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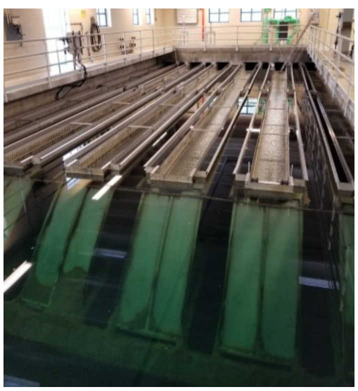

City of Englewood Water System Master Plan

Final Report
Hazen No. 70035-000
May 2020

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List of Acronyms

Abbreviation	Definition
AACEi	Advancement of Cost Engineering International
ADD	Average Daily Demand
AMI	Advanced Metering Infrastructure
AWWA	American Water Works Association
CAMP	Comprehensive Asset Management Program
CDPHE	Colorado Department of Public Health and Environment
cfs	Cubic feet per second
CIP	Capital Improvement Plan
CMMS	Computerized Maintenance Management Systems
CO	Certificate of Occupancy
CoF	Consequence of Failure
CPE	Comprehensive Performance Evaluation
CT	Concentration x Time
Cu	Copper
C&H	Clarkson and Hampden
C&P	Cornell and Pennsylvania
DEM	Digital Elevation Model
DIP	Ductile Iron Pipe
EAM	Enterprise Asset Management
EPA	Environmental Protection Agency
EPS	Extended Period Simulation
EUL	Estimated Useful Life
fps	Feet per second
FTE	Full Time Equivalent
GAC	Granular Activated Carbon
GIS	Geographical Information System

Abbreviation	Definition
gpcd	Gallons per capita per day
gpm	Gallons per minute
GPS	Global Positioning System
HDT	Hydraulic Detention Time
HGL	Hydraulic Grade Line
HLR	Hydraulic Loading Rate
HP	Horsepower
HSPS	High Service Pump Station
IWA	International Water Association
LCR	Lead and Copper Rule
LF	Linear Feet
LoF	Likelihood of Failure
LSI	Langelier Saturation Index
LSL	Lead Service Line
MCC	Motor Control Center
MDD	Maximum Daily Demand
MG	Million gallons
mgd	Million gallons per day
NORM	Naturally Occurring Radioactive Materials
O&M	Operation and Maintenance
PAC	Powdered Activated Carbon
Pb	Lead
PHD	Peak Hourly Demand
PLC	Programmable Logic Controller
PPE	Personal Protective Equipment
ppm	Parts per million
PRV	Pressure Reducing Valve

Abbreviation	Definition
PS	Pump Station
psi	Pounds per Square Inch
PVC	Polyvinyl Chloride
R/R	Repair and Replacement
SCADA	Supervisory Control and Data Acquisition
SDWA	Safe Drinking Water Act
SOP	Standard Operating Procedure
SOR	Surface Overflow Rate
TENORM	Technologically Enhanced Naturally Occurring Radioactive Materials
UDF	Unidirectional Flushing
UV	Ultraviolet
VFD	Variable Frequency Drive
WMP	Water Master Plan
W-T-W	Wire-to-Water
WTP	Water Treatment Plant

Executive Summary

Scope and Purpose

The City of Englewood (City) has chosen to initiate a comprehensive Water Master Plan for their water system. In September 2019, the City selected Hazen and Sawyer (Hazen) and our teammate Bai Engineers (Bai) to develop the Water Master Plan (Plan). This report establishes an initial Master Plan for the City's water system, providing an overall evaluation of the system and an understanding of existing and future needs. The Master Plan includes a proposed 15-year Capital Improvement Plan (CIP). This Plan will serve as an adaptive and evolving instrument for the City to use for long-term planning. It is intended that amendments or updates to the Plan will be developed as new information becomes available about the system and/or as the physical system or needs evolve.

An overview of the tasks included in this study is provided below, and each task is described in further detail throughout the report:

- Reviewed existing information available for the source water collection and transmission, treatment, distribution, pumping and storage systems
- Developed and calibrated a water distribution system hydraulic model
- Conducted distribution system hydraulic assessments and identified deficiencies
- Evaluated the Allen Water Treatment Plant (WTP) unit processes
- Performed a desktop condition assessment on water transmission mains and limited visual condition assessment on pump stations
- Developed recommended programs and projects (and costs) to increase water system reliability and effectively allocate water system funds and City resources
- Facilitated prioritization workshops with City staff
- Recommend a 15-year CIP

Existing System Review

The assessment for this Plan begins at the McLellan and Union Avenue Pump Station locations that convey water from the South Platte River to a water treatment facility. The McLellan Pump Station transfers water to the McLellan Reservoir for storage and to the City Ditch. The City Ditch consists of elevated flumes, earthen canals, and underground pipelines. It should be noted that Englewood's existing source water supply system consists of several mountain area ditches and water rights that were not evaluated as part of this Plan.

The Union Avenue Pump Station system consists of a diversion structure at the river, a forebay, an activated carbon feed system to mitigate taste and odor issues in the water, and a chemical feed system to treat for manganese that can be present in the source water. This facility pumps water to the North Pond that is adjacent to the Allen WTP.

The existing treated water system consists of the Allen WTP and associated distribution system that serves over 30,000 people throughout the City. The Allen WTP is in the southcentral service area of the distribution system. The water distribution system includes three different pressure zones to provide acceptable pressures at various ground elevations. The distribution system contains approximately 166 miles of pipe ranging from 4 to 36 inches in diameter, two high-service pump stations located at the Allen WTP, two booster stations, and three storage tanks. The distribution system serves 11,005 water service connections.

Water Model Development

The water distribution system hydraulic model developed for this Plan includes water distribution mains 8 inches in diameter and larger, with some smaller mains included for connectivity. The City provided Hazen with geographical information system (GIS) data, record drawings, water billing records, water production data and Supervisory Control and Data Acquisition (SCADA) data for use in building the hydraulic model. The model includes a network incorporating two primary elements: links (water pipes) and nodes (including pipe junctions, tanks, pumps and other operational elements). Major observations from the water modeling effort are as follows:

- Typical model calibration compares the results of the model simulations to actual field data such as measured pressures, flow rates and tank water levels. Because critical information is not available (e.g., pump curves, pump set points, valve settings, and tank control valve settings), the model still needs to be fully calibrated. However, a preliminary attempt to verify some model inputs is documented in this report. An updated model can be used to test different operational changes and their impact on tank turnover and water age, which is included in the recommended programs.
- The Cornell and Pennsylvania (C&P) booster station, one of the two booster stations serving Zone 3, rarely runs. The City should consider alternating between the two booster stations or abandoning the C&P station after further hydraulic analysis.
- Based on the 2019 billing and production records, non-revenue and non-metered water combined accounts for about 15 percent of the total water supplied to the system. The non-metered water includes over 1,200 customer accounts that are currently on flat rate billing.

Distribution System Hydraulic Assessments

The distribution system model was used to conduct various hydraulic assessments (storage capacity, velocities, pressures) and identify system deficiencies under existing and future water demand conditions.

Storage capacity was evaluated based on three components: equalization, fire, and emergency storage. The overall water distribution system was found to have adequate storage based on the specified storage requirements. However, Zone 2 has a storage deficit of approximately 0.9 million gallons (MG).

Model simulations indicate that the majority of the system operates within the recommended operating range of 40 to 100 psi. There are a number of locations with pressures below 40 psi during peak hour demand, but most of these locations are transmission mains without any customer connections. No minimum pressures below 20 psi were predicted by the model. Therefore, based on the model simulations completed, pressures within the water system are acceptable.

System Risk Assessment

A desktop risk assessment was performed for water transmission mains (18 inches in diameter or larger) and a limited visual condition assessment was completed for the source water and distribution system pump stations. This established the existing condition of critical assets and identified and prioritized repair and replacement (R/R) projects included in the CIP. Each asset was assigned Likelihood of Failure (LoF) and Consequence of Failure (CoF) scores. These scores were then combined to form an overall risk score, which was used to recommend the best management approach for each asset. For the transmission mains, LoF was based on pipe age (where available), pipe material, and geo-coded main break records. CoF was based on the pipe's location, depth, and diameter. One replacement project was identified for a transmission main on Hampden Avenue. For the other transmission mains, it is recommended that the City perform additional assessment/inspection to identify and prioritize R/R projects.

For the six pump stations, visual observations of the assets were recorded during normal operations. An asset condition score was assigned to each major pump station asset and these condition scores were used to generate the recommendations. LoF scores were based on the asset's condition. CoF scores were based on industry standards. All six pump stations have aging components that are at the end of their useful life. The two booster stations from Zone 1 to Zone 3 (Clarkson and Hampden, Cornell and Pennsylvania) are in generally poor condition. All six pump stations are critical facilities that should be evaluated further within the next year and upgraded based on this comprehensive assessment.

Allen Water Treatment Plant Performance

Major unit processes (e.g., flocculation, sedimentation, filtration, disinfection and chemical systems) at the Allen WTP were reviewed. Unit process capacities were compared to Colorado Department of Public Health and Environment (CDPHE) design guidelines and the age and general condition noted. Due to the age and general condition of some systems, an in-depth plant condition assessment is recommended. Additionally, a comprehensive performance evaluation is recommended to optimize treatment performance.

Operations noted known issues including variable hydraulic differences between north and south filter trains, increased filter ripening time (suspected underdrain issues) with Filter 2 and potentially others, and leaking filter effluent valves. A filter improvement project was previously planned by the City and has been added to the CIP. In addition, routine filter surveillance is recommended to inspect the condition of the media, underdrains, and document filter performance over time. Improvements to chemical systems were also identified to provide redundancy and increase available storage.

Lead Service Line Replacement Program

The City of Englewood, like most utilities in the nation, will have to address issues related to the soon to be revised Lead and Copper Rule (LCR) in the next few years. This has a potentially significant impact on Englewood's CIP as the new rule will probably encourage or require the replacement of existing lead service lines (LSLs) in the distribution system. The following lists the recommended actions Englewood can implement now to prepare for the revised LCR:

- Develop and maintain an LSL Inventory - The current LCR encourages utilities to maintain and update an inventory of all service line material in the distribution system. This part of the LCR has not be consistently enforced until recently. A sound inventory will assist in long-term capital project financing.
- Review the corrosion control method applied at the Allen WTP - It is recommended that after the details of the revised LCR are known, the City conduct a desk-top and/or bench-top study to verify the existing corrosion control method.
- Re-assess the sampling program used to verify compliance - Again, regulators have an increased interest in verifying compliance with the existing LCR. It is recommended that the City review their testing program, including which homes are sampled, in the next 12 to 24 months.
- Investigate opportunities to reduce costs for LSL replacements - The current and anticipated LCR will probably not require Englewood to replace LSLs. However, should Englewood implement a replacement program, the City may consider combining these efforts with water main, sewer, and street improvements when they occur. Another effective policy to consider is to require significant home and business redevelopment efforts to replace the entire service line regardless of the age or material. This assures a property has updated infrastructure and no LSL.
- Consider policies on payments for replacements - Almost all drinking water utilities need to consider what part of the overall LSL replacement program is paid for by the ratepayers and what is paid by the property owner. Several utilities have created new policies that range from full customer payment to full utility payment. Recent studies have shown the most effective programs have the utility pay for at least partial replacement with programs for customers to pay off the replacement over time on their water bills.

Based on the maximum estimate of remaining LSLs in Englewood's system and assuming the City will pay for the replacement from the main to the property line, Hazen is including $20 million over the next 15 years in this Master Plan for consideration. As the LCR rulemaking continues, Englewood staff should stay updated on the latest direction of the rule and the schedule to comply with the revisions.

Key Master Plan Findings

The following describes the key findings used to develop the 15-year CIP. These are the top priority issues found during this project.

- The McLellan and Union Avenue Pump Stations have experienced periodic outages that require emergency repair. The deterioration of these assets and overall age could disrupt treatment and eventually service to all customers if these pump stations are offline for an extended period of time. Additionally, several components of the distribution system pump stations are nearing or at the end of their useful life.

- Specific chemical feed systems are outdated and are in jeopardy of not properly functioning without necessary maintenance and upgrades. Some key chemicals require redundant storage systems.
- The Big Dry Creek source water can adversely impact operating costs. A project has been successfully permitted in early 2020 to address this issue.
- The drinking water in Englewood continues to be hard (i.e., has excess calcium) which can cause scaling of pipe and plumbing systems.
- Important electrical and control systems associated with pumping and treatment are nearing the end of their useful life.
- The Operations Complex at the Allen WTP has very little space to perform necessary day-to-day functions.
- The status of emergency interconnections with Denver Water is unknown.
- Over 1,200 customer accounts are not metered, meaning they pay a flat rate for water service.
- The City will need to eventually address how to remove the remaining lead service lines to customer homes. A comprehensive program to address these lines should be established.
- The utility is in need of several formal programs that can proactively address maintenance and upgrades to aging infrastructure.
- Existing policies do not adequately address the type of redevelopment that the City is experiencing.

Water Program and Capital Project Identification

The City can make significant improvements to the existing water system through the establishment of formal programs and the execution of specific capital improvement projects. Programs are on-going activities intended to proactively maintain and upgrade infrastructure. They vary in size and cost with several continuing indefinitely. As each program is implemented, the City will gain a more comprehensive understanding of the water infrastructure. Correspondingly, projects are discrete, one-time activities with limited scope and duration.

This Plan also prioritizes programs and projects into the following three categories:

- High Priority: If these projects and programs are not completed, risk of service disruption to customers is significant and more immediate. High priority projects and programs should begin in the next 1 to 2 years.
- Medium Priority: If these projects and programs are not completed, risk of service disruption to customers may be possible in the future. Medium priority projects and programs should begin in the next 3 to 5 years.

- Long Range: These projects and programs should be considered for implementation after 5 years.

Based on a comprehensive analysis of the water system, various water programs were recommended for the distribution system, Allen WTP, and the overall system. In addition, several policy recommendations were identified based on discussions with the City's Utilities staff and review of the City's existing policies. Capital improvement project recommendations are based on the water system evaluation, which includes discrete projects to correct existing deficiencies, improve system reliability or upgrade assets near or at the end of their useful life.

The following lists the High Priority Projects recommended for Englewood's water system:

- McLellan and Union Avenue Pump Station Improvements – These two facilities are the only sources of drinking water for Englewood. The McLellan Pump Station recently had an emergency outage. This project determines and implements the needed improvements to address the resiliency of these systems.

- Big Dry Creek Diversion – This stream blends with water in the South Platte River just upstream of the Union Avenue Pump Station. It contains elevated levels of uranium that is removed during treatment but is contained in the waste product at the WTP. The cost for disposal of this product is high. Therefore, diverting this creek around the Union Avenue Pump Station has been permitted and is planned to be completed in 2020.

- Distribution System Pump Station Improvements (Phase 1) – These four pump stations convey water to the three pressure zones and many of the existing components are aging. This project determines and implements the needed improvements to address the resiliency of these critical assets. This project is the first of two phases over 5 years with the most important systems to be addressed in the next 1 to 2 years.

- Elevated Flumes Structural Assessment – The source water conveyance system associated with the McLellan Pump Station partially consists of elevated flumes made of structural steel. It is recommended to assess the structural integrity of these systems and make the necessary repairs to keep these structures sound for the foreseeable future.

- Dewatering Spare Parts Purchase – The dewatering system at the WTP is a potential single point of failure. Purchasing the long-lead spare parts for this system is recommended to minimize outage periods for this process.

- Distribution Zone 1 Isolation Valve – An existing isolation valve is inoperable according to City staff. This project replaces the existing valve that isolates Zone 1 from the Allen WTP.

- Emergency Interconnections with Denver – The status of any existing emergency interconnections with Denver Water is unknown. It is recommended that any interconnections be evaluated, and additional interconnections installed if necessary, in coordination with Denver Water.

- Electrical and Control System Upgrades (Phase 1) – Much of the water system was last updated 20 to 30 years ago. This recommended project first conducts detailed analyses of equipment, then recommends the specific replacement of components to maintain service to customers. This project is the first of two phases over 5 years with the most important systems to be addressed in the next 1 to 2 years.

- Chemical Feed System Improvements (Phase 1) – The main components of the essential chemical feed systems are reaching the end of their useful life and need to be replaced. This project replaces these components and addresses the need to have redundant small pumps and storage tanks. This project is the first of two phases over 5 years with the most important systems to be addressed in the next 1 to 2 years.
- Flash Mixer Replacement – This mixer is a potential single point of failure for the treatment process. Because the current equipment is about 20 years old, it should be replaced or significantly rehabilitated soon.
- Treatment Plant Water Softening Assessment – It is recommended to complete an assessment of alternatives to determine how to address the hard water issue in Englewood. Implementing a softening project will mitigate the need for home water softeners and avoid excessive scaling in the distribution system.
- Operations Complex Space/Concept Study – This study determines how to address the space limitations at the Allen WTP and within the Utilities Department.

The following lists the Medium Priority Projects recommended for Englewood's water system:

- Electrical and Control System Upgrades (Phase 2) – Much of the water system was last updated 20 to 30 years ago. This recommended project first conducts detailed analyses of equipment, then recommends the specific replacement of components to maintain service to customers. This project is the second of two phases with the most important systems to be addressed in the first 1 to 2 years.
- Chemical Feed System Improvements (Phase 2) – The main components of the essential chemical feed systems are reaching the end of their useful life and need to be replaced. This project replaces these components and addresses the need to have redundant small pumps and storage tanks. This project is the second of two phases with the most important systems to be addressed in the first 1 to 2 years.
- Distribution System Pump Station Improvements (Phase 2) – These four pump stations convey water to the three pressure zones and many of the existing components are aging. This project determines and implements the needed improvements to address the resiliency of these critical assets. This project is the second of two phases with the most important systems to be addressed in the first 1 to 2 years.
- Hampden Avenue Transmission Main Replacement – This 18-inch transmission main has a history of breaks and is located near a critical hospital facility. It is recommended that the main be replaced in conjunction with a high priority stormwater replacement project in the same corridor as a cost saving measure.

- Zone 1 and 2 Pressure Reducing Valve – The existing connection between the two zones does not include a pressure reducing valve. A valve is recommended to maintain suitable pressures in each zone when the connection is open.

- Union Avenue and North Pond Assessments – These assessments consider how to maintain these ponds for long-term use within the source water system.

- Distribution System Optimization – There are operational challenges in the distribution system including inefficient pumping and inadequate storage tank turnover. An optimization study is recommended to evaluate operational changes to improve water quality, reduce energy consumption, and streamline operations.

- Instrument Assessment and Calibration – Periodic calibration of flow, pressure, and level instruments is needed to correctly track performance of infrastructure. This will help optimize operations of the complete system.

The following lists the Long-Range Projects recommended for Englewood's water system:

- Softening Project Implementation – After the optimal plan has been determined, this project implements the plan to soften the water, addressing the high hardness water issue Englewood has experienced over the past few decades.

- New Zone 2 Storage Tank – Review of storage requirements by pressure zone identified a 0.9 MG storage capacity deficiency in Zone 2. This project includes design and construction of a new tank following model updates/verification of tank sizing and location.

- Operations Complex Expansion – After the optimized plan has been determined to address the space constraints at the Allen WTP and within Utilities, this project designs and constructs the expansion and/or retrofits needed.

- Overhead Tanks Replacement – The Overhead Tanks are over 30 years old and have already been repaired to extend their useful life. Budgeting for the eventual replacement of these tanks should be included near the end of the 15-year CIP, or sooner based on the results of a comprehensive condition assessment of the tanks.

- Filter Improvements Project – Because the filtration systems at the Allen WTP were installed in the late 1990s, this project addresses any improvements needed to maintain uninterrupted operations at this facility.

- Source Water Projects – These are projects that have been identified to improve and maintain the ditches and conveyance structures owned by Englewood in the mountains. This project provides a budget allowance to complete these projects.

- Comprehensive Water Treatment Facility Evaluation – Hazen recommends the City complete a formalized evaluation of the WTP periodically to benchmark performance against current industry standards and regulations. This project is recommended to be completed within the next 5 to 7 years.

- Records Conversion Project – This project simply develops a strategy to maintain readily available and searchable records in the future. This will be important as staff turns over and equipment needs to be replaced.

- Radio Study –This project is recommended in the next few years as technology improves and having real-time access to remote information becomes more important for system operations. This project will determine what type of communications systems should be used in the future.

The High Priority Programs recommended for Englewood's water system are outlined below:

- GIS System Update – The City has an excellent water GIS database but there are data gaps that need to be addressed. This program is a one-time update of the existing GIS data to fill in these gaps followed by additional regular updates of the GIS as new information becomes available or the physical system changes.

- On-Call Field Services Contracts – On-call contracts will address the need for quick responses to emergency system outages caused by equipment failure. These contracts will focus on electrical and mechanical contracts.

- Meter Installation for Non-metered Accounts – The City has over 1,200 non-metered accounts. This program would provide for the installation of meters at all properties to eliminate flat-rate billing.

- Water Model Expansion and Re-calibration – The model developed under this Master Plan should be expanded to include smaller diameter mains and re-calibrated based on field testing results. This will provide better confidence in the hydraulic assessments performed with the model.

- Transmission Main Inspections – It is recommended that transmission main assessments/inspections be completed to identify and prioritize rehabilitation and repair projects for the large diameter water mains.

- Valve Inspection and Exercising – A formal program should be established to periodically inspect, operate, and maintain the City's 3,000 valves.

- Hydrant Flushing and Testing – The City currently flushes and inspects all 660 fire hydrants annually using traditional flushing. This program will transition the City to unidirectional flushing which uses less water and better addresses water quality issues.

- Emergency Repair Projects – Distribution System – Funding should be allocated to an annual emergency repair program to address critical defects in the distribution system as they occur.

The Medium Priority Programs recommended for Englewood's water system are outlined below:

- Water Distribution Main Replacement – The City typically repairs water mains only as breaks occur. A program is recommended to systematically replace aging and problematic water distribution mains to improve system reliability.
- Granular Activated Carbon (GAC) Replacement – Historical operations at the Allen WTP have included GAC replacement for filters every two to four years. It is recommended that a GAC Replacement Program be included in the CIP to capitalize these significant recurring expenditures.
- Valve Replacement – This program will budget for the replacement of inoperable valves as identified during the valve exercising program.
- Transmission Main Replacement – A program is recommended to replace the City's transmission mains as needed based on the results of the transmission main assessment/inspection program.
- Meter Replacement – The larger commercial water meters are old and inaccurate according to City staff. It is recommended that they be replaced.
- Filter Surveillance Program – It is recommended that filter surveillance be conducted every three years (or one filter per year) to facilitate knowledge transfer among operations staff and evaluate process issues and remedies related to filter media, underdrains, and operations.
- Storage Tank Cleaning and Inspections – Both interior and exterior inspections are recommended to ensure the storage tank's physical integrity, security, and water quality every five years. Cleaning should be conducted based on the findings of the inspections.
- Enterprise Asset Management (EAM) – EAM systems facilitate work planning, execution, reporting, and system analysis. The City's Infor EAM system should be assessed, and work processes updated to leverage the full capabilities of the system.
- Comprehensive Asset Management Program – This program promotes preventative maintenance and scheduled replacement of each asset based on condition and criticality. The results are an evolving prioritized plan for asset renewal, system upgrades and operations and maintenance (O&M) activities to minimize risk.
- Program Management – The recommended programs and projects will require dedicated resources to manage the scope, budget, and schedule of implementation.
- Construction Management – The recommended programs and projects will require dedicated resources to manage schedule, cost, quality and safety of the construction contracts.

The following lists the Long-Range Programs recommended for Englewood's water system:

- Water Loss Control Study – Performing a water loss control study is the first step in developing a comprehensive water loss control program. Audits help determine the extent of water lost in the distribution system due to leakage, unauthorized consumption and meter failures.

- Advanced Metering Infrastructure (AMI) – AMI enables the frequent and detailed measurement of water consumption for each meter. A business case analysis is recommended to assess the costs and benefits of transition to an AMI system.
- Water Master Plan and Water Model Update – Models and Master Plans are intended to be adaptive and evolving tools for long-term planning. They should be updated periodically based on system changes and evolving needs/priorities.

Capital Improvement Program Budget Estimate

The projected cost of the programs and individual capital improvement projects for the entire water system is estimated to be approximately $161 million over the next 15 years, based on 2020 dollars. **Table ES-1** summarizes the budgeted costs for all recommended programs and projects.

Table ES-1: Budget Summary of Recommended CIP Programs and Projects

Category	15-Year Budget Cost[1]
Projects – High Priority	$13,000,000
Projects – Medium Priority	$10,000,000
Projects – Long-Range	$41,900,000
Programs – High Priority	$14,600,000
Programs – Medium Priority	$53,800,000
Programs – Long-Range	$7,500,000
Lead Service Lines	$20,000,000
Total	**$160,800,000**

[1]Program costs include a Class 5 contingency of 30 percent.

The CIP schedule is based on beginning implementation in 2020 but is dependent on available funding followed by other critical path factors including, but not limited to: study, design, permitting, construction, and program management activities and durations. A detailed, one-page sheet has been developed for each program and each project describing the recommendations, costs, schedule, and assumptions. Program and project sheets are provided in **Appendices I** through **L**.

1. Introduction

The City of Englewood, Colorado (City or Englewood) is a community located south of Denver. The City is generally bounded by Denver to the north, Cherry Hills Village to the east, Littleton to the south, and Sheridan to the west. The City spans just under seven square miles.

The City's water system consists of a surface water treatment facility and distribution system that serves over 30,000 people throughout the City. The City owns and operates the Charles Allen Water Treatment Plant (Allen WTP) located in the southcentral service area of the distribution system. The water distribution system includes three different pressure zones to provide acceptable pressures at various ground elevations. The distribution system contains approximately 166 miles of pipe ranging from 4 to 36 inches in diameter, 3,031 system valves, 660 fire hydrants and 11,005 water service connections.

1.1 Scope and Purpose

The City of Englewood has chosen to initiate a comprehensive Water Master Plan for their water system. In September 2019, the City selected Hazen and Sawyer (Hazen) and our teammate Bai Engineers (Bai) to develop the Water Master Plan (Plan). This report establishes an initial Master Plan for the City's water system, providing an overall evaluation of the system and an understanding of existing and future needs. The scope of this study included the following tasks:

- Reviewed existing information available for the source water collection and transmission, treatment, distribution, pumping and storage systems (**Appendix A**)
- Developed a GIS-based water model for distribution pipelines 8-inches in diameter and larger
- Determined current demands and calibrated the water model
- Input future water demands into the model assuming a uniform three percent increase in demands across the water system by year 2030
- Performed hydraulic assessments using the water model under baseline and future demands
- Developed system deficiency criteria and identified deficiencies for baseline and future demands
- Performed a desktop condition assessment on water transmission mains 18-inches in diameter and larger and a limited visual condition assessment on pump stations
- Completed Allen WTP unit process performance assessment and condition review
- Identified programs to address capital and operations and maintenance (O&M) needs
- Identified capital projects to address system deficiencies and needs
- Prioritized recommended programs and projects through workshops with City staff
- Developed cost estimates for prioritized programs and projects
- Recommended a 15-year Capital Improvement Plan (CIP)

The purpose of this Plan is to serve as a guiding document for the City to:

- Increase water system reliability
- Assess system adequacy
- Improve operational efficiency, and
- Effectively allocate funds and resources for implementation of recommended programs and capital projects.

The utility master planning process must be continual and comprehensive so that the Water System Master Plan remains updated. The Master Plan is to be kept up to date by incorporating supplemental studies that are adopted between updates of the Master Plan. The Master Plan itself should be updated every five years.

The City is also conducting a Water Rights Study as a separate effort in parallel with the Water System Master Plan. As a result, this Plan does not address the City's supply resources or water rights status. For CIP budget planning, the City has provided a budget allowance for mountain-area source water capital projects that are planned for the next few years.

2. Existing Water System

The City of Englewood treated water system consists of a surface water treatment facility and distribution system that serves over 30,000 people throughout the City. The City owns and operates the Allen WTP that is primarily supplied by the South Platte River. The plant has a current design capacity of 28 million gallons per day (mgd). The plant uses conventional treatment to meet drinking water standards. The water distribution system consists of three pressure zones, two high-service pump stations (HSPSs) located at the Allen WTP, two booster stations, and three storage tanks. An overview of the City of Englewood water system is shown in **Figure 2-1**.

2.1 Supply

The Allen WTP obtains most of its surface water from the South Platte River, which is located west of the treatment facility. The Union Avenue Pump Station delivers source water from the South Platte River to the Allen WTP. The McLellan Pump Station moves water from the Chatfield Reservoir to the McLellan Reservoir, Englewood's water storage facility in the south metro area. Water from the McLellan Reservoir is then delivered by City Ditch to an 80 million gallon (MG) capacity source water storage reservoir located north of the treatment facility (North Reservoir). The City Ditch consists of elevated flumes, earthen canals, and underground pipelines.

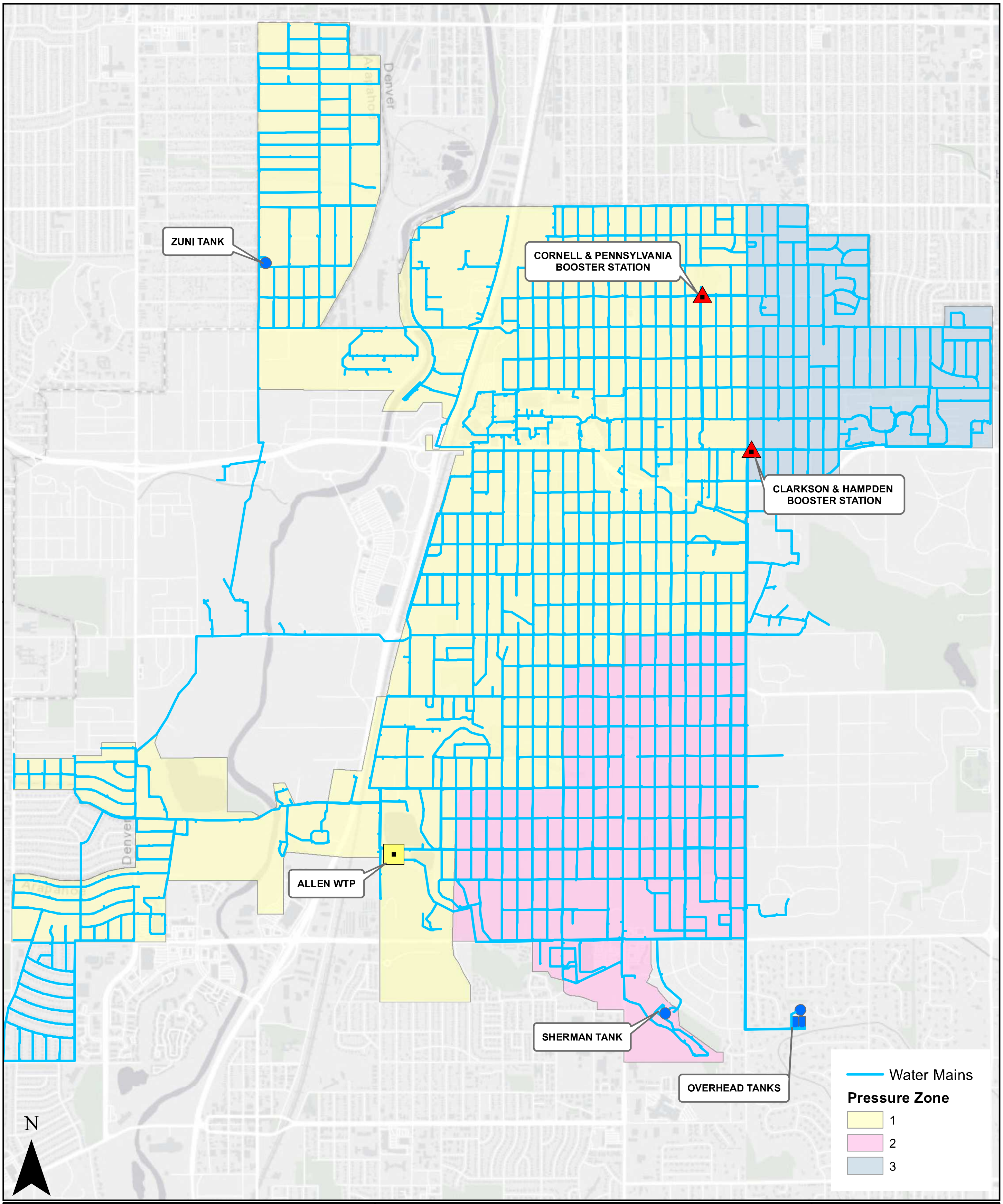

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FIGURE 2-1: ENGLEWOOD WATER SYSTEM OVERVIEW

2,600 1,300 0
1 Inch = 2,584 Feet

DATE: MAY 2020

2.2 Allen WTP

An overview of the Allen WTP is shown in **Figure 2-2**. The Allen WTP uses coagulation, flocculation, sedimentation, filtration, and chemical and ultraviolet light disinfection processes. A 14 MG capacity residuals pond (South Reservoir) is located east of the treatment facility to provide storage for residuals generated during the treatment process.

Figure 2-2: Allen WTP Overview

2.3 Distribution System

A schematic of the water distribution system is shown in **Figure 2-3**. The water distribution system includes three different pressure zones to provide acceptable pressures at various ground elevations. Two high service pump stations (HSPSs) located at the Allen WTP and two booster stations located in the distribution system supply water to the various pressure zones. Zone 1 consists of a service area in the western part of the system, which is supplied by the Zone 1 HSPS located at the Allen WTP. The Zone 2 HSPS at the Allen WTP supplies Zone 2, located in a service area in the southeast corner of the system (**Table 2-1**). Booster Station 1 is named the Clarkson and Hampden (C&H) station, and Booster Station 2 is named the Cornell and Pennsylvania (C&P) station (**Table 2-2**). Each booster station pumps water from Zone 1 to Zone 3, which is located in the northeast area of the system. The system also includes three storage tanks: the Zuni Tank, which is located on the northwestern edge of Zone 1, and the Overhead and Sherman Tanks, which are located on the southern edge of Zone 2 (**Table 2-3**).

Under typical operations, Zone 1 and Zone 2 are not connected, and Zone 3 is supplied from booster stations in Zone 1. However, there is an existing interconnection between Zones 1 and 2 at the Allen WTP that can be used. In addition, there are valves on the west side of Clarkson Street that are typically closed, but could be opened to connect the Zone 3 and Zone 1 distribution systems. There are no pressure reducing valves (PRVs) at the existing interconnections between the zones; these existing valves are normally closed.

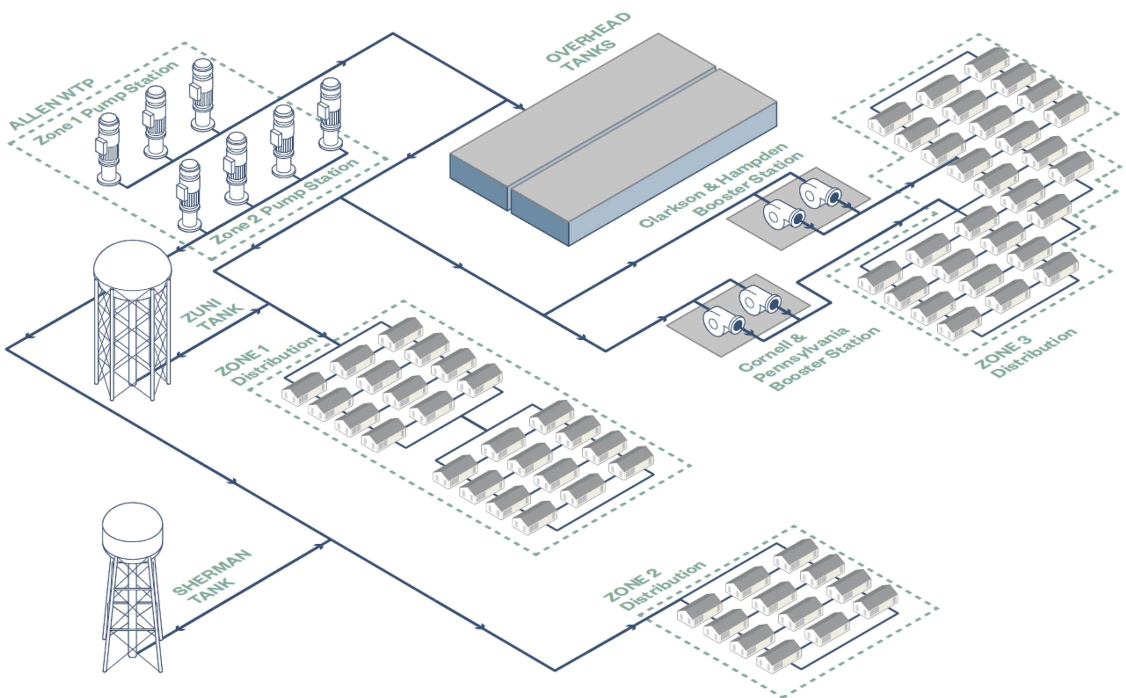

Figure 2-3: Englewood Water Distribution System Schematic

Table 2-1: HSPS Data

Parameters	Zone 1 HSPS	Zone 2 HSPS
Finish Floor Elevation, ft	5,321	5,321
Number of Pumps	3 (450 HP each)	4 total - 2 larger (350 HP each) and 2 smaller (200 HP each)
Installed VFD?	Yes	Yes
SCADA or PLC Control to Tank Level?	No	Yes
Pump Control Methods	Keep Overhead Tank level between 10 and 12. Zuni Tank is always at 22 feet.	Keep Sherman Tank level at 23 feet or 58.2 psi at Pressure Transmitter.

Table 2-2: Booster Station Data

Parameters	Pump-from-Zone	Pump-to-Zone	Pump Data[1]	Finished Floor Elevation, ft
Booster Station 1: Cornell & Pennsylvania	Zone 1	Zone 3	Unavailable.	5,319.90
Booster Station 2: Clarkson & Hampden	Zone 1	Zone 3	Unavailable.	5,345.31

[1]There are two pumps (lead/lag operation) at each booster station.

Table 2-3: Storage Tank Data

Parameters	Zone 1		Zone 2
	Zuni Tank	Overhead Tanks	Sherman Tank
Nominal Capacity, MG	0.5	6.0	0.2
High Water Level Elevation, ft	5,499	5,499	5,575.7
Bottom of Tank Elevation, ft	5,465	5,483.5	5,547
Ground Elevation, ft	5,394.18	5,500.5	5,441.95
Tank Shape	Ellipsoid	Rectangular	Ellipsoid

Figure 2-4 shows a hydraulic profile of the entire distribution system.

The distribution system contains approximately 166 miles of pipe ranging from 4 to 36 inches in diameter, 3,031 system valves, 660 fire hydrants and over 11,000 water service connections. **Figure 2-5** shows the percentages of different pipe materials present in the City's distribution system.

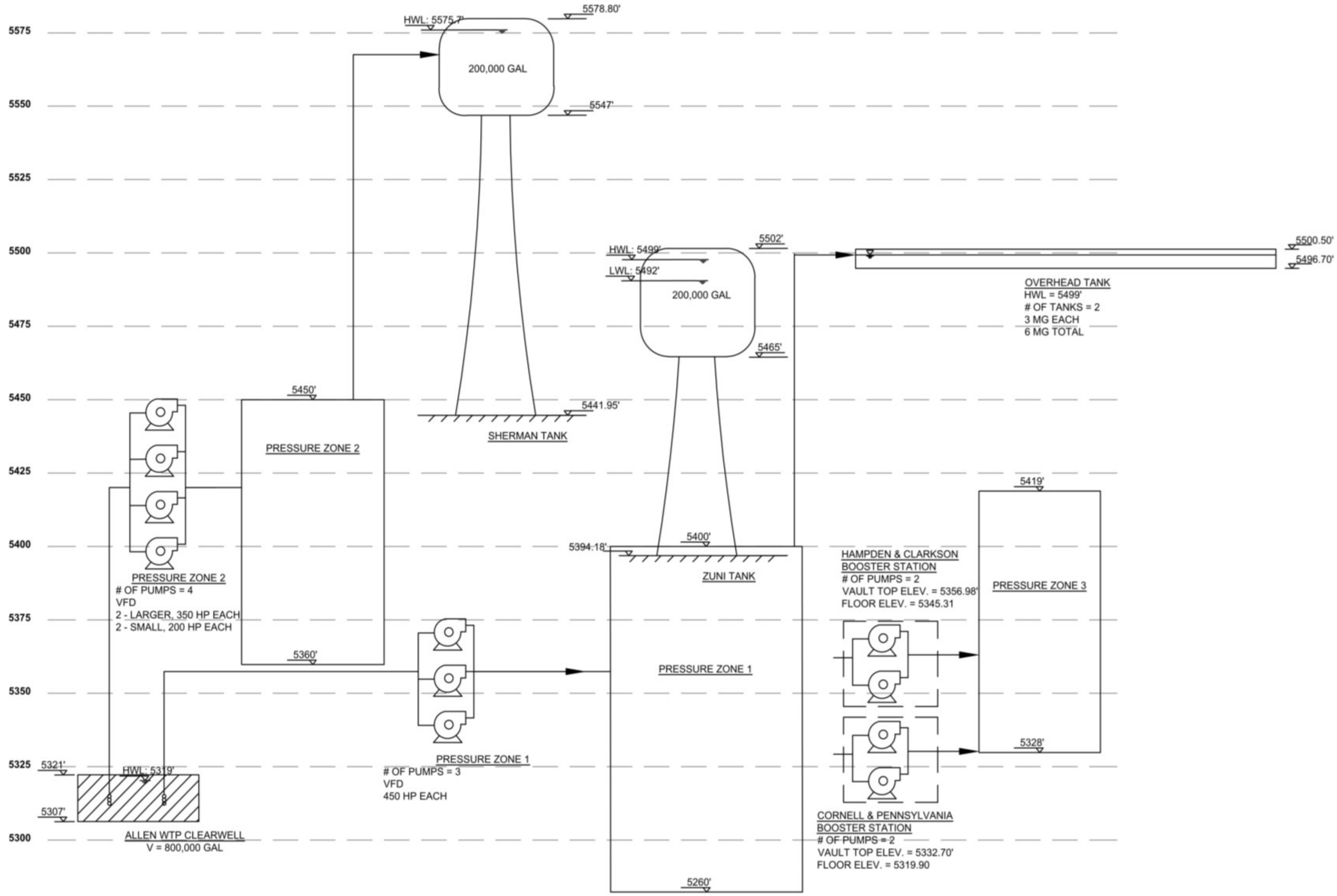

Figure 2-4: Distribution System Hydraulic Profile

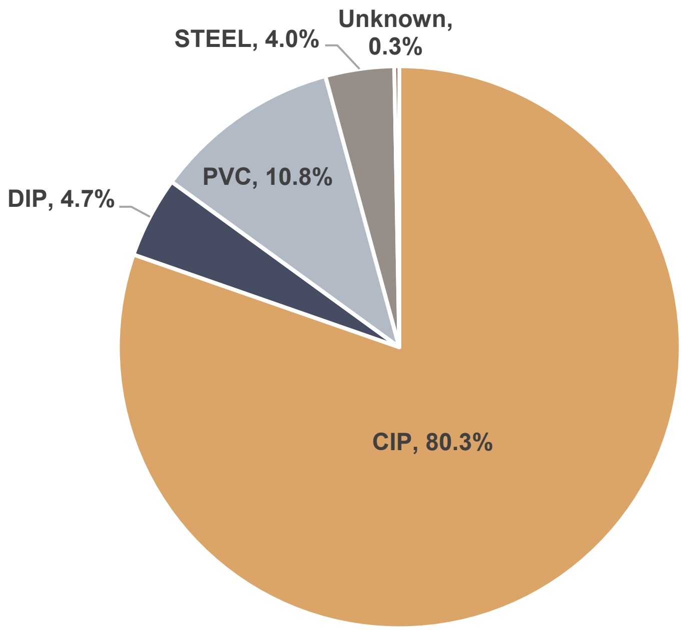

Figure 2-5: Water Main Material Distribution

Table 2-4 and **Figure 2-6** characterize the City's water distribution system by pipe diameters.

Table 2-4: City Water Mains by Pipe Diameter

Pipe Diameter (in)	Length of Water Mains (Miles)	Number of Water Mains
4	35.5	836
6	60.6	3,160
8	24.8	937
10	2.1	95
12	19.3	644
14	3.9	60
16	3.5	55
18	2.9	48
20	1.1	25
24	6.5	83
27	0.9	23
30	1.9	46
36	2.5	30
TOTAL	**165.5**	**6,042**

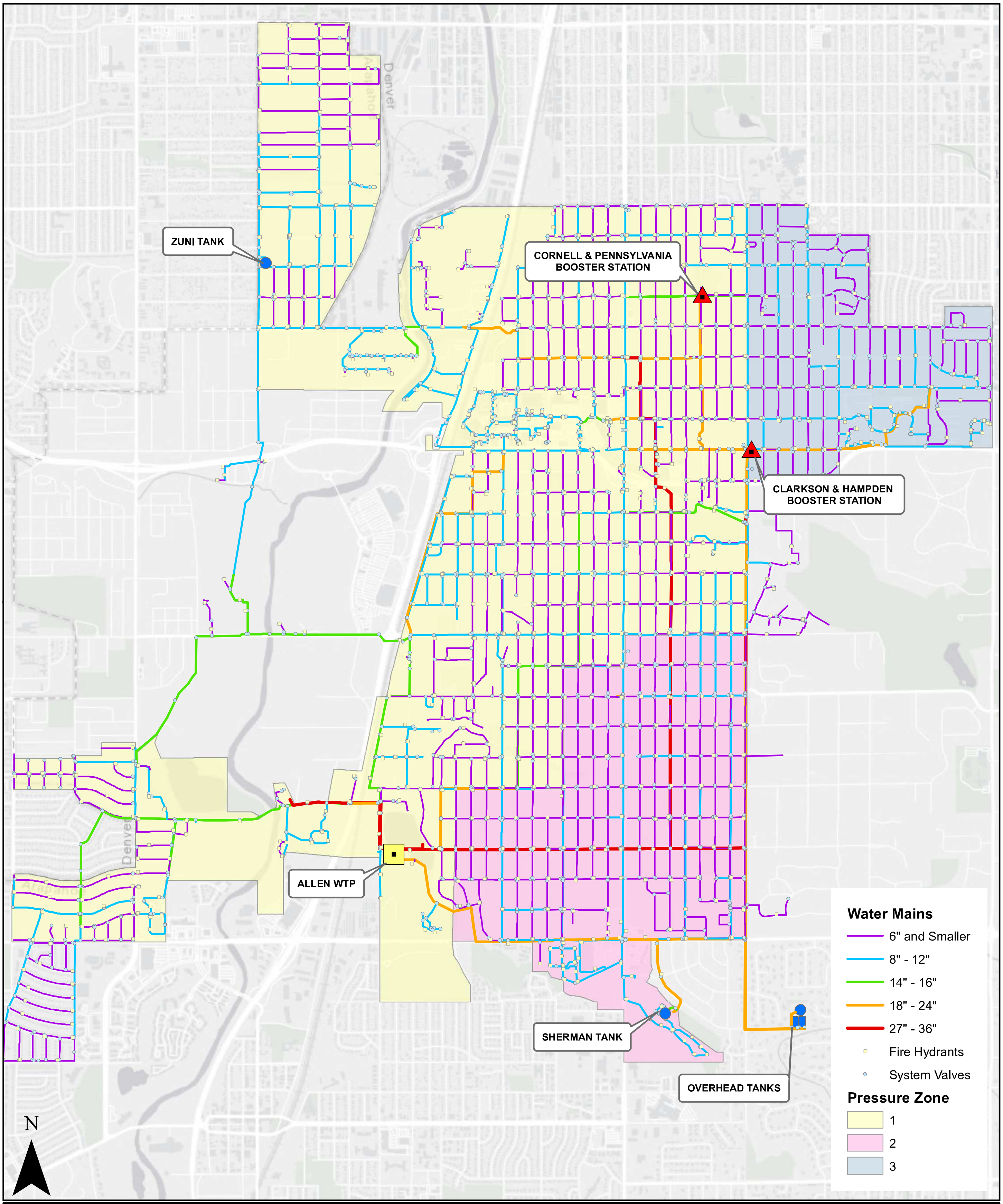

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FIGURE 2-6: WATER DISTRIBUTION SYSTEM MAP

2,600 1,300 0

1 Inch = 2,584 Feet

DATE: MAY 2020

3. Distribution System Hydraulic Model

3.1 Model Overview

A hydraulic model is a computer program that predicts the performance (flows and pressures) of a water distribution system under different demand and/or operating scenarios. Hydraulic models are powerful tools that can be used for evaluating operating conditions, identifying potential hydraulic issues within the system and assessing the impact of future demands. The hydraulic model was developed using Innovyze InfoWater® software version 12.4.

InfoWater was selected for use in modeling the City's water distribution system. InfoWater uses a user-friendly, GIS-based, graphical object-oriented interface from which to develop and execute the model's functions. InfoWater is a water modeling and management software application that performs fast, accurate, reliable simulations to represent the hydraulic behavior of water distribution systems.

3.2 Model Development

3.2.1 Model Input Data Sources

The City provided Hazen with geographical information system (GIS) data, record drawings, water billing records, water production data and SCADA data to build the hydraulic model. **Table 3-1** lists the data used in model development.

Table 3-1: Summary of Data Sources for Model Development

Data	Description
GIS Data	City's water distribution GIS shapefiles received on October 3, 2019
Quadrant Maps	City's water distribution quad maps received on October 3, 2019
Billing Records	Billing records for 8 quarters (November 2017-October 2019) received on November 3,2019
SCADA Data	• Hourly flow data recorded at the Zone 1 and Zone 2 HSPSs from October 17, 2019 to October 23, 2019 • Level data recorded at the three storage tanks • Pressure data recorded at the intersection of Logan Street and Belleview Avenue

3.2.2 Model Network

The InfoWater model includes a network that consists of two primary elements: links (water pipes) and nodes (including pipe junctions, tanks, pumps and other operational elements). The model developed for this Master Plan generally includes water distribution mains 8 inches in diameter and larger, with some smaller mains included for connectivity, as required by the scope for this Plan. **Figure 3-1** illustrates the model network. The model is a subset of the actual distribution system, and as such contains 94 miles of water mains.

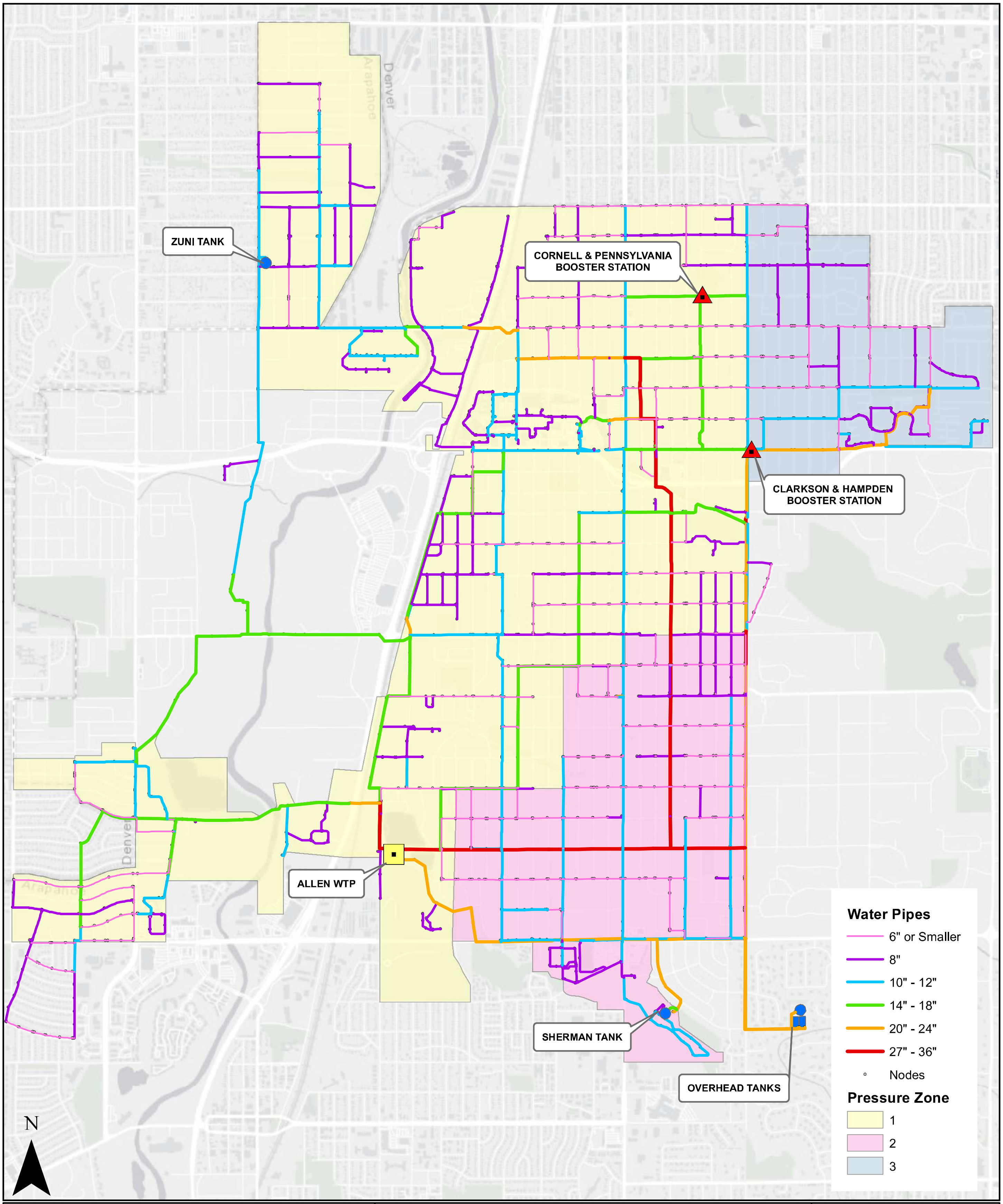

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FIGURE 3-1: WATER MODEL NETWORK

2,600 1,300 0

1 Inch = 2,584 Feet

DATE: MAY 2020

3.2.3 Pipe (Link) Data

Water pipe data required for model calculations consist of pipe size/diameter and lengths. Pipe data was obtained from the City's GIS data. **Table 3-2** summarizes the modeled pipe inventory. Pipe connectivity was examined, and any issues were corrected before finalizing the model network. Disconnections are typically caused by incorrectly joined or missing pipes, disconnected junctions and overlapping pipes. Correcting these issues is necessary to develop an accurate model. The updates to the City's GIS data are described further in the Model-Ready GIS Dataset for Water Network Technical Memorandum in **Appendix B**.

Table 3-2: Modeled Pipe Inventory[1]

Diameter (in)	Length (ft)
6 and smaller	133,642
8	132,493
10	10,992
12	101,827
14	20,733
16	18,386
18	15,540
20	5,674
24	33,988
27	3,415
30	9,597
36	8,939
TOTAL	**495,226**

[1]As discussed in Section 3.2.2, the modeled pipe inventory generally includes water mains 8 inches in diameter and larger, with some smaller mains included for connectivity, as required by the scope for the Plan.

3.2.4 Node Data

The primary functions of a node in a hydraulic model include connecting pipes (links), storing elevation data and allowing water to enter and leave the system. Nodes are also used to represent operational elements such as a tank, pump or valve. Additionally, nodes are required when pipe attributes change such as diameter or material, which impacts hydraulic calculations. These nodes were manually added to the model. Elevations were assigned to model nodes using the City's Digital Elevation Model (DEM).

3.3 Existing Demand Allocation

3.3.1 Billed Water Usage

The City provided billing records from November 2017 to October 2019. Analysis of the billing records identified 9,658 unique metered users over the defined time period. The total billed water usage was determined to be approximately 1.7 billion gallons (BG) and 1.6 BG in 2018 and 2019, respectively, corresponding to an average daily use of 4.64 million gallons per day (mgd) in 2018 and 4.34 mgd in 2019. The 2019 data was used in the model. **Figure 3-2** summarizes the water consumption from billing data.

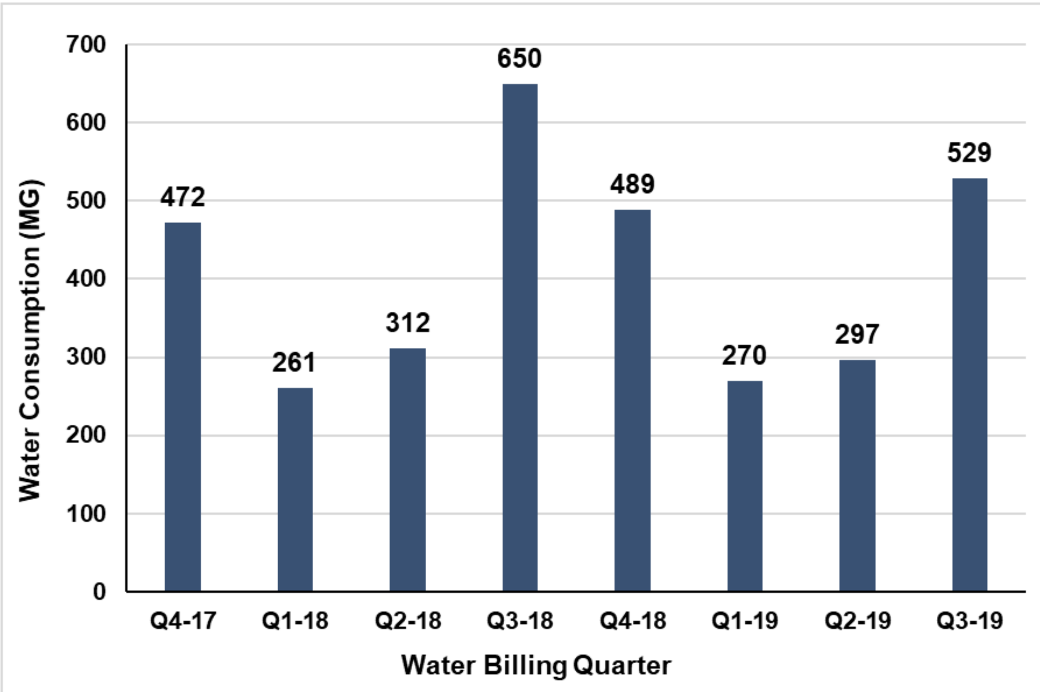

Figure 3-2: Water Consumption from Billing Records

Demand allocation was performed by matching addresses and account numbers from the billing records to those in the City's water service line GIS data. Approximately 94% of the accounts were matched successfully and 3.89 mgd was distributed in the model. Water demand was allocated to each matched service line based on the 2019 billing records. The usage from the remaining 6%, or 603, unmatched accounts was accounted for as part of the non-revenue/non-metered water adjustment (**Section 3.3.3**). The total average demand for these unmatched customers was 0.45 mgd which is approximately 10.4% of the total billed water usage, or 8.7% of the annual average production.

3.3.2 Water Production Data

Water production records from the Allen WTP were obtained from January 1, 2018 to November 19, 2019. An average of 6.11 mgd and 5.12 mgd was supplied to the system in 2018 and 2019, respectively. The 2019 water production data was compared with the billing records to determine non-revenue/non-metered water, which is the difference between billed, metered consumption and the water delivered to the system. In 2019, non-revenue/non-metered water totaled 0.78 mgd. This represents approximately 15.2% of the total water supplied to the system. Non-revenue/non-metered water often includes lost water due to leakage, unmetered flat rate billing accounts, flushing activities, unauthorized consumption, meter failures, and water used for firefighting.

3.3.3 Demand Summary

The 2019 billing and water production records were used for the model. The average daily demand for the whole system is 5.12 mgd. The initial demand allocation of 3.89 mgd in the model was adjusted by distributing an additional 1.23 mgd proportionally to each demand location to account for the unmatched accounts and the non-revenue/non-metered water.

Approximately 85% of the water supplied to the system was sold to residential/commercial customers with 13.2% of that to the top ten commercial users. **Figure 3-3** summarizes the distribution of the water production.

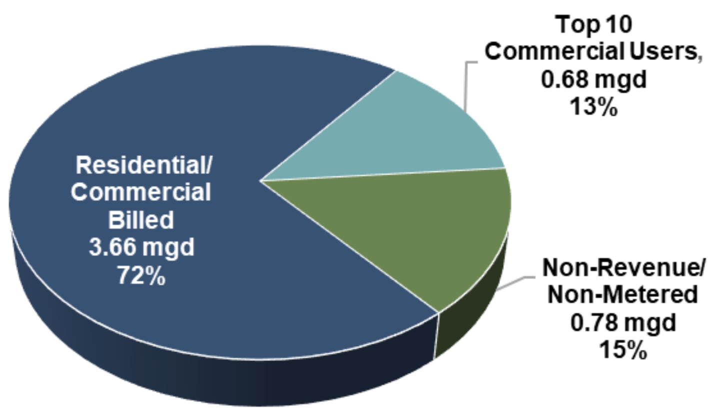

Figure 3-3: Distribution of Water Production

Maximum day demand represents the day with the highest total demand during the year, which for the City occurred in August in 2019. The minimum day demand represents the day with the lowest total demand during the year, which for the City occurred in January in 2019. The total production data between November 2018 and October 2019 is presented in **Figure 3-4.**

As discussed previously, the 2019 production data was utilized for the baseline existing demand calculations. A detailed analysis of billing and production records and demand allocation is presented in the Water Demand Determination and Allocation Technical Memorandum in **Appendix C**.

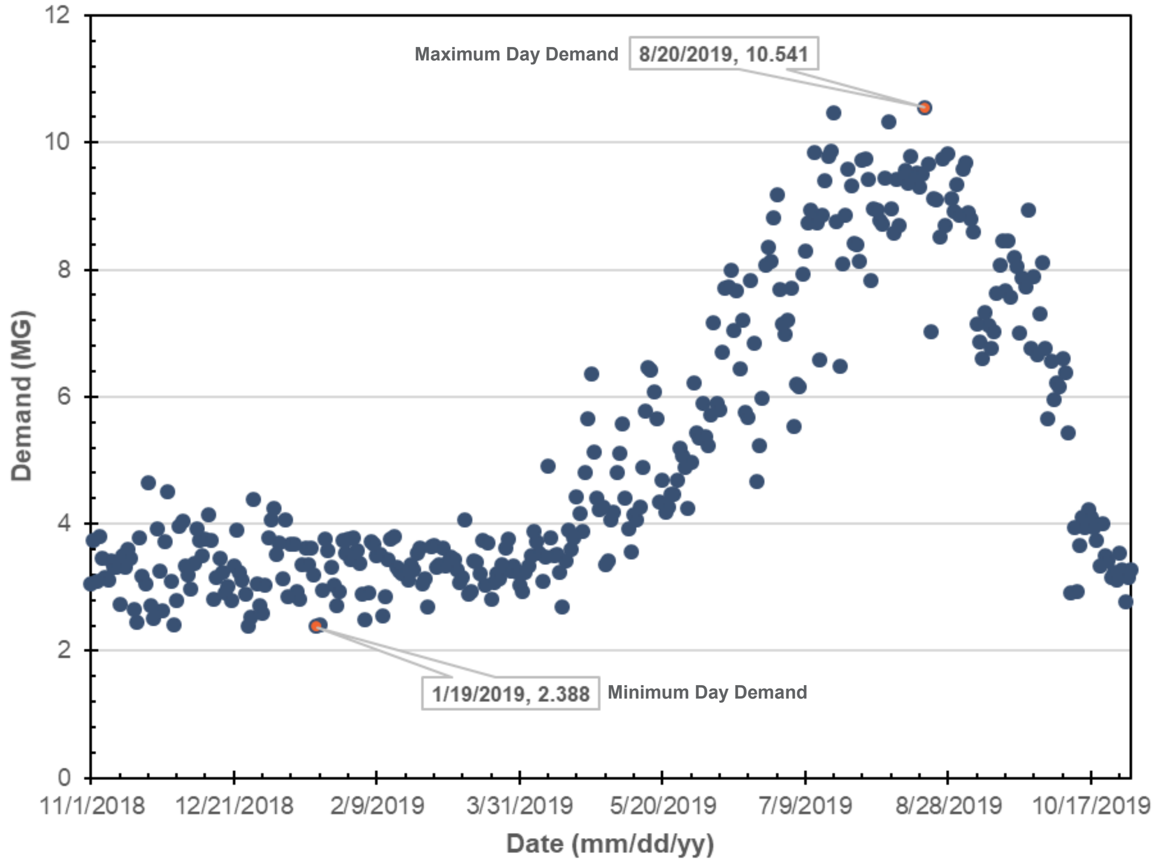

Figure 3-4: Production Data for November 2018 – October 2019

Based on the production data, the estimated total per capita water use is currently 150 gpcd (**Table 3-3**). These values are slightly higher than Denver Water's current overall per capita use of about 140 gpcd.

Table 3-3: Englewood Estimated Average Per Capita Water Demand by Year

Year	Demand (gpcd)
2009	149
2010	172
2011	163
2012	172
2013	146
2014	155
2015	139
2016	146
2017	151
2018	158
2019	150

3.4 Diurnal Demand Pattern

Water demand diurnal patterns for Zone 1 (plus Zone 3) and Zone 2 were determined using SCADA data from the Allen WTP and the three storage tanks. The demand for Zone 1 and Zone 3 equals the water supplied to Zone 1 plus the discharge from Zuni Tank and the discharge from the Overhead Tanks. The Zone 2 demand is the water supplied to Zone 2 and the discharge from Sherman Tank. **Figure 3-5** shows the diurnal patterns for the three pressure zones. Water demands also vary throughout the year due to seasonal changes in weather and population. Peaking factors are used to capture the high and low demand conditions for analysis purposes. The diurnal curves help determine the peak hour demand factors. The peak hour demand factor for Zones 1 and 3 is 1.6 and for Zone 2 it is 1.25. The more conservative factor of 1.6 was used in the model to reflect daily variation in demand and operations.

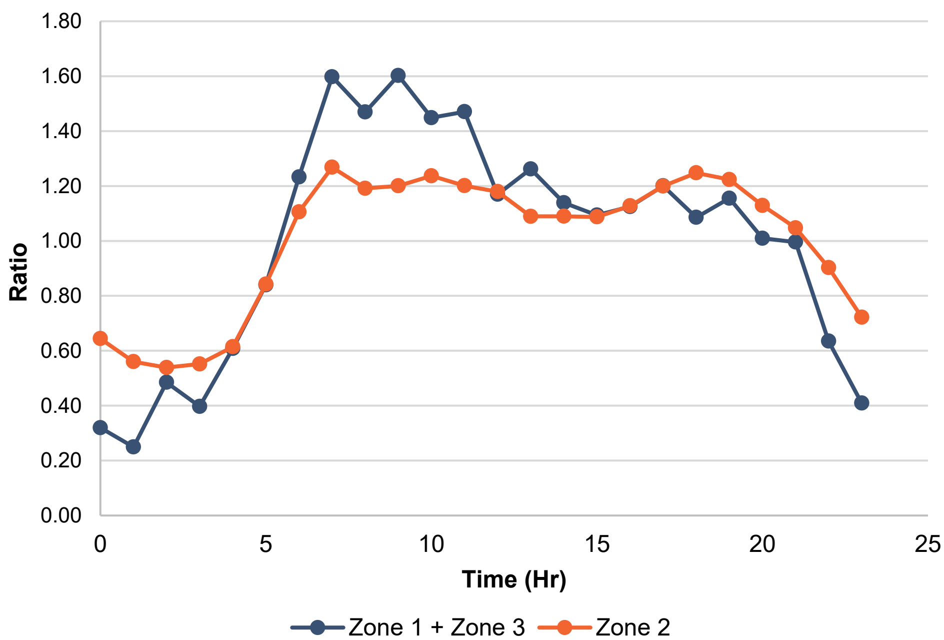

Figure 3-5: Water Demand Diurnal Curves

3.5 Model Verification and Calibration

Calibration is performed by comparing the model's predictions with measured data and adjusting the model to obtain agreement within reasonable tolerances. Calibration often uncovers distribution system problems such as closed valves or anomalies in input data such as GIS errors. Calibration helps ensure the model's accuracy. Calibration is typically performed by comparing the results of the model simulations to actual field data such as measured pressures, flow rates and tank water levels. Due to critical information such as pump curves, pump set points, valve settings, and tank control valve settings not being available, the model calibration was limited. However, a preliminary attempt to verify some model inputs is documented in this report. Additional details on the model calibration are provided in the Water Hydraulic Model Calibration Technical Memorandum in **Appendix D**.

3.5.1 Extended Period Simulation (EPS) Calibration

The model was calibrated by running an extended period simulation (EPS) and comparing the predicted tank levels from the model to the water levels recorded by the City' SCADA system. SCADA flow data for Monday, October 18, 2019 was used for this calibration (**Figure 3-6**). A global multiplier of 0.7676 was used on all demand nodes to reduce the average demand in the nodes (determined from annual billing records) to match production data from October 18, 2019.

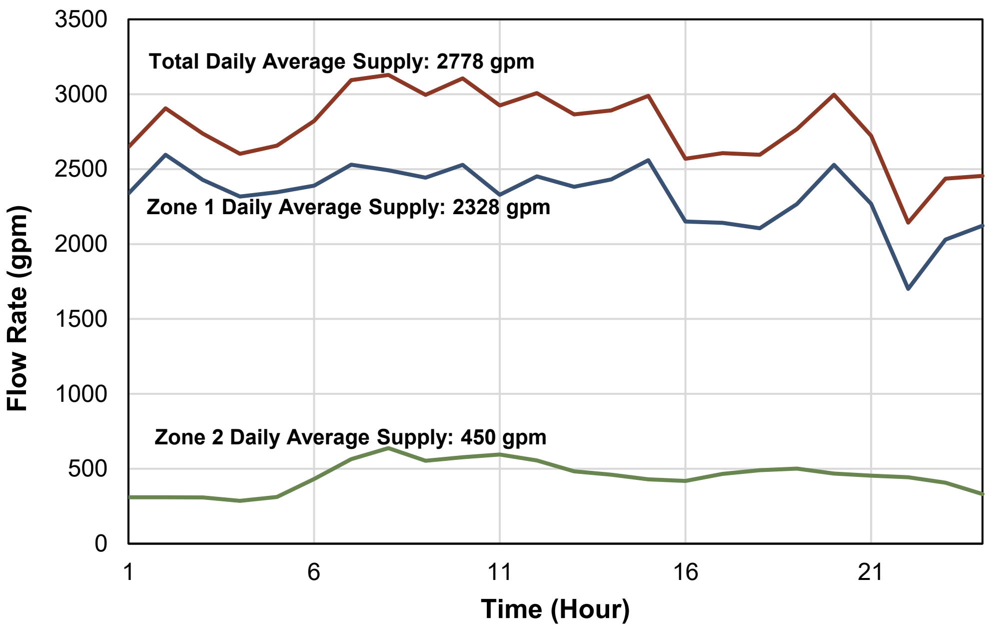

Figure 3-6: Water Demand Used for Calibration (Date: 10/18/2019)

The initial comparison of the model to SCADA data revealed the following:

- SCADA data shows that the water level in Sherman Tank (Zone 2) remains unchanged during normal operation. This indicates there is no tank filling or draining cycle. It appears the City operates the Zone 2 high service pumps to constantly match the demand on an hourly basis. This should be confirmed as an absence of cycling could cause a degradation of water quality. See **Section 4.8.2** for additional discussion of operational recommendations for the storage tanks.
- The model-predicted tank levels for Zuni Tank (Zone 1) were approximately 7 feet higher than SCADA data. SCADA data does not show any tank water level variations with diurnal demands. This implies that the tank is hydraulically isolated from the system, but the model was not reflecting this operation. The model was adjusted by adding an altitude control valve set to close at 22.1 feet to match actual operations.
- A valve was closed at the intersection of Washington Street and Layton Avenue. The model was adjusted to match the existing valve status in the system.

Pump curve information was not available for the Zone 1 and 2 high service pumps. Therefore, two alternative methodologies were tested for the EPS calibration: modeling the HSPSs as two junctions being assigned with negative water supply (negative inflow setting) and modeling the HSPSs as reservoirs with pressure reducing valves (PRVs). Calibration results showed that the best way to represent actual conditions was to model the Zone 1 HSPS as a reservoir with PRV and to model the Zone 2 HSPS with the negative inflow setting. This hybrid approach provided the best results possible given the limited data available. Results of the calibration are shown in **Figure 3-7** through **Figure 3-10.**

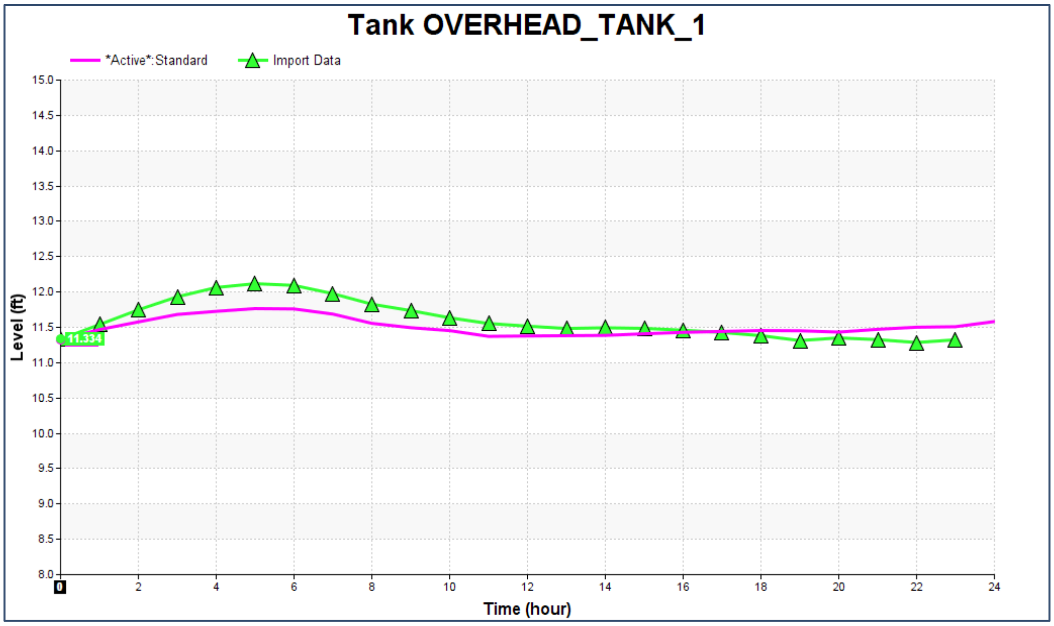

Figure 3-7: Modeled Overhead Tank (Zone 1) Level Compared to SCADA

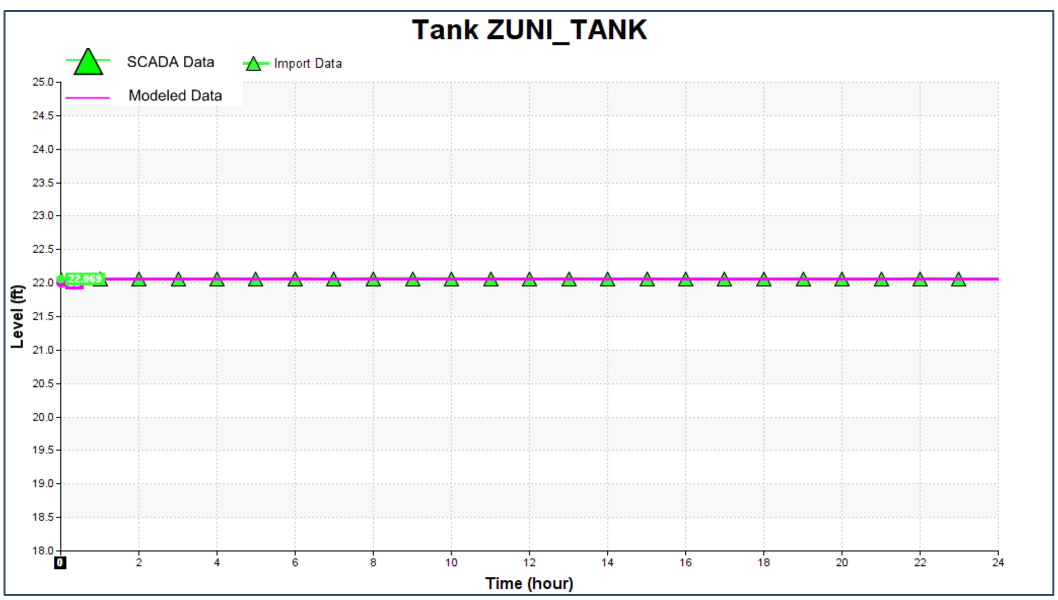

Figure 3-8: Modeled Zuni Tank (Zone 1+3) Level Compared to SCADA

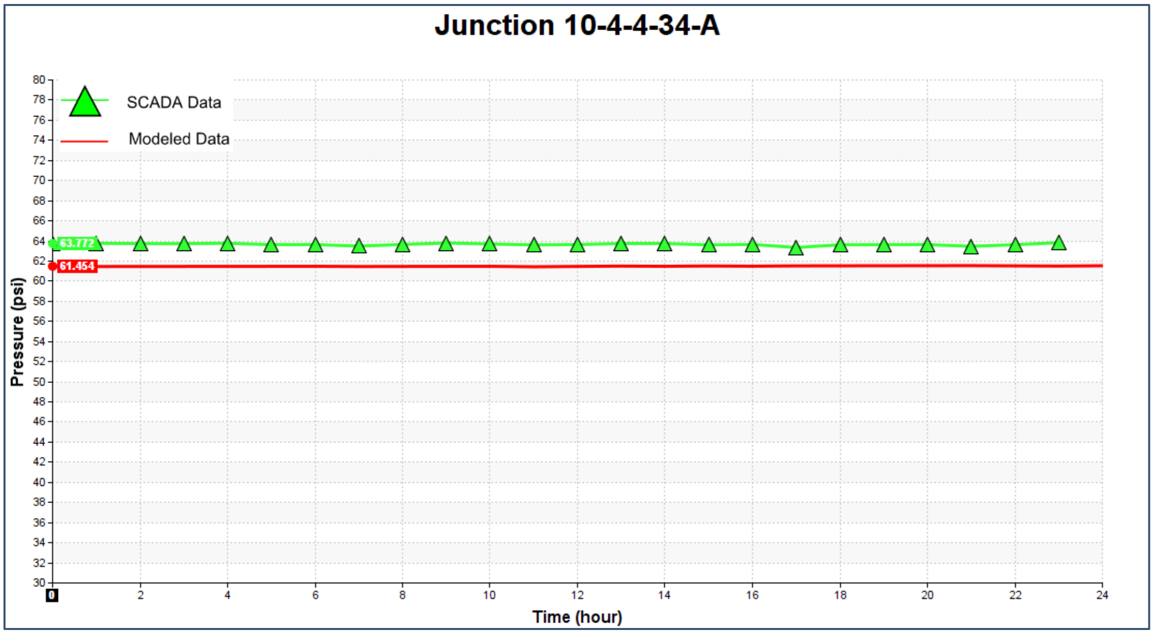

Figure 3-9: Modeled Pressure at Logan and Belleview (Zone 2) Compared to SCADA

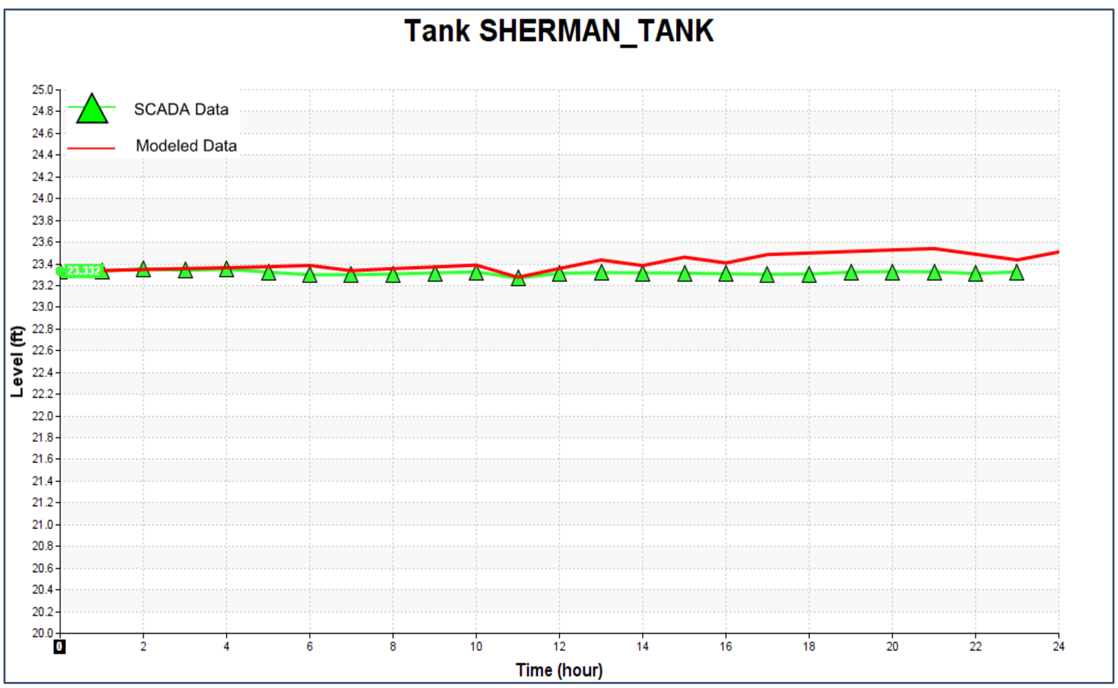

Figure 3-10: Modeled Sherman Tank (Zone 2) Level Compared to SCADA

4. Distribution System Hydraulic Evaluation

The distribution system model was used to conduct various hydraulic assessments (storage capacity, velocities, pressures) and identify system deficiencies under existing and future water demand conditions.

4.1 Storage Capacity

AWWA M32 Manual – Computer Modeling of Water Distribution Systems provides guidelines on storage criteria to support normal and emergency system operation. The manual identifies the following three primary storage components:

- Equalization Storage: Amount of water required to meet demands in excess of normal production and delivery capabilities.
- Fire Storage: Volume of water based on the maximum fire flow requirement in each pressure zone.
- Emergency Storage: Amount of storage necessary to provide water during emergency events such as facilities failures or power outages.

A summary of the storage capacity required for each zone is given in **Table 4-1**.

Table 4-1: Required Storage Criteria

Component	Description	Storage Capacity Required	
		Zone 1 and 3	Zone 2
Equalization	Volume of water supplied above the average daily demand	0.37 MG	0.08 MG
Fire	Two Hours of 2,000 gpm	0.24 MG	0.24 MG
Emergency	24 hours of average daily flow	4.16 MG	0.75 MG
	TOTAL	**4.77 MG**	**1.07 MG**

The storage capacity analysis indicates that there is a deficit of storage in the Zone 2 pressure zone, while there is adequate storage in Zones 1 and 3. A summary of the storage capacity analysis is presented in **Table 4-2**. Additional details on the storage tank capacity evaluation are provided in the Water System Operation Data Technical Memorandum in **Appendix E**.

Table 4-2: Storage Capacity Summary

Component	Zone 1 and 3	Zone 2
	Overhead and Zuni Tanks	Sherman Tank
Storage Required (MG)	4.77	1.07
Storage Available (MG)	6.50	0.20
Criterion Met?	Yes, surplus of 1.73 MG	No, deficit of -0.87 MG

The overall water distribution system was found to have adequate storage based on the specified storage requirements in **Table 4-1**. However, Zone 2 has a storage deficit of approximately 0.9 MG. A new storage tank for Zone 2 is included in the recommended water distribution system projects (**Section 8.1.4**).

4.2 Demand Projections

As required by the scope for this Master Plan, the demand projections for the capacity evaluation are based on assumed uniform three percent increase in demands across the water system by year 2030.

4.3 Performance Criteria

The criteria used to assess the adequacy of the City's distribution system relative to pressures and velocities are described in the following paragraphs. Additional details on the performance criteria and system evaluation are provided in the Water Distribution System Analysis Technical Memorandum in **Appendix F**.

4.3.1 Pressure Assessment Criteria

The goal of the water distribution system is to provide the necessary water demand while maintaining acceptable minimum pressures. Excessive pressures increase non-revenue water and can negatively impact household plumbing. The purpose of analyzing system pressures is to ensure that certain minimum standards are maintained to protect public health and provide ample pressure at hydrants for fire protection. The pressure criteria used to assess the City's system is summarized in **Table 4-3**.

Table 4-3: Pressure Criteria[1]

Category	Criteria
Minimum Operating Pressure	40 psi
Maximum Operating Pressure	100 psi

[1]Criteria were selected during a workshop with City staff on 1/9/20. Design criteria from neighboring municipalities, including Denver Water and Castle Rock, were used in development of this criteria

4.3.2 Pipeline Velocity Criteria

Pipeline internal velocity limitations help improve system life by limiting damage to internal coatings and gaskets and reducing water hammer and also help improve system efficiency by limiting energy losses. Excessive velocities can indicate inefficient system design or operations due to aging pipes and partially closed of fully closed valves. The velocity criteria used is listed in **Table 4-4**.

Table 4-4: Velocity Criteria[1]

Category	Criteria
Maximum Pipe Velocity, Peak Hourly Demand (PHD)	10 fps
Maximum Pipe Velocity, Maximum Day Demand (MDD)	5 fps

[1]Criteria were selected during a workshop with City staff on 1/9/20. Design criteria from neighboring municipalities, including Denver Water and Castle Rock, were used in development of this criteria

4.4 Velocity Analysis

No pipeline deficiencies were identified under existing or future demand conditions. All velocities were less than 5 feet per second (fps). Future demand conditions, however, did not include the intense redevelopment on-going in certain parts of the City which might lead to pipeline deficiencies or impacts to velocities, residual pressures, etc. This needs to be included as the next logical step for evaluating and improving the water distribution system as discussed in **Section 4.7.2**.

4.5 Pressure Analysis

Maximum pressures were evaluated by running a steady-state simulation of average daily demand (5.12 mgd). Minimum pressures were evaluated with a steady-state simulation at peak hour demand (16.8 mgd). **Figure 4-1** through **Figure 4-4** show model-predicted pressure results from both simulations for both existing and future demand conditions. Little difference was observed in pressures and velocities between existing and future demand conditions.

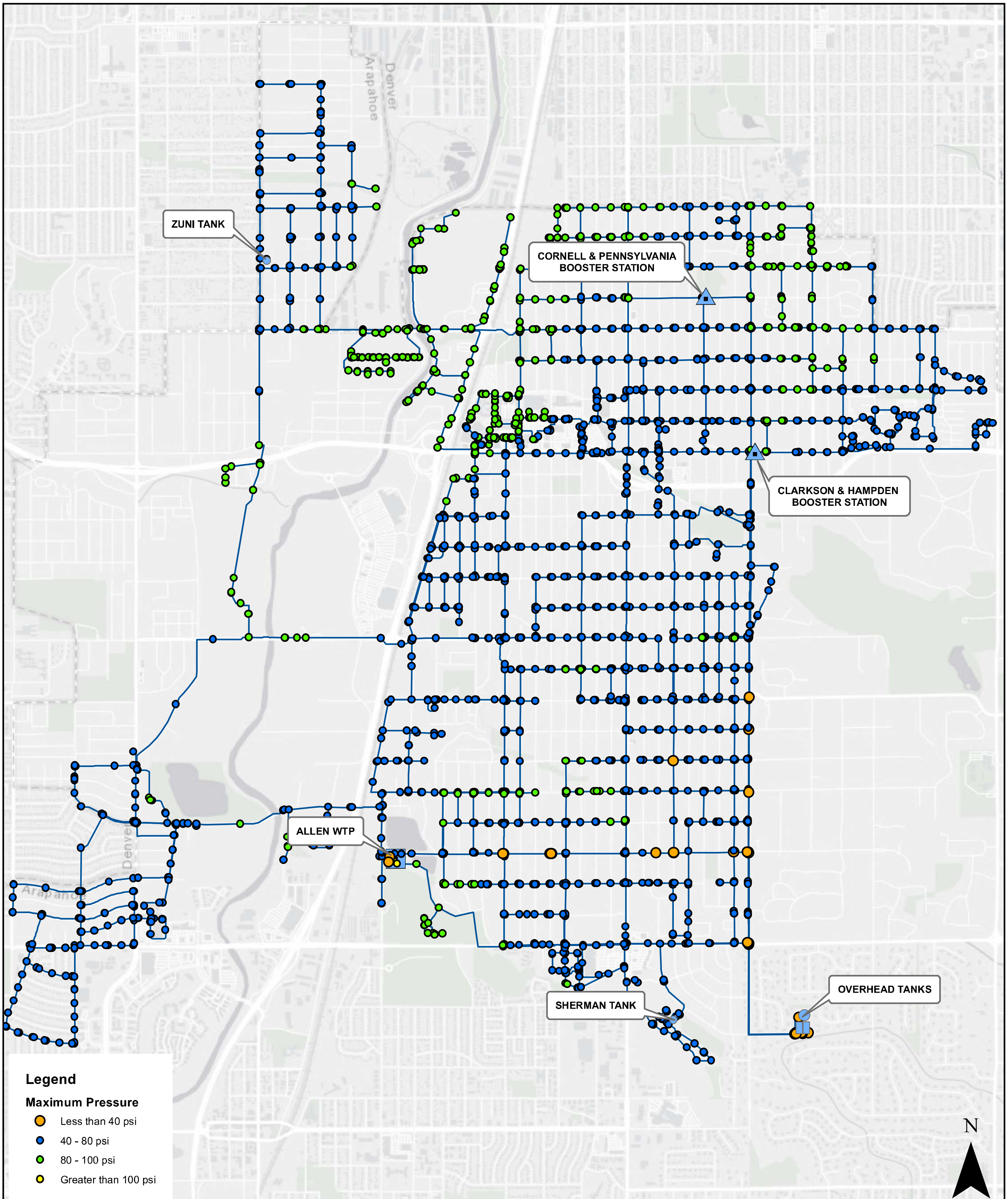

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FIGURE 4-1: MODEL-PREDICTED AVERAGE DAY MAXIMUM PRESSURES - EXISTING DEMANDS

2,600 1,300 0

1 Inch = 2,584 Feet

DATE: MAY 2020

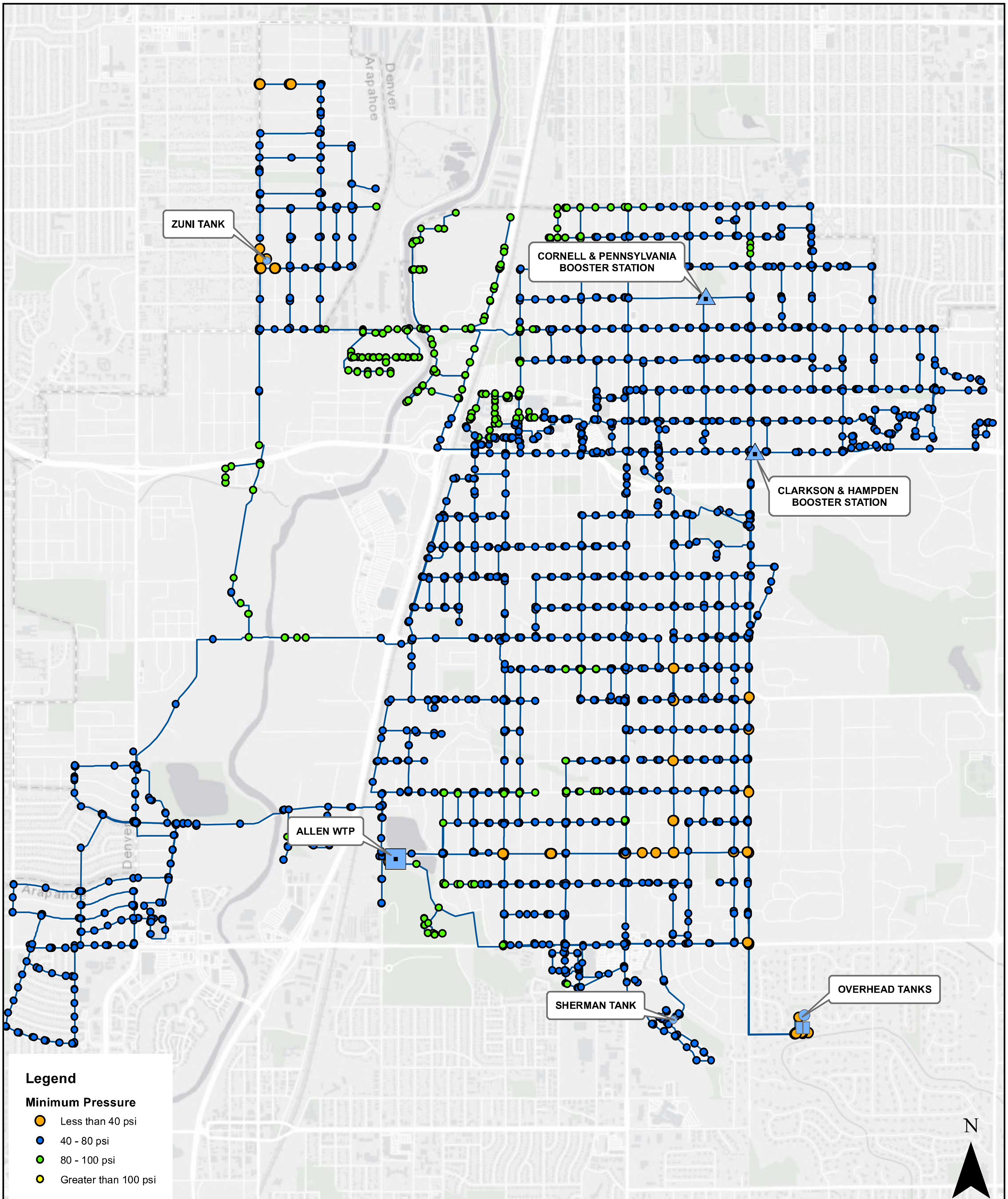

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FIGURE 4-2: MODEL-PREDICTED PEAK HOUR MINIMUM PRESSURES - EXISTING DEMANDS

2,600 1,300 0

1 Inch = 2,584 Feet

DATE: MAY 2020

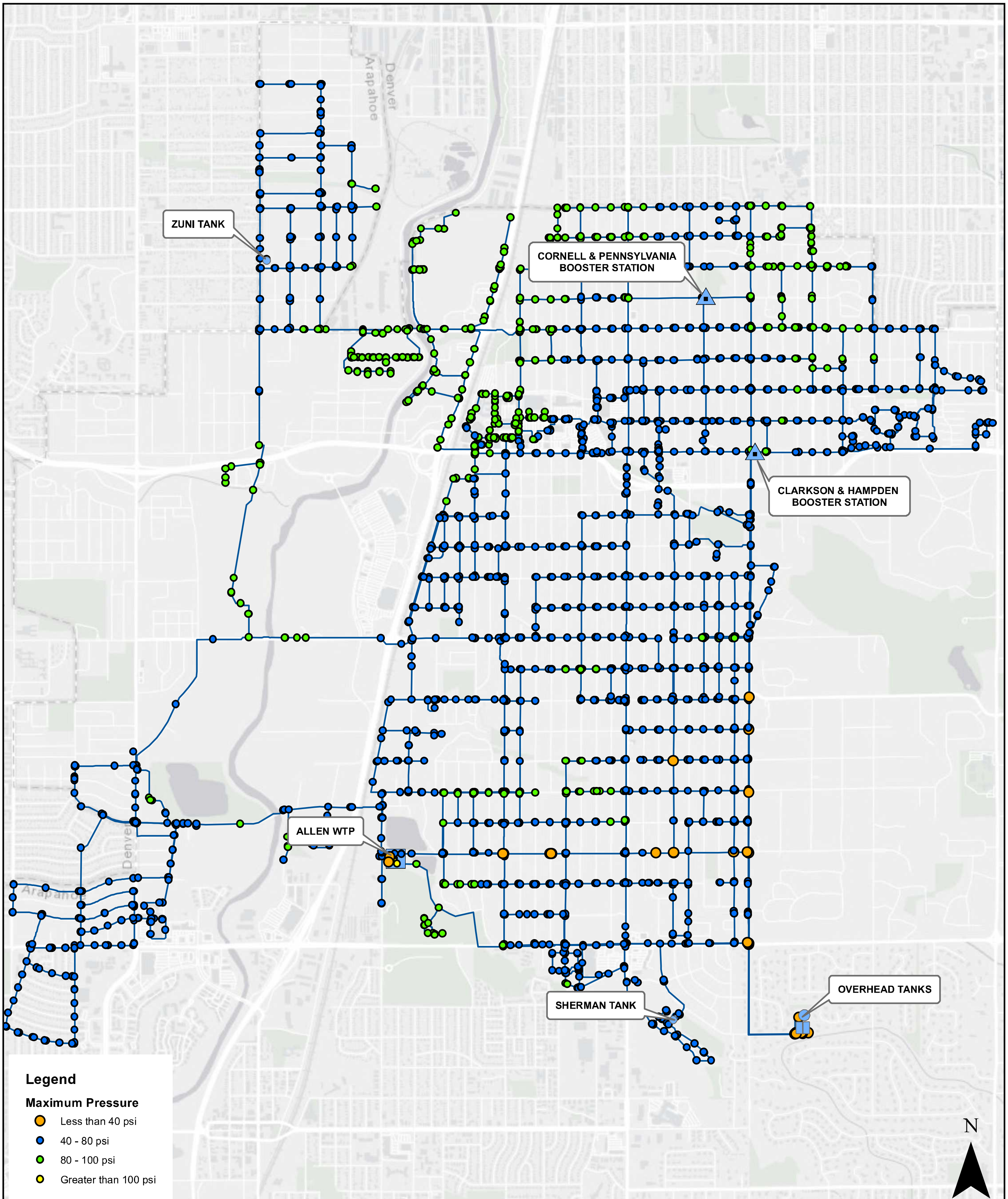

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FIGURE 4-3: MODEL-PREDICTED AVERAGE DAY MAXIMUM PRESSURES - FUTURE DEMANDS

2,600 1,300 0

1 Inch = 2,584 Feet

DATE: MAY 2020

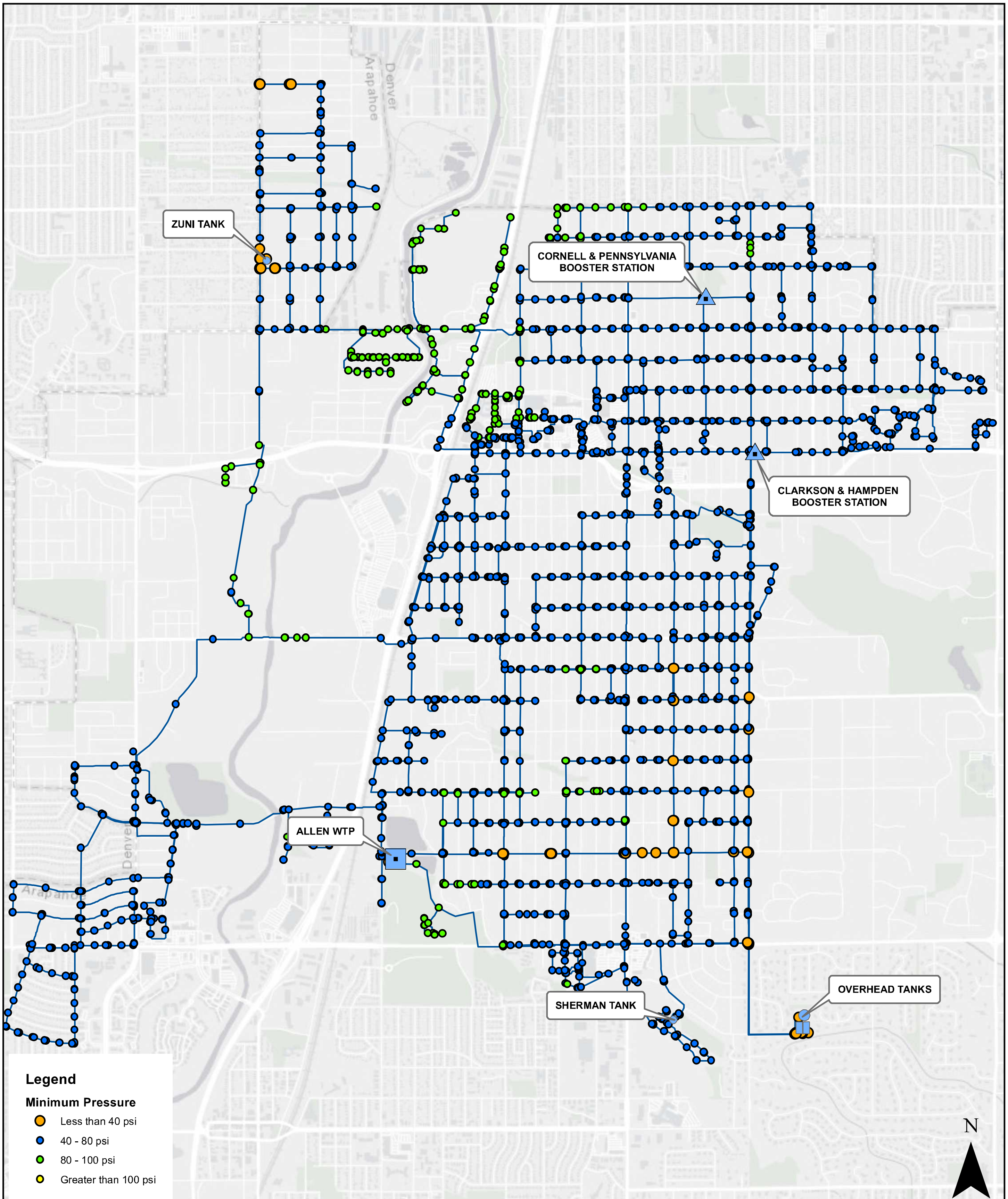

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FIGURE 4-4: MODEL-PREDICTED PEAK HOUR MINIMUM PRESSURES - FUTURE DEMANDS

2,600 1,300 0

1 Inch = 2,584 Feet

DATE: MAY 2020

Model simulations indicate that the majority of the system operates within the recommended operating range of 40 to 100 psi. The only model predicted pressures above 100 psi are located at the Allen WTP. Under the minimum pressure evaluation most of the system is operating above 40 psi. As shown in **Figure 4-1** through **Figure 4-4**, there are a number of locations below 40 psi during average day and peak hour demands. However, none of these locations have a minimum pressure below 20 psi. The majority of these low pressures are located on transmission mains that do not have any customer connections. The low pressures are transmission system pressures not zone pressures. Therefore, based on the model simulations completed, pressures within the water system are acceptable. Areas of lower pressure based on the modeling could be field verified or compared with customer low pressure complaints to further assess the system.

4.6 Model Limitations

Pump stations are boundary conditions in hydraulic models. Without accurate inputs on boundary conditions, confidence in model predictions is limited. Understanding and simulating the high service pumps and the booster pumps will significantly improve the accuracy of the model results going forward. Additional information about the operation of the system will also help refine results.

Additionally, EPS calibration does not include any stress on the piping system to observe potential head loss. Further calibration by inducing head loss internally would also improve model accuracy.

4.7 Model Refinement Recommendations

The model is highly limited by the availability and quality of the data used to build and hydraulically calibrate the model. The following recommendations will help enhance the distribution model and enable a more accurate calibration.

4.7.1 Field Tests

Distribution system tests investigate the condition of the existing system. These tests serve several purposes. The tests produce input data needed for the hydraulic model and provide field measurements for model calibration. The tests also check for unusual conditions such as closed valves or GIS errors. The following field tests are recommended in order to update and re-calibrate the hydraulic model to obtain more confidence in hydraulic model predictions.

- Pump Tests: The intent of a pump test is to obtain a specific curve for each pump in the distribution system so that they can be accurately reflected in the hydraulic model.
- Hydraulic Grade Line Tests: Obtain calibration information for large transmission mains connecting the most important components of the distribution system. The hydraulic grade line (HGL) is the change in hydraulic grade with distance. HGL tests are performed by installing pressure gauges and logging systems at fire hydrants. These pressure measurements are then used to develop hydraulic gradients for comparison to model predictions.

- Hydrant Flow Tests: Flow tests assess localized hydraulic model calibration at particular test locations. Multiple hydrant flow tests should be performed covering the entire geography of the distribution system.
- Remote Pressure Sensors: Consider remote pressure sensors at various locations in the distribution system to validate model performance.

4.7.2 Future Demand Analysis

Accurate population projections are required to adequately estimate future demands. Population change is primarily influenced by birth rates, mortality rates, immigration patterns and economic changes. Although population is affected by these factors, projections can be made based on historical trends, future land use and development plans. For the purposes of this Master Plan, a population increase of 3 percent was assumed by year 2030 as required by the Plan's scope. Englewood's population has remained relatively flat over the last 40 years; however, more recent vertical development has resulted in increased population density and potential for population growth. It is recommended that the City perform a more in-depth population projection for the entire water service area and update the hydraulic model.

4.8 Operational Recommendations

4.8.1 Pump Stations

As discussed previously, pump curves were not available for any of the pump stations. Flow data from SCADA was only available for the high service pump stations. It is recommended that the City add pressure sensors on the suction side and flow meters to the discharge side of the pumps. Based on conversations with the City, the Cornell and Pennsylvania (C&P) pump station hardly runs. The Clarkson and Hampden (C&H) pump station is at a higher elevation on the hydraulic profile of the system and therefore C&H supplies the water to Zone 3. The City should consider either alternating the pump stations' usage or decommissioning the C&P pump station after further hydraulic analysis and as part of a distribution system operations optimization study (see **Section 8.1.2**).

4.8.2 Storage Tanks

To prevent water quality problems in the distribution system, water turnover in the storage tanks should be improved. The model can be used to test different pumping scenarios for tank turnover and their impact on water age. The model could also be used to test different locations for additional storage (per **Section 4.1**), including impacts on hydraulics and water age. This work should be performed as part of the distribution system operations optimization study (see **Section 8.1.2**).

5. Allen WTP Evaluation

This section presents a summary of the Allen WTP treatment process performance and general condition. Source water supply and water rights are currently being evaluated by others[1] and were not evaluated as part of this Water System Master Plan; however, an overview of the source water supplies is presented below for background.

5.1 Water Sources

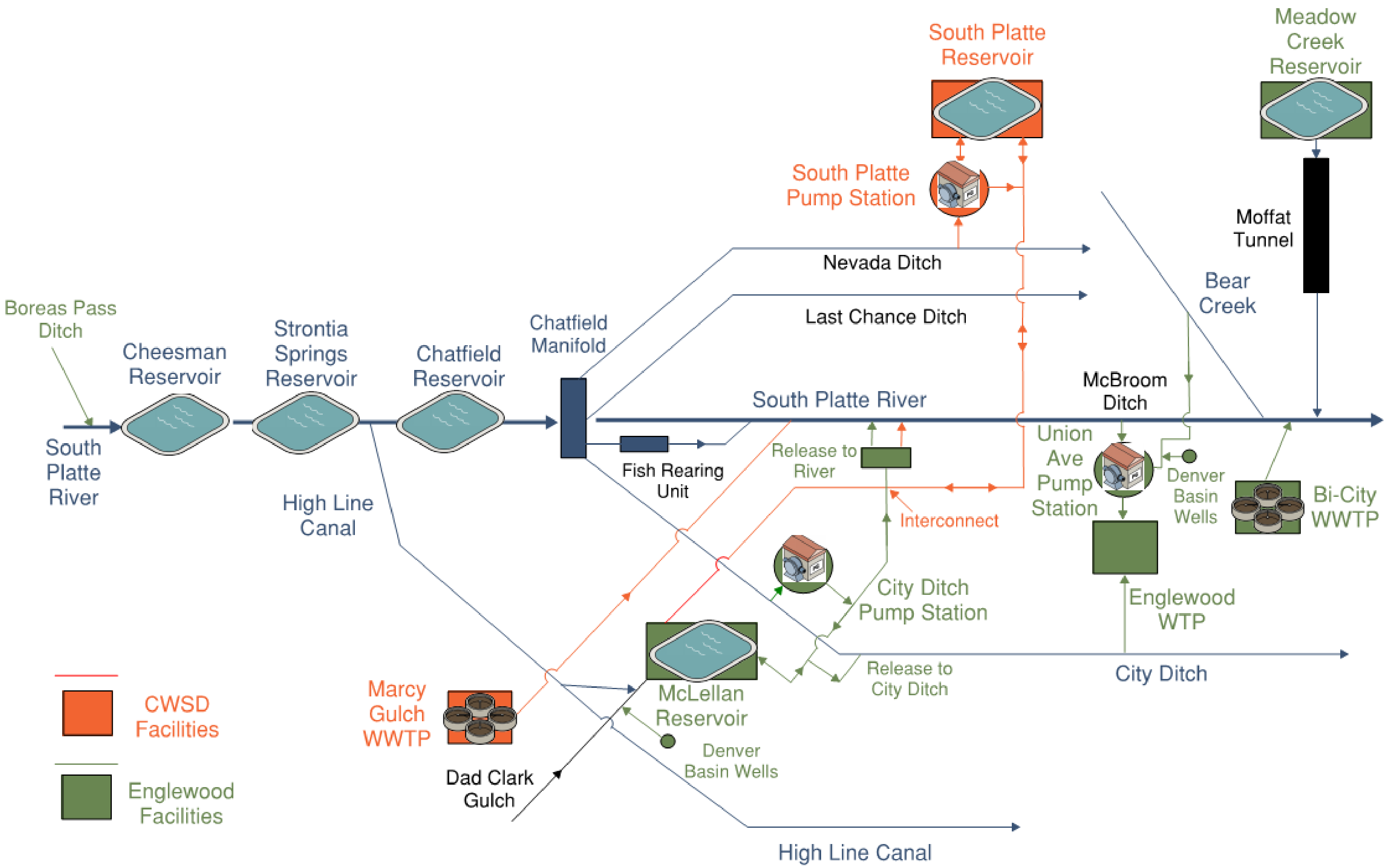
The South Platte River diversion at the Union Avenue Pump Station provides most of the supply to the Allen WTP. The remainder comes from Chatfield Reservoir through City Ditch and water diverted from Bear Creek to the Union Avenue Pump Station. An overview of the water sources and facilities, as provided by the City, is provided in **Figure 5-1** with a descriptive summary in **Table 5-1**.

5.1.1 Big Dry Creek Diversion Project

Water in Big Dry Creek has approximately twice the hardness of the South Platte River above Big Dry Creek. The increased hardness in the South Platte River below Big Dry Creek adversely affects water quality at the intake at the Union Avenue Pump Station. Big Dry Creek also contains elevated concentrations of uranium that is measured for regulatory purposes as gross alpha emitting particles. The City evaluated the Diversion of Big Dry Creek around the Union Avenue Pump Station source water intake as a raw water management practice to reduce gross alpha entering the Allen WTP. The analysis resulting in a planned project that diverts the Big Dry Creek flow to a point on the South Platte River below the intake for the Union Avenue Pump Station, via a small dam, intake structure, and 21-inch pipeline.

Regulatory approval for this project has been granted according to the City and this project is in the 2020 budget at $750,000.

[1] Martin and Wood, 2020



Human Health and Risk Assessment and Evaluation of Residuals Management, Integral Consulting, 12 June 2017, page 109

Figure 5-1: Allen WTP Source Water System Overview

Table 5-1: Water Sources and Systems Serving the Allen WTP

Source / System	Description	Operation
Union Avenue Pump Station	Located below the confluence of Big Dry Creek with the South Platte River.	South Platte River water is diverted to a forebay. Three centrifugal pumps feed water to the Allen WTP and/or the North Reservoir. Activated carbon and permanganate are periodically fed at this facility.
Chatfield Reservoir	350,000 acre-feet reservoir located on the South Platte River south of the City. The City does not have water storage rights in Chatfield Reservoir.	The City has rights to water diverted from Boreas Pass that flows down the South Platte River and through Chatfield Reservoir to the City Ditch.
Bear Creek	Originates at Summit Lake near Mount Evans and flows into the South Platte River just south of Denver.	Water from Bear Creek is conveyed to the Union Avenue Pump Station through the McBroom Ditch and pipeline.
McLellan Pump Station (City Ditch Pump Station) and Reservoir System	Source water conveyance and storage for South Platte River rights. System owned by Englewood and has a storage capacity of 5,940 acre-feet. Reservoir can be fed from four sources including Dad Clark Gulch, City Ditch, Nevada Ditch, and the High Line Canal.	The City of Englewood leases 3,900 acre-feet of storage (60 percent of capacity) in McLellan Reservoir to the Centennial Water and Sanitation District (CWSD). Water is pumped from either the City Ditch or South Platte Reservoir.
Dad Clark Gulch	Flows directly into McLellan Reservoir.	See McLellan Reservoir operation. Englewood does not have rights for this water.
City Ditch	Owned by the City and provides a portion of the drinking water supply for the City and irrigation supply for Denver. The City Ditch also supplies water to other users along the route.	Water from Chatfield Reservoir is supplied through the City Ditch, which flows by gravity north on the west side of Santa Fe Drive and crosses the highway before flowing along the east side of the Allen WTP site.
Nevada Ditch	Water from the Nevada Ditch is diverted into South Platte Reservoir and is subsequently transferred to McLellan Reservoir by the CWSD.	See McLellan Reservoir operation.
High Line Canal	Dirt-lined 600 cfs canal owned and operated by Denver Water.	Denver Water operates the canal intermittently between April and October with average flow around 100 cfs.
Big Dry Creek	The City's raw water intake at the Union Avenue Pump Station is located below the confluence of Big Dry Creek with the South Platte River (See Section 5.1.1 for more).	See Union Avenue Pump Station operation.

5.2 Plant Production

The Allen WTP currently produces approximately 10 to 11 mgd for the City during peak water demand days in the summer. Annual average water production is approximately 5 to 6 mgd (**Figure 5-2**). As shown, the WTP has historically operated well below its design capacity of 28 mgd and the slightly decreasing demand over time is representative of national demand trends. Based on historical production data, if significant plant improvements are identified for the Allen WTP in the future, the City could consider de-rating the facility to reduce improvement costs.

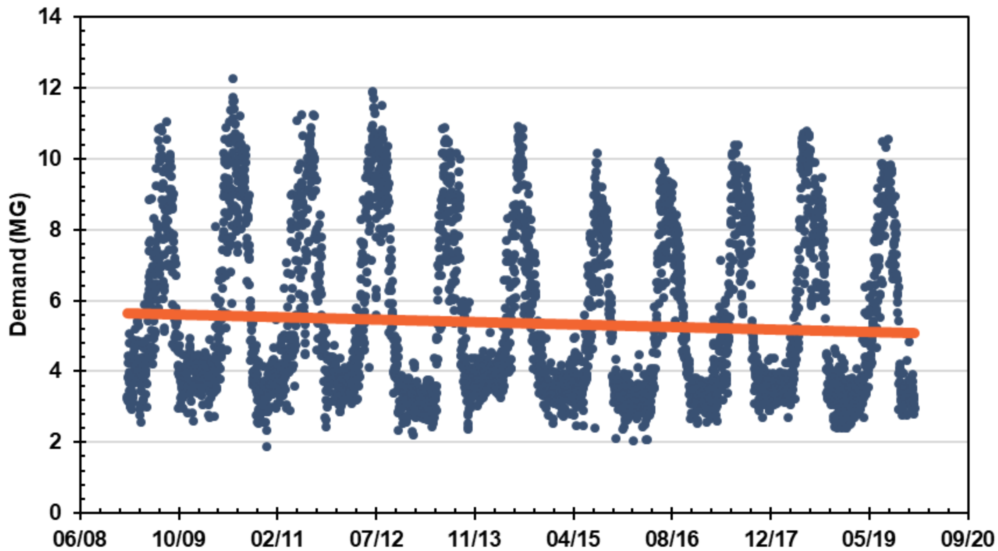


Figure 5-2: Allen WTP Demand Data (2009 to 2019)

5.3 Facility Improvements

The treatment processes used at the Allen WTP currently consists of flocculation-sedimentation followed by granular media filtration, UV disinfection, and chloramination, as illustrated in **Figure 5-3**. The facility has two parallel flocculation-sedimentation basins and five dual-media filters with a rated capacity of 28 mgd. The Allen WTP has undergone several process upgrades since it was built in 1951. Facility improvements that have occurred over time are summarized in **Table 5-2**.

5.4 Assessment Approach

The Allen WTP assessment included:

1. **Unit process capacity** summary that was compared to CDPHE design guidelines.
2. **Site visits** that were conducted with operations staff to appreciate the plant history and current condition of major process equipment, understand routine monitoring practices, and identify available drawings and records.
3. **Program and project** recommendations for the Allen WTP were identified for the CIP.

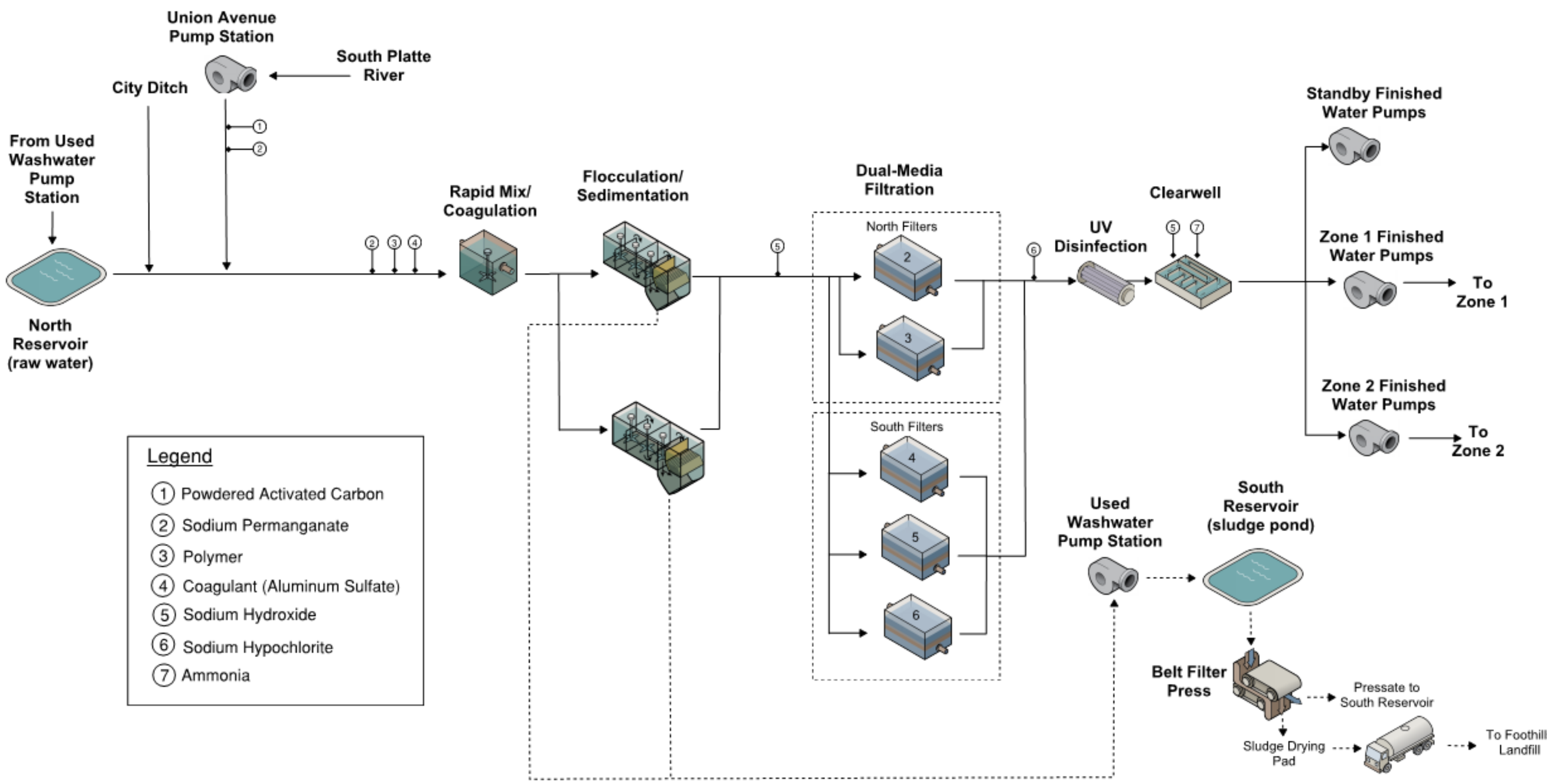


Figure 5-3: Allen WTP Process Flow Diagram

Table 5-2: Allen WTP and Union Avenue Pump Station Improvements

Year	Major Allen WTP Upgrades
1951	• Allen WTP built as 16 mgd lime-softening facility with two sedimentation basins, dual media filters, and a 14 MG raw water reservoir. • All sludge produced in the sedimentation basins and all backwash water discharged directly to Big Dry Creek.
1953	• 80 MG reservoir constructed.
1978, 1979	• Filter building extension • Clearwell addition • Finished water pump station addition • Backwash pump station constructed to return backwash water and sedimentation basin sludge to the 14 MG pond which was converted to the backwash pond. • Settled water from backwash pond decanted to the North 80 MG reservoir.
1980	• Plant converted to direct filtration. • Sedimentation basins and mixing tanks bypassed. • Increased treatment capacity to approximately 34 mgd.
1989	• Residuals dewatering facility constructed with belt filter press. • Hydraulic dredge mounted on floating barge installed in 80 MG reservoir.
1997	• City Ditch turnout structure • Union Avenue Pump Station improvements including modified intake screen and the addition of a potassium permanganate feed facility. • Two flocculation-sedimentation basins constructed with new lamella plate settlers, longitudinal effluent launders, and Trac-Vac sludge collectors. • Chlorine contact clearwell baffling and miscellaneous concrete repairs • South Reservoir outlet and baffle curtain wall • Blower and dewatering buildings • Sludge drying bed adjacent to dewatering building
2001	• Filters 1 – 5: Replaced filter underdrain support system and filter media.
2002	• Addition of aqua ammonia feed system
2003	• PAC feed building and aqua ammonia system improvements
2012	• UV disinfection system installed

5.5 Unit Process Capacity

Major unit processes were evaluated to determine their potential to achieve desired levels of performance during periods of design flow (28 mgd). The objective of this evaluation was to identify significant deficiencies in process performance with respect to basin size and unit process capacity. If the capacity for any unit process is insufficient to meet design flow requirements, the City should first consider modifications to these processes to avoid the need for major capital improvements.

The major unit processes evaluated were flocculation, sedimentation, filtration, and disinfection. **Table 5-3** provides a summary of the major unit processes evaluated and the criteria utilized to rate each process. The plant's design specifications were used to determine unit process capacities.

Table 5-3: Major Unit Process Criteria

Unit Process	Description	Criteria
Flocculation	Raw water flows by gravity from the North Reservoir or is pumped from the Union Avenue Pump Station into two parallel basins. Each basin has three tapered flocculation zones separated by baffle walls. Each flocculation zone contains one horizontal paddle wheel mixer (three mixers per train).	• All basins in service • Type: Mechanical turbines, 3 stages • Paddles per basin = 2 • Number of basins = 2 • Volume per basin = 208,000 gal • HDT (at design flow) = 20 min
Sedimentation	Flocculated suspended and colloidal solids settle in these basins via plate settlers. Both basins are normally operated in parallel. MRI Tracvac sludge collectors remove the settled solids. The sludge collectors operate intermittently (typically 4x/day for 1hr). Residuals are pumped to the South reservoir.	• All basins in service • Type: Lamella plate settlers • Number of basins = 2 • Volume per basin = 269,600 gal • SOR (at design flow) = 3 gpm/sf • HDT (at design flow) = 27.7 min
Filtration	5 dual media filters consisting of sand and granular activated carbon (GAC) operate at a constant flow rate with increasing head. Filter backwash is initiated when the water surface elevation reaches the high-level control point in each filter, when the headloss setpoint is reached, or after a filter run of 120 hrs. Waste backwash water is conveyed via gravity to the Used Washwater Pump Station, then is pumped to the South Reservoir.	• 4 of 5 filters in service • Type: dual-media, gravity • Surface area per filter = 900 sq. ft. • HLR = 3.9 gpm/sf (at design flow - North filters 2 & 3) • HLR = 5.4 gpm/sf (at design flow - South filters 3, 4 & 5)
Disinfection	Filtered water is disinfected with UV light followed by chlorine contact and chloramination for residual in the distribution system. Three parallel UV reactors are equipped with medium pressure high output lamps. Englewood has more than sufficient disinfection and provides redundancy to treat twice as much water as needed	• Disinfectant: free chlorine • Application point: clearwell • Number of basins = 1 • Clearwell volume = 800,000 gals • Baffling factor = 0.5 • Required log inactivation of *Giardia* lamblia = 0.5 • Required log inactivation of viruses = 2.0

The comparison between rated unit process capacity to the design flow was made using a performance potential graph, as shown in **Figure 5-4**. The capacity of the flocculation, sedimentation, and disinfection processes met or exceeded the design flow requirement. However, the filtration unit process was observed to be approximately 86 percent of design capacity (28 mgd) with one filter out of service.

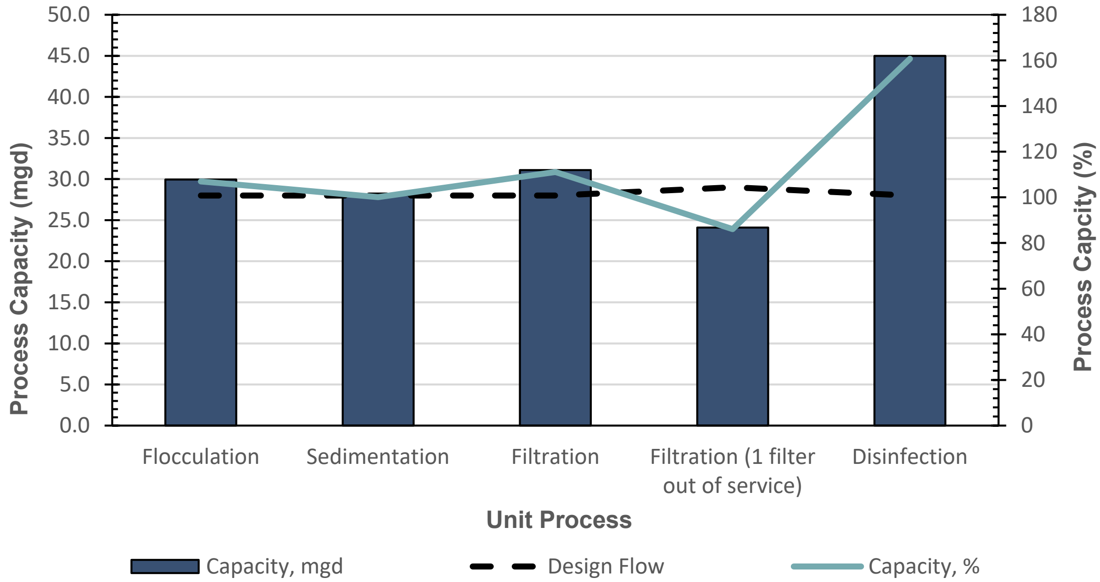


Figure 5-4: Unit Process Capacity Performance Potential

Unit process capacity performances are compared with State of Colorado Design Criteria for Potable Water Systems[2] in **Table 5-4**. While these criteria are applicable to the construction of new WTPs and do not apply to previously approved facilities such as the Allen WTP, they do provide guidance on what criteria are considered by CDPHE to reliably produce drinking water in compliance with Regulation 11.

Table 5-4: State of Colorado Design Criteria

Unit Process	CDPHE Requirements	Allen WTP[2]
Flocculation	Min HDT = 30 min	HDT = 20 min
Sedimentation	Application rates for plates must maintain a maximum plate loading rate of 0.7 gpm/sf	0.5 gpm/sf
Filtration	HLR limited to 5 gpm/sf unless approved by CDPHE Filters must be capable of meeting the plant design capacity at the approved filtration rate with one filter removed from service	3.9 to 5.4 gpm/sf (North and South Filters, respectively) Normally operate well below these values
Disinfection	• 3-log removal/inactivation of *Giardia lamblia* • 4-log removal/inactivation of viruses • 2-log removal/inactivation of *Cryptosporidium*	• ≥ 0.8-log inactivation (1.7 CT ratio)[1] *Giardia lamblia* • ≥ 23.5-log inactivation (11.7 CT ratio)[1] of viruses

[1] Assumed pH = 8.0, Cl_2 residual of 2.5 mg/L, and temperature of 10°C for inactivation by Free Chlorine. Note additional credits (*Cryptosporidium* inactivation) provided with UV disinfection.

[2] The Allen WTP is rated at 28 mgd but only treats as much as 12 mgd on peak day each year. Therefore, it operates well within the CDPHE requirements.

[2] State of Colorado Design Criteria for Potable Water Systems, Water Quality Control Division Safe Drinking Water Program Implementation Policy #5, December 15, 2017

5.5.1 Chemical Storage

Chemicals used at the Allen WTP and pre-treatment facilities include aluminum sulfate, cationic polymer, liquid sodium permanganate, powdered activated carbon (PAC), sodium hydroxide, sodium hypochlorite, and aqueous ammonia. Chemical storage facilities were evaluated to determine if deficiencies in chemical storage exist. State of Colorado design criteria require liquid storage tanks hold 1.5 truckloads and that day tanks be sized to hold 20 to 30 hours of supply at expected peak flow. Ten State Standards require at least 30 days of chemical supply. To compare to the chemical storage capacities at the Allen WTP, the following basis was used:

- Max month flow (9.8 mgd, August 2011) and average dose
- Max day flow (12.3 mgd, July 16, 2010) and max dose

Table 5-5 provides a summary of the range of calculated storage in days that shows adequate capacity exists. The excess capacity provided in the polymer tank should be addressed to allow product turnover. The polymer tank was originally designed for alum storage and would provide needed redundancy and additional storage (discussed further in site visits section below). The caustic system capacity should be evaluated to provide additional redundancy in the event that a low alkalinity source water event requires the maximum dosing for an extended period.

Table 5-5: Chemical Storage Criteria

Chemical	Description	Avg. Dose	Max. Dose	Total Storage Capacity	Days of Storage	
					max mo. flow and avg. dose	max daily flow and max. dose
Powdered Activated Carbon	Taste and odor control, iron and manganese oxidation	5 mg/L	7 mg/L	50,000 lb (dry)	122	70
Sodium Permanganate	Oxidation of iron and manganese	0.5 mg/L	2.0 mg/L	500 gal	25	5
Aluminum sulfate	Coagulant	25 mg/L	45 mg/L	9,623 gal	16	7
Polymer	Coag. /Floc. Aid and Filter Aid	1.65 mg/L	3.0 mg/L	9,623 gal	305	134
Sodium Hypochlorite	Added for disinfection and filter operations	2.88 mg/L (clearwell) 1 mg/L (upstream of filters)	3.25 mg/L (clearwell)	8,883 gal	38	27
Caustic Soda	pH adjustment (typ. 8.0 for positive LSI in finished water)	15 mg/L	35 mg/L	4,942 gal	14	5
Aqueous ammonia	Used with chlorine to produce chloramines for disinfection residual in the distribution system	0.72 mg/L	0.81 mg/L	2,250 gal	55	39

5.5.2 Residuals Handling

Residuals handling at the Allen WTP includes a wash water lagoon to process filter backwash water (including recycle of decant to the North Reservoir), a South Reservoir to process the settled residuals collected from sedimentation, a floating dredge to transfer settled solids to an equalization tank, transfer pumps and a belt press. Naturally Occurring Radioactive Materials (NORMs) present in the raw water at low levels become concentrated in the residuals handling process at the Allen WTP, or technologically enhanced. The Technologically Enhanced Naturally Occurring Radioactive Materials (TENORMs) in the waste residuals require handling and disposal per Colorado regulations. In 2018, a bill was passed that granted the CDPHE the authority to develop rules for the safe management of TENORM. The bill requires the CDPHE to do the following:

- Review and consider TENORM residual management and regulatory limits from other states
- Include input provided by a CDPHE-convened stakeholder group
- Consider background radiation levels in the state
- Investigate TENORM waste stream identification and quantification techniques
- Evaluate use and disposal practices of industries that generate TENORM
- Consider current engineering practices of industries that manage TENORM wastes
- Evaluate laboratory analysis methods for constituents found in TENORM wastes
- Evaluate economic impacts from proposed TENORM regulations
- Identify data gaps

The TENORM stakeholder process is currently underway. In 2017, the City conducted a Human Health Risk Assessment and Evaluation of Residuals Management at the Allen WTP. Recommendations from that study included operational practices (e.g., residuals storage and disposal, PPE, monitoring, etc.), as well as raw water control such as the Big Dry Creek Diversion Project.

5.5.3 Comprehensive Performance Evaluation (CPE)

A comprehensive performance evaluation (CPE) is a thorough review and analysis of a water treatment plant's performance-based capabilities and associated administrative, design, operation, and maintenance practices. It is conducted to identify factors that may be adversely impacting optimal plant performance. Major unit processes were evaluated with respect to design criteria, age, and general condition in the development of this Plan; however, a CPE is recommended. This would also include a full assessment of existing plant performance with a detailed water quality audit. The CPE concept is used by AWWA for the Partnership for Safe Water program. As discussed later in this Master Plan, Englewood should consider participating in this program.

5.6 Site Visits

Hazen met with operations staff to review the condition of primary equipment at the Allen WTP (pump stations are discussed in further detail in **Section 6**). Operations does an excellent job maintaining this facility. The plant walkthrough and review of available records identified the following:

- **North Reservoir**. This 80MG reservoir (also known as Belisle) was recently inspected by the Division of Water Resources Dam Safety Division[3]. The Engineer's Inspection Report indicated that it is still accurate to maintain a Significant Hazard Classification. It was acknowledged that the City has done an excellent job of maintaining the surfaces of the embankment. Overall, it was considered conditionally satisfactory with the following recommended actions for the City:
    - Prepare a detailed schematic of all pipes that penetrate the dam and travel the toe.
    - Provide a written SOP for discharge water in the event of an emergency.
    - Conduct video inspection of the pipes that penetrate the embankment to evaluate their condition.
    - Perform additional monitoring/observation of the upstream slope for continued oversteepening and potential sloughing (repair as necessary) and regularly observe depression at southern toe with standing water (clear as necessary).
- **Pretreatment Instrumentation**. Pretreatment instruments including flow meters, turbidimeters, pH, and chlorine residual and streaming current analyzers were also installed in 1999 and may be reaching the end of their useful life.
- **Flash Mix.** The original flash mixer from 1999 may be reaching the end of its useful life. The City has purchased a backup motor; however, installation methods require assessment due to space restrictions.
- **Flocculation / Sedimentation**. The basins and associated mechanical equipment were installed in 1999. The original Trac-Vac system is becoming maintenance intensive and has only one installed compressor (no redundancy).
- **Filtration**. Major filter improvements including underdrain replacement last occurred in 1998-2001. GAC filter media is replaced approximately every 3 to 4 years. Operations noted known issues including variable hydraulic differences between north and south filter trains, increased filter ripening time (suspected underdrain issues) with Filter 2 and potentially others, and leaking filter effluent valves. Like the Zone 1 and Zone 2 HSPS pumps, the filter backwash pumps were put in service in 1980 and require condition assessment. A filter improvement project to address these issues was previously planned by the City and this project was included in the WMP CIP. In addition, routine filter surveillance is recommended to inspect the condition of the media, underdrains, and document filter performance over time.
- **Chemical Systems.** Chemical storage calculations were presented in the unit process capacity section above. Additional observations included:
    - *PAC***.** The PAC system was put in service in 2003. PAC is typically dosed seasonally to the raw water at 5 to 7 mg/L to address taste and odor. The mechanical equipment is well-maintained, and operations noted no known issues.
    - *Permanganate*. The liquid sodium permanganate system at Union Avenue includes a two-tank system (one tank on the upper deck to receive chemical delivery and a second on the lower level for storage and metering. Replacement of this system is recommended to increase storage volume and provide updated instrumentation, as well as delivery provisions to improve safety. The

[3] BELISLE DAM, DAMID 080405, Water Division 1, Water District 08, Dam Safety Engineer's Inspection Report (December 12, 2018)

pretreatment system at the plant was put in service in 1999 and a condition assessment is recommended.

- *Alum*. The 1999 improvements design included provisions for two 10,000-gallon alum tanks; however, one was converted to a polymer tank at installation. While over 30 days storage is available at an average dose, a single tank provides no redundancy in the event of a tank failure.
- *Cationic Polymer*. The 1999 improvements design included provisions for two, 800-gallon tanks located in filter building; however, during installation one of the alum tanks was converted to a polymer tank. The use of this tank for polymer results in long storage times (over 100 days) and does not provide redundancy in the event of a tank failure. It is recommended that a new polymer system be installed to allow this tank to be converted back to a second alum tank. Potential space is available in the pretreatment building sodium permanganate room.
- *Nonionic Polymer*. The 1999 improvements design included provisions for 6 55-gal drums.
- *Caustic soda*. The caustic system includes a 5,000-gallon tank with mixer (1980) and two Watson Marlow feed pumps (1999). Like the alum and polymer systems, no redundancy is available in the event of a tank failure.
- *Sodium Hypochlorite*. This system consists of two 10,000-gallon tanks and two Watson Marlow feed pumps that were placed in service in 1999. While redundancy is provided, due to the age of equipment a condition assessment is recommended to assess the remaining useful life.
- *Ammonia***.** Operations have had to configure a temporary cooling system including fan and pipe insulation on the ammonia feed line located in the pump room. While much of the ammonia system was put in service in 2002, some equipment has been upgraded (feed pumps were replaced in 2009) or was originally in service prior to the ammonia system conversion (1980 day tank).

Example photos of each of these systems are provided in **Figure 5-5** from the site visits. The age of process equipment at the Allen WTP spans 20 to 30 years. While operations have done an excellent job of maintaining these systems, they could be reaching the end of their useful life. Typical industry planning values for equipment useful life are provided in **Table 5-6**. A detailed conditions assessment and multiple chemical systems improvements projects are recommended in the WMP CIP to replace or maintain equipment to extend its useful life.

Figure 5-5: Site Visit Photos

Table 5-6: Expected Useful Life of Process Equipment

Process Equipment	Expected Useful Life (Years)	Estimated Current Age (Years)
Mechanical Equipment		
Flocculation/Sedimentation Equipment	15 to 30	23
Filtration Equipment	20	At least 23
Chlorination Equipment	10 to 20	20
Ammonia Disinfection Equipment	10	10
UV Disinfection Equipment	20	8
Chemical Feed Systems	10 to 15	18 to 23
Electrical and I&C Equipment		
Transformers/Switchgears/Wiring	15 to 30	8 to 40
Motor Controls/VFD's	10	3 to 20
Sensors	6	Not available
SCADA Equipment	15	1 to 30
Instrumentation and Controls, RTUs	10	5 to 23
Valves		
Air Relief Valves, General Valves, Blow Off Valves, Backflow Prevention Valves	15 to 30	5 to 40
Mechanical Valves	15 to 30	10 to 40
Gate Valves, Actuated Valves	20 to 30	10 to 40
Other Equipment		
Building Superstructure	35	8 to 60
Water Bearing Concrete Structures	50 to 70	23 to 80
Lab/Monitoring Equipment	10 to 15	Updated as needed

6. Risk Assessment

6.1 Risk Assessment Methodology

6.1.1 Overview

Hazen conducted a risk assessment of water transmission mains (18 inches in diameter and larger) and the source water and distribution pump stations. The purpose of the risk assessment was to establish the existing condition of critical assets and to identify and prioritize repair and replacement (R/R) projects to be included in the CIP. This section describes the methodology used and summarizes the results of the risk assessment. Detailed descriptions of the approach used for the transmission mains and the pump stations are included in **Appendix G** and **Appendix H,** respectively.

6.1.2 Risk Assessment of Linear Assets (Desktop Analysis)

The risk assessment of the water transmission mains was performed by first creating an asset register of all water mains 18 inches in diameter and larger and then analyzing pipe-specific characteristics such as size, material, and age along with surrounding environment characteristics such as depth and proximity to critical facilities to calculate risk of failure. The asset register includes only water mains 18-inches in diameter and larger per the scope for this Plan.

An asset register is a record of physical assets within a system which includes pertinent asset data characteristics, asset status and condition, which should be continuously updated as part of an asset management program. The asset register for this Master Plan is provide in an Excel spreadsheet in **Appendix G**. However, the asset register should be expanded to include additional assets (e.g., pump stations, smaller diameter water mains) and transitioned to the City's Enterprise Asset Management software as part of the programs discussed in **Sections 7.3.2** and **7.3.3**.

6.1.3 Risk Assessment of Vertical Assets (Visual Inspections)

Visual inspections of major assets were conducted to determine their condition. City operations and maintenance staff accompanied Hazen personnel during the field visits and provided insight regarding the challenges of individual equipment. Inspections consisted of visual observations of the assets during normal operation of the facilities. Only those assets easily accessible were inspected.

During the limited visual condition assessment process, an asset condition score was assigned to each asset. The condition scoring system uses a rating range from 1 (excellent condition) to 5 (poor condition). These condition scores, along with the criticality scores for each asset, were utilized to develop overall risk scores.

6.1.4 Likelihood of Failure

The likelihood of failure (LoF) measures an asset's likelihood of, or timing to, failure. The LoF is directly correlated to the asset's condition. Lower condition scores correspond to better condition, hence lower probability (or likelihood) of failure.

Likelihood of failure scores for linear assets were determined based on available GIS data for water mains (pipe age and material) and geo-located water main break history provided by the City. Scoring criteria were developed for each LOF category. Pipe assets were given a score on a scale of 1-5 (best to worst) for each of the categories and then an overall weighted LoF score was calculated for each water main.

Likelihood of failure scores for vertical assets are equivalent to their condition score.

6.1.5 Consequence of Failure

Consequence of failure (CoF), or criticality of an asset, measures the direct and indirect impacts and costs associated with asset failure. Criticality assessment is often performed on linear pipe networks using GIS tools for determining impacts from failures on surrounding infrastructure, critical users such as hospitals, and the environment. Criticality of vertical assets considers how necessary the asset is for meeting the defined levels of service and whether redundant assets exist to allow for periodic downtime of the asset.

Consequence of failure can vary from a minor inconvenience to a major disruption of service. For example, failure of electrical equipment has significant consequences, including loss of pumping capability; while the failure of a sump pump has minor consequences. Similarly, failure of a large transmission main that services a hospital or a school has significant consequences while failure of small diameter main servicing a small number of customers has far less consequence of failure.

The CoF scores assigned to vertical assets were based on industry standards and discussions with City staff. For these assets, it is recommended that as a part of a future comprehensive asset management program, CoF scores be refined based on operation staff's knowledge of the criticality of each asset and where warranted, additional study.

Criticality scores for the transmission mains were determined based on three main categories: location, pipe depth and pipe diameter as described in **Table 6-1.** Scoring criteria were developed for each of these CoF categories. Pipe assets were given a score on a scale of 1-5 (best to worst) for each of the categories and then an overall weighted score was calculated for each water main.

Table 6-1: Consequence of Failure Categories – Linear Assets

Category	Description
Location	• Proximity to critical facilities (schools, hospitals, fire stations, police stations, light rail stations and city hall) • Proximity to water bodies (streams, rivers and reservoirs) • Proximity to railroads and major highways
Pipe Depth	Depth to pipe invert. Impact of pipe repair is directly correlated to the pipe depth.
Pipe Diameter	Diameter of pipe is often correlated to the overall number of customers affected by failure, as well as the cost and time required to repair the failure

6.1.6 Risk-Based Assessment

Risk scores are used as the basis for prioritizing asset repair and replacement. Replacement of assets with a higher risk score should be funded prior to the replacement of assets with a lower risk score. The equation to compute risk is presented below:

Risk Score = LoF Score x CoF Score

As the equation shows, the risk score is equally weighted between the LoF and CoF scores. Assets in poor condition (i.e. high LoF score) and a high CoF pose the greatest risk. Likewise, assets in excellent condition (i.e. low LoF score) and a low CoF pose the lowest risk.

6.2 Risk Assessment Results

6.2.1 Water Transmission Mains

A risk score was calculated and documented for each transmission main in the asset register (City water mains 18-inches in diameter or larger). The risk score can provide an indication of the best management approach for each of the assets. For low CoF and low LoF assets, a run-to-failure approach may be most appropriate. For high CoF and high LOF assets, immediate action, such as replacement or repair, may be needed. For those assets with high CoF but low LoF, frequent inspection may be the best management approach to monitor any deterioration of the critical asset over time. Finally, for those assets with low CoF but high LoF, the merits of renewal versus continued maintenance should be considered, to provide the highest level of service at the lowest life cycle cost to the City. **Figure 6-1** illustrates a typical risk matrix showing the various management strategies for different risk profiles.

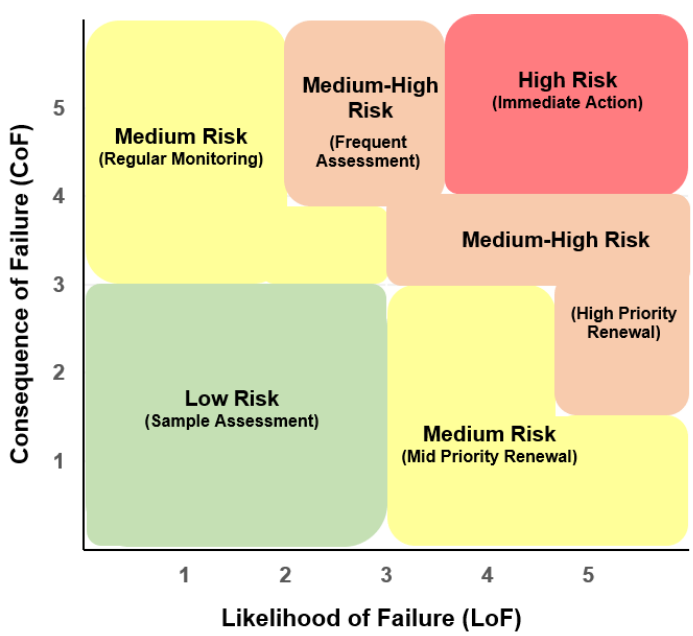


Figure 6-1: Typical Risk Matrix and Associated Management Approaches

From the calculated risk scores, a relative risk rating was assigned to each pipe segment analyzed. The results of the risk-based assessment are summarized in **Table 6-2**.

Figure 6-2 shows a map of all the transmission mains color-coded based on their risk ratings.

Table 6-2: Summary of Transmission Mains Risk Ratings

Risk Rating	No. of Pipe Segments	Linear Feet	% of Mains Assessed
High	1	295	0.5
Medium-High	56	32,418	26.3
Medium	95	35,061	44.6
Low	61	12,220	28.6
Total	**213**	**79,994**	**100.0**

The majority of the City's transmission mains (approximately 71 percent) that were assessed under this exercise had either "medium" or "medium-high" risk ratings. The main that received a "high" risk rating is a small section of the 24-inch transmission main on Belleview Avenue east of Sherman Street. The high-risk score was due to its age (installed in 1953), material (steel), location (underneath a major road), and pipe diameter (24-inch). This transmission main, however has only two main break records in the GIS database, which are concentrated in one area near 300 E. Belleview Ave. Field notes indicated that these breaks were holes in the main where a 3-inch or 4-inch threaded pipe (nipple) was welded onto the main and capped to repair the leaks.

Due to the size of the transmission mains and potential significant cost of replacement, it is recommended that the City perform further assessment and/or inspections of their transmission mains before identifying replacement projects. The methodology developed for this risk assessment can be used by the City as a baseline for prioritizing transmission mains for either further assessment or inspections. Following completion of the assessment/inspections, the LoF scores for each asset should be updated to incorporate the inspection results.

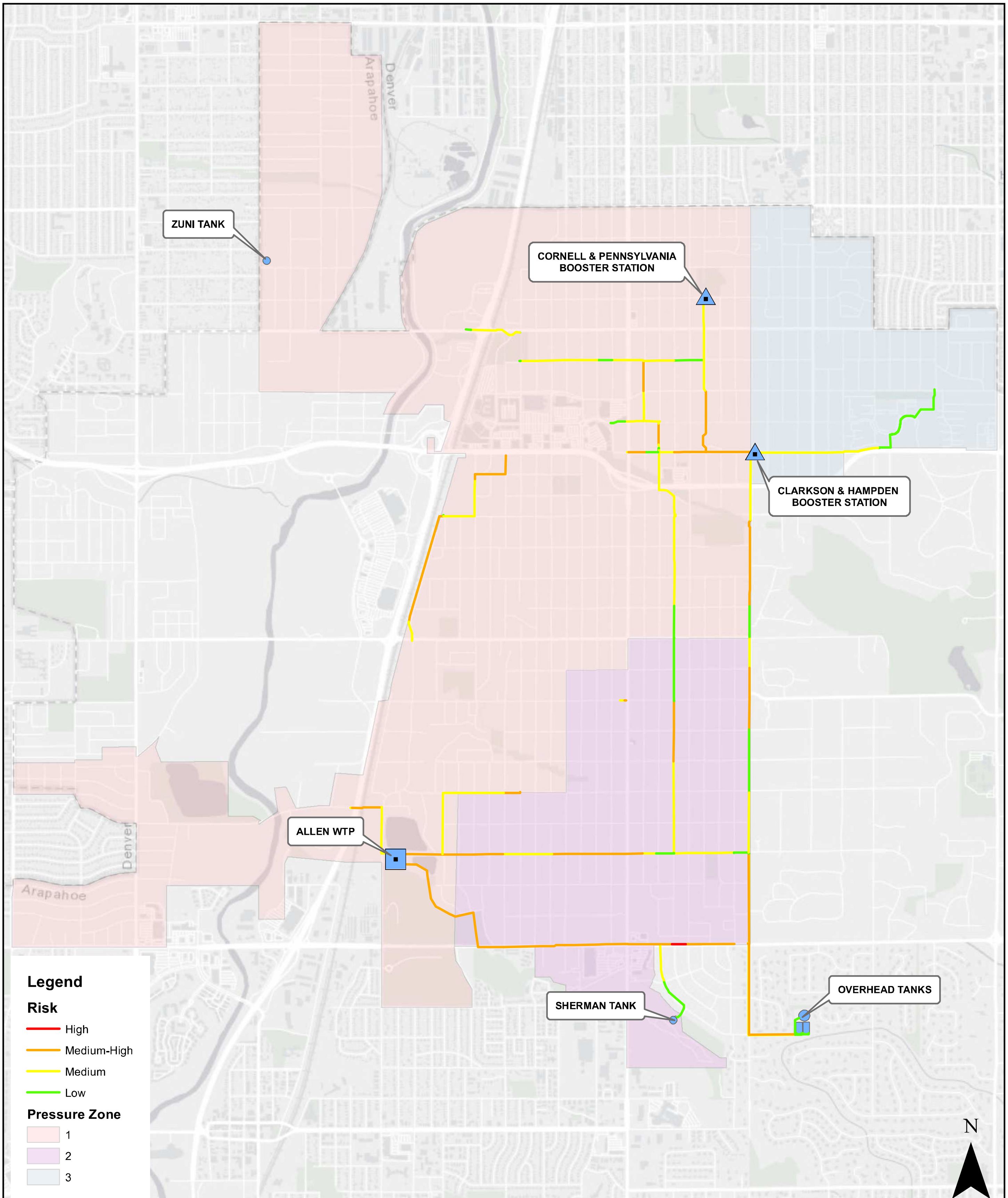


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FIGURE 6-2: TRANSMISSION MAINS RISK

2,600 1,300 0

1 Inch = 2,584 Feet

DATE: MAY 2020

It is important to note that desktop risk assessment relies heavily on good quality data. Where data such as pipe depth, material, size and installation year were not available in the GIS database, assumptions were made. These data gaps should be closed over time so that better analysis will be possible in the future. AWWA recommends the following strategies to improve data collection efforts (and future risk assessment)[4]. The City is already implementing some of the strategies listed below:

1. Whenever a water main is exposed, City staff should document its diameter, material, and coating. Whenever a hot-tap is performed, record the lining and wall thickness. Records should be updated to reflect field data.
2. Record detailed water main break and repair information such as: date of break, type of break and exact location (including photos).
3. Consider collecting systemwide soil corrosivity data to assist in estimating pipe corrosion potential.
4. Engage operations and maintenance staff and obtain their support in collecting meaningful data.

6.2.2 Pump Stations

6.2.2.1 Union Avenue Pump Station

The Union Avenue Pump Station consists of an intake structure, storage pond, powder activated carbon (PAC) storage and feed facilities and pump station building. This condition assessment only evaluated the major assets inside the pump station building. The condition scores of the major assets evaluated at this facility are presented in **Table 6-3** below. Mechanical components such as piping and valves were determined to be in average condition. The pumps and pump motors have substantial wear and corrosion visible and some of the pump shafts appear to be unbalanced. The Motor Control Center (MCC) is outdated and minimally supported by the manufacturer.

Continued inspection of these assets and replacement during a future rehabilitation project is recommended.

[4] *Manual M77 - Condition Assessment of Water Mains*. American Water Works Association. 2019.

Table 6-3: Condition of Major Assets at Union Avenue Pump Station

Asset Description	Condition Score
Pumps	5 - Poor
Motors	4 - Fair
Piping	3 - Average
Valves	3 - Average
Building Structure	1 - Excellent
Access Platform and Supports	4 - Fair
Electrical Panels	4 - Fair
VFDs	1 - Excellent

6.2.2.2 *McLellan Pump Station*

The McLellan Pump Station is an extremely critical facility as it moves water from the Chatfield Reservoir to the McLellan Reservoir, the City's primary water storage facility. Additionally, more than 40 percent of CWSD's water comes from the McLellan Reservoir. Therefore, failure of this pump station has significant consequences. The pumps and the majority of the auxiliary equipment is original, installed circa 1964. The only recent improvement done at this facility is the installation of VFDs. The condition scores of the major assets evaluated at this facility are presented in **Table 6-4**. Critical assets at this facility are in poor condition and must be addressed.

Continued inspection of these assets and replacement during a future rehabilitation project is recommended. It is also recommended that at a minimum, the City consider lifting up the MCCs onto a concrete housekeeping pad to avoid water intrusion into the cabinet.

Table 6-4: Condition of Major Assets at McLellan Pump Station

Asset Description	Condition Score
Pumps	5 - Poor
Motors	5 - Poor
Piping	3 - Average
Valves	4 - Fair
Building Structure	3 - Average
Access Platform and Supports	2 - Good
Electrical Panels	4 - Fair
VFDs	3 - Average

6.2.2.3 *Zone 1 and Zone 2 High Service Pump Stations*

The Zone 1 and Zone 2 High Service Pump Stations are located at the Allen WTP. The Zone 1 Pump Station consists of three 450 horsepower (HP) pumps, 24-inch pump discharges and a 42-inch header pipe. The Zone 2 Pump Station consists of two 350 HP pumps and two 200 HP pumps, 16-inch pump discharges and a 24-inch header. These pump stations are highly critical as they serve the entire City. The condition scores of the major assets evaluated at this facility are presented in **Table 6-5**.

Continued inspection of these assets and replacement during a future rehabilitation project is recommended.

Table 6-5: Condition of Major Assets at Zone 1 and 2 HSPSs

Asset Description	Condition Score
Pumps	4 - Fair
Piping	3 - Average
Valves	4 - Fair
Building Structure	2 - Good
Electrical Equipment	3 - Average

6.2.2.4 Clarkson and Hampden Booster Station

The Clarkson and Hampden Pump Station is located at the intersection of East Hampden Avenue and South Clarkson Street and is entirely below grade. This pump station serves the northeastern portion of the City, also known as Pressure Zone 3. The condition scores of the major assets evaluated at this facility are presented in **Table 6-6** below. This pump station is generally in poor condition. The pumps, motors, piping and valves all exhibit significant corrosion.

Continued inspection of these assets and replacement during a future rehabilitation project is recommended. It is also recommended that the City consider moving the electrical equipment outside of the pump station vaults and install them aboveground nearby.

Table 6-6: Condition of Major Assets at Clarkson and Hampden Booster Station

Asset Description	Condition Score
Pumps	5 - Poor
Motors	5 – Poor
Piping	5 – Poor
Valves	5 – Poor
Structure	2 - Good
Electrical Equipment	3 - Average

6.2.2.5 Cornell and Pennsylvania Booster Station

The Cornell and Pennsylvania Pump Station is located at the intersection of East Cornell Avenue and South Pennsylvania Street and is entirely below grade. This pump station boosts pressures for the northeastern portion of the City, also known as Pressure Zone 3. The condition scores of the major assets evaluated at this facility are presented in **Table 6-7**. This pump station is generally in poor condition, and all of the major mechanical assets need repair or replacement.

In addition, there are some electrical code violations at this facility. The National Electrical Code requires a 3-foot minimum clear space in front of all electrical equipment. As shown on the photo below, the drives are installed directly above and behind the piping, making access to this equipment out of compliance. The City should consider moving the electrical equipment outside of the vaults as part of a future pump station rehabilitation project.

Figure 6-3: Cornell & Pennsylvania Booster Pump Station

Based on conversations with City staff, this pump station does not operate often. Continued inspection of these assets and replacement during a future rehabilitation project is recommended if this booster station will remain in service. As discussed in **Section 4.8.1**, the City should consider either alternating the C&P and C&H booster stations or decommissioning the C&P station based on the results of a distribution system operations optimization study.

Table 6-7: Condition of Major Assets at Cornell and Pennsylvania Booster Station

Asset Description	Condition Score
Pumps	4 - Fair
Motors	5 – Poor
Piping	5 – Poor
Valves	5 – Poor
Structure	2 - Good
Electrical Equipment	3 - Average

6.3 Recommended Improvement Projects

6.3.1.1 Hampden Avenue Transmission Main Replacement

The only transmission main recommended for replacement at this time is the 18-inch, steel main on Hampden Avenue, near the Swedish Medical Center on the north side of the City. The majority of this segment was determined to have a "medium-high" risk score due to its size, material, age (1950) and proximity to a critical facility (hospital). This particular segment also has a history of failures with eight breaks recorded in the GIS database. The location of this main is in the same corridor as a stormwater main that was identified in the Stormwater System Master Plan as being in urgent need of replacement.

The City should consider replacing 2,300 LF of water main from the intersection of Clarkson Street and Hampden Avenue west to Lincoln Street as shown in **Figure 6-4** in conjunction with the stormwater main replacement as a cost-saving opportunity. The cost of mobilization, excavation and restoration can be shared between Utilities and Public Works.

6.3.1.2 Pump Station Upgrades

Inspections conducted for this condition assessment consisted of visual observations of the assets during normal operation of the facilities. Only those assets that were easily accessible were inspected visually. It should be noted that the determination of condition scores was largely based upon the experience of the inspector as well as the City staff that provided insight on the equipment. No specific testing such as vibrational analysis, thermographic imaging, etc. of equipment was conducted. It is recommended that the City, as part of a comprehensive asset management program, perform a more detailed assessment of the pump stations, including performing pump testing. However, in order to help the City with developing a CIP budget, it was assumed that full rehabilitation of the pump stations will be necessary. Results of the risk assessment analysis described in **Section 6.2** were used to prioritize the pump stations as shown in **Table 6-8**.

All six pump stations have aging components that are at the end of their useful life. The two booster stations from Zone 1 to Zone 3 (Clarkson and Hampden, Cornell and Pennsylvania) are in generally poor condition. All six pump stations are critical facilities that should be evaluated further within the next year and upgraded based on this comprehensive assessment.

Table 6-8: Pump Station Rehabilitation Prioritization

Priority	Pump Station	System	Risk Score
1	McLellan PS[1]	Source Water	19.6
2	Union Avenue[1]	Source Water	18.8
3	Clarkson and Hampden	Distribution	16.5
4	Cornell and Pennsylvania[2]	Distribution	15.8
5	Zone 1 and 2 HSPS	Distribution	13.4

[1]Source water pump stations prioritized over distribution pump stations due to highly critical nature.

[2]Cornell and Pennsylvania is 4th on the list because based on conversations with City staff, this booster station does not operate often, while Clarkson and Hampden does.

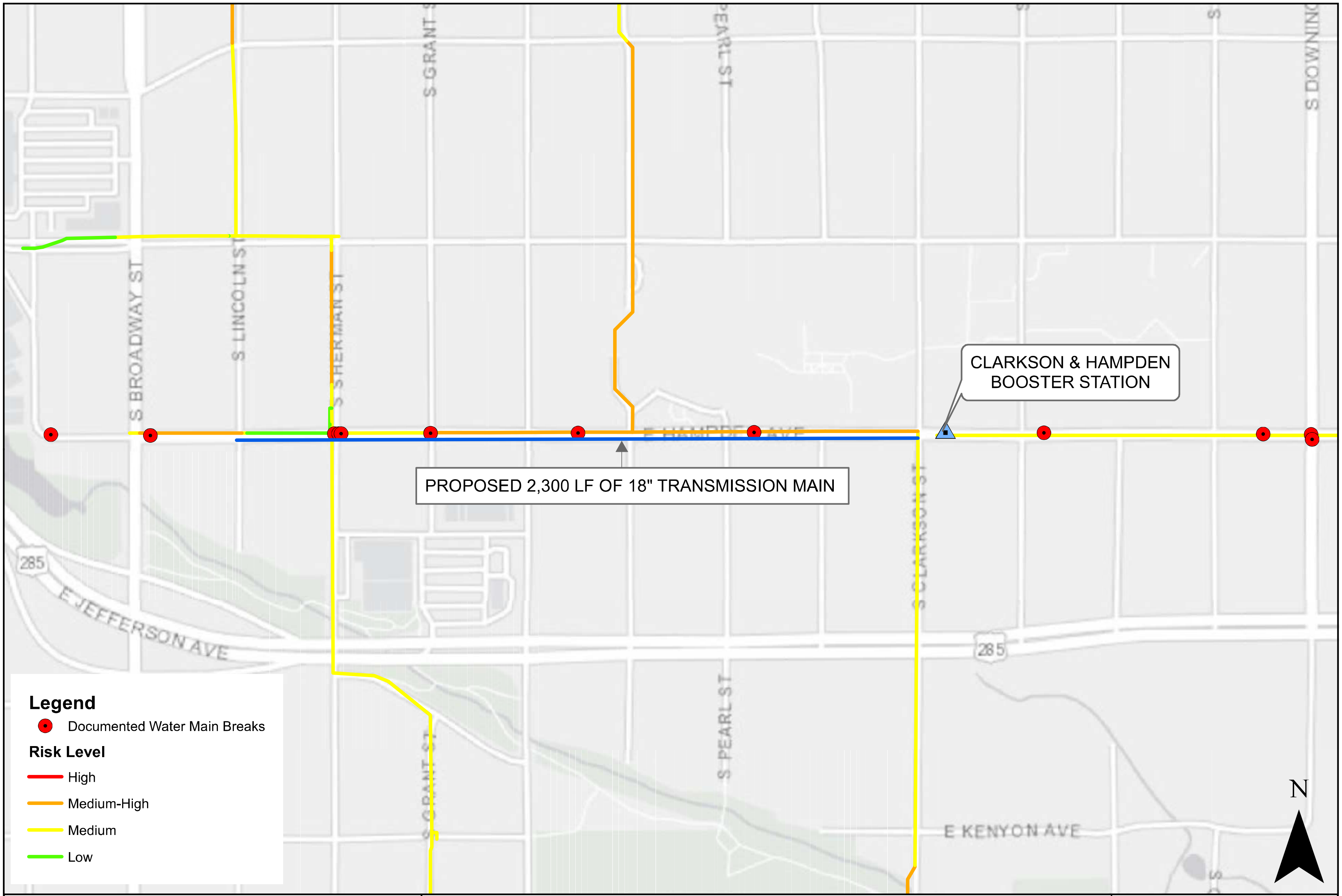

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FIGURE 6-4: HAMPDEN AVENUE TRANSMISSION MAIN REPLACEMENT

600 300 0
1 Inch = 417 Feet

DATE: FEBRUARY 2020

7. Water System Programs

The City's water system is aging and has been the subject of corrective maintenance instead of the more preferred preventative maintenance practices. Therefore, programs have been identified with the goal of obtaining additional data on the existing system and improving the City's water system management and renewal approach.

Programs are defined as on-going activities intended to proactively assess, maintain and upgrade aging infrastructure. They vary in size and cost with several continuing indefinitely. As each program is implemented, the City will gain a more comprehensive understanding of the water system infrastructure. As a result of discussions with the City's Utilities staff and analysis of the City's existing data and activities, several key programs have been identified to assist the City in transitioning from a reactive to a proactive water system management approach. This section presents recommended programs that will help the City improve their level of service, operability, water quality and efficiency of operations.

Each program has been assigned a unique identifier (i.e., PRG-XXX-X-XXX). Programs for the distribution system and the Allen WTP are summarized in **Table 7-1** and **Table 7-2**, respectively. Some of these programs have been implemented previously, but due to limited City resources many of the program activities have been deferred.

Program costs and prioritization are provided in **Section 10**: **Capital Improvement Plan**. Individual program sheets detailing recommendations, costs, schedule and assumptions are provided in **Appendices I** and **J**.

Table 7-1: Distribution System Programs

Program ID	Program Name
PRG-WAT-D-008	Geographic Information System (GIS) Update
PRG-WAT-D-009	Program Management - Distribution System
PRG-WAT-D-010	Water Model Expansion, Re-Calibration and Updates
PRG-WAT-D-011	Enterprise Asset Management - Distribution System
PRG-WAT-D-012	Comprehensive Asset Management Program - Distribution System
PRG-WAT-D-013	Valve Inspection and Exercising
PRG-WAT-D-014	Valve Replacement
PRG-WAT-D-015	Hydrant Flushing and Testing
PRG-WAT-D-016	Transmission Main Inspections
PRG-WAT-D-017	Water Distribution Main Replacement
PRG-WAT-D-018	Transmission Main Replacement
PRG-WAT-D-019	Meter Replacement
PRG-WAT-D-020	Meter Installation for Non-Metered Accounts
PRG-WAT-D-021	Storage Tank Cleaning and Inspections
PRG-WAT-D-022	Water Loss Control Study
PRG-WAT-L-023	Lead Service Line Replacement
PRG-WAT-D-024	Advanced Metering Infrastructure (AMI)
PRG-WAT-D-025	Emergency Repair Projects – Distribution System
PRG-WAT-D-026	Construction Management – Distribution System
PRG-WAT-D-027	Water Master Plan and Water Model Update

Table 7-2: Allen WTP Programs

Program ID	Program Name
PRG-WAT-T-001	Granular Activated Carbon (GAC) Replacement
PRG-WAT-T-002	Filter Surveillance Program
PRG-WAT-T-003	Enterprise Asset Management - WTP
PRG-WAT-T-004	Comprehensive Asset Management Program - WTP
PRG-WAT-T-005	Program Management - WTP
PRG-WAT-T-006	Construction Management - WTP
PRG-WAT-T-007	On-Call/Emergency Field Services Contracts

7.1 Distribution System

7.1.1 Geographic Information System (GIS) Update

The City has an excellent GIS database for the water distribution system. However, there are remaining data gaps within the pipe, meter, valve and hydrant tables that should be addressed. These include meter, pipe and hydrant installation dates and detailed information about valves such as valve type, size, number of turns and open/close direction. This program is intended to be a one-time update of the City's existing GIS data to fill in any missing data and populate any additional data fields for the water assets followed by additional regular updates of the GIS as new information becomes available or the physical system changes.

Regular updates are currently being performed by the City's GIS Analyst. Performing regular GIS updates is important to maintain an accurate representation of the water distribution system. This is crucial for operators who rely on GIS for their daily operations and maintenance activities and more importantly, during emergency situations such as water main breaks. Accurate GIS information will also improve water model inputs and therefore Master Plan recommendations. It is recommended that the City continue to regularly update GIS with the following, as a minimum:

- Improvements and additions made to the system through either CIP projects or new developments
- Information obtained through other O&M programs (i.e., valve attributes through the valve exercising program, meter replacements, etc.)
- Redlines/field notes from operators
- Maintenance and repair activities currently captured in GIS (i.e., water main breaks, bacteriological sampling, etc.)

7.1.2 Water Model Expansion, Re-Calibration and Updates

The model prepared for this Master Plan is a "skeletonized" model, containing only a percentage of the actual pipes existing in the distribution system. In order to better understand the distribution system, the following model refinements are recommended:

- Expand the hydraulic model to include all distribution mains 4-inches in diameter and larger
- Perform fire flow, pump and hydraulic grade line tests to obtain pressure and flow measurements
- Perform a detailed future demand analysis
- Calibrate the model based on the additional data including field testing results
- Perform an updated hydraulic assessment of the pumps, tanks, and distribution mains for existing and future conditions including an assessment of pump station firm capacity
- Perform water age/quality analysis
- Perform fire flow analysis

Following the initial model expansion and re-calibration, this program will include regular updates to the model as new information becomes available or the physical system changes.

7.1.3 Valve Inspection and Exercising

Distribution system valves must be inspected and exercised routinely to ensure they are accessible and operational. The City has approximately 3,000 valves in their water distribution system. The City currently has a valve exercising truck that was purchased but the City has not established a systematic valve inspection and exercising program, primarily due to lack of personnel.

AWWA recommends that all valves 16-inches and larger and critical valves be exercised annually at a minimum while all other valves should be exercised every 3-5 years[5]. Critical valves are those that isolate a large service area and those that service critical customers such as hospitals and schools. It is recommended that the City develop and implement a valve inspection and exercising program including a dedicated field crew responsible for inspecting, operating and maintaining the distribution system valves. The City should inspect and exercise all of the system valves in the first year in order to identify critical valves, thoroughly document the condition of all system valves and obtain key information about the valves to be included in the City's GIS database including valve physical data (size and type), location characteristics (GPS coordinates) and operational characteristics (turns, position, direction to close). Inoperable valves should be added to the valve replacement program. It should be noted that a number of valves will break when exercised and the City should be prepared to replace them. Funding for these can come from the Emergency Repair Projects program or the Valve Replacement program.

7.1.4 Hydrant Flushing and Testing

Flushing is crucial to maintaining adequate water quality in the distribution system. Flushing restores disinfectant residual, reduces bacterial growth, removes sediments and eliminates taste and odor problems. Currently, the City flushes and inspects all of their 660 fire hydrants annually via traditional flushing. Traditional flushing consists of a hydrant being opened and flushed for a specified period of time (usually long enough to raise the chlorine residual). While this method is easy to perform, it requires large amounts of water and does not always thoroughly clean the mains. This program will transition the City to unidirectional flushing which uses less water and better addresses water quality issues.

Unidirectional flushing (UDF) involves the systematic closing of distribution system valves and opening of hydrants to create a flow of water in a single direction at high velocity to scour/clean the water mains. This highly effective process can resolve water quality issues within a shorter timeframe and using less water than traditional flushing. The major disadvantage of UDF is that its implementation requires detailed planning in advance compared to traditional flushing to identify valves to be closed, hydrants to be opened and most important, the sequence of operation of valves and hydrants. However, the InfoWater hydraulic model developed as part of this Master Plan can be used to develop an optimized UDF program. It is important that all valves are located, assessed, and operational before UDF is implemented. UDF is especially helpful for cleaning unlined cast-iron pipes.

[5] *M44 Distribution Valves: Selection, Installation, Field Testing and Maintenance*. AWWA. Third Edition.

7.1.5 Transmission Main Inspections

It is recommended that the City perform assessment and/or inspections of the transmission mains (14-inches and larger) before identifying rehabilitation and replacement (R/R) projects. This could be limited to a desktop assessment as additional data on the existing water system is identified, collected and organized. Further assessment of the mains can also be accomplished using non-destructive methods to directly measure in-situ conditions. Non-destructive methods include using electromagnetic, ultrasonic or acoustic technologies to identify leaks and measure wall thickness and defects. The inspections can be prioritized according to the asset risk ratings developed under this Master Plan. Following the completion of the desktop assessment and/or inspections, the likelihood of failure scores of each asset should be updated to incorporate the results.

7.1.6 Water Distribution Main Replacement

The City's water distribution system contains more than 165 miles of water mains, with 85 percent having diameters 12-inches and smaller. The City does not currently have an established program for the replacement of aging and problematic water mains to improve system reliability. Typically, the City repairs water mains only as breaks occur. The City should establish a dedicated water main replacement program for all water distribution mains (12-inch and smaller) and focus on identifying and prioritizing unlined cast iron mains first as they can result in hydraulic restrictions as well as water quality problems. The program should include the use of a risk-based approach to prioritize projects based on the results of the Comprehensive Asset Management Program. Typical industry standard for annual water main replacement is one percent of the total length of water mains. For the City, this translates to the annual replacement of approximately 7,500 linear feet of water mains.

The Water Distribution Main Replacement program should be coordinated with the Public Works department. Program funds should be available to replace distribution mains in conjunction with Public Works projects for street reconstruction or stormwater replacement, for cost savings.

7.1.7 Transmission Main Replacement

The City's water distribution system contains approximately 10 miles of water transmission mains (14-inches and larger). The City does not currently have an established program for the replacement of aging and problematic transmission mains. This project will enable to City to budget for the replacement of transmission mains based on the results of the Comprehensive Asset Management Program and Transmission Main Inspections. All unlined cast-iron pipes should be prioritized first.

The Transmission Main Replacement program should be coordinated with the Public Works department. Program funds should be available to replace transmission mains in conjunction with Public Works projects for street reconstruction or stormwater replacement, for cost savings.

7.1.8 Meter Replacement

Water meters deteriorate with age, losing accuracy resulting in inaccurate billing. The replacement of older meters ensures customers are billed accurately and can reduce non-revenue water. The City currently replaces approximately 60 residential meters per month. However, City staff have stated that the majority of the larger meters (1.5-inch and larger) throughout the City are old and inaccurate. It is recommended that the City implement a meter replacement program targeting the larger, commercial meters. According to the City's GIS, there are approximately 450 meters 1.5-inch and larger.

The City should also assess the types of large meters that should utilized moving forward. Specifications for large meters should be developed to ensure accuracy and longevity of the meters. For the purpose of this CIP program, it is assumed that all large meters will be replaced. However, the City may choose to implement a meter testing protocol to test meter accuracy prior to replacement as a cost-saving measure.

7.1.9 Valve Replacement

This program is aimed at replacing inoperable valves as determined from the valve exercising program and other maintenance activities. It is recommended the City develop and implement a valve replacement program where valve replacements are prioritized ensuring critical valves are replaced first and valve replacement is systematically planned by location to minimize the cost of mobilization and restoration.

7.1.10 Meter Installation for Non-Metered Accounts

Water meters allow utilities to monitor water usage and are the primary means by which they produce revenue. The City currently has over 1,200 non-metered water service accounts that are billed using a flat rate. The City has implemented a policy that requires the installation of meters when homeownership changes. However, it is recommended that the City establish a more aggressive program to eliminate flat-rate users. This program will allow the City to install meters at these properties over a five-year period.

7.1.11 Advanced Metering Infrastructure (AMI)

AMI enables the frequent and detailed measurement of water consumption information. The City has over 11,000 water service accounts. Some of the benefits of AMI include reduction of non-revenue water, improved efficiencies in monthly billing and revenue collection, water conservation and improved data for planning, engineering and GIS. The biggest downside of AMI is the significant capital costs associated with its implementation. It is recommended that City first perform a business case analysis to thoroughly analyze the costs, benefits and implementation alternatives before embarking on the transition to an AMI system.

7.1.12 Lead Service Line Replacement

The most common source of lead in drinking water is lead pipes and preliminary analysis indicates that there could be over 8,000 lead service lines within the City. The Lead and Copper Rule (LCR) has undergone a variety of minor and short-term revisions since the rule was passed in 1991. In 2019, the Environmental Protection Agency (EPA) proposed long-term regulatory revisions to the LCR that would include new required actions for water systems including but not limited to the following:

- Requires water systems to prepare and update an inventory of LSLs and requires LSL replacement when the Pb concentration exceeds 0.015 ppm in a sample

- Establishes a new Pb "trigger level" of 0.010 ppm to initiate actions to control corrosion (does not change the action level of 0.015 ppm)
- Requires water systems to replace LSLs as requested by customers
- Requires water systems to follow improved sampling procedures and to adjust sampling sites to more effectively target locations with higher levels of Pb
- Requires water systems to notify customers within 24 hours if a sample exceeds 0.015 ppm of Pb
- Requires water systems to sample schools and childcare centers where high risk populations for Pb health effects are present

These are not requirements currently and the public comment period for the revised LCR was closed in early 2020. The new rule is scheduled to be published in late-summer 2020.

To prepare for the revised LCR the City should consider re-assessing the sampling program used to verify compliance, reviewing the corrosion control method applied at the Allen WTP and developing and maintaining an LSL inventory. These recommended actions are discussed in further detail in **Section 9.5** which discusses LSL policies. Based on the results of these initial efforts an LSL replacement program can be developed and implemented. The CIP presented in **Section 10** includes $20 million over the next 15 years for LSL replacement. Assuming the City will pay for the replacement from the main to the property line, and based on the maximum estimate of remaining LSLs in Englewood's system, the total cost to replace all remaining LSLs would be $50 million. As the LCR rulemaking continues, Englewood staff should stay updated on the latest direction of the rule and the schedule to comply with the revisions.

The LSL replacement program should be coordinated with the Public Works department. Program funds should be available to replace LSLs in conjunction with Public Works projects for street reconstruction or stormwater replacement, for cost savings. The LSL inventory will be critical to identifying locations where LSLs overlap with Public Works construction projects.

7.1.13 Water Loss Control Study

A water loss control study, also known as a water audit, is an accounting of all of the water in a water system. Performing a water loss control study is the first step in developing a comprehensive water loss control program. Comprehensive water audits help determine the extent of water lost in the distribution system due to leakage, unauthorized consumption, meter failures, or other losses.

The International Water Association (IWA) and AWWA recommend water audits be performed annually. There are two approaches to performing a water audit: top-down and bottom-up. The top-down approach is a desktop analysis performed using existing records to perform a water balance. The bottom-up approach is a much more labor-intensive process that is typically implemented after several top-down audits have been performed. The bottom-up approach involves performing a number of activities such as flow verification tests, testing of meters, field investigations, leak detection surveys and detailed analysis in order to compile a more accurate and reliable water audit. The top-down approach is recommended as a starting point for the City. The Colorado Water Conservation Board has a Water Loss Initiative that follows AWWA Manual M36: Water Audits and Loss Control Programs. It is recommended that the City begin this process using the Water Loss Initiative as a guideline. This program should begin once meters have been installed on all non-metered accounts, as the current flat-rate billing accounts will make it difficult to analyze non-revenue water in the system.

7.1.14 Water Master Plan and Water Model Update

Models and Master Plans are intended to be adaptive and evolving tools for long-term planning. They should be updated periodically based on system changes and evolving needs/priorities. At five-year intervals, it is recommended that the City perform flow, pump and hydraulic grade line tests as well as other field tests and perform a verification of the model calibration. Demand projections should also be updated at this time. The results of these activities will be captured in a complete Master Plan update and revised Capital Improvement Plan.

7.1.15 Storage Tank Cleaning and Inspections

The CDPHE handbook recommends routine inspection and cleaning of finished water storage tanks to comply with the applicable requirements in Section 11.28 of the Colorado Primary Drinking Water Regulations, 5 CCR 1002-11 ("Regulation 11"). The City should perform both interior and exterior inspections to ensure the tank's physical integrity, security, and water quality every five (5) years. This is inclusive of the clearwell tank at Allen WTP. Cleaning should be conducted based on the findings of the inspections.

7.1.16 Emergency Repair Projects – Distribution System

As the City embarks on more robust programs to assess, maintain and upgrade the system, critical defects may be identified within the system that were previously unknown. To be financially prepared, funding should be allocated to an annual emergency repair program to address critical defects in the distribution system as they occur. The types of emergency repairs will vary in size and scope but may include the following: pipe, valve or hydrant replacement, excavation, backfill, and surface restoration. The City will need to evaluate whether internal resources are adequate to perform these emergency repairs or if the City should engage with an emergency/on-call contractor for this work.

7.2 Allen WTP

7.2.1 Granular Activated Carbon (GAC) Replacement

The adsorption capacity and media characteristics of GAC media degrade over time, requiring replacement to maintain treatment performance. Historical operations at the Allen WTP have included GAC replacement for filters every two to four years. It is recommended that at GAC Replacement Program be included in the CIP to capitalize these significant recurring expenditures.

7.2.2 Filter Surveillance

Filter surveillance is a crucial component of optimizing the filtration process. Filter surveillance involves the assessment of a variety of water quality and operational parameters to evaluate filter performance as part of an on-going and plant-specific program. It is recommended that filter surveillance be conducted at least every three years (or one filter per year) to facilitate knowledge transfer among operations staff and evaluate process issues and remedies related to filter media, underdrains, and operations.

7.2.3 On-Call/Emergency Field Services Contracts

To address unexpected and urgent matters, funding should be allocated to an annual on-call/emergency field services contracts program. On-call contracts will address the need for quick responses to emergency system outages caused by equipment failure. The City will need contracts for specific trade contractors (e.g., electrical and mechanical).

7.3 Overall System Programs

7.3.1 Program Management

Program management is the process of managing several projects. The Capital Improvement Plan includes several programs and projects, varying in scope, budget and schedule that will need dedicated staff to manage. Program management can be led by City staff or outsourced to a consulting firm. Utilizing a consulting firm provides greater flexibility of resources and allows City staff to remain focused on key initiatives. It is recommended that the City develop resources to perform program management for the various water system programs. If the City decides to perform the program management internally, the City should review available staff resources and determine additional staff needs.

7.3.2 Enterprise Asset Management

Enterprise Asset Management (EAM) Systems, also referred to as Computerized Maintenance Management Systems (CMMS), are utilized to facilitate work planning, inventory management, work execution, reporting and system analysis. Presently, the City owns Infor EAM software licenses; however, the software is not being used to its full capabilities by the majority of staff as related to water system management. It is recommended that the City develop optimized water system (distribution and Allen WTP) work management processes and workflows, then determine the type of management reporting needed. Once defined, these work processes should be modeled in Infor or another appropriate CMMS/EAM software.

7.3.3 Comprehensive Asset Management Program

A Comprehensive Asset Management Program (CAMP) provides for effective, pro-active management of water assets based on business risk. It is recommended that the City implement a CAMP including all water system infrastructure (distribution system and Allen WTP) to create a prioritized plan for asset renewal, capacity upgrades and O&M activities based upon business risk exposure. The EPA identifies the following benefits of asset management[6].

- Prolonging asset life and improving decisions about asset rehabilitation, repair and replacement
- Meeting consumer demands with a focus on system sustainability
- Setting rates based on sound operational and financial planning
- Budgeting focused on critical activities for sustained performance
- Meeting service expectations and regulatory requirements
- Improving responses to emergencies and the security and safety of assets

The result of a sound asset management program is a system that provides resiliency as the system ages and needs evolve.

7.3.4 Construction Management

Construction management provides effective management of schedule, cost, quality, safety, scope and function of construction projects. The CIP includes programs and projects that will need dedicated staff for construction management. Construction management can be led by City staff or outsourced to a consulting firm. As with Program Management, utilizing a consulting firm provides greater flexibility for resource planning. It is recommended that the City develop resources to perform construction management for the construction programs and projects identified in this CIP. If the City decides to perform the construction management internally, the City should review available staff resources and determine additional staff needs.

[6] *Asset Management for Water and Wastewater Utilities.* Environmental Protection Agency. Sustainable Water Infrastructure.

8. Water System Projects

The hydraulic assessment, WTP evaluation and risk assessment described in **Sections 4 through 6** resulted in several specific capital improvement project recommendations. Unlike the water system programs identified in **Section 7**, these are discrete projects to correct existing deficiencies, improve system reliability or upgrade assets near the end of their useful life. These projects are one-time activities with limited scope and duration.

Each project has been assigned a unique identifier (i.e., CIP-XXX-X-XXX). Projects for the distribution system, the source water system and the Allen WTP are summarized in **Table 8-1, Table 8-2, and Table 8-3**, respectively.

Project costs and prioritization are provided **in Section 10: Capital Improvement Plan**. Individual project sheets detailing recommendations, costs, schedule and assumptions are provided in **Appendix K** and **L**.

Table 8-1: Distribution System Projects

CIP ID	Project Name
CIP-WAT-D-020	Zone 1 Isolation Valve Replacement
CIP-WAT-D-021	Emergency Interconnections
CIP-WAT-D-022	Distribution System Operations Optimization Study
CIP-WAT-D-023	New Storage Tank for Zone 2
CIP-WAT-D-024	Distribution Pump Station Improvements (Phases 1 and 2)
CIP-WAT-D-025	Hampden Avenue Transmission Main Replacement
CIP-WAT-D-026	Overhead Tanks Replacement
CIP-WAT-D-027	Zone 1 and Zone 2 Interconnection – Pressure Reducing Valve

Table 8-2: Source Water System Projects

CIP ID	Project Name
CIP-WAT-T-001	Big Dry Creek Diversion Project
CIP-WAT-T-002	Elevated Flumes Structural Assessment
CIP-WAT-T-003	McLellan Pump Station Improvements
CIP-WAT-T-004	Union Ave Pump Station Efficiency and Upgrade Project
CIP-WAT-T-005	Union Avenue Facility - Pond Assessment, Flavor Profile Analysis and PAC Dosing Plan
CIP-WAT-T-006	Union Avenue Facility - Sodium Permanganate System Replacement
CIP-WAT-T-007	North/Belisle Pond Assessment
CIP-WAT-T-008	Source Water Projects

Table 8-3: Allen WTP Projects

CIP ID	Project Name
CIP-WAT-T-009	Comprehensive Water Treatment Facility Evaluation
CIP-WAT-T-010	Filter Improvements Project
CIP-WAT-T-011	Electrical and Control System Upgrades
CIP-WAT-T-012	Instrument Assessment and Calibration Program Development
CIP-WAT-T-013	Radio Study
CIP-WAT-T-014	Chemical Feed System Improvements Projects
CIP-WAT-T-015	Flash Mixer Replacement
CIP-WAT-T-016	Dewatering Facility Spare Parts
CIP-WAT-T-017	Records Conversion Project
CIP-WAT-T-018	Water Softening Project
CIP-WAT-T-019	Operations Complex Space Improvement

8.1 Water Distribution System Projects

8.1.1 Emergency Interconnections

The status of emergency interconnections with Denver Water is unknown. At one time, the City had a few interconnections with Denver Water which involved vaults with a spool piece that had to be connected for emergency interconnection. Some of these vaults have been demolished and the two systems have been physically disconnected at the former interconnect locations.

The City also had an emergency interconnection agreement in place with Denver Water to interconnect their water systems through temporary fire hydrant connections. This agreement is dated October 29, 1982 and it is unknown if this agreement is still valid.

Based on the information provided during development of this Plan, the City's water system is completely isolated and as such does not have an alternate drinking water supply in the event of a short-term or long-term outage. Outages can be caused by emergency situations such as contamination of a source water, failure of the water treatment plant and catastrophic failure of pump stations and/or critical water transmission mains.

In order to have a backup drinking water supply the City should pursue interconnections with Denver Water. First, the status of any existing interconnections should be determined through records research and fieldwork, as needed. However, this project assumes that following this initial research, new interconnections will still need to be installed, in coordination with Denver Water. Due to the design of the City's distribution system, (pressure zone 1 and 2 are disconnected from each other under typical operations and pressure zone 3 is served by zone 1 booster stations under typical operations) it is recommended that an interconnect be made at each of the three pressure zones to provide complete coverage. An interconnection feasibility study and hydraulic evaluation should be performed first to determine appropriate interconnect locations, confirm pressure and flow requirements and to ensure overall feasibility and determine operating procedures for using emergency supplies.

The interconnections should be equipped with appropriate backflow prevention devices where required to prevent bi-directional flow, pressure sustaining features to prevent excessive flows and pressure drops from Denver Water, and pressure reducing features to prevent over-pressurization of the City's system.

In the past, these types of interconnections were considered temporary and acceptable to CDPHE. Current regulations may now make it necessary to complete a blending study to verify continued compliance with all Safe Drinking Water Act (SDWA) regulations if the interconnection were to be used. One significant difference between the treated water for Englewood and Denver Water is the pH. Denver Water has a pH around 8.8 and Englewood has a pH of about 7.8. It would be prudent to coordinate with CDHPE before the interconnections are used.

8.1.2 Distribution System Operations Optimization Study

As discussed in **Section 4**, there are a number of operational challenges in the distribution system including inefficient pumping and inadequate storage tank turnover. The City should perform an optimization study that will holistically assess the operations of the distribution system and evaluate operational changes to improve water quality, reduce energy consumption and streamline system operations. It is recommended that this study be performed after the hydraulic model is updated and re-calibrated as recommended in **Section 7.1.2**.

8.1.3 Distribution Pump Station Improvements (Phases 1 and 2)

These four pump stations convey water to the three pressure zones and many of the existing components are aging. Based upon the risk assessment performed, it is recommended that the City rehabilitate the high service and booster pump stations following a comprehensive assessment of these assets to verify rehabilitation needs and prioritization. This project determines and implements the needed improvements to address the resiliency of these critical assets. This project is split into two phases over the first five (5) years of the CIP.

8.1.4 New Zone 2 Storage Tank

As discussed in **Section 4** of this Master Plan, review of storage requirements by pressure zone identified a 0.9 MG storage capacity deficiency in Zone 2. Design and construction of a new 1 MG tank will increase system storage capacity and reliability in Zone 2. The City should expand the existing model, re-calibrate the model based on field testing and additional data collection efforts and perform future demand analysis as recommended in **Section 7.1.2** and use the updated model to confirm storage tank sizing and location.

8.1.5 Overhead Tanks Replacement

The Overhead Tanks, which are underground, are over 30 years old and have already been repaired to extend their useful life. The City had the tank roofs patched fifteen years ago in order to avoid a full replacement. The third tank has been abandoned in place because the structural tendons snapped. Budgeting for the eventual replacement of the two remaining tanks should be included near the end of the 15-year CIP, or sooner based on the results of full condition assessment of the tanks.

8.1.6 Zone 1 Isolation Valve Replacement

According to City staff, a 24-inch valve on the Zone 1 transmission main directly outside of Allen WTP is inoperable (See **Appendix M**). This is a highly critical valve as it allows the City to isolate the Zone 1 distribution system from the Allen WTP. This project replaces the existing valve that isolates Zone 1 from the Allen WTP.

8.1.7 Hampden Avenue Transmission Main Replacement

The only transmission main recommended for replacement at this time is the 18-inch steel main on Hampden Avenue on the north side of the City. This transmission main has a history of breaks and is located near a critical hospital facility (Swedish Medical Center). The location of this main is in the same corridor as a stormwater main that was identified in the Stormwater System Master Plan as being in urgent need of replacement. It is recommended that the City replace this transmission main in conjunction with the stormwater main replacement as a cost saving measure. The cost of mobilization, excavation and restoration can be shared between Utilities and Public Works.

8.1.8 Zone 1 and Zone 2 Interconnect – Pressure Reducing Valve

The existing connection between the two zones, a valve at the Allen WTP, does not include a pressure reducing valve. Installation of a pressure reducing valve is recommended to maintain suitable pressures in each zone when the connection is open.

8.2 Source Water System Projects

8.2.1 Big Dry Creek Diversion Project

This project diverts the Big Dry Creek flow to a point on the South Platte River below the intake for the Union Avenue Pump Station, via a small dam, intake structure, and pipeline. The purpose of this pipeline is to avoid using water from Big Dry Creek that is high in TENORM and hardness. Diverting this flow will reduce operating costs at the Allen WTP. According to the City, this project has received regulatory approval and is in the 2020 budget at $750,000.

8.2.2 Elevated Flumes Structural Assessment

The source water conveyance system associated with the McLellan Pump Station partially consists of elevated flumes made of structural steel. It is recommended to assess the structural integrity of these systems and make the necessary repairs to keep these structures sound for the foreseeable future.

8.2.3 McLellan Pump Station Improvements

Based upon the findings of the site investigations, it is recommended that the City plan on the rehabilitation of the McLellan Pump Station as presented **Section 6**. Rehabilitation of this critical pump station asset will extend the useful life of the pump stations and increase system reliability. This project includes a detailed assessment of MCCs, control panels, pump curves, wire-to-water (W-T-W) efficiency, mechanical inspection to define improvements, and complete replacements of all critical assets.

8.2.4 Union Ave Pump Station Efficiency and Upgrade Project

Based upon the findings of the site investigations, it is recommended that the City plan on the rehabilitation of the Union Avenue Pump Station as presented **Section 6**. The rehabilitation project for the Union Ave. Pump Station includes detailed assessment of MCCs, control panels, pump curves, wire-to-water (W-T-W) efficiency, mechanical inspection to define improvements, and a complete replacement of all critical assets.

8.2.5 Union Avenue Facility – Pond Assessment, Flavor Profile Analysis and PAC Dosing Plan

Source water to the Allen WTP can be affected by algal blooms and taste and odor. There is aeration equipment in the Union Avenue Pond that along with source water PAC addition are important components for managing taste and odor. A bathymetric survey assessment of the pond is recommended, along with condition assessment of the aeration system equipment. To manage potential future taste and odor events training additional staff on flavor profile analysis and performing testing to develop a response (PAC dosing) plan is recommended. The PAC system upgrades are included in the overall chemical feed system upgrades. Because the PAC system is in satisfactory condition and relatively new, it should be included in second phase of the chemical feed projects shown in **Section 10** of this report.

8.2.6 Union Avenue Facility – Sodium Permanganate System Replacement

The liquid sodium permanganate system at Union Avenue include a two tank system (one tank on the upper deck to receive chemical delivery and a second on the lower level for storage and metering). Replacement of this system is recommended to increase storage volume and provide updated instrumentation, as well as delivery provisions to improve safety. The permanganate system upgrades are included in the overall chemical feed system upgrades. Because this system is relatively old, it should be included in early phase of the chemical feed projects shown in **Section 10** of this report.

8.2.7 North Pond Assessment

The recently completed inspection by the Division of Water Resources Dam Safety Division included recommended actions for the City that could be completed in a North Pond Assessment Project. Key components would include (1) preparing a detailed schematic of all pipes that both penetrate the dam and travel along the toe; (2) providing a written Standard Operating Procedure (SOP) for steps required to discharge water in the event of an emergency; (3) conducting video inspection of the pipes that penetrate the embankment to evaluate their condition; (4) preparing a monitoring plan for routine observation of the upstream slope for continued oversteepening and potential sloughing and of standing water at the depression at the southern toe.

8.2.8 Source Water Projects

These are projects that have been identified to improve and maintain the ditches and conveyance structures owned by Englewood in the mountains. The Boreas Ditch diversion structure is maintained by a third-party contractor and the City has budgeted about $5,000 to $10,000 per year for this system. City staff anticipate expenses for the Meadow Creek and Boreas Ditch system starting in 2020. This project provides a budget allowance to complete these projects.

8.3 Allen WTP Projects

8.3.1 Comprehensive Performance Evaluation and Condition Assessment

A Comprehensive Performance Evaluation (CPE) is a thorough review and analysis of a water treatment plant's performance-based capabilities and associated administrative, design, operation and maintenance practices. It is conducted to identify factors that may be adversely impacting optimal plant performance. Major unit processes were evaluated with respect to design criteria, age, and general condition in the development of this Plan; however, a CPE is recommended. This would also include a full assessment of existing plant performance with a detailed water quality audit. A detailed condition assessment should also be included as part of this effort. **Appendix M** provides a preliminary condition assessment of some critical assets. The findings indicated a need for further condition assessment. The City may eventually consider participating in the AWWA Partnership for Safe Water program. This program sets a high standard for performance of specific elements of the treatment system. It uses the concepts developed for CPE assessments.

8.3.2 Filter Improvements

Major filter improvements including underdrain replacement last occurred in 1998-2001. GAC filter media is replaced approximately every 4 years. Operations noted known issues including variable hydraulic differences between north and south filter trains, increased filter ripening time that could be caused by underdrain issues with Filter 2 and potentially others, and leaking filter effluent valves. The filter backwash pumps were put in service in 1980 and require condition assessment. A filter improvement project, which usually consists of underdrain replacement, may be needed to address these issues. The filter improvement project was previously planned by the City and is included in the CIP. In addition, routine filter surveillance is recommended to inspect the condition of the media, underdrains, and document filter performance over time (see **Section 7.2.2**).

8.3.3 Electrical and Control System Upgrades

MCCs are original to the plant and have reached the end of their useful life. Replacement of all MCCs is recommended, including assessment of appropriate configuration (arc flash and/or network connected) and switchgear for the main service connection point. PLC cards are no longer manufactured and require custom rebuilds. The City has a defined a PLC improvements project for the WMP CIP. It is recommended to implement the replacement program in two phases over the first five years of the CIP.

8.3.4 Instrument Assessment and Calibration

Accurate calibration is vital to the entire operation. Flow, level, pressure, temperature, analytical and safety leak detection instrumentation all must be calibrated by plant instrument technicians. Not calibrating instruments could have detrimental effects on drinking water treatment. For instance, chemical dosing levels for disinfection are adjusted based on flow and pH level. Even small errors over time will affect water quality. It is recommended that a standardized instrument calibration program be developed to both assess the effective useful life (EUL) of instrumentation and manage calibrations performed on a routine basis. Leverage asset management or maintenance management software to record and archive the work performed.

8.3.5 Radio Study

Known interferences with the current radio network exist. Conduct radio study to recommend improvements on communications options.

8.3.6 Chemical Feed Systems Improvements Projects

The age of chemical systems equipment at the Allen WTP spans 20 to 30 years. While operations have done an excellent job of keeping the systems operational, some have reached the end of their useful life. Multiple chemical systems improvements projects are recommended in the CIP to provide redundancy and replace or maintain equipment to extend its useful life. For the purpose of this Master Plan, it is recommended to complete these improvements in two phases over the next 3 to 6 years.

8.3.7 Flash Mixer Replacement

The original flash mixer from 1999 has reached the end of its useful life. The City has purchased a backup motor and should replace that when possible. At that time, the wetted elements of the flash mixer should be inspected and evaluated for wear.

8.3.8 Dewatering Facility Spare Parts

The residuals handling process, including the South Reservoir, equalization tank, belt press, and drying beds are a crucial component of the treatment process. The system is aging and does not have complete redundant elements. To minimize process downtime, it is recommended that key spare parts be purchased as soon as possible.

8.3.9 Records Conversion Project

Multiple databases are difficult to maintain. GIS data can be prepared for the Allen WTP from existing as-built (e.g., record drawings) information to ready the hydraulic model update with accurate topology and necessary attribute data. Update water system geodatabase network design and convert as-built plans and system atlas to geodatabase format.

8.3.10 Water Softening Project

It is recommended to complete an assessment of alternatives to determine how to address the hard water issue in Englewood. Implementing a softening project will mitigate the need for home water softeners and avoid excessive scaling in the distribution system. This should occur within the next 2 years. A softening project should be implemented after the optimum process is selected.

8.3.11 Operations Complex Space Improvement

To address the space limitations at the Allen WTP and within the Utilities Department, the first phase of this project should engage in a study of alternatives. After the optimized plan has been determined to address the space constraints, the second phases of this project designs and constructs the expansion and/or retrofits needed.

9. Policy Recommendations

In addition to the program recommendations presented in **Section 7**, several policy issues been identified based on discussions with the City's Utilities staff and review of the City's existing policies.

9.1 Design and Construction Standards

The purpose of design and construction standards is to identify minimum design standards and specifications, submittal requirements and approval or acceptance procedures to be used for water systems that will be maintained by the City. These standards typically apply to private development projects containing utilities that will be turned over to the City as well as all capital improvement projects. The City currently has a set of design and construction standards that are not publicly available. It is recommended that the City invest in updating them to the latest industry standards. The update should include a design manual, standard detail drawings, technical specifications, list of approved products, and detailed as-built submittal requirements including GIS layers so that the City's GIS database can be kept up to date after the completion of CIP projects or new developments.

9.2 City Building/Redevelopment Standards

Existing policies do not adequately address the type of redevelopment that the City is experiencing. The City should consider implementing policies relative to the impact of development on the water distribution system. The City currently has a detailed application process for new developers. However, it would be beneficial for the City to establish a policy and develop requirements specific to the Utilities Department.

Requirements may include:

- Plan review checklists based on the City's design/construction standards
- Hydraulic analysis requirements (including necessary field testing, as required and as directed by the City)
- Record submittal requirements – require a complete set of signed and sealed as-builts for records prior to releasing the final Certificate of Occupancy (CO)
- Utility testing and inspection requirements
- Allocation of responsibility for water system upgrade needs

9.3 Benchmarking Program

Benchmarking utility performance indicators support continuous improvement and allow utilities to track their own performance and to compare their results to peers to identify areas that could be strengthened. AWWA's Utility Benchmarking Program is an option for the City to consider that provides a framework for improving both operational efficiency and managerial effectiveness for all utilities. Areas of the program includes organization development, business operations, customer service, and water operations.

9.4 Water Infrastructure Ownership

The City should establish a policy that clearly delineates the ownership of water service lines and meters. Across the nation, a variety of service line and meter ownership models exist.

9.5 Lead Service Line (LSL) Replacement

The Environmental Protection Agency's (EPAs) current Lead and Copper Rule (LCR) includes actions to reduce lead (Pb) and copper (Cu) exposure in drinking water. Currently, the LCR requires water systems to monitor Pb and Cu concentrations at consumer taps. If Pb concentrations exceed the "action level" of 0.015 parts per million (ppm) in greater than 10% of consumer taps sampled, actions must be taken to inform the public about steps they can take to protect their health and lead service lines (LSLs) may need to be replaced. If Cu concentrations exceed the action level of 1.3 ppm in greater than 10% of consumer taps sampled, actions must be taken to control corrosion. Based on results over the past several years, Englewood is in full compliance with the current regulation.

The City of Englewood, like most utilities in the nation, will have to address issues related to the soon to be revised Lead and Copper Rule (LCR) in the next few years. This has a potentially significant impact Englewood's CIP as the new rule will probably encourage or require the replacement of existing lead service lines (LSLs) in the distribution system. The following lists the recommended actions Englewood can implement now to prepare for the revised LCR:

- Develop and maintain an LSL Inventory - The current LCR encourages utilities to maintain and update an inventory of all service line material in the distribution system. This part of the LCR has not be consistently enforced until recently. A sound inventory will assist in long-term capital project financing.
- Review the corrosion control method applied at the Allen WTP - It is recommended that after the details of the revised LCR are known, the City conduct a desk-top and/or bench-top study to verify the existing corrosion control method.
- Re-assess the sampling program used to verify compliance - Again, regulators have an increased interest in verifying compliance with the existing LCR. It is recommended that the City review their testing program, including which homes are sampled, in the next 12 to 24 months.
- Investigate opportunities to reduce costs for LSL replacements - The current and anticipated LCR will probably not require Englewood to replace LSLs. However, should Englewood implement a replacement program, the City may consider combining these efforts with water main, sewer, and street improvements when they occur. Another effective policy to consider is to require significant home and business redevelopment efforts to replace the entire service line regardless of the age or material. This ensures a property has updated infrastructure and no LSL.
- Consider policies on payments for replacements - Almost all drinking water utilities need to consider what part of the overall LSL replacement program is paid for by the ratepayers and what is paid by the property owner. Several have created new policies that range from full customer payment to full utility payment. Recent studies have shown the most effective programs have the utility pay for at least partial replacement with programs for customers to pay off the replacement over time on the water bills.

Based on the maximum estimate of remaining LSLs in Englewood's system and assuming the City will pay for the replacement from the main to the property line, Hazen is including $20 million over the next

15 years in this Master Plan for consideration. As the LCR rulemaking continues, Englewood staff should stay updated on the latest direction of the rule and the schedule to comply with the revisions.

9.6 Universal Metering

It is recommended that the City develop a policy to transition the remaining 1,200 flat rate billing accounts to metered billing. The program associated with this policy is described in **Section 7.1.10**.

9.7 Main Replacement Rate

Sections 7.1.6 and **7.1.7** describe programs for distribution main (12-inch and smaller) and transmission main (greater than 12-inch diameter) replacement. The City should develop a policy on the rate of replacement for its aging water mains to improve system reliability. This policy should also include a framework for coordination between Utilities and Public Works so that water main replacement, stormwater projects and street reconstruction projects can be coordinated as a cost saving measure.

9.8 Water Hardness

For the past few decades, the hardness, or calcium content, of water delivered to customers is considered in the high range, or above 200 mg/l as calcium carbonate. Thus, many customers have home treatment systems to minimize the impacts of hard water such as pipe and fixture scaling and excessive use of household detergents and soaps. As part of the recommended water softening project, it will be desired to establish a policy or goal of the hardness level that will be acceptable to customers. One utility in the Denver Metro area recently addressed this issue and set a policy to match the hardness level in their best source water and to implement a treatment system that meets this goal.

9.9 Compensation Plan Model

The City has recently published a solicitation seeking a consultant to prepare a new compensation plan and create a sustainable model that can be updated annually. This policy update will include the following tasks:

- Determine the City's philosophy on compensation
- Utilize the most current surveys (external equity)
- Identify matches for current jobs
- Identify job grades (internal equity)
- Build a compensation model
- Calculate a market average
- Address inconsistencies and make adjustment decisions
- Create an implementation plan

- Develop a communication plan

The goal of this policy update is to attract, motivate and retain employees and mitigate risk.

10. Capital Improvement Program

10.1 Cost Basis

Estimated project and program costs are considered Class 5 as defined by the Association for the Advancement of Cost Engineering International (AACEi). The class designation is determined based upon the information available for estimation and the maturity of the design. AACEi sets an accuracy range from –20% to –50% on the low side to +30% to +100% on the high side, depending on the complexity of the project for Class 5 estimates

Costs were developed using planning level costs based upon experience with similar types of programs and projects. For internal staff costs, salary rates were obtained from the City's online financial portal and a 1.35 loaded multiplier was used to account for overhead expenses (insurance, retirement plans, paid time off, etc.). Assumptions were made regarding whether resources needed for each program would be internal or external (e.g., consulting engineer or contractor), or a combination thereof. Costs include planning, engineering and construction costs where applicable. All costs are shown in 2020 dollars.

It is important to note that construction costs are currently increasing due to industry demands and our experience in recent years is that bid prices are often higher than projected. The costs developed for this Master Plan are meant to be conservative for budgeting purposes. As the CIP progresses and uncertainties reduce, costs estimates should be revised to reflect actual conditions.

10.2 Prioritization of Programs and Projects

Prioritization is necessary to focus the City's financial resources on the most critical programs and projects first. As programs and projects are completed, new initiatives and projects may require re-prioritization. This plan prioritized programs and projects into the following three categories:

- High Priority: If these projects and programs are not completed, risk of service disruption to customers is significant and more immediate. High priority projects and programs should begin in the next 1 to 2 years.
- Medium Priority: If these projects and programs are not completed, risk of service disruption to customers may be possible in the future. Medium priority projects and programs should begin in the next 3 to 5 years.
- Long-Range: These projects and programs should be considered for implementation after 5 years.

Based on a comprehensive analysis of the water system as previously described, 27 programs and 27 projects were recommended for the water system. As shown in **Tables 10-1 through 10-6**, these programs and projects have been classified as High Priority, Medium Priority or Long-Range according to the descriptions above. The projected cost of the programs and individual capital improvement projects for the entire water system is estimated to be approximately $161 million over the next 15 years, based on 2020 dollars.

Program costs and prioritization are provided in **Table 10-1** and **Table 10-2** for the distribution system and Allen WTP, respectively. A summary of program costs for the overall water system is provided in **Table 10-3**.

Project costs and prioritization are provided in **Table 10-4, 10-5** and **10-6** for the distribution system, Allen WTP and source water systems, respectively.

Table 10-1: Budget Summary of CIP Programs – Distribution System

CIP ID	Program Name	Prioritization	Timeframe to Start Implementation[1]	Total Budget Cost over 15-Year CIP[2]
PRG-WAT-D-008	Geographic Information System (GIS) Update	High Priority	1-2 Years	$320,000
PRG-WAT-D-009	Program Management - Distribution System	*Cost included in Overall Water System CIP Programs (Table 10-3)*		
PRG-WAT-D-010	Water Model Expansion, Re-Calibration and Updates	High Priority	1-2 Years	$540,000
PRG-WAT-D-011	Enterprise Asset Management - Distribution System	*Cost included in Overall Water System CIP Programs (Table 10-3)*		
PRG-WAT-D-012	Comprehensive Asset Management Program - Distribution System	*Cost included in Overall Water System CIP Programs (Table 10-3)*		
PRG-WAT-D-013	Valve Inspection and Exercising	High Priority	1-2 Years	$660,000
PRG-WAT-D-014	Valve Replacement	Medium Priority	3-5 Years	$1,690,000
PRG-WAT-D-015	Hydrant Flushing and Testing	High Priority	1-2 Years	$530,000
PRG-WAT-D-016	Transmission Main Inspections	High Priority	1-2 Years	$1,120,000
PRG-WAT-D-017	Water Distribution Main Replacement	Medium Priority	3-5 Years	$29,770,000
PRG-WAT-D-018	Transmission Main Replacement	Medium Priority	3-5 Years	$8,160,000
PRG-WAT-D-019	Meter Replacement	Medium Priority	3-5 Years	$2,500,000
PRG-WAT-D-020	Meter Installation for Non-Metered Accounts	High Priority	1-2 Years	$4,200,000
PRG-WAT-D-021	Storage Tank Cleaning and Inspections	Medium Priority	3-5 Years	$260,000
PRG-WAT-D-022	Water Loss Control Study	Long-Range	5-16 Years	$100,000
PRG-WAT-L-023	Lead Service Line Replacement	Long-Range	5-16 Years	$20,000,000
PRG-WAT-D-024	Advanced Metering Infrastructure (AMI)	Long-Range	5-16 Years	$6,720,000
PRG-WAT-D-025	Emergency Repair Projects – Distribution System	High Priority	1-2 Years	$2,730,000
PRG-WAT-D-026	Construction Management – Distribution System	*Cost included in Overall Water System CIP Programs (Table 10-3)*		
PRG-WAT-D-027	Water Master Plan and Water Model Update	Long-Range	5-16 Years	$660,000
			TOTAL	**$79,960,000**

[1]Timing of implementing each program is dependent on funding.
[2]Costs include a Class 5 contingency of 30 percent.

Table 10-2: Budget Summary of CIP Programs – Allen WTP

CIP ID	Program Name	Prioritization	Timeframe to Start Implementation[1]	Total Budget Cost over 15-Year CIP[2]
PRG-WAT-T-001	Granular Activated Carbon (GAC) Replacement	Medium Priority	3-5 Years	$2,015,000
PRG-WAT-T-002	Filter Surveillance Program	Medium Priority	3-5 Years	$56,000
PRG-WAT-T-003	Enterprise Asset Management - WTP	*Cost included in Overall Water System CIP Programs (Table 10-3)*		
PRG-WAT-T-004	Comprehensive Asset Management Program - WTP	*Cost included in Overall Water System CIP Programs (Table 10-3)*		
PRG-WAT-T-005	Program Management - WTP	*Cost included in Overall Water System CIP Programs (Table 10-3)*		
PRG-WAT-T-006	Construction Management – WTP	*Cost included in Overall Water System CIP Programs (Table 10-3)*		
PRG-WAT-T-007	On-Call/Emergency Field Services Contracts	High Priority	1-2 Years	$4,500,000
			TOTAL	**$6,570,000**

[1]Timing of implementing each program is dependent on funding.
[2]Costs include a Class 5 contingency of 30 percent.

Table 10-3: Budget Summary of CIP Programs – Overall Water System

Program Name	Prioritization	Timeframe to Start Implementation[1]	Total Budget Cost over 15-Year CIP[2]
Program Management	Medium Priority	3-5 Years	$3,647,000
Enterprise Asset Management	Medium Priority	3-5 Years	$716,000
Comprehensive Asset Management Program	Medium Priority	3-5 Years	$543,000
Construction Management	Medium Priority	3-5 Years	$4,412,000
		TOTAL	**$9,320,000**

[1]Timing of implementing each program is dependent on funding.
[2]Costs include a Class 5 contingency of 30 percent.

Table 10-4: Budget Summary of CIP Projects – Distribution System

CIP ID	Program Name	Prioritization	Timeframe to Start Implementation[1]	Total Budget Cost over 15-Year CIP[2]
CIP-WAT-D-020	Zone 1 Isolation Valve Replacement	High Priority	1-2 Years	$200,000
CIP-WAT-D-021	Emergency Interconnections	High Priority	1-2 Years	$510,000
CIP-WAT-D-022	Distribution System Operations Optimization Study	Medium Priority	3-5 Years	$100,000
CIP-WAT-D-023	New Storage Tank for Zone 2	Long-Range	6-15 Years	$3,580,000
CIP-WAT-D-024	Distribution Pump Station Improvements (Phase 1)	High Priority	1-2 Years	$1,980,000
	Distribution Pump Station Improvements (Phase 2)	Medium Priority	3-5 Years	$3,660,000
CIP-WAT-D-025	Hampden Avenue Transmission Main Replacement	Medium Priority	3-5 Years	$1,040,000
CIP-WAT-D-026	Overhead Tanks Replacement	Long-Range	6-15 Years	$16,950,000
CIP-WAT-D-027	Zone 1 and 2 Interconnect – Pressure Reducing Valve	Medium Priority	3-5 Years	$200,000
			TOTAL	**$28,220,000**

[1]Timing of implementing each program is dependent on funding.
[2]Costs include a Class 5 contingency of 30 percent.

Table 10-5: Budget Summary of CIP Projects – Source Water System

CIP ID	Project Name	Prioritization	Timeframe to Start Implementation[1]	Total Budget Cost over 15-Year CIP[2]
CIP-WAT-T-001	Big Dry Creek Diversion Project	High	1-2 Years	$750,000
CIP-WAT-T-002	Elevated Flumes Structural Assessment	High	1-2 Years	$60,000
CIP-WAT-T-003	McLellan Pump Station Improvements	High	1-2 Years	$2,600,000
CIP-WAT-T-004	Union Ave Pump Station Efficiency and Upgrade Project	High	1-2 Years	$2,000,000
CIP-WAT-T-005	Union Avenue Facility - Pond Assessment, Flavor Profile Analysis and PAC Dosing Plan	Medium	3-5 Years	$60,000
CIP-WAT-T-006	Union Avenue Facility - Sodium Permanganate System Replacement	High	1-2 Years	$300,000
CIP-WAT-T-007	North/Belisle Pond Assessment	High	1-2 Years	$20,000
CIP-WAT-T-008	Source Water Projects	High	1-2 Years	$1,980,000
			TOTAL	**$7,770,000**

[1]Timing of implementing each program is dependent on funding.
[2]Costs include a Class 5 contingency of 30 percent.

Table 10-6: Budget Summary of CIP Projects – Allen WTP

CIP ID	Project Name	Prioritization	Timeframe to Start Implementation[1]	Total Budget Cost over 15-Year CIP[2]
CIP-WAT-T-009	Comprehensive Water Treatment Facility Evaluation	Long-Range	6-15 Years	$100,000
CIP-WAT-T-010	Filter Improvements Project	Long-Range	6-15 Years	$1,100,000
CIP-WAT-T-011	Electrical and Control System Upgrades (Phase 1)	High	1-2 Years	$1,710,000
	Electrical and Control System Upgrades (Phase 2)	Medium	3-5 Years	$3,840,000
CIP-WAT-T-012	Instrument Assessment and Calibration Program Development	Medium	3-5 Years	$40,000
CIP-WAT-T-013	Radio Study	Medium	3-5 Years	$20,000
CIP-WAT-T-014	Chemical Feed System Improvements Projects (Phase 1)	High	1-2 Years	$360,000
	Chemical Feed System Improvements Projects (Phase 2)	Medium	3-5 Years	$1,040,000
CIP-WAT-T-015	Flash Mixer Replacement	High	1-2 Years	$300,000
CIP-WAT-T-016	Dewatering Facility Spare Parts	High	1-2 Years	$30,000
CIP-WAT-T-017	Records Conversion Project	Long-Range	6-15 Years	$200,000
CIP-WAT-T-018	Water Softening Project (Phase 1)	High	1-2 Years	$100,000
	Water Softening Project (Phase 2)	Long-Range	6-15 Years	15,000,000
CIP-WAT-T-019	Operations Complex Space Improvement (Phase 1)	High	1-2 Years	$75,000
	Operations Complex Space Improvement (Phase 2)	Long-Range	6-15 Years	$5,000,000
			TOTAL	**$28,920,000**

[1]Timing of implementing each program is dependent on funding.
[2]Costs include a Class 5 contingency of 30 percent.

10.3 City Resources

The City's Utilities Department is responsible for the day-to-day operation and maintenance of the Allen WTP, the water distribution system and the sanitary sewer collection system.

The Allen WTP operations group consists of 15 full-time staff that are supervised by the Water Production Superintendent. The group consists of water operators (8), mechanic specialist (1), water resource technician (1), belt press operator (1), facilities maintenance technician (1), water quality technicians (2), and a seasonal administrative assistant (1).

The water distribution/sewer collection group consists of 12 full-time field staff supervised by the Water Distribution/Sewer Collection Superintendent and five full-time office staff. This group is responsible for the City's 166 miles of water distribution piping, valves and hydrants that serve more than 11,000 water service accounts. This group also handles the operation and maintenance of the sewer collection system.

With the proposed CIP, there are opportunities to increase the Utilities field staff allowing the City to manage some aspects of the programs internally. A summary of the additional full-time equivalents (FTEs) recommended to implement the CIP programs is provided in **Table 10-7**.

Table 10-7: Summary of FTE

Program Name	FTE 2020-2024[1]	FTE 2025-2029[1]	FTE 2030-2034[1]	Staff Description
Geographic Information System (GIS) Update	1.25	1.0	1.0	GIS analyst
Valve Inspection and Exercising	3.63	1.69	1.69	Field crew (2 people)
Hydrant Flushing and Testing	2.03	0.85	0.85	Field crew (2 people)
Meter Installation	0.81	0.2	0.0	Water Distribution Operations Staff
Storage Tank Cleaning and Inspections	0.3	0.5	0.5	Water Distribution Operations Staff
Water Loss Control Study	0.0	0.4	0.4	Engineering Staff
GAC Replacement	0.1	0.1	0.1	WTP Operations Staff
Filter Surveillance Program	0.1	0.1	0.1	WTP Operations Staff
Enterprise Asset Management	0.5	0.83	0.83	Asset Management Subject Matter Expert
Comprehensive Asset Management Program	0.5	0.83	0.83	Asset Management Subject Matter Expert
TOTAL	**9.22**	**6.5**	**6.3**	

[1]Represents the total FTEs needed over a five-year period, not per year. Based on assumptions (as detailed in the program sheets) on whether programs will be performed with internal or external resources, or a combination thereof.

Table 10-7 provides only a general indication of the additional staffing needs and timing for the Utilities department. It is recommended that the Utilities department leadership utilize this table as a starting point for refining the staffing needs for program implementation and developing the hiring plan for the department.

10.4 Recommendations

It is recommended that the City of Englewood implement the programs and projects summarized in **Table 10-1** through **Table 10-6**. The total cost of these programs and projects is estimated at approximately $161 million over the next 15 years. The CIP schedule is based on beginning implementation in 2020 but is dependent on available funding followed by other critical path factors including, but not limited to: study, design, permitting, construction, and program management activities and durations.

A detailed breakdown by year of the proposed CIP is provided in **Appendices N and O**.