City of
FRESNO

Drinking Water Infrastructure
Renewal and Replacement Plan

AUGUST 2019
FINAL

Prepared By:

AKEL ENGINEERING GROUP, INC.

In Coordination with:

KLEINFELDER
Bright People. Right Solutions.

City of FRESNO

CITY OF FRESNO

2019

Drinking Water Infrastructure

Renewal and Replacement Plan

Final

August 2019

REGISTERED PROFESSIONAL ENGINEER
ANTOINE A AKEL
C 041682
CIVIL
STATE OF CALIFORNIA
8/26/19

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Smart Planning Our Water Resources

August 26, 2019

City of Fresno
2101 G Street, Bldg A
Fresno, Ca 93706-1620

Attention: Dejan Pavic, P.E.
Project Engineer

Subject: Drinking Water Infrastructure Renewal and Replacement Plan – Final

Dear Dejan:

We are pleased to submit the report for the City of Fresno Drinking Water Infrastructure Renewal and Replacement Plan (R&R). This plan was a collaborative effort with the Kleinfelder team and resulted with the development of the risk or criticality of the drinking water infrastructure along with R&R recommendations for a 5-year horizon. The renewal and replacement plan documents the risk framework, risk analysis and 5-Year recommendations for the following drinking water assets:

- Distribution System
- Well and Pump
- Groundwater Wellhead Treatment Facilities
- Surface Water Treatment Facility

We extend our thanks to you; Dejan Pavic, Project Engineer; Mike Carbajal, Director of Public Utilities; and other City staff whose courtesy and cooperation were valuable components in completing this study.

Sincerely,

AKEL ENGINEERING GROUP, INC.

Tony Akel, P.E.
Principal

Enclosure: Report

7433 N. FIRST STREET, SUITE 103 • FRESNO, CALIFORNIA 93720 • (559) 436-0600 • FAX (559) 436-0622
www.akeleng.com

Acknowledgements

DPU Management Personnel

Mike Carbajal, Director of Public Utilities

Dejan Pavic, Project Engineer (Project Manager)

Bud Tickel, Assistant Director

DPU Water Division Staff

Bob Little, Water Division Supervisor

Cynthia Fischer, Water System Supervisor

Christopher Carroll, Water System Supervisor

Eric Campbell, Water System Supervisor

Robert Diaz, Supervising Engineering Technician

Chad Colby, Water System Supervisor

Steve Western, Distribution Supervisor

Lito Bucu, Supervising Engineering Technician

Glenn Knapp, Program Management and Engineering Office

Russell Guilliams, Water Treatment Plant Supervisor

DPU Program Management Personnel

Gino Rapagna, Senior Program Manager

Paul Amico, Former Senior Project Manager

City of Fresno
Infrastructure Renewal and Replacement Plan

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APPENDICES

EXECUTIVE SUMMARY

This executive summary presents a brief background and plan objectives for the City of Fresno's water distribution system Renewal and Replacement (R&R) Plan, and provides a 5-year R&R budget expenditure summary.

ES.1 BACKGROUND AND PLAN OBJECTIVES

The City of Fresno delivers quality water to 500,000 customers and operates and maintains the following water infrastructure assets:

- **Supply system** that includes 240 active groundwater supply wells, three surface water treatment facilties (Northest Surface Water Treatment Facility, and Southeast Surface Water Treatment Facility, and T3).
- A **transmission/distribution system** with over 1,800 miles of mains, in addition to service lines, pumps and storage tanks.

The condition of the drinking water infrastructure assets degrades over time, and unless repaired or replaced before the end of their useful life, they begin to fail. The objective of the Renewal and Replacement (R&R) plan for the City of Fresno is to meet the desired levels of service (LOS) expected by the customer, with the most cost-efficient investment in infrastructure. Benefits of the R&R Plan include:

- Optimizing limited available funds
- Moving from reactive replacement to proactive replacement (replace infrastructure at the right time, not when it fails)
- Justifying annual financial investments
- Maintaining consistent level of service
- Reducing infrastructure life cycle costs

ES.2 RENEWAL AND REPLACEMENT PLANNING OVERVIEW

Renewal and Replacement planning is a critical element of the asset management program. It includes identifying critical project improvements which are needed for budgeting purposes.

The first stages of an R&R Plan focus on creating an asset inventory or registry. This starts by defining asset types. An asset type is the smallest infrastructure piece for which maintenance is being tracked over time. The identification of asset types and their relationship to their parent asset is important because it drives risk analysis and the life-cycle cost analysis.

This Renewal and Replacement Plan followed the asset management planning process, and covered many steps included in a typical asset management plan: defining levels of service, asset inventory, identify critical assets, renewal and replacement planning, and developing prioritized projects for financial planning and budgeting

This information typically allows agencies in more accurately projecting 5-year (or more) budgets based on the most pressing needs. It also helps agencies in determining if the existing rate structure or other revenue generating mechanisms are adequate

ES.3 COST SUMMARY

Cost estimates presented as part of this pipeline replacement plan were prepared for general planning purposes. Final costs of a project will depend on several factors including the final project scope, costs of labor and material, and market conditions during construction. The costs in this report are intended for developing an "Order of Magnitude" estimate and do not account for site specific conditions, labor and material costs during the time of construction, final project scope, implementation schedule, and other various factors.

ES.1.1 Distribution System R&R Cost Summary

The 5-year costs of implementing the distribution system R&R recommendations was estimated at $29.6 million for an average annual cost of about $5.9 million. Total costs for distribution R&R recommendations are presented in **Table ES.1** and the complete prioritized list of R&R recommendations is presented in Chapter 2.

Table ES.1 Distribution System R&R 5-year Cost Summary

Year 1	Year 2	Year 3	Year 4	Year 5	Total[1]
$5,926,600	$5,926,600	$5,926,600	$5,926,600	$5,926,600	**$29,633,000**

Note:

1. Contingency: 30% for construction costs and 25% for engineering and management

ES.1.2 Well R&R Cost Summary

Assessment of the condition and performance of all wells within the City's system indicates a significant backlog of necessary renewal and replacement activities. Almost all active wells were recommended for at least one R&R action with most wells recommended for multiple R&R actions. While competition of these R&R activities requires an initial cost investment, addressing outstanding issues and establishing a proactive maintenance strategy based on well priority will prevent excessive costs in the future. Proactive maintenance will help to delay and limit costly R&R actions including full replacements of pumps and motors. A focus should be placed on addressing renewal and replacement activities for high priority wells first to maintain a sustainable and productive system of groundwater supply wells.

Total costs for well R&R recommendations are presented in **Table ES.2** and the complete prioritized list of R&R recommendations is presented in **Appendix F**. The 5-year costs of implementing the R&R recommendations described in the above sections was estimated as $19,643,260 with a 30% contingency for construction costs, not including costs for water quality treatment at wells.

Table ES.2 Well R&R 5-year Cost Summary

Year 1	Year 2	Year 3	Year 4	Year 5	Total
Video Condition Inspection and Investigation					
$30,600	$12,000	$17,400	$0	$0	**$60,000**
Diagnostics: Performance Testing (OPE)					
$21,200	$11,200	$19,200	$6,400	$29,600	**$87,600**
Restoration: Pump Maintenance and Replacement					
$264,000	$100,000	$173,000	$18,000	$153,000	**$708,000**
Restoration: Motor Maintenance and Replacement					
$270,000	$135,000	$230,000	$80,000	$355,000	**$1,070,000**
Restoration: Well Development, Rehabilitation, and Chemical Treatment					
$1,011,950	$1,053,000	$952,550	$1,437,400	$704,700	**$5,159,600**
Water Quality Treatment (Not included in total)					
$7,200,000	$800,000	$6,400,000	$1,600,000	$16,000,000	**$32,000,000**
Site Security and Improvements					
$350,000	$70,000	$70,000	$0	$35,000	**$525,000**
Well Replacement or Abandonment					
$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	**$7,500,000**
Sub-Total					
$3,447,750	$2,881,200	$2,962,150	$3,041,800	$2,777,300	**$15,110,200**
Total (including 30% contingency)					
$4,482,075	**$3,745,560**	**$3,850,795**	**$3,954,340**	**$3,610,490**	**$19,643,260**

0.0.1 ES.1.3 Wellhead Treatment R&R Cost Summary

The 5-year costs of implementing the wellhead R&R recommendations was estimated at $9,409,442 with a 30% contingency for construction costs for an average annual cost of about $1.9 million. Total costs for wellhead treatment R&R recommendations are presented in **Table ES.3** and the complete prioritized list of R&R recommendations is presented in Chapter 4.

Table ES.3 Wellhead Treatment R&R 5-year Cost Summary

Treatment	Total
PTA/GAC Treatment (2 sites)	**$288,272**
Oxidation and Filtration Treatment (3 sites)	**$576,000**
GAC and Blending Treatment (10 sites)	**$2,224,000**
GAC treatment (17 sites)	**$2,741,760**
De-gassing Treatment (11 sites)	**$1,408,000**
Sub-Total	**$7,238,032**
Total (including 30% contingency)	**$9,409,442**

ES.1.4 NESWTF R&R Cost Summary

The 5-year costs of implementing the NESWTF R&R recommendations was estimated at $4,986,842 with a 20% contingency for construction costs for an average annual cost of about $1.0 million. Total costs for NESWTF R&R recommendations are presented in **Table ES.4** and the complete prioritized list of R&R recommendations is presented in Chapter 5.

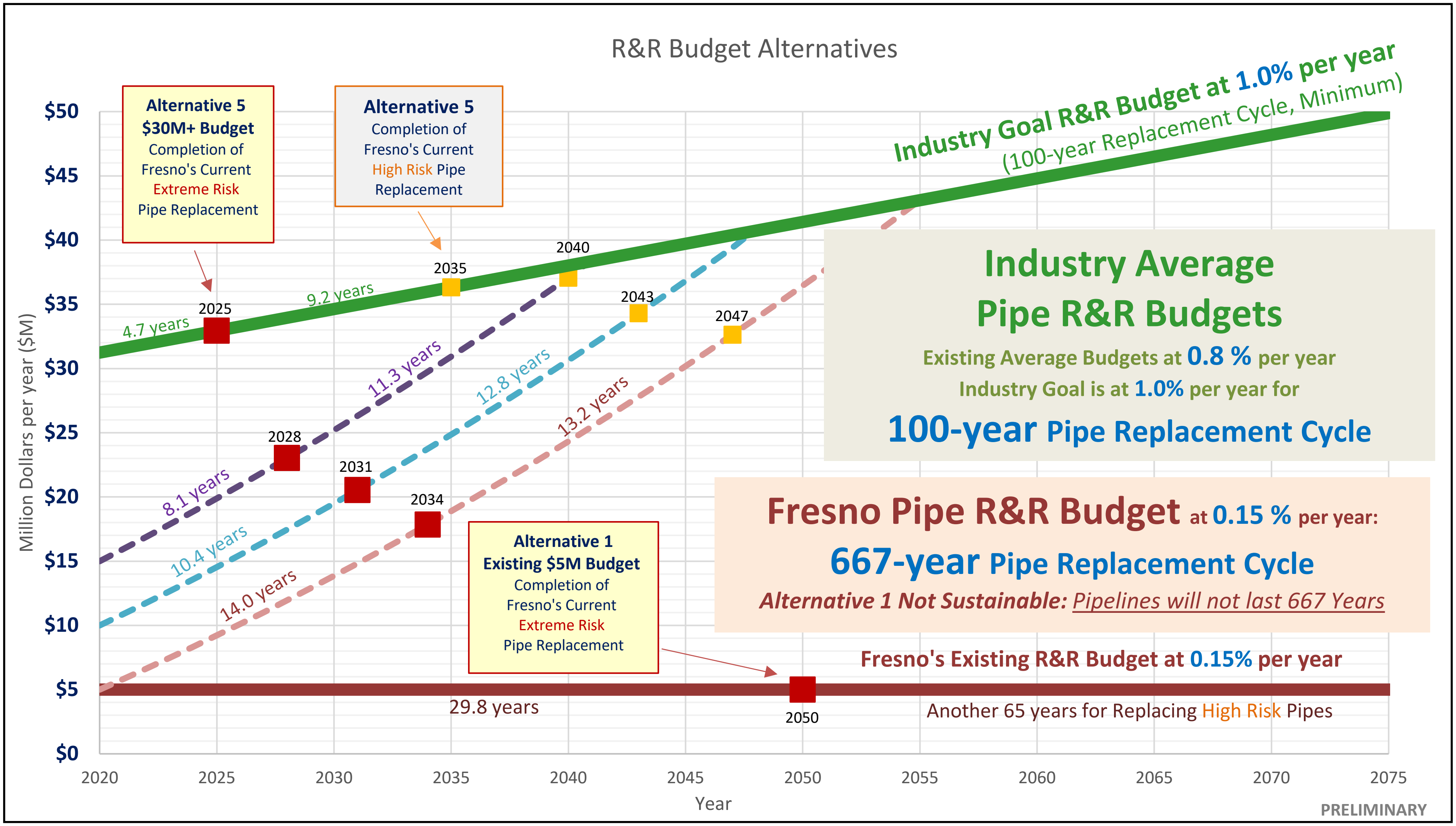
Table ES.4 Northeast Surface Water Treatment Facility R&R 5-year Cost Summary

Treatment Facility	Total
Water Intake	$203,320
Raw Water Pump	$0
Plant Intake and Flash Mixer	$7,800
Clarification Basins/Actiflo	$1,051,863
Ozone System	$1,279,915
Filters	$245,700
Chemical Building	$970,604
Operations Building	$32,500
Treated Water Pump Station	$364,000
Sub-Total	$4,155,702
Total (including 20% contingency)	**$4,986,842**

ES.4 LONG-TERM RECOMMENDATIONS

This renewal and replacement plan should act as the first step to developing a full asset management plan for the drinking water infrastructure of the City of Fresno. This plan has established the foundation for an asset management plan by addressing the current state of the drinking water assets, the required level of service, and identifying critical assets. The City should continue to invest in the long-term performance of their assets which will result with the lowest cost of ownership. By implementing a proactive renewal and replacement strategy the long-term performance of the asset can be sustained and increase the overall asset lifecycle and subsequently increase the City's fiscal sustainability.

Renewing and replacing the water infrastructure will require an increase of capital budgets as the current level of investment will not suffice. For example, the water distribution system contains over 1,800 miles of pipeline varying significantly in their age and material with approximately 725 miles of pipelines that have been in service longer than 50 years. Based on recent replacement projects, the City has replaced approximately 3.0 miles per year which results with a 0.15% system replacement or a 667-year replacement cycle. The City will be unable to maintain the required level of service with the current replacement rate and therefore, an increase in capital improvement funds must be made. Figure ES.1 documents the current pipeline replacement rate versus the industry goal of 1% system replacement per year. This figure illustrates a clear budget gap that will continue to increase as the system ages and expands if new funding is not made available.



LEGEND

- Alternative 1: Existing Budget (667-year cycle, 0.15% System Replacement)
- Alternative 2: Ramp from $5M (35 Years to Reach 1% System Replacement)
- Alternative 3: Ramp from $10M (28 year to 1% System Replacement)
- Alternative 4: Ramp from $15M (21 years to 1% System Replacement)
- Alternative 5: 1% System Replacement per Year (Industry Goal) (100-year Cycle)

Assumptions:

1. System Growth: 20 miles of new construction per year (based on historical construction)
2. All costs in 2019 dollars

Note: *Industry Average Pipe Replacement based on 2018 Utility Survey: Water Main Breaks in the USA and Canada: A Comprehensive Study.* *Utah State University (March 2018).*

281 *Total Utilities surveyed.* ***98*** *Utilities provided detailed responses:*

Current Average Annual R&R Budget = 0.8%

August 27, 2019

AKEL ENGINEERING GROUP, INC.

Figure ES.1

Pipeline Replacement Financial Sustainability Alternatives

Drinking Water Infrastructure Renewal and Replacement Program

City of Fresno

CHAPTER 1 – ASSET MANAGEMENT PLANNING

This chapter provides a brief description of the project objectives, the asset management process, the renewal and replacement plan, and the report organization.

1.1 PROJECT OBJECTIVES

The condition of the drinking water infrastructure assets degrades over time, and unless repaired or replaced before the end of their useful life, they begin to fail. These drinking water infrastructure assets in Fresno include

- Supply: groundwater supply wells, Northest Surface Water Treatment Facility, Southeast Surface Water Treatment Facility, and T3.
- Transmission and distribution mains, storage tanks, pump stations, service lines, and other related appurtenances.

The objective of the Renewal and Replacement (R&R) plan for the City of Fresno is to meet the desired levels of service (LOS) expected by the customer, with the most cost-efficient investment in infrastructure. Benefits of the R&R Plan include:

- Optimizing limited available funds
- Moving from reactive replacement to proactive replacement (replace infrastructure at the right time, not when it fails)
- Justifying annual financial investments
- Maintaining consistent level of service
- Reducing infrastructure life cycle costs

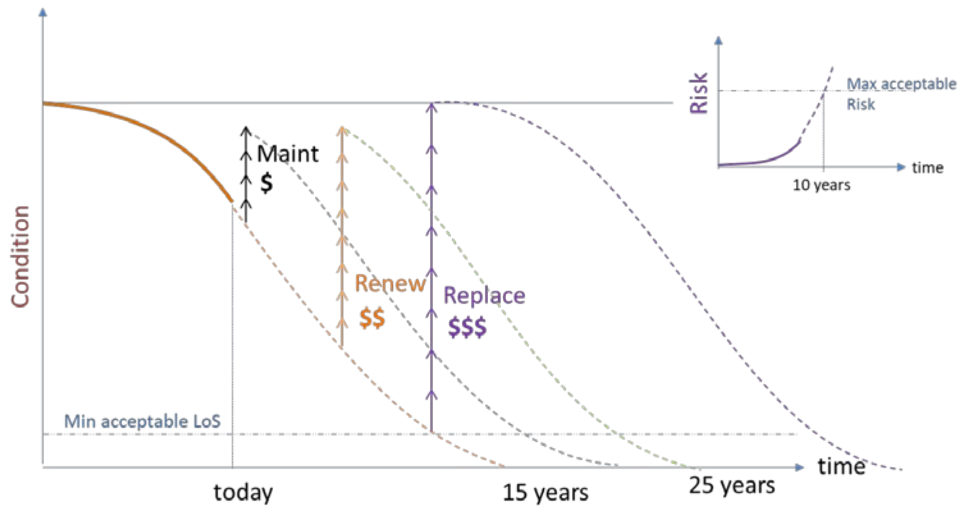
The City's existing capital improvement projects (CIP), which are generally identified through master planning, include projects related to mitigating system deficiencies, improving performance, and expansion for future growth. The projects recommended in this R&R plan are intended to replace or refurbish the existing assets that are close to or have exceeded their useful life. The plan will assist the City in managing and maintaining the existing water infrastructure along with developing a full asset management plan.

1.2 5-YEAR BUDGET GOAL

This R&R plan prioritizes the asset renewals, identifies the costs, and determines the target renewal/replacement frequency and associated target annual budget level. Although the risk analysis and assessment included in this project was based on a system wide review, the R&R Plan identified and recommended priority projects for the 5-year budget planning horizon.

By focusing on maintaining and renewing infrastruture, the long-term performance of the asset can be sustained and increase the life cycle costs as shown in the example on **Figure 1.1**. This plan has prioritized asset needs based on risk, which includes each facilities likelihood and consequence of failure, based on historical information from maintenance records

Figure 1.1 Infrastructure Lifecycle Costs



1.3 DRINKING WATER ASSETS

The City of Fresno delivers quality water to 500,000 customers and operates and maintains the following water infrastructure assets:

- **Supply system** that includes 240 active groundwater supply wells, three surface water treatment facilties (Northest Surface Water Treatment Facility, and Southeast Surface Water Treatment Facility, and T3).
- A **transmission/distribution system** with over 1,800 miles of mains, in addition to service lines, pumps and storage tanks.

Though the Southeast Surface Water Treatment Facility (SESWTF) is new, most of the existing water infrastructure is aging and consequently failures rates are expected to increase. The adverse consequences of these failures include: customer supply interruptions, property damage by flooding, costly repairs, and lost water. Typical life expectancy of water system facilties are generally estimated as follows;

- Production Wells:
  - o Typical life expectancy of wells is 50-100 years
- Pipelines:
  - o Typical life expectancy 50-100 years

    - Industry goal: 1.0-1.5% of the system replaced per year, leading to a replacement cycle of 67 to 100 years.

- Surface Water Treatment Facility:
    - Typical equipment life expectancy 25-30 years

1.4 ASSET MANAGEMENT PLANNING OVERVIEW

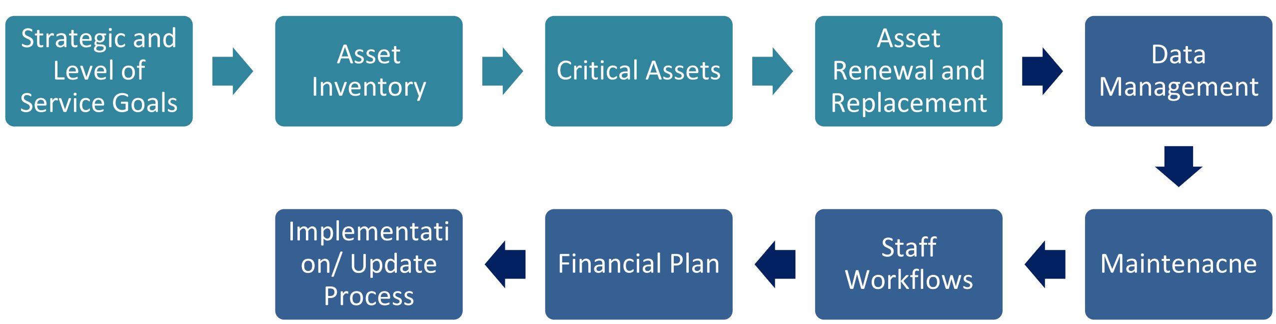
Asset Management is an approach that is effectively used by agencies in making better decisions on maintaining, repairing, or replacing the drinking water infrastructure assets. The ultimate aim of Asset Management is to service residents and business customers, at an expected acceptable level of service, at the lowest investment cost.

Asset Management will assist an agency in documenting (and understanding) the assets they have, how long these aging assets may last, and how much it will cost to repair, rehabilitate, or replace them. Asset management starts with building an inventory of the assets (know what we own), scheduling and tracking the operation and maintenance (O&M) through work orders, and managing the budgeted expenses (costs) compared with the revenue.

This information typically allows agencies in more accurately **projecting 5-year (or more) budgets** based on the most pressing needs. It also helps agencies in determining if the existing rate structure or other revenue generating mechanisms are adequate.

Similar to the development of a comprehensive water system master plan, which is intended to develop capital improvement plans addressing system capacity and growth, the development of asset management plans (AMP) is a process requiring engagement and leadership throughout the agency. The typical AMP steps are documented on **Figure 1.2** and described as follows;

Figure 1.2 Asset Management Planning



Step 1. Level of Service Goals. These goals focus on the overall objectives, and desired levels of service, and establish the guiding direction of the AMP. The goals are based on the overall agency's vision/mission statement. The Level of Service (LOS) goals include, as an example, maintaining a specific minimum pressure at a customer's meter, and are used to prioritize projects.

As an example, and in the case of water distribution pipelines, the service goals which usually are at the heart of a water agency operation include assuring 1) adequate hydraulic capacity, 2) acceptable physical integrity, and 2) safe water quality.

Also using pipelines as an example, risk analysis includes completing an analysis that considers several indices associated with the likelihood of failure (LOF) and other indices associated with the consequence of failure (COF). Risk analysis (Risk) is defined as the combined analysis results from both LOF and COF analysis.

Step 2. Asset Inventory. It is critical for agencies to know the assets they own, and what is their current condition. Data inventory includes the size, capacity, physical condition, construction date, material type, and remaining useful life. Relevant cost data includes the original costs, maintenance, and replacement costs.

Step 3. Identify Critical Assets. Identifying critical assets within an agency is important to better prioritize projects and to focus the limited available maintenance and capital improvement funds. The criticality of assets depends on their importance to the functioning of a system, and the resulting consequence should that asset fail. For example, a pipe that serves 4 houses on a cul-de-sac in a rural neighborhood is less critical than a pipe located in the downtown area and serving many homes and businesses. Criticality is determined by understanding and determining likelihood and consequence of failure.

Step 4. Renewal and Replacement Planning. It is important and critical for an agency to better understand their assets capabilities and know when repairs and replacements to existing aging infrastructure will be needed, and how much it will cost. This information is needed for sound budgetary planning, and knowing where the limited available funds are best spent to provide adequate and acceptable service to customers.

Step 5. Data Management. This includes existing tools and databases related to maintenance, finance, GIS, documents, procurements. Linking these documents will result with efficiencies and improve the decision-making process. A simple database can include data in Microsoft Excel. A more complex system could include an asset management software package or a CMMS (computerized maintenance management system) software package that is configured with asset inventory information, to include work orders and service requests, including the cost of work performed. The best option is usually a specifically designed asset management software program.

Step 6. Maintenance. The challenge for agencies is usually finding the right balance between spending resources on the more pressing corrective maintenance which are in direct responses to either system failures or customer calls versus preventive/routine maintenance. Most often, 90% of resources are spent on the corrective maintenance, with 10% spent on preventive maintenance. Asset management planning typically recommends the balance be at 50% for corrective maintenance and 50% for preventive maintenance.

Sep 7. Staff Workflow. This task includes streamlining the way staff work together to implement asset management processes, how they gather data, as it is critical to achieving strategic asset management. Some important processes to develop include: responding to customer requests, work identification and planning/scheduling, responding to work orders, identifying CIP projects, and budgeting.

Step 8. Financial Plan. This step is important since it allow agencies to understand how much funding is required to manage the system's assets in accordance with the established level of service. The costs form the basis for the operations, maintenance, and capital improvement budgets.

Step 9. Implementation and Update Process. The asset management plan is a long-term commitment for a sustainable effective planning.

1.5 RENEWAL AND REPLACEMENT PLANNING OVERVIEW

Renewal and Replacement planning is a critical element of the asset management program. It includes identifying critical project improvements which are needed for budgeting purposes.

The first stages of an R&R Plan focus on creating an asset inventory or registry. This starts by defining asset types. An asset type is the smallest infrastructure piece for which maintenance is being tracked over time. The identification of asset types and their relationship to their parent asset is important because it drives risk analysis and the life-cycle cost analysis.

This Renewal and Replacement Plan followed the asset management planning process, and covered many steps included in the previous section: defining levels of service, asset inventory, identify critical assets, renewal and replacement planning, and developing prioritized projects for financial planning and budgeting.

1.5.1 Risk Framework and Analysis

Risk assessment and analysis is at the heart of asset management planning, and is one of the primary tools used for identifying and prioritizing renewal projects with the highest urgency. This process results with optimized decisions on financial planning, and for choosing where the limited available public funds are more wisely spent.

Risk analysis consists of assessing the probability (or likelihood) of an asset failing, and more importantly linking it to a consequence if such failure was to occur. This analysis allows the agency to identify existing and future risks that potentially impact the level of customer service and the associated costs. Thus, the risk, also known as the business risk exposure (BRE), is calculated by multiplying the probability or likelihood of failure (LOF) by the consequence of failure (COF).

Risk = Likelihood of Failure (LOF) x Consequence of Failure (COF)

The probability (or likelihood) of failure analysis allows a prediction of failure timing for a particular asset. Did the asset fail to meet the level of service? Has capacity become inadequate? How is the structural condition? Is the lifecycle cost efficient? A numerical LOF score is assigned to each asset based on this assessment.

The consequence of failure analysis assesses the impact of such failure on the residential or business environment, and the resulting anticipated economic loss.

A total of 5 categories were used to assign numerical scores to each likelihood of failure and consequence of failure category. Furthermore, each identifies category was assigned a weight based on its criticality. The 5 Risk rating categories include: Extreme, High, Moderate, Low, and Very Low, as documented on **Table 1.1**. High scores are associated with the Extreme and High rating categories and represent at risk assets that require immediate attention. Low scores are associate with the Very Low or Low rating categories and may represent new or low risk assets.

Table 1.1 Risk Rating and Scores

Risk Rating	Score
Extreme	**5**
High	**4**
Moderate	**3**
Low	**2**
Very Low	**1**

Thus, Renewal and Replacement optimization consisted of setting up computer simulation models that determined the lowest cost strategy to maintain the desired levels of service at an acceptable level of risk across the entire asset portfolio. The level of risk, or the business risk exposure, was the numerical value rating based the LOF times the COF. This risk value was used in this plan to select the high priority needed improvements over the next 5 years.

The Risk Assessment Matrix on **Figure 1.3** illustrates how assets were classified in the Extreme rating category (red) or High rating category (orange), by combining their LOF and COF scores. Thus, the red and orange zone on this figure indicate the projects requiring immediate attention for either renewal or replacement. The yellow zone highlights assets for more aggressive monitoring. The green and blue zone require simple monitoring.

Figure 1.3 Risk Assessment Matrix

Risk Assessment Matrix		Likelihood of Failure				
		Very Low	Low	Moderate	High	Extreme
Consequence of Failure	Extreme	*Medium*	*High*	*High*	*Extreme*	*Extreme*
	High	*Medium*	*Medium*	*High*	*Extreme*	*Extreme*
	Moderate	*Medium*	*Medium*	*High*	*Extreme*	*Extreme*
	Low	*Low*	*Medium*	*Medium*	*High*	*High*
	Very Low	*Negligible*	*Low*	*Medium*	*High*	*High*

1.5.2 Risk Framework Development

The risk framework for each asset included in the risk assessment was calculated as the product of a total consequence of failure (COF) score and a total likelihood of failure (LOF) score. The calculation of the COF and LOF scores incorporates criteria based on characteristics of each asset. Developing a risk framework included the following tasks:

1. Identifying asset types and hierarchy
2. Identifying failure modes per each asset type
3. Determining consequence factors
4. Identifying the risk matrix per asset type (not all types of failure have the same consequences, for example, an asset that fails because it doesn't have enough capacity may not have necessarily an environmental impact).
5. Determining the scoring system to be used for both consequence factors and likelihood of failure
6. Determining the methodology and rules for assessing likelihood of failure under each failure mode, per each asset type, data needs, proxies and key performance indicators.
7. Determining the methodology and rules for assigning consequence of failure scores to each asset type
8. Developing the mathematical expression to calculate a risk score from failure modes scores, consequence factors and hierarchical level.

1.6 SCOPE OF WORK

Realizing the need for a proactive replacement plan the City of Fresno City Council approved Akel Engineering Group Inc. (Akel) to prepare a Renewal and Replacement Plan in May of 2017. The

R&R Plan was completed in coordination with Kleinfelder Group, Inc. (Kleinfelder) and includes the following tasks:

- Risk Framework Development
- Distribution System R&R
- Well and Pump R&R
- Groundwater Wellhead Treatment Facilities R&R
- Surface Water Treatment Facility R&R

This 5-year R&R Plan is intended to serve as a tool to prioritize water assets needs based on a risk analysis

1.7 REPORT ORGANIZATION

The renewal and replacement plan was a collaborative effort between Akel and Kleinfelder, and was organized into the following chapters:

Chapter 1 – Asset Management Planning. This chapter provides a brief description of the project objectives, the asset management process, the renewal and replacement plan, and the report organization. *This chapter was completed by Akel.*

Chapter 2 – Distribution System. This chapter documents the domestic water distribution system, explains the methodology for determining the distribution system risk, and develops recommended improvements based on the risk or criticality analysis. *The tasks in this chapter were completed by Akel.*

Chapter 3 - Wells. This chapter documents the domestic water well asset inventory and explains the risk assessment methodology followed to identify and prioritize the water supply wells renewal and replacement recommendations. *The tasks in this chapter were completed by Kleinfelder.*

Chapter 4 – Wellhead Treatment Facilities. This chapter documents the wellhead treatment facility asset inventory and explains the risk assessment methodology followed to identify and prioritize the wellhead treatment renewal and replacement recommendations. *The tasks in this chapter were completed by Kleinfelder.*

Chapter 5 – Northeast Surface Water Treatment Facility. This chapter documents the Northeast Surface Water Treatment Facility (NESWTF) asset inventory and explains the risk analysis methodology followed to identify and prioritize the NESWTF renewal and replacement recommendations. *The tasks in this chapter were completed by Kleinfelder.*

CHAPTER 2 – DISTRIBUTION SYSTEM

This chapter documents the domestic water distribution system, explains the methodology for determining the distribution system risk, and develops recommended improvements based on the risk or criticality analysis.

2.1 SPECIFIC GOALS OF THE DISTRIBUTION SYSTEM EVALUATION

The purpose of this evaluation is to identify pipelines in the distribution system with the largest risk based on its likelihood of failure and consequence of failure to provide near-term improvement recommendations so the system can maintain levels of service desired by the City and expected by the customer. This evaluation will aid City staff in justifying capital improvement budgets and help change from a reactive repair strategy to a proactive renewal and replacement strategy by identifying high risk pipelines.

This chapter documents the methodology used to identify risk and prioritize distribution system pipeline improvement recommendations. Some of the criteria included in the improvement prioritization evaluation are pipeline age, material, diameter, flow, maintenance history, and system pressures.

2.2 AVAILABLE DATA

The datasets available for this project are documented in this section, including format, source, and comments about data completeness. In general, the data provided is relatively complete for the water distribution system.

- **Hydraulic Model –** The City of Fresno currently maintains a water system hydraulic model that combines information on the physical characteristics of the system (pipelines, wells, booster stations, tanks) as well as operational characteristics (how they operate). The model was developed from the City's pipeline GIS which includes the pipeline spatial location, diameters, materials, and construction year. The hydraulic model was also used to extract pipeline flows, available fire flow, and maximum pressures.
- **Maintenance History –** The City provided the pipeline maintenance history from two sources; Naviline (2007-2017) and Hansen (2017 – 2018). The Naviline data contains pipe repair/maintenance for years 2007-2017, however this data does not differentiate between service line and main line repairs. The Hansen data contains pipeline repair history for main line and service line separately.
- **Water Meters –** GIS shapefiles were provided with the special locations for the water meters.
- **Road Types and Railroads –** GIS shapefiles of the roads and the General Plan circulation maps were provided to identify the road types and railroad locations.

- **Critical Facilities –** The City provided GIS shapefiles of the parcels which contained land use.

2.3 SYSTEM INVENTORY AND CONDITION

The City of Fresno (City) services over 500,000 residential, commercial, and industrial users within their services area. Their current water supply includes approximately 240 active groundwater wells and three surface water treatment facilities (NESWTF, SESWTF, and T3). The City relies on its transmission grid mains (TGMs) for conveying water from wells to customers and on regional transmission mains (RTMs) for conveying water from the Surface Water Treatment Facilities to the TGMs. In general, TGM pipe sizes vary between 10 and 16 inches while RTM pipe size are 18 inches and larger. The domestic water distribution system consists of approximately 1,800 miles of pipelines ranging from ¾ inch to 66-inch in diameter. An inventory of the domestic water pipelines by diameter is documented on **Table 2.1**. The distribution system is primarily comprised of Cast Iron Pipe (CIP), Polyvinyl Chloride (PVC), and Asbestos-Cement Pipe (ACP) as summarized on **Table 2.2**. The pipelines summarized by construction material and decade installed are documented on **Table 2.3**.

The water distribution system has an average age of 42 years old with approximately 725 miles of pipe older than 50 years. In 2017, the City repaired approximately 84 main bursts and leaks.

2.4 RISK ANALYSIS

The risk assessment utilized the software InfoAsset Planner by Innovyze Inc. This software incorporates information about the water system extracted from the hydraulic model as well as user-defined risk assessment criteria to perform a risk analysis for each pipeline included in the analysis. The results of this analysis can be used to prioritize capital projects throughout the City, focusing on the areas of highest risk first and developing an improvement plan for the near-term recommendations (5-year).

2.4.1 Methodology

The risk score for each pipeline included in the risk assessment is calculated as the product of a total consequence of failure (COF) score and a total likelihood of failure (LOF) score. The calculation of the COF and LOF scores incorporates criteria based on characteristics of the pipelines included in the risk assessment. The criteria established include the following components:

Criterion Type: The various criteria can be categorized differently based on the information evaluated. Some of the various criteria types included in this risk assessment are briefly summarized as follows:

Table 2.1 Model Pipeline Inventory, by Diameter

Drinking Water Infrastructure Renewal and Replacement Program
City of Fresno

Pipe Diameter (in)	Length (ft)	Length (miles)	Percent of Total System
0.75	1,303	0.25	0.01%
1	7,057	1.34	0.07%
1.25	5,613	1.06	0.06%
1.5	11,058	2.09	0.11%
2	32,113	6.08	0.33%
3	5,053	0.96	0.05%
4	290,443	55.01	3.02%
6	2,606,515	493.66	27.08%
8	3,711,405	702.92	38.56%
10	334,071	63.27	3.47%
12	1,484,683	281.19	15.42%
14	821,796	155.64	8.54%
16	155,695	29.49	1.62%
18	365	0.07	0.00%
20	1,367	0.26	0.01%
24	55,729	10.55	0.58%
30	22,013	4.17	0.23%
36	31,312	5.93	0.33%
42	12,646	2.40	0.13%
48	9,199	1.74	0.10%
54	10,713	2.03	0.11%
60	2,759	0.52	0.03%
66	13,223	2.50	0.14%
Total	**9,626,130**	**1,823.13**	**100.0%**

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Table 2.2 Model Pipeline Inventory, by Material

Drinking Water Infrastructure Renewal and Replacement Program

City of Fresno

Pipe Diameter (in)	Pipe Length by Material (ft) DIP	PVC	ACP	CIP	STLL	WLDSTL	GAL	COP	Unknown	Total
0.75	—	—	—	406	184	—	105	393	215	1,303
1	—	268	—	2,426	1,341	—	1,139	1,270	614	7,057
1.25	—	316	—	149	632	—	1,475	1,938	1,102	5,613
1.5	—	159	634	1,412	1,285	—	2,483	3,377	1,708	11,058
2	250	9,504	865	2,190	7,548	—	7,039	3,082	1,634	32,113
3	1,053	8	1,807	190	1,762	—	—	232	—	5,053
4	1,314	3,609	71,566	129,248	84,549	—	—	79	78	290,443
6	104,032	63,665	663,174	1,353,970	416,634	—	—	34	5,006	2,606,515
8	95,715	1,965,834	855,399	681,907	111,769	—	—	—	780	3,711,405
10	10,412	1,399	78,878	173,942	69,207	—	—	—	234	334,071
12	325,194	259,536	248,918	626,236	23,670	—	—	—	1,130	1,484,683
14	121,264	528,671	164,977	6,839	—	—	—	25	20	821,796
16	55,936	82,305	12,301	3,160	1,987	—	—	—	5	155,695
18	—	—	—	—	—	—	—	—	365	365
20	—	—	—	—	1,350	—	—	—	17	1,367
24	36,955	17,951	—	—	813	—	—	—	10	55,729
30	7,117	613	—	—	717	13,475	—	—	92	22,013
36	—	11	—	—	8,775	22,526	—	—	—	31,312
42	—	—	—	—	—	12,646	—	—	—	12,646
48	—	—	—	—	1,217	7,982	—	—	—	9,199
54	—	—	—	—	—	10,713	—	—	—	10,713
60	—	—	—	—	—	2,759	—	—	—	2,759
66	—	—	—	—	—	13,223	—	—	—	13,223
Total	**759,242**	**2,933,848**	**2,098,519**	**2,982,076**	**733,440**	**83,324**	**12,241**	**10,431**	**13,009**	**9,626,130**

Table 2.3 Model Pipeline Inventory, Decade Installed and Material

Drinking Water Infrastructure Renewal and Replacement Program

City of Fresno

Install Decade	Pipe Length by Material and Decade Install (ft)									Total
	DIP	PVC	ACP	CIP	STLL	WLDSTL	GAL	COP	Unknown	
1900	—	—	—	360	31	—	—	—	—	**391**
1910	—	—	—	43	13	—	—	—	—	**56**
1920	14	—	—	3,130	18,419	—	290	90	180	**22,123**
1930	3,233	62	5,339	244,267	44,732	—	971	310	351	**299,266**
1940	4,322	410	4,710	205,194	265,480	—	1,485	518	810	**482,928**
1950	7,080	3,202	289,548	922,156	283,182	—	3,694	765	2,822	**1,512,450**
1960	23,297	3,680	211,291	1,199,158	52,601	—	4,850	3,420	1,348	**1,499,645**
1970	289,192	6,669	577,233	378,017	23,071	—	349	2,154	4,882	**1,281,568**
1980	204,469	24,694	813,937	12,566	6,050	—	108	—	664	**1,062,488**
1990	122,705	1,164,249	140,948	9,642	22,002	—	395	563	956	**1,461,460**
2000	70,698	1,331,704	19,179	2,884	11,559	—	—	1,674	814	**1,438,512**
2010	34,232	399,178	36,336	4,660	6,299	83,324	99	936	182	**565,245**
Total	**759,242**	**2,933,848**	**2,098,519**	**2,982,076**	**733,440**	**83,324**	**12,241**	**10,431**	**13,009**	**9,626,130**

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- Proximity to specific locations or infrastructure elements (critical facilities such as schools or hospitals, active service connections, critical pumping facilities, railroads, major roads or freeways)
- Hydraulic results (pipeline flows, velocities, maximum pressures, available fire flow)
- Maintenance records (year of installation, historical leak repair information, problematic materials)
- Pipeline material and age

Criterion Score: Each criterion assigns a score, typically between one and five, to a pipeline based on a scale specific to each criterion. A score of one indicates that a given criterion will minimally

contribute to the total consequence or likelihood of failure for a specific pipeline, while a score of five indicates a criterion will maximally contribute to the pipeline's total score.

Criterion Weight: Each criterion includes a weight that determines how much contribution it makes to the total COF or LOF scores. A higher weight means the score for a pipeline from a particular criterion will contribute more to total COF or LOF score than a criterion with a lower weight.

The criteria type, score, and weight for both the COF and LOF calculations was established through multiple workshops with City staff before being incorporated into the risk assessment software.

2.4.2 Consequence of Failure Criteria

The COF criteria are intended to qualitatively identify the consequences of the failure of pipelines within the system and are used in the calculation of the COF score; the measure or proxy, scale, and weights vary for each criterion. These criteria, as well as the scores and weights, were reviewed and approved by City staff before incorporation into the risk assessment. The specific score values and weights for each COF criteria are summarized on **Table 2.4** and a brief description for each is as follows:

- **Pipe Flow (25%):** This criterion characterizes the pipelines based on the peak flow experienced during maximum day demand conditions. The failure of a pipeline with higher flow can have a greater impact to the level of service of the water system. The peak flow in each pipe was extracted from the hydraulic model.
- **Pipe Diameter (20%):** This criterion characterizes the pipelines based on the diameter. The failure of a large diameter pipeline can have a greater impact to the level of service of the water system.
- **Available Fire Flow (15%):** This criterion characterizes the pipelines based on the available fire flow the distribution system can provide. Pipelines that fail in areas with low available fire flows can negatively impact the systems capability to fight a fire and therefore

Table 2.4 Consequence of Failure Score Card - Water Mains

Drinking Water Infrastructure Renewal and Replacement Program

City of Fresno

				Consequence of Failure	Very Low	Low	Moderate	High	Extreme	
				Rating	1	2	3	4	5	
1	2	3	4	5	6	7	8	9	10	11
No.	Consequence Categories	Description	Weighting	Measure or Proxy	Consequence Scale					Impact to Core Values
1	**Pipe Flow**	Failures in pipelines with higher flow can result in higher disruption of level of service.	**25%**	Flow	≤ 100 gpm	100 - 500 gpm	500 - 1,000 gpm	1,000 - 1,500 gpm	> 1,500 gpm	A. Customer B. Economic C. Operational
2	**Pipe Diameter**	Failure in mains larger than 10" negatively impacts the delivery of water to the distribution system.	**20%**	Diameter	≤ 6"	8"	10-12"	14-16"	>16"	A. Customer B. Economic C. Operational
3	**Available Fire Flow Pressure**	Pipe capacity versus the residual pressure during the required fire flow	**15%**	Residual Pressure	> 40 psi	-	40-30 psi	30 - 20 psi	< 20 psi	A. Customer
4	**Critical Facilities Proximity**	Critical facilities include schools, hospitals, and large water users	**10%**	Proximity to Critical Facilities	Other	-	-	Large water users	Hospitals and Schools	A. Customer
5	**Number of Service Connections**	Failures of pipelines with more service connections will have a greater level of service interruption.	**10%**	Number of Service Connections	0 - 2	3 - 5	6 - 15	16 - 25	> 25	A. Customer B. Economic
6	**Road Type**	Water main breaks in high traffic areas can be more costly to repair and can involve multiple jurisdictions.	**10%**	Road Type	Local Roads	Collectors	Expressway	Arterials, Pipes located in backyards	Freeway	A. Customer B. Economic
7	**Railroad Crossings**	Water main breaks in railroad and HSR crossings can be more costly to repair and can involve multiple jurisdictions.	**5%**	Rail crossings	-		Railroad Crossing	-	High Speed Rail Crossing	B. Economic
8	**Impacts to Water Quality**	Failures of pipelines near plume management wells could cause disruption to groundwater quality efforts	**5%**	Impacts of ability to control plume from water main failure	Other Pipelines	-	-	-	Pipelines near plume management wells	D. Environmental
	Total		**100%**							

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have a higher consequence if a failure were to occur. The available fire flow was extracted from the hydraulic model.

- **Critical Facility Proximity (10%):** This criterion characterizes the proximity of pipelines to critical public facilities such as hospitals, schools and large water users. Failures near critical facilities can negatively impact important public facilities.
- **Number of Service Connections (10%):** This criterion characterizes pipelines based on the number of active service connections associated with each pipe. The failure of a pipeline with more service connections will result in a greater disruption to level of service.
- **Road Type (10%):** This criterion identifies pipelines that cross freeways or are within major road ways. Water main breaks in high traffic areas can be costlier to repair and can involve multiple jurisdictions. The road types were determined by using the GIS road shapefile and comparing each street to the General Plan circulation map.
- **Railroad Crossings (5%):** This criterion identifies pipelines that cross railroad or high-speed rail (HSR) track. Pipelines crossing railroads or the HSR can be costlier to repair and involve multiple jurisdictions.
- **Impacts to Water Quality (5%):** This criterion identifies the pipelines that are near groundwater plume management wells. Pipeline failures near plume management wells can impact groundwater quality efforts.

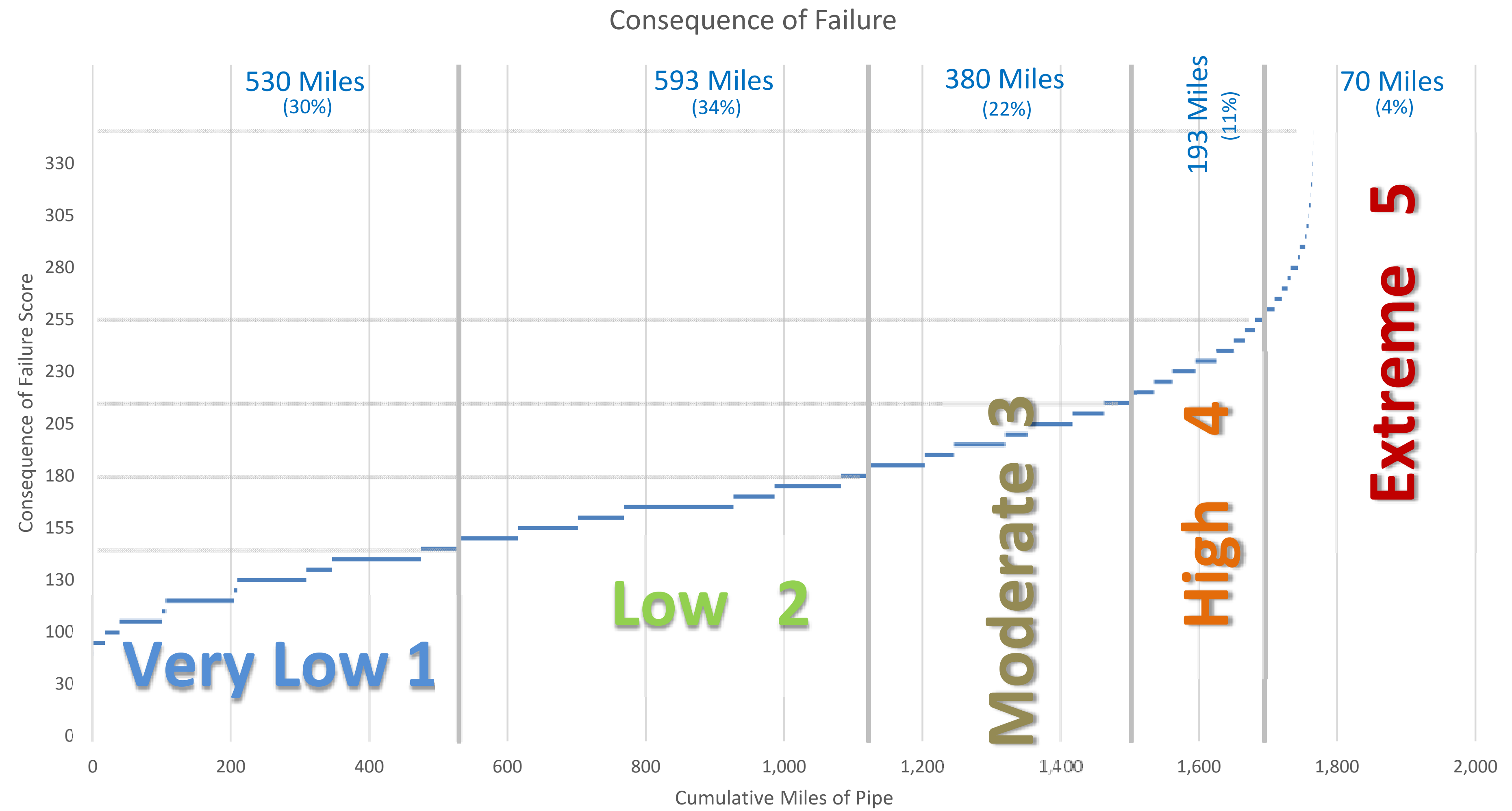
Appendix A contains figures documenting the pipelines identified in each of the COF criteria. Based on the consequence of failure criteria each pipeline was assigned a score. The breakdown of the pipeline COF is documented on Figure 2.1 and summarized as follows;

- Very Low: 530 miles (30%)
- Low: 593 miles (34%)
- Moderate: 380 miles (22%)
- High: 193 miles (11%)
- Extreme: 70 miles (4%)

2.4.3 Likelihood of Failure Criteria

These criteria are intended to qualitatively identify the likelihood of the failure of pipelines within the system and are used in the calculation of the total LOF score; the types, score values, and weights vary for each criterion. These criteria, as well as the scores and weights, were reviewed and approved by City staff before incorporation into the risk assessment. The specific score values and weights for each LOF criterion are summarized on Table 2.5 and a brief description for each is as follows:

- **Leakage History (35%):** This criterion assesses the number of leaks repaired on individual pipelines. Based on leak repair records received from City staff, the total number of leak repairs for the pipelines included in the risk assessment was determined. It was



LEGEND

Note: Cumulative miles of pipeline shown represent distribution system and do not include RTMs.

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Figure 2.1
Consequence of Failure

Drinking Water Infrastructure Renewal and Replacement Plan
City of Fresno

City of FRESNO

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Table 2.5 Likelihood of Failure Score Card - Water Mains

Drinking Water Infrastructure Renewal and Replacement Program

City of Fresno

				Likelihood of Failure	Very Low	Low	Moderate	High	Extreme	
				Rating	1	2	3	4	5	
1 No.	2 Likelihood Categories	3 Description	4 Weighting	5 Measure or Proxy	6 Likelihood Scale	7	8	9	10	11 Failure Modes
1	**Leakage History**	Pipelines with more frequent maintenance have higher likelihoods of failing.	**35%**	Leak Repair History	0	0.1	0.1-1	1-3	>3	A. Physical Integrity
2	**Pipe Material Failure History**	Based on City maintenance records certain types of pipeline are more prone to failure.	**25%**	Material and Maintenance Records	Other		14" DR-25 PVC (>2004 install)		14" DR-25 PVC (1990-2004 install)	A. Physical Integrity
3	**Pipe Maintenance Trends**	Based on review of leak repair history, pipelines constructed in certain years may have higher number of leak repairs per mile of installed pipeline.	**15%**	Number of Leak Repairs per Mile (Trends of Year Constructed/Material)	Other		1 - 3 leaks per mile of pipeline installed		> 3 leaks per mile of pipeline installed	A. Physical Integrity
4	**Percent Design Capacity**	Design Capacity vs peak flow based on City pipe velocity criteria (5 fps)	**15%**	Peak flow from Hydraulic Model vs Design Flow	≤ 25%	25 - 50%	50 - 100%	100 - 150%	> 150%	B. Performance
5	**Maximum Pressures**	High water pressure can increase risk of pipeline failure and negatively impact customer level of service.	**5%**	Maximum Pressure	35 - 50 psi	50 - 60 psi	60 - 70 psi	70 - 80 psi	> 80 psi	B. Performance
6	**Pipeline Age**	Pipeline age can contribute to increased likelihood of failure	**5%**	Pipeline Age	< 20	20 - 40	40 - 60	60 - 80	> 80 years	A. Physical Integrity
	Total		**100%**							

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assumed that pipelines with a higher number of leaks have a greater likelihood of failure than those with few to no leaks.

- **Pipe Material Failure History (25%):** This criterion assigns a score based on problematic materials in the system. City staff identified 14-inch DR-25 PVC as having a history of prematurely failing and therefore these materials have a high likelihood of failure.

- **Pipe Maintenance Trends (15%):** Following a review of the leak repair history data received from City staff, service requests per mile of pipe based on material and age were determine to identify pipelines with numerous repairs. Pipelines that have a greater number of leaks repaired per mile are more likely to fail than those with fewer to no leaks repaired per mile of pipeline installed.

- **Percent Design Capacity (15%):** This criterion assigns a score to each pipeline based on the pipelines design capacity. The City of Fresno has a pipeline design capacity of 5 feet per second. Based on the peak day velocity, a percentage was applied to each pipe. Pipelines with higher velocities have a higher chance of failure than pipelines with low velocities.

- **Maximum Pressure (5%):** This criterion characterizes the maximum pressure serviced by individual pipelines. It is expected that pipelines regularly operating under high pressures present a higher likelihood of failure than those operating within a typical operating range of 40 to 60 psi.

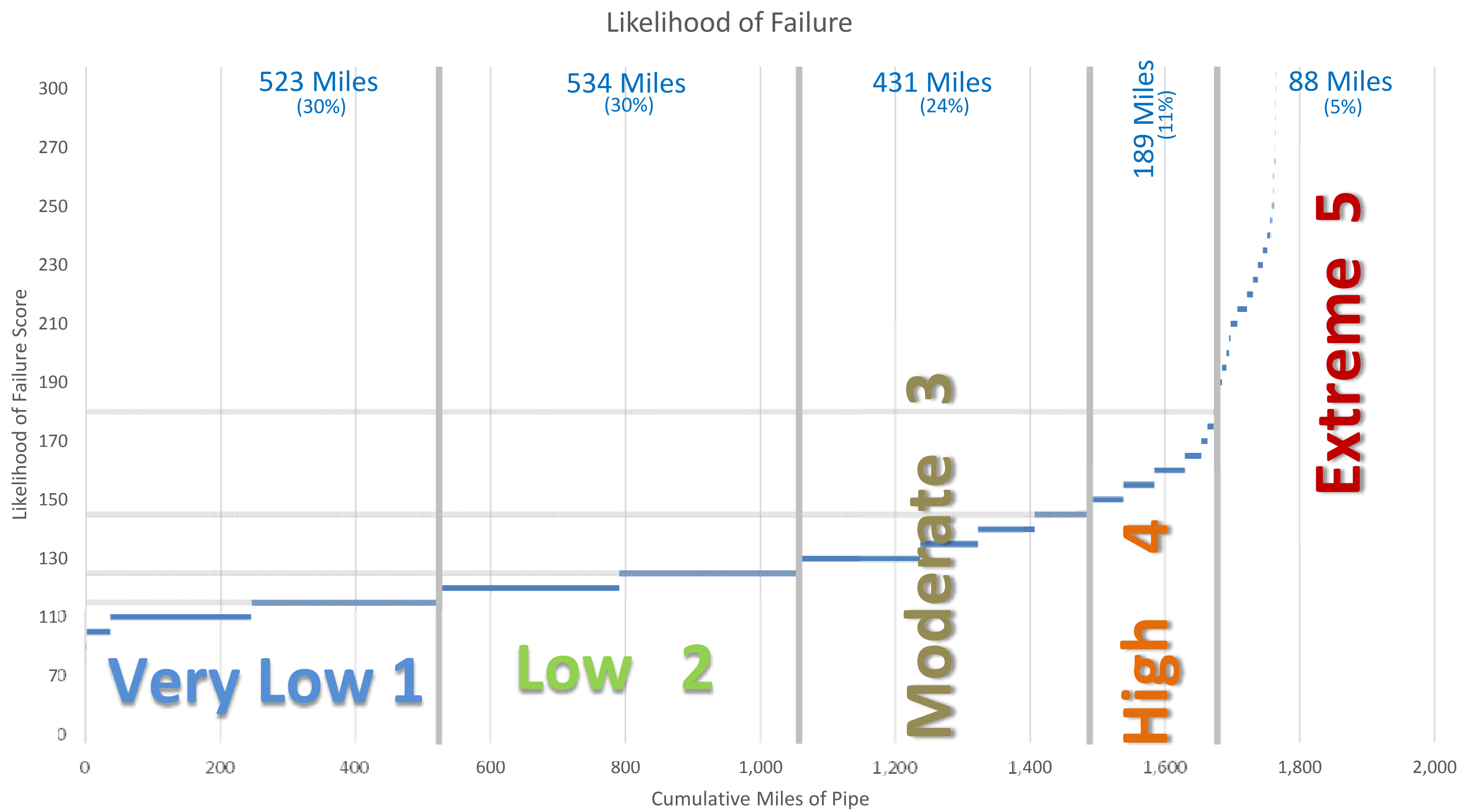
- **Pipeline Age (5%):** This criterion assigns a score to each pipeline based on the year of installation. It was assumed that the condition of a pipeline deteriorates as it ages and older pipelines can be more likely to fail than new pipelines.

Appendix B contains figures documenting the pipelines identified in each of the LOF criteria. Based on the likelihood of failure criteria each pipeline was assigned a score. The breakdown of the pipeline LOF is documented on **Figure 2.2** and summaries as follows;

- Very Low: 523 miles (30%)
- Low: 534 miles (30%)
- Moderate: 431 miles (24%)
- High: 189 miles (11%)
- Extreme: 88 miles (5%)

2.4.4 Risk Assessment Results

Following the calculation of the COF and LOF scores a pipeline risk assessment was conducted. Based on practical budgetary constraints, discussions with City staff, and the breakdown of the COF and LOF scores, thresholds were determined to classify the pipelines as Very Low, Low, Moderate, High, and Extreme risk. The risk thresholds are briefly summarized as follows:



LEGEND

Note: Cumulative miles of pipeline shown represent distribution system and do not include RTMs.

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Figure 2.2
Likelihood of Failure

Drinking Water Infrastructure Renewal and Replacement Plan
City of Fresno

City of FRESNO

- **Very Low:** Pipelines with a COF and LOF score less than or equal to 145 and 115, respectively, were categorized as Very Low risk. Approximately 610.7 miles of pipelines were categorized as Very Low risk, which represents 34% of all pipelines included in the risk assessment.

- **Low:** Pipelines with a COF score between 145 and 180 and a LOF score between 115 and 125 were categorized as Low risk. Approximately 585.1 miles of pipelines were categorized as Low risk, which represents 33% of all pipelines included in the risk assessment.

- **Moderate:** Pipelines with a COF score between 180 and 215 and a LOF score between 125 and 145 were categorized as Moderate risk. Approximately 293.4 miles of pipelines were categorized as Moderate risk, which represents 17% of all pipelines included in the risk assessment.

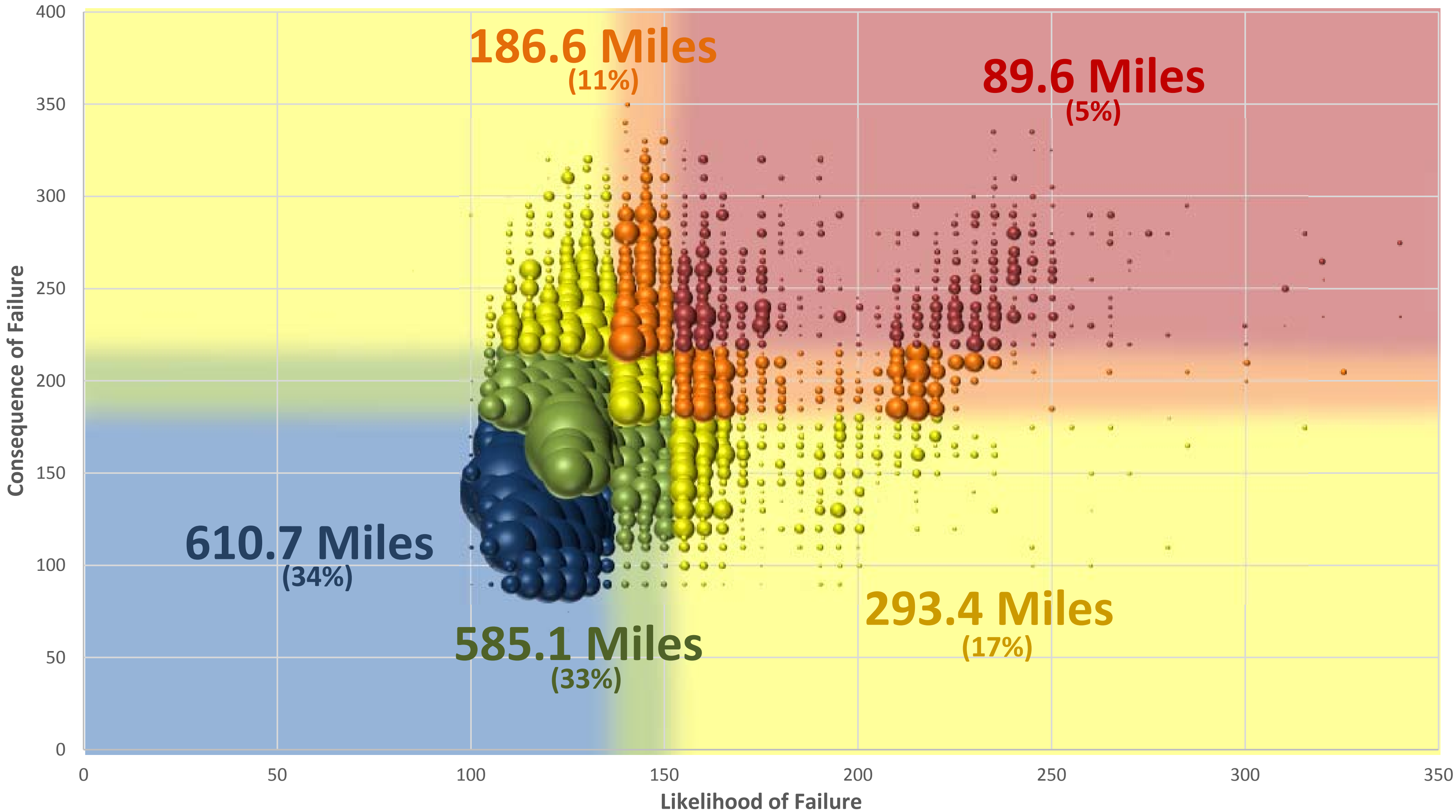
- **High:** Pipelines with a COF score between 215 and 255 and a LOF score between 145 and 180 were categorized as High risk. Approximately 186.6 miles of pipelines were categorized as High risk, which represents 11% of all pipelines included in the risk assessment.

- **Extreme:** Pipelines with a COF score greater than 255 and a LOF score greater than 180 were categorized as Extreme risk. Approximately 89.6 miles of pipelines were categorized as Extreme risk, which represents 5% of all pipelines included in the risk assessment.

The results of the risk assessment are tabulated on **Figure 2.3** and shown graphically on **Figure 2.4**; furthermore, **Figure 2.5** documents only the High and Extreme risk pipelines. Additional information of the risk scores based on length and diameter of pipes are documented on **Table 2.6**.

2.4.5 Risk Analysis Conclusions

The results of the risk analysis have identified approximately 16% of the system as high or extreme risk with approximately 6% being 14-inch DR-25 PVC. If the risk assessment was based solely on physical characteristics (e.g. age and material) many of the older downtown area pipes (e.g. cast iron) would be flagged as extreme risk due to age and typical performance of these materials. However, since this analysis combined many other important criteria including repair/maintenance history and pipeline performance criteria into the analysis, the results indicate the 14-inch DR-25 PVC as having the highest risk in the system. Even though these 14-inch DR-25 PVC were more recently installed (approximately 1990-2004) these pipes have a high failure rate, a high severity of break, convey a large amount of flow, and are located primarily in arterial streets and thus cause a much larger impact to service than older distribution mains.



Legend

Risk Ranking, by Pipe

- Extreme
- High
- Moderate
- Low
- Very Low

Miles of Pipeline

0.5, 2.5, 5, 7, 15, 35

Note: Miles of pipeline shown represent distribution system and do not include RTMs.

May 1, 2018

Figure 2.3
Tabulated Risk Assessment

Drinking Water Infrastructure Renewal and Replacement Plan
City of Fresno

City of FRESNO

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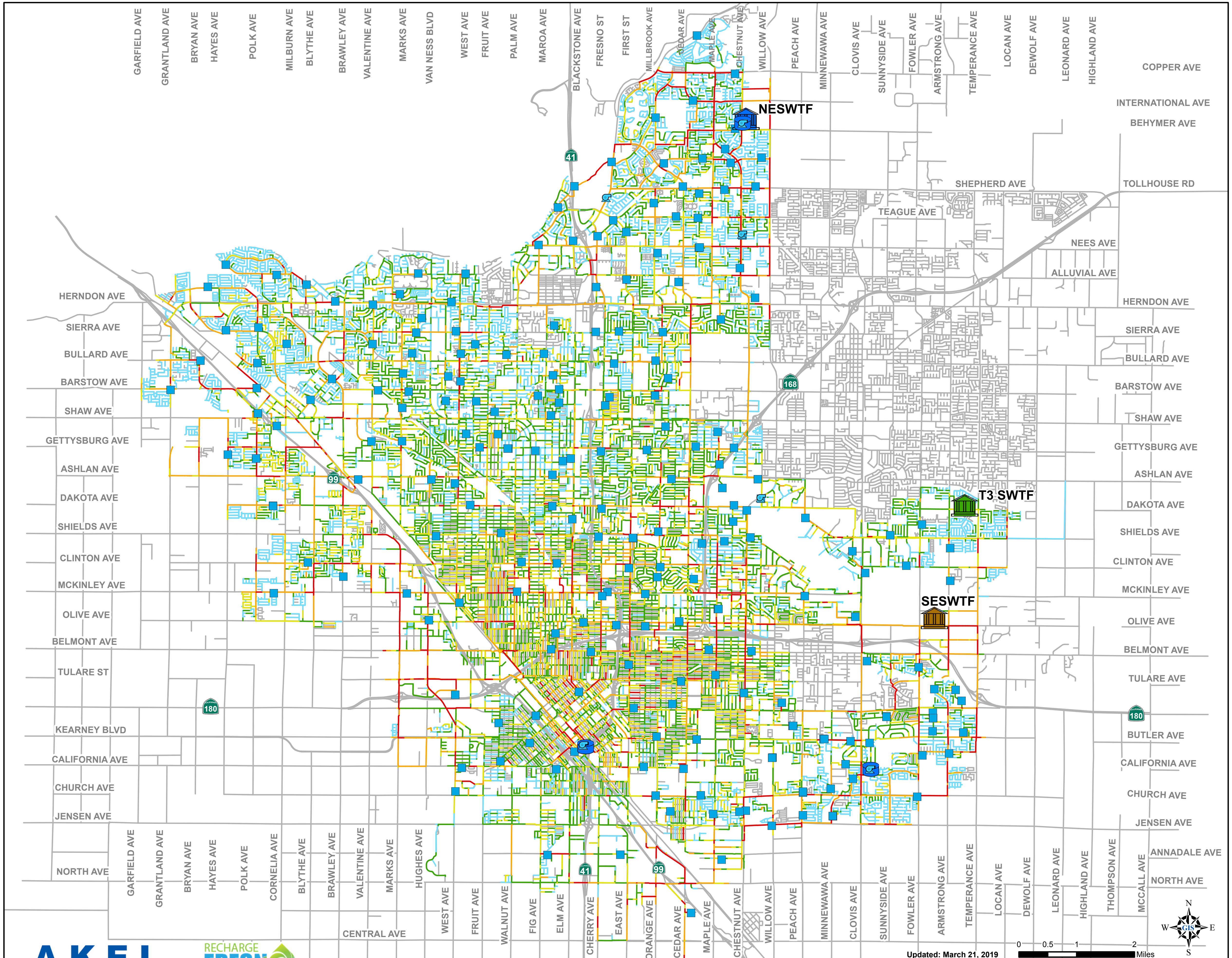

Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Pipeline Risk

- Very Low (610.7 miles, 34.2%)
- Low (585.0 miles, 32.7%)
- Moderate (293.4 miles, 16.4%)
- High (209.7 miles, 11.7%)
- Extreme (89.6 miles, 5.0%)
- Streets

Figure 2.4
Pipeline Risk Assessment

Drinking Water Infrastructure
Renewal and Replacement Plan

City of FRESNO

AKEL ENGINEERING GROUP, INC.

RECHARGE FRESNO
Securing Our Water Future

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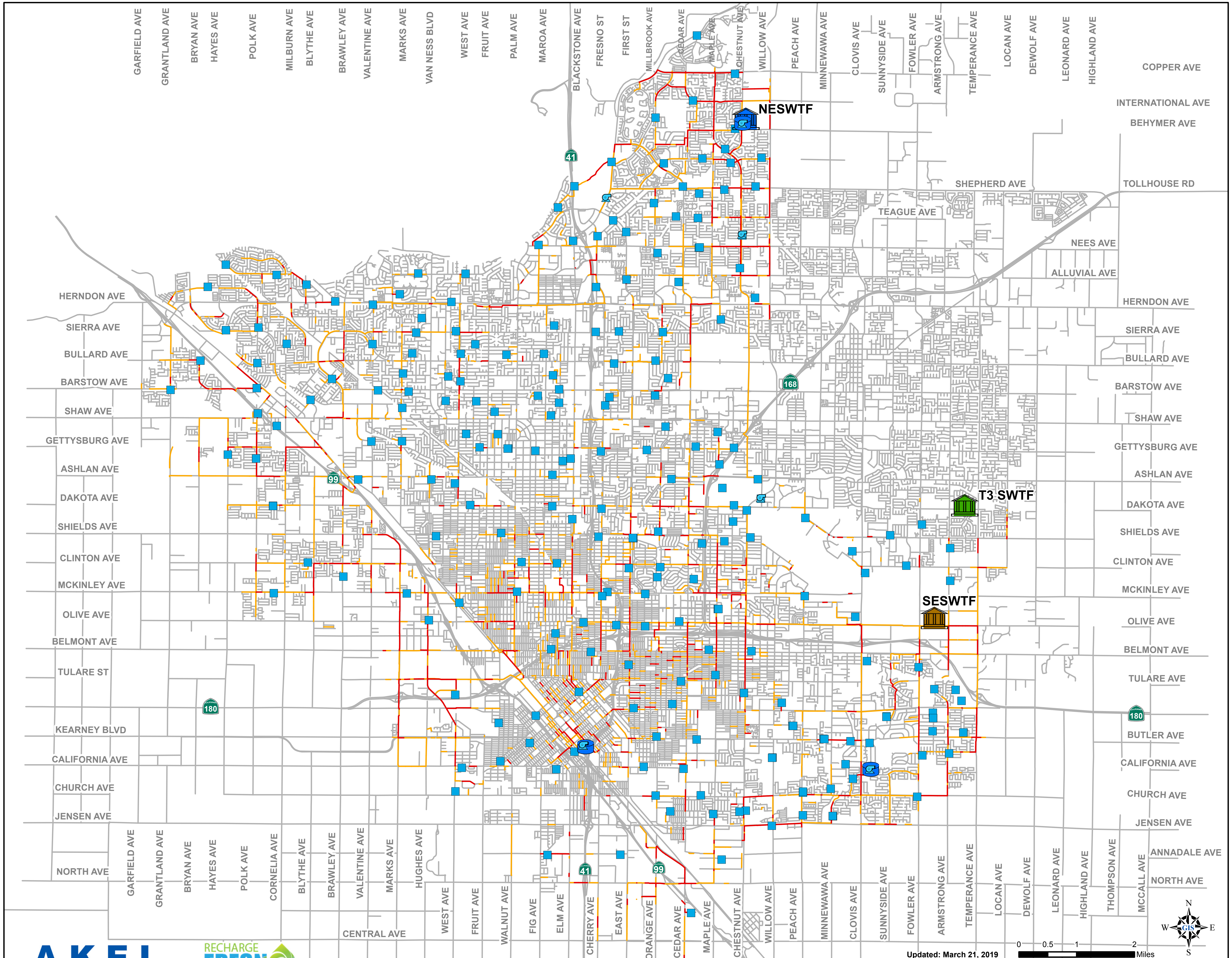

Updated: March 21, 2019

Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Pipeline Risk

- High (209.7 miles, 11.7%)
- Extreme (89.6 miles, 5.0%)
- Streets

Figure 2.5
High and Extreme Risk Pipelines

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

AKEL ENGINEERING GROUP, INC.

RECHARGE FRESNO Securing Our Water Future

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Table 2.6 Total Pipe Length, by Risk Score

Drinking Water Infrastructure Renewal and Replacement Program
City of Fresno

Pipe Diameter (in)	Total Pipe Length, by Risk Score					
	Very Low (mi)	Low (mi)	Medium (mi)	High (mi)	Extreme (mi)	Total (mi)
Less than 6"	29.55	24.76	11.36	0.95	-	66.6
6	162.21	209.40	74.90	15.35	2.04	463.9
8	381.68	211.00	83.13	17.17	5.35	698.3
10	4.88	23.67	18.83	12.04	3.84	63.3
12	27.99	102.25	67.23	56.45	27.08	281.0
14	1.10	9.86	24.95	72.31	47.32	155.6
16	3.29	3.91	7.45	10.92	3.92	29.5
18	-	-	0.04	0.02	-	0.1
24	0.01	0.11	5.34	5.33	0.01	10.8
30	-	0.01	0.10	4.06	-	4.2
36	-	-	-	5.93	-	5.9
42	-	-	-	2.40	-	2.4
48	-	0.01	0.03	1.71	-	1.7
54	-	-	-	2.03	-	2.0
60	-	-	-	0.52	-	0.5
66	-	-	-	2.50	-	2.5
Total	**610.7**	**585.0**	**293.4**	**209.7**	**89.6**	**1,788.3**
	34%	**33%**	**16%**	**12%**	**5%**	

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Note:

1. Total pipe length shown includes distribution system and RTMs.

2.5 RECOMMENDED ACTIONS AND COSTS

The following section summarizes the pipeline replacement plan. The purpose of the pipeline replacement plan is to estimate costs and recommend pipeline improvements for the next 5 years, based on the results of the risk assessment. This section also includes discussion of unit costs, project area groupings, total capital improvement costs, and replacement project prioritization.

2.5.1 Unit Costs and Contingencies

Cost estimates presented as part of this pipeline replacement plan were prepared for general planning purposes. Final costs of a project will depend on several factors including the final project scope, costs of labor and material, and market conditions during construction.

The unit cost estimates used in developing capital improvement costs for the pipeline replacement plan are summarized on **Table 2.7**. Domestic water pipeline unit costs are based on length of pipes, in feet. The unit costs are intended for developing an "Order of Magnitude" estimate and do not account for site specific conditions, labor and material costs during the time of construction, final project scope, implementation schedule, investigation of alternative routings for pipes, and other various factors.

The estimated construction costs in this plan include a 30 percent contingency allowance to account for unforeseen events and unknown field conditions. Additionally, the capital improvement costs account for project-related costs, comprising of engineering design, project administration (developer and City staff), construction management and inspection, and legal costs; the project related costs in this master plan were estimated by applying an additional 25 percent to the estimated construction costs

For planning purposes, the improvements were separated into 5 improvement groups. Each improvement group contains multiple pipeline replacement projects. A key map showing the improvement groups is shown on **Figure 2.6**.

Project Group 1

This project group includes pipeline improvements in south and southeast Fresno (**Figures 2.7** to **2.11**). This group includes five pipeline replacement projects, totaling 3.7 miles, for a total cost of $7.7 million.

Project Group 2

This project group includes pipeline improvements between Shaw Avenue and Belmont Avenue in the central band of the City (**Figures 2.12** to **2.16**). This group includes seven pipeline replacement projects, totaling 3.7 miles, for a total cost $7.6 million.

Table 2.7 Pipeline Unit Costs

Drinking Water Infrastructure Renewal and Replacement Program
City of Fresno

Pipeline Replacement[1]	
Diameter (in)	Unit Cost ($/Linear Foot)
8	121
10	151
12	181
14	212
16	242
24	365
30	485
36	602
42	716
48	881
Bore and Jack	
$18/inch-diameter	

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Notes:

1. Unit costs based on City of Fresno Metro Plan Phase 2 Report.
2. Unit costs escalated based on March 2018 ENR CCI OF 10,598.

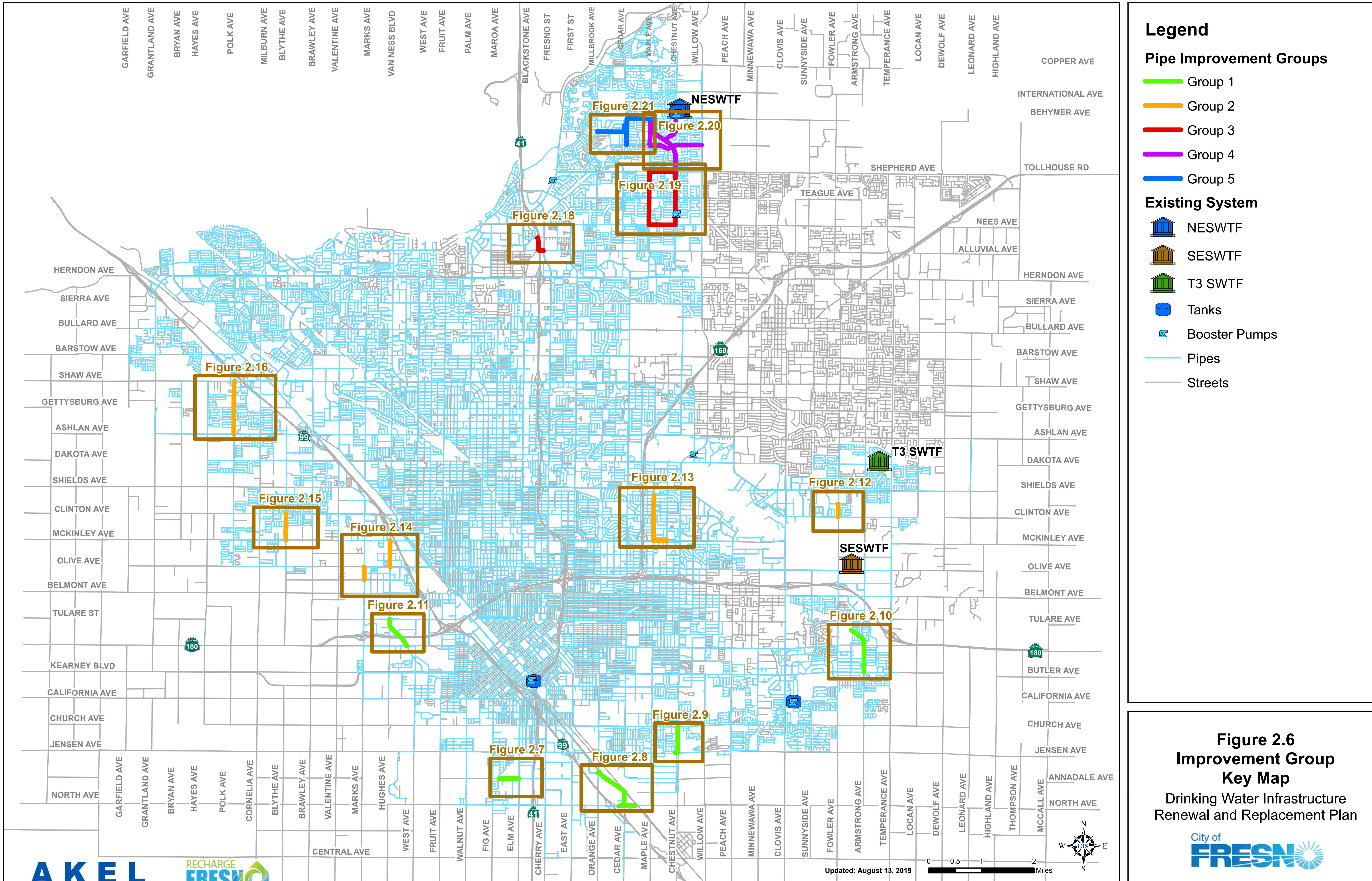
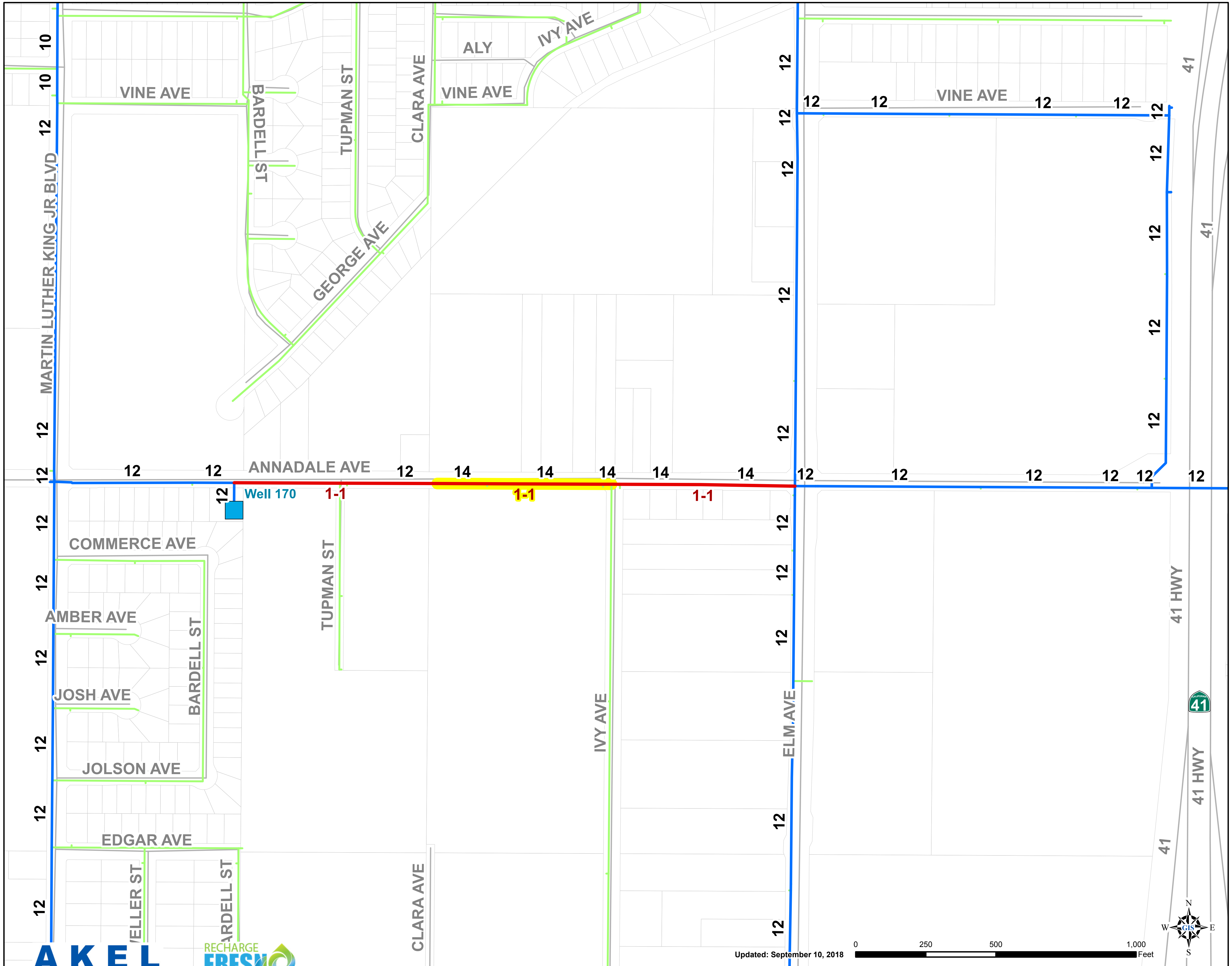


Figure 2.6
Improvement Group Key Map
Drinking Water Infrastructure Renewal and Replacement Plan
City of FRESNO



Legend

- Pipe Replacement
- Priority Pipe Replacement

Existing System

- Wells

Pipes by Diameter

- 8" and Smaller
- 10" and Larger
- Streets
- Parcels

Figure 2.7
Project Group 1
Improvement 1-1

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

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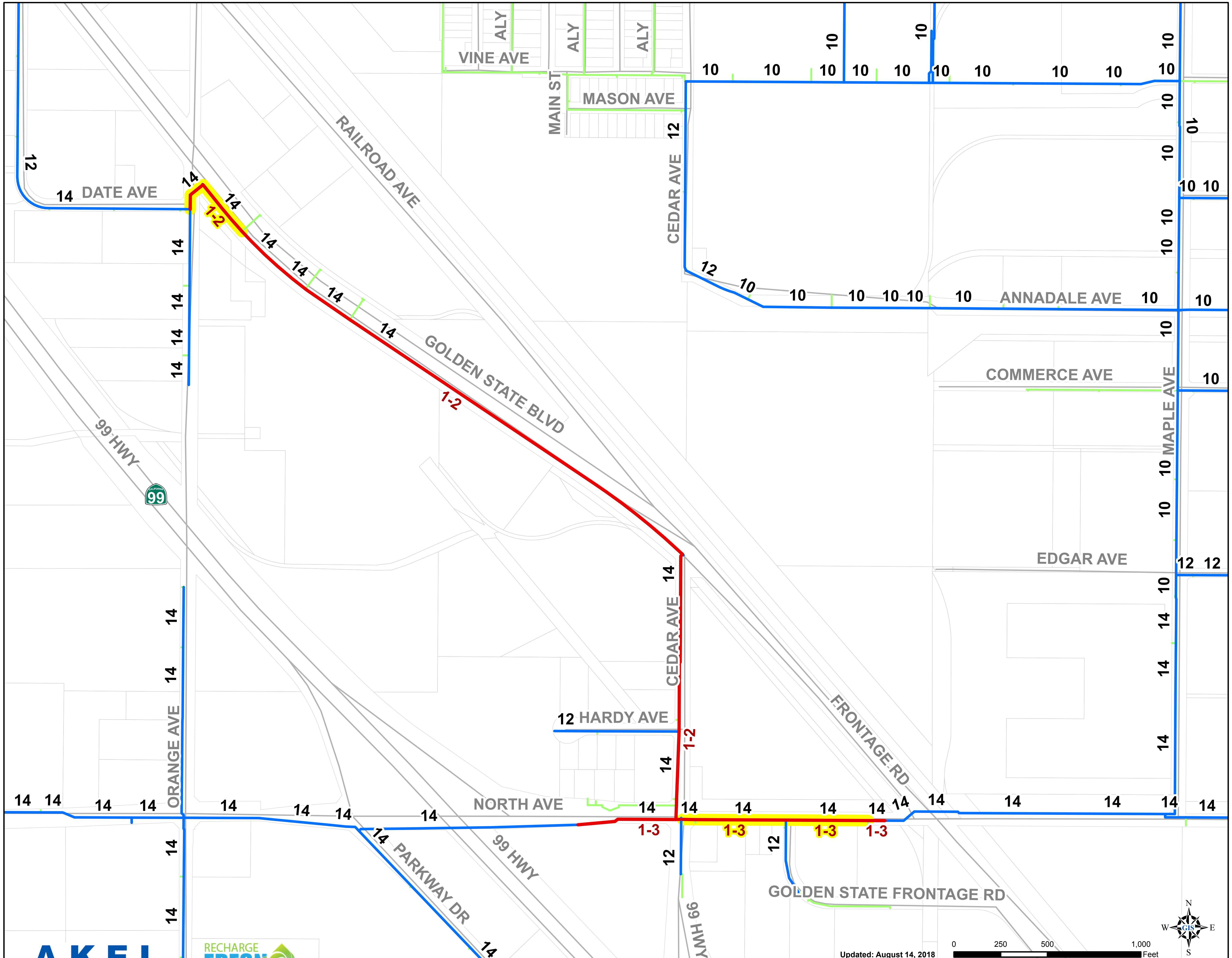

Legend

- Pipe Replacement
- Priority Pipe Replacement

Existing System

- Wells

Pipes by Diameter

- 8" and Smaller
- 10" and Larger
- Streets
- Parcels

Figure 2.8
Project Group 1
Improvements 1-2 & 1-3
Drinking Water Infrastructure
Renewal and Replacement Plan

City of FRESNO

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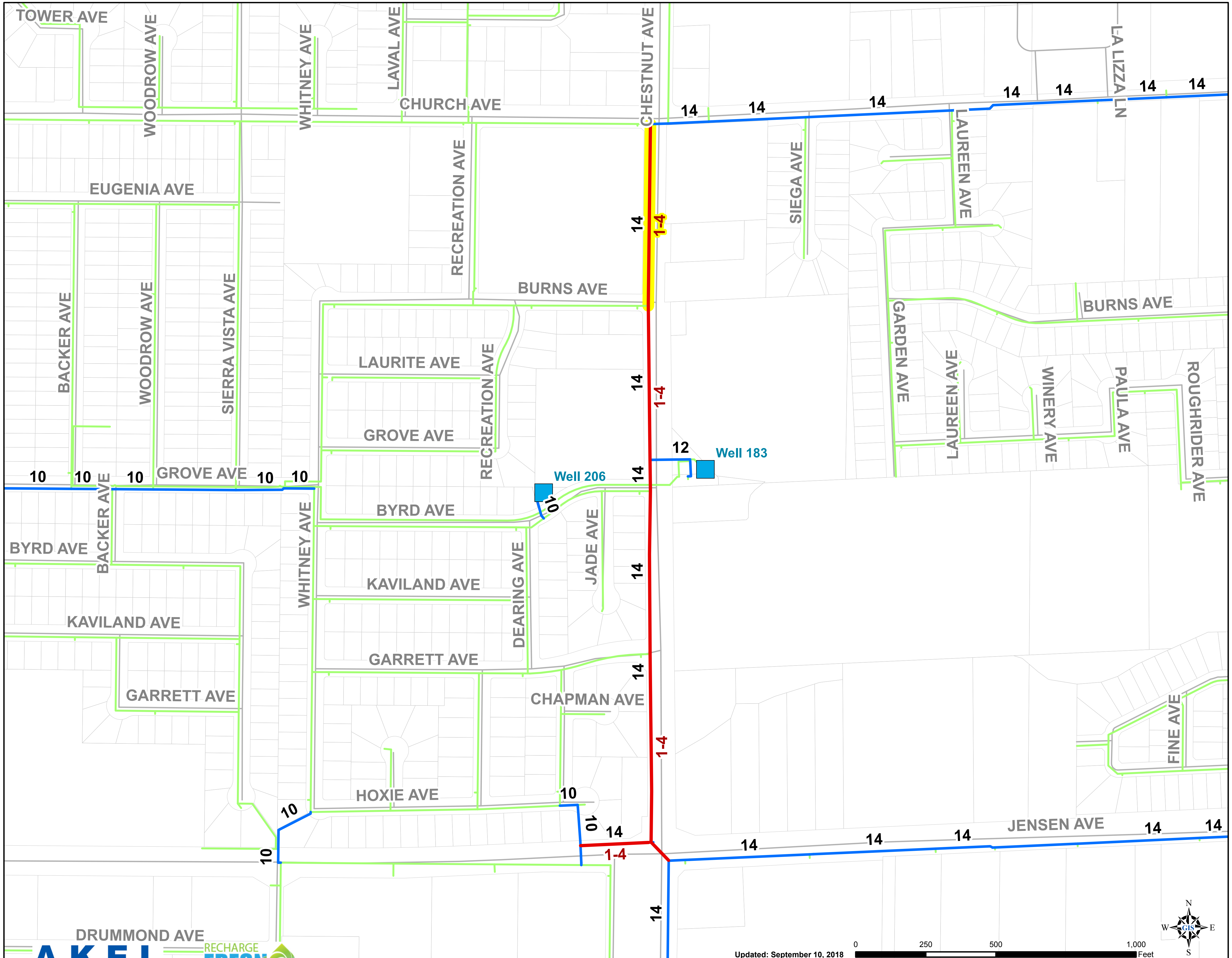

Figure 2.9
Project Group 1
Improvement 1-4
Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

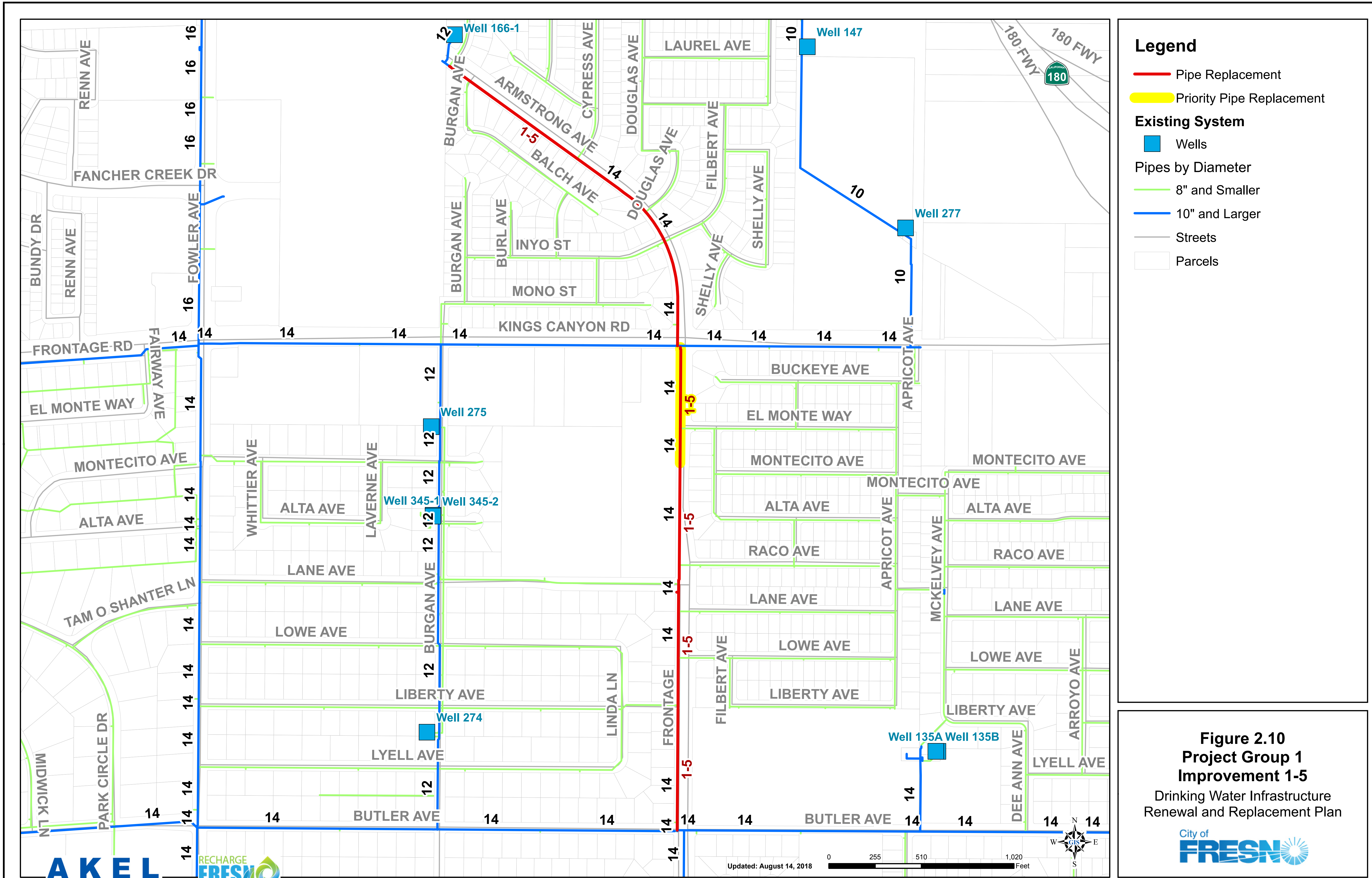

Figure 2.10
Project Group 1
Improvement 1-5
Drinking Water Infrastructure Renewal and Replacement Plan

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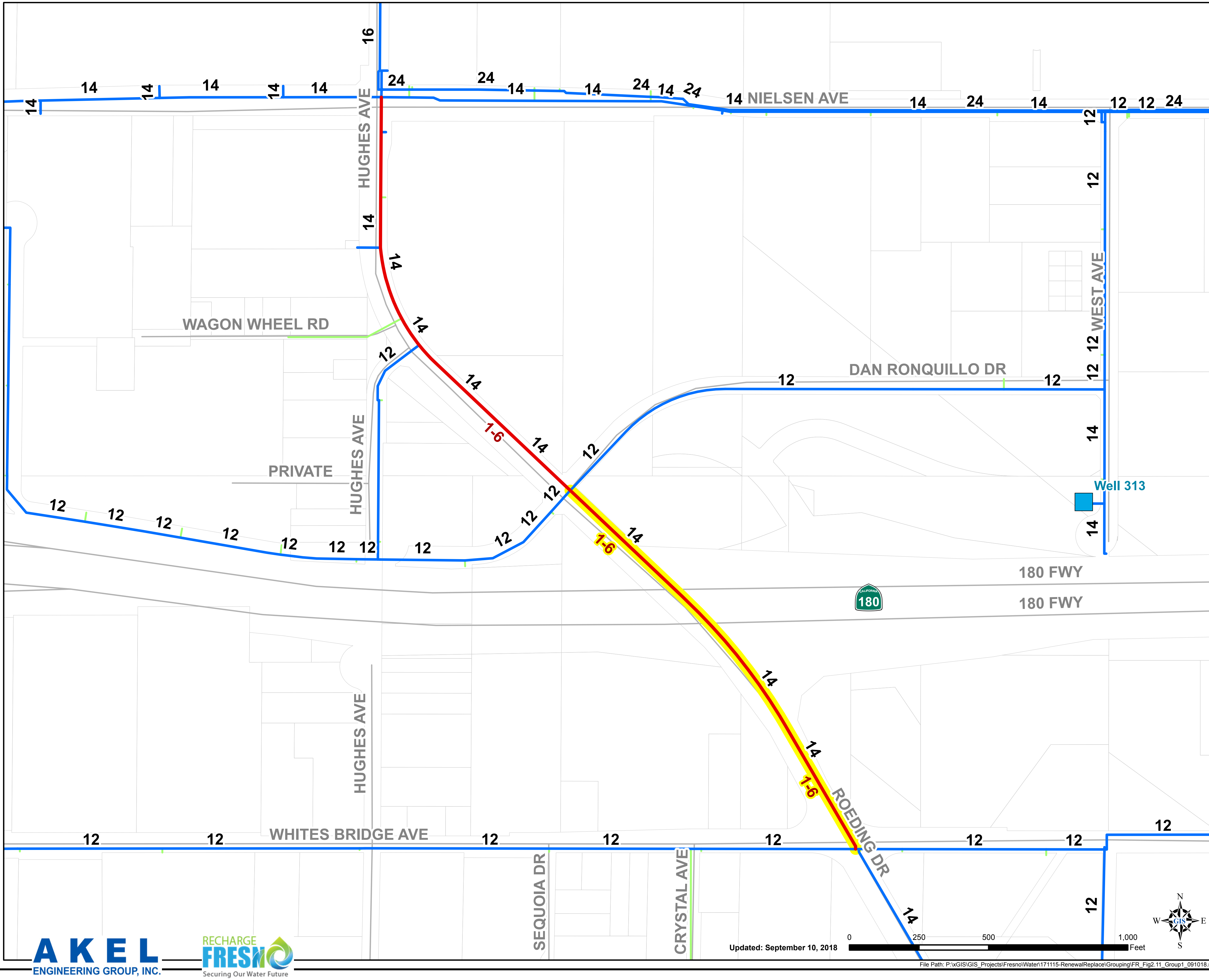
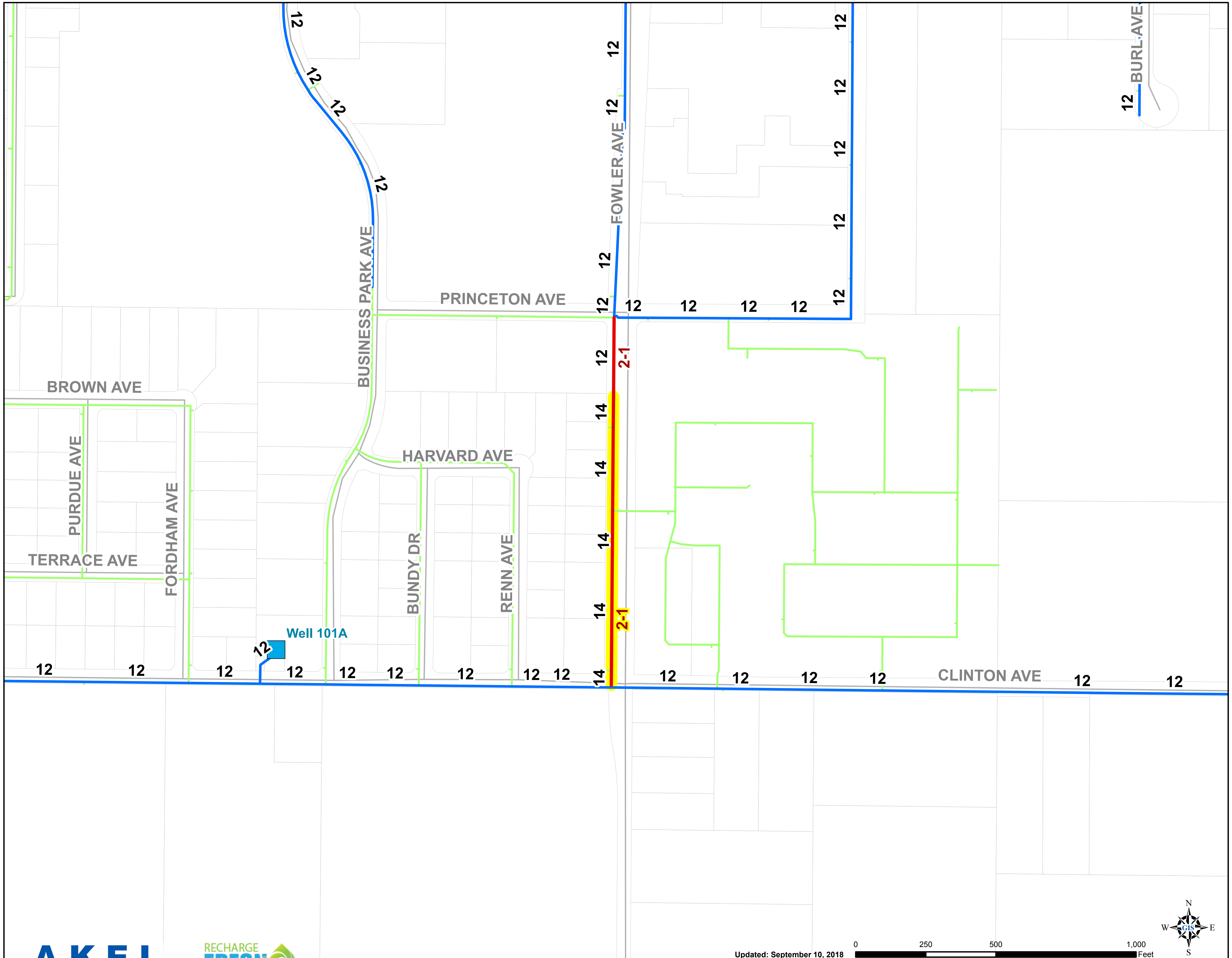


Figure 2.11
Project Group 1
Improvement 1-6
Drinking Water Infrastructure
Renewal and Replacement Plan
City of FRESNO



Legend

Pipe Replacement

Priority Pipe Replacement

Existing System

Wells

Pipes by Diameter

8" and Smaller

10" and Larger

Streets

Parcels

Figure 2.12
Project Group 2
Improvement 2-1

Drinking Water Infrastructure
Renewal and Replacement Plan

City of FRESNO

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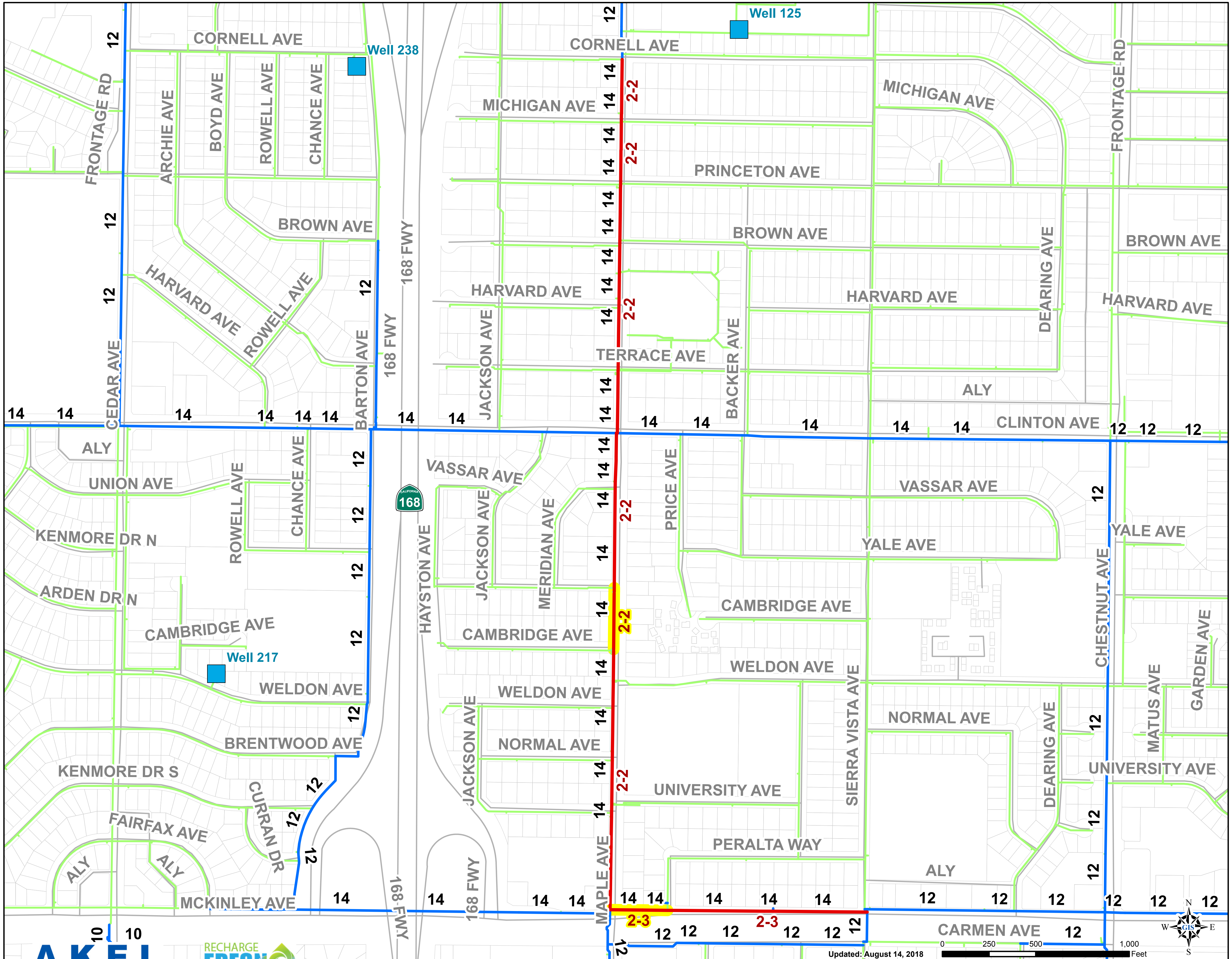

Legend

- Pipe Replacement
- Priority Pipe Replacement

Existing System

- Wells

Pipes by Diameter

- 8" and Smaller
- 10" and Larger
- Streets
- Parcels

Figure 2.13
Project Group 2
Improvements 2-2 & 2-3

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

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Figure 2.14
Project Group 2
Improvements 2-4 & 2-5
Drinking Water Infrastructure
Renewal and Replacement Plan

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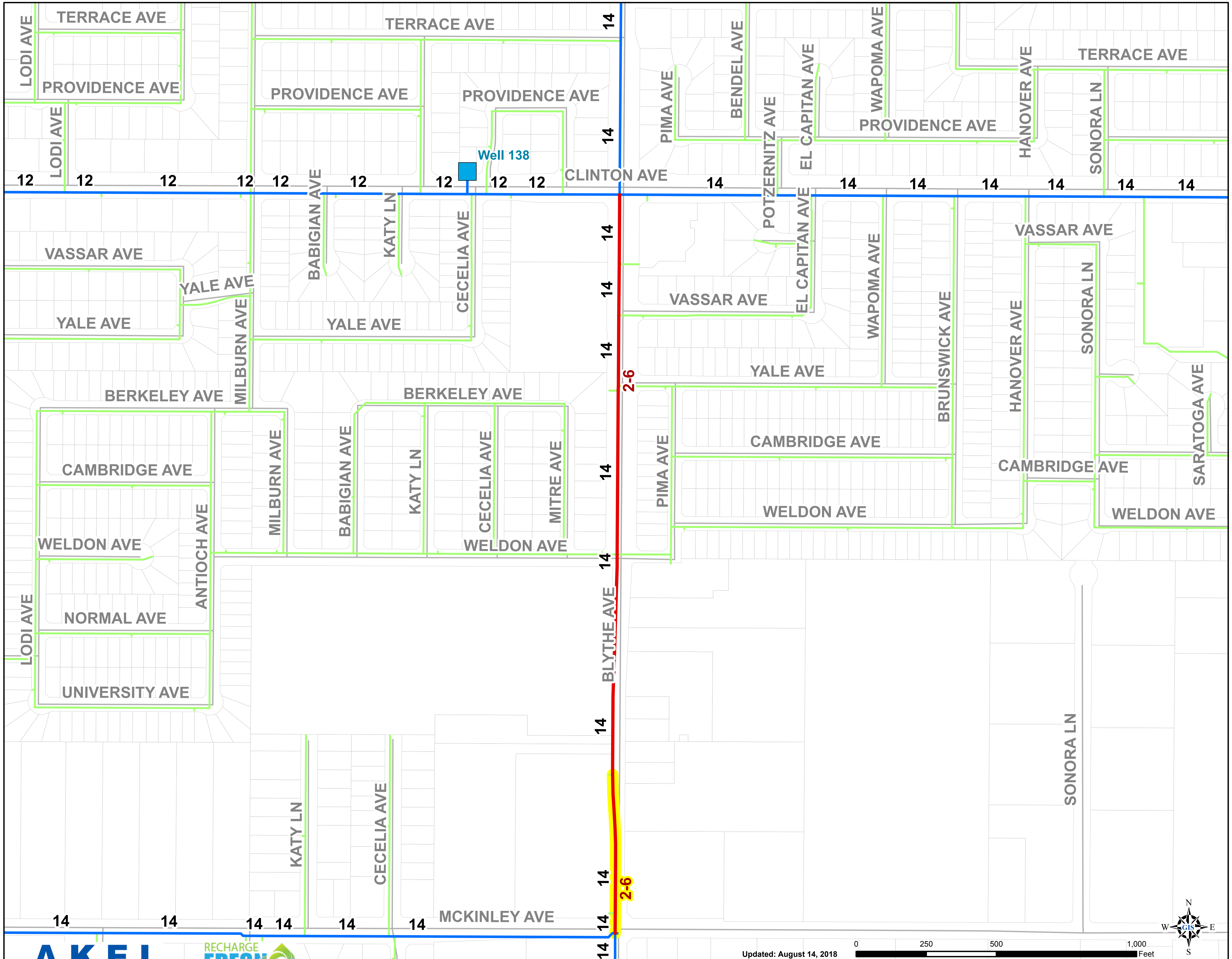

Legend

- Pipe Replacement
- Priority Pipe Replacement

Existing System

- Wells

Pipes by Diameter

- 8" and Smaller
- 10" and Larger
- Streets
- Parcels

Figure 2.15
Project Group 2
Improvement 2-6

Drinking Water Infrastructure
Renewal and Replacement Plan

City of FRESNO

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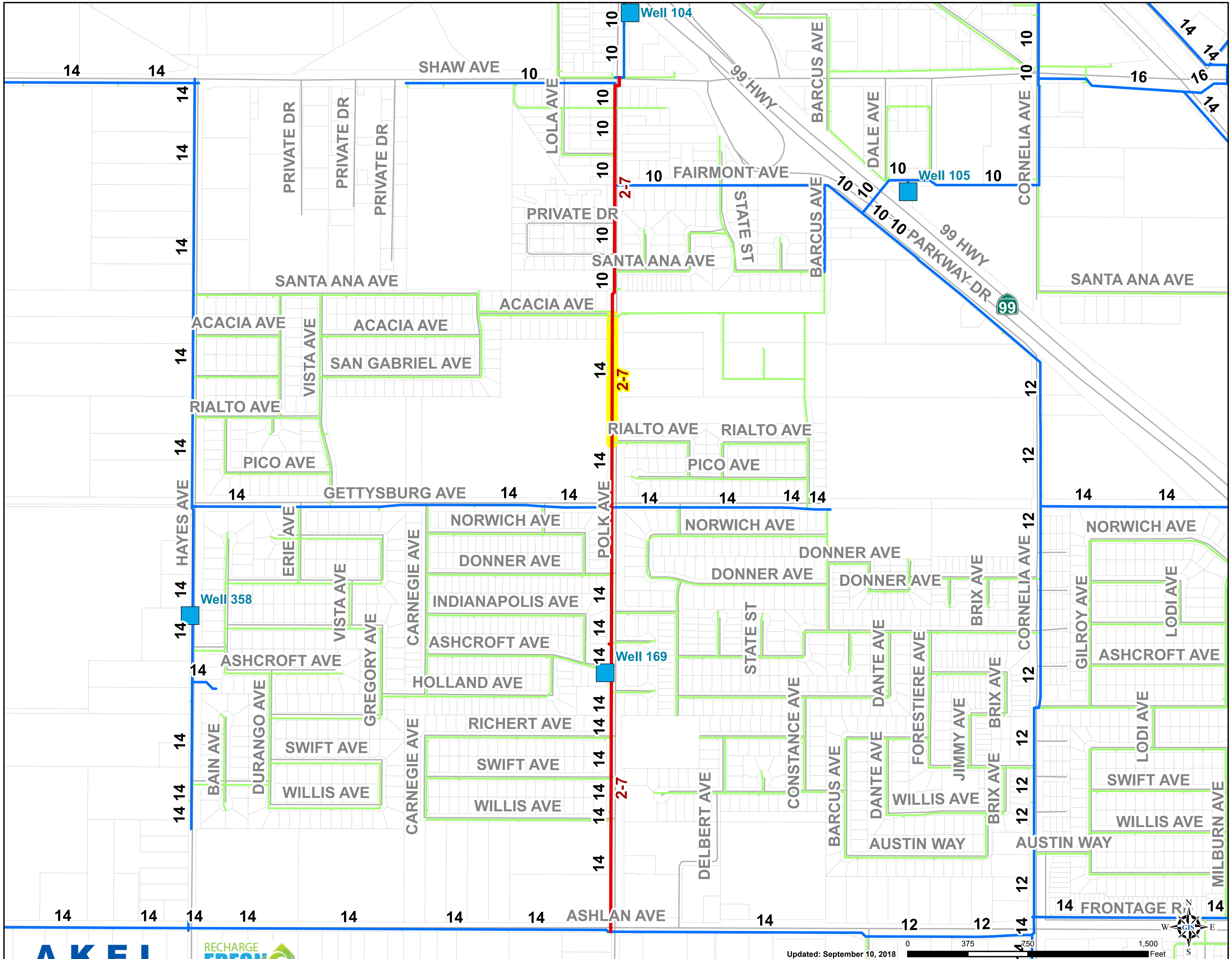

Updated: September 10, 2018

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Legend

- Pipe Replacement
- Priority Pipe Replacement

Existing System

- Wells

Pipes by Diameter

- 8" and Smaller
- 10" and Larger
- Streets
- Parcels

Figure 2.16
Project Group 2
Improvement 2-7

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

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Project Group 3

This project group includes pipeline improvements between Shepherd Avenue and Herndon Ave in north Fresno (**Figures 2.17** to **2.18**). This group includes five pipeline replacement projects, totaling 2.4 miles, for a total cost $4.6 million.

Project Group 4

This project group includes pipeline improvements within the north-south boundary of Behymer Avenue and Shepherd Avenue and east-west boundary of Willow Avenue and Maple Avenue (**Figure 2.19**). This group includes four pipeline replacement projects, totaling 3.0 miles, for a total cost $6.3 million.

Project Group 5

This project group includes pipeline improvements within the north-south boundary of Behymer Avenue and Perrin Avenue and east-west boundary of Maple Avenue and Millbrook Avenue (**Figure 2.20**). This group includes three pipeline replacement projects, totaling 1.6 miles, for a total cost $3.4 million.

2.5.2 Pipeline Replacement Capital Improvement Costs

The capital improvement costs associated with the pipeline replacement plan are summarized on **Table 2.8**. This table summarizes the alignment and limits of each pipeline replacement project as well as the length and diameter of the replacement pipelines. Additionally, the baseline costs, estimated construction costs, and capital improvement costs are summarized; the costs are calculated based on the unit costs and contingencies discussed previously. The 5-year pipeline replacement plan includes approximately 14.4 miles of improvements for a total cost of $29.6 million.

2.5.3 Pipeline Replacement Project Rankings

In order to facilitate the prioritization of the projects included in the pipeline replacement plan, each pipeline replacement project has been ranked based on its risk score. These project rankings are documented on **Table 2.8** with each projects COF and LOF documented on **Figures 2.21** and **2.22**.

It should be noted that the improvement project rankings are intended to be used for planning purposes only. Specific on-site conditions, available funds, and other factors should be taken into consideration when preparing to schedule and construct the projects included in the pipeline replacement plan

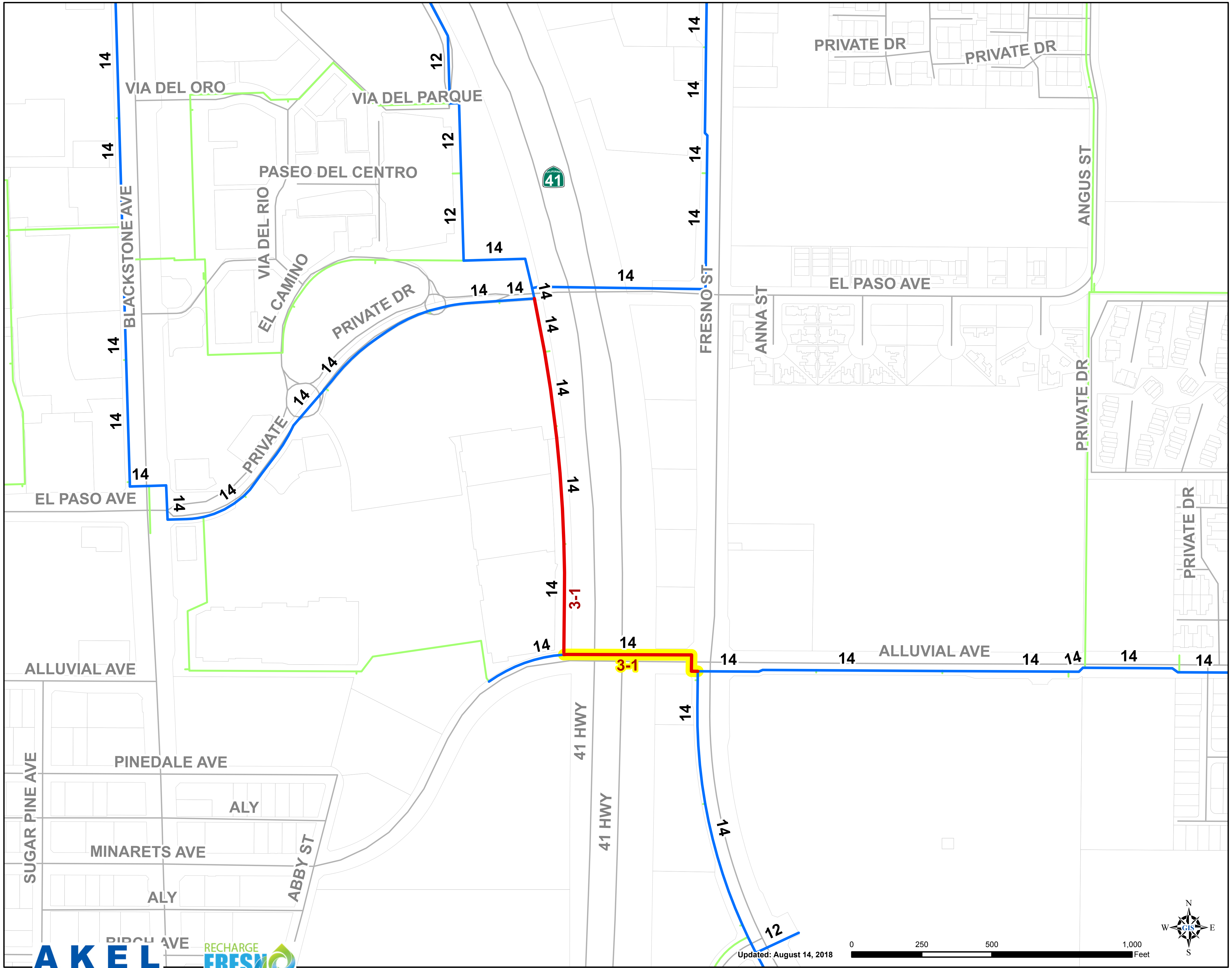

Figure 2.17
Project Group 3
Improvement 3-1
Drinking Water Infrastructure Renewal and Replacement Plan

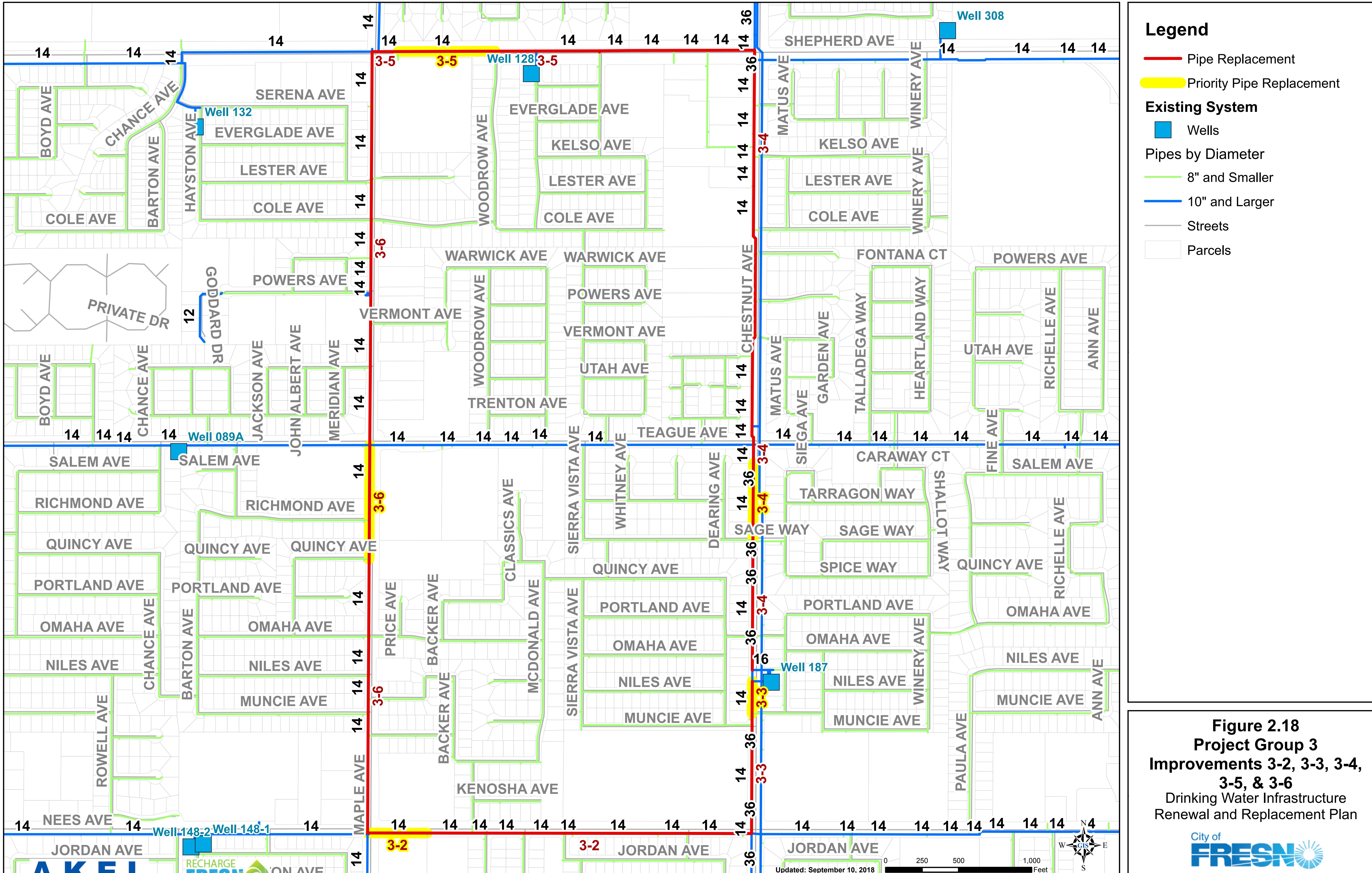

Figure 2.18
Project Group 3
Improvements 3-2, 3-3, 3-4, 3-5, & 3-6
Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

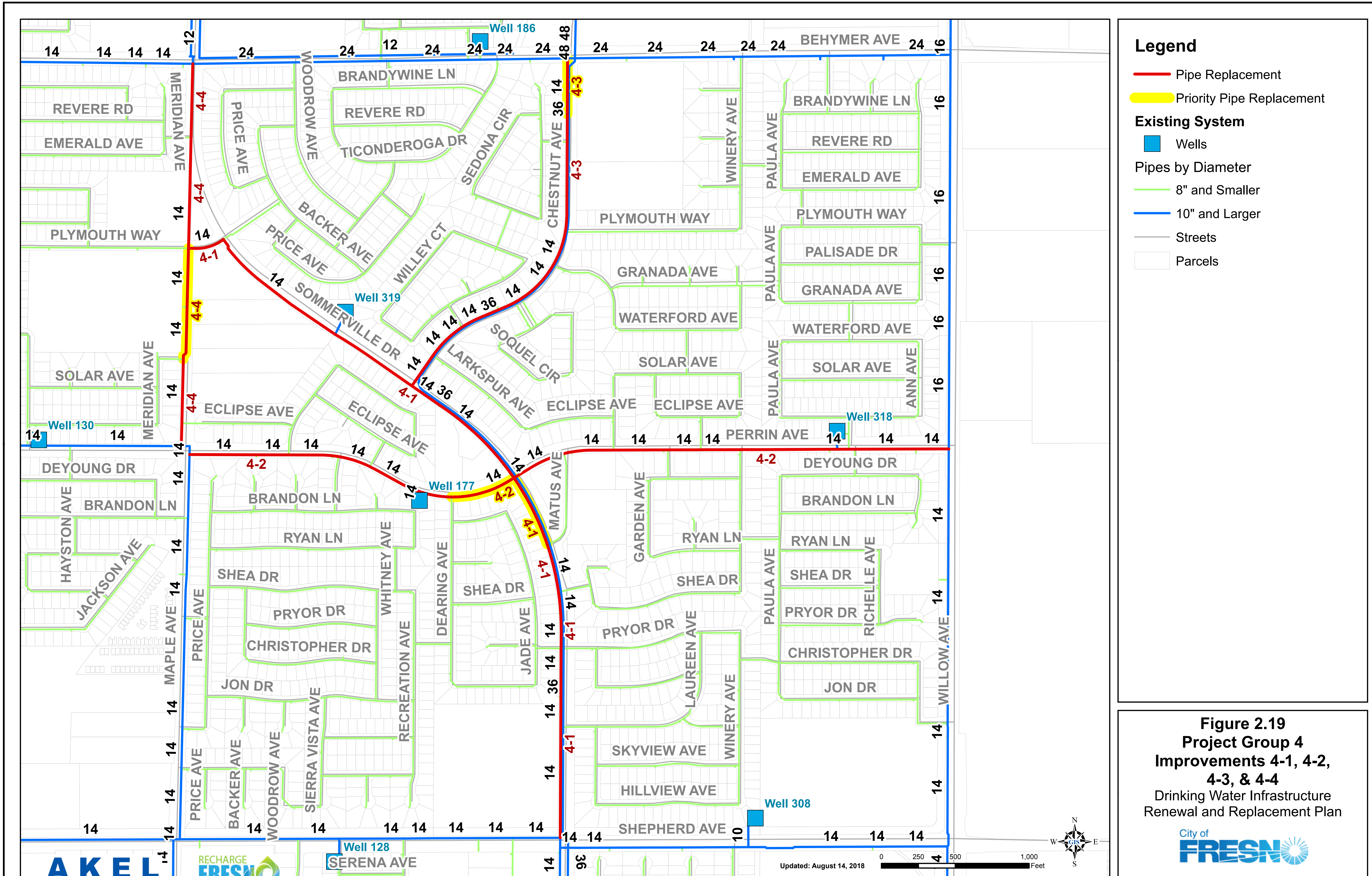

Figure 2.19
Project Group 4
Improvements 4-1, 4-2, 4-3, & 4-4
Drinking Water Infrastructure Renewal and Replacement Plan

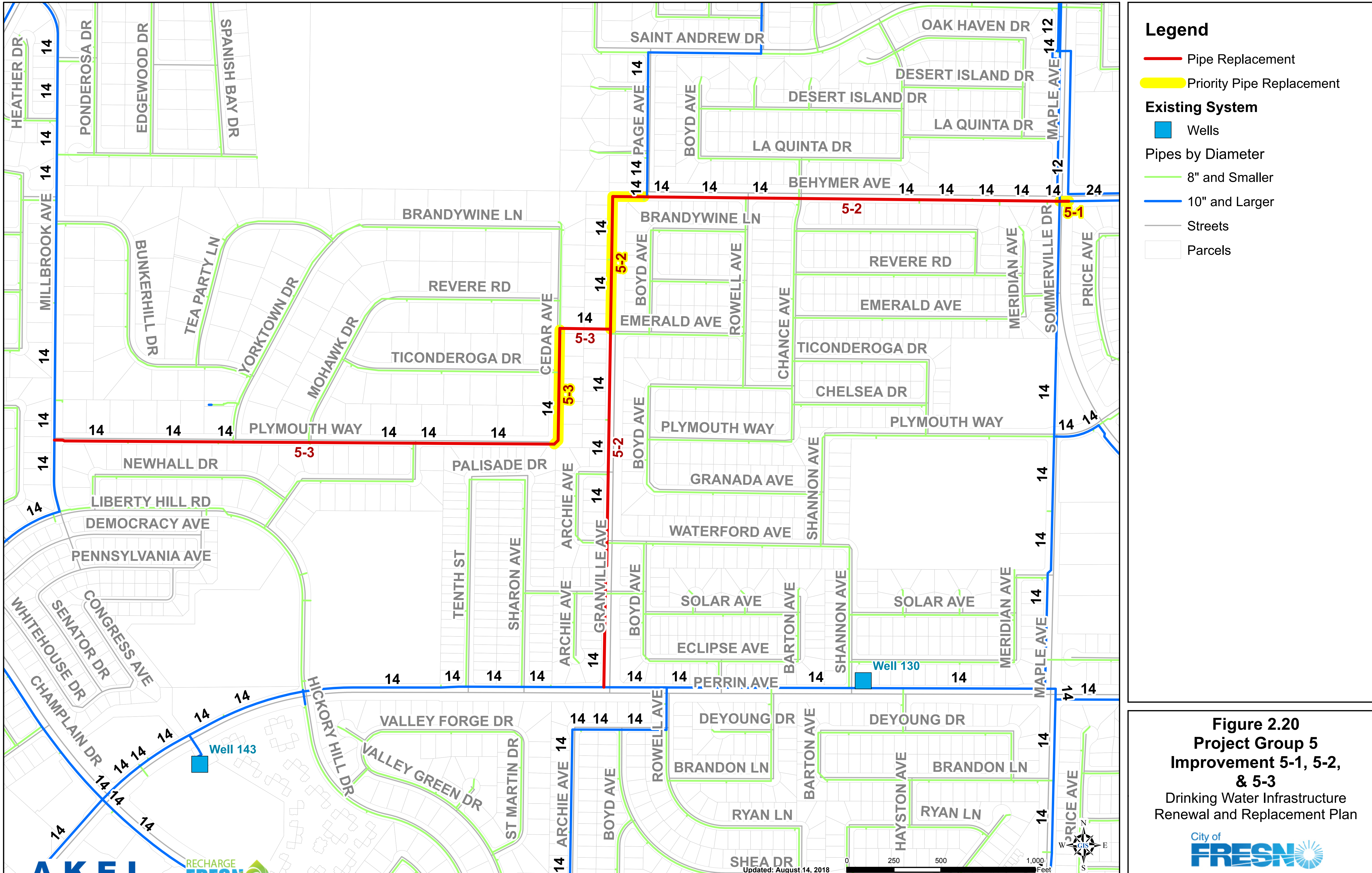

Figure 2.20
Project Group 5
Improvement 5-1, 5-2, & 5-3
Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

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Table 2.8 Project Costs

Drinking Water Infrastructure Renewal and Replacement Plan
City of Fresno

Improvement ID	Alignment	Limits	Improvement Rank	Improvement Information: Existing Diameter (in)	Improvement Information: Replacement Diameter (in)	Improvement Construction Cost: Unit Cost ($)	Improvement Construction Cost: Length (ft)	Improvement Construction Cost: Improvement Cost ($)	Capital Improvement Costs: Baseline Construction Cost ($)	Capital Improvement Costs: Estimated Construction Cost[1] ($)	Capital Improvement Costs: Capital Improvement Cost[2] ($)
Improvement Group 1											
1-1	Annadale Ave	From Well 170 to Elm Ave	22	14	16	242	2,050	495,912	496,000	645,000	807,000
1-2	Cedar Ave and Golden State Blvd	From Orange Ave to North Ave	13	14	16	242	4,850	1,173,255	1,174,000	1,527,000	1,909,000
1-3	North Ave	From approx. 500' w/o Cedar Ave to Golden State Blvd	3	14	16	242	1,650	399,149	400,000	520,000	650,000
1-4	Chestnut Ave	From Church Ave to Jensen Ave	18	14	16	242	2,800	677,343	678,000	882,000	1,103,000
1-5	Armstrong Ave	From Burgan Ave to Butler Ave	13	14	16	242	4,800	1,161,160	1,162,000	1,511,000	1,889,000
1-6	Roeding Dr	From Nielsen Ave to Whitesbridge Ave	6	14	16	242	3,350	810,393	811,000	1,055,000	1,319,000
				Subtotal - Improvement Group 1				**4,717,211**	**4,721,000**	**6,140,000**	**7,677,000**
Improvement Group 2											
2-1	Fowler Ave	From Princeton Ave to Clinton Ave	2	12	16	242	1,350	326,576	327,000	426,000	533,000
2-2	Maple Ave	From Cornell Ave to McKinley Ave	4	14	16	242	4,550	1,100,682	1,101,000	1,432,000	1,790,000
2-3	McKinley Ave	From Maple Ave to Sierra Vista Ave	25	14	16	242	1,400	338,672	339,000	441,000	552,000
2-4	Hughes Ave	From McKinley Ave to Olive Ave	10	14	16	242	2,700	653,152	654,000	851,000	1,064,000
2-5	Marks Ave	From Olive Ave to Dudley Ave	4	14	16	242	1,350	326,576	327,000	426,000	533,000
2-6	Blythe Ave	From Clinton Ave to McKinley Ave	12	14	16	242	2,650	641,057	642,000	835,000	1,044,000
2-7	Polk Ave	From Shaw Ave to Ashlan Ave	19	14	16	242	5,400	1,306,304	1,307,000	1,700,000	2,125,000
				Subtotal - Improvement Group 2				**4,693,020**	**4,697,000**	**6,111,000**	**7,641,000**
Improvement Group 3											
3-1	Alluvial and existing ROW	From Fresno St to El Paso Ave	13	14	16	242	1,850	447,530	448,000	583,000	729,000
3-2	Nees Ave	From Maple Ave to Chestnut Ave	10	14	16	242	2,650	641,057	642,000	835,000	1,044,000
3-3	Chestnut Ave	From Well 187 to Nees Ave	6	14	14	212	1,050	222,253	223,000	290,000	363,000
3-4	Chestnut Ave	From Shepherd Ave to Well 187	1	14	14	212	4,250	899,596	900,000	1,170,000	1,463,000
3-5	Shepherd Ave	From Maple Ave to Chestnut Ave	9	14	16	242	2,650	641,057	642,000	835,000	1,044,000
				Subtotal - Improvement Group 3				**2,851,493**	**2,855,000**	**3,713,000**	**4,643,000**
Improvement Group 4											
4-1	Sommerville Dr	From Shepherd Dr to Plymouth Wy	19	14	16	242	5,300	1,282,114	1,283,000	1,668,000	2,085,000
4-2	Perrin Ave	From Maple Ave to Willow Ave	13	14	16	242	5,300	1,282,114	1,283,000	1,668,000	2,085,000
4-3	Chestnut Ave	From Sommerville Dr to Behymer Ave	13	14	16	242	2,750	665,248	666,000	866,000	1,083,000
4-4	Maple Ave	From Perrin Ave to Behymer Ave	24	14	16	242	2,600	628,961	629,000	818,000	1,023,000
				Subtotal - Improvement Group 4				**3,858,436**	**3,861,000**	**5,020,000**	**6,276,000**

Table 2.8 Project Costs

Drinking Water Infrastructure Renewal and Replacement Plan
City of Fresno

Improvement ID	Alignment	Limits	Improvement Rank	Improvement Information: Existing Diameter (in)	Improvement Information: Replacement Diameter (in)	Improvement Construction Cost: Unit Cost ($)	Improvement Construction Cost: Length (ft)	Improvement Construction Cost: Improvement Cost ($)	Capital Improvement Costs: Baseline Construction Cost ($)	Capital Improvement Costs: Estimated Construction Cost[1] ($)	Capital Improvement Costs: Capital Improvement Cost[2] ($)
Improvement Group 5											
5-1	Behymer Ave	Crossing Sommerville Dr	8	14	24	365	50	18,264	19,000	25,000	32,000
5-2	Behymer Ave and Granville Ave	From Maple Ave to Perrin Ave	19	14	16	242	5,000	1,209,541	1,210,000	1,573,000	1,967,000
5-3	Emerald Ave, Cedar Ave, and Plymouth Wy	From Grangeville Ave to Millbrook Ave	22	14	16	242	3,550	858,774	859,000	1,117,000	1,397,000
						Subtotal - Improvement Group 5		**2,086,580**	**2,088,000**	**2,715,000**	**3,396,000**
Improvement Group Totals											
						Improvement Group 1		4,717,211	4,721,000	6,140,000	7,677,000
						Improvement Group 2		4,693,020	4,697,000	6,111,000	7,641,000
						Improvement Group 3		2,851,493	2,855,000	3,713,000	4,643,000
						Improvement Group 4		3,858,436	3,861,000	5,020,000	6,276,000
						Improvement Group 5		2,086,580	2,088,000	2,715,000	3,396,000
						Total - Improvement Groups 1-5		**18,206,740**	**18,222,000**	**23,699,000**	**29,633,000**

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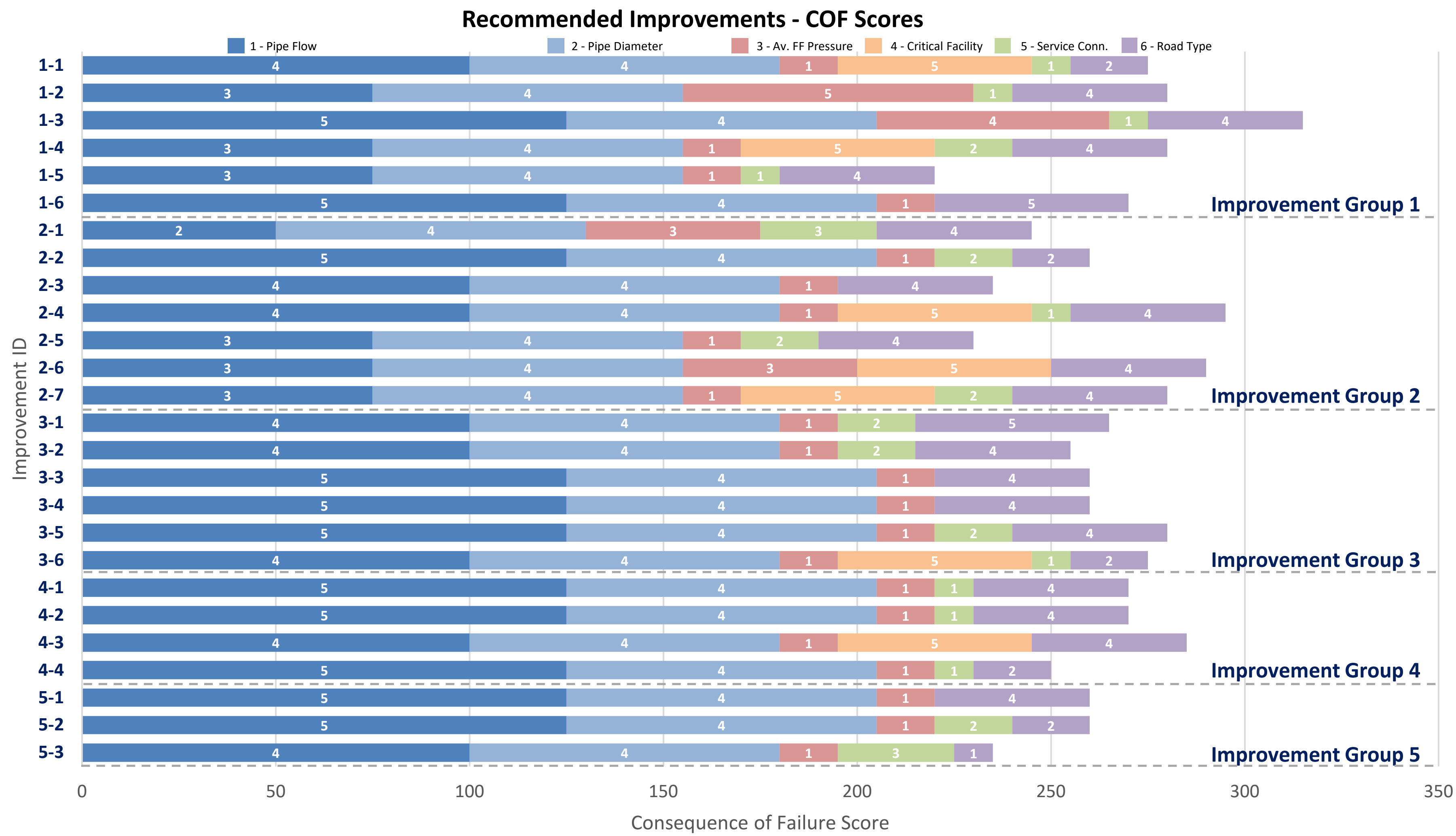
9/10/2018

Notes:

1. Estimated Construction Cost includes baseline construction cost plus 30% contingency.
2. Estimated Capital Improvement Cost includes estimated construction cost plus 25% contingency for engineering and management.



LEGEND

- 1 - Pipe Flow
- 2 - Pipe Diameter
- 3 - Available Fire Flow Pressure
- 4 - Critical Facilities Proximity
- 5 - Number of Service Connections
- 6 - Road Type
- 7 - Railroad Crossings
- 8 - Impacts to Water Quality

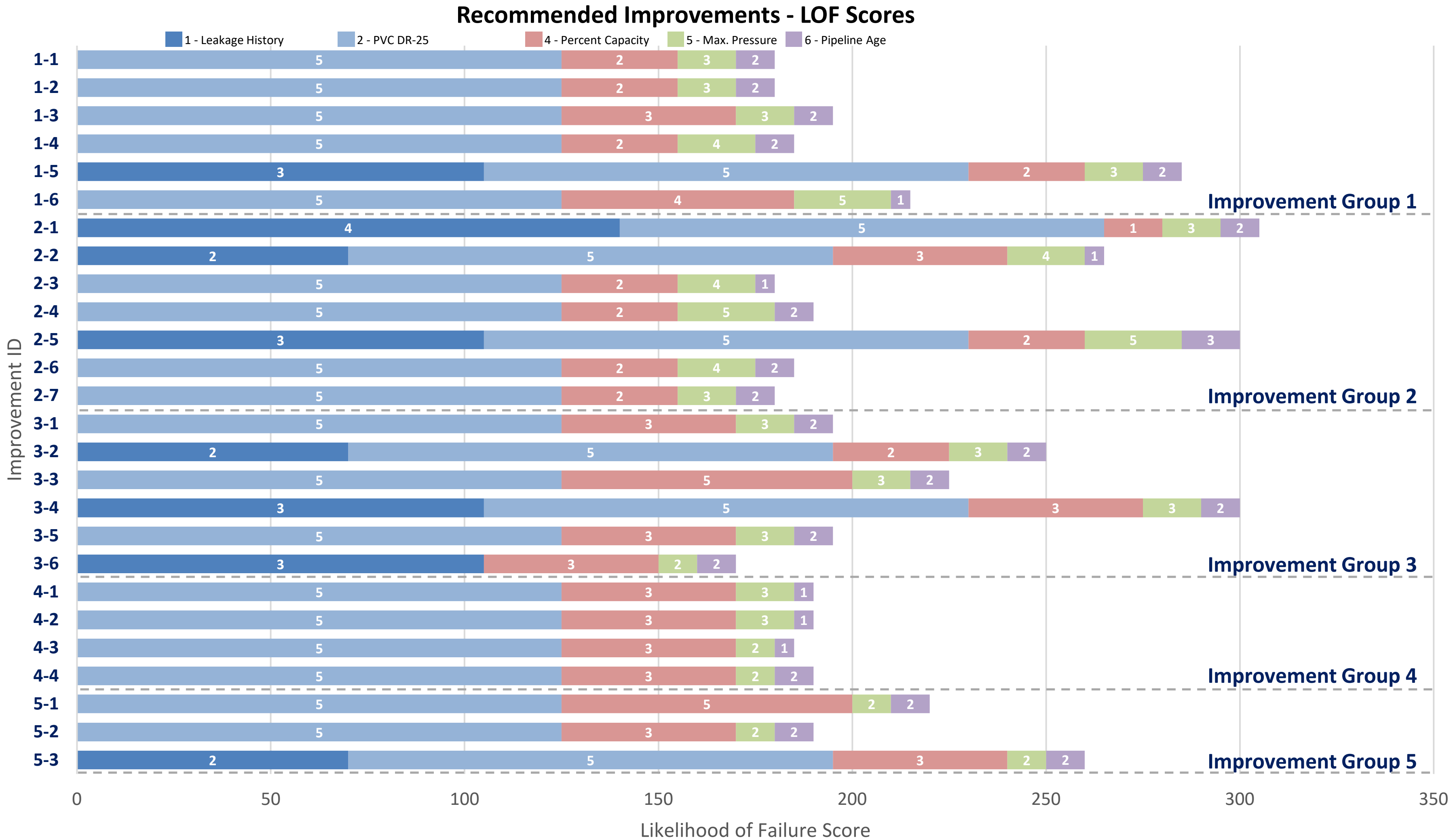
AKEL ENGINEERING GROUP, INC.

September 11, 2018

Figure 2.21
High Ranked Improvements (COF)

Drinking Water Infrastructure
Renewal and Replacement Plan
City of Fresno

City of FRESNO



LEGEND

- 1 - Leakage History
- 2 - PVC DR-25
- 3 - Pipe Maintenance Trends
- 4 - Percent Design Capacity
- 5 - Maximum Pressures
- 6 - Pipeline Age

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September 11, 2018

Figure 2.22
High Ranked Improvements (LOF)

Drinking Water Infrastructure Renewal and Replacement Plan
City of Fresno

City of FRESNO

2.5.4 Other On-going Pipeline Replacement Efforts

In addition to the high risk pipeline replacement projects identified in the risk analysis, City staff have supported the continuation of on-going backyard pipeline replacement efforts along with concentrating on pipelines that are greater than 80 years old. Many of these pipelines have a lower overall risk score due to the smaller consequence of failure scores (small diameters, low flow, minimal leak history, etc.), however, due to the age, condition, and accessibility concerns (if a failure were to occur) the City can supplement the R&R plan improvements with these planned projects at their discretion. **Figure 2.23** documents the currently planned replacement areas along with the pipelines that are greater than 80 years old.

2.5.5 Fiscal Sustainability

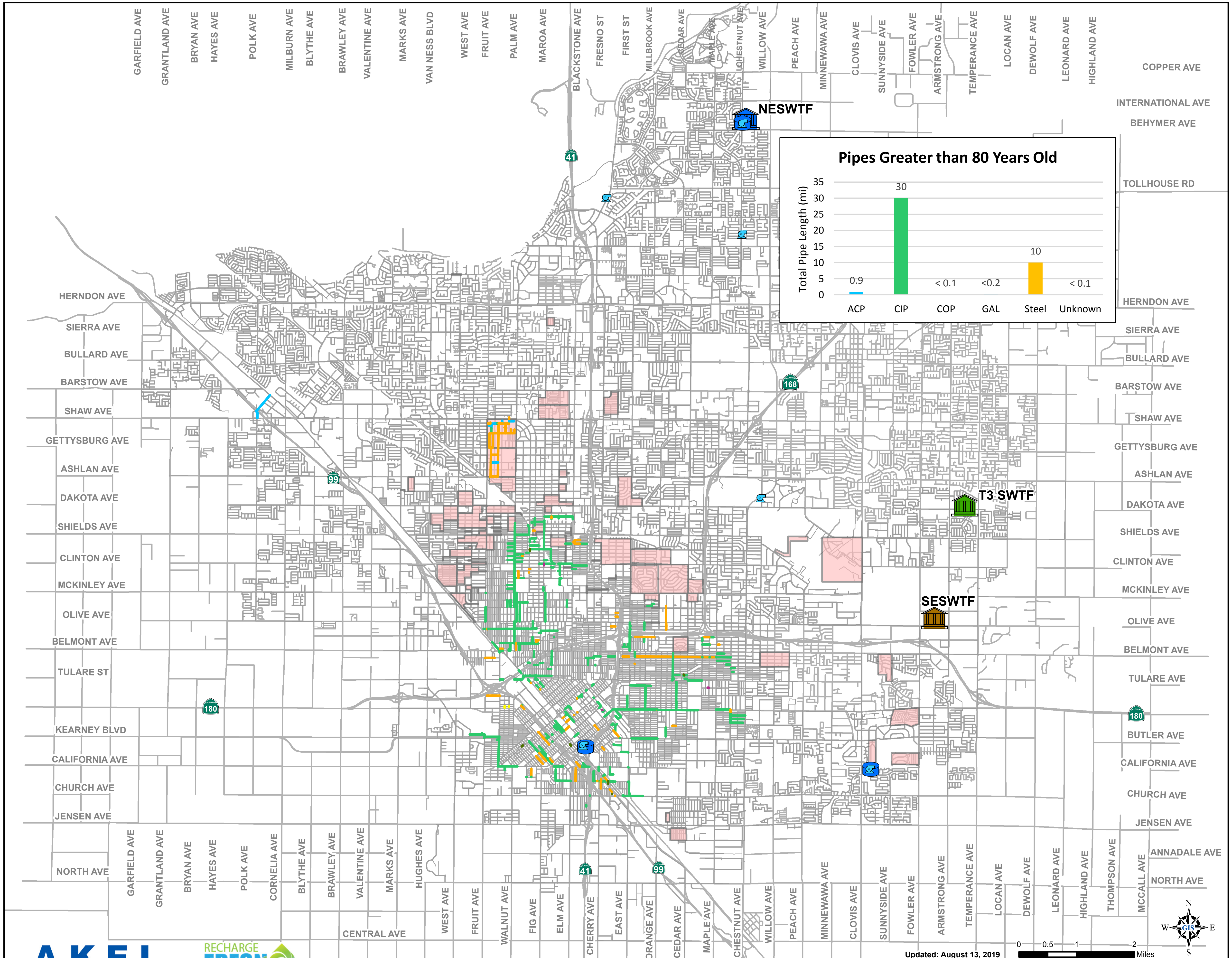
The City's water distribution system contains over 1,800 miles of pipeline varying significantly in their age and material with approximately 725 miles of pipelines that have been in service longer than 50 years. Based on recent replacement projects, the City has replaced approximately 3.0 miles per year which results with a 0.15% system replacement or a 667-year replacement cycle.

In 2018 Utah State University released the *Water Main Breaks in the USA and Canada: A Comprehensive Study.* This study surveyed 281 utilities to determine the amount of water main breaks and current annual renewal and replacement budgets. The study found that current annual R&R budgets are approximately 0.8% which results with a 125-year replacement cycle. Since the typical life span of pipelines is 50 to 100 years the recommended pipeline replacement rates are between 1.0% and 1.6% of the system which is equivalent to 100-year and 60-year replacement cycles respectively.

The R&R Plan has identified approximately 90 miles (5%) of extreme risk pipes and 190 miles (11%) of high-risk pipes. With the current replacement program budget, approximately $5M per year or 0.15% of the system (667-year replacement cycle), it will take 31 years to replace the extreme risk pipelines and an additional 71 year to replace the high-risk pipelines. As the system ages, more pipeline will become high and extreme risk and more budget will need to be allocated to replace these pipelines.

Figure 2.24 compares the current replacement plan with alternatives get to a 1.0% system replacement per year. If incremental increases are made to the R&R budget if will take approximately 27 years to replace the extreme and high-risk pipes and an additional 9 years to get to a 1% system replacement per year. This figure illustrates a clear budget gap that will continue to increase as the system ages and expands if new funding is not made available. The other two alternative identified on **Figure 2.24** demonstrate that if the initial budget can be increased to $10 million or $15 million the extreme and high-risk pipelines can be replaced in 23 and 19 years respectively. **Table 2.9** summarizes the R&R alternative budget goals for each year.

The City will be unable to maintain the same high-quality level of service with the current replacement budget and therefore, an increase in capital improvement funds must be made. An increase in capital budgets will allow the City to establish a proactive renewal and replacement program to avoid costly pipeline failures and increase its fiscal sustainability.



Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps

Pipes Greater than 80 Years Old (41.2 miles, 2.3%)

- ACP (0.9 miles, 2.3%)
- CIP (30 miles, 72.7%)
- COP (400 feet, 0.2%)
- GAL (932 feet, 0.4%)
- Steel (10 miles, 24.4%)
- Unknown (180 feet, 0.1%)

Pipes 80 Years and Newer

- (1,747.1 miles, 97.7%)
- Streets
- Planned Pipeline Replacement Area

Figure 2.23
Pipelines Greater than 80 Years Old

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

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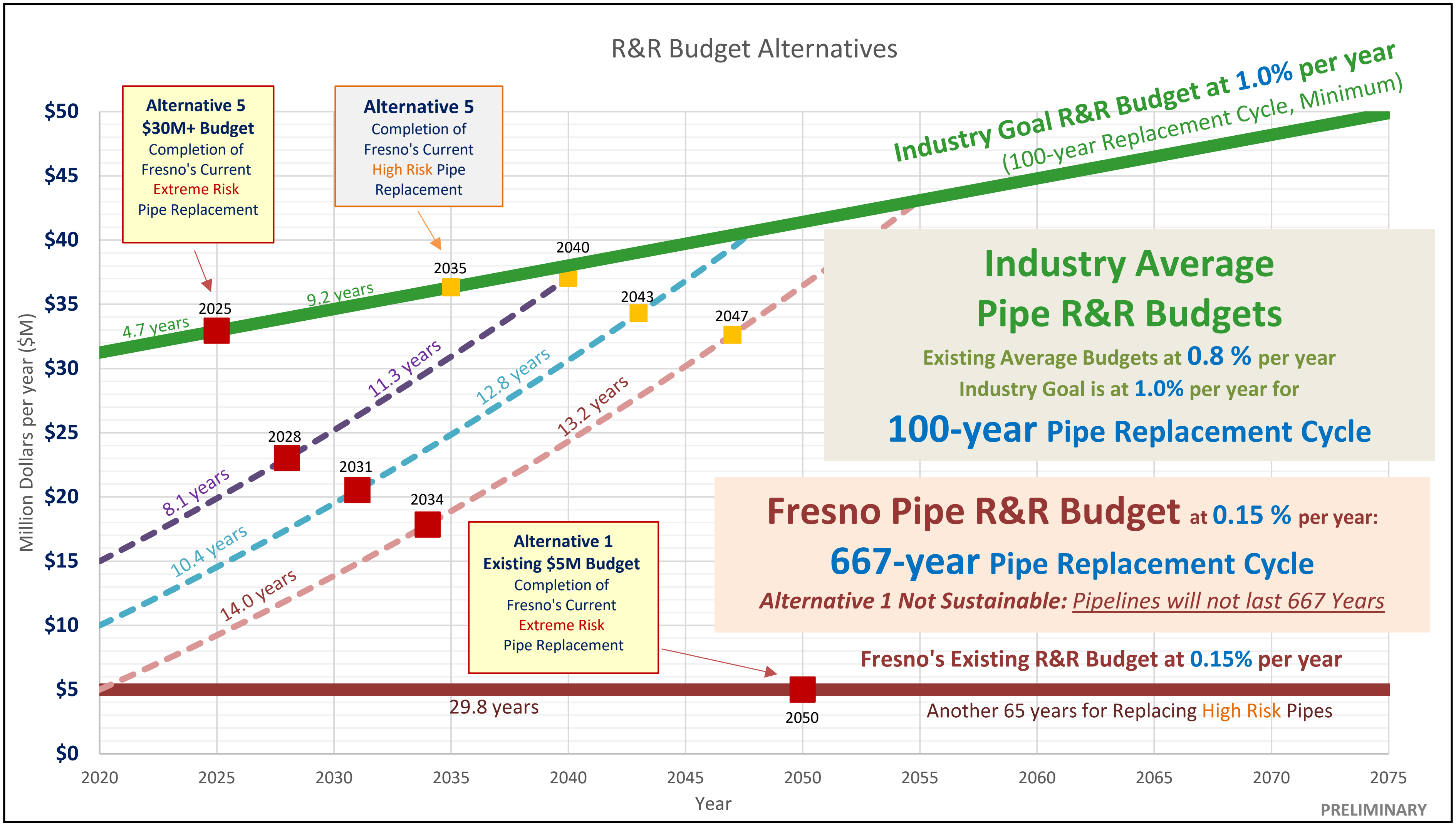

LEGEND

- Alternative 1: Existing Budget (667-year cycle, 0.15% System Replacement)
- Alternative 2: Ramp from $5M (35 Years to Reach 1% System Replacement)
- Alternative 3: Ramp from $10M (28 year to 1% System Replacement)
- Alternative 4: Ramp from $15M (21 years to 1% System Replacement)
- Alternative 5: 1% System Replacement per Year (Industry Goal) (100-year Cycle)

Assumptions:
1. System Growth: 20 miles of new construction per year (based on historical construction)
2. All costs in 2019 dollars

Note: *Industry Average Pipe Replacement based on 2018 Utility Survey: Water Main Breaks in the USA and Canada: A Comprehensive Study.* *Utah State University (March 2018).*
281 *Total Utilities surveyed.* ***98*** *Utilities provided detailed responses:*
Current Average Annual R&R Budget = 0.8%

August 27, 2019

AKEL ENGINEERING GROUP, INC.

Figure 2.24
Pipeline Replacement Financial Sustainability Alternatives
Drinking Water Infrastructure Renewal and Replacement Program
City of Fresno

City of FRESNO

Table 2.9 R&R Budget Alternatives

Drinking Water Infrastructure Renewal and Replacement Program

City of Fresno

Year	Alternative 1 Existing Budget (0.15% System Replacement)		Alternative 2 Ramp Up from $5M (35 Years to Reach 1% System Replacement)			Alternative 3 Ramp Up from $10M (28 year to 1% System Replacement)			Alternative 4 Ramp Up from $15 M (21 years to 1% System Replacement)			Alternative 5 1% System Replacement per Year (Industry Goal)		
	Annual ($M)	Cumulative ($M)	Annual ($M)	Percent Change (%)	Cumulative ($M)	Annual ($M)	Percent Change (%)	Cumulative ($M)	Annual ($M)	Percent Change (%)	Cumulative ($M)	Annual ($M)	Percent Change (%)	Cumulative ($M)
2020	5.0	5	5.0	-	5	10.0	-	10	15.0	-	15	31.2	-	31
2021	5.0	10	5.8	16%	11	10.9	9%	21	15.9	6%	31	31.6	1%	63
2022	5.0	15	6.6	14%	17	11.8	8%	33	16.9	6%	48	31.9	1%	95
2023	5.0	20	7.5	13%	25	12.7	8%	45	17.9	6%	66	32.3	1%	127
2024	5.0	25	8.3	12%	33	13.6	7%	59	18.9	6%	85	32.6	1%	160
2025	5.0	30	9.2	11%	42	14.5	7%	73	19.9	5%	104	32.9	1%	193
2026	5.0	35	10.1	10%	53	15.5	7%	89	20.9	5%	125	33.3	1%	226
2027	5.0	40	11.0	9%	64	16.5	6%	105	22.0	5%	147	33.6	1%	259
2028	5.0	45	12.0	8%	76	17.5	6%	123	23.0	5%	170	34.0	1%	293
2029	5.0	50	12.9	8%	88	18.5	6%	141	24.1	5%	194	34.3	1%	328
2030	5.0	55	13.9	7%	102	19.5	6%	161	25.2	5%	220	34.6	1%	362
2031	5.0	60	14.8	7%	117	20.5	5%	181	26.3	4%	246	35.0	1%	397
2032	5.0	65	15.8	7%	133	21.6	5%	203	27.4	4%	273	35.3	1%	433
2033	5.0	70	16.8	6%	150	22.7	5%	226	28.6	4%	302	35.6	1%	468
2034	5.0	75	17.8	6%	168	23.7	5%	249	29.7	4%	332	36.0	1%	504
2035	5.0	80	18.9	6%	187	24.9	5%	274	30.9	4%	363	36.3	1%	540
2036	5.0	85	19.9	6%	206	26.0	5%	300	32.1	4%	395	36.7	1%	577
2037	5.0	90	21.0	5%	227	27.1	4%	327	33.3	4%	428	37.0	1%	614
2038	5.0	95	22.1	5%	250	28.3	4%	356	34.6	4%	463	37.3	1%	652
2039	5.0	100	23.2	5%	273	29.4	4%	385	35.8	4%	499	37.7	1%	689
2040	5.0	105	24.3	5%	297	30.6	4%	416	37.1	4%	536	38.0	1%	727
2041	5.0	110	25.5	5%	323	31.8	4%	447	38.4	3%	574	38.4	1%	766
2042	5.0	115	26.6	5%	349	33.1	4%	481	38.7	1%	613	38.7	1%	804
2043	5.0	120	27.8	4%	377	34.3	4%	515	39.0	1%	652	39.0	1%	843
2044	5.0	125	29.0	4%	406	35.5	4%	550	39.4	1%	691	39.4	1%	883
2045	5.0	130	30.2	4%	436	36.8	4%	587	39.7	1%	731	39.7	1%	922
2046	5.0	135	31.4	4%	468	38.1	3%	625	40.1	1%	771	40.1	1%	962
2047	5.0	140	32.6	4%	500	39.4	3%	665	40.4	1%	811	40.4	1%	1,003
2048	5.0	145	33.9	4%	534	40.7	3%	705	40.7	1%	852	40.7	1%	1,044
2049	5.0	150	35.2	4%	569	41.1	1%	747	41.1	1%	893	41.1	1%	1,085
2050	5.0	155	36.4	4%	606	41.4	1%	788	41.4	1%	934	41.4	1%	1,126
2051	5.0	160	37.7	4%	643	41.7	1%	830	41.7	1%	976	41.7	1%	1,168
2052	5.0	165	39.1	3%	683	42.1	1%	872	42.1	1%	1,018	42.1	1%	1,210
2053	5.0	170	40.4	3%	723	42.4	1%	914	42.4	1%	1,061	42.4	1%	1,252
2054	5.0	175	41.7	3%	765	42.8	1%	957	42.8	1%	1,103	42.8	1%	1,295
2055	5.0	180	43.1	3%	808	43.1	1%	1,000	43.1	1%	1,147	43.1	1%	1,338
-----	---													
2114	5.0	475												

Legend:

4/29/2019

17.8	Year the extreme risk water mains will be replaced (Required budget: $149M)
32.6	Year the high risk water mains replaced (Required budget $326M, Cumulative $475M)
38.4	Annual budget reaches Industry Goal of 1% system replacement per year

CHAPTER 3 – WELLS

This chapter documents the domestic water well asset inventory and explains the risk assessment methodology followed to identify and prioritize the water supply well renewal and replacement recommendations.

3.1 SPECIFIC GOALS OF THE WELL EVALUATION

The purpose of this evaluation was to identify mid-term (1-5 years) needs and recommendations to ensure that Fresno's groundwater wells system can:

1) Meet peak-demands after new water treatment facility comes online
2) Meet average daily demand in case of emergency shut-off of the new water treatment plant
3) Meet the above water-quantity goals while maintaining water-quality standards required by California regulations
4) Meet current system's demands and water quality requirements

Evaluation criteria included energy needs to operate, reliability, and water quality. The evaluation results were used to identify and prioritize R&R recommendations for the wells.

3.2 SUMMARY OF PREVIOUS WORK

In 2016, Kleinfelder worked with the City of Fresno to do a Preliminary Asset Management Plan (PAMP) for a subset of the city's wells. In this PAMP a risk-based strategy was developed to prioritize wells. The PAMP identified key performance indicators (KPIs) for the wells including:

- water quality trends over time, which impact public health and are therefore regulated,
- changes in specific capacity over time – the ratio of flow over drawdown, which is an indicator of the productivity of the well over time,
- operating plant efficiency (OPE) or 'wire to water' efficiency – the relationship between the amount of energy consumed and the flow rate of a well at a given head,
- energy use over time, which demonstrates trends in pumping efficiency, and
- remaining useful life, which is a forecasted value of how much longer a well can operate prior to replacement based on the age and attributes of the well and its components.

An example of these KPIs are shown with sample data for a single well in **Figure 3.1**. The trends below show that, based on the KPIs, likelihood of failure increased over time. For example, in the top left quadrant, the flow rate per unit of energy inputs was declining over time, indicating that the well is becoming less energy efficient.

Figure 3.1: Example of KPIs for Energy Use, Specific Capacity, and Change in Efficiency over time for Well 36

During a planning workshop in September 2017, Kleinfelder discussed with the City the use of each of these KPIs as potential metrics for the well assessment. The City agreed on the use of these KPIs to the extent possible given the availability of data. The pilot report is presented in **Appendix C**.

Data for measuring the KPIs identified in the pilot study were not available for the entire portfolio of well assets. As discussed in subsequent sections, the framework outlined in the PAMP for evaluating the performance of wells was used where possible. Additional well performance metrics were also developed.

3.3 AVAILABLE DATA

The datasets available for this project are listed and described here, including original format, source, and comments about level of completeness. In general, the data provided is relatively complete for active wells. Where data were missing, the system average was used within the analyses.

- **Well Inventory** – The City maintains an Excel Spreadsheet with Well IDs, address, associated pump station, status, type, installation dates, and other well characteristics. Most of the static data, such as type, depth, and head, is complete. Dynamic data, such as status and standard flow, is less complete. Where other data sources (or input from stakeholders) was available, dynamic data from this inventory was superseded. The dataset was last updated in March 2018. Additional details and fields are shown in **Table 3.1**.
- **GIS shapefile** – this GIS provided the spatial location of wells and pump stations. Some wells from the Inventory, primarily those which were destroyed, were not included in this shapefile.
- **Water quality sampling records -** The City provided Excel worksheets which contained approximately 530,000 records of sampling results collected between 2007 and 2017. Analytical Laboratory sample results were associated with the sampling location and date.
- **Well Production** – The City provided historic well production data, exported from SCADA, from 2011-2016.
- **PG&E Energy Charges** – The City provided historic energy costs to operate for each well from 2008-2016. This data, provided in March 2018, was used to validate the analyses.
- **Demands** – 2018 Average Daily Demand (ADD) were exported from the hydraulic model by mixing area. Maximum daily demand was derived based on an estimated 2.0 multiplier over ADD.
- **Maintenance History** - Limited maintenance history information was available for wells.
- **City of Fresno Strategic Business Plan (2013-2015)** – PDF provided by the City. Contains information about the City's priorities and desired levels of service for the water and wastewater systems.

Table 3.1 Well Attribute Data, Source, and Percent Complete

Infrastructure Renewal and Replacement Plan
City of Fresno

Attribute	Data Source(s)	Last Updated	Notes
Well ID	2018 Well Data Sheet	March 2018	-
Status	2018 Well Data Sheet 2017 City Well Destructions	March 2018	-
Standard Flow Rate (gpm)	Well SCADA Production_041018	April 2018	66 wells missing standard flow rate
Overall Plant Efficiency (OPE)	Official OPE Comparison Spreadsheet 2016	2016	43 wells missing OPE
Well Type	2018 Well Data Sheet	March 2018	8 wells missing well type
Date Drilled	2018 Well Data Sheet	March 2018	>95%
Hydraulic Head (ft)	2018 Well Data Sheet	March 2018	43 wells missing head
Pump Horsepower	2018 Well Data Sheet	March 2018	41 wells missing data for horsepower
Specific Capacity	Flushing Report records (36 forms from 2017) Official OPE Comparison Spreadsheet 2016 (155 records from H20 Testers and Mid Valley Pump Testers between 2011-2017)	October 2018	185 of 277 wells with two or more specific capacity values and dates
Condition Scores	Preliminary: "Edited 2017 03 24 Ranking Wells" Spreadsheet Updates: Stakeholder Workshops	All wells scored overall in March 2015 Scores revised for high priority wells and their components in 2018	-
TCE Plume Control	T5.3 - Well Operational WQ Constraints_102317	October 2017	-
TCP Wells	TCP Wells	September 2017	-
Generator on Site	2018 Well Data Sheet	April 2018	-
Production	Well SCADA Production_041018	April 2018	-
Hydraulic Run-time %	Well SCADA Production_041018	April 2018	-
Energy Use	Annual PG&E dbase history 2008-2017	February 2018	-
Operational Notes	Well Verifications_032918	April 2018	-

3.4 APPROACH OVERVIEW

The goal of this analysis was to identify wells that should be prioritized for renewal and replacement over the next five years with the understanding that, in most areas of the City, the groundwater wells will supplement or provide backup to surface water supplies. Asset management strategies such as *risk-based prioritization* is effective for objectively comparing needs arising from different types of assets. To accomplish this numerical analysis, it is necessary to define a risk framework, which describes the methodology for calculating likelihood of failure scores and consequence of failure scores for all asset types involved in the analysis. With an inventory of more than 260 wells, the City of Fresno has redundancy in their water supply systems, and therefore consequence of failure factors was similar and of low value for most wells. Although likelihood of failure was different between wells, this approach did not reveal significant differences in risk between wells.[1] For that reason, we developed an alternative approach to identify the *groups of wells* that performed best, in terms of the City's objectives. We incorporated components of a risk-based prioritization and used KPI's identified in the PAMP, where possible.[2] The approach for prioritizing R&R recommendations for Wells followed these steps:

1. Classified wells by operational status and mixing area (geographic area in which a well provides water)
2. Identified demands by mixing area
3. For each well, calculated a water-quality score, an energy efficiency score, and a reliability score (the objectives)
4. Developed an optimization model to identify groups of wells, across each mixing area, which will collectively provide water with high water quality, energy efficiency, and reliability.
5. Refined well prioritization based on operational realities and institutional knowledge
6. Defined a risk framework
7. Prioritized wells on the basis of the most valuable well analysis, consequence of failure, and risk
8. Identified near-term (5-year) R&R recommendations and costs for wells based on well condition using the prioritized list of wells

Figure 3.2 represents this approach and the flow of data used to develop the R&R recommendations. The sections that follow explain the details of each step.

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[1] This approach is valid for other types of assets within Fresno's system, such as water mains. Failure of a water main results in different consequences depending on where the failure occurs. That is not the case for the City's wells, where in general, if a well fails, another can come online to replace it.

[2] Kyle et al, 2002 & Augusto et al. 2012

Objectives

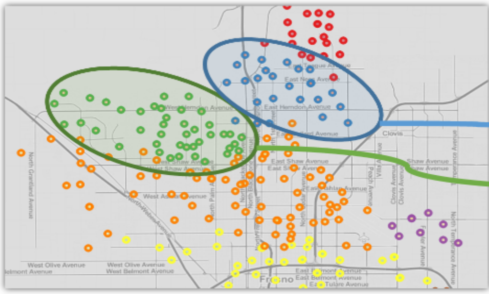
Pilot Study (PAMP)

Well Performance Data

Water Quality KPI	Energy Efficiency KPI	Reliability KPI

The City identified three objectives for prioritizing wells for R&R. Each well was assigned a performance score (KPI) for each of the three objectives. These scores were inputs in an optimization model.

Optimization Model



Wells by Mixing Area

Scenarios

Well	A	B	C	D	E	F	Count
1	On	On	On	On	On	On	6
2	On	Off	On	On	On	Off	4
3	On	On	On	Off	Off	Off	3
4	Off	On	On	On	Off	Off	3
5	On	On	Off	On	Off	Off	3
6	On	Off	Off	Off	Off	Off	1

A preferred set of wells for each mixing area was identified based on the results of the optimization model. Each set of wells was refined based on feedback from stakeholders.

Preferred Sets of Wells

Refinement & Metric Validation

Well	Count	Flow	Priority
1	6	1000	High
2	4	2500	High
3	3	1750	High
4	3	2500	High
5	3	500	Low
6	1	1000	Low

Well R&R Recommendations

Well R&R Strategies

Well R&R Budget

Well	Priority	R&R	Year	Cost, $
1	High	Repair	2020	$400K
2	High	Maintain	2021	$100K
3	High	Nothing		
4	High	Maintain	2022	$200K
5	High	Maintain	2022	$100K
6	Low	Nothing		

A prioritized list of R&R recommendations was developed incorporating the refined optimization results, risk, existing well management and capital improvement plans, and budget considerations

March 5, 2019

Figure 3.2

Representation of the Inputs and Process Used to Prioritize Wells for R&R

Infrastructure Renewal and Replacement Plan

City of Fresno

This process, presented here as sequential steps, was iterative and was developed with stakeholder input during multiple meetings and workshops with the City, as listed in **Table 3.2**.

Table 3.2: Workshop Dates and Topics

Date	Workshop Topics
September 1, 2017	Levels of Service; Well Prioritization Process Overview
October 18, 2017	Risk Framework (Likelihood of Failure & Consequence of Failure); Review of Well Prioritization Results for Pilot Area
March 28, 2018	Review and Refinement of Well Prioritization Results
April 2, 2018	Review and Refinement of Well Prioritization Results

3.5 ASSET INVENTORY

3.5.1 Operational Status and Mixing Area

Kleinfelder reviewed the Well Inventory spreadsheet and the GIS shapefile for wells. The well inventory included 299 groundwater wells. The City reviewed the inventory for accuracy and up-to-date information related to operational status and flow rate of wells, through a series of workshops and meetings in spring 2018. Wells were classified by Operational Status as:

- Active: used on a regular basis to supply water
- Inactive: temporarily offline due to operational or maintenance issues
- Proposed: new, proposed wells (online within the duration of this 5-year Plan)
- Abandoned or Destroyed: wells that are not currently used and will not be used within the next 5 years

Each of the 299 wells were assigned a value for operational status. Abandoned/Destroyed wells were excluded from the analysis. The 7 proposed wells included in the inventory were also excluded from the analysis since neither well had performance data (such as flow rate) and therefore could not be compared against other wells. Of the 299 wells, 44 had a status listed as abandoned or destroyed and these were excluded from the analysis. **Table 3.3** provides a summary of the number of wells categorized by status.

Table 3.3: Summary of Wells by Status

Status	Active	Inactive	Proposed	Abandoned or Destroyed
Code	ACTV	INACTV	PROP	ABAN/DEST
Count of Wells	230	18	7	44
Included in Analysis	Yes	Yes	No	No

Eight mixing areas were defined using the distribution system hydraulic model and institutional knowledge of the Fresno distribution system. Wells were assigned mixing area designation based on the estimated geographic area in which a well provides water, as shown in **Figure 3.3**.

In **Figure 3.3**, the shading color of each mixing area indicates what drinking water source or sources are available. For example, mixing areas 1-4 are each served by the Southeast Fresno Surface Water Treatment Facility (SESWTF) and also have groundwater sources available if the surface water treatment plant is offline or are required to supplement the supply of surface water. Conversely, in mixing area 6, groundwater is the primary water source. The water sources available in each mixing area are listed in **Table 3.4**. The differences in water source availability influence the redundancy of wells in the area and the consequence of failure scoring.

Table 3.4: City of Fresno 2018 Estimated Demand by Mixing Area

Mixing Area	Number of Wells	Average Day Demand (gpm)	Maximum Day Demand (gpm)	Drinking Water Source(s)
1	11	5,003	10,006	SESWTF & Groundwater
2	44	7,643	15,287	SESWTF & Groundwater
3	34	12,664	25,327	SESWTF & Groundwater
4	74	25,806	51,613	SESWTF & Groundwater
5	7	1,474	2,949	T3 (3 mgd) & Groundwater
6	34	11,796	23,593	Primarily Groundwater
7	24	6,416	12,832	NESWTF (27 mgd) & Groundwater
8	20	6,357	12,714	NESWTF (27 mgd) & Groundwater
Total	**248**	**77,159**	**154,321**	

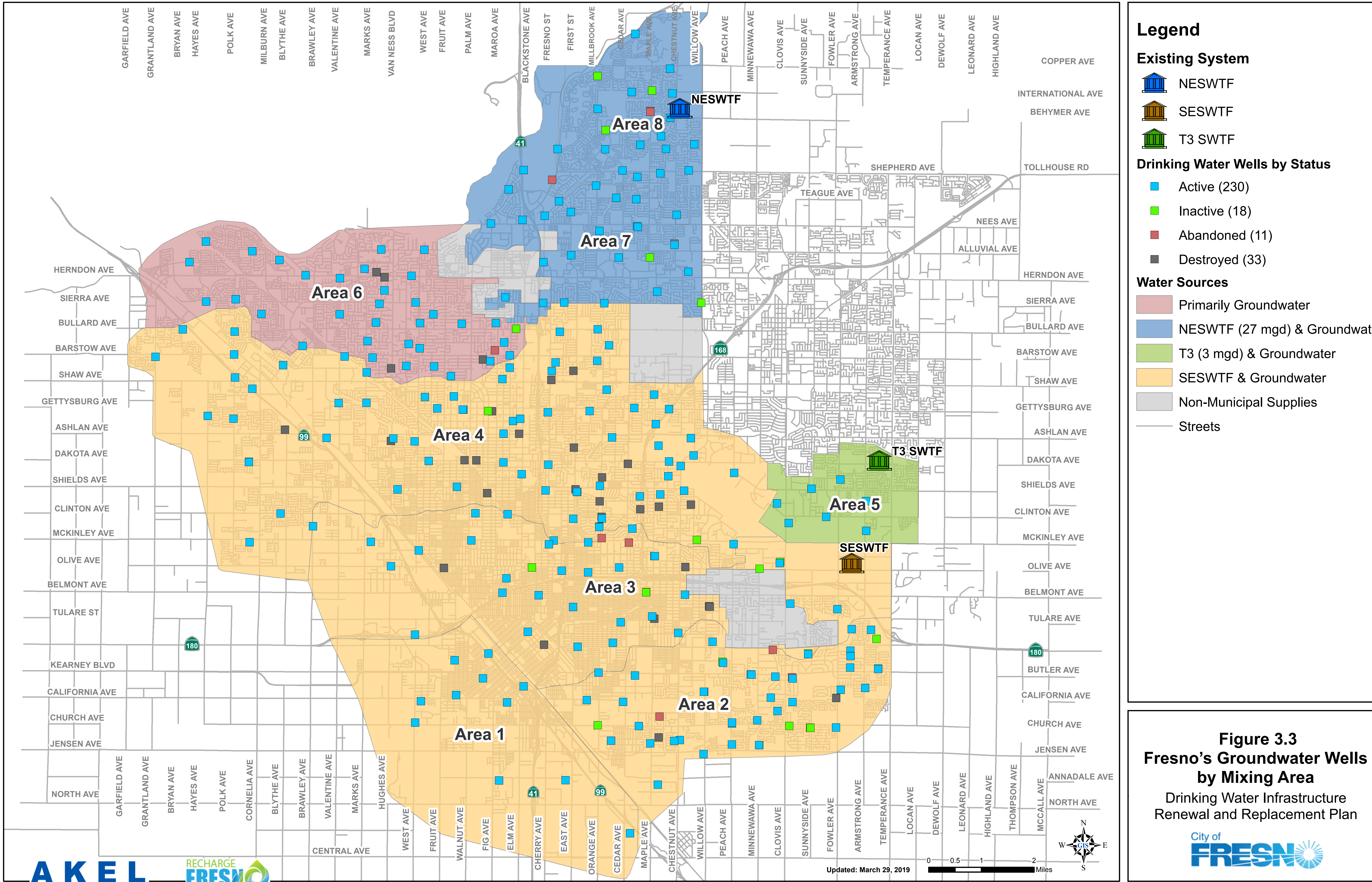


Figure 3.3
Fresno's Groundwater Wells by Mixing Area
Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

Historically, the City of Fresno grouped wells based on SCADA zones. In this evaluation, SCADA zones were used initially to group wells for prioritization and estimate present day demand. However, through the course of this evaluation, the City determined that it would be more appropriate to group wells based on the area that they serve.

3.5.2 Demand

In the analyses described in Section 3.6, Kleinfelder used the 2018 estimated average daily demand (ADD) for each mixing area. The City of Fresno should be commended for its water conservation efforts over the last five years of drought which resulted in a substantial decrease in daily water usage. Based on steadily declining rate of residential water use from 2013-2017, the demand values used in this evaluation are assumed to be conservative over the next 5 years. Maximum day demand (MDD) was estimated at a peaking factor of 2 times ADD. The demand values by mixing area, number of wells serving demand, and the available drinking water sources are presented in **Table 3.4**.

3.6 MOST VALUABLE WELLS ANALYSIS

The following sections describe the process of developing a prioritization model for wells. A representation of the model is shown, above, in **Figure 3.2**.

3.6.1 Methodology

Kleinfelder developed a spreadsheet-based model to determine the set of Fresno's groundwater wells that best meet the three objectives: energy use, water quality degradation, and reliability. The optimization model was run using OpenSolver, an add-in for Excel. The model was used to determine the set of Fresno's groundwater wells within each Mixing Area could effectively address all three objectives in aggregate, while providing the necessary volume of water to meet demand.

Since these three objectives can be at odds, it was not possible to find a single set of wells that was optimal for all objectives. Instead, with input from stakeholders, Kleinfelder varied the emphasis on each objective and applied various operational conditions. These variations, or scenarios, offered insights on the sets of wells that functioned well regardless of the weights assigned to each of the three objectives.

3.6.2 Scenarios

Twelve scenarios were developed and run for each mixing area. Each scenario had a different set of weights for the objectives, demand constraints, and operational controls. Scenarios were developed based on input from the City of Fresno at a workshop on October 18, 2017. Collectively, developing this combination of scenarios allowed for the City to identify which wells appear in the greatest number of scenarios, indicating which wells best meet the combination of objectives. These scenarios are described in **Table 3.5**.

Table 3.5: List of Scenarios

#	Scenario Description	Demand Constraint	Weights	Controls
1	Balanced objectives	ADD	Equal Weights	None
2		MDD	Equal Weights	None
3	Energy as only objective	ADD	Energy only	None
4		MDD	Energy only	None
5	Water Quality as only objective	ADD	Water Quality only	None
6		MDD	Water Quality only	None
7	Reliability as only objective	ADD	Reliability only	None
8		MDD	Reliability only	None
9	Prioritize well managing TCE	ADD	Equal Weights	TCE Plume Management Wells On
10		MDD	Equal Weights	TCE Plume Management Wells On
11	Prioritize wells which could provide water with treatment plant(s) offline or during a power supply failure	ADD	Equal Weights	Wells with Generators on site On
12		MDD	TCE Plume Management Wells On	TCE Plume Management Wells On

For each scenario, the optimal solution was defined by the set of wells which met all constraints and controls and achieved the best score in the model.

3.6.3 Preliminary Results and Refinement

Wells were prioritized based on the number of scenarios in which they appeared (out of a total of 12), since the more frequent a well appears as a part of an optimal solution, the better it was in meeting the various objectives of the prioritization model. For each mixing area, high priority wells were shaded in yellow and orange, as indicated by the solution set as “ADD & MDD” or “MDD”. An example subset of high priority wells in Mixing Area 8 is displayed with this shading in Figure 3.4**.** These solution sets represent the wells with the best quality water, energy efficiency, and reliability, as compared to other groupings of wells with the same capacity. The preliminary results are presented as **Appendix D**.

Figure 3.4: A Subset of High Priority Wells in Mixing Area 8

		Well ID	Number of Scenarios	Average Flow Rate (gpm)	Status	Hydraulic Model Runtime % (Annual)	TCE Plume Management (Y/N)	TCP Management (Y/N)	Operational Notes	Prioritization Notes	Solution Set
Mixing Area	8	132 (V)	11	960	ACTV	0%	N	N			ADD & MDD
ADD (gpm)	6,357	187 (V)	8	1,040	ACTV	0%	N	N			ADD & MDD
MDD (gpm)	12,714	128	8	1,410	ACTV	0%	N	N			ADD & MDD
		330 (V)	6	1,110	ACTV	0%	N	N	manganese treatment; replacing backwash currently; air issues likely related to private well use and increased size of pump		ADD & MDD
		319 (V)	6	1,130	ACTV	0%	N	Y	TCP		ADD & MDD
		321 (V)	6	610	ACTV	0%	N	Y	bad air pump; unreliable		ADD & MDD
		151 (V)	4	950	ACTV	0%	N	N			ADD & MDD
		318	3	1,540	ACTV	0%	N	N			MDD
		143 (V)	2	970	ACTV	0%	N	N			MDD
		140	2	830	ACTV	0%	N	N			MDD

The City reviewed the results of the optimization model through workshops on March 28 and April 2, 2018. The City provided additional input on the prioritization process to incorporate operational considerations and preferences. For example, any wells which are being operated for TCE plume management were marked as high priority, since they must remain operational to mitigate negative public health impacts. Additionally, through the refinement process discussed below, the City of Fresno identified multiple wells with operational considerations which will prohibit either future use or rehabilitation efforts. Such wells were removed from the prioritization process and are listed at the bottom of a mixing area’s prioritization list, as applicable. Excluded wells for each Mixing Area are summarized in **Table 3.6**.

Table 3.6 Excluded Wells

Drinking Water Infrastructure Renewal and Replacement Plan
City of Fresno

Well #	Justification for Exclusion
Mixing Area 1	
22A	Pump failed; well video; investigation in progress; R&R pump
26A	This is not a good well; drop to bottom; replace with 26B
40A	Water quality (Nitrate) concerns; Currently only runs in summer 24/7; well is not plumb, many issues
162	Exceeding MCL for TCP - remove from prioritization
Mixing Area 2	
274	Blends with 275 which must run, nitrate slougher
152	Well inactive due to water quality concerns requiring treatment for Nitrate; No runtime
277	DBCP; Offline due to nitrates. Unable to blend at this time due to complicated connectivity; suggest CBA for blending
135B (V)	Water quality (manganese and arsenic MCL) concerns
Mixing Area 3	
155-2	Lost to nitrate (destroyed/abandoned)
10A	Will need to be converted to electric power
84	Well inactive due to water quality concerns requiring treatment; No runtime
Mixing Area 4	
63	Offline since 2006 due to Water quality (TCP); land-locked; would need new property to install treatment; suggest drop; No runtime
212	Well is plugged with pump and may become abandoned; significant mechanical failure may require removal for R&R
Mixing Area 5	
347	Treatment needed (manganese); inactive; location between 2 surface water plants
329	Treatment needed (manganese); inactive; location between 2 surface water plants
326	Water quality complaints (odor); sulfide
Mixing Area 6	
-	
Mixing Area 7	
-	
Mixing Area 8	
295	Well inactive due to water quality concerns requiring treatment; No runtime
185 (V)	Groundwater well does not pump to the distribution system (pumps to treatment facility)
133 (V)	Well inactive due to water quality concerns requiring treatment; No runtime; Will be very difficult to rehabilitate (off-gas system) due to dual cased well
130	Needs treatment

10/2/2018

3.7 KEY PERFORMANCE INDICATORS

3.7.1 Water Quality, Energy Efficiency and Reliability

From reviewing the PAMP and the City's Strategic Plan, three metrics were selected for the analysis: *water quality, energy efficiency, and reliability*. These are commonly used in management strategies across the country[3]. The City expressed interest in prioritizing R&R for the set of wells that: required the least amount of energy to operate, wells which will be reliable over the next 5-years, and wells which provide water that meets regulatory requirements for quality. These metrics aligned with of the City's values of:

- providing water of quality to their customers
- maintaining financial viability
- having infrastructure stability[4]

To assess the subset of wells that best meet certain goals while subject to certain constraints, Kleinfelder developed a methodology to measure these objectives and identify which wells are optimal for achieving all three objectives. Water quality, energy efficiency and reliability were the primary parameters (or KPIs) used in the optimization. The methodology used for defining KPI values for each well is presented below.

3.7.2 Water Quality

The water quality degradation (WQD) score was used as a key performance indicator (KPI) representing the lack of water quality for each well. This KPI is aligned with the City's mission of providing water of high quality to its residents. It is also a health and safety KPI and a customer satisfaction KPI.

The City of Fresno provided regulatory compliance sampling records from 2007-2017. The data was provided as separate spreadsheet (one per year); had slightly inconsistent schemas; and had variation between the naming convention of sample sites, names of analytes, and units for each analyte. Kleinfelder cleaned and compiled the information. Once compiled, Kleinfelder compared over 530,000 analytical sample results of more than 380 different analytes to their respective regulatory limit, called a Maximum Contaminant Limit (MCL). MCLs were based on State of California Water Supply Regulations (dated September 23, 2016). The results of this analysis were used to develop a KPI and a water quality score for each well.

3.7.2.1 Water Quality Degradation KPI

The water quality KPI was defined as the frequency of samples at a well which exceeded the MCL. This KPI measures water quality degradation:

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[3] *Santa Clara, CA; Dallas and Fort Worth, TX*

[4] *City of Fresno Strategic Plan*

Water Quality Degradation (WQD) = Count of samples exceeding MCL/ Count of total Samples

Higher scores for water quality degradation represented wells with poorer water quality.
The water quality KPI incorporated into the optimization model used recent water sample data, from 2014-2017, since this water quality data was determined to be a better indicator of future trends.

3.7.2.2 Specific Water Quality Concerns: TCP and TCE

Related to the WQD KPI, the City identified two contaminants of concern: 1,2,3-Trichloropropane (TCP) and Trichloroethylene (TCE), which required special treatment in the model. Wells with historic samples showing impairments for TCP are highly regulated by the state. Water from wells impacted by TCP require treatment, usually with Granular Activated Carbon (GAC) and ion exchange. Kleinfelder identified 38 wells that had TCP samples exceeding the MCL within the past 10 years. Installing wellhead treatment at these 38 wells could be cost prohibitive; however, this alternative may be suitable at certain locations. Wells with historic detections of TCP but without on-site treatment were excluded from consideration in this most valuable well analysis.

The City actively manages a TCE chemical plume present in the City's groundwater system. This chemical is an environmental and health and safety concern. Six wells were identified with historical detections of TCE, some of which are used to manage the plume. As required because of litigation, plume management wells must remain on constantly. The wells which were manually prioritized for R&R recommendations due to their criticality for TCE management include: 70 (V), 283, 279 (V), and 264.

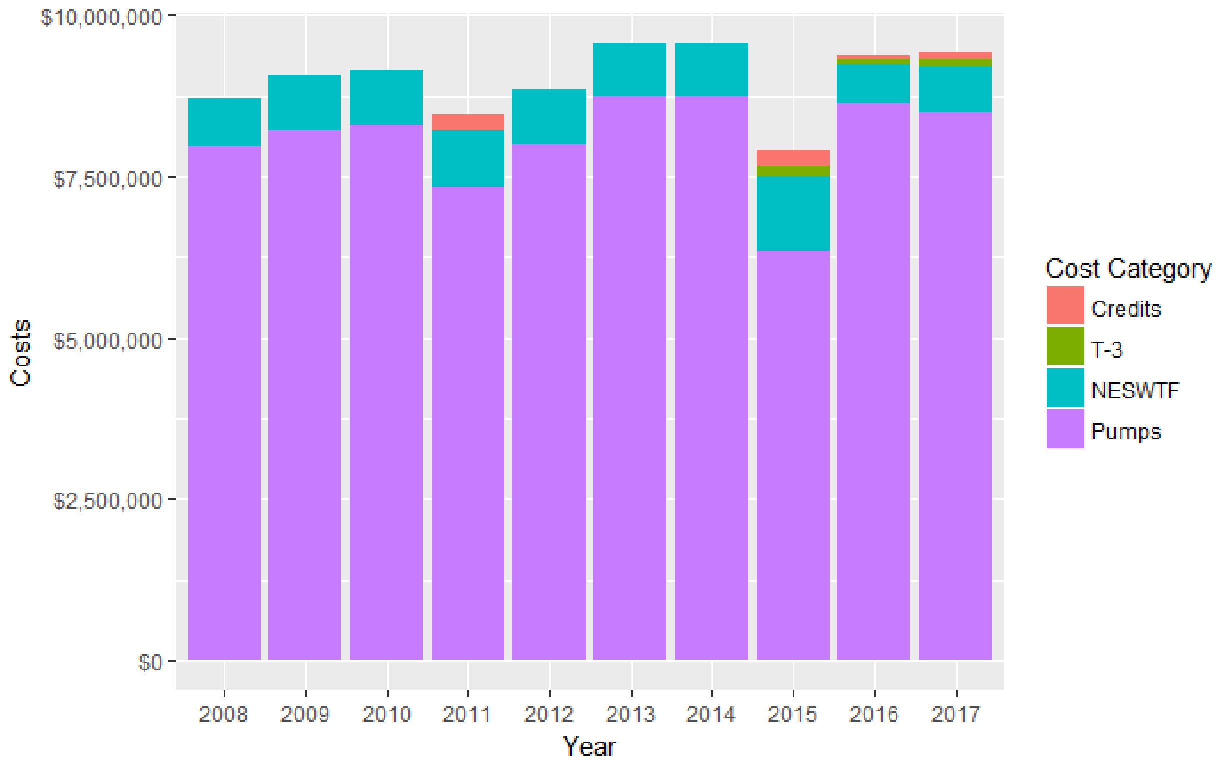
3.7.3 Energy Efficiency

Energy conservation is an important component of financial sustainability and greenhouse gas emission reduction. Energy-efficiency management practices can reduce operating costs and can extend the life of assets by ensuring they operate at their optimal performance point. Since water efficiency practices relate to the maintenance, operations, and tracking of energy consumption of the system assets, energy conservation was incorporated into the well prioritization evaluation to focus limited resources on assets that can perform efficiently. Across each Mixing Area, there is redundancy in terms of water quantity and there are a variety of combinations of wells that could produce the desired volume of water. It was therefore important to include energy as a consideration in this evaluation to identify and prioritize the set of energy efficient.

The City invests a large part of its operating budget on energy. In 2017, the City of Fresno's Water Division spent approximately $9.5 million on energy with operation of groundwater wells and pumps accounting for approximately $8.5 million (90%) of these costs (
Figure 3.5). Studies of water and wastewater systems in North America indicate that most utilities, regardless of their size, could potentially improve their energy efficiency by 10 to 30

percent. For the City of Fresno's water system, conceptually, more energy efficient operation would translate to a potential savings of $950,000 to $2,850,000 a year, thus the emphasis on this efficiency objective. The City recognized this opportunity to reduce groundwater pumping costs, as discussed in the City's Budget, and anticipates capturing about $1.5 million in annual savings through operating the SESWTF and a decreased reliance on water from groundwater wells.[5]

Figure 3.5: Water Division PG&E Reported Energy Costs, 2008-2017



In the PAMP, three energy-related KPIs were introduced:

- Overall Plant Efficiency (OPE) – also known as "wire to water efficiency", this is a KPI for the overall efficiency of a pumping system. It includes the efficiency of the pump, its motor, a variable speed drive. On multiple pump systems, it considers the losses in the piping fittings that surround the pumps. wire-to-water efficiency is the energy that is imparted to the water divided by the energy that came in over the electrical wires. The metric is a percentage. Data for OPE was available for approximately 75% of the wells. OPE was used as a component of the KPI used for energy prioritization. Where data was not available, the system average was used.

[5] *https://www.fresno.gov/finance/wp-content/uploads/sites/11/2018/05/FY2019ProposedBudgetWEBPAGE.pdf*

- Energy Costs to Operate – cost of producing a given amount of water (measured in dollars per acre-feet). This KPI is subject to changes in the rate structure and can obscure results over time. Data was not available at the time of analysis to use this KPI.
- Change in Energy Consumption over time – reflects changes in the operating environment of the well that may indicate a reduction in efficiency or changes in the aquifer hydraulics. Data was not available at the time of analysis to use this KPI but was used to validate the KPI used in analyses.

For this evaluation, the City expressed interest in identifying the set of wells that required the least amount of energy per unit of water produced. We introduced a new KPIs for this analysis: required energy.

3.7.3.1 Required Energy KPI

We used the standard horsepower equation to estimate the amount of energy a pump needed to produce water. This Required Energy KPI, was calculated as the product of the hydraulic head (in feet) times the flow rate (gpm), and OPE:

$$\text{Required Energy} = \mathrm{Q} * \mathrm{H} \,/\, (3960 * \mathrm{OPE})$$

Where:

Q = Standard flow rate (in gal/min),
H = hydraulic head (in feet), and
OPE = pump efficiency (as a decimal value)

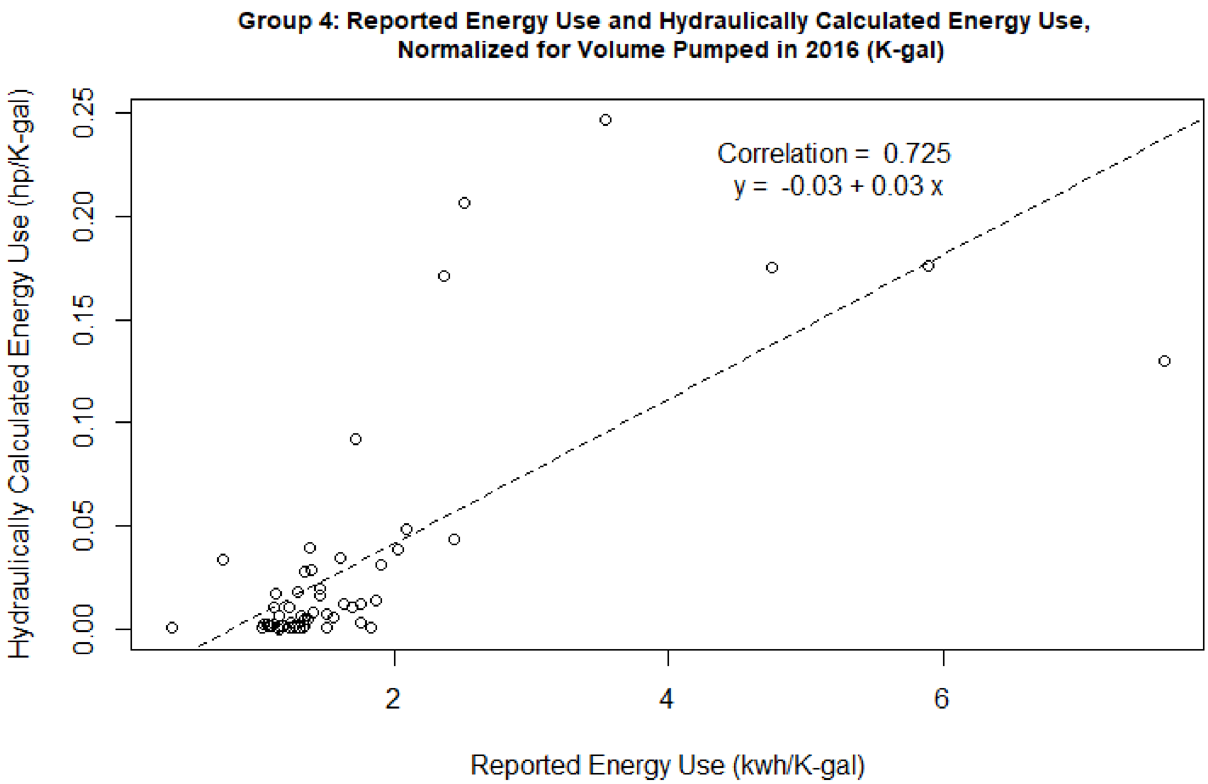
The values for average flow rate, head, and OPE per well were provided in the Well Inventory Spreadsheet. Wells with no OPE data we assigned the system's average OPE. Since both the flow rate and pump efficiency are dynamic, the primary advantage of this calculated KPI is that it can be updated in the model when significant changes are made to the hydraulics of the system or the performance of the well.

3.7.3.2 Validation of Energy KPI

To conduct a sensitivity analysis of Energy efficiency KPIs, Kleinfelder developed an alternative KPI based on historic energy use for each well and actual water production. Kleinfelder used PG&E Reported Energy Consumption Data from 2008-2017 and monthly water use data for each well to estimate energy efficiency for each well in this KPI. Energy use was reported monthly, by well, both in terms of number of kilowatt hours (KWH). For this comparison, energy use, in kilowatt hours (KWH), was normalized by the annual thousand gallons pumped (kwh/K-gal) to correct for differences in pumped amounts between wells. Kleinfelder compared the results of the hydraulically calculated required energy KPI with that of the historically observed energy consumption KPI. A summary of the methods and results of the sensitivity analysis for the energy term is presented below and are described in greater detail in **Appendix E**.

The sensitivity analysis was completed specifically for the Mixing Area with the greatest number of wells, Mixing Area 4. This analysis demonstrated that there was a moderately strong linear relationship (R^2 of 0.725) between Energy Efficiency KPI values and the Energy Consumption KPI. This relationship is shown in **Figure 3.6**.

Figure 3.6: Correlation between Two Energy Terms



As a final validation step, Kleinfelder interchanged the two terms within the prioritization model and compared the results. After correcting for manual adjustments in the prioritization process due to operational considerations, there were few differences between the two sets of results in terms of well priority. This supported the use of the hydraulically calculated energy values within the well prioritization model.

3.7.4 Reliability

During the development of this evaluation, the City emphasized the importance of identifying which wells are likely to perform well now and in the future. Even with the surface water treatment facility coming online, the City will still rely on groundwater to cover for peak demands and supply areas of the City that are not served by the surface water supplies. Operational wells will also be needed in the event that the treatment facilities go offline. Given the redundancy of water supply wells, is understandable to prioritize the renewal of reliable wells over those less reliable or at the end of their service life.

3.7.4.1 Water Quality Degradation KPI

To address the goal of identifying the performance of wells, Kleinfelder developed a measure to assess well reliability based on the following three metrics: remaining useful life (RUL), OPE, and condition. Reliability scores were derived based on each well's attributes, as described below. The worst (highest) of the three metrics was used as the reliability score for the well.

3.7.4.2 Remaining Useful Life (RUL)

Remaining useful life is a common indicator for estimating future replacement needs. The service life of an asset is defined as the time in which it is able to provide a sufficient level of service prior to failure. As described in the Preliminary Asset Management Plan, the age of a well's casing is typically used to estimate the service life of the well. Remaining useful life was calculated value based on the typical service life of an asset and its current age. The number of years since the well was drilled was used as the age of the well. This calculation is shown in Equation 2, below:

$$\frac{\text{Estimated Service Life} - \text{Age of Asset}}{\text{Estimated Service Life}} = \text{Remaining Useful Life (RUL)} \quad (2)$$

Estimated Service Life was assigned to each well, as follows, based on discussions with City during the Risk Workshop in October 2017:

- 100 years - when year installed was more recent than 2010 (since the City's newer well casings were designed to last longer than materials used historically)
- 80 years - for well types "Gravel Packed" or "Cased, Gravel-Packed" installed prior to 2010
- 50 years - for well types "Open-bottom" or "Open Bottom; Telescopic" installed prior to 2010
- 65 years - used as an average value for wells with missing data for well type and year installed was prior to 2010

The calculated decimal value for remaining useful life, was then converted into a score from 1-5 as shown in **Table 3.7**.

Table 3.7: RUL to Reliability Conversion Factors

Reliability Score	RUL %	Interpretation / Description
1	0.75-1.00	
2	0.15-0.75	Asset's estimated remaining useful life exceeds the duration of this 5-year plan
3	0.10-0.15	
4	0-0.10	Asset may exceed its remaining service life in the near-term (within 5 years)
5	<0	Asset has exceeded its remaining service life

3.7.4.3 *OPE*

Operating plant efficiency (OPE) or 'wire to water' efficiency expresses the relationship between the amount of energy consumed and the flow rate of a well at a given head. OPE values provided through the spreadsheet Official OPE Comparison Spreadsheet 2016. This spreadsheet stores the results of approximately 275 OPE tests conducted from 2010-2015. The results were then converted to a 1-5 scale for reliability, as documented in **Table 3.8**, based on the values described in the Preliminary Asset Management Plan.

Table 3.8: OPE to Reliability Conversion Factors

Reliability Score	OPE %	Interpretation / Description
1	>70%	Asset is operating cost efficiently
2	65% to 70%	
3	60% to 65%	Asset is operating with the system's average efficiency
4	55% to 60%	
5	<0.55%	Asset is not operating cost efficiently

3.7.4.4 Condition

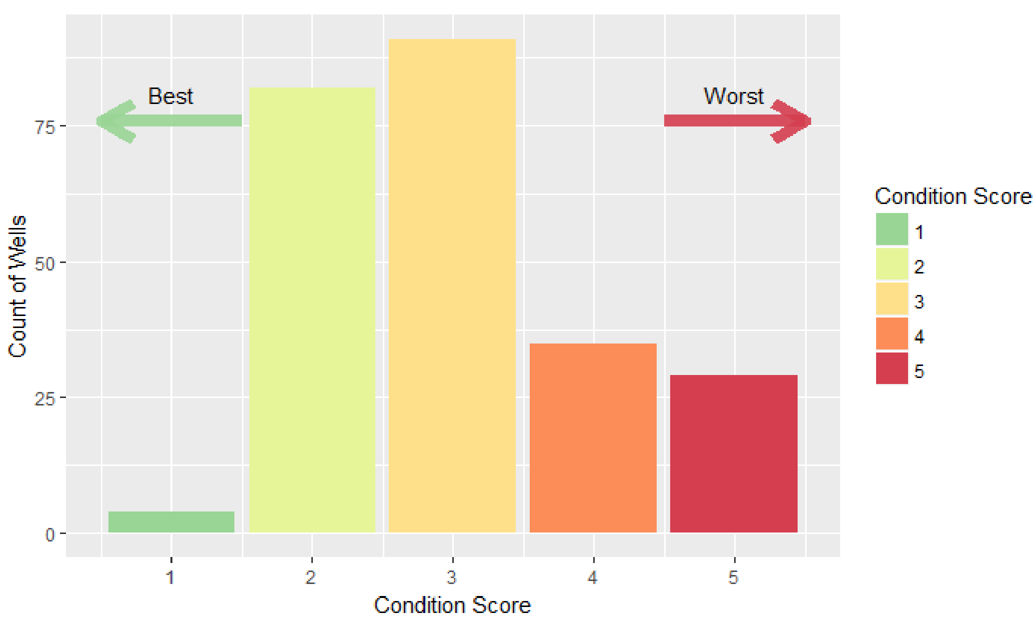
The City provided condition scores from March 2017, which were determined based on institutional knowledge of each well. The original data incorporated information on the overall reliability and maintenance needs of their well assets. Condition scores were provided on a 1-25 scale, where wells rated 1-14 were considered dependable and wells scored 15-25 were in need of repairs. For comparison purposes, these condition scores were converted to a 1-5 metric, as shown in **Table 3.9**.

Table 3.9: Condition to Reliability Conversion Factors

Reliability Score	Condition Score	Description
1	1-5	Excellent condition
2	6-10	Good condition
3	11-15	Fair condition
4	15-20	Poor condition
5	21-25	Asset failed

Figure 3.7 shows the distribution of condition scores after conversion to a 1-5 scale.

Figure 3.7: Distribution of Condition Scores



The distribution of condition scores was skewed left. Of the 241 wells assessed, 164 were rated with a condition score of 1-3 (excellent, fair, or good). 35 wells were identified as poor condition and 29 were in failed condition. Of the wells with poor or failed 2017 condition scores, some were repaired or rehabilitated (including well 284) or were scheduled for repairs or rehabilitation in FY19 (including wells 31A, 36, 42, 43, 54, and 222-1). While the overall prioritization does not incorporate updated condition information from March 2018, the City provided 2018 condition information to inform R&R needs for high priority wells. Since the prioritization process was intended to provide a system-level understanding of R&R needs, the City provided a description of condition related issues and condition scores at the sub-asset level (well, screen, pump, motor, controls, treatment, and structure/grounds) for high priority wells based on their knowledge of the system, rather than inspections for each well. The condition information and specific information on the wells operation were used to validate the results and are included in **Appendix D**.

3.8 RESULTS

The full refined results of the most valuable well analysis are presented as **Appendix D**. High priority wells (wells needed to meet ADD) are listed in **Table 3.10**:

Table 3.10: High priority wells (wells needed to meet ADD)

Well No.			
2B	85 (V)	157 (V)	225
3A	97	158	264
4B	98 (V)	159 (V)	279 (V)
6B (V)	*101A*	169	283
8A	125	170	307
9A	128	172	*319 (V)*
11A	132 (V)	174	320 (V)
18A	139	*179*	321 (V)
30B	141	184	323
33A	142 (V)	187 (V)	330 (V)
35A	145	189	339
46A	148-2	199	341 (V)
66	151 (V)	201 (blend w/36)	
70 (V)	153-1	213A	
82-2	153-2	223-3	

Wells in italic have been lost to TCP contamination

High priority wells (needed to meet MDD) are listed in **Table 3.11**:

Table 3.11: High priority wells (wells needed to meet MDD)

Well No.				
5A	60	89A (V)	171-2	287
13A	61A	90	176	304
16A	62A (V)	105	*177*	308 (V)
24B	64	117	186	313
26B	68	140	192	318
32B	69A	143 (V)	198	322 (V)
34A	73	144	206	327
36	74	148-1	222-1	337
39A	77	154	226-3	338
49A	79	160	251	345-2 (V)
53	83A	*165-1*	258	358
55-2	88-2	171-1	271	364

Wells in italic have been lost to TCP contamination

Low priority wells (wells not needed to meet ADD or MDD) are listed in **Table 3.12**:

Table 3.12: Low priority wells (wells not needed to meet ADD or MDD)

Well No.				
1B	56A	103	182-1	257
4A	57	104	183	266
14A	58A-1	118	188	267
15B	58A-2	131 (V)	193	272
19B	65	134	197	273
20	67	135A	*203A*	275
21A	71	136	205	280
22A	72	137	209	284
25	75	138	211	286 (V)
26A	76	146	*217*	289-2
27A	78	147	220-2	291
31A	80	150 (V)	223-1	292
37	81	155-1	224	295
38A	82-1	161	230A	297-1
42	86	163	232	297-2
43	87	164-1	234 (V)	300
44A	91	164-2	235	306
45	92	*165-2*	238	310
47A	94	*166*	242	331
48	95	175-2	244	345-1 (V)
50A	96	178	245	354
51	100-1	180-1	250	
52A	100-2	180-2	250A	
54	*102*	181	252	

Wells in italic have been lost to TCP contamination

Wells which were excluded from this evaluation (due to status, operational considerations, condition, performance, or other reasons) are listed in **Table 3.13**:

Table 3.13: Excluded Wells

Well No.		
10A	135B (V)	274
40A	152	277
63	155-2	326
84	162	329
130	185 (V)	347
133 (V)	212	

Additionally, based on this analysis, the wells in mixing area 5 cannot meet a maximum daily demand of 2,949 gpm (4.24 mgd) demand with existing groundwater supplies. The maximum rated flow from available wells is approximately 2,330 gpm (3.35 mgd) excluding wells with identified performance or condition related concerns.

3.9 RISK ANALYSIS

3.9.1 Risk Framework and Analysis

Kleinfelder worked with the City to develop a preliminary risk framework for the wells, water mains, and facility assets through a series of workshops in fall 2017. During these workshops, the City participated in discussions on the fundamentals of risk. Workshops focused on levels of service, well performance data, how risk is calculated, and how it can be used as a prioritization tool across asset types. Typically, when an asset management approach to R&R is implemented, risk is the predominate factor used to prioritize R&R provided that a common scale is used to calculate risk, since it provides an objective means to compare needs across systems. Risk is calculated as the product of likelihood of failure and consequence of failure. The development of proxies for assessing these two components of risk is described below.

During workshops in fall 2017, the City developed a preliminary risk score card for wells. The City determined an appropriate way to assess likelihood (through a proxy) for each failure mode and developed a scale for measuring the likelihood of failure for each proxy. The scale for each proxy was from 1-5, with a 5 indicating 100% likelihood of failure. For wells, failure modes were grouped into two categories:

- physical integrity, which included proxies for specific capacity, condition, and remaining useful life; and
- performance, which incorporated energy efficiency and water quality measures.

To develop a preliminary framework for consequences of failure, the City reviewed its Operational Plan and discussed levels of service goals. Through a discussion of proxies and common scores across assets, the City expressed that, in general, due to redundancy across the system, the maximum consequence of failure for wells is lower than for other asset types. Consequence of failure for wells were categorized as:

- customer impacts, as customers are negatively affected when a well cannot provide sufficient water or water of adequate quality
- economic impacts, since when certain wells fail it would result in a financial penalty (primarily as it relates to plume management litigation agreements), and
- operational impacts, since the failure of certain wells have an impact on the hydraulics of the system and that the failure of high priority wells results in the operation and maintenance of less effective wells to replace that demand.

Consequence of failure scores were primarily based on the concept of redundancy. Redundancy is the ability to replace an asset with another upon failure, while maintaining the same level of service. With the surface water treatment plants online, wells in several mixing areas will primarily serve as the supplemental or backup water supply source if the other system fails. Typically, water utilities do not have as much redundancy in their supply as the City of Fresno anticipates in the near-term with surface water available in much of the service area. The notable exception to this is in mixing area 6, which is primarily served by groundwater sources. To ensure the risk framework accurately captured the redundancy for wells, the City of Fresno rated wells in mixing area 6 with a higher consequence of failure score under this proxy, since a well failure in Mixing Area 6 would have a larger relative impact on operations and would reduce the redundancy of the system to a greater degree than other wells. The preliminary risk framework for wells is included below in **Table 3.14** and **Table 3.15.**

Table 3.14 Likelihood of Failure Risk Framework - Supply Wells

Drinking Water Infrastructure Renewal and Replacement Plan

City of Fresno

				Likelihood of Failure Category	Very Low	Low	Moderate	High	Extreme	
				Rating	1	2	3	4	5	
No.	**Consequence Categories**	**Description**	**Weight**	**Measure or Proxy**	**Likelihood Scale**					**Failure Modes**
1	**Change in Specific Capacity**	Specific capacity decreases over time	**15%**	Current specific capacity compared to original	> 90%	90-85%	84-80%	79-50%	< 40%	Physical Integrity
2	**Condition**	Condition of the well	**60%**	Most recent condition assessment record	Excellent condition	Good Condition	Average Condition	Poor Condition	Failed/ Inoperable	Physical Integrity
3	**Remaining Useful Life (RUL)**	Remaining useful life as % of estimated service life	**25%**	Year of installation, type of well, screen type are used to calculate RUL as defined in report	>=25%	10-25%	10-5 %	2-5%	<2%	Physical Integrity
		Total - Physical Integrity	**100%**	Final LoF for Physical Integrity = Weighted average of the proxies						
4	**Energy Efficiency**	Lower OPE indicates that a well is not energy efficient	**50%**	OPE %	>70%	70-65%	65-60%	60-55%	<50%	Performance
5	**Treatment Needs (Water Quality)**	The well does not produce water of adequate quality or the water quality is degrading over time	**25%**	Treatment requirements	No treatment needed				Not treatable. Consistently exceeds MCL	Performance
6	**Recent Sampling Exceedances (Water Quality)**	Near-term trends in water quality sampling results (in the past 3 years)	**15%**	Number of MCL exceedances over the total samples (as percentage)	0%	<4%	4%-5%	>5% - 15%	>15%	Performance
7	**Historic Sampling Exceedances (Water Quality)**	Historical trends in water quality sampling results (in the past 4-10 years)	**10%**	Number of MCL exceedances over the total samples (as percentage)	0%	<4%	4%-5%	>5% - 15%	>15%	Performance
		Total - Performance	**100%**	Final LoF for Performance = Weighted average of the proxies						
			Likelihood of Failure Score	**Maximum of the failure modes**						

Table 3.15 Consequence of Failure Risk Framework - Supply Wells

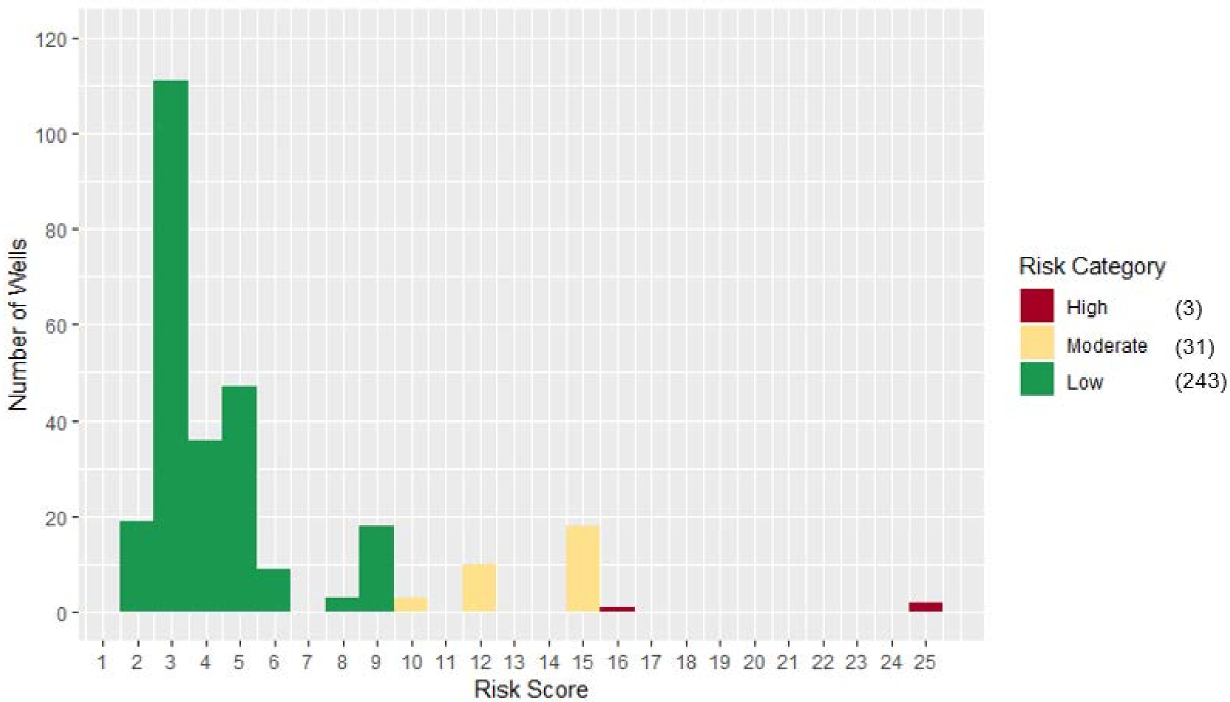
Drinking Water Infrastructure Renewal and Replacement Plan

City of Fresno

			Consequence of Failure	Very Low	Low	Moderate	High	Extreme
			Rating	1	2	3	4	5
No.	Consequence Categories	Description	Measure or Proxy	Consequence Scale				
1	Water Source Redundancy (Water Quantity)	There is redundancy in the system in terms of water sources. This factor is assigned based on the characteristics of the well's mixing area.	Redundancy of Sources within Mixing Area - criticality based on ability to meet demand with surface water plant offline	Complete Redundancy with Surface Water Treatment Plant	Partial source type redundancy	Low-no source type redundancy (primarily groundwater)	N/A	N/A
2	Well Redundancy (Water Quantity)	Some mixing areas have a higher redundancy of wells than others; in the cases where there is no next best well to replace a well than goes offline, the consequence of failure would be high. This is assigned to each well based on the redundancy of wells within a certain mixing area.	Redundancy of Wells within Mixing Area - criticality based on ability to meet demand with well offline	Demand met by well could be replaced by another well in mixing area when it is offline (by a factor of 2 or more)	Demand met by well could be replaced by another well in mixing area when it is offline (by a factor of less than 2)	Unable to meet maximum day demand with well offline	Unable to meet average day demand with well offline	N/A
3	Water Quality	Wells with high quality water (regulations, public health, odor, color) have a larger impact to customers when replaced with wells without water quality impairments or considerations	Not assessed; incorporated into prioritization					
		Total - Impacts to Customers		Calculated as the maximum of all categories				
4	TCE Litigation	Some wells are operated to manage plumes of TCE and must remain on to avoid financial penalties under litigation agreements	Assigned based on TCE = Yes field	Well not currently used to manage TCE plumes	N/A	N/A	N/A	Well used to manage TCE plumes
5	Replacement Cost	Repair costs depend on well characteristics, with replacement costs varying primarily by casing depth and diameter	Not assessed					
		Total - Economic Impacts		Calculated as the maximum of all categories				
6	System Hydraulic Impacts	Some wells are critical for filling tanks, which help to maintain pressure of the system. Without this well online, the system would have inadequate pressure to fight fires or meet levels of service	Operational Notes lists wells directly responsible for filling tanks	Not solely responsible for filling a storage tank			Well is critical for filling a storage tank	
7	Prioritization of Wells	Failure of a well results in need to use a well that is worse at meeting energy, water quality, and likelihood of failure metrics	Wells are prioritized using the optimization spreadsheet; the results of the optimization are categorizing wells as either high priority (needed to meet demand) or low priority (not needed to meet demand), with demand set to 2018 maximum daily demand	Well was removed from prioritization	Low Priority (well not needed to meet present day demand)	High priority (well needed to meet MDD)	High priority (well needed to meet ADD & MDD)	N/A
		Total Operational Impacts		Calculated as the maximum of all categories				
		Consequence of Failure Score		Maximum of all Consequence of Failure factors				

Risk scores were calculated for each well based on the above framework. Where data was not readily available, the component was excluded. Under this framework, risk scores could range from 1-25. Higher values, closer to 25, represented higher risk wells. **Figure 3.8** shows the distribution of risk scores across all well assets. The distribution was skewed right, with a risk score of 3 as the most frequent risk score.

Figure 3.8: Distribution of Risk Scores for Groundwater Wells



243 of the 277 (88%) had risk scores less than 10, indicating that most wells have low risk, based on this analysis. Of the remaining wells, 31 (11%) had a risk score less than or equal to 15 (moderate risk) and only 3 wells (1%) scored above 15 (high risk). These risk category thresholds are approximate to provide an illustration of the City's risk space for wells and could be adjusted based on the City's preferences.

Figure 3.9, **Figure 3.10**, and **Figure 3.11** show the spatial distribution of risk scores, likelihood of failure (LoF), and consequence of failure (CoF), respectively.

Figure 3.9: Spatial Distribution of Risk Scores for Wells

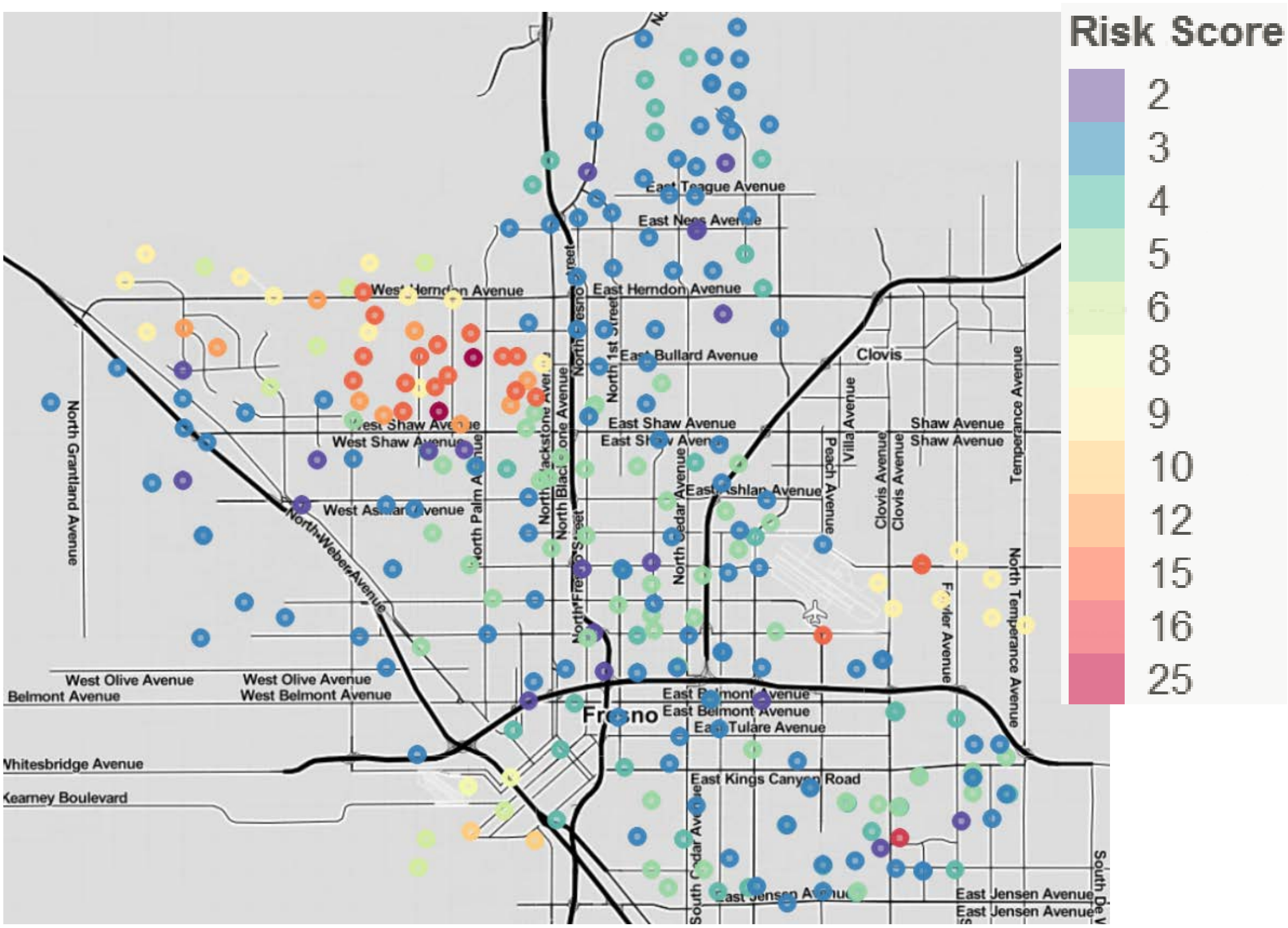


Figure 3.10: Spatial Distribution of LoF Scores for Wells

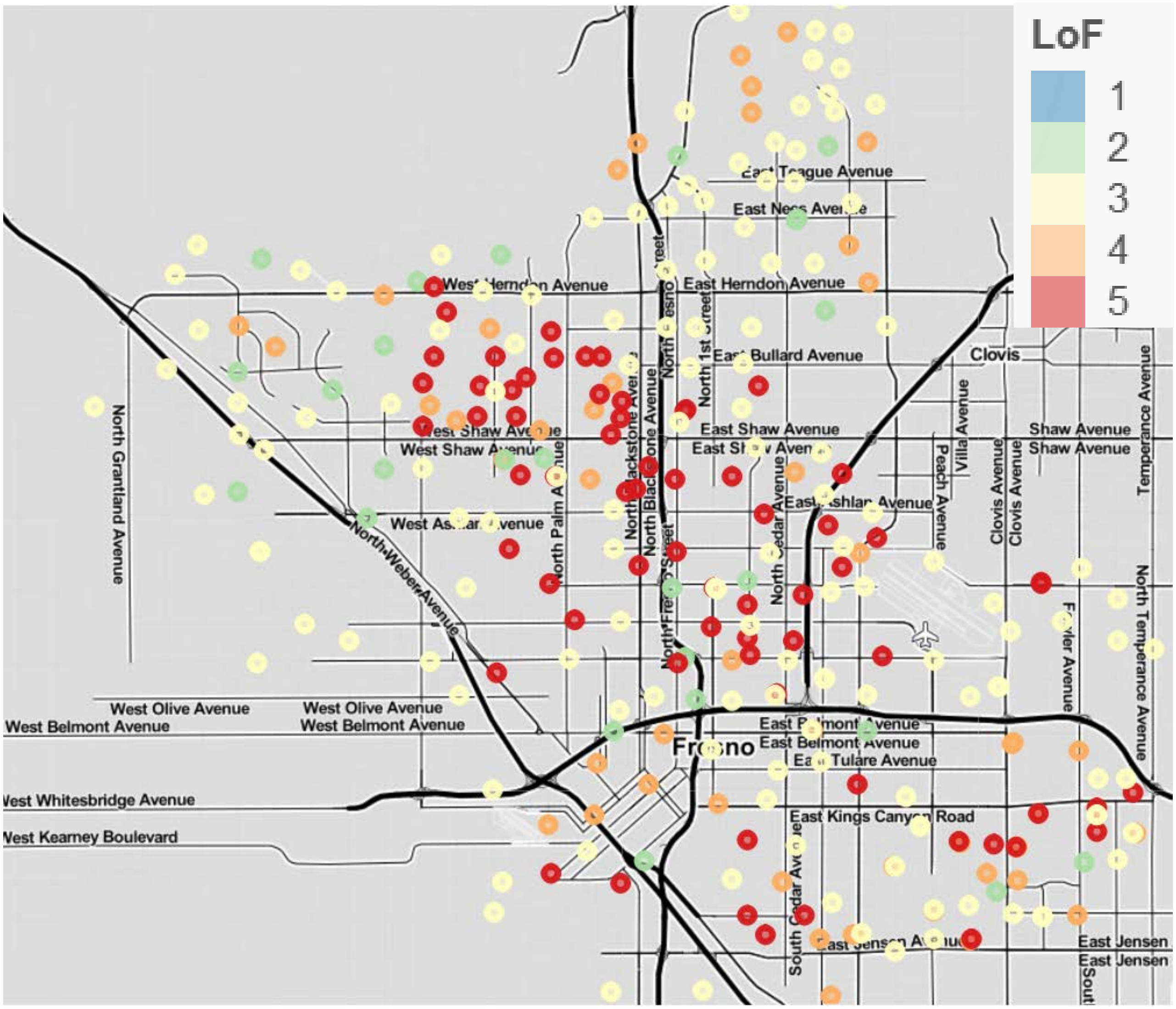
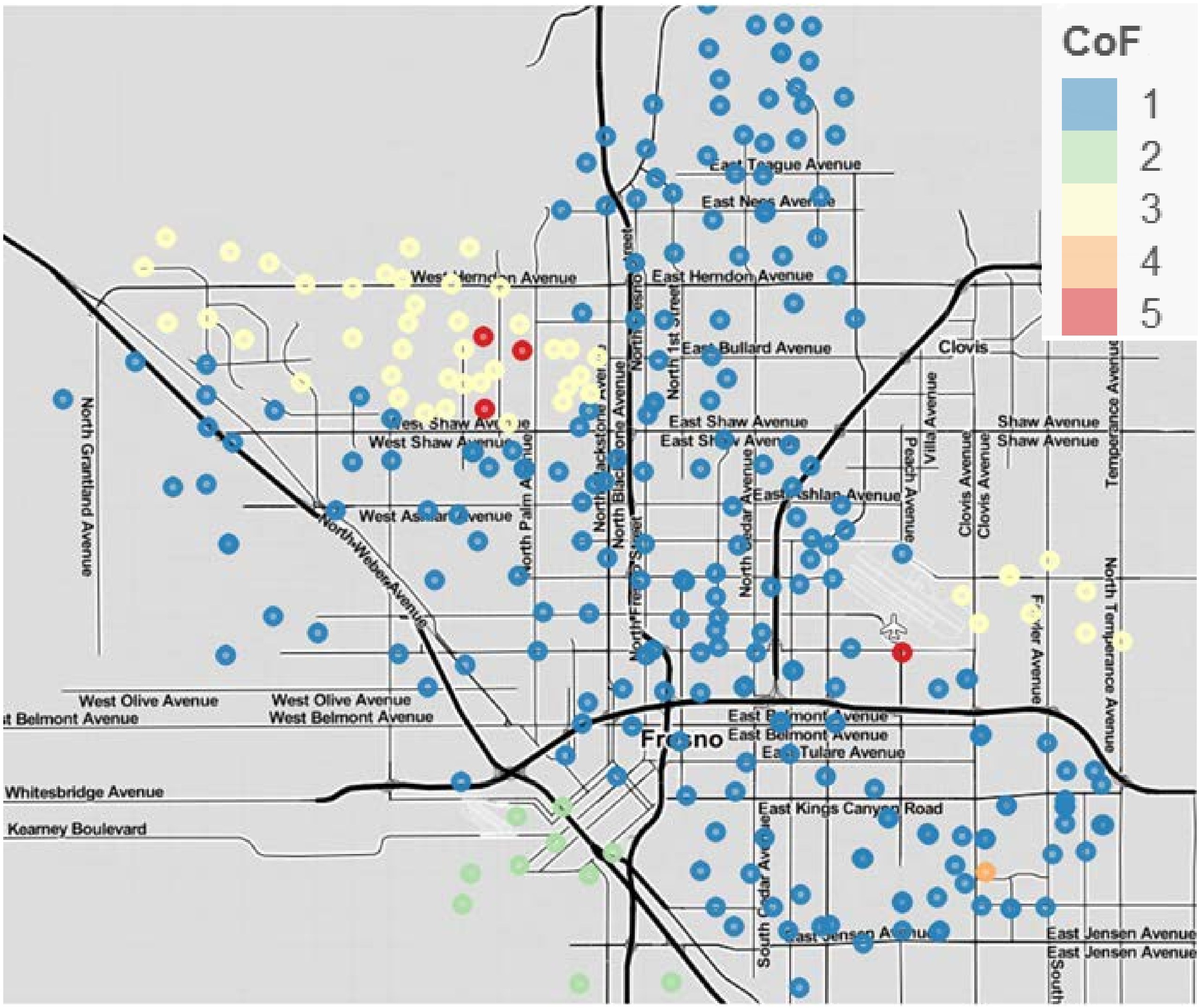


Figure 3.11: Spatial Distribution of CoF Scores for Wells



As shown in **Figure 3.9**, the distribution of risk is not random. Mixing Area 6 accounted for the greatest proportion of medium to moderate and high-risk wells relative to the rest of the system (26 of 32). This is driven by the high consequence of failure scores for water quantity. **Table 3.16** lists the mixing areas with moderate and high-risk wells, sorted by risk score. **Figure 3.12** shows the moderate and high-risk wells specifically in mixing area 6.

Table 3.16: Moderate and High-Risk Wells grouped by Mixing Area and Risk Score

Mixing Area	Risk Score	Number of Wells
6	25	2
2	16	1
4	15	1
5	15	2
6	15	15
6	12	9
1	10	2

Figure 3.12: Moderate and High-Risk Wells in Mixing Area 6

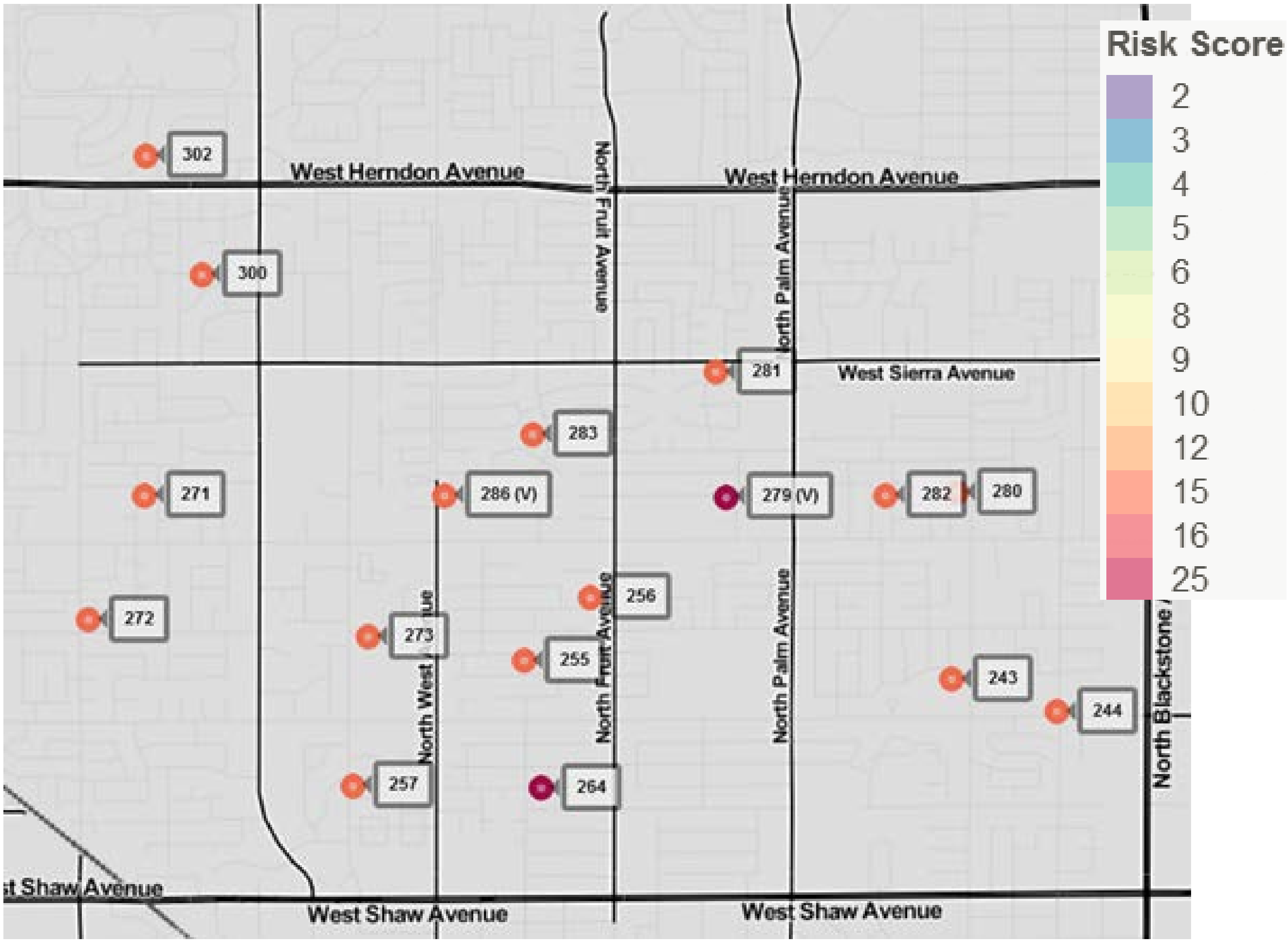
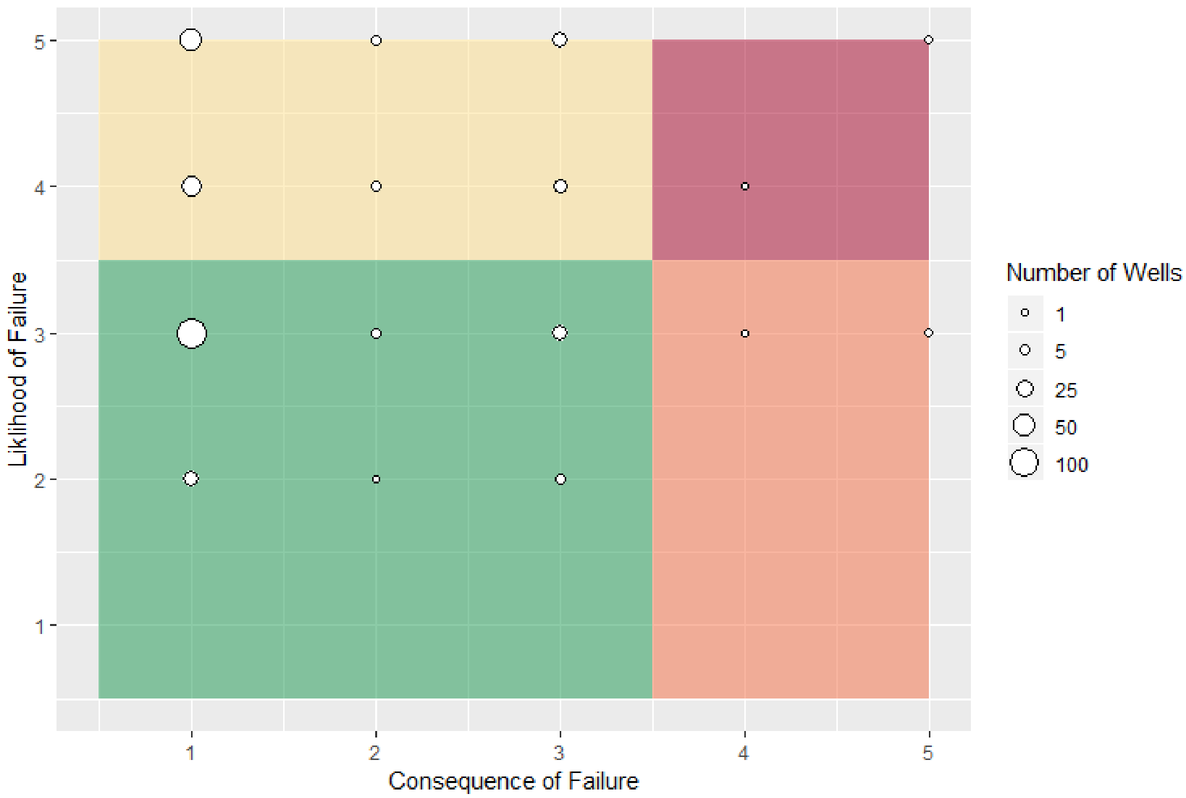


Figure 3.13 shows an additional visual representation of the City's preliminary risk space for wells. The quadrants are used to interpret risk with each quadrant color-coded based on the combination of consequence of failure and likelihood of failure scores. Rather than solely using the product of these two terms to prioritize wells, different maintenance strategies are recommended based on the quadrant, as described further below. The size of each circle is proportionate to the number of wells with the same combination of consequence of failure and likelihood of failure scores. The threshold for each quadrant was set for demonstrative purposes, based typical values, rather than by financial constraints or operational considerations and could be adjusted based on the City's preferences. The thresholds were slightly lower than what was shown in **Figure 3.8**.

Figure 3.13: Preliminary Risk Space for Groundwater Wells



Through this preliminary risk analysis, 160 of 277 (58%) of wells had a low risk score. These wells are shown in the area shaded green. Under a purely risk-based prioritization framework, these wells would be lowest priority for R&R. The percentage of low risk wells is lower than using solely the risk score, as this method of prioritization separates wells based on the combination of likelihood of failure and consequence of failure, rather than the product of the two terms.

The next highest priority wells, those in the yellow region, are wells that have a high likelihood of failure within the next 5-years, based on the risk framework. This quadrant had the second highest number of wells, with 112. These wells would not necessarily warrant immediate attention due to their low criticality, but should be considered for R&R.

Assets in the orange region are traditionally considered the second highest priority, as these are critical assets. Over time, assets in this quadrant will increase in likelihood of failure as condition deteriorates. Therefore, these assets require maintenance and monitoring. In this framework, Well 70 (V) and Well 283 were the two critical wells identified, due to their role in plume management.

Finally, 3 high risk assets, located in the area shaded red, were identified as the highest priority for R&R, since they are both critical and have a high likelihood of failure score. Using this risk framework, wells 184, 264, and 279 (V) were identified with high risk scores. Well 184 was rated as high risk primarily due to hydraulic considerations, since this well fills water storage tank T1.

Well 264 was rated as high risk with consideration to its role in plume management and its 2017 condition assessment. Well 279 (V) was ranked high for the same reason, and in addition, had an OPE score indicating a high likelihood of failure.

3.9.2 Risk Analysis Conclusions

As shown in the preceding section, the majority of the City of Fresno's wells had low risk scores. In large part, this is due to the water supply redundancy in the system. Of the wells with moderate and high-risk scores, nearly all were within Mixing Area 6. If R&R Recommendations were solely based on risk, these wells would be prioritized for R&R due to the lower amount of redundancy in this mixing area compared to others. In an exclusively risk-based prioritization strategy, this would result in recommendations to maintain wells in a limited geographic area, which was not suitable for this R&R plan.

Instead of using an exclusively risk-based prioritization for Well R&R, the results of the most valuable well analysis were used as the first method of prioritization. This ensures that the performance of wells and likelihood of failure is taken into consideration. Consequence of failure was used as the second component of the prioritization process. When integrated with the most valuable well analysis, this risk analysis approach resulted in a more balanced R&R strategy which incorporated the City's objectives and appropriately adapted elements of traditional asset management for this system. The prioritization is described further in the next section.

3.10 RECOMMENDED ACTIONS AND COSTS

This section presents a summary of the City's existing 2017 O&M Plan and how that plan was adapted into a 5-year R&R Plan for Wells based on the analyses presented above.

3.10.1 2017 Operation & Maintenance Plan for Wells

In March 2017, the City developed an operations and maintenance (O&M) budget and capital improvement plan for groundwater wells. The plan presented recommendations for a multi-year cycle of planned operation and maintenance (O&M) as well as major capital improvements (such as well replacement projects) scheduled from 2018-2025. Well maintenance activities included:

- video inspection and investigation,
- performance testing (OPE),
- proactive maintenance of pumps,
- proactive maintenance of motors,
- well development,
- screen rehabilitation and lining, and
- chemical cleaning.

Wells were prioritized based on their SCADA zone, as shown in **Table 3.17**.

Table 3.17: Prioritization of Wells based on SCADA Zone (2017 O&M Plan)

Priority Ranking	SCADA Zone
1	2
2	19
3	13
4	6
5	21
6	18
7	4
8	14
9	12
10	10
11	11
12	8
13	3
14	9
15	7
16	20
17	15
18	16
19	5
20	17
21	1

The March 2017 O&M Plan included a list of 26 wells which were recently rehabilitated (from 2009-2017). Since these wells were recently rehabilitated, they may not require capital improvements in the near-term. Recently rehabilitated wells are listed in **Table 3.18** Note that since the condition data provided by the City through the 5-year R&R project reflected the outcome of these rehabilitations and since the rehabilitation actions were not provided, in the recommendations listed in Section 3.10.2, recently rehabilitated wells were prioritized without distinction to their listed maintenance history.

Table 3.18: Maintenance History Data

Well	Rehabilitation Year
37	2009
10A	2010
21A	2010
211	2011
64	2012
92	2012
118	2012
148-1	2012
148-2	2012
145	2013
330	2014
102	2014
79	2014
197	2014
55-2	2014
101A	2014
86	2014
251	2014
304	2014
70	2014
76	2015
75	2015
62A	2017
80	2017
97	2017
150	2017
244	2017
284	2017

Wells in italic have been lost to TCP contamination

The resulting improvements plan prioritized O&M actions for a total of 46 wells with a recommended start year from 2018-2025. These dates were listed for planning and budgeted purposes rather than an exact timeline of planned activities.

Adapting the 2017 O&M Plan for the R&R Plan

Kleinfelder analyzed how resources were allocated in the 2017 O&M Plan compared to the results of the Most Valuable Well analysis. Of the 46 planned actions identified in the 2017 O&M Plan, only 6 were for high priority wells (those needed to meet ADD & MDD), 14 were on wells needed to meet maximum day demand, and 26 were assigned to low priority wells (those not needed to meet MDD) based this analysis. There were 31 wells with a recommendation to avoid capital expenditures, since they were slated to be abandoned or replaced due to inadequate site size or anticipated future performance issues. The remaining 163 wells were listed with a recommendation to perform one or more typical operation and maintenance activities on a recurring basis (i.e.: video or diagnostics, performance testing, pump repair, motor repair). Since these planning-level recommendations were generalized across a large majority of the wells in the system, Kleinfelder only incorporated the recommended actions for wells with associated dates to shift resources primarily to high priority wells.

A summary of the planned actions and cost are presented below in **Table 3.19**. In this table, wells were grouped based on the priority determined in the Most Valuable Well analysis to demonstrate how these funded recommendations were historically allocated compared to this R&R Plan.

Table 3.19: Planned O&M, FY18-FY26, by Priority Group (2017 Plan)

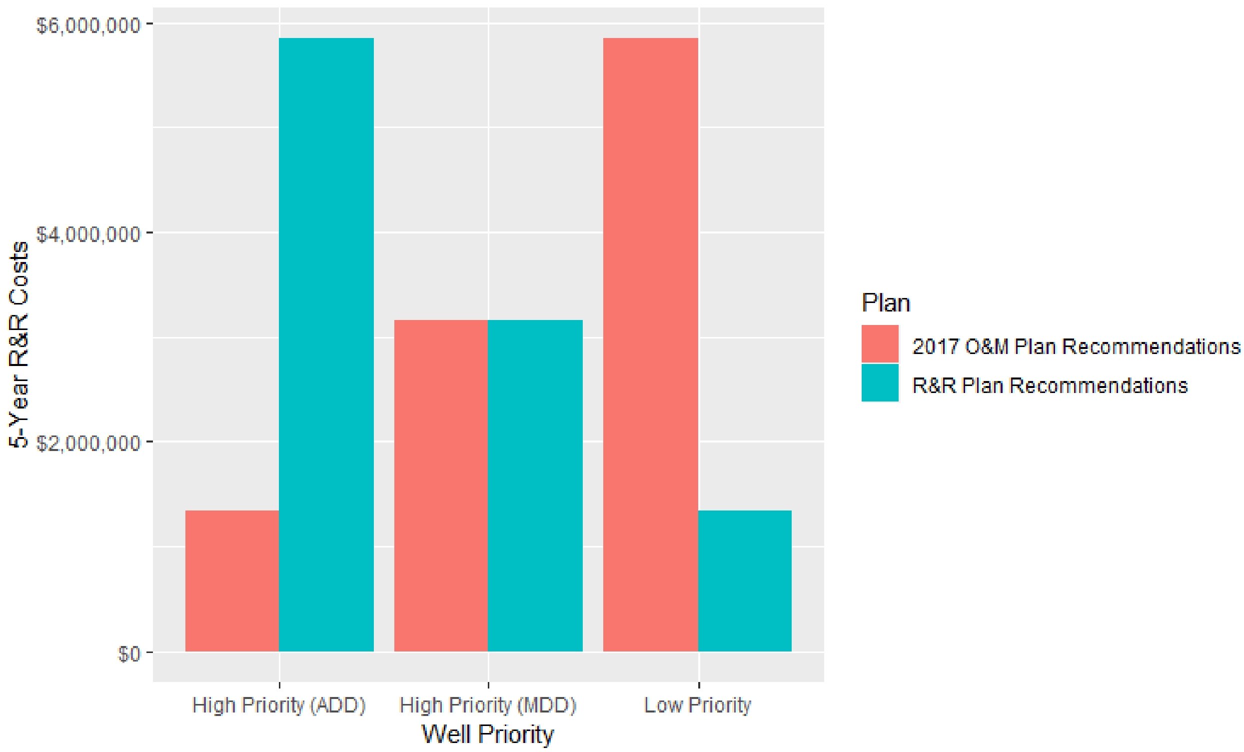
Group	Number of Wells with Planned O&M	Number of Wells in Group	Proportion of Wells with Planned O&M	Estimated O&M Costs[1]	Proportion of Planned O&M Budget
High Priority (ADD)	6	57	10%	$1,350,000	13.00%
High Priority (MDD)	14	60	23%	$3,150,000	30.50%
Low Priority	26	160	16%	$5,850,000	56.50%

Notes:

1. The 2017 O&M Plan listed average costs of $225,000 per well for recommended improvements (2017 USD).

In the recommendations presented in Section 3.10.2, the recommended R&R actions were reallocated to **prioritize the high priority wells first.** This prioritization policy inverts the recommended allocation of resources presented in the 2017 O&M Plan by focusing investments and maintaining the most valuable wells. This conceptual reallocation of resources is illustrated below in **Figure 3.14** and presented in further detail in the following section.

Figure 3.14: Estimated 5-Year R&R Costs by Priority



3.10.2 Recommended R&R Actions and Costs

The City currently practices a mix of proactive and reactive strategies to maintain their well assets. The 2017 O&M Plan describes recommendations for evaluating and implementing operation and maintenance on a scheduled basis. However, under the current strategies, when a problem is identified at a well, it is repaired using one of the O&M strategies described below regardless of its criticality to the system. This practice is considered reactive maintenance.

Many drinking water utilities are moving away from a reactive maintenance and Kleinfelder prepared the list of recommended R&R Actions based on the philosophy that proactive maintenance of high priority wells will be more cost-effective use of resources going forward. Given the City's goal to move towards proactive maintenance, Kleinfelder recommends implementing a single system for collecting and storing performance data on the well assets. Such a system, if implemented through a work management software, could generate an automated schedule of planned maintenance based on an asset's work history. Additionally, dynamic well performance metrics (for example: pumping level, drawdown, and change in specific capacity) which could indicate the need for maintenance, should be incorporated into this system.[6] The City

[6] *Evaluation and Restoration of Water Supply Wells*, Lucinda N. Noble, Mary Ann Borch, and Stuart A. Smith, 1993, Book, AWWA Research Foundation and American Water Works Association

currently maintains records of performance data, but it is not fully integrated into such a decision-support tool for O&M and Capital Improvements.

Kleinfelder prepared a set of recommendations based on a similar set of renewal and replacement strategies and costs provided in the existing 2017 O&M Plan, the condition of well assets, and performance data used in the above analyses. The prioritization of these actions was largely based on the results of the Most Valuable Well analyses (as discussed further below).

Kleinfelder prioritized wells for R&R first based on the results of the most valuable well assessment. The sort order prioritizes first R&R recommendations for wells which were required to meet "ADD & MDD" in the optimization model. Since this incorporates wells from across all mixing areas, criticality was used next to prioritize wells that are most important within this group. This prioritized wells with higher consequence of failure (i.e.: TCE Plume Management Wells). A well's risk score was used as the third sorting field. This process was repeated for wells designated as required to meet "MDD" and for wells not needed to meet demand based on the results of the optimization model. Wells which were excluded from analysis are listed at the bottom of the prioritized list of wells. The sorting is illustrated in Figure 3.15.

Figure 3.15: Example Well Prioritization Sorting Algorithm

Mixing Area 1		
Well ID	**Most Valuable Well Analysis**	**Consequence of Failure**
Well A	ADD & MDD	5
Well B	MDD	2
Well C		4

Mixing Area 2		
Well ID	**Most Valuable Well Analysis**	**Consequence of Failure**
Well D	ADD & MDD	4
Well E	MDD	1
Well F	Excluded	3

Prioritized List of Well R&R Recommendations was sorted first based on the **most valuable well** analysis, then by **consequence of failure,** then by **risk score** (not shown).

Prioritized List of Well R&R Recommendations			
Well ID	**R&R Recommendation**	**Est. Cost**	**Year**
Well A	Rehabilitation	$750K	2018
Well D	Maintain	$250K	2019
Well B	Maintain	$250K	2020
Well E	Investigate	$10K	2021
Well C	Do nothing	-	
Well F	Do nothing	-	

Recommended reactive maintenance actions were based on the condition scores provided by the City of Fresno. The City had records of condition scores (on a 1-25 scale) from March 2017, which designated whether a well required maintenance (above 14) or would likely not require maintenance in the near term (<14). Through the workshops in spring 2018, these conditions scores were updated and refined based on institutional knowledge. The workshops focused on wells which scored highly on the most valuable well analysis. Condition scores on a 1-5 scale were assigned to each well's screen, pump, motor, controls, treatment, and overall structure. Scores of 4 or 5 indicated that a well required work immediately, or within the next 5-years, respectively. Where limited condition information was available, the recommended R&R strategies were generalized, for cost estimating purposes, based on the overall characteristics of the system. Operators should use the best available well performance information from operational records, well and pump inspections, and additional diagnostic tests (as needed) to determine the appropriateness of implementing a specific R&R strategy. Recommendations were also made based on the understanding that, in most areas of the City, groundwater wells will supplement or provide backup to surface water supplies.

The R&R recommendations presented below prioritizes spending on proactive strategies to improve water supply wells that performed well in the most valuable well analysis and other wells which will be used over the next 5-year period. High priority wells without reactive maintenance needs (determined based on current condition scores) were recommended for planned maintenance activities on a recurring basis. Wells with reactive maintenance needs were recommended for R&R in this plan. As additional funding is available, wells listed as "low priority" in the most valuable well analysis should be maintained. Each recommended action also includes estimated costs and an assigned start year.

While the cost to implement the full set of 5-year R&R recommendations presented below exceed recent budgets for the City's groundwater wells, the City has the opportunity to save costs by implementing only a portion of the program. The R&R recommendations presented below are accompanied by one or more implementation strategies so that the City can implement a tiered program. The intent of this is to provide a sequence of recommended actions that is applicable, flexible, and adaptable if funding allocations or R&R implementation timelines change. This way, the City may choose to implement a full and complete R&R program, as described below, or tailor the program recommendations to meet the City's goals and resource constraints.

3.10.2.1 Diagnostics: Video Condition Inspection and Investigation

The City regularly performs video camera condition inspections using in-house equipment. The equipment can be used on wells to a depth of approximately 300 feet. For wells with a depth greater than 300 feet, the City contracts with a vendor at a rate of $600 per well to conduct a well condition assessment. In the well inventory, approximately 212 wells exceed this depth.

The 2017 O&M Plan and the PAMP recommended assessing approximately 10% of wells per year. Kleinfelder recommends that the City conduct condition inspections on high priority wells with known condition concerns first, followed next by other high priority wells. For budgeting purposes, the R&R recommendations assume that the City will conduct condition inspections on 112 wells over the next five years. Of these 112 wells, the costs presented in **Table 3.20** assume that about 50 (or 10 per year) will require service from a vendor.

Table 3.20: Recommendations for Well Condition Inspections

Activity	Implementation Strategy	Unit Cost	Estimated Costs per year
Conduct in-house Condition Inspections	10% of wells per year prioritized for wells with reactive maintenance needs and high priority wells	$0 (assumes in-house labor is budgeted separately)	$0
Conduct contracted Condition Inspections		$600 per well (assumes 10 per year will require service from vendor; only wells deeper than 300 feet)	$6,000

3.10.2.2 Diagnostics: Performance Testing (OPE)

This R&R Plan presents recommendations for OPE testing under three instances. The City's 2017 O&M Plan recommended that OPE tests for each pump prior to and after maintenance or replacement of a pump or motor. In addition to the recommendations from the 2017 O&M Plan, Kleinfelder recommends that OPE tests be conducted for each of the 92 active wells without data on a recent OPE test.[7] Kleinfelder also recommends the City conducts OPE tests for wells with scores indicating suboptimal operating efficiently. Thirdly, this plan assumes that the City will implement a proactive or planned 10-yer cycle of testing. Recommendations for OPE Testing are summarized in **Table 3.21.**

The City's 2017 O&M Plan estimated costs at approximately $200 per OPE test. This value accounts for rebates available from PG&E's Advanced Pumping Efficiency Program. For cost purposes, this R&R plan assumed that wells with an OPE score less than the current system average of 0.65 will be tested prior to and after any maintenance activities.

[7] *Additional data on OPE would allow the City to assess performance changes over time and refine the most valuable well analysis. Kleinfelder recommends that the most valuable well analysis be updated after additional OPE tests are completed.*

Table 3.21: Recommendations for OPE Testing

Activity	Implementation Strategy	Unit Cost	Estimated Cost per year
Conduct maintenance related OPE tests	Test before and after significant maintenance (pump or motor repair/replacement). Assumes 30 wells per year and two tests per well	$200 per test	$12,000
Conduct initial OPE tests	Assumes 92 wells over next 5 years (wells without available data for OPE scores)		$3,680
Recurring cycle of testing	10% per year (begin once initial OPE tests are completed)		$4,800

3.10.2.3 Restoration: Pump Maintenance and Replacement

Based on condition scores, six wells had a known pump condition issue: 8A, 22A, 89A (V), 304, 321 (V), and 330 (V). These pumps may require a full replacement at an estimated cost of approximately $55,000 per pump. Five of the six failed pumps are high priority wells and therefore there may be cost savings if the pump at the lower priority well (22A) is not replaced in this 5-year period.

Well pumps require routine maintenance to operate efficiently. Kleinfelder recommends that the first set of R&R actions addresses high priority wells with known pump condition issues. Next, a proactive maintenance strategy should be implemented based on the priority of the well and the performance of the pump (based on the results of OPE tests). High priority wells with reduced efficiency or production rates should be repaired through this strategy. Wells with an OPE score less than the system average of 0.65 were identified as having reduced efficiency or production rates, though the City may be able to use alternative data sources, such as pump performance curves, to determine which wells should be maintained or replaced through this strategy. The City's 2017 O&M Plan recommended a 10-year planned maintenance schedule (10% of pumps per year) at a cost of $9,000 per pump. Recommendations for pumps are summarized in **Table 3.22.**

Table 3.22: Recommendations for Pumps

Activity	Implementation Strategy	Unit Cost	Estimated Cost per year
Inspect and repair pumps	10% per year based on priority and performance	$9,000	$216,000
Replace backlog of failed pumps	Assumes replacing 6 pumps over 5 years (as listed above)	$55,000	$330,000
Replace additional failed pumps	As needed. Assumes 3 per year	$55,000	$165,000

3.10.2.4 Restoration: Motor Maintenance and Replacement

The City is presently aware of one well, 321 (V), that with motor repair or replacement needs. This motor may require a full replacement at an estimated cost of approximately $15,000.

The City contracts with a vendor to conduct motor repairs. The City provided 53 motor repair reports dating from 2013-2016. Kleinfelder associated these records with the well and wells with a record of repairs or replacements since 2013 were not recommended for R&R in this Plan.

This plan assumes that 5% of wells per year will be inspected and repaired at a unit cost of $5,000 per motor and that one motor per year will be replaced at a unit cost of $15,000 per motor. Kleinfelder recommends that high priority wells with known motor condition issues be addressed first. Next, a proactive maintenance strategy be implemented based on the priority and performance of the well and its motor. Recommendations for motors are summarized in **Table 3.23.**

Table 3.23: Recommendations for Motors

Activity	Implementation Strategy	Unit Cost	Estimated Cost per year
Inspect and repair motors	5% per year	$5,000	$60,000
Replace backlog of failed motors	Assumes replacing 1 failed pump (at Well 321 (V))	$15,000	$15,000
Replace failed motors	Assumes 1 per year	$15,000	$15,000

3.10.2.5 *Restoration: Well Development, Rehabilitation, and Chemical Treatment*

Well restoration activities were divided into two types: activities to restore structural integrity of the well screen and casing (lining) and activities to improve water quality (development, flushing, and chemical treatment). The remaining useful life of a well is associated with the casing or screen and was therefore used to make recommendations on R&R activities. Primarily, the recommendations listed below are based on known issues related to pumping sand and gravel, which indicate that the casing or screen is in poor condition.

Well Casing Lining and Well Rehabilitation

Over time, the condition of wells deteriorates because of natural groundwater conditions (such as sanding and corrosion) as well as maintenance activities (such as redevelopment).[8] The City's current program includes funding for rehabilitation of water wells, according to the FY19 Budget, which is required when production output is diminished due to mineral buildup on the well casing and in the gravel pack. To improve the structural integrity of their wells, the City planned to line the following 7 open-bottom wells in FY2019 (under WC00017):

- Well 31A
- Well 36
- Well 42
- Well 43
- Well 48
- Well 54
- Well 222-1

Additional wells were identified with existing problems related to the screen or casing. Predominantly, the issue was related to wells producing sand or gravel. This indicates that a replacement of these components may be needed at the following locations:

- Well 9A (open bottom)
- Well 341 (V)
- Well 16A (open bottom)
- Well 36 (open bottom)
- Well 206
- Well 64
- Well 304

The City's 2017 O&M Plan estimated the cost of materials and labor for lining one open bottom well at $79,300. However, this cost was determined based on the depth of the well requiring

[8] *Casing Liners for Large-Diameter Water Wells: An Approach to Repair Damaged Steel Casing or Screen, Roscoe Moss Company*

lining. The O&M Plan included a fixed cost for gravel at $3,800 per well and two estimates for cost of lining per foot based on the type of casing ($195/ft and $375/ft). For simplicity, cost estimates for lining individual open bottom wells were calculated assuming a base cost of $3,800 plus a cost of $250/ft for the entire casing depth of the well. For non-open bottom wells the City's 2017 O&M Plan estimated the cost of well rehabilitation at $202,500 per well.

A total of 38 wells, including some of the wells listed above, were identified as having little to no remaining useful life. Kleinfelder recommends conducting well investigations of these wells, starting with the highest priority wells, to determine what R&R activities may be suitable. The City's 2017 O&M Plan recommended a 10-year planned well rehabilitation schedule (10% of wells per year) for non-open bottom wells. For open bottom wells, the City's 2017 O&M Plan recommended a 20-year planned well rehabilitation schedule (5% of wells per year). Recommendations for casing lining and well rehabilitation are summarized in **Table 3.24.** After repairs or lining, these wells should be maintained through chemical cleaning on a periodic basis, as described below.

Overall, about half of the $3.2 million in estimated well casing lining and rehabilitation costs were for high priority wells. There may be cost savings of about $1.6 million over a five-year period by tailoring the R&R implementation for only high priority wells.

Table 3.24: Recommendations for Casing Lining and Well Rehabilitation

Activity	Implementation Strategy	Unit Cost	Estimated Cost per year
Inspect and repair or replace screen or casing (open bottom wells)	5% per year	$3800 fixed cost plus additional $250 per foot of casing depth	$951,600
Inspect and repair or replace screen or casing (non-open bottom wells)	10% per year	$202,500	$2,430,000

Well Development

Well development is one method for improving well performance by removing fines including sand and gravel from the vicinity of the well screen. Common methods of well development include surging, over-pumping, jetting and bailing.

The City identified three additional wells, 2B, 89A (V), and 341 (V), with well condition scores which indicate the need for further diagnostics and potentially implementation of reactive maintenance, such as redevelopment or casing lining.

The City indicated that Well 304, a cased gravel-packed well which was recently rehabilitated, pumps gravel at high flow rates. Kleinfelder recommends that the City investigates the potential benefits of well development or alternative screening at this site. Three additional wells were identified as candidates for redevelopment, based on operational notes on sand production: 9A, 64, and 206.

Kleinfelder recommends that well development be conducted on an as needed basis. Wells that could potentially benefit from well development should be identified based on condition and operational notes regarding sand and gravel production. A planned recurring maintenance cycle is not provided for this activity. The cost per year of well development was estimated using an assumption that 5 wells will be developed each year at a unit cost of $8,000 for vendor labor. Recommendations for well development are summarized in **Table 3.25**.

Table 3.25: Recommendations for Well Development

Activity	Implementation Strategy	Unit Cost	Estimated Cost per year
Well Development	As needed, assuming 5 wells per year	$8,000	$96,000

Flushing and Chemical Treatment

Flushing and chemical treatment of wells is essential maintenance to ensure proper well performance and maintain well water quality. Flushing and chemical treatment can be achieved by swabbing the well with chemical and then using an airlift pump as a flushing method to clean the well. The City identified one well, 6B (V), which needs flushing or chemical treatment. In addition, Kleinfelder recommends flushing and chemical treatment wells following major well repairs or rehabilitations including replacement of the screen or casing (lining). Wells without any recent repairs or rehabilitation should still be cleaned on a periodic basis. The City's 2017 O&M Plan recommended a 10-year planned flushing and chemical cleaning schedule (10% of pumps per year) at an estimated cost of $50,000 per well. Recommendations for flushing and chemical treatment are summarized in **Table 3.26.**

Overall, about one-third of the $1.9 million in estimated treatment costs were for high priority wells. There may be cost savings of about $1.2 million over a five-year period by tailoring the R&R implementation for only high priority wells.

Table 3.26: Recommendations for Flushing and Chemical Treatment

Activity	Implementation Strategy	Unit Cost	Estimated Cost per year
Flushing and Chemical Treatment	10% of wells per year	$50,000	$1,200,000

3.10.2.6 Water Quality Treatment

The California Environmental Protection Agency has a Public Health Goal for 1,2,3,-Trichloropropane (TCP), which impacts multiple City wells. Based on the requirements outlined in a letter from the Division of Drinking Water (DDW) dated December 29, 2017, wells with an average concentration above the maximum contaminant level (MCL) of 5 parts per trillion will not be able to operate going forward without treatment.[9] All affected wells will be offline by August 2018. A total of 40 wells have water quality concerns related to TCP which may benefit from on-site treatment. Due to the significant cost of wellhead treatment, it is not feasible to install and operate GAC treatment at all 40 wells with water quality concerns related to TCP.

Granular Activated Carbon (GAC) treatment was identified as the Best Available Technology (BAT) for the removal of 1,2,3 - TCP. This method of treatment is currently used at several of the City's wells. According to the City of Fresno's Metropolitan Water Resources Management Plan, the estimated cost of installing and operating GAC treatment for one well for 15 years is $1.7 - $2.6 million. This treatment technology has an average annual cost of approximately $143,000 for 15 years plus the cost of financing. For this evaluation, a unit cost of $2.4 million was used per GAC treatment installation. Averaged over 15 years, this a value of $160,000 per year per unit was used.

Overall, installing GAC treatment at each of the 40 wells with identified water quality concerns would be cost prohibitive over a 5-year period. About 40% of the wells with identified treatment needs are high priority wells. To the extent that it is cost effective and water demands warrant this type of capital improvement, Kleinfelder recommends considering the installation and operation of GAC treatment at one or more of the following high priority wells with treatment needs: 70 (V), 184, 9A, 30B, 179, 319 (V), 321 (V), 213A, 85 (V). Recommendations for wellhead water quality treatment are summarized in **Table 3.27.**

[9] *https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/123tcp/pws_123tcp_122917.pdf*

Table 3.27: Recommendations for Wellhead Water Quality Treatment

Activity	Implementation Strategy	Cost per year
GAC treatment	As needed for wells with water quality concerns related to TCP	Average of $160,000 per well per year over a 15-year period

3.10.2.7 Site Security and Improvements

The City of Fresno passed the Unhealthy and Hazardous Camping Act in August 8, 2017, which makes homeless camping on public or private property illegal.[10] The City periodically receives complaints regarding homeless encampments near pump station facilities and has operational and maintenance costs associated with ensuring the security of their well sites. To mitigate future maintenance costs, the City identified 15 well sites that would benefit from increased site security. These wells are (from highest to lowest priority):

- Well 70 (V)
- Well 145
- Well 3A
- Well 172
- Well 142 (V)
- Well 157 (V)
- Well 18A
- Well 320 (V)
- Well 46A
- Well 4B
- Well 271
- Well 77
- Well 165-1
- Well 74
- Well 56A

Estimated costs for site hardening will vary by size and type of upgrades. Costs were estimated at approximately $35,000 per facility (replace masonry wall with taller metal fence) but this should be refined further based on the site size and security needs. Additionally, Well 320 (V) requires

[10] https://fresno.legistar.com/LegislationDetail.aspx?ID=3109583&GUID=CBA6996D-A186-4B34-819F-39F8CB83DF4B

additional work to improve the structural integrity of the pump station. No structure exists at Well 271, however, no cost estimate is provided for these R&R actions.

14 of the 15 wells with security upgrade needs are for high priority wells. However, since the City has expressed an interest in completing upgrades for each of the 15 sites regardless of their priority, no potential cost savings was estimated for this R&R activity. Recommendations for site security are summarized in **Table 3.28**.

Table 3.28: Recommendations for Site Security

Activity	Implementation Strategy	Estimated Cost per year
Install site security	Assumes 3 sites per year to complete all 15 sites over 5 years.	$105,000
Improve pump station structure	As needed	No estimate provided, varies by well
Build pump station structure	As needed	No estimate provided, varies by well

3.10.2.8 Well Replacement or Abandonment

Planned Replacements

The City provided a list of planned improvements for FY2019, which included a replacement of Well 243. The City estimated replacement costs at approximately $1,500,000 per well.

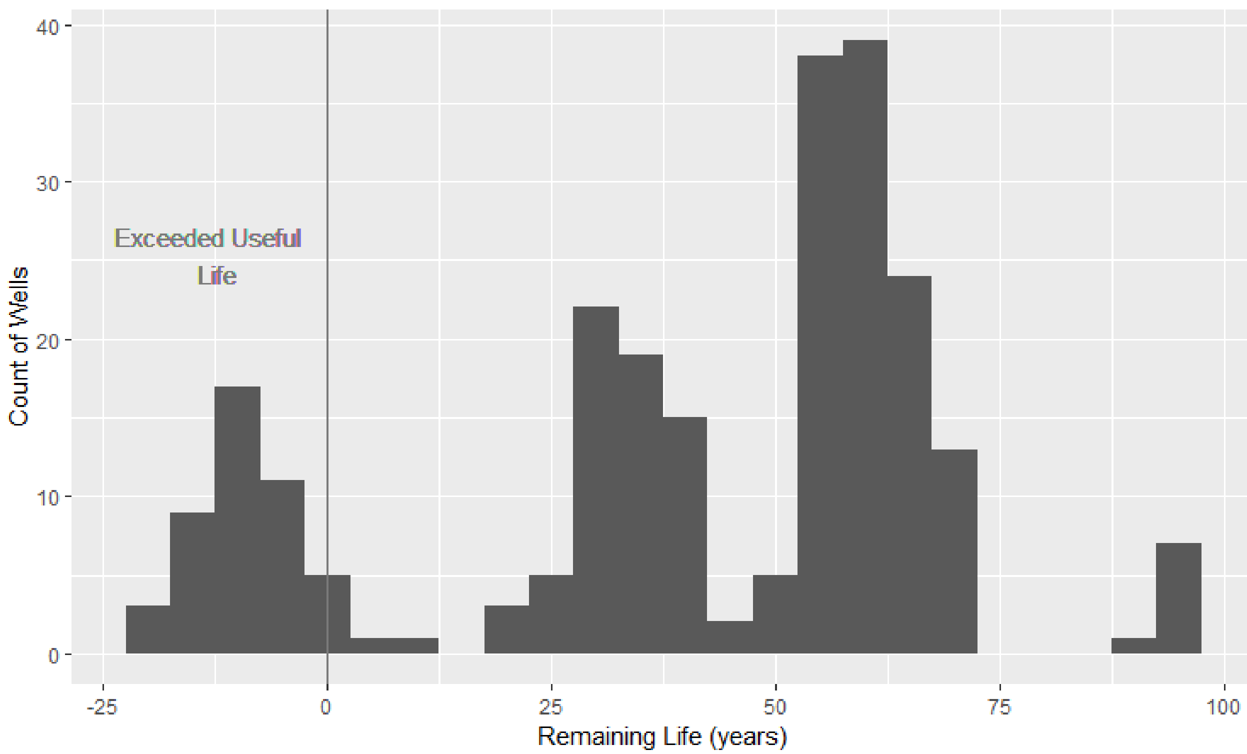
Supply Enhancement

Based on the results of the optimization model, Mixing Area 5 cannot meet a maximum daily demand of 2,949 gpm (4.24 MGD) demand with existing groundwater supplies. The City noted that several wells in this mixing area have performance or condition related issues and therefore should not be considered. The maximum rated flow from the available wells is approximately 2,330 gpm (3.35 MGD). The City may consider supplementing groundwater supplies within this mixing area by replacing one or more high output well in this area. With consideration of this demand deficiency and well performance issues, the following wells should be considered for replacement: 55-1 (V), 326, 329, 342, and 347.

3.10.2.9 Performance and Metric-based Recommendations

Wells which are currently not producing water or are impacted by silt/sand infiltration, water quality degradation, well corrosion, or structural failure, which cannot be addressed through the above maintenance strategies, should be considered for replacement or abandonment. Beyond current performance, the City should begin reviewing the list of wells which have high likelihood of failure based on its remaining useful life. The City has 41 active wells within 5 years of exceeding or already exceeding their remaining useful life as displayed in **Figure 3.16**. As R&R is conducted on these wells, to ensure remaining useful life is accurate, this metric should be updated.

Figure 3.16: Estimated Remaining Useful Life of Wells



In the 2017 O&M Plan, 10 wells were listed as not suitable for rehabilitation due to their extremely poor condition. These wells were excluded from the prioritization process along with the wells excluded from the most valuable well analysis due to operational considerations. Additional wells, 16A and 60, 100-1, 100-2,105, were added to this list of excluded wells excluded from R&R recommendations with reasoning as listed in **Table 3.29**.

Table 3.29: Wells Excluded from R&R Recommendations

Well	Justification
16A	Cannot be rehabilitated due to critical condition
26A	Cannot be rehabilitated due to critical condition
60	Site of insufficient size to rehabilitate
100-1 100-2	Site cannot be rehabilitated due to nearby canal maintenance
105	Site may be lost due to freeway expansion
235	Cannot be rehabilitated due to critical condition
238	Cannot be rehabilitated due to critical condition
245	Cannot be rehabilitated due to critical condition
242	Cannot be rehabilitated due to critical condition
217	Cannot be rehabilitated due to critical condition, TCP
274	Cannot be rehabilitated due to critical condition
225	Cannot be rehabilitated due to critical condition
295	Cannot be rehabilitated due to critical condition
297-2	Cannot be rehabilitated due to critical condition

3.10.3 5-Year and Long-Term Recommended R&R Actions and Costs

3.10.3.1 Historical Program Budget

In FY2019, a total budget of $1.4 million was requested for the City's water well rehabilitation program.[11] This budget was used as a guidance, rather than a formal constraint, for setting R&R recommendations. Resource availability should be considered when the R&R program is implemented, and the City should also consider potential cost saving opportunities for well R&R due to its reduced dependency on wells with the new surface water sources now available.

[11] https://www.fresno.gov/finance/wp-content/uploads/sites/11/2018/05/FY2019ProposedBudgetWEBPAGE.pdf

3.10.3.2 R&R Assessment

Assessment of the condition and performance of all wells within the City's system indicates a significant backlog of necessary renewal and replacement activities. Almost all active wells were recommended for at least one R&R action with most wells recommended for multiple R&R actions. While competition of these R&R activities requires an initial cost investment, addressing outstanding issues and establishing a proactive maintenance strategy based on well priority will prevent excessive costs in the future. Proactive maintenance will help to delay and limit costly R&R actions including full replacements of pumps and motors. A focus should be placed on addressing renewal and replacement activities for high priority wells first to maintain a sustainable and productive system of groundwater supply wells.

3.10.3.3 5-year R&R Costs

Total annual costs for R&R recommendations are presented in **Table 3.30** and the complete prioritized list of R&R recommendations is presented in **Appendix D**. Costs presented in the left-hand column represent renewal and replacement of all high priority wells. Whereas, values shown in the right-hand column provide a cost estimate for renewal and replacement of all active wells regardless of their priority.

Table 3.30: Estimated Annual Costs based on Two R&R Implementation Strategies

Year	Estimated Annual Cost of Renewal and Replacement Activities for High Priority Wells (Minimum)	Estimated Annual Cost of all Recommended Renewal and Replacement Activities
1	$3,447,750	$3,447,750
2	$2,881,200	$2,881,200
3	$2,084,100	$2,962,150
4	$1,500,000	$3,041,800
5	$1,500,000	$2,777,300
5 Year Sub-Total	$11,413,050	$15,110,200
Total (With 30% Contingency)	**$14,836,965**	**$19,643,260**
5- year Annual Average	**$2,967,393**	**$3,928,652**

Notes:

1. These cost estimates exclude costs to install and operate at GAC at new well sites.
2. Cost estimates assume one well replacement per year at $1,500,000 per well.

The 5-year costs of implementing the R&R recommendations described in the above sections was estimated as $19,643,260 with a 30% contingency for construction costs, not including costs for water quality treatment at wells. Since the City has made a significant investment in a new surface water source and surface water treatment, the City may choose to prioritize other investments over R&R for wells. Should this strategy be implemented, the 5-year R&R costs for high priority wells was estimated at $14,836,965 (30% contingency), for an average annual cost of about $3.0 million. Note that these costs could be spread more evenly over a 5-year period than presented in **Table 3.30**. In **Appendix F**, R&R recommendations are presented in descending order of priority and therefore the schedule is ultimately constrained by budget and the implementation is adaptable to the selected R&R implementation strategy.

Cost Assumptions: Note that the cost estimates presented exclude the cost of installing and operating new GAC treatment at identified wells and do not consider inflation or anticipated price changes for R&R activities. Estimates assume one well replacement per year at $1,500,000 per well.

3.10.3.4 *Long Term Outlook*

The City's system contains 240 active groundwater wells varying significantly in their age, well type and remaining useful service life. The estimated service life of each well varies depending on the well type and the date of installation. Over the next 50 years, approximately 32 active wells will reach or extend past their estimated service life, in addition to the 43 active wells that are already beyond their estimated service life (**Figure 3.16**). A proactive replacement strategy would require replacement of approximately 1.5 wells per year over the next 50 years to offset this degradation in the system due to aging wells.

Over the next 50-100 years, approximately 91 active wells will reach or extend past their estimated service life. This would require an average replacement rate of 1.8 wells per year to offset the degradation in the system by the end of the 100 years. However, most of these wells have an estimated remaining service life of 50-60 years. A proactive replacement strategy should be prepared to increase the rate of well replacement prior to and during this 100-year period to maintain the current system of active wells

CHAPTER 4 – WELLHEAD TREATMENT FACILITIES

This chapter documents the wellhead treatment facility asset inventory and explains the risk assessment methodology followed to identify and prioritize the wellhead treatment renewal and replacement recommendations.

4.1 SPECIFIC GOALS OF THE TREATMENT FACILITY EVALUATION

The City of Fresno has total of 230 active wells providing water supply to the City's residential and commercial users. Water quality of most of the wells meets state and federal water quality standards requiring only disinfection. However, there are a number of wells (total of 82) with water quality constituents exceeding maximum contaminant levels (MCL) and that may require treatment before delivered to the City's water distribution system. The major water constituents requiring treatment include Dibromochloropropane (DBCP), Trichloroethylene (TCE), 1,2,3, Trichloropropane (TCP), nitrate, carbon dioxide, and air. Wellhead treatment facilities to address these water quality issues are installed at 48 wells.

The City wells were constructed and in operation dating from 1948 with first wellhead treatment facilities constructed as early as in 1991 (GAC for Well 277 followed by well 85 and 89A). With regular maintenance, most of the wells including wellhead treatment facilities are operational providing the City with a reliable source of good quality water supply. However, the City wants to assess physical conditions and to establish baseline requirements for scheduled and planned repairs and replacements (R&R) of the currently installed wellhead treatment facilities. More specifically, the principal goals of this R&R are to:

- Assess condition of the existing wellhead treatment facilities
- Identify process equipment deficiencies and recommend R&R improvements
- Assess costs of the improvements
- Prioritize R&R improvements

This R&R report includes condition assessment of the currently installed treatment equipment with associated instrumentation. Although power requirements for the installed equipment are identified in this report, assessment of the electrical and power supply equipment was not included in the scope of this R&R engineering effort. Similarly, hydraulic capacity and fitness of the installed equipment to control undesirable water quality constituents were not assessed.

4.2 FACILITIES INVENTORY

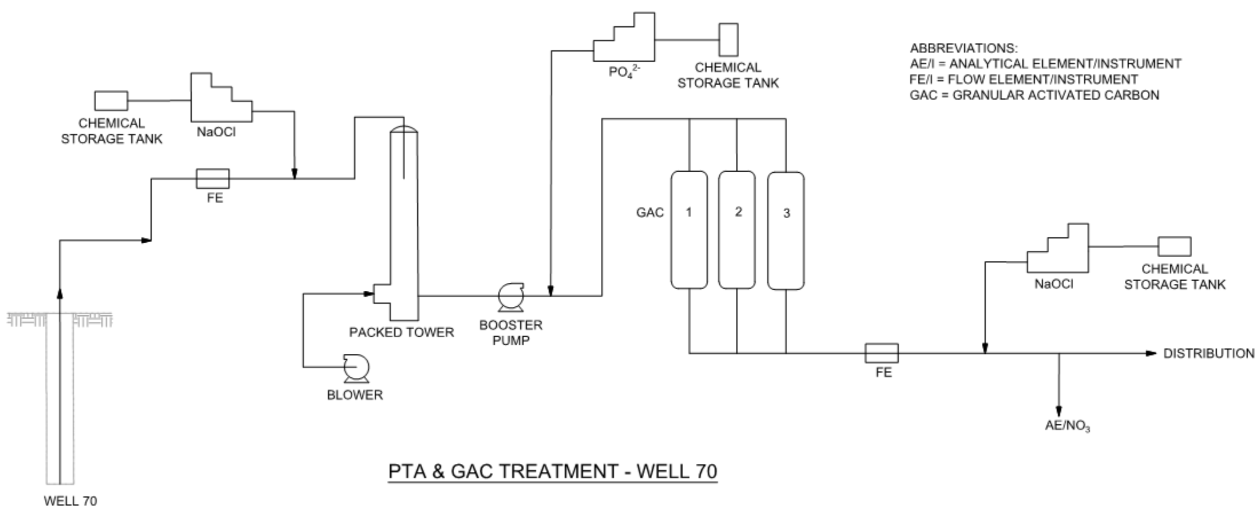
There are six water treatment facility types installed at the existing wellheads, including:

- Pack Tower Aeration (PTA)/Granular Activated Carbon Treatment (GAC) Facilities
- Oxidation and Filtration Treatment Facilities
- GAC and Blending Treatment Facilities

- GAC Only Treatment Facilities
- Wellhead Degassing Facilities
- PTA Only Facilities

The *PTA/GAC* treatment is installed at Well 70 with the objective to control volatile organic contaminants (VOCs), mainly TCE and TCP. The typical process train consists of an aeration tower packed with plastic media that allows cross-counter flow of air and water, a booster pump and multiple GAC vessels installed for an in-parallel operation. **Figure 4.1** shows a typical PTA/GAC process train as-installed at Well 70.

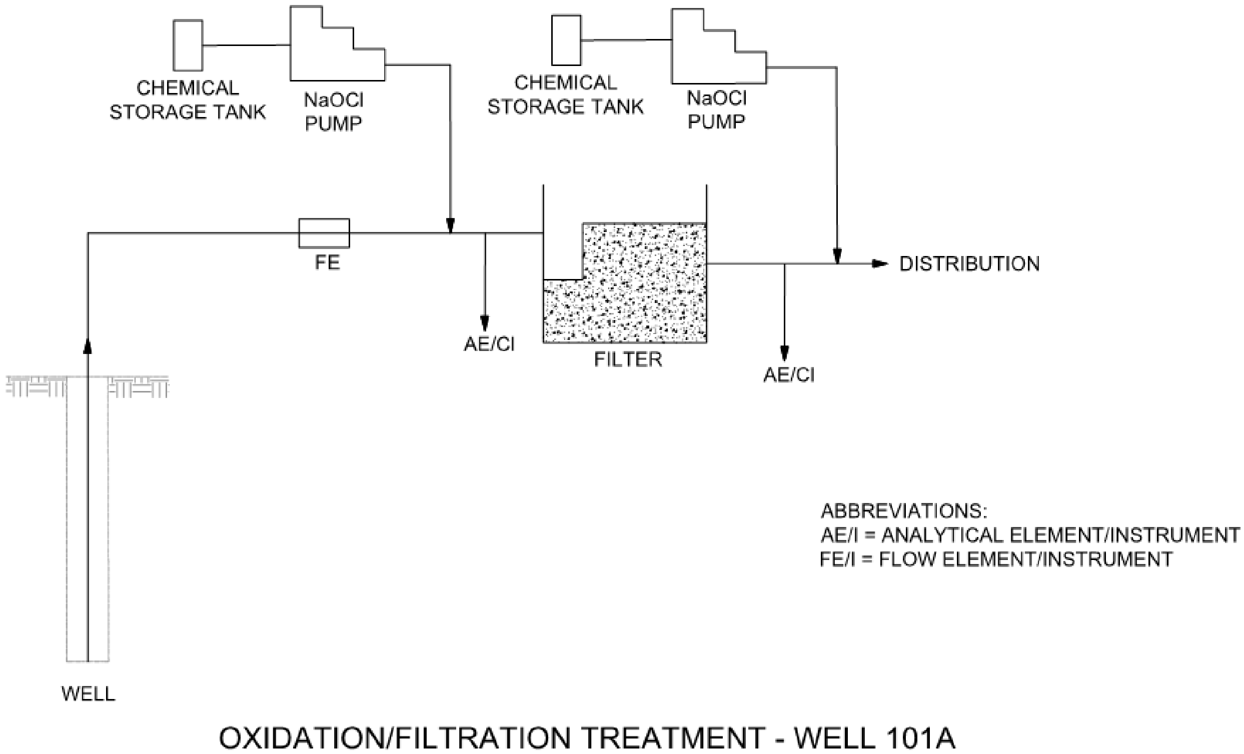
Figure 4.1 Well 70 Wellhead Treatment Schematic



A sodium hypochlorite system (NaOCl) consisting of a storage tank and chemical feed pump is placed upstream of the packed tower. Similarly, a phosphate system (PO_4^{2-}) also consisting of a storage tank and chemical feed pump is installed downstream of the packed tower and upstream of the GAC vessels. Final disinfection is provided by another chemical pump system that injects sodium hypochlorite in the final product water before delivering to the distribution system. Typical instruments that are installed to monitor and control treatment include individual flowmeters at each GAC vessel, pressure gauges, and a Cl_2 residual monitor.

Oxidation followed by filtration treatment is installed at Well 101A, Well 326, and Well 330 with objective to control manganese, although the water from these wells is also contaminated with hydrogen sulfide, nitrate, and TCP. The typical process consists of chemical oxidation and multiple media filter vessels. **Figure 4.2** shows a typical oxidation-filtration process train as-installed at Well 101A.

Figure 4.2 Well 101A Wellhead Treatment Schematic

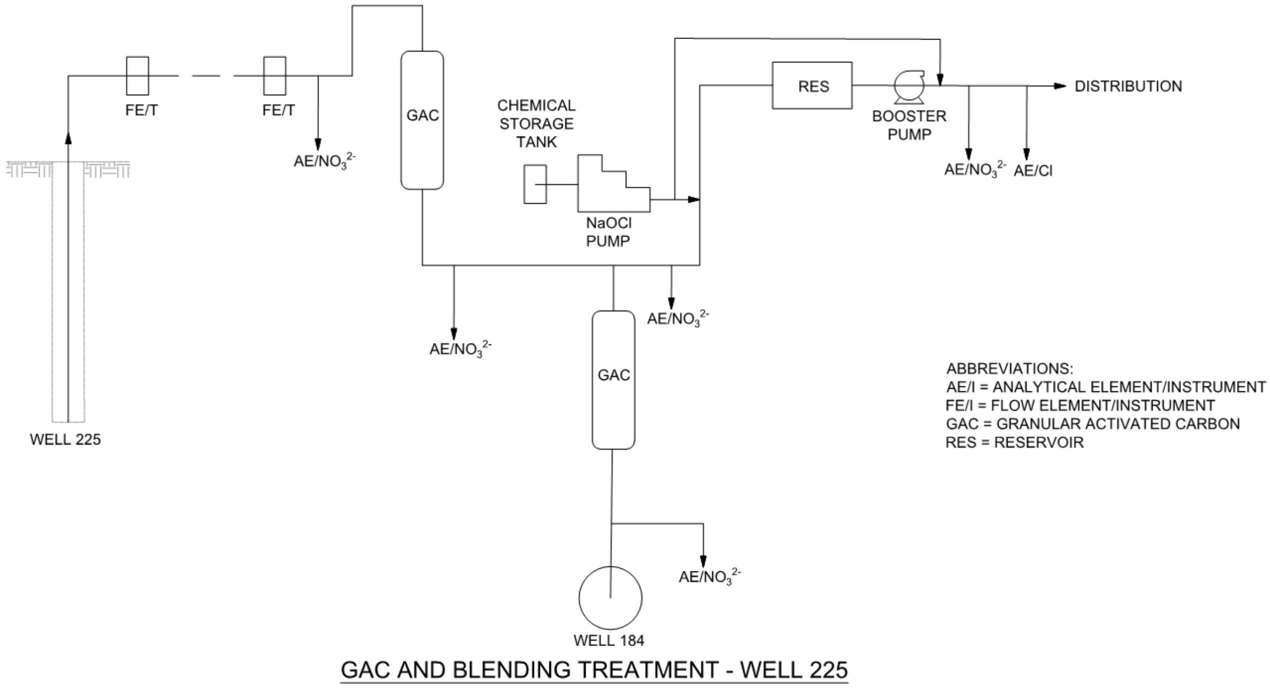


Sodium hypochlorite system consisting of a storage tank and chemical feed pump is placed upstream of the filters. Final disinfection is provided by another chemical pump system that injects sodium hypochlorite in the final product water before delivering to the distribution system. Typical instruments that are installed to monitor and control treatment include flowmeters, pressure gauges, pH probes and on-line chlorine probes.

GAC and blending treatment systems are installed at Well 225, as well as Wells 153-2, 180-2, 224, 225, 274, 297-2, 100-1, 100-2, 180-1, 153-1 with the primarily objective to control DBCP, a synthetic organic chemical, although the water from these wells is also contaminated with nitrate and TCP. The typical process train consists of a pressurized GAC vessel and a tank where the treated water is blended with non-treated water from other well(s). **Figure 4.3** shows a typical GAC and blending treatment process train as-installed at Well 225.

Sodium hypochlorite system consisting of a storage tank and chemical feed pump is placed downstream of GAC vessel providing chlorine disinfection of the GAC effluent before discharging in the blending reservoir.

Figure 4.3 Well 225 Wellhead Treatment Schematic

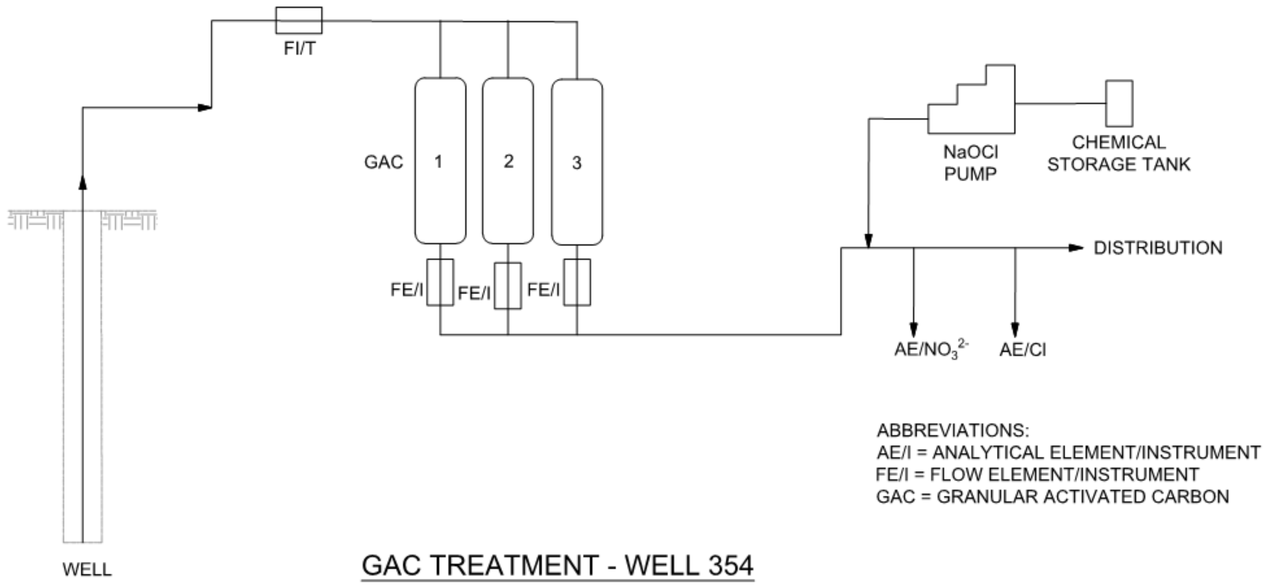


Typical instruments that are installed to monitor and control treatment include flowmeters, pressure gauges, pH probes as well as nitrate and chlorine analyzers.

GAC only treatment systems are installed at Well 354 and Wells 85, 135A, 137, 164-2, 171-2, 175-2, 176, 185, 201, 205, 277, 283, 354, 36, 184, and 275 with the primary objective to control DBCP, TCP and TCE, although the water from some of these wells is also contaminated with nitrate and carbon dioxide. Treated water from Well 201 and Well 36 are blended to maintain nitrate concentrations below MCL. The typical process train consists of multiple pressurized GAC vessels installed for an in-parallel operation. **Figure 4.4** shows a GAC process train as-installed at Well 354.

A sodium hypochlorite system consisting of a storage tank and chemical feed pump is placed downstream of GAC vessels providing chlorine disinfection of the GAC effluent before being delivered into the distribution system. Typical instruments that are installed to monitor and control the treatment process include flowmeters, pressure gauges, pH probes, and nitrate and chlorine analyzers.

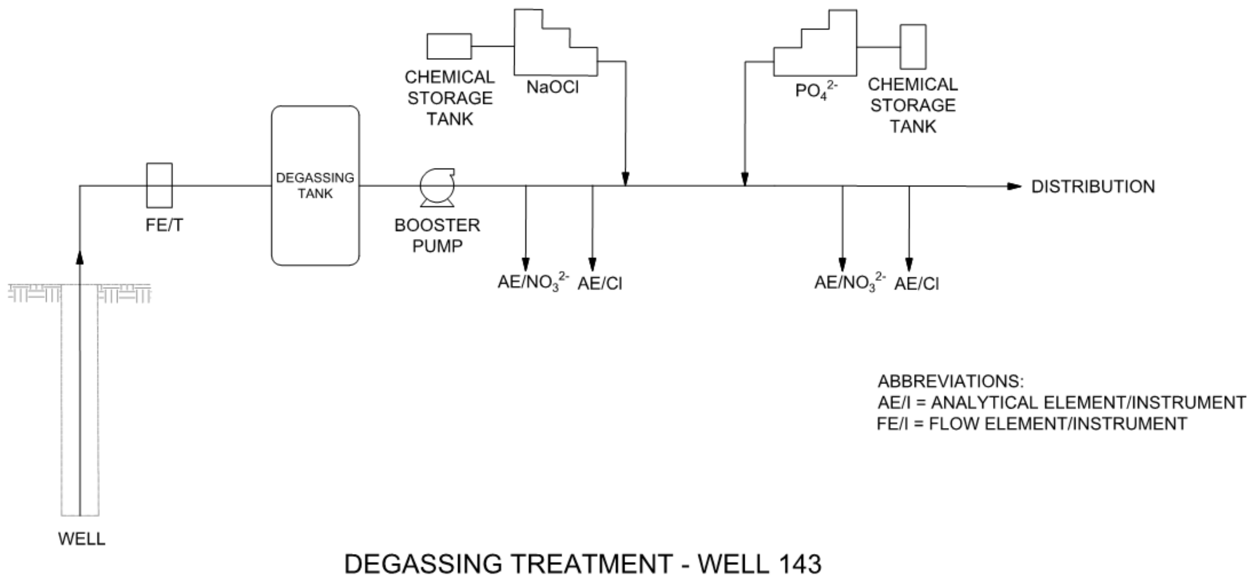
Figure 4.4 Well 354 Wellhead Treatment Schematic



Wellhead degassing is installed at Well 143 and Wells 321, 83A, 143, 133, 151, 176, 308, 319, 150, 89, 132, and 157 with the primary objective to remove carbon dioxide and air from the water. Typical well water (Well 143) degassing system consists of a steel tank where the water is retained for sufficient time for gas to separate from the water and escape into the air.

The field inspected Well 143 is furnished with a sodium hypochlorite system and ortho-polyphosphate system, each consisting of a storage tank and chemical feed pumps. Instruments that are installed to monitor and control degassing include flowmeters, pressure gauges, pH probes, and chlorine analyzers. **Figure 4.5** shows the degassing processing train as-installed at Well 143.

Figure 4.5 Well 143 Wellhead Degassing Schematic



4.3 ASSET TYPES AND SYSTEM HIERARCHY

A ground water well is a valuable asset consisting of several asset components such as the well itself, wellhead equipment and the well site improvements. In general terms, the well itself as an asset component consists of deep well hole, casing, screen, filter, and packing. Similarly, wellhead equipment consists of multiple components, such as the well pump, piping system with valves and other accessories, water treatment systems (if needed), power supply, electrical equipment, instrumentation and control, and SCADA. The well site is a civil and structural asset and may include well site fencing, access road(s), blow-off pond, and wellhead building(s).

Although the other asset components may be covered elsewhere in this report, the well asset that is the focus of this chapter is the wellhead water treatment system. The previously discussed five typical wellhead treatment facilities are installed at the existing 82 well sites with objectives to control VOCs, synthetic organics, nitrate, manganese, and some other contaminants as well as to remove air and gasses. Condition assessment and R&Rs for the process mechanical equipment and instrumentation, only, are presented in the following sections of this Chapter. Power supply and electric equipment were not included in the scope of work for this study. However, it is recommended to complete a similar exercise to include condition assessment and R&Rs for the electrical equipment since it is an integral part of the treatment for all of the wellhead facilities.

4.4 AVAILABLE DATA

The following sources of information were utilized by Kleinfelder for this study:

- Wellhead site inventory information and operational data
- Comments from operations staff during in-person meetings
- Field data collected from condition assessments as part of this study

Other pertinent information, such as historical data regarding equipment failures, down times, installation and replacement dates were not available and were thus not used in this study. Record drawings, operations and maintenance (O&M) manuals, and/or other design documents were also not available for this study.

Sources of the data used for this study are presented in the following sections.

4.4.1 Well Inventory and Operational Data

A spreadsheet containing a comprehensive list of all well sites within the City's jurisdiction was provided to the Kleinfelder and Akel project team. The spreadsheet included information such as:

- Well Number
- Notes from operational staff
- Location
- Capacity
- Operational status
- Known water quality issues and treatment type
- Date drilled

The information from this spreadsheet was used as an organizing tool to group wells of similar treatment type together. When dates of installation of equipment on the wellhead sites were unknown, the date of well drilling was used to produce an educated guess. The notes from operational staff provided insight to status of current well operation and whether wells were being blended with others.

4.4.2 Meetings with City Operations Staff

Two in-person meetings were held between Kleinfelder's team and the City's well operations staff to provide additional data regarding the wellhead treatment facilities. The first meeting was held before the field condition assessment was conducted, and the second meeting was held after findings from the field condition assessment were recorded and organized. Both meetings were held at the City of Fresno's Water System Department.

During the first meeting, Kleinfelder's team met with the City's operations staff to identify and organize wellhead sites by their respective treatment types. The five types of wellhead treatments are presented in Section 3.2. From each type of wellhead treatment, one representative wellhead was chosen that contained a comprehensive set of critical treatment components. These critical components were identified by Kleinfelder and the City's well operations staff. The typical wells and their treatment schematics are presented in Section 3.2. Once all critical components of each type of treatment system were identified, a plan was developed to assess the physical conditions of these components in-field. The chosen well that encompassed all critical components was used as a model for all wells with similar treatment systems.

During the second meeting, information derived from the field condition assessment was presented to the City's operations staff to provide comments on findings and any assumptions made prior to providing R&R recommendations. The City provided comments on the Kleinfelder presented R&R spreadsheet for the five typical wellhead treatment facilities. The City's comments are incorporated in this R&R report.

4.5 RISK ANALYSIS METHODOLOGY

Equipment "Serviceability" or "Likelihood of failure" as well as "Consequences of Failure" were numerically assessed to calculate risk for the wellhead treatment assets i.e. wellhead treatment facilities and their associated components.

4.5.1 Equipment Serviceability/Likelihood of Failure Analysis

The four-tier Serviceability/Likelihood of Failure analysis initially planned to utilize:

- Statistical analysis of the equipment past performance,
- Field equipment condition assessment,
- City well operations staff assessment of the equipment operational condition, and,
- The equipment's remaining useful service life.

For each of the four tiers, each equipment component would be numerically rated with the averaged numerical rating denoted as asset (equipment component) Serviceability/Likelihood of Failure rating.

Due to the large number of wellhead treatment facilities and to reduce otherwise extensive field work, the equipment field condition assessment was simplified by selecting typical facilities that represents each of the five existing wellhead facility types. The typical facilities were chosen as follows:

- Well 70 as a typical of all PTA/GAC wellhead treatment facilities
- Well 101A as typical of all oxidation-filtration wellhead treatment facilities
- Well 225 as typical GAC and blending wellhead treatment facilities
- Well 354 as typical of all GAC only wellhead treatment facilities
- Well 143 as typical of all Wellhead Degassing facilities

Statistical Analysis of Past Performance: The existing wellhead treatment facilities have been operated and maintained, and currently are running satisfactory providing good water quality to the City's water distribution system. However, historical data of the wellhead treatment facilities' shutdowns, maintenance and troubleshooting, as well as malfunctions and failures were not available for this document. Therefore, statistical analysis of the past performance as basis for prediction of future likelihood of failure was not performed.

Field Equipment Condition Assessment: For each typical wellhead treatment facility, unit processes were identified and further broken down in unit process components and subcomponents. During the two-day field surveillance, physical and operational conditions were assessed for each individual component and its subcomponents. The field condition of the inspected equipment was documented and presented in the Section 3.6, below with recorded comments provided by the wellhead treatment operator(s).

Field physical equipment condition of each of the component is rated using a numerical rating from 1 to 5, as follows:

- New, 1
- Asset in good condition, 2
- Asset in fair condition, 3
- Asset in poor condition, 4
- Asset unusable/not operational/failed, 5

City Well Operation Staff Rating: During a one-day workshop/meeting, the City well operation staff provided their ratings for each wellhead treatment components for the five typical wellhead treatment facilities. To rate operability and functionality of the wellhead treatment for each component (asset), the City staff used the numerical rating from 1 to 5 as follows:

- Asset works as supposed to, 1
- Asset works as expected 80% of time, 2
- Asset functions below its expected level/Works 1/2 time/requires re-starting/has limited functionality, 3
- Asset only works occasionally or most of its functionality is impaired, 4
- Asset not operational, 5

Equipment Remaining Useful Service Life: The rating of the equipment useful service life is based the percent of the remaining useful service life, which is calculated based on the formula:

$$RUSL = \frac{RSL}{SL} \, x100$$

Where:

RUSL is remaining useful service life expressed as a percent of 100 percent

RSL is remaining service life in number after 2018 expressed in number of years

SL is total asset’s service life expressed in number of years

Based on the year when the wellhead treatment system was installed, or when any of the component is replaced or rehabilitated, the remaining service life (RSL) was assessed with 2018 as the reference year i.e. the remaining service life time after year 2018. The total asset's service life (SL) was allocated for each equipment component (assets), based on the guidelines from City of San Diego Asset Management Program, or if not available, based on industry standards and/or manufacturer's recommendations

The numerical rating of the equipment remaining useful service life is 1 to 5, as follows.

- 80% to 100% remaining useful service life, 1
- 60% to 80% remaining useful service life, 2
- 40% to 60% remaining useful service life, 3
- 20% to 40% remaining useful service life, 4
- 0% to 20% remaining useful service life, 5

The numerical average of the Field Condition Assessment, City Well Operations Staff and Equipment Remaining Useful Service Life ratings are denoted as the equipment "Serviceability" rating or the equipment "Likelihood of Failure" rating for future risk assessment.

4.5.2 Consequence of Failure Analysis

Two consequences of failure of the well head treatment equipment were analyzed for risk assessment, including:

1. Consequence on water quality, and,
2. Consequence on plant capability to produce flow.

Consequence on Water Quality: Impacts of a failure to produce the targeted water quality for each wellhead treatment components were evaluated and rated with numeric scores ranging from 1 to 5, as follows:

- No impact on water quality, 1
- Partial impact on water quality (loss of redundancy, >3+1), 2
- Intermediate impact on water quality (loss of redundancy, 2+1), 3
- Substantial impact on water quality (loss of redundancy, 1+1), 4
- Catastrophic impact on water quality - renders plant shut down (no redundancy), 5

Equipment redundancy was considered as a safeguard of the ability of the wellhead treatment facility to produce the targeted water quality. For example, if the chemical feed system has two duty and one standby chemical pump, failure of one pump will not have impact and failure of two pumps will have only partial impact on plant's ability provide the needed water quality. Hence, a score of 3 was provided for this scenario.

Consequence on Flow: Similar to the water quality assessment, impacts of a failure to produce the targeted product water flow for each wellhead treatment component was also evaluated and rated with numeric scores ranging from 1 to 5, as follows:

- No consequence, well runs at full capacity, 1
- Well capacity reduced by 25% (loss of redundancy, >3+1), 2
- Well capacity reduced by 50% (loss of redundancy, 2+1), 3
- Well capacity reduced by 75% (loss of redundancy, 1+1), 4
- Catastrophic impact on flow capacity - renders well shut down (no redundancy), 5

As for the water quality, equipment redundancy was considered as a safeguard to ability of the wellhead treatment facility to produce the targeted product water flows. For example, if the distribution system booster pumping system has one duty and one standby pump, failure of one pump will not have immediate impact on well's ability produce needed water flow. However, this component scores 4 because of the risk that standby pump may not be operational when required or may fail without backup.

The numerical averaged Consequence on Water quality and Consequence on Flow ratings are denoted for the further risk assessment as the overall Consequence of Failure rating.

4.5.3 Risk Scoring and Prioritization

A risk score for each individual equipment component (asset) is calculated as a product of multiplication of the Likelihood of Failure rating and the Consequence of Failure rating. Since the lowest numerical rating for both risk components is 1 and the highest 5, the lowest possible risk score is 1 and the highest possible risk score is 25.

To prioritize the City's action in addressing the issues of possible equipment failure, all assets are grouped in three priority categories as follows:

- Priority 1 (High Priority) – Assets scored a risk score of 15 or higher, immediate action required
- Priority 2 (Intermediate Priority) – Assets scored a risk score of 5 to 15, action required in 5-year span
- Priority 3 (Low Priority) – Assets scored a risk score below 5, action required after 5 years

4.5.4 R&R Recommendations

All asset (equipment components) R&R recommended improvements are grouped in five categories as follows:

A - Regular Scheduled Maintenance: assumes cleaning, lubrication, scheduled part replacements and similar.

B – On-Site Repairs, assumes minor repairs to bring equipment to operational condition such as seal replacement, corrosion removal, paint touch ups and similar.

C – On-Site Refurbishment, assumes on-site or in-plant shop refurbishment to clean, remove corrosion, repair paint, replace used up parts, and similar.

D – On-Site or Off-Site Refurbishment/Rehabilitation, assumes major undertaking to bring the equipment near to new condition or adding new features to the unit or facility.

E - Replacement, assumes in-kind replacement with identical equipment unit.

4.5.5 Cost Estimates of R&R Recommended Improvements

A budgetary (+35/-30%) level cost estimate was prepared for the recommended improvements.

The conventional approach for cost estimating uses design plans and specifications. This approach was not applicable for recommended R&R improvements at an operating wellhead treatment site.

Therefore, a “direct” cost estimating approach was employed to obtain budgetary cost estimates for the recommended equipment upgrades. Existing information such as model numbers, serial numbers, and photographs of units were provided to the equipment’s original manufacturers and vendors, and quotes were obtained for in-kind equipment replacements with upgraded technologies, if needed, since the manufacturer may no longer support the technologies of the currently-installed equipment. Engineer’s institutional knowledge was also used in estimating the price of general materials such as piping and valves.

The estimated costs assume that all R&R improvements will be completed by an outside contractor. Also, the cost estimates do not include regular maintenance that is performed by the City maintenance staff.

Taxes and construction costs were also added to the equipment quotes, as quotes from equipment vendors and manufacturers did not include these costs. To estimate construction costs for the equipment, a multiplier of 1.6 was added. This is assumed to cover construction, contractor overhead and profit.

4.6 CONDITION ASSESSMENT RESULTS

4.6.1 Field Condition and Operator’s Assessment

Findings from the field condition assessment as well as comments from the operators are presented in the following sections. The results from these well assessments are intended to be extrapolated to all other well sites receiving similar treatment. Scores pertaining to each equipment unit’s field condition assessment and plant operator’s ratings are found in **Table 4.1**.

4.6.2 GAC Only Treatment – Well 354

Wellhead 354, located at 2504 South Maple Avenue, was observed as a typical unit for Granular Activated Carbon (GAC) treatment. The wellhead site receives an average flow of 2,000 gallons per minute (GPM) and at 280 feet of total dynamic head (TDH). The wellhead site’s treatment functions are currently active with no-known operational issues.

4.6.2.1 *Flow Meter No. 1*

<u>Description</u>

The influent flow meter is an Ultra Mag magnetic flow meter with 316 stainless steel electrodes and a McCrometer display. The size of the flow meter appears to be 12”. All components are above-ground and exposed. **Figure 4.6** shows the Well 354 flow meter and **Figure 4.7** shows the flow meter nameplate.

<u>Operator’s Comments</u>

The components have been fully operational without significant shutdowns. The flow meters require calibration every two weeks as part of routine maintenance. The flow meter was recently refurbished in 2013.

Figure 4.6: Flow Meter No. 1 Nameplate

Figure 4.7: Well 354 Flow Meter No. 1

<u>Equipment Conditions</u>

The components show some signs of deterioration of the coating due to sun light exposure and minor corrosion especially around bolt locations. However, these defects appear to be purely cosmetic.

4.6.2.2 ***GAC Vessels No.1, No. 2, & No. 3***

Description

Three GAC vessels are located on site to treat extracted groundwater. The GAC vessel is provided by Calgon Carbon Corporation and was certified in 2008. Each GAC vessel is a welded tank of unknown capacity, and includes inlet and outlet piping, three stainless steel injection and sample ports, an outlet valve, and an outlet flow meter. **Figure 4.8** shows the Well 354 GAC vessels and **Figure 4.9** shows the GAC vessel 2 nameplate.

Operator's Comments

Operation's staff noted that there are no existing issues with the GAC vessels and associated piping components. Regular maintenance is performed on these components. One issue that the GAC vessel pit is frequently trespassed on by transients. The GAC is backwashed and replaced as-needed.

Equipment Field Conditions

The GAC vessels appear to be in good condition with no signs of major defects.

Figure 4.8: GAC Vessels at Wellhead Site 354

Figure 4.9: GAC Vessel 2 Name-plate

There are signs of minor corrosion in localized areas, particularly around small injection ports. Some signs of oil leaks around valve housings were observed. Flanged connections exhibited some signs of corrosion but were in overall good condition as shown on **Figure 4.10.** No bypass piping was observed within the treatment train at the GAC vessels.

Figure 4.10: Minor Corrosion at GAC Vessel Piping Flanged Connections

4.6.2.3 *GAC Outlet Flow Meters and Sensors No. 1, No. 2, & No. 3*

Description

The GAC vessel outlet flow meters and sensors are Seametrics Model TX110S insertion turbine flow sensors and have been in operation since 2013. The flow sensors transfer information to flow meters that are in an on-site housing away from the GAC vessels. **Figure 4.11** shows the GAC outlet flow meter No. 3.

Operator's Comments

The operators noted that the flow meters and sensors must be calibrated every two weeks as part of routine maintenance.

Equipment Conditions

The flow meters and sensors appeared to be in good condition, with only minor corrosion around the points of injection.

Figure 4.11: GAC Outlet Flow Meter No. 3

4.6.2.4 *Sodium Hypochlorite Pump*

Description

The chlorine pump is a Grundfos Type DDA 7.5-16 dosing pump that has been in operation since 2011. It regularly doses chlorine from an on-site chlorine storage tank into the treatment stream downstream of the GAC vessels. The pump and storage tank are housed in an on-site, ventilated housing with a locking door. Figure 4.12 shows the chorine dosing pump at Well 354.

Figure 4.12: Chlorine Dosing Pump at Wellhead Site 354

Operator's Comments

The dosing tubing inside the pump require frequent replacement as they typically have a short lifespan. Routine and as-needed maintenance are performed. No other issues have been experienced with the pumps.

Equipment Condition

The pump appeared to be in good condition, with no signs of wear or corrosion.

4.6.2.5 *Nitrate analyzer*

Description

The nitrate analyzing system is a Hach system with a Hach sc200 controller and has been in operation since 2013. The system is located in a ventilated enclosure with a locking door. Nitrate is measured downstream of the GAC vessels. Figure 4.13 shows the nitrate analyzer at Well 354.

Operator's Comments

The operators had no comments on the nitrate analyzers as they have been operating as intended with no issues.

Figure 4.13: Nitrate Analyzer at Wellhead Site 354

Equipment Condition

The analyzers appear to be in good overall working condition with no signs of wear.

4.6.2.6 *Chlorine Analyzer*

Description

The chlorine analyzing system is a ProMinent Fluid Controls, Inc. analyzing system, with a measuring range of 1-10 PPM. The system has been in operation since 2017. The system is located in a ventilated enclosure with a locking door. Chlorine is measured downstream of the GAC vessels and downstream of the chlorine injection points. **Figure 4.14** shows the chlorine analyzing system at Well 354.

Operator's Comments

The operators had no comments on the chlorine analyzers as they have been operating as intended with no issues.

Figure 4.14: Chlorine Analyzing System at Wellhead Site 354

Equipment Condition

The analyzers appear to be in good overall working condition with no signs of wear.

4.6.3 GAC & Blending – Well 225

Well Site 225, drilled in 1962 and located behind 5470 Columbia Drive, is a typical treatment site for GAC and blending treatment. Wellhead sites that treat for blending produce water with high amounts of nitrates and therefore must be blended with water from other sites that contain lower levels of nitrates to lower the average nitrate concentration. Water from wellhead site 225 blends with water from site 184, which is located approximately half a mile downstream of wellhead site 225. Wellhead site 184 was not observed for this condition assessment. Wellhead site 225 also treats for dibromochloropropane (DBCP), which is treated by GAC. The site produces an average flow of 800 gpm at a depth 280 feet (210ft TDH). The site's treatment functions are currently active with no-known operational issues.

4.6.3.1 *Flow Meter No. 1*

Flow meter No. 1 measures the flow from wellhead site 184. This flow meter is located off site from wellhead site 225 and was not observed.

4.6.3.2 *GAC Vessel*

Description

The GAC vessel is located on-site to treat the groundwater. The GAC vessel is certified by ITEQ Storage Systems, Inc and was built in the year 2000. The GAC vessel has 7,895-gallon capacity, and includes an inlet and outlet piping, three (3) stainless steel injection and sample ports, an outlet valve, and an outlet flow meter. **Figure 4.15** shows the Well 225 GAC vessels and **Figure 4.16** shows the GAC vessel nameplate.

Figure 4.15: GAC Vessel at Wellhead Site 225

Figure 4.16: GAC Vessel Nameplate at Wellhead Site 225

Operator's Comments

The operator noted that there are no existing issues with the GAC vessels and associated piping components. Regular maintenance is performed on these components. The GAC is replaced as-needed.

Equipment conditions

The GAC vessel appears to be in good condition with no signs of major defects. There are signs of corrosion in localized areas, particularly around small injection ports and flanged connections. Some signs of oil leaks around valve housings were observed. Flange connections exhibited some signs of corrosion but were in overall good condition as shown of **Figure 4.17**. No bypass piping was observed at the location of the vessel.

Figure 4.17: Corrosion at GAC Vessel Outlet Piping

4.6.3.3 *Nitrate Analyzers*

Description

The nitrate analyzing system is comprised of a Hach OptiQuant Interface Module and a Sentry Sample Sequencer. The system was installed in 2010 and is located adjacent to the treatment piping. Nitrate is measured at multiple points throughout the treatment stream, including the influent and effluent of the GAC vessel, effluent of the site, and influent and effluent to the storage tank. The sampler sequences the analysis between the different points. **Figure 4.18** shows the Well 225 nitrate analyzing system.

Figure 4.18: Nitrate Analyzing System at Wellhead Site 225

Operator's Comments

The operators had no comments on the nitrate analyzers as they have been operating as intended with no issues.

Equipment Condition

The analyzers appear to be in good overall working condition with no signs of wear.

4.6.3.4 *Chlorine Analyzer*

Description

The chlorine analyzing system is a ProMinent Fluid Controls, Inc. analyzing system, with a measuring range of 1-10 PPM that was installed in 2013. Chlorine is measured downstream of the storage tank prior to distribution. **Figure 4.19** shows the Well 225 chlorine analyzing system.

Figure 4.19: Chlorine Analyzing System at Wellhead Site 225

<u>Operator's Comments</u>

The chlorine analyzers require calibration every two weeks as part of routine maintenance.

<u>Equipment Condition</u>

The analyzers appear to be in good overall working condition with no signs of abnormal wear.

4.6.3.5 *Sodium Hypochlorite Pump*

<u>Description</u>

The chlorine pump is a Grundfos Type DDA 7.5-16 dosing pump and was installed in 2011. It regularly doses chlorine from an on-site chlorine storage tank into the treatment stream downstream of the GAC vessels. The pump and storage tank are housed in an on-site, ventilated housing with a locking door. Figure 4.20 shows the Well 225 sodium hypochlorite tank and pump.

Figure 4.20: Sodium Hypochlorite Tank and Pump at Wellhead Site 225

Operator's Comments

The dosing tubing inside the pump require frequent replacement as they typically have a short lifespan. Routine and as-needed maintenance are performed. No other issues have been experienced with the pumps.

Equipment Condition

The pump appeared to be in good condition, with no signs of abnormal wear or corrosion.

4.6.3.6 *Booster Pumps*

Description

The booster pumps are Floway vertical turbine pumps with 50 HP General Electric vertical motors and were installed in 1996. There are four (4) pumps, with space for two (2) additional pumps. **Figure 4.21** shows the Well 225 booster pump No. 1 and **Figure 4.22** shows the booster pump motor No. 1 nameplate.

Operator's Comments

The operator noted that the pumps worked well with no major issues. The pumps are regularly maintained for upkeep of their operation.

Figure 4.21: Booster Pump #1 at Wellhead Site 225

Figure 4.22: Booster Pump Motor #1 Nameplate

Equipment conditions

The pumps exhibited some corrosion and buildup at ports and bolt locations as shown on **Figure 4.23**. The pumps did not turn on at the time of observation.

Figure 4.23: Corrosion at Boost Pump #1

4.6.3.7 *Well 184/225 connection*

Description

Treated water from Wells 225 and 184 blends at Wellhead site 225. The connection consists of a welded-tee connection shown on **Figure 4.24,** of Well 184 effluent into Well 225 effluent, and control valves on both lines as shown on **Figure 4.25**.

Figure 4.24: Welded Tee Connection Between Wells 184 & 225

Figure 4.25: Well 225 Effluent Control Valve

4.6.3.8 *Flow Meter 2*

Description

Flow meter no. 2 at wellhead site 225 measures the flow of the effluent water from the site. It was installed in 2000 and is located in a deep vault on the outside perimeter of the site. This valve was visually seen from the ground level, but its physical condition could not be observed. **Figure 4.26** shows the Well 225 flow meter No. 2.

Figure 4.26: Flow Meter No. 2 at Wellhead Site 225

Operator's Comments

This flow meter is not frequently accessed since it is buried. Frequent failures are experienced with SCADA communication between the flow meter and the receiving equipment.

Equipment Conditions

Visual inspection did not provide much insight as to the physical condition of the flow meter since it was buried below ground.

4.6.3.9 *2-MG Tank*

Description

The 2-MG tank on-site is served to store treated water blended from wellhead sites 184, 225 and 223-3. It is a cylindrical, partially-buried prestressed concrete tank. Figure 4.27 shows the 2 MG storage tank.

Operator's Comments

The inside of the tank is serviced and cleaned every two years to clean out sediment buildup. The tank and components are in maintained in very good condition.

Figure 4.27: 2-MG Storage Tank at Wellhead Site 225

Equipment Condition

No equipment condition observations were made for this component.

4.6.4 Degassing – Well 143

Wellhead site 143, located at 957 East Perrin Ave, was observed as a site typical for de-gassing treatment. The extracted groundwater exhibits gas issues, which has found to be due to carbon dioxide. The wellhead site receives an average flow of 800 GPM and at well depth of 242 feet. The wellhead site's treatment functions are currently active with no-known operational issues.

4.6.4.1 *Booster Pump*

Description

The booster pump boosts pump from the extracted groundwater within the well. The pump type is unknown as no nameplate was visible. The motor is a 40 HP Emerson motor. The Well 143 booster pump and motor are shown on **Figure 4.28**. The pump and motor are housed in a separate, ventilated enclosure with a locking door.

Figure 4.28: Booster Pump and Motor at Wellhead Site 143

Operator's Comments

No known major issues. The pump and motor go under routine maintenance.

Equipment Condition

The pump exhibited some oil leaking, corrosion, and buildup from the shaft as shown on **Figure 4.29**. The pump was in overall good condition.

Figure 4.29: Corrosion at Booster Pump

4.6.4.2 *Degassing Tank and Level Elements*

Description

The degassing tank on site contains a Rosemount pressure analyzer that detects the water level inside the tank. **Figure 4.30** shows the Well 143 degassing tank level instrument and **Figure 4.31** shows the level instrument nameplate.

Figure 4.30: Degassing Tank Level Instrument at Wellhead Site 143

Figure 4.31: Level Instrument Nameplate

Operator's Comments

This component is fairly new.

Equipment Condition

The equipment appeared to be in good overall condition.

4.6.4.3 *Flow Meter No. 1*

Description

The influent flow meter is a Krohne Enviromag 2000 F CSA electromagnetic flow meter with a Krohne KFC 100W display. The size of the flow meter appears to be 8". All components are above-ground and exposed. **Figure 4.32** shows Well 143 flow meter No. 1 and **Figure 4.33** shows the flow meter No. 1 nameplate.

Figure 4.32: Flow Meter No. 1 at Wellhead Site 143

Figure 4.33: Flow Meter No. 1 Nameplate

Operator's Comments

The components have been fully operational without significant shutdowns. The flow meters require calibration every two weeks as part of routine maintenance.

Equipment Field Conditions

The components show no signs of wear or corrosion and seem fairly new.

4.6.4.4 *Chlorine Pump*

Description

The chlorine pump is a Stenner S3007 dosing pump. The pump and storage tank are housed in an on-site, ventilated housing with a locking door. Figure 4.34 shoes the Well 143 chlorine and dosing pump and Figure 4.35 shows the chlorine dosing pump nameplate.

Figure 4.34: Chlorine & Dosing Pump at Wellhead Site 143

Figure 4.35: Chlorine Dosing Pump Nameplate

Operator's Comments

The dosing tubing inside the pump require frequent replacement as they typically have a short lifespan. Routine and as-needed maintenance are performed. No other issues have been experienced with the pumps.

Equipment Condition

The pump appeared to be in good condition, with no signs of wear or corrosion.

4.6.4.5 *Orthopolyphosphate Pump*

Description

The orthophosphate pump is a Stenner S3007 dosing pump. The pump and storage tank are housed in an on-site, ventilated housing with a locking door. Figure 4.36 shows the Well 143 chlorine and Orthopolyphosphate pump and Figure 4.37 shows the dosing pump nameplate.

Figure 4.36: Chlorine & Orthopolyphosphate Dosing Pump at Wellhead Site 143

Figure 4.37: Chlorine & Orthopolyphosphate Dosing Pump Nameplate

Operator's Comments

The dosing tubing inside the pump require frequent replacement as they typically have a short lifespan. Routine and as-needed maintenance are performed. No other issues have been experienced with the pumps.

Equipment Condition

The pump appeared to be in good condition, with no signs of wear or corrosion.

4.6.4.6 *Chlorine Analyzer*

Description

The chlorine analyzing system is a ProMinent Fluid Controls, Inc. analyzing system, with a measuring range of 1-10 PPM. Chlorine is measured downstream of the storage tank prior to distribution. The prominent analyzers used at degassing sites also include pH probes. Figure 4.38 shows the Well 143 chlorine analyzing system and Figure 4.39 shows the chlorine analyzer nameplate.

Figure 4.38: Chlorine Analyzing System at Wellhead Site 143

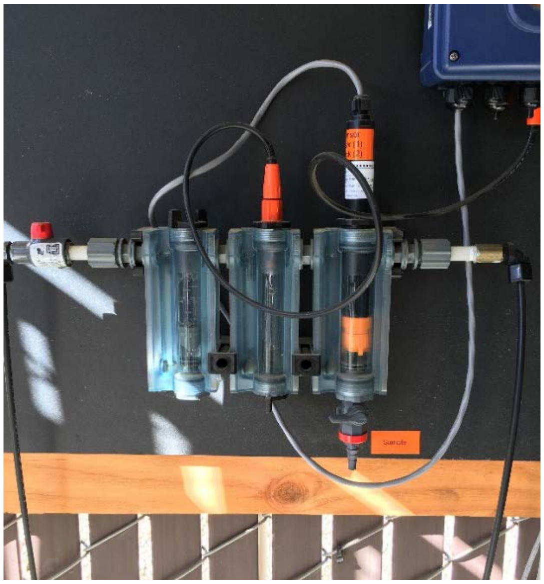
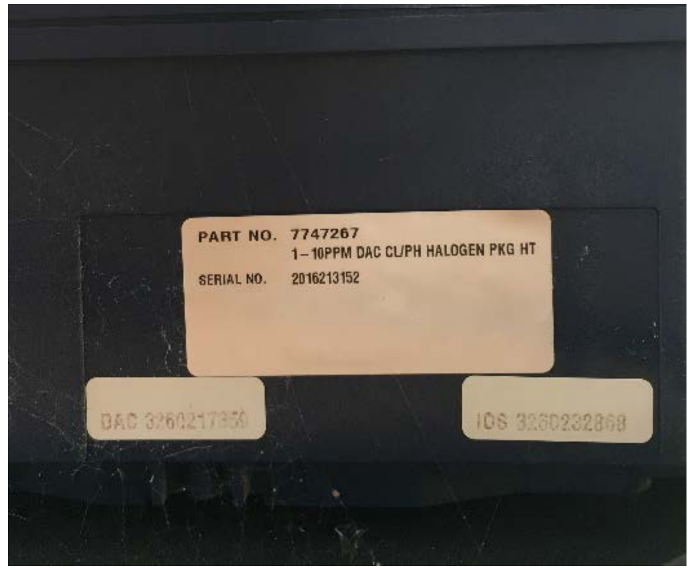


Figure 4.39: Chlorine Analyzer Nameplate



<u>Operator's Comments</u>

Typically, two to three hours are required to allow the distributed water to come into the analyzing probe due to the small supply line and low flow rates. The chlorine analyzers require calibration every two weeks as part of routine maintenance.

<u>Equipment Condition</u>

The analyzers appear to be in good overall working condition with no signs of wear.

4.6.4.7 *pH Analyzer*

<u>Description</u>

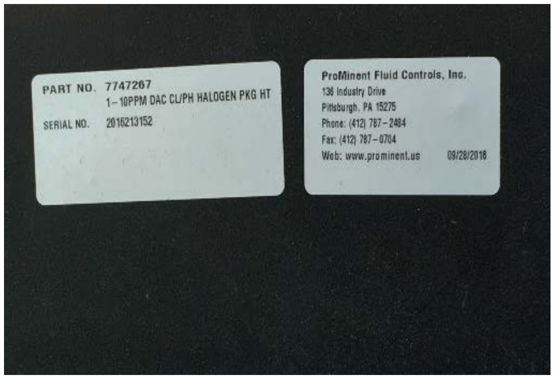
The pH is analyzed using a ProMinent Fluid Controls, Inc. pH analyzing system. The system is located in a ventilated enclosure with a locking door. The distribution water is measured for pH. All sites in north-east Fresno with Orthopolyphosphate include pH probes. **Figure 4.40** shows Well 143 pH analyzer and **Figure 4.41** shows the pH analyzer nameplate.

<u>Operator's Comments</u>

The operators had no comments on the pH analyzers as they have been operating as intended with no issues.

Figure 4.40: pH Analyzer at Wellhead Site 143

Figure 4.41: pH Analyzer Nameplate



<u>Equipment Condition</u>

The analyzers appear to be in good overall working condition with no signs of wear.

4.6.5 Oxidation & Filtration Treatment – Well 330

Wellhead Site 330, located at 11625 N. Alicante Drive, was observed as a typical treatment site for oxidation and filtration treatment. Oxidation and filtration are typically used as a treatment for high level of manganese and hydrogen sulfide. Wellhead site 330 produces an average flow of 1,800 gpm at a depth of 350 feet. The site's treatment functions are currently active with no-known operational issues.

4.6.5.1 *Flow Meter No. 1*

<u>Description</u>

The influent flow meter is a Siemens magnetic flow meter with 316 stainless steel electrodes. The size of the flow meter appears to be 12". All components are above-ground and exposed. **Figure 4.42** shows Well 330 flow meter No. 1 and **Figure 4.43** shows the flow meter No. 1 nameplate.

<u>Operator's Comments</u>

The components have been fully operational without significant shutdowns. The flow meters require calibration every two weeks as part of routine maintenance.

Figure 4.42: Flow Meter No. 1 at Wellhead Site 330

Figure 4.43: Flow Meter No. 1 Nameplate

<u>Equipment Conditions</u>

The components show some signs of deterioration of the coating due to sun light exposure and minor corrosion especially around bolt locations. However, these defects appear to be purely cosmetic.

4.6.5.2 *Filters*

<u>Description</u>

The filters vessels are located on-site to treat the groundwater. The filter vessels are ATEC

Systems media filters. There are eight (8) filters in series. An Alex-Tronix control panel is located on site. Figure 4.44 shows the Well 330 filter vessel and Figure 4.45 shows the filter control panel.

<u>Operator's Comments</u>

The operator noted that there are no existing issues with the filter vessels and associated piping components. However, some operational issues arise when the filters are being backwashed. Backwash cycles frequently go out of sync to due manual input of backwash volume by the operators. This volume needs to run against production volume, which varies by season.

Figure 4.44: Filter Vessel at Wellhead Site 143

Figure 4.45: Filter Control Panel

Equipment conditions

The filter vessels and associated components appear to be in good condition with no signs of major defects.

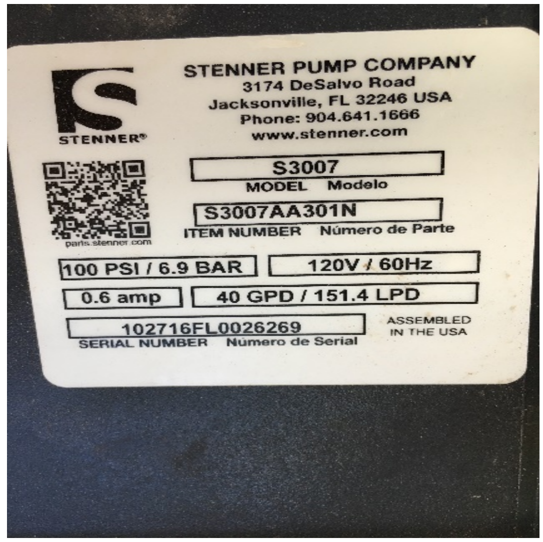
4.6.5.3 *Chlorine Pump*

Description

The chlorine pump is a Stenner S3007 dosing pump. The pump and storage tank are housed in an on-site, ventilated housing with a locking door. **Figure 4.46** shows the Well 330 Orthopolyphosphate Dosing Pump and **Figure 4.47** shows the dosing pump nameplate.

Figure 4.46: Chlorine & Orthopolyphosphate Dosing Pump

Figure 4.47: Chlorine Dosing Pump Nameplate



<u>Operator's Comments</u>

The dosing tubing inside the pump require frequent replacement as they typically have a short lifespan. Routine and as-needed maintenance are performed. No other issues have been experienced with the pumps.

<u>Equipment Condition</u>

The pump appeared to be in good condition, with no signs of wear or corrosion.

4.6.5.4 *Orthopolyphosphate Pump*

<u>Description</u>

The orthophosphate pump is a Stenner S3007 dosing pump. The pump and storage tank are housed in an on-site, ventilated housing with a locking door.

<u>Operator's Comments</u>

The dosing tubing inside the pump require frequent replacement as they typically have a short lifespan. Routine and as-needed maintenance are performed. No other issues have been experienced with the pumps.

<u>Equipment Condition</u>

The pump appeared to be in good condition, with no signs of wear or corrosion as shown on **Figure 4.48**.

Figure 4.48: Chlorine & Orthopolyphosphate Dosing Pump

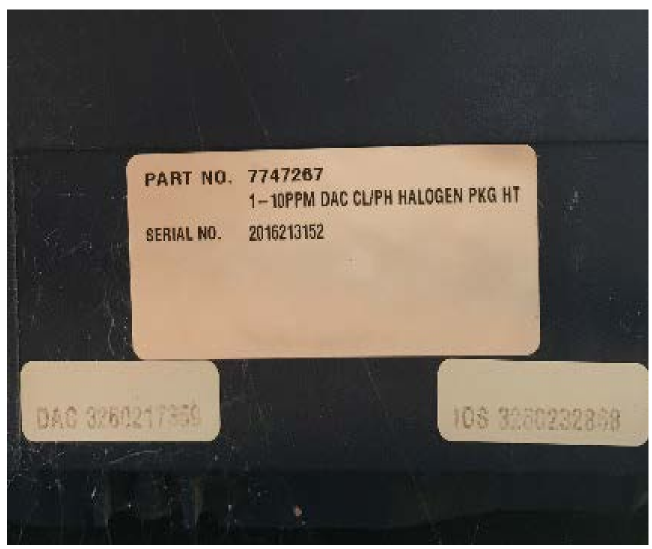
4.6.5.5 *Chlorine Analyzer*

Description

The chlorine analyzing system is a ProMinent Fluid Controls, Inc. analyzing system, with a measuring range of 1-10 PPM. Chlorine is measured pre- and post-filtration. **Figure 4.49** shows the Well 330 chlorine analyzing system and **Figure 4.50** shows the chlorine analyzer nameplate.

Figure 4.49: Chlorine Analyzing System at Wellhead Site 330

Figure 4.50: Chlorine Analyzer Nameplate



Operator's Comments

The influent chlorine analyzing chamber is darkly discolored due to the high levels of manganese experienced at this well site. High levels of manganese also cause issues with chlorine analysis. The chlorine analyzers require calibration every two weeks as part of routine maintenance.

Equipment Condition

The analyzers appear to be in good overall working condition with no signs of wear.

4.6.6 PTA/GAC Treatment - Well 70

Well 70, located at 1590 N. Peach Avenue, was observed as a typical unit for packed tower aeration (PTA) and GAC treatment. The wellhead site treats for trichloropropane and trichloroethylene. The wellhead site receives an average flow of 950 GPM and at a depth of 210 feet. The wellhead site's treatment functions are currently active with no-known operational issues.

4.6.6.1 *Pre-Chlorination Pump*

Description

The chlorine pump is a Grundfos Type DDA 7.5-16 dosing pump. It regularly doses chlorine from an on-site chlorine storage tank into the treatment stream at the head of the treatment process. The pump and storage tank are housed in an on-site, ventilated housing with a locking door. **Figure 4.51** shows the Well 70 chlorine dosing pump and **Figure 4.52** shows the pre-chlorine pump nameplate.

Figure 4.51: Chlorine Dosing Pump at Wellhead Site 70

Figure 4.52: Pre-Chlorination Pump Nameplate

Operator's Comments

The dosing tubing inside the pump require frequent replacement as they typically have a short lifespan. Routine and as-needed maintenance are performed. No other issues have been experienced with the pumps.

Equipment Condition

The pump appeared to be in good condition, with no signs of wear or corrosion.

4.6.6.2 *Packed Tower*

Description

The packed tower is located on site to treat extracted groundwater. No information regarding the manufacturer and type of packed tower is known. **Figure 4.53** shows the Well 70 packed tower.

Figure 4.53: Packed Tower at Well 70

Operator's Comments

Operation's staff noted that the geodesic balls within the packed tower had been recently changed. The tower undergoes routine maintenance. No known issues are experienced with the packed tower.

Equipment Field Conditions

No conditional comments regarding the packed tower.

4.6.6.3 *Air Blower*

Description

The air blower is located upstream of the packed tower. It is a 24-inch New York Blower Company fume exhauster. **Figure 4.54** shows the Well 70 air blower and **Figure 4.55** shows the air blower nameplate.

Figure 4.54: Air Blower at Wellhead Site 70

Figure 4.55: Air Blower Nameplate

Operator's Comments

The air blower undergoes routine maintenance. No other known issues are experienced.

Equipment Field Conditions

Minor corrosion, chipping paint, and oil drippings are exhibited around the housing as shown on **Figure 4.56.**

Figure 4.56: Corrosion and Chipping Paint at Air Blower

4.6.6.4 *Booster Pump*

Description

The booster pump is a vertical turbine pumps with 75 HP US Motors vertical motor. **Figure 4.57** shows the Well 70 booster pump and **Figure 4.58** shows the booster pump motor nameplate.

Operator's Comments

The operator noted that the pumps worked well with no major issues as shown on **Figure 4.59**. The pump is regularly maintained for upkeep.

Equipment field conditions

The pumps exhibited some corrosion and buildup at ports and bolt locations. The pump did not run at the time of observation

Figure 4.57: Booster Pump at Wellhead Site 70

Figure 4.58: Booster Pump Motor Nameplate

Figure 4.59: Minor Corrosion of Motor

4.6.6.5 ***Flow Meter No. 1***

<u>Description</u>

The influent flow meter is an Altometer K480 10-inch magnetic flow meter with a Krohne digital display. All components are above-ground and exposed. **Figure 4.60** shows the Well 70 flow meter No. 1 and **Figure 4.61** shows the flow meter No. 1 nameplate.

<u>Operator's Comments</u>

The components have been fully operational without significant shutdowns. The flow meters require calibration every two weeks as part of routine maintenance.

<u>Equipment Field Conditions</u>

The components show some signs of deterioration of the coating due to sun light exposure and minor corrosion especially around bolt locations. However, these defects appear to be purely cosmetic.

Figure 4.60: Flow Meter No. 1 at Wellhead Site 70

Figure 4.61: Flow Meter No. 1 Nameplate

4.6.6.6 ***GAC Vessels No.1, No. 2, & No. 3***

Description

Three GAC vessels are located on site to treat extracted groundwater. The GAC vessels are certified by Trusco Tank Inc. Each GAC vessel is a 7,895-gallon welded tank, and includes inlet and outlet piping, three stainless steel injection and sample ports, an outlet valve, and an outlet flow meter. **Figure 4.62** shows the Well 70 GAC vessels and **Figure 4.63** shows the GAC vessel 2 nameplate.

Operator's Comments

Operation's staff noted that there are no existing issues with the GAC vessels and associated piping components. Regular maintenance is performed on these components. The GAC is replaced regularly. One issue is that the GAC vessels are vandalized as the site is trespassed on by transients frequently.

Equipment Conditions

The GAC vessels appear to be in good condition with no signs of major defects. There are signs of minor corrosion in localized areas, particularly around small injection ports. Some signs of oil leaks around valve housings were observed. Flanged connections exhibited some signs of corrosion but were in overall good condition as shown on **Figure 4.64**.

Figure 4.62: GAC Vessels at Wellhead Site 70

Figure 4.63: GAC Vessel 2 Nameplate

Figure 4.64: Oil and Minor Corrosion at Valve Housings

4.6.6.7 *Chlorine Analyzer*

Description

The chlorine analyzing system is a ProMinent Fluid Controls, Inc. analyzing system, with a measuring range of 1-10 PPM. Chlorine is measured downstream of the storage tank prior to distribution. **Figure 4.65** shows the Well 70 chlorine analyzing system and **Figure 4.66** shows the chlorine analyzer nameplate.

Operator's Comments

Typically, two to three hours are required to allow the distributed water to come into the analyzing probe due to the small supply line and low flow rates. The chlorine analyzers require calibration every two weeks as part of routine maintenance.

Equipment Condition

The analyzers appear to be in good overall working condition with no signs of wear.

Figure 4.65: Chlorine Analyzing System at Wellhead Site 70

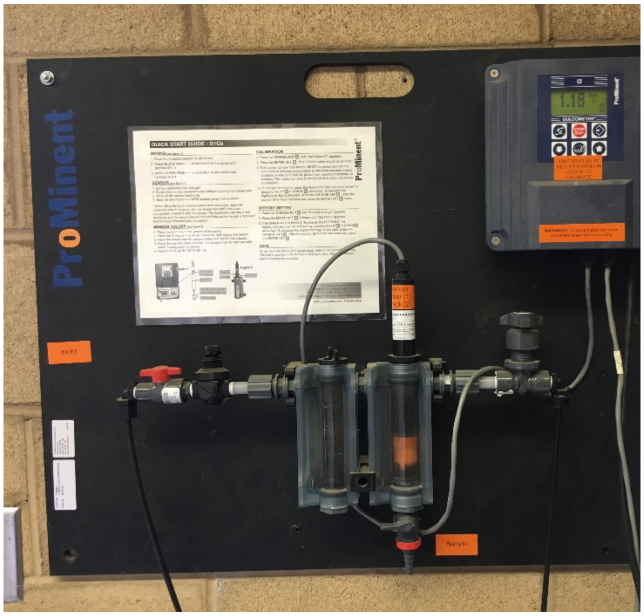


Figure 4.66: Chlorine Analyzer Nameplate

4.6.6.8 *Chlorination Pump*

Description

The chlorine pump is a Grundfos Type DDA 7.5-16 dosing pump. It regularly doses chlorine from an on-site chlorine storage tank into the treatment stream downstream of the GAC vessels. The pump and storage tank are housed in an on-site, ventilated housing with a locking door. **Figure 4.67** shows the Well 70 post-chlorine dosing pump and **Figure 4.68** shows the post-chlorine pump nameplate.

Operator's Comments

The dosing tubing inside the pump require frequent replacement as they typically have a short lifespan. Routine and as-needed maintenance are performed. No other issues have been experienced with the pumps.

Equipment Condition

The pump appeared to be in good condition, with no signs of wear or corrosion.

Figure 4.67: Post-Chlorine Dosing Pump at Wellhead Site 70

Figure 4.68: Post-Chlorination Pump Nameplate

4.6.6.9 ***Orthopolyphosphate Pump***

<u>Description</u>

The chlorine pump is a ProMinent Gamma/5 dosing pump. It regularly doses orthopolyphosphate from an on-site storage tank into the treatment stream downstream of the packed tower aeration. The pump and storage tank are housed in an on-site, ventilated housing with a locking door. **Figure 4.69** shows the Well 70 ortopolyphosphate dosing pump and **Figure 4.70** shows the orthopolyphosphate pump nameplate.

<u>Operator's Comments</u>

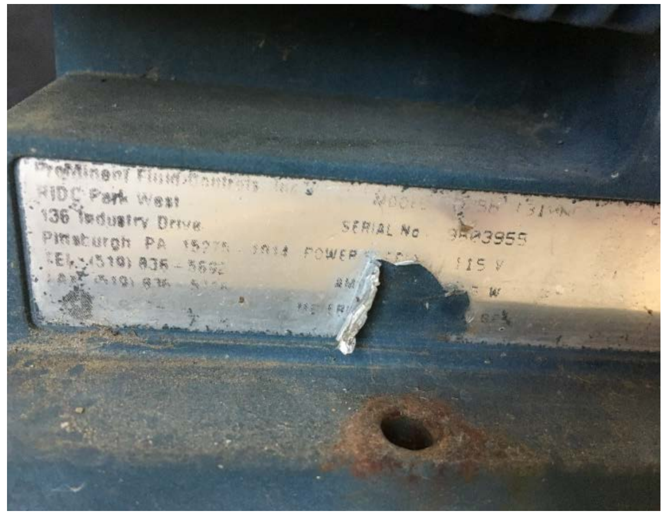
The dosing tubing inside the pump require frequent replacement as they typically have a short lifespan. Routine and as-needed maintenance are performed. No other issues have been experienced with the pumps.

<u>Equipment Condition</u>

The pump appeared to be aged, however exhibiting signs of abnormal wear and corrosion.

Figure 4.69: Orthopolyphosphate Dosing Pump at Wellhead Site 70

Figure 4.70: Orthopolyphosphate Pump Nameplate



4.7 RISK SCORES, RECOMMENDATIONS, AND COSTS

Risk scores for each of the equipment units are found in **Table 4.1**, Wellhead Treatment R&R Summary Table. Recommendations to "add bypass" were given to units that are integral to the treatment train that do not currently possess a bypass to allow for removal of the units without rendering a complete shutdown of the well. A bypass includes piping and associated valves to allow for the treatment train to operate while the unit is taken offline.

Recommendations to "add on-shelf spare" were given to units that are lacking redundant units within the treatment train and would otherwise suffer significant consequences to flow or water quality (scores of 3, 4, or 5.) In this situation, an identical unit is recommended to build redundancy.

The following risk scores, recommendations, and costs were provided for the equipment at each of the representative wellhead treatment facilities:

Well 70 – Representative of PTA/GAC Treatment

Priority 1: None of the equipment received scores greater than 15, therefore no need for immediate R&R improvements action.

Priority 2: The following equipment were given scores between 5-15 and require R&R recommended improvements to be implemented within 5 years:

- *Packed Tower: Risk score 6.67; recommended on-site refurbishment – add bypass*
- *GAC Vessel: Risk score 6.00; regular maintenance recommended*
- *Chlorine analyzer: Risk score 5.00; recommended to add an on-shelf spare*

Priority 3: The following equipment were given scores between 0-5 and require long term action (after 5 years):

- *Pre-chlorination pump: Risk score 4.00; regular maintenance recommended*
- *Post-chlorination pump: Risk score 4.00; regular maintenance recommended*
- *Flow meter: Risk score 4.00; recommended to add bypass*
- *Air blower: Risk score 3.33; recommended to replace once past useful service life*
- *GAC vessel pressure reducing valve: Risk score 1.67; regular maintenance recommended*

Cost of recommended R&R improvements at Well 70: $144,136
Cost of recommended R&R improvements at all PTA/GAC treatment sites (two total): **$288,272**

Well 330 – Representative of Oxidation & Filtration Treatment

Priority 1: None of the equipment received scores greater than 15, and no need for immediate R&R improvement is required

Priority 2: The following equipment were given scores between 5-15 and require action within 5 years:

- *Manganese filters: Risk score 8.00; recommended on-site refurbishment – add bypass*
- *Chlorine pump: Risk score 5.00; regular maintenance recommended*
- *Chlorine analyzer: Risk score 5.00; recommended to add an on-shelf spare*

Priority 3: The following equipment were given scores between 0-5 and require action after 5 years:

- *Flow meter: risk score 4.00; recommended to add bypass*

Cost of recommended R&R improvements at Well 330: $192,000

Cost of recommended R&R improvements at all Oxidation & Filtration treatment sites (three total): **$576,000**

Well 225 – Representative of GAC & Blending Treatment

Priority 1: None of the equipment received scores greater than 15, and no need for immediate R&R improvement is required.

Priority 2: The following equipment were given scores between 5-15 and require action within 5 years:

- *GAC vessel: risk score 10.00; recommended to add bypass*
- *Chlorine pump: Risk score 6.00; regular maintenance recommended*
- *Chlorine analyzer: Risk score 6.00; recommended to add on-shelf spare*
- *Flow meter 1: Risk score 6.00; recommended to replace*
- *Flow meter 2: Risk score 5.33; recommended to replace*

- *2-MG reservoir: Risk score 5.00; regular maintenance recommended*
- *Well 184 pipe connection: Risk score 5.00; regular maintenance recommended*

Priority 3: The following equipment were given scores between 0-5 and require action after 5 years:

- *Nitrate Analyzer: Risk score 4.67; regular maintenance recommended*
- *Nitrate sequencer: Risk score 2.67; regular maintenance recommended*

Cost of recommended R&R improvements at Well 225: $222,400

Cost of recommended R&R improvements at all GAC & Blending treatment sites (10 total): **$2,224,000**

Well 354 – Representative of GAC Treatment

Priority 1: None of the equipment received scores greater than 15¸ and no need for immediate R&R improvement is required.

Priority 2: The following equipment were given scores between 5-15 and require action within 5 years:

- *Chlorine pump: Risk score 7.00; regular maintenance recommended*
- *Nitrate analyzer: Risk score 6.00; regular maintenance recommended*
- *GAC vessels: Risk score 5.33; recommended to add bypass*
- *Orthophosphate pump: Risk score 5.33; regular maintenance recommended*
- *Chlorine analyzer: Risk score 5.00; regular maintenance recommended*
- *Flow meter: Risk score 5.00; regular maintenance recommended*

Priority 3: The following equipment were given scores between 0-5 and require action after 5 years:

- Flow meters: risk score 3.33; regular maintenance recommended

Cost of recommended R&R improvements at Well 354: $161,280

Cost of recommended R&R improvements at all GAC treatment sites (17 total): **$2,741,760**

Well 143 – Representative of De-gassing Treatment

Priority 1: None of the equipment received scores greater than 15, and no need for immediate R&R improvement is required.

Priority 2: The following equipment were given scores between 5-15 and require action within 5 years:

- *De-gassing tank: Risk score 8.33; recommended to blast-in-place and repaint*
- *Booster pump VFD: Risk score 5.33; regular maintenance recommended*

- *Chlorine pump: Risk score 5.00; regular maintenance recommended*
- *Chlorine analyzer: Risk score 5.00; regular maintenance recommended*

Priority 3: The following equipment were given scores between 0-5 and require action after 5 years:

- *Booster pump: Risk score 4.67; recommended to replace*
- *Orthophosphate pump: Risk score 4.00; regular maintenance recommended*
- *pH Analyzer: Risk score 4.00; regular maintenance recommended*
- *Flow meter: Risk score 3.33; regular maintenance recommended*
- *De-gassing tank level element: Risk score 1.33; regular maintenance recommended*

Cost of recommended R&R improvements at Well 143: $128,000

Cost of recommended R&R improvements at all De-gassing treatment sites (11 total): **$1,408,000**

Total cost of recommended R&R at all well treatment sites, including 30% contingency: **$9,409,442**

A summary of all equipment risk scores, recommendations, and costs are provided in **Table 4.1**.

Table 4.1 Wellhead Treatment R&R Summary Table

Drinking Water Infrastructure Renewal and Replacement Plan

City of Fresno

#	Well Numbers	Unit Processes	Asset Type / Component	Sub - Component	# of Units	Asset Code	Well Installation Year	Typical Service Life	Remaining Service life	Percentage of Remaining Service life	Remaining Service Life Rating	Condition Assessment: Field Condition Assessment - Comments	Condition Assessment: Field Condition Rating	Plant Operations: Plant Operations - Comments	Plant Operations: Operator's Comments	Plant Operations: Plant Operations Rating	LOF/Serviceability [(M+O+R)/3)]	Consequence of Failure: Water Quality	Consequence of Failure: Flow	Consequence of Failure: CoF Rating [(Y+Z)/2]	Consequence of Failure: Comments	Risk Score	Recommendations	Equipment Cost Estimates	Labor, Taxes, OH&P	Total	Cost Estimates - All Wellhead Treatments
	Well 70 Wellhead Treatment Representative of PTA/GAC Treatment					1010007-204																			-	-	
	Representative for Wells 70 and 279																						**Total Well 70 R&R, $**	90,085	54,051	144,136	All 2 Wells
1	Well 70	PTA & GAC	Pre-chlorination Pump		1	204-1*	2011	15	8	53%	3	Good	2	Asset functions as supposed to	Regular scheduled maintenance	1	2.00	3	1	2		4.00	A, Regular Maintenance	$ -	$ -	$ -	
2	Well 70	PTA & GAC	Post-chlorination Pump		1	204-2*	2011	15	8	53%	3	Good	2	Asset functions as supposed to	Regular scheduled maintenance	1	2.00	3	1	2		4.00	A, Regular Maintenance	$ -	$ -	$ -	
3	Well 70	PTA	Packed Tower		1	204-3*	1997	30	9	30%	2	Good	2	Asset functions as supposed to	Regular scheduled maintenance. Level elements and air flow sensors have problems.	1	1.67	3	5	4	Assumed no bypass	6.67	D, Regular Maintenance, add bypass	$ 30,000	$ 18,000	$ 48,000	
4	Well 70	PTA	Air Blower		1	204-4*	1997	25	4	16%	1	Fair, some corrosion	3	Asset functions as supposed to	Runs 24/7	1	1.67	3	1	2		3.33	E, Replace	$ 48,750	$ 29,250	$ 78,000	
5	Well 70	PTA	Booster Pump		1	204-5*	2014	25	21	84%	1	Good, minor cosmetic defects	2	Asset functions as supposed to	New, 3-4 years old	1	1.33	1	5	3	No backup	4.00	A, Regular Maintenance	$ -	$ -	$ -	
6	Well 70	GAC	Orthophosphate Pump		1	204-6*	2001	15	-2	-13%	5	Good	2	Asset functions as supposed to	Needs paint, cosmetic.	1	2.67	3	1	2		5.33	A, Regular Maintenance	$ -	$ -	$ -	
7	Well 70	GAC	GAC Vessel 1		1	204-7*	1997	50	29	58%	3	Good	2	Asset functions as supposed to	-	1	2.00	3	3	3	Assumed no bypass	6.00	A, Regular Maintenance	$ -	$ -	$ -	$ 288,272
8	Well 70		GAC Vessel 1 PRV		1	204-8*	2007	15	4	27%	2	Good	2	Asset functions as supposed to	Pressure vessel works 95% of time	1	1.67	1	1	1		1.67	A, Regular Maintenance		$ -	$ -	
9	Well 70	GAC	GAC Vessel 2		1	204-9*	1997	50	29	58%	3	Good	2	Asset functions as supposed to	-	1	2.00	3	3	3	Assumed no bypass	6.00	A, Regular Maintenance	$ -	$ -	$ -	
10	Well 70		GAC Vessel 2 PRV		1	204-10*	2007	15	4	27%	2	Good	2	Asset functions as supposed to	Pressure vessel works 95% of time	1	1.67	1	1	1		1.67	A, Regular Maintenance		$ -	$ -	
11	Well 70	GAC	GAC Vessel 3		1	204-11*	1997	50	29	58%	3	Good	2	Asset functions as supposed to	-	1	2.00	3	3	3	Assumed no bypass	6.00	A, Regular Maintenance	$ -	$ -	$ -	
12	Well 70	GAC	GAC Vessel 3 PRV		1	204-12*	2007	15	4	27%	2	Good	2	Asset functions as supposed to	Pressure vessel works 95% of time	1	1.67	1	1	1		1.67	A, Regular Maintenance	$ -	$ -	$ -	
13	Well 70	GAC	Flow Meter		1	204-13*	1997	30	9	30%	2	Good	2	Asset works as expected 80% of the time	-	2	2.00	1	3	2		4.00	D, Regular Maintenance, add bypass	$ 6,000	$ 3,600	$ 9,600	
14	Well 70	PTA & GAC	Chlorine Analyzer		1	204-16*	2015	15	12	80%	1	Good	2	Asset works as expected 80% of the time	Requires calibration	2	1.67	5	1	3	Assumed no spare	5.00	D, Regular Maintenance, add on-shelf spare	$ 5,335	$ 3,201	$ 8,536	
	Well 330 Wellhead Treatment Representative of Oxid. & Filter. Treatment					1010007-643																			-	-	
	Representative for Wells 330, 101A and 326																						**Total Well 330 R&R, $**	120,000	72,000	192,000	All 3 Wells
1	Well 330	Oxidation & Filtration	Flow meter		1	643-1*	2000	30	12	40%	3	Good, minor cosmetic defects	2	Asset functions as supposed to	-	1	2.00	1	3	2		4.00	A, Regular Maintenance	$ -	$ -	$ -	
2	Well 330	Oxidation	Chlorine Pump		1	643-2*	2016	15	13	87%	1	Good, minor cosmetic defects	2	Asset works as expected 80% of the time	-	2	1.67	5	1	3		5.00	A, Regular Maintenance	$ -	$ -	$ -	
3	Well 330	Oxidation	Chlorine Analyzer		1	643-3 *	2016	15	13	87%	1	Good	2	Asset works as expected 80% of the time	-	2	1.67	5	1	3		5.00	A, Regular Maintenance	$ -	$ -	$ -	
4	Well 330	Oxidation & Filtration	Manganese Filter 1		1	643-4*	2005	30	17	57%	3	Good	2	Asset functions as supposed to	Routine maintenance every 2-3 years	1	2.00	3	5	4	Assumed no bypass	8.00	D, Regular Maintenance, add bypass	$ 12,000	$ 7,200	$ 19,200	
5	Well 330	Oxidation & Filtration	Manganese Filter 2		1	643-5*	2005	30	17	57%	3	Good	2	Asset functions as supposed to	-	1	2.00	3	5	4	Assumed no bypass	8.00	D, Regular Maintenance, add bypass	$ 12,000	$ 7,200	$ 19,200	
6	Well 330	Oxidation & Filtration	Manganese Filter 3		1	643-6*	2005	30	17	57%	3	Good	2	Asset functions as supposed to	-	1	2.00	3	5	4	Assumed no bypass	8.00	D, Regular Maintenance, add bypass	$ 12,000	$ 7,200	$ 19,200	
7	Well 330	Oxidation & Filtration	Manganese Filter 4		1	643-7*	2005	30	17	57%	3	Good	2	Asset functions as supposed to	-	1	2.00	3	5	4	Assumed no bypass	8.00	D, Regular Maintenance, add bypass	$ 12,000	$ 7,200	$ 19,200	$ 576,000
8	Well 330	Oxidation & Filtration	Manganese Filter 5		1	643-8*	2005	30	17	57%	3	Good	2	Asset functions as supposed to	-	1	2.00	3	5	4	Assumed no bypass	8.00	D, Regular Maintenance, add bypass	$ 12,000	$ 7,200	$ 19,200	
9	Well 330	Oxidation & Filtration	Manganese Filter 6		1	643-9*	2005	30	17	57%	3	Good	2	Asset functions as supposed to	-	1	2.00	3	5	4	Assumed no bypass	8.00	D, Regular Maintenance, add bypass	$ 12,000	$ 7,200	$ 19,200	
10	Well 330	Oxidation & Filtration	Manganese Filter 7		1	643-10*	2005	30	17	57%	3	Good	2	Asset functions as supposed to	-	1	2.00	3	5	4	Assumed no bypass	8.00	D, Regular Maintenance, add bypass	$ 12,000	$ 7,200	$ 19,200	
11	Well 330	Oxidation & Filtration	Manganese Filter 8		1	643-11*	2005	30	17	57%	3	Good	2	Asset functions as supposed to	-	1	2.00	3	5	4	Assumed no bypass	8.00	D, Regular Maintenance, add bypass	$ 12,000	$ 7,200	$ 19,200	
12	Well 330	Oxidation & Filtration	Manganese Filter 9		1	643-12*	2005	30	17	57%	3	Good	2	Asset functions as supposed to	-	1	2.00	3	5	4	Assumed no bypass	8.00	D, Regular Maintenance, add bypass	$ 12,000	$ 7,200	$ 19,200	
13	Well 330	Oxidation & Filtration	Manganese Filter 10		1	643-13*	2005	30	17	57%	3	Good	2	Asset functions as supposed to	-	1	2.00	3	5	4	Assumed no bypass	8.00	D, Regular Maintenance, add bypass	$ 12,000	$ 7,200	$ 19,200	
14	Well 330	Oxidation & Filtration	Chlorine Analyzer		1	643-14*	2016	15	13	87%	1	Good	2	Asset works as expected 80% of the time	-	2	1.67	5	1	3		5.00	A, Regular Maintenance	$ -	$ -	$ -	
	Well 225 Wellhead Treatment Representative of GAC & Blend. Treatment					1010007-036																			-	-	
	Representative for Wells 153-2, 180-2, 224, 225, 274, 297-2, 100-1, 100-2, 180-1, 153-1																						**Total Well 225 R&R, $**	139,000	83,400	222,400	All 10 Wells
1	Well 225	GAC & Blending	Flow meter 1		1	036-1*	2000	30	12	40%	3	Good	2	Asset functions below its expected level. Works 1/2 time or requires re-starting, or has limited	Frequent failures in SCADA communication	3	2.67	1	3	2		5.33	E, Replace	$ 12,000	$ 7,200	$ 19,200	
2	Well 225	GAC & Blending	Flow meter 2		1	036-2*	2000	30	12	40%	3	Fair	3	Asset functions below its expected level. Works 1/2 time or requires re-starting, or has limited	Frequent failures in SCADA communication	3	3.00	1	3	2		6.00	E, Replace	$ 12,000	$ 7,200	$ 19,200	
3	Well 225	GAC	Nitrate Analyzer 1 (GAC inlet)		1	036-3*	2010	15	7	47%	3	Good	2	Asset works as expected 80% of the time	Requires calibration	2	2.33	3	1	2		4.67	A, Regular Maintenance	$ -	$ -	$ -	
4	Well 225	GAC & Blending	Nitrate Sequencer		1	036-4*	2010	15	7	47%	3	Good, minor cosmetic defects	2	Asset works as expected 80% of the time	-	2	2.33	3	1	2		2.33	A, Regular Maintenance	$ -	$ -	$ -	
5	Well 225	GAC	GAC Vessel		1	036-5*	2000	50	32	64%	2	Fair, some corrosion	3	Asset functions as supposed to	Inside building, good condition	1	2.00	5	5	5	Assumed no bypass	10.00	D, Regular Maintenance, add bypass	$ 30,000	$ 18,000	$ 48,000	$ 2,224,000
6	Well 225	Blending	Well 184 Pipe Connection		1	036-6*	2000	50	32	64%	2	Fair, some corrosion	3		-		1.67	5	1	3		5.00	A, Regular Maintenance	$ -	$ -	$ -	
7	Well 225	GAC & Blending	Chlorine Pump		1	036-8*	2011	15	8	53%	3	Good	2	Asset functions as supposed to	-	1	2.00	5	1	3		6.00	A, Regular Maintenance	$ -	$ -	$ -	
8	Well 225	GAC & Blending	2-MG Reservoir		1	036-9*	1995	50	27	54%	3	Good	2		Level indicator, overflow instrumentation not working		1.67	1	5	3		5.00	A, Regular Maintenance	$ -	$ -	$ -	
9	Well 225	GAC & Blending	Booster Pump		4	036-10*	1996	25	3	12%	1	Fair, some corrosion	3	Asset functions as supposed to	-	1	1.67	1	3	2		3.33	E, Replace	$ 85,000	$ 51,000	$ 136,000	
10	Well 225	GAC & Blending	Chlorine Analyzer		1	036-12*	2013	15	10	67%	2	Good	2	Asset works as expected 80% of the time	Requires calibration	2	2.00	5	1	3		6.00	A, Regular Maintenance, add on-shelf spare	$ -	$ -	$ -	

Table 4.1 Wellhead Treatment R&R Summary Table

Drinking Water Infrastructure Renewal and Replacement Plan

City of Fresno

#	Well Numbers	Unit Processes	Asset Type / Component	Sub - Component	# of Units	Asset Code	Well Installation Year	Typical Service Life	Remaining Service life	Percentage of Remaining Service life	Remaining Service Life Rating	Condition Assessment: Field Condition Assessment - Comments	Condition Assessment: Field Condition Rating	Plant Operations: Plant Operations - Comments	Plant Operations: Operator's Comments	Plant Operations: Plant Operations Rating	LOF/Serviceability [(M+O+R)/3)]	Consequence of Failure: Water Quality	Consequence of Failure: Flow	Consequence of Failure: CoF Rating [(Y+Z)/2]	Consequence of Failure: Comments	Risk Score	Recommendations	Equipment Cost Estimates	Labor, Taxes, OH&P	Total	Cost Estimates - All Wellhead Treatments
	Well 225 Wellhead Treatment Representative of GAC & Blend. Treatment					1010007-036																			-	-	
	Representative for Wells 153-2, 180-2, 224, 225, 274, 297-2, 100-1, 100-2, 180-1, 153-1																						**Total Well 225 R&R, $**	139,000	83,400	222,400	All 10 Wells
1	Well 225	GAC & Blending	Flow meter 1		1	036-1*	2000	30	12	40%	3	Good	2	Asset functions below its expected level. Works 1/2 time or requires re-starting, or has limited	Frequent failures in SCADA communication	3	2.67	1	3	2		5.33	**E,** Replace	$ 12,000	$ 7,200	$ 19,200	
2	Well 225	GAC & Blending	Flow meter 2		1	036-2*	2000	30	12	40%	3	Fair	3	Asset functions below its expected level. Works 1/2 time or requires re-starting, or has limited	Frequent failures in SCADA communication	3	3.00	1	3	2		6.00	**E,** Replace	$ 12,000	$ 7,200	$ 19,200	
3	Well 225	GAC	Nitrate Analyzer 1 (GAC inlet)		1	036-3*	2010	15	7	47%	3	Good	2	Asset works as expected 80% of the time	Requires calibration	2	2.33	3	1	2		4.67	**A,** Regular Maintenance	$ -	$ -	$ -	
4	Well 225	GAC & Blending	Nitrate Sequencer		1	036-4*	2010	15	7	47%	3	Good, minor cosmetic defects	2	Asset works as expected 80% of the time	-	2	2.33	3	1	2		2.33	**A,** Regular Maintenance	$ -	$ -	$ -	
5	Well 225	GAC	GAC Vessel		1	036-5*	2000	50	32	64%	2	Fair, some corrosion	3	Asset functions as supposed to	Inside building, good condition	1	2.00	5	5	5	Assumed no bypass	10.00	**D,** Regular Maintenance, add bypass	$ 30,000	$ 18,000	$ 48,000	$ 2,224,000
6	Well 225	Blending	Well 184 Pipe Connection		1	036-6*	2000	50	32	64%	2	Fair, some corrosion	3		-		1.67	5	1	3		5.00	**A,** Regular Maintenance	$ -	$ -	$ -	
7	Well 225	GAC & Blending	Chlorine Pump		1	036-8*	2011	15	8	53%	3	Good	2	Asset functions as supposed to	-	1	2.00	5	1	3		6.00	**A,** Regular Maintenance	$ -	$ -	$ -	
8	Well 225	GAC & Blending	2-MG Reservoir		1	036-9*	1995	50	27	54%	3	Good	2		Level indicator, overflow instrumentation not working		1.67	1	5	3		5.00	**A,** Regular Maintenance	$ -	$ -	$ -	
9	Well 225	GAC & Blending	Booster Pump		4	036-10*	1996	25	3	12%	1	Fair, some corrosion	3	Asset functions as supposed to	-	1	1.67	1	3	2		3.33	**E,** Replace	$ 85,000	$ 51,000	$ 136,000	
10	Well 225	GAC & Blending	Chlorine Analyzer		1	036-12*	2013	15	10	67%	2	Good	2	Asset works as expected 80% of the time	Requires calibration	2	2.00	5	1	3		6.00	**A,** Regular Maintenance, add on-shelf spare	$ -	$ -	$ -	
	Well 354 Wellhead Treatment Facility - Typical of GAC Treatment					1010007-699																			-	-	
	Representative for Wells 85, 135A, 137, 164-2, 171-2, 175-2, 176, 185, 201, 205, 277, 283, 354, 28, 36, 184 and 275																						**Total Well 354 R&R, $**	100,800	60,480	161,280	All 17 Wells
1	Well 354	GAC	Flow Meter		1	699-1*	2015	30	27	90%	1	Good, minor cosmetic defects	2	Asset works as expected 80% of the time	Requires calibration	2	1.67	1	5	3		5.00	**A,** Regular Maintenance	$ -	$ -	$ -	
2	Well 354	GAC	GAC Vessel 1		1	699-2*	2008	50	40	80%	1	Good	2	Asset functions as supposed to	-	1	1.33	3	5	4	Assumed no bypass	5.33	**D,** Regular Maintenance, add bypass	$ 33,600	$ 20,160	$ 53,760	
3	Well 354	GAC	GAC Vessel 2		1	699-3*	2008	50	40	80%	1	Good	2	Asset functions as supposed to	-	1	1.33	3	5	4	Assumed no bypass	5.33	**D,** Regular Maintenance, add bypass	$ 33,600	$ 20,160	$ 53,760	
4	Well 354	GAC	GAC Vessel 3		1	699-4*	2008	50	40	80%	1	Good	2	Asset functions as supposed to	-	1	1.33	3	5	4	Assumed no bypass	5.33	**D,** Regular Maintenance, add bypass	$ 33,600	$ 20,160	$ 53,760	
5	Well 354	GAC	Flow Meter 1		1	699-5*	2013	30	25	83%	1	Good	2	Asset works as expected 80% of the time	Requires calibration	2	1.67	1	3	2		3.33	**A,** Regular Maintenance	$ -	$ -	$ -	$ 2,741,760
6	Well 354	GAC	Flow Meter 2		1	699-6*	2013	30	25	83%	1	Good	2	Asset works as expected 80% of the time	Requires calibration	2	1.67	1	3	2		3.33	**A,** Regular Maintenance	$ -	$ -	$ -	
7	Well 354	GAC	Flow Meter 3		1	699-7*	2013	30	25	83%	1	Good	2	Asset works as expected 80% of the time	Requires calibration	2	1.67	1	3	2		3.33	**A,** Regular Maintenance	$ -	$ -	$ -	
8	Well 354	GAC	Chlorine Pump		1	699-8*	2011	15	8	53%	3	Good	2	Asset works as expected 80% of the time	Requires calibration	2	2.33	5	1	3		7.00	**A,** Regular Maintenance	$ -	$ -	$ -	
9	Well 354	GAC	Nitrate Analyzer		1	699-9*	2013	15	10	67%	2	Good	2	Asset works as expected 80% of the time	Requires calibration	2	2.00	5	1	3		6.00	**A,** Regular Maintenance	$ -	$ -	$ -	
10	Well 354	GAC	Chlorine Analyzer		1	699-10*	2017	15	14	93%	1	Good	2	Asset works as expected 80% of the time	Requires calibration	2	1.67	5	1	3		5.00	**A,** Regular Maintenance	$ -	$ -	$ -	
	Well 143 Wellhead Treatment Facility - Typical of De-gassing Treatment					1010007-268																			-	-	
	Representative for Wells 321, 143, 133, 151, 176, 308, 319, 150, 89, 132, and 157																						**Total Well 143 R&R, $**	80,000	48,000	128,000	All 11 Wells
1	Well 143	De-gassing	Flow meter		1	268-1*	2013	30	25	83%	1	Good	2	Asset works as expected 80% of the time	Requires calibration	2	1.67	1	3	2		3.33	**A,** Regular Maintenance	$ -	$ -	$ -	
2	Well 143	De-gassing	De-Gassing tank		1	268-2*	1991	30	3	10%	1	Good, minor cosmetic defects	2	Asset works as expected 80% of the time	-	2	1.67	5	5	5		8.33	**B,** Blast in place, repaint	$ 40,000	$ 24,000	$ 64,000	
3	Well 143		De-Gassing tank Level Element		1	268-3*	2015	15	12	80%	1	Good	2	Asset functions as supposed to	-	1	1.33	1	1	1		1.33	**A,** Regular Maintenance	$ -	$ -	$ -	
4	Well 143	De-gassing	Booster Pump		1	268-4*	2004	25	11	44%	3	Fair, some corrosion	3	Asset functions as supposed to	VFD programming/operating range not properly set to adjust to distribution system changes 5% of the time	1	2.33	1	3	2		4.67	**E,** Replace	$ 40,000	$ 24,000	$ 64,000	
5	Well 143	De-gassing	Booster Pump VFD		1	268-5*	~~1991~~	~~25~~	~~-2~~	~~-8%~~	5	Good	2	Asset functions as supposed to	-	1	2.67	1	3	2		5.33	**A,** Regular Maintenance	$ -	$ -	$ -	$ 1,408,000
6	Well 143	De-gassing	Orthophosphate Pump		1	268-6*	2016	15	13	87%	1	Good	2	Asset functions as supposed to	-	1	1.33	5	1	3		4.00	**A,** Regular Maintenance	$ -	$ -	$ -	
7	Well 143	De-gassing	Chlorine pump		1	268-7*	2016	15	13	87%	1	Good	2	Asset works as expected 80% of the time	-	2	1.67	5	1	3		5.00	**A,** Regular Maintenance	$ -	$ -	$ -	
8	Well 143	De-gassing	Chlorine analyzer		1	268-8*	2016	15	13	87%	1	Good	2	Asset works as expected 80% of the time	Requires calibration	2	1.67	5	1	3		5.00	**A,** Regular Maintenance	$ -	$ -	$ -	
9	Well 143	De-gassing	pH analyzer		1	268-9*	2016	15	13	87%	1	Good	2	Asset functions as supposed to	-	1	1.33	5	1	3		4.00	**A,** Regular Maintenance	$ -	$ -	$ -	
																									Total Estimates	**847,816**	**7,238,032**
																									Contingency 30%	**254,345**	**2,171,410**
																									R&R Total	**1,102,161**	**9,409,442**

* These Asset Codes are assigned specific to this project

Legend:

YEAR	Derived from equipment nameplate
YEAR (yellow)	Unknown
YEAR (grey)	Educated guess based on observed information

LEGEND & ASSUMPTIONS:

1 Remaining Service Life = Year of Installation+Amortized Service life - 2018

2 Remaining Service Life Rating
- 80%-100%= 1
- 60%-80%= 2
- 40%-60%= 3
- 20%-40%= 4
- 0%-20%= 5

3 30 Equipment amortized service life per City of San Diego's NCWRP

4 15 Assumed equipment amortized service life per for the NEWFP

5 Field Condition Rating
- New = 1
- Good = 2
- Fair = 3
- Poor = 4
- Unusable/Not operational/Failed = 5

6 Plant Operation Rating
- Asset works as supposed to = 1
- Asset works as expected 80% of time = 2
- Asset functions below its expected level/Works 1/2 time/requires re-starting/has limited functionality = 3
- Asset only works occasionally or most of its functionality is impaired = 4
- Asset not operational = 5

7. Consequence of Failure Rating
- 7.1 Water Quality
  - No impact on water quality = 1
  - Partial impact on WQ = 2 (loss of redundancy >3+1)
  - Intermediate impact on WQ = 3 (loss of redundancy 2+1)
  - Substantial impact on WQ = 4 (loss of redundancy 1+1)
  - Catastrophic impact on WQ,, renders plant shut down = 5 (no redundancy)
- 7.2 Flow (plant hydraulic capacity)
  - No consequence, plant runs at full capacity = 1
  - Plant capacity reduced by 25% = 2 (loss of redundancy >3+1)
  - Plant capacity reduced by 50% = 3 (loss of redundancy 2+1)
  - Plant capacity reduced by 75% = 4 (loss of redundancy 1+1)
  - Catastrophic impact on plant capacity, renders plant shut down = 5

R&R Recommendation Codes

A - Regular Scheduled Maintenance: Cleaning, lubrication

B - On Site Repairs, assumes minor functional repairs to bring equipment to operational conditions, remove corrosion, paint touch ups and similar

C - On Site Refurbishment, assumes in-site or in plants shop refurbishment to clean, remove corrosion, repair paint, replace used up parts, ands similar

D - On Site or Off Site Refurbishment/Rehabilitation, assumes major undertaking to bring the equipment near to new condition or adding new

E - Replacement, assumes in-kind replacement with identical equipment unit

Cost estimates

A - Cost estimates doe not include regular maintenance, only replacements, fixes and new stuff

CHAPTER 5 – NORTHEAST SURFACE WATER TREATMENT FACILITY

This chapter documents the Northeast Surface Water Treatment Facility (NESWTF) asset inventory and explains the risk analysis methodology followed to identify and prioritize the NESWTF renewal and replacement recommendations.

5.1 SPECIFIC GOALS OF THE TREATMENT FACILITY EVALUATION

The City of Fresno has two active surface water treatment plants to provide water to the City's residential and commercial users including the Northeast Surface Water Treatment Facility (NESWTF, Plant) and the T-3 Surface Water Treatment and Storage Facility (T-3 SWTSF). The 30-million gallons per day (MGD) NESWTF was designed by Montgomery Watson and constructed in 2004 with a planned future expansion to 60 MGD. The Plant has been in operation since then.

Source(s) of raw water that feed the NESWTF include Millerton or Pine Flat Lake located at the foothills of the Sierra Nevada Mountains east of Fresno. The raw water is supplied to the Plant via the Fresno Irrigation District's Enterprise Canal. To increase reliability of the raw water supply to the Plant, the City of Fresno is constructing a new pipeline that will provide a supplemental and/or alternative water supply for the Plant.

With regular maintenance, the Plant provided the City with a reliable source of good quality water supply. However, the City wants to assess the physical conditions and to establish baseline requirements for scheduled and planned repairs and replacements (R&R) of the currently installed equipment within the Plant. More specifically, the principal goals of this R&R are to:

- Assess condition of the existing equipment within the Plant
- Identify process equipment deficiencies and recommended R&R improvements
- Assess costs of the improvements
- Prioritize R&R improvements

This R&R report includes condition assessment of the Plant's currently installed equipment with associated instrumentation. Although power requirements for the installed equipment are identified in this report, assessment of the electrical and power supply equipment was not included in the scope of this R&R. Similarly, hydraulic capacity and fitness of the installed equipment to control undesirable water quality constituents were not assessed.

5.2 FACILITIES INVENTORY

The NESWTF is designed as a modified conventional surface water treatment plant consisting of chemical pretreatment (Initial Flash Mixing), with coagulation-flocculation-sedimentation processes provided by a proprietary Actiflo system (Actiflo Basin), followed by ozonation (Ozone Contact Basin), deep bed dual media filtration (Deep Bed GAC/Sand Filters), and chemical post treatment consisting of disinfection (Chemical Mixing system) and final product water polishing (CO_2 and Caustic Soda Stabilization). The other NESWTF facility components at the Plant's inlet include Raw Water Intake Structure, Raw Water Pump Station and influent flow metering facility (Inlet Facility). The finished product water delivery system consists of the Treated Water Reservoir and the Treated Water Pump Station (see **Figure 5.1**).

For purposes of the assessment, the Plant was broken down into nine Plant components (Unit Processes in **Table 5.1**), including:

- Water intake
- Raw water pump station
- Plant inlet meter and initial flash mix
- Clarification (Actiflo Basin)
- Ozone system
- Filters
- Chemical building chemical systems
- Operations building pumping systems (including washwater and decant pump stations)
- Treated water pump station

Water intake consists of equipment pertinent to the water intake system that diverts and screens the source feed water. Condition assessment for equipment of this unit process included the travelling screen, inlet gate, and diversion gate.

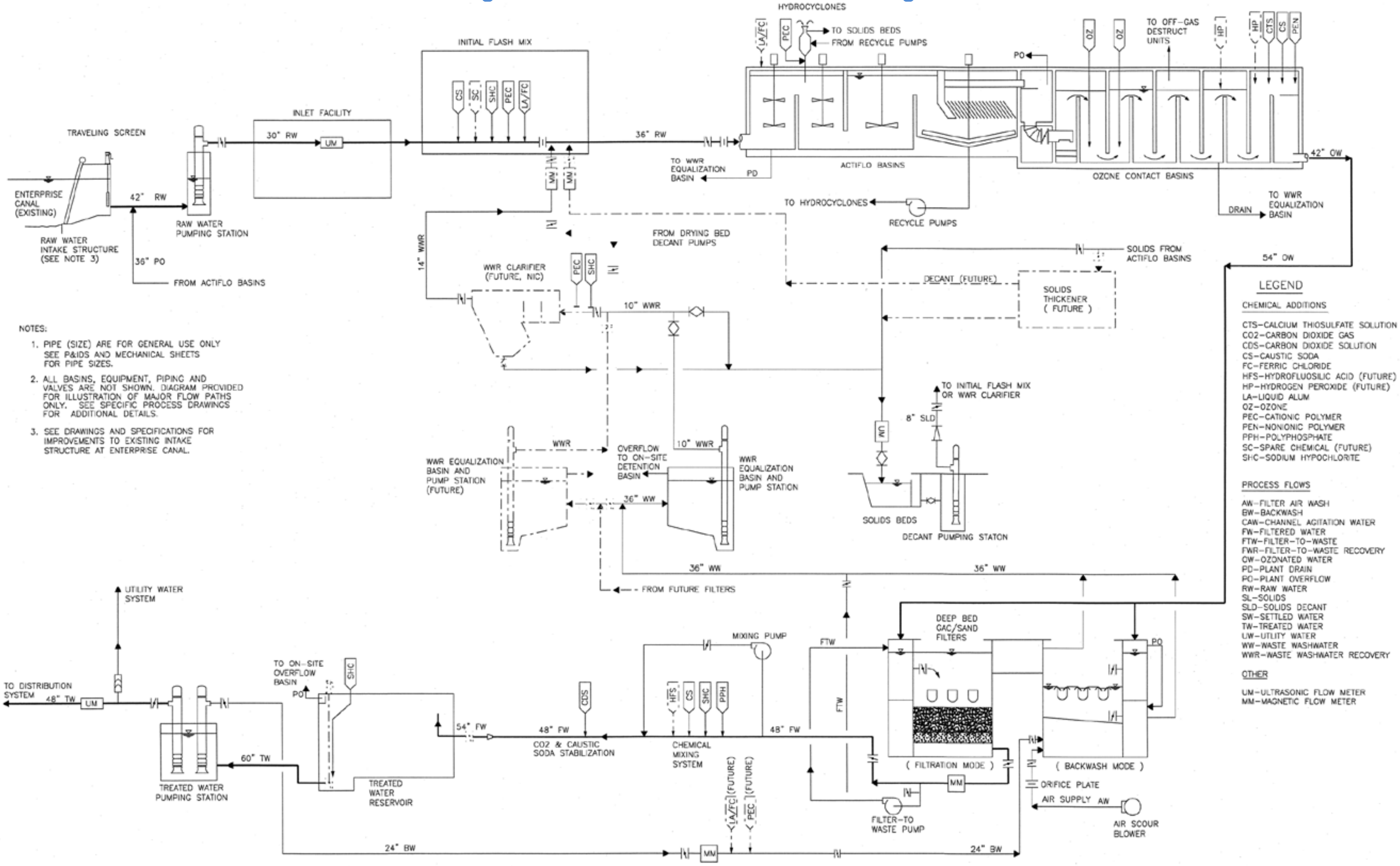
The Raw Water Pump Station consists of the pumps and motors that pumps raw water from the Enterprise Canal to the Plant for treatment. Condition assessment for equipment of this unit process included four pumps and four electric motors.

The Plant Inlet Meter and Initial Flash Mix consist of an ultra-sonic meter and chemical feed injection system that provide influent flow metering and chemical pre-treatment by injecting caustic soda, sodium hypochlorite, cationic polymer and coagulant, either liquid alum or ferric chloride. Condition assessment for equipment of this unit process included the Plant inlet flow meter and raw water sample pump.

Clarification (Actiflo Basin) provides for coagulation, flocculation and sedimentation of the Plant fed raw water and consists of mixing, flocculation, sludge scraping and pumping and sludge solid-sand separation. Condition assessment for equipment of this unit process included two injection mixers, two coagulation mixers, two flocculation mixers, two sludge scrapers, four hydrocyclones, four sludge wasting pumps, and two sampling pumps.

Ozone System provides for pre-disinfection, taste and odor control and consists of ozone generation and ozone contacting. Condition assessment for equipment of this unit process included liquid oxygen storage tank, two liquid oxygen vaporizers, two air particulate filters, two

Figure 5.1: NESWTF Process Flow Diagram



ozone generators, two moisture demisters, two zone destruction units, and two exhaust gas blowers.

Filters provide filtering of the Actiflo settled water including removal of remaining colloidal matter, bacteria and other filter removable contaminants. The filtration unit process consists of six deep-bed dual media filters, filter backwash system and the filtrate to waste pump system. Condition assessment for equipment of this unit process included two backwash water pumps and electric motors, air scour blower and electric motor, filter to waste water pump with electric motor, six filter influent valves and actuators, six filtered water valves and actuators, six backwash water valves and actuators, six air scour valves and actuators, six drain valves and actuators, and six filter to waste valves and actuators.

Chemical Building houses several chemical systems that provide chemical feed along the main water treatment process train including: 1. sodium hypochlorite system, 2. cationic polymer system, 3. non-ionic polymer system, 4. liquid alum or alternative ferric chloride system, 5. caustic chemical system, 6. polyphosphate system, 7. carbon dioxide system, and 8. Chemical Building drainage system. Condition assessment for equipment of this unit process included: 1. two storage tanks and three chemical feed pumps for sodium hypochlorite system, 2. one dry polymer batch unit and three chemical feed pumps for the cationic polymer system, 3. one dry polymer batch unit and three chemical feed pumps for the nonionic polymer system, 4. two storage tanks and three chemical feed pumps for the liquid alum/ferric chloride system, 5. two storage tanks and three chemical feed pumps for the caustic chemical system, 6. two weight scales and two chemical feed pumps for the polyphosphate system, 7. one storage tank, one vaporizer, one vapor heater and two carrier water pumps for the carbon dioxide system, and 8. four sump pumps for the Chemical Building drainage system.

Operations Building houses the Plant's potable water booster pump station and the washwater recovery system pumps. Condition assessment for equipment of these pumping systems included one pressure vessel and two pumps from the Plant's potable water booster pumping system, three washwater decant return pumps, three washwater equalization tank pumps, and the clearwell drain pump.

Treated Water Pump Station pumps the Plant's finished product water into City's distribution network. Condition assessment for equipment of this unit process included four pumps and four electric motors.

5.3 ASSET TYPES AND SYSTEM HIERARCHY

The NESWTF is a complex asset consisting of multiple components that are designed and constructed to provide the Plant's hydraulic capacity of 30 MGD and treatment process to produce finished product water quality that satisfies drinking water standards. To achieve these two principal objectives, the NESWTF is equipped with complex process mechanical equipment, multiple pump and piping systems with associated valves and other accessories, power supply, electrical equipment, instrumentation and control, and SCADA.

The treatment facility assets that are the focus of this document is the Plant's equipment described in Section 4.2 of this document, which includes condition assessment and R&Rs for the process mechanical equipment and most of the instrumentation, only. Power supply, electric equipment, Plant SCADA and the Plant's structures were not included in this study. However, considering that the Plant's structures are fairly new and apparently in good condition, it is recommended to complete a similar exercise to include condition assessment and R&Rs for the electrical equipment, all instruments and Plant's SCADA system since these are integral parts of the functionality of the entire water treatment facility.

5.4 AVAILABLE DATA

The following sources of information were utilized by Kleinfelder for this study:

- *Design drawings produced by Montgomery Watson in 2004*
- *Comments from operations staff during in-person meetings*
- *Operations and maintenance (O&M) manuals*
- *Field data collected from condition assessments as part of this study*

Historical records of Plant equipment failures and repairs, Plant maintenance records, as well as construction shop drawings, specifications, and/or other design documents were not available for this study.

Sources of the data used for this study are presented in the following sections.

5.4.1 Design Drawings

The City provided Kleinfelder's team with both electronic and hard copies of the design drawings from the Plant's original design by Montgomery Watson in 2004.The drawings were organized by area and discipline. Kleinfelder utilized the design drawings to study and understand the Plant's treatment systems, identify unit process with their equipment components and sub-components, and to organize its condition assessment approach and reporting.

Process schematics (process flow diagram) and hydraulic profiles were utilized to understand the Plant's treatment process and to identify key unit processes. The process mechanical design and instrumentation and control diagram (P&ID) drawings were utilized to identify components and sub-components of the identified unit processes. A list of the equipment for condition assessment was derived and organized based on and following the original design drawings. Additional review of the design P&IDs, mechanical, civil, and structural drawings was performed for each respective area to confirm the list of critical equipment components and sub-components for each treatment unit process.

5.4.2 Meetings with City Operations Staff

Three in-person meetings were held between Kleinfelder's team and the City's NESWTF operation staff to obtain additional information regarding operation and condition of the Plant's equipment. The first meeting was held before the field condition assessment was conducted, and the second meeting was held at the end of the field condition assessment. Both meetings were held at the Plant. Third meeting was held at the City's water operation yard with objective to receive comments on the initial condition assessment findings and recommendations.

The first meeting provided Kleinfelder with a comprehensive, organized list of treatment systems and their critical equipment components and sub-components. Kleinfelder reviewed the list of critical equipment derived from the design document reviews with operations staff to confirm the list was comprehensive of all critical equipment units. This meeting also served the purpose of verifying the number of installed equipment units as compared to the design drawings, for example, to confirm whether the number of hydrocyclones shown on the record drawings matched what was installed. This meeting also provided some verbal insights of historical equipment failures, replacements, and/or refurbishments.

The second meeting consisted of presenting information derived from the field condition assessment to the Plant's operations staff. The Plant's staff provided comments on findings from the Kleinfelder completed field condition assessment, with hopes of providing some explanations and insights for observed conditions. During the meeting, the operation staff provided additional information of failures, repairs and replacement of equipment that was not noted in the initial meeting. Finally, the Plant's staff provided rating for each unit process component and subcomponent based on current operation, which was later used for risk assessment.

During the third meeting Kleinfelder presented initial condition assessment findings and recommendations to the City staff. At that occasion, the City staff provided comments on the initial condition assessment results, which are incorporated in the draft final report.

5.5 RISK ANALYSIS METHODOLOGY

Equipment "Serviceability" or "Likelihood of failure" as well as "Consequences of Failure" were numerically assessed to calculate risk for the treatment and process assets i.e. treatment and process equipment and their associated components and sub-components.

5.5.1 Equipment Serviceability/Likelihood of Failure Analysis

The four-tier Serviceability/Likelihood of Failure analysis were initially planned to utilize:

- Statistical analysis of the equipment past performance,
- Field equipment condition assessment,
- City Plant operation staff assessment of the equipment operational condition, and,
- The equipment's remaining useful service life.

For each of the four tiers, each equipment component was to be numerically rated with rating ranks from 1 (as the best condition) to 5 (as the worst condition). For each equipment component (asset), the averaged numerical rating was calculated, which is denoted as the asset, Serviceability or Likelihood of Failure rating.

Statistical Analysis of Past Performance: The existing NESWTF has been operated and maintained, and currently is running satisfactory providing good water quality to the City's water distribution system. However, historical data of the Plant's shutdowns, maintenance and troubleshooting, as well as malfunctions and failures were not available for this document. Therefore, statistical analysis of the past performance as basis for prediction of future likelihood of failure was not performed.

Field Equipment Condition Assessment: For each treatment unit process at the Plant, unit process equipment components and subcomponents were listed. During the four-day field surveillance, physical and operational conditions were assessed for each individual component and its subcomponents. The field condition of the inspected equipment along with comments provided by the Plant's operator(s) was documented and is presented in the Section 4.6. Field physical equipment condition of each of the component is rated using a numerical rating from 1 to 5, as follows:

- New, 1
- Asset in good condition, 2
- Asset in fair condition, 3
- Asset in poor condition, 4
- Asset unusable/not operational/failed, 5

Plant Operation Staff Rating: During a one-day workshop/meeting, the Plant's operation staff provided their ratings for each of the Plant's components and sub-components. To rate the operability and functionality of each component (asset), the City staff used the numerical rating from 1 to 5 as follows:

- Asset works as supposed to, 1
- Asset works as expected 80% of time, 2
- Asset functions below its expected /Works 1/2 time/requires re-starting/has limited functionality, 3
- Asset works only occasionally or most of its functionality is impaired, 4
- Asset not operational, 5

Equipment Remaining Useful Service Life: The rating of the equipment useful service life is based the percent of the remaining useful service life, which is calculated based on the formula:

$$RUSL = \frac{RSL}{SL}\,x100$$

Where:

RUSL is remaining useful service life expressed as a percent of 100 percent

RSL is remaining service life in number after 2018 expressed in number of years
SL is total asset's service life expressed in number of years

Based on the year when the Plant was installed, or when any of the component is replaced or rehabilitated, the remaining service life (RSL) was assessed with 2018 as the reference year i.e. the remaining service life time after year 2018. The total asset's service life (SL) was allocated for each equipment component (assets), based on the guidelines from City of San Diego Asset Management Program, or if not available, based on industry standards and/or manufacturer's recommendations

The numerical rating of the equipment remaining useful service life is 1 to 5, as follows.

- 80% to 100% remaining useful service life, 1
- 60% to 80% remaining useful service life, 2
- 40% to 60% remaining useful service life, 3
- 20% to 40% remaining useful service life, 4
- 0% to 20% remaining useful service life, 5

The numerical average of the Field Condition Assessment, Plant Operations Staff and Equipment Remaining Useful Service Life ratings are denoted as the equipment "Serviceability" rating or the equipment "Likelihood of Failure" rating for future risk assessment.

5.5.2 Consequence of Failure Analysis

Two consequences of failure of the Plant's process and treatment equipment were analyzed for risk assessment, including:

1. Consequence on water quality, and,
2. Consequence on plant capability to produce flow.

Consequence on Water Quality: Impacts of a failure to produce the targeted water quality for of the Plant's process and treatment components were evaluated and rated with numeric scores ranging from 1 to 5, as follows:

- No impact on water quality, 1
- Partial impact on water quality (loss of redundancy, >3+1), 2
- Intermediate impact on water quality (loss of redundancy, 2+1), 3
- Substantial impact on water quality (loss of redundancy, 1+1), 4
- Catastrophic impact on water quality - renders plant shut down (no redundancy), 5

Equipment redundancy was considered as a safeguard of the ability of the Plant to produce the targeted water quality. For example, if the chemical feed system has two duty and one standby chemical pump, failure of one pump will not have impact and failure of two pumps will have only partial impact on plant's ability to provide the needed water quality. Hence, a score of 3 was provided for this scenario.

Consequence on Flow: Similar to the water quality assessment, impacts of a failure to produce the targeted product water flow for each Plant component was also evaluated and rated with numeric scores ranging from 1 to 5, as follows:

- *No consequence, plant runs at full capacity, 1*
- *Plant capacity reduced by 25% (loss of redundancy, >3+1), 2*
- *Plant capacity reduced by 50% (loss of redundancy, 2+1), 3*
- *Plant capacity reduced by 75% (loss of redundancy, 1+1), 4*
- *Catastrophic impact on flow capacity - renders plant shut down (no redundancy), 5*

As for the flow, equipment redundancy was considered as a safeguard to ability of the Plant to produce the targeted product water flows. For example, if the filter backwash supply system has one duty and one standby pump, failure of one pump will not have immediate impact on plant's ability to produce needed water flow. However, this component scores 4 because of the risk that standby pump may not be operational when required or may fail without backup.
The numerical averages of the Consequence on Water Quality and Consequence on Flow ratings are denoted for the further risk assessment as the overall Consequence of Failure rating.

5.5.3 Risk Scoring and Prioritization

A risk score for each individual equipment component (asset) is calculated as a product of multiplication of the Likelihood of Failure rating and the Consequence of Failure rating. Since the lowest numerical rating for both risk components is 1 and the highest 5, the lowest possible risk score is 1 and the highest possible risk score is 25.

To prioritize the City's action in addressing the issues of possible equipment failure, all assets are grouped in three priority categories as follows:

- *Priority 1 (High Priority) – Assets scored with a risk score of 15 or higher, immediate action required*
- *Priority 2 (Intermediate Priority) – Assets scored with a risk score of 5 to 15, action required in 5-year span*
- *Priority 3 (Low Priority) – Assets scored a with risk score below 5, action required after 5 years*

5.5.4 R&R Recommendations

All asset (equipment components) R&R recommended improvements are grouped in five categories as follows:

A - Regular Scheduled Maintenance: assumes cleaning, lubrication, scheduled part replacements and similar.
B – On-Site Repairs, assumes minor repairs to bring equipment to operational condition such as seal replacement, corrosion removal, paint touch ups and similar.
C – On-Site Refurbishment, assumes on-site or in-plant shop refurbishment to clean, remove corrosion, repair paint, replace used up parts, and similar.

D – On-Site or Off-Site Refurbishment/Rehabilitation, assumes major undertaking to bring the equipment near to new condition or adding new features to the unit or facility.

E - Replacement, assumes in-kind replacement with identical equipment unit.

5.5.5 Cost Estimates of R&R Recommended Improvements

A budgetary (+35/-30%) level cost estimate was prepared for the recommended improvements.

The conventional approach for cost estimating uses design plans and specifications. Since design specifications for the identified and recommended R&Rs were not available, the conventional construction cost estimate approach was not applicable.

Therefore, a "direct" cost estimating approach was employed to obtain budgetary cost estimates for the recommended equipment upgrades. The direct cost included direct cost of material/equipment and cost to implement the recommended R&R improvements. Existing information such as model numbers, serial numbers, and photographs of equipment units were provided to the equipment's original manufacturers and vendors, and cost quotes were obtained for in-kind equipment. Cost of upgraded technologies of equipment were utilized if needed or in case when the identical to the currently installed equipment is no longer manufactured. Equipment manufacturer historical knowledge was helpful, as many of the manufacturers have records of the original installation at the Plant, and thus could provide updated cost quotes for the equipment units. Manufacturer published cost for off-shelf items such as for and general materials such as valves and other smaller equipment were used for estimating cots of the R&R recommended improvements. Kleinfelder's institutional knowledge on cost of equipment and systems from similar facilities was also utilized.

The estimated costs of installation of the proposed R&R improvements assumes that all R&R improvements will be implemented by an outside contractor. It needs to be noted that regular maintenance that is performed by the City maintenance staff is not included in the estimated R&R improvement costs.

Taxes and shipment cost were also added to the equipment quotes, as the quotes from equipment vendors and manufacturers did not include these costs. To estimate installation costs for the recommended R&R improvements, a multiplier of 1.6 was applied on the cost of material and equipment supplies.

5.6 CONDITION ASSESSMENT RESULTS

Findings from the field condition assessment as well as comments from the operators are presented in the following sections. Scores pertaining to each equipment unit's field condition assessment and plant operator's ratings are found in **Table 5.1**.

5.6.1 Water Intake

The water intake system includes a travelling screen, inlet gate, and a diversion gate. These are located on the northern central part of the property adjacent to North Chestnut Road. The water intake system is shown in **Figure 5.2**.

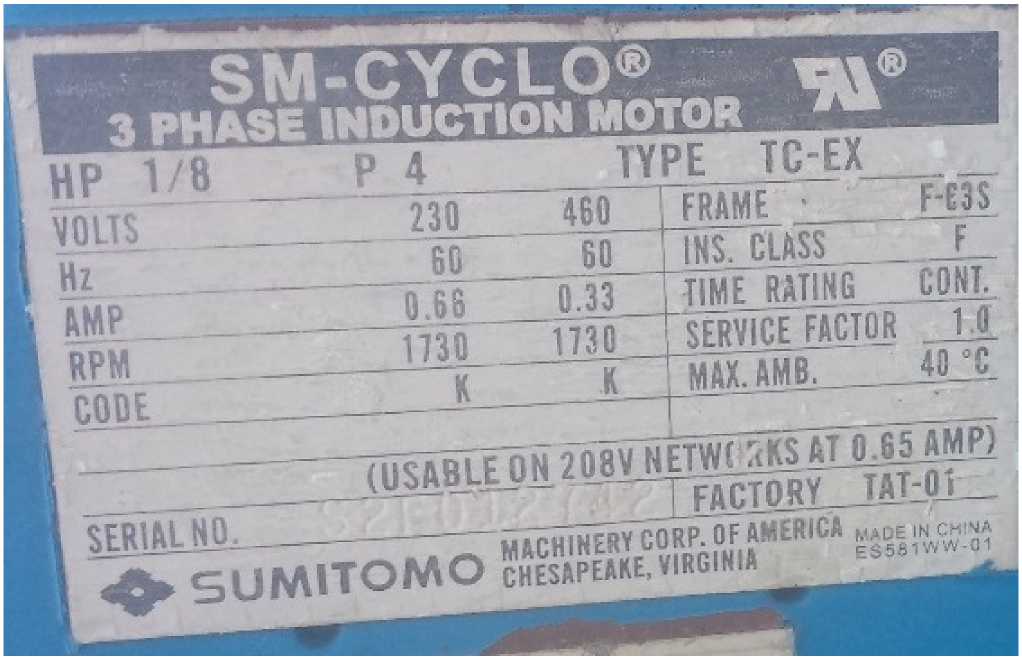
Figure 5.2: General View of Water Inlet Process

5.6.1.1 *Travelling Screen*

Description

The travelling screen is located in a fenced enclosure on the northern central part of the property adjacent to North Chestnut Road. The tag number on the record drawings is 1-ME-11, however a field tag number was not found. The screen is powered by a 1/8 HP Sumitomo 3 phase induction electric motor. The make and model of the screen is unknown. **Figure 5.3** shows the motor nameplate.

Figure 5.3: Travelling Screen Electric Motor Nameplate



Plant Staff Comments

The travelling screen has been repaired and operating properly since 2013. The plant operators were satisfied with the condition of the bar screens themselves and did not feel a need for rehabilitation or replacement.

Equipment Field Conditions

The travelling screen was properly functioning during the site investigation, the mechanical equipment was properly oiled and moving without difficulties.

5.6.1.2 *Inlet Gate*

Description

The inlet gate is adjacent and located south of the travelling screen. It is manually operated by a hand-wheel to regulate the inlet flow, see **Figure 5.4**. The inlet gate is normally completely open except during plant shut-downs.

Figure 5.4: Inlet Gate Top View

Plant Staff Comments

The inlet gate has not presented any major issues.

Equipment Field Conditions

At the time of the field inspection the inlet gate was submerged and functioning properly. The tag number on the record drawings is 1-ME-12, however a field tag number was not found. Visual inspection of the inlet gate was possible to perform.

5.6.1.3 *Diversion Gate*

Description

The diversion gate is adjacent and located north of the travelling screen. It is operated by the electric Rotork electric actuator. See **Figure 5.5** for diversion gate electric actuator nameplate. The actuator tag number on the record drawings is 1-MOV-10, however a field tag number was not found. The gate was submerged at the time of the inspection.

Figure 5.5: Diversion Gate Electric Actuator Nameplate

Plant Staff Comments

The electric actuator was installed in 2010, no major issues have been reported.

Equipment Field Conditions

Both the electric component and the mechanical components appear to be in good condition.

5.6.2 Raw Water Pump Station

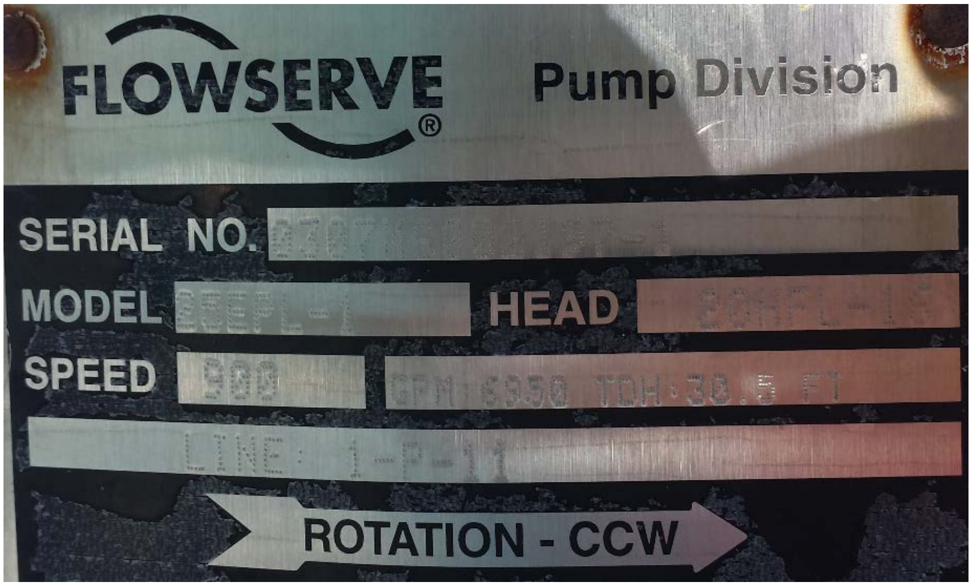
The Raw Water Pump Station is located west of the Chemical Building and it consists of four pumps and their electric motors.

5.6.2.1 *Raw Water Pump Station Pumps*

Description

All four pumps are Flowserve model 25EPL-1 with a rated capacity of 6,950 GPM at 30.5 feet of TDH and an operating speed of 900 RPM. Figure 5.6 shows the nameplate of one pump.

Figure 5.6: Raw Water Pump Plate Information



Plant Staff Comments

All pumps have worked properly since being installed in 2004. In 2015 pump 1-P-11 and 1-P-12 were pulled for regular maintenance.

Equipment Field Conditions

The raw water pumps were identified by the field tags 1-P-11, 1-P-12, 1-P-13, and 1-P-14. At the time of the site investigation only 1-P-12 and 1-P-13 were operating. The pumps appear to be in overall good condition as shown in **Figure 5.7**.

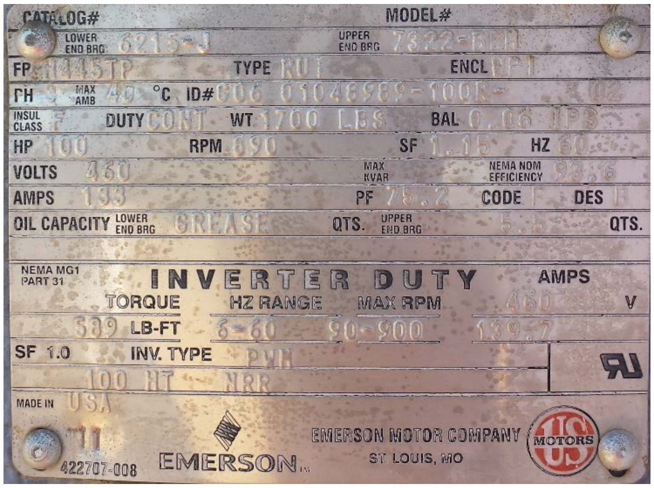
Figure 5.7: Raw Water Pumps

5.6.2.2 ***Raw Water Pump Station Electric motors***

<u>Description</u>

The raw water pump electric motors were all manufactured by Emerson Motor Company (US Motors) and are rated 100 HP. **Figure 5.8** shows the typical plate for the motors.

Figure 5.8: Raw Water Pump Electric Motor Nameplate



<u>Plant Staff Comments</u>

All motors have been working properly since installation in 2004.

<u>Equipment Field Condition</u>

All motors appear to be in overall good condition.

5.6.3 Plant Inlet Meter and Flash Mixing

5.6.3.1 ***Influent Flow Meter***

<u>Description</u>

The Influent Flow Meter measures the Plant's influent flow pumped by the Raw Water Pump Station through a 36-inch pipeline. The flow meter is a magnetic flow meter manufactured by Siemens. The tag number identified on the as-built drawings is FE/FIT-001, however no field tag number was found. **Figure 5.9** shows the Plant Influent Flow Meter and **Figure 5.10** shows the flow meter nameplate.

Figure 5.9: Plant Influent Flow Meter

Figure 5.10: Flow Meter Nameplate

<u>Plant Staff Comments</u>

No comments were provided.

<u>Equipment Field Condition</u>

The influent flow meters appear to be in overall good condition. A bird nest was observed on the flow meter control panel as shown in **Figure 5.11**.

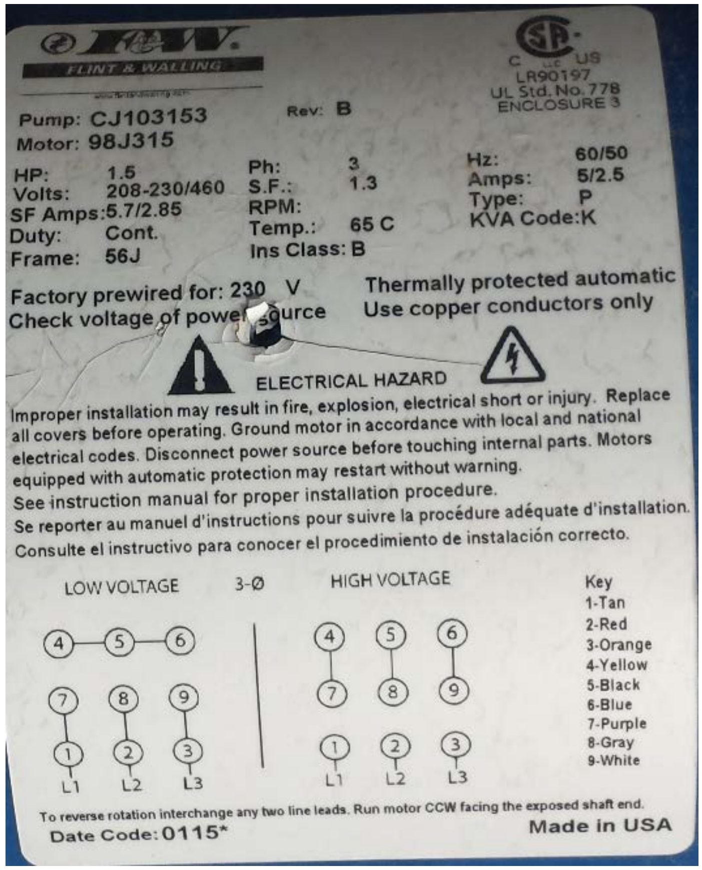
Figure 5.11: Flow Meter Control panel

5.6.3.2 *Influent Sample Pump*

Description

The Influent Sample Pump is located adjacent to the Influent Flow Meter. The pump is identified as 2-P-11 by a field tag. The sample pump is a 1.5 HP pump manufactured by Flynt and Walling. **Figure 5.12** shows the technical characteristics of the pump and electric motor. The pump was running properly at the time of inspection.

Figure 5.12: Influent Sample Pump and Motor Nameplate



<u>Plant Staff Comments</u>

The sample pump has always been functional and has never had major issues.

<u>Equipment Field Condition</u>

The equipment was running properly at the time of inspection and it appears to be in good condition. The fittings appear to be in good condition with no apparent leaks.

5.6.4 Clarification Basin/Actiflo

There are two Actiflo units at the Plant located on the east central part of the site, adjacent to the management office and maintenance building, Figure 5.13 shows the approximate location of the units on site. The two units have been in operation since 2004 when the plant was first commissioned.

Figure 5.13: Site View with Highlighted Actiflo Units.

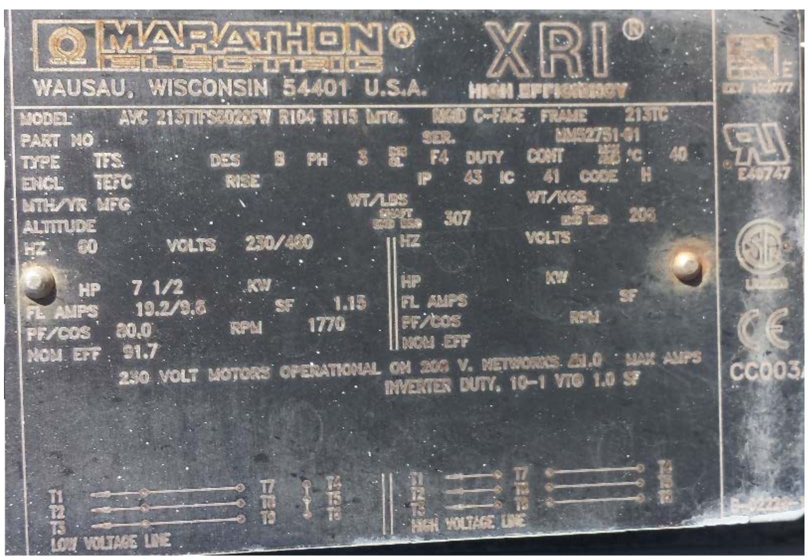
5.6.4.1 *Coagulation Mixers*

Description

There are a total two coagulation mixers. The coagulation mixers were identified by the field tag 3-ME-11 and 3-ME-21. One for mixer is dedicated to each Actiflo treatment train. The mixers are Philadelphia mixers with a ratio of 38.4 to 1 and an output speed of 45 RPM. See **Figure 5.14** for the nameplate information of one of the mixers. The mixers are powered by a 7.5 HP Marathon Electric motor. **Figure 5.15** shows the nameplate of one of the electric motors.

Figure 5.14: Coagulation Mixer Nameplate

Figure 5.15: Coagulation Mixers Electric Motor Nameplate



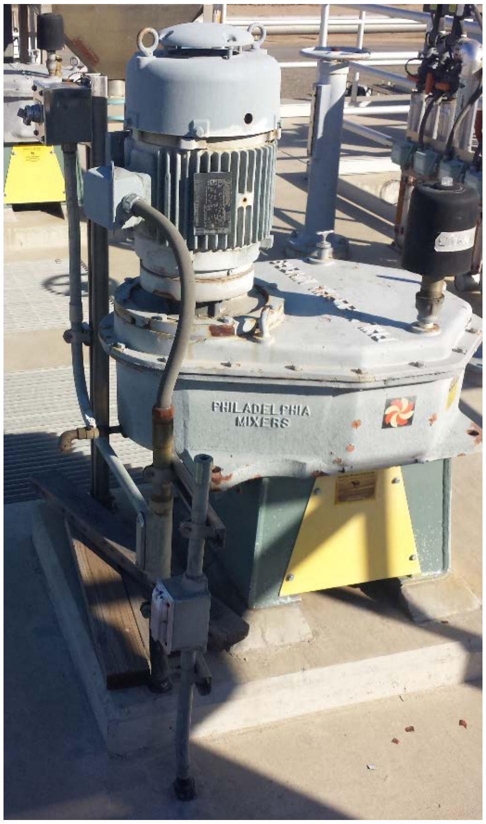
Plant Staff Comments

No comments were provided.

Equipment Field Condition

The mixers were submerged at the time of the inspection and were not able to be observed. The equipment above the top deck appeared to be in good condition. There was some chipped paint on top and around the electric motor and gear box. **Figure 5.16** shows a photo of one motor and gearbox.

Figure 5.16: Coagulation Mixer Electric Motor and Gear box

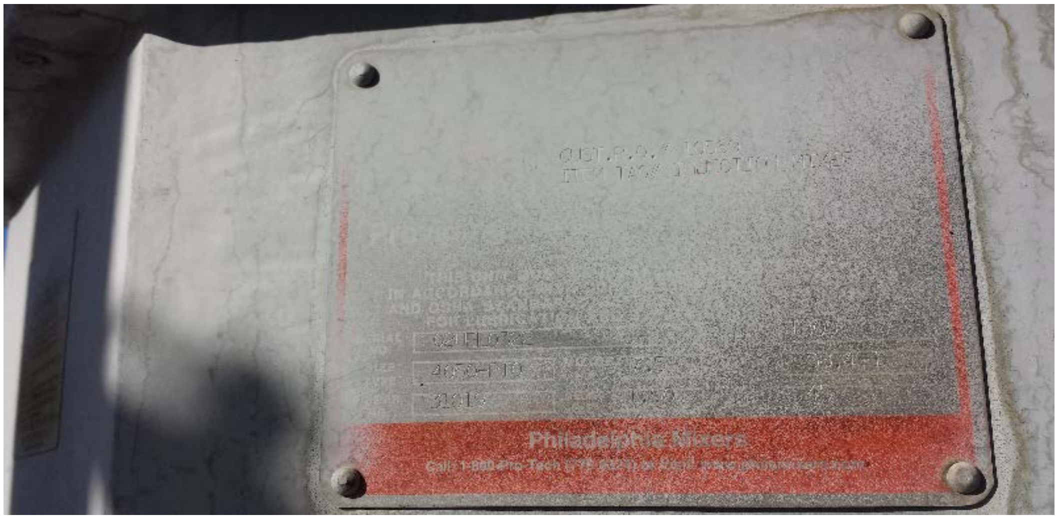


5.6.4.2 *Injection Mixers*

Description

The Injection Mixers were identified by field tags 3-ME-12 and 3-ME-22. The coagulation mixers were Philadelphia Mixers with a ratio of 38.4 to 1 and an output speed of 45 RPM. The mixers are each powered by 7.5 HP Marathon Electric motors. **Figure 5.17** shows the nameplate of one of the Injection Mixers.

Figure 5.17: Injection Mixer Nameplate



<u>Plant Staff Comments</u>

The plant operator reported that the blades of the injection mixers have broken multiple times. The rupture of the blades appears to occur at the same location on the blade – close to the shaft where the blades are bolted to the shaft as shown in **Figure 5.18**. The Plant staff has attempted to reach out to Philadelphia and Actiflo. The plant operator reported representatives from Actiflo noted this event is unique to the NESWTF and has not yet been reported by other facilities. This issue has not been resolved. The blades were most recently replaced in 2016.

Figure 5.18: Example of the Injection Mixer Broken Blades

Equipment Field Condition

The equipment is in overall good condition. Some chipping paint was observed on top and around the electric motor and gear box as shown in **Figure 5.19**. The mixer was submerged at the time of the inspection. The motor was running properly at the time of the inspection and no sounds were heard.

Figure 5.19: Injection Mixer Motor and Gear Box

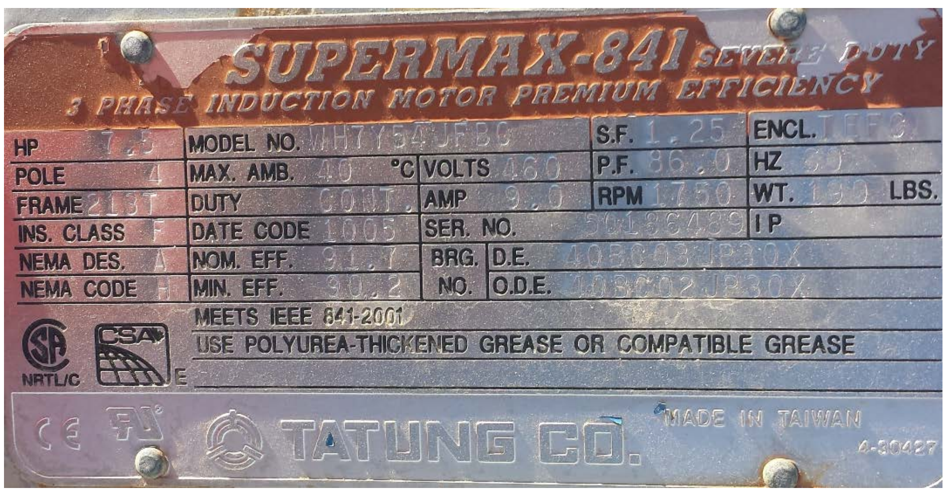
5.6.4.3 *Flocculation Mixers*

Description

The flocculation mixer uses a Philadelphia mixer with a ratio of 70.6 – 1, an input RPM of 1,800 and an output RPM of 45 as shown in **Figure 5.20**. The electric components of the injection mixers emerging at the Clarifier Deck were identified by the field tags 3-ME-13 and 3-ME-23. The mixer is operated by a Tatung Co. 3-phase induction motor of 7.5 HP. **Figure 5.21** shows the technical characteristic of the electric motor.

Figure 5.20: Flocculation Mixer Nameplate

Figure 5.21: Flocculation Mixer Electric Motor Nameplate



<u>Plant Staff Comments</u>

The component has worked properly since installation

<u>Equipment Field Conditions</u>

The mixer was submerged at the time of the inspection. The equipment is in good condition, see **Figure 5.22**. The motor was running properly at the time of the inspection and no particular sounds were heard.

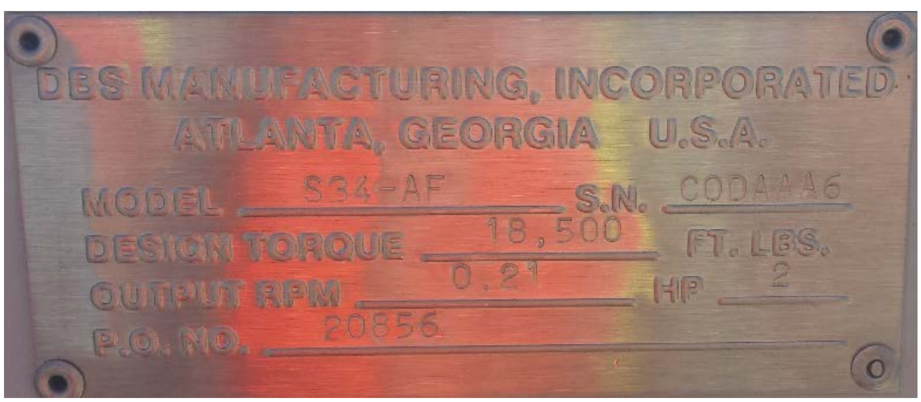
Figure 5.22: Flocculation Mixer Electrical Components at Clarifier Deck

5.6.4.4 *Sludge Scrapers*

Description

The Sludge Scrapers are manufactured by DBS Manufacturing, Incorporated. The scrapers were identified by the field tag 3-ME-14 and 3-ME-24. **Figure 5.23** shows the nameplate one of the Sludge Scrapers.

Figure 5.23: Sludge Scraper Electric Motor Plate Information



Plant Staff Comments

No comments were provided.

Equipment Field Condition

The electric motor and gear box of the sludge scraper at the Clarifier Deck were inspected as the scraper blades were submerged at the time of the inspection. The equipment observed appears to be in overall good condition as shown in **Figure 5.24**. The sludge scrapers were running at the time of the inspection.

Figure 5.24: Sludge Scraper Electric Components at the Clarifier Deck

5.6.4.5 ***Hydrocyclone***

Description

There are two hydroclyclones units for each Actiflo. The units were not identified by a field tag number. Each unit is composed of two Krebbs cyclones, one on duty and one stand-by. The record drawings show eight hydrocyclone units, four for each Actiflo unit, identified as 3-ME-15, 3-ME-16, 3-ME-17, 3-ME-18 and 3-ME-25, 3-ME-26, 3-ME-27, 3-ME-28. **Figure 5.25** shows two of the hydrocyclones.

Figure 5.25: Hydrocyclones at Actiflo No. 1

Plant Staff Comments

No comments were provided.

Equipment Field Condition

Both units were operating at the time of the inspection. Per the record drawings it appears there should be eight Hydrocyclones, four for each Actiflo unit. These units have been custom made specifically for this plant.

5.6.4.6 *Solids Pumps*

Description

There are four centrifugal pumps located in the Solids Pump Room identified by the field tags 3-P-11, 3-P-12, 3-P-21 and 3-P-22. All four pumps are McLanahan and are rated 15 HP. **Figure 5.26** shows the nameplate for the pump.

Figure 5.26: Solids Pump Nameplate

Plant Staff Comments

The pumps have worked properly since installation in 2006.

Equipment Field Condition

The pump was off at the time of the field investigation. All connected supporting equipment is functional and well kept. Connections and fittings are in good condition as seen in **Figure 5.27**. No leak stains or traces of corrosion have been observed. Some oil stains were found around the motor, which is likely attributed to maintenance activities.

Figure 5.27: Solids Pump and Electric Motor

Cracks in the concrete walls and ceilings of the room where the Solids Pumps are located were observed as shown in **Figure 5.28**. A structural condition assessment is recommended by a licensed structural engineer as structural inspections are out of the scope of this condition assessment report.

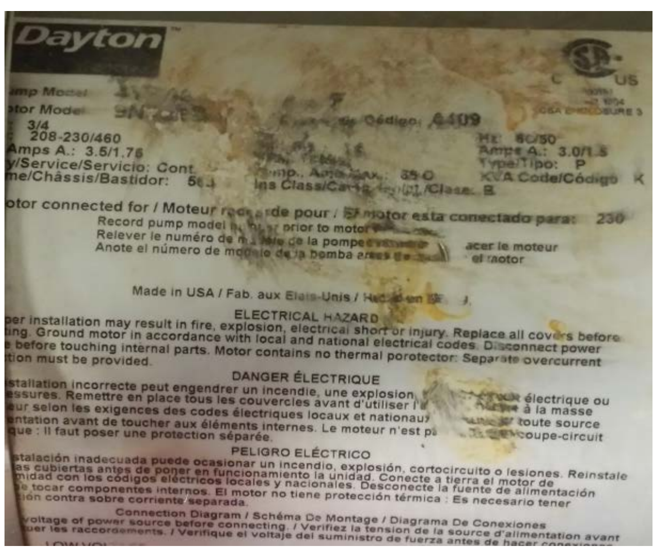
Figure 5.28: Ceiling of Solids Pump Room

5.6.4.7 *Overflow Sample Pump*

<u>Description</u>

Two overflow sample pumps, identified by the field tags 3-P-13 and 3-P-23, are located on the eastern wall of the Sand Pump room. Figure 5.29 shows the nameplate of the pump.

Figure 5.29: Overflow Sample Pump Nameplate



<u>Plant Staff Comments</u>

The units were recently replaced in 2015.

Equipment Field Conditions and Recommendation

The equipment was functioning at the time of the site inspection. **Figure 5.30** shows the overflow sample pump. Some corrosion of fittings in multiple locations was causing some leaking as shown in **Figure 5.31**.

Figure 5.30: Overflow Sample Pump

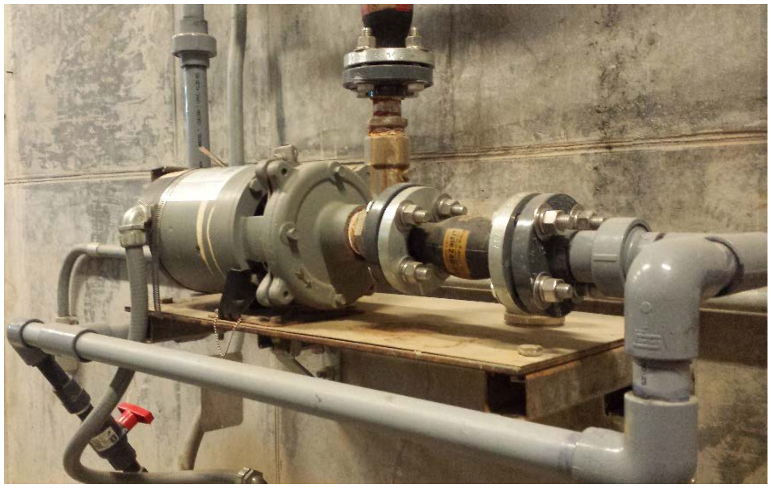
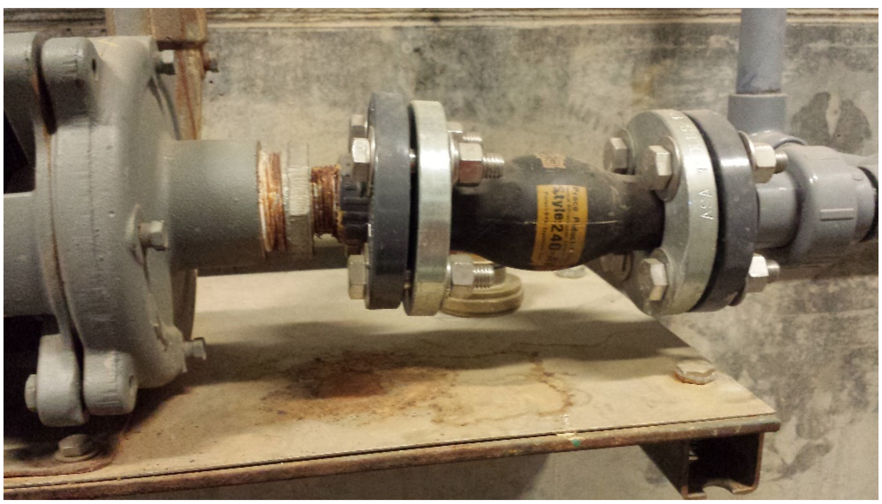


Figure 5.31: Corroded Fittings of the Overflow Sample Pump



5.6.5 Ozone System

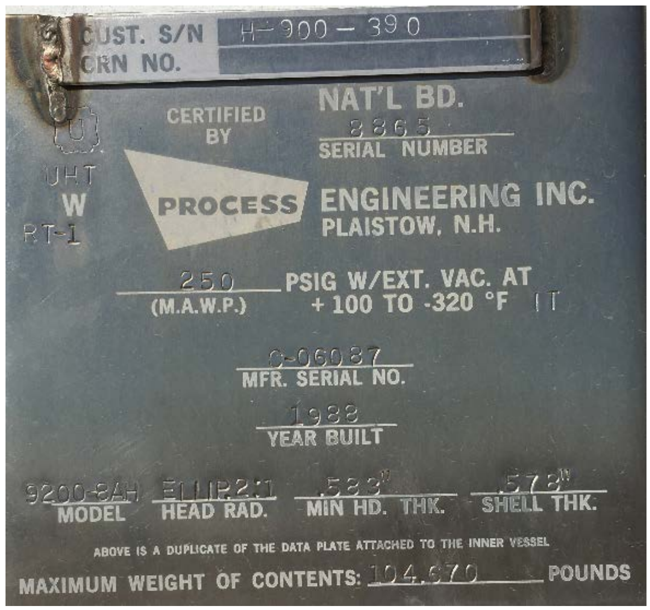
The Ozone system equipment include a liquid oxygen storage tank, two vaporizers, two air compressors, two particulate filters, two ozone generators, two ozone destruct units, and two exhaust gas blowers. Most of the equipment of Ozone system are located in the maintenance building below the office, with the exception of the liquid oxygen (LOX) storage tank and the respective vaporizers which are located outside, north of the chemical building.

5.6.5.1 *LOX Storage Tank*

Description

The LOX storage tank is manufactured by Process Engineering, Inc, **Figure 5.32** shows the tank nameplate. The tag number on the record drawings is 4-T-11, however a field tag number was not found.

Figure 5.32: LOX Storage Tank Nameplate



Plant Staff Comments

No comments were provided.

Equipment Field Conditions

The LOX storage tank is in overall good physical conditions, the connection and fittings are also in good condition. It was noticed that during operation, when liquid oxygen passes throughout the exposed pipeline that connect to the vaporizer unit, water from the atmosphere condensates on the metal surface of the pipe building up a significant layer of ice. **Figure 5.33** shows the ice build-up around the pipe where liquid oxygen is flowing.

Figure 5.33: LOX Storage Tank with Ice Build-up on the Pipe

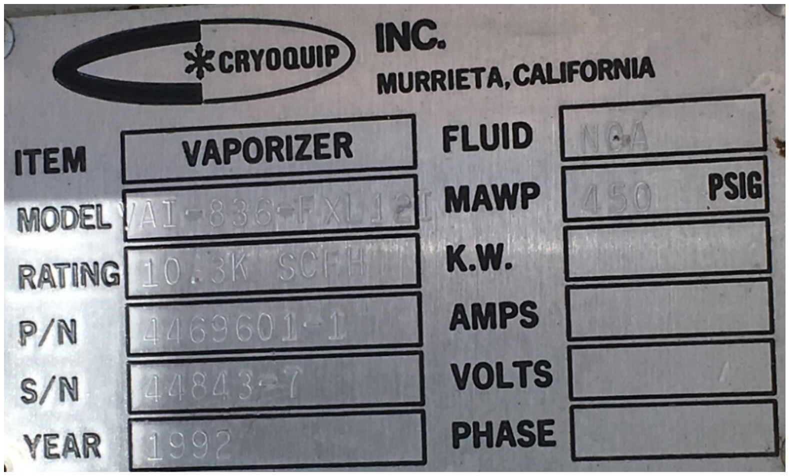
Adjacent pipes that were not operation during the site visit, and thus did not have ice build-up, did not show signs of damage and were in overall good condition. Ice build-up may increase the weight of the pipe and may cause damage to the piping, fittings, and connected appurtenances.

5.6.5.2 *Vaporizers*

<u>Description</u>

The two vaporizer units are located east of the LOX storage tank. The tanks were not identified by field tag numbers, however per the record drawings they are reported as 4-ME-11 and 4-ME-12. These two components work in conjunction with the LOX storage tank. At the time of the investigation one unit was working while the second was in stand-by. The vaporizer units were manufactured by Cryoquip, Inc. in 1992. They have a maximum allowable working pressure (MAWP) of 450 psig, as reported on the nameplate shown **Figure 5.34**.

Figure 5.34: Vaporizer Nameplate



Plant Staff Comments

No comments were provided.

Equipment Field Condition

The exteriors of both vaporizers are in good condition and do not present visible signs of physical wear or corrosion. Components connections and gaskets are observed to be in good overall physical conditions. Figure 5.35 shows a general view of both vaporizer units.

Figure 5.35: Vaporizer Units

5.6.5.3 *Air Compressors*

Description

The air compressor units are both located together with the other ozone system components in a room in the maintenance building below the offices. Only one of the two units is regularly operated, while the second unit is on standby. The air compressor units are operated by a 5 HP Baldor Reliance electrical motor. The units were not identified by a field tag number, however per the record drawings they are reported as 4-ME-23 and 4-ME-24. **Figure 5.36** shows the air compressor nameplate.

Figure 5.36: Air Compressor Nameplate

Plant Staff Comments

The component has worked properly since installation.

Equipment Field Condition

Both units were observed to be in very good conditions, only one of the two was operating at the time of the site visit. Vibration appeared to be normal. **Figure 5.37** shows the air compressor unit that was operating at the time of the site visit.

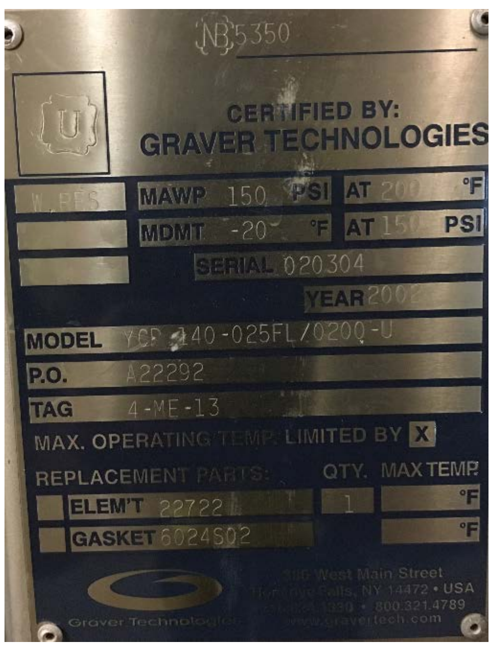
Figure 5.37: Air Compressor

5.6.5.4 ***Particulate Filters***

<u>Description</u>

The particulate filters were manufactured by Graver Technologies. The filters have a MAWP of 150 psi at 200 °F. Only one of the two filters were identified in the field by the tag 4-ME-13. The second filter was assumed to be 4-ME-14, per the record drawings. **Figure 5.38** shows the nameplate.

Figure 5.38: Particulate Filters Nameplate



<u>Plant Staff Comments</u>

No comments were provided.

Equipment Field Condition

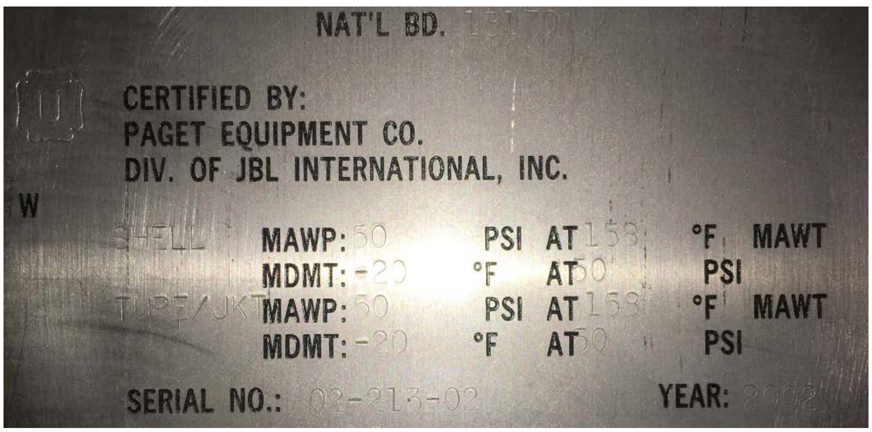
Both filters were observed to be in good condition. No signs of corrosion or wear was present. Gaskets and connections were also observed to be in good condition.

5.6.5.5 *Ozone Generator*

Description

There are two ozone generator units at NESWTF located in the ozone room of the maintenance building below the offices. The ozone generator units are manufactured by Ozonia North America. Neither components had a field identification tag, however per the record drawings they are reported as 4-ME-21 and 4-ME-22. **Figure 5.39** shows the plate information.

Figure 5.39: Ozone Generator Nameplate



Plant Staff Comments

No comments were provided

Equipment Field Condition

The ozone generator unit and their related components and connections appear to be in good condition as shown in **Figure 5.40.** Only one of the two units was operating during the site visit.

Figure 5.40: Ozone Generator Unit No. 1

5.6.5.6 *Ozone Destruct Systems*

Description

There are two ozone destruct systems. Each system is comprised of an ozone destruct unit and an exhaust blower. Per the record drawings, the ozone destruct units were identified by tags as 4-ME-61 and 4-ME-62. Exhaust fans are comprised of a Cincinnati Fan blower are powered by a 3 HP electric motor from Baldor Reliance. The motors were identified by tags 4-ME-63 and 4-ME-64.

Plant Staff Comments

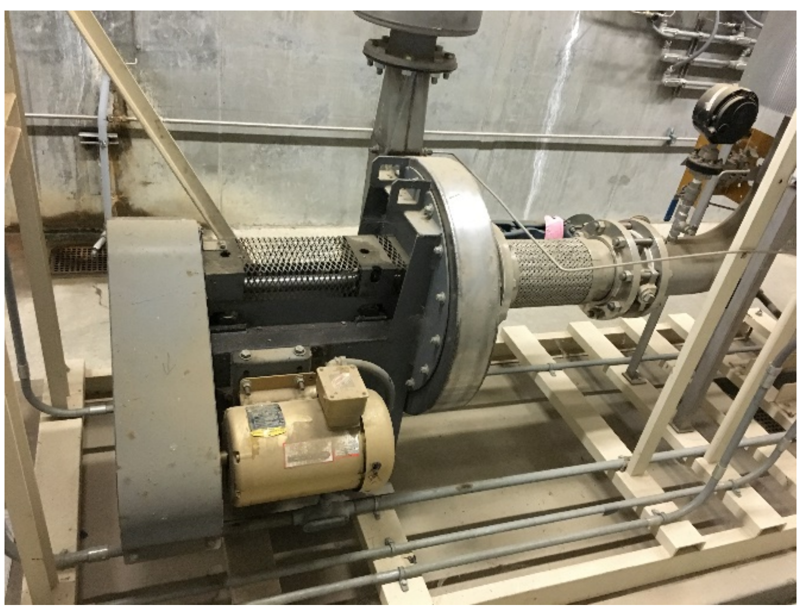
No comments were provided.

Equipment Field Condition

Only unit 4-ME-61 was operational during the site visit. Unit 4-ME-62 was covered in dust and appeared to be out of service. **Figure 5.41** shows Ozone Destruct Unit No. 1 and **Figure 5.42** shows the exhaust blower.

Figure 5.41: Ozone Destruct Unit No. 1

Figure 5.42: Ozone Destruct Unit No. 1 Exhaust Blower



5.6.6 Filters

Filter valves and actuators are located on different locations on site per their functions.

5.6.6.1 *Filter Beds – Influent valves*

<u>Description</u>

There are six 10-inch DeZurik influent valves, operated by a Rotork IQFM actuator, identified by the field tags 5-MOV-11, 5-MOV-21, 5-MOV-31, 5-MOV-41, 5-MOV-51, and 5-MOV-61. **Figure 5.43** shows a typical influent valve actuator.

Figure 5.43: Influent Valve Actuator

<u>Plant Staff Comments</u>

General comments: Valves have been refurbished several years ago to replace worn gaskets and seats. Media screens at the bottom of the filter beds have come loose and allowed carbon and sand to enter the tanks.

<u>Equipment Field Condition</u>

Deterioration of plastic components on the actuator housing from sun exposure and minor corrosion was observed. All valves were submerged at the time of field visit so visual inspection was not possible.

5.6.6.2 *Filter Beds – Filter Water Valves*

<u>Description</u>

There are six 10-inch DeZurik filter water valves, motor-operated by Rotork IQFM size 18 and 21 PRPM speed actuator, identified by the field tags 5-MOV-12, 5-MOV-22, 5-MOV-32, 5-MOV-42, 5-MOV-52, and 5-MOV-62.

Plant Staff Comments

No comments were provided

Equipment Field Condition

All valves housings appeared to be in good physical condition, with some minor corrosion. **Figure 5.44** shows a typical filter water valve actuator.

Figure 5.44: Filter Water Valve and Actuator

5.6.6.3 *Filter Beds – Backwash Valves*

Description

There are six 10-inch DeZurik backwash valves, motor-operated by Rotork IQFM size 18 and 21 PRPM speed actuators, identified by the field tags 5-MOV-15, 5-MOV-25, 5-MOV-35, 5-MOV-45, 5-MOV-55, and 5-MOV-65.

Plant Staff Comments

No comments were provided

Equipment Field Condition

All MOV housings seem to be in good physical condition, without major physical defects. **Figure 5.45** shows a typical backwash valve and actuator.

Figure 5.45: Backwash Valve and Actuator

5.6.6.4 *Filter Beds – Air Scour valves*

Description

There are six 10-inch DeZurik air scour valves, motor-operated by Rotork IQFM size 18 and 21 PRPM speed actuators, identified by the field tag 5-MOV-14, 5-MOV-24, 5-MOV-34, 5-MOV-44, 5-MOV-54, and 5-MOV-64.

Plant Staff Comments

No comments were provided

Equipment Field Condition

Deterioration of plastic components on the actuator housing from sun exposure and minor corrosion was observed. All valves were submerged at the time of field visit so visual inspection was not possible.

5.6.6.5 *Filter Beds – Drain Valves*

Description

There are six 10-inch DeZurik drain valves, motor-operated by Rotork IQFM size 18 and 21 PRPM speed actuators identified by the field tag 5-MOV-13, 5-MOV-23, 5-MOV-33, 5-MOV-43, 5-MOV-53, and 5-MOV-63.

Plant Staff Comments

No comments were provided

Equipment Field Condition

Deterioration of plastic components on the actuator housing from sun exposure and minor corrosion was observed. All valves were submerged at the time of field visit so visual inspection was not possible. Figure 5.46 shows the valve actuator with some corrosion around the actuator connection to the valve stem housing.

Figure 5.46: Drain Valve Actuator

5.6.6.6 *Filter Beds – Filter to Waste Valves*

Description

There are six 10-inch DeZurik filter to waste valves, motor-operated by Rotork IQFM size 18 and 21 PRPM speed actuators, identified by the field tags 5-MOV-16, 5-MOV-26, 5-MOV-36, 5-MOV-46, 5-MOV-56, and 5-MOV-66.

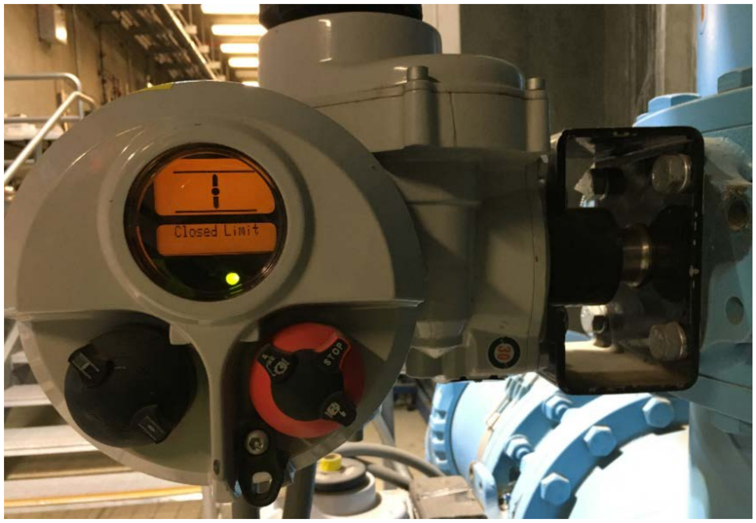
Plant Staff Comments

No comments were provided.

Equipment Field Condition and Recommendations

All actuator housings were in good condition. **Figure 5.47** shows the filter to waste valve actuator.

Figure 5.47: Filter to Waste Valve and Actuator



5.6.6.7 *Filter Waste Pump, Actuator and Valve*

Description

Filter waste pump, actuator and valve are located south of the filter tanks. The pump is a 20 HP Flowserve centrifugal pump with a rated capacity of 3,550 GPM at 13 feet of TDH and an operating speed of 845 RPM. The pump is driven by a 20HP motor manufactured by US Electric Motors. The valve is a 14-inch DeZurik 14. **Figure 5.48** shows the entire pump, actuator, and valve system.

Figure 5.48: Filter Waste Pump Actuator and Valve

Plant Staff Comments

No comments were provided

Equipment Field Condition

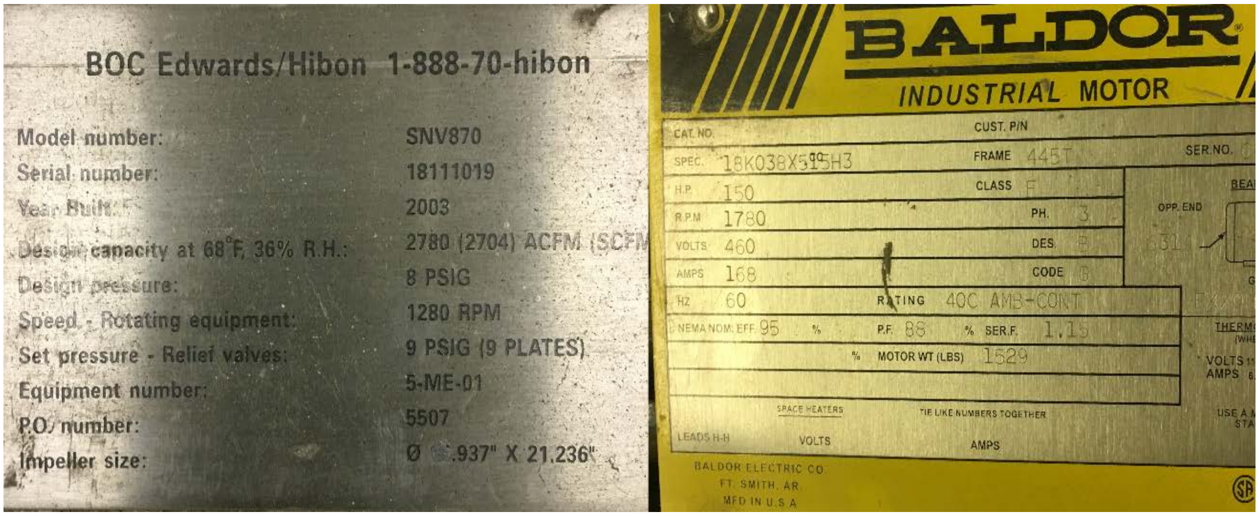
Some corrosion and chipping paint were observed throughout, with some signs of leaks.

5.6.6.8 *Air Scour Blower*

Description

The air scour blower is located in the building south-west on the property adjacent to the treated water pump building. The unit was identified by field tag 5-ME-01. The blower was manufactured by BOC Eduard Hibson and is powered by a 150 HP Baldor Industrial Motor. **Figure 5.49** shows the nameplate of the air scour blower (left) and the electric motor (right).

Figure 5.49: Air Scour Blower Nameplate (left) and Electric Motor Nameplate (right)



Plant Staff Comments

No comments provided.

Equipment Field Conditions

The air scour blower was not in operation during the site visit. All components appeared to be in good physical condition as showed in **Figure 5.50**.

Figure 5.50: Air Scour Blower

5.6.6.9 ***Backwash Water Supply Pumps***

Description

The backwash supply pumps are grouped together with the treated water pumps in a building located south east of the property, see **Figure 5.51** for a general view. The pumps are 300 HP Flowserve vertical turbine pumps and are identified by tags 5-P-07 and 5-P-08. The pumps operate at 13,500 GPM at 59 feet of TDH, with an operating speed of 898 RPM.

Figure 5.51: Backwash Supply Pumps

Plant Staff Comments

The pump has worked properly since installation with regular maintenance as required.

Equipment Field Condition

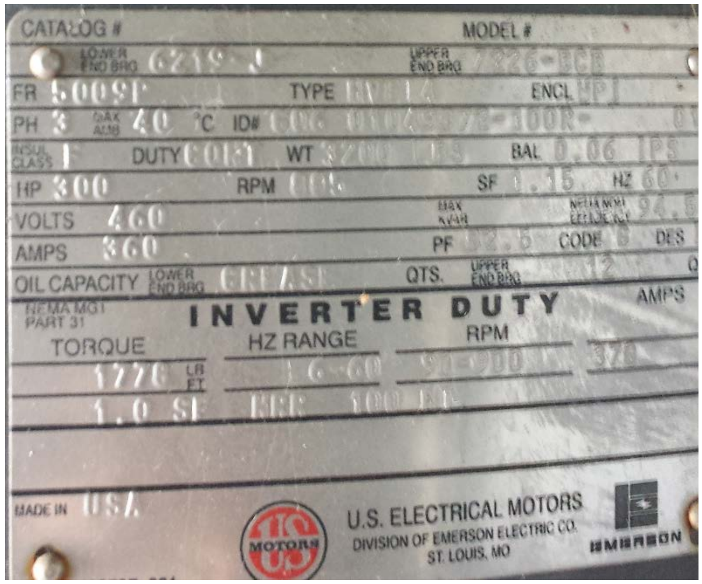
Neither pump was operating at the time of observation. The pumps appear to be in overall good condition.

5.6.6.10 ***Backwash Water Supply Pump Electric Motors***

Description

The backwash supply pump motors are both 300 HP electric motors manufactured by US Electrical Motors. **Figure 5.52** shows the nameplate for one of the motors.

Figure 5.52: Backwash Supply Pump Electric Motor Nameplate



<u>Plant Staff Comments</u>

Both motors have worked properly since installation, with normal maintenance provided.

<u>Equipment Field Conditions and Recommendation</u>

The electric motors appear to be in good condition. Some oil stains appear around the motor's head, which are likely a result of regular maintenance activities.

5.6.7 Chemical Building

5.6.7.1 *Sodium Hypochlorite System*

The sodium hypochlorite system is composed by two storage tanks and two feed pump systems.

Sodium Hypochlorite Storage Tank

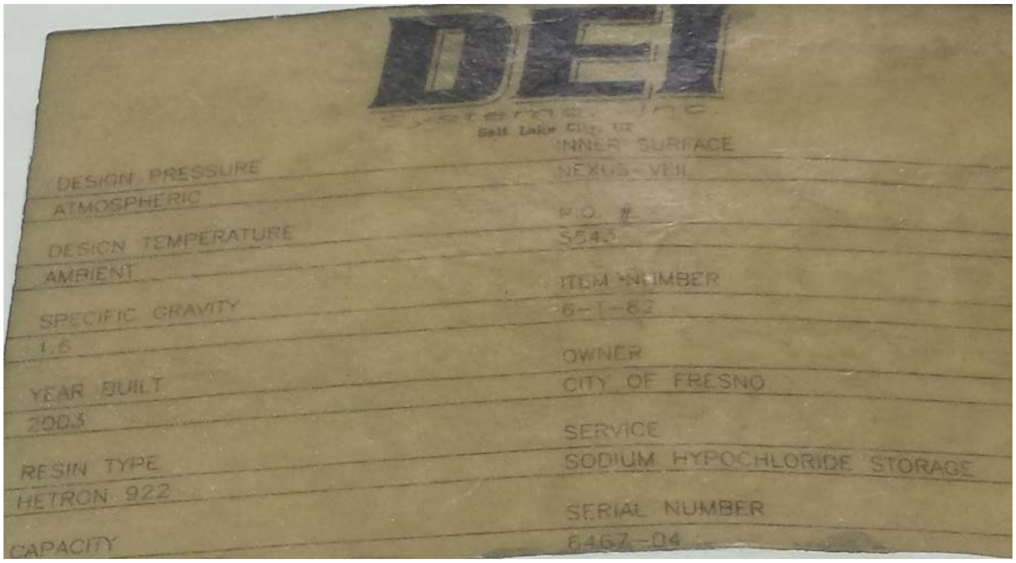
<u>Description</u>

There are two 13,000-gallon double wall storage tanks used for storing sodium hypochlorite located in the chemical building. The storage tanks were identified by field tags 6-P-81 and 6-P-82. The storage tanks were manufactured by DEI Systems, Inc. **Figure 5.53** shows the tank nameplate.

<u>Plant Staff Comments</u>

No comments provided

Figure 5.53: Sodium Hypochlorite Storage Tank Nameplate



Equipment Field Condition

There is some cracking all around the anchor locations of both tanks and some leaking has been observed at drain flange and connections as showed in **Figure 5.54**. The tanks are in overall good condition.

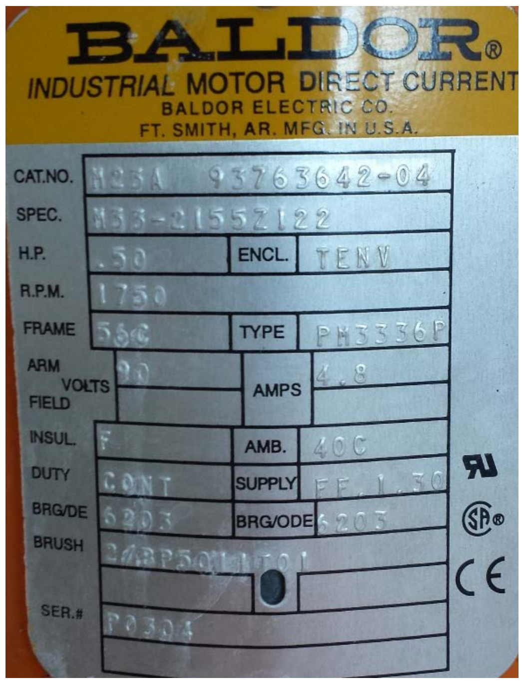
Figure 5.54: Leaking at Sodium Hypochlorite Tank Flanged Connection

Sodium Hypochlorite Feed Pump and Motor

Description

There are two sodium hypochlorite (SHC) feed pumps for sodium hypochlorite located adjacent to the respective storage tanks. Both pumps are manufactured by ProMinent Fluid Controls, Inc and are driven by a 0.5 HP Baldor Electric Co. motor. The pump skids were identified by the field tags 6-FD-81 and 6-FD-83. **Figure 5.55** shows the field nameplate of the electric motor.

Figure 5.55: SHC Feed Pump Sodium Hypochlorite Electric Motor Nameplate



Plant Staff Comments

The pumps have worked properly since installation. Pumps 6-FD-81 and 6-FD-82 have been recently replaced.

Equipment Field Conditions

Pump skid 6-FD-82 was not installed at the time of observation. Both pumps 6-FD-81 and 6-FD-83 were not in operation at the time of the field investigation. The pumps exhibit signs of leaking throughout various fittings and connections, and some paint chipping of pump housing. The pumps appear to be in overall good condition, see **Figure 5.56**.

Figure 5.56: Sodium Hypochlorite Feed Pump

5.6.7.2 *Polymer Batching System – Cationic Polymer*

Description

There are two polymer batching systems at the NESWTF. Both systems process cationic polymer, and both systems are in a room adjacent to the chemical building. The systems were identified by the field tags 6-ME-71 and 6-ME-72.

Plant Staff Comments

No comments provided

Equipment Field Condition

There is significant chemical build-up and scaling around the system framing as showed in Figure 5.57. There is corrosion on the motor housing and pumps, as well all signs of leaking and spills.

Figure 5.57: Polymer Batching System

5.6.7.3 *Polymer Feed Pump – Cationic Polymer*

Description

There are five feed pumps for the cationic polymer, as there are no feed pumps allocated for the non-ionic polymer. All five pumps are located in the chemical building with the storage tanks. Per the record drawings, the pump skids are identified by the field tags 6-FD-71, 6-FD-72, 6-FD-73, 6-FD-51 and 6-FD-52. The pump in the space for 6-FD-52 is labeled as 6-FD-74. The pumps are all manufactured by ProMinent Fluid Controls, Inc. and utilize a 0.5 HP Baldor Electric Co. motor. **Figure 5.58** shows the motor nameplate.

Figure 5.58: Cationic Pumps Electric Motor Nameplate

<u>Plant Staff Comments</u>

No comment provided.

<u>Equipment Field Condition</u>

All components, fittings and connections appear to be in good condition as showed in **Figure 5.59**. The pumps were not in operation at the time of observation. There are spill stains on the floor beneath pumps 6-FD-71 and 6-FD-72.

Figure 5.59: Cationic Polymer Feed Pump System

5.6.7.4 *Aluminum/Ferric Chloride Feed System*

The Aluminum/Ferric Chloride system is composed of two storage tanks and three feed pumps.

Storage Tank

<u>Description</u>

There are two 13,000-gallon, double-wall storage tanks used for alum/ferric chloride storage located in the chemical building. The tanks were identified by the field tags 6-T-11 and 6-T-12. The storage tanks were manufactured by DEI Systems.

<u>Plant Staff Comments</u>

No comments provided

Equipment Field Condition

The tanks, components, connections, and fittings all appear to be in good condition. Both tanks show signs of some stains, possibly due to a minor spill. There is some build-up on some pipe fittings as shown in **Figure 5.60**.

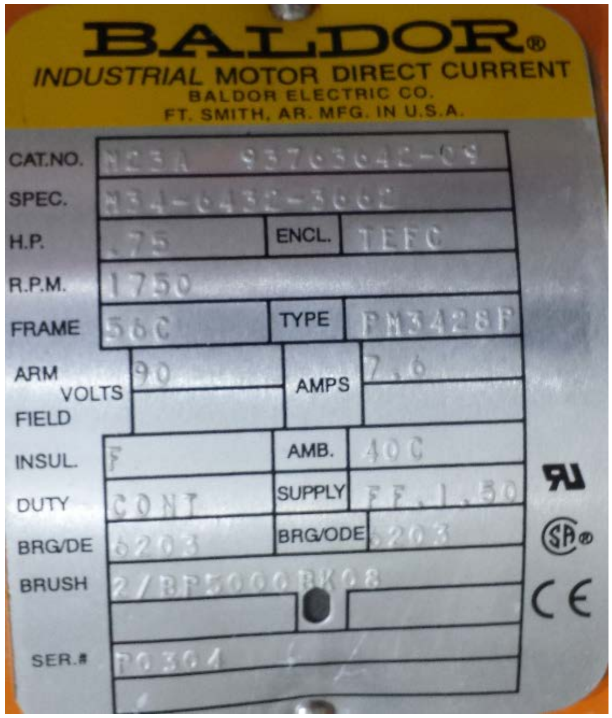
Figure 5.60: Build-up on Alum/Ferric Storage Piping

Feed Pump – Alum/Ferric Feed System

Description

There are three feed pump systems for the Alum/Ferric feed system, they are located near the respective storage tanks. The pumps are all manufactured by ProMinent Fluid Controls, Inc. and are each driven by a 0.5 HP Baldor Electric Co. motor. The pump skids where identified by the field tags 6-FD-11, 6-FD-12, and 6-FD-13. **Figure 5.61** shows the motor nameplate.

Figure 5.61: Alum/Ferric Pump Electric Motor Nameplate



Plant Staff Comments

No comments provided.

Equipment Field Condition

There are some minor signs of build up around the fittings and some stains are visible around the pump, overall the pumps appear to be in good condition. Figure 5.62 shows the overall alum/ferric feed pump system.

Figure 5.62: Alum/Ferric Feed Pump System

5.6.7.5 *Caustic System*

The caustic system is composed of two storage tanks, two feed pumps, and one mixing pump.

Caustic Storage Tank

Description

Two 14,000-gallon double-wall storage tanks used for the caustic system located in the chemical building. Both tanks were identified by the field tags 6-T-21 and 6-T-22. The storage tanks were manufactured by Palmen MFG. & Tank Inc. **Figure 5.63** shows the tank nameplate.

Plant Staff Comments

The tanks have worked properly since installation.

Equipment Field Conditions

Tank 6-T-21 is in good condition and shows no signs of major cracking or leaking. Tank 6-T-22 showed concrete cracks at the foundation at anchor locations with signs of scaling as shown in **Figure 5.64**.

Figure 5.63: Caustic System Storage Tank Plate

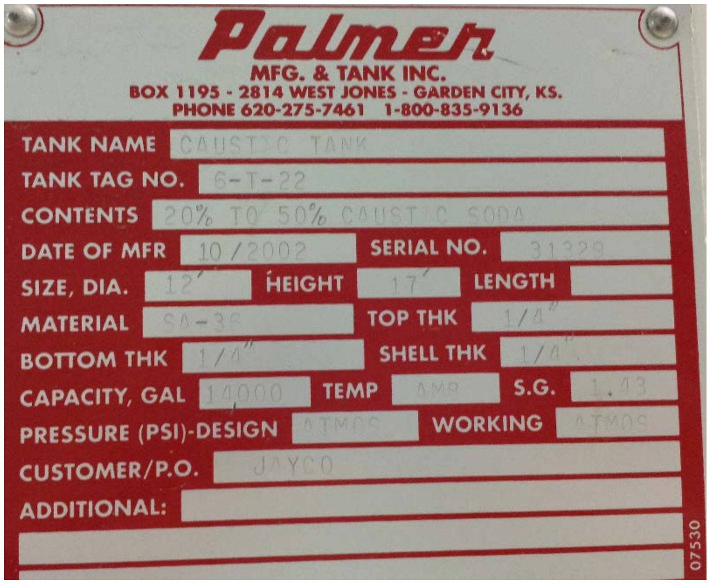


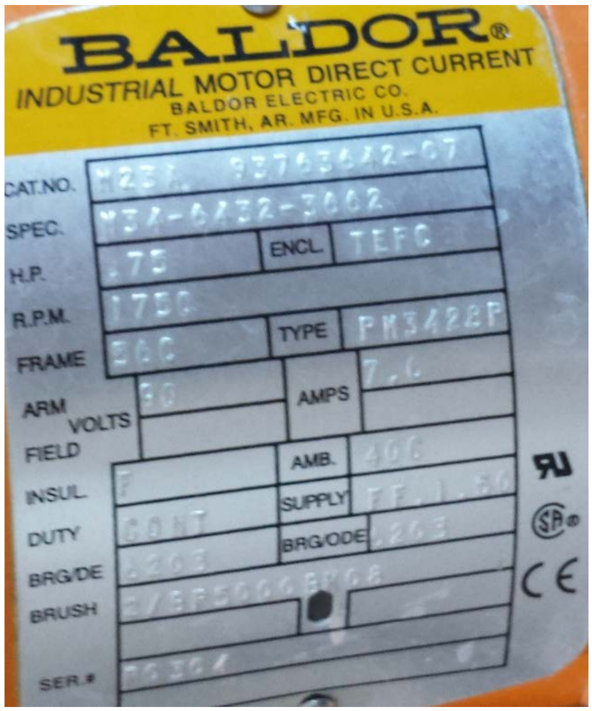
Figure 5.64: Caustic System Storage Tank Foundation

Caustic Feed Pump

Description

There are two feed pump systems for the caustic system located near the respective tanks. Both pumps have been manufactured by ProMinent Fluid Controls, Inc., and each utilize a 0.75 HP Baldor Electric Co. motor. The caustic system feed pump skids were identified by the field tags 6-FD-21 and 6-FD-22. **Figure 5.65** shows the electric motor nameplate.

Figure 5.65: Caustic System Pump Electric Motor Nameplate



Plant Staff Comments

No comments were provided.

Equipment Field Conditions

The system 6-FD-21 showed signs of leaking around fittings throughout the system, with several areas of caustic build-up, as shown in **Figure 5.66**. This feed system was not in operation at the time of observation. Feed system 6-FD-22 showed only very few signs of leaks and some staining at the pump base.

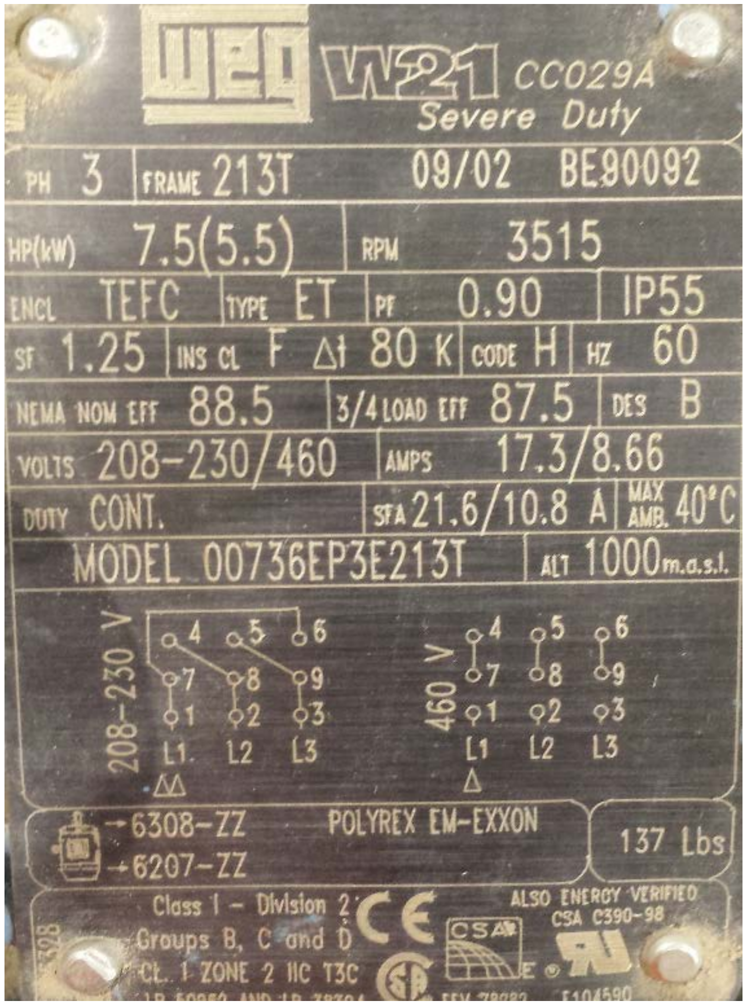
Figure 5.66: Feed pump caustic system

Caustic Mixing Pump

<u>Description</u>

There is only one pump used as mixing pump for the caustic system and it is located in between the two storage tanks. The pump was identified by the field tag 6-P-21. The pump is manufactured by R.F. MacDonald Co. and has a 0.75 HP electric motor manufactured by WEG. **Figure 5.67** shows the motor nameplate.

Figure 5.67: Mixing Pump Caustic System Electric Motor Nameplate



<u>Plant Staff Comments</u>

Pump 6-FD-22 has recently been replaced.

<u>Equipment Field Condition</u>

The pump was not in operation at the time of observation. Some signs of corrosion were observed. The pump appeared to be in overall good condition as shown in **Figure 5.68**.

Figure 5.68: Caustic System Mixing Pump

5.6.7.6 *Polyphosphate System*

Weigh Scale

Description

There are two weight scales for polyphosphate located in the adjacent room to the chemical building. The weight scales were not identified by a field tag number, however on the record drawings they are tagged as 6-WS-31 and 6-WS-91. Figure 5.69 shows a general view of the scales.

Figure 5.69: Weigh Scales for Polyphosphate

Plant Staff Comments

No comments provided.

Equipment Field Condition

The scales were functional and appeared to be in good condition at the time of the field investigation. It is recommended the weigh scales be refurbished.

Polyphosphate Feed Pump

Description

One feed pump is assigned for polyphosphate addition. The feed system and pump skid are located in the chemical building. The pump skid was identified by the field tag 6-FD-31. The pump is manufactured by ProMinent Fluid Controls, Inc. and is driven by a 0.5 HP Baldor Electric Co. motor. **Figure 5.70** shows the motor nameplate.

Figure 5.70: Polyphosphate Pump Motor Nameplate

Plant Staff Comments

No comments provided.

Equipment Field Condition

The system has build-up in various places, with stains around the pump base and signs of leaking around the piping and floor. There is some paint chipping of the pump motor as shown in **Figure 5.71**.

Figure 5.71: Polyphosphate Feed Pump

5.6.7.7 *Carbon Dioxide System*

Storage Tank – Carbon Dioxide

Description

The storage tank for carbon dioxide is located outside and north of the chemical building. The tag number per the record drawings is 6-T-41, however a field tag number was not found. The tank was manufactured by Linde. A nameplate for the tank was not found. **Figure 5.72** shows a general view of the tank.

Figure 5.72: Carbon Dioxide Storage Tank

Plant Staff Comments

The plant operators do not provide maintenance for this unit. Service is performed by a manufacture's service company.

Equipment Field Condition

The tank appears to be in overall good physical condition. There is some minor corrosion and build-up around the equipment and instrument connections at the front of the tank. **Figure 5.73** shows various instruments and equipment installed on the tank.

Figure 5.73: Carbon Dioxide Tank Instruments and Equipment

Vaporizer – Carbon Dioxide

<u>Description</u>

The carbon dioxide vaporizer and vapor heater are located inside the maintenance shed on the front of the carbon dioxide storage tank. The tag number on the record drawings is 6-ME-41, however a field tag number was not found.

<u>Plant Staff Comments</u>

No comments were provided.

<u>Equipment Field Conditions</u>

The equipment appears to be in overall fair condition, with some observed buildup around connection ports and appurtenances. **Figure 5.74** shows the compressor of the vaporizer. It is recommended the system be refurbished.

Figure 5.74: Vaporizer Compressor

Carrier Water Pump – Carbon Dioxide

Description

There are two carrier water pumps for carbon dioxide. Both pumps are manufactured by RSTH Pumps and Equipment and they are powered by a 10 HP electric motor manufactured by Marathon Electric. The carrier water pumps for the carbon dioxide were identified by the field tag 6-P-41 and 6-P-42. **Figure 5.75** shows the motor nameplate.

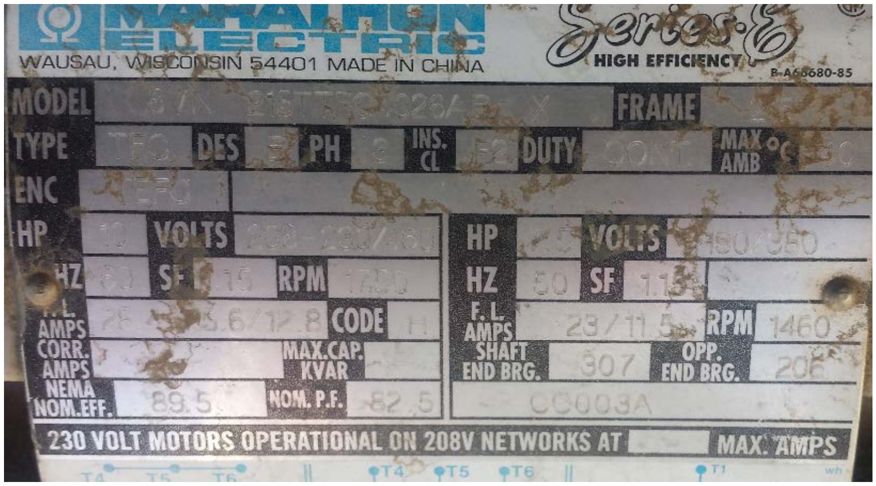
Plant Staff Comments

No comments provided.

Equipment Field Condition

The pumps were not in operation at the time of the site visit. The pumps appear to be in overall good condition. It is recommended the pumps be refurbished.

Figure 5.75: Carrier Water Pump Carbon Dioxide Electric Motor Nameplate



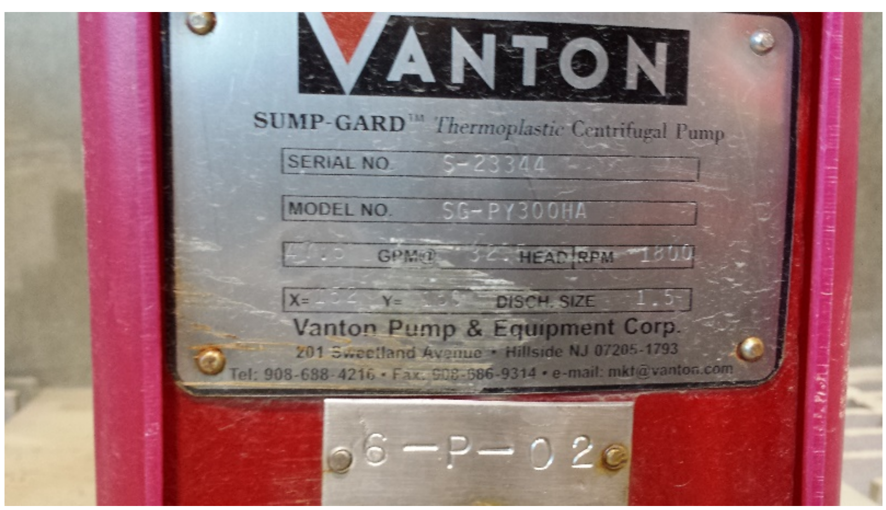
5.6.7.8 *Chemical Building Drainage System*

Chemical Sump Pumps

<u>Description</u>

Only two out of four Chemical sump pumps were identified in the field and both are located in the chemical building in the northern and southern corner of the building, respectively. The other two chemical sump pumps are located in a vault placed outside, in between the chemical and the maintenance buildings. The chemical sump pumps were identified by the field tags 6-P-01 and 6-P-02. The pumps are centrifugal pumps manufactured by Vanton Pump & Equipment Corp with a capacity of 47.5 GPM at 32 feet of TDH. The pumps are driven by a 2 HP motor manufactured by WEG. **Figure 5.76** shows pump 6-P-02 nameplate.

Figure 5.76: Chemical Sump Pump 6-P-02 Nameplate



Plant Staff Comments

The pumps have worked properly since installation.

Equipment Field Condition

There were no observed signs of corrosion or leaking. The pumps were not operating at the time of the site visit. The pumps appear to be in overall in good condition as shown in **Figure 5.77**.

Figure 5.77: Typical Chemical Sump Pump

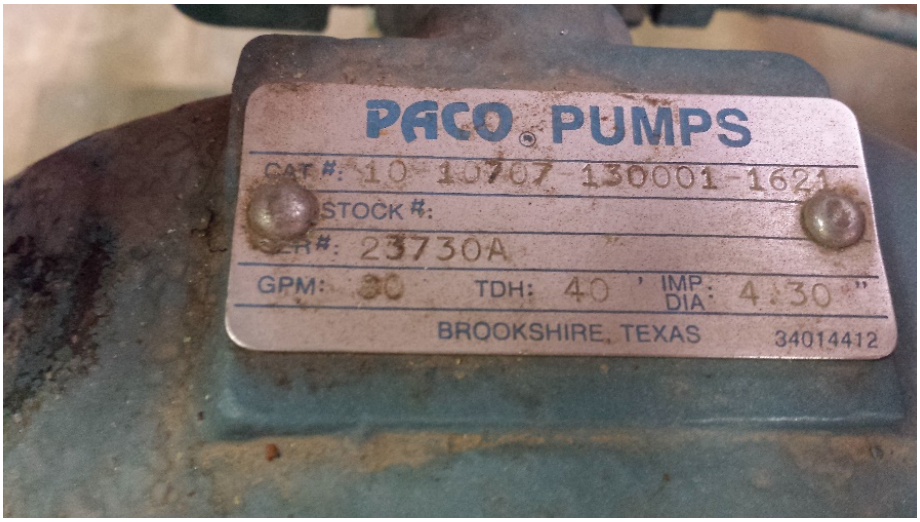
5.6.8 Operation Building

5.6.8.1 *Potable Water Booster Pump*

Description

There are two potable water booster pumps located in a room in the maintenance building. The pumps were not identified by a field tag, however, per the record drawings, they are reported as 6-P-91 and 6-P-92. The pumps were manufactured by Paco Pumps and have a capacity of 80 GPM at 40 feet of TDH. The pumps are powered by a 3 HP Baldor industrial electric motor. **Figure 5.78** shows the pump nameplate.

Figure 5.78: Potable Water Booster Pump Nameplate



Plant Staff Comments

No comments were provided.

Equipment Field Condition

There were some oil stains around and on top of the pumps, but they otherwise appear to be in overall good condition as shown in **Figure 5.79**.

Figure 5.79: Potable Water Booster Pump

5.6.8.2 *Pressure Vessel*

Description

The pressure vessel is located close to the potable water booster pumps. No nameplate or pertinent information regarding the pressure vessel was found in-field. **Figure 5.80** shows the pressure vessel.

Figure 5.80: Pressure Vessel

Plant Staff Comments

No comments were provided.

Equipment Field Condition and Recommendations

Equipment appears to be in overall in good condition.

5.6.8.3 *Washwater pump*

Description

There are two washwater pumps located outside near the equalization tank. The washwater pumps were identified by the field tags 7-P-11 and 7-P-12. The pumps are vertical turbine pumps manufactured by Flowserve with a capacity of 450 GPM at 22 feet of TDH and an operating speed of 1,770 RPM. Each pump is driven by a 5 HP Emerson Motor Company (US Motors) electric motor. **Figure 5.81** shows the pump nameplate and **Figure 5.82** shows the electric motor nameplate.

Figure 5.81: Washwater Pump Nameplate

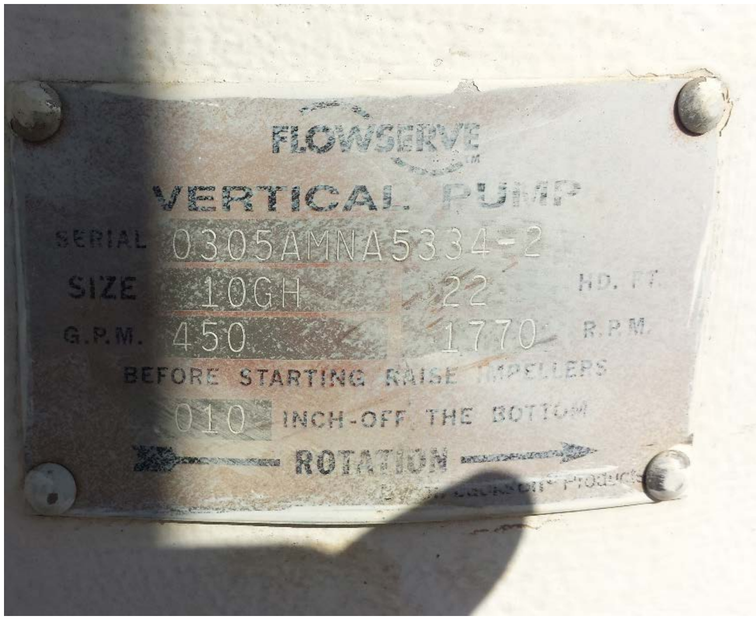
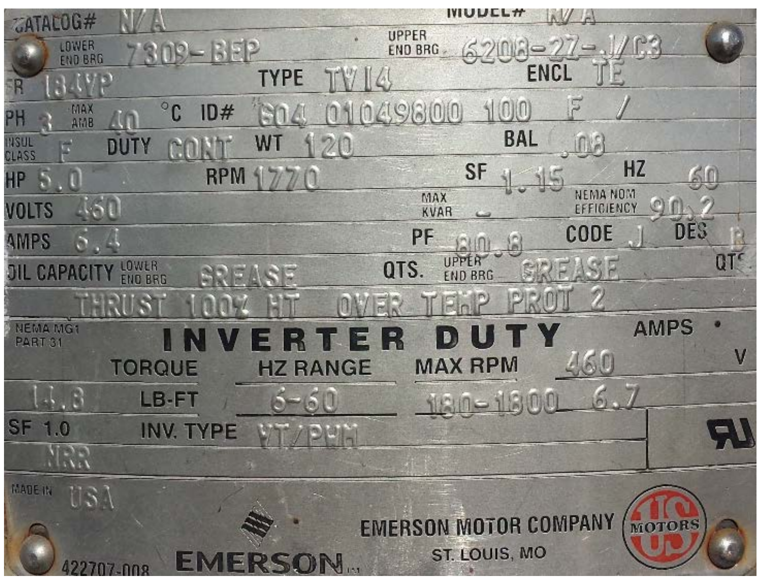


Figure 5.82: Washwater Pump Electric Motor Nameplate



Plant Staff Comments

Plant staff reported issues with leaking around the pump packing.

Equipment Field Condition

There is minor corrosion and chipping paint on the pump and motor housing, and some oil stains as shown in **Figure 5.83**. Neither pump was operating at the time of observation.

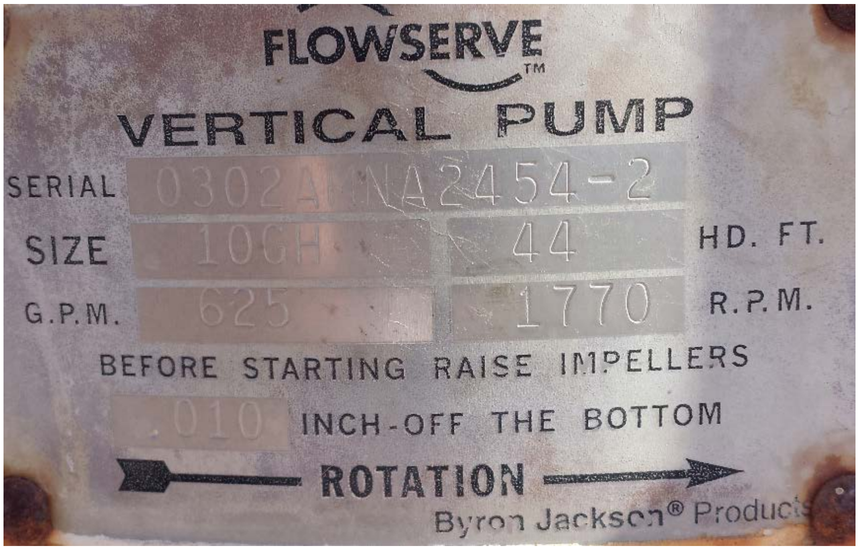
Figure 5.83: Oil Stains Around Washwater Pump and Motor

5.6.8.4 *Decant Pump*

Description

There are two decant pumps located near to the lagoons. Both pumps are vertical turbine pumps manufactured by Flowserve with a capacity of 625 GPM at 44 feet of TDH. The pumps were identified by the field tags 7-P-31 and 7-P-32. **Figure 5.84** shows the pump nameplate. The pumps are driven by a 10 HP electric motor manufactured by US electrical Motors. **Figure 5.84** shows the pump nameplate.

Figure 5.84: Decant Pump Nameplate



Plant Staff Comments

Plant staff has noted that the pumps have worked properly since installation and require regular maintenance. The pumps were replaced in 2015.

Equipment Field Conditions and Recommendation

The pumps appear to be in good condition as shown in **Figure 5.85**. Pump 7-P-31 exhibited oil residue at the pump pedestal.

Figure 5.85: Decant Pump 7-P-31 and Electric Motor

5.6.9 Treated Water Pump Station

5.6.9.1 *Treated Water Pumps*

Description

The treated water pumps are grouped together with the backwash pumps and are in the building located south-east on the property. The pumps were identified by the field tags 9-P-01, 9-P-02, 9-P-03 and 9-P-04. The pumps are vertical turbine pumps manufactured by Flowserve, with a capacity of 7,000 GPM at 168 feet of TDH. The pumps are driven by 400 HP electric motors manufactured by US Motors. The pump nameplate is shown in **Figure 5.86** and the electric motor nameplate is shown in **Figure 5.87**.

Figure 5.86: Treated Water Pump 9-P-11 Nameplate

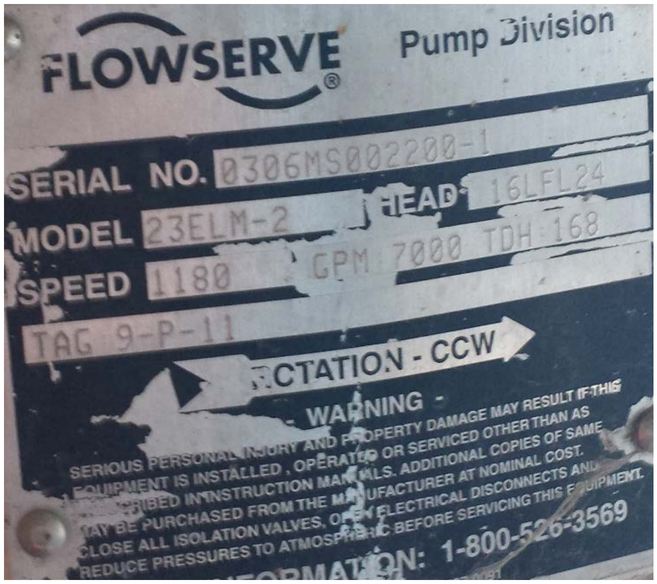
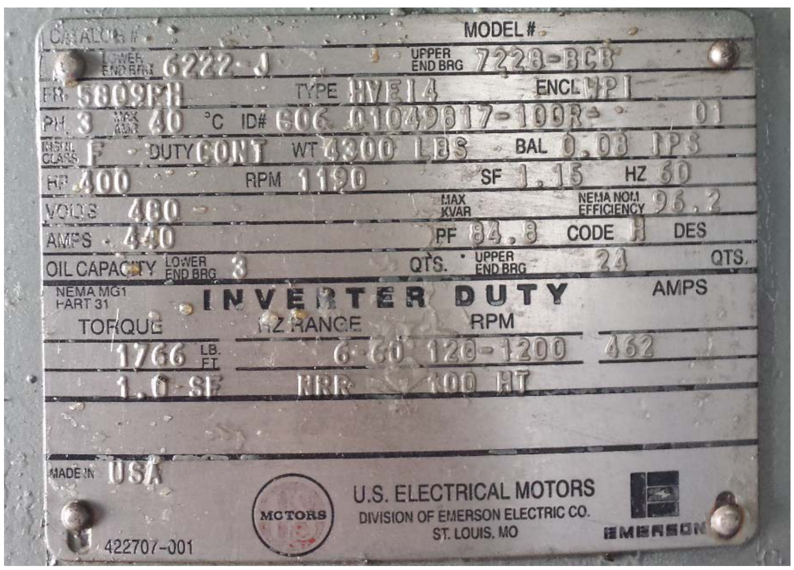


Figure 5.87: Treated Water Pump Electric Motor Nameplate



Plant Staff Comments

Pump 9-P-01 requires packing since it is leaking from the shaft. All other pumps work properly. Motors were refurbished in 2014.

Equipment Field Conditions and Recommendation

Pumps 9-P-01 and 9-P-03 were operating during the field inspection. Pump 9-P-01 was leaking from the shaft. All pumps appear to be in overall good condition as shown in Figure 5.88.

Figure 5.88: Treated Water Pumps

5.7 RISK SCORES, RECOMMENDATIONS, AND COSTS

Risk scores for each equipment unit are found in **Table 5.1**.

The following risk scores, recommendations, and costs were provided for the equipment for each of the Plant's water treatment unit processes:

Water Intake

Priority 1: None of the equipment received scores greater than 15, therefore no need for immediate R&R improvements action.

Priority 2: The following equipment were given scores between 5-15 and require R&R recommended improvements to be implemented within 5 years:

- *Traveling screen: Risk score 8.00; recommended to refurbish*
- *Inlet gate: Risk score 7.00; recommended to be refurbished*
- *Diversion gate: Risk score 8.00; recommended to be refurbished*

Priority 3: None of the following equipment were given scores between 0-5.

Cost of recommended R&R improvements for Water Intake: **$203,320**

Raw Water Pump Station

Priority 1: None of the equipment received scores greater than 15, and no need for immediate R&R improvement is required.

Priority 2: None of the equipment received scores between 5-10.

Priority 3: The following equipment were given scores between 0-5 and require action after 5 years:

- *Raw water pumps: Risk score 3.00; regular scheduled maintenance recommended*
- *Raw water pump electric motors: Risk score 2.50; regular scheduled maintenance recommended*

Cost of recommended R&R improvements for the Raw Water Pump Station: **$0**

Plant Inlet Meter and Flash Mix

Priority 1: None of the equipment received scores greater than 15, and no need for immediate R&R improvement is required.

Priority 2: None of the equipment received scores between 5-10.

Priority 3: The following equipment were given scores between 0-5 and require action after 5 years:

- *Flow meter: Risk score 4.00; regular maintenance recommended*
- *Sample pump: Risk score 3.00; regular maintenance recommended*

Cost of recommended R&R improvements for the Plant Inlet Meter and Flash Mix: **$7,800**

Clarification Basins/Actiflo

Priority 1: None of the equipment received scores greater than 15¸ and no need for immediate R&R improvement is required.

Priority 2: The following equipment were given scores between 5-15 and require action within 5 years:

- *Coagulation mixers: Risk score 6.67; replacement recommended*
- *Flocculation mixers: Risk score 6.67; replacement recommended*
- *Injection mixer (3-ME-22): Risk score 6.67; replacement recommended*
- *Sludge scrapers: Risk score 5.00; refurbishment recommended*

Priority 3: The following equipment were given scores between 0-5 and require action after 5 years:

- *Hydrocyclones: Risk score 4.00; units not recently replaced recommended to be replaced; regular maintenance recommended for units 3-ME-15*
- *Injection mixer (3-ME-12): Risk score 3.33; regular maintenance recommended*
- *Sample pumps: Risk score 3.33; regular maintenance recommended*
- *Sludge wasting pumps: Risk score 3.00; refurbishment recommended*

Cost of recommended R&R improvements for the Clarification Basins/Actiflo: **$1,051,863**

Ozone System

Priority 1: None of the equipment received scores greater than 15, and no need for immediate R&R improvement is required.

Priority 2: The following equipment were given scores between 5-15 and require action within 5 years:

- *Ozone generators: Risk score 7.50; refurbishment of internal components recommended*
- *LOX Vaporizers: Risk score 5.83; refurbishment of internal components recommended*
- *Particulate filters: Risk score 5.00; refurbishment recommended*

Priority 3: The following equipment were given scores between 0-5 and require action after 5 years:

- *LOX storage tank: Risk score 4.67; refurbishment recommended*
- *Ozone destruct unit: Risk score 2.67; refurbishment of internal components recommended*
- *Exhaust gas blower (4-ME-63): Risk score 2.67; replacement recommended*
- *Air compressors: Risk score 2.50; regular maintenance recommended*
- *Exhaust gas blower (4-ME-64): Risk score 1.67; regular maintenance recommended*

Cost of recommended R&R improvements for the Ozone System: **$1,279,915**

Filters

Priority 1: None of the equipment received scores greater than 15, and no need for immediate R&R improvement is required.

Priority 2: The following equipment were given scores between 5-15 and require action within 5 years:

- *Filter waste pump: Risk score 9.00; refurbishment recommended*
- *Air scour blower: Risk score 8.00; refurbishment recommended*
- *Backwash supply pump: Risk score 8.00; refurbishment recommended*
- *Filter waste pump actuator and valve: Risk score 7.50; regular maintenance recommended*
- *Backwash supply pump electric motors: Risk score 6.67; refurbishment recommended*

Priority 3: The following equipment were given scores between 0-5 and require action after 5 years:

- *Filter water valve actuators: Risk score 4.00; regular maintenance recommended*
- *Influent valve actuators: Risk score 4.00; regular maintenance recommended*
- *Backwash valves and actuators: Risk score 4.00; regular maintenance recommended*
- *Air scour valve actuators: Risk score 4.00; regular maintenance recommended*
- *Air scour valves: Risk score 4.00; refurbishment recommended*
- *Drain valve actuators: Risk score 4.00; regular maintenance recommended*
- *Filter to waste valve actuators: Risk score 4.00; regular maintenance recommended*

- *Filter to waste valves: Risk score 4.00; refurbishment recommended*
- *Influent valves: Risk score 2.67; regular maintenance recommended*
- *Filter water valves: Risk score 2.67; regular maintenance recommended*
- *Backwash valves: Risk score 2.67; regular maintenance recommended*
- *Drain valves: Risk score 2.67; regular maintenance recommended*

Cost of recommended R&R improvements for Filters: **$245,700**

Chemical Building

Priority 1: None of the equipment received scores greater than 15, and no need for immediate R&R improvement is required.

Priority 2: The following equipment were given scores between 5-15 and require action within 5 years:

- *Sodium hypochlorite feed pump 6-FD-83: Risk score 6.67; replacement recommended*
- *Dry polymer batch units: Risk score 6.67; replacement recommended*
- *Caustic storage tanks: Risk score 6.67; refurbishment recommended*
- *Polyphosphate feed pumps: Risk score 6.67; replacement recommended*
- *Cationic polymer feed pumps: Risk score 6.00; replacement recommended*
- *Caustic feed pumps 6-FD-21 and 6-FD-23: Risk score 6.00; replacement recommended*
- *Sodium hypochlorite storage tanks: Risk score 5.83; refurbishment recommended*
- *Alum/ferric storage tanks: Risk score 5.83; refurbishment recommended*
- *Nonionic polymer feed pumps: Risk score 5.33; replacement recommended*
- *Alum/ferric feed pumps: Risk score 5.33; replacement recommended*

Priority 3: The following equipment were given scores between 0-5 and require action after 5 years:

- *Caustic mixing pump: Risk score 4.67; refurbishment recommended*
- *Carbon dioxide vaporizer: Risk score 4.67; refurbishment recommended*
- *Carbon dioxide carrier water pump 6-P-42: Risk score 4.67; refurbishment recommended*
- *Carbon dioxide carrier water pump 6-P-41: Risk score 4.00; refurbishment recommended*
- *Sodium hypochlorite feed pumps: Risk score 4.00; regular maintenance recommended*
- *Carbon dioxide storage tank: Risk score 4.00; refurbishment of internal components recommended*
- *Caustic feed pump 6-FD-22: Risk score 3.33; regular maintenance recommended*
- *Chemical building drainage sump pumps: Risk score 2.76; replacement recommended*
- *Polyphosphate weigh scale 6-WS-91: Risk score 2.33; replacement recommended*
- *Polyphosphate weigh scale 6-WS-31: Risk score 2.00; replacement recommended*

Cost of recommended R&R improvements for the Chemical Building: **$970,604**

Operations Building

Priority 1: None of the equipment received scores greater than 15, and no need for immediate R&R improvement is required.

Priority 2: None of the equipment were given scores between 5-15.

Priority 3: The following equipment were given scores between 0-5 and require action after 5 years:

- *Equalization tank pumps: Risk score 4.67; refurbishment recommended*
- *Decant return pump 7-P-31: Risk score 4.17; regular maintenance recommended*
- *Decant return pump 7-P-32: Risk score 3.33; regular maintenance recommended*
- *Potable water booster pump pressure vessel: Risk score 2.00; refurbishment recommended*
- *Potable water booster pumps: Risk score 2.00; refurbishment recommended*

Cost of recommended R&R improvements for the Operations Building: **$32,500**

Treated Water Pump Station

Priority 1: None of the equipment received scores greater than 15, and no need for immediate R&R improvement is required.

Priority 2: None of the equipment were given scores between 5-15.

Priority 3: The following equipment were given scores between 0-5 and require action after 5 years:

- *Treated water pumps: Risk score 3.50; refurbishment recommended*
- *Treated water pump motors: Risk score 2.00; regular maintenance recommended*

Cost of recommended R&R improvements for the Treated Water Pump Station: **$364,000**

Total cost of recommended R&R improvements for NESWTF (with 20% contingency): **$4,986,842**

A summary of all equipment risk scores, recommendations, and costs are provided in **Table 5.1**.

Table 5.1 NESWTF Renewal and Replacement Results Summary

Drinking Water Infrastructure Renewal and replacemnt Plan

City of Fresno

							Field Condition Assessment		Amortized Asset Service Life					Plant Operation Assessment			Historical Operation Rating						Consequence of Failure									
Facility Name	Unit Processes	Component	Sub - Component	# of Units	Component Code	Installation or Replacement Year	Field Condition Assessment - Comments	Field Condition Assessment Rating	Component Service Life	Remaining Service Life	Percentage of Remaining Service Life	Remaining Service Life Rating	Condition Rating	Plant Operations - Rating	Plant Operations Rating	Plant Operations - Comments	Type of Failure	Frequency of Failure (times/year)	Duration between failures (months)	Time to repair (hours)	Historical Failure Rating	LOF/Serviceability [(N+R+U)/3)]	Water Quality	WQ Rating Comments	Plant Capacity (Flow)	Plant Capacity Comments	CoF Rating [AA+AB)/2]	Risk Score	R&R Recommendations	Equipment Cost Estimates, $	Construction Cost, $	R&R Cost Estimates, $
	Water Intake																												**Total Water Intake R&R, $**	**78,200**	**125,120**	**203,320**
NESWTF		Water Intake	Traveling Screen	1	1-ME-11	2004	Good, regular scheduled maintenance	3	20	6	30%	4	3.5	Asset functions as supposed to	1	-	ELEC					2.667	1	No plant WQ impact	5	No redundancy	3.00	8.00	**D**, close to end of service life	$60,000	$96,000	$156,000
NESWTF		Water Intake	Inlet gate	1	1-ME-12	2004	Good, , regular scheduled maintenance	3	30	16	53%	3	3	Asset functions as supposed to	1	-	MECH					2.333	1	No plant WQ impact	5	No redundancy	3.00	7.00	**C**, at mid of service life	$7,000	$11,200	$18,200
NESWTF		Water Intake	Diversion Gate	1	1-MOV-10	2004	Good, , regular scheduled maintenance	3	20	6	30%	4	3.5	Asset functions as supposed to	1	-	ELEC					2.667	1	No plant WQ impact	5	No redundancy	3.00	8.00	**D**, close to end of service life	$11,200	$17,920	$29,120
	Raw Water Pump Station			1									0																**Total Raw Water Pump Station R&R, $**	-	-	-
NESWTF		Raw Water Pump	Pump	1	1-P-11	2004	Good	2	30	16	53%	3	1	Asset functions as supposed to	1	-	MECH					2.000	1	No plant WQ impact	2	4 Pumps (3+1)	1.50	3.00	**A**, regular scheduled maintenance	$0	$0	$0
NESWTF		Raw Water Pump	Electric motor	1	1-P-11	2004	Good	2	50	36	72%	2	2	Asset functions as supposed to	1	Refurbished in 2013, preventive	ELEC					1.667	1	No plant WQ impact	2	4 E. motors (3+1)	1.50	2.50	**A**, regular scheduled checkups	$0	$0	$0
NESWTF		Raw Water Pump	Pump	1	1-P-12	2004	Good	2	30	16	53%	3	2.5	Asset functions as supposed to	1	-	MECH					2.000	1	No plant WQ impact	2	4 Pumps (3+1)	1.50	3.00	**A**, regular scheduled maintenance	$0	$0	$0
NESWTF		Raw Water Pump	Electric motor	1	1-P-12	2004	Good	2	50	36	72%	2	2	Asset functions as supposed to	1	Refurbished in 2013, preventive	ELEC					1.667	1	No plant WQ impact	2	4 E. motors (3+1)	1.50	2.50	**A**, regular scheduled checkups	$0	$0	$0
NESWTF		Raw Water Pump	Pump	1	1-P-13	2004	Good	2	30	16	53%	3	2.5	Asset functions as supposed to	1	-	MECH					2.000	1	No plant WQ impact	2	4 Pumps (3+1)	1.50	3.00	**A**, regular scheduled maintenance	$0	$0	$0
NESWTF		Raw Water Pump	Electric motor	1	1-P-13	2004	Good	2	50	36	72%	2	2	Asset functions as supposed to	1	Refurbished in 2013, preventive	ELEC					1.667	1	No plant WQ impact	2	4 E. motors (3+1)	1.50	2.50	**A**, regular scheduled checkups	$0	$0	$0
NESWTF		Raw Water Pump	Pump	1	1-P-14	2004	Good	2	30	16	53%	3	2.5	Asset functions as supposed to	1	-	MECH					2.000	1	No plant WQ impact	2	4 Pumps (3+1)	1.50	3.00	**A**, regular scheduled maintenance	$0	$0	$0
NESWTF		Raw Water Pump	Electric motor	1	1-P-14	2004	Good	2	50	36	72%	2	2	Asset functions as supposed to	1	Refurbished in 2014, preventive	ELEC					1.667	1	No plant WQ impact	2	4 E. motors (3+1)	1.50	2.50	**A**, regular scheduled checkups	$0	$0	$0
	Plant Inlet Meter and Flash Mix												0																**Total Inlet Meter and Flush Mixing, $**	**3,000**	**4,800**	**7,800**
NESWTF		Influent Sample Pump	Sample Pump	1	2-P-11	2016	New	1	15	13	87%	1	1	Asset functions as supposed to	1	Replaced 2016						1.000	1	No plant WQ impact	5	No redundancy	3.00	3.00	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Influent Flow Meter	Flowmeter	1	FE/FIT-001	2012	Good, requires cleaning	2	30	24	80%	1	1.5	Asset functions as supposed to	1	Replaced 2012						1.333	1	No plant WQ impact	5	No redundancy	3.00	4.00	**B**, on-site cleaning, calibration	$3,000	$4,800	$7,800
	Clarification Basins/Actiflo												0																**Total Clarification Basin R&R**	**404,563**	**647,300**	**1,051,863**
NESWTF		Clarification	Coagulation Mixer	1	3-ME-11	2004	Good	2	10	-4	-40%	5	3.5	Asset functions as supposed to	1	-						2.667	4	2 Trains (1+1)	1	No flow impact	2.50	6.67	**E**, exceeded service life	$68,737	$109,979	$178,716
NESWTF		Clarification	Injection Mixer	1	3-ME-12	2016	Good	2	10	8	80%	1	1.5	Asset functions as supposed to	1	Blades replaced in 2016						1.333	4	2 Trains (1+1)	1	No flow impact	2.50	3.33	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Clarification	Flocculation Mixer	1	3-ME-13	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	4	2 Trains (1+1)	1	No flow impact	2.50	6.67	**E**, at the end of service life	$68,737	$109,979	$178,716
NESWTF		Clarification	Sludge Scraper	1	3-ME-14	2004	Good	2	30	16	53%	3	2.5	Asset functions as supposed to	1	-						2.000	4	2 Trains (1+1)	1	No flow impact	2.50	5.00	**C**, at mid of service life	$7,125	$11,400	$18,525
NESWTF		Solids Separation	Hydrocyclon	1	3-ME-15	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	Replaced interior of recover sand box						2.667	2	8 Hydrociclones (>3+1)	1	No flow impact	1.50	4.00	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Solids Separation	Hydrocyclon	1	3-ME-16	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	2	8 Hydrociclones (>3+1)	1	No flow impact	1.50	4.00	**E**, at the end of service life	$4,000	$6,400	$10,400
NESWTF		Solids Separation	Hydrocyclon	1	3-ME-17	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	Replaced interior of recover sand box						2.667	2	8 Hydrociclones (>3+1)	1	No flow impact	1.50	4.00	**E**, at the end of service life	$4,000	$6,400	$10,400
NESWTF		Solids Separation	Hydrocyclon	1	3-ME-18	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	2	8 Hydrociclones (>3+1)	1	No flow impact	1.50	4.00	**E**, at the end of service life	$4,000	$6,400	$10,400
NESWTF		Clarification	Coagulation Mixer	1	3-ME-21	2004	Good	2	10	-4	-40%	5	3.5	Asset functions as supposed to	1	-						2.667	4	2 Trains (1+1)	1	No flow impact	2.50	6.67	**E**, exceeded service life	$64,489	$103,182	$167,671
NESWTF		Clarification	Injection Mixer	1	3-ME-22	2004	Good	2	10	-4	-40%	5	3.5	Asset functions as supposed to	1	-						2.667	4	2 Trains (1+1)	1	No flow impact	2.50	6.67	**E**, exceeded service life	$64,489	$103,182	$167,671
NESWTF		Clarification	Flocculation Mixer	1	3-ME-23	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	4	2 Trains (1+1)	1	No flow impact	2.50	6.67	**E**, at the end of service life	$71,861	$114,978	$186,839
NESWTF		Clarification	Sludge Scraper	1	3-ME-24	2004	Good	2	30	16	53%	3	2.5	Asset functions as supposed to	1	-						2.000	4	2 Trains (1+1)	1	No flow impact	2.50	5.00	**C**, at mid of service life	$7,125	$11,400	$18,525
NESWTF		Solids Separation	Hydrocyclon	1	3-ME-25	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	Replaced interior of recover sand box						2.667	2	8 Hydrociclones (>3+1)	1	No flow impact	1.50	4.00	**E**, at the end of service life	$4,000	$6,400	$10,400
NESWTF		Solids Separation	Hydrocyclon	1	3-ME-26	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	2	8 Hydrociclones (>3+1)	1	No flow impact	1.50	4.00	**E**, at the end of service life	$4,000	$6,400	$10,400
NESWTF		Solids Separation	Hydrocyclon	1	3-ME-27	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	Replaced interior of recover sand box						2.667	2	8 Hydrociclones (>3+1)	1	No flow impact	1.50	4.00	**E**, at the end of service life	$4,000	$6,400	$10,400
NESWTF		Solids Separation	Hydrocyclon	1	3-ME-28	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	2	8 Hydrociclones (>3+1)	1	No flow impact	1.50	4.00	**E**, at the end of service life	$4,000	$6,400	$10,400
NESWTF		Clarification	Sludge Wasting Pump	1	3-P-11	2006	Good	2	20	8	40%	3	2.5	Asset functions as supposed to	1	Replaced in 2006	MECH					2.000	2	4 Pumps (3+1)	1	No flow impact	1.50	3.00	**C**, at mid of service life	$6,000	$9,600	$15,600
NESWTF		Clarification	Sludge Wasting Pump	1	3-P-12	2006	Good	2	20	8	40%	3	2.5	Asset functions as supposed to	1	Replaced in 2006	MECH					2.000	2	4 Pumps (3+1)	1	No flow impact	1.50	3.00	**C**, at mid of service life	$6,000	$9,600	$15,600
NESWTF		Clarification	Sludge Wasting Pump	1	3-P-21	2006	Good	2	20	8	40%	3	2.5	Asset functions as supposed to	1	Replaced in 2006	MECH					2.000	2	4 Pumps (3+1)	1	No flow impact	1.50	3.00	**C**, at mid of service life	$6,000	$9,600	$15,600
NESWTF		Clarification	Sludge Wasting Pump	1	3-P-22	2006	Good	2	20	8	40%	3	2.5	Asset functions as supposed to	1	Replaced in 2006	MECH					2.000	2	4 Pumps (3+1)	1	No flow impact	1.50	3.00	**C**, at mid of service life	$6,000	$9,600	$15,600
NESWTF		Clarification	Sample pump	1	3-P-13	2015	New, Requires maintenance of fittings	2	15	12	80%	1	1.5	Asset functions as supposed to	1	Replaced 2015	MECH					1.333	1	No plant WQ impact	4	2 Overflows (1+1)	2.50	3.33	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Clarification	Sample pump	1	3-P-23	2015	New, Requires maintenance of fittings	2	15	12	80%	1	1.5	Asset functions as supposed to	1	Replaced 2015	MECH					1.333	1	No plant WQ impact	4	2 Overflows (1+1)	2.50	3.33	**A**, reg. maintn. recently replaced	$0	$0	$0
	Ozone System												0																**Total Ozone System R&R**	**492,275**	**787,640**	**1,279,915**
NESWTF		Liquid Oxygen System	LOX Storage Tank	1	4-T-11	2004	ood, Requires pipe maintenan	3	25	11	44%	3	3	Asset functions as supposed to	1	-						2.333	3	Intermediate WQ impact	1	No flow impact	2.00	4.67	**C**, at mid of service life	$37,500	$60,000	$97,500
NESWTF		Liquid Oxygen System	LOX Vaporizer	1	4-ME-11	2004	Good	2	20	6	30%	4	3	Asset functions as supposed to	1	-						2.333	4	2 Vaporizers (1+1)	1	No flow impact	2.50	5.83	**D,** at mid of service life	$4,200	$6,720	$10,920
NESWTF		Liquid Oxygen System	LOXVaporizer	1	4-ME-12	2004	Good	2	20	6	30%	4	3	Asset functions as supposed to	1	-						2.333	4	2 Vaporizers (1+1)	1	No flow impact	2.50	5.83	**D,** at mid of service life	$4,200	$6,720	$10,920
NESWTF		Air System	Air Compressor	1	4-ME-23	2014	New	1	20	16	80%	1	1	Asset functions as supposed to	1	Compressor rebuilt in 2014						1.000	4	2 Compressors (1+1)	1	No flow impact	2.50	2.50	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Air System	Air Compressor	1	4-ME-24	2014	New	1	20	16	80%	1	1	Asset functions as supposed to	1	Compressor rebuilt in 2014						1.000	4	2 Compressors (1+1)	1	No flow impact	2.50	2.50	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Ozone Generation System	Particulate Filter	1	4-ME-13	2004	Good	2	25	11	44%	3	2.5	Asset functions as supposed to	1	-						2.000	4	2 Pt. filters (1+1)	1	No flow impact	2.50	5.00	**C**, at mid of service life	$2,250	$3,600	$5,850
NESWTF		Ozone Generation System	Particulate Filter	1	4-ME-14	2004	Good	2	25	11	44%	3	2.5	Asset functions as supposed to	1	-						2.000	4	2 Pt. filters (1+1)	1	No flow impact	2.50	5.00	**C**, at mid of service life	$2,250	$3,600	$5,850
NESWTF		Ozone Generation System	Ozone Generator	1	4-ME-21	2004	Good	1	20	6	30%	4	2.5	Asset functions as supposed to	4	Various repair have been made						3.000	4	2 Ozone generators (1+1)	1	No flow impact	2.50	7.50	**C**, at mid of service life	$126,250	$202,000	$328,250
NESWTF		Ozone Generation System	Ozone Generator	1	4-ME-22	2004	Good	1	20	6	30%	4	2.5	Asset functions as supposed to	4	Various repair have been made						3.000	4	2 Ozone generators (1+1)	1	No flow impact	2.50	7.50	**C**, at mid of service life	$126,250	$202,000	$328,250
NESWTF		Ozone Contactor	Demister	1	4-ME-41	2004	NOT INSTALLED	NA	NA	NA	NA	1	NA		N/A	Not installed						NA	NA	NA	NA	NA	NA	NA	N/A	N/A	N/A	N/A
NESWTF		Ozone Contactor	Demister	1	4-ME-51	2004	NOT INSTALLED	NA	NA	NA	NA	1	NA		N/A	Not installed						NA	NA	NA	NA	NA	NA	NA	N/A	N/A	N/A	N/A
NESWTF		Ozone Contactor	Ozone Destruction Unit	1	4-ME-61	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	1	No plant WQ impact	1	No flow impact	1.00	2.67	**E**, at the end of service life	$63,125	$101,000	$164,125
NESWTF		Ozone Contactor	Ozone Destruction Unit	1	4-ME-62	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	1	No plant WQ impact	1	No flow impact	1.00	2.67	**E**, at the end of service life	$63,125	$101,000	$164,125
NESWTF		Ozone Contactor	Exhaust Gas Blower	1	4-ME-63	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	1	No plant WQ impact	1	No flow impact	1.00	2.67	**E**, at the end of service life	$63,125	$101,000	$164,125
NESWTF		Ozone Contactor	Exhaust Gas Blower	1	4-ME-64	2016	New	1	15	13	87%	1	1	Asset functions as supposed to	3	Motor and shaft bearings replaced in 2016						1.667	1	No plant WQ impact	1	No flow impact	1.00	1.67	**A**, reg. maintn. recently replaced	0	0	$0

Table 5.1 NESWTF Renewal and Replacement Results Summary

Drinking Water Infrastructure Renewal and replacemnt Plan

City of Fresno

							Field Condition Assessment		Amortized Asset Service Life					Plant Operation Assessment			Historical Operation Rating						Consequence of Failure									
Facility Name	Unit Processes	Component	Sub - Component	# of Units	Component Code	Installation or Replacement Year	Field Condition Assessment - Comments	Field Condition Assessment Rating	Component Service Life	Remaining Service Life	Percentage of Remaining Service Life	Remaining Service Life Rating	Condition Rating	Plant Operations - Rating	Plant Operations Rating	Plant Operations - Comments	Type of Failure	Frequency of Failure (times/year)	Duration between failures (months)	Time to repair (hours)	Historical Failure Rating	LOF/Serviceability [(N+R+U)/3]	Water Quality	WQ Rating Comments	Plant Capacity (Flow)	Plant Capacity Comments	CoF Rating [(AA+AB)/2]	Risk Score	R&R Recommendations	Equipment Cost Estimates, $	Construction Cost, $	R&R Cost Estimates, $
	Filters												0																**Total Filters R&R, $**	**94,500**	**151,200**	**245,700**
NESWTF		Filter Waste Pump	Pump	1	5-P-01	2004	Good	2	30	16	53%	3	2.5	Asset functions as supposed to	1	-						2.000	4	2 Pumps (1+1)	5	No redundancy	4.50	9.00	**C**, at mid of service life	$8,000	$12,800	$20,800
NESWTF		Filter Waste Pump	Actuator and valve	1		2014	Good	2	15	11	73%	2	2	Asset functions as supposed to	1	Actuator replaced in 2014						1.667	4	2 Pumps (1+1)	5	No redundancy	4.50	7.50	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Air Scour Blower	Blower	1	5-ME-01	2004	Good	2	25	11	44%	3	2.5	Asset functions as supposed to	3	-						2.667	3	Intermediate WQ impact	3		3.00	8.00	**C**, at mid of service life	$22,500	$36,000	$58,500
NESWTF		Backwash Supply Pump	Pump	1	5-P-08	2004	Good	2	30	16	53%	3	2.5	Asset functions as supposed to	1	-						2.000	4	2 Pumps (1+1)	4	2 BW Pumps(1+1)	4.00	8.00	**C**, at mid of service life	$30,000	$48,000	$78,000
NESWTF		Backwash Supply Pump	Electric motor	1	5-P-08	2004	Good	2	50	36	72%	2	2	Asset functions as supposed to	1	-						1.667	4	2 EL. motors(1+1)	4	2 El. motors(1+1)	4.00	6.67	**A**, regular scheduled checkups	$0	$0	$0
NESWTF		Backwash Supply Pump	Pump	1	5-P-07	2004	Good	2	30	16	53%	3	2.5	Asset functions as supposed to	1	-						2.000	4	2 Pumps (1+1)	4	2 BW Pumps(1+1)	4.00	8.00	**C**, at mid of service life	$30,000	$48,000	$78,000
NESWTF		Backwash Supply Pump	Electric motor	1	5-P-07	2004	Good	2	50	36	72%	2	2	Asset functions as supposed to	1	-						1.667	4	2 EL. motors(1+1)	4	2 El. motors(1+1)	4.00	6.67	**A**, regular scheduled checkups	$0	$0	$0
NESWTF		Filter Beds	Influent valves	6	Mult	2013	Good	2	25	20	80%	1	1.5	Asset functions as supposed to	1	2013 Replaced seats						1.333	2	6 Filter s(>3+1)	2	Redundant Filters (>3+1)	2.00	2.67	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Filter Beds	Influent Valve Actuator	6	Multi	2014	Good, Requires regular maintenance	3	15	11	73%	2	2.5	Asset functions as supposed to	1	Actuator Replaced in 2014						2.000	2	6 Filter s(>3+1)	2	Redundant Filters (>3+1)	2.00	4.00	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Filter Beds	Filter Water Valves	6	Mult	2013	Good	2	25	20	80%	1	1.5	Asset functions as supposed to	1	2013 Replaced seats						1.333	2	6 Filter s(>3+1)	2	Redundant Filters (>3+1)	2.00	2.67	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Filter Beds	Filter Water Valve Actuator	6	Multi	2014	Good, Requires regular maintenance	3	15	11	73%	2	2.5	Asset functions as supposed to	1	Actuator Replaced in 2014						2.000	2	6 Filter s(>3+1)	2	Redundant Filters (>3+1)	2.00	4.00	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Filter Beds	Backwash Valves	6	Mult	2013	Good	2	25	20	80%	1	1.5	Asset functions as supposed to	1	2013 Replaced seats						1.333	2	6 Filter s(>3+1)	2	Redundant Filters (>3+1)	2.00	2.67	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Filter Beds	Backwash Valve Actuator	6	Multi	2014	Good, Requires regular maintenance	3	15	11	73%	2	2.5	Asset functions as supposed to	1	Actuator Replaced in 2014						2.000	2	6 Filter s(>3+1)	2	Redundant Filters (>3+1)	2.00	4.00	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Filter Beds	Air Scour Valves	6	Mult	2004	Good	2	25	11	44%	3	2.5	Asset functions as supposed to	1	-						2.000	2	6 Filter s(>3+1)	2	Redundant Filters (>3+1)	2.00	4.00	**C**, at mid of service life	$2,000	$3,200	$5,200
NESWTF		Filter Beds	Air Scour Valve Actuator	6	Multi	2014	Good, Requires regular maintenance	3	15	11	73%	2	2.5	Asset functions as supposed to	1	Actuator Replaced in 2014						2.000	2	6 Filter s(>3+1)	2	Redundant Filters (>3+1)	2.00	4.00	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Filter Beds	Drain valves	6	Mult	2015	Good	2	25	22	88%	1	1.5	Asset functions as supposed to	1	Replaced 2015						1.333	2	6 Filter s(>3+1)	2	Redundant Filters (>3+1)	2.00	2.67	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Filter Beds	Drain Valve Actuator	6	Multi	2014	Good, Requires regular maintenance	3	15	11	73%	2	2.5	Asset functions as supposed to	1	Actuator Replaced in 2014						2.000	2	6 Filter s(>3+1)	2	Redundant Filters (>3+1)	2.00	4.00	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Filter Beds	Filter to waste valves	6	Mult	2004	Good	2	25	11	44%	3	2.5	Asset functions as supposed to	1	-						2.000	2	6 Filter s(>3+1)	2	Redundant Filters (>3+1)	2.00	4.00	**C**, at mid of service life	$2,000	$3,200	$5,200
NESWTF		Filter Beds	Filter to Water Valve Actuator	6	Multi	2014	Good, Requires regular maintenance	3	15	11	73%	2	2.5	Asset functions as supposed to	1	Actuator Replaced in 2014						2.000	2	6 Filter s(>3+1)	2	Redundant Filters (>3+1)	2.00	4.00	**A**, reg. maintn. recently replaced	$0	$0	$0
	Chemical Building																												**Total Chemical Building R&R, $**	**373,309**	**597,295**	**970,604**
NESWTF		Sodium Hypochlorite System	Storage Tank	1	6-T-81	2004	Good	2	20	6	30%	4	3	Asset functions as supposed to	1	-						2.333	4	2 Tanks(1+1)	1	No Plt flow impact	2.50	5.83	**C**, at mid of service life	$16,250	$26,000	$42,250
NESWTF		Sodium Hypochlorite System	Storage Tank	1	6-T-82	2004	Good	2	20	6	30%	4	3	Asset functions as supposed to	1	-						2.333	4	2 Tanks(1+1)	1	No Plt flow impact	2.50	5.83	**C**, at mid of service life	$16,250	$26,000	$42,250
NESWTF		Sodium Hypochlorite System	SHC Feed Pump	1	6-FD-81	2017	Good, recently replaced	4	15	14	93%	1	2.5	Asset functions as supposed to	1	-						2.000	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	4.00	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Sodium Hypochlorite System	SHC Feed Pump	1	6-FD-82	2017	Good, recently replaced	4	15	14	93%	1	2.5	Asset functions as supposed to	1	Repurposed PO4						2.000	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	4.00	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Sodium Hypochlorite System	SHC Feed Pump	1	6-FD-83	2004	Good	4	15	1	7%	5	4.5	Asset functions as supposed to	1	-						3.333	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	6.67	**E**, at the end of service life	$14,236	$22,777	$37,013
NESWTF		Cationic Polymer System	Dry Polymer Batch Unit	1	6-ME-71	2004	Good, Requires fitting maintenance	3	20	6	30%	4	3.5	Asset functions as supposed to	1	-						2.667	4	2 Polymer systems(1+1)	1	No Plt flow impact	2.50	6.67	**D,** at mid of service life	$5,971	$9,554	$15,525
NESWTF		Cationic Polymer System	Polymer Feed Pump	1	6-FD-71	2004	Good, Requires fitting maintenance	3	15	1	7%	5	4	Asset functions as supposed to	1	-						3.000	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	6.00	**E,** close to the end of service life	$13,641	$21,826	$35,467
NESWTF		Cationic Polymer System	Polymer Feed Pump	1	6-FD-72	2004	Good, Requires fitting maintenance	3	15	1	7%	5	4	Asset functions as supposed to	1	-						3.000	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	6.00	**E**, at the end of service life	$13,641	$21,826	$35,467
NESWTF		Cationic Polymer System	Polymer Feed Pump	1	6-FD-73	2004	Good, Requires fitting maintenance	3	15	1	7%	5	4	Asset functions as supposed to	1	-						3.000	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	6.00	**E**, at the end of service life	$13,641	$21,826	$35,467
NESWTF		Nonionic Polymer System	Dry Polymer Batch Unit	1	6-ME-72	2004	Good, Requires fitting maintenance	3	20	6	30%	4	3.5	Asset functions as supposed to	1	-						2.667	4	2 Polymer systems(1+1)	1	No Plt flow impact	2.50	6.67	**E,** close to the end of service life	$5,971	$9,554	$15,525
NESWTF		Nonionic Polymer System	Polymer Feed Pump	1	6-FD-51	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	5.33	**E**, at the end of service life	$13,641	$21,826	$35,467
NESWTF		Nonionic Polymer System	Polymer Feed Pump	1	6-FD-52	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	5.33	**E**, at the end of service life	$13,641	$21,826	$35,467
NESWTF		Nonionic Polymer System	Polymer Feed Pump	1	6-FD-53	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	5.33	**E**, at the end of service life	$13,641	$21,826	$35,467
NESWTF		Aluminum/Ferric System	Storage Tank	1	6-T-11	2004	Good	2	20	6	30%	4	3	Asset functions as supposed to	1	-						2.333	4	2 Tanks(1+1)	1	No Plt flow impact	2.50	5.83	**C**, at mid of service life	$16,250	$26,000	$42,250
NESWTF		Aluminum/Ferric System	Storage Tank	1	6-T-12	2004	Good	2	20	6	30%	4	3	Asset functions as supposed to	1	-						2.333	4	2 Tanks(1+1)	1	No Plt flow impact	2.50	5.83	**C**, at mid of service life	$16,250	$26,000	$42,250
NESWTF		Aluminum/Ferric System	AL/FC Feed Pump	1	6-FD-11	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	5.33	**C**, at mid of service life	$3,454	$5,527	$8,982
NESWTF		Aluminum/Ferric System	AL/FC Feed Pump	1	6-FD-12	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	5.33	**E**, at the end of service life	$13,818	$22,109	$35,926
NESWTF		Aluminum/Ferric System	AL/FC Feed Pump	1	6-FD-13	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	5.33	**E**, at the end of service life	$13,818	$22,109	$35,926
NESWTF		Caustic System	Storage Tank	1	6-T-21	2004	Good, Requires concrete anchor inspect.	3	20	6	30%	4	3.5	Asset functions as supposed to	1	-						2.667	4	2 Tanks(1+1)	1	No Plt flow impact	2.50	6.67	**C**, at mid of service life	$17,500	$28,000	$45,500
NESWTF		Caustic System	Storage Tank	1	6-T-22	2004	Good, Requires concrete anchor inspect.	3	20	6	30%	4	3.5	Asset functions as supposed to	1	-						2.667	4	2 Tanks(1+1)	1	No Plt flow impact	2.50	6.67	**C**, at mid of service life	$17,500	$28,000	$45,500
NESWTF		Caustic System	Caustic Feed Pump	1	6-FD-21	2004	Good, Requires concrete anchor inspect.	3	15	1	7%	5	4	Asset functions as supposed to	1	-						3.000	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	6.00	**E**, at the end of service life	$13,604	$21,766	$35,370
NESWTF		Caustic System	Caustic Feed Pump	1	6-FD-22	2018	Good, Requires concrete anchor inspect.	3	15	15	100%	1	2	Asset functions as supposed to	1	Replaced 2018						1.667	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	3.33	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Caustic System	Caustic Feed Pump	1	6-FD-23	2004	Good, Requires concrete anchor inspect.	3	15	1	7%	5	4	Asset functions as supposed to	1	-						3.000	3	3 Pumps (2+1)	1	No Plt flow impact	2.00	6.00	**E**, at the end of service life	$13,604	$21,766	$35,370
NESWTF		Caustic System	Mixing Pump	1	6-P-21	2004	Good	2	20	6	30%	4	3	Asset functions as supposed to	1	-						2.333	3	Intermediate WQ impact	1	No Plt flow impact	2.00	4.67	**C**, at mid of service life	$3,750	$6,000	$9,750
NESWTF		Polyphosphate System	Weigh Scale	1	6-WS-31	2004	Good	2	30	16	53%	3	2.5	Asset functions as supposed to	1	-						2.000	1	No plant WQ impact	1	No Plt flow impact	1.00	2.00	**C**, at mid of service life	$5,000	$8,000	$13,000
NESWTF		Polyphosphate System	Weigh Scale	1	6-WS-91	2004	Good, Requires fitting maintenance	3	30	16	53%	3	3	Asset functions as supposed to	1	-						2.333	1	No plant WQ impact	1	No Plt flow impact	1.00	2.33	**C**, at mid of service life	$5,000	$8,000	$13,000
NESWTF		Polyphosphate System	Polyphosphate Feed Pump	1	6-FD-31	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	4	2 Pumps(1+1)	1	No Plt flow impact	2.50	6.67	**E**, at the end of service life	$10,368	$16,589	$26,957
NESWTF		Polyphosphate System	Polyphosphate Feed Pump	1	6-FD-91	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	4	2 Pumps (1+1)	1	No Plt flow impact	2.50	6.67	**E**, at the end of service life	$10,368	$16,589	$26,957
NESWTF		Carbon Dioxide System	Storage Tank	1	6-T-41	2004	Good	2	30	16	53%	3	2.5	Asset functions as supposed to	1	-						2.000	3	Intermediate WQ impact	1	No Plt flow impact	2.00	4.00	**C**, at mid of service life	$30,000	$48,000	$78,000
NESWTF		Carbon Dioxide System	Vaporizer	1	6-M-41	2004	Good	2	20	6	30%	4	3	Asset functions as supposed to	1	-						2.333	3	Intermediate WQ impact	1	No Plt flow impact	2.00	4.67	**D**, rehab to extend service life	$10,500	$16,800	$27,300
NESWTF		Carbon Dioxide System	Vapor Heater	1	6-M-42	2004	Good	2	20	6	30%	4	3	Asset functions as supposed to	1	-						2.333	3	Intermediate WQ impact	1	No Plt flow impact	2.00	4.67	**D**, rehab to extend service life	$10,000	$16,000	$26,000
NESWTF		Carbon Dioxide System	Carrier Water Pump	1	6-P-41	2004	Good	2	25	11	44%	3	2.5	Asset functions as supposed to	1	-						2.000	3	Intermediate WQ impact	1	No Plt flow impact	2.00	4.00	**D**, rehab to extend service life	$6,000	$9,600	$15,600
NESWTF		Carbon Dioxide System	Carrier Water Pump	1	6-P-42	2004	Fair	3	25	11	44%	3	3	Asset functions as supposed to	1	-						2.333	3	Intermediate WQ impact	1	No Plt flow impact	2.00	4.67	**D**, rehab to extend service life	$6,000	$9,600	$15,600
NESWTF		Chemical Building Drainage Syst	Sump Pump	1	6-P-01	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	1	No plant WQ impact	1	No Plt flow impact	1.00	2.67	**E**, at the end of service life	$5,000	$8,000	$13,000

Table 5.1 NESWTF Renewal and Replacement Results Summary

Drinking Water Infrastructure Renewal and replacemnt Plan

City of Fresno

							Field Condition Assessment		Amortized Asset Service Life					Plant Operation Assessment			Historical Operation Rating						Consequence of Failure									
Facility Name	Unit Processes	Component	Sub - Component	# of Units	Component Code	Installation or Replacement Year	Field Condition Assessment - Comments	Field Condition Assessment Rating	Component Service Life	Remaining Service Life	Percentage of Remaining Service Life	Remaining Service Life Rating	Condition Rating	Plant Operations - Rating	Plant Operations Rating	Plant Operations - Comments	Type of Failure	Frequency of Failure (times/year)	Duration between failures (months)	Time to repair (hours)	Historical Failure Rating	LOF/Serviceability [(N+R+U)/3]	Water Quality	WQ Rating Comments	Plant Capacity (Flow)	Plant Capacity Comments	CoF Rating [(AA+AB)/2]	Risk Score	R&R Recommendations	Equipment Cost Estimates, $	Construction Cost, $	R&R Cost Estimates, $
NESWTF		Chemical Building Drainage Syst	Sump Pump	1	6-P-02	2004	Good	2	15	1	7%	5	3.5	Asset functions as supposed to	1	-						2.667	1	No plant WQ impact	1	No Plt flow impact	1.00	2.67	**E**, at the end of service life	$5,000	$8,000	$13,000
NESWTF		Chemical Building Drainage Syst	Sump Pump	1	6-P-03	2004	NOT INSPECTED		NA	NA		NA	#VALUE!		NA							NA	NA		NA		NA		NA	NA	NA	NA
NESWTF		Chemical Building Drainage Syst	Sump Pump	1	6-P-04	2004	NOT INSPECTED		NA	NA		NA	#VALUE!		NA							NA	NA		NA		NA		NA	NA	NA	NA
		Operations Building																				0.000							**Total Operations Building R&R, $**	**12,500**	**20,000**	**32,500**
NESWTF		Potable Water Booster Pump	Pressure Vessel	1	6-T-91	2004	Good	2	25	11	44%	3	2.5	Asset functions as supposed to	1	-						2.000	1	No plant WQ impact	1	No Plt flow impact	1.00	2.00	**C**, at mid of service life	$2,500	$4,000	$6,500
NESWTF		Potable Water Booster Pump	Booster Pump	1	6-P-91	2004	Good	2	30	16	53%	3	2.5	Asset functions as supposed to	1	-						2.000	1	No plant WQ impact	1	No Plt flow impact	1.00	2.00	**C**, at mid of service life	$1,875	$3,000	$4,875
NESWTF		Potable Water Booster Pump	Booster Pump	1	6-P-92	2004	Good	2	30	16	53%	3	2.5	Asset functions as supposed to	1	-						2.000	1	No plant WQ impact	1	No Plt flow impact	1.00	2.00	**C**, at mid of service life	$1,875	$3,000	$4,875
NESWTF		Washwater Recovery System	Decant Return Pumps	1	7-P-31	2015	Good, Requires regular maintenance	3	30	27	90%	1	2	Asset functions as supposed to	1	Impeller replaced 2015						1.667	1	No plant WQ impact	4	2 BW Pumps(1+1)	2.50	4.17	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Washwater Recovery System	Decant Return Pumps	1	7-P-32	2015	Good	2	30	27	90%	1	1.5	Asset functions as supposed to	1	Impeller replaced 2015						1.333	1	No plant WQ impact	4	2 BW Pumps(1+1)	2.50	3.33	**A**, reg. maintn. recently replaced	$0	$0	$0
NESWTF		Washwater Recovery System	Decant Return Pumps	1	7-P-33	2004	NOT INSTALLED	NA	NA	NA		NA	#VALUE!		NA	-						NA	NA		NA		NA	NA	NA	NA	NA	NA
NESWTF		Washwater Recovery System	Equalization Tank Pump	1	7-P-11	2004	Good, Requires regular maintenance	3	30	16	53%	3	3	Asset functions as supposed to	1	-						2.333	1	No plant WQ impact	3	3 WW Rec. Pumps (2+1)	2.00	4.67	**C**, at mid of service life	$3,125	$5,000	$8,125
NESWTF		Washwater Recovery System	Equalization Tank Pump	1	7-P-12	2004	Good, Requires regular maintenance	3	30	16	53%	3	3	Asset functions as supposed to	1	-						2.333	1	No plant WQ impact	3	3 WW Rec. Pumps (2+1)	2.00	4.67	**C**, at mid of service life	$3,125	$5,000	$8,125
NESWTF		Washwater Recovery System	Equalization Tank Pump	1	7-P-13	2004	NOT INSTALLED	NA	NA	NA		NA	#VALUE!		NA	-						NA	NA		NA		NA	NA	NA	NA	NA	NA
NESWTF		Clearwell Drain Pump	Pump	1	7-P-01	2004	NOT INSTALLED	NA	NA	NA		NA	#VALUE!		NA	-						NA	NA		NA		NA	NA	NA	NA	NA	NA
		Treated Water Pump Station																				0.000							**Total Treated Water PS**	**140,000**	**224,000**	**364,000**
																						0.000									-	
NESWTF		Treated Water Pump Station	Pump	1	9-P-11	2004	Good, Requires regular maintenance	3	30	16	53%	3	3	Asset functions as supposed to	1	-						2.333	1	No plant WQ impact	2	4 Pumps (3+1)	1.50	3.50	**C**, at mid of service life	$35,000	$56,000	$91,000
NESWTF		Treated Water Pump Station	Electric motor	1	9-P-11	2014	Good	2	50	46	92%	1	1.5	Asset functions as supposed to	1	Refurbished 2014						1.333	1	No plant WQ impact	2	4 E. motors (3+1)	1.50	2.00	**A**, regular scheduled checkups	$0	$0	$0
NESWTF		Treated Water Pump Station	Pump	1	9-P-12	2004	Good, Requires regular maintenance	3	30	16	53%	3	3	Asset functions as supposed to	1	-						2.333	1	No plant WQ impact	2	4 Pumps (3+1)	1.50	3.50	**C**, at mid of service life	$35,000	$56,000	$91,000
NESWTF		Treated Water Pump Station	Electric motor	1	9-P-12	2014	Good	2	50	46	92%	1	1.5	Asset functions as supposed to	1	Refurbished 2014						1.333	1	No plant WQ impact	2	4 E. motors (3+1)	1.50	2.00	**A**, regular scheduled checkups	$0	$0	$0
NESWTF		Treated Water Pump Station	Pump	1	9-P-13	2004	Good, Requires regular maintenance	3	30	16	53%	3	3	Asset functions as supposed to	1	-						2.333	1	No plant WQ impact	2	4 Pumps (3+1)	1.50	3.50	**C**, at mid of service life	$35,000	$56,000	$91,000
NESWTF		Treated Water Pump Station	Electric motor	1	9-P-13	2014	Good	2	50	46	92%	1	1.5	Asset functions as supposed to	1	Refurbished 2014						1.333	1	No plant WQ impact	2	4 E. motors (3+1)	1.50	2.00	**A**, regular scheduled checkups	$0	$0	$0
NESWTF		Treated Water Pump Station	Pump	1	9-P-14	2004	Good, Requires regular maintenance	3	30	16	53%	3	3	Asset functions as supposed to	1	-						2.333	1	No plant WQ impact	2	4 Pumps (3+1)	1.50	3.50	**C**, at mid of service life	$35,000	$56,000	$91,000
NESWTF		Treated Water Pump Station	Electric motor	1	9-P-14	2014	Good	2	50	46	92%	1	1.5	Asset functions as supposed to	1	Refurbished 2014						1.333	1	No plant WQ impact	2	4 E. motors (3+1)	1.50	2.00	**A**, regular scheduled checkups	$0	$0	$0
																													TOTAL Estimates	**1,598,347**	**2,557,355**	**$ 4,155,702**
																													Contingency 20%			**$ 831,140**
																													R&R TOTAL			**$ 4,986,842**

LEGEND & ASSUMPTIONS:

1 Remaining Service Life = Year of Installation+Amortized Service life - 2018

2 Remaining Service Life Rating

80%-100%= 1

60%-79%= 2

40%-59%= 3

20%-39%= 4

0%-19%= 5

3 30 Equipment amortized service life per City of San Diego's NCWRP

4 **15** Assumed equipment amortized service life per for the NEWFP

5 Field Condition Rating

New = 1

Good = 2

Fair = 3

Poor = 4

Unusable/Not operational/Failed = 5

6 Plant Operation Rating

Asset works as supposed to = 1

Asset works as expected 80% of time = 2

Asset functions below its expected level/Works 1/2 time/requires re-starting/has limited functionality = 3

Asset only works occasionally or most of its functionality is impaired = 4

Asset not operational = 5

4 - Russ' corrections

7. Consequence of Failure Rating

7.1 Water Quality

No impact on water quality = 1

Partial impact on WQ = 2 (loss of redundancy >3+1)

Intermediate impact on WQ = 3 (loss of redundancy 2+1)

Substantial impact on WQ = 4 (loss of redundancy 1+1)

Catastrophic impact on WQ,, renders plant shut down = 5

7.2 Flow (plant hydraulic capacity)

No consequence, plant runs at full capacity = 1

Plant capacity reduced by 25% = 2 (loss of redundancy >3+1)

Plant capacity reduced by 50% = 3 (loss of redundancy 2+1)

Plant capacity reduced by 75% = 4 (loss of redundancy 1+1)

Catastrophic impact on plant capacity, renders plant shut down = 5

R&R Recommendation Codes

A - Regular Scheduled Maintenance: Cleaning, lubrication

B - On Site Repairs, assumes minor functional repairs to bring equipment to operational conditions, remove corrosion, paint touch ups and similar

C - On Site Refurbishment, assumes in-site or in plants shop refurbishment to clean, remove corrosion, repair paint, replace used up parts, ands similar

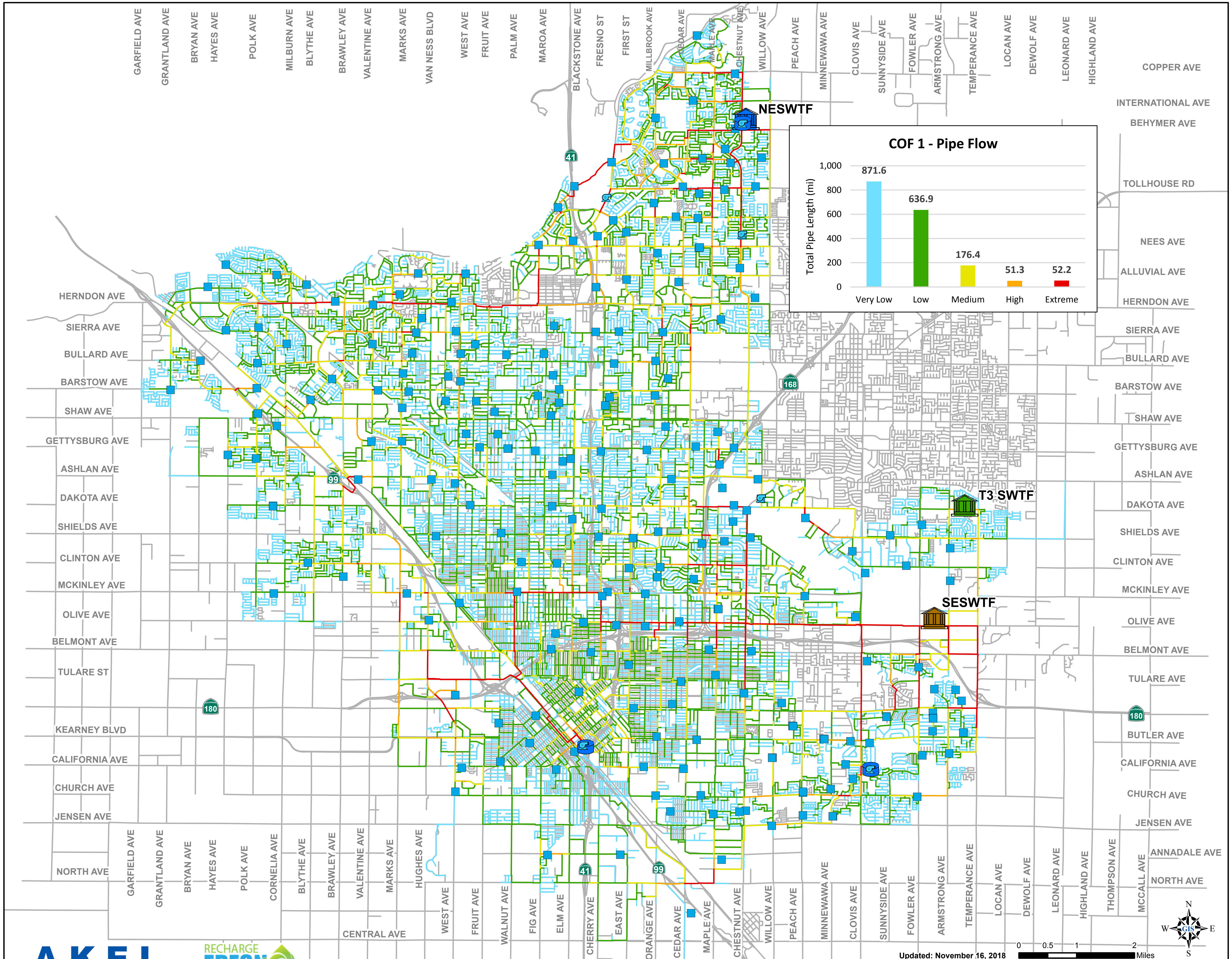
D - On Site or Off Site Refurbishment/Rehabilitation, assumes major undertaking to bring the equipment near to new condition

E - Replacement, assumes in-kind replacement with identical equipment unit

APPENDICES

APPENDIX A

Distribution System Consequence of Failure Figures



Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Consequence Score

- Very Low (100 gpm or Less) (871.6 Miles, 48.7%)
- Low (100 - 500 gpm) (636.9 Miles, 35.6%)
- Moderate (500 - 1,000 gpm) (176.4 Miles, 9.9%)
- High (1,000 - 1,500 gpm) (51.3 Miles, 2.9%)
- Extreme (1,500 gpm or More) (52.2 Miles, 2.9%)
- Streets

Figure 1
COF 1 - Pipe Flow
Drinking Water Infrastructure Renewal and Replacement Plan

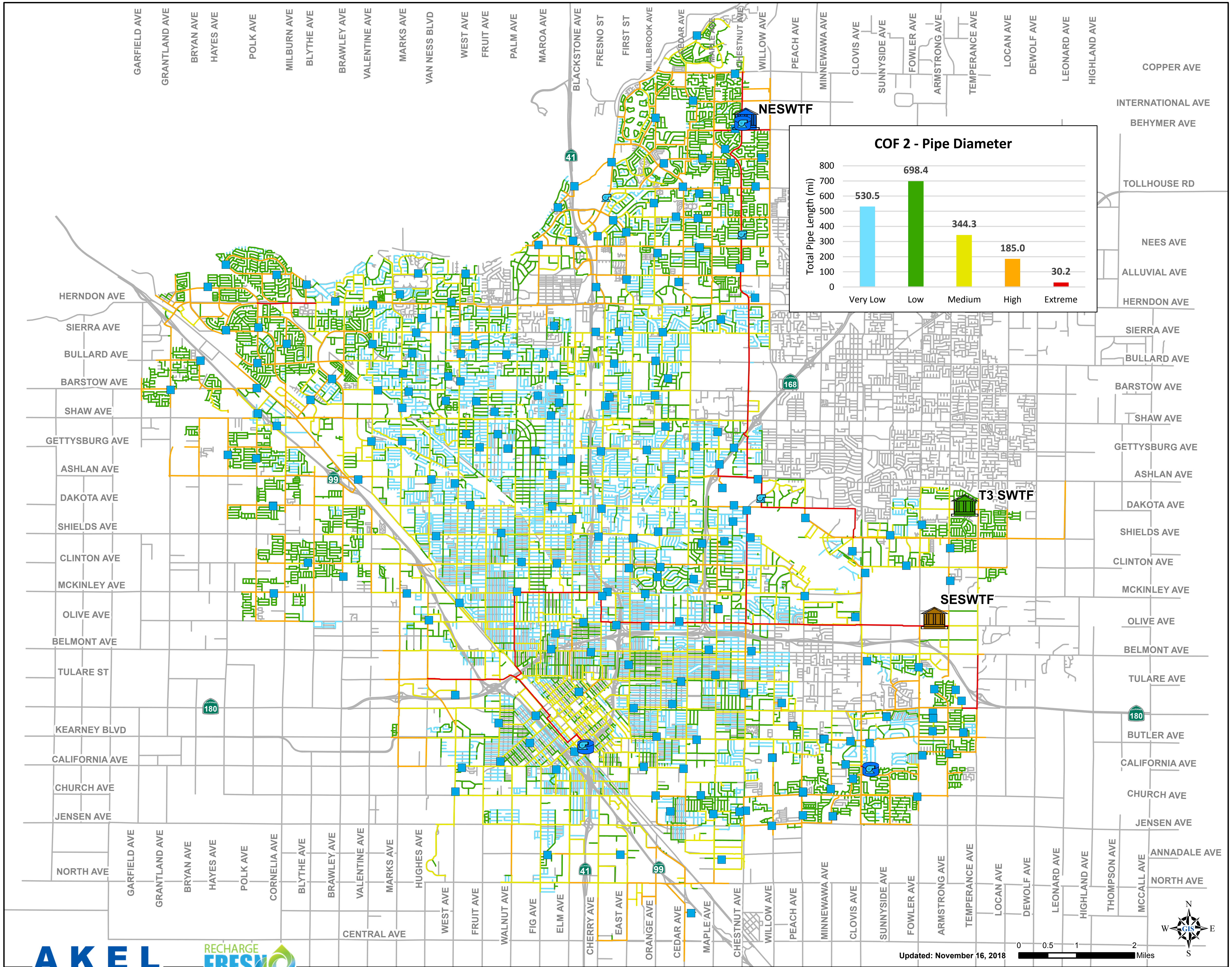
City of FRESNO

Updated: November 16, 2018

AKEL ENGINEERING GROUP, INC.

RECHARGE FRESNO Securing Our Water Future

File Path: P:\xGIS\GIS_Projects\Fresno\Water\171115-RenewalReplace\Appdx\FR_Fig1_PipeFlowAssessment_111618.mxd



Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Consequence Score

- Very Low (6" or Less) (530.5 Miles, 29.7%)
- Low (8") (698.4 Miles, 39.0%)
- Moderate (10 - 12") (344.3 Miles, 19.3%)
- High (14 - 16") (185.0 Miles, 10.3%)
- Extreme (16" or Greater) (30.2 Miles, 1.7%)
- Streets

Figure 2
COF 2 - Pipe Diameter
Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

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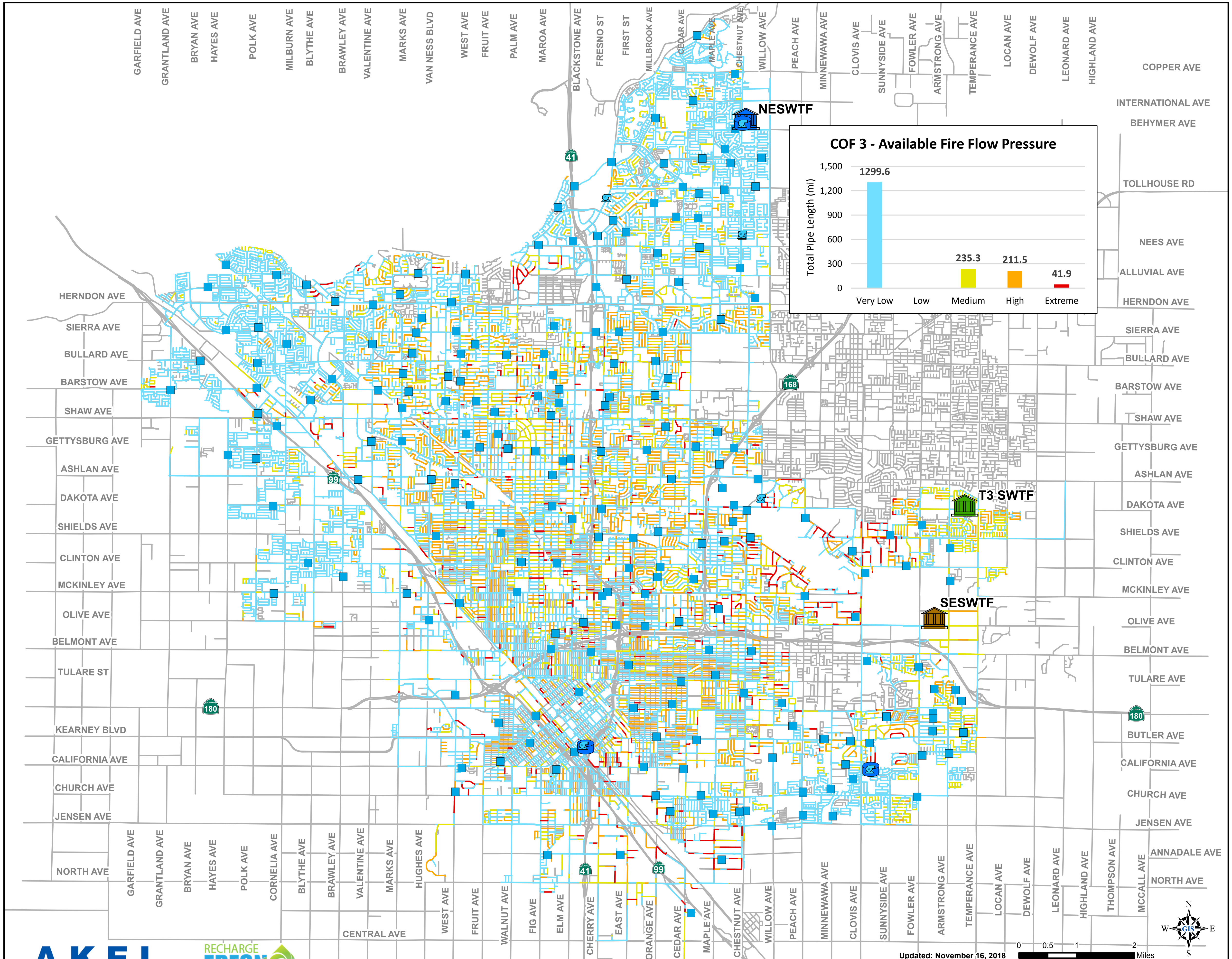

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File Path: P:\xGIS\GIS_Projects\Fresno\Water\171115-RenewalReplace\Appdx\FR_Fig3_FireFlowAssessment_111618.mxd

Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

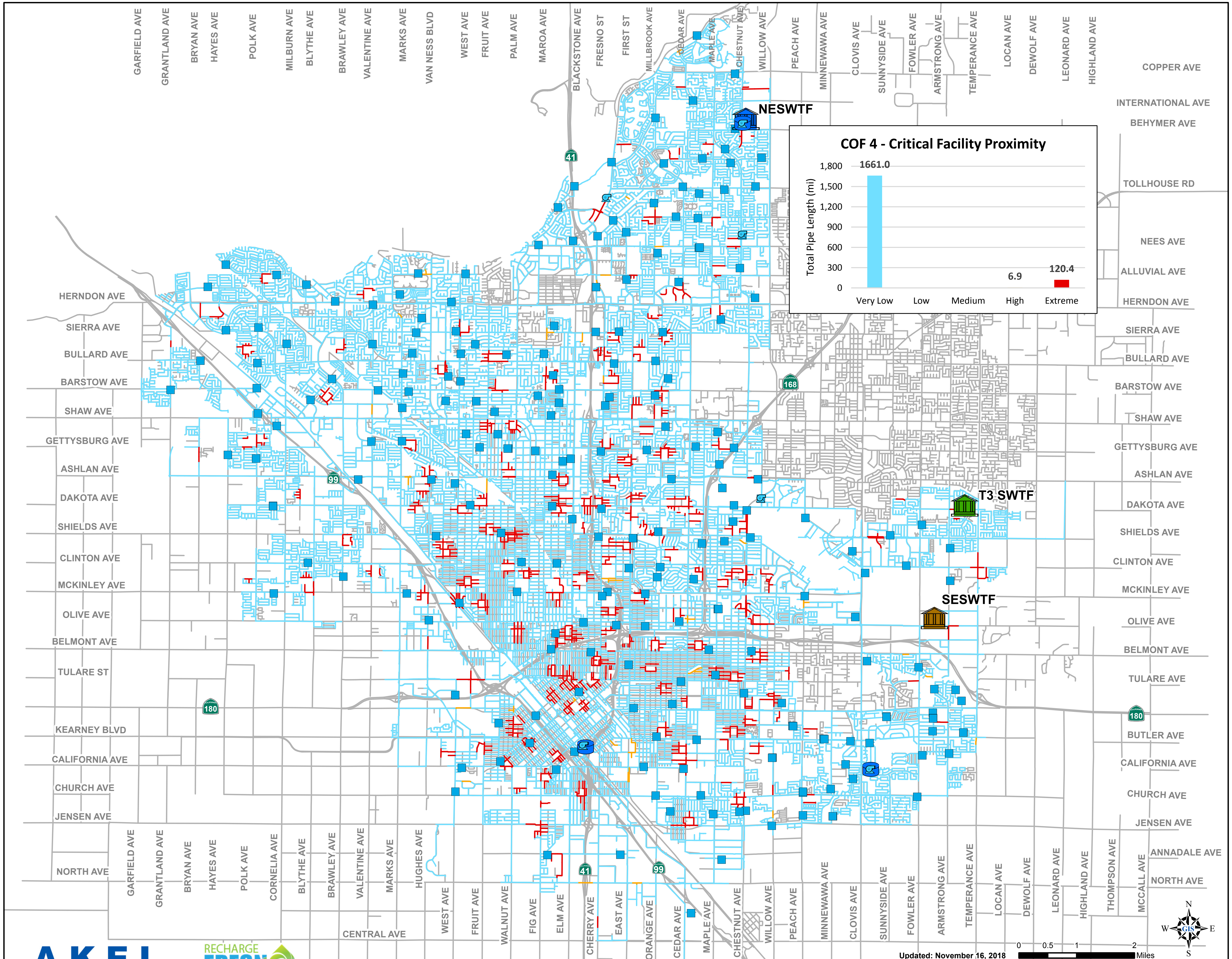
Consequence Score

- Very Low (Greater than 40 psi) (1,299.6 Miles, 72.7%)
- Moderate (30 - 40 psi) (235.3 Miles, 13.2%)
- High (20 - 30 psi) (211.5 Miles, 11.8%)
- Extreme (Less than 20 psi) (41.9 Miles, 2.3%)
- Streets

Figure 3
COF 3 - Available Fire Flow Pressure

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO



Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Consequence Score

- Very Low (Other Pipelines) (1,661.0 Miles, 92.9%)
- High (Large Water Users) (6.9 Miles, 0.4%)
- Extreme (Hospitals and Schools) (120.4 Miles, 6.7%)
- Streets

Figure 4
COF 4 - Critical Facility Proximity

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

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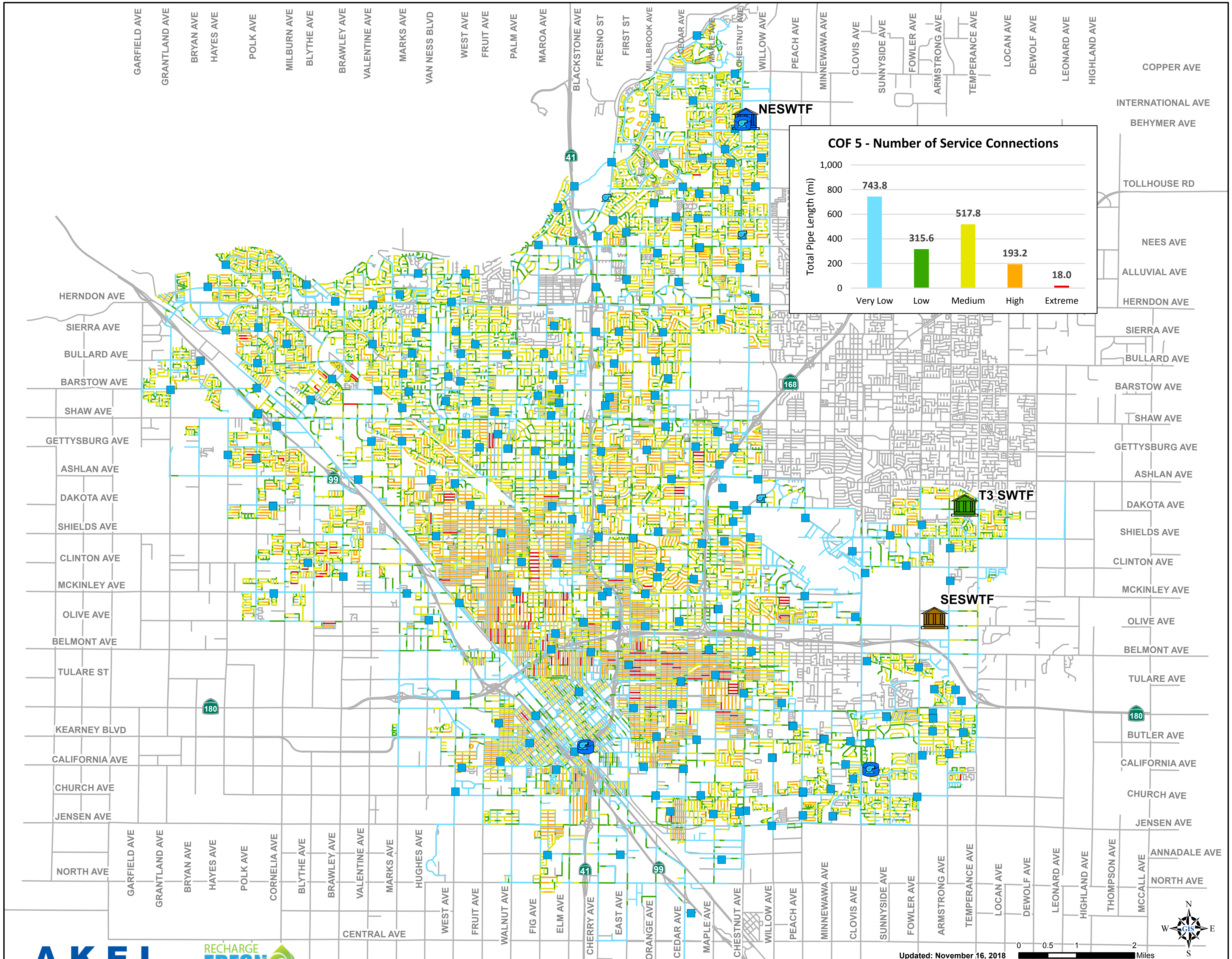
File Path: P:\xGIS\GIS_Projects\Fresno\Water\171115-RenewalReplace\Appdx\FR_Fig4_CriticalFacilities_111618.mxd



File Path: P:\xGIS\GIS_Projects\Fresno\Water\171115-RenewalReplace\Appdx\FR_Fig5_NumberofServiceConnections_111618.mxd

Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Consequence Score

- Very Low (0-2) (743.8 Miles, 41.6%)
- Low (3 - 5) (315.6 Miles, 17.6%)
- Moderate (6-15) (517.8 Miles, 29.0%)
- High (16 - 25) (193.2 Miles, 10.8%)
- Extreme (Greater than 25) (18.0 Miles, 1.0%)
- Streets

Figure 5
COF 5 - Number of Service Connections

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

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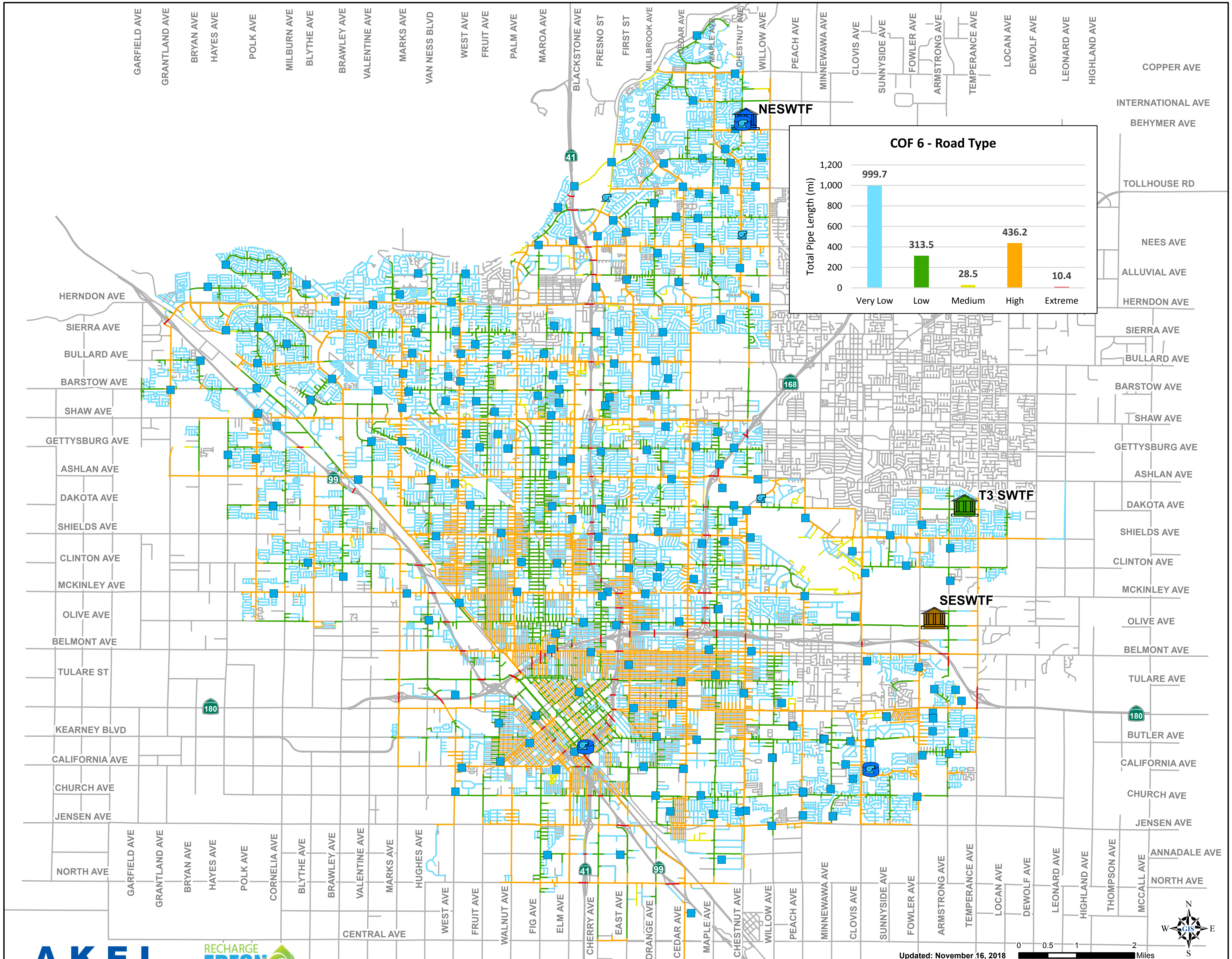

Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Consequence Score

- Very Low (Local Road) (999.7 Miles, 55.9%)
- Low (Collector) (313.5 Miles, 17.5%)
- Moderate (Expressway) (28.5 Miles, 1.6%)
- High (Arterial or in Alleys/Backyards) (436.2 Miles, 24.4%)
- Extreme (Freeway) (10.4 Miles, 0.6%)
- Streets

Figure 6
COF 6 - Road Type

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

AKEL ENGINEERING GROUP, INC.

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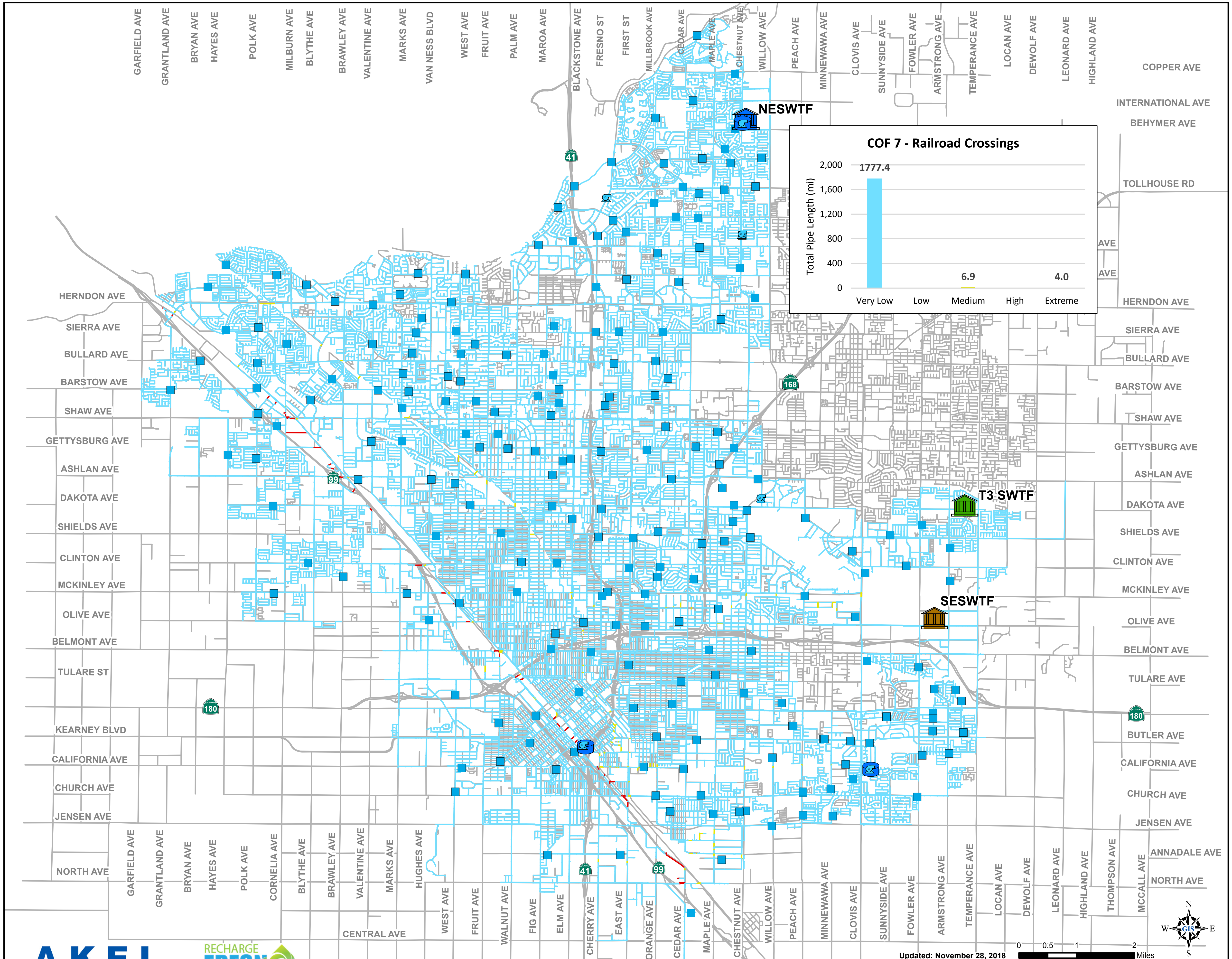
File Path: P:\xGIS\GIS_Projects\Fresno\Water\171115-RenewalReplace\Appdx\FR_Fig6_RoadTypeAssessment_111618.mxd



Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Consequence Score

- Very Low (Other Pipelines) (1,777.4 Miles, 99.4%)
- Moderate (Railroad) (6.9 Miles, 0.4%)
- Extreme (High Speed Rail) (4.0 Miles, 0.2%)
- Streets

Figure 7
COF 7 - Railroad Crossings

Drinking Water Infrastructure
Renewal and Replacement Plan

City of FRESNO

AKEL ENGINEERING GROUP, INC.

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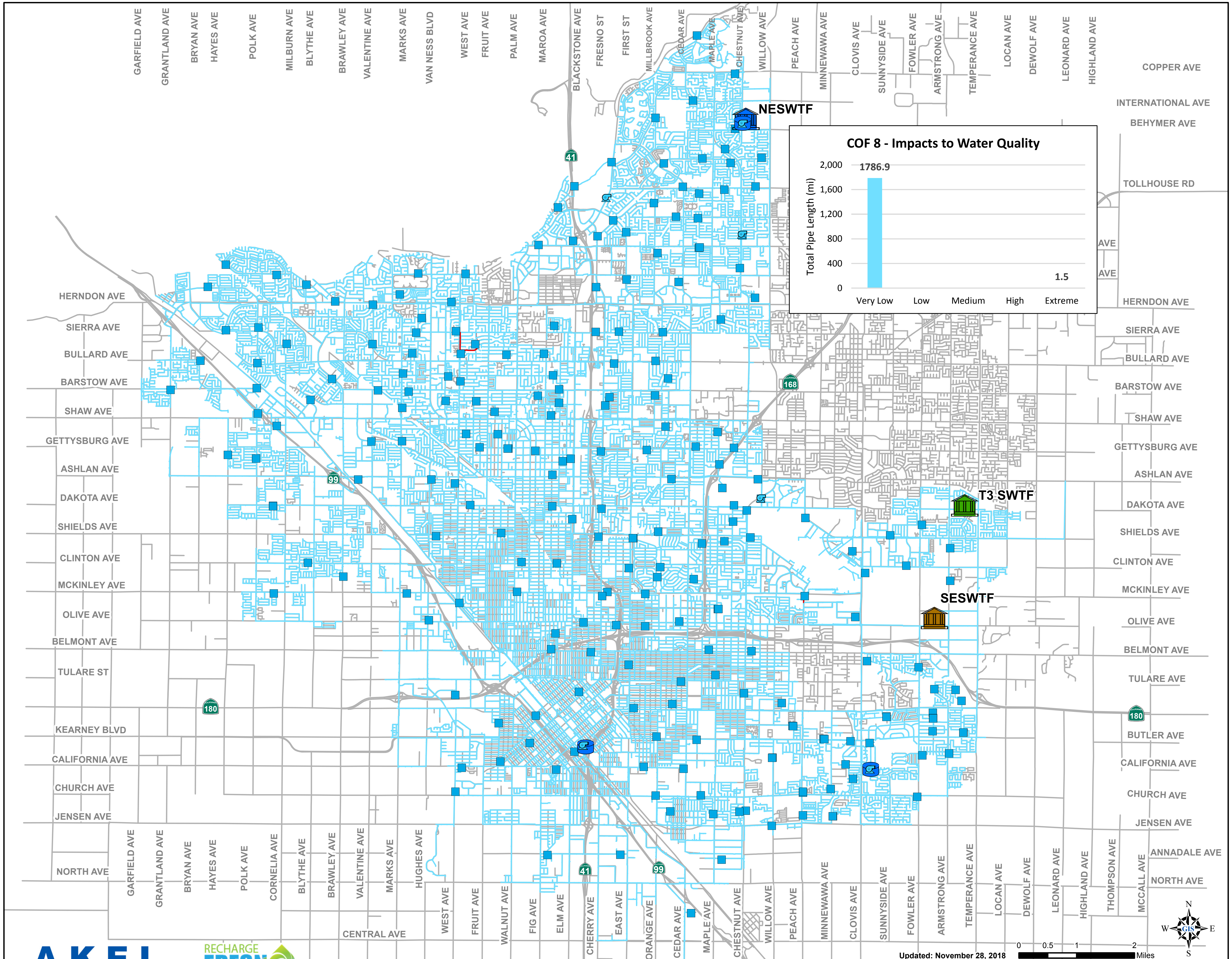
File Path: P:\xGIS\GIS_Projects\Fresno\Water\171115-RenewalReplace\Appdx\FR_Fig7_RailroadCrossingAssessment_112818.mxd



Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Consequence Score

- Very Low (Other Pipelines) (1,786.9 Miles, 99.9%)
- Extreme (Plume Management Pipelines) (1.5 Miles, 0.1%)
- Streets

Figure 8
COF 8 - Impacts to Water Quality

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

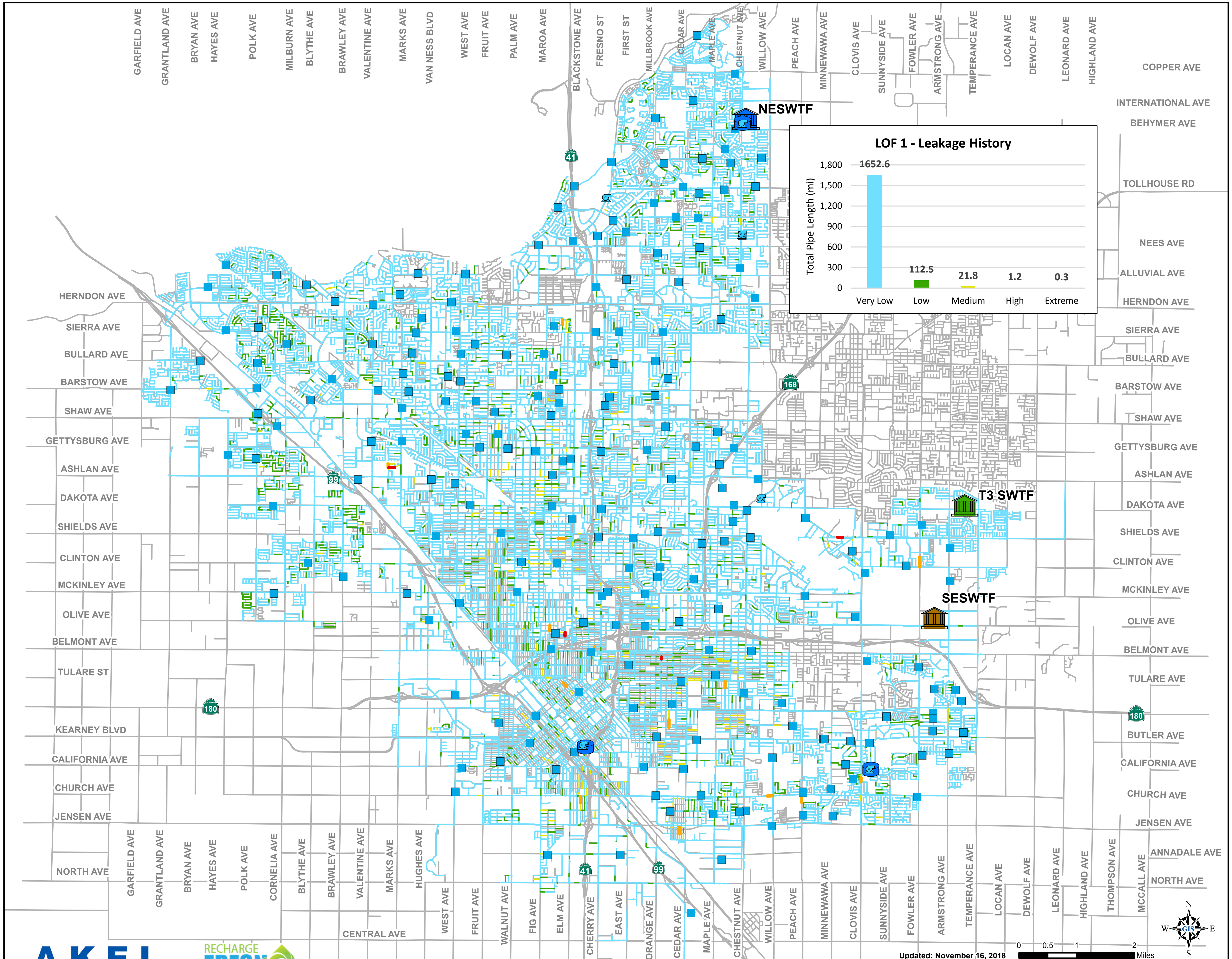
AKEL ENGINEERING GROUP, INC.

RECHARGE FRESNO Securing Our Water Future

File Path: P:\xGIS\GIS_Projects\Fresno\Water\171115-RenewalReplace\Appdx\FR_Fig8_WaterQuality_112818.mxd

APPENDIX B

Distribution System Likelihood of Failure



Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Likelihood Score

- Very Low (0) (1,652.6 Miles, 92.4%)
- Low (0 - 0.1) (112.5 Miles, 6.3%)
- Moderate (0.1 - 1) (21.8 Miles, 1.2%)
- High (1 - 3) (1.2 Miles, 0.1%)
- Extreme (Greater than 3) (0.3 Miles, 0.0%)
- Streets

Figure 9
LOF 1 - Leakage History
Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

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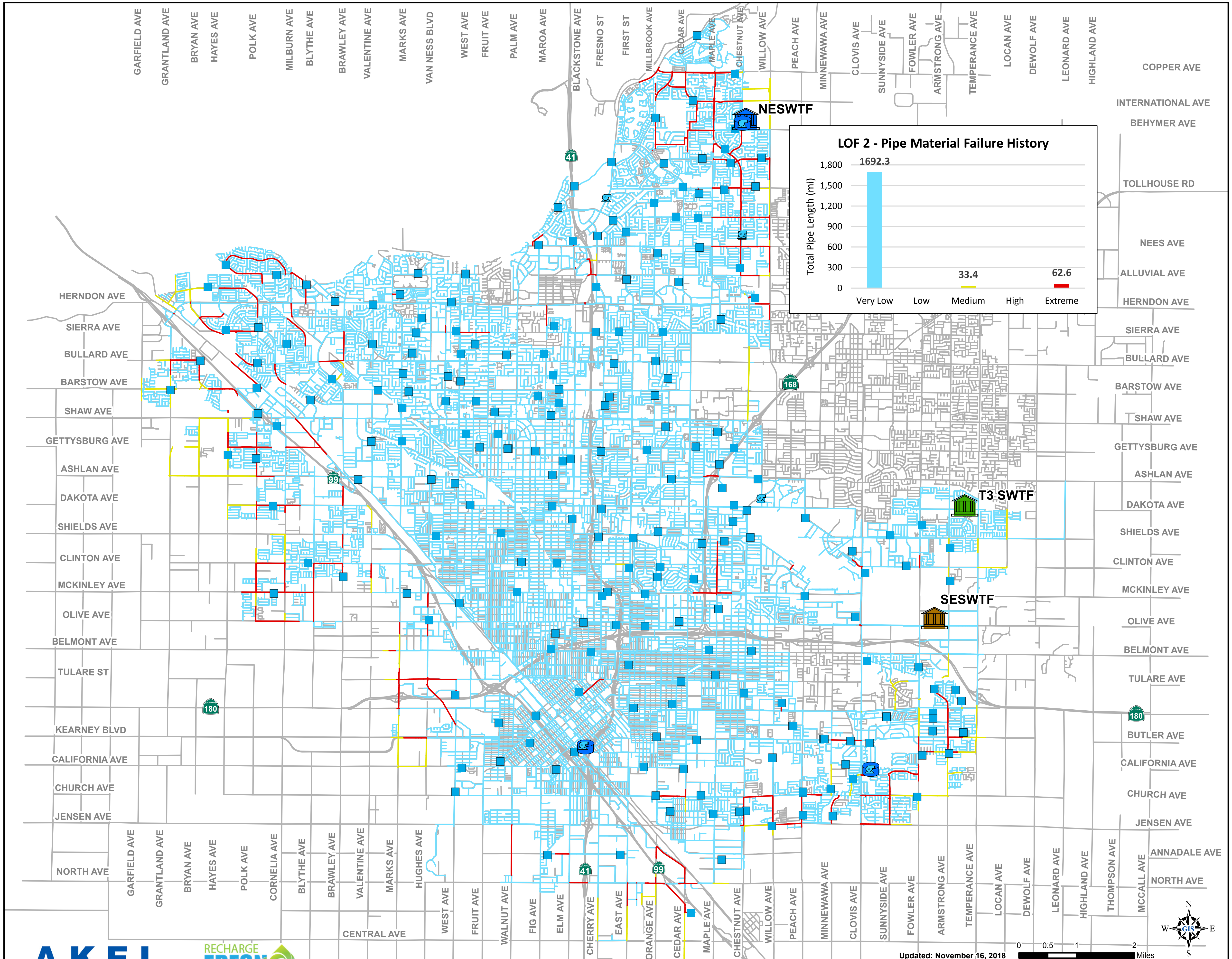

Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Likelihood Score

- Very Low (Other Pipelines) (1,692.3 Miles, 94.6%)
- Moderate (14" PVC Installed after 2004) (33.4 Miles, 1.9%)
- Extreme (14" PVC Installed 1990-2004) (62.6 Miles, 3.5%)
- Streets

Figure 10
LOF 2 - Pipe Material Failure History

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

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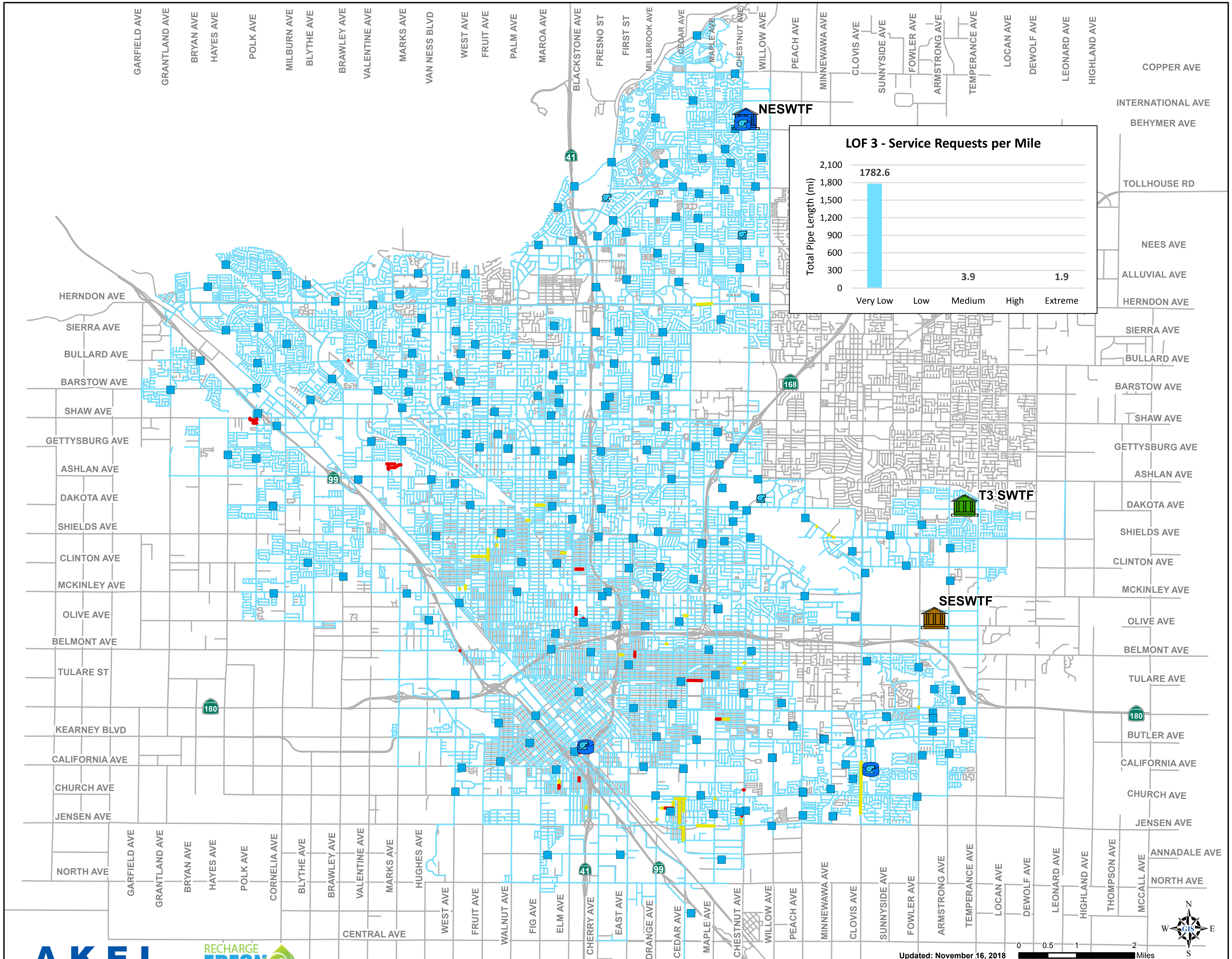
File Path: P:\xGIS\GIS_Projects\Fresno\Water\171115-RenewalReplace\Appdx\FR_Fig10_PVC14Assessment_11618.mxd



Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Likelihood Score

- Very Low (Other Pipelines) (1,782.6 Miles, 99.7%)
- Moderate (1 - 3 Leaks per Mile) (3.9 Miles, 0.2%)
- Extreme (Greater than 3 Leaks per Mile) (1.9 Miles, 0.1%)
- Streets

Figure 11
LOF 3 - Pipe Maintenance Trends

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

AKEL ENGINEERING GROUP, INC.

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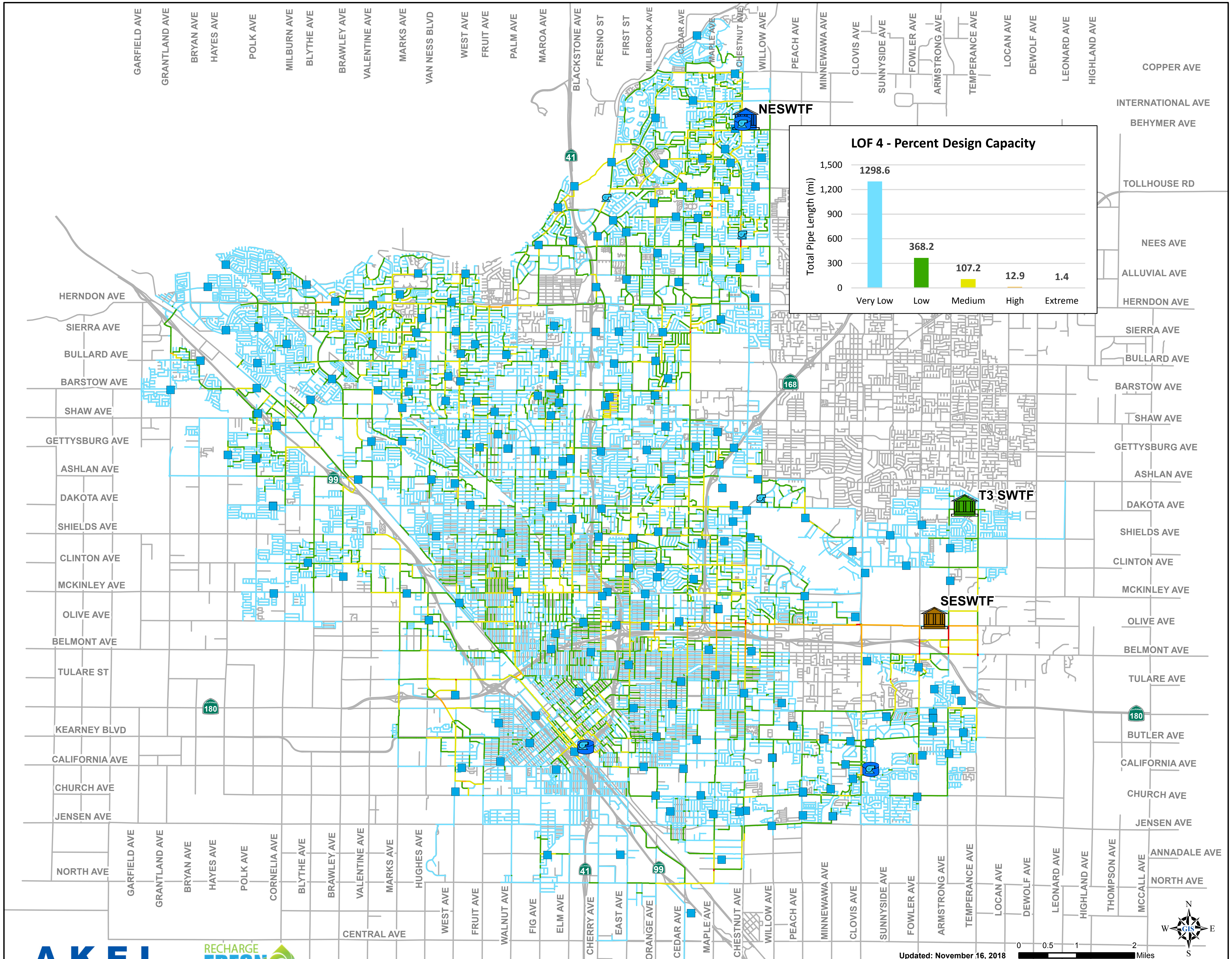
File Path: P:\xGIS\GIS_Projects\Fresno\Water\171115-RenewalReplace\Appdx\FR_Fig11_PipeMaintenanceTrends_111618.mxd



Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Likelihood Score

- Very Low (25% or Less) (1,298.6 Miles, 72.6%)
- Low (25 - 50%) (368.2 Miles, 20.6%)
- Moderate (50 - 100%) (107.2 Miles, 6.0%)
- High (100 - 150%) (12.9 Miles, 0.7%)
- Extreme (Greater than 150%) (1.4 Miles, 0.1%)
- Streets

Figure 12
LOF 4 - Percent Design Capacity

Drinking Water Infrastructure Renewal and Replacement Plan

City of FRESNO

AKEL ENGINEERING GROUP, INC.

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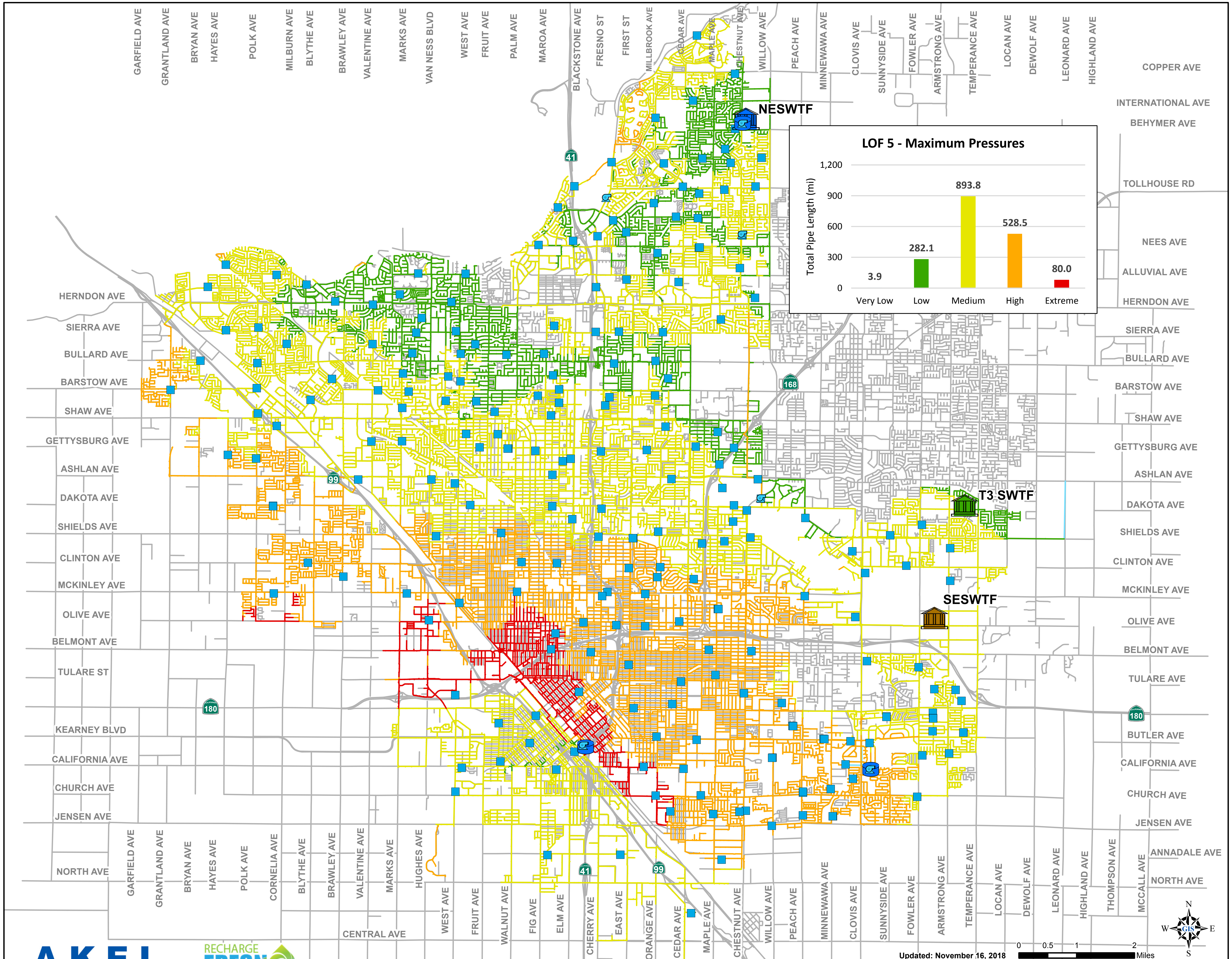
File Path: P:\xGIS\GIS_Projects\Fresno\Water\171115-RenewalReplace\Appdx\FR_Fig12_CapacityAssessment_111618.mxd



Legend

Existing System

- NESWTF
- SESWTF
- T3 SWTF
- Tanks
- Booster Pumps
- Wells

Likelihood Score

- Very Low (Less than 50 psi) (3.9 Miles, 0.2%)
- Low (50 - 60 psi) (282.1 Miles, 15.7%)
- Moderate (60 - 70 psi) (893.8 Miles, 50.0%)
- High (70 - 80 psi) (528.5 Miles, 29.6%)
- Extreme (80 psi or Greater) (80.0 Miles, 4.5%)
- Streets

Figure 13
LOF 5 - Maximum Pressure
Drinking Water Infrastructure
Renewal and Replacement Plan

City of FRESNO

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File Path: P:\xGIS\GIS_Projects\Fresno\Water\171115-RenewalReplace\Appdx\FR_Fig13_MaximumPressure_111618.mxd

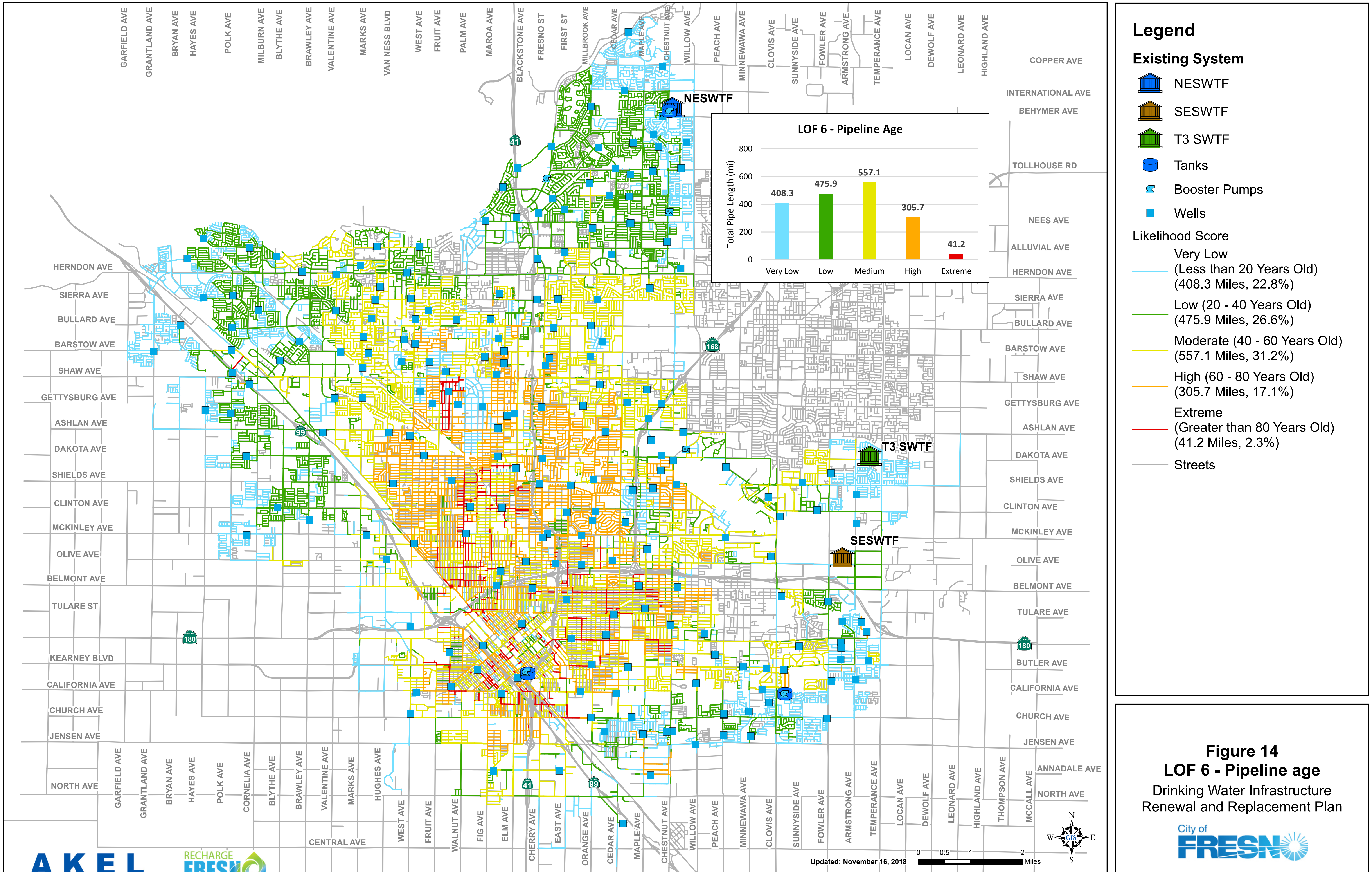

Figure 14
LOF 6 - Pipeline age
Drinking Water Infrastructure
Renewal and Replacement Plan

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APPENDIX C

2016 Preliminary Asset Management Plan

Preliminary Asset Management Plan For City of Fresno Groundwater Wells Revision 1

Prepared for
City of Fresno Department of Public Utilities

Prepared by

KLEINFELDER
Bright People. Right Solutions.

2882 Prospect Park Drive, Suite 200
Rancho Cordova, CA 95670

May 4, 2016

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1 INTRODUCTION

The City of Fresno (City) maintains over 260 groundwater wells located throughout the City that currently supply about 88 percent of domestic water needs for over 500,000 Fresno residents. While plans are underway to reduce reliance on groundwater through the Recharge Fresno program, groundwater wells will remain an integral component of the City's water supply well into the future. It is therefore in the interest of the City to assure that the wells are cost effectively managed to produce an adequate supply of high quality water at minimal risk.

The City's groundwater wells are unique and usually have site specific well construction and performance attributes. These unique elements include:

- Final completion depth,
- Production flow rates,
- Production water quality,
- Operation and Maintenance history,
- Location (vertical and horizontal),
- Age,
- Bottom type (i.e. open bottom or enclosed with or without a sump design),
- Water level history,
- Casing materials,
- Screen material type and interval lengths,
- Pump types and sizes,
- Turbine pump bowl designs, and
- Separate aquifer zones and their hydrogeologic configurations.

Every one of these elements effect how each well performs. So key to managing the well portfolio is to assure that these elements are sustainably monitored to acquire reliable data that is processed into information that well managers can quickly access for decision making. Also key are the metrics and trends used to trigger the right decision at the right time in order to maximize well up time and avert failures before they occur.

Fresno's groundwater well team (Team) is striving to become more efficient but has found that the reactionary management practices currently in place are not sufficient to address the increasing challenges. There is little planning for long term maintenance, existing records are stored in a variety of sources, lack of resources obstruct initiatives to obtain reliable data, and the challenges are increasing as the wells age, aquifer levels drop, threats from contaminants rise, and water resource management and environmental regulations increase.

These are significant challenges that cannot be quickly addressed. There needs to be a plan in place to change the management paradigm and position the Team with a pro-active decision making framework. This preliminary asset management plan (PAMP) represents a first step in this direction.

This PAMP begins with an assessment of the current operational state of the Team and then builds on current practices to develop an asset management framework that introduces some asset management best practices as a first step toward helping the Team achieve the following goals as established early in the process.

Fresno Team goals:
Provide a data driven decision making framework based in asset management for prioritizing well activity; maintenance, monitoring, inspections/cleaning, rehabilitation, decommissioning, replacement.
More specifically the Plan will define a preliminary framework that will help:

- Move from a reactive mode of operation to a pro-active mode
- Optimize costs including energy consumption
- Determine when an asset might fail
- Find the right level of inspections and cleanings to optimize well life expectancies
- Prioritize maintenance and capital expenditures
- Track and report on activities performed – (ex. report on which motors were rehabilitated last year)
- Develop a dashboard with key performance indicators

While this PAMP has been developed with these goals in mind, it is qualified as 'preliminary' because it was developed with a less comprehensive process than what would normally take place to develop a fully qualified asset management plan. Absent from the process is a Strategic Asset Management Plan (SAMP) that would communicate policy and strategic objectives at the organizational level for the asset management plan to align with (as specified in publications such as ISO 55000 – the international standard for asset management). More specifically, this PAMP has the following limitations:

- It focuses specifically on the operational management of the groundwater well assets.

  - While recognizing that there are City level considerations such as Recharge Fresno that could influence how the wells are managed, this level of consideration is not yet taken into account.

- It does not take into full account regional aquifer management considerations.

- The water quality group was not directly involved in the creation of this plan, but is represented through information gathered from the production and telemetry and electrical groups.

- Only nine wells in Zone 20 were analyzed as a pilot study in order to illustrate how asset management best practices can be implemented using framework tools for assessing condition, performance and risk for decision making.

Nevertheless, this plan delivers a framework rooted in asset management best practices that serves as crucial first steps for the Team to move forward with.

2 CURRENT STATUS

The current status of the City's data, operations and maintenance management was documented by Kleinfelder in November 2015. Overall findings revealed a knowledgeable and dedicated staff who are using available resources to keep the groundwater wells operational and productive. However, it was also discovered that the available systems, especially Hansen 7, are constraining staff from utilizing data management, preventive maintenance and inspection processes that would be required for a cost effective asset management approach. Fortunately, the City is about to implement the next generation of Hansen\Infor software that should provide the tools that the Team needs to support more asset management practices.

The following two sections summarize Kleinfelder's findings and recommendations. The first section 'Groundwater Well Asset Data' focuses on data management and data requirements for groundwater wells, while the second section 'Groundwater well operations and management' focuses on findings and recommendations in regards to operations and management.

2.1 GROUNDWATER WELL ASSET DATA FINDINGS AND RECOMMENDATIONS

The City maintains the elements of a water well asset registry through the use of a geographic information system (GIS), Asset Management software (Hansen), Excel, SCADA, a library of scanned documents and other data sources.

Asset registry data is considered to be attributes that describe the location and characteristics of the well asset and its components that are not directly associated with the current condition and performance levels of the asset. For the most part these data remain static for the life of the asset or component. Well status is dynamic, but included in this discussion because it is currently tracked within the databases used to track attribute data. Each data source investigated is described in more detail on the following pages.

2.1.1 GIS

Data from the City's GIS is widely available throughout City offices using a web based AutoDesk MapGuide application called iView

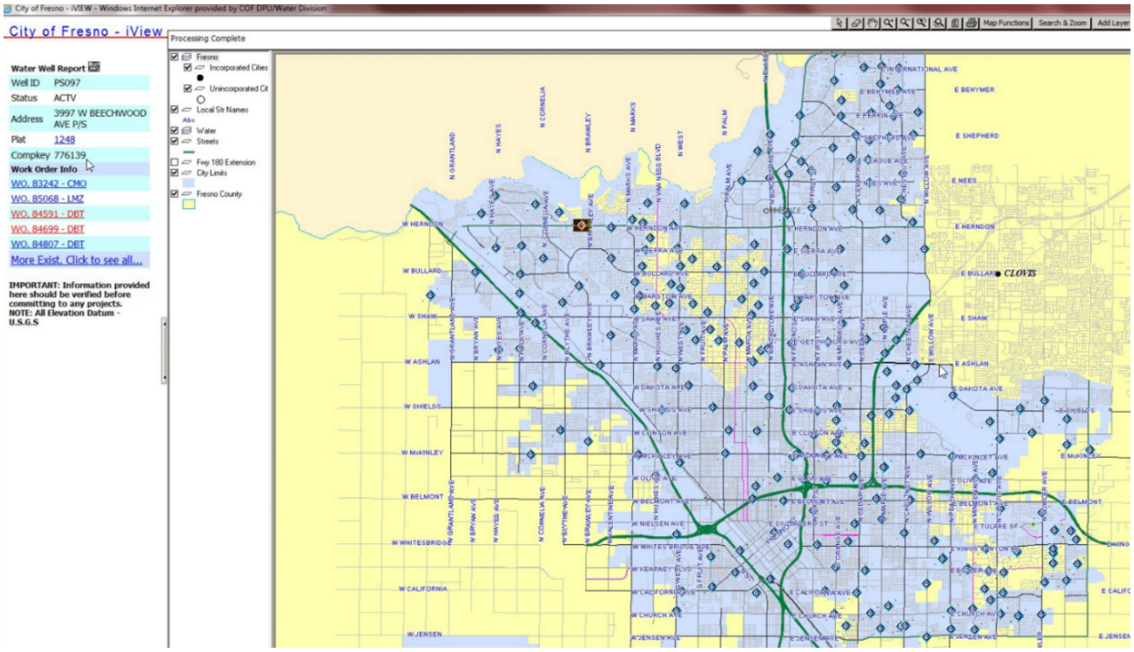


Image provided by the City of Fresno

Water Well locations and status can be viewed in the City's iView application

The data maintained in the GIS consists of fields for location data (coordinates and address) and a field for well status. Well status is indicated by one of five values:

GIS WELL STATUS CODES and DESCRIPTION	
Code	**Description**
ACTV	Active Well
PROP	Proposed Well Location
PRIV	Private Well
ABAN	Abandoned Well
REMV	Removed Well

Note: *Private wells are tracked here for lack of any other field for tracking ownership. Private wells do not contribute to the public water system but are tracked because they may influence public well placement and well performance.*

The GIS data provided to Kleinfelder indicates that there are 262 active wells out of 381 well locations identified in the database as of November 2015. This was reflected on the City's public utilities web site where it states "…approximately 260 wells..." active wells.

The well information in the City's GIS is kept up to date through a coordinated work flow between the water system production group and centralized City GIS staff. The process is usually completed within a day after the information is received. GIS features are maintained through established work flows where the features are originated in AutoCAD, exported as shapefiles, imported into an Oracle spatial database, and then managed through ESRI ArcGIS software.

The GIS database is connected to the Hansen 7 database through a Compkey field that is common to the features in the GIS (such as well assets). This relationship enables staff to see which work orders have been generated against each well in iView. Presented as hyperlinks, it appears that the interface was intended to allow the user to view work order information, but this capability was not functional at the time of this investigation.

iView presents location and status data along with a list of Work Orders from Hansen for the selected well.

Image provided by the City of Fresno

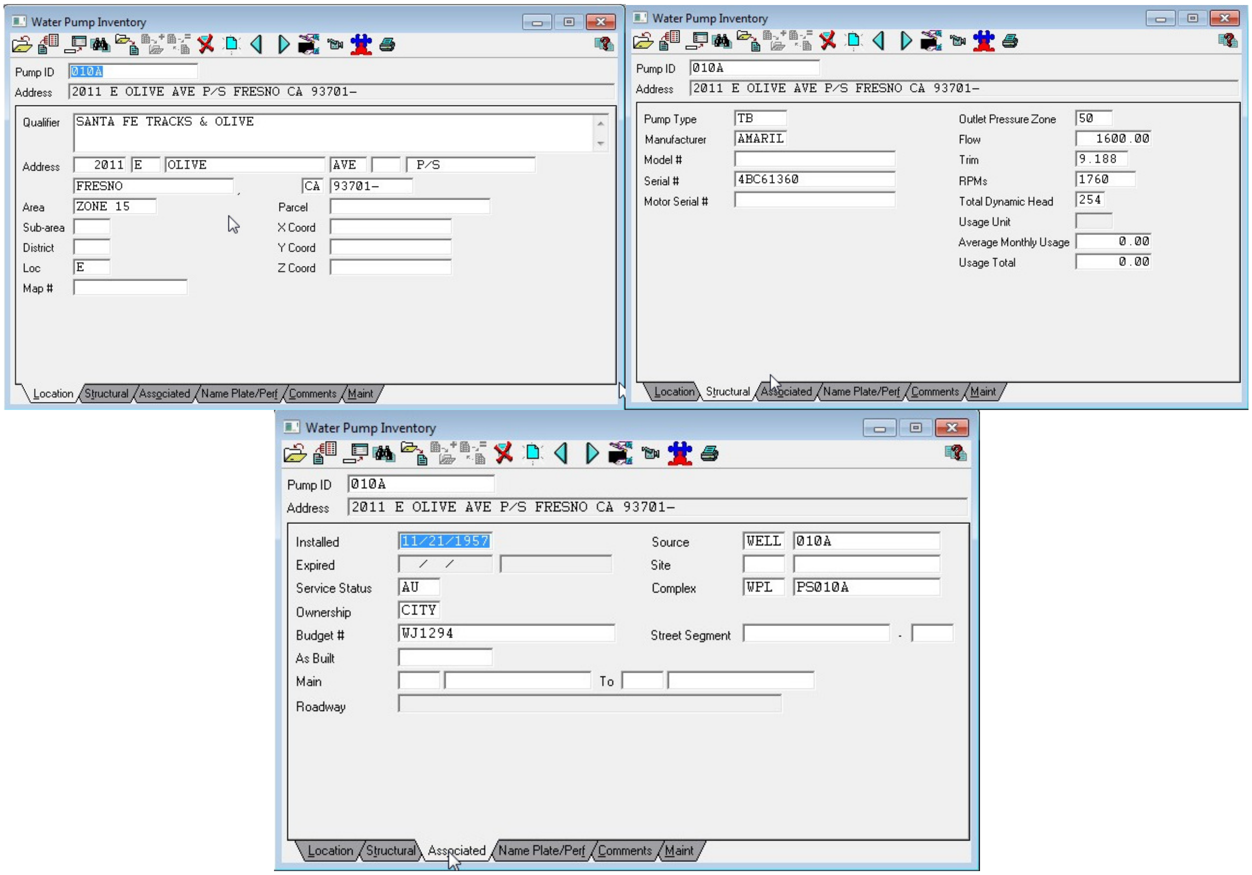
iView presents location and work order history information for each well

2.1.2 Hansen 7

The water system production group provided Kleinfelder a comprehensive overview of how the Hansen 7 software is being utilized. The Hansen database is stored in Oracle.

This section focuses specifically on the data registry element of Hansen. See the Operations and Maintenance management practices section for how Hansen is utilized to schedule work activities.

Water well asset data is maintained in Hansen 7 by the water system production group. The data kept in Hansen includes pump data for each well as shown in the screen captures below:



Images provided by the City of Fresno

Pump data stored in Hansen for each well site

These data are relevant to the pump at the time it was installed and therefore does not require significant resources to maintain. Data updates occur when pumps are rehabilitated or installed.

2.1.3 Excel

The City provided an Excel workbook with well data for each well in Zone 20. These data are available for all wells. This appears to be the most comprehensive source of attribute data available. Below is a partial screen shot of what the workbook looks like.

	A	B	C	D	E	F	G	H	I	J	K	L
1	WELL SITE #	LOCATION	ADDRESS	HP / BOOSTER	TYPE WELL	CASING SIZE inches	WELL DIAMETER inches	COMPLETED DEPTH Feet	CASING DEPTH Feet	DATE DRILLED	BOWL SET (Feet)	PROBE DEPTH (Feet)
2	36	Church & Orange	**3591 E. Church**	150	C	20	20	236	210	4/6/1961	150	150
3	36A	Church E of Orange	**3632 E. Church**									
4	108	Annoosian - N Pump	**4656 E. Pitt**	100	C	14	14	172	169	7/9/1978	140	140
5	162	Cedar S/O of Muscat	**2091 E. Muscat**	125	RR	16	28	440	440	3/23/1995	120	120
6	170	MLK & Annadale	**1084 E. Annadale**	150	RR	16	26	650	650	3/5/1994	200	200
7	197	SW Cedar /California	**2202 S. Cedar**	100	RR	14	26	420	420	2/15/1997	180	180
8	201	NWC Barton Sq	**3867 Barton Sq.**	40	C	14	14	224	167	1/26/1961	140	100
9	203A	E/Maple &	**4650 E.**	150	RR	16	28	700	700	2/1/2000	220	220

Data provided by the City of Fresno

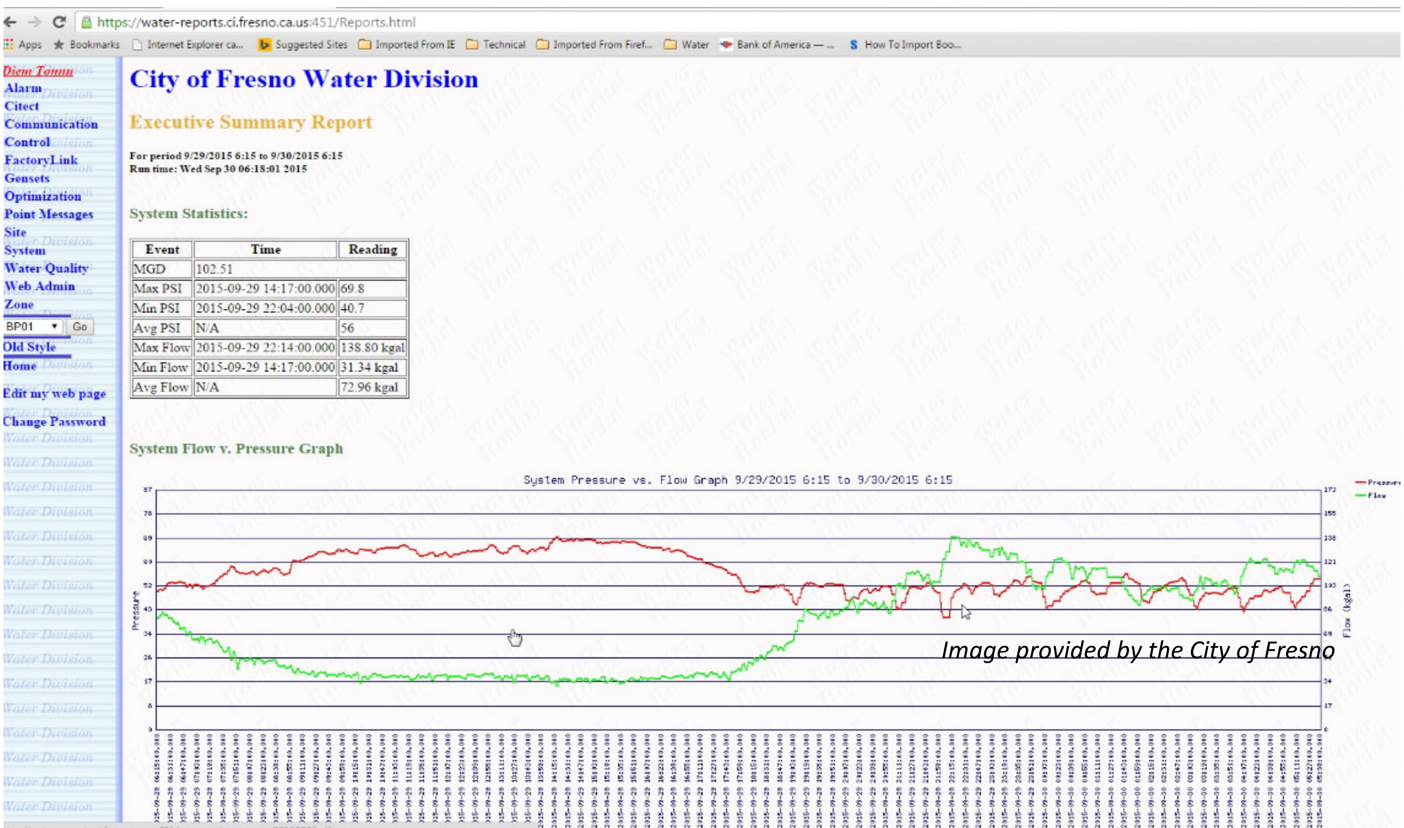
Partial screen shot of well data maintained in Excel

The water system production group keeps these data up to date on a regular basis primarily for the use of field staff. One of the most actively maintained fields is well status. The following codes are used to describe well status:

EXCEL WELL STATUS CODES and DESCRIPTION	
Code	**Description**
AB	Abandoned
AG	Agricultural/Irrigation
AR	Active Raw
AT	Active Treated
AU	Active Untreated
CM	Combination/Blend Mixed
CR	Combination/Blend Raw
CT	Combination/Blend Treated
CU	Combination/Blend Untreated
DR	Distribution Raw
DS	Destroyed
DT	Distribution Treated
IR	Inactive Raw
IT	Inactive Treated
IU	Inactive Untreated
SR	Standby Raw
ST	Standby Treated
SU	Standby Untreated

2.1.4 SCADA

The City's SCADA system provides real time and historical data in terms of flow, run time, power consumption, pumping levels and other data as required to monitor the operational characteristics, specific capacity (SC) and Overall Plant Efficiency (OPE) for each well. Historical data stored in the SCADA database can be retrieved for a period of over ten years.



A SCADA graph showing system pressure (red) vs Flow (green) over a twenty-four hour period

This is just one of many data views available through SCADA

The water system production group recently initiated a task to add the data maintained in the Excel workbook to the SCADA database. While the data was initially imported to SCADA from Excel (thereby maintaining data integrity) the data will be maintained by keying into both locations.

2.1.5 Other Data Sources

Paper documents and records are scanned and saved to the corresponding well folder to a location on the City's network mapped locally as the "H" drive. Sub-folders are created under each well folder to categorize the documents. Driller logs, well tests and other documents are stored here.

Water quality data is maintained by the water quality group and therefore beyond the scope of this investigation.

2.1.6 Summary of Attribute Data Observations

Kleinfelder offers the following observations regarding the attribute data maintained on the groundwater wells.

- There are currently three primary database sources for attribute data; GIS, Hansen and Excel. SCADA is now a fourth source to store attribute data as a replica of the data maintained in Excel. Scanned documents stored on the “H” drive may be considered a fifth source of data even though there is no database element involved.
- Data stored in the databases is primarily top level data associated with overall well characteristics. More detailed component level data is generally not available within the databases other than some pump information stored in the Hansen database. Information regarding the components is presumed to be contained within the various documents stored on the “H” drive.
- The processes used to keep data up to date are implemented by cognizant staff who are dedicated to maintaining the integrity, completeness and accuracy of the data. However, data is entered into each data source independently and this investigation found no documented process for coordinating data entry among the different data sources.
- Anyone who seeks specific data about a well needs to know which data source to consult. The water system production group consult the Excel files and documents stored in the “H” drive where most of the data is kept. However, other staff will consult SCADA. With no processes in place to preserve the integrity of the data across these systems there is a risk of data disparity developing between these two databases.
- There exists two different methods for reporting well status between the GIS and the Excel databases. Each involves an independent list of codes. In each case the codes are manually entered, not selected from a pick list. This investigation did not find a coordinated approach to report well status between these systems.
- While the Hansen database primarily stores data associated with the pump, there are many fields that store the same data stored in the Excel workbook. Some of these fields

vary in name from the Excel workbook even though they store some of the same data. For instance, the closest match to 'location' in Excel would be 'Qualifier' in Hansen.

2.1.7 Data Availability – Gap Analysis

The Team appears to be data rich, but challenged with the management of all the data that is being collected which thereby influences the integrity of the data. Accompanying this PAMP is an Excel workbook called 'Well and Component Attributes' that represents a first step toward organizing these data for usability. This workbook includes well data already maintained by the water system production group along with attributes recommended by Kleinfelder for each well site in Zone 20. Data that is readily available has been entered into the workbook. Most of these data came from the Excel workbooks that the water system production group maintain. Findings indicate that data that describes the general well characteristics is fairly complete, but there exists a 'gap' in the readily available data for well components such as the motor, screen, bowl, pump, and other components. The data that is missing includes attributes such as size, manufacturer, model, warranty dates, rehab/replace dates and other attributes for all the components at each well site. Additionally, fields used to calculate original SC and OPE along with a field for driller name were added to tables. All these data are deemed important for the long term operational and preventive maintenance of the wells. It is believed that these data may be available in the documents stored on the "H" drive.

2.1.8 Recommendations for Maintaining Well and Component Attributes

Kleinfelder recommends that the Team initiate the following data management actions:

- With the City's commitment to migrate to the next generation of Hansen/Infor software in the next 12 to 18 months, now is the time for water well operations to pursue the development of a data model that incorporates the capabilities of the new Hansen/Infor database integrated with SCADA, GIS, "H" drive documents, water quality data, and the attribute fields in the accompanying 'Well and Component Attributes' workbook.
- The 'Well and Component Attributes' workbook provides a preliminary structure for static well data, static component data, and dynamic data. This workbook should be further developed as a first step toward building the attribute data model within the next generation of Hansen\Infor.

  - The data currently maintained by the water system production group is incorporated in the recommended data model in the 'Well and Component Attribute' workbook with the following exceptions.

    - Static data fields that store data used to calculate original SC and OPE have been added as it is anticipated that individual well performance may be rated in consideration of the well's performance at the time it is initially brought online. Furthermore, these data provide the capability as the beginning point for trending well performance.

    - Data that is specific to components has been moved to the corresponding component. For instance, the horsepower field has been moved to the pump motor within the components section. Likewise, the well casing inside diameter attribute is now a well casing attribute.

    - Dynamic data including data that contributes to current performance measures and well status is incorporated into a separate dynamic data table.

- A complete inventory of well components and their attributes is recommended in recognition that each component contributes to the reliability, efficiency and safe operation of the well. Tracking data at this level allows the division to plan and track maintenance activities, tag operational requirements, analyze trends, and forecast replacement needs at the component level.

- Consolidate the two methods of reporting well status (GIS and Excel) by adopting one set of universal codes and definitions. Eliminate codes that don't reflect well status from the list. This may require that a separate database of private and agricultural wells be maintained that can be spatially related to City owned wells (and subsequently track how the wells influence each other).

- The practice to key in duplicate well data into both an Excel workbook and to SCADA should be investigated further. One possible scenario is to enter the data only into SCADA and then output the data to Excel for distribution to staff who do not have access to SCADA.

- Identify all data that is duplicated across the GIS, Hansen and Excel data sources. Define a plan to consolidate the data to one source and thus eliminate keying in of similar data across the systems. For example, location data is currently stored in different structures in each database (GIS, Hansen, Excel). It may be possible to utilize Hansen 7 as the database where the location data is keyed in, then utilize database views and\or other database methods to make that data available in other systems through key fields that relate the data to each well. There already exists a relationship between GIS and Hansen through the Hansen Compkey field that may be used as a basis for this purpose.

2.2 GROUNDWATER WELL OPERATIONS AND MAINTENANCE MANAGEMENT

The water system production group currently maintain work activity records in Hansen, Excel and Request Tracker (RT). The telemetry and electrical group maintain work activity records in RT with status changes noted in SCADA.

While the maintenance management approach is self-described as reactionary and 'run to failure', there are efforts under way to utilize performance and condition data as a basis for pro-active/predictive decision making.

2.2.1 Water System Production Work Activity Scheduling and Recording

The Hansen 7 Preventive Maintenance feature is currently utilized to schedule the following four activities for water system production crews to perform at each well site annually:

Code	Description
CMO	Change Pump Motor Oil
DBT	DB (Decibel) Test
LMZ	Lube Motor Zerts
VT	Vibration Test

Preventive maintenance activities recorded in Hansen

The production supervisor reviews quarterly reports generated by Hansen to check on the status and progress of these activities.

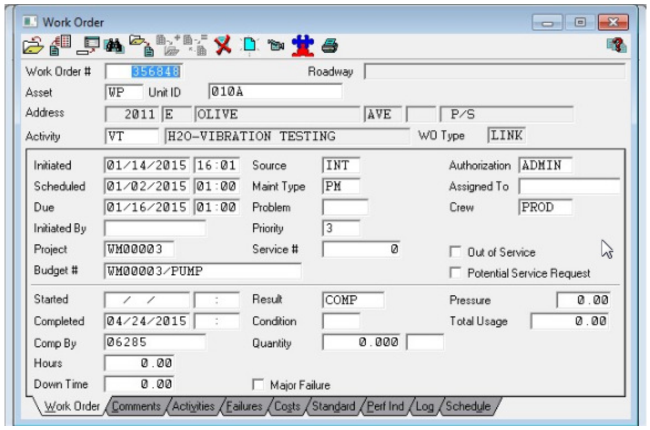


Image provided by the City of Fresno

A Hansen work order record for vibration testing

The amount that Hansen is actually utilized by the water system production group is described as 'minimal' because substantially more activities are performed every day that are captured through other means. Meter replacements, motor rehabs (performed by vendors), valve maintenance, surge tank compressors, disinfection/flushing, well efficiency tests (performed by others), production site checks, swing checks, sanding related activities, seal repair, liners, and other maintenance activities have been tracked in Excel for over seven years. The water production staff is considering using RT for tracking activity, but RT will not be able to capture the data from production site tests and other activity.

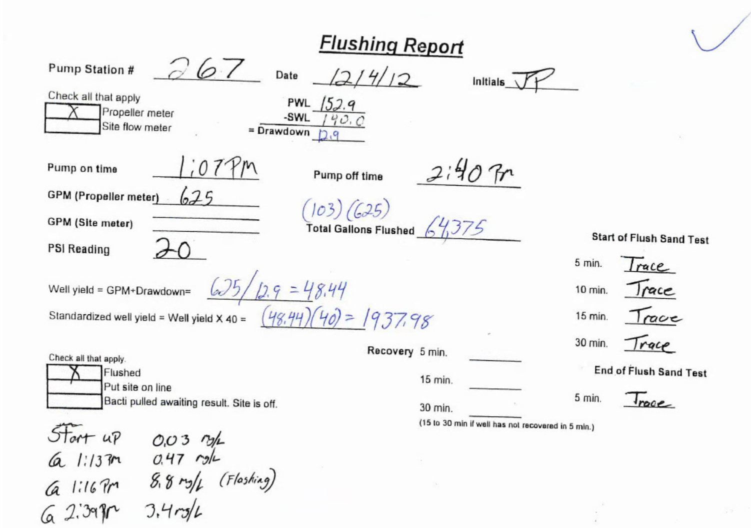
No preventative maintenance activities are set up to occur on any kind of schedule other than the four tracked in Hansen. Most work activities occur as a result from a site visit for some other purpose. The site visit may be conducted by the water system production group to conduct a Hansen scheduled activity, or it may be conducted by the telemetry and electrical group or water quality group.

A typical scenario that generates work activity may proceed as follows: A water quality team visits a site to conduct a regularly scheduled water quality test. They notice that the pump sounds louder than normal and inform the production staff. The issue gets recorded in RT and production staff proceed to investigate the issue by running a production site test. The test may reveal a flow rate of only 400 gpm when 1200 gpm is expected. Further investigation may reveal an excessive amount of vibration. Consequently it is discovered that the pump shaft is bent. The pump is shut down and the shaft is replaced. Other activity such as flushing and water quality testing follow before the well is brought back online. During the work the water production staff fill out the flushing form and confirm that the well is producing at the expected level. Other pertinent data is collected as hand written notes on the Flushing Report form.

This scenario describes a reactionary work flow that effectively addresses the immediate need, but was never planned for. One of the fundamental goals of an asset management system is to reduce these types of situations through more aggressive monitoring, preventive and predictive activities. Return on investment may be measured by tracking the costs saved by reducing the amount of reactionary work against the cost of monitoring and prevention activity.

2.2.2 Status of Water System Production Data Gathering and Analysis

Knowing that preventive maintenance and trend analysis for predictive activities requires data, the water system production supervisor put procedures in place three to four years ago to record pertinent well parameters through Flushing Report and Production Site Check forms.



Flushing Report

Pump Station # 267 Date 12/4/12 Initials JP

Check all that apply
[X] Propeller meter
[ ] Site flow meter

PWL 152.9
-SWL 140.0
= Drawdown 12.9

Pump on time 1:07PM Pump off time 2:40Pm

GPM (Propeller meter) 625

GPM (Site meter) ____

(103)(625)
Total Gallons Flushed 64,375

PSI Reading 20

Well yield = GPM÷Drawdown= 625/12.9 = 48.44

Standardized well yield = Well yield X 40 = (48.44)(40) = 1937.98

Start of Flush Sand Test
5 min. Trace
10 min. Trace
15 min. Trace
30 min. Trace

Recovery 5 min. ____
15 min. ____
30 min. ____
(15 to 30 min if well has not recovered in 5 min.)

End of Flush Sand Test
5 min. Trace

Check all that apply.
[X] Flushed
[ ] Put site on line
[ ] Bacti pulled awaiting result. Site is off.

Start up 0.03 mg/L
@ 1:13Pm 0.47 mg/L
@ 1:16Pm 8.8 mg/L (Flushing)
@ 2:39Pm 3.4 mg/L

Image provided by the City of Fresno

Typical Flushing Report

The completion of these forms is conducted by water system production crews as a standard operating procedure. Hundreds of forms have been completed since the time the program was put into place.

The challenge that these paper based documents presents is that all this data is only available through viewing scanned documents of hand written data. It has not yet been entered into a database where it can be utilized to develop trends.

In an attempt to develop long term trends in well efficiency, water production engaged a vendor to perform 100 efficiency tests per year several years ago. Logistical, personnel, and financial challenges limited this program to only 43 the first year, followed by another 50 the second year. The program was discontinued after that. At this point the well efficiency tests are conducted more on an ad-hoc basis. They are needed especially when motors are rehabilitated to qualify for PG&E's reimbursement program. The submissions required by PG&E are carried on by personnel at Fresno state on behalf of the City.

Another process that is currently underway is the creation of an Excel Well Analysis Workbook. This workbook is being prepared by a sub-consultant to CH2M. The state of the workbook as provided may be best described as a work in progress. With over 40 worksheets the workbook is being used to establish trends and decision making capabilities using data from SCADA and (presumably) data collected in the flushing and production site tests. The water production supervisor informed Kleinfelder that the workbook was able to analytically identify the same highest priority wells that she had also identified through her own processes. Kleinfelder searched the workbook for formulas that would reveal the algorithms used in the analysis, but found only hand entered numbers in the sheet labeled 'Final Evaluation Table'. Reportedly this workbook is going through an update.

2.2.3 Telemetry and Electrical Group Processes

The telemetry and electrical group adopted the use of RT several years ago when it became apparent the group required greater control over how work assignments are allocated. Since the RT system is primarily a work request system it was implemented so that City staff from other departments must first enter the request in RT for the telemetry and electric group to schedule the activity. Since RT is a web based system it was fairly easy to make available throughout City offices for this purpose.

The system is capable of sending out notifications to the telemetry and electrical supervisors who in turn assign the work to crews based on the priority of the work and availability of staff. It also provides notes and comments fields to describe the request and follow-up actions. RT tickets can be routed to different individuals who need to be involved through to resolution of the request.

Image provided by the City of Fresno

A screen shot of active requests in RT

As is the case with the production staff, the instrumentation and metering staff are fully aware that their current system is entirely reactionary and they too endeavor to evolve to a system that utilizes preventive and predictive criteria for setting up planned work activity.

Instrumentation and metering staff also enter status and change messages into SCADA:

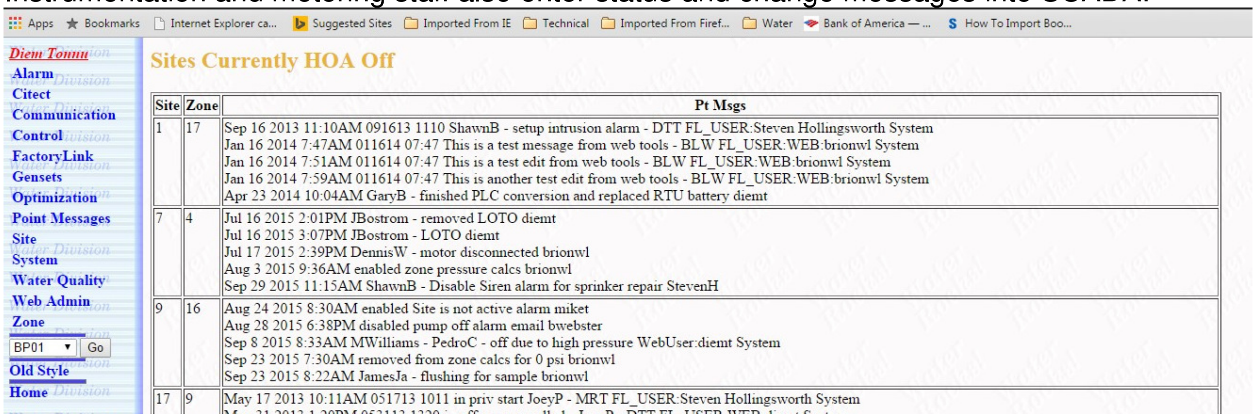


Image provided by the City of Fresno

A screen shot of messages in SCADA

2.2.4 Recommendations for Operations and Maintenance

While the current systems and practices are adequate for tracking reactionary work there are legitimate concerns that the current mode of operation is inefficient and presents some risks due to inadequate methods for assessing condition and performance that could lead to costly failures that might otherwise be preventable.

A widely published graph in the realm of asset management illustrates that organizations must seek the right balance of reactionary work with pro-active inspections and preventive maintenance to achieve cost optimization:

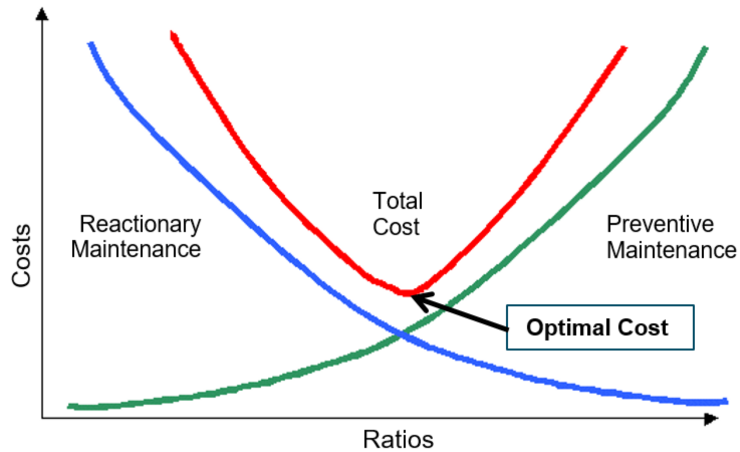


Image provided by Kleinfelder

Illustration of optimizing reactionary and preventive maintenance costs

The Team understand their current state and that they are attempting to better the situation within the resources that they have available. Enacting work flows to capture analytic data can be a challenging endeavor even with the right tools available, so the water production staff should be commended for establishing these work flows. Unfortunately, without an adequate database it has proven to be challenging to effectively utilize the information that is being gathered.

The next version of Hansen/Infor should be able capture these data with the establishment of work order forms designed after the Flushing Report, the Production Site Tests, and other forms as deemed necessary. From here reporting tools can be leveraged to create reports on work status, work scheduled, and the KPIs used to drive the decision making process.

However, achieving this goal is not as simple as installing or upgrading software. To make the most out of the system plans should start now to map out the work flows and data flows required to achieve the desired purpose. Metrics and thresholds need to be established to determine what should happen given the current status and KPIs that may involve data from both SCADA and the new version of Hansen/Infor. Furthermore, maintenance management plans need to be established using cost/benefit criteria to determine the most cost effective preventive maintenance and inspection activities and the frequency that they should occur. While this is beyond the scope of this PAMP, a maintenance management plan should be considered as adjunct to a full asset management plan.

3 CONDITION AND PERFORMANCE ASSESSMENT

This section summarizes recommended processes and data models for assessing the Condition and Performance of Fresno's groundwater wells toward an asset management framework. The criteria and process recommendations presented here are based on information provided by the Team and structured by Kleinfelder. Much of the data is already being used by the groundwater team to some capacity and documented as KPIs. The purpose of this task is to illustrate how these data may be better structured and presented for both long term and short term decision making in an asset management approach.

The following KPIs are selected at this time as components of the preliminary asset management framework. It is anticipated that with use more insight will be gained that will allow the entire Team to enhance the list.

3.1 KEY PERFORMANCE INDICATORS

The Key Performance Indicators (KPI) selected at this time are:

Specific Capacity (SC) – The ratio of flow over drawdown is a relative indicator of the overall health of the well site over time. The value typically decreases over time as the well site ages.

Overall Plant Efficiency (OPE) – Often expressed as the 'wire to water' efficiency this value expresses the relationship between the amount of energy consumed and the flow rate of a well at a given pumping head. This is an absolute indicator where a value above 70% is considered highly efficient whereas a value below 50% indicates an opportunity to increase efficiency and save energy costs.

Note: *Causes for decreasing SC or poor OPE values may be related to the health of the aquifer, changes to the hydraulics, issues with the gravel pack, clogging of the screen, a deteriorating motor, deteriorating impellers, head loss increases due to clogging, scaling and/or pitting in the pipes. A downhole video inspection may be required to determine the specific cause.*

Water Quality – Water quality is a critical KPI that directly affects the health and safety of the customer and is thereby heavily regulated. While the water quality group is not directly represented within the scope of this project we acknowledge that each well is regularly monitored, tested and treated to assure that the delivered product is safe for customers to consume. Changes in water quality are mostly attributed to the health of the aquifer, where the potential for agricultural and industrial contamination plumes are of highest concern. However, deteriorated water quality may also be caused by localized microbial action that takes place as the screen or filter pack becomes biofouled, which leads to corrosion.

For example: Increases in ferrous oxide are a sign that biofouling and casing or screen corrosion may be occurring. A low pH value also increases the chance of corrosion.

Energy Cost to Operate – This is a direct indicator related to the cost of producing water in terms of dollars per acre-ft. Most likely trends with OPE. Best used for determining the most cost effective wells to operate.

Change in Energy Consumption - This is a value that will most likely trend along with SC and OPE. While Energy Cost to Operate measures cost against a threshold value, the change in energy consumption will reflect changes in the operating environment of the well that may indicate a reduction in efficiency or changes in the aquifer hydraulics.

Remaining Life – Remaining life is a fundamental measure in asset management used to predict when an asset will need to be replaced in order to perform at the level it is designed for or currently required. Remaining life is used to forecast long term capital replacement costs and as a factor for near term investment decisions. For a well site, remaining life is best attributed to the life span of the casing or screen (It may not be cost effective to replace a motor in a well near the end of its life). By monitoring these components, predicting remaining life of a well site may be done by using one or more of the following measures:

- Plotting corrosion rates by material and age
- Trend casing thickness and condition
- Trend water quality for ferrous oxide and pH
- Identify possible galvanic action by identifying wells where screen material is different from casing material, improper grounding etc.
- Also:
  - Significant Increases in sand production may indicate screen degradation

- Remaining life of a well with no gravel makeup tube may be connected to gravel pack degradation

If these data are not readily available then remaining life may be estimated from historical life expectancy data. Indications are that a good value for life expectancy of a well-constructed groundwater well is about ninety years. This value may vary significantly from well to well depending on the factors listed above as well as the quality of construction.

3.2 MEASURES THAT CONTRIBUTE TO THE CALCULATION OF KPIS

In the final analysis the following measures were determined to be important KPI contributors but not KPIs by themselves. They remain important in terms of monitoring and calculating the KPIs and may be used in ensuing analysis after the KPIs trigger an action.

Drawdown – Changes in drawdown reflect the health of the aquifer and may be affected by other wells in the vicinity. Drawdown should be analyzed in conjunction with both the **static water level** (SWL) and the **pumping water level** (PWL) and is captured as a component of SC.

Discharge pressure – A lower discharge pressure may indicate higher head losses at the screen or in the piping. It could also be an indicator of hydraulic changes, a deteriorating pump, or motor inefficiencies. Contributes to the OPE calculation.

Flow - Reduced flow rates could indicate greater head losses at the screen or in the piping. It could also be an indicator of hydraulic changes, a deteriorating pump, or motor inefficiencies. Contributes to SC and OPE calculations.

3.3 UTILIZING KPIs TO ASSESS PERFORMANCE AND CONDITION

The following table provides unit of measure and threshold guidance on how the KPIs may trigger further action.

WELL KPI	Method of Assessment	Unit of Measure	Acceptable Performance Threshold
Specific Capacity	SCADA / PSC	Percent of original	Greater than 70%
Operating Plant Efficiency	SCADA / PSC	Percentage	Greater than 55%
Water Quality - health	Water Quality group	EPA / State Requirements	Within regulatory requirements
Water Quality - corrosion	Water Quality group	Field testing (i .e. MIC Kits[1]) / corrosion indexes (i. e. Langelier / Rhyznar[2])	Defined by method instructions
Energy Cost to Operate	SCADA / PSC	$ per acre-feet	Less than $150.00
Energy Consumption	PG&E Meters	% of Original	Less than 150%
Remaining Life	Material, age, corrosion rates of casing and screen	% life expectancy	Greater than 20%

1. Microbially induced corrosion (MIC) Kits allow field sampling and analysis for certain types of bacteria associated with corrosion potential.
2. Langelier Saturation Index or the Ryznar Stability Index

KPI Acceptable Performance Thresholds

While this table provides guidance on when further investigation is warranted (being a reactionary event), more detail is required to assess where the KPI lands on a scale and how it is trending in order to provide information sufficient for pro-active planning. For this purpose we employ the use of another fundamental asset management metric called the **Likelihood of Failure (LoF)**.

3.4 LIKELIHOOD OF FAILURE

Likelihood of Failure (LoF) can be either a quantitative or qualitative measure for assessing how likely (or probable) a failure will occur in terms of the failure mode, or key performance indicator being measured. For the purposes of this PAMP we will utilize a qualitative assessment of failure likelihood. By reporting all KPIs in terms of LoF we are in essence normalizing all measures to a common scale where a 1% LoF indicates that the asset is performing exceptionally well and 100% indicates that the asset has failed in respect to the KPI being measured.

As an example, the following describes how LoF is applied to SC. As we know, SC is a relative indicator of asset performance that requires the value to be compared or trended against the original or a prior SC value. Thus we can express SC as a percentage of the prior value. By doing this we can set up a scale that reflects our normal response to the SC measure relative to the original value and how likely the value indicates that the asset will or has failed. Recall that failure does not necessarily imply that the well is no longer functioning, but rather indicates that performance is at unacceptable levels. Below is the table created to determine failure likelihood in regard to SC.

Specific Capacity		
% Of Original	LoF	
100%	1%	
90%	5%	
83%	10%	
75%	15%	
70%	25%	←Threshold value
60%	35%	
55%	50%	
50%	60%	
48%	70%	
45%	80%	
43%	90%	

Likelihood of Failure values applied to Specific Capacity

By using this table we can assess how urgently we need to address a problem related to SC. If the measure is at or just below the threshold value we can most likely schedule a time to investigate the causes behind the low reading, while if the value is significantly below the threshold value then we may need to react faster.

Another part of our decision making process involves how fast the SC value is changing. If the value is near the threshold but has not changed significantly in the past five years we may not need to react as fast as we would for a well with higher SC ratio that has dropped significantly in the past year. This describes Trending Factors that can be applied to modify LoF based on the rate of change. The following table presents a list of preliminary trending factors.

Trending Factors			
Δ 5 Years	LoF multiplier	Δ 1 year	LoF multiplier
< 5%	1	< 2%	1
5% to 7%	1.1	2% to 5%	1.2
7% to 10%	1.2	5% to 7%	1.4
10% to 12%	1.4	7% to 10%	1.7
12% to 15%	1.8	10% to 12%	2
15% to 20%	2.3	12% to 15%	2.5
20% to 25%	3	15% to 20%	3.2
25% to 35%	3.5	20% to 25%	4
> 35%	4	> 25%	5

Trending factors can be used to modify the LoF score

These trending factors can be applied when there is a change in the KPI to modify the LoF according to how significant the change is. For example, if the SC is determined to be 80% then the LoF would be approximately 10%. However, if it is determined that SC has changed by 10% in the last year we would modify this value by a factor of 2, resulting in a LoF of 20%.

The following are the LoF tables created for other KPIs:

Water Quality - General	
Status	**LoF**
Meets Regulations	1%
Treatable with existing methods	25%
Requires new treatment	50%
non-treatable	100%

Operating Plant	
OPE	**LoF**
> 70%	1%
65% to 70%	5%
60% to 65%	10%
55% to 60%	30%
50% to 55%	70%
< 50%	90%

Energy Usage Change	
% of Original	**LoF**
80%	1%
90%	3%
100%	10%
110%	20%
120%	33%
130%	45%
140%	60%
150%	75%
160%	90%

Water Quality - Any Contaminant Trend			
% Change			
Δ 5 Years	**LoF**	Δ 1 year	**LoF**
< 5%	5%	< 2%	5%
5% to 7%	10%	2% to 5%	10%
7% to 10%	20%	5% to 7%	20%
10% to 12%	30%	7% to 10%	30%
12% to 15%	40%	10% to 12%	40%
15% to 20%	50%	12% to 15%	50%
20% to 25%	70%	15% to 20%	70%
25% to 35%	90%	20% to 25%	90%
> 35%	100%	> 25%	100%

Energy Cost to Operate	
$ per acre-ft	**LoF**
$181	90%
$180	75%
$170	60%
$160	40%
$150	30%
$145	20%
$125	10%
$100	5%
$75	1%

Likelihood of Failure tables

3.5 CONDITION AND PERFORMANCE ASSESSMENTS

Remaining life can be approximated by trending the age of the well against the normal expected life. However, it may vary significantly based on the condition of the casing, the screen, or the gravel pack if no gravel makeup tube exists. For this reason, condition assessments can greatly improve the forecasted remaining life. They may also prolong the life of the well if signs of early deterioration are found that can be mitigated through cleanings set at an interval rate proportionate to the rate of biofouling. For these reasons planned condition assessments should be part of the overall maintenance management strategy.

Downhole video inspections are the best method for assessing the condition of the casing and the screen. These assessments are typically performed at a time when one or more KPIs indicates that there are issues with the well or when the motor is in need of rehabilitation. The inspections are currently not performed in a manner that provides data that allows the condition to be trended over time or compared objectively to other wells. To do this requires that the condition of both the casing and screen be rated on a numeric scale. The simplest and most common scale used across a variety of assets is a 1 to 5 scale as defined in the following table:

Rating	Description	Lof
1 - Excellent	No visible degradation, like new	1%
2 - Good	Slightly visible degradation	10%
3 - Moderate	Visible degradation	40%
4 - Poor	Integrity of Component Moderately Compromised	70%
5 - Failed	Integrity of Component Severely Compromised	100%

Condition ratings used to assess static components such as screens and casings

While this scale reflects a subjective assessment it provides a means to rate numerically and thereby to track and trend condition over time.

3.6 OTHER METHODS TO PREDICT WELL REMAINING LIFE

Another method that could be used to predict life expectancy and remaining life based on corrosion rates is to use either the Langelier Saturation Index or the Ryznar Stability Index. These indexes do not measure corrosivity directly, but are based on the ability of water to precipitate a calcium carbonate film that can protect the metal surface against generalized corrosion. The use of these indexes is limited because they do not account for the microbial factors, other compounds that may prohibit the creation of the calcium carbonate film, or for flow velocity. However, they are easy to calculate and may serve as an indication that the water may be capable of forming the protective film in the right environment. Conversely, a high Saturation Index might result in the over precipitation of calcium carbonate leading to clogging of screen intervals, reduction in production rates and decreasing SC. Both methods use the difference between the measured pH value of the water and the pH value of the water if saturated with calcium hardness ($CaCO_3$) (*Reference: ASCE Manuals and Reports on Engineering Practice No. 127: Hydraulics of Wells; Ahmed, Taylor, and Sheng, Copyright 2014 by ASCE*). Investigating the applicability of these methods to Fresno's groundwater wells is beyond the scope of this PAMP, but may be considered in the future.

3.6.1 Predicting Remaining Life with Condition

Predicting the remaining life of any physical asset is never an exact science, but by using available information and an asset management process we can at least illustrate that the likelihood of well failure increases with well age and that the reliability of our prediction increases by tracking the physical condition of the casing and screen over time. For assets where substantial cost is involved to perform a visible inspection (as is the case for groundwater wells) it may be necessary to track both. The following table was created as a guide to illustrate how this data can be tracked:

Date/ Time	Casing					
	Condition Rating	LoF	Age	Expected Life	Remaining Life Age	Remaining Life Condition
4/6/1961	1	0.1	0	90	90	90
6/30/2015	3.1	0.5	54	90	36	25

Remaining Life due to condition example

This example uses well #36 that was drilled on 4/6/1961 making it 54 years old in 2015 (The condition scores are fictitious for exemplary purposes). If no condition score was available on this well the best indicator of remaining life is the initial Expected Life of 90 years minus the current age, or 36 as placed in the Remaining Life – Age column. However, a condition assessment allows us to approximate remaining life with less uncertainty. In the example the casing was given a condition score of 3.1. When plotted on a deterioration curve this equates to a Remaining Life based on Condition of only 25 years.

More sophisticated prediction models use historical records to develop deterioration curves to predict remaining life. For non-mechanical assets (such as casing and screens) a third order polynomial provides a reasonable curve for asset life expectancy, as it illustrates that after an initial decline the rate of deterioration levels off for an extended period of time, and then accelerates as the asset approaches the end of its expected life.

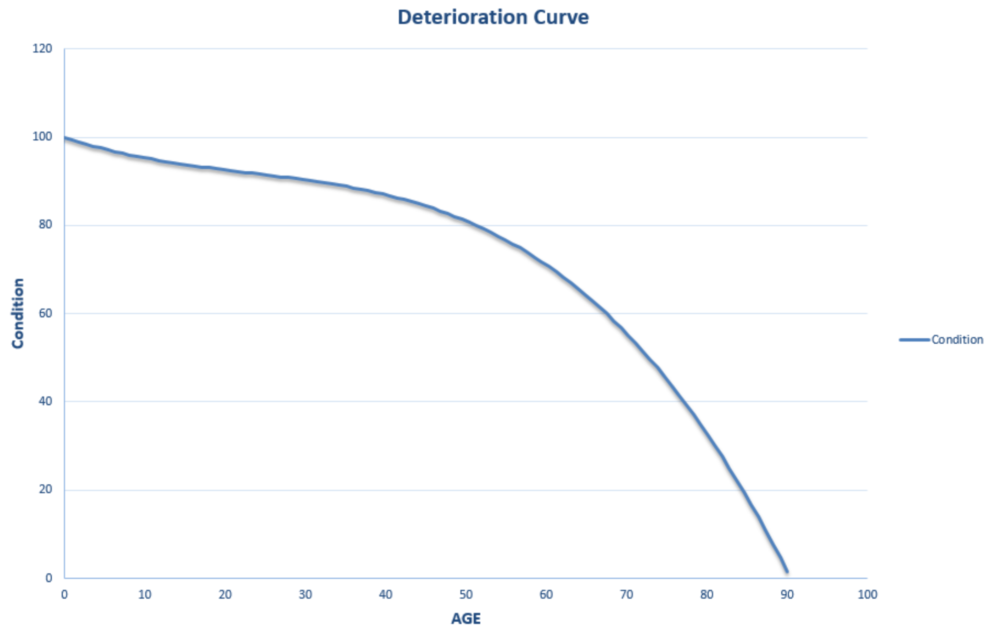


Image provided by Kleinfelder

Typical deterioration curve for static assets

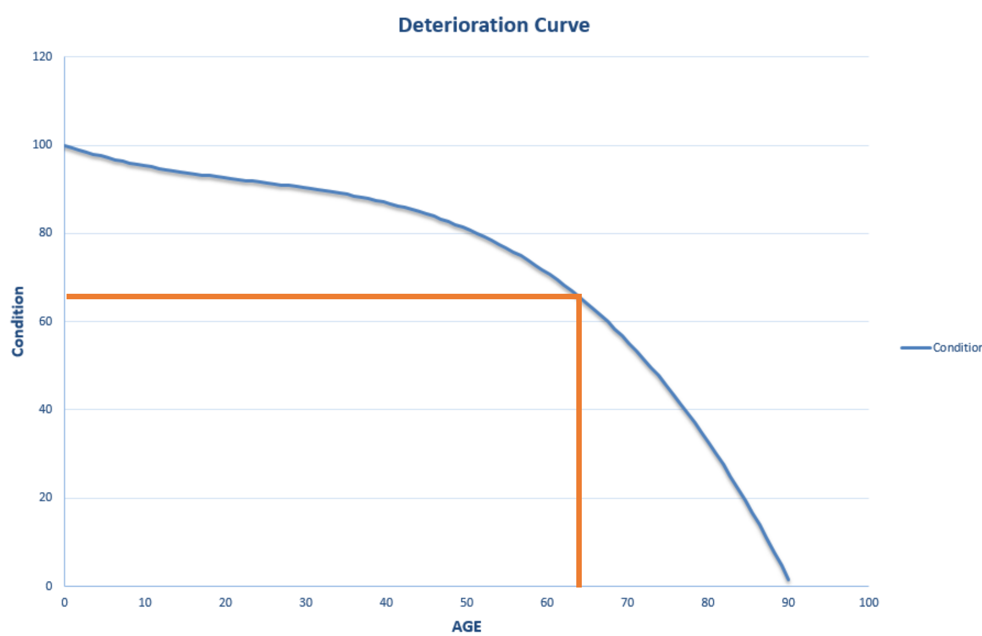


Image provided by Kleinfelder

Typical deterioration curve can be used to calculate effective age

With condition data, this curve can be further utilized to predict remaining life by plotting the condition on the y axis and intersecting the curve to determine the effective age due to condition:

In this example the condition (y) axis has been normalized to a scale of 0 to 100 where 100 represents new condition. The normalized condition score has been plotted at 62, and when intersected with the deterioration curve calculates to an effective age of 65 years. This value would then take precedence over the actual age to calculate remaining life.

Utilizing this method is beyond the scope of the PAMP but is presented here for future consideration. It should be noted that this method could be applied to pump motors and other well components as well as the casing and the screen. Mechanical assets would be assigned a 4th order polynomial for an initial deterioration curve as this would reflect a faster deterioration rate at the beginning of the asset's life.

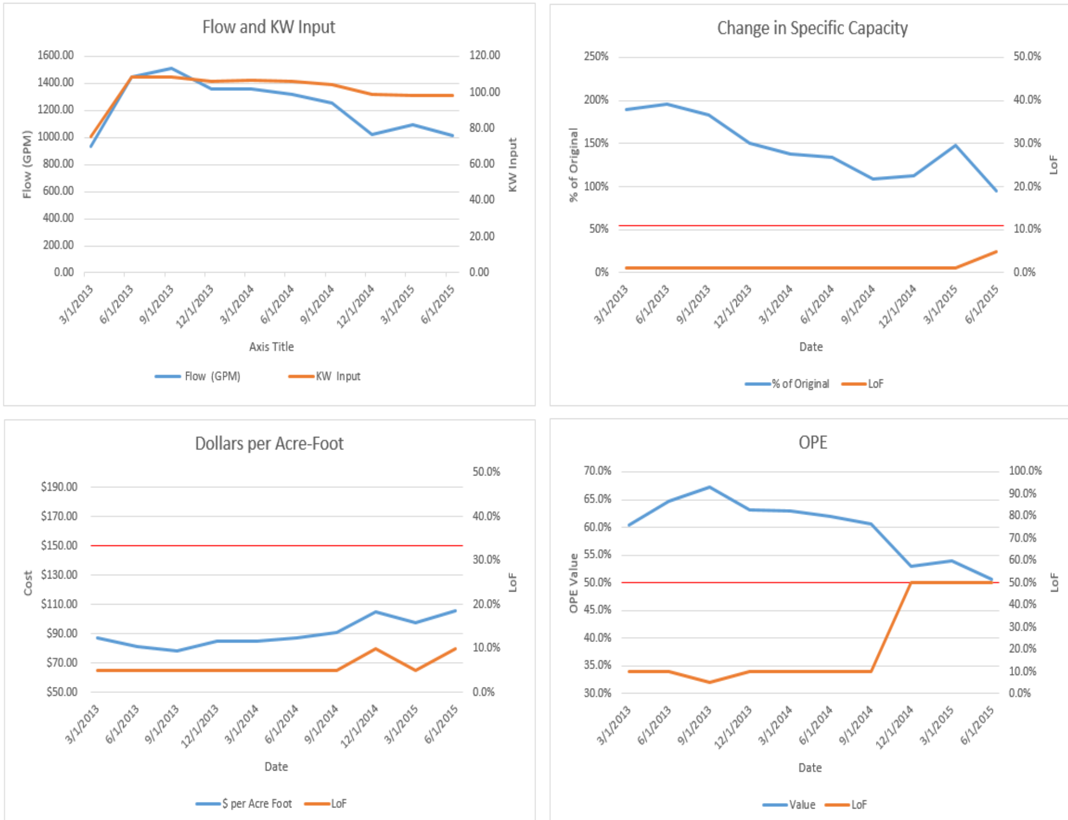
3.7 UTILIZING THE KEY PERFORMANCE INDICATORS

With the basis of the KPIs established Kleinfelder asked the Team to provide available data for the wells in Zone 20 so that we could illustrate some of the metrics that can result from this approach. The data provided covers a span of the last three years broken down by months. Kleinfelder further processed the data to break down by quarter and then created an Excel work book that calculates both values and LoF for:

- Change in SC
- Overall Plant Performance (OPE)
- Energy Usage
- Energy Cost to Operate
- Change in Energy Consumption

It also tracks flow, pressure, and power input. The purpose of the workbook is to illustrate how the data can presented in a dashboard like interface.

WELL 36



Example Dashboard for Well 36 with KPIs

Note: This dashboard is presented for exemplary purposes in order to illustrate how asset management metrics and process may be utilized for decision making. Some of the data from the time the well was put into service was approximated in order to create these graphs. Therefore, the data presented here should not be used for action without further research.

In this example each graph illustrates how each KPI is trending over the past three years on a quarterly average basis. The horizontal red line represents the acceptable threshold values for each KPI (maximum or minimum). With this graphic we can quickly see that SC and OPE are trending downward. While SC has not yet reached the threshold trigger value, OPE has. Depending on the decision model this may trigger an action to investigate this well further. Other metrics, such as the age of the motor, and the effective age of the well based on the casing and the screen could be added to this dashboard to provide better clues as to why the OPE has dropped. Fortunately the well does not appear to be too costly to operate at this time so this may be a situation that calls for closer monitoring without deploying field crews.

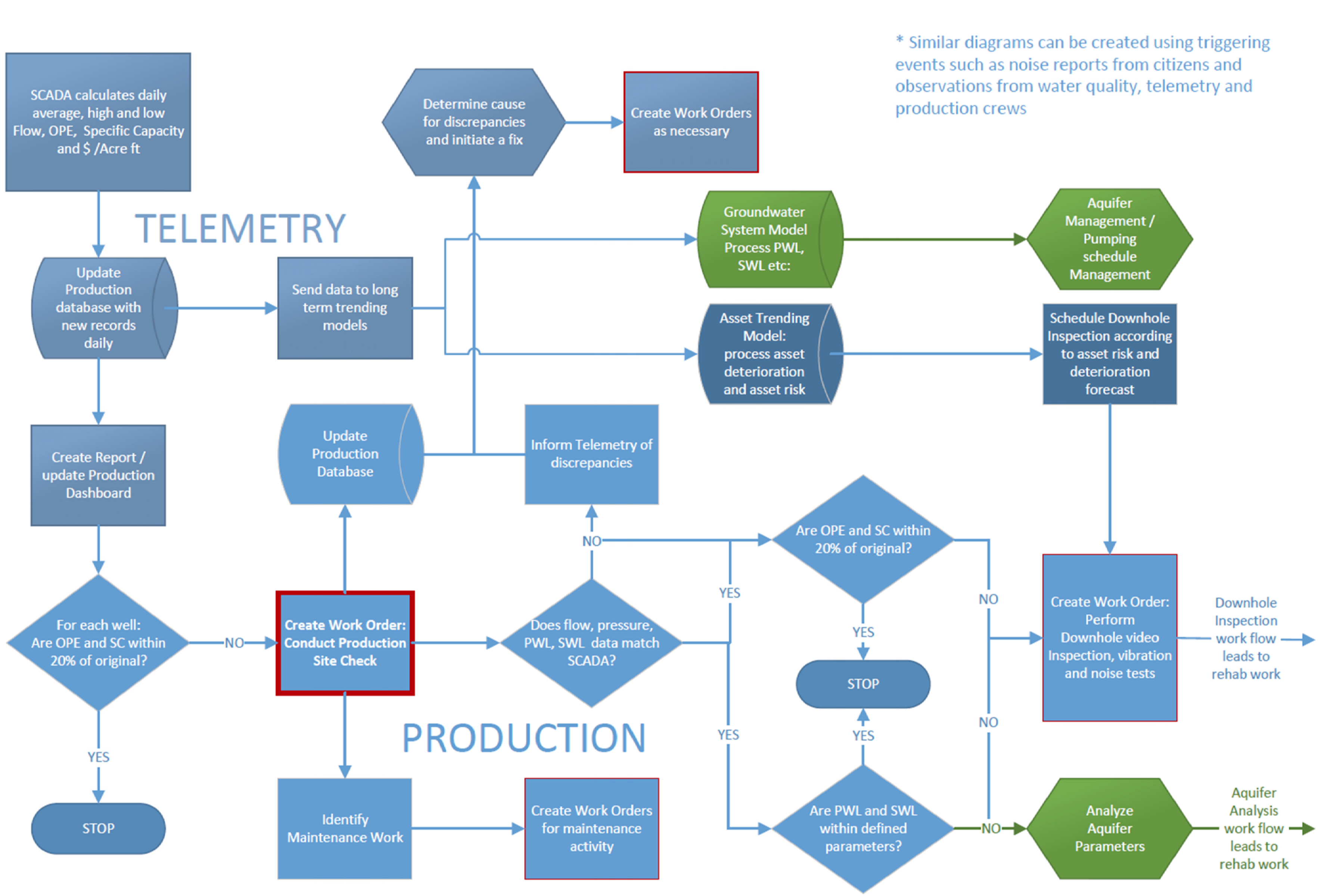
The next major section of this document introduces the concept of consequence of failure which will further help the decision on whether to take action and what type of action to take.

3.8 REGARDING PROCESS AND WORK FLOW

Perhaps the most challenging aspect of utilizing data are the processes that must be in place to assure that the data is continuously available and reliable for decision making purposes. It may be the most important aspect. Indeed, this investigation has discovered that values from SCADA (usually the SWL) must be monitored and checked regularly in order to provide the well production group data they can rely on in order to take proper action.

To illustrate how work flows and process can be utilized Kleinfelder created the flow diagram presented on the following page as an example. It illustrates how work management (with work orders from the upcoming Infor system) are a key element to track work flow and provide the data integrity sought. The diagram builds off of current work flow processes, and illustrates how, with some adjustments (and the proper systems to support the work flow), work activity can be organized by both reactionary and planned toward the goal of more effective well management.

Draft Work Flow / Data Flow Framework triggered by SCADA data*



* Similar diagrams can be created using triggering events such as noise reports from citizens and observations from water quality, telemetry and production crews

4 GROUNDWATER WELL CRITICALITY AND RISK

This section expands on how to develop and use the components of criticality and risk in an asset management framework. These components include:

a) Consequences of Failure
b) Likelihood of Failure
c) Failure modes
d) Criticality
e) Risk

The following terms are used throughout this section:

Consequence of Failure (CoF)
The impact that will occur to stakeholders due to asset failure. Quantified in terms of severity.

Likelihood of Failure (LoF)
The chance or possibility of a failure occurring. 'Likelihood' is synonymous with 'probability' but without rigorous statistical analysis

Failure
An asset may be considered to have 'failed' when it can no longer do what is required within established parameters

Critical Assets
Assets for which the consequences of failure are sufficiently severe to justify pro-active inspection and rehabilitation

Risk
The following 3 definitions are presented in order to more fully define this important term:

- A value representing the product of a consequence of an occurrence and the likelihood of the occurrence. - *Implementing Asset Management, a practical guide*

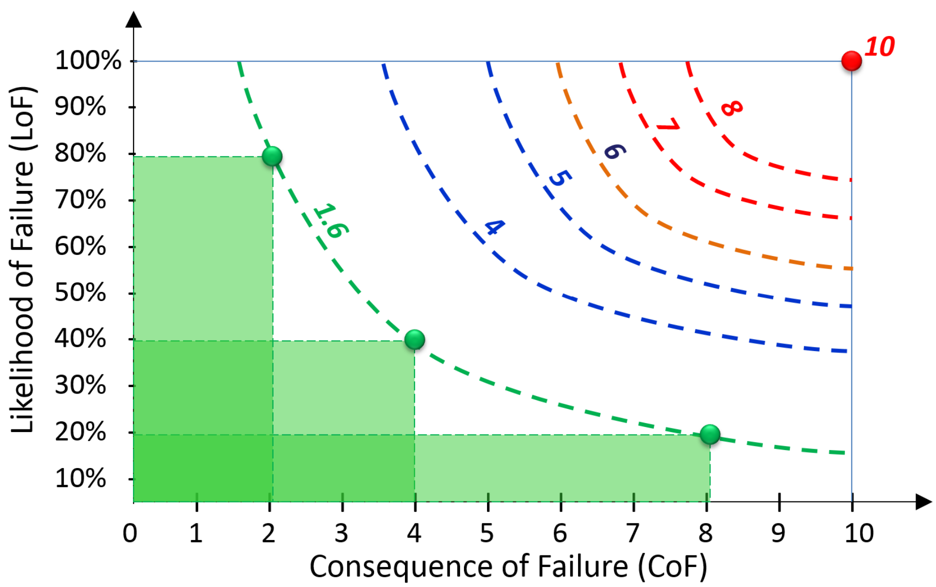
- The possibility that something bad or unpleasant (such as an injury or a loss) will happen - *Merriam-Webster (online)*

- The potential of gaining or losing something of value-*Wikipedia*

4.1 THE COMPONENTS OF RISK IN AN ASSET MANAGEMENT FRAMEWORK

In an asset management system Risk is calculated as the product of Consequence of Failure and Likelihood of Failure. Section 3.0 of this preliminary plan described how to assign Likelihood of Failure as a precentage based on condition and performance data. In this section we will expand on how to numerically define Consequence of Failure, but first we will take a look at why it is important to look at LoF and CoF as well as Risk in an asset management decision model.

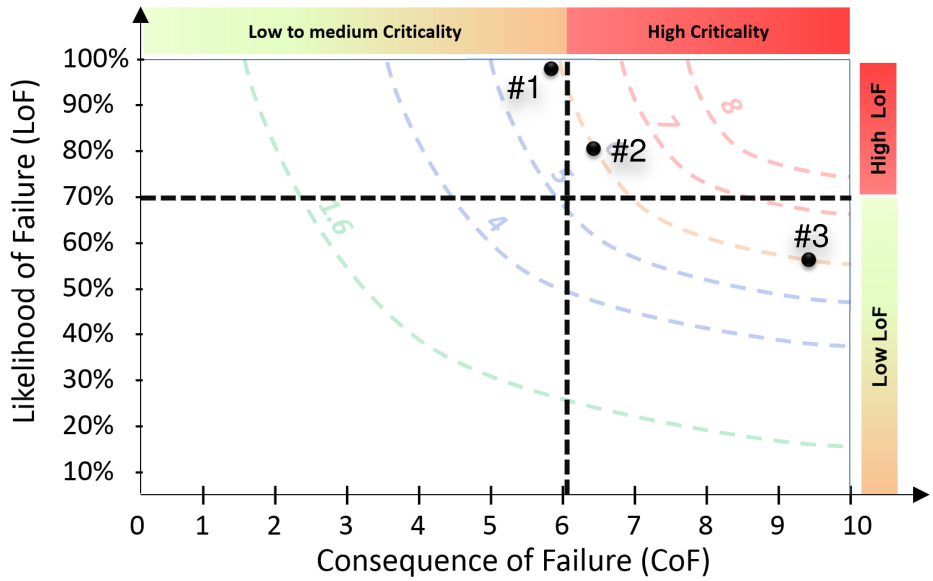
In the graphic below CoF is numerically represented on an arbitrary scale of 1 to 10, where 10 represents a high consequence if a failure occurs.



Different values of CoF and LoF may produce the same Risk score

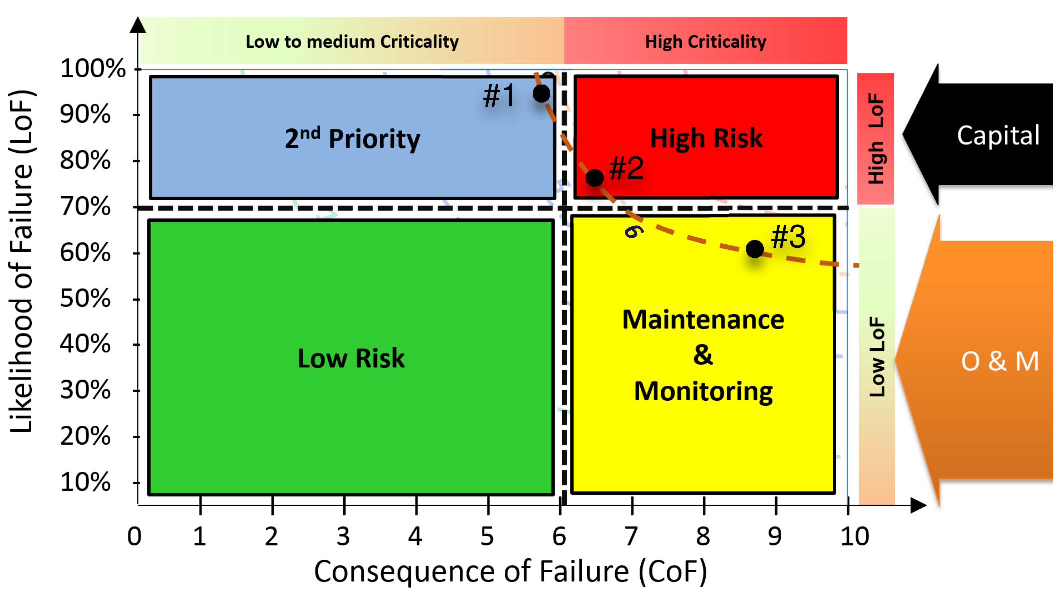
Each of the dashed curved lines represents equal values of Risk. For example, the green line represents the same Risk score (1.6) based on the product of different values of LoF and CoF. 80% x 2, 40% x 4, and 20% x 8 all equal the same Risk score of 1.6.

The basis of a Risk matrix is formed as the Risk values increase from lower left to upper right.



Elements of a Risk matrix

In the graphic above we introduce the term "Criticality" as it relates to assets with a high CoF value (see definition of "Critical Assets" on previous page). The straight dashed black lines represent threshold values for LoF and CoF. These lines are used to distinguish high and low LoF and CoF values. The 3 black dots represent 3 assets with the same Risk score, but the decision how to address each asset varies because of the differences in LoF and CoF values. In this case asset #2 would receive priority treament because it is the only one that falls in the high risk qaudrant. The next diagram illustrates what types of decision may be made based on where the asset falls in the Risk matrix.



Risk matrix decision framework

Plotting the three assets that share a common Risk score on the Risk matrix illustrates how three different management strategies would be applied. Asset #2 will be rehabilitated or replaced soon because it is more critical than asset #1 even though asset #1 is more likely to fail. Asset #3 is more critical than #2 but it is less likely to fail so it will receive an agressive monitoring and maintainance schedule to keep it from moving into the high Risk area as long as practical (it will move into high Risk eventually). It is rare for an asset to become more critical with age, so it is unlikely that #1 will ever be a high Risk asset, but since it's LoF is high, the organization should make sure there is budget available to replace it. As a 2nd priority the organization may decide to run the asset to failure but more likely it will be replaced or rehabiliated after the organzation has funded projects that fall in the high risk quadrant.

4.1.1 Consequence of Failure Criteria

Consequences of Failure are best expressed in terms depicting the negative impact that would occur with a failure. They are developed by first considering stakeholder values, and then expressing those values in terms that can be applied across many asset classes as illustrated in the following table.

Stakeholder Values	In terms of Consequence
Reliable Service	Unreliable service
Public Safety	Injury or loss of life
Public Health	Loss of health or life
Financial impact	High cost to repair, High cost to operate, Loss of income
Public relations	Loss of business, Disruption to the community, Property damage, High rates
Regulatory Compliance	Regulatory incompliance

Use stakeholder values to develop Consequences

The following is an example of the process used to develop a list of consequences for water wells:

SC is an indicator that there may be less water produced with more work as the value goes down. In other words, a drop in SC may indicate that flow is going down while power needs go up. The consequence of low flow may be that fire suppression and medical needs cannot be met. While it may suffice to make 'inadequate fire suppression' and 'incapability to meet medical needs' as consequences, the better practice is to express these consequences in terms that can be applied across a variety of asset classes, being:

1. Injury or Loss of Life (the consequences that occur when there is inadequate fire suppression)

2. Loss of Health or Life (the consequences that happens when there is inadequate supply to meet medical needs)

The severity of the consequence may vary from well to well, necessitating the need to develop criteria to rate severity of the impact to the system for each well. A start was made during a workshop to create such as table, then Kleinfelder proceeded after the workshop to develop the following draft table to exemplify how this criteria is framed:

Consequence Severity Criteria						
Consequences	**Weight**	**Very low - 1**	**Low - 3**	**Moderate - 5**	**High - 7**	**Severe - 10**
Unreliable Service	8	All other wells in zone can produce 150% peak demand without this well	All other wells in zone can produce 120% peak demand without this well	All other wells in zone can produce 100% peak demand without this well	All other wells in zone can meet ave daily demand without his well, but not peak	All other wells in zone can not meet ave daily demand without this well
Injury or loss of life	10	All other wells in zone can produce 200% peak fire flow demand without this well	All other wells in zone can produce 150% peak fire flow demand without this well	All other wells in zone can produce 120% peak fire flow demand without this well	All other wells in zone can produce 100% peak fire flow demand without this well	fire flow demand in zone can not be met without this well
Loss of health or Life	10	Water produced from this well requires no WQ treatment	Water produced from this well requires only chlorine treatment	Well will be infiltrated by a growing contaminant plume within 5 years	Well is within a plume with low contaminant levels	Well is within a plume with high contaminant levels
High cost to operate	7	Zone $/acre-ft would be less without this well	Zone $/acre-ft would not be affected without his well	Zone $/acre-ft would rise < 10% without his well	Zone $/acre-ft would rise 10% to 20% without his well	Zone $/acre-ft would rise more than 20% without his well
Disruption to the community due to noise	4	No dwelling within 200 ft of well	No dwelling within 100 ft of well	Well is located in a low density residential area	Well is located in a medium density residential area	Well is located in a high density residential area

Example/Draft consequence severity criteria table

As a first draft, this table serves as a good starting point to further refine the consequences and associated rating criteria. The table reflects some of the concerns expressed during the workshop such as contaminant plumes. The weight column captures the relative importance of each consequence.

4.1.2 Likelihood of Failure Criteria

Likelihood of Failure was introduced in Section 3.0 where the KPIs were set up with Likelihood of Failure tables. While any of the KPIs may be considered candidates for the failure modes used to calculate Risk, we chose the following as they are good indicators of where the wall is in its overall life cycle.

Failure Mode/KPI	Reason for selection
OPE	Good indicator of cost and efficiency
Change in Specific Capacity	Good indicator of flow and aquifer condition
Casing Condition	Casing is a critical component used to for determining effective life used
Screen Condition	The screen is a critical component that can have significant impact on well performance and effective life used
Water Quality Trend	The trend in water quality could cause the well to fail in terms of public health or financial impact
% Life Used	All assets have an expected life that can be used as a proxy for condition

Failure modes selected for calculating well risk

Using the methods presented in Section 3.0, a table of was created for each failure mode to match failure likelihood with the failure mode values. In the case of the three condition ratings, the condition evaluation is presented on a scale of 1 to 10 (where 10 is failed) to provide further granularity than the typical 1 to 5 ratings presented in Section 35.0.

% Live Used		% Change in Specific Capacity		OPE	
% Life	LoF	% Original	LoF	OPE	LoF
0%	1%	1%	99%	10%	99%
10%	6%	30%	90%	30%	90%
20%	10%	40%	60%	40%	80%
30%	14%	50%	50%	45%	60%
40%	20%	60%	35%	50%	50%
50%	30%	70%	25%	55%	30%
60%	42%	75%	15%	60%	10%
70%	60%	80%	10%	65%	5%
80%	78%	90%	5%	70%	2%
90%	90%	100%	1%	80%	1%
100%	95%	150%	1%		

Water Quality Trend		Screen Condition		Casing Condition	
% Change	LoF	Rating	LoF	Rating	LoF
1%	5%	1	1%	1	1%
5%	10%	2	6%	2	6%
7%	20%	3	10%	3	10%
10%	30%	4	15%	4	15%
12%	40%	5	22%	5	22%
15%	50%	6	32%	6	32%
20%	70%	7	45%	7	45%
25%	80%	8	63%	8	63%
35%	90%	9	80%	9	80%
50%	100%	10	95%	10	95%

Likelihood of Failure tables

Other modes of failure that were considered include motor failure, pump failure, and water treatment system failure. While these components are absolutely critical to the operation of a well, they were not used in this analysis because a failure of these components does not preclude the end of life of a well to the extent that one of the selected failure modes does. However, it is expected that these components will either need to be replaced or rehabilitated three to four times over the life of a well, attributing to hard costs that must be included in the life cycle plan for each well.

4.1.3 Development of an Excel Workbook Tool to Calculate Well Risk

All the information used to calculate risk was assembled into an Excel workbook called 'Risk Calculator.xlsx'. The risk calculator utilizes the methods presented in this document to calculate Likelihood of Failure, Consequence of Failure, and Risk for each well in Zone 20. The workbook is designed as a tool that can be edited and modified as required. It should be noted that due to the lack of data the risk calculator is currently populated with data generated for the purpose of illustrating how the tool works. It is, in essence, a framework for decision making that should help the Team focus on acquiring the quality data needed for the risk calculator tool to function as the decision support tool it is designed to be.

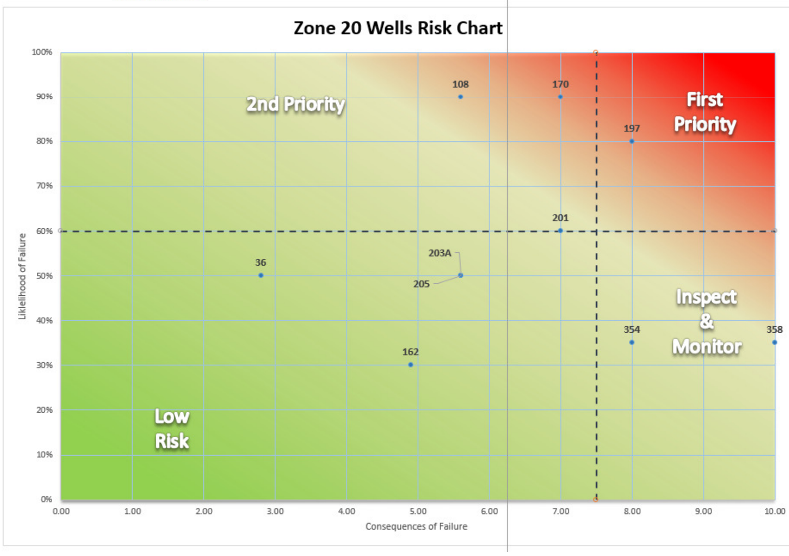
The Risk Ratings tab in the risk calculator tool is the main page for presenting results as well as entering data that drives the likelihood of failure side of the equation.

Risk Calculator for Wells in Zone 20

IMPORTANT: DATA NOT SUFFICIENT FOR USE. Much of the data in this tool was entered for illustrative purposes and does not reflect actual data that would be required to use this tool for decision making purposes

Risk Rating Data (calculated)					Edit data in these columns to update Likelihood of Failure														
WELL	Risk Rating	Most concerning issue	CoF Rating	LoF Rating	Expected Life	Current Specific Capacity	Original Flow (GPM)	Current Flow (GPM)	Water Quality Trend	Screen Condition	Casing Condition	Current OPE	Original Drawdown (FT)	Original Pressure (PSI)	Original PWL	Original SWL	Original KW	Original HP
36	1.40	Disruption to Community due to OPE	2.80	50%	90	93	1890	1250	2%	3	3	50.60%	23.00	50.00	93.0	70.0	106.00	142.15
108	5.04	Unreliable Service due to OPE	5.60	90%	90	20	1400	1059	2%	3	2	31.00%	30.00	53.00	80.0	50.0	67.11	90.00
162	1.47	High Cost to Operate due to OPE	4.90	30%	90	36	1480	300	3%	4	3	57.90%	43.37	69.00	97.6	54.2	93.21	125.00
170	6.30	Injury or Loss of Life due to % Change in Specific Capacity	7.00	90%	90	84	2500	1200	1%	5	2	46.00%	10.00	21.04	90.0	80.0	93.21	125.00
197	6.40	Loss of Health or Life due to Water Quality Trend	8.00	80%	90	25	1300	920	25%	2	2	28.00%	40.00	54.00	95.0	55.0	75.00	100.58
201	4.20	Injury or Loss of Life due to % Live Used	7.00	60%	90	15	780	400	2%	3	5	50.00%	40.00	51.00	80.0	40.0	40.00	53.64
203A	2.80	Unreliable Service due to OPE	5.60	50%	90	22	1400	300	10%	2	2	50.00%	41.00	49.00	155.0	114.0	100.00	134.10
205	2.80	Unreliable Service due to OPE	5.60	50%	90	12	750	600	8%	1	3	50.00%	39.00	48.70	80.0	41.0	38.00	50.96
354	2.80	Injury or Loss of Life due to % Change in Specific Capacity	8.00	35%	90	30	2000	1500	6%	2	1	60.00%	40.00	50.20	160.0	120.0	175.00	234.68
358	3.50	Injury or Loss of Life due to % Change in Specific Capacity	10.00	35%	90	40	2500	1700	1%	3	1	50.00%	40.00	49.60	190.0	150.0	200.00	268.20

Edit Global Settings



Set threshold lines on chart

CoF Threshold	LoF Threshold
7.5	60%

Risk Ratings tab in Risk Calculator tool

The tool is driven by a risk calculation for each well as presented on each well tab.

Well: 36

ASSET RISK CALCULATOR

Instructions: Edit Severity in green shaded area

Edit Global Settings

Risk Ratings

CONSEQUENCE CALCULATION						LIKELIHOOD OF FAILURE AND RISK CALCULATION							
								X					
CONSEQUENCES	Severity (v.low low mod hi v.hi)	Asset Severity Score	Contri-buting Weight	Calculate Weight	Cons-equence Scores	% Live Used 20%	% Change in Specific Capacity 1%	OPE 50%	Water Quality Trend 5%	Screen Condition 10%	Casing Condition 10%		
Unreliable Service	low	3	8	0.205	**2.40**		0.02	1.20		0.24	0.24	1.20	
Injury or Loss of Life	v.low	1	10	0.256	**1.00**	0.20	0.01				0.10	0.20	
Loss of Health or Life	mod	7	10	0.256	**7.00**				0.35			0.35	
High Cost to Operate	v.low	1	7	0.179	**0.70**	0.14	0.01	0.35	0.04	0.07	0.07	0.35	
Disruption to Community	mod	7	4	0.103	**2.80**	0.56		1.40			0.28	**1.40**	X
	v.low	0	0	0.000	**0.00**								
	v.low	0	0	0.000	**0.00**								
	v.low	0	0	0.000	**0.00**								
	v.low	0	0	0.000	**0.00**								

Consequence Factor: 2.80 (out of 10)

Risk Factor: 1.40 (out of 10)

SUMMARY

Most Concerning Issue:	Disruption to Community due to OPE	
Likelihood of Failure:	50%	Likelihood of Failure associated with Highest Risk
Consequence Factor:	2.80	Highest Consequence associated with Highest Risk
Risk Factor:	1.40	

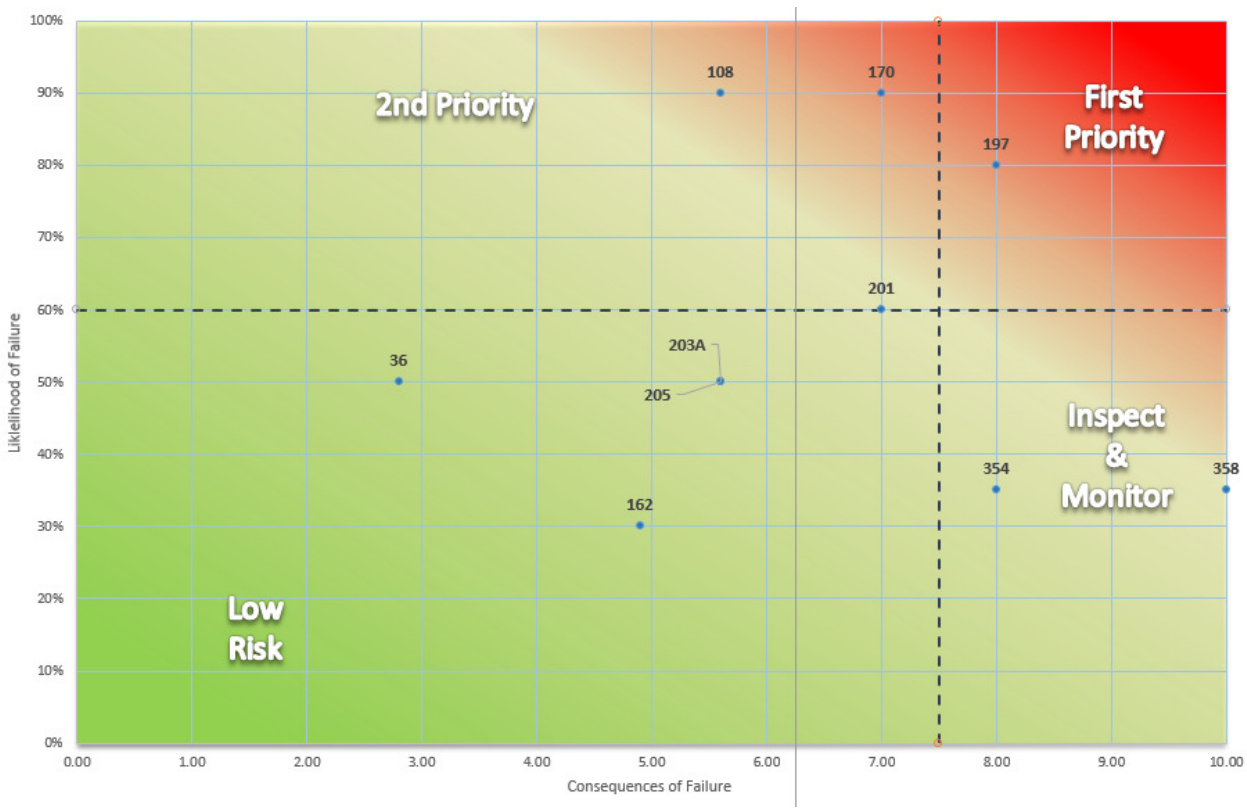
FAILURE MODE VALUES					
% Live Used	% Change in Specific Capacity	OPE	Water Quality Trend	Screen Condition	Casing Condition
47%	113%	51%	0.02	3.00	3.00

Detailed Risk calculation for Well 36

Referring to the screenshot above, each consequence is rated for severity relative to the well. This rating is modified by the relative rank (weight) of the consequence and normalized to a scale of 1 to 10. The highest consequence score is set as the Consequence Factor. To determine the Risk Factor, each consequence score is multiplied by the Likelihood of Failure for each Failure Mode within the matrix. The highest scores for each consequence (shown in red) are compared to determine the highest value. The highest value is then set as the Risk Factor for the well.

By tracking the consequence and failure mode combination that results in the Risk Factor the tool is able to create the most concerning issue statement. In the case of the example above the most concerning issue is Disruption to the Community due to OPE. Referencing the aforementioned consequence severity table, the underlying issue may be increased noise may be the result of an inefficient pump. However, even though this is the "most" concerning issue for this well, the low risk factor tells us that the issue is a very low priority.

This same calculation is performed for each well. The chart on the Risk Ratings tab may provide the best summary of all the wells in terms of actions to be taken.



Zone 20 Risk Chart

This chart reflects the principles of charting assets based on CoF and LoF presented in this document to determine what course of action is required. The dashed lines are adjustable to reflect where the water operations staff determine the thresholds for action should be using this table:

Set threshold lines on chart	
CoF Threshold	LoF Threshold
7.5	60%

Table for setting CoF and LoF threshold levels

As illustrated in the table above, these threshold values have been set to 7.5 and 60% respectively. For illustrative purposes the water treatment system condition for well 197 was set to a poor rating of 7 and the consequence severity was set to high (8). This combination calculates to a risk score of 5.6 and places the well in the first priority quadrant, indicating that immediate action is required.

This chart illustrates how important it is to consider each part of the risk calculation. If we looked at just the risk factor, we might conclude that well 170 requires more immediate action, but (according to our threshold zones) well 170 falls in 2nd priority zone, implying that well 197 is the highest priority.

We should also note that the chart is indicating that wells 354 and 358 should be inspected. These wells get high consequence scores because they were assigned high production rates, and are therefore critical to overall production needs (such as fire flow) for Zone 20. More critical wells require more attention, thus they fall into the inspect and monitor quadrant.

5 CONCLUSION AND RECOMMENDED ACTION ITEMS

The investigatory sections of this PAMP revealed that the City's Team is striving to break from a mode of operation that is tilted toward a reactionary management paradigm in favor of a more cost effective pro-active management strategy.

While there are some positive steps that the department of public utilities (DPU) can take toward this goal within the current management framework (as outlined in Section 3.0), this PAMP presents an asset management framework that will require some change in management style and tools in order to fully realize the benefits of an asset management approach.

The methods presented in this plan build on current processes and data by invoking some asset management best practices (mainly the components of Risk) to provide a sustainable and consistent decision making framework**. Most important to this approach is a change to how data is collected, stored and utilized in order to provide the information that the groundwater team needs in a pro-active decision making model.**

However, this plan is not entirely conclusive because it was developed without reference to a Strategic Asset Management Plan for the entire water system. A Strategic Asset Management Plan would identify policy, mission, system wide objectives and system wide levels of service goals for all stakeholders. With a SAMP in place Asset Management Plans for specific asset classes (such as groundwater wells) can be implemented with the assuredness that the management of these critical assets is in step with system wide objectives.

The following are the major recommended action items for the DPU and the Team to take in to consideration:

1. If one does not already exist, develop a Strategic Asset Management Plan (SAMP) for the Department of Public Utilities and/or the entire Water System. Include vision, mission, policy and level of service goals for all stakeholders at the system level. Include a listing of all Asset Management Plans that will be developed.
    - Include aquifer management policies that take into consideration the Sustainable Groundwater Management Act (SGMA). This would include integrating existing

well data, groundwater data and hydrogeologic data into an operational focused hydrogeologic conceptual model.

2. Update this PAMP to a full asset management plan that summarizes the state of the entire portfolio of groundwater wells and establishes a plan based on the SAMP with consideration to the recommendations listed here.

3. Fully document work processes with work flow diagrams with emphasis on processes designed to capture data used for KPIs. Identify responsible parties for specific tasks. Define processes to assure data integrity. Map out how data is processed into information required for KPIs.

4. Develop a plan to get the most benefit out of the upcoming Infor/Hansen upgrade based on the workflows developed in item 3. Work with the Infor implementation team to assure that the system can accommodate data from flushing reports and production site tests.

5. Develop a plan to migrate from RT to Infor so that everyone is on the same system with full work management capabilities. Work with the Infor implementation team to assure that the Telemetry and Electrical Group has all the functionality of RT available through Infor.

6. Determine to what degree Infor can be utilized to support the asset management framework. Specify reports, dashboard items and data sources (including SCADA) that are required. If Infor cannot fully support these requirements then find a third party solution to supplement and integrate with Infor.

7. Develop a plan to mine the "H" drive for data required for KPIs that is locked in scanned documents and make it accessible through Infor and/or an integrated database system (related to item 4).

8. Specify a data model that defines how and where all data enters the system, where it is stored, and how it is accessed. Identify how different systems (such as Infor and GIS) will be integrated. The goals being to provide one primary point of entry, eliminate duplicate data, and utilize a common source of data for all reports and dashboards across the City.

9. Assess the operational requirements and reliability of the SCADA system. (*This plan did not evaluate the SCADA system but it appears that it may be aging, that maintenance of the system requires significant resources, and that the data generated from it may not be as reliable as it could be*).

10. Invoke a well inspection program that involves downhole inspections and cleaning of the casing and screens. Begin the program with the most critical wells. Develop work flow and data flows to optimize processes for cost effectiveness. Establish a funding strategy that allows critical wells to be re-inspected and cleaned every 7 to 10 years or as trend analysis indicates.

These recommendations are designed to complement and be in addition to other recommendations incorporated within this PAMP.

APPENDIX D

Well Prioritization Results

Well Prioritization Results
City of Fresno, CA

		Well ID	Number of Scenarios	Average Flow Rate (gpm)	Status	Hydraulic Model Runtime % (Annual)	TCE Plume Management (Y/N)	TCP Management (Y/N)	Operational Notes	Prioritization Notes	Solution Set
Mixing Area	**1**	9A	0	1,800	ACTV	0%	N	Y	Sander; must be on 24/7; purchased property adjacent	Prioritized; See Operational Notes	ADD & MDD
ADD (gpm)	**5,003**	3A	9	2,440	ACTV	3%	N	N			ADD & MDD
MDD (gpm)	**10,006**	170	6	1,970	ACTV	3%	N	N			ADD & MDD
		16A	6	1,360	ACTV	0%	N	N	Sander; must be on 24/7; will run to failure	Prioritized; See Operational Notes	MDD
		88-2	2	1,260	ACTV	0%	N	N			MDD
		26B	0	2,440	ACTV	0%	N	N			MDD
		27A	1	1,540	ACTV	0%	N	N			
		22A	1	2,330	ACTV	0%	N	N	pump failed; well video; investigation in progress; R&R pump	See Operational Notes	
		26A	5	1,710	ACTV	0%	N	N	This is not a good well; drop to bottom; replace with 26B	See Operational Notes	
		162	1	1,210	ACTV	0%	N	Y	exceeding MCL for TCP - remove from prioritization	Remove/De-Prioritize	
		40A	10	1,940	ACTV	0%	N	Y	Water quality (Nitrate) concerns; Currently only runs in summer 24/7; well is not plumb, many issues	Remove/De-Prioritize	

Mixing Area	2
ADD (gpm)	7,643
MDD (gpm)	15,287

Well ID	Number of Scenarios	Average Flow Rate (gpm)	Status	Hydraulic Model Runtime % (Annual)	TCE Plume Management (Y/N)	TCP Management (Y/N)	Operational Notes	Prioritization Notes	Solution Set
153-2	0	490	ACTV	13%	N	N	DBCP/NO3; Blends with 153-1 which must run	Prioritized; See Operational Notes	ADD & MDD
153-1	0	800	ACTV	13%	N	N	Well must run for blending of 153-2 and 224	Prioritized; See Operational Notes	ADD & MDD
225	2	740	ACTV	100%	N	N	Blends with 184 which must run and 223-3, nitrate slougher; cannot rehabilitate again due to condition of casing… wire wrapped, bird nested (already rehabbed 3x); suggest move to top	Prioritized; See Operational Notes	ADD & MDD
223-3	2	490	ACTV	100%	N	N	good; required for nitrate blending with 184	Prioritized; See Operational Notes	ADD & MDD
184	2	1,080	ACTV	100%	N	Y	CRITICAL for filling T-1 tank; must be online for hydraulics; nitrate slougher; TCP treatment required; suggest move to top	Prioritized; See Operational Notes	ADD & MDD
201	2	475	ACTV	0%	N	N	DBCP/NO3; Will blend with 36 which must run; major water quality issues which will benefit from Air Stripper to treat DCE	Prioritized; See Operational Notes	ADD & MDD
82-2	1	570	ACTV	0%	N	N	usually on 24/7; reprioritized higher	Prioritized; See Operational Notes	ADD & MDD
341 (V)	9	1,260	ACTV	0%	N	N	casing requires well rehab? Patch? To be investigated	See Operational Notes	ADD & MDD
339	9	1,040	ACTV	0%	N	N	no issues		ADD & MDD
33A	9	1,700	ACTV	0%	N	N	good well; no issues		ADD & MDD
337	7	980	ACTV	2%	N	N	no issues		MDD
36	6	1,730	INACTV	0%	N	N	Has been inactive for >2 years due to sanding issue; has GAC; PS-201 will come online for blending nitrates; on 2019 rehab plan	See Operational Notes	MDD
77	6	1,070	ACTV	0%	N	N	good well; been offline for ~2 months… flushed for bacteria?		MDD
206	6	1,030	ACTV	0%	N	N	no issues; historically a sander well		MDD
61A	5	810	ACTV	0%	N	N	no issues		MDD
338	5	700	ACTV	0%	N	N	No existing runtime since wells is new and not currently online; online in Summer 2018		MDD
327	3	810	ACTV	0%	N	N	no issues		MDD
345-2 (V)	3	400	ACTV	13%	N	N	new site; one of two new wells (then 274 & 275 + blending online; complicated blending); not ready to operate		MDD

		Well ID	Number of Scenarios	Average Flow Rate (gpm)	Status	Hydraulic Model Runtime % (Annual)	TCE Plume Management (Y/N)	TCP Management (Y/N)	Operational Notes	Prioritization Notes	Solution Set
Mixing Area	2 (continued)	100-1	3	660	ACTV	8%	N	N	good well; cannot improve site due to canal maintenance with City and developers; blending source for 100-2 (which would need nitrate & DBCP treatment)		
		82-1	7	960	INACTV	5%	N	Y	May be inactive for >5 years; planning to replace gas motor with electric motor; borderline TCP issues (plume)-suggested drop lower	See Operational Notes	
		188	2	840	ACTV	0%	N	N	off; MCL for DBCP exceeded; may need treatment		
		354	2	1,380	ACTV	0%	N	N	DBCP; Potential nitrate slougher		
		20	2	1,470	ACTV	0%	N	N			
		345-1 (V)	2	400	ACTV	18%	N	N	not ready to operate		
		147	1	480	ACTV	0%	N	N			
		180-1	1	460	ACTV	9%	N	N			
		100-2	1	570	ACTV	3%	N	N			
		183	1	330	ACTV	0%	N	N			
		275	1	250	ACTV	0%	N	Y			
		164-2	1	680	ACTV	0%	N	Y	Potential nitrate slougher		
		166	1	300	ACTV	0%	N	Y			
		205	1	730	ACTV	0%	N	N	DBCP; Potential nitrate slougher		
		135A	0	470	ACTV	0%	N	Y	DBCP; Single well, nitrate slougher		
		203A	0	950	ACTV	0%	N	Y			
		180-2	0	440	ACTV	0%	N	N	Requires 180-1 for blending		
		164-1	0	500	ACTV	0%	N	Y			
		182-1	0	680	INACTV	0%	N	N	Well inactive due to water quality concerns requiring treatment; No runtime		
		197	0	900	ACTV	0%	N	N			
		224	0	760	ACTV	13%	N	N	DBCP/NO3; Potential nitrate slougher		
		331	0	550	ACTV	0%	N	N			
		274	1	340	ACTV	0%	N	Y	Blends with 275 which must run, nitrate slougher	Remove/De-Prioritize	
		152	11	820	INACTV	0%	N	N	Well inactive due to water quality concerns requiring treatment for Nitrate; No runtime	Remove/De-Prioritize	
		277	4	820	INACTV	0%	N	Y	DBCP; Offline due to nitrates. Unable to blend at this time due to complicated connectivity; suggest CBA for blending	Remove/De-Prioritize	
		135B (V)	6	360	ACTV	0%	N	N	Water quality (manganese and arsenic MCL) concerns	Remove/De-Prioritize	

Well Prioritization Results
City of Fresno, CA

Mixing Area	3
ADD (gpm)	12,664
MDD (gpm)	25,327

Well ID	Number of Scenarios	Average Flow Rate (gpm)	Status	Hydraulic Model Runtime % (Annual)	TCE Plume Management (Y/N)	TCP Management (Y/N)	Operational Notes	Prioritization Notes	Solution Set
18A	11	1,780	ACTV	0%	N	N	no issues		ADD & MDD
66	10	1,700	ACTV	0%	N	N			ADD & MDD
2B	9	2,060	ACTV	0%	N	N	TCE; No nitrate issues		ADD & MDD
172	9	2,940	ACTV	0%	N	N			ADD & MDD
30B	7	2,080	INACTV	0%	N	Y	Water quality concerns (requires treatment for TCP)	See Operational Notes	ADD & MDD
174	7	2,200	ACTV	0%	N	N			ADD & MDD
313	7	2,220	ACTV	0%	N	N			MDD
49A	5	1,320	ACTV	0%	N	N	issue; ??		MDD
32B	5	1,340	ACTV	0%	N	Y	TCP		MDD
198	5	2,130	ACTV	0%	N	Y	TCP		MDD
39A	4	1,310	ACTV	0%	N	Y	TCP		MDD
165-1	4	290	ACTV	0%	N	Y	TCP impacted; also 165-2		MDD
13A	4	1,690	ACTV	0%	N	N			MDD
60	3	1,840	ACTV	0%	N	N	will be replaced with 60-A; purchased property adjacent to 60; to be abandoned.; site is too small		MDD
24B	3	2,210	ACTV	0%	N	Y			MDD
19B	2	1,130	ACTV	0%	N	Y			
14A	2	1,720	ACTV	0%	N	Y			
165-2	2	470	ACTV	0%	N	Y	TCP impacted; also 165-1		
21A	2	1,640	ACTV	0%	N	N			
54	1	1,760	ACTV	0%	N	N			
4A	1	1,530	ACTV	0%	N	N	replaced with 4B already but still in use		
48	1	1,490	ACTV	0%	N	Y			
289-2	1	600	ACTV	0%	N	Y	top impacted; GAC in place; needs Carbon		
50A	1	1,670	ACTV	0%	N	N			
102	0	1,570	ACTV	0%	N	Y			
297-1	0	720	INACTV	0%	N	N			
297-2	0	610	ACTV	0%	N	N	Single well, nitrate slougher		
1B	0	1,200	ACTV	0%	N	Y			
217	0	410	ACTV	0%	N	Y	will be lost to TCP; heavy sander & only 170 feet; oldest well		
15B	0	650	ACTV	0%	N	N			
155-1	0	330	ACTV	0%	N	N			
155-2	0	600	INACTV	0%	N	N	lost to nitrate (inactive)	Remove/De-Prioritize	
10A	9	1,540	INACTV	0%	N	N	Will need to be converted to electric power	Remove/De-Prioritize	
84	8	1,220	INACTV	0%	N	Y	Well inactive due to water quality concerns requiring treatment; No runtime	Remove/De-Prioritize	

Mixing Area	**4**
ADD (gpm)	**25,806**
MDD (gpm)	**51,613**

Well ID	Number of Scenarios	Average Flow Rate (gpm)	Status	Hydraulic Model Runtime % (Annual)	TCE Plume Management (Y/N)	TCP Management (Y/N)	Operational Notes	Prioritization Notes	Solution Set
70 (V)	9	1,300	ACTV	100%	Y	Y	Highest TCP well. Offline will migrate plume to Bakman	Prioritized; See Operational Notes	ADD & MDD
320 (V)	11	2,460	ACTV	21%	N	N			ADD & MDD
169	10	1,940	ACTV	0%	N	N			ADD & MDD
213A	10	2,040	ACTV	0%	N	N	Water quality concerns	See Operational Notes	ADD & MDD
158	10	1,970	ACTV	0%	N	N			ADD & MDD
199	10	2,190	ACTV	47%	N	N			ADD & MDD
35A	9	1,800	ACTV	12%	N	N	hydraulic issues- water hammer; system pressures? Very loud when it turns off (backflow device blows off)		ADD & MDD
46A	8	2,170	ACTV	34%	N	N			ADD & MDD
4B	8	2,040	ACTV	0%	N	N			ADD & MDD
142 (V)	8	1,490	ACTV	0%	N	N			ADD & MDD
179	8	2,080	ACTV	0%	N	Y	TCP		ADD & MDD
307	8	1,880	ACTV	0%	N	N			ADD & MDD
11A	7	1,700	ACTV	15%	N	N			ADD & MDD
125	6	540	ACTV	0%	N	N	land-locked		ADD & MDD
323	6	980	ACTV	0%	N	N			ADD & MDD
64	6	1,560	ACTV	12%	N	N	sander		MDD
69A	6	1,850	ACTV	0%	N	N			MDD
322 (V)	6	1,920	ACTV	0%	N	N	has never operated		MDD
358	6	2,040	ACTV	2%	N	N			MDD
62A (V)	5	2,030	ACTV	0%	N	N	condition = 1; lots of rehabs since last score		MDD
74	4	1,770	ACTV	0%	N	N			MDD
68	4	1,560	ACTV	0%	N	N			MDD
226-3	4	1,680	ACTV	0%	N	N			MDD
73	4	1,570	ACTV	0%	N	N	land-locked		MDD
171-2	4	1,490	ACTV	0%	N	N	DBCP; New GAC well, expected online summer 2017; look into difference in 171-1		MDD
364	4	890	ACTV	0%	N	N			MDD
222-1	3	650	ACTV	0%	N	N			MDD
5A	3	1,270	ACTV	0%	N	N			MDD
171-1	3	550	ACTV	0%	N	N	GAC Treatment system installed; will be back online shortly (may need 171-2 for blending)		MDD
251	2	530	ACTV	0%	N	N			MDD
53	2	1,720	ACTV	0%	N	N			MDD
192	2	1,500	ACTV	1%	N	N			MDD
105	2	1,250	ACTV	0%	N	N	could lose to freeway expansion		MDD

		Well ID	Number of Scenarios	Average Flow Rate (gpm)	Status	Hydraulic Model Runtime % (Annual)	TCE Plume Management (Y/N)	TCP Management (Y/N)	Operational Notes	Prioritization Notes	Solution Set
Mixing Area	4 (continued)	238	2	450	ACTV	0%	N	N			
		71	2	1,710	ACTV	38%	N	N			
		31A	2	1,770	ACTV	0%	N	N			
		76	2	1,680	ACTV	3%	N	N	condition = 1		
		104	2	1,270	ACTV	0%	N	N			
		78	2	1,870	ACTV	12%	N	N			
		37	2	1,210	ACTV	0%	N	N			
		42	2	1,170	ACTV	0%	N	N			
		245	1	530	ACTV	47%	N	N			
		38A	1	1,200	ACTV	6%	N	N			
		230A	1	1,410	ACTV	0%	N	N			
		45	1	1,530	ACTV	3%	N	N			
		232	1	830	ACTV	0%	N	N			
		235	1	280	ACTV	21%	N	N			
		67	1	1,850	ACTV	0%	N	N			
		209	1	780	ACTV	0%	N	N			
		252	1	880	ACTV	0%	N	N			
		56A	1	2,360	ACTV	28%	N	N			
		72	1	1,830	ACTV	13%	N	N			
		25	1	1,820	ACTV	7%	N	N			
		234 (V)	1	520	ACTV	0%	N	N			
		250	1	990	ACTV	0%	N	N			
		80	1	1,080	ACTV	0%	N	N			
		242	1	570	ACTV	21%	N	N			
		81	1	1,670	ACTV	0%	N	N			
		43	1	1,340	ACTV	0%	N	N			
		47A	1	2,110	ACTV	3%	N	N			
		58A-1	0	1,200	ACTV	0%	N	N	Flow rate seems high; confirmed via email from 3/30/2018	See Operational Notes	
		193	0	1,560	ACTV	0%	N	N			
		220-2	0	1,200	ACTV	0%	N	N			
		211	0	620	ACTV	0%	N	N			
		57	0	1,760	ACTV	21%	N	N			
		291	0	290	ACTV	11%	N	N			
		87	0	1,710	ACTV	17%	N	N			
		51	0	1,710	ACTV	8%	N	N			
		65	0	1,640	ACTV	51%	N	N			
		306	0	860	ACTV	3%	N	N			
		138	0	1,750	ACTV	6%	N	N			
		58A-2	0	1,300	ACTV	31%	N	N	VFD; Flow rate seems high; updated from 2500 gpm via email from 3/30/2018	See Operational Notes	
		63	3	950	INACTV	0%	N	Y	offline since 2006 due to Water quality (TCP); land-locked; would need new property to install treatment; suggest drop; No runtime	Remove/De-Prioritize	
		212	8	1,500	INACTV	0%	N	N	Well is plugged with pump and may become abandoned; significant mechanical failure may require removal for R&R; remove	Remove/De-Prioritize	

		Well ID	Number of Scenarios	Average Flow Rate (gpm)	Status	Hydraulic Model Runtime % (Annual)	TCE Plume Management (Y/N)	TCP Management (Y/N)	Operational Notes	Prioritization Notes	Solution Set
Mixing Area	**5**	8A	3	600	ACTV	0%	N	N	At MCL for nitrates; pump broken (remove or blend with 145 using dedicated line, about 1/4 mile)		ADD & MDD
ADD (gpm)	**1,474**	101A	3	920	ACTV	0%	N	Y	Currently has treatment for manganese; TCP issues	See Operational Notes	ADD & MDD
MDD (gpm)	**2,949**	145	0	240	ACTV	2%	N	N	landlocked; potential blender for 8A		ADD & MDD
		55-2	0	570	ACTV	14%	N	N			MDD
Notes	Cannot meet demand with wells in MDD solution set	347	3	320	ACTV	0%	N	N	Treatment needed (manganese); inactive; location between 2 surface water plants	Remove/De-Prioritize	
		329	1	790	ACTV	0%	N	N	Treatment needed (manganese); inactive; location between 2 surface water plants	Remove/De-Prioritize	
		326	9	850	ACTV	0%	N	N	Water quality complaints (odor); sulfide	Remove/De-Prioritize	

Mixing Area	6
ADD (gpm)	11,796
MDD (gpm)	23,593

Well ID	Number of Scenarios	Average Flow Rate (gpm)	Status	Hydraulic Model Runtime % (Annual)	TCE Plume Management (Y/N)	TCP Management (Y/N)	Operational Notes	Prioritization Notes	Solution Set
283	2	790	ACTV	100%	Y	N	No nitrate issues; top treatment site (do not turn off, "sacred")	Prioritized; See Operational Notes	ADD & MDD
279 (V)	4	450	ACTV	100%	Y	N	Air Stripper		ADD & MDD
264	3	850	ACTV	100%	Y	N			ADD & MDD
97	11	1,640	ACTV	30%	N	N	hydraulic limitations (could pump 5000 gpm)		ADD & MDD
189	11	1,600	ACTV	0%	N	N			ADD & MDD
141	11	2,370	ACTV	36%	N	N			ADD & MDD
159 (V)	9	2,150	ACTV	74%	N	N			ADD & MDD
139	9	2,310	ACTV	4%	N	N			ADD & MDD
160	6	2,260	ACTV	0%	N	N			MDD
90	6	1,550	ACTV	39%	N	N			MDD
304	5	640	ACTV	47%	N	N	pumps gravel at high flow		MDD
79	5	890	ACTV	18%	N	N			MDD
271	5	540	ACTV	51%	N	N			MDD
117	5	1,387	INACTV	0%	N	N	Well has treatment under construction; will blend with another well (284?); Well inactive due to water quality concerns requiring treatment; No runtime		MDD
34A	4	2,280	ACTV	5%	N	N			MDD
287	0	800	ACTV	2%	N	N	Blends with 283, which manages TCE	Prioritized; See Operational Notes	MDD
258	4	860	ACTV	41%	N	N			MDD
154	3	2,250	ACTV	0%	N	N	recommend move up	Prioritized; See Operational Notes	MDD
267	4	750	ACTV	13%	N	N	landlocked		
136	3	2,060	ACTV	13%	N	N			
280	3	550	ACTV	14%	N	N			
286 (V)	3	1,000	ACTV	46%	N	N			
161	2	1,730	ACTV	0%	N	N			
292	2	890	ACTV	47%	N	N			
284	2	870	ACTV	0%	N	N	currently offline due to PCE; may pump to 117 for treatment (condition to be determined)		
146	2	1,610	ACTV	0%	N	N			
273	2	950	ACTV	25%	N	N			
244	0	780	ACTV	25%	N	N			
91	0	1,480	ACTV	96%	N	N			
300	0	560	ACTV	56%	N	N			
257	1	500	ACTV	23%	N	N			
44A	0	1,580	ACTV	26%	N	N			
266	0	550	ACTV	66%	N	N			
272	0	630	ACTV	50%	N	N			

Mixing Area	7
ADD (gpm)	**6,416**
MDD (gpm)	**12,832**

Well ID	Number of Scenarios	Average Flow Rate (gpm)	Status	Hydraulic Model Runtime % (Annual)	TCE Plume Management (Y/N)	TCP Management (Y/N)	Operational Notes	Prioritization Notes	Solution Set
85 (V)	10	1,410	ACTV	0%	N	N	Single well, nitrate slougher		ADD & MDD
157 (V)	9	1,780	ACTV	0%	N	N	off-gas treatment		ADD & MDD
148-2	8	1,150	ACTV	26%	N	N			ADD & MDD
6B (V)	6	2,040	ACTV	20%	N	N			ADD & MDD
98 (V)	6	2,110	ACTV	11%	N	N			ADD & MDD
89A (V)	6	1,200	ACTV	0%	N	N	booster needed; low pressure		MDD
144	6	1,080	ACTV	2%	N	N			MDD
148-1	5	900	ACTV	30%	N	N			MDD
131 (V)	4	860	ACTV	0%	N	N			
118	4	480	ACTV	14%	N	N			
150 (V)	3	710	ACTV	28%	N	N			
134	2	1,540	INACTV	0%	N	N	R&R for Water Quality Planned / On-Going; Well inactive due to water quality concerns requiring treatment; No runtime		
92	2	780	ACTV	38%	N	N			
75	2	1,510	ACTV	0%	N	N	rehabbed recently; good condition = 1		
94	2	1,030	ACTV	11%	N	N			
181	1	730	ACTV	3%	N	N			
137	1	1,100	ACTV	0%	N	Y	DBCP; No Nitrate Issues		
163	1	590	ACTV	0%	N	N			
86	0	730	ACTV	8%	N	N			
95	0	1,470	INACTV	0%	N	N	Well inactive due to water quality concerns requiring treatment; No runtime		
178	0	500	ACTV	0%	N	N			
96	0	590	ACTV	15%	N	N			
103	0	820	ACTV	2%	N	N			
175-2	0	850	ACTV	3%	N	N	DBCP; No nitrate issues		

Mixing Area	8
ADD (gpm)	6,357
MDD (gpm)	12,714

Well ID	Number of Scenarios	Average Flow Rate (gpm)	Status	Hydraulic Model Runtime % (Annual)	TCE Plume Management (Y/N)	TCP Management (Y/N)	Operational Notes	Prioritization Notes	Solution Set
132 (V)	11	960	ACTV	0%	N	N			ADD & MDD
187 (V)	8	1,040	ACTV	0%	N	N			ADD & MDD
128	8	1,410	ACTV	0%	N	N			ADD & MDD
330 (V)	6	1,110	ACTV	0%	N	N	manganese treatment; replacing backwash currently; air issues likely related to private well use and increased size of pump		ADD & MDD
319 (V)	6	1,130	ACTV	0%	N	Y	TCP		ADD & MDD
321 (V)	6	610	ACTV	0%	N	Y	bad air pump; unreliable		ADD & MDD
151 (V)	4	950	ACTV	0%	N	N			ADD & MDD
318	3	1,540	ACTV	0%	N	N			MDD
143 (V)	2	970	ACTV	0%	N	N			MDD
140	2	830	ACTV	0%	N	N			MDD
176	2	670	ACTV	1%	N	N	DBCP; Potential nitrate slougher; pumps to 168 for DBCP treatment. 168 has no functional pump; needs booster for long-term use. Has GAC		MDD
308 (V)	2	650	ACTV	4%	N	N			MDD
83A	2	710	ACTV	4%	N	N			MDD
177	2	940	ACTV	0%	N	Y			MDD
186	0	580	ACTV	0%	N	Y	may become higher priority for hydraulic conditions; TCP MCL exceeded; will pump to 176; should move up; support low pressure area - Brad to verify	Prioritized; See Operational Notes	MDD
310	0	0	INACTV	0%	N	N	Well inactive due to water quality concerns requiring treatment for manganese; No runtime		
295	0	300	INACTV	0%	N	N	Well inactive due to water quality concerns requiring treatment; No runtime	Remove/De-Prioritize	
185 (V)	12	1,330	ACTV	0%	N	Y	Groundwater well does not pump to the distribution system (pumps to treatment facility)	Remove/De-Prioritize	
133 (V)	10	1,260	INACTV	0%	N	N	Well inactive due to water quality concerns requiring treatment; No runtime; Will be very difficult to rehabilitate (off-gas system) due to dual cased well	Remove/De-Prioritize	
130	4	710	ACTV	3%	N	N	Treatment needs	Remove/De-Prioritize	

APPENDIX E

Well Prioritization Using Reported Energy Use Data

MEMORANDUM

TO: Cynthia Fischer, Water System Supervisor, City of Fresno

FROM: Andrew Goldberg, Kleinfelder

DATE : May 2, 2018

SUBJECT: City of Fresno Water System 5-Year Repair & Replacement (R&R) Plan – Well Prioritization using Reported Energy Use Data

CC: Tony Akel, Akel Engineering

Summary

As part of our ranking process for wells, expected energy use was one of three performance metrics used. To date, we have used hydraulic calculations based on rated flow, observed well depth, and overall plant efficiency, since these parameters can be easily changed to simulate potential future conditions that might alter energy needs. The City of Fresno provided reported energy use data on April 2, 2018, which Kleinfelder used to validate the prioritization model and hydraulically calculated energy estimate. This memo discusses the validation methods and results.

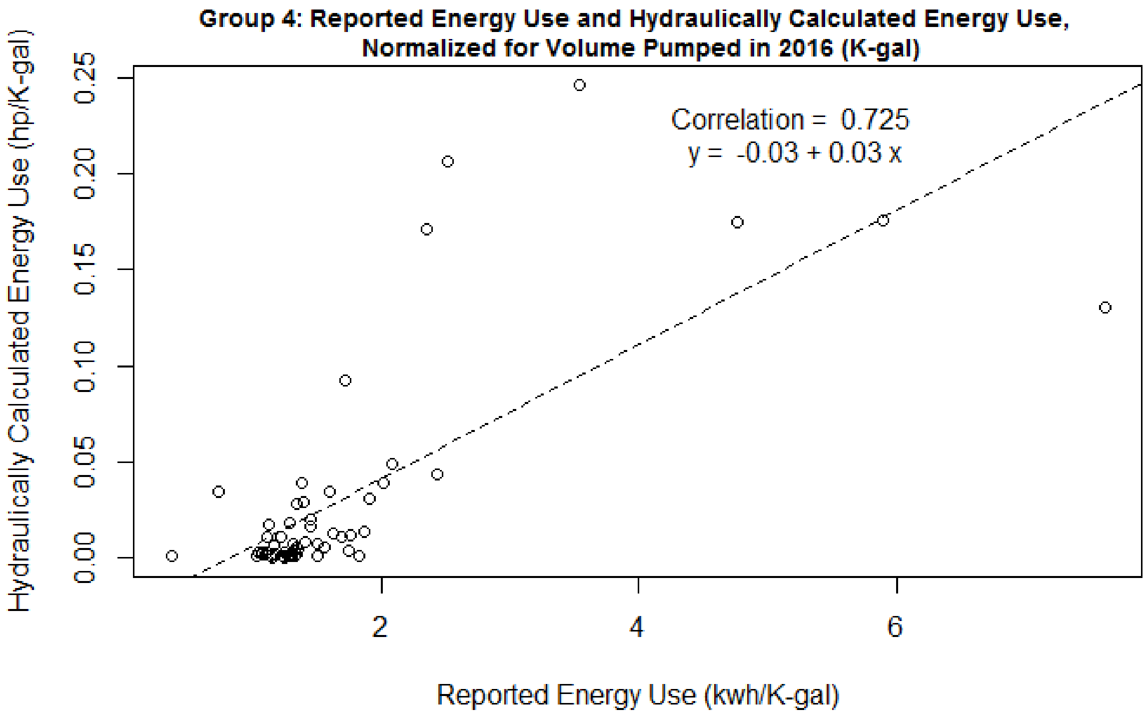
After analyzing the relationship between reported energy use and hydraulically calculated energy, Kleinfelder incorporated reported energy use and production data into the well prioritization model. The hydraulically calculated energy values were substituded with reported energy use values. Kleinfelder re-ran optimization scenarios for the largest group of wells (Mixing Area 4 with 80 wells) and observed that both sets of energy terms result in similar well prioritizations. For Mixing Area 4, 87.5% of the wells were categorized with the same prioritization when the hydraulically calculated energy parameter was substituted with the reported values.

Since there is a substantial overlap between prioritization lists when the energy parameter is substituted, we recommend continuing to the use the hydraulically calculated energy values for the well prioritization and R&R recommendations. This will allow the validated model to adapt to new hydraulic conditions (flow, depth, or efficiency) as needed.

One Beacon Street, Suite 8100 Boston, MA 02108

Methods

Kleinfelder aggregated well production data & energy use data by well. Readily available production and energy data from 2016 was used for this analysis. The energy use metric, in kilowatt hours, was normalized by the annual thousand gallons pumped (kwh/K-gal). We calculated the correlation between this normalized energy metric and the hydraulically calculated energy value previously used in the prioritization model. For wells within Mixing Area 4, there was a moderately strong linear relationship (R^2= 0.725) between hydraulically calculated energy estimates and the City's reported energy consumption, as we would expect based on the physics of the wells. This correlation is shown in the figure below.



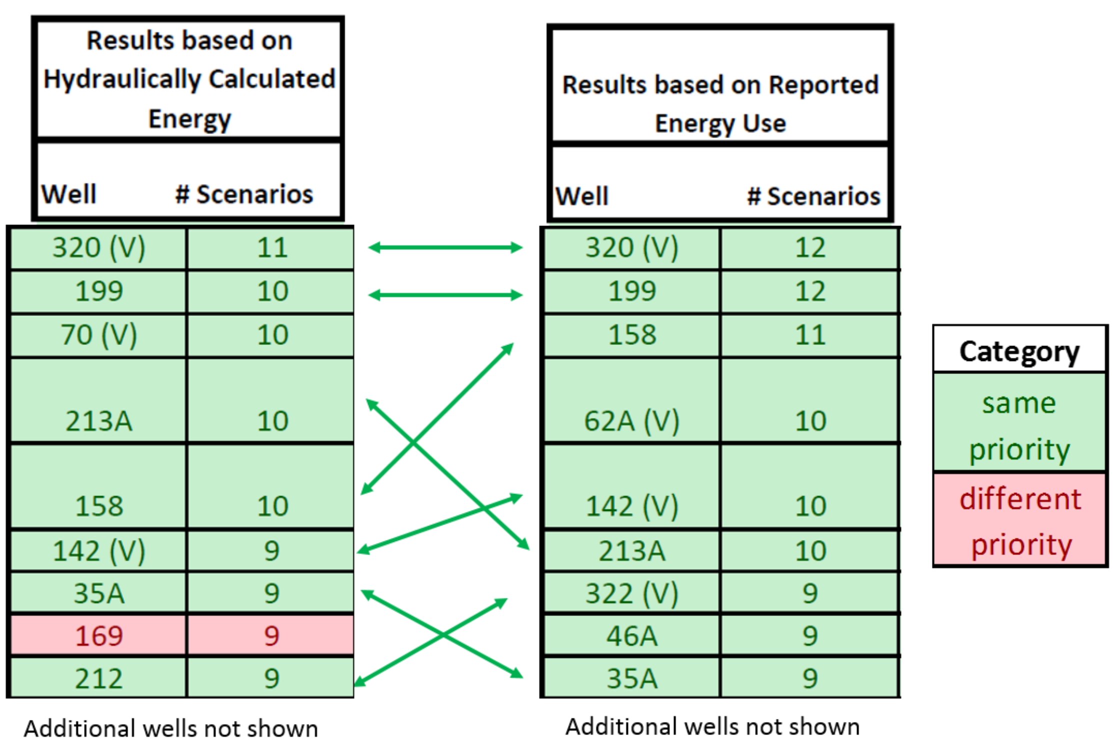
There was sufficient variability in the data to test the impact of changing the energy metrics on the results. To further validate the approach, we substituted the hydraulically calculated energy with the reported energy use metric within the prioritization model and compared results for the largest group of wells, Mixing Area 4. Of the 80 wells in the Mixing Area, 57 wells had non-zero energy use and non-zero production data. Where either production or energy data was unavailable, the value was replaced in the model with the system's median for the energy use metric.
For the purpose of the Well R&R, each well was assigned a priority of either high or low, defined as follows:

1) High Priority: A high performing well (where energy needs are one of three performance metrics) which is suitable for meeting maximum daily demand (MDD), with treated surface water unavailable, <u>or</u>
2) Low Priority: Any remaining well which is not necessary to meet the above demand scenarios if high performing wells are in use

To determine priority, Wells were sorted by the number of scenarios in which they appeared, up to the total number of scenarios run (12). The highest performing wells were included in the high priority group until maximum day demand was met. At the demand threshold for Mixing Area 4, multiple wells had the same number of scenarios. Due to ties in the number of scenarios, Kleinfelder designated the 31 top-performing wells in both of the two analyses as high priority. Based on the standard flow rate provided, this is a conservative estimate for the number of wells needed to meet MDD.

<u>Results</u>

67 of the 80 wells (83.75%) stayed as the same priority across the two analyses. 13 wells (16.25%) changed priority group when the energy metric was substituted. Full optimization results for Wells in Mixing Area 4 are provided in an attachment to this memorandum and a comparison of the top-performing wells across the two analyses is shown in the figure below.



While this list sorts wells based on the number of scenarios a well appears, note that the final prioritized list of wells will take into account additional operational considerations, as discussed during prior project meetings.

Conclusions

We observed a clear correlation between hydraulically calculated energy estimates and the City's reported energy consumption. To further validate the model, the results of the well prioritization were compared when the energy metric was substituted in the model. The results of the comparison show that there is a substantial overlap between the prioritization of wells when the energy metric is substituted. This confirms that both sets of data generally indicate the same priority wells for R&R and therefore, Kleinfelder recommends continuing to the use the hydraulically calculated energy values within the well prioritization model to make R&R recommendations.

Attachment 1

Comparison of Well Prioritization Rankings, Group 4

Results based on Hydraulically Calculated Energy			Results based on Reported Energy Use		
Well	# of Scenarios	Priority	Well	# of Scenarios	Priority
320 (V)	11	High	320 (V)	12	High
199	10	High	199	12	High
70 (V)	10	High	158	11	High
213A	10	High	62A (V)	10	High
158	10	High	142 (V)	10	High
142 (V)	9	High	213A	10	High
35A	9	High	322 (V)	9	High
169	9	High	46A	9	High
212	9	High	35A	9	High
4B	7	High	70 (V)	8	High
11A	7	High	358	8	High
179	7	High	212	7	High
125	7	High	4B	7	High
46A	7	High	65	6	High
322 (V)	7	High	68	6	High
323	7	High	69A	6	High
358	7	High	73	5	High
62A (V)	6	High	230A	5	High
307	6	High	56A	5	High
226-3	5	High	72	5	High
171-1	5	High	323	4	High
64	5	High	64	4	High
69A	4	High	307	4	High
73	4	High	125	3	High
171-2	4	High	11A	3	High
74	4	High	47A	3	High
63	4	High	232	3	High

Summary		
Category	Count	Frequency
same priority	67	0.8375
different priority	13	0.1625

Results based on Hydraulically Calculated Energy			Results based on Reported Energy Use		
Well	# of Scenarios	Priority	Well	# of Scenarios	Priority
68	4	High	5A	3	High
364	4	High	171-2	3	High
5A	3	High	226-3	3	High
238	3	High	81	3	High
234 (V)	3	Low	71	2	Low
232	2	Low	138	2	Low
43	2	Low	63	2	Low
104	2	Low	31A	2	Low
209	2	Low	80	2	Low
31A	2	Low	169	2	Low
76	2	Low	238	2	Low
71	2	Low	171-1	2	Low
105	2	Low	25	2	Low
192	2	Low	234 (V)	2	Low
78	2	Low	179	2	Low
242	2	Low	76	2	Low
80	2	Low	67	1	Low
37	2	Low	43	1	Low
42	2	Low	38A	1	Low
235	1	Low	193	1	Low
65	1	Low	251	1	Low
251	1	Low	51	1	Low
245	1	Low	250	1	Low
291	1	Low	242	1	Low
38A	1	Low	245	1	Low
56A	1	Low	235	1	Low
25	1	Low	192	1	Low
252	1	Low	364	1	Low
45	1	Low	45	1	Low
67	1	Low	250A	0	Low

Results based on Hydraulically Calculated Energy			Results based on Reported Energy Use		
Well	**# of Scenarios**	**Priority**	**Well**	**# of Scenarios**	**Priority**
250	1	Low	87	0	Low
72	1	Low	237	0	Low
47A	1	Low	306	0	Low
193	1	Low	218	0	Low
53	1	Low	57	0	Low
230A	1	Low	226-1	0	Low
81	0	Low	58	0	Low
58A-2	0	Low	252	0	Low
58A-1	0	Low	58A-1	0	Low
51	0	Low	105	0	Low
87	0	Low	58A-2	0	Low
218	0	Low	220-2	0	Low
222-1	0	Low	37	0	Low
211	0	Low	222-1	0	Low
226-1	0	Low	209	0	Low
57	0	Low	74	0	Low
237	0	Low	052A	0	Low
58	0	Low	78	0	Low
220-2	0	Low	211	0	Low
306	0	Low	291	0	Low
138	0	Low	42	0	Low
052A	0	Low	53	0	Low
250A	0	Low	104	0	Low

APPENDIX F

Recommended Well R&R Actions and Costs

Year 1 Recommended R&R Actions and Costs

Drinking Water Infrastructure Renewal and Replacement Plan
City of Fresno

Well ID	Priority Category	Video Condition Inspection and Investigation	Performance Testing (OPE)	Pump Maintenance	Pump Replacement	Motor Maintenance	Motor Replacement	Well Casing Replacement / Lining	Well Development	Well Flushing and Chemical Treatment	Water Quality Treatment	Site Security and Improvements	Well Replacement	Well Abandonment
279 (V)	High	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ 71,300.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
264	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ 76,300.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
70 (V)	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ 35,000.00	$ -	$ -
283	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
184	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
8A	High	$ 600.00	$ 400.00	$ -	$ 55,000.00	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
101A	High	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
145	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ 35,000.00	$ -	$ -
97	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
189	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
159 (V)	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
141	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
139	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
9A	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 89,800.00	$ 8,000.00	$ 50,000.00	$ 800,000.00	$ -	$ -	$ -
170	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
3A	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ 35,000.00	$ -	$ -
153-2	High	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
201	High	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 45,550.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
153-1	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
225	High	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
223-3	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
6B (V)	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ 202,500.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
82-2	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
341 (V)	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ -	$ -	$ 202,500.00	$ 8,000.00	$ 50,000.00	$ -	$ -	$ -	$ -
33A	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
66	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
172	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ 35,000.00	$ -	$ -
30B	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
174	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
199	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
35A	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
142 (V)	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ 35,000.00	$ -	$ -
179	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
11A	High	$ 600.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
125	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
323	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
157 (V)	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ 35,000.00	$ -	$ -
98 (V)	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
132 (V)	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
187 (V)	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
330 (V)	High	$ 600.00	$ 400.00	$ -	$ 55,000.00	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
319 (V)	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
321 (V)	High	$ 600.00	$ 400.00	$ -	$ 55,000.00	$ -	$ 15,000.00	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
151 (V)	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
339	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
18A	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ 35,000.00	$ -	$ -
2B	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ 8,000.00	$ -	$ -	$ -	$ -	$ -
320 (V)	High	$ 600.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 35,000.00	$ -	$ -
169	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
213A	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
158	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
46A	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ 35,000.00	$ -	$ -
4B	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ 35,000.00	$ -	$ -
307	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
85 (V)	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
148-2	High	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
128	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	High Priority	**$ 30,600**	**$ 21,200**	**$ 99,000**	**$ 165,000**	**$ 255,000**	**$ 15,000**	**$ 687,950**	**$ 24,000**	**$ 300,000**	**$ 7,200,000**	**$ 350,000**	**$ 1,500,000**	**$ -**
	All Wells	**$ 30,600**	**$ 21,200**	**$ 99,000**	**$ 165,000**	**$ 255,000**	**$ 15,000**	**$ 687,950**	**$ 24,000**	**$ 300,000**	**$ 7,200,000**	**$ 350,000**	**$ 1,500,000**	**$ -**

	Cost	(30% Contingency)
Estimated Annual Cost of Renewal and Replacement Activities for High Priority Wells (Minimum)	$ 3,447,750	$ 4,482,075
Estimated Annual Cost of all recommended Renewal and Replacement Activities	$ 3,447,750	$ 4,482,075

Notes:
1. These costs estimates exclude costs to install and operate GAC at new wells sites.
2. Costs estimates assume one well replacement per year at $1,500,000 per well

Year 2 Recommended R&R Actions and Costs

Drinking Water Infrastructure Renewal and Replacement Plan
City of Fresno

Well ID	Priority Category	Video Condition Inspection and Investigation	Performance Testing (OPE)	Pump Maintenance	Pump Replacement	Motor Maintenance	Motor Replacement	Well Casing Replacement / Lining	Well Development	Well Flushing and Chemical Treatment	Water Quality Treatment	Site Security and Improvements	Well Replacement	Well Abandonment
186	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
55-2	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
271	High	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 45,800.00	$ -	$ 50,000.00	$ -	$ 35,000.00	$ -	$ -
79	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
287	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
160	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
90	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
304	High	$ -	$ 400.00	$ -	$ 55,000.00	$ 5,000.00	$ -	$ 202,500.00	$ 8,000.00	$ 50,000.00	$ -	$ -	$ -	$ -
117	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
258	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
34A	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
154	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
16A	High	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
88-2	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
26B	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
36	High	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 56,300.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
60	High	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
322 (V)	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
62A (V)	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
222-1	High	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 41,800.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
5A	High	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 62,800.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
251	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
53	High	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 75,300.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
206	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 202,500.00	$ 8,000.00	$ 50,000.00	$ -	$ -	$ -	$ -
73	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
143 (V)	High	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
140	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
176	High	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
308 (V)	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
77	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ 35,000.00	$ -	$ -
	High Priority	**$ 12,000**	**$ 11,200**	**$ 45,000**	**$ 55,000**	**$ 135,000**	**$ -**	**$ 687,000**	**$ 16,000**	**$ 350,000**	**$ 800,000**	**$ 70,000**	**$ 1,500,000**	**$ -**
	All Wells	**$ 12,000**	**$ 11,200**	**$ 45,000**	**$ 55,000**	**$ 135,000**	**$ -**	**$ 687,000**	**$ 16,000**	**$ 350,000**	**$ 800,000**	**$ 70,000**	**$ 1,500,000**	**$ -**

		(with 30% contingency)
Estimated Annual Cost of Renewal and Replacement Activities for High Priority Wells (Minimum)	**$ 2,881,200**	**$ 3,745,560**
Estimated Annual Cost of all recommended Renewal and Replacement Activities	**$ 2,881,200**	**$ 3,745,560**

Notes:
1. These costs estimates exclude costs to install and operate GAC at new wells sites.
2. Costs estimates assume one well replacement per year at $1,500,000 per well

Year 3 Recommended R&R Actions and Costs

Drinking Water Infrastructure Renewal and Replacement Plan
City of Fresno

Well ID	Priority Category	Video Condition Inspection and Investigation	Performance Testing (OPE)	Pump Maintenance	Pump Replacement	Motor Maintenance	Motor Replacement	Well Casing Replacement / Lining	Well Development	Well Flushing and Chemical Treatment	Water Quality Treatment	Site Security and Improvements	Well Replacement	Well Abandonment
61A	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
338	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
327	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
345-2 (V)	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
313	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
49A	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
198	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
39A	High	$ 600.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
165-1	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ 35,000.00	$ -	$ -
13A	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
24B	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
64	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 202,500.00	$ 8,000.00	$ 50,000.00	$ -	$ -	$ -	$ -
358	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
74	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ 35,000.00	$ -	$ -
68	High	$ 600.00	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
171-2	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
364	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
171-1	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
192	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
105	High	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
89A (V)	High	$ 600.00	$ 400.00	$ -	$ 55,000.00	$ 5,000.00	$ -	$ -	$ 8,000.00	$ -	$ -	$ -	$ -	$ -
144	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
318	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
83A	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
177	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
337	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
32B	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
69A	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
226-3	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
148-1	High	$ 600.00	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
280	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ 52,800.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
286 (V)	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
273	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
244	Low	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
300	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 89,550.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
302	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
257	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ -	$ -	$ 67,800.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
272	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 57,800.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
267	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
292	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
284	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
146	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
44A	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
266	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
161	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
91	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
136	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
26A	Low	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
27A	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
22A	Low	$ -	$ 400.00	$ -	$ 55,000.00	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
20	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 66,300.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
275	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 49,800.00	$ -	$ 50,000.00	$ 800,000.00	$ -	$ -	$ -
	High Priority	**$ 17,400**	**$ 11,200**	**$ 27,000**	**$ 55,000**	**$ 135,000**	**$ -**	**$ 202,500**	**$ 16,000**	**$ 50,000**	**$ 4,800,000**	**$ 70,000**	**$ 1,500,000**	**$ -**
	All Wells	**$ 17,400**	**$ 19,200**	**$ 63,000**	**$ 110,000**	**$ 230,000**	**$ -**	**$ 586,550**	**$ 16,000**	**$ 350,000**	**$ 6,400,000**	**$ 70,000**	**$ 1,500,000**	**$ -**

		(with 30% contingency)
Estimated Annual Cost of Renewal and Replacement Activities for High Priority Wells (Minimum)	$ 2,084,100	$ 2,709,330
Estimated Annual Cost of all recommended Renewal and Replacement Activities	$ 2,962,150	$ 3,850,795

Notes:
1. These costs estimates exclude costs to install and operate GAC at new wells sites.
2. Costs estimates assume one well replacement per year at $1,500,000 per well

Year 4 Recommended R&R Actions and Costs

Drinking Water Infrastructure Renewal and Replacement Plan
City of Fresno

Well ID	Priority Category	Video Condition Inspection and Investigation	Performance Testing (OPE)	Pump Maintenance	Pump Replacement	Motor Maintenance	Motor Replacement	Well Casing Replacement / Lining	Well Development	Well Flushing and Chemical Treatment	Water Quality Treatment	Site Security and Improvements	Well Replacement	Well Abandonment
205	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
180-2	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
223-1	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 28,800.00	$ -	$ 50,000.00	$ 800,000.00	$ -	$ -	$ -
224	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 55,550.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
54	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 52,800.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
4A	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 55,800.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
48	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 91,300.00	$ -	$ 50,000.00	$ 800,000.00	$ -	$ -	$ -
297-1	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
217	Low	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
238	Low	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
31A	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 76,300.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
42	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 77,800.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
245	Low	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
45	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 70,800.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
232	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ 50,050.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
235	Low	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
209	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 39,300.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
252	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 49,800.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
25	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 76,300.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
250	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 62,800.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
	High Priority	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 1,500,000**	**$ -**
	All Wells	**$ -**	**$ 6,400**	**$ 18,000**	**$ -**	**$ 80,000**	**$ -**	**$ 787,400**	**$ -**	**$ 650,000**	**$ 1,600,000**	**$ -**	**$ 1,500,000**	**$ -**

		(with 30% contingency)
Estimated Annual Cost of Renewal and Replacement Activities for High Priority Wells (Minimum)	**$ 1,500,000**	**$ 1,950,000**
Estimated Annual Cost of all recommended Renewal and Replacement Activities	**$ 3,041,800**	**$ 3,954,340**

Notes:
1. These costs estimates exclude costs to install and operate GAC at new wells sites.
2. Costs estimates assume one well replacement per year at $1,500,000 per well

Year 5 Recommended R&R Actions and Costs

Drinking Water Infrastructure Renewal and Replacement Plan
City of Fresno

Well ID	Priority Category	Video Condition Inspection and Investigation	Performance Testing (OPE)	Pump Maintenance	Pump Replacement	Motor Maintenance	Motor Replacement	Well Casing Replacement / Lining	Well Development	Well Flushing and Chemical Treatment	Water Quality Treatment	Site Security and Improvements	Well Replacement	Well Abandonment
102	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
297-2	Low	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
1B	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
37	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
234 (V)	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
137	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
103	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
175-2	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
295	Low	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
100-1	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
82-1	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
345-1 (V)	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
147	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
183	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
166	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
164-1	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
182-1	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
331	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
19B	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
14A	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
165-2	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
15B	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
155-1	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
71	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
76	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
104	Low	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
78	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
38A	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
230A	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
67	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
56A	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ 35,000.00	$ -	$ -
72	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
81	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
47A	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
58A-1	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
193	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
220-2	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
211	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
87	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
65	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
306	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
138	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
58A-2	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
052A	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ 202,500.00	$ -	$ 50,000.00	$ -	$ -	$ -	$ -
131 (V)	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
118	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
150 (V)	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
134	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
92	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
75	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
94	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
181	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
163	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
86	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
95	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
178	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
96	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
310	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
168-1 (V)	Low	$ -	$ 400.00	$ -	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
129	Low	$ -	$ 400.00	$ 9,000.00	$ -	$ 5,000.00	$ -	$ -	$ -	$ -	$ 800,000.00	$ -	$ -	$ -
	High Priority	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,500,000	$ -
	All Wells	$ -	$ 29,600	$ 153,000	$ -	$ 355,000	$ -	$ 454,700	$ -	$ 250,000	$ 16,000,000	$ 35,000	$ 1,500,000	$ -

		(with 30% contingency)
Estimated Annual Cost of Renewal and Replacement Activities for High Priority Wells (Minimum)	$ 1,500,000	$ 1,950,000
Estimated Annual Cost of all recommended Renewal and Replacement Activities	$ 2,777,300	$ 3,610,490

Notes:
1. These costs estimates exclude costs to install and operate GAC at new wells sites.
2. Costs estimates assume one well replacement per year at $1,500,000 per well