Asset Management Master Plan

Prepared for

Carlsbad Municipal Water District & the City of Carlsbad

June 2019

City of Carlsbad

Carlsbad Municipal Water District

Asset Management Master Plan Update Log

For use by City of Carlsbad for Asset Management Master Plan Updates

Version No.	Update Date	Summary of Updates	Updated By
0	5/2019	Asset Management Master Plan Created	HDR, Carlsbad MWD & City of Carlsbad

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Acronyms and Abbreviations

AMP	Asset Management Master Plan
BRE	business risk exposure
CCFRPM	Centrifugally Cast Fiberglass Reinforced Polymer Mortar
CCTV	closed-circuit television
CIP	capital improvement project
CIPP	cured-in-place pipe
City or CMWD	City of Carlsbad and Carlsbad Municipal Water District
COF	consequence of failure
d/D	flow depth to pipe diameter
ea	each
FTE	full time equivalent
FY	fiscal year
LD	large diameter
LF	Linear feet
LOF	likelihood of failure
mi	miles
NASSCO	National Association of Sewer Service Companies
POF	probability of failure
SD	small diameter
SLD	straight line depreciation
SSMP	Sewer System Management Plan
SSO	sanitary sewer overflow
SWQCB	State Water Quality Control Board
USGS	United States Geological Survey
WDR	Waste Discharge Requirements

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1 Introduction

This section includes the purpose and focus of the Asset Management Master Plan (AMP), the asset management program overview, AMP organization, AMP development participants, summary of assets and study areas included in the AMP.

1.1 Purpose of the Asset Management Master Plan

The City of Carlsbad and Carlsbad Municipal Water District (City) operate, maintain, and renew sanitary sewer, potable water, and recycled water infrastructure. The replacement cost of this infrastructure is estimated to be over $2.1 billion per Section 1.5. **As the system continues to age and deteriorate, the City seeks to sustain high levels of service at acceptable levels of risk, while minimizing cost.**

This AMP provides a strong foundation for condition assessment and capital improvement program (CIP) planning that aligns with and supports the 2018 Potable Water, Recycled Water and Sewer Master Plan Updates (Master Plan Updates). This initial AMP focuses in detail on the following infrastructure:

- Gravity sewer mains and manholes
- Potable water pipelines, valves, service laterals and appurtenances
- Recycled water pipelines valves, service laterals and appurtenances

CIP development and asset valuation is also included for wastewater force mains, all pump stations, and all reservoirs. This AMP is intended to be a living document that is updated as City programs evolve.

1.2 Asset Management Program Overview

The primary goal of the Asset Management Program is to minimize the total cost of owning and operating infrastructure assets, while delivering the level of service that stakeholders demand, at acceptable levels of risk. It is clear that the City has been managing assets effectively, when compared to regional and local averages, from the high level of service provided to customers and low asset failure rates. A summary of the City's level of service goals, system performance and the value of investing in a performance and condition-based asset management program versus an age based renewal program is provided below. The details of how these estimated cost savings were determined are provided in subsequent chapters.

In the wastewater collection systems industry, a key metric is sanitary sewer overflow (SSO) count per 100 miles of sewer per year. The City is located in State Water Quality Control Board (SWQCB) Region 9 and the average performance in Region 9 of sewer systems without sewer lateral responsibility is currently between 1 and 1.5 SSOs per 100 miles per year. The City is currently performing better than this average SSO rate, which indicates a higher than average level of service provided to customers. The City's wastewater level of service goal for gravity sewers and manholes is zero structural condition-caused SSOs. **The City did not experience any structural condition-caused SSOs in 2018, thus meeting its level of service goal of zero incidences.**

In the water and recycled water industry, system performance is often measured in terms of “break rate,” which measures the annual number of main breaks per 100 miles of pipe operated. Recent research[1] indicates that the average break rate in the California/Nevada region is 9.7 annual breaks per 100 miles. The City’s combined potable and recycled water systems have experienced break rates of 1.7 and 0.5 respectively over the past ten years. (Of the total length of the combined system, the potable water mains represent 85% and recycled water mains are 15%). These systems are combined for break rate comparisons and analysis. **The system-wide break rate for the City’s potable and recycled water system is 1.5 or roughly six times better than the regional average.** Even in Southern California, where soil condition and the materials used tend to result in longer useful lives, and where the cost of water drives utilities to manage aging infrastructure more proactively, the City operates within the top quartile of utilities in terms of system performance.

The water and recycled water level of service goal for mains in the near term is a break rate less than or equal to 2 main breaks per 100 miles of pipe per year on average. Over time the City may evaluate level of service against cost and adjust the level of service goal as the system deteriorates. Figure 1-1 presents utility performance relative to other utilities[2] with break rate on the x-axis and the annual system replacement rate on the y-axis. **The proposed 5-year CIP in the AMP for water and recycled water pipeline replacement is the same system replacement rate as other utilities with similar break rates and is appropriate for the City’s system performance. However, as the system ages, increases in water pipe replacement will be needed to maintain low break rates.**

The capacity of wastewater, water and recycled water systems is becoming less of a driver for capital improvements due to conservation and growth forecasts as presented in the 2018 Master Plan Updates. In contrast, the system conditions have become a more significant driver for capital improvements. As the systems age and deteriorate the City will need to increase investments in condition-related capital improvements and continue to implement asset management strategies to proactively maintain or improve service levels.

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[1] The average break rate in California and Nevada is 9.7 per Folkman’s 2018 report titled Water Main Break Rates in the USA AND Canada: A Comprehensive Study.

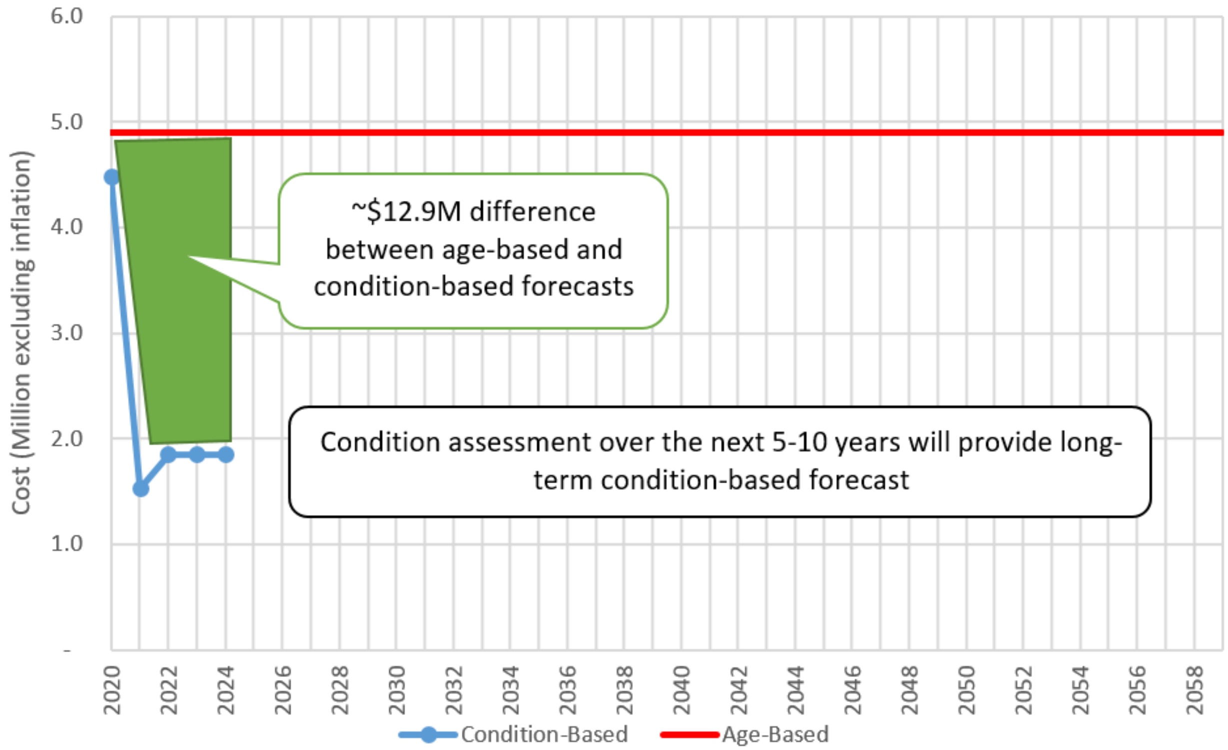
[2] The “other” utilities identified in this figure are Vista Irrigation Vista Irrigation District, San Dieguito WD, Rainbow MWD, Padre Dam MWD, Helix WD, Sweetwater Authority, City of San Juan Capistrano, Mesa WD, City of Buena Park, City of Long Beach, Contra Costa WD, East Bay MWD, City of Phoenix, and Denver Water. A table of these results is included in Appendix I.

Figure 1-1. Water Main and Recycled Water Main Performance

Based on age alone, significant investment in the City's water and sewer infrastructure would be required, totaling approximately $1.1 billion through FY2058/2059. However, industry experience and City staff experience informs us that age alone is not a good predictor of condition or system investment need. Continued investments in the asset management program is expected to result in lower infrastructure renewal costs than identified through age-based forecasts. These continued investments in asset management will identify the best value for the City and ratepayers. Significant potential savings have been identified through the City's asset management programs including the following.

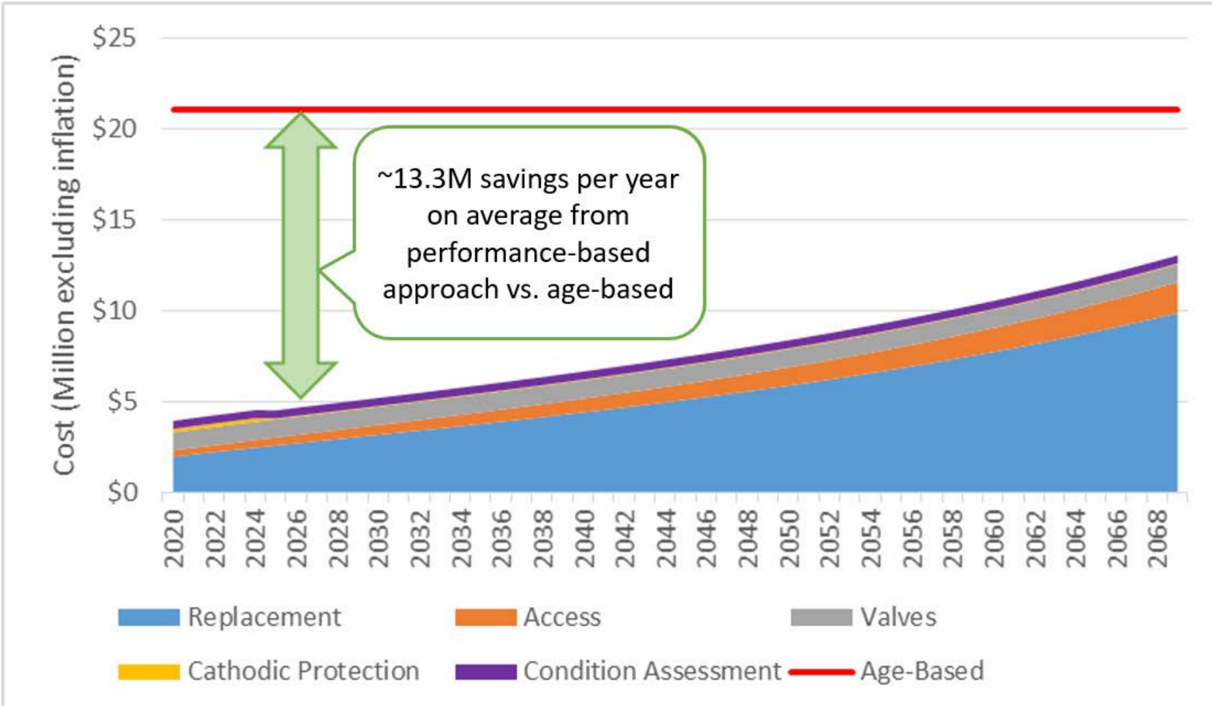
- City staff have adopted maintenance strategies to avoid costly capital renewal, to minimize the cost of owning infrastructure and to extend infrastructure useful life. One of those strategies is to clean gravity sewer pipes more frequently rather than replace pipes with moderate sags. This strategy has saved the City approximately $4 million in capital investment at the expense of approximately $70,000 in gravity sewer cleaning per year.
- The condition-based and performance-based asset management approach is saving the City approximately $12.9 million when compared to the age-based forecast for gravity sewer and manhole renewal over the next 5 years. The condition-based forecast and age-based forecast comparison is presented in Figure 1-2. This forecast utilizes the average cost per year for the age-based forecast over the next 40 years and does not include inflation.

Figure 1-2. Gravity Sewer and Manhole Renewal Cost Forecast



- By moving from an age-based to a performance-based program, Figure 1-3 shows that the City will save approximately $665 million dollars in unnecessary potable water and recycled water pipeline, valve and service replacement (an average of $13.3 million per year). This forecast utilizes the average cost per year for the age-based forecast over the next 50 years and does not include inflation. A table of the results presented in Figure 1-3 is included in Appendix J.

Figure 1-3. Potable and Recycled Water Pipeline, Valve and Services Cost Forecast



One key investment need identified through the AMP development process is the need to fill the vacant asset management support staff position. This staff position should be maintained in the City's asset management program and filled as soon as practicable. Skills needed for this position include knowledge of NASSCO PACP condition defect coding, Tableau, InfoMaster, GIS, and database management and analysis. This recommendation is based on the workload required to support key asset management program components including:

- Performance metrics – approximately 0.1 full time equivalent (FTE) staff
- Condition and break data management, QA/QC and assessment – approximately 0.3 FTE staff
- Condition Repair and rehabilitation planning support – approximately 0.5 FTE staff
- Scheduling support – approximately 0.1 FTE staff

A second key investment need is to develop a roadmap for implementing ongoing asset management program improvements. This roadmap will take this AMP to the next step, providing a clear communication tool regarding the path forward, including opportunities identification, initiative priorities and schedule. Opportunities for further enhancement to the City's ongoing asset management program are captured in the subsequent chapters of the AMP for each system.

1.3 Asset Management Master Plan Organization

The organization of this AMP was initially developed through a series of workshops with City staff. The AMP is divided into two sections:

- **Section 2 – Wastewater**. The Wastewater section includes asset management planning for the sanitary sewer system. The focus of this section is gravity sewers and manholes.
- **Section 3 – Potable Water and Recycled Water**. This section includes asset management planning for the potable water and recycled water systems. The focus of this section is pipelines, valves, service laterals, and appurtenances.

1.4 Program Participants

The AMP was developed through a series of workshops and reviews by the Asset Management Team, which included both City staff members and HDR staff. City participants include the following:

- Stephanie Harrison – Utilities Asset Manager (Project Manager)
- Terry Smith – Engineering Manager
- Don Wasko – Utilities Manager
- Jesse Castaneda – Utilities Supervisor
- Lindsey Stephenson – Senior Engineer
- Lindsay Leahy – Associate Engineer
- Tim Smith – Utilities Maintenance Planner
- Brian Alcala – Wastewater Utilities Staff
- Eric Sanders – Utilities Supervisor
- Matt Jacobs – Utilities Supervisor
- Mark Biskup – Associate Engineer
- Cathy Nhothsavath – Assistant Engineer

AMP development was supported by HDR staff including:

- Jennifer Duffy, Project Manager
- Eric Scherch, Deputy Project Manager
- Dave Spencer, Asset Manager
- Joel Engleson, Hydraulic Modeling and Asset Management Support
- Amanda Leipard, Risk Model and Business Decision Logic Programming
- Tom McCormack, Asset Management Support
- Ernesto Mejia, Programming

1.5 Overview of Wastewater, Potable Water and Recycled Water Assets

The City owns and manages approximately $2.1 billion in infrastructure supporting its wastewater, potable water and recycled water systems. Included in Table 1-1 is a summary of key assets owned by the City including asset count, asset length, and replacement cost.

Table 1-1. Carlsbad Asset Summary

System	Asset Type	Asset Count	Length of Assets (feet)	Replacement Cost ($)
Wastewater	Gravity Sewers	6,699	1,402,949	$398,000,000
	Manholes	5,881	-	$85,000,000
	Force Mains	11	22,974	$14,000,000
	Pump Stations	11	-	$31,000,000
	Wastewater Subtotal	12,602	1,425,923	$528,000,000
Potable Water	Water Main	16,629	2,374,643	$983,000,000
	Valves	13,542	-	
	Service Line	36,380	790,454	
	Pump Stations	3	-	$29,000,000
	Reservoirs	12	-	$273,000,000
	Potable Water Subtotal	66,566	3,165,097	$1,285,000,000
Recycled Water	Water Main	1,451	410,527	$187,000,000
	Service Line	1,036	34,989	
	Valves	826	-	
	Pump Stations	4	-	$44,000,000
	Reservoirs	4	-	$66,000,000
	Recycled Water Subtotal	3,320	445,516	$297,000,000
Total		**82,488**	**5,036,536**	**$2,110,000,000**

Notes:
Replacement costs are for capital costs including soft and construction costs and are in 2019 dollars.
Agua Hedionda and Buena Vista wastewater force mains are not included.

1.6 Study Areas

The study areas for the AMP are the Carlsbad MWD water and recycled water service area and the City of Carlsbad sewer service area, which are shown in Figure 1-4 and Figure 1-5, respectively.

Figure 1-4. Water and Recycled Water Service Area

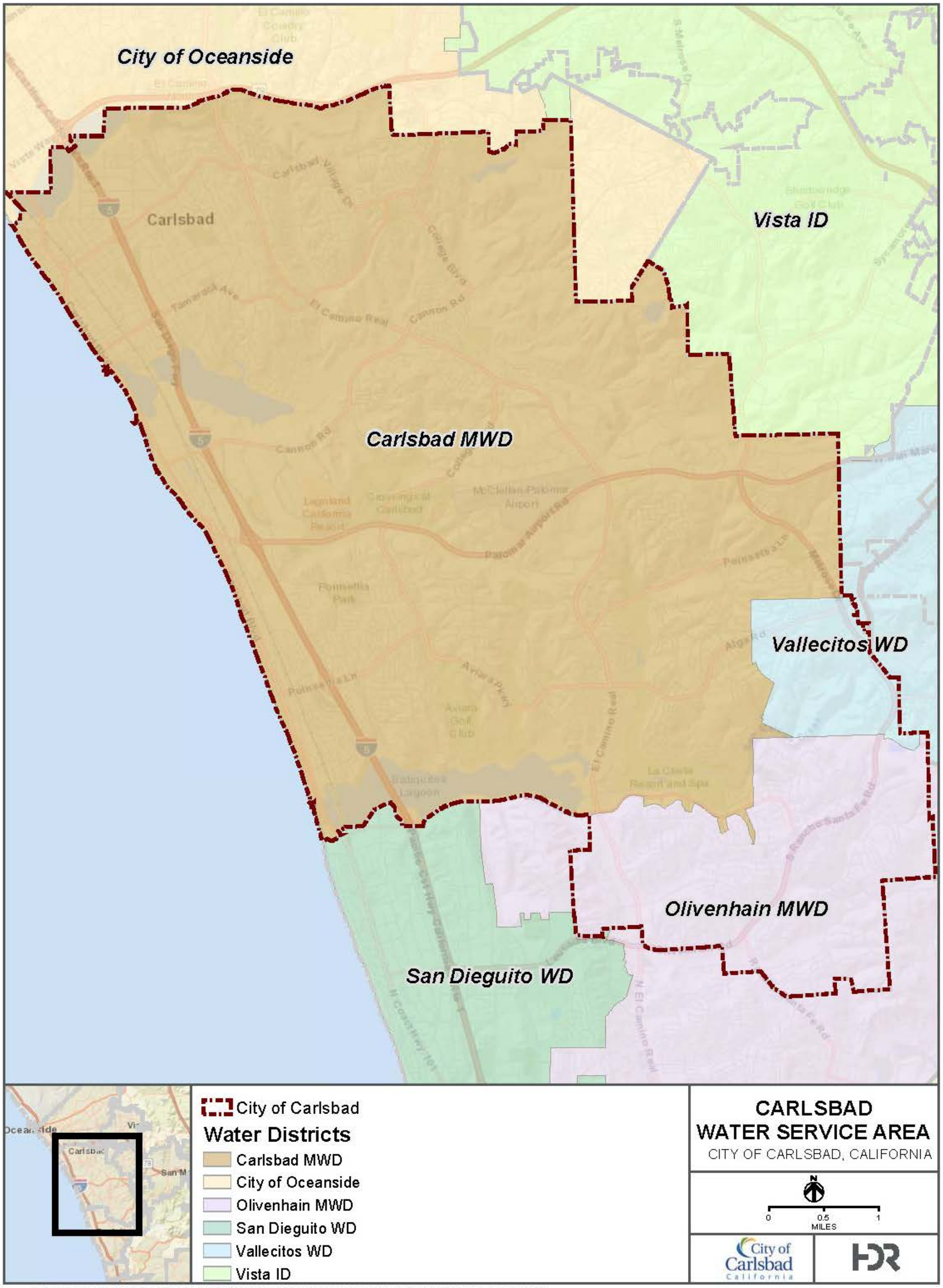
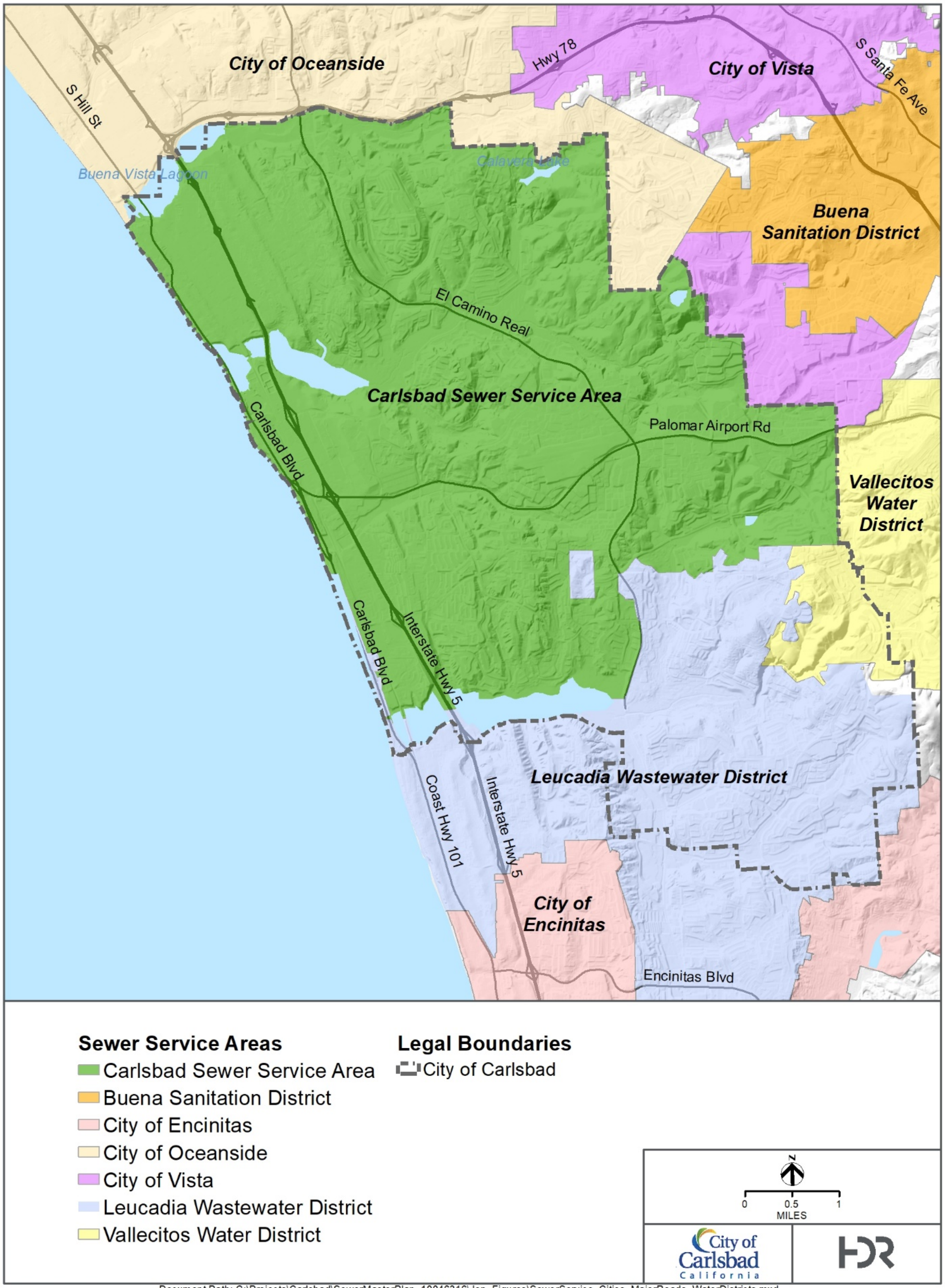


Figure 1-5. Sewer Service Area



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2 Wastewater

This section focuses on asset management planning for the sanitary sewer system and includes a summary of system condition and performance, age-based and performance-based condition assessment and renewal forecasts, and CIP recommendations for gravity sewers and manholes. Also included in this section are opportunities for continuous improvement of the sewer asset management program.

2.1 System Inventory, Performance & Replacement Cost

A summary of the City's wastewater infrastructure with length and count of assets and replacement cost is included in Table 1-1. These results are based on the City's infrastructure database of record, which is the City's Geographic Information System (GIS). Carlsbad provided readily available GIS files with updates as of May 30, 2018, specifically GIS layers containing data on gravity mains, manholes, pumps, and pressurized mains. The analysis excluded infrastructure not owned by Carlsbad[3].

The sewer system performance monitoring and measurements are driven by SWQCB Waste Discharge Requirements (WDRs) and are documented in the City's Sewer System Management Plan (SSMP). A key metric is SSO count per 100 miles of sewer per year. The City is located in SWQCB Region 9 and the average performance of medium sized sewer systems with between 100 and 500 miles of sewer in Region 9 in 2017 and 2018 is 1.5 SSOs per 100 miles per year. The City is currently performing better than this average SSO rate in 2017 and 2018 which indicates a higher than average level of service provided to customers. In 2018, the City experienced zero structural condition-caused SSOs.

The sewer system is aging. Figure 2-1 presents the miles of gravity sewer pipe by install year and material with the install years grouped into 5-year periods. However, age is typically not a good indicator of condition for specific infrastructure as many factors contribute to deterioration. The City's condition assessment program includes readily available higher quality data for 63 percent of gravity sewer mains inspected after January 1, 2015 and 76 percent of manholes. The City has lower quality, older condition assessment data in a readily available format for approximately 30 percent of gravity sewers. All readily available condition data indicates that approximately 3.6 percent of gravity sewer mains and 1.7 percent of manholes are recommended for renewal based on the selection criteria identified in the AMP. These percentages are low, indicating the system is performing well with respect to condition. As the City continues to inspect the sewer system, additional renewal projects will be identified.

The current replacement cost of the gravity sewers and manholes is $483 million dollars. A summary of existing pipeline infrastructure and replacement costs are included in Table 2-1 and Table 2-2. The basis for the replacement unit cost estimates includes recent

[3] Infrastructure with an OWNEDBY field of "CBD" in GIS is included. The SHAPELENGTH field is used for length. Infrastructure with a STATUS field of Abandoned, Not in Service and Future were excluded. Gravity sewer interceptors with cost sharing between regional utilities are included for those portions of the interceptors identified with the OWNEDBY of "CBD" in GIS.

bid costs from the City and other utilities and assumed soft costs for planning, design, legal, construction administration, ownership administration, and contingencies.

Figure 2-1. Gravity Sewer Pipe by Install Year

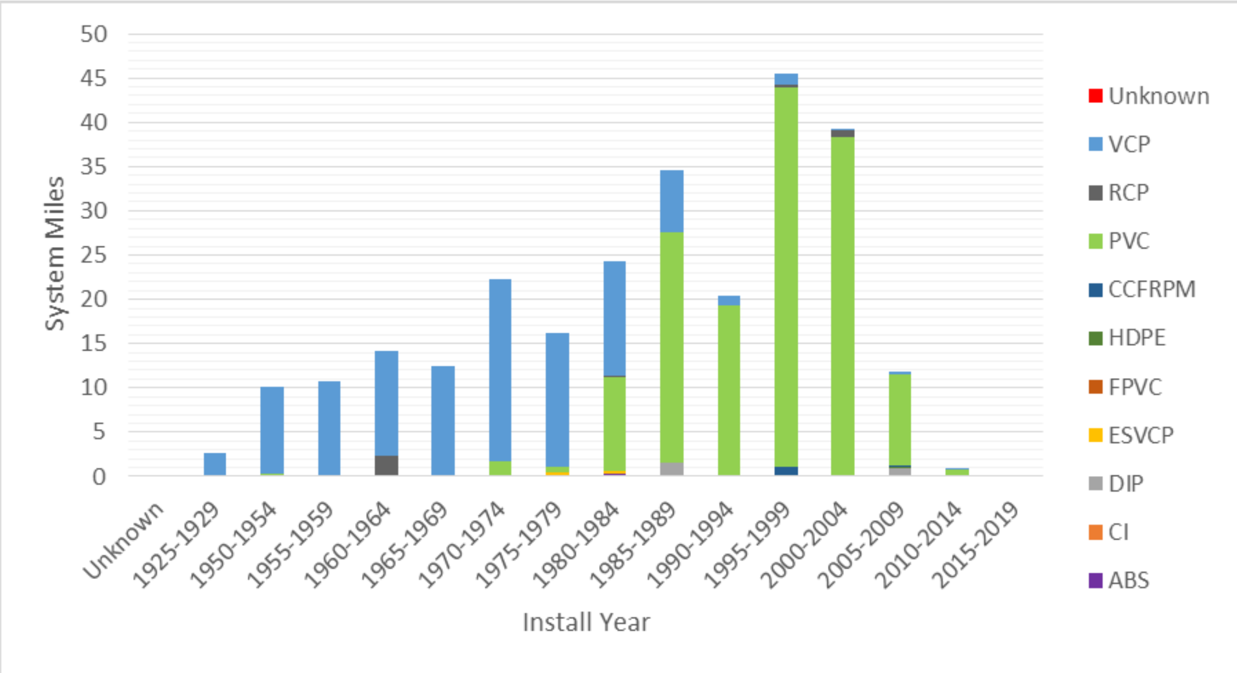


Table 2-1. Gravity Sewer Replacement Cost

Gravity Sewers			
Diameter	Unit Cost ($ per Mile)	Miles	Replacement Cost (Million)
4	$846,230	0.006	$0.004
6	$846,230	15.56	$13.2
8	$846,230	201.86	$170.8
10	$1,057,790	17.75	$18.8
12	$1,269,350	10.93	$13.9
14	$1,480,900	-	-
15	$1,586,680	2.70	$4.3
16	$1,692,460	0.09	$0.1
18	$1,904,020	2.04	$3.9
20	$2,115,580	0.51	$1.1
21	$2,221,360	1.35	$3.0
24	$2,538,690	4.28	$10.9

Table 2-1. Gravity Sewer Replacement Cost

Gravity Sewers			
Diameter	Unit Cost ($ per Mile)	Miles	Replacement Cost (Million)
27	$2,856,030	0.98	$2.8
30	$3,173,370	0.01	$0.03
36	$3,490,700	2.07	$7.9
39	$3,808,040	0.25	$1.0
42	$4,125,380	3.94	$17.5
48	$4,442,710	1.00	$5.1
60	$5,077,390	0.07	$0.4
	Subtotal	265.40	$274.7

Soft Cost Percentage of Construction Cost		
Type	Percentage	Cost (Million)
Planning (CEQA and Permitting)	3%	$8.2
Design	10%	$27.5
Legal	2%	$5.5
Construction Administration	15%	$41.2
Ownership Administration	5%	$13.7
Contingency	10%	$27.5
Total Soft Costs	45%	$123.6
	Total Replacement Cost	**$398.3**

Table 2-2. Manhole Replacement Cost

Manholes		
Count of Manholes	**Unit Cost (each)**	**Replacement Cost (Million)**
5881	$10,529.18	$61.9
Soft Cost Percentage of Construction Cost		
Soft Cost Type	**Percentage**	**Cost (Million)**
Planning (CEQA and Permitting)	3%	$1.9
Design	2%	$1.2
Legal	2%	$1.2
Construction Administration	15%	$9.3
Ownership Administration	5%	$3.1
Contingency	10%	$6.2
Total Soft Costs	45%	$27.9
	Total Replacement Cost	**$84.8**

2.2 Gravity Sewers and Manholes

This section documents the age-based and performance-based forecasts for gravity sewers and manholes.

2.2.1 Age-Based Forecast

Age-based gravity sewer and manhole replacement costs were developed using unit costs established in Section 2.1 and Appendix C, an assumed 2% annual inflation factor, City-documented infrastructure installation years, and City-provided useful life estimates, which are summarized in Table 2-3.

Table 2-3. Age-based Useful Life

Class	Assumed Useful Life (Years)
Wastewater Pipe-ABS	75
Wastewater Pipe-ACP	25
Wastewater Pipe-CI	25
Wastewater Pipe-CI-Critical	20
Wastewater Pipe-DIP	25

Table 2-3. Age-based Useful Life

Class	Assumed Useful Life (Years)
Wastewater Pipe-ESVCP	75
Wastewater Pipe-FPVC	75
Wastewater Pipe-FPVC Forcemain[1]	50
Wastewater Pipe-HDPE	100
Wastewater Pipe-HDPE Force Main[1]	50
Wastewater Pipe-CCFRPM-Force Main	50
Wastewater Pipe-CCFRPM-NP	75
Wastewater Pipe-PVC	100
Wastewater Pipe-PVC-Critical	50
Wastewater Pipe-PVC-Force Main	50
Wastewater Pipe-RCP	75
Wastewater Pipe-RCP-Force Main	50
Wastewater Pipe-VCP	75
Wastewater Pipe-VCP-Critical	50
Wastewater Pipe-VCP-Force Main	50
Wastewater Pipe-STL-Force Main[1]	50
Manholes[2]	75

Notes:
[1] Based on similar values provided by Carlsbad
[2] Based on industry experience

Table 2-4 summarizes the results of a 40-year age-based replacement forecast. Including inflation, this method forecasts an average of $7.0 million dollars per year. A summary of age-based forecasts for gravity sewers, manholes, force mains, and pump stations is included in Appendix D.

Table 2-4. 40-Year Age-based Renewal Forecast

Timeframe	Cost without Inflation (Million)	Cost with Inflation (Million)
Cumulative (FY19/20-FY58/59)	$196.0	$280.4
Average Annual (FY19/20-FY58/59)	$4.9	$7.0

2.2.2 Performance-Based Forecast

The performance-based forecast for gravity sewers and manholes incorporates sewer system performance, institutional knowledge, and City condition data. **The approach used to develop the performance-based forecast for gravity sewer and manhole condition assessment and renewal needs utilizes a condition risk mitigation decision logic (decision logic).**

The decision logic for gravity sewers and manholes provides a transparent, defensible, and consistent approach for decision makers and is used to communicate risk, level of service, and cost to stakeholders. The decision logic is also used to develop high confidence risk mitigation forecasts.

The decision logic leverages the City's closed-circuit television (CCTV) inspections and other readily available data for gravity sewers to recommend a preliminary renewal or condition assessment action, identify risk associated with each inspected gravity sewer, and associate a cost with each recommended mitigation action. City staff review and update preliminary recommendations made by the decision logic when packaging projects. Although the rules built into the decision logic are based on professional and engineering judgment, they do not replace the need for review and validation by skilled professionals.

The purpose of this section is to document the development process, decision logic inputs, methodology for assessing risk and the risk mitigation actions. The City will refine the decision logic over time based on adaptive management principals and lessons learned through implementing the decision logic.

The City has selected InfoMaster software by Innovyze to manage the risk model and decision logic.

Development Process

A series of workshops were conducted in 2018 with City staff to develop the decision logic, risk model and CIP recommendations on July 25, September 12, September 19, October 24, October 29, and December 18. A summary of the content of each workshop by workshop number is included below:

1. Identification of priorities for the AMP.
2. Gathering information about the City's current risk mitigation decision making policies and practices. The Asset Management Team discussed business risk exposure scoring (BRE) including likelihood of failure (LOF) and consequence of failure (COF) risk.
3. Detailed review of defects; Grouping of defects by severity and renewal methods (e.g., replacement, open-cut point repair, lining, trenchless repair, robotic cutting); Review of COF mapping of gravity sewers; Initial review of decision logic for gravity mains and manholes.
4. Discussion of large diameter sewer pipes that do not have inspection data.
5. Review of potential monitoring schedules.
6. Review of decision logic results, risk scores, unit costs, condition assessment and renewal forecast scenarios.

Gravity Sewer Main Inputs

The decision logic includes four key inputs including CCTV inspection data, gravity sewer cleaning frequencies, hydraulic model data, and GIS data. Each input is described in the sub-sections below.

CCTV Data

The City's ongoing CCTV inspection program is comprised of the following inspection programs:

- **Proactive Monitoring** – The City proactively inspects gravity sewers with CCTV inspection. The majority of CCTV inspection data is collected through this program. City staff currently perform proactive monitoring of small diameter gravity sewers that are less than or equal to 12 inches in diameter. Large diameter gravity sewers that are greater than 12 inches in diameter are typically inspected by contractors.
- **Requests** – Referrals resulting from SSOs, customer calls, and City crews are examples of how CCTV inspections are generated in the Requests program
- **Construction Acceptance** – After completion of new construction, repairs, rehabilitation or replacement of gravity sewers, the renewal work is inspected using CCTV.

As of summer 2017, the City has CCTV data on approximately 93 percent of the gravity sewer collection system. The City historically utilized CUES CCTV software and a custom CCTV defect coding system. Currently, the City collects data in the National Association of Sewer Service Companies (NASSCO) Pipeline Assessment Certification Program (PACP) format in CUES CCTV software GraniteNet. The CCTV data includes defect codes that identify structural condition defects in gravity sewer pipes. This CCTV data is a primary input that drives the decision logic results and data quality is important. City staff indicate that data collected prior to January 1, 2015 utilized different inspection data collection priorities and practices and the data quality is not as consistent as data collected after January 1, 2015. As a result, City staff review of decision logic recommendations will be important. CCTV inspections are recommended to be planned in the near-term to close this data gap. This AMP utilizes the historical CUES CCTV data for forecasts.

HDR industry experience analyzing defect deterioration over time indicates that defects such as cracks in the pipe barrel (not at the joint) with roots through the cracks deteriorate significantly over time. Consequently, the CUES CCTV data was updated to identify these defects with a new defect code "CrackRoots" if a crack defect and root defect were located within 1 foot of each other. Another finding is that defects with displaced soil behind the defect, such as holes in pipe with voids visible, deteriorate significantly faster over time than other Grade 5 structural defects. These have been incorporated into the use of CCTV data in the decision logic.

Cleaning Data

CCTV data documents pipe condition at the time of inspection. However, gravity pipes can deteriorate at different rates. In particular, frequent gravity sewer cleaning can result in pipe deterioration. The City's gravity sewer cleaning frequencies range from 3 months to 4 years. The gravity sewer GIS layer includes these cleaning frequencies which were used to approximate deterioration rates. Table 2-5 displays the gravity sewer system's cleaning frequency. Typically, the system is cleaned over a 4 year period.

Table 2-5. Gravity Sewer Cleaning Frequency

Cleaning Frequency	Attribute Name
3 months	QT- Quarterly
6 months	SAN-Semi-Annually
12 months	ANN-Annually
12 months	SCH – School Schedule
24 months	24M-1-24 Month Schedule – Year 1 24M-2-24 Month Schedule – Year 2
36 months	36M-1-36 Month Schedule –Group 1 36M-2-36 Month Schedule – Group 2
48 months	48M – 48 Month Schedule
None	NP- Not in Program

Hydraulic Model Data

The City has hydraulic capacity information for gravity sewers based on analysis of their hydraulic model. Pipes with less available capacity can have a higher risk of SSO if a structural collapse or blockage due to condition issues occurs. Hydraulic model capacity data is incorporated into the risk model.

GIS Data

The City has extensive GIS data for their assets including gravity sewers and manholes. This data, along with publicly available GIS information for waters of the state are incorporated into the decision logic. A description of how this data was utilized is included in the following sections.

Business Risk Exposure Score

All inspected pipes are prioritized for further renewal or monitoring action based on the business risk exposure (BRE) score. The BRE is a numerical value representing the relative business risk for each pipe based on the LOF and COF. A BRE of 100 represents the highest possible risk where a BRE of 0 represents the lowest possible risk. The BRE calculation was developed specifically for the City based on a combination of existing City decision making processes, staff input, and industry experience.

During decision logic calibration, the BRE thresholds that trigger specific risk mitigation recommendations (trenchless repair, replacement, etc.) were refined and set at the level necessary to balance cost and risk. These thresholds may be adjusted by the City over time as additional condition assessment data is gathered and the program is refined. The

BRE is determined by the pipe's LOF[4] and COF. During development workshops, the Asset Management Team refined the relative weighting that the decision logic would place on each of these components. The BRE is comprised of the individual components listed in Table 2-6.

Table 2-6. Business Risk Exposure Score Components and Weights

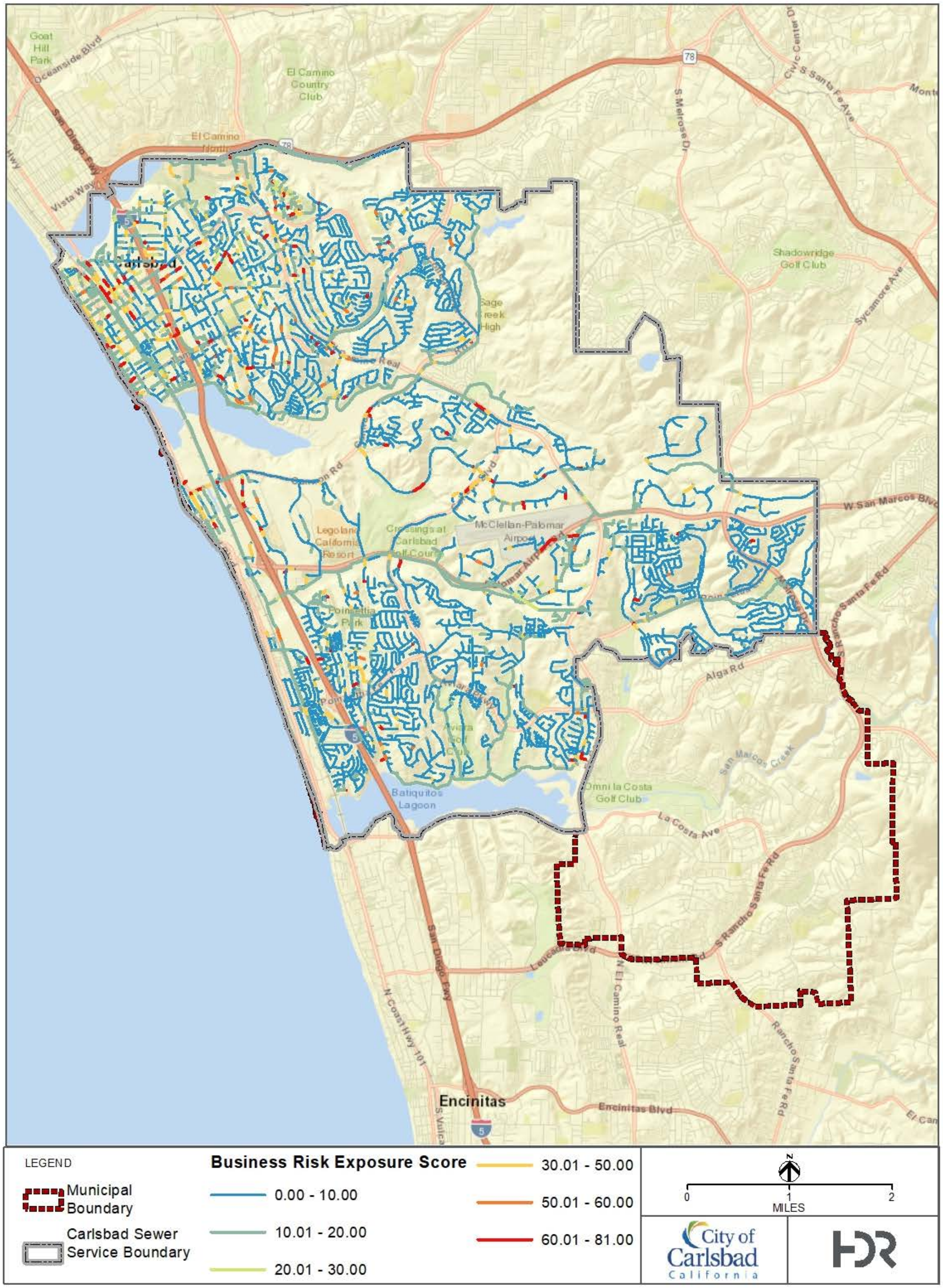
Business Risk Exposure Score Component	Percent of Business Risk Exposure Score (%)
Likelihood of Failure (LOF)	
Defect Score	60
Count of Defects Score	10
Cleaning Frequency Score	5
Pipe Capacity	5
Subtotal	*80*
Consequence of Failure (COF)	
Spill Volume Potential: Pipe Diameter or Hydraulic Model	7
Public Health and Environmental Impact Proximity to Pedestrian Areas or Proximity to Waterways	7
Emergency Response Impact Traffic Control Maintenance/Repair Constraints	6
Subtotal	*20*
Total	**100**

The Asset Management Team has deliberately chosen to place a higher importance on the LOF than the COF. This ratio was determined based on lessons learned from other industry leading utilities with mature decision logic and the City's practices. A risk mitigation action typically reduces the LOF significantly, but has limited or no impact on the COF. When COF is weighted higher, gravity sewers in good condition that are located in high consequence areas such as next to a water body can be prioritized higher than gravity sewers in very poor condition in low consequence areas.

Weighting the COF lower than LOF is in line with City practices and identifies the pipes with the greatest risk of failure with a higher score and priority for renewal, while still adequately factoring COF into the decision-making process. The BRE score for each gravity sewer is mapped in Figure 2-2.

[4] LOF is also referred to as the probability of failure in some prior risk model work completed for the City. The word "probability," as defined in the dictionary includes a statistics related definition including "the relative possibility that an event will occur, as expressed by the ratio of the number of actual occurrences to the total number of possible occurrences." The risk model does not calculate actual occurrences so LOF is used in the AMP.

Figure 2-2. Gravity Sewer Business Risk Exposure



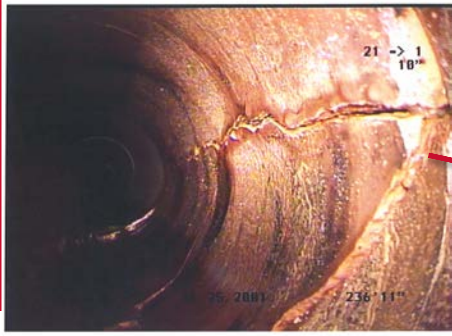
Some industry guidance on risk such as the Water Environment Research Foundation (WERF) Sustainable Infrastructure Management Program Learning Environment (SIMPLE) guidance consider multiplying LOF and COF scores to assess risk. The additive approach outlined above is based on the ISO31000 multi-criteria decision analysis approach and was selected by the Asset Management Team because calibrating the additive approach to match actual prioritization practices is simpler, more efficient, and more effective.

Figure 2-3 illustrates this concept. Figure 2-3 shows two fracture defects and one large hole defect with three different LOF and COF scores, including one additive as described above and two multiplicative. The large hole is the most severe defect and the longitudinal fracture is the least severe based on City and typical industry practices. Adding the COF and LOF scores produces a total score that aligns with the City's practices for identifying risk. Put simply, COF is still a factor, but COF does not outweigh LOF. Of the two multiplicative examples shown in Figure 2-3, Example A shows that multiplying COF and LOF results in the same BRE of 300 for the three defects, which is not in line with City practices for identifying gravity sewer risk. Example B uses an equation for BRE equal to 1 + COF / 100 multiplied by LOF, which produces results that are closer to City practices, but do not result in COF having any significant impact on the BRE. A third method could be used for the multiplicative approach that would yield accurate results, but this would require developing a custom weighting system for different defects and extensive calibration. Consequently, the additive approach was found to be the best and most effective approach for the City.

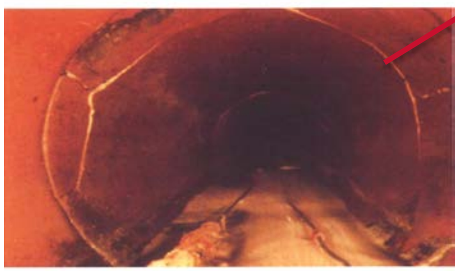
Figure 2-3. Additive BRE versus Multiplicative BRE

LOF + COF is Easier to Calibrate than LOF x COF

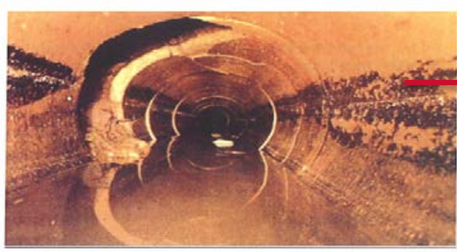
Fracture - Longitudinal (FL)



FRACTURE – MULTIPLE (FM)



Hole (H)



LOF Score	COF Score	Selected Additive BRE Approach COF + LOF	Alternative Multiplicative BRE Approach Example A COF x LOF	Alternative Multiplicative BRE Approach Example B (1 + COF/100) x LOF
20	5	25	100	21
20	10	30	200	22
20	**15**	**35**	**300**	**23**
20	20	40	400	24
30	5	35	150	32
30	**10**	**40**	**300**	**33**
30	15	45	450	35
30	20	50	600	36
40	5	45	200	42
40	10	50	400	44
40	15	55	600	46
40	20	60	800	48
50	5	55	250	53
50	10	60	500	55
50	15	65	750	58
50	20	70	1000	60
60	**5**	**65**	**300**	**63**
60	10	70	600	66
60	15	75	900	69
60	20	80	1200	72

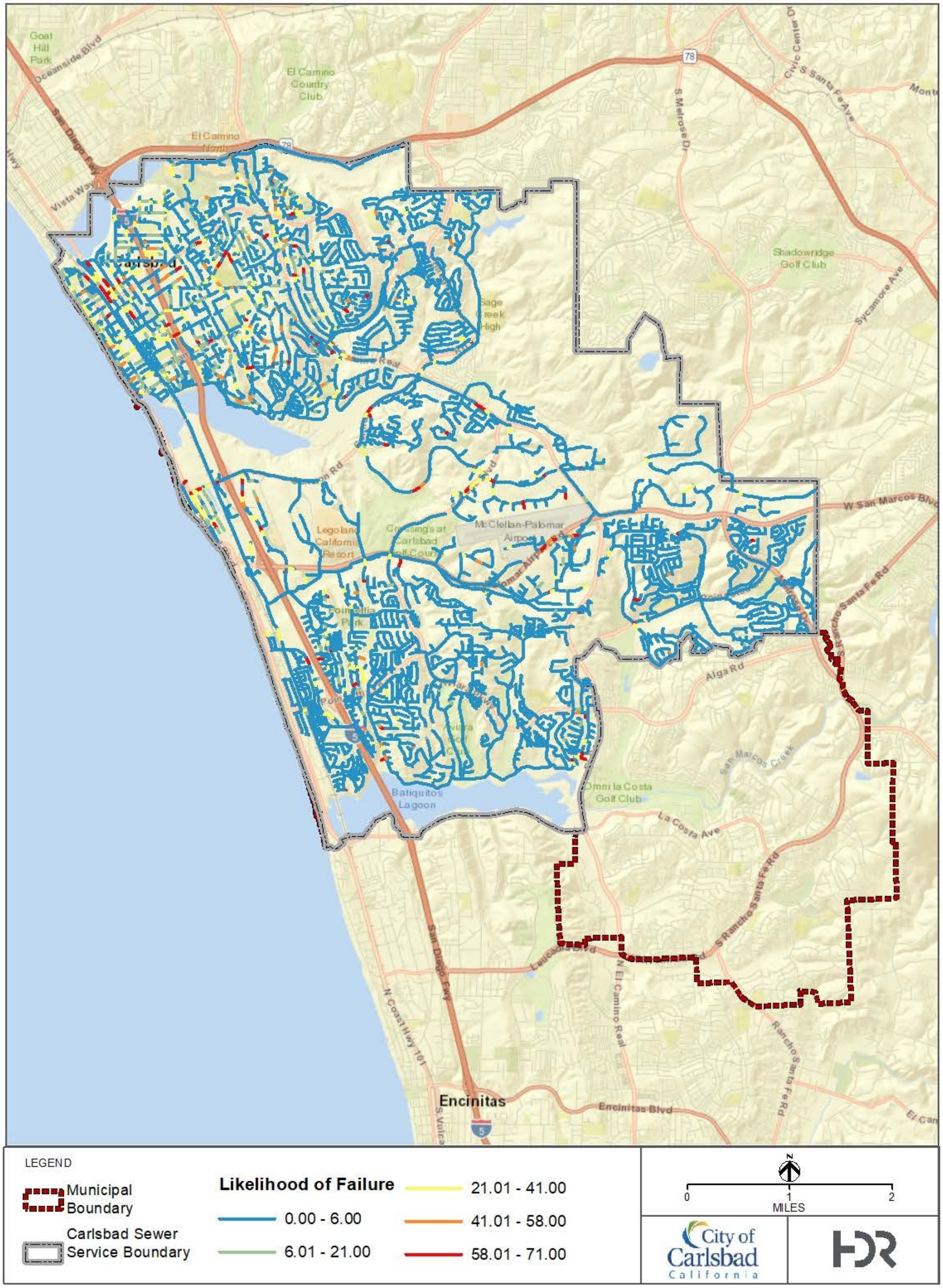
Likelihood of Failure

A workshop was conducted with City staff to refine existing factors for LOF and to weight each factor. The LOF is 80 percent of the total BRE. LOF is calculated using the following factors and weights:

LOF = [Defect Score (Max 60)] + [Structural Defect Count (Max 10)] + [Maintenance Deterioration (Max 5)] + [Capacity (Max 5)]

The LOF score is mapped for each gravity sewer and presented in Figure 2-4.

Figure 2-4. Gravity Sewer Likelihood of Failure



DEFECT SCORE

A primary component driving the likelihood of pipe failure is the worst structural defect present on the pipe. Therefore, the worst defect present in a pipe is the most heavily weighted factor used to rank and prioritize pipes based on risk.

Defect scores identified through CCTV are grouped by the severity of defect into seven groups and are scored between 60-0. Defect Severity Group is primarily based on the structural severity of the defect, with Group 1 generally being the most severe and highest priority and Group 7 the least severe and lowest priority. The City's custom defect coding system includes a severity modifier of small, medium, or large for most defect codes. Also, some defect codes are more severe than others (e.g., collapsed pipe defect is more severe than a cracked pipe defect). The Asset Management Team used images of defects to group typical condition defects by severity using the following general criteria:

- Group 1 – Defect could potentially result in an emergency repair by contractor
- Group 2 – Defect could potentially be prioritized to the top of the repair list
- Group 3 – Some defects could be prioritized for a near term CIP project and others may be monitored in the future
- Group 4 – Some defects could be prioritized for a CIP project and others could be monitored in the future
- Group 5 – Most defects could be monitored in the future and others could result in a CIP project
- Group 6 and Group 7 – Defect could be monitored in the future

Figure 2-5 shows images for the defects by score. Table 2-7 displays the defect scoring groups and corresponding scores. The defect severity score for each defect code is included in Appendix A.

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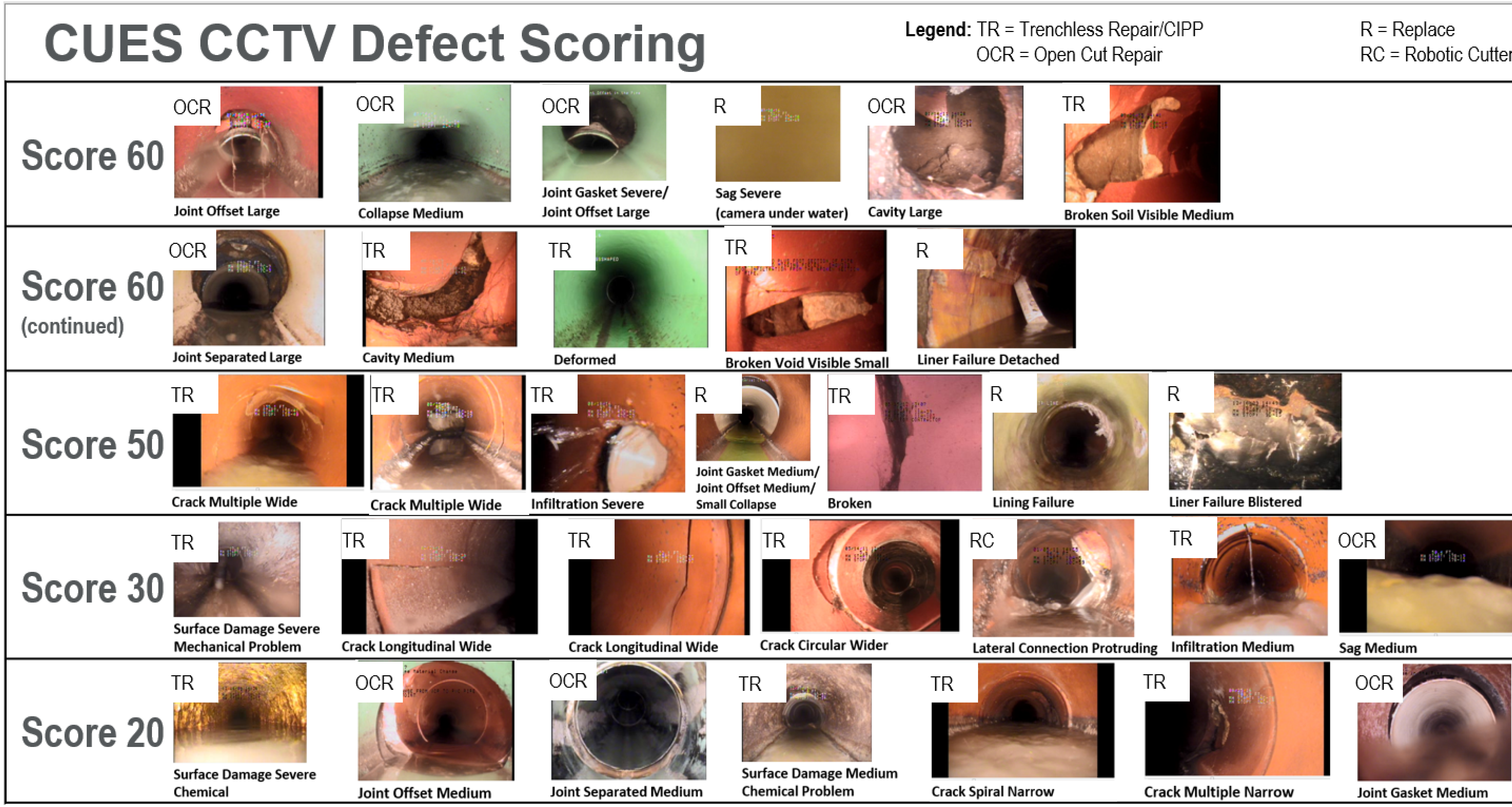
Figure 2-5. Defect Images Used for Defect Score Development



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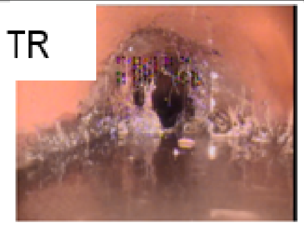
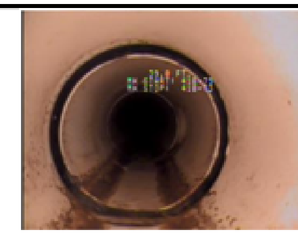
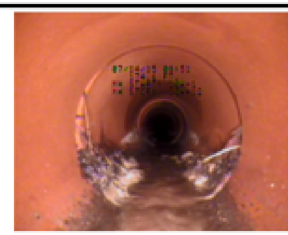
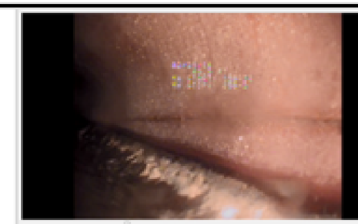
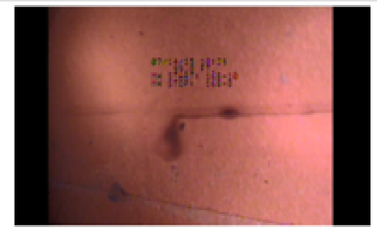
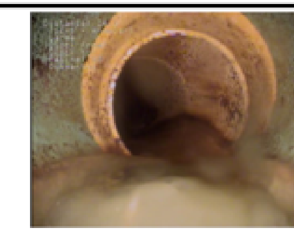
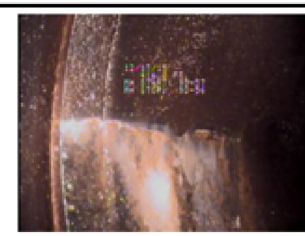
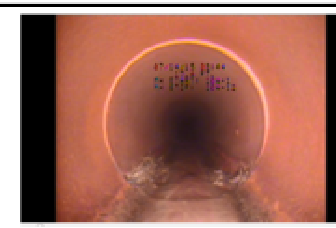
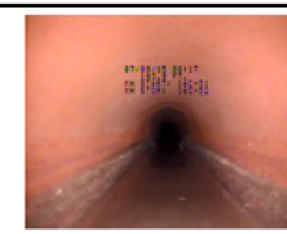
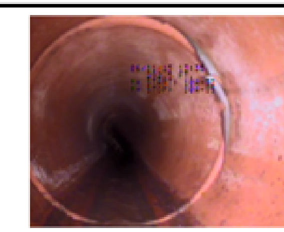
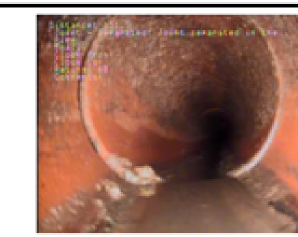
Score 10	 Roots Heavy	 Joint Angular Large	 Joint Separated Small				
Score 5	 Roots Medium	 Crack Longitudinal Narrow	 Crack Longitudinal Narrow	 Crack Circular Narrow	 Joint Angular Medium		
Score 1	 Surface Damage Light	 Infiltration Light	 Roots Light	 Sag Light	 Joint Gasket Light	 Flattened	 Joint Angular Small

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Table 2-7. Defect Score

Defect Group	Defect Score
Group 1	60
Group 2	50
Group 3	30
Group 4	20
Group 5	10
Group 6	5
Group 7	1

COUNT OF DEFECTS

The Count of Defects Score represents the component of the BRE determined by the total number of significant defects present on a pipe. Significant defects are defects in groups 1 through 4 that receive a defect score of 20 through 60. The Count of Defects Score assigns a maximum of 10 and the basis for calculating this score is presented in Table 2-8.

Table 2-8. Count of Defects Score

Number of Significant Defects	Defect Count Score
1	0
2-3	2
4-5	4
5-7	6
8-10	8
>10	10

CLEANING FREQUENCY

The Cleaning Frequency Score is based on the pipe's scheduled cleaning frequency, as cleaning activities can increase the rate of a pipe's deterioration or the severity of a defect over time. The Cleaning Frequency Score detail is included in Table 2-9.

Table 2-9. Cleaning Frequency Score

Scheduled Cleaning Frequency	Cleaning Frequency Score
48 months or greater	0
36 months	0
24 months	1
Annually (12 months)	3
Semi-Annually (6 months)	5

Table 2-9. Cleaning Frequency Score

Scheduled Cleaning Frequency	Cleaning Frequency Score
Quarterly (3 months) or greater	5

CAPACITY

The hydraulic model information was utilized for a component of the BRE score for a maximum score of 5. Current hydraulic model criteria for depth of flow to diameter of pipe ratio (d/D) is utilized. Pipes with a depth of flow to diameter of pipe ratio greater than 0.9 are considered capacity deficient. The greater the capacity constraint the larger the capacity score. The Capacity Score detail is included in Table 2-10.

Table 2-10. Capacity

Hydraulic Model Capacity d/D	Capacity Score
<=0.25 or Blank	0
>0.25-0.5	1
>0.5-0.9	3
>0.9-1	5
Greater than 1	5

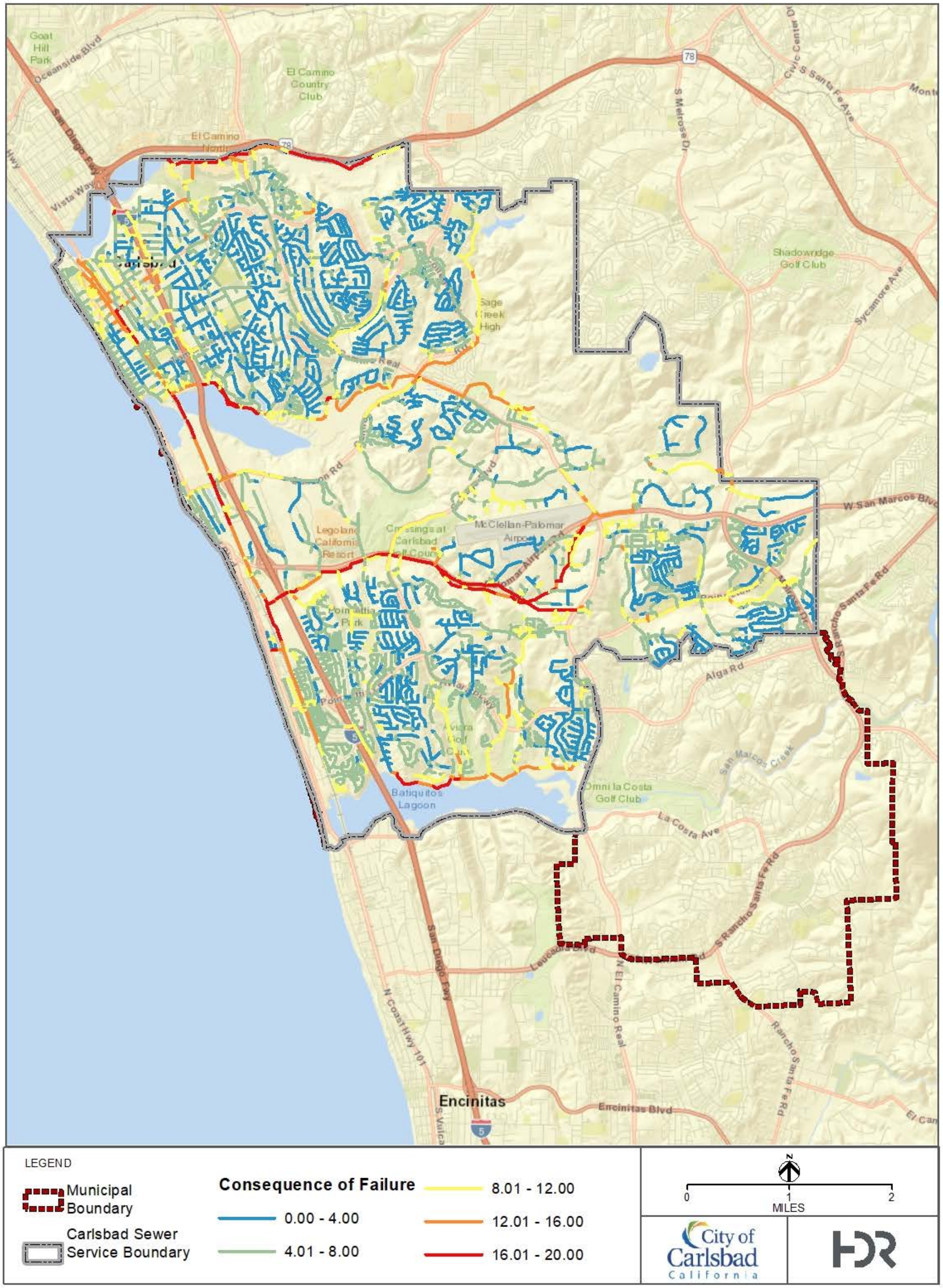
CONSEQUENCE OF FAILURE

A workshop was conducted with City staff to refine existing factors for COF and to weight each factor. The COF is 20 percent of the total BRE. COF is calculated using the following factors and weights:

COF = [Spill Volume Potential (Max 7)]) + [Public Health and Environmental Impact (Max 7)] + [Emergency Response (Max 6)]

The resulting COF score for each gravity sewer is mapped in Figure 2-6.

Figure 2-6. Gravity Sewer Consequence of Failure



SPILL VOLUME POTENTIAL

The spill volume potential takes into account the diameter of the pipe or the hydraulic model flow in the pipe. As the pipe diameter increases or as the hydraulic model indicates an increase in flow the COF score increases. The risk model uses the highest score between either of the two categories, as detailed in Table 2-11 below.

Table 2-11. Spill Volume Potential

Hydraulic Model Flow (Million Gallons per Day)	Diameter	Spill Volume Score
<=0.25	<=8 inches	0
>0.25-0.46	>8 to 12 Inches	1
0.461-1.03	>12 to 21 Inches	3
1.031-3.20	>21 to 27 inches	6
Greater than 3.2 or unknown	>27 inches or unknown	7

PUBLIC HEALTH AND ENVIRONMENTAL IMPACT

The public health and environmental impact takes into account the gravity mains near pedestrian areas or near waterways such as streams, beaches, or lagoons. The pedestrian areas include schools, parks, and highly visited areas such as LEGOLAND® and the Carlsbad Village area. The United States Geological Survey (USGS) waterline and water bodies were used to determine the proximity to water. The highest score from proximity to waterways or proximity to pedestrian areas is used. The public health and environmental impact score is detailed in Table 2-12 below.

Table 2-12. Public Health and Environmental Impact

Proximity to Water (feet)	Proximity to Pedestrian Areas (feet)	Public Health and Environmental Impact Score
>2000	>500	0
>1000-2000	--	1
>500-1000	>100-500	3
>100-500	>1-100	5
<=100 feet	<=1 Within a High Pedestrian Area	7

Emergency Response Impact

The emergency response impact of the COF is indicated by the proximity of gravity mains to roadway and traffic control types as well as failures within restricted access areas. Gravity mains near high traffic areas or highly restricted areas such as railroads or private property increases the COF score. Pipe failure within these areas get a higher score because of increased difficulty of renewal and the potential for longer duration failure events. The highest score from traffic control or maintenance and repair constraint areas is used. The emergency response impact score is presented in Table 2-13.

Table 2-13. Emergency Response Impact

Traffic Control (Type)	Maintenance and Repair Constraint Areas	Emergency Response Impact Score
Local or All Others	All Others	0
Collector or Secondary Arterial	Thick Pavement (State Street)	1
Major Arterial Street or Access Issue	Poor Access (Easement)	3
Prime Arterial	Restricted Access (Habitat or Private Property)	5
Freeway	No Access – Railroad	6

Detailed implementation notes on the risk model development in InfoMaster software is included in Appendix E.

Manhole Inputs

Business Risk Exposure Score

Similar to the gravity main BRE, the manhole BRE is a numerical value representing the relative structural risk for each manhole that has been inspected based on the condition assessment finding and COF. A BRE of 100 represents the highest possible risk and a score of 0 represents the lowest possible risk. The BRE calculation was developed specifically for the City based on a combination of existing City decision making processes, staff input, and industry experience.

During decision logic calibration, the BRE thresholds that trigger specific risk mitigation recommendations (replacement/rehabilitation or monitor) were refined and set at the level necessary to balance cost and risk. These thresholds may be adjusted by the City over time as additional condition assessment data is gathered and the program is refined.

The BRE is determined by the manhole's LOF and COF. During development workshops, the Asset Management Team determined the relative weighting that the decision logic would place on each of these components. The BRE is comprised of the individual components listed in Table 2-14.

Table 2-14. Business Risk Exposure Score Components and Weights

Business Risk Exposure Score Component	Percent of Business Risk Exposure Score (%)
Likelihood of Failure	
Defect Score: Overall Manhole Condition Rating or Manhole Bench Rating	80
Subtotal	*80*
Consequence of Failure	
Spill Volume Potential: Pipe Diameter or Hydraulic Model	7

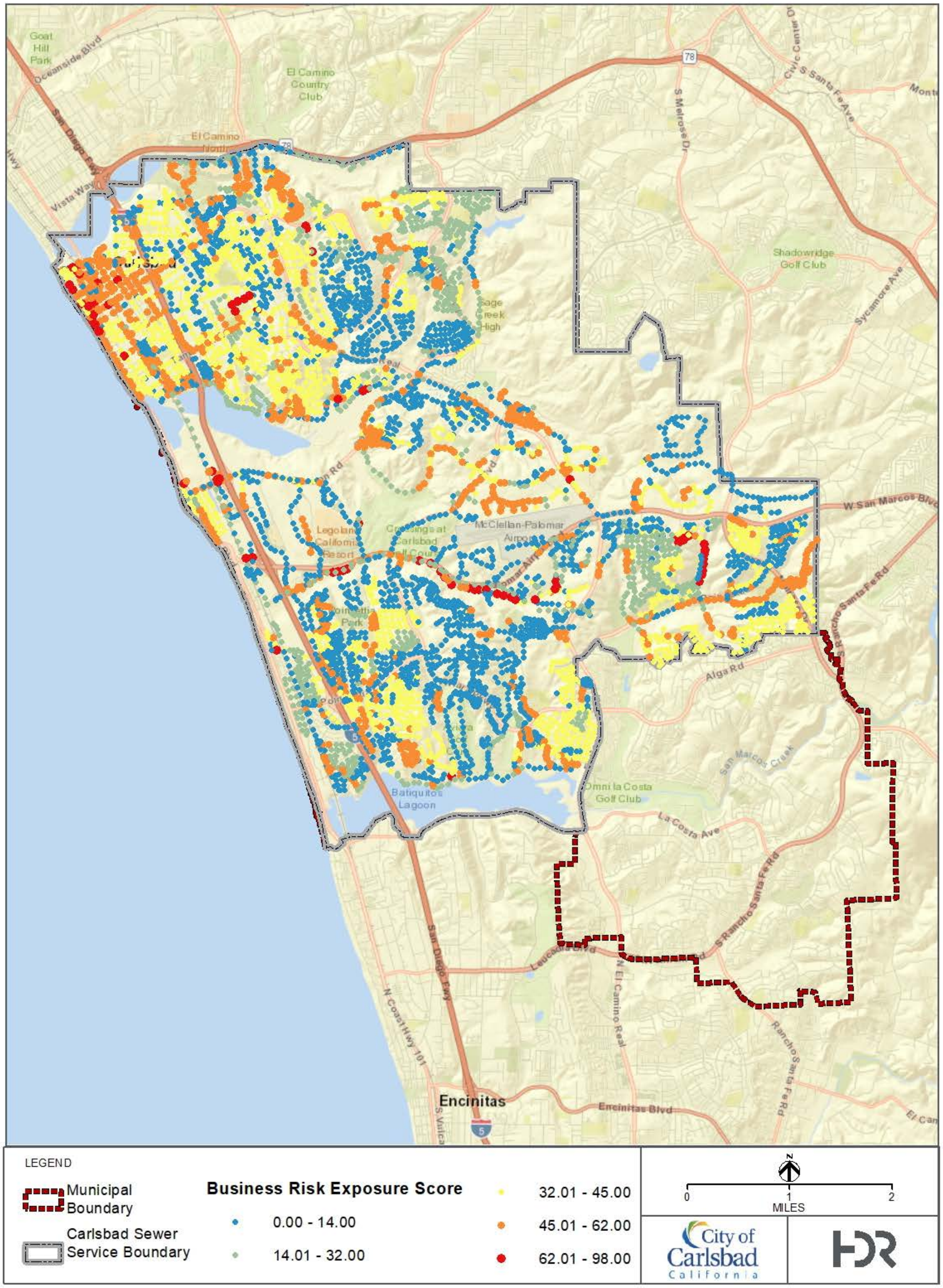
Table 2-14. Business Risk Exposure Score Components and Weights

Business Risk Exposure Score Component	Percent of Business Risk Exposure Score (%)
Public Health and Environmental Impact Proximity to Pedestrian Areas or Proximity to Waterways	7
Emergency Response Impact Traffic Control Maintenance/Repair Access Constraints	6
Subtotal	*20*
Total	**100**

Similar to gravity mains, the Asset Management Team has deliberately chosen to place a higher importance on the LOF than the COF. This ratio was determined based on lessons learned from other industry leading utilities with mature decision logic. A risk mitigation action typically reduces the LOF significantly but has limited or no impact on the COF. When COF is weighted higher, manholes that are in good condition but are located in high consequence areas can be prioritized higher than manholes in very poor condition.

Weighting the condition assessment findings in this manner ensures that the manholes with the greatest risk of structural failure will be scored higher and prioritized for renewal, while still adequately factoring COF into the decision-making process. Figure 2-7 presents the BRE for manholes.

Figure 2-7. Manhole Business Risk Exposure



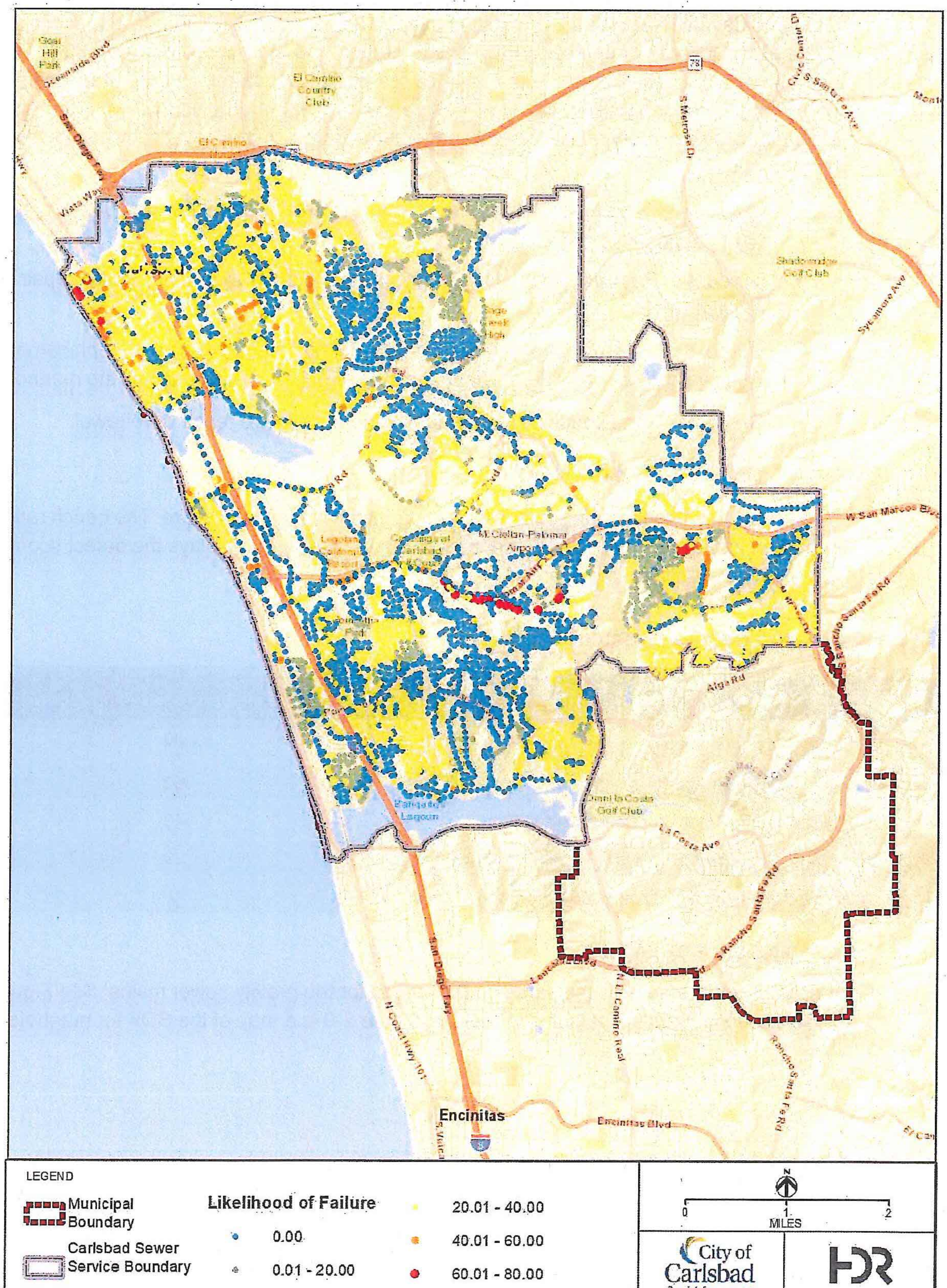
LIKELIHOOD OF FAILURE

A workshop was conducted with City staff to identify factors for LOF and to weight each factor. The LOF is 80 percent of the total BRE. LOF is calculated using the following factors and weights:

LOF = [Condition Assessment score: Overall Condition Rating or Bench Rating Score (Max 80)]

The LOF for each manhole is mapped in Figure 2-8.

Figure 2-8. Manhole Likelihood of Failure



The primary components driving the LOF are the overall manhole condition rating and structural defects present on the manhole bench. Defects identified through inspection are grouped by severity of defect into five grade groups and are scored between 80-0. The overall condition rating grade is primarily based on the structural severity of the defect, with Group 5 generally being the most severe and highest priority and Group 1 the least severe and lowest priority. The Asset Management Team grouped severity by the following general criteria:

- Grade 5 – Severe condition issues with significant condition deterioration that requires repair or replacement.
- Grade 4 – Poor condition with condition deterioration that may require repair or replacement.
- Grade 3 – Fair condition where defects do not require repair or replacement. Renewal may be considered when gravity sewer CIP projects impact the manhole.
- Grade 2 – Good condition where defects do not require repair or renewal.
- Grade 1 – Excellent condition.

Additionally the bench rating score is a component driving the LOF score. The bench rating is broken into three categories Good, Fair or Poor. Table 2-15 displays the defect scoring groups and corresponding scores.

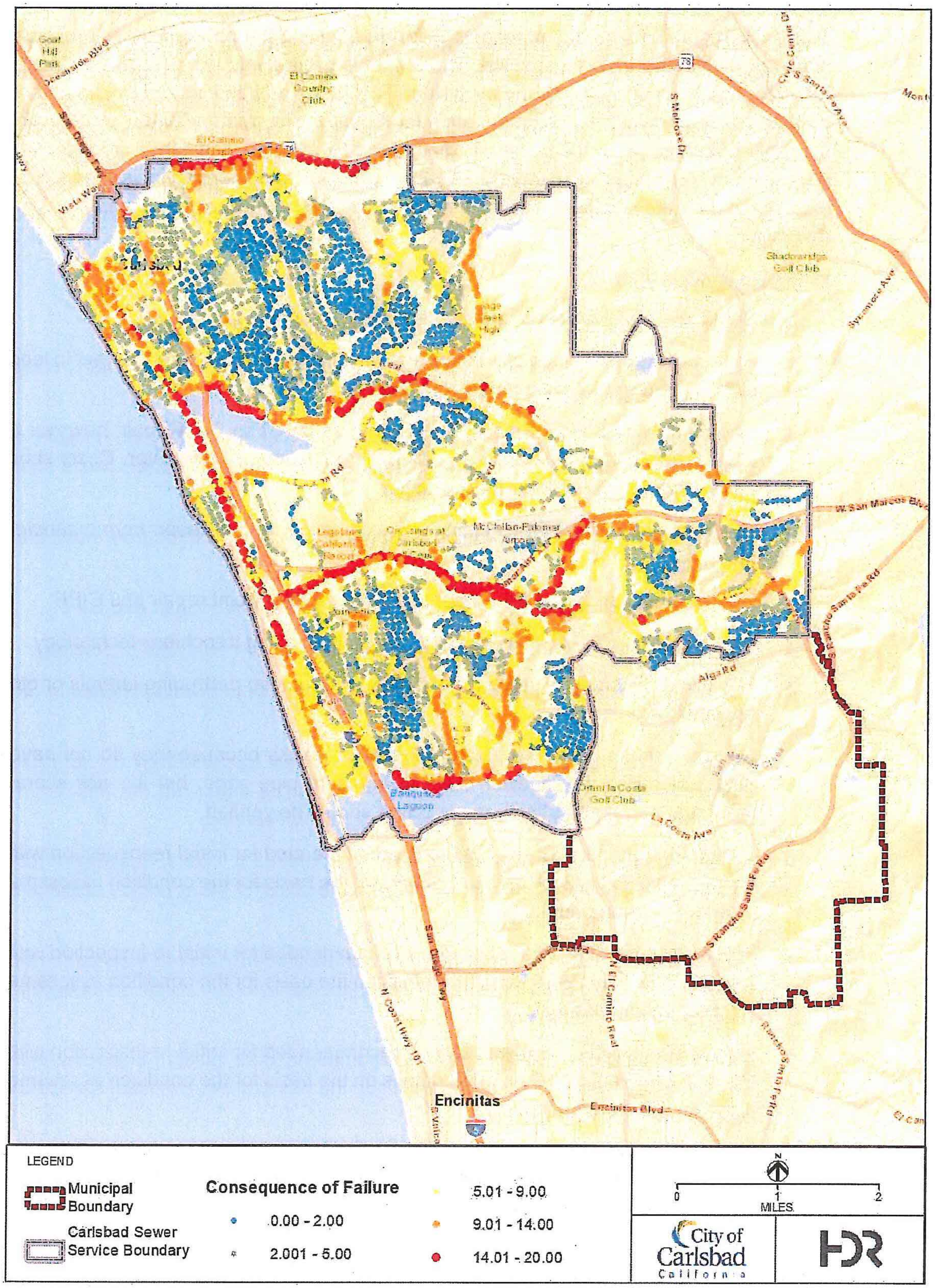
Table 2-15. Condition Assessment Scoring

Grade or Group	MH Condition Assessment Score
Overall Condition Rating Grade 5 or Bench Rating Poor	80
Overall Condition Rating Grade 4	60
Overall Condition Rating Grade 3 or Bench Rating Fair	40
Overall Condition Rating Grade 2	20
Overall Condition Rating Grade 1 or Bench Rating Good	0

CONSEQUENCE OF FAILURE

The COF for manholes is the same as the criteria for the gravity sewer mains. See Figure 2-6 and subsequent subsections for details. Figure 2-9 is a map of the COF for manholes.

Figure 2-9. Manhole Consequence of Failure



Risk Mitigation Actions and Other Outputs

Gravity Main Risk Management Actions

This section summarizes the methodology for determining the appropriate risk mitigation action for each pipe that is inspected. The output is divided into two categories including recommended action and secondary notes. The recommended action documents the primary risk management recommendation for the pipe. The primary action is categorized by small diameter (SD), 12 inches in diameter and smaller, and large diameter (LD), greater than 12 inches in diameter, because renewal and monitoring is planned and executed differently for different size pipe. The secondary notes include information for the reviewer

Primary actions include:

- Replace – replacement of gravity sewer from manhole to manhole
- Open Cut Repair – open cut gravity sewer point repair typically 6 to 8 feet in length unless there are multiple repairs that overlap
- Open Cut Repair Cost Review – the same as an Open Cut Repair, however the cost is determined differently due to implementation in InfoMaster. Costs should be reviewed in more detail for this action.
- Cured-in-place Pipe (CIPP) Lining – gravity sewer rehabilitation from manhole to manhole
- Open Cut Repair and CIPP – open cut gravity sewer point repair and CIPP
- Trenchless Repair – gravity sewer pipe patching using trenchless technology
- Cut Tap or Obstacle – utilize robotic cutting to remove protruding laterals or other obstructions.
- Review – these pipes are recommended for review because they do not have a defect identified for renewal, such as medium pipe sags, but the risk score is moderate and a potential renewal action should be verified.
- 5-Year Monitor LD – Gravity sewer is recommended for initial re-inspection within 5 years. See Table 2-18 for more details on the basis for the condition assessment program recommendations.
- 8-Year Monitor SD – Gravity sewer is recommended for initial re-inspection within 8 years. See Table 2-18 for more details on the basis for the condition assessment program recommendations.
- 4-Year Monitor SD – Gravity sewer is recommended for initial re-inspection within 4 years. See Table 2-18 for more details on the basis for the condition assessment program recommendations.
- 2-Year Monitor SD – Gravity sewer is recommended for re-inspection within 2 years. See Table 2-18 for more details on the basis for the condition assessment program recommendations.

- No CUES CCTV Data – this indicates that there is no historical CUES CCTV in the InfoMaster model. These pipes will be inspected with NASSCO PACP data to close this data gap.

Secondary notes include:

- Abandoned inspection – Abandoned CCTV inspection, review cause.
- Point Repair – Gravity sewers with a previously completed point repair will be flagged with a comment. A static list of repairs from SewerRepairs.xlsx is currently being used.
- JAngularL– Pipe bend – Gravity sewers with a pipe bend are flagged for manhole installation review
- Pipe Depth greater than or equal to 8 feet – Gravity sewers with a pipe depth of greater or equal to 8 feet are flagged with a comment
- Pipe Depth greater than or equal to 25 feet – Gravity sewers with downstream invert elevations greater than or equal to 25 feet below grade, review primary action accordingly

CCTV defects are grouped by typical primary action types in order to associate appropriate renewal recommendations with each defect in InfoMaster software. These are referred to as the Rehab Method in InfoMaster. These structural defect Rehab Methods are categorized by the Rehab Method and include:

- Open Cut Point Repair – Defects that are typically addressed by open cut repair.
- Trenchless Repair – Defects that typically are addressed through CIPP lining, patching, or other trenchless repair methods.
- Replacement – Defects that are typically addressed by complete pipe replacement.
- Robotic Cutter – Defects that are typically addressed through robotic cutting.

As previously illustrated, Figure 2-5 shows the Rehab Method by defect codes, which are listed in Appendix A.

The flow diagram shown in Figure 2-10 documents the decision logic for gravity mains. Primary actions are represented by circles in bold and underlined text, secondary notes are represented by circles at the beginning of the flow diagram in regular font text, and decision points are represented by diamonds in the flow chart.

Additional description of some decision points in the decision logic include the following:

- Gravity sewers with at least one replacement type defect are recommended for replacement.
- Gravity sewers with at least one open cut point repair type defect and more than four open cut point repair or trenchless point repair type defects are recommended for replacement. This approach is more economical and in line with existing City practices.

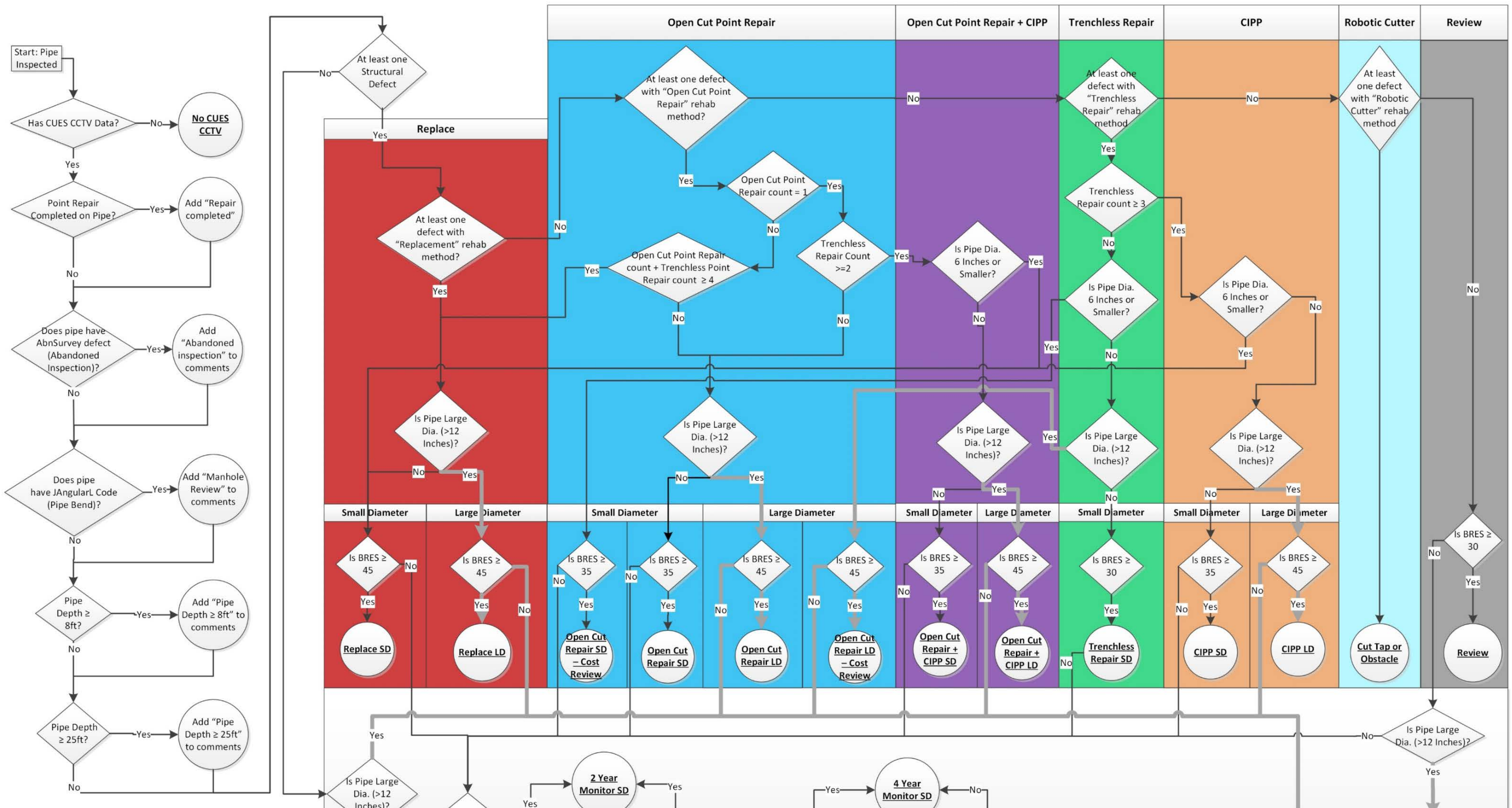
- Gravity sewers with three or more trenchless repairs are recommended for CIPP lining.
- Gravity sewers with pipe diameter equal to 6 inches or smaller will not be renewed with CIPP or trenchless repair.

BRE thresholds are critical decision points in the decision logic. These thresholds are used to determine whether a gravity sewer is recommended for a renewal action or future condition assessment monitoring action. If the BRE threshold is set to 30, for example, gravity sewers with a BRE greater than 30 will be recommended for renewal or more frequent monitoring. Setting and adjusting the BRE thresholds allows the City to balance cost, risk, and level of service appropriately and deliver the most value to ratepayers. The BRE thresholds vary by risk mitigation action to deliver the most value per dollar spent on renewal. Higher thresholds are used for more costly renewal actions and lower BRE thresholds are used for cheaper renewal actions. This approach mitigates the most risk at the lowest cost. The following example scenario illustrates this approach.

Example Scenario: Five gravity sewers have a BRE of 30. One of those gravity sewers is recommended for CIPP which could cost over $10,000. The remaining four pipes are recommended for a trenchless repair, which could cost $2,500 each or $10,000 total. Setting the BRE threshold to 35 for the CIPP renewal and the BRE threshold to 30 for the trenchless point repair renewal will result in the decision logic recommending spending $10,000 on trenchless repairs and mitigating the risk on four gravity sewers, vs. spending $10,000 on mitigating the same risk on one gravity sewer.

A description of the BRE thresholds for the City's decision logic is included in Table 2-16. The BRE thresholds are included in the decision logic and are typically shown immediately prior to the risk mitigation action.

Figure 2-10. Gravity Sewer Condition Risk Mitigation Decision Logic Flow Diagram



Note:
1. BRES = Business Risk Exposure Score
2. Large diameter sewers will be inspected per Settlement Schedule. Decision logic is intended to recommend subsequent inspection schedule. Large Diameter flow arrows shown with thicker gray lines.

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Gravity Main BRE Results

The BRE is a numerical value representing the relative risk for each gravity sewer that has been inspected and includes the sum of LOF and COF scores. A summary of the BRE results is presented in Table 2-16 and includes all pipe in the City's GIS.

Table 2-16. Business Risk Exposure Summary

BRE	Count of Gravity Sewer Mains	Length of Gravity Sewer Mains (feet)	Percent by Length (%)
0-4	1970	427,223	27.4%
5-9	3125	572,331	36.7%
10-14	1343	275,124	17.7%
15-19	508	135,651	8.7%
20-24	89	32,631	2.1%
25-29	36	7,486	0.5%
30-34	49	12,971	0.8%
35-39	93	22,511	1.4%
40-44	84	21,745	1.4%
45-49	21	5,906	0.4%
50-54	21	5,375	0.3%
55-59	31	7,590	0.5%
60-64	43	10,542	0.7%
65-69	34	6,327	0.4%
70-74	44	9,771	0.6%
75-79	12	3,374	0.2%
80-84	3	913	0.1%
Total	7506	**1,557,470**	100.0%

Manhole Risk Management Actions

This section summarizes the methodology for determining the appropriate risk mitigation action for each manhole that is inspected. The primary action documents the primary risk management action for the manholes.

Primary actions include:

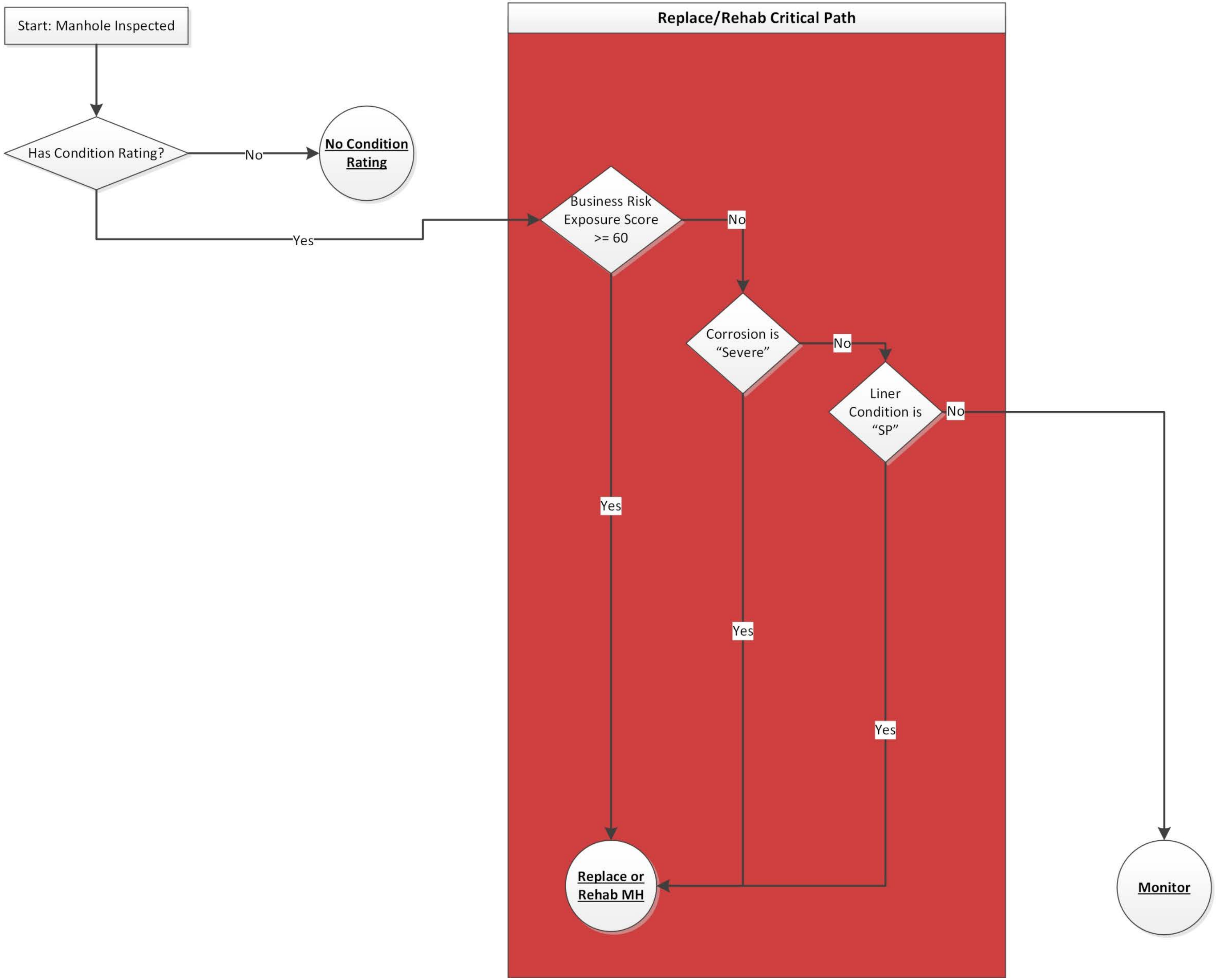
- Replace or Rehab – Replacement or rehabilitation of the Manhole
- Monitor – Manhole has minor structural defects and is recommended for re-inspection as part of current gravity main cleaning or CCTV inspection activities
- No Condition Rating – Manhole does not have inspection data

The manhole condition defects are the factors that determine if renewal is recommended for the manhole. The structural defects that are recommended for renewal include:

- Business Risk Exposure >=60
- Bench condition is poor
- Corrosion is severe
- Liner Condition is poor

The flow diagram shown in Figure 2-11 documents the decision logic for manholes. Primary actions are represented by circles at the end of the flow diagram in bold and underlined text and decision points are represented by diamonds in the flow chart.

Figure 2-11. Manhole Condition Risk Mitigation Decision Logic Flow Diagram



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Condition CIP, Renewal and Assessment Forecast

This section documents details of the renewal and condition assessment forecasts including unit costs, BRE thresholds that trigger a risk mitigation action and forecast results.

Unit Costs

Unit costs were developed based on recent costs from contracted work within the City's collection system and recent industry experience at nearby utilities. Unit costs are calculated by summing the following costs for each gravity sewer pipe diameter and renewal type:

- **Material Cost** – Typically the unit cost provided on a construction project bid tabulation
- **Installation Factor** – Assumed to address costs such as mobilization, fittings, excavation, bedding, backfill, traffic control, by-pass pumping, equipment, labor, pavement or non-ROW patching or improvements.
- **Capital Cost Factor** – Assumed to address costs related to agency administration, design, construction management, and construction contingency.

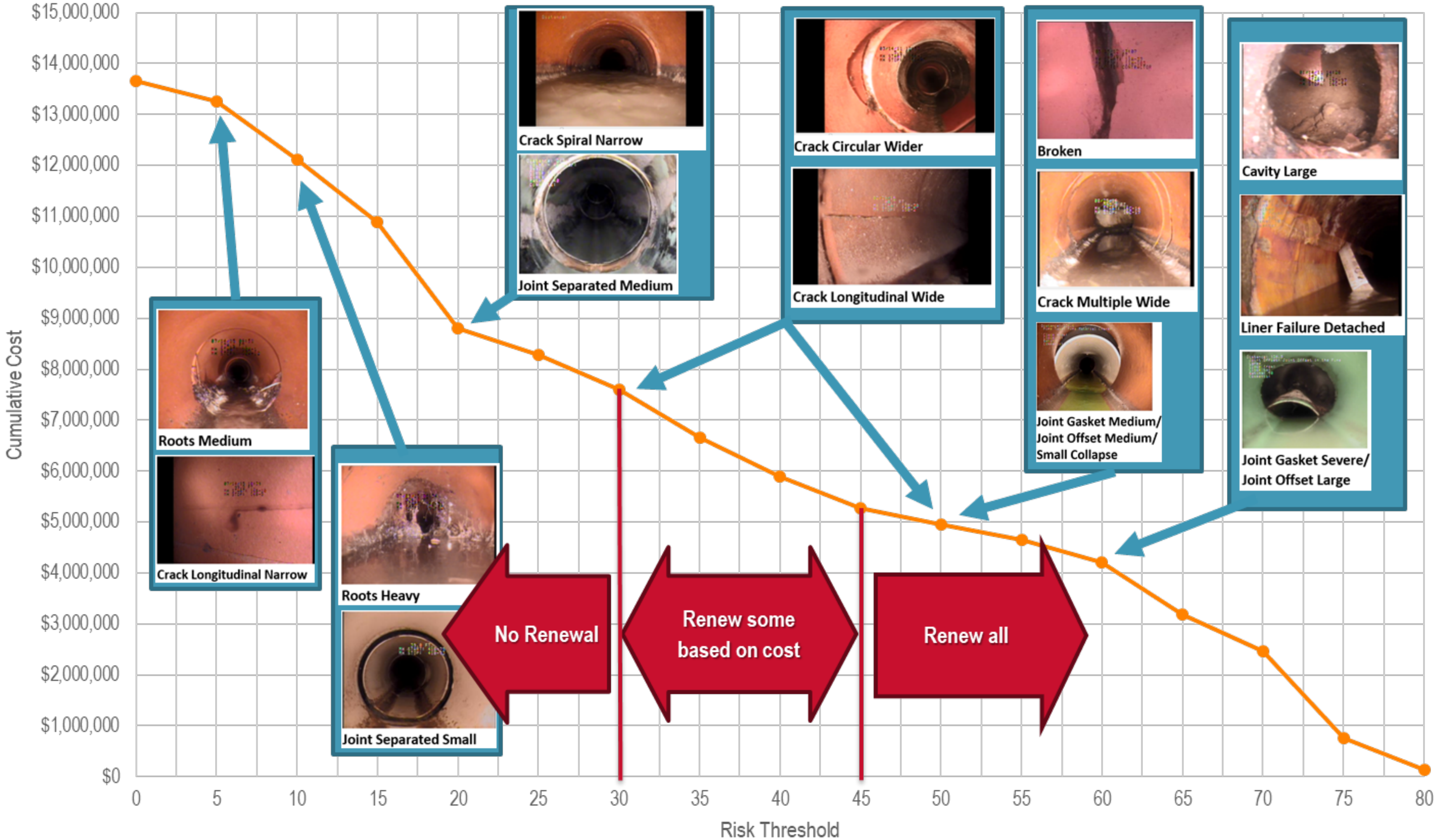
The unit costs and cost factors for gravity sewers and manholes are included in Appendix C.

BRE Results and Level of Service Thresholds

Using the decision logic and unit costs, a dashboard tool in Microsoft Excel was developed to provide results in real time with adjustments to BRE thresholds that trigger renewal actions. This allowed the Asset Management Team to evaluate cost against risk. This tool was used to evaluate initial BRE thresholds for the City based on the distribution of BRE scores for the City's sewer pipelines. This section presents the development of BRE thresholds.

Gravity sewers with a BRE greater than the BRE threshold are recommended for renewal or increased frequency of condition assessment monitoring by the decision logic. Figure 2-12 shows the cost to renew gravity sewers at different BRE thresholds and level of service. The cost shown at each BRE threshold is the forecasted cost to perform the renewal actions identified for the decision logic for gravity sewers with a BRE greater than the threshold. Figure 2-12 shows that the cost forecast to complete all renewal identified by the decision logic for gravity sewers with a BRE greater than 30 is $7,600,000. Similarly, the cost to complete all renewal identified by the decision logic for gravity sewers with a BRE greater than 40 is $5,900,000.

Figure 2-12. Cost to Renew Gravity Sewers by BRE Thresholds



A different BRE threshold is assigned for each renewal type. This allows the City to focus on lower cost renewal methods and consequently provide the most risk mitigation per rate payer dollar spent. More expensive renewal actions are assigned a higher BRE threshold and less expensive renewal actions are assigned a lower BRE threshold as shown in Table 2-17.

Table 2-17. Renewal Action BRE Thresholds

Renewal Action	BRE Threshold	Renewal Cost Examples ($)
Replace SD	45	80,000
Open Cut Repair LD	45	57,000
CIPP LD	45	54,000
Open Cut Repair and CIPP SD	35	49,000
Open Cut Repair SD	35	26,000
CIPP SD	35	13,000
Trenchless Repair SD	30	2,500
Cut Tap or Obstacle	30	Nominal Capital Cost

Note: Renewal cost examples for SD renewal actions assume 8 inch diameter pipe. Renewal cost examples for LD renewal actions assume 24 inch diameter pipe. Renewal cost examples assume the renewal action is performed on approximately 200 feet of gravity sewer.

A similar approach was used to determine condition assessment monitoring BRE thresholds. Available crew productivity and input from staff regarding data quality are used along with BRE to determine the thresholds. Table 2-18 identifies the monitoring frequencies and basis for monitoring frequency recommendations. Less frequent inspection alternatives were evaluated including a 15-year and 12-year frequency for recently constructed gravity sewers and gravity sewers with no defects. However, data quality concerns for CCTV data completed prior to 1/1/2015, limited large diameter CCTV data in the database of record, and City staff concern about SSO risk resulted in the recommended frequencies presented in Table 2-18.

Table 2-18. Condition Assessment Monitoring Action Basis

Condition Assessment Monitoring Action	Basis
5-Year Monitor LD	The City has limited data on large diameter pipe in the CCTV database of record. The City plans to inspect large diameter pipe over 5 years to close this gap.
2-Year Monitor SD	Pipes with a BRE greater than or equal to 30 and pipes that are on a quarterly or semi-annual cleaning frequency.
4-Year Monitor SD	Pipes that do not meet the above criteria and; 1) have CCTV data prior to 1/1/2015 that may be of lower quality; or 2) non-plastic pipes.
8-Year Monitor SD	Pipes that do not meet the above criteria and are plastic.

Estimated Useful Life

Determining a remaining useful life is challenging for gravity sewers and manholes because the time of failure is typically not known. Failure may occur when the gravity sewer is installed or later in the gravity sewer's life due to cleaning-caused degradation over time or a contractor dig-in. The City's CCTV data and manhole inspections provide a snapshot in time of the condition of a majority of the City's gravity sewers and manholes. Based on the BRE thresholds selected by the Asset Management Team, gravity sewers with a renewal recommendation are assumed to exceed their useful life within the next 5 to 8 years. Gravity sewers recommended for monitoring are expected to exceed their useful life sometime beyond 8 years after their next planned inspection. These assumptions may change as the City performs repeat inspections of gravity sewers and determines more accurate remaining useful life.

Renewal and Condition Assessment Forecasts

This section includes renewal forecasts and condition assessment forecasts for gravity sewer and manhole infrastructure.

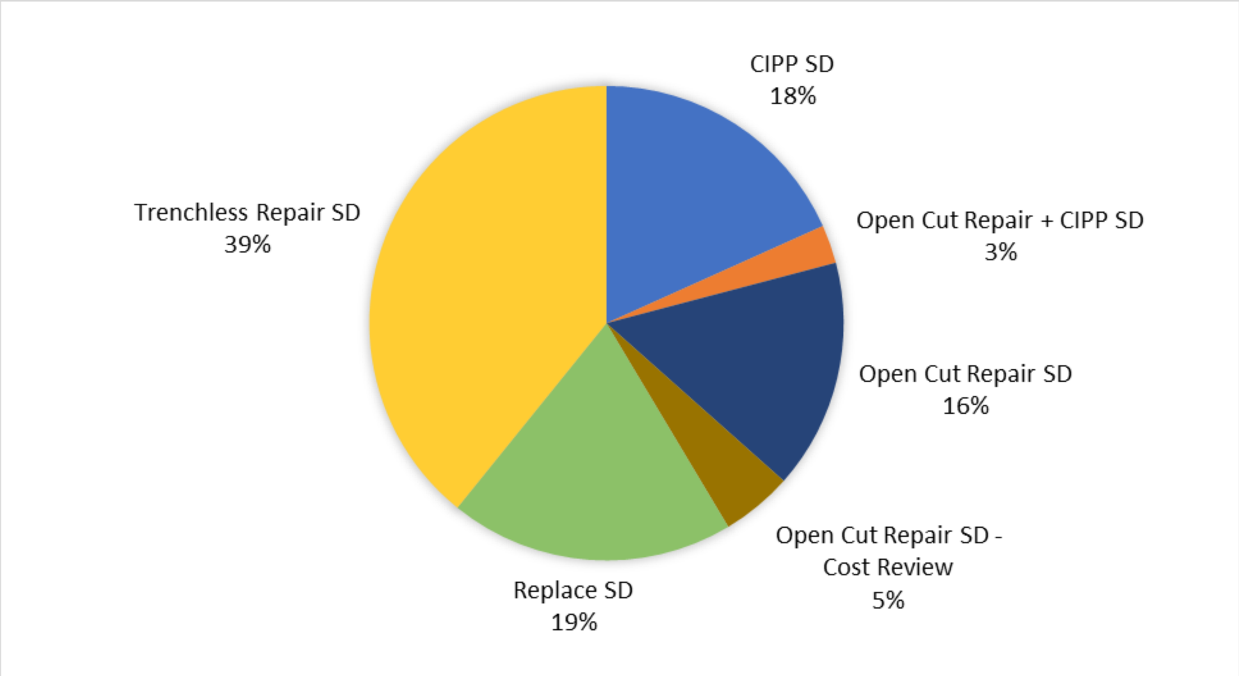
Renewal Forecasts

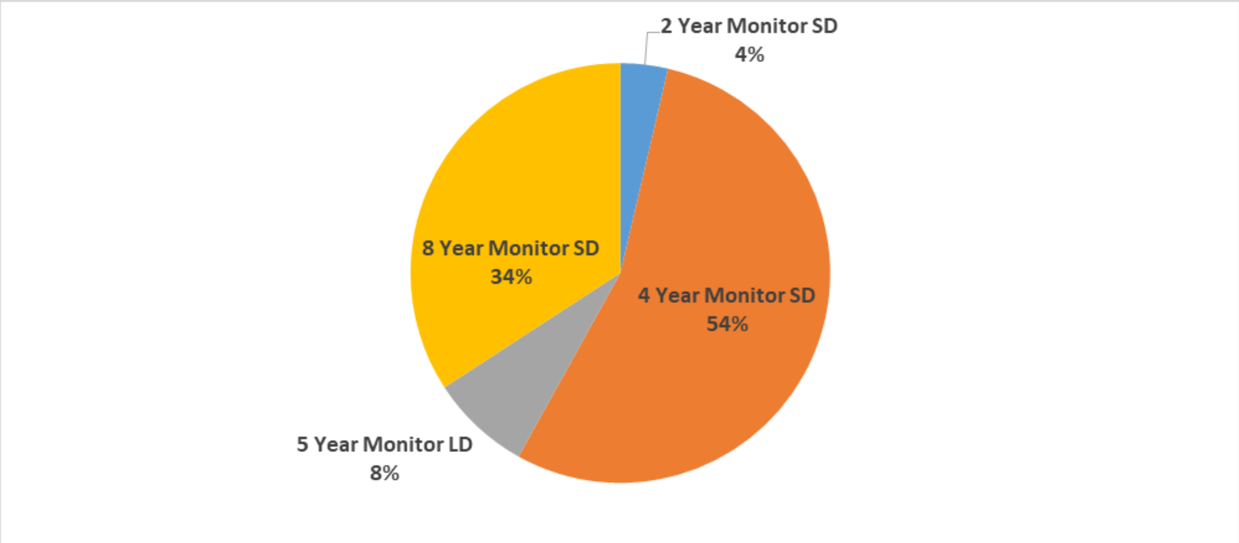
The BRE thresholds in Table 2-17 and the decision logic were used to forecast renewal recommendation quantities, condition assessment monitoring quantities and costs for gravity sewers and manholes. These recommendations from the decision logic will cost effectively meet the City's desired renewal and monitoring program policies and are expected to result in minimal structural SSOs. Table 2-19 and Figure 2-13 summarize the risk mitigation actions by length and percentage for gravity sewers owned by the City.

Table 2-19. Gravity Sewer Risk Mitigation Action Results

Risk Mitigation Actions	Gravity Sewer Length (Feet)	Percent by Length (%)
CIPP SD	14,142	1.0
Open Cut Repair + CIPP SD	1,954	0.1
Open Cut Repair SD	8,733	0.6
Open Cut Repair SD - Cost Review	2,905	0.2
Replace SD	12,253	0.9
Trenchless Repair SD	25,321	1.8
2 Year Monitor SD	47,638	3.4
4 Year Monitor SD	709,010	50.6
5 Year Monitor LD	101,161	7.2
8 Year Monitor SD	445,370	31.8
Review SD	32,125	2.3
Review LD	703	0.1
Total	**1,401,316**	**100**

Figure 2-13. Gravity Sewer Renewal and Monitoring Action Results





The renewal actions from the decision logic results are presented in Figure 2-14. Monitoring actions from the decision logic results are presented in Figure 2-15.

Figure 2-14. Condition Risk Mitigation Decision Logic Renewal Results for Gravity

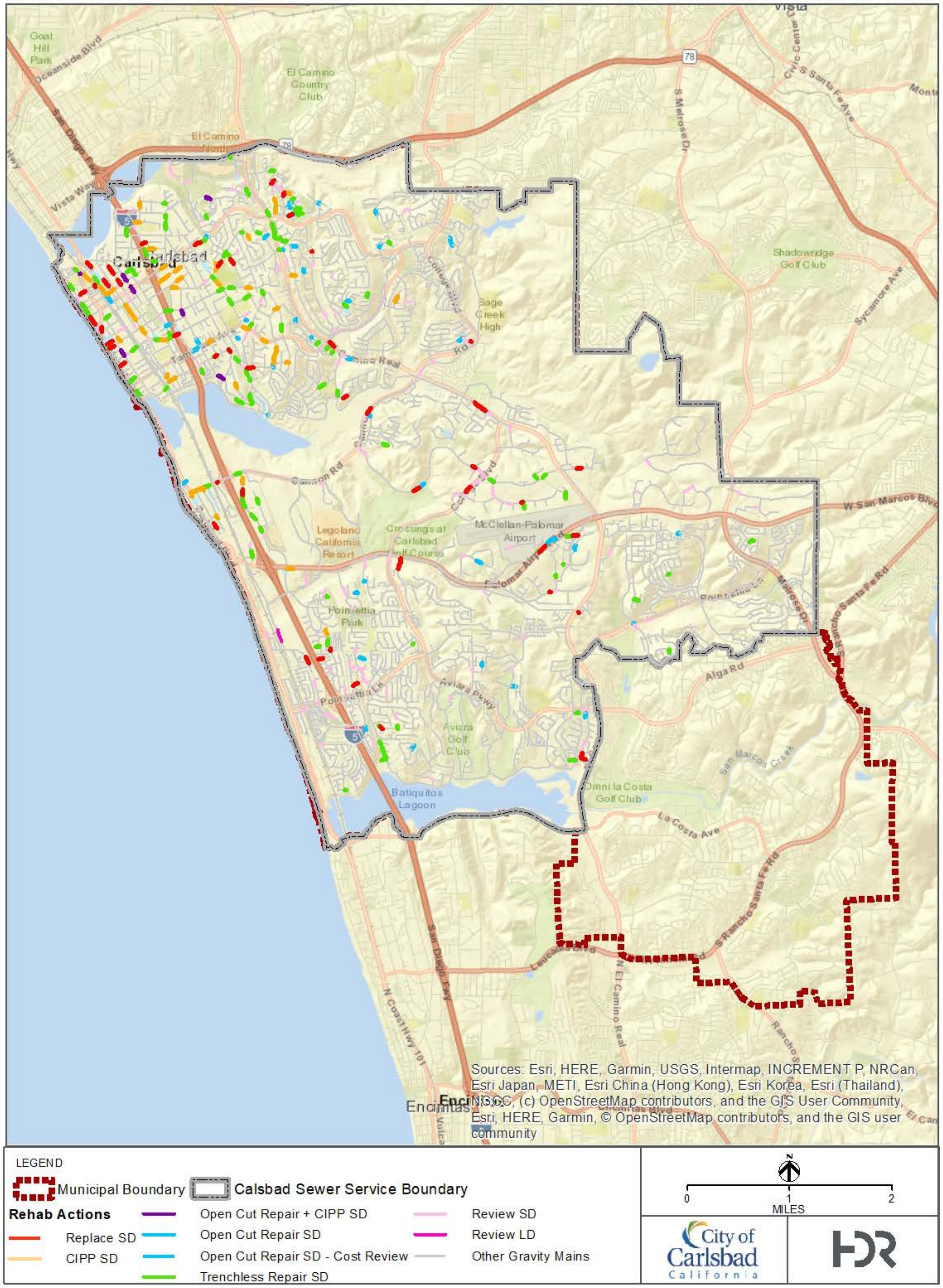
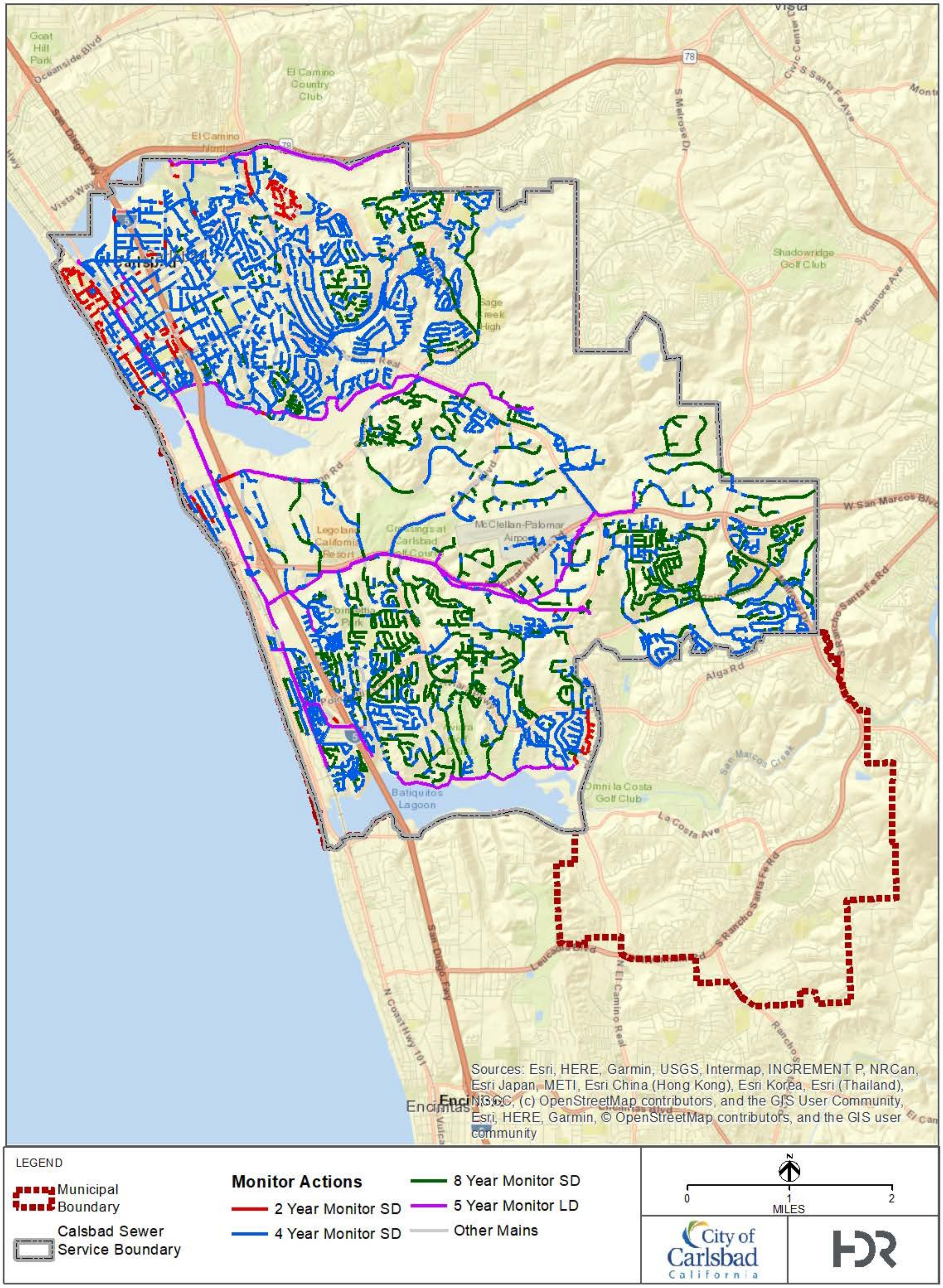


Figure 2-15. Condition Risk Mitigation Decision Logic Monitoring Results for Gravity Sewers



Costs forecasts for gravity sewer CIP renewal actions for gravity sewers owned by the City are shown in Figure 2-16 and Table 2-20.

Figure 2-16. Gravity Sewer CIP Renewal Cost Forecast Results

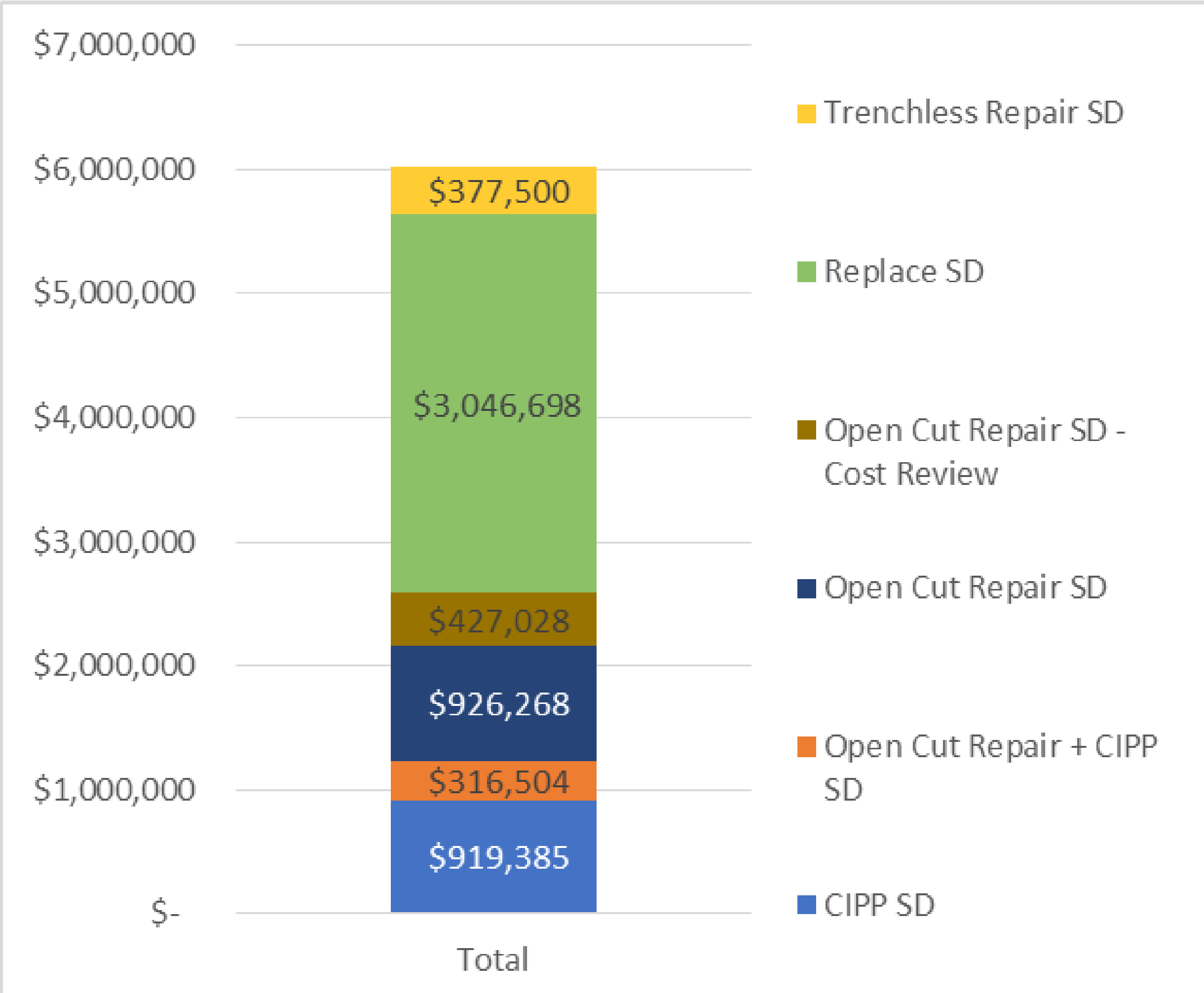


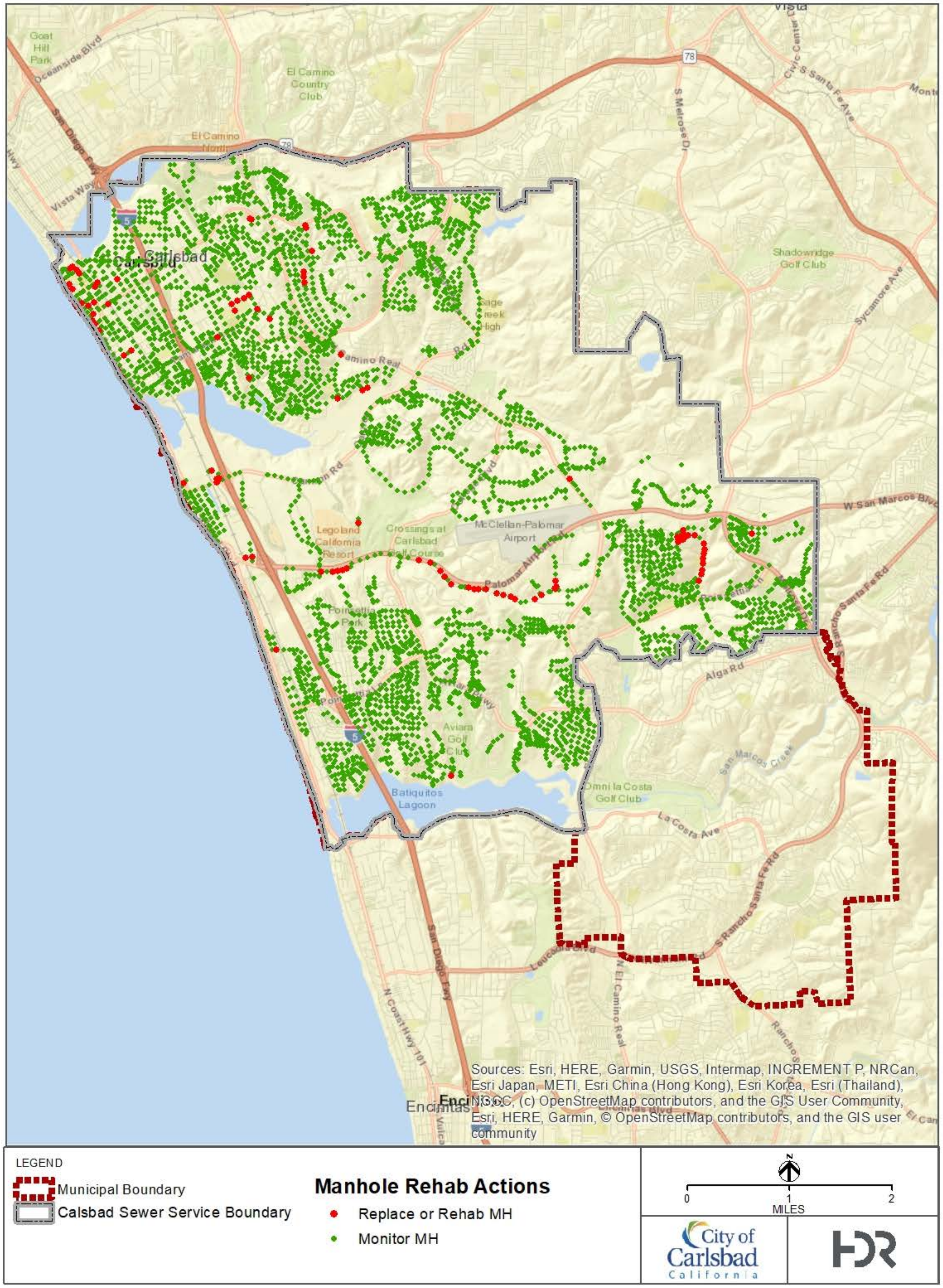
Table 2-20. Gravity Sewer CIP Renewal Cost Forecast

Renewal Action	Total
CIPP SD	$919,385
Open Cut Repair + CIPP SD	$316,504
Open Cut Repair LD - Cost Review	$0
Open Cut Repair SD	$926,268
Open Cut Repair SD - Cost Review	$427,028
Replace SD	$3,046,698
Trenchless Repair SD	$377,500
Total	**$6,013,382**

The City will be inspecting large diameter gravity sewer over the next several years. Approximately 30,000 linear feet is assumed to be inspected per year based on the plan for a 5-year monitoring schedule. The yield rate for large diameter pipes that have a BRE greater than 45 is approximately 3 percent of inspected large diameter pipe based on the results of the decision logic. This 3 percent yield rate multiplied by the 30,000 linear feet of planned inspection results in 900 linear feet of projected large diameter renewal per year. The average unit cost for 14 to 24 inch diameter pipe for CIPP and replacement is $353 per linear foot. This unit cost is applied to the 900 linear feet of projected renewal resulting in a forecast of $320,000 per year. Based on input from City staff regarding inspection schedules, renewal work for large diameter pipe is expected to start in FY2021/2022. The large diameter renewal forecast for years 6-15 is based on the age-based forecast described in this section and Appendix D.

The manhole decision logic was used to forecast renewal recommendation quantities and costs for manholes. The decision logic identified 98 manholes for replacement. These manholes for renewal are shown in Figure 2-17.

Figure 2-17. Condition Risk Mitigation Decision Logic Results for Manholes



The 98 manholes identified for renewal represent approximately 1.7 percent of all manholes. An additional 5 manholes per year are assumed to be identified for renewal based on input from City staff. A unit cost of $14,425 for replacement of each manhole (including soft costs) is used to forecast the costs over 5 and 7 years. Table 2-21 presents the quantities and costs for manhole replacement over a 5 year and 7 year time period.

Table 2-21. Manhole CIP Renewal Cost Forecast

Renewal Action	Timeframe (years)	Count of Manholes	Total
Replacement (Decision Logic)	5	98	$1,413,648
Replacement (Assumed)	5	25	$360,625
Total		**123**	**$1,774,273**
Replacement (Decision Logic)	7	98	$1,413,648
Replacement (Assumed)	7	35	$504,874
Total		**133**	**$1,918,523**

Condition Assessment Monitoring Forecasts

Forecasted gravity sewer CCTV inspection to be performed by City crews on small diameter gravity sewers (12-inch diameter and smaller) is presented in Table 2-22 and is based on the decision logic results. City staff plan to complete inspections and cleaning of this average mileage per year, however historical CCTV inspection mileage per year is approximately 46 miles. The City could utilize City staff overtime to complete the CCTV inspection miles per year if staff are unable to complete the work within regular hours. Alternatively, the cost forecast for a contractor to complete the difference of approximately 7.2 miles per year at an assumed unit cost of $1.80 per linear foot is $70,000 per year and is included in the monitoring CIP forecast. Additional unit costs for CCTV are included in Appendix C.

Table 2-22. Small Diameter Gravity Sewer CCTV Inspection Forecast

CCTV Inspection Frequency	Average Miles per Year
2 year	6.1
4 year	34.1
8 year	10.5
As-Needed Requests[1]	2.5
Total	**53.2**

Notes:

[1] As-needed request are assumed to be approximately 1 percent of the system mileage per year based on the output of the decision logic and SSO rate.

The forecast for large diameter gravity sewers is based on an inspection frequency of 5 years. The City is currently completing inspections as part of a third party regulatory action and the 5 year inspection frequency for cost forecasting and planning purposes is assumed to begin in FY2019/2020. The 5 year frequency was determined by staff to mitigate risk and to provide CCTV data in the NASSCO PACP format utilized in the decision logic for future decision making. Potential near term inspections of large diameter gravity sewers, based on City staff input, include:

- North Batiquitos Reach 6-9
- North Batiquitos Reach 1-4
- North Agua Hedionda Interceptor

Table 2-23 presents the large diameter gravity sewer assessment cost forecast. Cleaning costs are currently included with inspection costs based on current City practices. Unit costs for CCTV inspection and cleaning are included in Appendix C.

Table 2-23. Large Diameter Gravity Sewer CCTV Inspection Forecast

Diameter	Linear Feet	CCTV and Clean Unit Cost	Cost
15	14,117	$4.10	$57,879
16	450	$4.10	$1,846
18	10,782	$4.70	$50,674
20	2,692	$4.70	$12,655
21	7,150	$4.70	$33,606
24	22,812	$9.00	$205,304
27	5,166	$9.00	$46,493
30	45	$9.00	$408
36	10,940	$11.30	$123,622
39	1,182	$19.50	$23,056
42	20,790	$19.50	$405,412
48	5,281	$19.50	$102,978
60	352	$33.00	$11,627
Total	**101,760**	**N/A**	**$1,075,559**

2.2.3 Recommended Investment Levels

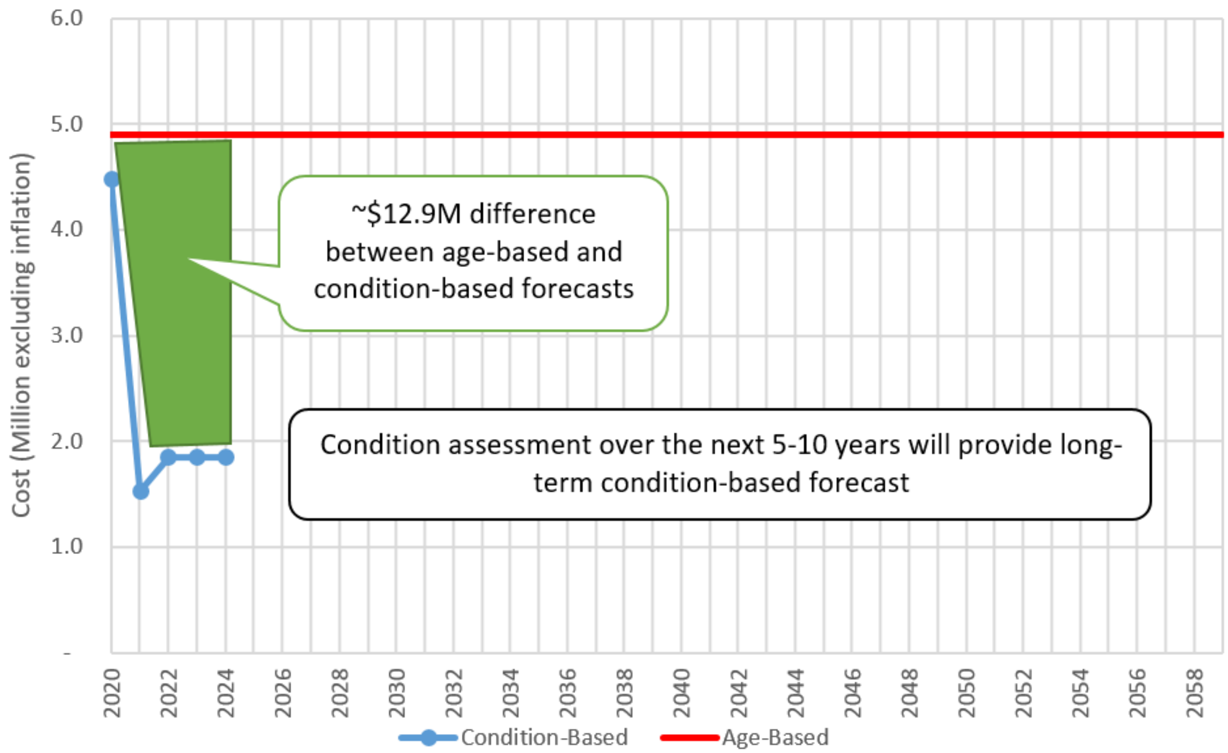
The condition-based renewal forecasts for gravity sewers and manholes are through the next 5 years. Beyond 5 years the condition and performance data and forecasts are less accurate for gravity sewers and manholes, however these forecasts are used to provide costs for the 15 year CIP in Section 2.2.4.

The condition-based forecasts in Table 2-20 and Table 2-21 and the 40-year age-based forecast are presented in Figure 2-18 without inflation. The performance-based forecast result in $12.9 million in savings vs the age-based forecast over the next 5 years. Continued condition assessment over the next 5 to 10 years will result in additional data that may be used to develop longer-term condition-based forecasts.

Condition-based forecasts in FY2019/2020 (2020 in the Figure) include an additional $3 million for CIP Project ID 55011 Buena Interceptor Sewer Pipeline and Manhole

Rehabilitation and additional funds in CIP Project ID 55031 Sewer Line Refurbishments and Replacement above the forecasted $1.2 million per year.

Figure 2-18. Gravity Sewer and Manhole Renewal Cost Forecast



2.3 CIP Recommendations

There are several AMP related CIP projects in the current 15 year CIP program for wastewater. Updates are included in this section for the following projects:

- CIP Project ID 55031 Sewer Line Refurbishments and Replacement
- CIP Project ID 55131 Sewer Line Condition Assessment

The following CIP Projects were discussed and City staff indicated the current CIP budget is appropriate at this time.

- CIP Project ID 38401 Sewer Lift Station Repairs and Upgrades
- CIP Project ID 55201 Odor and Corrosion Prevention Assessment

The 15-year CIP forecast for CIP Project ID 55031 Sewer Line Refurbishments and Replacement is presented in Table 2-24. This forecast includes costs for gravity sewers and manholes based on the results of the decision logic as described in previous sections. Years 6-15 utilize the age-based forecast for large diameter gravity sewers and Years 6-15 for small diameter gravity sewers and manholes assume the cost per year in the Year 1-5 forecast. These costs include 2% annual inflation.

Table 2-24. CIP Forecast for Sewer Line Refurbishments and Replacement

Project Title	Year 1 2019-20	Year 2 2020-21	Year 3 2021-22	Year 4 2022-23	Year 5 2023-24	Year 6-10 2025-29	Year 11-15 2030-34
Sewer Line Refurbishments and Replacement (Includes Manholes)	**$1,530,000**	**$1,530,000**	**$1,850,000**	**$1,850,000**	**$1,850,000**	**$13,350,000**	**$14,050,000**
Proposed Small Diameter	$1,240,000	$1,240,000	$1,240,000	$1,240,000	$1,240,000	$6,800,000	$7,400,000
Proposed Large Diameter	$0	$0	$320,000	$320,000	$320,000	$4,950,000	$4,950,000
Proposed Manhole	$290,000	$290,000	$290,000	$290,000	$290,000	$1,600,000	$1,700,000

Notes:
Includes 2% inflation

The 15-year annual CIP forecast for CIP Project ID 55131 Sewer Line Condition Assessment is presented in Table 2-25 based on the results of the decision logic described in previous sections. Small diameter gravity sewer condition assessment is assumed to be address through existing City staff and a different budget after completion of some additional assessment in Years 1-5 to close data gaps. The large diameter gravity sewers forecast in years 6-15 assume the cost per year the Year 1-5 forecast. These costs include 2% annual inflation.

Table 2-25. CIP Forecast for Sewer Line Condition Assessment

Project Title	Year 1 2019-20	Year 2 2020-21	Year 3 2021-22	Year 4 2022-23	Year 5 2023-24	Year 6-10 2025-29	Year 11-15 2030-34
Sewer Line Condition Assessment (Includes Manholes)	**$300,000**	**$300,000**	**$300,000**	**$300,000**	**$300,000**	**$1,240,000**	**$1,370,000**
Proposed small diameter	$75,000	$75,000	$75,000	$75,000	$75,000	$0	$0
Proposed Large Diameter	$225,000	$225,000	$225,000	$225,000	$225,000	$1,240,000	$1,370,000
Proposed Manhole	$0	$0	$0	$0	$0	$0	$0

Notes:

Includes 2% annual inflation

2.4 Condition and Capacity CIP Project Coordination

All current CIP projects were compared to the condition renewal identified in the AMP using a tabular analysis to compare unique pipe IDs between the CIP projects GIS shapefile and decision logic output. There is no overlap between the condition and capacity projects. The capacity projects are identified in the 2018 Sewer Master Plan.

2.5 Opportunities

Throughout development of the AMP, the Asset Management Team identified potential opportunities for continuous improvement to the asset management program. The City should consider these opportunities when developing an Asset Management Roadmap that clearly communicates to stakeholders the prioritized initiatives and a schedule for implementation. A list of these opportunities for wastewater are included below

- Consider staffing needs resulting from recent vacancy in asset management support position and potential scheduling support needs.
- Consider utilizing an experienced construction inspector for CIPP to ensure quality delivery by contractors. Consider NASSCO CIPP construction inspection certification.
- Update risk for gravity sewer mains to account for the distance to a storm drain inlet and storm drain outlet. Gravity sewer mains that could spill immediately upstream from a storm drain outlet are higher risk of an SSO to waters of the state than gravity sewer mains located thousands of feet upstream from a storm drain outlet. Utilize the City's storm sewer “quilt” map to support the analysis.
- Consider opportunities to pilot pipe bursting renewal technologies. City staff identified a potential pipe bursting location at Cannon Road between the I-5 and Avenida Encinas.
- Consider evaluation of field notes for gravity sewers to better support cleaning maintenance. Publish maps of gravity sewer cleaning defects identified through CCTV for use by crews to support cleaning maintenance.
- Consider developing a GIS layer of key trails or other pedestrian areas to be added to the risk model in the future.
- Develop in InfoMaster a risk model and decision logic for the City’s NASSCO PACP format CCTV data for use in prioritizing renewal and planning future CIP projects. Align InfoMaster data update quick reference and project packaging workflows provided in Appendix E with City practices. Consider updating from InfoMaster to InfoAsset Planner software. Leverage risk model and decision logic developed for the AMP.
- After implementation of new CCTV truck and equipment, update business processes for inspection and renewal decision making and conduct training on updated business processes.

- Review gravity sewer decision logic recommendations for high risk pipe renewal and develop a construction contract for this work. Review gravity sewers recommended for review in the decision logic.
- Evaluate CCTV monitoring schedule for small diameter gravity mains using the initial recommendations provided by the decision logic.
- Consider opportunities to solicit more bids from contractors on inspection work.
- Consider developing a schedule for inspection of each large diameter gravity sewer and import large diameter gravity sewer CCTV data into the CCTV database of record. Near term inspections could include North Batiquitos Reach 6-9, North Batiquitos Reach 1-4, North Agua Hedionda Interceptor.
- Document the pump station and force main condition assessment program and develop data management to move towards performance-based renewal planning versus age-based.
- When a significant portion of the gravity sewer mains and manholes have been inspected for a second time, analyze the data to determine deterioration forecasts and long-term projections for renewal that are performance-based versus age-based.
- Update the AMP annually with significant changes or modifications to the program.

2.6 Asset Valuation

The total asset replacement valuation for wastewater assets is $528 million. The replacement cost for gravity sewers, manholes, force mains, and lift stations is summarized in Table 1-1. This valuation is based on data that is readily available such as GIS data, financial records, maintenance and repair records, and replacement and renewal records. The City currently utilizes an Original Cost Less Depreciation valuation approach. Where performance-based forecasts were not developed, age was the basis for the straight-line depreciation calculations using estimated useful life by asset classes to estimate the asset service life and estimated replacement costs. Assets were "bundled" into one facility asset or group of facility assets, such as water reservoir or sewer lift station mechanical, and the total construction cost of the asset value and the useful life for the facility were applied.

The asset valuation details including useful life assumptions and long-term funding forecasts by year are included in Appendix D.

2.7 InfoMaster and Project Packaging Workflow

Included in Appendix E are an InfoMaster data update quick reference, InfoMaster field mapping for CCTV and sewer system data, and project packaging workflows. The data update quick reference provides a quick reference with instructions for updating data in InfoMaster when the sewer system changes or the City makes changes to the risk model or decision logic elements in InfoMaster. The field mapping presented in Appendix E documents how the CCTV and sewer system data is imported into InfoMaster. The project workflows are intended to provide a high level overview of how InfoMaster is used in the renewal project packaging and project close-out process.

3 Potable and Recycled Water

This section includes asset management planning for the potable and recycled water pipelines, valves and service laterals which includes a summary of system condition and performance, asset inventory, asset replacement costs, and condition assessment and replacement forecasts.

3.1 System Inventory, Performance, & Replacement Cost

A summary of the City's infrastructure with length and count of assets and replacement cost is included in Table 1-1.

The City's infrastructure database of record is GIS. The City has two distinct operating systems for potable and recycled water. Carlsbad provided readily available GIS files with updates as of November 30, 2016. The datasets used as the basis of this report were Water_Main, Water_Valve, and Water_Service_Line. Infrastructure that was not owned by Carlsbad was excluded[5]. Carlsbad keeps installation dates in several fields. To estimate the installation year of each pipe, the following procedure was used:

1. Use DWGSIGNDAT, if not populated
2. Use DWGASBUILT, if not populated
3. Use INSTALLDAT, if not populated
4. Use ACCEPTANCE, if not populated
5. Use the year in which the PROJECTNUM associated to the service was constructed, if not populated
6. Mark as unknown

A summary of active system infrastructure by installation era is included in Table 3-1.

[5] Infrastructure with an OWNEDBY field of "CMWD" is included. The SHAPELENGTH field is used for length. Infrastructure with a STATUS field of Abandoned and Not in Service was excluded. Infrastructure with a STATUS field of Future is included due to the age of the GIS data used.

Table 3-1. Summary of Pipe Infrastructure by Installation Decade

Installation Era	Potable (mi)	Recycled (mi)	Total (mi)
Unknown	5	-	5
<1960	7	-	7
1960-1969	34	-	34
1970-1979	76	-	76
1980-1989	108	4	112
1990-1999	122	28	151
2000-2009	92	43	135
2010-2017	6	2	8
Total	**450**	**78**	**527**

In the industry, system performance is often measured in terms of “break rate” which measures the annual number of main breaks per 100 miles of pipe operated. Recent research[6] indicates that the average break rate in the Region is 9.7 annual breaks per 100 miles. The City’s potable and recycled water system has experienced break rates of 1.7 and 0.5 respectively over the past ten years. The system-wide break rate is 1.5 or roughly six times better than the regional average. Even in Southern California where materials used and soil conditions tend to result in longer useful lives and the cost of water drives utilities to manage aging infrastructure more proactively, the City is within the top quartile of utilities in terms of system performance. While the vast majority of the City’s infrastructure is expected to have a long life, variables[7] will cause some City pipes to deteriorate much faster than the average. In order to sustain good service levels, the City will need to make modest investments in condition assessment and replacement to identify, prioritize, and replace pipes in poor condition.

The current replacement cost of the potable and recycled water pipeline infrastructure[8] is $1.7 billion dollars. A summary of existing pipeline infrastructure and replacement costs are included in Table 3-2. The basis for this replacement cost estimate includes recent City and other utility bid costs and assumed soft costs for planning, design, legal, construction administration, ownership administration, and contingencies.

[6] The average break rate in California and Nevada is 9.7 per Folkman’s 2018 report titled Water Main Break Rates in the USA AND Canada: A Comprehensive Study.

[7] Variables that may cause accelerated deterioration include manufacturing quality, construction quality, internal pressure, external loading, and soil characteristics such as corrosivity and shrink-swell potential.

[8] The pipeline replacement cost includes both hard and soft costs for mains, services, and valves. The cost excludes pressure reducing stations, pump stations, tanks, and other facilities.

Table 3-2. Current Water Pipe Replacement Cost

Diameter (inches)	Total Unit Cost ($/mile)	Miles			Replacement Cost (Million)		
		Potable	Recycled	Total	Potable	Recycled	Total
6 or less	$1,725,000	48	11	58	$82	$19	$101
8	$1,875,000	211	29	240	$395	$54	$449
10	$2,100,000	56	1	57	$117	$3	$120
12	$2,250,000	72	19	91	$161	$42	$204
14	$2,625,000	10	1	11	$26	$3	$29
16	$3,000,000	30	3	33	$91	$8	$99
18	$3,150,000	4	3	7	$12	$10	$22
20	$3,525,000	1	2	2	$2	$5	$8
21	$3,863,000	3	-	3	$13	-	$13
24	$4,200,000	5	5	10	$21	$19	$41
27	$4,725,000	2	0.4	2	$8	$2	$10
30	$5,250,000	4	4	8	$22	$22	$44
33	$5,775,000	0.2	-	0.2	$1	-	$1
36	$6,300,000	4	-	4	$25	-	$25
42	$7,350,000	1	-	1	$7	-	$7
	Total	**450**	**78**	**527**	**$983**	**$187**	**$1,173**

Soft Costs Percentage of Construction Cost

Type	Percentage	Potable ($M)	Recycled ($M)	Total ($M)
Planning	3%	$29	$6	$35
Design	10%	$98	$19	$117
Legal	2%	$20	$4	$23
Construction Administration	15%	$147	$28	$176
Ownership Administration	5%	$49	$9	$59
Contingency	10%	$98	$19	$117
Total Soft Costs	45%	$442	$84	$528
Total Replacement Cost		**$1,425**	**$271**	**$1,701**

3.2 Pipelines, Valves, and Service Laterals

Over time, pipeline infrastructure (including mains, valves, and service laterals) will deteriorate, break more often, and ultimately will need to be replaced. This section establishes prudent, transparent, and justifiable CIP budgets to address aging potable and recycled water pipeline infrastructure. The CIP budget will enable the City to sustain desired services levels, maximize the life of existing infrastructure, and mitigate the risk of large and unplanned rate increases due to aging pipeline infrastructure.

3.2.1 Age-Based Forecast

An age-based pipeline renewal forecast was developed using unit costs established in Section 3.1, an assumed 2% annual inflation factor, City infrastructure installation years[9], and published useful life estimates from the America Water Works Association (AWWA) report titled *Buried No Longer: Confronting America's Water Infrastructure Challenge* as summarized in Table 3-3.

[9] Approximately one percent of infrastructure had an unknown installation year. The average installation year of City infrastructure is 1990. For budgeting purposes, it was assumed that this infrastructure was installed in the average installation year of known City infrastructure (1990).

Table 3-3. Age-Based Useful Life

Material	Assumed Useful Life (Years)	Miles
PVC	70	240.1
Asbestos Cement	75	234.5
Steel	95	37.3
Ductile Iron	100	12.0
PCCP	75	3.1
Cast Iron	75	0.3
Copper	30	0.2
HDPE	70	0.1

Table 3-4 summarizes the results of a 50-year age-based assessment renewal forecast for potable water and recycled water pipelines, valves and services. Including inflation, this method forecasts an average of $44.6 million dollars per year. The 50 year time horizon was used to account for significant additional potential age-based replacement in the 40 to 50 year timeframe. A summary of age-based forecasts for pipelines, reservoirs, and pump stations is included in Appendix D.

Table 3-4. 50-Year Age-based Renewal Forecast

Timeframe	Cost without Inflation (Million)	Cost with Inflation (Million)
Cumulative (FY19/20-FY69/70)	$1,055.0	$2,229.0
Average Annual (FY19/20-FY69/70)	$21.1	$44.6

3.2.2 Performance-Based Forecast

Figure 3-1 illustrates that age alone is a poor indicator of pipe condition and remaining useful life.

Figure 3-1. Age Alone is a Poor Indicator of Pipe Condition and Remaining Useful Life

Institutional knowledge and industry expertise[10] suggest that the City's infrastructure will last significantly longer than age-based estimates. To verify this, the City has initiated a water pipeline asset management program to measure infrastructure condition. This has included a system-wide leak detection program[11] and measurement of the remaining effective wall thickness at five locations[12]. While some pipes will deteriorate faster than others, this work has verified that on average, City infrastructure is in good condition and will last significantly longer than industry standard useful life estimates document in Section 3.2.1.

Pipeline Renewal

In an effort to establish prudent, transparent, and data driven investment levels that maximize the life of existing infrastructure, a benchmarking effort was initiated to compare City performance and investment levels to other similar utilities. Utilities were benchmarked based on break rate (i.e., annual breaks per 100 miles of pipe owned) and replacement rate measured as the percentage of the system replaced annually. For example, it would take 100 years to replace the entire system at a replacement rate of 1% per year. Figure 3-2, benchmarks the City's performance versus other similar utilities where the orange circle is the City and the blue diamonds represent these utilities:

- Vista Irrigation District
- San Dieguito Water District
- Rainbow Municipal Water District
- Padre Dam Municipal Water District
- Helix Water District
- Sweetwater Authority
- City of San Juan Capistrano
- Mesa Water District
- City of Buena Park
- City of Long Beach
- Contra Costa Water District

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[10] Approximately 90% of the City infrastructure is made up of AC and PVC pipe materials. The predominant vintages of AC pipe (installed 1970s and later) tend to last much longer than prior vintages of AC pipe due to advances in manufacturing. Additionally, soils conditions (e.g. low shrink-swell potential) and modest pressure fluctuations result in relatively low stress levels applied to pipes promoting longer than average useful life.

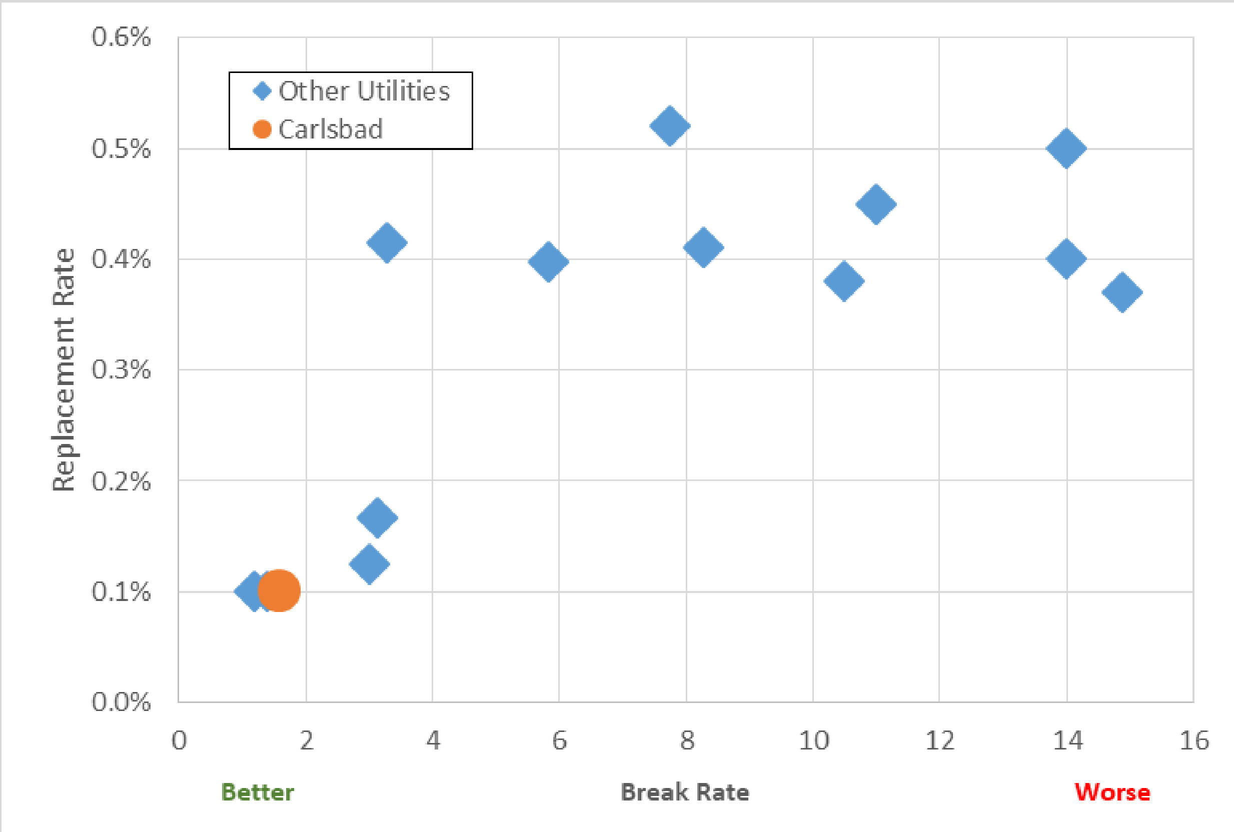
[11] Using acoustic sensors, the system was evaluated for active leaks. Over time, water leaks will accelerate pipe deterioration and eventually result in a break that disrupts service and the community. The leak detection effort identified a relatively small number of active leaks on City owned infrastructure and those leaks were concentrated in fittings and services as opposed to the main. These leaks were investigated and resolved.

[12] See Appendix H for a detailed discussion of the condition assessment sample results.

- East Bay MWD
- City of Phoenix
- Denver Water

A table of the results presented in Figure 3-2 is included in Appendix I.

Figure 3-2. Benchmarking of City Performance & Investment Levels



Each community must find the appropriate balance between service levels and near-term cost for their community. In general, systems that are performing well do not require significant investment levels. However, as pipes deteriorate and break more often, increased investments in pipeline replacement are warranted. Figure 3-3 quantifies this relationship for the utilities that were benchmarked.

Figure 3-3. System Performance verses Investment Level Relationship

Currently, the City break rates are good relative to other utilities benchmarked. However, as this infrastructure continues to age and deteriorate, break rates will increase and the City should consider increasing investment levels to sustain desired service levels. To quantify how the performance of City infrastructure may deteriorate over the next fifty years, pipes were categorized into three asset classes (AC, PVC, and metallic) and readily available deterioration curves from other utilities with similar pipe vintages were leveraged. For example, Figure 3-4 shows how AC pipe at Vista Irrigation District have deteriorated as they age. Currently, City AC pipes are breaking at a rate of 2.1. This curve was used to estimate City AC breaks rates in the future. For example, this curve was used to estimate the increase in City AC break rates from 2.1 to 6.1 over the next twenty years.

Figure 3-4. Deterioration of AC Pipe at Vista Irrigation District

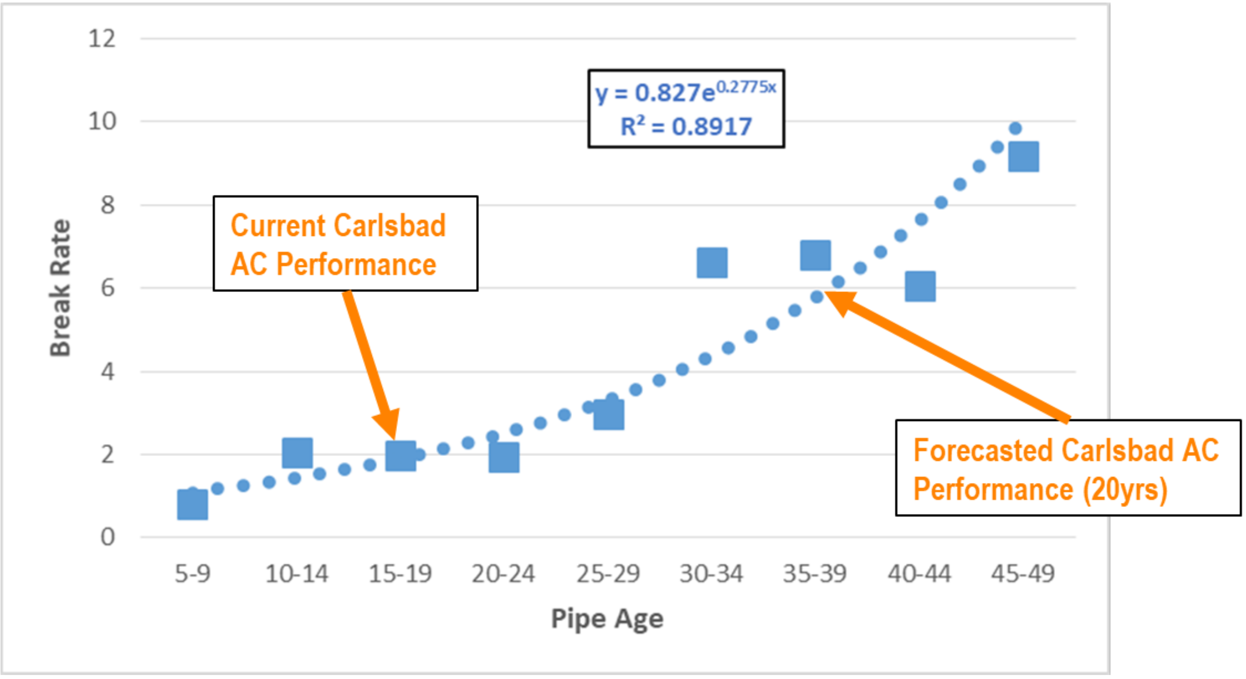
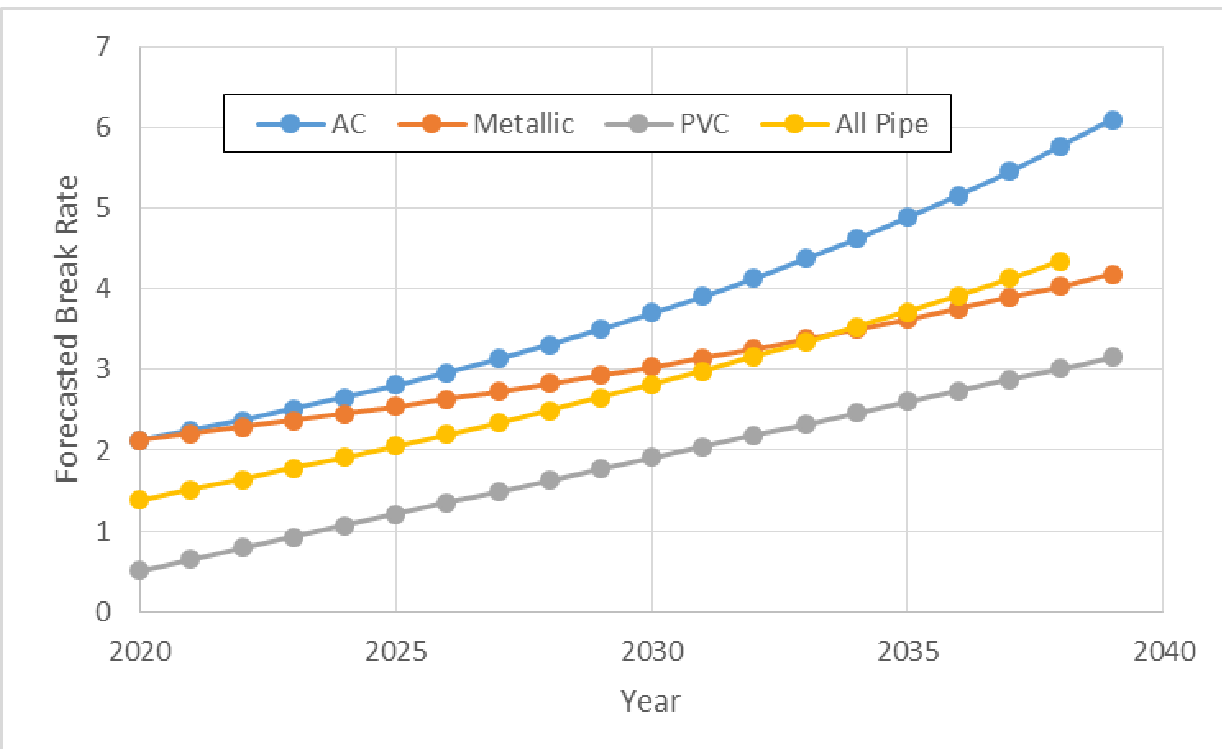


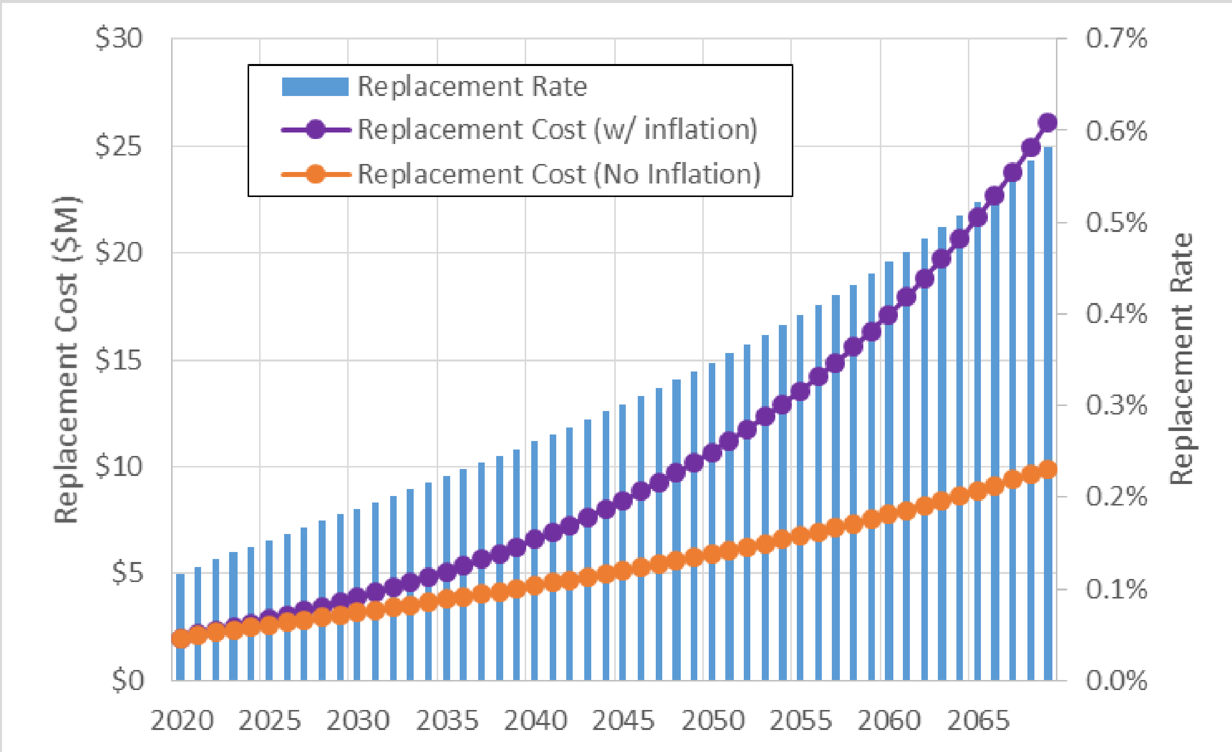
Figure 3-5 summarizes the twenty year forecasted break rate for each City asset class as well as an “All Pipe” break rate which considers the quantity of each material class to estimate overall system performance.

Figure 3-5. Forecasted Deterioration of City Pipelines



The All Pipe break forecast was applied to estimate investment needs over the next 50 years. Figure 3-6 summarizes these investment needs by replacement rate and replacement cost with and without a 2% inflation factor.

Figure 3-6. 50-year City Pipeline Replacement Forecast



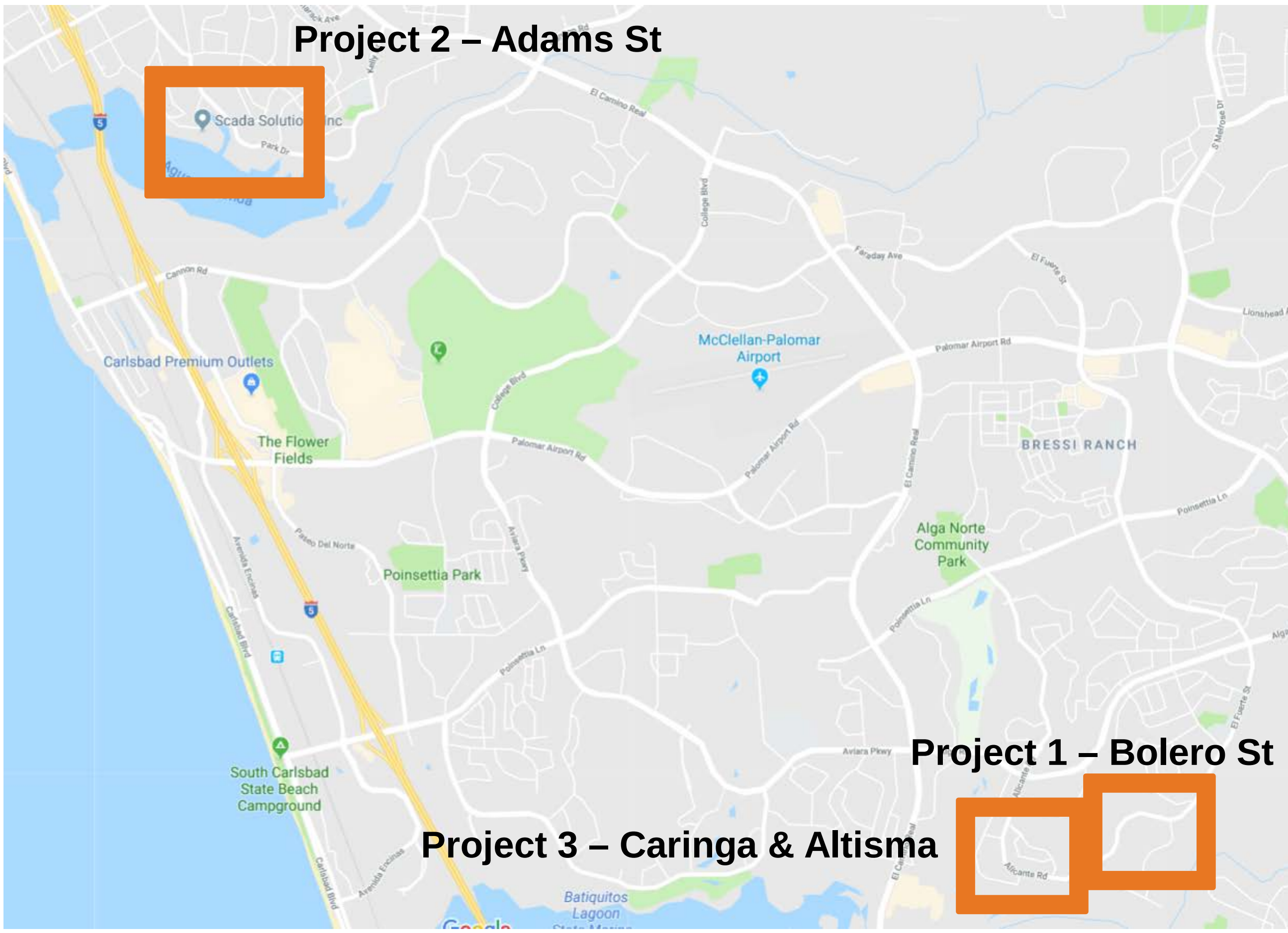
The recycled water system is performing approximately three times better than the potable water system. Over the next 50 years, the long term forecast model indicates that approximately 89% of all water pipeline investments should be targeted to the potable system and the remaining 11% should be targeted to the recycled water system. Since the recycled water system is relatively young, near term investments are expected to be even more focused on the potable water system.

Pipeline Renewal Projects

While most City pipeline infrastructure is expected to last well beyond the average published useful life estimates from AWWA, the useful life of particular pipes can vary significantly depending on manufacturing quality, installation quality, variations in deterioration factors (e.g. soil corrosivity, water corrosivity, presence of ground water), and variations in pipe stresses (e.g. pressure, ground movement, external loading).

Readily available data was evaluated[13] to identify potential near-term pipe replacement candidates. These projects were reviewed with staff to identify and remove any projects where a current renewal project was already planned and budgeted. The result was the identification of three near-term replacement projects shown in Figure 3-7. The basis for each project is described in more detail below. **The total cost of these projects is expected to be approximately $8.0 million dollars.** The recommended pipe renewal budget is included in Chapter 3.3 of this report and should allow enough budget to identify one additional pipeline replacement project in the 5-year budget if a new problem pipe emerges.

Figure 3-7. Near-term Pipeline Replacement Project Map



[13] Project renewal identification included a review of clusters of main breaks and service breaks which may indicate the pipe is nearing the end of its useful life. The consequence of failure, pipe construction quality, stress factors (e.g. pressure, ground movement), and the accessibility of pipes were evaluated. Additional information such as leak detection and condition assessment data was used where it was readily available.

Project 1 – Bolero Street

The first project identified has a mainline performance issue on Bolero Street, just south of El Fuerte Street. An aerial map of the project location is included in Figure 3-8. This 12-inch AC pipe was installed in 1975 by a single contractor. The pipeline is installed along a relatively steep slope which causes large pressure changes. Pipes are symbolized as:

- Dark blue lines – Pipes exposed to lower pressures at the top of the hill along Acuna Court
- Light blue lines - Pipes exposed to moderate pressures.
- Purple lines - Pipes at the bottom of the hill that are exposed to high pressures.

Pressure reducing valves are symbolized in orange. The pipe south of those pressure reducing valves are exposed to low pressure and are symbolized as dark blue. The main line pipe breaks in this area (red stars) are concentrated in the portion of this project that is exposed to high pressure. Therefore, the condition of the pipe in this project may be similar, however since the pipes in purple experience much higher stresses, breaks are concentrated in those areas. One additional break has occurred on the moderate pressure pipe. Three service breaks (yellow stars) have occurred in the cul-de-sacs off of El Fuerte and Bolero. Breaks in this area can be particularly consequential due to the relatively steep slope, high pressure, large diameter, and brittle pipe material[14]. Since this area has a relatively high consequence of failure and high concentration of breaks, a pipeline replacement project is recommended. The approximate boundaries of the replacement project should include the purple and light blue pipes as well as the associated services and appurtenances. The dark blue lines likely have significant useful life remaining since they are experiencing much lower pressures. Therefore, the replacement of the dark blue lines is not recommended. Based on the unit costs in Section 3.1, the estimated cost of this project is summarized in Table 3-5. The cost and length is summarized by the type of issue addressed including condition and access issues. The exact extents of the project should be finalized during design of this pipe replacement.

[14] A brittle pipe that fractures generally damages more property and is more difficult to repair than an equally-sized ductile pipe that merely “leaks.” AC and PVC pipe often fracture during failure. Steel and ductile iron are more likely to leak.

Figure 3-8. Map of Project 1 – Bolero Street

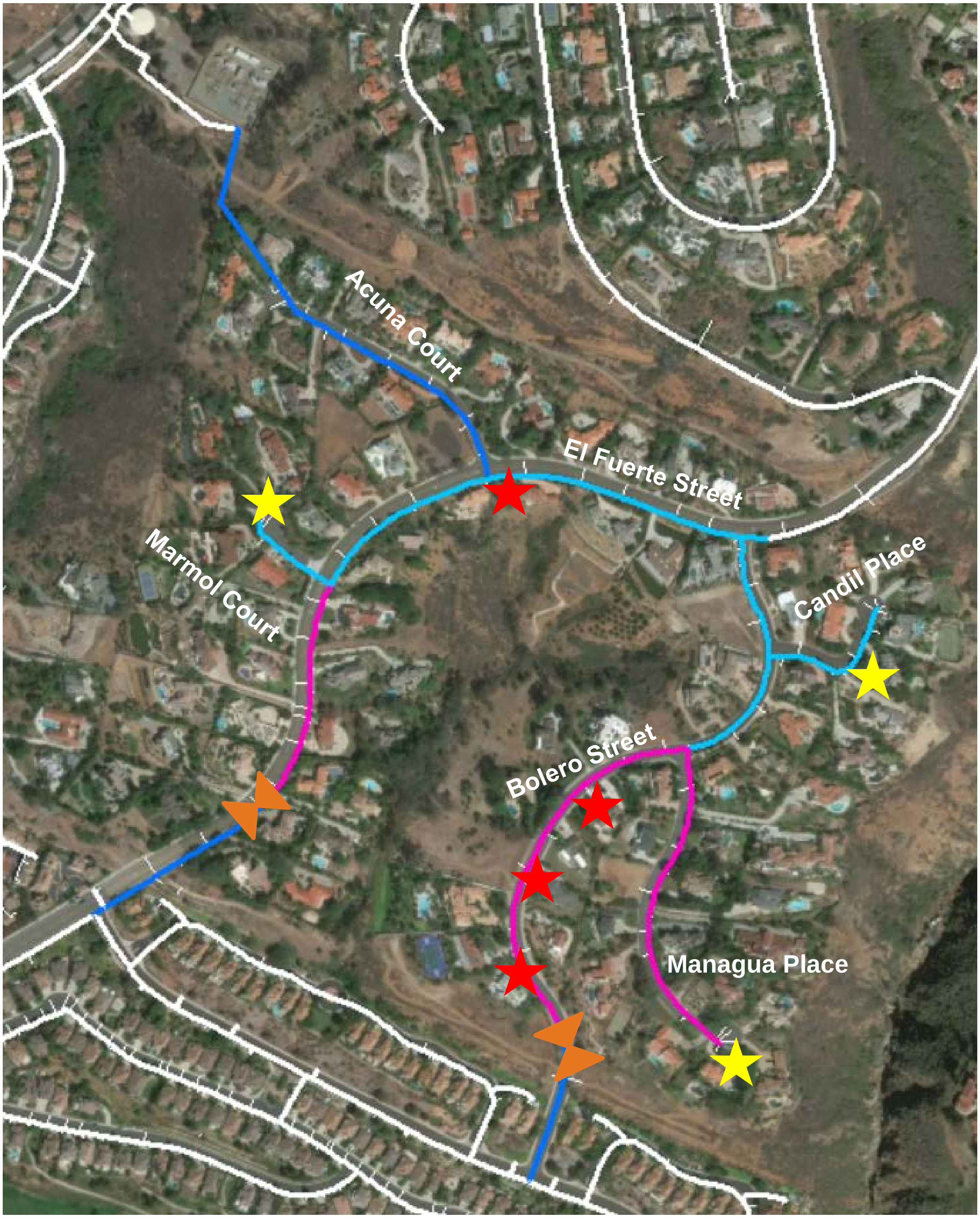


Table 3-5. Opinion of Cost for Project 1 – Bolero Street

Diameter (inches)	Total Unit Cost ($/mile)	Miles			Replacement Cost (Million)		
		Condition	Access	Total	Condition	Access	Total
8	$1,875,000	0.33	0	0.33	$0.62	$0	$0.62
12	$2,250,000	0.76	0	0.76	$1.72	$0	$1.72
Construction Cost		1.10	0	1.10	$2.34	$0	$2.34
Soft Costs (% of construction cost)						**Percentage**	**Total ($M)**
Planning, Design Legal, Construction Admin, Contingency						45%	$1.05
Total Replacement Cost							**$3.40**

Project 2 – Adams Street

Project 2 identified a mainline performance issue on Adams Street near Park Drive and Cove Drive. An aerial map of the project location in is included in Figure 3-9. This 10-inch AC pipe was installed in 1969. There have been five mainline breaks (red stars) and two service breaks (yellow stars) on the pipe. The pipe in Adams runs along a short but steep slope as shown in Figure 3-10. A difficult to access pipe traverses this slope and ties into a pipe on Cove Drive to provide some limited redundancy in the area.

Figure 3-9. Map of Project 2 – Adams Street

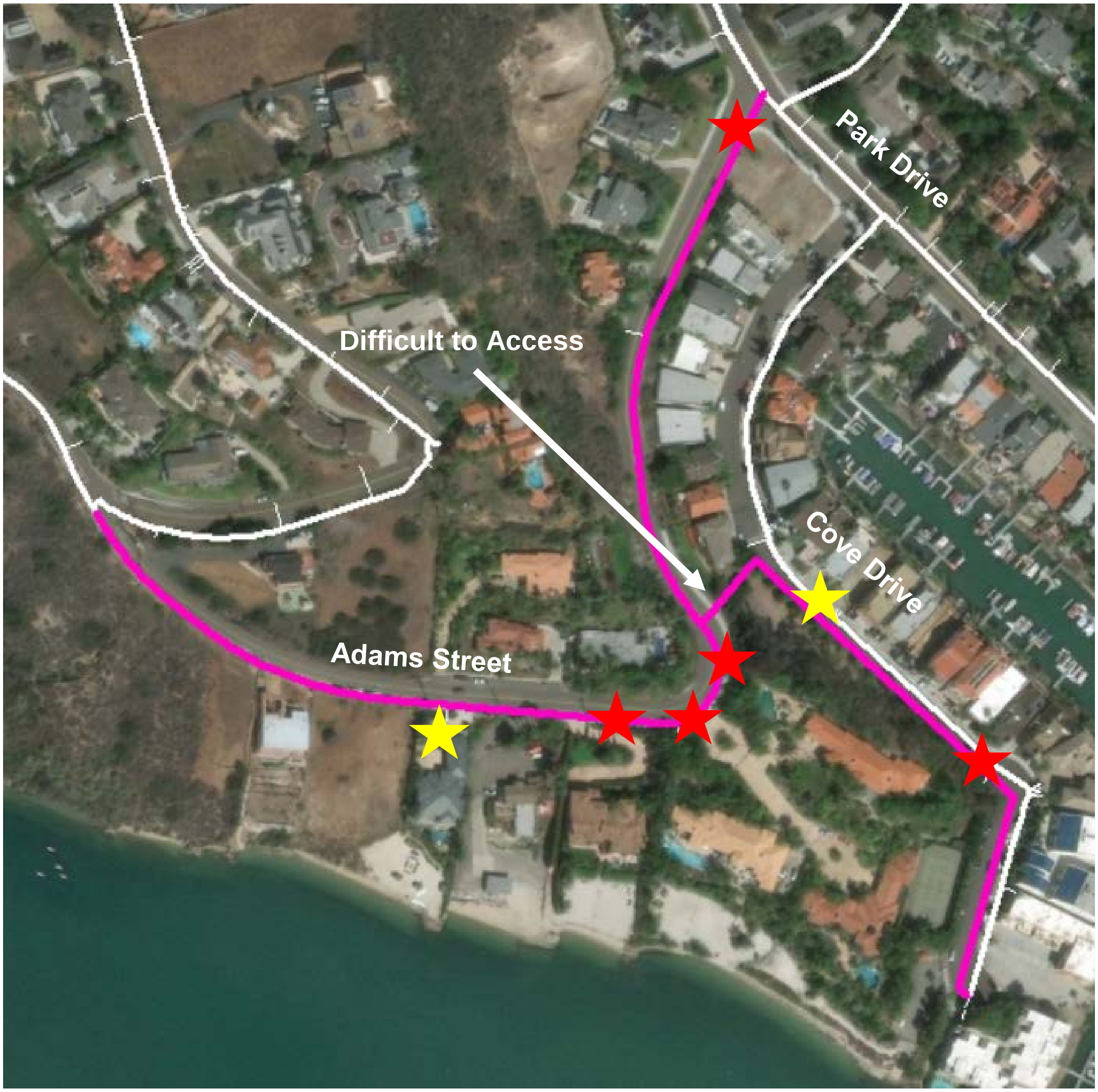


Figure 3-10. Map of Difficult to Access Pipe

Breaks in this area can be particularly consequential due to the relatively steep slope, large diameter, environmental impacts due to the proximity to Agua Hedionda, and brittle pipe material[15]. Since this area has a relatively high consequence of failure and high concentration of breaks, a pipeline replacement project is recommended. The approximate boundaries of the replacement project should include the purple line as well as the associated services and appurtenances shown in Figure 3-9. Based on the unit costs in Section 3.1, the estimated cost of this project is summarized in Table 3-6. The exact extents of the project should be finalized during design of this pipe replacement. In particular, the design should consider options to relocate the limited access pipe while considering any tradeoffs in terms of loss of redundancy. In addition to condition and access issues, the Water Master Plan identifies potential projects to address fire flows. During design, these pipes identified for fire flow improvements should be considered.

[15] A brittle pipe that fractures generally damages more property and is more difficult to repair than an equally-sized ductile pipe that merely "leaks." AC and PVC pipe often fracture during failure. Steel and ductile iron is more likely to leak.

Table 3-6. Opinion of Cost for Project 2 – Adams Street

Diameter (inches)	Total Unit Cost ($/mile)	Miles			Replacement Cost ($M)		
		Condition	Access	Total	Condition	Access	Total
10	$2,100,000	0.49	0.03	0.52	$1.03	$0.06	$1.09
	Construction Cost	0.49	0.03	0.52	$1.03	$0.06	$1.09
					Soft Costs (% of construction cost)	**Percentage**	**Total ($M)**
					Planning, Design Legal, Construction Admin, Contingency	45%	$0.49
						Total Replacement Cost	**$1.58**

Project 3 – Caringa & Altisma

Project 3 identified a mainline performance issue near the intersection of Caringa Way and Altisma Way. An aerial map of the project location is included in Figure 3-11. This 6-inch and 8-inch AC pipe was installed in the early 1970s. Five main breaks (red stars), two service breaks (yellow stars), and two leaks (pink triangles) were documented in this area. Breaks in this area can be particularly consequential due to the brittle pipe material[16] and difficult to access areas. A summary of the difficult to access (DTA) areas are included below. Pipes are symbolized as:

- Red lines – Pipes with a condition issue
- Yellow lines - Pipes with an access issue.
- Orange lines - Pipes both an access and a condition issue.

[16] A brittle pipe that fractures generally damages more property and is more difficult to repair than an equally-sized ductile pipe that merely “leaks.” AC and PVC pipe often fracture during failure. Steel and ductile iron is more likely to leak.

Figure 3-11. Map of Project 3 – Caringa & Altisma

DIFFICULT TO ACCESS #1

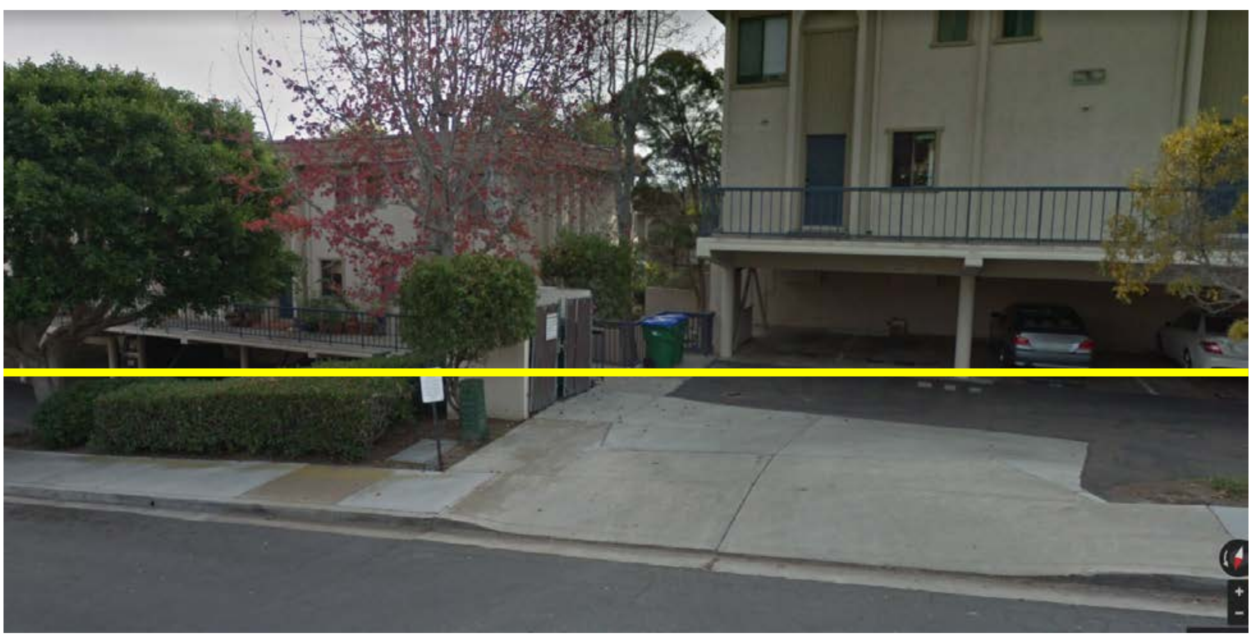
Difficult to Access area number one (DTA #1) includes a pipe that runs under a narrow, tree lined walkway that runs through a condominium complex as shown in Figure 3-12. During design, consider addressing this access issue and alternatives to relocate the main into the driveway to enable the City to access, maintain, and repair the infrastructure.

Figure 3-12. Picture of Difficult to Access Area #1

DIFFICULT TO ACCESS #2

Difficult to Access area number two (DTA #2) includes a pipe that runs under a car port roof structure and traverses under several retaining walls as shown in Figure 3-13. During design, consider addressing this access issue and consider alternatives to relocate the main into the street to avoid the roof structure and retaining walls and enable the City to access, maintain, and repair the infrastructure.

Figure 3-13. Picture of Difficult to Access Area #2



DIFFICULT TO ACCESS #3

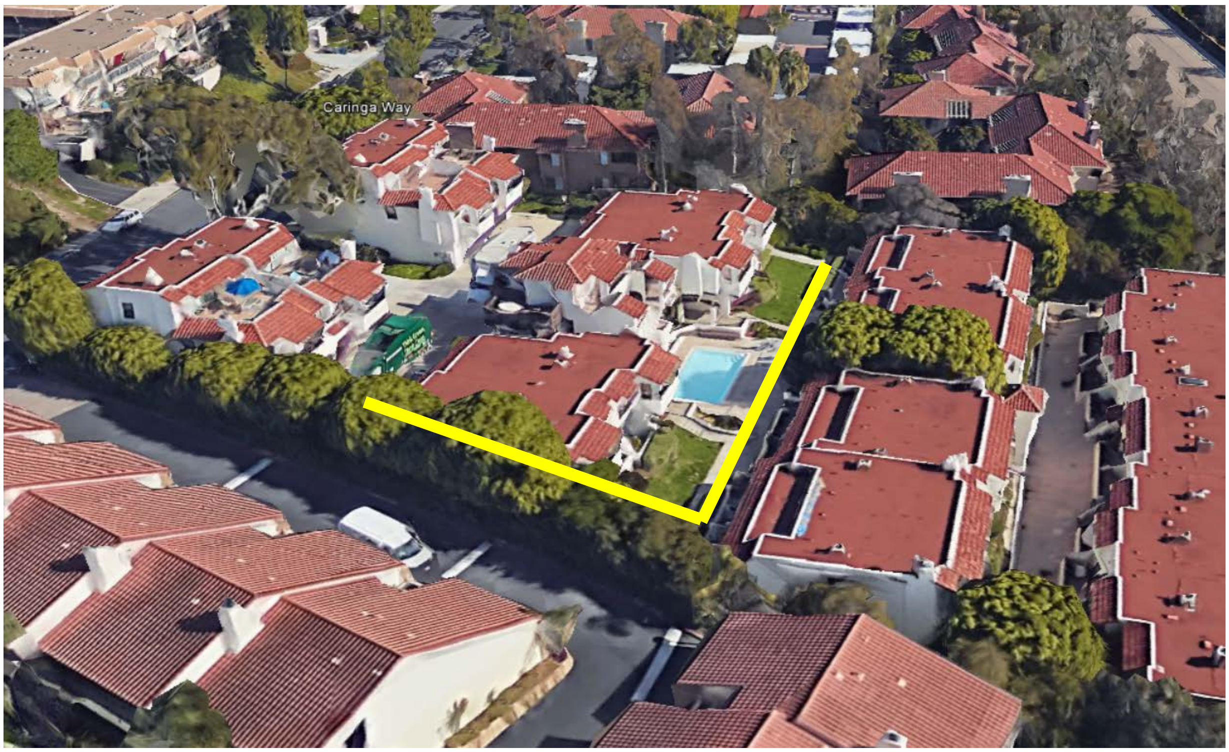
Difficult to Access area number three (DTA #3) includes multiple pipes that run between narrow gaps within a condominium complex as shown in Figure 3-14. During design, consider addressing this access issue and alternatives to relocate the main into the street to enable the City to access, maintain, and repair the infrastructure or transfer ownership.

Figure 3-14. Picture of Difficult to Access Area #3

DIFFICULT TO ACCESS #4

Difficult to Access area number four (DTA #4) includes a pipe that runs between narrow gaps within a condominium complex and pool as shown in Figure 3-15. During design, consider addressing this access issue and consider alternatives to relocate the main or transfer ownership to enable the City to access, maintain, and repair the infrastructure.

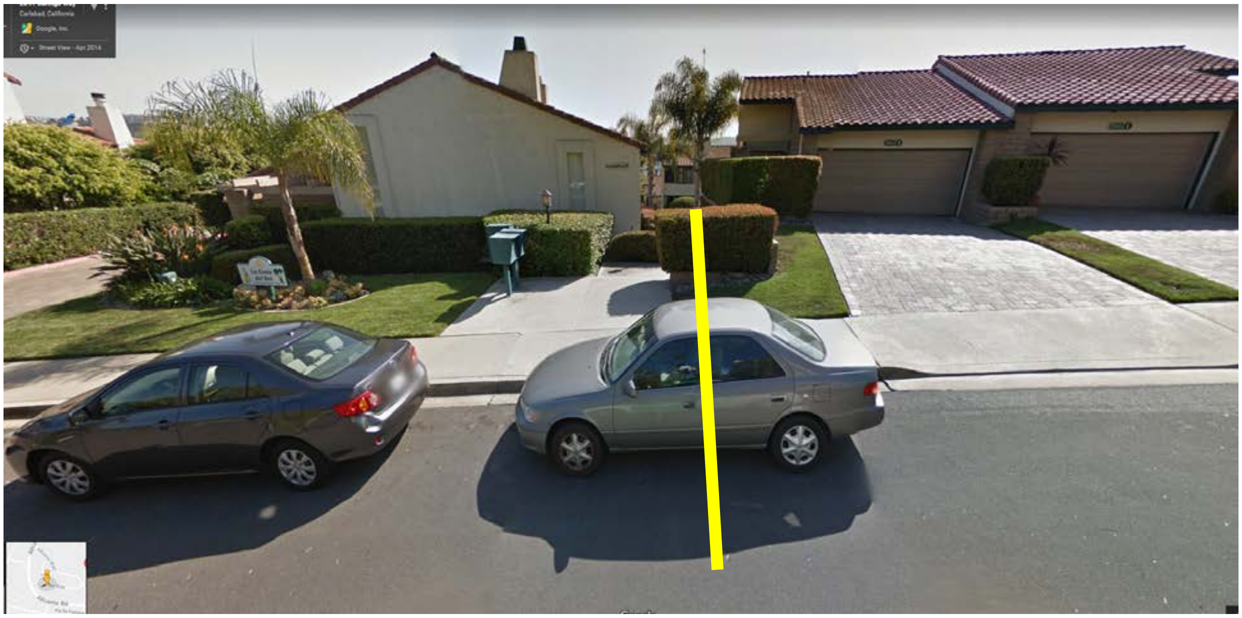
Figure 3-15. Picture of Difficult to Access Area #4



DIFFICULT TO ACCESS #5

Difficult to Access area number five (DTA #5) includes a pipe that runs between a narrow gap within a condominium complex as shown in Figure 3-16. During design, consider addressing this access issue and alternatives to relocate the main into the driveway to enable the City to access, maintain, and repair the infrastructure.

Figure 3-16. Picture of Difficult to Access Area #5



DIFFICULT TO ACCESS #6

Difficult to Access area number six (DTA #6) includes a pipe that runs between a narrow gap within a condominium complex as shown in Figure 3-17. During design, consider addressing this access issue and consider alternatives to relocate the main into the driveway to enable the City to access, maintain, and repair the infrastructure.

Figure 3-17. Picture of Difficult to Access Area #6

PROJECT #3 RECOMMENDATION

Since Project #3 has a relatively high consequence of failure and high concentration of breaks, a pipeline replacement project is recommended. The approximate boundaries of the replacement project should include the red and orange pipes and should consider alternatives to address the difficult to access pipes in Figure 3-11. Based on the unit costs in Section 3.1, the estimated cost of this project is summarized in Table 3-7. The exact extents of the project should be finalized during design of this pipe replacement.

Table 3-7. Opinion of Cost for Project 3 – Caringa & Altisma

Diameter (inches)	Total Unit Cost ($/mile)	Miles			Replacement Cost (Million)		
		Condition	Access	Total	Condition	Access	Total
6 or less	$1,725,000	0.17	0.37	0.54	$0.29	$0.64	$0.93
8	$1,875,000	0.61	0	0.61	$1.14	$0	$1.14
Construction Cost		0.78	0.37	1.15	$1.43	$0.64	$2.07
Soft Costs (% of construction cost)						**Percentage**	**Total ($M)**
Planning, Design Legal, Construction Admin, Contingency						45%	$0.93
Total Replacement Cost							**$3.00**

Inaccessible Infrastructure

A significant portion of City water main infrastructure is located in areas that are difficult for City staff to access, maintain, and repair the infrastructure. City staff have developed a planning level map of known inaccessible areas which is included in Appendix F and the current replacement cost of this infrastructure based on this map and replacement unit costs presented in Section 3.1 is $55 million. However the actual cost to eliminate this access issue is likely significantly higher as pipes that currently run through inaccessible areas often take the shortest path. Relocating this infrastructure to accessible areas such as streets would likely increase the costs. Some of the inaccessible infrastructure also provides important system redundancy and improves water quality. Quantifying the most cost effective alternative would require a significant amount of planning and design and in some cases, the analysis may conclude that the current configuration is optimum.

In order to cost effectively mitigate inaccessible infrastructure in the near-term, it is recommended that project specific evaluations of adjacent inaccessible infrastructure be conducted during the planning and design of pipeline replacement projects that are triggered for another reason (e.g. break history, condition, capacity constraint, water quality, growth). In this way, inaccessible infrastructure issues can be evaluated and mitigated as part of construction to minimize cost as well as the impact to the community during construction.

In Section 3.2.2, this approach was incorporated into the pipeline replacement planning process. Of the infrastructure recommended for replacement, 2.37 miles were based on condition and 0.40 miles (i.e. 17% more pipes) were triggered because inaccessible pipe was near a recommended construction project. In order to budget for addressing inaccessible infrastructure in the future, the factor observed in the planning of these projects (17%) was applied to performance-based pipeline renewal budget documented in Section 3.2.2 to identify a budget of $337,000 per year to address access issues.

Pipeline Condition Assessment

A targeted pipeline condition assessment program will support cost effective system management and risk mitigation by:

- extending the life of some pipes found to be in good condition,
- preventing unnecessary breaks in other pipes found to be in poor condition,
- identifying the most cost-effective renewal technology and project extents, and
- increasing confidence in decision making.

The purpose of this section is to quantify future condition assessment strategies, budgets, and near-term priorities at a planning level. The City should move forward with plans to develop a tactical pipeline condition assessment plan which will build off of this effort to further define projects, priorities, and the most cost effective way to leverage this budget. The planning level condition assessment strategy has been developed based upon pipeline material and diameter. A summary of the City’s pipeline condition assessment forecast is included in Table 3-8. A description of assumptions used in the development of this forecast are included below. The unit costs used in this section are based on recent similar work at other utilities and is intended to be used for systematic planning and budgeting. Project specific costs will vary based on the unique operating context of each pipe.

Table 3-8. Opinion of Cost for 30-year Condition Assessment Program

Condition Assessment Task	Quantity Assessed		Cost		
	Value	Units	Cost per Unit	Total	Annual
Plastic					
Failure Analysis	0.5	ea/yr	$6,000	$3,000	$3,000
Asbestos Cement					
Testing	20	ea/yr	$1,250	$25,000	$25,000
Analysis	1	ea/yr	$25,000	$25,000	$25,000
Metallic					
Tactical Condition Assessment Plan	1	ea	$200,000	$200,000	$7,000
Soil Survey: 10-inches and larger	49	miles	$13,200	$646,000	$22,000
Assessment: 10-inch to 16-inch	15	miles	$74,000	$1,144,000	$38,000
Assessment: 18-inches and larger	33	miles	$275,000	$9,177,000	$306,000
Assessment: 8-inch and smaller	5	miles	$79,000	$410,000	$14,000
				Total Annual Cost	**$440,000**

Plastic Pipe Condition Assessment Budget

Approximately 45% of the City's system is plastic. Currently, the industry does not have a proven and industry accepted method for proactive condition assessment of plastic pipe. However, an opportunistic condition assessment focused on identifying the root cause of failure has proven to be cost effective. Plastic pipe has a low break rate compared with other materials, however when multiple breaks occur on a plastic pipe this can be an indicator of poor manufacturing and/or construction techniques and future breaks. In these cases, the City should perform a failure analysis on the pipe sample. This analysis may include the following:

- Measurement per ASTM D2122
- Visual and microscopic examination of the pipe and fracture surfaces
- Acetone immersion testing per ASTM D2152
- Heat reversion test per ASTM F1057
- Tensile testing per ASTM D638
- Izod impact testing per ASTM D256

An example of this failure assessment is shown in Figure 3-18. These tests should be performed by a laboratory with experience testing plastic pipe. For budgeting purposes, it is assumed that one PVC sample will be assessed every other year. The estimated cost of each assessment is $6,000 or approximately $3,000 per year.

Figure 3-18. Example of Plastic Pipe Failure Analysis

Asbestos Cement Condition Assessment Budget

Approximately 45% of the City's system is asbestos cement (AC). Based on industry research[17], Appendix G summarizes how AC pipe corrodes and how that corrosion can be measured through Energy Dispersive Spectroscopy (EDS) testing. Proactive condition assessment of AC pipe can be expensive and disruptive to the community because the pipe must be isolated, exposed, and a sample from the pipe must be taken. However, when a pipe is exposed for another reason (e.g. service tap, break, valve replacement, pipe replacement), it provides a unique opportunity to cost effectively gather EDS data since roughly 90% of the cost of testing is in accessing the pipe.

In order to cost effectively manage aging AC pipe, the City is implementing an Opportunity Condition Assessment Program (OCAP). As part of the valve replacement program, the City has an experienced laboratory perform EDS testing. At the time of this report, five samples have been tested and associated to a pipe. As documented in Appendix H, the results of these tests have shown that four of the five pipes are in good condition and one pipe has shown modest signs of deterioration. All five samples have at least 70% of the design wall thickness remaining and are expected to have decades of remaining useful life.

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[17] Based on Water Research Foundation Project 4480 Development of an Effective Management Strategy for Asbestos Cement Pipe.

The City should continue to perform EDS testing during valve replacement. This cost is already embedded in the valve replacement budget. The City should also begin to collect and test AC when other opportunities arise such as break response and service taps. Assuming approximately 20 additional samples are collected and tested per year at a cost of approximately $1,250 each and approximately $25,000 per year is budgeted for support in data management, training, and decision making; the cost of the AC condition assessment program is approximately $50,000 per year.

Metallic Pipe Condition Assessment Budget

While only 10% of the City's system is metallic, many of these pipes are larger and more critical transmission mains which should be managed proactively. For budgeting purposes, it is assumed that each metallic pipe 6-inches and larger[18] will be assessed once every thirty years using non-destructive testing. For pipes 10-inches and larger, it is assumed that a soil corrosivity assessment (shown in Figure 3-19) will be performed to support condition assessment prioritization at a cost of $2.50 per foot.

Figure 3-19. Example of Soil Survey

For pipes 10-inches to 16-inches, it is assumed that close-interval survey (or cell-to-cell testing in paved areas) will be used to measure the location and severity of active corrosion (shown in Figure 3-20). This information will be used to determine whether excavation and measurement of pipe wall thickness is warranted. Assuming on average a modest number

[18] Metallic mains smaller than 6-inches make up only 0.06% of the system. They typically have a lower consequence of failure and do not have a cost effective condition assessment technology. Therefore, no condition assessment program is warranted.

of excavation are triggered (shown in Figure 3-21), this work is estimated to cost approximately $14 per foot. It is assumed that this data will be sufficient to make renewal decisions on pipes 10-inches to 16-inches.

Figure 3-20. Example of Close-Interval Survey

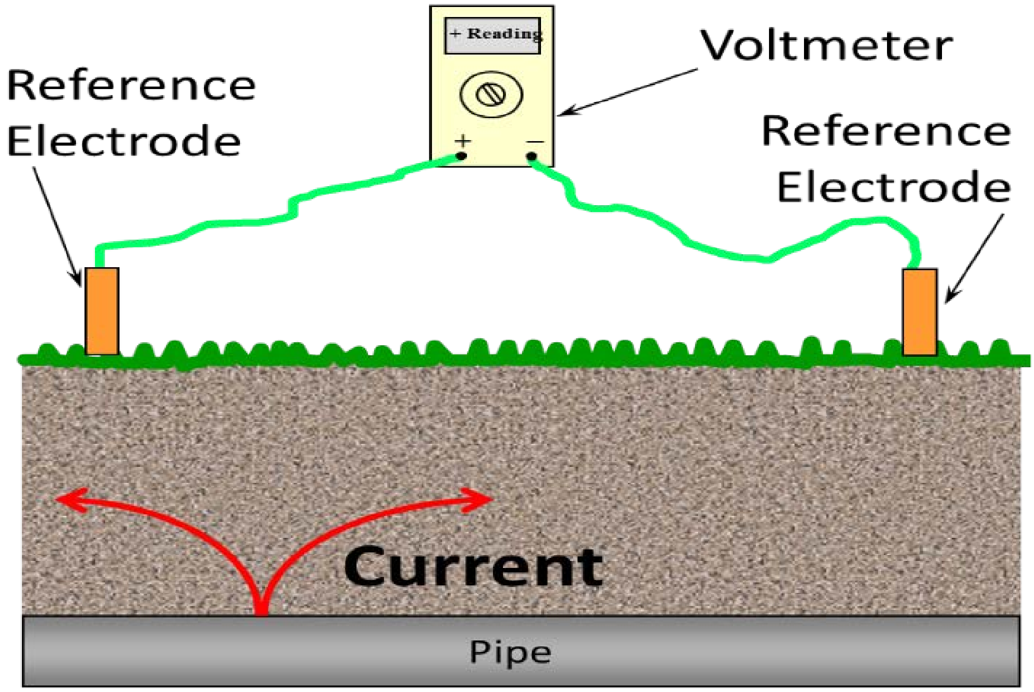


Figure 3-21. Example of Targeted Excavation and Measurement of Pipe Wall Thickness

For pipes 18-inches and larger that are often more critical and expensive to replace, it is assumed that higher resolution in-pipe electromagnetic technology will be required to make prudent and justifiable decisions (shown in Figure 3-22). This work is estimated to cost approximately $52 per foot.

Figure 3-22. Example of In-Pipe Electromagnetic Technology

For 6-inch and 8-inch pipes, a similar high resolution technology can be employed at a reduced cost since access may be achieved through a fire hydrant (shown in Figure 3-23). The estimate unit cost for these pipes is approximately $15 per foot.

Figure 3-23. Example of Small Diameter In-Pipe Electromagnetic Technology

Initial Metallic Pipe Condition Assessment Priorities

Based on break history and institutional knowledge, a preliminary list of near term metallic pipe condition assessment projects were identified and prioritized. This is summarized in Table 3-9. The highest priority project was identified as an 8-inch metallic pipe within the airport. This is a relatively short pipe with a significant portion of the cost embedded in mobilization of the contractor. If the City proceeds with this project, they should also consider executing other high priority condition assessment projects as part of a larger project that will use the same technology[19] to obtain more value from contractor mobilization.

[19] Other high priority projects that use the same technology include project number 4 and 5.

Table 3-9. Initial Metallic Pipe Condition Assessment Prioritization

Project #	Description	Priority	Condition Assessment Type	Length (ft)
1	8" Pipe in Airport Site[20]	1	Assessment: 8-inch and smaller	2,500
2	8" El Camino 490 Pipe	2	Assessment: 8-inch and smaller	3,000
3	20" & 24" Cannon Rd Recycled Pipe	2	Assessment: 18-inches and larger	13,500
4	24" & 27" Stl from Maerkle to El Camino	2	Assessment: 18-inches and larger	8,000
5	Parallel 18" pipes southeast of tank on Janis Way	3	Assessment: 18-inches and larger	2,000
6	Pipe Crossing Railroad & Major Roads	4	Assessment: 8-inch and smaller	Unknown
7	16" Stl Cannon Rd	5	Assessment: 10-inch to 16-inch	9,000
8	27" Stl Palomar Airport Rd	5	Assessment: 18-inches and larger	6,500
9	36" CMLC Santa Fe 2	5	Assessment: 18-inches and larger	3,500
10	14" Stl Valley St.	6	Assessment: 10-inch to 16-inch	1,300

Pipeline Cathodic Protection

The primary driver for metallic pipe deterioration is corrosion. Cathodic protection can slow corrosion and extend the useful life of pipeline infrastructure. The City has previously budgeted approximately $1 million dollars for development and implementation of a cathodic protection program. It is assumed that this budget will be spent over the next five years and that approximately $50,000 per year will be required to maintain the cathodic protection system after the first five years based on cathodic protection maintenance contracts for similar utilities.

Valve Replacement

While the City's pipeline infrastructure on average is expected to last well over one-hundred years, the City's valves will occasionally fail. These failures may include leakage, inoperability, and the inability to perform their primary function of isolating flow. This function is important to limit the consequence of system failures and support operation and maintenance of the system. Recently, the City has budgeted approximately $1 million for valve replacement. This investment has been able to stabilize the backlog of known inoperable valves. Since valve replacement is less efficient than pipe replacement (which includes replacing adjacent valves, services, and other appurtenances creating opportunities for efficiency), it is ideal to limit valve replacement to inoperable valves and adjacent high priority valves. With this in mind, it is recommended that the valve replacement budget be continued in the near term and periodically reevaluated to verify

[20] Length unknown; Consider potential future airport improvements.

these investment levels enable the City to sustain a manageable backlog of inoperable valves.

3.2.3 Recommended Investment Levels

Figure 3-24 shows the cumulative annual investment need over the next 50 years by investment type without inflation:

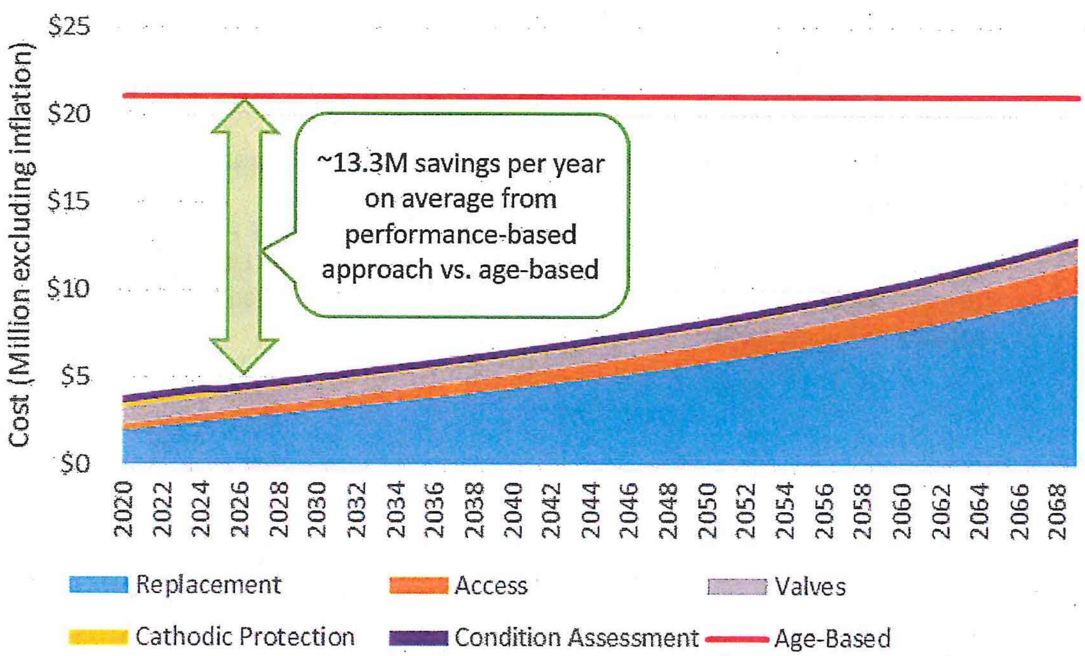
- Replacement – Pipe replacement due to condition and performance issues. During replacement, adjacent valves, services, and other appurtenances will also be replaced.
- Access – When a pipe replacement project is triggered, the cost to address additional access issues in a single project.
- Valves – The cost to replace critical inoperable valves when the adjacent pipe has significant remaining useful life.
- Cathodic Protection – The cost to develop and maintain cathodic protection systems to extend the life of metallic pipe.
- Condition Assessment – The cost to perform non-destructive condition assessment and ensure the right pipes are replaced at the right time.

Table 3-10 shows the summary performance-based forecast over the next 50 years compared to the age-based forecast without inflation. Figure 3-24 and Table 3-10 show that the City will save approximately $665 million dollars without inflation in unnecessary pipe replacement (an average of $13.3 million per year over 50 years) by moving to a performance-based program. Appendix J includes a table of the results presented in Figure 3-24.

Table 3-10. Renewal Forecast Comparison

Forecast	Timeframe	Cost without Inflation (Million)	Cost with Inflation (Million)
Age-based	FY19/20-FY69/70	$1,055.0	$2,229.0
Performance-based	FY19/20-FY69/70	$389.2	$807.3
Savings		$665.8	$1,421.7

Figure 3-24. Savings by Evolving from an Age-based to Performance-based Program



3.3 CIP Recommendations

Based on Section 1.2, the recycled water system is performing approximately three times better than the potable water system. Over the next 50 years, the long term forecast model indicates that approximately 89% of all water pipeline investments should be targeted to the potable system and the remaining 11% should be targeted to the recycled water system. Since the recycled water system is relatively young, near term investments were expected to be even more focused on the potable water system. This proved to be true as all three near-term replacement projects identified were in the potable water system. The 89% to 11% split in forecasted investment needs was applied to the remaining 15-year CIP recommendations as well as the other investment categories (valve replacement, condition assessment, and cathodic protection). The resulting 15-year CIP recommendation for pipelines, valves, and service laterals is summarized in Table 3-11. These costs include 2% inflation.

There are several AMP related CIP projects in the current 15 year CIP program. Updates are included in this section for the following CIP projects:

- CIP Project ID 39041 Water Pipeline Replacement and Rehabilitation Program
- CIP Project ID 50191 Water Valve Repair/Replacement Program
- CIP Project ID 50351 Limited Access Pipeline Relocation Program
- CIP Project ID 50241 Reservoir Repair and Maintenance Program
- CIP Project ID 50511 Water Infrastructure Condition Assessment Program

- CIP Project ID 52111 Recycled Water Condition Assessment Program
- CIP Project ID 52121 Recycled Water Valve & Appurtenance Replacement Program

The following CIP Project was discussed and City staff indicated the current CIP budget is appropriate at this time.

- CIP Project ID 50201 Pressure Reducing Station Program

New potential CIP projects were identified for recycled water pipeline replacement and cathodic protection as a result of splitting pipeline related costs between potable water and recycled water in the forecast. These projects could be combined with other projects in the forecast or kept separate.

Table 3-11. CIP Forecast for Potable & Recycled Water Pipelines, Valves and Service Laterals

CIP Project ID	System	Project Title	Year 1 2019-20	Year 2 2020-21	Year 3 2021-22	Year 4 2022-23	Year 5 2023-24	Year 6-10 2025-29	Year 11-15 2030-34
39041 and 50351	Potable	Identified Pipeline Replacement & Access Issue Resolution	$2,320,000	$2,530,000	$2,730,000	$640,000	$0	$0	$0
39041 and 50351	Potable	Miscellaneous Pipeline Replacement & Access Issue Resolution	$0	$0	$0	$2,050,000	$2,800,000	$17,390,000	$23,580,000
50191	Potable	Miscellaneous Valve Repair & Replacement	$890,000	$910,000	$930,000	$940,000	$960,000	$5,110,000	$5,650,000
50071	Potable	Cathodic Protection Program	$180,000	$180,000	$190,000	$190,000	$190,000	$260,000	$280,000
50511	Potable	Condition Assessment	$390,000	$400,000	$410,000	$410,000	$420,000	$2,250,000	$2,480,000
New	Recycled	Miscellaneous Pipeline Replacement	$0	$0	$0	$250,000	$350,000	$2,150,000	$2,910,000
52121	Recycled	Miscellaneous Valve Repair & Replacement	$110,000	$110,000	$110,000	$120,000	$120,000	$630,000	$700,000
New	Recycled	Cathodic Protection Program	$20,000	$20,000	$20,000	$20,000	$20,000	$30,000	$30,000
52111	Recycled	Condition Assessment	$50,000	$50,000	$50,000	$50,000	$50,000	$280,000	$310,000

Notes:
Includes 2% inflation

The 15-year CIP forecast for CIP Project ID 50241 Reservoir Repair and Maintenance Program is presented in Table 3-12. This forecast includes costs for “Washout, painting, exterior/interior coating” as identified in the reservoir maintenance schedule presented in Table 3-13. Washout, painting, exterior/interior coating is assumed to be required every 10 years. Costs for other activities in the reservoir maintenance schedule are addressed through different budgets.

Table 3-12. Reservoir Repair and Maintenance CIP

Project Title	Year 1 2019-20	Year 2 2020-21	Year 3 2021-22	Year 4 2022-23	Year 5 2023-24	Year 6-10 2025-29	Year 11-15 2030-34
RESERVOIR REPAIR AND MAINTENANCE PROGRAM[1]	**$0**	**$0**	**$0**	**$0**	**$2,958,829**	**$3,068,428**	**$3,606,796**

Notes:

[1] Costs are based on bids received by the City for Tanks C, D1, D2, D3, Elm, Ellery, and Skyline. Calculated costs use Tank C and D3 cost per million gallons of storage. Costs include 2% inflation.

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Table 3-13.Reservoir Maintenance Schedule and Costs

Tank	Year 0 FY 2018/19	Year 1 FY 2019/20	Year 2 FY 2020/21	Year 3 FY 2021/22	Year 4 FY 2022/23	Year 5 FY 2024/25	YEAR[3] 6-10 FY 2025-29	YEAR[3] 11-16 FY 2030-34	Bid Year	Bid Costs[2]	Calculated Cost[1,2]
C **1.5 MG**	Washout, painting, exterior/interior coating	**Warranty** & Periodic inspection & repairs	Washout, periodic inspection & repairs	**Warranty** & periodic inspection & repairs	Washout, periodic inspection & repairs	**Warranty** & periodic inspection & repairs	Washout, painting, exterior/interior coating		2018	$1,324,831	
D3 **8.5 MG**	Washout, painting, exterior/interior coating	**Warranty** & Periodic inspection & repairs	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Washout, periodic inspection & repairs	Washout, painting, exterior/interior coating				
D1 **1.25 MG**	Washout, periodic inspection & repairs	**Warranty** & periodic inspection / repairs	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Washout, painting, exterior/interior coating		Washout, painting, exterior/interior coating	2012	$667,718	
D2 **1.25 MG**	Washout, periodic inspection & repairs	**Warranty** & periodic inspection / repairs	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Assumed for Washout, painting, exterior/interior coating based on 2012/2013 project		Washout, painting, exterior/interior coating			
Ellery **5.0 MG**	Sanitary/Safety Inspection	Washout, periodic inspection & repairs	**Warranty** & Periodic inspection & repairs	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Assumed for Washout, painting, exterior/interior coating based on 2014 project		Washout, painting, exterior/interior coating	2014	$1,060,380	
Elm **1.5 MG**	Sanitary/Safety Inspection	Washout, periodic inspection & repairs	**Warranty** & Periodic inspection & repairs	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Assumed for Washout, painting, exterior/interior coating based on 2014 project		Washout, painting, exterior/interior coating			
Skyline **1.5 MG**	Washout, periodic inspection & repairs	**Warranty** & Periodic inspection & repairs	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Washout, painting, exterior/interior coating		Washout, painting, exterior/interior coating			
La Costa Hi **6.0 MG**	Washout, periodic inspection & repairs	**Warranty** & Periodic inspection & repairs	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Washout, painting, exterior/interior coating		Washout, painting, exterior/interior coating			$794,899
Santa Fe II **9.0 MG**	Washout, painting, exterior/interior coating	**Warranty** & Periodic inspection & repairs	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Washout, periodic inspection & repairs	Washout, painting, exterior/interior coating				$1,192,348
TAP **6.0 MG**	Washout, periodic inspection & repairs	**Warranty** & Periodic inspection & repairs	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Washout, periodic inspection & repairs	Washout, painting, exterior/interior coating				$794,899

Table 3-13.Reservoir Maintenance Schedule and Costs

Tank	Year 0 FY 2018/19	Year 1 FY 2019/20	Year 2 FY 2020/21	Year 3 FY 2021/22	Year 4 FY 2022/23	Year 5 FY 2024/25	YEAR[3] 6-10 FY 2025-29	YEAR[3] 11-16 FY 2030-34	Bid Year	Bid Costs[2]	Calculated Cost[1,2]
MKL 10.0 MG	Washout, periodic inspection & repairs	**Warranty** & Periodic inspection & repairs	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Washout, periodic inspection & repairs	Washout, painting, exterior/interior coating				$1,324,831
MKL 200 MG	Cover, Periodic inspection & repairs	**Warranty** & Periodic inspection & repairs	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Sanitary/Safety Inspection	Washout, periodic inspection & repairs					Already Included in CIP

Notes:
1 Calculated costs use Tank C and D3 cost per million gallons of storage.
2 Bid Costs and Calculated Costs are for activities identified as "Washout, painting, exterior/interior coating" in the schedule.
3 Year 6-10 and Year 11-15 assume that “Washout, painting, exterior/interior coating” is required every 10 years.

3.4 Condition and Capacity CIP Project Prioritization

All current CIP projects, proposed hydraulic projects, and proposed condition projects were evaluated to coordinate investments and ensure there is no overlap. For example, low risk fire flow constraints typically aren't included in a near term investment project. However, since a replacement program is already recommended for Adams Street where a fire flow issue exists, the project was refined to address the condition, fire flow, and difficult to access area simultaneously to minimize community disruption and cost effectively address lower priority issues.

3.5 Opportunities

Throughout development of the Asset Management Master Plan, the Asset Management Team identified potential opportunities for continuous improvement to the asset management program. The City should consider these opportunities when developing an Asset Management Roadmap that clearly communicates to stakeholders the prioritized initiatives and a schedule for implementation. The below includes a list of these opportunities for water:

- Develop guidelines to establish when inaccessible infrastructure should be addressed and what potential alternatives exist. A significant portion of inaccessible City water mains traverse through business, condominium, and apartment complexes and are not accessible via a public or private road. Water mains often run under walkways, near community pools, between buildings, and under overhangs. Determine if ownership transfer is a viable alternative when determining how to address inaccessible infrastructure.
- The primary driver for metallic pipe deterioration is corrosion. Cathodic protection can slow corrosion and extend the useful life of pipeline infrastructure. Develop, implement, and maintain a cost effective cathodic protection system.
- On an annual basis, review break history to identify clusters of main breaks that may warrant a future pipeline replacement project.
- Refine the way inoperable valves are identified to ensure a single database of record exists for all known inoperable valves.
- Develop and implement a valve risk model to identify and prioritize valve replacement. Develop guidelines on how to use this model to generate valve replacement projects.
- Continue to collect, test, and analyze AC pipe samples during valve and pipe replacement projects.
- Currently, the City is sampling and testing AC pipes during contracted valve replacement work. Readily available samples were evaluated as part of this study. Continue to develop and execute an opportunity condition assessment program to collect, test, and analyze AC pipe samples when other opportunities arise (e.g. service tapping and break response).

- Develop a tactical metallic pipe condition assessment program to identify and prioritize condition assessment projects, manage project execution, and leverage the data collected to make renewal decisions. The program should leverage and refine the initial condition assessment strategies and priorities identified in this Asset Management Master Plan.
- Refine the current water main COF assessment approach to quantify the number of customers, type of customers, and flow not delivered if a particular pipe fails. Leverage this information for both pipe and valve replacement prioritization.
- Continue to perform proactive leak detection on a regular basis such as once every three to five years.
- Consider opportunities to develop the computerized maintenance management system.
- Update the AMP annually with significant changes or modifications to the program.

3.6 Asset Valuation

The total asset replacement valuation for potable water is $1.29 billion and for recycled water is $297 million. The replacement costs are summarized in Table 1-1. This valuation is based on data that is readily available such as GIS data, financial records, maintenance and repair records, and replacement and renewal records. The City currently utilizes an Original Cost Less Depreciation valuation approach. Where performance-based forecasts were not developed, age is the basis for the straight-line depreciation calculations using estimated useful life by asset classes to estimate the asset service life and estimated replacement costs. Assets were "bundled" into one facility asset or group of facility assets, such as water reservoir or pump station mechanical, and the total construction cost of the asset value and the useful life for the facility were applied.

The asset valuation details including useful life assumptions and long-term funding forecasts by year are included in Appendix D.

Appendix A. Defect Codes and Scores

Appendix A includes the CUES CCTV defect codes, associated scores, and the rehabilitation method used in InfoMaster.

Defect Code	Default Score	Type	Description	Rehab. Method
AbnSurvey	0	MISCELLANEOUS	Abandoned Survey	
Broken	50	STRUCTURAL	Broken	TRENCHLESS REPAIR
BrokenH	50	STRUCTURAL	BrokenHole	TRENCHLESS REPAIR
BrokenSVM	60	STRUCTURAL	BrokenSoil Visible - Medium	TRENCHLESS REPAIR
BrokenSVS	60	STRUCTURAL	BrokenVoid Visible - Small	TRENCHLESS REPAIR
CAF	0	MISCELLANEOUS	CONT. AGAINST FLOW	
Cavity	60	STRUCTURAL	Cavity	TRENCHLESS REPAIR
CavityL	60	STRUCTURAL	CavityLarge	OPEN CUT POINT REPAIR
CavityM	60	STRUCTURAL	CavityMedium	TRENCHLESS REPAIR
CavityS	50	STRUCTURAL	CavitySmall	TRENCHLESS REPAIR
Cleanout	0	CONSTRUCTION	Cleanout	
CollapseM	60	STRUCTURAL	CollapsedMedium	OPEN CUT POINT REPAIR
CollapseS	50	STRUCTURAL	CollapsedSmall	OPEN CUT POINT REPAIR
Crack	50	STRUCTURAL	Crack	TRENCHLESS REPAIR
CrackCN	5	STRUCTURAL	CrackCircular - Narrow	
CrackCW	30	STRUCTURAL	CrackCircular - Wider	TRENCHLESS REPAIR
CrackLN	5	STRUCTURAL	CrackLongitudinal - Narrow	
CrackLW	30	STRUCTURAL	CrackLongitudinal - Wider	TRENCHLESS REPAIR
CrackMN	20	STRUCTURAL	CrackMultiple - Narrow	TRENCHLESS REPAIR
CrackMW	50	STRUCTURAL	CrackMultiple - Wider	TRENCHLESS REPAIR

Defect Code	Default Score	Type	Description	Rehab. Method
CrackRoots	50	STRUCTURAL	Crack with Roots	TRENCHLESS REPAIR
CrackSN	20	STRUCTURAL	CrackSpiral - Narrow	TRENCHLESS REPAIR
CrackSW	30	STRUCTURAL	CrackSpiral - Wider	TRENCHLESS REPAIR
CUW	0	STRUCTURAL	Camera Under Water	
Debris	0	SERVICE	Debris	
Debris10	0	SERVICE	Debris<=10%	
Debris20	0	SERVICE	Debris<=20%	
Debris30	0	SERVICE	Debris<=30%	
Debris31	0	SERVICE	Debris>30%	
Deform	60	STRUCTURAL	Deformed	TRENCHLESS REPAIR
Deform10	60	STRUCTURAL	Deformed<=10%	TRENCHLESS REPAIR
Deform11	50	STRUCTURAL	Deformed>10%	OPEN CUT POINT REPAIR
DepositsL	0	SERVICE	DepositsLight	
DepositsM	0	SERVICE	DepositsMedium	
DepositsS	0	SERVICE	DepositsSevere	
EndOfPipe	0	MISCELLANEOUS	End of Pipe	
FH	0	MISCELLANEOUS	FH	
Flattened	1	STRUCTURAL	Flattened	
FlattenedL	1	STRUCTURAL	FlattenedLight	
FlattenedM	1	STRUCTURAL	FlattenedMedium	
GO	0	MISCELLANEOUS	GO	
GreaseL	0	SERVICE	GreaseLight	
GreaseM	0	SERVICE	GreaseMedium	
GreaseS	0	SERVICE	GreaseSevere	
Infiltrat	50	STRUCTURAL	Infiltration	TRENCHLESS REPAIR
InfiltratL	1	STRUCTURAL	InfiltrationLight	

Defect Code	Default Score	Type	Description	Rehab. Method
InfiltratM	30	STRUCTURAL	InfiltrationMedium	TRENCHLESS REPAIR
InfiltratS	50	STRUCTURAL	InfiltrationSevere	TRENCHLESS REPAIR
IntrSelRng	0	SERVICE	Intruding Sealing Ring	
JAngular	10	STRUCTURAL	Joint - Angular	
JAngularL	10	STRUCTURAL	Joint - AngularLarge	
JAngularM	5	STRUCTURAL	Joint - AngularMedium	
JAngularS	1	STRUCTURAL	Joint - AngularSmall	
JGasketLte	1	STRUCTURAL	Joint - GasketLight	
JGasketM	20	STRUCTURAL	Joint - GasketMedium	OPEN CUT POINT REPAIR
JGasketSev	60	STRUCTURAL	Joint - GasketSevere	OPEN CUT POINT REPAIR
JOffset	20	STRUCTURAL	Joint Offset	OPEN CUT POINT REPAIR
JOffsetL	60	STRUCTURAL	Joint OffsetLarge	OPEN CUT POINT REPAIR
JOffsetM	20	STRUCTURAL	Joint OffsetMedium	OPEN CUT POINT REPAIR
JOffsetS	10	STRUCTURAL	Joint OffsetSmall	
JSepL	60	STRUCTURAL	Joint - SeparatedLarge	TRENCHLESS REPAIR
JSepM	20	STRUCTURAL	Joint - SeparatedMedium	TRENCHLESS REPAIR
JSepS	10	STRUCTURAL	Joint - SeparatedSmall	
LatAbnUnsl	1	STRUCTURAL	Lateral Abandoned - Unsealed	
LatConPr	1	STRUCTURAL	Lateral Connection Problem	
LatConPrBl	1	STRUCTURAL	Lateral Connection ProblemLateral Blocked	
LatConPrFD	1	STRUCTURAL	Lateral Connection ProblemFactory Defective Pipe	
LatConPrPD	1	STRUCTURAL	Lateral Connection ProblemConnection Pipe Damaged	
LatConPrPr	30	STRUCTURAL	Lateral Connection ProblemConnection Protruding	ROBOTIC CUTTER
Lateral	0	CONSTRUCTION	Lateral	

Defect Code	Default Score	Type	Description	Rehab. Method
LateralCap	0	CONSTRUCTION	LateralCapped	
LatLiveCon	0	MISCELLANEOUS	LateralLive Connection	
LinFailBLn	50	STRUCTURAL	Lining FailureBlistered lining	REPLACE
LinFailDet	60	STRUCTURAL	Lining FailureDetached	REPLACE
LiningFail	50	STRUCTURAL	Lining Failure	REPLACE
Pipe Size	0	MISCELLANEOUS	Pipe Size	
Pipe Type	0	MISCELLANEOUS	Pipe Type	
PipeContin	0	MISCELLANEOUS	Pipe Continue	
Root	5	STRUCTURAL	Root	TRENCHLESS REPAIR
RootHeavy	10	STRUCTURAL	RootHeavy	TRENCHLESS REPAIR
RootInJnt	10	STRUCTURAL	Root-in-Joint	TRENCHLESS REPAIR
RootInJntH	10	STRUCTURAL	Root-in-JointHeavy	TRENCHLESS REPAIR
RootInJntL	1	STRUCTURAL	Root-in-JointLight	TRENCHLESS REPAIR
RootInJntM	5	STRUCTURAL	Root-in-JointMedium	TRENCHLESS REPAIR
RootInLat	5	STRUCTURAL	Root-in-Lateral	TRENCHLESS REPAIR
RootInLatH	10	STRUCTURAL	Root-in-LateralHeavy	TRENCHLESS REPAIR
RootInLatL	1	STRUCTURAL	Root-in-LateralLight	TRENCHLESS REPAIR
RootInLatM	5	STRUCTURAL	Root-in-LateralMedium	TRENCHLESS REPAIR
RootLight	1	STRUCTURAL	RootLight	TRENCHLESS REPAIR
RootMedium	5	STRUCTURAL	RootMedium	TRENCHLESS REPAIR
Sag	30	STRUCTURAL	Sag	
SagLight	1	STRUCTURAL	SagLight	
SagMedium	30	STRUCTURAL	SagMedium	
SagSevere	60	STRUCTURAL	SagSevere	REPLACE

Defect Code	Default Score	Type	Description	Rehab. Method
SDamLChemP	1	STRUCTURAL	Surface DamageLight Material Damage - Chemical Pro	
SDamLMechP	1	STRUCTURAL	Surface DamageLight Material Damage - Mechanical P	
SDamMChem P	20	STRUCTURAL	Surface DamageMedium Material Damage - Chemical Pr	
SDamMMechP	20	STRUCTURAL	Surface DamageMedium Material Damage - Mechanical	
SDamSChemP	20	STRUCTURAL	Surface DamageSevere Material Damage - Chemical Pr	
SDamSMechP	30	STRUCTURAL	Surface DamageSevere Material Damage - Mechanical	TRENCHLESS REPAIR
StartAgFlw	0	MISCELLANEOUS	START AGAINST FLOW	
StartWiFlw	0	MISCELLANEOUS	START WITH FLOW	
STOP	0	MISCELLANEOUS	STOP	
SurfaceDam	30	STRUCTURAL	Surface Damage	TRENCHLESS REPAIR
Vermin	0	MISCELLANEOUS	Vermin	
Vermin	0	MISCELLANEOUS	VerminMice	
Vermin	0	MISCELLANEOUS	VerminRat	
VerminCRch	0	MISCELLANEOUS	VerminCockroach	
WatLev	1	STRUCTURAL	Water Level	
WatLevGT25	1	STRUCTURAL	Water Level>=25%	
WatLevGT50	1	STRUCTURAL	Water Level>=50%	
WatLevGT75	1	STRUCTURAL	Water Level>=75%	
WatLevLT25	1	STRUCTURAL	Water Level<25%	
WatMark	1	STRUCTURAL	Water Mark	
WatMark50	1	STRUCTURAL	Water Mark>=50%	
WatMark75	1	STRUCTURAL	Water Mark>=75%	

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Appendix B. InfoMaster Risk Model Implementation Notes

Gravity Sewer Mains

Import CCTV

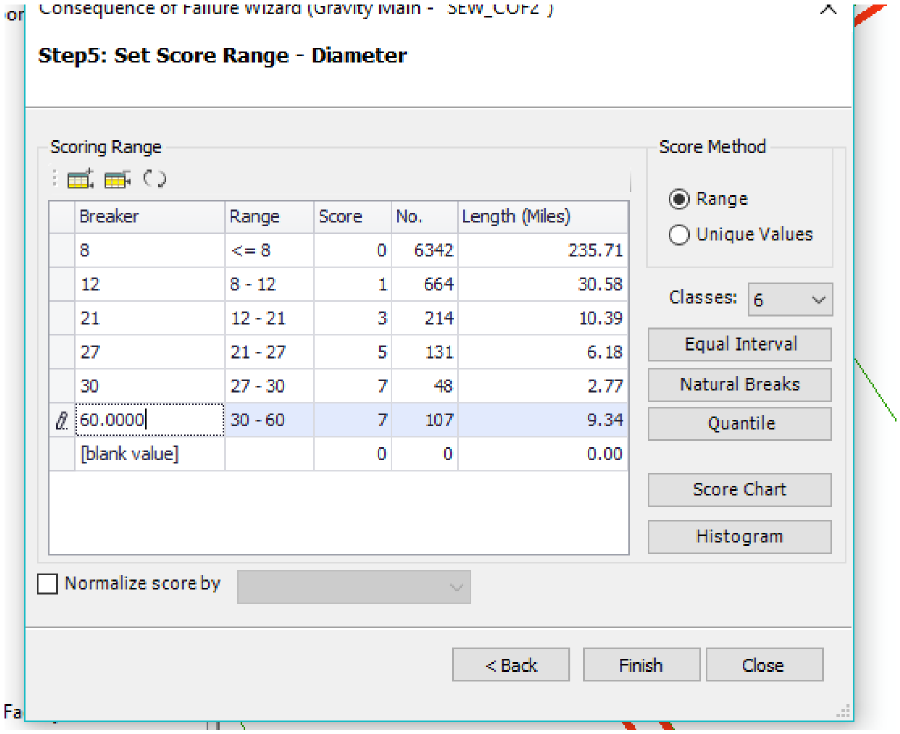
1) Update CCTV_Import with new conditions
    a. Remove blank row of CCTV conditions table (Excel file: Main Conditions CCTV_071118_withCrackRootsv2.xlsx)
    b. Clone CCTV_Import rename CCTV_Import_Updated
    c. Load IMIC_Inspections_CCTV_Import_Updated for inspection table
    d. Load excel as conditions table (Excel file: Main Conditions CCTV_071118_withCrackRootsv2.xlsx)
    e. Check field mappings
    f. Insert and Update (overwrite) as Import Options:
        i. 0 inspections inserted
        ii. 6208 inspections updated
        iii. 0 inspections ignored
    g. Geocode inspections

LOF/POF (Potential of Failure Rating Factors for Wastewater Gravity Mains):

1) Defects Score (Max Score) [LOF 2, LOF 11-15] :
    a. Defects score shows up in InfoMaster results table Pipe Score_CCTV_Import_Updated in the field Structural Peak Score.
    b. Created individual LOFs for potential scores (60, 50, 30, 20, 10, 5) and scored each as 10 in IM initially. Weighting is used when LOF and COF are combined later to produce the final defect score.
2) Count of Defects [LOF 10]
    a. Count group 1-4 (Defect scores >=20) –verify with Eric
    b. Loaded IMIC_Continuous_CCTV_Import_updated layer.
        i. Run Defect Count Data miner tool
            1. The tool exports a table used in this risk calculation. Load this table to Arc Map to use in InfoMaster.
3) Cleaning Frequency – Updated Maintenance Failure - Cleaning Schedule 3 [LOF 6]
    a. Field = Cleaning Frequency
        i. 24 Month = 24M-1,24M-2
        ii. 36 Month = 36M-1,36M-2
        iii. 12 Month = ann , SCH
        iv. 6 Month = SAN
        v. 3 Month = QTY
4) Capacity – Created new LOF : Capacity (Modeled PWWD d/D) [LOF 16]
    a. Fields: Pipe ID = FacilityID, CapacityDD
5) LOF to use: LOF2,LOF6, LOF 10, LOF 11, LOF 12, LOF 13, LOF 14, LOF 15, LOF 16

COF (Consequence of Failure Rating Factors for Wastewater Gravity Mains):

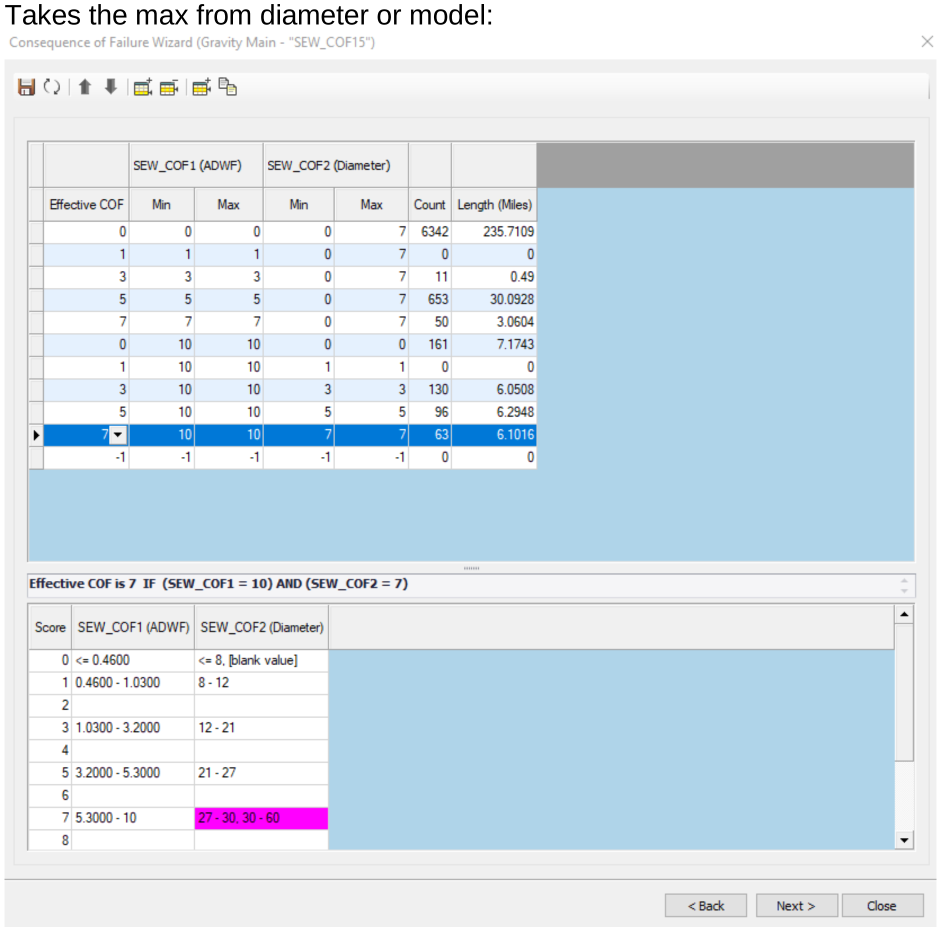
1) Spill Volume Potential
    a. Modeled ADWF, mgd. Attribute already added into IM. Updated [COF1] with scoring only.
    b. Pipe Diameter [COF 2]– updated scoring check breaks confusing in spreadsheet:



Breaker	Range	Score	No.	Length (Miles)
8	<= 8	0	6342	235.71
12	8 - 12	1	664	30.58
21	12 - 21	3	214	10.39
27	21 - 27	5	131	6.18
30	27 - 30	7	48	2.77
60.0000	30 - 60	7	107	9.34
[blank value]		0	0	0.00

c. Multi Parameter - Spill Volume Potential (updated Regulatory Compliance COF) [COF 15]:

i. Takes the max from diameter or model:



	SEW_COF1 (ADWF)		SEW_COF2 (Diameter)			
Effective COF	Min	Max	Min	Max	Count	Length (Miles)
0	0	0	0	7	6342	235.7109
1	1	1	0	7	0	0
3	3	3	0	7	11	0.49
5	5	5	0	7	653	30.0928
7	7	7	0	7	50	3.0604
0	10	10	0	0	161	7.1743
1	10	10	1	1	0	0
3	10	10	3	3	130	6.0508
5	10	10	5	5	96	6.2948
7	10	10	7	7	63	6.1016
-1	-1	-1	-1	-1	0	0

Score	SEW_COF1 (ADWF)	SEW_COF2 (Diameter)
0	<= 0.4600	<= 8, [blank value]
1	0.4600 - 1.0300	8 - 12
2		
3	1.0300 - 3.2000	12 - 21
4		
5	3.2000 - 5.3000	21 - 27
6		
7	5.3000 - 10	27 - 30, 30 - 60
8		

2) Public Health and Environmental Impact
    a. COF 3- Schools, Church, Care Facility [Updated COF 3]
        i. Layer: CitySchoolChurchLicensedCareFacilityParcel
        ii. Query: "FacilityType" IN ('School' ,'Carlsbad-owned')
        iii. Max Distance 100,000 in order to capture all mains.
        iv. Break note: <1 indicates within area
    b. COF 4- [Updated COF 4] – Village View
        i. Layer: VillageReviewArea – taken from the general plan GIS layers
        ii. Max Distance 100,000 in order to capture all mains
        iii. Break note: <1 indicates within area
    c. COF 5 [Updated] Legoland
        i. GIS Layer created for Legoland_HPA
        ii. Max Distance 100,000 in order to capture all mains
        iii. Break note: <1 indicates within area
    d. COF 8 – Environmental Impact Waterways – WaterlineUSGS(Updated COF 8)
        i. Layer: WaterlineUSGS
        ii. I did not query any fields
        iii. Max Distance 100,000 in order to capture all mains
    e. COF 9- Environmental Impact Waterways – Waterbodies (Updated COF 9)
        i. Layer: Waterbody
        ii. Max Distance 100,000 in order to capture all mains
    f. COF 16 (updated) Multi Parameter Public Health and Environmental Impact:
        i. Combines COF 3 – 9 to get max value.

Consequence of Failure Wizard (Gravity Main - "SEW_COF16")

	SEW_COF3 (Critical Facilities - School,Church, Care Facility)		SEW_COF4 (Critical Facilities - Village View)		SEW_COF5 (Critical Facilities - Legoland)		SEW_COF8 (Critical Facilities - Waterbody)		SEW_COF9 (Critical Facilities - Water)			
Effective COF	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Count	Length (Miles)
7	7	7	0	7	0	7	0	7	0	7	58	2.371
7	0	7	7	7	0	7	0	7	0	7	139	6.7179
7	0	7	0	7	7	7	0	7	0	7	0	0
7	0	7	0	7	0	7	7	7	0	7	64	4.567
7	0	7	0	7	0	7	0	7	7	7	50	2.1627
5	5	5	0	7	0	7	0	7	0	7	77	3.1711
5	0	7	5	5	0	7	0	7	0	7	14	0.5761
5	0	7	0	7	5	5	0	7	0	7	0	0
5	0	7	0	7	0	7	5	5	0	7	32	1.6022
5	0	7	0	7	0	7	0	7	5	5	337	13.6975
3	3	3	0	7	0	7	0	7	0	7	228	9.5897
3	0	7	3	3	0	7	0	7	0	7	3	0.1668
3	0	7	0	7	3	3	0	7	0	7	0	0
3	0	7	0	7	0	7	3	3	0	7	115	4.9365
3	0	7	0	7	0	7	0	7	3	3	324	13.0082
1	0	7	0	7	0	7	1	1	0	7	0	0
1	0	7	0	7	0	7	0	7	1	1	986	33.4877
0	0	0	0	7	0	7	0	7	0	7	0	0
0	0	7	0	0	0	7	0	7	0	7	0	0
0	0	7	0	7	0	0	0	7	0	7	0	0
0	0	7	0	7	0	7	0	0	0	7	0	0
0	0	7	0	7	0	7	0	7	0	0	0	0

Effective COF is 7 IF (SEW_COF3 = 7) AND (0 <= SEW_COF4 <= 7) AND (0 <= SEW_COF5 <= 7) AND (0 <= SEW_COF8 <= 7) AND (0 <= SEW_COF9 <= 7)

Score	SEW_COF3 (Critical Facilities - School,Church, Care Facility)	SEW_COF4 (Critical Facilities - Village View)	SEW_COF5 (Critical Facilities - Legoland)	SEW_COF8 (Critical Facilities - Waterbody)	SEW_COF9 (Critical Facilities - Water)
0	500 - 4673.3802, [blank value]	500 - 37956.0707, [blank value]	500 - 23549.7079, [blank value]	2000 - 6516.4833, [blank value]	2000 - 9479.8272, [blank value]
1				1000 - 2000	1000 - 2000
2					
3	100 - 500	100 - 500	100 - 500	500 - 1000	500 - 1000
4					
5	1 - 100	1 - 100	1 - 100	100 - 500	100 - 500
6					
7	<= 1	<= 1	<= 1	<= 100	<= 100
8					
9					

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3) <u>Emergency Response Impact</u>

a. Traffic Control COF 10 and COF 12

i. COF 10: Emergency Response Traffic Impact - Road Classification (Local -Prime Arterial) [Updated]
Intersect
Layer: RoadCenterline
Query: "ROADTYPE" IN (50, 51, 40, 30, 20, 10, 62, 60)
Buffer distance =60

-This is for the road categories below:

All Others
Local –Roadway Type =51 & 50
Collector or Secondary Arterial Roadway Type =40 & 30
Major Arterial Street or Private (access issue) Roadway Type =20, 60, 62 Prime Arterial Roadway Type =10

ii. COF 12: Emergency Response Traffic Impact – Freeways & Rail [Updated]
Intersect
Layer: GeneralPlanLandUse
Query: "DESCRIPTION" = 'Transportation Corridor'
Buffer Distance = 60

b. COF 13 Emergency Response Maintenance/Repair Constraints - Restricted Access (Habitat/Private)

Intersect
Layer: GeneralPlanLandUse
Buffer =0
Query: "DESCRIPTION" IN ('Community Facilities' ,'General Commercial' ,'Local Shopping Center' ,'Local Shopping Center/Community Facilities' ,'Office' ,'Open Space' ,'Planned Industrial' ,'Planned Industrial/Office' ,'Regional Commercial' ,'Residential 0-1.5 du/ac' ,'Residential 0-4 du/ac' ,'Residential 15-23 du/ac' ,'Residential 23-30 du/ac' ,'Residential 4-8 du/ac' ,'Residential 8-15 du/ac' ,'Residential 8-15 du/ac / Office' ,'Residential 8-15 du/ac/Local Shopping Center' ,'Residential 8-15 du/ac/Visitor Commercial' ,'Village', 'Visitor Commercial' ,'Visitor Commercial/Open Space')

c. COF 14 Emergency Response Traffic Impact - Repair Constraints - Poor Access – Easements (Updated)
Intersect
Layer: Public Works Easement
Buffer =0

Query: none

d. COF 19 Emergency Response Traffic Impact - Repair Constraints - Thick Pavement
Intersect
Layer: Queried Centerline for Roadway Name = ‘State Street’ GIS layer created for Thick Pavement
Buffer =0
Query: none

e. COF 18- Multi - Emergency Response Impact (updated)

i. Combines COF 10,12,14,& 19 into 1 with Max values aggregated into single COF

Consequence of Failure Wizard (Gravity Main - "SEW_COF18")

	SEW_COF10 (Intersection - RoadCenterline)		SEW_COF12 (Intersection - GeneralPlanLandUse)		SEW_COF13 (Intersection - GeneralPlanLandUse)		SEW_COF14 (Intersection - PublicWorksEasement)		SEW_COF19 (Intersection - Thick_Pavement)			
Effective COF	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Count	Length (Miles)
6	0	5	6	6	0	5	0	3	0	1	317	16.0985
5	5	5	0	6	0	5	0	3	0	1	140	7.4071
5	0	5	0	6	5	5	0	3	0	1	2931	96.3871
3	3	3	0	6	0	5	0	3	0	1	355	14.0297
3	0	5	0	6	0	5	3	3	0	1	713	31.0195
1	1	1	0	6	0	5	0	3	0	1	209	10.1445
1	0	5	0	6	0	5	0	3	1	1	5	0.2383
0	0	0	0	6	0	5	0	3	0	1	0	0
0	0	5	0	0	0	5	0	3	0	1	0	0
0	0	5	0	6	0	0	0	3	0	1	0	0
0	0	5	0	6	0	5	0	0	0	1	2836	119.6507
0	0	5	0	6	0	5	0	3	0	0	0	0

Effective COF is 6 IF (0 <= SEW_COF10 <= 5) AND (SEW_COF12 = 6) AND (0 <= SEW_COF13 <= 5) AND (0 <= SEW_COF14 <= 3) AND (0 <= SEW_COF19 <= 1)

Score	SEW_COF10 (Intersection - Road Centerline)	SEW_COF12 (Intersection - General Plan Land Use)	SEW_COF13 (Intersection - General Plan Land Use)	SEW_COF14 (Intersection - Public Works Easement)	SEW_COF19 (Intersection - Thick_Pavement)
0	[blank value], 50, 51	False	False	False	False
1	30, 40				True
2					
3	20, 60, 62			True	
4					
5	10		True		
6		True			
7					
8					
9					
10					

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4) Risk 1 – Base Risk Updated with the following Weights

a. Updated for Cumulative Risk (LOF + COF) Max Score = 100

Assess Risk

Facility Scope

(•) Full Network

( ) Selection

( ) Zone

Select Whole Network or choose a selection, consequences and likelihood of failures with the same selection will be listed on right side.

Then choose consequences and likelihood of failures which you want, and set weight and exponent.

Consequence of Failures

		ID	Weight	Exponent	Category	Parameter	Description
7	☐	SEW_COF7	1	1	Critical Facilities	Critical Facilities - Waterbodies	Public Health - Proximity to Public Swimming Areas
8	☐	SEW_COF8	1	1	Critical Facilities	Critical Facilities - Waterbody	Environmental Impact - Proximity to Waterways - WaterlineUSGS
9	☐	SEW_COF9	1	1	Critical Facilities	Critical Facilities - DischargePoint	Environmental Impact - Proximity to Waterways - Storm Drain Outlet
10	☐	SEW_COF10	1	1	Intersection	Intersection - RoadCenterline	Emergency Response Traffic Impact - Road Classification (Local -Prime Art
11	☐	SEW_COF11	1	1	Pipe Attribute	Material	Emergency Response Traffic Impact - Repair Constraints - Contractor Assis
12	☐	SEW_COF12	1	1	Intersection	Intersection - GeneralPlanLandUse	Emergency Response Traffic Impact - Freeways and Rail
13	☐	SEW_COF13	1	1	Intersection	Intersection - GeneralPlanLandUse	Emergency Response Maintenance/Repair Constraints - Restricted Acces
14	☐	SEW_COF14	1	1	Intersection	Intersection - PublicWorksEasement	Emergency Response Traffic Impact - Repair Constraints - Poor Access - E
15	☑	SEW_COF15	1	1	Multi-Parameter	SEW_COF1,SEW_COF2	Multi - Spill Volume Potential
16	☑	SEW_COF16	1	1	Multi-Parameter	SEW_COF3,SEW_COF4,SEW_COF5,SEW_COF8	Multi - Public Health and Environmental Impact
17	☐	SEW_COF17	1	1	Multi-Parameter	SEW_COF8,SEW_COF9	Multi - Environmental Impact
18	☑	SEW_COF18	1	1	Multi-Parameter	SEW_COF10,SEW_COF12,SEW_COF13,SEW_COF14,SEW_COF19	Multi - Emergency Response Impact (Updated)
19	☐	SEW_COF19	1	1	Intersection	Intersection - Thick_Pavement	Emergency Response Traffic Impact - Repair Constraints - Thick Pavement
20	☐	Sum of Vertical Asset	1	1		Sum of Vertical Asset COF	Sum of Vertical Asset COF
21	☐	Max of Vertical Asset	1	1		Max of Vertical Asset COF	Max of Vertical Asset COF
22	☐	Avg of Vertical Asset	1	1		Avg of Vertical Asset COF	Avg of Vertical Asset COF
23	☐	Median of Vertical Asset	1	1		Median of Vertical Asset COF	Median of Vertical Asset COF
24	☐	Mode of Vertical Asset	1	1		Mode of Vertical Asset COF	Mode of Vertical Asset COF

Likelihood of Failures

		ID	Weight	Exponent	Category	Parameter	Description
1	☐	SEW_LOF1	1	1	Soil Type	Soil Type	Soil Type
2	☑	SEW_LOF2	6	1	Pipe Inventory	Struct_Peak	Structural Failure -60 Structural Defect Rating (Updated)
3	☐	SEW_LOF3	1	1	Pipe Attribute	Percent_Consumed	Structural Failure - Percent Consumed
4	☐	SEW_LOF4	1	1	Pipe Inventory	OM_Peak	Maintenance Failure - PACP Maintenance Defect Rating
5	☐	SEW_LOF5	1	1	Pipe Attribute	Redundancy	Maintenance Failure - Unscheduled Work Orders
6	☑	SEW_LOF6	1	1	Pipe Attribute	CLEANINGFREQUENCY	Maintenance Failure - Cleaning Schedule (Updated)
7	☐	SEW_LOF7	1	1	Pipe Attribute	WWFlow_qQ	Capacity Failure - WWF q/Q
8	☐	SEW_LOF8	1	1	Multi-Parameter	SEW_LOF2,SEW_LOF3	Multi - Structural Failure
9	☐	SEW_LOF9	1	1	Multi-Parameter	SEW_LOF4,SEW_LOF5,SEW_LOF6	Multi - Maintenance Failure
10	☑	SEW_LOF10	1	1	Pipe Inventory	COUNT_StructScore	Structural Failure - Defect Count
11	☑	SEW_LOF11	5	1	Pipe Inventory	Struct_Peak	Structural Failure -50 Structural Defect Rating (Updated)
12	☑	SEW_LOF12	3	1	Pipe Inventory	Struct_Peak	Structural Failure -30 Structural Defect Rating (Updated)
13	☑	SEW_LOF13	2	1	Pipe Inventory	Struct_Peak	Structural Failure -20 Structural Defect Rating (Updated)
14	☑	SEW_LOF14	1	1	Pipe Inventory	Struct_Peak	Structural Failure -10 Structural Defect Rating (Updated)
15	☑	SEW_LOF15	0.5	1	Pipe Inventory	Struct_Peak	Structural Failure -5 Structural Defect Rating (Updated)
16	☑	SEW_LOF16	1	1	Pipe Inventory	CAPACTY_DD	Capacity (Modeled PWWF d/D)
17	☐	Sum of Vertical Asset	1	1		Sum of Vertical Asset LOF	Sum of Vertical Asset LOF
18	☐	Max of Vertical Asset	1	1		Max of Vertical Asset LOF	Max of Vertical Asset LOF
19	☐	Avg of Vertical Asset	1	1		Avg of Vertical Asset LOF	Avg of Vertical Asset LOF

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5) Decision Logic
    a. Notes:
        i. Depth – Added a calculate Depth Field in the Gravity Mains layer using GIS (Upstream Elev – Downstream Elev.). The InfoMaster interpolate tool was used to clean up the results and remove blanks.

Manholes

LOF

1. Structural Risk Score
    a. LOF 17 – Imported Table from MH condition spreadsheet -
        i. Score 0-8
        ii. Rating 5 = 8
        iii. Rating 0 or1 =0
        iv. Weighting applied when LOF and COF are combined to bring score to 80 out of 100.
    b. LOF 22 – from MH condition spreadsheet - Bench Condition field
        i. Good = 0 Poor = 8
    c. Use Multi Parameter to pull Max Score between
    d. In Risk can do x10 and get scores of 80, 40, etc.

COF

1. COF – See notes above for pipes. The same process is used.

    Risk 1 – Base Risk Updated with the following Weights
    Updated for Cumulative Risk (LOF + COF) Max Score = 100
        i. Weight = 10 for MH condition risk.

Logic

1) Mainly Using MH Condition Table. Created a Facility Selection for step 1 of logic “if has MH Condition”.
2) Corrosion “Severe” =”L”

Appendix C. Cost Factors

Sewer Cost Factors											
	Factor Description	Replacement		CIPP		Open Cut Point Repair		Trenchless Repair		Manholes	
Installation Cost Factor (Applied first)	Installation Cost Factor is based on CIPP bid tabs and addresses the costs related to items such as mobilization, fittings, excavation, bedding, backfill, traffic control, by-pass pumping, equipment, labor, pavement or non-ROW patching or improvements.	Replacement	1.60	CIPP SD	1.30	Open Cut Point Repair	1.2	Trenchless Repair	1.0	Manhole	N/A
		N/A	N/A	CIPP LD	1.60	N/A	N/A	N/A	N/A	N/A	N/A
Capital Cost Factor	The capital cost factor addresses the costs related to agency administration, design, construction management, and contingencies.	Replacement (Uses the sum of the below percentages)	1.45	CIPP (Uses the sum of the below percentages)	1.45	Open Cut Point Repair (Uses the sum of the below percentages)	1.40	Trenchless Repair (Uses the sum of the below percentages)	1.37	Point Repair (Uses the sum of the below percentages)	1.37
		Planning	3%	Planning	3%	Planning	3%	Planning	3%	Planning	3%
		Design	10%	Design	5%	Design	5%	Design	2%	Design	2%
		Legal	2%	Legal	2%	Legal	2%	Legal	2%	Legal	2%
		Construction Administration	15%	Construction Administration	15%	Construction Administration	15%	Construction Administration	15%	Construction Administration	15%
		Owner Administration	5%	Owner Administration	5%	Owner Administration	5%	Owner Administration	5%	Owner Administration	5%
		Contingency	10%	Contingency	10%	Contingency	10%	Contingency	10%	Contingency	10%
		Subtotal Capital Cost Factor	45%	Subtotal	40%	Subtotal	40%	Subtotal	37%	Subtotal	37%

Sewer Cost Tables		
Assumptions	**Cost per inch diameter per LF (Z in Unit Cost Table Below)**	**Unit cost notes**
Replacement SD	$11.90	Note: Bid tab prices are approximately $29/In-Dia/LF for 8" dia pipe for limited quantities. Carlsbad 2012 MP costs escalated to 2018 are $11.90/In-Dia/LF for >3000 LF quantities. $11.90/In-Dia/LF is assumed.
Replacement LD	$20.00	
CIPP SD 12 inch	$4.00	Based on bid tab PWS-17-34
CIPP LD	$4.75	$4.75 aligns with LD bid tab for 36-inch pipe CIPP project from City of Vista
Historical Inflation Tables		
Assumed Historical Inflation	1.75%	RS Means National Average
Years of Inflation	3	2016 to 2019

Sewer Manholes	A	B	C = A x B	
Description	**Construction Cost**	**Capital Cost Factor**	**Capital Costs**	**Units**
Manhole Replacement	$10,529	1.37	$14,425	Each

Sewer Unit Costs	Y	A = Z (from cost table above) x Y	B	C = A x B	F	G = F x E	H
Renewal Action	**Diameter**	**Material Cost per LF or Point Repair**	**Installation Factor**	**Construction Cost (No MHs) / LF or Point Repair [Used to check against bid tabs]**	**Capital Cost Factor**	**Capital Costs**	**Units**
Replace SD	0	$100	1.60	$16	1.45	$232	Linear Foot
Replace SD	3	$100	1.60	$160	1.45	$232	Linear Foot
Replace SD	4	$100	1.60	$160	1.45	$232	Linear Foot
Replace SD	6	$100	1.60	$160	1.45	$232	Linear Foot
Replace SD	8	$100	1.60	$160	1.45	$232	Linear Foot
Replace SD	10	$125	1.60	$200	1.45	$290	Linear Foot
Replace SD	12	$150	1.60	$240	1.45	$349	Linear Foot
Replace LD	14	$176	1.60	$280	1.45	$407	Linear Foot
Replace LD	15	$188	1.60	$301	1.45	$436	Linear Foot
Replace LD	16	$201	1.60	$321	1.45	$465	Linear Foot
Replace LD	18	$226	1.60	$361	1.45	$523	Linear Foot
Replace LD	20	$251	1.60	$401	1.45	$581	Linear Foot
Replace LD	21	$263	1.60	$421	1.45	$610	Linear Foot
Replace LD	24	$301	1.60	$481	1.45	$697	Linear Foot
Replace LD	27	$338	1.60	$541	1.45	$784	Linear Foot
Replace LD	30	$376	1.60	$601	1.45	$871	Linear Foot
Replace LD	33	$414	1.60	$661	1.45	$959	Linear Foot
Replace LD	36	$451	1.60	$721	1.45	$1,046	Linear Foot
Replace LD	39	$489	1.60	$781	1.45	$1,133	Linear Foot
Replace LD	42	$527	1.60	$841	1.45	$1,220	Linear Foot
Replace LD	48	$602	1.60	$962	1.45	$1,394	Linear Foot
Replace LD	54	$677	1.60	$1,082	1.45	$1,569	Linear Foot
Replace LD	60	$752	1.60	$1,202	1.45	$1,743	Linear Foot
CIPP SD	0	$34	1.30	$44	1.45	$64	Linear Foot
CIPP SD	3	$27	1.30	$36	1.45	$52	Linear Foot
CIPP SD	4	$27	1.30	$36	1.45	$52	Linear Foot
CIPP SD	6	$27	1.30	$36	1.45	$52	Linear Foot
CIPP SD	8	$34	1.30	$44	1.45	$64	Linear Foot
CIPP SD	10	$38	1.30	$49	1.45	$71	Linear Foot
CIPP SD	12	$51	1.30	$66	1.45	$95	Linear Foot
CIPP LD	14	$59	1.30	$77	1.45	$111	Linear Foot
CIPP LD	15	$63	1.60	$101	1.45	$146	Linear Foot
CIPP LD	16	$67	1.60	$108	1.45	$156	Linear Foot
CIPP LD	18	$76	1.60	$121	1.45	$176	Linear Foot

Sewer Unit Costs	Y	A = Z (from cost table above) x Y	B	C = A x B	F	G = F x E	H
Renewal Action	Diameter	Material Cost per LF or Point Repair	Installation Factor	Construction Cost (No MHs) / LF or Point Repair [Used to check against bid tabs]	Capital Cost Factor	Capital Costs	Units
CIPP LD	20	$84	1.60	$135	1.45	$195	Linear Foot
CIPP LD	21	$88	1.60	$141	1.45	$205	Linear Foot
CIPP LD	24	$101	1.60	$162	1.45	$234	Linear Foot
CIPP LD	27	$114	1.60	$182	1.45	$264	Linear Foot
CIPP LD	30	$126	1.60	$202	1.45	$293	Linear Foot
CIPP LD	33	$139	1.60	$222	1.45	$322	Linear Foot
CIPP LD	36	$152	1.60	$242	1.45	$352	Linear Foot
CIPP LD	39	$164	1.60	$263	1.45	$381	Linear Foot
CIPP LD	42	$177	1.60	$283	1.45	$410	Linear Foot
CIPP LD	48	$202	1.60	$323	1.45	$469	Linear Foot
CIPP LD	54	$228	1.60	$364	1.45	$527	Linear Foot
CIPP LD	60	$253	1.60	$404	1.45	$586	Linear Foot
Open Cut Point Repair SD	0	$1,534	1.20	$1,841	1.40	$2,577	Linear Foot
Open Cut Point Repair SD	3	$1,534	1.20	$1,841	1.40	$2,577	Linear Foot
Open Cut Point Repair SD	4	$1,534	1.20	$1,841	1.40	$2,577	Linear Foot
Open Cut Point Repair SD	6	$1,534	1.20	$1,841	1.40	$2,577	Linear Foot
Open Cut Point Repair SD	8	$1,534	1.20	$1,841	1.40	$2,577	Linear Foot
Open Cut Point Repair SD	10	$1,700.00	1.20	$2,040	1.40	$2,856	Linear Foot
Open Cut Point Repair SD	12	$1,900.00	1.20	$2,280	1.40	$3,192	Linear Foot
Open Cut Point Repair LD	14	$2,200.00	1.20	$2,640	1.40	$3,696	Linear Foot
Open Cut Point Repair LD	15	$2,500.00	1.20	$3,000	1.40	$4,200	Linear Foot
Open Cut Point Repair LD	16	$2,800.00	1.20	$3,360	1.40	$4,704	Linear Foot
Open Cut Point Repair LD	18	$3,200.00	1.20	$3,840	1.40	$5,376	Linear Foot
Open Cut Point Repair LD	20	$3,600.00	1.20	$4,320	1.40	$6,048	Linear Foot
Open Cut Point Repair LD	21	$3,800.00	1.20	$4,560	1.40	$6,384	Linear Foot
Open Cut Point Repair LD	24	$4,200.00	1.20	$5,040	1.40	$7,056	Linear Foot
Open Cut Point Repair LD	27	$4,600.00	1.20	$5,520	1.40	$7,728	Linear Foot
Open Cut Point Repair LD	30	$5,000.00	1.20	$6,000	1.40	$8,400	Linear Foot
Open Cut Point Repair LD	33	$5,400.00	1.20	$6,480	1.40	$9,072	Linear Foot
Open Cut Point Repair LD	36	$5,400.00	1.20	$6,480	1.40	$9,072	Linear Foot
Open Cut Point Repair LD	39	$5,800.00	1.20	$6,960	1.40	$9,744	Linear Foot
Open Cut Point Repair LD	42	$5,800.00	1.20	$6,960	1.40	$9,744	Linear Foot
Open Cut Point Repair LD	48	$6,200.00	1.20	$7,440	1.40	$10,416	Linear Foot
Open Cut Point Repair LD	54	$6,600.00	1.20	$7,920	1.40	$11,088	Linear Foot

Sewer Unit Costs	Y	A = Z (from cost table above) x Y	B	C = A x B	F	G = F x E	H
Renewal Action	Diameter	Material Cost per LF or Point Repair	Installation Factor	Construction Cost (No MHs) / LF or Point Repair [Used to check against bid tabs]	Capital Cost Factor	Capital Costs	Units
Open Cut Point Repair LD	60	$7,000.00	1.20	$8,400	1.40	$11,760	Linear Foot
Open Cut Point Repair SD Cost Review	0	Open Cut Point Repair Cost Review = Open Cut Point Repair Unit Cost per LF * 1.5 open cut point repairs per pipe / 210 average pipe length from Manhole to Manhole				$147	Linear Foot
Open Cut Point Repair SD Cost Review	3					$147	Linear Foot
Open Cut Point Repair SD Cost Review	4					$147	Linear Foot
Open Cut Point Repair SD Cost Review	6					$147	Linear Foot
Open Cut Point Repair SD Cost Review	8					$147	Linear Foot
Open Cut Point Repair SD Cost Review	10					$163	Linear Foot
Open Cut Point Repair SD Cost Review	12					$182	Linear Foot
Open Cut Point Repair LD Cost Review	14					$211	Linear Foot
Open Cut Point Repair LD Cost Review	15					$240	Linear Foot
Open Cut Point Repair LD Cost Review	16					$269	Linear Foot
Open Cut Point Repair LD Cost Review	18					$307	Linear Foot
Open Cut Point Repair LD Cost Review	20					$346	Linear Foot
Open Cut Point Repair LD Cost Review	21					$365	Linear Foot
Open Cut Point Repair LD Cost Review	24					$403	Linear Foot
Open Cut Point Repair LD Cost Review	27					$442	Linear Foot
Open Cut Point Repair LD Cost Review	30					$480	Linear Foot
Open Cut Point Repair LD Cost Review	33					$518	Linear Foot
Open Cut Point Repair LD Cost Review	36					$518	Linear Foot
Open Cut Point Repair LD Cost Review	39					$557	Linear Foot
Open Cut Point Repair LD Cost Review	42					$557	Linear Foot
Open Cut Point Repair LD Cost Review	48					$595	Linear Foot
Open Cut Point Repair LD Cost Review	54					$634	Linear Foot
Open Cut Point Repair LD Cost Review	60					$672	Linear Foot
Point Repair and CIPP SD	0	Point Repair + CIPP = CIPP unit cost per LF + (Open Cut Point Repair Cost * 1 Open Cut Point Repair per Pipe / 210 feet average sewer Manhole to Manhole length)				$162	Linear Foot
Point Repair and CIPP SD	3					$150	Linear Foot
Point Repair and CIPP SD	4					$150	Linear Foot
Point Repair and CIPP SD	6					$150	Linear Foot
Point Repair and CIPP SD	8					$162	Linear Foot
Point Repair and CIPP SD	10					$180	Linear Foot
Point Repair and CIPP SD	12					$217	Linear Foot
Point Repair and CIPP LD	14					$252	Linear Foot
Point Repair and CIPP LD	15					$306	Linear Foot
Point Repair and CIPP LD	16					$335	Linear Foot

Sewer Unit Costs	Y	A = Z (from cost table above) x Y	B	C = A x B	F	G = F x E	H
Renewal Action	**Diameter**	**Material Cost per LF or Point Repair**	**Installation Factor**	**Construction Cost (No MHs) / LF or Point Repair [Used to check against bid tabs]**	**Capital Cost Factor**	**Capital Costs**	**Units**
Point Repair and CIPP LD	18					$381	Linear Foot
Point Repair and CIPP LD	20					$426	Linear Foot
Point Repair and CIPP LD	21					$448	Linear Foot
Point Repair and CIPP LD	24					$503	Linear Foot
Point Repair and CIPP LD	27					$558	Linear Foot
Point Repair and CIPP LD	30					$613	Linear Foot
Point Repair and CIPP LD	33					$668	Linear Foot
Point Repair and CIPP LD	36					$697	Linear Foot
Point Repair and CIPP LD	39					$752	Linear Foot
Point Repair and CIPP LD	42					$781	Linear Foot
Point Repair and CIPP LD	48					$865	Linear Foot
Point Repair and CIPP LD	54					$950	Linear Foot
Point Repair and CIPP LD	60					$1,034	Linear Foot
Trenchless Repair SD	0	Costs per discussion with Carlsbad				$2,500	Each
Trenchless Repair SD	4					$2,500	Each
Trenchless Repair SD	6					$2,500	Each
Trenchless Repair SD	8					$2,500	Each
Trenchless Repair SD	10					$2,500	Each
Trenchless Repair SD	12					$2,500	Each
Cut Tap or Obstacle	0	Costs per discussion with Carlsbad				$500	Each
Cut Tap or Obstacle	4					$500	Each
Cut Tap or Obstacle	6					$500	Each
Cut Tap or Obstacle	8					$500	Each
Cut Tap or Obstacle	10					$500	Each
Cut Tap or Obstacle	12					$500	Each
Cut Tap or Obstacle	14					$500	Each
Cut Tap or Obstacle	15					$500	Each
Cut Tap or Obstacle	16					$500	Each
Cut Tap or Obstacle	18					$500	Each
Cut Tap or Obstacle	20					$500	Each
Cut Tap or Obstacle	21					$500	Each
Cut Tap or Obstacle	24					$500	Each
Cut Tap or Obstacle	27					$500	Each
Cut Tap or Obstacle	30					$500	Each

Sewer Unit Costs	Y	A = Z (from cost table above) x Y	B	C = A x B	F	G = F x E	H
Renewal Action	**Diameter**	**Material Cost per LF or Point Repair**	**Installation Factor**	**Construction Cost (No MHs) / LF or Point Repair [Used to check against bid tabs]**	**Capital Cost Factor**	**Capital Costs**	**Units**
Cut Tap or Obstacle	33					$500	Each
Cut Tap or Obstacle	36					$500	Each
Cut Tap or Obstacle	39					$500	Each
Cut Tap or Obstacle	42					$500	Each
Cut Tap or Obstacle	48					$500	Each
Cut Tap or Obstacle	54					$500	Each
Cut Tap or Obstacle	60					$500	Each

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Force Main Replacement Unit Costs

Diameter (inches)	Unit Cost ($/ft)	With Capital Cost Factor of 45% (Planning, Legal, Design, Construction Admin, Construction Management, Contingency in $/ft)
2	$326.70	$473.72
2.5	$326.70	$473.72
3	$326.70	$473.72
4	$326.70	$473.72
6	$326.70	$473.72
8	$355.11	$514.91
10	$397.73	$576.70
12	$426.14	$617.90
14	$497.16	$720.88
15	$532.67	$772.37
16	$568.18	$823.86
18	$596.59	$865.06
20	$667.61	$968.04
21	$731.63	$1,060.86
24	$795.45	$1,153.41
27	$894.89	$1,297.59
30	$994.32	$1,441.76
33	$1,093.75	$1,585.94
36	$1,193.18	$1,730.11
42	$1,392.05	$2,018.47

Water Main and Recycled Water Main Replacement Unit Costs (Including Services and Valves)

Main Diameter (inches)	Unit Cost ($/ft)	With Capital Cost Factor of 45% (Planning, Legal, Design, Construction Admin, Construction Management, Contingency in $/ft)
2	$326.70	$473.72
2.5	$326.70	$473.72
3	$326.70	$473.72
4	$326.70	$473.72
6	$326.70	$473.72
8	$355.11	$514.91
10	$397.73	$576.70
12	$426.14	$617.90
14	$497.16	$720.88
15	$532.67	$772.37
16	$568.18	$823.86
18	$596.59	$865.06
20	$667.61	$968.04
21	$731.63	$1,060.86
24	$795.45	$1,153.41
27	$894.89	$1,297.59
30	$994.32	$1,441.76
33	$1,093.75	$1,585.94
36	$1,193.18	$1,730.11
42	$1,392.05	$2,018.47

Sewer CCTV and Cleaning Unit Costs

Diameter (inches)	CCTV Unit Cost (per linear foot)	Cleaning Unit Cost (per linear foot)	Total
4	$1.80	$1.50	$3.30
6	$1.80	$1.50	$3.30
7	$1.80	$1.50	$3.30
8	$1.80	$1.50	$3.30
10	$1.80	$1.60	$3.40
12	$1.80	$1.90	$3.70
14	$1.80	$2.30	$4.10
15	$1.80	$2.30	$4.10
16	$1.80	$2.30	$4.10
18	$1.90	$2.80	$4.70
19	$1.90	$2.80	$4.70
20	$1.90	$2.80	$4.70
21	$1.90	$2.80	$4.70
24	$3.00	$6.00	$9.00
25	$3.00	$6.00	$9.00
26	$3.00	$6.00	$9.00
27	$3.00	$6.00	$9.00
28	$3.00	$6.00	$9.00
29	$3.00	$6.00	$9.00
30	$3.00	$6.00	$9.00
33	$3.80	$7.50	$11.30
34	$3.80	$7.50	$11.30
35	$3.80	$7.50	$11.30
36	$3.80	$7.50	$11.30
39	$6.00	$13.50	$19.50
42	$6.00	$13.50	$19.50
48	$6.00	$13.50	$19.50
54	$7.50	$18.00	$25.50
60	$10.50	$22.50	$33.00

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Appendix D. Asset Valuation and Replacement Costs

Included in the tables below are age-based costs forecasts for each infrastructure type including summaries for use in financial analyses. In addition, replacement cost details and the useful life information used to determine the age-based forecasts for force mains, pump stations, and reservoirs are included below. Inflation is assumed to be 2% in the summary tables.

Asset Valuation

Small Diameter Gravity Sewer Mains (12-inch diameter and smaller) Cost Forecast Summary

Description	Condition-based (Million)	Condition-based with Inflation (Million)	Age-based (Million)	Age-based with Inflation (Million)	Notes
5-year (FY19/20-FY23/24)	$6.0	$6.2	$3.5	$3.6	
7-year (FY19/20-FY25/26)	$8.5	$9.0	$3.5	$3.7	Assumes risk scores increase by 10 and a 9% increase is applied to account for pipes that will be inspected for this first time.
22-year (FY19/20-FY40/41)	N/A	N/A	$46.5	$56.1	
30-year (FY19/20-FY48/49)	N/A	N/A	$74.9	$97.4	
40-year (FY19/20-FY58/59)	N/A	N/A	$111.7	$159.8	

Large Diameter Gravity Sewer Mains (Greater than 12-inch diameter) Cost Forecast Summary

Description	Condition-based (Million)	Condition-based with Inflation (Million)	Age-based (Million)	Age-based with Inflation (Million)
5-year (FY19/20-FY23/24)	$0.0	$0.0	$9.3	$9.6
7-year (FY19/20-FY25/26)	$0.0	$0.0	$9.3	$9.8
22-year (FY19/20-FY40/41)	N/A	N/A	$30.6	$36.9
30-year (FY19/20-FY48/49)	N/A	N/A	$43.9	$57.1
40-year (FY19/20-FY58/59)	N/A	N/A	$55.0	$78.7

Sewer Manhole Cost Forecast Summary

Description	Condition-based (Million)	Condition-based with Inflation (Million)	Age-based (Million)	Age-based with Inflation (Million)
5-year (FY19/20-FY23/24)	$1.8	$1.8	$0.7	$0.7
7-year (FY19/20-FY25/26)	$1.9	$2.0	$0.7	$0.7
22-year (FY19/20-FY40/41)	N/A	N/A	$10.3	$12.4
30-year (FY19/20-FY48/49)	N/A	N/A	$17.4	$22.6
40-year (FY19/20-FY58/59)	N/A	N/A	$29.3	$41.9

Total Gravity Sewers and Manholes Cost Forecast Summary

Description	Condition-based (Million)	Condition-based with Inflation (Million)	Age-based (Million)	Age-based with Inflation (Million)
5-year (FY19/20-FY23/24)	$7.8	$8.1	$13.5	$14.0
7-year (FY19/20-FY25/26)	$10.4	$11.0	$13.5	$14.2
22-year (FY19/20-FY40/41)	N/A	N/A	$87.4	$105.5
30-year (FY19/20-FY48/49)	N/A	N/A	$136.0	$176.9
40-year (FY19/20-FY58/59)	N/A	N/A	$196.0	$280.4

Wastewater Force Main Cost Forecast Summary

Description	Age-based (Million)	Age-based with Inflation (Million)
40-year (FY19/20-FY58/59)	$12.6	$18.1

Wastewater Pump Stations Cost Forecast Summary

Description	Age-based (Million)	Age-based with Inflation (Million)
40-year (FY19/20-FY58/59)	$48.1	$68.8

Wastewater Gravity Sewer and Manhole Condition Assessment Cost Forecast Summary

Description	Cost (Million)	Cost with Inflation (Million)
40-year (FY19/20-FY58/59)	$9.0	$12.7

Water Mains, Valves and Services Cost Forecast Summary

Description	Performance-based (Million)	Performance-based with Inflation (Million)	Age-based (Million)	Age-based with Inflation (Million)[1]
5-year (FY19/20-FY23/24)	$19.8	$20.7	$0.4	$0.4
7-year (FY19/20-FY25/26)	$28.0	$30.0	$0.4	$0.4
22-year (FY19/20-FY40/41)	$105.4	$136.5	$69.0	$96.0
30-year (FY19/20-FY48/49)	$159.5	$233.3	$215.0	$337.0
40-year (FY19/20-FY58/59)	$242.5	$418.7	$478.0	$849.0
50-year (FY19/20-FY68/69)	$347.2	$719.4	$988.0	$2,067.0

Notes:
[1] Despite the low cost forecast based on age in the near term, the City has been budgeting approximately $3.5 to $4.5 million per year (including balances carried forward) to address aging infrastructure

Water Pump Stations Cost Forecast Summary

Description	Age-based (Million)	Age-based with Inflation (Million)
40-year (FY19/20-FY58/59)	$43.8	$62.7

Water Reservoirs Cost Forecast Summary

Description	Age-based (Million)	Age-based with Inflation (Million)
40-year (FY19/20-FY58/59)	$218.4	$312.5

Recycled Water Mains, Valves and Services Cost Forecast Summary

Description	Performance-based (Million) [1]	Performance-based with Inflation (Million) [1]	Age-based (Million)	Age-based with Inflation (Million)
5-year (FY19/20-FY23/24)	$1.5	$1.5	$0.0	$0.0
7-year (FY19/20-FY25/26)	$2.5	$2.7	$0.0	$0.0
22-year (FY19/20-FY40/41)	$12.0	$15.9	$0.0	$0.0
30-year (FY19/20-FY48/49)	$18.7	$27.8	$0.6	$2.0
40-year (FY19/20-FY58/59)	$29.0	$50.8	$1.0	$1.7
50-year (FY19/20-FY68/69)	$41.9	$87.9	$67.0	$162.0

Notes:
[1] Performance-based forecasts assume 11% of potable and recycled water forecasts for recycled water. Actual investments are likely to be more focused on potable water in the near term.

Recycled Water Pump Stations Cost Forecast Summary

Description	Age-based (Million)	Age-based with Inflation (Million)
40-year (FY19/20-FY58/59)	$67.3	$96.3

Recycled Water Reservoirs Cost Forecast Summary

Description	Age-based (Million)	Age-based with Inflation (Million)
40-year (FY19/20-FY58/59)	$52.6	$75.2

Replacement Costs and Useful Life Assumptions

Wastewater Gravity Sewer Main and Manhole as well as Potable Water and Recycled Water Pipeline, Valve and Service Lateral Replacement Costs and Useful Life Assumptions are included in the Asset Management Master Plan.

Pump Station and Reservoir Replacement Cost Detail

*Class 5 Estimate - The WaterCost Model used to develop these replacement costs is a planning level cost tool (Estimate Class 5) which means that estimate accuracy will range from 50 to 20% BELOW to 30 to 100% ABOVE actual cost. The construction cost estimates are prepared by HDR Constructors, Inc. (HDRC) using the Timberline cost estimating software. Construction costs are derived from default input values.

Wastewater Pump Stations Replacement Cost

Construction Costs*	Cannon LS	Chinquapin LS	El Fuerte LS	Fox's Landing LS	Home Plant LS	Knots LS	N Batiquitos LS	Poinsettia LS	Sand Shell LS	TerraMar LS	Villas LS
1. Structure/Site	$2,405,939	$877,370	$1,195,913	$2,291,176	$1,807,684	$647,836	$2,139,753	$2,062,713	$606,230	$573,381	$717,903
2. Mechanical	$1,521,678	$613,499	$833,060	$1,470,662	$1,255,730	$623,095	$1,403,348	$1,369,101	$560,506	$523,197	$490,639
3. Electrical/Instrumentation	$695,754	$361,044	$412,543	$681,328	$620,551	$344,752	$662,293	$652,609	$336,460	$329,022	$333,361
Total Project Capital Cost*	**$4,623,372**	**$1,851,914**	**$2,441,516**	**$4,443,166**	**$3,683,966**	**$1,615,683**	**$4,205,394**	**$4,084,423**	**$1,503,196**	**$1,425,600**	**$1,541,903**

Notes:
Capacity information for small pump stations at Pine Beach Bathroom and Tamarack/Frazee Beach Bathroom are not readily available in GIS and are not included.

Water and Recycled Water Pump Station Replacement Cost

Construction Costs*	Bressi PS	Bressi RC PS	Calavera Hills RC PS	Calavera PS	Carlsbad Water Recycling PS	D Site RC PS	Maerkle PS
1. Structure/Site	*$3,457,793*	*$2,202,799*	*$1,867,510*	*$1,651,488*	*$9,536,423*	*$4,725,297*	*$5,002,368*
2. Mechanical	*$3,976,690*	*$1,697,507*	*$1,614,034*	*$1,667,768*	*$13,180,170*	*$5,425,690*	*$4,946,268*
3. Electrical/Instrumentation	*$621,410*	*$265,302*	*$291,004*	*$277,439*	*$1,898,762*	*$848,468*	*$831,555*
Total Project Capital Cost*	***$8,055,892***	***$4,165,608***	***$3,772,548***	***$3,596,694***	***$24,615,354***	***$10,999,455***	***$10,780,190***

Notes:
The below flow rates are not in GIS and are assumed for each pump station and used to calculate head for determining cost for water pump stations.

	Bressi PS	Bressi RC PS	Calavera Hills RC PS	Calavera PS	Carlsbad Water Recycling PS	D Site RC PS	Maerkle PS
Assumed Flow	*3000*	*1800*			*11000*	*3500*	*3500*
Calculated Head	*110*	*110*			*120*	*110*	*110*

Pump Station Assumed Useful Life

Construction Cost Element	Assumed Useful Life (Years)	Source
Structure/Site	50	IRS Pub946 Table B
Mechanical	20	WEF Simple and Industry Experience
Electrical/Instrumentation	15	WEF Simple and Industry Experience

Water Reservoir Replacement Cost

Water Reservoir	ELM	ELLERY	SKYLINE	E	D3	LA COSTA LO	PAJAMA	BUENA VISTA	B (T.A.P.)	MAERKLE #2	LA COSTA HI	SANTA FE 2
Tank Type	*Steel*	*Steel*	*Steel*	*Steel*	*Steel*	*Steel*	*Steel*	*Steel*	*Prestressed Concrete*	*Prestressed Concrete*	*Prestressed Concrete*	*Prestressed Concrete*
Capacity, MG	*1.5*	*5.0*	*1.5*	*1.5*	*8.50*	*1.5*	*0.010*	*0.01 (Assumed)*	*6.0*	*10.0*	*6.0*	*9.0*
Construction Costs*												
1. Structure/Site	*$19,780,007*	*$37,774,809*	*$19,780,007*	*$19,780,007*	*$58,306,806*	*$19,780,007*	*$185,096*	*$185,096*	*$9,929,054*	*$16,524,406*	*$9,929,054*	*$14,875,568*
2. Mechanical	*$2,655,941*	*$5,055,525*	*$2,655,941*	*$2,655,941*	*$7,795,998*	*$2,655,941*	*$24,900*	*$24,900*	*$1,404,989*	*$2,325,731*	*$1,404,989*	*$2,095,545*
3. Electrical/Instrumentation	*$1,186,086*	*$2,258,545*	*$1,186,086*	*$1,186,086*	*$3,483,856*	*$1,186,086*	*$11,107*	*$11,107*	*$947,354*	*$1,575,585*	*$947,354*	*$1,418,527*
Total Project Capital Cost	***$23,622,033***	***$45,088,880***	***$23,622,033***	***$23,622,033***	***$69,586,661***	***$23,622,033***	***$221,103***	***$221,103***	***$12,281,396***	***$20,425,722***	***$12,281,396***	***$18,389,640***

Recycled Water Reservoir Replacement Cost

Recycled Water Reservoir	SANTA FE 1	C	D1	D2
Tank Type	*Prestressed Concrete*	*Steel*	*Steel*	*Steel*
Capacity, MG	*2.5*	*1.0*	*1.25*	*1.25*
Construction Costs*				
1. Structure/Site	*$4,158,363*	*$15,464,425*	*$17,622,216*	*$17,622,216*
2. Mechanical	*$603,959*	*$2,080,350*	*$2,368,145*	*$2,368,145*
3. Electrical/Instrumentation	*$398,058*	*$927,960*	*$1,057,023*	*$1,057,023*
Total Project Capital Cost	***$5,160,379***	***$18,472,734***	***$21,047,384***	***$21,047,384***

Reservoir Assumed Useful Life

Construction Cost Element	Assumed Useful Life (Years)	Source
Tank	50	Industry Experience

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Appendix E. InfoMaster Updates

This appendix provides additional details of the InfoMaster and project packaging workflows and a guideline for updating data and results in InfoMaster.

Making Significant Changes

When making significant changes to InfoMaster consider setting up a development InfoMaster project and ArcMap .MXD file for each potential City user to allow users to utilize the software without impacting the InfoMaster project and system database of record before changes are finalized. Consider limiting access to the InfoMaster project and system database of record to certain staff for making updates.

Workflows

InfoMaster software is a tool that is used as part of the overall pipe renewal workflow process. The figure below illustrates the role InfoMaster will play in the workflow process and summarizes the overall pipe renewal decision making workflow process.

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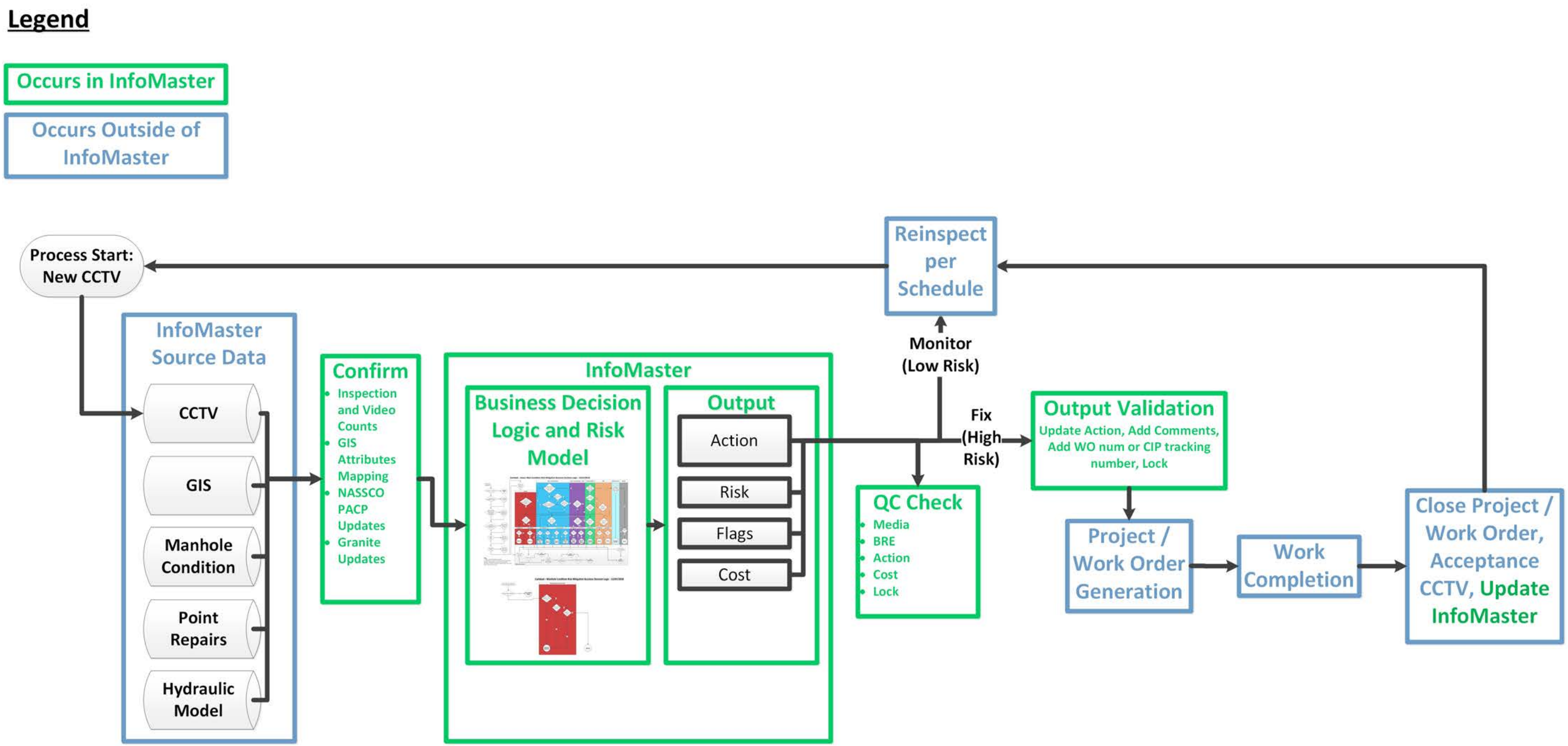
Figure E-1. InfoMaster Gravity Sewer and Manhole Renewal Workflow



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InfoMaster software is used to develop the risk model and the InfoMaster Rehabilitation Plan which includes the recommended renewal action, BREs and flags for reviewers. Once the data has been processed in InfoMaster, the results should be reviewed for quality control, including verifying CCTV video media are linked to assets, risk scores and renewal actions are appropriate, and InfoMaster records that are locked should be locked.

The next steps include validating the output, developing work orders or projects, and developing costs. The City has results summarized for CUES CCTV data in the Asset Management Master Plan. Results in InfoMaster will be validated and projects will initially be identified using InfoMaster. After completion of the work order or project, close-out procedures are performed including updating or unlocking InfoMaster records. A typical workflow for validating the output through close-out is show on Figure E-2.

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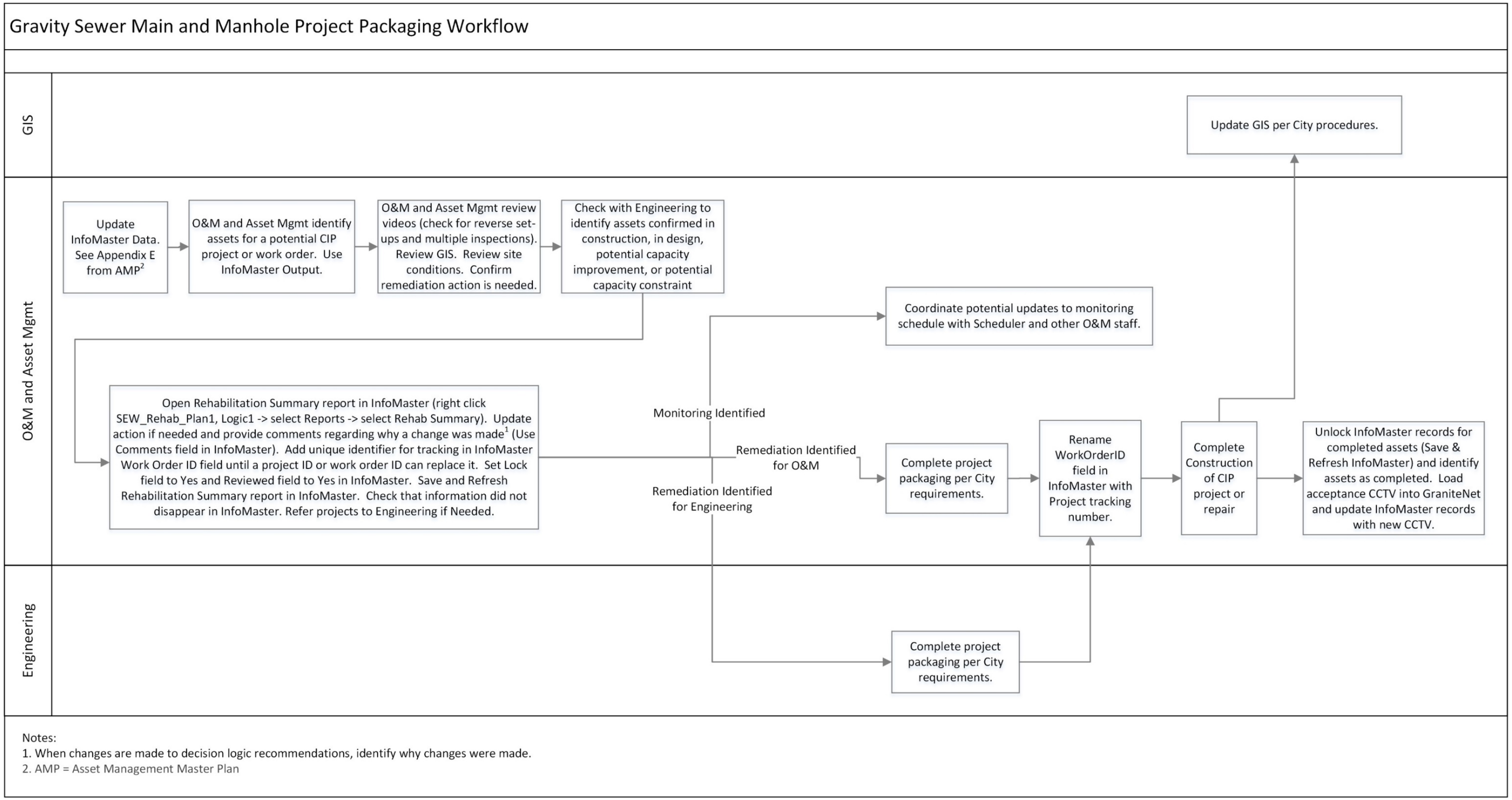
Figure E-2. Output Validation and Project Packaging Workflow



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InfoMaster Closed-Circuit Television Data and Analysis Updates

The City will not need to update the CCTV data in InfoMaster periodically for the CUES CCTV data because the City no longer inspects gravity sewers with this data format. However, the City may choose to update the decision logic or defect code information in InfoMaster and the City may choose to update sewer and manhole data associated with the CUES CCTV data format. In the future, the City will need to update the CCTV data in InfoMaster when NASSCO PACP data is analyzed in InfoMaster.

These updates require the CCTV data to be imported, risk models rerun, rehabilitation plan rerun, and facilities updated. The *InfoMaster: Update Data and Analysis Quick Reference* below documents the steps to update the data in InfoMaster.

InfoMaster Closed-Circuit Television Data Update and Analysis Quick Reference

1. Facilities (Sewer Mains and Manholes)
    a. InfoMaster drop down menu > Import Facility Data
    b. Click Next
    c. Navigate to the sewer main and manhole location on the City's servers. The CUES data uses the C:\InfoMaster\Carlsbad IMSewer Draft Model and Files02052019\Carlsbad IMSewer Draft Model and Files\CarlsbadDataToInnovyze.gdb
    d. Set Manhole and gravity main
    e. Refer to below quick reference guides for field mapping, query definition, and import settings
2. CCTV Inspections, Observations, and Video links
    a. Update the Survey data
        i. Relies on the Sewer Data Import to link Facilities to Surveys
        ii. Right click CCTV_Import_Updated_High_v3, > Choose Import
        iii. Leave the defaults and click next
        iv. Navigate to the CCTV inspection and observations databases on the City's servers. The CUES data is already uploaded to InfoMaster.
        v.
        vi. Set the Inspections, Conditions, and Media tables to the location of data on the City's servers
        vii. Refer to quick reference guide included in the Asset Mgmt Master Plan Appendix for table/field mapping and import settings

b. Update the Defect Scores (this may be used to adjust the severity of defects for CUES or future PACP data)

   i. Relies on the defects code table in InfoMaster

   ii. Update the condition geocoding (placement along the line in GIS)

   iii. If displaying the analysis results (defects) in the map, these layers MUST be removed from the map first or an error will occur in processing.

   iv. Right click CCTV_Import_Updated_High_v3 > Choose Run for the CUES data.

   v. To display the results in the map right click the CCTV_Import_Updated_High_v3 and choose Map Display>All Defect Layers for the CUES data.

3. Consequence of Failure (COF)

   a. Relies on GIS data

   b. Run the Analysis (*replaces existing analysis). 2 Options

      i. You can run each COF score individually by right clicking each one and choosing RUN, or;

      ii. You can run them all at once by right clicking consequence of failure (COF) and choosing Batch Run.

4. Likelihood of Failure (LOF)

   a. Relies on inspection, cleaning frequency and capacity data

   b. Run the Analysis (*replaces existing analysis). 2 Options

      i. You can run each LOF score individually by right clicking each one and choosing RUN

      ii. You can run them all at once by right clicking likelihood of failure (LOF) and choosing Batch Run.

5. Risk

   a. Relies on the consequence of failure (COF) and likelihood of failure (LOF) tables

   b. Right click SEW_Risk 1, COF + LOF > choose Run

6. Failure/Deterioration Model: Skip we don’t use it

7. Rehabilitation Plan (Decision Logic)

   a. Relies on GIS data and Risk analysis

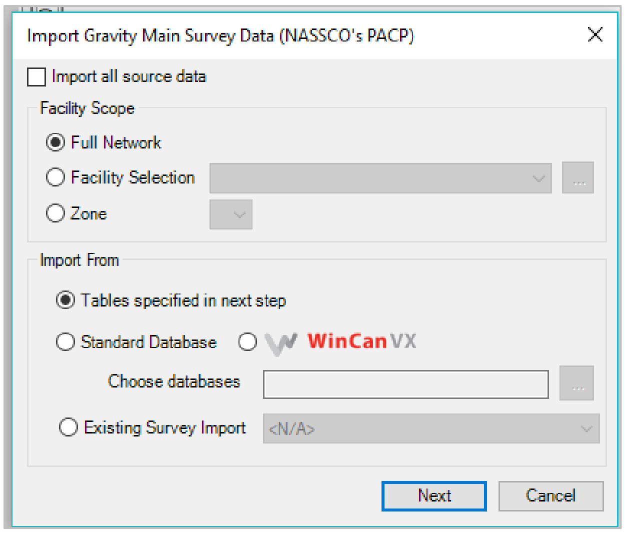
   b. Right click SEW_RehabPlan1, SewerMain Renewal_Plan > choose Run

CCTV Data Import Settings and Field Mapping

The City will not need to update the CCTV data in InfoMaster periodically for the CUES CCTV data because the City no longer inspects gravity sewers with this data format. However, generic information is provided below for the City's reference.

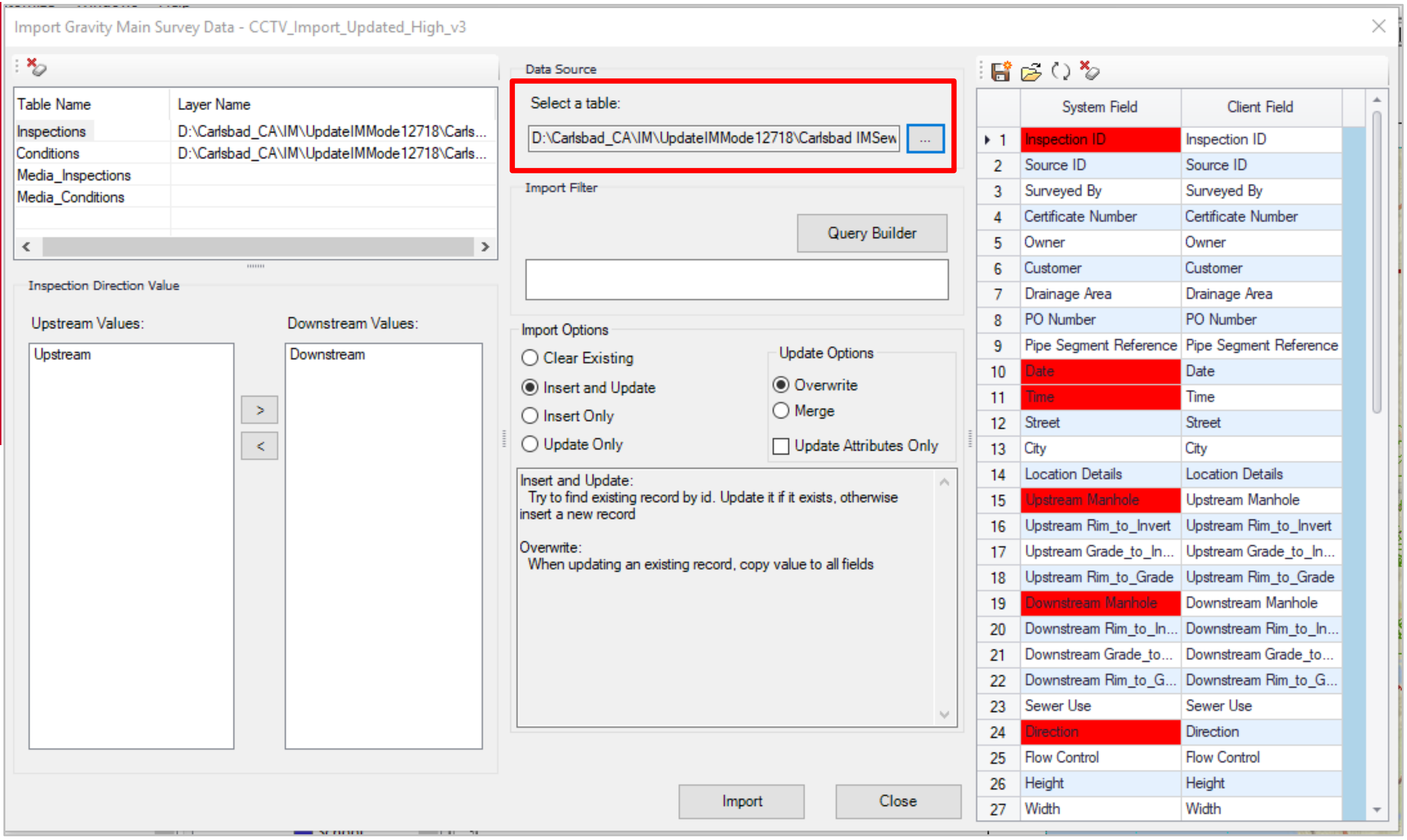
CCTV Data Import Settings

Right click CCTV_Import_Updated_High_v3> Choose Import for CUES data. Note, the CUES data will not need to be updated.



Leave the defaults and click next.

Load the Inspections, Conditions, and Media tables by navigating to the table file locations using the 'Select a table' button (red outline below).



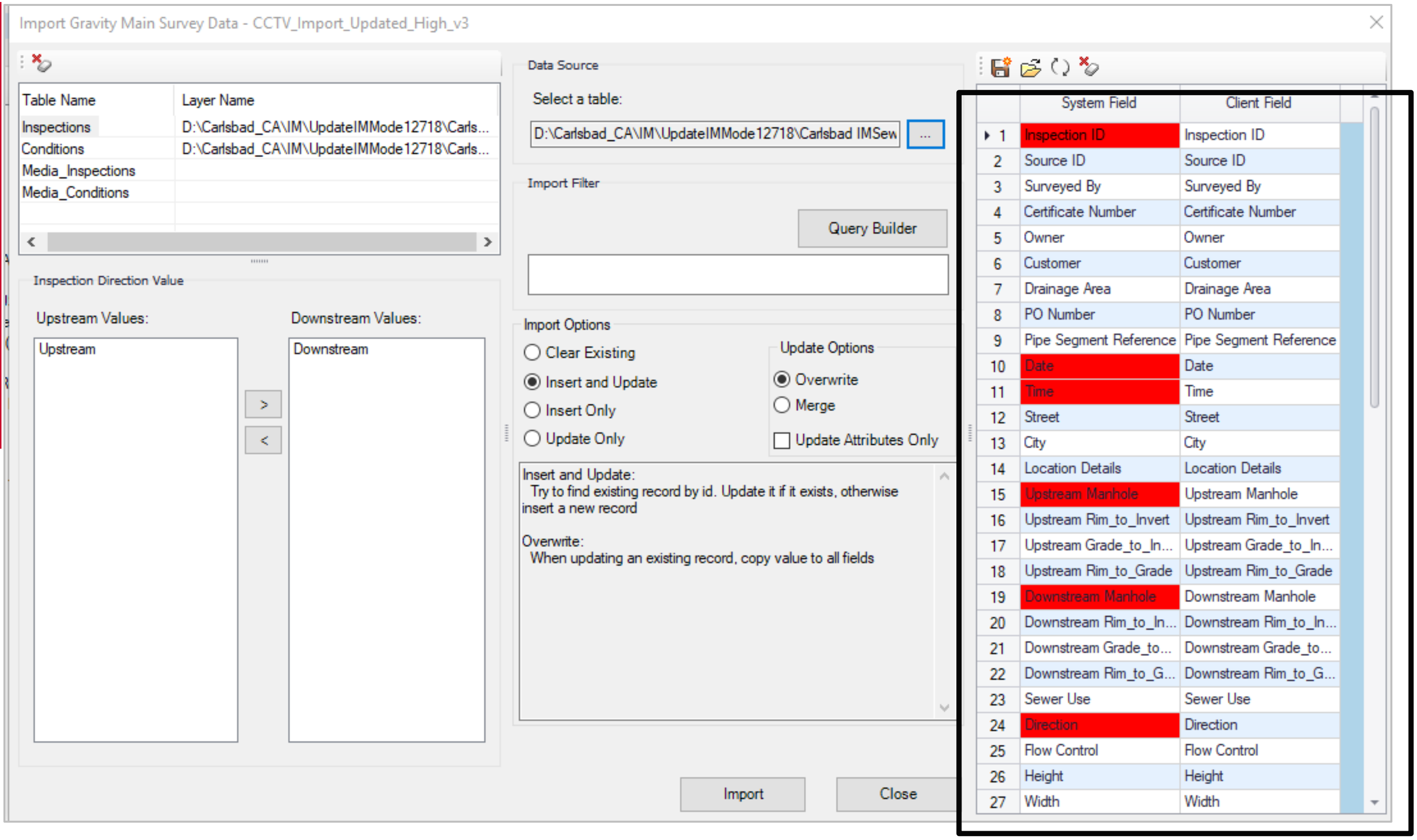
See below for field mapping and import settings.

Field Mapping for Inspections

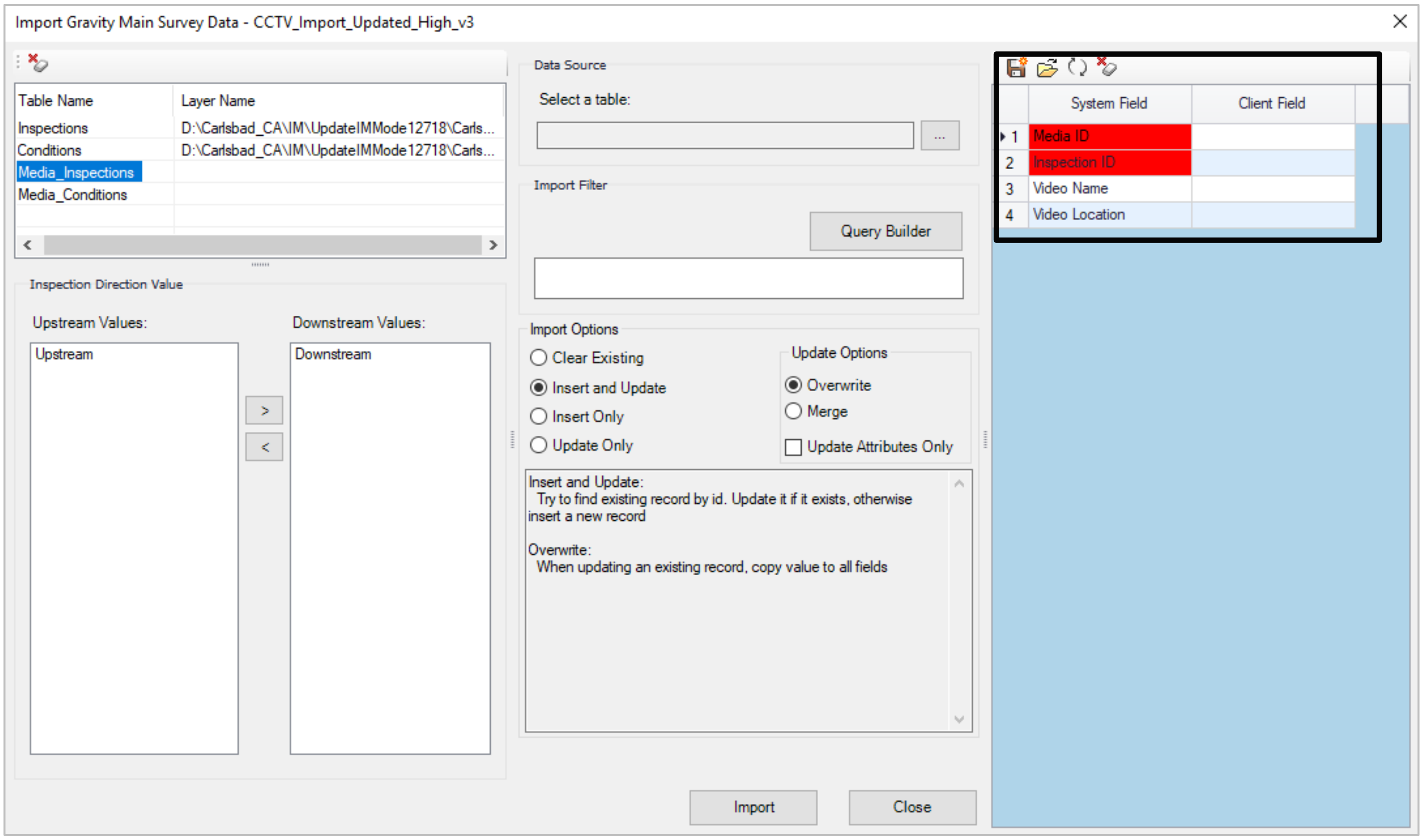
Field mapping translates the CCTV inspections outside of the InfoMaster model and imports the data into the InfoMaster project database. CUES data has already been uploaded. PACP format may be utilized by the City in the future.

PACP Format
InspectionID
OriginalID
Owner
Date_
Time_
Upstream_MH
Downstream_MH
Direction
Width
Total_Length

The system field is the InfoMaster Survey import field and the Client field is the adjustable fields. The required fields are highlighted in red.


Import Gravity Main Survey Data - CCTV_Import_Updated_High_v3
Table Name
Layer Name
Inspections
D:\Carlsbad_CA\IM\UpdateIMMode12718\Carls...
Conditions
D:\Carlsbad_CA\IM\UpdateIMMode12718\Carls...
Media_Inspections
Media_Conditions
Inspection Direction Value
Upstream Values:
Downstream Values:
Upstream
Downstream
Data Source
Select a table:
D:\Carlsbad_CA\IM\UpdateIMMode12718\Carlsbad IMSew
Import Filter
Query Builder
Import Options
Clear Existing
Insert and Update
Insert Only
Update Only
Update Options
Overwrite
Merge
Update Attributes Only
Insert and Update:
Try to find existing record by id. Update it if it exists, otherwise insert a new record
Overwrite:
When updating an existing record, copy value to all fields
Import
Close
System Field
Client Field
1 Inspection ID Inspection ID
2 Source ID Source ID
3 Surveyed By Surveyed By
4 Certificate Number Certificate Number
5 Owner Owner
6 Customer Customer
7 Drainage Area Drainage Area
8 PO Number PO Number
9 Pipe Segment Reference Pipe Segment Reference
10 Date Date
11 Time Time
12 Street Street
13 City City
14 Location Details Location Details
15 Upstream Manhole Upstream Manhole
16 Upstream Rim_to_Invert Upstream Rim_to_Invert
17 Upstream Grade_to_In... Upstream Grade_to_In...
18 Upstream Rim_to_Grade Upstream Rim_to_Grade
19 Downstream Manhole Downstream Manhole
20 Downstream Rim_to_In... Downstream Rim_to_In...
21 Downstream Grade_to... Downstream Grade_to...
22 Downstream Rim_to_G... Downstream Rim_to_G...
23 Sewer Use Sewer Use
24 Direction Direction
25 Flow Control Flow Control
26 Height Height
27 Width Width

Field Mapping for Inspection Media



The below includes Media Instructions for CUES CCTV Data.

1) Video Name, location, and path need to be in the required format:

   a. Video file name updates:

Existing video information in the CCTV_Observations Table.Video field	Video Name updated to remove path to the following for InfoMaster
\\fdstore01\wdvideo\Wdvideo\Media\Video\WW ZONE 9-16B-24-16B-90-TAMARACK AVE.mpg	WW ZONE 9-16B-24-16B-90-TAMARACK AVE.mpg

   Video name must be in the media inspections table

   b. Video folder Location (relative location):
      Folder location for the individual videos. Video location must be in the media inspection table as a relative path.

      \\shares\wdvideo\Wdvideo\Media\Video\

   c. Media folder path (root):
      Root path where the video folder location is.

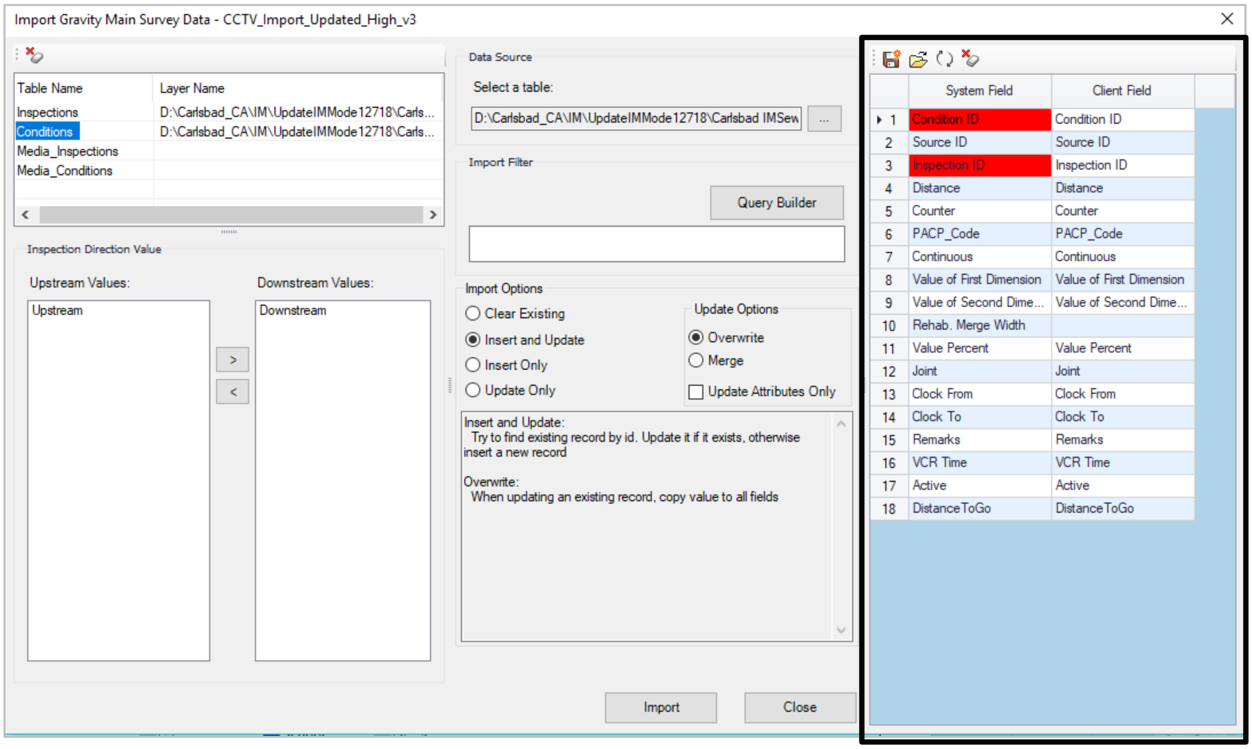
      \\shares\wdvideo\Wdvideo\Media\

InfoMaster concatenates the video root path to video path and video name to get the location to play the video.

Field Mapping for Conditions

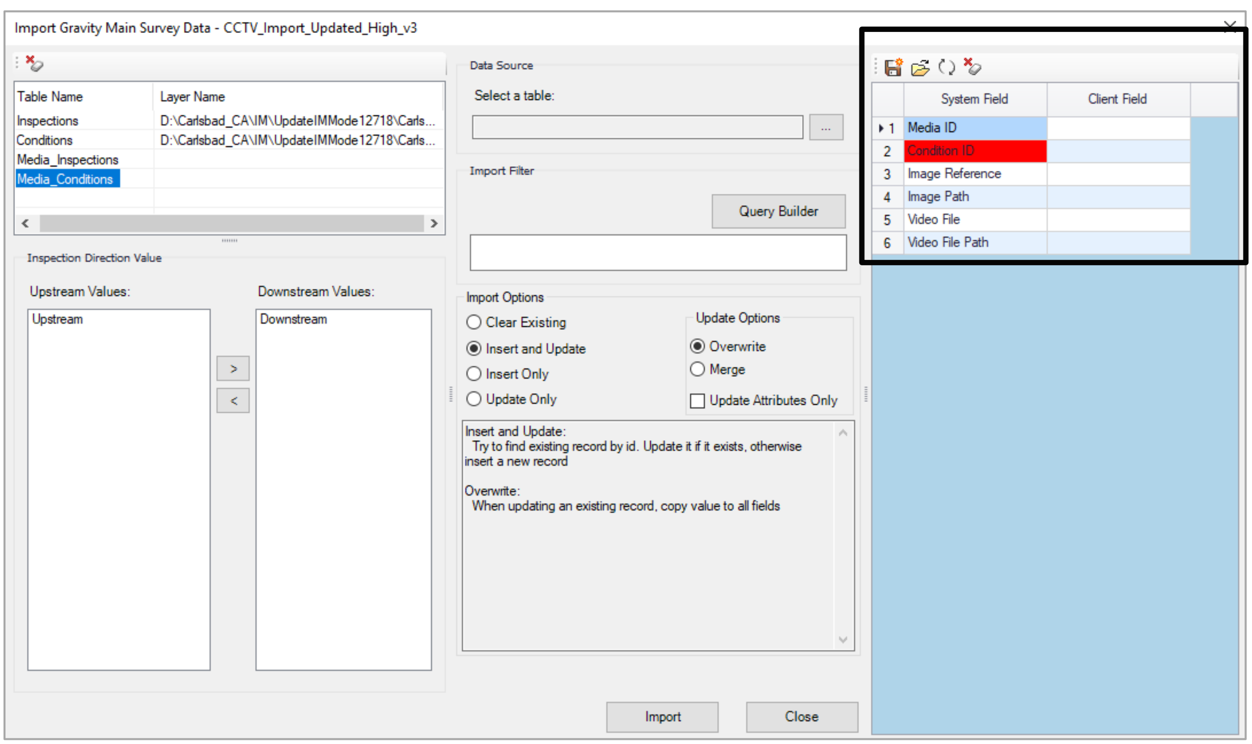
Field mapping translates the CCTV observations outside of the InfoMaster model and imports the data into the InfoMaster project database as conditions. The system field is the InfoMaster Survey import field and the Client field is the adjustable fields. The required fields are highlighted in red. CUES data has already been uploaded. PACP format may be utilized by the City in the future.

PACP Format
ConditionID
OriginalID
InspectionID
Distance
PACP_Code
Continuous
Joint
Clock_At_From
Clock_To
Remarks



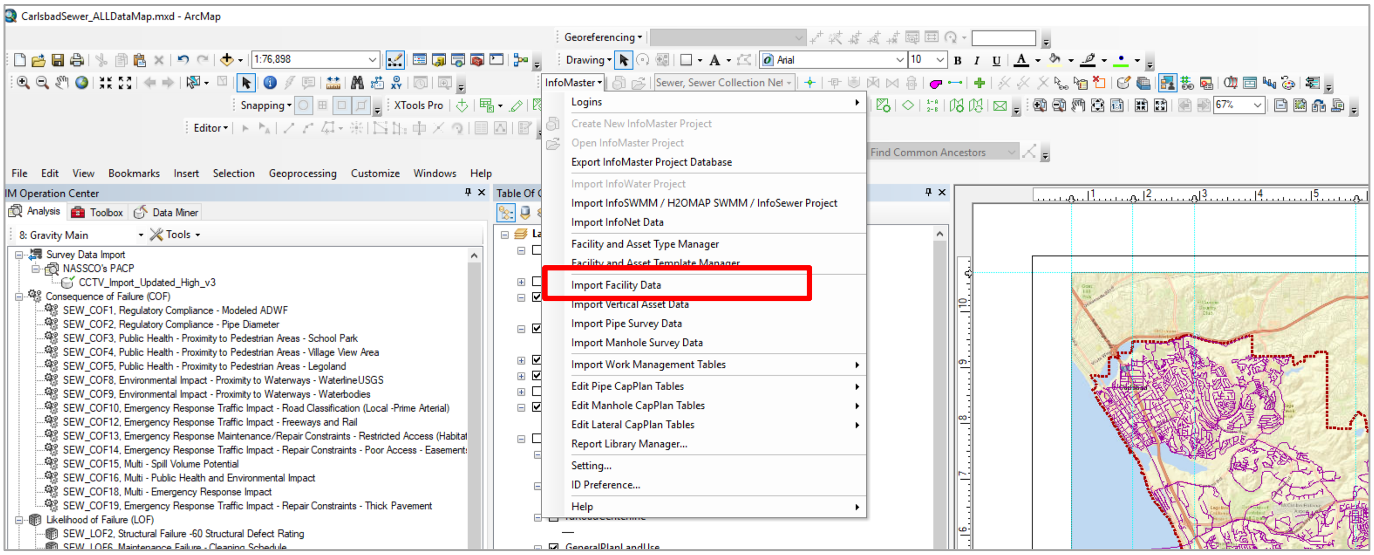
Field Mapping for Conditions Media

Conditions media was not readily available for CUES data and was not imported.

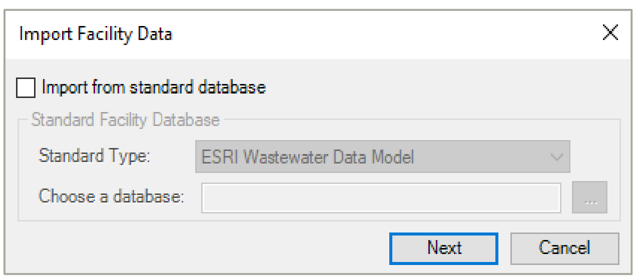


GIS Data Import Settings

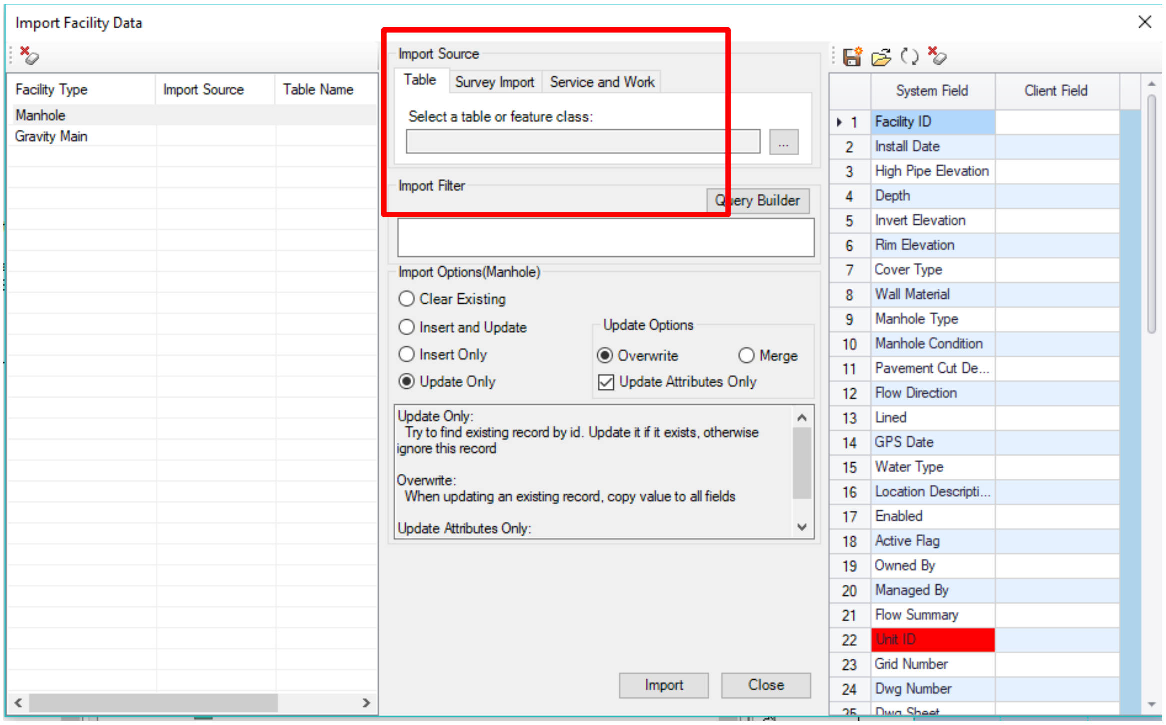
The Import Facility manager is used to import or update GIS facility data into the Infomaster Project Database. The Import facility manager is found on the Infomaster tool bar shown below:



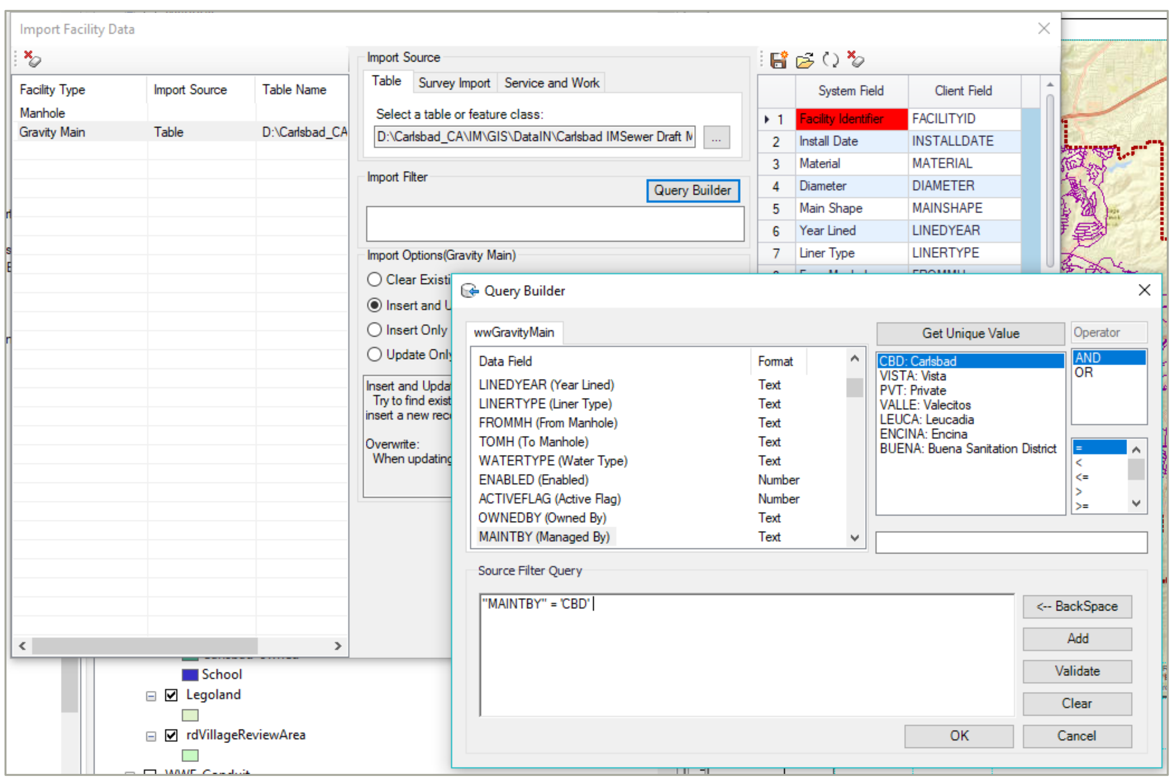
Click next or import a standard database:



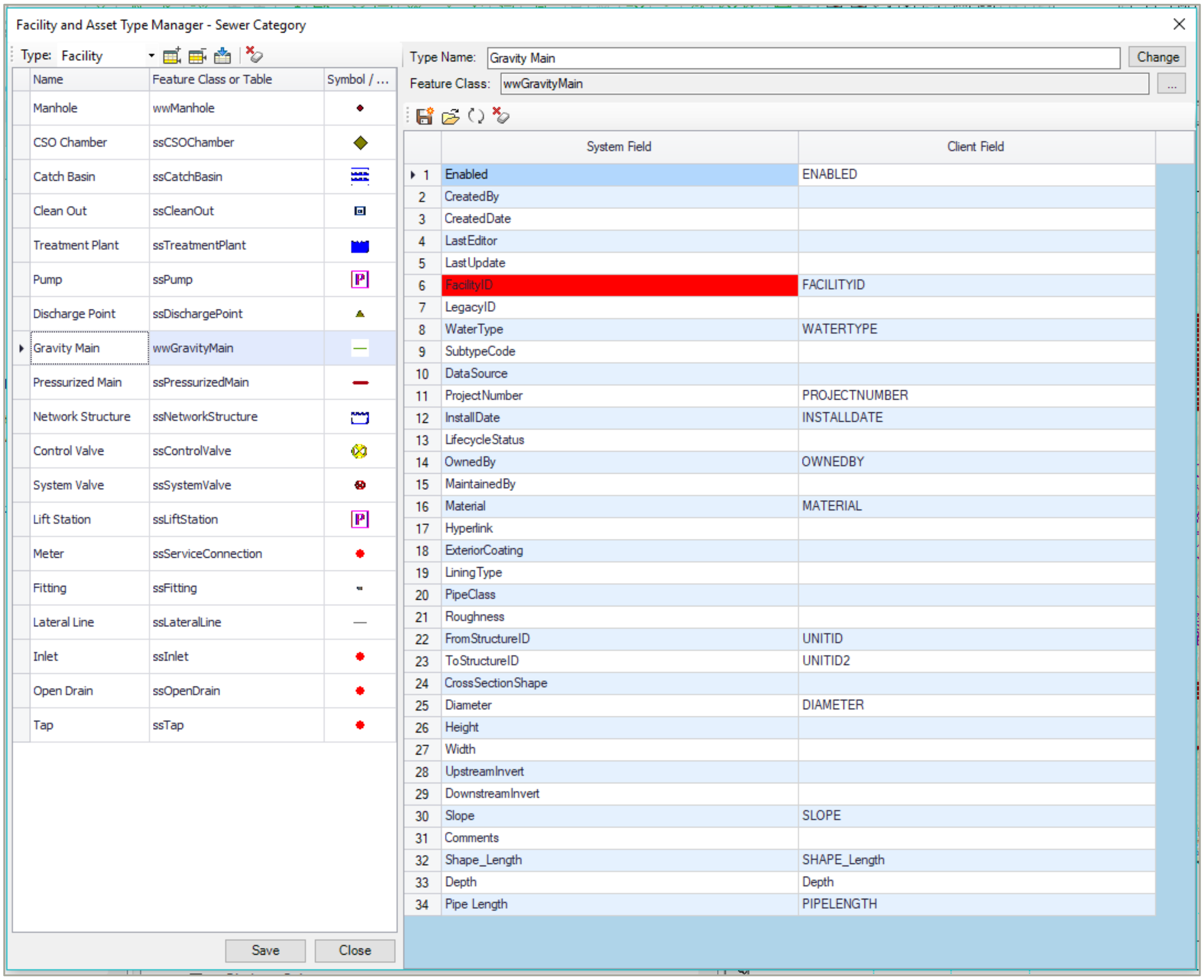
Similar to CCTV data import the import source table fields are used to populate the facility data into the InfoMaster project database.



Import Queries can be used here as well. For example all gravity mains managed by Carlsbad would be:



Full facility information can be mapped into the Infomaster project database. The model will keep previous mapping fields per category (facility type) which can be found in the Facility and Asset Type Manager.



Sewer Main Mapping

Location:

C:\InfoMaster\Carlsbad IMSewer Draft Model and Files02052019\Carlsbad IMSewer Draft Model and Files\CarlsbadDataToInnovyze.gdb for CUES data.

Field Mapping:

Type Name: Gravity Main

Feature Class: wwGravityMain

	System Field	Client Field
1	Enabled	ENABLED
2	CreatedBy	
3	CreatedDate	
4	LastEditor	
5	LastUpdate	
6	FacilityID	FACILITYID
7	LegacyID	
8	WaterType	WATERTYPE
9	SubtypeCode	
10	DataSource	
11	ProjectNumber	PROJECTNUMBER
12	InstallDate	INSTALLDATE
13	LifecycleStatus	
14	OwnedBy	OWNEDBY
15	MaintainedBy	
16	Material	MATERIAL
17	Hyperlink	
18	ExteriorCoating	
19	LiningType	
20	PipeClass	
21	Roughness	
22	FromStructureID	UNITID
23	ToStructureID	UNITID2
24	CrossSectionShape	
25	Diameter	DIAMETER
26	Height	
27	Width	
28	UpstreamInvert	
29	DownstreamInvert	
30	Slope	SLOPE
31	Comments	
32	Shape_Length	SHAPE_Length
33	Depth	Depth
34	Pipe Length	PIPELENGTH

Manhole Mapping

Location:

C:\InfoMaster\Carlsbad IMSewer Draft Model and Files02052019\Carlsbad IMSewer Draft Model and Files\CarlsbadDataToInnovyze.gdb for CUES data

Field Mapping:

Type Name: Manhole

Feature Class: wwManhole

	System Field	Client Field
1	AncillaryRole	
2	Enabled	ENABLED
3	CreatedBy	
4	CreatedDate	
5	LastEditor	
6	LastUpdate	
7	FacilityID	UNITID
8	LegacyID	
9	WaterType	WATERTYPE
10	DataSource	
11	ProjectNumber	PROJECTNUMBER
12	InstallDate	INSTALLDATE
13	LifecycleStatus	
14	OwnedBy	OWNEDBY
15	MaintainedBy	
16	LocationDescription	
17	SymbolRotation	
18	Hyperlink	
19	AccessDiameter	
20	AccessType	
21	GroundType	
22	HighPipeElevation	
23	RimElevation	RIMELEV
24	InvertElevation	INVERTELEV
25	ManholeDrop	
26	InteriorDrop	
27	WallMaterial	WALLMAT
28	StructuralShape	
29	ManholeType	
30	Metered	
31	Manufacturer	
32	Depth	DEPTH

Appendix F. Map of Water Access Issues

Note: This map is included in the PDF version of the Asset Management Master Plan due to the size of the map.

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Maintenance Constraint Areas
Carlsbad Municipal Water District
CITY OF CARLSBAD CALIFORNIA
CMWD Potable Water System
Water Main
Other District
CMWD; Potable
CMWD; Reclaimed
Private
Private; Reclaimed
Maintenance Constraint Mains
Carlsbad Desalination Pipeline
SDWA Transmission
Water Pump Station
Water Pressure Reducing Station
InterTie
Meter Vault
Water Reservoir
CWA Connection Point
Maintenance Constraint 25ft Buffer
CMWD
OMWD
VWD
Municipal Boundary
Parcel Boundary
OCEANSIDE
VISTA
SAN MARCOS
ENCINITAS
S.D. COUNTY
OLIVENHAIN
VALLECITOS
CWA Connection #4
CWA Connection #3
CWA Connection #6
CWA Connection #2
0
0.75
1.5
3 Miles
N

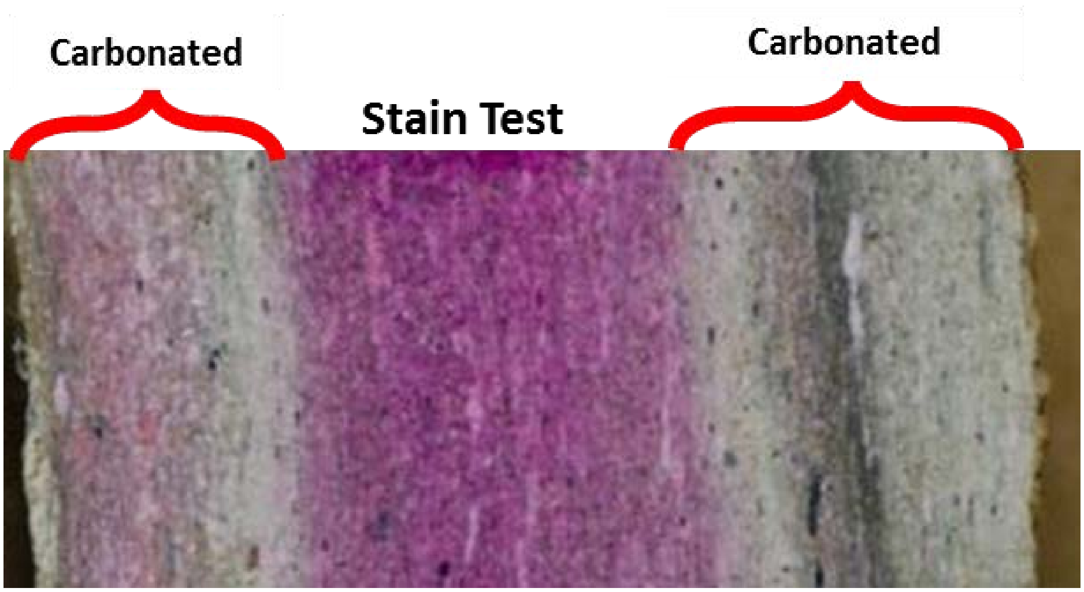
Appendix G. Corrosion of AC Pipe

The corrosion of AC pipe follows a two-step process as documented in *Water Research Foundation Project 4480 – Development of an Effective Strategy for Asbestos Cement Pipe*:

- Step 1 – Conversion of free lime ($Ca(OH)_2$) to calcium carbonate ($CaCO_3$)
- Step 2 – Calcium carbonate dissolution and transported away

The first step involves the conversion of free lime to calcium carbonate. This step can be measured by spraying phenolphthalein stain (i.e. Stain test) on a freshly exposed cross-section of the pipe wall. The portion of the pipe wall that stains is un-carbonated. The portion of the pipe wall that is unstained is carbonated. Figure G-1 shows a pipe that has been recently tested where the left side is the inner portion of the pipe wall and the right side is the outer portion of the pipe wall.

Figure G-1. Stain Test Results



Carbonation starts at both the inner and outer wall surface. Over time, it progresses towards the center of the pipe wall which is typically un-carbonated. In asbestos cement and other non-reinforced concrete applications, carbonation itself does not weaken the pipe. In fact, studies in non-reinforced concrete actually show a minor strengthening effect after carbonation. However, in AC pipes, carbonation is a precursor to corrosion.

In step two of the AC pipe corrosion process, if the environment allows for calcium carbonate to be dissolved and carried away from the calcium-silicate-hydrate and other cement products in the concrete matrix, strength is lost and the pipe becomes more susceptible to failure.

The extent of this degradation process can be measured by assessing the remaining calcium (Ca) content using the Energy Dispersive X-Ray Spectroscopy test (EDS test).

Figure G-2 shows the EDS test results for the same sample shown in Figure G-1. In this test, calcium content is measured at multiple points (i.e. wall locations) along the thickness of the pipe. At installation, calcium content was relatively uniform across the pipe wall thickness. As the AC pipe wall corrodes from the inner and outer wall surfaces towards the center of the wall, the calcium content will be significantly lower than the calcium content at the center of the pipe wall.

The remaining calcium content at each wall location is reported as a percentage and calculated as the calcium content at that location divided by the maximum calcium content measured at all locations along the wall. Where the remaining calcium content is high, the pipe is healthy and strong and less likely to break. Where the remaining calcium content is relatively low, the pipe is not healthy and more likely to break. Typically, active corrosion is occurring over a relatively narrow portion of the pipe wall.

Figure G-2. EDS Test Results

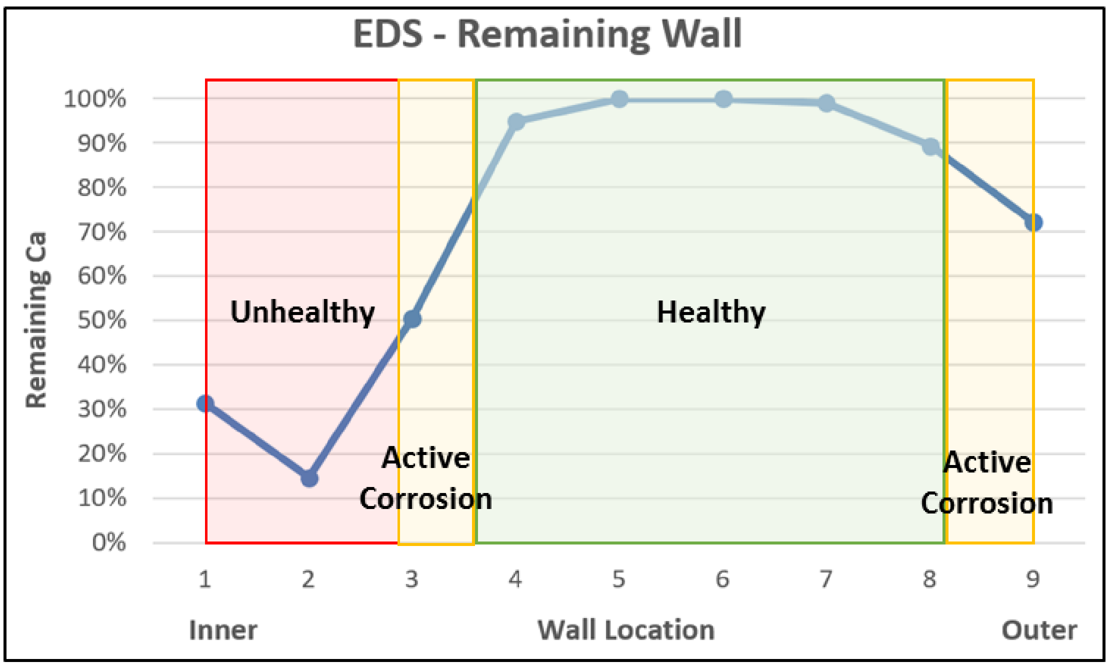
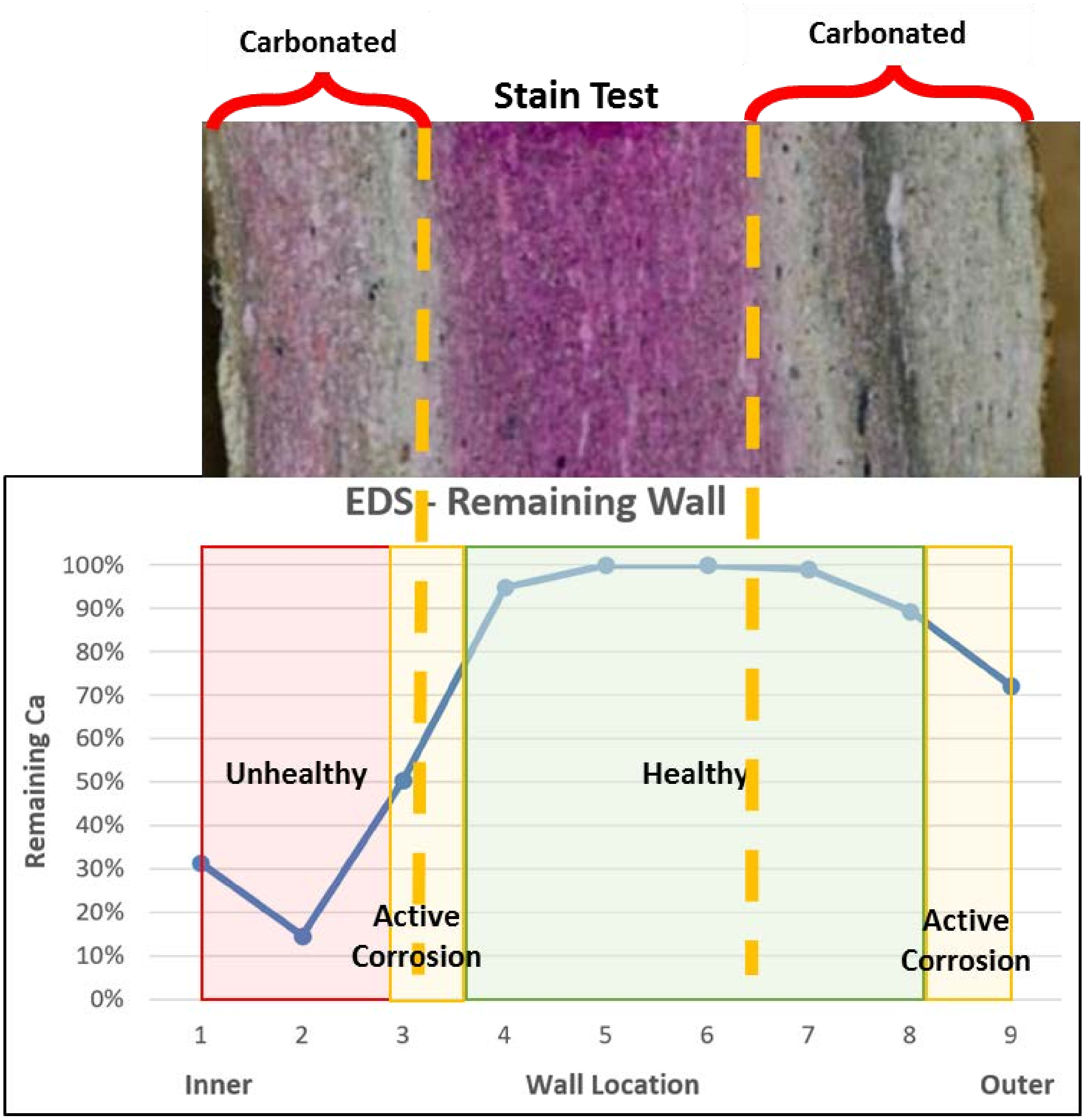


Figure G-3 orients both tests for a single sample to each other to correlate the results. On the inner portion of the pipe wall, the fresh water conveyed by the pipe is an ideal medium to dissolve and carry away calcium carbonate (Step 2 of the corrosion process). As a result, shortly after each layer carbonates (Step 1) the pipe corrodes (Step 2). This means that Stain and EDS tests typically correlate very well to each other on the inner pipe wall. However, on the outer pipe wall, there is not a consistent medium to dissolve and carry away the calcium carbonate. Therefore, carbonation can often penetrate deep into the pipe but the pipe may not corrode nor lose strength.

Figure G-3. EDS Versus Stain Test Correlation



Therefore, it is recommended that EDS data be used to determine the severity of corrosion. The remaining wall thickness was calculated as the average remaining calcium at all wall locations divided by the maximum remaining calcium multiplied by the measured wall thickness.

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Appendix H. Assessment of City AC Testing

At the time of this report, the City has collected five AC pipe samples as part of a valve replacement project. Additional samples are being collected by the City and will be analyzed in the future as they become available.

Figure G-1 below shows an example of the data provided in the EDS report. This includes a photograph of the sample and a table of the EDS measurements. As described in Appendix G, the relative calcium content is the best measure of the effective wall thickness. Calcium is reported as a percentage of elements within each point tested. Calcium is measured at ten equally spaced points along the wall thickness from the outer edge of the wall (Spectrum #1) to the inner edge of the wall (Spectrum #10). Where calcium levels are relatively low, significant corrosion has occurred. Where calcium levels are relatively high, significant corrosion has not occurred.

Figure H-1. AC Pipe EDS Test Example

Photograph #27	Remarks
	Area from sample 31902 that appeared to

Spectrum	C %	O %	Mg %	Al %	Si %	Ca %	Fe %
1	4.4	51.2	7.0	1.7	17.3	13.4	4.9
2	6.9	54.0	6.1	1.6	12.2	16.6	2.7
3	6.9	51.5	3.6	1.1	8.7	25.7	2.4
4	5.7	48.6	3.5	1.0	7.9	30.3	3.0
5	6.0	48.4	2.7	0.9	7.0	32.9	2.1
6	6.3	52.1	12.1	0.8	11.0	15.4	2.3
7	3.8	55.6	5.2	3.9	14.9	11.7	5.0
8	3.2	53.7	8.4	1.8	14.1	14.5	4.3
9	3.7	56.1	10.4	2.2	14.3	9.8	3.5
10	3.4	52.3	6.7	2.1	15.5	13.3	6.8
Mean	5	52	7	1.7	12	18	4
Sigma	2	3	3	0.9	4	8	2

Fe % annotations: Significant Deterioration (spectrum 1); Active Deterioration (spectrum 2); Healthy Pipe (spectra 3–5); Active Deterioration (spectrum 6); Significant Deterioration (spectra 7–10)

Table 1 EDS quantification results for sample 31902 (RJLG#10454360). The averaged elemental

The data was consolidated into a single spreadsheet which includes the sample #, the measured diameter, the measured thickness, original design thickness, the location, the sample type (e.g. break, valve replacement, and service tap), the ten Ca readings, and the ten hardness readings (where available).

While the physical wall thickness does not change over time, the effective wall thickness decreases over time as cement leaches from the pipe wall. This thinning of the effective wall will continue until the effective wall thickness can no longer resist the stresses on the pipe (e.g. internal pressure, external loads, bending due to ground movement) resulting in a break. EDS testing measures the effective wall thickness. Typically, corrosion occurs from the outer and inner wall towards the core which is commonly deteriorated. Therefore, the remaining wall thickness is calculated as the average remaining calcium at all wall locations divided by the maximum remaining calcium. Since larger pipes require thicker walls to resist a particular load, the percent of the design thickness remaining is used to determine the condition of a pipe. Therefore, the percent of the design thickness remaining is calculated as:

$$T_R = (Ca_{Ave} * T_{Measured}) / (Ca_{Max} * T_{Design})$$

Where:

T_R = *Percent of the original class 200 design thickness remaining*

Ca_{Ave} = *Average calcium content across the sample thickness*

Ca_{Max} = *Maximum calcium content across the sample thickness*

T_{Design} = *The design wall thickness for class 200 pipe*

$T_{Measured}$ = *The measured wall thickness*

The five readily available samples are concentrated in two geographic areas. The first area is adjacent to the La Costa Golf Course near Navarra Drive and Vista Mariana as shown in Figure H-2. This area contains three samples from 8-inch pipe. The second is near the intersection of Carlsbad Village and Valley Street. This area contains two samples from 8-inch pipe as shown in Figure H-3.

Figure H-2. Map of EDS Testing in La Costa Area

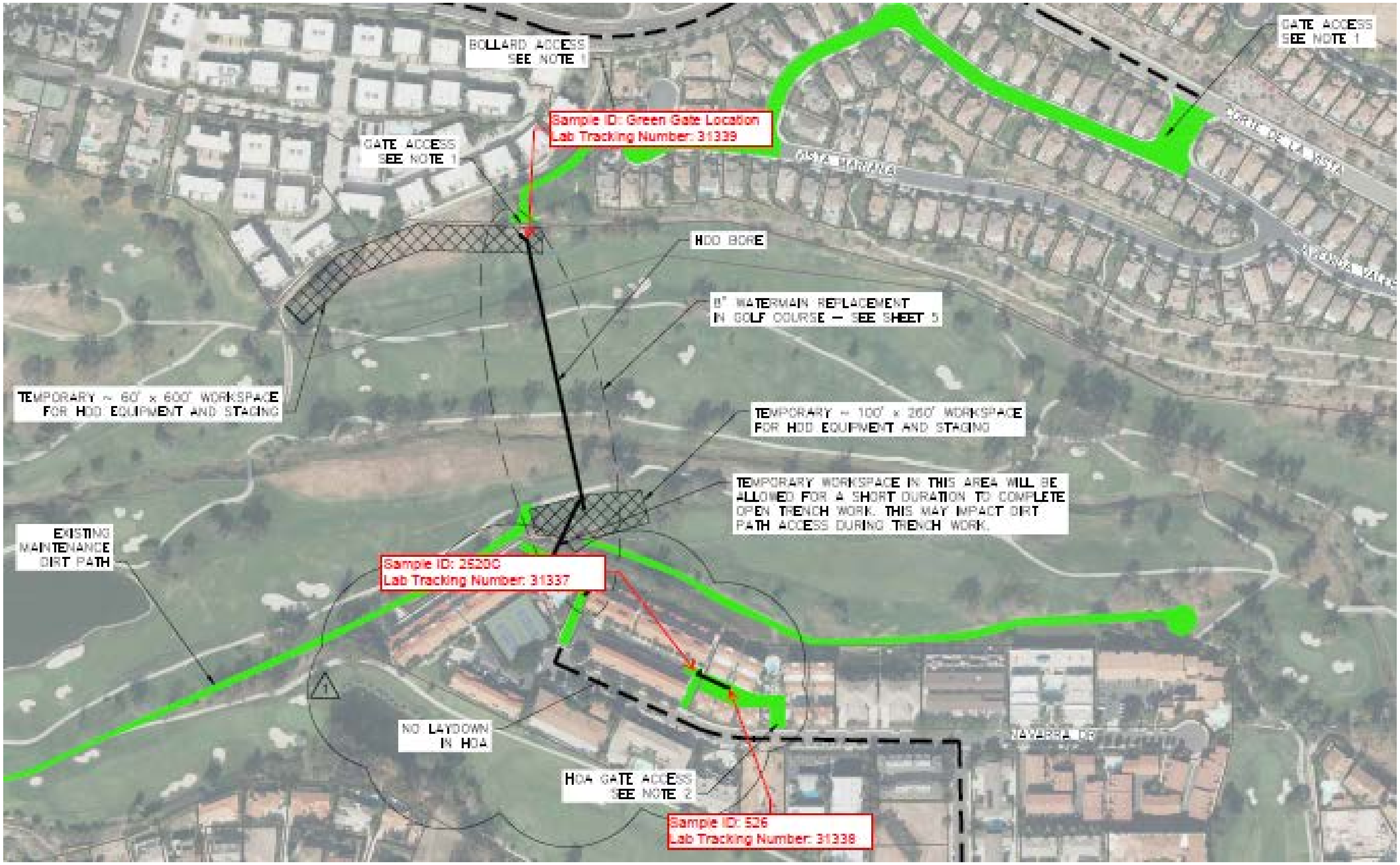

Figure H-3. Map of EDS Testing Near Carlsbad Village & Valley Street

The condition assessment results are summarized in Table H-1. All five samples have at least 70% of their original design thickness remaining. These pipes should have significant remaining useful life, particularly the pipe near the intersection of Carlsbad Village and Valley.

Table H-1. Summary of EDS Testing Results

Area	LabSampleID	Diameter	T_{Design}	$T_{Measured}$	Ca_{Ave}	Ca_{Max}	$T_{remaining}$
Carlsbad Village & Valley	31598	14	1.28	1.3	27.6%	34.0%	83%
Carlsbad Village & Valley	31599	14	1.28	1.3	26.8%	33.0%	83%
La Costa Golf Course	31339	8	0.75	0.83	21.6%	33.9%	70%
La Costa Golf Course	31338	8	0.75	0.77	24.4%	32.6%[21]	77%
La Costa Golf Course	31337	8	0.75	0.71	22.4%	29.8%	71%

[21] An abnormally large Ca reading (47.9%) was reported but removed from this sample. It is believed to be a laboratory reporting error.

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Appendix I. Break Rate and Replacement Rate Comparison

A comparison of break rates and replacement rates for selected utilities is included in the table below.

Utility/Entity	Break Rate	Replacement Rate
Vista Irrigation District	8	0.4%
Helix Water District	6	0.4%
Mesa Water District	3	0.1%
East Bay MUD	11	0.5%
Contra Costa Water District	1	0.4%
Padre Dam Municipal Water District	3	0.2%
Buena Park	1	0.1%
San Juan Capistrano	9	0.1%
Carlsbad	2	0.1%
Rainbow MWD	14	0.5%
Denver	11	0.4%
City of Phoenix	14	0.4%
Sweetwater Authority/South Bay Irrigation District	8	0.5%
San Dieguito	1	0.1%
Long Beach	3	0.4%

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Appendix J. Water Pipeline and Valve Cumulative Annual Investment

The table below shows the estimated cumulative annual investment need for recycled water and potable water pipelines and valves over the next 50 years by investment type without inflation:

- Replacement – Pipe replacement due to condition and performance issues. During replacement, adjacent valves, services, and other appurtenances will also be replaced.
- Access – When a pipe replacement project is triggered, the cost to address additional access issues in a single project.
- Valves – The cost to replace critical inoperable valves when the adjacent pipe has significant remaining useful life.
- Cathodic Protection – The cost to develop and maintain cathodic protection systems to extend the life of metallic pipe.
- Condition Assessment – The cost to perform non-destructive condition assessment and ensure the right pipes are replaced at the right time.

Year	Replacement (million)	Access (million)	Valve (million)	Cathodic Protection (million)	Condition Assessment (million)	Total (million)
2020	$1.98	$0.34	$1.00	$0.20	$0.44	$3.96
2021	$2.12	$0.36	$1.00	$0.20	$0.44	$4.12
2022	$2.24	$0.38	$1.00	$0.20	$0.44	$4.26
2023	$2.37	$0.40	$1.00	$0.20	$0.44	$4.41
2024	$2.49	$0.42	$1.00	$0.20	$0.44	$4.55
2025	$2.60	$0.44	$1.00	$0.05	$0.44	$4.54
2026	$2.72	$0.46	$1.00	$0.05	$0.44	$4.68
2027	$2.84	$0.48	$1.00	$0.05	$0.44	$4.81
2028	$2.96	$0.50	$1.00	$0.05	$0.44	$4.95
2029	$3.07	$0.52	$1.00	$0.05	$0.44	$5.09
2030	$3.19	$0.54	$1.00	$0.05	$0.44	$5.22
2031	$3.31	$0.56	$1.00	$0.05	$0.44	$5.36
2032	$3.43	$0.58	$1.00	$0.05	$0.44	$5.50
2033	$3.55	$0.60	$1.00	$0.05	$0.44	$5.64

Year	Replacement (million)	Access (million)	Valve (million)	Cathodic Protection (million)	Condition Assessment (million)	Total (million)
2034	$3.67	$0.62	$1.00	$0.05	$0.44	$5.78
2035	$3.79	$0.64	$1.00	$0.05	$0.44	$5.93
2036	$3.92	$0.67	$1.00	$0.05	$0.44	$6.07
2037	$4.04	$0.69	$1.00	$0.05	$0.44	$6.22
2038	$4.17	$0.71	$1.00	$0.05	$0.44	$6.37
2039	$4.30	$0.73	$1.00	$0.05	$0.44	$6.52
2040	$4.43	$0.75	$1.00	$0.05	$0.44	$6.67
2041	$4.57	$0.78	$1.00	$0.05	$0.44	$6.83
2042	$4.70	$0.80	$1.00	$0.05	$0.44	$6.99
2043	$4.84	$0.82	$1.00	$0.05	$0.44	$7.15
2044	$4.98	$0.85	$1.00	$0.05	$0.44	$7.32
2045	$5.13	$0.87	$1.00	$0.05	$0.44	$7.49
2046	$5.28	$0.90	$1.00	$0.05	$0.44	$7.66
2047	$5.43	$0.92	$1.00	$0.05	$0.44	$7.84
2048	$5.58	$0.95	$1.00	$0.05	$0.44	$8.02
2049	$5.74	$0.98	$1.00	$0.05	$0.44	$8.21
2050	$5.90	$1.00	$1.00	$0.05	$0.44	$8.40
2051	$6.07	$1.03	$1.00	$0.05	$0.44	$8.59
2052	$6.24	$1.06	$1.00	$0.05	$0.44	$8.79
2053	$6.41	$1.09	$1.00	$0.05	$0.44	$8.99
2054	$6.59	$1.12	$1.00	$0.05	$0.44	$9.20
2055	$6.77	$1.15	$1.00	$0.05	$0.44	$9.41
2056	$6.96	$1.18	$1.00	$0.05	$0.44	$9.63
2057	$7.15	$1.22	$1.00	$0.05	$0.44	$9.86
2058	$7.35	$1.25	$1.00	$0.05	$0.44	$10.09
2059	$7.55	$1.28	$1.00	$0.05	$0.44	$10.32
2060	$7.76	$1.32	$1.00	$0.05	$0.44	$10.56
2061	$7.97	$1.35	$1.00	$0.05	$0.44	$10.81

Year	Replacement (million)	Access (million)	Valve (million)	Cathodic Protection (million)	Condition Assessment (million)	Total (million)
2062	$8.19	$1.39	$1.00	$0.05	$0.44	$11.07
2063	$8.41	$1.43	$1.00	$0.05	$0.44	$11.33
2064	$8.64	$1.47	$1.00	$0.05	$0.44	$11.60
2065	$8.88	$1.51	$1.00	$0.05	$0.44	$11.88
2066	$9.13	$1.55	$1.00	$0.05	$0.44	$12.17
2067	$9.38	$1.59	$1.00	$0.05	$0.44	$12.46
2068	$9.64	$1.64	$1.00	$0.05	$0.44	$12.76
2069	$9.90	$1.68	$1.00	$0.05	$0.44	$13.07
2070	$10.18	$1.73	$1.00	$0.05	$0.44	$13.40

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