented flooding that occurred west of Tuttle Creek Blvd.

Fortunately, no serious injuries or deaths are known to have occurred as a direct result of the flood waters, although the potential clearly existed given the conditions that developed. The following are photos and documentation of some of the major flooding issues:

1. Flooding along Manhattan Avenue associated with overflows from Campus Creek

Campus Creek collects runoff from the Kansas State University campus and eventually flows into the City's stormwater system at Bertrand Street. During the May 2015 event, overflow from Campus Creek exceeded the capacity of the Bertrand Stormwater system and spilled onto Manhattan Avenue and eventually onto Bluemont Avenue. The water then made its way east down Bluemont and a number of east-west streets north of Bluemont to Tuttle Creek Blvd., causing flooding along the way and significant flooding to the west of Tuttle Creek Blvd.

Figure 2-2: Flooding along Manhattan Avenue, contributed heavily by overflow from Campus Creek (image source: fox4kc.com)

2. Flooding along Anderson Avenue and Bluemont Avenue

Overflow from multiple stormwater systems eventually reaches Anderson Avenue. As water flows east it bypasses stormwater systems at N. 16th Street and N. 14th Street which were at capacity, reaching Manhattan Ave. where it breaks out of the Downtown West Watershed into the Downtown East Watershed spilling onto Bluemont Avenue.

During the May 2015 event, surcharging occurred on stormwater systems along Anderson Avenue, Juliette Avenue, Bertrand Street, and Campus Creek. Once the surcharged overland flow reaches Bluemont Avenue, it becomes a primary route for water to flow to the east, which led to significant ponding in the area.

Figure 2-3: Flooding along Bluemont Avenue, near the intersection of Manhattan Avenue (image source: NWS)

3. Flooding along 3rd Street

North of Bluemont Avenue, surcharging to the west of Tuttle Creek Boulevard eventually reaches 3rd Street. The topography in this area is lower than the surrounding terrain, and inefficiencies in the stormwater system prevented water from escaping during the May 2015 event. This caused significant flooding along 3rd Street, between Bluemont Avenue and Bertrand Street.

Figure 2-4: Flooding along 3rd Street near Kearney Street (image source: Manhattan Traffic Operations)

Figure 2-5: Flooding near 3rd Street and Bluemont Avenue (image source: FloodList)

4. Flooding along Poyntz Avenue and Houston Street

Along Poyntz Avenue west of the mall, overflow travels to the east and eventually reaches 3rd Street. The topography in this area is somewhat lower than the surrounding terrain, and water can only exit the system through stormwater systems that eventually take it east through the levee. Inefficiencies in the system caused flooding in the streets during the May 2015 event. Note that in this area water was literally lapping at the doors of businesses. An additional six inches of depth in this area could have potentially increased flood damages by an order of magnitude.

Figure 2-6: Flooding at the intersection of Poyntz Avenue and 4th Street
(image source: Manhattan Traffic Operations)

5. Flooding near 12th Street and Poyntz Avenue

Figure 2-7: Flooding in the City Hall parking lot near the intersection of 11th Street and Houston Street, looking toward 12th Street
(image source: fox4kc.com)

South of Poyntz Avenue near 12th Street, the topography is somewhat lower than the surrounding terrain. The stormwater systems in this area direct flow south along Manhattan Avenue and East along Poyntz Avenue. Overflow from the west and north is accumulated in the relatively low area along 12th Street. Due to these factors, ponding was experienced in this area during the May 2015 event.

2.3 Project Scope of Work

Amec Foster Wheeler was tasked to evaluate the existing stormwater system, and provide recommendations and budget level costs for addressing specific system deficiencies. Specifically, the City's Downtown East and West Watersheds were studied and recommendations made once possible improvements to the stormwater system were evaluated. By performing this analysis, a better understanding of the needs and requirements of the City's current stormwater infrastructure was developed.

Evaluation of available data was performed for the downtown watersheds. Data included the City's stormwater inventory as well as LiDAR datasets, which were provided by the City. Field investigations were also performed to collect additional data and verify existing data. Once the data was assessed and finalized, it was incorporated into the modeling efforts for the watersheds.

As part of the City's goal for the development of an urban watershed study and proposed improvements for downtown Manhattan, Amec Foster Wheeler performed hydrologic and hydraulic analyses for the Downtown East and West Watersheds. The goal of the modeling effort was to develop a global model for these basins to assist in identifying systemic deficiencies with the existing stormwater infrastructure. Hydrologic and hydraulic analyses were performed using Bentley's SewerGEMS Urban Sanitary and Combined Sewer Modeling software, which was available to City personnel through a licensing agreement at the time of this study. Existing conditions were modeled for subsurface and surface systems within the study area for multiple storm events and calibrated using available high water marks from the May 2015 flooding event. Alternatives models were then developed to determine appropriate Capital Improvement Projects for reducing flood issues.

It is important to note that the overall goal of this project is to identify systemic capacity deficiencies in the existing stormwater system within the two watersheds, and develop solutions to those issues. Recommended solutions are intended to address significant infrastructure needs, which have the ability to substantially reduce flooding. However, it was not the intent of this study, nor is it practical or feasible, to evaluate the flood risk to every home or business within the watersheds, and provide solutions for each of these flooding issues. The recommended improvements from this study address large scale improvements, which if implemented, will provide an overall reduction to the flood risk within the watersheds.

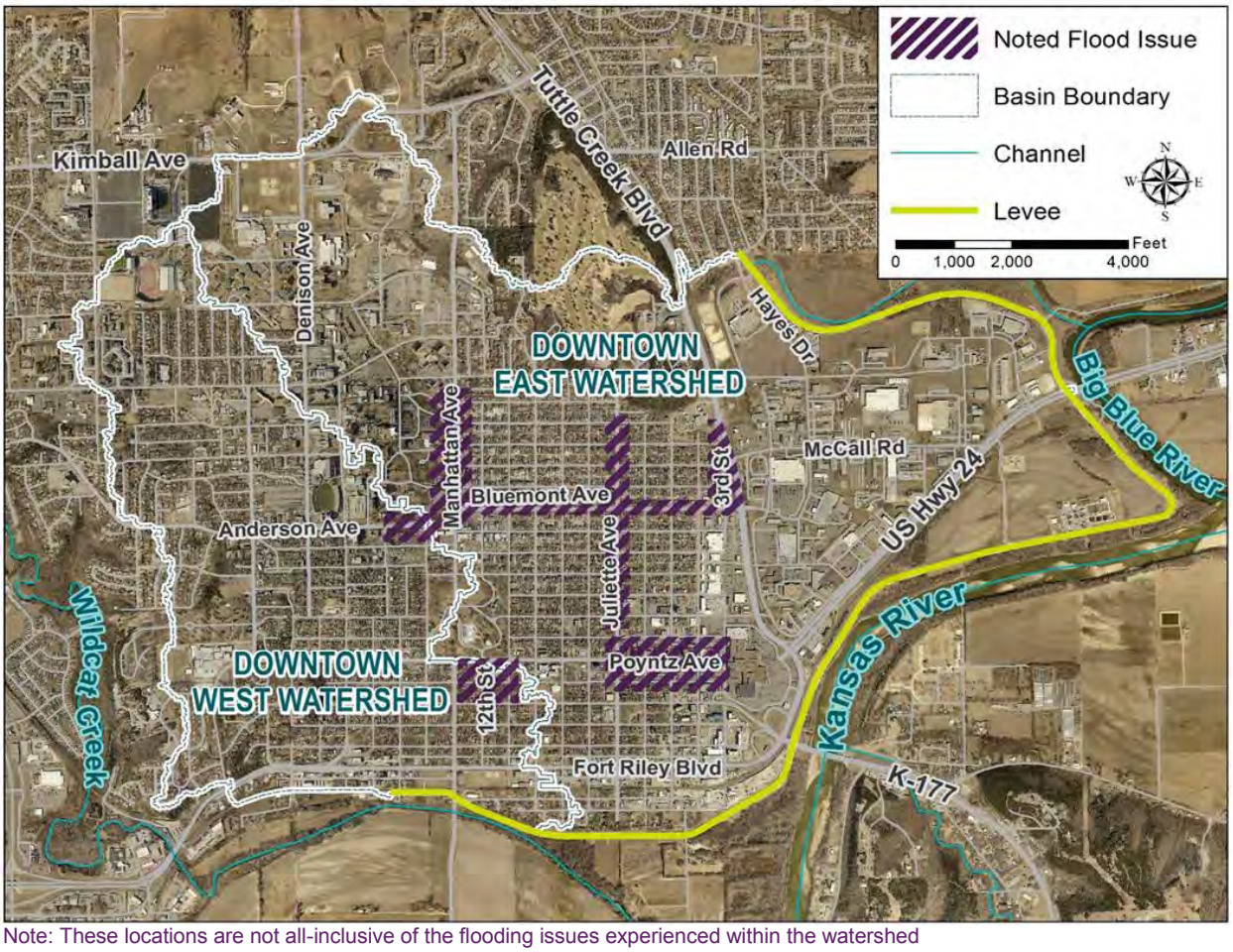
3. Modeling Approach

3.1 Data

3.1.1 2015 Historic Flood Event

In May of 2015, the City of Manhattan was impacted by a significant flooding event. The area experienced approximately five inches of rainfall within three hours, during the night of May 4th, 2015. Flooding issues occurred in many locations across the downtown Manhattan study area. The fact that this flood event occurred during the course of this study provided a unique opportunity to assess specific needs within the watershed and accurately calibrate the model for existing conditions. Rainfall data, field visit information, and input from City staff was utilized to determine the extent of flooding within the downtown watersheds. Figure 3-1 provides an overview of the problem areas specifically described by City Staff during the flooding event. The problem areas shown in the figure highlight the most notable flooding issues with the watershed, though they are not all-inclusive

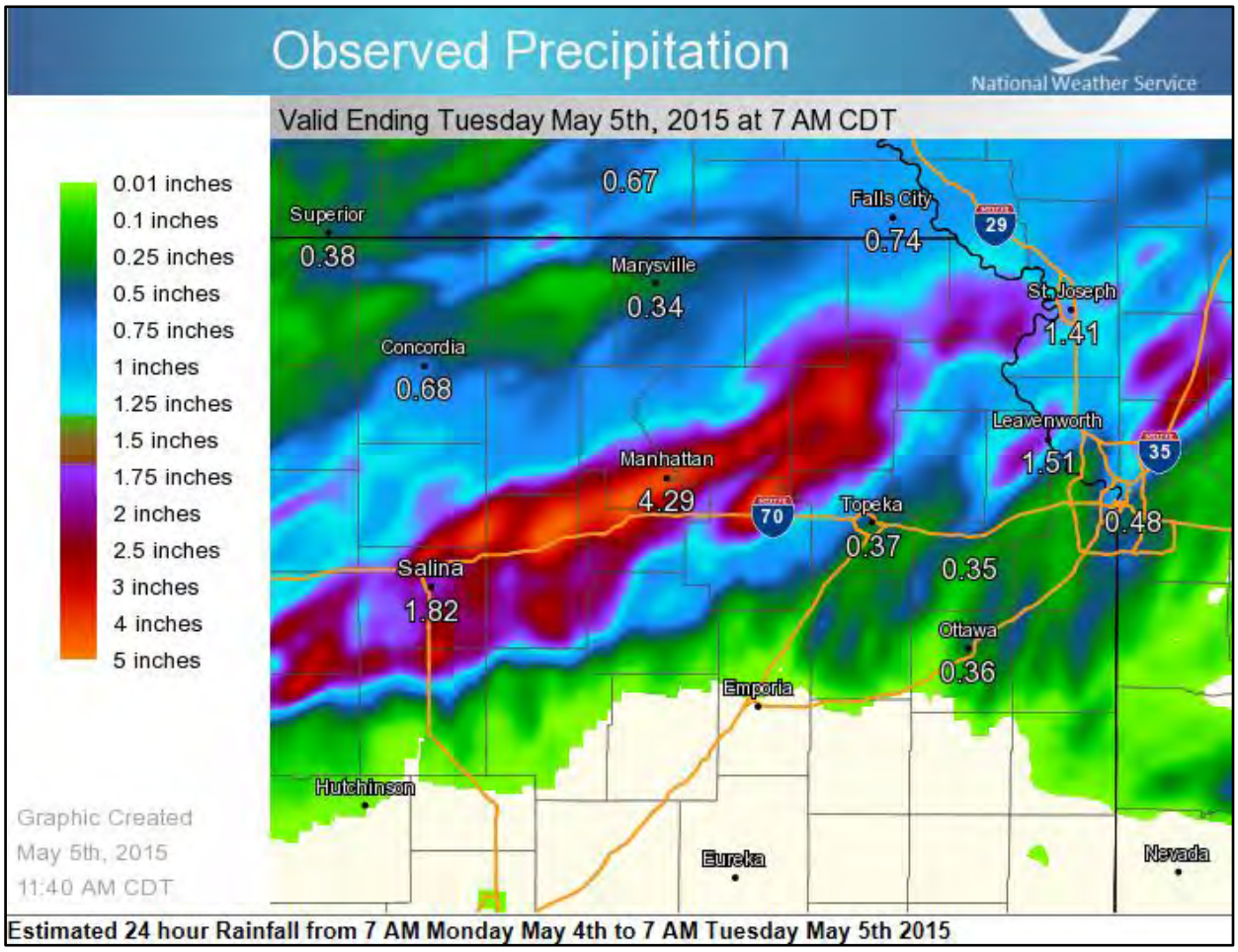
Figure 3-1: Overview of significant flood issues experienced during May 2015 event



Note: These locations are not all-inclusive of the flooding issues experienced within the watershed

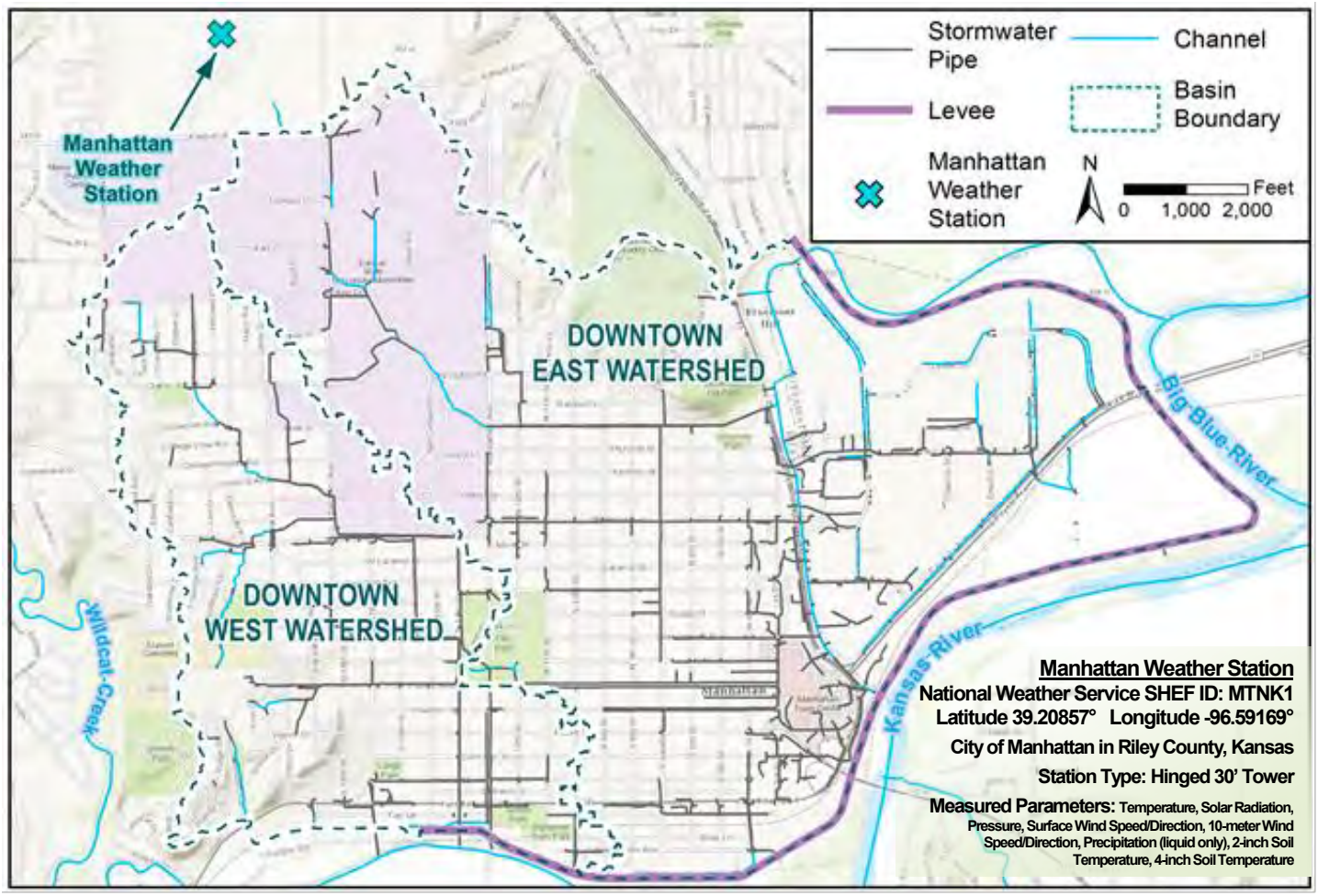
Precipitation data for the May 2015 flood event was available from the National Weather Service (NWS) and the Kansas Mesonet. Initial estimates from the NWS indicated approximately 4.3 inches of total rainfall, as indicated in Figure 3-2.

Figure 3-2: National Weather Service 24-hour rainfall for May 2015 flood event



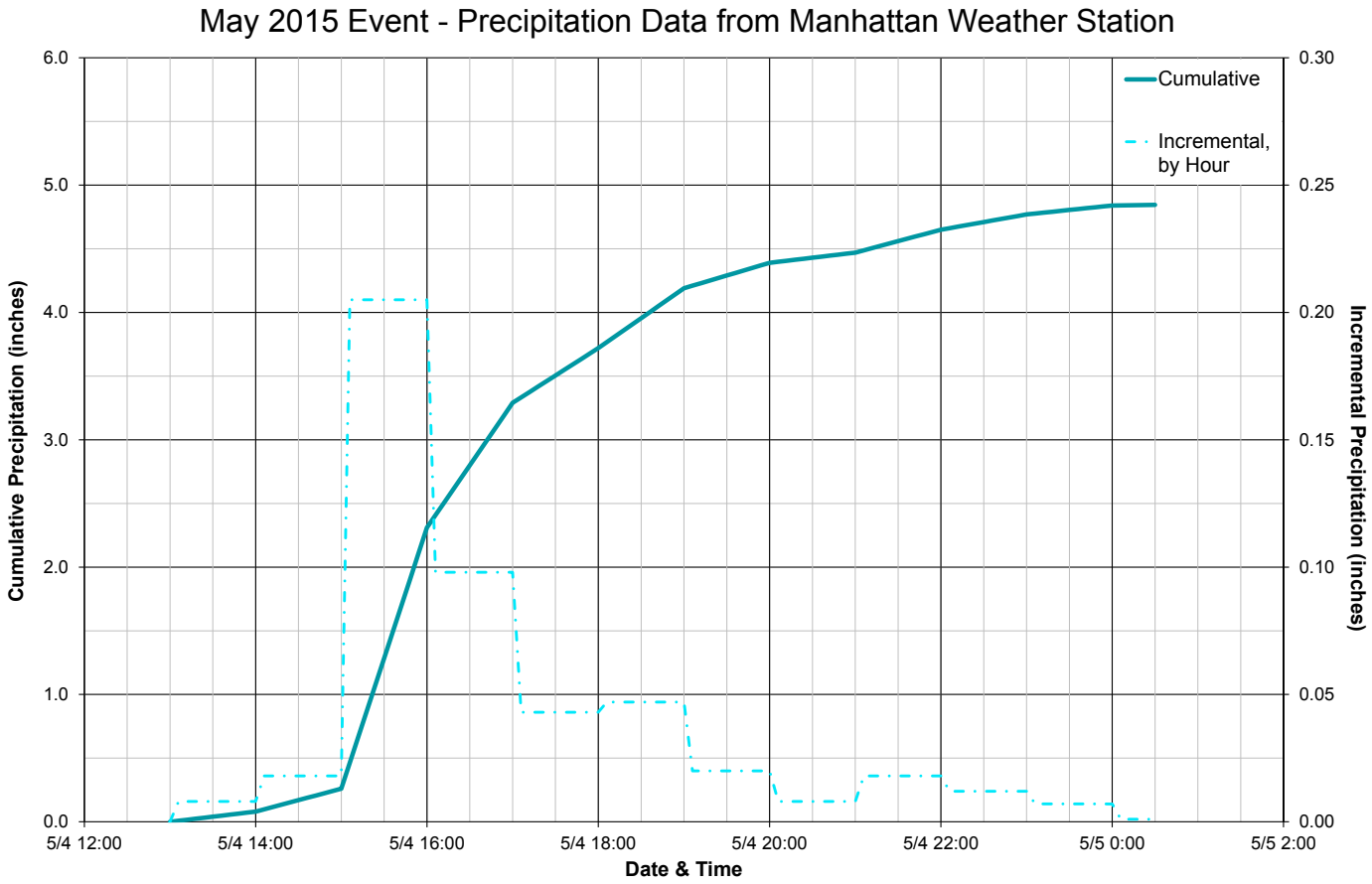
Gridded observed precipitation data downloaded from the NWS website indicate a value of as much as 4.6 inches. Total cumulative rainfall taken from the Kansas Mesonet Station in Manhattan, shown in Figure 3-3, was 4.85 inches. Rainfall totals were also available from local reports, which ranged from three inches to six inches of total rainfall for the Manhattan area.

Figure 3-3: Location of Weather Station Relative to Downtown Watersheds



Based on data from the Kansas Mesonet station in Manhattan, the highest intensity rainfall occurred at about 4:00 PM on the evening of May 4th. The graph in Figure 3-4: Precipitation Data from Manhattan Weather Station for May 2015 Event shows the rainfall depth and distribution at the Manhattan weather station. The vicinity of the weather station to the downtown watersheds made it a reliable source for the distribution and timing of rainfall during the storm. Due to variation in reported rainfall totals across the City, and because the weather station is located just outside of the study area, total cumulative rainfall was adjusted slightly to 5.0 inches based on discussions with City staff.

Figure 3-4: Precipitation Data from Manhattan Weather Station for May 2015 Event



To account for tail water effects from the river-side of the Manhattan levee system, water surface elevations at the time of the actual storm event were obtained at nearby USGS river gages. Two gages were considered, as shown in Figure 3-. One gage is located on the Kansas River and the other gage is located on the Big Blue River.

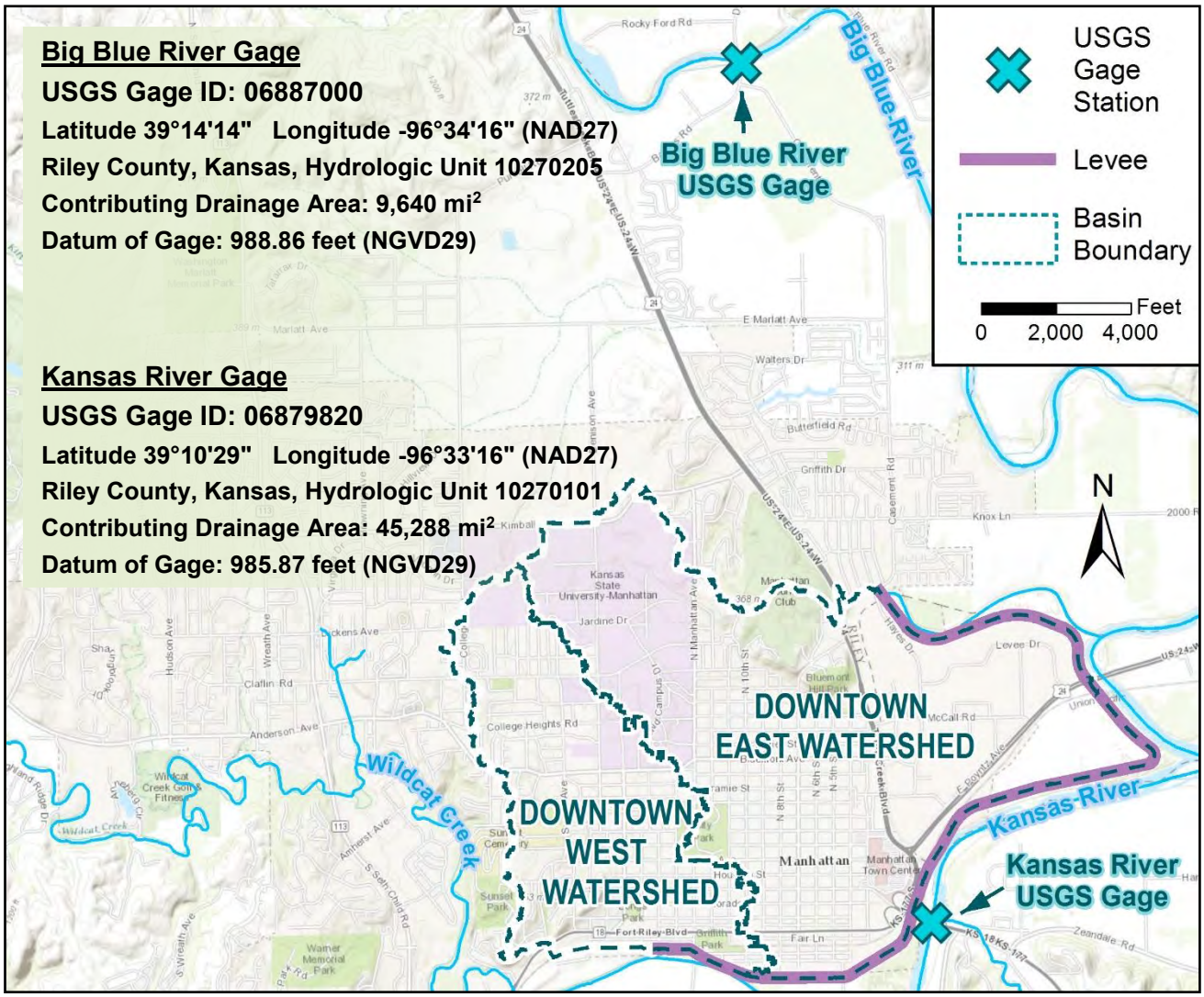
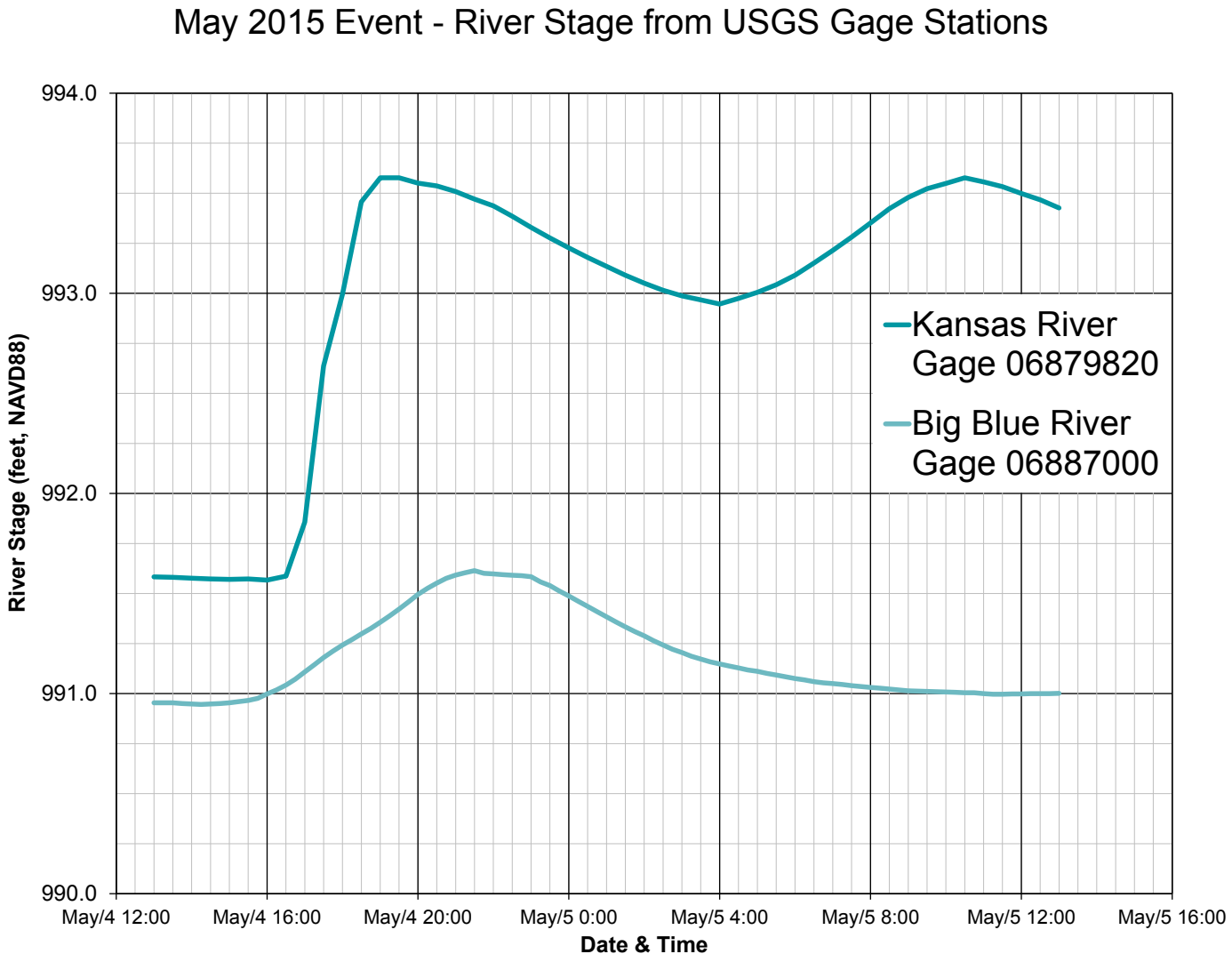


Figure 3-5: Location of USGS stream gages for river stage

River stage data was available in 30-second increments for the May 2015 event. To transform elevations to National American Vertical Datum of 1988 (NAVD88), a conversion factor of 0.4 feet was obtained from the National Geodetic Survey's VERTCON tool. Figure 3-6 shows the water surface elevations at both gage locations during the May 2015 event. Due to the lower river stages on the Big Blue River, which is controlled by Tuttle Creek Dam, it was not used to compute the tail water on the Manhattan levee system. Instead, elevations from the Kansas River gage were utilized as it was the controlling factor during the May 4th event.



River stages at the gage site were translated upstream and downstream along the Kansas River based on HEC-RAS hydraulic modeling performed as part of the Manhattan Levee Certification Project, which are the effective hydraulic models for the current FEMA floodplain maps. These water surface elevations indicate a slight tail water effect on the Poyntz Pump Station, resulting in approximately 3.5 feet of water above the invert of the 10-foot concrete gravity box outlet. The remaining levee conveyance structures had high enough outfalls to avoid tail water effects from the Kansas River.

3.1.2 NOAA Atlas 14 Rainfall Depths

In addition to rainfall from the May 2015 Event, rainfall for multiple design storms were obtained. A 24-hour duration design storm was selected for the 50%, 20%, 10%, 4%, 2%, 1%, and 0.2%-annual-chance events. Corresponding rainfall depths were obtained from the NOAA Atlas 14 partial duration analysis, Volume 8, version 2. These values are listed in Table 3-1 of the hydrologic summary.

3.1.3 Stormwater Inventory

The City completed a multi-year, comprehensive GIS stormwater inventory in 2015. This data was supplied by the City to Amec Foster Wheeler for incorporation into the existing-conditions model. Pipe inverts, lengths, geometries, material, and location were included in the stormwater inventory data and utilized in the analyses. Figure 3-7 provides an overview of the stormwater network's spatial extent. This comprehensive data set developed and provided by the City was critical to the success of project. The City spent an immense amount of time at the beginning of this project cleaning up this inventory data and ensuring the accuracy for use in modeling. Amec verified this data at a number of locations over the course of the project, and found this network to be highly accurate and representative of the geometry and material of the existing system.

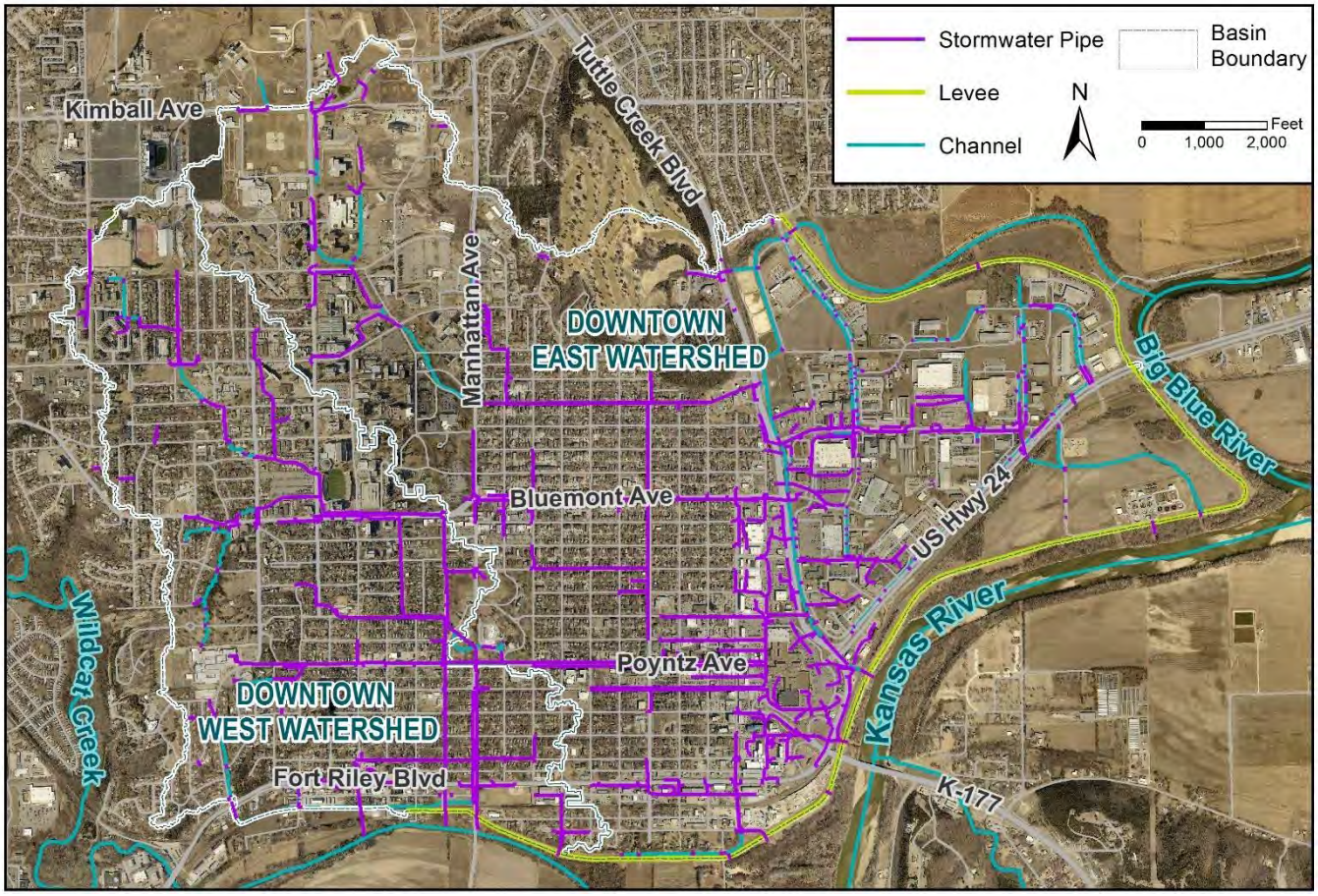
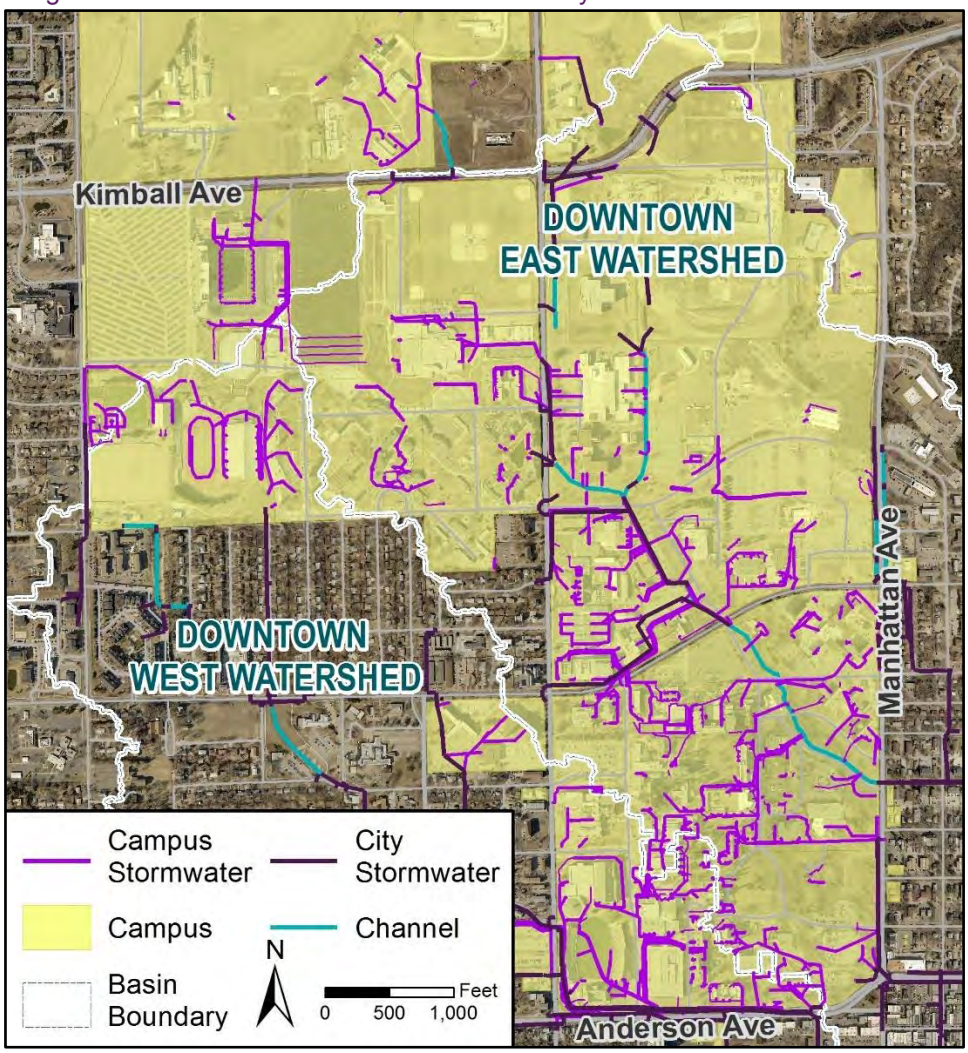


Figure 3-7: Overview of City of Manhattan's Stormwater Inventory

Data for Kansas State University's stormwater network was also obtained through the City. Figure 3-8 shows an overview of the university's stormwater data. While the campus was not modeled in detail as part of this project, stormwater information in the area was used to determine general flow rates and direction, and identify locations where Campus stormwater ties into City infrastructure.

Figure 3-8: Overview of Kansas State University's Stormwater Inventor



3.1.4 LiDAR Topography

In August of 2015, the City obtained new LiDAR Topography within the entire City Limits as part of the 2015 Riley County, Kansas LiDAR project. The LiDAR provides a highly detailed ground surface for use in the completion of this study; as the elevation data was used to develop basin boundaries, determine surface slope, and supplement stormwater inventory information. Figure 3-9 provides a graphical overview of the LiDAR elevation data.

The 2015 LiDAR project was executed by the Sanborn Map Company and encompassed 622 square miles of area covering Riley County. Of this area, 455 square miles were collected at specifications meeting a quality level rating of three as described by the USGS National Geospatial Program's Lidar Base Specification. The remaining area, including the City of Manhattan, met a higher quality level rating of two. LiDAR elevations utilize the National American Vertical Datum of 1988 (NAVD88).

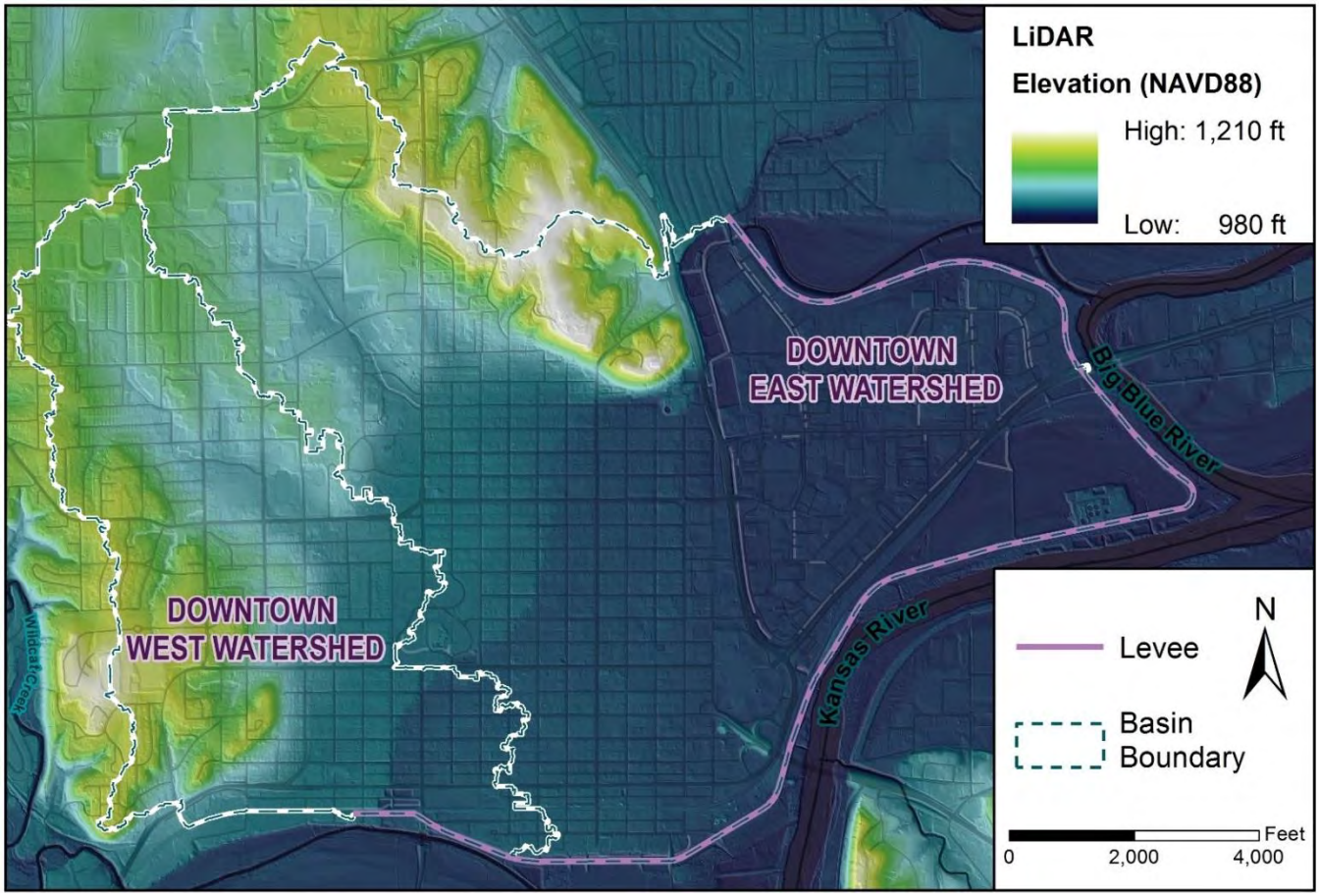


Figure 3-9: Overview of the 2015 LiDAR

3.1.5 Aerial Imagery

In 2014, the City obtained new aerial imagery across the entire study area. The imagery provides a highly detailed view of existing surface conditions for use in the completion of this study. Aerial imagery was used to identify relevant features; supplement land use data development; and to measure surface feature dimensions, such as area inlets, where appropriate.

Within the City, the 2014 imagery has a four-inch spatial resolution. The imagery was obtained in the springtime using a DMC sensor flown at a nominal height of 4,800 feet above mean terrain.

3.1.6 Levee Operation and Maintenance manual

For conveyance structures that transport water through the Manhattan Levee System, information was obtained from the Levee Operation and Maintenance (O&M) Manual. This document, originally dated 1963, was recently amended in 2012 as part of the Manhattan Levee Certification Project. Conveyance structure inverts, lengths, geometries, pipe material, and pump discharges were taken from as-built drawings and pump design data.

3.1.7 Stormwater Management Master Plan

The 1995 Stormwater Master Plan, prepared by BG Consultants and Burns & McDonnell, was used to obtain design criteria for the City of Manhattan's stormwater system. The criteria was then utilized in conjunction with hydrologic and hydraulic modeling to determine feasible improvements to the existing system.

3.1.8 Manhattan Levee Project

As part of the Manhattan Levee Certification Project, portions of the Big Blue River, Kansas River, and Wildcat Creek in Riley County and Pottawatomie County were studied in 2012. In addition, an interior drainage analysis was performed to determine the locations and extent of interior flooding within the levee system. These analyses were done to meet the requirements of FEMA levee certification under 44 CFR 65.10.

The interior drainage analysis utilized multiple models developed using PC-SWMM software. Figure 3-10 shows an overview of the model and layout of its elements. As part of the analysis, an independent system analysis was performed between the levee interior drainage areas and both the Kansas River and Big Blue River tail water conditions. This was done to account for the differences in likelihood of flooding on each of the three sources.

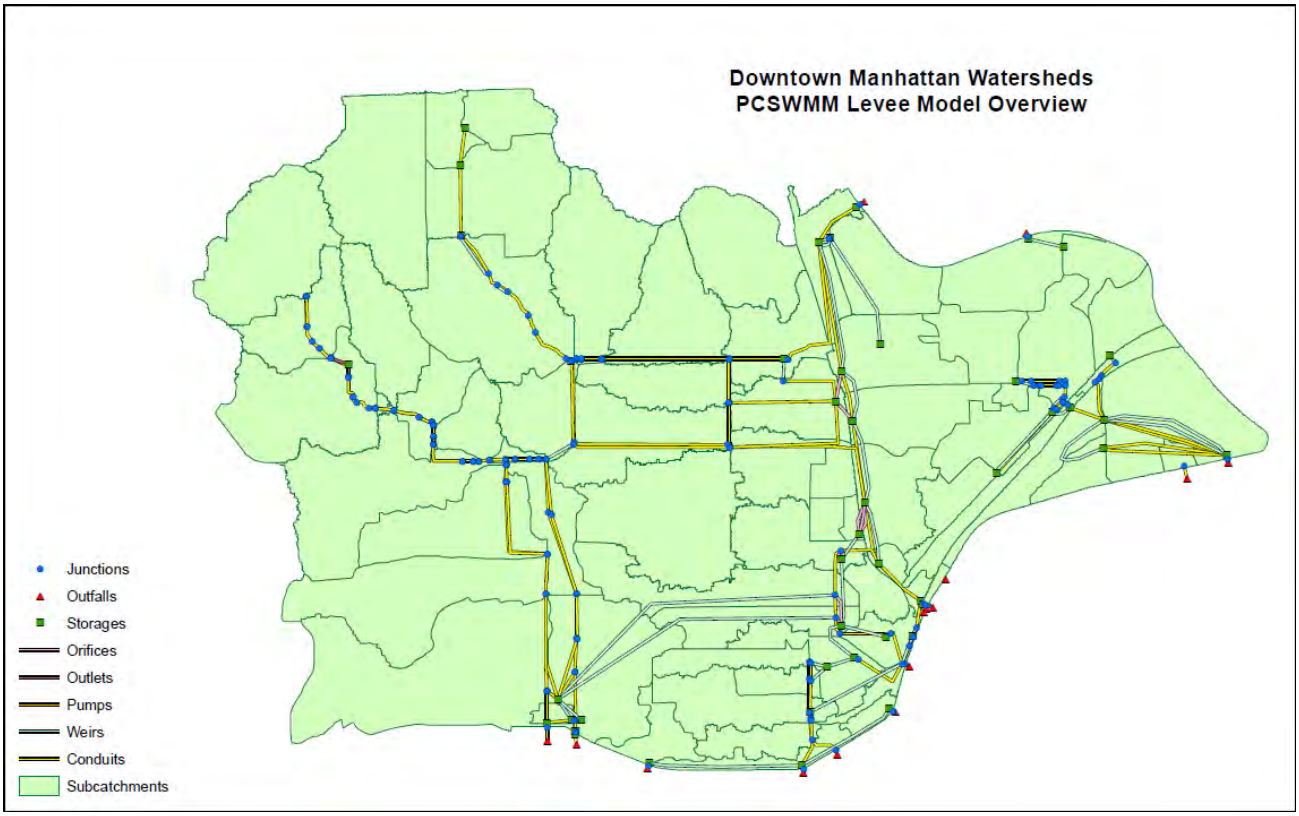


Figure 3-10: Overview of PC-SWMM models developed during Manhattan Levee Project

3.1.9 City Input

Over the course of this project, multiple meetings with City Staff and City Officials occurred. During the May 4th flooding event as well as previous flooding events; the City made a strong effort to put boots on the ground to

assess, evaluate and document the conditions. Due to their extensive knowledge of the system's performance, the City brought a number of staff into the discussions to ensure all of the system's performance data was understood by the entire team. Staff included surveyors, field staff, engineers and GIS professionals. These discussions were absolutely key in driving the progression of this project, and were utilized to improve calibration of the existing conditions model. They were also critical in determining the most feasible improvement projects and to avoid recommendations that would not be practical for the City to implement.

3.2 Modeling Overview

Hydrologic and hydraulic analyses were performed using Bentley's SewerGEMS software (version 08.11.05.58). Existing conditions were modeled for subsurface and surface systems within the study area for multiple storm events, and then calibrated. Figure 3-11 shows an overview of the existing conditions model, including all model elements. In addition, alternatives models were developed to determine appropriate Capital Improvement Projects for reducing flood issues.

All model scenarios include a 48-hour simulation time. The SewerGEMS software contains multiple solvers, including the rational method, gradually varied flow, implicit dynamic wave, and the explicit SWMM engine. For this project, the SWMM engine was selected to properly account for storage effects and shared flow that can commonly occur in flatter watersheds.

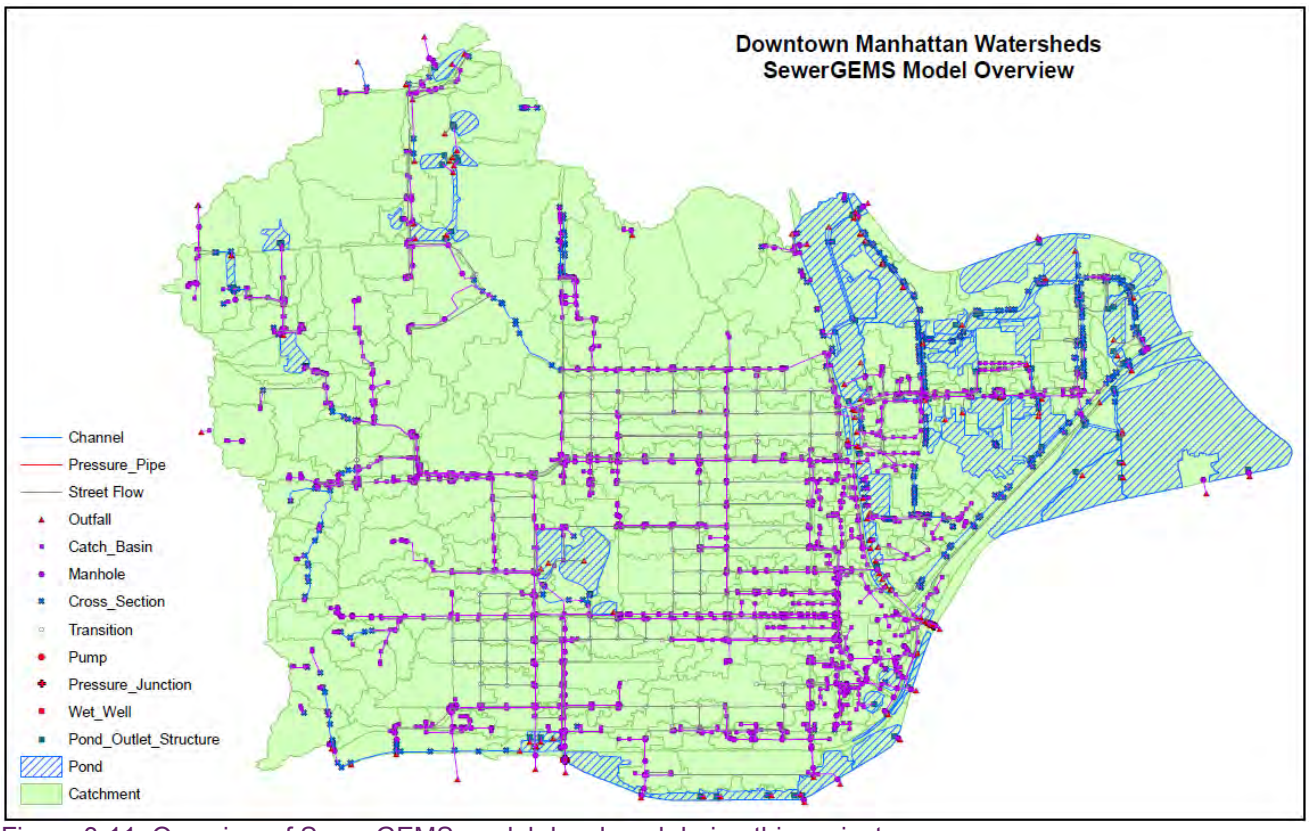


Figure 3-11: Overview of SewerGEMS model developed during this project

3.3 Hydrologic Modeling Summary

The SewerGEMs software offers multiple options for modeling each piece of the hydrology calculations. The following sections discuss the selected methodologies and specific parameters that were utilized.

3.3.1 Rainfall Distribution

An SCS 24-hour, Type II rainfall distribution was used for the 50%, 20%, 10%, 4%, 2%, 1%, and 0.2%-annual-chance events. NOAA Atlas 14 was used to derive the rainfall depths for the 50% to 0.2%-annual-chance storm events. The contributing drainage area of the downtown watershed is small and therefore areal reduction is not necessary. Additionally, precipitation for the historic flood event of May 2015 was included. As previously discussed, this storm event resulted in approximately five inches of precipitation to fall within roughly three hours. Table 3-1 provides a summary of the rainfall depths utilized in this analysis.

Table 3-1: Rainfall Depths

Storm Event	Rainfall Depth (inches)
50%-Annual-Chance	3.40
20%-Annual-Chance	4.22
10%-Annual-Chance	4.94
4%-Annual-Chance	5.98
2%-Annual-Chance	6.84
1%-Annual-Chance	7.73
0.2%-Annual-Chance	9.99
May 2015 Storm Event	5.00

3.3.2 Drainage Area Delineations

Initial drainage areas were determined based on automated delineations from the 2015 LiDAR using GIS software. Delineations were then checked and manually edited as necessary based on LIDAR topography, aerial imagery, and stormwater inventory data.

The size and detail of the delineated catchments was dependent on their position within the watershed, with more detailed catchments delineated in the highly urbanized areas. The final model includes 429 catchments with an average drainage area of 7.7 acres.

3.3.3 Infiltration Method

Infiltration was calculated using the SCS Curve Number method, using Natural Resource Conservation Service (NRCS) Technical Release 55 (TR-55) methodologies. Land use data was digitized based on Manhattan parcel data, supplemented with aerial imagery. Fifteen land use designations were used to represent the project area. The land use designations were joined with soil data to obtain an area-weighted curve number for each drainage basin. Soil data was taken from the NRCS Web Soil Survey, which provides soil hydrologic group classification. Table 3-2 displays the land use categories and associated curve numbers

for each soil type. Composite curve numbers for each sub-basin were determined using an automated area-weighting process.

Table 3-2: Pervious CN and % Impervious Designations for Land Use and Soil Hydrologic Groups				
	CN by Soil Hydrologic Group			
Land Use Description	A	B	C	D
Residential Lots: Lot ≤ 1/8 acre	77	85	90	92
Residential Lots: 1/8 acre > Lot <= 1/4 acre	61	75	83	87
Residential Lots: 1/4 acre > Lot <= 1/3 acre	57	72	81	86
Residential Lots: 1/3 acre > Lot <= 1/2 acre	54	70	80	85
Residential Lots: 1/2 acre > Lot <= 1 acre	51	68	79	84
Residential Lots: 1 acre > Lot <= 2 acre	46	65	77	82
Residential Lots: Lot >= 2 acre	46	65	77	82
Industrial & Manufacturing	81	88	91	93
Commercial and Business	89	92	94	95
Kansas State University (Developed Area)	89	92	94	95
Open Spaces -Urban (Good Condition)	39	61	74	80
Open Space (Urban)/Agriculture (Fair Condition)	49	69	79	84
Open Spaces -Urban (Poor Condition)	68	79	86	89
Streets, Parking Lots, Roads & Highways	98	98	98	98
Open Water	100	100	100	100

3.3.4 Hydrology Transform Method

To determine the shape and distribution of the modeled runoff hydrograph, an SCS unit hydrograph was utilized, as outlined in the SCS National Engineering Handbook.

The longest flow length for each catchment was determined based on LiDAR and stormwater data. Time of concentration was calculated after breaking the flow path into multiple flow regimes including sheet, shallow concentrated, and channelized flow.

3.4 Hydraulic Modeling Summary

The SewerGEMs software offers multiple options for modeling each piece of the hydraulic calculations. The following sections discuss the selected methodologies and specific parameters that were utilized.

3.4.1 Routing Methodologies

The dynamic wave routing method was used so that the models can properly estimate reverse flow in pipes, tail water effects, and open channel flows. Inertial terms of the dynamic wave method were dampened. Super

critical flow was defined using both Froude number and slope. The Hazen-Williams method was used to calculate friction within pressure pipes.

3.4.2 Links

Links are used to represent open channels, pipe networks, pumps, weirs, or orifices. Pipe lengths, diameter, roughness coefficients, and entrance and exit loss coefficients were established based on stormwater data and aerial photography. Channel shapes and weir dimensions were estimated based on LiDAR elevation data using GIS processes, and adjusted as necessary based on engineering judgment. Gutters were used to represent surface flow from curb and area inlets. Pressure pipes were utilized at pump stations to account for pressurized flow.

3.4.3 Nodes

Nodes are used to represent manholes, junctions, channel cross sections, storage areas, or outfalls. Junction invert and maximum depth elevations were taken from stormwater data and aerial imagery.

Curb and area inlet dimensions were taken from the stormwater data and represented using catch basin elements within the model. Where necessary, dimensions were measured from the high-resolution aerial imagery. Manholes and transition nodes were utilized within the system where no inlets were present.

Cross section nodes were used in conjunction with Channel links to model open channel flow. Cross section shapes were cut from the LiDAR data, while Manning's roughness coefficients were derived from aerial imagery.

Ponding nodes, represented as polygons within SewerGEMS, were used where significant ponding may result from tail water or from a depression (pond). In locations where ponding did occur, a ponding area was used with an associated rating curve. Depth-storage-area rating curves were estimated from the LIDAR topography using an automated area-volume tool within GIS, at 0.5-foot intervals.

Outfalls were placed at all conveyances through the levee with flap gates on the downstream side of each conveyance structure.

3.5 Pump Stations

Two pump stations were evaluated and recognized in the modeling; located at levee stationing 20+13 (South Manhattan Pump Station) and 101+26 (Poyntz Pump Station). These pump stations are currently identified as part of the flood control system and meet Corps of Engineers inspection checklist requirements, and therefore have been included in this analysis. These pump stations were modeled based on start and stop elevations, and with pump curves included in the Operations and Maintenance Manuals. The pumps were modeled with dynamic head, where flow varies continuously with the head difference between the inlet and outlet nodes.

<u>South Manhattan Pump Station</u>

As indicated by its name, the Manhattan Avenue Pump Station is located where Manhattan Avenue intersects the levee system (levee stationing 20+13). It includes two pumping units, both of which are Model 12MCJS-1 12" prop pumps manufactured by Worthington, with a maximum flow rate of 15.8 cfs (7,100 gpm) total.

Poyntz Pump Station

The Poyntz Pump Station is located at the southern outlet of the Tuttle Creek Boulevard Channel, near the intersection of E Poyntz Avenue and Tuttle Creek Boulevard (levee stationing 101+26). It includes two pumping units, both of which are Model 3MS5648A 24" prop pumps manufactured by Cascade, with a maximum flow rate of 38.2 cfs (17,160 gpm) each.

3.6 Levee System and Tail water Interaction

As part of the Manhattan Levee Project, an interior drainage analysis was performed to determine the locations and extent of interior flooding within the levee system. As part of the analysis, an independent system analysis was performed between the levee interior drainage areas and both the Kansas River and Big Blue River tail water conditions. This was done to account for the differences in likelihood of flooding on each of the three sources. Procedures from the Corps of Engineers' Hydrologic Analysis of Interior Areas were followed, and further explanation can be found within documentation for the Manhattan Levee Project and in the Appendix of this report.

Tail water elevations along the Kansas and Big Blue Rivers were taken from the previous project's independent system analysis and applied to this study's modeling. Elevations were obtained for each outfall that feeds into either river for all design storms. It should be noted that, though the tail water elevations match, interior ponding elevations will not be identical between the two studies due to the higher level of detail contained within the model completed for this study.

As has been previously discussed, tail water for the May 2015 event was taken from the USGS stream gage on the Kansas River.

3.7 Model Calibration

The timing of the May 2015 Flood event, which occurred during the early stages of this project, offered a unique opportunity to calibrate the model to a high-flow event. Flooding issues occurred in many locations across the downtown Manhattan study area. These issues were documented in various forms and utilized in calibrating the model.

In order to accurately model the 2015 event, rainfall depth and duration along with river stage information were taken from the data sources previously discussed. The documented rainfall duration, in the form of a rainfall hyetograph for the particular event, and documented tail water conditions were ran through the stormwater model. After initial model runs of the May 4th event and review of the results with City staff, modifications were made to the model to better replicate the May 2015 flood event. However, it should be noted that in general the initial model matched the May 4th, 2015 event very closely at most locations prior to making any adjustments to the model. The changes that were made to better match the May 4th flooding were relatively minor and were targeted at specific locations, with the most notable being some adjustments to stormwater inlet capacities at specific locations to better match the existing geometry of the inlets. This was first done where there there is a lack of existing inlet capacity in the system and the inlets cannot supply enough water to keep the system full, although inlets were updated throughout the watersheds. Following the calibration adjustments to the model, the model output was reviewed in detail by both City and Amec Foster Wheeler staff, and it was determined that the model predicted the 2015 flooding event very accurately.

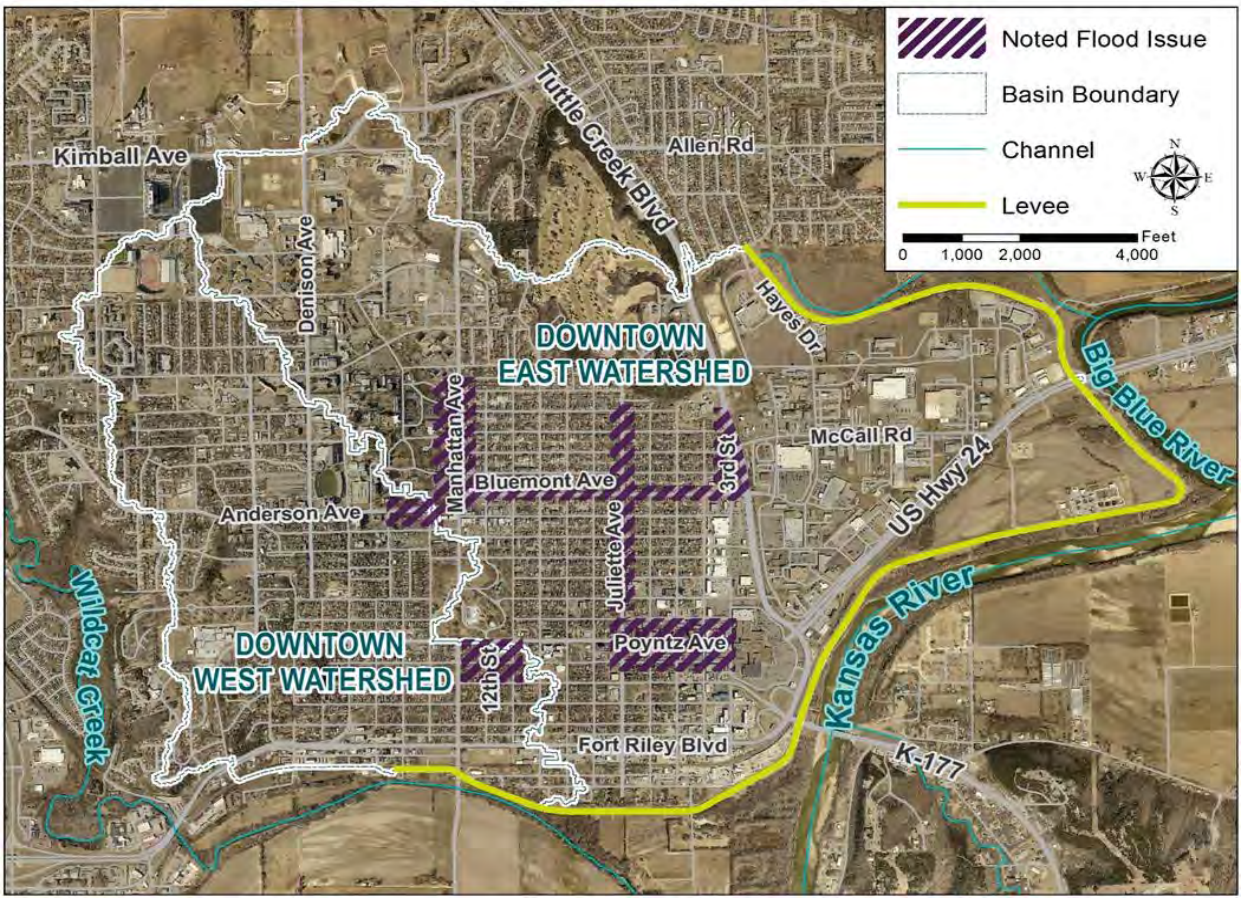
4. Existing System Performance

Amec Foster Wheeler evaluated the performance of the City's existing stormwater system throughout the Downtown East and West Watersheds. The existing stormwater system was evaluated using the hydrology and hydraulic analyses performed for the Downtown East and West Watersheds, and supplemented with input from the City Staff. Performance was evaluated on a global-level to assist in identifying systemic deficiencies with the existing stormwater infrastructure. By performing this analysis, Amec Foster Wheeler provided the City a general understanding of the needs and requirements of the City's current storm water infrastructure.

4.1 Known Flooding Issues

Several locations within the study area experience various degrees of flooding during large storm events. As has been previously discussed, the flooding event in May of 2015 provided an opportunity to identify the major deficiencies in the stormwater system. During the event, flooding issues occurred in many locations across the downtown Manhattan study area. Figure 4-1 provides an overview of the problem areas specifically described by City Staff during the flooding event.

Figure 4-1: Overview of significant flood issues experienced during May 2015 event



Note: These locations are not all-inclusive of the flooding issues experienced within the watershed

4.2 Flood Frequency

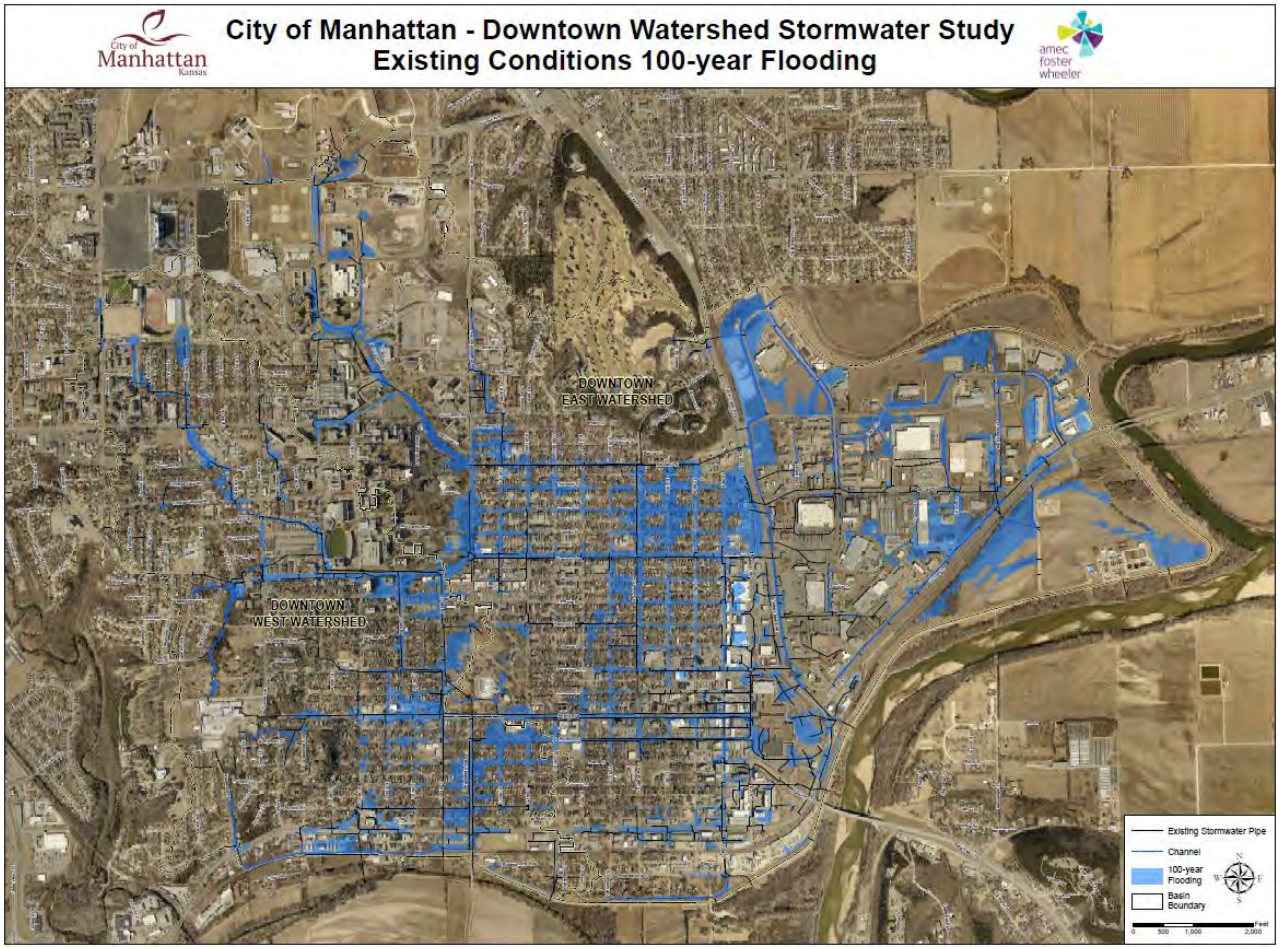
Different sections of the City's stormwater system provide varying levels of protection depending on the frequency of a flood event. As a whole, it is difficult to determine the exact level of protection for a given section of the system due to its interconnected manner; some areas may experience flooding due to overflow from an adjacent system or due to downstream backwater effects even if the system is sized appropriately for the local drainage. In general, deficiencies in the system for each modeled storm event are visible in the plotted inundation areas. In this way, the system's level of service can be surmised for different areas of the watershed. This data is provided in digital format in Appendix B, and printouts are provided in Appendix A.

4.3 Flood Depths

In addition to the results contained with the SewerGEMS models, several products were developed for the multiple model runs. Plotted floodplains and depth grids were prepared for existing and proposed conditions, to evaluate flood conditions and ultimately the impacts of proposed improvements, which will be discussed in Sections 5 and 6 of this report. The GIS data and maps were critical in our project team meetings when evaluating system performance and proposed improvements to the system.

The existing conditions 100-year inundation plot is shown in Figure 4-2 as one example of the plots included in the Appendix A, which utilize the digital GIS data included in Appendix B.

Figure 4-2: Example Inundation Map



As an example, the existing conditions 100-year depth grid is shown in Figure 4.3.

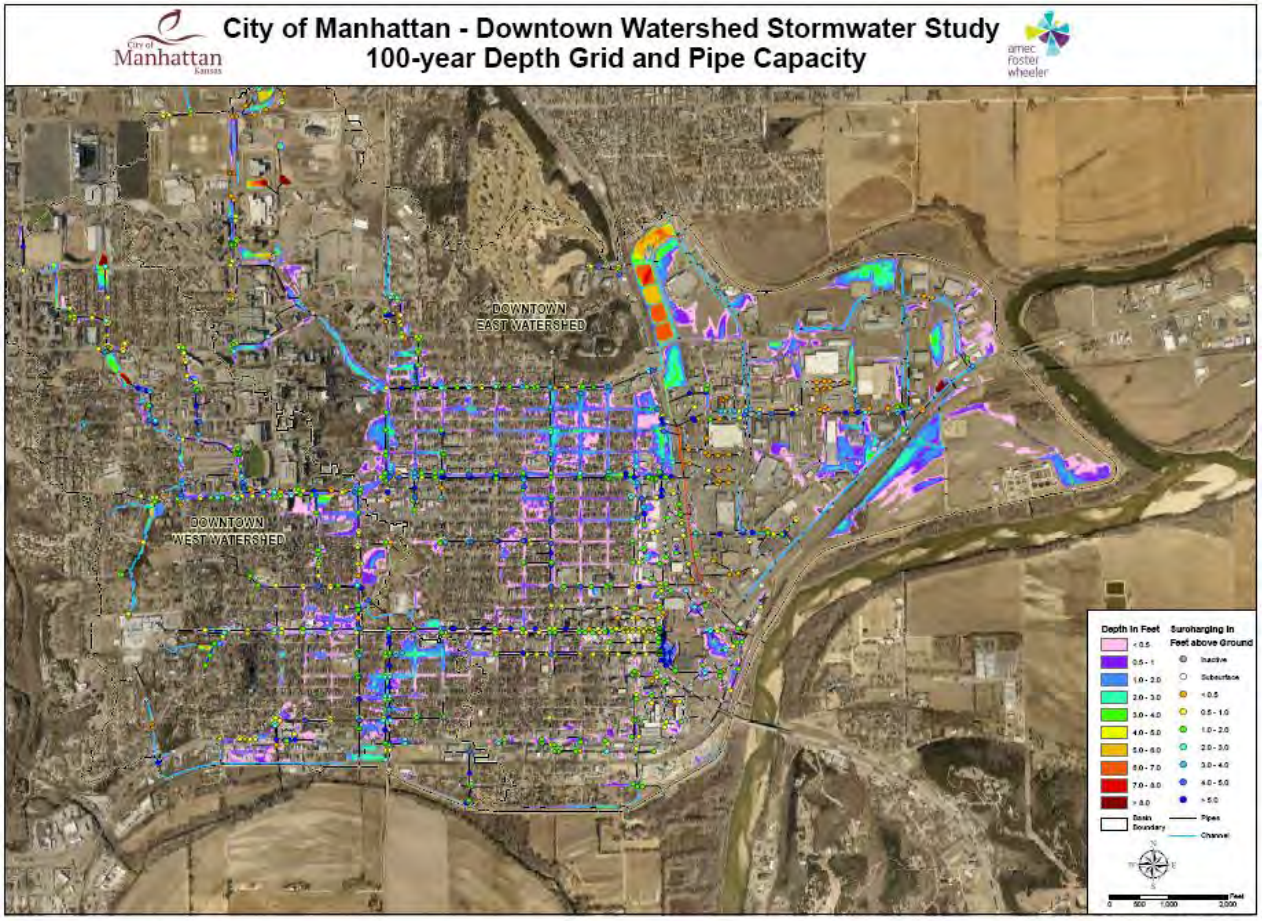


Figure 4-3: Example Depth Grid Map

4.4 Flood Impacts

Flooding of the downtown watersheds has caused a variety of negative impacts, and has the potential to devastate the downtown watersheds. The magnitude of these impacts would obviously depend on the frequency and intensity of the storm event, coupled with the tail water of the Kansas and Big Blue rivers at the time of the events. It also depends on the capacity and condition of the City's stormwater system at the time of a flood event. It is therefore critical that the City work to maintain the condition and capacity of the existing system, as well as implement improvements to better handle flood events in the future.

Flood impacts throughout the downtown watersheds depend heavily on tail water conditions at the levee system. Had tail water conditions been higher, the recent flood event would have certainly caused even more damage than what the City experienced, including potential catastrophic flooding of numerous business along the east side of Tuttle Creek Blvd, and higher water and more flood damages on the west side of Tuttle Creek Blvd.

The recent flood event of May 4, 2015 caused significant disruption to the City of Manhattan in several regards. The most critical hazard caused by this flooding was the risk to human life. The City was fortunate

that no major injuries were reported due to the flood event. However, the degree of flooding in certain areas was certainly enough to pose a significant risk to human life. Social media in the days following the flooding event showed people standing near storm sewer outfalls in waist deep or even deeper water that were at risk, and cars submerged over their windows and in some cases over the tops of the vehicle.

During the flood event, high water levels in the streets impeded travel along many major roads in the downtown area. Businesses west of Tuttle Creek Blvd. near 3rd and 4th streets experienced significant ponding depths. Floodwaters lapped at the doors of businesses along Poyntz Avenue in the downtown area, and along Moro Street in the Aggieville area. Floodwaters just touched a few businesses along Bluemont Street, but nearly missed a much larger number of businesses just west of Tuttle Creek Blvd.

While the May 4, 2015 flooding event will be remembered for a number of years, it doesn't in any way represent the damages that could occur in the event of a larger flooding event. Consider a 1% annual chance frequency event occurrence in a given year (100-year event), with a joint probability tail water condition as discussed previously in this report. Flood water would likely flood a majority of downtown businesses along Poyntz Avenue. As bad as flooding was along Manhattan Avenue and Bluemont Avenue, it would be significantly worse; likely permanently damaging City infrastructure, flooding homes and apartments on and east of Manhattan Avenue between Bertrand Street and Houston Street, and experiencing flood depths several feet higher on the west side of Tuttle Creek Blvd. near 3rd and 4th Streets.

While it is not possible to prevent every flooding scenario, specifically a large interior event at the time of a high flow event on the Kansas and/or Big Blue River, it is possible to make improvements that will dramatically improve the performance of the existing storm water infrastructure. These improvements can reduce damages for events causing shallow nuisance flooding occurring as frequently as a 50% chance in a given year, up to and beyond a 0.2% annual chance (500-yr) flooding event. With this in mind, CIP projects were considered to help improve the overall performance of the system, reduce flooding to businesses and residents, reduce risk to City infrastructure, and most importantly reduce risk to human life.

5. Evaluated System Improvements

5.1 Alternatives Overview

Multiple alternatives scenarios were considered in order to determine feasible CIP locations. Based upon City of Manhattan criteria, the design guidance considered was that the 1%-annual-chance event should be contained within the City right-of-way, and the 2% event should not flood arterial streets. These guidelines were utilized in evaluating the effectiveness of proposed CIPs.

Figure 5-1: Major flooding sources and considered conveyance improvement routes

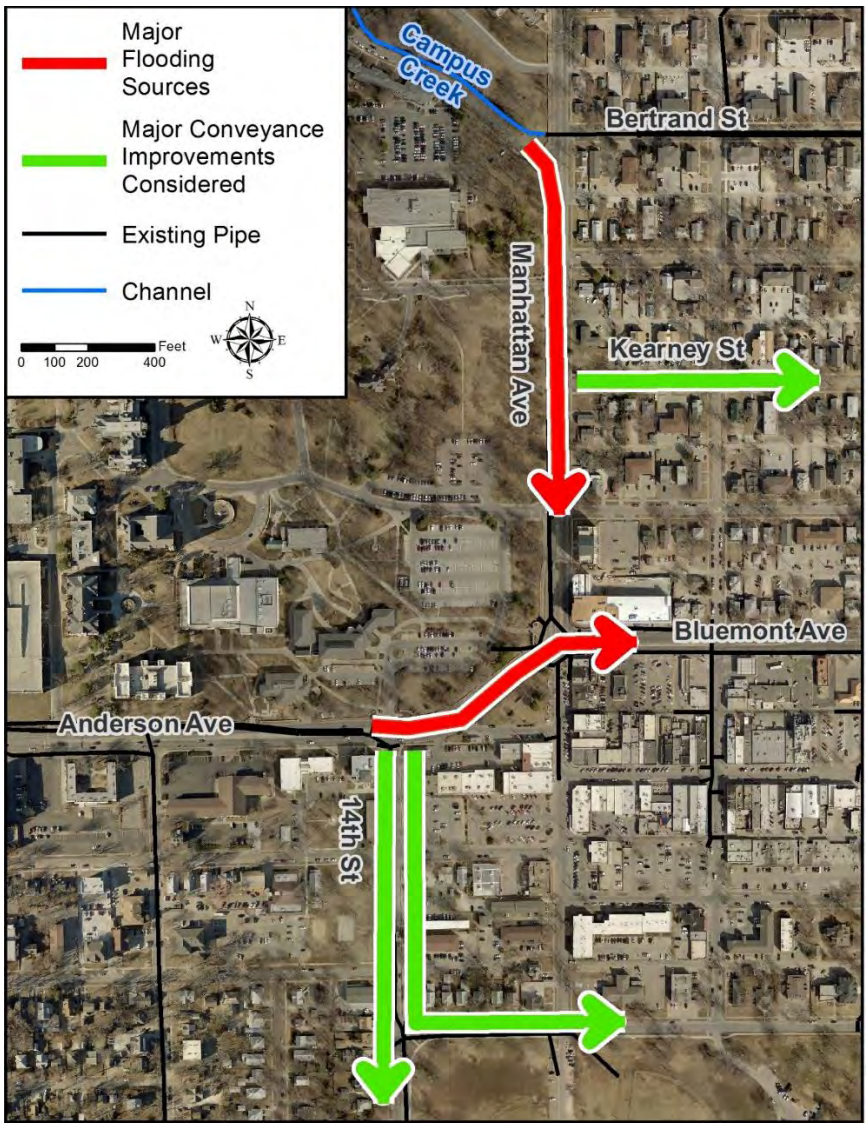


Figure 5-1 is a simplistic representation of the two single largest flooding issues in the Downtown Watersheds, and the alternatives considered to address these concerns. The two red arrows represent the floodwater overflows from Campus Creek flowing onto Manhattan Avenue, and the overflows from the Downtown West Watershed along Anderson Ave. into the Downtown East Watershed along Bluemont Street. Based upon discussions and input from City staff, three distinctly different concepts or scenarios were considered in addressing these flooding issues.

The green arrows represent the locations where the excess floodwater was proposed to be directed. Scenario A was to direct all the floodwaters from both flooding issues down a new storm sewer along Kearney Street. Scenario B was to direct the Campus Creek overflows down a new storm sewer along Kearney Street, and direct the Anderson Ave. overflows southeast along various side streets eventually tying into an improved stormwater system along Leavenworth Street. Scenario C was to direct the Campus Creek overflows down a new storm sewer along Kearney Street, and direct the Anderson Ave. overflows down 14th Street and then Manhattan Ave. until it ties into the location of the South Manhattan Pump Station.

5.2 Alternatives Modeling

Scenario A directs overflow from Campus Creek and from Anderson down the proposed Kearney Line. All three scenarios include improvements along Kearney Street, Houston Street, Leavenworth Street, Juliette Street, 3rd Street, and the Tecumseh-Quivera Project.

Figure 5-2: Initial alternatives modeling – Scenario A

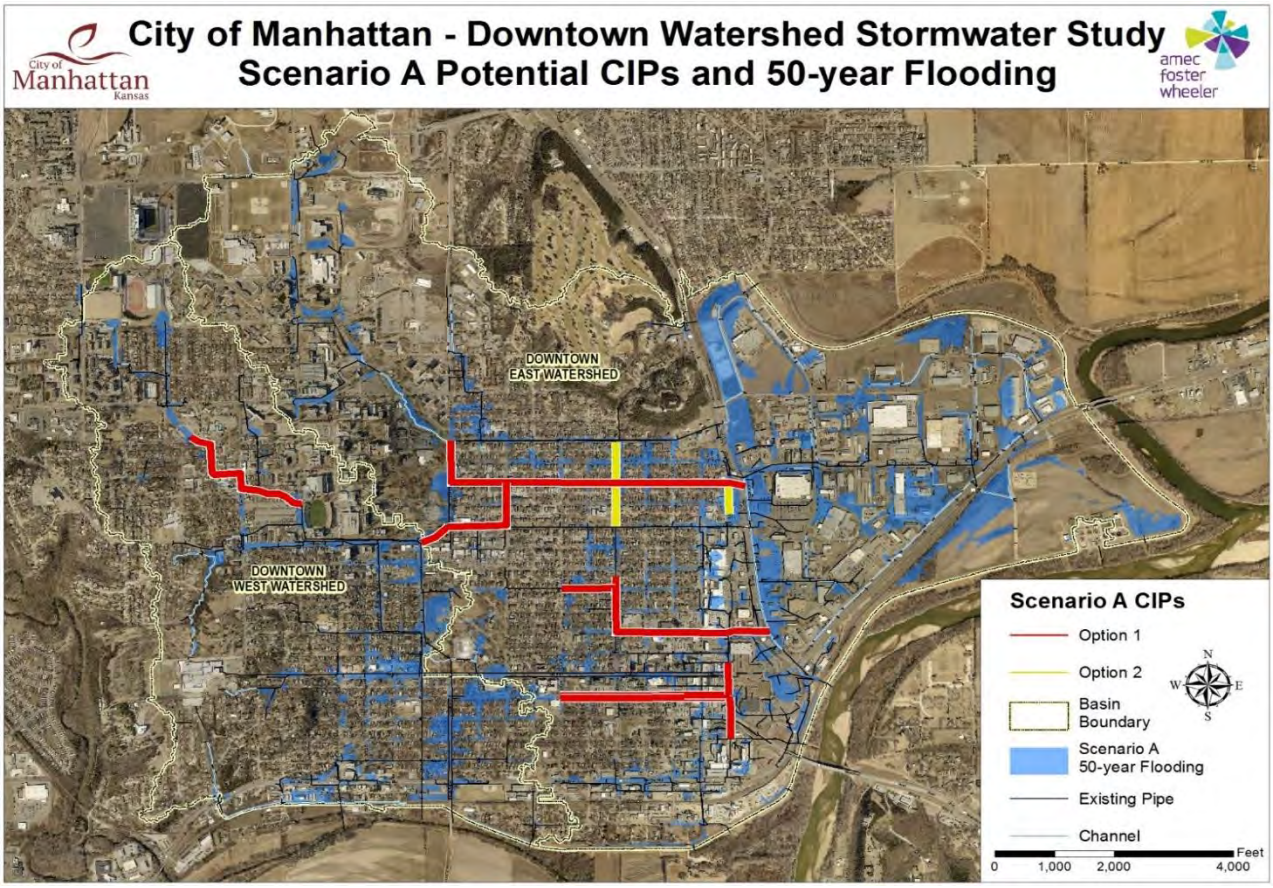


Figure 5-3: Initial alternatives modeling – Scenario B

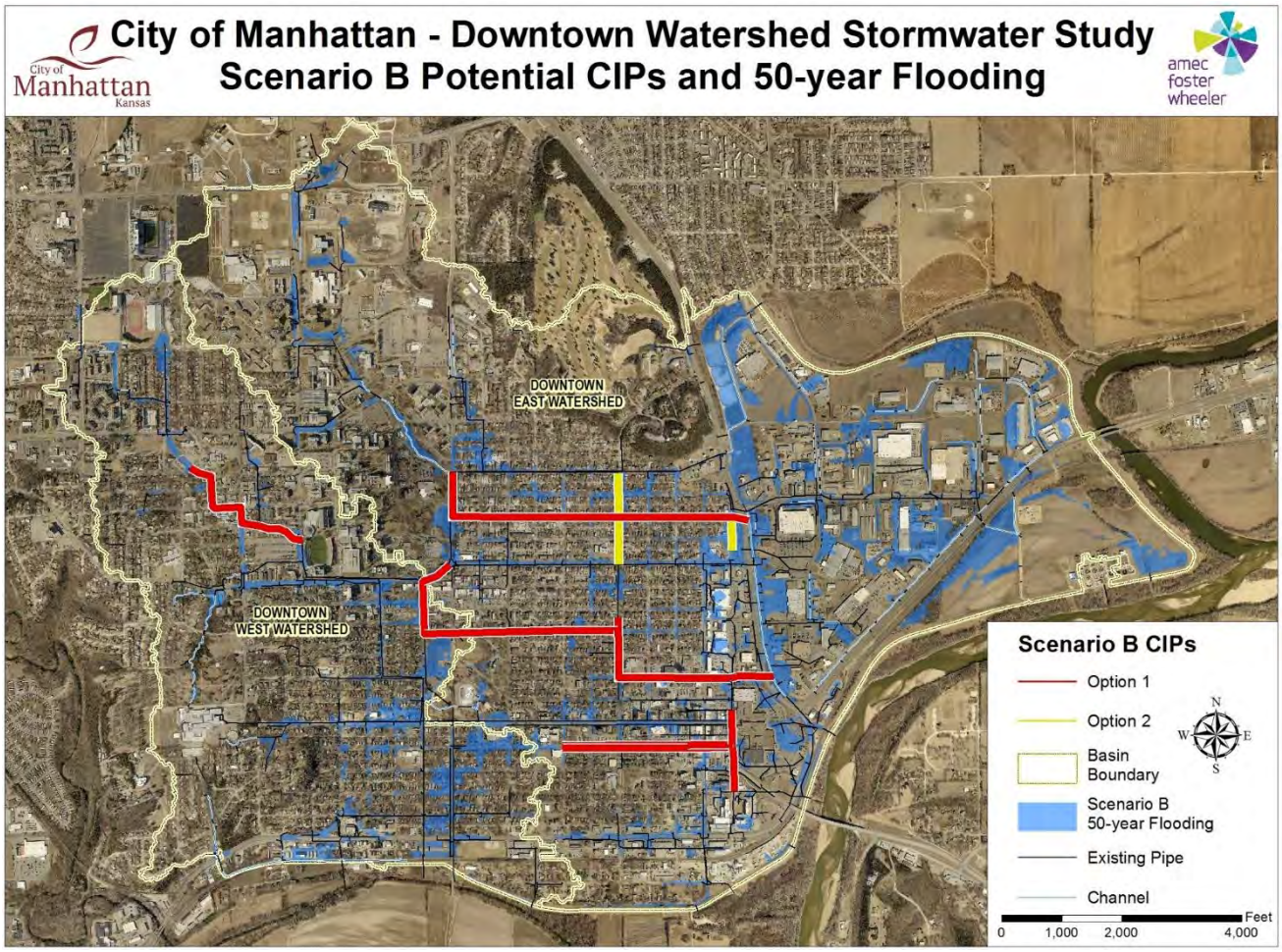
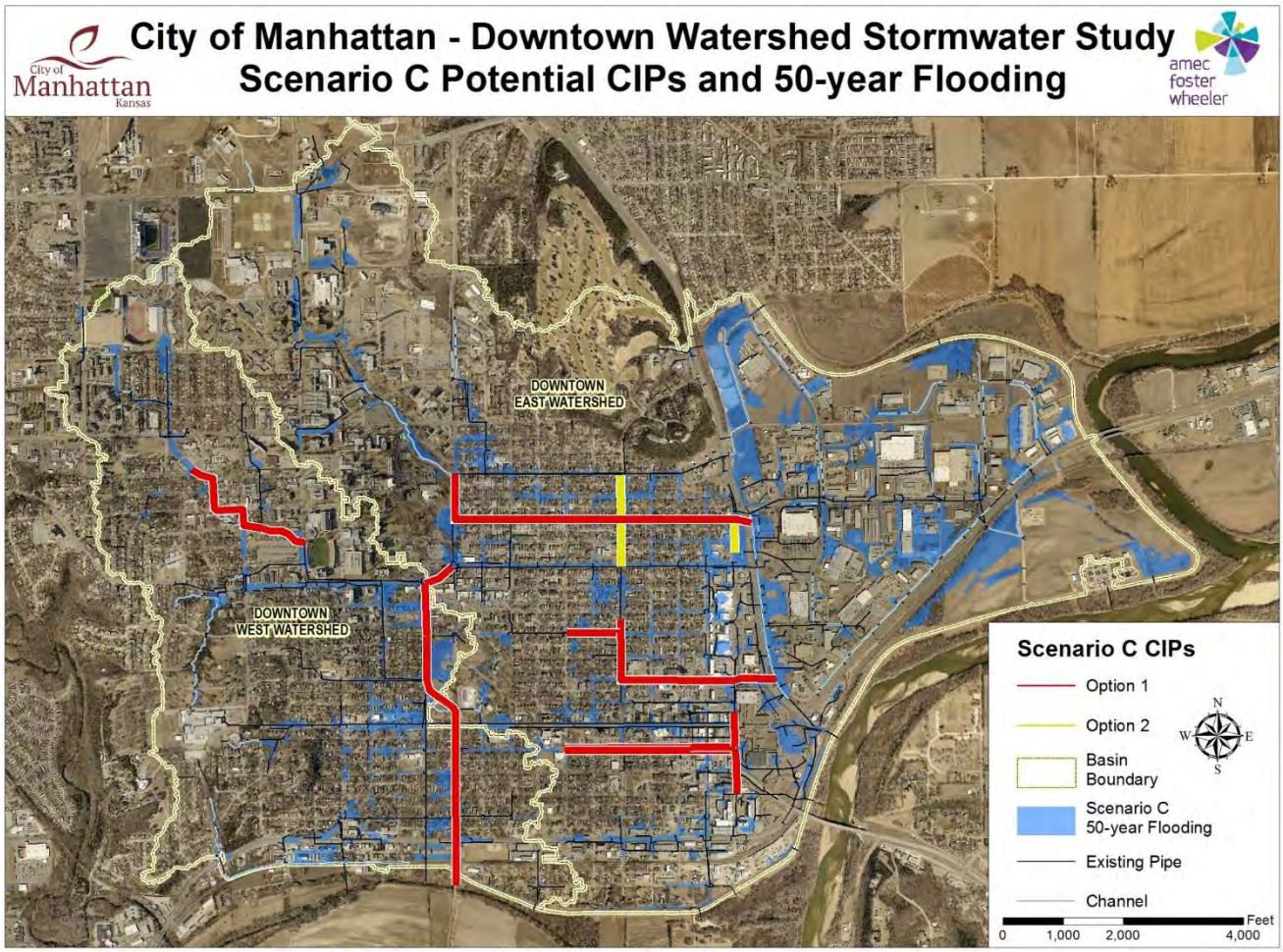


Figure 5-4: Initial alternatives modeling – Scenario C



The above three figures show the 50-yr flooding as an example frequency for the three scenarios. However, all frequency of events were evaluated for each scenario, and the 50-yr event is only being shown as an example as it is the event we are attempting to size the proposed infrastructure to carry, whenever possible. Each scenario was evaluated and the results were discussed with City Staff. In general, the improvements reduce flooding in the upstream areas, but the increased efficiency of the system causes more flooding along the east side of Tuttle Creek Blvd. For example, scenarios A and B, which direct more flow to the east, cause significantly more flooding along the Tuttle Creek Boulevard Channel east of Tuttle Creek Blvd, where scenario C causes less of an increase in flooding at that location since Anderson Avenue overflows are directed to the south, which is the intent of the existing stormwater system.

Scenario B was quickly eliminated, as it causes the most disruption during construction and has the most linear feet of improvements, which would translate into the highest cost. Scenario A was initially looked at very favorably by the project team, as it represents the least linear feet of improvements and is the simplest to construct. Unfortnuately, the increased flows and resulting flooding to the channel to the east of Tuttle Creek Blvd. were simply too great to mitigate, and therefore this solution became not viable. After careful consideration, the Scenario C option became the scenario that was used to begin further refining the CIP projects.

After evaluating the benefits and negative consequences of the projects within Scenario C, adjustments were made and the impacts were re-evaluated. This process was iterated until acceptable CIPs were developed that maximized benefits and minimized cost, all of which decreased flooding for all frequency of events at all locations within the Downtown watersheds. In order to accomplish this, multiple improvement projects were considered and several were ultimately recommended along the channel to the east of Tuttle Creek Blvd. Increasing channel capacity to the south of McCall Road was considered, but determined to not be feasible based on costs, disruptions during construction, and given the fact that this channel was just recently reconstructed. The following general improvements were considered and added to Scenario C, east of Tuttle Creek Blvd, in order to prevent increases in flooding:

- Improve the channel north of McCall Road
- Improve an RCB at Hayes Drive
- Improve the gravity outlet structure through the levee at the north end of the channel
- Construct a pump station at the levee at the north end of the channel outlet
- Relocate the gate structure north of McCall toward McCall road
- Increase the size of the gravity outfall structure at the Poyntz Pump Station Location
- Increase the Capacity of the Poyntz Pump Station

Other refinements that were added to Scenario C to further reduce flooding included:

- Extending the Houston Street system to Poyntz Ave to further reduce flooding
- Realigning the Houston/Poyntz improvement outlet to reduce construction impacts and avoid additional disturbances downtown
- Extending the Tecumseh-Quivera Project east along Anderson Ave. to prevent increased flooding downstream of the originally proposed project
- Pump station improvements to the South Manhattan Pump Station

No final scenarios were included that increased flood risk at any location.

The following two figures, 5-5 and 5-6, represent flooding conditions along the channel east of Tuttle Creek Blvd. Figure 5-5 shows the existing conditions 50-yr water surface elevations with and without pumping capacity, and the proposed conditions 50-yr water surface elevations with and without pumping capacity. All frequency events were looked at, but the 50-yr profiles were selected to represent the fact that water surface elevations are reduced. It should be noted that the black dashed line represents the location where flooding of commercial properties begins to occur.

Figure 5-6 represents existing and proposed conditions flooding for more extreme events beyond City design criteria. It represents existing and proposed conditions flooding for a 500-yr event, and also for a 2-yr event with a 100-yr tail water condition. Note that while some flooding would occur under these two conditions, the improvements significantly reduce the flooding that would occur as a result of these events.

One final thing to note is that should a significant interior event occur, such as an event in excess of a 50-yr event, combined with a high tail water event, such as a 50-yr river stage on the Kansas and/or Big Blue Rivers, these improvements will do little to improve the catastrophic flooding situation that would result from this type of scenario in the lower reaches of the system. The increased pumping capacity would provide some benefits, but at some point pump station capacity would be exceeded.

Figure 5-5: 50-year water surface elevations along Tuttle Creek Boulevard Channel

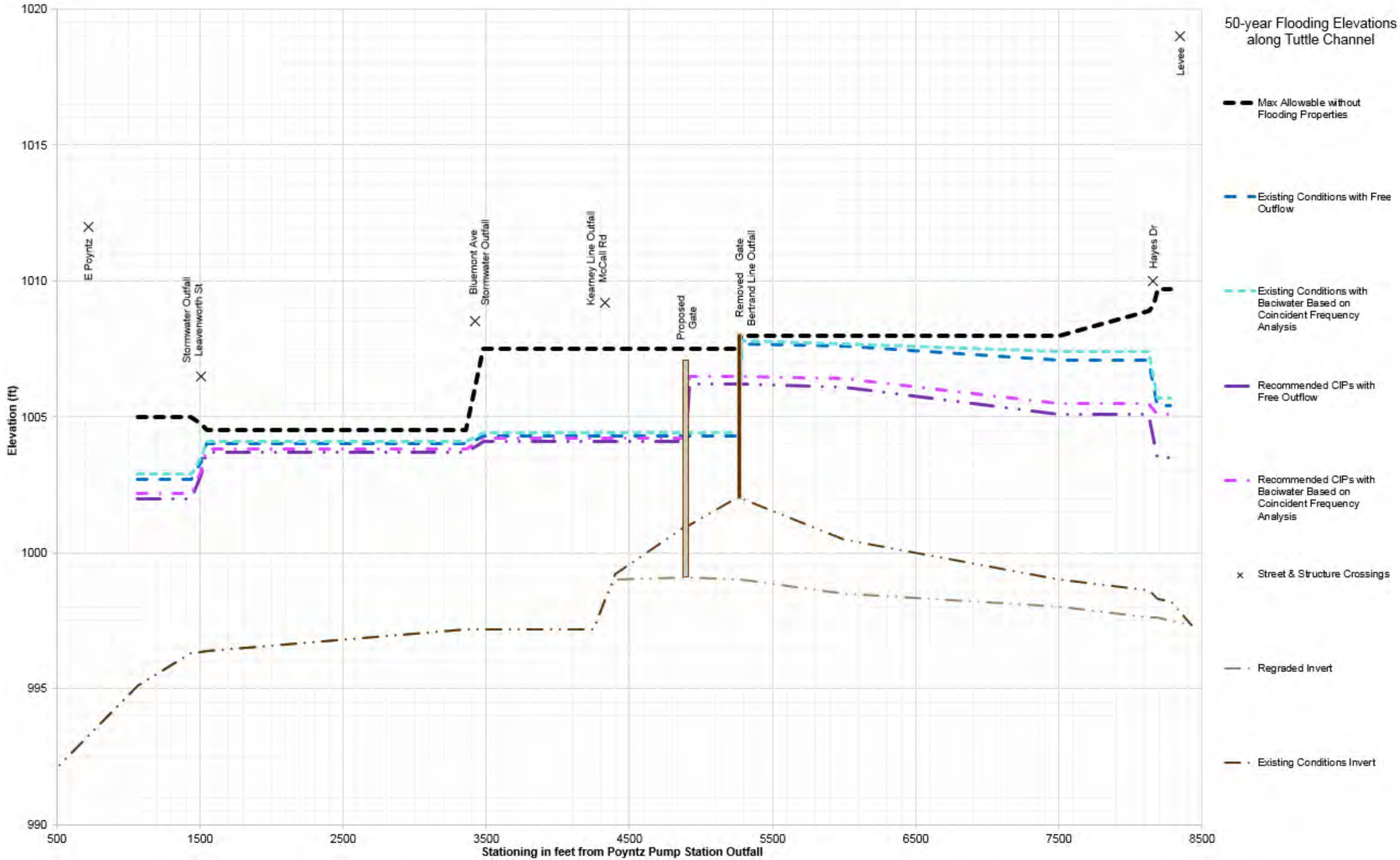
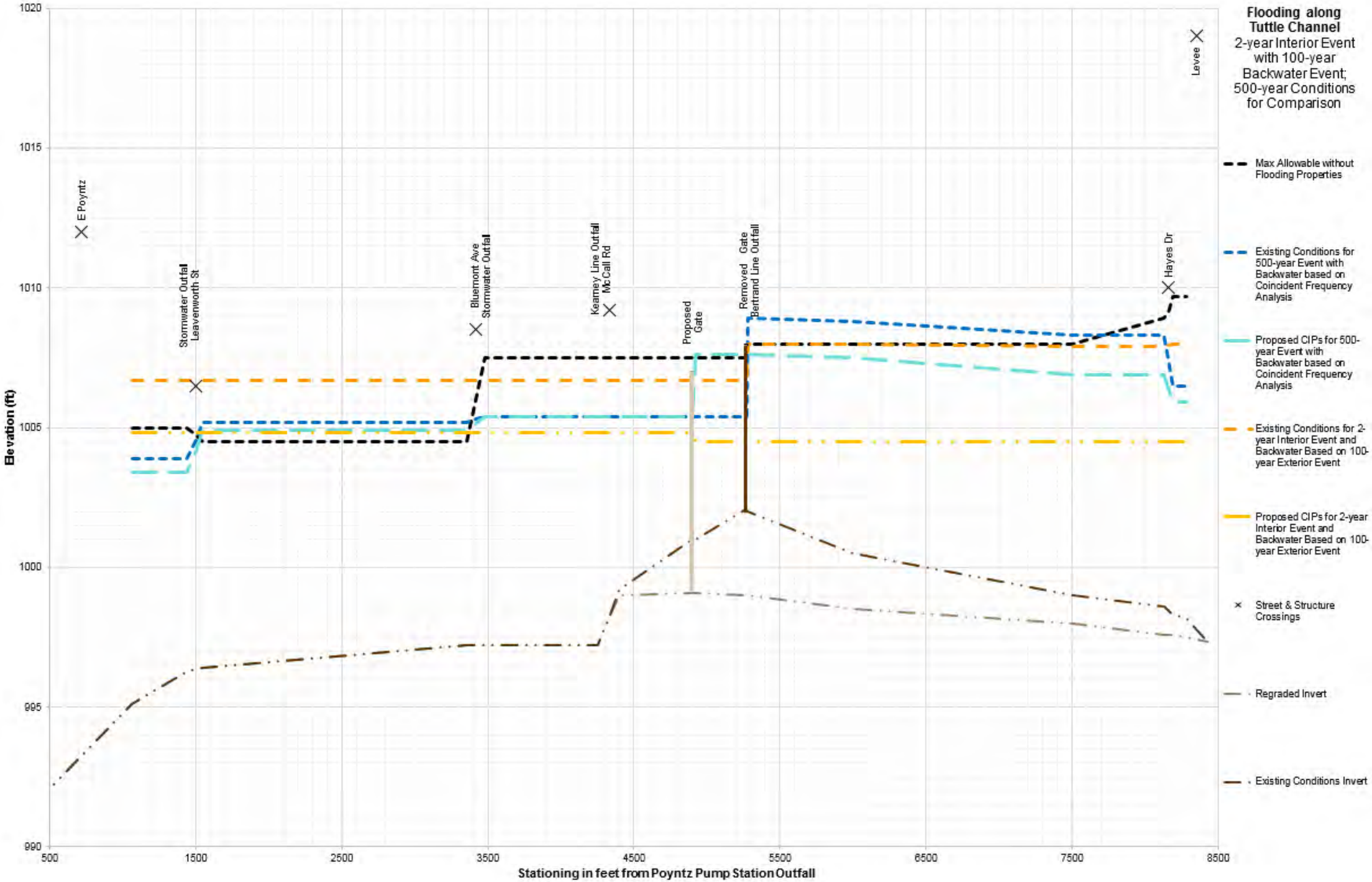


Figure 5-6: Tuttle Creek Boulevard Channel water surface elevations - impacts of tail water on the system

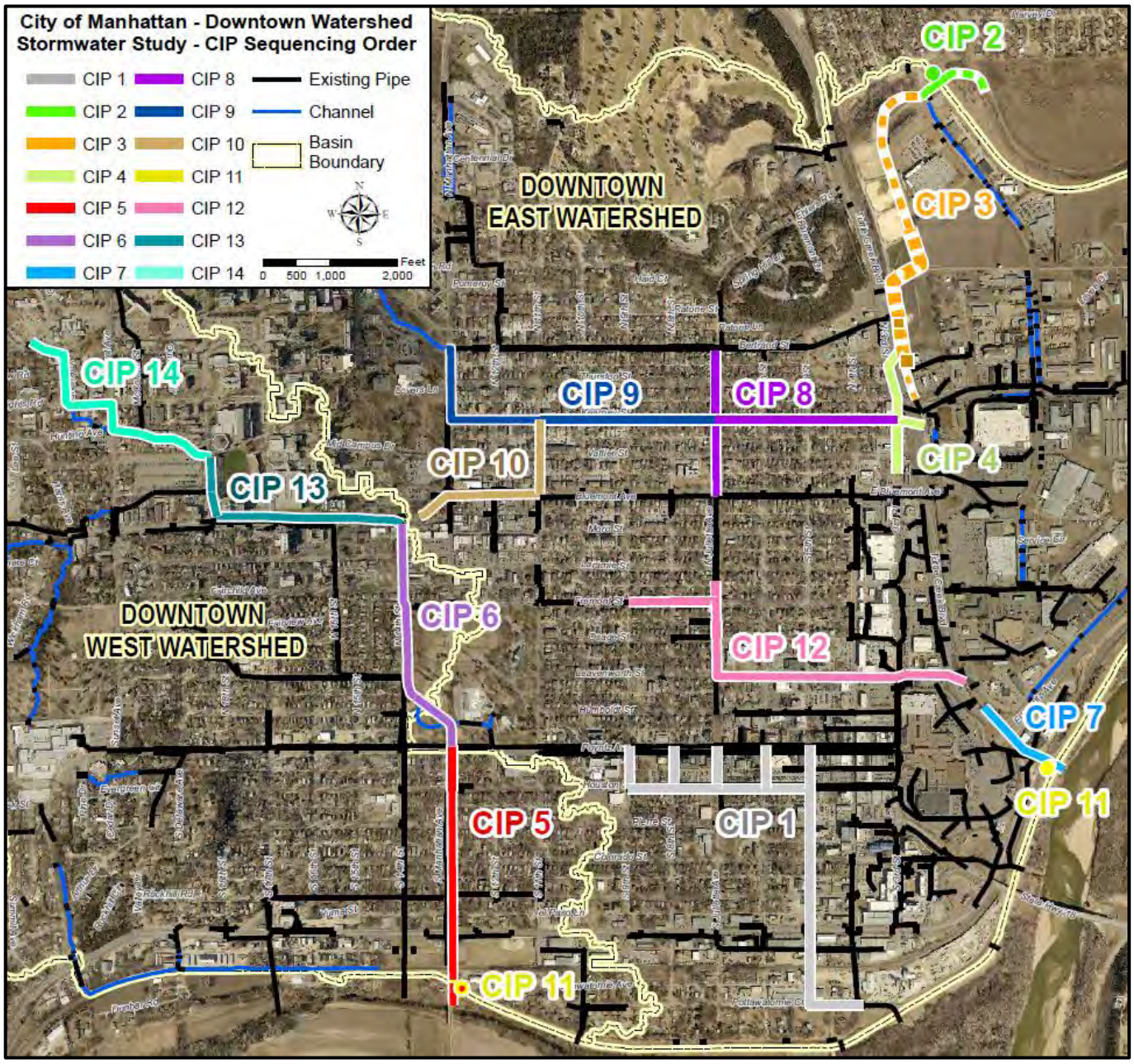


5.3 Capital Improvement Projects

Improvement recommendations have been provided for those systems where CIPs will provide flood reduction benefits. Systems were upsized and flow was redirected in order to provide the required capacity and reduce overflow. Design requirements were based on City criteria, which states that the 1%-annual-chance event should be contained within the City right-of-way, the 2% event should not flood arterial streets, and pipe sizes should not decrease going downstream. As a general rule the existing overall pipe grade was maintained for proposed projects unless adjustments were deemed necessary. It should be noted that, while it was the goal of this project to meet all stormwater criteria for the City of Manhattan, there are cases where flooding escapes the right-of-way during the 100-year event, primarily due to limitations in the feasibility of increasing system capacity further. However, the proposed CIPs still alleviate flooding issues significantly throughout the watershed.

A detailed cost benefit analysis of alternatives was not performed for each recommendation. However, consideration was given to limit recommendations to those that would be cost effective and achievable. After iterating through modifications to the model during the alternatives analyses, CIPs were determined, which are shown in Figure 5.7. A brief summary of the CIPs is given in this section of the report, while a more detailed discussion is presented in the following sections.

Figure 5-7: Spatial overview of recommended CIPs



CIP 1 – Poyntz Avenue / Houston Street Interceptor

CIP 1 involves increasing the system capacity along Houston Street and directing it to the south through the levee near 4th Street. Lateral lines would be added to pick up additional overflows from Poyntz Avenue. This would reduce surcharging along Poyntz Avenue, Houston Street, and other Downtown areas. By redirecting flows, it would also reduce water surface elevations along the Tuttle Creek Boulevard Channel.

CIPs 2 & 3 – Tuttle Creek North Channel Improvements

CIP 2 and CIP 3 involve modifications to the portion of the Tuttle Creek Boulevard Channel north of McCall Road. The channel is proposed to be regraded and widened, while capacities of the Hayes Drive and levee structures would be increased, including the addition of a pump station sized equal to the existing Poyntz Pump Station. In addition, the existing gate structure is proposed to be removed and a new sluice gate is proposed be installed to the south, but still to the north of McCall Road. The gate would generally be operated as closed, but it would allow the option to move water north or south during a flood fight should one of the two pump stations go down. These modifications will increase channel capacity and improve the system's efficiency, preventing upstream recommended CIPs from flooding the channel.

CIPs 4, 8, 9, & 10 – Kearney Street Collector

CIPs 4, 8, 9, and 10 involve adding system capacity along Kearney Street. Overflow from Campus Creek would be collected and directed below the surface along Manhattan Avenue to Kearney Street. Lateral lines would be added at Juliette Ave. and 3rd St. Finally, the outfall into the Tuttle Creek Boulevard Channel would be constructed such that lower flows would be directed south. But, the majority of the flows would be directed to the north once the capacity to the south is exceeded. This project would reduce surcharging north of Bluemont Avenue (including 3rd Street, 4th Street, and Juliette Avenue), as well as along Manhattan Avenue.

CIP 5 & 6 – South Manhattan and 14th Street Interceptors

CIPs 5 and 6 involve increasing the system capacity along 14th Street and S Manhattan Avenue, from Bluemont Avenue to the levee. This project would reduce surcharging along Bluemont Avenue by redirecting flow that would otherwise overflow to the east. It would also help prevent increased water surface elevations along the Tuttle Creek Boulevard Channel, and would also provide some relief to areas south of the park, near 12th Street, due to the increased capacity of the system.

CIP 7 – Tuttle Creek South Outlet Improvements

CIP 7 involves increasing the capacity of the levee outfall structure at the Poyntz Pump Station. This project would help reduce flooding along the Tuttle Creek Boulevard Channel, by preventing an increase in water surface elevation due to increased flows from other CIP projects, and slightly reducing existing conditions water surface elevations.

CIP 11 – Poyntz Pump Station / South Manhattan Pump Station Improvements

CIP 11 involves increasing the pump capacities at the South Manhattan Pump Station and the Poyntz Pump Station. At this time it is thought that the existing Poyntz pumps can be utilized to increase the South Manhattan Pump Station capacity. This project would help reduce flooding along the Tuttle Creek Boulevard Channel, as well as along the line running along S Manhattan Avenue.

CIP 12 – Leavenworth Street Collector

CIP 12 involves increasing the system capacity along Leavenworth Street and adjusting the existing outfall structure to feed into the Tuttle Creek Channel south of Leavenworth Street. Lateral lines would be added to pick up flows from Juliette Avenue as well as Fremont Street. This project would reduce surcharging along Juliette Avenue, Fremont Street, and Leavenworth Street.

CIP 13 & 14 – Anderson-Tecumseh-Quivera Collector

CIP 13 & 14 involve increasing the system capacity along Anderson Avenue up to and including the previously proposed Tecumseh-Quivera project. By carrying the increased capacity down Anderson Avenue, the project would prevent increased surcharges from the upstream system improvements.

6. Capital Improvement Plan

After determining the CIPs, the projects were ranked and sequenced based on feasibility of implementation and input from City Staff. Cost estimates for each CIP were determined and final recommendations are included in this section.

6.1 Project Ranking and Sequencing

Projects were broken up into specific capital improvement projects based on the level of benefit, cost and required sequencing of each project. In general, projects were sequenced from downstream to upstream, so that capacity of the receiving system is not overwhelmed by upstream system improvements. Larger projects were also broken up into smaller CIPs based on cost and spatial locations, with significant guidance from City Staff. Finally, projects were ranked in the following order, which is also indicated by the CIP numbering. A short summary of the reasoning for each project's relative ranking is also provided. It is recommended that CIPs not be implemented until all prerequisite projects are completed.

<u>Phase I Projects</u>

1. Poyntz Avenue / Houston Street Interceptor

   This project will provide relief to the downtown area without the necessity of prerequisite projects. There is an immediate return on this investment as it does not rely upon other CIP projects to fully recognize the flood reduction benefits.

2. Tuttle Creek North Channel Improvements - Phase 1

   This project will help direct water through the levee system more efficiently, which will be required once upstream CIPs are completed. Early completion of this project is required to prevent upstream CIPs from causing adverse effects in downstream areas. Immediate benefits from the construction of an additional pump station will be recognized in the event of an interior event with a high Blue River elevation.

3. Tuttle Creek North Channel Improvements - Phase 2

   Early completion of this project is required to prevent upstream CIPs from causing adverse effects in downstream areas. It should be designed with the prerequisite Phase 1 project in mind, as well as consideration of the outfall structure that will be required to be constructed for CIP 4.

4. Lower Kearney Street Collector

   This project will provide immediate relief to the area of 3rd Street north of Bluemont Avenue. Completion of this project must precede the Middle and Upper Kearney Street Collector projects to prevent adverse effects in downstream areas. Similarly, the Tuttle Creek North Channel Improvements must be completed before this project is implemented. Note that while the full benefits of this project will not be recognized until CIPs 8, 9 and 10 are constructed, it will provide substantial relief to the flooding on the west side of Tuttle Creek Blvd. immediately for a large event such as the May 4, 2016 event.

5. South Manhattan Interceptor (1st Half - Levee to Poyntz)

   This project will provide relief to the area along Manhattan Avenue south of Poyntz. It will eventually receive flows from the 14th Street Interceptor and should therefore precede this project. It is a prerequisite project to CIP 6, which will provide substantial benefits to Bluemont Street once completed.

6. 14th Street Interceptor (2nd Half - Poyntz to Anderson)

   This project will divert flows from Anderson Avenue, which would otherwise overflow to the east, and redirect them toward the south. It must be completed before the Anderson-Tecumseh-Quivera Collector, but must also be preceded by CIP 5. Once constructed, it will provide significant relief to Bluemont Street, as it will cut off significant overflow from Anderson Ave. to Bluemont Ave.

7. Tuttle Creek South Outlet Improvements

   This project will help direct water through the levee system more efficiently, which is required prior to construction of CIPs 8, 9 and 10. It must also precede the Leavenworth Street Collector, referred to as CIP 12, which feeds into Tuttle Creek South Channel.

8. Middle Kearney Street Collector

   This project will provide relief to the area near Kearney Street and Juliette Avenue. Completion of this project must precede the Upper Kearney Street Collector to prevent adverse effects in downstream areas. Similarly, the Lower Kearney Street Collector and Tuttle Creek North Channel Improvements must be completed before this project is implemented.

9. Upper Kearney Street Collector

   This project will help contain overflows from Campus Creek onto Manhattan Avenue, solving a significant flooding issue for the Downtown East Watershed. In order to complete this project, prerequisite projects 2, 3, 4, 7 and 8 must all be completed.

10. Bluemont Avenue Collector

    This project will provide relief to the area along Bluemont Avenue near Manhattan Avenue, completing the improvements for flood reduction along Bluemont Avenue. All downstream CIPs that are part of the Kearney Street Collector and Tuttle Creek North Channel Improvements must be completed before this project is implemented, which includes CIPs 2, 3, 4, 7, 8 and 9.

<u>Phase 2 Projects</u>

11. Poyntz / South Manhattan Pump Station Improvements

    This project will help direct water through the levee system more efficiently. This project will provide additional pumping capacity for all stormwater systems exiting through the levee, and provides much needed additional protection for a large interior system event falling during a high river stage event. It also increases recovery time to get any floodwaters out of the system during a high Kansas River or Big Blue River flooding event.

12. Leavenworth Street Collector

    This project will provide relief to portions of Leavenworth Street, Juliette Avenue, and Freemont Street. It is not a prerequisite for any other project, but should be preceded by the Tuttle Creek South Outlet Improvements (CIP 7).

13. Anderson-Tecumseh-Quivera Collector - Phase 1

    This project will provide relief in the area of Denison Avenue and Anderson Avenue. The 14th Street and South Manhattan Avenue Interceptors should be completed before this project is implemented. At the time this project is considered for design, a feasibility study should be completed to ensure that the benefits out way the costs.

14. Anderson-Tecumseh-Quivera Collector - Phase 2

    This project will provide relief to portions of Tecumseh Road, Quivera Drive, College Heights, and Hunting Avenue. The 14th Street and South Manhattan Avenue Interceptors, as well as Phase 1 of this project, should be completed before this CIP is implemented. At the time this project is considered for design, a feasibility study should be completed to ensure that the benefits out way the costs.

6.2 Project Cost Estimates

Preliminary budget level cost estimates for the recommended capital improvements were developed based on the designs presented in the previous section of this report. Cost estimates for each CIP include the estimated construction cost, which incorporates a 30% contingency. Construction costs are based on a combination of bid tabulation information taken from KDOT; other City bid tabulations including Wichita, Topeka and Kansas City; and projects recently bid that were designed by Amec Foster Wheeler. Design and Construction Oversight Costs are based upon a 20% multiplier of the construction cost. If the City does in house inspection, this cost should come down 8 to 10%. Table 6-1 provides a summary of the CIP cost estimates.

Consideration was also given to utility locations when developing the concepts. However, exact utility locations were not available, with the exception of water and wastewater infrastructure. Therefore, during the design phase of these projects utility locations will be determined and may impact the final design. The costs estimates provided do not include utility relocation costs, although it is anticipated that this cost will be covered by the project contingency. Finally, these costs do not include right-of-way or easement acquisition cost. Improvements were designed on public right-of-way; however, there may be a need to acquire right-of-way or temporary construction easements in certain locations. Some of these costs are likely captured in the 30% contingency; however; significant right-of-way acquisition may not be accounted for in these estimates.

All cost estimates are based on 2014 and 2015 values. No inflation has been added to these cost estimates as it is unknown where the specific projects will be bid or constructed. Variations in unit costs can vary greatly depending on economic conditions and project design complexities. Several general assumptions were made to develop these estimates, including the following:

- Excavation and pavement removal and replacement quantities were based on an average of 1.5 times the RCB or RCP width. Excavation quantities were also based on the RCB or RCP height plus 3'.
- It was estimated that 85% of RCB and RCP replacements occur beneath pavement.
- Quantities for inlets and manholes were based on 300' average spacing, with special consideration for areas where additional inlet capacity may be needed.
- Quantities for storm sewer vaults vary depending on several factors; including a minimum spacing of 800', based on maintenance needs, and at locations in which multiple conduit systems come together.
- Costs do not include any utility relocation needs; however, it is believed that much of this cost is covered in the contingency.
- A construction contingency of 30% was assessed to each project.

- A project fee of 20% was assessed to each project to cover general projects fees, such as administrative and engineering design fees.
- Many other special considerations were made, such as pricing of complex vaults where flow is split, pricing of boring and jacking under Tuttle Creek Blvd, and other special considerations.
- Pump station pricing was based on actual pump station prices for similar sized stations that have been constructed in Kansas and Missouri in 2013, 2014 and 2015.
- In many cases, storm sewer pricing was based upon complete removal and replacement of existing systems. In some cases, savings may be able to be recognized during the design phase by utilizing and adding to existing capacity. However, for this budget level estimate, that was not assumed in most cases, as grades and spacing within right-of-way may not always allow for the use of the existing structure.

Table 6-1: Downtown Watersheds Stormwater CIP Cost Estimates

CIP #	Project Name	Estimated Construction Cost	Design / Construction Oversight Cost	Total Cost
Phase I Projects				
1	Poyntz Avenue / Houston Street Interceptor	$3,037,870	$607,574	$3,645,444
2	Tuttle Creek North Channel Improvements - Phase 1	$3,271,304	$654,261	$3,925,565
3	Tuttle Creek North Channel Improvements - Phase 2	$2,427,767	$485,553	$2,913,320
4	Lower Kearney Street Collector	$4,450,993	$890,199	$5,341,192
5	South Manhattan Interceptor (1st Half - Levee to Poyntz)	$7,311,485	$1,462,297	$8,773,782
6	14th Street Interceptor (2nd Half - Poyntz to Anderson)	$3,213,199	$642,640	$3,855,839
7	Tuttle Creek South Outlet Improvements	$2,355,141	$471,028	$2,826,169
8	Middle Kearney Street Collector	$5,742,260	$1,148,452	$6,890,711
9	Upper Kearney Street Collector	$7,346,425	$1,469,285	$8,815,710
10	Bluemont Avenue Collector	$1,944,468	$388,894	$2,333,362
	Subtotals	**$41,100,911**	**$8,220,182**	**$49,321,093**
Phase 2 Projects				
11	Poyntz / South Manhattan Pump Station Improvements	$4,420,000	$884,000	$5,304,000
12	Leavenworth Street Collector	$3,199,330	$639,866	$3,839,197
13	Anderson-Tecumseh-Quivera Collector - Phase 1	$6,951,400	$1,390,280	$8,341,680
14	Anderson-Tecumseh-Quivera Collector - Phase 2	$3,279,085	$655,817	$3,934,902
	Subtotals	**$17,849,816**	**$3,569,963**	**$21,419,779**
	Totals	**$58,951,000**	**$11,790,000**	**$70,741,000**

6.3 Detailed Project Descriptions

CIP 1 – Poyntz Avenue / Houston Street Interceptor

Overview

Phase I Project
Located within Downtown East Watershed
Total Cost Estimate: $3,645,444
Prerequisite Projects: None

Relevant Flooding Issues

System deficiencies, coupled with larger storm events cause surcharging along Poyntz Avenue, Houston Street, and other areas of downtown.

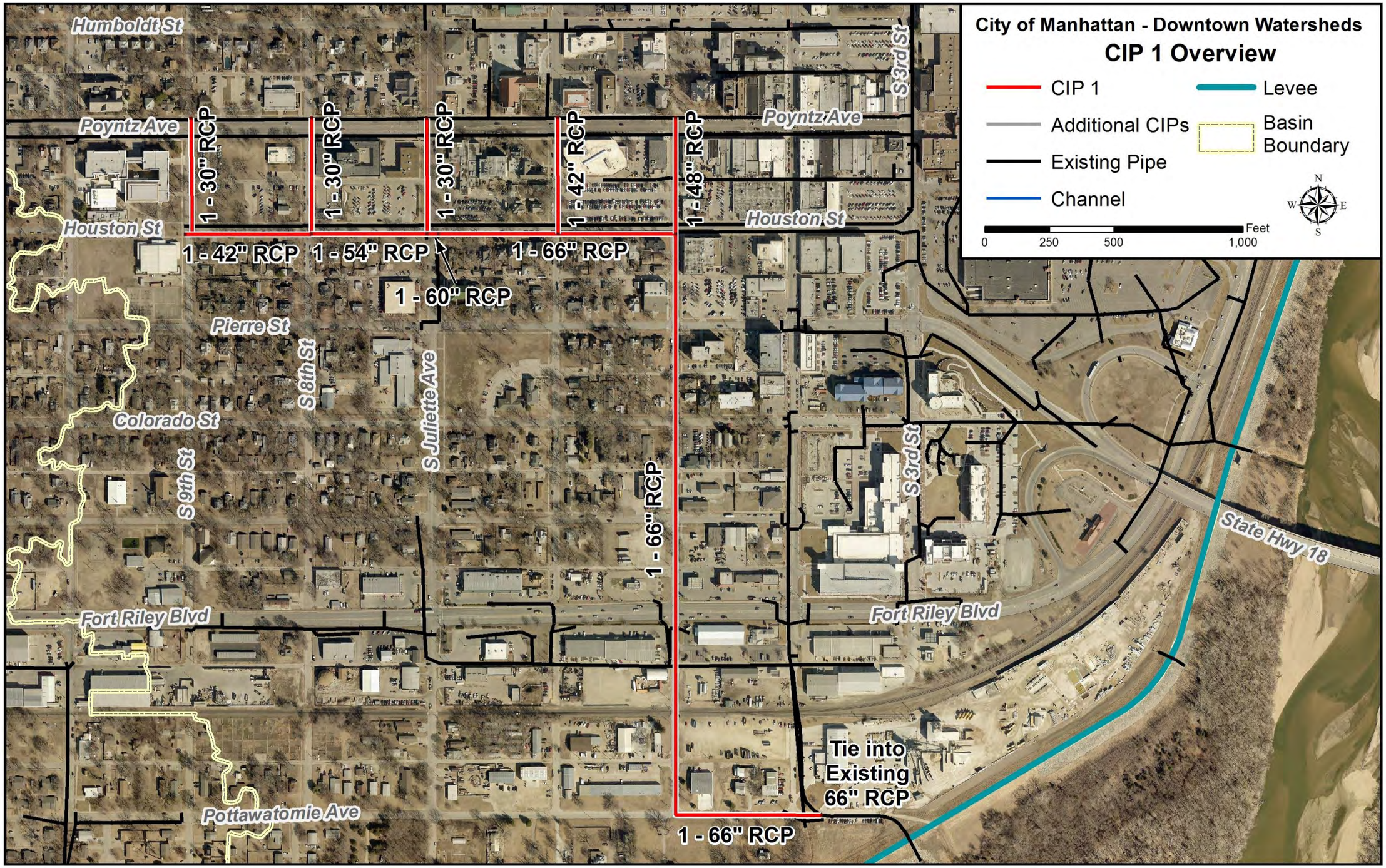
Recommended Improvements

System capacity along Houston Street would be increased and directed to the south, tying into the existing 66" RCP that conveys flows through the levee near 4th Street. Lateral lines would be added to pick up additional overflows from Poyntz Avenue. The following map provides an overview of this CIP. Surcharging and flooding in the downtown area would be reduced, and increased water flooding along the Tuttle Creek Boulevard Channel would be prevented.

Table 6-2: CIP Project Summary Sheet for CIP 1

Total Length (ft)	Proposed CIP
3,736	1 - 66" RCP with Inlets & Manholes
43	1 - 60" RCP with Inlets & Manholes
448	1 - 54" RCP with Inlets & Manholes
452	1 - 48" RCP with Inlets & Manholes
940	1 - 42" RCP with Inlets & Manholes
1,344	1 - 30" RCP with Inlets & Manholes

Figure 6-1: CIP 1 Overview



CIP 2 – Tuttle Creek North Channel Improvements – Phase 1

Overview

Phase I Project
Located within Downtown East Watershed
Total Cost Estimate: $3,925,565
Prerequisite Projects: None

Relevant Flooding Issues

Deficiencies throughout the watershed's storm system cause surcharging in multiple locations, as discussed in previous sections of this report. Various systems that eventually flow into the Tuttle Creek Boulevard Channel would be impacted by this CIP, as this project is required before those upstream projects can be completed.

Recommended Improvements

Capacity of the Tuttle Creek Boulevard Channel would be increased north of McCall Road. The channel would be regraded and widened, while capacities of the Hayes Drive and Levee Structures would be increased, including the addition of a pump station. The following map provides an overview of this CIP. These modifications would increase capacity and improve system efficiency moving flow through the levee, preventing upstream recommended CIPs from flooding the channel.

Special Considerations

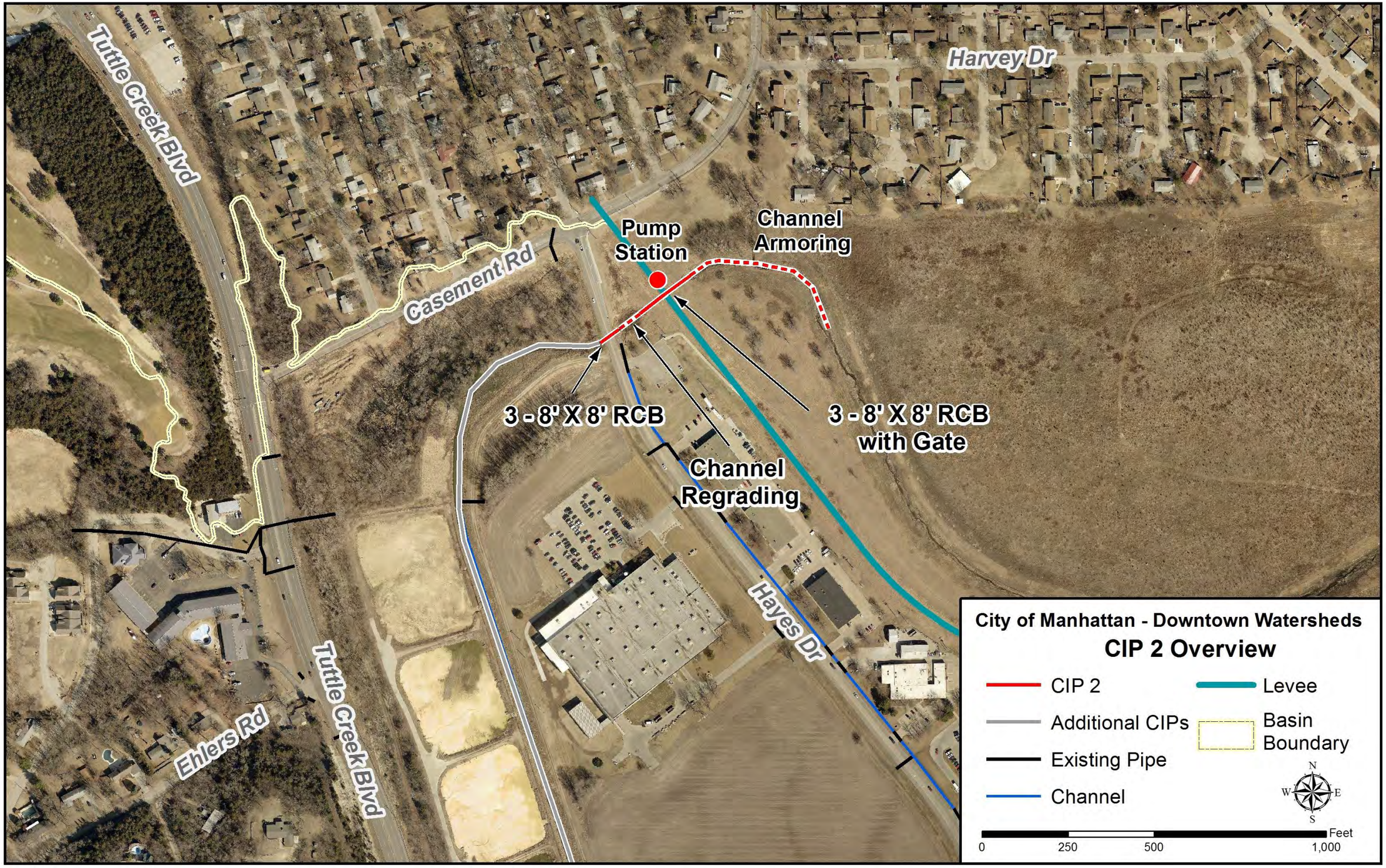
Pump sizing may be further optimized during the design phase if desired. For this study, the proposed pump station was sized to be identical to the Poyntz Avenue pump station to allow pump components to be interchangeable. This pump station is adequately sized to provide sufficient capacity for the design storm events. In the rare event of a large interior flooding event coupled extremely high River Stages, this pump station will not be adequate to keep up with demands. However, sizing a pump station with capacity for a 100-yr interior and exterior event is not feasible.

In addition, construction of this project and additional CIPs that drain through this location may cause some minor increase in overtopping downstream at the Water Well access road. At the time this project is designed and constructed, the City should consider increasing culvert capacity or lowering the profile and slightly increasing overtopping frequency of this City access road to offset this impact. The access road should be sized to pass a flow of 3,306 cfs at or below a water surface elevation of 1005.1 feet, to maintain existing conditions elevations. If no improvements are made to the road, a backwater impact of 0.22 feet will result from the CIP projects, potentially impacting a few homes along the channel.

Table 6-3: CIP Project Summary Sheet for CIP 2

Total Length (ft)	Proposed CIP
251	3 – 8'X8' RCB
73	Regraded & Widened Channel
448	Channel Armoring – 40' Bottom Width
-	Pump Station

Figure 6-2: CIP 2 Overview



CIP 3 – Tuttle Creek North Channel Improvements – Phase 2

Overview

Phase I Project
Located within Downtown East Watershed
Total Cost Estimate: $2,913,320
Prerequisite Projects: CIP 2

Relevant Flooding Issues

Deficiencies throughout the watershed's storm system cause surcharging in multiple locations, as discussed in previous sections of this report. Various systems that eventually flow into the Tuttle Creek Boulevard Channel would be impacted by this CIP.

Recommended Improvements

Overall capacity of the Tuttle Creek Boulevard Channel would be increased north of McCall Road. The channel would be regraded and widened. In addition, the existing gate structure would be removed and a new sluice gate would be installed. The following map provides an overview of this CIP. These modifications would increase channel capacity and improve the systems efficiency, preventing upstream recommended CIPs from flooding the channel.

Special Considerations

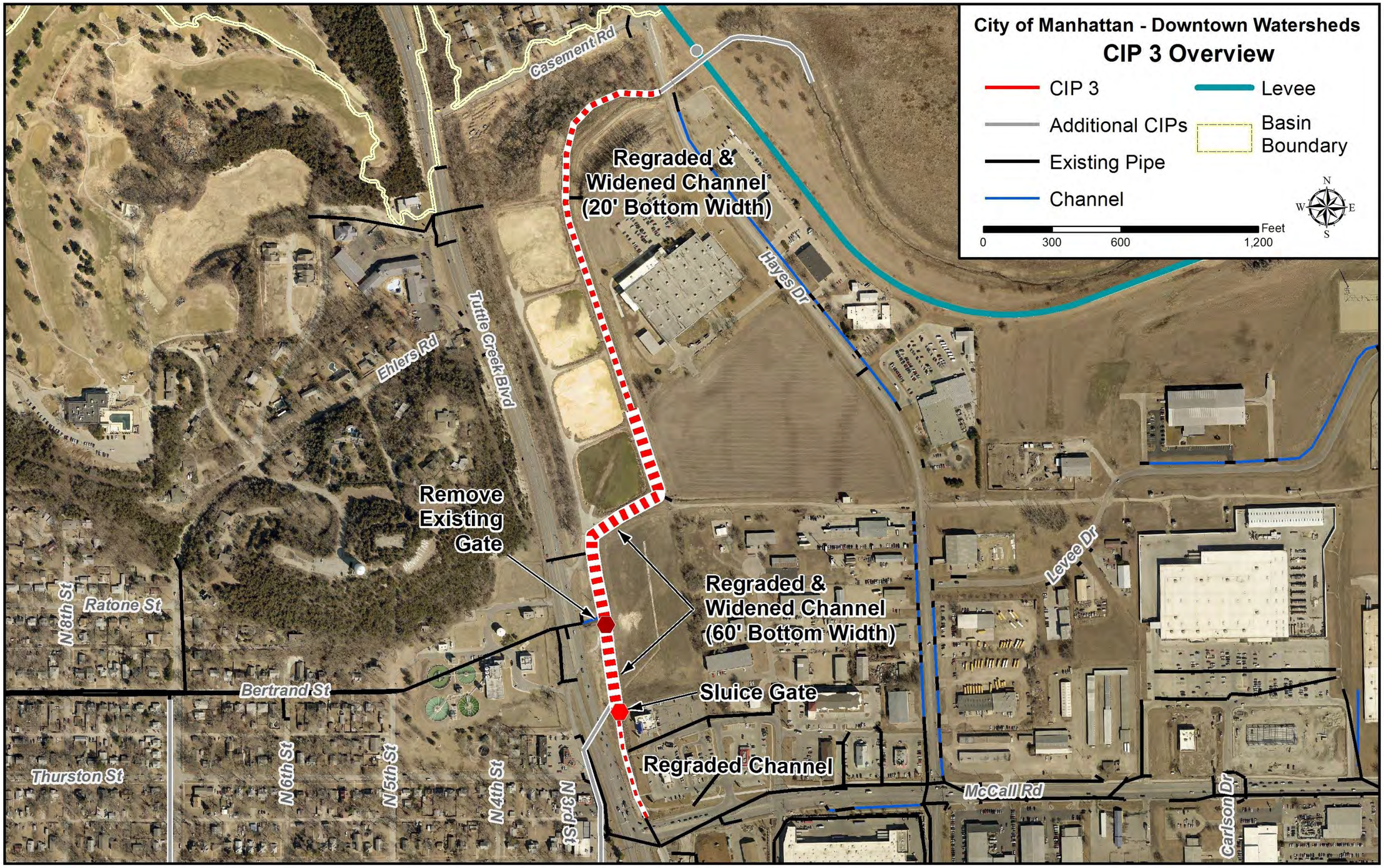
To provide sufficient capacity for the proposed inflows, a trapezoidal channel with 3-to-1 side slopes and a 60-foot bottom width is proposed. To avoid encroaching on the property currently owned by Parker Hose Products Division, the channel can transition to a 20-foot wide bottom width as shown. Because of the channel grade and hydraulic properties, this channel reduction does not limit capacity upstream, and modeling results indicate that this reduction in channel size is sufficient to alleviate flooding.

During the design phase, special attention should be given to the regraded inverts to ensure that the structures and outfalls associated CIP 4 will remain feasible, as vertical space is limited under the associated roads. In addition, energy dissipation and outfall location for CIP 4 should be considered in the construction of this CIP.

Table 6-4: CIP Project Summary Sheet for CIP 3

Total Length (ft)	Proposed CIP
1,716	Regraded, Widened Channel – 20' Bottom Width
1,516	Regraded, Widened Channel – 60' Bottom Width
474	Regraded Channel
-	Sluice Gate Structure

Figure 6-3: CIP 3 Overview



CIP 4 – Lower Kearney Street Collector

Overview

Phase I Project
Located within Downtown East Watershed
Total Cost Estimate: $5,341,192
Prerequisite Projects: CIP 2 & 3 (with special consideration for CIP 7)

Relevant Flooding Issues

Deficiencies throughout the watershed's storm system cause surcharging in multiple locations, as discussed in previous sections of this report. Various systems that eventually flow into the Tuttle Creek Boulevard Channel would be impacted by this CIP.

Recommended Improvements

CIP 4 would involve adding system capacity to transport flow from the area of 3rd Street to the Tuttle Creek Boulevard Channel. The improvements would be constructed such that the majority of flows would be directed to the northeast; however, base flows would first be directed east then south. Eventually, overflow from Campus Creek would be routed through CIP 4 via the remaining Kearney Street Collector projects. The following map provides an overview of this CIP. This project would reduce surcharging north of Bluemont Avenue (including 3rd Street, 4th Street, and Juliette Avenue), as well as along Bluemont Avenue.

Special Considerations

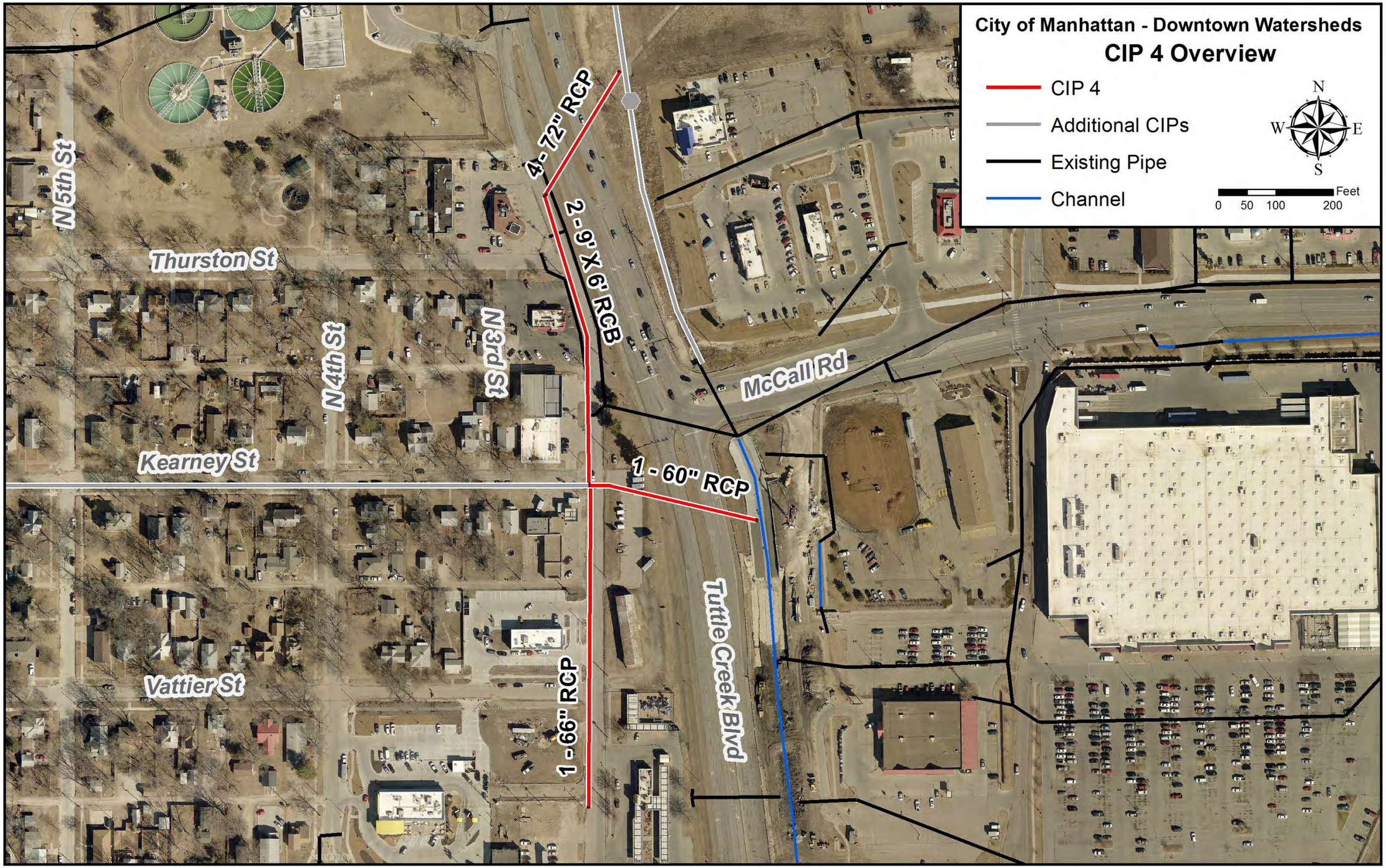
The 60" RCP that outlets to the east then south should be closed until CIP 7 is completed, directing all flows to the northeast. Once CIP 7 is competed, then the 60" RCP should be brought online.

It is assumed that complete closure of Tuttle Creek Boulevard is not feasible. Therefore, cost estimates for all structures through Tuttle Creek Boulevard were considered with boring and jacking included. Finally, the junction of the two outlets should be constructed in a way that once fully functional (with the completion of CIP 7), low flows are directed east then south through the 60" RCP, and overflows are then directed to the northeast once the capacity of the 60" RCP is achieved.

Table 6-5: CIP Project Summary Sheet for CIP 4

Total Length (ft)	Proposed CIP
526	2 - 9' X 6' RCB with Inlets & Manholes
250	4 - 72" RCP (Bored and Jacked)
250	1 - 60" RCP (Bored and Jacked)
561	1 - 66" RCP with Inlets & Manholes
50	1 - 60" RCP with Inlets & Manholes

Figure 6-4: CIP 4 Overview



CIP 5 – South Manhattan Interceptor

Overview

Phase I Project
Located within Downtown West Watershed
Total Cost Estimate: $8,773,782
Prerequisite Projects: None

Relevant Flooding Issues

Deficiencies in the storm system south of Poyntz Avenue cause surcharging in the area of 11th and 12th Streets.

Recommended Improvements

System capacity along S Manhattan Avenue would be increased from Poyntz Avenue to the Levee. The following map provides an overview of this CIP. This project would provide relief to areas south of the park, near 12th Street due to the increased capacity of the system. Eventually, this project would tie into CIP 6 and thereby reduce surcharging along Bluemont Avenue by redirecting flow that would otherwise become overflow to the east.

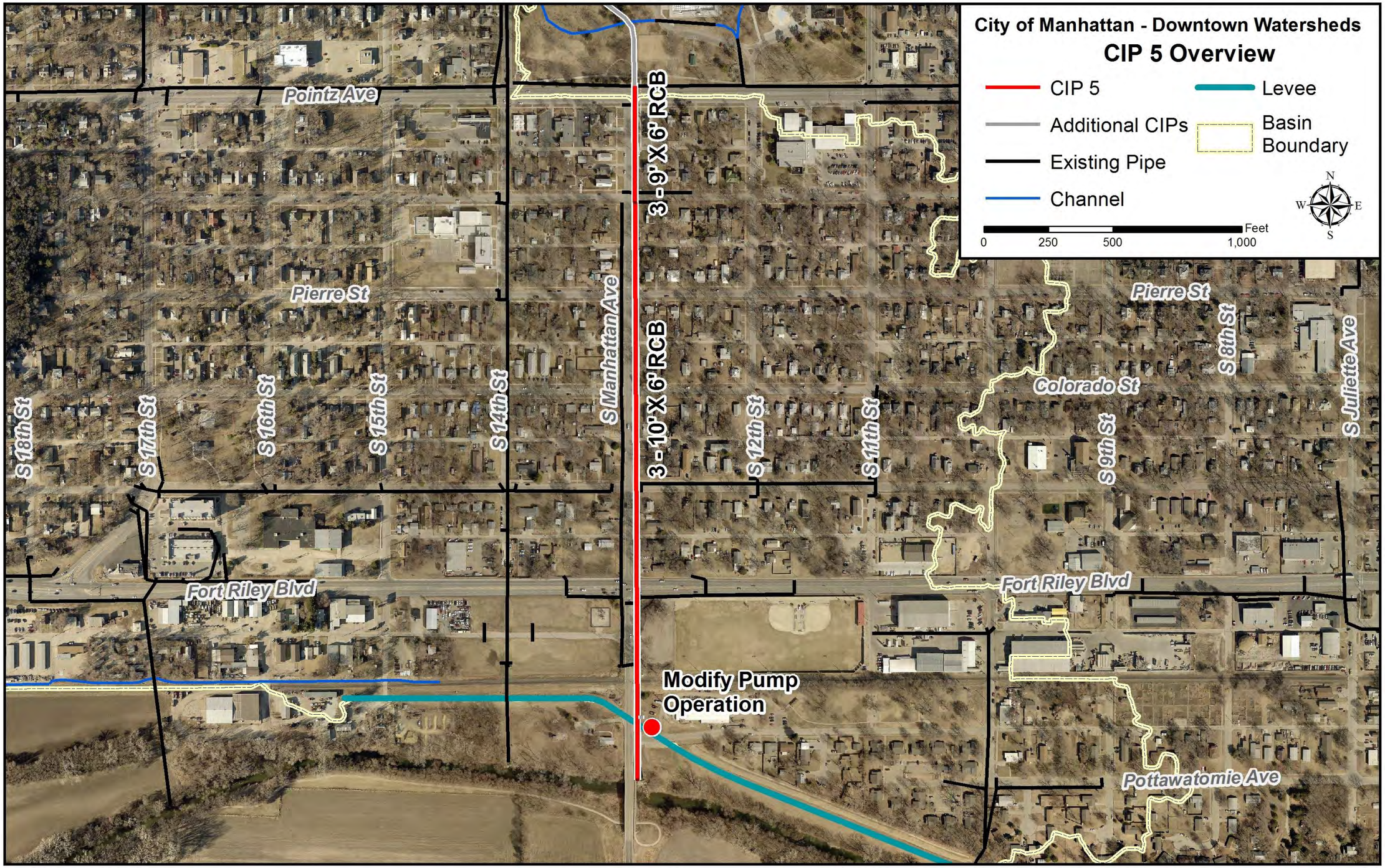
Special Considerations

While no structural changes are required at the South Manhattan Pump station, modification to the operation of the pumps is recommended. Specifically, the pump station should be utilized earlier (i.e. lower interior water surface elevations) to help keep up with increased inflows. According to current operation procedures, the two pump units are set to be turned on when the wet well depth reaches 4.99 feet and 5.74 feet, and to turn off at depths of 2.99 feet and 3.74 feet, respectively. Operation of the pumps should be adjusted to turn on at depths of 4.49 feet and 4.74 feet, and to turn off at depths of 0.5 feet and 0.75 feet, or the minimum possible depth for pump operation as determined during the design phase. This modification can be made at any time, and we recommend the operations be tweaked upon completion of an updated operations plan, and review and approval by the Kansas City USACE.

Table 6-6: CIP Project Summary Sheet for CIP 5

Total Length (ft)	Proposed CIP
2,239	3 - 10' X 6' RCB with Inlets & Manholes
462	3 - 9' X 6' RCB with Inlets & Manholes

Figure 6-5: CIP 5 Overview



CIP 6 – 14th Street Interceptor

Overview

Phase I Project
Located within Downtown West Watershed
Total Cost Estimate: $3,855,839
Prerequisite Projects: CIP 5

Summary

CIP 6 would involve increasing the system capacity along 14th Street from Bluemont Avenue to Poyntz Avenue. The following map provides an overview of this CIP. This project would reduce surcharging along Bluemont Avenue by redirecting flow that would otherwise become overflow to the east. It would also help prevent increased water surface elevations along the Tuttle Creek Boulevard Channel by directing flows to the south.

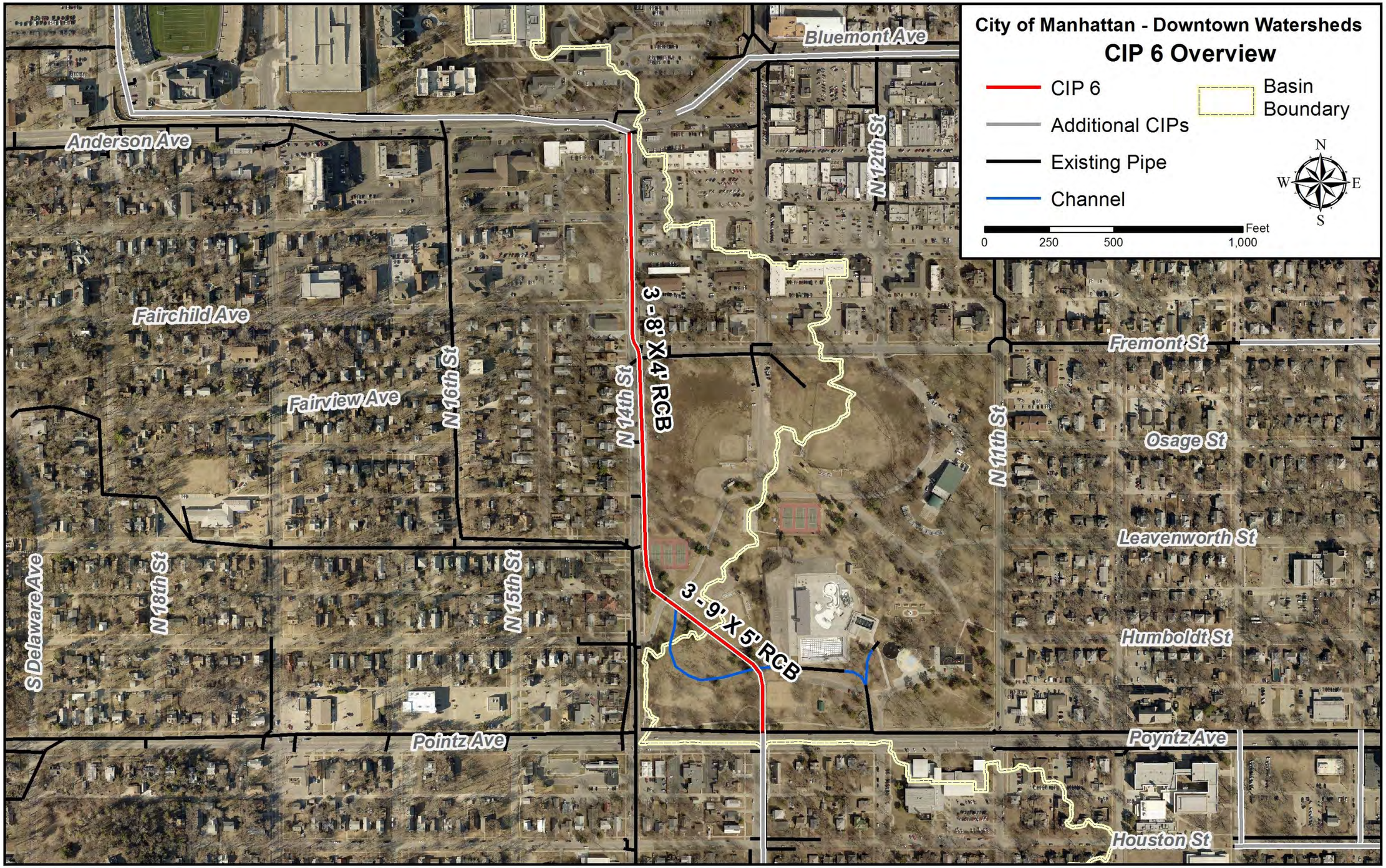
Special Consideration

During the design phase, it should be considered whether the upstream limit of this project should be tied into CIP 10 with an overflow box. Advantages to doing so would be that sub-surface flow could stay below the surface, and not have to be recaptured as surface flow.

Table 6-7: CIP Project Summary Sheet for CIP 6

Total Length (ft)	Proposed CIP
1,839	3 - 8' X 4' RCB with Inlets & Manholes
698	3 - 9' X 5' RCB with Inlets & Manholes

Figure 6-6: CIP 6 Overview



CIP 7 – Tuttle Creek South Outlet Improvements

Overview

Phase I Project
Located within Downtown East Watershed
Total Cost Estimate: $2,826,169
Prerequisite Projects: None

Relevant Flooding Issues

Deficiencies throughout the watershed's storm system cause surcharging in multiple locations, as discussed in previous sections of this report. Various systems that eventually flow into the Tuttle Creek Boulevard Channel would be benefitted by this CIP, and completion of this CIP is a prerequisite of completion of CIP projects 8, 9 and 10, as well as the full implementation of CIP project 4.

Recommended Improvements

CIP 7 would involve increasing the capacity of the levee outfall structure at the Poyntz Pump Station. The following map provides an overview of this CIP. This project would help reduce flooding along the Tuttle Creek Boulevard Channel.

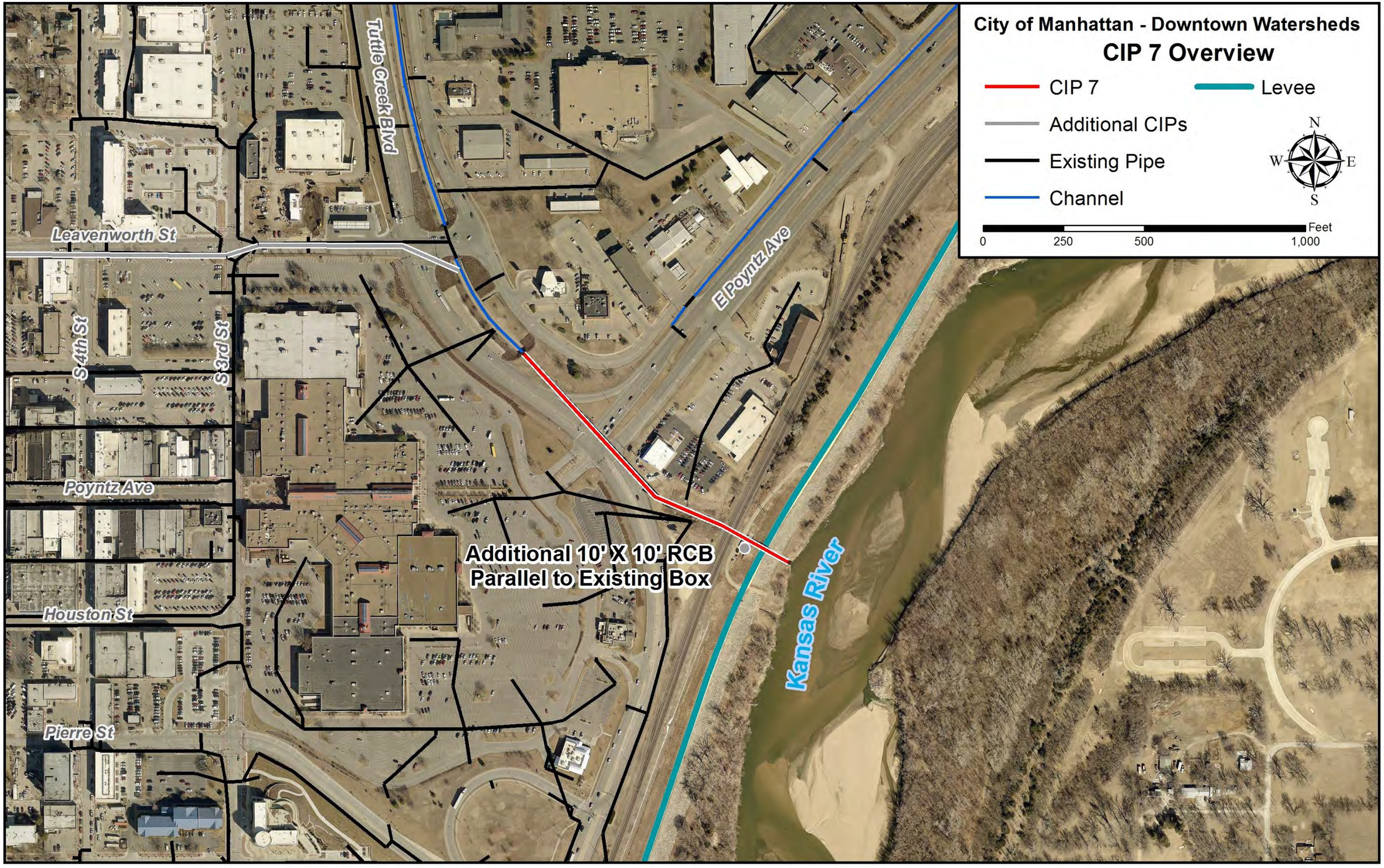
Special Considerations

It is assumed that running a box parallel to the existing structure would be most cost effective. However, this should be evaluated during the design phase for this project.

Table 6-8: CIP Project Summary Sheet for CIP 7

Total Length (ft)	Proposed CIP
1,069	Additional 10' X 10' RCB (through Levee)

Figure 6-7: CIP 7 Overview



CIP 8 – Middle Kearney Street Collector

Overview

Phase I Project
Located within Downtown East Watershed
Total Cost Estimate: $6,890,711
Prerequisite Projects: CIP 2, 3, 4 and 7

Relevant Flooding Issues

Surcharging in systems to the north and to the west creates overflow that causes overflow in the area along Juliette Avenue and along Bluemont Avenue.

Recommended Improvements

System capacity along Kearney Street would be increased between 3rd Street and Juliette Avenue, tying into CIP 4. Lateral lines would be added at Juliette Avenue and 3rd Street. The following map provides an overview of this CIP. This project would reduce surcharging north of Bluemont Avenue along Juliette Avenue and along Kearney Street, as well as along Bluemont Avenue.

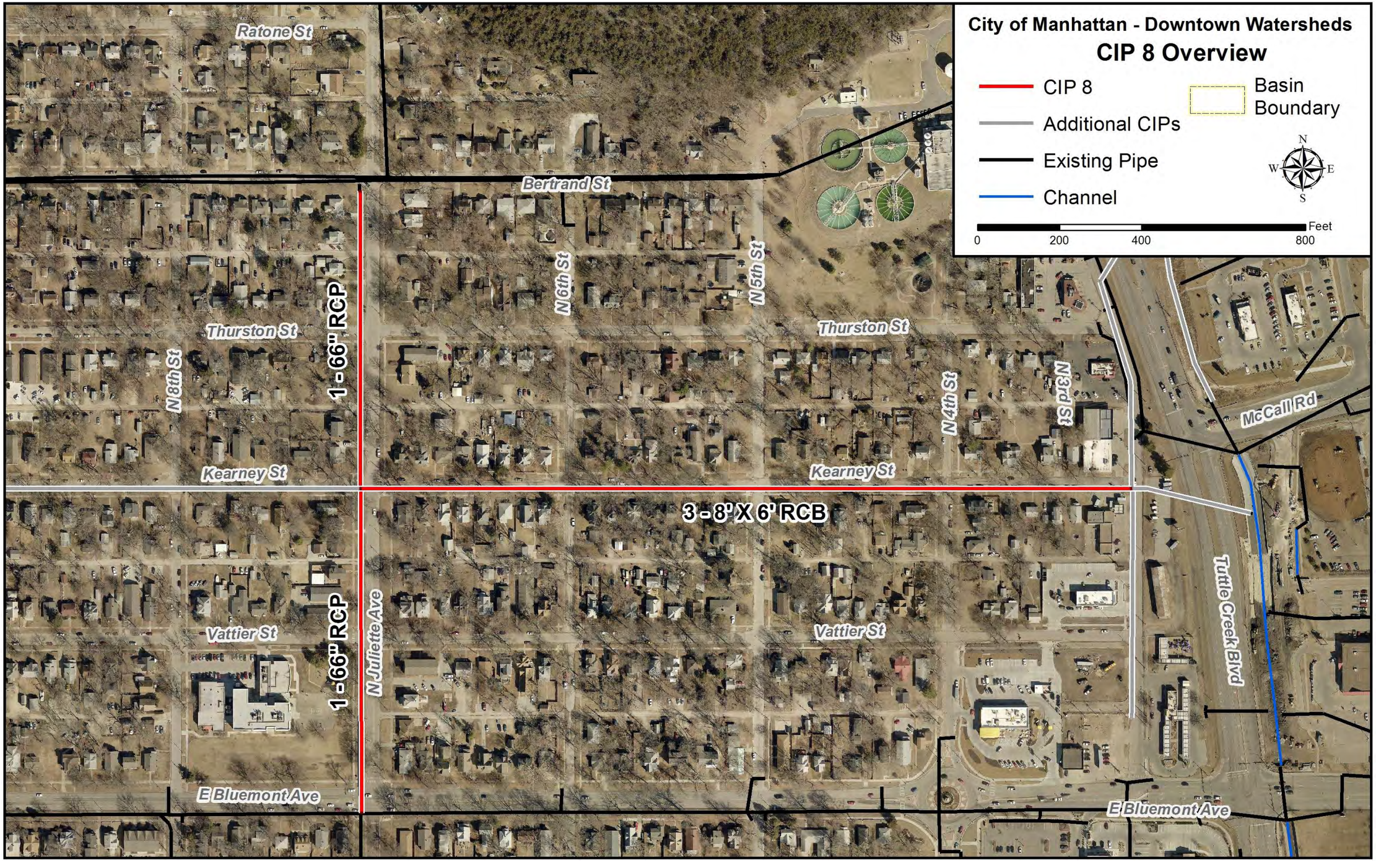
Special Considerations

For this project, the south lateral line was connected to the stormwater line along Bluemont Avenue, to further alleviate surcharging in this area. It should be noted that connecting or disconnecting this line makes very little difference in the overall elevations. However, but connecting the line to the Bluemont line, it allows the outfalls to equalize, maximizing outfall capacity during flooding events. The final decision on whether or not to connect the line should be a design decision, as there are minimal impacts either way beyond maximizing capacity as discussed above. The north lateral line remains disconnected from the stormwater line along Bertrand Street, though overflows from the Bertrand line may still flow into the proposed system. However, in order to keep the Bertrand line flowing full we have proposed to keep these lines disconnected, and recollect any surcharge flow not handled by the Bertrand line.

Table 6-9: CIP Project Summary Sheet for CIP 8

Total Length (ft)	Proposed CIP
1,880	3 - 8' X 6' RCB with Inlets & Manholes
1,516	1 - 66" RCP with Inlets & Manholes

Figure 6-8: CIP 8 Overview



CIP 9 – Upper Kearney Street Collector

Overview

Phase I Project
Located within Downtown East Watershed
Total Cost Estimate: $8,815,710
Prerequisite Projects: CIP 2, 3, 4, 7 and 8

Relevant Flooding Issues

Surcharging in systems to the north and to the west creates overflow that causes flooding in the area along Juliette Avenue and along Bluemont Avenue.

Recommended Improvements

CIP 9 would involve adding system capacity along Kearney Street between Juliette and Manhattan Avenues, tying into CIP 8. Overflow from Campus Creek would be captured and directed through the proposed stormwater system along Manhattan Avenue to Kearney Street. The following map provides an overview of this CIP. This project would reduce surcharging along Manhattan Avenue, along Bluemont Avenue, and along residential streets north of Bluemont Avenue.

Special Considerations

Where Campus Creek feeds into the system, the inlet box should designed to allow flow to move into both the proposed system and the existing system along Bertrand Street, with lower flows being directed into the proposed system, and the existing system acting as overflow capacity.

Table 6-10: CIP Project Summary Sheet for CIP 9

Total Length (ft)	Proposed CIP
1,706	3 - 6' X 5' RCB with Inlets & Manholes
1,830	3 - 8' X 6' RCB with Inlets & Manholes
	Inlet/Junction Box at Manhattan Ave.

Figure 6-9: CIP 9 Overview

CIP 10 – Bluemont Avenue Collector

Overview

Phase I Project
Located within Downtown East Watershed
Total Cost Estimate: $2,333,362
Prerequisite Projects: CIP 2, 3, 4, 7, 8 and 9

Relevant Flooding Issues

By constructing CIP 5 and 6, much of the surcharging along Anderson Ave. will be addressed. By constructing CIP 9, the overflow from Campus Creek will be addressed. CIP 10 is a catch all to collect any localized or excess flows at the intersection of Manhattan and Bluemont Ave. to capture and collect any remaining flows at this location.

Recommended Improvements

System capacity along Bluemont Avenue would be increased between 11th Street and 14th Street, tying into CIP 9. Overflow along Bluemont Avenue would be intercepted and directed along 11th Street to Kearney Street. The following map provides an overview of this CIP. This project would reduce surcharging along Bluemont Avenue.

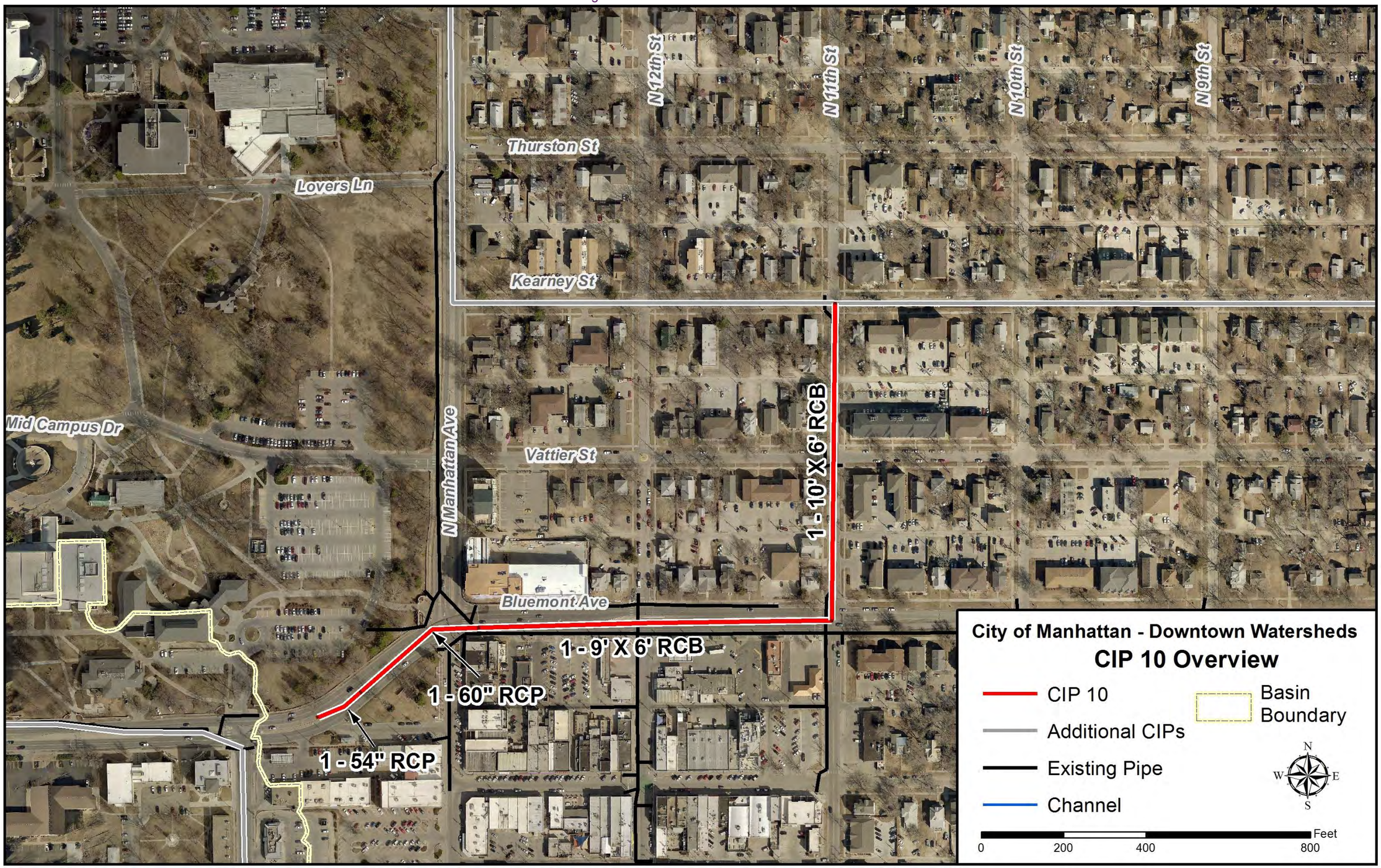
Special Considerations

During the design phase, it should be considered whether the upstream limit of this project should tie into CIP 6 with an overflow box. This project assumes that the two systems will remain disconnected; however, it may be beneficial to connect the two systems, provided that CIP 10 acts solely as an overflow for CIP 6 once its capacity is exhausted.

Table 6-11: CIP Project Summary Sheet for CIP 10

Total Length (ft)	Proposed CIP
771	1 - 10' X 6' RCB with Inlets & Manholes
860	1 - 9' X 6' RCB with Inlets & Manholes
342	1 - 60" RCP with Inlets & Manholes
311	1 - 54" RCP with Inlets & Manholes

Figure 6-10: CIP 10 Overview



CIP 11 – Poyntz / South Manhattan Pump Station Improvements

Overview

Phase II Project
Located within Downtown East & West Watersheds
Total Cost Estimate: $5,304,000
Prerequisite Projects: None

Relevant Flooding Issues

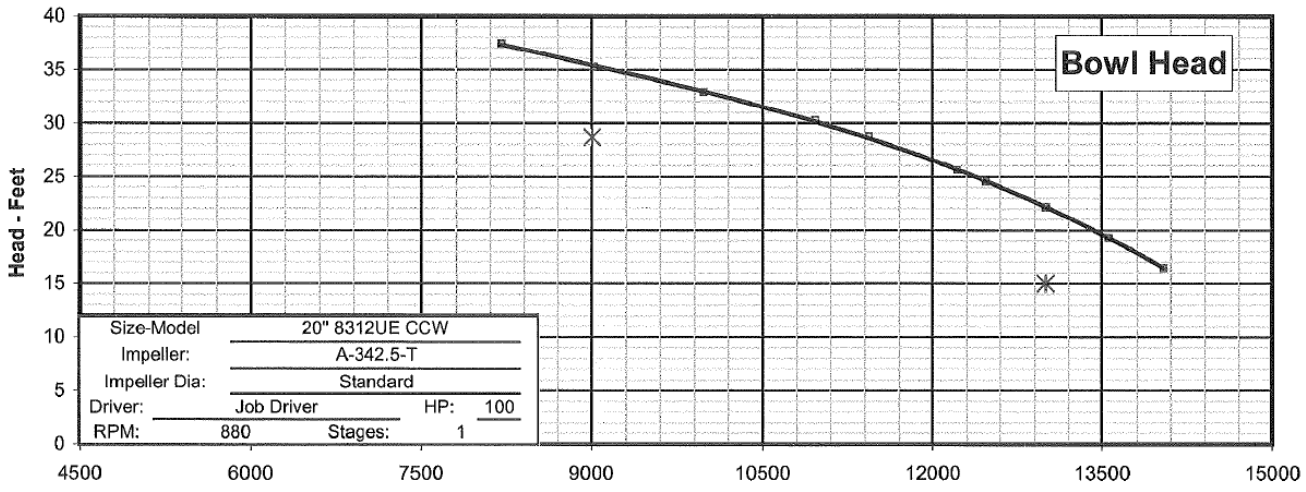
Deficiencies throughout the watershed's storm system cause surcharging in multiple locations, as discussed in previous sections of this report. Various systems that eventually flow into the Tuttle Creek Boulevard Channel would be impacted by this CIP. In addition, systems that flow into the stormwater line along S Manhattan Avenue would also be impacted.

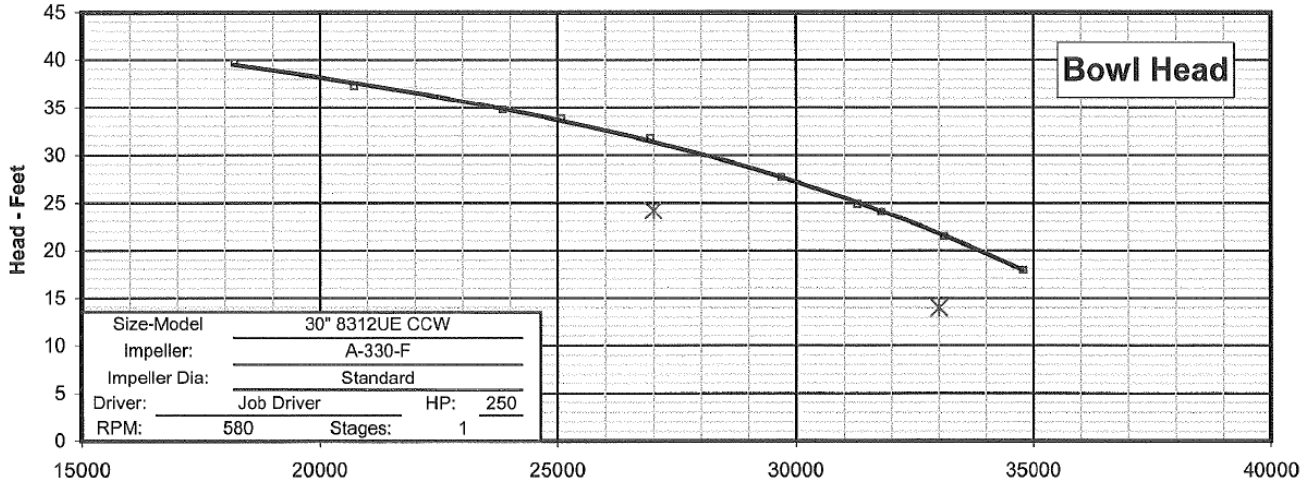
Recommended Improvements

CIP 11 would involve increasing the pump capacities at the Poyntz Pump Station and the South Manhattan Pump Station. The following map provides an overview of this CIP. This project would help reduce flooding along the Tuttle Creek Boulevard Channel, as well as along the line along S Manhattan Avenue.

Special Considerations

The proposed South Manhattan Pump Station should include a larger pump house and pumping units with capacities similar to those shown in the pump curves below. For this design, two pumps each were included with the capacities shown in the three pump curves. Pump sizing should be considered during the design phase of the project to account for any changes in the watershed that may occur after this study. For this study, the desire for interchangeable pump units was considered and therefore the proposed South Manhattan Pump units were sized to be identical to the existing Poyntz Pump Station, as well as the proposed units at the northern pump station.





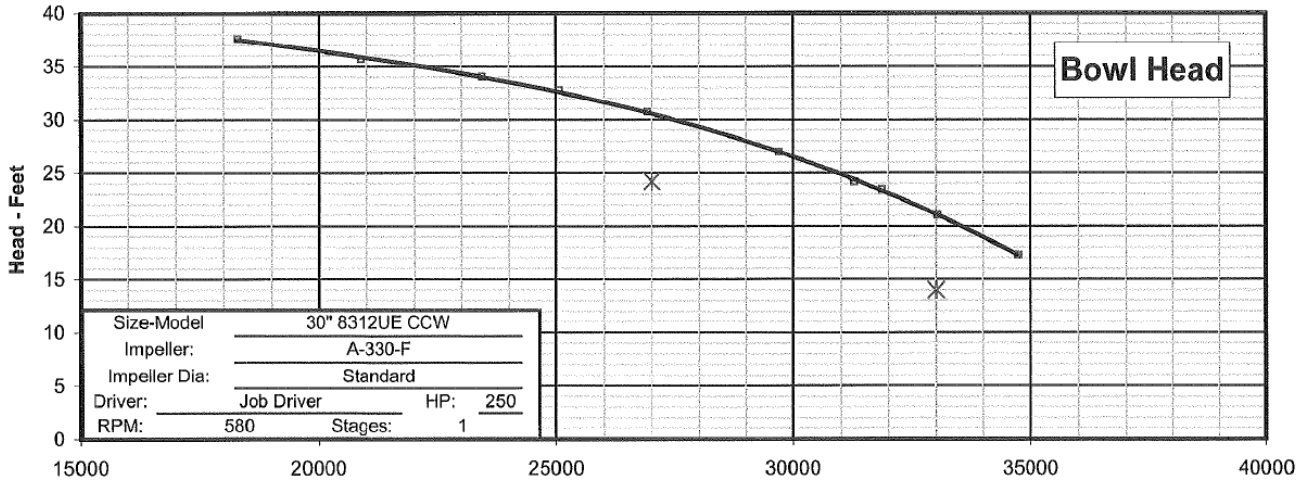
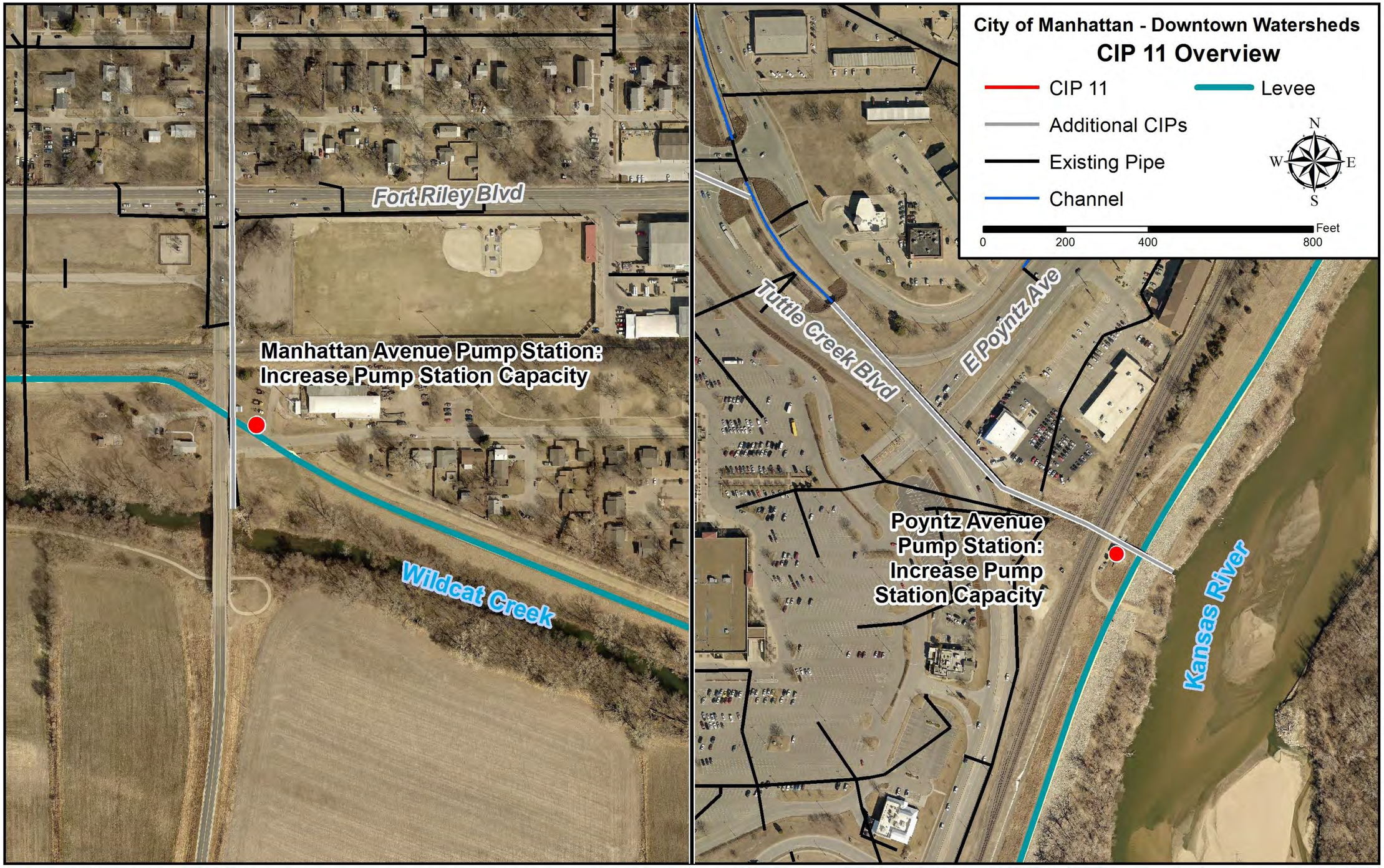


Table 6-12: CIP Project Summary Sheet for CIP 11

Total Length (ft)	Proposed CIP
-	South Manhattan Pump Station Capacity Improvements
-	Poyntz Avenue Pump Station Capacity Improvements

Figure 6-11: CIP 11 Overview



CIP 12 – Leavenworth Street Collector

Overview

Phase II Project
Located within Downtown East Watersheds
Total Cost Estimate: $3,839,197
Prerequisite Projects: CIP 7

Relevant Flooding Issues

Surcharging in systems to the north and to the west creates overflow that causes flooding in the area along Juliette Avenue, along Fremont Street, and along Leavenworth Street.

Recommended Improvements

System capacity along portions of Leavenworth Street, Juliette Avenue, and Fremont Street would be increased. The outfall structure would be directed into the Tuttle Creek Channel south of Leavenworth Street. Moving the outfall out of the existing Leavenworth Street structure downstream into the channel is key to increasing capacity of the overall system. The following map provides an overview of this CIP. This project would reduce surcharging along Juliette Avenue, Fremont Street, and Leavenworth Street.

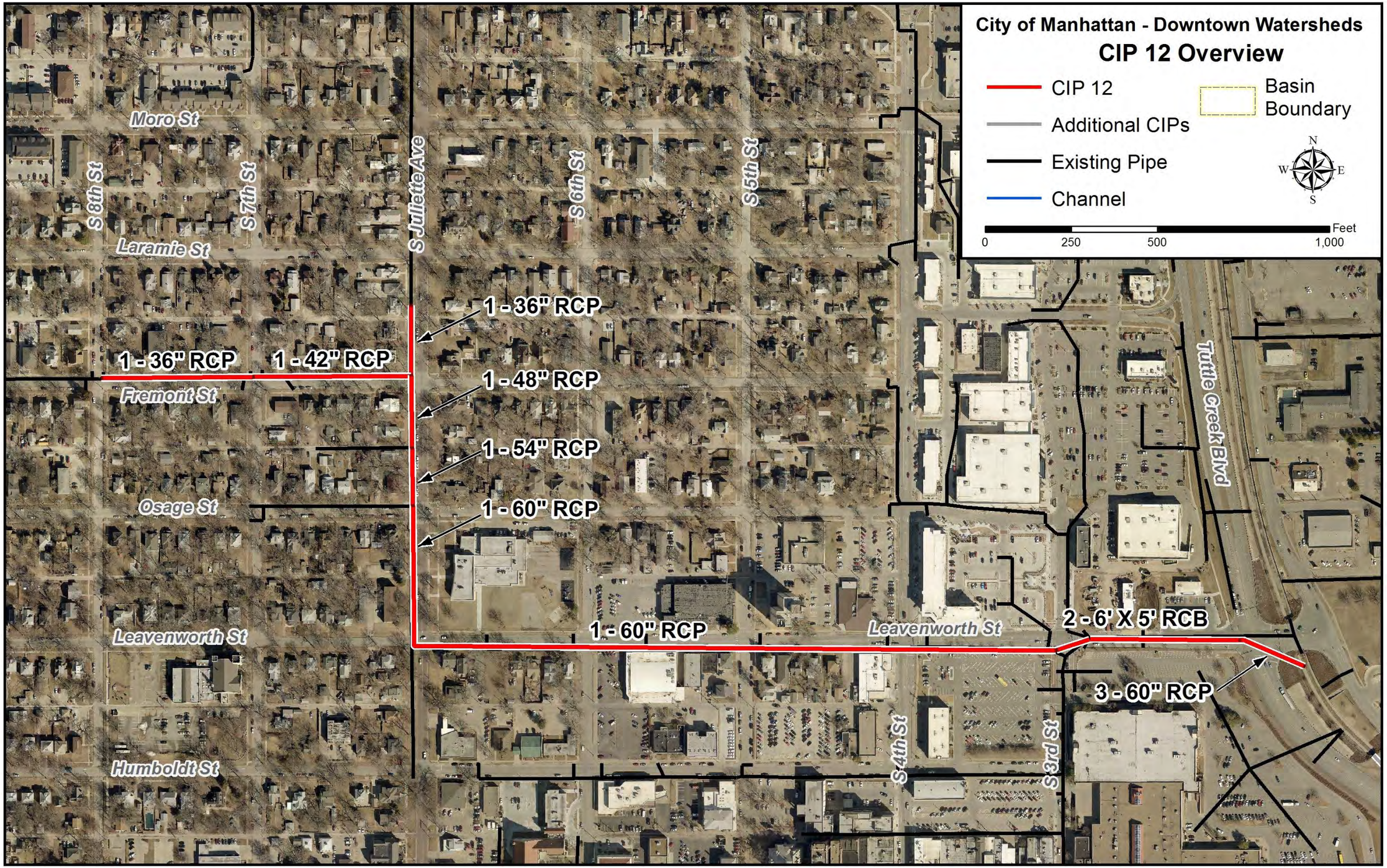
Special Considerations

In addition to redirecting the system's outfall into the channel, cost estimates for the structure through Tuttle Creek Boulevard were considered with boring and jacking included. This is based on the assumption that complete closure of Tuttle Creek Boulevard is not feasible.

Table 6-13: CIP Project Summary Sheet for CIP 12

Total Length (ft)	Proposed CIP
539	2 - 6' X 5' RCB with Inlets & Manholes
200	3 - 60" RCP (Bored & Jacked)
2,270	1 - 60" RCP with Inlets & Manholes
168	1 - 54" RCP with Inlets & Manholes
211	1 - 48" RCP with Inlets & Manholes
460	1 - 42" RCP with Inlets & Manholes
643	1 - 36" RCP with Inlets & Manholes

Figure 6-12: CIP 12 Overview



CIP 13 – Anderson-Tecumseh-Quivera Collector – Phase 1

Overview

Phase II Project
Located within Downtown West Watersheds
Total Cost Estimate: $8,341,680
Prerequisite Projects: CIP 5, 6

Relevant Flooding Issues

Surcharging in systems to the west creates overflow that causes flooding in the area along Denison and Bluemont Avenues.

Recommended Improvements

CIP 13 would involve increasing the system capacity along Anderson Avenue up to the previously proposed Tecumseh-Quivera project. The following map provides an overview of this CIP. By carrying the increased capacity down Anderson Avenue, the project would prevent surcharges from the upstream system improvements.

Special Considerations

This CIP is anticipated to be designed and constructed a number of years in the future from the completion of this report. While this CIP certainly has benefits, and is a prerequisite project to CIP 14 which also has benefits, the two projects should be closely evaluated to verify that a positive benefit cost ratio exists at the beginning of the design phase.

Table 6-14: CIP Project Summary Sheet for CIP 13

Total Length (ft)	Proposed CIP
1,936	2 - 12' X 4' RCB with Inlets & Manholes
260	2 - 10' X 4' RCB with Inlets & Manholes
369	2 - 8' X 4' RCB with Inlets & Manholes

Figure 6-13: CIP 13 Overview

CIP 14 – Anderson-Tecumseh-Quivera Collector – Phase 2

Overview

Phase II Project
Located within Downtown West Watersheds
Total Cost Estimate: $3,934,902
Prerequisite Projects: CIP 5, 6, 13

Relevant Flooding Issues

Surcharging in systems to the north and to the west creates overflow that causes overflow in the area along Juliette Avenue and along Bluemont Avenue.

Recommended Improvements

CIP 14 would involve increasing the system capacity along Hunting Avenue, Sunset Avenue, College Heights Road, Quivera Drive, and Tecumseh Road. This project covers the extent of the previously proposed Tecumseh-Quivera project. The following map provides an overview of this CIP. By carrying the increased capacity, the project would intercept surcharges from the upstream stormwater system.

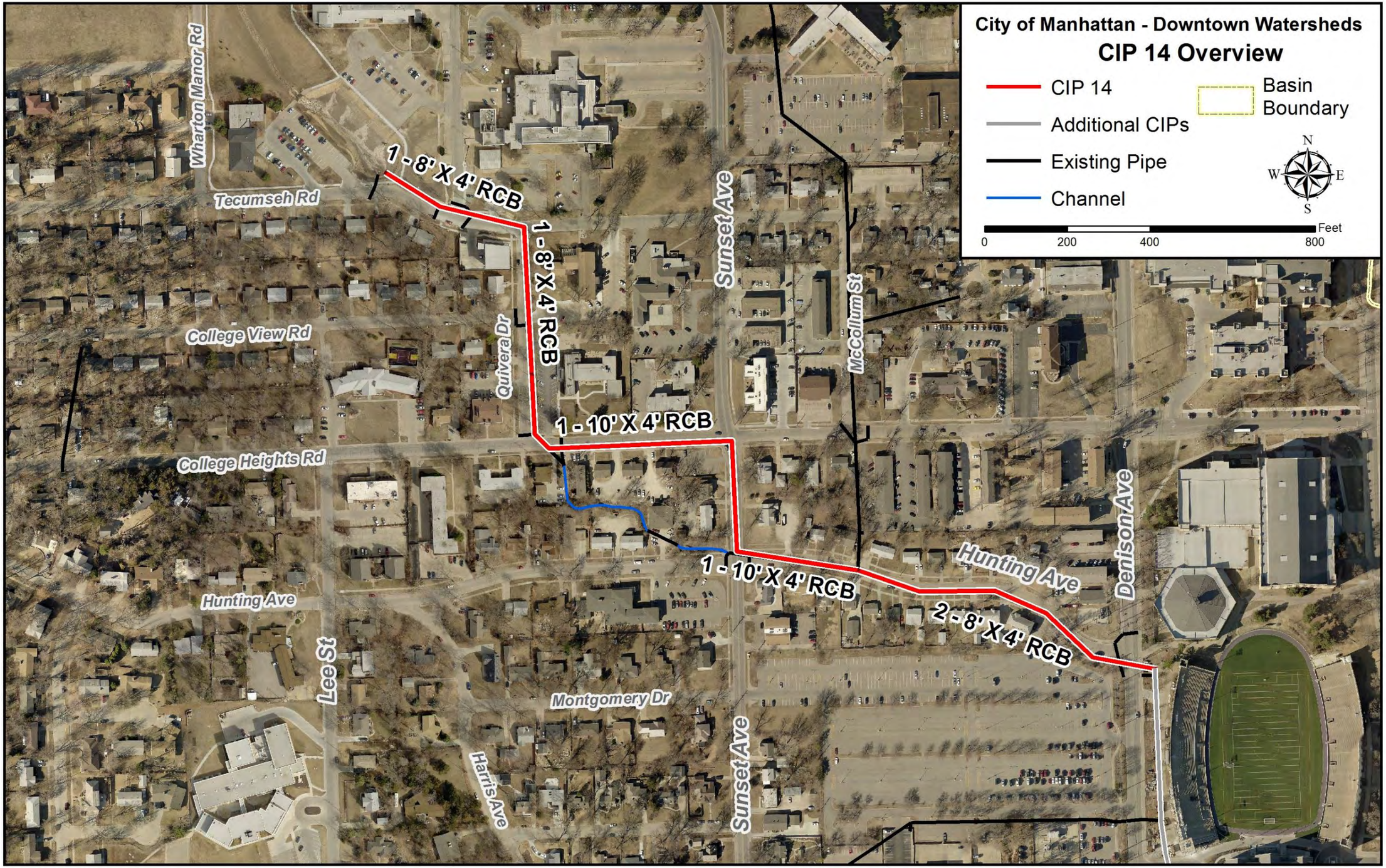
Special Considerations

Design of this project was based on the proposed Tecumseh-Quivera project. Stormwater plans were provided by the City, which were utilized in determining pipe sizes for this system. This CIP is anticipated to be designed and constructed a number of years in the future from the completion of this report. While this CIP certainly has benefits, this project should be closely evaluated to verify that a positive benefit cost ratio exists at the beginning of the design phase.

Table 6-15: CIP Project Summary Sheet for CIP 14

Total Length (ft)	Proposed CIP
785	2 - 8' X 4' RCB with Inlets & Manholes
1,202	1 - 10' X 4' RCB with Inlets & Manholes
722	1 - 8' X 4' RCB with Inlets & Manholes

Figure 6-14: CIP 14 Overview



7. Conclusions and Recommendations

Flooding of the downtown area has the potential to produce a variety of negative impacts, as was seen in the May 2015 flooding event. The magnitude of these impacts is dependent on the frequency, intensity, extent, and timing of the storm event. It also depends heavily on tail water conditions at the levee system. Negative impacts would also depend on the capacity and condition of the City's stormwater system at the time of a flood event. It is therefore critical that the City work to maintain the existing system, as well as implement improvements to better handle flood events.

After evaluating the performance of the City's existing stormwater system throughout the Downtown East and West Watersheds, Amec Foster Wheeler recommends the implementation of the various CIPs presented in this report.

The 14 CIPs listed below are recommended for implementation throughout the downtown watersheds. The implementation of these CIPs will address multiple system deficiencies across the watersheds.

CIP 1 – Poyntz Avenue / Houston Street Interceptor
CIP 2 – Tuttle Creek North Channel Improvements – Phase 1
CIP 3 – Tuttle Creek North Channel Improvements – Phase 2
CIP 4 – Lower Kearney Street Collector
CIP 5 – South Manhattan Interceptor
CIP 6 – 14th Street Interceptor
CIP 7 – Tuttle Creek South Outlet Improvements
CIP 8 – Middle Kearney Street Collector
CIP 9 – Upper Kearney Street Collector
CIP 10 – Bluemont Avenue Collector
CIP 11 – Poyntz / South Manhattan Station Improvements
CIP 12 – Leavenworth Street Collector
CIP 13 – Anderson-Tecumseh-Quivera Collector – Phase 1
CIP 14 – Anderson-Tecumseh-Quivera Collector – Phase 2

All proposed improvements are proposed and sequenced in a way to decrease flooding at all locations within the City. The CIPs presented in this report are intended to provide preliminary sizing, routes and costs that can be utilized to begin the design phase of each project. Adjustments to the final design may be required, though flow capacity should be maintained within the design. In general, CIPs should be implemented in the order that they are presented for reasons discussed within this report.

8. References

(1) *SewerGEMS Urban Sanitary and Combined Sewer Modeling Version 08.11.05.58*, Bentley, Haestad Methods Solution Center, Watertown, CT, 2015.

(2) National Oceanic and Atmospheric Administration, *Atlas 14 Volume 8 Precipitation Frequency Estimates*, 2013.

(3) National Weather Service: http://water.weather.gov/precip/about.php

(4) Kansas Mesonet Manhattan Station: http://mesonet.k-state.edu/metadata/ http://mesonet.k-state.edu/weather/historical/#!

(5) Additional Rainfall Reports:
http://www.weather.gov/top/HeavyRainAndFlashFloodingMay42015

http://floodlist.com/america/usa/record-rain-causes-flash-floods-kansas-texas

http://fox4kc.com/2015/05/05/kansas-state-university-floods-due-to-large-amounts-of-rain/

http://cjonline.com/news/2015-05-04/manhattan-sees-record-rainfall-one-day-after-storm-brings-flooding

https://weather.com/forecast/regional/news/flood-threat-drought-plains-may2015

(6) USGS Gage data: http://nwis.waterdata.usgs.gov/ks/nwis/inventory/?site_no=06879820&agency_cd=USGS

(7) Vertcon Datum Conversion: http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl

(8) 2015 Riley County, Kansas LiDAR Project, Sanborn Map Company, Colorado Springs, CO, 2015.

(9) Lidar Base Specification, Chapter 4 of Section B, USGS Survey Standards, Book 11, Collection and Delineation of Spatial Data, USGS National Geospatial Program, November 2014

(10) Big Blue and Kansas River, Manhattan-Kansas, Flood Protection Project, Operation and Maintenance Manual, Section I, U.S. Army Corps of Engineers, Kansas City, 1963. (Amended August 2012)

(11) City of Manhattan Stormwater Management Master Plan Manhattan, BG Consultants and Burns & McDonnell, 1995

(12) City of Manhattan (Stormwater Inventory, Parcel Data, Aerial Imagery etc.)

(13) Manhattan, KS Levee Certification, Appendix E, Interior Drainage Analysis Report, Manhattan Levee Project. AMEC Environment & Infrastructure, August 2012

(14) Hydrologic Analysis of Interior Areas, USACE Engineering Manual 1110-2-1413, Jan 15 1987.

(15) TR-55

(16) National Engineering Handbook, Section 4, Soil Conservation Service, 1972

(17) Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/.

9. Appendices

9.1 Appendix A – Map Products

9.1.1 Existing Conditions Inundation Plots

9.1.2 Existing Conditions Flood Depth Plots

9.1.3 Proposed Conditions Inundation Plots

9.1.4 Proposed Conditions Flood Depth Plots

9.2 Appendix B – Digital Data

The following data has been provided to the City of Manhattan on an external thumb drive:

9.2.1 Digital Copy of Report

9.2.2 SewerGEMS Models

9.2.2.1 Existing Conditions SewerGEMS Model

9.2.2.2 Proposed Conditions SewerGEMS Model

9.2.3 Inundation Shapefiles

9.2.4 Depth Grids

9.2.5 Drainage Ditch HEC-RAS model (contains both existing and proposed conditions flows)