City of Whittier

Water Master Plan Update

Michael Baker
INTERNATIONAL

City of Whittier
WATER MASTER PLAN UPDATE

City of Whittier

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SECTION 1 - Executive Summary

1.1 Introduction

The Water Master Plan Update (WMP) is an update to the Water Master Plan prepared in 2008 by AKM Consulting. The WMP is an update to pertinent sections based on changes in the system that have taken place since the 2008 report was completed. The previous H20MAP hydraulic model was updated in 2010 for the Pumping Plant No. 2 Replacement Project Preliminary Design Analysis, which was then converted to Innovyze's InfoWater hydraulic modeling program as a part of this project. The hydraulic model has been utilized and calibrated to current conditions to provide the most effective tool for analysis. The purposes of the WMP include:

- Calibrate the existing hydraulic model to current conditions based on current demands and field conducted hydrant tests.
- Conduct a comprehensive water system analysis including analysis of pressure zones, distribution facilities, detailed 464 pressure zone analysis, fire flow analysis, and analyzing operations of Pumping Plant No. 2 (also known as Marshall R. Bowen Pumping Plant).
- Provide a realistic and achievable CIP that allows the City to implement improvements in accordance with their budget.

1.2 Study Area

The City of Whittier resides within the County of Los Angeles. It is generally located south of the 60 Freeway, east of the I-605 Freeway, and north of Imperial Highway (90). The City is bounded by the cities of La Habra, Santa Fe Springs, Pico Rivera, City of Industry, La Habra Heights, and other unincorporated areas of Los Angeles County. The water service area is within the City boundary and comprises roughly the western half of the City of Whittier.

The water service area for the City of Whitter is generally located west of Catalina Avenue, north of Whittier Boulevard, and east of the I-605 Freeway. This is the northwest region of the City. Approximately 50,850 people reside within the incorporated 3,492 acres of service area. About 52% of residents and businesses within the City boundary receive water from the City's water service area. All other parts of the City receive their water service from either Suburban Water Company, California Domestic Water Company, or the San Gabriel Valley Water Company.

1.3 Existing System

The City obtains one hundred percent of its water supply from groundwater wells located in the Main San Gabriel Basin and Central Basin. Water from the Main San Gabriel Basin is provided by five (5) City wells. Water from the Central Basin is provided by two (2) City wells, and water from two (2) wells in the Central Basin Water Quality Protection Plant facility is wheeled through the system to the cities of Pico Rivera and Santa Fe Springs. Transmission mains deliver water from the Main San Gabriel Basin and Central Basin to the City's Pumping Plant No. 2 (PP2), which is also known as Marshall R. Bowen Pumping Plant. PP2 has a firm capacity of 13,700 gpm and is the primary pumping facility that conveys all water supply into the City's distribution system.

The distribution system is divided into six main pressure zones (Zone 464, Zone 577, Zone 670A, Zone 670B, Zone 997A, and Zone 997B). Zone 464 is the largest pressure zone by area and it includes all of the City's interconnections with adjacent water facilities. Overall, the city's distribution system consist of twelve (12) reservoirs, six (6) pump station facilities, 143 miles of pipeline ranging from 4 to 30-inches in main diameter, twenty three (23) pressure reducing valves, ten (10) pressure relief valves, three (3) pressure sustaining valves, and eleven (11) emergency connections between pressure zones.

1.4 Water Use

Water consumption has averaged 7,100 AFY over the last 12 years (2006 to 2017), however, since 2015 there has been a significant drop in water use – 6,387 AFY. This is in sharp contrast to the period studied for the 2008 Water Master Plan where the average water consumption was 8,257 AFY from 2000 to 2007. Within recent years, water conservation has become an increasingly important factor that has influenced monthly water demand.

1.5 System Analysis

A hydraulic model of the City's water distribution system was updated and calibrated to existing conditions for this Water Master Plan. The new hydraulic model was updated and converted to Innovyze's InfoWater program, which is fully integrated into ESRI's ArcGIS ArcMap program and therefore works seamlessly with other ArcGIS features. The hydraulic model was calibrated to field conditions within approximately 5% accuracy.

The hydraulic model was used to conduct the system analysis. Aspects of the system that were analyzed include supply, storage, pump stations, system operations, pressure zone interconnections, fire flow adequacy, and system pressure. The findings from the analysis were developed into capital improvement projects.

<u>Supply Analysis:</u>

Since the local groundwater wells can currently provide at least 1.5 times the maximum day demand of the system, no new wells are recommended.

Storage Analysis:

The analysis produced no recommendations for new storage facilities; however, the City has a need to replace storage due to age of the reservoirs and other factors. The surplus in Zone 464 can be pumped to higher zones. In addition, higher zone pumping facilities should include permanent on-site generators and/or connections for portable generators to pump the surplus storage from Zone 464 to the upper zones.

Pump Station, Systems Operations, and Washington Pump Station Analysis

A pump station analysis was conducted based on the pump station criteria identified in Section 6. As a result of this analysis, no new pump stations or pumps at existing pump stations are recommended.

As described in Section 7, an analysis was conducted to maximize the water level in Ocean View Reservoir while eliminating the need to operate Washington Pump Station. However, implementing the system operations changes would result in service pressure increases in some parts of the system. Due to the concern that the service pressure increases would result in negative impacts to the system, an alternate project of replacing the existing Washington Pump Station was investigated. Based on discussions with the City, it is preferred to implement the Washington Pump Station replacement, rather than implementing the system operation changes that would result in service pressure increases in some parts of the system. The CIP includes the project to replace Washington Pump Station at its current location.

Other pump station related improvements include connections for portable generator connections at Murphy Pump Station and Rideout Pump Station so all pump stations will either have a permanent generator or portable generator connection on-site and can be operated during a local loss of power.

Fire Flow Analysis

A large number of improvements in the CIP are pipeline projects to mitigate fire flow deficiencies. The improvements typically recommend replacing undersized pipe, or adding new pipelines for looping and improved distribution. These improvements provide a measurable improvement in the fire flow availability for each area, while also not altering operations of the system.

Pipe Break Improvements

An analysis of historical pipe break data demonstrated that smaller diameter mains in areas with maximum service pressures of 80 psi and greater showed a higher frequency of pipe breaks. Therefore, numerous smaller diameter pipes with these qualities were identified and nearby recommended pipeline projects were considered such that additional smaller diameter pipes were added and grouped into larger projects geographically for efficiencies during construction. The majority of recommended pipeline improvements in the CIP are related to documented pipeline breaks. The benefit of these improvements are they increase system reliability by replacing old and undersized pipes and further improve the fire flow availability for each area.

Murphy West Reservoir Analysis:

A condition assessment performed in November 2016 identified Murphy West Reservoir as having significant deficiencies and recommended either performing major repairs or constructing a new reservoir. Based on discussions with City staff, the full replacement of both the Murphy West and East Reservoirs is the preferred project in the CIP.

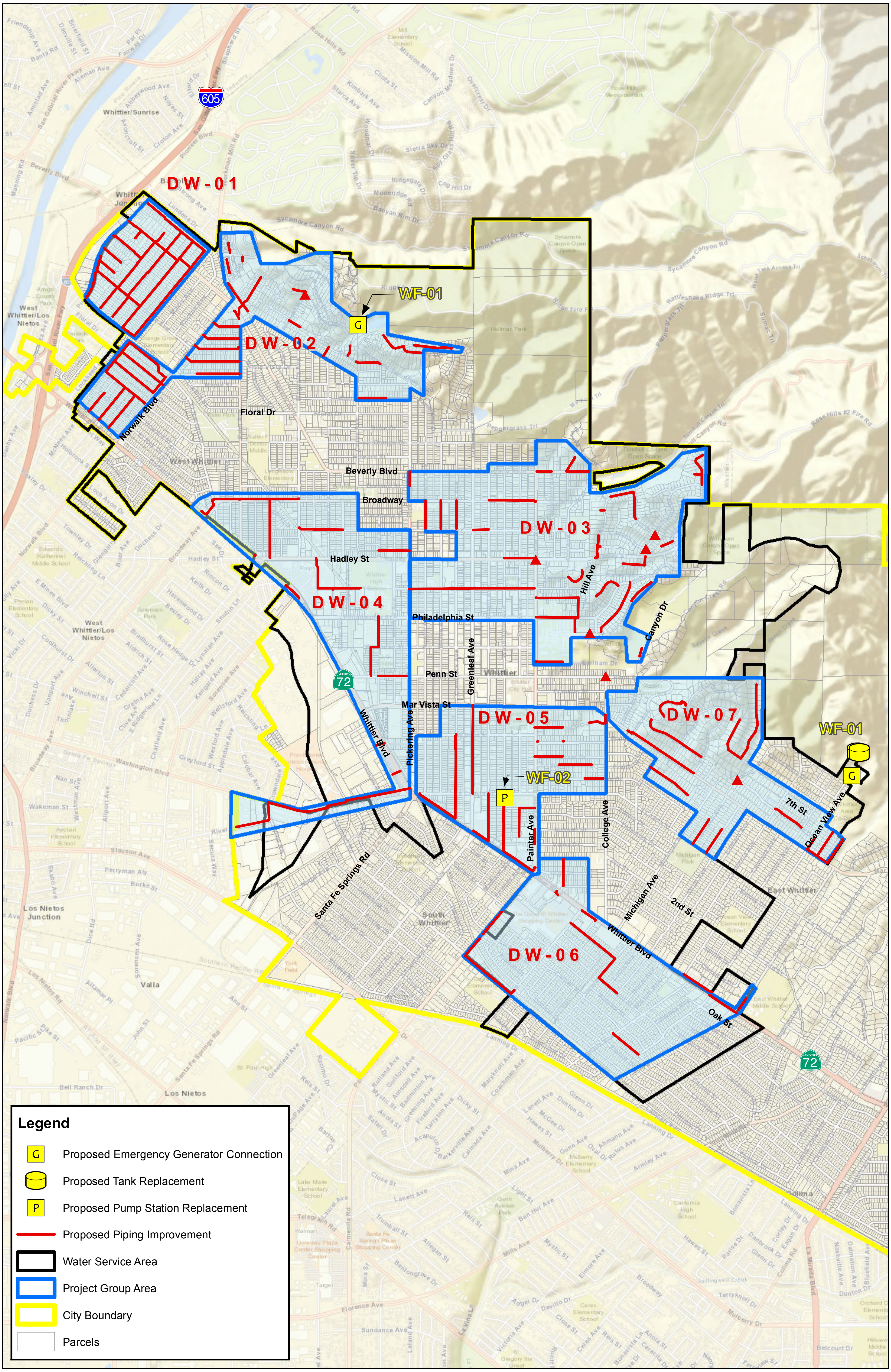
Other Analyses:

Analyses were conducted for low and high pressure areas in the system, as well as deficient pipelines based on velocity criteria. Although some deficiencies were identified, no projects were recommended based on the deficiency. The deficiencies were either mitigated or improved based on other recommended projects, or feasible CIP projects could not be implemented to improve the deficiency.

Multiple locations were identified for pressure zone interconnection projects. Locations for new pressure reducing stations were identified to provide an additional supply point to a pressure zone.

1.6 Capital Improvement Program

A master table of the recommended CIP projects is shown in Table 1-1, which lists each project identification, project title, recommended implementation year, and estimated project cost. Recommended project locations throughout the City are shown on Exhibit 1-1. The total cost of completing all projects in this CIP (in 2017 dollars) is estimated to be $71.5 M.



3/29/2018 JN M:\Mdata\151940\GIS\MXD\FinalProjectReport\Ex8-1 Capital Improvement Projects_ProjectGroups11x17P.mxd

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0 1000 2000 4000 Feet

Source: City of Whittier, Esri Street Maps

CITY OF WHITTIER MASTER PLAN

Capital Improvement Projects

Exhibit 1-1

Table 1-1: Capital Improvement Projects

Project ID	Category Project Title	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	TOTAL [1]
	Distribution System Improvements													
DW-01	West Distribution System Improvements Group No. 1	$ 3,753,000	$ 1,200,000	$ 1,600,000										**$ 6,553,000**
DW-02	West Distribution System Improvements Group No. 2			$ 1,290,000		$ 2,292,000	$ 1,360,000	$ 1,593,000	$ 1,000,000					**$ 7,535,000**
DW-03	Central Distribution System Improvements Group No. 1					$ 1,000,000	$ 2,000,000	$ 2,329,000	$ 2,560,000					**$ 7,889,000**
DW-04	Central Distribution System Improvements Group No. 2									$ 4,024,500	$ 2,024,500			**$ 6,049,000**
DW-05	South Distribution System Improvements Group No. 1									$ 2,221,000	$ 1,000,000	$ 2,000,000		**$ 5,221,000**
DW-06	South Distribution System Improvements Group No. 2											$ 2,473,000	$ 1,000,000	**$ 3,473,000**
DW-07	South Distribution System Improvements Group No. 3												$ 5,672,000	**$ 5,672,000**
	Water Facility Replacement													
WF-01	Murphy West and East Reservoir Replacement		$ 3,190,000											**$ 3,190,000**
WF-02	Washington Pump Station Replacement						$ 2,393,000							**$ 2,393,000**
WF-03	Greenleaf/Hoover Storage Replacement			$ 300,000	$ 6,000,000									**$ 300,000**
WF-04	Murphy Hills Pump Station							$ 2,000,000						**$ 2,000,000**
WF-05	Rideout Reservoir Replacement								$ 2,000,000					**$ 2,000,000**
WF-06	Starlight Reservoir Redundancy									$ 1,000,000				**$ 1,000,000**
WF-07	Hazzard Reservoir Replacement											$ 2,000,000		**$ 2,000,000**
WF-08	College Hills Reservoir Replacement										$ 4,000,000			**$ 4,000,000**
WF-09	Booster Station Repair	$ 100,000	$ 100,000			$ 200,000			$ 200,000					**$ 600,000**
WF-10	Oceanview Reservoir Improvements													
	Pipeline Replacement Program													
WR-01	Cylindrical Steel Pipeline Replacement Program	$ 400,000		$ 1,000,000		$ 2,000,000								**$ 3,400,000**
	Valve Replacement Program													
VR-01	Large Valve Replacement Program	$ 200,000		$ 200,000		$ 200,000		$ 200,000		$ 200,000				**$ 1,000,000**
VR-02	Valve Replacement Program	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	**$ 1,200,000**
	Interconnection Improvements													
WI-01	Santa Fe Springs Transmission Main													**$ -**
	TOTAL [1]	**$ 4,553,000**	**$ 4,590,000**	**$ 4,490,000**	**$ 6,100,000**	**$ 5,792,000**	**$ 5,853,000**	**$ 6,222,000**	**$ 5,860,000**	**$ 7,545,500**	**$ 7,124,500**	**$ 6,573,000**	**$ 6,772,000**	**$71,475,000**

[1] All costs are in 2017 Dollars

Section 2
Introduction

SECTION 2 - Introduction

The City of Whittier (City) provides reliable, safe, and fairly-priced drinking water to its customers, which comprise approximately 52% of the residences and businesses within the City boundary. The City has contracted with Michael Baker International (MBI) to prepare a Water Master Plan Update. This section describes the purpose, scope of work, acknowledgements, abbreviations, and references used to prepare this report.

2.1 Purpose

The Water Master Plan Update (WMP) is an update to the Water Master Plan prepared in 2008 by AKM Consulting. The WMP is an update to pertinent sections based on changes in the system that have taken place since the 2008 report was completed. The previous H20MAP hydraulic model was updated in 2010 for the Pumping Plant No. 2 Replacement Project Preliminary Design Analysis, which was then converted to Innovyze's InfoWater hydraulic modeling program as a part of this project. The hydraulic model has been utilized and calibrated to current conditions to provide the most effective tool for analysis. The purposes of the WMP include:

- Calibrate the existing hydraulic model to current conditions based on current demands and field conducted hydrant tests.
- Conduct a comprehensive water system analysis including analysis of pressure zones, distribution facilities, detailed 464 pressure zone analysis, fire flow analysis, and analyzing operations of Pumping Plant No. 2 (also known as Marshall R. Bowen Pumping Plant).
- Provide a realistic and achievable CIP that allows the City to implement improvements in accordance with their budget.

2.2 Scope of Work

A summarized list of the scope of work is included below.

<u>Collect and Review Data</u>

- Collect and review all of the pertinent reports and data to ensure consistency among planning documents, including the 2010 Urban Water Management Plan, the 2008 Water Master Plan, the existing hydraulic model, GIS data, billing data, water supply data, SCADA data, and the City's current General Plan.

System Evaluation Criteria

- Establish planning and evaluation criteria to be used for the analysis and CIP development.

Demand Evaluation

- Conduct an evaluation of the existing potable water demands based on billing records provided by the City.
- Calculate the existing average day demand, maximum day demand and peak hour demand based on billing data from each meter within the service area.
- Calculate City-wide peaking factors for maximum day and peak hour.
- Develop a system-wide 24-hour diurnal curve, using SCADA data and production data, for use in the hydraulic model evaluation.
- Utilize the meter data to allocate demands in the model.

Hydraulic Model

- Review and update the City's existing H20MAP Water hydraulic model to reflect the current facilities and operation. Update existing facilities (booster stations, storage facilities, PRV stations, pipelines, etc.) attributes and settings, adding newly constructed facilities into the model. Updates include system changes that have occurred since completion of the 2008 report.
- Update system demands and reallocate based on the average day demand developed in the Demand Evaluation. Use the hydraulic model Water Demand Allocation tools to allocate metered sales to junctions, and scale the total demand as appropriate to agree with City production data.
- Direct and assist with field hydrant tests over the course of 2 full days. Conduct model calibration to an EPS Average Day Scenario.
- Develop specific C-factors for the hydraulic model based on hydrant test data.
- Calibrate hydraulic model to within 10% accuracy, or to a level where further model adjustment does not yield more accurate results. Calibrate model to a level sufficient for master planning and decision making purposes. Average day demand scenario to be peaked and adjusted to establish the other scenarios needed for analyses.

Water System Analysis

- Utilize the model to identify system deficiencies, such as: Low Pressure, High Pressure, High Velocity, and Fire Flow Availability.
- Include finalized discussions and conclusions on specific analyses that address issues such as the comprehensive analysis of 464 pressure zone, the need for additional storage facilities, available fire flow in the Uptown District, operational settings of Pumping Plant No. 2.
- Conduct an evaluation of the City's existing storage capacity. Consider both the existing demand condition and the ultimate demand condition.
- Evaluate the location of pressure zone and sub-zone boundaries, and the number of pressure zones. Determine if there is good reason to modify pressure zone boundaries to improve system performance.
- Evaluate the existing pump station capacity for each zone within the City. Determine if the existing pumping capacity is adequate to meet the established pumping criteria under existing and ultimate demand conditions.
- Recommend operation adjustments and capital improvements necessary for the water system to operate at the highest efficiency and lowest cost.

Capital Improvement Program

- Identify improvement projects to mitigate the deficiencies identified in the system analysis. Prioritize the projects based on the severity of the deficiency and risk to the City. Determine the capital cost of each project and develop a 10-year Capital Improvement Program.

Water Master Plan

- Provide a comprehensive Water Master Plan report that documents the analysis, findings, and recommendations.
- The report shall be concise and clearly written, and utilize exhibits, tables, and figures to convey important information.

2.3 Acknowledgements

Key staff members involved in the preparation of the WMP include team members from the City and MBI. Key staff members of the project team are shown in Table 2-1. MBI wishes to thank all those involved in the preparation of this Master Plan.

Table 2-1: Project Staff

Name	Title/Role	Company/Agency
David Schickling	Public Works Director	City of Whittier
Hye Jin Lee	Former Assistant Public Works Director	City of Whittier
Kyle Cason	Assistant Public Works Director	City of Whittier
Jared Macias	Former Water/Sewer Manager	City of Whittier
Dan McKenna	Water Production Supervisor/ Water Manager	City of Whittier
Bob Campagne	Water Distribution Supervisor	City of Whittier
Chris Waggener	Water Production Supervisor	City of Whittier
John Nagle	Principal In Charge	MBI
Tori Yokoyama	Project Manager	MBI
Safa Kamangar	Technical Manager	MBI
Troy Edwards	Design Engineer/Hydraulic Modeler	MBI
Charlie Marr	QAQC	MBI
Edgar Gomez	Assistant Engineer	MBI

2.4 References

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California Department of Finance, Demographic Research Unit. May 2016. Population and Housing Estimates for Cities, Counties, and the State, January 1, 2011-2016, with 2010 Benchmark.

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Section 3
Study Area

SECTION 3 - Study Area

The purpose of this section is to describe the City of Whittier's water service area which is the study area for this report. This includes the regional location, study area description, topography, climate, land use and zoning, housing, and population.

3.1 Location

The City of Whittier resides within the County of Los Angeles, it is generally located south of the 60 Freeway, east of the I-605 Freeway, and north of Imperial Highway (90). The City is bounded by the cities of La Habra, Santa Fe Springs, Pico Rivera, City of Industry, La Habra Heights, and other unincorporated areas of Los Angeles County. The water service area is within the City boundary and comprises roughly the western half of the City of Whittier. Exhibit 3-1 shows the overall region and location of the City, and the water service area is shown in Exhibit 3-2.

3.2 Study Area

The water service area for the City of Whitter is generally located west of Catalina Avenue, north of Whittier Boulevard, and east of the I-605 Freeway. This is the northwest region of the City, as seen in Exhibit 3-2. Approximately 50,850 people reside within the incorporated 3,492 acres of service area. About 52% of residents and businesses within the City boundary receive water from the City's water service area. All other parts of the City receive their water service from either Suburban Water Systems, California Domestic Water Systems, or the San Gabriel Valley Water Company.

The service area elevations vary from about 154 feet to 756 feet above mean sea level. Six pressure zones, established by reservoir high water elevations, have been designed to accommodate the elevation range within the service area. These six zones include:

- Zone 464
- Zone 577
- Zone 670A
- Zone 670B
- Zone 997A
- Zone 997B (Closed zone served by a hydropneumatic pump station)

In addition, there are two closed zones served through pressure regulating facilities:

- Sub-Zone 400
- Sub-Zone 997A

Pressure zone boundaries are displayed on Exhibit 4-3. Some of the higher pressure zones are not continuous and require multiple reservoir sites and pumping facilities because of the extended service area ranging from the northwest to southeast.

3.3 Topographical Description

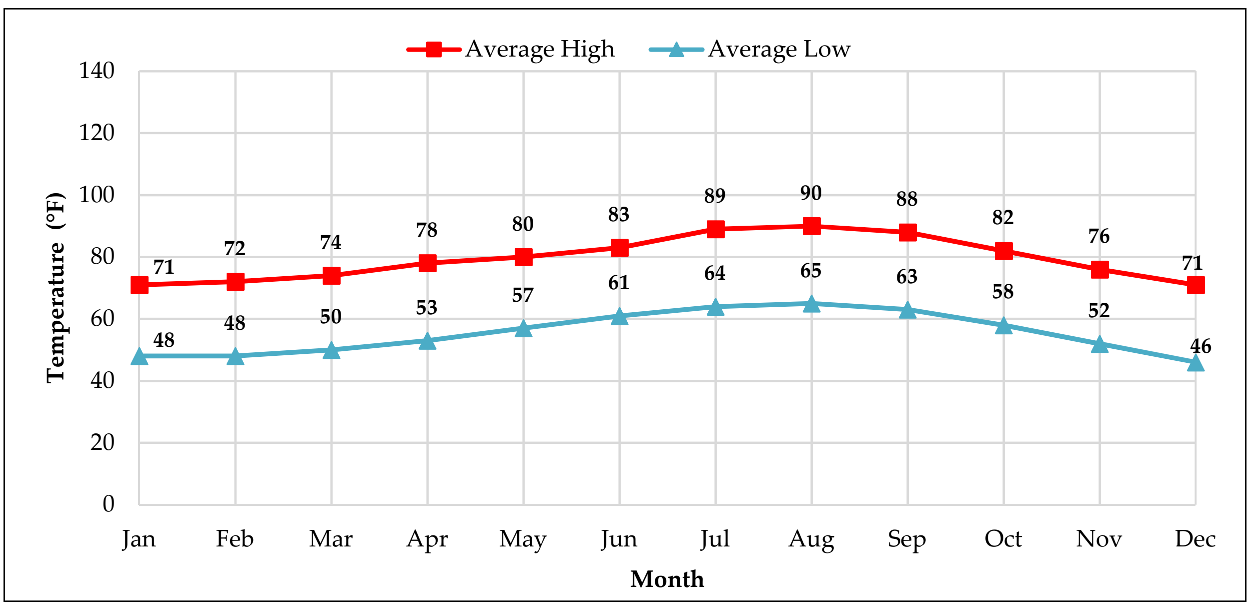
Most of the City's service area generally slopes from northeast to southwest. The lowest part of the service area is located near Rivera Road and Chetle Avenue, which is part of Zone 464. The highest part of the service area is part of Zone 997 and is located at the end of Decliff Drive, west of Southwind Drive. Starlight Reservoir and booster pumps feed water to Zone 997.

3.4 Climate

Temperature

August, July, and September are the months with the highest temperatures, with average high temperatures of 90° F, 89° F, and 88° F, respectively. December, January, and February are the months with the lowest temperatures, with average lows of 46° F, 48° F, and 48° F, respectively. Figure 3-1 shows the average high, and average low temperatures of the City. This data displays a fairly moderate change in year round temperature.

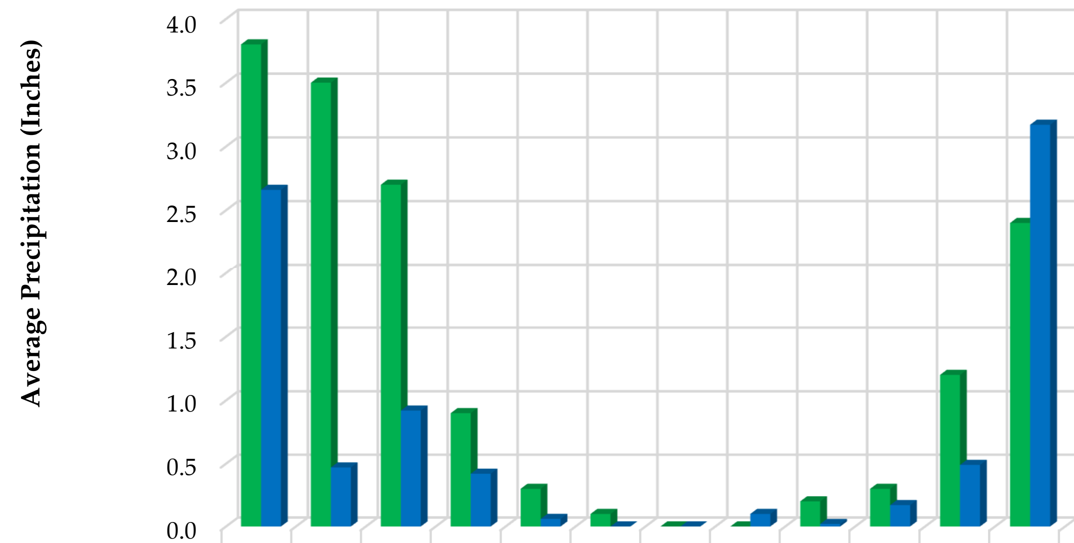
Figure 3-1: Monthly Temperature Range



Precipitation

The City of Whittier receives an average of 15.4 inches of rain per year. However, the City of Whittier received 8.5 inches of rain for the most recent year of 2015. This was a 45% reduction in precipitation compared to the average, clearly illustrating the current drought conditions that California is facing. The average number of days per year with precipitation is 31. There is an average of 278 sunny days per year. The wettest months are January, February, and March, in descending order. The driest months are July, August, and June, in descending order. Figure 3-2 shows the average monthly precipitation, and the 2015 monthly precipitation.

Figure 3-2: Monthly Precipitation



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Precipitation	3.80	3.50	2.70	0.90	0.30	0.10	0.00	0.00	0.20	0.30	1.20	2.40
2015 Precipitation	2.66	0.47	0.92	0.42	0.06	0.00	0.00	0.10	0.02	0.17	0.49	3.17

3.5 Land Use and Zoning

Zoning for the City of Whittier is divided into commercial, industrial, and residential regions that guide the development and land use of the City.

<u>Residential Zoning</u>

Hillside Residential (H-R) is considered a large lot residential development. The allowed density is 2 dwelling units per acre.

Residential Estate (R-E) and **Single Family Residential (R-1)** are located in low density residential neighborhoods. The allowed density range is 6 to 7 dwelling units per acre.

Light Multiple Residential (R-2) includes a mix of single family detached and attached units, duplex, triplex, and garden apartments. The allowed density is 15 dwelling units per acre.

Medium Multiple Residential (R-3) developments include multi-family projects, apartments, condominiums, and planned units. These developments have an allowed housing density of 25 dwelling units per acre.

Heavy Multiple Residential (R-4) are multi-family developments and special housing projects. The allowed density for these establishments is 35 dwelling units per acre.

Commercial Zoning

Commercial Office (C-O) are developments with business, medical, professional, and administrative uses. The allowed average floor area ratio is 0.5 to 2.0.

Light Commercial (C-1), **General Commercial (C-2)**, and **Commercial Manufacturing (C-3)** are retail, trade, and service uses. The allowed average floor area ratio is 0.25 to 0.5.

Manufacturing Zoning

Manufacturing (M) is all of the industrial and manufacturing uses, including warehouses. The allowed average floor area ratio is 0.6 to 1.0.

Other Zoning

Open Space (OS) includes areas with wetlands, wildlife, and natural ecosystems that are protected or conserved.

The summed acreages and densities of the zoning for both the water service area and the entire city boundary is summarized within Table 3-1.

Table 3-1: Zoning for Entire City and Water Service Area

Zoning Description		Density (DU/Ac) or (FAR [1])	Service Area (Ac)	Outside Service Area (Ac)	Total City (Ac)
H-R	Hillside Residential	2	459	70	529
R-E	Residential Estate	2	0	516	516
R-1	Single Family Residential	6 to 7	1,804	1,972	3,776
R-2	Light Multiple Residential	15	217	50	267
R-3	Medium Multiple Residential	25	56	20	76
R-4	Heavy Multiple Residential	35	178	33	211
		Residential Subtotal	**2,714**	**2,661**	**5,375**
C-O	Commercial Office	0.5 to 2.0	44	8	52
C-1	Light Commercial	0.5 to 2.0	11	0	11
C-2	General Commercial	0.25 to 0.5	34	48	82
C-3	Commercial Manufacturing		1	0	1
		Commercial Subtotal	**90**	**56**	**146**
M	Manufacturing	0.6 to 1.0	140	38	178
		Manufacturing Subtotal	**140**	**38**	**178**
OS	Open Space		68	1,273	1,341
SP	Specific Plan		480	228	708
T	Transition Zone		0	11	11
		Miscellaneous Subtotal	**548**	**1,512**	**2,060**
		Total	**3,492**	**4,267**	**7,759**

1. Floor Area Ratio (FAR) is the ratio of the floor area of the building to the area of the lot.

The zoning of the City is shown on Exhibit 3-3.

Zoning guides the land use of the City. The majority of the commercial land use is located along Whittier Boulevard, Painter Avenue, Greenleaf Avenue, and Hadley Street. Manufacturing land use is concentrated at the northwest region of Whittier Boulevard and is primarily bounded between Philadelphia Street, and Washington Boulevard. Single family residential makes up the majority of residential land use. The majority of high density residential is bounded by Whittier Boulevard, Broadway Avenue, Pickering Avenue, and Painter Avenue.

3.6 Housing Units

City and Service Area Housing Units

Housing units for the City of Whittier are reported as single detached, single attached, two to four, five plus, or mobile home by The California Department of Finance. The single family detached housing unit is the predominant housing unit type for the City. A total of 29,607 housing units exist within the City, with 975 of those housing units currently vacant. Therefore, the vacancy rate is 3.3%. Table 3-2 shows the housing structure type and number of units for the year of 2016. Table 3-3 displays the residential zoning within the service area.

Table 3-2: The City of Whittier Housing Units

Type of Structure	Number of Units for the Year of 2016	
	Service Area	Total City
Single Detached **[1]**	9,082	19,365
Single Attached **[1]**	547	1,167
Mobile Home **[1]**	91	193
Single Family Subtotal	**9,720**	**20,725**
Two to Four **[2]**	1,879	2,308
Five Plus **[2]**	5,351	6,574
Multi-Family Subtotal	**7,230**	**8,882**
Total Units	**16,950**	**29,607**

1. Single family residential dwelling unit. Number of units in service area based upon the total City number of units multiplied by the service area percentage for single family residential in Table 3-3.
2. Multi-family residential dwelling unit. Number of units in service area based upon the total City number of units multiplied by the service area percentage for multi-family residential in Table 3-3.

Table 3-3: Residential Zoning

Zoning Description	Service Area (Ac)	Total City (Ac)	Service Area Percentage
Single Family Residential **[1]**	2,263	4,821	46.9%
Multi-Family Residential **[2]**	451	554	81.4%
Residential Subtotal	**2,714**	**5,375**	**-**

1. Single family residential includes the H-R, R-E, and R-1 zoning from Table 3-1.
2. Multi-family residential includes the R-2, R-3, and R-4 zoning from Table 3-1.

3.7 Population

City Population

The City of Whitter was incorporated in 1898 with a population of 585 people. After World War II, the City experienced an exponential growth in population, which was in response to Southern California's housing shortage. The City then experienced a second rapid growth period in 1961. This was when the City annexed portions of Whittier Boulevard and East Whittier and added over 28,000 residents, increasing the total population to about 67,000. Figure 3-3 shows the population change since the City was incorporated.

From 2007 to 2016, the City population increased from 87,190 to 88,341. This represents 1.3% population growth since the previous 2008 Water Master Plan. The population has remained fairly stable over the last 9 years since most of the City is developed. For 2016, the average population density of persons per household was calculated to be 3 persons per household (88,341 people / 29,607 dwelling units = 3 persons per dwelling unit).

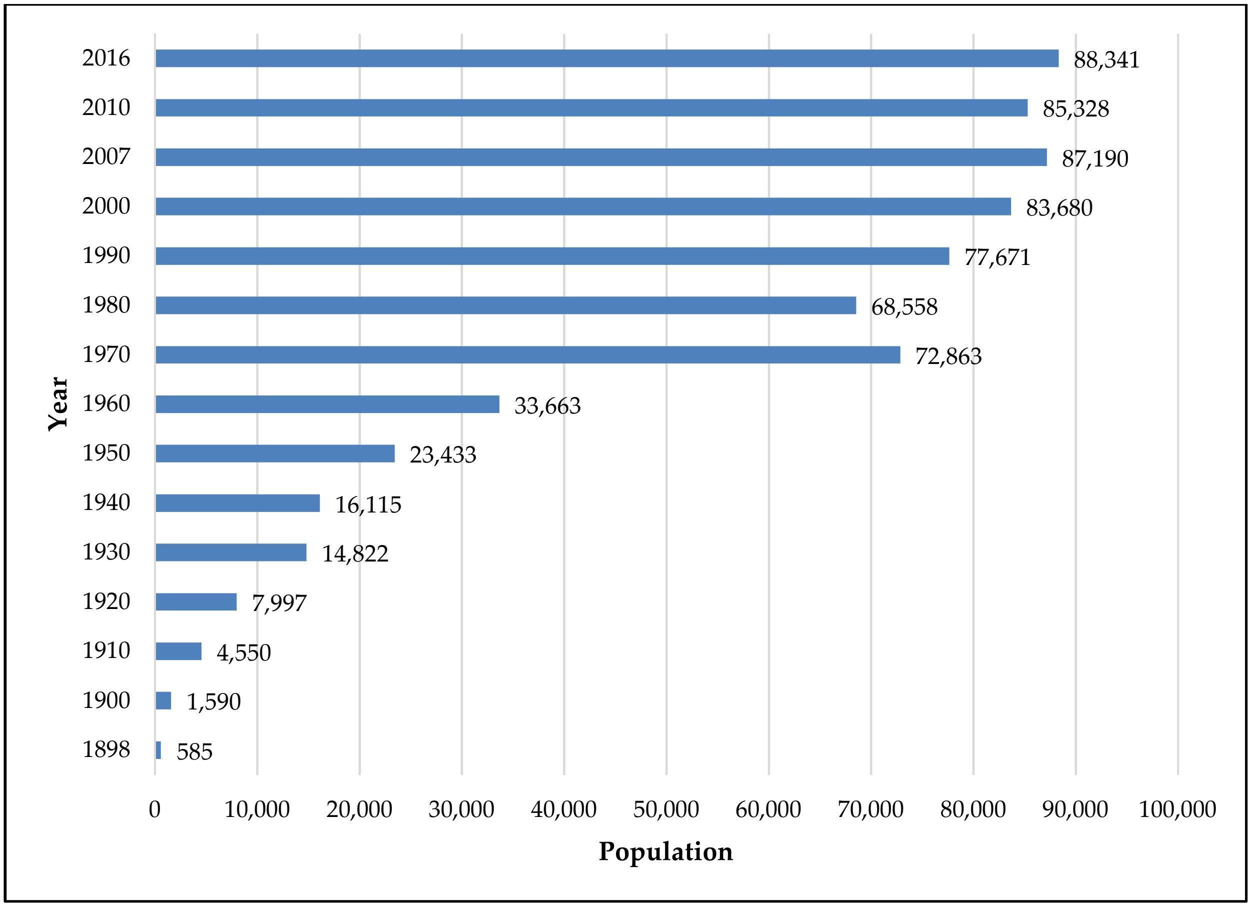
Service Area Population

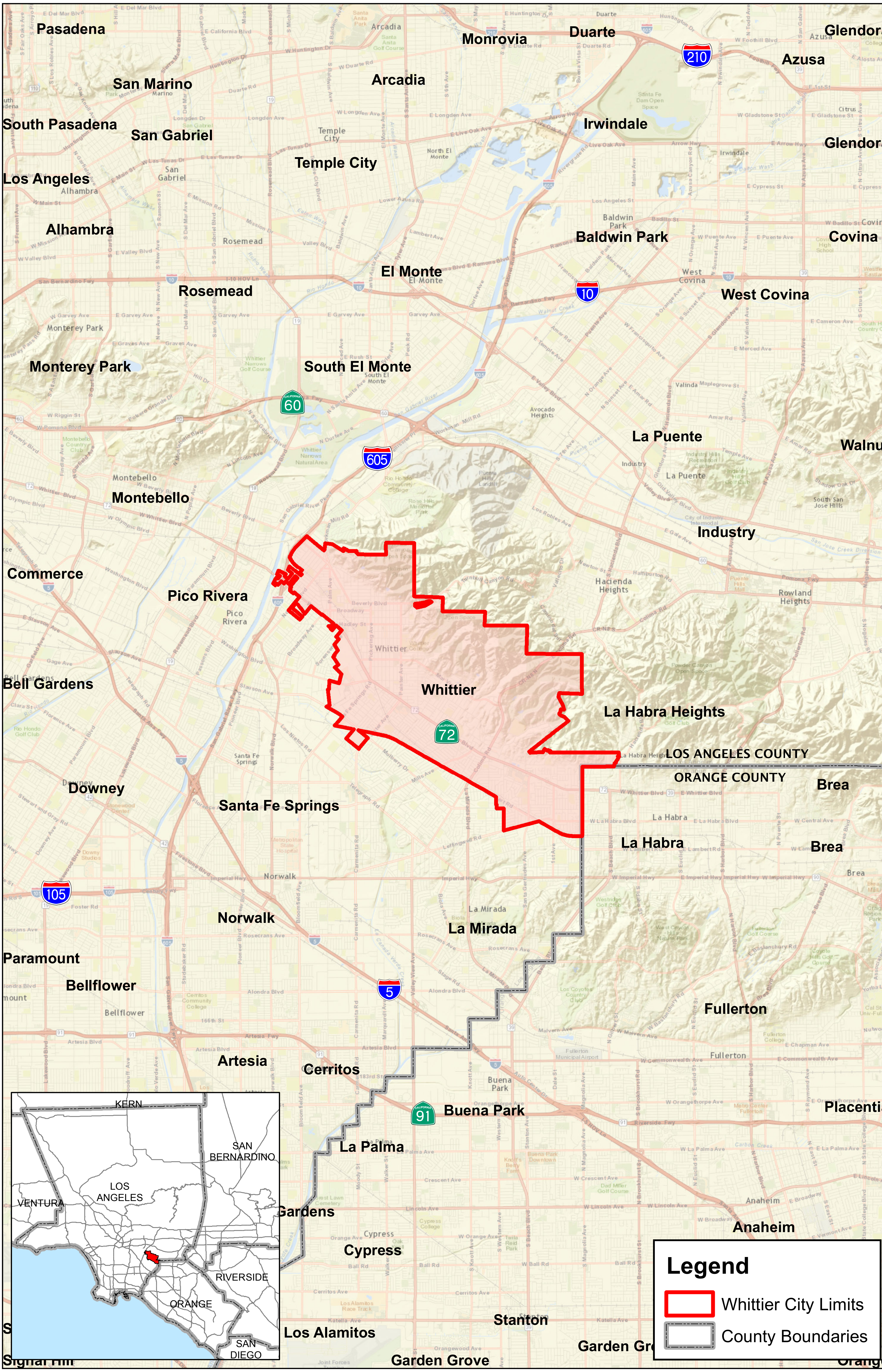
The City's estimated population within the water service area is around 50,850. The residential dwelling units within the service area and the population density of people per household were used to approximate service area population (16,950 service area dwelling units * 3 persons per dwelling unit = 50,850 people).

Ultimate Service Area Population

As mentioned previously, from 2007 to 2016 the City's population increased from 87,190 to 88,341. This represents a 1.3% increase in population which is not considered a substantial increase. The City's total population has remained relatively constant since 2007 at approximately 87,000. With the exception of small infill areas and some potential densification, the population of the City is not expected to increase significantly in the future due to few remaining undeveloped areas.

Figure 3-3: The City of Whittier Population History





Michael Baker INTERNATIONAL

0 0.75 1.5 3 Miles

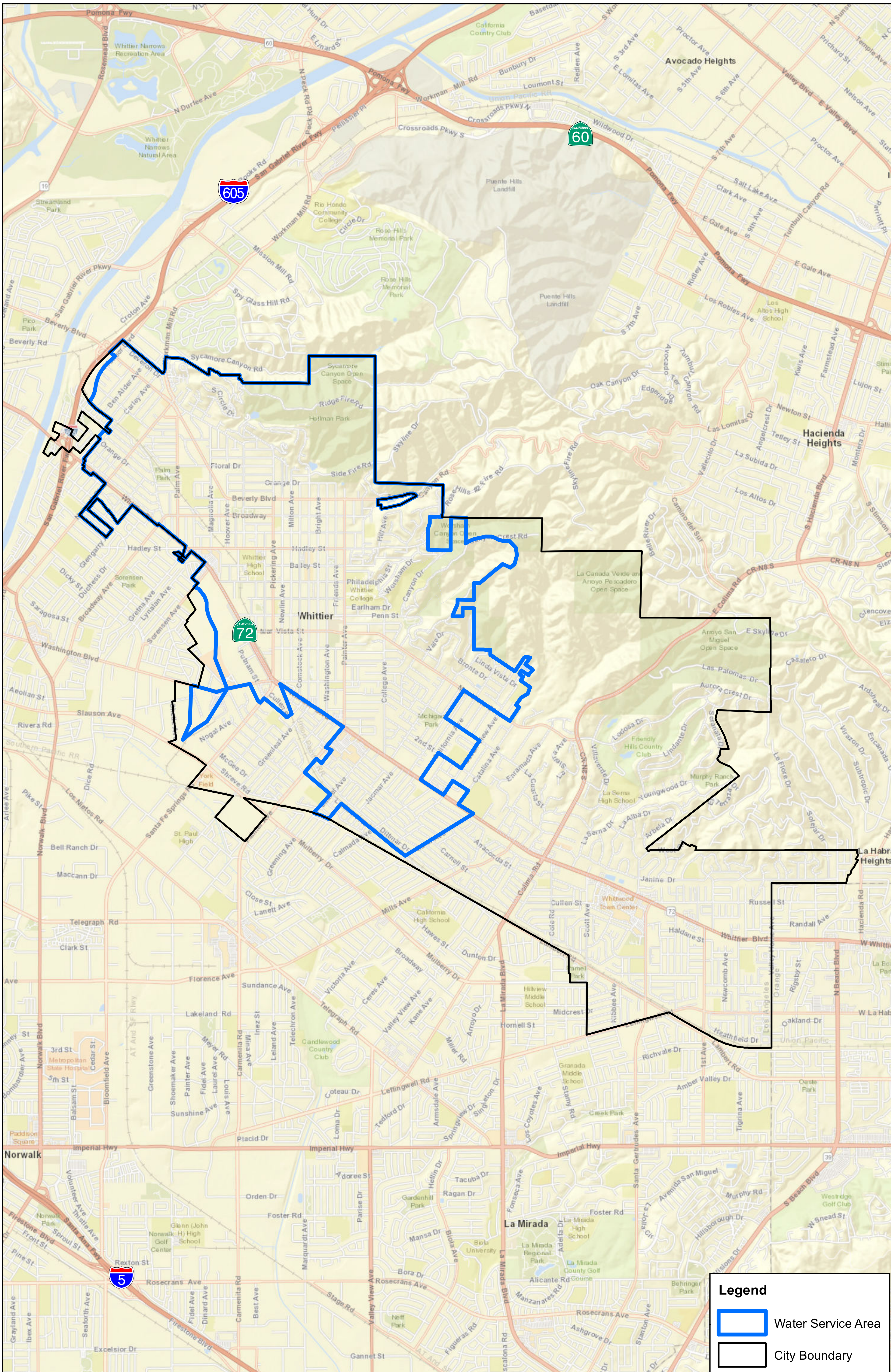
Source: City of Whittier, Esri Street Maps

CITY OF WHITTIER MASTER PLAN

Regional Location Map

Exhibit 3-1

9/9/2016 JN M:\Mdata\151940\GIS\MXD\Ex3-1 Regional Location Map_11x17P.mxd



3/13/2017 JN M:\Mdata\151940\GIS\MXD\Ex3-2 Water Service Map_11x17P.mxd

Michael Baker INTERNATIONAL

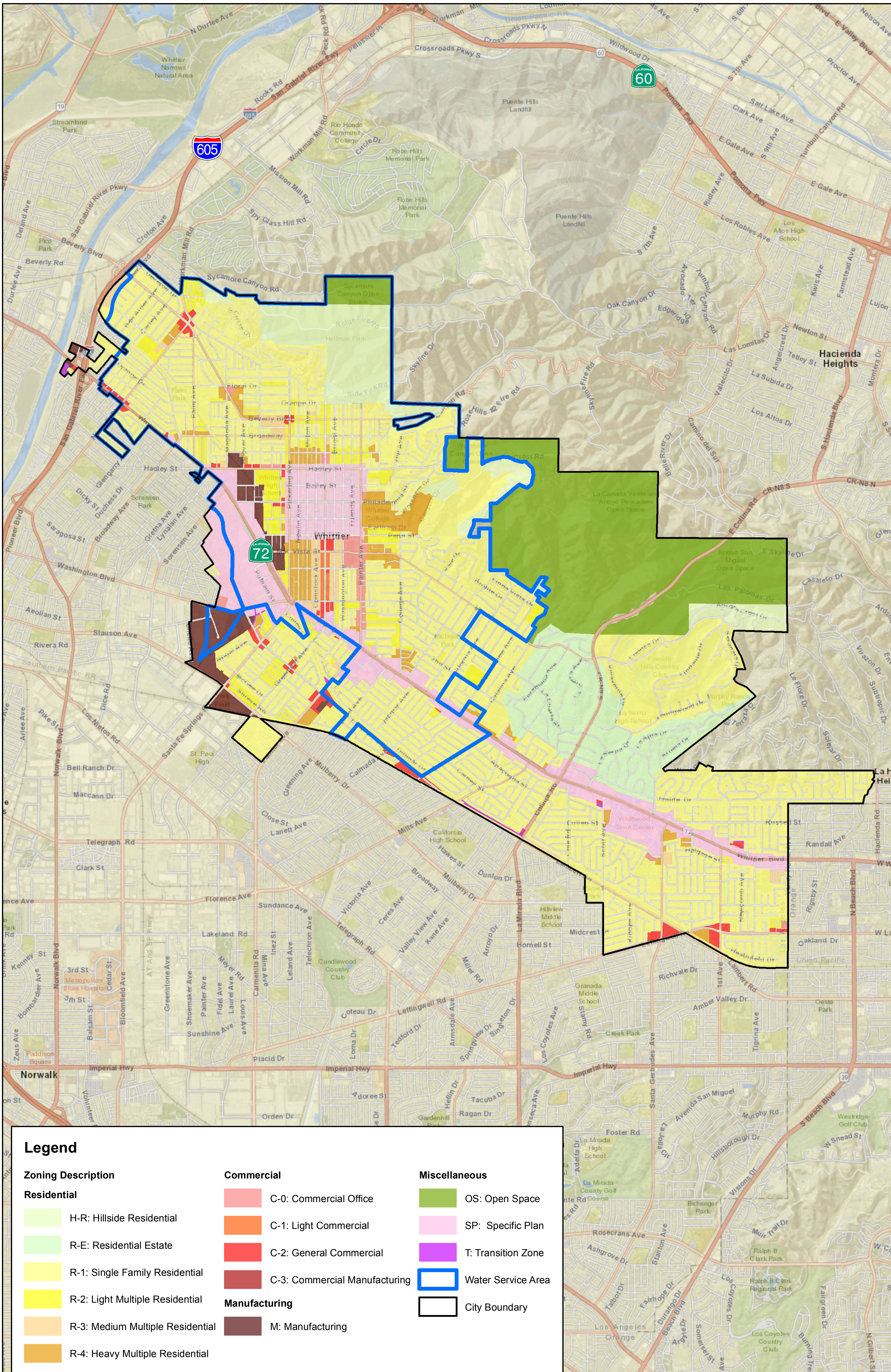
0 0.25 0.5 1 Miles

Source: City of Whittier, Esri Street Maps

CITY OF WHITTIER MASTER PLAN

Water Service Area

Exhibit 3-2



9/9/2016 JN M:\Mdata\151940\GIS\MXD\Ex3-3 Zoning Map_11x17P.mxd

Michael Baker INTERNATIONAL

Source: City of Whittier, Esri Street Maps

CITY OF WHITTIER MASTER PLAN

Zoning

Exhibit 3-3

Section 4
Existing Water System

SECTION 4 - Existing Water System

The purpose of this section is to describe and quantify the City of Whittier's existing water infrastructure, including the sources of water supply, historical water rights and usage, groundwater transmission mains, major pumping facilities, water storage reservoirs, transmission and distribution mains, system control valves, interconnections with adjacent water systems, and emergency connections between pressure zones. The existing water system hydraulic schematic is shown in Exhibit 4-1, a map of water supply facilities is shown on Exhibit 4-2, and a map of the water system facilities and pressure zones is shown in Exhibit 4-3.

4.1 Source of Supply

The City obtains one hundred percent of its water supply from groundwater wells located in the Main San Gabriel Basin and Central Basin. The City has five wells (Wells 13, 15, 16, 17, 18) in the Main San Gabriel Basin. The City has two wells (Wells 8, 14) in the Central Basin, and also wheels a portion of water supplies from the Central Basin Municipal Water District's (CBMWD) Water Quality Protection Plant (WQPP) facility to connections with the Cities of Pico Rivera and Santa Fe Springs.

Main San Gabriel Basin

The Main San Gabriel Basin water rights were adjudicated in 1973, and the City of Whittier obtained a prescriptive right to 4.18519% of the operating safe yield (OSY) of the basin. The OSY is established each year by the Main San Gabriel Watermaster based on groundwater availability, and is defined as the quantity of water that can be pumped from the basin prior to the Watermaster needing to purchase additional water supplies to replenish the basin. The OSY was set at 200,000 acre-feet in fiscal year 2012-13 and was subsequently lowered to 150,000 acre-feet for fiscal years 2013-14 and 2014-15. The Watermaster currently has established the OSY to be 150,000 acre-feet for fiscal year 2015-16, and reduced it to 130,000 acre-feet for the next four years.

Central Basin

The Central Basin has historically provided much of the regional water supplies to municipalities within the Los Angeles coastal plain. It is situated to the east of the Newport-Inglewood uplift, a series of discontinuous faults which form a partial barrier to groundwater flow and thus delineate the separation between the Central Basin and West Coast Basin. As early as 1950, formal efforts were made to provide supplemental water supplies to the region, limit groundwater pumping, and regulate the groundwater rights of users. In 1966, the State of California Department of Water Resources was appointed as Watermaster of the Central Basin.

The Central Basin Judgment limits the amount of groundwater each user is able to extract each year to an Allowed Pumping Allocation (APA). The City of Whittier has an APA of 895 acre feet for the Central Basin, which does not include leased water or carryover water from previous years. One amendment to the Judgment allows users to carryover water supplies from one year to the other and over extract 20% of the APA or 20 acre feet, whichever is greater. In general, users must make up any over extractions beyond carryover water amounts the following year, subject to the specific directive of the Watermaster.

Water Quality Protection Plant

In 2004, the Central Basin Municipal Water District implemented the Central Basin Water Quality Protection Plant to prevent additional migration of trichloroethylene (TCE) and tetrachloroethylene (PCE) contamination that had been transported from the Main San Gabriel Basin into the Central Basin at the Whittier Narrows area. The WQPP is located at the City of Whittier's Pumping Plant No. 2, and treats groundwater from wells (CB-1 and CB-2, refer to Exhibit 4-1). Treated water is delivered to the City of Pico Rivera and the City of Santa Fe Springs by means of the City of Whittier's Pumping Plant No. 2 and distribution system. CBMWD owns the WQPP facility which is operated by City of Whittier.

Whittier Narrows Operable Unit

As of May 2013 the City of Whittier no longer operates the Whittier Narrows Operable Unit (WNOU). The EPA transferred financial responsibility and oversight of operation to the Department of Toxic Substances Control (DTSC) due to an agreement between the Federal and State government. On May 17, 2013 the cooperative agreement between the City of Whittier and the EPA expired. DTSC then entered into an agreement with San Gabriel Valley Water Company (SGVWC) to serve as the new operator beginning May 17, 2013. The location of the WNOU is shown on Exhibit 4-2.

Currently the operation of the WNOU has been limited to refilling Legg Lake, and is not operated at its optimum capacity. The City has been invited by the DTSC and EPA to participate in a stakeholder forum to discuss the possibility of retaking operation on behalf of the DTSC.

4.2 Historical Water Rights and Usage

A summary of the City's historical water rights, production, and carryover from the Central Basin and Main San Gabriel Basin wells over the past three years is displayed in Table 4-1.

Table 4-1: Historical Water Rights, Production, and Carryover

Fiscal Year	Central Basin				Main San Gabriel Basin			
	Total Production Right (AF)	Carry Over from Previous Year (AF)	Amount Pumped (AF)	Carry Over to Next Year (AF)	Total Production Right (AF)	Carry Over from Previous Year (AF)	Amount Pumped (AF)	Carry Over to Next Year (AF)
12-13	4,816	21	4,410	406	7,830	5,459	3,575	4,255
13-14	4,301	406	4,280	21	9,788	4,255	4,466	5,322
14-15	3,916	21	3,031	885	9,599	5,322	4,792	4,807
Average	**4,344**	**-**	**3,907**	**437**	**9,072**	**-**	**4,278**	**4,794**

4.3 City Wells

The City has five (5) wells located in the Main San Gabriel Basin (Wells 13, 15, 16, 17, 18) and two (2) wells located in the Central Basin (Wells 8, 14). Well No. 7 is abandoned and no longer contributes to the City's water supply. The City also operates the Water Quality Protection Plan Treatment Plant, located on the Pumping Plant 2 site, and its two associated wells, CB-1 and CB-2, located in Pico Rivera. A summary of the City's wells is listed in Table 4-2.

Table 4-2: Existing City Wells

Basin	Active/ Inactive	City Well No.	State Well No.	Year Drilled	Depth (ft)	Casing Size (in)	Design Capacity (gpm)	Current Capacity (gpm) [1]
Central	Active	8	2S/1107H01S	1930	302	24	3,200	400
Central	Active	14	2S/11W-05N04S	1929	365	18	1,500	1,500
Central	Active	CB-1	002S011W07D010S	2003	350	18	3,200	1,800
Central	Active	CB-2	002S011W07C005S	2003	350	18	2,000	1,800
Subtotal							**4,700**	**5,500**
Main San Gabriel	Active	13	2S/11W-05G02	1931	280	18	1,525	0
Main San Gabriel	Active	15	2S/11W-05C07	1977	732	24	4,500	3,000
Main San Gabriel	Active	16	S2S/11W-05G	1989	820	18	4,240	2,700
Main San Gabriel	Active	17	2S/11W-05G08	1991	860	18	4,050	2,700
Main San Gabriel	Active	18	2S/11W-05G09	1991	870	24	4,050	2,700
Subtotal							**23,565**	**11,100**
TOTAL							**28,265**	**16,600**

[1] Due to reduced water table levels in the Central and Main San Gabriel Basins

4.4 Groundwater Transmission Mains

Groundwater from the City's Wells 13, 14, 15, 16, 17, and 18 is delivered to the City's Pumping Plant No. 2 (PP2) facility, which is also known as Marshall R. Bowen Pumping Plant, via two transmission mains. The two groundwater transmission mains are each 24-inch outside high-density polyethylene (HDPE) pipes, which generally parallel the San Gabriel River transporting groundwater supplies to PP2. Near PP2, the two transmission mains transition to two 24-inch cement mortar lined and coated (CML&C) steel pipelines which convey flows to a single 36-inch CML&C steel pipeline. A separate 24-inch CML&C steel pipeline connects to the 36-inch pipeline to deliver groundwater supplies from Well 8 and WQPP. Chlorine injection occurs downstream of the 24-inch connection. The flow is then conveyed to a 66-inch diameter CML&C steel pipe and the PP2 forebays. The locations of the City's groundwater wells are shown on Exhibit 4-2.

4.5 Water Quality Protection Plan Treatment Plant

The Water Quality Protection Plan Treatment Plant (WQPPTP) was built by Central Basin Municipal Water District (CBMWD) in 2003. WQPPTP consists of two wells and ten liquid phase granular activated carbon (LPGAC) vessels configured in five parallel treatment trains. WQPPTP was constructed specifically downstream of the Whittier Narrows Dam to extract contaminated groundwater, consisting primarily of PCE and TCE, from the intermediate aquifer of the Central Basin that has migrated from the Main San Gabriel Basin. The LPGAC vessels are on the PP2 property. WQPPTP treated water is currently flows into the forebays at PP2 before being pumped into Whittier's distribution system. CBMWD has transferred maintenance and operations of the WQPPTP to the City of Whittier with the intent of transferring the entire system.

4.6 Pumping Plant No. 2

Pumping Plant No. 2 is located in the City of Pico Rivera and is accessible from San Gabriel River Parkway north of Beverly Boulevard. The PP2 Replacement Project was recently completed in 2015. PP2 is the primary pumping facility for the service area, and pumps directly into Zone 464.

From the groundwater transmission mains discussed in the previous section, a 66-inch diameter CML&C steel pipe conveys flows to a 36-inch diameter ductile iron inlet pipe, then splits into two 30-inch diameter DI inlets which deliver water to Forebay No. 1 and No. 2, each having a nominal capacity of 2.20 MG.

Forebay No. 1 and No. 2 each include 36-inch diameter outlets which converge and deliver chlorinated water via a 42-inch diameter suction pipe for the PP2 pumps. The pump station facility consists of five (5) vertical turbine pumps, with piping for a sixth future pump. Each pump is equipped with constant speed electric motors. Additional detail about each pump and motor is listed in Table 4-3. Currently PP2 has a firm capacity of 13,700 gpm, and with a sixth future pump, PP2 will have a firm capacity of 17,500 gpm.

Table 4-3: Pumping Plant No. 2 Pumps

Pump Data						Motor Data		
Pump No.	**Model**	**Type**	**No. of Stages**	**Design Capacity (gpm)**	**TDH (ft)**	**Engine Type**	**HP**	**RPM**
1	Flowserve 15EHL	VT	4	2,300	330	Electric	250	1,790
2	Flowserve 15EBM	VT	5	3,800	330	Electric	400	1,780
3	Flowserve 15EBM	VT	5	3,800	330	Electric	400	1,780
4	Flowserve 15EBM	VT	5	3,800	330	Electric	400	1,780
5	Flowserve 15EBM	VT	5	3,800	330	Electric	400	1,780

It should be noted that the pump room at the PP2 station was designed to accommodate a future natural gas engine to power each pump motor. Each pump discharges to a single 36-inch DI pipe. A pressure relief valve included on the discharge piping will activate (open) if a set discharge pressure is exceeded, and route flow back to the 42-inch suction pipeline. A 13,500 gallon surge tank adjacent to the pump building provides additional protection to Zone 464 from potential pressure transients. The PP2 discharge system connects to two (2) 30-inch distribution mains that cross the San Gabriel River and into the City's Zone 464, as well as a 16-inch pipeline that provides WQPP water to the City of Pico Rivera. The discharge pipeline also connects to a 36-inch DI bypass pipeline which loops back to the forebay outlets and is normally closed.

4.7 Pressure Zones

The distribution system is divided into six main pressure zones:

- Zone 464
- Zone 577
- Zone 670A
- Zone 670B
- Zone 997A
- Zone 997B

A pressure zone is an area of service supplied by a source, or a number of sources, that provides supply at a nominal hydraulic gradient. Typically, this hydraulic gradient is provided by the high water level of the reservoir serving the pressure zone. In the distribution system, some pressure zones have multiple reservoirs with different high water levels, and therefore the nominal hydraulic gradient for each pressure zone is considered to be the lowest high water level. For pressure zones with no gravity storage, the hydraulic gradient may be provided by pressure reducing valve settings or in some cases by pumping. The corresponding hydraulic grade line (HGL) of each pressure zone is listed in Table 4-4. A map of the City's water service area, pressure zones, and system facilities is shown Exhibit 4-3.

Table 4-4: Pressure Zones

Pressure Zone	HGL (ft) [1]
464	469.6
577	581.5
670A	687.2
670B	680.0
997A	1006.1
997B	997.0

1. All HGLs are based on NAVD88.

Zone 464 (HGL = 469.6 feet)

Zone 464 is the largest pressure zone in the distribution system with the lowest HGL. It receives all of its water supplies from PP2 and stores water in:

- Greenleaf Reservoir (6.00 MG)
- Greenleaf II Reservoir (10.00 MG)
- Ocean View Reservoir (4.00 MG)

Hoover Reservoir (9.75 MG) is also part of the facilities in Zone 464 but is currently out-of-service. The vast majority of water storage in the distribution system is provided in Zone 464, and the largest in-service reservoir is Greenleaf II Reservoir. The HGL of Zone 464 is controlled by the high water level in Ocean View Reservoir. Both of the inlets on Greenleaf Reservoir and Greenleaf II Reservoir have pressure sustaining valves, which further regulate the hydraulic gradient of Zone 464 as described in Section 4.11. Other than PP2, Zone 464 has a single pump station, Washington Booster Pump Station, which has a firm capacity of 4,000 gpm and boosts pressure on the eastern portion of Zone 464. The facilities in Zone 464 supply water to interconnections with the City of Pico Rivera and the City of Santa Fe Springs, as well as four booster pump stations:

- Rideout Booster Pump Station
- Greenleaf Booster Pump Station
- College Hills Booster Pump Station
- Murphy Booster Pump Station

Zone 464 has four (4) other emergency interconnections with the following water agencies:

- California Domestic Water Company, one (1) interconnection
- San Gabriel Valley Water Company, one (1) interconnection
- Suburban Water Company, two (2) interconnections

Zone 464 also has three (3) interconnections with higher pressure zones in the distribution system, namely Zone 577 and Zone 670A.

Zone 464 also supplies water to Sub-Zone 400, which is physically split into two pressure-reduced service areas because of geography. Both areas are shown in Exhibit 4-3, and are generally located to the south of Whittier Boulevard on the western and southern ends of the distribution system service area. The nominal hydraulic gradients of each area of Sub-Zone 400 are controlled by the pressure reducing valve settings. In general, the western Sub-Zone 400 area has a HGL of 347.8 feet, while the southern Sub-Zone 400 area has a HGL of 411.8 feet.

Zone 577 (HGL = 581.5 feet)

Zone 577 receives all of its water supply from Zone 464 through two booster pump station facilities:

- Murphy Booster Pump Station
- Greenleaf Booster Pump Station

Murphy Booster Pump Station, located near Ocean View Reservoir, has a firm capacity of 1,250 gpm and provides water to the southern portion of Zone 577. Greenleaf Booster Pump Station, located at the Greenleaf II Reservoir site, has a firm capacity of 2,300 gpm and provides water to the northern and central portion of Zone 577. Water supplies are stored in:

- Painter Reservoir (1.00 MG), near Greenleaf Booster Pump Station
- Murphy East Reservoir (0.50 MG), near Murphy Booster Pump Station

Murphy West Reservoir (0.50 MG) is also part of the facilities in Zone 464 but is currently out-of-service. The HGL of Zone 577 is controlled by the high water level in the Murphy East Reservoir. Zone 577 has two (2) interconnections that can provide water to Zone 464. In addition, Zone 577 has five (5) interconnections with Zone 670A and two (2) interconnections with Zone 670B.

Zone 670A (HGL = 687.2 feet)

Zone 670A receives all of its water supply from Zone 464 through two booster pump station facilities:

- Rideout Booster Pump Station
- Greenleaf Booster Pump Station

Rideout Booster Pump Station, located near the former Hoover Reservoir site, has a firm capacity of 350 gpm and provides water to the northern portion of Zone 670A. Greenleaf Booster Pump Station, located at the Greenleaf II Reservoir site, has a firm capacity of 1,000 gpm and provides water to the southern portion of Zone 670A. Water supplies are stored in:

- Rideout Resevoir (0.15 MG), supplied by Rideout Booster Pump Station
- Hazzard Reservoir (0.15 MG), near Painter Reservoir No. 1

The HGL of Zone 670A is controlled by the high water level in Rideout Reservoir. The pressure zone boundary between Zone 670A and Zone 670B is formed by a closed 6-inch diameter valve located north of the intersection of Hill Avenue and Camilla Street. Zone 670A has five (5) emergency interconnections that can provide water to Zone 577 and one (1) emergency interconnection that can provide water to Zone 464. In addition, Zone 670A has one (1) emergency interconnection with Zone 997A.

Zone 670B (HGL = 680.0 feet)

Zone 670B receives all of its water supply from Zone 464 through a single booster pump station:

- College Hills Booster Pump Station

College Hills Booster Pump Station, located west of the intersection of Byrn Mawr Way and Hillside Lane, has a firm capacity of 1,000 gpm. Water supplies are stored in:

- College Hills West Reservoir (0.30 MG) and College Hills East Reservoir (0.475 MG), both located on a ridge off of Canyon Crest Road

Zone 670B has two (2) emergency interconnections that can provide water to Zone 577.

Zone 997A (HGL = 1006.1 feet)

Zone 997A receives all of its water supply from Zone 464 through two pumps at Greenleaf Booster Pump Station, located near Greenleaf II Reservoir. Greenleaf Booster Pump Station has a firm capacity of 600 gpm. Water supplies are stored in Starlight Reservoir (0.30 MG), located on a ridge north of Carinthia Drive. Zone 997A has numerous pressure reducing stations which reduce system pressure to residences on progressively lower terraces. Zone 997A has one (1) emergency interconnection that can provide water to Zone 670A.

Zone 997B (HGL = 997.0 feet)

Zone 997B receives all of its water supply from Zone 670B and is a closed pressure zone with a booster pump station and hydropnuematic tank. Summit Booster Pump Station, located south of the intersection of Summit Drive and Marsha Lane, boosts water to Zone 997B and has a firm capacity of 125 gpm under normal conditions and a 1,700 gpm fire pump. Zone 997B is the smallest pressure zone in the distribution system, and the only pressure zone with a hydropneumatic tank and no water storage reservoirs.

4.8 Pump Stations

In addition to PP2, the City has six (6) pump station facilities. Pump stations are typically used by the City to boost water supplies from a pressure zone of a lower hydraulic gradient to one of a higher hydraulic gradient. Pump stations can also be used to supplement gravity storage to meet fire flow demands during an emergency, or provide fire flow if no gravity storage exists in a pressure zone. A summary of the existing pumps at each pump station is listed in Table 4-5.

Table 4-5: Existing Booster Pump Data

General Data				Pump Data						Motor Data	
Pump Station	Year Constructed	Supply Zone	Pumps to Zone	Pump No.	Model	Type	No. of Stages	TDH (ft)	Flow (gpm)	H.P.	RPM
Painter (Greenleaf)	2003	464	577	5	Peerless 14MD	VT	2	155	2,300	150	1,790
				6	Peerless 14MD	VT	2	155	2,300	150	1,790
Hazzard (Greenleaf)	2003	464	670A	3	Peerless 12LDT	VT	7	252	1,000	100	1,790
				4	Peerless 12LDT	VT	7	252	1,000	100	1,790
Starlight (Greenleaf)	2003	464	997A	1	Peerless 12MB	VT	4	560	600	150	1,790
				2	Peerless 12MB	VT	4	560	600	150	1,790
Washington	1956	464	464	1	Peerless 12L	HSC			4,000	125	1,800
				2	Peerless 12L	HSC			4,000	125	1,800
Murphy	1954	464	577	1	Johnston	VT			1,365	50	1,800
				2	Johnston	VT			1,250	50	1,800
Rideout	1932	464	670A	1	Kirst Pump	HSC		225	350	30	3,525
				2	Kirst Pump	HSC		225	350	30	3,25
College Hills	1932	464	670B	1	Aurora Model 421BF	HSC		220	1,000	100	1,790
				2	Aurora Model 421BF	HSC		220	1,000	100	1,790
Summit	1959	670B	997B	1	Peerless 2TU12	HSC	2	240	125	25	1,800
				2	Peerless 2TU12	HSC	2	240	125	25	1,800
				3	Peerless 6AE18	HSC			1,700	200	1,775

4.9 Reservoirs

In addition to the forebay storage at PP2, the City's water distribution system is comprised of twelve (12) reservoirs. The Hoover Reservoir and Murphy West Reservoir are currently out of service. The City's distribution system has a cumulative nominal water storage capacity of 22.88 MG. Additional details about each reservoir are listed in Table 4-6.

Table 4-6: Existing Reservoirs

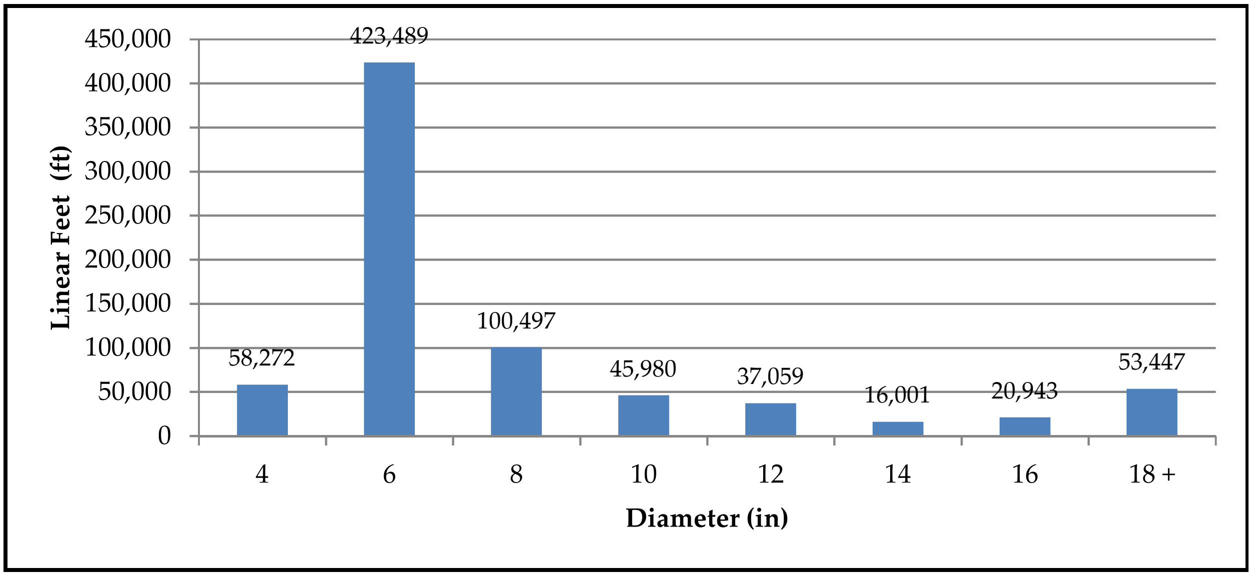
Facility No.	Reservoir Name	Material	Year Constructed	Zone Served	Diameter (ft)	Capacity (MG)	Floor Elevation (ft) [3]	High Operating Level (ft)
1	Painter	Pre-Stressed Concrete	1987	577	102	1.00	568.7	18
2	Greenleaf	Concrete	1920	464	Irregular [1]	6.00	448.5	22
3	College Hills West	Concrete	1926	670B	72.5	0.30	669.8	10.2
4	Hoover [4]	Concrete	1931	464	Trapezoid	9.75	442	24
5	Rideout	Concrete	1934	670A	30.75	0.15	667.2	20
6	Hazzard	Pre-stressed Concrete	1937	670A	30.75	0.15	662.6	25
7A	Greenleaf II	Pre-Stressed Concrete	2002	464	220	10.00	437	35
8	College Hills East	Concrete	1951	670B	90	0.48	669.8	10.2
9	Ocean View	Concrete	1955	464	Rectangle Hopper Bottom [2]	4.00	451.3	18.3
10	Murphy West [4]	Concrete	1955	577	60	0.50	557.5	24
11	Murphy East	Concrete	1955	577	60	0.50	557.5	24
12	Starlight	Concrete	1959	997A	50	0.30	984.1	22

1. Irregularly shaped; dimensions approximately 323 ft x 275 ft.
2. Rectangular shaped; dimensions 161 ft x 293 ft with hopper bottom.
3. All floor elevations are based on NAVD88 standards.
4. Currently out of service.

4.10 Pipelines

The City of Whittier's water distribution system is comprised of approximately 143 miles of pipelines. Pipeline diameters range from 4-inch to 30-inch diameter, with the majority of pipes being 6-inch diameter. See Figure 4-1 for the distribution pipeline quantities by diameter.

Figure 4-1: Pipe Diameter



4.11 Pressure Reducing Stations

Pressure reducing stations are used by the City to transport water from a pressure zone of a higher hydraulic gradient to one of a lower hydraulic gradient at constant downstream pressure. Pressure reducing stations can also be used for emergency situations, such as a fire emergency, when pressure drops significantly.

The City currently operates a total of twenty-three (23) pressure reducing valves within the distribution system. Several pressure reducing valves located along Whittier Boulevard are used to deliver water supplies from Zone 464 to Sub-Zone 400. In Zone 997A, several pressure reducing valves operate to reduce service pressures for lower service elevations. Other pressure reducing valves operate to provide water supplies from Zone 670 to Zone 577 and from Zone 997 to Zone 670. A summary of the existing pressure reducing valves is listed in Table 4-7.

Table 4-7: Pressure Reducing Valves

Valve No.	Atlas Sheet	Upstream Zone	Downstream Zone	Diameter (in)	Setting (psi)	Function
CV-1	4	997A	670A	6 [1]	-	Normally Closed
CV-2	10	464	Sub-Zone 400	10 [1]	70	Normally Open
CV-3	42	464	Sub-Zone 400	10 [1]	70	Normally Open
CV-4	42	464	Sub-Zone 400	8 [1]	70	Normally Open
CV-5	43	464	Sub-Zone 400	8 [1]	70	Normally Open
CV-6	52	464	Sub-Zone 400	12 [1]	65	Normally Open
CV-7	36	464	Sub-Zone 400	4	57	Backup
CV-8	36	464	Sub-Zone 400	4	70	Normally Open
CV-9	12	670A	577	6	70	Normally Closed
CV-10	11	997A	997A	6	45	Normally Open
CV-11	11	997A	997A	2	40	Backup
CV-12	12	997A	997A	6	50	Normally Open
CV-13	12	997A	997A	2	60	Backup
CV-14	65	997A	997A	6	50	Normally Open
CV-15	65	997A	997A	4	55	Backup
CV-16	51	997A	997A	8	50	Normally Open
CV-17	51	997A	997A	4	55	Backup
CV-18	51	997A	997A	6	70	Normally Open
CV-19	51	997A	997A	6	70	Normally Open
CV-20	6	670A	670A	1	40	Normally Open
CV-21	6	997A	670A	8	90	Normally Open
CV-22	5	997A	997A	8	150	Normally Open
CV-23	5	997A	997A	2	150	Normally Open
CV-24	12	997A	670A	10	-	-
CV-25	12	670A	577	10	-	-

1. CV-1, CV-2, CV-3, CV-4, CV-5, and CV-6 also have bypass lines which are normally closed.

The distribution system is also equipped with ten (10) pressure relief valves. Pressure relief valves open and discharge water to relieve excess pressure in a pressure zone. The valves are used to prevent over-pressurization in the event that a lower pressure zone is subject to a higher pressure zone's hydraulic gradient. For example, the opening of normally closed isolation valves, incorrect upstream settings, or the failure of upstream PRVs could create conditions requiring these valves to open. A summary of the existing pressure relief valves is listed in Table 4-8.

Table 4-8: Pressure Relief Valves

Valve No.	Atlas Sheet	Zone Relieved	Diameter (in)	Setting (psi)
CV-101	44	Sub-Zone 400	6	86
CV-102	48	Sub-Zone 400	6	88
CV-103	36	Sub-Zone 400	6	64
CV-104	18	997A	6	107
CV-105	12	997A	6	62
CV-106	51	997A	6	100
CV-107	51	997A	6	124
CV-108	51	997A	6	120
CV-109	6	997A	4	172
CV-110	12	670A	4	80

4.12 Pressure Sustaining Valves

The City currently has a total of three (3) pressure sustaining valves within the distribution system, all located in Zone 464. Pressure sustaining valves are used by the City to maintain a constant upstream pressure in areas of the distribution system in order to improve control of the HGL within the pressure zone. The two pressure sustaining valves on the inlets of Greenleaf Reservoir and Greenleaf II Reservoir control the HGL in the zone at the inlets to control flow into the reservoirs. During the model calibration process (see Section 7.2), the sustaining valves were set in the open position and therefore were not active with a pressure setting in order to match the current operation of the system. A summary of the existing pressure sustaining valves is listed in Table 4-9.

Table 4-9: Pressure Sustaining Valves

Valve No.	Atlas Sheet	Zone Sustained	Diameter (in)	Setting (psi)
CV-300	7	464	10	55
CV-301	12	464	16	**[1]**
CV-302	12	464	16	**[1]**

1. Currently not in operation.

4.13 Interconnections with Adjacent Water Systems

The City has six (6) interconnections with adjacent water systems, all of which are within Zone 464. Interconnections with the City of Pico Rivera and the City of Santa Fe Springs are used to deliver water supplies to those cities from the CBMWD's WQPP facility. Interconnections with California Domestic Water Company, San Gabriel Valley Water Company, and Suburban Water Company are all emergency interconnections. Emergency interconnections are not considered to be part of the City's primary water supplies as they are not used during normal operations. A summary of the interconnections with adjacent water systems is listed in Table 4-10.

Table 4-10: Interconnections to Adjacent Water Systems

Agency	Diameter (in)	One-Way/ Two-Way [1]	Location	Pressure Zone
California Domestic Water Company	12	Two-Way	Pioneer Boulevard, south of Strong Avenue	464
City of Pico Rivera	16	One-Way	At PP2	464
San Gabriel Valley Water Company	16	Two-Way	6001 Pioneer Boulevard	464
City of Santa Fe Springs	10	One-Way	12082 Rivera Road	464
Suburban Water Company	8	Two-Way	8420 Painter Avenue	464 (Sub-Zone 400)
Suburban Water Company	12	One-Way	12302 Washington Boulevard	464

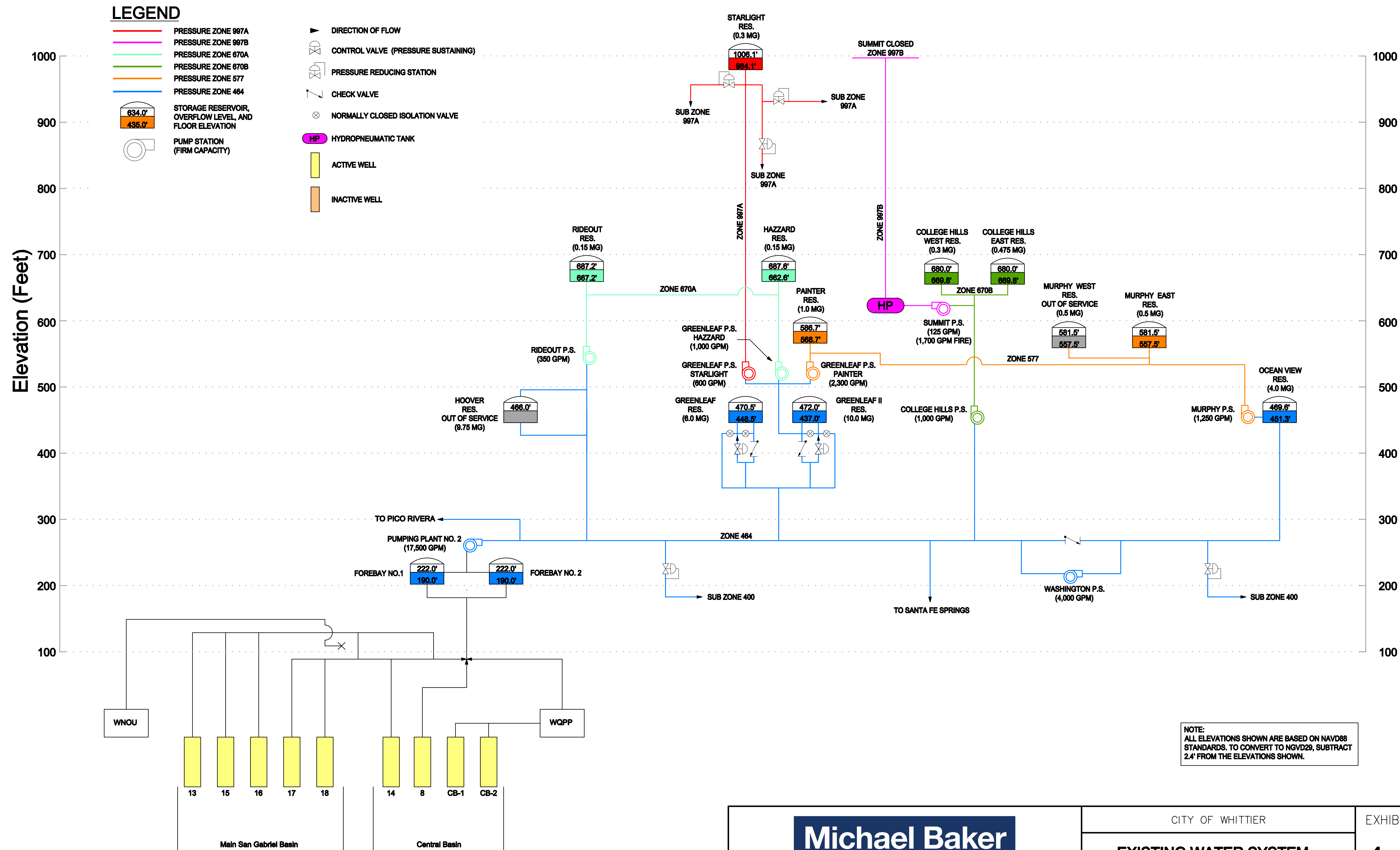
1. One-way connections can only flow from the City of Whittier to the other Agency.

4.14 Emergency Connections between Pressure Zones

The City operates eleven (11) emergency connections between pressure zones. Each emergency connection is a normally-closed gate valve located at a pressure zone boundary. The gate valve can be opened to supply water to the pressure zone at a lower hydraulic gradient. A summary of the emergency connections between pressure zones is listed in Table 4-11.

Table 4-11: Emergency Connections between Pressure Zones

Location	Atlas Sheet	Diameter (in)	From Pressure Zone	To Pressure Zone
Greenleaf Booster Pump Station	12	10	997A	670A
Greenleaf Booster Pump Station	12	10	670A	577
Penn Street at College Avenue	2	6	670B	577
Philadelphia Street to west of Bryn Mawr Way	6	4	670B	577
Haviland Avenue at Broadway	5	6	670A	577
Beverly Boulevard at Painter Avenue	5	6	670A	577
Honolulu Terrace at Pickering Avenue	12	8	670A	577
Avalon Road at Arrambide Drive	19	4	670A	577
To southwest of Hoover Reservoir No. 4	18	6	670A	464
Friends Avenue at Hadley Street	6	6	577	464
Eastridge Drive at Bacon Road	37	6	577	464



Michael Baker
INTERNATIONAL

CITY OF WHITTIER

EXISTING WATER SYSTEM
HYDRAULIC SCHEMATIC

EXHIBIT
4-1

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CITY OF WHITTIER MASTER PLAN

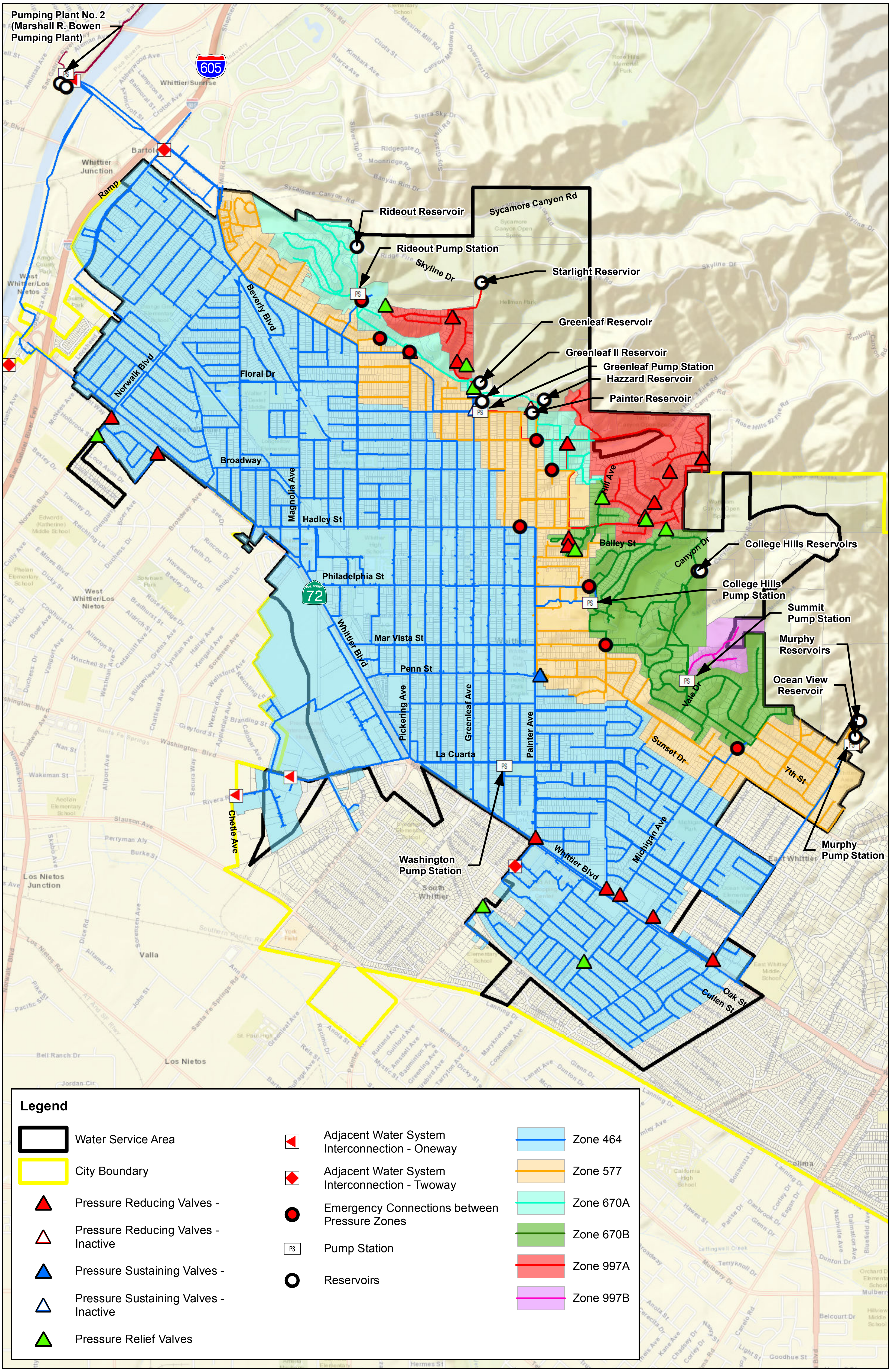
Michael Baker INTERNATIONAL

0 700 1400 Feet

Source: City of Whittier, ESRI, NearMap 2017

WNOU and City Well Supply System

Exhibit 4-2



3/22/2017 JN M:\Mdata\151940\GIS\MXD\FinalProjectReport\Ex4-3 WaterFacilities_PressureZones_11x17P.mxd

Michael Baker INTERNATIONAL

0 1000 2000 4000 Feet

Source: City of Whittier, Esri Street Maps

CITY OF WHITTIER MASTER PLAN

Water Facilities and Pressure Zone Map

Exhibit 4-3

Section 5
Water Use

SECTION 5 - Water Use

5.1 Historic Water Production

The City of Whittier obtains all of its water supply from the Main San Gabriel Basin and Central Basin, where water production is entirely from groundwater wells. The City owns and operates a total of seven (7) wells, five (5) of which are located in the Main San Gabriel Basin (Wells 13, 15, 16, 17, and 18) and two (2) in the Central Basin (Wells 8, and 14). The City also operates the Water Quality Protection Plan Treatment Plant, located on the Pumping Plant 2 site, and its two associated wells, CB-1 and CB-2, located in Pico Rivera. Since 1992, Well 7 has been inactive because of high manganese and iron levels. In the past, treated water has also been utilized from the Whittier Narrows Operable Unit (WNOU) and the Central Basin Water Quality Protection Plant (WQPP). However, the last time water was utilized from WNOU and WQPP was in May 2013 and May 2007, respectively, based on data received from the City through the first quarter of 2016.

Total water production from the Main San Gabriel Basin and Central Basin is shown in Figure 5-1. The total water production is the sum of the Main San Gabriel Basin and Central Basin water production. Data from January 2006 to December 2015 was used to calculate the averages. The annual water production averaged a total of 7,100 acre feet per year (7.05 mgd; 4,898 gpm; 10.91 cfs). The Main San Gabriel Basin and the Central Basin annual water production average was 5,888 and 2,014 acre feet per year, respectively. Figure 5-1 also shows that, for the last three years, water production from each basin has been roughly equivalent.

The 10-year historic water demand data shows a cyclical deviation from the average. Total water production has deviated from the average by a range of about -13.3% to +10.2%. The total annual water production for 2015 experienced a 9.5% reduction from the calculated average.

Historical water production on a monthly basis is shown in Figure 5-2. The total monthly water production averaged 658 acre feet. Production from the Main San Gabriel Basin and the Central Basin averaged 491 and 168 acre feet per month, respectively.

Table 5-1 and 5-2 list the average, minimum, and maximum water production of the Main San Gabriel Basin, Central Basin, as well as annual and monthly total production, respectively.

Figure 5-1: Annual Historical Water Production

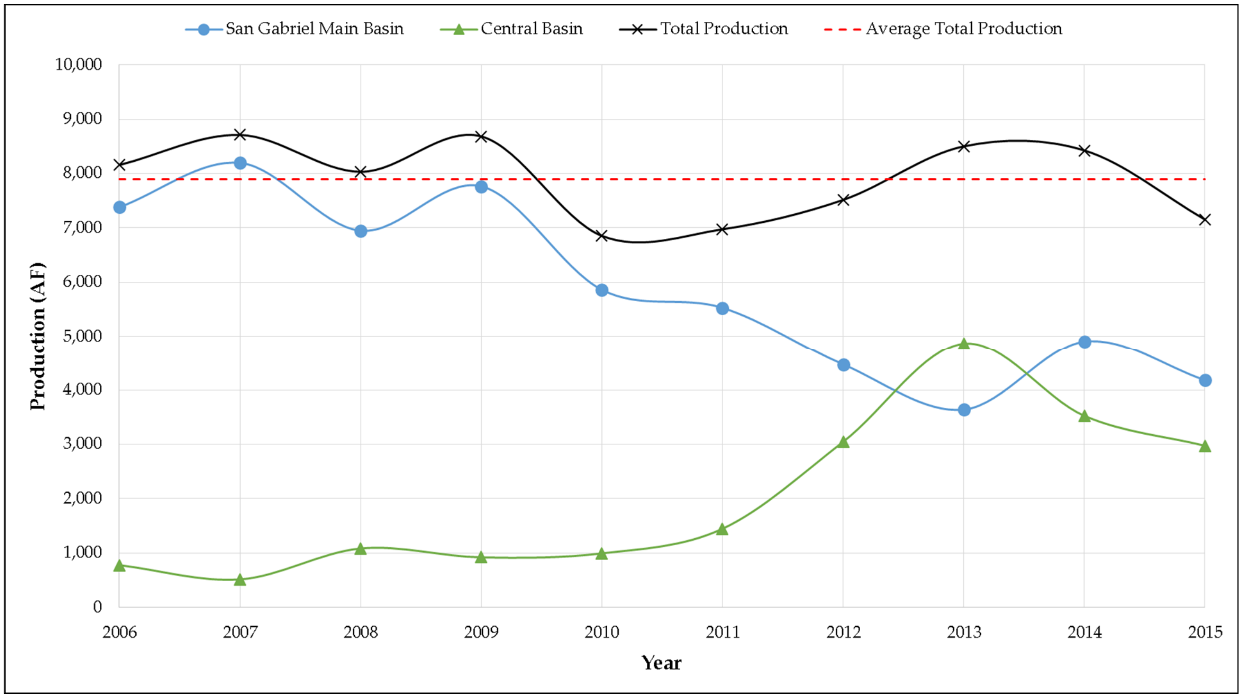


Figure 5-2: Monthly Historical Water Production

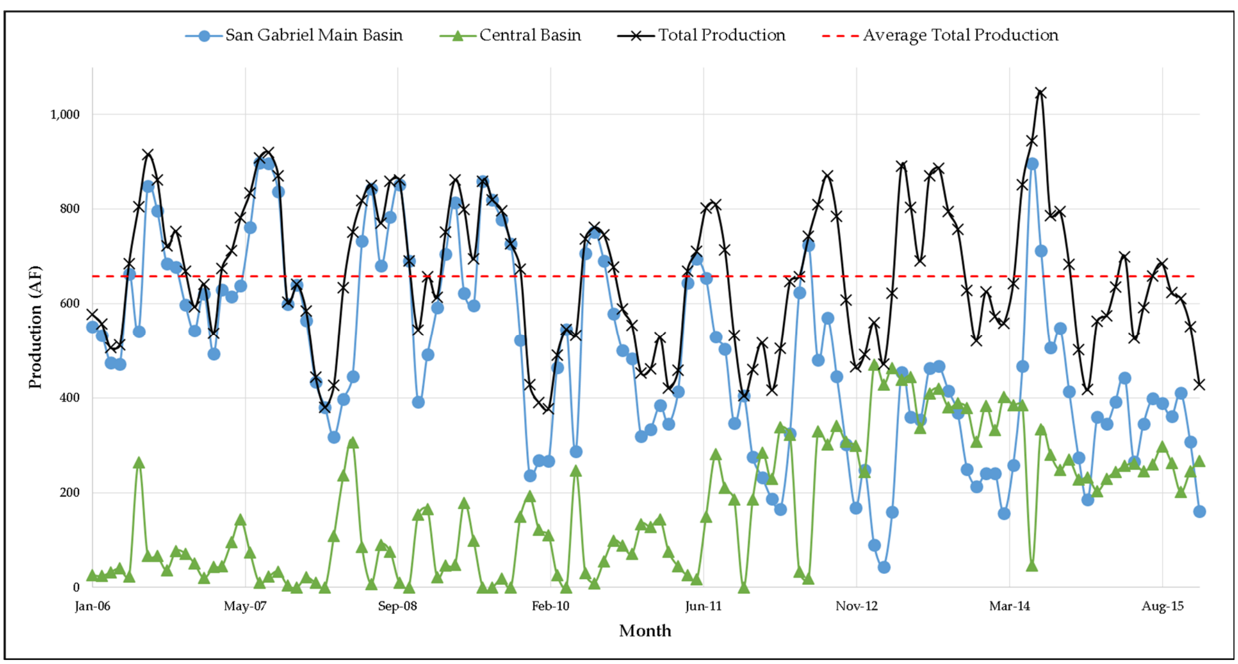


Table 5-1: Annual Historical Water Production Statistical Metrics

	Main San Gabriel Basin	Central Basin	Total Production
Average	5,888	2,014	7,901
Min	3,637	514	6,854
Max	8,197	4,865	8,711

Table 5-2: Monthly Historical Water Production Statistical Metrics

	Main San Gabriel Basin	Central Basin	Total Production
Average	491	168	658
Min	44	0	377
Max	898	470	1046

5.2 Water Consumption versus Water Production

Water consumption is not equal to the water production. This is due to water meter inaccuracy, water loss during system maintenance, and leakage throughout the water distribution system. Water meter inaccuracies can be linked to the calibration, maintenance, and age of the device. The on-going operation and maintenance of the infrastructure is also a source of water loss due to water main flushing and fire hydrant testing. Continuous water leakage can also occur at pipe joints and fittings from several factors.

Table 5-3 shows the water production versus the water consumption for the previous 12 years. From 2013 to 2017, an average of 8.71% of the produced water was unaccounted for.

Table 5-3: Water Consumption versus Water Production

Year	Production (AF)	Consumption (AF)	Unaccounted (AF)	Percent Unaccounted
2006	8,158	7,447	711	8.71% [1]
2007	8,711	7,952	759	8.71% [1]
2008	8,033	7,333	700	8.71% [1]
2009	8,685	7,929	756	8.71% [1]
2010	6,854	6,257	597	8.71% [1]
2011	6,975	6,367	608	8.71% [1]
2012	7,516	6,861	655	8.71% [1]
2013	8,502	7,542	960	11.29%
2014	8,426	7,716	710	8.43%
2015	7,153	6,387	766	10.72%
2016	6,795	6,347	448	6.59%
2017	6,918	6,466	451	6.53%
Average	**7,727**	**7,050**	**677**	**8.71%**

1. Assumed based on the average unaccounted water from 2013 to 2017.

5.3 Water Demand Variations

Water demand variations have been grouped into monthly and hourly variations for the purpose of the system analysis.

Monthly water demand varies due to seasonal factors. As expected, water demand increases during summer months and decreases during winter months. This is due to the variations in seasonal changes in temperature, humidity, and precipitation.

Within recent years, water conservation has become an increasingly important factor that has influenced monthly water demand. Due to recent drought conditions, customers have become more "water wise" with their selection of gardens and indoor water use units. Water conservation mandates such as the Governor's executive orders in 2014 and 2015 have been effective in reducing municipal water usage. Some other initiatives have included new standards for plumbing fixtures, new landscape ordinances, and new green building standards. All of these conservation efforts are expected to have a lasting effect on water usage.

Daily water demand variation is primarily influenced by the customer's lifestyle. The peak residential water demand hours are typically between 6:00 am and 8:00 am when customers begin their daily routine. The diurnal demand curve shows the hourly demand variations used in the system analysis to accurately simulate demand fluctuations throughout the day. The demand factor at any given time of day is the ratio of hourly demand to the average demand.

5.4 Monthly Demand Variations

Monthly demand factors were calculated as a ratio of the monthly demand to the average annual demand. The monthly water demand factors over the past 10 years are shown in Table 5-4 which are calculated using the average, sum, maximum, and rank for each year.

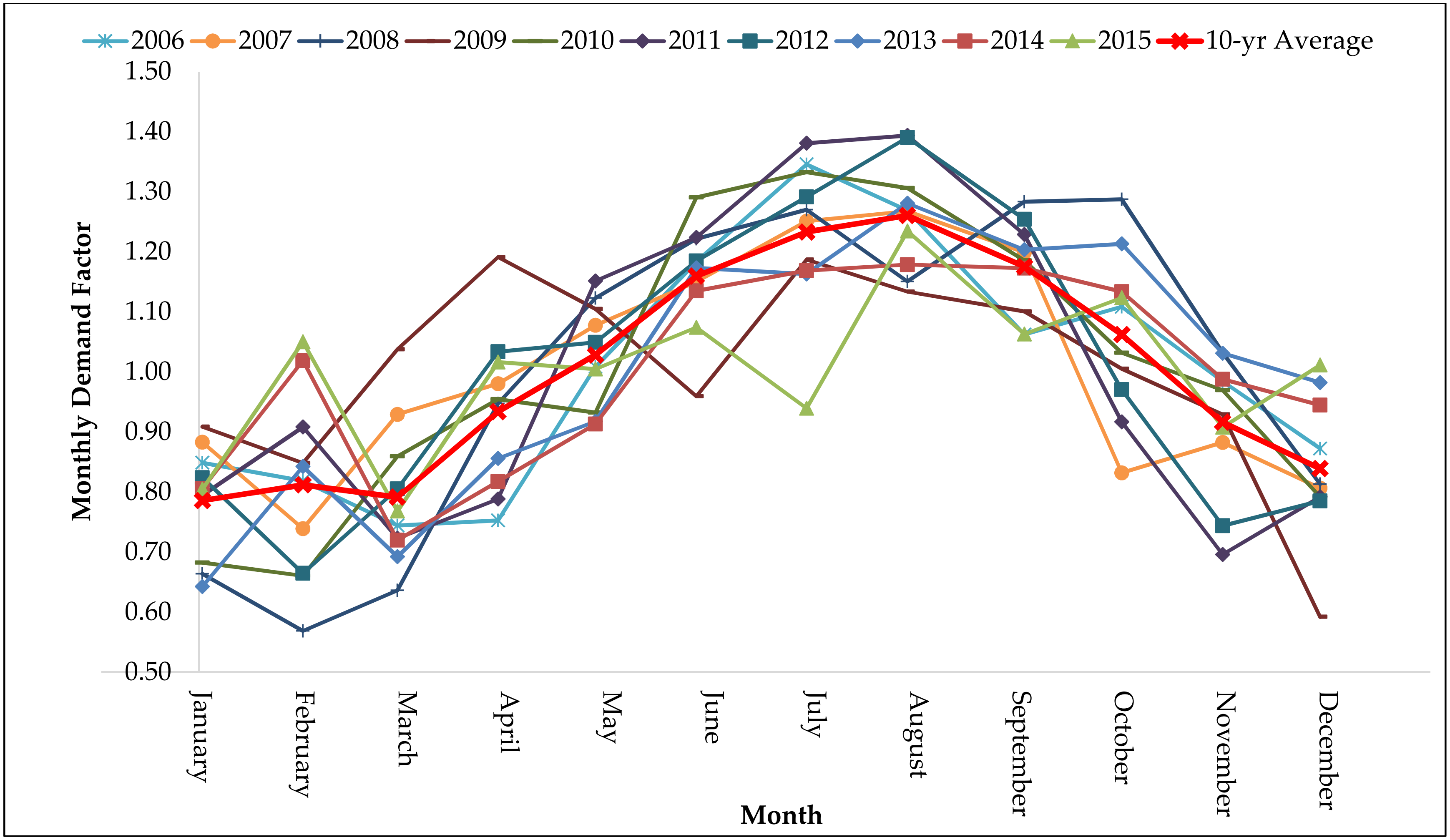
Table 5-4 shows that the three maximum water demand months occurred during July, August, and September. The three minimum water demand months occurred during January, February, and March. This annual water use fluctuation is typical for Southern California, with higher usage during summer months and lower usage during winter months. Additionally, Table 5-4 shows that current water demand is at or near its lowest in the last 10 years.

Figure 5-3 shows the data from Table 5-4 in graphical form and identifies qualitative trends.

Table 5-4: Monthly Water Demand (AF)

		January	February	March	April	May	June	July	August	September	October	November	December	Sum	Max	Rank
2006	Demand (AF)	519	500	455	460	616	723	822	775	649	677	601	533	**7,330**	**822**	**2**
	Factor	0.85	0.82	0.74	0.75	1.01	1.18	1.35	1.27	1.06	1.11	0.98	0.87	-	-	-
2007	Demand (AF)	576	482	606	640	703	750	816	827	782	543	576	526	**7,827**	**827**	**1**
	Factor	0.88	0.74	0.93	0.98	1.08	1.15	1.25	1.27	1.20	0.83	0.88	0.81	-	-	-
2008	Demand (AF)	399	342	383	570	675	735	764	692	772	775	621	489	**7,218**	**775**	**6**
	Factor	0.66	0.57	0.64	0.95	1.12	1.22	1.27	1.15	1.28	1.29	1.03	0.81	-	-	-
2009	Demand (AF)	591	552	675	775	719	624	772	737	716	654	604	385	**7,803**	**775**	**5**
	Factor	0.91	0.85	1.04	1.19	1.11	0.96	1.19	1.13	1.10	1.01	0.93	0.59	-	-	-
2010	Demand (AF)	350	339	441	490	479	663	684	670	609	530	498	407	**6,159**	**684**	**9**
	Factor	0.68	0.66	0.86	0.95	0.93	1.29	1.33	1.31	1.19	1.03	0.97	0.79	-	-	-
2011	Demand (AF)	415	474	378	412	602	639	721	728	642	479	364	414	**6,268**	**728**	**8**
	Factor	0.79	0.91	0.72	0.79	1.15	1.22	1.38	1.39	1.23	0.92	0.70	0.79	-	-	-
2012	Demand (AF)	464	374	453	582	591	667	727	783	706	546	419	442	**6,754**	**783**	**4**
	Factor	0.82	0.66	0.81	1.03	1.05	1.19	1.29	1.39	1.25	0.97	0.74	0.79	-	-	-
2013	Demand (AF)	404	530	435	538	577	738	731	805	756	763	648	617	**7,542**	**805**	**3**
	Factor	0.64	0.84	0.69	0.86	0.92	1.17	1.16	1.28	1.20	1.21	1.03	0.98	-	-	-
2014	Demand (AF)	518	655	463	526	587	730	752	758	754	729	635	608	**7,716**	**758**	**7**
	Factor	0.81	1.02	0.72	0.82	0.91	1.14	1.17	1.18	1.17	1.13	0.99	0.94	-	-	-
2015	Demand (AF)	428	559	409	541	535	572	500	657	566	598	483	538	**6,387**	**657**	**10**
	Factor	0.80	1.05	0.77	1.02	1.00	1.07	0.94	1.23	1.06	1.12	0.91	1.01	-	-	-
2016	Demand (AF)	395	441	502	597	588	639	724	773	707	528	444	457	**6795**	**773**	**-**
	Factor	0.70	0.78	0.89	1.05	1.04	1.13	1.28	1.36	1.25	0.93	0.78	0.81	-	-	-
2017	Demand (AF)	425	352	486	578	536	602	759	654	654	720	507	643	**6918**	**759**	**-**
	Factor	0.74	0.61	0.84	1.00	0.93	1.04	1.32	1.13	1.14	1.25	0.88	1.12	-	-	-
12-Year	**Average Factor**	**0.77**	**0.79**	**0.80**	**0.95**	**1.02**	**1.15**	**1.24**	**1.26**	**1.18**	**1.07**	**0.90**	**0.86**			

Figure 5-3: Monthly Demand Factors



5.5 Hourly Demand Variations

Analyzing a water distribution system and its capacity to meet customer water demands should consider hourly water demand variations over a 24-hour period. Diurnal demand curves are used in the analysis to identify hourly demands.

Demand data, from the Supervisory Control and Data Acquisition (SCADA) system, for an entire 24-hour period was used to construct the total system diurnal demand curve. Data from Wednesday March 16, 2016 was converted to 1-hour increments to obtain comparable time steps among all data sets. The demand for each hour was calculated using a mass balance. The total system hourly demand is then equal to the flow into the system minus the flow out of the system and the flow out of the reservoirs, as shown below:

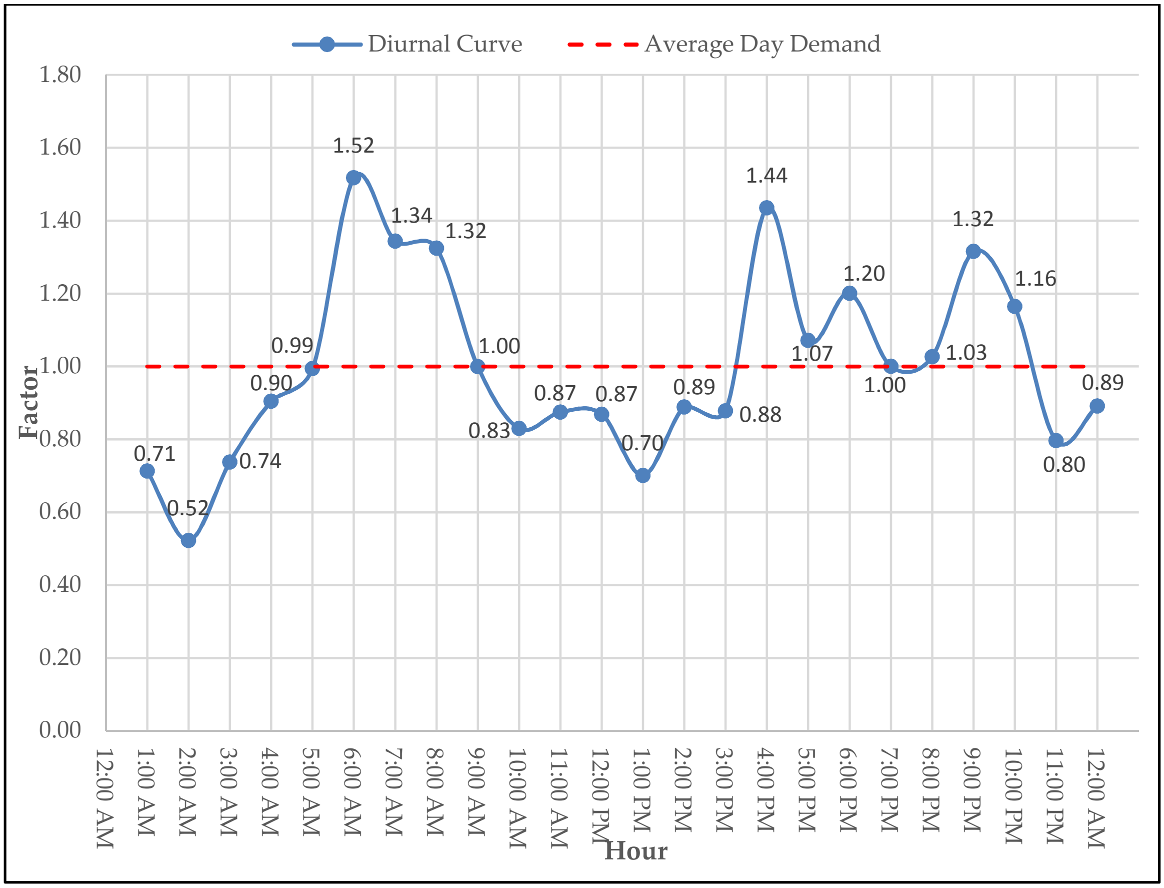
Total System Hourly Demand = (Volume IN) – (Volume OUT) – (ΔReservoir Volume)

Where: (Volume IN) is the volume of flow into the system
(Volume OUT) is the volume of flow out of the system to outside agencies
(ΔReservoir Volume) is the difference in volume at the storage tanks for the time period analyzed

The volume of water "into" the system is taken from Pumping Plant No. 2 (also known as Marshall R. Bowen Pumping Plant). No volume came out of the system since the City did not send water to adjacent agencies during the analysis period. Change in reservoir volume occurred at College Hills Reservoirs, Greenleaf Reservoirs, Hazzard Reservoir, Murphy Reservoirs, Ocean View Reservoir, Painter Reservoir, Rideout Reservoir, and Starlight Reservoir. The average flow into the system each hour was 5,801 gpm, the maximum flow occurred at 8:00 AM and was 7,770 gpm. The minimum flow occurred at 4:00 PM and was 2,948 gpm.

The calculated total system demand curve is shown in Figure 5-4. The curve starts at 1:00 AM and ends at 12:00 AM. The hourly demand factor is a ratio of the hourly demand to the average demand over the 24-hour period (hourly demand / average demand). The total system diurnal curve had its highest peak period between 6:00 AM to 7:00 AM. The maximum factor for this peak-hour period was 1.52 and it occurred at 6:00 AM. The next highest peak occurred between 4:00 PM and 5:00 PM at 1.44. The minimum demand of the total system occurred at 2:00 AM, with a corresponding peaking factor of 0.52.

Figure 5-4: Total System Diurnal Demand Curve



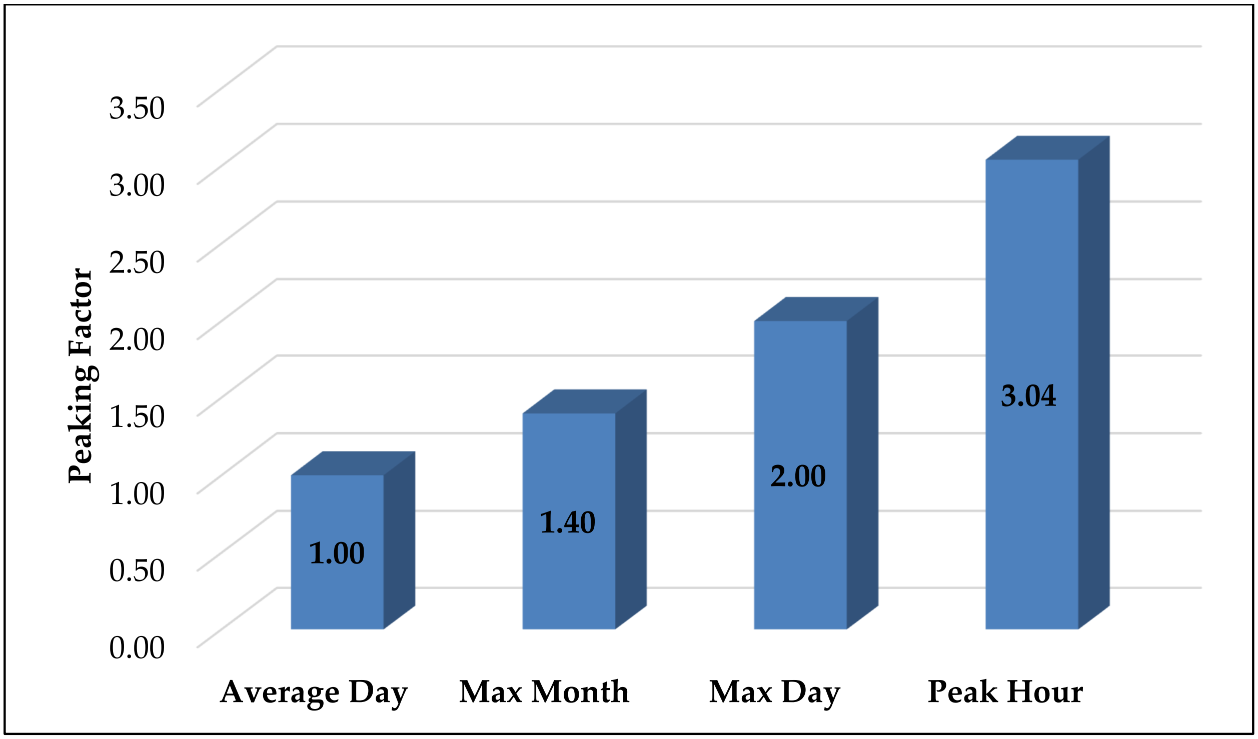
5.6 System Demands and Peaking Factors

Water distribution systems are typically designed to meet the maximum demands. The maximum day demands are used for analyzing reservoir storage and system transmission needs. The peak hour demand factor is used for analyzing the 'worst case condition' of the system. Table 5-5 and Figure 5-5 summarizes system demands and peaking factors.

Table 5-5: Water System Demands and Peaking Factors

Demand Description	10-yr average		Peaking Factor
	(AF/yr)	(gpm)	
Average Day	7,100	4,401	1.00
Max Month	9,923	6,152	1.40
Max Day	14,199	8,803	2.00
Peak Hour	21,583	13,380	3.04

Figure 5-5: Water Demand Peaking Factors



Existing Demands

Average Day

The average day demand factor was calculated by taking the 10-year average daily water consumption. The resulting flowrate is 7,100 AF/yr or 4,401 gpm.

Maximum Month

The maximum month demand factor of 1.40 was calculated by dividing the 10-year maximum monthly consumption by the 10-year average day demand. The resulting flowrate is 9,923 AF/yr or 6,152 gpm.

Maximum Day

The maximum day demand factor was assumed to be 2.00, which is consistent with the 2008 Water Master Plan, as well as industry standards. The resulting flowrate is 14,199 AF/yr or 8,803 gpm.

Peak Hour

The peak hour demand factor of 3.04 was calculated as the product between the maximum day demand factor (2.00) and the maximum 24-hour diurnal factor (1.52). The resulting flowrate is 21,583 AF/yr or 13,380 gpm.

Ultimate Demands

The City's water service area is essentially fully developed. Furthermore, from 2010 to 2016 the population of the City increased from 85,328 to 88,341. This increase amounted to a nominal 3.5% increase in population growth over six years. Although 2016 is the highest population of the City to date, it was only greater than the population of 2007 by 1,151, which is a marginal 1.3% increase. This shows that the City has fluctuations in population but typically remains steady. For that reason, the ultimate demands are not expected to be changed based on population. In addition, the water use reduction mandates imposed due to drought conditions are expected to stabilize current demands and not significantly impact future water demand patterns.

5.7 Adjacent Agency Demands Provided by the City of Whittier System

Water connections exist between the City's system and California Domestic Water Company, City of Pico Rivera, San Gabriel Valley Water Company, City of Santa Fe Springs, and Suburban Water Company through various interconnections. The City of Pico Rivera and the City of Santa Fe Springs connections historically served as wholesale service connections from the City of Whittier. The connections with California Domestic Water Company, San Gabriel Valley Water Company, and Suburban Water Company serve as emergency interconnections and are not part of normal operation.

The City no longer provides wholesale water to neighboring water agencies based on data received from the City through the first quarter of 2016.

5.8 Unit Flow Factors

Unit flow factors are useful for estimating the water usage of new development areas. These values are based on the average day demand calculation (Section 4) and are an average of the specific land use purpose (Section 3). It is important to note that these numbers were not used in the development of the hydraulic model.

Table 5-6: Unit Flow Factors

Land Use	Designation	Unit Flow Factor
Single Family Residential	H-R, R-E, R-1	282 gpd/du [1]
Multiple Family Residential	R-2, R-3, R-4	197 gpd/du [1]
Commercial / Industrial	C-O, C-1, C-2, C-3, M	2,104 gpd/ac [2]

1. Unit flow factor for each land use is the ratio between total water demand for that land use obtained from the hydraulic model and the total number of units for that land use as described in Table 3-2.
2. Unit flow factor for commercial/industrial land use is the ratio between total water demand for those land uses obtained from the hydraulic model and the total zoning acreage for those land uses as described in Table 3-1.

Section 6
Service Criteria

SECTION 6 - Service Criteria

The purpose of this section is to establish the operating criteria to evaluate the performance of the existing water distribution system. When establishing service criteria, it is important to differentiate between service criteria for existing facilities, and service criteria for new facilities. Service criteria for new facilities tend to be more conservative than service criteria for existing facilities. The Master Plan considers specific criteria listed in General Order 103-A (Public Utilities Commission of the State of California) as well as criteria that is based on industry accepted standards and best practices. The service criteria for the existing system listed in this section is a combination of the requirements of General Order 103-A, and industry accepted standards and best practices. The Capital Improvement Program (CIP) includes the projects that are recommended based on the service criteria described in this section.

6.1 Storage

Storage criteria are typically divided into three categories: operational, fire, and emergency storage. Storage criteria are based on industry standards and best practices, and should be developed based on the characteristics of each particular water system. For example, the emergency storage component can vary widely between different water purveyors.

Operational storage is the amount of storage required to meet normal fluctuations in daily demand and short-term interruptions between pumping and storage facilities. Operational storage is usually based on a factor of maximum day demand. It can vary from typically a minimum of one day of maximum day demand, up to multiple days of maximum day demands. The City has previously used a factor of 1.33 x maximum day demand and it is recommended to continue to use the same factor.

Fire storage is the amount of storage required to meet the largest fire flow within the pressure zone for the required duration. Minimum fire flow requirements for proposed developments are set by the local fire authority or the requirements of the California Fire Code. For the purposes of master planning, fire flow requirements can be established by land use type based on the California Fire Code, and recent projects. The recommended fire flow requirements for the purposes of the Master Plan are included in Section 6.5.

Emergency storage is the storage required to meet demands during temporary interruption of water supply. The City has a reliable and local water supply and can pump water via wells from separate groundwater basins. Since the groundwater basins provide ample storage for emergency purposes, it is not necessary to require an additional emergency storage component. Therefore, the storage criteria is calculated as follows:

$$\textbf{Storage Criteria} = (\mathbf{1.33})\mathbf{x}(\textbf{Maximum Day Demand}) + (\textbf{Largest Fire Flow})\mathbf{x}(\textbf{Duration})$$

6.2 Pump Stations

Pump station facilities are typically sized to meet maximum day demands in their respective service areas. Firm capacity is defined as the pump station's capacity with the largest pump out of service. Industry standards and best practices generally govern pump station design with firm capacity to meet maximum day demands. Additionally, it is more economical to operate pump stations during non-peak hours of the day with lower tiered pricing for electrical power. Therefore, it is recommended the firm capacity of each pump station be able to supply the total volume of maximum day demands in sixteen (16) hours.

For pump stations that pump into a closed zone (no storage facilities), the pump station must meet peak hour demands as well as the worst-case fire flow requirement of the pressure zone.

The pump station criteria are summarized below in Table 6-1.

Table 6-1: Pump Station Criteria

Pump Station Type	Criteria
Pumping to a Reservoir	Firm capacity shall be Maximum Day Volume supplied in a 16-hour period.
Pumping to a Closed Zone	Firm capacity shall be Peak Hour Demand plus dedicated fire flow pump.

6.3 Service Pressure

General service pressure criteria listed in Table 6-2 below are based upon the current California Code of Regulations, California Fire Code, and industry standards.

Table 6-2: Service Pressure Criteria

Category	Criteria
Service Pressure	Minimum Pressure at Peak Hour = 40 psi **[1]**
Service Pressure	Preferred Static Pressure = 60 – 80 psi
Service Pressure	Maximum Pressure = 150 psi
Service Pressure	All lots with greater than 80 psi static pressure shall have pressure regulators
Fire Flow Pressure	Minimum = 20 psi residual pressure at any demand/ service location in the system

[1] General Order 103-A requires a minimum service pressure of 30 psi during peak hour periods.

6.4 Transmission and Distribution Pipelines

General velocity criteria for transmission and distribution pipelines are listed in Table 6-3 and are based on the current California Code of Regulations, California Plumbing Code, and industry standards.

Table 6-3: Pipe Velocity Criteria

Operating Condition	Maximum Criteria
Maximum Day Demand	5 fps
Peak Hour Demand	10 fps
Fire Flow Scenario	15 fps

6.5 Fire Flow Criteria

General guidelines for fire flow requirements by land use are listed below in Table 6-4 based on the 2013 California Fire Code, Title 32 – Fire Code of the Los Angeles County Code, and typical requirements from experience working with local fire authorities.

Table 6-4: Fire Flow Guidelines

Land Use	Fire Flow (gpm)	Duration (hrs)
Single Family Residential	1,250	2
Multi-Family Residential	2,250	2
Institutional/ Commercial/Industrial	3,000	3

6.6 Summary of Service Criteria

A summary of all criteria for the existing system described in the previous sections is shown in Table 6-5. This criteria was used for developing projects in the CIP.

Table 6-5: Summary of Service Criteria

Description	Criteria	
Pressure	Peak Hour	Minimum 40 psi
	Preferred	60 - 80 psi
	Maximum	150 psi
	Pressure Regulators for Lots	> 80 psi
	Fire Flow + Max Day	Minimum 20 psi
Velocity	Maximum Day Demand	5 fps
	Peak Hour Demand	10 fps
	Fire Flow Scenario	15 fps
Storage	Operational/ Short-Term Pumping Interruptions	133% of Maximum Day Demand
	Fire	(Largest Fire Flow) x (Duration)
Pumping	Firm Capacity to Reservoir	Maximum Day Demand in 16 hours
	Firm Capacity to Closed Zone	Maximum Day Demand in 16 hours. Additional dedicated Fire Flow Pump.
Fire Flow	Single Family Residential	1,250 gpm for 2 hours
	Multi-Family Residential	2,250 gpm for 2 hours
	Institutional / Commercial / Industrial	3,000 gpm for 3 hours

Section 7
System Analysis

SECTION 7 - System Analysis

The purpose of this section is to describe the hydraulic model building and calibration process, and assess the City's water distribution system compared to the service criteria established in Section 6. Aspects of the system that were analyzed include supply, storage, pump stations, system operations, pressure zone interconnections, fire flow adequacy, and system pressure. The findings from the analysis were developed into capital improvement projects.

7.1 Hydraulic Model

Hydraulic models are computer simulations of real world water distribution systems. Hydraulic models utilize input data for infrastructure (pipes, junctions, reservoirs, pumps, valves, etc.) and associated parameters (length, diameter, demand, operational settings.). Model simulation programs translate input into outputs for the entire system and predict results. Hydraulic models can accurately predict system conditions as well as future conditions if changes to system infrastructure and parameters are made. Hydraulic models are a proven tool used in water system evaluations.

A hydraulic model of the City's water distribution system was updated and calibrated to existing conditions for this Water Master Plan. The original hydraulic model was created by AKM Consulting Engineers for the 2008 Water Master Plan using Innovyze's H20Map Water program and was updated in 2010 for the Pumping Plant No. 2 Replacement Project Preliminary Design Analysis. The new hydraulic model was updated and converted to Innovyze's InfoWater program, which is fully integrated into ESRI's ArcGIS ArcMap program and works seamlessly with other ArcGIS features. InfoWater Suite 12.1, Update #1 was used for model development and system analysis in conjunction with ArcMap version 10.3.1.

<u>Model Infrastructure and Parameters Update</u>

The infrastructure of the existing model was both verified and updated using the current City water system atlas maps and GIS data. Modifications to the model were made based on recent construction projects, including the Pumping Plant No. 2 Replacement Project. Additional modifications were made to the Summit Booster Pump Station to more accurately model the existing hydropnematic tank and pump configuration including the addition of a tank, fire pump, and reconfiguration of modeled piping.

All junction elevations were updated using GIS data provided by the City, which contained elevations in the NAVD88 datum. All reservoir floor elevations and high water levels were verified and updated based upon a field survey conducted by Michael Baker International on July 9, 2014. Elevations at or adjacent to valves and pumps were modified accordingly with the updated junction elevations surrounding them. A comprehensive verification and update for the settings and controls for all booster pumps, pressure reducing valves, and pressure sustaining valves was also conducted based upon information provided by the City.

Demand Allocation

As a part of the model update, demands were reallocated throughout the system based on individual water meter data. Water usage data for the first three (3) months of 2016 was used to match customer demands to the respective geocoded water meters. A modified meter layer file was created with the demands by meter, and the demand allocation was performed using the "Closest Junction" method. The "Closest Junction" method allocates all of a meter's demand to the junction that is closest to the meter in the model. A special selection set was created in order to only allocate to designated demand nodes and not features such as fire hydrants or other non-demand nodes.

7.2 Model Calibration

The original hydraulic model was last calibrated for the 2008 Water Master Plan. A new calibration was performed for this project on the new hydraulic model. Model calibration is the process of revising a model to reflect a specific real world condition. In this case, SCADA data from March 16, 2016 was obtained as well as the historical hydrant test data from City staff. The model calibration process involved modifying the hydraulic model to closely match the real world condition on March 16, 2016 and applicable hydrant test data.

The goal of the model calibration process is for modeled conditions to match real world conditions within 10% accuracy, which is of sufficient accuracy for master planning purposes. Model calibration is considered complete once this accuracy tolerance is achieved, or further revisions to the model do not improve calibration results.

Once the model calibration scenario has been completed to acceptable accuracy tolerances, the model demand conditions can be modified (such as maximum day demand), and the model will adjust accordingly and accurately to simulate real world conditions. The model calibration process included developing the model calibration scenario, then using that scenario as the starting point for modeling different demand conditions for the analysis. The subsequent description describes the calibration process.

C-Factor Calibration

C-Factors from the original hydraulic model were used as a starting point for systematically adjusting C-Factors to match hydrant test data obtained by City staff. In order to use hydrant test data for calibration, test data needs to include at minimum observed static pressure, dynamic pressure when flowing, the flow rate discharged, and a test date to determine the approximate demand condition.

Of the hydrant test data containing the minimum required information, six (6) tests were conducted in the year 2017 and nine (9) tests were conducted in 2004. Test data from 2004 was excluded given 2004 is outside the 10-year historical window examined for this Water Master Plan. The testing time of day was not included in any test data, so static runs were conducted in the model under the appropriate demand condition to determine static and dynamic pressure at each of the hydrants. For each model run at each hydrant, incremental adjustments were made to the C-Factors of local distribution pipe until both the static and dynamic pressure calibration goals were met. Additional runs were conducted for all hydrants after all modifications to C-Factors were incorporated to ensure the accuracy of the calibration. C-Factors were generally lowered from the 2008 values to meet model calibration goals, which is consistent with observed conditions over this timeframe as described by City staff.

Demand

As described previously, model demands were initially allocated based on average water meter data from the first three (3) months of 2016. However, to develop the calibration scenario, model demands were scaled to the monthly data to match the actual system demand on March 16, 2016 based on SCADA data. The SCADA data showed that the actual demands should be scaled to 5,229 gpm, compared with the average demand over the first three (3) months of 3,330 gpm. For the greatest level of accuracy, the system demand distribution from the allocation process was not changed; each junction demand was scaled equally.

Model Parameters Adjustment

After obtaining initial results, several adjustments were made to model parameters in order to improve model accuracy. For the calibration scenario only, time-based controls were added to all pumps at PP2 in order to match the operating times shown in the SCADA data. Modifications were made at both Greenleaf Reservoir No. 2 and No. 7A to better simulate reservoir levels and flow in and out of the tank. The following modifications to pump control settings at the Summit Booster Pump Station were made to better match field observations: lead pump on setting lowered to 125 psi, lead pump off setting lowered to 138 psi, lag pump on setting lowered to 120 psi, lag pump off setting lowered to 138 psi. Based on hydrant test results, two adjustments were made to existing PRV settings to better match field observations. The setting for CV-8 was set to 60 psi, and the setting for CV-10 was set to 54 psi.

Calibration Results

The accuracy of the hydraulic model was evaluated based upon the average error of hourly measurements for the discharge of Pumping Plant No. 2 (also known as Marshall R. Bowen Pumping Plant), the water level in each reservoir (including pressure in the Summit hydropnuematic tank), and the error for both static and dynamic pressure at each residual hydrant from the useable hydrant test data. For all categories of results, the percent difference of modeled values were well within 10% of observed values. Table 7-1 summarizes calibration results. Detailed graphs and tables showing observed versus modeled conditions and percent error are provided in Appendix A.

Table 7-1: Calibration Results Summary

Category	Percent Difference [1]
Pumping Plant No. 2 Discharge	-6.1%
Reservoir Level	1.1%
Static Pressure at Hydrant	2.2%
Dynamic Pressure at Hydrant	-0.5%

[1] Percent difference = $\frac{([\text{Model}] - [\text{Field}])}{[\text{Field}]}$

7.3 Supply Analysis

The City's groundwater wells provide a local and reliable supply for the entire distribution system. The groundwater wells have a total design capacity of over 23,000 gpm, and current capacity of 13,000 gpm. The maximum day demand for the system is 8,803 gpm (based on the last 10 years of production and consumption data). Since the local groundwater wells can currently provide 1.5 times the maximum day demand of the system, no new wells are recommended.

7.4 Storage Analysis

Using the storage criteria set forth in Section 6, Table 7-2 was compares existing storage to recommended storage based on demand conditions averaged over the last ten years, calculating storage surplus/deficiency by pressure zone.

Table 7-2: Storage Analysis

Zone	Maximum Day Demand (MGD)	Recommended Storage			Available Storage			Surplus/ Deficency (MG)
		Fire Storage (MG)	Operational Storage (MG)	Total Storage (MG)	Reservoir	Reservoir Capacity (MG)	Total Storage (MG)	
464	9.34	0.54	12.42	12.96	Greenleaf Greenleaf II Ocean View -	6.00 10.00 4.00	20.00	7.04
577	2.08	0.54	2.77	3.31	Painter Murphy East -	1.00 0.50	1.50	-1.81
670A	0.25	0.15	0.34	0.49	Rideout Hazzard	0.15 0.15	0.30	-0.19
670B	0.57	0.54	0.75	1.29	College Hills West College Hills East -	0.30 0.475	0.78	-0.52
997A	0.40	0.15	0.53	0.68	Starlight	0.30	0.30	-0.38
997B	0.04	0.15	0.06	0.21		0.00	0.00	-0.21
TOTAL	12.68	2.07	16.86	18.93	-	-	22.88	3.95

Table 7-2 shows there is a substantial surplus in Zone 464, with lesser deficiencies in the upper zones. Looking at the system as a whole, there is an overall surplus of 3.95 MG. Although there are deficiencies when analyzing each zone individually, there are no recommendations for new storage facilities. The surplus in Zone 464 can be pumped to higher zones. Additional pumping capacity for the higher zones is essential to make up for the storage shortfall. In addition, higher zone pumping facilities should include permanent on-site generators and/or connections for portable generators to pump the surplus storage from Zone 464 to the upper zones.

7.5 Pump Station Analysis

Using the capacity criteria set forth in Section 6, Table 7-3 summarizes the comparison of existing capacity to recommended capacity based on demand conditions averaged over the last ten years, and calculates capacity surplus/deficiency by pressure zone.

Table 7-3: Pumping Analysis

Zone	Maximum Day Demand (gpm)	Maximum Day Demand (16-hr) (gpm)	Pumping Station	Firm Capacity (gpm)	Total Zone Firm Capacity (gpm)	Surplus/ Deficency (gpm)
464	6,485	9,728	Pumping Plant No. 2 **[1]** Washington **[2]**	13,700 4,000	13,700	3,972
577	1,444	2,166	Murphy Greenleaf (Painter)	1,250 2,300	3,550	1,384
670A	176	264	Rideout Greenleaf (Hazzard)	350 1,000	1,350	1,086
670B	393	589	College Hills	1,000	1,000	411
997A	276	415	Greenleaf (Starlight)	600	600	185
997B **[3][4]**	29	45	Summit	125	125	80
TOTAL	8,803	13,205	-	-	20,325	7,120

[1] Ultimate firm capacity of Pumping Plant No. 2 is 17,500 gpm.
[2] Washington Pump Station not included in Total Zone Firm Capacity since both its suction and discharge are within Zone 464.
[3] The largest fire flow in Zone 997B is 1,250 gpm and this flow can be met using the 1,700 gpm fire pump at Summit PS.
[4] Pump Station criteria uses Peak Hour Demand for Summit PS since it is serving a closed zone.

Table 7-3 shows there is a pumping surplus in every pressure zone, therefore, no new pumping facilities are recommended based on capacity needs. The surplus also has an added benefit in being able to provide additional capacity to pump up surplus storage in Zone 464 to the higher pressure zones.

Improvements are recommended to provide portable generator connections at the following pump stations:

- Murphy Pump Station
- Rideout Pump Station

With these improvements implemented, all pump stations will either have a permanent generator or portable generator connection on-site and can be operated during a local loss of power.

7.6 System Operations Analysis

A system-wide analysis of overall system operations was conducted. The purpose of the analysis was to confirm the recommended system improvements and modifications that would result in:

- Maximizing water level in Ocean View Reservoir without using Washington Pump Station
- Shutting down Washington Pump Station without adversely affecting service
- Maximizing capacity out of PP2 without adversely affecting service

The hydraulic model was used to determine the most effective operational changes as well as system improvements to achieve the goals of this analysis. Initially, a scenario was run with no changes to the system and with Washington Pump Station out of service. As a result, the system was unable to fill Ocean View Reservoir, and the reservoir eventually drained completely.

In analyzing the current situation of needing Washington Pump Station to maintain water level in Ocean View Reservoir, the initial assumption was there was a system restriction that was causing excessive head losses. However, it was determined that this is not the case. Head losses from the Greenleaf Reservoirs to Ocean View Reservoir vary from 2 to 5 feet in different scenarios, which is a reasonable amount of head loss, and indicative that there is not a system restriction or "bottleneck" creating excessive head losses. It was concluded that pipeline improvements like a new transmission main would only marginally increase water levels at Ocean View Reservoir, and therefore this option is not recommended.

The primary reason for the need for Washington Pump Station is because Zone 464 currently operates at a lower HGL for the western part of the zone, and the Washington Pump Station is used to increase the HGL for the eastern part of the zone enough to maintain water level in Ocean View Reservoir. As stated previously, with the lowered HGL and no Washington Pump Station, the Zone 464 HGL on the eastern side of the zone is too low and the Ocean View Reservoir drains and cannot be refilled.

In order to address this issue, the HGL of the zone must be increased within acceptable levels. System operational changes were explored to determine if the existing system infrastructure could achieve the goals of this analysis. Under existing operations, the pumps at PP2 are programmed as shown in Table 7-4.

Table 7-4: Existing PP2 Pump Operations

PP2 Pump	Initial Status	ON		OFF	
		ft [1]	HGL	ft [1]	HGL
1	ON	19	456	20.5	457.5
2	ON	18	455	19.5	456.5
3	ON	17	454	18.5	455.5
4	OFF	16	453	17.5	454.5
5	OFF	15	452	16.5	453.5
6 (Future)	OFF	14	451	15.5	452.5

[1] All elevations in feet correspond to the water level in Greenleaf II Reservoir

The Zone 464 maximum HGL is 469.6 feet, and the current pump settings support a maximum HGL of 457.5 feet. With the head losses observed in the model, Ocean View Reservoir can only fill to approximately a level of 4 feet under the settings. Therefore, it is recommended to revise the pump settings to pump up to the maximum Zone 464 HGL as detailed in Table 7-5.

Table 7-5: Recommended PP2 Pump Operations

PP2 Pump	Initial Status	ON		OFF	
		ft [1]	HGL	ft [1]	HGL
1	ON	23	460	32	469
2	ON	22	459	31	468
3	ON	21	458	30	467
4	OFF	20	457	29	466
5	OFF	19	456	28	465
6 (Future)	OFF	18	455	27	464

[1] All elevations in feet correspond to the water level in Greenleaf II Reservoir

The analysis showed that these changes alone are not enough to maximize the water level in Ocean View Reservoir significantly enough without Washington Pump Station in operation. At Greenleaf Reservoir and Greenleaf II Reservoir, pressure sustaining valves were installed at each reservoir inlet. These valves maintain a specific upstream HGL by opening when upstream pressure exceeds the setting (and filling the reservoir), and remaining closed when upstream pressure is below the setting. City staff had informed Michael Baker these valves are currently not operated and are set in the open position.

The hydraulic model showed significant improvement to the operating level in Ocean View Reservoir by using the pressure sustaining valves to maintain an HGL of 469 feet, in conjunction with the recommended PP2 pump settings. Under both of these operational changes, Ocean View

Reservoir levels cycle to approximately 461 feet, or a tank level of approximately 10 feet, without Washington Pump Station in service. Therefore, it is recommended to utilize each pressure sustaining valve at the Greenleaf Reservoirs as follows:

- Set pressure sustaining valves at Greenleaf Reservoirs to an HGL of 469 feet.

Impacts to system operating pressure at service nodes in Zone 464 were monitored as a part of this analysis. With the recommended operational changes without using Washington Pump Station, the following impacts were observed in the pressure zone during maximum day demand conditions:

- Average of service pressure change ranges from – 2 psi to + 9 psi

The conclusion was that these recommended operational changes provide a significant benefit in being able to shutdown Washington Pump Station, while maintaining acceptable water levels in Ocean View Reservoir, and mildly increasing pressures within the pressure zone. These results are accomplished without implementing a major construction project such as a new transmission main. In addition, these operational improvements can be implemented entirely by City staff.

As an alternative to implementing these system operational changes, an alternate project to replace Washington Pump Station is discussed in the next section.

7.7 Washington Pump Station Replacement

As described in the previous section, implementing the system operations changes would result in service pressure increases in some parts of the system. Due to the concern that the service pressure increases would result in negative impacts to the system, an alternate project of replacing the existing Washington Pump Station was investigated. The three options investigated for replacing Washington Pump Station include:

- Replacing Washington Pump Station at its current location at Washington Avenue and La Cuarta Street.
- A new pump at the existing multi-zone pump station at Greenleaf II Reservoir, and associated discharge piping.
- A new pump station facility at a proposed parking garage on Comstock Avenue, north of Philadelphia Street, and associated discharge piping.

7.7.1 Option 1: Replace Washington Pump Station at Current Location

Option 1 includes a complete replacement of Washington Pump Station at its current location. It is assumed the new pump station will include the same pump configuration as existing. Major components of this option include:

- Demolition of the existing vault walls down to the current foundation.
- Replacement of the vault including increased length to the north and south.
- All new mechanical and piping including pumps, valving, and piping in vault.
- All new electrical and control located above ground along the sidewalk.
- Temporary pumping system while pump station is out of service.
- Site improvements along sidewalk, street, and school property that is impacted by construction.

Total estimated cost for Option 1 including design and construction is $2.4 M. A breakdown of costs is shown on Table 7-6.

Table 7-6: Option 1 Cost Estimate

Item	Cost
Demo Existing Pump Station	$ 50,000
New Pump Station Vault	$ 200,000
Pumps, Piping, and Valving	$ 700,000
Electrical, Instrumentation, and Control	$ 400,000
Site Improvements	$ 150,000
Temporary Pumping System	$ 150,000
Construction Contingency (20%)	$ 330,000
Design and Administration (25%)	$ 413,000
Total	**$ 2,400,000**

7.7.2 Option 2: New Pump at Existing Pump Station at Greenleaf II Reservoir

Option 2 includes a new pump and associated piping at the existing multi-zone pump station at Greenleaf II Reservoir. The existing pump station has an extra pump "can" and discharge pipe assembly that was installed for a future pump. This option includes installing one (1) pump at 4,000 gpm. Although it is preferred to have a primary and back up pump, it is assumed that a temporary pumping system can be brought in when the one pump requires servicing.

Additional piping would also be associated with this project so the new pump would optimally fill the Ocean View Reservoir. It was found that the discharge piping should connect to the system at the existing Washington Pump Station location to match the current operation, which results in a 10,000 LF discharge pipeline from the Greenleaf site. Major components of this option include:

- Abandonment of the existing pump station.
- One (1) vertical turbine pump at 4,000 gpm.
- Additional on-site piping and valving.
- Electrical, instrumentation, and control improvements.
- Discharge piping to the connection point – 10,000 LF.

Total estimated cost for Option 2 including design and construction is $5.1 M. A breakdown of costs is shown on Table 7-7.

Table 7-7: Option 2 Cost Estimate

Item	Cost
Abandon Existing Pump Station	$ 10,000
One (1) Vertical Turbine Pump	$ 150,000
On-site Piping and Valving	$ 150,000
Electrical, Instrumentation, and Control	$ 150,000
Discharge Piping to Connection Point ($300/LF)	$ 3,000,000
Construction Contingency (20%)	$ 692,000
Design and Administration (25%)	$ 865,000
Total	**$ 5,100,000**

7.7.3 Option 3: New Pump Station at Proposed Parking Garage on Comstock Avenue

Option 3 includes a complete replacement of Washington Pump Station at a proposed parking garage. It is assumed the new pump station will include the same pump configuration as existing. It was found that the discharge piping should connect to the system at the existing Washington Pump Station location to match the current operation, which results in a 6,000 LF discharge pipeline from the parking garage site. Major components of this option include:

- Abandonment of the existing pump station.
- Complete new pump station facility including pumps, piping, valving, electrical, instrumentation, and control. All located in a new building at the proposed parking garage.
- Site work and civil improvements.
- Discharge piping to the connection point – 6,000 LF.

Total estimated cost for Option 3 including design and construction is $4.8 M. A breakdown of costs is shown in Table 7-8.

Table 7-8: Option 3 Cost Estimate

Item	Cost
Abandon Existing Pump Station	$ 10,000
Building	$ 300,000
Pumps, Piping, and Valving	$ 700,000
Electrical, Instrumentation, and Control	$ 350,000
Site Improvements	$ 100,000
Discharge Piping to Connection Point ($300/LF)	$ 1,800,000
Construction Contingency (20%)	$ 652,000
Design and Administration (25%)	$ 815,000
Total	**$ 4,800,000**

A potential fourth option that could be considered is to locate a new property in the vicinity of the current Washington Pump Station. Pipeline costs are significant, as indicated in the estimates for Options 2 and 3. If the City could locate a property near Washington Pump Station, this would reduce pipeline costs considerably. Potential options could be purchasing private residential or commercial properties, or purchasing a portion of a property such as school district property.

Of the three primary options, Option 1 to replace Washington Pump Station at its current location is the preferred option. Without having to construct an additional discharge pipeline, the overall construction costs and community impacts are significantly minimized compared with Options 2 and 3.

7.8 Murphy West Reservoir Analysis

A technical memorandum entitled Condition Assessment of Murphy West Reservoir #10, dated November 3, 2016, was prepared by Tetra Tech for the City. City staff first documented a leak from the reservoir sometime after the Whittier Narrows earthquake in 1987, and significant leakage was first noticed in 2015. After recognizing the significant leak, the City made at least two attempts to repair the leak, both of which were unsuccessful. Currently Murphy West Reservoir is out-of-service.

Tetra Tech performed both a visual examination and seismic analysis of the reservoir. Although several circumferential cracks were visible, no defective concrete was found. The majority of the floor slab appeared to be in good condition, with the exception of a circumferential crack at the southern end of the tank. Slightly lower finish floor elevations were observed at the southern end of the tank as well. Also, the column capital was noted to be damaged with a large portion of one of the corners broken off. Using current design standards, it was determined the tank is stable for both sliding and overturning, but lacks adequate freeboard. Further geotechnical investigations suggested there is a discrepancy between allowable soil bearing pressure between the northern and southern ends of the tank; the southern portion of the footings were noted to be founded on undocumented fill. Lastly, the tank did not appear to have adequate horizontal reinforcing in some locations and record drawings suggested the joint between the wall footing and wall may be inadequate as well.

The memorandum recommended two general options to address the issues with the reservoir: repair the existing reservoir, or demolish the existing reservoir and replace it with a new one. In order to repair the existing reservoir, work would need to include a foundation retrofit, repair of existing leaks, and balancing of the soil load on the tank. The memorandum recommends demolishing the existing reservoir and constructing a new one in its place given the cost is similar to a complete retrofit and a new concrete tank would be constructed on an appropriate foundation to current standards. A steel tank was not recommended as a replacement due to periodic recoating work and overall higher maintenance costs.

It should be noted both the Murphy West and East Reservoirs were constructed in 1955. Given both reservoirs have been in service for over 60 years, City staff suggested both the replacement of Murphy West Reservoir and Murphy East Reservoir should be constructed at the same time as a part of the same project. Therefore, a project to replace both reservoirs is included as a part of the CIP.

7.9 Fire Flow Analysis

A fire flow analysis was conducted using the maximum day demand scenario. The analysis included placing a fire flow demand at each hydrant based on the applicable land use. The distribution system should be capable of providing the maximum day demand plus the minimum required fire flow with a minimum residual pressure of 20 psi in the system. The hydraulic model calculates the available flow in the system at a residual pressure of 20 psi. This is the value that is used to determine fire flow availability.

The minimum required fire flow for any particular location is determined by the local fire authority. For the purposes of this analysis, required fire flow demands were assumed to be as shown below.

Single Family Res.	**1,250 gpm for 2 hours**
Med/High Density Res.	**2,250 gpm for 2 hours**
School/Commercial	**3,000 gpm for 3 hours**

Fire flow demands were placed at each hydrant based on the worst-case land use that a particular hydrant would have to serve. It should be noted that hydrants that were not considered in the evaluation were hydrants located at facility sites, such as pump stations or reservoirs. These hydrants are typically at a location where it would be hydraulically impossible to provide a standard fire flow, such as on the inlet piping for a reservoir.

The hydraulic model revealed that several hydrants throughout the system could not meet the criteria, as shown on Exhibit 7-1 and Table 7-9.

A large number of improvements in the CIP are pipeline projects to mitigate fire flow deficiencies. The improvements typically recommend replacing undersized pipe, or adding new pipelines for looping and improved distribution. The benefit of these improvements are they provide a measurable improvement in the fire flow availability for each area, while also replacing older and undersized pipelines.

An evaluation was performed to quantify the improvement to available fire flow if the proposed projects in the CIP are implemented. A summary of the increase in available fire flow is shown in Table 7-9.

Table 7-9: Improvement in Available Fire Flow from Proposed Projects

ID	Fire-Flow Demand (gpm)	Existing Available Flow at Hydrant (gpm)	Available Flow at Hydrant with CIP Projects (gpm) [1]	Increase in Available Flow (gpm)
28464560	1,250	560	7,269	6,709
28464570	1,250	722	7,249	6,527
28464055	1,250	234	6,377	6,143
28464080	1,250	459	6,210	5,751
28464075	1,250	201	5,855	5,654
16464485	3,000	2,593	7,187	4,594
8464435	3,000	1,623	6,184	4,561
16464505	2,250	1,177	5,510	4,333
21464480	3,000	451	4,737	4,286
16464460	2,250	1,023	5,305	4,282
16464385	2,250	2,134	5,933	3,799
35464115	1,250	379	4,123	3,744
21464405	3,000	2,068	5,755	3,688
46464095	3,000	2,987	6,627	3,640
54464170	3,000	2,925	6,480	3,556
54464155	3,000	2,958	6,409	3,450
6577545	3,000	963	4,389	3,426

ID	Fire-Flow Demand (gpm)	Existing Available Flow at Hydrant (gpm)	Available Flow at Hydrant with CIP Projects (gpm) [1]	Increase in Available Flow (gpm)
46464155	3,000	2,798	6,183	3,385
46464160	3,000	2,802	6,145	3,343
14464515	3,000	1,587	4,921	3,334
16464430	3,000	2,751	6,052	3,301
54464140	3,000	2,930	6,135	3,204
10464330	3,000	2,840	6,036	3,196
42464075	3,000	1,667	4,732	3,064
28464465	3,000	2,429	5,480	3,051
54464120	3,000	2,318	5,363	3,045
8464475	3,000	1,517	4,467	2,949
55464035	3,000	1,949	4,827	2,878
46464020	3,000	2,718	5,556	2,839
6577535	3,000	978	3,772	2,795
48464040	3,000	1,113	3,902	2,789
48464080	3,000	886	3,671	2,785
48464085	3,000	949	3,715	2,766
8464445	1,250	832	3,506	2,674
6577300	3,000	806	3,476	2,670
14464525	3,000	1,953	4,578	2,625
54464110	3,000	1,784	4,401	2,617
54464090	3,000	2,232	4,785	2,553
9464280	1,250	748	3,284	2,536
21464085	3,000	2,678	5,166	2,488
14464320	3,000	1,876	4,357	2,481
9464440	3,000	1,336	3,784	2,448
15464895	3,000	2,043	4,422	2,379
27464305	3,000	2,048	4,393	2,345
7577600	3,000	1,413	3,728	2,315
14464310	3,000	2,063	4,297	2,234
9464490	1,250	454	2,687	2,233
8464490	1,250	815	3,035	2,220
17464125	3,000	2,625	4,806	2,181
8464400	1,250	380	2,541	2,162
17464130	3,000	2,587	4,735	2,148

ID	Fire-Flow Demand (gpm)	Existing Available Flow at Hydrant (gpm)	Available Flow at Hydrant with CIP Projects (gpm) [1]	Increase in Available Flow (gpm)
16464500	3,000	2,590	4,676	2,086
54464070	3,000	2,101	4,137	2,036
28577155	1,250	988	2,975	1,986
46464035	3,000	2,461	4,445	1,984
14464120	1,250	666	2,645	1,978
6464740	3,000	2,494	4,405	1,911
7577340	3,000	1,749	3,637	1,888
24577290	1,250	1,063	2,912	1,850
52464195	3,000	2,682	4,521	1,839
6464180	3,000	2,665	4,491	1,826
14464090	2,250	1,341	3,084	1,743
28577200	3,000	1,372	3,048	1,676
5577170	1,250	806	2,479	1,673
54464030	3,000	1,973	3,612	1,640
46464050	3,000	2,309	3,917	1,608
6577015	1,250	691	2,287	1,596
21464505	3,000	2,485	4,038	1,552
14464500	3,000	2,400	3,899	1,499
35577330	1,250	1,118	2,597	1,479
14464415	3,000	2,776	4,246	1,470
22464565	3,000	2,441	3,900	1,459
23464135	3,000	2,875	4,310	1,435
52464220	3,000	2,675	4,097	1,422
2577085	1,250	1,065	2,482	1,417
21464530	3,000	2,172	3,586	1,414
28577145	1,250	510	1,895	1,386
1670195	3,000	2,659	3,986	1,327
52464140	3,000	2,208	3,534	1,326
35577275	1,250	1,071	2,392	1,320
40464310	1,250	1,058	2,377	1,319
7577320	3,000	2,670	3,979	1,309
35577380	1,250	1,069	2,355	1,286
14464100	2,250	1,863	3,136	1,272
21464495	3,000	2,865	4,132	1,267

ID	Fire-Flow Demand (gpm)	Existing Available Flow at Hydrant (gpm)	Available Flow at Hydrant with CIP Projects (gpm) [1]	Increase in Available Flow (gpm)
51670210	1,250	387	1,637	1,250
35577350	1,250	1,046	2,265	1,218
6464675	3,000	2,147	3,349	1,202
35577290	1,250	1,073	2,269	1,195
40464295	1,250	1,022	2,207	1,186
6464190	3,000	2,340	3,512	1,172
14464080	2,250	1,706	2,858	1,153
8577425	2,250	1,577	2,729	1,151
35577235	1,250	1,000	2,151	1,151
1670440	1,250	484	1,615	1,132
1670490	1,250	901	2,022	1,122
35577360	1,250	1,030	2,147	1,116
7577805	3,000	2,591	3,695	1,104
9464545	1,250	1,201	2,302	1,101
6464755	3,000	2,216	3,316	1,100
35577410	1,250	978	2,054	1,075
5577385	1,250	715	1,786	1,071
6577525	2,250	1,189	2,259	1,070
52464125	2,250	1,256	2,321	1,065
13577400	1,250	799	1,838	1,039
51997510	1,250	787	1,773	985
38577215	1,250	1,165	2,142	977
2577095	1,250	1,044	2,021	977
6464710	3,000	2,901	3,877	975
1670480	1,250	858	1,818	960
35577425	1,250	927	1,871	944
23464185	3,000	2,534	3,474	940
27464040	3,000	2,792	3,715	923
18997035	1,250	1,050	1,958	908
14464480	3,000	2,370	3,268	898
23464085	3,000	2,295	3,190	895
22464495	3,000	2,172	3,062	890
51997590	1,250	777	1,662	885
16464510	3,000	1,884	2,732	847

ID	Fire-Flow Demand (gpm)	Existing Available Flow at Hydrant (gpm)	Available Flow at Hydrant with CIP Projects (gpm) [1]	Increase in Available Flow (gpm)
18577190	1,250	518	1,364	846
6464165	3,000	2,514	3,358	844
18997005	1,250	1,142	1,981	839
38577190	1,250	853	1,688	835
14464330	3,000	2,282	3,103	821
2670550	1,250	832	1,649	817
35577450	1,250	854	1,650	796
38577245	1,250	916	1,708	792
18577170	1,250	847	1,635	788
11997130	1,250	1,170	1,953	783
11997115	1,250	942	1,707	765
35577475	1,250	852	1,616	764
9464550	1,250	1,243	2,005	761
57670045	1,250	674	1,427	753
8464580	1,250	1,157	1,902	745
28577170	3,000	1,157	1,899	742
57670050	1,250	831	1,565	734
18670100	1,250	558	1,283	725
46464175	2,250	1,689	2,413	724
35577485	1,250	823	1,532	709
27464095	3,000	2,143	2,838	694
39577085	2,250	2,116	2,806	689
6577030	1,250	879	1,561	682
35577460	1,250	788	1,463	674
39464210	1,250	872	1,516	644
37670015	1,250	1,064	1,676	612
11997125	1,250	1,100	1,660	561
51997495	1,250	813	1,369	556
10464390	3,000	2,960	3,501	541
65670110	1,250	1,026	1,500	474
2670540	1,250	1,150	1,621	471
35577530	1,250	676	1,135	459
9464190	1,250	1,196	1,635	439
5670300	1,250	943	1,366	422

ID	Fire-Flow Demand (gpm)	Existing Available Flow at Hydrant (gpm)	Available Flow at Hydrant with CIP Projects (gpm) [1]	Increase in Available Flow (gpm)
40577320	1,250	1,173	1,556	383
7577610	3,000	2,810	3,192	381
24577280	1,250	1,118	1,497	379
13464120	2,250	1,892	2,269	377
15464760	3,000	2,989	3,351	362
32464180	3,000	2,814	3,170	356
15464650	3,000	2,964	3,289	325
22464125	3,000	2,900	3,222	322
35577500	1,250	618	930	311
20464345	2,250	2,127	2,438	311
35577515	1,250	612	914	302
19577385	1,250	1,085	1,379	294
15464085	3,000	2,727	3,012	284
20464360	2,250	2,227	2,499	272
51670160	1,250	805	1,041	236
15464805	3,000	2,243	2,475	232
51670175	1,250	1,002	1,215	213
27464285	3,000	2,818	3,001	182
37670345	1,250	1,224	1,379	156
25464445	3,000	1,550	1,703	153
65997075	1,250	1,171	1,314	143
20464065	1,250	1,246	1,383	137
8464455	1,250	1,193	1,300	107
26464445	1,250	1,194	1,288	94
6577125	2,250	2,213	2,273	60
37670040	1,250	1,241	1,289	48
36464015	1,250	1,245	1,292	47
52464100	2,250	1,760	1,801	40
37670265	1,250	783	812	29
10464135	3,000	2,980	3,000	20
37577060	1,250	1,191	1,196	4
5577045	1,250	423	424	1
18670060	1,250	1,215	1,216	0
18670055	1,250	910	910	0

ID	Fire-Flow Demand (gpm)	Existing Available Flow at Hydrant (gpm)	Available Flow at Hydrant with CIP Projects (gpm) [1]	Increase in Available Flow (gpm)
11997065	1,250	-3,755	-3,755	0
34670020	1,250	1,080	1,080	0
34670070	1,250	-795	-795	0
34670075	1,250	845	845	0
58577140	3,000	-4,669	-4,669	0
1670345	1,250	-3,452	-3,499	-47

1. Available flow at hydrant calculated from Fire Flow simulation in hydraulic model.

7.10 System Pressure Analysis

Low pressure areas were identified using the hydraulic model as shown in Exhibit 7-2. Most of low pressure areas are located in Zone 464. However, improvements for the low pressure areas are not recommended. Projects recommended in the CIP will substantially resolve most of the fire flow deficiencies in low pressure areas. In addition, many low pressure areas are too high in elevation to simply be converted to a higher pressure zone and would need to be served under new pressure sub-zones with additional PRVs and numerous closed valves. Given these conditions, it was not viewed as a priority to implement additional projects for low pressure areas.

High pressure areas were identified using the hydraulic model as shown in Exhibit 7-2. All of the high pressure locations are located with Zone 997A. However, improvements for the high pressure areas are not recommended. It was not viewed as a priority to implement projects for areas that currently have high pressure and are accustomed to operating with those higher pressures.

7.11 Pipeline Velocity Analysis

Deficient pipelines were identified using the hydraulic model, and in general the deficiencies identified were negligible considering the system as a whole. Therefore, no improvements related to pipeline velocity criteria are recommended.

7.12 Pipeline Break Analysis

Although a formal condition assessment was not performed as a part of this Master Plan Update, past discussions with the City have suggested there are areas within the distribution system where pipelines are older and have had a greater historical frequency of pipe break occurrences. After the conclusion of the Pumping Plant No. 2 Replacement Project, the City had Michael Baker examine options to mitigate potential system pressure impacts if the City utilized the full capacity of the new Pumping Plant No. 2. These analyses focused on the creation of potential sub-zones in the western region of Zone 464 where several pipeline breaks had occurred in 2015. Conceptual plans for the creation of sub-zones in these areas showed there would be significant construction impacts to the community as well as increased maintenance requirements for the distribution system if the projects were implemented. It was concluded that a more efficient use of City budget and resources would be to analyze pipeline break history, and include pipeline replacement projects in the CIP that would improve areas with older pipelines and areas that have experienced pipeline breaks in the past.

For the analysis, the City provided a record of pipeline breaks during the years 2007 to 2016 in an excel table format. Data provided was organized into a geocoded shapefile based upon the address cited in the record. This new shapefile was then compared with system infrastructure and modeled operational characteristics (i.e. operating pressure) and integrated into a single geocoded file describing the following, but not limited to:

- Break location.
- Identification as a service, main, or hydrant break.
- Corresponding operating pressure.

The organized data was then analyzed to search for any trends. The following information was gathered from analysis:

- Most breaks were service breaks (57%), followed by main breaks (42%), and hydrants (1%).
- There was not an observed trend in the year the break occurred.
- Most main breaks were on 6-inch pipelines (70%), followed by 4-inch pipelines (16%).
- Main breaks happened more frequently with both 4-inch and 6-inch pipelines.
- Main breaks were most common in Zone 464 (68%), followed by Zone 577 (19%).
- A higher concentration of main breaks occurred when the maximum service pressure was greater than 80 psi.

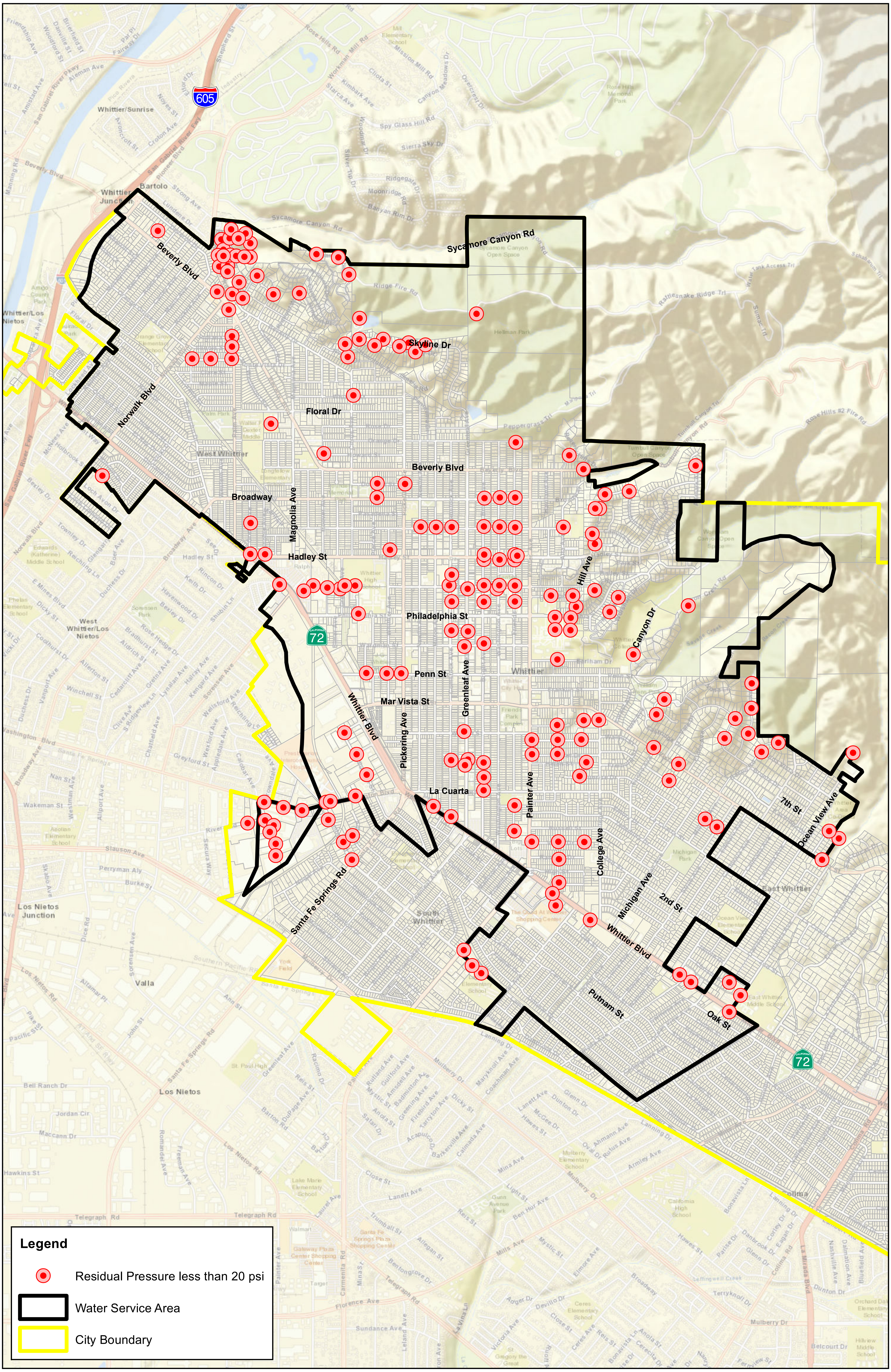
As a result of the analysis, numerous smaller diameter pipes were identified that had a history of at least one main break and service pressures in the immediate area of greater than 80 psi. These new projects were compared to projects recommended from the fire flow analysis and were grouped geographically at first to loosely define larger project areas. More pipeline replacement projects for smaller diameter pipelines were added, given the trends previously discussed, to fill in gaps within each larger project area with a minimum of 5,000 LF of pipeline construction for each project. Larger projects are beneficial to the City because higher contract values result in more interest from bidders, more competitive bidding which lowers the overall price per foot of construction, and increases efficiencies in construction by improving more compact areas at the same time. A more detailed discussion of overall project development and prioritization is provided in Section 8.3.

7.13 Zone Interconnections

As discussed in Section 4.13, the City has several locations where normally closed valves could be opened to supply water to the pressure zone at a lower HGL. However, almost all of these locations would not protect services in the lower HGL pressure zone from the higher pressure zone's HGL and could unintentionally cause further issues. Only one zone interconnection, located at Honolulu Terrace/Pickering Avenue, consists of a PRV in between closed isolation valves. It is desirable to have a PRV at zone interconnection locations to protect services in the lower HGL pressure zone, and to provide an additional supply point to the pressure zone. Locations were identified as recommended locations for zone interconnections with PRVs as described in Table 7-10.

Table 7-10: Proposed Zone Interconnection Projects

Location	Higher Zone	Lower Zone	Factors
Hadley Street/ Painter Avenue	577	464	• 12" (Zone 577) and 12"/14" (Zone 464) pipeline mains • Near other proposed zone interconnections • Near low pressure area in Zone 464
College Avenue/ Penn Street	670B	577	• Existing zone interconnection location • Hydraulically remote location in Zone 577 from both reservoirs
Eastridge Drive/ Bacon Road	577	464	• Existing zone interconnection location • Hydraulically remote location in Zone 464 if emergency with Ocean View Reservoir



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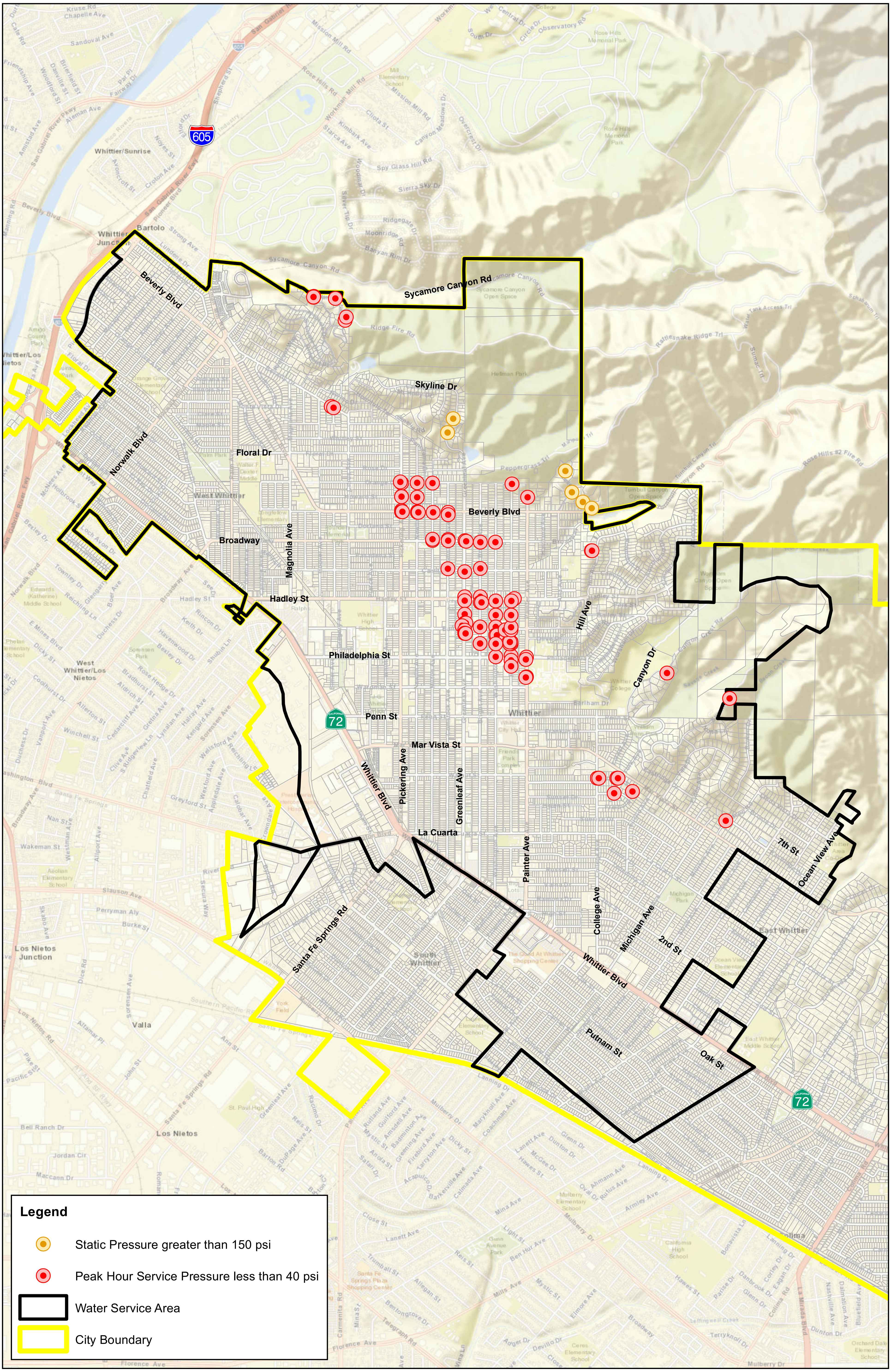
0 1000 2000 4000 Feet

Source: City of Whittier, Esri Street Maps

CITY OF WHITTIER MASTER PLAN

Deficient Fire Flow Locations

Exhibit 7-1



CITY OF WHITTIER MASTER PLAN

High and Low Pressure Locations

Exhibit 7-2

Section 8
Capital Improvement Program

Section 8
Capital Improvement Program

SECTION 8 - Capital Improvement Program

8.1 Introduction

The Capital Improvement Program (CIP) is a phased 10-year program that includes all projects recommended as part of the system analysis using the calibrated hydraulic model. The system analysis included evaluation of adequate storage facilities, pump station facilities, supply, interconnections, and the distribution system. The distribution system analysis identified low pressure areas, high pressure areas, fire flow deficient areas, and pipe break areas. The details of the system analysis are included in Section 7.

In developing the CIP, a realistic approach to project recommendations and implementation was employed. It was a goal to not recommend substantial changes or complications to the way the system currently operates. This would include significant zone boundary changes or new reduced pressure zones. Those types of improvements were not completely ruled out, but priority was placed on finding other alternatives. Also, project recommendations were preliminarily checked to not have significant "real world" obstacles. For example, some pipelines in easements between houses were originally identified as deficient. However, the use of current technologies allowing aerial imagery and street views on a computer screen allowed for quick assessment and removing replacement risks to the City.

8.2 Project Basis Descriptions

The projects included in the CIP are improvements based on the system analysis. A description for the basis for the various projects is provided.

<u>Storage Related Improvements</u>

A storage analysis was conducted based on the storage criteria identified in Section 6. As a result of the analysis, there is a large surplus of storage in Zone 464, and minor storage deficiencies in some of the upper zones. However, the existing pump stations and calculations using system data shows that pumping the storage surplus in Zone 464 to the upper zones is feasible. Therefore, no new storage facilities have been recommended.

<u>Pump Station Related Improvements</u>

A pump station analysis was conducted based on the pump station criteria identified in Section 6. As a result of this analysis, no new pump stations or pumps at existing pump stations are recommended.

As described in Section 7, an analysis was conducted to maximize the water level in Ocean View Reservoir while eliminating the need to operate Washington Pump Station. However, implementing the system operations changes would result in service pressure increases in some parts of the system. Due to the concern that the service pressure increases would result in negative impacts to the system, an alternate project of replacing the existing Washington Pump Station was investigated. Based on discussions with the City, it is preferred to implement the Washington Pump Station replacement, rather than implementing the system operation changes that would result in service pressure increases in some parts of the system. The CIP includes the project to replace Washington Pump Station at its current location.

Other pump station related improvements include installation of portable generator connections at Murphy Pump Station and Rideout Pump Station so all pump stations will either have a permanent generator or portable generator connection on-site and can be operated during a local loss of power.

Fire Flow Improvements

A large number of improvements in the CIP are pipeline projects to mitigate fire flow deficiencies. The improvements typically recommend replacing undersized pipe, or adding new pipelines for looping and improved distribution. The benefit of these improvements are, they provide a measurable improvement in the fire flow availability for each area, while also not altering operations of the system.

Pipe Break Improvements

An analysis of historical pipe break data demonstrated that smaller diameter mains in areas with maximum service pressures of 80 psi and greater showed a higher frequency of pipe breaks. Therefore, numerous smaller diameter pipes with these qualities were identified and were added and grouped into larger projects geographically for efficiencies during construction. The majority of recommended pipeline improvements in the CIP are related to documented pipeline breaks. The benefit of these improvements are they increase system reliability by replacing old and undersized pipes and further improve the fire flow availability for each area.

Murphy West Reservoir Analysis

A condition assessment performed in November 2016 identified Murphy West Reservoir as having significant deficiencies and recommended either performing major repairs or constructing a new reservoir. Based on discussions with City staff, the full replacement of both the Murphy West and East Reservoirs is the preferred project, which is included in the CIP.

Zone Interconnections

Locations were identified to install pressure reducing valve (PRV) stations at zone boundaries to provide emergency or additional supply to a lower HGL pressure zone.

8.3 Project Development and Prioritization

Both the fire flow and pipe break analyses were utilized to identify numerous pipeline replacement projects. Pipeline projects from both analyses were grouped geographically at first to define larger project areas. Next, additional pipeline replacement projects were added based on the pipe break analysis to create larger project areas with a minimum of 5,000 LF of pipeline replacements. Larger projects are beneficial because they result in more interest from bidders, which leads to more competitive bidding and greater value for the City. Improvements such as installing pressure reducing valves, pressure relief valves, new fire hydrant connections, and emergency interconnections were included with other larger projects.

Recommended projects such as the Murphy West and East Reservoir Replacement Project (see Section 8.5.8) and Washington Pump Station Replacement Project (see Section 8.5.9) are not only large enough as stand-alone projects but were kept as stand-alone projects given they require different construction specialties. The recommended portable generator connection installations at Murphy Pump Station and Rideout Pump Station were added to the Murphy West and East Reservoir Replacement Project given the electrical work at the reservoirs site would already be required to complete that project.

The projects were then prioritized for the 10-year CIP. The most critical projects for the City's water infrastructure are placed in the first few years of the CIP to ensure improvements can be completed as soon as possible. Distribution system improvements for Zone 464 were prioritized first, especially in areas with high concentrations of historical pipeline breaks and high service pressures (i.e. areas closer to I-605) and areas near Whittier's developing Uptown area. Next, the Murphy West and East Reservoir Replacement project is recommended to safeguard the storage of water supplies in Zone 577. Projects thereafter are prioritized based upon pressure zone and service pressure, with projects in Zone 464 in areas with higher service pressures to be completed before work in other pressure zones.

8.4 Cost Basis Parameters

Estimated costs for pipeline projects were based on recent construction bid results on pipeline projects throughout southern California. For small diameter pipeline projects of varying complexity (6" to 12" diameter), overall project costs have been observed to vary between $200/LF to well over $400/LF.

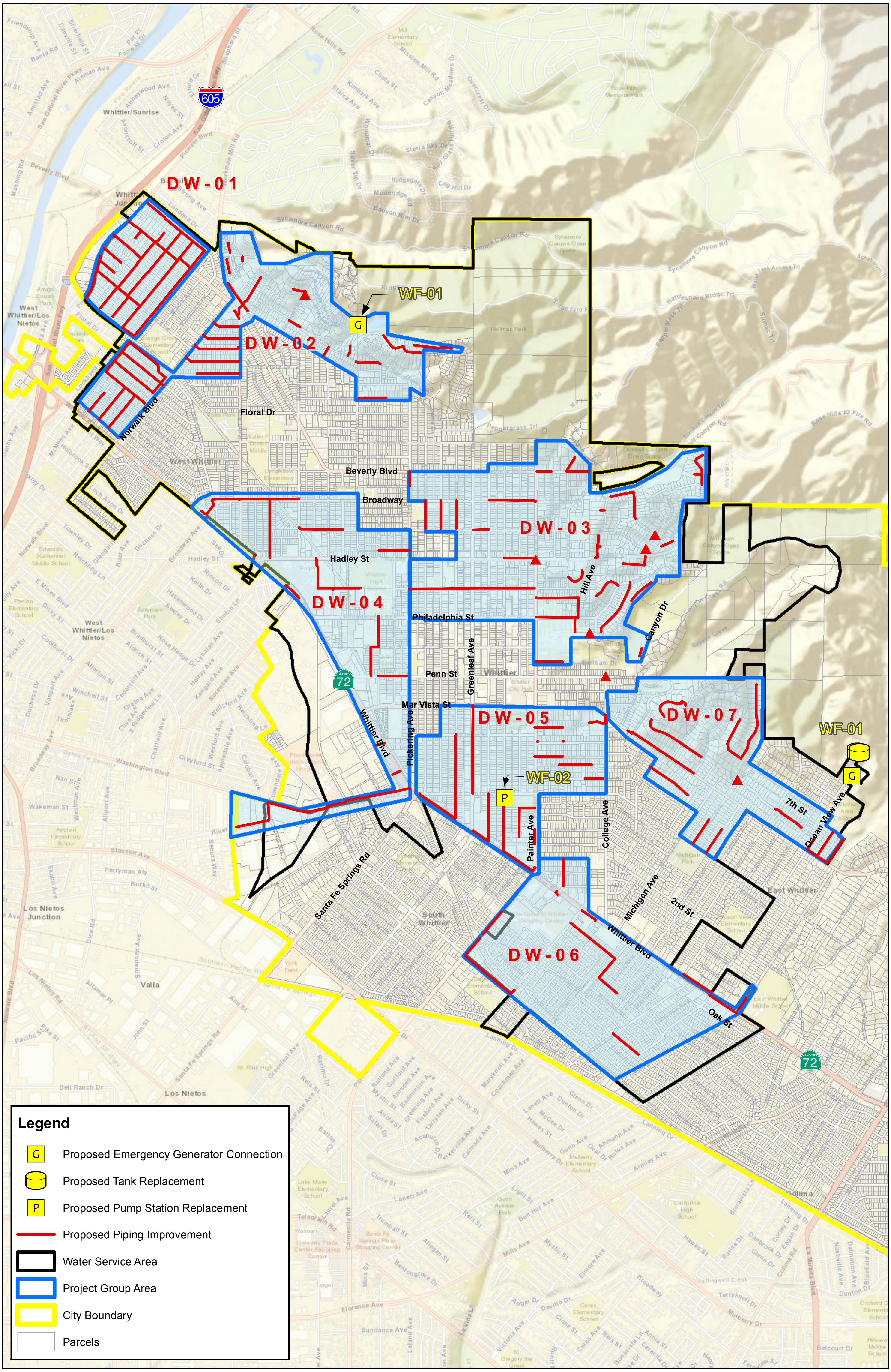
Knowing that the recommended pipeline projects include a mix of residential streets and busy arterial streets, the estimated costs for pipeline projects in the CIP use a unit cost for 8-inch pipe of $250/LF for residential streets and $300/LF for busier arterial streets, a unit cost for 10-inch pipe of $300/LF for residential streets, a unit cost for 12-inch pipe of $350 for both residential and busier arterial streets, plus an additional 20% for construction contingency, and 25% for engineering and administration fees.

Other project cost estimates are based on recent similar projects and engineering judgement.

8.5 Recommended Projects

Recommended improvements are generally grouped by geographic location and type of work into larger projects for competitive bidding and efficiencies during construction. Each project has its own individual CIP number, which is comprised of a two-letter prefix indicating the facility category followed by a two-digit project number. The prefix conventions are as follows: DW for distribution system improvements, and WF for water facility replacements. A master table of the recommended projects is shown in Table 8-1, which lists each project identification, project title, recommended implementation year, and estimated project cost.

Project locations throughout the City are shown on Exhibit 8-1. Individual project estimates and location maps are shown at the end of this section. The total cost of completing all projects in this CIP (in 2017 dollars) is estimated to be approximately $71.5 M.



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CITY OF WHITTIER MASTER PLAN

Capital Improvement Projects

Exhibit 8-1

3/29/2018 JN M:\Mdata\151940\GIS\MXD\FinalProjectReport\Exb-1 Capital Improvement Projects_ProjectGroups11x17P.mxd

Table 8-1: Capital Improvement Projects

Project ID	Category Project Title	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	TOTAL [1]
	Distribution System Improvements													
DW-01	West Distribution System Improvements Group No. 1	$ 3,753,000	$ 1,200,000	$ 1,600,000										**$ 6,553,000**
DW-02	West Distribution System Improvements Group No. 2			$ 1,290,000		$ 2,292,000	$ 1,360,000	$ 1,593,000	$ 1,000,000					**$ 7,535,000**
DW-03	Central Distribution System Improvements Group No. 1					$ 1,000,000	$ 2,000,000	$ 2,329,000	$ 2,560,000					**$ 7,889,000**
DW-04	Central Distribution System Improvements Group No. 2									$ 4,024,500	$ 2,024,500			**$ 6,049,000**
DW-05	South Distribution System Improvements Group No. 1									$ 2,221,000	$ 1,000,000	$ 2,000,000		**$ 5,221,000**
DW-06	South Distribution System Improvements Group No. 2											$ 2,473,000	$ 1,000,000	**$ 3,473,000**
DW-07	South Distribution System Improvements Group No. 3												$ 5,672,000	**$ 5,672,000**
	Water Facility Replacement													
WF-01	Murphy West and East Reservoir Replacement		$ 3,190,000											**$ 3,190,000**
WF-02	Washington Pump Station Replacement						$ 2,393,000							**$ 2,393,000**
WF-03	Greenleaf/Hoover Storage Replacement			$ 300,000	$ 6,000,000									**$ 300,000**
WF-04	Murphy Hills Pump Station							$ 2,000,000						**$ 2,000,000**
WF-05	Rideout Reservoir Replacement								$ 2,000,000					**$ 2,000,000**
WF-06	Starlight Reservoir Redundancy									$ 1,000,000				**$ 1,000,000**
WF-07	Hazzard Reservoir Replacement											$ 2,000,000		**$ 2,000,000**
WF-08	College Hills Reservoir Replacement										$ 4,000,000			**$ 4,000,000**
WF-09	Booster Station Repair	$ 100,000	$ 100,000			$ 200,000			$ 200,000					**$ 600,000**
WF-10	Oceanview Reservoir Improvements													
	Pipeline Replacement Program													
WR-01	Cylindrical Steel Pipeline Replacement Program	$ 400,000		$ 1,000,000		$ 2,000,000								**$ 3,400,000**
	Valve Replacement Program													
VR-01	Large Valve Replacement Program	$ 200,000		$ 200,000		$ 200,000		$ 200,000		$ 200,000				**$ 1,000,000**
VR-02	Valve Replacement Program	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	**$ 1,200,000**
	Interconnection Improvements													
WI-01	Santa Fe Springs Transmission Main													**$ -**
	TOTAL [1]	**$ 4,553,000**	**$ 4,590,000**	**$ 4,490,000**	**$ 6,100,000**	**$ 5,792,000**	**$ 5,853,000**	**$ 6,222,000**	**$ 5,860,000**	**$ 7,545,500**	**$ 7,124,500**	**$ 6,573,000**	**$ 6,772,000**	**$71,475,000**

[1] All costs are in 2017 Dollars

8.5.1 CIP No. DW-01: West Distribution System Improvements Group No. 1

A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in Deveron Drive, Lorene Street, Ben Alder Avenue, Adele Avenue, Carley Avenue, Beverly Boulevard, Lenvale Avenue, Mesagrove Avenue, Sherrill Street, Brian Court, Lyle Street, Orange Grove Avenue, and Pioneer Boulevard.

In addition, a new pipeline is recommended to improve fire flow capacity in an alleyway east of Beverly Boulevard.

8.5.2 CIP No. DW-02: West Distribution System Improvements Group No. 2

A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in El Rancho Drive, Floral Drive, Rose Drive, Orange Drive, Redman Avenue, McNees Avenue, Rockne Avenue, Morrill Avenue, Norwalk Boulevard, Hunter Avenue, Indiana Avenue, Illinois Avenue, Monte Vista Drive, Clare Street, Palm Avenue, Beverly Boulevard, Workman Mill Road, Javalambre Drive, Andalucia Court, Tierra Encanta Drive, Capri Drive, Norino Drive, Hoover Avenue, Citrus Grove Place, Carinthia Drive, and Mount Holly Drive.

In addition, a new pipeline is recommended to improve fire flow capacity in Norino Drive and upsize existing 3.5" lateral to 8" lateral to the fire hydrant northeast of Rideout Booster Pump Station. It is also recommended to upsize the existing pipeline to improve fire flow capacity within Carinthia Drive, Whitley Street, and a hydrant lateral in Beverly Boulevard.

Other work includes replacing an existing check valve in Rideout Way with an 8" pressure reducing valve (Zone 670A to Zone 577). The recommended pressure setting is 48 psi as the new PRV is intended for fire service in 577 Zone only.

In order to complete remaining distribution system improvements recommended as part of the Pumping Plant No. 2 Replacement Project, install a 6" vacuum relief valve at the Hoover Reservoir site and a 4" vacuum relief valve on the 24" transmission main near the intersection of Beverly Drive and Pickering Avenue.

8.5.3 CIP No. DW-03: Central Distribution System Improvements Group No. 1

A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in Beverly Boulevard, Olive Drive, Stanford Way, Philadelphia Street, Haverhill Road, Pine Bluff Way, Ridge Road, Park Street, Terrace Place, Altmark Avenue and Capiz Court. On Havenhill Road, it is proposed to abandon an existing 6" pipeline and reconnected all services and fire hydrants to the adjacent new upsized pipeline.

In addition, new pipelines are recommended to improve fire flow capacity in Broadway, Camilla Street, Hadley Street, and Bailey Street. It is also recommended to upsize the existing pipelines to improve fire flow capacity within Pickering Avenue, Newlin Avenue, Milton Avenue, Comstock Avenue, Alta Avenue, Beverly Boulevard, Roundhill Drive, Hill Avenue, Hillside Lane, Terrace Place, Earlham Drive and Worsham Drive. It is proposed to reconnect an existing Zone 670B hydrant to the Zone 997A piping as well as modify two PRV settings to serve the same HGL at Roundhill Drive/Southwind Drive and Camilla Street/Southwind Drive. The recommended PRV settings are to lower CV-18 from 70 psi to 60 psi and increase CV-19 from 70 psi to 79 psi. An existing closed valve (Zone 997A) between sub-zones at Camilla Street/Hill Avenue will need to be opened to complete the work.

Other work includes installing a new emergency interconnection vault with a PRV and isolation valves (normally closed) at Hadley Street/Painter Avenue.

In order to complete remaining distribution system improvements recommended as part of the Pumping Plant No. 2 Replacement Project, install a 2" vacuum relief valve near the suction side of College Hills Pump Station.

8.5.4 CIP No. DW-04: Central Distribution System Improvements Group No. 2

A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in Broadway, Camilla Street, an alleyway north of Hadley Street, Whittier Boulevard, Pierce Avenue, Wardman Street, and Union Avenue.

In addition, it is recommended to upsize the existing pipeline to improve fire flow capacity within Gretna Avenue, Canobie Avenue, City Yard Hadley Street, Bailey Street, Penn Street, Washington Boulevard, Rivera Road and adding pipelines to connect the two existing water mains in Whittier Boulevard.

Other work includes disconnecting a hydrant at Bailey Street/Hoover Avenue from a 2” pipeline in Hoover Avenue and reconnecting the hydrant to a 6” pipeline in Bailey Street.

8.5.5 CIP No. DW-05: South Distribution System Improvements Group No. 1

A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in Whittier Boulevard, Comstock Avenue, Greenleaf Avenue, Bright Avenue, Washington Avenue, Mooreland Drive, Friends Avenue, Painter Avenue, Via del Palma Avenue, Sunset Drive, and Helen Street.

In addition, it is recommended to upsize the existing pipeline to improve fire flow capacity with Via Del Palma Avenue and Sunrise Drive.

Other work includes disconnecting the first two fire hydrants in Walnut Street (from Painter Avenue) from existing 4" pipeline and reconnecting both hydrants to existing 8" pipeline. On Whittier Boulevard between Bright Avenue and Washington Avenue, it is proposed to abandon an existing 4" pipeline and reconstruction connections to the adjacent existing 8" pipeline in Whittier Boulevard.

8.5.6 CIP No. DW-06: South Distribution System Improvements Group No. 2

A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in Whittier Boulevard, Oak Street, Jacmar Avenue, Chestnut Street, La Forge Street, and Catalina Avenue.

In addition, new pipelines are recommended to improve fire flow capacity in Painter Avenue, Lambert Road, and Laurel Avenue. Upsizing existing pipes to improve fire flow capacity is also recommended in Painter Avenue and Whittier Boulevard. Upsizing a hydrant lateral in Whittier Boulevard is also recommended to improve fire flow capacity.

8.5.7 CIP No. DW-07: South Distribution System Improvements Group No. 3

A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in Mar Vista Street, Eastridge Drive, Sunset Drive, Bowen Drive, and Davista Drive.

In addition, upsizing existing pipes to improve fire flow capacity is also recommended in Bronte Drive, Summit Drive, Mar Vista Street, Milliken Avenue, Strub Avenue, Ocean View Avenue, and Catalina Avenue.

Other work includes installing new emergency interconnection vaults with a PRV and isolation valves (normally closed) at Eastridge Drive/Bacon Road and College Avenue/Penn Street.

8.5.8 CIP No. WF-01: Murphy West and East Reservoirs Replacement

Both the Murphy West and East Reservoirs were constructed in 1955. Given both reservoirs have been in service for over 60 years and the current issues preventing Murphy West Reservoir from being in operation, this project is to replace both the Murphy West Reservoir and Murphy East Reservoir at the same time. In general, the work will include demolishing each existing reservoir, constructing two (2) new 0.5 MG prestressed concrete tanks, and the replacement/reconstruction of all other site infrastructure. Other work includes installing portable generator connections at Murphy Pump Station and Rideout Pump Station as a part of this project.

8.5.9 CIP No. WF-02: Washington Pump Station Replacement

Due to the concerns over system operational changes that would result in service pressure increases in some parts of the distribution system, this project is to replace the Washington Pump Station with a new pump station. Washington Pump Station will be replaced in its current location at Washington Avenue/La Cuarta Street. Work would include, but is not limited to demolishing the existing pump station and constructing a new pump station vault, installing new pumps, piping, valves, electrical, instrumentation, and control equipment, operation of a temporary pumping system, and miscellaneous site improvements to complete the project.

8.5.10 CIP No. WR-01: Cylindrical Steel Pipeline Replacement Program

The Cylindrical Steel Pipelines in Whittier are the critical transmission mains that bring water from the Pumping Plant to the distribution system. These 10 miles of pipes are all over 80 years old. This project, along with VR-01 will allow for a replacement of the transmission main network. The Cylindrical Steel Pipeline replacements will fall in the areas between the newly replaced large valves.

8.5.11 CIP No. VR-01: Large Valve Replacement Program

Due to the aging of our larger transmission mains and valves, as well as the projected transmission main replacement projects, this project would begin to replace our large valves enabling us to ensure proper shutdowns and isolations to facilitate any repairs or improvements needed on our transmission mains, while also improving our system reliability. In general, work would include possible line stops, excavation of valves and main, custom collars and flanges to compensate for non-standard pipe OD's, installation of new valves, pressure testing and pipeline disinfection.

8.5.12 CIP No. VR-02: Valve Replacement Program

Due to the aging of our distribution system, the valves are worn and broken in many areas. Phase 1 of this project is to turn and index all of our system valves to determine their current usability. Phase 2 is to identify and replace the critical valves while implementing a regular maintenance and replacement program. Work may include line stops in critical situations.

8.5.13 CIP No. WI-01: Santa Fe Springs Transmission Main

The City of Santa Fe Springs has a number of customers served directly from their Metropolitan Water District (MWD) connection at Carmenita Road and Imperial Highway, approximately 3.5 miles from the City's service area. This project would allow the City to serve water to this area of Santa Fe Springs. This transmission main would also be capable of delivering water back to the City of Whittier from Santa Fe Springs MWD connection in case of emergency.

8.5.14 CIP No. WF-03: Greenleaf/Hoover Storage Replacement

The construction of Greenleaf II Reservoir (7A) created redundancy in the system. However, with the elimination Hoover Reservoir (4) and its 9.75 MG capacity, Greenleaf Reservoir (2) has remained in service. Greenleaf Reservoir (2) is approaching 100 years old and its 6.00 MG capacity needs to be replaced. Phase 1 of this project is a feasibility study to determine the options the City would have. A number of options can be studied to replace the Greenleaf (2) storage on the current property, at the Hoover property, or perhaps elsewhere. Redundancy can be created with a pump station added at the Hoover property, which is in close proximity to all pressure zones, and would replace the antiquated Rideout Pump Station. Phase 2 of this project is to implement the recommendations of the feasibility study.

8.5.15 CIP No. WF-04: Murphy Pump Station Improvements

The Murphy Pump Station was constructed in 1954. The electrical equipment is old, and the rehabilitation recommended in 1996 has not been implemented. Because the pump station must be maintained to fill the Murphy Reservoirs, this pump station should be replaced with a new facility.

8.5.16 CIP No. WF-05: Rideout Reservoir (5) Replacement

The Seismic Evaluation Study (2000) indicated that the reinforcement used in this reservoir is less than the minimums required by current codes. Additionally, the tank may be subject to overturning due to a seismic event. In order to address these problems, and to eliminate the storage deficiency, the reservoir should be replaced with a 0.7 million gallon tank.

8.5.17 CIP No. WF-06: Starlight Reservoir (12) Redundancy

Starlight Reservoir (12) currently has one transmission main to and from the reservoir. Should this transmission main have a problem, a number of customers, including those in Hadley Hills, would be without water. This project would create a hydropneumatic tank at the Greenleaf Reservoir (2) area to pressurize the system.

8.5.18 CIP No. WF-07: Replacement of the Hazzard Reservoir (6)

The Seismic Evaluation Study (2000) indicated that the reinforcement used in this reservoir is less than the minimums required by current codes. Additionally, the tank may be subject to overturning due to a seismic event. A 0.7 million gallon replacement reservoir is recommended to eliminate the storage deficiency of Zone 670, and address the structural problems of the existing reservoir.

8.5.19 CIP No. WF-08: Replacement of the College Hills Reservoirs (3 and 8)

The College Hills East Reservoir (8) was constructed in 1951. The Seismic Evaluation Study (2000) indicates that the reinforcement for both of this reservoir is less than the minimum required by current codes. A 1.0 million gallon replacement reservoir is recommended with a high water elevation of 677 feet to match the high water elevation of Hazzard and Rideout Reservoirs.

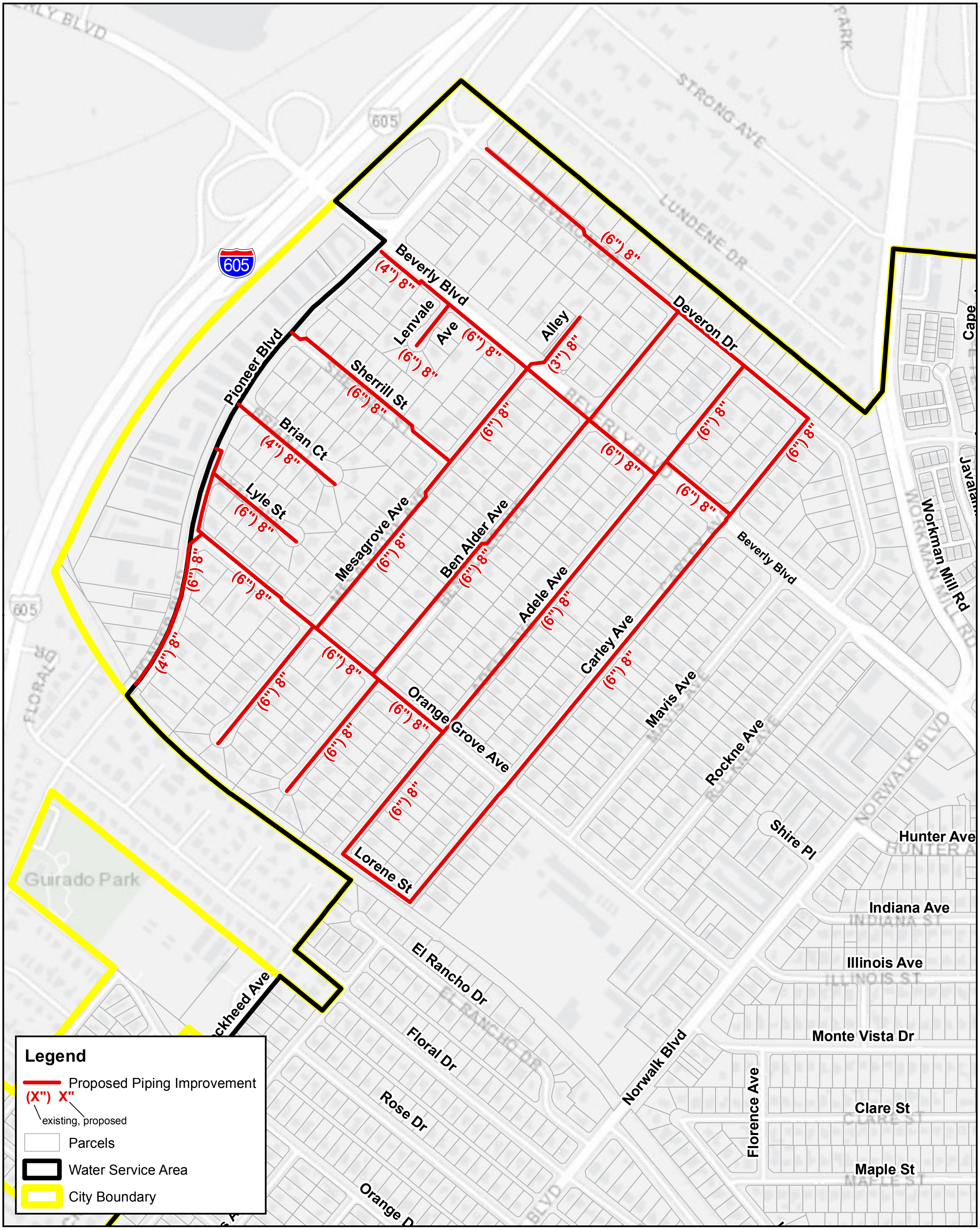
The College Hills West Reservoir (3) was constructed in 1926, and its roof was replaced in 1932. The Seismic Evaluation Study (2000) indicates that the reinforcement for both of this reservoir is less than the minimum required by current codes. A 1.0 million gallon replacement reservoir is recommended with a high water elevation of 677 feet.

8.5.20 CIP No. WF-09: Booster Station Repair

Improvements to the Summit Booster Station and the College Hills Booster Station. For Summit Booster Station, the entire system and tank will be replaced. For College Hills Booster Station emergency connections will be made for a generator.

8.5.21 CIP No. WF-10: Oceanview Reservoir (9) Improvements

Only a portion of the volume available in the Ocean View Reservoir is used due to loss of disinfectant residual. This problem can be mitigated by installing a chlorination facility at the Oceanview Reservoir site.



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Michael Baker INTERNATIONAL

0 500 1000 Feet

Source: City of Whittier, Esri Street Maps

CITY OF WHITTIER MASTER PLAN

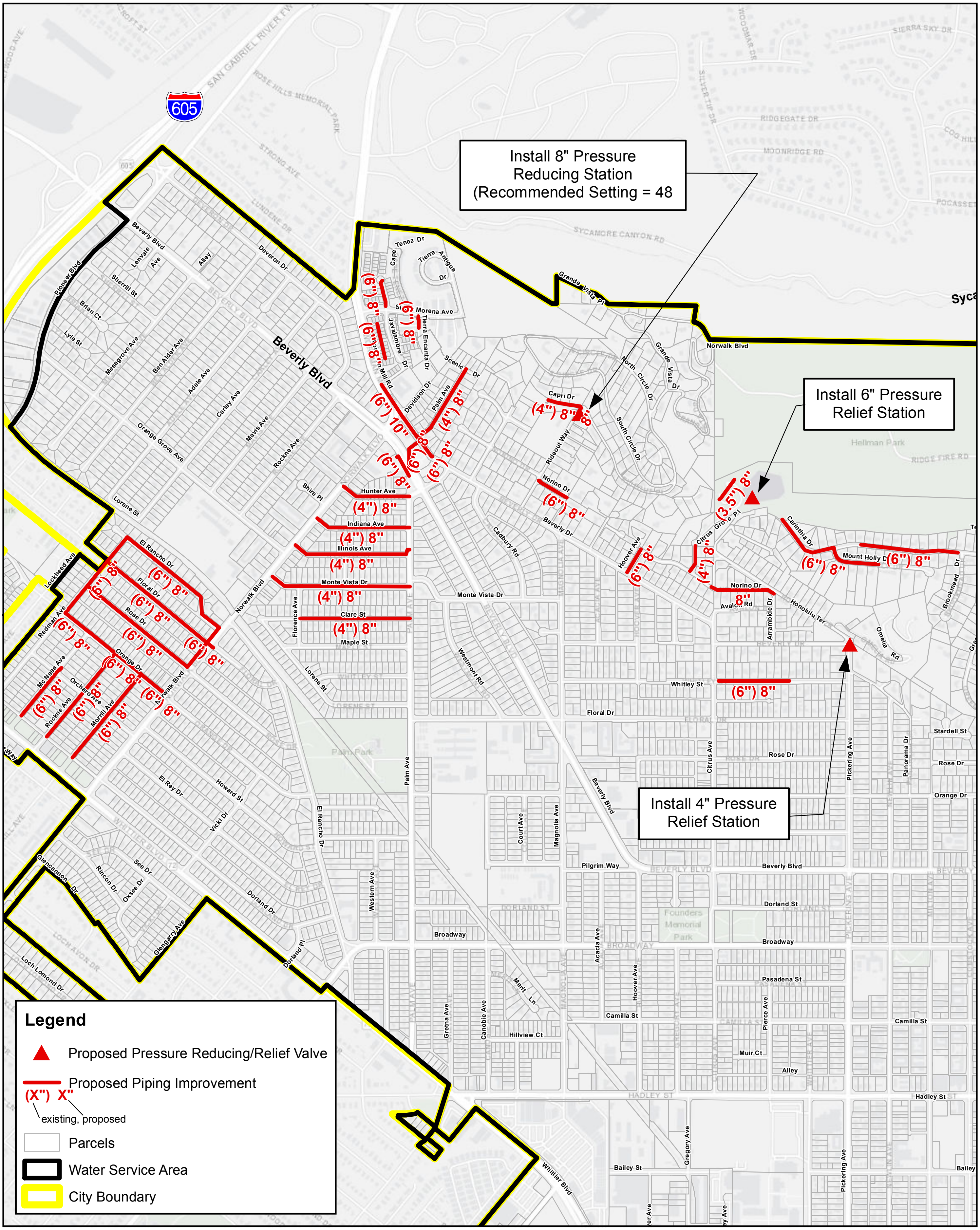
West Distribution System Improvements Group No. 1

Project DW-01

City of Whittier Water Master Plan Update
West Distribution System Improvements Group No. 1
CIP Project DW-01

Description/ Purpose:	A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in Deveron Drive, Lorene Street, Ben Alder Avenue, Adele Avenue, Carley Avenue, Beverly Boulevard, Lenvale Avenue, Mesagrove Avenue, Sherrill Street, Brian Court, Lyle Street, Orange Grove Avenue, and Pioneer Boulevard. In addition, a new pipeline is recommended to improve fire flow capacity in an alleyway east of Beverly Boulevard.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Install 8" Pipeline	15,863	LF	$ 250	$ 3,965,750
2	Install 8" Pipeline	1,845	LF	$ 300	$ 553,500
				Subtotal	$ 4,519,000
				Construction Contingencies (20%)	$ 904,000
				Engineering and Administration (25%)	$ 1,130,000
				Projected Cost Estimate	**$ 6,553,000**
				Fiscal Year	2017/18



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Michael Baker INTERNATIONAL

0 1100 2200 Feet

Source: City of Whittier, Esri Street Maps

CITY OF WHITTIER MASTER PLAN

West Distribution System Improvements Group No. 2

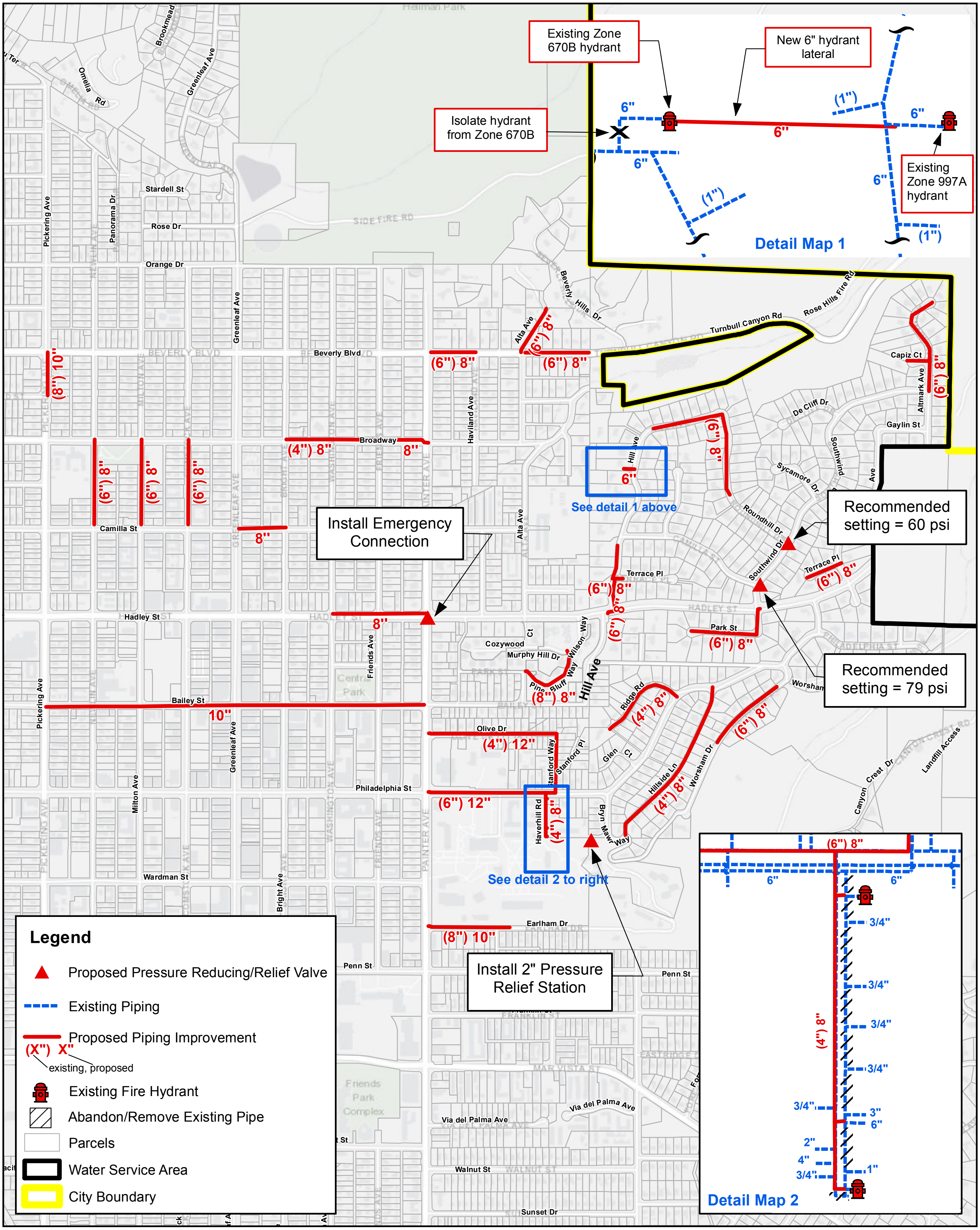
Project DW-02

City of Whittier Water Master Plan Update
West Distribution System Improvements Group No. 2
CIP Project DW-02

Description/ Purpose:	A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in El Rancho Drive, Floral Drive, Rose Drive, Orange Drive, Redman Avenue, McNees Avenue, Rockne Avenue, Morrill Avenue, Norwalk Boulevard, Hunter Avenue, Indiana Avenue, Illinois Avenue, Monte Vista Drive, Clare Street, Palm Avenue, Beverly Boulevard, Workman Mill Road, Javalambre Drive, Andalucia Court, Tierra Encanta Drive, Capri Drive, Norino Drive, Hoover Avenue, Citrus Grove Place, Carinthia Drive, and Mount Holly Drive. In addition, a new pipeline is recommended to improve fire flow capacity in Norino Drive and upsize existing 3.5” lateral to 8” lateral to the fire hydrant northeast of Rideout Booster Pump Station. It is also recommended to upsize the existing pipeline to improve fire flow capacity within Carinthia Drive, Whitley Street, and a hydrant lateral in Beverly Boulevard. Other work includes replacing an existing check valve in Rideout Way with an 8” pressure reducing valve (Zone 670A to Zone 577). The recommended pressure setting is 48 psi as the new PRV is intended for fire service in 577 Zone only. In order to complete remaining distribution system improvements recommended as part of the Pumping Plant No. 2 Replacement Project, install a 6" vacuum relief valve at the Hoover Reservoir site and a 4" vacuum relief valve on the 24" transmission main near the intersection of Beverly Drive and Pickering Avenue.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Install 6" Pipeline	220	LF	$ 250	$ 55,000
2	Install 8" Pipeline	18,609	LF	$ 250	$ 4,652,250
3	Install 8" Pipeline	717	LF	$ 300	$ 215,160
4	Install 10" Pipeline	614	LF	$ 300	$ 184,200
5	Install 8" Pressure Reducing Station	1	LS	$ 30,000	$ 30,000
6	Install 6" Pressure Relief Station	1	LS	$ 30,000	$ 30,000
7	Install 4" Pressure Relief Station	1	LS	$ 30,000	$ 30,000

Subtotal	$ 5,197,000
Construction Contingencies (20%)	$ 1,039,000
Engineering and Administration (25%)	$ 1,299,000
Projected Cost Estimate	**$ 7,535,000**
Fiscal Year	2020/21



Michael Baker INTERNATIONAL

CITY OF WHITTIER MASTER PLAN

Central Distribution System Improvements Group No. 1

Project DW-03

City of Whittier Water Master Plan Update

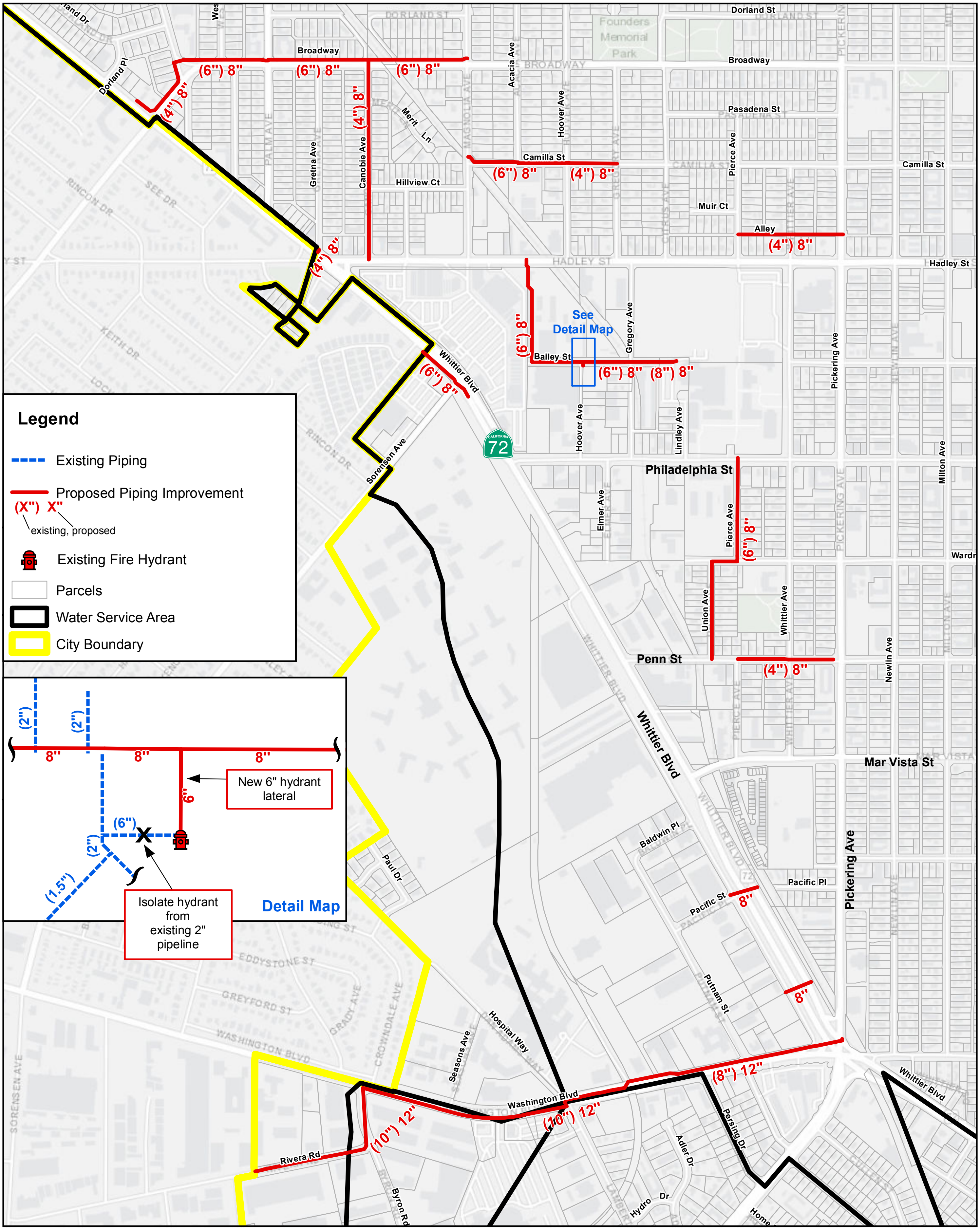
Central Distribution System Improvements Group No. 1

CIP Project DW-03

Description/ Purpose:	A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in Beverly Boulevard, Olive Drive, Stanford Way, Philadelphia Street, Haverhill Road, Pine Bluff Way, Ridge Road, Park Street, Terrace Place, Altmark Avenue and Capiz Court. On Havenhill Road, it is proposed to abandon an existing 6" pipeline and reconnected all services and fire hydrants to the adjacent new upsized pipeline. In addition, new pipelines are recommended to improve fire flow capacity in Broadway, Camilla Street, Hadley Street, and Bailey Street. It is also recommended to upsize the existing pipelines to improve fire flow capacity within Pickering Avenue, Newlin Avenue, Milton Avenue, Comstock Avenue, Alta Avenue, Beverly Boulevard, Roundhill Drive, Hill Avenue, Hillside Lane, Terrace Place, Earlham Drive and Worsham Drive. It is proposed to reconnect an existing Zone 670B hydrant to the Zone 997A piping as well as modify two PRV settings to serve the same HGL at Roundhill Drive/Southwind Drive and Camilla Street/Southwind Drive. The recommended PRV settings are to lower CV-18 from 70 psi to 60 psi and increase CV-19 from 70 psi to 79 psi. An existing closed valve (Zone 997A) between sub-zones at Camilla Street/Hill Avenue will need to be opened to complete the work. Other work includes installing a new emergency interconnection vault with a PRV and isolation valves (normally closed) at Hadley Street/Painter Avenue. In order to complete remaining distribution system improvements recommended as part of the Pumping Plant No. 2 Replacement Project, install a 2" vacuum relief valve near the suction side of College Hills Pump Station.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Install 8" Pipeline	10,467	LF	$ 250	$ 2,616,750
2	Install 8" Pipeline	2,431	LF	$ 300	$ 729,300
3	Install 10" Pipeline	3,752	LF	$ 300	$ 1,125,600
4	Install 12" Pipeline	2,354	LF	$ 350	$ 823,900
5	Install Emergency Interconnection	1	LS	$ 100,000	$ 100,000
6	Install 2" Pressure Relief Station	1	LS	$ 30,000	$ 30,000
7	New Hydrant Connection	1	LS	$ 15,000	$ 15,000

Subtotal	$ 5,441,000
Construction Contingencies (20%)	$ 1,088,000
Engineering and Administration (25%)	$ 1,360,000
Projected Cost Estimate	**$ 7,889,000**
Fiscal Year	2018/19



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Michael Baker INTERNATIONAL

0 600 1200 Feet

Source: City of Whittier, Esri Street Maps

CITY OF WHITTIER MASTER PLAN

Central Distribution System Improvements Group No. 2

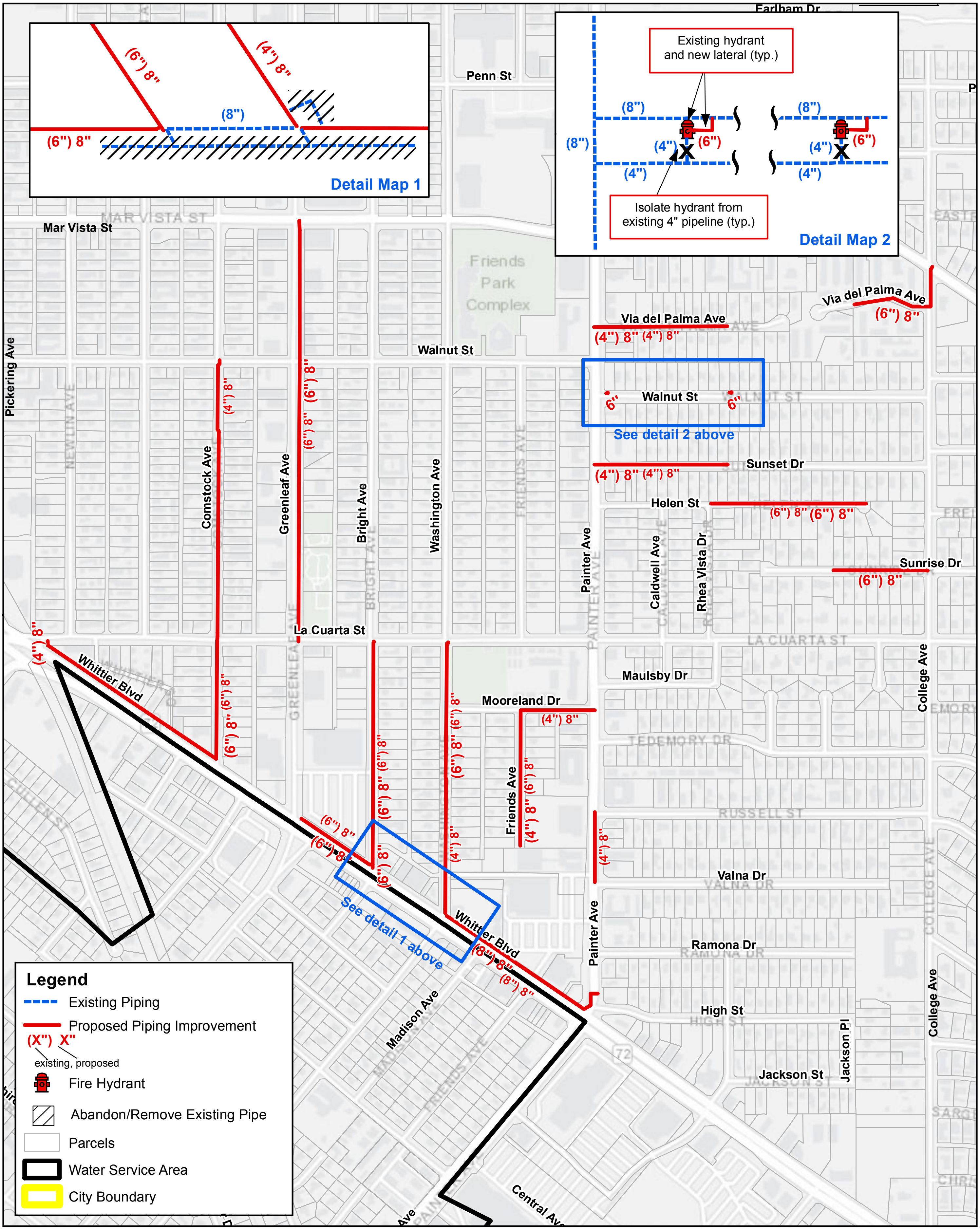
Project DW-04

City of Whittier Water Master Plan Update
Central Distribution System Improvements Group No. 2
CIP Project DW-04

Description/ Purpose:	A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in Broadway, Camilla Street, an alleyway north of Hadley Street, Whittier Boulevard, Pierce Avenue, Wardman Street, and Union Avenue. In addition, it is recommended to upsize the existing pipeline to improve fire flow capacity within Gretna Avenue, Canobie Avenue, City Yard Hadley Street, Bailey Street, Penn Street, Washington Boulevard, Rivera Road and adding pipelines to connect the two existing water mains in Whittier Boulevard. Other work includes disconnecting a hydrant at Bailey Street/Hoover Avenue from a 2" pipeline in Hoover Avenue and reconnecting the hydrant to a 6" pipeline in Bailey Street.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Install 8" Pipeline	9,382	LF	$ 250	$ 2,345,500
2	Install 8" Pipeline	803	LF	$ 300	$ 240,900
3	Install 12" Pipeline	1,150	LF	$ 350	$ 402,500
4	Install 12" Pipeline	3,351	LF	$ 350	$ 1,172,850
5	New Hydrant Connection	1	LS	$ 10,000	$ 10,000

Subtotal	$ 4,172,000
Construction Contingencies (20%)	$ 834,000
Engineering and Administration (25%)	$ 1,043,000
Projected Cost Estimate	**$ 6,049,000**
Fiscal Year	2019/20



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Michael Baker INTERNATIONAL

0 600 1200 Feet

Source: City of Whittier, Esri Street Maps

CITY OF WHITTIER MASTER PLAN

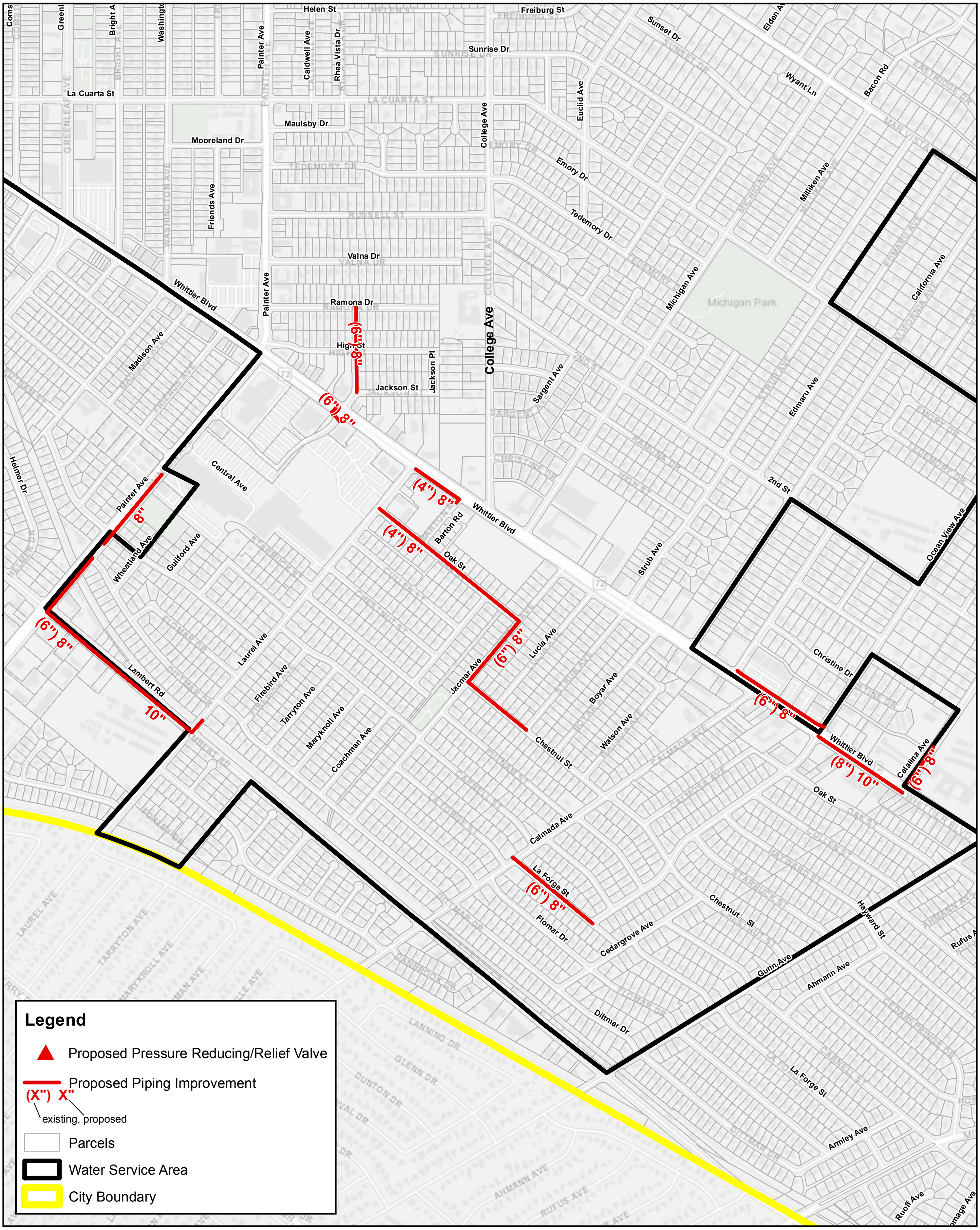
South Distribution System Improvements Group No. 1

Project DW-05

City of Whittier Water Master Plan Update
South Distribution System Improvements Group No. 1
CIP Project DW-05

Description/ Purpose:	A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in Whittier Boulevard, Comstock Avenue, Greenleaf Avenue, Bright Avenue, Washington Avenue, Mooreland Drive, Friends Avenue, Painter Avenue, Via del Palma Avenue, Sunset Drive, and Helen Street. In addition, it is recommended to upsize the existing pipeline to improve fire flow capacity with Via Del Palma Avenue and Sunrise Drive. Other work includes disconnecting the first two fire hydrants in Walnut Street (from Painter Avenue) from existing 4" pipeline and reconnecting both hydrants to existing 8" pipeline. On Whittier Boulevard between Bright Avenue and Washington Avenue, it is proposed to abandon an existing 4" pipeline and reconstruction connections to the adjacent existing 8" pipeline in Whittier Boulevard.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Install 8" Pipeline	8,277	LF	$ 250	$ 2,069,250
2	Install 8" Pipeline	5,073	LF	$ 300	$ 1,521,900
3	New Hydrant Connections	1	LS	$ 10,000	$ 10,000
				Subtotal	$ 3,601,000
				Construction Contingencies (20%)	$ 720,000
				Engineering and Administration (25%)	$ 900,000
				Projected Cost Estimate	**$ 5,221,000**
				Fiscal Year	2021/22



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Michael Baker INTERNATIONAL

0 900 1800 Feet

Source: City of Whittier, Esri Street Maps

CITY OF WHITTIER MASTER PLAN

South Distribution System Improvements
Group No. 3

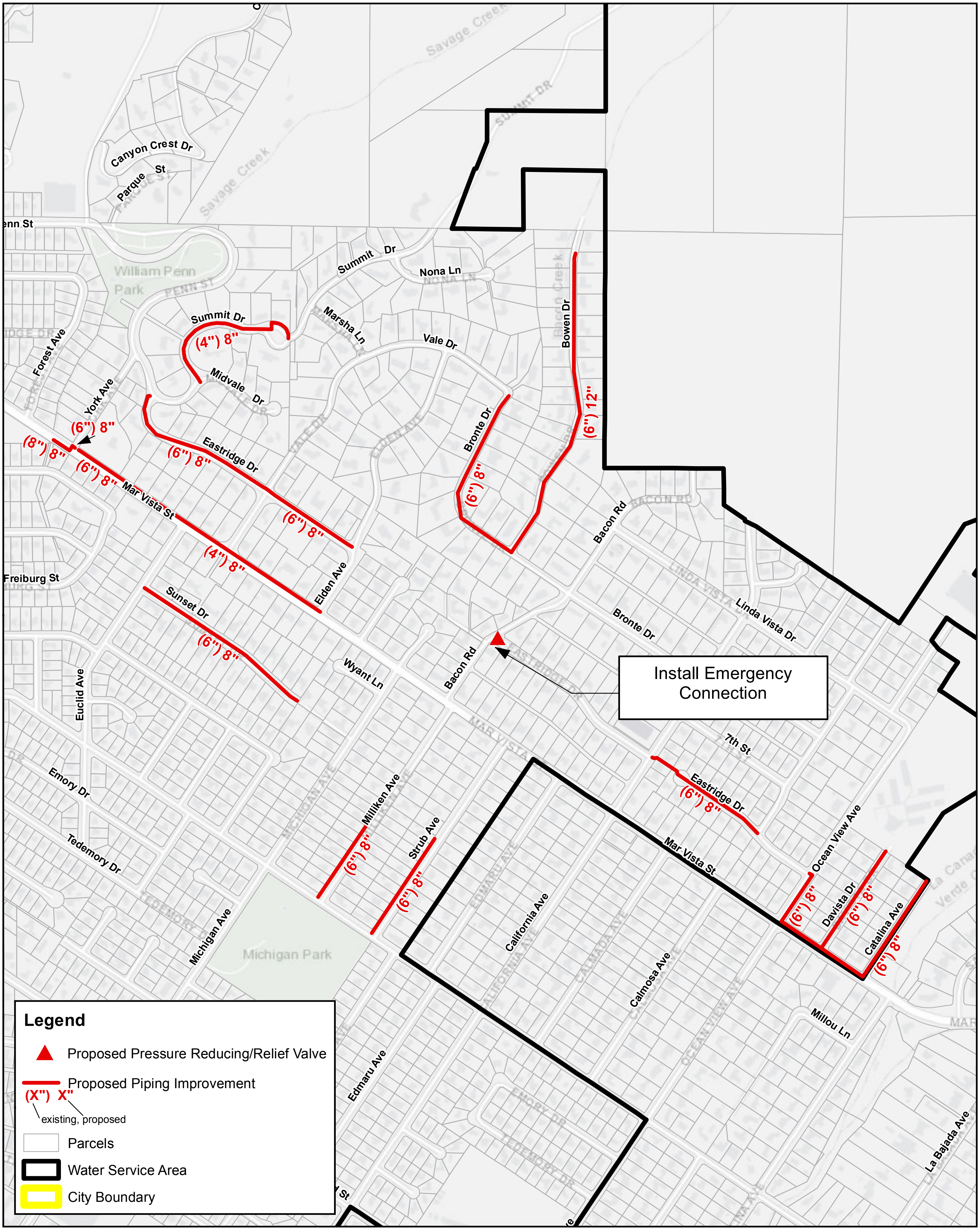
Project DW-06

City of Whittier Water Master Plan Update
South Distribution System Improvements Group No. 2
CIP Project DW-06

Description/ Purpose:	A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in Whittier Boulevard, Oak Street, Jacmar Avenue, Chestnut Street, La Forge Street, and Catalina Avenue. In addition, new pipelines are recommended to improve fire flow capacity in Painter Avenue, Lambert Road, and Laurel Avenue. Upsizing existing pipes to improve fire flow capacity is also recommended in Painter Avenue and Whittier Boulevard. Upsizing a hydrant lateral in Whittier Boulevard is also recommended to improve fire flow capacity.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Install 8" Pipeline	4,057	LF	$ 250	$ 1,014,250
2	Install 8" Pipeline	3,074	LF	$ 300	$ 922,200
3	Install 10" Pipeline	1,530	LF	$ 300	$ 459,000

Subtotal	$ 2,395,000
Construction Contingencies (20%)	$ 479,000
Engineering and Administration (25%)	$ 599,000
Projected Cost Estimate	**$ 3,473,000**
Fiscal Year	2023/24



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Michael Baker INTERNATIONAL

Source: City of Whittier, Esri Street Maps

CITY OF WHITTIER MASTER PLAN

South Distribution System Improvements Group No. 3

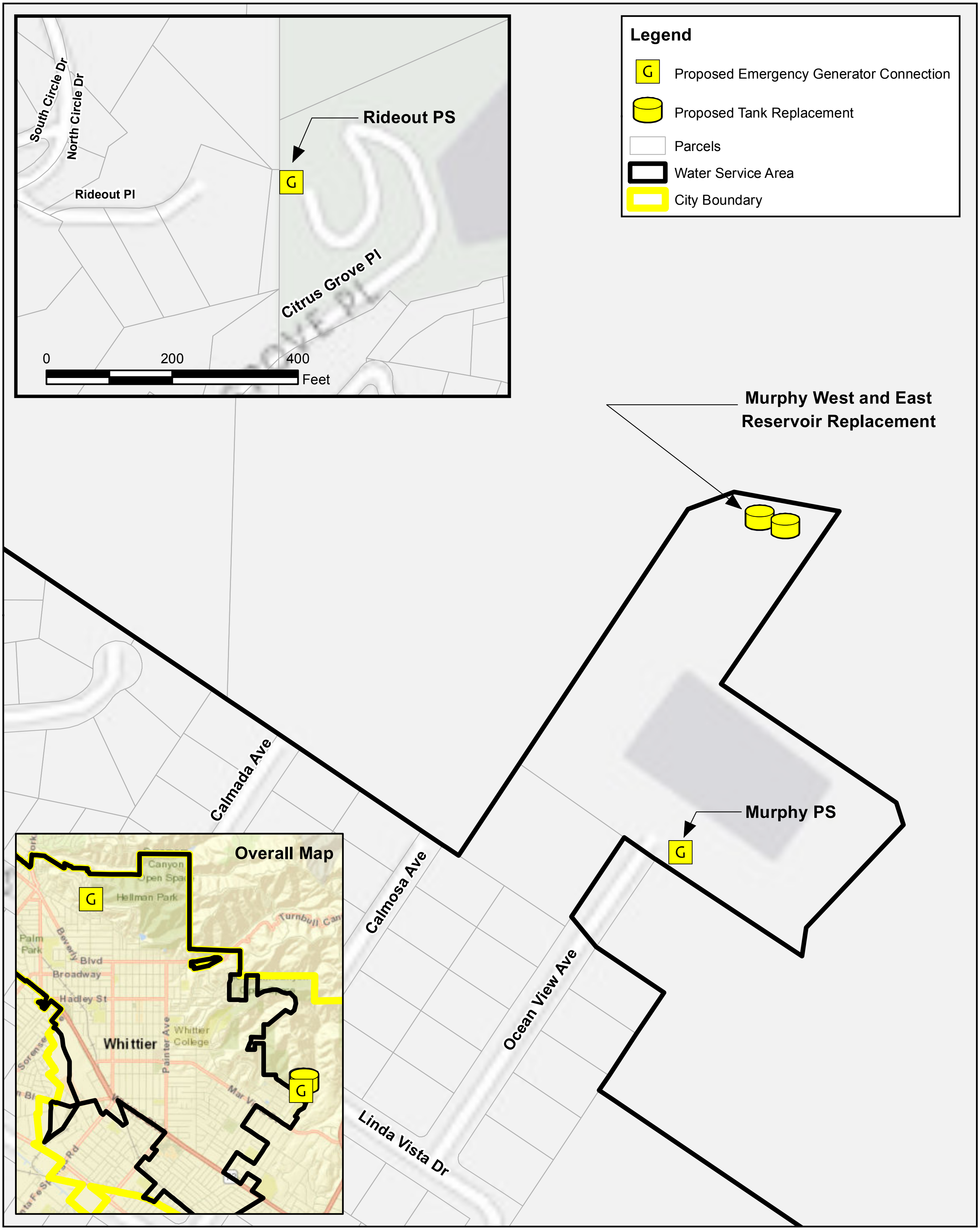
Project DW-07

City of Whittier Water Master Plan Update
South Distribution System Improvements Group No. 3
CIP Project DW-07

Description/ Purpose:	A group of pipeline replacement projects are recommended to address recorded pipe breaks and condition related issues in Mar Vista Street, Eastridge Drive, Sunset Drive, Bowen Drive, and Davista Drive. In addition, upsizing existing pipes to improve fire flow capacity is also recommended in Bronte Drive, Summit Drive, Mar Vista Street, Milliken Avenue, Strub Avenue, Ocean View Avenue, and Catalina Avenue. Other work includes installing new emergency interconnection vaults with a PRV and isolation valves (normally closed) at Eastridge Drive/Bacon Road and College Avenue/Penn Street.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Install 8" Pipeline	12,185	LF	$ 250	$ 3,046,250
2	Install 8" Pipeline	154	LF	$ 300	$ 46,200
3	Install 12" Pipeline	1,770	LF	$ 350	$ 619,500
4	Install Emergency Interconnections	2	EA	$ 100,000	$ 200,000

Subtotal	$	3,912,000
Construction Contingencies (20%)	$	782,000
Engineering and Administration (25%)	$	978,000
Projected Cost Estimate	**$**	**5,672,000**
Fiscal Year		2024/25



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CITY OF WHITTIER MASTER PLAN

Michael Baker INTERNATIONAL

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Source: City of Whittier, Esri Street Maps

West and East Murphy Reservoir Replacement

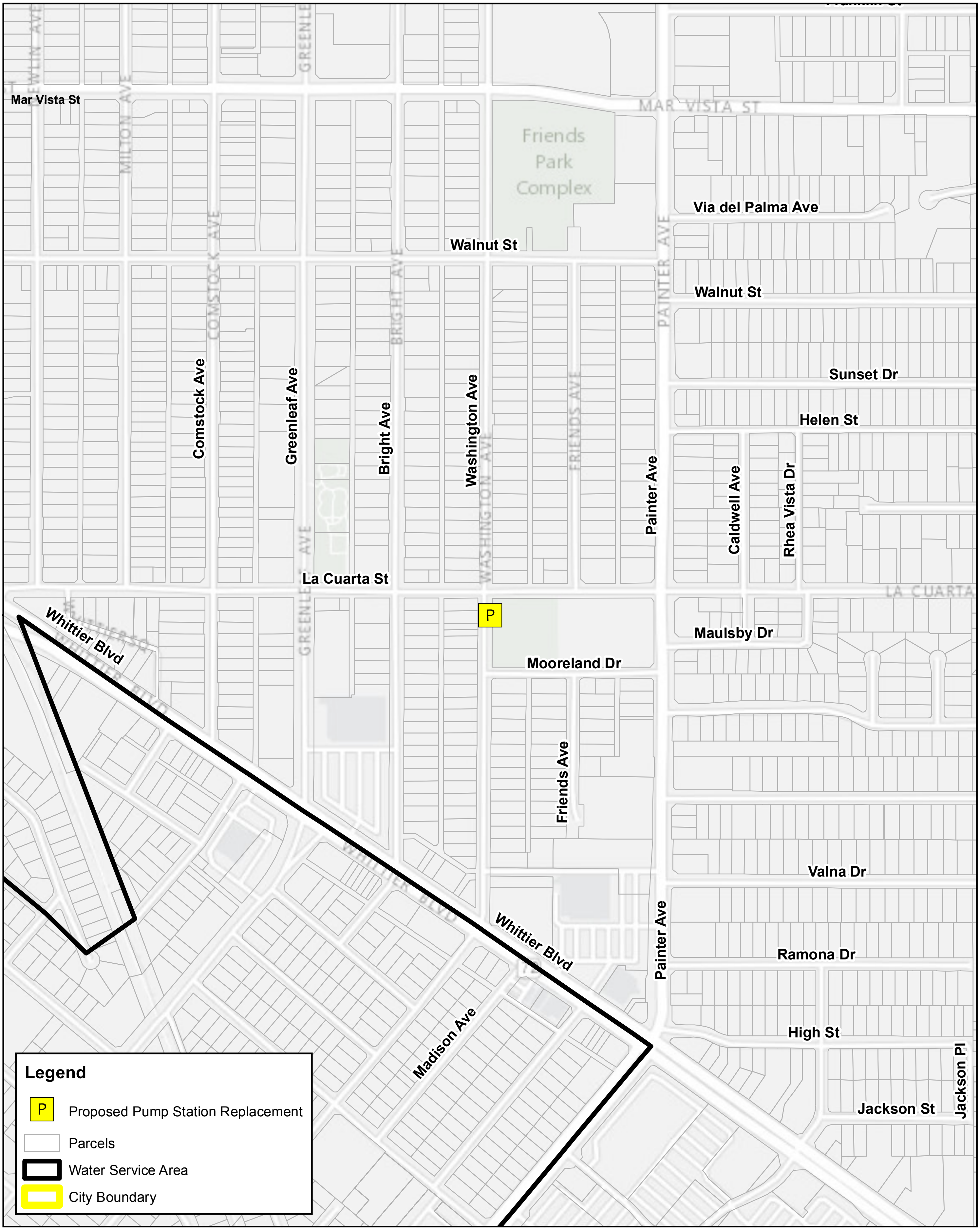
Project WF-01

City of Whittier Water Master Plan Update
Murphy West and East Reservoirs Replacement
CIP Project WF-01

Description/ Purpose:	Both the Murphy West and East Reservoirs were constructed in 1955. Given both reservoirs have been in service for over 60 years and the current issues preventing Murphy West Reservoir from being in operation, this project is to replace both the Murphy West Reservoir and Murphy East Reservoir at the same time. In general, the work will include demolishing each existing reservoir, constructing two (2) new 0.5 MG prestressed concrete tanks, and the replacement/reconstruction of all other site infrastructure. Other work includes installing portable generator connections at Murphy Pump Station and Rideout Pump Station as a part of this project.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Install New Tanks [1]	1	LS	$ 2,100,000	$ 2,100,000
2	Install Portable Generator Connections	1	LS	$ 100,000	$ 100,000
				Subtotal	$ 2,200,000
				Construction Contingencies (20%)	$ 440,000
				Engineering and Administration (25%)	$ 550,000
				Projected Cost Estimate	**$ 3,190,000**
				Fiscal Year	2019/20

[1] Estimated cost is based upon Technical Memorandum: Condition Assessment of Murphy Reservoir #10 (Tetra Tech)



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Michael Baker INTERNATIONAL

CITY OF WHITTIER MASTER PLAN

Washington Pump Station Elimination

Project WF-02

City of Whittier Water Master Plan Update
Washington Pump Station Replacement
CIP Project WF-02

Description/ Purpose:	Due to the concerns over system operational changes that would result in service pressure increases in some parts of the distribution system, this project is to replace the Washington Pump Station with a new pump station. Washington Pump Station will be replaced in its current location at Washington Avenue/La Cuarta Street. Work would include, but is not limited to demolishing the existing pump station and constructing a new pump station vault, installing new pumps, piping, valves, electrical, instrumentation, and control equipment, operation of a temporary pumping system, and miscellaneous site improvements to complete the project.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Install New Pump Station	1	LS	$ 1,650,000	$ 1,650,000
				Subtotal	$ 1,650,000
				Construction Contingencies (20%)	$ 330,000
				Engineering and Administration (25%)	$ 413,000
				Projected Cost Estimate	**$ 2,393,000**
				Fiscal Year	2022/23

City of Whittier Water Master Plan Update
Cylindrical Steel Pipeline Replacement Program
CIP Project WR-01

Description/ Purpose:	Systemic replacement of cylindrical steel pipe, well field/production pipe, and Pumping Plant piping in three parts.				
Item No.	**Item Description**	**Quantity**	**Unit**	**Unit Cost**	**Cost**
1	Cylindrical Steel Pipe Replacement	4,200	LF	$ 500	$ 2,100,000
2	Piping at Pumping Plant	275	LF	$ 300	$ 82,500
3	Well Field Piping	275	LF	$ 300	$ 82,500
				Subtotal	$ 2,265,000
				Construction Contingencies (20%)	$ 453,000
				Engineering and Administration (25%)	$ 566,000
				Projected Cost Estimate	**$ 3,284,000**
				Fiscal Year	18/19, 20/21, 22/23

City of Whittier Water Master Plan Update
Large Valve Replacement Program
CIP Project VR-01

Description/ Purpose:	Due to the aging of our larger transmission mains and valves, as well as the projected transmission main replacement projects, this project would begin to replace our large valves enabling us to ensure proper shutdowns and isolations to facilitate any repairs or improvements needed on our transmission mains, while also improving our system reliability. This project should go on yearly until all transmission main valves have been exercised and verified of functionality to ensure our transmission mains have reliable valves when needed In general, work would include possible line stops, excavation of valves and main, custom collars and flanges to compensate for non-standard pipe OD's,

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	30" Butterfly Valve	1	LV	$ 9,000	$ 9,000
2	24" Butterfly Valve	1	LV	$ 5,000	$ 5,000
3	16" Butterfly Valve	1	LV	$ 3,800	$ 3,800
4	Contruction & Installation	3	LS	$ 40,000	$ 120,000
5	30" Line Stop	2	EA	$ 28,000	$ 56,000
6	30"X24"X30" Tee	1	LV	$ 14,000	$ 14,000
7	Custom Collar for Non-Standard Pipe OD's	6	LV	$ 4,000	$ 24,000
				Subtotal	$ 232,000
				Construction Contingencies (20%)	$ 46,000
				Engineering and Administration (25%)	$ 58,000
				Projected Cost Estimate	**$ 336,000**
				Fiscal Year	On-Going

City of Whittier Water Master Plan Update
Valve Replacement Program
CIP Project VR-02

Description/ Purpose:	Systemic replacement of valves in the distribution system.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Replace Valve	25	EA	$ 8,000	$ 200,000

Subtotal	$ 200,000
Construction Contingencies (20%)	$ 40,000
Engineering and Administration (25%)	$ 50,000
Projected Cost Estimate	**$ 290,000**
Fiscal Year	On-going

City of Whittier Water Master Plan Update
Santa Fe Springs Transmission Main
CIP Project WI-01

Description/ Purpose:	The City of Santa Fe Springs has a number of customers served directly from their Metropolitan Water District (MWD) connection at Carmenita Road and Imperial Highway, approximately 3.5 miles from the City's service area. This project would allow the City to serve water to this area of Santa Fe Springs. This transmission main would also be capable of delivering water back to the City of Whittier from Santa Fe Springs MWD connection in case of emergency. Cost would be negotiated between two entities				
Item No.	**Item Description**	**Quantity**	**Unit**	**Unit Cost**	**Cost**
1	18 inch transmission main	3.5	MI	$ 1,500,000	$ 5,250,000
				Subtotal	$ 5,250,000
				Construction Contingencies (20%)	$ 1,050,000
				Engineering and Administration (25%)	$ 1,313,000
				Projected Cost Estimate	**$ 7,613,000**
				Fiscal Year	TBD

City of Whittier Water Master Plan Update
Greenleaf/Hoover Storage Replacement
CIP Project WF-03

Description/ Purpose:	The construction of Greenleaf II Reservoir (7A) created redundancy in the system. However, with the elimination Hoover Reservoir (4) and its 9.75 MG capacity, Greenleaf Reservoir (2) has remained in service. Greenleaf Reservoir (2) is approaching 100 years old and its 6.00 MG capacity needs to be replaced. Phase 1 of this project is a feasibility study to determine the options the City would have. A number of options can be studied to replace the Greenleaf (2) storage on the current property, at the Hoover property, or perhaps elsewhere. Redundancy can be created with a pump station added at the Hoover property, which is in close proximity to all pressure zones, and would replace the antiquated Rideout Pump Station. Phase 2 of this project is to implement the recommendations of the feasibility study.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Feasibility Study	1	LS	$ 300,000	$ 300,000
2	Booster Station	1	LS	$ 2,000,000	$ 1,800,000
3	Reservoir	1	LS	$ 2,000,000	$ 1,800,000
3	Piping	1,000.0	LF	$ 350	$ 350,000

Subtotal	$ 4,250,000
Construction Contingencies (20%)	$ 850,000
Engineering and Administration (25%)	$ 1,063,000
Projected Cost Estimate	**$ 6,163,000**
Fiscal Year	20/21, 21/22

City of Whittier Water Master Plan Update
Murphy Pump Station Replacement
CIP Project WF-04

Description/ Purpose:	The Murphy Pump Station was constructed in 1954. The electrical equipment is old, and the rehabilitation recommended in 1996 has not been implemented. Because the pump station must be maintained to fill the Murphy Reservoirs, this pump station should be replaced with a new facility.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Pump Station Replacement	1.0	LS	$ 2,000,000	$ 2,000,000
				Subtotal	$ 2,000,000
				Construction Contingencies (20%)	$ 400,000
				Engineering and Administration (25%)	$ 500,000
				Projected Cost Estimate	**$ 2,900,000**
				Fiscal Year	24/25

City of Whittier Water Master Plan Update
Rideout Reservoir Replacement
CIP Project WF-05

Description/ Purpose:	The Seismic Evaluation Study (2000) indicated that the reinforcement used in this reservoir is less than the minimums required by current codes. Additionally, the tank may be subject to overturning due to a seismic event. In order to address these problems, and to eliminate the storage deficiency, the reservoir should be replaced with a 0.7 million gallon tank.				
Item No.	**Item Description**	**Quantity**	**Unit**	**Unit Cost**	**Cost**
1	Reservoir Replacement	1.0	LS	$ 2,000,000	$ 2,000,000
				Subtotal	$ 2,000,000
				Construction Contingencies (20%)	$ 400,000
				Engineering and Administration (25%)	$ 500,000
				Projected Cost Estimate	**$ 2,900,000**
				Fiscal Year	25/26

City of Whittier Water Master Plan Update
Starlight Reservoir Redundancy
CIP Project WF-06

Description/ Purpose:	Starlight Reservoir (12) currently has one transmission main to and from the reservoir. Should this transmission main have a problem, a number of customers, including those in Hadley Hills, would be without water. This project would create a hydropneumatic tank at the Greenleaf Reservoir (2) area to pressurize the system.				
Item No.	**Item Description**	**Quantity**	**Unit**	**Unit Cost**	**Cost**
1	Hydropneumatic Tank and hookups	1.0	LS	$ 1,000,000	$ 1,000,000
				Subtotal	$ 1,000,000
				Construction Contingencies (20%)	$ 200,000
				Engineering and Administration (25%)	$ 250,000
				Projected Cost Estimate	**$ 1,450,000**
				Fiscal Year	26/27

City of Whittier Water Master Plan Update
Hazzard Reservoir Replacement
CIP Project WF-07

Description/ Purpose:	The Seismic Evaluation Study (2000) indicated that the reinforcement used in this reservoir is less than the minimums required by current codes. Additionally, the tank may be subject to overturning due to a seismic event. A 0.7 million gallon replacement reservoir is recommended to eliminate the storage deficiency of Zone 670, and address the structural problems of the existing reservoir.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Reservoir Replacement	1.0	LS	$ 2,000,000	$ 2,000,000
				Subtotal	$ 2,000,000
				Construction Contingencies (20%)	$ 400,000
				Engineering and Administration (25%)	$ 500,000
				Projected Cost Estimate	**$ 2,900,000**
				Fiscal Year	28/29

City of Whittier Water Master Plan Update
College Hills Reservoir Replacement
CIP Project WF-08

Description/ Purpose:	The College Hills East Reservoir (8) was constructed in 1951. The Seismic Evaluation Study (2000) indicates that the reinforcement for both of this reservoir is less than the minimum required by current codes. A 1.0 million gallon replacement reservoir is recommended with a high water elevation of 677 feet to match the high water elevation of Hazzard and Rideout Reservoirs. The College Hills West Reservoir (3) was constructed in 1926, and its roof was replaced in 1932. The Seismic Evaluation Study (2000) indicates that the reinforcement for both of this reservoir is less than the minimum required by current codes. A 1.0 million gallon replacement reservoir is recommended with a high water elevation of 677 feet.

Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Reservoir Replacement	2.0	LS	$ 3,000,000	$ 6,000,000
			Subtotal		$ 6,000,000
			Construction Contingencies (20%)		$ 1,200,000
			Engineering and Administration (25%)		$ 1,500,000
			Projected Cost Estimate		**$ 8,700,000**
			Fiscal Year		27/28, TBD

City of Whittier Water Master Plan Update
Booster Station Repair
CIP Project WF-09

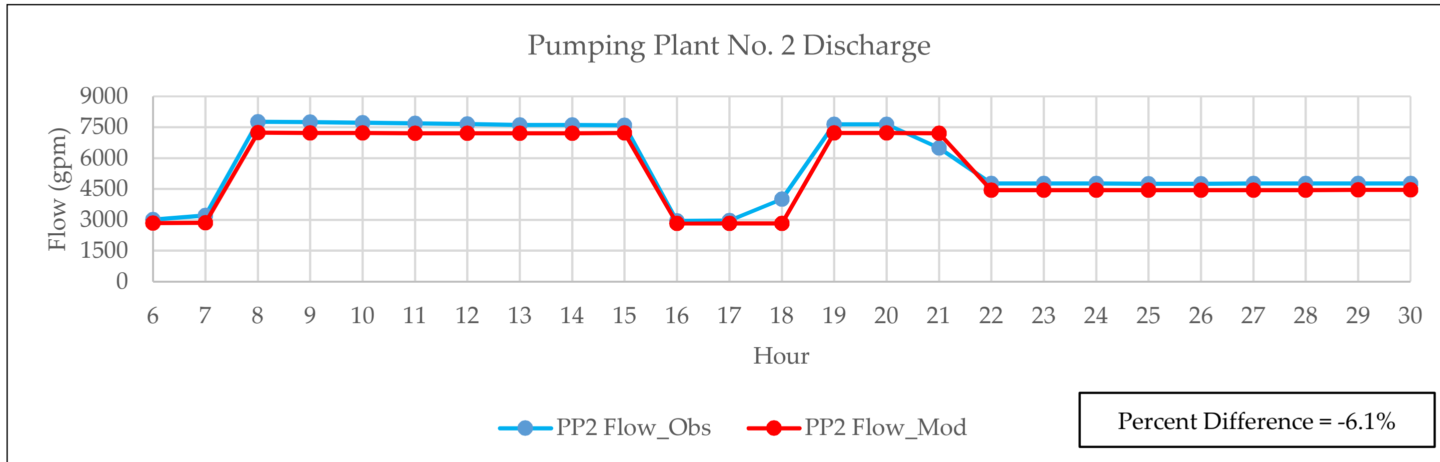
Description/ Purpose:	Improvements to the Summit Booster Station and the College Hills Booster Station. For Summit Booster Station, the entire system and tank will be replaced. For College Hills Booster Station emergency connections will be made for a generator.				
Item No.	**Item Description**	**Quantity**	**Unit**	**Unit Cost**	**Cost**
1	Booster Station Improvements	2.0	LS	$ 200,000	$ 400,000
			Subtotal		$ 400,000
			Construction Contingencies (20%)		$ 80,000
			Engineering and Administration (25%)		$ 100,000
			Projected Cost Estimate		**$ 580,000**
			Fiscal Year		18/19, 19/20, 22/23

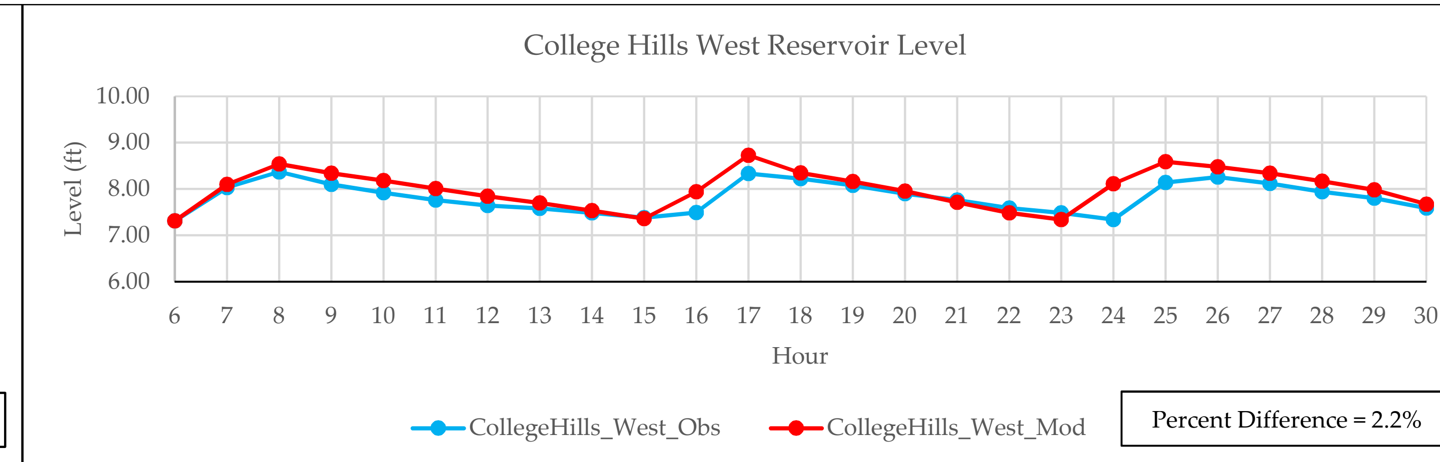
City of Whittier Water Master Plan Update
Oceanview Reservoir Improvements
CIP Project WF-10

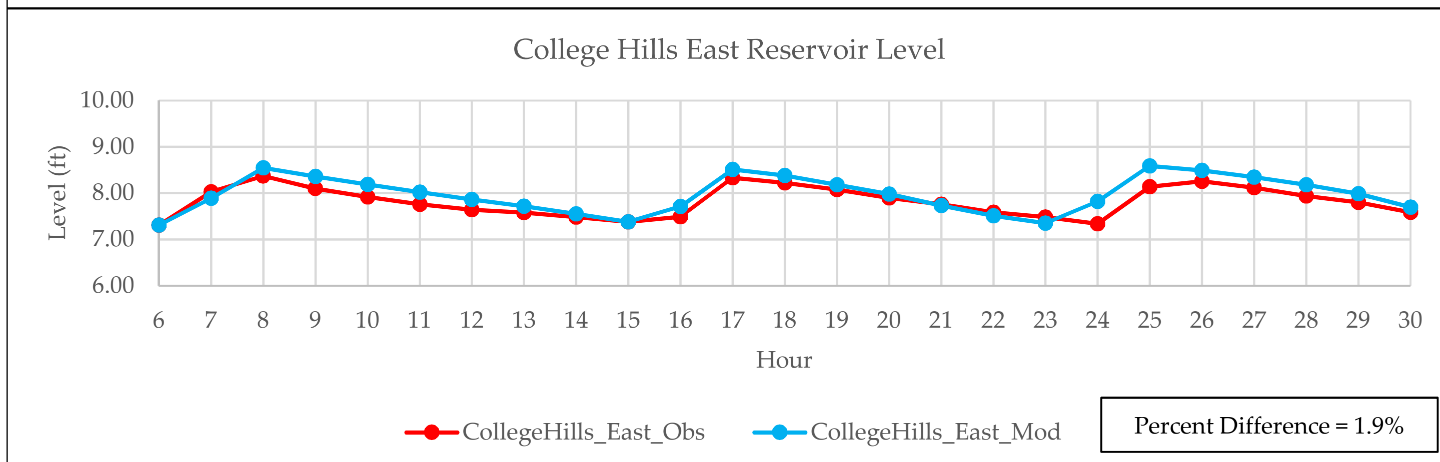
Description/ Purpose:	Only a portion of the volume available in the Ocean View Reservoir is used due to loss of disinfectant residual. This problem can be mitigated by installing a chlorination facility at the Oceanview Reservoir site.

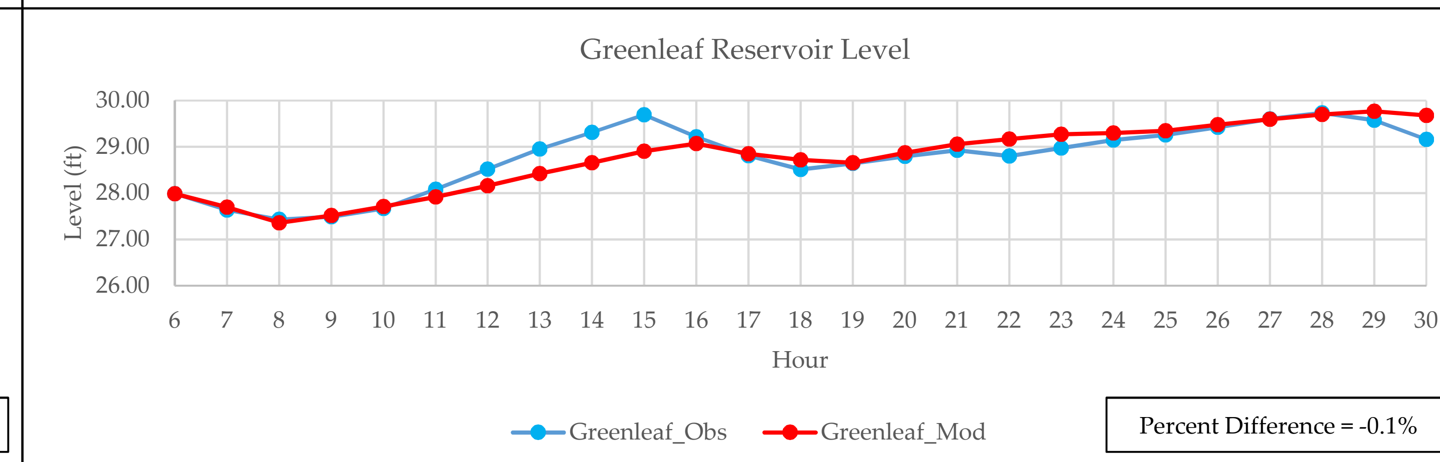
Item No.	Item Description	Quantity	Unit	Unit Cost	Cost
1	Chlorination Station	1.0	LS	$ 500,000	$ 500,000
			Subtotal		$ 500,000
			Construction Contingencies (20%)		$ 100,000
			Engineering and Administration (25%)		$ 125,000
			Projected Cost Estimate		**$ 725,000**
			Fiscal Year		TBD

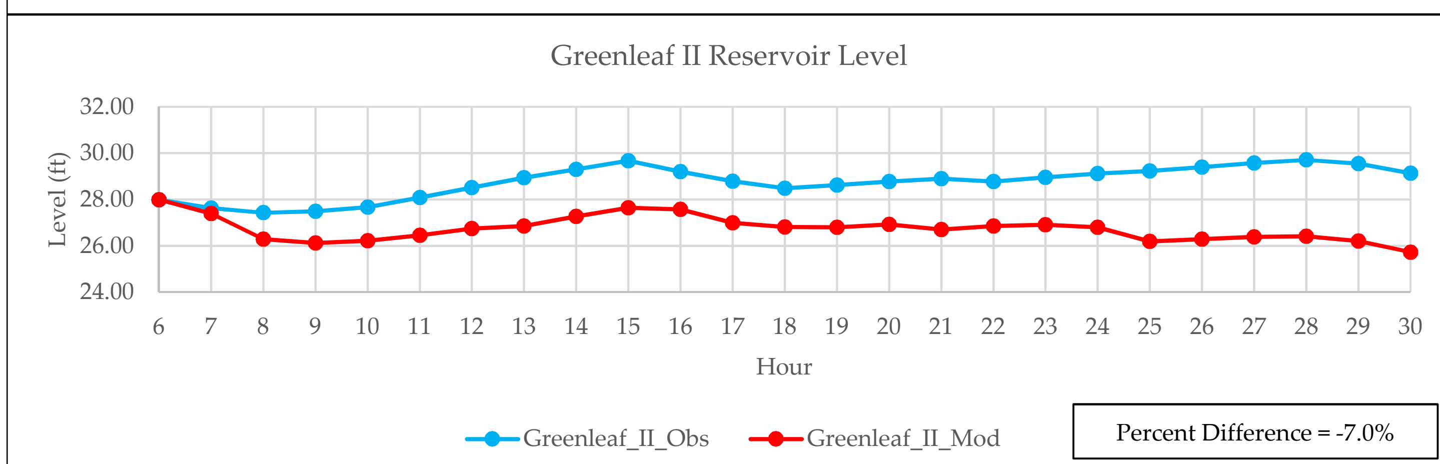
Appendix A
Model Calibration Results

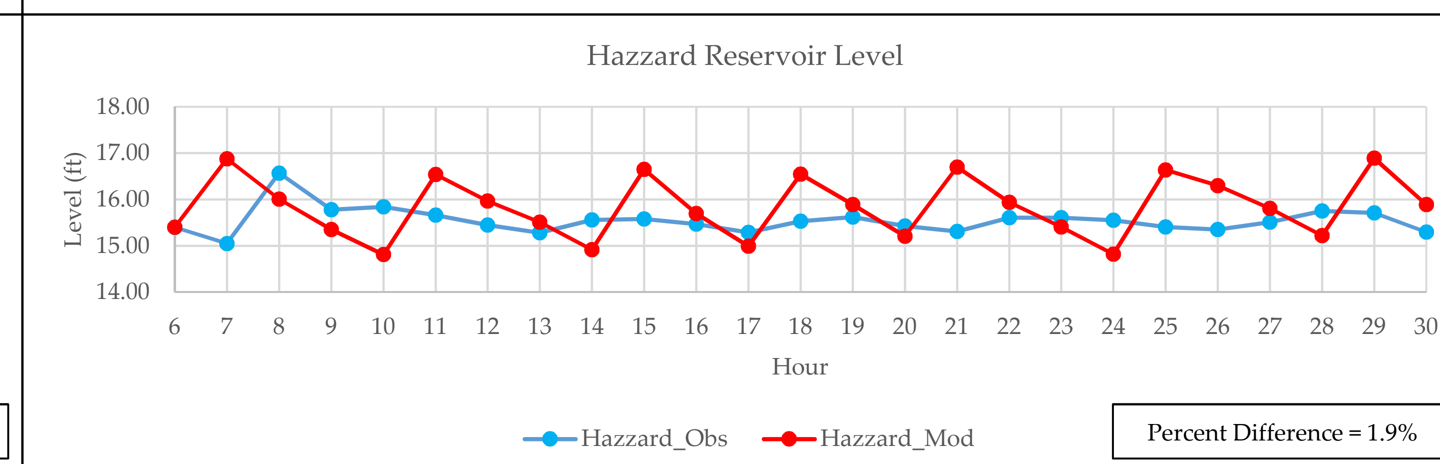

Pumping Plant No. 2 Discharge
Flow (gpm)
Hour
PP2 Flow_Obs
PP2 Flow_Mod
Percent Difference = -6.1%

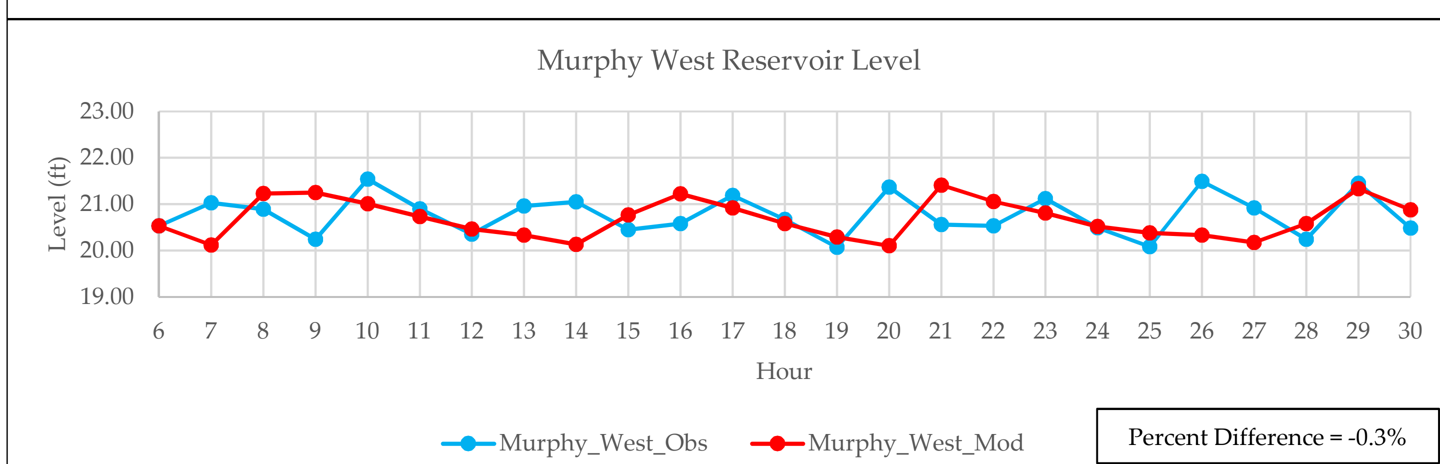

College Hills West Reservoir Level
Level (ft)
Hour
CollegeHills_West_Obs
CollegeHills_West_Mod
Percent Difference = 2.2%

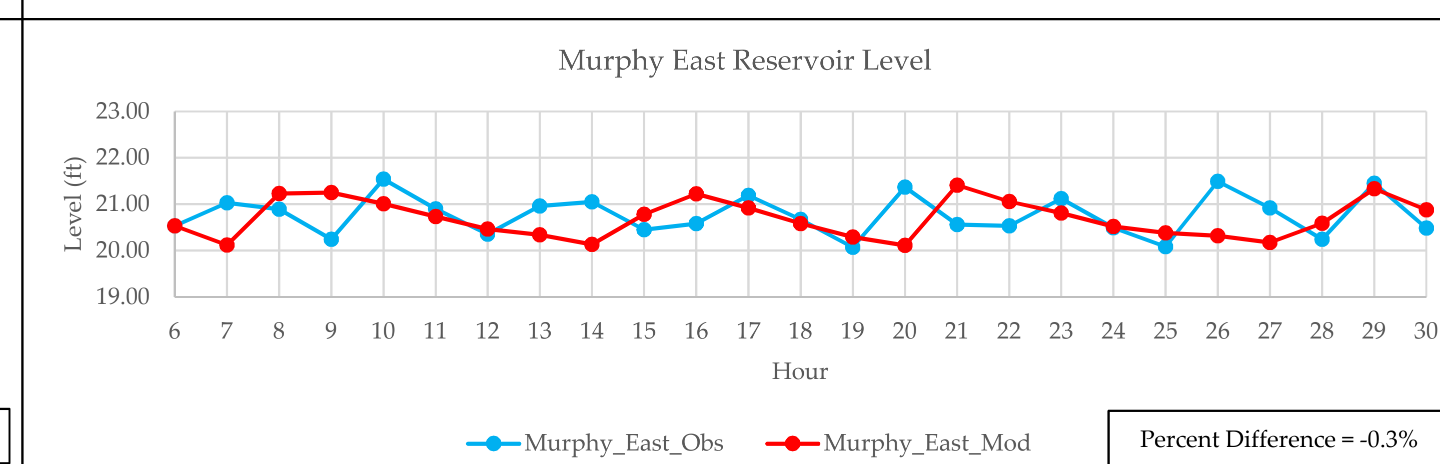

College Hills East Reservoir Level
Level (ft)
Hour
CollegeHills_East_Obs
CollegeHills_East_Mod
Percent Difference = 1.9%

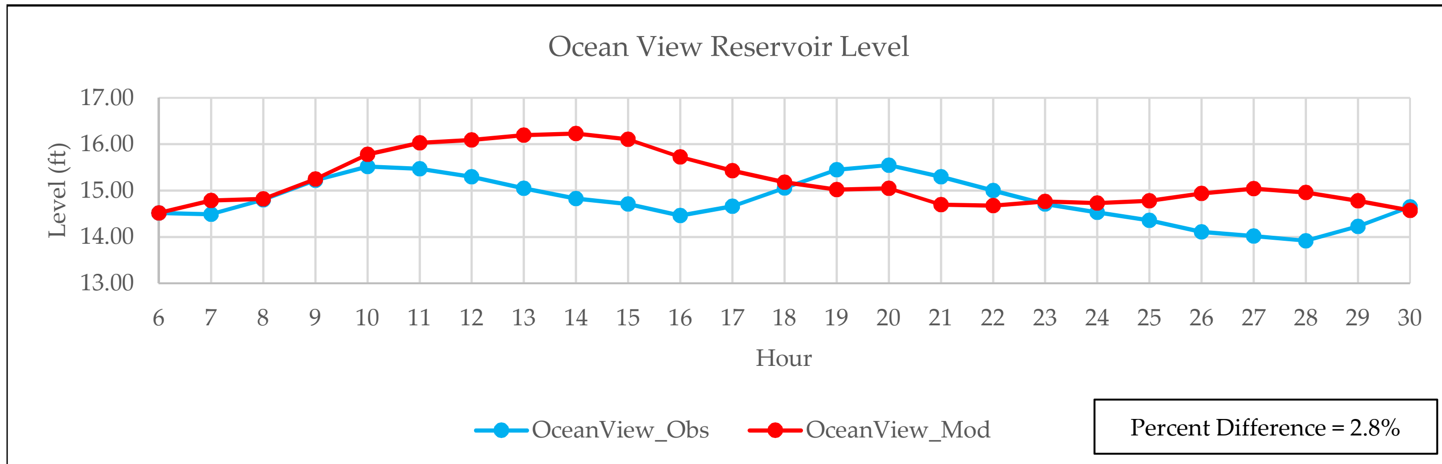

Greenleaf Reservoir Level
Level (ft)
Hour
Greenleaf_Obs
Greenleaf_Mod
Percent Difference = -0.1%

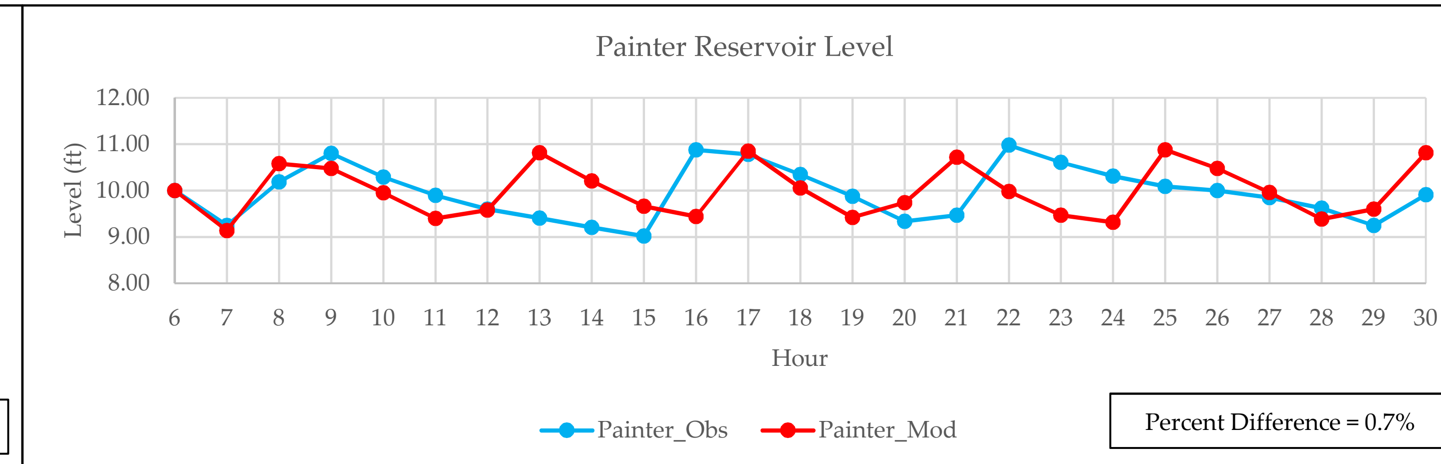

Greenleaf II Reservoir Level
Level (ft)
Hour
Greenleaf_II_Obs
Greenleaf_II_Mod
Percent Difference = -7.0%

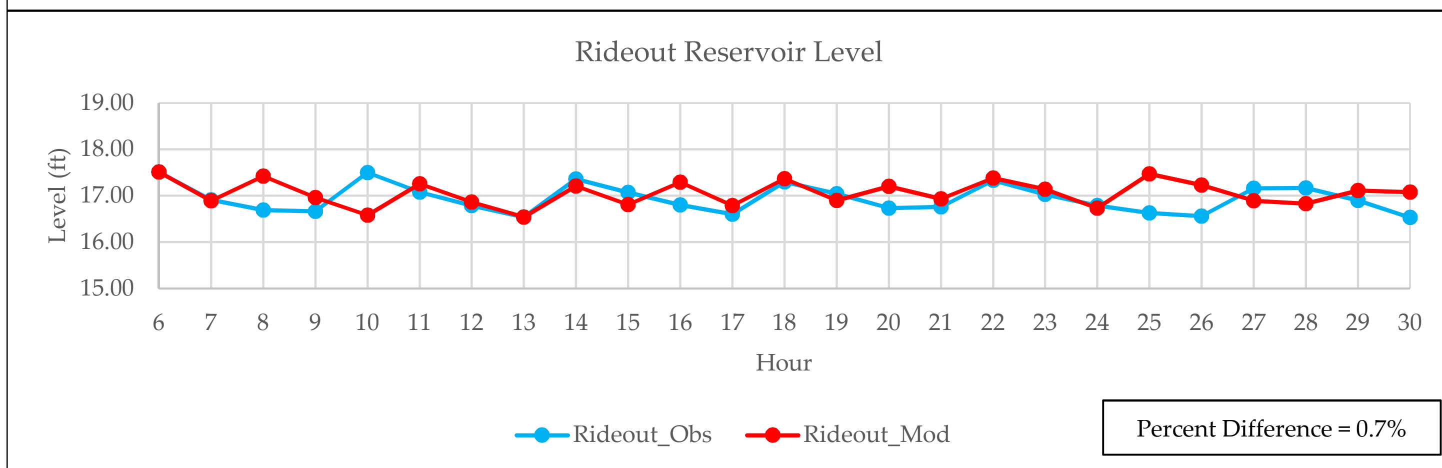

Hazzard Reservoir Level
Level (ft)
Hour
Hazzard_Obs
Hazzard_Mod
Percent Difference = 1.9%

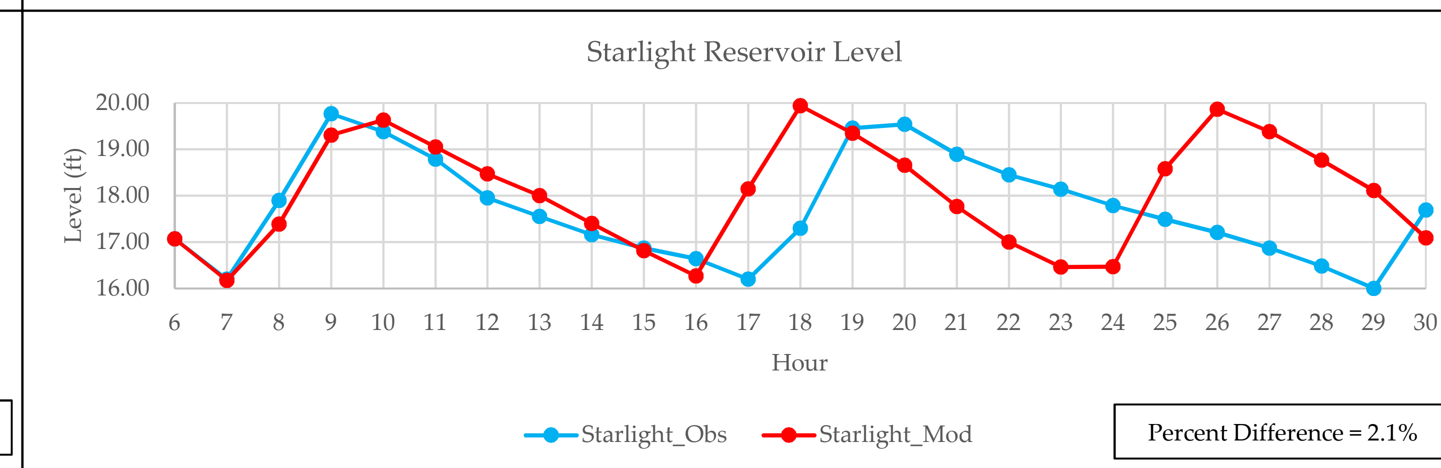

Murphy West Reservoir Level
Level (ft)
Hour
Murphy_West_Obs
Murphy_West_Mod
Percent Difference = -0.3%

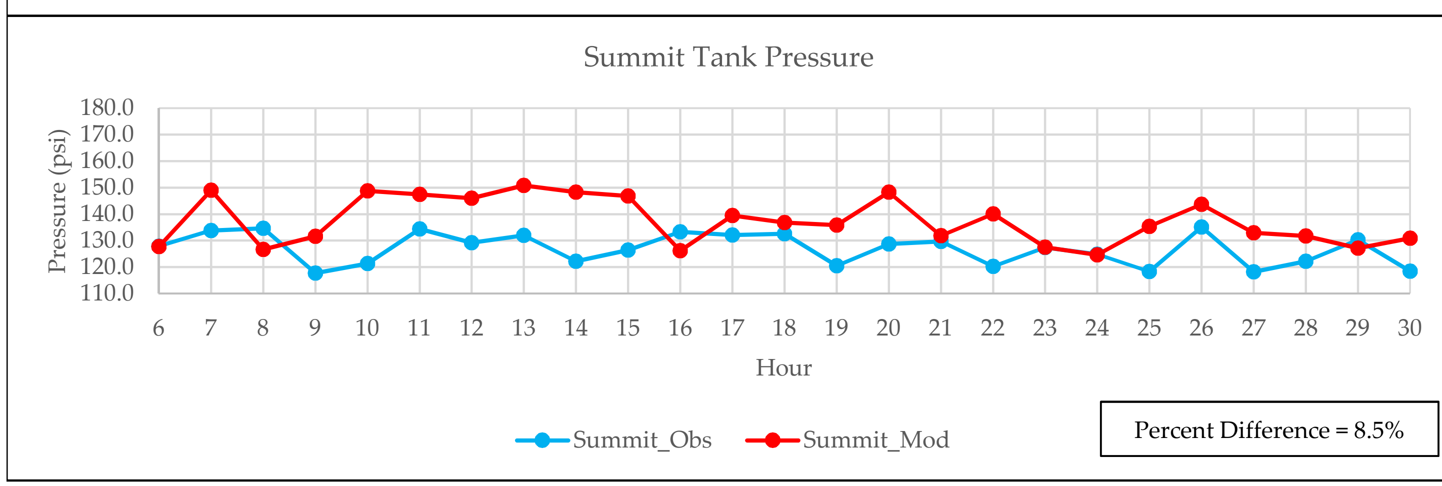

Murphy East Reservoir Level
Level (ft)
Hour
Murphy_East_Obs
Murphy_East_Mod
Percent Difference = -0.3%


Ocean View Reservoir Level
Level (ft)
17.00
16.00
15.00
14.00
13.00
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Hour
OceanView_Obs
OceanView_Mod
Percent Difference = 2.8%


Painter Reservoir Level
Level (ft)
12.00
11.00
10.00
9.00
8.00
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Hour
Painter_Obs
Painter_Mod
Percent Difference = 0.7%


Rideout Reservoir Level
Level (ft)
19.00
18.00
17.00
16.00
15.00
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Hour
Rideout_Obs
Rideout_Mod
Percent Difference = 0.7%


Starlight Reservoir Level
Level (ft)
20.00
19.00
18.00
17.00
16.00
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Hour
Starlight_Obs
Starlight_Mod
Percent Difference = 2.1%


Summit Tank Pressure
Pressure (psi)
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Hour
Summit_Obs
Summit_Mod
Percent Difference = 8.5%

Reservoir Level - Model

Day	Hour	College Hills Res 3 (ft)	College Hills Res 8 (ft)	Greenleaf Res 2 (ft)	Greenleaf Res 7A (ft)	Hazzard Res 6 (ft)	Murphy Res 10 (ft)	Murphy Res 11 (ft)	Ocean View Res 9 (ft)	Painter Res 1 (ft)	Rideout Res 5 (ft)	Starlight Res 12 (ft)	Summit (psi)
3/16/2016	6	7.31	7.31	27.99	27.99	15.40	20.53	20.53	14.52	10.00	17.51	17.07	127.79
3/16/2016	7	8.10	7.89	27.70	27.39	16.88	20.12	20.12	14.79	9.14	16.89	16.17	148.99
3/16/2016	8	8.54	8.55	27.36	26.29	16.01	21.23	21.23	14.82	10.58	17.42	17.39	126.68
3/16/2016	9	8.34	8.36	27.52	26.12	15.35	21.25	21.25	15.25	10.48	16.96	19.31	131.55
3/16/2016	10	8.18	8.19	27.71	26.22	14.81	21.01	21.01	15.78	9.95	16.58	19.63	148.74
3/16/2016	11	8.01	8.02	27.92	26.46	16.54	20.73	20.73	16.03	9.40	17.26	19.05	147.39
3/16/2016	12	7.84	7.86	28.16	26.74	15.97	20.46	20.46	16.09	9.58	16.86	18.47	146.04
3/16/2016	13	7.70	7.72	28.42	26.85	15.51	20.33	20.34	16.20	10.82	16.54	18.00	150.82
3/16/2016	14	7.53	7.55	28.66	27.27	14.92	20.13	20.13	16.23	10.21	17.21	17.40	148.24
3/16/2016	15	7.36	7.38	28.91	27.65	16.65	20.77	20.78	16.11	9.66	16.81	16.81	146.82
3/16/2016	16	7.94	7.71	29.07	27.58	15.70	21.22	21.22	15.73	9.44	17.29	16.27	126.16
3/16/2016	17	8.73	8.51	28.85	26.99	14.99	20.92	20.92	15.43	10.85	16.79	18.15	139.41
3/16/2016	18	8.35	8.38	28.72	26.81	16.55	20.58	20.58	15.18	10.06	17.37	19.94	136.75
3/16/2016	19	8.16	8.18	28.66	26.80	15.89	20.29	20.29	15.02	9.42	16.90	19.35	135.88
3/16/2016	20	7.95	7.98	28.87	26.93	15.21	20.10	20.11	15.05	9.74	17.20	18.66	148.35
3/16/2016	21	7.71	7.73	29.06	26.71	16.70	21.41	21.41	14.70	10.72	16.93	17.77	131.87
3/16/2016	22	7.48	7.51	29.17	26.85	15.94	21.06	21.06	14.68	9.98	17.38	17.00	140.10
3/16/2016	23	7.34	7.35	29.27	26.91	15.41	20.81	20.81	14.77	9.47	17.14	16.46	127.52
3/16/2016	24	8.11	7.82	29.30	26.80	14.82	20.52	20.52	14.73	9.32	16.73	16.47	124.59
3/17/2016	25	8.59	8.59	29.35	26.19	16.64	20.38	20.38	14.78	10.88	17.47	18.58	135.38
3/17/2016	26	8.48	8.49	29.48	26.29	16.30	20.33	20.32	14.94	10.48	17.23	19.87	143.69
3/17/2016	27	8.34	8.35	29.60	26.39	15.81	20.17	20.17	15.04	9.96	16.89	19.38	132.93
3/17/2016	28	8.17	8.18	29.70	26.41	15.22	20.58	20.59	14.96	9.39	16.83	18.77	131.77
3/17/2016	29	7.98	7.99	29.77	26.20	16.89	21.33	21.33	14.78	9.60	17.11	18.11	127.17
3/17/2016	30	7.67	7.70	29.68	25.73	15.89	20.88	20.88	14.57	10.82	17.08	17.09	130.84
Percent Difference		**2.2%**	**1.9%**	**-0.1%**	**-7.0%**	**1.9%**	**-0.3%**	**-0.3%**	**2.8%**	**0.7%**	**0.7%**	**2.1%**	**8.5%**
Overall Percent Difference		**1.1%**											

Hydrant Static and Residual Pressures - Model

Fire Hydrant ID	Model Node ID	Test Date	Flow (gpm)	Static Pressure (psi)	Percent Difference	Dynamic Pressure (psi)	Percent Difference	Comments
FH-0208	14464130	10/25/2017	990	59	9.8%	55	9.4%	Very hot day (100°F); assume maximum day demand conditions.
FH-0139	16464450	10/25/2017	1,130	84	2.1%	66	8.7%	Very hot day (100°F); assume maximum day demand conditions.
FH-0141	16464485	10/25/2017	1,350	92	6.8%	69	-8.6%	Very hot day (100°F); assume maximum day demand conditions.
FH-0326	28464080	11/2/2017	444	91	-8.9%	27	-4.2%	Assume calibration scenario demand conditions.
FH-0396	28464560	11/2/2017	531	90	3.1%	28	0.8%	Assume calibration scenario demand conditions.
FH-0640	31464095	9/7/2017	1,679	125	0.1%	111	-9.1%	Assume calibration scenario demand conditions.
Overall Percent Difference					**2.2%**		**-0.5%**	

[1] All results are obtained from a steady state scenario run given no time of day information was available.

Michael Baker
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