Innovative approaches
Practical results
Outstanding service

WATER, WASTEWATER, AND REUSE SYSTEM MASTER PLAN

Prepared for:

City of Fredericksburg

February 2017

Prepared by:

FREESE AND NICHOLS, INC.
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FREESE AND NICHOLS, INC.
TEXAS REGISTERED
ENGINEERING FIRM
F-2144

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FNI Project Number: FRB15439

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EXECUTIVE SUMMARY

1.0 INTRODUCTION

The City of Fredericksburg is a community located in central Texas, within Gillespie County. The City currently provides water and wastewater service to over 10,000 people. The population within the service area is projected to grow by almost 3,000 people in the next 20 years. Accommodating this growth in an efficient and effective manner, while also focusing on the maintenance of existing water, wastewater, and reuse system assets, is the purpose of this Water, Wastewater, and Reuse System Master Plan. This report has been prepared to provide to the City of Fredericksburg a planning tool that will serve as a guide for short-term and long-term improvements to infrastructure within the water, wastewater, and reuse systems.

2.0 POPULATION AND NON-RESIDENTIAL LAND USE

Growth projections are an important component of the water master planning process. The magnitude and distribution of the growth in population and non-residential development will dictate where future infrastructure is required. FNI worked with City staff to identify the magnitude and timing of specific proposed developments. It is important to note that projecting future population is challenging, especially for relatively small geographic areas such as individual cities because it can be difficult to predict how fast or slow development will occur. For the purposes of this report, future population projections were developed for four planning years: 2015, 2020, 2025, and 2035. **Table ES-1** presents a summary of the residential population projections and projected non-residential acreage.

Table ES-1: Population and Non-Residential Acre Projections

Year	Population	Non-Residential Acres
2015	11,018	2,288
2020	11,701	2,308
2025	12,426	2,528
2035	14,014	2,916

3.0 WATER DEMAND PROJECTIONS

Water demands were projected for 2015, 2020, 2025, and 2035 conditions for the of Fredericksburg. The evaluation of historical trends in the per capita data provided a basis for determining the design criteria used to project average day water demands. **Table ES-2** summarizes the design criteria used to calculate

the water demand projections, and **Table ES-3** shows the demand projections for 2015, 2020, 2025, and 2035.

Table ES-2: Water Demands Design Criteria

Residential Average Day Demand (gpcd)	Non-Residential Gallons per Acre per Day	Maximum Day to Average Day Peaking Factor	Peak Hour to Maximum Day Peaking Factor	Calculated Overall Average Day Demand (gpcd)
90	600	2	2	215

Table ES-3: Water Demand Projections

Year	Average Day Demand (MGD)	Maximum Day Demand (MGD)	Peak Hour Demand (MGD)
2015	2.36	4.73	9.46
2020	2.44	4.88	9.75
2025	2.64	5.27	10.54
2035	3.01	6.02	12.04

The 2016 TWDB Region K Plan does not show an average annual shortage until 2060. FNI's evaluation of supplies and demand indicates that the City may have an average day shortage in 2050. Adding additional water supply will allow for growth beyond the 2050 and will provide redundancy for the future. There is also no guarantee that existing wells will continue to have the same production capacity in the future, and adding additional supply will provide redundancy. Expanding the existing Hahn well field is limited given the potential impact to existing wells discussed previously. Based on the potential impact to existing well fields, it is recommended that the City consider purchasing additional property with existing wells with known production in close proximity to the existing Boerner well fields or existing infrastructure. It is possible that the City could explore purchasing additional property and developing test wells, but there is no guarantee that a well field would provide the needed production.

4.0 WATER SYSTEM ANALYSES

The City of Fredericksburg's water distribution system currently consists of two major pressure planes that contain a network of lines ranging from 1-inch to 16-inches, five ground storage tanks, four pump

stations, and two active well fields. The system has two major pressure planes, a hydropneumatic zone serving the Stone Ridge neighborhood, and one small booster pump station serving the Windcrest neighborhood.

A risk based assessment of water system facilities was conducted to assist in the prioritization of recommended improvements. The assessment was based on the condition and criticality of existing water system facilities. Site visits were performed by FNI and City staff to evaluate the condition of the facilities, and redundancy and population served were used to measure criticality. A scoring system was developed to provide an analytical and quantitative method to evaluate the condition and criticality of each pump station and ground storage tank. The results of both the criticality and condition analysis were input to a matrix to provide an overall ranking of potential rehabilitation projects.

A hydraulic water model was developed in H2OMap Water® software by Innovyze. The model pipeline network was developed from the City's geographic information system (GIS) and design plans. Demands were allocated using metered billing data provided by the City.

A hydraulic model analysis was performed under existing demand conditions to evaluate system operations and residual pressures throughout the distribution system. A 24-hour extended period simulation (EPS) model run was performed with 2015 maximum day demands. EPS modeling provides a means to evaluate the system over time to assess response to hourly changes in demand, pump cycling, and tanks filling or draining.

As a public water utility, the City of Fredericksburg must comply with the rules and regulations for public water systems set forth by the Texas Commission on Environmental Quality (TCEQ) in Chapter 290, Public Drinking Water. The City is required to meet the TCEQ elevated storage capacity requirement of 100 gallons per connection and total storage capacity requirement of 200 gallons per connection. In addition to storage requirements, the City is also required to meet the TCEQ pumping capacity requirements. The City provides at least 200 gallons per connection of elevated storage resulting in a TCEQ pumping requirement of 0.6 gpm/connection. The City reported having 5,631 active connections as of September 2015. TCEQ capacity requirements were evaluated by pressure plane (PP). The City is currently violating TCEQ regulations by not providing elevated storage or a hydropneumatic tank to the Windcrest pressure plane. The recommendations in this report address this violation. TCEQ also requires the City to provide 0.6 gpm per connection of water supply. The City has 8,200 gpm of water supply which exceeds the TCEQ requirement of 3,379 gpm.

Hydraulic analyses were performed on the distribution system under future demand conditions. A 24-hour EPS model run was performed under maximum day demand conditions for each future planning period to identify areas of concern and to develop recommended improvements.

5.0 WATER SYSTEM CAPITAL IMPROVEMENTS PLAN

A capital improvements plan (CIP) was developed for the City of Fredericksburg based on hydraulic modeling results and the risk based assessment. The recommended improvements will provide the required capacity and reliability to meet projected water demands through 2035 conditions. Locations shown for new mains and other recommended improvements were generalized for hydraulic analysis. Specific alignments and sites will be determined as part of the design process. It is recommended that these projects be constructed generally in the order listed. However, development patterns may make it necessary to construct some projects sooner or later than anticipated. Detailed descriptions and cost estimates for the proposed water system projects are included in **Appendix H**.

Table ES-4 summarizes the cost estimates of the water capital improvements plan for the City of Fredericksburg. The cost estimates are in 2016 dollars and include an allowance for engineering, surveying, and contingencies. Cost estimates do not include allowances for right-of-way or land acquisition.

Table ES-4: Water System Capital Improvements Plan

Phase	CIP No.	Project Name	Cost
5-Year	1	Goehmann Lane Pump Station Rehabilitation	$598,000
	2	North Pressure Plane Pressure Reducing Valve	$134,600
	3	Cross Mountain Ground Storage Tank	$1,868,800
	4	Boot Ranch Ground Storage Tank	$1,868,800
	5	Windcrest Area Improvements	$885,100
	6	12-inch Line from South Heights Pump Station	$807,300
	7	12-inch Line to New Development	$598,000
	8	1,000 gpm Pump at South Heights Pump Station	$299,000
	9	400 gpm Pump at Windcrest Pump Station	$149,500
	10	0.5 MG Elevated Storage Tank	$2,706,000
			$9,915,100
10-Year	11	16-inch Line to Proposed Pump Station	$6,879,200
	12	Proposed Pump Station and Ground Storage Tank	$7,242,600
	13	12-inch Line along Summit Forest	$418,600
	14	12-inch Line along Hale Street	$1,883,700
	15	12-inch Line along Highway 87	$3,698,700
	16	12-inch Line along North Adams Street	$1,390,400
			$21,513,200
20-Year	17	12-inch Line along Morning Glory Drive	$2,362,100
	18	12-inch Line along East Centre Street	$1,166,100
			$3,528,200
			$34,956,500

6.0 WASTEWATER FLOW PROJECTIONS

Future wastewater flows for the 2020, 2025 and 2035 planning periods were developed based on development identified by The City and FNI. Flow from these developments were added to 2015 historical flow recorded through October 2015 to determine future average day flows. Design criteria for developing the average day flows for the 2020, 2025, and 2035 planning periods were developed by analyzing the historical wastewater flows, water distribution and billing records, populations, and

commercial acreage. **Table ES-5** summarizes the wastewater flow rates utilized to calculate projected average day wastewater flows, and **Table ES-6** summarizes the projected wastewater flows.

Table ES-5: Wastewater Flow Rate Design Criteria

Wastewater Flow Type	Flow Rate
Residential	54 gpcd
Commercial	360 gpad

Table ES-6: Projected Wastewater Flows

	Average Day Flow (MGD)	Projected Peak Flow (MGD)
2015	1.06[1]	2.67[2]
2020	1.10	2.77
2025	1.22	3.12
2035	1.45	3.74

(1) Based on data collected at the WWTP January to October, 2015
(2) Based on flow monitoring data collected from October 24, 2015 to

FNI conducted flow monitoring at 7 locations and gathered rainfall depths within Fredericksburg's wastewater system. The flow monitoring and rainfall data was used to characterize dry weather and wet weather flows at key points within the wastewater system, evaluate wet weather inflow/infiltration (I/), calibrate the hydraulic model of the wastewater collection system

A wet weather analysis was performed to calculate the volume of I/I in six flow monitor basins. The discrete volume of I/I within each sub basin has been categorized as high, moderate, or low. These categories are summarized in **Table ES-7**.

- One basin had I/I considered to be high
- One basin had moderate I/I volumes
- The remaining four basins had low I/I

The flow monitor basins, SSES priority rankings, discrete I/I volumes, and categories of I/I are summarized in **Table ES-8**.

Table ES-7: Categories of I/I

(gal/LF)	Description
I/I Greater than 4.0	*High* amount of I/I
I/I Between 2.0 - 3.9	*Moderate* amount of I/I
I/I Less than 2.0	*Low* amount of I/I

Table ES-8: Normalized RDII Rates by Flow Meter Basin

Flow Monitor Basin	Normalized RDII (Gal/Linear Foot)
FRB-01	6.4
FRB-01A	-
FRB-02	2.43
FRB-03	1.52
FRB-04	0.65
FRB-05	1.06
FRB-06	1.23

7.0 WASTEWATER SYSTEM ANALYSES

A risk based assessment was performed on all of the City's lift stations to develop a prioritized list of maintenance and improvement projects. A risk based assessment consists of a condition assessment and a criticality assessment. The condition assessment included a visual inspection of each lift station. The criticality, or consequence of failure, assessment included an analysis of the proximity of each lift station to critical areas, as well as the residential population served. Each lift station was assigned a condition and criticality score based on the results on the assessments. The results of both the criticality and condition analysis were input to a matrix to provide an overall ranking of projects.

FNI developed a hydraulic model of the existing wastewater system in the Innovyze H20Map SWMM software. This model consists of the majority of 8-inch and larger sewer lines including all lines surveyed as a part of the field data collection effort, their associated manholes, and 10 lift stations and their associated force mains.

The Master Plan scope included an effort organized and performed by the City to survey manholes within the wastewater collection system. Updated X, Y coordinates, rim elevations, and invert elevations were gathered throughout the wastewater system to serve as basis in building the hydraulic model and update the City's GIS database. The remaining information necessary for constructing the hydraulic model was

obtained through as built drawings, information collected from lift station site visits, linear interpolation, and engineering judgement.

Hydraulic analyses were conducted to identify deficiencies in the City of Fredericksburg's existing wastewater collection system and to establish a capital improvements plan to improve the existing system and accommodate the projected wastewater flows through 2035. A 5-year, 6-hour design storm was utilized for the existing and future system analyses. This design storm is commonly used in Texas and provides a reasonable balance between level of service and wastewater infrastructure costs. Various combinations of improvements and modifications were investigated to determine the most appropriate approach for conveying projected flows. Parameters used in developing the improvements plan included consolidation of lift stations, conveying peak wet weather flows, and reducing surcharging within the collection system.

8.0 WASTEWATER SYSTEM CAPITAL IMPROVEMENTS PLAN

A wastewater system capital improvements plan (CIP) was developed for the City of Fredericksburg based on hydraulic modeling results and the risk based assessment. The recommended improvements will provide the required capacity and reliability to meet projected wastewater flows through 2035 conditions. Locations shown for new sewer lines and other recommended improvements were generalized for hydraulic analysis. Specific alignments and sites will be determined as part of the design process. It is recommended that these projects be constructed generally in the order listed. However, development patterns may make it necessary to construct some projects sooner or later than anticipated. Detailed descriptions and cost estimates for the proposed water system projects are included in **Appendix M**.

Table ES-9 summarizes the cost estimates of the wastewater capital improvements plan for the City of Fredericksburg. The cost estimates are in 2016 dollars and include an allowance for engineering, surveying, and contingencies. Cost estimates do not include allowances for right-of-way or land acquisition.

Table ES-9: Wastewater System Capital Improvement Plan

Phase	CIP No.	Project Name	Cost
5 Year	1	Boot Ranch Lift Station Capacity Expansion and Rehabilitation	$3,214,300
	2	San Antonio Street Sewer Line Expansion	$2,898,200
	3	Friendship Lane Sewer Line Expansion	$1,504,000
	4	Adams Street Sewer Line Expansion	$1,936,100
	5	Fair Grounds Lift Station Expansion	$2,393,500
			$11,946,100
10 Year	6	Creek Street Sewer Expansion	$1,554,800
	7	Green Meadow Lift Station Expansion	$2,960,100
	8	Windcrest Lift Station Decommission	$1,674,400
	9	Heritage Hill Country Lift Station Expansion	$919,500
	10	Highway 87 South Lift Station Sewer Line Expansion	$5,281,900
			$12,390,700
20 Year	11	Walk Bridge Lift Station Expansion	$3,305,500
	12	Milam Street Lift Station Expansion	$4,290,700
	13	West Morse Sewer Line Expansion	$699,700
	14	Highway 290 West Sewer Line Expansion	$1,115,300
	15	West Schubert Sewer Line Expansion	$1,178,100
	16	Highway 16 South Lift Station and Sewer Line	$4,170,400
	17	Goehmann Lane Sewer Line Extension	$660,800
			$15,420,500
			$39,757,300

9.0 NON-POTABLE REUSE SYSTEM EVALUATION

The City of Fredericksburg currently has a successful water reuse program which provides non-potable reuse water from its Wastewater Reclamation Plant (WWTP) to the Boot Ranch development and to the Lady Bird Johnson Golf Course for irrigation purposes. In order to expand the available usage of this resource, the City tasked FNI to evaluate ways to increase the flexibility of matching reuse water supply and demand.

The non-potable reuse system evaluation results and recommendations are summarized below:

- The City is limited by the ability to meet summer month peak reuse demands with the amount of current reuse supply at the WWTP. The current peak demand is only able to be met using the storage in the customer's on-site ponds in addition to the pumping supply from the WWTP.
- During the winter low irrigation demand time periods, there is approximately 130 MG of effluent that is discharged downstream due to the City not having adequate storage at the WWTP. It is recommended that the City construct additional reuse storage ponds to collect and store this wintertime wastewater effluent flows and convey the additional volume to existing and potential customers during the summertime months.
- In order to provide the most flexibility and access to the additional reuse supply that would be provided, it is recommended that the City maximize the storage volume at the WWTP as that water could be used for either the Lady Bird or Boot Ranch system.
- By utilizing the existing City effluent lagoon and additional City owned land at the WWTP, FNI recommends that the City construct a 13.5-acre storage pond that would have a volume of approximately 43 million gallons. It is also recommended that the City construct a new reuse pump station that could be utilized for both the Boot Ranch and Lady Bird systems.

1.0 INTRODUCTION

The City of Fredericksburg is a community located in central Texas, within Gillespie County. The City currently provides water and wastewater service to over 10,000 people. The population within the service area is projected to grow by almost 3,000 people in the next 20 years. Accommodating this growth in an efficient and effective manner, while also focusing on the maintenance of existing water, wastewater, and reuse system assets, is the purpose of this Water, Wastewater, and Reuse System Master Plan. This report has been prepared to provide to the City of Fredericksburg a planning tool that will serve as a guide for short-term and long-term improvements to infrastructure within the water, wastewater, and reuse systems.

1.1 SCOPE OF WORK

Freese and Nichols, Inc. (FNI) was retained in 2015 by the City of Fredericksburg to prepare a Water, Wastewater, and Reuse System Master Plan. The goals of the Water, Wastewater, and Reuse System Master Plan were to evaluate the integrity of the existing water, wastewater, and reuse systems and to recommend a phased capital improvement plan (CIP) through the year 2035. The recommended improvements will serve as a basis for the design, construction and financing of facilities required to meet Fredericksburg's water, wastewater, and reuse capacity and system renewal needs. The major elements of the scope of this project included:

- Population and Non-residential Growth Projections
- Water and Wastewater Condition Assessments
- Water Demand Projections and Water Supply Evaluation
- Water Model Development, Field Testing, and Calibration
- Water System Analyses
- Wastewater Flow Projections
- Wastewater Model Development, Field Testing, and Calibration
- Wastewater System Analyses
- Reuse Demand Projections
- Reuse System Evaluation
- Water, Wastewater, and Reuse Capital Improvements Plans
- Water, Wastewater, and Reuse System Master Plan Report

1.2 LIST OF ABBREVIATIONS

Table 1-1 provides a list of abbreviations used in this report.

Table 1-1: List of Abbreviations

Abbreviation	Full Nomenclature
AADF	Average Annual Daily Flow
AD	Average Day Demand
ADS	ADS Environmental Services
CIP	Capital Improvements Plan
d/D	depth-to-diameter
EPS	Extended Period Simulation
FNI	Freese and Nichols, Inc.
GCD	Groundwater Conservation District
GIS	Geographic Information System
gpad	gallons per acre per day
gpcd	gallons per capita per day
gpm	gallons per minute
GST	Ground Storage Tank
I/I	Infiltration and Inflow
MAG	Modeled Available Groundwater
MD	Maximum Day Demand
MG	Million Gallons
MGD	Million Gallons per Day
PFD	Dry Weather Peaking Factor
PFW	Wet Weather Peaking Factor
PH	Peak Hour Demand
PP	Pressure Plane
PRV	Pressure Reducing Valve
PS	Pump Station
psi	pounds per square inch
RDII	Rainfall Derived Inflow and Infiltration
SCADA	Supervisory Control and Data Acquisition
TCEQ	Texas Commission on Environmental Quality
TWDB	Texas Water Development Board
USGS	United States Geological Survey
WWTP	Wastewater Treatment Plant

2.0 POPULATION AND NON-RESIDENTIAL LAND USE

Growth projections are an important component of the master planning process. The magnitude and distribution of the growth in population and non-residential development will dictate where future infrastructure is required. It is important to note that projecting future population is challenging, especially for relatively small geographic areas such as individual cities because it can be difficult to predict how fast or slow development will occur. For the purposes of this report, future population projections were developed for four planning years: 2015, 2020, 2025, and 2035.

2.1 SERVICE AREA

The City of Fredericksburg provides water and wastewater service to the existing city limits and the Boot Ranch development. The City's future service area was expanded to include areas of potential future growth outside of the existing city limits. **Figure 2-1** illustrates the city limits and the future water and wastewater service area.

2.2 HISTORICAL POPULATION

The City of Fredericksburg provided historical population for each year from 2010 to 2014. **Table 2-1** presents the historical populations and annual growth rates. The average annual growth rate over the last five years was 0.83%, with a maximum growth rate of 0.84% occurring from 2010 to 2011.

Table 2-1: Historical Population

Year	Population[(1)]	Growth Rate
2010	10,530	-
2011	10,619	0.84%
2012	10,708	0.83%
2013	10,797	0.82%
2014	10,886	0.82%
Average	**-**	**0.83%**

(1) Based on data provided by the City.

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FIGURE 2-1
CITY OF FREDERICKSBURG
WATER AND WASTEWATER SERVICE AREAS

LEGEND

- Road
- Stream
- Service Area
- City Limit
- ETJ

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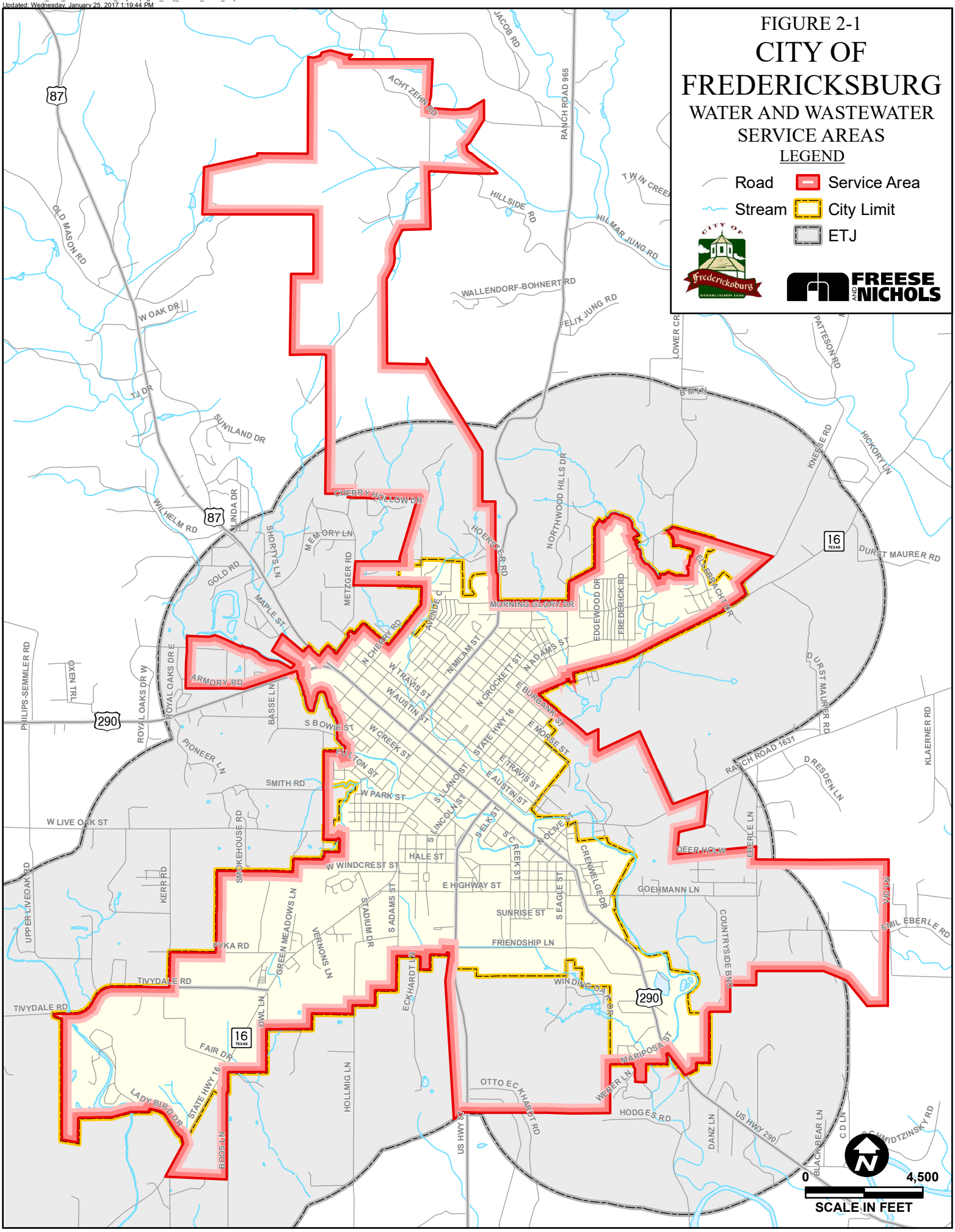

2.3 RESIDENTIAL POPULATION PROJECTIONS

The magnitude and distribution of the growth in population will dictate where future water and wastewater infrastructure is required. It is important to note that projecting future population is challenging, especially for relatively small geographic areas such as individual cities because it can be difficult to predict how fast or slow development will occur when there are a variety of circumstances that can impact it. FNI used a 1.21% annual growth rate for population projections based on the City's Comprehensive Plan. **Table 2-2** contains the residential population projections for each planning year.

Table 2-2: Population Projections

Year	Population[(1)]
2015	11,018
2020	11,701
2025	12,426
2035	14,014

(1) Population growth 2015 to 2035 assumes 1.21% growth per year

2.4 NON-RESIDENTIAL LAND USE PROJECTIONS

To capture growth within the service area related to commercial, retail, office, entertainment, institutional, and industrial development, a non-residential developed acreage for each planning period was calculated. To estimate an existing non-residential developed acreage, the City-provided water billing meter data was utilized. Any parcel with an associated meter coded as non-residential was assumed to be a non-residential parcel. The acreage of all non-residential parcels were then summed to calculate an existing non-residential developed acreage. For future planning years, the acreages of all future non-residential growth areas were summed. Non-residential development areas were identified by the City as developing within the next 5, 10, or 20 years and added to the existing commercial acreage to calculate the 2020, 2025, and 2035 non-residential developed acreage, respectively. Non-residential developed acreage projections for each planning year are provided in **Table 2-3**. **Figure 2-2** shows the projected residential and non-residential growth areas, as well as the phasing of each area (i.e. 5-year development, 10-year development, or 20-year development). Detailed tables of growth information by development are provide in **Appendix A**.

Table 2-3: Non-residential Land Use Projections

Year	Non-residential Acres
2015	2,288
2020	2,308
2025	2,528
2035	2,916

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FIGURE 2-2
CITY OF FREDERICKSBURG
FUTURE GROWTH AREAS

LEGEND

- Commercial Development
- 5-Year Development
- 10-Year Development
- 20-Year Development
- Road
- Stream
- Parcel
- City Limit
- ETJ

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ID #
2020 Population or Acres
2025 Population or Acres
2035 Population or Acres

R6
240 People
440 People
1120 People

R3
86 People
86 People
86 People

R7
167 People
359 People
359 People

R5
0 People
0 People
150 People

R9
0 People
0 People
54 People

R4
0 People
0 People
150 People

C1
15 Acres
15 Acres
15 Acres

C11
4 Acres
4 Acres
4 Acres

C12
1 Acres
1 Acres
1 Acres

C8
0 Acres
0 Acres
33 Acres

C14
0 Acres
10 Acres
10 Acres

C7
0 Acres
0 Acres
42 Acres

C9
0 Acres
0 Acres
17 Acres

R1
0 People
0 People
119 People

C13
0 Acres
10 Acres
10 Acres

C6
0 Acres
0 Acres
38 Acres

C3
0 Acres
0 Acres
98 Acres

R8
233 People
400 People
478 People

C2
0 Acres
116 Acres
116 Acres

R2
190 People
250 People
478 People

C4
0 Acres
0 Acres
52 Acres

C10
0 Acres
84 Acres
84 Acres

C5
0 Acres
0 Acres
108 Acres

0 4,500
SCALE IN FEET

3.0 WATER DEMAND PROJECTIONS

3.1 HISTORICAL WATER DEMANDS

A water utility must be able to supply water at rates that fluctuate over time. Yearly, monthly, daily, and hourly variations in water use occur, with higher use typically occurring during dry years and in hot months. Also, water use typically follows a diurnal pattern, being low at night and peaking in the early morning and late afternoon. Flow rates most important to the hydraulic design and operation of a distribution system are average day (AD), maximum day (MD), and peak hour (PH) demands. Average day use is the total annual water use divided by the number of days in the year. The average day demand rate is used as a basis for estimating maximum day and peak hour demands. Maximum day demand is the maximum quantity of water used on any one day of the year. Water supply facilities are typically designed based on the maximum day demand. Peak hour use is the peak rate at which water is required during any one hour of the year. Since minimum distribution pressures are usually experienced during peak hour, the sizes and locations of distribution facilities are generally determined based on this condition.

Reviewing historical water demands provides insight into selecting design criteria used to project future water demands. For this study, historical consumption data was provided by the City for 2010 through 2014. Consumption data comes from metered billing data, which provides a record of the amount of water used by each household. Historical AD demand was calculated for each year from 2010 to 2014 by dividing the annual usage in gallons by days in the year. Historical usage rates in gallons per capita per day (gpcd) were calculated by dividing the historical AD demand in gallons per day by the residential population for each year from 2010 through 2014. **Table 3-1** shows the historical AD demand in millions gallons per day (MGD) and historical per capita usage.

To calculate historical maximum day to average day peaking factors (PF), maximum day demand data from the City for the years of 2013 through 2014 were divided by the calculated average day demand for the corresponding year. A summary of historical maximum day demands and peaking factors is shown in **Table 3-1**.

Table 3-1: Historical Water Consumption

Year	Average Day Demand (MGD)[1]	Average Day Demand (gpcd)	Maximum Day Demand (MGD)	Maximum to Average Day Peaking Factor
2010	1.99	189	--	--
2011	2.45	231	--	--
2012	2.05	192	--	--
2013	2.16	200	4.31	2.00
2014	2.03	187	3.90	1.92
Average		**200**		**1.96**
Maximum		**231**		**2.00**

(1) Based on data provided by the City.

3.2 WATER DEMAND PROJECTIONS

Water demands were projected for 2015, 2020, 2025, and 2035 conditions for the City of Fredericksburg. The evaluation of historical trends in the per capita data provided a basis for determining the design criteria used to project average day water demands. Based on the review of this data and the need to plan for low rainfall (dry) years with minimal water restrictions, FNI recommended a design residential per capita usage of 90 and a design non-residential gallons per acre per day (gpad) of 600. These values yield average day demands similar to those calculated by multiplying residential population by 215 gpcd. A design maximum day to average day peaking factor of 2.0 was selected based on the peaking factors calculated for 2013 through 2014. A design peak hour to maximum day peaking factor of 2.0 was selected based on input from the City. **Table 3-2** summarizes the design criteria used to calculate the water demand projections, and **Table 3-3** shows the demand projections for 2015, 2020, 2025, and 2035. **Figure 3-1** provides a graphical illustration of the historical and projected water demands through 2035.

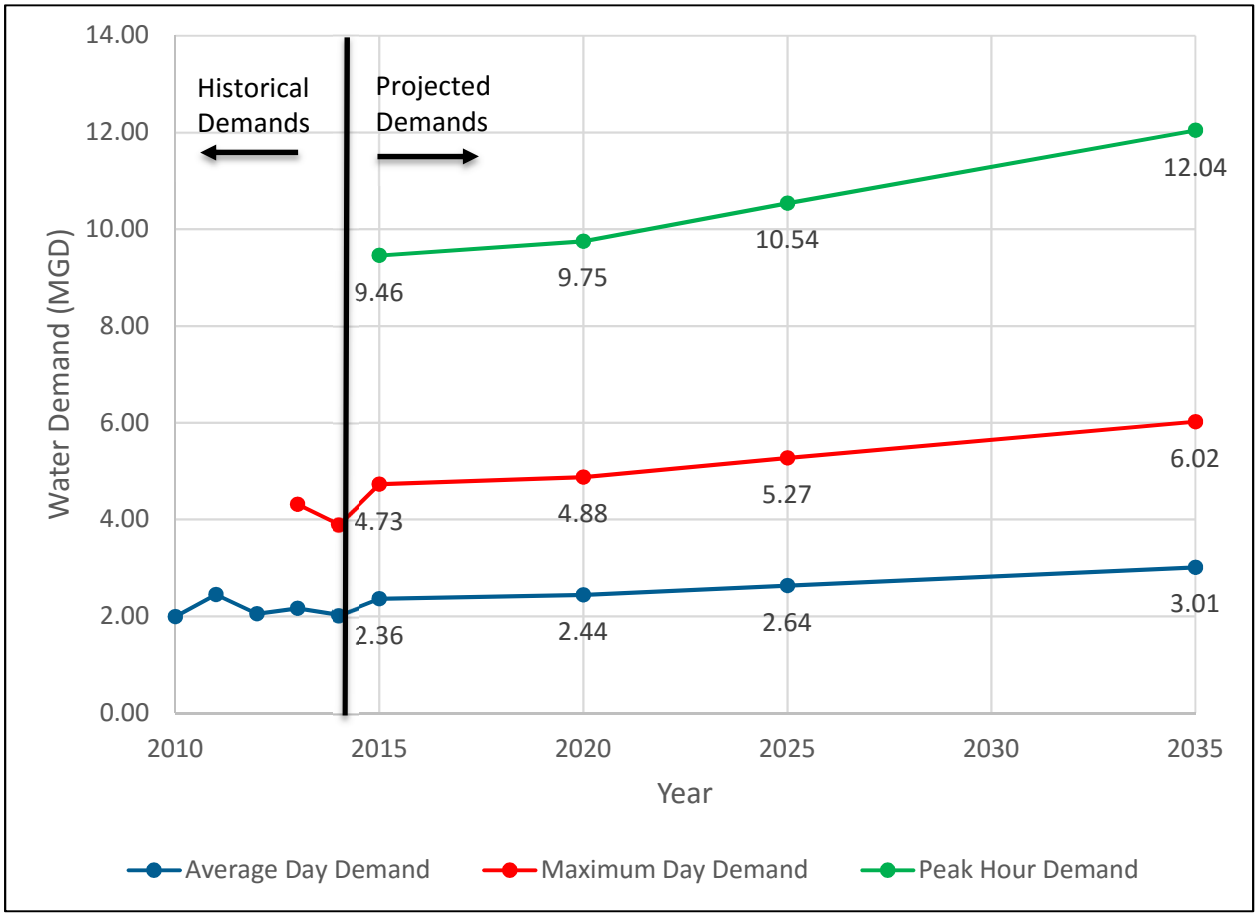
Table 3-2: Water Demands Design Criteria

Residential Average Day Demand (gpcd)	Non-Residential Gallons per Acre per Day	Maximum Day to Average Day Peaking Factor	Peak Hour to Maximum Day Peaking Factor	Calculated Overall Average Day Demand (gpcd)
90	600	2.0	2.0	215

Table 3-3: Projected Water Demands

Year	Pressure Plane	Average Day Demand (MGD)	Maximum Day Demand (MGD)	Peak Hour Demand (MGD)
2015	North Pressure Plane	0.50	1.00	2.01
	South Pressure Plane	1.84	3.68	7.35
	Windcrest	0.00	0.00	0.01
	Stone Ridge	0.02	0.04	0.09
	Total	2.36	4.73	9.46
2020	North Pressure Plane	0.57	1.14	2.27
	South Pressure Plane	1.85	3.70	7.41
	Windcrest	0.02	0.03	0.07
	Total	2.44	4.88	9.75
2025	North Pressure Plane	0.60	1.21	2.41
	South Pressure Plane	2.01	4.03	8.06
	Windcrest	0.02	0.03	0.07
	Total	2.64	5.27	10.54
2035	North Pressure Plane	0.70	1.39	2.79
	South Pressure Plane	2.27	4.55	9.10
	Windcrest	0.04	0.08	0.16
	Total	3.01	6.02	12.04

Figure 3-1: Historical and Projected Water Demands



3.3 WATER SUPPLY EVALUATION

The City of Fredericksburg currently owns and operates three well fields. The estimated capacity of the in-service wells is 11.81 MGD as shown in **Table 3-4**. These wells pump water from two groundwater formations, the Ellenburger-San Saba Aquifer and the Hickory Aquifer. The Ellenburger-San Saba Aquifer is about 76 to 1,251 feet deep and the Hickory Aquifer is about 2,091 to 2,420 feet deep. According to the 2016 Region K Plan prepared for the Texas Water Development Board (TWDB), the majority of the City's existing supply comes from Ellenburger-San Saba Aquifer.

Table 3-4: Existing Well Capacity

Facility	Pressure Plane	Aquifer	Production (gpm)	Production (MGD)	In Service?
Stehling Well 2	North Pressure Plane	Hickory	300	0.43	No
Boot Ranch Well	North Pressure Plane	Hickory	500	0.72	No
Boerner Well 3	South Pressure Plane	Ellenburger-San Saba	1,500	2.16	Yes
Boerner Well 4	South Pressure Plane	Ellenburger-San Saba	1,200	1.73	Yes
Boerner Well 5	South Pressure Plane	Ellenburger-San Saba	1,800	2.59	Yes
Hahn 1	South Pressure Plane	Ellenburger-San Saba	1,500	2.16	Yes
Hahn 2	South Pressure Plane	Ellenburger-San Saba	350	0.50	No
Weimers 3	South Pressure Plane	Ellenburger-San Saba	300	0.43	No
Knauth 2	South Pressure Plane	Ellenburger-San Saba	1,000	1.44	No
Knauth 3	South Pressure Plane	Ellenburger-San Saba	1,100	1.58	Yes
Knauth 6	South Pressure Plane	Ellenburger-San Saba	1,100	1.58	Yes
Total Production from In Service Wells			**8,200**	**11.81**	**-**

3.3.1 Analysis of Increased Production Near Hahn Wellfield

An analysis of increased production near the Hahn wellfield was completed by LBG-Guyton Associates as a sub consultant. A summary of their findings is included here and the entire text of their memorandum is included in **Appendix B**. In order to evaluate increased production near the Hahn well field, the Ellenburger Groundwater Availability Model for the Hill Country Underground Water District was used. The model was updated to reflect drought conditions experienced during 2011 and 2012 and the period end date was extended from 2004 to 2015. Four scenarios were evaluated using this model to assess the potential impact.

- Scenario 1 assumed a repeat of 2011 pumping in City wells in 2012, but did not increase pumping from any other wells.
- Scenario 2 assumes the addition of three test wells located on the Hahn Ranch pumping 25,000 gallons per day from 2005 through 2012.
- Scenario 3 is the same as scenario 2, but adds a hypothetical supply well in the Hahn well field that pumps 500 gpm from 2005 through 2012.
- Scenario 4 is the same as Scenario 3, but doubles the pumping rate of the hypothetical well to 1,000 gpm from 2005 through 2012.

Based on the analysis, Scenario 2 indicates that the City could add three additional test wells (52 gpm) with a resulting two to three feet of additional drawdown from Scenario 1. Scenario 3 indicates that

increasing the pumping 550 gpm above 2011 levels results in a water level decline of about 40 to 42 feet in existing wells. This leaves some water above the pumps (as currently set) but may not be an acceptable drawdown for the City or the Hill Country Underground Water District. The modeling indicates that Scenario 4 with an additional 1,000 gpm of pumping would decrease water levels below current pump setting during drought conditions. These model results indicate that increased pumping (Scenario 3) may affect existing well production and in order to produce an additional 500 gpm without impacting their existing wells the City should consider wells or a wellfield on another property.

3.3.2 Evaluation of Future Water Supply Sources

The 2016 Region K Water Plan prepared for the TWDB evaluated the demand and available supply for the City of Fredericksburg. The average annual supply available for the City of Fredericksburg in the Region K Plan is 3.42 MGD. This does not account for any peaking factors and does not evaluate whether the existing supply can meet maximum day or other operational demands. Shortages for the City of Fredericksburg are 0.03 MGD in 2060 increasing to 0.20 MGD in 2070 as shown in **Table 3-5**. The Region K Plan recommends water conservation and drought management to meet these shortages.

Table 3-5: 2016 TWDB Region K Plan Demand and Supply

Year	Population	Demand (MGD)	Per Capita (gpcd)	Supply (MGD)	Surplus/Need (MGD)
2020	11,318	2.81	248	3.42	0.62
2030	12,146	2.97	245	3.42	0.45
2040	12,829	3.10	242	3.42	0.32
2050	13,630	3.28	241	3.42	0.15
2060	14,367	3.45	240	3.42	-0.03
2070	15,083	3.62	240	3.42	-0.20

The water demands developed by FNI for the master plan are presented in **Section 3.2.** These population and demand projections were developed in conjunction with the City of Fredericksburg and use a lower gpcd due to recent conservation efforts. FNI has also evaluated various operational constraints such as well production capacity and maximum day and peak hour demands. Given these demand projections and operational constraints shown in **Table 3-6**, it appears that the City may need additional production capacity by 2050 to meet average day demands.

Table 3-6: FNI Water Demand and Supply

Year	Population[(1)]	Average Day Demand (MGD)	Average Annual Supply (MGD)	Surplus/ Need (MGD)	Maximum Day Demand (MGD)	Well Capacity (MGD)	Maximum Day Surplus/ Need (MGD)
2015	11,018	2.36	3.42	1.06	4.73	11.81	7.09
2020	11,701	2.44	3.42	0.98	4.88	11.81	6.93
2025	12,426	2.64	3.42	0.80	5.27	11.81	6.57
2030	13,220	2.83	3.42	0.59	5.66	11.81	6.15
2035	14,014	3.01	3.42	0.42	6.02	11.81	5.81
2040	15,062	3.22	3.42	0.20	6.45	11.81	5.36
2050	17,158	3.67	3.42	-0.25	7.35	11.81	4.46
2060	19,253	4.12	3.42	-0.70	8.24	11.81	3.57
2070	21,349	4.57	3.42	-1.15	9.14	11.81	2.67

(1) Population assumes a 1.21% growth rate

As mentioned previously, increased production near the Hahn wellfield was analyzed in a separate analysis. The analysis indicated that increased production of 500 gpm would lead to significant water level decline in existing wells. Thus the FNI analysis for future water supply sources focused on identifying wells or wellfields on another property. Key considerations for the evaluation of future water supply sources included:

- Proximity to the City of Fredericksburg and existing infrastructure.
- Wells with known production obtained from the TWDB Groundwater Database.
- Wells within Gillespie County to minimize any Groundwater Conservation District (GCD) import/export requirements.

The 2016 Region K plan indicates that there is unallocated water available in several aquifers in Gillespie County. The unallocated water is the difference between the currently available supplies allocated to various users and the Modeled Available Groundwater (MAG). The greatest availability is in the Ellenburger-San Saba Aquifer. The available groundwater is summarized in **Table 3-7**.

Table 3-7: Groundwater Availability in Gillespie County After MAG Limit

Year	Edwards-Trinity-Plateau Aquifer (MGD)	Ellenburger-San Saba Aquifer (MGD)	Hickory Aquifer (MGD)	Trinity Aquifer (MGD)	Total Available Groundwater Supply (MGD)
2020	0.86	1.11	0.16	0.16	2.28
2030	0.86	1.11	0.16	0.16	2.28
2040	0.86	1.11	0.16	0.16	2.28
2050	0.86	1.11	0.16	0.16	2.28
2060	0.86	1.11	0.16	0.16	2.28
2070	0.86	1.11	0.16	0.16	2.28

Several figures were developed to show the relative location of the City's existing well fields to the various aquifers. **Figure 3-2** shows the major aquifers (Edwards-Trinity Plateau and Trinity Aquifers) as defined by the TWDB. **Figure 3-3** shows the minor aquifers (Ellenburger-San Saba and Hickory Aquifers) as defined by the TWDB. **Figure 3-4** shows the location of wells with known production data based on the TWDB Groundwater database. This figure shows a 5-mile and 10-mile buffer from the City of Fredericksburg and well production categorized by color. Based on this map there may be some productive wells in the vicinity of the Knauth well field that would also correspond with the Ellnburger-San Saba Outcrop.

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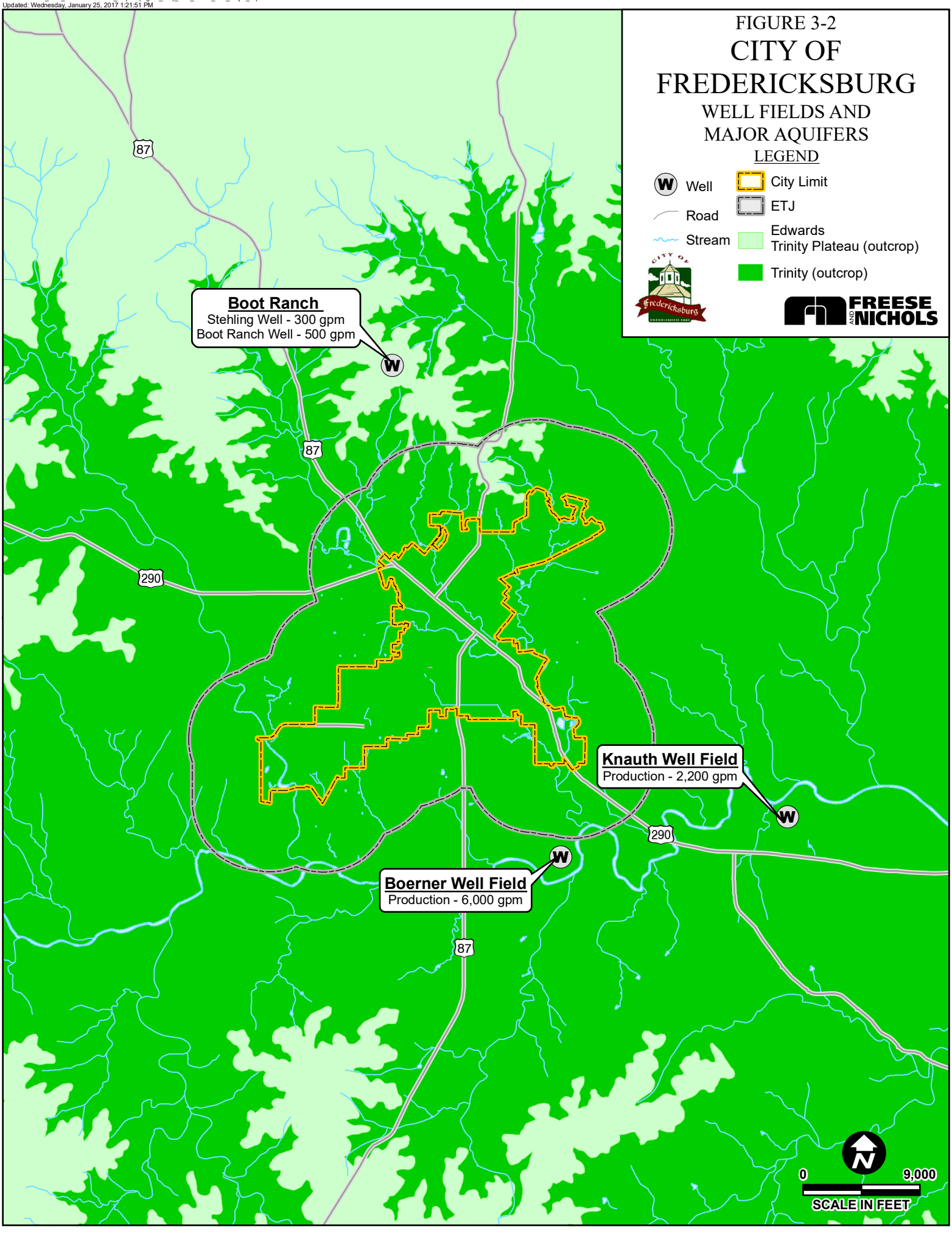

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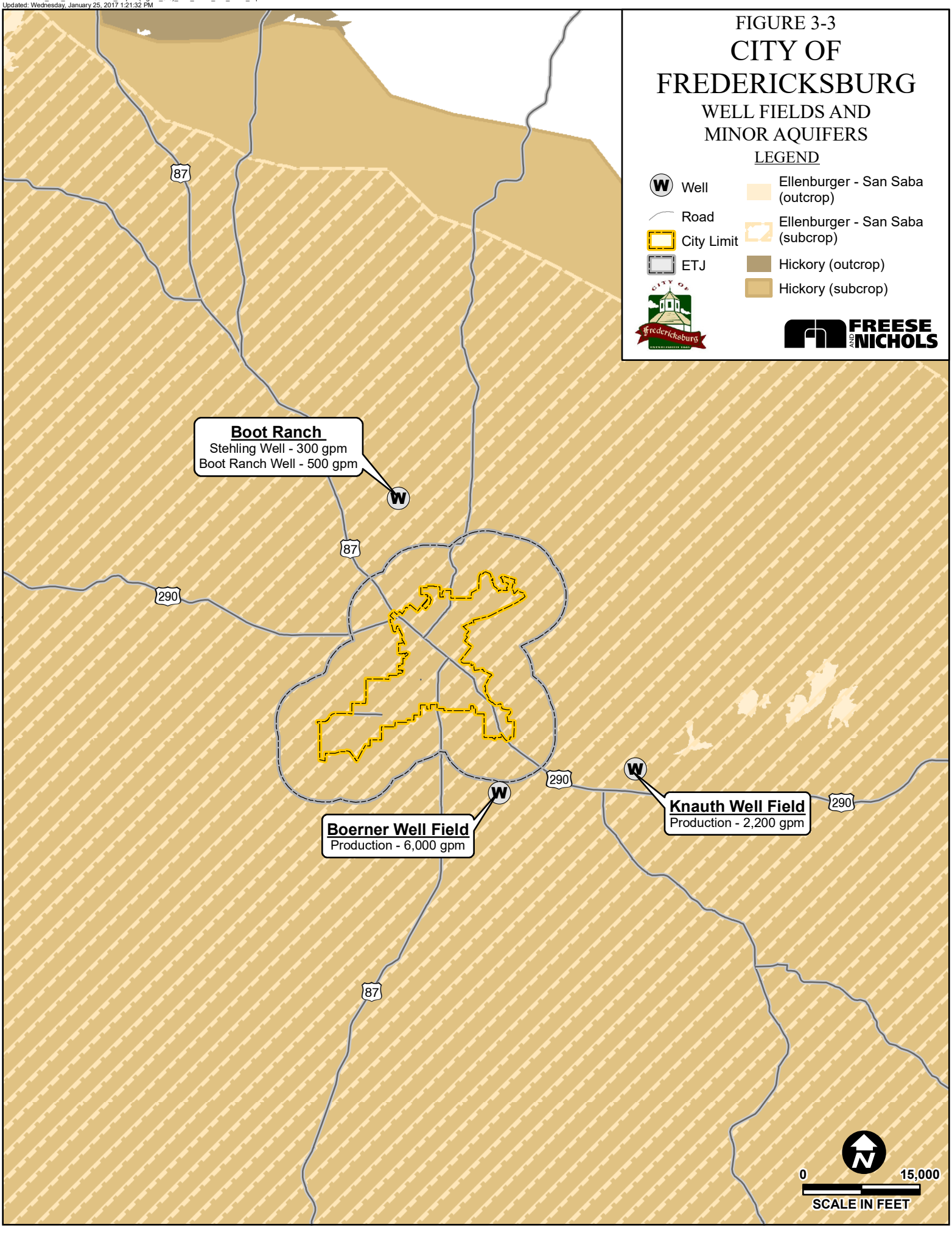

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FIGURE 3-4

CITY OF FREDERICKSBURG

WELL FIELDS AND PRODUCTION WELLS

LEGEND

Production (GPM)

- 0.5 - 50
- 50 - 100
- 100 - 500
- 500 - 1,500

- Fredericksburg Well
- Road
- 5-mile Buffer
- 10-mile Buffer
- City Limit
- ETJ

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Boot Ranch
Stehling Well - 300 gpm
Boot Ranch Well - 500 gpm

Knauth Well Field
Production - 2,200 gpm

Boerner Well Field
Production - 6,000 gpm

87 290

0 15,000
SCALE IN FEET

3.3.3 Water Supply Recommendations

The 2016 TWDB Region K Plan does not show an average annual shortage until 2060. FNI's evaluation of supplies and demand indicates that the City may have an average day shortage in 2050. Adding additional water supply will allow for growth beyond the 2050 and will provide redundancy for the future. There is also no guarantee that existing wells will continue to have the same production capacity in the future, and adding additional supply will provide redundancy. Expanding the existing Hahn well field is limited given the potential impact to existing wells discussed previously. Based on the potential impact to existing well fields, it is recommended that the City consider purchasing additional property with existing wells with known production in close proximity to the existing Boerner well fields or existing infrastructure. It is possible that the City could explore purchasing additional property and developing test wells, but there is no guarantee that a well field would provide the needed production. The following are triggers that FNI has developed for when the City should begin pursuing additional water supplies.

- If demand conditions are consistent with those outlined above, the City should begin pursuing the purchase of additional land in 2040 which would allow ten years before the increased production capacity is needed.
- If population or demands increase at a faster rate than outlined above, the City should begin pursuing purchase of additional land to develop a well field earlier than 2040.
- If the City reaches Stage 4 of its Drought Contingency Plan and remains in this condition for three consecutive months.
- If the capacity of the current wellfields is reduced due to loss of well production, water quality or other reasons the City should begin purchasing additional land.
- The City should consider implementing its water conservation programs, and if demand is decreased from these programs, the City may be able to defer the need for an additional supply beyond the scope of this study.
- If the Hill Country Underground Water District were to curtail or set pumping limits on the City's existing wells that would reduce the capacity below current production levels on a long-term basis.

4.0 WATER SYSTEM ANALYSES

4.1 EXISTING WATER SYSTEM

The City of Fredericksburg's water distribution system consists of four independent pressure planes, a network of water lines ranging in diameter from 1-inches to 16-inches, five ground storage tanks, four pump stations, and two active well fields. The South Pressure Plane encompasses a majority of the City. The North Pressure Plane includes most of the area north of Broadmoor Street. A small hydropneumatic zone serves the Stone Ridge neighborhood, and the Windcrest subdivision is served by a small pump station at the Windcrest Tank. **Figure 4-1** displays the existing water distribution system ins schematic form. The existing distribution system and pressure plane boundaries are shown on **Figure 4-2**.

The Boerner well field supplies water to the South Heights Pump Station and Ground Storage Tank. The Stone Ridge Pump Station pumps from the North Pressure Plane to a hydropenumatic zone. The Knauth well field supplies water to the Goehmann Lane Pump Station and Ground Storage Tank. The Windcrest and Cross Mountain Tanks are ground storage tanks on a hill that act as elevated storage for the South Pressure Plane. The South Heights and Goehmann Lane Pump Stations supply water to the Cross Mountain Tank and Pump Station that serve the North Pressure Plane. The North Pressure Plane also includes the Boot Ranch Tank, a ground tank on a hill that acts as elevated storage. Summaries of the storage and pumping facilities are presented in **Tables 4-1** and **4-2**, respectively.

Table 4-1: Storage Facilities Summary

Pressure Plane	Facility	Type	Volume (MG)
North Pressure Plane	Cross Mountain	Ground Storage Tank	0.37(1)
	Boot Ranch	Elevated Storage Tank(2)	1.00
South Pressure Plane	South Heights	Ground Storage Tank	0.50
	Cross Mountain	Elevated Storage Tank	0.63(1)
	Windcrest	Elevated Storage Tank(2)	1.00
	Goehmann Lane	Ground Storage	0.50

(1) The Cross Mountain Tank is a 1.0 MG tank that serves as ground storage for the North Pressure Plane (0.37 MG) and elevated storage for the South Pressure Plane (0.63 MG).
(2) Ground storage tanks that serve as elevated storage.

Figure 4-1: Existing System Schematic

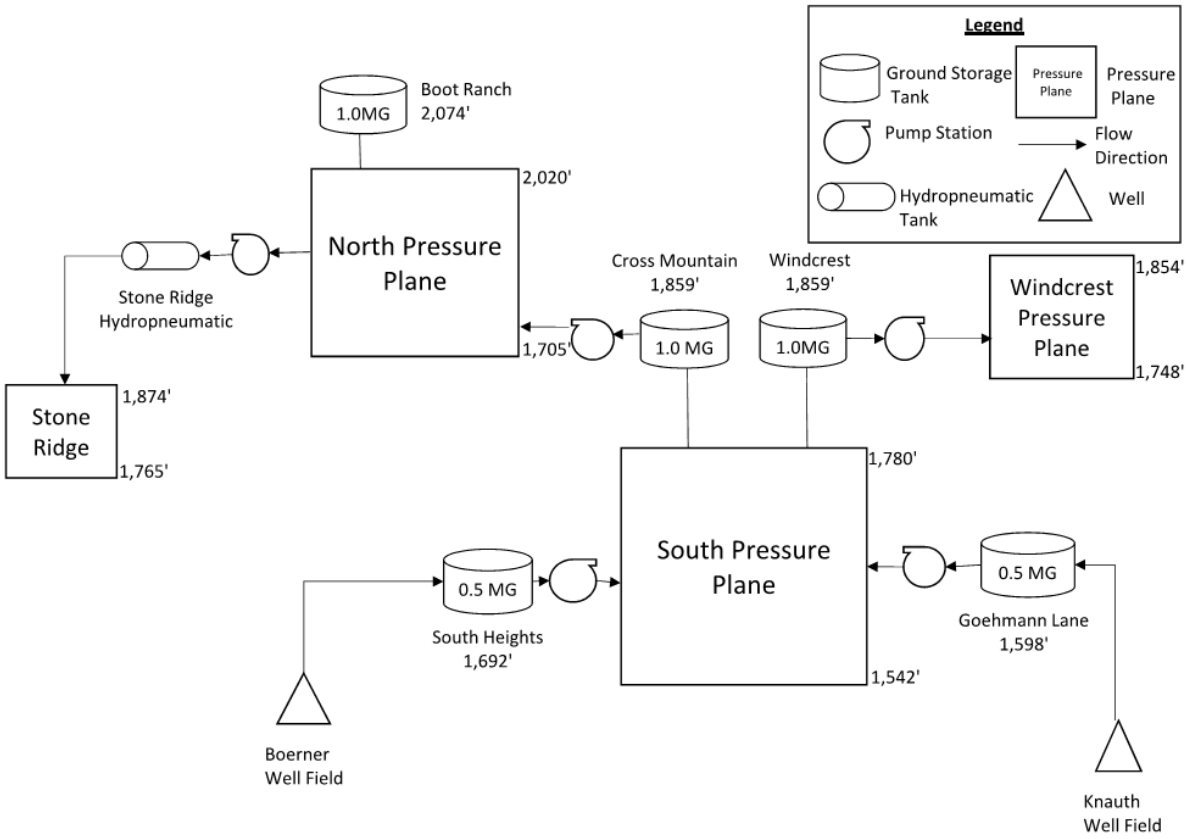

FIGURE 4-2
CITY OF FREDERICKSBURG
EXISTING WATER SYSTEM

LEGEND

- Well
- Storage Tank
- Pump Station
- 8" and Smaller Water Line
- 10" and Larger Water Line
- Transmission Line
- Road
- Stream
- City Limit
- ETJ Boundary

PRESSURE PLANES

- North Pressure Plane
- South Pressure Plane

Boot Ranch Tank
Overflow Elevation: 2,074'
(1) - 1.0 MG GST
Stehling Well - 300 gpm
Boot Ranch Well - 500 gpm

Cross Mountain Tank
Overflow Elevation: 1,859'
(1) - 1.0 MG GST
(2) - 1,360 gpm pump

Stone Ridge Pump Station
(1) - Hydroneumatic Tank
(3) - 450 gpm pumps

Windcrest Tank
Overflow Elevation: 1,859'
(1) - 1.0 MG GST
(2) - 400 gpm pumps
(1) - 750 gpm pump

South Heights Pump Station
(3) - 1,000 gpm pumps
(1) - 0.50 MG GST

Goehmann Lane Pump Station
(2) - 1,050 gpm pumps
(1) - 0.50 MG GST

Knauth Well Field
Production - 2,200 gpm

Boerner Well Field
Production - 6,000 gpm

0 1,900 3,800
SCALE IN FEET

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Table 4-2: Pumping Facilities Summary

Pressure Plane	Pump Station	Pump Number	Rated Capacity (gpm)	Rated Capacity (MGD)
North Pressure Plane	Cross Mountain	1	1,360	1.96
		2	1,360	1.96
		Total Capacity	2,720	3.92
		Firm Capacity	1,360	1.96
South Pressure Plane	South Heights	1	1,000	1.44
		2	1,000	1.44
		3	1,000	1.44
		Total Capacity	3,000	4.32
		Firm Capacity	2,000	2.88
	Goehmann Lane	1	1,050	1.51
		2	1,050	1.51
		Total Capacity	2,100	3.02
		Firm Capacity	1,050	1.51
Windcrest	Windcrest	1	400	0.58
		2	400	0.58
		3	750	1.08
		Total Capacity	1,550	2.23
		Firm Capacity	800	1.15

4.2 WATER SYSTEM RISK BASED ASSESSMENT

A risk based assessment of facilities was conducted to assist in the prioritization of recommended improvements. The assessment was based on the condition and criticality of existing water system facilities. Site visits were performed by FNI and City staff to evaluate the condition of the facilities, and redundancy and population served were used to measure criticality. A scoring system was developed to provide an analytical and quantitative method to evaluate the condition and criticality of each pump station and ground storage tank. The results of both the criticality and condition analysis were input to a matrix to provide an overall ranking of projects.

4.2.1 Water Facilities Condition Scoring

Table 4-3 displays the condition rating system utilized to score each component of a facility. A condition rating of 1 signified that the component was new and met or exceeded all the current standards that applied. A rating of 5 indicated that the component was in very poor shape and required immediate

rehabilitation or replacement. Each component of all evaluated facilities received a score between 1 and 5. Components were assigned a weighted percentage, and a total score was calculated for each facility. **Table 4-4** summarizes numeric ranges of the total score to determine whether the overall facility is in very good, good, fair, poor, or very poor condition.

Table 4-3: Facility Condition Scoring

Description	Condition Rating
New, perfect condition	1
Good condition, no improvements recommended to maintain function	2
Fair condition, improvements recommended to improve performance or efficiency	3
Poor condition, improvements recommended to maintain reliability	4
Eminent failure, rehabilitation or replacement required	5

Table 4-4: Facility Condition Assessment Scoring

Score	Condition Assessment Scoring Definition
Very Good	Sound physical condition. Total Score ≤ 1.25
Good	Acceptable physical condition. 1.25 < Total Score ≤ 2
Fair	Normal wear and tear. 2 < Total Score ≤ 3
Poor	Failure likely in short to medium term. 3 < Total Score ≤ 4
Very Poor	Failed or near failure. Total Score > 4 Major work or replacement required urgently.

A. Pump Station Condition

All the pump stations in the distribution system were evaluated. **Table 4-5** shows the weightings for each component of the pump stations, and **Table 4-6** displays the weighted score for each pump station from worst to best.

Table 4-5: Pump Station Condition Scoring

Component Group	Weight Factor
Electrical – MCC, Switch Gear, Alternate Power	25%
Pumps and Motors	30%
Instrumentation - SCADA, alarms	10%
Structure - Walls, Roof, Foundation	20%
Mechanical - HVAC, Piping, Valves, Meters	15%
Total Inspection Score	100%

Table 4-6: Pump Station Condition Rating Summary

Pump Station	Weighted Score	Overall Condition
Goehmann Lane Pump Station	4.15	Very Poor
Windcrest Pump Station	3.35	Poor
South Heights Pump Station	3.00	Fair
Stone Ridge PS and Hydro Tank	2.65	Fair
Cross Mountain Pump Station	2.40	Fair

The pump station scores ranged from 2.40 to 4.15. The Goehmann Lane pump station is in very poor condition and is in need of immediate repair. Detailed summary sheets for pump stations from the site visits can be found in **Appendix C**.

B. Storage Facilities Condition

The City's ground storage tanks were evaluated as part of the condition assessment. **Table 4-7** shows the weightings for each component of the ground storage tanks and **Table 4-8** displays the weighted score for each ground storage tank.

Table 4-7: Ground Storage Condition Scoring

Component Group	Weight Factor
Mechanical-Piping, Hatches, Valves, Vents	20%
Tank Structure and Roof Slope	50%
Instrumentation and SCADA	10%
Tank Overflow	10%
Site - Drainage, Access Drive, Security, Fencing	10%
Total	100%

Table 4-8: Ground Storage Condition Rating Summary

Storage Facility	Weighted Score	Overall Condition
Goehmann Lane GST	1.1	Very Good
South Heights GST	1.1	Very Good
Windcrest GST	1.3	Good
Cross Mountain GST	2.1	Fair
Boot Ranch GST	2.2	Fair

Ground storage condition scores ranged from 1.1 to 2.2. All of the tanks were in very good, good, or fair condition. Detailed summary sheets for ground storage tanks from the site visits can be found in **Appendix C**. The all of tanks were judged to be in structurally sound condition.

4.2.2 Water Facilities Criticality Scoring

The criticality of a facility can also be defined as the consequence of a failure. Factors to consider include:

- Number of customers affected
- Redundancy within the system
- Repair and response time

Since repair time for facilities is based on many factors and cannot be easily estimated, only population served and redundancy within the system were considered for criticality evaluation of facilities. **Table 4-9** presents the scoring parameters used and the weighting factors assigned to each water facility. **Table 4-10** shows the scores associated with the rating categories of the criticality assessment. The final criticality scores are shown in **Table 4-11.**

Table 4-9: Criticality Scoring Categories and Weighting

Population Served (100%)	System Redundancy Adjustment (+/- 1)
> 6,000 = 5	Provides Exclusive Service Adjustment = +1
3,001 – 6,000 = 4	
1,501 – 3,000 = 3	Provides Non-Exclusive Service Adjustment = -1
501 – 1,500 = 2	
≤ 500 = 1	

Table 4-10: Criticality Score Ranges

Score	Criticality Scoring Range
Very Low Impact	Total Score ≤ 1.25
Low Impact	1.25 < Total Score ≤ 2
Moderate Impact	2 < Total Score ≤ 3
High Impact	3 < Total Score ≤ 4
Very High Impact	Total Score > 4

Table 4-11: Facility Criticality Scoring Results

Facility	Weighted Score	Overall Criticality
Goehmann Lane Pump Station	4.00	High
South Heights Pump Station	4.00	High
Windcrest Pump Station	2.00	Low
Cross Mountain Pump Station	4.00	High
Stone Ridge PS and Hydro Tank	2.00	Low
Goehmann Lane GST	4.00	High
South Heights GST	4.00	High
Windcrest GST	6.00	Very High
Cross Mountain GST	4.00	High
Boot Ranch GST	4.00	High

4.2.3 Water Facilities Analysis Summary

The results of both the criticality and condition analysis were input to a matrix to give facilities an overall combined ranking. The facility matrix is shown on **Figure 4-3**. The boxes in red represent short term critical needs and include the Goehmann Lane Pump Station. Due to the poor condition and high impact of the Goehmann Lane Pump Station, it is addressed in the short-term CIP.

Figure 4-3
Summary of Water Facility Risk Based Analysis

Risk Rating = Condition + Criticality	Condition Ranking				
Criticality Ranking	Very Good	Good	Fair	Poor	Very Poor
Very Low Impact					
Low Impact		Windcrest GST	Stone Ridge PS	Windcrest PS	
Moderate Impact					
High Impact		Goehmann Ln GST South Heights GST	Cross Mtn PS South Heights PS Cross Mtn GST Boot Ranch GST		Goehmann Ln PS
Very High Impact					

Condition Score Ranges

Condition Score	Description
0.00 - 1.25	Very Good
1.25 - 2.00	Good
2.00 - 3.00	Fair
3.00 - 4.00	Poor
4.00 - 5.00	Very Poor

Criticality Score Ranges

Risk Score	Description
0.00 - 1.25	Very Low
1.25 - 2.00	Low
2.00 - 3.00	Moderate
3.00 - 4.00	High
4.00 - 5.00	Very High

4.3 PRESSURE TESTING

Temporary field pressure testing was conducted September 26 – October 25, 2015. Ten Telog® brand pressure recorders were installed throughout the distribution system. Locations of the pressure recorders are illustrated on a map in **Appendix D**. The City also provided Supervisory Control and Data Acquisition (SCADA) data during the pressure testing period. Hourly readings of flow, tank level, and pressure were recorded for the Goehmann Lane Pump Station. **Appendix D** contains graphs of the pressure recording data.

4.4 WATER MODEL DEVELOPMENT AND CALIBRATION

The water model was built in H2OMAP Water® hydraulic modeling software by Innovyze, which makes use of engineering equations and mathematical algorithms to determine the flows and pressures that would occur in a distribution system under a specified set of conditions. In general, the flow and gradient patterns depend upon the magnitude and location of system supplies and demands and on the characteristics of the water mains and other facilities in the distribution network. The headloss through each main is a function of the flow rate and the pipe diameter, length, and interior roughness.

4.4.1 Pipeline Network Development

The model pipeline network was developed from the City's geographic information system (GIS) and design plans. The process that was used to create an accurate representation of Fredericksburg's distribution system is summarized in the following sections.

A. GIS Data

The City provided GIS shapefiles containing water system data. The "water" shapefile contained 2,101 records and included information on each pipe in the distribution system. H2OMAP Water® requires each pipe to have a unique identifier so a field was created in the "WaterLines" shapefile called "ID" and a unique numeric value was entered for each record. The pipes were then imported using the import manager in H2OMAP Water®. **Table 4-12** lists the field that were imported into the model.

Table 4-12: Fields Mapped from GIS to Model

Shapefile Field Name	Description	Corresponding Model Field Name
DIAMETER	Diameter of Pipe	Diameter
TYPE_	Material of Pipe	Material
ID	Unique ID of Pipe	ID

B. Network Topology

In H2OMAP Water®, a node defines the first or last vertex of a line. Two lines that are connected will share a node to create topology. The pipe-node topology was created using the H2OMAP Water® "Convert Polyline" command by creating junctions at each pipe endpoint. Pipes were automatically connected if an endpoint was within 0.01 feet of another endpoint. To ensure proper connectivity, the network was reviewed using the following tools:

- *Locate/Fix Nodes in Close Proximity* – areas where nodes were within 5 feet of another node were reviewed. In cases where "undershoots" or "overshoots" were observed, the nodes were merged in order to connect pipes. **Appendix E** shows examples of nodes in close proximity.
- *Locate/Fix Pipe Split Candidates* – each instance where a pipe endpoint was within 10 feet of a pipe edge was reviewed. Pipes were connected in cases where invalid dead-ended pipes were observed. **Appendix E** shows examples of pipe split candidates.
- *Locate/Fix Crossing/Intersecting Pipes* – pipes that were crossing but not connected were reviewed. Most intersections that were identified were not changed due to the nature of the connection, such as transmission lines crossing distributions lines. **Appendix E** shows examples of crossing/intersecting pipes.
- *Locate Parallel Pipes* – pipes that had the same "from" and "to" nodes were identified and reviewed for unintended duplicate pipes. No duplicate pipes were found. All pipes that were identified were valid parallel or looped pipes. **Appendix E** shows examples of parallel pipes.
- *Trace Network* – the network was traced from various points throughout the system to ensure there were no disconnected portions of the system.

4.4.2 Facility Attributes

Each element of a model requires certain parameters in order to perform the necessary hydraulic calculations. Facility information was input to the model based on data provided by the City of Fredericksburg.

A. Pipelines

Diameter, length, and a roughness coefficient are required for each pipeline for modeling purposes. The pipeline diameter was imported from the "water" shapefile and the length of each pipe was auto-calculated based on its spatial location. Pipelines were assigned a Hazen-Williams roughness coefficient (C-value) based on diameter and material after they were imported to the model. The C-values were assigned according to **Table 4-13**.

Table 4-13: Initial C-Value Assignment

Materials in Model	Less than or Equal to 12-Inch Diameter	Greater than 12- inch Diameter
AC	100	110
C900	100	110
C909	100	110
CI	80	--
FL	100	--
GALV	100	--
PVC	120	130
PVC SDR35	120	130
Unknown	100	100

B. Junctions

Elevation values are required at model junctions to calculate pressures. The "Elevation Interpolation" command was used to assign elevations to all junctions in the model using 5-foot contour data.

C. Pumps

The City provided information on the existing pumps at each pump station. The 2007 Water and Wastewater Capital Improvement Plan Report included information on the design point for each pump. Each pump was input to the model with its specified design point (head in feet and flow in gpm). The design point for each pump is summarized in **Table 4-14**.

Table 4-14: Distribution Pump Specifications

Pump	Design Flow (gpm)	Design Head (feet)
Cross Mountain Pump #1	1,360	221
Cross Mountain Pump #2	1,360	221
South Heights Pump #1	1,000	200
South Heights Pump #2	1,000	200
South Heights Pump #3	1,000	200
Goehmann Lane Pump #1	1,050	270
Goehmann Lane Pump #2	1,050	270
Windcrest Pump #1	400	140
Windcrest Pump #2	400	140
Windcrest Pump #3	750	160

D. Tanks

Floor elevation, minimum level, and maximum level were input to the model for all tanks based on as-built drawings. A summary of the tank dimensions input in the model can be found in **Table 4-15**.

Table 4-15: Storage Tank Dimensions

Tank	Volume (MG)	Ground Elevation (feet)	Overflow Elevation (feet)	Diameter (feet)
Cross Mountain	1.00	1,829	1,859	74
Boot Ranch	1.00	2,044	2,074	74
South Heights	0.50	1,661	1,692	53
Windcrest	1.00	1,830	1,859	77
Goehmann Lane	0.50	1,570	1,598	55

E. Valves

The City maintains closed valves between the North and South pressure planes, as well as a two pressure reducing valves (PRVs) at the Cross Mountain pump station. The pressure plane valves were modeled as closed pipes, and the pressure reducing valves were set with a value of 80 psi for the northern line from Cross Mountain and 38 psi for the southern line for calibration.

4.4.3 Demand Allocation

The distribution, or allocation, of water demands is a crucial step in developing a hydraulic model. The spatial location and relative magnitude of demands significantly impact the hydraulics of a water distribution system. In master planning, an accurate distribution of demands facilitates the development of sound capital improvements. This distribution was achieved using metered billing data provided by the City. The metered billing data included the total consumption in gallons for every customer as well as the address and size of each meter. The active meters were geocoded using parcel and street centerline data. Geocoding is a GIS technique used to generate a geographic location (x-y coordinates) from an address. During the geocoding process 5,279 meters out of 5,361 meters were matched to an address, accounting for 99% of the metered water usage. **Appendix F** contains a map showing the location and usage of each meter. September 2015 water demands were allocated to the model by spatially joining the meters to the nearest model node in H2OMap Water® using the Demand Allocator module. The non-residential water usage was input to the model in the Demand1 field and the residential usage was input in the Demand2 field. The residential and non-residential demands were then scaled to match the demand experienced during the calibration day, and are discussed further in **Section 4.4.4**.

4.4.4 Extended Period Simulation Model Calibration

To verify that the hydraulic model accurately represented the actual distribution system, an extended period simulation (EPS) model calibration analysis was performed. The calibration process involved adjusting system operation, C-values, demand allocation, and peaking factors to match a known condition. October 6, 2015 was selected for calibration because it was a week day with the most complete data.

Demands were allocated to the model from metered billing data provided by the city for September 2015. The demands were then scaled to match the average day demand for September 2015 for calibration. The actual demand on October 6th could not be calculated due to lack of SCADA data. Based on the September 2015 demand, the calibration demand was 2.95 MGD. Since a diurnal pattern could not be developed with the available SCADA data, the diurnal pattern from a similar hill country community was utilized. This diurnal pattern is presented in **Appendix G.**

During the EPS calibration, adjustments were made to the model in order to match the pressure recorder data on October 6, 2015. FNI adjusted pump run times and initial tank levels. The settings on the pressure reducing valves were also adjusted. The results of the EPS calibration are summarized on the graphs

included in **Appendix G**. The graphs show modeled pressures versus recorded data at pressure recorder locations. The results suggest a good correlation between recorded and modeled values. This degree of calibration provides confidence in the accuracy of the model. Therefore, the model is considered suitable for the development of a water system CIP and master planning purposes.

4.4.5 TCEQ Requirements

As a public water utility, the City of Fredericksburg must comply with the rules and regulations for public water systems set forth by the Texas Commission on Environmental Quality (TCEQ) in Chapter 290, Public Drinking Water. The City is required to meet the TCEQ elevated storage capacity requirement of 100 gallons per connection and total storage capacity requirement of 200 gallons per connection. In addition to storage requirements, the City is also required to meet the TCEQ pumping capacity requirements. The City provides at least 200 gallons per connection of elevated storage in the North and South pressure planes resulting in a TCEQ pumping requirement of 0.6 gpm/connection in most areas. The City provides less than 200 gallons per connection of elevated storage in the Windcrest pressure plane, making the pumping requirement 2.0 gpm per connection. The City is currently violating TCEQ regulations by not providing elevated storage or a hydropneumatic tank to the Windcrest pressure plane. The recommendations in this report address this violation. The City reported having 5,631 active connections as of September 2015. TCEQ capacity requirements were evaluated by pressure plane (PP). The existing PP boundary is presented on **Figure 4-2**. Existing storage and pumping capacities were evaluated and are summarized in **Tables 4-16** through **4-18**. TCEQ also requires the City to provide 0.6 gpm per connection of water supply. The City has 8,200 gpm of water supply which exceeds the TCEQ requirement of 3,379 gpm.

Table 4-16: TCEQ Required Pumping

TCEQ Requirement	Pressure Plane	Connections	Required Pumping Capacity (gpm)	Required Pumping Capacity (MGD)	Available Total Pumping Capacity (MGD)	Available Firm Pumping Capacity (MGD)[1]	TCEQ Requirement Met?
0.6 gpm per connection	North Pressure Plane	1,073	644	0.93	3.92	1.96	Yes
0.6 gpm per connection	South Pressure Plane	4,458	2,675	3.85	7.34	4.39	Yes
2.0 gpm per connection	Windcrest	100	200	0.29	2.23	1.15	Yes
0.6 gpm per connection	**Total**	5,631	3,379	4.87	13.49	7.50	Yes

(1) Capacity with the largest pump out of service.

Table 4-17: TCEQ Required Elevated Storage

TCEQ Requirement	Pressure Plane	Connections	Required Elevated Storage (MG)	Available Elevated Storage Volume (MG)	TCEQ Requirement Met?
100 gallons per connection	North Pressure Plane	1,073	0.11	1.00	Yes
100 gallons per connection	South Pressure Plane	4,458	0.45	1.63[1]	Yes
100 gallons per connection	Total	5,631	0.56	2.63	Yes

(1) The Cross Mountain Tank has 0.63 MG that serves as elevated storage.

Table 4-18: TCEQ Required Total Storage

TCEQ Requirement	Connections	Required Total Storage (MG)	Available Total Storage (MG)	TCEQ Requirement Met?
200 gallons per connection	5,631	1.13	4.00	Yes

4.5 STORAGE AND PUMPING RECOMMENDATIONS

This section summarizes an evaluation of the storage and pumping capacity for the City based on criteria developed by FNI. These criteria are typically more stringent than the TCEQ requirements and take into consideration additional factors including operational flexibility, fire suppression, system redundancy, and energy efficiency. The design criteria used to analyze elevated storage tank capacity is the volume required to provide adequate equalization storage for peak hour demands plus emergency storage for fire protection. It is typically assumed that half of the elevated storage tank capacity is used to meet peak hourly demands in excess of the maximum day rate (equalization volume), while the other half of the tank is used for fire protection and emergency conditions (fire/emergency volume). This evaluation assumes that pumping will meet 60% of peak hour demands and elevated storage will meet the remaining 40% of peak hour demands. **Table 4-19** shows the recommended elevated storage by pressure plane.

Table 4-19: Recommended Elevated Storage

Year	Pressure Plane	Peak Demand (MGD)(1)	Peak Volume (MG)(2)	Fire Volume (MG)(3)	Total (MG)(4)	Available Elevated Storage Volume (MG)
2015	North Pressure Plane	0.84	0.14	0.63	0.77	1.00
	South Pressure Plane	2.94	0.49	0.63	1.12	1.63
2020	North Pressure Plane	0.91	0.15	0.63	0.78	1.00
	South Pressure Plane	2.98	0.50	0.63	1.13	1.63
2025	North Pressure Plane	0.97	0.16	0.63	0.79	1.00
	South Pressure Plane	3.24	0.54	0.63	1.17	1.63
2035	North Pressure Plane	1.11	0.19	0.63	0.82	1.00
	South Pressure Plane	3.64	0.61	0.63	1.24	1.63

(1) Equals 40% of peak hour demand
(2) Required volume to supply the peak demand for a duration of 4 hours
(3) Assuming highest fire flow required is 3,500 gpm for 3 hour duration
(4) The greater of twice the peaking volume or the peaking volume plus fire volume

The recommended firm pumping capacity was calculated based on meeting 60% of the peak hour demands. Firm pumping capacity is defined as the total available pumping capacity with the largest pump out of service. **Table 4-20** presents the recommended firm pumping capacity. The recommended firm pumping capacity exceeds the existing available firm pumping capacity for the South PP; therefore, additional pumping capacity is required. This deficiency was addressed as part of the Master Plan.

Table 4-20: Recommended Firm Pumping Capacity

Year	Pressure Plane[1]	Recommended Firm Pumping [2] (MGD)	Available Total Pumping Capacity (MGD)	Available Firm Pumping Capacity (MGD)
2015	North Pressure Plane	1.26	3.92	1.96
	South Pressure Plane	5.67	7.34	4.39
	Windcrest	0.01	2.23	1.15
2020	North Pressure Plane	1.36	3.92	1.96
	South Pressure Plane	5.85	7.34	4.39
	Windcrest	0.01	2.23	1.15
2025	North Pressure Plane	1.45	3.92	1.96
	South Pressure Plane	6.32	7.34	4.39
	Windcrest	0.01	2.23	1.15
2035	North Pressure Plane	1.67	3.92	1.96
	South Pressure Plane	7.22	7.34	4.39
	Windcrest	0.09	2.23	1.15

(1) South pressure plane calculations are for the total system demand.

(2) Recommended pumping is 60% of the peak hour demand

Recommended ground storage capacity was calculated based on providing storage equivalent to 8-12 hours of maximum day demand. Storage volumes equivalent to 8, 10, and 12 hours of MD demand were calculated, and range from least conservative to most conservative, respectively. **Table 4-21** presents the recommended ground storage capacity by pressure plane. Additional ground storage is recommended for the North PP and South PP as part of the Master Plan.

Table 4-21: Recommended Ground Storage

Year	Pressure Plane[1]	8 Hours of Maximum Day Demand (MG)	10 Hours of Maximum Day Demand (MG)	12 Hours of Maximum Day Demand (MG)	Available Ground Storage (MG)
2015	North Pressure Plane	0.35	0.44	0.52	0.37
	South Pressure Plane	1.58	1.97	2.36	1.00
2020	North Pressure Plane	0.38	0.47	0.57	0.37
	South Pressure Plane	1.62	2.03	2.44	1.00
2025	North Pressure Plane	0.40	0.50	0.60	0.37
	South Pressure Plane	1.76	2.19	2.63	1.00
2035	North Pressure Plane	0.46	0.58	0.70	0.37
	South Pressure Plane	2.01	2.51	3.01	1.00

(1) South pressure plane calculations are for the total system demand.

4.6 HYDRAULIC MODELING ANALYSIS

4.6.1 Existing System Analysis

A hydraulic analysis was performed under existing demand conditions to evaluate system operations and residual pressures throughout the distribution system. A 24-hour EPS analysis was performed with 2015 maximum day demands. EPS modeling provides a means to evaluate the system over time to assess response to hourly changes in demand, pump cycling, and tanks filling or draining. **Figures 4-4** and **4-5** present the modeled pumping and tank levels during simulated 2015 maximum day demand conditions. During a maximum day EPS analysis, the peak hour demand condition is also simulated by setting the highest hourly peaking factor in the diurnal demand pattern equal to the peak hour to maximum day peaking factor. Peak hour demand represents the single hour of the year with the highest system demand. Peak hour simulations are used to assess the ability of the distribution system to maintain residual pressures because the highest demand period typically induces the lowest pressure due to increased headloss throughout the system. **Figure 4-6** shows the minimum pressure observed in the model under existing demand conditions. This map helped identify potential problem areas in the system and was used as a tool to assure that reasonable pressure ranges were maintained throughout the system. The TCEQ minimum required pressure within a distribution system is 35 pounds per square inch (psi) under normal demand conditions. As seen on **Figure 4-6**, most of the system is able to meet that minimum requirement, but the areas surrounding the Windcrest neighborhood and north of the Stone Ridge Pump Station show

modeled pressures below 35 psi. There are also pressure below 35 psi in the Boot Ranch development, but there are no service connections in the low pressure area. These modeled pressures were validated by the measured values collected during field testing.

To evaluate the fire suppression capabilities of the system, a fire flow analysis was conducted under existing maximum day demand conditions. TCEQ requires a minimum residual pressure of 20 psi be maintained while delivering the fire flow demand. For this analysis, a steady-state model run was utilized to calculate the available fire flow at each node in the system with a pressure of 20 psi. **Figure 4-7** shows the results of the fire flow simulation. The majority of the water system can provide at least 1,000 gpm, which is a typical residential fire flow demand. Available fire flows below 1,000 gpm are due to small diameter lines in isolated areas. Upsizing of smaller lines and looping are two methods to improve low fire flow. Available fire flow for commercial, multi-family, and industrial land uses should be evaluated on a case by case basis.

Figure 4-4: 2015 Maximum Day Demand Pumping and Storage - South Pressure Plane

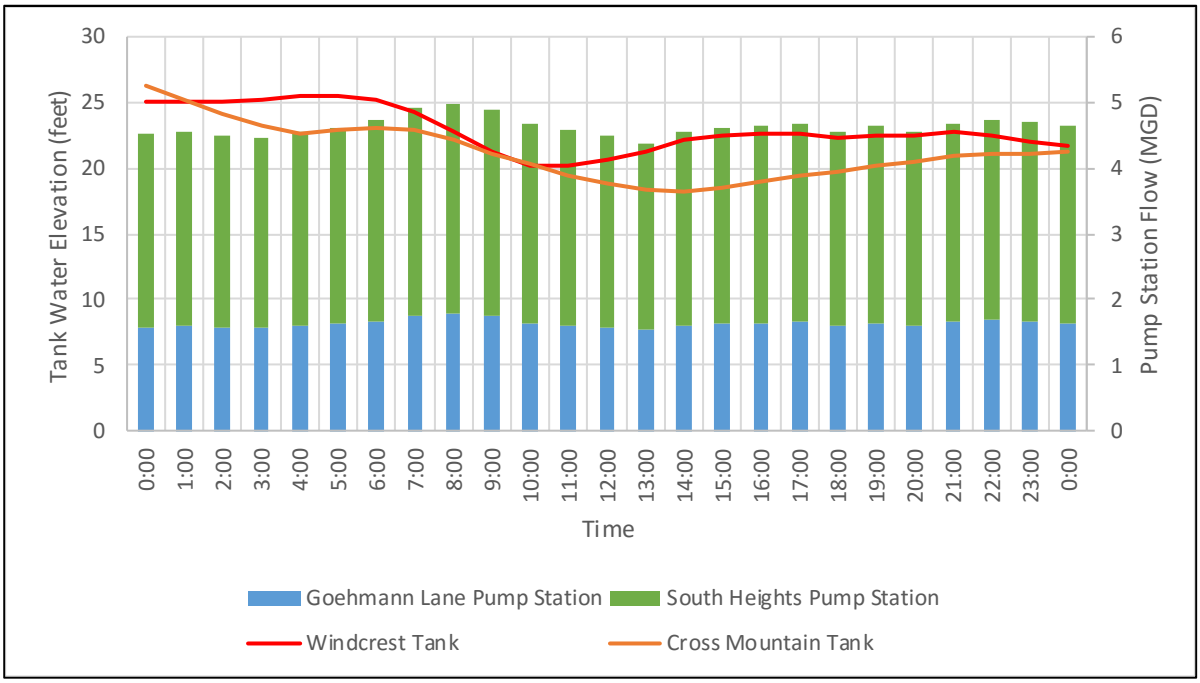

Figure 4-5: 2015 Maximum Day Demand Pumping and Storage – North Pressure Plane

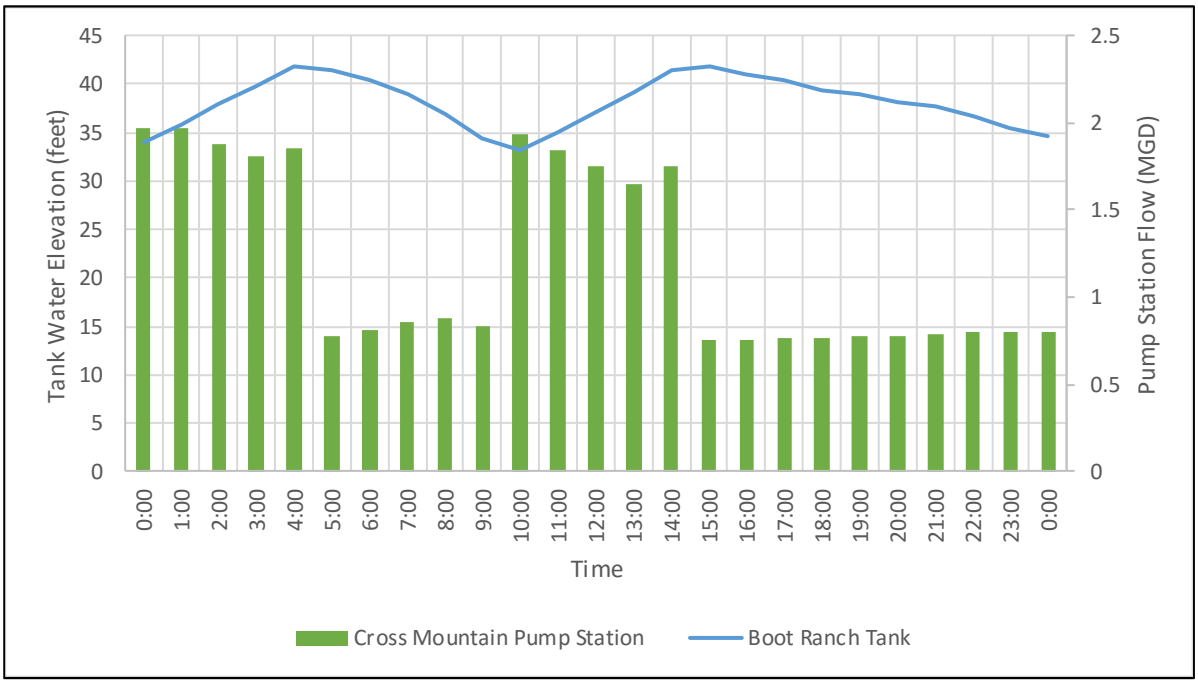

FIGURE 4-6
CITY OF FREDERICKSBURG
EXISTING WATER SYSTEM PEAK HOUR PRESSURES

LEGEND

Peak Hour Pressure

- Less than 35 psi
- 35 - 50 psi
- 50 - 80 psi
- 80 - 100 psi
- Greater than 100 psi
- Well
- Storage Tank
- Pump Station

- 8" and Smaller Water Line
- 10" and Larger Water Line
- Transmission Line
- Road
- Stream
- City Limit

FREESE AND NICHOLS

CITY OF Fredericksburg ESTABLISHED 1846

PRESSURE PLANES

- North Pressure Plane
- South Pressure Plane

Boot Ranch Tank
Overflow Elevation: 2,074'
(1) - 1.0 MG GST
Stehling Well - 300 gpm
Boot Ranch Well - 500 gpm

Cross Mountain Tank
Overflow Elevation: 1,859'
(1) - 1.0 MG GST
(2) - 1,360 gpm pump

Stone Ridge Pump Station
(1) - Hydroneumatic Tank
(3) - 450 gpm pumps

Windcrest Tank
Overflow Elevation: 1,859'
(1) - 1.0 MG GST
(2) - 400 gpm pumps
(1) - 750 gpm pump

South Heights Pump Station
(3) - 1,000 gpm pumps
(1) - 0.50 MG GST

Goehmann Lane Pump Station
(2) - 1,050 gpm pumps
(1) - 0.50 MG GST

Knauth Well Field
Production - 2,200 gpm

Boerner Well Field
Production - 6,000 gpm

0 2,000 4,000
SCALE IN FEET

Created By Freese and Nichols, Inc.
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Location: H:\W_WW_PLANNING\Final_Report\(Figure_4-6)_Peak_Hour_Pressure.mxd
Updated: Wednesday, January 25, 2017 1:24:49 PM

FIGURE 4-7
CITY OF FREDERICKSBURG
EXISTING WATER SYSTEM AVAILABLE FIRE FLOW

LEGEND

Available Fire Flow

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 2,000 gpm
- 2,000 - 3,000 gpm
- Greater than 3,000 gpm
- Well
- Storage Tank
- Pump Station

- 8" and Smaller Water Line
- 10" and Larger Water Line
- Transmission Line
- Road
- Stream
- City Limit
- ETJ Boundary

FREESE AND NICHOLS

CITY OF Fredericksburg ESTABLISHED 1846

Boot Ranch Tank
Overflow Elevation: 2,074'
(1) - 1.0 MG GST
Stehling Well - 300 gpm
Boot Ranch Well - 500 gpm

Cross Mountain Tank
Overflow Elevation: 1,859'
(1) - 1.0 MG GST
(2) - 1,360 gpm pump

Stone Ridge Pump Station
(1) - Hydroneumatic Tank
(3) - 450 gpm pumps

Windcrest Tank
Overflow Elevation: 1,859'
(1) - 1.0 MG GST
(2) - 400 gpm pumps
(1) - 750 gpm pump

South Heights Pump Station
(3) - 1,000 gpm pumps
(1) - 0.50 MG GST

Goehmann Lane Pump Station
(2) - 1,050 gpm pumps
(1) - 0.50 MG GST

Knauth Well Field
Production - 2,200 gpm

Boerner Well Field
Production - 6,000 gpm

0 2,000 4,000
SCALE IN FEET

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4.6.2 Future System Analysis

Using the recommended criteria outlined in **Section 4.5**, water system improvements were developed to accommodate the anticipated residential and non-residential growth over the next 20 years. Challenges facing the water system include improving areas of low pressure and available fire flow, providing redundancy in ground storage to the North PP, providing additional pumping to the South PP, and providing service to areas of future growth where little or no infrastructure currently exists. The following key observations and recommendations result from modeling and evaluating the distribution system.

A. Improve System Pressures

The existing distribution system has low pressures near the Oaks of Windcrest neighborhood and in the North PP in the Stone Ridge neighborhood. FNI recommends expanding the service area of the Windcrest pump station and adding a hydropneumatic tank to improve the system pressures. The Stone Ridge hydropneumatic tank can be taken out of service if a new pressure reducing valve is added along Ellebracht Drive to allow the area to be served from the Boot Ranch tank. This pressure reducing valve would create a pressure reducing valve zone in the North PP.

B. Pumping and Storage

The Windcrest PS and South Heights PS both have empty slots available for additional pumps. At the Windcrest PS, an additional pump will allow for more operational flexibility and ability to make repairs on the existing pumps. An additional pump at the South Heights PS will provide additional pumping capacity to serve growth. Longer term, FNI also recommends a new pump station along Highway 290 to pump water from the Knauth well field. This pump station will provide capacity to meet future demands and redundancy for pump station repairs or line breaks. New ground storage tanks are recommended at Cross Mountain and Boot Ranch to allow for repairs and maintenance on the existing ground storage tanks. A new elevated storage tank is recommended in the Stone Ridge neighborhood to provide operational flexibility.

C. Growth

New distribution mains are required to provide service to new developments in the water service area. Lines were sized based on the demands of each specific area served and a minimum diameter of 8-inches.

Once these improvements were added to the existing water system, hydraulic analyses were performed under 2035 maximum day demand conditions. Any areas of high headloss, high velocity, or low pressure were adjusted accordingly to ensure appropriate sizing of system improvements. The improvements were phased by planning year depending on when the areas being served (shown in **Figure 2-2**) were projected to develop and the needed capacity recommendations by pressure plane. To ensure the improvements would operate correctly as phased, a 24-hour EPS model run was performed under maximum day demand conditions for each future planning period. **Figures 4-8** to **4-13** present the modeled pumping and tank levels for 2020, 2025, and 2035, respectively.

Figure 4-8: 2020 Maximum Day Demand Pumping and Storage – South Pressure Plane

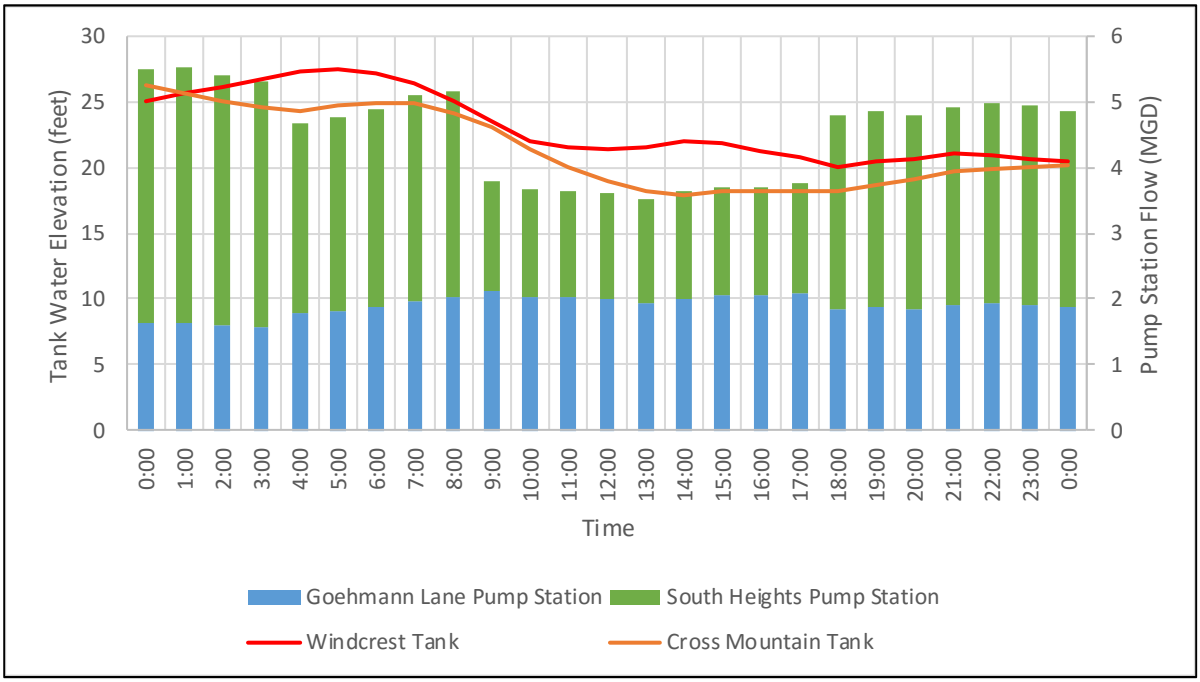


Figure 4-9: 2020 Maximum Day Demand Pumping and Storage - North Pressure Plane

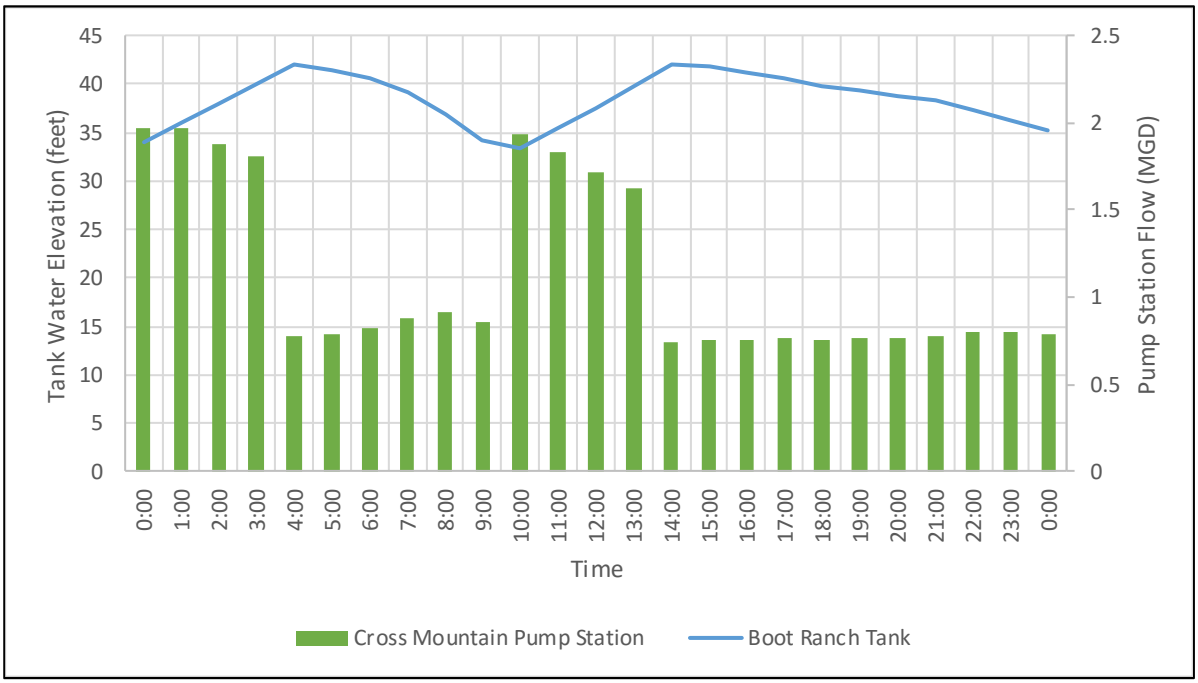


Figure 4-10: 2025 Maximum Day Demand Pumping and Storage - South Pressure Plane

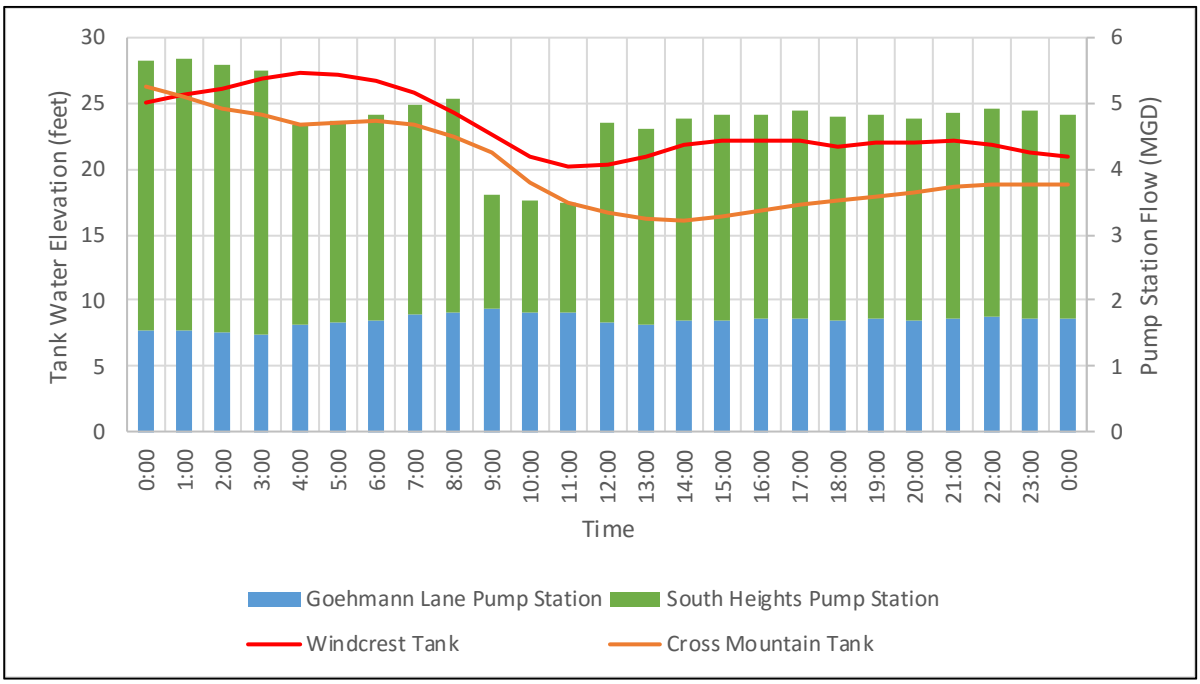


Figure 4-11: 2025 Maximum Day Demand Pumping and Storage - North Pressure Plane

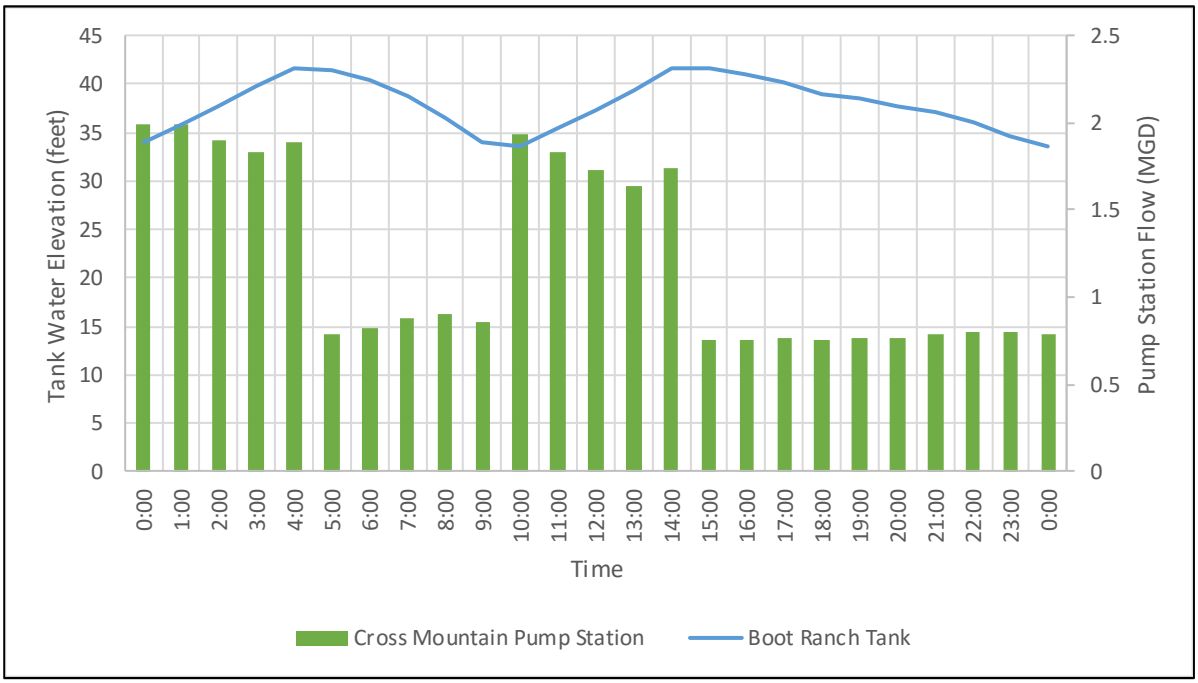


Figure 4-12: 2035 Maximum Day Demand Pumping and Storage - South Pressure Plane

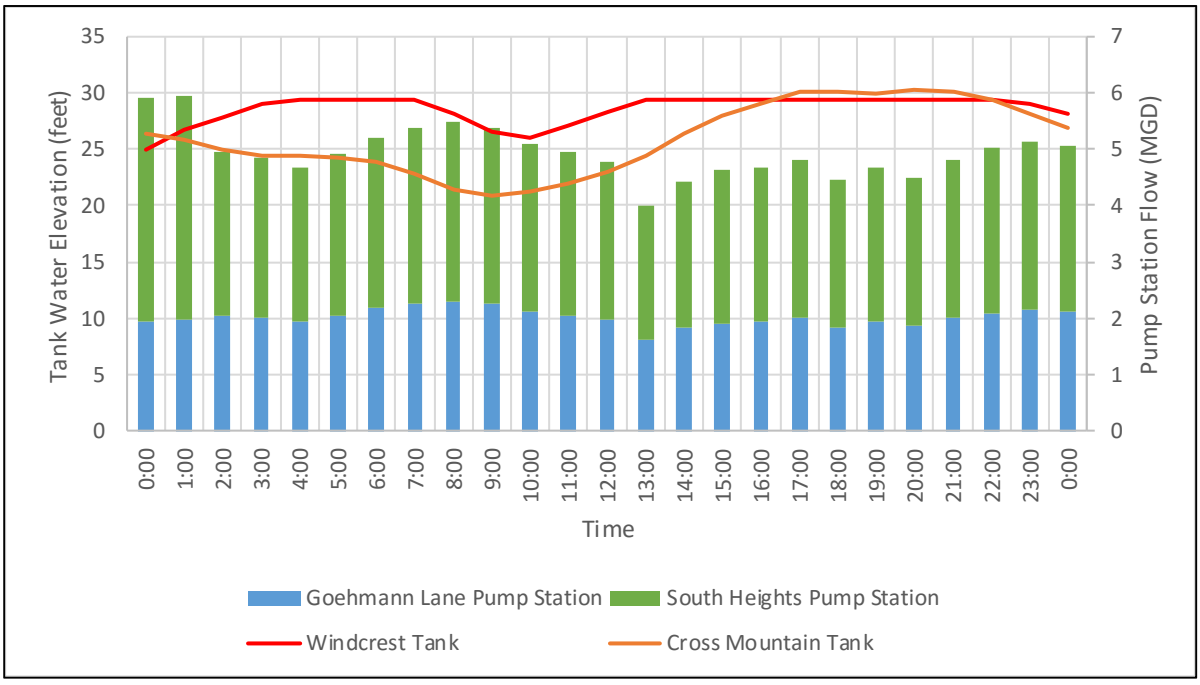


Figure 4-13: 2035 Maximum Day Demand Pumping and Storage - North Pressure Plane

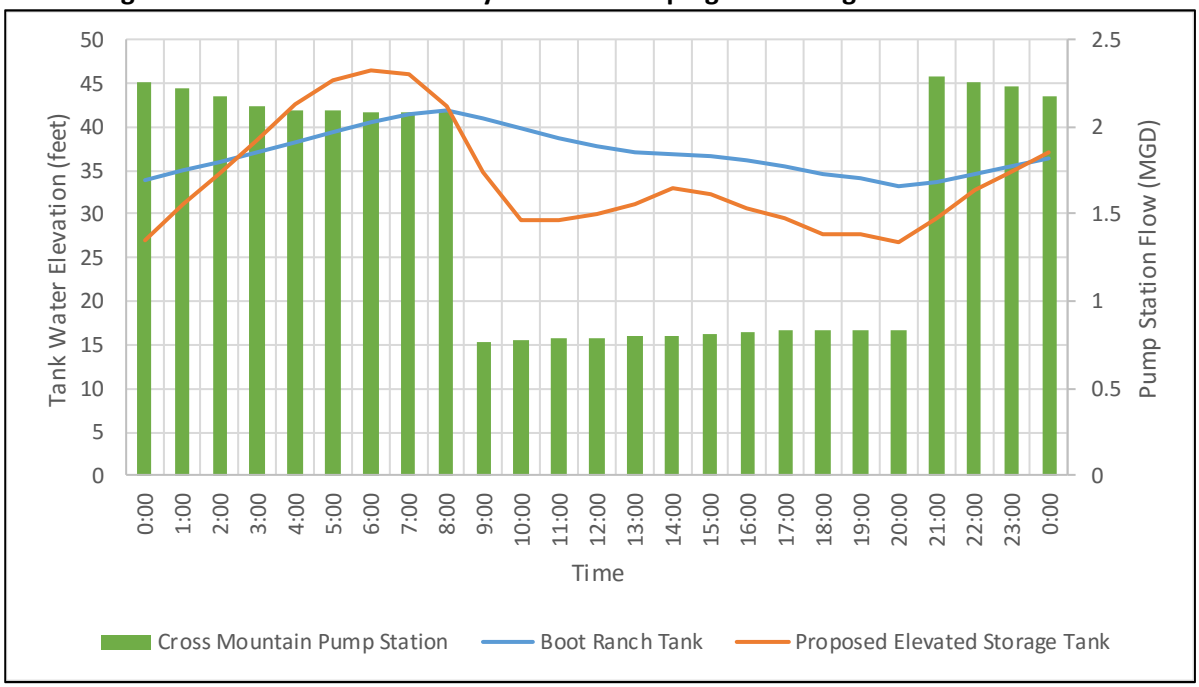


Figure 4-14 shows minimum pressures during 2035 maximum day demand conditions. Minimum pressures shown on the map represent the lowest value of the pressures experienced during the 24-hour simulation, usually occurring during the peak hour demand. No pressures below 35 psi were observed in the modeling results. **Figure 4-15** shows available fire flows during 2035 maximum day demand conditions.

FIGURE 4-14
CITY OF FREDERICKSBURG
2035 WATER SYSTEM PEAK HOUR PRESSURES

LEGEND

Peak Hour Pressure

- Less than 35 psi
- 35 - 50 psi
- 50 - 80 psi
- 80 - 100 psi
- Greater than 100 psi
- Proposed Pressure Reducing Valve
- Proposed Closed Valve
- Proposed Pump Station
- Proposed Ground Storage Tank
- Proposed Elevated Storage Tank
- Proposed Hydropneumatic Tank
- Proposed Water Line Improvement
- Proposed Transmission Line
- Well
- Ground Storage Tank
- Pump Station
- 8" and Smaller Existing Water Line
- 10" and Larger Existing Water Line
- Transmission Line
- Road
- Stream
- City Limit
- ETJ Boundary

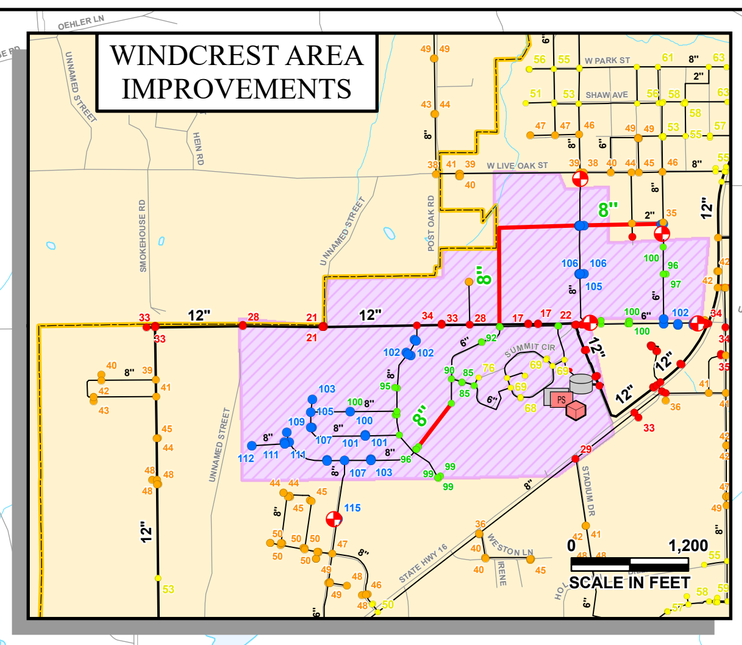
FREESE AND NICHOLS

CITY OF Fredericksburg ESTABLISHED 1846

PRESSURE PLANES

- Revised North
- North PRV
- South
- Windcrest

WINDCREST AREA IMPROVEMENTS



Boot Ranch Tank
Overflow Elevation: 2,074'
(1) - 1.0 MG GST
Stehling Well - 300 gpm
Boot Ranch Well - 500 gpm

Proposed 1.0 MG Ground Storage Tank

Cross Mountain Tank
Overflow Elevation: 1,859'
(1) - 1.0 MG GST
(2) - 1,360 gpm pump

Proposed 1.0 MG Ground Storage Tank

Proposed 0.5 MG Elevated Storage Tank
Overflow Elevation: 2,074'

Proposed Pressure Reducing Valve

Stone Ridge Pump Station
(1) - Hydropneumatic Tank
(3) - 450 gpm pumps
(Decommission)

Windcrest Tank
Overflow Elevation: 1,859'
(1) - 1.0 MG GST
(2) - 400 gpm pumps
(1) - 400 gpm pump

Proposed Hydropneumatic Tank

South Heights Pump Station
(3) - 1,000 gpm pumps
(1) - 0.50 MG GST
(1) - 1,000 gpm pump

Goehmann Lane Pump Station
(2) - 1,050 gpm pumps
(1) - 0.50 MG GST
Rehabilitation

Knauth Well Field
Production - 2,200 gpm

Boerner Well Field
Production - 6,000 gpm

Proposed 1.0 MG Ground Storage Tank
(2) - 1,050 gpm pump

0 2,000 4,000
SCALE IN FEET

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FIGURE 4-15
CITY OF FREDERICKSBURG
2035 WATER SYSTEM AVAILABLE FIRE FLOW

AVAILABLE FIRE FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 2,000 gpm
- 2,000 - 3,000 gpm
- Greater than 3,000 gpm

LEGEND

- Proposed Pressure Reducing Valve
- Proposed Closed Valve
- Proposed Pump Station
- Proposed Ground Storage Tank
- Proposed Elevated Storage Tank
- Proposed Hydropneumatic Tank
- Proposed Water Line Improvement
- Proposed Transmission Line
- Pump Station
- Ground Storage Tank
- 8" and Smaller Existing Water Line
- 10" and Larger Existing Water Line
- Transmission Line
- Road
- Stream
- City Limit
- ETJ Boundary

FREESE AND NICHOLS

CITY OF Fredericksburg ESTABLISHED 1846

Boot Ranch Tank
Overflow Elevation: 2,074'
(1) - 1.0 MG GST
Stehling Well - 300 gpm
Boot Ranch Well - 500 gpm

Proposed
1.0 MG Ground Storage Tank

Cross Mountain Tank
Overflow Elevation: 1,859'
(1) - 1.0 MG GST
(2) - 1,360 gpm pump

Proposed
1.0 MG Ground Storage Tank

Proposed
0.5 MG Elevated Storage Tank
Overflow Elevation: 2,074'

Proposed
Pressure Reducing Valve

Stone Ridge Pump Station
(1) - Hydropneumatic Tank
(3) - 450 gpm pumps
(Decommission)

Windcrest Tank
Overflow Elevation: 1,859'
(1) - 1.0 MG GST
(2) - 400 gpm pumps
(1) - 400 gpm pump

South Heights Pump Station
(3) - 1,000 gpm pumps
(1) - 0.50 MG GST
(1) - 1,000 gpm pump

Proposed
Hydropneumatic Tank

Goehmann Lane Pump Station
(2) - 1,050 gpm pumps
(1) - 0.50 MG GST
Rehabilitation

Knauth Well Field
Production - 2,200 gpm

Boerner Well Field
Production - 6,000 gpm

Proposed
1.0 MG Ground Storage Tank
(2) - 1,050 gpm pump

0 2,000 4,000
SCALE IN FEET

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CIP projects were identified for each planning period based on modeling results and FNI capacity recommendations. Below is a summary of CIP projects and the issues that triggered them for each planning period.

- 2020:
  - Rehabilitation of the Goehmann Lane PS due to poor condition.
  - Add pressure reducing valve in the North PP to create the North PRV zone and improve system pressures.
  - Additional ground storage tanks to allow for redundancy and tank maintenance on existing tanks.
  - Line improvements to reduce headloss in the distribution system.
  - Increased pumping capacity at South Heights PS and Windcrest PS.
  - Additional elevated storage in the North PP to serve growth.
  - Boundary changes in the Windcrest PP to improve system pressures.
- 2025:
  - Additional pumping from Knauth well field to provide redundancy and serve growth.
  - Replace existing small diameter lines to improve fire flow and transmission capacity.
  - Added water lines in the South PP to serve development.
- 2035:
  - Line improvements to improve transmission capacity.

5.0 WATER SYSTEM CAPITAL IMPROVEMENT PLAN

A capital improvements plan (CIP) was developed for the City of Fredericksburg based on hydraulic modeling results and the condition of assets. The recommended improvements will provide the required capacity and reliability to meet projected water demands through 2035 conditions. The recommended projects are presented on **Figure 5-1**. Locations shown for new line and other recommended improvements were generalized for hydraulic analysis. Specific alignments and sites will be determined as part of the design process. It is recommended that these projects be constructed generally in the order listed. However, development patterns may make it necessary to construct some projects sooner or later than anticipated. Detailed descriptions and cost estimates for the proposed water system projects are included in **Appendix H**.

Table 5-1 summarizes the costs of the water capital improvements plan for the City of Fredericksburg. The costs are in 2016 dollars and include an allowance for engineering, surveying, and contingencies. Cost estimates do not include allowances for right-of-way acquisition.

Table 5-1: Water System Capital Improvements Plan

Phase	CIP No.	Project Name	Cost
5-Year	1	Goehmann Lane Pump Station Rehabilitation	$598,000
	2	North Pressure Plane Pressure Reducing Valve	$134,600
	3	Cross Mountain Ground Storage Tank	$1,868,800
	4	Boot Ranch Ground Storage Tank	$1,868,800
	5	Windcrest Area Improvements	$885,100
	6	12-inch Line from South Heights Pump Station	$807,300
	7	12-inch Line to New Development	$598,000
	8	1,000 gpm Pump at South Heights Pump Station	$299,000
	9	400 gpm Pump at Windcrest Pump Station	$149,500
	10	0.5 MG Elevated Storage Tank	$2,706,000
			$9,915,100
10-Year	11	16-inch Line to Proposed Pump Station	$6,879,200
	12	Proposed Pump Station and Ground Storage Tank	$7,242,600
	13	12-inch Line along Summit Forest	$418,600
	14	12-inch Line along Hale Street	$1,883,700
	15	12-inch Line along Highway 87	$3,698,700
	16	12-inch Line along North Adams Street	$1,390,400
			$21,513,200
20-Year	17	12-inch Line along Morning Glory Drive	$2,362,100
	18	12-inch Line along East Centre Street	$1,166,100
			$3,528,200
			$34,956,500

FIGURE 5-1
CITY OF FREDERICKSBURG
WATER SYSTEM CAPITAL IMPROVEMENTS PLAN

LEGEND

2020 Proposed Improvements

- Proposed Pressure Reducing Valve
- Proposed Closed Valve
- Proposed Pump Station
- Proposed Ground Storage Tank
- Proposed Elevated Storage Tank
- Proposed Hydropneumatic Tank
- Proposed Water Line Improvement

2025 Proposed Improvements

- Proposed Pump Station
- Proposed Ground Storage Tank
- Proposed Water Line Improvement
- Proposed Transmission Line

2035 Proposed Improvements

- Water Line Improvement

Existing Water System

- Well
- Pump Station
- Ground Storage Tank
- 8" and Smaller Existing Water Line
- 10" and Larger Existing Water Line
- Transmission Line
- Road
- Stream
- City Limit
- ETJ Boundary

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2020 Project ID
2025 Project ID
2035 Project ID

PRESSURE PLANES
- Revised North
- North PRV
- South
- Windcrest

WINDCREST AREA IMPROVEMENTS

Boot Ranch Tank
Overflow Elevation: 2,074'
(1) - 1.0 MG GST
Stehling Well - 300 gpm
Boot Ranch Well - 500 gpm

Proposed 1.0 MG Ground Storage Tank — 4

Cross Mountain Tank
Overflow Elevation: 1,859'
(1) - 1.0 MG GST
(2) - 1,360 gpm pump

Proposed 1.0 MG Ground Storage Tank — 3

Proposed 0.5 MG Elevated Storage Tank
Overflow Elevation: 2,074' — 10

Proposed Pressure Reducing Valve — 2

Stone Ridge Pump Station
(1) - Hydropneumatic Tank
(3) - 450 gpm pumps
(Decommission) — 2

Windcrest Tank
Overflow Elevation: 1,859'
(1) - 1.0 MG GST
(2) - 400 gpm pumps
(1) - 400 gpm pump — 9

Proposed Hydropneumatic Tank — 5

South Heights Pump Station
(3) - 1,000 gpm pumps
(1) - 0.50 MG GST
(1) - 1,000 gpm pump — 8

Goehmann Lane Pump Station
(2) - 1,050 gpm pumps
(1) - 0.50 MG GST
Rehabilitation — 1

Knauth Well Field
Production - 2,200 gpm

Boerner Well Field
Production - 6,000 gpm

Proposed 1.0 MG Ground Storage Tank
(2) - 1,050 gpm pump — 12

0 2,000 4,000
SCALE IN FEET

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6.0 WASTEWATER FLOWS

The performance of a wastewater collection system is dependent on the amount of water being conveyed through the system. To determine locations where future capacity improvements are necessary, existing and future wastewater flow projections must be developed. Fredericksburg's wastewater flows are generated by residential and non-residential sources. Future population and non-residential wastewater usage projections are critical to the development of short and long term capital improvements. FNI developed projected wastewater flows for the 5-year, 10-year, and 20-year planning periods for the Wastewater Master Plan. These flows were utilized in the wastewater hydraulic model to plan future wastewater system improvements. Wastewater collection system infrastructure, including lift stations, is sized to convey peak wastewater flows.

6.1 HISTORICAL WASTEWATER FLOWS

Historical wastewater treatment plant (WWTP) influent flows were provided by the City. The average day flows to the WWTP for the past five years are summarized in **Table 6-1**.

Table 6-1: Historical WWTP Flows

	Average Daily WWTP Influent (MGD)	Total Rainfall Depth (Inches)
2010	1.07	19.3
2011	1.03	10.3
2012	1.02	19.9
2013	0.99	23.7
2014	0.98	24.1
2015	1.06	34.4

A sewer return rate was calculated for the wastewater collection system based on water production and WWTP flows from 2010 to 2015. FNI calculated the percentage of the water consumed based on historical water production data. The resulting rates are presented in **Table 6-2**.

Table 6-2: Historical Wastewater Return Rates

	Average Daily Water Production (MGD)	Average Daily WWTP Influent (MGD)	Return Rate (%)
2010	1.99	1.07	54%
2011	2.45	1.03	42%
2012	2.05	1.02	50%
2013	2.16	0.99	46%
2014	2.03	0.98	48%
2015	2.09	1.06	51%
Average	**2.13**	**1.02**	**48%**

6.2 PROJECTED WASTEWATER FLOWS

Future wastewater flows were developed by combining flow based on design criteria for projected growth to 2015 historical wastewater flow data gathered through October to determine future average day flows. Design criteria used for developing the average day flows for the 2020, 2025, and 2035 planning periods was developed by analyzing the historical wastewater flows, water distribution and billing records, populations, and commercial acreage. Based on this analysis, FNI recommends a 54 gpcd for residential population and 360 gpad for non-residential acres. These values represent a conservative 60% wastewater return rate of the projected water demand criteria. **Table 6-3** summarizes the wastewater flow rates utilized to calculate projected average day wastewater flows.

Table 6-3: Wastewater Flow Rate Design Criteria

Wastewater Flow Type	Flow Rate
Residential	54 gpcd
Non-Residential	360 gpad

Future average day wastewater flows were calculated by applying the design criteria in **Table 6-3** only to the new population and non-residential acreage in each planning period. Peak wastewater flows from future growth were calculated using the peak flow to average day flow peaking factor measured during the wastewater flow monitoring as a part of this master plan and is discussed in **Section 6.3**. All calculated future flows were added to the existing flows to determine the total projected wastewater flows in each planning period. **Table 6-4** summarizes the total projected average day wastewater flows by planning

period. Total historical and projected average day flows for the WWTP are graphed against the current TCEQ permitted capacities of the WWTP on **Figure 6-1**.

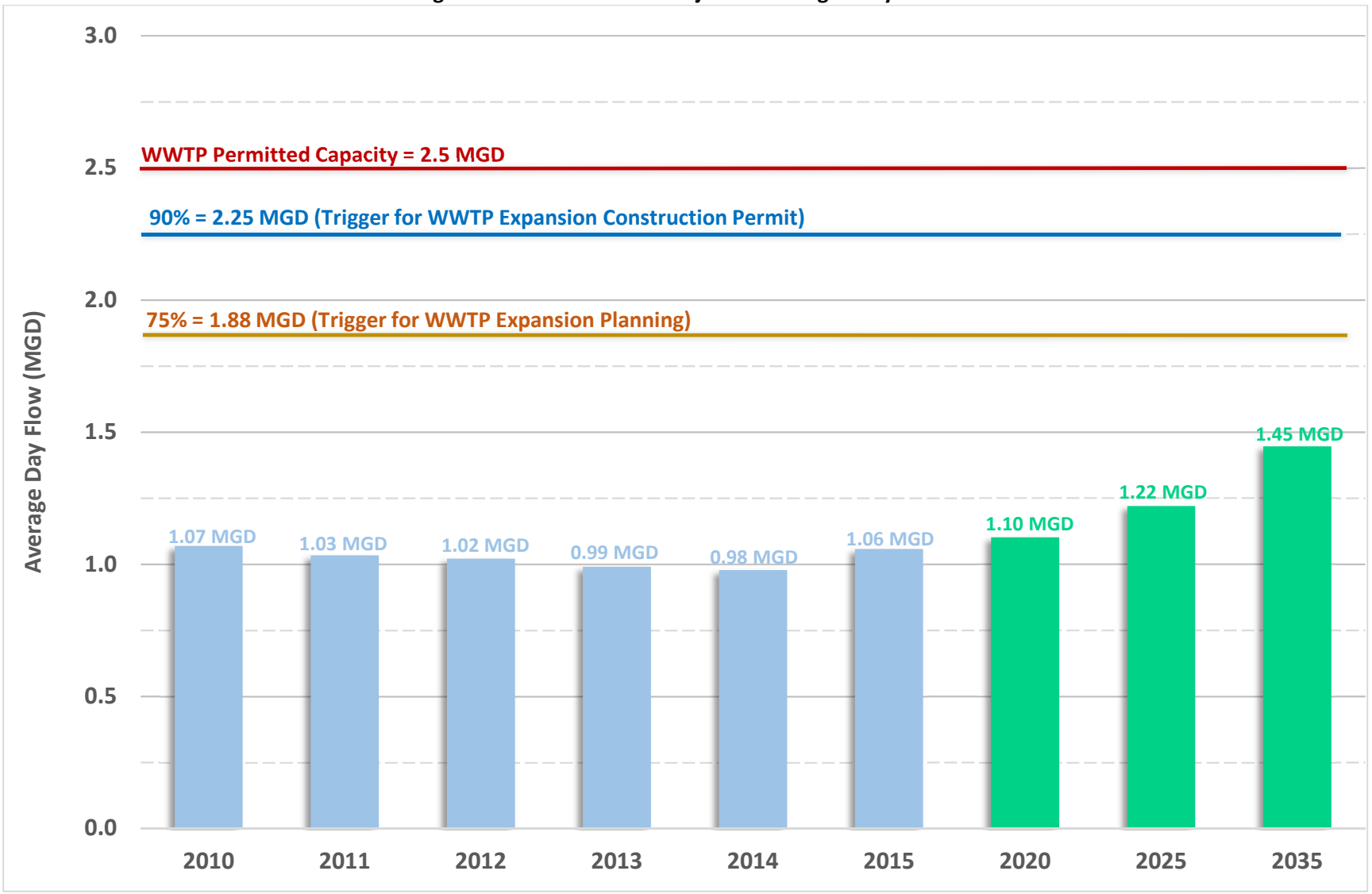
Table 6-4: Projected Wastewater Flows

	Average Day Flow (MGD)	Projected Peak Flow (MGD)
2015	1.06[1]	2.67[2]
2020	1.10	2.77
2025	1.22	3.12
2035	1.45	3.74

(1) Based on data collected at the WWTP January to October, 2015
(2) Based on flow monitoring data collected from October 24, 2015 to

TCEQ §305.126, commonly referred to as the 75/90 rule, requires a WWTP permit holder to begin planning for expansion of the treatment facility when the average daily or average annual flow reaches 75% of the permitted capacity. When the average daily or average annual flow reaches 90% of the permitted capacity, the permit holder shall obtain necessary authorization from the commission to commence construction of the necessary additional treatment facilities. By 2035 projected flows reach 58% of the WWTP permitted capacity. No actions for expansion of the WWTP will be necessary before 2035.

Figure 6-1: Historical and Projected Average Daily Flows



6.3 FLOW MONITORING

FNI conducted flow monitoring and recorded rainfall as a part of the Master Plan. The flow meter and rainfall data was used to characterize dry weather and wet weather flows at key points within the wastewater system, evaluate wet weather inflow and infiltration (I/I), and calibrate the hydraulic model of the wastewater collection system.

The installation and maintenance of the flow meters and rain gauges was performed by ADS Environmental Services (ADS). The following sections summarize the collected flow and rainfall data, as well as the characterization of I/I levels within the wastewater collection system. The full flow monitoring report, as prepared by ADS, is provided in **Appendix I**.

6.3.1 Field Data Collection

Field data collection was performed in the wastewater collection system over a 45-day period beginning October 21,2015. One flow monitor was relocated on November 30, 2015 and data was collected for another 45 day period ending on January 15, 2016, a total of 87 days. Dry weather and wet weather performance within the existing wastewater system was evaluated by installing temporary sewer flow meters to observe and document existing flow conditions. The locations for flow meters, rain gauges and flow meter basins are shown on **Figure 6-2**. A schematic of the flow meter locations is shown on **Figure 6-3**. Rainfall data was simultaneously collected with rain gauges located at the WWTP. A total of six flow monitors and two rain gauges were used for this study.

FIGURE 6-2
CITY OF FREDERICKSBURG
FLOW MONITOR LOCATIONS

SEWER METER BASINS

- FRB-01
- FRB-01A
- FRB-02
- FRB-03
- FRB-04
- FRB-05
- FRB-06

LEGEND

- Flow Monitor Location
- Rain Gauge
- Lift Station
- Wastewater Treatment Plant
- 8" and Smaller Sewer Line
- 10" and Larger Sewer Line
- Force Main
- Road
- 5ft Contour
- Stream
- City Limit
- ETJ

CITY OF Fredericksburg ESTABLISHED 1846

FREESE AND NICHOLS

Boot Ranch D
Lift Station
36 gpm

Boot Ranch A
Lift Station
170 gpm

Boot Ranch B
Lift Station
171 gpm

Boot Ranch C
Lift Station
206 gpm

Walk Bridge
Lift Station
120 gpm

Herb Farm
Lift Station
20 gpm

Milam Street
Lift Station
80 gpm

FBG Inn & Suites
Lift Station

Windcrest
Lift Station
300 gpm

Green Meadows
Lift Station
1,000 gpm

Bob White
Lift Station

Consolidated Warehouse
Lift Station
131 gpm

Park
Lift Station

Fairgrounds
Lift Station
225 gpm

Beverly Drive
Lift Station

East Side
Lift Station

Wastewater Treatment Plant
Permitted Capacity = 2.5 MGD

Heritage Hill Country
Lift Station
185 gpm

Hill Country University
Lift Station

FRB-01 FRB-01A FRB-02 FRB-03 FRB-04 FRB-05 FRB-06

RG-01 RG-02

0 1,500 3,000
SCALE IN FEET

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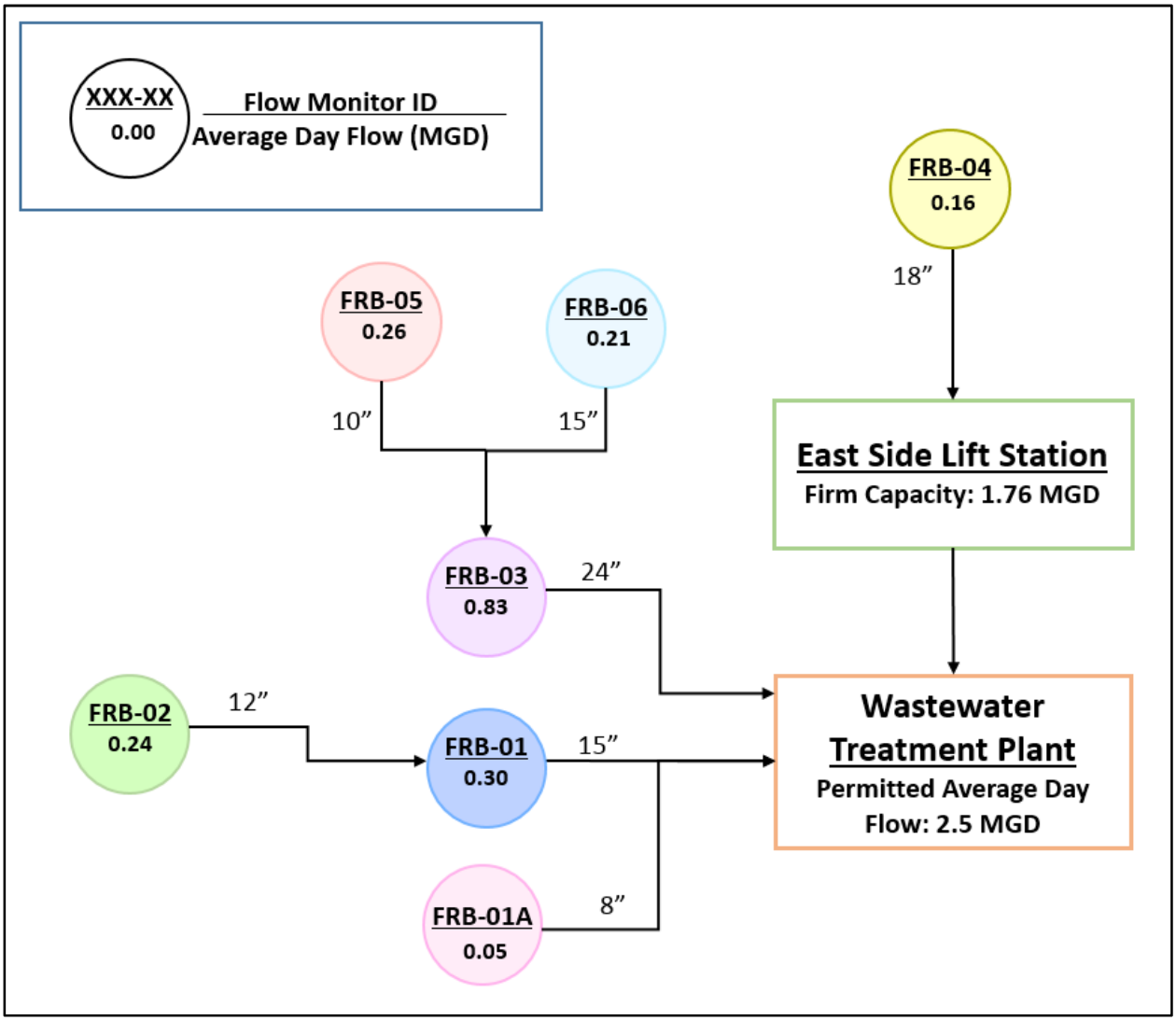
Figure 6-3: Flow Meter Connectivity Schematic



6.3.2 Flow Monitor and Rain Gauge Data Evaluation

Flow meter and rain gauge data were collected in 15-minute time step intervals. The flow meter and rain gauge data for the entirety of the field testing period were evaluated by FNI. Hydrographs and flow depth plots for each flow meter site are provided in **Appendix J**. The hydrographs display flow rate data vs. time for the duration of the field testing period, along with the observed rainfall intensities. Similarly, the depth plots show the depth of flow vs. time.

A. Rain Gauge Data Evaluation

A total of three rainfall events were observed during the flow monitoring period. This rainfall data and associated measured flow responses were used to calibrate the hydraulic model to observed wet weather conditions. Total rainfall depths and durations for the observed rainfall events during the field testing period are given in **Table 6-5**. The observed 15-minute rainfall intensities are plotted with the flow meter data on the hydrographs in **Appendix J**.

Table 6-5: Rainfall Event Data during Flow Monitoring

Date	Duration (Hours)	Rain Gauge Total (Inches)	
		FRB-RG1	FRB-RG2
10/23/2015	32	3.30	3.16
10/30/2015	23	1.47	1.47
12/13/2015	7	1.15	1.04

B. Flow Monitoring Data Evaluation

Dry weather flow conditions are characterized by evaluating flow monitor data observed during normal conditions, excluding wet weather events and the periods associated with the recovery from these events. The average dry weather and maximum dry weather flow rates are determined from the dry weather diurnal pattern for each flow monitor location and are summarized in **Table 6-6**. The resulting dry weather peaking factor (PF_D) is also provided. The wet weather peaking factor (PF_W) is also provided. Wet weather peaking factors above 4.0 are considered to be excessive. The highest peaking factor occurs in FRB-02. No basin's wet weather peaking factor exceeds 4.0.

Table 6-6: Summary of Flow Monitoring Data

Flow Monitor	Average Dry Weather Flow (MGD)	Maximum Dry Weather Flow (MGD)	Maximum Wet Weather Flow (MGD)	Dry Weather Peaking Factor (PF_D)	Wet Weather Peaking Factor (PF_W)
FRB-01	0.30	0.41	0.57	1.38	1.93
FRB-01A	0.05	0.11	0.15	2.16	3.06
FRB-02	0.24	0.33	0.75	1.38	3.13
FRB-03	0.83	1.07	1.95	1.29	2.34
FRB-04	0.16	0.25	0.29	1.55	1.85
FRB-05	0.26	0.37	0.69	1.42	2.62
FRB-06	0.21	0.33	0.57	1.56	2.71

The maximum flow depths during dry weather and wet weather flows, the wet weather depth-to-diameter (d/D) ratios, and the surcharge and manhole depths at each flow monitoring site are provided in **Table 6-7**. The wet weather d/D ratios show that none of the flow meter locations surcharged.

Table 6-7: Summary of Flow Monitoring Data – Depth

Flow Monitor	Diameter (Inches)	Maximum Dry Weather Depth (Inches)	Dry Weather Depth / Diameter (%)	Maximum Wet Weather Depth (Inches)	Wet Weather Depth / Diameter (%)
FRB-01	15	3.89	26%	9.27	62%
FRB-01A	8	2.81	35%	3.91	49%
FRB-02	12	5.34	45%	6.72	56%
FRB-03	24	7.12	30%	10.02	42%
FRB-04	18	1.64	9%	1.88	10%
FRB-05	10	5.31	53%	7.02	70%
FRB-06	15	3.81	25%	5.41	36%

C. Rainfall Derived Inflow and Infiltration (RDII) Analysis

Rainfall Derived inflow and infiltration (RDII) rates were calculated for each flow meter basin. Dry weather flow rates were correlated with the wet weather flow responses from the rainfall events to calculate an average normalized RDII rate for each basin. The results of the RDII analysis are presented in **Table 6-8**.

Table 6-8: Normalized RDII Rates by Flow Meter Basin

Flow Monitor Basin	Normalized RDII (Gal/Linear Foot)
FRB-01	6.40
FRB-01A	-
FRB-02	2.43
FRB-03	1.52
FRB-04	0.65
FRB-05	1.06
FRB-06	1.23

FIGURE 6-4
CITY OF FREDERICKSBURG
NORMALIZED RDII RANKINGS

FLOW MONITORING
RDII RANKINGS

- Low (0 - 2 gal/LF)
- Medium (2 - 4 gal/LF)
- High (+4 gal/LF)

LEGEND

- Flow Monitor Location
- Lift Station
- Wastewater Treatment Plant
- 8" and Smaller Sewer Line
- 10" and Larger Sewer Line
- Force Main
- Road
- 5ft Contour
- Stream
- City Limit
- ETJ

FREESE AND NICHOLS

Boot Ranch D
Lift Station
36 gpm

Boot Ranch A
Lift Station
170 gpm

Boot Ranch B
Lift Station
171 gpm

Boot Ranch C
Lift Station
206 gpm

FRB-06
(1.23 gal/LF)

FRB-05
(1.06 gal/LF)

FRB-04
(0.65 gal/LF)

FRB-03
(1.52 gal/LF)

FRB-02
(2.43 gal/LF)

FRB-01
(6.4 gal/LF)

Walk Bridge
Lift Station
120 gpm

Herb Farm
Lift Station
20 gpm

Milam Street
Lift Station
80 gpm

FBG Inn & Suites
Lift Station

Windcrest
Lift Station
300 gpm

Beverly Drive
Lift Station

East Side
Lift Station

Green Meadows
Lift Station
1,000 gpm

Bob White
Lift Station

Consolidated Warehouse
Lift Station
131 gpm

Park
Lift Station

Fairgrounds
Lift Station
225 gpm

Wastewater Treatment Plant
Permitted Capacity = 2.5 MGD

Hill Country University
Lift Station

Heritage Hill Country
Lift Station
185 gpm

0 1,500 3,000
SCALE IN FEET

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FRB-01A was not in place during the rainfall events used in the RDII analysis. For that reason, FRB-01A was not included in the analysis. RDII values equal to or greater than 4.0 gallons per linear foot is deemed to be excessive. Values less than 4.0 are moderate and values less than 2.0 gallons per linear foot are deemed low. FRB-01 was the only basin to register a value greater than 4.0. Since the upstream flow meter only registered moderate levels of RDII, FRB-01 is thought to have been affected by flow conditions at the WWTP. This is also discussed in the Wet Weather Calibration **Section 7.3.5.**

7.0 WASTEWATER SYSTEM ANALYSES

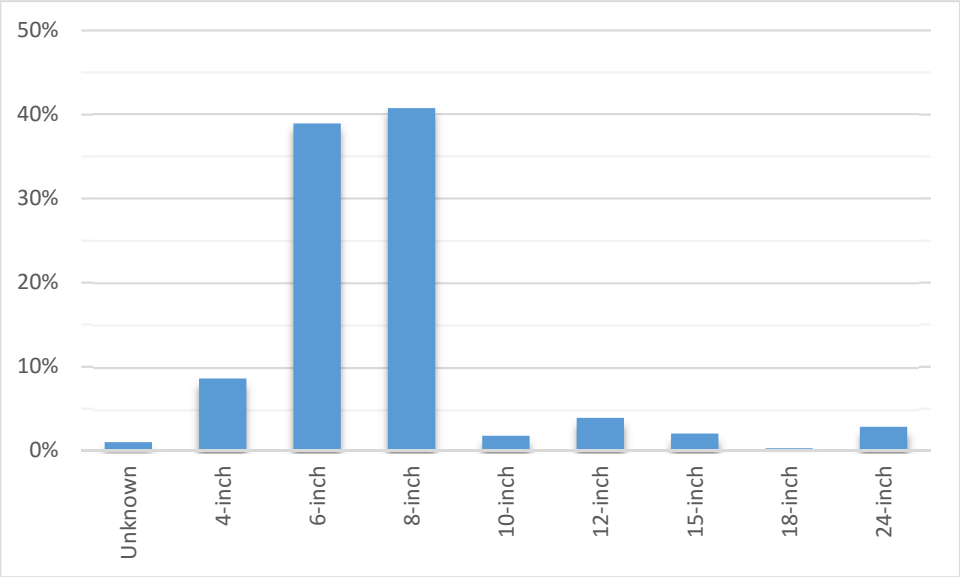
7.1 EXISTING WASTEWATER SYSTEM

The City of Fredericksburg's wastewater system consists of 17 lift stations and associated force mains, a wastewater treatment plant, and a network of gravity mains 4-inches to 24-inches. The City of Fredericksburg owns and operates one wastewater treatment plant (WWTP). The plant has a current permitted capacity of 2.5 MGD annual average day flow (AADF). **Figure 7-2** shows the current collection system for the City of Fredericksburg.

7.1.1 Collection System

The wastewater collection system consists of over 100 miles of collector main and force mains. Wastewater line diameters range from 4- to 24-inches. The majority of the collection system, approximately 90%, is comprised of 8-inch and smaller lines. **Figure 7-1** illustrates the percentage of wastewater line length by diameter. There are three main interceptors serving the eastern, southern, and central portions of the system. Flow from the eastern portion of the system is pumped to the WWTP by the Eastside lift station. Flow from the central portion of the system enters the WWTP through a 24-inch line while the southern portion flows through a 15-inch line.

Figure 7-1: Wastewater Line Size by Length



7.1.2 Lift Stations

There are 19 lift stations within the Fredericksburg collection system. The City owns and maintains 18 lift stations. **Table 7-1** provides a summary of each of the lift stations along with the existing firm capacity (maximum pumping rate with the largest pump out of service) and force main sizes.

FIGURE 7-2
CITY OF FREDERICKSBURG
EXISTING WASTEWATER SYSTEM

LEGEND

- Lift Station
- Wastewater Treatment Plant
- 8" and Smaller Sewer Line
- 10" and Larger Sewer Line
- Force Main
- Road
- Stream
- City Limit
- ETJ

Boot Ranch D
Lift Station
36 gpm

Boot Ranch A
Lift Station
170 gpm

Boot Ranch B
Lift Station
171 gpm

Boot Ranch C
Lift Station
206 gpm

Walk Bridge
Lift Station
120 gpm

Herb Farm
Lift Station
20 gpm

Milam Street
Lift Station
80 gpm

FBG Inn & Suites
Lift Station

Windcrest
Lift Station
300 gpm

Beverly Drive
Lift Station

East Side
Lift Station

Wastewater Treatment Plant
Permitted Capacity = 2.5 MGD

Green Meadows
Lift Station
1,000 gpm

Bob White
Lift Station

Consolidated Warehouse
Lift Station
131 gpm

Park
Lift Station

Fairgrounds
Lift Station
225 gpm

Hill Country
Lift Station

Heritage Hill Country
Lift Station
185 gpm

0 2,000 4,000
SCALE IN FEET

Table 7-1: Existing Lift Station Capacities and Force Mains

Lift Station Name	Firm Capacity (gpm)	Force Main Diameter (Inches)
East Side	1,191	12
Walk Bridge	120	6
Milam	80	6
Herb Farm	20	2
Windcrest	300	6
Green Meadows	1,000	6
Fair Grounds	225	6
Bob White	-	4
Warehouse	131	4
FBG Inn & Suites	300	6
Beverly Drive	195	4
Heritage Hill Country	185	6
Hill Country University	35	6
Park	-	4
Boot Ranch A	170	4
Boot Ranch B	171	4
Boot Ranch C	206	4
Boot Ranch D	36	2

7.2 WASTEWATER SYSTEM RISK BASED ASSESSMENT

FNI performed a risked based assessment on 17 of the City's lift stations. The risked based assessment considered condition and criticality components to evaluate the risk of failure of each lift station inspected. The condition assessment included a visual inspection of the lift station and its components. The criticality assessment, or consequence of failure, included an analysis of the proximity of the lift station to critical or environmentally sensitive areas, as well as the residential population served. Lift stations were assigned an overall condition and criticality scores based on the results of the assessments. These scores were used to assign a risk category (extreme, high, moderate, or low) to each asset. The results of this assessment were considered in the prioritization of projects for the capital improvements plan.

7.2.1 Lift Station Condition Scoring

FNI developed a list of electrical, structural, mechanical, and site components to be inspected at each lift station site. A condition weighting factor was assigned to each component group based on the relative importance of the component to the overall function of the lift station. Major components in each of these categories were evaluated separately. **Table 7-2** illustrates the condition component groups, parameters, and weighting for the lift station facilities.

Table 7-2: Condition Assessment Component Groups and Weighting

Component Group	Weight Factor
Pumps and Motors	20%
Electrical – MCC, Back-up Power, Cables	20%
Instrumentation –SCADA, alarms	15%
Structure – Wet Well, Hatches, Corrosion, Cracks, Leaking	20%
Piping and Valves	15%
Site - Drainage, Access Drive, Security, Fencing	10%

Site visits for the lift stations were performed on March 22 and 23, 2016. The condition inspections were conducted by a team of design, electrical and modeling engineers from FNI, as well as operations staff from the City. FNI assigned numerical scores ranging from 1 to 5 to each component group based on the physical condition as seen during the inspection and information provided by the City staff relating to its operational performance. **Table 7-3** shows the guidelines used during assignment of numerical scores for component groups.

Table 7-3: Facility Condition Scoring

Description	Condition Rating
New, perfect condition	1
Good condition, no improvements recommended to maintain function	2
Fair condition, improvements recommended to improve performance or efficiency	3
Poor condition, improvements recommended to maintain reliability	4
Eminent failure, rehabilitation or replacement required	5

Once the visual site inspections were completed, ranges were assigned for the condition scores, and categories were designated from very good to very poor as shown in **Table 7-4**. Final condition scores for each lift station are shown in **Table 7-5**. Detailed lift station risk based assessment sheets including facility information, individual component group scores for condition and criticality, and additional comments for each lift station are included in **Appendix I**.

Table 7-4: Facility Condition Assessment Scoring

Score	Condition Assessment Scoring Definition
Very Good	Sound physical condition. Total Score ≤ 1.25
Good	Acceptable physical condition. 1.25 < Total Score ≤ 2
Fair	Normal wear and tear. 2 < Total Score ≤ 3
Poor	Failure likely in short to medium term. 3 < Total Score ≤ 4
Very Poor	Failed or near failure. Total Score > 4 Major work or replacement required urgently.

Table 7-5: Condition Assessment Component Groups and Weighting

Lift Station Name	Weighted Score	Overall Condition
Boot Ranch C	4.15	Very Poor
Boot Ranch B	3.60	Poor
Green Meadows	3.40	Poor
Boot Ranch D	3.40	Poor
FBG Inn and Suites	3.35	Poor
Walk Bridge	3.30	Poor
Boot Ranch A	3.20	Poor
Consolidated Warehouse	3.10	Poor
Bob White	3.10	Poor
Milam Street	3.10	Poor
Herb Farm	3.10	Poor
Fair Grounds	3.05	Poor
Heritage Hill Country	3.00	Fair
Beverly Drive	2.90	Fair
Windcrest	2.90	Fair
Hill Country University	2.80	Fair
East Side	2.60	Fair

7.2.2 Lift Station Criticality Scoring

FNI performed a criticality assessment for each lift station based on three categories:

- Proximity to High Impact Areas
- Population Served
- Proximity to Environmentally Sensitive Areas

Table 7-6 shows the scoring parameters used and the weighting factors assigned to each lift station criticality category. Areas where the population gathers are considered to be more critical than areas where the population is less dense. If a lift station falls into multiple categories, the higher score is used.

Table 7-6: Criticality Assessment Component Groups and Weightings

Proximity to High Impact Areas (25%)	Population Served (50%)
≤ 2000 feet from hospital or school = 5	> 6,000 = 5
≤ 2000 feet from parks, recreational areas or ball fields = 4	3,001 – 6,000 = 4
≤ 500 feet from residential or commercial structure = 3	1,501 – 3,000 = 3
501 – 1,000 feet from residential or commercial structure = 2	501 – 1,500 = 2
None of the above = 0	≤ 500 = 1
Proximity to Environmentally Sensitive Areas (25%)	
≤ 250 feet from Ponds, Rivers, and Streams = 5	
251 – 500 feet from Ponds, Rivers, and Streams = 4	
501 – 1,000 feet from Ponds, Rivers, Streams = 3	
>1,001 feet from any water body = 2	
None of the above = 0	

GIS tools were utilized to determine the distance from each lift station to the high impact areas and environmentally sensitive areas. Geocoded water meters were used to determine the existing population within each lift station service area.

Once the proximity and population analyses were completed, ranges were assigned for the criticality scores, and categories were designated from very low impact to very high impact. **Table 7-7** shows the scores associated with the rating categories of the criticality assessment. Final criticality scores for each lift station are shown in **Table 7-8**.

Table 7-7: Criticality Score Ranges

Score	Criticality Scoring Range
Very Low Impact	Total Score ≤ 1.25
Low Impact	1.25 < Total Score <≤ 2
Moderate Impact	2 < Total Score <≤ 3
High Impact	3 < Total Score ≤ 4
Very High Impact	Total Score > 4

Table 7-8: Lift Station Criticality Score Summary

Lift Station Name	Criticality Score	Overall Criticality
East Side	3.25	High
Walk Bridge	2.5	Moderate
Hill Country University	2.25	Moderate
Beverly Drive	2.25	Moderate
FBG Inn and Suites	2.25	Moderate
Boot Ranch A	2.25	Moderate
Heritage Hill Country	2	Low
Fair Grounds	2	Low
Boot Ranch B	2	Low
Green Meadows	1.75	Low
Milam Street	1.75	Low
Herb Farm	1.5	Low
Boot Ranch C	1.5	Low
Consolidated Warehouse	1.25	Low
Bob White	1.25	Low
Windcrest	1.25	Low
Boot Ranch D	1.25	Low

7.2.3 Lift Station Analysis Summary

FNI utilized the results of the condition and criticality assessments to develop a risk based assessment of the City's lift stations. Risk scores were calculated by the summation of the condition and criticality scores for each lift station. These risk scores were divided into four ranges (extreme, high, moderate, and low) to assign a risk of failure to each lift station. The results of both the criticality and condition analysis were

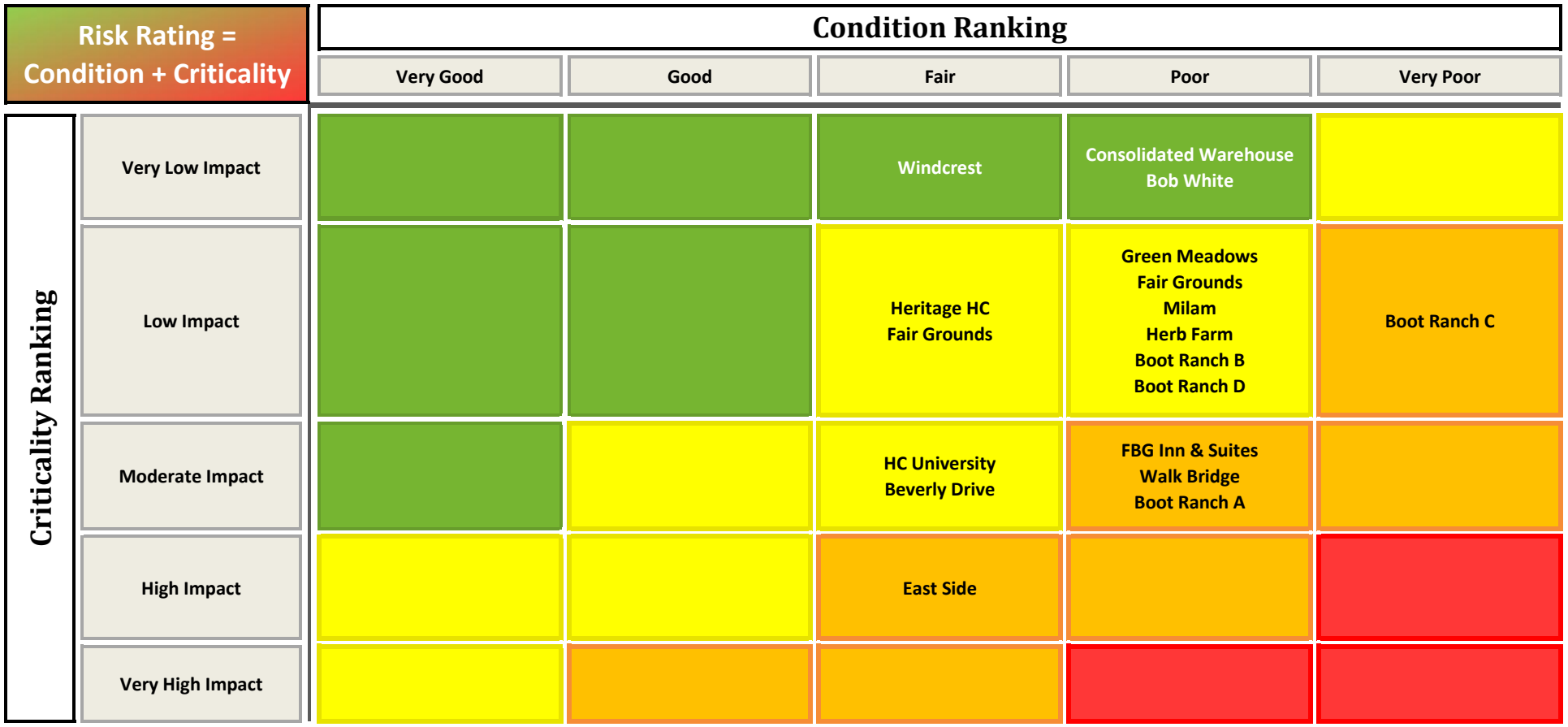
input to a matrix to give the lift stations an overall combined ranking. The lift station matrix is shown on **Figure 7-3**.

Several lift stations that received a good condition score received a moderate risk rating due to the high criticality score. These lift stations should continue to be well maintained to minimize lift station downtime given the high consequence of failure of these facilities. A summary of the risk assessment scores can be seen in **Table 7-9**.

Table 7-9: Summery of Lift Station Risk Assessment

Lift Station	Condition Rating	Criticality Rating	Risk Rating
East Side	2.60	3.25	5.85
Walk Bridge	3.30	2.50	5.80
Boot Ranch C	4.15	1.50	5.65
FBG Inn and Suites	3.35	2.25	5.60
Boot Ranch B	3.60	2.00	5.60
Boot Ranch A	3.20	2.25	5.45
Beverly Drive	2.90	2.25	5.15
Green Meadows	3.40	1.75	5.15
Hill Country University	2.80	2.25	5.05
Fair Grounds	3.05	2.00	5.05
Heritage Hill Country	3.00	2.00	5.00
Milam Street	3.10	1.75	4.85
Boot Ranch D	3.40	1.25	4.65
Herb Farm	3.10	1.50	4.60
Consolidated Warehouse	3.10	1.25	4.35
Bob White	3.10	1.25	4.35
Windcrest	2.90	1.25	4.15

Figure 7-3
Summary of Lift Station Risk Based Analysis



Condition Score Ranges

Condition Score	Description
0.00 - 1.25	Very Good
1.25 - 2.00	Good
2.00 - 3.00	Fair
3.00 - 4.00	Poor
4.00 - 5.00	Very Poor

Criticality Score Ranges

Risk Score	Description
0.00 - 1.25	Very Low
1.25 - 2.00	Low
2.00 - 3.00	Moderate
3.00 - 4.00	High
4.00 - 5.00	Very High

7.3 WASTEWATER MODEL DEVELOPMENT AND CALIBRATION

FNI developed and calibrated the hydraulic model of the Fredericksburg wastewater system to reflect flow monitor data during both dry and wet weather. H2OMap SWMM® software by Innovyze was selected as the hydraulic modeling software. FNI built the hydraulic model based on GIS information provided by the city as well as survey data collected by the City. For this study, wastewater lines with invert information as well as the majority of lines with diameters larger than 8-inches were included in the hydraulic model. FNI calibrated this model to serve as the basis for future modeling scenarios and development of a capital improvements plan.

7.3.1 Field Data Collection

As a part of the Master Plan, the City performed field data collection of manholes throughout the wastewater system. FNI coordinated with the City to identify manholes to be surveyed. Every third or fourth manhole along 10-inch and larger lines was surveyed. Effort was made capture wastewater line information at key locations to provide connectivity data necessary for the hydraulic model. Locations of the surveyed manholes are presented on **Figure 7-4**. Data collected at sewer manholes included:

- X, Y coordinates
- Rim elevations
- Measure downs to inverts of all incoming and outgoing lines

7.3.2 Model Network Development

The completed hydraulic model consists of approximately 1,016 manholes, 925 wastewater lines, one outfall, 10 lift stations, and 22 pumps. FNI reviewed the modeled wastewater network for proper connectivity.

A. Manholes

FNI updated the X, Y coordinate data of the City's sewer manholes to match the surveyed locations. Missing manhole rim elevations were assigned using various sources, including 5-foot ground contours and design plans.

FIGURE 7-4
CITY OF FREDERICKSBURG
MODELED NETWORK
LEGEND

- Flow Monitor Location
- Surveyed Manhole
- Wastewater Treatment Plant
- 5-foot Contour
- Road
- Stream
- City Limit
- ETJ

Excluded Network

- Lift Station
- 8" and Smaller Sewer Line
- Force Main

Modeled Network

- Lift Station
- Manhole
- 8" and Smaller Sewer Line
- 10" and Larger Sewer Line
- Force Main

SEWER BASINS

- FRB-01
- FRB-01A
- FRB-02
- FRB-03
- FRB-04
- FRB-05
- FRB-06

Boot Ranch D Lift Station 36 gpm
Boot Ranch A Lift Station 170 gpm
Boot Ranch B Lift Station 171 gpm
Boot Ranch C Lift Station 206 gpm
Walk Bridge Lift Station 120 gpm
Herb Farm Lift Station 20 gpm
Milam Street Lift Station 80 gpm
FBG Inn & Suites Lift Station
Windcrest Lift Station 300 gpm
Green Meadows Lift Station 1,000 gpm
Bob White Lift Station
Consolidated Warehouse Lift Station 131 gpm
Park Lift Station
Fairgrounds Lift Station 225 gpm
Beverly Drive Lift Station
East Side Lift Station
Hill Country University Lift Station
Heritage Hill Country Lift Station 185 gpm

FRB-06, FRB-04, FRB-05, FRB-03, FRB-02, FRB-01, FRB-01A

Wastewater Treatment Plant Permitted Capacity = 2.5 MGD

0 1,500 3,000
SCALE IN FEET

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B. Wastewater Lines

FNI adjusted the GIS sewer pipe network alignments to reflect the corrected manhole locations. Line diameters were imported into the model from the GIS sewer line files. Invert data for the wastewater lines was populated based on the measure downs data from the field surveys. Where available, invert data was populated using design plans from the City. Remaining invert data was populated with linear interpolation between known inverts, minimum slopes, and engineering judgement. A manning's roughness coefficient of 0.013 was assigned to most wastewater lines.

C. Lift Stations and Force Mains

FNI input lift stations and force mains into the model based on data provided by the City and general knowledge of the lift station based on the condition assessment site visits. Modeled pumping capacities were based on pump curves obtained from the City. Force main high points were determined by ground elevations. The following 10 lift stations were included in the hydraulic model.

- East Side
- Heritage Hill Country
- Green Meadows
- Fair Grounds
- Walk Bridge
- Milam
- Boot Ranch A
- Boot Ranch B
- Boot Ranch C
- Boot Ranch D

The WWTP was modeled as a free outfall at the elevation of the influent line inverts. This allows for hydraulic capacity analysis of the wastewater system in an unrestricted flow condition.

7.3.3 Flow Allocation

Geocoded water meter billing data was used for existing wastewater flow allocation. For the wastewater model, all irrigation meters were removed and the city-wide wastewater return rate was applied to the billed residential and commercial water. These wastewater loads were distributed and allocated to the nearest manhole included in the model.

7.3.4 Dry Weather Calibration

Dry weather calibration is performed on a wastewater model to ensure consistency between model output and actual dry weather system operation. Dry weather flows represent residential, commercial, industrial and groundwater flows during a period without any additional measurable I/I due to rainfall. FNI chose a seven day period from November 9, 2015 to November 15, 2015 for the dry weather calibration. Since FRB-01A was not in place at that time, it was calibrated to a seven day dry period from January 11, 2016 to January 17, 2016.

Diurnal patterns for each flow monitor basin were loaded into the model, based on the patterns observed during the flow monitoring period to match dry weather peak flows. The dry weather wastewater flows were then factored as necessary until the aggregate flows in each wastewater basin closely matched the observed flow monitor data. The desired accuracy for dry weather flow calibration is +/- 5% of the metered dry weather flow data. This was achieved for the average daily flows at each of the 7 flow monitor sites. The results of the dry weather flow calibration are presented in **Table 7-10**. Basins that achieved a less than 5% difference in average day flow are highlighted in green. Dry weather calibration graphs for the seven-day calibration period can be found in **Appendix L**.

Table 7-10: Dry Weather Flow Calibration Results

Flow Monitor	Average Dry Flow [1] (MGD)		
	Flow Monitor Data	Modeled Data	Difference (%)
FRB-01	0.29	0.28	4%
FRB-01A [2]	0.05	0.05	1%
FRB-02	0.25	0.25	0%
FRB-03	0.89	0.91	2%
FRB-04	0.15	0.15	0%
FRB-05	0.28	0.29	4%
FRB-06	0.21	0.22	2%

(1) Average day flow observed during 7 day calibration period from November 9 to 15, 2015
(2) Average day flow observed during 7 day calibration period from January 11, 2016 to January 17, 2016

7.3.5 Wet Weather Calibration

Wet weather calibration builds upon the dry weather calibration and is performed so that the model closely matches observed wet weather flows. These wet weather flows represent the sum of the dry weather flows plus the additional I/I that enters the wastewater system during a rainfall event. FNI chose the observed rainfall events from October 23, 2016 for the wet weather calibration. As in the case of the dry weather calibration, FRB-01A was not in place during this time and was calibrated to a rainfall event occurring on December 13, 2016. Total rainfall on October 23, 2015 was 3.30. Total rainfall on December 13, 2015 was 1.15.

FNI utilized the RTK hydrograph method to model the additional flows that entered the wastewater system during the observed calibration storms. This method utilizes three hydrographs that each contain three parameters which are modified to achieve calibration: flow of water into the system (R), the time to peak flow (T), and the ratio of time until normalization of flow to time to peak (K). The combination of the three component hydrographs form the total response (additional I/I) that is observed in the wastewater system. The RTK parameters and the component hydrographs are illustrated on **Figure 7-5** and **Figure 7-6**.

Figure 7-5: RTK Parameters

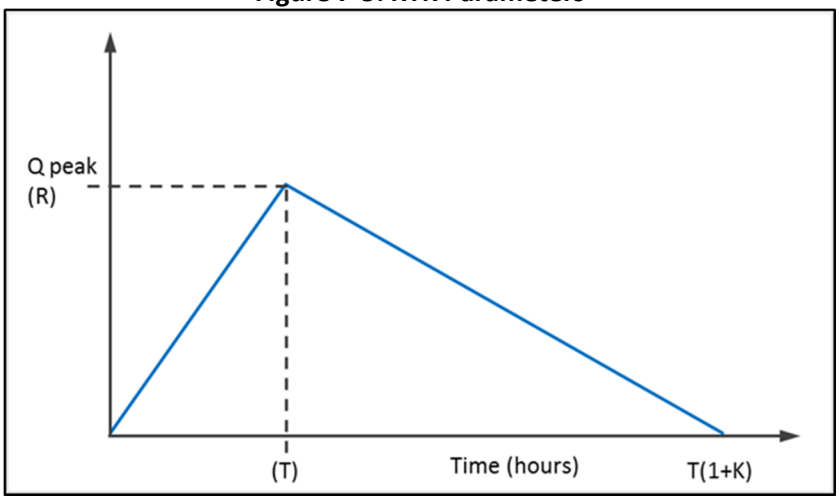
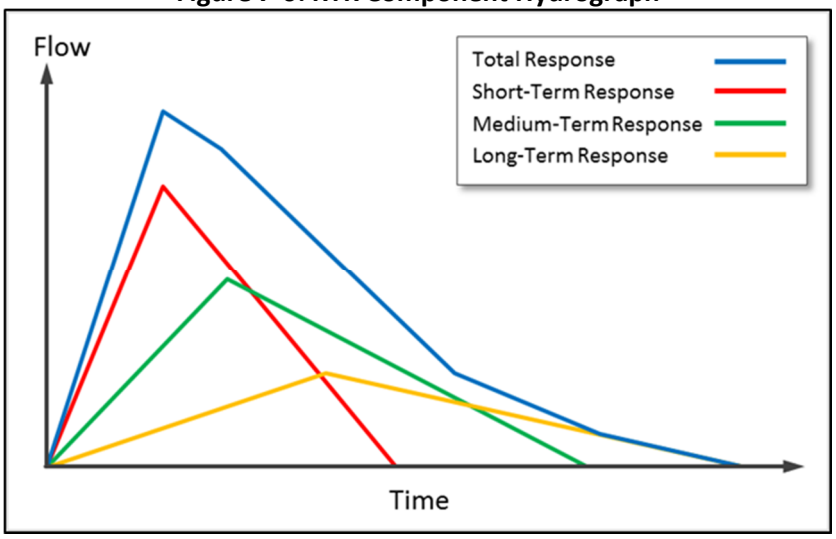


Figure 7-6: RTK Component Hydrograph



Separate RTK hydrographs were developed for each wastewater basin to account for the different land uses, soil properties, amounts of impervious cover, and condition of the wastewater lines in each basin. In H2OMap SWMM®, the RTK hydrographs were applied to the manholes in each wastewater basin. The observed rainfall hyetograph measured during the calibration rainfall events was then applied to the model. The model calculates the I/I that enters the wastewater system using the values in the RTK hydrographs and the contributing area of each manhole's sewershed. These values were adjusted until the modeled wet weather flows closely matched the observed wet weather flows. The desired accuracy for wet weather calibration in +/- 10% of the observed peak flows. This was achieved for nearly every flow monitor site with the exception of FRB-01. This may have been due to a backwater effect caused at

the plant. This is evidenced by sudden dips in flow and velocity corresponding to spikes in depth. The results of the wet weather calibration are presented in **Table 7-11**. Meter basins that achieved a less than 10% difference in wet weather peak are highlighted in green. Greater than 10% differences are highlighted in red. Wet weather calibration graphs are presented in **Appendix L.**

Table 7-11: Wet Weather Flow Calibration Results

Flow Monitor	Peak Wet Weather Flow [1] (MGD)		
	Flow Monitor Data	Modeled Data	Difference (%)
FRB-01	0.61	0.82	35%
FRB-01A [2]	0.18	0.17	4%
FRB-02	0.79	0.79	0%
FRB-03	1.99	2.02	2%
FRB-04	0.32	0.29	9%
FRB-05	0.73	0.75	3%
FRB-06	0.59	0.64	8%

(1) Peak wet weather flow observed during October 23, 2015 rainfall event
(2) Peak wet weather flow observed during December 13, 2015 rainfall event

The dry and wet weather calibration results provide a high level of confidence that the model is closely matching real world conditions and is suitable to use for hydraulic analyses and CIP development.

7.4 EXISTING WASTEWATER SYSTEM MODELING ANALYSIS

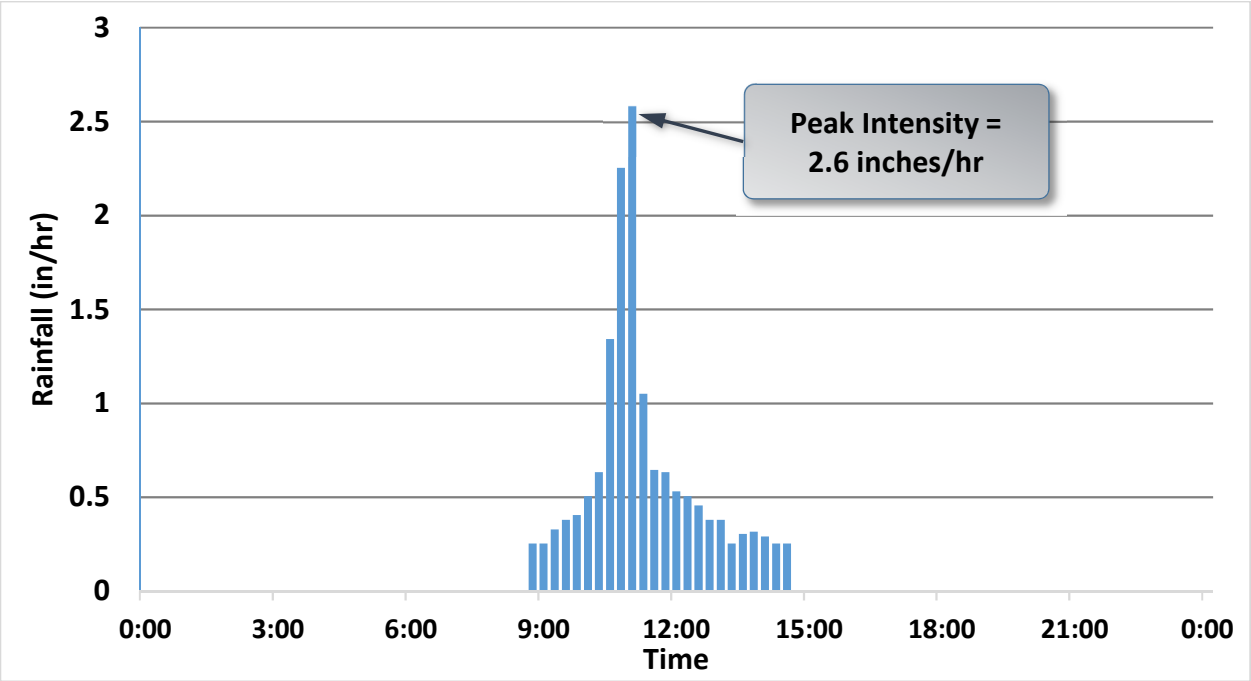
Hydraulic modeling analyses were conducted to identify deficiencies in the City of Fredericksburg's existing wastewater collection system and to establish a capital improvements plan to improve the existing system and accommodate the projected wastewater flows through 2035. Various combinations of improvements and modifications were investigated to determine the most appropriate approach for conveying projected flows. Parameters used in developing the improvements plan included increasing system reliability, simplifying system operations, consolidation of lift stations, conveying peak wet weather flows, and reducing surcharging and sanitary sewer overflows observed in the model.

7.4.1 Design Storm

A 5-year 6-hour design storm was utilized for the existing and future system analyses. This design storm is commonly used in Texas and provides a reasonable balance between level of service and wastewater

infrastructure cost. The size of the 5-year 6-hour storm was determined using historical storm event data for the region of Fredericksburg. The historical data was analyzed and summarized in the United States Geological Survey (USGS) Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas. The 5-year, 6-hour design storm for the City of Fredericksburg is an 3.8 inch rainfall event. The shape of the design storm was defined using a NRCS Type-II curve. The 5-year, 6-hour design storm hyetograph that was applied to the wastewater model is shown in **Figure 7-7**.

Figure 7-7: 5-year 6-hour Design Storm Hyetograph



7.4.2 Existing System Analysis Results

The critical flow condition for analyzing a wastewater collection system is peak wet weather. Flow, depth, and velocity are important factors when analyzing the peak wet weather simulations. When the design storm is applied to the calibrated model, the effects of I/I in the system can be seen. As the storm intensifies additional flow enters the system. The model determines the point in time when the amount of water from the design storm event reaches the peak within the system. This peak represents the most taxing load the system experiences under the design storm event. **Figure 7-8** displays a color coded map that illustrates the state of modeled lines and manholes under existing peak conditions of a 5-year, 6-hour design storm event (3.8 inches) for Fredericksburg. Red, orange and yellow lines indicate where the model predicts surcharging, flow greater than 80%, and flow greater than 60% of the pipe capacity, respectively.

FIGURE 7-8
CITY OF FREDERICKSBURG
EXISTING WASTEWATER SYSTEM ANALYSIS

SEWER METER BASINS

- FRB-01
- FRB-01A
- FRB-02
- FRB-03
- FRB-04
- FRB-05
- FRB-06

LEGEND

- Manhole Overflow
- Surcharged Within 3ft of MH Rim
- Manhole
- Lift Station
- Wastewater Treatment Plant
- Less than 60% Full
- 60% to 80% Full
- 80% to 100% Full
- Surcharge
- 8" and Smaller Sewer Line
- 10" and Larger Sewer Line
- 8" and Smaller Force Main
- 10" and Larger Force Main
- Road
- Stream
- City Limit
- ETJ

FREESE AND NICHOLS

CITY OF Fredericksburg ESTABLISHED 1846

Boot Ranch D
Lift Station
36 gpm

Boot Ranch A
Lift Station
170 gpm

Boot Ranch B
Lift Station
171 gpm

Boot Ranch C
Lift Station
206 gpm

Walk Bridge
Lift Station
120 gpm

Herb Farm
Lift Station
20 gpm

Milam Street
Lift Station
80 gpm

FBG Inn & Suites
Lift Station

Windcrest
Lift Station
300 gpm

Green Meadows
Lift Station
1,000 gpm

Bob White
Lift Station

Consolidated Warehouse
Lift Station
131 gpm

Park
Lift Station

Fairgrounds
Lift Station
225 gpm

Beverly Drive
Lift Station

East Side
Lift Station

Wastewater Treatment Plant
Permitted Capacity = 2.5 MGD

Hill Country
Lift Station

Heritage Hill Country
Lift Station
185 gpm

87 290

0 1,500 3,000
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Surcharging can occur due to a lack of capacity in that gravity line segment or a downstream restriction (i.e. insufficient lift station pumping or insufficient capacity in a downstream line). Locations where the predicted maximum hydraulic grade line (HGL) rises to within 3 feet of the manhole rim are shown as yellow circles on the map. The locations of predicted sanitary sewer overflows as a result of the modeled 5-year 6-hour storm are shown as red circles on the map.

The following section summarizes observations from the existing system analysis by flow meter basin.

- Sewer Basin FRB-02
    - The model shows a capacity restriction along a portion of the 12-inch gravity line along Friendship lane. This restriction could primarily be a result of shallow slopes at this section of the sewer line.
    - The sewer line extending downstream of the Green Meadows lift station is shown as being unable to convey the pumped flow and peak flows along this portion of the line. Smaller diameter lines and moderate slopes are the cause of the restrictions in this area.
    - The model indicates that small diameter lines upstream of the Green Meadows lift station are unable to convey flow from the Fair Grounds lift station during peak flow events.
- Sewer Basin FRB-05
    - The model shows the sewer line extending along Creek Street from South Elk Street to North Bowie Street as being unable to convey the peak flows generated by the south side of downtown. The majority of the surcharging is a result of undersized lines.
    - The Walk Bridge lift station is shown as unable to pump the peak flows generated upstream. Increased flow from the area in addition to pumped flow from the Milam lift station surcharge the lines above the Walk Bridge wet well.
    - The model indicates the lines upstream of the Milam lift station as unable to convey the peak flow generated in the area. In addition, the Milam lift station is also limited in capacity and unable to pump all of the influent. Surcharging in the line extends from the lift station to Shaw Avenue.
- Sewer Basin FRB-06

- There are two areas within this basin where 8-inch diameter lines flow into 6-inch diameter lines. At these locations there is minimal surcharging within the line. In these situations, sewer lines are susceptible to blockages.

7.5 FUTURE WASTEWATER SYSTEM ANALYSIS

Wastewater system improvement alternatives were developed to accommodate the anticipated residential and non-residential growth through 2035 planning period. To serve the future growth, the City of Fredericksburg must upsize existing infrastructure and provide additional service to areas of growth.

7.5.1 Existing System Future Flow Analysis Results

FNI created future hydraulic model scenarios to analyze needed improvements. These scenarios applied projected peak wastewater loads for each planning period to the existing system. This approach shows what improvements are needed in each of the three CIP planning periods (2020, 2025, and 2035). **Figure 7-9** displays the modeled results of the 5-Year 6-Hour design storm with projected 2035 flows on the existing wastewater system. The following areas of concern were identified (in addition to those discussed in **Section 7.5.2**).

- Sewer Basin FRB-01A
  - The model shows the Heritage Hill Country lift station as being unable to pump the incoming peak flows. As a result, lines immediately upstream of the wet well are observed in the model as surcharged.
- Sewer Basin FRB-05
  - The model indicates increased surcharging along West Morse Street and continuing upstream until Avenue C. This is a result of the line diameter decreasing from an 8-inch to a 6-inch.

FIGURE 7-9
CITY OF FREDERICKSBURG
EXISTING SYSTEM 2035 ANALYSIS

SEWER METER BASINS

- FRB-01
- FRB-01A
- FRB-02
- FRB-03
- FRB-04
- FRB-05
- FRB-06

LEGEND

- Manhole Overflow
- Surcharged Within 3ft of MH Rim
- Manhole
- Lift Station
- Wastewater Treatment Plant
- Less than 60% Full
- 60% to 80% Full
- 80% to 100% Full
- Surcharging
- 8" and Smaller Sewer Line
- 10" and Larger Sewer Line
- Force Main
- Road
- Stream
- City Limit
- ETJ

FREESE AND NICHOLS

CITY OF Fredericksburg ESTABLISHED 1846

Boot Ranch D
Lift Station
36 gpm

Boot Ranch A
Lift Station
170 gpm

Boot Ranch B
Lift Station
171 gpm

Boot Ranch C
Lift Station
206 gpm

Walk Bridge
Lift Station
120 gpm

Herb Farm
Lift Station
20 gpm

Milam Street
Lift Station
80 gpm

FBG Inn & Suties
Lift Station

Windcrest
Lift Station
300 gpm

Beverly Drive
Lift Station

East Side
Lift Station

Green Meadows
Lift Station
1,000 gpm

Wastewater Treatment Plant
Permitted Capacity = 2.5 MGD

Bob White
Lift Station

Consolidated Warehouse
Lift Station
131 gpm

Hill Country
Lift Station

Park
Lift Station

Fairgrounds
Lift Station
225 gpm

Heritage Hill Country
Lift Station
185 gpm

0 1,500 3,000
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8.0 WASTEWATER SYSTEM CAPITAL IMPROVEMENT PLAN

FNI developed a Capital Improvement Plan (CIP) for the City's wastewater collection system based on hydraulic modeling results and results from the risk based condition assessment. Capital costs were calculated for all recommended improvements and do not include individual service connections or internal subdivision infrastructure and are summarized in **Table 8-1**. The costs are provided as estimates based on previous similar engineering experience in 2016 dollars and include an allowance for engineering, surveying, and contingencies. Recommended projects are presented on **Figure 8-1**. Locations of projects have been generalized during the hydraulic analysis. Specific locations of project alignment and location will be determined as a part of the design process. It is suggested that projects be constructed in the order indicated. In the case of development occurring earlier or later, projects may be delayed or expedited as needed. Detailed description of projects and cost estimates can be found in **Appendix M**.

Table 8-1: Wastewater Capital Improvement Plan

Phase	CIP No.	Project Name	Cost
5 Year	1	Boot Ranch Lift Station Capacity Expansion and Rehabilitation	$3,214,300
	2	San Antonio Street Sewer Line Expansion	$2,898,200
	3	Friendship Lane Sewer Line Expansion	$1,504,000
	4	Adams Street Sewer Line Expansion	$1,936,100
	5	Fair Grounds Lift Station Expansion	$2,393,500
			$11,946,100
10 Year	6	Creek Street Sewer Expansion	$1,554,800
	7	Green Meadow Lift Station Expansion	$2,960,100
	8	Windcrest Lift Station Decommission	$1,674,400
	9	Heritage Hill Country Lift Station Expansion	$919,500
	10	Highway 87 South Lift Station Sewer Line Expansion	$5,281,900
			$12,390,700
20 Year	11	Walk Bridge Lift Station Expansion	$3,305,500
	12	Milam Street Lift Station Expansion	$4,290,700
	13	West Morse Sewer Line Expansion	$699,700
	14	Highway 290 West Sewer Line Expansion	$1,115,300
	15	West Schubert Sewer Line Expansion	$1,178,100
	16	Highway 16 South Lift Station and Sewer Line	$4,170,400
	17	Goehmann Lane Sewer Line Extension	$660,800
			$15,420,500
			$39,757,300

FIGURE 8-1
CITY OF FREDERICKSBURG
WASTEWATER SYSTEM CAPITAL IMPROVEMENTS PLAN

LEGEND

2020 Proposed Improvements
- Proposed Lift Station
- Proposed Wastewater Line
- Proposed Force Main

2025 Proposed Improvements
- Proposed Lift Station
- Proposed Wastewater Line
- Proposed Force Main

2035 Proposed Improvements
- Proposed Lift Station
- Proposed Wastewater Line
- Proposed Force Main

Existing Water System
- Manhole
- Lift Station
- Wastewater Treatment Plant
- 8" and Smaller Wastewater Line
- 10" and Larger Wastewater Line
- 8" and Smaller Force Main
- 10" and Larger Force Main
- Road
- Stream
- City Limit
- ETJ Boundary

SEWER BASINS
- FRB-01
- FRB-01A
- FRB-02
- FRB-03
- FRB-04
- FRB-05
- FRB-06

Boot Ranch D
Lift Station
36 gpm

Boot Ranch A
Lift Station
170 gpm

Boot Ranch B
Lift Station
171 gpm

Boot Ranch C
Lift Station
206 gpm
Rehabilitation and Expansion to 350 gpm

Proposed Lift Station
350 gpm

Herb Farm
Lift Station
20 gpm

Milam Street
Lift Station
80 gpm
Expansion to 200 gpm

Walk Bridge
Lift Station
120 gpm
Expansion to 340 gpm

FBG Inn & Suites
Lift Station

Windcrest
Lift Station
300 gpm
Decommission

Green Meadows
Lift Station
1,000 gpm
Expand to 1,300 gpm

Park
Lift Station

Fairgrounds
Lift Station
225 gpm
Expand to 575 gpm

Proposed
Lift Station
130 gpm

Bob White
Lift Station

Consolidated Warehouse
Lift Station
131 gpm

Beverly Drive
Lift Station

East Side
Lift Station

Wastewater Treatment Plant
Permitted Capacity = 2.5 MGD

Hill Country University
Lift Station

Heritage Hill Country
Lift Station
185 gpm
Expand to 350 gpm

Proposed Lift Station
630 gpm

0 1,500 3,000
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9.0 NON-POTABLE REUSE SYSTEM EVALUATION

The City of Fredericksburg currently has a successful water reuse program which provides non-potable reuse water from its Wastewater Treatment Plant (WWTP) to the Boot Ranch development and to the Lady Bird Johnson Golf Course for irrigation purposes. The non-potable reuse supply essentially augments the City's water supply by removing these water demands off the City's potable water distribution system. In order to expand the available usage of this resource, the City tasked FNI to evaluate ways to increase the flexibility of matching water supply and demand. The goals of this study are to:

- Evaluate the existing non-potable reuse system
- Assess current reuse supply quantity and quality
- Identify potential reuse customers
- Provide recommendations for the City to optimize its non-potable reuse supply

Figure 9-1 shows the City's existing non-potable reuse system as well as potential reuse customers.

9.1 CURRENT REUSE AUTHORIZATION

The City of Fredericksburg is currently permitted as a distributor and bulk user of reclaimed water by the Texas Commission on Environmental Quality (TCEQ) under reuse authorization No. R14969-001. The existing authorization permits the City to use reclaimed water for irrigation of golf courses, greenbelts and common areas, landscapes, soccer and athletic fields, school campuses, emergency fire assistance, road and building construction, and repair activities.

The uses permitted under the existing authorization are of Type I Reclaimed Water Uses. TCEQ Chapter 210 categorizes Type I Reclaimed Water Uses as ones that "include irrigation or other use in areas where the public may come in contact with the reclaimed water." A copy of the City's current Reuse Authorization is located in **Appendix N** of this report.

9.2 EXISTING CITY NON-POTABLE REUSE SYSTEM

The City of Fredericksburg currently treats wastewater at the City's Wastewater Treatment Plant (WWTP). The existing reuse system provides the treated wastewater effluent from the WWTP as reuse water to the Boot Ranch development and to the Lady Bird Johnson Golf Course. The Boot Ranch system is operated independently of the Lady Bird Johnson system.

FIGURE 9-1
CITY OF FREDERICKSBURG
EXISTING REUSE SYSTEM WITH EXISTING AND POTENTIAL CUSTOMERS

LEGEND

Potential Customers

- City of Fredericksburg
- Fredericksburg Community Health Center
- Fredericksburg Hospital Authority
- Fredericksburg Independent School District

- Wastewater Treatment Plant
- Reuse Water Line
- Reuse_Ponds
- Current Reuse Customer
- Highway
- Road
- Lake/River
- Parcel
- City Limit
- ETJ Boundary

Boot Ranch Golf Course Reuse Pond

Boot Ranch Golf Course

10"

RANCH ROAD 965

10"

Cross Mountain Reuse Booster Station
1 - 700 gpm Pump
1 - 350 gpm Pump

Cross Mountain

10"

10"

10"

10"

Elementary School

Elementary School Park

10"

STATE HWY 16

87

16 TEXAS

MILAM ST

290

Middle School

Marktplatz and Town Pool

Frantzen Park

Recycling Center

Old Fair Park

Fredericksburg Hospital Authority

Fredericksburg Hospital Authority

High School and Primary School

12"

12"

12"

12"

12"

12"

12"

12"

12"

12"

12"

12"

TIVYDALE RD

STATE HWY 16

Fredericksburg Utilities

Wastewater Treatment Plant and Reuse Pond
1 - 9 acre-Foot Pond
2 - 750 gpm Pumps
1 - 700 gpm Pump
1 - 350 gpm Pump

WWTP

Fort Martin Scott

Fredericksburg Community Health Center

Texas Hill Country University Center

Lady Bird Johnson Park and Golf Course Reuse Pond

Oak Crest Park

Lady Bird Johnson Park and Golf Course, Oak Crest Park and Fredericksburg Nature Center

0 1,600 3,200

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For the Boot Ranch system, there are two pumps (one 750 gpm pump and one 350 gpm pump) at the WWTP that send water to Boot Ranch a distance of 45,200 feet through a 10-inch pipeline from the reuse pump station to the reuse water storage pond at Boot Ranch. Due to a large ground elevation increase from the WWTP to Boot Ranch, there is a booster pump station with two pumps (one 750 gpm pump and one 350 gpm pump) at Cross Mountain that provides the additional pressure to get the reuse water to the Boot Ranch delivery point.

For the Lady Bird Johnson system, there are two 750 gpm pumps at the WWTP that send reuse water to Lady Bird Johnson Park a distance of 30,300 feet through a 12-inch pipeline from the reuse pump station to an on-site reuse water storage pond.

9.3 REUSE SUPPLY EVALUATION

Reuse supply, demand and water quality are inter-related and inter-dependent. Reuse supply is dependent on available treated effluent and varies seasonally, daily, and hourly. Reuse demands are typically higher when reuse supply is lower during summer month. The customer type depends on the available effluent quality. Because it is typically more difficult to operate the plant during peak flow events, it is also more difficult to meet quality requirements under these conditions.

Historical WWTP Influent Flows

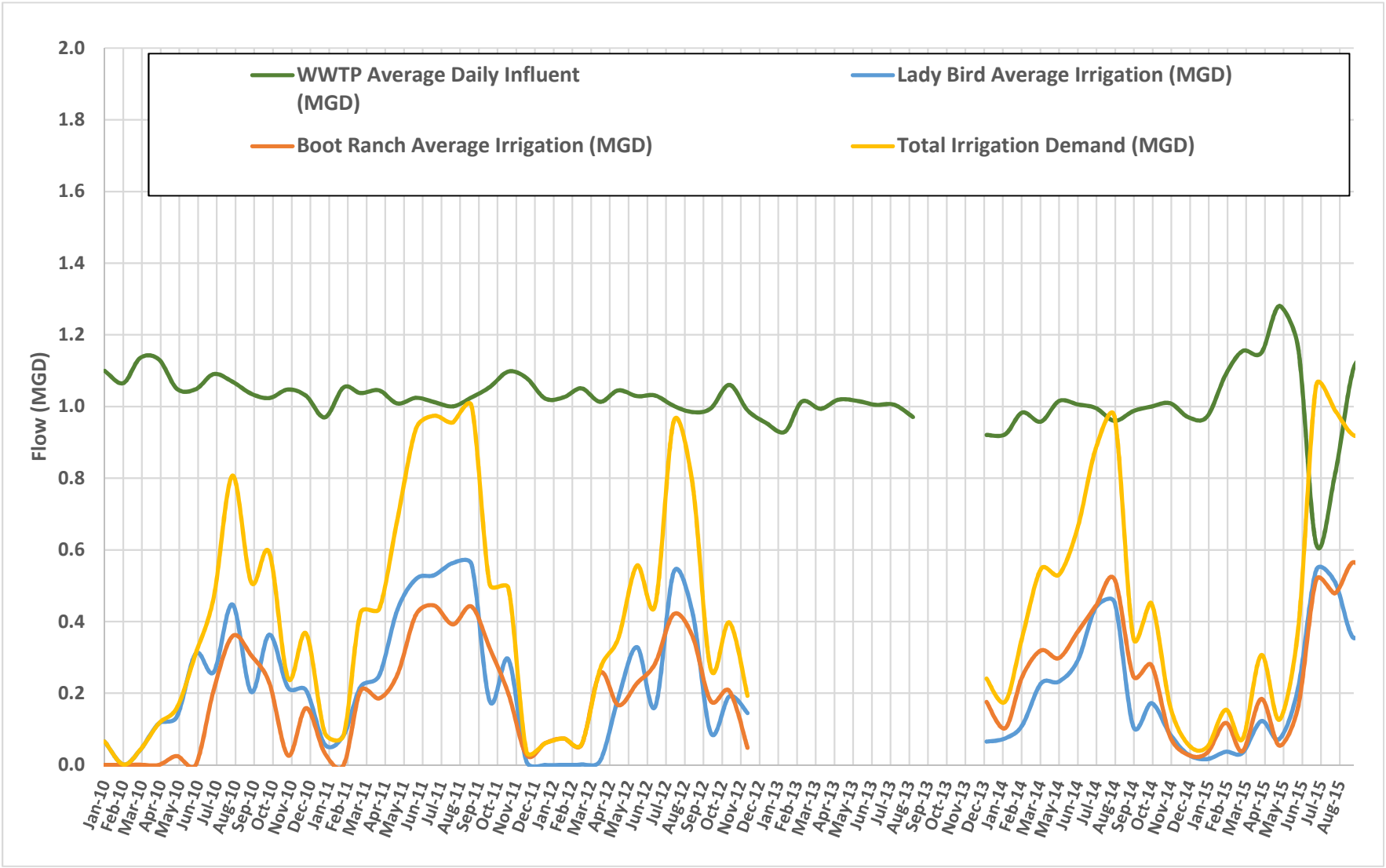
The City provided daily WWTP influent flow data from 2010 –2015. This influent flow is what is available for the City to treat and supply to its reuse customers. Historical data shows that the average daily available reuse supply is approximately 1.0 MGD.

Historical Reuse Demands

The City provided daily irrigation demands for both Boot Ranch and Lady Bird from January 2010 through December 2012 and from January 2014 through August 2015.

Figure 9-2 shows a plot of both the historical WWTP influent flows as well as the reuse irrigation demands for both Boot Ranch and Lady Bird. The figure shows that during the summer peak irrigation demand time periods, the irrigation demands are about the same as the reuse supply and therefore limits the City's ability to provide additional reuse supply to existing or future customers.

Figure 9-2: Historical WWTP Reuse Supply and Demands



9.4 POTENTIAL REUSE CUSTOMERS

City staff indicated that both Boot Ranch and Lady Bird could utilize more reuse water for irrigation in the summer if it was available. In addition to the existing reuse customers, FNI identified the sixteen top potable system irrigation users, existing parks and future potential developments illustrated on **Figure 9-1** as potential reuse customers.

While reuse water demands vary on a monthly, daily and hourly basis, only annual and monthly non-potable water demands were available for existing customers. FNI analyzed the historical water demands based on billing data for each existing customer as shown in **Table 9-1**. Due to its high demand and proximity to existing reuse pipeline infrastructure, Oak Crest Park would represent the most beneficial customer to bring on to the non-potable reuse system.

Table 9-1: Potential Reuse Customers Historical Demands

Potential Reuse Irrigation Customers		Historical Annual Demands (MG)				
Customer Name	Address	2011	2012	2013	2014	2015
Oak Crest Park	100 FAIR DR	4.41	3.21	2.15	1.88	1.94
Elementary School	1608 N ADAMS ST	--	--	--	1.35	1.34
High School and Primary School	1126 S ADAMS ST - FOOTBALL FIELD	--	--	--	1.31	0.61
High School and Primary School	1135 S MILAM ST - SOFTBALL FIELD	--	--	--	0.69	0.38
Fredericksburg Hospital Authority	1020 S STATE HWY 16	12.13	11.02	8.59	12.31	8.28
Middle School	205 W COLLEGE ST	4.10	3.33	3.61	2.97	2.32
Middle School	211 W COLLEGE ST	0.38	0.15	0.22	0.26	0.38
High School and Primary School	1107 S STATE HWY 16	1.90	1.97	2.22	2.74	2.08
High School and Primary School	1110 S ADAMS ST	0.46	0.46	0.48	0.49	0.47
Old Fair Park	410 S LINCOLN ST	2.77	2.06	1.62	1.84	1.73
Fredericksburg Health Center	140 INDUSTRIAL LOOP	0.37	0.32	0.27	0.38	0.21
Fredericksburg Utilities	233 FRIENDSHIP LN 600	0.39	0.14	0.17	0.19	0.20
Fredericksburg Utilities	233 FRIENDSHIP LN	0.32	0.20	0.14	0.12	0.11
Marketplatz	126 W MAIN	0.10	0.11	0.14	0.16	0.13
Cross Mountain	1510 N MILAM ST #A	--	--	--	--	0.03
Recycling Center	302 E UFER ST	0.05	0.02	0.02	0.02	0.02

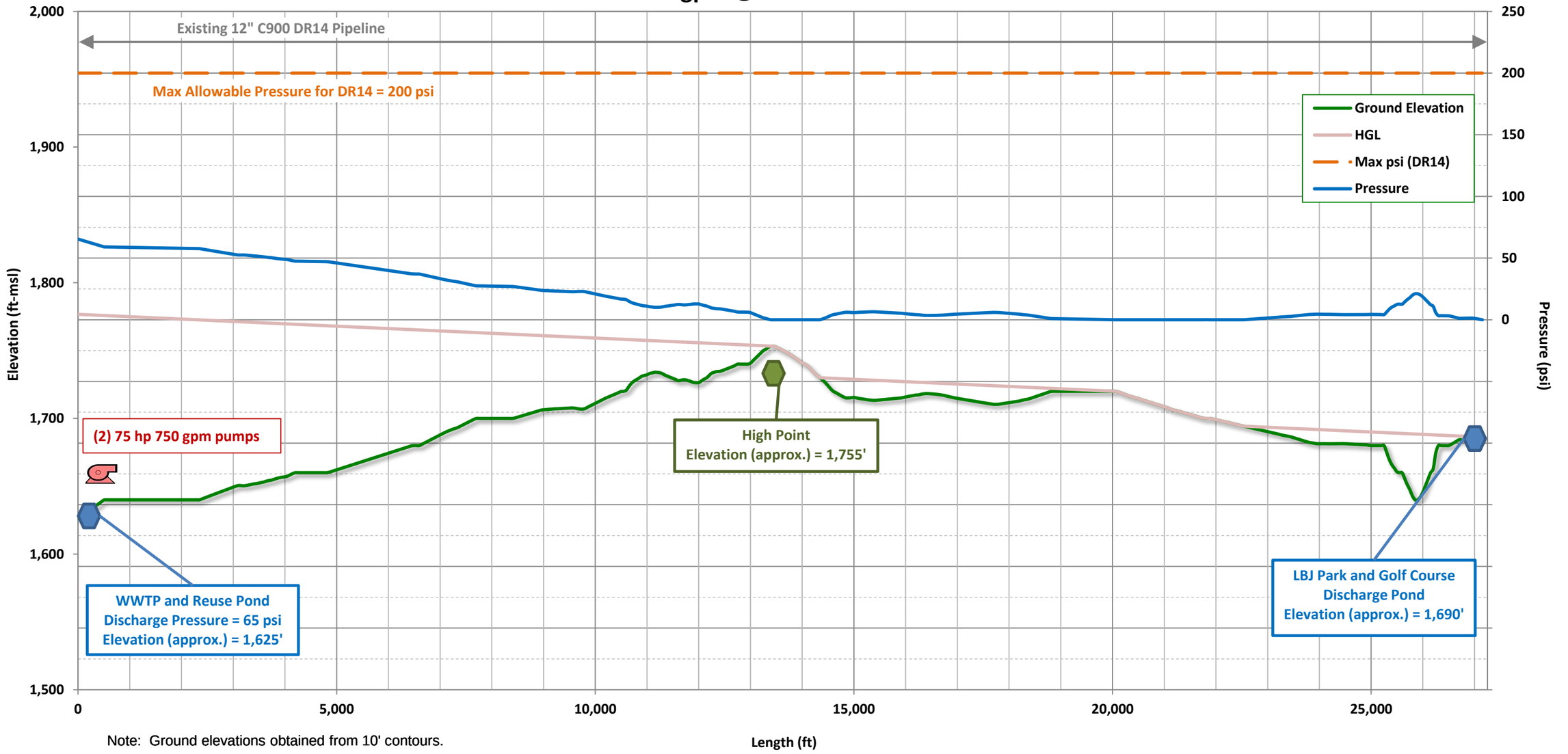
9.5 EXISTING REUSE TRANSMISSION AND PUMPING ANALYSES

In order to evaluate the City's existing reuse system, FNI developed a hydraulic model in H2OMap Water® software by Innovyze software package using existing GIS data provided by the City. This model was used to determine system pressures in the existing Boot Ranch and Lady Bird systems. The modeled hydraulic grade line and pressure profiles for the Lady Bird system and the Boot Ranch system are shown on **Figure 9-3** and **Figure 9-4**, respectively.

The model results show that the Lady Bird system maintains a maximum pressure of 65 psi while delivering 750 gpm to the Lady Bird reuse storage pond. The maximum operating pressure for the C-900 DR14 pipeline is 200 psi. The Lady Bird system has the capacity to add more customers such as Oak Crest Park.

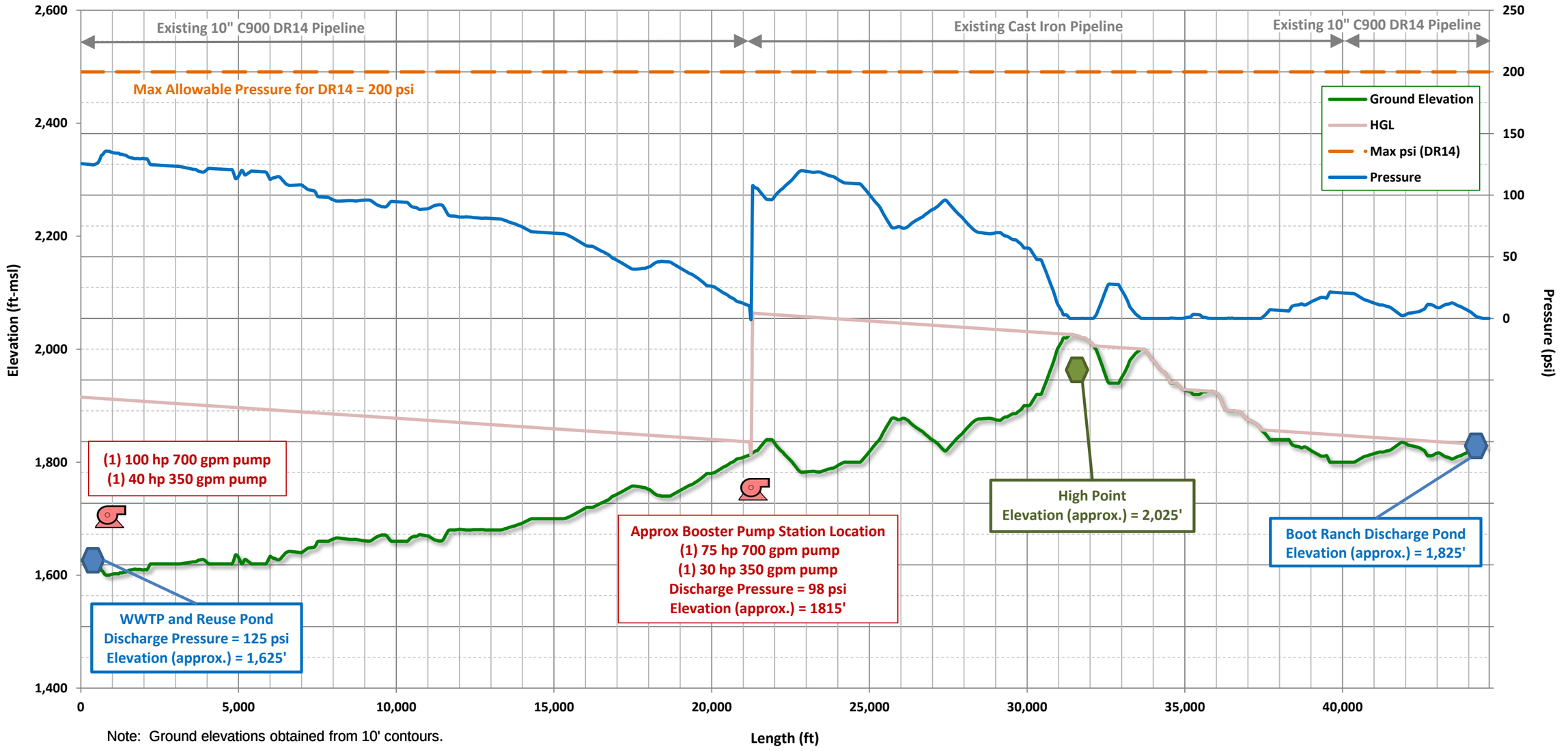
The model shows that the Boot Ranch system maintains a maximum pressure of 135 psi while delivering 700 gpm to the Cross Mountain Booster Station which then pumps to the Boot Ranch reuse storage pond. The segment in between the WWTP and Cross Mountain is a C-900 DR14 pipeline and the max operating pressure for that pipe is 200 psi. The segment between Cross Mountain and Boot Ranch experiences a maximum pressure of 98 psi at a flow of 700 gpm. This segment is mostly cast iron pipe and has a maximum operating pressure of 150 psi.

Figure 9-3
Existing Reuse System Hydraulic Grade Line Profile
WWTP to LBJ Park and Golf Course
750 gpm @ WWTP



Note: Ground elevations obtained from 10' contours.

Figure 9-4
Existing Reuse System Hydraulic Grade Line Profiles
WWTP to Boot Ranch Golf Course
700 gpm @ WWTP and Booster Pump Station



Note: Ground elevations obtained from 10' contours.

9.6 EXISTING REUSE STORAGE EVALUATION

The City's reuse system currently has storage ponds at the WWTP and at each reuse customer's delivery point. According to the City staff, the storage pond at the WWTP is an 8.5-acre pond and is in poor condition and not currently used for reuse water storage. The storage pond at Boot Ranch is 4.5 acres and approximately 8 million gallons in volume. The pond at Lady Bird is 2 acres and approximately 5 million gallons in volume.

As shown in Section 9-3, during the winter low irrigation demand time periods, there is approximately 130 MG of effluent that is discharged downstream due to the City not having adequate storage at the WWTP. Since seasonal demand variations make it impossible to match available reuse supply with demand, to expand the available usage of this resource, the City would need to increase the volume of storage. The storage ponds would collect and store wintertime wastewater effluent flows and convey the additional volume to existing and potential customers during the summertime months. To provide the most flexibility and access to the additional reuse supply that would be provided, it is recommended that the City maximize the storage volume at the WWTP as that water could be used for either the Lady Bird or Boot Ranch system.

As part of the reuse storage evaluation in this study, FNI considered available geotechnical information at the WWTP, 100-year floodplain boundaries, property lines, and ground elevations for locating and optimizing the reuse storage pond at the WWTP. The considerations for sizing the storage pond from an area and depth standpoint are the following:

- Keep the pond footprint within City owned property
- Maximum excavation depths will be above groundwater level
- Avoid building in the 100-year floodplain
- Utilize existing pond area and infrastructure as much as possible
- Maximize storage volume while minimizing construction costs

Given these considerations, a proposed reuse pond layout at the City's WWTP is shown on **Figure 9-5**. The proposed pond area is approximately 13.5 acres with a bottom of pond elevation of 1602 feet MSL. This bottom elevation is recommended in order to stay above recently measured groundwater depths in the area. This layout would equate to a reuse storage pond volume of approximately 43 million gallons. It is recommended that the City construct a new reuse pump station that could be utilized for both the

Boot Ranch and Lady Bird systems. The estimated project cost for the WWTP Reuse Pond would be approximately $10.2 million including allowances for engineering and contingency. A detailed Opinion of Probable Construction Cost for the WWTP reuse pond is shown in **Table 9-2.**

The City also requested that FNI evaluate a proposed pond site at the Lady Bird Johnson Park. This proposed site is shown on **Figure 9-6**. Using the same considerations as the WWTP Reuse Pond, the area of this pond is approximately 2 acres with a bottom of pond elevation of 1667 feet MSL. This layout would equate to a reuse storage pond volume of approximately 1.3 million gallons. The estimated project cost for the Lady Bird Reuse Pond would be approximately $2.4 million including allowances for engineering and contingency. An Opinion of Probable Construction Cost for the Lady Bird reuse pond is shown in **Table 9-3**.

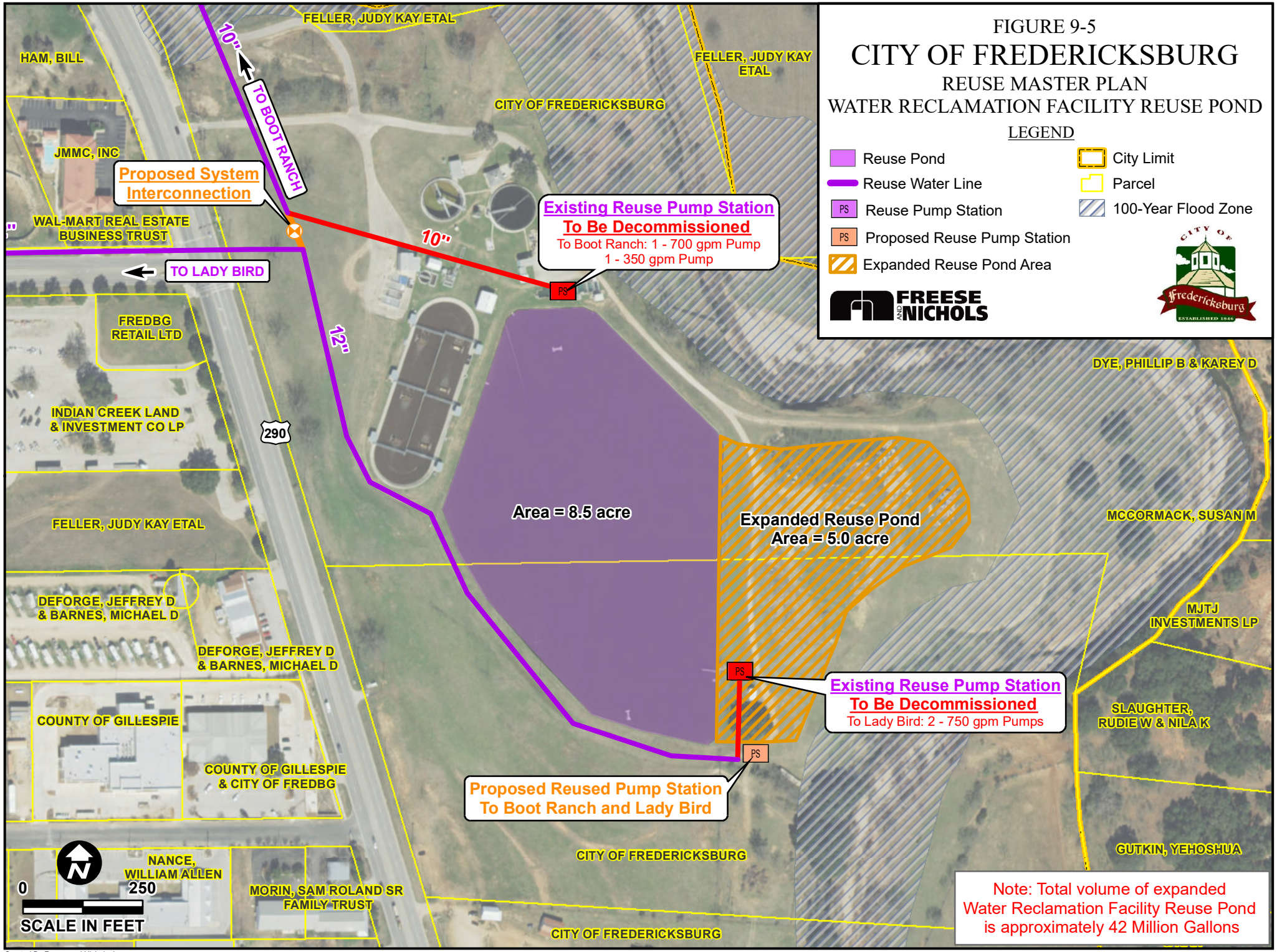


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Table 9-2: WWTP Reuse Pond OPCC

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

OPINION OF PROBABLE CONSTRUCTION COSTS

PROJECT TITLE	**43 MG Reuse Storage Pond at WWTP**	DATE	9/2/2016
CLIENT	City of Fredericksburg	GROUP	1147
% OF SUBMITTAL	Conceptual	PM	Richard Weatherly, P.E.

ESTIMATOR	CHECKED BY	FNI PROJECT NO.
Brian Beach, P.E.	JMN	FRB15439

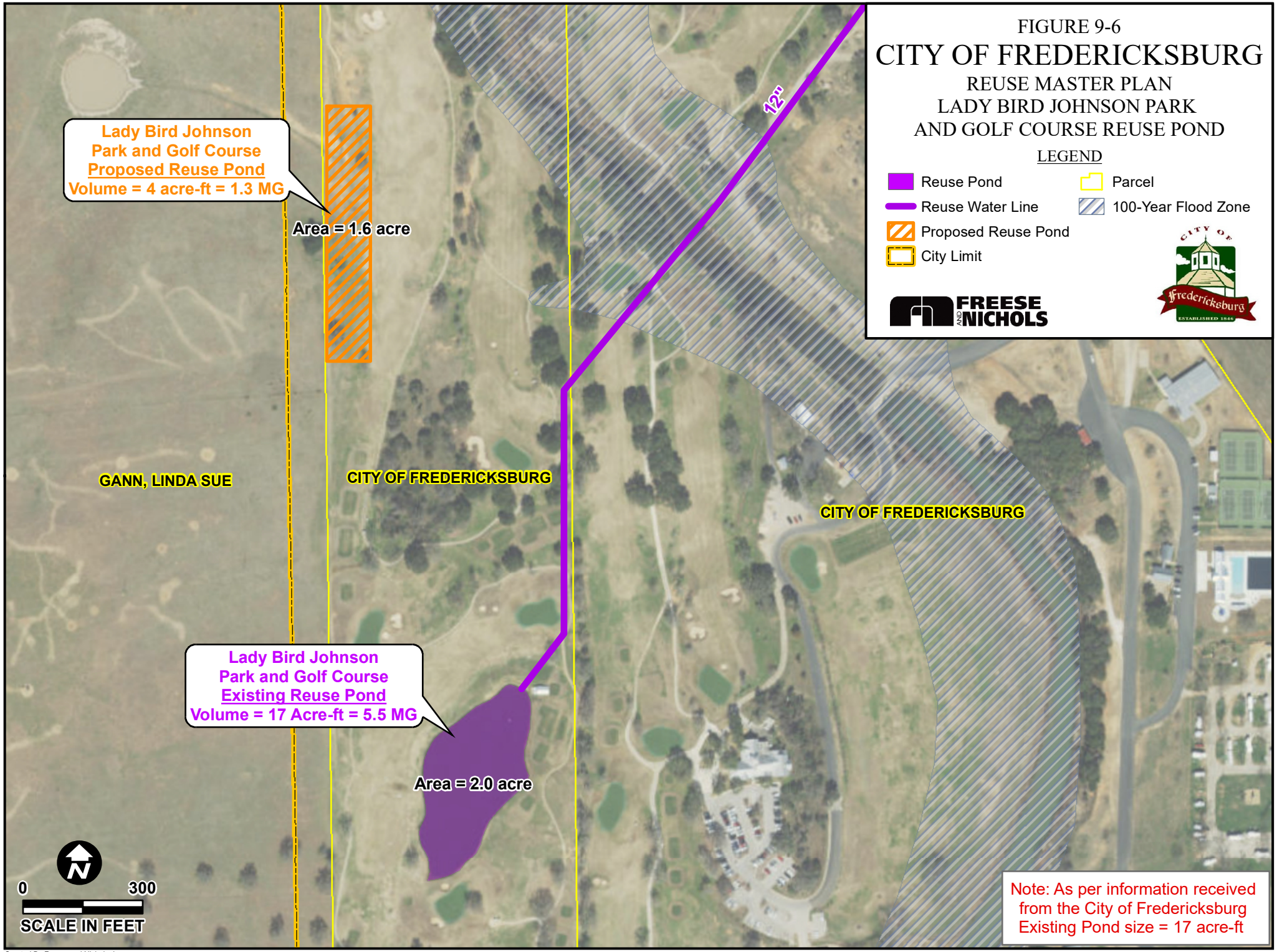
ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Temp. Erosion and Sediment Control	1	LS	$ 60,000.00	$60,000
2	Clearing and Grubbing	41,200	SY	$ 0.60	$24,720
3	General Excavation	175,200	CY	$ 6.00	$1,051,200
4	Fill Dirt	16,516	CY	$ 6.00	$99,096
5	Haul off Excess Dirt	158,700	CY	$ 8.40	$1,333,080
5	Soil Cement	18,000	CY	$ 104.00	$1,872,000
6	Geonet Composite w/Geotextile	66,300	SY	$ 7.20	$477,360
7	HDPE Geomembrane	66,300	SY	$ 7.80	$517,140
8	Underdrain System - 8" pipe	1	LS	$ 420,000.00	$420,000
9	Topsoil	7,000	CY	$ 12.00	$84,000
10	Grassing	9	AC	$ 6,000.00	$51,000
11	Site Improvements	1	LS	$ 240,000.00	$240,000
12	Reuse Pump Station Upgrades	1	LS	$ 600,000.00	$600,000
		SUBTOTAL:			$6,829,600
		CONTINGENCY		30%	$2,048,880
		SUBTOTAL:			$8,878,480
		ENGINEERING		15%	$1,331,780

PROJECT TOTAL **$10,210,300**

NOTES:

1. Estimate based on conceptual drawings

2. The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.



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Updated: Wednesday, January 25, 2017 1:40:54 PM

Table 9-3: Lady Bird Reuse Pond OPCC

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

OPINION OF PROBABLE CONSTRUCTION COSTS

PROJECT TITLE	**Reuse Storage Pond at Lady Bird**	DATE	9/2/2016
CLIENT	City of Fredericksburg	GROUP	1147
% OF SUBMITTAL	Conceptual	PM	Richard Weatherly, P.E.

ESTIMATOR	CHECKED BY	FNI PROJECT NO.
Brian Beach, P.E.	JMN	FRB15439

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Temp. Erosion and Sediment Control	1	LS	$ 30,000.00	$30,000
2	Clearing and Grubbing	8,800	SY	$ 0.60	$5,280
3	General Excavation	10,500	CY	$ 4.20	$44,100
4	Backfill	2,500	CY	$ 12.00	$30,000
5	Spread Dirt on Site	7,900	CY	$ 3.30	$26,070
5	Soil Cement	1,900	CY	$ 104.00	$197,600
6	Geonet Composite w/Geotextile	65,000	SY	$ 7.20	$468,000
7	HDPE Geomembrane	65,000	SY	$ 7.80	$507,000
8	Underdrain System - 8" pipe	1	LS	$ 180,000.00	$180,000
9	Topsoil	800	CY	$ 12.00	$9,600
10	Grassing	2	AC	$ 6,000.00	$12,000
11	Site improvements	1	LS	$ 120,000.00	$120,000
	SUBTOTAL:				$1,629,650
	CONTINGENCY			30%	$488,900
	SUBTOTAL:				$2,118,550
	ENGINEERING			15%	$317,790

PROJECT TOTAL **$2,436,400**

NOTES:

1. Estimate based on conceptual drawings

2. The Engineer has no control over the cost of labor, materials, equipment, or over the Contractor's methods of determining prices or over competitive bidding or market conditions. Opinions of probable costs provided herein are based on the information known to Engineer at this time and represent only the Engineer's judgment as a design professional familiar with the construction industry. The Engineer cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from its opinions of probable costs.

9.7 NON-POTABLE REUSE SYSTEM RECOMMENDATIONS

The non-potable reuse system evaluation results and recommendations are summarized below:

- The City should expand their non-potable water reuse programs in order to decrease potable water system demand and potentially defer the need for an additional supply.
- The City's existing transmission infrastructure is adequately sized to deliver the required reuse flow to the existing customer's delivery points.
- Potential reuse water users will be evaluated on a case by case basis by the cost of extending service and those with large summer irrigation demands. It is assumed that all of the potential users will use reuse water for irrigation and will require Type I quality reuse water.
- The City is limited by the ability to meet summer month peak reuse demands with the amount of current reuse supply at the WWTP. The current peak demand is only able to be met using the storage in the customer's on-site ponds in addition to the pumping supply from the WWTP.
- During the winter low irrigation demand time periods, there is approximately 130 MG of effluent that is discharged downstream due to the City not having adequate storage at the WWTP. It is recommended that the City construct additional reuse storage ponds to collect and store this wintertime wastewater effluent flows and convey the additional volume to existing and potential customers during the summertime months.
- In order to provide the most flexibility and access to the additional reuse supply that would be provided, it is recommended that the City maximize the storage volume at the WWTP as that water could be used for either the Lady Bird or Boot Ranch system.
- By utilizing the existing City effluent lagoon and additional City-owned land at the WWTP, FNI recommends that the City construct a 13.5-acre storage pond that would have a volume of approximately 43 million gallons. It is also recommended that the City construct a new reuse pump station at the WWTP that could be utilized for both the Boot Ranch and Lady Bird systems.

APPENDIX A
RESIDENTIAL AND NON-RESIDENTIAL GROWTH BY PLANNING AREA

Appendix A
City of Fredericksburg
Residential and Non-Residential Growth by Planning Area

Table A-1: Residential Development Areas

Development ID	2020 Population	2025 Population	2035 Population
R1	0	0	119
R2	190	250	478
R3	86	86	86
R4	0	0	150
R5	0	0	150
R6	240	440	1,120
R7	167	359	359
R8	0	233	400
R9	0	0	54
R10	0	40	80
Total	**683**	**1,408**	**2,996**

Table A-2: Non-Residential Development Areas

Development ID	2020 Non-Residential Acres	2025 Non-Residential Acres	2035 Non-Residential Acres
C1	15	15	15
C2	0	116	116
C3	0	0	98
C4	0	0	52
C5	0	0	108
C6	0	0	38
C7	0	0	42
C8	0	0	33
C9	0	0	17
C10	0	84	84
C11	4	4	4
C12	1	1	1
C13	0	10	10
C14	0	10	10
Total	**20**	**240**	**628**

APPENDIX B
WATER SUPPLY MEMORANDUM

LBG-GUYTON ASSOCIATES

TECHNICAL MEMORANDUM

TO: Clinton Bailey and Tom Gooch

FROM: James Beach, P.G. and Brant Konetchy

SUBJECT: Analysis of Increased Production Near Hahn Wellfield

DATE: May 11, 2016

INTRODUCTION

The City of Fredericksburg (City) asked LBG-Guyton Associates to address several questions relating to groundwater availability at the Hahn wellfield located southeast of the City. The inquiry related to overall groundwater availability from the property and the potential for developing more water from the property. To address these questions, LBG-Guyton updated an Ellenburger Groundwater Availability Model that was originally developed by LBG-Guyton for the Hill Country Underground Water Conservation District (HCUWCD) and the City of Fredericksburg in 2005. This model was used as a basis to assess the long-term groundwater availability of the Ellenburger aquifer in Gillespie County. The model was updated and used to estimate the impact of additional pumping from the Hahn Ranch test wells on the City of Fredericksburg water supply wells in the Hahn and Boerner wellfields. This assessment focused on impacts to the Boerner Well #5 (GM-00009), Boerner Well #4 (GM-00008), and Hahn Well #1 (GM-00014). Figure 1 shows the location of the wells. The water levels for these wells were estimated from the updated calibrated model for a base case (no pumping from test wells) and four different scenarios. In Scenario 1, the model was used to extend the drought conditions (recharge and pumping) during 2011 into 2012 to evaluate the impact on water levels in wells under extended drought conditions. Scenario 2 evaluated the impact of adding production from the three test wells on the Hahn property for local use by the landowner. Scenario 3 used scenario 2 conditions with an additional supply well added to the Hahn property pumping at 500 gpm. Scenario 4 was the same as scenario 3 except pumping was increased at the additional supply well to 1,000 gpm.

MODEL UPDATE

The original model was updated and extended from its original end date of 2004 to 2015. The model continued to use monthly time steps and the number of months in the model increased from 230 to 362. Pumping from City wells was based on monthly meter readings obtained from HCUWCD. Historical monthly pumping data from Boerner Well #5, Boerner Well #4, and Hahn Well #1 were available from district records and were updated

in the model. Paul Tybor, general manager of HCUWCD, indicated that the estimates for the pumping for irrigation and other demands in the area were the same as those estimated for the original model. Therefore, other pumping from the aquifer was extended to 2015 by cycling through 2004's monthly pumping data, or maintaining pumping rates as they were in 2004 till the end of 2015. For example, the July pumping rate in 2004 would be used for July 2005, July 2006, and so on.

Recharge from precipitation was estimated using the same method as in the original Ellenburger model in which an initial recharge rate was calculated from the average annual precipitation for the period of record (1940 – 2015), and then a recharge factor was applied to it based on the annual precipitation rate for each year. The recharge factor was based on the ratio of the annual precipitation to the average annual precipitation. For example, 2014 precipitation 25.74 inches, and the average annual rate was 29.30, which would give 2014 a recharge factor of 0.88. Water level measurements collected between 2005 and December 2015 were used to compare to simulated water levels from the model. The root mean squared error (RMSE) is a standard measure to compare model results to observed data. The RMSE for the calibration period that was extended through 2015 was 15.4 feet, similar to the RMSE of 15.1 feet in the original model. This RMSE indicates that the model is acceptable for the current evaluation. Figures 2, 3 and 4 show the measured water levels (red dots) in Boerner Well #4 (GM-00008), Boerner Well #5 (GM-00009), and Hahn Well #1 (GM-00014), respectively compared to the simulated water level (thick blue line) during 2011 and 2012.

ANALYSIS

To determine the effect of additional pumping from wells near the Hahn wellfield on City wells, four scenarios were developed. Because the City desired to address water level decline and potential groundwater availability during very dry conditions, the hydrologic and pumping conditions of 2011 were selected for evaluation. Because 2011 was a dry year and the Hahn and Boerner wells were used heavily to meet City demands during that year, the four scenarios developed for this study simulated a repeat of pumping and recharge conditions during 2011 into 2012 to simulate a more stressful period for the aquifer and wellfields. This would essentially produce drought conditions over a two-year period and was named Scenario 1. Scenario 1 assumed a repeat of 2011 pumping in City wells in 2012, but did not increase pumping from any other wells.

In order to assess the potential impact from the four scenarios, graphs of observed and simulated water levels for the three main production wells in the Boerner and Hahn wellfields were developed. The results of Scenario 1 are shown in Figures 2, 3 and 4 as the thin green line. Note that the results from the calibrated model (thick blue line) and the water levels from Scenario 1 (thin green line) overlap in 2011 as they should because there is no difference in 2011. However, in 2012 the Scenario 1 changes are implemented and thus the simulated water levels from Scenario 1 are lower in 2012. This is due to the repeat of the 2011 pumping and drought conditions in 2012 for Scenario 1.

Scenario 2 is the same as scenario 1, except that the three test wells located on the Hahn Ranch were assumed to pump 25,000 gallons per day from 2005 through 2012. The pumping estimate of 25,000 gallons per day was selected as that is the maximum volume that can be produced from a well for domestic and livestock purposes without obtaining a permit. The results of Scenario 2 are shown in Figures 2, 3 and 4 as a thin orange line that falls below the Scenario 1 results (thin green line). Simulated water level decline in Scenario 2 is lower than Scenario 1 due to the increase in production on the Hahn property. Results will be discussed in more detail below.

The City also wanted to investigate the potential for increasing production from the Hahn property if another productive well was drilled and produced. Specifically, the City wanted to know if the area might support more production without causing significantly reduced water levels and lost production from existing wells. Scenarios 3 and 4 were designed to help answer these questions. Scenario 3 is the same as scenario 2, but adds a hypothetical supply well in the Hahn well field that pumps 500 gpm from 2005 through 2012. The location of the hypothetical well is shown in Figure 1 on the north side of the Hahn property. The location was not selected based on any hydrogeologic information, but rather to show how hypothetical increased production from this area would impact water level declines in the existing City wells. The placement of the well and the assumed production from the well is hypothetical and more research would need to be completed to assess where an additional well might be located. Scenario 4 is the same as Scenario 3, but doubles the pumping rate of the hypothetical well to 1,000 gpm from 2005 through 2012.

The simulations incorporating Scenarios 1, 2, 3, and 4 ended in December of 2012 because the purpose of the simulations was to assess the lowest water levels in the City wells during an extended dry period with heavy production. Comparison of the simulated water levels to the current pump settings in the wells and the total depth of the wells provides insight into the risk of increasing production in the area near the Hahn and Boerner wellfields.

RESULTS

The hydrographs for Boerner Well #4 (Figure 2), Boerner Well #5 (Figure 3), and Hahn Well #1 (Figure 4) indicate that the water levels simulated with the calibrated model (blue line) follow the trends in the observed water level measurements (red dots) fairly well. As discussed in the original modeling report, there are many reasons why there are differences between simulated and observed water level measurements, including simulating pumping as a monthly average instead of daily rate, comparing a daily water level measurement to a simulated monthly average water level, uncertain estimates on non-municipal water use, and limitations due to lack of data on hydrogeologic structure, the conceptual model and hydraulic properties to name a few. However, the model provides a reasonable comparison and insight into the water level trends in the area.

EFFECT OF EXTENDED DROUGHT

The difference between the blue line and the green line on the hydrographs provides insight into the impact of extending the drought for another year (into 2012). In 2012, there is an

increased drawdown of about 15 feet in the wells due to the extended drought. The effect of drought alone can be seen in Scenario 1 causing a maximum drop in water level of about 17 feet as seen in Hahn Well #1 (Figure 4).

EFFECT OF INCREASED DOMESTIC PUMPING ON HAHN PROPERTY

Scenario 2 results indicate that the additional pumping by landowners will cause an additional water level decline of about 2-3 feet. Table 1 shows all maximum water level differences for the three wells and for the four scenarios relative to the simulated water level with the calibrated model. The table also shows how much water is still above the pump and bottom of the well for each of the maximum drawdown cases. From the table it can be seen that the two Boerner wells are not as affected by the drought or additional pumping as the Hahn well in Scenario 2, which is most likely due to the shorter distance between the Hahn well and the additional pumping wells. While the additional pumping does cause a decline in water levels, the majority of water level decline is due the drought conditions. The water remaining above the pump and bottom of the well are all maintained at a reasonable level, and there is no concern that the wells would pump dry during scenario 2.

EFFECT OF INCREASED MUNICIPAL PUMPING ON HAHN PROPERTY

Scenario 3 shows a much larger decline in water levels than the previous scenarios, with decline from about 40 to 43 feet. Scenario 4 water level declines range from about 57 to 68 feet in three wells. While Scenario 2 caused larger decline to the Hahn well #1, Scenario's 3 and 4 have more of an effect on the Boerner wells. This increase in drawdown at all wells is due to the increased pumping at the hypothetical well for Scenario 3 (500 gpm increase) and Scenario 4 (1000 gpm increase). Recall that Scenarios 3 and 4 are meant to estimate the general effect an additional production in the area on existing supply wells, and the values reported could change based on the location of actual production, the rate of production, and other hydrogeologic factors.

Regardless of the precise location of the hypothetical production, increased pumping would still have an effect on all the wells water levels. This effect can be seen by comparing how much water is located above the current pump setting and above the bottom of the wells. Table 1 shows that Scenario 3 reduce the available drawdown (water above the pump) to about 22 to 32 feet. More detailed engineering analysis would need to be completed to assess whether the current pump depths are sufficient with that level of head on the pumps. It appears that all the wells may still have room to lower the pump if necessary based on our current understanding of the wells, but a more detailed assessment would need to be completed to develop final recommendations regarding lowering the pumps in the wells.

Scenario 4 results indicate that producing another 1000 gpm in the area might reduce water levels to near the current pump settings, and the Boerner #5 pump would be above the simulated water level. This result indicates that a more thorough analysis of well construction and potential pump settings would need to be completed to better understand the potential for expanding the production on the Hahn property.

Table 1: Maximum Water Level Declines and Remaining Water above Pump Setting and Total Depth of Wells

Well Name	Scenario	Water Level Decline from Calibrated Model (feet)	Water Remaining Above Pump Setting (feet)	Water Remaining Above the Bottom of Well (feet)
Boerner #4	1	14.4	58.2	149.2
	2	16.7	56.0	147.0
	3	40.2	32.4	123.4
	4	63.3	9.4	100.4
Boerner #5	1	15.1	50.2	83.2
	2	17.5	47.8	80.8
	3	42.5	22.7	55.7
	4	67.5	-2.2	30.8
Hahn #1	1	17.4	47.5	148.5
	2	19.9	45.1	146.1
	3	40.4	23.4	124.4
	4	57.3	5.6	106.6

RECOMMENDATIONS

We recommend that based on the water that remains above the current pump setting in the three major supplies wells for Scenario 2 that the city could allow the three additional test wells located on the Hahn property to be pumped at a rate of 25,000 gpd. The model showed the additional pumping from the three wells (52 gpm) would cause a water level decline of about 2 to 3 feet, which would be manageable at the current pump settings during drought conditions. Scenario 3 indicates that increasing the pumping by 550 gpm above 2011 levels results in a water level decline of about 40 to 42 feet in the existing wells and probably leaves enough water above the pumps (as currently set) to be manageable. However, the modeling indicates that production of an additional 1000 gpm or more on the Hahn property during drought conditions current pump settings would be problematic.

Consideration for the pumping rate and location of wells should be assessed further to determine the optimal location and pumping rate to minimize the effect on the water level of nearby wells if an additional well is needed. In addition, because of the karst nature of the aquifer and limited hydrogeologic data, it is difficult to predict the location of another highly productive well, if such a location exists. Developing another highly productive well on the Hahn property may require several test holes. These results and recommendations only consider the limited technical issues addressed in this study and do not consider other legal, political or strategic issues.

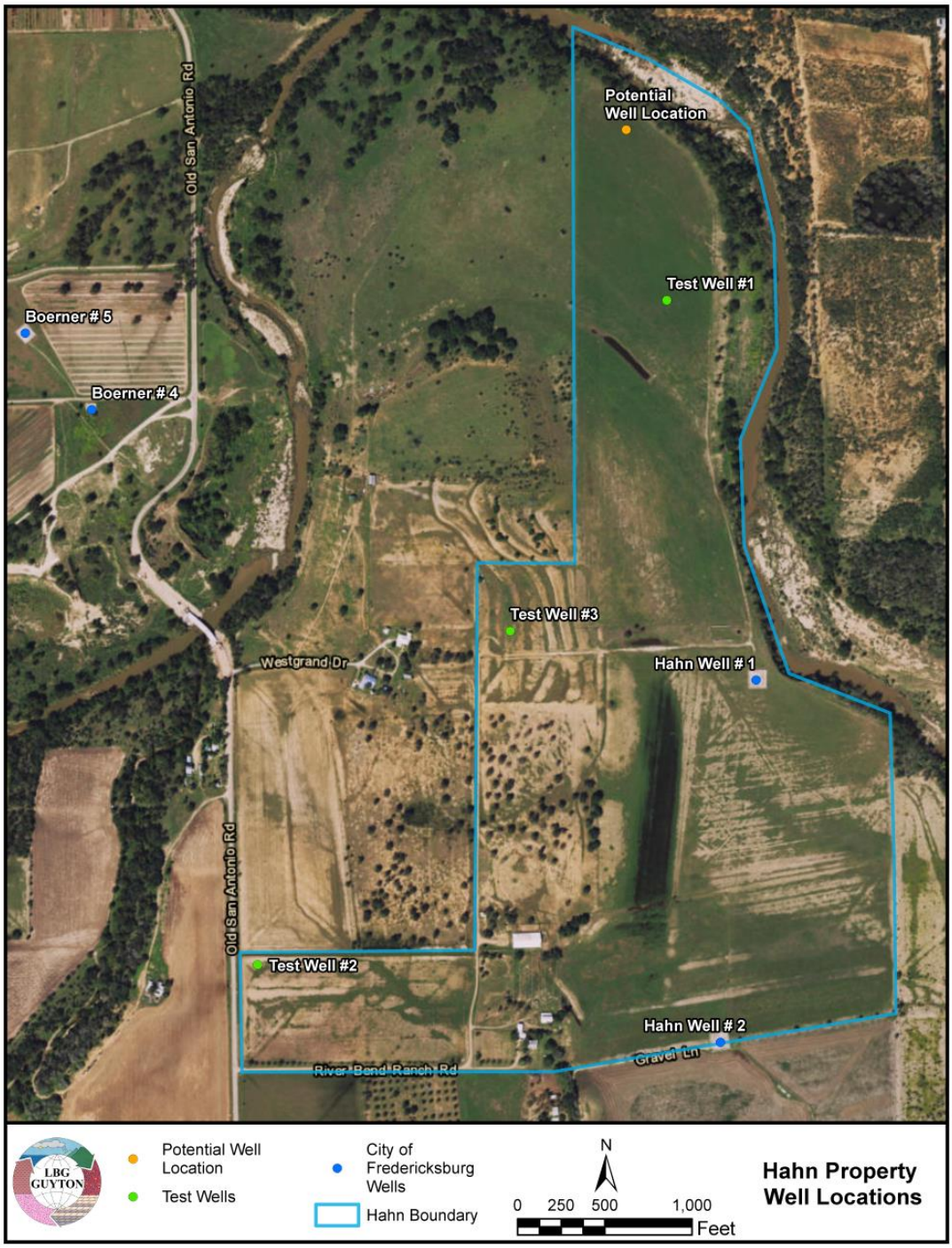

Figure 1. Location Map of Hahn Property Wells

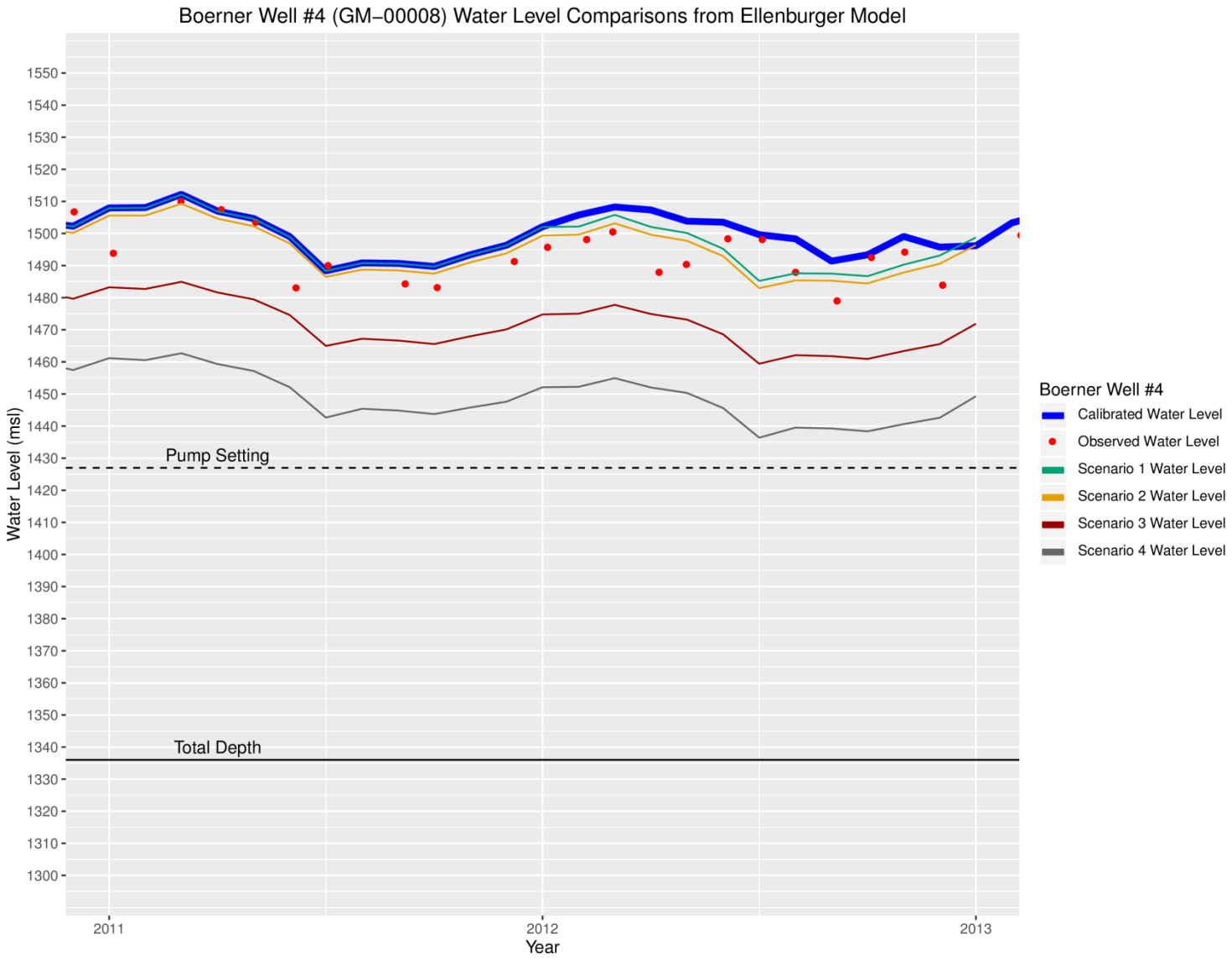

Figure 2. Hydrographs of Boerner Well #4

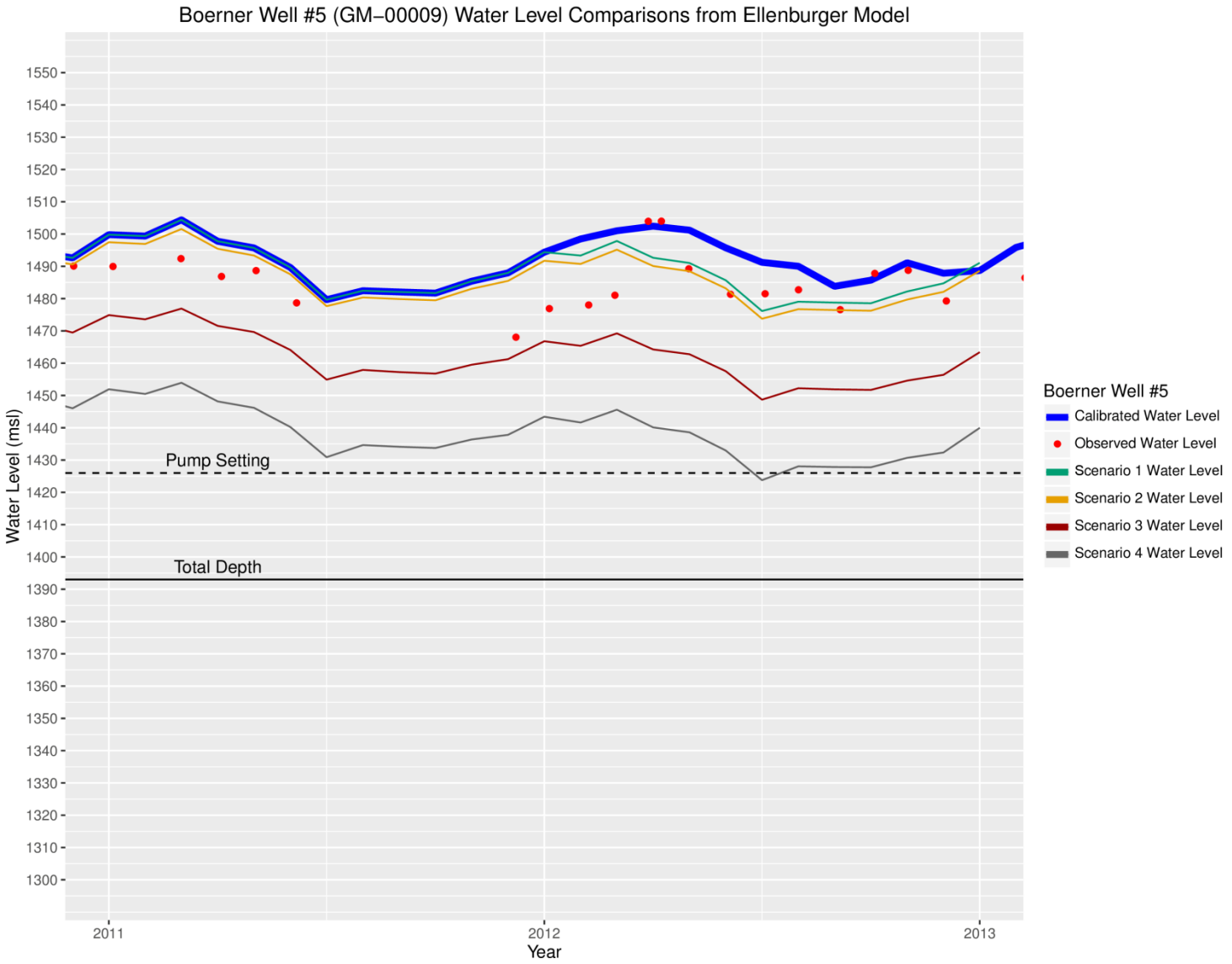

Figure 3. Hydrographs of Boerner Well #5

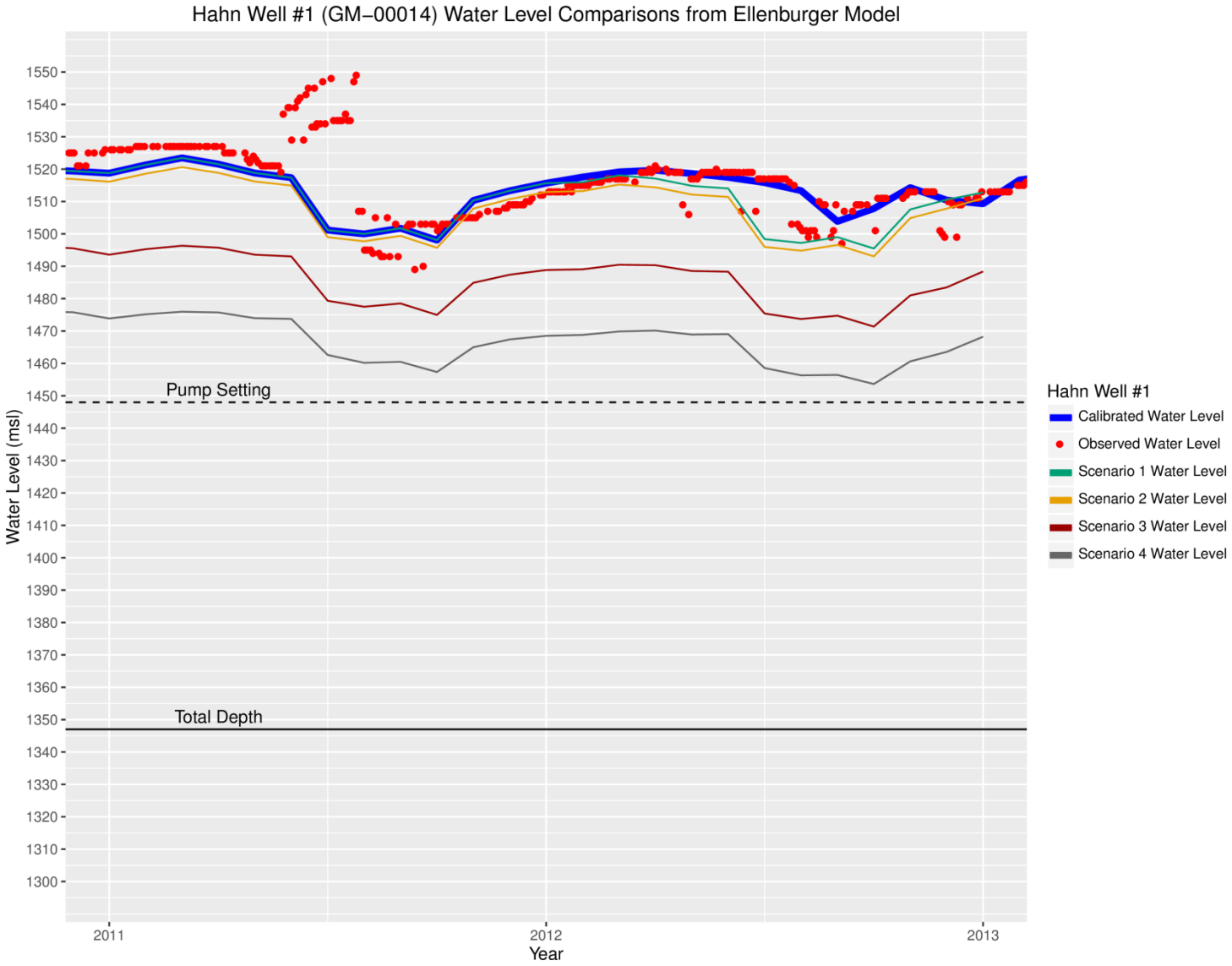

Figure 4. Hydrographs of Hahn Well #1

APPENDIX C
WATER SYSTEM SITE VISIT SHEETS

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Goehmann Lane Pump Station

Inspection Date: 3/22/2016

Facility Information	
Address:	4310 Goehmann Lane
Year in Service:	1994
Type of Facility:	Horizontal Booster Pump Station
Number of Pumps:	3
Pumping (gpm):	2 - 1,050
Horsepower:	
Monitoring:	
Generator:	

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Switch Gear, Alternate Power	5	25%	1.25	Soft Starter, No backup power
Pumps and Motors	3	30%	0.90	Up to 2 pumps at a time, Some corrosion on pump casing, 3rd pump inoperable, Rewound after tornado, Terminal box coupling busted on motor
Instrumentation - SCADA, alarms	4	10%	0.40	Unable to read most instramentation on site, Must read via SCADA
Structure - Walls, Roof, Foundation	5	20%	1.00	Tornado damage, Temporary roof, Cracks and disturbances in foundation
Mechanical - HVAC, Piping, Valves, Meters	4	15%	0.60	No working HVAC, Minimal corrosion on pipes, Valves good, Can only read meter on SCADA and not on site
Total Inspection Score	-	100%	4.15	
Condition Rating	-	-	**4.15**	**Very Poor**

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Population Served	5	100%	5.00	Serves North and South Pressure Plane, Population: 11020
System Redundancy Adjustment			-1.00	non-exclusive service
Criticality Rating	-	100%	**4.00**	**High**

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	**4.15**	**4.00**	**8.15**	**Extreme Risk**

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

South Heights Pump Station

Inspection Date: 3/22/2016

Facility Information	
Address:	910 East Main Street
Year in Service:	
Type of Facility:	Horizontal Booster Pump Station
Number of Pumps:	4
Firm Capacity:	3 - 1,000, 1 - 3,750 booster
Horsepower:	
Monitoring:	
Generator:	

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Switch Gear, Alternate Power	4	25%	1.00	No backup power
Pumps and Motors	3	30%	0.90	3 of 4 pumps work - one is not sized properly, 2 of 3 pumps run at a time, corrosion of pump casing prevalent
Instrumentation - SCADA, alarms	4	10%	0.40	Pressure transducer and meter insufficient
Structure - Walls, Roof, Foundation	2	20%	0.40	Some broken windows, Multitude of trees above roof, debris on roof, Small chips in foundation
Mechanical - HVAC, Piping, Valves, Meters	2	15%	0.30	AC unit minimal use due to under sizing, Some corrosion, especially at supports, Meter is leaving tank, no meter downstream of PS
Total Inspection Score	-	100%	3.00	
Condition Rating	-	-	**3.00**	**Fair**

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Population Served	5	100%	5.00	Serves North and South Pressure Plane, Population: 11020
System Redundancy Adjustment			-1.00	Non-exclusive service
Criticality Rating	-	100%	**4.00**	**High**

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	**3.00**	**4.00**	**7.00**	**High Risk**

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Windcrest Pump Station

Inspection Date: 3/22/2016

Facility Information	
Address:	490 Summit Circle
Year in Service:	1950 - 1960
Type of Facility:	Horizontal Booster Pump Station
Number of Pumps:	3
Firm Capacity:	2 - 400, 1 - 750
Horsepower:	
Monitoring:	
Generator:	

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Switch Gear, Alternate Power	5	25%	1.25	No backup power, tower is for LCRA communication, Safety issues
Pumps and Motors	3	30%	0.90	One pump reworked 8 - 10 years ago, large pump not utilized, could be removed for additional 400 GPM to decrease run time of others
Instrumentation - SCADA, alarms	3	10%	0.30	
Structure - Walls, Roof, Foundation	3	20%	0.60	Window cracked, exposed insulation, holes, exposed to the outside with pipe penetrations, Foundation good
Mechanical - HVAC, Piping, Valves, Meters	2	15%	0.30	Fan not set for cooling, Minimal corroding, No check valves for isolation, Meter is outside building
Total Inspection Score	-	100%	3.35	
Condition Rating	-	-	3.35	Poor

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Population Served	1	100%	1.00	Serves Windcrest Pressure Plane, Population: 240
System Redundancy Adjustment			1.00	Exclusive Service
Criticality Rating	-	100%	2.00	Low

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.35	2.00	5.35	Moderate Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Cross Mountain Pump Station

Inspection Date: 3/22/2016

Facility Information

Address:	1526 N Milam Street
Year in Service:	2006
Type of Facility:	Horizontal Booster Pump Station
Number of Pumps:	2
Firm Capacity:	2 - 1,360
Horsepower:	
Monitoring:	
Generator:	

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Switch Gear, Alternate Power	3	25%	0.75	No alternate power
Pumps and Motors	2	30%	0.60	One pump reworked 2011, Only one pump operates at a time on VFD, Bearings very loud
Instrumentation - SCADA, alarms	2	10%	0.20	Can control via SCADA
Structure - Walls, Roof, Foundation	2	20%	0.40	Walls show some surge issues/settlement, wood supports, A few cracks in pump foundation
Mechanical - HVAC, Piping, Valves, Meters	3	15%	0.45	Passive HVAC, Piping need saddle for supports, signs of thrust wear, coating on pipe deteriorating, Pump pit gets filled with water periodically
Total Inspection Score	-	100%	2.40	
Condition Rating	-	-	**2.40**	**Fair**

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Population Served	3	100%	3.00	Serves North Pressure Plane, Population: 2660
System Redundancy Adjustment			1.00	Exclusive service
Criticality Rating	-	100%	**4.00**	**High**

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	**2.40**	**4.00**	**6.40**	**High Risk**

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Stone Ridge Pump Station and Hydro Tank

Inspection Date: 3/23/2016

Facility Information

Address:	2221 Hedgestone
Year in Service:	1997
Type of Facility:	Horizontal Booster Pump Station & HydroTank
Number of Pumps:	3
Firm Capacity:	
Horsepower:	
Monitoring:	
Generator:	

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Switch Gear, Alternate Power	4	25%	1.00	No backup power
Pumps and Motors	2	30%	0.60	Lots of cycling required for operation, All three pumps run at once if required
Instrumentation - SCADA, alarms	4	10%	0.40	Tank level monitored by visual inspection, Not connected to SCADA
Structure - Walls, Roof, Foundation	1	20%	0.20	No issues
Mechanical - HVAC, Piping, Valves, Meters	3	15%	0.45	Some coating inconsistencies, Thrust harness showing signs of warping/incorrect installation, no meter
Total Inspection Score	-	100%	2.65	
Condition Rating	-	-	**2.65**	**Fair**

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Population Served	1	100%	1.00	Serves Stone Ridge Pressure Plane, Population: 2660
System Redundancy Adjustment			1.00	Non-exclusive service
Criticality Rating	-	100%	**2.00**	**Low**

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	**2.65**	**2.00**	**4.65**	**Moderate Risk**

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Goehmann Lane GST

Inspection Date: 3/22/2016

Facility Information	
Address:	4310 Goehmann Lane
Year in Service:	2015
Type of Facility:	Pre-Stressed Concrete GST
Capacity (MG):	0.5
Overflow Elevation:	1598.7
Diameter (feet):	55
Monitoring:	
Tank Entry Point:	Roof Hatch & Access Manway

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Mechanical-Piping, Hatches, Valves, Vents	1	20%	0.20	No visible issues.
Tank Structure and Roof Slope	1	50%	0.50	Pre-stressed concrete cylinder tank was built in 2015.
Instrumentation and SCADA	1	10%	0.10	No visible issues.
Tank Overflow	2	10%	0.20	Drainage over roadway can be an issue during tank overflow.
Site - Drainage, Access Drive, Security, Fencing	1	10%	0.10	Existing 0.3 MG tank on site is not in use. Site access and fencing is sufficient.
Total Inspection Score	-	100%	1.10	
Condition Rating	-	-	**1.10**	**Very Good**

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Population Served	5	100%	5.00	Serves North and South Pressure Plane, Population: 11020
System Redundancy Adjustment			-1.00	Non-exclusive service
Criticality Rating	-	100%	**4.00**	**High**

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	**1.10**	**4.00**	**5.10**	**Moderate Risk**

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

South Heights GST

Inspection Date: 3/22/2016

Facility Information	
Address:	910 East Main Street
Year in Service:	2015
Type of Facility:	Pre-Stressed Concrete GST
Capacity (MG):	0.5
Overflow Elevation:	1692.0
Diameter (feet):	53
Monitoring:	
Tank Entry Point:	Roof Hatch & Access Manway

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Mechanical-Piping, Hatches, Valves, Vents	1	20%	0.20	No visible issues.
Tank Structure and Roof Slope	1	50%	0.50	Pre-stressed concrete cylinder tank was built in 2015.
Instrumentation and SCADA	1	10%	0.10	No visible issues.
Tank Overflow	2	10%	0.20	Berm has been built up downstream of overflow pad.
Site - Drainage, Access Drive, Security, Fencing	1	10%	0.10	Site access and fencing is sufficient.
Total Inspection Score	-	100%	1.10	
Condition Rating	-	-	**1.10**	**Very Good**

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Population Served	5	100%	5.00	Serves North and South Pressure Plane, Population: 11020
System Redundancy Adjustment			-1.00	Non-exclusive service
Criticality Rating	-	100%	**4.00**	**High**

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	**1.10**	**4.00**	**5.10**	**Moderate Risk**

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Windcrest GST

Inspection Date: 3/22/2016

Facility Information	
Address:	493 Summit Circle
Year in Service:	1951, Rehab 2015
Type of Facility:	Steel GST
Capacity (MG):	1
Overflow Elevation:	1859.0
Diameter (feet):	75
Monitoring:	
Tank Entry Point:	Roof Hatch & Access Manway

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Mechanical-Piping, Hatches, Valves, Vents	2	20%	0.40	Discharge piping concrete support should be replaced with saddle support.
Tank Structure and Roof Slope	1	50%	0.50	The steel ground storage tank was recently rehabbed in 2015, including new coating.
Instrumentation and SCADA	1	10%	0.10	No issues.
Tank Overflow	1	10%	0.10	None.
Site - Drainage, Access Drive, Security, Fencing	2	10%	0.20	Site fencing needs improvements.
Total Inspection Score	-	100%	1.30	
Condition Rating	-	-	**1.30**	**Good**

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Population Served	1	100%	1.00	Serves Windcrest Pressure Plane, Population: 240
System Redundancy Adjustment			1.00	Exclusive service to Windcrest
Criticality Rating	-	100%	**2.00**	**Low**

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	**1.30**	**2.00**	**3.30**	**Low Risk**

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Cross Mountain GST

Inspection Date: 3/22/2016

Facility Information	
Address:	1526 N Milam Street
Year in Service:	1962, Rehab 2010
Type of Facility:	Steel GST
Capacity (MG):	1
Overflow Elevation:	1859.0
Diameter (feet):	
Monitoring:	
Tank Entry Point:	Roof Hatch & Access Manway

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Mechanical-Piping, Hatches, Valves, Vents	3	20%	0.60	Coating issues on inlet piping, emergency tank outlet piping abandoned
Tank Structure and Roof Slope	2	50%	1.00	Slight rusting at bottom of tank.
Instrumentation and SCADA	2	10%	0.20	Antenna sideways, but good communication
Tank Overflow	1	10%	0.10	Tank drains by side of road, no issues
Site - Drainage, Access Drive, Security, Fencing	2	10%	0.20	Site fencing has some breaks
Total Inspection Score	-	100%	2.10	
Condition Rating	-	-	2.10	Fair

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Population Served	3	100%	3.00	Serves North and South Pressure Plane, Population: 2660
System Redundancy Adjustment			1.00	Exclusive service to North Pressue Plane
Criticality Rating	-	100%	4.00	High

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	2.10	4.00	6.10	High Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Boot Ranch GST

Inspection Date: 3/22/2016

Facility Information

Address:	3190 Boot Ranch Circle
Year in Service:	2006
Type of Facility:	Steel GST
Capacity (MG):	1
Overflow Elevation:	2074.0
Diameter (feet):	74
Monitoring:	
Tank Entry Point:	Roof Hatch & Access Manway

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Mechanical-Piping, Hatches, Valves, Vents	3	20%	0.60	Inlet piping lacking coating.
Tank Structure and Roof Slope	2	50%	1.00	Minimal cracking in concrete slab, grout cracking
Instrumentation and SCADA	2	10%	0.20	Pressure transducer replaced 8 - 9 months ago, No lightning protection
Tank Overflow	1	10%	0.10	Good overflow drainage
Site - Drainage, Access Drive, Security, Fencing	3	10%	0.30	Access roadway not all weather
Total Inspection Score	-	100%	2.20	
Condition Rating	-	-	2.20	Fair

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Population Served	3	100%	3.00	Serves Boot Ranch and North Pressure Plane, Population: 2660
System Redundancy Adjustment			1.00	Exclusive Service
Criticality Rating	-	100%	4.00	High

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	2.20	4.00	6.20	High Risk

APPENDIX D
PRESSURE RECORDER DATA

FIGURE D-1
CITY OF FREDERICKSBURG
PRESSURE RECORDER LOCATIONS

LEGEND

- Pressure Recorder
- Well
- Storage Tank
- Pump Station
- 8" and Smaller Water Line
- 10" and Larger Water Line
- Transmission Line
- Road
- Stream
- City Limit
- ETJ

PRESSURE PLANES

- North Pressure Plane
- South Pressure Plane

PR8 FH#
~104 W Boot Ranch Ridge

Boot Ranch Tank
Overflow Elevation: 2,074'
1 - 1.0 MG GST
Stehling Well - 300 gpm
Boot Ranch Well - 500 gpm

Cross Mountain Tank
Overflow Elevation: 1859'
1 - 1.0 MG GST
2 - 1,360 gpm pumps

PR6 #E-87
Intersection Stone Meadow and Summit Forest

Stone Ridge Pump Station
(1) - Hydroneumatic Tank
(3) - 450 gpm pumps

PR5 #E-44
Intersection of Ridgewood Dr. and Edgewood Dr.

PR7 #E-36
Intersection of North Crockett and Trailmoore

PR9 #D-11
Intersection of N Edison St. and W Austin St.

PR10 #F-16
Intersection of Elk and Center

South Heights Pump Station
3 - 1,000 gpm pumps
1 - 0.5 MG GST

Windcrest Tank
Overflow Elevation: 1859'
1 - 1.0 MG GST
2 - 400 gpm pumps
1 - 750 gpm pump

PR2 #C-22
101 Medical Dr.

PR1 #B-37
233 Friendship Ln.

PR3 #C-72
Corner of Cross Wind and Airport Rd.

PR4 #A-45
316 Chase Oaks Place

Goehmann Lane Pump Station
2 - 1,050 gpm pumps
1 - 0.5 MG GST

Knauth Well Field
Production - 2,200 gpm

Boerner Well Field
Production - 6,000 gpm

0 2,000 4,000
SCALE IN FEET

Created By Freese and Nichols, Inc.
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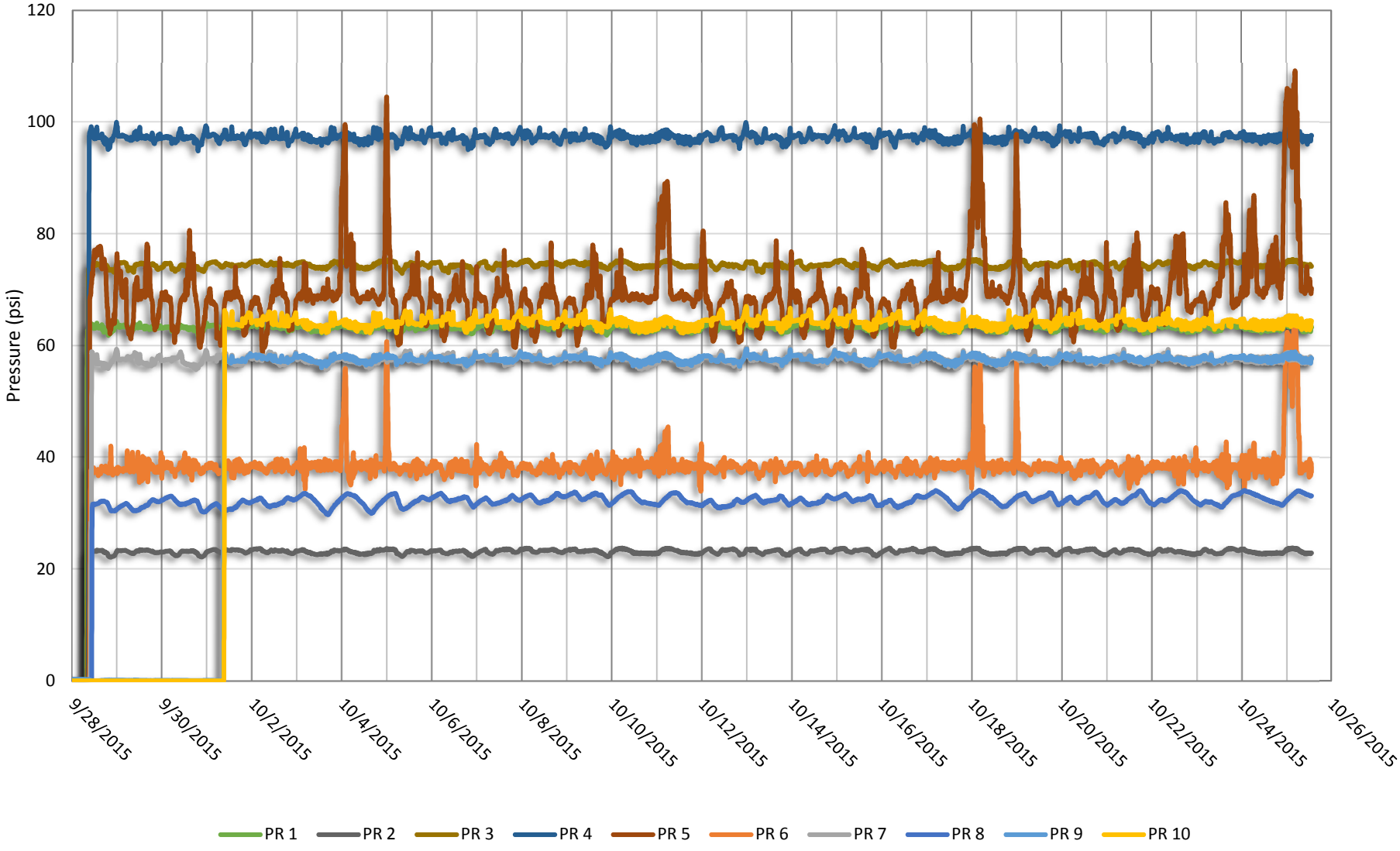
City of Fredericksburg
Figure D-2 - Pressure Testing Results
September 28 - October 26, 2015

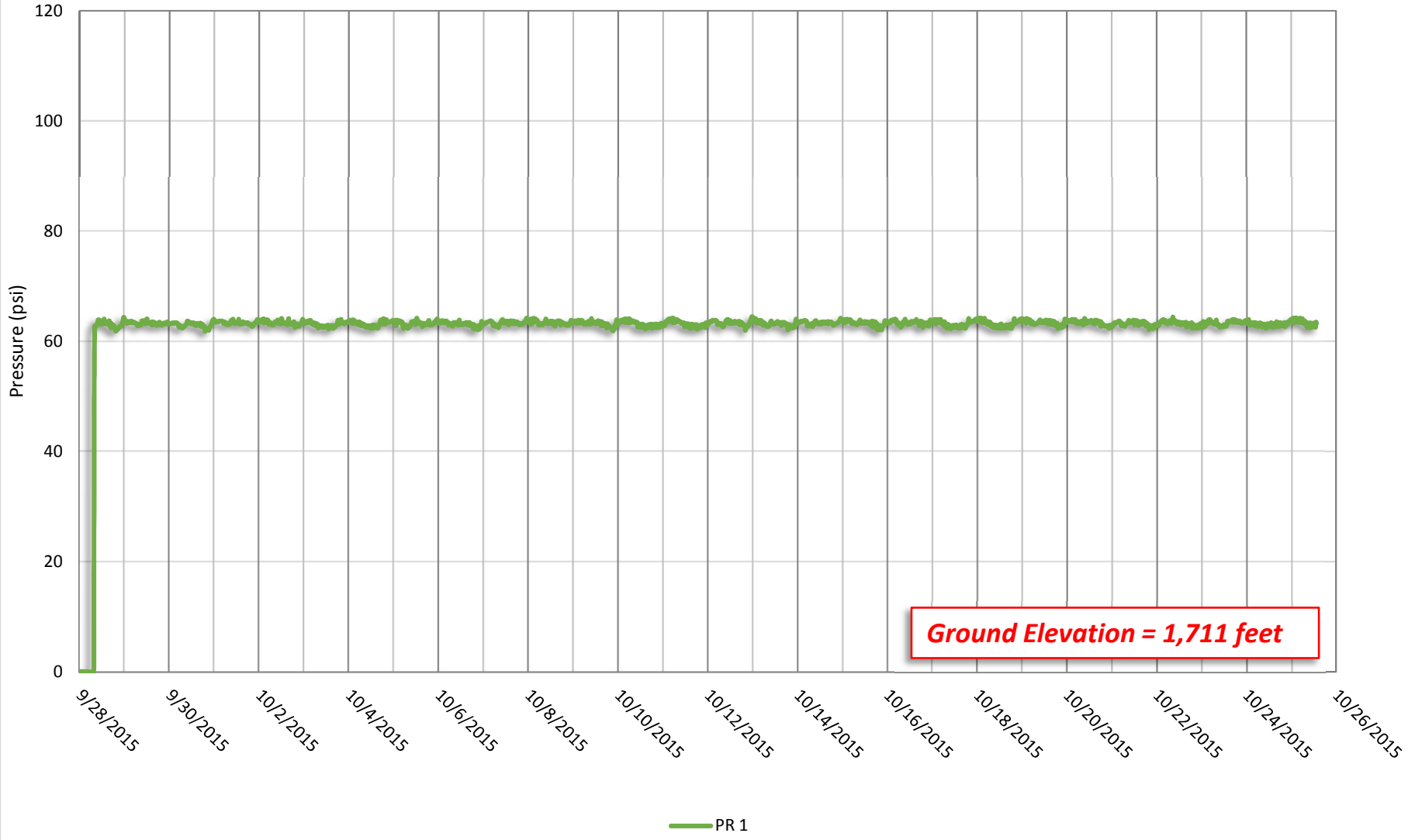


City of Fredericksburg

Figure D-3 - PR 1 Pressure Testing Results

233 Friendship Ln

September 28 - October 26, 2015

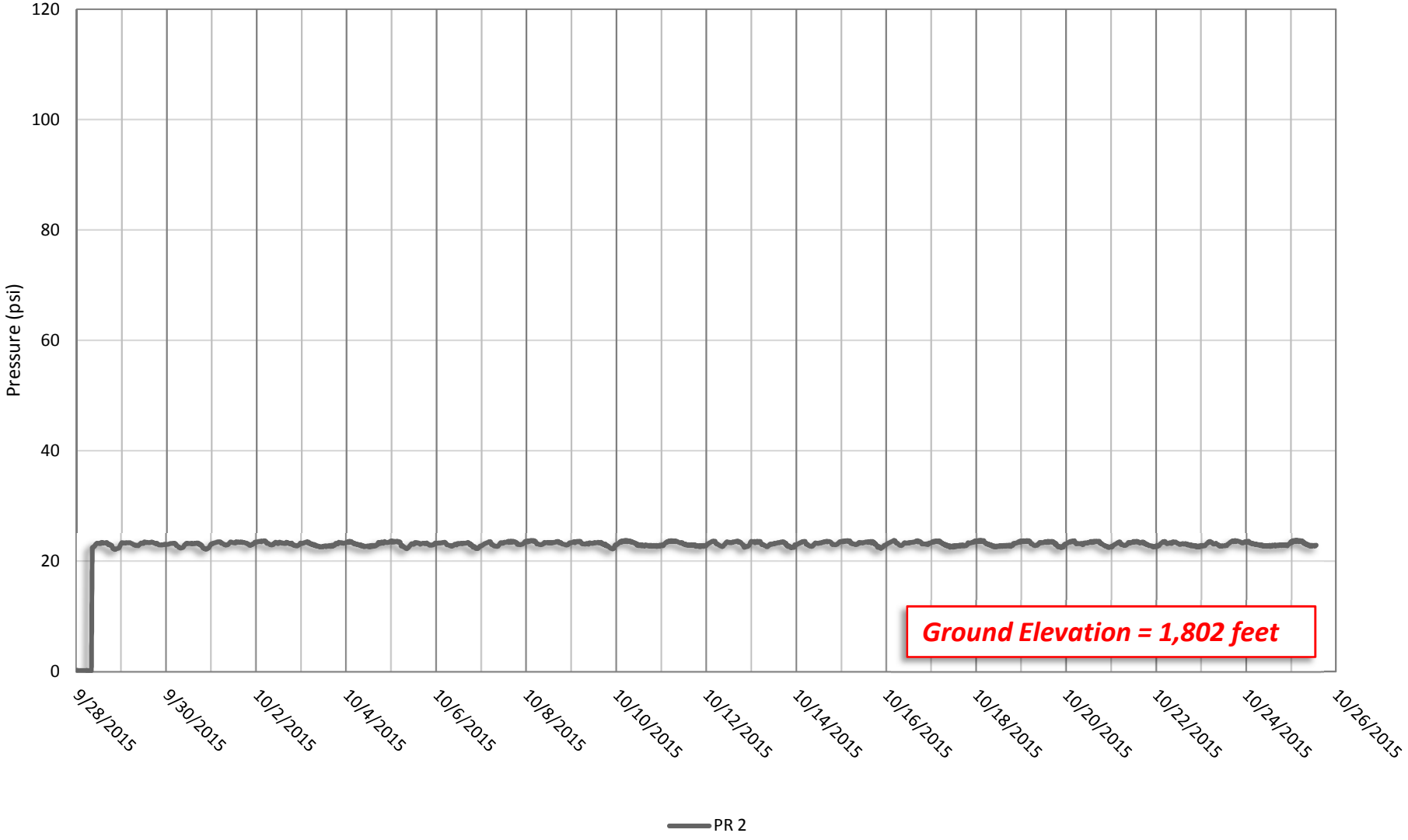


City of Fredericksburg

Figure D-4 - PR 2 Pressure Testing Results

100 Block Wind Crest

September 28 - October 26, 2015

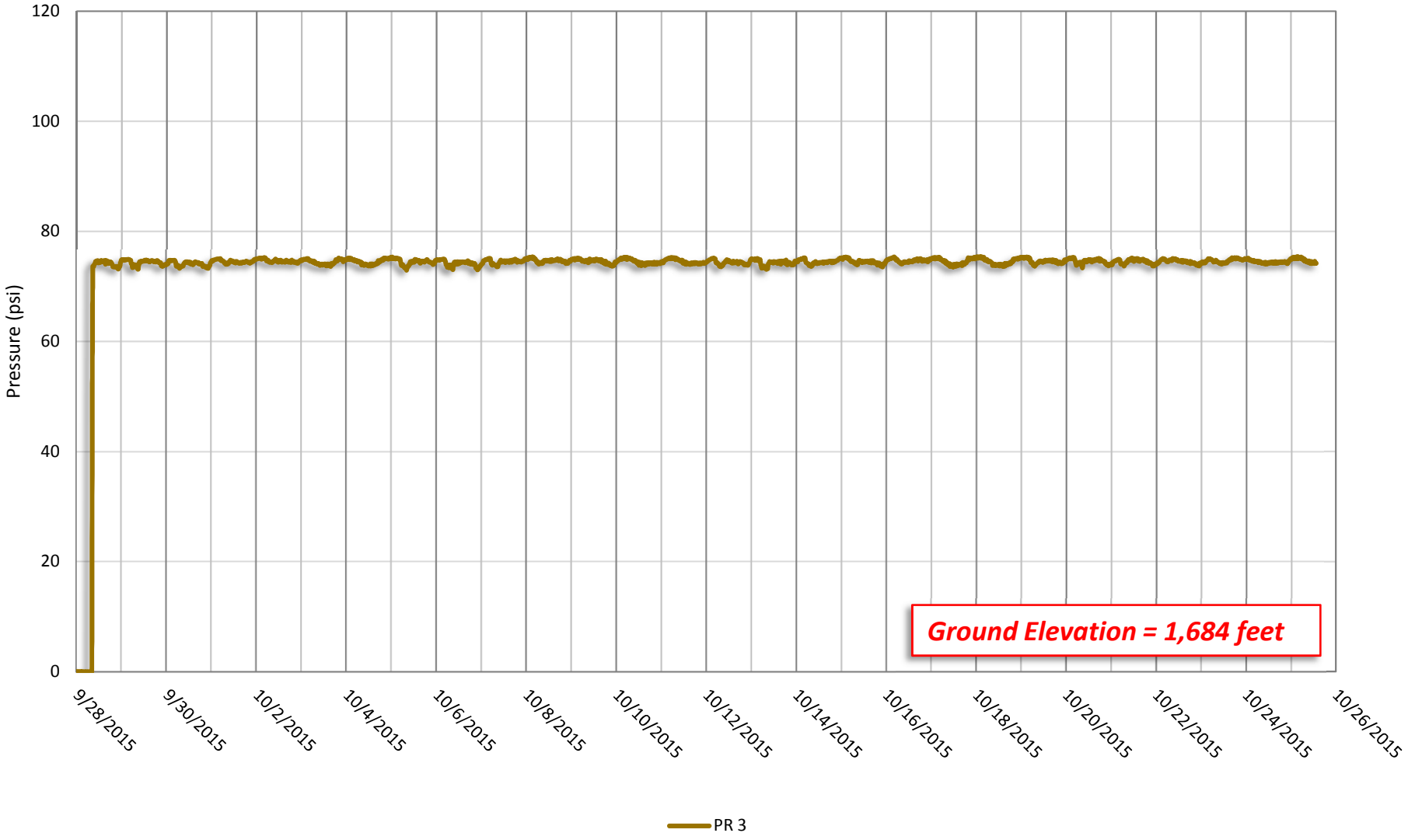


City of Fredericksburg

Figure D-5 - PR 3 Pressure Testing Results

Corner of Cross Wind and Airport Rd

September 28 - October 26, 2015

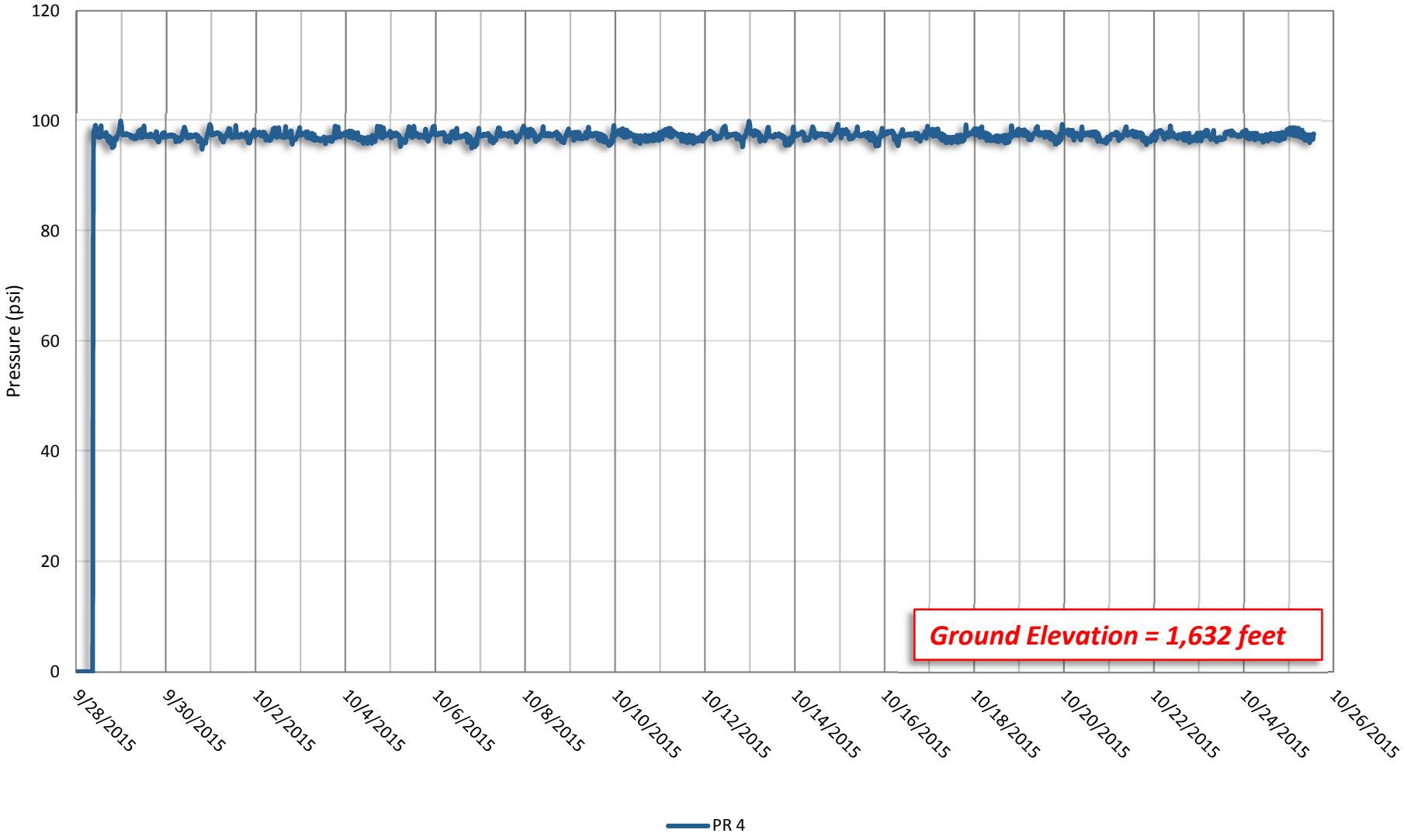


City of Fredericksburg

Figure D-6 - PR 4 Pressure Testing Results

316 Chase Oaks Place

September 28 - October 26, 2015

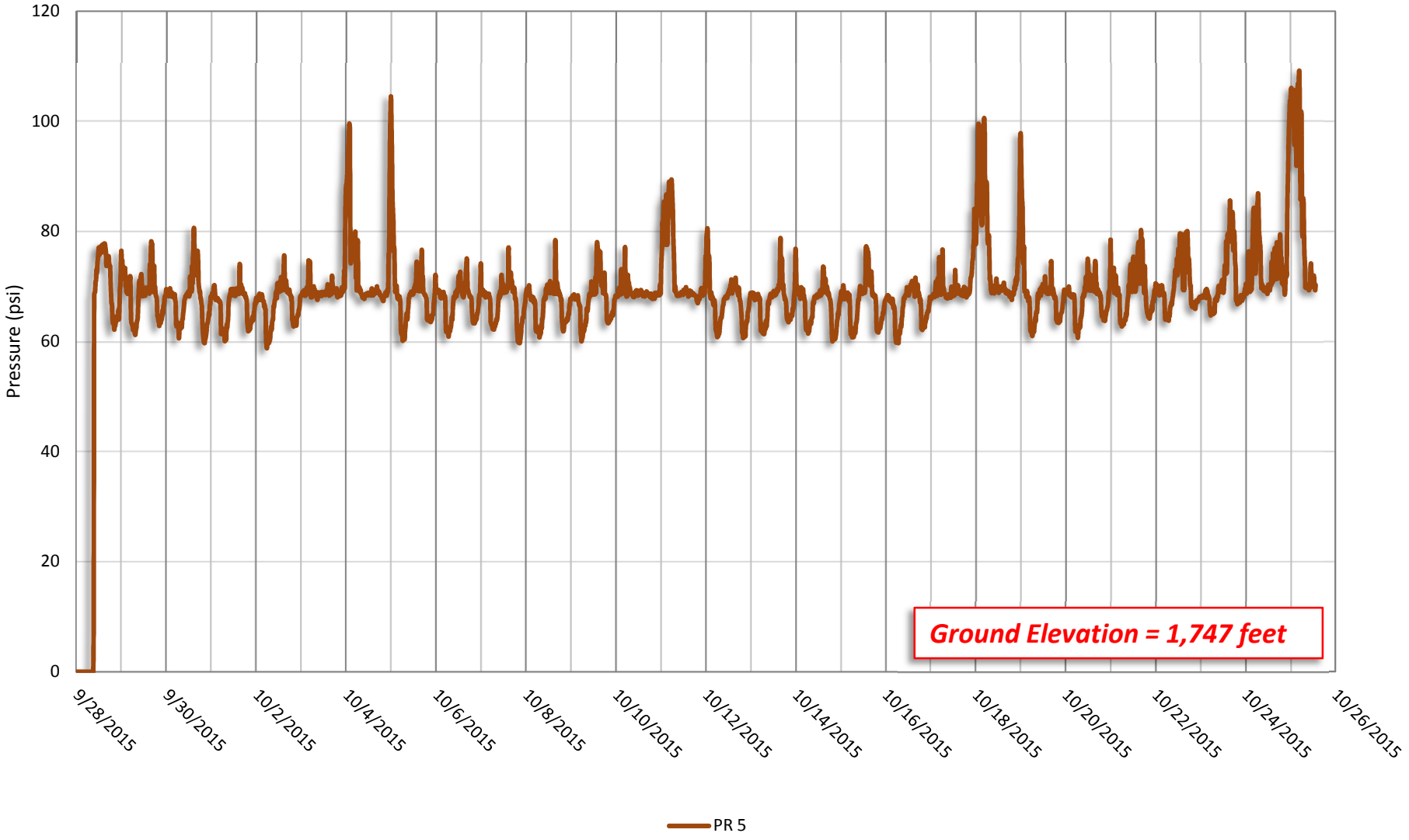


City of Fredericksburg

Figure D-7 - PR 5 Pressure Testing Results

Edgewood and Ridgewood

September 28 - October 26, 2015

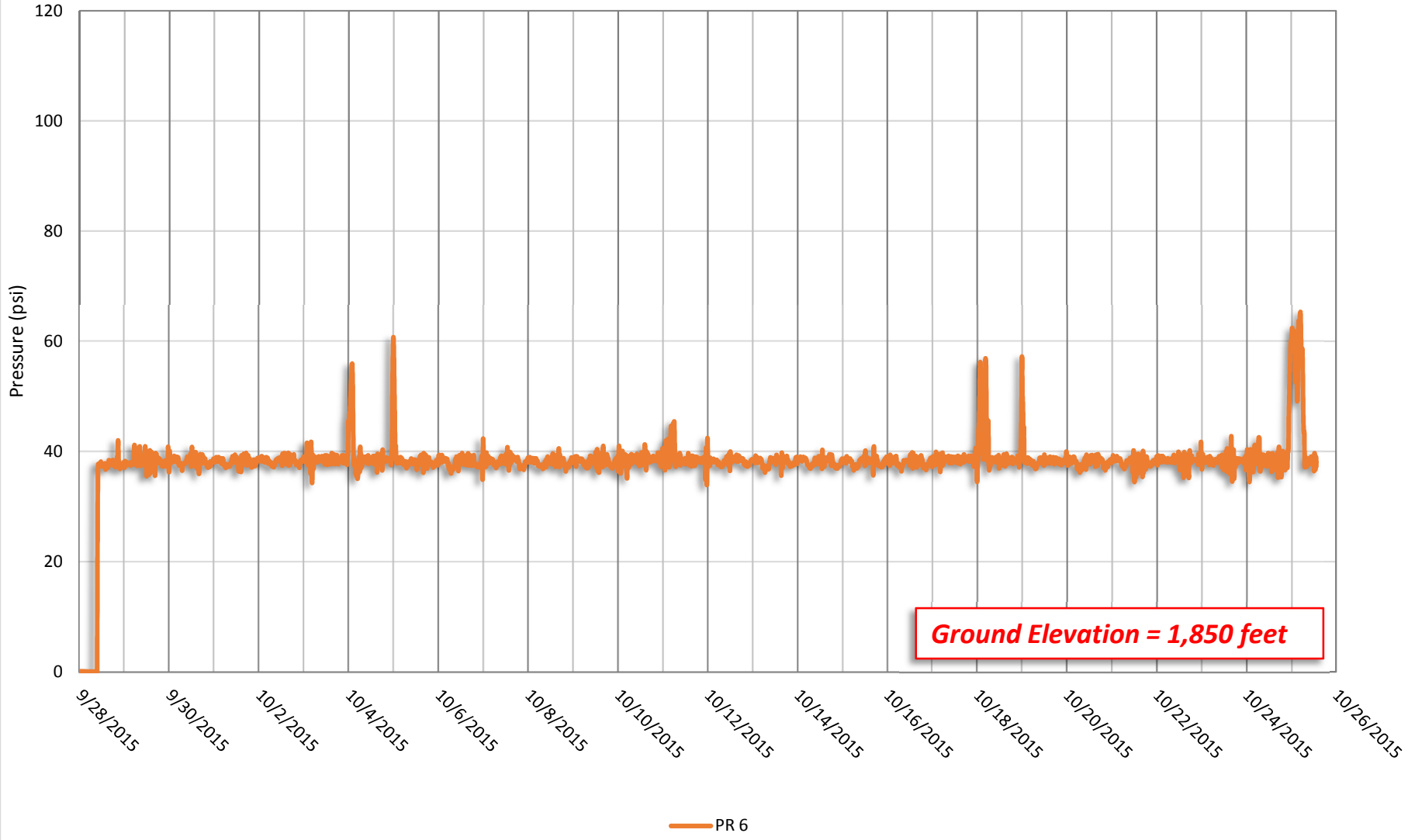


City of Fredericksburg

Figure D-8 - PR 6 Pressure Testing Results

Stone Meadow and Summit Forest

September 28 - October 26, 2015



City of Fredericksburg

Figure D-9 - PR 7 Pressure Testing Results

North Crockett and Trailmoore

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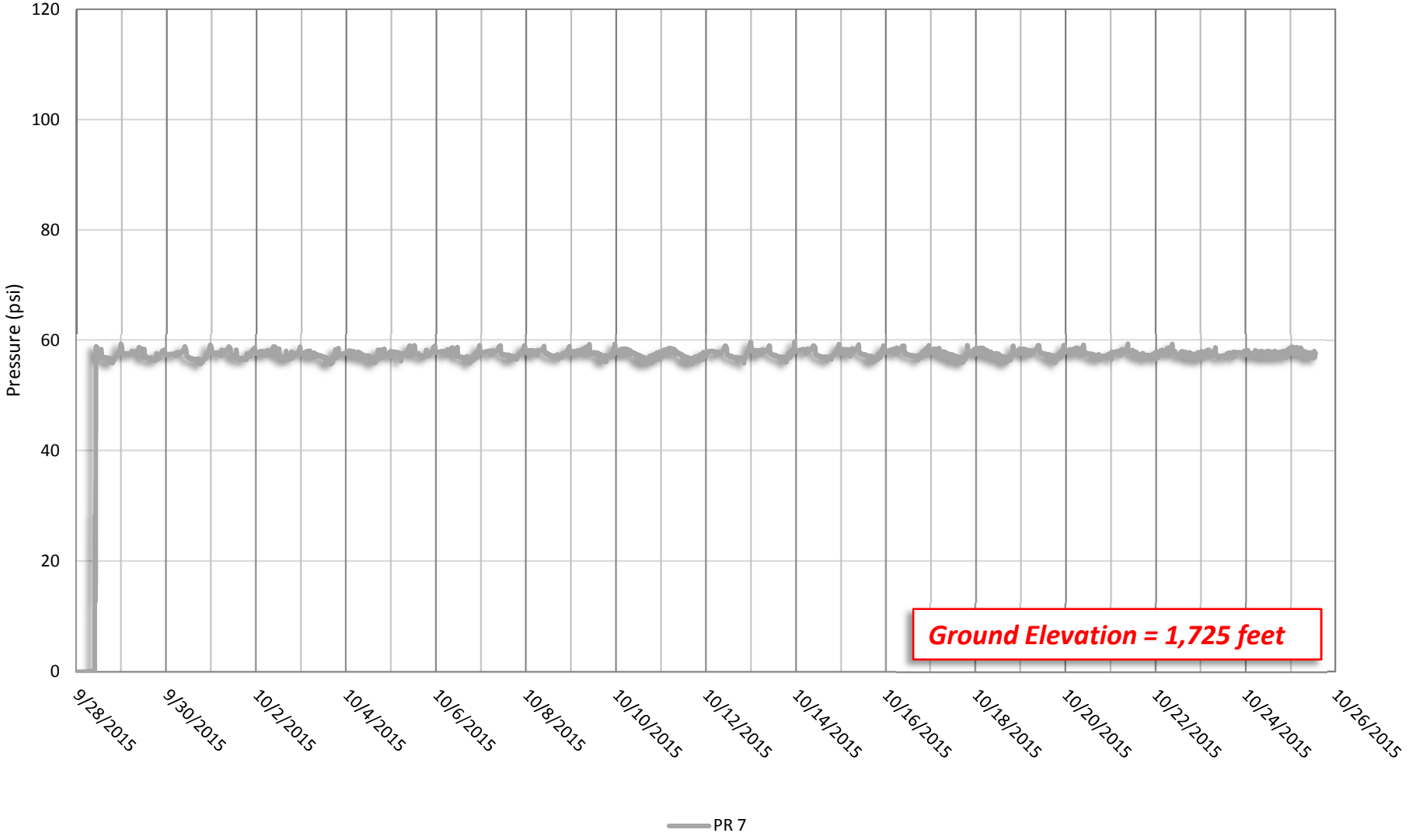
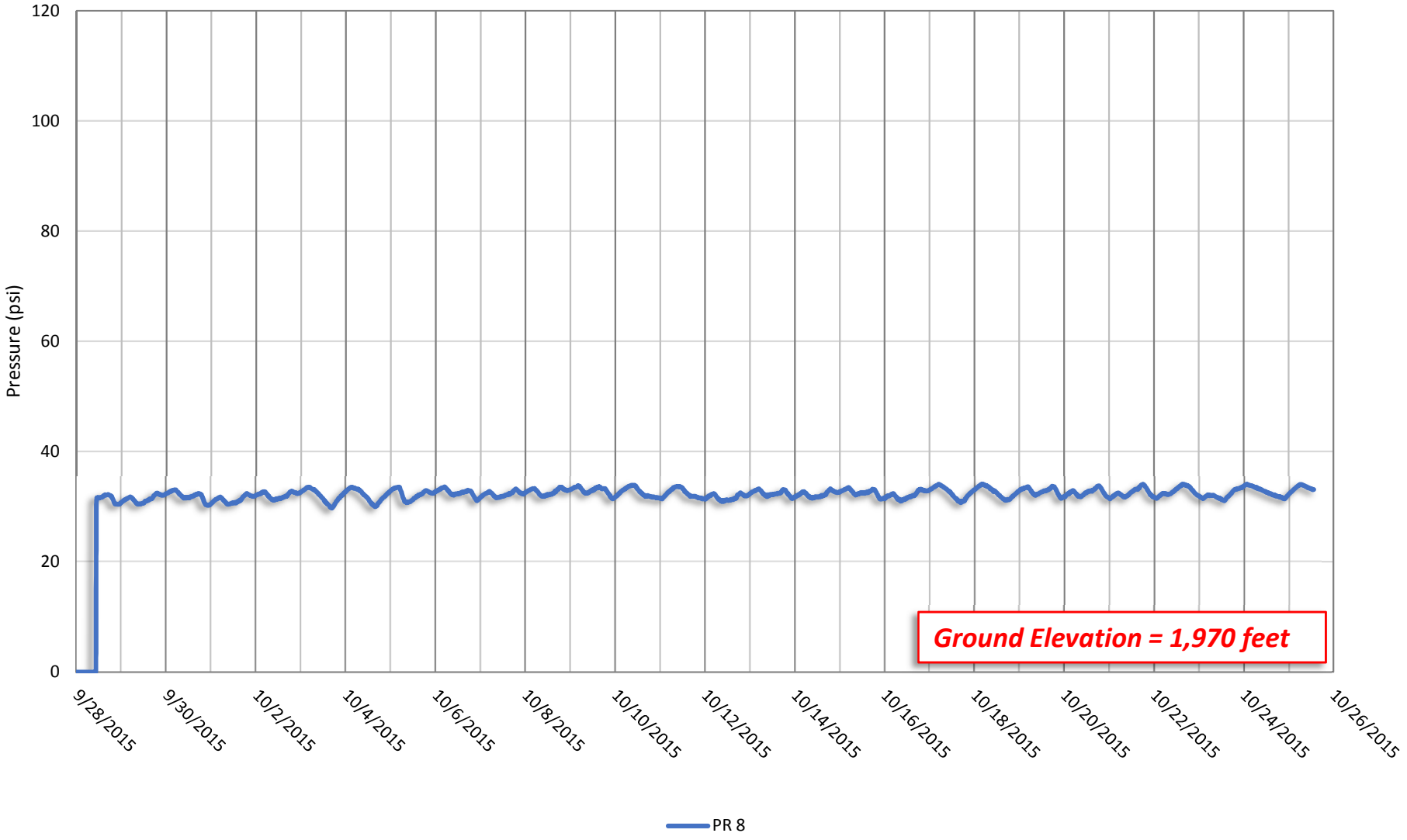


City of Fredericksburg

Figure D-10 - PR 8 Pressure Testing Results

Boot Ranch Ridge

September 28 - October 26, 2015

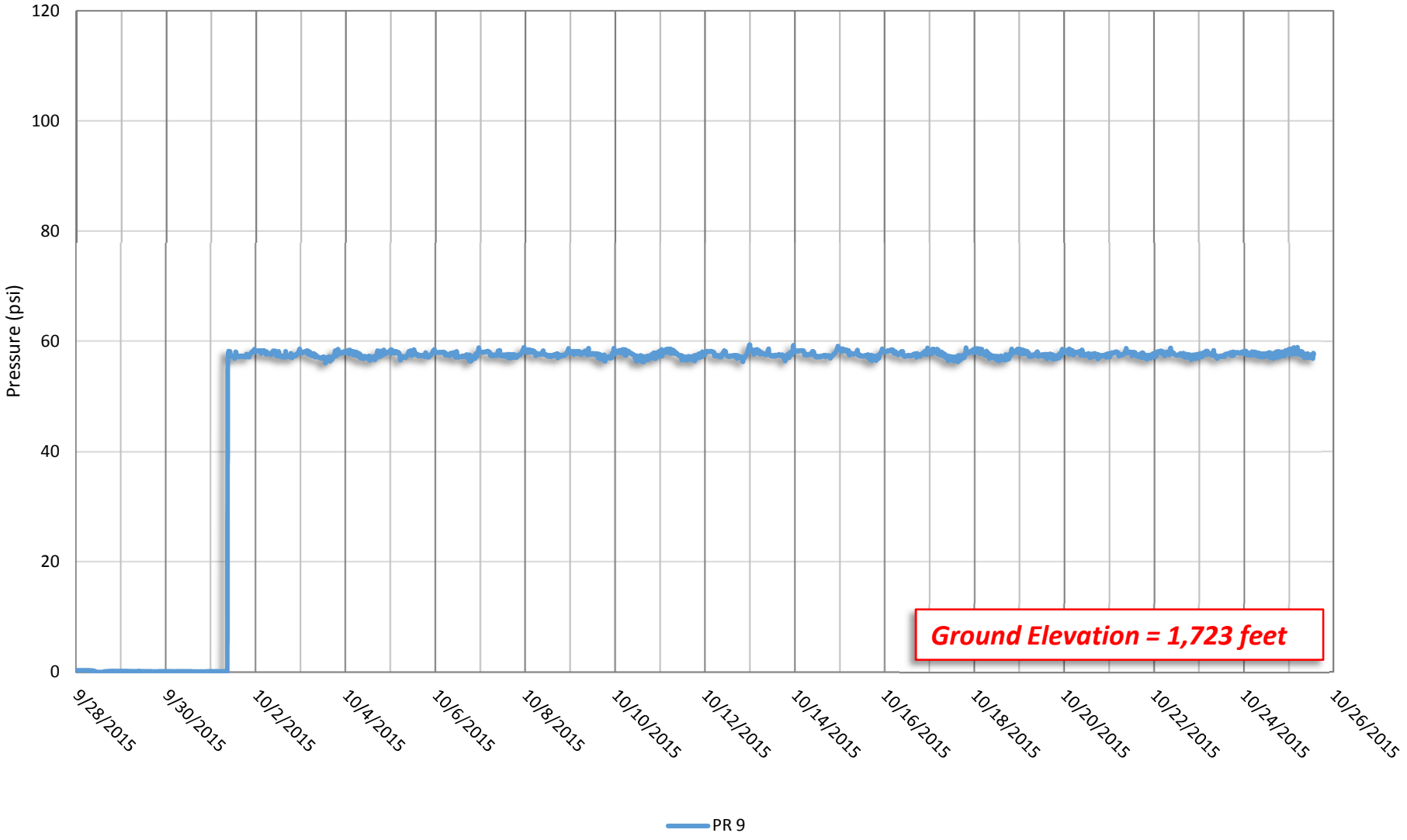


City of Fredericksburg

Figure D-11 - PR 9 Pressure Testing Results

Edison and Austin

September 28 - October 26, 2015

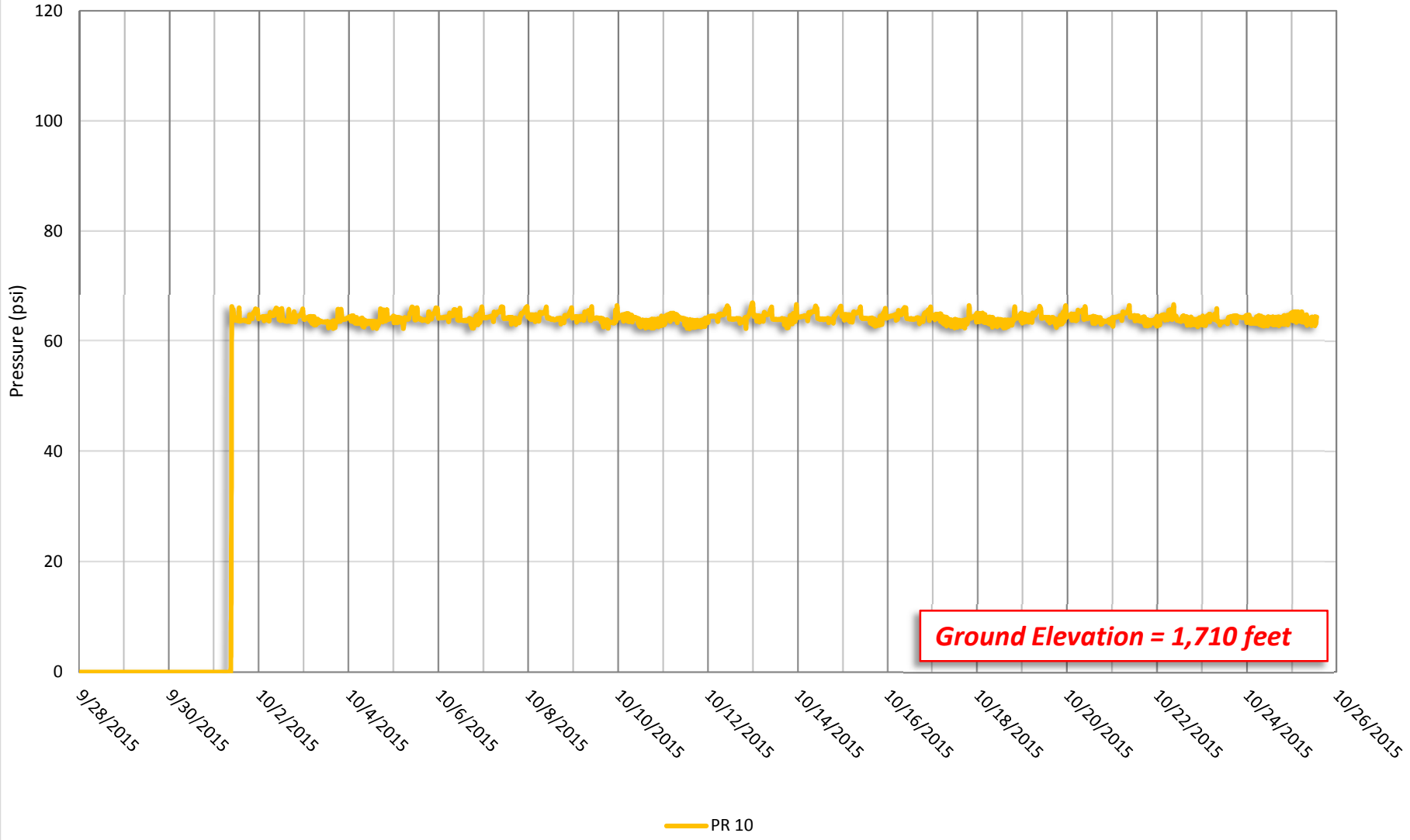


City of Fredericksburg

Figure D-12 - PR 10 Pressure Testing Results

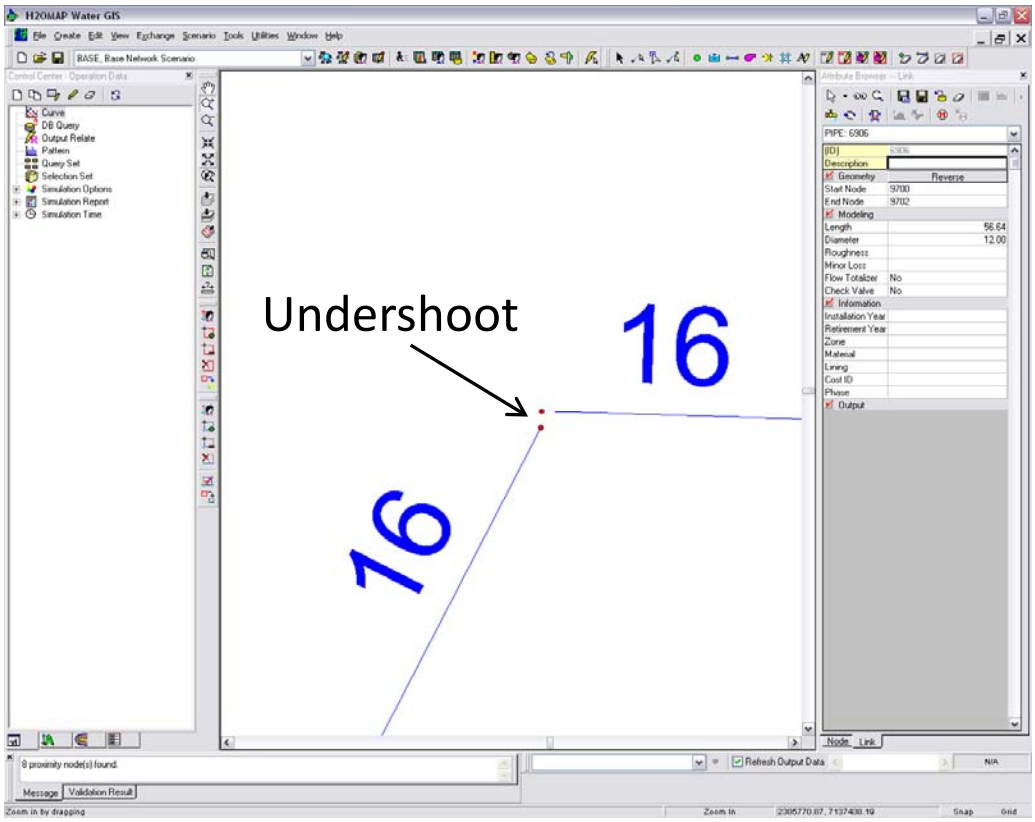
Elk and Center

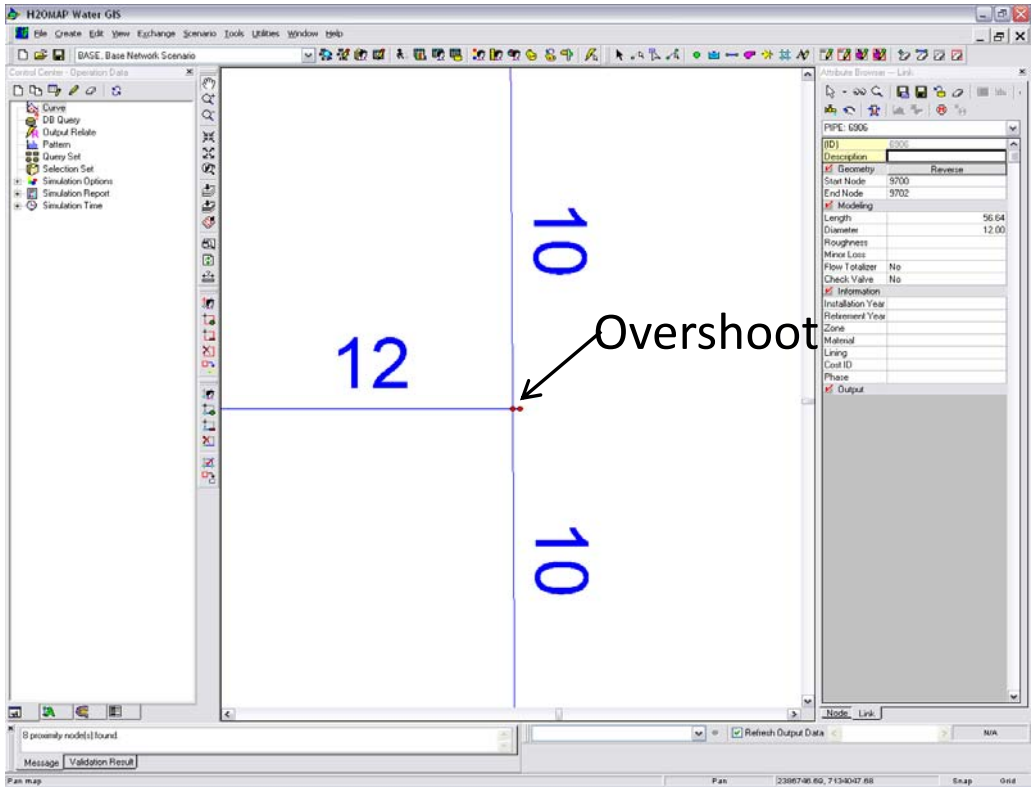
September 28 - October 26, 2015



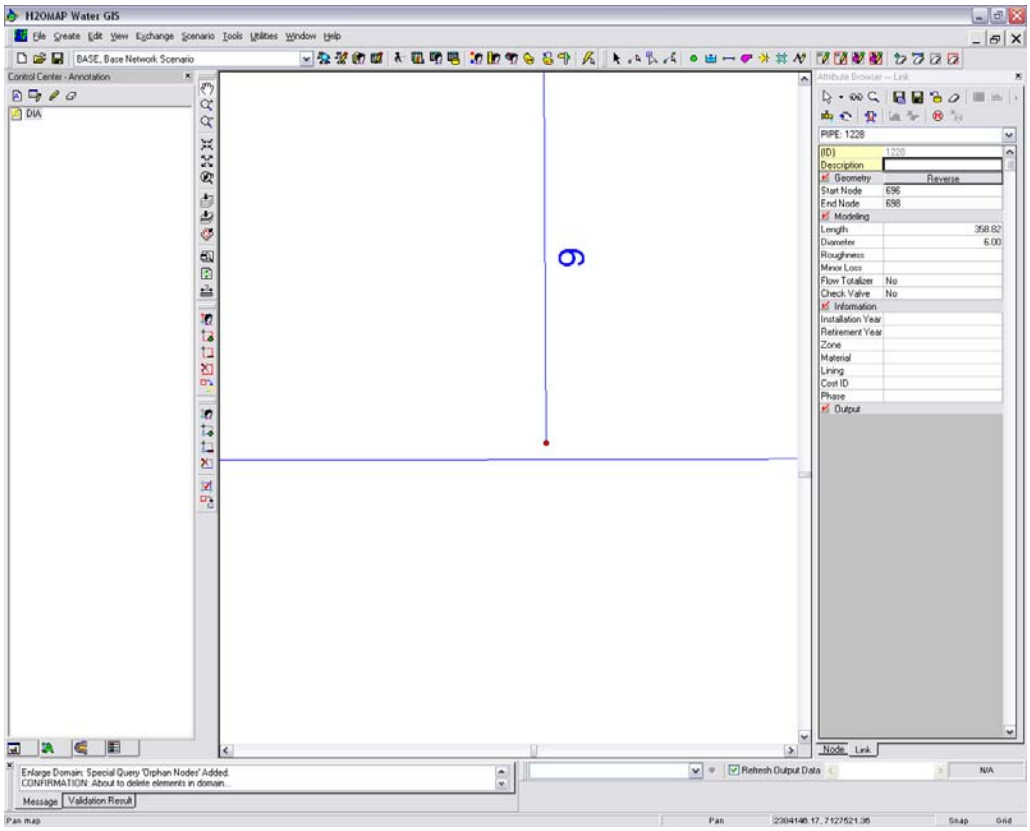
APPENDIX E
MODEL NETWORK REVIEW

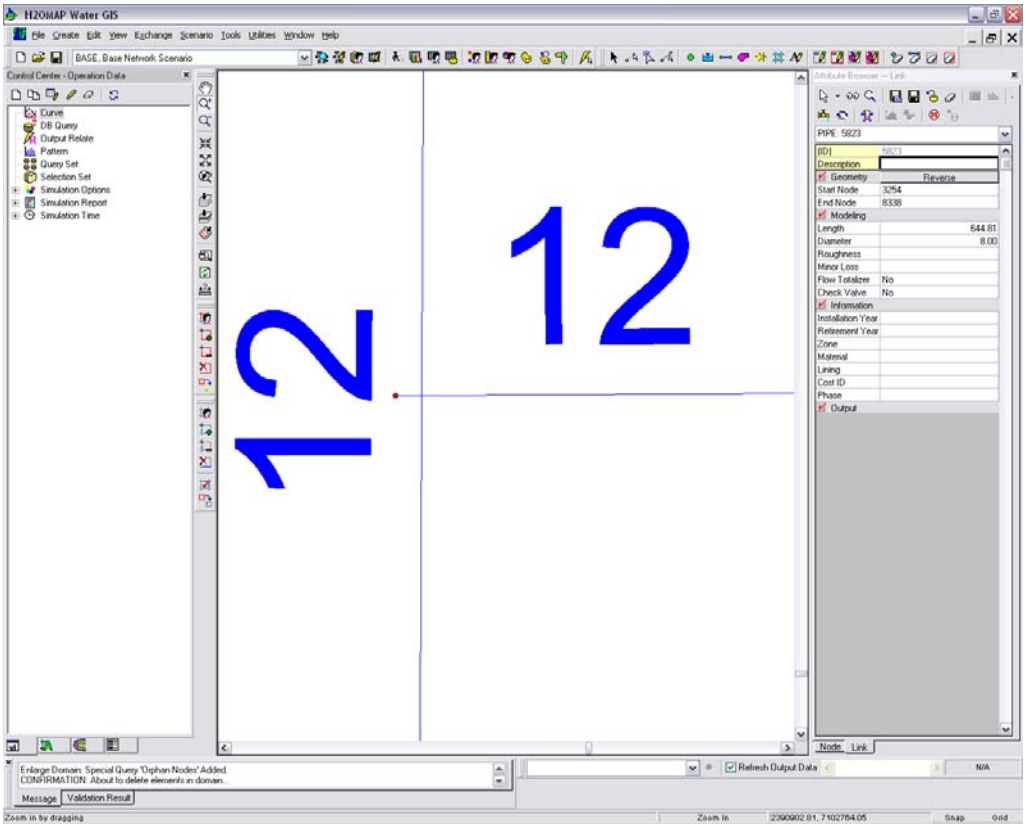
Nodes in Close Proximity



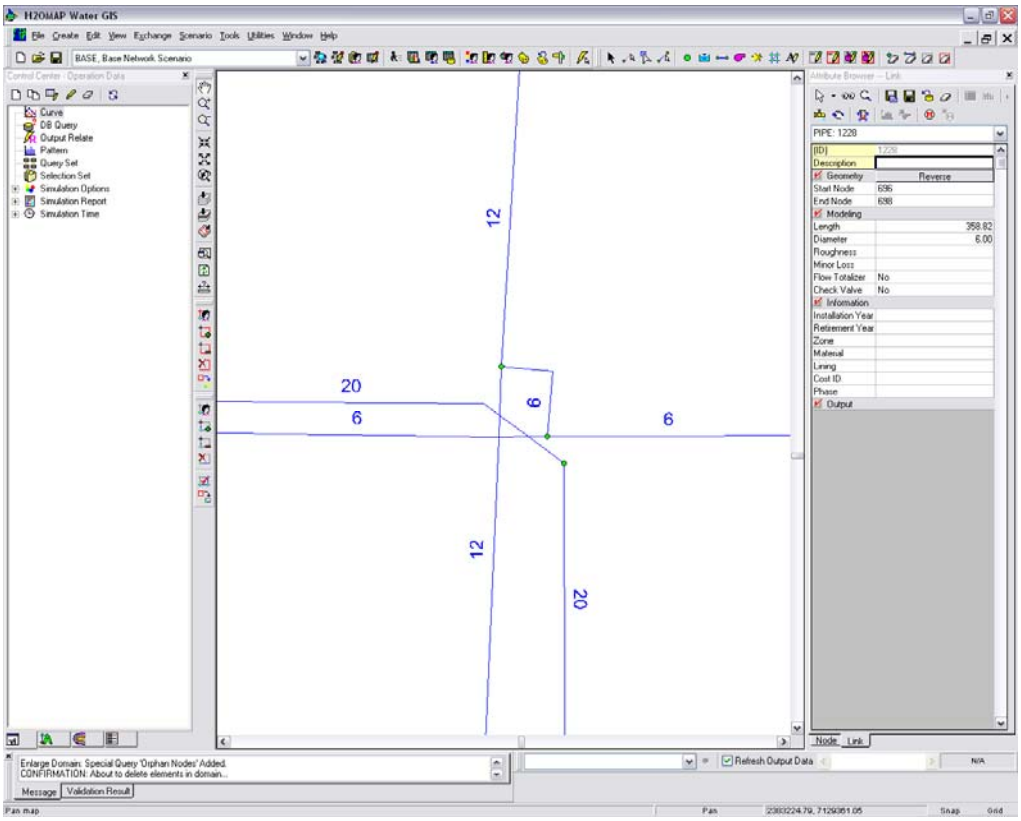


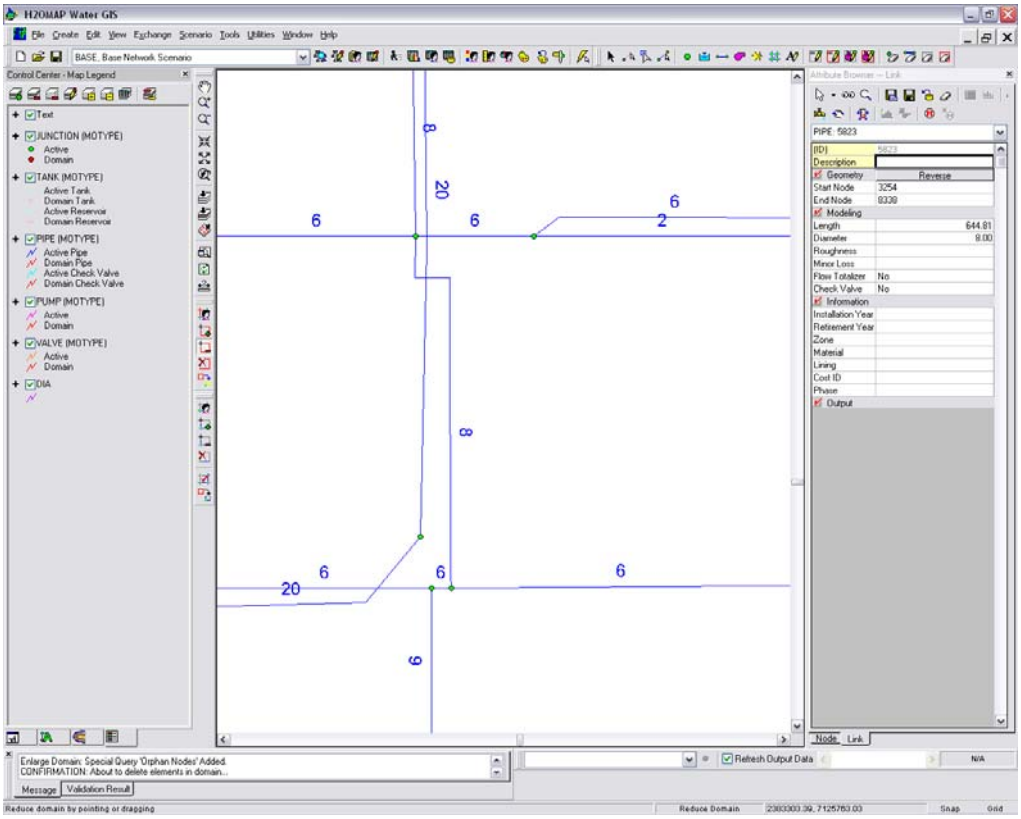
Pipe Split Candidates



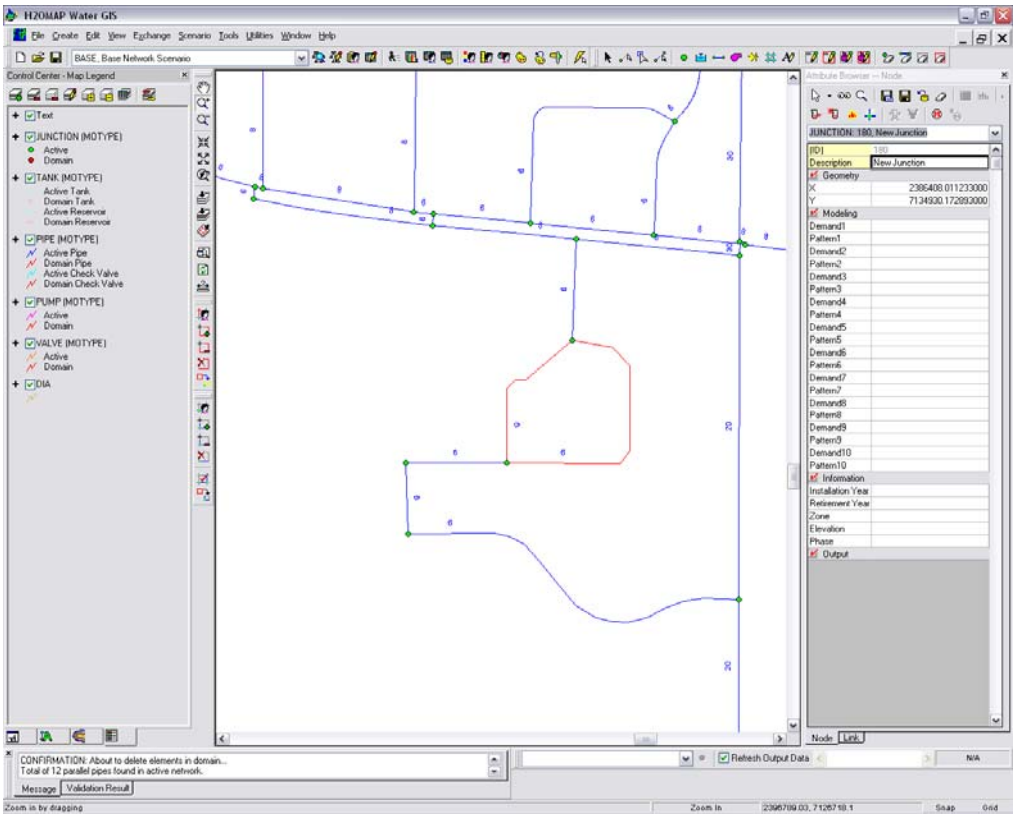


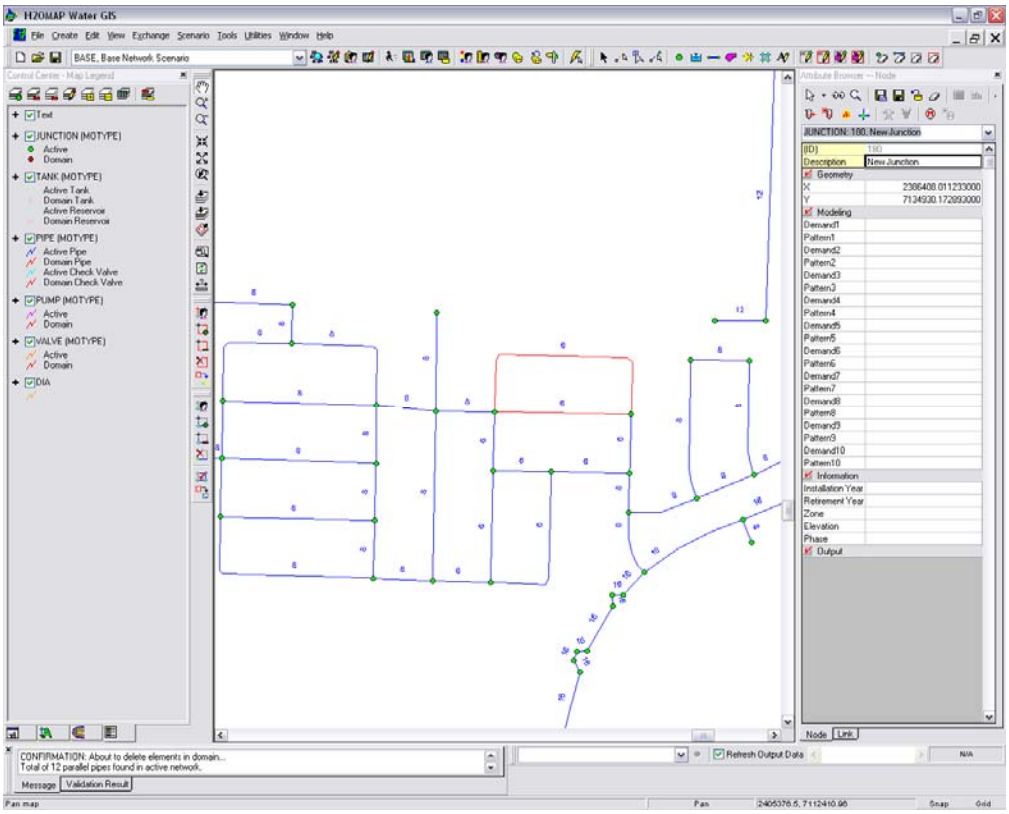
Crossing/Intersecting Pipes





Parallel Pipes





APPENDIX F
GEOCODED WATER METER DATA

FIGURE F-1
CITY OF FREDERICKSBURG
WATER DEMAND BY BILLING METER

LEGEND

*Demand in Gallons per Day**

- Less than 1,000 gpd
- 1,000 to 1,500 gpd
- 1,500 to 2,000 gpd
- 2,000 to 5,000 gpd
- 5,000 to 10,000 gpd
- Greater than 10,000 gpd

- Highway
- Road
- Stream
- Parcel
- City Limit
- ETJ Boundary

FREESE AND NICHOLS

CITY OF Fredericksburg ESTABLISHED 1846

* Values shown reflect September 2015 Average Day Demand

0 1,400 2,800

SCALE IN FEET

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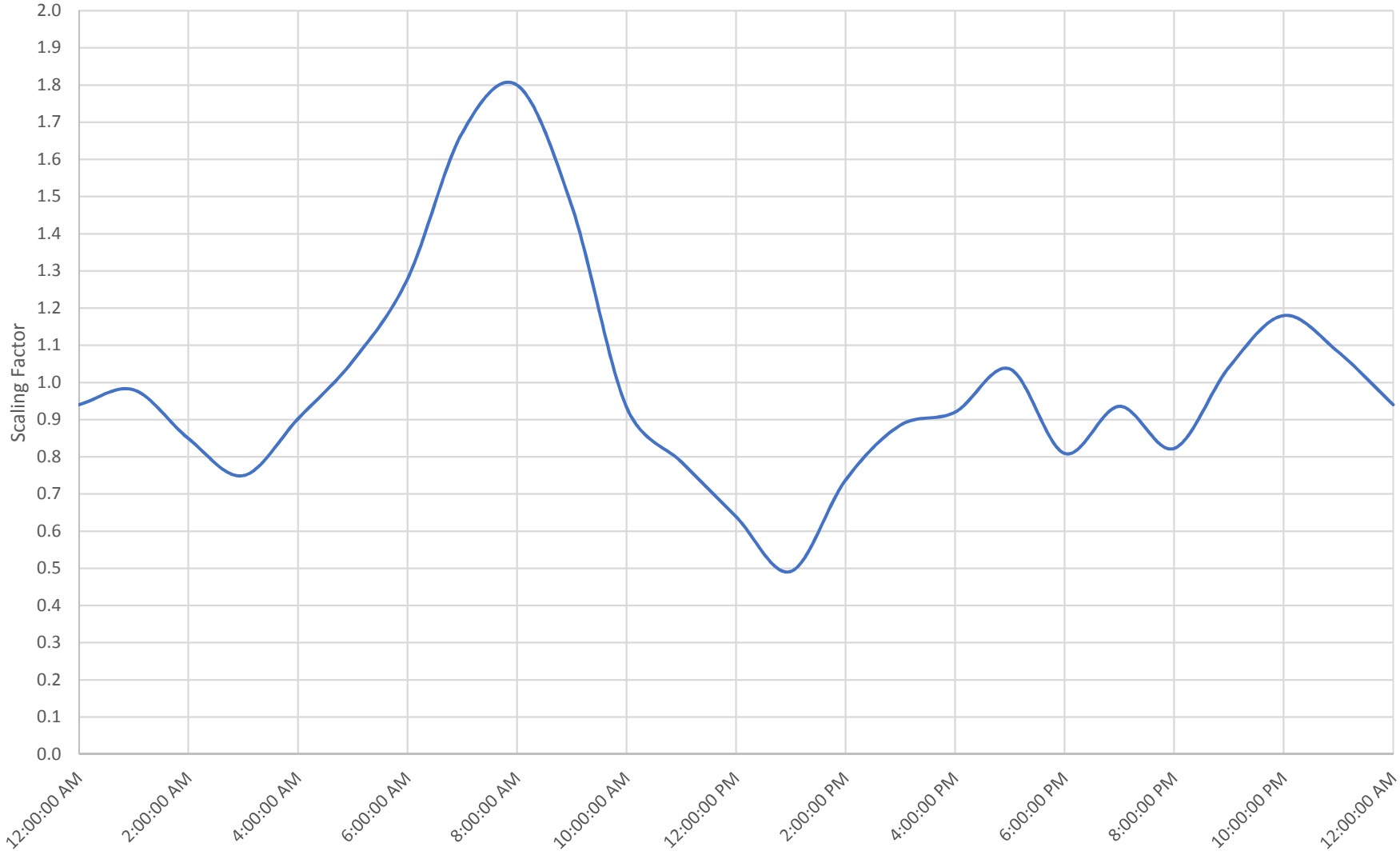
APPENDIX G
MODEL CALIBRATION RESULTS

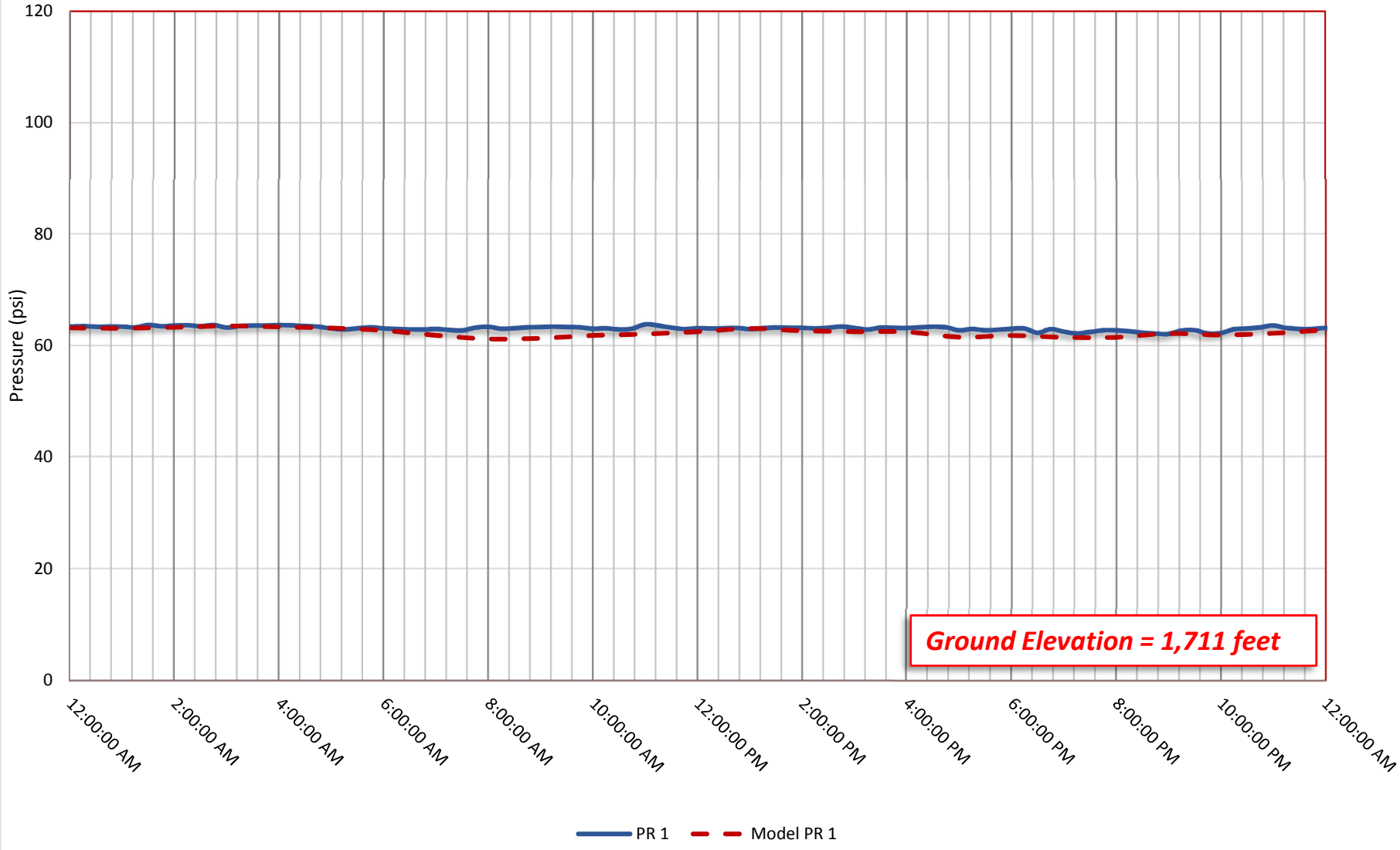
City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Water Demand Diurnal Pattern



City of Fredericksburg
EPS Water Model Calibration
October 6, 2015 - PR 1



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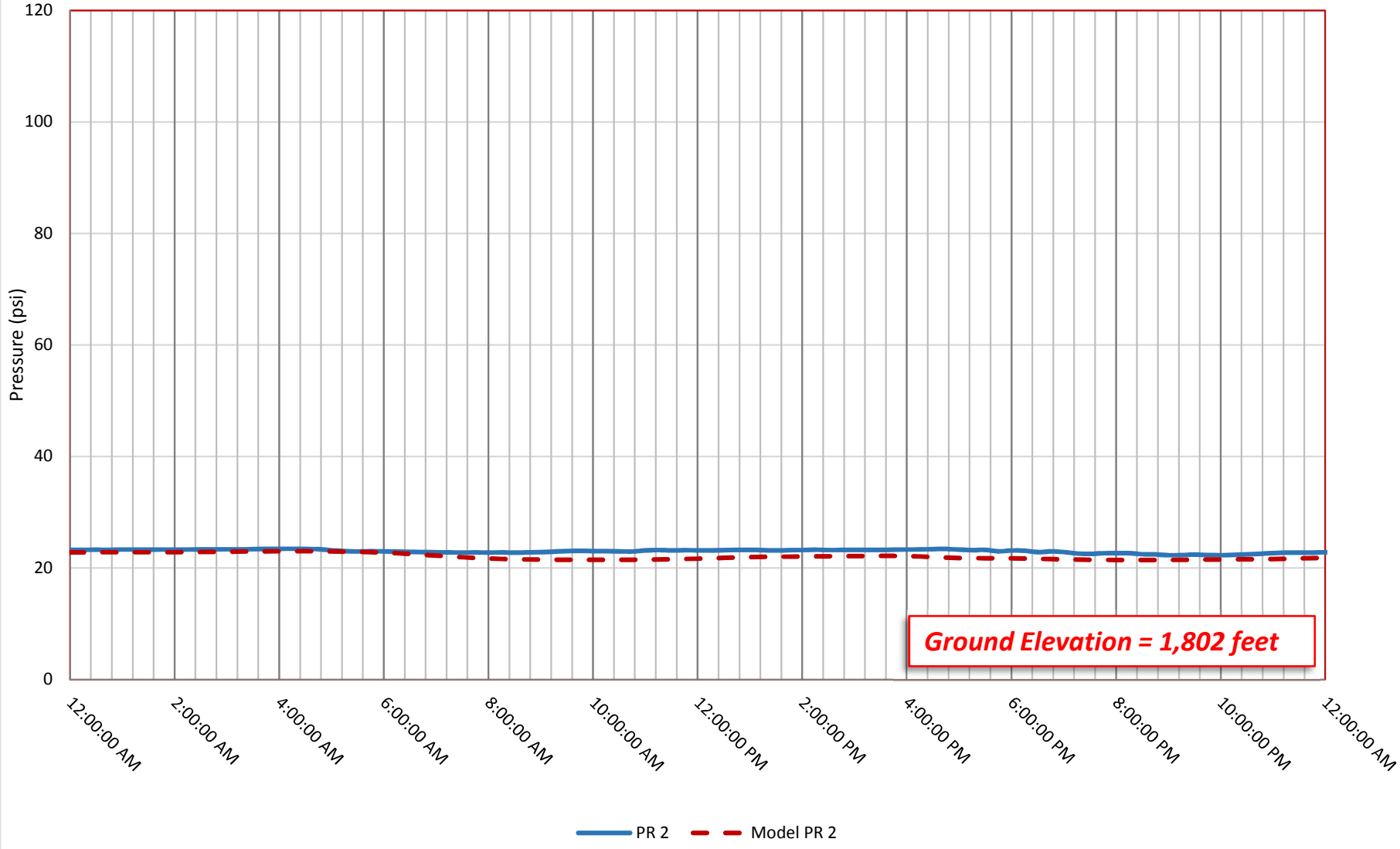

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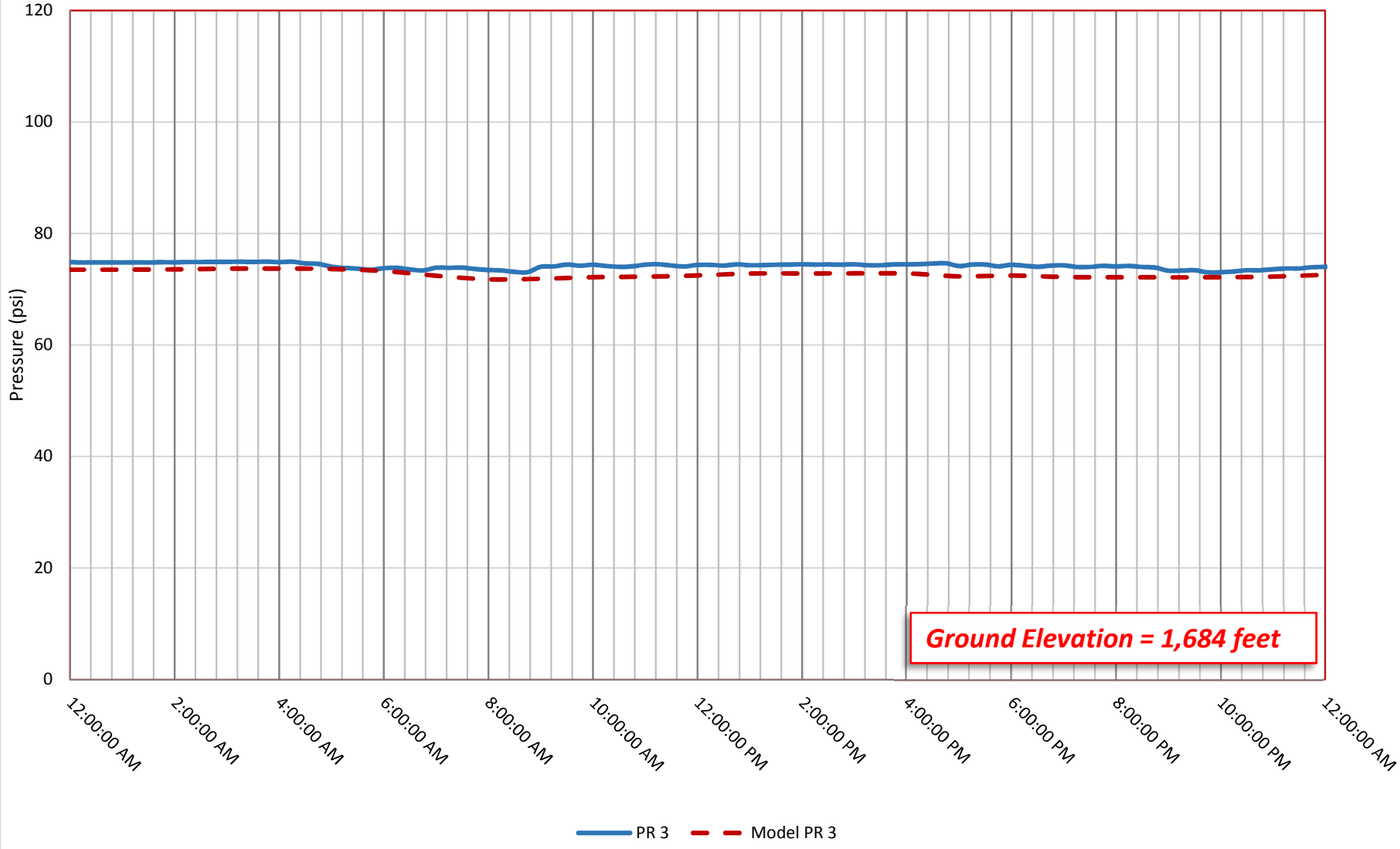

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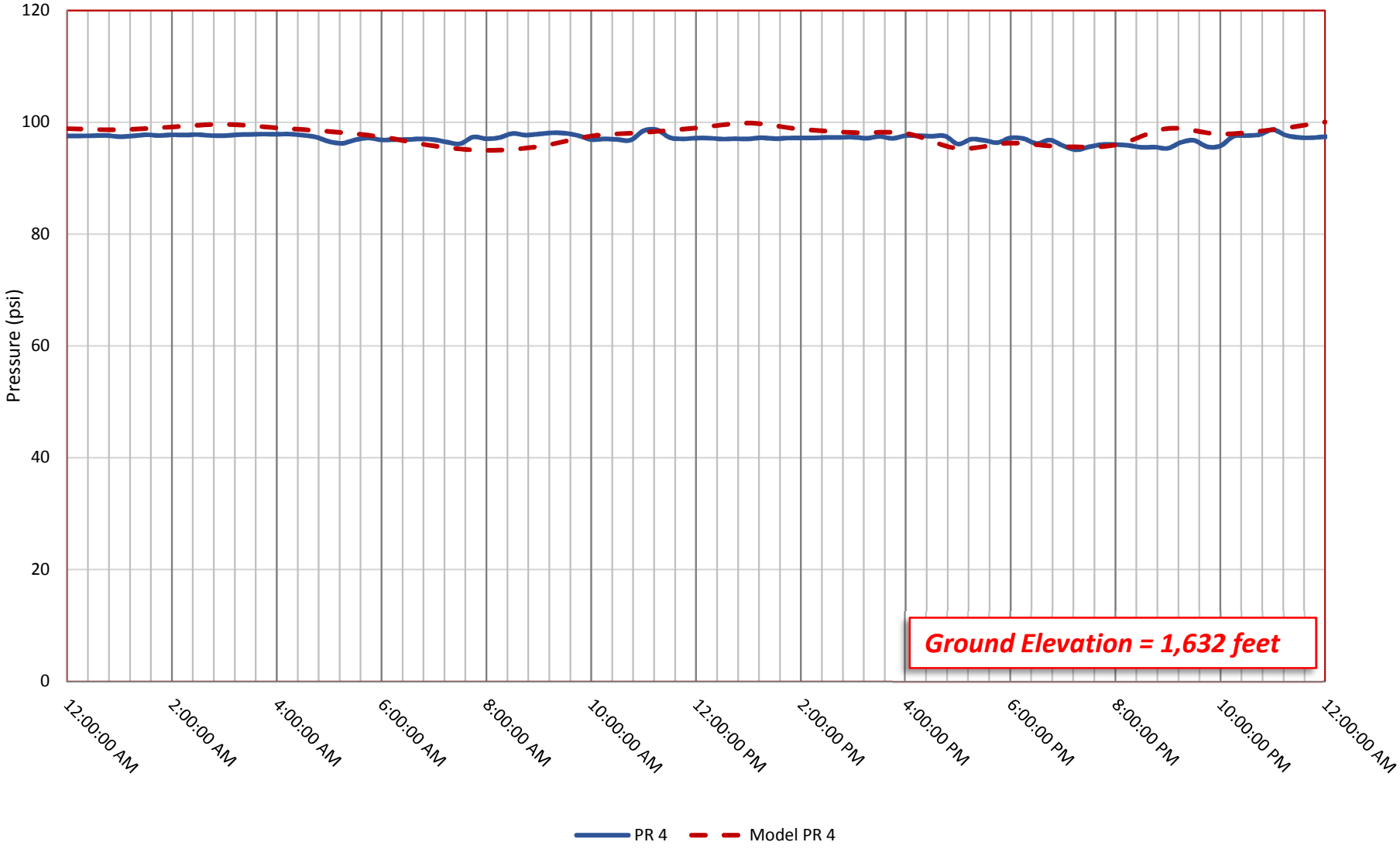
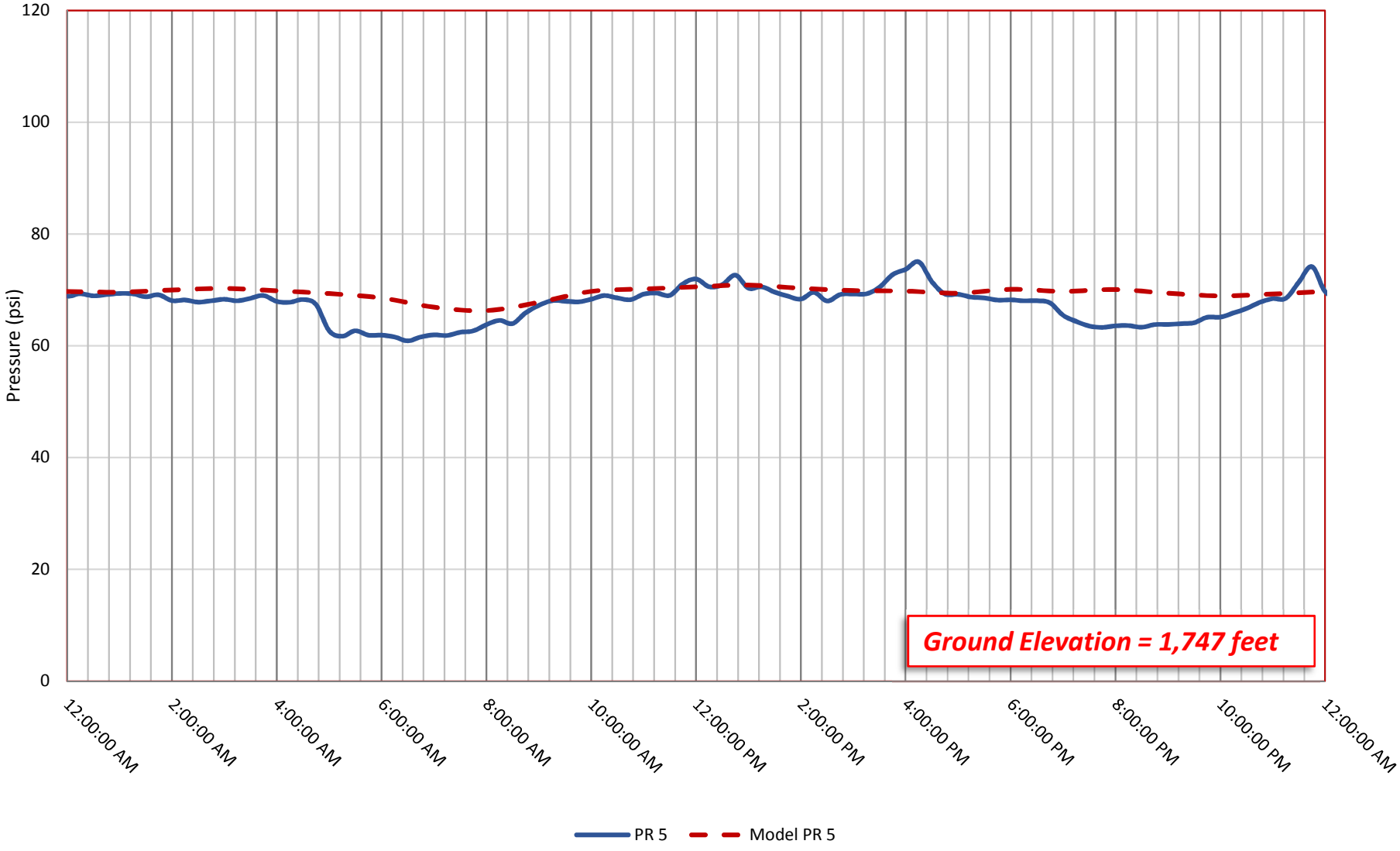
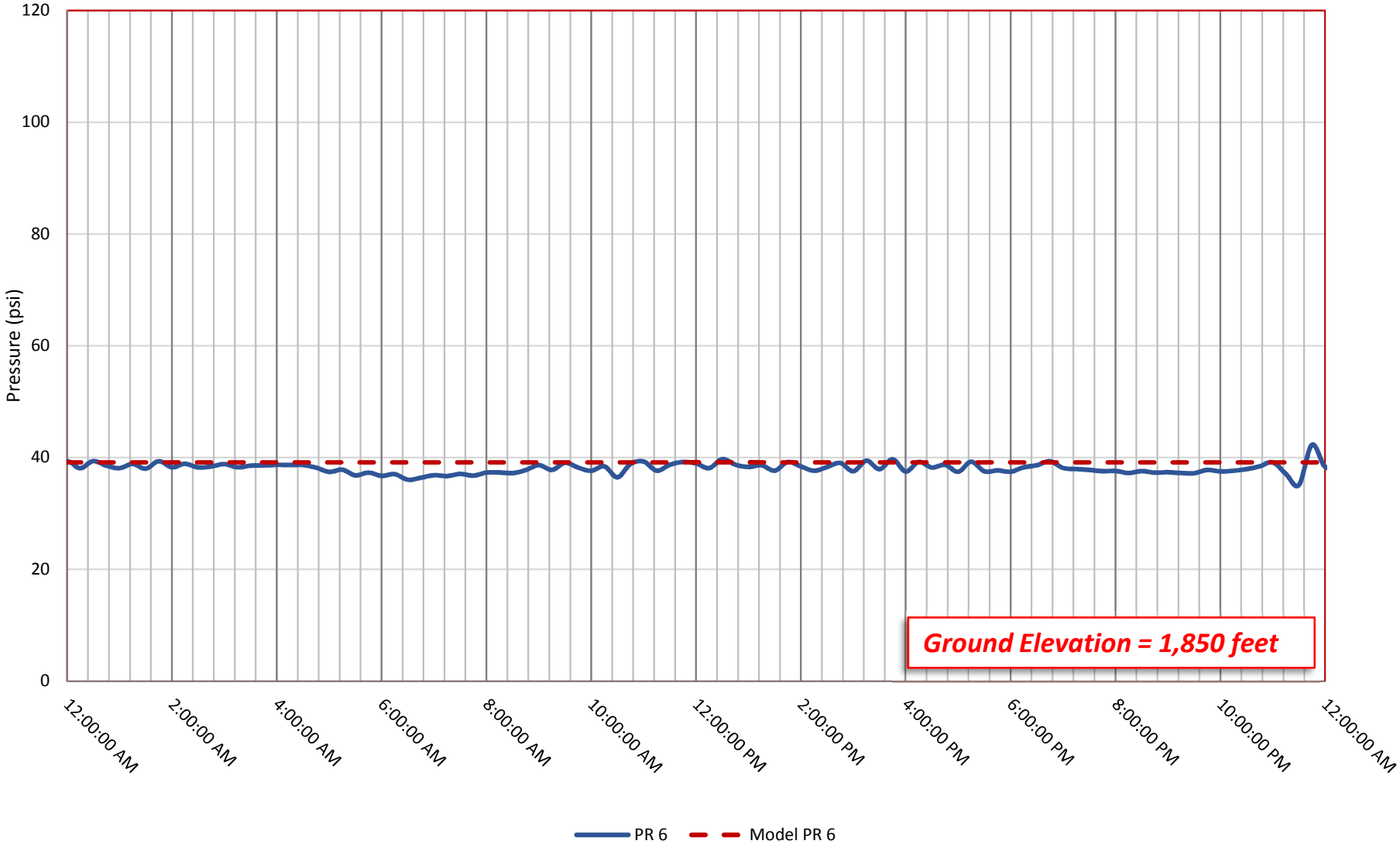


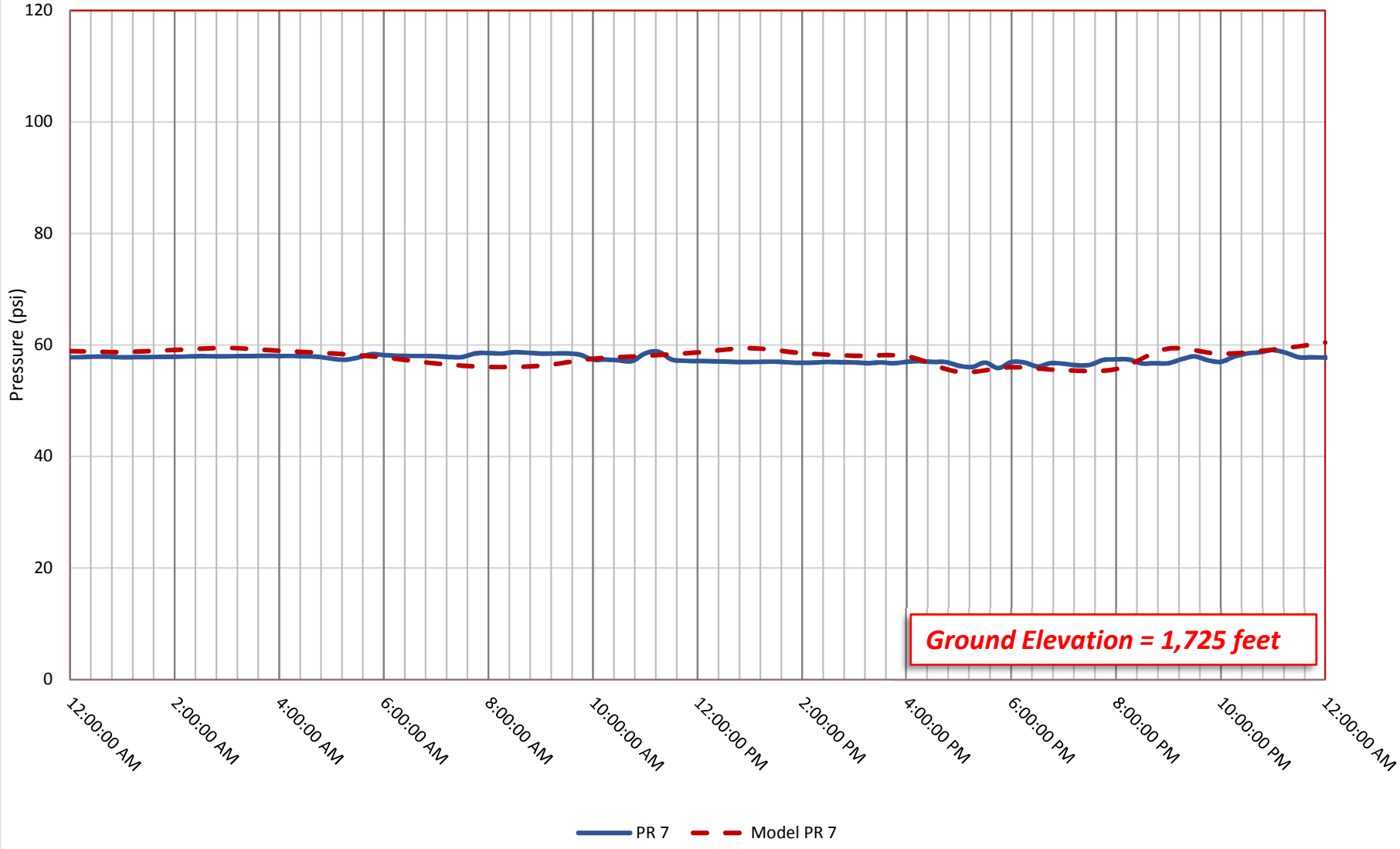
City of Fredericksburg
EPS Water Model Calibration
October 6, 2015 - PR 5



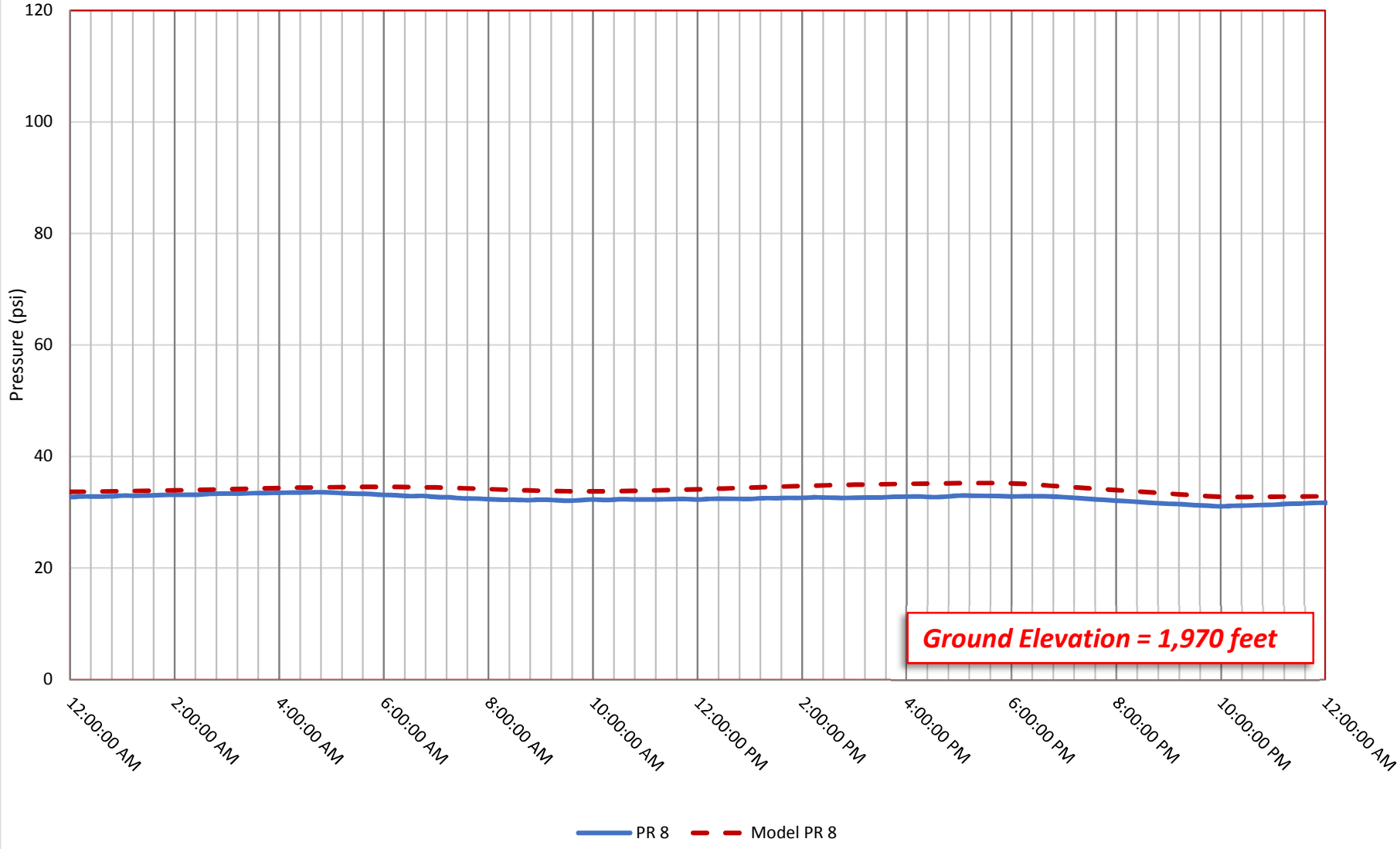
City of Fredericksburg
EPS Water Model Calibration
October 6, 2015 - PR 6



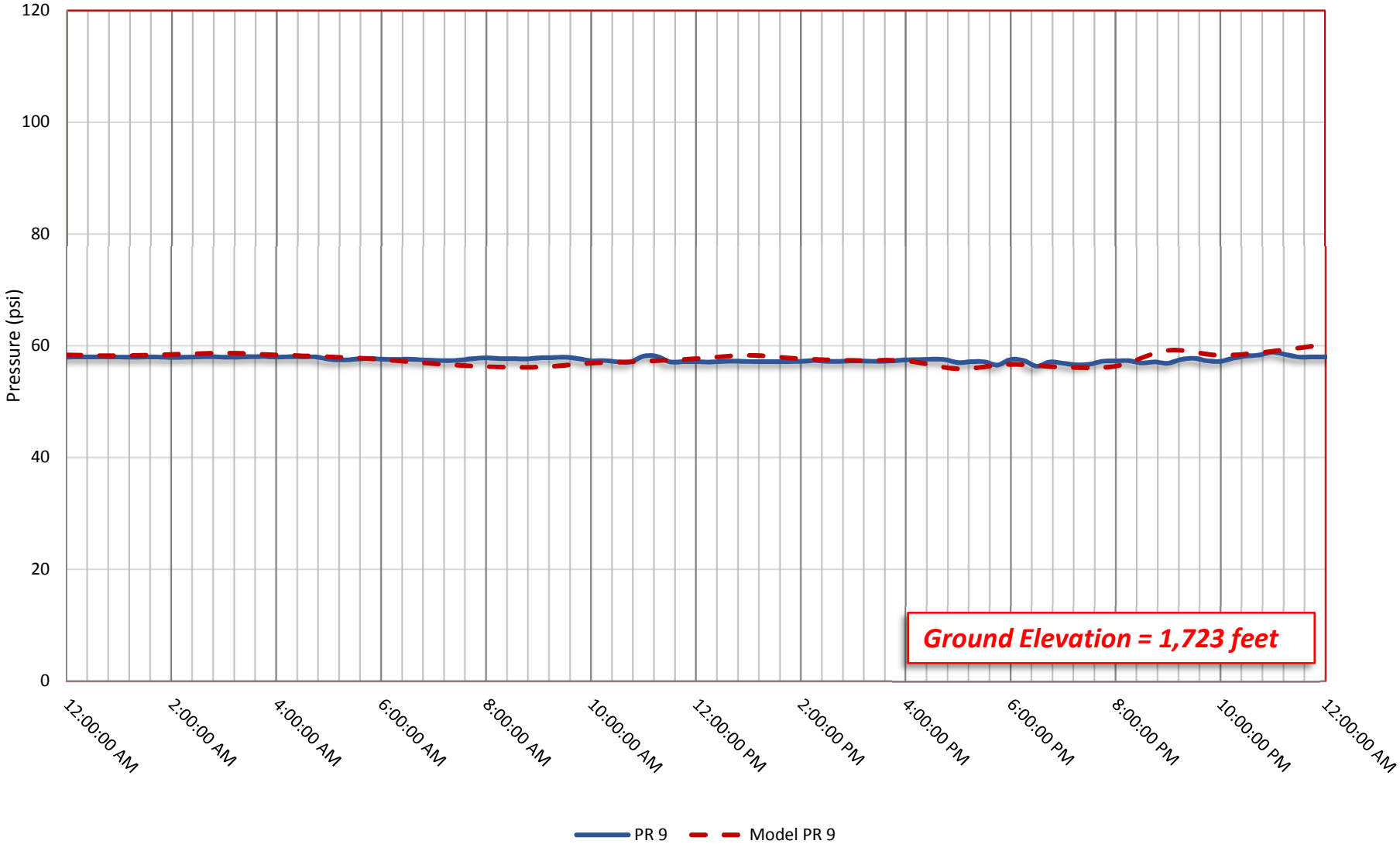
City of Fredericksburg
EPS Water Model Calibration
October 6, 2015 - PR 7



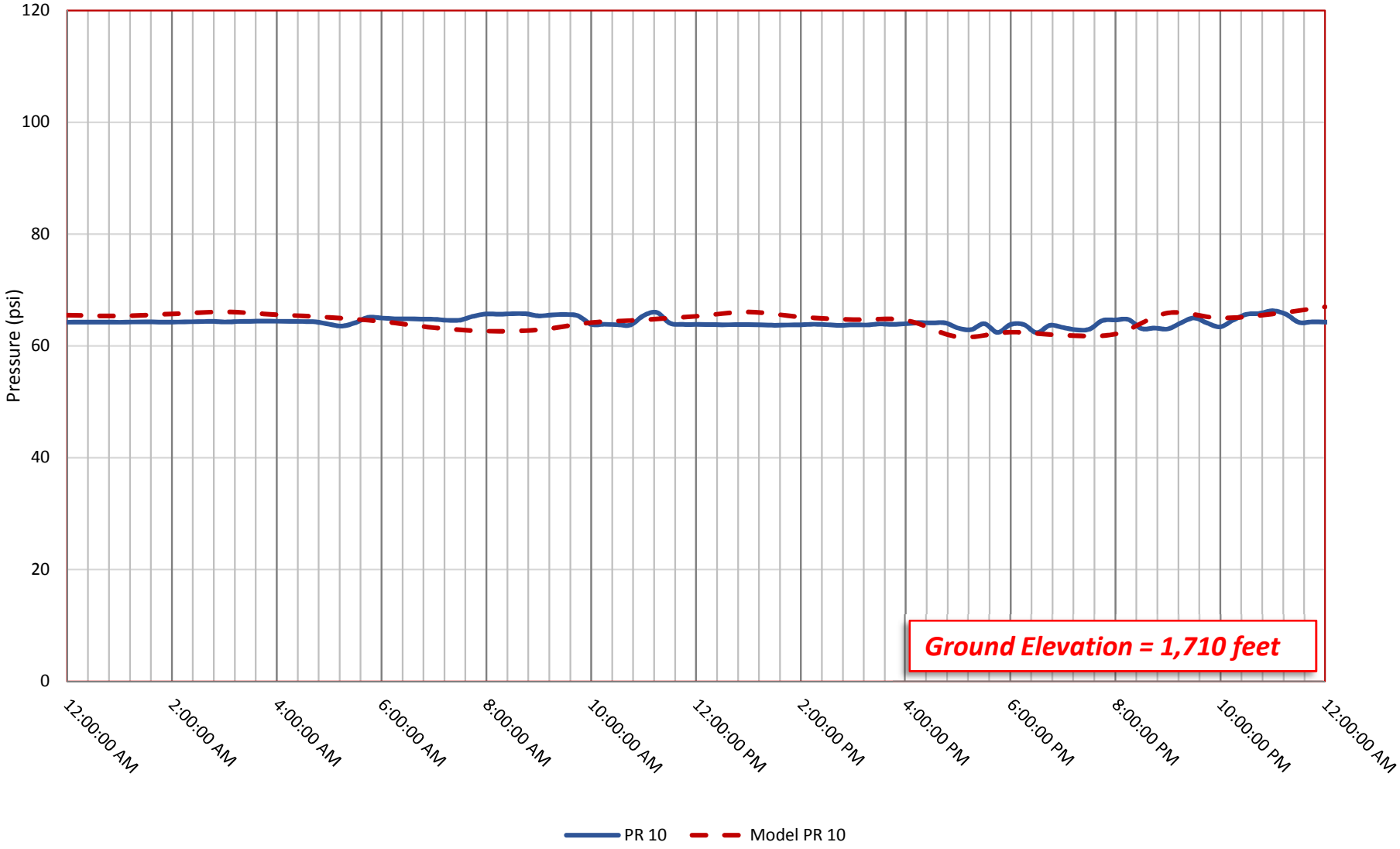
City of Fredericksburg
EPS Water Model Calibration
October 6, 2015 - PR 8



City of Fredericksburg
EPS Water Model Calibration
October 6, 2015 - PR 9



City of Fredericksburg
EPS Water Model Calibration
October 6, 2015 - PR 10



APPENDIX H
WATER CAPITAL IMPROVEMENT PLAN COST ESTIMATES

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 1 — **Planning Period:** 5 Years

Project Name: Goehmann Lane Pump Station Rehabilitation

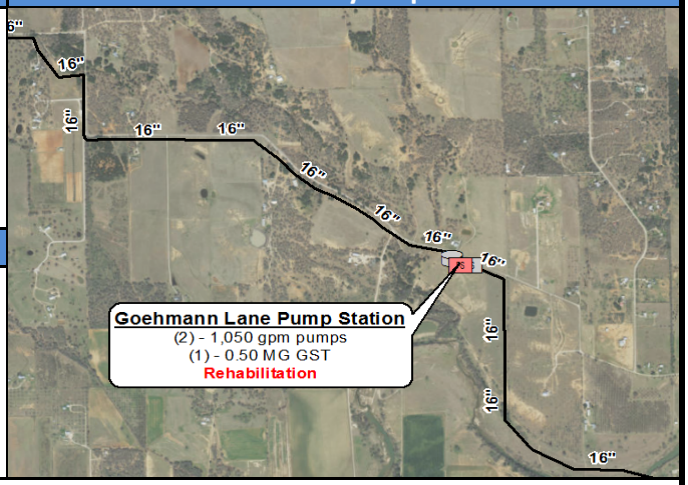
Project Description:

This project rehabilitates the Goehmann Lane Pump Station and provides backup power.

Project Drivers:

The Goehmann Lane Pump Station was recently damaged by a tornado and requires structural improvements. This project also provides backup power to the pump station.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Structural Improvements	1	EA	$ 150,000	$ 150,000
2	Back-up power generator	1	EA	$ 250,000	$ 250,000
			SUBTOTAL:		**$ 400,000**
		CONTINGENCY		30%	$ 120,000
			SUBTOTAL:		**$ 520,000**
		ENG/SURVEY		15%	$ 78,000
			SUBTOTAL:		**$ 598,000**
				Estimated Project Total:	**$ 598,000**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 2 — **Phase:** 5 Years

Project Name: North Pressure Plane Pressure Reducing Valve

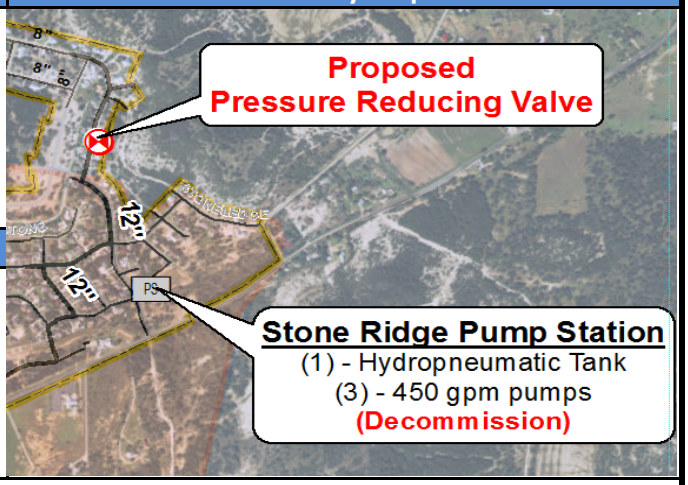
Project Description:

This project consists of a pressure reducing valve along Summit Forest between the North Pressure Plane and the North Pressure Plane PRV Zone.

Project Drivers:

This project allows water to move from the North Pressure Plane to the North PRV zone. It also prevents dead-end lines and improves system pressures. Once this project is complete, the valves between the North Pressure Plane and the North PRV Zone should be closed.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Pressure Reducing Valve	1	LS	$ 50,000	$ 50,000
2	Decommission Hydropneumatic Tank	1	LS	$ 40,000	$ 40,000
			SUBTOTAL:		**$ 90,000**
		CONTINGENCY		30%	$ 27,000
			SUBTOTAL:		**$ 117,000**
		ENG/SURVEY		15%	$ 17,600
			SUBTOTAL:		**$ 134,600**
				Estimated Project Total:	**$ 134,600**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 3 — **Phase:** 5 Years

Project Name: Cross Mountain Ground Storage Tank

Project Description:

This project consists of a second 1.0 MG ground storage tank at Cross Mountain off of North Milam Street.

Project Drivers:

This project allows the existing Cross Mountain Ground Storage Tank to be taken out of service for maintenance. It provides additional ground storage to the North Pressure Plane and elevated storage to the South Pressure Plane.

Vicinity Map

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	1.0 MG Ground Storage Tank	1	LS	$ 1,250,000	$ 1,250,000

SUBTOTAL:		**$ 1,250,000**
CONTINGENCY	30%	$ 375,000
SUBTOTAL:		**$ 1,625,000**
ENG/SURVEY	15%	$ 243,800
SUBTOTAL:		**$ 1,868,800**
Estimated Project Total:		**$ 1,868,800**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 4 — **Phase:** 5 Years

Project Name: Boot Ranch Ground Storage Tank

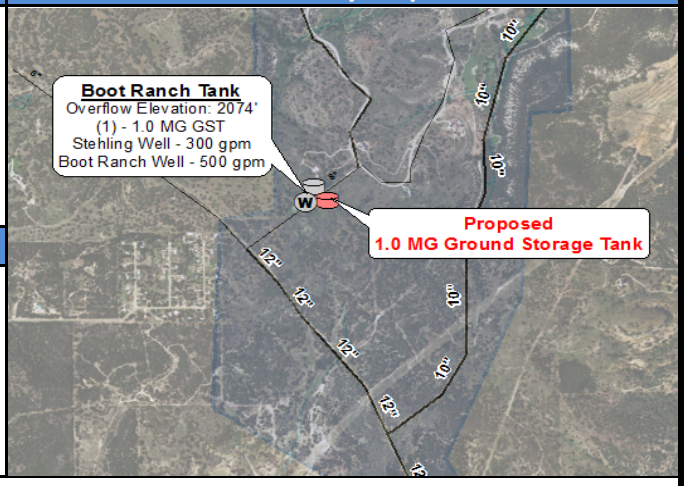
Project Description:

This project consists of a second 1.0 MG ground storage tank at Boot Ranch.

Project Drivers:

This project allows the existing Boot Ranch Ground Storage Tank to be taken out of service for maintenance. It provides elevated storage to the North Pressure Plane.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	1.0 MG Ground Storage Tank	1	LS	$ 1,250,000	$ 1,250,000

SUBTOTAL:		**$ 1,250,000**
CONTINGENCY	30%	$ 375,000
SUBTOTAL:		**$ 1,625,000**
ENG/SURVEY	15%	$ 243,800
SUBTOTAL:		**$ 1,868,800**
Estimated Project Total:		**$ 1,868,800**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 5 — **Phase:** 5 Years

Project Name: Windcrest Area Improvements

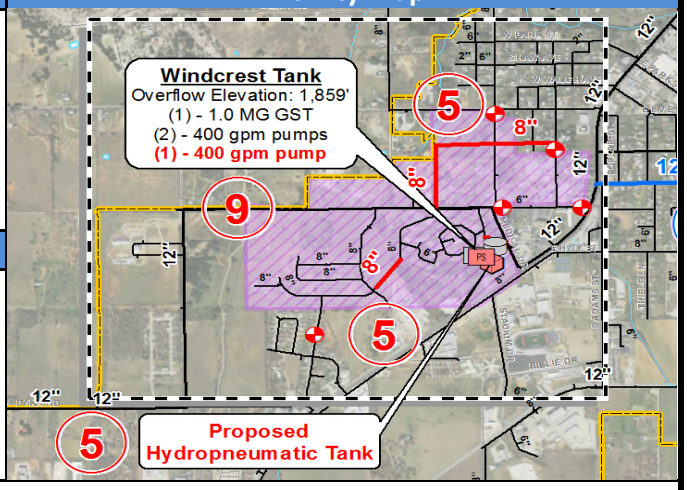
Project Description:

This project consists of a hydropneumatic tank and 8-inch water lines in the Wincrest Pressure Plan.

Project Drivers:

This project expands the service area of the Windcrest pressure plane and improves low pressures. This project also puts the existing hydropneumatic tank back in service to provide storage to the pressure plane.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	8" WL & Appurtenances	3,700	LF	$ 80	$ 296,000
2	Pavement Repair	3,700	LF	$ 80	$ 296,000
				SUBTOTAL:	**$ 592,000**
			CONTINGENCY	30%	$ 177,600
				SUBTOTAL:	**$ 769,600**
			ENG/SURVEY	15%	$ 115,500
				SUBTOTAL:	**$ 885,100**
				Estimated Project Total:	**$ 885,100**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 6 — **Phase:** 5 Years

Project Name: 12-inch Line from South Heights Pump Station

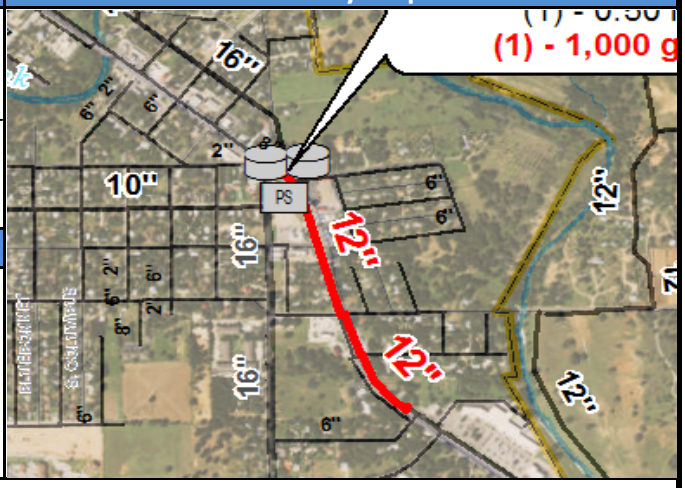
Project Description:

This project consists of a 12-inch water line along Highway 290 south of the South Heights Pump Station. This project parallels the existing 8-inch water line.

Project Drivers:

This project addresses bottle neck in transmission capacity in the distribution system and reduces high velocities and headlosses.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	12" WL & Appurtenances	2,700	LF	$ 120	$ 324,000
2	Pavement Repair	2,700	LF	$ 80	$ 216,000
				SUBTOTAL:	**$ 540,000**
			CONTINGENCY	30%	$ 162,000
				SUBTOTAL:	**$ 702,000**
			ENG/SURVEY	15%	$ 105,300
				SUBTOTAL:	**$ 807,300**
				Estimated Project Total:	**$ 807,300**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

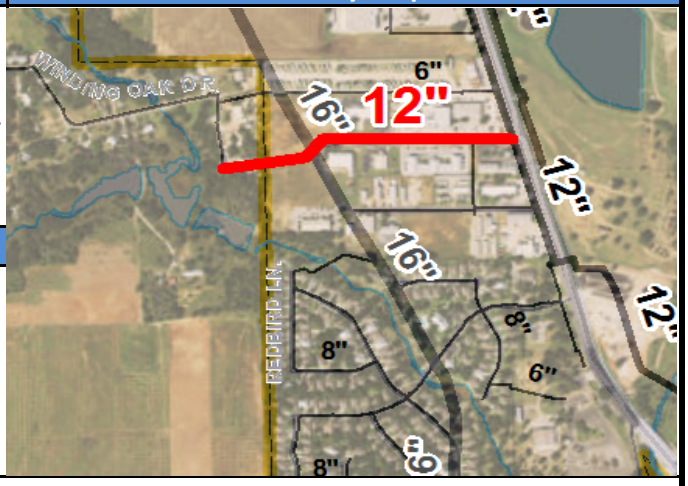
Construction Project Number: 7 — **Phase:** 5 Years

Project Name: 12-inch Line to New Development

Project Description:

This project consists of a 12-inch water line along Industrial Boulevard.

Vicinity Map



Project Drivers:

This project connects the existing 12-inch water line along Highway 290 to the new residential developments. Construction of project will be dependent on timing of development construction.

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	12" WL & Appurtenances	2,000	LF	$ 120	$ 240,000
2	Pavement Repair	2,000	LF	$ 80	$ 160,000
				SUBTOTAL:	**$ 400,000**
			CONTINGENCY	30%	$ 120,000
				SUBTOTAL:	**$ 520,000**
			ENG/SURVEY	15%	$ 78,000
				SUBTOTAL:	**$ 598,000**
				Estimated Project Total:	**$ 598,000**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 8 — **Phase:** 5 Years

Project Name: 1,000 gpm Pump at South Heights Pump Station

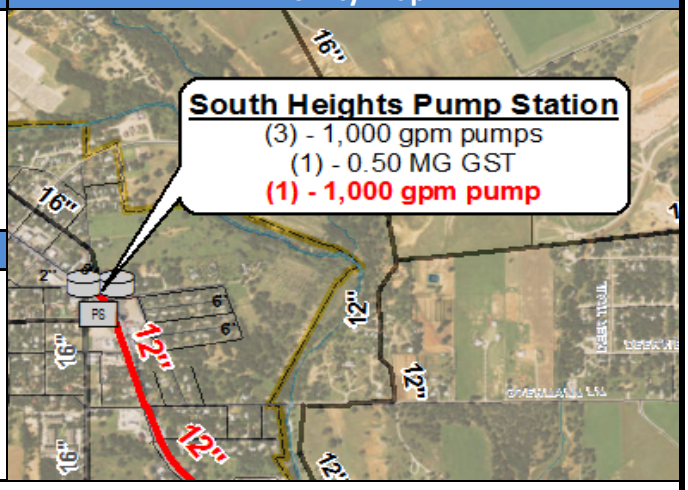
Project Description:

This project consists of an additional 1,000 gpm pump at the South Heights Pump Station along Highway 290.

Project Drivers:

This project will provide capacity for future growth and increase the firm capacity of the pump station.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	1,000 gpm Pump Station Expansion	1	LS	$ 200,000	$ 200,000
			SUBTOTAL:		$ 200,000
			CONTINGENCY	30%	$ 60,000
			SUBTOTAL:		$ 260,000
			ENG/SURVEY	15%	$ 39,000
			SUBTOTAL:		$ 299,000
			Estimated Project Total:		$ 299,000

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 9 — **Phase:** 5 Years

Project Name: 400 gpm Pump at Windcrest Pump Station

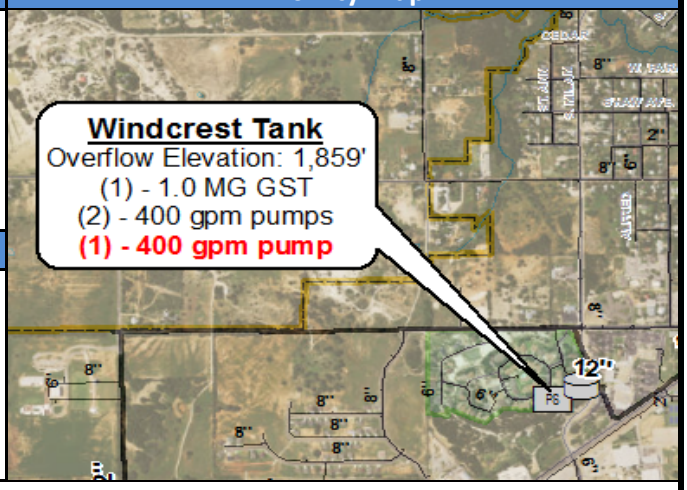
Project Description:

This project consists of an additional 400 gpm pump at the Windcrest Pump Station between Summit Circle and South Milam Street.

Project Drivers:

This project will increase the provide redundancy at the Windcrest Pump Station and allow for more operation flexibility.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	400 gpm Pump Station Expansion	1	LS	$ 100,000	$ 100,000

		SUBTOTAL:	**$ 100,000**
	CONTINGENCY	30%	$ 30,000
		SUBTOTAL:	**$ 130,000**
	ENG/SURVEY	15%	$ 19,500
		SUBTOTAL:	**$ 149,500**
		Estimated Project Total:	**$ 149,500**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 10 — **Phase:** 5 Years

Project Name: 0.5 MG Elevated Storage Tank

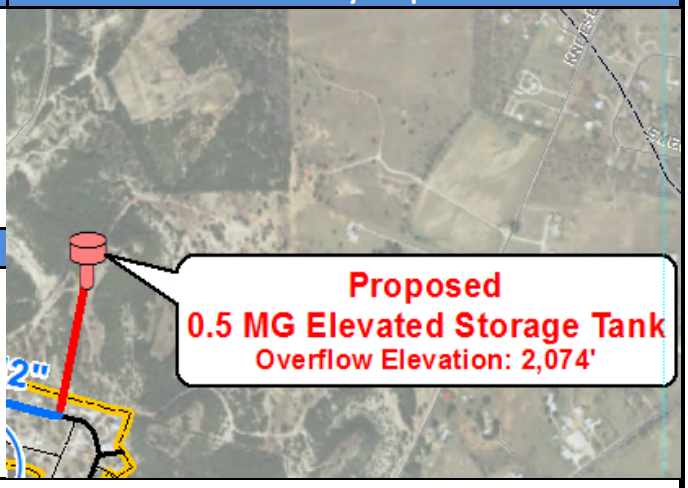
Project Description:

This project consists of a new 0.5 MG elevated storage tank in the North Pressure Plane.

Project Drivers:

This project provides additional elevated storage capacity in the North Pressure Plane.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	0.5 MG Elevated Storage Tank	1	LS	$ 1,750,000	$ 1,750,000
2	12" WL & Appurtenances	500	LF	$ 120	$ 60,000
			SUBTOTAL:		**$ 1,810,000**
		CONTINGENCY		30%	$ 543,000
			SUBTOTAL:		**$ 2,353,000**
		ENG/SURVEY		15%	$ 353,000
			SUBTOTAL:		**$ 2,706,000**
				Estimated Project Total:	**$ 2,706,000**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 11 — **Planning Period:** 10 Years

Project Name: 16-inch Line to Proposed Pump Station

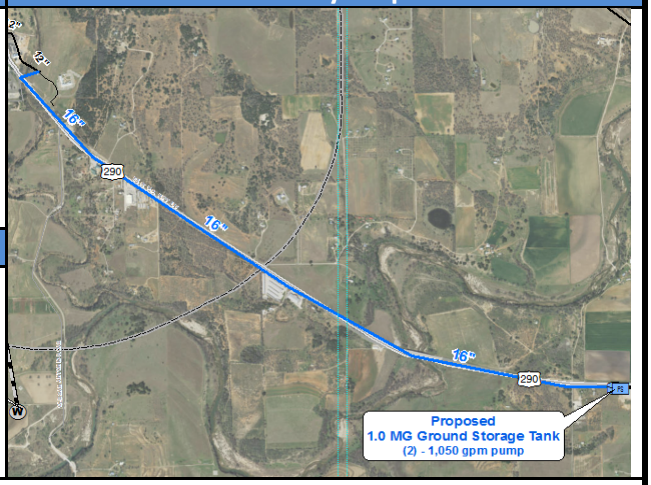
Project Description:

This project consists of a 16-inch water line along Highway 290 north from the proposed pump station.

Project Drivers:

This project provides transmission capacity from the proposed pump station. It also provides redundancy in the event of a line break on the transmission line from the Goehmann Lane pump station.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	16" WL & Appurtenances	17,860	LF	$ 160	$ 2,857,600
2	Pavement Repair	17,860	LF	$ 80	$ 1,428,800
3	30" Boring and Casing	600	LF	$ 525	$ 315,000
				SUBTOTAL:	**$ 4,601,400**
				CONTINGENCY 30%	$ 1,380,500
				SUBTOTAL:	**$ 5,981,900**
				ENG/SURVEY 15%	$ 897,300
				SUBTOTAL:	**$ 6,879,200**
				Estimated Project Total:	**$ 6,879,200**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 12 — **Phase:** 10 Years

Project Name: Proposed Pump Station and Ground Storage Tank

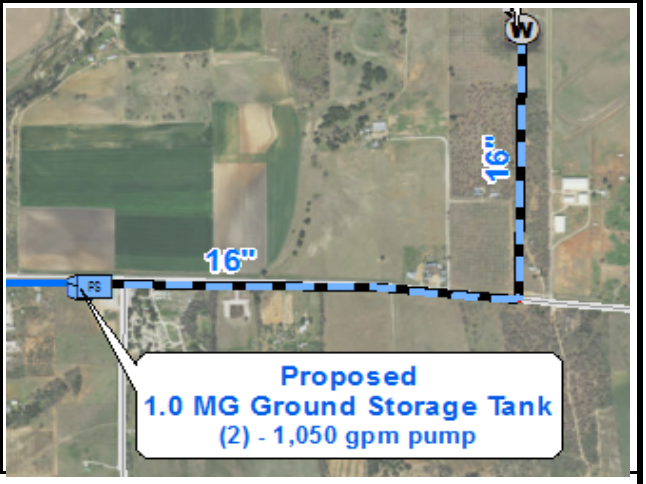
Project Description:

This project consists of a 1.0 MG ground storage tank and a proposed pump station with two 1,050 gpm pumps located off of Highway 290. This project also includes a 16-inch transmission line from the Knauth well field to the pump station.

Project Drivers:

This project provides additional pumping capacity and ground storage. It also provides system redundancy to allow for maintenance at the Goehmann Lane pump station.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	3.0 MGD PS & 1.0 MG GST	1	LS	$ 3,000,000	$ 3,000,000
2	16" WL & Appurtenances	8,900	LF	$ 160	$ 1,424,000
3	Pavement Repair	4,600	LF	$ 80	$ 368,000
4	30" Boring and Casing	100	LF	$ 525	$ 52,500
				SUBTOTAL:	**$ 4,844,500**
				CONTINGENCY 30%	$ 1,453,400
				SUBTOTAL:	**$ 6,297,900**
				ENG/SURVEY 15%	$ 944,700
				SUBTOTAL:	**$ 7,242,600**
				Estimated Project Total:	**$ 7,242,600**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 13 — **Phase:** 10 Years

Project Name: 12-inch Line along Summit Forest

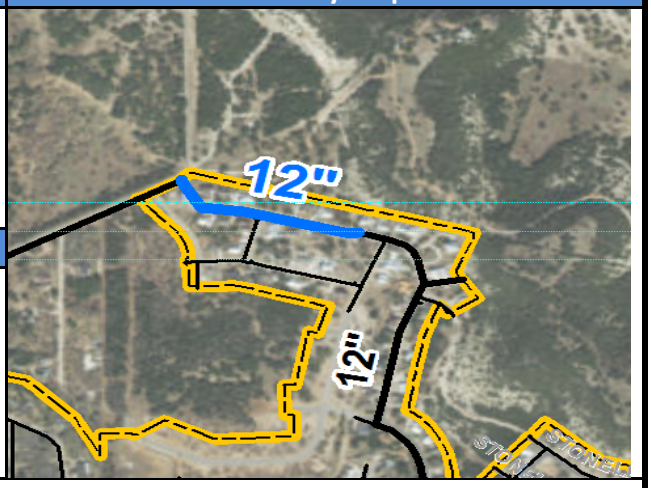
Project Description:

This project consists of a 12-inch water line from Lower Crabapple Road along Summit Forest.

Project Drivers:

This project connects existing 12-inch water lines in the Revised North pressure plane and provides additional transmission capacity by elimating a bottleneck.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	12" WL & Appurtenances	1,400	LF	$ 120	$ 168,000
2	Pavement Repair	1,400	LF	$ 80	$ 112,000
				SUBTOTAL:	**$ 280,000**
			CONTINGENCY	30%	$ 84,000
				SUBTOTAL:	**$ 364,000**
			ENG/SURVEY	15%	$ 54,600
				SUBTOTAL:	**$ 418,600**
				Estimated Project Total:	**$ 418,600**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 14 — **Phase:** 10 Years

Project Name: 12-inch Line along Hale Street

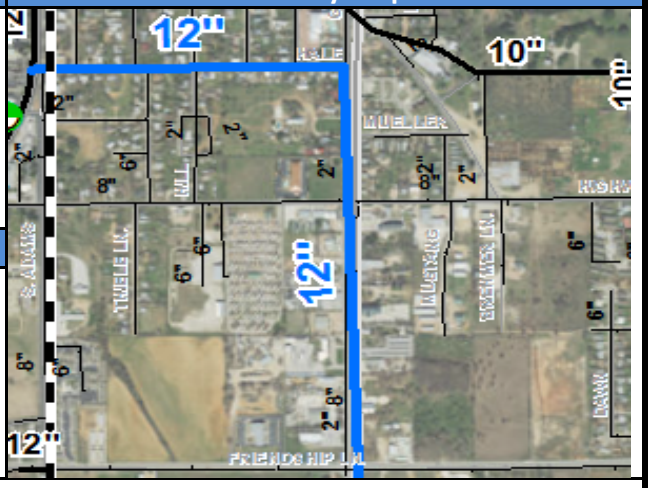
Project Description:

This project consists of a 12-inch water line from Highway 16 South along Hale Street then along Highway 87 to Friendship Lane.

Project Drivers:

This project connects an existing 12-inch water line to the proposed 12-inch water line to serve new development.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	12" WL & Appurtenances	6,300	LF	$ 120	$ 756,000
2	Pavement Repair	6,300	LF	$ 80	$ 504,000
				SUBTOTAL:	**$ 1,260,000**
			CONTINGENCY	30%	$ 378,000
				SUBTOTAL:	**$ 1,638,000**
			ENG/SURVEY	15%	$ 245,700
				SUBTOTAL:	**$ 1,883,700**
				Estimated Project Total:	**$ 1,883,700**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 15 — **Phase:** 10 Years

Project Name: 12-inch Line along Highway 87

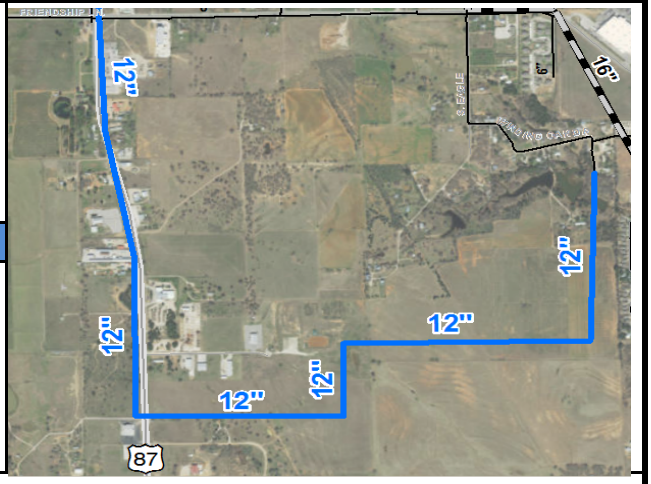
Project Description:

This project consists of a 12-inch water line along Highway 87 from Friendship Lane to Winding Oak Drive.

Project Drivers:

The project serves new development and provides system looping.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	12" WL & Appurtenances	15,900	LF	$ 120	$ 1,908,000
2	Pavement Repair	6,200	LF	$ 80	$ 496,000
3	20" Boring and Casing	200	LF	$ 350	$ 70,000
			SUBTOTAL:		**$ 2,474,000**
			CONTINGENCY	30%	$ 742,200
			SUBTOTAL:		**$ 3,216,200**
			ENG/SURVEY	15%	$ 482,500
			SUBTOTAL:		**$ 3,698,700**
			Estimated Project Total:		**$ 3,698,700**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 16 — **Phase:** 10 Years

Project Name: 12-inch Line along North Adams Street

Project Description:

This project consists of a 12-inch water line along North Adams Street from Highway 290 to West Hackberry.

Project Drivers:

This project provides additional capacity in the distribution system and replaces a line with a history of water leaks.

Vicinity Map

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	12" WL & Appurtenances	4,300	LF	$ 120	$ 516,000
2	Pavement Repair	4,300	LF	$ 80	$ 344,000
3	20" Boring and Casing	200	LF	$ 350	$ 70,000
				SUBTOTAL:	**$ 930,000**
				CONTINGENCY 30%	$ 279,000
				SUBTOTAL:	**$ 1,209,000**
				ENG/SURVEY 15%	$ 181,400
				SUBTOTAL:	**$ 1,390,400**
				Estimated Project Total:	**$ 1,390,400**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

Construction Project Number: 17 — **Planning Period:** 20 Years

Project Name: 12-inch Line along Morning Glory Drive

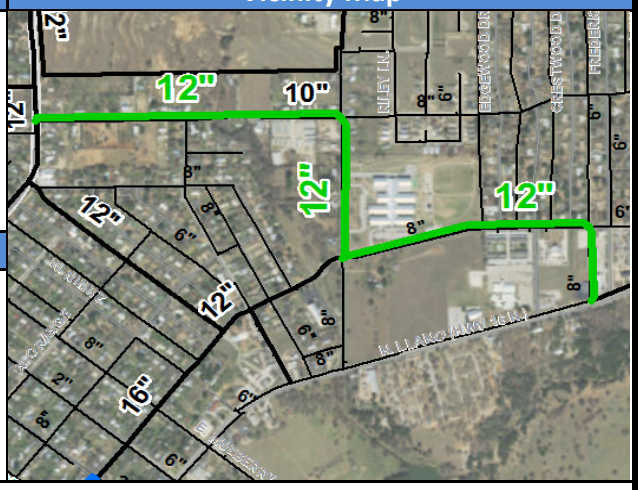
Project Description:

This project consists of a 12-inch water line along Morning Glory Drive to Highway 16.

Project Drivers:

This project provides additional capacity in the North PRV zone and connects existing 12-inch water lines.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	12" WL & Appurtenances	7,900	LF	$ 120	$ 948,000
2	Pavement Repair	7,900	LF	$ 80	$ 632,000
			SUBTOTAL:		**$ 1,580,000**
		CONTINGENCY		30%	$ 474,000
			SUBTOTAL:		**$ 2,054,000**
		ENG/SURVEY		15%	$ 308,100
			SUBTOTAL:		**$ 2,362,100**
				Estimated Project Total:	**$ 2,362,100**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 1/27/2017**

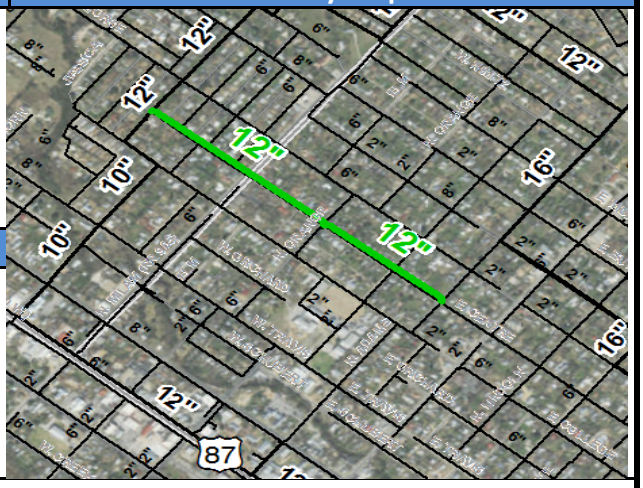
Construction Project Number: 18 — **Phase:** 20 Years

Project Name: 12-inch Line along East Centre Street

Project Description:

This project consists of a 12-inch water line along East Centre Street from Avenue A to North Adams Street.

Vicinity Map



Project Drivers:

This project replaces an existing 2-inch water line and connects large diameter lines to provide system looping.

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	12" WL & Appurtenances	3,900	LF	$ 120	$ 468,000
2	Pavement Repair	3,900	LF	$ 80	$ 312,000
			SUBTOTAL:		**$ 780,000**
		CONTINGENCY		30%	$ 234,000
			SUBTOTAL:		**$ 1,014,000**
		ENG/SURVEY		15%	$ 152,100
			SUBTOTAL:		**$ 1,166,100**
				Estimated Project Total:	**$ 1,166,100**

APPENDIX I
FLOW MONITORING REPORT

PROJECT NUMBER 25203.11

Sewer System Performance Report

Fredericksburg, Texas

PREPARED FOR

Freese & Nichols
2711 North Haskell Avenue, Suite 3300
Dallas, TX 75204

SUBMITTED

February 23, 2016

ADS ENVIRONMENTAL SERVICES®

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CD-ROM with electronic copy of report and associated data accompanies this report.

Introduction

ADS Environmental Services (ADS) was retained by the Freese & Nichols (Engineer) to gather and evaluate flow monitor and rainfall data within selected portions of the existing sanitary sewer system located in Fredericksburg, Texas. The scope of this study is to characterize dry weather and wet weather flow conditions at key locations within the sewer system, evaluate key performance indicators, and rank the relative severity of observed rain dependent inflow and infiltration (RDII) to assist the Engineer to direct subsequent planning, condition assessment, and rehabilitation activities.

Methodology

Dry weather and wet weather performance data were obtained within the current project area by installing sewer flow monitors to observe and document existing flow conditions. Descriptions of the flow monitor, locations, equipment, study period, and data format are detailed in the following sections.

Flow Monitor and Rain Gauge Locations

Preliminary flow monitor and rain gauge locations were selected by the Engineer, and final locations were determined by ADS based on observed flow conditions, site access, and site safety considerations. The geographic location of each sewer basin and associated flow monitors are shown on the map provided in Figure 1. Descriptions of each sewer basin and its associated flow monitor are provided in Table 1.

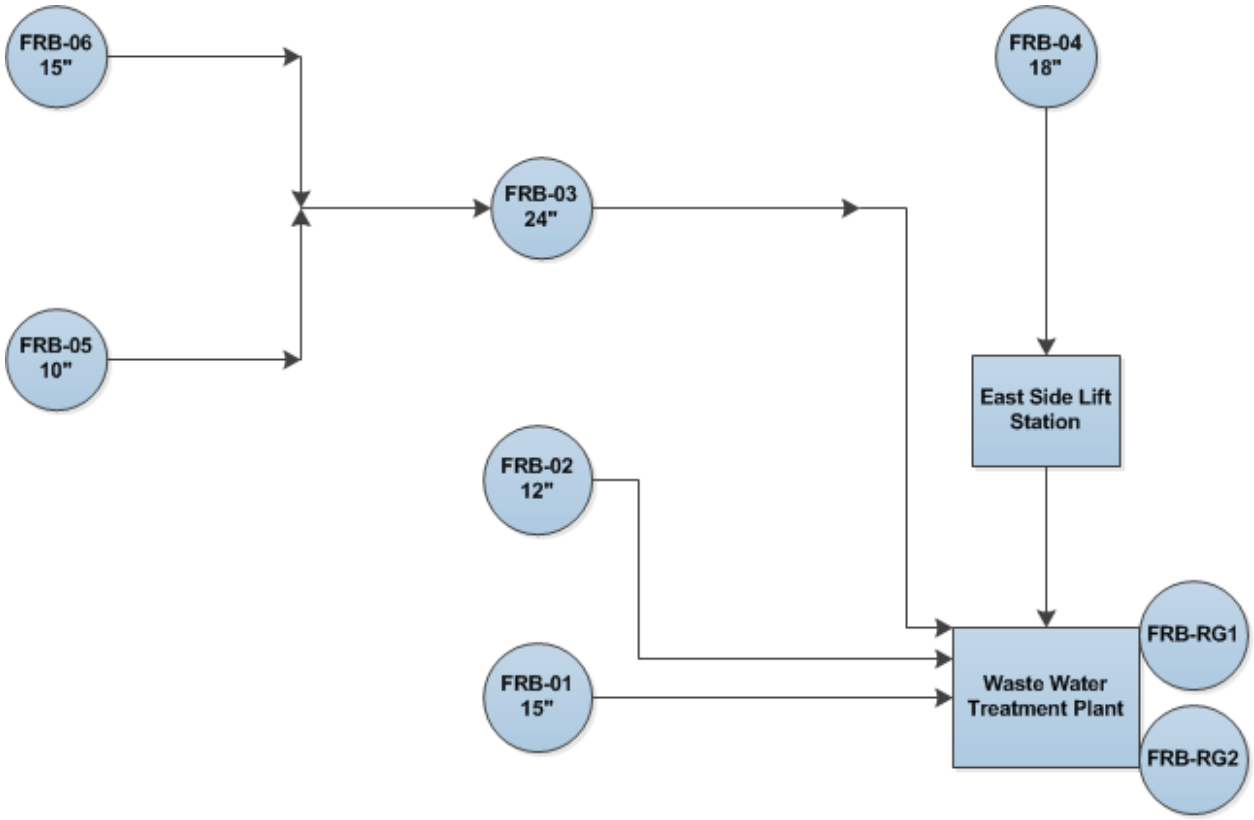
Figure 1: Flow Monitor and Rain Gauge Location Map

TABLE 1: Flow Monitor Locations

Monitor	Location	Diameter (inches)	Basin Size (LF)
FRB-01	N 30.25407, W 98.84860	15	15,465
FRB-01A	N 30.25304, W 98.84810	8	—
FRB-02	N 30.25613, W 98.85299	12	78,279
FRB-03	N 30.25783, W 98.85278	24	61,849
FRB-04	N 30.26896, W 98.85368	18	86,639
FRB-05	N 30.26817, W 98.86512	10	97,005
FRB-06	N 30.27244, W 98.86364	15	153,815

A general schematic showing the upstream and downstream relationship between each flow monitor is provided in Figure 2.

FIGURE 2: Flow Monitor Schematic



Flow Monitor Equipment

Sewer flow monitoring was performed using a combination of Flowshark and Triton area-velocity flow monitors manufactured, installed, and maintained by ADS. Product specifications for these flow monitors are provided in the attached appendices. Each flow monitor is mounted near the top of a manhole and is connected to flow depth and velocity sensors positioned in an incoming sewer. Each flow monitor is equipped with an ultrasonic depth sensor, a velocity sensor, and a pressure depth sensor mounted in the invert of the sewer line.

Flow monitor locations are visited periodically for routine maintenance. During site visits, the flow data are reviewed to verify data quality, the flow monitor battery is checked, and the sensors are cleaned, if necessary. Independent flow depth and velocity measurements are obtained to confirm the accuracy of the flow monitor. If problems are identified, they are

corrected, or the flow monitor is replaced. All information for each field visit is recorded in maintenance logs to assist when analyzing the data.

Flow Monitor Study Period

This monitoring period for this project was 45 days beginning on 10/21/2015. After the relocation of FRB-01A on 11/30/2015 another 45-day monitoring period was allotted. The final date for the study period was 1/15/2016. The total study period was conducted from 10/21/2015 to 01/15/2016 – a total of 87 days. Unfortunately, from a wet weather perspective, the events occurring on 12/27/2015 and 01/02/2016 were very minimal and did not elicit a notable response at the flow monitor locations. Therefore, these storms were not further evaluated.

Flow Monitor Data Format

Flow depth (d), flow velocity (v), and flow rate (Q) data from each sewer flow monitor are plotted on a variety of hydrographs and scattergraphs provided in the attached appendices. Hydrographs display flow rate data vs. time for the duration of the observed period, along with associated rainfall data. Scattergraphs display flow depth vs. velocity data for each location. Electronic copies of the data are provided in Microsoft Excel format.

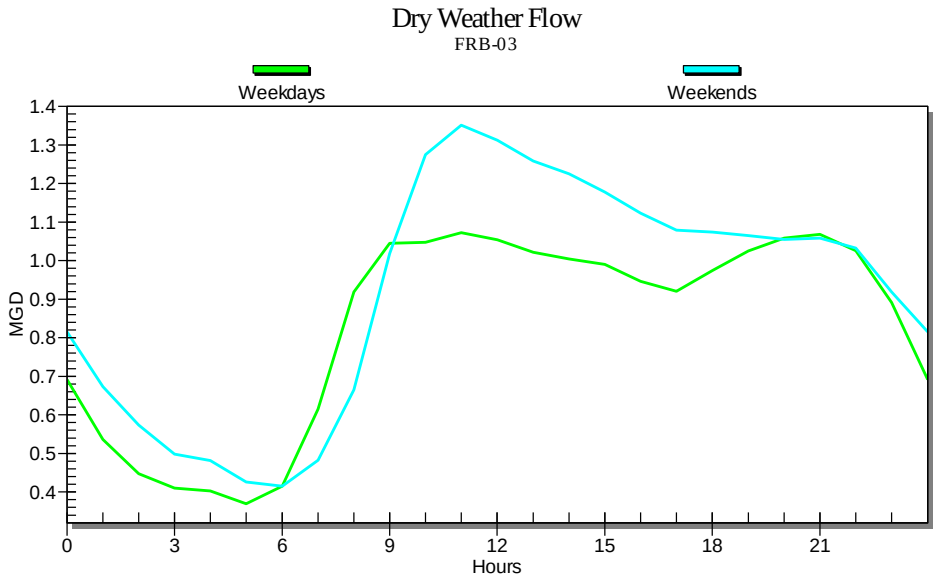
Results

Flow monitor data provide insight into sewer performance – revealing important information about how the existing sewer system accommodates observed flow rates. The following sections evaluate flow monitor data observed within the study period during both dry weather and wet weather periods using a variety of key performance indicators (KPIs).

Flow Rates and Peaking Factors

Dry weather flow conditions are characterized by evaluating flow monitor data observed during normal conditions, excluding wet weather events and the periods associated with the recovery from these events. The average dry day pattern is identified as a diurnal pattern and results from the collective residential, commercial, industrial, and institutional sewer use located upstream from a given flow monitor. Land use within a particular area affects the shape of the diurnal pattern. An example of a representative diurnal pattern observed during this study period is shown in Figure 3.

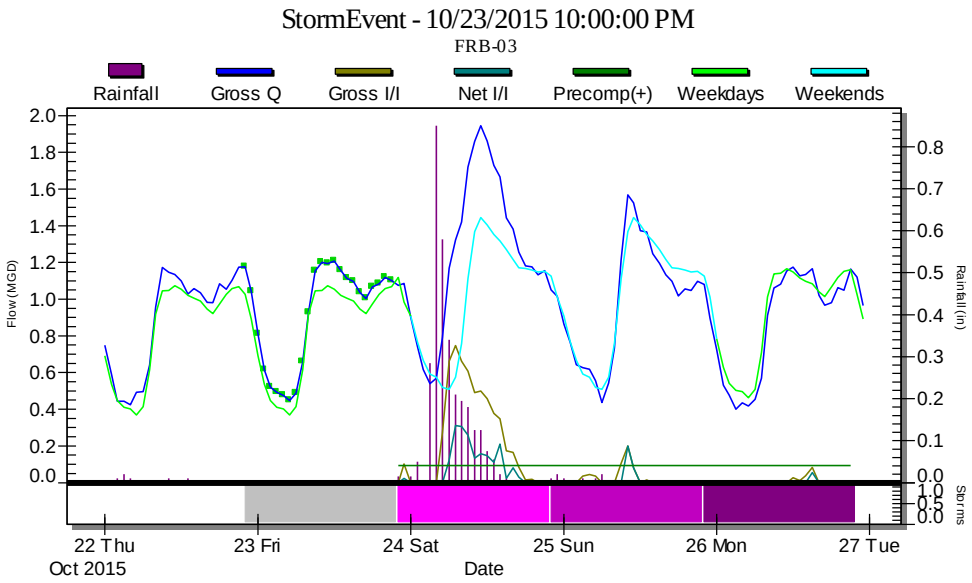
FIGURE 3: Dry Weather Hydrograph



Wet weather flow conditions are characterized by evaluating flow monitor data observed during significant storm events that occurred during the study period. An example of a representative wet weather storm decomposition hydrograph observed during the study period is provided in Figure 4 and shows the observed flow rate during a storm event compared to the average dry day diurnal pattern. The difference between the two is the rain-dependent inflow and infiltration

(RDII) measured by the flow monitor. The storm event is depicted by the purple bands, and a precompensation period prior to the storm is depicted by the light gray band. Precompensation is used when needed to adjust the average dry day diurnal pattern to more closely match observed conditions prior to each storm event for proper RDII analysis.

FIGURE 4: Wet Weather Storm Decomposition Hydrograph



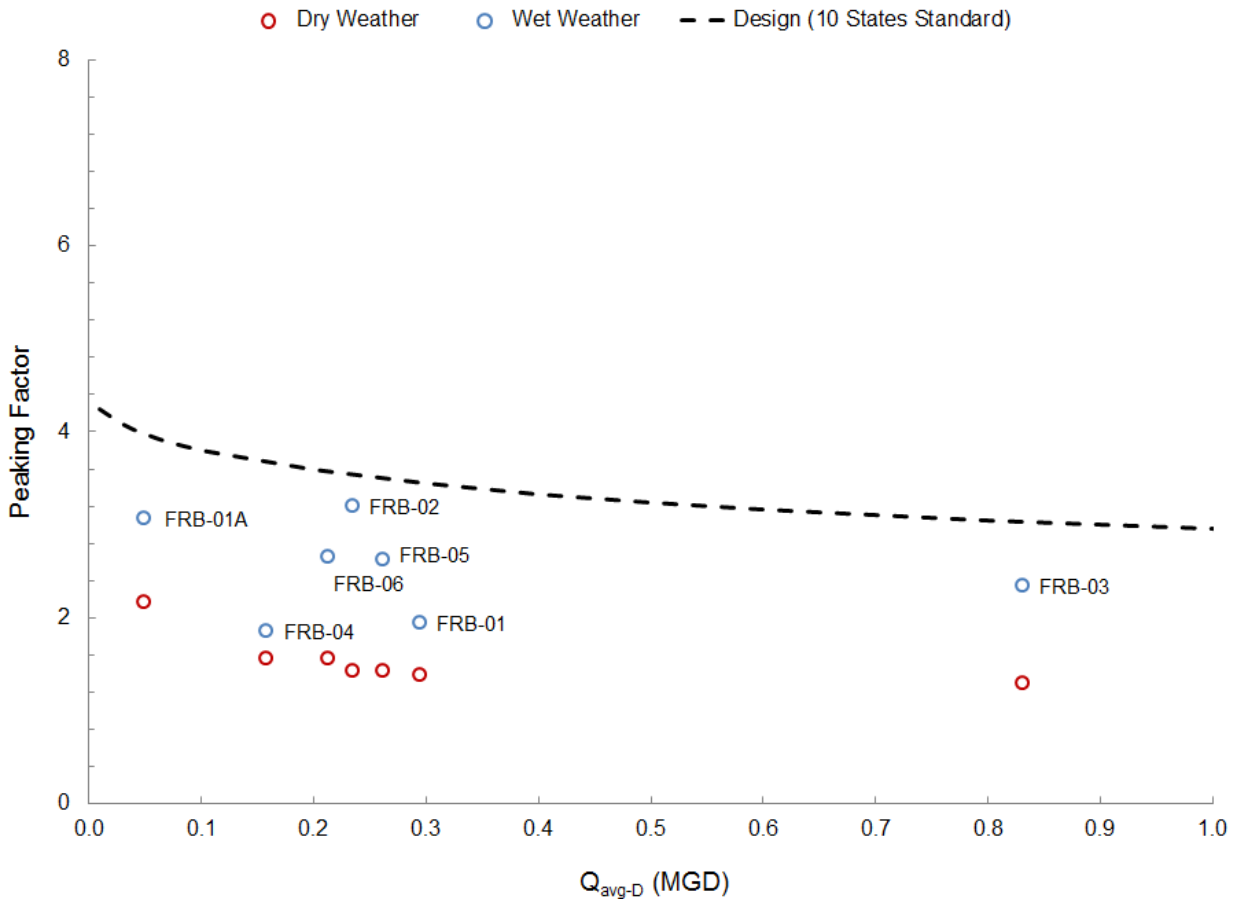
The minimum, average, and maximum dry weather flow rates (Q_{min-D}, Q_{avg-D}, and Q_{max-D}) are determined from the dry weather diurnal pattern for each flow monitor location and are provided in Table 2, along with the resulting dry weather peaking factor (PF_D). The maximum wet weather flow rate (Q_{max-W}) determined for each flow monitor location is also provided, along with the resulting wet weather peaking factor (PF_W).

TABLE 2: Dry and Wet Weather Flow Rates and Peaking Factors

Monitor	Q_{min-D} (MGD)	Q_{avg-D} (MGD)	Q_{max-D} (MGD)	Q_{max-W} (MGD)	Peaking Factor PF_D	Peaking Factor PF_W
FRB-01	0.114	0.295	0.407	0.570	1.38	1.93
FRB-01A	0.021	0.050	0.108	0.153	2.16	3.06
FRB-02	0.109	0.235	0.334	0.751	1.42	3.20
FRB-03	0.369	0.831	1.073	1.945	1.29	2.34
FRB-04	0.053	0.159	0.246	0.294	1.55	1.85
FRB-05	0.102	0.262	0.371	0.686	1.42	2.62
FRB-06	0.068	0.214	0.333	0.566	1.56	2.64

Peaking factors are commonly used to estimate maximum flow rates based on average flow rate estimates and play a key role in sewer design. Peaking factors are inversely proportional to the population served and generally decrease as the average dry weather flow rate increases. Dry weather and wet weather peaking factors observed during the study period are compared with corresponding design guidance from the American Society of Civil Engineers (ASCE) and the Water Environment Federation (WEF), and the results are shown in Figure 5.

FIGURE 5: Peaking Factors Compared to Design Guidance



Dry weather and wet weather peaking factors observed during the study period fall within design guidelines, indicating that variations observed in sewer flow rates typically fall within normal variations assumed in sewer design. The largest wet weather peaking factor observed during the study period was a value of 3.20 at Site FRB-02.

Depth-to-Diameter Ratios

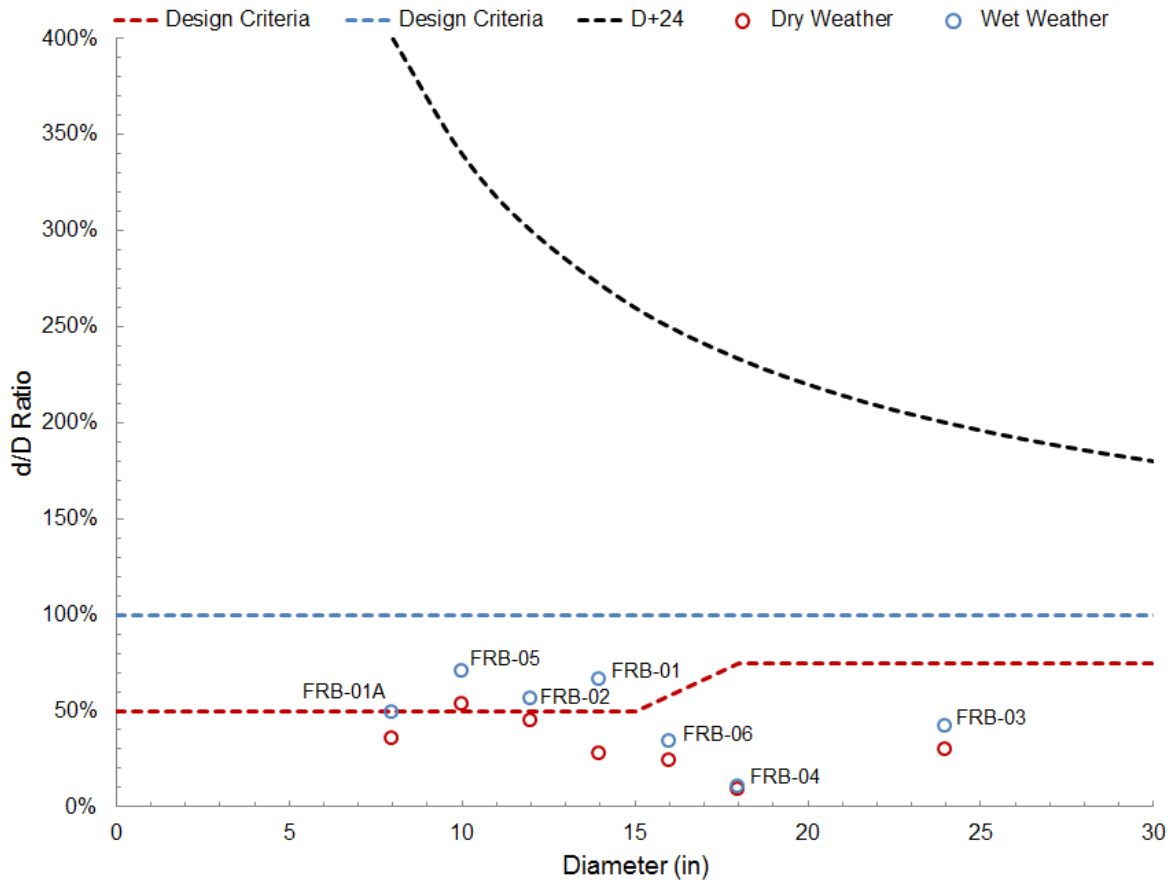
Once dry weather and wet weather flow rates are characterized, the hydraulic conditions under which they occur are evaluated. The maximum flow depths observed during dry weather (d_{max-D}) and wet weather (d_{max-W}) and their corresponding flow depth-to-diameter (d/D) ratios observed during the study period are provided in Table 3. The maximum dry weather flow depth is the flow depth associated with the maximum dry weather flow rate and is the maximum flow depth that is consistently observed each day during normal dry weather conditions. The maximum wet weather flow depth may or may not be directly associated with the maximum wet weather flow rate, depending on the hydraulic conditions observed at a given flow monitor location.

TABLE 3: Dry and Wet Weather Depth-to-Diameter Ratios

Monitor	D (inches)	d_{max-D} (inches)	d_{max-D} / D (%)	d_{max-W} (inches)	d_{max-W} / D (%)
FRB-01	15	3.89	28%	9.27	66%
FRB-01A	8	2.81	35%	3.91	49%
FRB-02	12	5.34	45%	6.72	56%
FRB-03	24	7.12	30%	10.02	42%
FRB-04	18	1.64	9%	1.88	10%
FRB-05	10	5.31	53%	7.02	70%
FRB-06	15	3.81	24%	5.41	34%

The d/D ratio is a performance indicator used to assess sewer capacity. Sewers are often designed to flow under open channel flow conditions with some reserve capacity. As a result, ASCE and WEF recommend that sewers with diameters up to 15 inches be designed to flow with dry weather d/D ratios of 50%, and larger diameter sewers be designed to flow with dry weather d/D ratios of 75%. Sewers are not generally designed to operate under surcharge conditions with wet weather d/D ratios greater than 100%. Observed wet weather d/D ratios are also compared to additional capacity assurance criteria, designed to highlight portions of the sewer system where flow depths are greater than 24 inches above the crown of the sewer (D+24) or are within 36 inches of the manhole rim (R-36). These design and capacity assurance criteria are useful for comparison to observed d/D ratios as shown in Figure 6.

FIGURE 6: Flow Depth-to-Diameter Ratios Compared to Design Guidance



During dry weather conditions, all observed dry weather d/D ratios are within design criteria recommended by ASCE and WEF, except Site FRB-05 which has a dry weather d/D ratio of 53%. Note also that Site FRB-01A has a dry weather d/D ratio 35%, which represents an hourly average value. However, this location is heavily influenced by a lift station that causes instantaneous flow depth measurements at or near full-pipe conditions. Wet weather d/D ratios observed at all flow monitor locations are within design criteria recommended by ASCE and WEF, indicating that here is sufficient capacity to accommodate maximum observed wet weather flows at these locations without surcharge conditions.

Self-Cleansing Status

Self-cleansing is an important aspect of sanitary sewer design and is desired to minimize the deposition of silt, sediment, and debris. The Tractive Force Method is used to design sewers to achieve self-cleansing conditions based on a required critical shear stress (τ_c) and is recommended by ASCE and WEF to evaluate self-cleansing conditions.

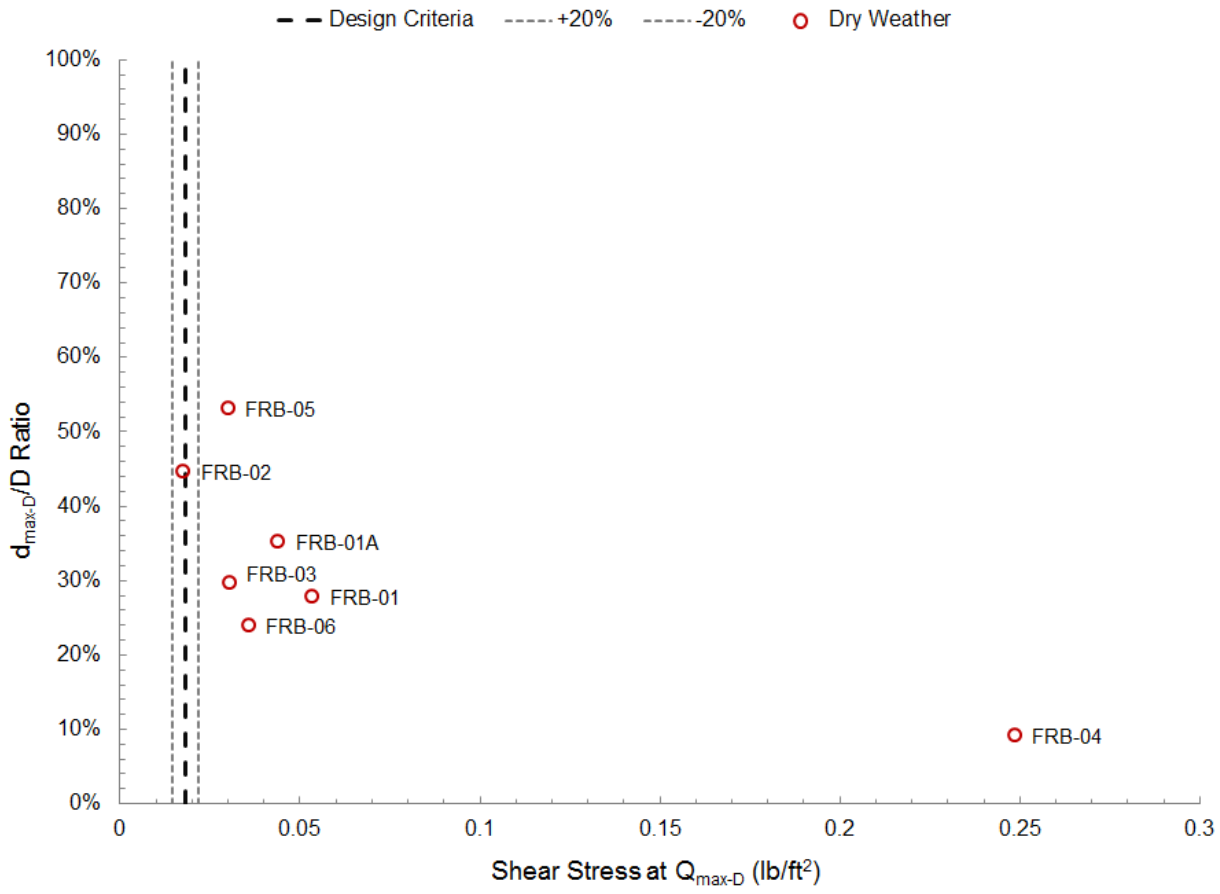
The Tractive Force Method can also be extended from the design of new sewers to the evaluation of existing sewers and was applied to evaluate the self-cleansing status of each flow monitor location during the study period. The maximum dry weather flow depth (d_{max-D}) and flow velocity (v_{max-D}) from each flow monitor location are used to compute the actual shear stress (τ) observed at the maximum dry weather flow rate (Q_{max-D}). The results are compared to a threshold self-cleansing range, resulting in a classification of observed flow conditions. Silt observations recorded during the study period are also provided for comparison, and the results are provided in Table 4.

TABLE 4: Self-Cleansing Classification

Monitor	D (in)	d_{max-D} (in)	v_{max-D} (ft/s)	τ (lb/ft^2)	Classification	Silt (in)
FRB-01	15	3.89	2.54	0.0538	1	—
FRB-01A	8	2.81	2.16	0.0440	1	—
FRB-02	12	5.34	1.52	0.0179	2	—
FRB-03	24	7.12	2.12	0.0307	1	—
FRB-04	18	1.64	4.81	0.2488	1	—
FRB-05	10	5.31	1.95	0.0360	1	—
FRB-06	15	3.81	2.08	0.0360	1	—

The required critical shear stress recommended by ASCE and WEF for application of the Tractive Force Method is 0.0181 lb/ft^2. The actual shear stress achieved under normal dry weather conditions is compared to this design guidance in Figure 7. Sewers predicted to be self-cleansing are shown to the right of the recommended critical shear stress, and sewers predicted to be non-cleansing are shown to the left. Research by ADS has shown that the transition from self-cleansing to non-cleansing generally occurs within ±20% of this recommended value. As a result, the hydraulic conditions at each flow monitor location are classified as Class 1 – Self-Cleansing, Class 2 – Marginal Cleansing, or Class 3 – Non-Cleansing.

FIGURE 7: Self-Cleansing Status Compared to Design Guidance



Based on hydraulic conditions observed during the study period, six locations are described as Class 1 – Self-Cleansing, and one location is described as Class 2 – Marginal Cleansing. No silt or debris was observed by ADS field personnel during any of the site visits made during the study period.

Base Infiltration

Basin performance indicators – including base infiltration (BI) and RDII – help identify individual basins where infiltration and inflow originate and rank their relative severity. The wastewater flow measured by each flow monitor is referred to as Gross Flow (Gross Q), and the Net Flow (Net Q) associated with each sewer basin is determined by subtracting the Gross Q conveyed into the basin from the Gross Q conveyed out of the basin. Net Q computations are the foundation for basin performance indicators.

During dry weather periods, wastewater flow is comprised of contributions from residential, commercial, industrial, and institutional sources, along with BI from groundwater sources. BI can be estimated from flow monitor data using a variety of methods, and the Stevens-Schutzbach Equation is applied here to estimate BI based on $Q_{min\text{-}D}$ and $Q_{avg\text{-}D}$ at each flow monitor location. This equation is best applied to residential areas, and the reliability of this approach decreases in non-residential areas or in areas heavily influenced by pump station activity. It is important to understand that when using flow monitor data, BI can only be estimated and that only through more rigorous means of flow isolations can actual BI values be determined. Despite these limitations, the Stevens-Schutzbach Equation has been determined to be one of the most robust methods for deriving BI estimates from flow monitor data. BI estimates for each basin are provided in Table 5.

TABLE 5: Base Infiltration

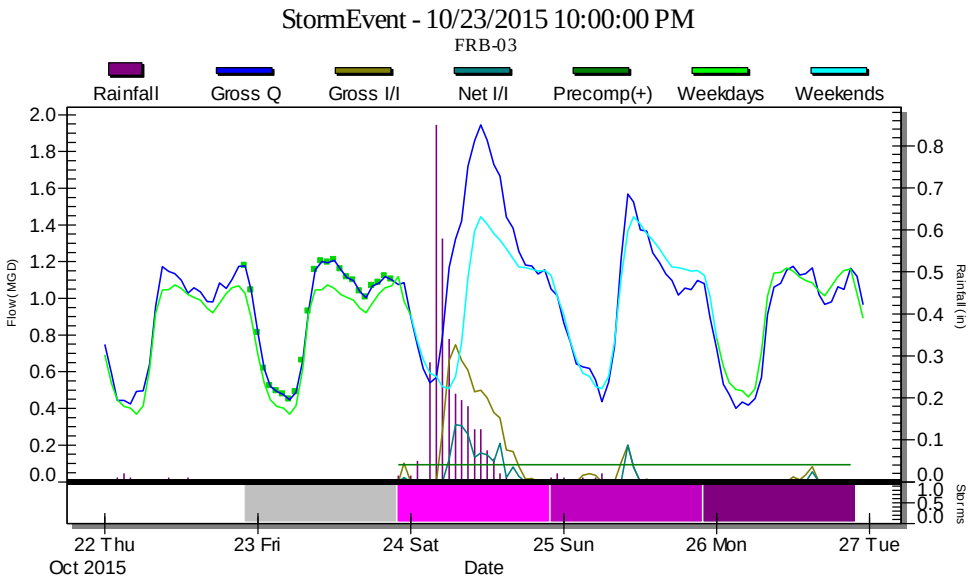
Monitor	Net Q_{BI} (MGD)	Net Q_{BI} (% $Q_{avg\text{-}D}$)	Ranking
FRB-01	0.104	35%	1
FRB-01A	0.017	34%	2
FRB-02	0.080	34%	2
FRB-03	0.066	8%	7
FRB-04	0.038	24%	5
FRB-05	0.070	27%	4
FRB-06	0.046	21%	6

The percentage of base infiltration is highest in Basins FRB-01, FRB-01A, FRB-02, and FRB-05.

Rain-Dependent Inflow and Infiltration

During wet weather events, significant amounts of extraneous water can enter a sewer system, resulting in sanitary sewer overflows (SSOs), basement backups, and/or problems at the wastewater treatment plant (WWTP). A comparison of flow monitor data from dry weather and wet weather periods provides a quantification of rain-dependent inflow and infiltration (RDII), which is calculated by subtracting the measured flow during a rainfall event from the flow during an average dry day. A wet weather storm decomposition hydrograph from a storm event that occurred during the study period is provided in Figure 8.

FIGURE 8: Storm Decomposition Hydrograph



A total of three storm events of interest were observed and evaluated during the study period, with cumulative rainfall totals ranging from 1.04 to 3.30 inches. The duration and total rainfall for each rain gauge can be found in Table 6 for each storm event. The return frequencies of all storm events were less than one year at all durations.

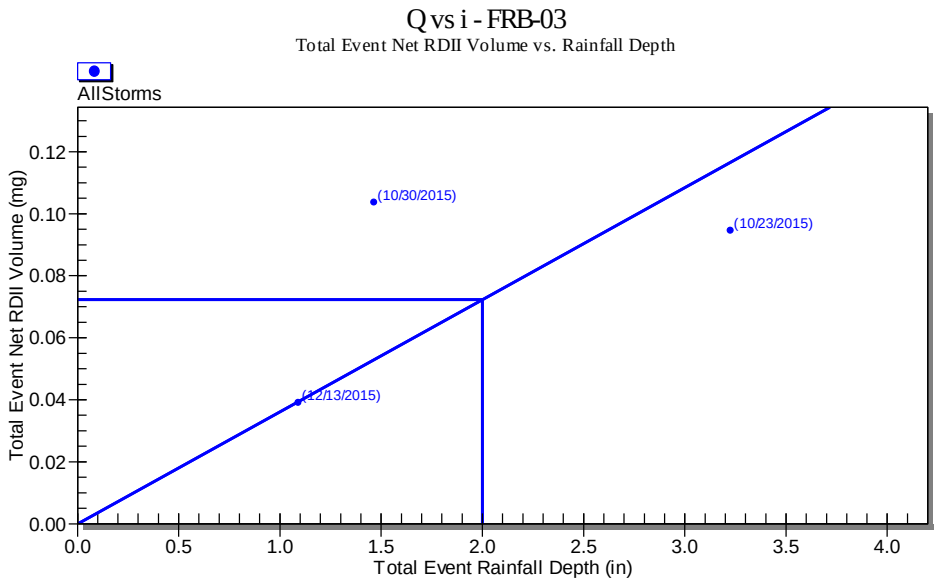
TABLE 6: Storm Summary

Date	Duration (min)	Duration (hours)	Rain Gauge Total FRB-RG1	Rain Gauge Total FRB-RG2
10/23/2015	1920	32	3.30	3.16
10/30/2015	1380	23	1.47*	1.47
12/13/2015	420	7	1.15	1.04

*FRB-RG1 experienced a blockage during the 10/30/2015 event. Due to the fact that these rain gauges were co-located, data from FRB-RG02 was substituted for this event.

After the RDII calculations are determined for each storm event, the results are plotted as a function of rainfall total. An example is shown in Figure 9 in which the relationship between the Storm Event RDII (MG) is plotted with respect to the Storm Event rainfall (inches) for all significant storm events. These relationships can then be used to evaluate the consistency of rainfall responses within the sanitary sewer system and estimate the RDII response for various rainfall amounts. RDII vs. rainfall graphs for each flow monitor basin are provided in the attached appendices.

FIGURE 9: RDII Response vs. Rainfall Depth



Based on the results obtained during the study period, Net RDII are reported for each flow monitor for each storm event at the request of the Engineer. RDII was not calculated for Site FRB-01A. This site was installed midway through the monitoring period. Due to a lack of

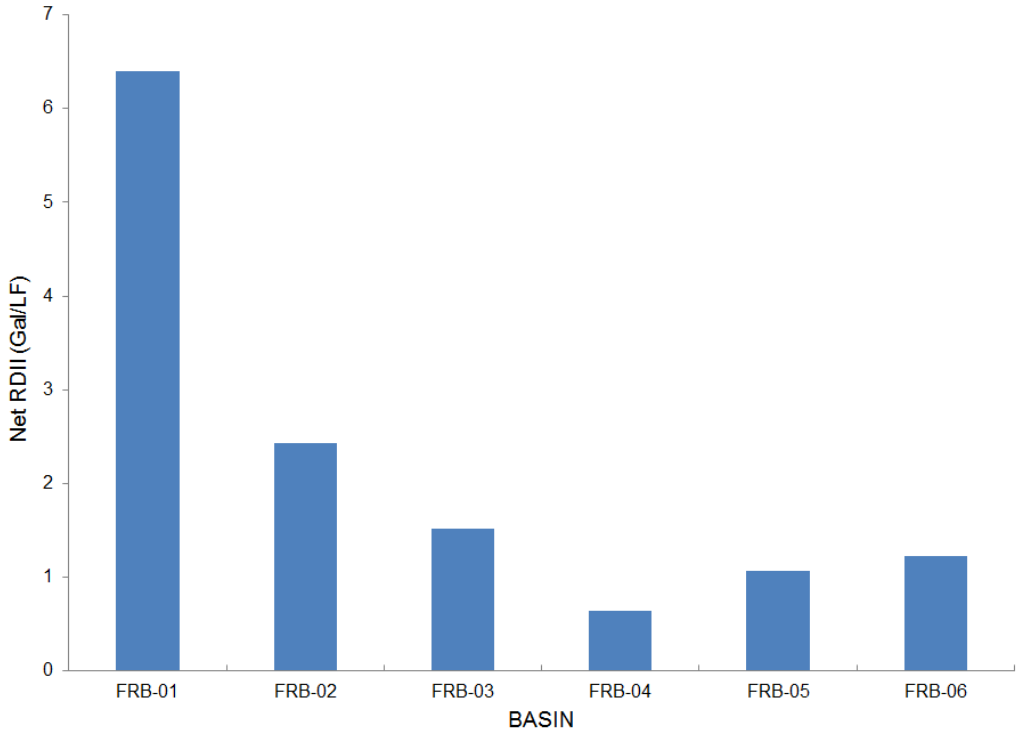
significant rainfall events during this time period, additional RDII analysis could not be performed for this location. Net RDII volumes are computed by subtracting the Gross RDII volume of any upstream flow monitor basin from the Gross RDII volume measured at the outlet of each flow monitor basin. This process identifies and isolates RDII to the basin sizes shown in Table 1. Normalized Net RDII is then calculated by dividing the net RDII volume by the associated basin size, and the results are shown in Table 6.

TABLE 6: Normalized RDII (Gal/LF) for All Storm Events

Date	FRB-01	FRB-02	FRB-03	FRB-04	FRB-05	FRB-06
10/23/2015	6.40	2.43	1.52	0.65	1.06	1.23
10/30/2015	4.66	1.38	1.67	0.61	0.70	1.59
12/13/2015	—	3.61	0.63	0.49	0.70	1.70

The normalized ranked results from the largest rain event, 10/23/2015, are shown in Figure 10. Based on the analysis during this rain event, Site FBR-01 is the highest (worst) ranked basin during the study period, followed by Site FRB-02, and Site FRB-03.

Figure 10: Normalized RDII 10/23/2015 Storm Event



Conclusions and Recommendations

The conclusions and recommendations in this study are based on data gathered using seven temporary flow monitors and two temporary rain gauges. The study period was conducted from 10/21/2015 to 01/15/2016 – a total of 87 days. Up to three rain events of interest were observed for each flow monitor during the study period, with rainfall totals ranging from 1.04 inches to 3.30 inches. A detailed analysis of dry weather and wet weather periods was performed and included an evaluation of various key performance indicators. Specific recommendations for further planning, evaluation, or condition assessment activities are provided below:

Dry Weather Performance

During dry weather conditions, all of the observed dry weather d/D ratios, except for Site FRB-05, are within design criteria recommended by ASCE and WEF, indicating that there is sufficient capacity to accommodate dry weather flow rates at these locations. Site FRB-05 has a dry weather d/D ratio of 53%. However, a review of monitoring data and field crew observations indicates that the manhole in which the flow monitor is installed is the source of the increased d/D ratio. Flow moves effectively through the downstream sewer but has more difficulty transitioning through this particular manhole.

Based on hydraulic conditions observed during the study period, six locations are defined as Class 1 – Self-Cleansing, and one location is defined as Class 2 – Marginal Cleansing. Class 2 – Marginal Cleansing sewers should be inspected periodically by the City as part of a preventive sewer cleaning program to determine the frequency of cleaning needed at these locations.

Wet Weather Performance

The largest wet weather peaking factor observed during the study period was a value of 3.20 at Site FRB-02 and occurred during the 10/23/2015 storm event. Wet weather peaking factors at the remaining flow monitor locations ranged from 1.85 to 3.06. Flow increases at all flow monitor locations occur quickly during wet weather events and then quickly return to normal. This behavior suggests the minimal presence of traditional inflow and infiltration sources.

All of the wet weather d/D ratios observed during the study period are less than 100% and are within design criteria recommended by ASCE and WEF, indicating that there is sufficient capacity to accommodate maximum observed wet weather flows at these locations without surcharge conditions.

Base Infiltration

The highest base infiltration level that was estimated for the study period was in Basin FRB-01, where base infiltration represents 35% of the average dry day flow. Base Infiltration is estimated to contribute to 25% or more of the average dry day flow at three sites during the study period. Night time flow isolations and closed-circuit television (CCTV) inspection are recommended in these basins to locate and identify sources of base infiltration.

Rainfall-Dependent Inflow and Infiltration

Based on the analysis of the 10/23/2015 rain event, Site FRB-01 is the highest (worst) ranked basin during the study period, followed by Basins FRB-02, FRB-03, and FRB-06. ADS recommends condition assesment activities – including manhole inspections, smoke testing, and CCTV inspections -- within these areas if the City seeks to identify the sources of the limited RDII observed in these areas.

Definitions

Basin – a designation given to a series of interconnected sewers within a sanitary sewer system that collect and convey wastewater to a common manhole or pump station. The size and geographic extent of a given basin are system specific. Basin designations are established to provide a consistent nomenclature for system components to facilitate effective planning, operation, and maintenance.

CCTV Inspection – a common diagnostic method used to visually inspect and document the general location, connectivity, and condition of a sewer. CCTV inspection is accomplished using a variety of specially designed camera systems.

Depth-to-Diameter (d/D) Ratio – a ratio of maximum flow depth to sewer diameter. d/D ratios are often calculated to describe both dry weather and wet weather periods and are one measure used to assess sewer capacity utilization. In this study, d/D ratios are computed using hourly average data.

Infiltration – water that enters a sanitary sewer system from the ground through defective system components including, but not limited to, defective sewers, manholes, service connections, or other system appurtenances. Infiltration is primarily dependent upon groundwater elevations, but may also be influenced by storm events and leaking water mains.

Inflow – storm water runoff that enters a sanitary sewer system from direct connections including, but not limited to, building downspouts, clean-outs, foundation drains, sump pumps, basement and area drains, and cross connections with storm sewer systems.

Manhole Inspection – a common diagnostic method used to visually inspect and document the location and condition of a manhole. Manhole inspection can be accomplished using confined space entry or non-entry techniques.

Peaking Factor (PF) – a ratio of maximum flow rate to average flow rate. Peaking factors are often calculated to describe both dry weather and wet weather periods, where maximum flow rates are compared to average dry weather flow rates. In this study, peaking factors are computed using hourly average data.

Rain-Dependent Inflow and Infiltration (RDII) – the collective inflow and infiltration that enter a sewer system as a direct result of rainfall.

Sanitary Sewer Overflow (SSO) – a discharge of untreated wastewater from a sanitary sewer system, caused by a variety of reasons including, but not limited to, inadequate sewer design and construction, insufficient operation and maintenance, power failures, and vandalism.

Sanitary Sewer System – a collection of sewers, manholes, pump stations, and other appurtenances designed for the collection and transportation of wastewater.

Sewer Cleaning – a common method used to dislodge and remove accumulated debris, grease, and roots within a sewer line to achieve desired conditions for CCTV inspection. Under routine conditions, sewer cleaning is performed using hydraulic jetting and vacuum debris removal techniques.

Smoke Testing – a common diagnostic method used to locate and identify potential infiltration and inflow sources within a sanitary sewer system. During smoke testing, a special non-toxic, non-staining smoke is blown into a selected portion of the system. Potential infiltration and inflow sources are evidenced by visible smoke.

Tractive Force Method – a method used to evaluate the self-cleansing status of gravity sewers. This approach is recommended by the American Society of Civil Engineers and the Water Environment Federation.

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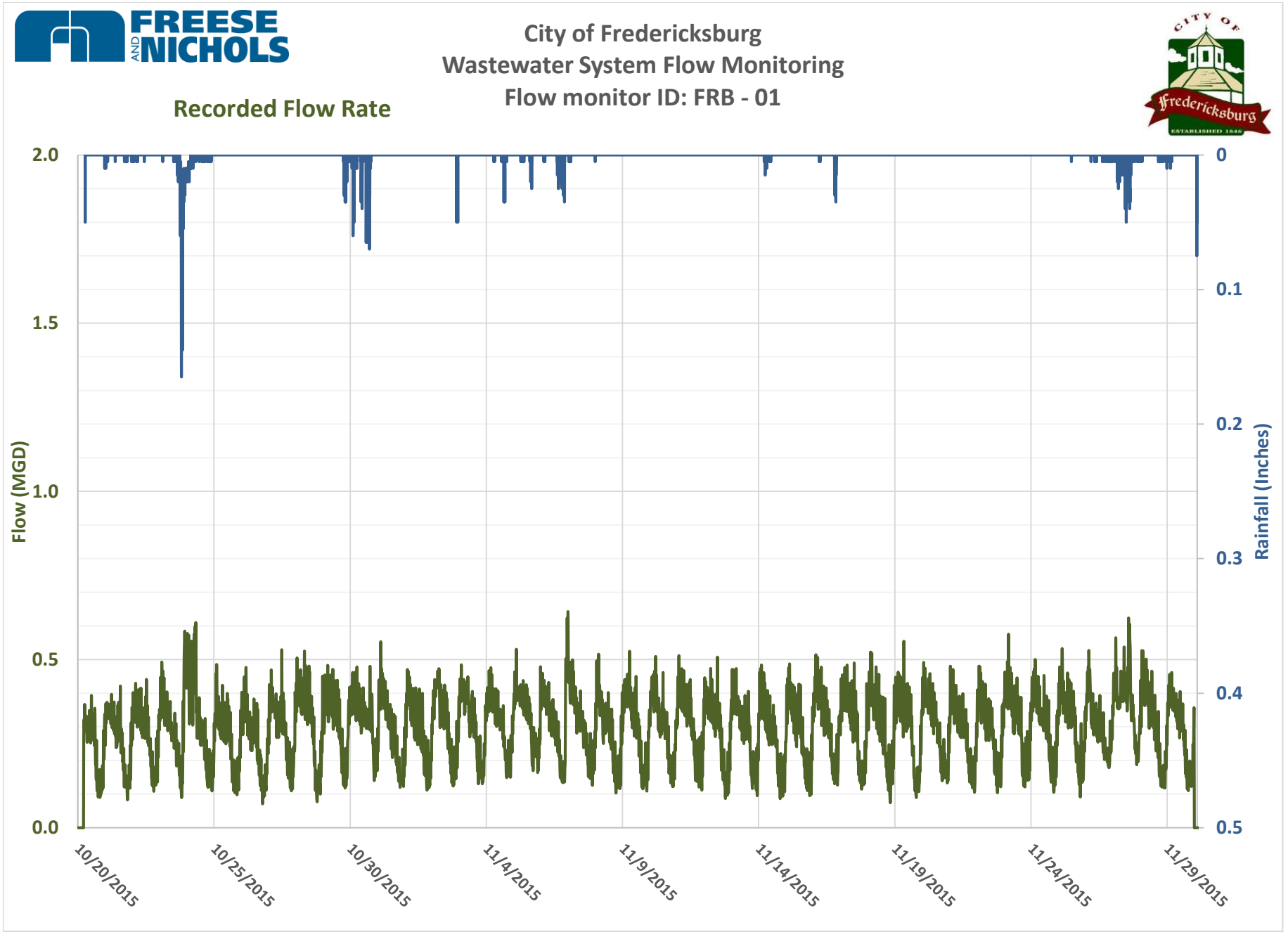
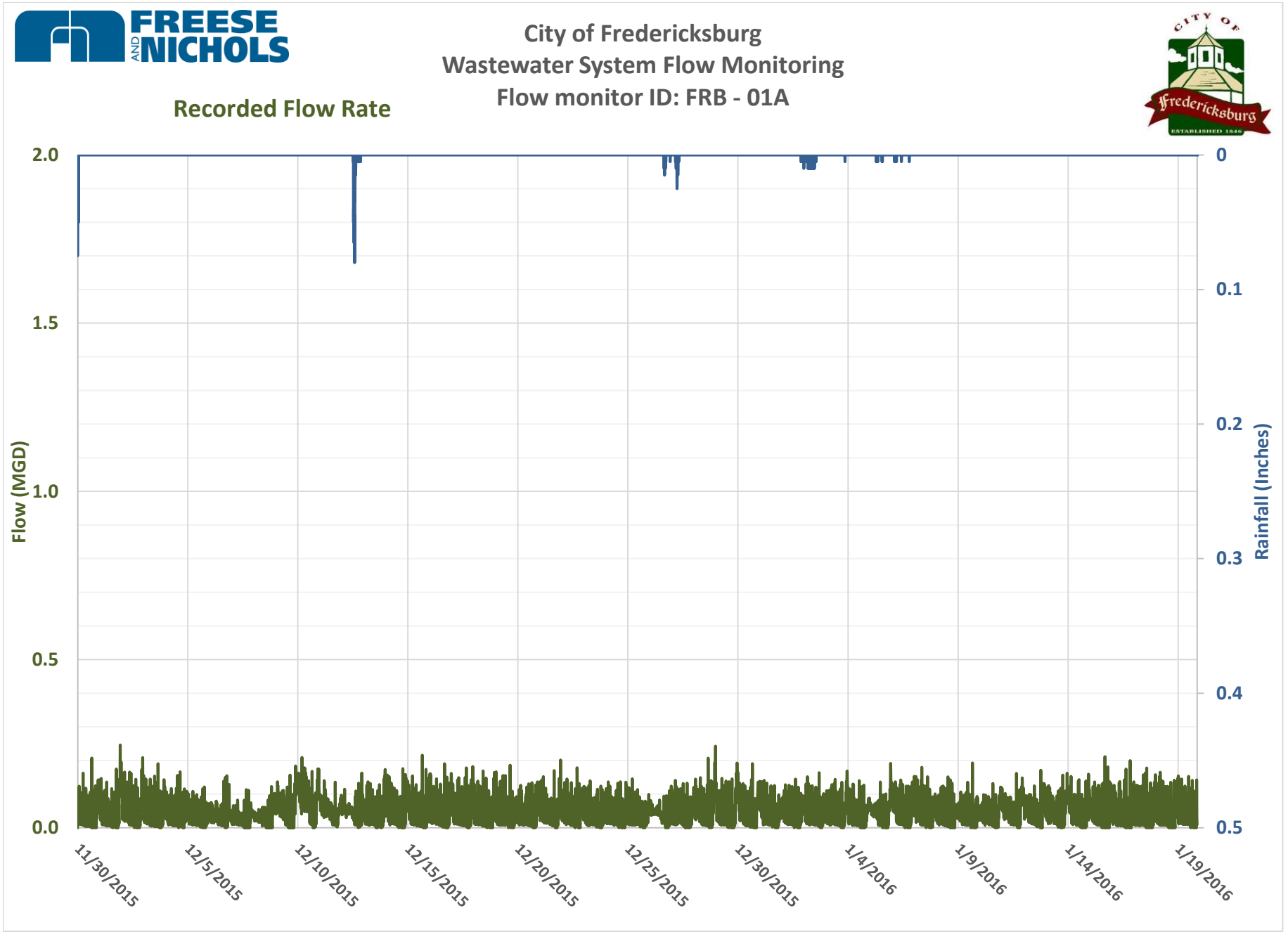
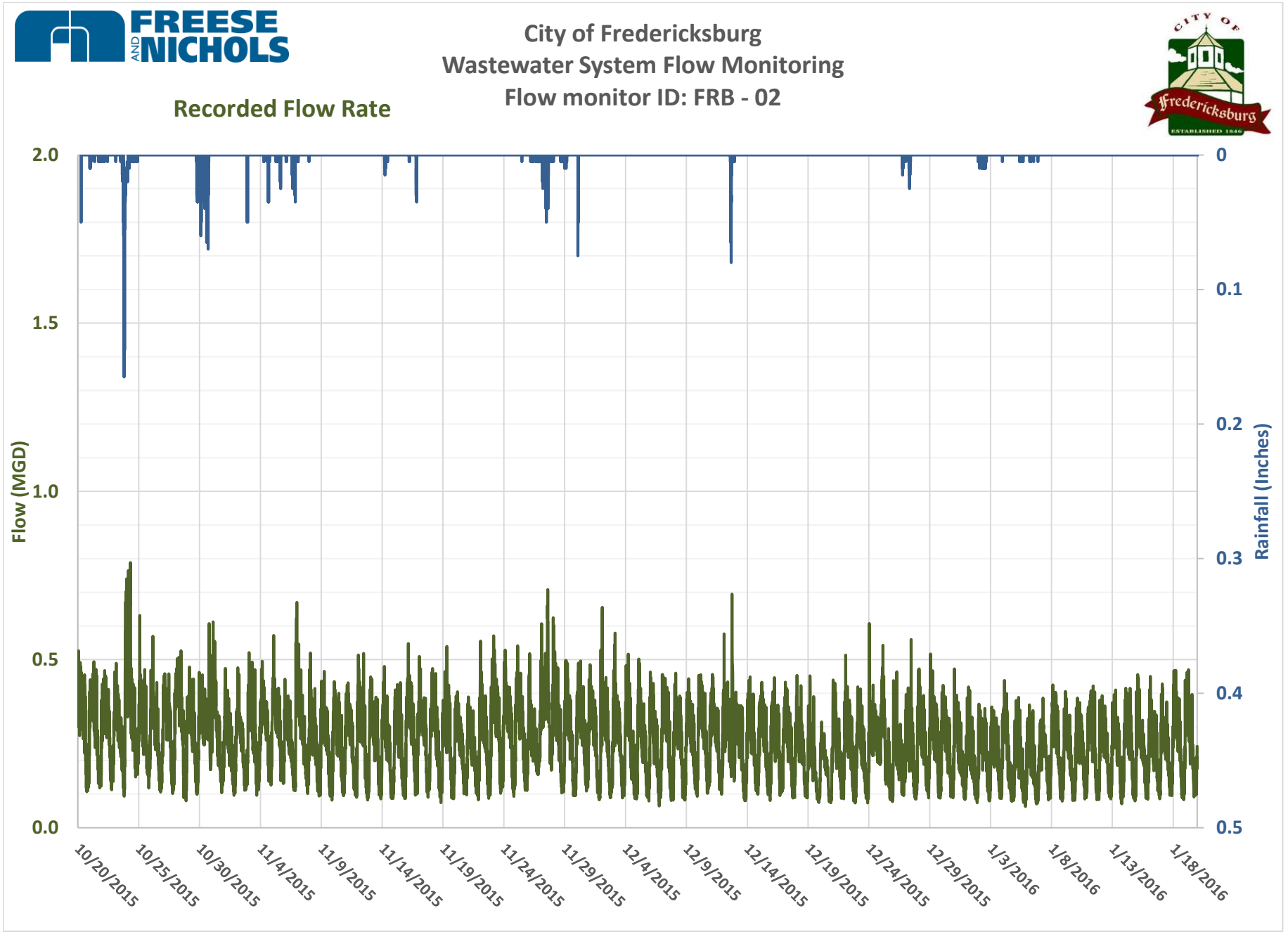
APPENDIX J
FLOW AND DEPTH GRAPHS


FREESE AND NICHOLS
City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 01
Recorded Flow Rate
CITY OF Fredericksburg ESTABLISHED 1846
Flow (MGD)
2.0
1.5
1.0
0.5
0.0
Rainfall (Inches)
0
0.1
0.2
0.3
0.4
0.5
10/20/2015
10/25/2015
10/30/2015
11/4/2015
11/9/2015
11/14/2015
11/19/2015
11/24/2015
11/29/2015

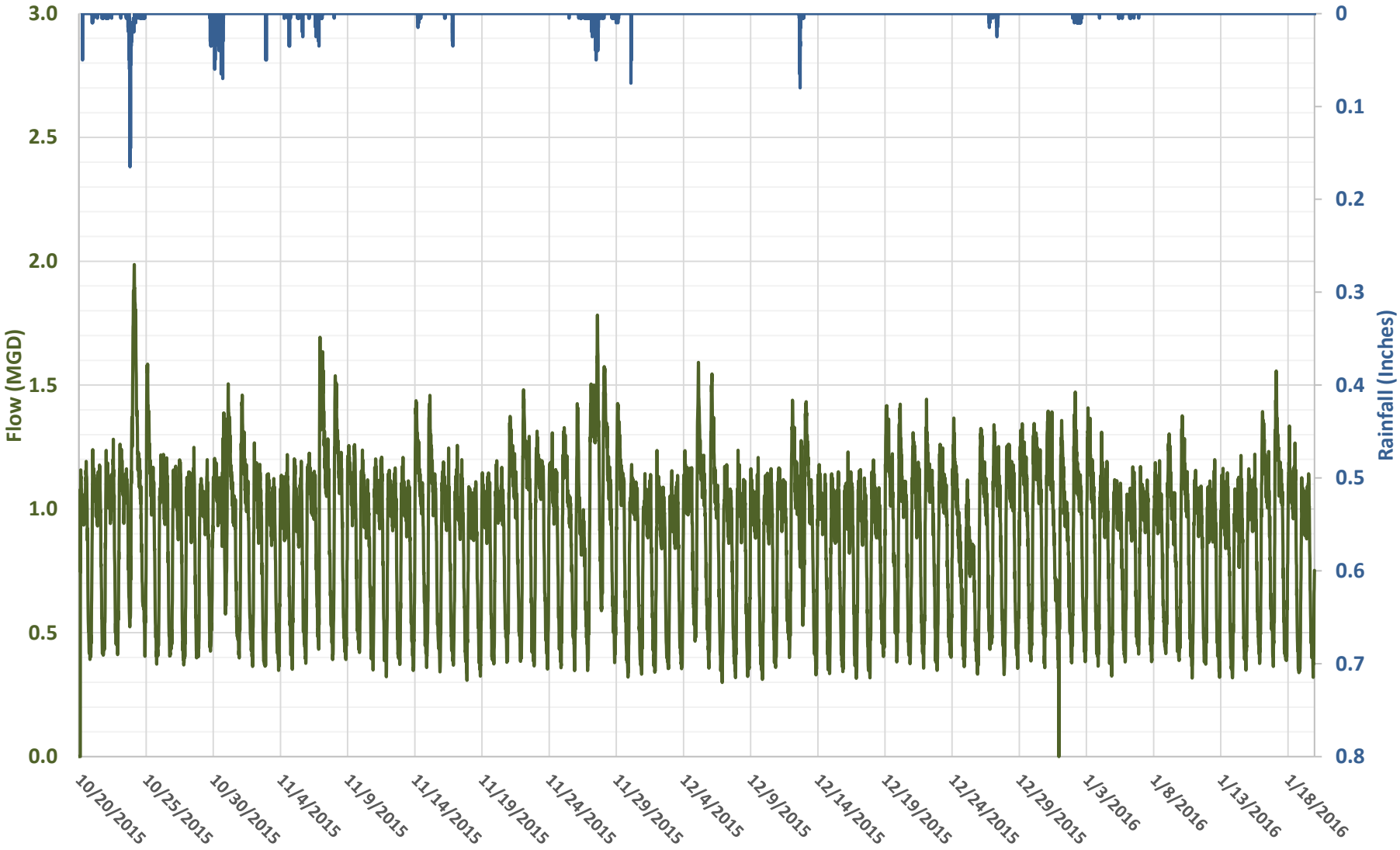

FREESE AND NICHOLS
City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 01A
Recorded Flow Rate
CITY OF Fredericksburg ESTABLISHED 1846
2.0
1.5
1.0
0.5
0.0
Flow (MGD)
0
0.1
0.2
0.3
0.4
0.5
Rainfall (Inches)
11/30/2015
12/5/2015
12/10/2015
12/15/2015
12/20/2015
12/25/2015
12/30/2015
1/4/2016
1/9/2016
1/14/2016
1/19/2016


FREESE AND NICHOLS
City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 02
Recorded Flow Rate
CITY OF Fredericksburg ESTABLISHED 1846
Flow (MGD)
Rainfall (Inches)
2.0
1.5
1.0
0.5
0.0
0
0.1
0.2
0.3
0.4
0.5
10/20/2015
10/25/2015
10/30/2015
11/4/2015
11/9/2015
11/14/2015
11/19/2015
11/24/2015
11/29/2015
12/4/2015
12/9/2015
12/14/2015
12/19/2015
12/24/2015
12/29/2015
1/3/2016
1/8/2016
1/13/2016
1/18/2016

FREESE AND NICHOLS

City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 03

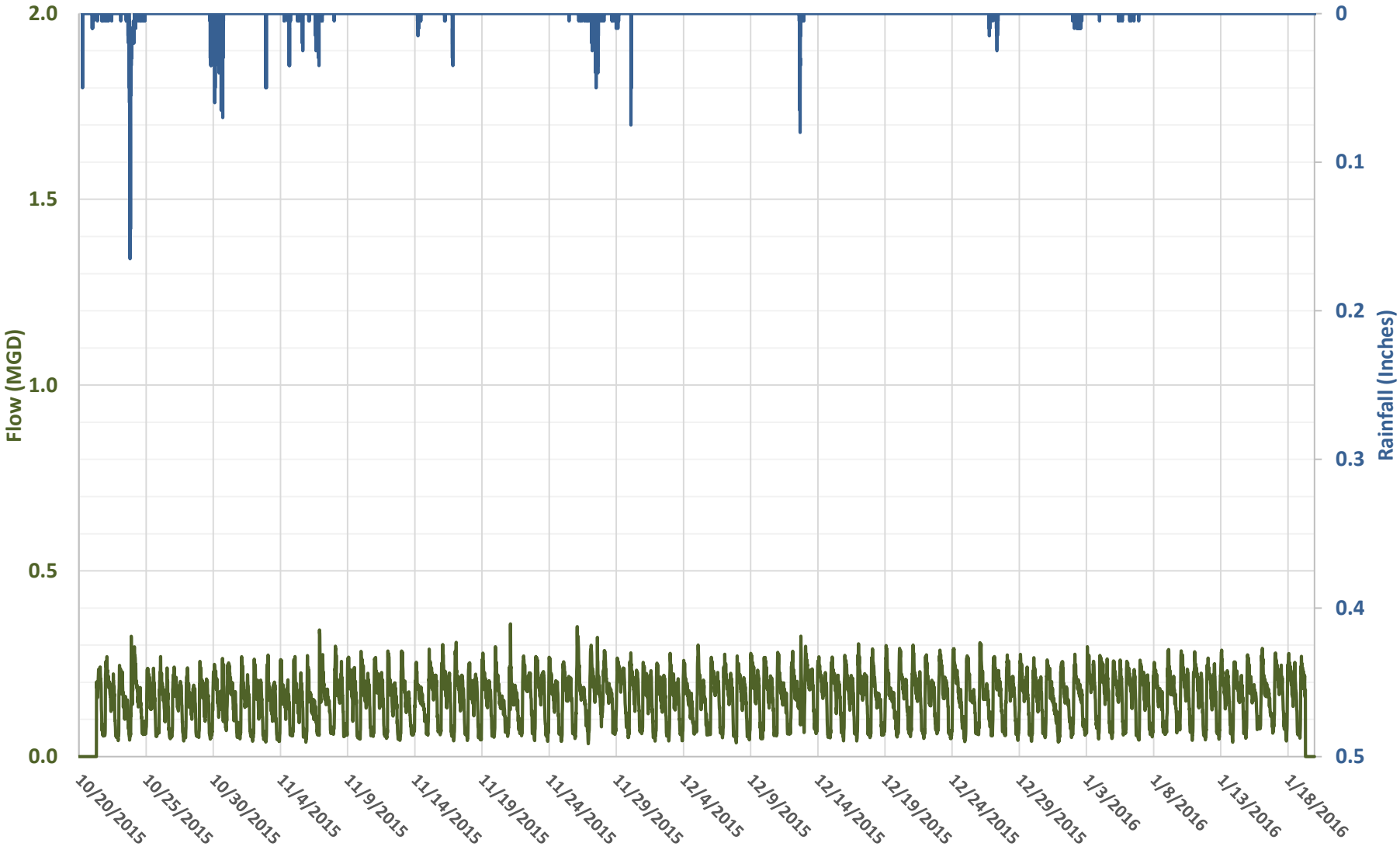
Recorded Flow Rate

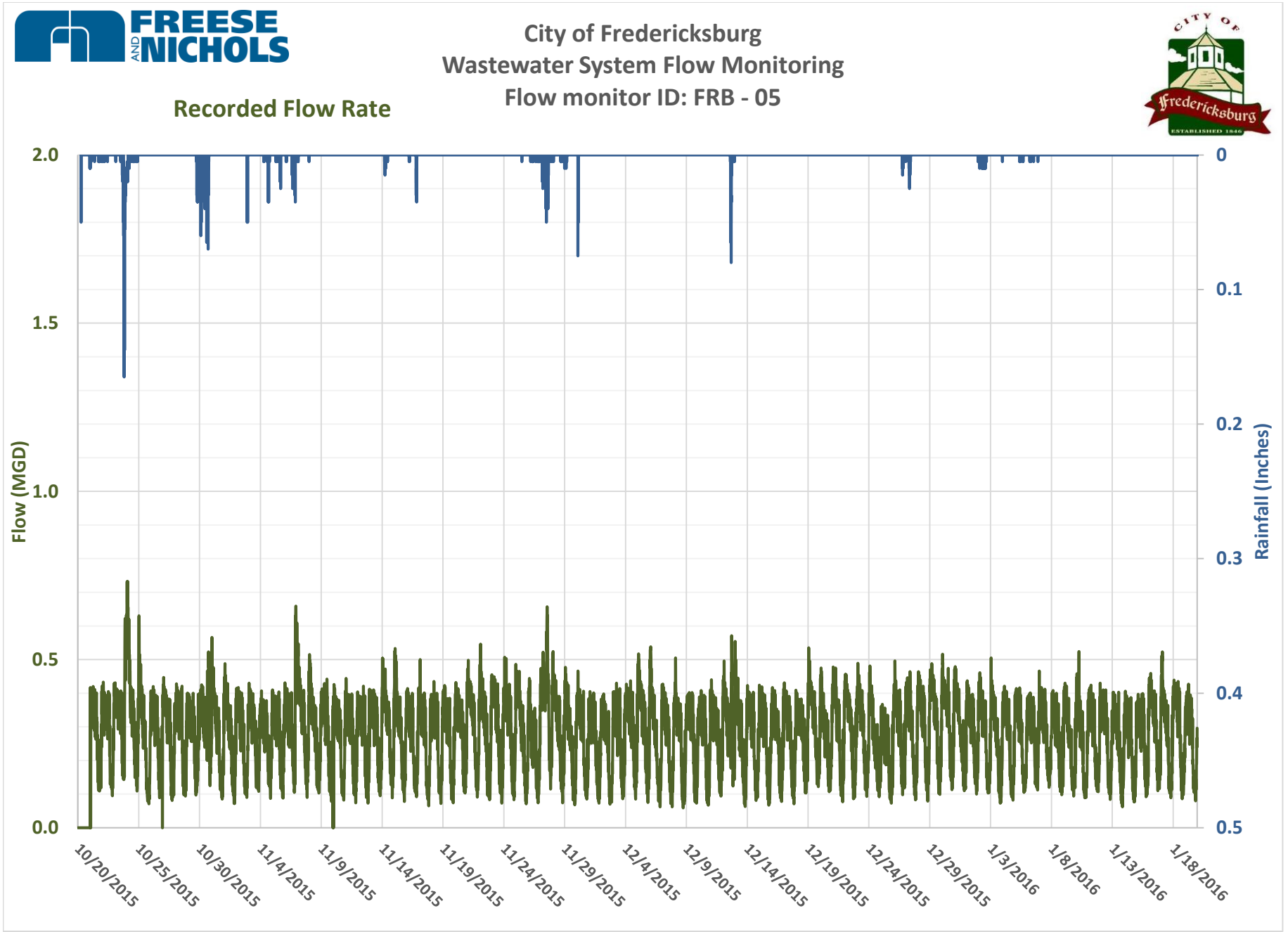


FREESE AND NICHOLS

City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 04

Recorded Flow Rate

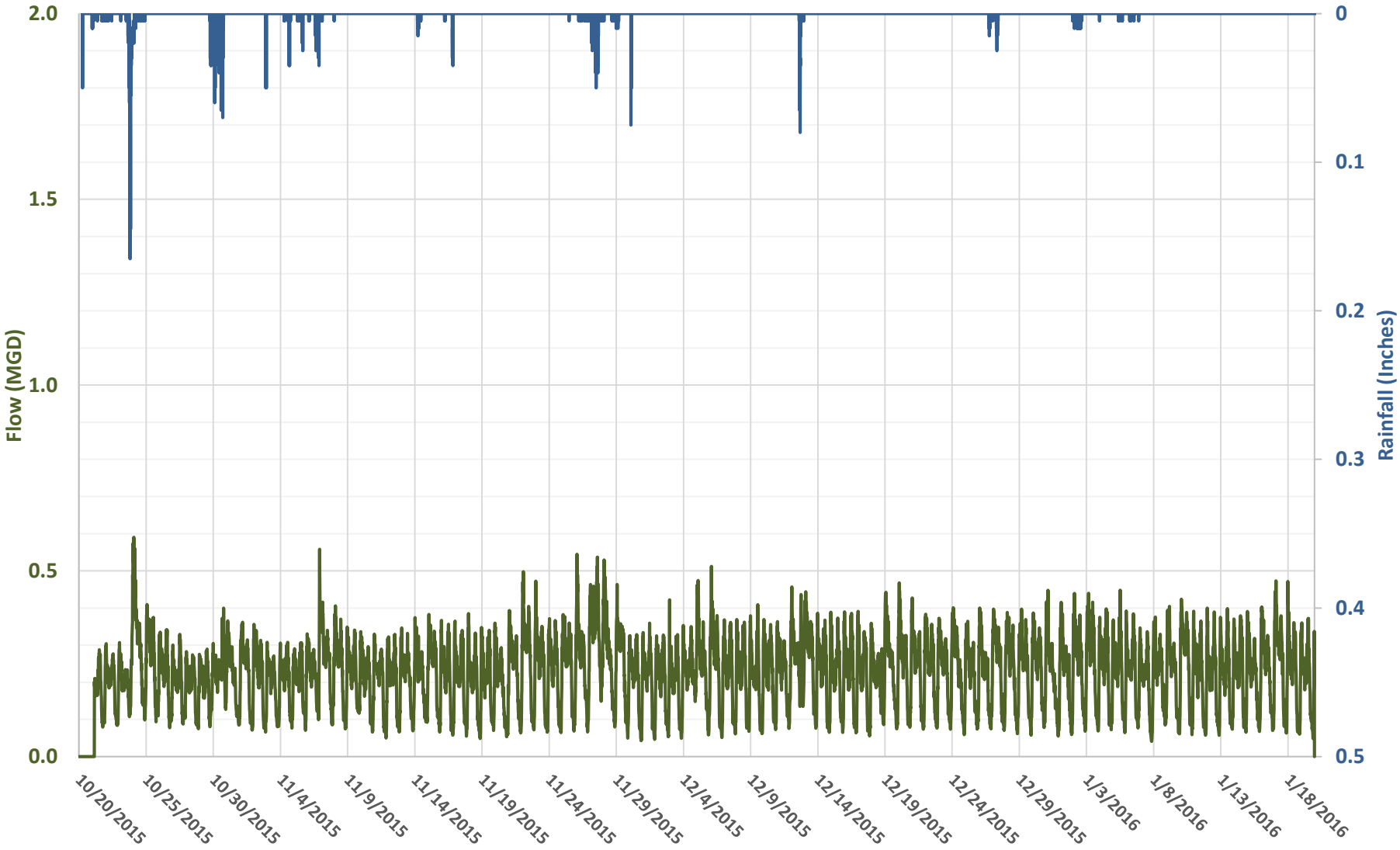


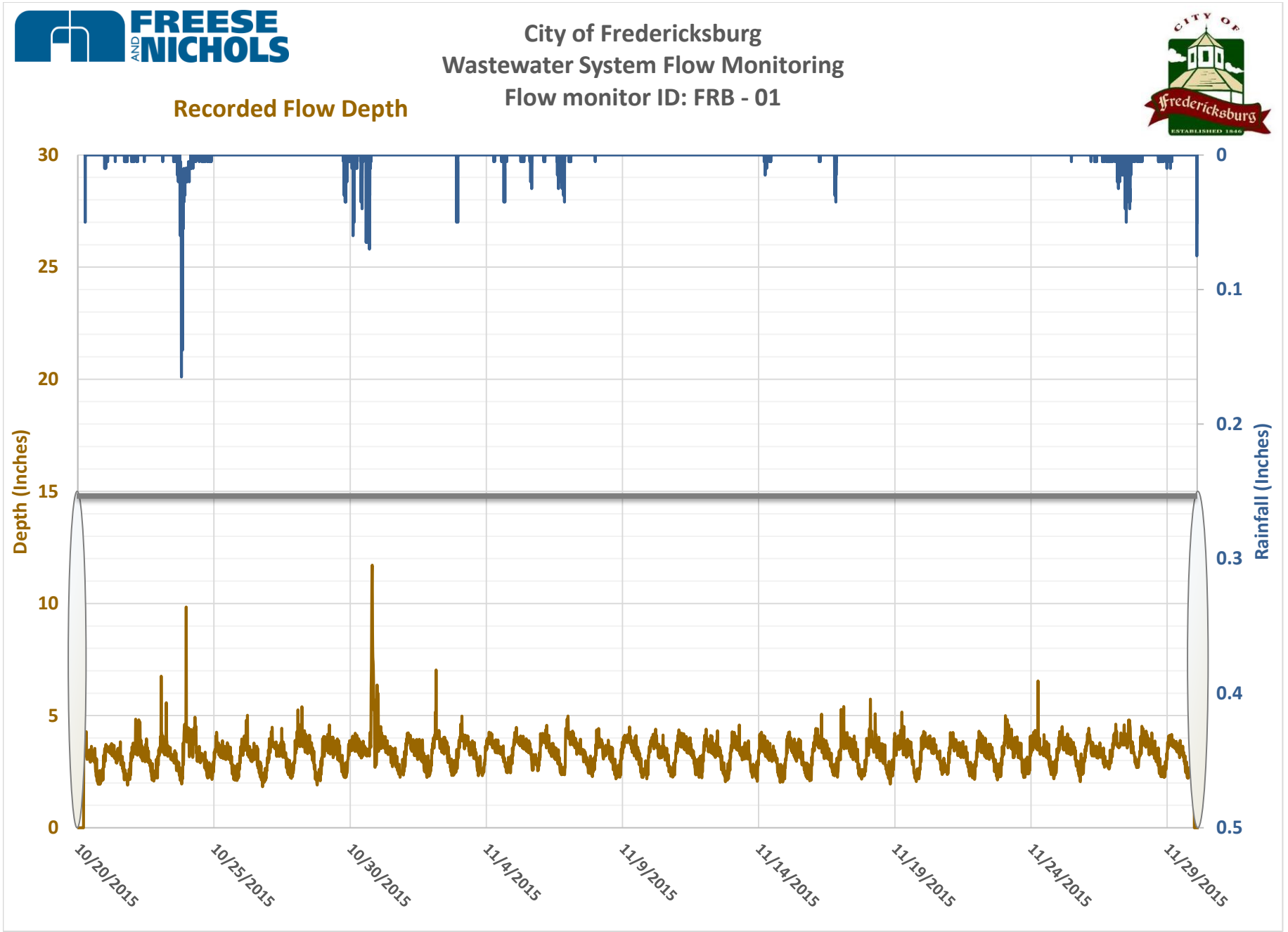

FREESE AND NICHOLS
City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 05
Recorded Flow Rate
CITY OF Fredericksburg ESTABLISHED 1846
Flow (MGD)
Rainfall (Inches)
2.0
1.5
1.0
0.5
0.0
0
0.1
0.2
0.3
0.4
0.5
10/20/2015
10/25/2015
10/30/2015
11/4/2015
11/9/2015
11/14/2015
11/19/2015
11/24/2015
11/29/2015
12/4/2015
12/9/2015
12/14/2015
12/19/2015
12/24/2015
12/29/2015
1/3/2016
1/8/2016
1/13/2016
1/18/2016

FREESE AND NICHOLS

City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 06

Recorded Flow Rate

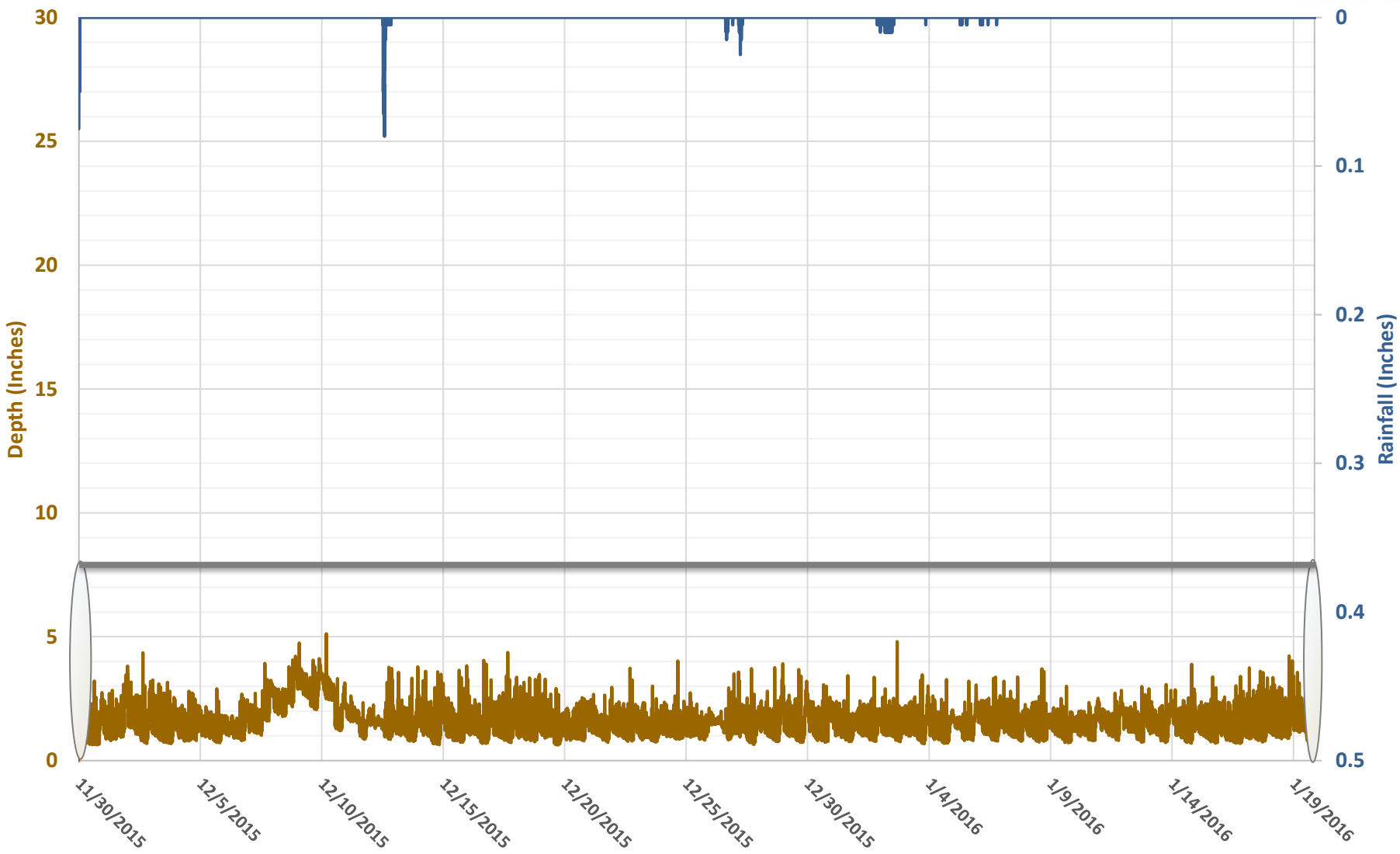



FREESE AND NICHOLS
City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 01
Recorded Flow Depth
CITY OF Fredericksburg ESTABLISHED 1846
Depth (Inches)
Rainfall (Inches)
30
25
20
15
10
5
0
0
0.1
0.2
0.3
0.4
0.5
10/20/2015
10/25/2015
10/30/2015
11/4/2015
11/9/2015
11/14/2015
11/19/2015
11/24/2015
11/29/2015

FREESE AND NICHOLS

Recorded Flow Depth

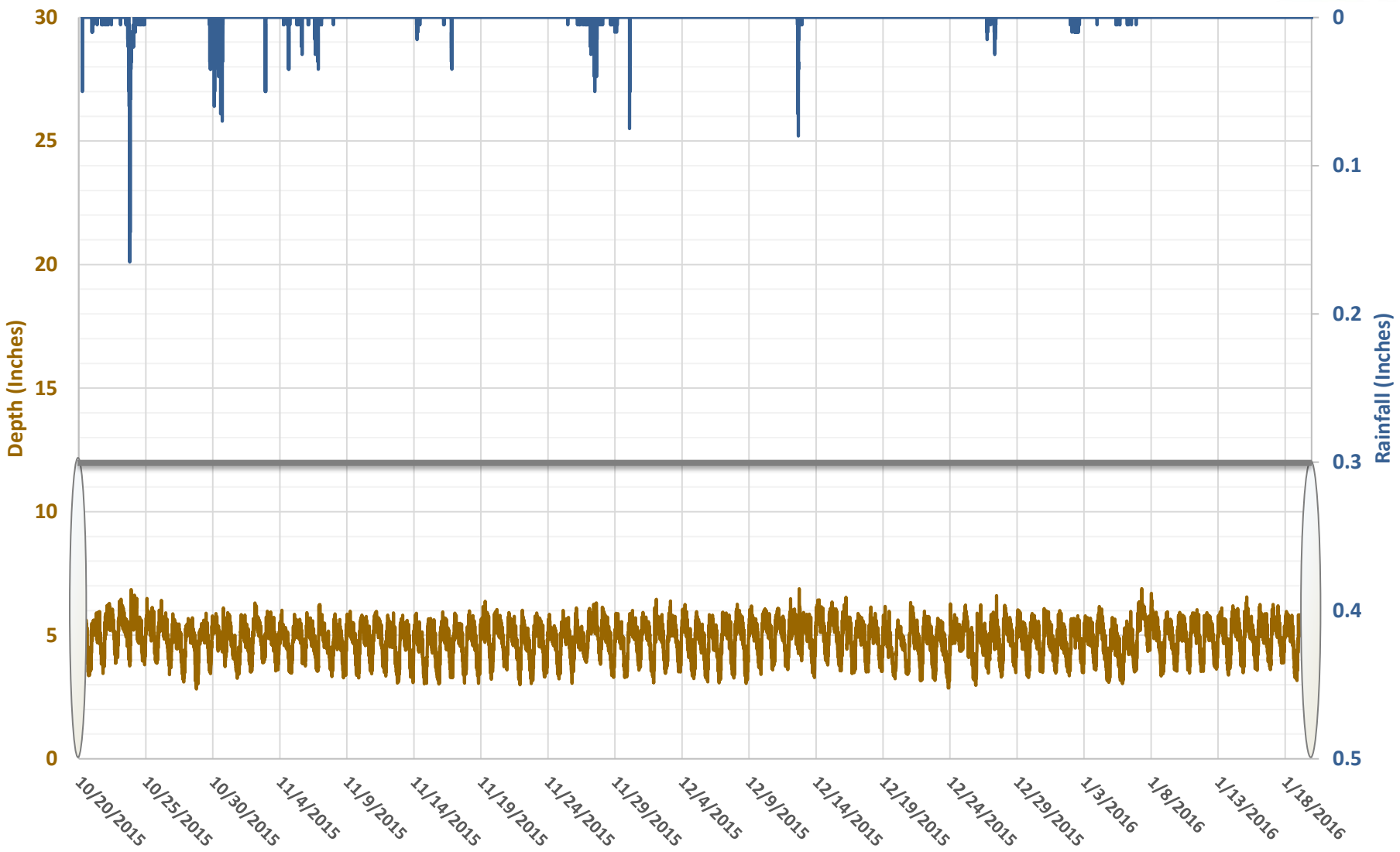
City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 01A



FREESE AND NICHOLS

City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 02

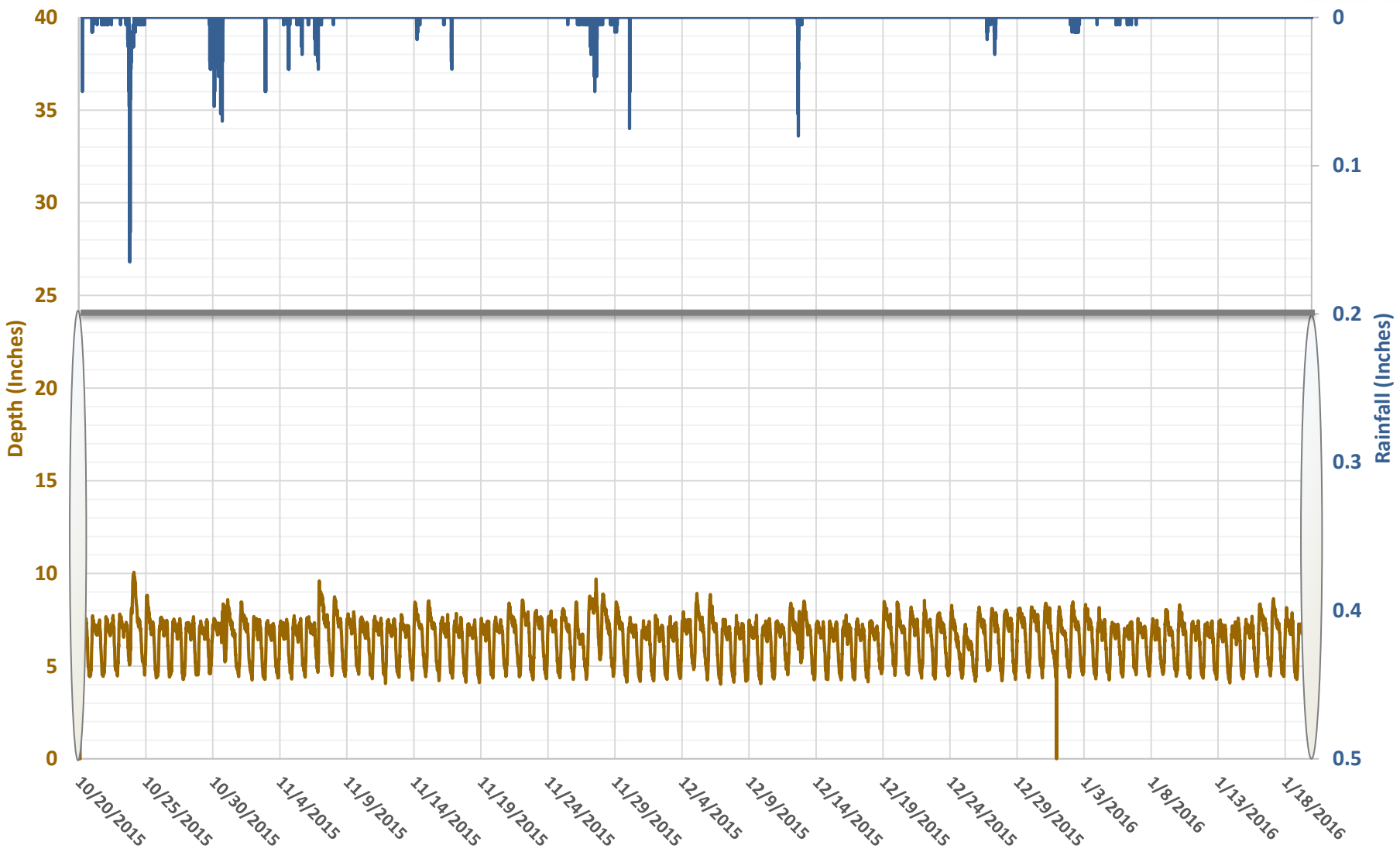
Recorded Flow Depth



FREESE AND NICHOLS

City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 03

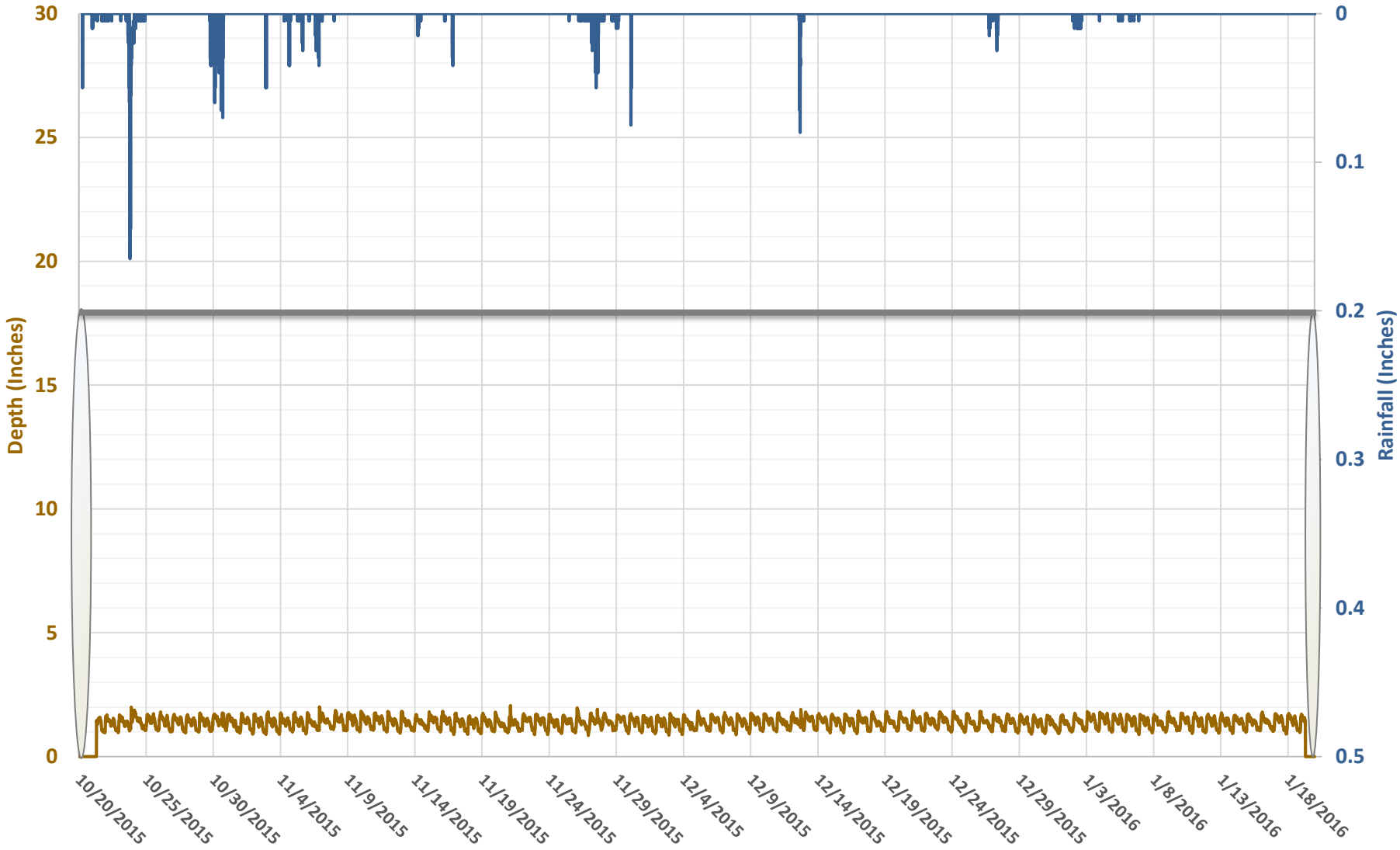
Recorded Flow Depth



FREESE AND NICHOLS

City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 04

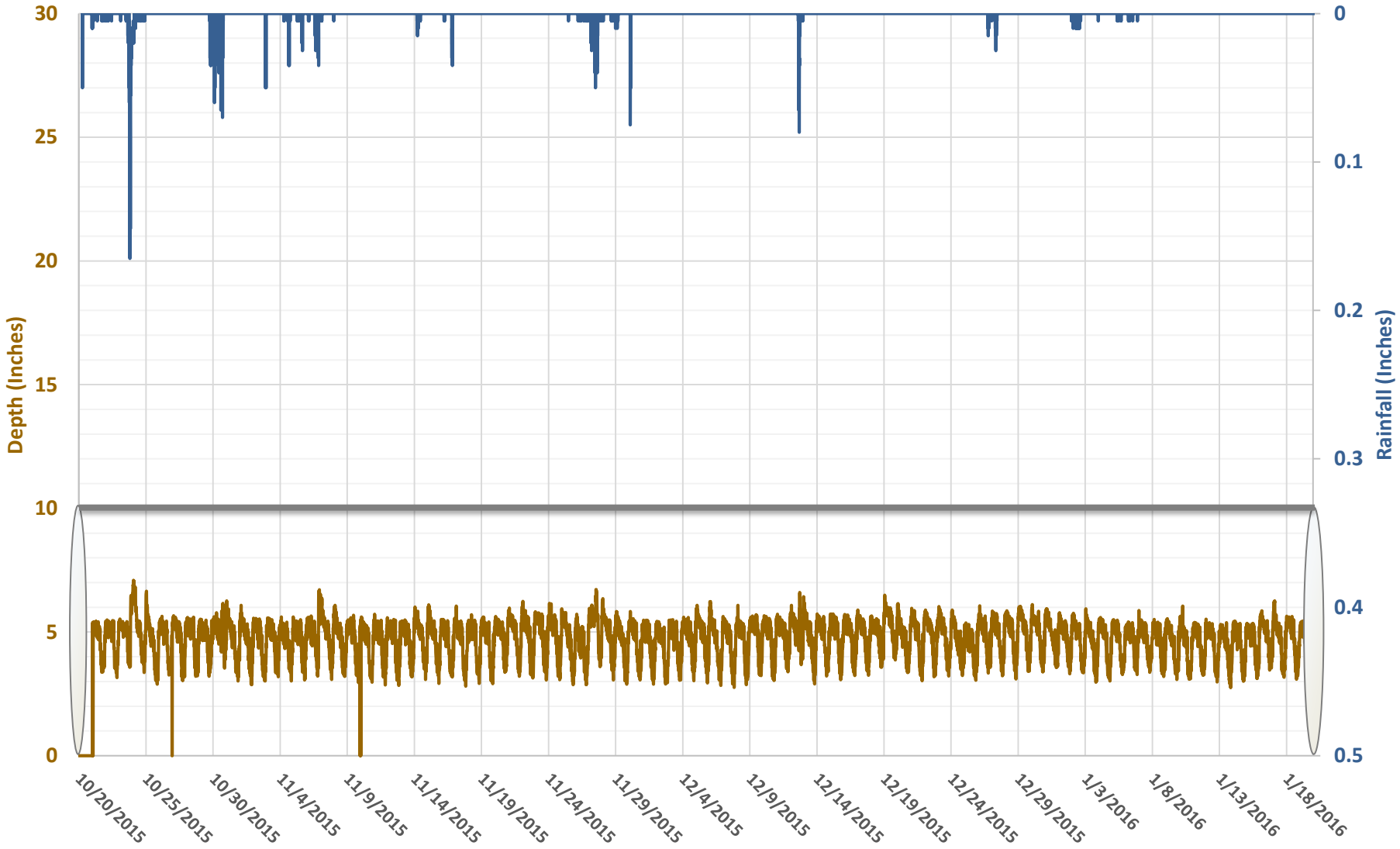
Recorded Flow Depth



FREESE AND NICHOLS

City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 05

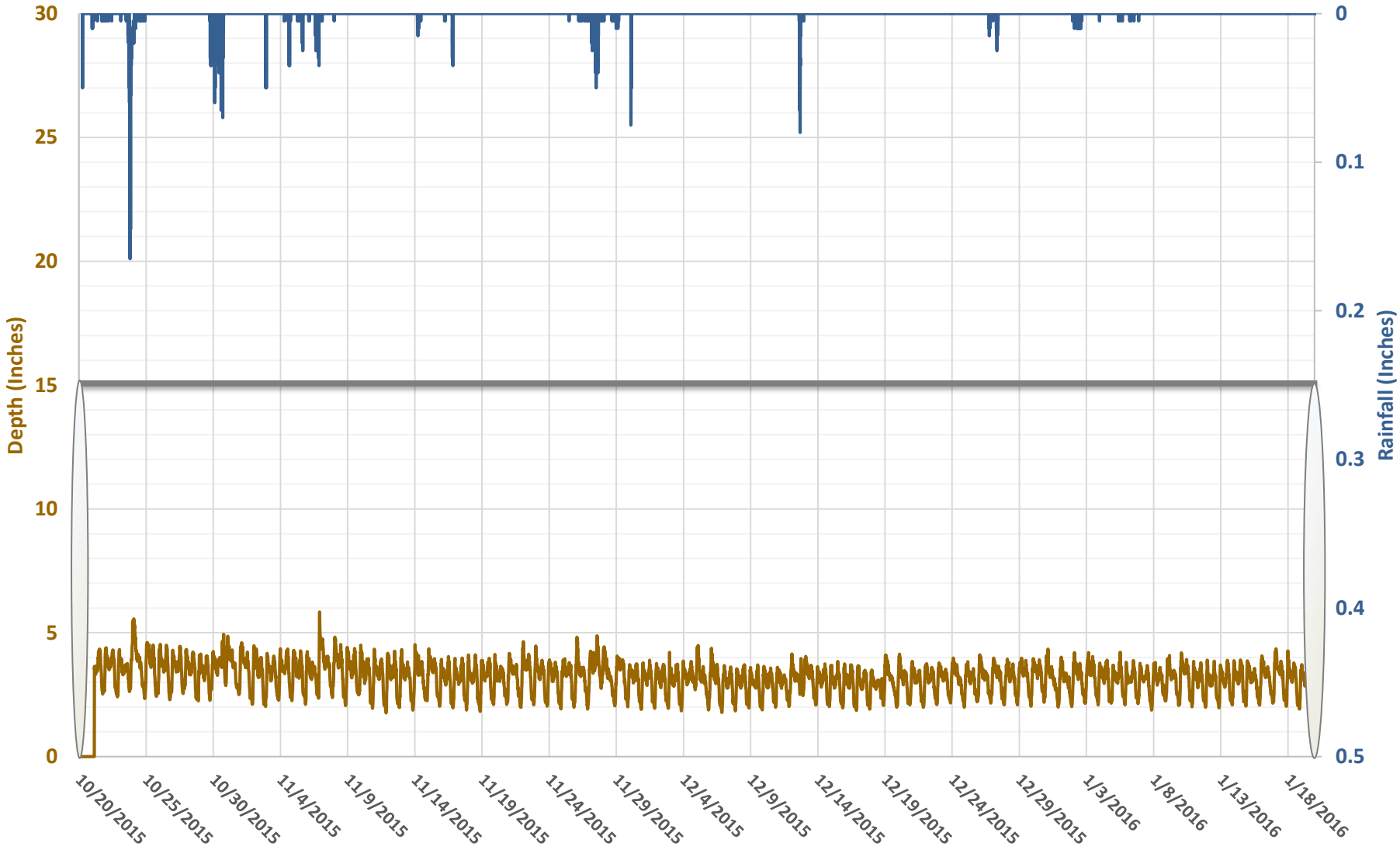
Recorded Flow Depth



FREESE AND NICHOLS

City of Fredericksburg
Wastewater System Flow Monitoring
Flow monitor ID: FRB - 06

Recorded Flow Depth



APPENDIX K
WASTEWATER SYSTEM SITE VISIT SHEETS

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

East Side Lift Station

Inspection Date: 3/22/2016

Facility Information	
Address:	1460 East Main Street
Year in Service:	2010
Type of Facility:	Two Dulpex Submersible Lift Stations
Number of Pumps:	4
Capacity (gpm):	1160.0
Horsepower:	
Monitoring:	No SCADA
Generator:	Portable Generator Connection

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	3	20%	0.60	Portable generator connection (City maybe has one)
Pumps and Motors	3	20%	0.60	2 wet wells float together, 4 pumps, pulling cables broken on pumps - should be replaced
Instrumentation - SCADA, alarms	4	15%	0.60	Not likely on SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	1	20%	0.20	Coating OK, very minimal corrosion
Piping and Valves	2	15%	0.30	Minimal corrosion, minimal water poling in valve vault.
Site - Drainage, Access Drive, Security, Fencing	3	10%	0.30	Barbed wire fence above wood fence is too low.
Total Inspection Score	-	100%	2.60	
Condition Rating	-	-	**2.60**	**Fair**

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	5	25%	1.25	
Population Served	3	50%	1.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	**3.25**	**High**

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	**2.60**	**3.25**	**5.85**	**High Risk**

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Consolidated Warehouse Lift Station

Inspection Date: 3/23/2016

Facility Information	
Address:	233 Friendship Lane
Year in Service:	2001
Type of Facility:	Dulpex Submersible Lift Station
Number of Pumps:	2
Capacity (gpm):	131.0
Horsepower:	
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	No back up power
Pumps and Motors	2	20%	0.40	No pump or overflow issues. Both pumps in working condition
Instrumentation - SCADA, alarms	4	15%	0.60	Not connected to SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	2	20%	0.40	Concrete in OK shape, rebar exposed in some locations
Piping and Valves	4	15%	0.60	Valve vault filled with water completely, some corrosion on discharge pipes
Site - Drainage, Access Drive, Security, Fencing	3	10%	0.30	In back of Warehouse, gate not locked, 6 foot fence with two strands of barbed wire
Total Inspection Score	-	100%	3.10	
Condition Rating	-	-	3.10	Poor

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	1	25%	0.25	
Population Served	1	50%	0.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	1.25	Very Low

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.10	1.25	4.35	Low Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Heritage Hill Country Lift Station

Inspection Date: 3/22/2016

Facility Information

Address:	124 Mariposa Drive
Year in Service:	1998
Type of Facility:	Dulpex Submersible Lift Station
Number of Pumps:	2
Capacity (gpm):	185.0
Horsepower:	
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	No back up power
Pumps and Motors	2	20%	0.40	Both pumps work and are not run too often, slightly older pumps
Instrumentation - SCADA, alarms	4	15%	0.60	Not connected to SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	3	20%	0.60	Hatch and piping in wet well showing signs of slight corrosion
Piping and Valves	2	15%	0.30	New check valves installed in 2014, vault not submerged
Site - Drainage, Access Drive, Security, Fencing	3	10%	0.30	Barbed wire gone from fencing, will be replaced
Total Inspection Score	-	100%	3.00	
Condition Rating	-	-	3.00	Fair

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	2	25%	0.50	
Population Served	2	50%	1.00	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	2.00	Low

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.00	2.00	5.00	Moderate Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Hill Country University Lift Station

Inspection Date: 3/22/2016

Facility Information	
Address:	2818 US Highway 290
Year in Service:	2008
Type of Facility:	Dulpex Submersible Lift Station
Number of Pumps:	2
Capacity (gpm):	
Horsepower:	15 hp
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	No back up power
Pumps and Motors	2	20%	0.40	Doesn't cycle very much, no issues with pumps
Instrumentation - SCADA, alarms	4	15%	0.60	Not connected to SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	3	20%	0.60	Due to lack of cycling, some buildup of scum in wet well
Piping and Valves	2	15%	0.30	PVC discharge No issue in vault
Site - Drainage, Access Drive, Security, Fencing	1	10%	0.10	No issues, 8 foot tall vault
Total Inspection Score	-	100%	2.80	
Condition Rating	-	-	**2.80**	**Fair**

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	5	25%	1.25	
Population Served	1	50%	0.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	**2.25**	**Moderate**

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	**2.80**	**2.25**	**5.05**	**Moderate Risk**

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Bob White Lift Station

Inspection Date: 3/23/2016

Facility Information

Address:	410 Hollmig Lane
Year in Service:	2005-2007
Type of Facility:	Dulpex Submersible Lift Station
Number of Pumps:	2
Capacity (gpm):	
Horsepower:	
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	Some cracking around conduit, No back up power
Pumps and Motors	2	20%	0.40	No issues with pumps
Instrumentation - SCADA, alarms	4	15%	0.60	Floats, no SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	2	20%	0.40	Minimal corrosion, overall in decent shape
Piping and Valves	4	15%	0.60	Valve submerged periodically, valve not exercised
Site - Drainage, Access Drive, Security, Fencing	3	10%	0.30	6 foot fence, no barbed wire
Total Inspection Score	-	100%	3.10	
Condition Rating	-	-	3.10	Poor

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	1	25%	0.25	
Population Served	1	50%	0.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	1.25	Very Low

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.10	1.25	4.35	Low Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Beverly Drive Lift Station

Inspection Date: 3/22/2016

Facility Information	
Address:	End of Beverly Drive
Year in Service:	Over 28 years
Type of Facility:	Wet Well with SP Pumps in Building
Number of Pumps:	2
Capacity (gpm):	195.0
Horsepower:	25 hp
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	No back up power
Pumps and Motors	2	20%	0.40	Both pumps work well
Instrumentation - SCADA, alarms	4	15%	0.60	No SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	3	20%	0.60	Some corrosion No ventilation, corrosion in building
Piping and Valves	2	15%	0.30	Discharge piping and valves housed in building. No issues.
Site - Drainage, Access Drive, Security, Fencing	2	10%	0.20	No fencing, but locked building and locked vault included.
Total Inspection Score	-	100%	2.90	
Condition Rating	-	-	**2.90**	**Fair**

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	5	25%	1.25	
Population Served	1	50%	0.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	**2.25**	**Moderate**

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	**2.90**	**2.25**	**5.15**	**Moderate Risk**

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Green Meadows Lift Station

Inspection Date: 3/23/2016

Facility Information

Address:	104 Green Meadows Road
Year in Service:	2003- redone
Type of Facility:	Dulpex Submersible Lift Station
Number of Pumps:	2
Capacity (gpm):	1000.0
Horsepower:	50 hp
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	No back up power
Pumps and Motors	2	20%	0.40	No major issues Not very much holding capacity
Instrumentation - SCADA, alarms	4	15%	0.60	Not connected to SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	3	20%	0.60	corrosion inside wet well, some hatch corrosion
Piping and Valves	4	15%	0.60	Some corrosion of piping, solids built up in vault & well. Valve vault shows signs of flooding.
Site - Drainage, Access Drive, Security, Fencing	4	10%	0.40	Hop curb to get in, area frequently floods, gapping in bottom of fence, 6 foot fence, no barbed wire
Total Inspection Score	-	100%	3.40	
Condition Rating	-	-	3.40	Poor

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	1	25%	0.25	
Population Served	2	50%	1.00	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	1.75	Low

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.40	1.75	5.15	Moderate Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Fair Grounds Lift Station

Inspection Date: 3/23/2016

Facility Information	
Address:	35 Fair Drive
Year in Service:	2000
Type of Facility:	Submersible Lift Station
Number of Pumps:	2
Capacity (gpm):	225.0
Horsepower:	75 hp
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	No back up power
Pumps and Motors	2	20%	0.40	Pumps in good shape. City has too much inflow into this LS
Instrumentation - SCADA, alarms	5	15%	0.75	Floats appears higher than affluent line, not connected to SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	2	20%	0.40	No coating on concrete, corrosion minimal, vent slightly rusty
Piping and Valves	2	15%	0.30	Corrosion on discharge piping, valve box not submerged at time of inspection
Site - Drainage, Access Drive, Security, Fencing	4	10%	0.40	6 foot fence, barbed wire, barbed wire not tight
Total Inspection Score	-	100%	3.05	
Condition Rating	-	-	3.05	Poor

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	4	25%	1.00	
Population Served	1	50%	0.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	2.00	Low

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.05	2.00	5.05	Moderate Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Windcrest Lift Station

Inspection Date: 3/22/2016

Facility Information

Address:	410 Windcrest Street
Year in Service:	Late 1960's
Type of Facility:	Wet Well with SP Pumps in Building
Number of Pumps:	2
Capacity (gpm):	300.0
Horsepower:	
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	No back up power
Pumps and Motors	1	20%	0.20	- 1 pump installed March 2015 - 1 pump in 2006
Instrumentation - SCADA, alarms	4	15%	0.60	No SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	3	20%	0.60	More solids accumulation, no odor issues
Piping and Valves	2	15%	0.30	Housed inside building
Site - Drainage, Access Drive, Security, Fencing	4	10%	0.40	No fence around full perimeter, locked door, no access drive
Total Inspection Score	-	100%	2.90	
Condition Rating	-	-	2.90	Fair

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	1	25%	0.25	
Population Served	1	50%	0.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	1.25	Very Low

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	2.90	1.25	4.15	Low Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

FBG Inn and Suites Lift Station

Inspection Date: 3/23/2016

Facility Information

Address:	201 Highway 87
Year in Service:	
Type of Facility:	Wet Well with SP Pumps in Building
Number of Pumps:	2
Capacity (gpm):	250.0
Horsepower:	15 hp
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	Pumps trip and room floods, no back up power
Pumps and Motors	2	20%	0.40	Skid mounted, 2 different pump drive types, operates frequently
Instrumentation - SCADA, alarms	4	15%	0.60	Not connected to SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	3	20%	0.60	Building has holes/unsealed, large pit, high solids, structure bolted down & locked
Piping and Valves	3	15%	0.45	Thrust harness in need of repair in building, piping has little support inside
Site - Drainage, Access Drive, Security, Fencing	5	10%	0.50	No access to this lift station, on creek, locked building
Total Inspection Score	-	100%	3.35	
Condition Rating	-	-	3.35	Poor

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	5	25%	1.25	
Population Served	1	50%	0.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	2.25	Moderate

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.35	2.25	5.60	High Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Milam Street Lift Station

Inspection Date: 3/23/2016

Facility Information

Address:	431 S Milam Street
Year in Service:	
Type of Facility:	Dulpex Submersible Lift Station
Number of Pumps:	2
Capacity (gpm):	80.0
Below average number of	
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	No back up power
Pumps and Motors	2	20%	0.40	Scum line very visible, pumps pulled weekly & inspected
Instrumentation - SCADA, alarms	4	15%	0.60	Not connected to SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	2	20%	0.40	Minimal cracking in structure, ventilation in good shape, foaming in pit
Piping and Valves	4	15%	0.60	Discharge piping somewhat corroded, valve vault full of water
Site - Drainage, Access Drive, Security, Fencing	3	10%	0.30	6 foot fence, no barbed wire, gravel drive
Total Inspection Score	-	100%	3.10	
Condition Rating	-	-	3.10	Poor

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	3	25%	0.75	
Population Served	1	50%	0.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	1.75	Low

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.10	1.75	4.85	Moderate Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Herb Farm Lift Station

Inspection Date: 3/23/2016

Facility Information	
Address:	600 Winfred Street
Year in Service:	
Type of Facility:	Dulpex Submersible Lift Station
Number of Pumps:	2
Capacity (gpm):	20.0
Horsepower:	
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	No back up power
Pumps and Motors	2	20%	0.40	This LS is not run very often, no issues.
Instrumentation - SCADA, alarms	4	15%	0.60	Not connected to SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	2	20%	0.40	Minimal corrosion in well
Piping and Valves	4	15%	0.60	PVC pipe in vault submerged w/ stormwater
Site - Drainage, Access Drive, Security, Fencing	3	10%	0.30	6 foot fence, no barbed wire, good access, gapping in fence bottom
Total Inspection Score	-	100%	3.10	
Condition Rating	-	-	3.10	Poor

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	2	25%	0.50	
Population Served	1	50%	0.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	1.50	Low

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.10	1.50	4.60	Moderate Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Walk Bridge Lift Station

Inspection Date: 3/23/2016

Facility Information	
Address:	402 Orange Street
Year in Service:	1998
Type of Facility:	Dulpex Submersible Lift Station
Number of Pumps:	2
Capacity (gpm):	120.0
Horsepower:	5 hp?
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	No back up power
Pumps and Motors	3	20%	0.60	Has had overflow events, critical multiple lift stations flow here
Instrumentation - SCADA, alarms	4	15%	0.60	Floats have rags attached, no SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	2	20%	0.40	Concrete in good shape, ventilation in good shape
Piping and Valves	4	15%	0.60	partially submerged piping in valve vault
Site - Drainage, Access Drive, Security, Fencing	3	10%	0.30	6 foot fence, no barbed wire, small gapping on hill, good access
Total Inspection Score	-	100%	3.30	
Condition Rating	-	-	3.30	Poor

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	4	25%	1.00	
Population Served	2	50%	1.00	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	2.50	Moderate

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.30	2.50	5.80	High Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Boot Ranch A Lift Station

Inspection Date: 3/22/2016

Facility Information	
Address:	934 Boot Ranch Circle
Year in Service:	2008
Type of Facility:	Dulpex Submersible Lift Station
Number of Pumps:	2
Capacity (gpm):	340.0
Horsepower:	7.5 hp
Monitoring:	No SCADA
Generator:	Generator on Site

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	Generator on site (not sure of condition)
Pumps and Motors	2	20%	0.40	No visible issues.
Instrumentation - SCADA, alarms	4	15%	0.60	Not connected to SCADA
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	3	20%	0.60	Concrete in decent shape. Small crack in vault about 10' down should be repaired. Discharge piping showing signs of corrosion at top bend.
Piping and Valves	4	15%	0.60	DI pipe corroding in vault due to water in vault, water mark visible on side of vault.
Site - Drainage, Access Drive, Security, Fencing	2	10%	0.20	Fence and Drainage pipeline in good shape. Placement of generator in drainage pit is not ideal. If drainage pipeline were to clog, could cause damage to generator.
Total Inspection Score	-	100%	3.20	
Condition Rating	-	-	3.20	Poor

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	5	25%	1.25	
Population Served	1	50%	0.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	2.25	Moderate

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.20	2.25	5.45	Moderate Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Boot Ranch B Lift Station

Inspection Date: 3/22/2016

Facility Information	
Address:	4511 Boot Ranch Circle
Year in Service:	2008
Type of Facility:	Dulpex Submersible Lift Station
Number of Pumps:	2
Capacity (gpm):	190.0
Horsepower:	7.5 hp
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	No back up power
Pumps and Motors	2	20%	0.40	no issues, doesn't pump very often
Instrumentation - SCADA, alarms	4	15%	0.60	Existing antenna can't communicate with SCADA.
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	5	20%	1.00	Coating cracking off wet well, discharge piping is coroded in lift station, recommend replacing coating and replacing discharge piping
Piping and Valves	4	15%	0.60	completely submerged valve box when it rains
Site - Drainage, Access Drive, Security, Fencing	2	10%	0.20	Dirt access road, good fencing
Total Inspection Score	-	100%	3.60	
Condition Rating	-	-	3.60	Poor

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	4	25%	1.00	
Population Served	1	50%	0.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	2.00	Low

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.60	2.00	5.60	High Risk

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Boot Ranch C Lift Station

Inspection Date: 3/22/2016

Facility Information	
Address:	4127 Boot Ranch Circle
Year in Service:	2008
Type of Facility:	Two Duplex LS (one wet pit, one dry pit)
Number of Pumps:	4
Capacity (gpm):	190.0
Horsepower:	5 hp
Monitoring:	No SCADA
Generator:	Generator not functioning

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	Generator onsite doesn't work
Pumps and Motors	4	20%	0.80	most critical lift station at boot ranch, only one pump can run due to hole in suction line
Instrumentation - SCADA, alarms	4	15%	0.60	Existing antenna can't communicate with SCADA.
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	5	20%	1.00	corrosion prevalent, no odor issues
Piping and Valves	5	15%	0.75	Hole in suction piping, air release valves in "drypit" corroded shut. Drypit appurtenances all corroded
Site - Drainage, Access Drive, Security, Fencing	2	10%	0.20	Small gaps in fencing at bottom
Total Inspection Score	-	100%	4.15	
Condition Rating	-	-	**4.15**	**Very Poor**

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	4	25%	1.00	
Population Served	1	50%	0.50	
High Impact Areas	0	25%	0.00	
Criticality Rating	-	100%	**1.50**	**Low**

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	**4.15**	**1.50**	**5.65**	**High Risk**

City of Fredericksburg
Water, Wastewater, and Reuse Master Plan
Risk Based Assessment

Boot Ranch D Lift Station

Inspection Date: 3/22/2016

Facility Information	
Address:	392 Boot Ranch Ridge
Year in Service:	2008
Type of Facility:	Dulpex Submersible Lift Station
Number of Pumps:	2
Capacity (gpm):	36.0
Horsepower:	
Monitoring:	No SCADA
Generator:	No Generator

CONDITION ASSESSMENT

Component Group	Component Condition Rating	Weight Factor	Weighted Component Rating	Comments
Electrical – MCC, Back-up Power, Cables	4	20%	0.80	Generator on site, not sure of condition
Pumps and Motors	2	20%	0.40	deep lift station, no issues with pumps
Instrumentation - SCADA, alarms	4	15%	0.60	Existing antenna can't communicate with SCADA.
Structure - Wet Well, Hatches, Corrosion, Cracks, Leaking, Ventilation, Odor Control	5	20%	1.00	Inlet pipe looks submerged due to level settings. Concrete cracking in vault due to new inlet pipe.
Piping and Valves	2	15%	0.30	PVC pipeline in vault, so no corrosion. Missing concrete ring in vault
Site - Drainage, Access Drive, Security, Fencing	3	10%	0.30	Large gap in fencing (over 6 inches)
Total Inspection Score	-	100%	3.40	
Condition Rating	-	-	3.40	Poor

CRITICALITY ASSESSMENT

Component Group	Component Criticality Rating	Weight Factor	Weighted Component Rating	Comments
Environmentally Sensitive Areas	1	25%	0.25	
Population Served	1	50%	0.50	
High Impact Areas	2	25%	0.50	
Criticality Rating	-	100%	1.25	Very Low

RISK BASED ASSESSMENT

	Condition Rating	Criticality Rating	Overall Risk Rating	Risk Category
Lift Station Risk Rating	3.40	1.25	4.65	Moderate Risk

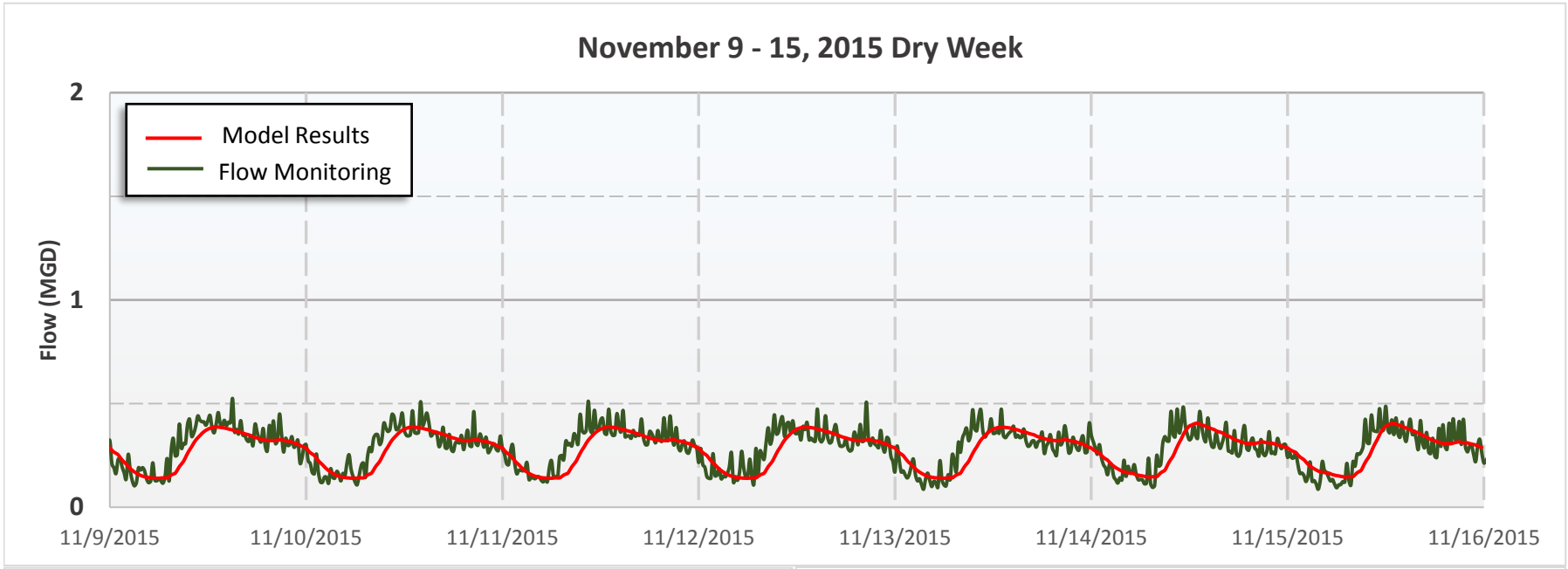
APPENDIX L
WASTEWATER MODEL CALIBRATION GRAPHS

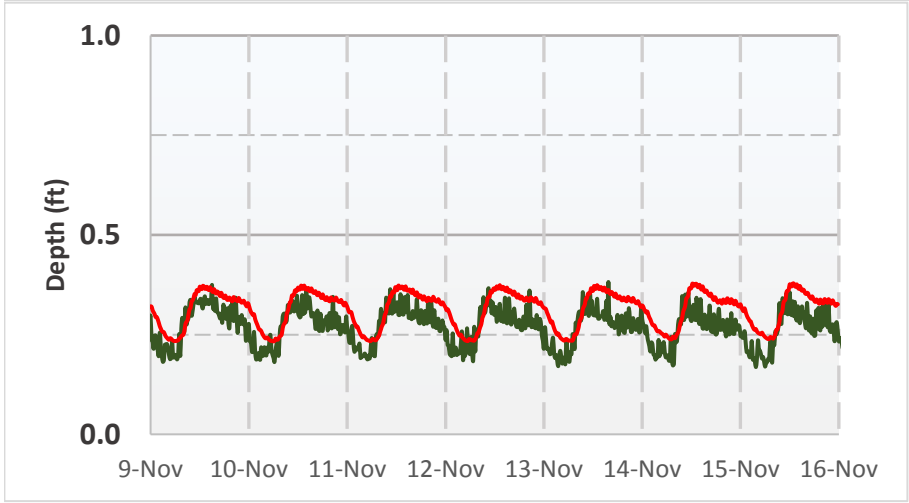
City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Dry Weather Calibration

Flow Monitor ID: FRB - 01





City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Dry Weather Calibration

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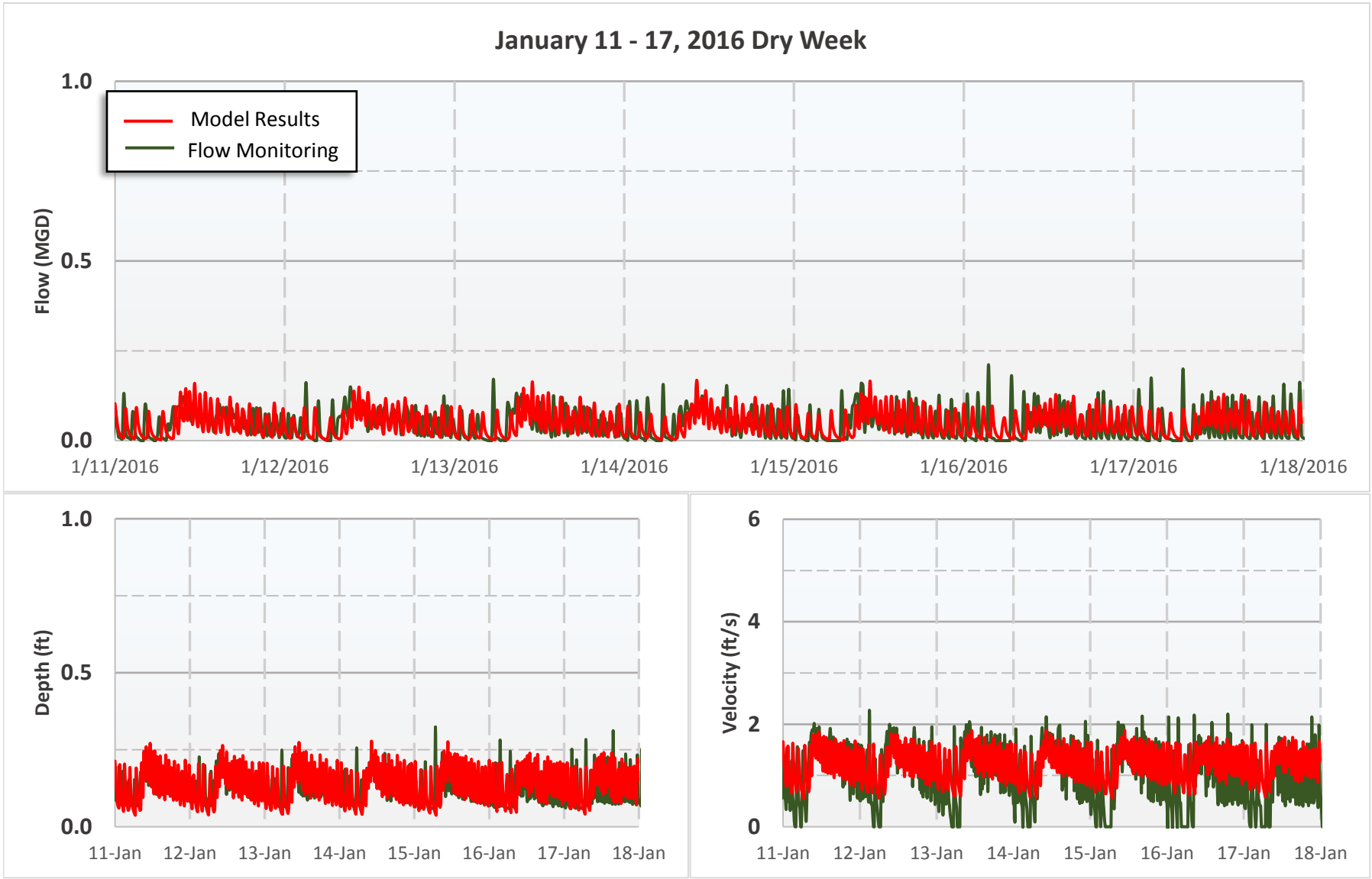

City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Dry Weather Calibration

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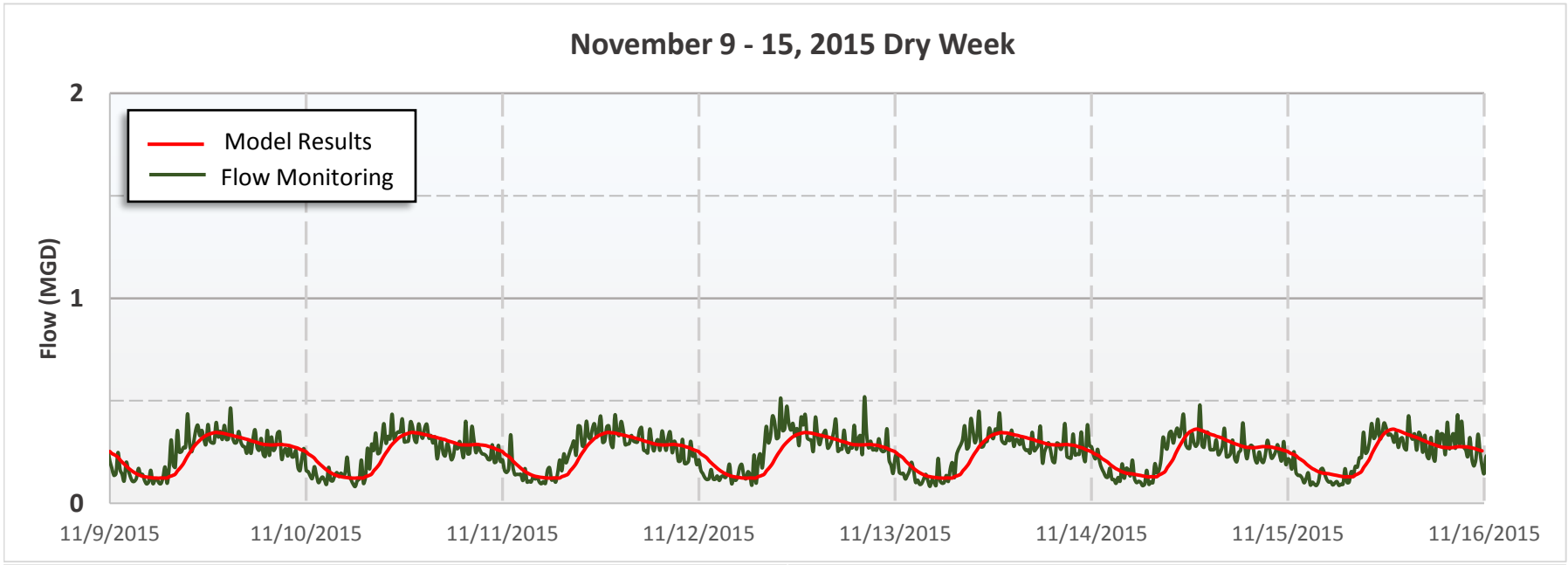
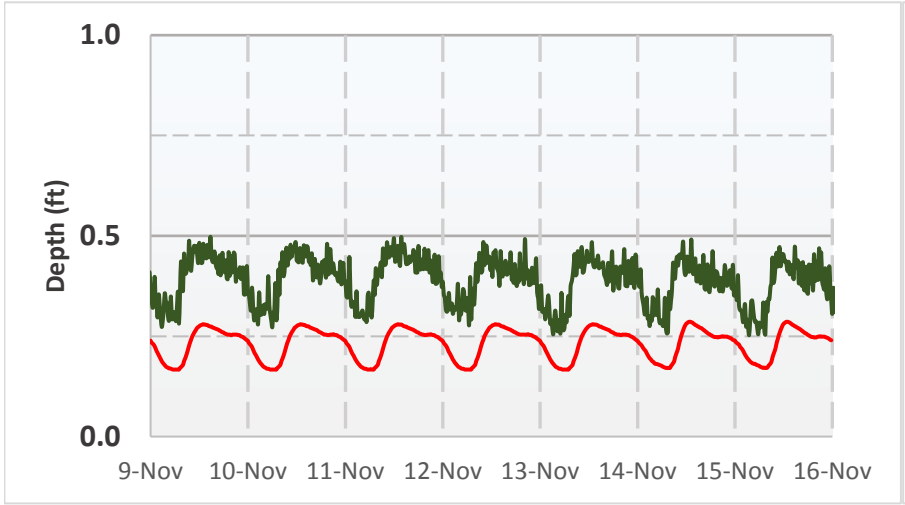
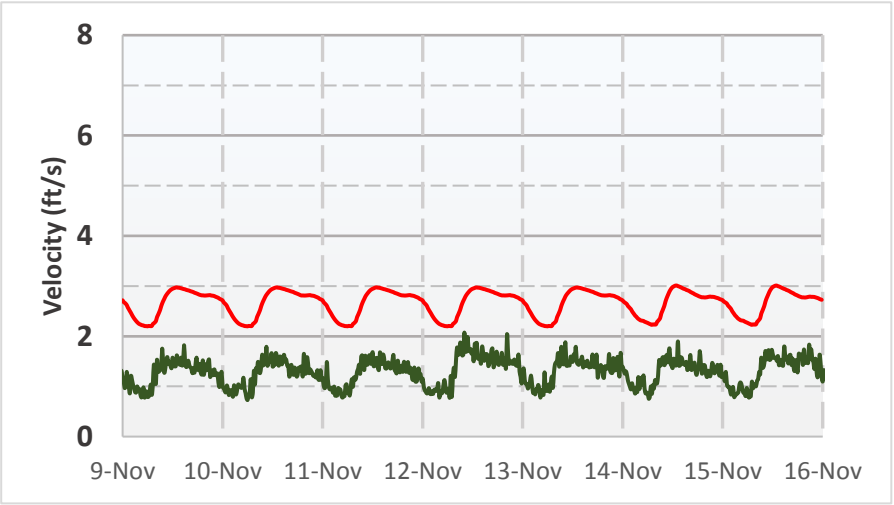




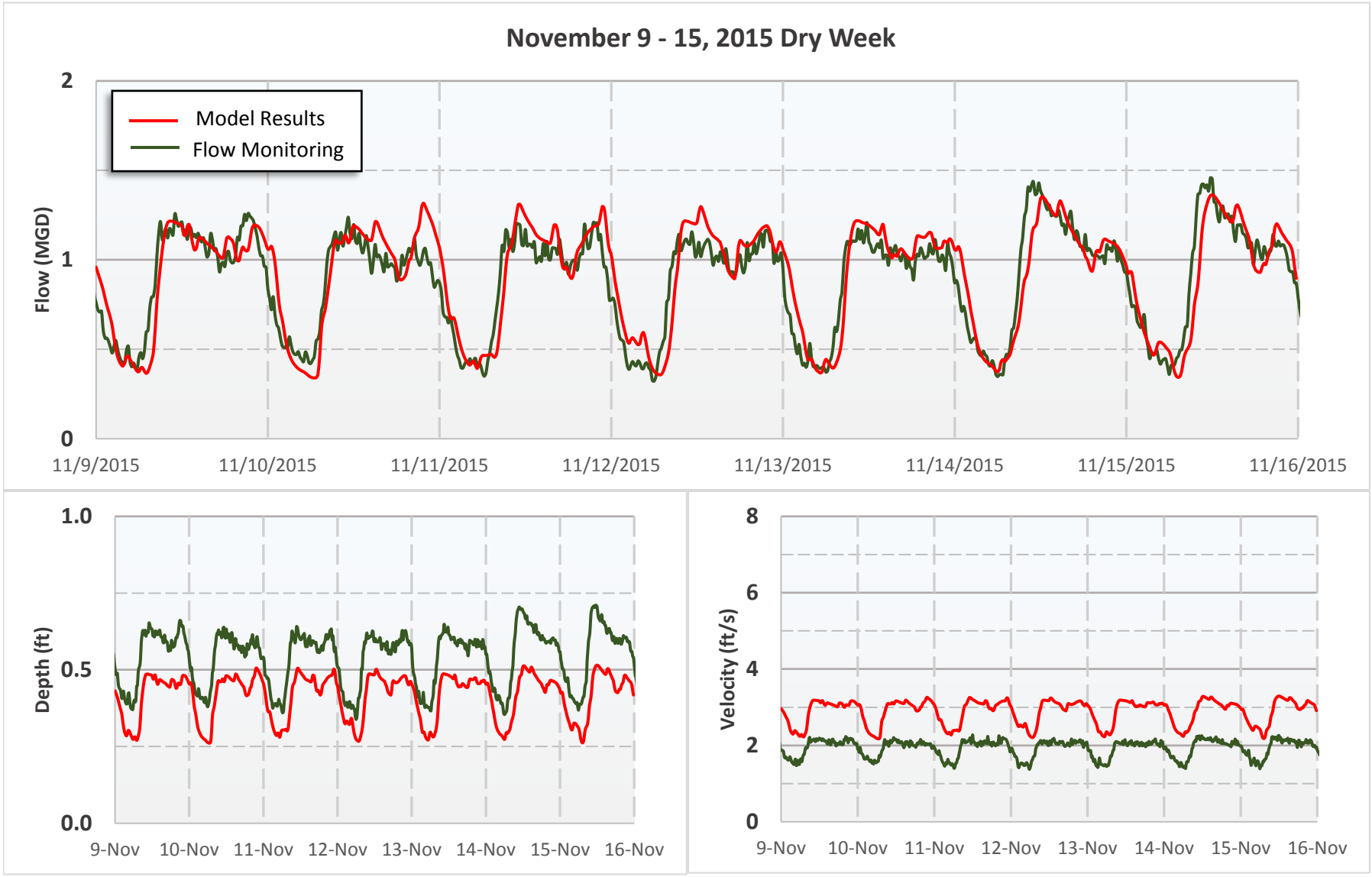


City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Dry Weather Calibration

Flow Monitor ID: FRB - 03

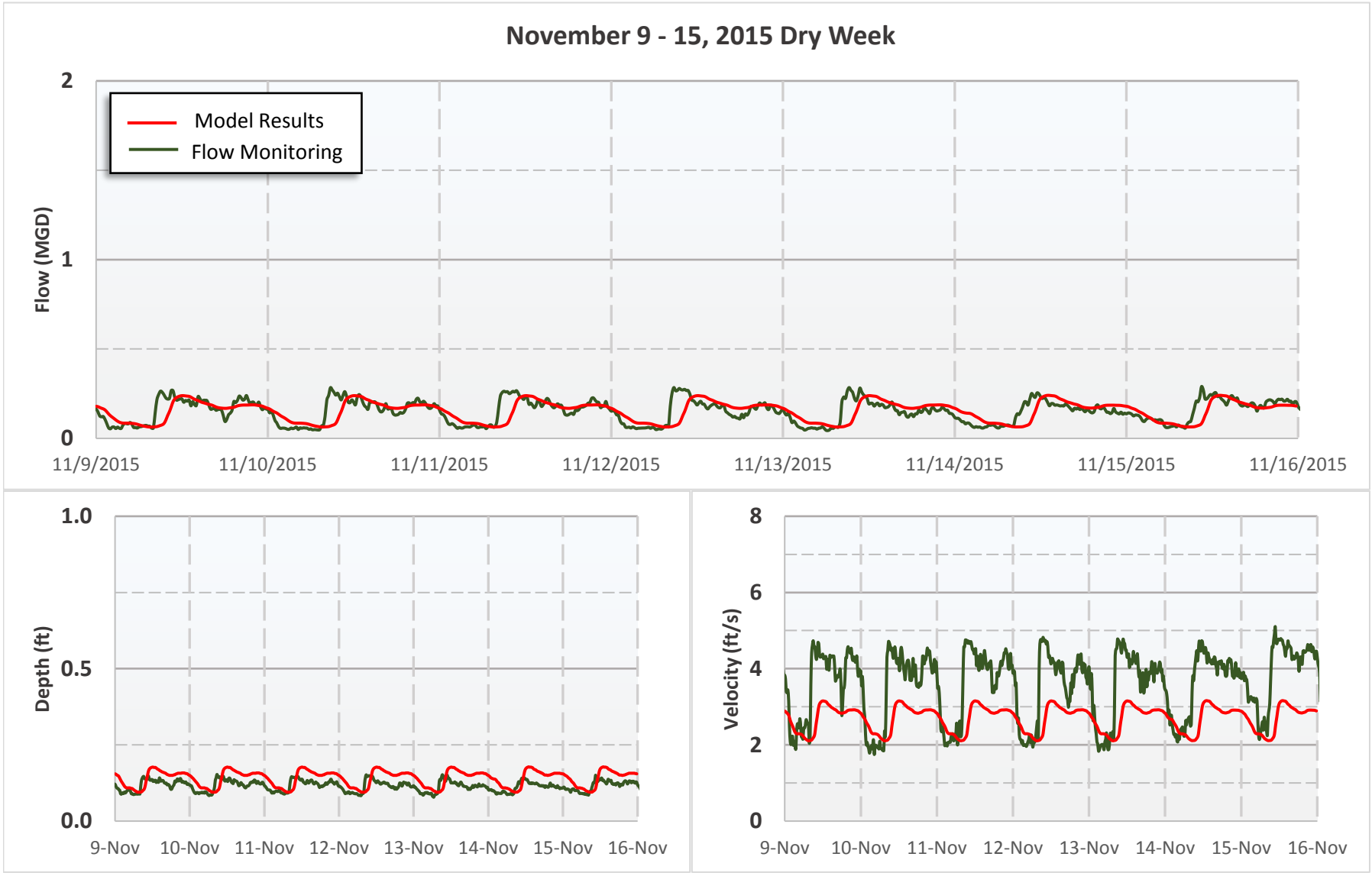


City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Dry Weather Calibration

Flow Monitor ID: FRB - 04



City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Dry Weather Calibration

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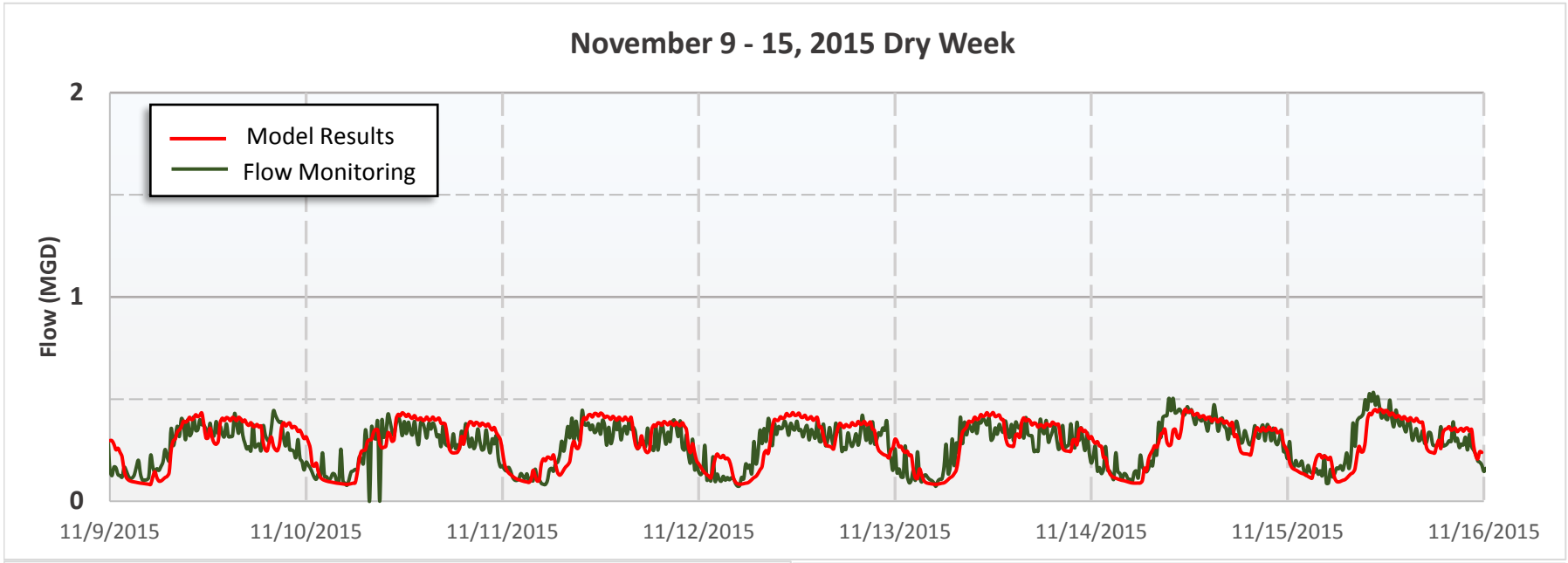
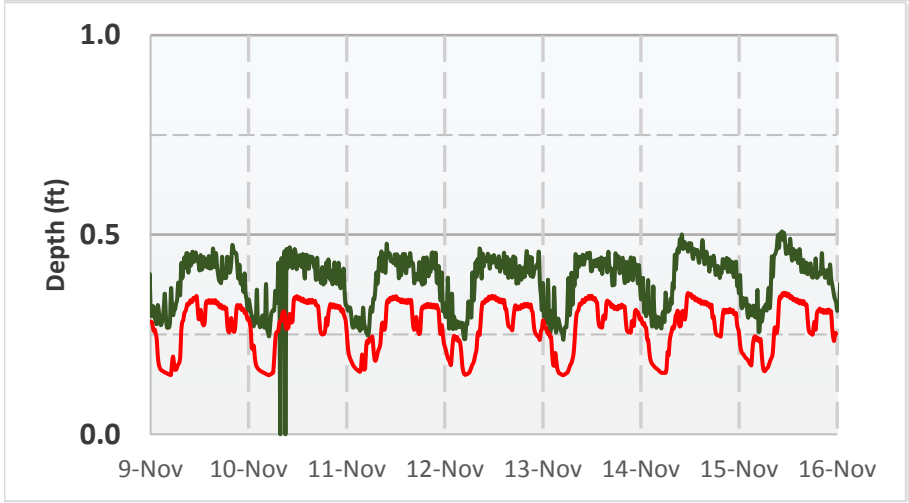
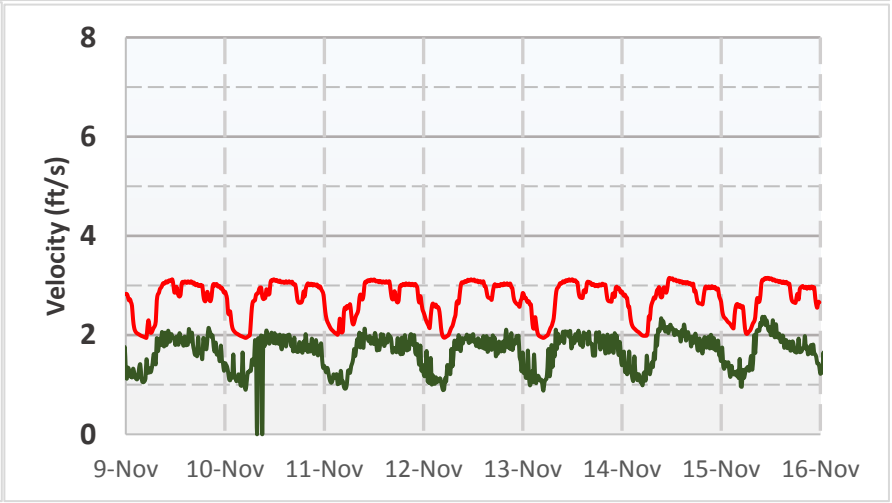




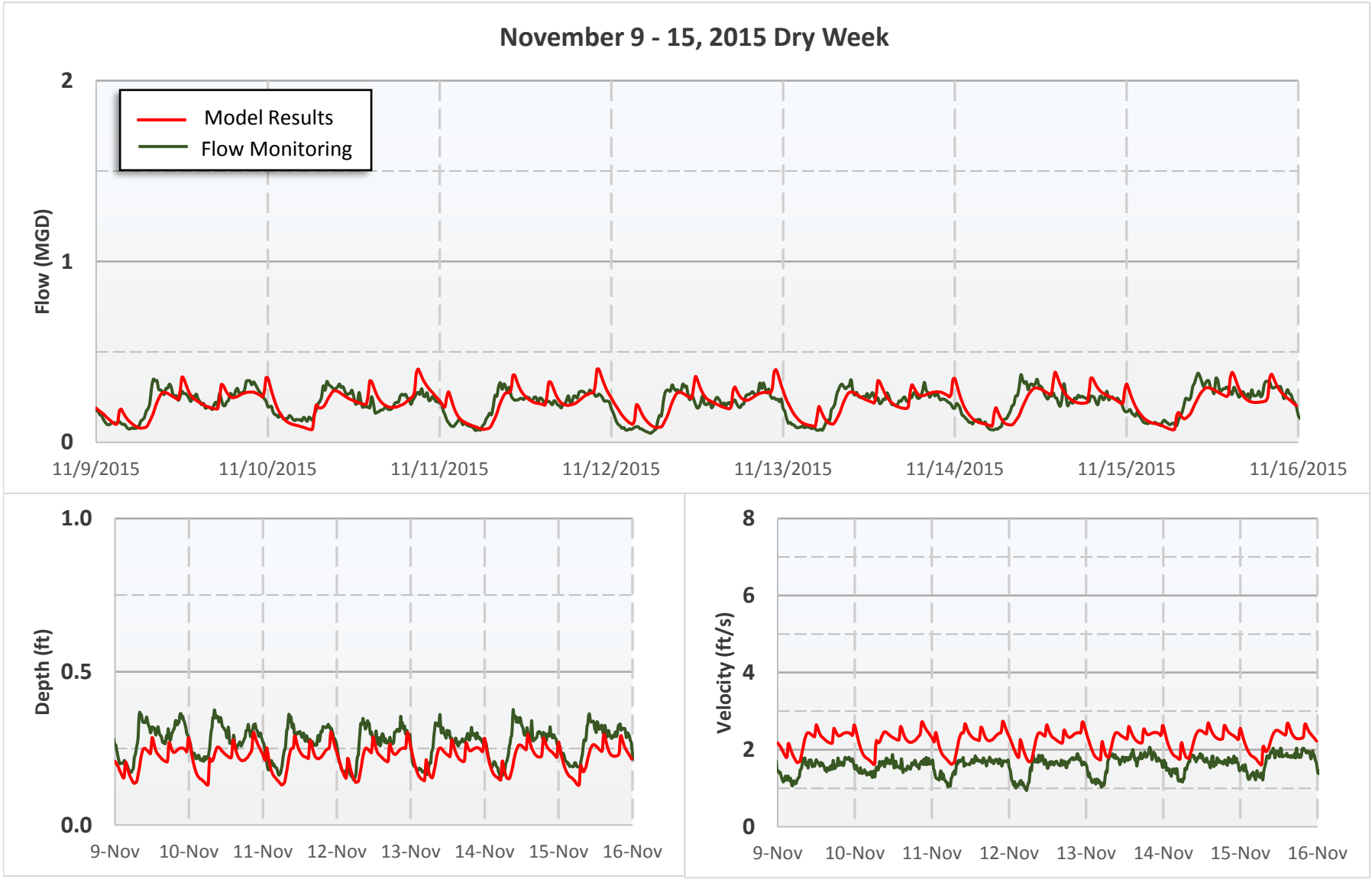


City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Dry Weather Calibration

Flow Monitor ID: FRB - 06

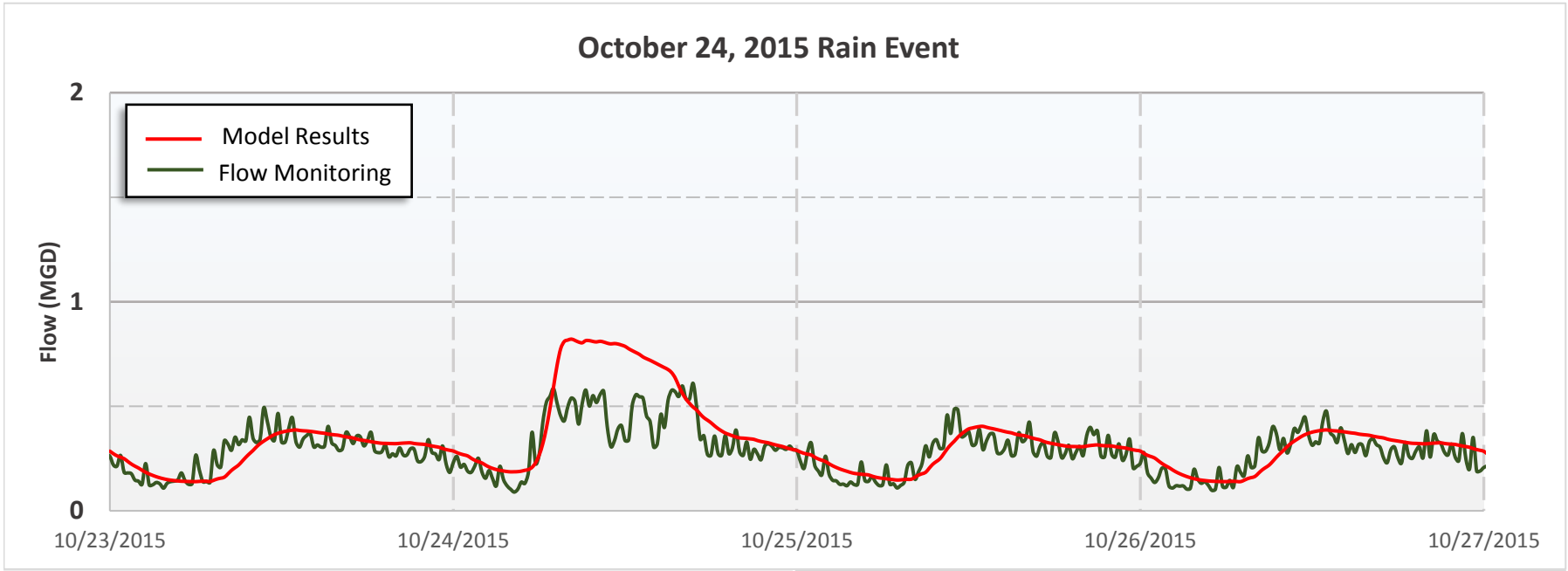


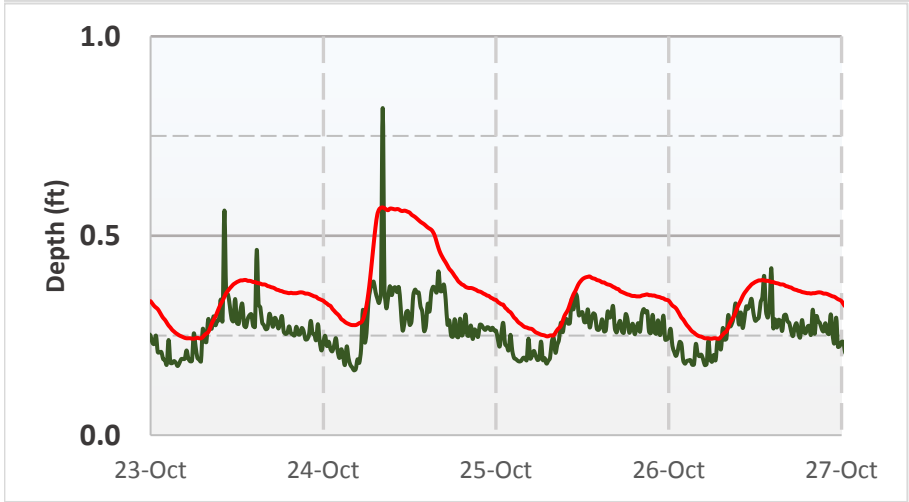
City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Wet Weather Calibration

Flow Monitor ID: FRB - 01





City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Wet Weather Calibration

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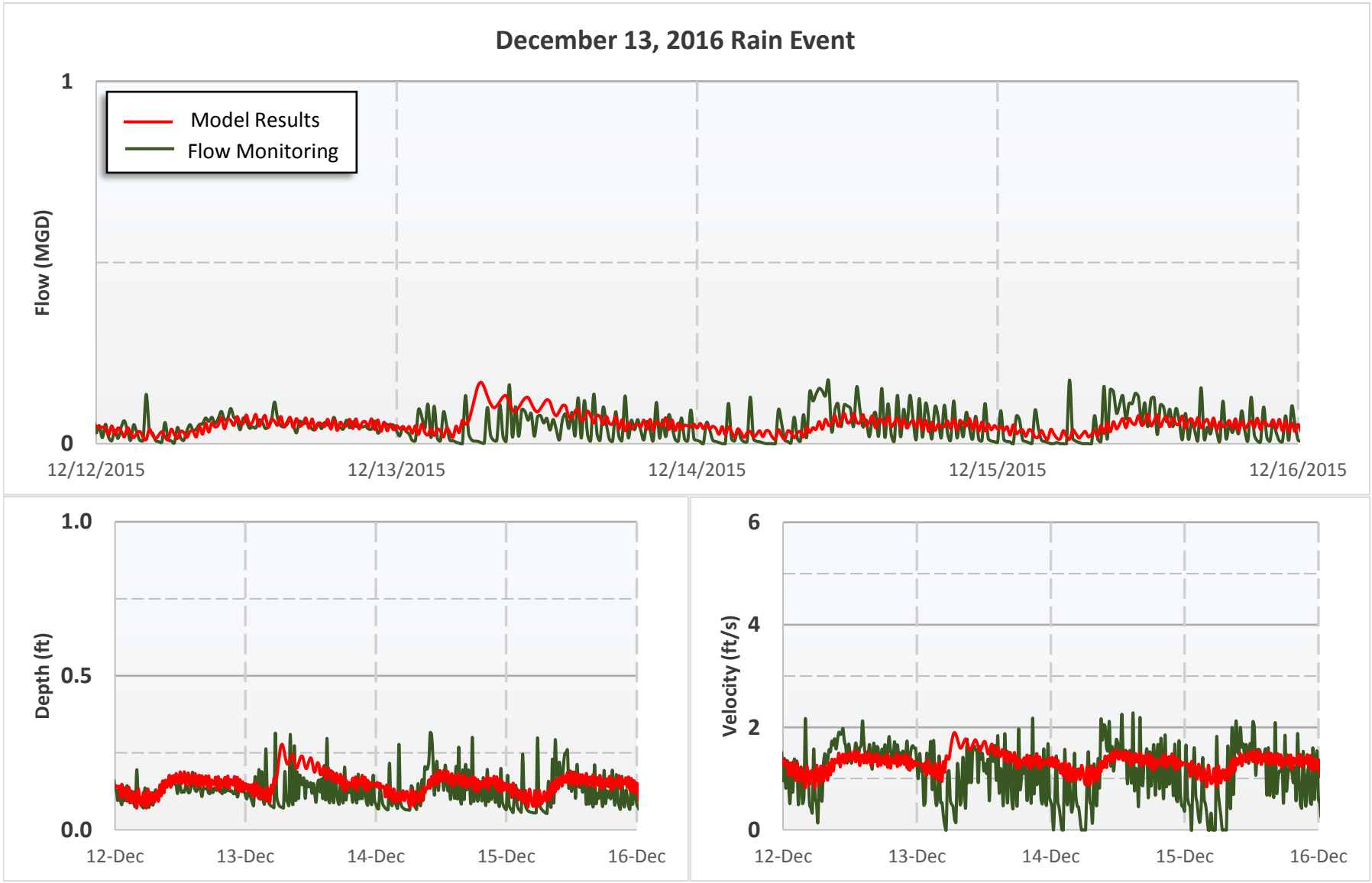

City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Wet Weather Calibration

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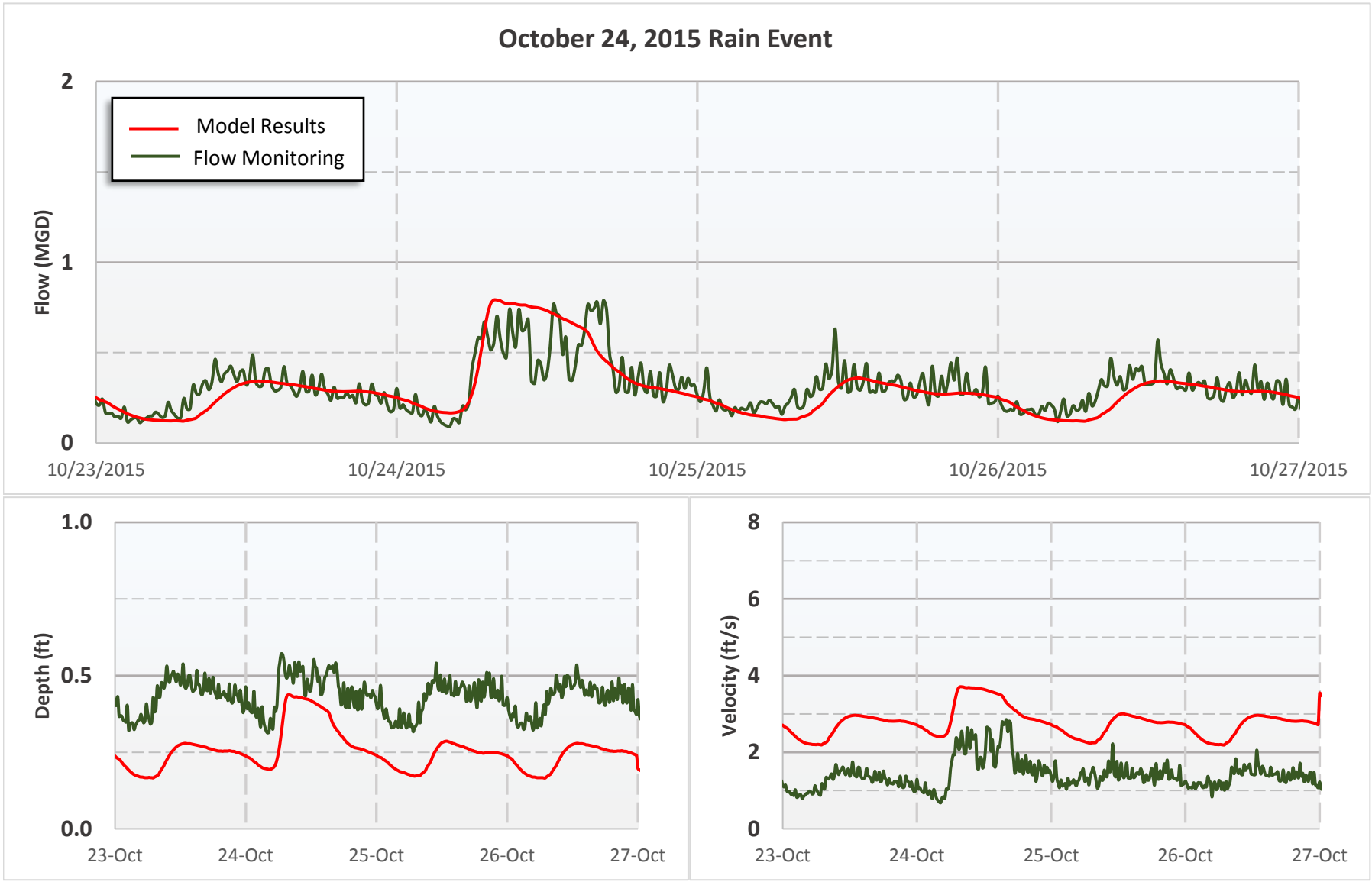
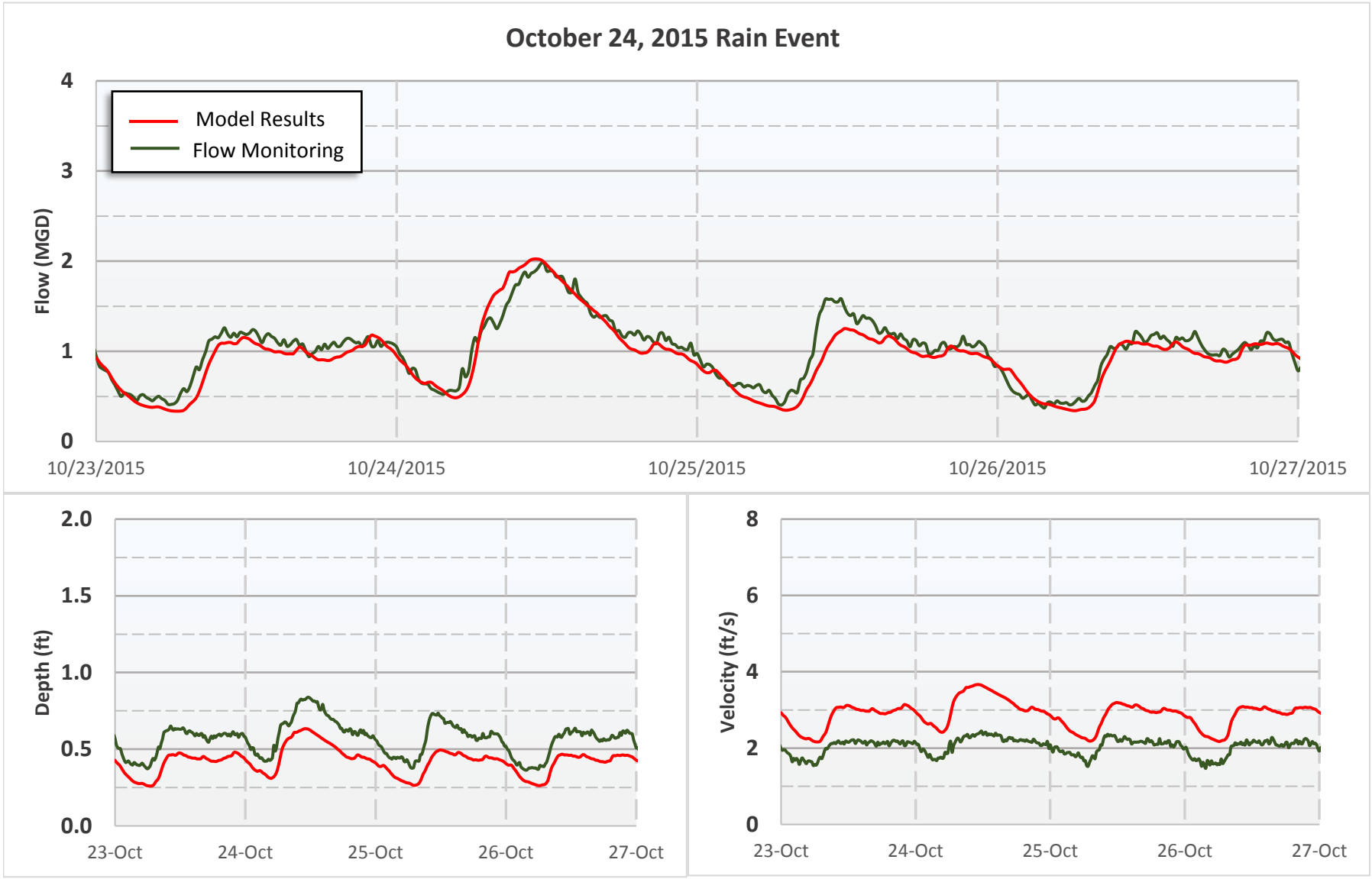


City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Wet Weather Calibration

Flow Monitor ID: FRB - 03

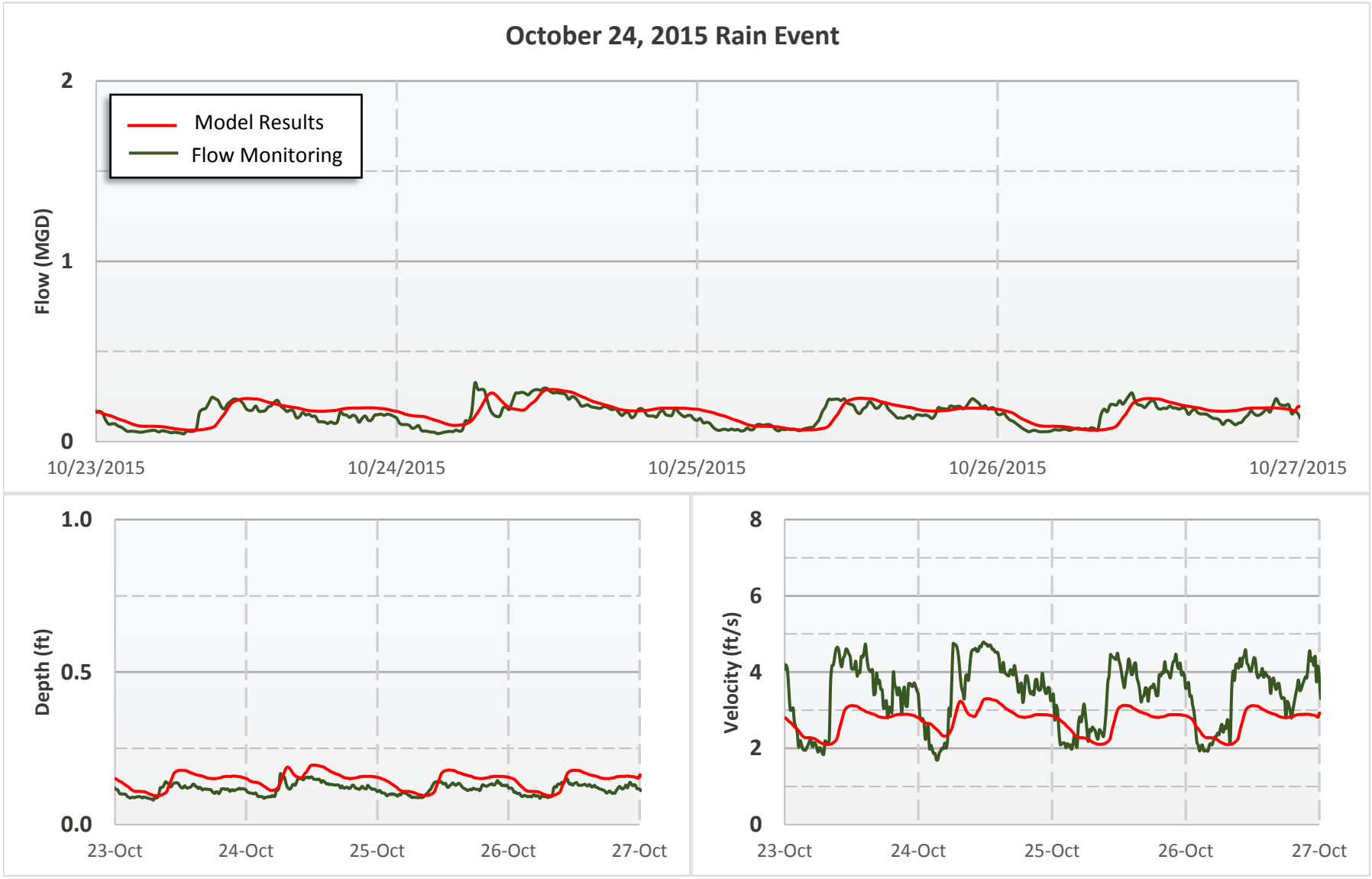


City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Wet Weather Calibration

Flow Monitor ID: FRB - 04



City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Wet Weather Calibration

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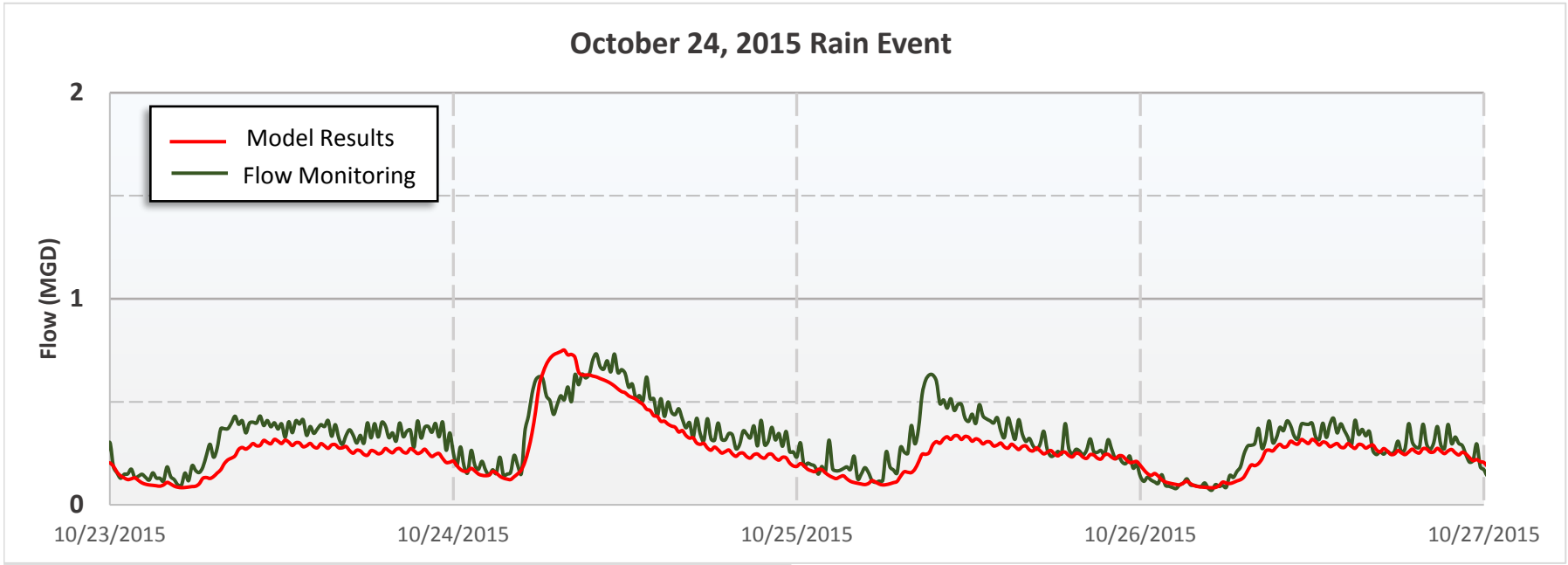
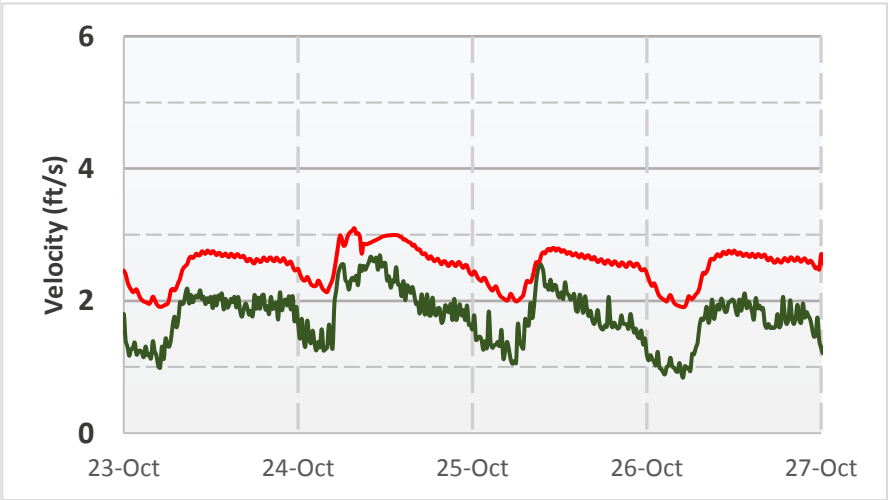


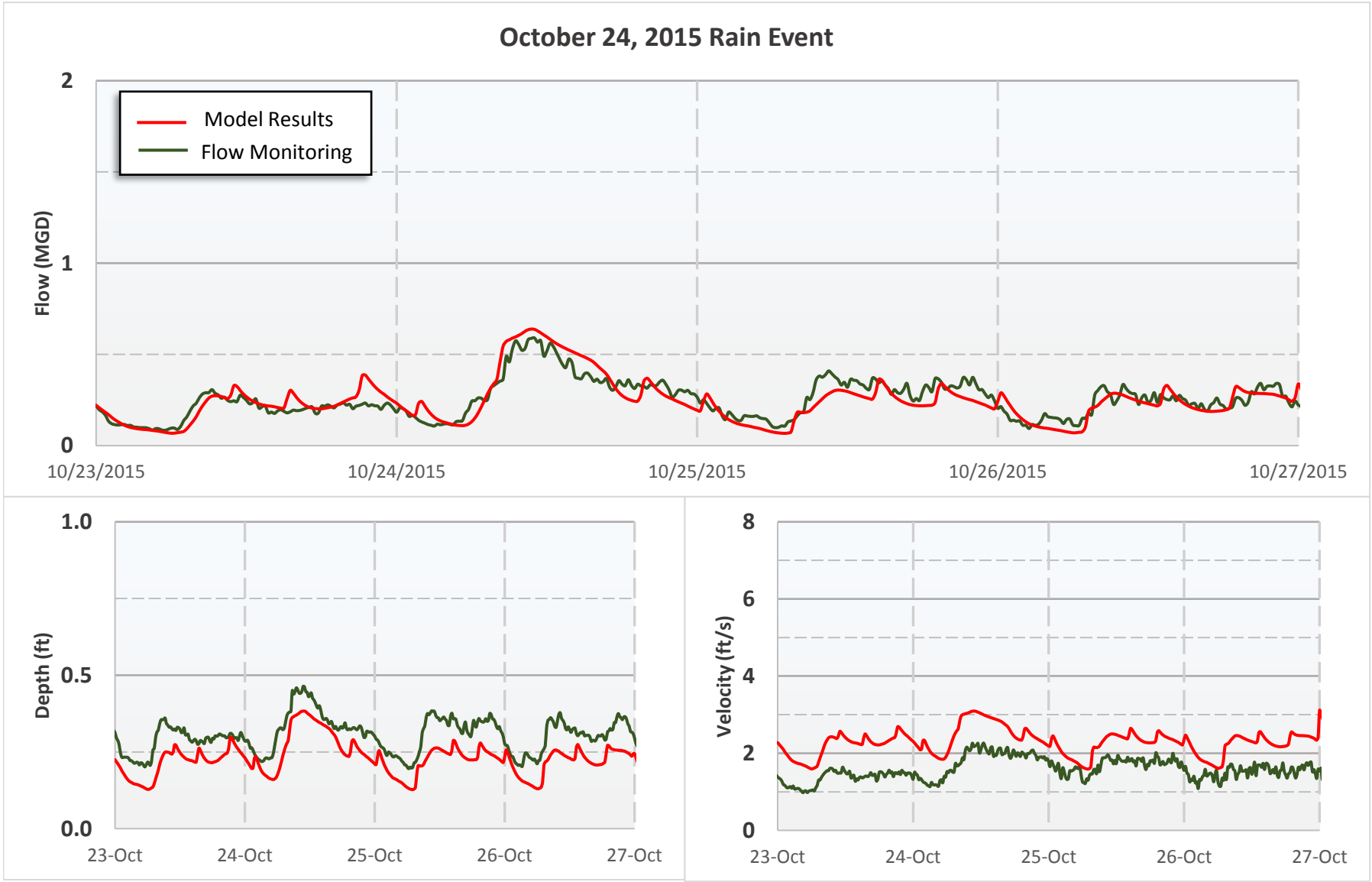


City of Fredericksburg

Water, Wastewater, and Reuse Master Plan

Wet Weather Calibration

Flow Monitor ID: FRB - 06



APPENDIX M
WASTEWATER CAPITAL IMPROVEMENT PLAN COST ESTIMATES

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

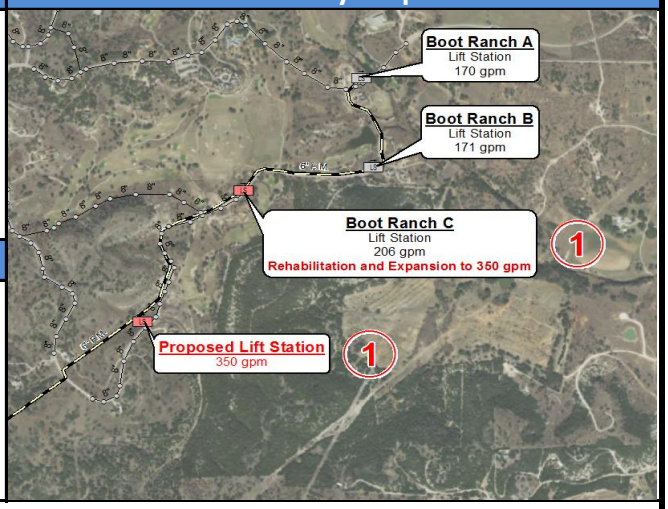
Construction Project Number: 1 — **Planning Period:** 5 Years

Project Name: Boot Ranch Lift Station Capacity Expansion and Rehabilitation

Project Description:

Expansion and rehabilitation of Boot Ranch C Lift Station including electrical, structural, pumping, and piping improvements. Adition of new lift station.

Vicinity Map



Project Drivers:

Current condition of the lift station puts this facility at high risk for failure. The lift station is highly critical as it is responsible for pumping all Boot Ranch flow to the collection system. Pumping flow from Boot Ranch requires pumps to over come extremely high head conitions. An additional lift station dimishes the pumping requirements for the Boot Ranch C lift station.

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Boot Ranch C Rehabilitation and Expansion	1	EA	$ 400,000	$ 400,000
2	350 GPM Lift Station	1	EA	$ 1,750,000	$ 1,750,000
				SUBTOTAL:	**$ 2,150,000**
			CONTINGENCY	30%	$ 645,000
				SUBTOTAL:	**$ 2,795,000**
			ENG/SURVEY	15%	$ 419,300
				SUBTOTAL:	**$ 3,214,300**
				Estimated Project Total:	**$ 3,214,300**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 2 — **Planning Period:** 5 Years

Project Name: San Antonio Street Sewer Line Expansion

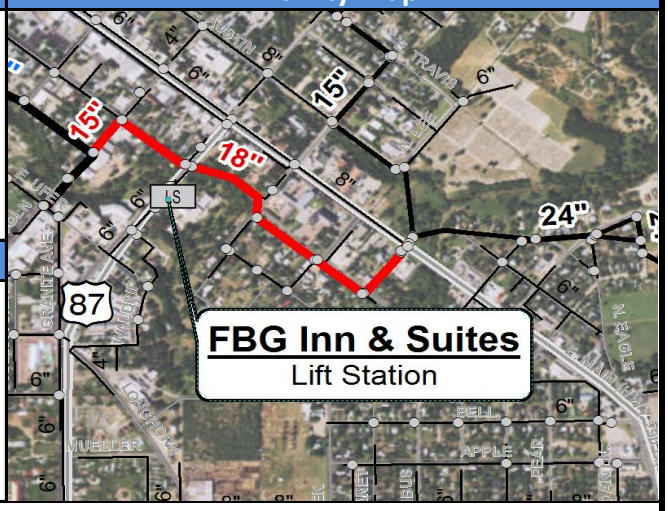
Project Description:

Replacement and expansion of existing 12-, 10-, and 8-inch sewer line to 18-, and 15-inches along San Antonio Street from Llano Street to Lee Street.

Project Drivers:

Project will address capacity restrictions to convey flow generated by future growth and wet weather events.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	18" Wastewater Line	6,300	LF	$ 175	$ 1,102,500
2	15" Wastewater Line	1,100	LF	$ 140	$ 154,000
3	60" Diameter Manhole	15	EA	$ 6,000	$ 90,000
4	Sewer Pavement Repair	7,400	LF	$ 80	$ 592,000
				SUBTOTAL:	**$ 1,938,500**
			CONTINGENCY	30%	$ 581,600
				SUBTOTAL:	**$ 2,520,100**
			ENG/SURVEY	15%	$ 378,100
				SUBTOTAL:	**$ 2,898,200**
				Estimated Project Total:	**$ 2,898,200**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 3 — **Planning Period:** 5 Years

Project Name: Friendship Lane Sewer Line Expansion

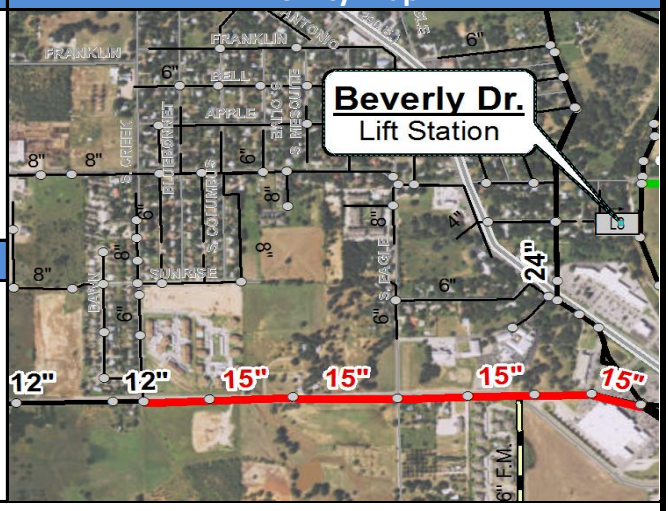
Project Description:

Replace existing 12-inch sewer with 15-inch sewer line along Friendship Lane from South Creek Street to west of Highway 290.

Project Drivers:

Project will address capacity restrictions to convey flow generated by future growth and wet weather events.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	15" Wastewater Line	4,300	LF	$ 140	$ 602,000
2	60" Diameter Manhole	10	EA	$ 6,000	$ 60,000
3	Sewer Pavement Repair	4,300	LF	$ 80	$ 344,000
			SUBTOTAL:		**$ 1,006,000**
			CONTINGENCY	30%	$ 301,800
			SUBTOTAL:		**$ 1,307,800**
			ENG/SURVEY	15%	$ 196,200
			SUBTOTAL:		**$ 1,504,000**
			Estimated Project Total:		**$ 1,504,000**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 4 — **Planning Period:** 5 Years

Project Name: Adams Street Sewer Line Expansion

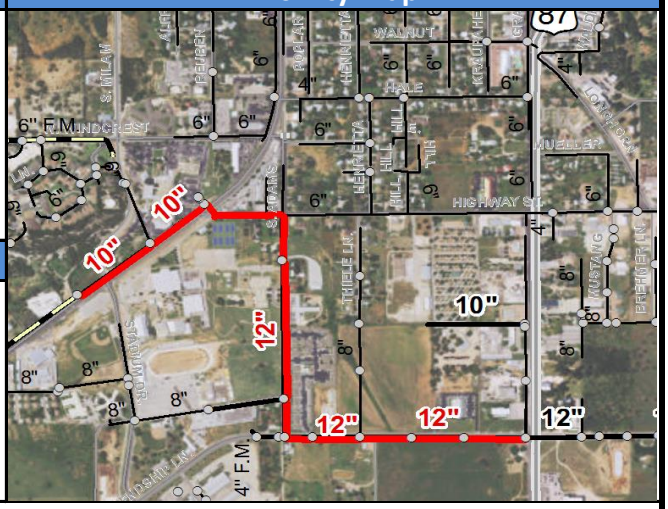
Project Description:

Replacement of existing 10-, and 8-inch sewer line with 12-, and 10-inch sewer line along Friendship Lane, Adams Street, and Highway 16 South.

Project Drivers:

Project addresses capacity constraints to convey flow generated by future growth and wet weather events.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	12" Wastewater Line	4,400	LF	$ 105	$ 462,000
2	10" Wastewater Line	2,300	LF	$ 90	$ 207,000
3	60" Diameter Manhole	15	EA	$ 6,000	$ 90,000
4	Sewer Pavement Repair	6,700	LF	$ 80	$ 536,000
				SUBTOTAL:	**$ 1,295,000**
			CONTINGENCY	30%	$ 388,500
				SUBTOTAL:	**$ 1,683,500**
			ENG/SURVEY	15%	$ 252,600
				SUBTOTAL:	**$ 1,936,100**
				Estimated Project Total:	**$ 1,936,100**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 5 — **Planning Period:** 5 Years

Project Name: Fair Grounds Lift Station Expansion

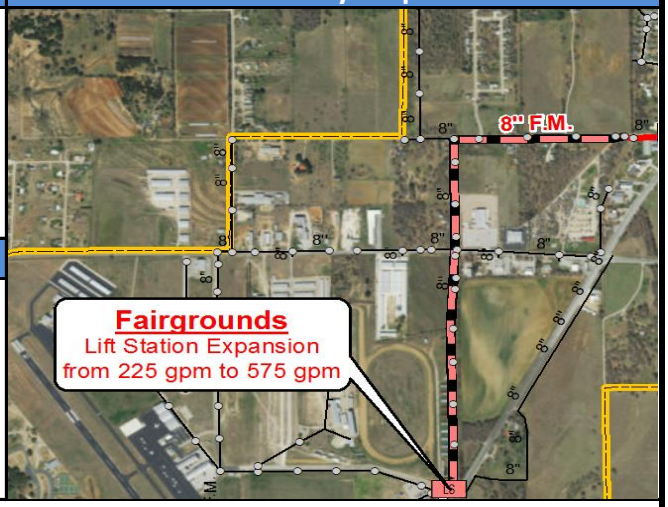
Project Description:

Expansion of Fairgrounds lift station from 225 gpm to 575 gpm and replacement of existing 6-inch force main with new 8-inch force main. Expansion of 8-inch sewer line to 12-inch down sewer line from force main discharge to Green Meadows lift station.

Project Drivers:

Lift station expansion to accommodate peak flow and future development along Highway 290 South.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Fairgrounds Lift Station Expansion	1	EA	$ 500,000	$ 500,000
2	8" Force Main	6,000	LF	$ 80	$ 480,000
3	12" Wastewater Line	600	LF	$ 105	$ 63,000
4	60" Diameter Manhole	5	EA	$ 6,000	$ 30,000
5	Sewer Pavement Repair	6,600	LF	$ 80	$ 528,000
				SUBTOTAL:	**$ 1,601,000**
			CONTINGENCY	30%	$ 480,300
				SUBTOTAL:	**$ 2,081,300**
			ENG/SURVEY	15%	$ 312,200
				SUBTOTAL:	**$ 2,393,500**
				Estimated Project Total:	**$ 2,393,500**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 6 — **Phase:** 10 Years

Project Name: Creek Street Sewer Expansion

Project Description:

Replacement of existing 8-inch sewer line with new 12- and 10-inch sewer line from South Edison Street to South Lincoln Street.

Project Drivers:

This project will alleviate capacity restrictions and accommodate increased flow due to wet weather events and future development.

Vicinity Map

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	12" Wastewater Line	2,800	LF	$ 105	$ 294,000
2	10" Wastewater Line	2,100	LF	$ 90	$ 189,000
3	60" Diameter Manhole	10	EA	$ 6,000	$ 60,000
4	Sewer Pavement Repair	4,900	LF	$ 80	$ 392,000
5	20" Boring and Casing	300	LF	$ 350	$ 105,000
				SUBTOTAL:	**$ 1,040,000**
			CONTINGENCY	30%	$ 312,000
				SUBTOTAL:	**$ 1,352,000**
			ENG/SURVEY	15%	$ 202,800
				SUBTOTAL:	**$ 1,554,800**
				Estimated Project Total:	**$ 1,554,800**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

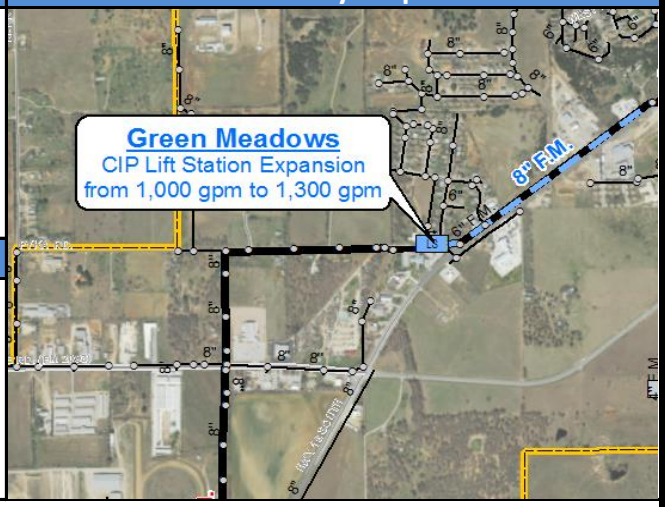
Construction Project Number: 7 — **Phase:** 10 Years

Project Name: Green Meadow Lift Station Expansion

Project Description:

Expansion of the Green Meadow lift station from 1,000 gpm to 1,300 gpm and replacement of existing 6-inch force main with new 8-inch force main along Highway 16 South.

Vicinity Map



Project Drivers:

This project will increase the capacity of the Green Meadows lift station in response to growth and increased service area from Windcrest.

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Green Meadow Lift Station Expansion	1	EA	$ 1,500,000	$ 1,500,000
2	8" Force Main	3,000	LF	$ 80	$ 240,000
3	Sewer Pavement Repair	3,000	LF	$ 80	$ 240,000
				SUBTOTAL:	**$ 1,980,000**
			CONTINGENCY	30%	$ 594,000
				SUBTOTAL:	**$ 2,574,000**
			ENG/SURVEY	15%	$ 386,100
				SUBTOTAL:	**$ 2,960,100**
				Estimated Project Total:	**$ 2,960,100**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 8 — **Phase:** 10 Years

Project Name: Windcrest Lift Station Decommission

Project Description:

Decommission of the Windcrest lift station and extension of an 8-inch wastewater line from the decommissioned lift station along West Windcrest.

Project Drivers:

This project removes the Windcrest lift station from service and routes flow from its service area to the Green Meadows lift station.

Vicinity Map

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Windcrest Lift Station - Decomm	1	LS	$ 1,000,000	$ 1,000,000
2	8" Wastewater Line	600	LF	$ 90	$ 54,000
3	60" Diameter Manhole	3	EA	$ 6,000	$ 18,000
4	Sewer Pavement Repair	600	LF	$ 80	$ 48,000
				SUBTOTAL:	**$ 1,120,000**
				CONTINGENCY 30%	$ 336,000
				SUBTOTAL:	**$ 1,456,000**
				ENG/SURVEY 15%	$ 218,400
				SUBTOTAL:	**$ 1,674,400**
				Estimated Project Total:	**$ 1,674,400**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

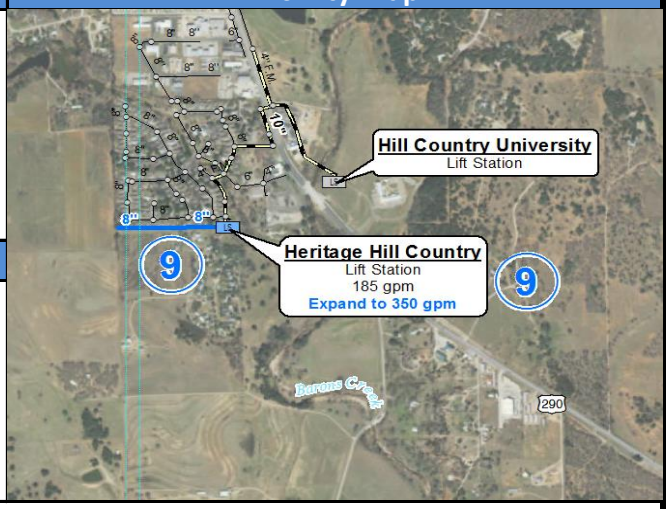
Construction Project Number: 9 — **Phase:** 10 Years

Project Name: Heritage Hill Country Lift Station Expansion

Project Description:

Expansion of the Heritage Hill Country lift station from 185 gpm to 350 gpm and extension of 8-inch sewer line from the Heritage Hill Country lift station to the city limit.

Vicinity Map



Project Drivers:

This project increases the pumping capacity of the Heritage Hill Country lift station to accommodate increase flow from future developments west of the Heritage Hill Country Development.

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Heritage Hill Country Lift Station Expansion	1	EA	$ 400,000	$ 400,000
2	8" Wastewater Line	1,300	LF	$ 90	$ 117,000
3	60" Diameter Manhole	3	EA	$ 6,000	$ 18,000
4	Sewer Pavement Repair	1,000	LF	$ 80	$ 80,000
			SUBTOTAL:		**$ 615,000**
			CONTINGENCY	30%	$ 184,500
			SUBTOTAL:		**$ 799,500**
			ENG/SURVEY	15%	$ 120,000
			SUBTOTAL:		**$ 919,500**
			Estimated Project Total:		**$ 919,500**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 10 — **Phase:** 10 Years

Project Name: Highway 87 South Lift Station Sewer Line Expansion

Project Description:

Construction of 10-inch gravity line, 630 gpm lift station and 6-inch force main.

Project Drivers:

This project extends sewer service along Highway 87 South to serve development project for the area.

Vicinity Map

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	630 GPM Lift Station	1	EA	$ 2,000,000	$ 2,000,000
2	6" Force Main	6,300	LF	$ 80	$ 504,000
3	10" Wastewater Line	5,100	LF	$ 90	$ 459,000
4	60" Diameter Manhole	11	EA	$ 6,000	$ 66,000
5	Sewer Pavement Repair	6,300	LF	$ 80	$ 504,000
				SUBTOTAL:	**$ 3,533,000**
			CONTINGENCY	30%	$ 1,059,900
				SUBTOTAL:	**$ 4,592,900**
			ENG/SURVEY	15%	$ 689,000
				SUBTOTAL:	**$ 5,281,900**
				Estimated Project Total:	**$ 5,281,900**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

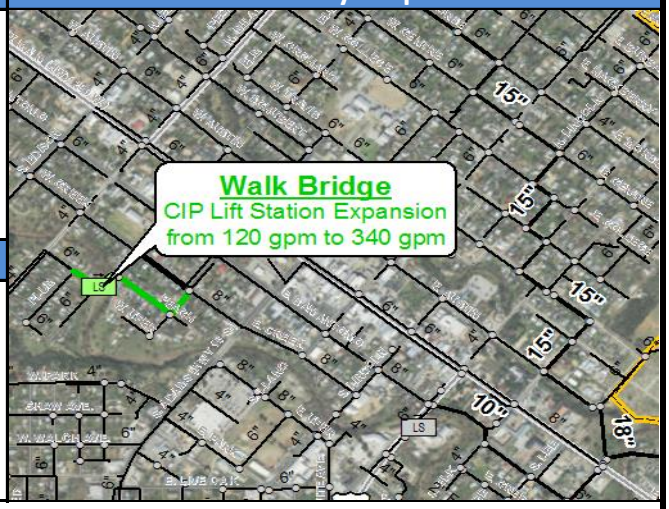
Construction Project Number: 11 — **Phase:** 20 Years

Project Name: Walk Bridge Lift Station Expansion

Project Description:

Expansion of Walk Bridge Lift Station from 120 gpm to 340 gpm and expansion of existing downstream 6-inch line to 10-inch line.

Vicinity Map



Project Drivers:

This project increases the pumping capacity of the Walk Bridge lift station to accommodate increased flow from future developments.

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Walk Bridge Lift Station Expansion	1	EA	$ 2,000,000	$ 2,000,000
2	10" Wastewater Line	1,100	LF	$ 90	$ 99,000
3	60" Diameter Manhole	4	EA	$ 6,000	$ 24,000
4	Sewer Pavement Repair	1,100	LF	$ 80	$ 88,000
			SUBTOTAL:		**$ 2,211,000**
			CONTINGENCY	30%	$ 663,300
			SUBTOTAL:		**$ 2,874,300**
			ENG/SURVEY	15%	$ 431,200
			SUBTOTAL:		**$ 3,305,500**
				Estimated Project Total:	**$ 3,305,500**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 12 — **Phase:** 20 Years

Project Name: Milam Street Lift Station Expansion

Project Description:

Expansion of Milam Street lift station from 80 gpm to 280 gpm and replacement of existing 6-inch sewer lines with 8-inch sewer lines from Milam Street lift station to Walk Bridge lift station.

Project Drivers:

This project increases the pumping capacity of the Milam lift station to accommodate flow from future developments.

Vicinity Map

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Milam Street Lift Station Expansion	1	EA	$ 2,500,000	$ 2,500,000
2	8" Wastewater Line	2,000	LF	$ 90	$ 180,000
3	60" Diameter Manhole	5	EA	$ 6,000	$ 30,000
4	Sewer Pavement Repair	2,000	LF	$ 80	$ 160,000
				SUBTOTAL:	**$ 2,870,000**
				CONTINGENCY 30%	$ 861,000
				SUBTOTAL:	**$ 3,731,000**
				ENG/SURVEY 15%	$ 559,700
				SUBTOTAL:	**$ 4,290,700**
				Estimated Project Total:	**$ 4,290,700**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 13 — **Phase:** 20 Years

Project Name: West Morse Sewer Line Expansion

Project Description:

Replacement of the existing 8-inch sewer line with 10-inch sewer line from Milam Street to Avenue C.

Vicinity Map

Project Drivers:

This project increase the flow capacity of the line to accommodate flow from wet weather events and future development.

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	10" Wastewater Line	2,400	LF	$ 90	$ 216,000
2	60" Diameter Manhole	10	EA	$ 6,000	$ 60,000
3	Sewer Pavement Repair	2,400	LF	$ 80	$ 192,000
				SUBTOTAL:	**$ 468,000**
			CONTINGENCY	30%	$ 140,400
				SUBTOTAL:	**$ 608,400**
			ENG/SURVEY	15%	$ 91,300
				SUBTOTAL:	**$ 699,700**
				Estimated Project Total:	**$ 699,700**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 14 — **Phase:** 20 Years

Project Name: Highway 290 West Sewer Line Expansion

Project Description:

Replacement of the existing 6-inch sewer line with 8-inch sewer line starting along Highway 290 at North Kay and continuing on East Creek Street.

Project Drivers:

This project alleviates flow restrictions caused by undersized lines to accommodate flow from future developments.

Vicinity Map

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	8" Wastewater Line	4,000	LF	$ 90	$ 360,000
2	60" Diameter Manhole	11	EA	$ 6,000	$ 66,000
3	Sewer Pavement Repair	4,000	LF	$ 80	$ 320,000
				SUBTOTAL:	**$ 746,000**
				CONTINGENCY 30%	$ 223,800
				SUBTOTAL:	**$ 969,800**
				ENG/SURVEY 15%	$ 145,500
				SUBTOTAL:	**$ 1,115,300**
				Estimated Project Total:	**$ 1,115,300**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 15 — **Phase:** 20 Years

Project Name: West Schubert Sewer Line Expansion

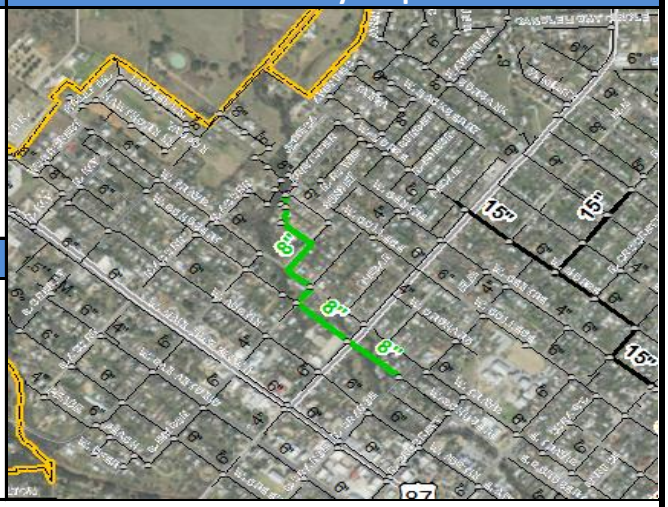
Project Description:

Replacement of the existing 6-inch sewer line with 8-inch sewer line beginning just north of West Schubert and extending southeast along West Schubert.

Project Drivers:

This project alleviates flow restrictions due to undersized lines during increased flow from wet weather events.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	8" Wastewater Line	3,800	LF	$ 90	$ 342,000
2	60" Diameter Manhole	12	EA	$ 6,000	$ 72,000
3	Sewer Pavement Repair	3,800	LF	$ 80	$ 304,000
4	20" Boring and Casing	200	LF	$ 350	$ 70,000
			SUBTOTAL:		**$ 788,000**
			CONTINGENCY	30%	$ 236,400
			SUBTOTAL:		**$ 1,024,400**
			ENG/SURVEY	15%	$ 153,700
			SUBTOTAL:		**$ 1,178,100**
			Estimated Project Total:		**$ 1,178,100**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 16 — **Phase:** 20 Years

Project Name: Highway 16 South Lift Station and Sewer Line

Project Description:

New 70 gpm CIP Lift Station and extension of 10-inch sewer line and force main north of the new CIP lift station along HWY 16 South.

Project Drivers:

This project extends sewer service along Highway 16 South for projected commercial development.

Vicinity Map

Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	130 GPM Lift Station	1	EA	$ 1,500,000	$ 1,500,000
2	10" Wastewater Line	4,300	LF	$ 90	$ 387,000
3	8" Force Main	5,000	LF	$ 80	$ 400,000
4	48" Diameter Manhole	9	EA	$ 5,000	$ 45,000
5	Sewer Pavement Repair	4,800	LF	$ 80	$ 384,000
6	20" Boring and Casing	210	LF	$ 350	$ 73,500
				SUBTOTAL:	**$ 2,789,500**
		CONTINGENCY		30%	$ 836,900
				SUBTOTAL:	**$ 3,626,400**
		ENG/SURVEY		15%	$ 544,000
				SUBTOTAL:	**$ 4,170,400**
				Estimated Project Total:	**$ 4,170,400**

City of Fredericksburg

Capital Improvement Cost Estimate — **DATE: 09/01/2016**

Construction Project Number: 17 — **Phase:** 20 Years

Project Name: Goehmann Lane Sewer Line Extension

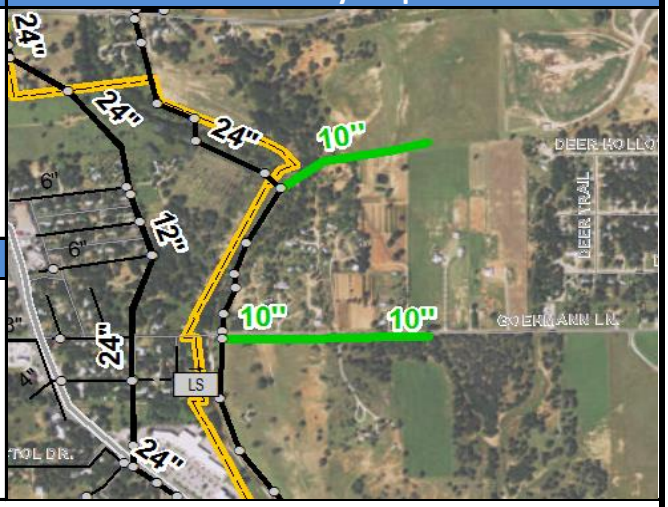
Project Description:

Extension of 2 separate 10-inch sewer lines. One along Goehmann Lane and the other just north of Goehmann Lane.

Project Drivers:

This project will extend sewer service to future developments north of Goehmann Lane.

Vicinity Map



Opinion of Probable Construction Cost

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	10" Wastewater Line	3,000	LF	$ 90	$ 270,000
2	60" Diameter Manhole	6	EA	$ 6,000	$ 36,000
3	Sewer Pavement Repair	1,700	LF	$ 80	$ 136,000
				SUBTOTAL:	**$ 442,000**
			CONTINGENCY	30%	$ 132,600
				SUBTOTAL:	**$ 574,600**
			ENG/SURVEY	15%	$ 86,200
				SUBTOTAL:	**$ 660,800**
				Estimated Project Total:	**$ 660,800**

APPENDIX N
CITY OF FREDERICKSBURG REUSE AUTHORIZATION

Bryan W. Shaw, Ph.D., P.E., *Chairman*
Toby Baker, *Commissioner*
Zak Covar, *Commissioner*
Richard A. Hyde, P.E., *Executive Director*

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

January 31, 2014

RECEIVED
FEB 03 REC'D

Mr. Patrick Lackey, P.E.
River City Engineering
3801 South First Street
Austin, Texas 78704

Re: City of Fredericksburg
Reuse Authorization No. R14969-001
Gillespie County, Texas
CN600527238, RN101917383

Dear Mr. Lackey:

The Texas Commission on Environmental Quality has completed its review of the application for the above referenced authorization. The authorization allows the reuse of Type I wastewater effluent from the City of Fredericksburg's Main Wastewater Treatment Facility.

Thank you for your cooperation during this review process. If you have any questions, please contact Louis C. Herrin, III of my staff at louis.herrin@tceq.texas.gov or at (512) 239-4552.

Sincerely,

Chris Linendoll, E.I.T., Manager
Wastewater Permitting Section
Water Quality Division

AUTHORIZATION FOR RECLAIMED WATER

Authorization No. R14969-001
This authorization supersedes and replaces
Authorization No. R14969-001 approved July, 19,2011

Producer: City of Fredericksburg
126 West Main Street
Fredericksburg, Texas 78624

Provider: City of Fredericksburg
126 West Main Street
Fredericksburg, Texas 78624

User: Any user within the service area authorized by the provider

Location: The wastewater treatment facility is located approximately ½ mile southeast of the City of Fredericksburg and immediately east of U.S. Highway 290 in Gillespie County, Texas.

Authorization: Type I reclaimed water from the City of Fredericksburg's Wastewater Treatment Facility (TPDES Permit No. WQ0014969001) is to be used for irrigation of landscape, public parks, schoolyards, athletic fields, golf courses, and food crops; maintenance of off channel water bodies; soil compaction or dust control in construction and public event areas where application procedures minimize aerosol drift to general public; and industrial process water. The service area is Gillespie County.

This authorization contains the conditions that apply for the use of reclaimed water. The approval of reclaimed water use under Chapter 210 does not affect any existing water rights. If applicable, a reclaimed water use authorization in no way affects the need of a producer, provider, or user to obtain a separate water right authorization from the commission. This authorization does not allow irrigation of any area authorized for irrigation under a Texas Land Application Permit.

Issue Date: January 31, 2014

Richard A. Hyde, P.E., Executive Director

I. General Requirements

A. No producer or provider may transfer reclaimed water to a user without first notifying the commission.

B. Reuse of untreated wastewater is prohibited.

C. Food crops that may be consumed raw by humans must not be spray irrigated. Food crops including orchard crops that will be substantially processed prior to human consumption may be spray irrigated. Other types of irrigation that avoid contact of reclaimed water with edible portions of food crops are acceptable.

D. There must be no nuisance conditions resulting from the distribution, the use, or storage of reclaimed water.

E. Reclaimed water must not be used in a way that degrades groundwater quality to a degree adversely affecting its actual or potential uses.

F. Reclaimed water stored in ponds must be prevented from discharging into waters in the state, except for discharges directly resulting from rainfall events or in accordance with a permit issued by the commission. All other discharges are unauthorized.

G. If an overflow of a holding pond occurs causing discharge into or adjacent to water in the state, the user or provider, as appropriate, shall report the noncompliance. A written submission of pertinent information must be provided to the TCEQ Region 13 office in San Antonio and to the TCEQ Enforcement Division (MC-149) in Austin, within five (5) working days after becoming aware of the overflow. The submission must contain:

1. a description of the noncompliance and its cause;
2. the potential danger to human health or safety, or the environment;
3. the period of noncompliance, including exact dates and times;
4. if the noncompliance has not been corrected, the anticipated time it is expected to continue; and
5. steps taken or planned to reduce, eliminate, and prevent recurrence of the noncompliance, and to mitigate its adverse effects.

H. Unless otherwise provided in this authorization, there must be no off-site discharge, either airborne or surface runoff of reclaimed water from the user's property except to a wastewater treatment collection system or wastewater treatment facility unless the reclaimed water user applies for and obtains a permit from the commission that authorizes discharge of the water.

I. All reclaimed water piping must be separated from potable water piping when trenched by a distance of at least nine feet for Type II effluent and four feet For Type I. All buried pipe must be manufactured in purple, painted purple, taped with purple metallic tape or bagged in purple. All exposed piping, hose bibs and faucets must be painted purple, designed to prevent connection to a standard water hose, and stenciled with a warning reading "NON-POTABLE WATER."

J. The design of any new distribution system that will convey reclaimed water to a user requires the approval of the executive director. Materials must be submitted to the executive director in accordance with the Texas Engineering Practice Act (Article 3271a, Vernon's Annotated Texas Statutes). The plans and specifications for any new

distribution system constructed pursuant to this authorization must be approved by the executive director. Failure to secure approval before commencing construction or making a transfer of reclaimed water is a violation of this authorization. Each day of a transfer is a separate violation until approval has been secured.

K. Nothing in this authorization modifies any requirements in 30 TAC Chapter 290, Public Drinking Water.

L. A major change from a prior notification for use of reclaimed water must be approved by the executive director before it can be implemented. A major change includes:

1. a change in the boundary of the approved service area, not including the conversion of individual lots within a subdivision to reclaimed water use;
2. the addition of a new provider;
3. a major change in the intended use, such as conversion from irrigation of a golf course to residential irrigation; or
4. a change from either Type I or Type II use.

M. The reclaimed water producer, provider, and user shall maintain current operation and maintenance plans on the sites over which they have operational control. The operation and maintenance plan must contain the following, as a minimum:

1. a copy of the signed contract between the user and provider and a copy of the signed contract between the provider and the producer, as applicable;
2. a labeling and separation plan for the prevention of cross connections between reclaimed water distribution lines and potable water lines;
3. the measures that will be implemented to prevent unauthorized access to reclaimed water facilities (e.g., secured valves);
4. procedures for monitoring reclaimed water;
5. a plan for how reclaimed water use will be scheduled to minimize the risk of inadvertent human exposure;
6. schedules for routine maintenance;
7. a plan for worker training and safety; and
8. contingency plan for system failure or upsets.

N. One of the following requirements must be met by the user or provider, for any area where reclaimed water is stored or where there are hose bibs or faucets:

1. Signs having a minimum size of eight inches by eight inches must be posted at all storage areas and on all hose bibs and faucets reading, in both English and Spanish, "Reclaimed Water, Do Not Drink" or similar warning.
2. The area must be secured to prevent access by the public.

O. Where a reclaimed water line parallels a sewer line, the reclaimed water line must be constructed in accordance with subsection (p) or (q) of this section. The horizontal separation distance must be three feet (outside to outside) with the reclaimed water line at the level of or above the sewer line. Reclaimed water lines that parallel sewer lines may be placed in the same benched trench. Where a reclaimed water line crosses a sewer line,

the requirement of 30 TAC §290.44(e)(4)(B), Water Line Installation—crossing lines, must be followed with the reclaimed water line substituted for the water line.

P. Reclaimed water pipes must meet the following requirements:

1. lines that transport reclaimed water under pressure must be sized according to acceptable engineering practices for the needs of the reclaimed water users.
2. reclaimed water force mains must have an expected life of at least as long as that of the associated lift station and must be suitable for the reclaimed water being pumped and operating pressure to which it will be subjected.
3. must be identified in the technical specifications with appropriate American Society for Testing and Materials, American National Standard Institute, or American Water Works Association standard numbers for both quality control (dimensions, tolerance, and installation such as bedding or backfill).
4. pipes and fittings must have a minimum working pressure rating of 150 pounds per square inch.
5. Final plans and specifications must describe required pressure testing for all installed reclaimed water force mains.
6. Minimum test pressure must be 1.5 times the maximum design pressure. Allowable leakage rates must be determined as described in 30 TAC §217.97, Pressure Sewer Systems.
7. Gravity flow reclaimed water lines must meet the requirements of 30 TAC Chapter 217, Subchapter C, Conventional Collection Systems. The provider shall prevent high velocity scouring and maintain adequate fluid velocity to prevent the deposition of solids in the lines.

Q. All exposed piping and piping within a building must be either purple pipe or painted purple. All exposed piping should be stenciled in white with a warning reading "NON-POTABLE WATER. All exposed or buried reclaimed water piping constructed at a wastewater treatment facility is exempt from the color-coding requirement of this section.

R. When applicable, in accordance with 30 TAC Chapter 217, Design Criteria for Domestic Wastewater Systems, the design of the distribution systems that will convey reclaimed water to a user must be submitted to the executive director and must receive an approval before the distribution system may be constructed. The design of the distribution systems must meet the criteria of 30 TAC Chapter 217, Design Criteria for Domestic Wastewater Systems. When a municipality is the plan review authority for certain sewer systems that transport primarily domestic waste, in lieu of the commission, design submittal will not be subject to submittal to the commission and instead must be approved by the municipality.

S. All ground level and elevated storage tanks must be designed, installed, and constructed in accordance with current AWWA standards with reference to materials to be used and construction practices to be followed, except for health-based standards strictly related to potable water storage and contact practices, where appropriately less restrictive standards may be applied.

II. Storage Requirements for Reclaimed Water

A. Storage facilities for retaining reclaimed water prior to use must not be located within a floodway.

B. Storage ponds must be hydraulically separated from waters in the state.

C. Any holding pond designed to contain Type I effluent, shall conform to the following requirements:

1. Ponds with an earthen liner must meet the following requirements
   a. A permeability of less than 1×10^{-4} cm/sec;
   b. The ponds must be designed and constructed to prevent groundwater contamination;
   c. Soils used for pond lining must be free from foreign material such as paper, brush, trees, and large rocks; and
   d. All soil liners must be of compacted material, at least 24 inches thick, compacted in lifts no greater than 6 inches thick and compacted to 95% of Standard Proctor Density;
   e. Soil liners must meet the following particle size gradation and Atterberg limits:
      i. 30% or more passing a number 200 mesh sieve; and
      ii. a liquid limit of 30% or greater; and
      iii. a plasticity index of 15 or greater;
   f. In situ liners at least 24 inches thick meeting a permeability less than or equal to 1×10^{-4} cm/sec are acceptable alternatives; In-situ clay soils meeting the soils liner requirements must be excavated and re-compacted a minimum of 6 inches below planned grade to assure a uniformly compacted finished surface.

D. Synthetic membrane linings must have a minimum thickness of 40 mils and have a leak detection system;

E. Certification by a Texas licensed professional engineer must be furnished stating that the pond liner meets the appropriate criteria prior to use of the facilities;

F. Soil embankment walls must have a top width of at least five feet. The interior and exterior slopes of soil embankment walls must be no steeper than one foot vertical to three feet horizontal unless alternate methods of slope stabilization are used. All soil embankment walls must be protected by a vegetative cover or other stabilizing material to prevent erosion. Erosion stops and water seals must be installed on all pipe penetrating the embankments; and

G. An alternative method of pond lining that provides equivalent or better water quality protection than provided under this section may be utilized with the prior approval of the executive director; and

H. Reclaimed water may be stored in leak-proof, fabricated tanks;

I. Subsequent holding ponds utilized for the receipt and storage of reclaimed water of a quality that could cause or causes a violation of a surface water quality standard or impairment of groundwater for its actual or intended use will be also subject to the

storage requirements of this section.

III. Specific Uses and Quality Standards for Reclaimed Water

A. Numerical parameter limits pertaining to specific reclaimed water use categories are contained in this section. These limits apply to reclaimed water before discharge to initial holding ponds or a reclaimed water distribution system.

B. The reclaimed water producer shall establish that the reclaimed water meets the quality limits at the sample point for the intended use in accordance with the monitoring requirements identified in Section IV, Sampling and Analysis.

C. Types and quality standards for reclaimed water.

1. Type I Reclaimed Water Use. The use of Type I reclaimed water is for situations where the public may come in contact with the reclaimed water. The uses allowed by this authorization are:

   a. Irrigation: landscape, public parks, schoolyards, athletic fields, golf courses, and food crops.
   b. Maintenance of off channel water bodies where recreational activities, such as wading or fishing, are anticipated even though the water body was not specifically designed for such a use.
   c. Soil compaction or dust control in construction and public event areas where application procedures minimize aerosol drift to general public.
   d. Industrial process water.

2. The following conditions apply to Type I use of reclaimed water. At a minimum, the reclaimed water producer shall transfer only reclaimed water of the following quality as described for Type I reclaimed water use. Type I reclaimed water on a 30-day average must have a quality of no more than:

Table 1. Type I Quality Requirements

Parameter	Limit	Limit Type
Turbidity	3 NTUs	30-day average
$CBOD_5$	5 mg/l	30-day average
E. coli	20/100 ml	30-day geometric mean (MPN or CFU)
E. coli	75/100 ml	maximum single grab sample (MPN or CFU)

D. Test Procedures

1. Test procedures for the analysis of pollutants must comply with procedures specified in 30 TAC §§319.11 - 319.12. Measurements, tests, and calculations must accurately represent the reclaimed water.

2. All laboratory tests submitted to demonstrate compliance with this authorization must meet the requirements of 30 TAC Chapter 25, *Environmental Testing Laboratory Accreditation and Certification.*

IV. Sampling and Analysis

A. The reclaimed water producer shall sample the reclaimed water prior to distribution to the entity that first received the reclaimed water after it leaves the wastewater treatment

facility (provider or user) to assure that the water quality meets the standard for the contracted use.

B. Analytical methods must be in compliance with 30 TAC Chapter 319, *Monitoring and Reporting*.

C. The minimum sampling and analysis frequency for Type I reclaimed water is twice per week when reclaimed water is being produced and shall be reported as outfall 800.

D. .The monitoring must be done after the final treatment unit.

E. The records of the monitoring must be kept on a monthly basis and be available at the facility site for inspection by representatives of the Commission for at least five years.

V. Record Keeping and Reporting

A. The reclaimed water provider and user shall maintain records on site for a period of at least five years.

B. The producer shall maintain the following records:

1. copies of notifications made to the commission concerning reclaimed water projects;
2. as applicable, copies of contracts with each reclaimed water user (this requirement does not include reclaimed water users at residences that have separate distribution lines for potable water);
3. records of the volume of water delivered to each reclaimed water user per delivery (this requirement does not apply to reclaimed water users at residences that have separate distribution lines for potable water); and
4. reclaimed water quality analyses.

C. The reclaimed water provider or producer shall report to the commission on a monthly basis the following information on forms furnished by the executive director. The reports are due by the 20th day of the month following the reporting period.

1. volume of reclaimed water delivered to each user; and
2. quality of reclaimed water delivered to a user or provider reported as a monthly average for each quality criteria, except those listed as "not to exceed" that must be reported as individual analyses.

VI. Transfer of Reclaimed Water

A. Reclaimed water must transfer from a provider to a user on a demand only basis. A reclaimed water user may refuse delivery of reclaimed water at any time.

B. All reclaimed water transferred to a user must be of at least the quality specified in Section IV, *Sampling and Analysis*.

C. Transfer must be by pipes or tank trucks.

D. The transfer of reclaimed water must be terminated immediately if a provider becomes aware of the misuse of the reclaimed water by the user, regardless of contract provisions.

VII. Restrictions

A. This authorization does not convey any property right and does not grant any exclusive privilege.

B. This authorization does not allow the use of reclaimed water on land that is authorize as a disposal site under either a Texas Pollutant Discharge Elimination System (TPDES) permit or a Texas Land Application Permit (TLAP).

VIII. Responsibilities and Contracts

A. The producer of reclaimed water is not liable for misapplication of reclaimed water by users, except as provided in this section. Both the reclaimed water provider and user have at least but are not limited to the following responsibilities:

1. The reclaimed water producer shall: transfer reclaimed water of at least the minimum quality required by this chapter at the point of delivery to the user;

   a. sample and analyze the reclaimed water and report the analyses in accordance with Section IV, Sampling and Analysis, and Section V, Recordkeeping and Reporting; and

   b. notify the executive director in writing within five (5) days after obtaining knowledge of reclaimed water use not authorized by the executive director.

2. The reclaimed water provider shall:

   a. ensure construction of reclaimed water distribution systems in accordance with 30 TAC Chapter 217, Design of Domestic Wastewater Systems, and in accordance with approved plans and specifications;

   b. transfer reclaimed water of at least the minimum quality required by this authorization at the point of delivery to the user;

   c. notify the executive director in writing within five (5) days after obtaining knowledge of reclaimed water use not authorized by the executive director; and

   d. not be found in violation of this chapter for the misuse of the reclaimed water by the user if transfer of such water is shut off promptly upon knowledge of misuse regardless of contract provisions.

3. The reclaimed water user shall:

   a. use the reclaimed water in accordance with this authorization; and

   b. maintain and provide records as required by Section V, Record Keeping and Reporting.

IX. Enforcement

If the producer, provider, or user fail to comply with the terms of this authorization, the executive director may take enforcement action provided by the Texas Water Code §26.019 and §26.136.

X. Standard Provisions

A. This authorization is granted in accordance with the rules and orders of the commission and the laws of the state of Texas.

B. Acceptance of this authorization constitutes an acknowledgment and agreement that the producer, provider and user will comply with all the terms, provisions, conditions, limitations and restrictions embodied in this authorization and with the rules and other orders of the commission and the laws of the state of Texas. Agreement is a condition precedent to the granting of this authorization