City of Santa Ana

Sewer Master Plan Update

Final Report

Prepared by:

RMC
water and environment

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List of Abbreviations

ADWF	Average Dry Weather Flow
APN	Assessor Parcel Number
BWF	Base Wastewater Flow
CCTV	Closed-Circuit Television
CIP	Capital Improvement Program or Capital Improvement Plan
CIPP	Cured-in-Place Pipe
City	City of Santa Ana
CMMS	Computerized Maintenance Management System
d/D	Ratio of flow depth to pipe diameter
DEM	Digital Elevation Model
DWF	Dry Weather Flow
ENR CCI	Engineering News Record Construction Cost Index
EPA	U.S. Environmental Protection Agency
fps	Feet per second
FY	Fiscal Year
GIS	Geographic Information System
gpd	Gallons per day
GWI	Groundwater Infiltration
HDPE	High Density Polyethylene (Pipe)
I/I	Infiltration and Inflow
MFR	Multi-Family Residential
mgd	Million Gallons per Day
MH	Manhole
NASSCO	National Association of Sewer Service Companies
OCSD	Orange County Sanitation District
PACP	Pipeline Assessment and Certification Program
PDWF	Peak Dry Weather Flow
PS	Pump Station
PVC	Polyvinyl Chloride (Pipe)
PWWF	Peak Wet Weather Flow
QSR	Quick Structural Rating

RCP	Reinforced Concrete Pipe
RDI/I	Rainfall Dependent Infiltration and Inflow
RMC	RMC Water and Environment
R/R	Rehabilitation/Replacement
SFR	Single Family Residential
SSES	Sewer System Evaluation Survey
SSMP	Sewer System Management Plan
SSO	Sanitary Sewer Overflow
VCP	Vitrified Clay Pipe
WWF	Wet Weather Facility or Wet Weather Flow
WWPF	Wet Weather Peaking Factor

Report Organization

The contents of each of the chapters and appendices of this Master Plan report are described below.

Executive Summary

The Executive Summary provides a brief, stand-alone summary of the Master Plan report, with emphasis on the major findings and recommendations.

Chapter 1- Introduction

This introductory chapter provides a description of the City's sewer system and service area, background on previous studies and regulatory history and current situation, the objectives and scope of the Master Plan, and the contents and organization of this report.

Chapter 2 – Basis of Planning

This chapter discusses the basis for the Master Plan in the context of regulatory and legal requirements, industry best practices, and the City's desired level of service to its customers. The chapter describes the methodology and criteria utilized for the City's Priority Pipe Rating Model, which was used to set priorities for the Master Plan CIP.

Chapter 3 – Capacity Assessment

This chapter describes the modeled sewer system, development of the model network and sewershed areas, basis for estimating model flows, and the calibration of the model for dry and wet weather conditions. This chapter also defines the basis for the capacity assessment of the system, including the design rainfall event and performance criteria; describes the identified capacity deficiencies based on the model results; and presents the needed capacity improvements.

Chapter 4 – Condition Assessment

This chapter describes the City's CCTV inspection program and summarizes the condition assessment of the system based on inspection data collected by the City and associated contractors.

Chapter 5 – Recommended Capital Improvement Program

This chapter presents the sewer projects that are recommended for inclusion in the City's 5-year CIP based on the results of the capacity and condition assessments and application of the Pipe Rating Model. The CIP includes a recommended schedule for project implementation and associated capital costs that will form the basis for updates, if needed, to the City's financial plan for the sewer system. Recommendations for project implementation are also provided.

The appendices to the report provide additional detailed information to support the findings and recommendations presented in the report chapters, including model calibration plots, selected model hydraulic profiles, and detailed tabulation of pipe rating model factors and scores.

Executive Summary

This report presents the results and recommendations of the Sewer Master Plan Update for the City of Santa Ana (City). The report was prepared by RMC Water and Environment (RMC) under an agreement with the City of Santa Ana. The Master Plan evaluates the capacity and condition of the City's sanitary sewer system and establishes the basis for the City's ten-year sewer system Capital Improvement Program (CIP).

ES-1 Existing Sewer System and Service Area

The study area for this Master Plan consists of the City of Santa Ana (City) and portions of Garden Grove and Orange that discharge wastewater into the City's sewer system. As of 2015, the City had an estimated population of 335,264 and a projected year 2040 population of 343,766, per CDR, 2015. The City is situated in the middle of Orange County along the Santa Ana River, and the largest city in Orange County, covering approximately 27.2 square miles. The City is now largely built out, with only a few areas of potential new redevelopment, primarily along the Harbor Boulevard corridor, areas west of Tustin Avenue, south of 6th Street to the I-5 Freeway, and areas bounded by First Street, Flower Street, Civic Center Drive, and Grand Avenue.

The City's sewer collection system consists of approximately 450 miles of sewer mains, including approximately 60 miles of OCSD trunk sewers within the City. The City's sewer system, shown in **Figure ES1-1**, operates largely by gravity and discharges at several locations into gravity trunk sewers owned and maintained by the Orange County Sanitation District (OCSD). Some of these OCSD trunk sewers serve only areas within the City, but others serve areas outside the City. All the OCSD sewers in the City collect and convey wastewater to the OCSD Treatment Plant Number 1 located just southwest of the City in Fountain Valley.

The majority of the City's sewers were built in the 1950s and 1960s, and are now over 60 years old. Portions of the City's sewer system date back to the 1920s, with sewers over 90 years old. The material of construction of the City's sewers has generally been vitrified clay until about 1992. Since that time, PVC plastic pipe has been used for sewers up to 12 inches in diameter. Vitrified clay pipes (VCP) makes up over 83 percent of the 97 miles of major sewers included in the capacity analysis. The remaining 17 percent consists of other material types or unknown materials. As a result of the 2003 Sewer Master Plan, the City has undertaken an effort to gradually replace or repair portions of the City's sewers that were identified as having capacity issues or condition defects.

The capacity analysis performed in this Sewer Master Plan Update applies to 97 miles of those sewers, including all the sewers indicated as major sewers in **Figure ES1-1**, and the OCSD trunk sewers that serve the City sewer service area. The sewers to be included in the model were jointly selected by City staff and RMC. The sewers to be indicated as minor sewers in **Figure ES1-1** are small sewers (6 or 8 inches in diameter) serving areas generally under 25 acres. The capacity of these small sewers is typically more than adequate, and they are therefore excluded from capacity analysis performed at the master planning level. The City's two lift stations (Maxine and Segerstrom) were included in the hydraulic model as part of this Sewer Master Plan Update.

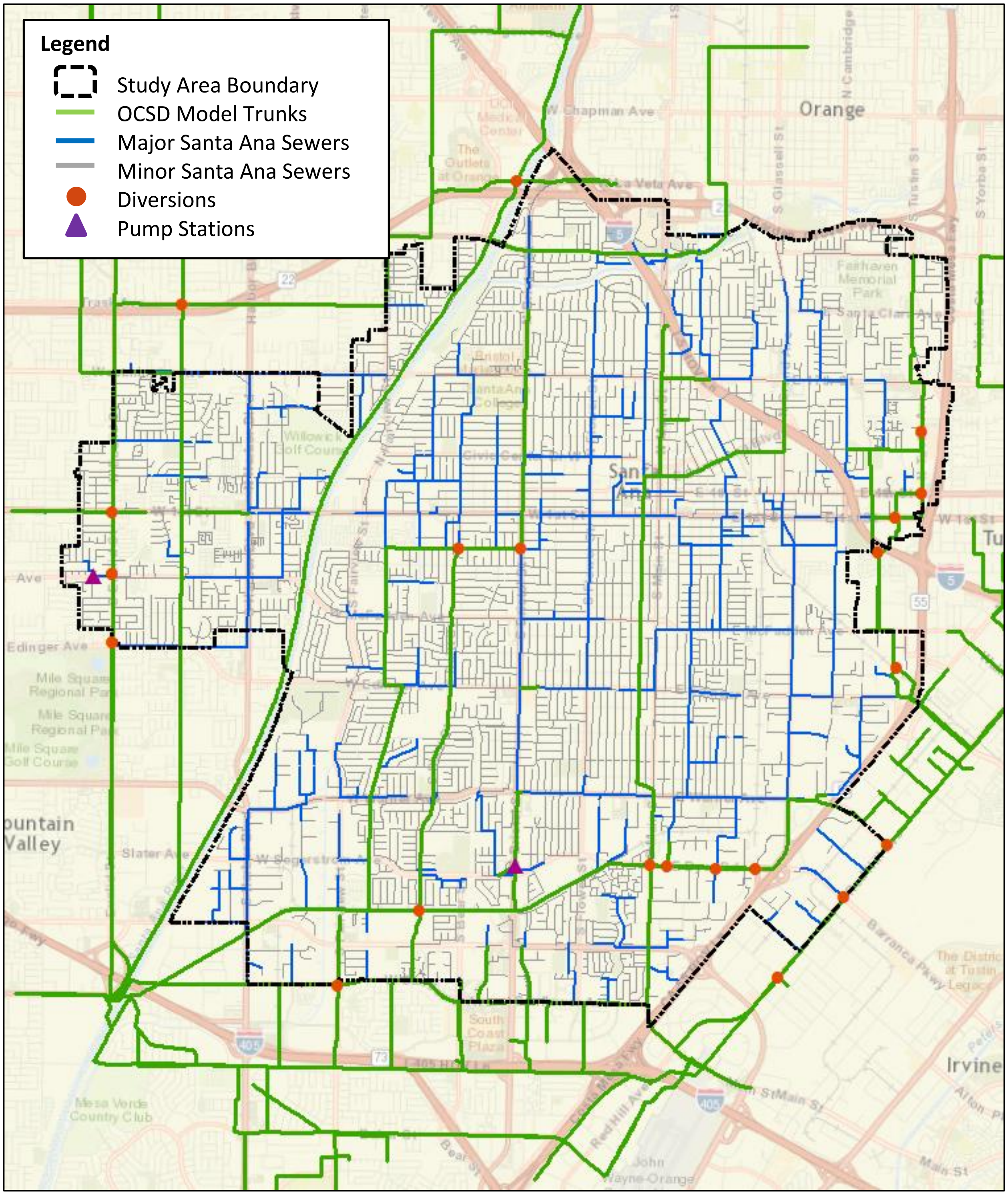


Figure ES1-1: City of Santa Ana Existing Sewer Collection System

ES-2 Background and Master Plan Objectives

The City last performed a Sewer Master Plan in 2003. The two main objectives of the 2003 Sewer System Master Plan were to: assess the hydraulic capacity of major sewers and lift stations with a dynamic computer model, and proactively identify required improvements to ensure adequate capacity for current and projected future wastewater flows; and perform a study to determine the extent of infiltration/inflow (I/I) of groundwater and storm water into the City's sewers, and recommend appropriate actions to address any identified I/I problems.

The City has experienced growth and changes to the City's General Plan since the 2003 Sewer Master Plan. Some of these changes include the Harbor Specific Plan, the Transit Zone Plan and several District Specific Zone modifications. Several of the Priority 1 Projects included in the 2003 Sewer Master Plan have been constructed. In addition, the City has implemented a sewer lining program by which more than 55,000 feet of main sewer lines have been lined. Since 2003, the City has also prepared the Sewer System Management Plan (SSMP) dated 2009 and the 2013 Sewer System Management Plan Internal Audit. In addition, the City in 2004 adopted a comprehensive Fats, Oils, and Grease (FOG) control program. Along with these addition plans and programs, the City has been performing a system-wide video inspection every eight years, which was last completed in 2010. The existing 2003 Sewer Master Plan needs to be updated to address these changes and additional information.

The City requires an update of the 2003 Sewer Master Plan to reflect subsequent growth/changes in the City's General Plan, reflect subsequent sewer improvements, and include the most recent CCTV inspections and Enhanced Maintenance Locations. The 2016 Sewer Master Plan Update shall analyze the age of the sewer infrastructure, and the capacity of the City's sewer collection system for existing and future peak flow conditions under both dry and wet weather conditions. In addition, this project shall include the summary of the rankings of the condition of the sewer pipes/manholes and the recommended rehabilitation and replacement of these sewers based on the most recent CCTV inspection reports.

A Capital Improvement Program (CIP) shall be developed to address identified hydraulic capacity deficiencies and structural deficiencies that are a risk of collapse or prone to more frequent blockages due to pipe defects. The primary focus of this project is to evaluate the collections system overall conditions and to provide new methods empowering the City staff to perform duties more effectively and efficiently. The primary tasks of the Sewer Master Plan Update are to:

- Use parcel-level water consumption billing records and income-based diurnal profiles to ensure accurate and detailed dry weather flows with only a small number of calibration meters.
- Use wet weather flow data from past Orange County Sanitation District (OCSD) and City flow monitoring programs, supplemented by a small number of wet weather flow meters in locations with potential capacity deficiencies, to cost-effectively incorporate the effects of the City's relatively low infiltration and inflow (I/I).
- Use City GIS data, field surveys, and digital elevation models to ensure that the capacity of the existing system is accurately represented.

- Integrate OCSD trunk sewers and flows into Santa Ana's hydraulic model to account for backwater from OCSD trunks and potentially identify cost-effective diversions and joint projects with OCSD.
- Use a risk-based condition assessment process to identify and prioritize sewer rehabilitation and replacement improvements based on impact as well as condition.
- Develop CIP recommendations that take into account City funding limitations as well as capacity, maintenance and structural deficiencies.
- Provide tools and data used in the risk-based maintenance and condition assessments as well as modeling software and data.
- Confirm that the system has adequate capacity to handle peak wet weather flows, as required for the System Evaluation and Capacity Assurance Plan element of the SSMP
- Establish a firm basis for project priorities and budgets in the City's 5-year Capital Improvement Program

ES-3 Basis of Planning

This Sewer Master Plan Update utilizes the information that the City has collected through its maintenance, inspection, and monitoring activities to perform an assessment of system condition and capacity; and utilizes the results of those assessment to identify and prioritize sewer system capital improvement needs. The basic tool used to develop the CIP is the Pipe Rating Model, which was developed for this project, assigns a risk score to each pipe in the system, and provides a means of prioritizing pipes for rehabilitation and replacement.

The risk of asset failure is calculated by quantifying the likelihood of failure (LOF) and consequence of failure (COF) for each sewer asset. LOF is the probability of asset failure, which can be a result of a structural failure, capacity deficiency, or maintenance issue that causes a blockage or overflow. COF is defined as the impact on level of service resulting from asset failure. The risk of failure is defined as:

Risk = LOF x COF

The following four LOF indicators were used in the Pipe Rating Model:

- Structural Condition
- Capacity Deficiency
- Regional I/I Issues
- Maintenance Condition

The following three COF indicators were used in the Pipe Rating Model:

- Flow Volume
- Community Impact.
- Environmental Impact

A scoring system was developing to quantify each of these factors based on relevant parameters (e.g., number and type of defects observed from sewer inspection; extent of sewer surcharge predicted by hydraulic modeling; location with respect to busy streets, commercial areas, creeks and drainage channels; etc.), and assign relative weights to each factor. The risk scores were then calculated for each pipe and used to establish priorities for rehabilitation and replacement. The City will also be able to use the Pipe Rating Model to update CIP needs and priorities on an ongoing basis as additional data is collected and conditions in the system change over time.

ES-4 Capacity Assessment

The capacity of the City's sewer system was assessed through use of an InfoWorks™ ICM hydraulic model. The hydraulic model includes all major trunk lines with diameters ranging from 10 to 39-inches. The model also includes connected OCSD interceptor and trunk lines which provide a contiguous network model for analyzing the hydraulic capacities. In total, the model network includes approximately 97 miles of City pipelines, 20 miles of OCSD trunks with diameters ranging from 10 to 39-inches and a total of 1,799 manholes. The hydraulic model includes the City's two major pump stations: Maxine and Segerstrom pump stations.

The City's sewer service area was divided into 516 sewersheds, called "subcatchments", ranging in size from 5 to 140 acres. Each subcatchment "loads" to a manhole in the modeled network and is used to capture the population-based base flows, and inflow and infiltration flows.

The data used to build the model network and associated attributes was obtained from the City's GIS, existing Santa Ana model network, the latest OCSD hydraulic model, and relevant as-built drawings of recent sewer improvements. The GIS includes the locations of sewer manholes and sewer mains; manhole IDs and rim elevations; and pipe diameters, lengths, material, and invert elevations. After the model network was defined, a procedure was followed to populate the model database, validate the network data, and create a fully connected network, as follows:

- The modeled network was checked for connectivity. This means that all manholes are connected by pipes, and that pipes are connected in the correct direction (from upstream to downstream) to create a fully-connected system.
- Manhole and pipe attribute data were populated based on rim, invert, length, and diameter data from the GIS. Where necessary, nominal diameters for pipes identified as HDPE or slip-lined VCP were converted to pipe inside diameter for modeling.
- Subcatchments were delineated to define areas tributary to the modeled pipe network. Each subcatchment was assigned to a manhole in the modeled system to define where the model load from that subcatchment enters the modeled sewer system.
- Global parameters which are required by the model were populated, such as manhole diameters (assumed to be 4 feet), Manning's 'n' (assumed to be 0.013 for all pipes), and headloss factors.

Existing residential base wastewater flows for Santa Ana were estimated using annual water use data compiled at the parcel level and then aggregated by model subcatchment. The total residential and non-residential BWF for each model subcatchment were calculated by summing the BWF for all parcels within that subcatchment. The dry weather flow calibration used flow data obtained from 8 meter sites installed during the period from March 4, 2015 through March 25, 2015.

The hydraulic model incorporated dry weather flows based on Year 2010 U.S. Census data and future (2015 to 2040) population and employment projections (2014 Orange County Projections, or OCP) by Traffic Analysis Zone (TAZ) developed by the Cal State Fullerton Center for Demographic Research (CDR) and allocated to each of the subcatchments.

The population projections were supplemented with additional development projections provided by the City's planning department. The effort resulted in a total of 15 significant developments being identified. Comparative analysis, as well as working with CDR and local planning staff was conducted to determine if the proposed development projects were included in the 2014 OCP population projections for Year 2040. Proposed projects currently under review by the City include the Harbor Corridor Plan, the Transit Zoning Code area, and the Metro East Mixed Use Overlay Zone.

The capacity of the system was assessed for existing and future (2040) base flow scenarios in addition to peak wet-weather flows (PWWF) derived from a 10-year design storm condition. Since the design storm peak wet weather flow (PWWF) represents a relatively infrequent return period event, the City considers it acceptable to allow surcharging over the pipe crown, provided the hydraulic grade line (water level) remains at least five feet below the ground surface. During peak dry weather conditions, however, sewers should be able to convey the peak flow without surcharge.

The hydraulic model was used to simulate flows for the design event and identify areas of the Santa Ana trunk sewer system that fail to meet the specified performance criteria during existing and future (2040) PWWF. No capacity deficiencies in the system were identified for dry weather conditions.

Figure ES4-1 shows the location of predicted surcharged sewers for the projected 2040 flow and peak wet-weather flow (PWWF) scenario. These surcharged pipes can increase the risk of sewer overflows occurring during significant rainfall events. Pipes shown in red are surcharged due to “throttle” conditions, indicating the full pipe capacity is less than the predicted peak flow. In these conditions, the hydraulic grade line exceeds the pipe slope indicating the pipe has in-sufficient capacity to convey peak flows. Pipes shown in blue also depict surcharging (ie; water level exceeding the pipe crown) which is caused by downstream throttle condition. It should be noted that the location of model-predicted surcharging may not reflect the actual locations where overflows would occur, due to other physical conditions (e.g., root intrusion or debris) that are not reflected in the model, or system storage that is available in the smaller diameter, un-modeled pipes. It should also be noted that the City has not reported any wet weather overflows in recent years.

The most significant areas of potential wet weather capacity deficiencies identified in the model are between Fairhaven Avenue and 17th Street running through Old Grand Street, to Santa Clara Avenue, and then onto Wright Street in the northeastern area of the City. Predicted peak flows result in surcharging with depths ranging from 2 to 5-feet above pipe crown, with some manholes less than 5-feet of freeboard.

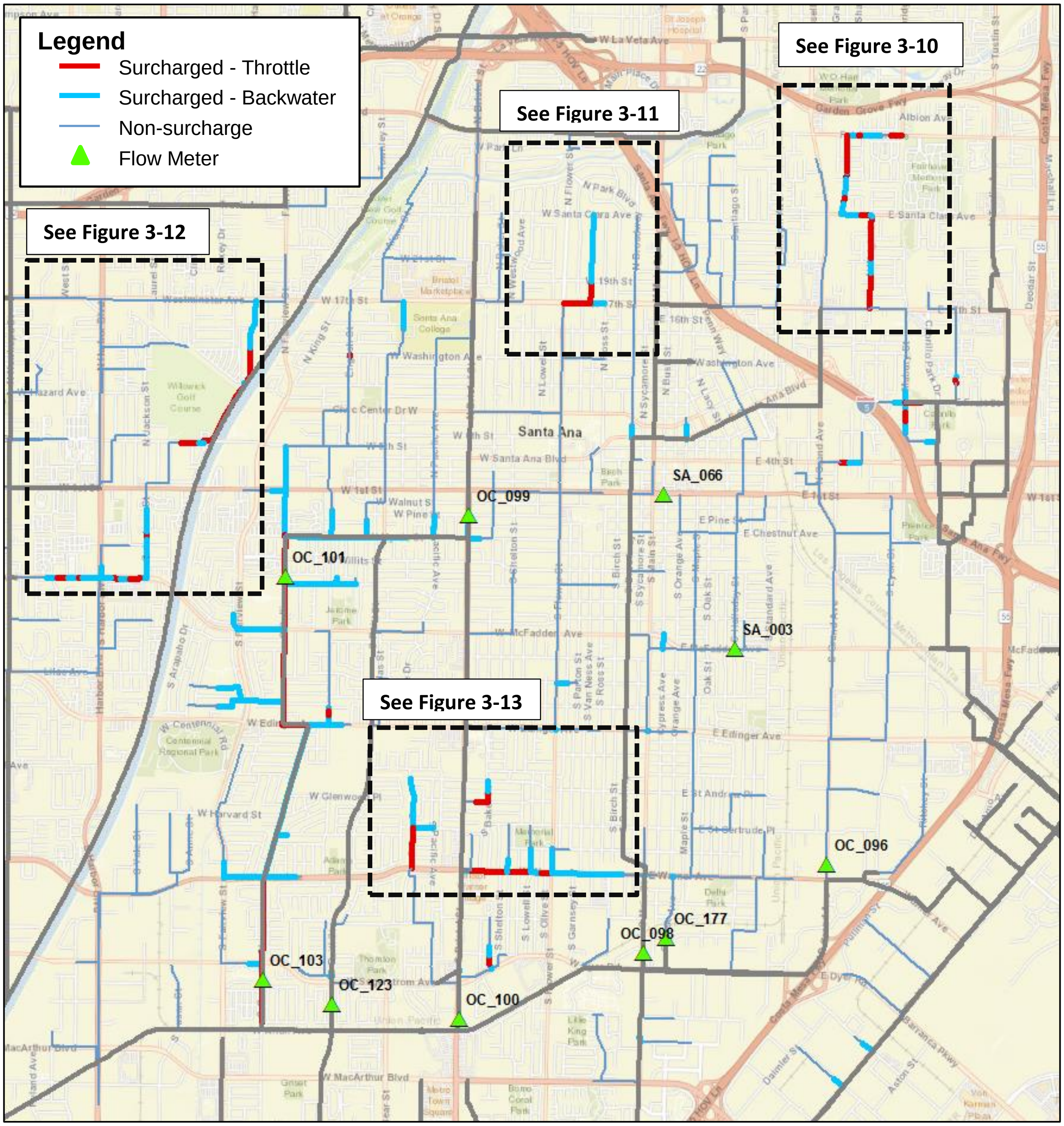


Figure ES4-1: Predicted Surcharge Pipes for Future Flows (2040) and PWWF

ES-5 Condition Assessment

CCTV inspection is the basic method used by the City to gather the data required to assess sewer condition. The City uses a specialist CCTV contractor to inspect pre-defined portions of the City's sewer system with the target of inspecting the entire system over a 5 to 8-year period. The CCTV contractor

(Houston & Harris) uses a NASSCO compliant standards and relevant software to capture and grade the pipe conditions.

This study included a 'spot-check' review of the CCTV inspection data to provide an independent assessment of the accuracy and consistency of the condition scores provided by the CCTV contractor. The review identified excessively high defect scores resulting from unusually long continuous defects (eg; longitudinal cracks). These defects, classed as Multiple Cracks (CM), are logged into the inspection software by starting and stopping a counter which measures the length of the defect. However, in some cases, the logging process was not stopped providing long CM defects resulting in excessively high defect scores. The spot check review identified 37 pipes with structural grade 4 or 5 defects. From this list, 10 pipes were identified with grading errors typically resulting from 'unclosed' CM defects. As a result from this analysis, the City requested the CCTV contractor to re-evaluate the inspection data and fix any outstanding errors. The updated inspection data was used to update the QSR scores in the City's GIS.

For purposes of evaluating the structural condition grade, a scoring system that consolidates the PACP grades was developed for this study. The scoring system provides a single 'Composite Condition Score' which ranges from 0 – 10 and accounts for multiple defect ratings and the number of defects. The number of defects that 'trigger' a high score were derived from discussions with the City and are shown below.

- Grade 1 Defect Count Trigger: 30
- Grade 2/3 Defect Count Trigger: 15
- Grade 4/5 Defect Count Trigger: 3

The results of the condition assessment for the City are presented in **Figure ES5-1** which shows a map of the Composite Condition Scores for each inspected sewer pipe. The map shows pipes with significant condition defects (depicted by the red and orange pipes) located in the central part of the City including the downtown area. This area is known to have older pipes compared to the outer neighborhoods and consequently has more defect issues. The results of the condition assessment analysis specifically the Consolidated Condition Score was used to calculate the Likelihood of Failure (LOF) as part of the Pipe Rating analysis.

ES-6 Recommended Capital Improvement Program

The Pipe Rating Model was used to calculate the total risk score for each pipe and prioritize the CIP projects. The risk scores represent the product of the Likelihood of Failure (LOF) and Consequence of Failure (COF) for each sewer pipe, considering its structural condition, capacity requirements, size, location, and other risk factors, as described in Chapter 2. The risk of asset failure is calculated by quantifying the likelihood of failure (LOF) and the consequence of failure (COF) of a sewer asset. The likelihood of failure is the possibility of asset failure and is synonymous with the "probability" of failure. The consequence of failure is defined as the impact on level of service resulting from asset failure. The risk equation is defined as follows:

Risk = [(Likelihood) x (Consequence)]

The scores generated from the analysis are weighted to emphasize a greater importance in pipe condition which drive future R&R projects. The weighting factors were presented and discussed with City staff and reevaluated to ensure critical pipe issues are ranked high in the eventual prioritized CIP project list.

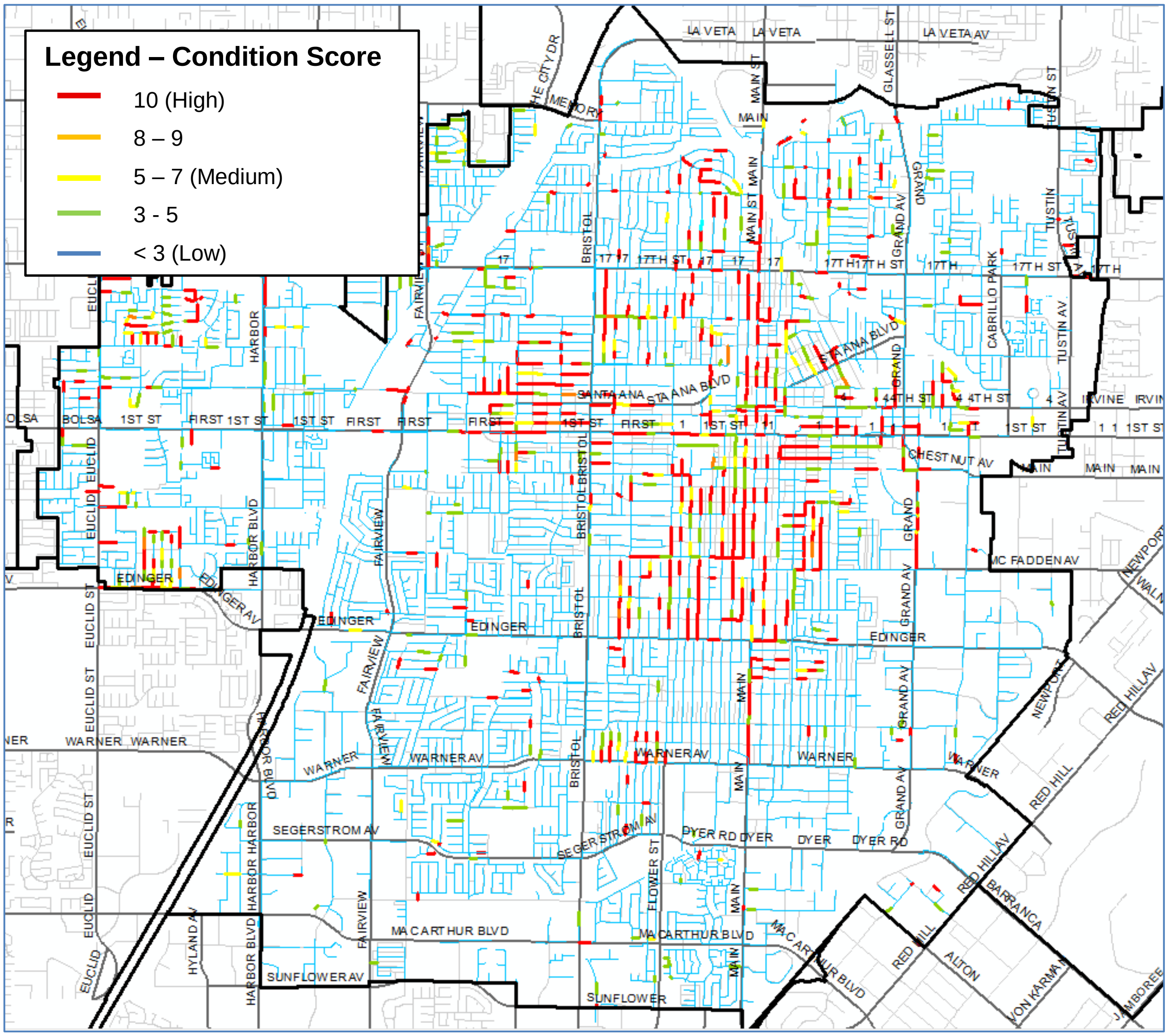


Figure ES5-1: Condition Assessment Map showing Composite Condition Scores

Capital improvement projects for sewer infrastructure are typically divided into two categories: 1) condition-based improvement projects utilizing replacement or rehabilitation (R&R) strategies, and 2) capacity improvement projects utilizing pipe upsizing or flow diversions (if applicable). Projects are triggered when; 1) existing pipe condition indicates risk of structural failure, and 2) existing and future flow projections exceed current hydraulic capacities. For this study, both condition and capacity projects were developed using a systematic process based on the following logical steps:

- Is the pipe surcharged resulting from insufficient capacity? If so, upsize pipe to convey future peak wet-weather flow (PWWF) projections.
- Has the pipe recently been lined? If so, then no project required but recommend on-going pipe inspection (CCTV).

- Does the pipe have major defects? (Weighted condition score = 5). If so, replace the pipe. If pipe is included in a planned capacity improvement project, then upsize pipe to meet future flow projections.
- Does the pipe have minor defects? (Weighted condition score < 1). If so, then no project required but recommend on-going pipe inspection (CCTV).
- Is it cheaper to replace than conduct spot repairs or lining? If so, replace pipe accordingly.
- Are spot repairs required? (Local grade 4 or 5 defects). If so, conduct spot repairs.
- Line remaining pipes NOT meeting the above criteria.

For purposes of grouping pipes into sewer rehabilitation projects, the improvement projects identified through the decision process were assigned to “mini-basins” delineated by Traffic Area Zone (TAZ) areas. The TAZ areas provide a mechanism for bundling pipe improvements into manageable projects which benefit from efficient cost savings through combined construction mobilization, collective and organized street closures, bulk cost savings for materials and equipment rentals and overall design and construction cost savings.

Capital improvement projects are prioritized to allocate available funds to critical projects based on risk of failure and level of impact to economic, social and environment issues. Similar to many public agencies, the City has an annual budget for replacing or rehabilitating aging infrastructure and therefore requires a systematic and defensible method for prioritizing both capacity and condition-based improvement projects. For this study, the improvement projects are based on the following factors:

- Priorities are applied to ‘bundled’ projects grouped by the ‘mini-basins’.
- Initially, projects are prioritized using the normalized and maximum risk scores derived from the Pipe Rating Model analysis.
- Capacity projects are ‘triggered’ when peak wet-weather flows (PWWF) exceed existing pipe capacities for 2015 flows overriding priorities derived from risk scores.
- Distribute capital improvement projects over a 5-year program with a total budget of $20m.

Based on the environmental and regulatory impact of sewer spills, capacity projects triggered on existing (2015) flows were considered a high priority and consequently superseded the risk scores derived from Pipe Rating Model. As a result, bundled projects delineated via the mini-basins that contain high priority capacity projects were separately identified on the CIP project list and elevated to the top of the project list with the exception of two rehabilitation projects driven by high condition ratings.

Table ES6-1 presents the recommended 5-year CIP developed by RMC and City staff by application of the four guiding criteria described above, and **Figure ES6-1** shows the location of the proposed projects. The City may elect to modify the CIP schedule as needed to accommodate budget constraints and changes in project priorities as additional inspection data and other information are collected over time. Such information may include the need for coordination with street paving or other infrastructure or utility projects; need to address new or recurring maintenance problems in the system; or specific data provided by OCSD as to priority areas for focusing I/I reduction efforts.

Capital improvement projects were identified for all pipes in the City’s collection system based on both hydraulic and structural defects. **Appendix D** shows all proposed projects ordered by risk score (percent) and risk grade. The total cumulative cost for completing all CIP projects is $93.2M allocated over a 25-year period. In addition, the projects are grouped into proposed 5-year budget cycles based on a $20M CIP budget allocated every 5-years. The cost estimate does not account for increased design and construction costs.

Table ES6-1: Recommended 5-Year Sewer System CIP

CIP Priority	Budget Year	CIP ID	Sewer Improvement Cost	Lateral Cost	Total Cost	Capacity Project ID	Cumulative Budget
1	FY 16/17	714	$3,729,070	$873,660.80	$4,602,731	CIP-CAP-002	$4,602,731
2	FY 17/18	784	$1,357,238	$440,933	$1,798,171	CIP-CAP-005	$6,400,902
3	FY 17/18	783	$456,390	$138,701	$595,091	CIP-CAP-007	$6,995,992
4	FY 17/18	785	$1,965,592	$168,254	$2,133,846		$9,129,839
5	FY 17/18	702	$175,965	$54,502	$230,467		$9,360,306
6	FY 18/19	793	$961,975	$284,685	$1,246,660	CIP-CAP-006	$10,606,966
7	FY 18/19	794	$462,387	$8,960	$471,347	CIP-CAP-006	$11,078,313
8	FY 18/19	711	$773,824	$251,941	$1,025,765	CIP-CAP-001	$12,104,078
9	FY 18/19	704	$876,383	$288,341	$1,164,724	CIP-CAP-001	$13,268,802
10	FY 18/19	757	$456,841	$158,912	$615,753		$13,884,555
11	FY 19/20	731	$119,186	$18,253	$137,439		$14,021,993
12	FY 19/20	815	$321,927	$82,706	$404,633		$14,426,626
13	FY 19/20	810	$299,146	$6,590	$305,736		$14,732,362
14	FY 19/20	752	$709,570	$197,104	$906,674		$15,639,036
15	FY 19/20	749	$1,017,023	$297,768	$1,314,791		$16,953,827
16	FY 19/20	701	$452,238	$10,214	$462,452		$17,416,280
17	FY 20/21	786	$1,235,857	$319,819	$1,555,676		$18,971,956
18	FY 20/21	744	$237,911	$57,818	$295,729		$19,267,685
19	FY 20/21	718	$990,358	$285,837	$1,276,195		$20,543,879
20	FY 20/21	717	$1,892,098	$545,131	$2,437,229		$22,981,109
		TOTAL:	**$18,490,979**	**$4,490,130**	**$22,981,109**		

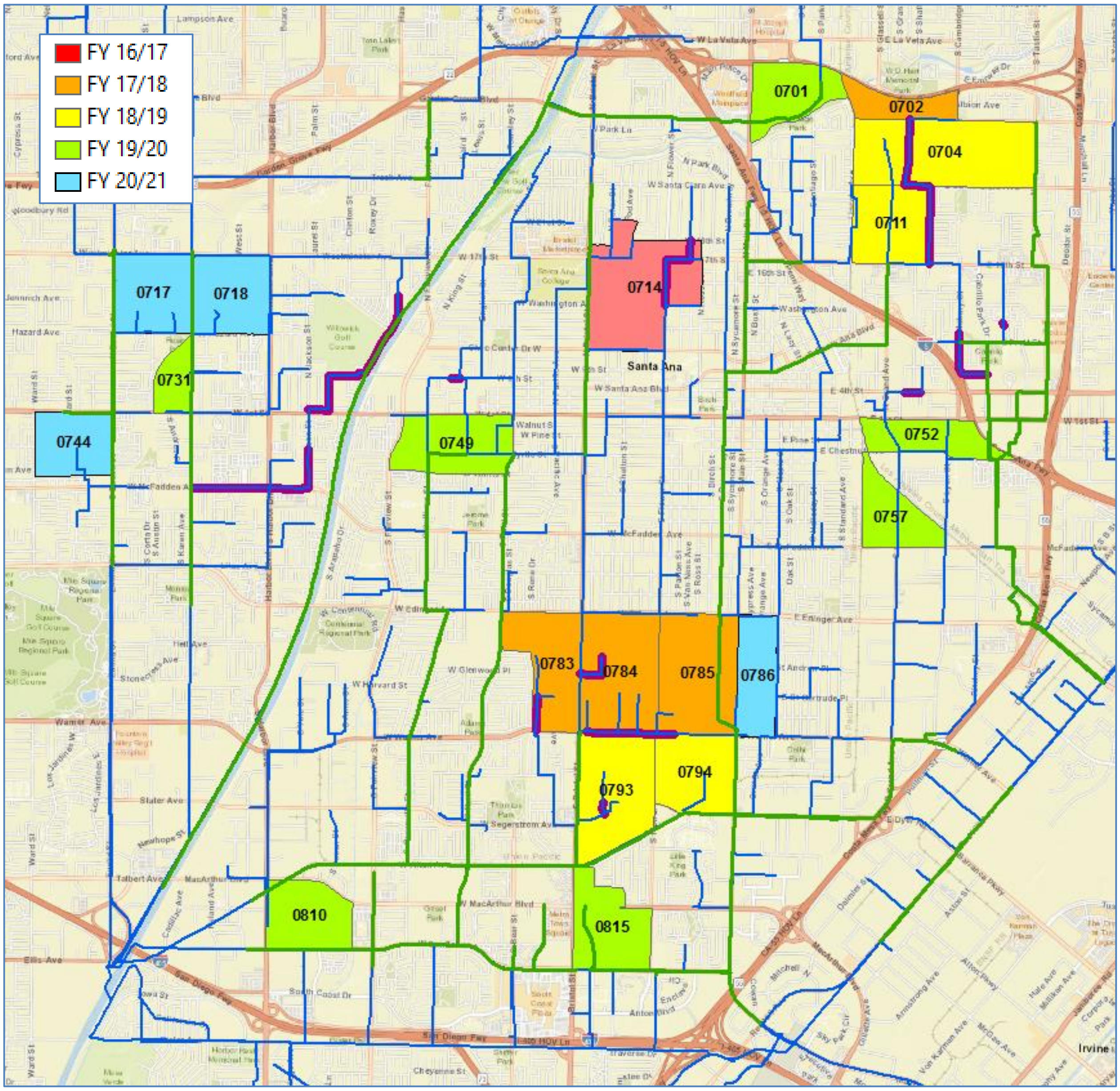


Figure ES6-1: Recommended 5-Year Sewer System CIP

Chapter 1 Introduction

This report presents the results and recommendations of the Sewer Master Plan Update for the City of Santa Ana (City). The report was prepared by RMC Water and Environment (RMC) under an agreement with the City dated August 05, 2014. This introductory chapter provides background information on the City's sewer system and service area, discusses the objectives and scope of the Master Plan Update, and describes the contents and organization of the Master Plan Update report.

1.1 Study Area

The study area for this Master Plan, shown in **Figure 1-1**, consists of the City of Santa Ana and small portions of the Cities of Garden Grove and Orange that discharge wastewater into the City's sewer system. As of 2015, the City had an estimated population of 335,264 and a projected year 2040 population of 335,605. Santa Ana is situated in the middle of Orange County along the Santa Ana River, the City of Santa Ana is one of the most populous largest cities in Orange County, covering approximately 27.2 square miles. Santa Ana is bounded on the north by the Cities of Garden Grove and Orange, on the east by the Cities of Tustin and Irvine, on the south by the City of Costa Mesa, and on the west by the Cities of Westminster and Fountain Valley.

Residential areas, which are primarily located in the central, northern and part of the western portions of the City, represent a large percentage of the City's land uses. Commercial uses are spread out along major corridors such as Harbor Boulevard, Bristol Street, Main Street, and Grand Avenue in the north/south direction and Seventeenth Street and First Street in the east/west direction. Industrial uses are concentrated in the southeastern and southwestern areas of the City.

The city is now largely built out, with only a few areas of potential new development, primarily along the Harbor Boulevard corridor, areas west of Tustin Avenue, south of 6th Street to the I-5 Freeway, and areas bounded by First Street, Flower Street, Civic Center Drive, and Grand Avenue.

1.2 Existing Sewer System

The City's existing sanitary sewer system is shown in **Figure 1-2**. The City's sewer system operates largely by gravity, and discharges at several locations into gravity trunk sewers owned and maintained by the Orange County Sanitation District (OCSD). Some of these OCSD trunk sewers serve only areas within the City, but others also serve large area outside the City. All the OCSD trunk sewers in the City convey wastewater to the OCSD Treatment Plant Number 1 located just southwest of the City in Fountain Valley.

The City's sewer collection system consists of approximately 390 miles of sewer mains, including approximately 60 miles of OCSD trunk sewers within the City. The capacity analysis performed in this Sewer Master Plan Update applies to 97 miles of those sewers, including all the sewers indicated as major sewers in **Figure 1-2**, and the OCSD trunk sewers that serve the City sewer service area. The sewers to be included in the model were jointly selected by City staff and RMC. The sewers to be indicated as minor sewers in **Figure 1-2** are small sewers (6 or 8 inches in diameter) serving areas generally under 25 acres. The capacity of these small sewers is typically more than adequate, and they are therefore excluded from capacity analysis performed at the master planning level. The City's two lift stations (Maxine and Segerstrom), however were included as part of this Sewer Master Plan Update.

Portions of the City's sewer system date back to the 1920s, however most of the City's sewers were built in the 1950s and 1960s, and are now 30 to 50 years old. The majority of the City's older sewers were built in the 1920s and are now about 80 years old. As a result of the 2003 Sewer Master Plan, the City has undertaken an effort to gradually replace or repair portions of the City's sewers that were identified as having capacity issues or condition defects. The age of sewers will be a consideration, along with their physical condition and hydraulic capacity, as part of the condition assessment portion of this Master Plan Update in supporting decisions on whether to replace or rehabilitate the sewers.

The material of construction of the City's sewers has generally been vitrified clay until about 1992. Since that time, PVC plastic pipe has been used for sewers up to 12 inches in diameter. Vitrified clay pipes (VCP) makes up over 83 percent of the 97 miles of major sewers included in the capacity analysis. The remaining 17 percent consists of other material types or unknown materials.

Table 1-1: Sewer System Inventory

Pipe Size (inch)	Count	Length (feet)	Length (Miles)	Percent of Total
< 6	42	5,275	1.0	1.0
6	630	196,877	37.3	38.9
8	741	180,790	34.2	35.7
10	174	45,120	8.5	8.9
12	114	29,222	5.5	5.8
14	4	1,201	0.2	0.2
15	84	22,542	4.2	4.4
18	13	4,687	0.8	0.9
21	43	12,840	2.4	2.5
24	6	750	0.1	0.1
27	9	3,289	0.6	0.6
30	6	1,841	0.4	0.4
33	4	1,874	0.4	0.4
48	1	365	0.1	0.1
TOTAL	**1871**	**506,672**	**96.0**	**100.0**

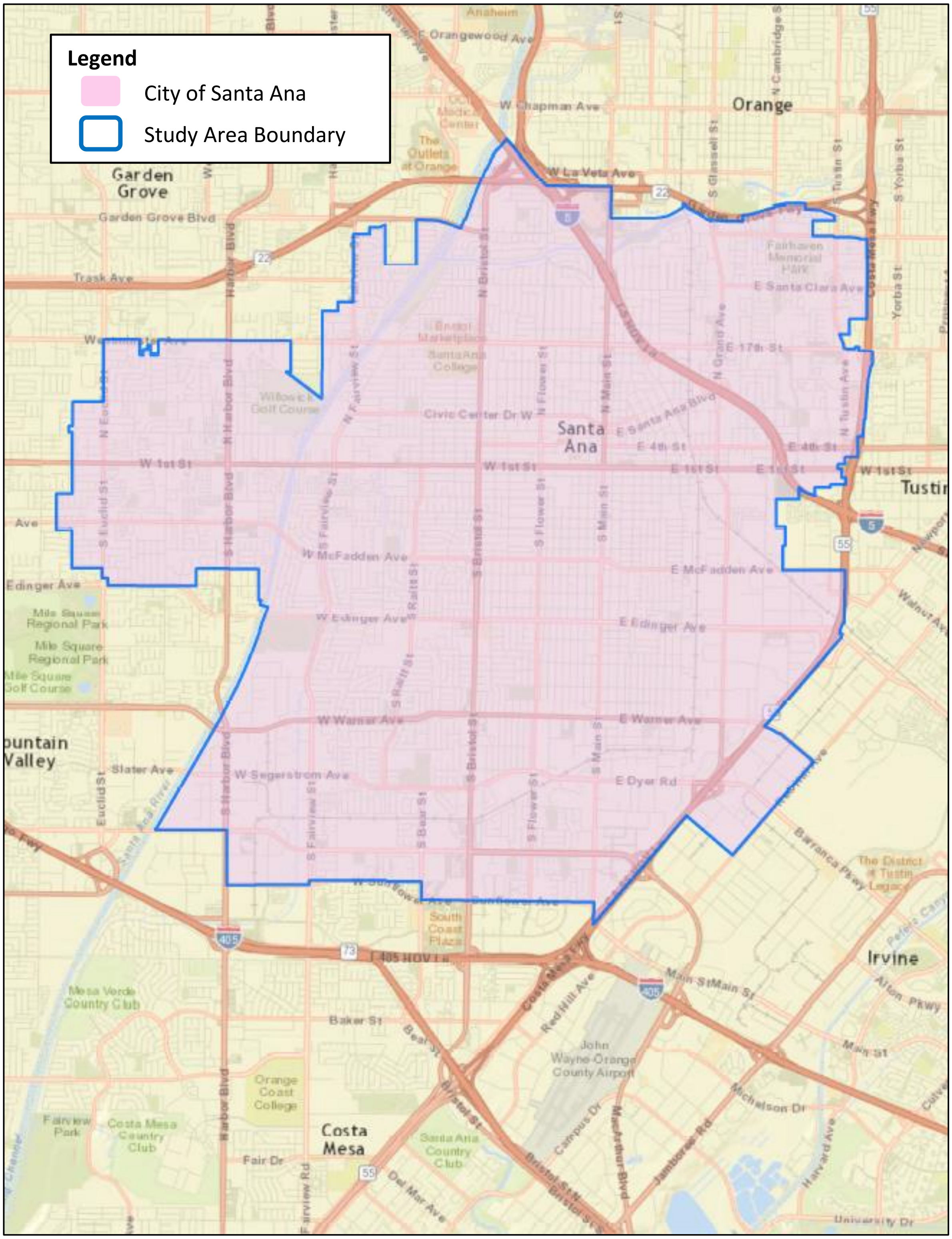


Figure 1-1: Study Area

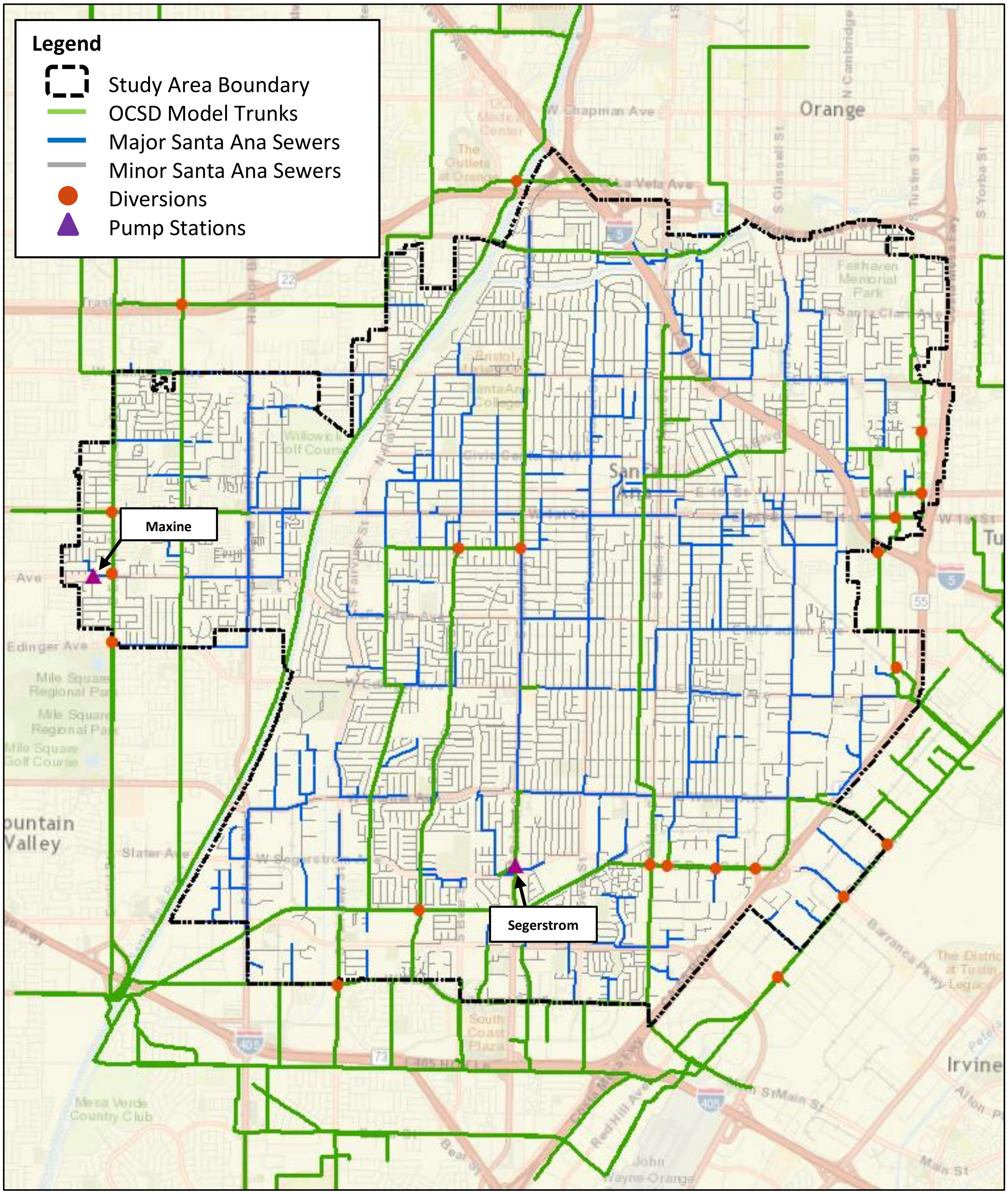


Figure 1-2: Existing Sewer (Collection) System

1.3 Background

The City last performed a Sewer Master Plan in 2003. The two main objectives of the 2003 Sewer System Master Plan were to: assess the hydraulic capacity of major sewers and lift stations with a dynamic computer model, and proactively identify required improvements to ensure adequate capacity for current and projected future wastewater flows; and perform a study to determine the extent of infiltration/inflow (I/I) of groundwater and storm water into the City's sewers, and recommend appropriate actions to address any identified I/I problems.

The City has experienced growth and changes to the City's General Plan since the 2003 Sewer Master Plan. Some of these changes include the Harbor Specific Plan, the Transit Zone Plan and several District Specific Zone modifications. Several of the Priority 1 Projects included in the 2003 Sewer Master Plan have been constructed. In addition, the City has implemented a sewer lining program by which more than 55,000 feet of main sewer lines have been lined. Since 2003, the City has also prepared the Sewer System Management Plan (SSMP) dated 2009 and the 2013 Sewer System Management Plan Internal Audit. In addition, the City in 2004 adopted a comprehensive Fats, Oils, and Grease (FOG) control program. Along with these addition plans and programs, the City has been performing a system-wide video inspection every eight years, which was last completed in 2010. The existing 2003 Sewer Master Plan needs to be updated to address these changes and additional information.

1.4 Study Objectives

The City requires an update of the 2003 Sewer Master Plan to reflect subsequent growth/changes in the City's General Plan, reflect subsequent sewer improvements, and include the most recent CCTV inspections and Enhanced Maintenance Locations. The 2016 Sewer Master Plan Update (Project) shall analyze the age of the sewer infrastructure, and the capacity of the City's sewer collection system for existing and future peak flow conditions under both dry and wet weather conditions. In addition, this project shall include the summary of the rankings of the condition of the sewer pipes/manholes and the recommended rehabilitation and replacement of these sewers based on the most recent CCTV inspection reports.

A Capital Improvement Program (CIP) shall be developed to address identified hydraulic capacity deficiencies and structural deficiencies that are a risk of collapse or prone to more frequent blockages due to pipe defects. The primary focus of this project is to evaluate the collections system overall conditions and to provide new methods empowering the City staff to perform duties more effectively and efficiently. The primary tasks of this Sewer Master Plan Update are to:

- Use parcel-level water consumption billing records and income-based diurnal profiles to ensure accurate and detailed dry weather flows with only a small number of calibration meters.
- Use wet weather flow data from past Orange County Sanitation District (OCSD) and City flow monitoring programs, supplemented by a small number of wet weather flow meters in locations with potential capacity deficiencies, to cost-effectively incorporate the effects of the City's relatively low infiltration and inflow (I/I).
- Use City GIS data, field surveys, and digital elevation models to ensure that the capacity of the existing system is accurately represented.

- Integrate OCSD trunk sewers and flows into Santa Ana's hydraulic model to account for backwater from OCSD trunks and potentially identify cost-effective diversions and joint projects with OCSD.
- Use a risk-based condition assessment process to identify and prioritize sewer rehabilitation and replacement improvements based on impact as well as condition.
- Develop CIP recommendations that take into account City funding limitations as well as capacity, maintenance and structural deficiencies.
- Provide tools and data used in the risk-based maintenance and condition assessments as well as modeling software and data.
- Confirm that the system has adequate capacity to handle peak wet weather flows, as required for the System Evaluation and Capacity Assurance Plan element of the SSMP
- Establish a firm basis for project priorities and budgets in the City's 5-year Capital Improvement Program

These objectives, and the basis of planning for the Master Plan, are discussed in more detail in Chapter 2 of this report.

1.5 Scope of Study

The scope of the Master Plan Update, as well as a brief discussion of work conducted under each task, is described below.

- **Task 1 –Data Collection and Review Existing Information.** This task involved reviewing maps, documents, and data related to the sewer system, including the City's GIS files; plans and reports; maps and drawings of sewer system facilities and recent sewer improvement projects; water use and customer account data; historical flow monitoring data; the City's General Plan and other relevant planning information; and sewer maintenance and CCTV inspection data.
- **Task 2 – Develop Sewer System Model.** In this task, a hydraulic model of the City's trunk sewer system was developed using InfoWorks™ ICM software. The hydraulic model includes all major sewer mains appropriate for hydraulic modeling. All of the sewer mains modeled in the 2003 Sewer Master Plan were included in the update. All OCSD trunks originating within the City are also included in the model. The two existing lift stations will not need to be analyzed by the update. The lift stations shall be included in the model only to transport the flows downstream.
- **Task 3 – Develop Wastewater Flows.** In this task, sewersheds (subcatchments) were delineated to define areas loading to the model, and flow loads to the model were determined using water use data and factors characterizing diurnal BWF patterns and I/I. Existing sewer base flows were derived from water billing data. Future flows were derived from population projections supplemented with future development projects identified and approved by the City.
- **Task 4 – Flow Monitoring.** Conduct flow monitoring to obtain dry and wet-weather flow data to be used for model calibration. Ten sites were selected to capture flow data across the City's service area connected to the OCSD trunk system. Conduct additional flow metering to capture potential wet-weather flows during the 2015 / 2016 El Nino wet season.
- **Task 5 – Sewer System Capacity Analysis.** The hydraulic model was used to assess the hydraulic capacity of the sewer system for existing and future flow scenarios. Peak wet-weather flows were

generated for a 10-year design storm and used to evaluate hydraulic issues occurring during rainfall events. Capacity improvements to resolve capacity deficiencies were identified and tested in the model, along with associated costs.

- **Task 6 – Summarize CCTV Inspection Results.** This task involved assessing the condition of the existing sewer system and developing a recommended program for sewer rehabilitation and replacement (R/R). The condition of the system was assessed based on closed-circuit television (CCTV) inspection data collected by the City since 2008. The Pipe Rating Model to prioritize sewers for rehabilitation, was developed to evaluate risk of failure and consequence of failure. The Pipe Rating model was then applied to the City's CCTV, maintenance, and GIS inventory databases to generate scores for each pipe and identify priorities for rehabilitation.
- **Task 7 – Capital Improvement Program.** Based on the results of Tasks 5 and 6, a 5-year CIP was developed for recommended capacity improvements (if needed) and sewer R/R. The estimated cost of the proposed CIP was compared to the City's current and required sewer replacement rate and associated annual budgets. An estimate was also developed of the amount of sewer replacement and budget required for R/R of the remaining portions of the sewer system not addressed in the 5-year CIP.
- **Task 8 – Deliverables and Project Management.** This report was prepared to present the results and recommendations of the study.

Chapter 2 Basis of Planning

The overall purpose of this Sewer Master Plan is to establish the basis for the City's Capital Improvement Program (CIP) for its sanitary sewer system for the next ten years. The Master Plan supports the City's goals for the management and operation of its sanitary sewer system, which include:

- Identifying existing and future hydraulic deficiencies accounting for planned growth and development within the City.
- Identify condition-based deficiencies and establish a replacement and rehabilitation program for maintaining the structural integrity of the sewer system.
- Updating the City's CIP with projects driven by capacity and condition-based needs and prioritizing CIP projects based on economic, social and environmental impacts
- Customer service, such that no capacity-related spills occur for storm conditions that do not exceed the City's design event; and such that spills and backups caused by sewer blockages are minimized to the greatest extent possible.
- Replacement of sewer assets in a manner that minimizes asset failures and reduces the amount of infiltration and inflow that enters the City's sewer system and the OCSD interceptors.

This Sewer Master Plan utilizes the information that the City has collected through its maintenance, inspection, and monitoring activities to perform an assessment of system condition and capacity; and utilizes the results of those assessments to identify and prioritize sewer system capital improvement needs. This chapter describes the data and tools that support the Sewer Master Plan efforts and the methodology for utilizing that data to develop priorities for sewer rehabilitation and replacement.

2.1 Data and Tools

This study utilized multiple data and tools to conduct the hydraulic analysis, evaluate pipe condition, and prioritize CIP projects. These include:

- ArcGIS - geographic information system data that provides multiple data layers including sewer mains and manholes with attribute information on all manholes and pipes in the collection system, including pipe diameters, rim and invert elevations, pipe material, and year of construction or rehabilitation.
- InfoWorks ICM - a hydraulic model of the sewer system used to analyze existing and future capacities.
- CCTV - closed-circuit television inspection reports and databases with associated videos and image files for sewer main CCTV inspections collected by the City's CCTV contractor.
- Pipe Rating Model – tool used to assign risk scores to each pipe based on likelihood and consequence of failure factors and provides a means of prioritizing pipes for rehabilitation and replacement. The Pipe Rating Model, described below, was the key tool used for project prioritization for this Sewer Master Plan and was refined and updated as part of the Master Plan work. Multiple tools were evaluated to conduct the pipe rating analysis including ArcGIS ModelBuilder and InfoMaster. InfoMaster was selected as this provided the required functionality and is currently being used for other City projects.

2.2 Pipe Rating Model

The methodology embodied in the Pipe Rating Model is based on guidelines recommended by the National Association of Clean Water Agencies (NACWA).[1] The methodology involves quantifying and assessing the risks posed by the failure or inability of the sewer system to provide the level of service needed to meet the City's sewer system management goals. Using this approach, risk scores can be calculated for each sewer pipe individually. Individual pipe scores can be then be analyzed for groups of pipes to prioritize sewer rehabilitation or replacement projects.

The risk of asset failure is calculated by quantifying the likelihood of failure (LOF) and the consequence of failure (COF) of a sewer asset. The likelihood of failure is the possibility of asset failure and is synonymous with the "probability" of failure. The consequence of failure is defined as the impact on level of service resulting from asset failure. The risk equation is defined as follows:

Risk = [(Likelihood) x (Consequence)]

2.2.1 Likelihood of Failure Categories

Two indicators of likelihood of failure were utilized in the Pipe Rating Model:

- Structural Condition: Structural condition was determined based CCTV inspection results, as stored in the WinCan CCTV database. If CCTV inspection data did not exist for a pipe segment, then the likelihood of failure was estimated based on pipe segment age. Structural condition is a strong indicator of likelihood of failure and was heavily weighted.
- Capacity Deficiency: This likelihood of failure factor is calculated from hydraulic modeling results. Sewers that are predicted to be heavily surcharged or potentially overflowing under a design event peak wet weather flow condition were considered to have a high likelihood of failure due to capacity deficiency.

2.2.2 Consequence of Failure Categories

Three consequence categories were developed for the Pipe Rating Model:

- Economic Impact: Larger sewer spills or failure of a sewer asset serving a large tributary area can have a significant impact on the community, environment, and cost to respond and affect a greater number of people. The size of the sewer was chosen as an indicator of the potential impact of large spills or failure of a major sewer asset.
- Community Impact: Sewer failures can significantly impact commuters, commercial areas, public facilities, and the community in general. Asset location in major roads, commercial areas, and near schools, parks, and public buildings were used as indicators of potential community impact.
- Environmental Impact: Sewer overflows that reach surface waters can adversely impact water quality and the environment. Distance to surface water was used as an indicator of the potential environmental impact of a sewer spill.

2.2.3 Risk Score Calculations

The Pipe Rating Model utilizes data directly from the GIS, hydraulic model (InfoWorks ICM) and CCTV inspection data scores as used for this Master Plan to compute LOF scores. Community and environmental

[1] National Association of Clean Water Agencies, *Implementing Asset Management: A Practical Guide*, 2007

COF scores were derived from GIS mapping. The risk score calculations were derived within the InfoMaster software and can be displayed on GIS maps.

Figure 2-1 is a conceptual diagram of the Pipe Rating Model framework, illustrating the calculation of asset risk scores. **Table 2-1** and **Table 2-2** present the scoring criteria and weights for the LOF and COF categories, respectively. More detail on the capacity assessment (basis for capacity deficiency LOF factor) and condition assessment (basis for structural condition LOF factor) are provided in Chapters 3 and 4 of this report. The overall risk score results are presented in Chapter 5 and used in the development of the sewer system CIP.

Table 2-1: Likelihood of Failure (LOF) Score Matrix

Likelihood Category	Indicator	Weight (%)	Likelihood Score				
			1 (Low)	3	5	8	10 (High)
Condition[1]	Composite Condition Score	50	<= 2	3 - 4	5 - 7	8 - 9	10
	Pipe Age		< 20 years	20 to < 40 years	40 to < 60 years	60 to < 80 years	>= 80 years
Operations	O&M Score (from CCTV)	20	<= 2	2 - 4	4 - 7	7 - 9	> 9
Capacity	Predicted Surcharge	30	No surcharge or not in model	Model predicts surcharge resulting from backwater conditions	Model shows surcharging due to throttle pipe	Model shows surcharging due to throttle pipe resulting in spills or less than 5-feet freeboard	Model shows surcharging due to throttle pipe resulting in spills or less than 5-feet freeboard for current (2015) flows

Table 2-2: Consequence of Failure (COF) Score Matrix

Consequence Category	Indicator	Weight (%)	Consequence Score				
			1 (Low)	3	5	8	10 (High)
Economic	Diameter (Flow Volume)	30	<= 8”	10” to 15”	18” to 21”	24” to 27”	> 27”

Consequence Category	Indicator	Weight (%)	Consequence Score				
			1 (Low)	3	5	8	10 (High)
Community (Social)	Road / Railway	10	Local	Arterial A	Arterial B	Arterial C	Freeway / Railway
	Land Use	10	Other	N/A	Commercial District	School, City Buildings	Hospital, Fire Station, Sheriff
	Easements	10	N/A	N/A	Yes	N/A	N/A
Environmental	Distance to Surface Waters	20	N/A	N/A	N/A	50 to < 250 ft.	< 50 ft.
	Distance to Storm Inlet	20	N/A	N/A	N/A	50 to < 250 ft.	< 50 ft.

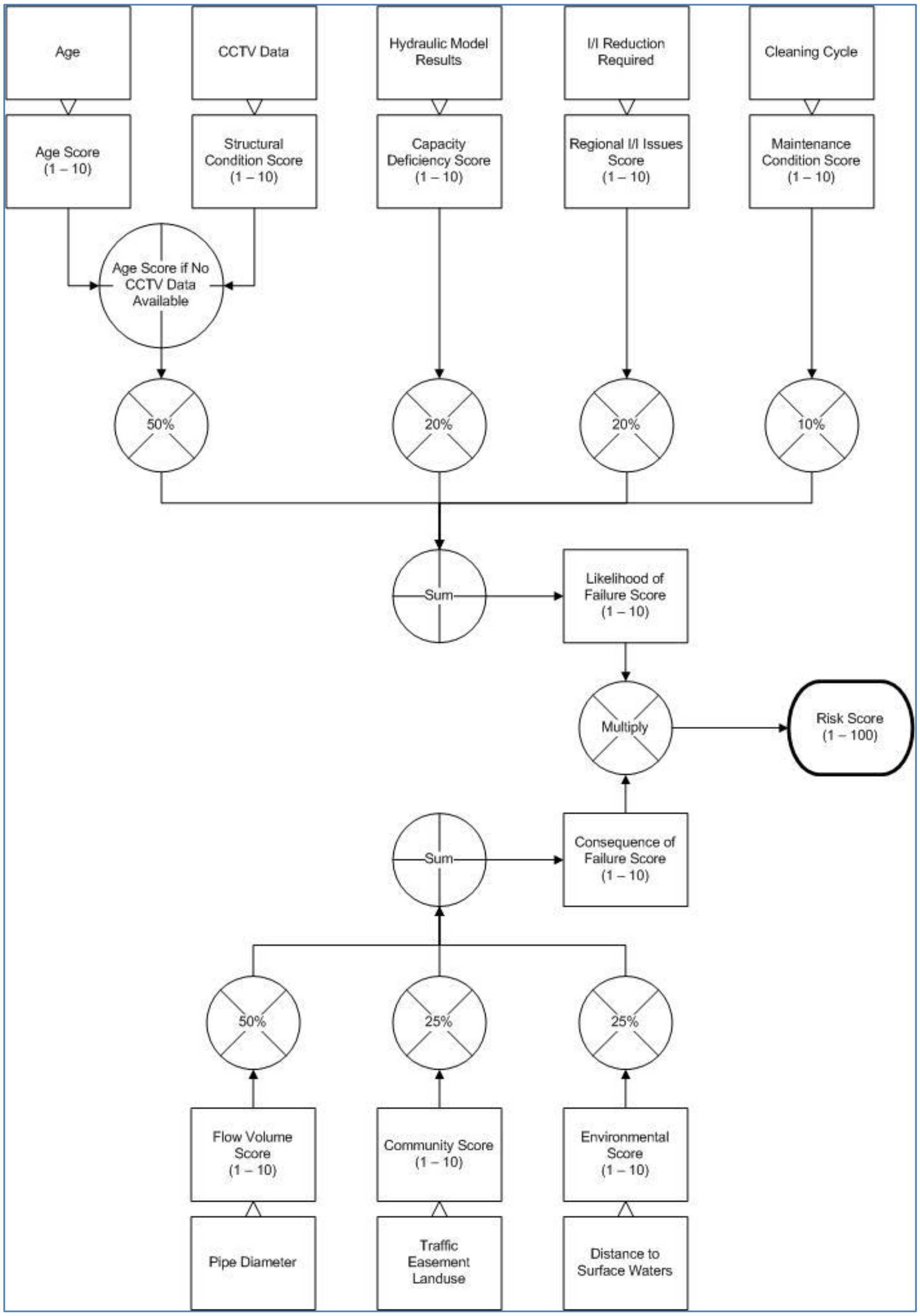


Figure 2-1: Pipe Rating Model Framework

Chapter 3 Capacity Assessment

This chapter documents the development of the hydraulic model that was used to assess the capacity of the City's sewer system and presents the results of the capacity assessment. The chapter provides an overview of the model development process, including descriptions of the modeled sewer network and sewersheds, and the water use and flow monitoring data used as the basis for estimating wastewater flows and calibrating the model. The chapter also documents the criteria on which the capacity assessment was based and presents the model results and required capacity improvements.

The modeling utilized InfoWorks™ ICM, a fully dynamic hydraulic modeling software supported by a GIS-based modeling interface.

3.1 Modeling Terminology

Key modeling terminology applicable to sewer model is defined below.

- **Network** refers to the representation of the physical facilities being modeled. Modeled network components include pipes, manholes, and other control structures such as diversion weirs.
- **Nodes** are primarily manholes and other sewer structures such as mainline cleanouts but also include pipe junctions without structures and model "outfalls" (discharge points from the modeled system). Key data associated with nodes are manhole ground elevations.
- **Conduits** are connections between nodes, primarily gravity sewer pipelines. Weirs are also represented as conduits in the model. Key data associated with pipes are upstream and downstream node IDs, pipe length, diameter, roughness factor, and upstream and downstream invert elevations. Data required for weirs include width, elevation, and weir coefficient.
- **Subcatchments** (also called sewersheds) are areas that contribute flow to the modeled sewer network and represent the unmodeled sewers in the sewer system. Data associated with subcatchments include sanitary flow (computed based on population, water use, or other available data), type of diurnal sanitary flow profile (which is a function of land use), infiltration/inflow (I/I) parameters, and the node at which the flow from the subcatchment enters the modeled system.
- **Model loads** are the flows entering the modeled sewer system from each subcatchment. Model loads include residential and commercial sanitary or base wastewater flow (BWF), groundwater infiltration (GWI), and rainfall-dependent I/I (RDI/I). As a sum, they represent the total wastewater flow applied to the model.
- **Models** are the combination of a modeled network, its associated subcatchments and loads, and other data files (e.g., rainfall, diurnal profiles, inflows from other areas, etc.) that comprise a specific model scenario.

3.2 Modeled System

The hydraulic model includes all major trunk lines with diameters ranging from 10 to 39-inches. The model also includes connected OCSD interceptor and trunk lines which provide a contiguous network model for analyzing the hydraulic capacities. In total, the model network includes approximately 97 miles of City pipelines, 20 miles of OCSD trunks with diameters ranging from 10 to 39-inches and a total of 1,799 manholes. The hydraulic model includes the City's two major pump stations: Maxine and Segerstrom pump stations.

The City's sewer service area was divided into 516 sewersheds, called "subcatchments", ranging in size from 5 to 140 acres. Each subcatchment "loads" to a manhole in the modeled network and is used to capture the population-based base flows, and inflow and infiltration flows.

3.2.1 Network Data Validation

The data used to build the model network and associated attributes was obtained from the City's GIS, existing Santa Ana model network, the latest OCSD model, and relevant as-built drawings of recent sewer improvements. The GIS includes the locations of sewer manholes and sewer mains; manhole IDs and rim elevations; and pipe diameters, lengths, material, and invert elevations.

As part of this project, an extensive data review and validation process was conducted to identify and correct data anomalies with the source GIS data. This process included comparing the spatial accuracy and data attributes (eg; invert elevations) with multiple data sources using spatial overlays and data queries, as well as manual inspection of the collection system data with record drawings provided by the City. In general, the City's GIS contained significant data gaps and anomalies that impacted the model construction which required additional investigation and data corrections. The primary investigations focused on resolving issues such as missing manholes, incorrect manhole IDs, missing or incorrect rim elevations, and incorrect/missing pipe inverts. **Table 3-1** describes in detail the types of issues and errors identified and actions taken to correct these problems required for the model.

Table 3-1: Summary of Data Errors and Corrections

Data Issue	Data Source	Description	Error Count	Corrections
Manholes - missing	City GIS	Missing manholes were identified when newer City GIS was compared to older SA Model.	71	Manholes flagged as missing, added to model.
Manholes – incorrect IDs	City GIS	Some manhole IDs were incorrect from older SA model.	5	Updated and changed MHs with correct IDs
Manholes – incorrect or missing rim elevations	Topographic Aerials	Incorrect or missing manhole rim elevations were identified.	47	Updated and estimated missing rim elevations.
Pipes – incorrect or missing inverts	Existing SA Model; City GIS	Investigated incorrect and missing pipe inverts in City collection system which caused problems with pipe slopes and connections.	161	Updated and estimated incorrect/missing inverts to accurately reflect pipe slopes.
Pipes – incorrect pipe connections	Existing SA and OCSD Model; City GIS; record drawings	Investigated and identified incorrect pipe inverts with many connections between City system and OCSD pipes.	50	Updated and estimated incorrect inverts to accurately reflect pipe slopes.

Data Issue	Data Source	Description	Error Count	Corrections
Pipes – incorrect pipe diameters	Existing SA Model; City GIS	Investigated and identified incorrect pipe diameters.	18	Updated incorrect pipe diameters.

3.2.2 Model Network Building

After the model network was defined, a procedure was followed to populate the model database, validate the network data, and create a fully connected network, as follows:

- The modeled network was checked for connectivity. This means that all manholes are connected by pipes, and that pipes are connected in the correct direction (from upstream to downstream) to create a fully-connected system.
- Manhole and pipe attribute data were populated based on rim, invert, length, and diameter data from the GIS. Where necessary, nominal diameters for pipes identified as HDPE or slip-lined VCP were converted to pipe inside diameter for modeling.
- Subcatchments were delineated to define areas tributary to the modeled pipe network. Each subcatchment was assigned to a manhole in the modeled system to define where the model load from that subcatchment enters the modeled sewer system.
- Global parameters which are required by the model were populated, such as manhole diameters (assumed to be 4 feet), Manning's 'n' (assumed to be 0.013 for all pipes), and headloss factors.

In general, the City's GIS was very complete, with few elements requiring correction or additional investigation. After comparing the model to GIS - The primary investigations were related to missing manholes, incorrect manhole IDs, missing or incorrect rim elevations, incorrect/missing pipe inverts. Also, needed to correct missing sewer improvements not in model. City staff provided as-built drawings to confirm all pipe parameters

3.2.3 Update Model with Completed Sewer Improvements

The hydraulic model was updated with recently completed sewer improvements projects. Project details were obtained from as-built drawings as provided by the City and used to update the hydraulic model. A summary of the key projects is shown in **Table 3-2**. Information from the drawings was cross-checked against the latest GIS to ensure the sewer improvements have been included in the GIS. In some cases, the GIS does not include the latest sewer improvements which are indicated in **Table 3-2**. These sewer improvement projects do not include proposed projects that were in the planning and design phase at the time of updating the hydraulic model.

Table 3-2: Summary of Built Sewer Improvement Projects

Project	Description	Location	Status	Complete	Model / GIS	Model	Plan No.
04-3506	New 12" pipe	In Fifth St. from Newhope to Hylars Ln.	Built	2004	GIS	Yes	SS-070
SS-039	New 15" line	At MacArthur Blvd. and Croddy Way to Harbor	Built	2004	Both	Edits made	SS-039
SS-054	New 15" line	Anne St. from Harvard to Pendleton Ave. to Susan St.	Built	2004	Both	Edits made	SS-054
3503	New 15" & 12" lines	Sullivan St., 5th St., Hawley St., and Civic Center Dr.	Built	2004	Both	Yes	SS-053
06-3511	New 18" & 15" lines	Civic Center Dr. - Bristol St. to Flower St.	Built	2006	GIS	Yes	SS-061
3089	New 12" line	Civic Center Dr. - Flower St. to Ross Street	Built	2003	GIS	No	SS-032
3097	New 10" lines	Durant St., Washington Ave., and Ross St.	Built	2003	GIS	No	SS-043
3501	New 12" & 10 " lines	Poinsettia St., Washington Ave., Santiago Ave.	Built	2005	Both	Edits made	SS-050
05-3509	New 10" line	Pine St. and Standard Ave.	Built	2007	GIS	Yes	SS-056
07-3515	New 12" line	McFadden Ave. and Shelton St.	Built	2008	Both	Edits made	SS-081
12-6605	New 15" line	Westminster Ave. to Roxy Dr.	Built	2014	GIS	Yes	SS-089

3.2.4 OCSD Model Pipes

The model network includes OCSD interceptors and trunks within the Santa Ana sewer service area. The OCSD sewer lines were included in the model to identify hydraulic deficiencies occurring within the OCSD lines that back-up and impact the City's collection system. In addition, OCSD model pipes were used to collectively capture dry weather flows draining from multiple City lines. These flows were compared with observed flow data during the model calibration. **Figure 3-1** shows the model network along with the OCSD sewer lines.

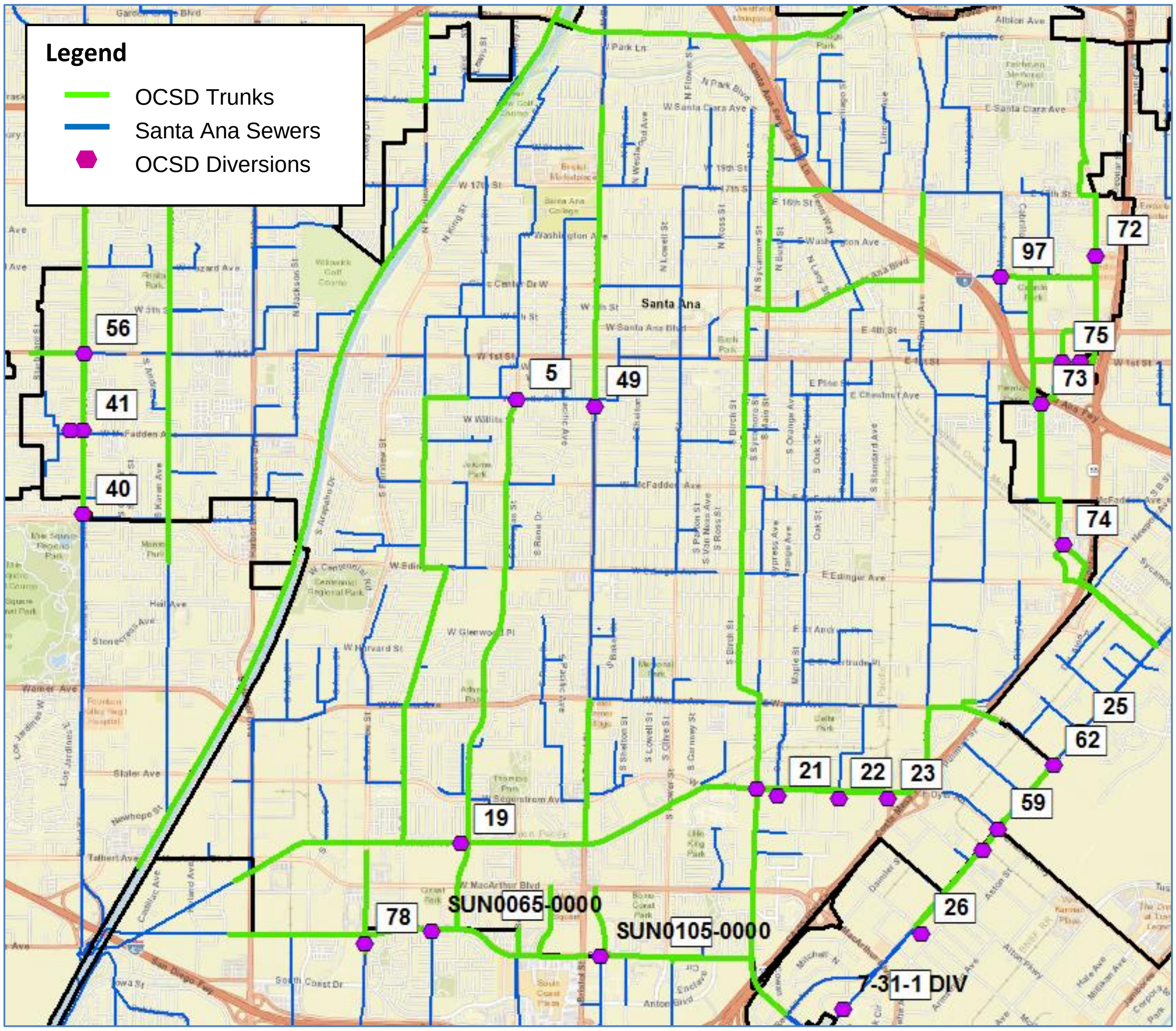


Figure 3-1: Modeled Sewer Network showing Santa Ana Sewer Pipes and OCSD Trunks

3.3 Flow Monitoring

The purpose of flow monitoring is to quantify flows in the system and to provide data with which to calibrate the hydraulic model (discussed later in this chapter). Two flow monitoring periods were conducted for this study. The first study collected flow data from ten (10) flow meters from March 4th – March 25th 2015. As this period provided minimal wet-weather flow data, additional flow monitoring was conducted from March 2nd to March 29th 2016. **Table 3-3** lists the flow meter locations and pipe diameters for both flow monitoring periods. **Figure 3-3** is a map showing the flow meter locations and the OCSD diversion structures. (Note: flow monitoring program also included two other meters specifically installed per City's request. These meters provided additional data for the model calibration.)

A total of 10 meter locations have been selected. The locations were determined based on the criteria identified in section below. In addition, two additional flow meters were added per City's request. **Table 3-3** summarizes the flow meters location, pipe diameter, and installation manhole number. Meters labeled as OC indicates the flow meters used during the previous sewer master planning effort. The same naming convention is carried forward for consistency. Additional two meters added by the City are labeled SA in **Table 3-3**. Out of the eight flow meters, six meters are located in OSCD trunk sewers. OCSD's Planning Division was contacted to obtain approval for accessing the OCSD manholes.

No major rainfall events were recorded during the initial flow monitoring period. **Figure 3-2** shows a typical plot of measured flow for one of the flow meters in Santa Ana during the 2014/15 wet weather season, illustrating typical dry weather flows. In addition, due to relatively low rainfall during the 2015/2016 El Nino wet season, no significant wet-weather flows were recorded for the second flow monitoring period.

3.3.1 Criteria for Flow Meter Location Selection

A number of criteria were considered when selecting locations for the eight flow meters for the project. These criteria, and the reason for considering them, are described below:

- **Maximize Captured Flow.** Flow meters are located to capture large percentage of the City's total flow as much as possible. This resulted in locating most of flow meters to southern end on the sewer shed along Dryer Road.
- **Quantify Flow Around Diversion Structure 49**. The City of Santa Ana Sewer Master Plan (MWH, 2003) determined capacity limitations in the City-owned reach of Bristol Trunk downstream of Diversion Structure 49. Potential deficiencies were also identified on the Orange County Sanitation District (OCSD)-owned reach of the Bristol Trunk. Following the 2003 Master Plan, OCSD conducted a study to evaluate relief alternatives for the Bristol Trunk (MWH, 2006). The study recommended diverting flows upstream of Diversion Structure 49 at Civic Center Drive to Raitt Trunk, which had some excess capacity, via Diversion Structure 5. Another study conducted in 2008 determined appropriate diversion settings at the Diversion Structures (RMC, 2008). Based on the conversation with the City staff, the required improvements have been completed which now provide flow diversion upstream of Diversion Structure 49 to Raitt Trunk.
- **System Hydraulics.** Meters were located in sites with minimal turbulence to maximize flow data accuracy.
- **Safety and Accessibility.** Meters were located away from major intersections and busy roads as much as possible to reduce permitting requirements and ensure the safety of the field crews. Sites that are remote and difficult for crews to reach will also be avoided.

Table 3-3: Flow Meter Locations

Meter ID	Santa Ana Manhole ID	OCSD Manhole ID	Pipe Diameter (inch)	Upstream Meters
OC_096	N11-005	--	21	
OC_098	P10-011	SUN0140-0070	33	
OC_099	I08-044	SUN0070-0180	24	
OC_100	Q07-026	SAN0195-0005	30	
OC_101	J05-039	SAN0135-0155	24	
OC_103	Q05-013	SAN0135-0010	27	101
OC_177	P10-011	--	21	
OC_123	Q06-040	SUN0070-0035	30	99
SA_003	K10-003	--	10	
SA_066	H10-066	--	12	

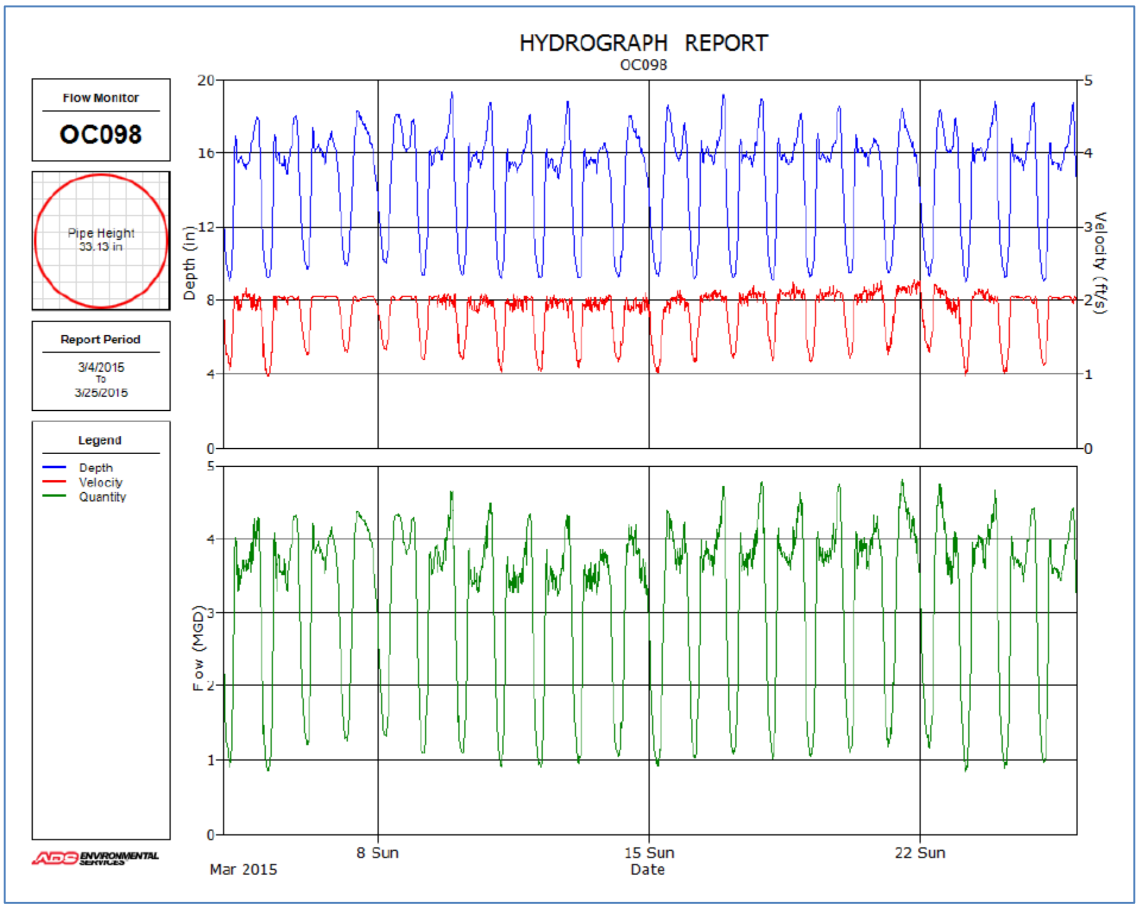


Figure 3-2: Example Flow Data Plots (Meter OC098, March, 2015)

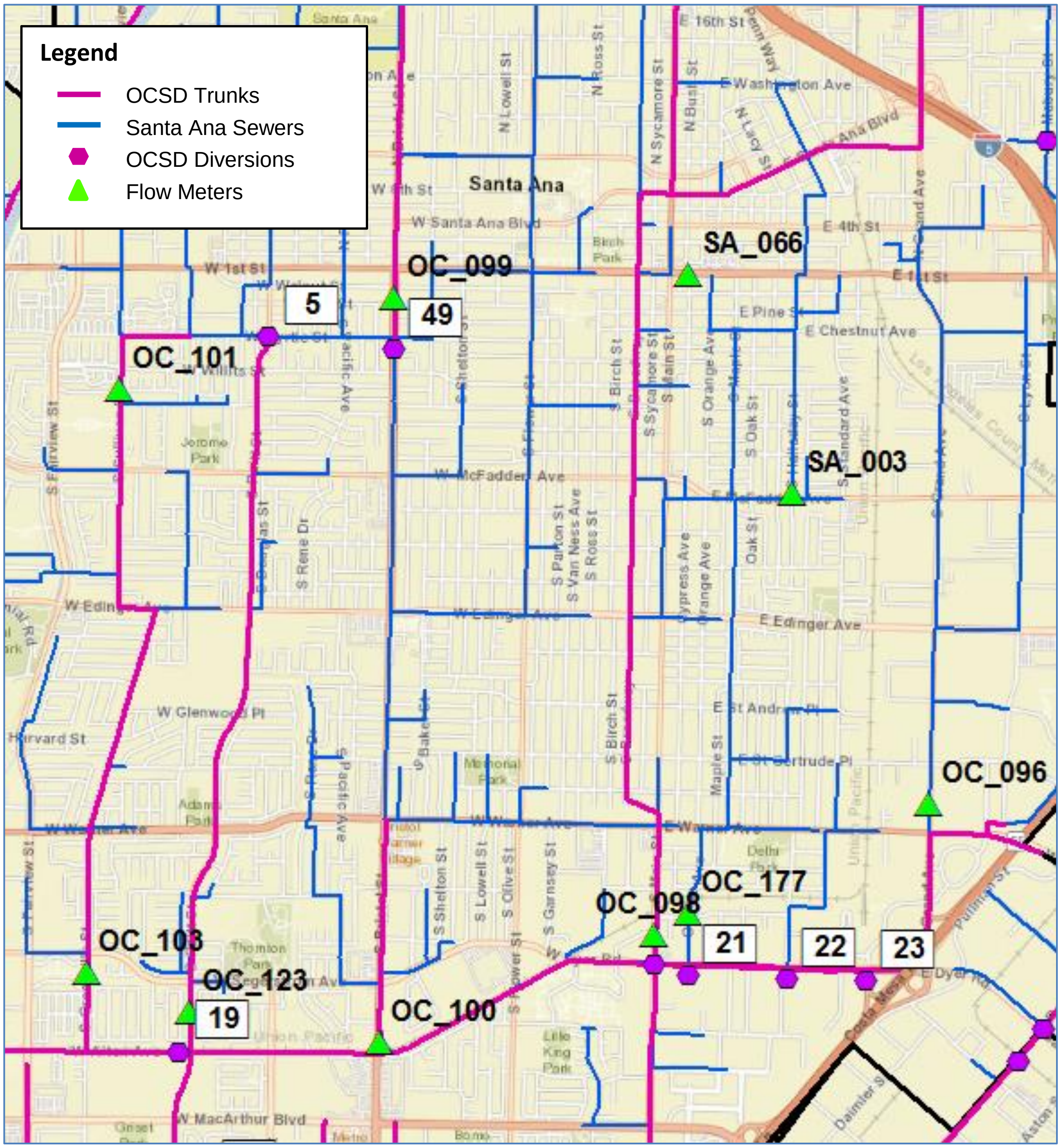


Figure 3-3: Flow Monitoring Locations (Green) and OCSD Diversion Structure (Purple)

3.4 Flow Estimating Methodology

This section describes the methodology for estimating wastewater flows for loading to the hydraulic model.

3.4.1 Wastewater Flow Components

Wastewater flows typically include three components: base wastewater flow (BWF), groundwater infiltration (GWI), and rainfall-dependent infiltration/inflow (RDI/I). BWF represents the sanitary and process flow contributions from residential, commercial, institutional, and industrial users of the system. GWI is groundwater that infiltrates into the sewer through defects in pipes and manholes. GWI is typically seasonal in nature and remains relatively constant during specific periods of the year. RDI/I is storm water inflow and infiltration that enter the system in direct response to rainfall events. RDI/I can occur through direct connections such as holes in manhole covers or illegally connected roof leaders or area drains (called "direct inflow"), or through defects in sewer pipes, manholes, and service laterals. RDI/I typically results in short term peak flows that recede quickly after the rainfall ends. These three flow components are illustrated conceptually in **Figure 3-4**.

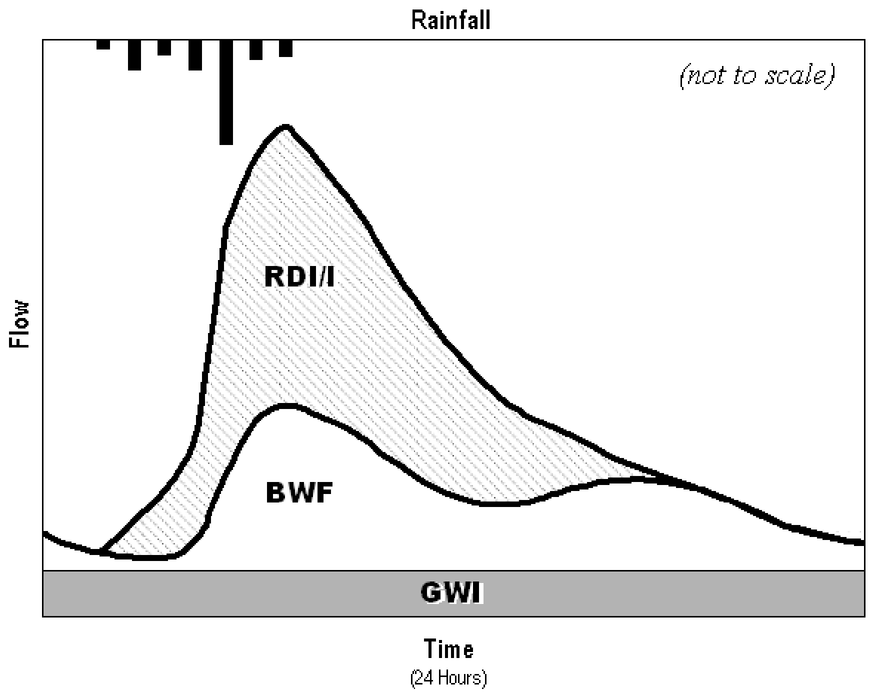


Figure 3-4: Wastewater Flow Components

3.4.2 Base Wastewater Flow

Existing residential base wastewater flows for Santa Ana were estimated using annual water use data compiled at the parcel level and then aggregated by model subcatchment. The total residential and non-residential BWF for each model subcatchment were calculated by summing the BWF for all parcels within that subcatchment.

Existing Flows

Existing BWF was determined based on Santa Ana use data for 2014. Water use during the winter months most closely approximates wastewater generation, since outdoor water use is at a minimum. However, due to the varied billing cycles, insufficient data was available for the winter period so annual average water consumption data was used as the basis for estimating BWF. The water use data was linked to individual parcels based on the geographic coordinates of each water service point (meter location) in the water use database. Each parcel was also assigned a user type (residential or non-residential) based on its land use code.

Future Flows

The hydraulic model incorporated dry weather flows based on Year 2010 U.S. Census data and future (2015 to 2040) population and employment projections (2014 Orange County Projections, or OCP) by Traffic Analysis Zone (TAZ) developed by the Cal State Fullerton Center for Demographic Research (CDR) and allocated to each of the subcatchments

For this Project, the 2014 OCP dataset was processed to allocate population and employment for years 2015 and 2040 to the refined sewersheds. This was done using a GIS-intensive methodology to compile and distribute the future populations. The process is complicated by the fact that the TAZ geographic units are considerably larger (median size of 250 acres) than the typical sewersheds (median size of 100 acres), while the 2010 census data are available at the very small block level (median size of 12 acres). To obtain the best possible level of accuracy for population and employment in each subcatchment, the process relies heavily on the census block data for establishing existing populations, and then determines the “incremental” increases based on the TAZ-level projections and allocates them to subcatchments.

The population projections were supplemented with additional development projections provided by the City’s planning department. The effort resulted in a total of 15 significant developments being identified. Comparative analysis, as well as working with CDR and local planning staff was conducted to determine if the proposed development projects were included in the 2014 OCP population projections for Year 2040. Proposed projects currently under review by the City include the Harbor Corridor Plan, the Transit Zoning Code area, and the Metro East Mixed Use Overlay Zone.

Of the 15 significant developments, it was determined by analysis and confirmation that all 15 projects were not included in the 2014 OCP population projections. For these developments, calculated proposed increases for residential and employment (commercial/industrial) populations were added to the hydraulic model to account for these proposed increases in base flows to the sewer system. **Table 3-4** summarizes the future developments that were incorporated into the model, as described above.

Table 3-4: Summary of Future Developments Included in the 2040 Model

Project Name	Agency Name	Land Use	Planned Dwelling Units	Planned Employment (sq-ft)	2014 OCP Projection
The Line	Santa Ana	Apartments & Commercial	228	4000	No
Santa Ana Lofts	Santa Ana	Apartments & Commercial	149	4400	No
C & C North Harbor, City Ventures: Harbor Project	Santa Ana	SFR 95/ Live work 15, Townhomes & Commercial	148	9450	No
Transit Zoning Code (SD 84A & SD 84B)	Santa Ana	Residential & Retail	510	43000	No
Metro East Mixed Use Overlay Zone	Santa Ana	Residential, Commercial, and Office	1665	495900	No
Charles Co. Housing, Live/Work on Fifth, West Fifth Villas	Santa Ana	Apartments, Live/work, Townhomes & Commercial	113	10700	No
Midores Project, Transit Zoning Code (SD 84A & SD 84B)	Santa Ana	Live/work, Residential & Retail	514	43000	No
Transit Zoning Code (SD 84A & SD 84B)	Santa Ana	Residential & Retail	509	43000	No
Transit Zoning Code (SD 84A & SD 84B)	Santa Ana	Residential & Retail	204	43000	No
Magnolia Lane	Santa Ana	Single Family Residence	28	0	No
Transit Zoning Code (SD 84A & SD 84B)	Santa Ana	Residential & Retail	509	43000	No
Artist Gateway, Transit Zoning Code (SD 84A & SD 84B)	Santa Ana	Live/work, Residential & Retail	523	43000	No
Transit Zoning Code (SD 84A & SD 84B)	Santa Ana	Residential & Retail	509	43000	No
Transit Zoning Code (SD 84A & SD 84B)	Santa Ana	Residential & Retail	408	43000	No
Transit Zoning Code (SD 84A & SD 84B)	Santa Ana	Residential & Retail	408	43000	No
Metro East Mixed Use Overlay Zone	Santa Ana	Residential, Commercial, and Office	3886	1157100	No
C & C North South	Santa Ana	Single Family Residence	35	0	No
Olson Residential, AMCAL Family Apartments	Santa Ana	Townhomes, Apartments	128	0	No
Park Estates: City Ventures	Santa Ana	Single Family Residence	17	0	No
Harbor/Kent	Santa Ana	Townhomes	79	0	No
Hapham Housing	Santa Ana	Townhomes	15	0	No
Heritage, Heritage	Santa Ana	Apartments	1221	0	No

BWF Diurnal Profiles

In domestic wastewater systems, base wastewater flow (BWF) varies throughout the day, typically peaking early on weekday mornings (later on weekends) and again in the evening hours in residential areas. BWF patterns in commercial and industrial areas depend on specific land use types but are typically characterized by a more uniform flow that lasts throughout working hours.

The variations in BWF on a typical day are represented by diurnal profiles. Diurnal profiles are defined by a set of hourly factors that are applied to the average BWF for each subcatchment. For Santa Ana, separate sets of diurnal profiles were defined for residential and non-residential development and for weekdays and weekends (for residential flow). The diurnal curves that were developed for the recent OCSD hydraulic model were reviewed and deemed appropriate for use in Santa Ana. **Figure 3-5** shows the diurnal profiles used in the model.

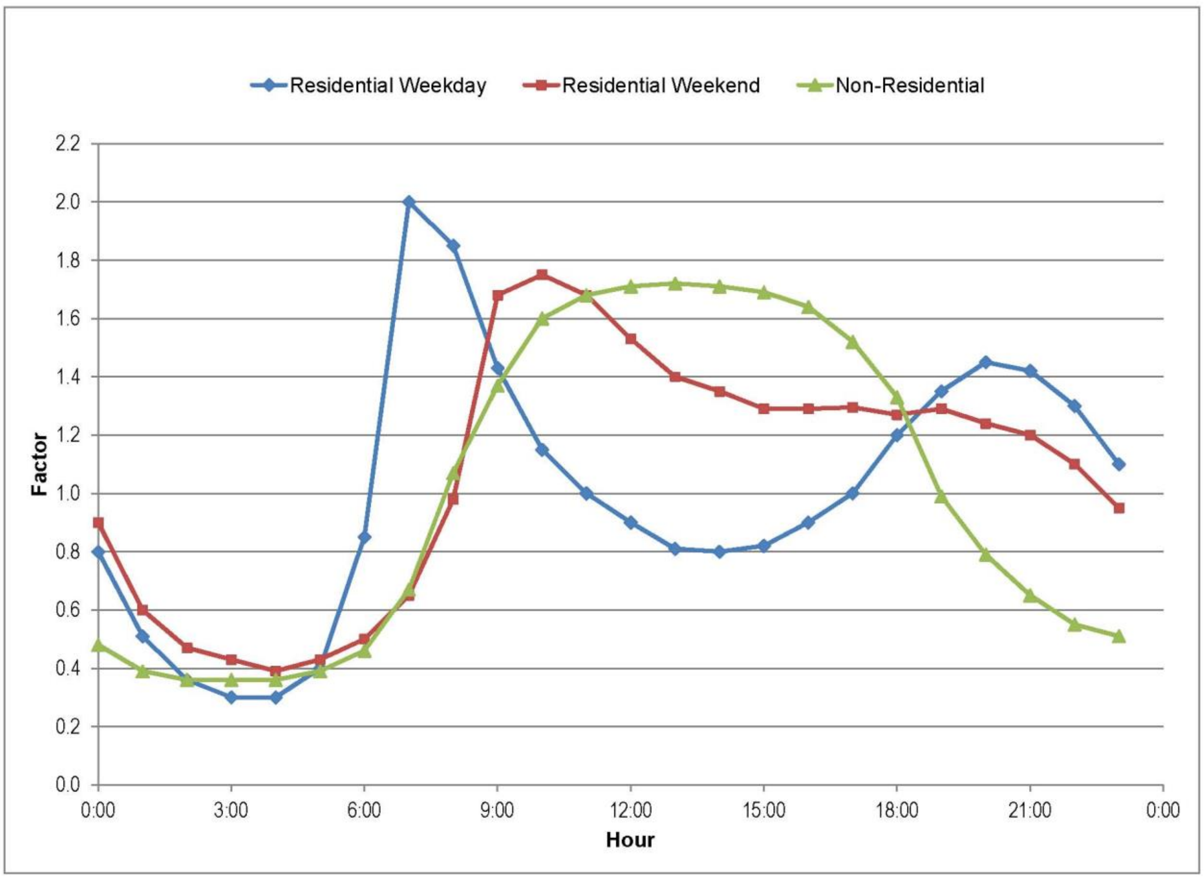


Figure 3-5: Diurnal Profiles

3.4.3 Groundwater Infiltration

Groundwater infiltration (GWI) is typically applied in the model as a constant load in addition to the BWF. The amount of GWI in any particular area is determined during model calibration by comparing the modeled flows to actual observed non-rainfall period flows at points in the system where flow meter data are available. Where the minimum modeled flow is less than monitored flow, the difference may be due to GWI. The GWI determined at the monitoring location is then distributed to the meter tributary area on a per-acre basis. Note that because GWI is seasonal in nature, the modeled GWI represents a typical GWI rate during the wet weather season rather than a dry season (summertime) GWI.

3.4.4 Rainfall-Dependent I/I

RDI/I flows result from rainfall events that produce infiltration and inflow of storm water runoff into the sewer system. RDI/I flows are defined by the magnitude, shape, and timing of the RDI/I response. RDI/I varies depending on many factors, including the magnitude and intensity of the storm event, area topography, type of soil, and the condition of the sewers, manholes, and sewer service laterals. In a dynamic model, RDI/I is typically computed as a percentage of the rainfall (sometimes referred to as the "R value") falling on the contributing area of a subcatchment for each of three or more hydrograph components, representing different response times to rainfall, e.g., fast, medium, and slow, as illustrated in **Figure 3-6.** (The contributing area is assumed to be the sum of the area of all developed parcels, except for large open areas such as parks, cemeteries, and parking lots.) Summing all of the component hydrographs for the entire duration of the rainfall event results in the total RDI/I hydrograph for the event for that subcatchment. Note that although the "slow" RDI/I component can contribute significantly to the total RDI/I volume, the "fast" component has the biggest impact on the magnitude of the peak wet weather flow.

The model parameters defining the RDI/I flows to the system within a given meter area are determined by comparing modeled wastewater flow at the meter location to the measured wastewater flow during one or more rainfall events, as discussed in the model calibration section later in this chapter. The same calibrated parameters are generally applied to all subcatchments within each meter area.

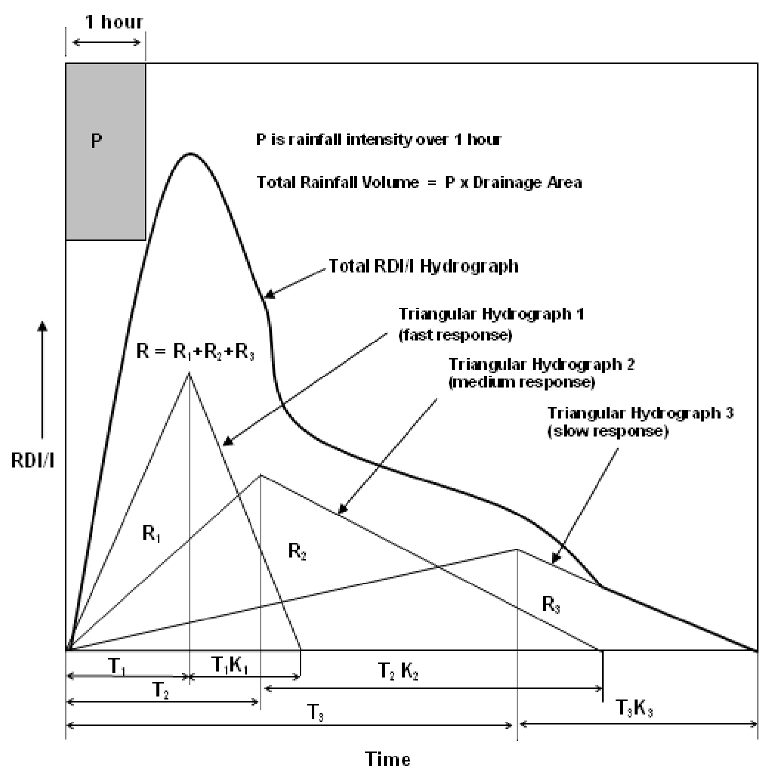


Figure 3-6: RDI/I Hydrograph Components

3.5 Model Calibration

Model calibration is the process of comparing model-computed flows to observed (monitored) flows and adjusting various model parameters until the model is accurately simulating flows in the sewer system. The model was calibrated for both dry and wet weather conditions.

3.5.1 Dry Weather Calibration

The dry weather flow calibration used flow data obtained from 8 meter sites installed during the period from March 4, 2015 through March 25, 2015. The sites were selected to monitor flows not only in the City sewer lines and its main tributary trunks, but also in OCSD trunk sewers collecting flows from the City's sewer network. In addition, selected meters were placed to capture flows downstream of two OCSD diversion structures as well as in other trunks that could potentially be affected by flow diversions. The flow data was used to calibrate the dry and wet weather flow parameters in the model and verify modeled flows at key locations. **Figure 3.2** shows the flow meter locations relevant to the City's pump stations and OCSD diversion structures.

The starting point for the model calibration was the updated hydraulic model containing equivalent residential and employment populations derived from recent billing data. The main dry weather calibration parameters are the unit flows rate per capita and per employee, and the diurnal profiles (24-hour flow patterns) for various land uses. The unit flows used for the previous master plan were initially used for the model calibration. These flow rates were found to vary from 50 gallons per day per capital (gpcd) to 85 gpcd depending on household size, with a value of 75 gpcd being most common. Three residential diurnal profiles having high, medium, and low peaking characteristics were defined, with the higher peaks associated with areas having higher per-capita income. A single value of 25 gpd per employee (gped) was applied throughout, with a standard non-residential profile or (rarely) a constant flow profile for selected dischargers known to operate 24 hours a day.

As unit flows have typically decreased due to water conservation, residential unit flow rates were reduced by 20 gpcd (e.g., from 75 gpcd to 55 gpcd) to achieve a good volumetric fit, and less-peaky diurnal profiles were derived to match peak dry weather flows. Per-employee flow rates were reduced from 25 gped to 20 gped.

Plots of the results of the dry weather calibration for the flow meters are presented in **Appendix A**. The calibration results were very favorable, with the exception of flow meter OC099 (Bristol Street / Pine Street), where the modeled flow was approximately 20 percent below than the observed flow. One possible explanation for the discrepancy is that the accuracy of this meter may be poor due to the unusually low depths, which ranged from only 2 to 5 inches in a 24-inch pipe. No additional effort was expended to resolve the issue given the uncertainties associated with this meter plus that fact that the downstream meters showed very good matches with the model. Therefore, none of the other calibration meters are affected by the quality of the calibration of this meter.

3.5.2 Wet Weather Calibration

Data from the same four area-velocity wastewater flow meters used to calibrate the dry weather flow parameters were assessed for use in calibrating the wet weather flow parameters. In additional, radar rainfall data obtained from an OCSD study local to the Santa Ana area was used to assess the magnitude of rainfall and suitability for wet weather calibration. The goal was to update the wet weather flow parameters in the model to better reflect today's sewer conditions as opposed to conditions in the previous sewer master plan.

Unfortunately, the 2015 wet weather season was particularly dry, with no substantial rainfall collected during the flow monitoring period (March 4th to March 25th 2015). The largest storms that wet season occurred in December 2014 and accounted for over half of the total rainfall, occurred during the total wet season. Those storms were the first storms to occur following months of dry weather, and thus fell on relatively dry soils. Because of that, there was initial concern that the storms would not be useful for updating the wet weather calibration. This later was proved to be a valid concern, based on analyses described in this section.

Typically, the percentage of rainfall that enters sewers as infiltration/inflow is greatest after soils have become saturated over a series of storms, and storms occurring under those conditions are used to calibrate wet weather models. The calibrated models are then run for design storm events that are assumed to occur on saturated soils. If a model is calibrated to rainfall events that occur on relatively dry soils, the resulting peak wet weather design flows can be grossly underestimated.

To determine if the existing wet weather calibration parameters used in the previous master plan are suitable for this study, a brief analysis of the 2014-2015 rainfall events and associated soil conditions was conducted. Inflow and infiltration entering a sewer system depends on the preceding rainfall which impacts the ground water which is evaluated by computing the antecedent precipitation index API 30 (a measure of soil moisture conditions, and therefore a measure of potential wet weather response). The API 30 was computed for the 2014-2015 wet weather season, and compared to the same index for the 2004-2005 wet weather season that was the basis for the calibrated wet weather parameters currently in the model that was used in the previous study. **Figure 3-7** shows this comparison, based on a representative rain gauge located at the Fullerton Municipal Airport.

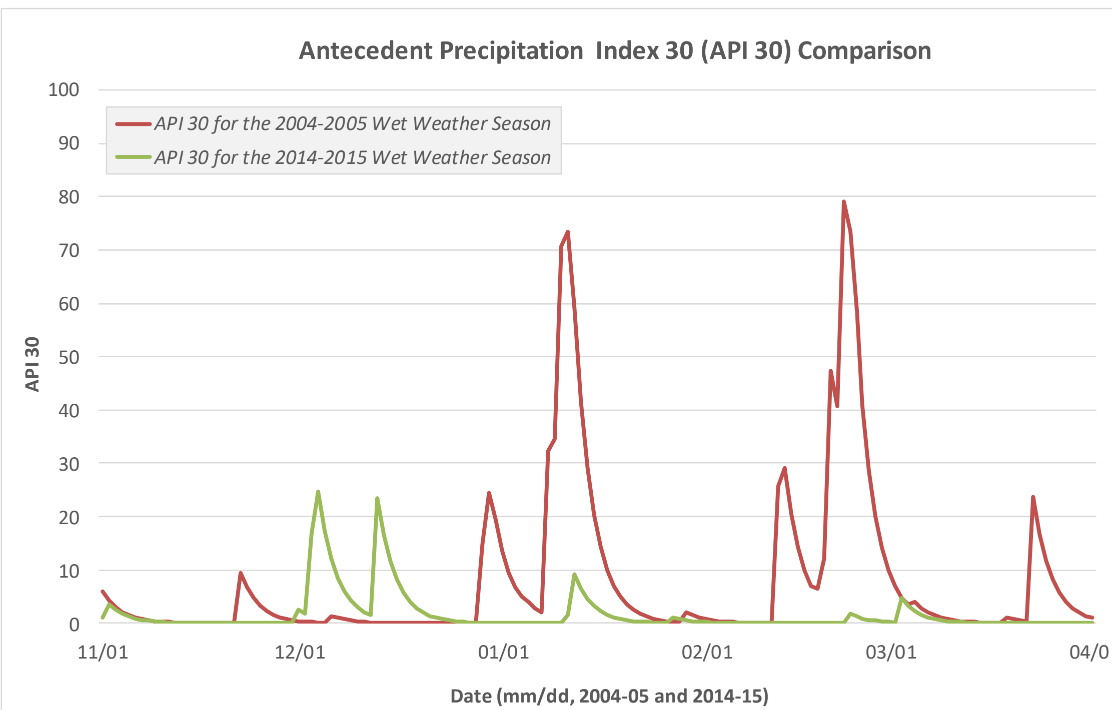


Figure 3-7: Comparison of Antecedent Precipitation Index (API 30) for the 2004-2005 and 2014-2015 Wet Weather Seasons

It is clear from this comparison that even the largest storms in the 2014-2015 were not sufficient to increase the soil moisture to levels anywhere close to that in the wet year of 2004-2005. The API 30 never exceeded 25 in 2014-2015, compared to an API as high as 80 in 2004-2005. This suggests that the wet weather response observed in 2004-2015 was probably much smaller as a percentage of rainfall than it was in 2014-2015, and therefore should not be used to update the wet weather model. For this reason, no update of the wet weather model calibration was performed.

3.6 Design Flow and Performance Criteria

Sewer system capacity is assessed with respect to the system's performance under a design flow condition. The subsections below define the design flow criteria used for the capacity assessment and the criteria for assessing system performance and identifying system capacity deficiencies.

3.6.1 Design Storm Condition

The use of wet weather design events as the basis for sewer capacity evaluation is a well-accepted practice. The approach is to first calibrate a hydraulic model of the system to match wet weather flows from observed storm(s), and then apply the calibrated model to a design rainfall event to identify capacity deficiencies and size needed improvement projects. The design event may be synthesized from rainfall statistics, or may be an actual historical rainfall event of appropriate duration and intensity. Other considerations for the design event include the spatial variation of the rainfall and the timing of the storm relative to the diurnal BWF pattern.

Selection of a design rainfall event is typically based on an allowable probability or frequency of occurrence (i.e., risk tolerance), often expressed as the return period. It is recognized that while wet weather overflows are highly undesirable, it is not cost-effective to provide capacity for the largest possible storm event. Regulatory agencies have not adopted standard criteria for return periods, so each agency must choose a target return period based on desired level of service, potential impacts of overflows, and cost. For this project, a 10-year design storm currently used by OCSD for collection system studies was use for the study. The design storm, originally developed for the 2006 Strategic Plan Update (2006 SPU) project and is described below.

The 2006 SPU used a 10-year design storm based on an actual rainfall event occurring on January 9, 2005 (one of the storm events used for model calibration). The January 9, 2005 event was the largest that occurred during OCSD's three-year long-term flow monitoring program. Gauge-adjusted radar rainfall data was provided by OneRain, Inc. throughout the flow monitoring program. Some 327 two-kilometer square pixels covered the OCSD service area, and rainfall depths were provided for each pixel at 15-minute intervals for all major storms during the flow monitoring period.

The SPU design storm hyetograph was selected as the observed rainfall for one of the radar rainfall pixels (pixel 203), with a 1.2 multiplier applied to bring the event up to a 10-year event according to the design rainfall depth-duration-frequency (DDF) curves from the Orange County Hydrology Manual. **Figure 3-8** shows the rainfall hyetograph for the SPU design storm.

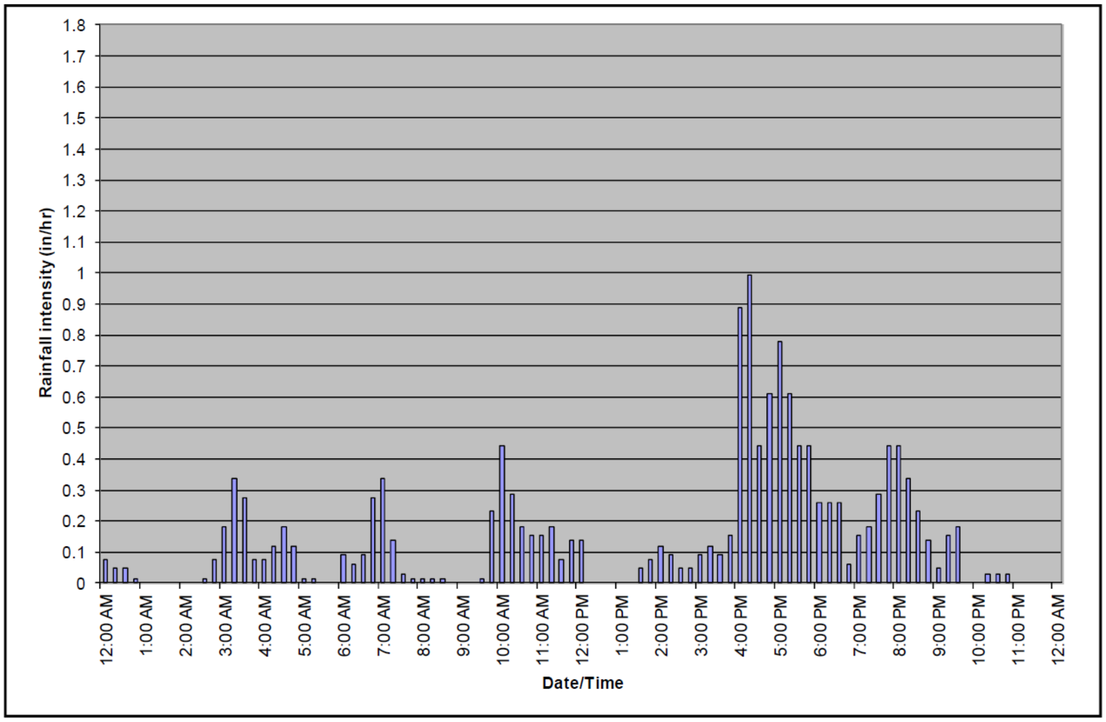


Figure 3-8: 15-Minute Rainfall Hyetograph for SPU 10-Year Design Storm

The timing of the design storm also affects the resultant peak wet weather flows. If the design storm is timed such that the peak RDI/I occurs at roughly the same time as the peak BWF ("peak-on-peak"), the total PWWF will be higher than if the design storm occurs under average or lower-than-average BWF conditions. The timing of the storm was set to peak at 4 to 6 pm, a period of slightly above-average dry weather flows.

The design event is also assumed to occur under saturated soil conditions, yielding maximum I/I response. This assumption, together with the timing the storm to produce peak-on-peak results, is generally thought to create a return period of the peak wastewater *flow* that is greater than the return period of the design rainfall event.

3.6.2 Capacity Deficiency Criteria

Capacity deficiency or performance criteria are used to determine when the capacity of a sewer pipeline is exceeded to the extent that a capacity improvement project (e.g., a relief sewer or larger replacement sewer) is required. Capacity deficiency criteria are sometimes called "trigger" criteria in that they trigger the need for a capacity improvement project. These criteria may differ from "design criteria" that are applied to determine the size of a new facility, which may be more conservative than the performance criteria.

It is important that the capacity deficiency criteria be coordinated with the peak design flow criteria. For example, if the peak design flow considers only peak dry weather flow and little or no I/I, the deficiency criteria should be conservative (e.g., require pipes to flow less than full during dry weather flow to allow capacity for I/I that may increase the flow under a wet weather condition). On the other hand, if the peak design flow includes I/I from a large, relatively infrequent design storm event, it is appropriate to allow the sewers to flow full or even surcharged to some extent, since the peak flows will be infrequent and brief in duration.

For Santa Ana, since the design storm peak wet weather flow (PWWF) represents a relatively infrequent return period event, the City considers it acceptable to allow surcharging over the pipe crown, provided the hydraulic grade line (water level) remains at least five feet below the ground surface. During peak dry weather conditions, however, sewers should be able to convey the peak flow without surcharge. The following summarizes the trigger and design criteria:

- Manning's n friction factor of 0.013 for all pipes
- Allowable depth of flow (PDWF) before triggering an improvement project:
    - d/D < 0.5 for less than 12-inches
    - d/D < 0.75 for 12-inches and greater
- Allowable depth of flow (PWWF) before triggering an improvement project:
    - 2-feet of surcharge for sewers over 12 inches in diameter
    - Full pipe for sewers smaller than 12 inches

- Free-board depth > 5-feet (depth from rim elevation to maximum water level)
- Design depth of flow (PWWF) for sizing improvements:
    - 75% of full pipe for all sewers

These hydraulic criteria for allowable depth of flow and design depth of flow are less conservative than in typical design standard for new pipes. In setting these hydraulic criteria for this project, the key consideration was that the peak design flows are based on a peak wet weather flow corresponding to a 10-year return period design storm. Given the low frequency and short duration of the peak wet weather flows, a moderate amount of surcharging (before triggering a project) and use of the full pipe capacity in larger sewers was deemed to be acceptable. The criteria are more stringent for smaller pipes (less than 12 inches) due to the greater relative effect on capacity of any sediment deposits or pipe defects in such small pipes.

3.7 Capacity Analysis Results

The hydraulic model was used to simulate flows for the design event and identify areas of the Santa Ana trunk sewer system that fail to meet the specified performance criteria during predicted design event PWWF. No capacity deficiencies in the system were identified for dry weather conditions.

Figure 3-9 shows the location of predicted surcharged sewers which can increase the risk of sewer overflows occurring during significant rainfall events. Pipes shown in red are surcharged due to "throttle" conditions, indicating the full pipe capacity is less than the predicted peak flow. In these conditions, the hydraulic grade line exceeds the pipe slope indicating the pipe has in-sufficient capacity to convey peak flows. Pipes shown in blue also depict surcharging (ie; water level exceeding the pipe crown) which is caused by downstream throttle condition. It should be noted that the location of model-predicted surcharging may not reflect the actual locations where overflows would occur, due to other physical conditions (e.g., root intrusion or debris) that are not reflected in the model, or system storage that is available in the smaller diameter, un-modeled pipes. It should also be noted that the City has not reported any wet weather overflows in recent years. The dashed boxes shown in **Figure 3-9** delineate pipes with significant surcharging exceeding the allowable depth and freeboard. Detailed maps for these areas are shown in **Figures 3-10 to 3-13**. Pipes within these boxes trigger capacity improvements which are described in Chapter 5.

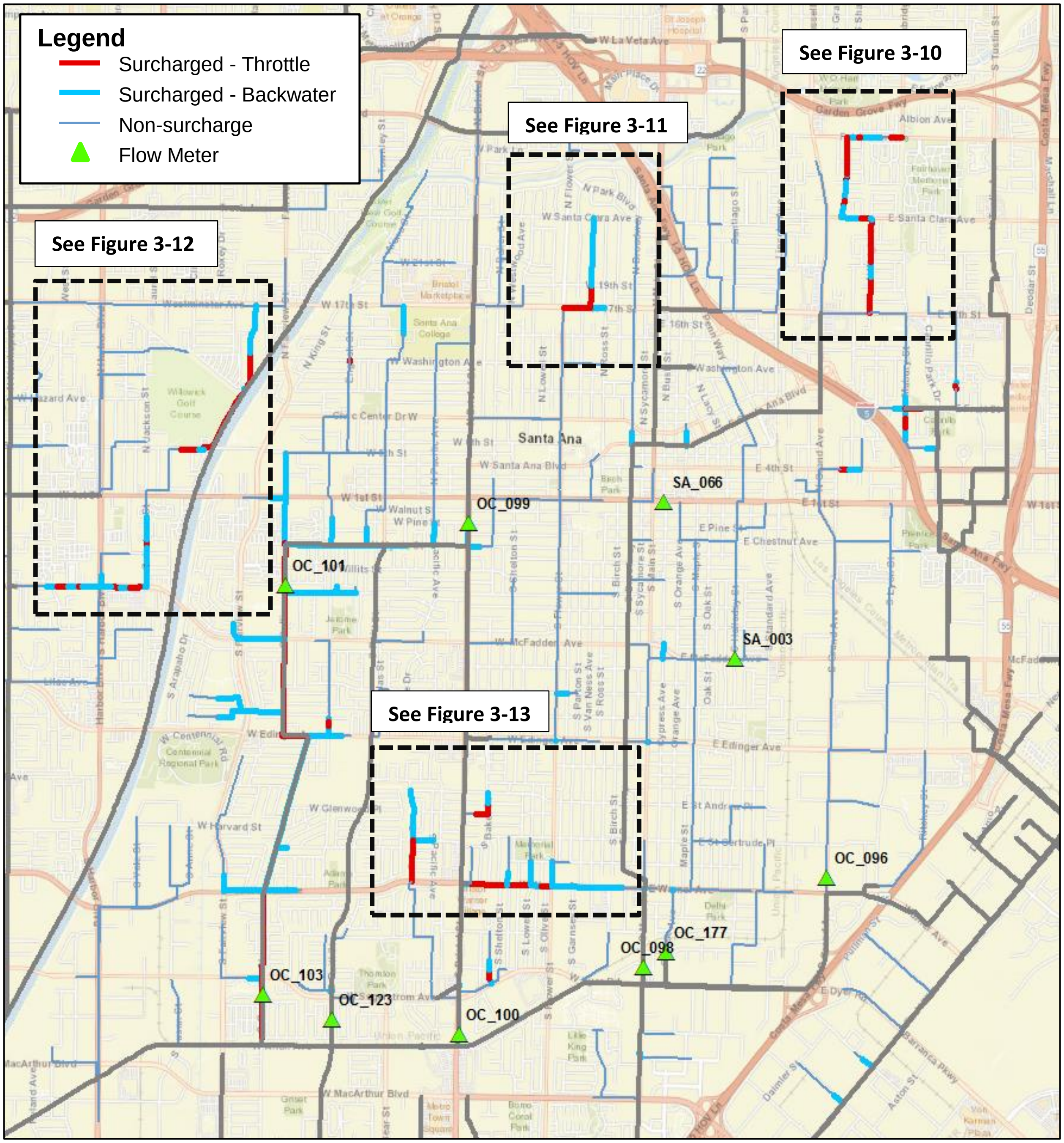


Figure 3-9: Predicted Surcharged Pipes for Future Flows (2040) and PWWF

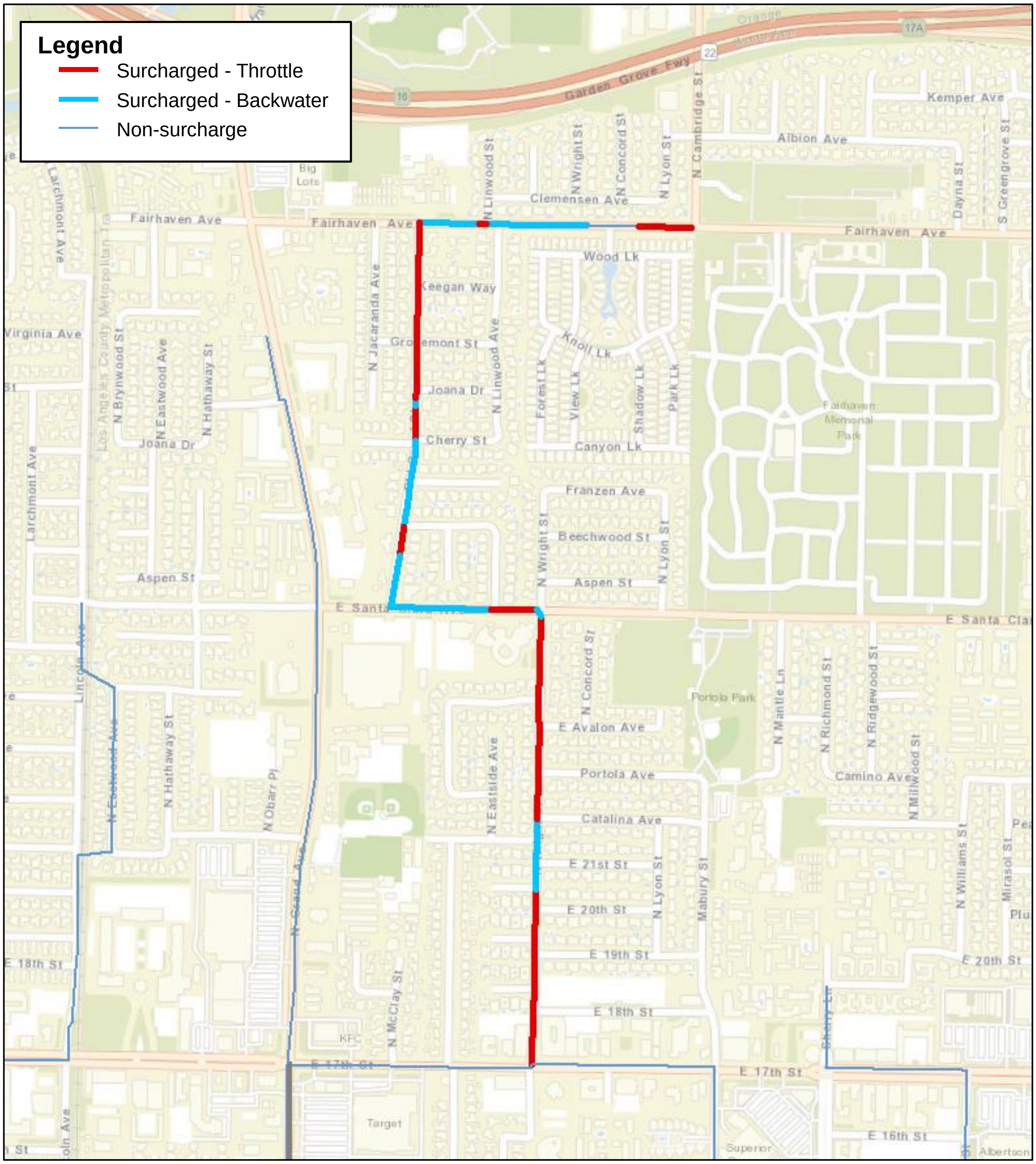


Figure 3-10: Hydraulic Deficiencies - Fairhaven Avenue, Old Grand Street and Wright Street

Figure 3-11: Hydraulic Deficiencies – Greenleaf Street and 17th Street

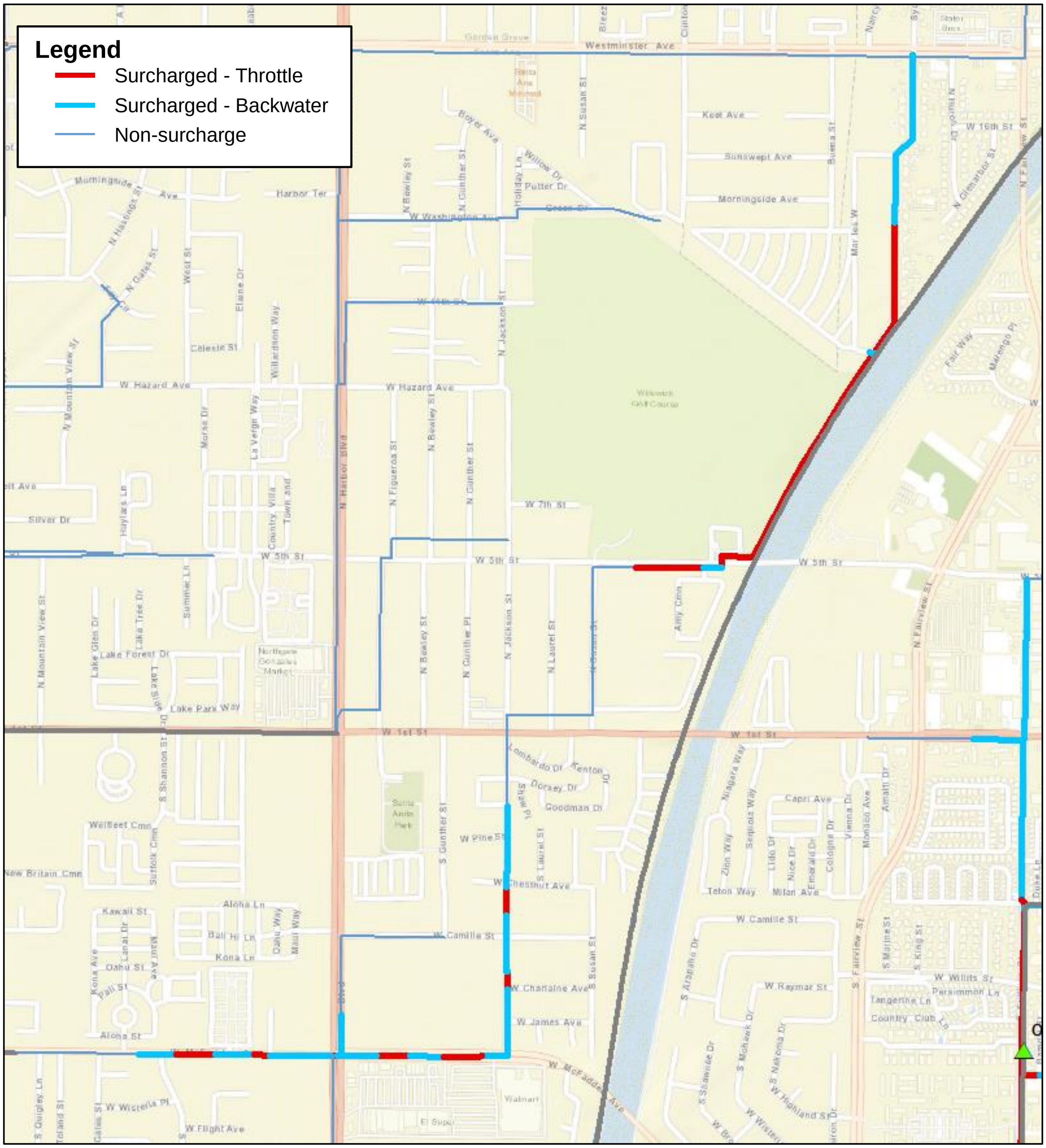


Figure 3-12: Hydraulic Deficiencies - Mar les Drive, McFadden Avenue and Shannon Street

Figure 3-13: Hydraulic Deficiencies - Rene Drive and Warner Avenue

The most significant areas of potential wet weather capacity deficiencies identified in the model are between Fairhaven Avenue and 17th Street running through Old Grand Street, to Santa Clara Avenue, and then onto Wright Street in the northeastern area of the City as depicted in **Figure 3-10**. Predicted peak flows result in surcharging with depths ranging from 2 to 5-feet above pipe crown, with some manholes less than 5-feet of freeboard (**Figure C1.1** in Appendix C).

The next area with significant wet weather capacity deficiencies is between Santa Clara Avenue and the intersection of 17th Street/Flower Street down Greenleaf Street. **Figure 3-11** shows this location. There was more than 5-feet of surcharging above crown, with some flows coming to the surface which would likely result in an overflow. Significant surcharging at the upstream end of this modeled section indicates further flow back-up may occur in the small diameter pipes upstream of the modeled pipes (**Figure C2.1** in Appendix C).

Figure 3-12 shows the location of another area of the system showing wet weather capacity deficiencies in the eastern portion of the City. The figure shows two separate portions of the same pipe that have capacity deficiencies. The first (or northern) section is in Mar les Drive between Westminster Avenue and east of the intersection of 5th Street/Susan Street. The second (or southern) section starts along Jackson Street at Calle del Sur, then down to McFadden Avenue, traveling west to just past Shannon Street along

McFadden Avenue. Surcharging along the first portion is significant, being as high as 6-feet above crown and within 3-feet of the surface. Surcharging in the second section is less extreme, however still exceeding the City's deficiency criteria (**Figures C3.1 and C4.1** in Appendix C).

One other area that is considered as violating the City's capacity deficiency criteria is along Rene Drive from St. Andres Place down to Warner Avenue. **Figure 3-13** shows the location. Peak flows cause surcharging anywhere from 2 to 4-feet above pipe crown, with some manholes only having 5-feet of freeboard (**Figure C7.1** in Appendix C).

Finally, the modeled trunk running along Warner Avenue from Broadway to Bristol Street predicts wet weather capacity deficiencies. **Figure 3-13** shows the location. Modeled peak flows show multiple pipes in the section exceeding the 2-feet above crown criteria, with various manholes exceeding the 2-feet freeboard criteria (**Figure C6.1** in Appendix C).

3.7.1 Pipes with Capacity Deficiencies

The results of the hydraulic modeling were used to assign Capacity Deficiency Likelihood of Failure (LOF) scores for modeled pipes. Specifically, scores were based on the magnitude of predicted sewer surcharge under design event PWWF conditions. As noted above, the sewer lines with significant surcharging were assigned a maximum Capacity Deficiency LOF score of 10. Other sewers that exceeded capacity performance criteria (surcharge to within five feet of ground) were assigned a Capacity Deficiency LOF score of 4 or 7, depending on the extent of surcharge. And any pipes without identified capacity deficiencies or not included in the model were assigned a score of 1.

Chapter 4 Condition Assessment

This chapter provides a brief summary of the overall physical condition of the Santa Ana sewer system based on closed-circuit television (CCTV) inspection results, and presents the methodology used to determine Structural Condition Likelihood of Failure (LOF) scores for the Pipe Rating Model. The condition assessment focuses on the structural condition of the sewer pipes. Since manholes are replaced or rehabilitated along with sewer mains as part of sewer rehabilitation and replacement projects, manhole condition was not specifically used as a parameter in the asset risk assessment and prioritization of sewer rehabilitation projects.

4.1 CCTV Inspection Program

CCTV inspection is the basic method used by the City to gather the data required to assess sewer condition. The City uses a specialist CCTV contractor to inspect pre-defined portions of the City's sewer system with the target of inspecting the entire system over a 5-year period. The CCTV contractor (Houston & Harris) uses a NASSCO compliant standards and relevant software to capture and grade the pipe conditions. Data obtained from the inspections, including the videos and electronic reports are sent to the City on a periodic basis for archiving on the City's server.

The inspection data is stored as separate packages and not in a single inspection database. As a result, this data was not suitable for conducting a detailed analysis of the inspection data. However, the City extracted the Quick Score Rating (QSR) per pipe from the individual CCTV data packages and entered the scores into the City's GIS. The QSR scores provide a concise scoring mechanism to evaluate critical defects for each inspected sewer main. Therefore, the City's GIS data along with the associated QSR scores was used to analyze the condition data.

4.2 CCTV Inspection Spot-Check Review

This study included a 'spot-check' review of the CCTV inspection data to provide an independent assessment of the accuracy and consistency of the condition scores provided by the CCTV contractor. Inspection data was obtained from the City for 40 selected pipes with a range of defect scores plus additional randomly selected pipes. **Figure 4-1** shows the pipes used for the spot-check review. Inspection reports, as example shown in **Figure 4-2**, were used to evaluate the total defect score based on the defects listed in the report and visible in the associated CCTV video. The review identified excessively high defect scores resulting from unusually long continuous defects (eg; longitudinal cracks). These defects, classed as Multiple Cracks (CM), are logged into the inspection software by starting and stopping a counter which measures the length of the defect. However, in some cases, the logging process was not stopped providing long CM defects resulting in excessively high defect scores.

The spot check review identified 37 pipes with structural grade 4 or 5 defects. From this list, 10 pipes were identified with grading errors typically resulting from 'unclosed' CM defects. As a result from this analysis, the City requested the CCTV contractor to re-evaluate the inspection data and fix any outstanding errors. The updated inspection data was used to update the QSR scores in the City's GIS.

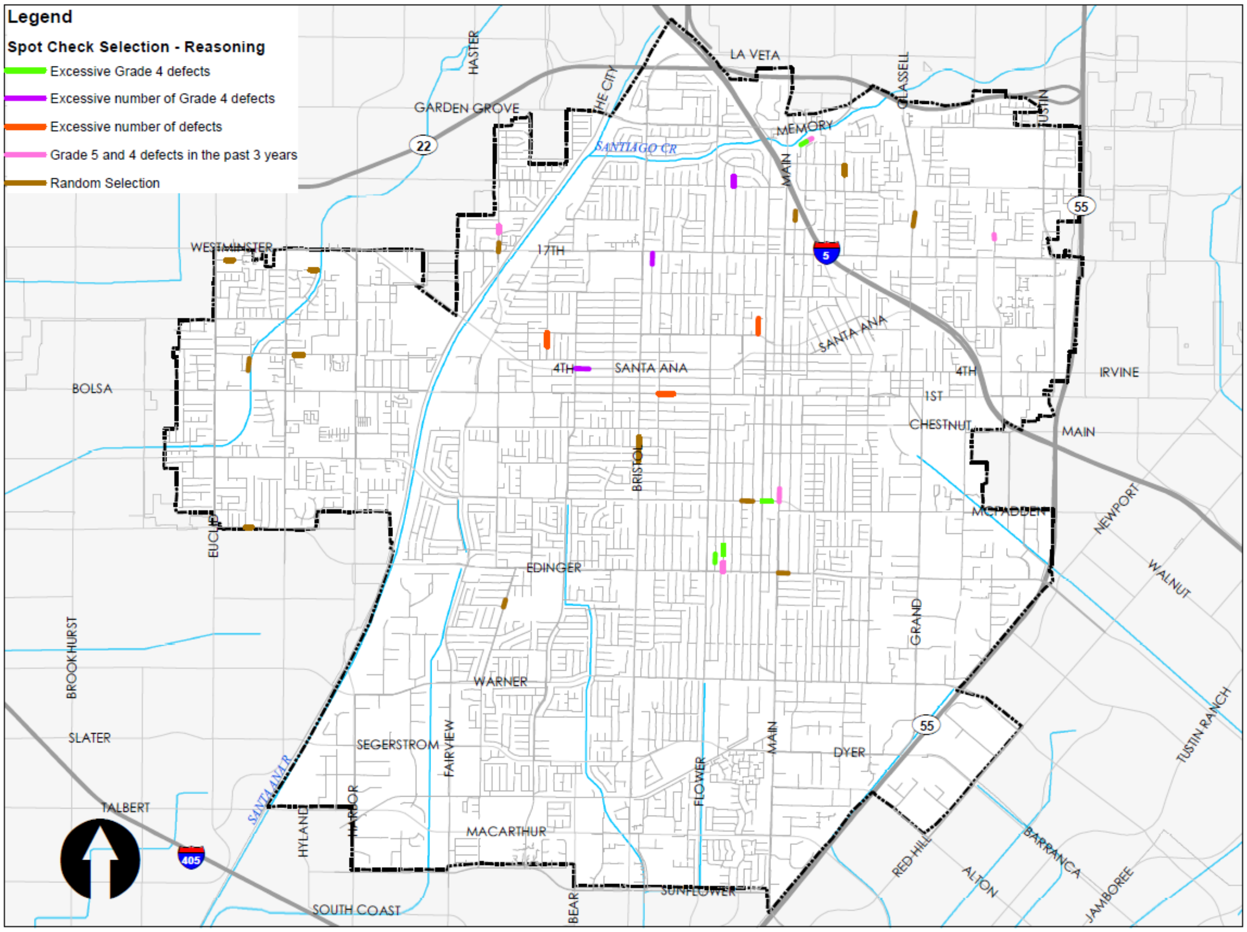
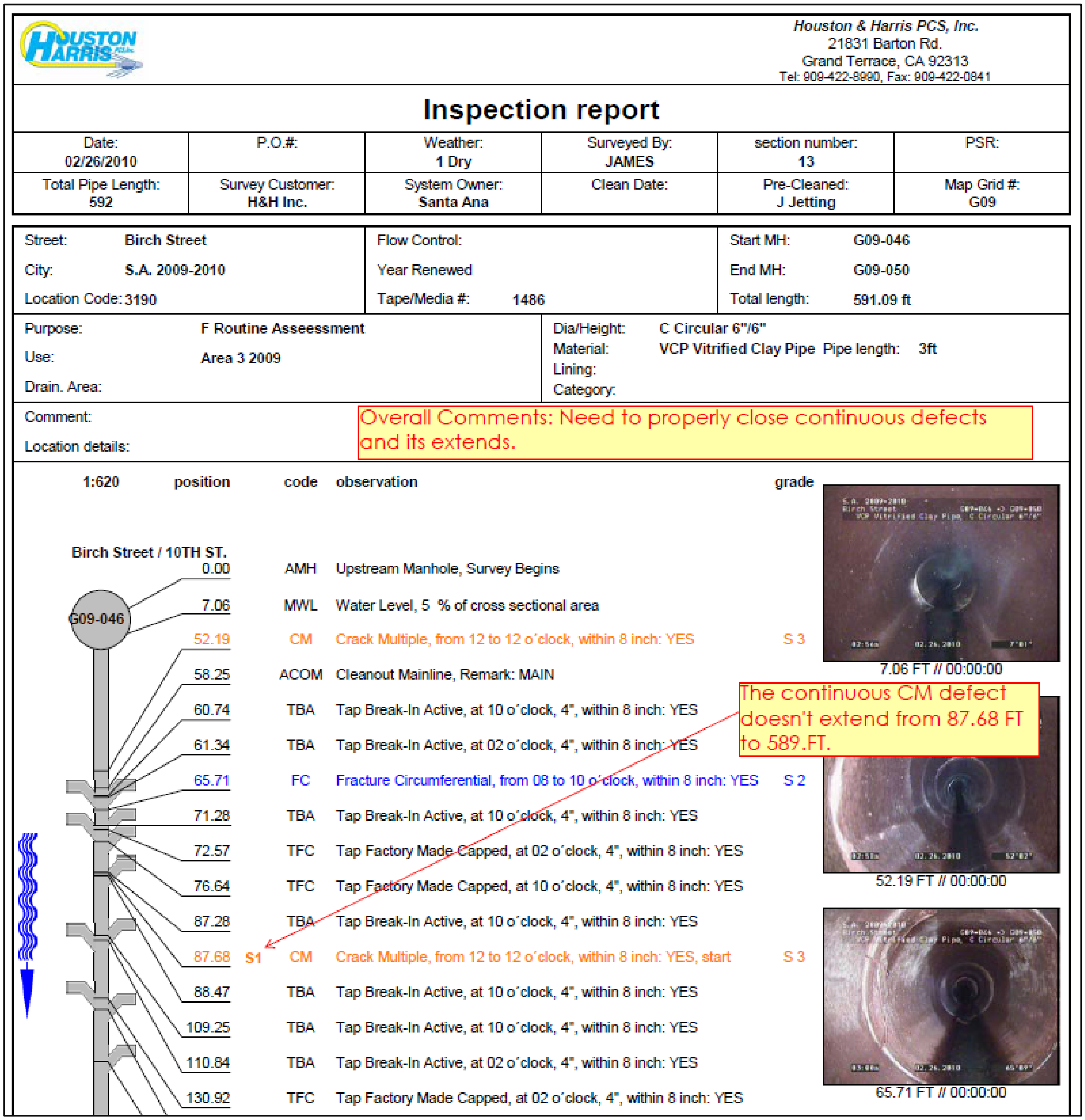


Figure 4-1: Map Showing Pipes used to Conduct Spot-Check Review



Houston & Harris PCS, Inc.
21831 Barton Rd.
Grand Terrace, CA 92313
Tel: 909-422-8990, Fax: 909-422-0841

Inspection report

Date: 02/26/2010	P.O.#:	Weather: 1 Dry	Surveyed By: JAMES	section number: 13	PSR:
Total Pipe Length: 592	Survey Customer: H&H Inc.	System Owner: Santa Ana	Clean Date:	Pre-Cleaned: J Jetting	Map Grid #: G09

Street: Birch Street	Flow Control:	Start MH: G09-046
City: S.A. 2009-2010	Year Renewed	End MH: G09-050
Location Code: 3190	Tape/Media #: 1486	Total length: 591.09 ft

Purpose: F Routine Assessment
Use: Area 3 2009
Drain. Area:
Dia/Height: C Circular 6"/6"
Material: VCP Vitrified Clay Pipe Pipe length: 3ft
Lining:
Category:

Comment:
Location details:

Overall Comments: Need to properly close continuous defects and its extends.

1:620 position	code	observation	grade
Birch Street / 10TH ST. 0.00	AMH	Upstream Manhole, Survey Begins	
7.06	MWL	Water Level, 5 % of cross sectional area	
52.19	CM	Crack Multiple, from 12 to 12 o´clock, within 8 inch: YES	S 3
58.25	ACOM	Cleanout Mainline, Remark: MAIN	
60.74	TBA	Tap Break-In Active, at 10 o´clock, 4", within 8 inch: YES	
61.34	TBA	Tap Break-In Active, at 02 o´clock, 4", within 8 inch: YES	
65.71	FC	Fracture Circumferential, from 08 to 10 o´clock, within 8 inch: YES	S 2
71.28	TBA	Tap Break-In Active, at 10 o´clock, 4", within 8 inch: YES	
72.57	TFC	Tap Factory Made Capped, at 02 o´clock, 4", within 8 inch: YES	
76.64	TFC	Tap Factory Made Capped, at 10 o´clock, 4", within 8 inch: YES	
87.28	TBA	Tap Break-In Active, at 10 o´clock, 4", within 8 inch: YES	
87.68 S1	CM	Crack Multiple, from 12 to 12 o´clock, within 8 inch: YES, start	S 3
88.47	TBA	Tap Break-In Active, at 10 o´clock, 4", within 8 inch: YES	
109.25	TBA	Tap Break-In Active, at 10 o´clock, 4", within 8 inch: YES	
110.84	TBA	Tap Break-In Active, at 02 o´clock, 4", within 8 inch: YES	
130.92	TFC	Tap Factory Made Capped, at 02 o´clock, 4", within 8 inch: YES	

G09-046

The continuous CM defect doesn't extend from 87.68 FT to 589.FT.

7.06 FT // 00:00:00

52.19 FT // 00:00:00

65.71 FT // 00:00:00

Figure 4-2: Example Inspection Report

4.3 Condition Grading and Structural Condition LOF Scores

The methodology embodied in the Pipe Rating Model is based on guidelines recommended by the National Association of Clean Water Agencies (NACWA).[2] The methodology involves quantifying and assessing the risks posed by the failure or inability of the sewer system to provide the level of service

[2] National Association of Clean Water Agencies, *Implementing Asset Management: A Practical Guide*, 2007

needed to meet the City's sewer system management goals. Using this approach, risk scores can be calculated for each sewer pipe individually. Individual pipe scores can be then be analyzed for groups of pipes to prioritize sewer rehabilitation or replacement projects.

The City use the Pipeline Assessment and Certification Program (PACP) system developed by the National Association of Sewer Service Companies (NASSCO), which has become the standard of the industry for sewer condition assessment. PACP utilizes standard observation codes to describe different types of structural and maintenance-related defects and construction features, with defect grades assigned to each defect based on its type and severity.

Under the PACP standard, all structural defects are assigned a Structural Grade of 1 to 5, with Grade 5 representing severe defects that require attention in the short-term and Grade 1 representing minor defects. (Maintenance defects are assigned similar O&M grades.) The grades for individual defects observed on a manhole-to-manhole pipe segment can be combined in various ways to determine an overall structural condition rating for the pipe. The PACP manual suggests several approaches for this purpose, including summing the grades of all defects or averaging the grades. While such approaches may be useful for screening pipes in terms of overall condition, they are not particularly useful for deciding which pipes require immediate or near-term attention. What is most important in such decisions is the presence of major defects and the number of such defects. For example, a single Grade 5 defect in a pipe may require immediate action, while five Grade 1 defects do not, even though they both have a PACP Segment Grade Score of 5.

For purposes of evaluating the structural condition grade, a scoring system that consolidates the PACP grades was developed for this study. The scoring system provides a single 'Composite Condition Score' which ranges from 0 – 10 and accounts for multiple defect ratings and the number of defects. The Composite Condition Score is calculated using the total defect scores per grade and maximum number of defects that equate to the highest score (10). Individual scores are interpolated using the total defect score and number of defects per grade then summed to give a combined Composite Condition Score. The number of defects that 'trigger' a high score were derived from discussions with the City and are shown below.

- Grade 1 Defect Count Trigger: 30
- Grade 2/3 Defect Count Trigger: 15
- Grade 4/5 Defect Count Trigger: 3

The Composite Condition Score is derived by summing the interpolated grade scores using the formula below. **Figure 4-3** shows the relationships between grade scores and defect count. If the base score plus adjustments exceeded 10, then the Composite Condition Score was set to 10, the maximum value. Finally, if a pipe has been recently rehabilitated, the Composite Condition Score is set to 1 overriding scores derived from structural defects or pipe age.

Score = Score Ratio (R) x Defect Count (C)

Total Score = $(R_{4/5} \times C_{4/5}) + (R_{2/3} \times C_{2/3}) + (R_1 \times C_1)$

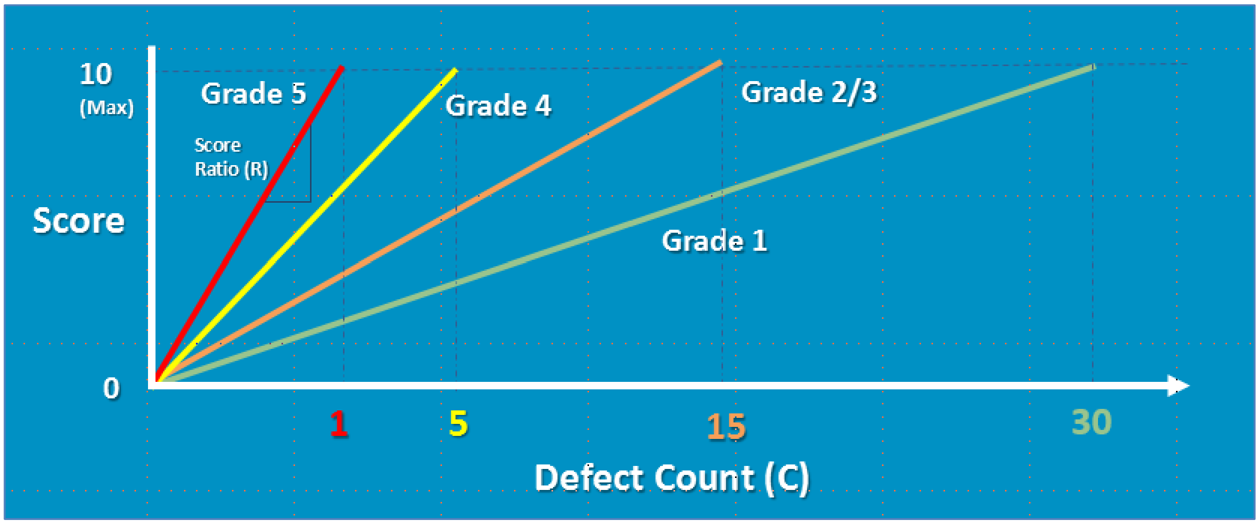


Figure 4.3: Relationship between Composite Condition Score and Defect Count

4.4 Condition Assessment Results

The results of the condition assessment for the City are presented in **Figure 4-4** which shows a map of the Composite Condition Scores each inspected sewer pipe. The map shows many pipes with significant condition defects (depicted by the red and orange pipes) located in the central part of the City including the downtown area. This area is known to have older pipes compared to the outer neighborhoods and consequently has may defect issues. The results of the condition assessment analysis specifically the Consolidated Condition Score was used to calculate the Likelihood of Failure (LOF) as part of the Pipe Rating analysis. This is described in further detail in Section 5.1

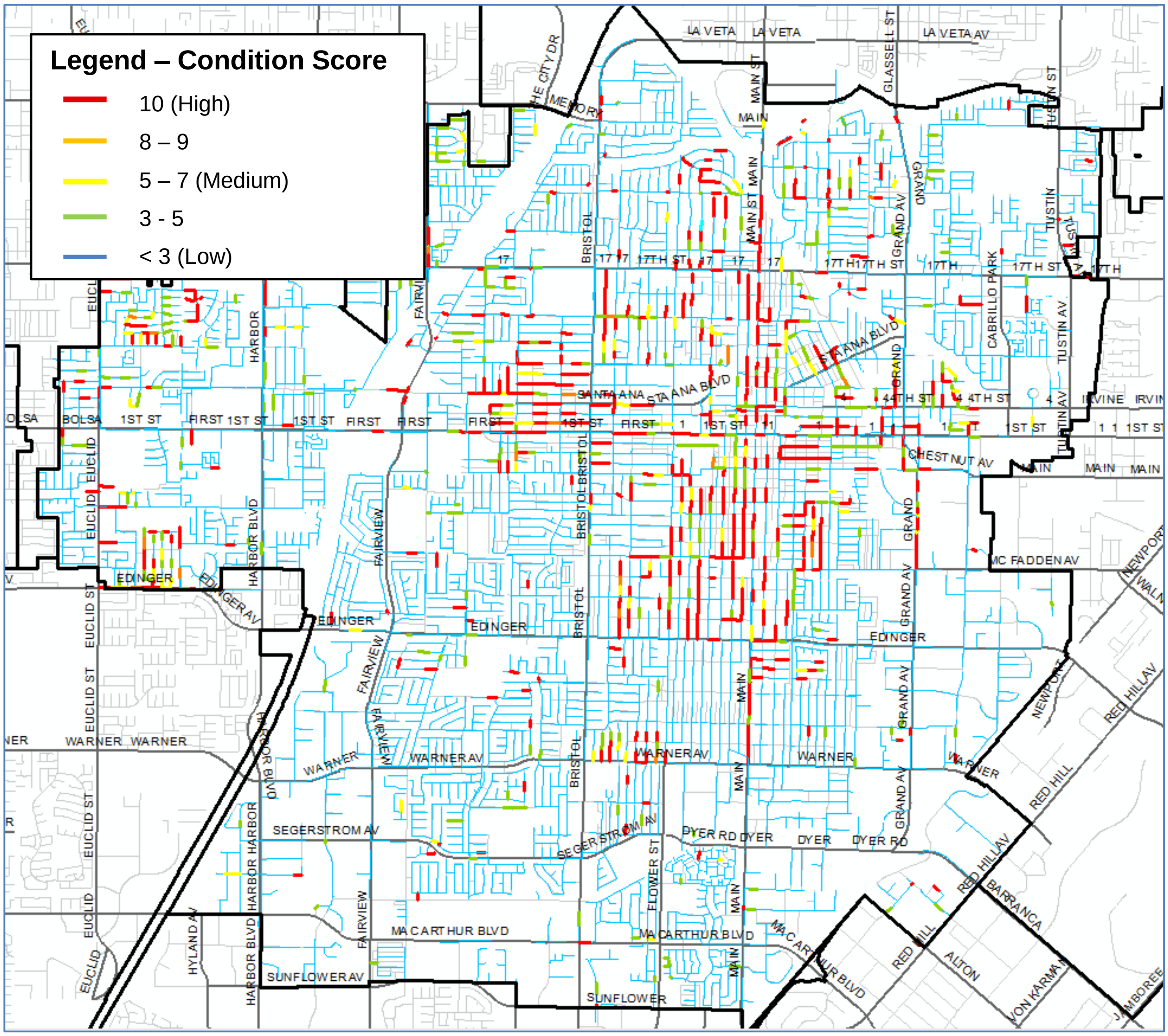


Figure 4-4: Distribution of Composite Condition Scores

Chapter 5 Recommended Capital Improvement Program

The previous chapters of this report presented the results of the capacity and condition assessments of the Santa Ana sewer system and the methodology used to quantify the structural pipe condition using the Consolidated Condition Score. This chapter presents the Pipe Rating Model methodology and results, describes the approach for grouping pipes into "mini-basins" in order to define and prioritize rehabilitation projects, and presents the recommended ten-year Capital Improvement Program (CIP) including estimated costs and schedule for improvements. Guidelines for implementation of the CIP are also presented at the end of the chapter.

5.1 Pipe Rating Analysis

The Pipe Rating Model was used to calculate the total risk score for each pipe in the Santa Ana sewer system. The risk scores represent the product of the Likelihood of Failure (LOF) and Consequence of Failure (COF) for each sewer pipe, considering its structural condition, capacity requirements, size, location, and other risk factors, as described in Chapter 2.

The risk of asset failure is calculated by quantifying the likelihood of failure (LOF) and the consequence of failure (COF) of a sewer asset. The likelihood of failure is the possibility of asset failure and is synonymous with the "probability" of failure. The consequence of failure is defined as the impact on level of service resulting from asset failure. The risk equation is defined as follows:

Risk = [(Likelihood) x (Consequence)]

5.1.1 Likelihood of Failure Categories

Two primary indicators of likelihood of failure were utilized in the Pipe Rating Model:

- Structural Condition: Structural condition was determined based CCTV inspection results, as stored in the WinCan CCTV database. If CCTV inspection data did not exist for a pipe segment, then the likelihood of failure was estimated based on pipe segment age. Structural condition is a strong indicator of likelihood of failure and was heavily weighted.
- Capacity Deficiency: This likelihood of failure factor is calculated from hydraulic modeling results. Sewers that are predicted to be heavily surcharged or potentially overflowing under a design event peak wet weather flow condition were considered to have a high likelihood of failure due to capacity deficiency.

5.1.2 Consequence of Failure Categories

Three consequence categories were developed for the Pipe Rating Model:

- Economic Impact: Larger sewer spills or failure of a sewer asset serving a large tributary area can have a significant impact on the community, environment, and cost to respond and affect a greater number of people. The size of the sewer was chosen as an indicator of the potential impact of large spills or failure of a major sewer asset.
- Community Impact: Sewer failures can significantly impact commuters, commercial areas, public facilities, and the community in general. Asset location in major roads, commercial areas, and near schools, parks, and public buildings were used as indicators of potential community impact.

- Environmental Impact: Sewer overflows that reach surface waters can adversely impact water quality and the environment. Distance to surface water was used as an indicator of the potential environmental impact of a sewer spill.

5.1.3 Total Risk Score Calculations

The Pipe Rating Model utilizes data directly from the City's GIS, Consolidated Condition Score and hydraulic results from the InfoWorks ICM model. Community and environmental COF scores were derived from GIS mapping.

The risk score calculations were processed using the Innovyze's InfoMaster software which combines a series of GIS processes to automate the risk analysis calculations. The InfoMaster tool can be re-used by the City to update the risk analysis following future data updates to the GIS and CCTV data. **Table 5-1** and **Table 5-2** present the scoring criteria and weights for the LOF and COF categories, respectively.

Table 5-1: Likelihood of Failure (LOF) Score Matrix

Likelihood Category	Indicator	Weight (%)	Likelihood Score				
			1 (Low)	3	5	8	10 (High)
Condition[1]	Composite Condition Score	50	<= 2	3 - 4	5 - 7	8 - 9	10
	Pipe Age		< 20 years	20 to < 40 years	40 to < 60 years	60 to < 80 years	>= 80 years
Operations	O&M Score (from CCTV)	20	<= 2	2 - 4	4 - 7	7 - 9	> 9
Capacity	Predicted Surcharge	30	No surcharge or not in model	Model predicts surcharge resulting from backwater conditions	Model shows surcharging due to throttle pipe	Model shows surcharging due to throttle pipe resulting in spills or less than 5-feet freeboard	Model shows surcharging due to throttle pipe resulting in spills or less than 5-feet freeboard for current (2015) flows

Table 5-2: Consequence of Failure (COF) Score Matrix

Consequence Category	Indicator	Weight (%)	Consequence Score				
			1 (Low)	3	5	8	10 (High)
Economic	Diameter (Flow Volume)	30	<= 8”	10” to 15”	18” to 21”	24” to 27”	> 27”
Community (Social)	Road / Railway	10	Local	Arterial A	Arterial B	Arterial C	Freeway / Railway
	Land Use	10	Other	N/A	Commercial District	School, City Buildings	Hospital, Fire Station, Sheriff
	Easements	10	N/A	N/A	Yes	N/A	N/A
Environmental	Distance to Surface Waters	20	N/A	N/A	N/A	50 to < 250 ft.	< 50 ft.
	Distance to Storm Inlet	20	N/A	N/A	N/A	50 to < 250 ft.	< 50 ft.

5.1.4 Pipe Rating Analysis Results

The results from the Pipe Rating Model are shown in **Figures 5-1 to 5-4**. **Figure 5-1** shows the total LOF scores generated from the ‘likelihood issues’ (structural, operational and hydraulic) identified from the capacity and condition assessment. The scores generated from the analysis are weighted to emphasize a greater importance in pipe condition which drive future R&R projects. The weighting factors, shown in **Table 5-1**, were presented and discussed with City staff and reevaluated to ensure critical pipe issues are ranked high in the eventual prioritized CIP project list. For example, condition-related LOF scores were assigned a 50-percent weighting as compared to 30-percent for hydraulic and 30-percent for operational issues.

Figure 5-2 shows the hydraulic issues identified separately from the capacity assessment. Comparing this figure with the total LOF scores (**Figure 5-1**) shows many of the hydraulic issues with relatively low LOF scores resulting from the 30-percent weighting criteria. However, to ensure critical hydraulic issues (excessive surcharging and low free-board) are addressed, separate capacity improvement projects were created and combined with the condition-based R&R projects described later in this report.

Figure 5-3 shows COF scores highlighting critical pipes with the greatest impact on economic, social and environmental issues. Large pipe sizes and major roads result in high scores which are depicted in this figure. The basis of the Pipe Rating Model analysis is the combined effect of likelihood of failure (LOF) and consequence of failure (COF) to produce a total risk score for each pipe. **Figure 5-4** shows the total risk scores highlighting critical pipes resulting from the combined effect of condition, hydraulic, economic, social and environmental impacts. The analysis and results allow the City to prioritize pipe improvements that satisfy all these needs. In some cases, the initial prioritization driven by the Pipe Rating Model will be adjusted for 1) pipes with known critical defects (grade 5), 2) capacity issues triggered by existing (2015) flows, and 3) pipes impacted by current development projects. Further discussion of how the Pipe Rating Model is used to prioritize CIP projects is described in Section 5.5.

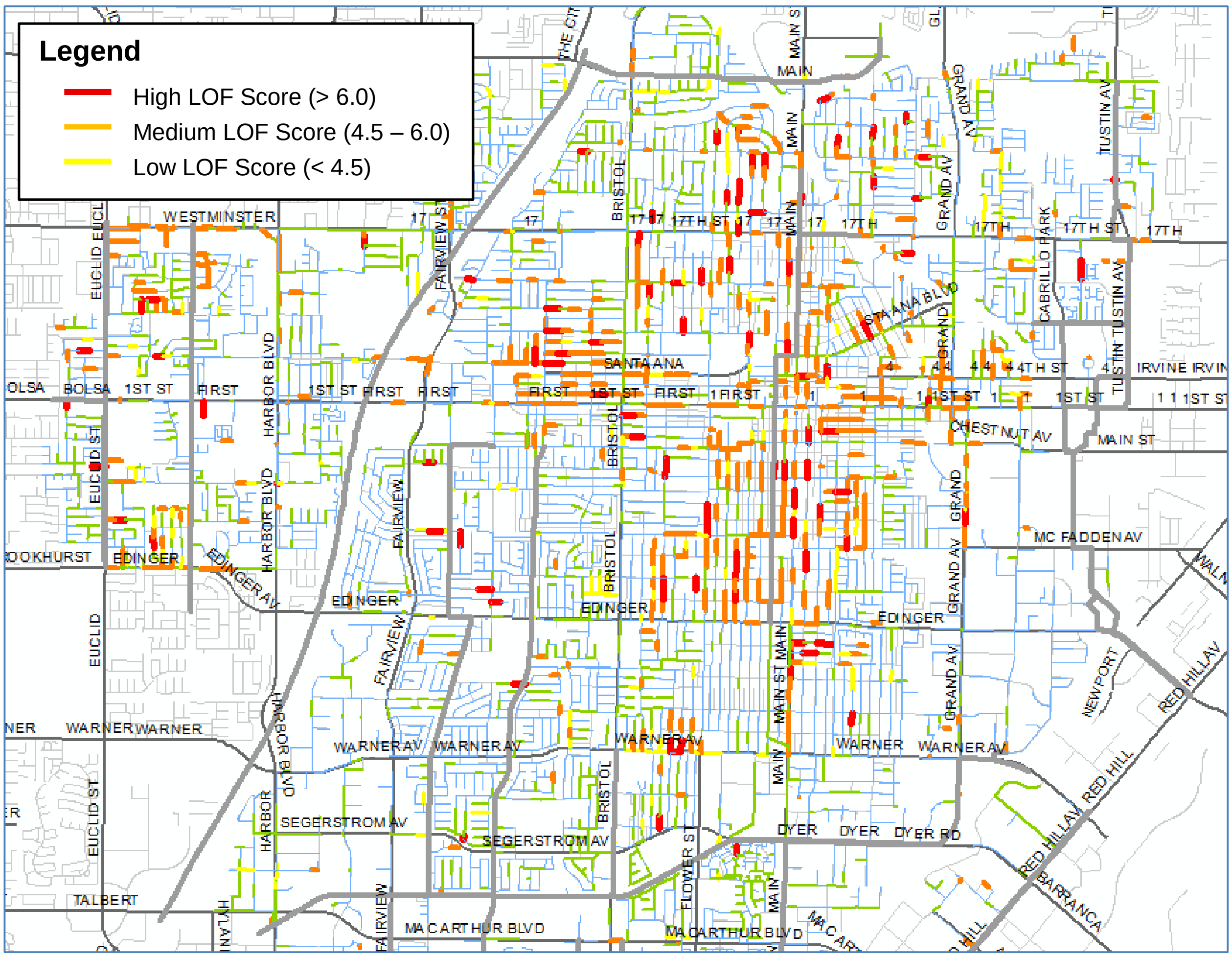


Figure 5-1: LOF Scores from the Pipe Rating Model

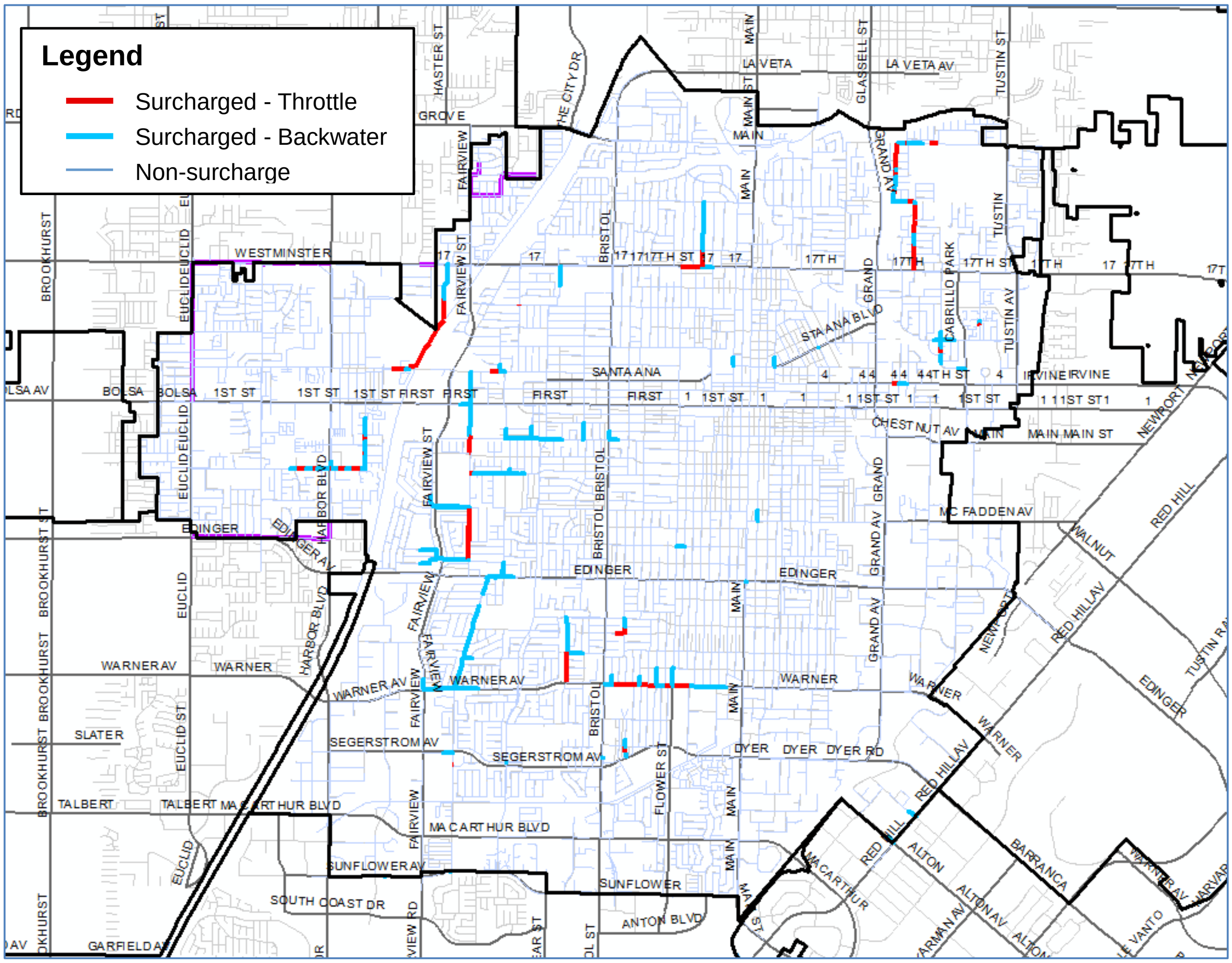


Figure 5-2: Distribution of Hydraulic Condition LOF Scores

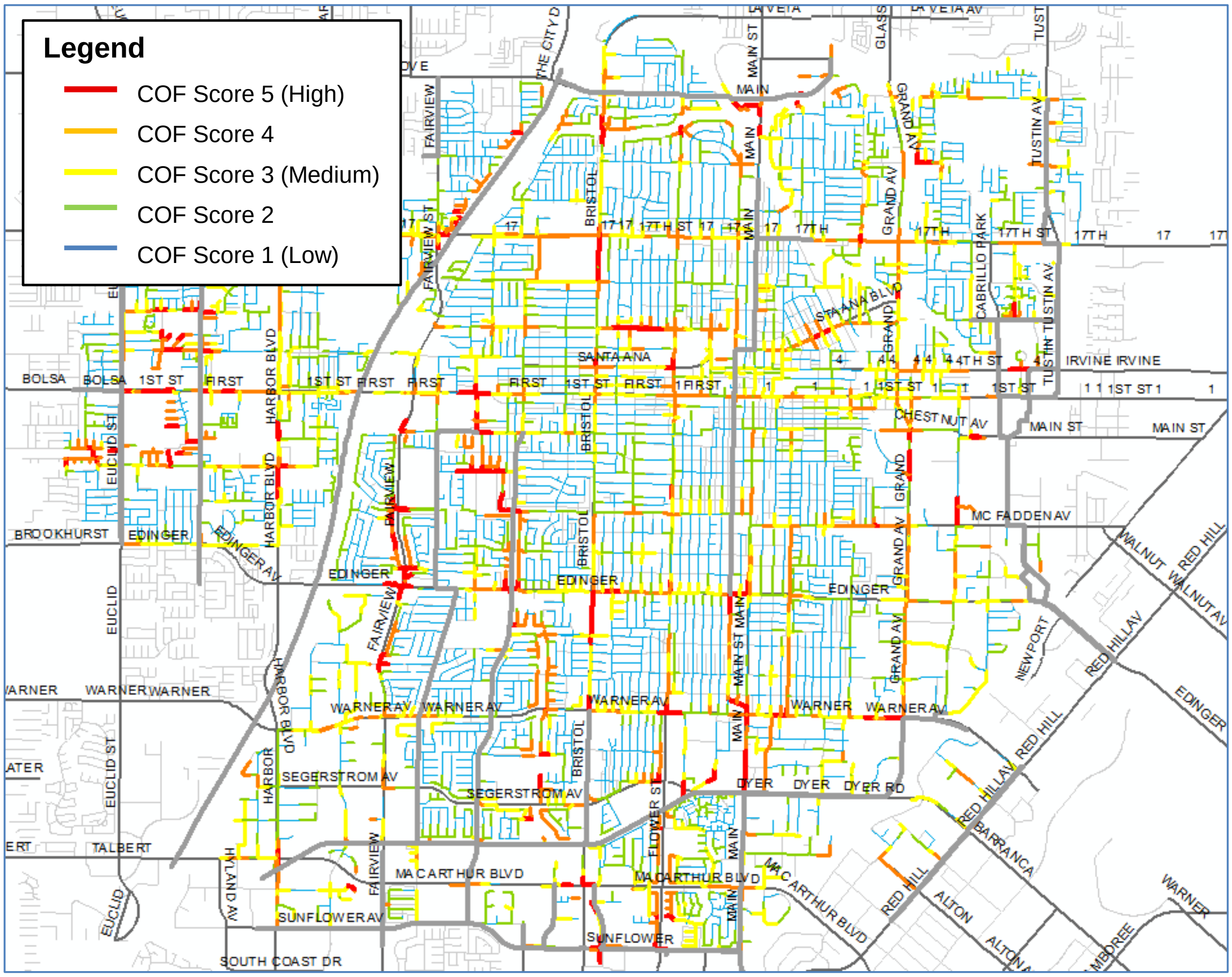


Figure 5-3: COF Scores from the Pipe Rating Model

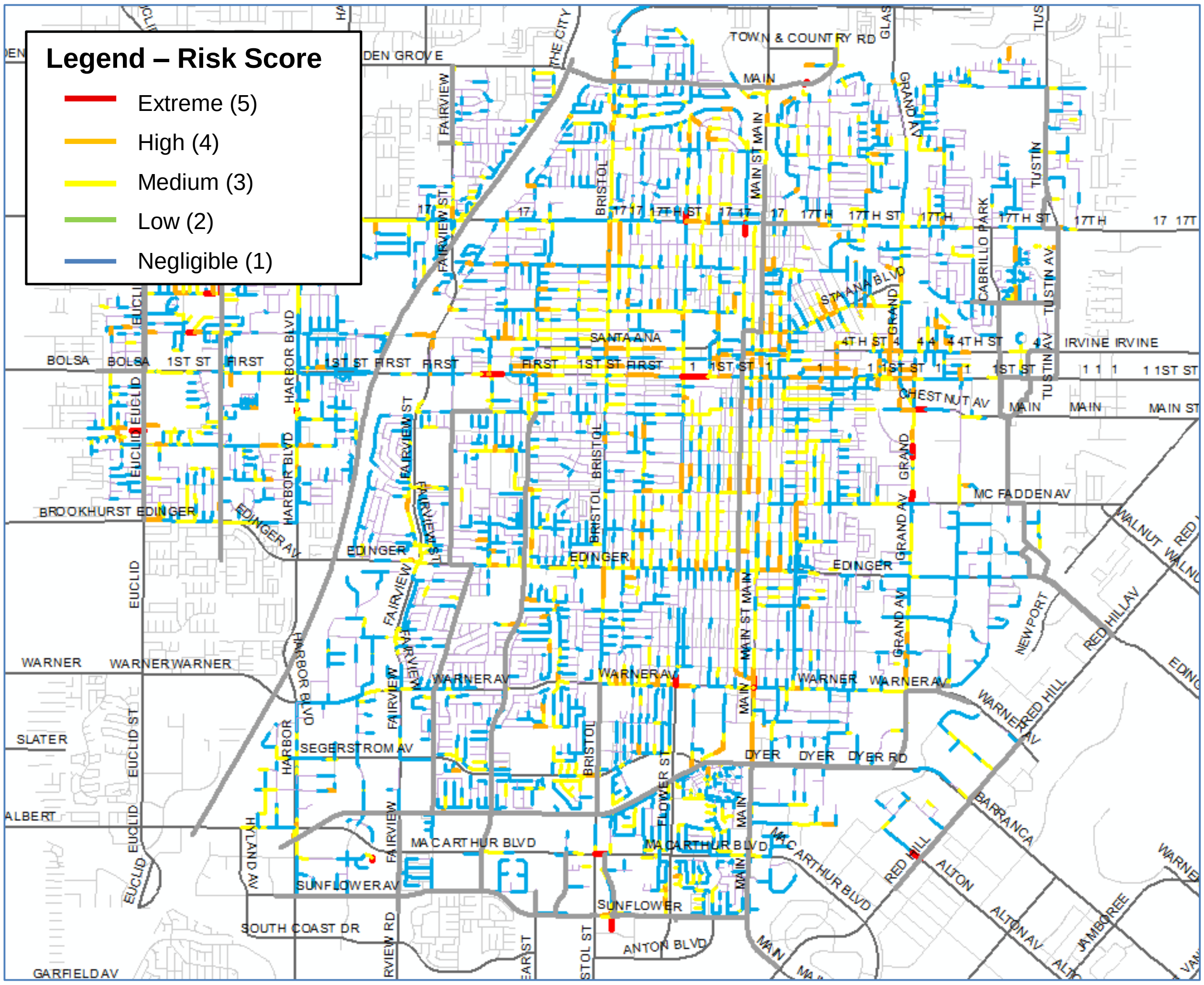


Figure 5-4: Total Risk Scores from the Pipe Rating Model

5.2 Project Definition

Capital improvement projects for sewer infrastructure are typically divided into two categories: 1) condition-based improvement projects utilizing replacement or rehabilitation (R&R) strategies, and 2) capacity improvement projects utilizing pipe upsizing or flow diversions (if applicable). Projects are triggered when; 1) existing pipe condition indicates risk of structural failure, and 2) existing and future flow projections exceed current hydraulic capacities. For this planning study, both condition and capacity projects were developed using a systematic process based on the following logical steps:

- Is the pipe surcharged resulting from insufficient capacity? If so, upsize pipe to convey future peak wet-weather flow (PWWF) projections.
- Has the pipe recently been lined? If so, then no project required but recommend on-going pipe inspection (CCTV).
- Does the pipe have major defects? (Weighted condition score = 5). If so, replace the pipe. If pipe is included in a planned capacity improvement project, then upsize pipe to meet future flow projections.
- Does the pipe have minor defects? (Weighted condition score < 1). If so, then no project required but recommend on-going pipe inspection (CCTV).
- Is it cheaper to replace than conduct spot repairs or lining? If so, replace pipe accordingly.
- Are spot repairs required? (Local grade 4 or 5 defects). If so, conduct spot repairs.
- Line remaining pipes NOT meeting the above criteria.

The above conditions along with input data and pipe improvement actions were compiled into a decision tree and entered into the InfoMaster software as shown in **Figures 5.5 and 5.6**. The decision process used the following input data to evaluate appropriate improvement actions:

- Capacity / surcharge score (based on model)
- Consolidated condition score (based on inspection QSR)
- Estimated defect count for grade 5 and 4 defects (derived from QSR score)
- Unit costs (spot-repairs vs. replacement)
- Sewer GIS providing existing lining, pipe size and pipe age

The decision tree was applied to all the City's sewer pipes (excluding private mains and laterals) to identify an improvement action for each pipe. Improvement actions include upsize, replace, point repair, line or CCTV (inspection). **Figure 5.7** shows a map of all the pipe improvement projects classified per improvement action. In addition to the improvement action, the decision process also assigned the total risk score to each pipe derived previously using the Pipe Rating Model. This parameter was used to support the project prioritization process described in Section 5.4.

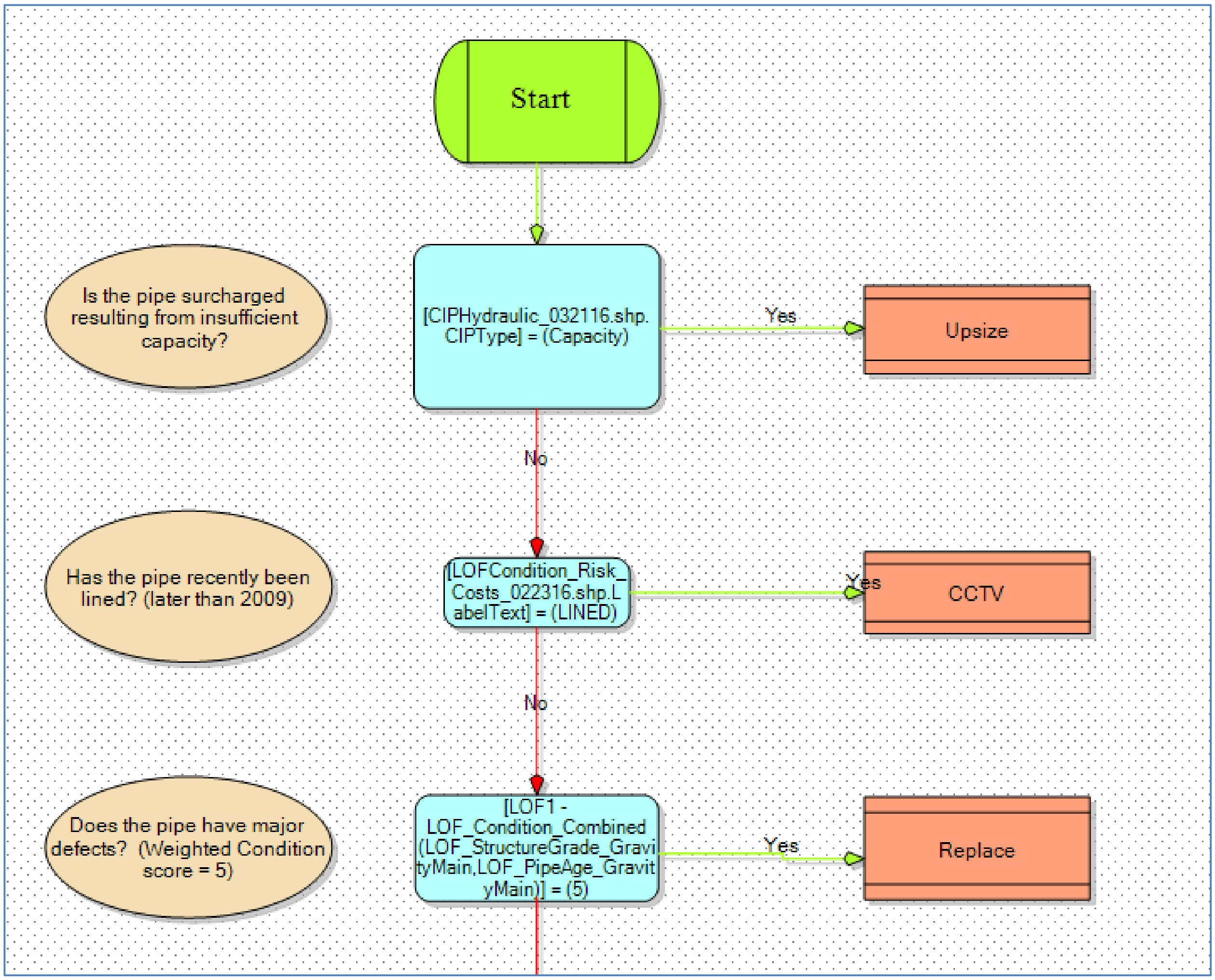


Figure 5.5: Pipe Improvement Decision Tree (Part 1)

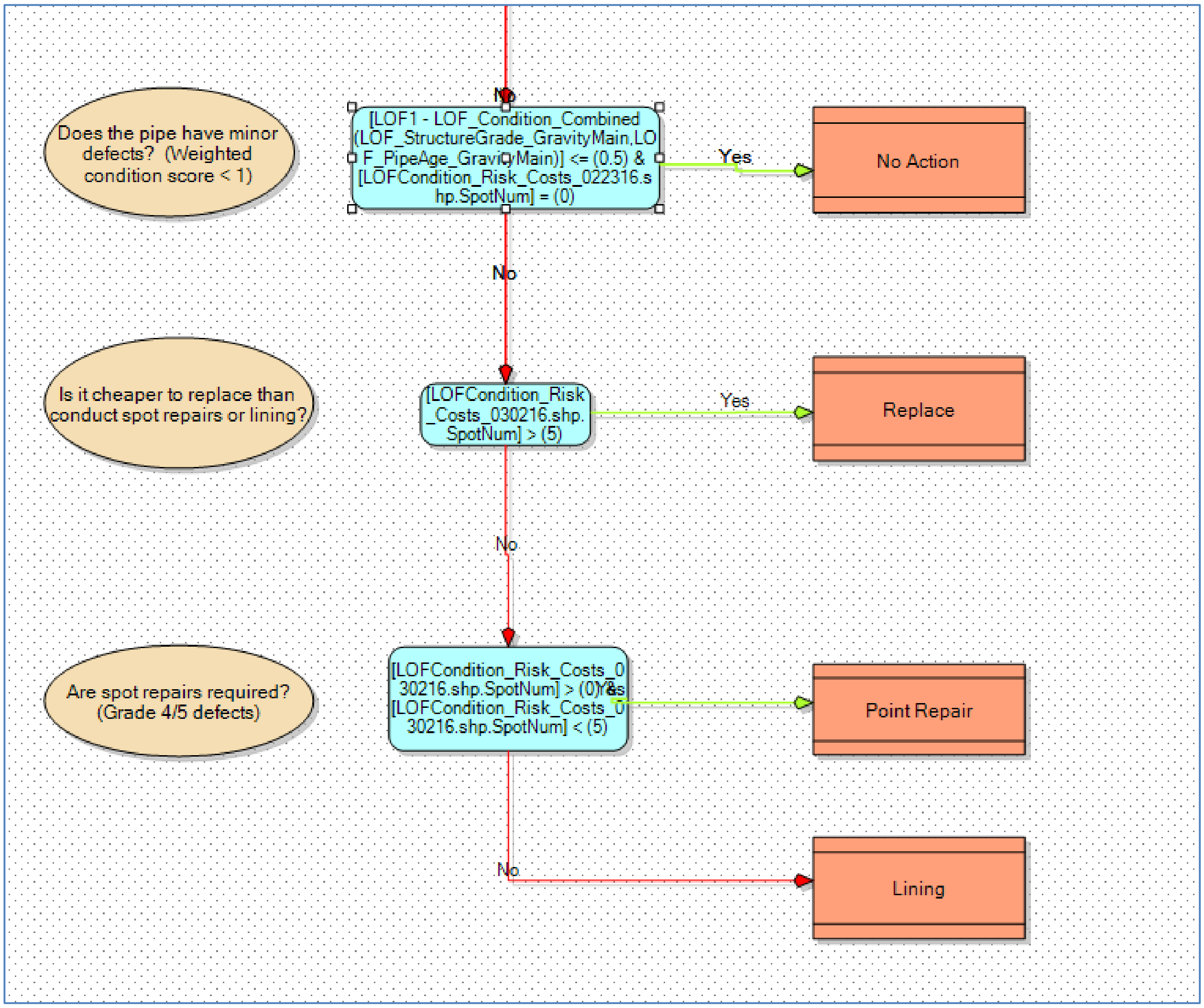


Figure 5.6: Pipe Improvement Decision Tree (Part 2)

For purposes of grouping pipes into potential sewer rehabilitation projects, the improvement projects identified through the decision process were assigned to “mini-basins” delineated by Traffic Area Zone (TAZ) areas. The TAZ areas provide a mechanism for bundling pipe improvements into manageable projects which benefit from efficient cost savings through combined construction mobilization, collective and organized street closures, bulk cost savings for materials and equipment rentals and overall design and construction cost savings.

A normalized and maximum risk score was computed for each mini-basin and used to prioritize the projects. In addition, individual capacity improvement projects where contained within mini-basins and not split between basins. This step ensures all pipes with capacity issues are upsized together providing a contiguous hydraulic solution for each capacity need. **Figure 5-8** shows a snapshot of TAZ ‘mini-basins’ used to bundle pipe improvement projects.

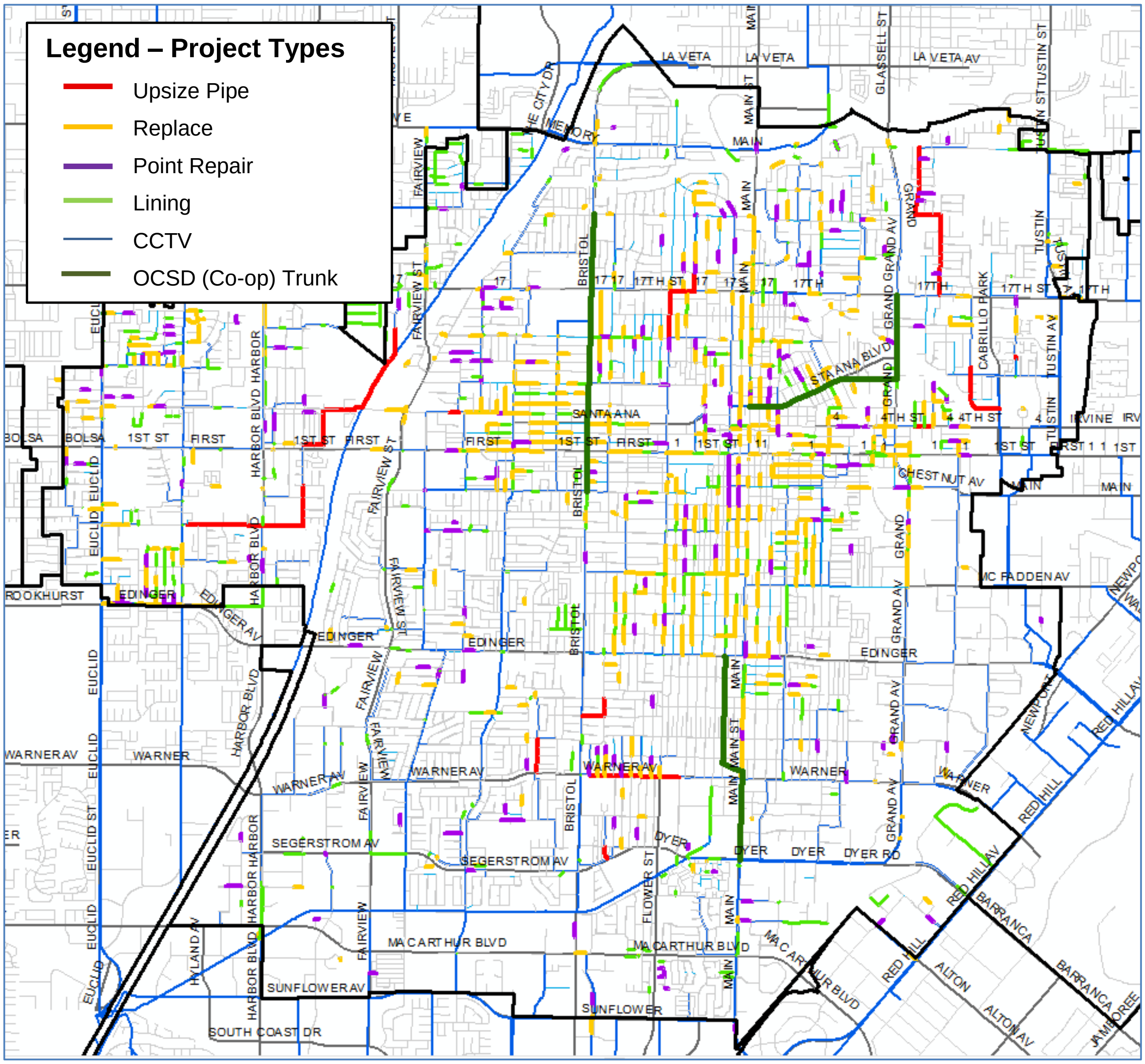


Figure 5.7: Pipe Improvement Projects

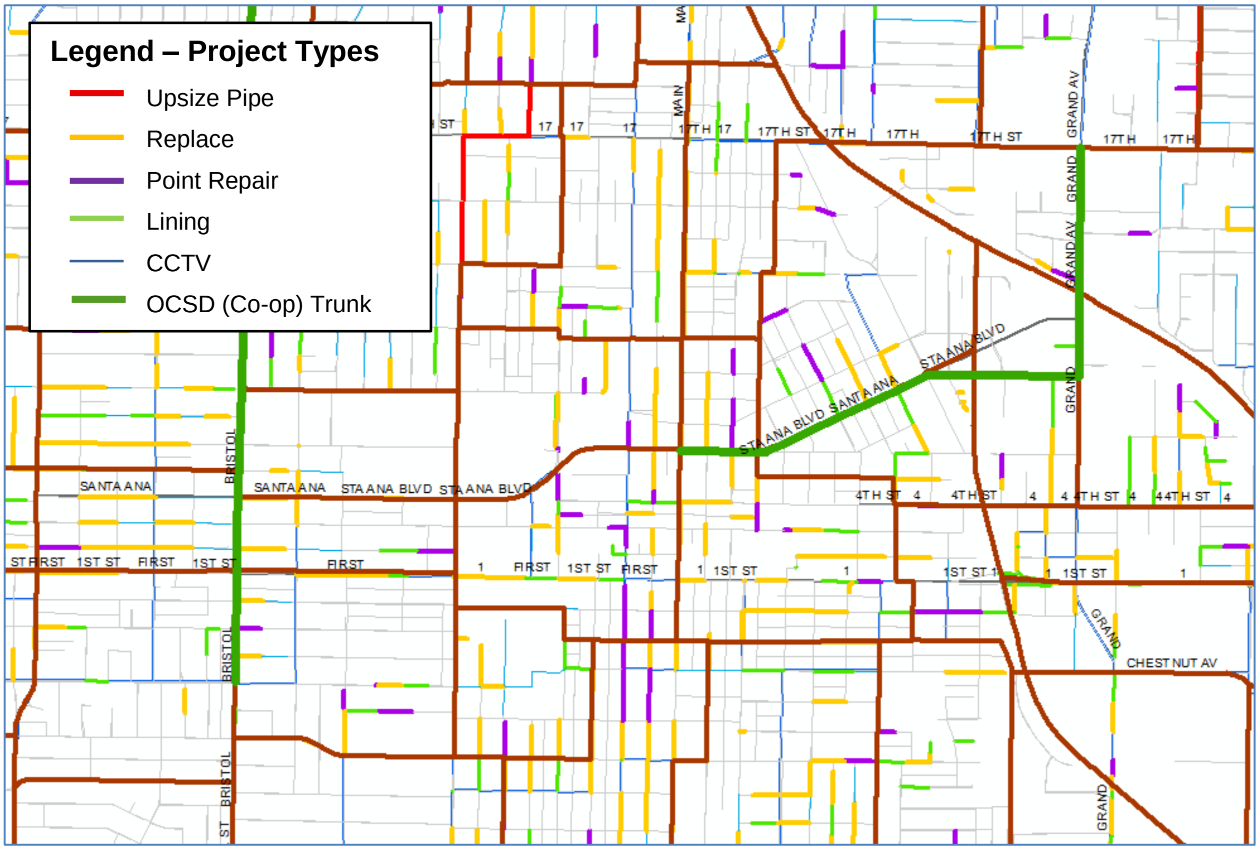


Figure 5.8: Snapshot Map showing TAZ 'Mini-Basins' used to Bundle Pipe Improvement Projects

5.3 Sewer Rehabilitation Costs

The City's approach to sewer rehabilitation typically involves either pipe lining or complete replacement of the sewer main and associated manholes and lower laterals. Replacement is typically done by pipe bursting or by open-cut remove-and-replace construction where pipe bursting is determined not to be feasible, and pipes are generally replaced with either HDPE or PVC pipe.

To develop average unit costs for sewer rehabilitation for use in estimating the costs of sewer projects for the CIP, cost estimates from recent sewer planning studies were reviewed. Costs from these studies were based on a variety of pipe rehabilitation methods including pipe bursting, and in some cases some open-cut replacement, of smaller diameter sewers (e.g., 6- to 12-inch) with replacement of associated manholes and lower laterals. Based on this review, unit cost estimates for each proposed rehabilitation method were developed for each pipe size present in the City's sewer system. **Table 5.3** summarizes the range of unit costs for each method along with the pipe size range.

The costs assume sewer main replacement (primarily by pipe bursting), and include replacement of manholes and lower laterals and installation of cleanouts at the property line. The unit costs include all associated construction costs (mobilization/demobilization, traffic control, bypass pumping, post-construction video and testing, etc.), as well as a 15 percent allowance for design engineering and construction management (based on experience from City's recent projects). The costs do not include additional City costs required to plan, manage and execute the projects.

Table 5-3: Summary of Unit Costs

Rehabilitation Method	Low Unit Cost ($/feet)	High Unit Cost ($/feet)	Min Size (inch)	Max Size (inch)
CCTV	10	10	8	84
LINING	160	740	8	84
POINT REPAIR	45	83	8	84
REPLACEMENT	225	855	8	84
UPSIZE	225	855	8	84

The cost estimates presented in this report are planning or conceptual level estimates, and are considered to have an estimated accuracy range of -30 to +50 percent. This level of accuracy corresponds to an "order of magnitude" or "Class 5" cost estimate as defined by the American Association of Cost Estimators. These estimates are suitable for use for budget forecasting, CIP development, and project evaluations, with the understanding that refinements to the project details and costs would be necessary as projects proceed into the design and construction phases.

5.4 Sewer Lateral Replacement Costs

The City propose to replace all sewer laterals impacted by the sewer improvement projects. Estimated unit costs for sewer lateral replacement were obtained from HomeAdvisor.com which compiles actual costs incurred by home owners in Southern California. Sewer lateral replacement costs have a varied range from $1,200 to $5,600 as paid by home owners. In comparison, an average lateral length was evaluated using the GIS and used to calculate replacement costs based on the above unit cost estimates. Based on an average 40-foot lateral at $225/feet unit cost, the average sewer replacement cost per lateral is $9,000.

Following discussions with City and accounting for the size and distribution of sewer laterals within the City, an average $4000 per lateral was used to evaluate the additional sewer lateral replacement costs. In addition, the cost estimation also assumed one lateral replaced every 45-feet of sewer replacement / rehabilitation. This value was derived from the City's GIS by comparing the lateral count with the total length of existing sewer lines.

5.5 CIP Prioritization

Capital improvement projects are prioritized to allocate available funds to critical projects based on risk of failure and level of impact to economic, social and environment issues. Similar to many public agencies, the City has an annual budget for replacing or rehabilitating aging infrastructure and therefore requires a systematic and defensible method for prioritizing both capacity and condition-based improvement projects. For this study, the improvement projects are based on the following factors:

- Priorities are applied to 'bundled' projects grouped by the 'mini-basins'.

- Initially, projects are prioritized using the normalized and maximum risk scores derived from the Pipe Rating Model analysis.
- Capacity projects are 'triggered' when peak wet-weather flows (PWWF) exceed existing pipe capacities for 2015 flows overriding priorities derived from risk scores.
- Distribute capital improvement projects over a 5-year program with a total budget of $20m.

The basis of the prioritization is the total risk score derived from Pipe Rating Model. This score accounts for both likelihood and consequence of failure and is normalized to provide scores ranging from 6 to 51. In addition, the maximum weighted risk score ranging from 0 – 5 was also used to identify critical problem projects (Max. score = 5). Both the normalized and maximum risk scores were combined to sort the projects from high to low priorities.

Based on the environmental and regulatory impact of sewer spills, capacity projects triggered on existing (2015) flows were considered a high priority and consequently superseded the risk scores derived from Pipe Rating Model. As a result, bundled projects delineated via the mini-basins that contain high priority capacity projects were separately identified on the CIP project list and elevated to the top of the project list with the exception of two rehabilitation projects driven by high condition ratings.

5.6 Sewer System Capital Improvement Program

The CIP was developed based on the following four primary criteria:

- Mitigate the risks of potential sewer spills by implementing capacity improvement projects.
- Utilize condition inspection findings to identify and quantify structural defects and implement appropriate rehabilitation / replacement projects.
- Maintain consistency with the City's annual capital improvement budget based on the financial plan and sewer service charge schedule that has been adopted by the City Council.
- Prioritize mini-basins for rehabilitation based on risk scores as calculated by the Pipe Rating Model.

The City's anticipated 5-year capital budget available for sewer rehabilitation projects is approximately $20,000,000 (in current dollars). Because some projects will have lower cost and some higher, the challenge is to find the most appropriate balance of cost and annual expenditure while still adhering to the mini-basin rankings indicated by the Pipe Rating Model risk scores to the greatest extent possible.

5.6.1 Sewer Rehabilitation Projects

Table 5-4 presents a list of mini-basins (TAZ areas) ranked by a combination of decreasing 1) normalized risk score, 2) maximum risk score and 3) surcharge 'trigger' year. The table shows sewer improvement costs which includes both condition and capacity projects, lateral costs and total project costs. In addition, the table highlights capacity improvement projects (Capacity Project ID) associated to the mini-basins allowing the City to track and implement critical capacity improvements while addressing on-going rehabilitation projects.

Table 5-5 presents the recommended 5-year CIP developed by RMC and City staff by application of the four guiding criteria described above, and **Figure 5-9 to 5-16** show the location of the proposed projects. **Table 5-6** summarizes the projected budget required to implement the CIP projects for each fiscal year starting with FY16/17. The City may elect to modify the CIP schedule as needed to accommodate budget constraints and changes in project priorities as additional inspection data and other information are collected over time. Such information may include the need for coordination with street paving or other infrastructure or utility projects; need to address new or recurring maintenance problems in the system; or specific data provided by OCSD as to priority areas for focusing I/I reduction efforts.

Table 5-4: Mini-Basin Rankings

Rank	CIP ID	Normalized Risk	Max Risk	Surcharge Year	Sewer Improve Cost	Lateral Cost	Total Cost	Capacity Project ID
1	714	20.4	5	2015	$3,729,070	$873,661	$4,602,731	CIP-CAP-002
2	784	18.3	5	2015	$1,357,238	$440,933	$1,798,171	CIP-CAP-005
3	783	28.2	4	2015	$456,390	$138,701	$595,091	CIP-CAP-007
4	785	28.1	4	-	$1,965,592	$168,254	$2,133,846	
5	702	27	4	-	$175,965	$54,502	$230,467	
6	793	25	4	2015	$961,975	$284,685	$1,246,660	CIP-CAP-006
7	794	15.7	4	2015	$462,387	$8,960	$471,347	CIP-CAP-006
8	711	14	4	2015	$773,824	$251,941	$1,025,765	CIP-CAP-001
9	704	13.2	4	2015	$876,383	$288,341	$1,164,724	CIP-CAP-001
10	757	42	5	-	$456,841	$158,912	$615,753	
11	731	38.3	5	-	$119,186	$18,253	$137,439	
12	815	37	5	-	$321,927	$82,706	$404,633	
13	810	32.9	5	-	$299,146	$6,590	$305,736	
14	752	31.4	5	-	$709,570	$197,104	$906,674	
15	749	30.1	5	-	$1,017,023	$297,768	$1,314,791	
16	701	28.6	5	-	$452,238	$10,214	$462,452	
17	786	27.5	5	-	$1,235,857	$319,819	$1,555,676	
18	744	25.8	5	-	$237,911	$57,818	$295,729	
19	718	23.6	5	-	$990,358	$285,837	$1,276,195	
20	717	21.7	5	-	$1,892,098	$545,131	$2,437,229	
21	735	20	5	-	$1,643,079	$323,371	$1,966,450	
22	807	17	5	-	$279,734	$51,138	$330,872	
23	748	17	5	2040	$556,040	$129,650	$685,690	CIP-CAP-004
24	715	14.5	5	-	$944,243	$262,786	$1,207,029	
25	759	53.5	4	-	$33,288	$13,150	$46,438	
26	761	50.9	4	-	$57,568	$0	$57,568	
27	616	45.9	4	-	$95,176	$37,600	$132,776	
28	494	44.6	4	-	$91,242	$36,046	$127,288	
29	615	40.5	4	-	$257,757	$71,904	$329,661	
30	745	36.6	4	-	$104,780	$40,888	$145,668	
31	770	33.4	4	-	$296,841	$97,622	$394,463	
32	1051	31.8	4	-	$49,591	$19,592	$69,183	
33	795	31.8	4	-	$901,263	$1,778	$903,041	
34	737	31.7	4	-	$279,888	$83,858	$363,746	
35	747	30.8	4	2040	$230,522	$63,112	$293,634	CIP-CAP-005
36	777	30.6	4	-	$506,571	$170,770	$677,341	
37	790	29.7	4	-	$159,561	$42,235	$201,796	

Rank	CIP ID	Normalized Risk	Max Risk	Surcharge Year	Sewer Improve Cost	Lateral Cost	Total Cost	Capacity Project ID
38	808	29.1	4	-	$88,651	$530	$89,181	
39	763	29	4	-	$534,724	$151,970	$686,694	
40	746	28.8	4	-	$190,710	$31,110	$221,820	
41	742	27	4	-	$770,906	$234,888	$1,005,794	
42	727	26.3	4	-	$604,369	$207,234	$811,603	
43	723	26	4	-	$184,093	$70,533	$254,626	
44	758	25.8	4	-	$179,897	$31,466	$211,363	
45	736	25.6	4	-	$2,304,434	$774,400	$3,078,834	
46	699	25.2	4	-	$575,862	$67,549	$643,411	
47	725	24.3	4	-	$1,108,175	$179,171	$1,287,346	
48	740	24.1	4	-	$531,420	$81,106	$612,526	
49	734	23.9	4	-	$458,177	$111,091	$569,268	
50	716	23.8	4	-	$1,326,874	$433,312	$1,760,186	
51	741	23.3	4	-	$383,016	$88,074	$471,090	
52	700	22.8	4	-	$101,249	$0	$101,249	
53	730	22.7	4	-	$337,883	$71,466	$409,349	
54	722	22.5	4	-	$1,043,242	$223,710	$1,266,952	
55	738	22.1	4	-	$879,785	$261,741	$1,141,526	
56	802	21.8	4	-	$254,734	$35,181	$289,915	
57	728	21.6	4	-	$398,911	$136,786	$535,697	
58	733	21.6	4	-	$1,233,517	$125,611	$1,359,128	
59	754	20.8	4	-	$1,910,223	$678,278	$2,588,501	
60	765	20.6	4	2040	$1,363,540	$333,070	$1,696,610	CIP-CAP-004
61	739	20.4	4	-	$1,200,858	$382,840	$1,583,698	
62	708	20.4	4	-	$730,408	$66,504	$796,912	
63	782	20.4	4	-	$172,650	$28,443	$201,093	
64	618	20.2	4	-	$62,273	$0	$62,273	
65	751	20	4	-	$1,052,005	$246,579	$1,298,584	
66	721	19.6	4	-	$761,497	$166,646	$928,143	
67	809	19.4	4	-	$406,080	$0	$406,080	
68	726	19.4	4	-	$797,610	$165,338	$962,948	
69	764	19.2	4	-	$2,093,512	$536,309	$2,629,821	
70	703	19.1	4	-	$1,120,494	$277,986	$1,398,480	
71	771	18.9	4	-	$141,152	$19,998	$161,150	
72	766	18.4	4	2040	$602,452	$122,086	$724,538	CIP-CAP-004
73	788	18.2	4	-	$136,471	$39,835	$176,306	
74	719	18.2	4	-	$1,145,428	$344,096	$1,489,524	
75	804	18.2	4	-	$809,492	$22,106	$831,598	
76	792	17.9	4	-	$292,593	$50,658	$343,251	
77	773	17.8	4	-	$1,472,035	$446,872	$1,918,907	
78	710	17.6	4	-	$310,316	$45,446	$355,762	
79	713	17.5	4	-	$218,594	$62,302	$280,896	
80	753	17.3	4	-	$813,218	$267,848	$1,081,066	
81	816	17.1	4	-	$183,588	$0	$183,588	
82	622	17	4	-	$2,489,742	$301,261	$2,791,003	

Rank	CIP ID	Normalized Risk	Max Risk	Surcharge Year	Sewer Improve Cost	Lateral Cost	Total Cost	Capacity Project ID
83	729	16.7	4	-	$314,141	$109,240	$423,381	
84	774	15.6	4	-	$2,431,849	$764,050	$3,195,899	
85	800	15.4	4	-	$767,324	$1,078	$768,402	
86	706	15.3	4	-	$974,823	$352,398	$1,327,221	
87	720	13.8	4	-	$1,714,595	$511,293	$2,225,888	
88	724	13.4	4	2040	$1,567,096	$460,658	$2,027,754	CIP-CAP-003
89	796	12.9	4	-	$211,372	$27,664	$239,036	
90	775	12.7	4	-	$537,085	$97,970	$635,055	
91	787	10.2	4	-	$307,865	$78,222	$386,087	
92	0	7.6	4	-	$970,747	$0	$970,747	
93	1017	26.1	3	-	$52,936	$0	$52,936	
94	621	25.3	3	-	$6,064	$1,101	$7,165	
95	768	23.6	3	-	$190,978	$44,888	$235,866	
96	614	22.9	3	-	$1,907	$0	$1,907	
97	769	22.4	3	-	$154,885	$28,888	$183,773	
98	712	21.5	3	-	$35,087	$5,778	$40,865	
99	803	20.5	3	-	$356,422	$0	$356,422	
100	743	18.7	3	-	$48,800	$0	$48,800	
101	798	18.2	3	-	$226,970	$0	$226,970	
102	797	17.8	3	-	$18,109	$7,154	$25,263	
103	617	17.7	3	-	$105,750	$13,333	$119,083	
104	709	17.6	3	-	$413,755	$155,306	$569,061	
105	799	14.5	3	-	$28,985	$0	$28,985	
106	781	13.5	3	-	$273,275	$62,040	$335,315	
107	780	13.4	3	-	$144,039	$0	$144,039	
108	496	13.2	3	-	$802,190	$23,110	$825,300	
109	760	13	3	-	$36,051	$0	$36,051	
110	791	12.8	3	-	$240,477	$28,355	$268,832	
111	755	12.3	3	-	$532,109	$135,901	$668,010	
112	608	11.3	3	-	$123,439	$29,533	$152,972	
113	756	10.3	3	-	$2,300,626	$679,973	$2,980,599	
114	789	8.6	3	-	$77,717	$25,867	$103,584	
115	772	8.6	3	-	$455,043	$0	$455,043	
116	750	7.8	3	-	$349,128	$66,875	$416,003	
117	609	6.3	3	-	$790,003	$0	$790,003	
118	705	6	3	-	$64,810	$17,955	$82,765	
119	707	6	3	-	$42,075	$10,667	$52,742	
120	811	21.3	2	-	$10,350	$0	$10,350	
121	1059	16.8	2	-	$12,060	$0	$12,060	
122	779	15	2	-	$5,310	$0	$5,310	
123	812	14.3	2	-	$2,242	$0	$2,242	
124	814	12.1	2	-	$21,408	$0	$21,408	
125	732	10	2	-	$104,147	$0	$104,147	
126	801	6.9	1	-	$10,810	$0	$10,810	

Table 5-5: Recommended 5-Year Sewer System CIP

CIP Priority	Budget Year	CIP ID	Sewer Improvement Cost	Lateral Cost	Total Cost	Capacity Project ID	Cumulative Budget
1	FY 16/17	714	$3,729,070	$873,660.80	$4,602,731	CIP-CAP-002	$4,602,731
2	FY 17/18	784	$1,357,238	$440,933	$1,798,171	CIP-CAP-005	$6,400,902
3	FY 17/18	783	$456,390	$138,701	$595,091	CIP-CAP-007	$6,995,992
4	FY 17/18	785	$1,965,592	$168,254	$2,133,846		$9,129,839
5	FY 17/18	702	$175,965	$54,502	$230,467		$9,360,306
6	FY 18/19	793	$961,975	$284,685	$1,246,660	CIP-CAP-006	$10,606,966
7	FY 18/19	794	$462,387	$8,960	$471,347	CIP-CAP-006	$11,078,313
8	FY 18/19	711	$773,824	$251,941	$1,025,765	CIP-CAP-001	$12,104,078
9	FY 18/19	704	$876,383	$288,341	$1,164,724	CIP-CAP-001	$13,268,802
10	FY 18/19	757	$456,841	$158,912	$615,753		$13,884,555
11	FY 19/20	731	$119,186	$18,253	$137,439		$14,021,993
12	FY 19/20	815	$321,927	$82,706	$404,633		$14,426,626
13	FY 19/20	810	$299,146	$6,590	$305,736		$14,732,362
14	FY 19/20	752	$709,570	$197,104	$906,674		$15,639,036
15	FY 19/20	749	$1,017,023	$297,768	$1,314,791		$16,953,827
16	FY 19/20	701	$452,238	$10,214	$462,452		$17,416,280
17	FY 20/21	786	$1,235,857	$319,819	$1,555,676		$18,971,956
18	FY 20/21	744	$237,911	$57,818	$295,729		$19,267,685
19	FY 20/21	718	$990,358	$285,837	$1,276,195		$20,543,879
20	FY 20/21	717	$1,892,098	$545,131	$2,437,229		$22,981,109
		TOTAL:	**$18,490,979**	**$4,490,130**	**$22,981,109**		

Table 5-6: Summary Budget Table

Budget Year	CIP ID	Capacity Project ID	Annual Budget
FY 16/17	714	CIP-CAP-002	$4,602,731
FY 17/18	784, 783,785,702	CIP-CAP-005, CIP-CAP-007	$4,757,575
FY 18/19	793, 794, 711, 704,757	CIP-CAP-001, CIP-CAP-006	$4,524,248
FY 19/20	731, 815, 810, 752, 749, 701		$3,531,725
FY 20/21	786, 744, 718, 717		$5,564,829
		TOTAL:	**$22,981,109**

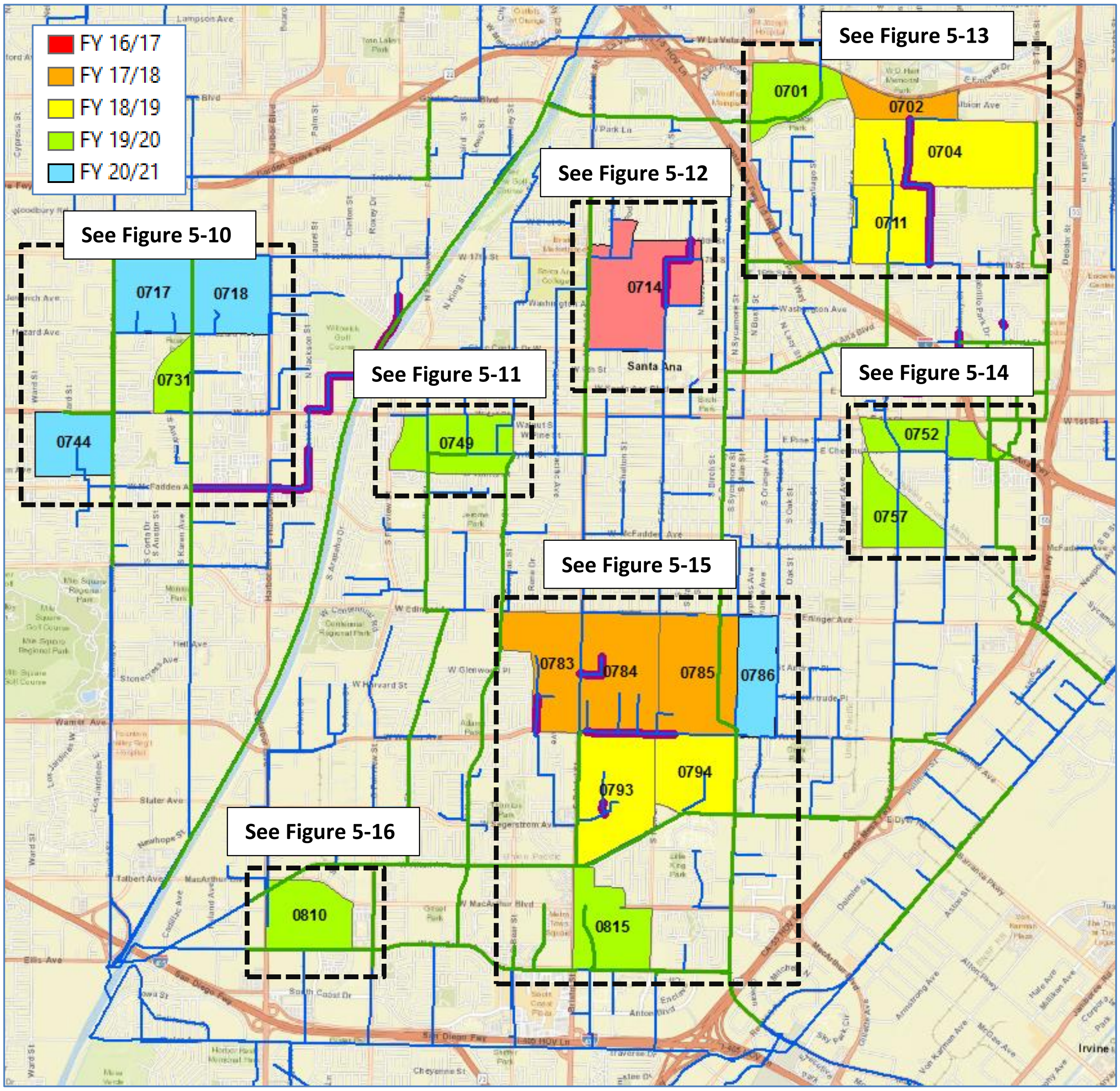


Figure 5-9: Recommended 5-Year Sewer System CIP

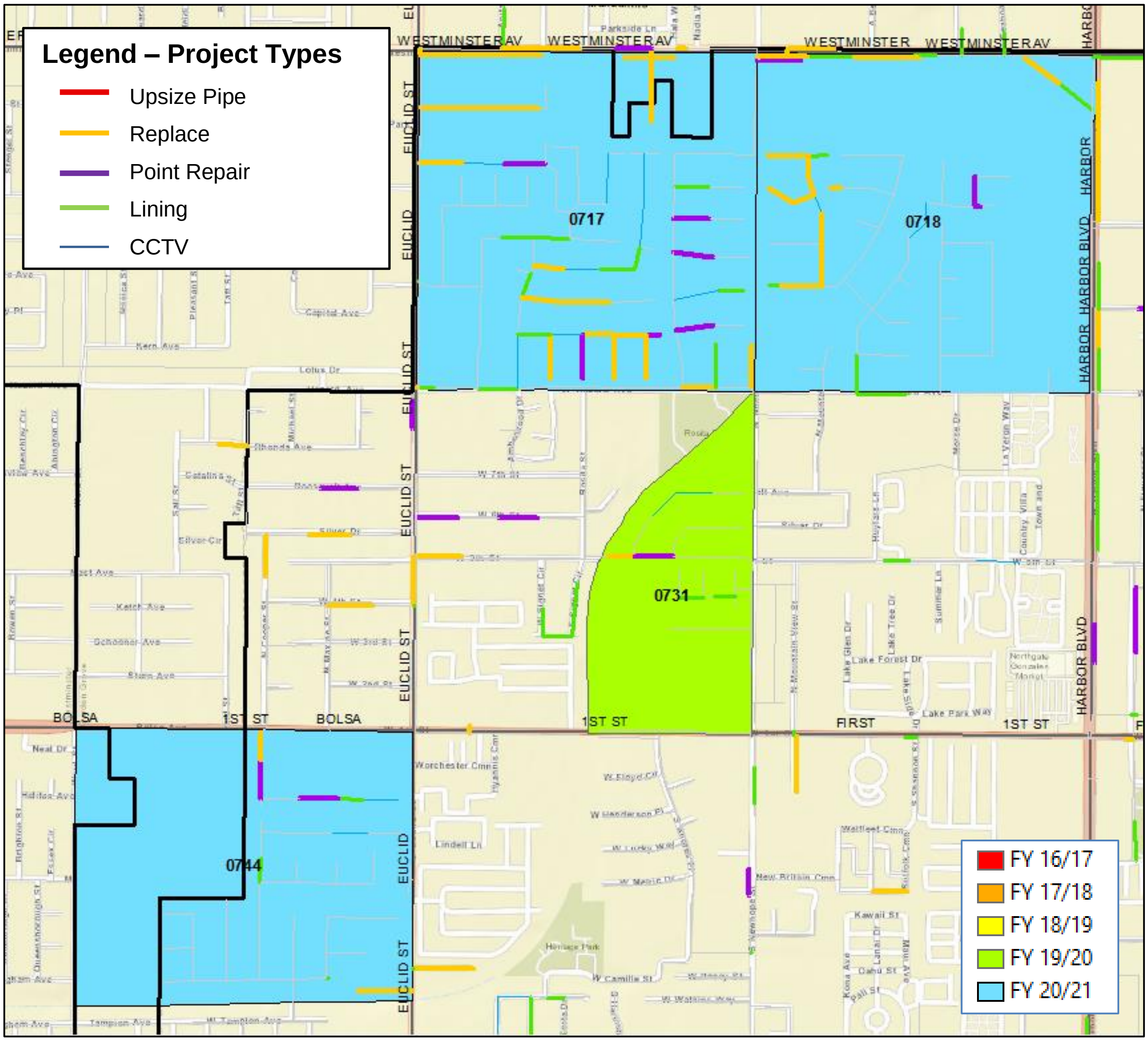


Figure 5-10: Recommended 5-Year Sewer System CIP (Detail View – 1/7)

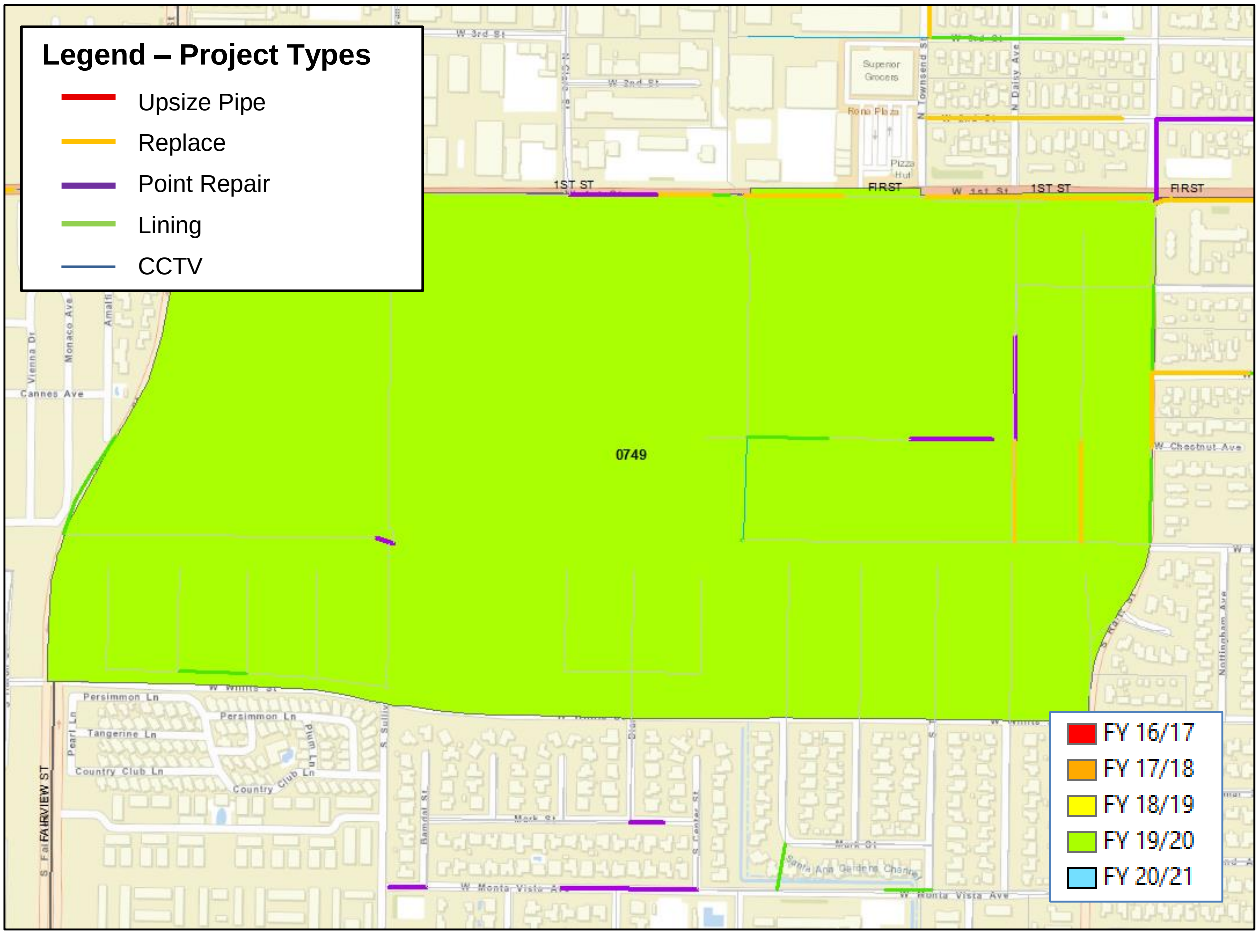


Figure 5-11: Recommended 5-Year Sewer System CIP (Detail View – 2/7)

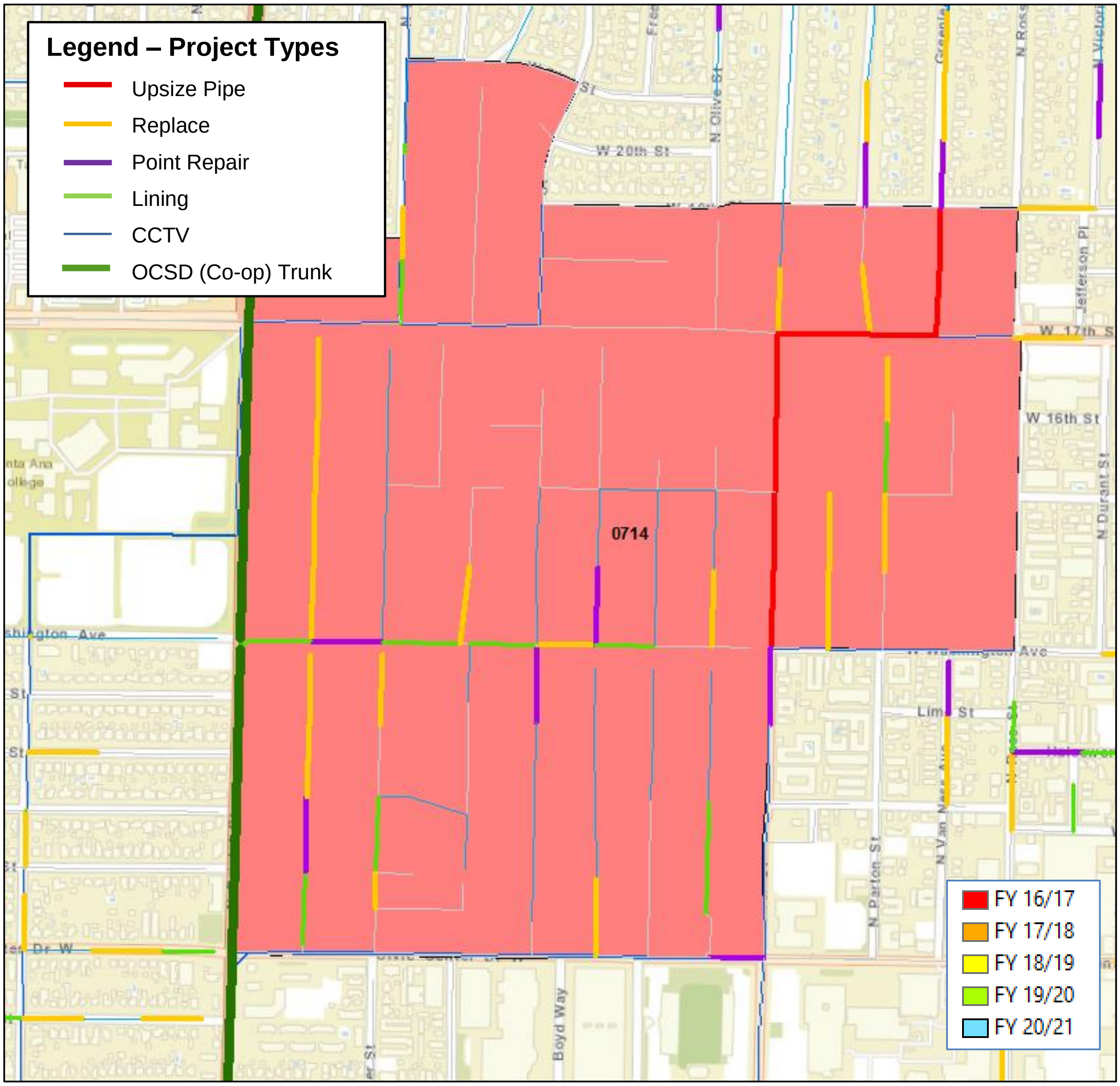


Figure 5-12: Recommended 5-Year Sewer System CIP (Detail View – 3/7)

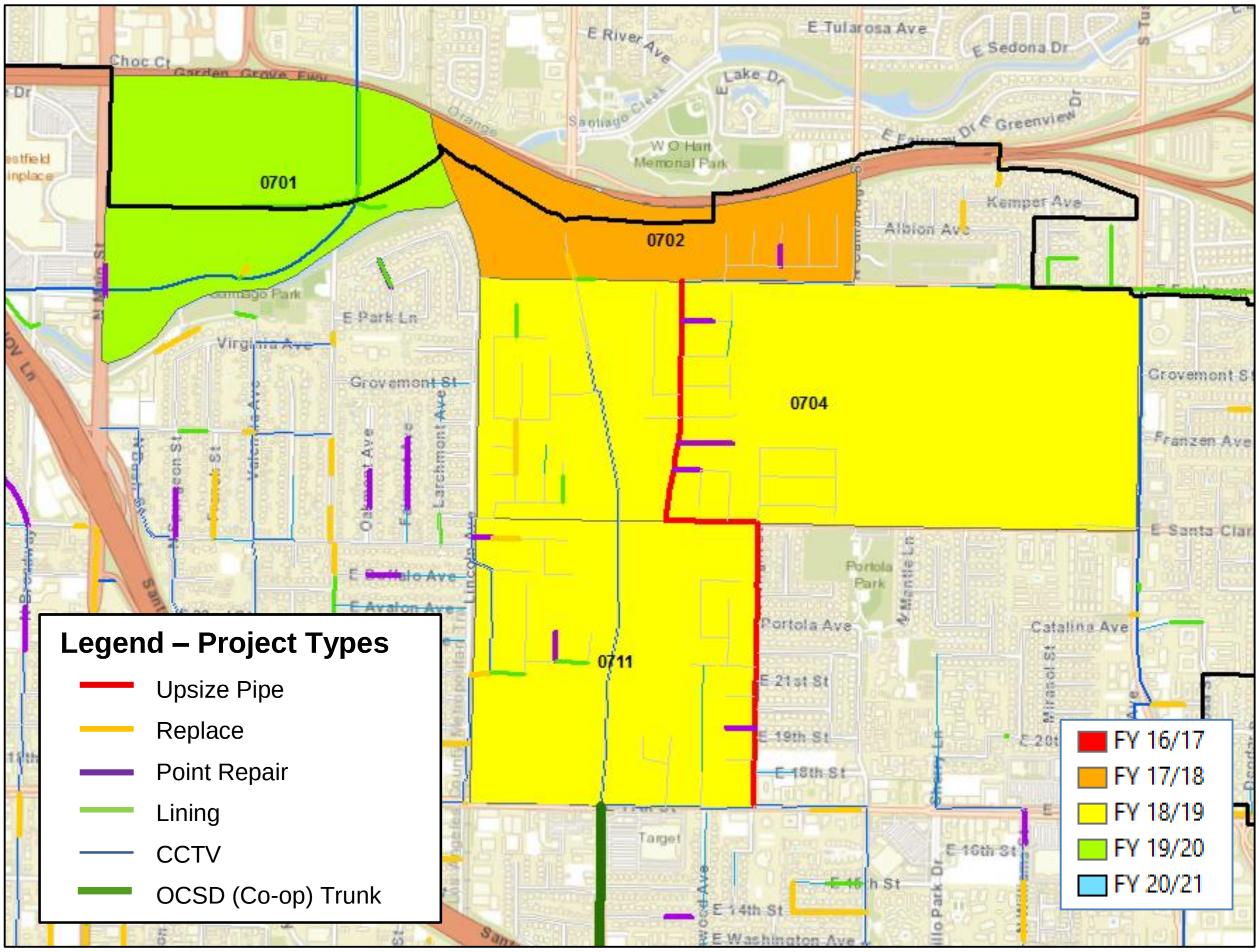


Figure 5-13: Recommended 5-Year Sewer System CIP (Detail View – 4/7)

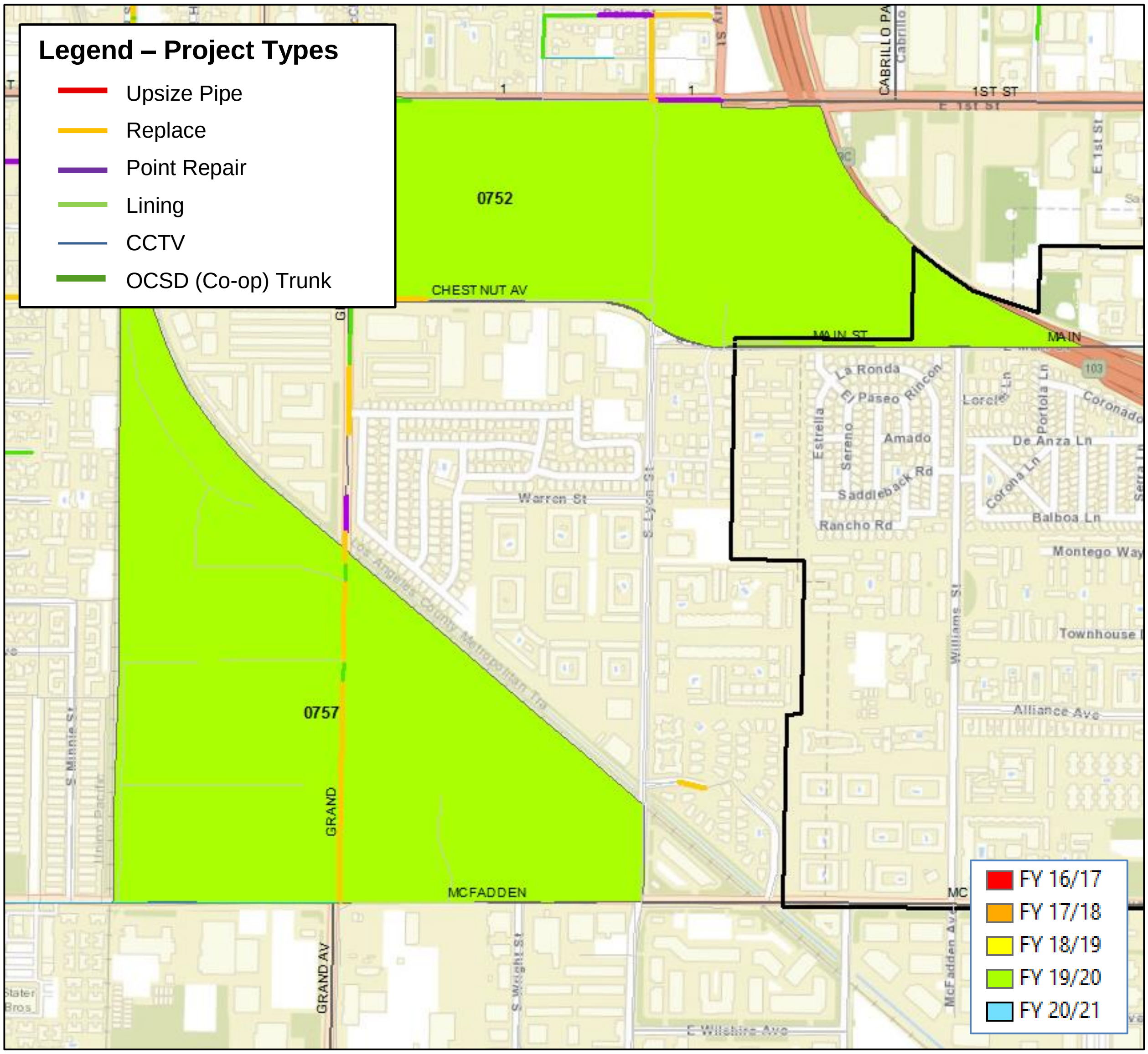


Figure 5-14: Recommended 5-Year Sewer System CIP (Detail View – 5/7)

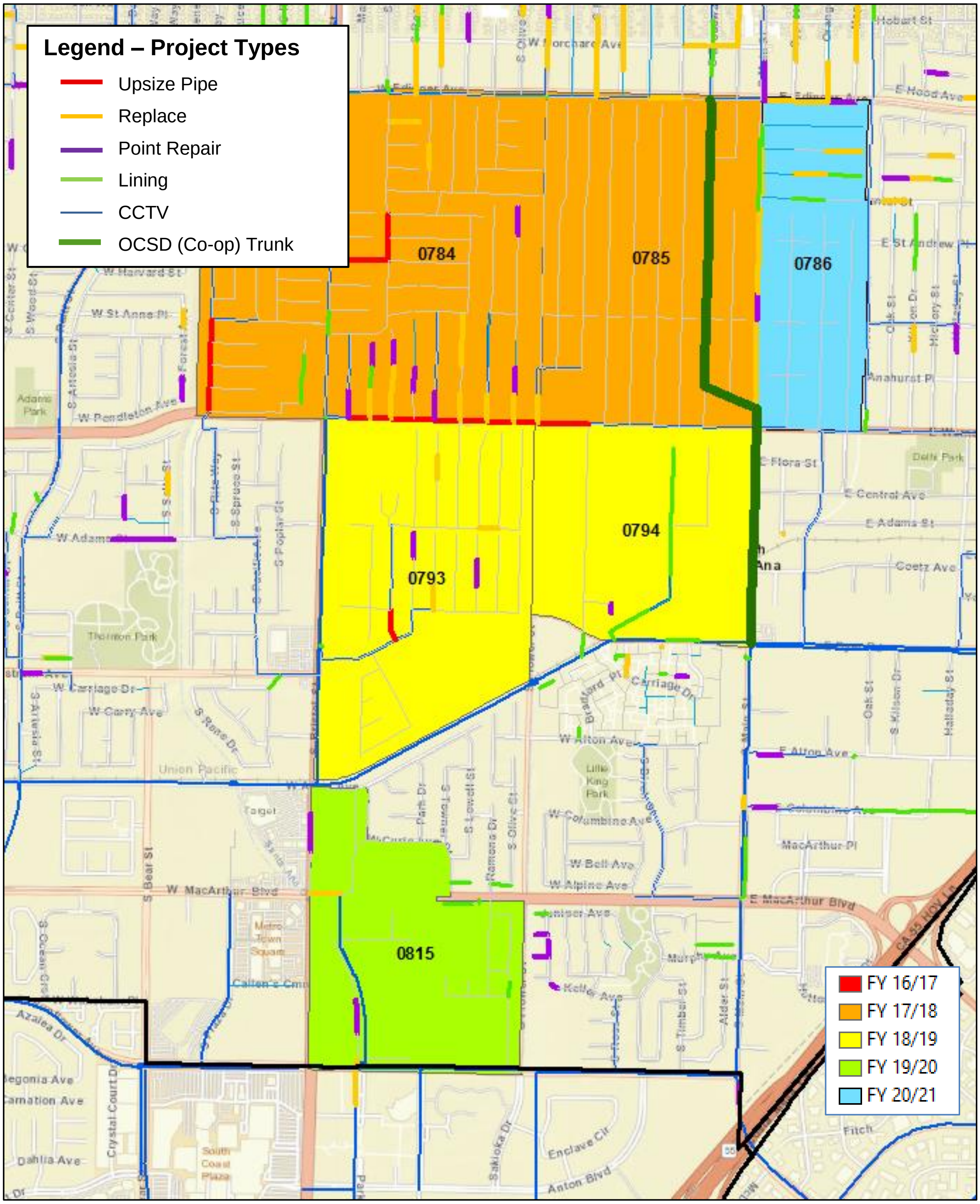


Figure 5-15: Recommended 5-Year Sewer System CIP (Detail View – 6/7)

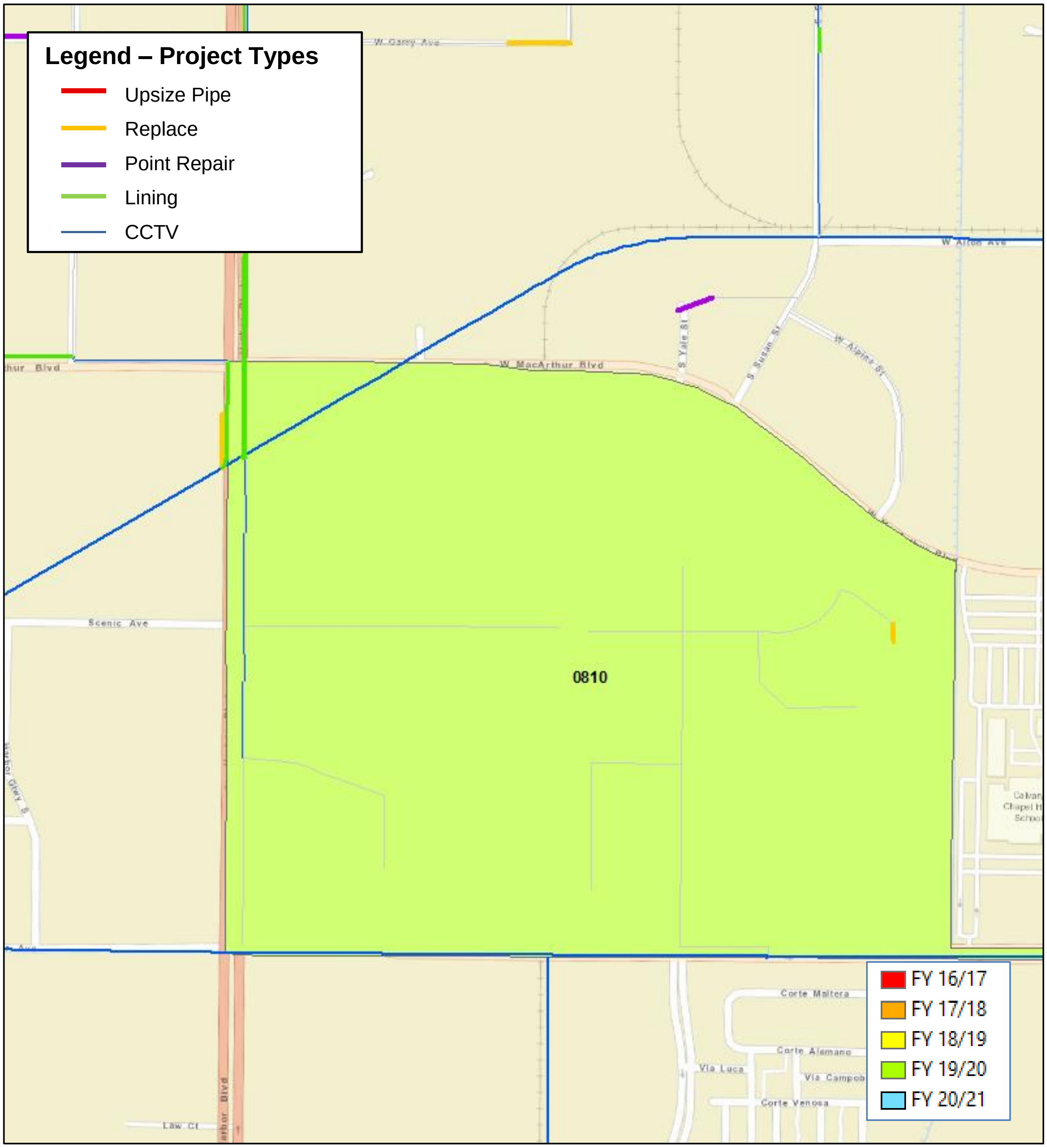


Figure 5-16: Recommended 5-Year Sewer System CIP (Detail View – 7/7)

5.6.2 Long-Term CIP Project Plan

Capital improvement projects were identified for all pipes in the City's collection system based on both hydraulic and structural defects. **Appendix D** shows all proposed projects ordered by risk score (percent) and risk grade. The total cumulative cost for completing all CIP projects is $93.2M allocated over a 25-year period. In addition, the projects are grouped into proposed 5-year budget cycles based on a $20M CIP budget allocated every 5-years. The cost estimate does not account for increased design and construction costs.

5.6.3 Capacity Improvements

The hydraulic assessment identified seven (7) capacity improvement projects resulting from peak wet-weather flows exceeding existing pipe capacities. Each project consists of upsized pipes to meet future flow projections (2040 – peak wet-weather flow). **Table 5-7** and **Figure 5-17** shows the capacity improvement projects identified by a capacity project ID (eg; CIP-CAP-001). Two alternative projects were developed for projects CIP-CAP-004 and CIP-CAP-006 which utilize existing sewer mains to divert excess flow. Cost estimates for these two alternatives are less than the upsized projects and present viable solutions if the original upsized pipes have no structural defects and do not need to be replaced.

The hydraulic analysis predicted when the capacity projects will be required to meet future flow projections by identifying a 'trigger' year. The analysis identified four locations that exceed existing capacities for today's base flows along with peak wet-weather flows (generated from the 10-year design event). As a result, the four projects developed to resolve immediate hydraulic, flagged as triggering in 2015 were ranked at the top of the CIP list (see **Table 5-5**) to ensure these projects are addressed in a timely manner by the City.

Table 5-7: Recommended Sewer Capacity CIP Project Locations

Project ID	Location	Description	Triggered	Old Diameter (in)	New Diameter (in)	Length (ft)	Cost ($)
CIP-CAP-001	Fairhaven Ave. to 17th St., along Old Grand St., Santa Clara Ave., and Wright St.	Pipe Upsize	2015	08 - 10	08 - 15	5,712	1,629,394
CIP-CAP-002	19th St. to Washington Ave., along Greenleaf Rd., 17th St., and Flower St.	Pipe Upsize	2015	08 - 12	10 - 15	2,971	852,691
CIP-CAP-003	Mar les Dr. between Westminster Ave. and just east of intersection of 5th St./Susan St.	Pipe Upsize	2040	10 - 12	15	6,045	1,740,096
CIP-CAP-004	Jackson St. at Calle del Sur, down to McFadden Ave., west to Shannon St.	Pipe Upsize	2040	15	18	5,302	1,884,152
CIP-CAP-004A	Intersection of McFadden Ave. and Harbor Blvd.	Flow Diversion and Pipe Upsize (in lieu of CIP-CAP-004)	2040	12 - 15	15 - 18	2,611	831,510
CIP-CAP-005	St. Andrew Pl. to Bristol St., along Baker St. and Glenwood Pl.	Pipe Upsize	2015	8	10	1,301	364,851
CIP-CAP-006	Warner Ave between Garnsey St. to Bristol St.	Pipe Upsize	2015	10 - 15	15 - 18	3,225	1,032,762
CIP-CAP-006A	Intersection of Warner Ave. and Garnsey Ave. down south of Segerstrom Ave.	Flow Diversion and Pipe Upsize (in lieu of CIP-CAP-006)	2015	08 - 15	10 - 18	955	273,515
CIP-CAP-007	Rene Dr. between St. Gertrude Pl. and Warner Ave.	Pipe Upsize	2015	08	12	1,139	319,584

Notes: For more detailed information, see Appendix B.

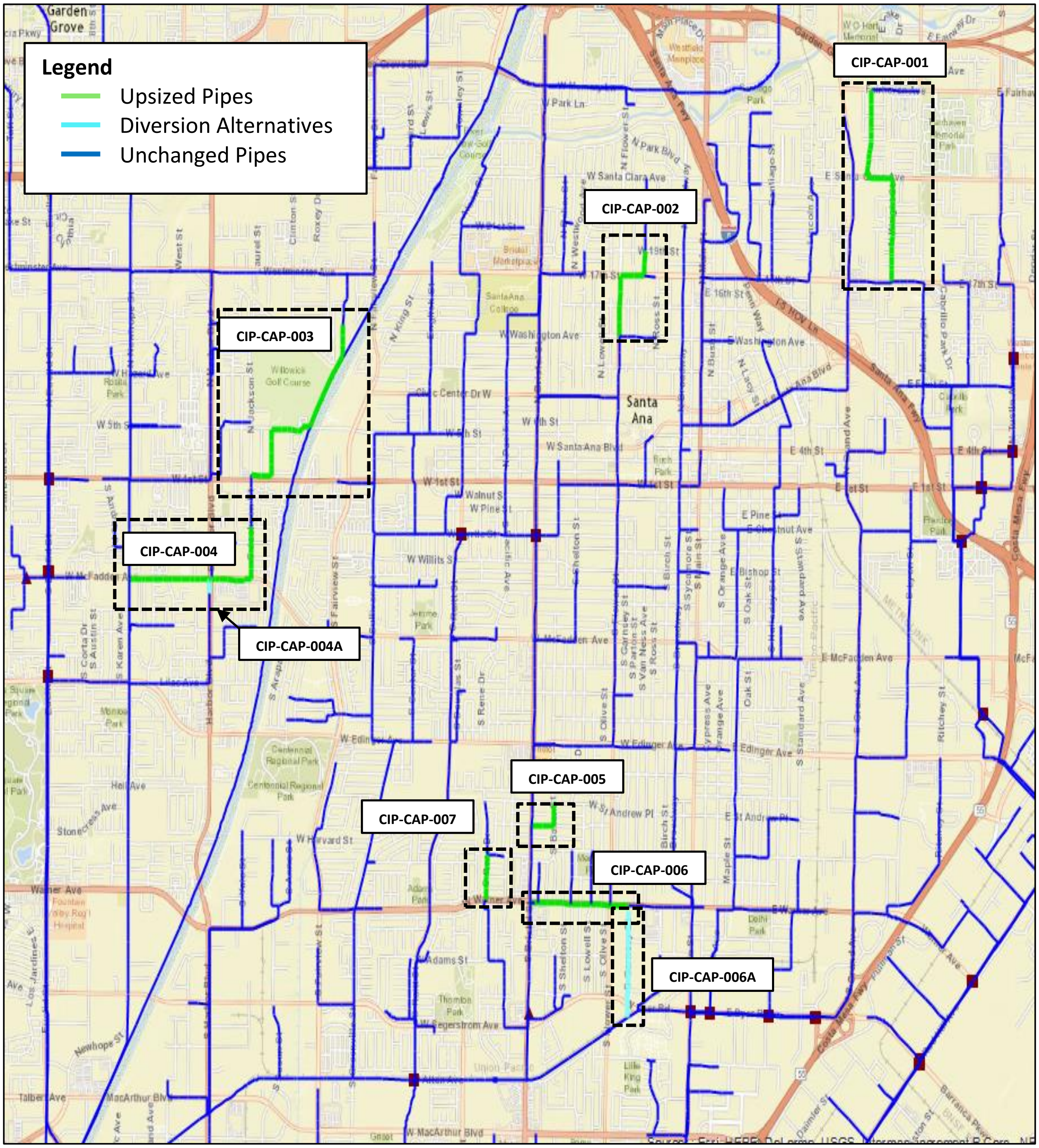


Figure 5-17: Recommended Sewer Capacity CIP Project Locations

5.7 Implementation Recommendations

The following paragraphs provide guidelines for implementing the CIP.

5.7.1 Flow Monitoring and Model Verification

While the hydraulic model has been calibrated as best possible based on available data, there are areas where the model results indicated capacity issues that have not been visually observed in the system. In these cases, it is recommended that these areas be further investigated to verify the model results. Such verification could be conducted by visual observation of flow levels during storm events, or if considered warranted, by temporary flow or surcharge monitoring. It is recommended that the City conduct a more extensive wet weather flow monitoring program, perhaps in conjunction with future monitoring conducted by OCSD, to update system flow estimates after completion of the 5-year CIP projects to identify any remaining capacity deficiencies that may still need to be addressed.

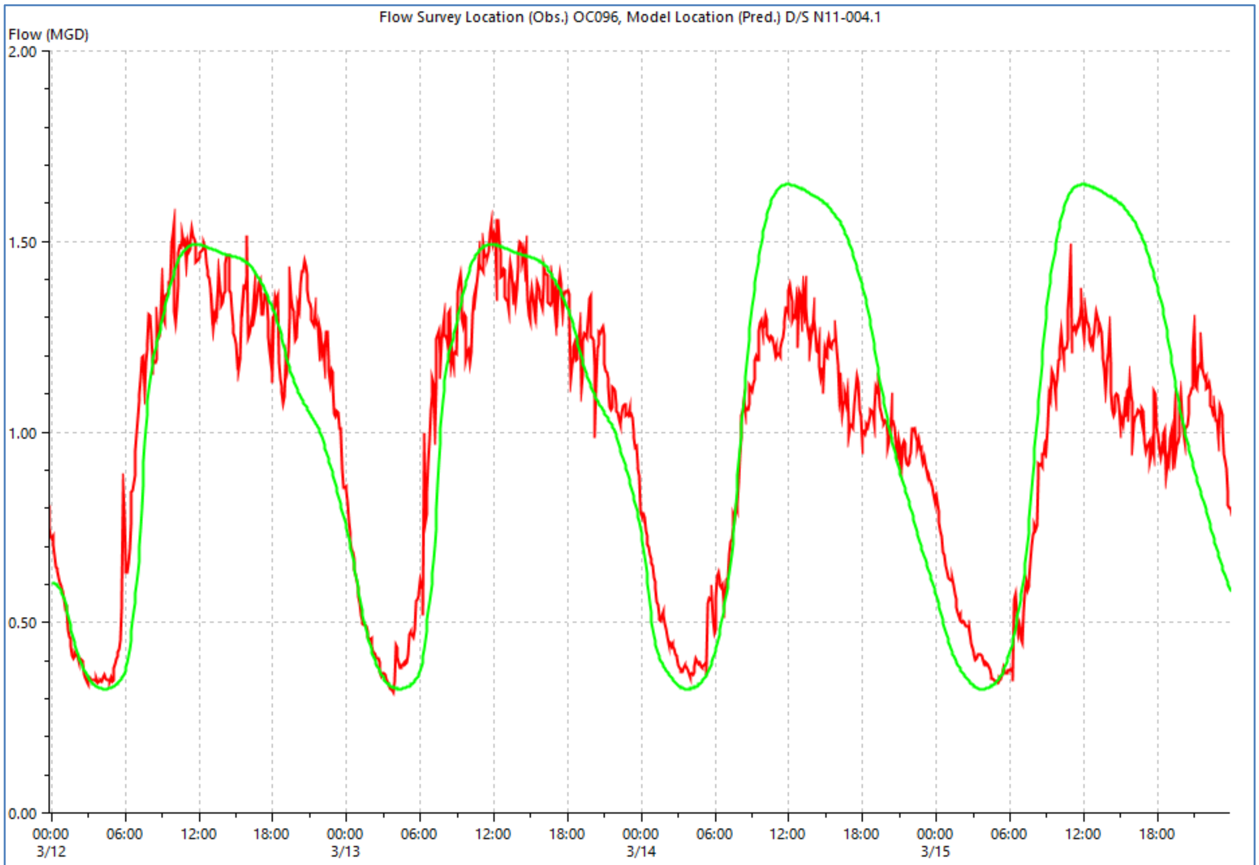
5.7.2 Pipe Rating Model Updates

The Pipe Rating Model is intended to be tool that the City can use to make on-going adjustments to the CIP as needed. The model should be updated on a regular basis (e.g., annually) as additional CCTV inspection data is collected, sewer pipes are rehabilitated and replaced, or changes are made to sewer maintenance schedules.

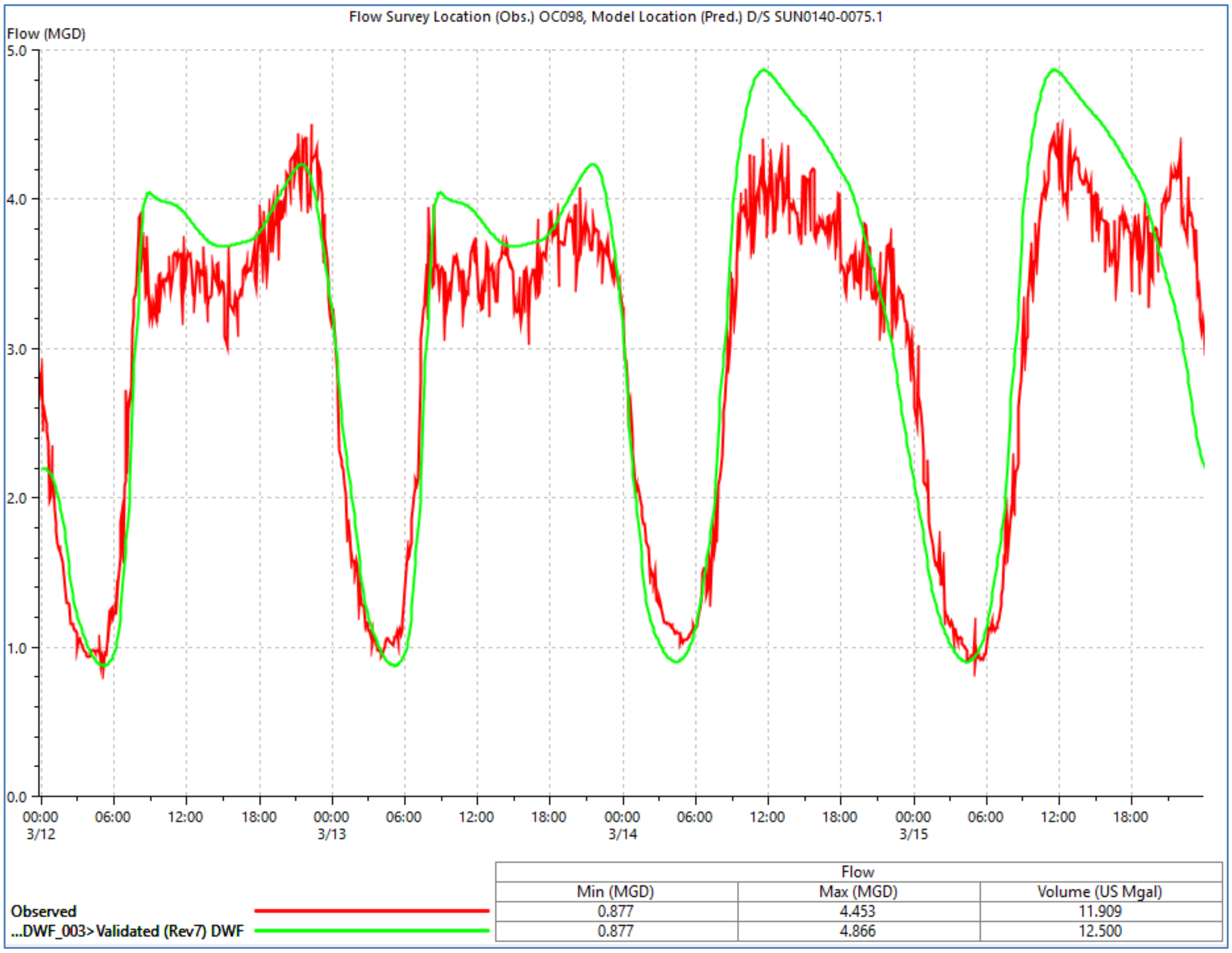
5.7.3 Master Plan Updates

This Master Plan has been prepared to facilitate both use of the information in capital improvement project planning and design, as well as to allow the City to update the Plan in the future as the need arises. The Master Plan should be updated whenever there are major changes in planning assumptions or model results, or at a minimum every eight to ten years.

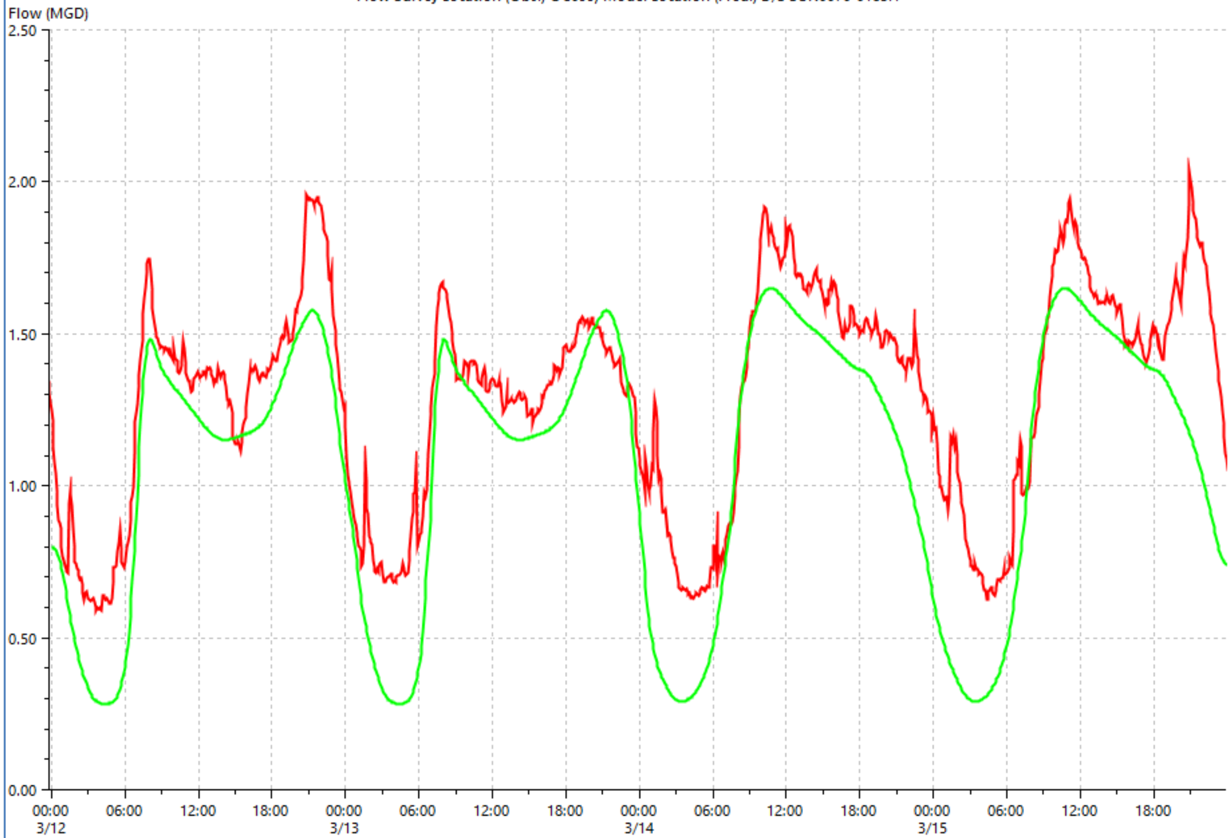
Appendix A - Model Calibration Plots



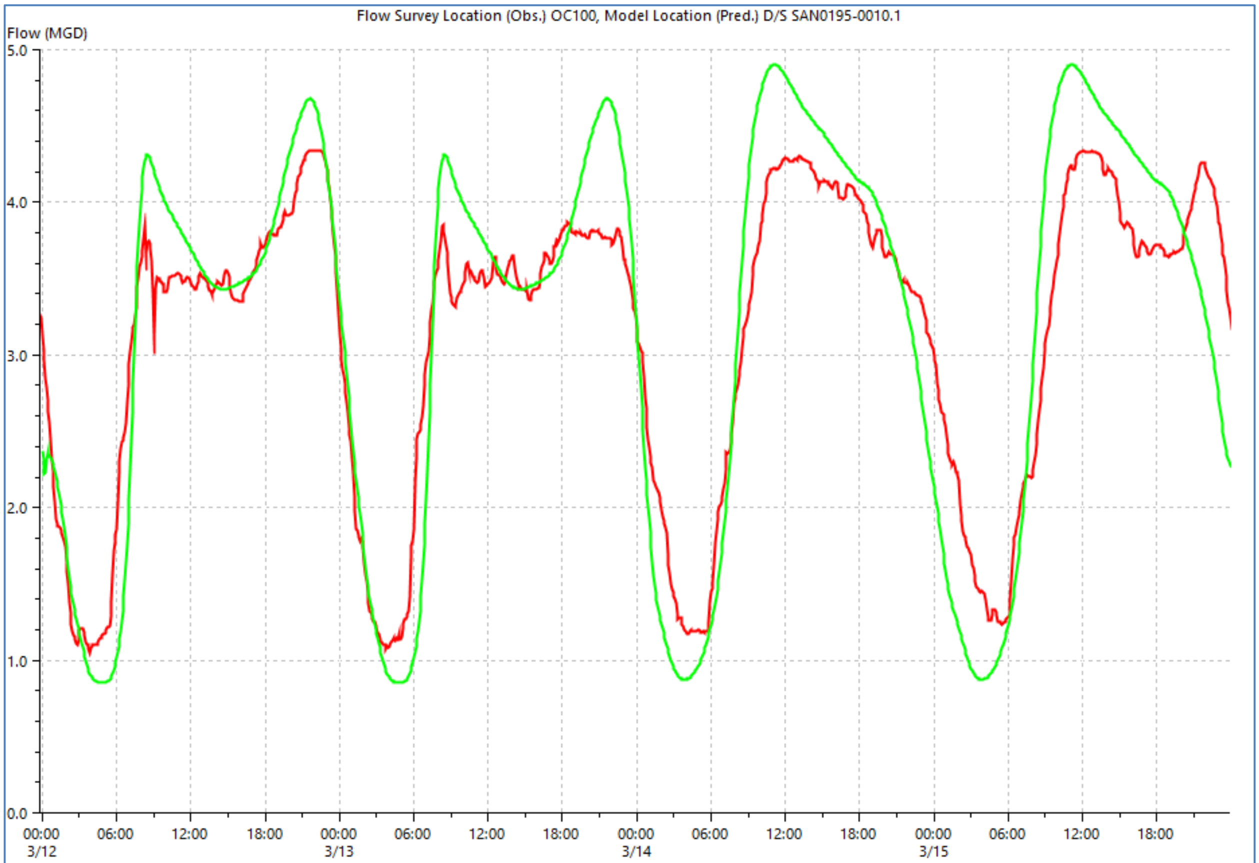
	Flow		
	Min (MGD)	Max (MGD)	Volume (US Mgal)
Observed	0.316	1.555	3.948
...DWF_003>Validated (Rev7) DWF	0.326	1.650	4.070


Flow Survey Location (Obs.) OC098, Model Location (Pred.) D/S SUN0140-0075.1
Flow (MGD)
5.0
4.0
3.0
2.0
1.0
0.0
00:00 3/12
06:00
12:00
18:00
00:00 3/13
06:00
12:00
18:00
00:00 3/14
06:00
12:00
18:00
00:00 3/15
06:00
12:00
18:00
Observed
...DWF_003>Validated (Rev7) DWF
Flow
Min (MGD) Max (MGD) Volume (US Mgal)
0.877 4.453 11.909
0.877 4.866 12.500

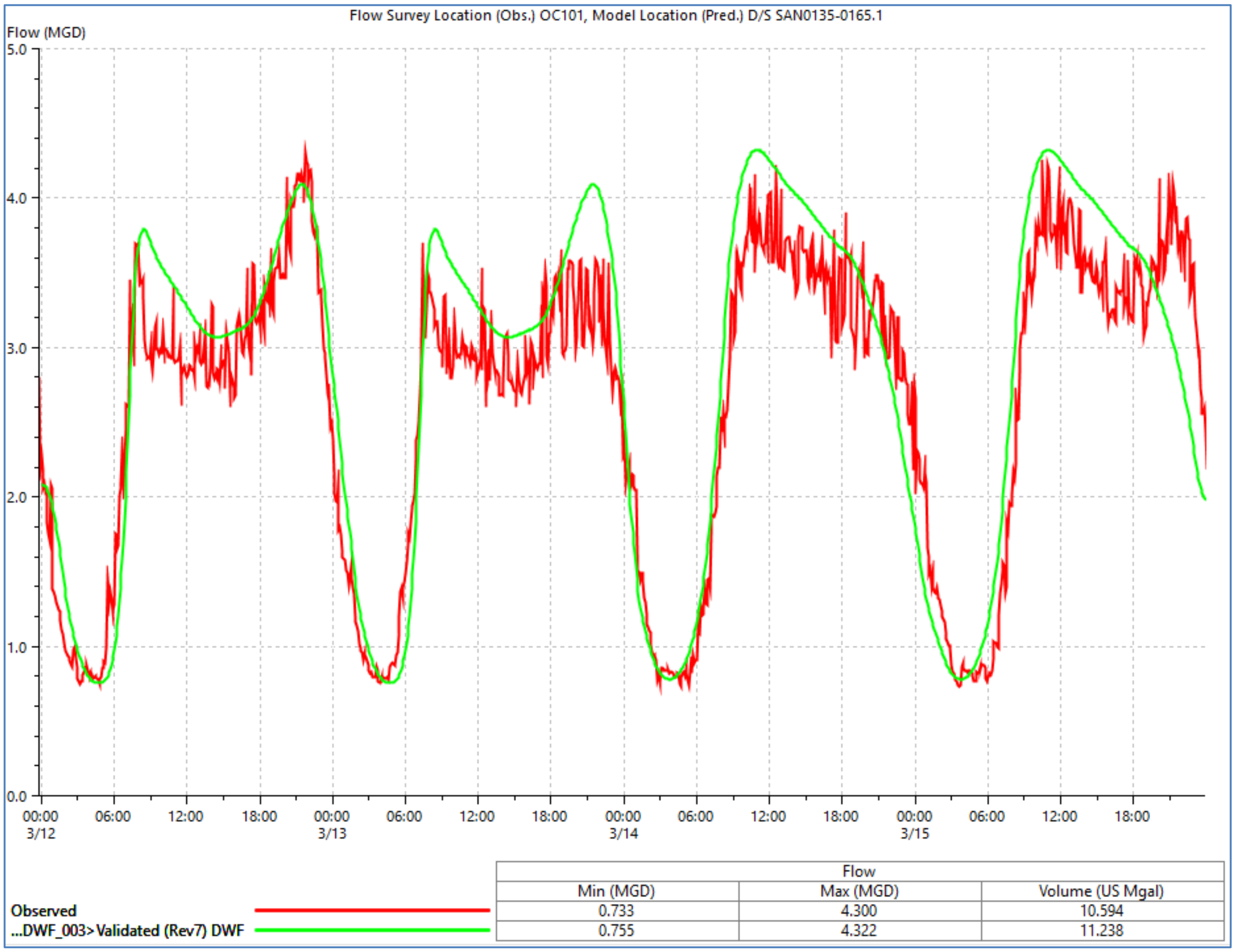
Flow Survey Location (Obs.) OC099, Model Location (Pred.) D/S SUN0070-0185.1



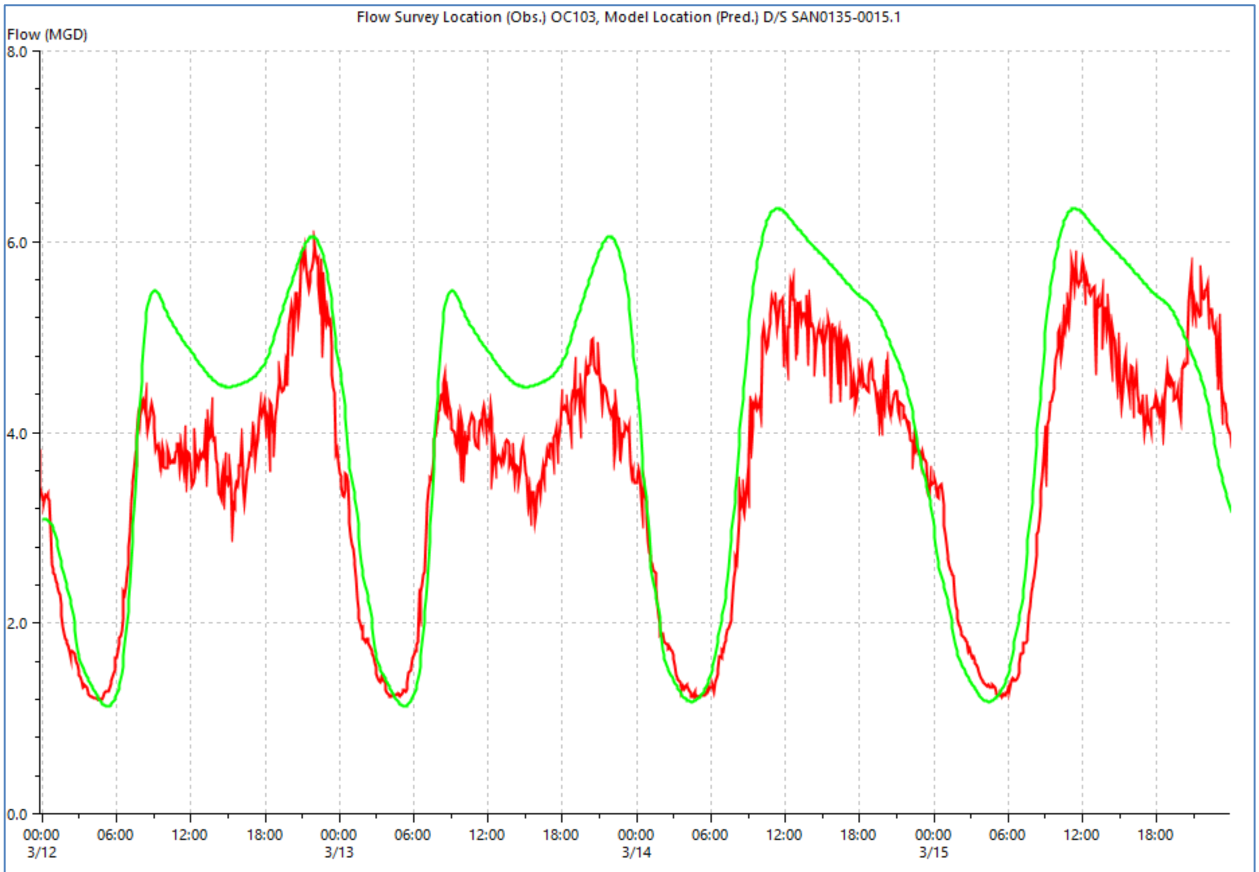
	Flow		
	Min (MGD)	Max (MGD)	Volume (US Mgal)
Observed	0.592	2.039	5.183
...DWF_003>Validated (Rev7) DWF	0.282	1.650	4.268



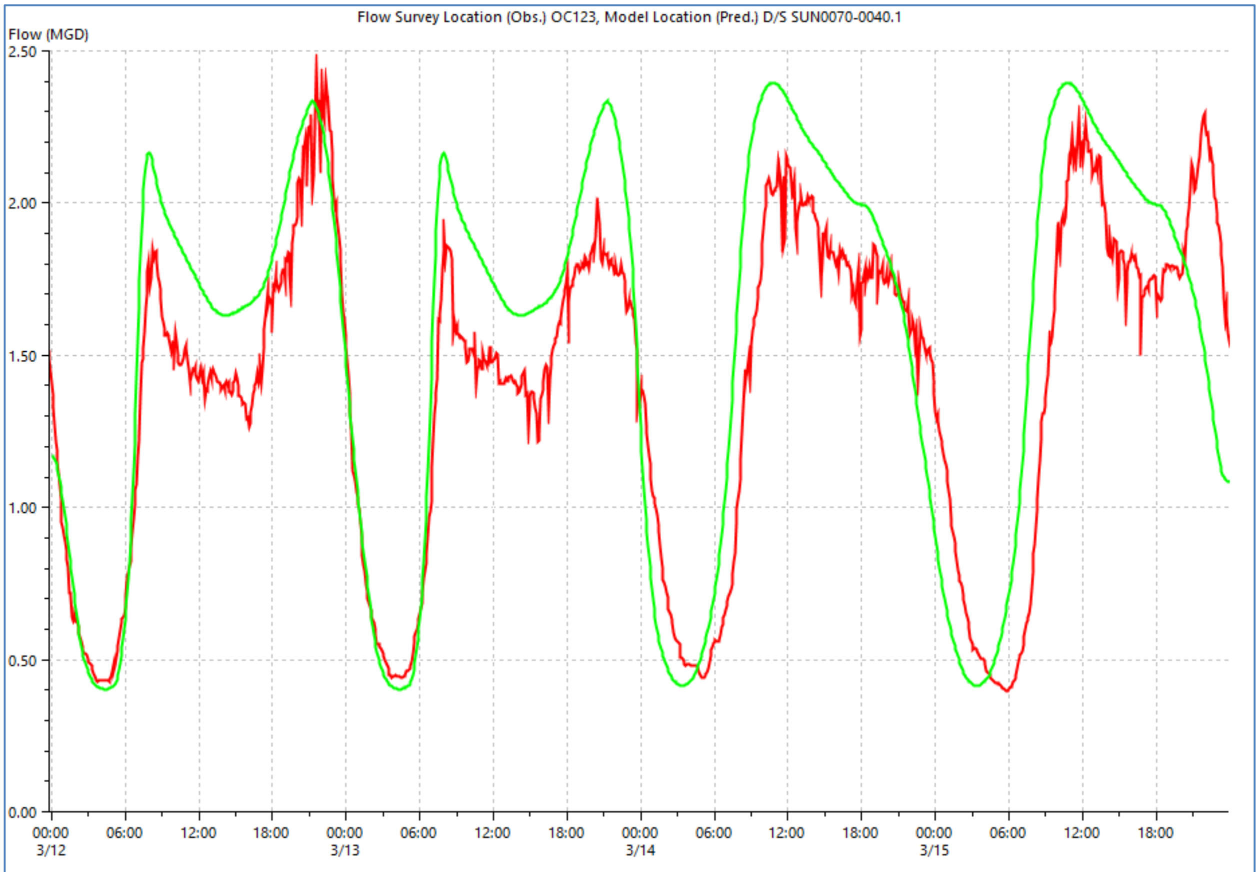
	Flow		
	Min (MGD)	Max (MGD)	Volume (US Mgal)
Observed	1.051	4.342	12.522
...DWF_003>Validated (Rev7) DWF	0.851	4.903	12.702



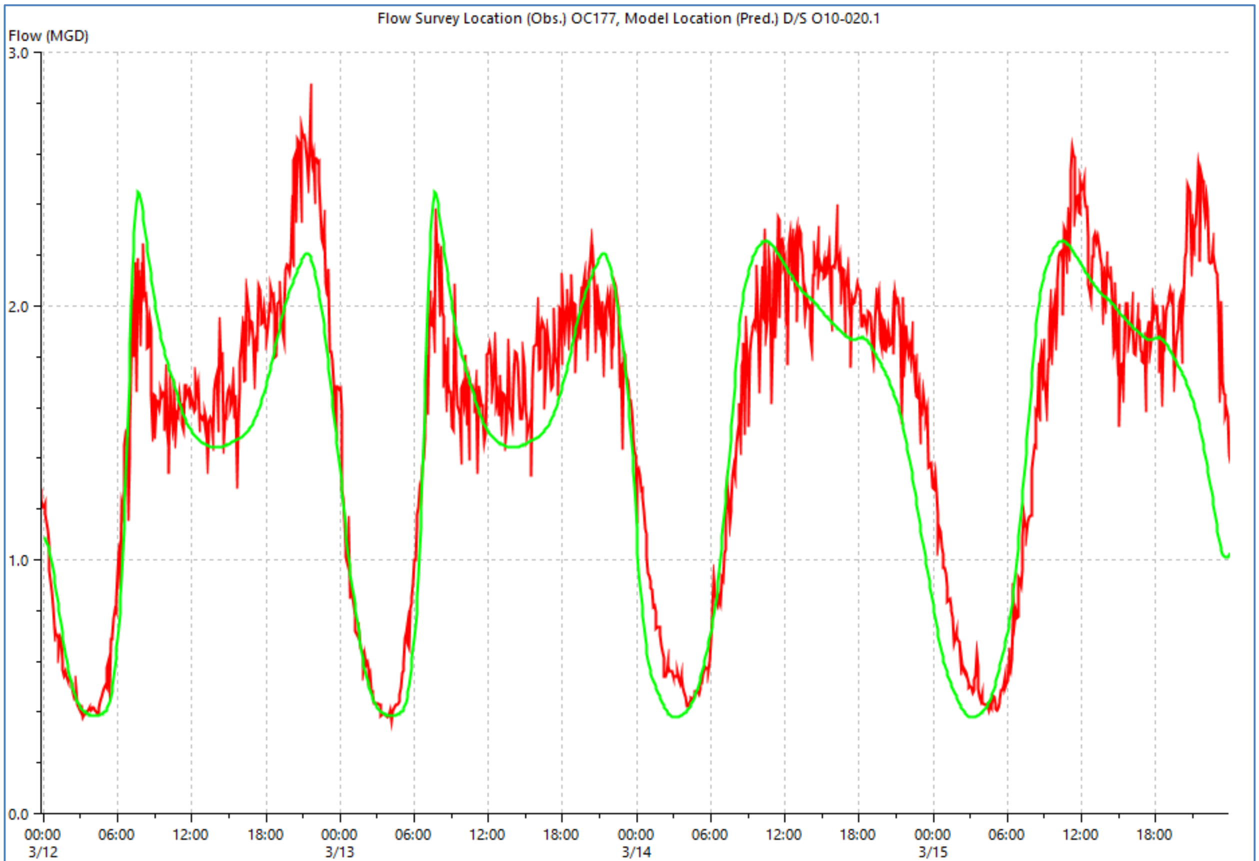
Flow		
Min (MGD)	Max (MGD)	Volume (US Mgal)
0.733	4.300	10.594
0.755	4.322	11.238



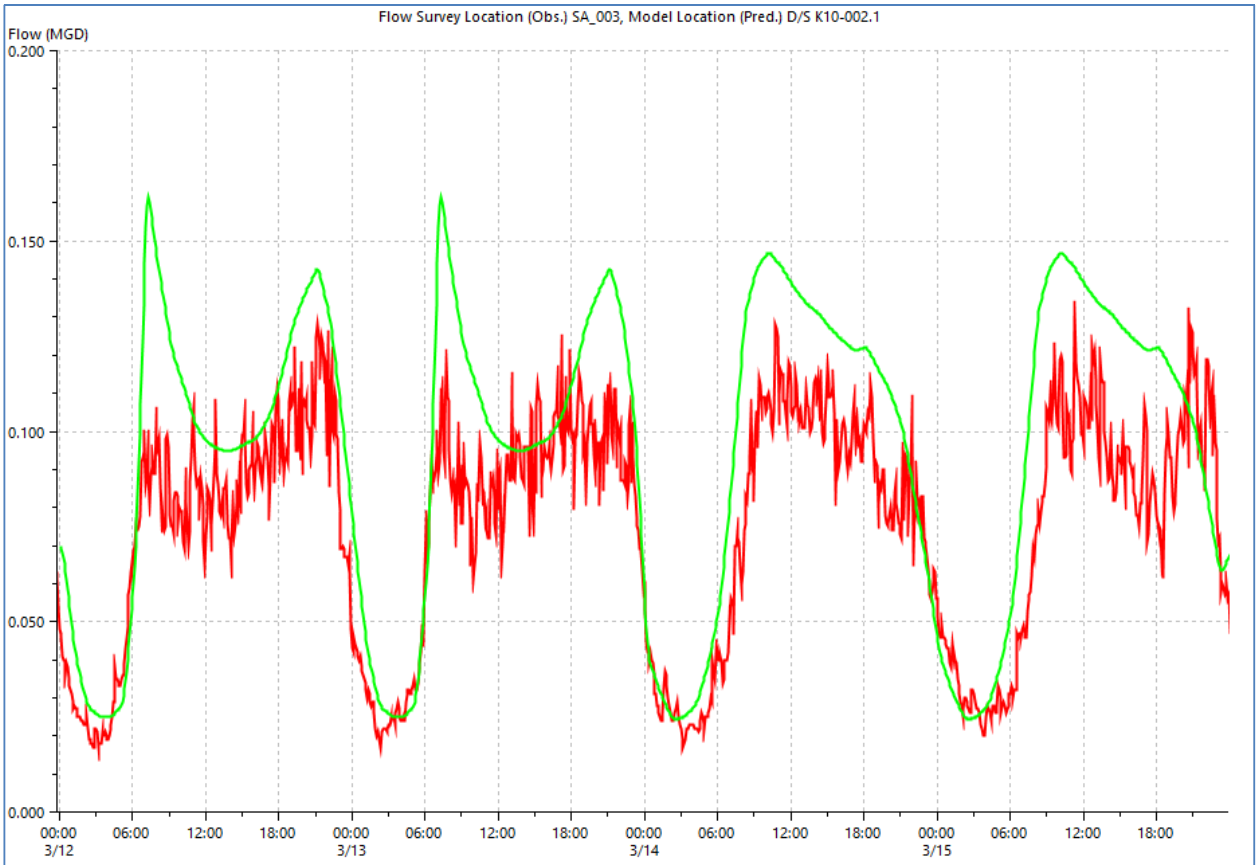
	Flow		
	Min (MGD)	Max (MGD)	Volume (US Mgal)
Observed	1.195	5.987	14.345
...DWF_003>Validated (Rev7) DWF	1.128	6.347	16.562



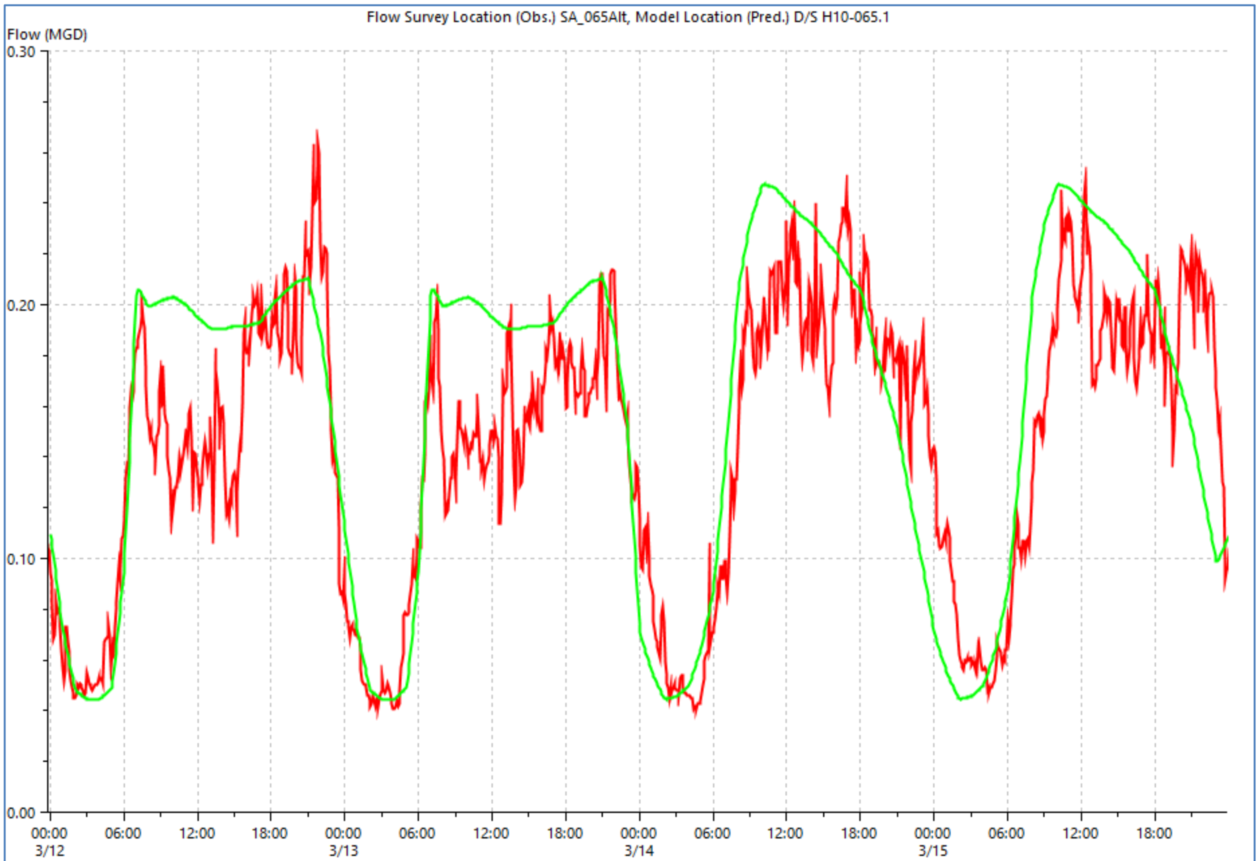
	Flow		
	Min (MGD)	Max (MGD)	Volume (US Mgal)
Observed	0.396	2.447	5.605
...DWF_003>Validated (Rev7) DWF	0.402	2.396	6.184



	Flow		
	Min (MGD)	Max (MGD)	Volume (US Mgal)
Observed	0.363	2.824	6.194
...DWF_003>Validated (Rev7) DWF	0.378	2.450	5.835



	Flow		
	Min (MGD)	Max (MGD)	Volume (US Mgal)
Observed	0.017	0.131	0.302
...DWF_003>Validated (Rev7) DWF	0.024	0.162	0.378



	Flow		
	Min (MGD)	Max (MGD)	Volume (US Mgal)
Observed	0.041	0.264	0.582
...DWF_003>Validated (Rev7) DWF	0.044	0.247	0.632

Appendix B - Capacity CIP Summary Sheets

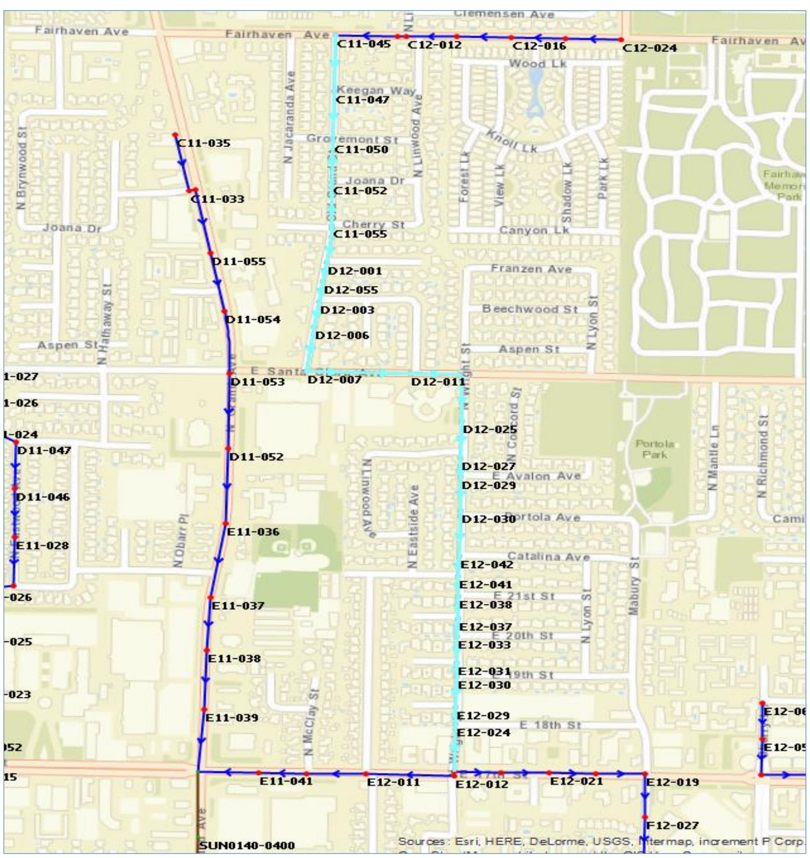
Project: CIP-CAP-001

Sewer Replacement – Wright Street

Project Description

Project ID:	CIP-CAP-001
Location:	Old Grand St. between Fairhaven Ave. to Santa Clara Ave.; then east on Santa Clara Ave. to Wright St.; then south on Wright Ave. to 17th St.
Brief Summary:	Upsizing 2,902 feet of 10 inch pipe to 15 inch pipe; upsizing 1,800 feet of 10 inch pipe to 12 inch pipe; and upsizing 1,010 feet of 08 inch pipe to 12 inch pipe.
Estimated Cost:	$ 1,629,394
Comments:	N/A
Assumptions:	New diameter is based on pipe replacement; sized for 2040 PWWF; Cost includes lateral replacement based on $2,500 per lateral.
Alternatives:	None
Triggered by 2015 PWWF:	Yes

Project Location



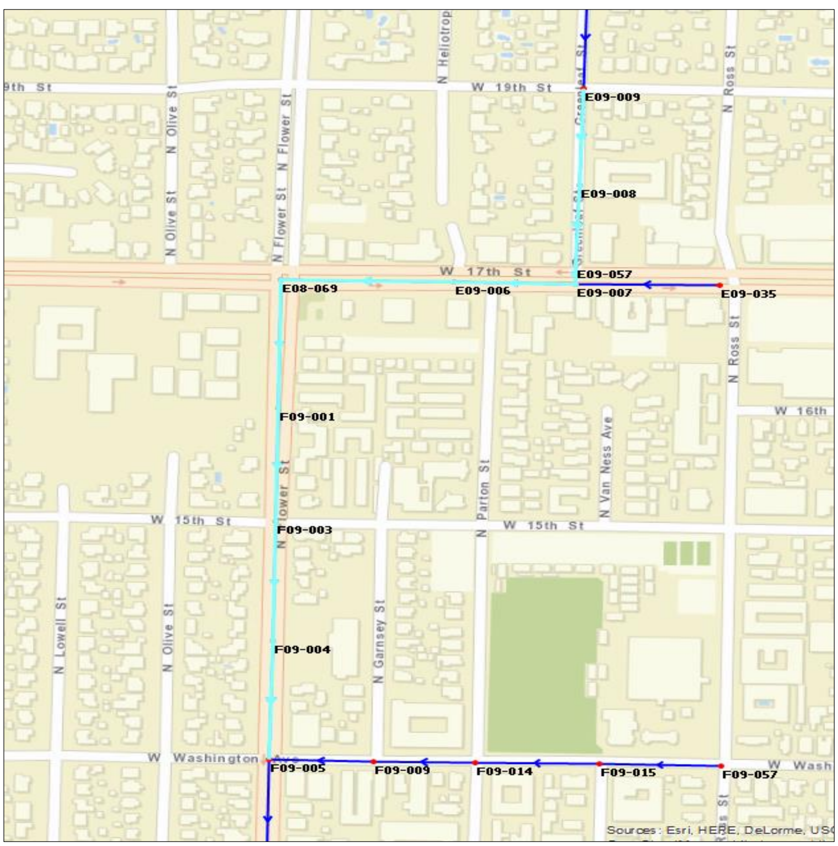
Project: CIP-CAP-002

Sewer Replacement – Flower Street

Project Description

Project ID:	CIP-CAP-002
Location:	Greenleaf between 19th St. to 17th St.; then west in 17th St. to Flower St.; then south in Flower St. to Washington Ave.
Brief Summary:	Upsizing 1,554 feet of 12 inch pipe to 15 inch pipe; upsizing 783 feet of 10 inch pipe to 15 inch pipe; and upsizing 634 feet of 08 inch pipe to 10 inch pipe.
Estimated Cost:	$ 852,691
Comments:	N/A
Assumptions:	New diameter is based on pipe replacement; sized for 2040 PWWF; Cost includes lateral replacement based on $2,500 per lateral.
Alternatives:	None
Triggered by 2015 PWWF:	Yes

Project Location



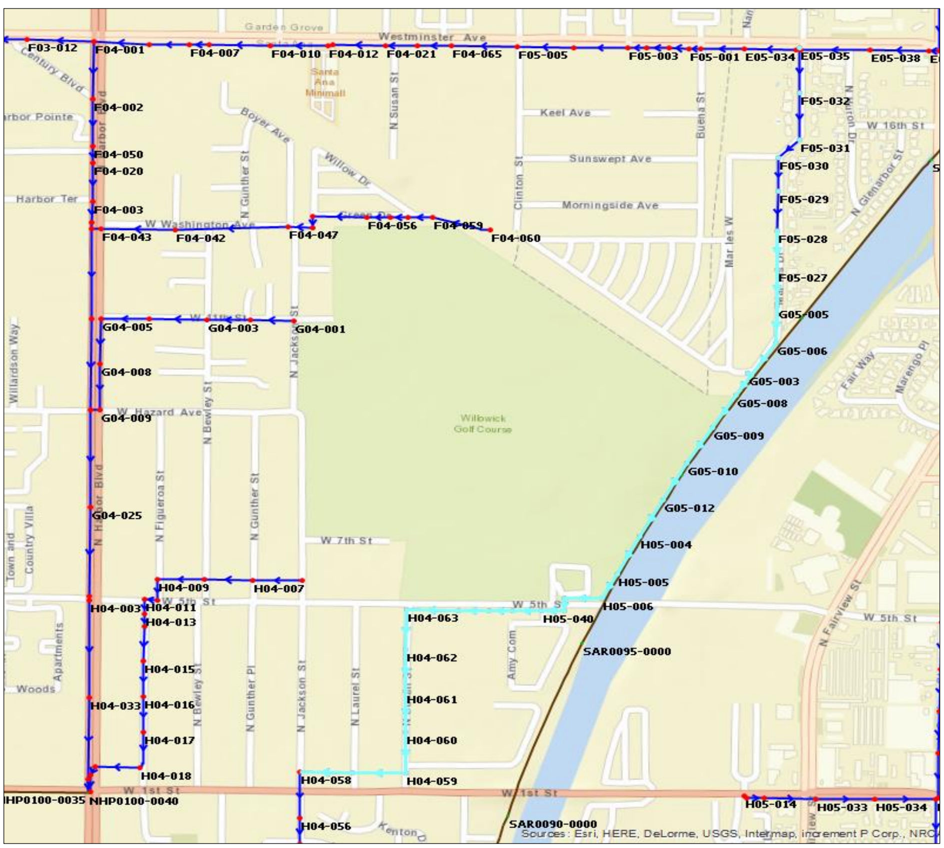
Project: CIP-CAP-003

Sewer Replacement – Mar les Drive

Project Description

Project ID:	CIP-CAP-003
Location:	Mar les Dr. south across Willowick Golf Course along SA River; west in 5th St. to Susan St.; then south to just north of 1st St.; west until Jackson St.
Brief Summary:	Upsizing 3,237 feet of 10 inch pipe to 15 inch pipe & 2,808 feet of 12 inch pipe to 15 inch pipe.
Estimated Cost:	$ 1,740,096
Comments:	N/A
Assumptions:	New diameter is based on pipe replacement; sized for 2040 PWWF; Cost includes lateral replacement based on $2,500 per lateral.
Alternatives:	None
Triggered by 2015 PWWF:	No

Project Location



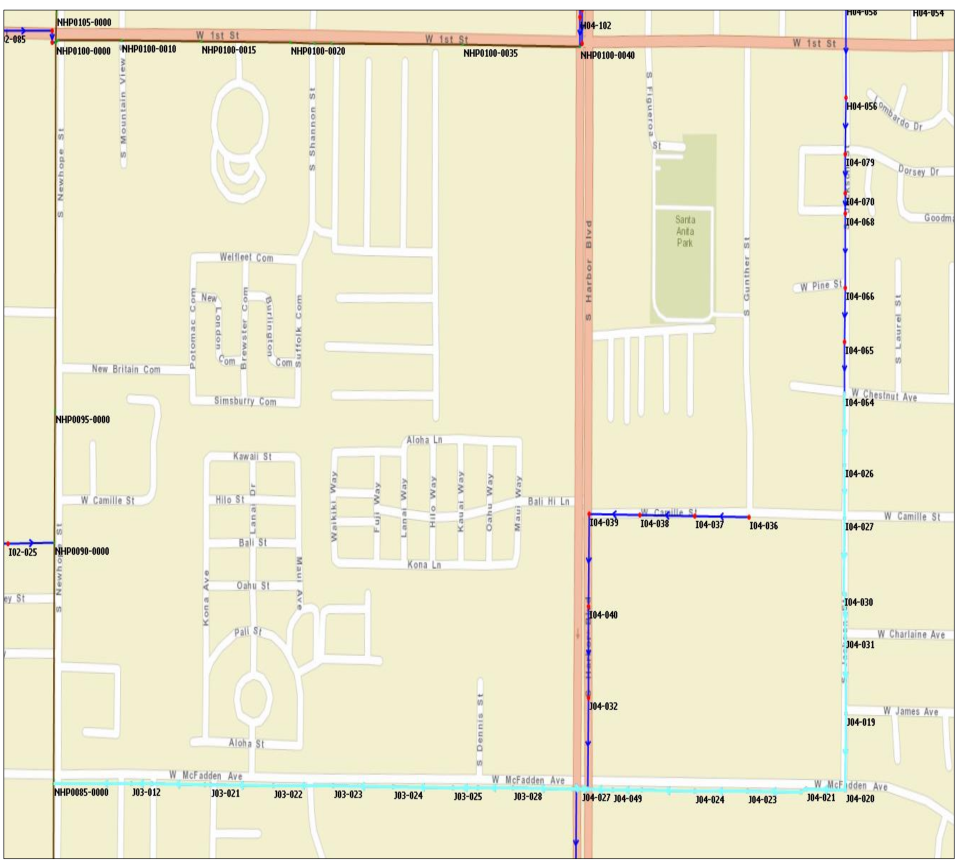
Project: CIP-CAP-004

Sewer Replacement – McFadden Avenue

Project Description

Project ID:	CIP-CAP-004
Location:	Jackson St. between Chestnut Ave. and McFadden Ave., then west in McFadden Ave. to Newhope St.
Brief Summary:	Upsizing 5,302 feet of 15 inch pipe to 18 inch pipe.
Estimated Cost:	$ 1,884,152
Comments:	N/A
Assumptions:	New diameter is based on pipe replacement; sized for 2040 PWWF; Cost includes lateral replacement based on $2,500 per lateral.
Alternatives:	Diversion CIP-CAP-004A
Triggered by 2015 PWWF:	No

Project Location



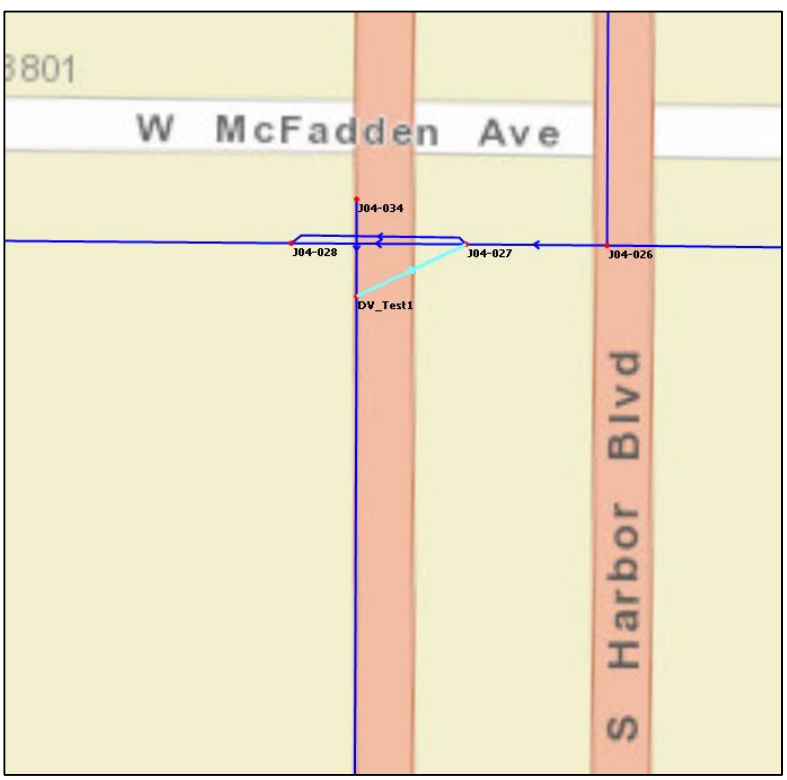
Project Alternative: CIP-CAP-004A

Sewer Diversion – McFadden Avenue

Project Description

Project ID:	CIP-CAP-004A
Location:	Approximately at the intersection of McFadden Ave. and Harbor Blvd.
Brief Summary:	Diverting flow traveling west in McFadden Ave. to divert into 12 inch southbound pipe in Harbor Blvd during more peak conditions. This would be accomplished by constructing a diversion structure (weir) set to a level at approximately 75% pipe full level in upstream pipe and a new pipe connection at MH J04-027, allowing flow to be diverted down to 12 inch Harbor Blvd pipe. Upsizing 974 feet of 15 inch pipe to 18 inch; upsizing 1,607 feet of 12 inch pipe to 15 inch pipe; constructing 30 feet of new 12 inch pipe.
Estimated Cost:	$ 831,510
Comments:	The 12 inch pipe in Harbor Blvd. has capacity to accept more flow. Pipe sag at MH K02-022 will need to be fixed in Edinger Ave. (this could affect pipe sizing).
Assumptions:	This assumes CIP-CAP-003 would be built upstream.
Results of Diversion:	This diversion appears to alleviate surcharging west on McFadden Ave., but causes backups upstream in McFadden/Jackson and downstream in Edinger Ave west of Newhope St. These areas of surcharging would be solved by upsizing these pipe segments accordingly.

Project Location



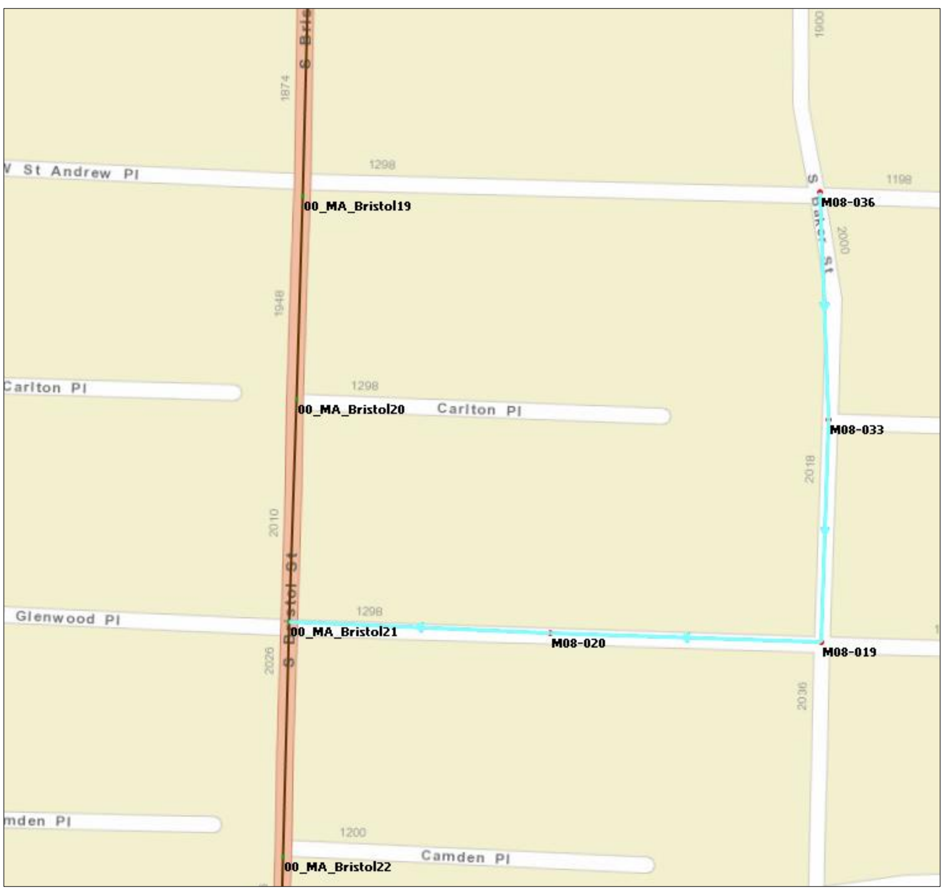
Project: CIP-CAP-005

Sewer Replacement – Glenwood Place

Project Description

Project ID:	CIP-CAP-005
Location:	Baker St. between St. Andrew Pl. and Glenwood Pl.; then west on Glenwood Pl. to Bristol St.
Brief Summary:	Upsizing 1,301 feet of 8 inch pipe to 10 inch pipe.
Estimated Cost:	$ 364,851
Comments:	N/A
Assumptions:	New diameter is based on pipe replacement; sized for 2040 PWWF; Cost includes lateral replacement based on $2,500 per lateral.
Alternatives:	None
Triggered by 2015 PWWF:	Yes

Project Location



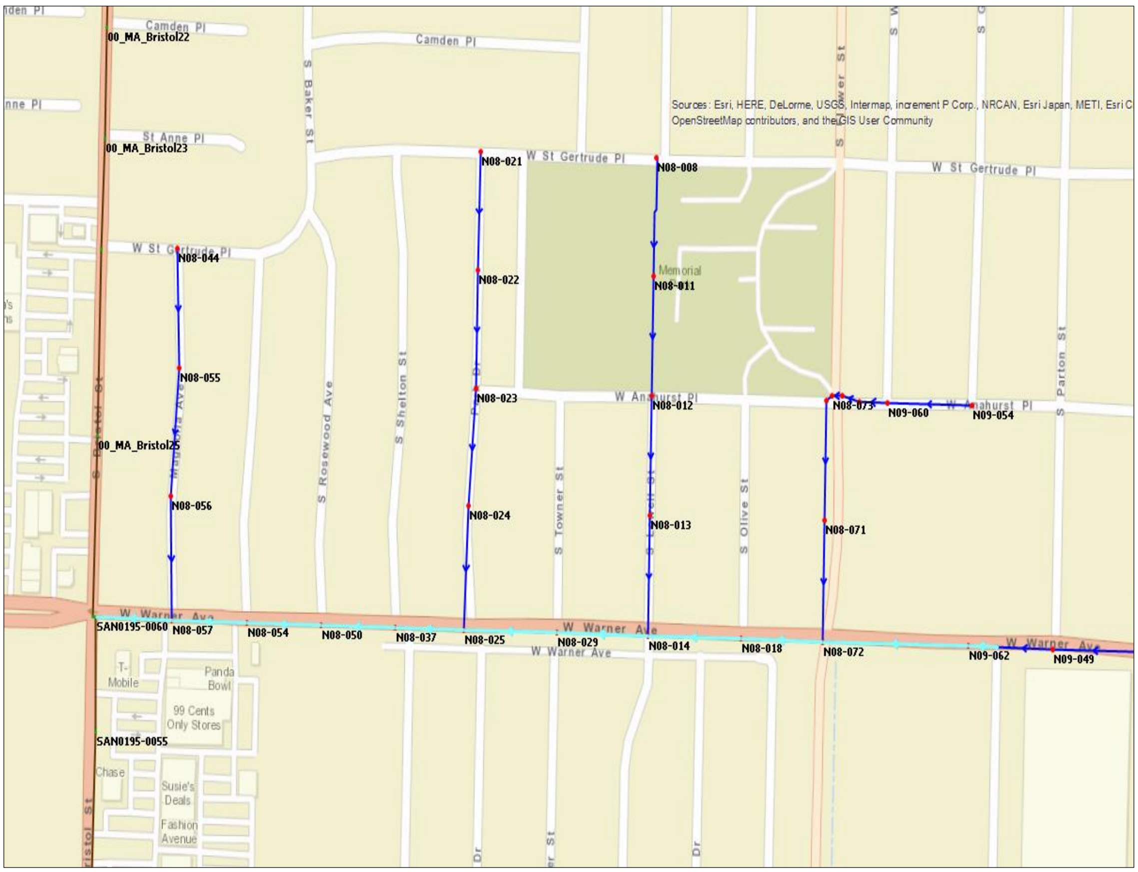
Project: CIP-CAP-006

Sewer Replacement – Warner Avenue

Project Description

Project ID:	CIP-CAP-006
Location:	Warner Ave. between Garnsey St. to Bristol St.
Brief Summary:	Upsizing 2,601 feet of 15 inch pipe to 18 inch pipe; upsizing 523 feet of 12 inch pipe to 15 inch pipe; and upsizing 101 feet of 10 inch pipe to 15 inch pipe.
Estimated Cost:	$ 1,032,762
Comments:	N/A
Assumptions:	New diameter is based on pipe replacement; sized for 2040 PWWF; Cost includes lateral replacement based on $2,500 per lateral.
Alternatives:	Diversion CIP-CAP-006A
Triggered by 2015 PWWF:	Yes

Project Location



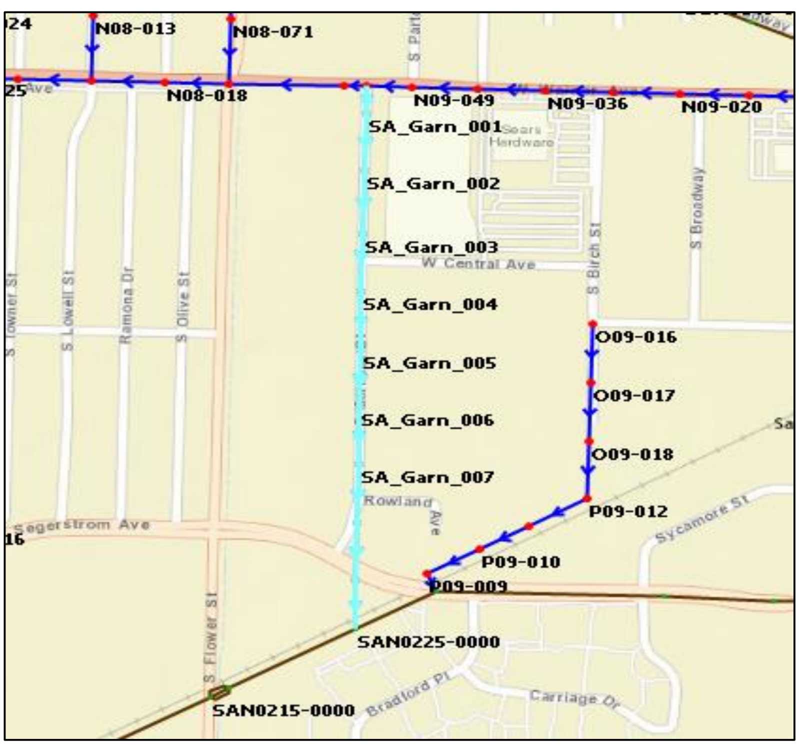
Project Alternative: CIP-CAP-006A

Sewer Diversion – Garnsey Street

Project Description

Project ID:	CIP-CAP-006A
Location:	Approximately at the intersection of Warner Ave. and Garnsey St.
Brief Summary:	Split flow from Warner Ave. into a nearby pipe in Garnsey St. down to Segerstrom Ave. This would be accomplished by constructing a new pipe connection between the existing pipes in Garnsey St. and in Warner Ave. at MH O09-029. Upsizing 513 feet of 15 inch pipe to 18 inch; upsizing 300 feet of 08 inch pipe to 10 inch pipe; constructing 142 feet of new 10 inch pipe.
Estimated Cost:	$ 273,515
Comments:	The 8/10 inch pipe in Garnsey St. appears to have adequate capacity to accept more flow. Further evaluation regarding hydraulic capacities and pipe condition will need to be conducted.
Assumptions:	This assumes that the condition of the pipe in Garnsey St. is sound enough to handle new flow; The first pipe segment in Garnsey St. is an 8 inch pipe, while the rest is 10 inch. This 8 inch pipe would be replaced with a 10 inch.
Results of Diversion:	This diversion appears to alleviate surcharging west on Warner and causes only minor backups downstream of diversion, which would be solved by upsizing two pipes. There is no surcharging down the Garnsey St. pipe.

Project Location



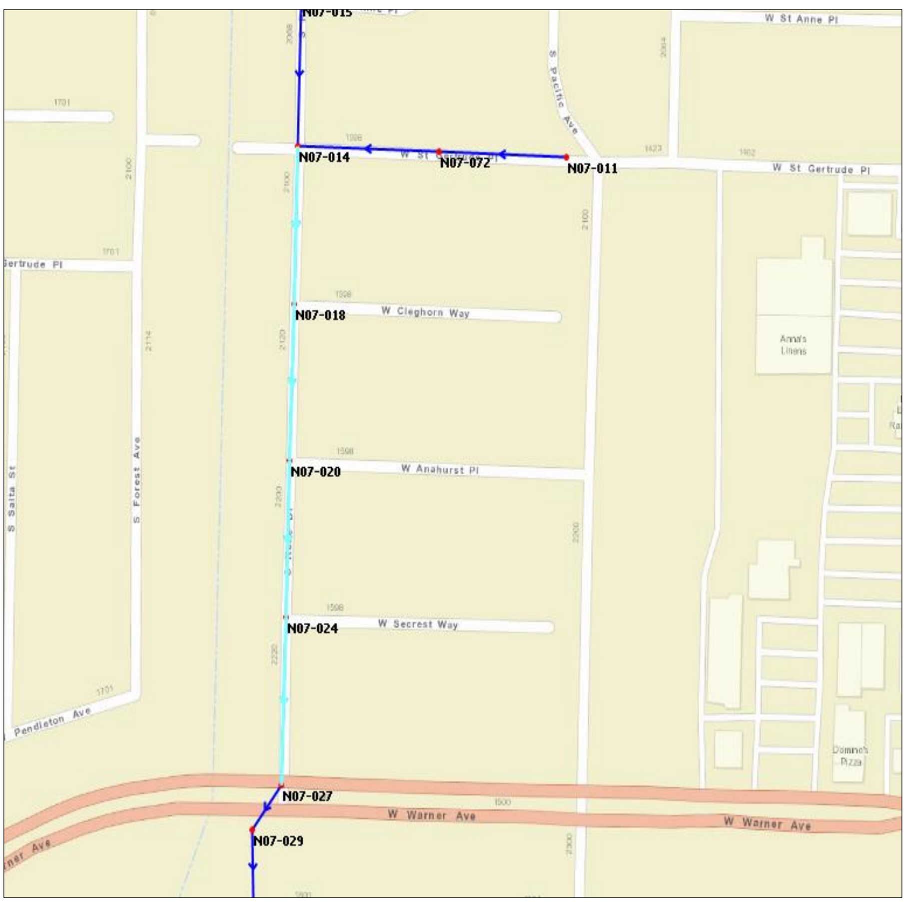
Project: CIP-CAP-007

Sewer Replacement – Rene Drive

Project Description

Project ID:	CIP-CAP-007
Location:	Rene Dr. between St. Gertrude Pl. and Warner Ave.
Brief Summary:	Upsizing 1,139 feet of 8 inch pipe to 12 inch pipe.
Estimated Cost:	$ 319,584
Comments:	N/A
Assumptions:	New diameter is based on pipe replacement; sized for 2040 PWWF; Cost includes lateral replacement based on $2,500 per lateral.
Alternatives:	None
Triggered by 2015 PWWF:	Yes

Project Location

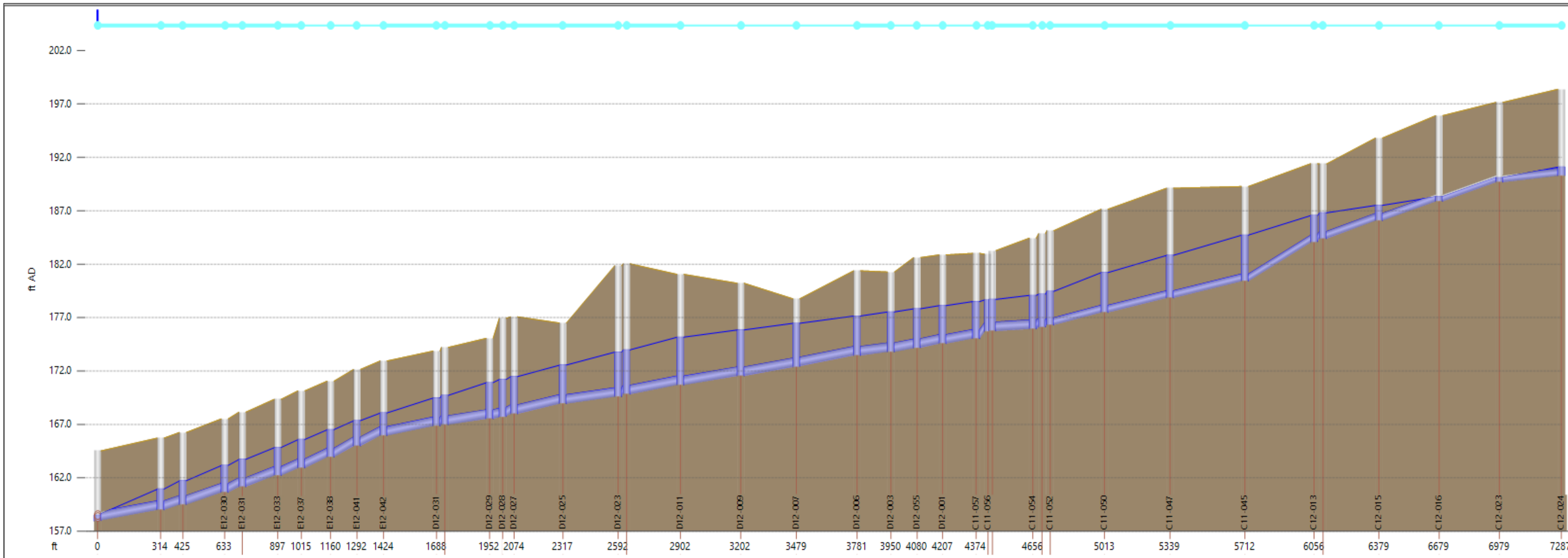


Appendix C - Hydraulic Profiles

Project: CIP-CAP-001

Sewer Replacement – Wright Street

Figure C1.1: Hydraulic Profile of Existing Sewer (2040 / Peak Wet Weather Scenario)



Link	E12-024.1	-	-	-	-	-	-	-	-	D12-031.1	-	-	-
height (in)	10.0	10.0	10.0	-	10.0	10.0	10.0	10.0	10.0	10.0	10.0	-	-
us inv (ft AD)	159.010	-	160.640	-	-	-	-	-	-	166.860	167.530	-	-
ds inv (ft AD)	158.030	-	159.510	-	-	-	-	-	-	165.960	166.980	-	-
pfc (MGD)	0.79	0.95	1.04	-	1.09	1.10	1.18	1.26	1.21	0.83	0.70	-	-
DS flow (MGD)	1.1849	-	1.1544	-	1.1022	-	-	-	-	1.0207	1.0194	-	-
DS depth (ft)	0.610	-	2.223	-	2.565	-	2.667	2.579	2.371	2.120	2.743	-	-

Link	D12-025.1	D12-023.1	D12-011.1	D12-009.1	D12-007.1	D12-006.1	-	-	-	-	-	-	-
height (in)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	-	10.0	-
us inv (ft AD)	168.950	169.600	170.700	171.540	172.370	173.460	-	-	-	-	-	175.940	-
ds inv (ft AD)	168.000	168.950	169.830	170.700	171.540	172.460	-	-	-	-	-	175.750	-
pfc (MGD)	0.89	0.69	0.81	0.75	0.78	0.82	0.64	0.73	0.77	0.76	-	0.44	-
DS flow (MGD)	0.9305	0.9298	0.9289	0.6584	0.6590	0.6672	0.6940	-	-	0.7123	-	0.6601	-
DS depth (ft)	3.479	3.610	4.151	4.473	4.307	4.010	3.690	3.732	-	3.553	-	2.952	-

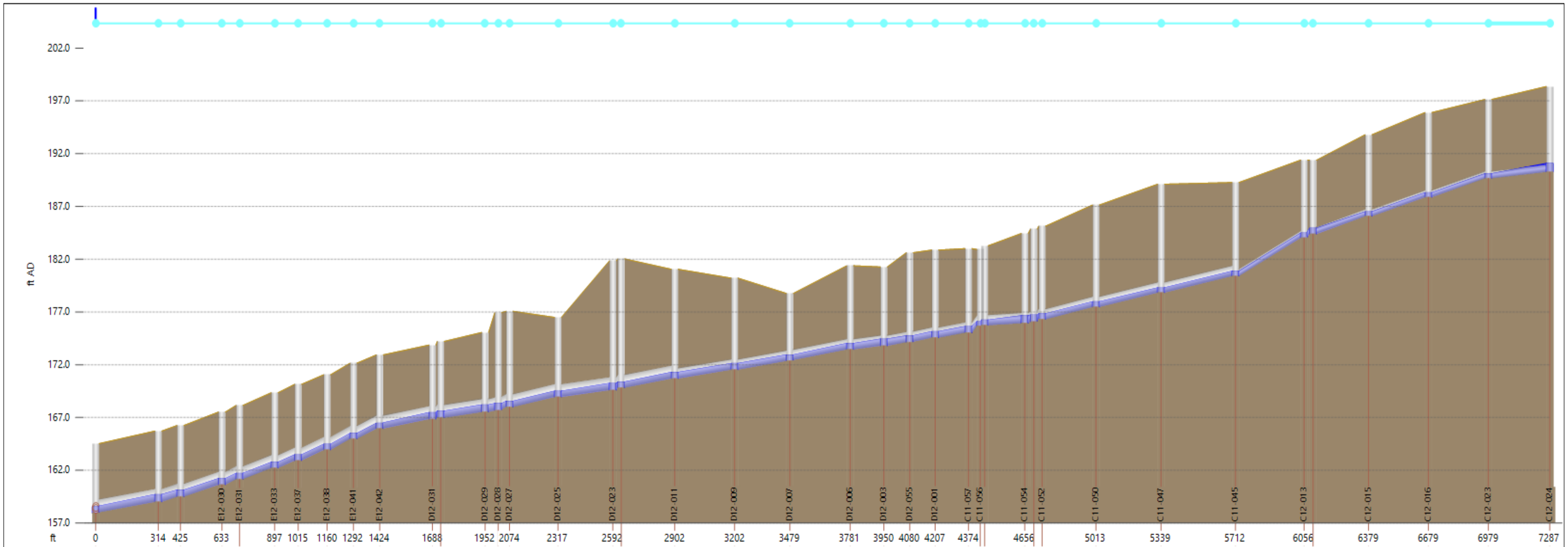
Link	C11-050.1	C11-047.1	C11-045.1	C12-013.1	-	C12-015.1	C12-016.1	C12-023.1	C12-024.1
height (in)	8.0	8.0	8.0	8.0	-	8.0	8.0	8.0	8.0
us inv (ft AD)	177.480	178.840	180.410	184.030	-	186.080	187.880	189.680	190.280
ds inv (ft AD)	176.310	177.480	178.840	180.410	-	184.390	186.080	187.880	189.680
pfc (MGD)	0.51	0.50	0.51	0.80	-	0.61	0.61	0.61	0.34
DS flow (MGD)	0.6647	0.5775	0.5789	0.5809	-	0.4029	0.4123	0.4117	0.4135
DS depth (ft)	3.147	3.736	3.989	4.312	-	2.414	1.425	0.430	0.420

Node: - - - - - - - - - - - - - - - - - D12-025 - - D12-011 D12-009 D12-007 D12-006 - - - - - - - - - C11-050 C11-047 C11-045 - - C12-015 C12-016 C12-023 -

Project: CIP-CAP-001

Sewer Replacement – Wright Street

Figure C1.2: Hydraulic Profile of Proposed Sewer Replacement (2040 / Peak Wet Weather Scenario)



Link	E12-024.1	-	-	-	-	-	-	-	-	D12-031.1	-	-
height (in)	15.0	15.0	15.0	-	15.0	15.0	15.0	15.0	15.0	15.0	15.0	-
us inv (ft AD)	159.010	-	160.640	-	-	-	-	-	-	166.860	167.530	-
ds inv (ft AD)	158.030	-	159.510	-	-	-	-	-	-	165.960	166.980	-
pfc (MGD)	2.33	2.80	3.08	-	3.23	3.24	3.49	3.72	3.58	2.44	2.07	-
DS flow (MGD)	1.3504	-	1.3136	-	1.2481	-	-	-	-	1.1466	1.1467	-
DS depth (ft)	0.579	-	0.616	-	0.543	-	0.541	0.525	0.507	0.532	0.631	-

Link	-	D12-025.1	D12-023.1	D12-011.1	D12-009.1	D12-007.1	D12-006.1	-	-	-	-	-
height (in)	-	15.0	15.0	15.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	-
us inv (ft AD)	-	168.950	169.600	170.700	171.540	172.370	173.460	-	-	-	-	-
ds inv (ft AD)	-	168.000	168.950	169.830	170.700	171.540	172.460	-	-	-	-	-
pfc (MGD)	-	2.61	2.03	2.38	1.22	1.26	1.33	1.03	1.20	1.26	1.23	-
DS flow (MGD)	-	1.0383	1.0384	1.0383	0.7637	0.7643	0.7646	0.7648	-	-	0.7654	-
DS depth (ft)	-	0.548	0.549	0.545	0.583	0.578	0.480	0.556	0.638	0.556	0.570	-

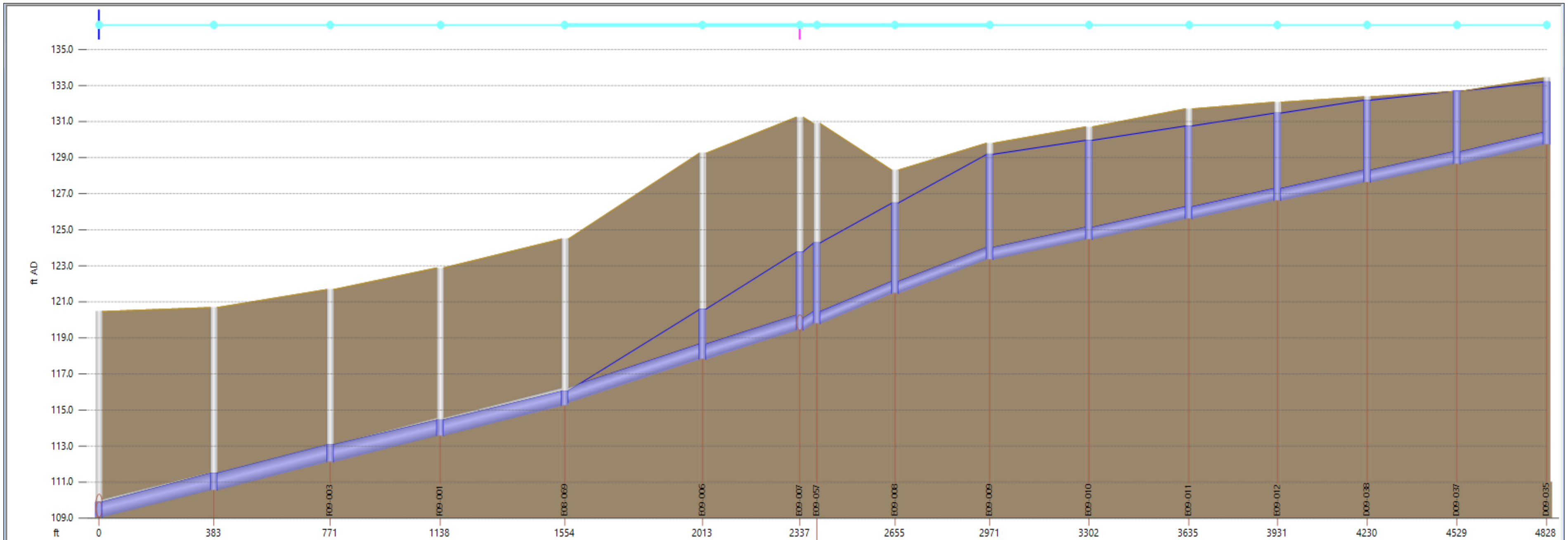
Link	-	-	C11-050.1	C11-047.1	C11-045.1	C12-013.1	-	C12-015.1	C12-016.1	C12-023.1	C12-024.1
height (in)	12.0	-	12.0	12.0	12.0	8.0	-	8.0	8.0	8.0	8.0
us inv (ft AD)	175.940	-	177.480	178.840	180.410	184.030	-	186.080	187.880	189.680	190.280
ds inv (ft AD)	175.750	-	176.310	177.480	178.840	180.410	-	184.390	186.080	187.880	189.680
pfc (MGD)	0.71	-	1.52	1.49	1.49	0.80	-	0.61	0.61	0.61	0.34
DS flow (MGD)	0.7016	-	0.7023	0.6132	0.6139	0.6148	-	0.4111	0.4118	0.4120	0.4134
DS depth (ft)	0.483	-	0.517	0.487	0.451	0.451	-	0.556	0.416	0.419	0.420

Node	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	D12-025	-	-	D12-011	D12-009	D12-007	D12-006	-	-	-	-	-	-	-	-	-	-	C11-050	C11-047	C11-045	-	-	C12-015	C12-016	C12-023	-

Project: CIP-CAP-002

Sewer Replacement – Flower Street

Figure C2.1: Hydraulic Profile of Existing Sewer (2040 / Peak Wet Weather Scenario)



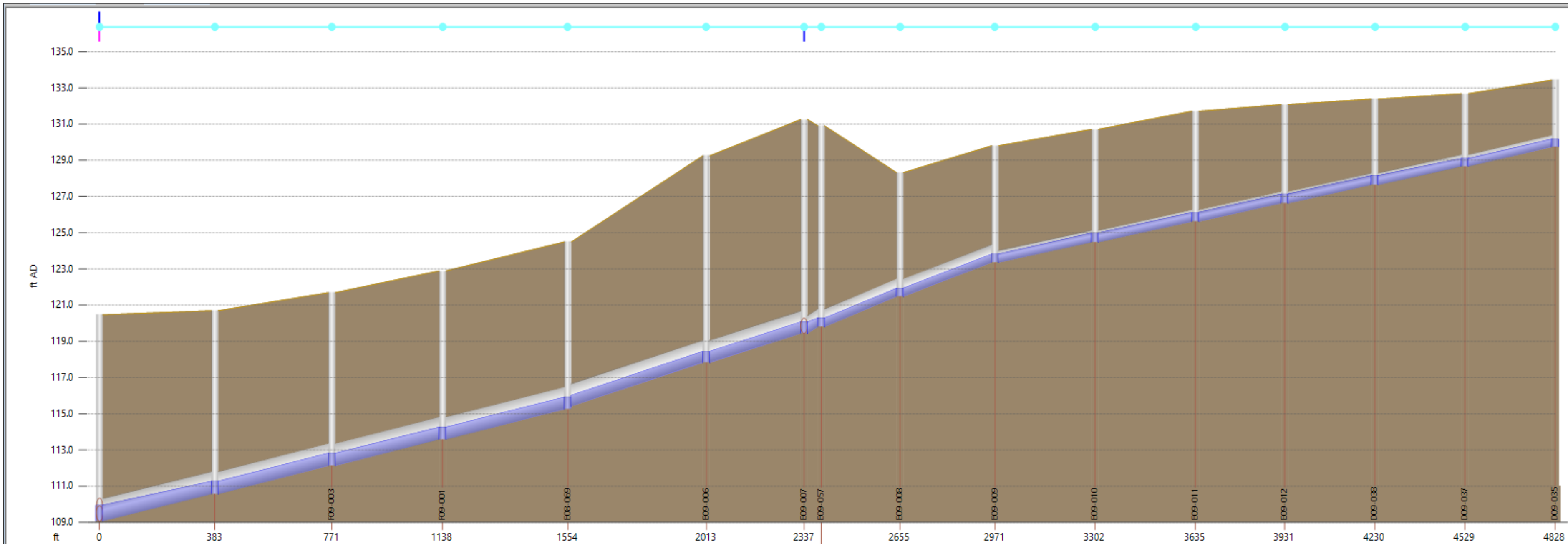
Link	F09-004.1	F09-003.1	F09-001.1	E08-069.1	E09-006.1	E09-007.1	-	E09-008.1	E09-009.1	E09-010.1	E09-011.1	E09-012.1	D09-038.1	D09-037.1	D09-035.1
height (in)	12.0	12.0	12.0	12.0	10.0	10.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
us inv (ft AD)	110.560	112.120	113.580	115.240	117.820	119.430	-	121.470	123.350	124.470	125.610	126.620	127.640	128.660	129.730
ds inv (ft AD)	109.070	110.560	112.120	113.580	115.410	117.820	-	119.796	121.470	123.350	124.470	125.610	126.620	127.640	128.660
pfc (MGD)	1.44	1.46	1.45	1.45	1.03	1.00	-	0.63	0.60	0.45	0.46	0.46	0.46	0.46	0.47
DS flow (MGD)	1.4322	1.4319	1.3705	1.3734	1.3822	1.3826	-	0.7126	0.7104	0.3789	0.3741	0.3796	0.3985	0.3362	0.3367
DS depth (ft)	0.824	0.937	0.952	0.864	0.658	2.781	-	4.482	5.023	5.836	5.494	5.153	4.854	4.553	4.032

Node	F09-005	F09-004	F09-003	F09-001	E08-069	E09-006	E09-007	E09-057	E09-008	E09-009	E09-010	E09-011	E09-012	D09-038	D09-037	-

Project: CIP-CAP-002

Sewer Replacement – Flower Street

Figure C2.2: Hydraulic Profile of Proposed Sewer Replacement (2040 / Peak Wet Weather Scenario)



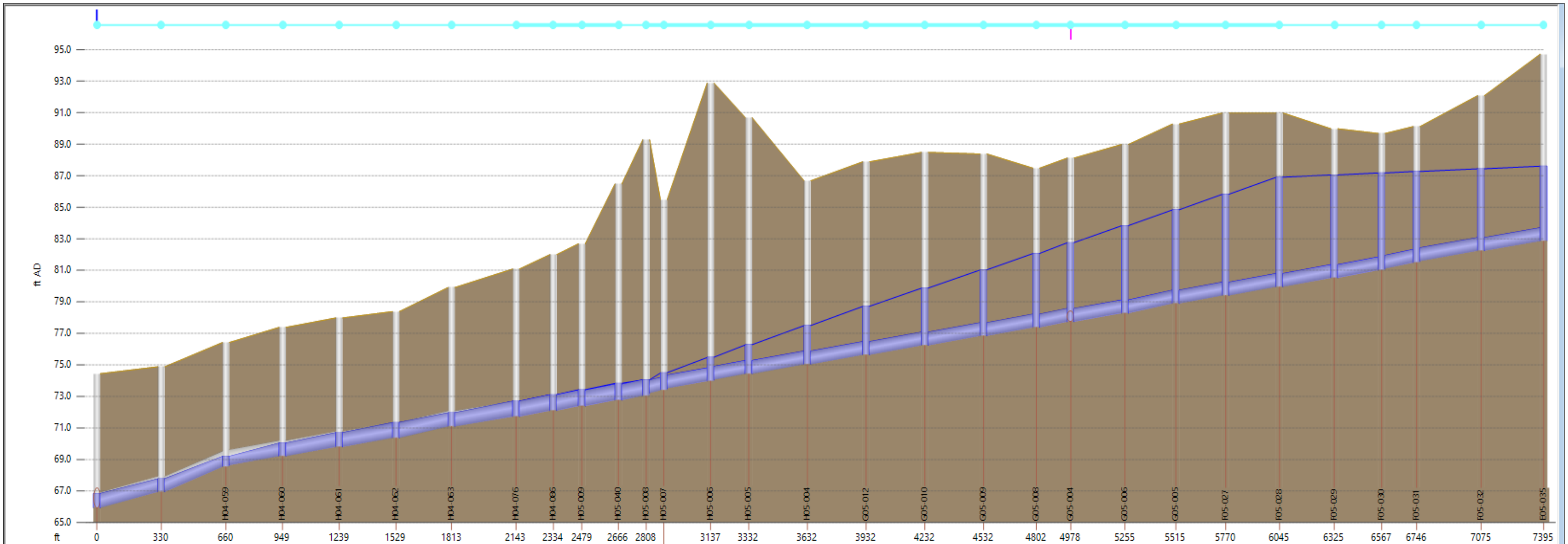
Link	F09-004.1	F09-003.1	F09-001.1	E08-069.1	E09-006.1	E09-007.1	-	E09-008.1	E09-009.1	E09-010.1	E09-011.1	E09-012.1	D09-038.1	D09-037.1	D09-035.1
height (in)	15.0	15.0	15.0	15.0	15.0	15.0	-	12.0	12.0	8.0	8.0	8.0	8.0	8.0	8.0
us inv (ft AD)	110.560	112.120	113.580	115.240	117.820	119.430	-	121.470	123.350	124.470	125.610	126.620	127.640	128.660	129.730
ds inv (ft AD)	109.070	110.560	112.120	113.580	115.410	117.820	-	119.796	121.470	123.350	124.470	125.610	126.620	127.640	128.660
pfc (MGD)	2.60	2.65	2.63	2.64	3.02	2.94	-	1.84	1.78	0.45	0.46	0.46	0.46	0.46	0.47
DS flow (MGD)	1.5218	1.5228	1.4550	1.4554	1.4572	1.4586	-	0.7540	0.7541	0.4043	0.4052	0.4057	0.4065	0.3365	0.3371
DS depth (ft)	0.873	0.699	0.692	0.670	0.603	0.619	-	0.485	0.460	0.461	0.504	0.501	0.506	0.510	0.435

Node															
F09-005	F09-004	F09-003	F09-001	E08-069	E09-006	E09-007	E09-057	E09-008	E09-009	E09-010	E09-011	E09-012	D09-038	D09-037	-

Project: CIP-CAP-003

Sewer Replacement – Mar les Drive

Figure C3.1: Hydraulic Profile of Existing Sewer (2040 / Peak Wet Weather Scenario)



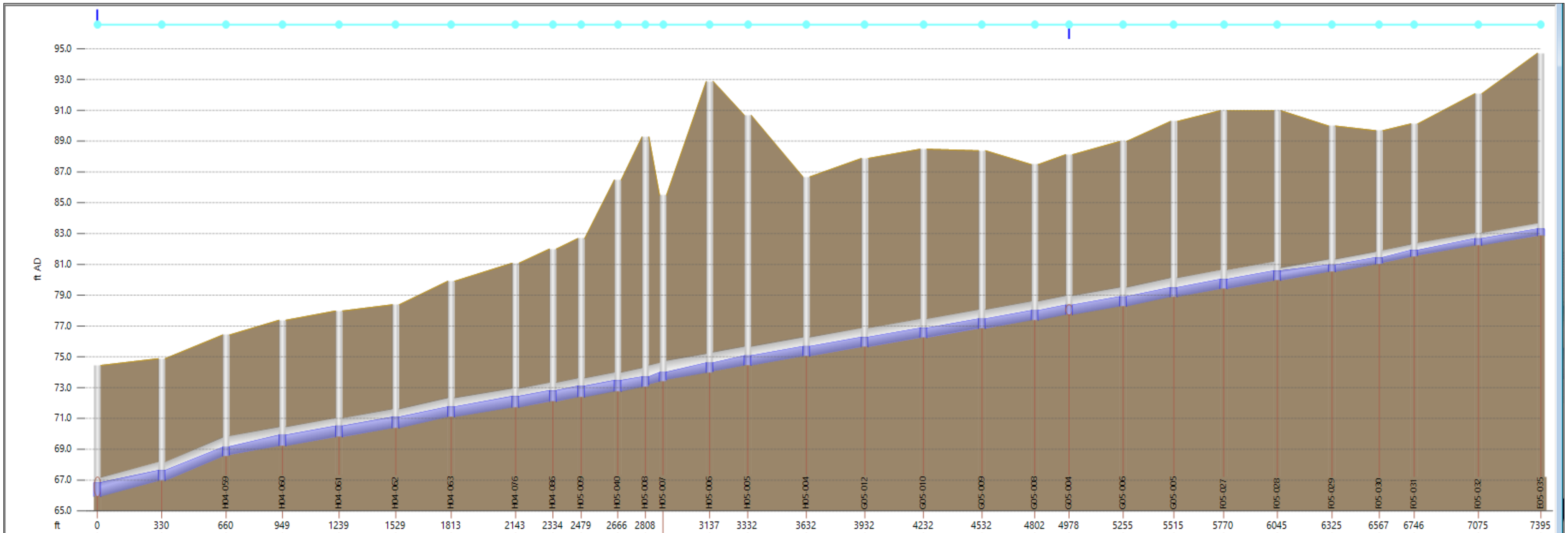
Link	H04-054.1	H04-059.1	H04-060.1	H04-061.1	H04-062.1	H04-063.1	H04-076.1	-	-	-	-	-	H05-006.1	-	H05-004.1	G05-012.1	G05-010.1	G05-009.1	G05-008.1	-	G05-006.1	G05-005.1	F05-027.1	F05-028.1	F05-029.1	F05-030.1	-	F05-032.1	E05-035.1
height (in)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	9.7	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
us inv (ft AD)	66.950	68.540	69.220	69.800	70.380	71.100	71.720	72.100	-	72.760	-	-	73.970	74.440	75.040	75.640	76.240	76.840	77.380	77.740	78.280	78.900	79.410	79.960	80.520	81.010	81.490	82.240	82.860
ds inv (ft AD)	65.940	66.950	68.640	69.220	69.800	70.380	71.100	71.720	-	72.390	-	-	73.520	74.070	74.440	75.040	75.640	76.240	76.840	77.380	77.740	78.280	78.900	79.410	79.960	80.520	81.110	81.590	82.240
pfc (MGD)	1.27	1.60	1.03	1.03	1.03	1.16	1.00	1.03	1.03	1.02	1.04	-	0.61	0.62	0.63	0.63	0.63	0.63	0.63	0.64	0.63	0.69	0.63	0.63	0.63	0.64	0.65	0.63	0.62
DS flow (MGD)	1.1928	1.1944	1.0495	1.0495	1.0498	1.0503	1.0517	1.0546	-	1.0575	-	-	0.8878	0.8881	0.8885	0.8889	0.8660	0.8660	0.8666	0.8675	0.8698	0.8718	0.8741	0.8765	0.3115	0.3120	0.3158	0.3201	0.3260
DS depth (ft)	0.896	0.825	0.553	0.817	0.898	0.959	0.859	0.976	1.010	1.038	1.076	-	0.987	1.417	1.845	2.462	3.079	3.636	4.193	4.695	5.020	5.554	5.944	6.424	6.948	6.532	6.067	5.680	5.200

Node	-	H04-054	H04-059	H04-060	H04-061	H04-062	H04-063	H04-076	-	-	-	-	-	-	H05-005	H05-004	G05-012	G05-010	G05-009	-	-	G05-006	G05-005	F05-027	F05-028	F05-029	-	F05-031	F05-032	-

Project: CIP-CAP-003

Sewer Replacement – Mar les Drive

Figure C3.2: Hydraulic Profile of Proposed Sewer Replacement (2040 / Peak Wet Weather Scenario)



Link	H04-054.1	H04-059.1	H04-060.1	H04-061.1	H04-062.1	H04-063.1	H04-076.1	-	-	-
height (in)	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
us inv (ft AD)	66.950	68.540	69.220	69.800	70.380	71.100	71.720	72.100	-	72.760
ds inv (ft AD)	65.940	66.950	68.640	69.220	69.800	70.380	71.100	71.720	-	72.390
pfc (MGD)	2.31	2.90	1.87	1.87	1.87	2.10	1.81	1.86	1.87	1.86
DS flow (MGD)	1.2672	1.2676	1.1081	1.1081	1.1083	1.1085	1.1085	1.1087	-	1.1089
DS depth (ft)	0.893	0.670	0.522	0.696	0.703	0.703	0.647	0.712	0.705	0.704

Link	-	-	H05-006.1	-	H05-004.1	G05-012.1	G05-010.1	G05-009.1	G05-008.1	-
height (in)	15.0	-	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
us inv (ft AD)	-	-	73.970	74.440	75.040	75.640	76.240	76.840	77.380	77.740
ds inv (ft AD)	-	-	73.520	74.070	74.440	75.040	75.640	76.240	76.840	77.380
pfc (MGD)	1.89	-	1.81	1.82	1.87	1.87	1.87	1.87	1.87	1.89
DS flow (MGD)	-	-	0.9314	0.9314	0.9314	0.9316	0.9000	0.9000	0.9001	0.9001
DS depth (ft)	0.705	-	0.477	0.531	0.629	0.627	0.627	0.618	0.618	0.618

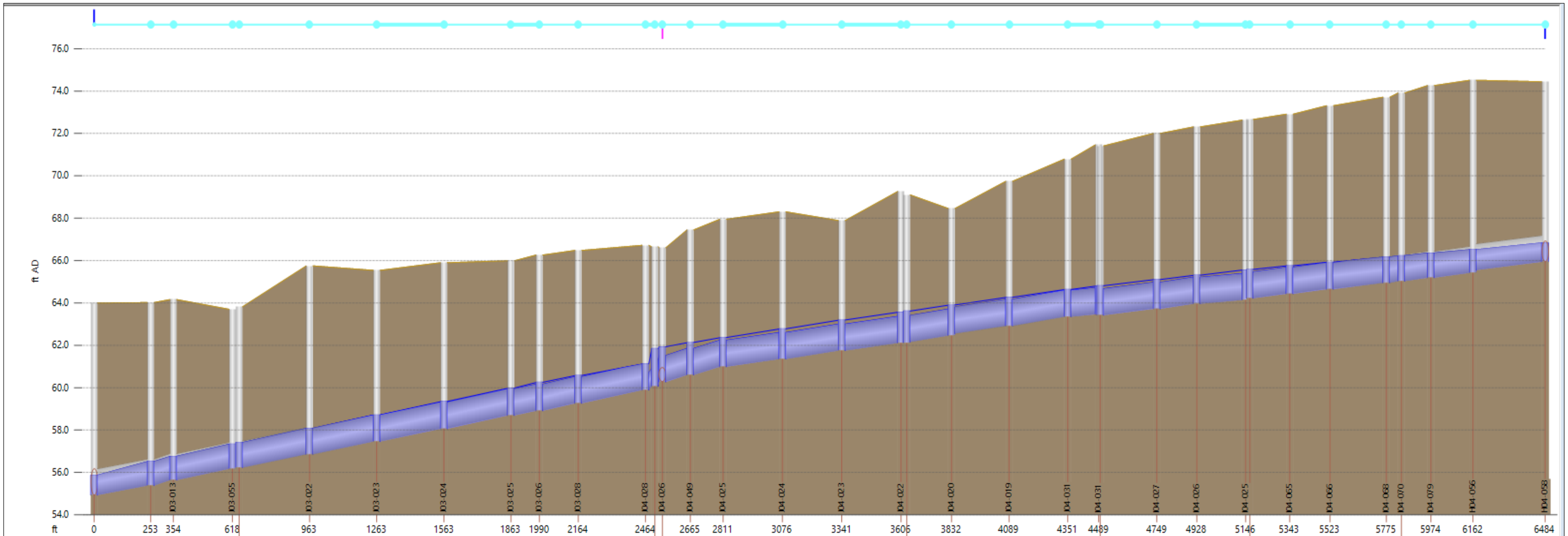
Link	G05-006.1	G05-005.1	F05-027.1	F05-028.1	F05-029.1	F05-030.1	-	F05-032.1	E05-035.1
height (in)	15.0	15.0	15.0	15.0	10.0	10.0	10.0	10.0	10.0
us inv (ft AD)	78.280	78.900	79.410	79.960	80.520	81.010	81.490	82.240	82.860
ds inv (ft AD)	77.740	78.280	78.900	79.410	79.960	80.520	81.110	81.590	82.240
pfc (MGD)	1.84	2.04	1.87	1.87	0.63	0.64	0.65	0.63	0.62
DS flow (MGD)	0.9001	0.9002	0.9003	0.9004	0.3313	0.3314	0.3316	0.3317	0.3318
DS depth (ft)	0.615	0.622	0.590	0.618	0.618	0.440	0.331	0.323	0.434

Node										
	-	H04-054	H04-059	H04-060	H04-061	H04-062	H04-063	H04-076	-	-
	-	-	-	-	H05-005	H05-004	G05-012	G05-010	G05-009	-
	-	G05-006	G05-005	F05-027	F05-028	F05-029	-	F05-031	F05-032	-

Project: CIP-CAP-004

Sewer Replacement – McFadden Avenue

Figure C4.1: Hydraulic Profile of Existing Sewer (2040 / Peak Wet Weather Scenario)



Link	J03-012.1	-	J03-055.1	J03-022.1	J03-023.1	J03-024.1	J03-025.1	-	-	J04-028.1	-
height (in)	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	-
us inv (ft AD)	55.380	-	56.170	56.860	57.460	58.060	58.690	-	59.260	59.890	-
ds inv (ft AD)	54.930	-	55.640	56.230	56.860	57.460	58.060	-	58.910	59.260	-
pfc (MGD)	1.76	2.12	1.87	1.87	1.87	1.87	1.91	1.74	1.87	1.91	-
DS flow (MGD)	1.9702	-	1.8917	1.8912	1.8911	1.8912	1.8914	-	1.7606	1.7599	-
DS depth (ft)	0.943	-	1.121	1.182	1.224	1.257	1.290	1.292	1.348	1.318	-

Link	-	-	J04-024.1	J04-023.1	J04-022.1	J04-020.1	J04-019.1	J04-031.1	-	I04-027.1
height (in)	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
us inv (ft AD)	-	60.990	61.350	61.750	62.110	62.460	62.920	63.350	63.460	63.720
ds inv (ft AD)	-	60.601	60.990	61.350	61.750	62.160	62.560	62.920	63.350	63.420
pfc (MGD)	2.15	2.15	1.54	1.62	1.54	1.62	1.56	1.69	1.18	1.44
DS flow (MGD)	-	1.6209	1.6208	1.6208	1.5529	1.5512	1.5503	1.5477	1.4019	1.3985
DS depth (ft)	1.663	1.535	1.377	1.431	1.445	1.458	1.344	1.348	1.287	1.393

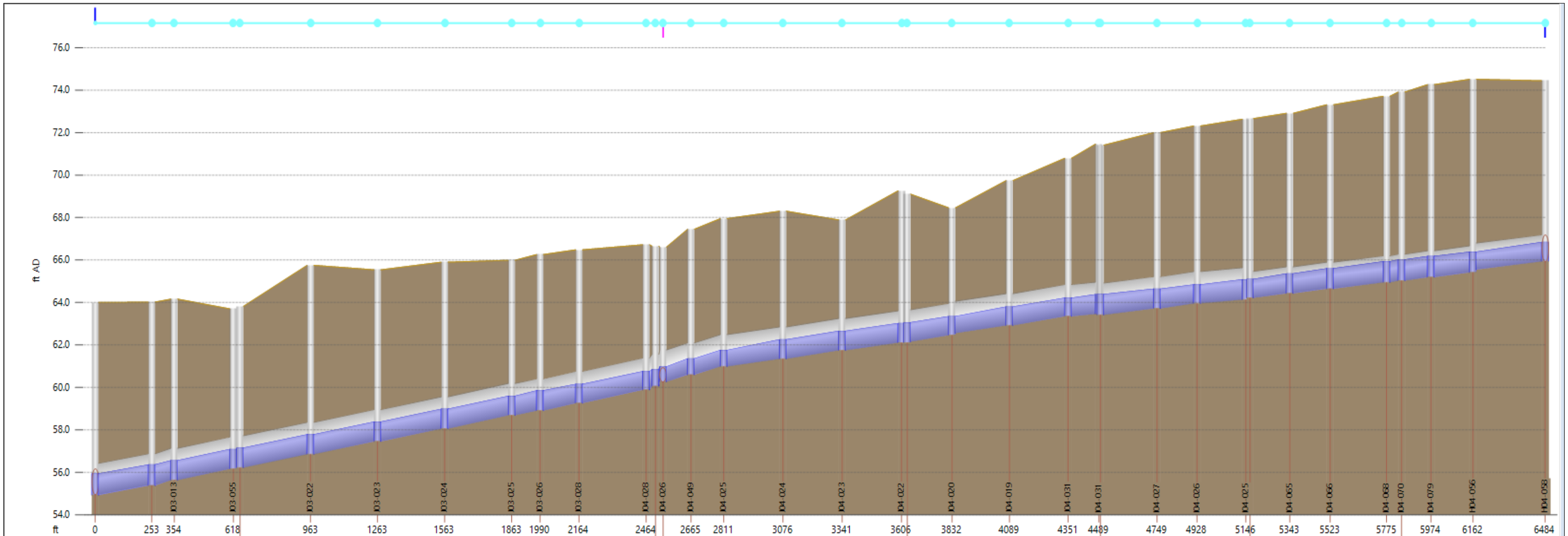
Link	-	I04-025.1	-	-	I04-068.1	-	-	-	H04-058.1
height (in)	15.0	15.0	15.0	15.0	15.0	-	15.0	15.0	15.0
us inv (ft AD)	63.960	64.140	64.430	64.650	64.950	-	-	65.420	65.940
ds inv (ft AD)	63.720	63.960	64.220	64.430	64.650	-	-	65.190	65.550
pfc (MGD)	1.53	1.20	1.43	1.46	1.44	-	1.45	1.46	1.45
DS flow (MGD)	1.3961	1.3944	1.2765	1.2738	1.2710	-	-	1.1811	1.1869
DS depth (ft)	1.383	1.349	1.364	1.324	1.275	-	1.199	1.167	0.965

Node																																	
-	-	-	-	-	J03-022	J03-023	J03-024	J03-025	-	J03-028	-	-	-	J04-025	J04-024	J04-023	-	-	J04-020	J04-019	J04-031	-	-	I04-027	I04-026	-	-	-	I04-066	-	-	-	H04-056	-

Project: CIP-CAP-004

Sewer Replacement – McFadden Avenue

Figure C4.2: Hydraulic Profile of Proposed Sewer Replacement (2040 / Peak Wet Weather Scenario)



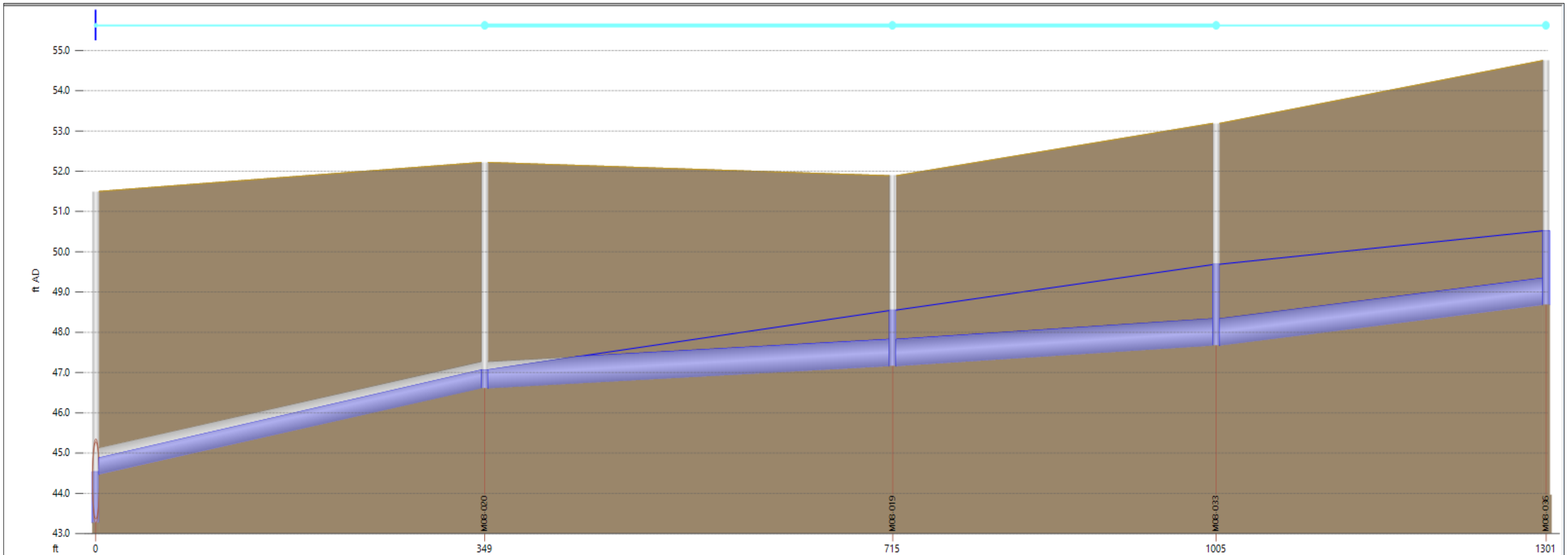
Link	J03-012.1	-	J03-055.1	J03-022.1	J03-023.1	J03-024.1	J03-025.1	-	-	J04-028.1	-	-	-	J04-024.1	J04-023.1	J04-022.1	J04-020.1	J04-019.1	J04-031.1	-	I04-027.1	-	I04-025.1	-	-	I04-068.1	-	-	-	H04-058.1
height (in)	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	-	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	15.0	15.0	15.0	-	15.0	15.0	15.0
us inv (ft AD)	55.380	-	56.170	56.860	57.460	58.060	58.690	-	59.260	59.890	-	-	60.990	61.350	61.750	62.110	62.460	62.920	63.350	63.460	63.720	63.960	64.140	64.430	64.650	64.950	-	-	65.420	65.940
ds inv (ft AD)	54.930	-	55.640	56.230	56.860	57.460	58.060	-	58.910	59.260	-	-	60.601	60.990	61.350	61.750	62.160	62.560	62.920	63.350	63.420	63.720	63.960	64.220	64.430	64.650	-	-	65.190	65.550
pfc (MGD)	2.86	3.45	3.04	3.04	3.04	3.04	3.11	2.83	3.05	3.11	-	3.50	3.50	2.50	2.64	2.50	2.63	2.54	2.75	1.92	2.34	2.49	1.95	1.43	1.46	1.44	-	1.45	1.46	1.45
DS flow (MGD)	2.1430	-	2.0591	2.0593	2.0597	2.0604	2.0607	-	1.9175	1.9172	-	-	1.7615	1.7614	1.7619	1.6772	1.6770	1.6777	1.6781	1.5045	1.5046	1.5048	1.5050	1.3641	1.3640	1.3646	-	-	1.2659	1.2659
DS depth (ft)	1.001	-	0.914	0.917	0.916	0.916	0.916	0.898	0.937	0.887	-	0.697	0.748	0.754	0.898	0.900	0.894	0.778	0.872	0.856	0.960	0.913	0.872	0.869	0.922	0.945	-	0.978	0.981	0.825

Node	-	-	-	-	-	J03-022	J03-023	J03-024	J03-025	-	J03-028	-	-	-	J04-025	J04-024	J04-023	-	-	J04-020	J04-019	J04-031	-	-	I04-027	I04-026	-	-	-	I04-066	-	-	-	H04-056	-

Project: CIP-CAP-005

Sewer Replacement – Glenwood Place

Figure C5.1: Hydraulic Profile of Existing Sewer (2040 / Peak Wet Weather Scenario)

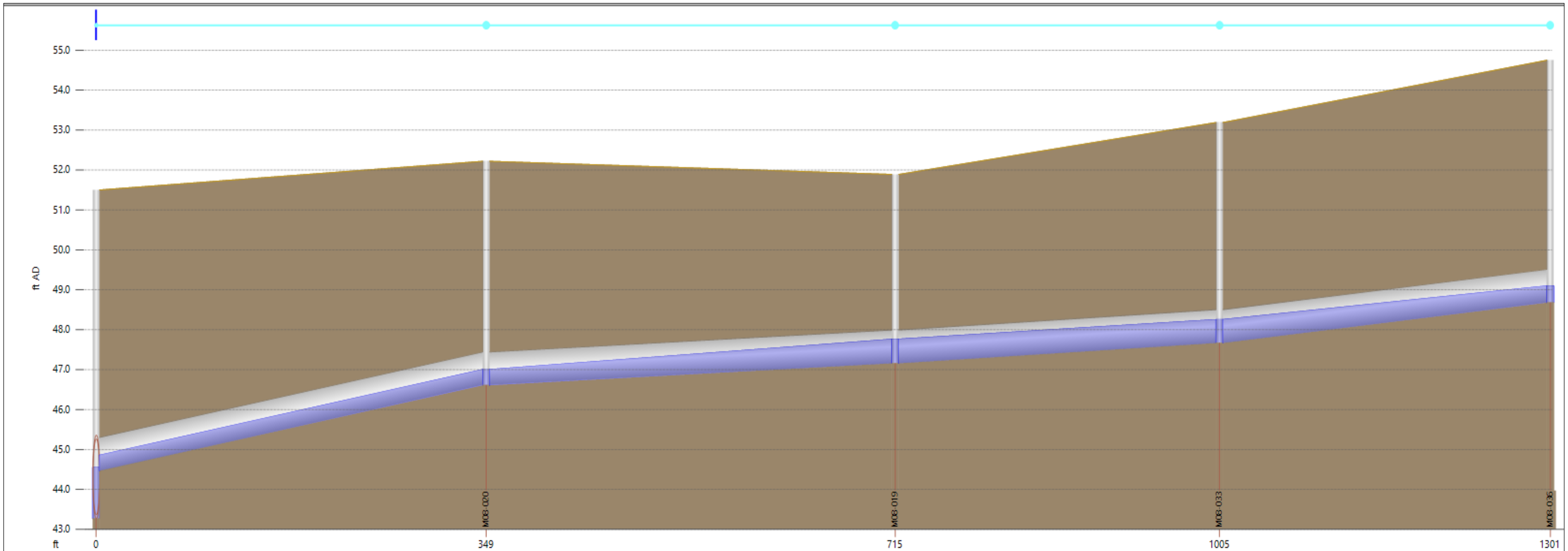


Link		M08-020.1	M08-019.1	M08-033.1	M08-036.1
height (in)		8.0	8.0	8.0	8.0
us inv (ft AD)		46.610	47.160	47.670	48.680
ds inv (ft AD)		44.470	46.610	47.160	47.670
pfc (MGD)		0.61	0.30	0.33	0.46
DS flow (MGD)		0.4780	0.4792	0.4801	0.4048
DS depth (ft)		0.412	0.460	1.393	2.021
Node	00_MA_Bristol21	M08-020	M08-019	M08-033	M08-036

Project: CIP-CAP-005

Sewer Replacement – Glenwood Place

Figure C5.2: Hydraulic Profile of Proposed Sewer Replacement (2040 / Peak Wet Weather Scenario)



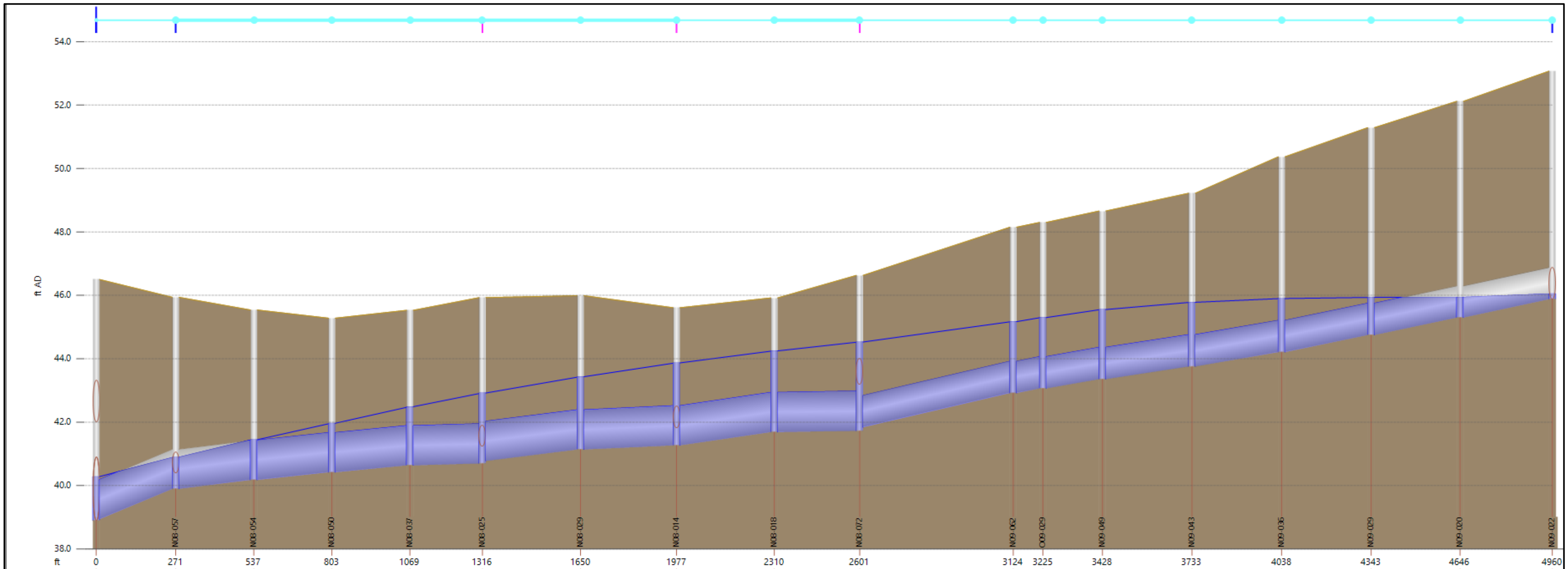
Link	M08-020.1	M08-019.1	M08-033.1	M08-036.1
height (in)	10.0	10.0	10.0	10.0
us inv (ft AD)	46.610	47.160	47.670	48.680
ds inv (ft AD)	44.470	46.610	47.160	47.670
pfc (MGD)	1.11	0.55	0.59	0.83
DS flow (MGD)	0.4795	0.4798	0.4811	0.4057
DS depth (ft)	0.386	0.392	0.604	0.586

Node	00_MA_Bristol21	M08-020	M08-019	M08-033	M08-036

Project: CIP-CAP-006

Sewer Replacement – Warner Avenue

Figure C6.1: Hydraulic Profile of Existing Sewer (2040 / Peak Wet Weather Scenario)



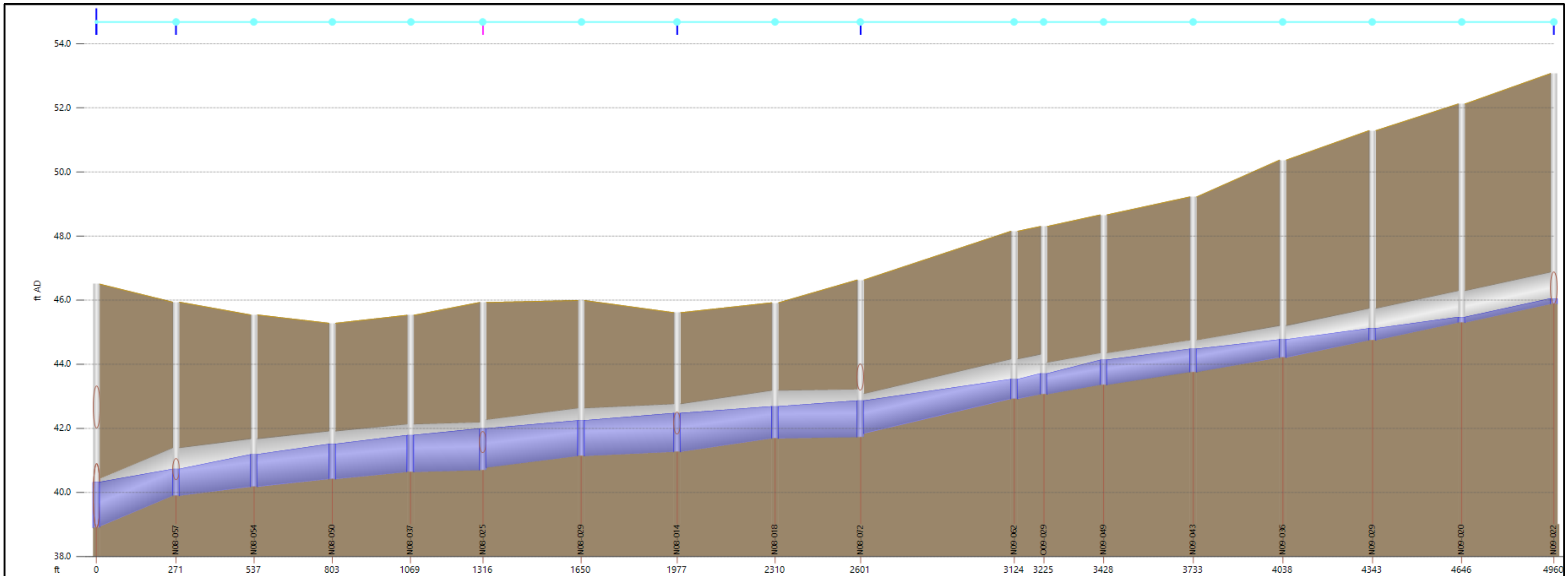
Link	N08-057.1	N08-054.1	N08-050.1	N08-037.1	N08-025.1	N08-029.1	N08-014.1	N08-018.1	N08-072.1	N09-062.1	-	N09-049.1	N09-043.1	N09-036.1	N09-029.1	N09-020.1	N09-022.1
height (in)	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
us inv (ft AD)	39.900	40.180	40.420	40.640	40.700	41.140	41.270	41.690	41.730	42.920	-	43.360	43.760	44.210	44.750	45.300	45.880
ds inv (ft AD)	38.940	39.900	40.180	40.420	40.640	40.780	41.140	41.270	41.690	41.840	-	43.066	43.360	43.760	44.210	44.750	45.300
pfc (MGD)	2.49	1.35	1.25	1.20	0.65	1.37	0.83	1.48	0.49	1.05	0.88	0.88	0.83	0.88	0.97	0.98	0.99
DS flow (MGD)	1.9863	1.8044	1.8057	1.8060	1.7056	1.6091	1.5067	1.3857	1.2775	0.7988	-	0.8091	0.6406	0.4634	0.2824	0.1059	0.0674
DS depth (ft)	1.344	0.994	1.267	1.547	1.849	2.139	2.293	2.600	2.559	2.688	2.251	2.233	2.192	2.021	1.689	1.185	0.637

Node	-	N08-057	N08-054	N08-050	N08-037	N08-025	N08-029	N08-014	N08-018	N08-072	N09-062	-	N09-049	N09-043	N09-036	N09-029	N09-020	N09-022

Project: CIP-CAP-006

Sewer Replacement – Warner Avenue

Figure C6.2: Hydraulic Profile of Proposed Sewer Replacement (2040 / Peak Wet Weather Scenario)



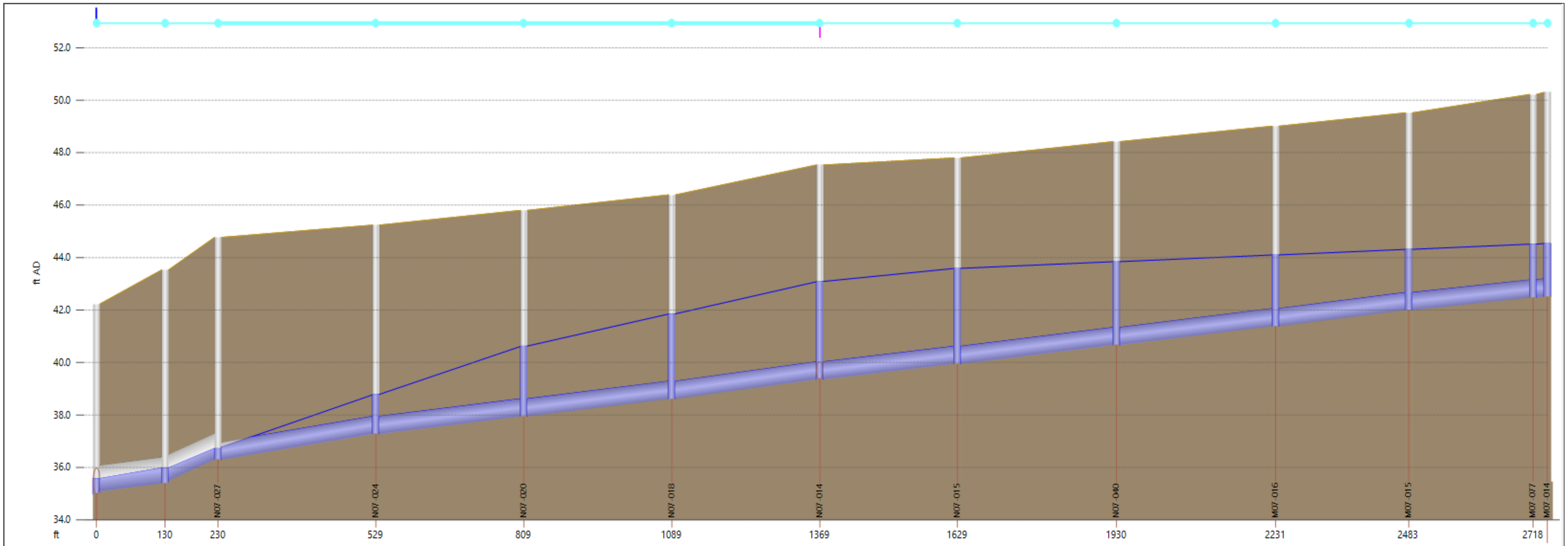
Link	N08-057.1	N08-054.1	N08-050.1	N08-037.1	N08-025.1	N08-029.1	N08-014.1	N08-018.1	N08-072.1	N09-062.1	-	N09-049.1	N09-043.1	N09-036.1	N09-029.1	N09-020.1	N09-022.1
height (in)	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	15.0	15.0	12.0	12.0	12.0	12.0	12.0	12.0
us inv (ft AD)	39.900	40.180	40.420	40.640	40.700	41.140	41.270	41.690	41.730	42.920	-	43.360	43.760	44.210	44.750	45.300	45.880
ds inv (ft AD)	38.940	39.900	40.180	40.420	40.640	40.780	41.140	41.270	41.690	41.840	-	43.066	43.360	43.760	44.210	44.750	45.300
pfc (MGD)	4.04	2.20	2.04	1.95	1.06	2.23	1.35	2.41	0.80	1.90	1.59	0.88	0.83	0.88	0.97	0.98	0.99
DS flow (MGD)	2.1129	1.9317	1.9326	1.9329	1.8300	1.7324	1.6260	1.5024	1.3881	0.8735	-	0.8760	0.6825	0.4863	0.2625	0.0511	0.0506
DS depth (ft)	1.381	0.826	1.004	1.088	1.143	1.212	1.102	1.199	0.990	1.020	0.607	0.642	0.771	0.714	0.557	0.363	0.166

Node																	
	-	N08-057	N08-054	N08-050	N08-037	N08-025	N08-029	N08-014	N08-018	N08-072	N09-062	-	N09-049	N09-043	N09-036	N09-029	N09-020	N09-022

Project: CIP-CAP-007

Sewer Replacement – Rene Drive

Figure C7.1: Hydraulic Profile of Existing Sewer (2040 / Peak Wet Weather Scenario)

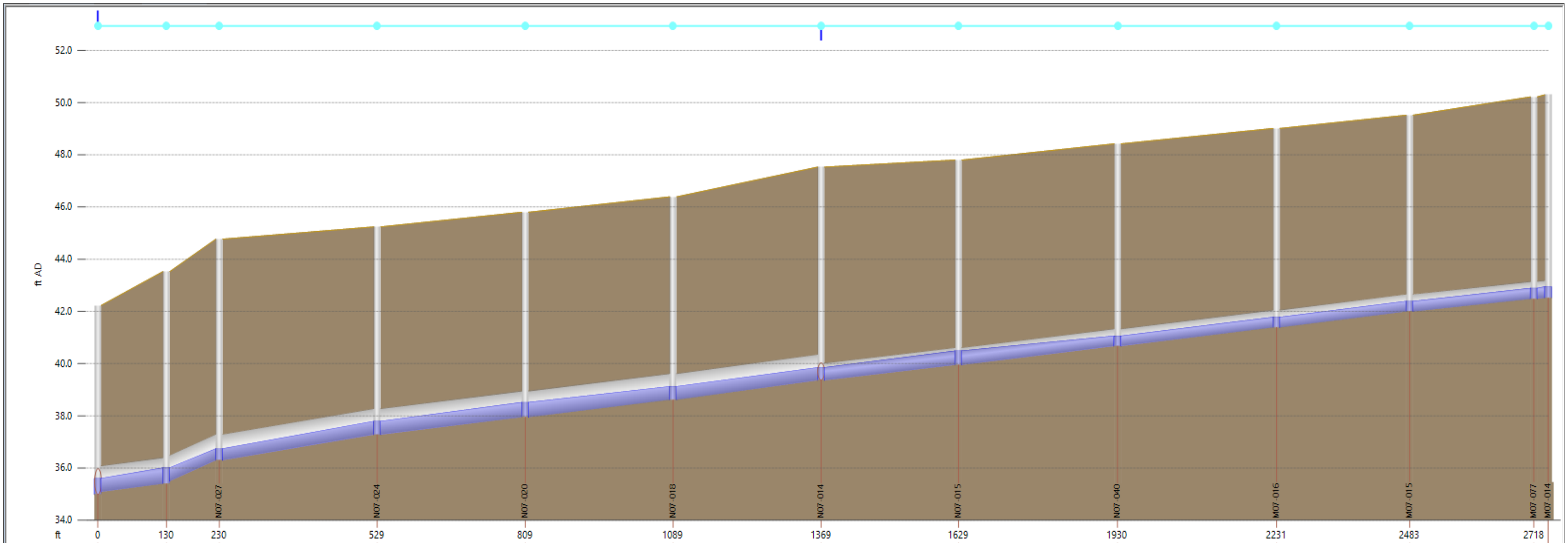


Link	N07-029.1	N07-027.1	N07-024.1	N07-020.1	N07-018.1	N07-014.1	N07-015.1	N07-040.1	M07-016.1	M07-015.1	M07-077.1	-
height (in)	12.0	12.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	-
us inv (ft AD)	35.400	36.300	37.280	37.950	38.620	39.360	39.950	40.670	41.390	42.000	42.480	-
ds inv (ft AD)	35.090	35.500	36.300	37.280	37.950	38.620	39.360	39.950	40.670	41.390	42.000	-
pfc (MGD)	1.12	2.06	0.45	0.38	0.38	0.40	0.37	0.38	0.38	0.38	0.35	-
DS flow (MGD)	0.7437	0.7436	0.6217	0.6219	0.5079	0.5079	0.3337	0.2203	0.2194	0.2204	0.2235	-
DS depth (ft)	0.486	0.484	0.469	1.506	2.678	3.238	3.731	3.640	3.175	2.711	2.316	-
Node	-	N07-029	N07-027	N07-024	N07-020	N07-018	N07-014	N07-015	N07-040	M07-016	M07-015	M07-077

Project: CIP-CAP-007

Sewer Replacement – Rene Drive

Figure C7.2: Hydraulic Profile of Proposed Sewer Replacement (2040 / Peak Wet Weather Scenario)



Link	N07-029.1	N07-027.1	N07-024.1	N07-020.1	N07-018.1	N07-014.1	N07-015.1	N07-040.1	M07-016.1	M07-015.1	M07-077.1	-
height (in)	12.0	12.0	12.0	12.0	12.0	12.0	8.0	8.0	8.0	8.0	8.0	-
us inv (ft AD)	35.400	36.300	37.280	37.950	38.620	39.360	39.950	40.670	41.390	42.000	42.480	-
ds inv (ft AD)	35.090	35.500	36.300	37.280	37.950	38.620	39.360	39.950	40.670	41.390	42.000	-
pfc (MGD)	1.12	2.06	1.32	1.13	1.13	1.18	0.37	0.38	0.38	0.38	0.35	-
DS flow (MGD)	0.7830	0.7829	0.6567	0.6565	0.5367	0.5370	0.3543	0.2330	0.2331	0.2331	0.2334	-
DS depth (ft)	0.508	0.504	0.433	0.503	0.558	0.494	0.482	0.533	0.384	0.384	0.383	-
Node	-	N07-029	N07-027	N07-024	N07-020	N07-018	N07-014	N07-015	N07-040	M07-016	M07-015	M07-077

Appendix D - Long-Term CIP Project List

CIP Group Reference	Risk Percent	Risk Grade	Pipe Length (feet)	Rehab Cost	Lateral Cost	Total Cost	Capacity Project ID	CIP Priority	Cumulative Cost	Budget Year	Proposed Budget Cycle
CIP-001	20.4	5	18540	$3,729,070	$873,661	$4,602,731	CIP-CAP-002	1	$4,602,731	Year 1	5-Year
CIP-002	18.3	5	7858	$1,357,238	$440,933	$1,798,171	CIP-CAP-005	2	$6,400,902	Year 2	5-Year
CIP-003	28.2	4	2219	$456,390	$138,701	$595,091	CIP-CAP-007	3	$6,995,993	Year 2	5-Year
CIP-004	28.1	4	7314	$1,965,592	$168,254	$2,133,846		4	$9,129,839	Year 2	5-Year
CIP-005	27.0	4	984	$175,965	$54,503	$230,468		5	$9,360,307	Year 2	5-Year
CIP-006	25.0	4	3910	$961,975	$284,685	$1,246,660	CIP-CAP-006	6	$10,606,967	Year 3	5-Year
CIP-007	15.7	4	2839	$462,387	$8,960	$471,348	CIP-CAP-006	7	$11,078,315	Year 3	5-Year
CIP-008	14.0	4	3997	$773,824	$251,941	$1,025,765	CIP-CAP-001	8	$12,104,080	Year 3	5-Year
CIP-009	13.2	4	4843	$876,383	$288,341	$1,164,724	CIP-CAP-001	9	$13,268,804	Year 3	5-Year
CIP-010	42.0	5	1992	$456,841	$158,911	$615,752		10	$13,884,556	Year 4	5-Year
CIP-011	38.3	5	861	$119,186	$18,253	$137,439		11	$14,021,996	Year 4	5-Year
CIP-012	37.0	5	1921	$321,927	$82,706	$404,632		12	$14,426,628	Year 4	5-Year
CIP-013	32.9	5	822	$299,146	$6,591	$305,737		13	$14,732,365	Year 4	5-Year
CIP-014	31.4	5	3728	$709,570	$197,104	$906,674		14	$15,639,038	Year 4	5-Year
CIP-015	30.1	5	5760	$1,017,023	$297,767	$1,314,790		15	$16,953,828	Year 4	5-Year
CIP-016	28.6	5	2780	$452,238	$10,214	$462,452		16	$17,416,280	Year 4	5-Year
CIP-017	27.5	5	5732	$1,235,857	$319,820	$1,555,676		17	$18,971,956	Year 5	5-Year
CIP-018	25.8	5	1654	$237,911	$57,817	$295,728		18	$19,267,684	Year 5	5-Year
CIP-019	23.6	5	5263	$990,358	$285,837	$1,276,196		19	$20,543,880	Year 5	5-Year
CIP-020	21.7	5	10438	$1,892,098	$545,130	$2,437,229		20	$22,981,109	Year 5	5-Year
CIP-021	20.0	5	10274	$1,643,079	$323,371	$1,966,450		21	$24,947,559	TBD	10-Year
CIP-022	17.0	5	1921	$279,734	$51,138	$330,872		22	$25,278,431	TBD	10-Year
CIP-023	17.0	5	2155	$556,040	$129,650	$685,690	CIP-CAP-004	23	$25,964,121	TBD	10-Year
CIP-024	20.6	4	5586	$1,363,540	$333,071	$1,696,610	CIP-CAP-004	24	$27,660,731	TBD	15-Year
CIP-025	18.4	4	2700	$602,452	$122,087	$724,538	CIP-CAP-004	25	$28,385,270	TBD	15-Year
CIP-026	14.5	5	5371	$944,243	$262,786	$1,207,029		26	$29,592,299	TBD	10-Year
CIP-027	53.5	4	148	$33,288	$13,151	$46,439		27	$29,638,738	TBD	10-Year
CIP-028	50.9	4	360	$57,568	$0	$57,568		28	$29,696,306	TBD	10-Year
CIP-029	45.9	4	423	$95,176	$37,601	$132,777		29	$29,829,083	TBD	10-Year
CIP-030	44.6	4	406	$91,242	$36,046	$127,289		30	$29,956,371	TBD	10-Year
CIP-031	40.5	4	1396	$257,757	$71,904	$329,661		31	$30,286,033	TBD	10-Year
CIP-032	36.6	4	468	$104,780	$40,889	$145,668		32	$30,431,701	TBD	10-Year
CIP-033	33.4	4	1901	$296,841	$97,623	$394,464		33	$30,826,165	TBD	10-Year

CIP Group Reference	Risk Percent	Risk Grade	Pipe Length (feet)	Rehab Cost	Lateral Cost	Total Cost	Capacity Project ID	CIP Priority	Cumulative Cost	Budget Year	Proposed Budget Cycle
CIP-034	31.8	4	220	$49,591	$19,592	$69,183		34	$30,895,347	TBD	10-Year
CIP-035	31.8	4	2485	$901,263	$1,778	$903,042		35	$31,798,389	TBD	10-Year
CIP-036	31.7	4	1366	$279,888	$83,857	$363,745		36	$32,162,134	TBD	10-Year
CIP-037	30.8	4	1098	$230,522	$63,111	$293,633		37	$32,455,768	TBD	10-Year
CIP-038	30.6	4	2729	$506,571	$170,769	$677,340		38	$33,133,108	TBD	10-Year
CIP-039	29.7	4	1019	$159,561	$42,234	$201,796		39	$33,334,903	TBD	10-Year
CIP-040	29.1	4	552	$88,651	$529	$89,180		40	$33,424,083	TBD	10-Year
CIP-041	29.0	4	2672	$534,724	$151,970	$686,694		41	$34,110,777	TBD	10-Year
CIP-042	28.8	4	1197	$190,710	$31,111	$221,821		42	$34,332,598	TBD	10-Year
CIP-043	27.0	4	3952	$770,906	$234,888	$1,005,794		43	$35,338,393	TBD	10-Year
CIP-044	26.3	4	3200	$604,369	$207,233	$811,602		44	$36,149,994	TBD	10-Year
CIP-045	26.0	4	810	$184,093	$70,532	$254,625		45	$36,404,620	TBD	10-Year
CIP-046	25.8	4	1398	$179,897	$31,466	$211,363		46	$36,615,983	TBD	10-Year
CIP-047	25.6	4	11047	$2,304,434	$774,400	$3,078,834		47	$39,694,816	TBD	10-Year
CIP-048	25.2	4	3241	$575,862	$67,549	$643,411		48	$40,338,228	TBD	10-Year
CIP-049	24.3	4	5664	$1,108,175	$179,172	$1,287,347		49	$41,625,575	TBD	10-Year
CIP-050	24.1	4	2963	$531,420	$81,105	$612,525		50	$42,238,100	TBD	10-Year
CIP-051	23.9	4	1972	$458,177	$111,091	$569,268		51	$42,807,368	TBD	10-Year
CIP-052	23.8	4	6507	$1,326,874	$433,312	$1,760,186		52	$44,567,554	TBD	10-Year
CIP-053	23.3	4	3012	$383,016	$88,074	$471,090		53	$45,038,644	TBD	10-Year
CIP-054	22.8	4	562	$101,249	$0	$101,249		54	$45,139,893	TBD	10-Year
CIP-055	22.7	4	2001	$337,883	$71,465	$409,348		55	$45,549,241	TBD	10-Year
CIP-056	22.5	4	5408	$1,043,242	$223,710	$1,266,952		56	$46,816,193	TBD	15-Year
CIP-057	22.1	4	4624	$879,785	$261,741	$1,141,526		57	$47,957,720	TBD	15-Year
CIP-058	21.8	4	1506	$254,734	$35,180	$289,915		58	$48,247,634	TBD	15-Year
CIP-059	21.6	4	2653	$398,911	$136,786	$535,696		59	$48,783,331	TBD	15-Year
CIP-060	21.6	4	5966	$1,233,517	$125,611	$1,359,128		60	$50,142,459	TBD	15-Year
CIP-061	20.8	4	10692	$1,910,223	$678,278	$2,588,501		61	$52,730,960	TBD	15-Year
CIP-062	20.4	4	5823	$1,200,858	$382,839	$1,583,697		62	$54,314,657	TBD	15-Year
CIP-063	20.4	4	3887	$730,408	$66,504	$796,912		63	$55,111,568	TBD	15-Year
CIP-064	20.4	4	1194	$172,650	$28,444	$201,094		64	$55,312,662	TBD	15-Year
CIP-065	20.2	4	389	$62,273	$0	$62,273		65	$55,374,935	TBD	15-Year
CIP-066	20.0	4	5666	$1,052,005	$246,579	$1,298,584		66	$56,673,519	TBD	15-Year
CIP-067	19.6	4	5082	$761,497	$166,647	$928,144		67	$57,601,663	TBD	15-Year
CIP-068	19.4	4	2864	$406,080	$0	$406,080		68	$58,007,743	TBD	15-Year
CIP-069	19.4	4	4797	$797,610	$165,337	$962,947		69	$58,970,690	TBD	15-Year
CIP-070	19.2	4	12188	$2,093,512	$536,308	$2,629,821		70	$61,600,510	TBD	15-Year
CIP-071	19.1	4	7913	$1,120,494	$277,985	$1,398,479		71	$62,998,989	TBD	15-Year
CIP-072	18.9	4	791	$141,152	$19,999	$161,151		72	$63,160,140	TBD	15-Year

CIP Group Reference	Risk Percent	Risk Grade	Pipe Length (feet)	Rehab Cost	Lateral Cost	Total Cost	Capacity Project ID	CIP Priority	Cumulative Cost	Budget Year	Proposed Budget Cycle
CIP-073	18.2	4	1240	$136,471	$39,834	$176,305		73	$63,336,445	TBD	15-Year
CIP-074	18.2	4	7339	$1,145,428	$344,096	$1,489,524		74	$64,825,969	TBD	15-Year
CIP-075	18.2	4	3990	$809,492	$22,106	$831,598		75	$65,657,567	TBD	20-Year
CIP-076	17.9	4	2498	$292,593	$50,658	$343,251		76	$66,000,818	TBD	20-Year
CIP-077	17.8	4	7781	$1,472,035	$446,872	$1,918,907		77	$67,919,725	TBD	20-Year
CIP-078	17.6	4	1917	$310,316	$45,446	$355,761		78	$68,275,486	TBD	20-Year
CIP-079	17.5	4	1081	$218,594	$62,303	$280,897		79	$68,556,383	TBD	20-Year
CIP-080	17.3	4	4168	$813,218	$267,847	$1,081,065		80	$69,637,448	TBD	20-Year
CIP-081	17.1	4	1609	$183,588	$0	$183,588		81	$69,821,036	TBD	20-Year
CIP-082	17.0	4	13454	$2,489,742	$301,260	$2,791,002	CIP-CAP-003	82	$72,612,038	TBD	20-Year
CIP-083	13.4	4	8722	$1,567,096	$460,658	$2,027,754	CIP-CAP-003	83	$74,639,792	TBD	20-Year
CIP-084	16.7	4	2065	$314,141	$109,240	$423,382		84	$75,063,174	TBD	20-Year
CIP-085	15.6	4	11944	$2,431,849	$764,050	$3,195,899		85	$78,259,073	TBD	20-Year
CIP-086	15.4	4	4600	$767,324	$1,078	$768,402		86	$79,027,475	TBD	20-Year
CIP-087	15.3	4	5805	$974,823	$352,398	$1,327,221		87	$80,354,696	TBD	20-Year
CIP-088	13.8	4	8885	$1,714,595	$511,292	$2,225,888		88	$82,580,583	TBD	20-Year
CIP-089	12.9	4	1521	$211,372	$27,664	$239,036		89	$82,819,619	TBD	20-Year
CIP-090	12.7	4	2688	$537,085	$97,970	$635,055		90	$83,454,674	TBD	20-Year
CIP-091	10.2	4	1783	$307,865	$78,222	$386,088		91	$83,840,761	TBD	20-Year
CIP-092	26.1	3	294	$52,936	$0	$52,936		92	$83,893,697	TBD	20-Year
CIP-093	25.3	3	33	$6,064	$1,102	$7,165		93	$83,900,862	TBD	20-Year
CIP-094	23.6	3	1258	$190,978	$44,888	$235,867		94	$84,136,729	TBD	20-Year
CIP-095	22.9	3	12	$1,907	$0	$1,907		95	$84,138,636	TBD	20-Year
CIP-096	22.4	3	836	$154,885	$28,889	$183,773		96	$84,322,409	TBD	20-Year
CIP-097	21.5	3	416	$35,087	$5,778	$40,865		97	$84,363,274	TBD	20-Year
CIP-098	20.5	3	2363	$356,422	$0	$356,422		98	$84,719,696	TBD	20-Year
CIP-099	18.7	3	305	$48,800	$0	$48,800		99	$84,768,496	TBD	20-Year
CIP-100	18.2	3	1534	$226,970	$0	$226,970		100	$84,995,467	TBD	20-Year
CIP-101	17.8	3	80	$18,109	$7,154	$25,263		101	$85,020,730	TBD	20-Year
CIP-102	17.7	3	600	$105,750	$13,333	$119,083		102	$85,139,813	TBD	20-Year
CIP-103	17.6	3	2165	$413,755	$155,305	$569,060		103	$85,708,873	TBD	25-Year
CIP-104	14.5	3	246	$28,985	$0	$28,985		104	$85,737,858	TBD	25-Year
CIP-105	13.5	3	1817	$273,275	$62,040	$335,316		105	$86,073,174	TBD	25-Year
CIP-106	13.4	3	1185	$144,039	$0	$144,039		106	$86,217,213	TBD	25-Year
CIP-107	13.2	3	4908	$802,190	$23,111	$825,301		107	$87,042,514	TBD	25-Year
CIP-108	13.0	3	786	$36,051	$0	$36,051		108	$87,078,565	TBD	25-Year
CIP-109	12.8	3	1616	$240,477	$28,356	$268,833		109	$87,347,397	TBD	25-Year
CIP-110	12.3	3	3035	$532,109	$135,901	$668,010		110	$88,015,407	TBD	25-Year
CIP-111	11.3	3	637	$123,439	$29,533	$152,972		111	$88,168,379	TBD	25-Year

CIP Group Reference	Risk Percent	Risk Grade	Pipe Length (feet)	Rehab Cost	Lateral Cost	Total Cost	Capacity Project ID	CIP Priority	Cumulative Cost	Budget Year	Proposed Budget Cycle
CIP-112	10.3	3	11811	$2,300,626	$679,973	$2,980,599		112	$91,148,978	TBD	25-Year
CIP-113	8.6	3	563	$77,717	$25,867	$103,584		113	$91,252,562	TBD	25-Year
CIP-114	8.6	3	2844	$455,043	$0	$455,043		114	$91,707,605	TBD	25-Year
CIP-115	7.8	3	1734	$349,128	$66,876	$416,004		115	$92,123,609	TBD	25-Year
CIP-116	6.3	3	5034	$790,003	$0	$790,003		116	$92,913,611	TBD	25-Year
CIP-117	6.0	3	323	$64,810	$17,956	$82,766		117	$92,996,377	TBD	25-Year
CIP-118	6.0	3	455	$42,075	$10,667	$52,742		118	$93,049,119	TBD	25-Year
CIP-119	21.3	2	230	$10,350	$0	$10,350		119	$93,059,469	TBD	25-Year
CIP-120	16.8	2	250	$12,060	$0	$12,060		120	$93,071,529	TBD	25-Year
CIP-121	15.0	2	118	$5,310	$0	$5,310		121	$93,076,839	TBD	25-Year
CIP-122	14.3	2	14	$2,242	$0	$2,242		122	$93,079,081	TBD	25-Year
CIP-123	12.1	2	476	$21,408	$0	$21,408		123	$93,100,489	TBD	25-Year
CIP-124	10.0	2	627	$104,147	$0	$104,147		124	$93,204,635	TBD	25-Year
CIP-125	6.9	1	230	$10,810	$0	$10,810		125	$93,215,445	TBD	25-Year