2.2 CURRENT SYSTEM OPERATION

The City currently operates seven pressure planes within the water distribution system, as described in Table 2-1. This WMP provides the City with guidance to reduce the number of pressure planes and consolidate operation of the system over the coming years. Chapter 6 describes these recommendations within each future modeled year.

Table 2-1: Existing Operational Pressure Planes

Pressure Plane	Nominal Operational Hydraulic Grade (ft.)
SWTP (Main)	810
Upper (Comanche)	936
Lower McCarty (McCarty Well)	857
Upper McCarty (Estates of San Marcos)	948
Oakridge	889
Deerwood	888
Kingswood	1060

In addition to the above-described planes, the City also has a few areas that operate at a lower hydraulic grade than the parent pressure plane, such as the area around the Municipal Airport (SWTP) and the Oak Ridge subdivision (Upper). These areas are served via a PRV.

Generally, the system is operated as follows. Raw surface water delivered to the SWTP is treated and pumped into the SWTP Pressure Plane and into the Cottonwood, Comanche, and Oakridge tanks. The Cottonwood Elevated Storage Tank (EST) and Comanche Standpipe Tank both serve as elevated storage for the SWTP Pressure Plane at a hydraulic grade of 810-feet. From the Comanche Tank, water is pumped again into the Upper Pressure Plane and into the Ranch Road 12 EST, which serves as elevated storage for the Upper Pressure Plane. Water also bleeds down from the Upper Pressure Plane through the Purgatory PRV into the McCarty Lower Pressure Plane and into the McCarty Tank. From the McCarty Plane, the water is pumped again to the McCarty Upper Pressure Plane.

From the Oakridge Ground Storage Tanks (GSTs), water is pumped into the Kingswood Pressure Plane. Some of the water pumped from the Oakridge Tanks bleeds down into the Oakridge and Deerwood Pressure Planes via PRVs.

When necessary to meet demand, groundwater from the Soyars well is pumped into the Soyars Tank and repumped into the SWTP Pressure Plane. The other well sites also supplement the surface water in the system when local demand conditions dictate need.

2.3 REGULATORY REQUIREMENTS

The rules and regulations for public water systems are established by the Texas Commission on Environmental Quality (TCEQ) in Title 30 of the Texas Administrative Code, Chapter 290, Subchapter D (30 TAC § 290). This chapter discusses the regulatory requirements applicable to the City's public water system (in both existing and future years) with respect to water supply, storage, and pumping capacity.

The code has recently been updated (September 2014) and changed how the number of service connections is defined for apartment complexes. This update states that "the number of service connections in an apartment complex would be equal to the number of individual apartment units". This change in the calculation has a significant effect on cities like San Marcos that have a large portion of their population made up of college students who are housed in apartment complexes since the TCEQ capacity requirements are based on the number of connections in a system.

Recently, the TCEQ provided the City with notice that their water supplies did not meet the requirements of 30 TAC § 290.45, which requires that systems have at least 0.6 gpm of water supply per connection. The new requirement based on the new definition of a connection appeared excessive as the City has never come close to utilizing all of its water supplies. The City applied for and received (June 11, 2015) a variance allowing an alternative capacity requirement (ACR) for their water supply requirements (more details in Chapter 2.3.1).

While the ACR was specific to the water supply requirements, APAI believes that the concept is applicable to other capacity requirements as well. APAI recommends that the City use the same reduction in capacity requirements when considering the adequacy of other water system components. This is further explained in the following Subchapters pertaining to the water supply, storage, and pumping capacity regulatory requirements.

2.3.1 Water Supply

The regulations found in 30 TAC § 290.45(b)(2) require that all surface water supplies meet a treatment plant capacity of 0.6 gpm per connection. The variance that the City received allowed a reduced total capacity requirement for production. The City was granted a minimum ACR as follows:

Total Production (Groundwater + Surface Water) >= 0.32 gpm/connection

Table 2-2 demonstrates that the City meets this ACR under existing and 2035 future conditions.

Table 2-2: Water Supply Summary

Pressure Plane/ Pump Station	2015 Current Total PS Capacity (gpm)	2035 Proposed Total PS Capacity (gpm)
SWTP	6,250	6,250
Spring Lake Wells	6,480	6,480
Comanche Well	2,700	2,700
Soyars Well	400	400
McCarty Well	1,428	1,428
Kingswood Well	400	400
Future Well	-	1,100
Total Capacity (gpm)	**17,658**	**18,758**
Estimated Number of Connections	30,897	49,436
Total PS gpm/conn Provided	0.572	0.379
Meets 0.32 gpm/connection ACR?	**Yes**	**Yes**

2.3.2 Storage

TCEQ requirements for storage are based on elevated and total storage in gallons per connection. Table 2-3 displays the total storage and storage per connection for existing (2015) conditions for the six existing pressure planes. Deficiencies are highlighted in red on this table. Using the new TCEQ method for counting service connections, this table shows that the City has a slight deficiency (0.35 MG) in elevated storage in the 810' Plane and a slight deficiency (0.18 MG) in total storage in the 936' Plane under existing conditions.

However, if the previous method of counting service connections is used, the number of connections is significantly lower and the existing storage tank capacities would be sufficient. Based on historic operations and the TCEQ approval of the ACR for water supply, additional storage does not appear to be warranted.

Currently, the two smaller pressure planes Kingswood and Oakridge/Deerwood are each served by a hydropneumatic pressure tank, which is a valid substitute for the storage requirements and provides more than the required 20 gallons per connection. Also highlighted in red in Table 2-3, the 948' Plane (Upper McCarty also known as the Estates of San Marcos) is currently served by the McCarty booster pumps, but does not have any elevated storage in this pressure plane. A small hydropneumatic tank should be added to this Plane to satisfy this requirement until this area is connected to the future 1063' Plane in 2025 (see Chapter 6.2).

Table 2-3: Existing Storage Facilities Summary

Storage Facilities by Pressure Plane	Proposed Active Head Range	Tank Style	2015 Estimated Number of Connections	Required Total Storage [1] (MG)	Current Active Total Storage (MG)	Required Elevated Storage [2] (MG)	Current Active Elevated Storage (MG)	Elevated Storage Gallons/ Connection
810 (SWTP) [3]			*20,494*	*4.10*	*6.57*	*2.05*	*1.71*	*83*
			7,720	**1.54**	**6.57**	**0.77**	**1.71**	**222**
SWTP Clearwells		Ground			3.00		-	
Spring Lake GST	610 - 636	Ground			1.50		-	
Comanche Standpipe	762 - 810	Elevated			0.71		0.71	
Cottonwood Elevated Tank	771 - 810	Elevated			1.00		1.00	
Soyars Standpipe	742 - 767	Ground			0.36		-	
936 (Upper/Comanche) [3]			*9,358*	*1.87*	*1.71*	*0.94*	*1.00*	*107*
			3,524	**0.70**	**1.71**	**0.35**	**1.00**	**284**
Comanche Standpipe	762 - 810	Ground			0.71		-	
Ranch Road 12	905 - 936	Elevated			1.00		1.00	
948 (McCarty Upper)			*108*	*0.02*	*0.52*	*0.01*	*0.00*	*-*
			108	**0.02**	**0.52**	**0.01**	**0.00**	**-**
McCarty Standpipe	756 - 855	Ground			0.52			
857 (McCarty Lower)			*238*	*0.05*	*0.52*	*0.02*	*0.52*	*2,197*
			238	**0.05**	**0.52**	**0.02**	**0.52**	**2,197**
	756 - 855	Elevated			0.52		0.52	
Facilities That Use Pressure Tanks in Lieu of Elevated Storage						**Required Pressure Tank Capacity [4] (gal)**	**Current Active Pressure Tank Capacity (gal)**	
889 (Oakridge) & 888 (Deerwood)			*269*	*0.05*	*0.09*	*5,380*	*15,000*	
			269	**0.05**	**0.09**	**5,380**	**15,000**	
Oakridge GSTs (2)	738.5 - 760	Ground			0.09			
1060 (Kingswood)			*168*	*0.034*	*0.038*	*3,360*	*20,000*	
			168	**0.034**	**0.038**	**3,360**	**20,000**	
Kingswood GST	884 - 900	Ground			0.038			
System Total [5]			**12,027**	**3.45**	**7.61**	**1.71**	**3.23**	**-**

Source: TAC 30, Ch. D, §290.45

1. Required total storage in each plane is 200 gallons per connection.
2. Required elevated storage in each plane is 100 gallons per connection when connections exceed 2,500.
3. The estimated number of connections and resulting storage requirements are shown using the current definition of connections in *ITALICS* (which counts apartment units as individual connections) and the previous definition in **BOLD**, which uses meter counts.
4. For systems with less than 2,500 connections, a pressure tank capacity of 20 gallons per connection may be used in lieu of elevated storage. If pressure tanks are used, a maximum capacity of 30,000 gallons is sufficient for up to 2,500 connections.
5. Total system storage only accounts for each tank once, although in a few cases a tank may serve two pressure planes at once.

The total storage and storage per connection under proposed conditions (2035) is described by Table 2-4. By 2035, two proposed projects will provide additional storage for future years. A 0.5 million gallon (MG) elevated storage tank (EST) at a hydraulic grade of 1063' is recommended to serve the proposed La Cima Development in northwest San Marcos. This tank will also serve Kingswood and other surrounding areas within the City's CCN incorporated into the 1063' Pressure Plane. Additionally, a 0.51 MG tank located on a hill top (named Trunk Hill) will provide elevated storage to the proposed Paso Robles Development and surrounding area. Future project details are described further in Chapter 6.

In future conditions, Table 2-4 shows that the 810' pressure plane exceeds the total storage requirements, however, the elevated storage requirement of 100 gallons per connection is not met (lacking 0.88 MG EST) using the new TCEQ definition of a connection. Based on the previous definition of a connection, the approximate number of connections in the 810 pressure plane would have been 12,370. Using the previous definition for a connection, the City would be required to have 1.24 MG of elevated storage, which is exceeded even under existing conditions (1.71 MG existing EST in Table 2-3). Under future conditions, elevated storage is estimated to be 2.35 MG, further exceeding the previous definition.

The 2003 Water Master Plan had proposed a 1 MG Northside EST, to be located just north of Post Road in the northeastern section of the 810' Plane. The addition of this EST to the system would meet the TCEQ storage requirements according to the new service connection calculation method. However, since all other hydraulic requirements are met (see Chapter 6) in the 2035 future model, additional elevated storage in the 810 pressure plane is not included. The City may wish to document the adequacy of the storage by applying for another ACR variance with TCEQ. Going through the variance process related to these storage requirements for the existing condition and the proposed EST capacity in the 810' Plane will save the City additional large capital expenditures.

Table 2-4: Proposed Storage Facilities Summary

Storage Facilities by Pressure Plane	Proposed Active Head Range	Tank Style	2035					
			Projected Number of Connections	Required Total Storage[1] (MG)	Proposed Active Total Storage (MG)	Required Elevated Storage[2] (MG)	Proposed Active Elevated Storage (MG)	Elevated Storage Gallons/ Connection
810 (SWTP) [3]			*32,263*	*6.45*	*6.85*	*3.23*	*2.35*	*73*
			12,254	**2.45**	**6.85**	**1.23**	**2.35**	**192**
SWTP Clearwells		Ground			3.00		-	
Spring Lake GST	610 - 636	Ground			1 50		-	
Comanche Standpipe	762 - 810	Elevated			0 71		0.71	
Cottonwood Elevated Tank	771 - 810	Elevated			1.00		1.00	
McCarty Standpipe	758 - 810	Elevated			0.29		0.29	
Soyars Standpipe	742 - 805	Elevated			0.36		0.36	
936 (Mid-Range) [3]			*13,325*	*2.66*	*2.65*	*1.33*	*1.50*	*112*
			5,805	**1.16**	**2.65**	**0.58**	**1.50**	**258**
Comanche Standpipe	762 - 810	Ground			0.71		-	
Soyars Standpipe	742 - 810	Ground			0.36		-	
Oakridge GSTs (2)	738.5 - 760	Ground			0.09		-	
Ranch Road 12	905 - 936	Elevated			1.00		1.00	
Trunk Hill (Future Tank)	870 - 936	Elevated			0.50		0.50	
1063 (Kingswood, Future La Cima)			*3,848*	*0.77*	*2.04*	*0.38*	*0.50*	*130*
			3,848	**0.77**	**2.04**	**0.38**	**0.50**	**130**
Ranch Road 12	905 - 936	Ground			1 00		-	
Trunk Hill (Future Tank)	870 - 936	Ground			0 50		-	
Kingswood GST	884 - 900	Ground			0.04		-	
La Cima (Future Tank)	1025 - 1063	Elevated			0.50		0.50	
System Total [4]			**21,906**	**4.38**	**11.54**	**2.19**	**4.35**	**-**

Source TAC 30, Ch D, §290 45

1 Required total storage in each plane is 200 gallons per connection
2 Required elevated storage in each plane is 100 gallons per connection when connections exceed 2,500
3 The estimated number of connections and resulting storage requirements are shown using the current definition of connections in *ITALICS* (which counts apartment units as individual connections) and the previous definition in **BOLD**, which uses meter counts
4 For systems with less than 2,500 connections, a pressure tank capacity of 20 gallons per connection may be used in lieu of elevated storage If pressure tanks are used, a maximum capacity of 30,000 gallons is sufficient for up to 2,500 connections
5 Total system storage only accounts for each tank once, although in a few cases a tank may serve two pressure planes at once

2.3.3 Pumping Capacity

TCEQ requirements for pumping are dependent upon available elevated storage. When a City has less than 200 gallons per connection of elevated storage (as does San Marcos), then the required pumping capacity is the lesser of 2.0 gallons per minute (gpm) per connection or the ability to meet peak hour demands with firm pumping capacity and a total capacity of at least 1,000 gpm. The calculated demand based on 2.0 gpm per connection would require a pumping capacity significantly greater than the current or future planned facilities for the City. Therefore, the ability to meet peak hour demands with firm pumping capacity is evaluated for current and future conditions.

Table 2-5 displays the existing pumping facility information compared to the peak hour demands for each pressure plane. Table 2-6 shows the same information for 2035. As can be seen in these tables, the City has adequate existing and planned pumping capacity to meet the TCEQ requirements.

Table 2-5: Existing Pumping Facilities Summary

Pressure Plane	Pump Station	2015 Estimated Number of Connections	Current Average Annual Demand (gpm)	Current Maximum Day Demand (gpm)	TCEQ Required Firm Capacity[1] (gpm)	Current Total PS Capacity (gpm)	Current Firm PS Capacity (gpm)
810 (SWTP)	SWTP	20,494	3,403	5,139	6,770	11,582	7,416
	Spring Lake					8,610	6,360
	Total per Plane					**20,192**	**13,776**
936 (Upper Comanche)	Comanche	9,358	1,554	2,347	3,092	3,000	1,800
	Soyars					1,380	780
	Total per Plane					**5,980**	**4,180**
948 (McCarty Upper)	McCarty PS	108	18	27	36	600	400
857 (McCarty Lower)	Served via McCarty PRV	238	40	60	79		
889 (Oakridge)	Oakridge PS	269	45	67	89	2,800	2,000
888 (Deerwood)	Served via Oakridge PRV						
1060 (Kingswood)	Kingswood PS	168	28	42	55	400	200
	Total	**30,635**	**5,087**	**7,682**	**10,120**		

Source: TAC 30, Ch. D, §290.45

1. A total capacity of at least 1,000 gpm and the ability to meet peak hourly demands with the largest pump out of service is the applicable required pumping capacity for this system. Demands presented here are discussed in more detail in Chapter 4.

Table 2-6: Proposed Pumping Facilities Summary

Pressure Plane	Pump Station	2035				Projected Total PS Capacity (gpm)	Projected Firm PS Capacity (gpm)
		Projected Number of Connections	Projected 2035 Average Annual Demand (gpm)	Projected 2035 Maximum Day Demand (gpm)	TCEQ Required Firm Capacity[1] (gpm)		
810 (SWTP)	SWTP (One new pump)	32,263	5,700	8,606	11,510	14,832	10,666
	Spring Lake					8,610	6,360
	Total per Plane					**23,442**	**17,026**
936 (Mid-Range)	Comanche	13,325	1,205	1,820	2,434	5,000	3,750
	Soyars					1,200	600
	McCarty					600	400
	Oakridge					2,400	1,600
	Total per Plane					**9,200**	**6,350**
1063 (Kingswood, Future La Cima)	Kingswood	3,848	778	2,189	3,718	400	200
	Trunk Hill (Future)					3,200	1,600
	Ranch Road 12 (Future)					4,200	2,820
	Total per Plane					**7,800**	**4,620**
	Total	**49,436**	**7,683**	**12,615**	**17,662**		

Source: TAC 30, Ch. D, §290.45

1. A total capacity of at least 1,000 gpm and the ability to meet peak hourly demands with the largest pump out of service is the applicable required pumping capacity for this system. Demands presented here are discussed in more detail in Chapter 4.
2. Pumps designated with "Future" represent pump station projects proposed in the CIP List.

3 Existing System Model Development & Calibration

For the 2016 Water Master Plan Update, the hydraulic model software was upgraded from Bentley WaterCAD to Innovyze InfoWater which embeds within a geographic information systems (GIS) environment. Prior to evaluating future conditions, the hydraulic model needed to be updated and recalibrated to existing conditions. Field data collected in April 2014 were used to perform the updated model calibration.

Much of the work regarding the existing system model development and calibration has been previously detailed in a November 2014 technical memorandum entitled "Existing System Hydraulic Model Development and Calibration", which can be found in Appendix A. Subsequent sections of this chapter will summarize that work.

3.1 EXISTING DEMANDS

In calibrating a hydraulic water distribution system model, often the most difficult component lies with the spatial distribution of demands. Unlike many utilities, the City of San Marcos has implemented advanced metering infrastructure (AMI) system-wide. This is a process by which all water meters were replaced with "smart meters" capable of transmitting data to a centralized data storage facility on an hourly basis. The availability of data from these meters vastly simplified the spatial distribution of demands within the model. In addition, having hourly data for all meters allowed the modelers to develop unique diurnal curves for each size meter based on actual data. The diurnal curves were then applied to nodes in the water distribution model based on the number and size of meters in close proximity.

For the April 4-16, 2014 calibration data collection event, water metering data showed that the average daily system-wide demand was approximately 3,520 gpm (5.07 MGD). A complete analysis of 2013 demands[1] suggested the average day demand for all of 2013 was 4,651 gpm (6.7 mgd), with a maximum daily average demand of 5,953 gpm (8.6 mgd) and peak hour demand of 7,843 gpm (11.3 mgd). A detailed description of how these demands were spatially distributed is described in Appendix A.

3.2 WATER LOSS

Like demand distribution, the distribution of water losses is also very difficult to determine by traditional means. However, the AMI data collected by the City was able to help distribute losses on a planar basis to some degree, improving the calibration. A full description of the process by which losses were calculated and distributed is available in Appendix A.

By comparing SCADA-based production data to metered consumption over the course of the 72-hour April 9-11 calibration period, it was determined that approximately 24.5 percent of the water entering the distribution system via the SWTP High Service Pump Station, well pumpage, and net storage decrease was not metered upon exit. On average, water was supplied to the system at a rate of approximately 4,670 gpm (6.72 MGD) while the average metered demand

[1] At the time of model calibration, 2013 was the last full year of demand data available.

was approximately 3,520 gpm (5.07 MGD) during the calibration period. While this percentage is higher than average for the City, water restrictions and lower overall usage may be increasing the percentage loss and the actual magnitude of the losses may not be appreciably different. The City is investigating the causes of increased water loss in the system and trying to determine if they are real or apparent water losses. AMI is a good tool in this effort, but cannot help when the source of loss is unmetered, unaccounted for water.

3.3 CALIBRATION

While many model calibrations are considered adequate if 24 or 48 consecutive hours of system operation can be simulated to within 10 percent of available data for pressures, tank levels, and pump flow rates, APAI decided to utilize a 72-hour calibration period and strive to improve the simulation error such that most modeling results are within 5 percent of the available supervisory control and data acquisition (SCADA) system data. The available AMI data made these targets quite reasonable. Appendix A describes the hydraulic model calibration process in detail. A summary of the calibration results follows.

In general, most pressure data was simulated to within 5 percent of measured values, while all stations were simulated to within 10 percent of SCADA data for the entire 72-hour calibration period. With respect to tank levels, simulations were quite accurate with respect to both cycle times and timing of peak and trough levels. Pumping simulations were also very accurate, as simulated flow rates at all stations where flow metering was available match the SCADA data to within 5 percent at nearly all times during the simulation. Appendix A contains a plot of every pressure node, pump, valve, and tank for which comparisons were made to collected SCADA or pressure data recorder data. The following figures show example plots of each type of calibration.

Figure 3-1: Cottonwood EST Calibration (April 9–11, 2014)

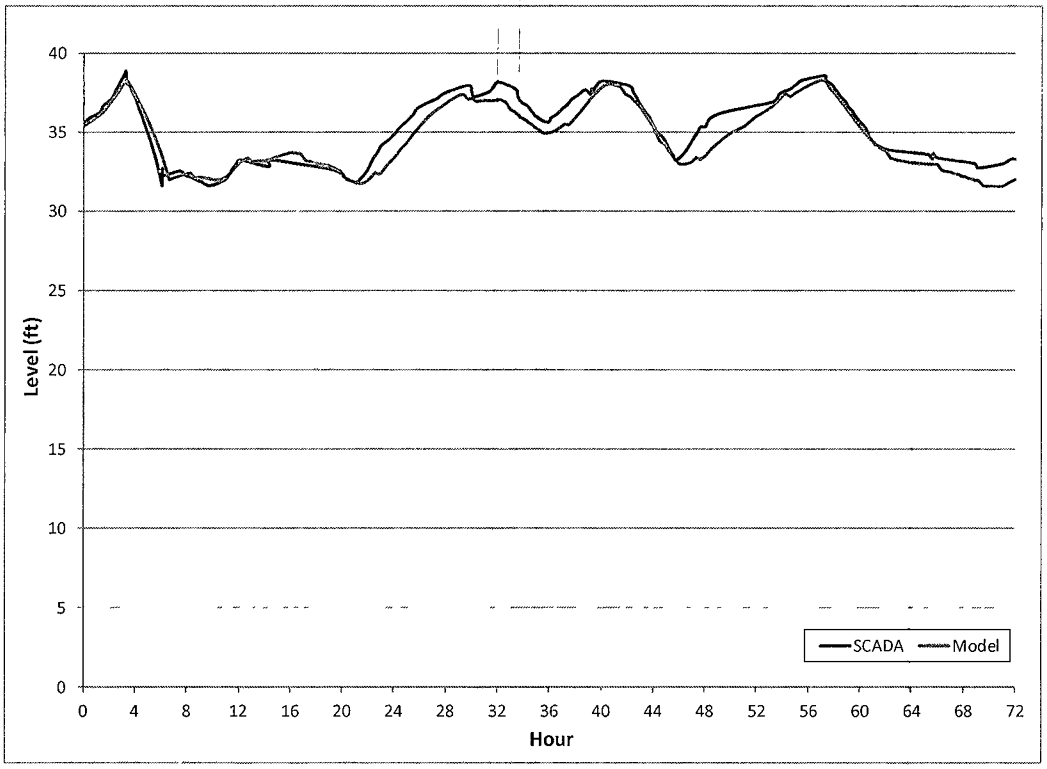


Figure 3-2: SWTP Pump Station Discharge Calibration (April 9–11, 2014)

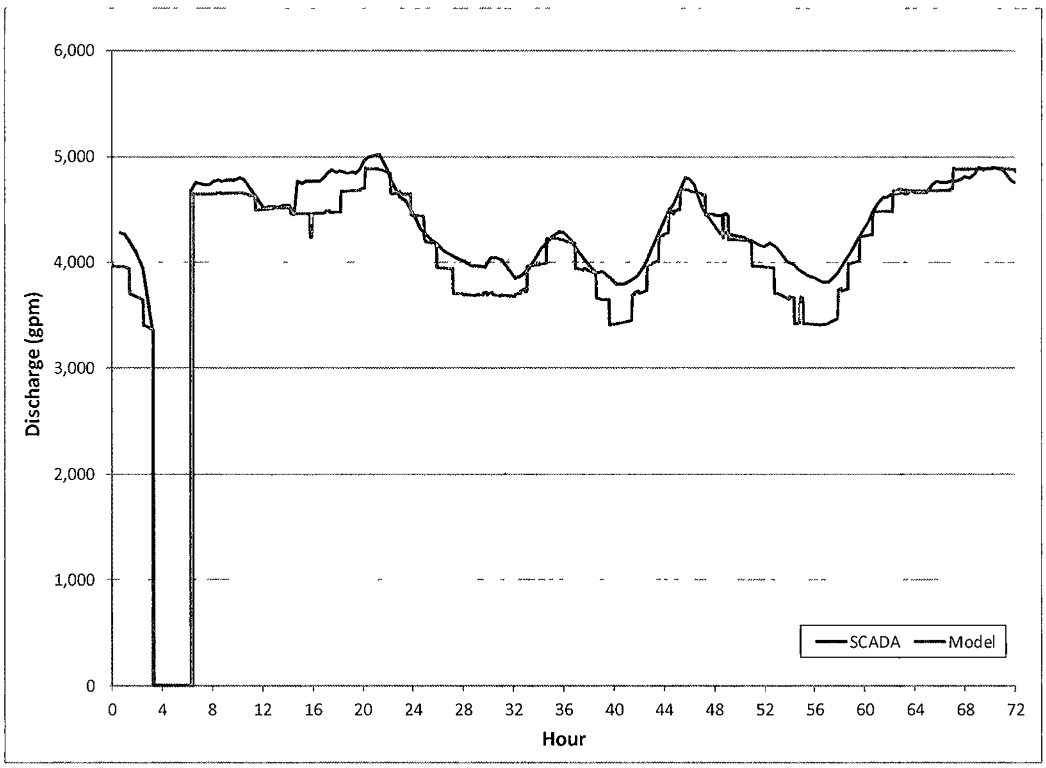


Figure 3-3: Old Bastrop Road Permanent Pressure Station Calibration (April 9-11, 2014)

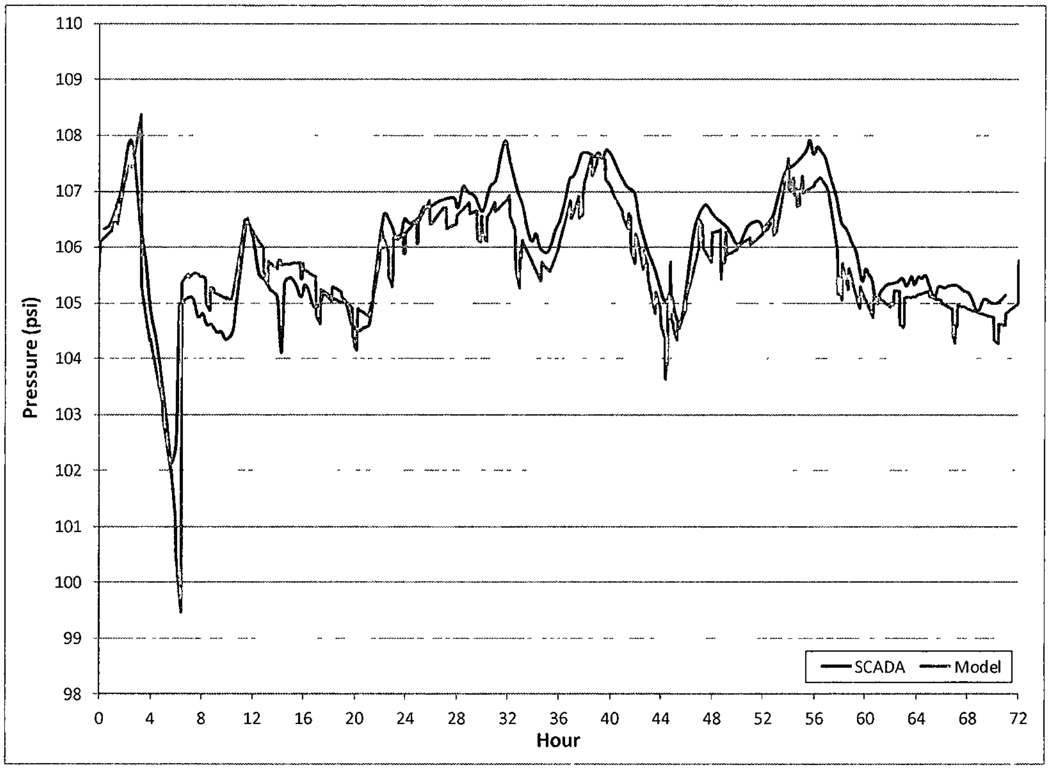
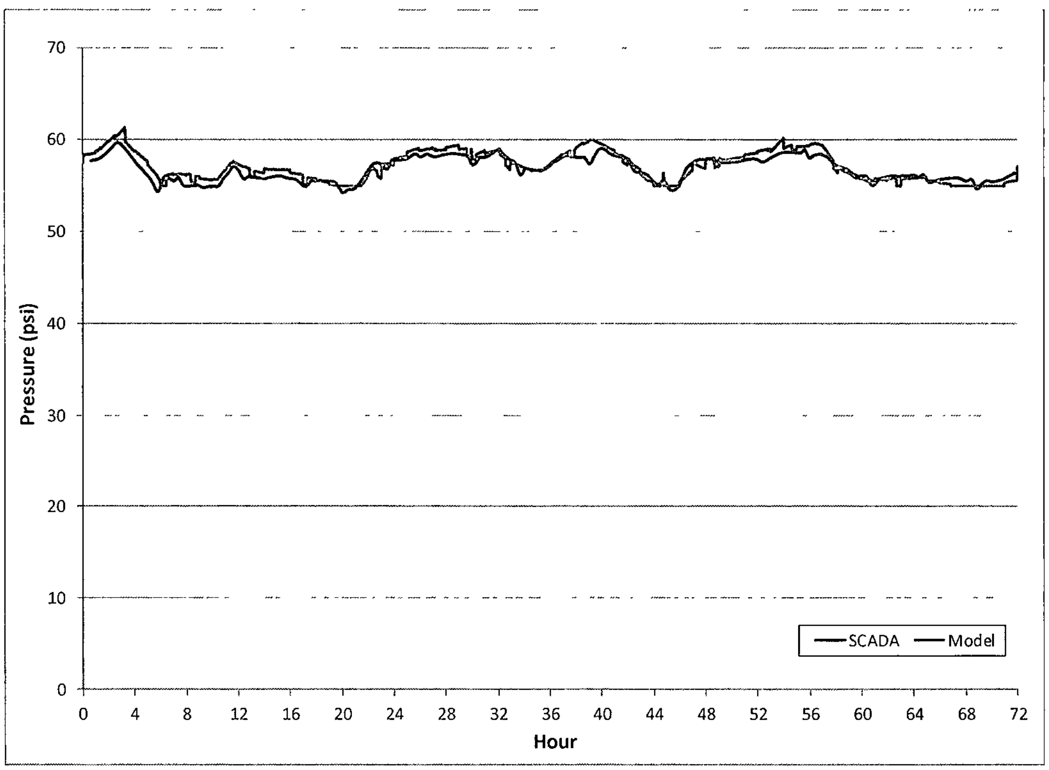


Figure 3-4: Prospect PRV Downstream Pressure Calibration (April 9-11, 2014)



4 Population and Water Demand Projections

Water service area population and water demand projections were based on the projections for future developments performed for the 2015 Wastewater Master Plan (WWMP). Adjustments were made to account for the differences between projections performed for the WWMP, the 2013 Comprehensive Plan, and the 2014 Water Conservation Plan. The following sections describe the methodology used to arrive at water demand projections used for input to the hydraulic model.

4.1 WATER SERVICE AREA POPULATION PROJECTIONS

In the City's 2013 Comprehensive Plan, residential and employment growth areas, as well as known proposed developments were identified. However, APAI noticed that the population projections used in the WWMP were considerably lower than the projections used for the 2014 Water Conservation Plan, and also did not agree with the projections in the 2013 Comprehensive Plan.

After consulting with City staff, APAI utilized the higher projections from the Conservation Plan (which are based on projected water service area growth). The final water service area population projections are displayed in Table 4-1.

Table 4-1: Water Population Projections

Year	Population	Annual Rate of Growth
2013	53,540	-
2020	71,117	4.14%
2025	77,968	1.86%
2035	92,989	1.78%

As shown, the Conservation Plan population projections expect fairly rapid growth through 2020. The following section describes the translation of water service population to water demand.

4.2 WATER DEMAND PROJECTIONS AND FUTURE DISTRIBUTION

To ensure that the 2016 Water Master Plan Update accounted for conservation targets in the Water Conservation Plan, APAI multiplied the gallons per capita per day (gpcd) usage targets from the Water Conservation Plan for each year by the population projection to arrive at total system average day demand. The gpcd targets specified in the 2014 Water Conservation Plan are shown in Table 4-2.

Table 4-2: 2014 Conservation Plan GPCD Targets

Year	Target (gpcd)
2013	124
2020	116
2025	114
2035	112

All population growth was added to the growth areas and development areas identified in the 2013 Comprehensive Plan. The residential demand associated with additional population growth resulting from the utilization of Conservation Plan projections over the WWMP values was added to the more general "growth areas" and to the development areas listed as mixed use neighborhoods. Populations associated with proposed developments for which lot/unit counts were known (such as planned apartment complexes) were not adjusted.

In addition to residential demands, employment demands (demands associated with business activities) were also calculated. As the employment "population" was estimated at 76 percent in the WWMP, this ratio was also used for continuity. Furthermore, data from the 2014 Water Conservation Plan suggest that approximately 19 percent of the total demand is commercial in nature. From these two assumptions, as well as the total gpcd values in the Water Conservation Plan, the total demand can be broken into employment and residential categories and also identify gpcd values for each category in future years. Figure 4-1 displays these projected areas on a map along with a table summarizing projected demand growth by development areas, growth areas, and employment areas in each future target year.

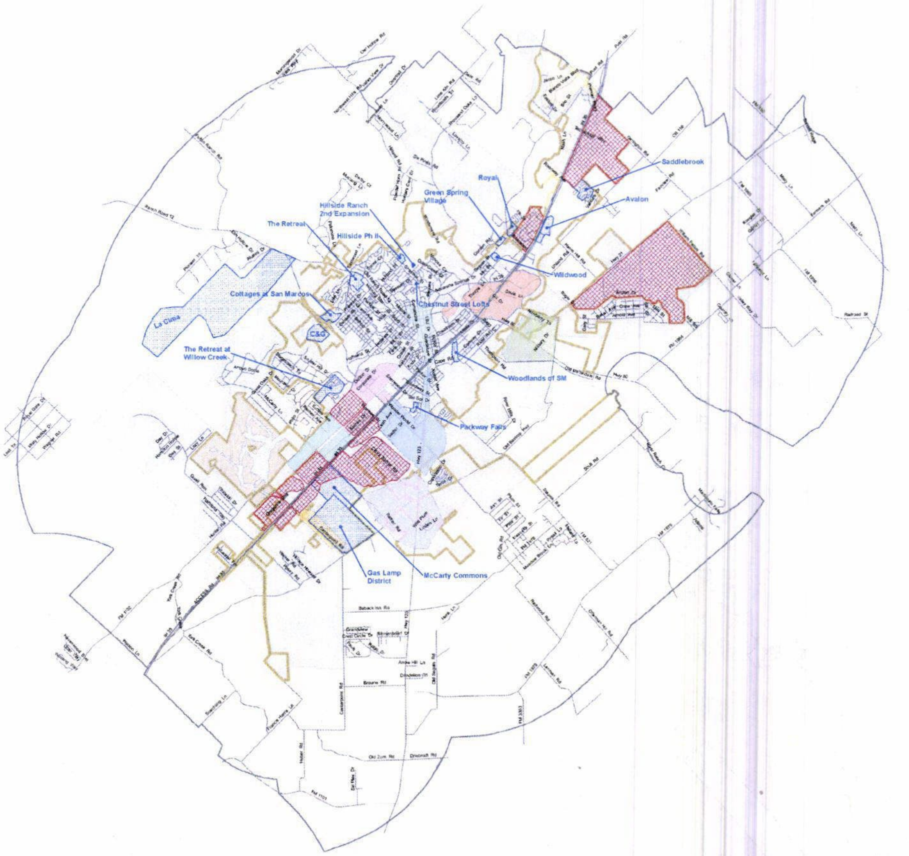
Population and employment demands were combined and results in the following overall average, maximum day, and peak hour demands for each target year (Table 4-3).

Table 4-3: Projected Water Demands

Year	2020	2025	2035
Average Day (AD) Demand (gpm, mgd)	5,828 gpm, 8.4 mgd	6,683 gpm, 9.6 mgd	7,683 gpm (11.1 mgd)
Maximum Day (MD) Demand (gpm, mgd)[1]	9,204 gpm, 13.3 mgd	10,961 gpm, 15.8 mgd	12,616 gpm, 18.2 mgd
Peak Hour PH Demand (gpm, mgd)[2]	12,126 gpm, 17.5 mgd	14,223 gpm, 20.5 mgd	16,872 gpm, 24.3 mgd
MD:AD Multiplier (system wide average)	1.58	1.64	1.64
PH: MD Multiplier (system wide average)	1.32	1.30	1.34

[1] The MD:AD ratio is 1.51 in all areas except La Cima. The La Cima Development Engineering Report stated the maximum day to average day ratio is 2 92

[2] The PH:MD ratio is dependent upon the diurnal curve assigned to each given node. The exception is the La Cima Development, whereas the Engineering Report stated the PH: MD ratio is 1.71 within their planned development.



	Growth Area/ Development Name	Demand Projection (gpm)		
		2020	2025	2035
Growth Areas	Blanco Vista	215	203	248
	Centerpoint Connector	11	26	50
	Downtown	79	132	290
	East Village	136	221	476
	South End	23	44	83
	Medical District	23	44	83
	Midtown	91	163	331
	Paso Robles	136	177	207
	Star Park	57	79	113
	Triangle	17	26	41
Proposed Developments	Avalon	65	64	63
	C&G	15	15	15
	Chesnut Street Lofts	15	15	15
	Cottages of San Marcos	54	57	57
	Gas Lamp District	0	22	62
	Green Spring Village	3	3	3
	Hillside Ranch 2nd Expansion	5	4	4
	Hillside Ranch Phase II	20	19	19
	McCarty Commons	0	44	62
	Parkway Falls	17	17	17
	Royal	10	10	10
	Saddlebrook	6	13	21
	The Retreat	51	50	49
	The Retreat at Willow Creek	27	28	29
	Wildwood	33	32	32
	Woodlands of SM (Capes Camp)	33	32	32
Employment Areas	Airport	80	112	174
	River Ridge	10	14	22
	1	8	11	18
	2	4	5	9
	3	8	11	17
	4	31	43	67
	5	5	7	11
	6	3	4	6
	7	6	9	14
	8	1	1	1
	9	3	5	7
	10	6	9	14
	11	36	50	78
	Total Cumulative Demand (gpm):	**1,343**	**1,823**	**2,847**
	Total Cumulative Demand (mgd):	**1.9**	**2.6**	**4.1**

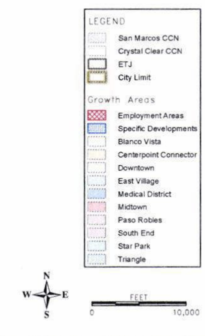


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FIGURE 4-1
City of San Marcos: Water Master Plan Update
Growth Areas

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4.3 DIURNAL CURVES

The diurnal curve refers to the variation of water demand over the course of a single day. The City's Advanced Metering Infrastructure (AMI) data would allow the identification of a diurnal curve for each meter in the distribution system. However, as hydraulic models will only accept ten to twenty such curves, the data were aggregated into 15 representative diurnal curves as a function of usage type (domestic or irrigation), pressure plane, and meter size. During model calibration, these representative curves (listed in Table 4-4) were identified by averaging AMI data for the calibration period.

The curves for each pattern were derived from 11 days of 2014 data gathered for model calibration. These curves are plotted and included in Appendix A.

Table 4-4: Diurnal Curve Patterns Developed from AMI Data

Pattern No.	Usage	Pressure Plane	Meter Size(s)
1	Irrigation	SWTP	- all sizes -
2	Irrigation	-all other planes-	- all sizes -
3*	Domestic	SWTP	>= 2"
4*	Domestic	Upper	>= 2"
5*	Domestic	SWTP	>= 0.75" and < 2"
6*	Domestic	Upper	>= 0.75" and < 2"
7	Domestic	Lower McCarty	>= 0.75" and < 2"
8	Domestic	Oakridge	>= 0.75" and < 2"
9*	Domestic	SWTP	5/8"
10*	Domestic	Upper	5/8"
11	Domestic	Lower McCarty	5/8"
12	Domestic	Upper McCarty	5/8"
13	Domestic	Deerwood	5/8"
14	Domestic	Oakridge	5/8"
15	Domestic	Kingswood	5/8"

* These patterns were applied to new demands in future year model simulations.

For new demands within future year simulations, a diurnal curve was assigned based on the pressure plane location and use. For example, a large apartment in the SWTP plane was assigned a curve for the SWTP pressure plane with a greater than or equal to two-inch diameter. No irrigation demands were specifically identified for future years.

5 Water Supply

The Water Mater Plan scope was limited to evaluating the ability of the system to distribute water from its source to the points of demand. As part of this scope, the water supply source capacities were compared to the TCEQ requirements based on a peak delivery scenario. The existing water sources have the capacity to meet the alternative demand requirements approved by TCEQ throughout the study period. However, another consideration is the overall volume of water needed on an annual basis. Wells are typically not operated 24 hours per day, seven days a week due to aquifer conditions.

5.1 CURRENT WATER SOURCES

The majority of the water in the distribution system is surface water treated at the SWTP by the Guadalupe-Blanco River Authority (GBRA). The surface water comes from the Guadalupe River via a raw water pipeline from the intake on a canal extending from Lake Dunlap.

Groundwater extracted at each of the five well sites provides additional supply as needed. In 2014, groundwater made up less than 10 percent of the total water production.

The City operates and maintains six wells as follows:

1. Two wells at the Spring Lake Pump Station
2. One well each at the Comanche, McCarty, Soyars, and Kingswood facilities

In addition, two wells at the Oakridge Pump Station have been recently decommissioned. At least one of them may be able to be restarted in an emergency situation.

5.2 FUTURE NEEDS

The City has completed separate studies to evaluate the overall volumes of water needed to meet the demands of their customers into the future. As a result of these studies, the City is a participant in the Hays-Caldwell Public Utility Authority (HCPUA). The HCPUA is currently planning for the implementation of a large project to bring groundwater into the area from Gonzalez County.

For modeling purposes, any HCPUA water obtained by the City during the planning horizon will be assumed to be delivered as treated water to the SWTP clearwells. No raw water transmission facilities have been included in the distribution system model.

6 Future Year Distribution System Evaluation

With water demand projections complete, hydraulic modeling scenarios could be developed for the average day and maximum day demand cases in each targeted future year. In general, the criteria used to identify the capital improvements needed to serve the projected demand in each target year were as follows:

- State regulatory criteria met for storage and pumping capacity,
- Meeting a target pressure of 35 psi during maximum day demand conditions at most points in the distribution system and an absolute minimum of 20 psi (except the suction side of pumps)
- Headloss rates less than 7 ft. per 1,000 ft. in all pipes,
- Pipe velocities below 7 ft./s during maximum day demand conditions,
- Adequate fire flow availability (including 1000 gpm for new connections, 500 gpm for existing connections) under maximum day demand conditions, and
- Reducing water age where feasible through looped connections.

The following sections describe the hydraulic model scenarios developed for each year.

6.1 2020 SYSTEM UPDATES

If the rapid growth projected over the next five years comes to pass, particularly the commencement of construction of two very large developments (La Cima and Paso Robles), there will be a significant level of capital improvements necessary to meet all water service criteria. Figure 4-1 showed the location of these two developments in the northwest and western side of the City, respectively.

Specifically, the creation of a new pressure plane at an overflow elevation of 1063 feet will be needed to serve the La Cima development (hereafter the 1063 Pressure Plane). The tank should be a 0.5 MG elevated tank, so that portions of the neighboring area can also be connected to the new higher pressure plane and served in the future (Subchapter 6.2). Alternatively, the 1063 Pressure Plane could operate off of a hydropneumatic tank until the elevated tank is built in the 2020 to 2025 time frame. To satisfy state regulatory criteria for this pressure plane, a new pump station at the Ranch Road 12 Tank site (CIP 2b) as well as a new elevated tank (CIP 2a) in the La Cima development will be needed. The La Cima Development Engineering Report has recommended a 300,000 gallon elevated tank to service this area. This would provide only the required storage for the La Cima development itself. Additional pumping capacity at the Comanche PS (CIP 1) will also be required to fill the Ranch Road 12 tank and keep up with the La Cima demands.

In order to serve the first phase of the proposed Paso Robles development, the Soyars Pump Station will be reconfigured (CIP 3). The Soyars tank will also be connected to the 810" pressure plane. An altitude valve will be installed on the supply side of the tank to keep it from overflowing. The existing line in Hunter Road will be converted to a 936' line and receive flow from the discharge side of the Soyars pump station to provide improved fire flow in this area (CIP 4).

Eventually, the Paso Robles development, the McCarty Lower Pressure Plane, and the Oakridge/Deerwood areas will all be combined with the Upper Pressure Plane at an overflow of 936 feet. In 2020, however, most of the system will operate as it does currently, with all seven existing major pressure planes still operating as they do now. A new hydropneumatic tank will be added at the Soyars Tank and the Soyars Pump Station will serve the Paso Robles Development on an interim basis with the hydropneumatic tank. One other change will take place with regard to the City's CCN boundary. The City of San Marcos and Crystal Clear Water Supply Company (CCWSC) will trade portions of the CCN boundary along the southern side of the City. Namely, the City will give CCWSC control over the Grandview Drive and Crest Circle Drive neighborhoods, which has high water age and is challenging for the City to serve.

Quite a few water line projects will be needed to serve the new developments proposed for 2020. They are described as follows:

- CIP 5: Close gap by extending 16" line from its terminus to near Soyars tank.
- CIP 6: Parallel Hunter Rd. with a 12" line from Quail Run to Centerpoint (near Soyars) in the 936 Plane.
- CIP 7: Complete 24" main by joining end of line at McCarty Rd. to IH-35 just north of Premium Outlets.
- CIP 8: Extend 12" line from end of Stagecoach to intersection of Belvin and Bishop to tie into existing 12" dead-end line.
- CIP 9: Upsize existing lines with 16" main along E. McCarty Ln. just north of Old Bastrop.
- CIP 10: Complete large diameter line loop (24") along State Highway 123 between existing 24" and existing 18" lines.
- CIP 11: Construct Phase I of Paso Robles, which includes a 24 home subdivision behind the Soyars Facility.
- CIP 12: Extend 16" line along Old Bastrop Highway (TX 123 to E. McCarty Lane) to serve new growth areas.
- CIP 13: Upsize small diameter lines to 12" along N. LBJ.
- CIP 14: Provide a 12" loop along South Hunter Rd. (connect existing 12" line (on 810 Plane) in Hunter Rd to a 12" in Industrial Fork Rd.)
- CIP 15: Upsize existing lines to 12" along IH-35 to the Civic Center Loop.
- CIP 16: Upgrade 8 existing water line crossings to 16" Between McCarty & Aquarena Springs Rd.
- CIP 17: Extend 12" line northeast along Airport Rd. to serve new growth.

Appendix B contains additional figures showing minimum pressure nodes and fire flow availability results for the 2020 system.

Figure 6-1 depicts the proposed 2020 system, with all pressure planes identified. Appendix B contains additional figures showing minimum pressure nodes and fire flow availability results for the 2020 system.

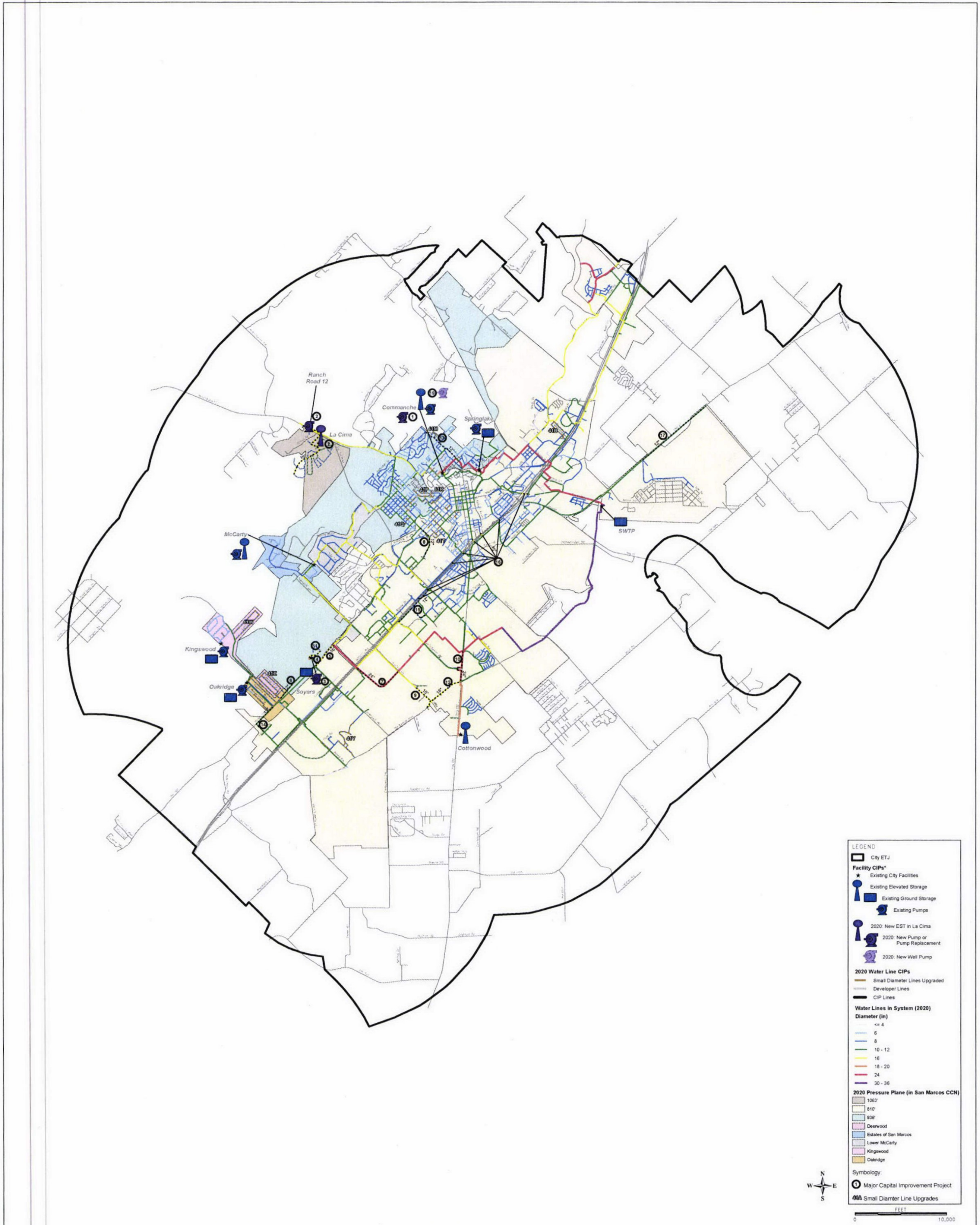

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FIGURE 6-1
City of San Marcos: Water Master Plan Update
System Overview with 2020 Capital Improvement Projects

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6.2 2025 SYSTEM UPDATES

By 2025, merging of the Upper, Lower McCarty, Oakridge, Deerwood, and Soyars pressure planes into a single 936-ft plane (hereafter the 936 Pressure Plane) will be complete. The Trunk Hill Elevated Tank, a new 0.5 MG elevated tank to serve the southern portion of the 936 Pressure Plane will be in place, along with a new pump station sited adjacent to the Trunk Hill Tank to boost supply to the 1063 Pressure Plane. The La Cima development and former Kinsgwood Pressure Plane will now be joined into a single 1063 Pressure Plane. Kingswood will benefit from being connected to the 1063 Pressure Plane because there are some borderline low pressures under existing and 2020 conditions in this area.

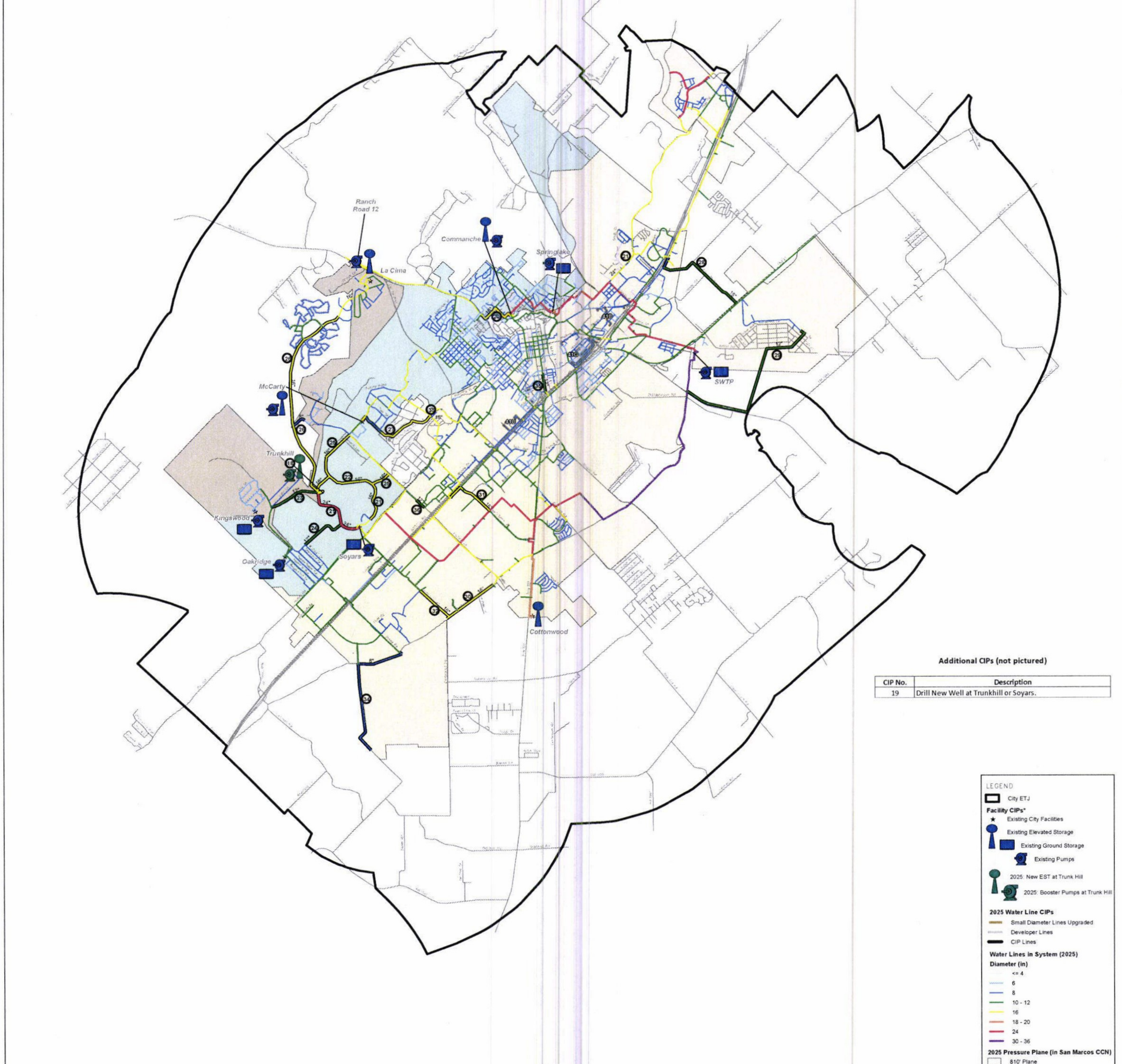
The McCarty Tank will now be connected to the 810 plane, providing additional elevated supply for this zone. The McCarty Tank will be operated at less than full as its overflow is currently 857.

The distribution system in 2025 will consist of only three major pressure planes (810, 936, and 1063), with the Estates of San Marcos now served via a PRV off a new 24" main coming from the Trunk Hill Pump Station in the 1063 Pressure Plane. Major pipeline projects in this time period include the following:

- CIP 20: Parallel the existing Comanche PS outlet main with a 16" line to Franklin St.
- CIP 21: Construct 16" and 24" mains, which comprise the southeast and southwest segments of the loop around Paso Robles Development.
- CIP 22: Construct a 16" main to continue the loop around the northeast side of Paso Robles.
- CIP 23: Construct a 12" line to connect Trunk Hill to Sleepy Hollow in Kingswood.
- CIP 24: Construct a 12" line to connect Paso Robles to Trails End in Oakridge.
- CIP 25: Use a 16" line to connect eastern Paso Robles to two existing McCarty Lane water lines.
- CIP 26: Connect Trunk Hill PS to La Cima with a 16" water main. This project also includes an 8" line off the main to serve to the Estates at San Marcos (PRV at 95 psi included).
- CIP 27: Connect the McCarty Standpipe Tank to the 810 Plane with a 16" line along Stage Coach.
- CIP 28: Build a north/south loop (12" line) from the Airport to River Ridge Parkway.
- CIP 29: Extend a 12" line from the existing 30" along State Highway 80 to edge of the City's CCN and then north to connect to the dead-end line at the Airport.
- CIP 30: Extend 16" line along Old Bastrop Road from McCarty to Centerpoint to serve new developments.
- CIP 31: Provide a 16" line along Clovis Barker to tie into existing 24". Also upgrade lines along IH-35 to tie into existing 16" lines.
- CIP 32: Extend 16" line along Centerpoint to Old Bastrop Road from existing dead-end.
- CIP 33: Upsize small diameter lines across Stage Coach Trail and Snyder Hill Drive intersection to tie into existing 16" to provide looped connection.
- CIP 34: Extend 8" line from existing terminus of 12" line in Old Bastrop Rd. to Francis Harris, then along Francis Harris to serve power plant.

- CIP 35: Upgrade small diameter lines along S. LBJ (IH-35 to E. Grove St.) with 12" line.
- CIP 36: Extend existing 12" line further south along E. McCarty Lane toward IH-35 to connect to future growth area.

Figure 6-2 depicts the proposed 2025 system, with all pressure planes identified and minimum pressures under maximum day conditions highlighted. Appendix C contains additional figures showing minimum pressure nodes and fire flow availability results for the 2025 system.



Additional CIPs (not pictured)

CIP No.	Description
19	Drill New Well at Trunkhill or Soyars.

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FIGURE 6-2
City of San Marcos: Water Master Plan Update
System Overview with 2025 Capital Improvement Projects

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6.3 2035 SYSTEM UPDATES

Between 2025 and 2035, the population growth rate is currently projected to slow down as compared with the previous decade. Furthermore, much of the major CIP needs to support the ultimate planning horizon of 2035 will have been completed by 2025. As a result, the capital projects planned for completion between 2025 and 2035 are mostly small diameter pipe upgrades with only a few larger diameter pipeline segments remaining for completion. A fourth high service pump is also anticipated to be required at the SWTP (CIP 37) in order to satisfy regulatory requirements for pumping capacity. The pipeline projects include the following:

- CIP 38: Extension of 12" line along Old Bastrop Road (Centerpoint to Posey Rd.),
- CIP 39: Construct 12" line along IH-35 North to complete the loop around Tanger Outlets, and
- CIP 40: Complete loop along Yarrington Rd. with 12" line (connects an existing 8" to an existing 16" dead-end).

Operationally, the distribution system will operate much like it does in 2025. The Paso Robles and La Cima developments are expected to be built out by this time frame.

Figure 6-3 depicts the proposed 2035 system, with all pressure planes identified and minimum pressures under maximum day conditions highlighted. Appendix D contains additional figures showing minimum pressure nodes and fire flow availability results for the 2025 system.

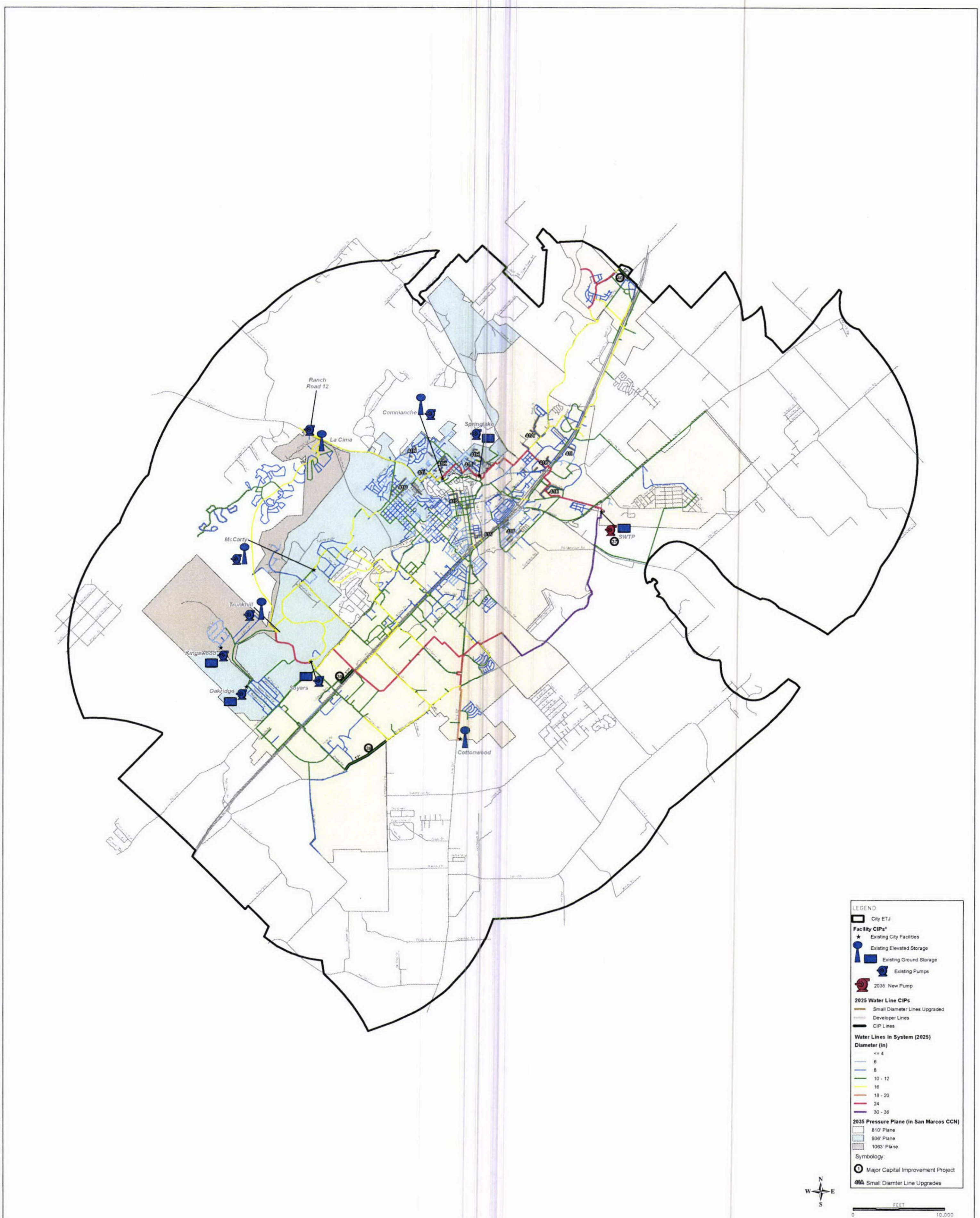

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FIGURE 6-3
City of San Marcos: Water Master Plan Update
System Overview with 2035 Capital Improvement Projects

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7 Water Quality Analyses

A water age evaluation was completed for the 2013, 2020, 2025, and 2035 average day scenarios. The hydraulic model can estimate water age for any node in the system by running an extended period simulation and determining the age of water based on travel time and model demands. This analysis is highly dependent upon system demand and the operational controls, of which there are many combinations. For each year, the average day model was run for a simulation period of 300 hours. This is a long enough period to determine water age at all points in the system.

In general, water age increases with distance from the fresh water source (the SWTP in this case). However, input from the active wells in the system will reduce water age by adding other fresh water inputs within local areas. The addition of major developments further from the source of most of the water in the distribution system (SWTP) will generate higher water ages than previously seen within the system. Since the City has already experienced high total trihalomethane (TTHM) and haloacetic acid (HAA) concentrations on occasion, service to these new areas comes with a concern for disinfection by-product related water quality related issues.

The following sections describe the results of the water age analysis for each year modeled and identify any water quality concerns. Appendix E contains figures depicting water age for each scenario. Dead end lines with zero demand nodes are not included in these figures because they will show a high water age regardless of the surrounding area's hydraulic characteristics. These are typically locations where flushing is needed to maintain chlorine residuals in the system.

7.1 EXISTING SYSTEM

Water age in the existing system varies from low water age (< 72 hours) in the central portion of the main SWTP and Upper Pressure Planes to medium water age (72 - 120 hours) as the system continues further out (Figure 7-1). Facilities at the end of long dead-end lines show the highest water age in the system. These areas of concern include the Ranch Road 12 EST and the dead-end water main serving the airport area (water age > 250 hours for both). Also, areas with a higher than average water age include the Cottonwood EST (about 150 - 200 hours) and the Blanco Vista Development (120 – 200 hours) in far northeast San Marcos.

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FIGURE 7-1
City of San Marcos: Water Master Plan Update
2013 Water Age (Average Day Run)

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7.2 2020 SYSTEM

After updating the system with the recommended 2020 projects (Figure 6-1), the water age run of the system includes the following observations (Figure 7-2). Water age in the central portion of the system (the main SWTP and Upper Pressure Planes) is still very good (generally < 48 hours). Some of the previous areas of concern show improvement. This includes the airport water mains and the Blanco Vista area (both < 48 hours now) due to increases in 2020 demands. The Cottonwood EST also shows a slight reduction in water age (now 120 – 150 hours). Phase I of the proposed La Cima Development comes online in 2020 and has a water age of 24 to 48 hours. Although this development is at the system's northwest extremity, the low water age is because all of the demand allocated to this development is fed by the proposed RR 12 EST and booster station which is fed by the Comanche tank, well, and booster pump station.

In comparison with the existing system water age run, a couple areas show a substantial increase of water age in 2020. This includes the Kingswood, Estates of San Marcos/Upper McCarty, and Hunter Road/Soyars areas. The Kingswood and Hunter Road areas now have a water age up to almost 200 hours. This is due to the Soyars well (a freshwater source in the area) being turned around to serve the first phase of the Paso Robles Development. Also, in this water age run the Kingswood well is not on. Making sure this well runs periodically is a good way to decrease the water age in this specific neighborhood. The higher water age in the Estates of San Marcos (about 200 – 250 hours) and Upper McCarty (48 – 72) is caused by the McCarty well not running in this model simulation. The Upper McCarty area feeds the Estates of San Marcos in this year. Again, running this well periodically will reduce water age in this area.

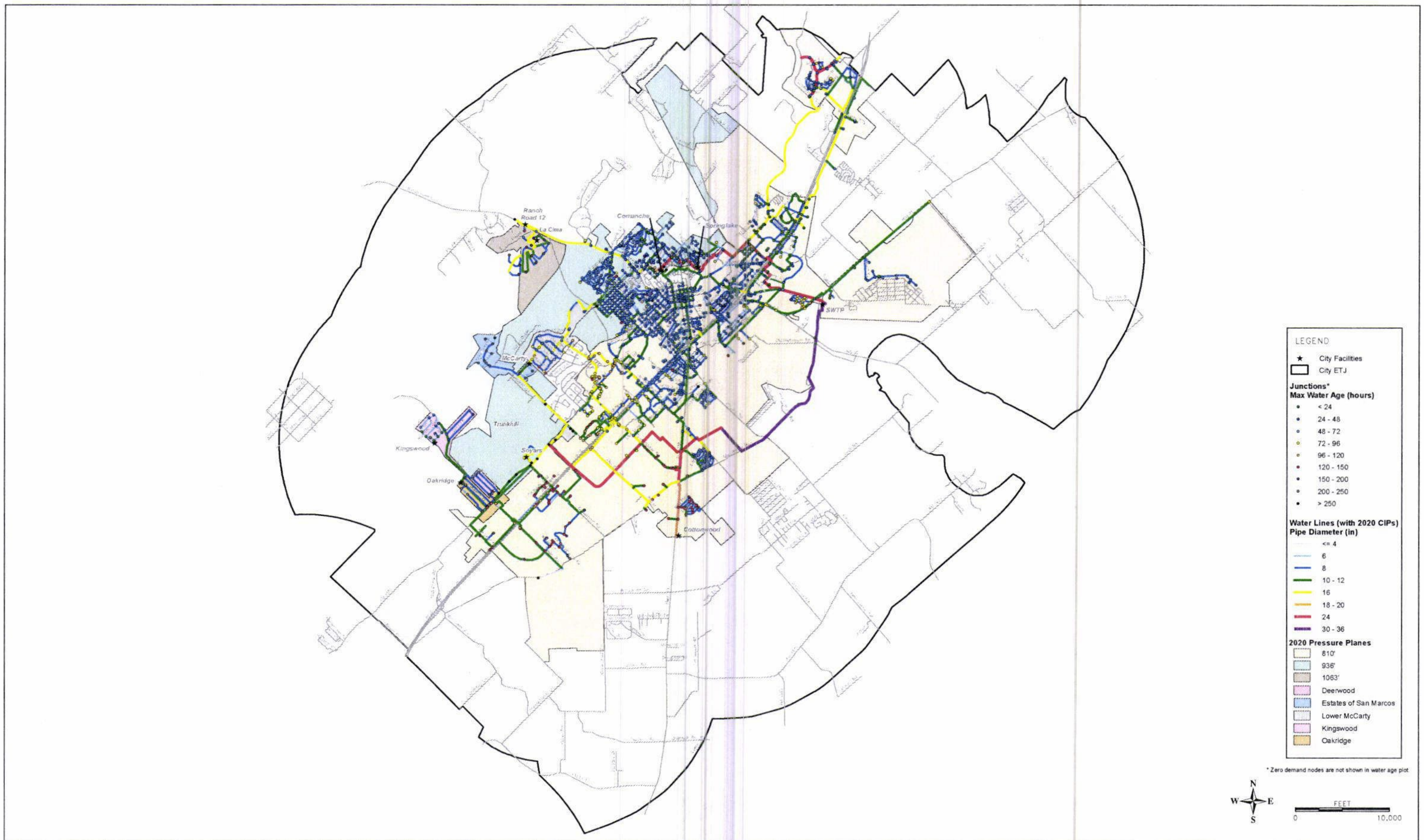

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FIGURE 7-2
City of San Marcos: Water Master Plan Update
2020 Water Age (Average Day Run)

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7.3 2025 SYSTEM

After updating the system with the recommended 2025 CIP List (Figure 6-2), the water age run of the system includes the following observations (Figure 7-3). Water age in the central portion of the system (the main SWTP and Upper Pressure Planes) is still very good. The central city part of the SWTP Plane is generally less than 48 hours and the central part of the Upper Pressure Plane is less than 72 hours.

The most significant change to the 2025 system is the expansion of the proposed Paso Robles Development which will include a new EST (Trunk Hill) and a booster pump station and connection to the La Cima Development. Paso Robles has an average water age of 72 to 96 hours. Introducing the connection from Paso Robles to La Cima increases the water age in La Cima to widely varied range (72 – 200 hours) lower in the west and higher to the east. However, as stated previously, this connection is important to provide redundancy and operational flexibility to the area. In 2025, the Estates of San Marcos is now served off the 936' Plane from a PRV on the Paso Robles to La Cima pipeline. This connection reduces the water age in the Estates of San Marcos to 48 to 120 hours.

The changes to the 2025 system also included reducing a short segment of the 16" Purgatory Creek water line (to 8") in order force the two halves of the 936' Plane to operate more independently (Subchapter 6.2). It is possible that this could be accomplish by partially closing one or more valves on this line. This change does increase the water age of the Upper McCarty Plane (72 to 120 hours).

In this scenario, water age is reduced in the Soyars/Hunter Road area (48 to 96 hours) to a medium range. This is due to the increased demands in this area as well as the completion of more sections of the Old Bastrop Highway mains and projects which complete the loop to the Soyars area (McCarty-Tanger Loop).

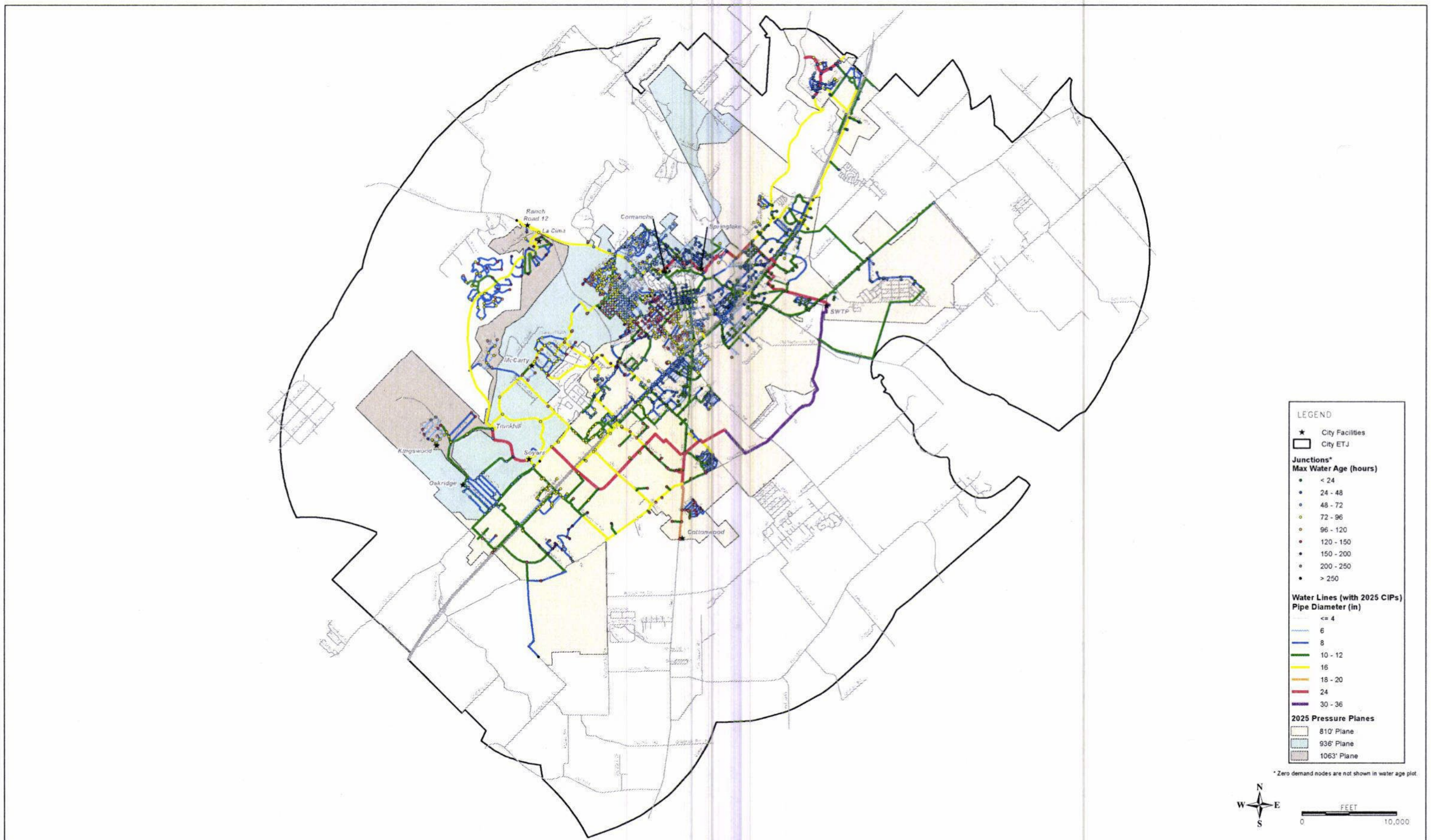

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FIGURE 7-3
City of San Marcos: Water Master Plan Update
2025 Water Age (Average Day Run)

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7.4 2035 SYSTEM

Very few projects or significant changes occur with the 2035 system CIP List (Figure 6-3). The water age run of this system includes the following observations (Figure 7-4). The additional demand in this future year scenario is the driver for water age reduction in several areas. The water age of the Cottonwood EST is reduced by about 30 hours to a medium range of 96 to 120 hours. The Kingswood area has a significant water age reduction although the range is still broad (48 – 120 hours). The central city area, the IH-35 corridor, the airport, Blanco Vista, and the Soyars/Hunter Road area all have a water age less than 72 hours. Water age in La Cima still shows a broad range (72 to 200 hours), which is greatly dependent upon demands and the water source (SWTP via Ranch Road 12 tank or SWTP via Trunk Hill EST).

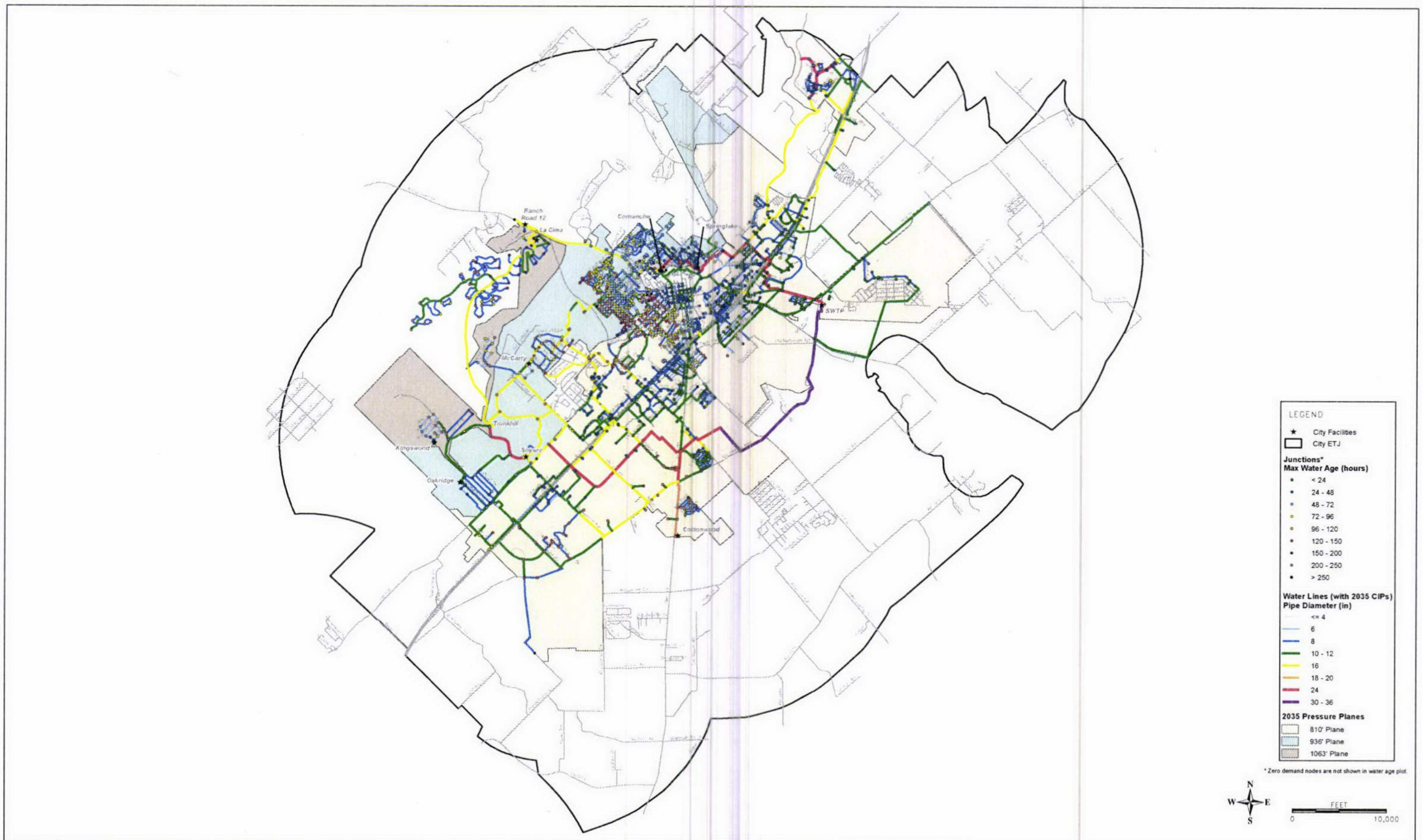

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FIGURE 7-4
City of San Marcos: Water Master Plan Update
2035 Water Age (Average Day Run)

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8 Recommended Capital Improvements

Based on the modeling scenarios run, a list of recommended capital improvements projects (CIP List) was developed for the interval between each future target year. In general, projects were identified for one of the following reasons:

- Satisfaction of regulatory requirements,
- Satisfaction of City criteria for minimum pressure,
- Improvement of water age/quality,
- Improvement of hydraulic efficiency (elimination of dead-ends, creation of looped systems), and
- Upgrading small-diameter connections (< 6-in diameter pipes)

8.1 DEVELOPMENT OF PROJECT LIST

CIP projects were identified through modeling iterations where minimum pressures, maximum headloss, elevated storage tank cycling, and water age runs were evaluated. Projects were added to address deficiencies in these areas. APAI also reviewed the regulatory requirements for supply, storage, and pumping for each pressure plane in the system (Subchapter 2.3), which resulted in the addition of a few projects. Information on proposed developments (both near-term and long-term) was reviewed and incorporated into this WMP. Two specific large developments that impact this CIP List are Paso Robles and La Cima Developments to be located in the west and northwest parts of the City. Finally, APAI met and communicated with the City on several occasions where their needs and goals for the system were conveyed. This also resulted in several additional projects. The City provided valuable input like their desire for the following:

- Upgrading all existing water lines crossing under Interstate Highway 35 (IH-35) with 16" size lines,
- Upgrading all existing water lines smaller than 8" with 8" lines by 2035. APAI included all lines that served more than one customer connection and any cul-de-sac line longer than 300-feet.
- Adding a new water well to the system by 2025 for water supply redundancy.

8.2 CIP LIST AND OPINIONS OF PROBABLE CONSTRUCTION COST

This section presents the CIP list for each future target year (Tables 8-1 through 8-3). The projects are also presented visually in Figure 8-1. The projects for each target year are listed in priority according to the information available at the time this WMP was developed. Acceleration or delay of development schedules could cause a change in priority of these projects. Appendix F contains the opinion of probable construction costs (OPCC) for the recommended CIPs. It is important to note that this CIP list is in addition to expenditures that will be required of the City due to its participation in the HCPUA project.

Table 8-1: 2020 CIP List – Pipeline and Pump Station Projects

CIP #	Description	Flow Rate or Volume	Units	TOTAL
1	New Pumps at Comanche to fill RR12 & 50 LF 16" yard piping	1250 GPM	4	$176,000
2a	New 0.5 MG Elevated Storage for 1063' Plane (La Cima EST)	0.5 MG	1	$1,347,000
2b	New Pumps at RR12 to fill La Cima Tank	720 GPM	2	$2,619,000
		1380 GPM	2	
3	Replace Soyars pumps to fill the 936' Pressure Plane (2020) and Trunk Hill in 2025.	600 GPM	2	$62,000
			2020 CIP Pump Station/Tank Total	**$4,204,000**

CIP #	Description	Diameter (in)	Length (LF)	TOTAL
4	Connect Soyars Tank to 810 Plane and temporarily convert Hunter Rd. to 936 Plane	16	1300	$266,000
5	Close gap between existing 16" in Hunter and Soyars tanks	16	2800	$567,000
6	Hunter Road from Quail Run to Centerpoint (near Soyars) Extension in 936 Plane	12	5300	$687,000
7	Complete 24" main by joining end of line at McCarty Rd to IH-35 just north of Tanger Outlets	24	6000	$2,240,000
8	Extend line from end of Stagecoach to intersection of Belvin and Bishop (existing 12" tie in).	12	3800	$504,000
9	Upsize existing 12" main to 16" main along E. McCarty Ln. just north of Old Bastrop Hwy.	16	2100	$401,000
10	Upsize 12" between existing 24" and 18" in SH 123 to 24"	24	4100	$1,531,000
11	Initial portion of Paso Robles Loop to Phase I of Development (24 homes)	16	1700	$248,000
		24	400	$103,000
12	TX 123 to E. McCarty Lane along Old Bastrop Highway	16	5000	$925,000
13	Upsize small diameter lines to 12"	12	4500	$641,000
14	Connect existing 12" (on 810 plane) in Hunter Rd to 12" in Industrial Fork Rd	12	3900	$505,000
15	Upsize 8" lines along IH-35 frontage road & provide connection to loop at Leah Ave.	12	6800	$1,227,000
16	Upgrade 8 existing IH-35 water line crossings to 16" Between McCarty & Aquarena Springs Rd.	16	3200	$1,887,000
17	Extend northeast along Airport Rd	12	9000	$1,038,000
41B	Upsize lines to 8" PVC that serve & connect Briarwood Drive neighborhood to system.	8	5100	$385,000

Table 8-1: 2020 CIP List – Pipeline and Pump Station Projects (continued)

CIP #	Description	Diameter (in)	Length (LF)	TOTAL
41M	Upsize lines to 8" PVC along Schulle Dr. in Sierra Circle neighborhood & Timbercrest St. in Tanglewood neighborhood.	8	1200	$143,000
41P	Upsize lines to 8" PVC in Southwest Hills neighborhood along N/S Loop St., Alto St., Midway St., Hazleton St., Allen St., and some surrounding side streets.	8	7900	$945,000
41Q	Upsize lines to 8" PVC in Willow Creek neighborhood (Stagecoach Trl. & Great Oaks Dr.) & Westover neighborhood (Franklin St., Progress St., & Dartmouth St.).	8	3100	$345,000
41R	Upsize lines to 8" PVC in the Heritage neighborhood along Lindsey St., Waco, St., Burt St., Hansen St., Rogers St., Scott St., Belvin St., Verimendi St., Mitchell Ave., AcAllister St., Pitt St., Harvey St., & Blanco St. Also, connect low pressure nodes along Burt, Hansen, and Blanco St. to 936' pressure plane.	8	7700	$856,000
41T	Upsize lines to 8" PVC in the Dunbar neighborhood along MLK Dr., S. Wilson St., Mead St., S. Bishop St., Faris St., Shady Ln., & Centre St.	8	5400	$601,000
41W	Upsize lines to 8" PVC in the Kingswood area (along Lazy Ln. & Mulberry Ct.).	8	8500	$1,016,000
41X	Upsize lines to 8" PVC in the Oakridge area (along Whitetail Dr., Deerwood Dr., Trails End, Hunter Ridge Rd., Hunter Rd., & Village West Dr.). Construct new 8" line between Hunter Ridge Rd and Quail Run.	8	20000	$2,391,000
41Y	Upsize lines to 8" PVC in streets along S. Old Bastrop Hwy in SE part of town (along Posey Rd., Daucshund Dr., Horace Howard Dr., & Primrose Way).	8	8900	$881,000
			2020 CIP Pipeline Total	**$20,333,000**

Table 8-2: 2025 CIP List – Pipeline and Pump Station Projects

CIP #	Description	Flow Rate or Volume	Units	TOTAL
18a	Pumps at Trunk Hill to fill La Cima Tank and deliver to 1063' pressure plane	1600 GPM	2	$2,463,000
18b	New 0.51 MG Elevated Storage for 936' pressure plane (Trunk Hill EST)	0.51 MG	1	$917,000
19	Add Well at Trunk Hill or Soyars	1100 GPM	1	$400,000
			2025 CIP Pump Station/Tank Total	**$3,780,000**

CIP #	Description	Diameter (in)	Length (LF)	TOTAL
20	Parallel of existing 20"/16" Comanche PS to Franklin St. & RR12	16	4000	$971,000
21	Central Loop in Development Phase I	16	4300	$630,000
		24	6000	$1,554,000
22	Central Loop in Development Phase 2	16	6500	$952,000
23	Connect Trunk Hill to Sleepy Hollow at Lazy Ln (include flow control valve)	12	4900	$442,000
24	Connect Paso Robles Loop to Trails End	12	4700	$424,000
25	Connect Paso Robles Loop to McCarty Ln waterlines	16	6800	$996,000
26	Trunk Hill to La Cima PS via new line to and through La Cima development. Also connect this loop to existing neighborhood (Estates of San Marcos) with an 8" new line along W. McCarty Ln. New 8" needs PRV to reduce pressure to 95 psi.	8	1300	$98,000
		16	20000	$3,097,000
27	Connect McCarty Standpipe to 810 plane via Stagecoach	16	8400	$2,038,000
28	Harris Hill Rd from Airport - connect to River Ridge Pkwy	12	9800	$1,271,000
29	Extend 12" line from existing 30" along SH 80 to edge of CCN, then north along property boundaries to connect to dead end at airport.	12	17000	$2,232,000
30	McCarty to Centerpoint Extension along Old Bastrop Highway	16	5400	$999,000
31	Upgraded lines along Clovis Barker to 16" to tie into existing 24". Also upgraded lines along IH-35 to 16" to tie into existing 16" lines.	16	5100	$1,040,000
32	Old Bastrop to Existing Line	16	3800	$703,000
33	Upsize 12" & 8" lines across Stagecoach Trail to tie into existing 16" lines on either side.	16	100	$24,000

Table 8-2: 2025 CIP List – Pipeline and Pump Station Projects (continued)

CIP #	Description	Diameter (in)	Length (LF)	TOTAL
34	Extend 8" line from existing terminus of 12" line in Old Bastrop to Francis Harris, then along Francis Harris to power plant.	8	13300	$772,000
35	Upgrade small diameter line in S. LBJ from E. Grove St. to IH-35 Crossing	12	1700	$242,000
36	Extend existing 12" line further south along E. McCarty Lane toward IH-35 to connect to future growth area.	12	1100	$157,000
41D	Upsize lines to 8" PVC along Aquarena Springs Dr. & nearby lines north of IH-35 (all in Millview West neighborhood).	8	3000	$309,000
41G	Upsize lines to 8" PVC in Rio Vista neighborhood (NW of IH-35 & RR 12).	8	6800	$700,000
41U	Upsize lines to 8" PVC in Victory Gardens (Sherwood St., Weatherford St., Jones St., & Armstrong St.) & Sunset Acres (Del Sol St.) neighborhoods.	8	3100	$319,000
			2025 CIP Pipeline Total	**$19,970,000**

Table 8-3: 2035 CIP List – Pipeline and Pump Station Projects

CIP #	Description	Flow Rate or Volume	Units	TOTAL
37	New Pump at SWTP Pump Station	3250 GPM	1	$473,000
			2035 CIP Pump Station/Tank Total	**$473,000**

CIP #	Description	Diameter (in)	Length (LF)	TOTAL
38	Centerpoint to Posey Rd Extension along Old Bastrop Highway, Include connection to existing line on Horace Howard Dr.	12	5700	$675,000
39	Connect existing 24" to end of proposed 12" developer line along IH-35 north of Centerpoint	12	2100	$379,000
40	New 12" line connecting end of 16" in Blanco Vista Blvd to 8" line in Post Rd via Yarrington Rd	12	1700	$201,000
41A	Upsize lines to 8" PVC along & north of Post Road including Claremont Dr.	8	5300	$634,000
41C	Upsize lines to 8" PVC that serve areas along IH-35 in Millview East neighborhood including Miller Tree & Meiners St.	8	1900	$196,000
41E	Upsize lines to 8" PVC along Davis Lane, south of IH-35 in Two Rivers East neighborhood area.	8	4200	$432,000
41F	Upsize lines to 8" PVC in Blanco Gardens neighborhood. Includes lines south of IH-35 in mostly residential area crossing Sherbarb St. & along Conway Dr.& Sturgeon Dr.	8	4100	$422,000
41H	Upsize lines to 8" PVC in Spring Lake Hills neighborhood (E. & W. Mimosa Circle & around Rodger's Ridge St.)	8	4800	$574,000
41I	Upsize lines to 8" PVC in Fairlawn neighborhood along Crepe Myrtle Dr. & IH-35 frontage road.	8	1300	$134,000
41J	Upsize lines to 8" PVC in Forest Hills neighborhood along cul-de-sacs on Quail Creek Dr. & near Peques St.	8	800	$96,000
41K	Upsize lines to 8" PVC in Sessom Creek neighborhood.	8	3100	$371,000
41L	Upsize lines to 8" PVC on short cul-de-sac streets in Holland Hills neighborhood.	8	300	$36,000

Table 8-3: 2035 CIP List – Pipeline and Pump Station Projects (continued)

CIP #	Description	Diameter (in)	Length (LF)	TOTAL
41N	Upsize lines to 8" PVC in Hughson Heights neighborhood (Hughson Ct., Manor Park Rd., & other side streets).	8	1300	$155,000
41O	Upsize lines to 8" PVC in Oak Heights neighborhood along Franklin St., Larue Dr., Indiana St., & Heavenly Hills.	8	5300	$634,000
41S	Upsize lines to 8" PVC in Downtown on Lindsey St., Pat Garison St., N. Fredericksburg St., & side streets/alleys along RR 12.	8	4100	$490,000
41V	Upsize lines to 8" PVC in East Guadalupe area (along Lee St., McKie St., Mariposa St., & Rincon St.) & Wallace Addition (y).	8	3600	$370,000
			2035 CIP Pipeline Total	**$5,799,000**

In developing the above CIP costs, the Texas Water Development Board's (TWDB) Unified Costing Model (UCM) was used as a guide for pipelines and pump stations. However, these values were also compared to recent bid tabulations for the City of San Marcos. Recent bids suggested that the UCM values should be adjusted by a factor of 1.48 for all pipelines. New pump stations were estimated using UCM values as a function of required horsepower. Individual pump costs were estimated by verifying costs with vendors. All costs based on the UCM values were then updated from the last UCM publication in March 2012 to July 2015 dollars using Engineering News Record (ENR) construction cost index (CCI) values.

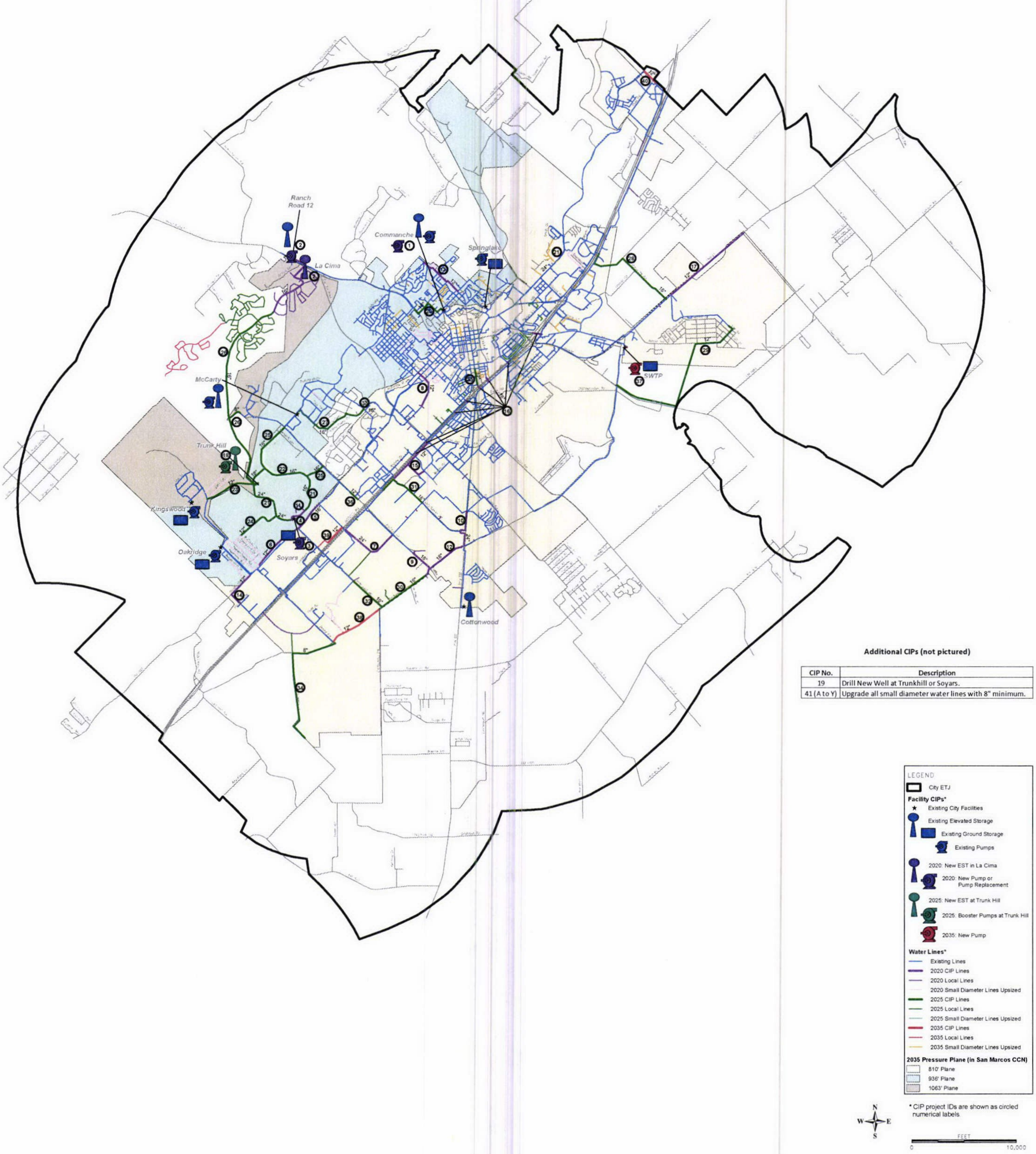
For pipelines, costs per linear foot were determined by estimating substrate type in the area (rock or soil) as well as the development density along the route (urban or rural), and then looking up the value for the proposed diameter in the appropriate table in the UCM. The UCM cost was then multiplied by the COSM adjustment factor of 1.48 and then brought to present value using the ENR CCI.

For new pump stations, required horsepower (HP) was determined and recent bid tabs were used to estimate costs for stations with HP values from 80 to 200. Stations with HP values outside this range were interpolated from the UCM table for new pump stations. Costs were then brought to present value using the ENR CCI.

For tanks, recent bid tabulations and UCM values were compared to estimate costs for new tanks. Costs were then brought to present value using the ENR CCI.

Land costs associated with easements were estimated using recent Hays County appraisal values where available. If no appraisal values were available in the area, best engineering judgement was used to estimate land costs.

Pavement repair costs were estimated using recent bid tabs. Costs were then brought to present value using the ENR CCI.



Additional CIPs (not pictured)

CIP No.	Description
19	Drill New Well at Trunkhill or Soyars.
41 (A to Y)	Upgrade all small diameter water lines with 8" minimum.

ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS

FIGURE 8-1
City of San Marcos: Water Master Plan Update
Capital Improvement Projects: 2020, 2025, & 2035

Document Path: M:\Projects\0600\022-01\GIS\REPORT_FIGURES\v4\FIG03_CIPs_34x44_v10_v2.mxd

8.3 IMPACT FEE PROJECTS

During the preparation of the WMP, the City requested that APAI evaluate the City's method for identifying the Service Unit Equivalents (SUE) used in the computation of its Impact Fees. APAI evaluated the method and compared the results to information obtained from the AMI data. APAI concluded that the number of SUEs assigned under the City's method did not accurately reflect the impacts that developments with larger meters have on the City's system. APAI recommended that the system be modified based on actual data from the City's AMI. A copy of the memorandum summarizing this evaluation is included in Appendix G.

As a result of this recommendation, as well as the update to the City's WMP, a new Impact Fee should be calculated. CIP Projects that are planned to be implemented in the next 10 years to meet future growth are eligible to be included in the development of a new Impact Fee. The following list of projects is considered to be projects intended to serve the growth of the system. In addition, all costs associated with the City's participation in the HCPUA should be considered eligible for Impact Fee inclusion.

Table 8-4: Impact Fee Eligible Projects

Pump Station and Tank Projects:

CIP #	Year	Description	Flow Rate or Volume	Units	TOTAL
1	2020	New Pumps at Comanche to fill RR12 & 50 LF 16" yard piping	1250 GPM	4	$176,000
2a	2020	New 0.5 MG Elevated Storage for 1063' Plane (La Cima EST)	0.5 MG	1	$1,347,000
2b	2020	New Pumps at RR12 to fill La Cima Tank	720 GPM	2	$2,619,000
			1380 GPM	2	
3	2020	Replace Soyars pumps to fill the 936' Pressure Plane (2020) and Trunk Hill in 2025.	600 GPM	2	$62,000
18a	2025	Pumps at Trunk Hill to fill La Cima Tank and deliver to 1063' pressure plane	1600 GPM	2	$2,463,000
18b	2025	New 0.5 MG Elevated Storage for 936' pressure plane (Trunk Hill EST)	0.51 MG	1	$917,000
19	2025	Add Well at Trunk Hill or Soyars	1100 GPM	1	$400,000
37	2035	New Pump at SWTP Pump Station	3250 GPM	1	$473,000

Table 8-4: Impact Fee Eligible Projects (continued)

Pipeline Projects:

CIP #	Year	Description	Diameter (in)	Length (LF)	TOTAL
4	2020	Connect Soyars Tank to 810 Plane	16	1300	$266,000
5	2020	Close gap between existing 16" in Hunter and Soyars tanks	16	2800	$567,000
7	2020	Complete 24" main by joining end of line at McCarty Rd to IH-35 just north of Tanger Outlets	24	6000	$2,240,000
8	2020	Extend line from end of Stagecoach to intersection of Belvin and Bishop (existing 12" tie in).	12	3800	$504,000
9	2020	Upsize existing 12" main to 16" main along E. McCarty Ln. just north of Old Bastrop Hwy.	16	2100	$401,000
10	2020	Upsize 12" between existing 24" and 18" in SH 123 to 24"	24	4100	$1,531,000
11	2020	Initial portion of Paso Robles Loop to Phase I of Development (24 homes)	16	1700	$351,000
			24	400	
12	2020	TX 123 to E. McCarty Lane along Old Bastrop Highway	16	5000	$925,000
15	2020	Upsize 8" lines along IH-35 frontage road & provide connection to loop at Leah Ave.	12	6800	$1,227,000
17	2020	Extend northeast along Airport Rd	12	9000	$1,038,000
20	2025	Parallel of existing 20"/16" Comanche PS to Franklin St. & RR12	16	4000	$971,000
21	2025	Central Loop in Development Phase I	16	4300	$630,000
			24	6000	$1,554,000
22	2025	Central Loop in Development Phase 2	16	6500	$952,000
24	2025	Connect Paso Robles Loop to Trails End	12	4700	$424,000
25	2025	Connect Paso Robles Loop to McCarty Ln waterlines	16	6800	$996,000
26	2025	Trunk Hill to La Cima PS via new line to and through La Cima development. Also connect this loop to existing neighborhood (Estates of San Marcos) with an 8" new line along W. McCarty Ln. New 8" needs PRV to reduce pressure to 95 psi.	16	20000	$3,097,000
27	2025	Connect McCarty Standpipe to 810 plane via Stagecoach	16	8400	$2,038,000
28	2025	Harris Hill Rd from Airport - connect to River Ridge Pkwy	12	9800	$1,271,000

Table 8-4: Impact Fee Eligible Projects (continued)

Pipeline Projects:

CIP #	Year	Description	Diameter (in)	Length (LF)	TOTAL
29	2025	Extend 12" line from existing 30" along SH 80 to edge of CCN, then north along property boundaries to connect to dead end at airport.	12	17000	$2,232,000
30	2025	McCarty to Centerpoint Extension along Old Bastrop Highway	16	5400	$999,000
31	2025	Upgraded lines along Clovis Barker to 16" to tie into existing 24". Also upgraded lines along IH-35 to 16" to tie into existing 16" lines.	16	5100	$1,040,000
32	2025	Old Bastrop to Existing Line	16	3800	$703,000
34	2025	Extend 8" line from existing terminus of 12" line in Old Bastrop to Francis Harris, then along Francis Harris to power plant.	8	13300	$772,000
36	2025	Extend existing 12" line further south along E. McCarty Lane toward IH-35 to connect to future growth area.	12	1100	$157,000
38	2035	Centerpoint to Posey Rd Extension along Old Bastrop Highway, Include connection to existing line on Horace Howard Dr.	12	5700	$675,000
39	2035	Connect existing 24" to end of proposed 12" developer line along IH-35 north of Centerpoint.	12	2100	$379,000

Appendix A

Existing System Hydraulic Model Development & Calibration Technical Memorandum

APAI, November 2014

ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS • DESIGNERS • SCIENTISTS

TECHNICAL MEMORANDUM

City of San Marcos
Water Master Plan Update
Existing System Hydraulic Model Development and Calibration

Project No.: 0600-022-01

Date: November 7, 2014

Prepared For: David Rabago, P.E. – City of San Marcos (COSM)

Prepared By: Jarad Stockton, P.E., PMP – Alan Plummer Associates, Inc. (APAI)

cc: Jon Clack, Laurie Moyer, Tom Taggart - COSM

PURPOSE

This memorandum details the steps taken to update and calibrate the City of San Marcos (City) water distribution system model, which was last calibrated in 2007. While the 2007 model was periodically updated in recent years to address new development, a recalibration has not been performed. In addition, the Water Master Plan Update model was rebuilt within a new software platform that resides within a geospatial information systems (GIS) environment. This new model, developed using Innovyze InfoWater Version 12 software, was constructed from the City's recently updated GIS data and calibrated to hydraulic data collected in April 2014. Modeled tank levels, pump status (and flow rates, when available), and system pressures were compared to actual data compiled during a data collection event in order to calibrate the updated model.

INTRODUCTION

The development of a water distribution system model requires input of three basic types of information. First, the locations and attributes of all physical components making up the distribution system (including pumping and storage facilities, storage tanks, distribution piping, and pressure reducing valves) must be identified. Second, the magnitude and spatial distribution of water demands associated with customer meters within the distribution system must be identified and simulated. Third, the hydraulic operation of the system must be documented and simulated using "controls" within the model. "Controls" are logical constraints that indicate the conditions upon which pumps (or valves) are to be operated such that appropriate pressures can be maintained within the system. Finally, to establish that the model is capable of representing the dynamic system operation and response, calibration of the model to field collected system data using an extended period simulation (EPS) is required. Alan Plummer Associates, Inc. (APAI) has calibrated the revised model to field testing data collected in April 2014 as described in the Field Data Summary Technical Memorandum, dated June 2014.

HYDRAULIC DATA COLLECTION

Over a ten day period from 12:00 a.m. April 4 through 12:00 a.m. April 16, the City deployed ten portable pressure data recorders in selected locations around the distribution system. This data, together with Supervisory, Control, and Data Acquisition (SCADA) data for tank levels, pump status (and flow rates where available), and other permanent pressure monitoring stations, provided the necessary hydraulic data on which to base the model calibration. From the ten days of available data, the 72-hour period from 12:00 a.m., April 9 through 12:00 a.m., April 12, was selected as the calibration period. Thus, the EPS will attempt to simulate SCADA and field data for this time frame.

Unfortunately, during the review of the SCADA data from the hydraulic data collection event, APAI identified several anomalies that would negatively affect the model calibration. Specifically, higher than expected pressures in the downtown area led to speculation of an open connection between pressure planes, as well as pump speed reporting errors caused by excessive power delivery to one of the pumps at the Surface Water Treatment Plant (SWTP) High Service Pump Station (HSPS).

A subsequent investigation by City staff identified a partially open valve on an 8-inch line in the vicinity of the abandoned Midway Tank which enabled water to bleed from the Upper Pressure Plane to the SWTP Pressure Plane. In addition, City staff have purposefully been bleeding water through a partially open valve on a 12-inch line from the Upper McCarty Pressure Plane to the Lower Pressure Plane just downstream of the McCarty Pump Station to minimize cavitation and cycling times in the significantly oversized pumps at that station.

Ultimately, however, model calibration was achieved successfully. The availability of hourly metering data was critical to the success of the calibration. The following sections describe the calibration procedure and results of the existing system model calibration effort.

PHYSICAL INFRASTRUCTURE

The first and most basic input to a hydraulic model reflects the physical infrastructure in place at the time calibration data is collected. As of April 2014, the City's water distribution system consisted of:

- Approximately 1,340,000 feet of pipe
- Approximately 3,000 modeled demand nodes
- Eight (8) wells and well pumps
- Nine (9) storage tanks
- Two (2) hydropneumatic tanks
- Six (6) active pump stations, with an additional station (Spring Lake) held in reserve (and occasionally cycled) for emergency needs; and
- Six (6) active pressure reducing valves (PRVs)

The above facilities serve a distribution system comprised of seven distinct pressure planes, as described below in Table 1.

Table 1: Pressure Planes

Pressure Plane	Operational Hydraulic Grade Overflow (ft)
SWTP	810
Upper	936
Lower McCarty	857
Upper McCarty	948
Oakridge	889
Deerwood	888
Kingswood	1,060

The following sections describe the distribution facilities in detail. Figure 1 depicts an overview of the entire distribution system.

Water Sources

The majority of the water in the distribution system is surface water treated at the SWTP by the Guadalupe-Blanco River Authority (GBRA). The surface water comes from the Guadalupe River via a raw water pipeline from the intake on a canal extending from Lake Dunlap.

The City also operates and maintains eight wells as follows:

1. Two wells each at the Spring Lake and Oakridge pump stations
2. One well each at the Comanche, McCarty, Soyars, and Kingswood pump stations

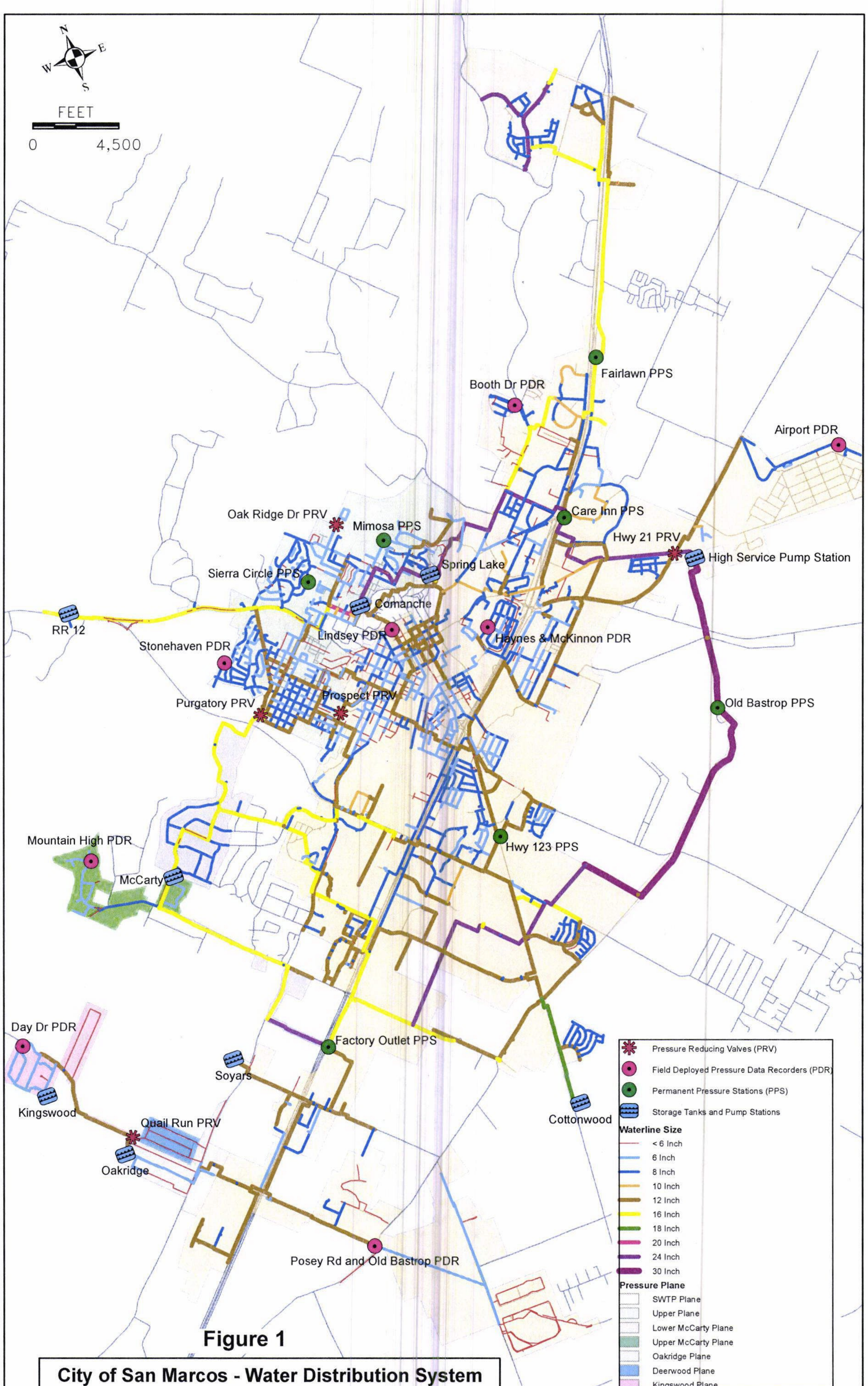


Figure 1

City of San Marcos - Water Distribution System

The wells at Spring Lake are maintained primarily as backup supply and are only activated occasionally to maintain the facilities (i.e., flushing the storage tank and exercising the well pumps). The two wells at Oakridge are also maintained only for emergency use, as these wells have had water quality issues in the past. The Oakridge wells may be abandoned altogether in the future. The wells at Comanche, McCarty, Kingswood, and Soyars pump stations are currently used to maintain tank levels at their respective stations.

All of these sources are generally modeled as free-surface "reservoirs" in the hydraulic model, with an appropriate surface elevation that roughly corresponds to the typical clearwell elevation at the SWTP and to aquifer levels at each of the wells.

Pump Stations

The primary inputs to the InfoWater model with respect to the pump stations include the pump curves (head versus flow relationship) of each individual booster pump (and the well pump(s), if present), as well as pump elevations. Under normal operation, the City's water distribution system is actively served by a total of six pump stations. An additional pump station (Spring Lake) is maintained for emergency use.

Since the system head versus pump output curve for each pump declines over time, APAI recommended pump performance testing on each pump at the SWTP High Service Pump Station and the Comanche Pump Station. These pumps serve the majority of the demand in the system. The pump curves determined by testing were input to the model directly, representing current performance. The results of pump performance testing were provided in the Field Data Summary Technical Memorandum (June 2014).

The remaining pumps at the Soyars, Oakridge, McCarty, Kingswood, and Spring Lake pump stations were not tested. Where appropriate, the factory pump curve was entered if the pumps were relatively new (such as for the Oakridge Pump Station). Otherwise, the curve input was used as a calibration knob to match system performance.

Storage Tanks

The City operates and maintains nine storage tanks within the distribution system. Ground storage tanks are present at the Comanche, McCarty, Soyars, Oakridge (two tanks), and Kingswood pump stations. The Comanche and McCarty tanks also serve as elevated storage for the SWTP and Lower McCarty pressure planes, respectively. In addition, the Ranch Road 12 (RR12) Tank serves as elevated storage for the Upper Pressure Plane and the Cottonwood Tank serves as elevated storage for the SWTP Plane.

The Spring Lake Tank is not active on a daily basis and serves primarily as emergency backup supply storage. GBRA operates the clearwell storage at the SWTP, which feeds the SWTP HSPS.

Tank geometry was input to the InfoWater model per the following table:

Table 2: Storage Tank Geometries

Name	Ground Elevation	Base Elevation	Overflow	Diameter	Operating Capacity (gal)	Inlet Diameter	Outlet Diameter
RR 12	905	905	936	74	1,000,000	16"	16"
Comanche	762	762	810*	50	750,000	24", 12"	12"
McCarty	758	758	857	30	500,000	N/A**	20"
Oakridge (2)	737.5	737.5	761	18	45,000	12"	12"
Kingswood	890	890	906	20	37,000	N/A	6"
Cottonwood	662.5	771	810	70	1,000,000	18"	18"
Spring Lake	628	628	654	100	1,500,000	N/A	24"
Soyars	735	735	805***	30	370,000	N/A	12"

*Comanche Tank overflow is physically 826', but the current maximum operating level is 810';
**N/A = inlet and outlet pipe are the same pipe,
***Soyars Tank overflow is physically 830', but the current maximum operating level is 805'.

In addition to the above storage tanks, two hydropneumatic tanks are currently in use within the City's distribution system. These two tanks are located downstream of the Oakridge and Kingswood Pump Stations. As InfoWater cannot directly simulate a hydropneumatic tank, APAI simulated these tanks using small diameter standpipes such that the geometry of the standpipe would simulate the behavior and outlet pressure of the hydropneumatic tank.

Pipe Network

The City of San Marcos distribution system consisted of over 1,340,000 feet of pipeline as of April 2014. The majority of this pipe is either ductile iron or polyvinyl chloride (PVC). The pipe network was input to the model through an import process based on the City's GIS data. Connectivity was established using InfoWater tools and APAI prior knowledge.

Friction factors (Hazen-Williams C-Factors) were assigned to each pipe based on the previously calibrated WaterCAD model. New PVC pipes were generally given C-Factors of 150, while new ductile iron pipes were given C-factors of 130. Some C-factors were adjusted during the calibration process. Since no hydrant flow tests were performed, individual site-specific C-Factors could not be determined[1].

Pressure Reducing Valves

There are six PRVs within the City's distribution system. Downstream pressure settings input to the InfoWater model are described in Table 3.

Table 3: Input Pressure Reducing Valves Setting

PRV	Upstream Pressure Plane	Downstream Pressure Plane	Downstream Pressure Setting (psi)	Downstream Head Setting (ft)
Highway 121	SWTP	SWTP (Airport)	78	753
Purgatory	Upper	Lower McCarty	74.5	844
Prospect	Upper	SWTP	55	796
Oak Ridge Dr.	Upper	Upper	46	840
Quail Run	Kingswood	Deerwood	59	888
Oakridge	Kingswood	Oakridge	64.4	889

SYSTEM DEMANDS

The second component of model input required for calibration is demand. The magnitude, spatial distribution, and timing of system demands must be representative of those present during the hydraulic data collection period for calibration to be successful.

Unlike many utilities, the City of San Marcos has implemented advanced metering infrastructure (AMI) system-wide, a process by which all water meters were replaced with "smart meters" capable of transmitting data to a centralized data storage facility on an hourly basis. This process was completed in 2013. As a result, the City was able to provide APAI with hourly usage data for every single metered connection active in the distribution system (approximately 11,000 meters) during the hydraulic data collection period of April 4 – 16. While hydraulic models cannot directly accept input data for that many individual meters, the presence of smart meters is nevertheless a boon to the calibration process. Normally, intraday diurnal curves can only be estimated from gross production and consumption data, which are then adjusted to match available tank level data. With AMI, diurnal patterns for various types of meters and pressure planes could be determined directly from the available demand data.

[1] Refer to the Technical Memorandum, Summary of Field Data Collection (June 2014)

Diurnal patterns input to the model were specified for the calibration period (April 9-11), as determined from hourly data. As such, each diurnal pattern consist of 72 hourly values, normalized to the average value over the 72-hour period. Individual meter data was aggregated into 15 different diurnal patterns as a function of usage type, pressure plane, and meter size. Table 4 describes the patterns used, while Figures 2 through16 depict the diurnal demand variation for each pattern.

Table 4: Pattern Descriptions

Pattern No.	Usage	Pressure Plane	Meter Size(s)
1	Irrigation	SWTP	- all sizes -
2	Irrigation	-all other planes-	- all sizes -
3	Domestic	SWTP	>= 2"
4	Domestic	Upper	>= 2"
5	Domestic	SWTP	>= 0.75" and < 2"
6	Domestic	Upper	>= 0.75" and < 2"
7	Domestic	Lower McCarty	>= 0.75" and < 2"
8	Domestic	Oakridge	>= 0.75" and < 2"
9	Domestic	SWTP	5/8"
10	Domestic	Upper	5/8"
11	Domestic	Lower McCarty	5/8"
12	Domestic	Upper McCarty	5/8"
13	Domestic	Deerwood	5/8"
14	Domestic	Oakridge	5/8"
15	Domestic	Kingswood	5/8"

Demand Distribution

To allocate demands from individual meters to model nodes, GIS analyses were performed to identify the closest node (on a pipe less than or equal to 12" in diameter) within the same pressure plane as the meter. As InfoWater can manage up to ten different demand values on a single node, the individual meter demands were aggregated onto the model nodes as function of usage and meter size categories. Each demand on a given node was then assigned a specific pattern based on the usage, meter size, and pressure plane of the node per Table 4. In this manner, the metered demands were aggregated onto the model nodes while retaining a pattern representative of the average metered demands as a function of usage, meter size, and pressure plane

Figure 2
Diurnal Demand Pattern
Irrigation Meters in SWTP Plane
April 9-11, 2014

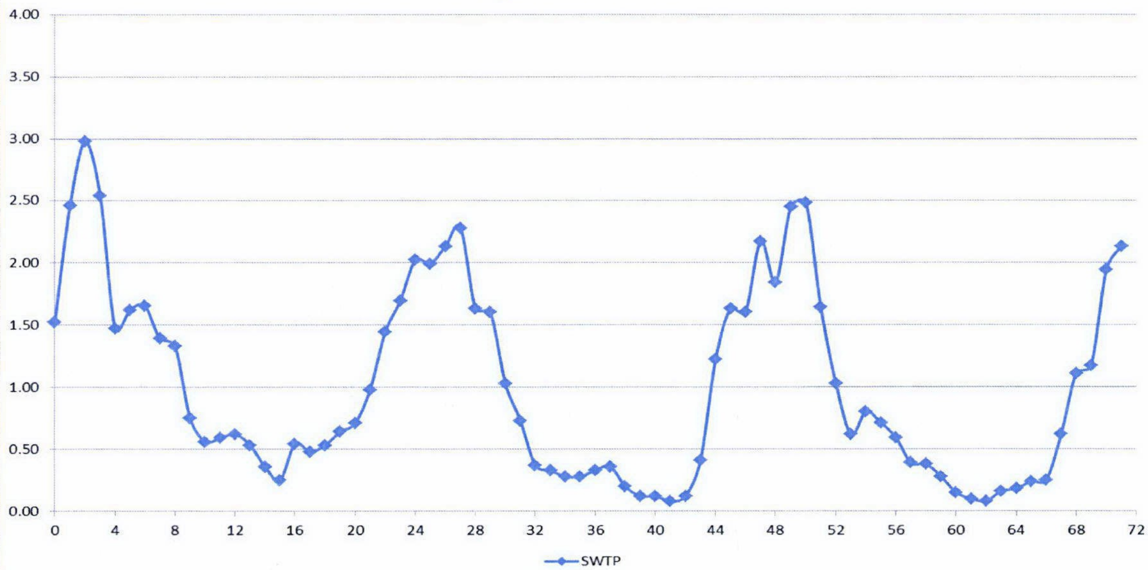


Figure 3
Diurnal Demand Pattern
Irrigation Meters Not in SWTP Plane
April 9-11, 2014

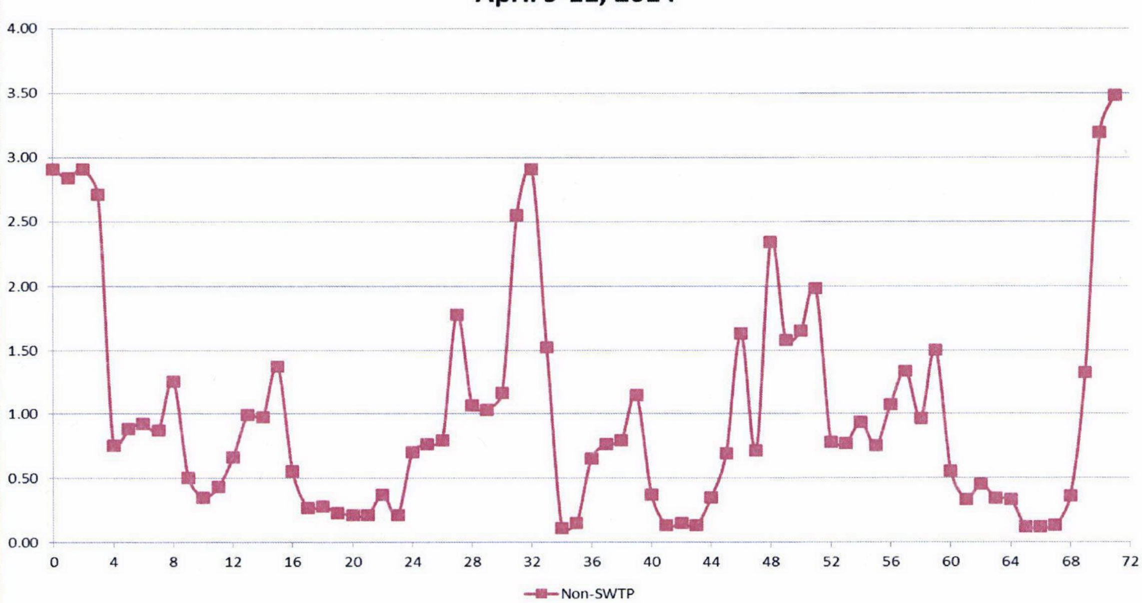


Figure 4
Diurnal Demand Pattern -
Domestic Meters (Dia. 2" and Greater) in SWTP Plane
April 9-11, 2014

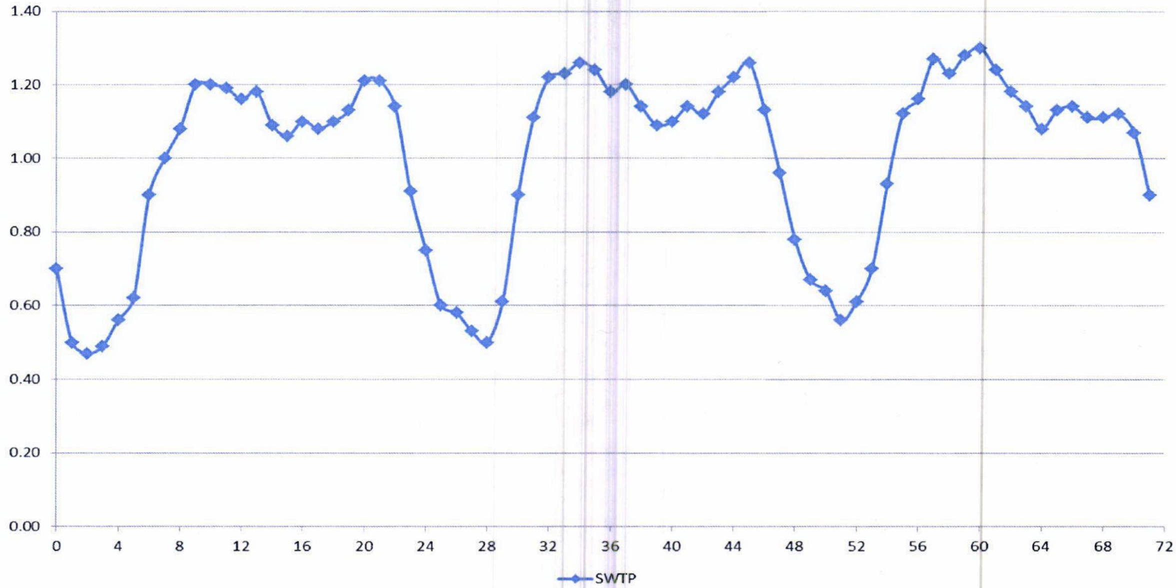


Figure 5
Diurnal Demand Pattern -
Domestic Meters (Dia. 2" and Greater) in Upper Plane
April 9-11, 2014

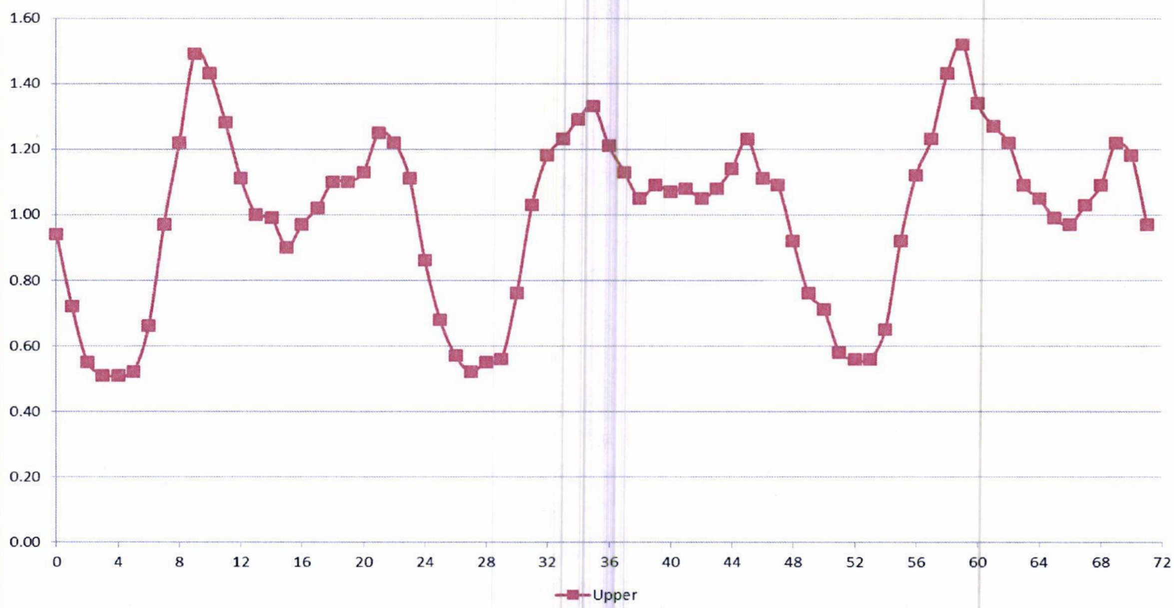


Figure 6
Diurnal Demand Pattern - Domestic Meters (Dia. 0.75" to 1.5") in SWTP Plane
April 9-11, 2014

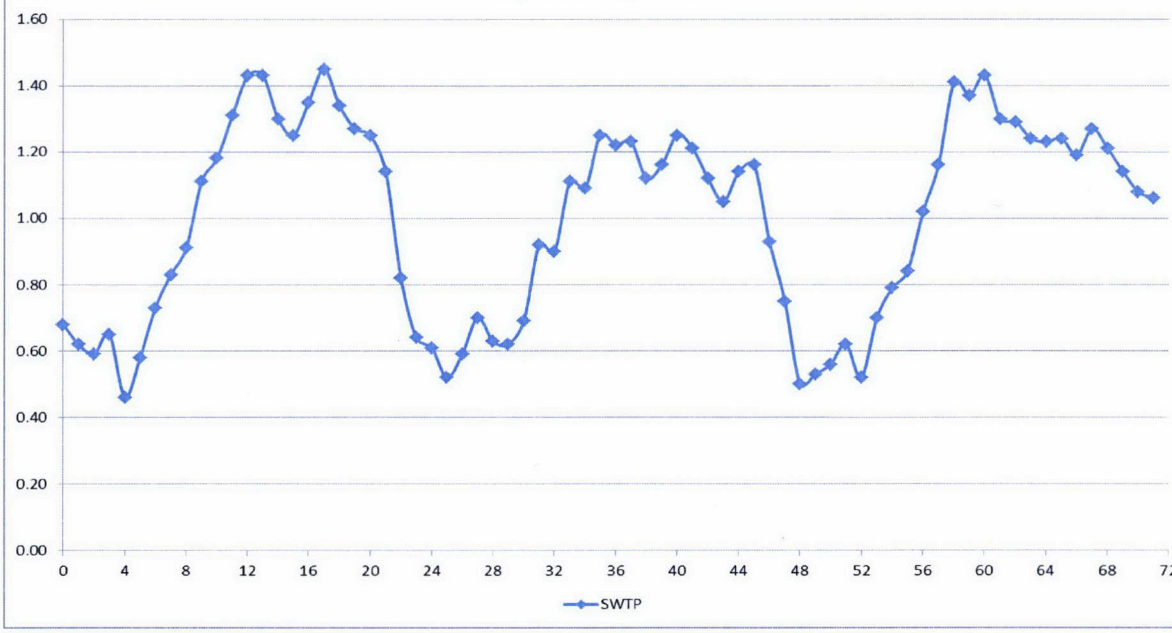


Figure 7
Diurnal Demand Pattern - Domestic Meters (Dia. 0.75" to 1.5") in Upper Plane
April 9-11, 2014

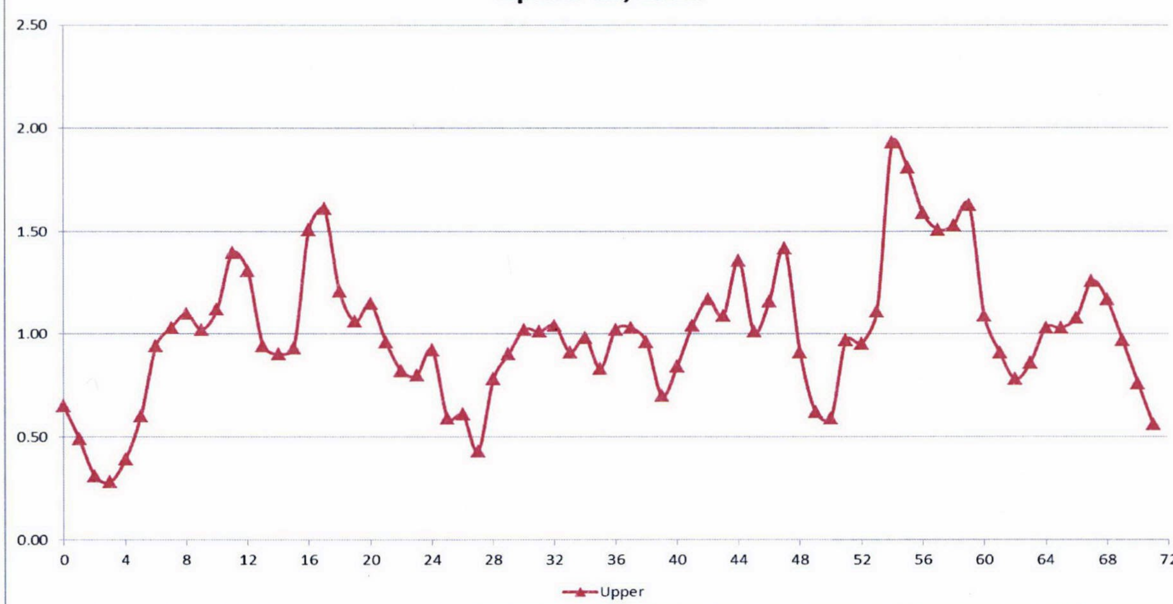


Figure 8
Diurnal Demand Pattern -
Domestic Meters (Dia. 0.75" to 1.5") in Lower McCarty Plane
April 9-11, 2014

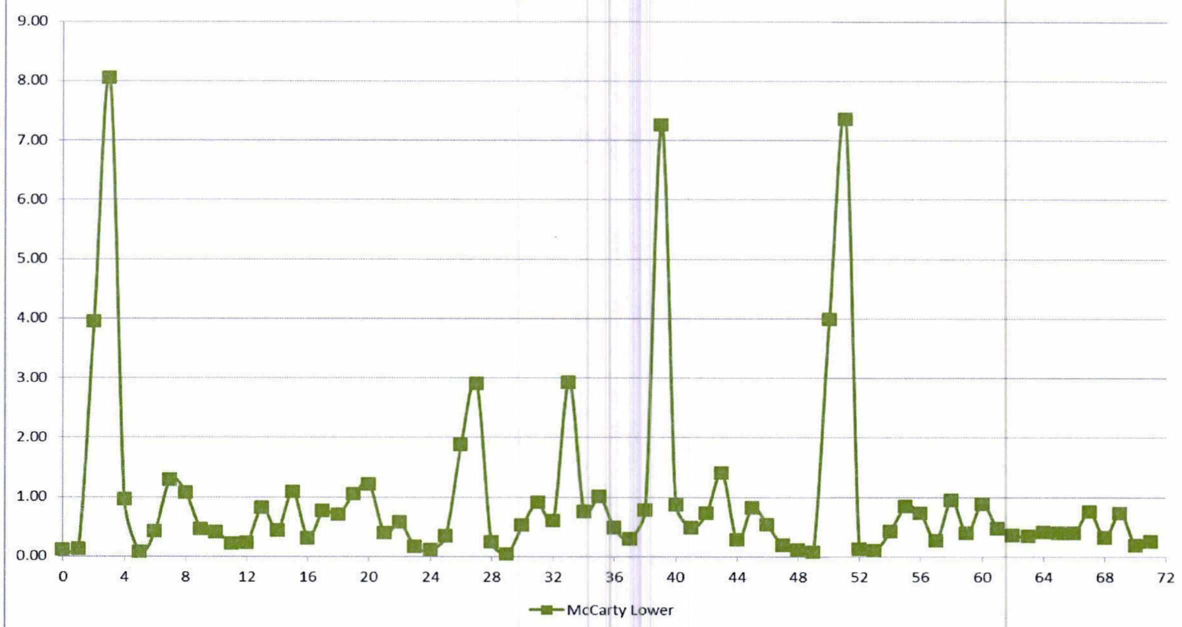
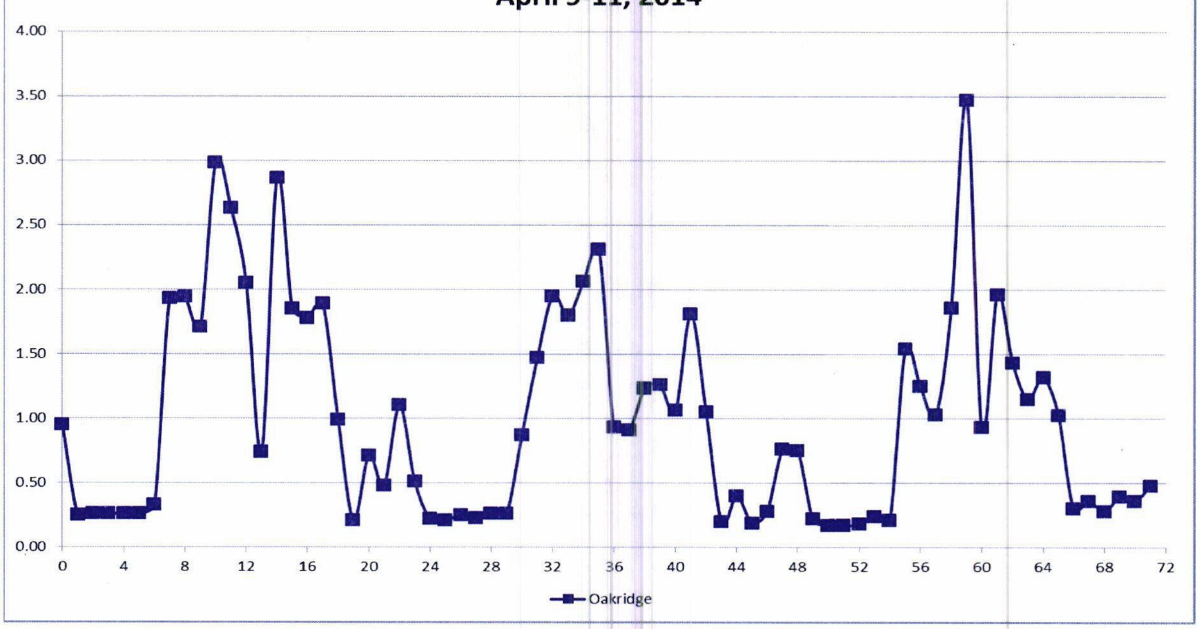


Figure 9
Diurnal Demand Pattern -
Domestic Meters (Dia. 0.75" to 1.5") in Oakridge Plane
April 9-11, 2014



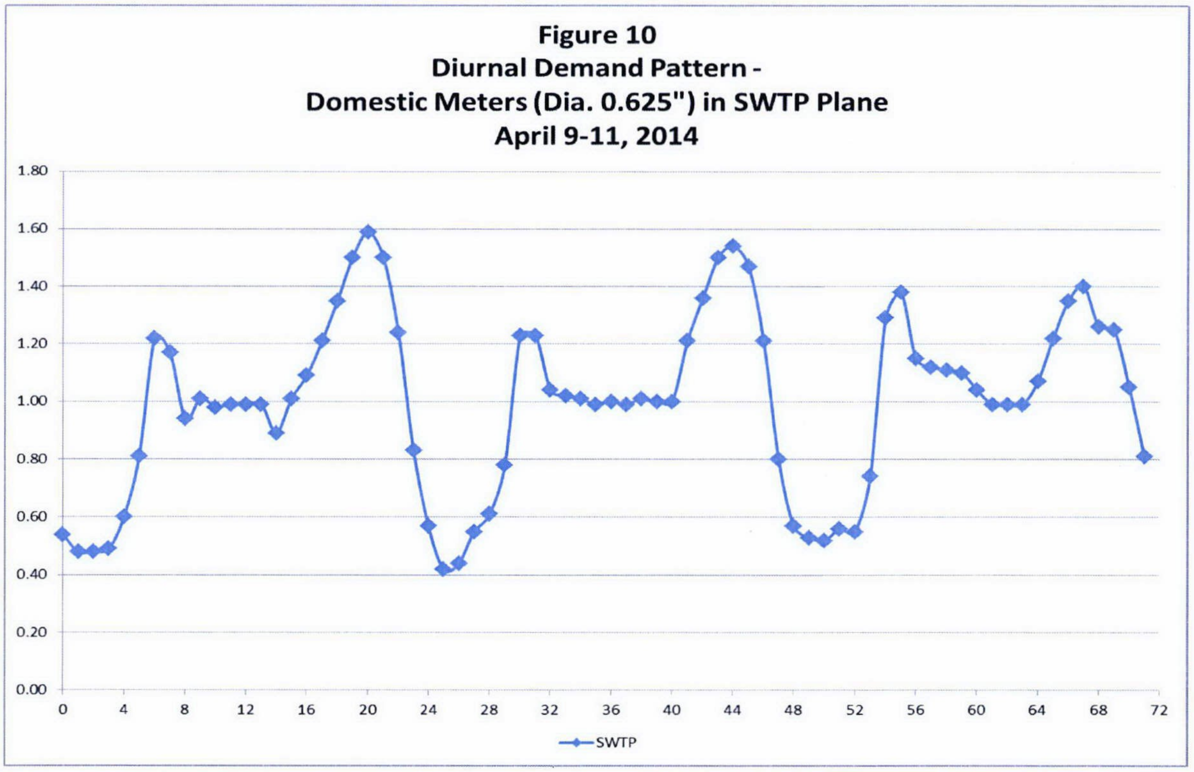


Figure 10
Diurnal Demand Pattern -
Domestic Meters (Dia. 0.625") in SWTP Plane
April 9-11, 2014
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
SWTP

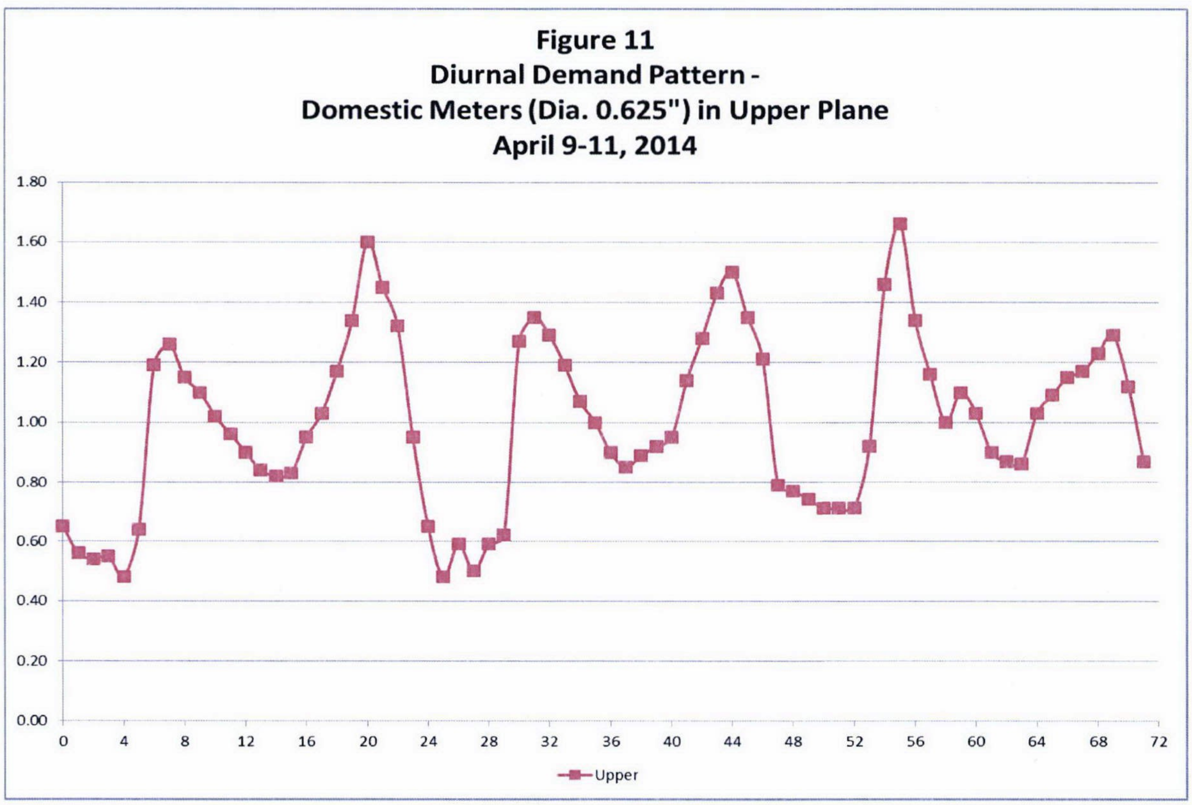


Figure 11
Diurnal Demand Pattern -
Domestic Meters (Dia. 0.625") in Upper Plane
April 9-11, 2014
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
Upper

Figure 12
Diurnal Demand Pattern - Domestic Meters (Dia. 0.625") in Lower McCarty Plane
April 9-11, 2014

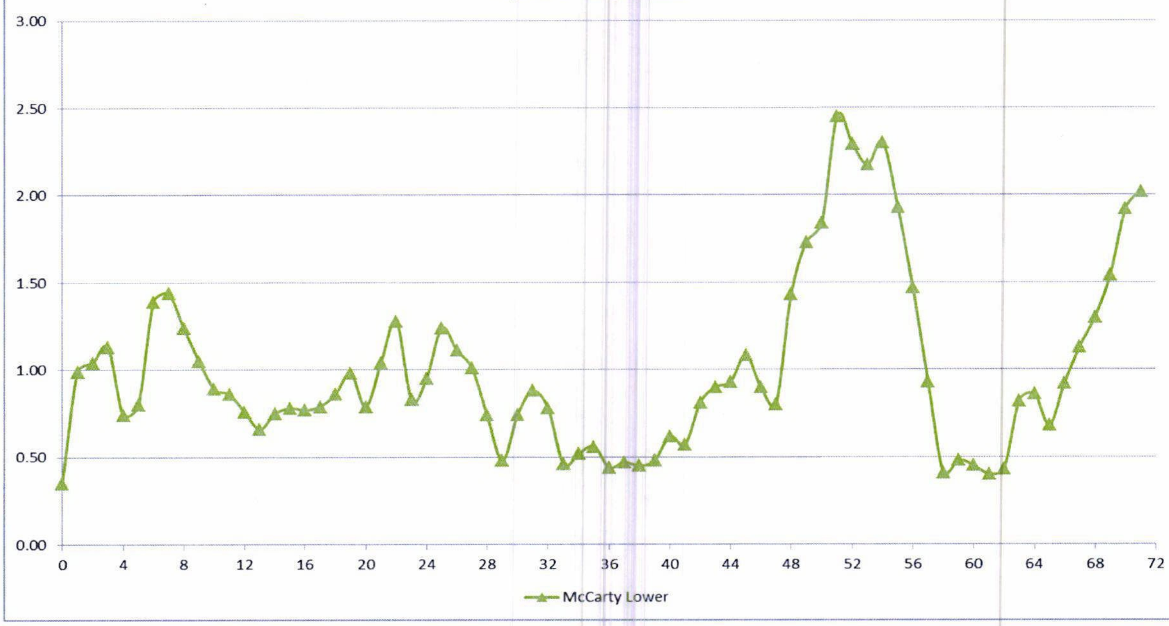


Figure 13
Diurnal Demand Pattern - Domestic Meters (Dia. 0.625") in Upper McCarty Plane
April 9-11, 2014

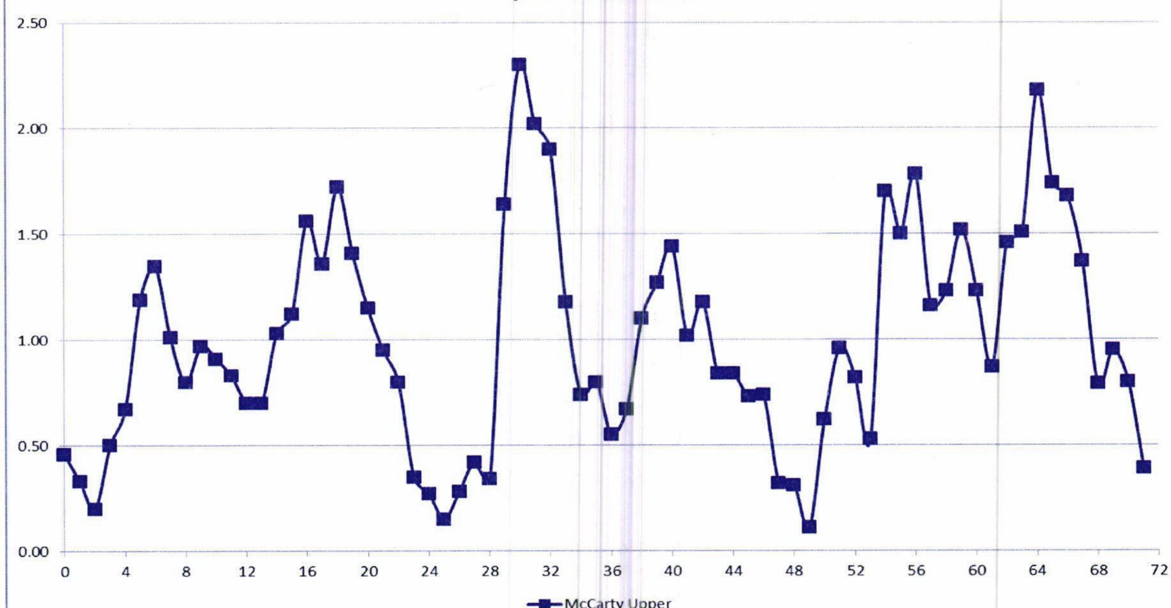


Figure 14
Diurnal Demand Pattern -
Domestic Meters (Dia. 0.625") in Deerwood Plane
April 9-11, 2014

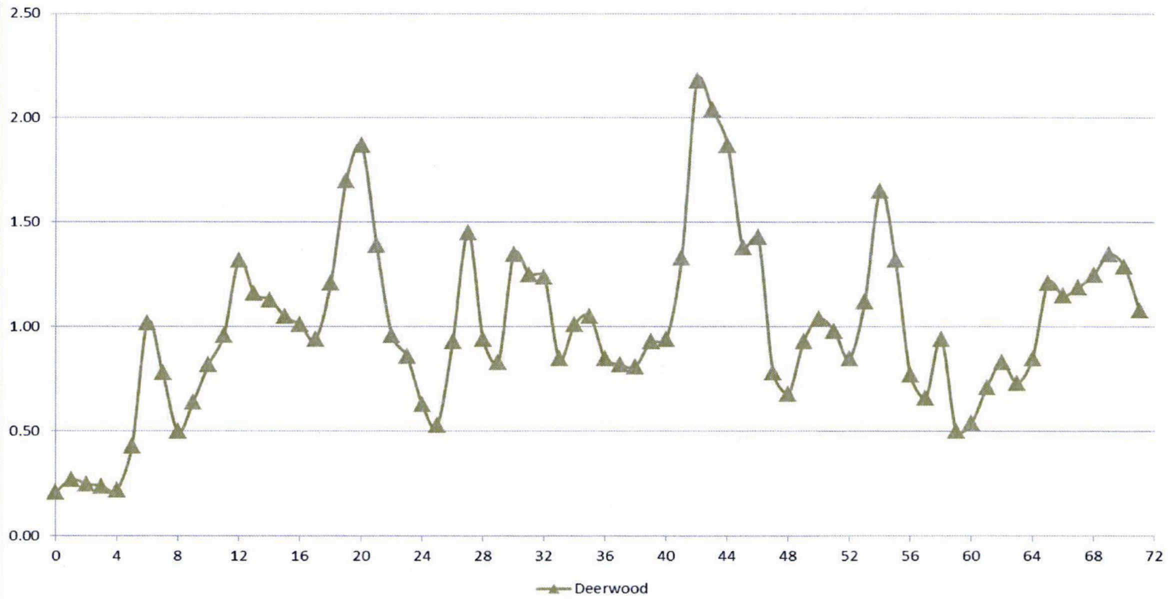
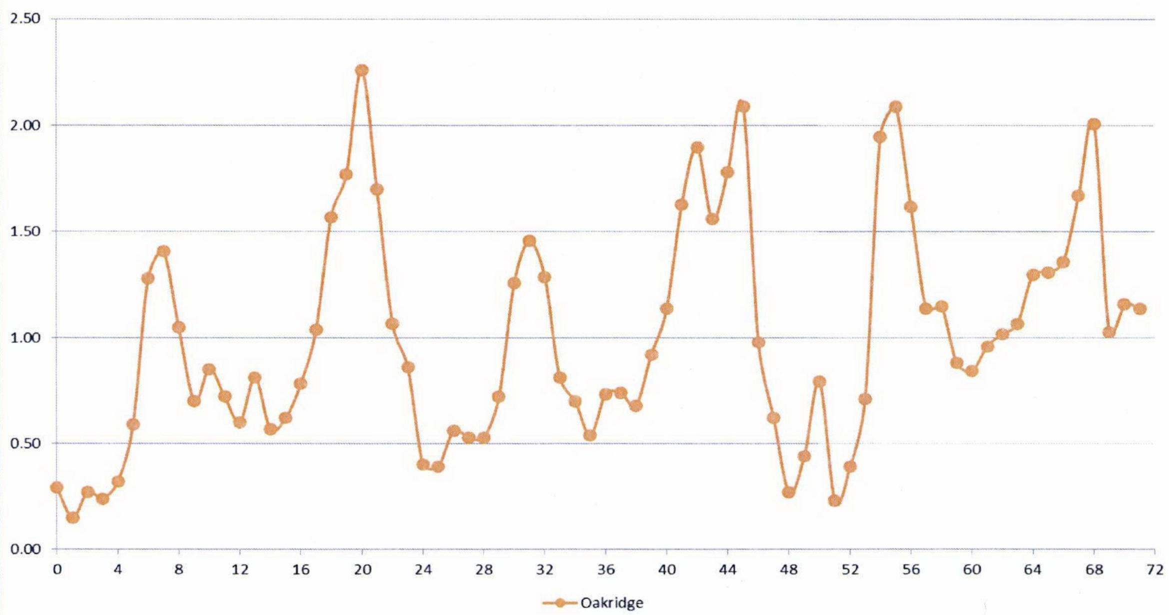
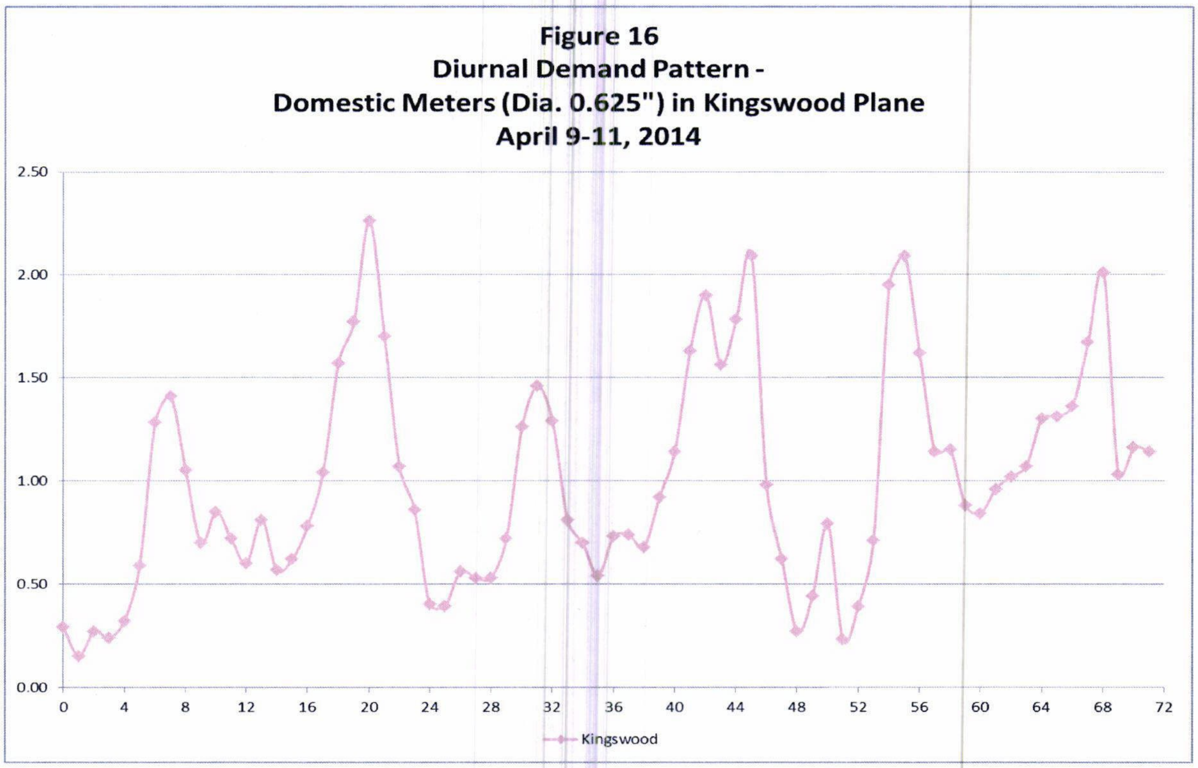


Figure 15
Diurnal Demand Pattern -
Domestic Meters (Dia. 0.625") in Oakridge Plane
April 9-11, 2014





Unaccounted-for Water (UAW)

By comparing SCADA-based production data to metered consumption over the course of the 72-hour April 9-11 calibration period, it was determined that approximately 24.5% of the water entering the distribution system via the SWTP HSPS, well pumpage, and net storage decrease was not metered upon exit. On average, water was supplied to the system at a rate of approximately 4,670 gpm (6.72 MGD) while the average metered demand was approximately 3,520 gpm (5.07 MGD) during the calibration period. Water supplied to the system but not metered is referred to as unaccounted-for water (UAW).

As a part of this study, no effort was made to break down the system UAW into real losses, apparent losses, and unbilled authorized consumption. However, a water loss audit performed in 2013 by JBS Water, Inc. revealed that for the period August 2012 to July 2013, the City experienced an average total UAW of approximately 17.3%. Of this percentage, approximately 0.3% was unbilled authorized consumption (municipal use, etc.), 2.8% was apparent loss due to metering inaccuracies or billing adjustments, and approximately 14.1% was real loss (physical leakage). A closer look at the water loss data provided by the City suggests that in the first three months of 2013, as well as in several other months in 2012 and 2013, UAW exceeded 20%, with a maximum of greater than 27% in January 2012. Thus, an UAW percentage of 24.5% for the calibration period is in line with previous measurements, though considerably higher than average for the City. It is possible that the UAW percentage is higher than usual due to lower than average overall demands due to watering restrictions, etc , and not due to additional real losses.

The challenge, with respect to the hydraulic model, is how to distribute these losses within the system. The typical procedure, with no other information to go on, would be to apply the losses equally to all demand nodes. However, since the City has incorporated AMI, it was possible to refine the loss distribution to some degree. By performing a water balance on each pressure plane, it is possible to estimate UAW as a function of pressure plane. However, because of unmetered PRVs as well as the presence of partially open valves between both the SWTP and Upper planes, as well as the Upper and Lower McCarty planes, it was not possible to calculate UAW on a planar basis in these areas.

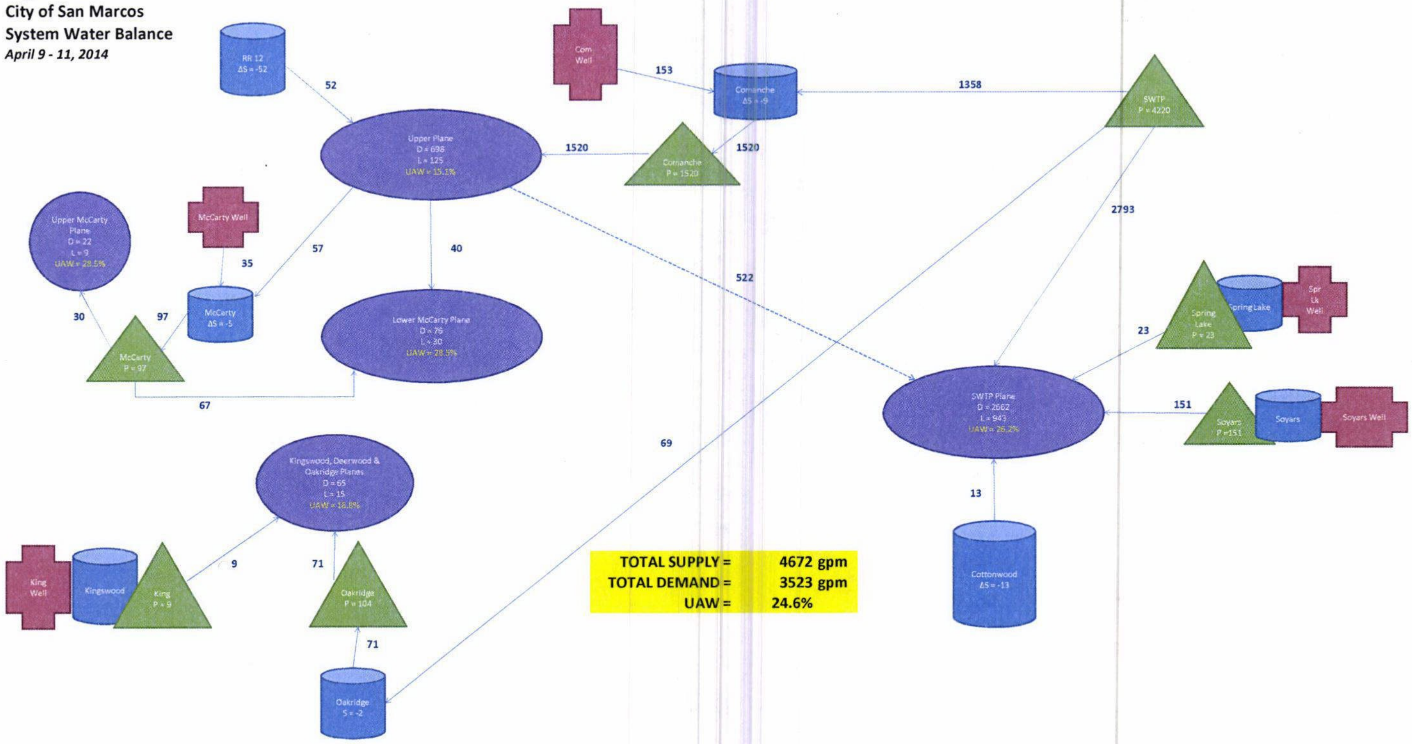
However, it was possible to calculate UAW for the Oakridge, Deerwood, and Kingswood planes as a group, since these planes are mostly isolated from the rest of the system. APAI determined an UAW of approximately 18.8% was appropriate for these pressure planes during the calibration period. Loss distribution for the remaining planes was calibrated to best fit SCADA data after assuming bleed rates for each of the two partially open valves. Calibration resulted in estimated UAW for the SWTP at approximately 26%, while a UAW of approximately 15% was deemed best fit for the Upper Pressure Plane. The Upper and Lower McCarty planes were assigned UAW of 28.5% through the calibration process. Figure 17 below depicts a water balance schematic of the entire system, including losses and the best-fit bleed rates from the identified partially open valves.

SYSTEM OPERATION

The third and final input to the hydraulic model necessary to achieve calibration is a representation of the control algorithms in place during the target calibration period. This information includes pump control setpoints, downstream pressure settings for PRVs, and minimum and maximum tank operating levels.

In general, there are two ways to input controls for a calibration run. One method is to simulate the controls as they are implemented in the system, by basing control actions off of the status of a second node. For instance, if a pump is controlled off of an elevated tank level, the high water level at which the pump turns off and the low water level at which the pump turns on would be input to the model. This is the most desirable input as it directly simulates the control algorithm utilized by the existing infrastructure. In some situations, however, the control algorithm in place might be too complicated to input directly, in which case time-based controls may be used. Under time controls, the example modeled pump would be turned on at a specific time, but not as a result of a target modeled tank level. Both types of controls and even a hybrid control scenario utilizing both time and level control can be effective calibration tools.

Figure 17
City of San Marcos
System Water Balance
April 9 - 11, 2014



all figures in gpm
D = demand
L = losses
ΔS = change in tank storage

Preliminary

Table 5: Calibration Run Pump Controls

Station	Pump(s)	Drive	Type	Target	Lead Pump On (ft)	Last Lag Pump On (ft)	All Pumps Off (ft)	Pressure Target (psi)	Notes
SWTP HSPS	SWTP #1	Constant Speed	*not used*						
	SWTP #2	VFD	Level	Cottonwood EST	32		39		speed varied from 94 3% to 99 4% with level
	SWTP #3	VFD	Level	Cottonwood EST	32		39		speed varied from 79 8% to 92 4% with level
Comanche	Comanche Booster #1	Constant Speed	Time	~~RR 12 Tank~~	~~19~~	~~16~~	~~29~~		time controls utilized in lieu of level controls due to lead/lag rotation
	Comanche Booster #2	Constant Speed	Time	~~RR 12 Tank~~	~~19~~	~~16~~	~~29~~		
	Comanche Booster #3	Constant Speed	Time	~~RR 12 Tank~~	~~19~~	~~16~~	~~29~~		
	Comanche Booster #4	Constant Speed	Time	~~RR 12 Tank~~	~~19~~	~~16~~	~~29~~		
	Comanche Well Pump #5	Constant Speed	Level	Comanche Tank	26		36		
McCarty	McCarty Booster #1	VFD	Pressure/Head	Pump Outlet				82	rapid pump cycling of 200 gpm pump not simulated due to very small time step requirement - simulated with pressure target and 100 gpm pump always on
	McCarty Booster #2	VFD	*not used*						
	McCarty Booster #3	VFD	*not used*						
	McCarty Well	Constant Speed	Level	McCarty Tank	83		96		
Soyars	Soyars Booster #1	Constant Speed	*always on*						In reality, Pumps 1 & 3 are rotated every 12 hr, but Pump 1 was left on for the simulation The pump curve of this pump was used as a calibration knob since it was not tested
	Soyars Booster #2	Constant Speed	*not used*						
	Soyars Booster #3	Constant Speed	*not used*						
	Soyars Booster #4	Constant Speed	*not used*						
	Soyars Well	Constant Speed	Level	Soyars Tank	20		25		The pump curve of this well pump was also tweaked to match fill rates in the Soyars Tank
Oakridge	Oakridge Booster #1	Constant Speed	*not used*						
	Oakridge Booster #2	Constant Speed	*not used*						
	Oakridge Booster #3	Constant Speed	*not used*						
	Oakridge Booster #4	Constant Speed	Level	Oakridge Hydropneumatic	310		332	139	Oakridge Hydropneumatic Tank simulated with 2 8 ft diameter standpipe, with a head variance from 310 to 332 ft (134 to 144 psi)
	Oakridge Booster #5	Constant Speed	*not used*						
Kingswood	Kingswood Booster #1	Constant Speed	*not used*						
	Kingswood Booster #2	Constant Speed	*not used*						
	Kingswood Jockey	Constant Speed	Level	Kingswood Hydropneumatic	160		177	73	Kingswood Hydropneumatic Tank simulated with 0 62 ft diameter standpipe, with a head variance from 160 to 177 ft (69 to 77 psi)
	Kingswood Well	Constant Speed	Level	Kingswood Tank	13 5		15		
Spring Lake	Spring Lake Booster #1	Constant Speed	*not used*						
	Spring Lake Booster #2	Constant Speed	Time						Booster Pump #2 exercised for approximately 15 min on at 6 21 AM on 4/10
	Spring Lake Booster #3	Constant Speed	Time						Booster Pump #3 exercised for approximately 1 8 hrs at 8 33 PM on 4/10
	Spring Lake Booster #4	Constant Speed	*not used*						
	Spring Lake Well Pump #1	Constant Speed	Time						Well Pump #1 exercised on 4/10 for approximately 40 min at 6 56 AM and for 25 min at 8 48 PM The pump curve of this pump was tweaked to match the fill rate of the Spring Lake Tank
	Spring Lake Well Pump #2	Constant Speed	*not used*						

Since InfoWater cannot simulate the lead/lag positional rotation of the four pumps at the Comanche Pump Station, all pumps were implemented with time controls. A hybrid time and level control scenario was implemented at the SWTP HSPS since Pump #2 does come on for a brief time during the calibration period. Table 5 describes the pump control algorithms input to the InfoWater model.

CALIBRATION PROCEDURE

With the physical infrastructure, system demands, and system operation input to the model, as well as a robust period of extensive system-wide hydraulic data available, the calibration process could begin. The calibration of a hydraulic model is an iterative process by which unknown variables such as C-factors, loss distribution, and in this case, flow rates through simulations of partially open valves, were varied until modeling results fit the available hydraulic data for a given calibration period. One of the first steps in the calibration process is to identify a 24-hour to 72-hour calibration period to simulate.

While many model calibrations are considered adequate if 24 or 48 consecutive hours of system operation can be simulated to within 10% of available data for pressures, tank levels, and pump flow rates, APAI decided to utilize a 72-hour calibration period and strive to improve the simulation error such that most modeling results are within 5% of the available SCADA data. The available AMI data made these targets quite reasonable. Unfortunately, the complications that were identified previously made achieving these targets more difficult than they otherwise would have been.

<u>Selection of Calibration Period and Time Step</u>

Originally, a model calibration period of April 8-10 was identified as optimal due to this period containing the least amount of missing SCADA and PDR data (SCADA pressure data was missing for several PRVs at various times during the hydraulic data collection period, and the Airport PDR failed on April 8). However, after it was discovered that on April 9-11 the relationship between Pump #3 and the Cottonwood Tank level was mostly linear, this period was selected as the calibration period.

A model time step of three minutes was ultimately selected for the final calibration run. This value represented a compromise between model run time and the desire to simulate the short pump cycle times at the Oakridge, Kingswood, and McCarty Pump Stations. Sensitivity testing suggested that shorter time steps did not add much accuracy and increased model run time.

<u>Friction Factors</u>

As an initial step, Hazen Williams C-factors from the 2007 model were imported to the InfoWater model where possible. New pipes added since 2007 were assigned an initial C-factor based on pipe material (ductile iron = 130, PVC = 150). Since no hydrant flow testing was performed, only small local changes were made to C-factors based on available pressure data. In general, model results suggest that

C-factors did not change enough to have a significant impact on system pressures since the last model calibration.

Complications

There were five major complications that substantially increased the difficulty of the calibration effort with the City's model, as follows:

1. The presence of open connections (partially open valves) and unmetered PRVs between pressure planes greatly decreased the accuracy with which losses could be spatially distributed. These open connections also introduced additional uncertainty as the bleed rate between the affected pressure planes had to be estimated and refined through trial-and-error.
2. The control strategy at the SWTP HSPS was not provided. It had to be inferred from the data for pump speed and Cottonwood Tank level.
3. The pump performance testing at the SWTP plant suggested that the SCADA system was not accurately reading the pump speed of SWTP Pump #3. As a result, the SCADA reported pump speed may not accurately reflect the true speed of the pump motor. This problem was likely related to overspinning of the motor.
4. A plot of SCADA reported data for pump speed versus the controlling Cottonwood level revealed that the pump control was not stable or strictly linear, but rather appeared to jump around between different linear relationships at various times in the hydraulic data collection period (see Figure 18 below). As a result, the SCADA speed reported was likely in error for the entirety of the hydraulic data collection period.
5. Finally, the very small pump cycle times (often 1-to-3 minutes) at the Oakridge and McCarty pump stations forces a very small model time step in order to accurately simulate.

Complications 2) and 3) are Complications 2) and 3) are very likely related, however, APAI was able to find a solution to the non-linearity of the Pump #3 control by identifying a 72-hour calibration period during which SWTP Pump #3 control did behave linearly (see Figure 19). The problem of the true pump speed not matching the SCADA reported pump speed remained, however. APAI recommends that the City discuss with GBRA the practice of over-spinning the motor on Pump #3, which may be increasing offset error in the proportional controller.

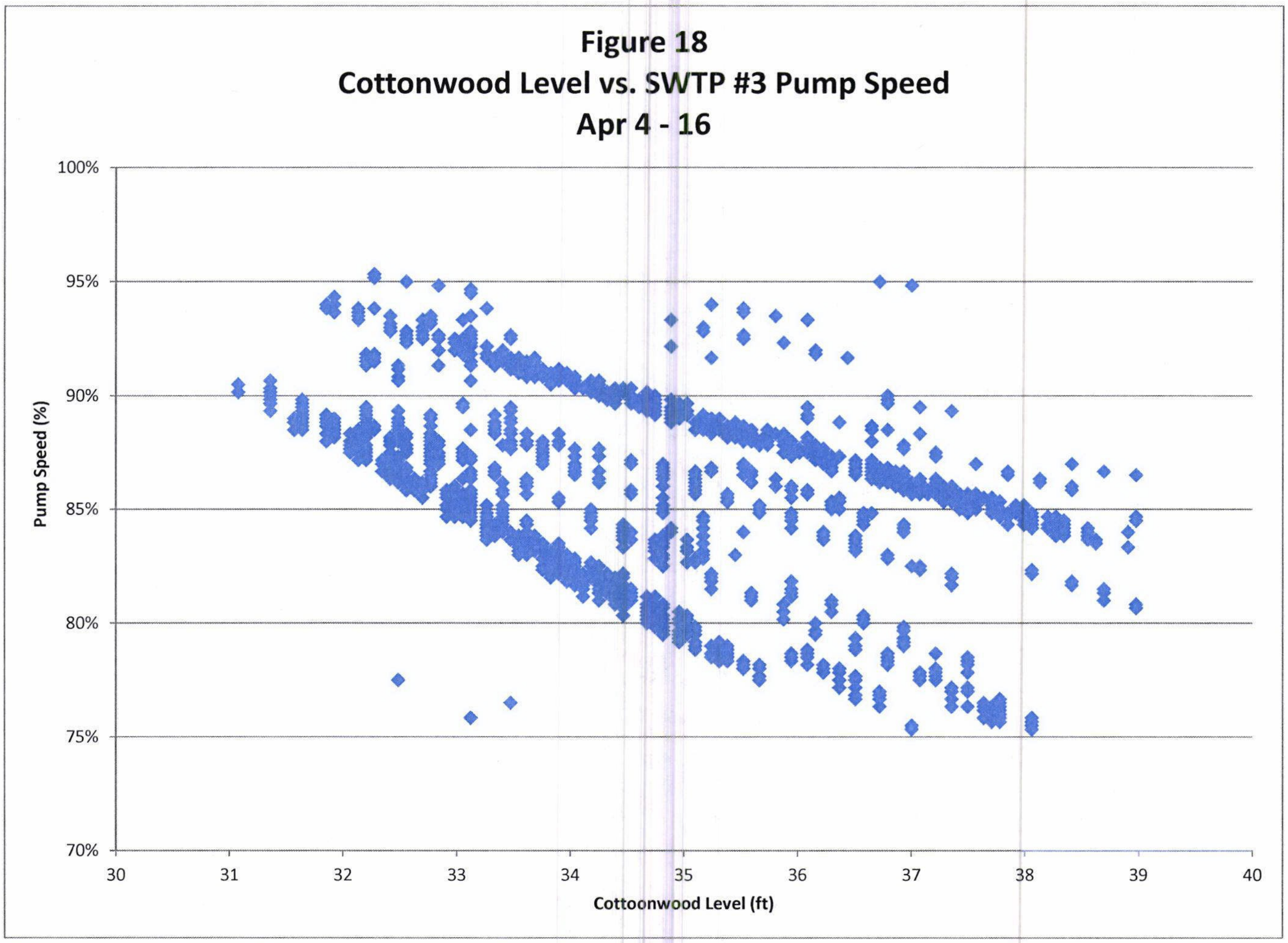


Figure 18
Cottonwood Level vs. SWTP #3 Pump Speed
Apr 4 - 16
100%
95%
90%
85%
80%
75%
70%
Pump Speed (%)
30
31
32
33
34
35
36
37
38
39
40
Cottoonwood Level (ft)

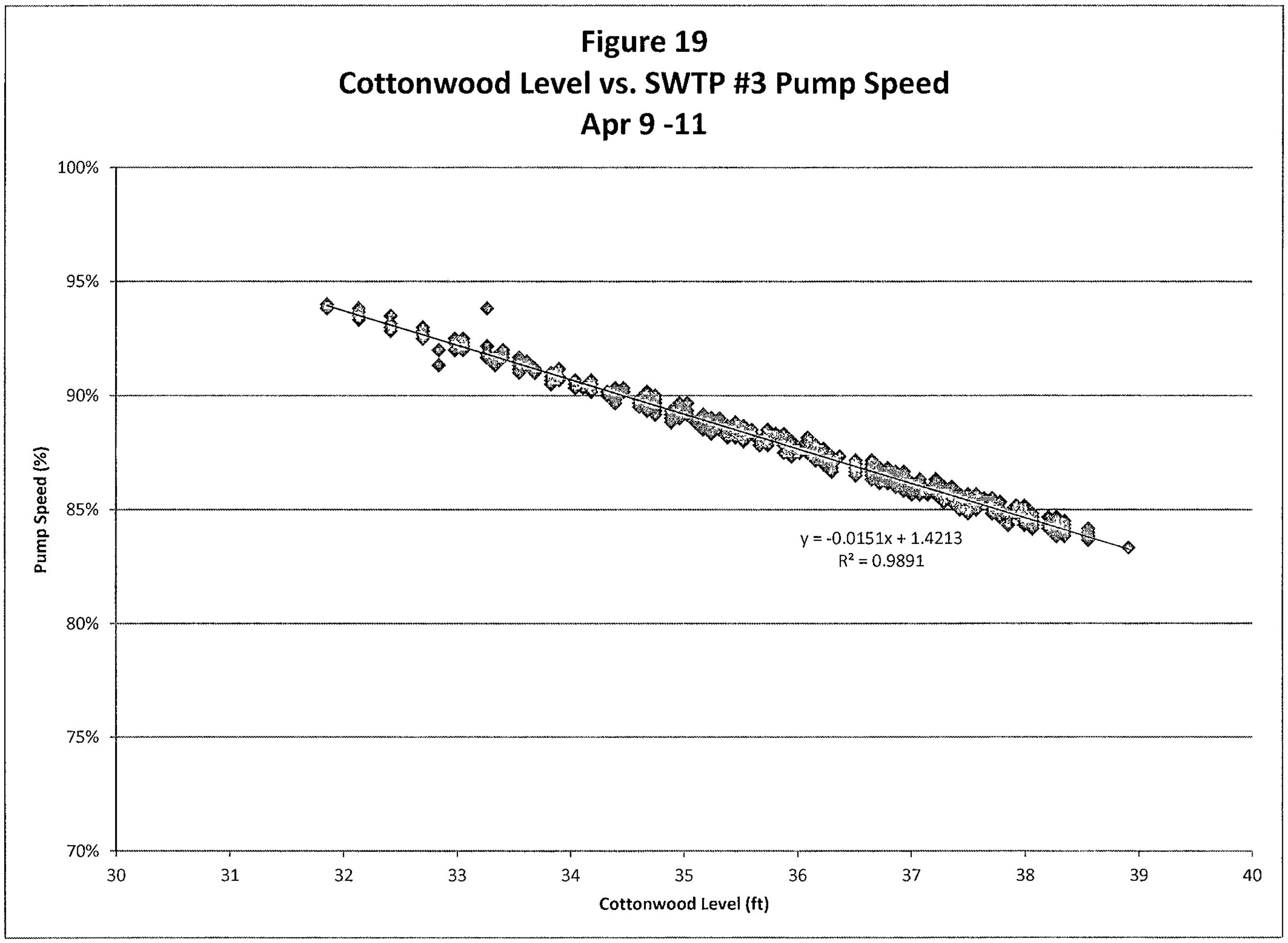


Figure 19
Cottonwood Level vs. SWTP #3 Pump Speed
Apr 9 -11
100%
95%
90%
85%
80%
75%
70%
Pump Speed (%)
y = -0.0151x + 1.4213
R² = 0.9891
30
31
32
33
34
35
36
37
38
39
40
Cottonwood Level (ft)

To address the inaccuracy of the SCADA reporting of speed for SWTP Pump #3 in the model representation, APAI compared the results of pump performance testing to the SCADA data and transformed the control strategy inferred from the data to a level midway between the pump performance testing readings and the SCADA data. Table 6 below describes this process.

Table 6: Motor Speed Transformation on SWTP Pump #3

SCADA Cottonwood Level	SCADA Speed	Revised Speed per Field Collected Hz Measurements (64 Hz = 100%)	Average (Input to Model as SWTP Pump #3 Control Algorithm)
32	93.8%	92.4%	93.1%
33	92.3%	90.6%	91.5%
34	90.8%	88.8%	89.8%
35	89.3%	87.0%	88.1%
36	87.8%	85.2%	86.5%
37	86.3%	83.4%	84.8%
38	84.8%	81.6%	83.2%
39	83.2%	79.8%	81.5%

In essence, since SCADA was assigning a value of 100% Speed to 64 Hz, the flow exiting the pump station was higher than it should have been according to the control algorithm. However, when the true speed was entered as an input control algorithm for the pump, too little flow was being delivered. This could be related to the offset error encountered as a result of the excess power supplied. As a result, a compromise level to speed ratio was input to the model that was equal to the average of the SCADA speed and the calculated true speed.

In addition to the above-described complications, the PDR deployed at Comanche Street and Lindsey Street downtown reported a hydraulic grade approximately 20 feet greater than the SWTP pumps were producing. As a result, these readings were assumed to be in error and were omitted from the calibration data. They are shown for reference in Attachment A.

CALIBRATION RESULTS

Overall, the calibration of the new hydraulic model was very successful, despite the complications previously described. This result can be primarily attributed to the availability of AMI data.

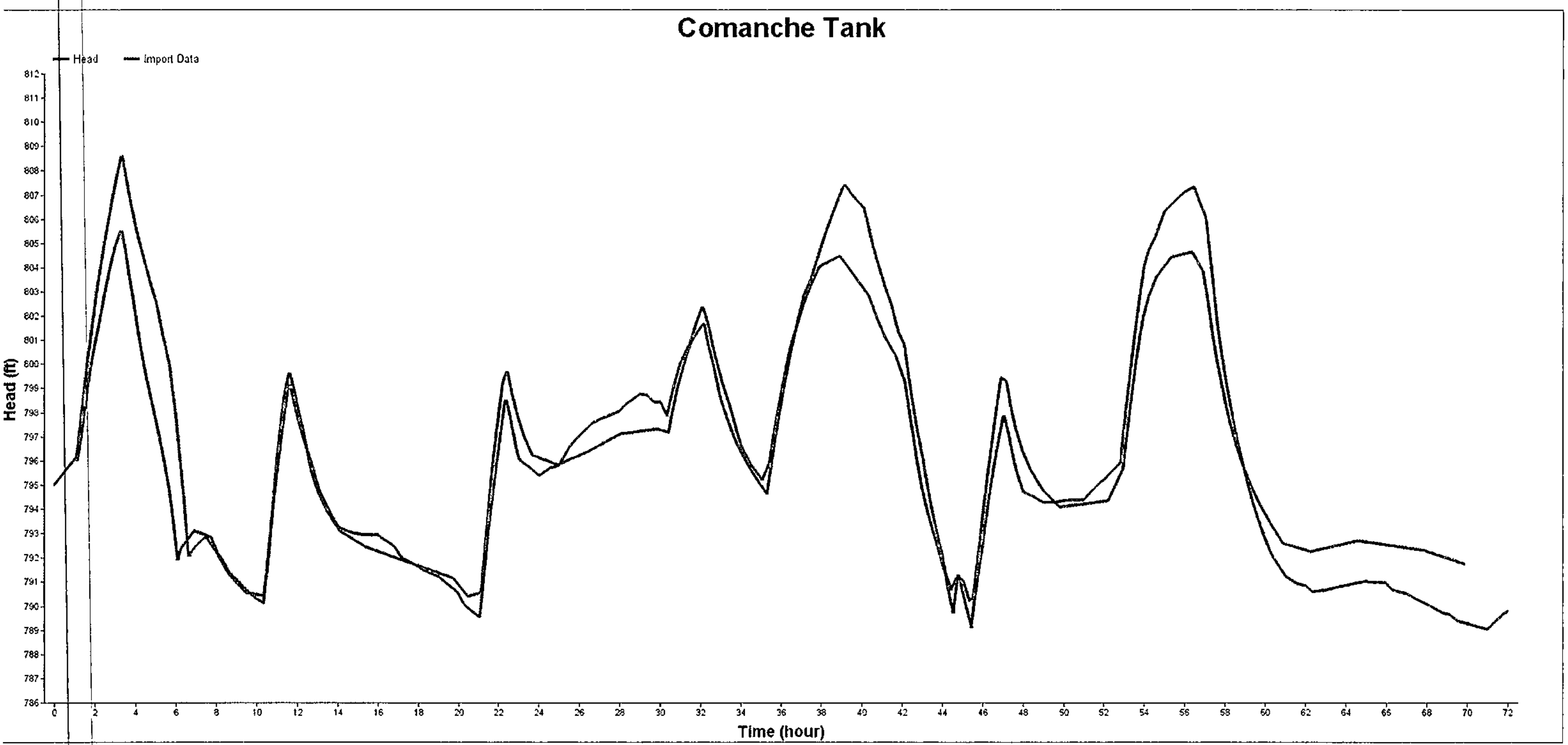
In general, most pressure data was simulated to within 5% of measured values, while all stations were simulated to within 10% of SCADA data for the entire 72-hour calibration period. With respect to tank levels, simulations were quite accurate with respect to both cycle times and timing of peak and trough levels. Pumping simulations were also very accurate, as simulated flow rates at all stations where flow metering was available match the SCADA data to within 5% at nearly all times during the simulation. Attachment A contains a plot of every pressure node, pump, valve, and tank for which comparisons were made to collected SCADA or PDR data.

Attachment A

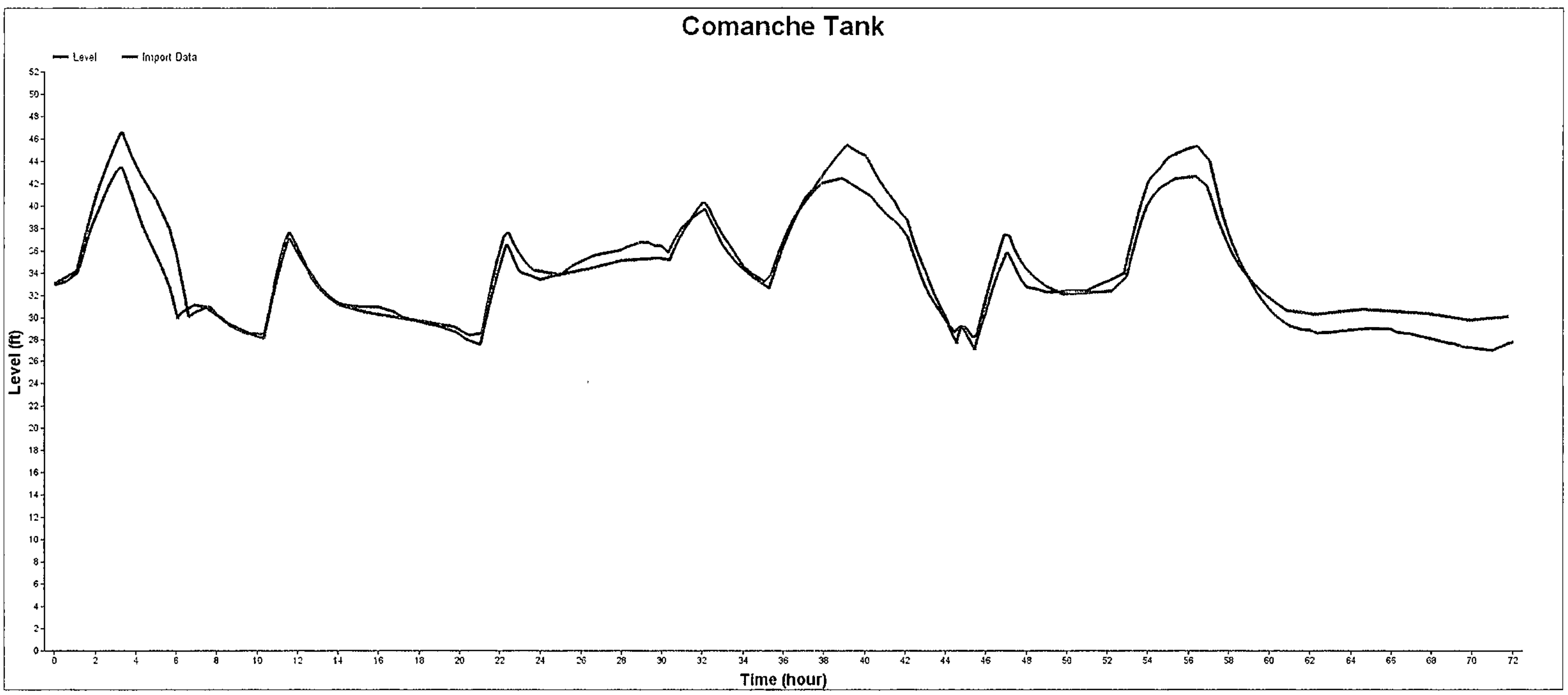
Model Output - Calibration Plots

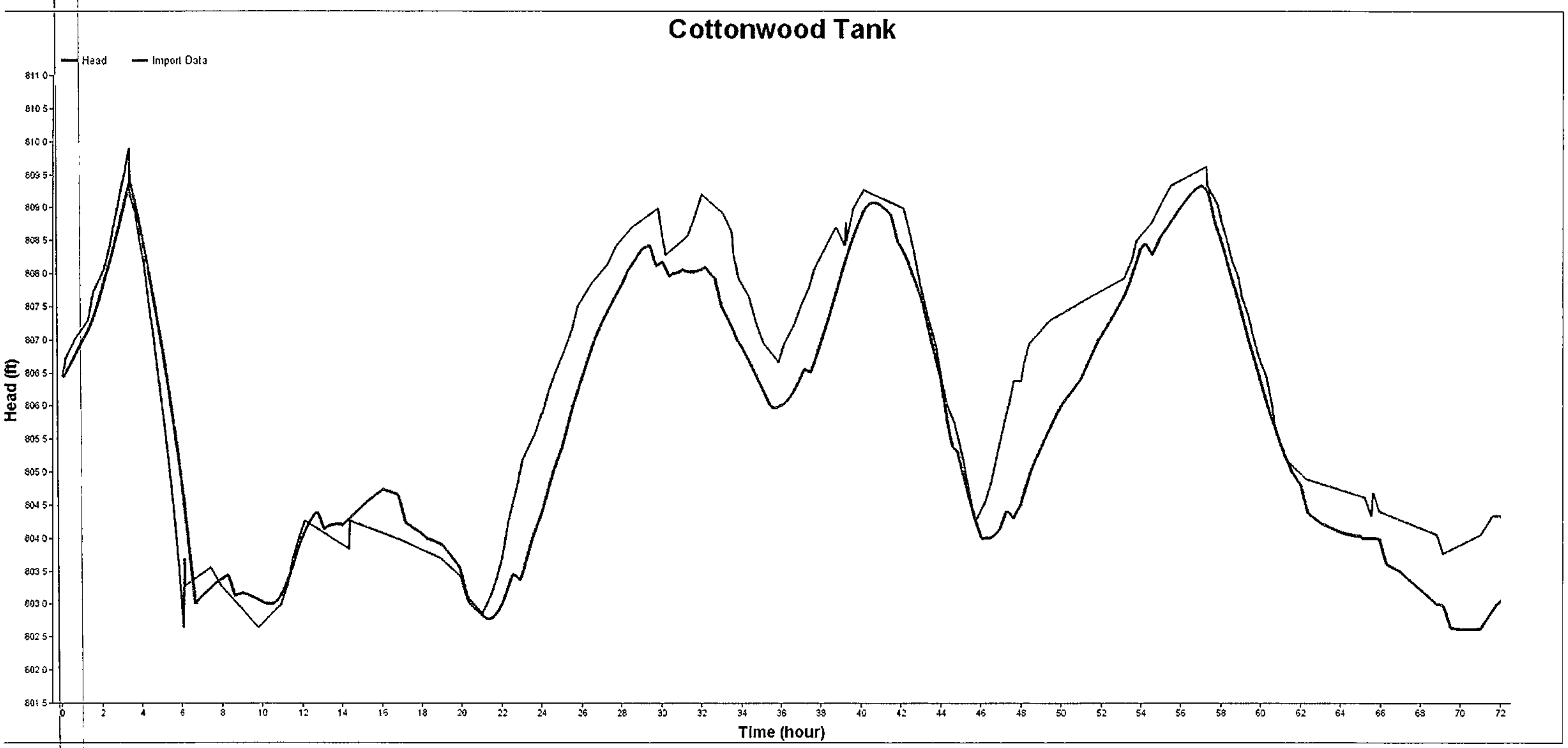
Red lines indicate modeling results;

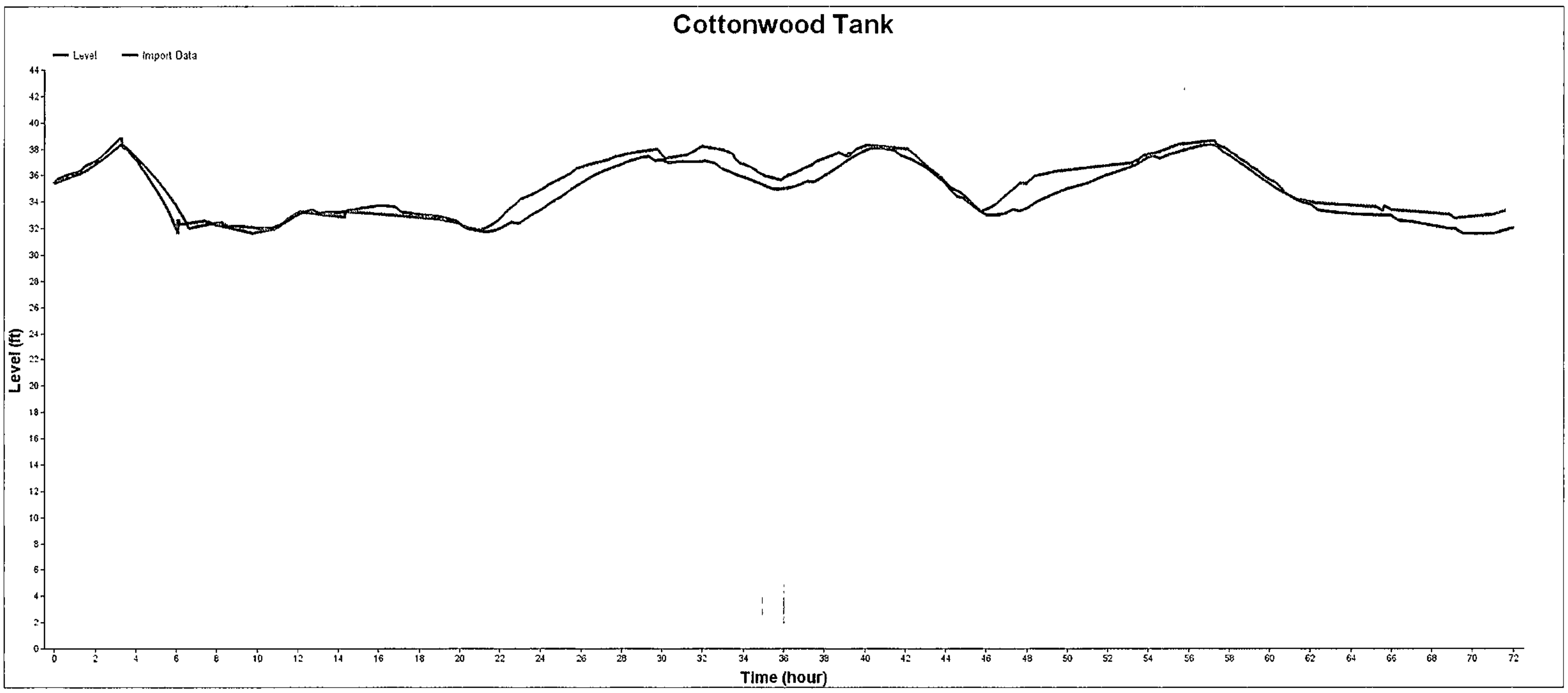
Green lines indicate field data



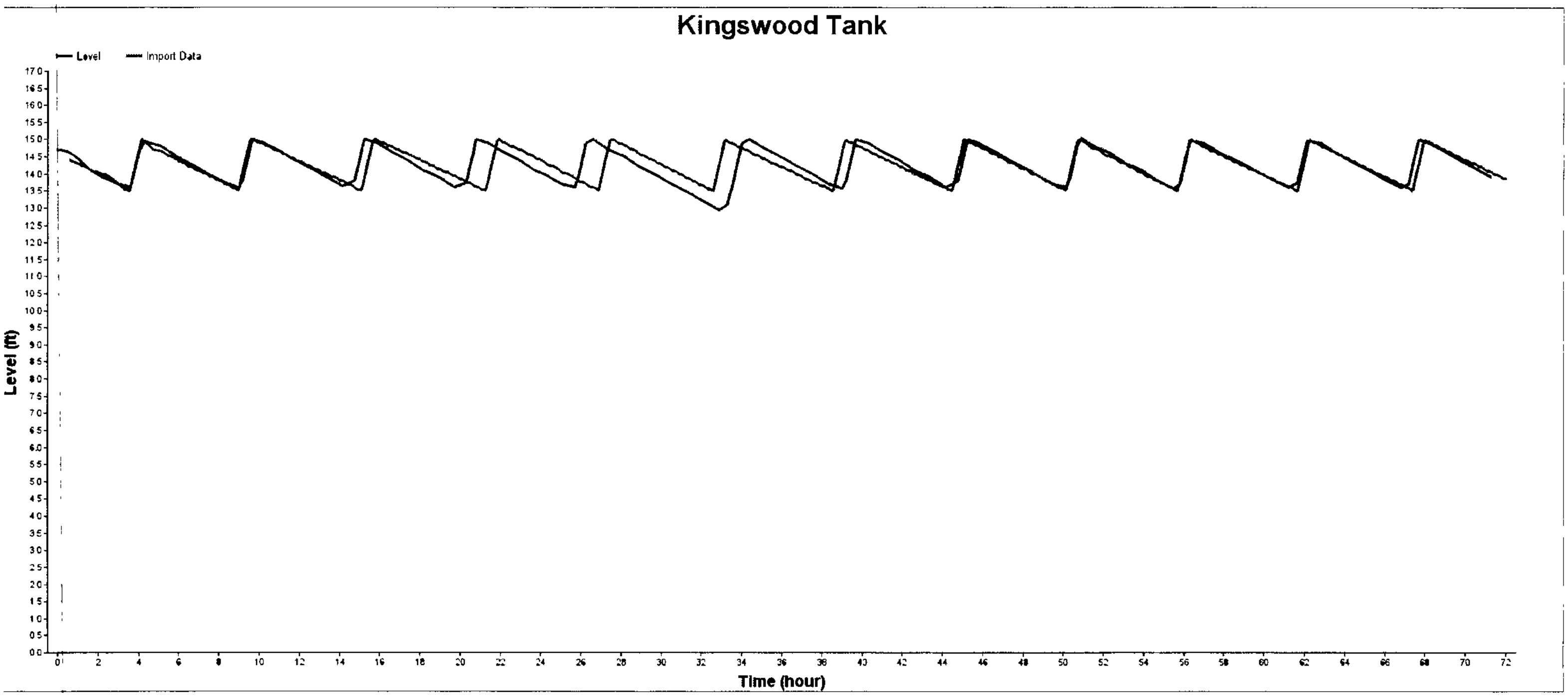
Comanche Tank
Head
Import Data
Head (ft)
Time (hour)


Comanche Tank
Level
Import Data
Level (ft)
Time (hour)

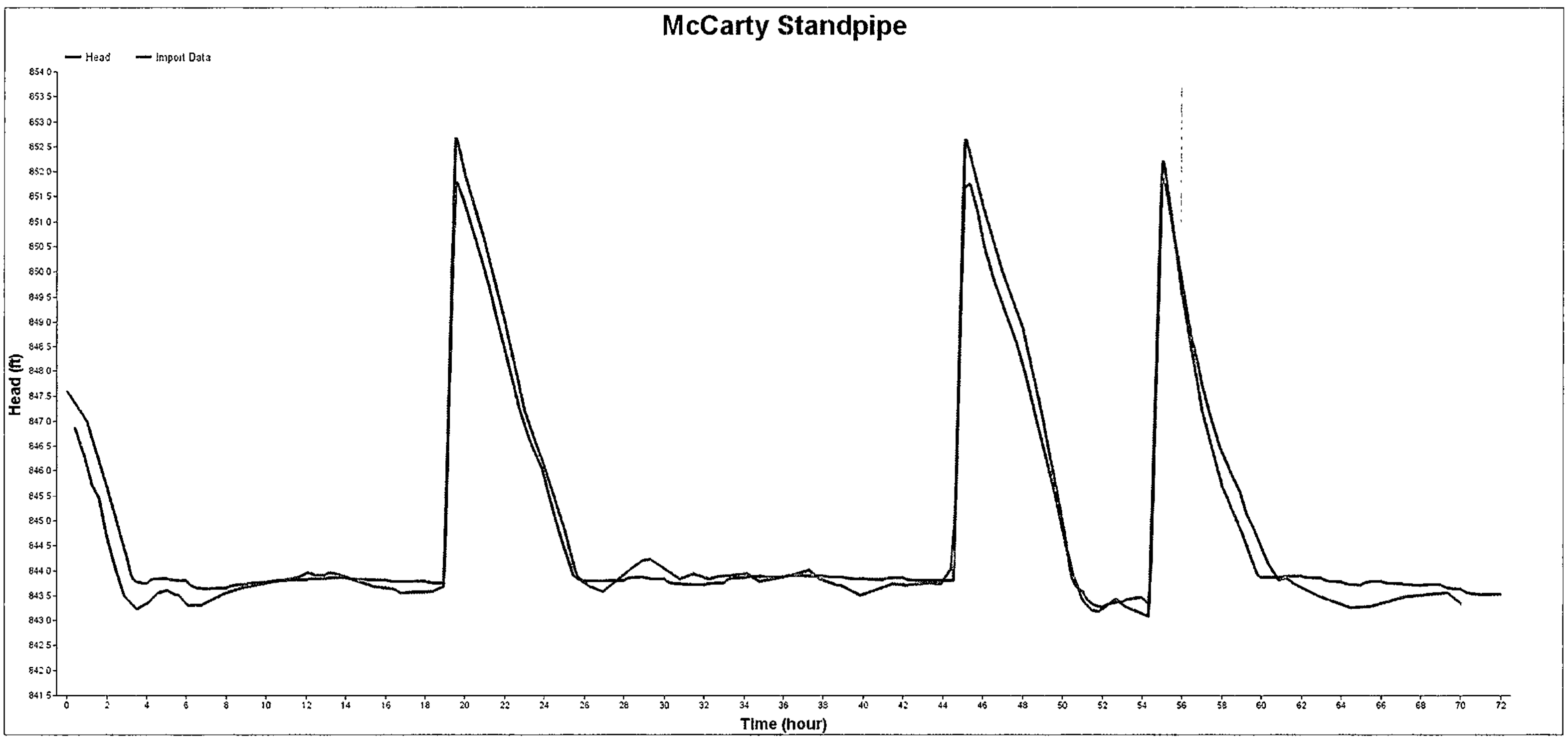


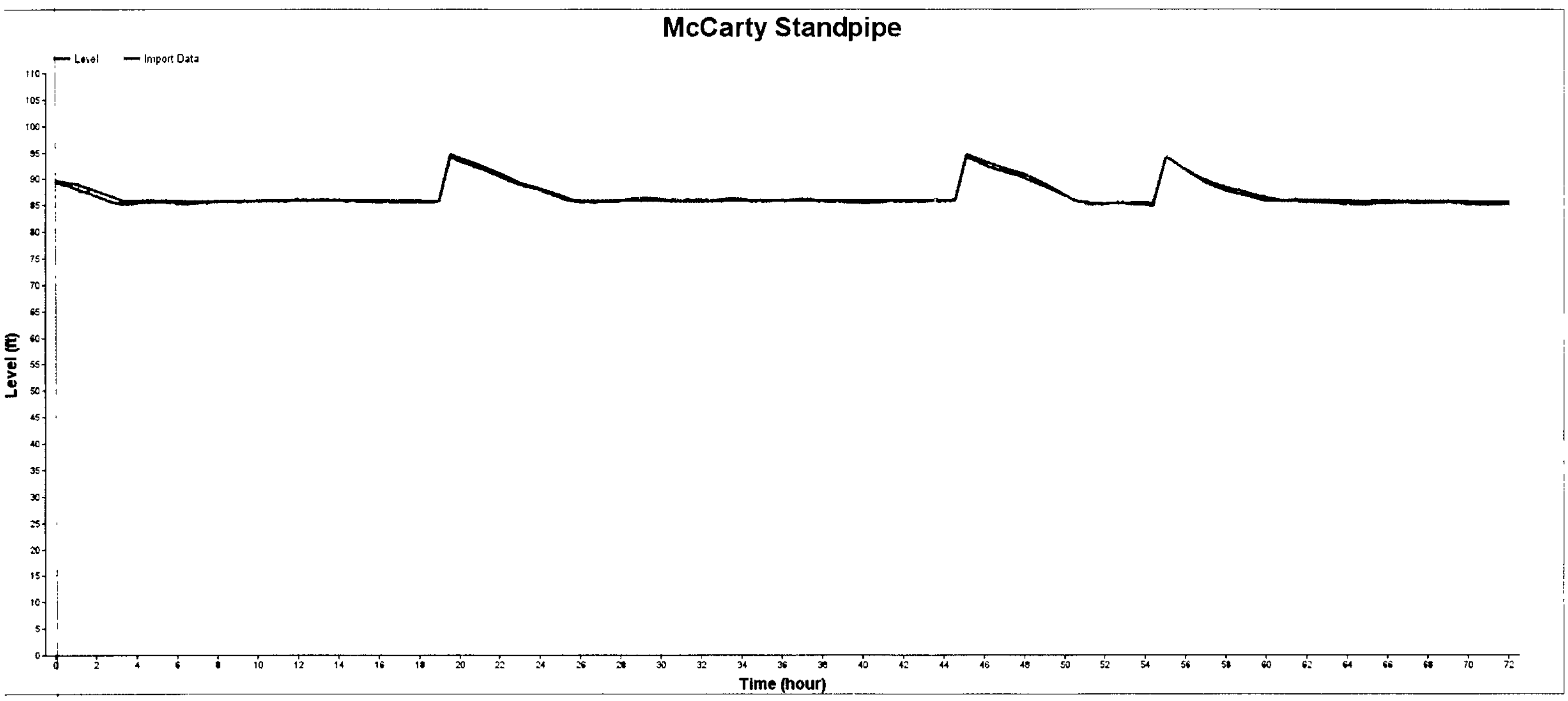


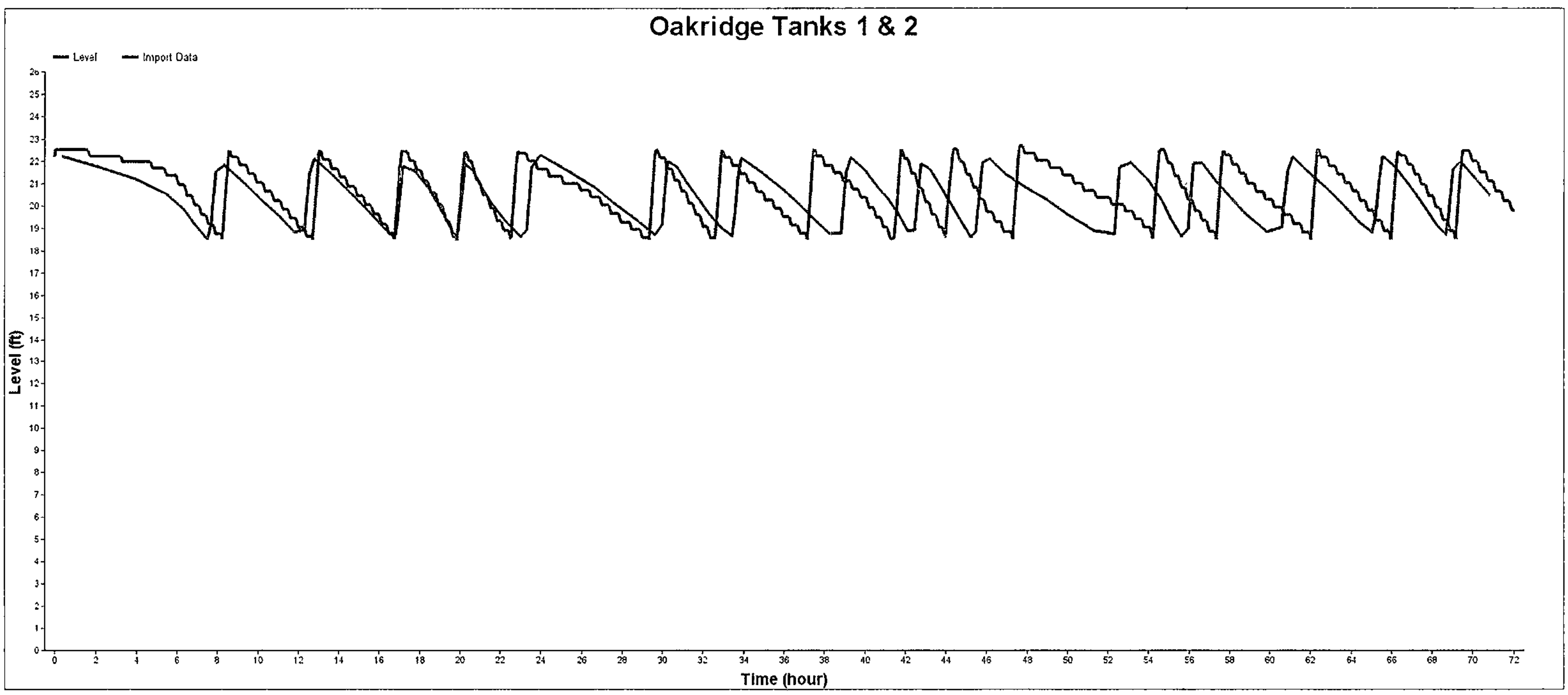
Cottonwood Tank
Level
Import Data
Level (ft)
Time (hour)



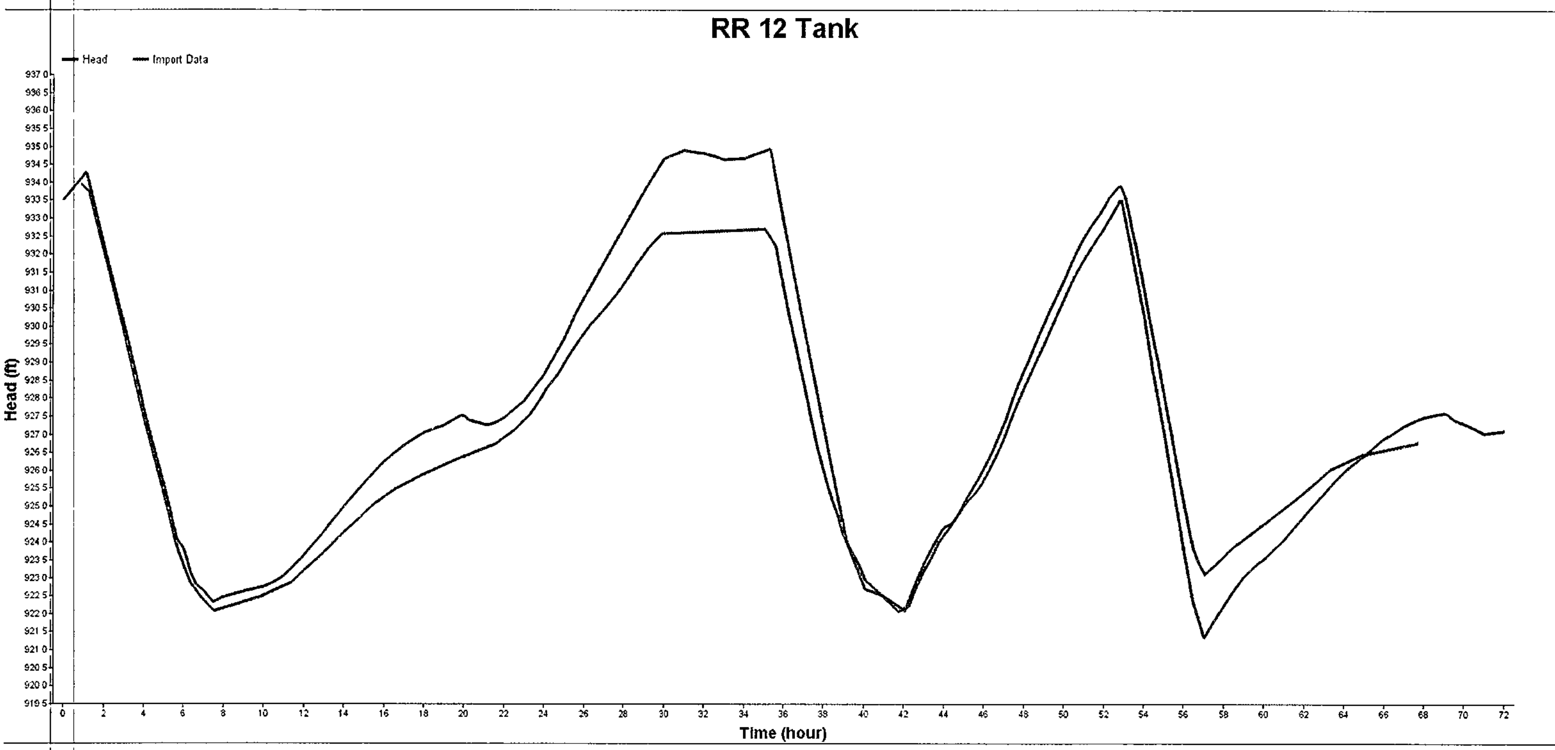
Kingswood Tank
Level
Import Data
Level (ft)
Time (hour)

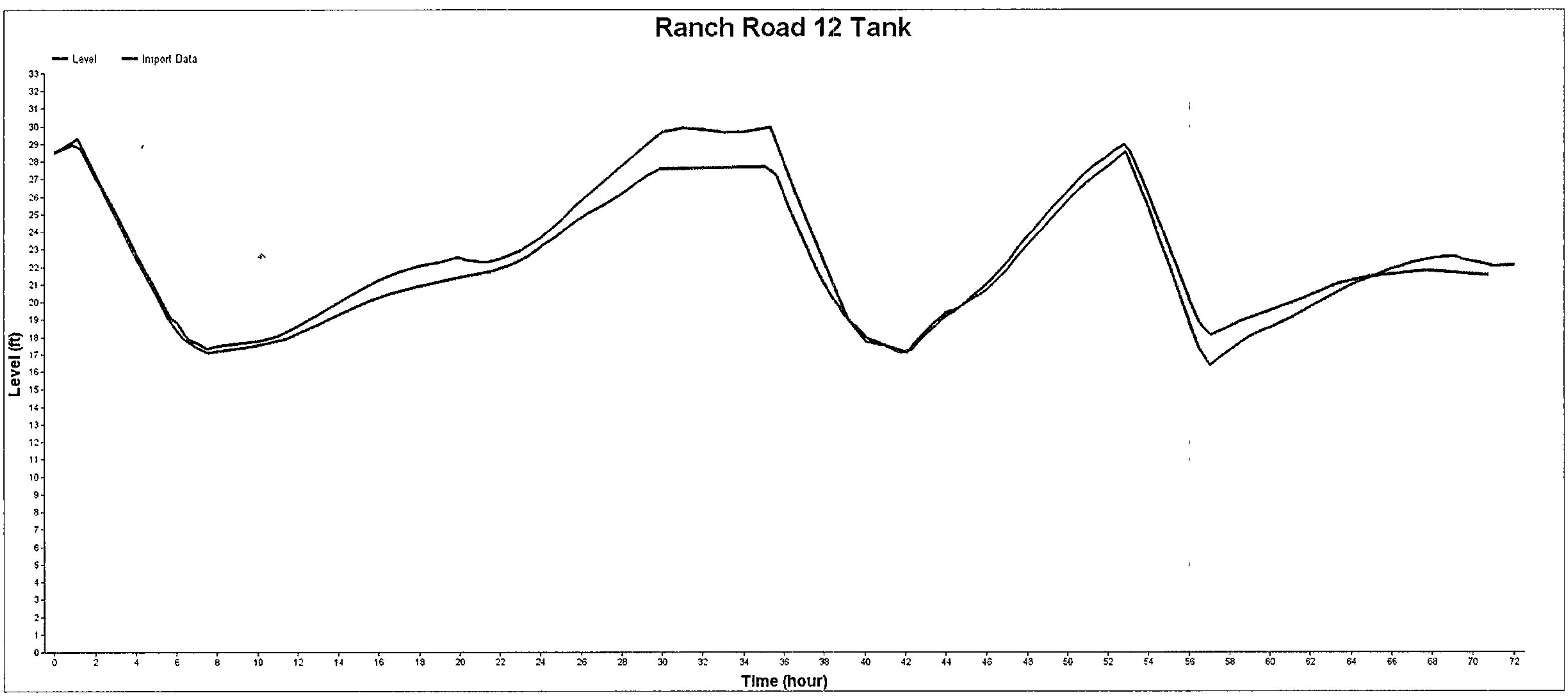

McCarty Standpipe
Head
Import Data
Head (ft)
Time (hour)


McCarty Standpipe
Level
Import Data
Level (ft)
Time (hour)

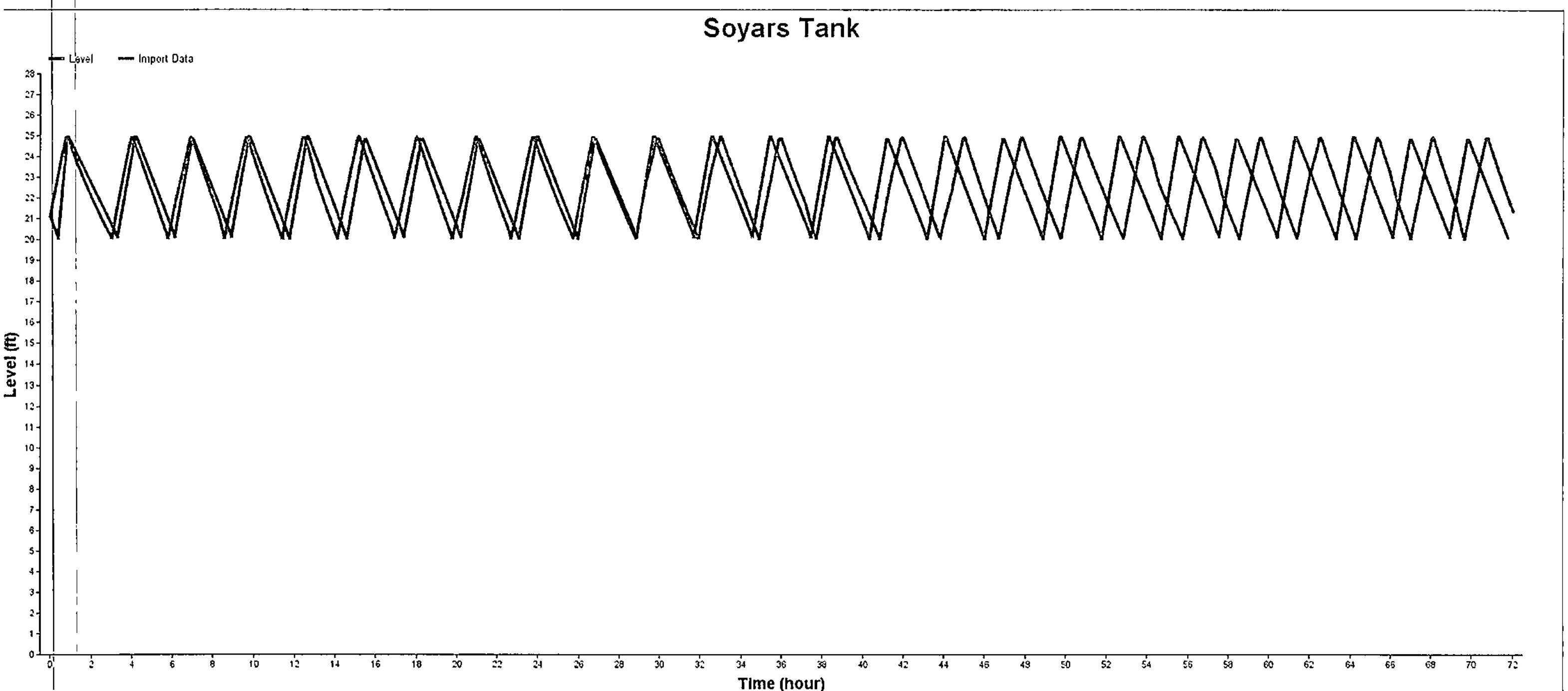


Oakridge Tanks 1 & 2
Level
Import Data
Level (ft)
Time (hour)

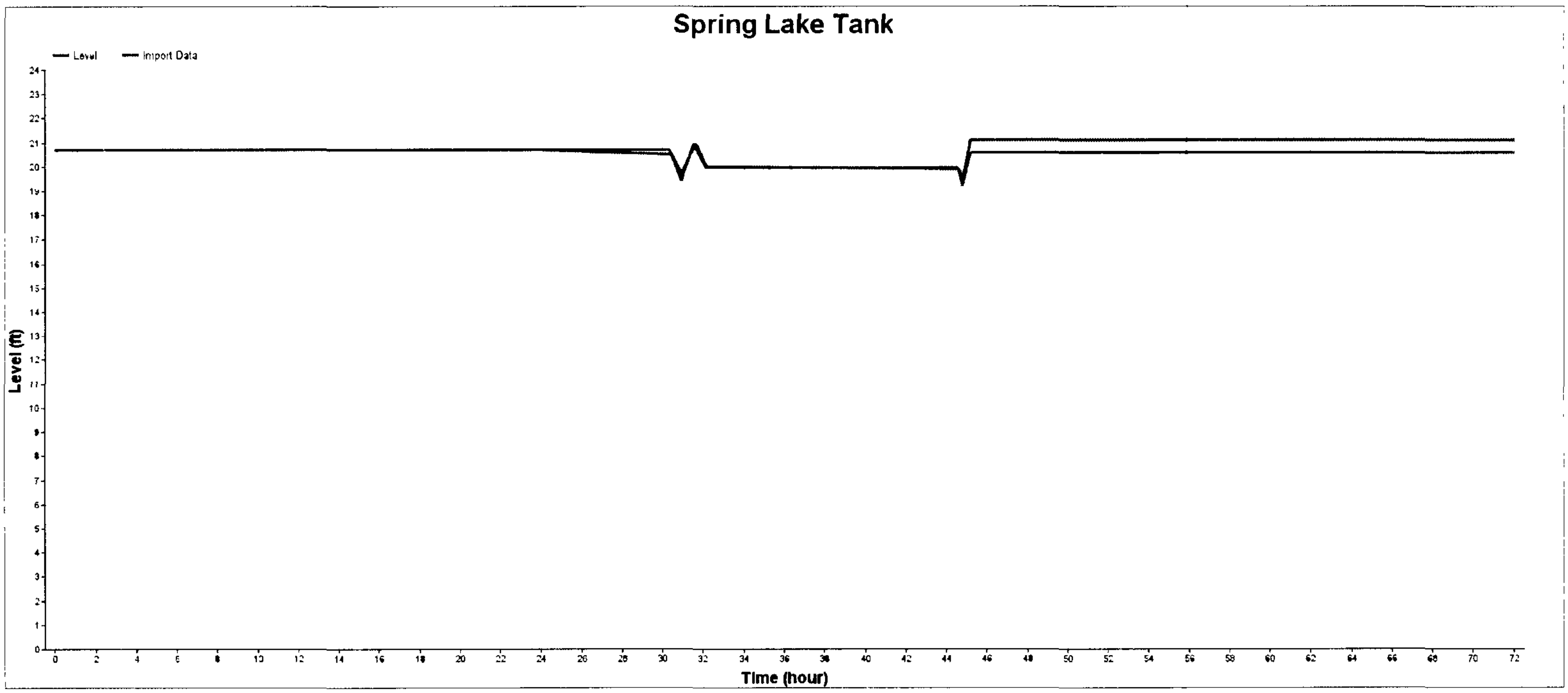

RR 12 Tank
Head
Import Data
Head (ft)
Time (hour)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72



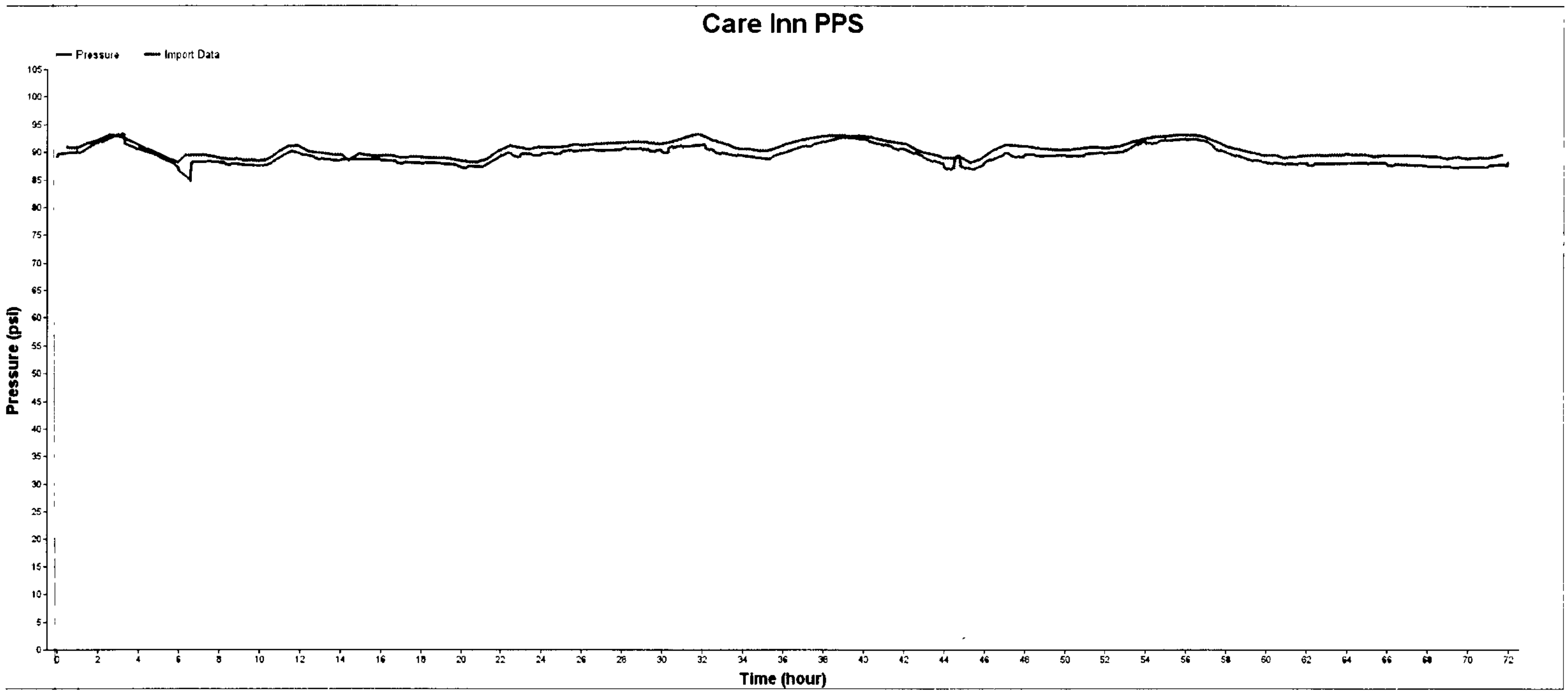
Ranch Road 12 Tank
Level
Import Data
Level (ft)
Time (hour)



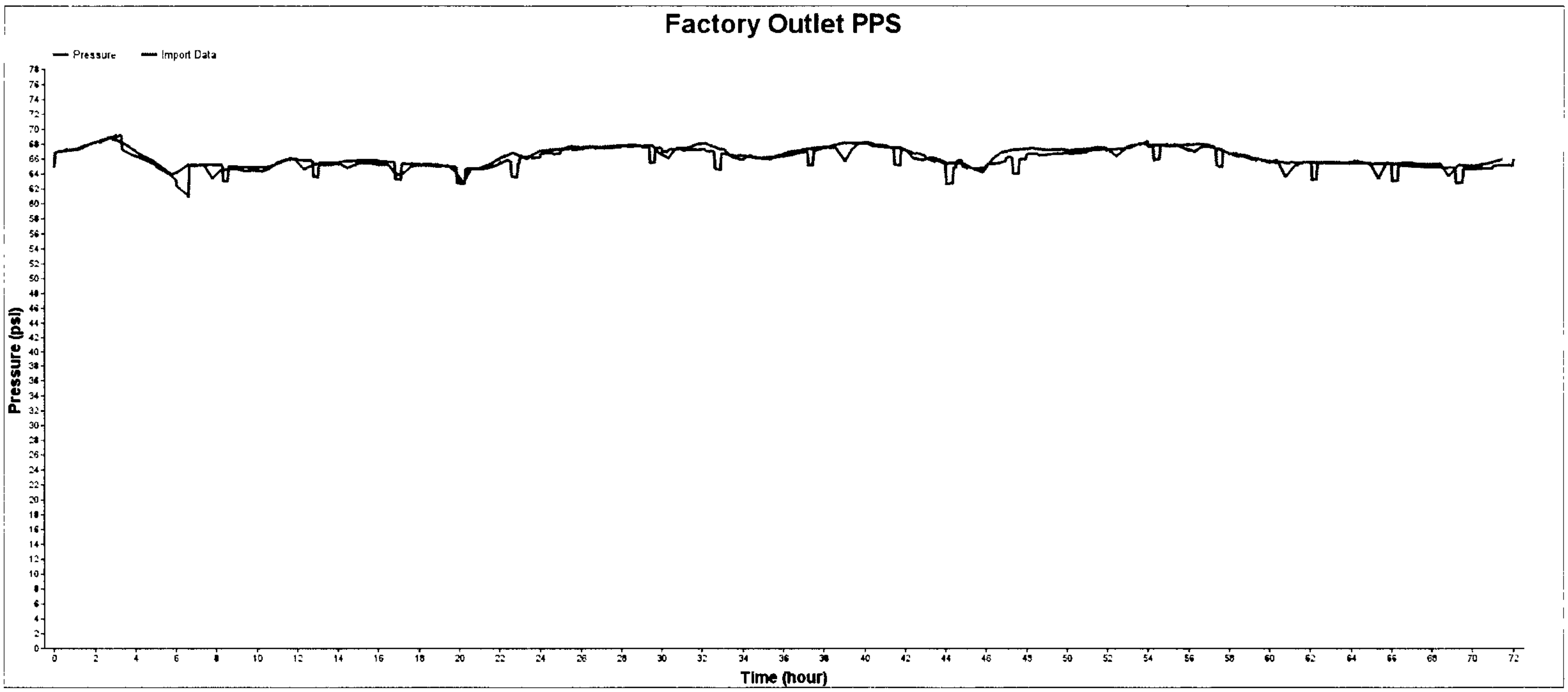
Soyars Tank
Level
Import Data
Level (ft)
Time (hour)

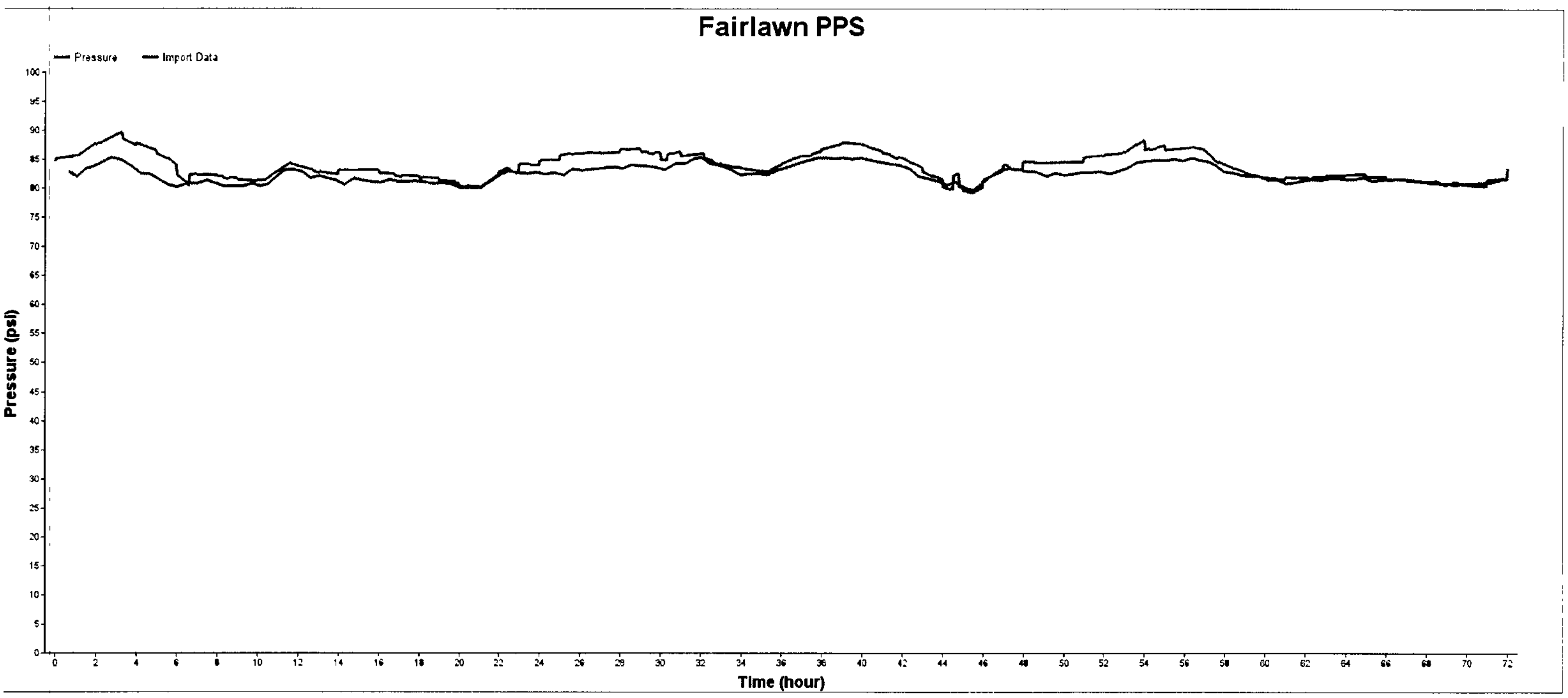


Spring Lake Tank
Level
Import Data
Level (ft)
Time (hour)

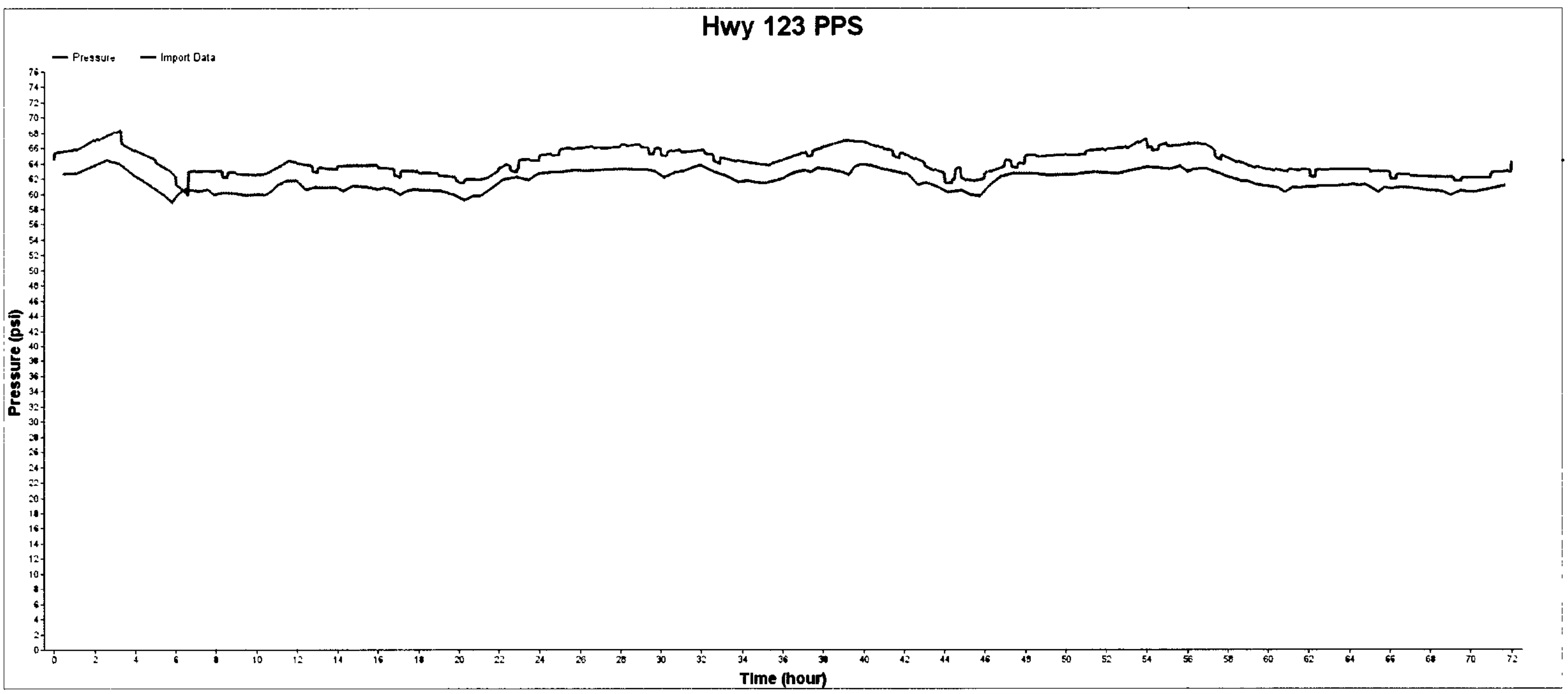


Care Inn PPS
Pressure
Import Data
Pressure (psi)
Time (hour)

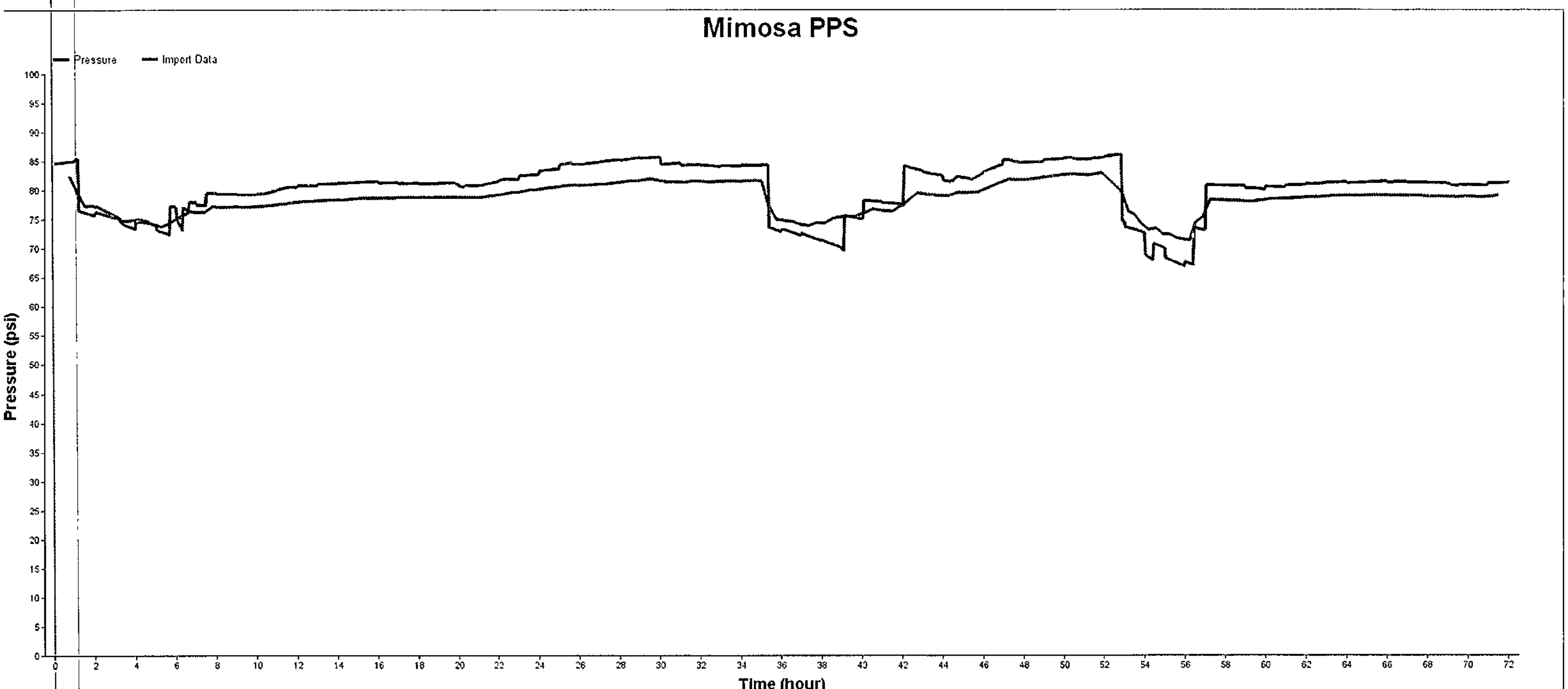

Factory Outlet PPS
Pressure
Import Data
Pressure (psi)
Time (hour)



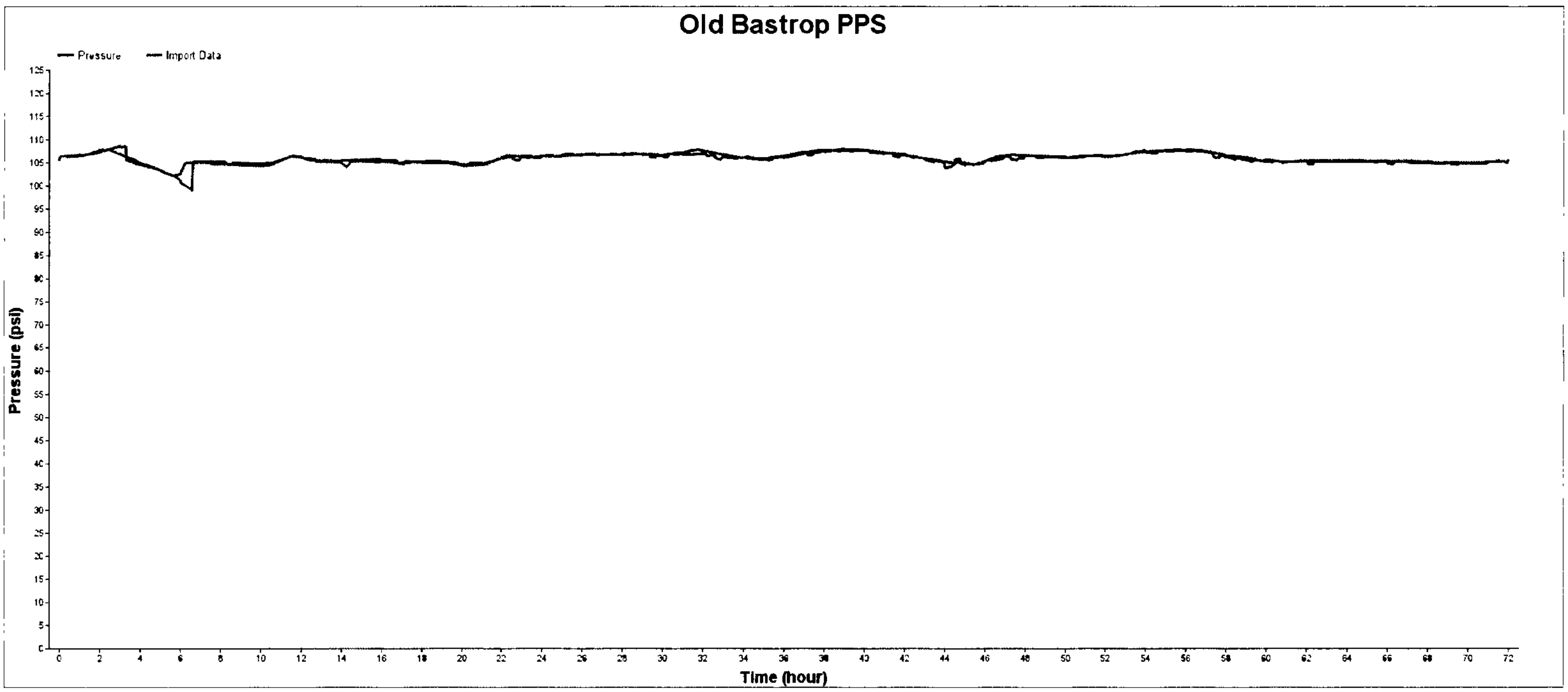
Fairlawn PPS
Pressure
Import Data
Pressure (psi)
Time (hour)



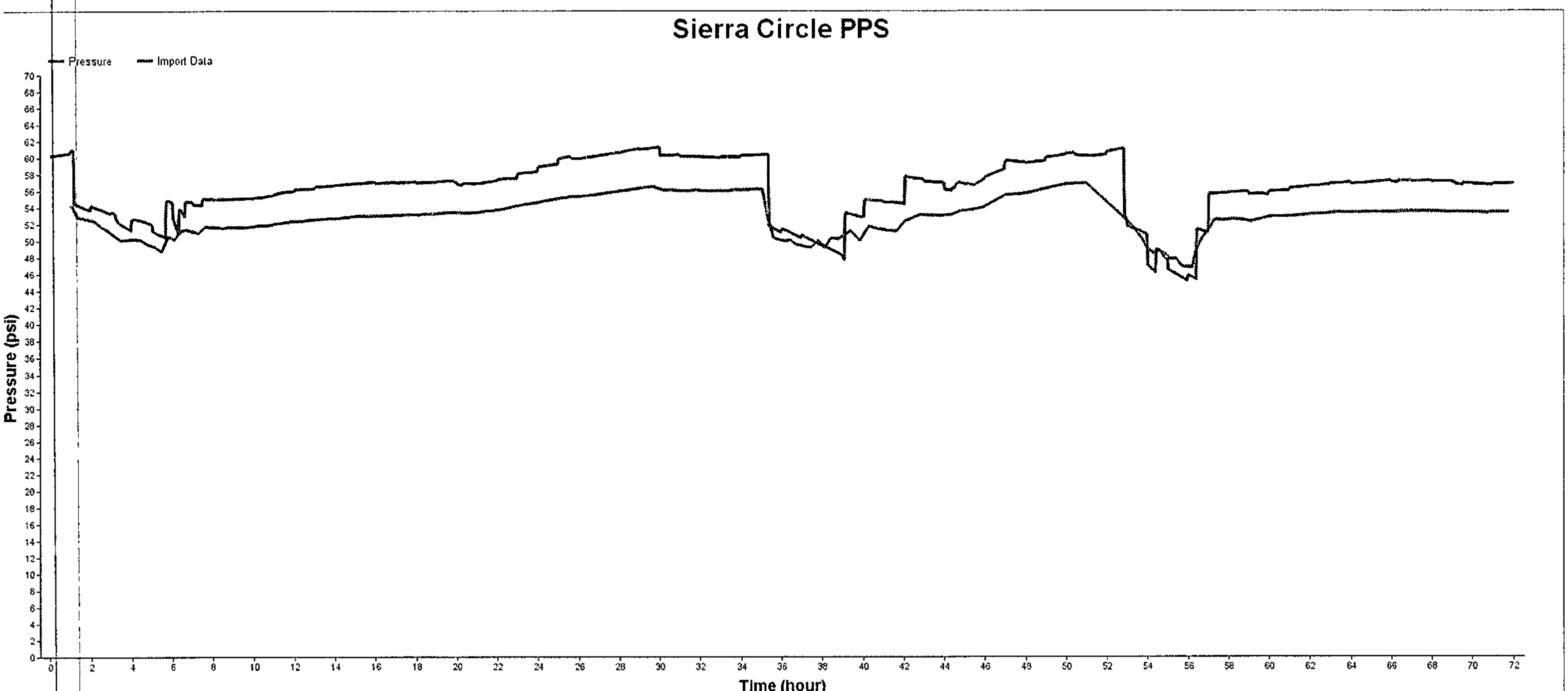
Hwy 123 PPS
Pressure
Import Data
Pressure (psi)
Time (hour)



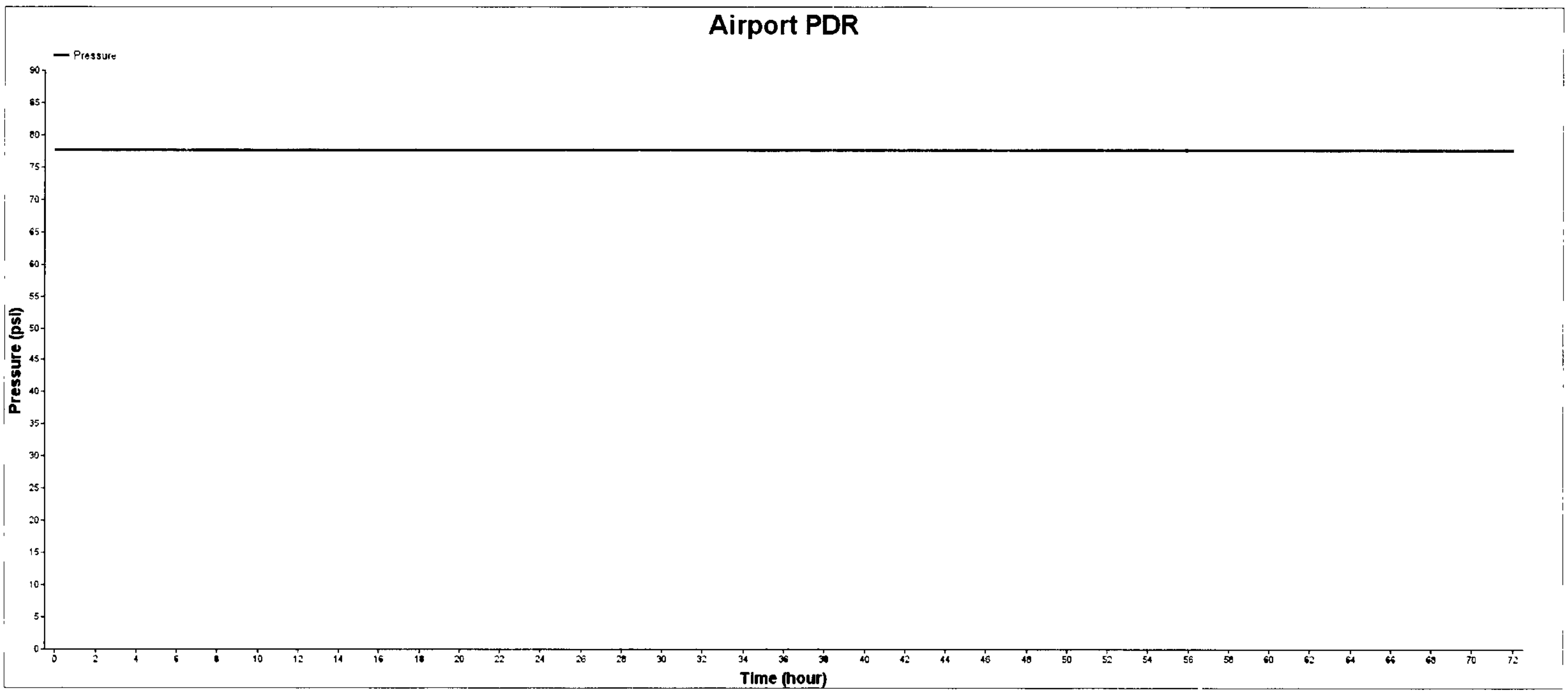
Mimosa PPS
Pressure
Import Data
Pressure (psi)
Time (hour)



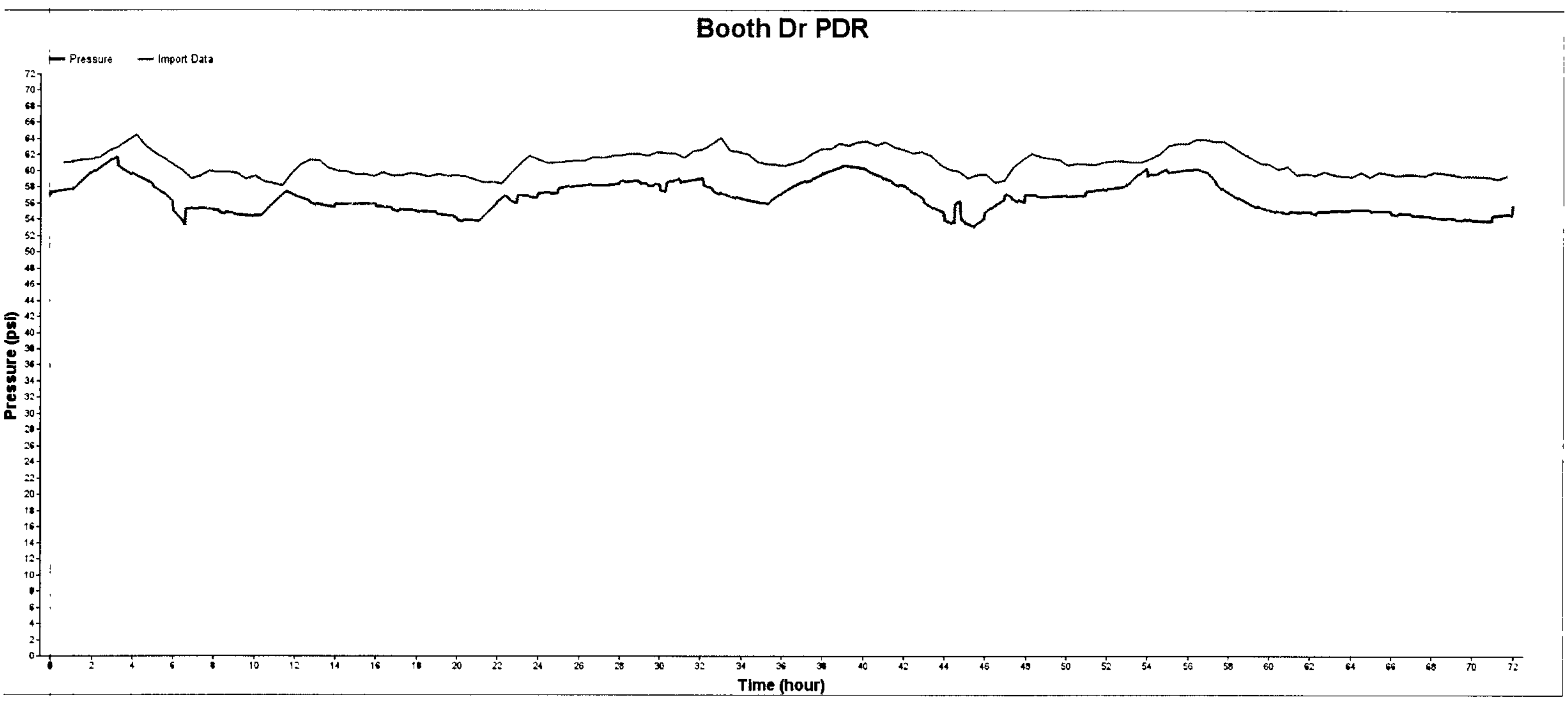
Old Bastrop PPS
Pressure
Import Data
Pressure (psi)
Time (hour)



Sierra Circle PPS
Pressure
Import Data
Pressure (psi)
Time (hour)

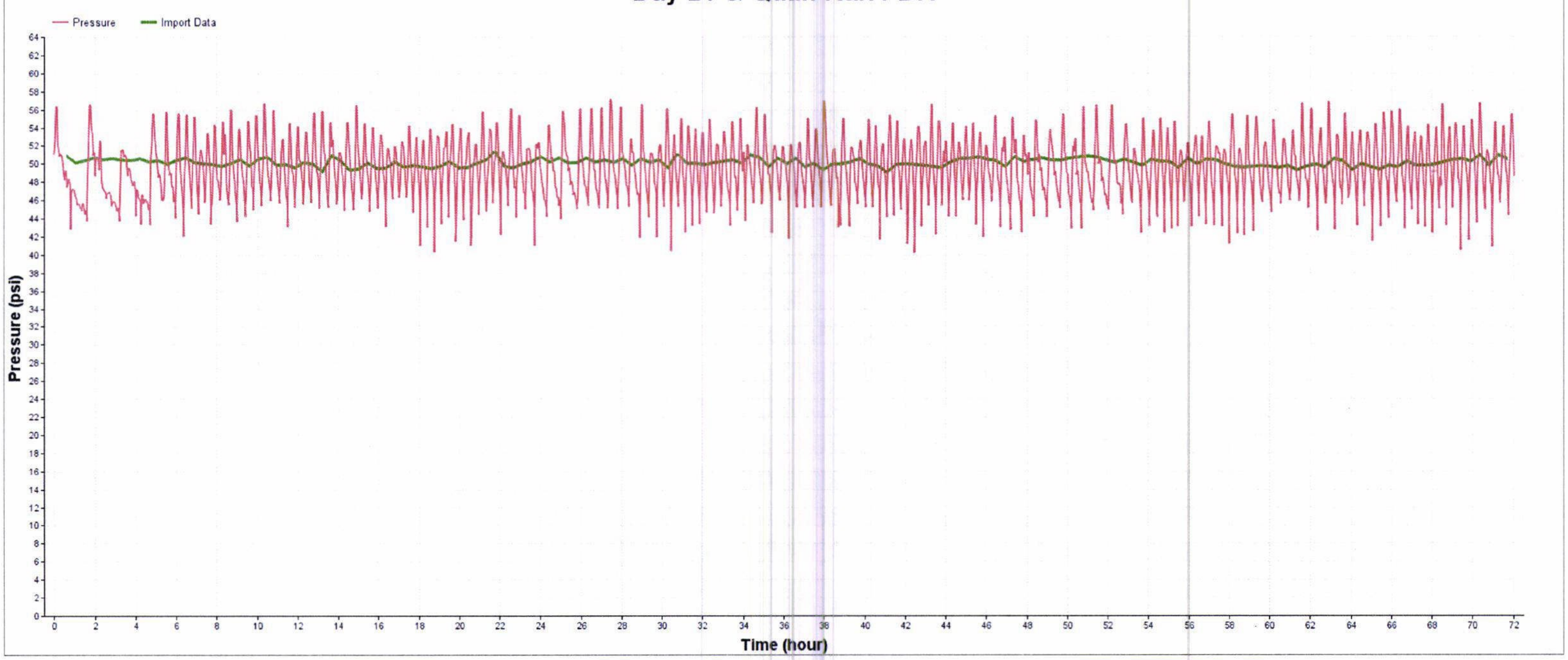


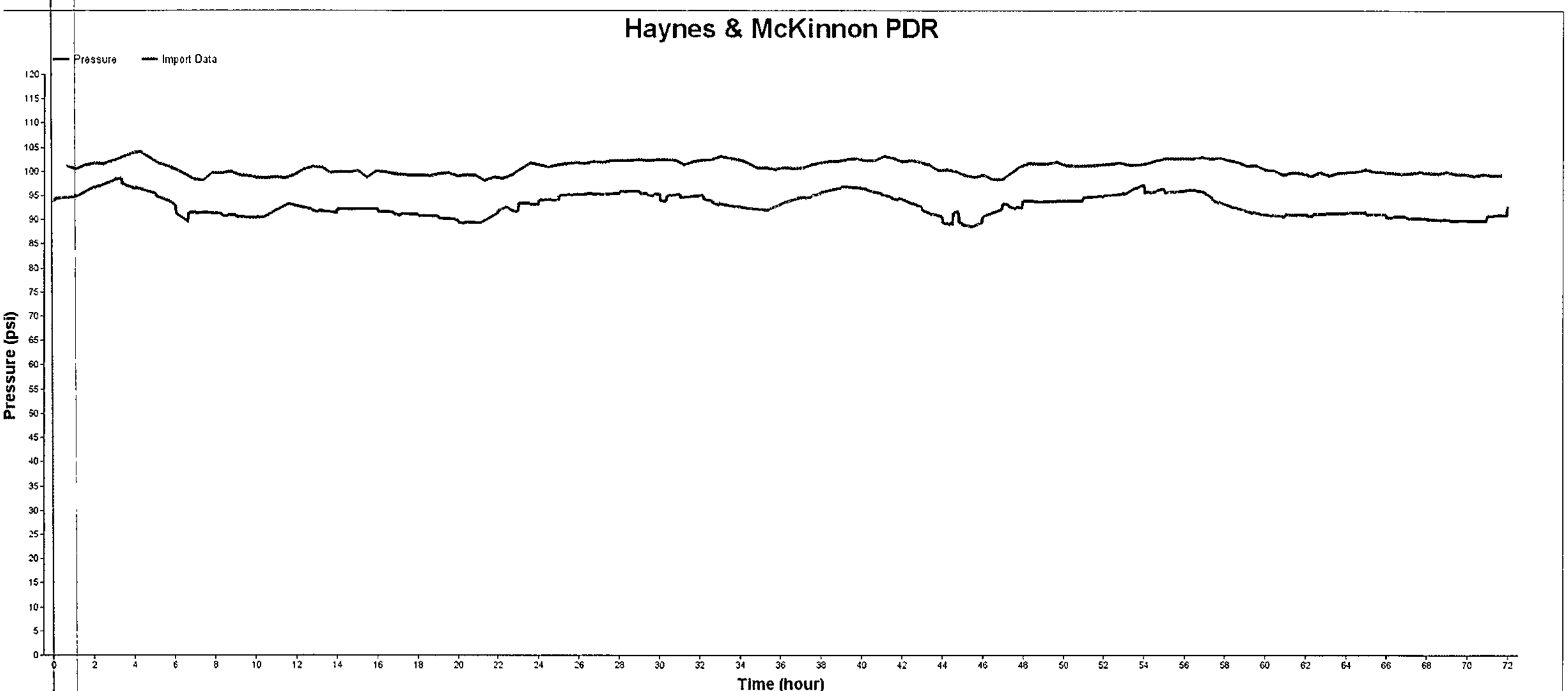
Airport PDR
Pressure
Pressure (psi)
Time (hour)



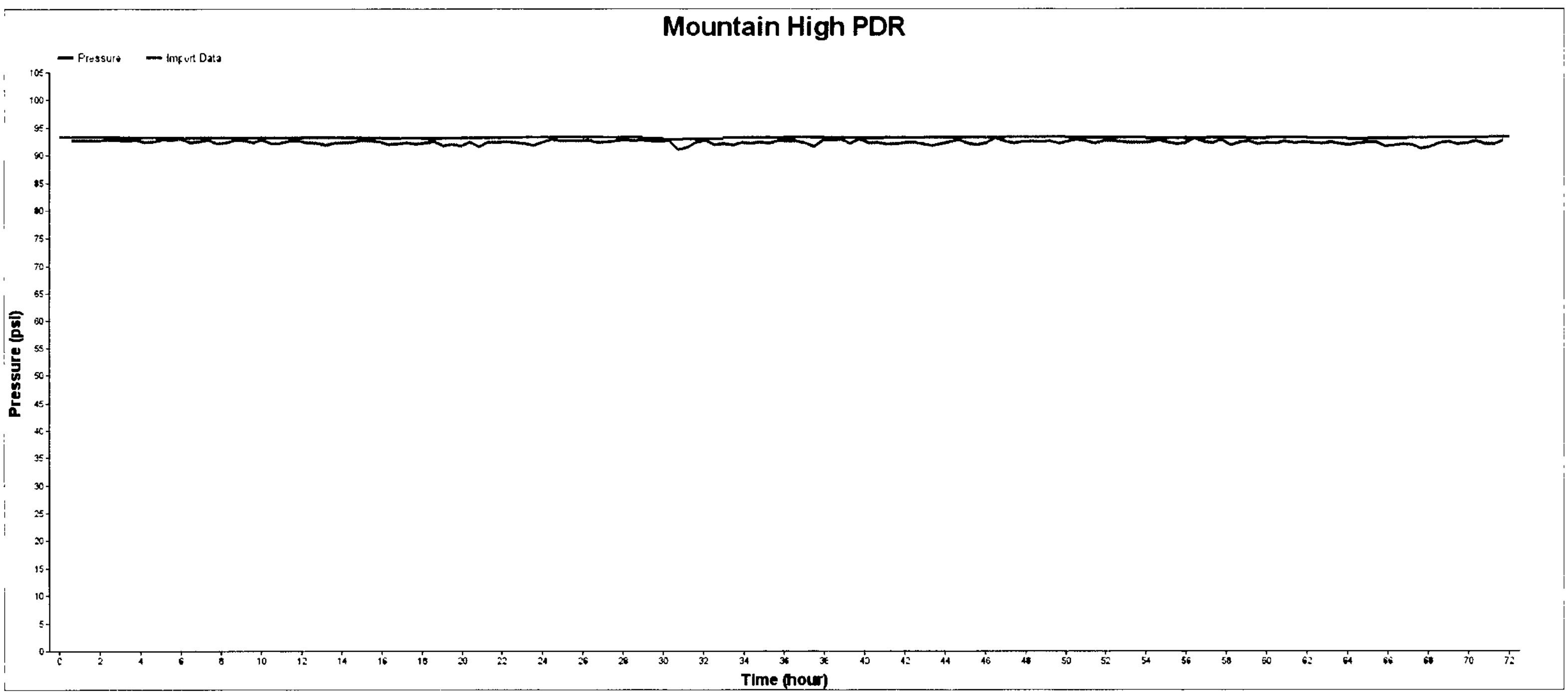
Booth Dr PDR
Pressure
Import Data
Pressure (psi)
Time (hour)

Day Dr & Quail Run PDR

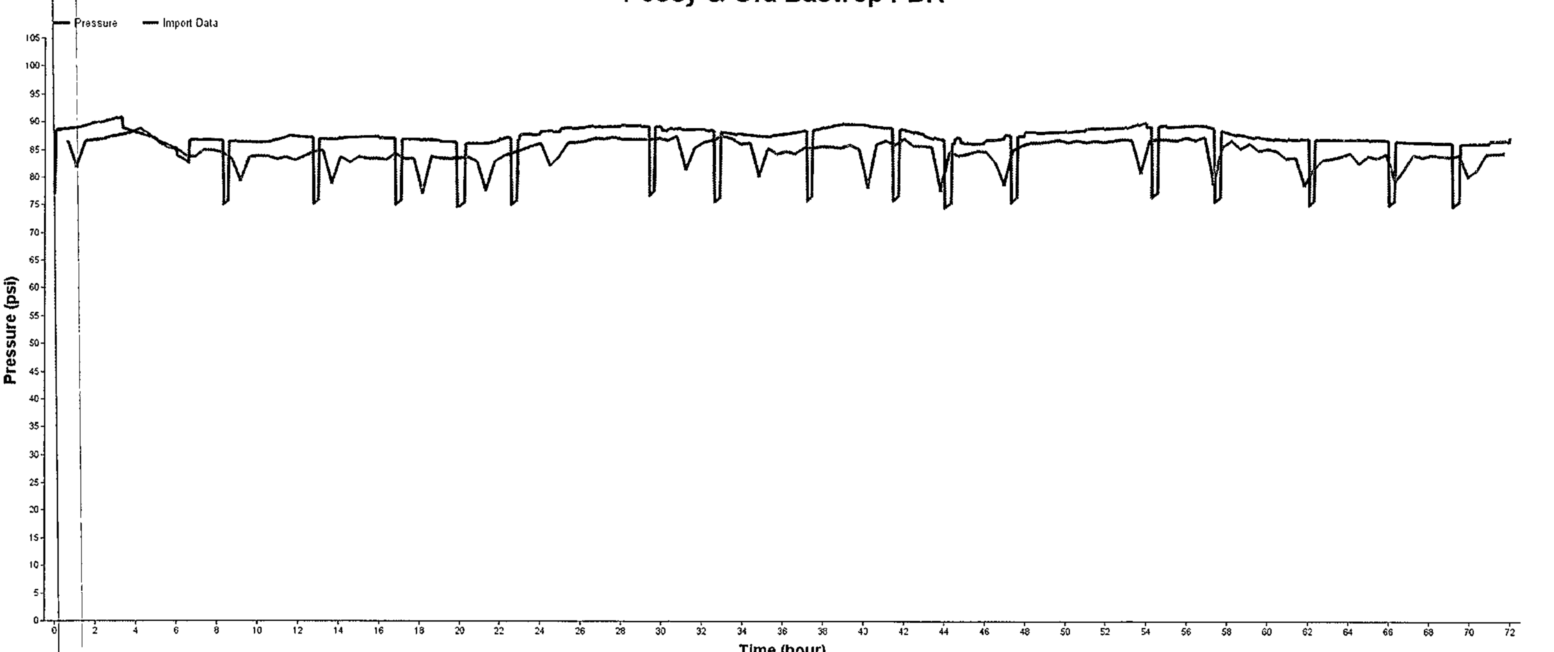


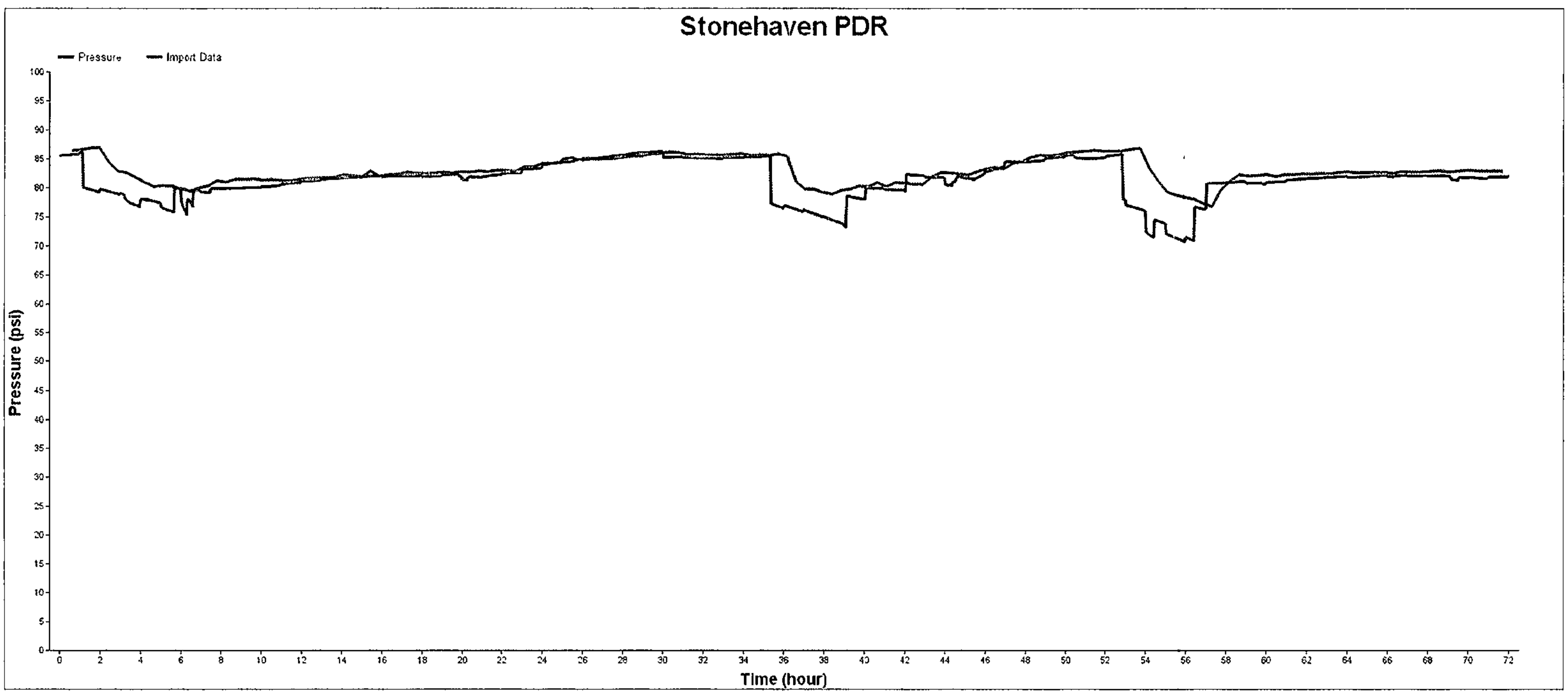


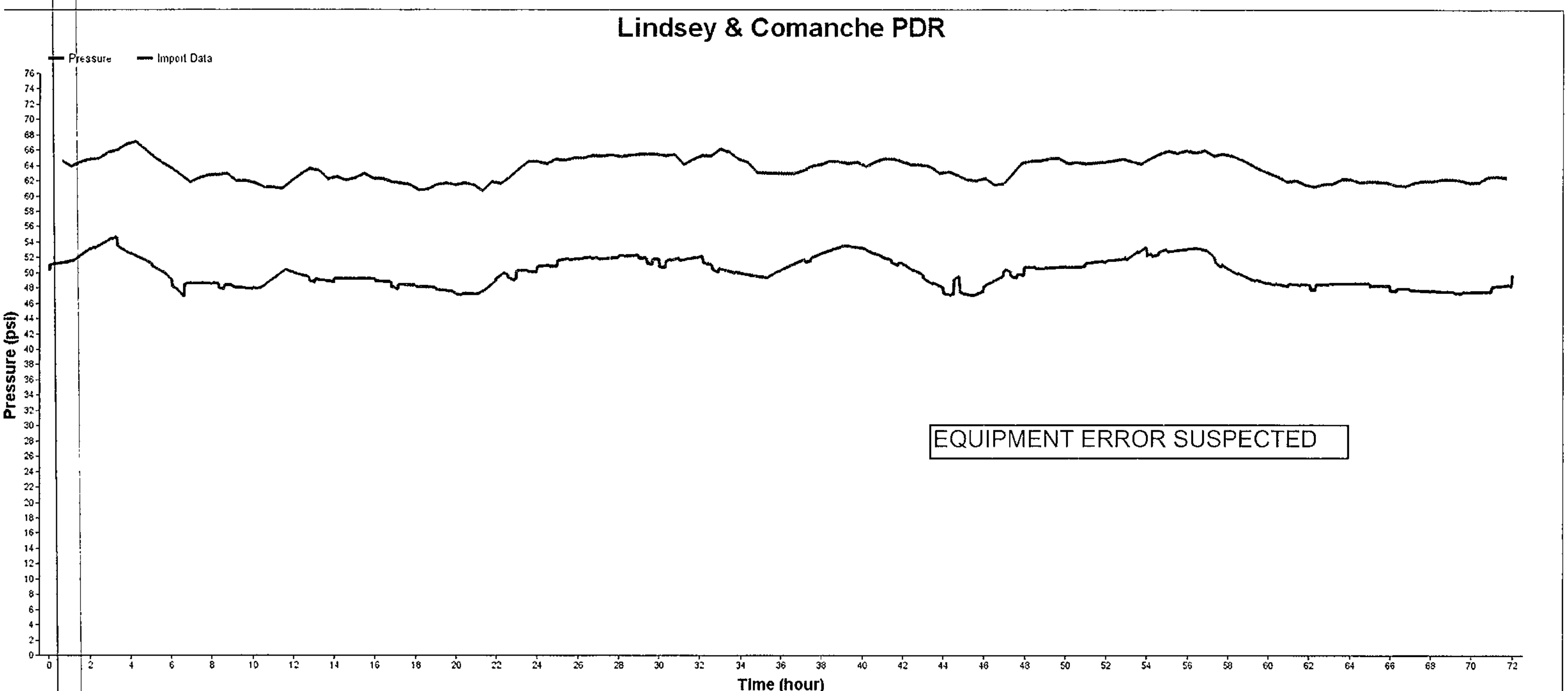
Haynes & McKinnon PDR
Pressure
Import Data
Pressure (psi)
Time (hour)

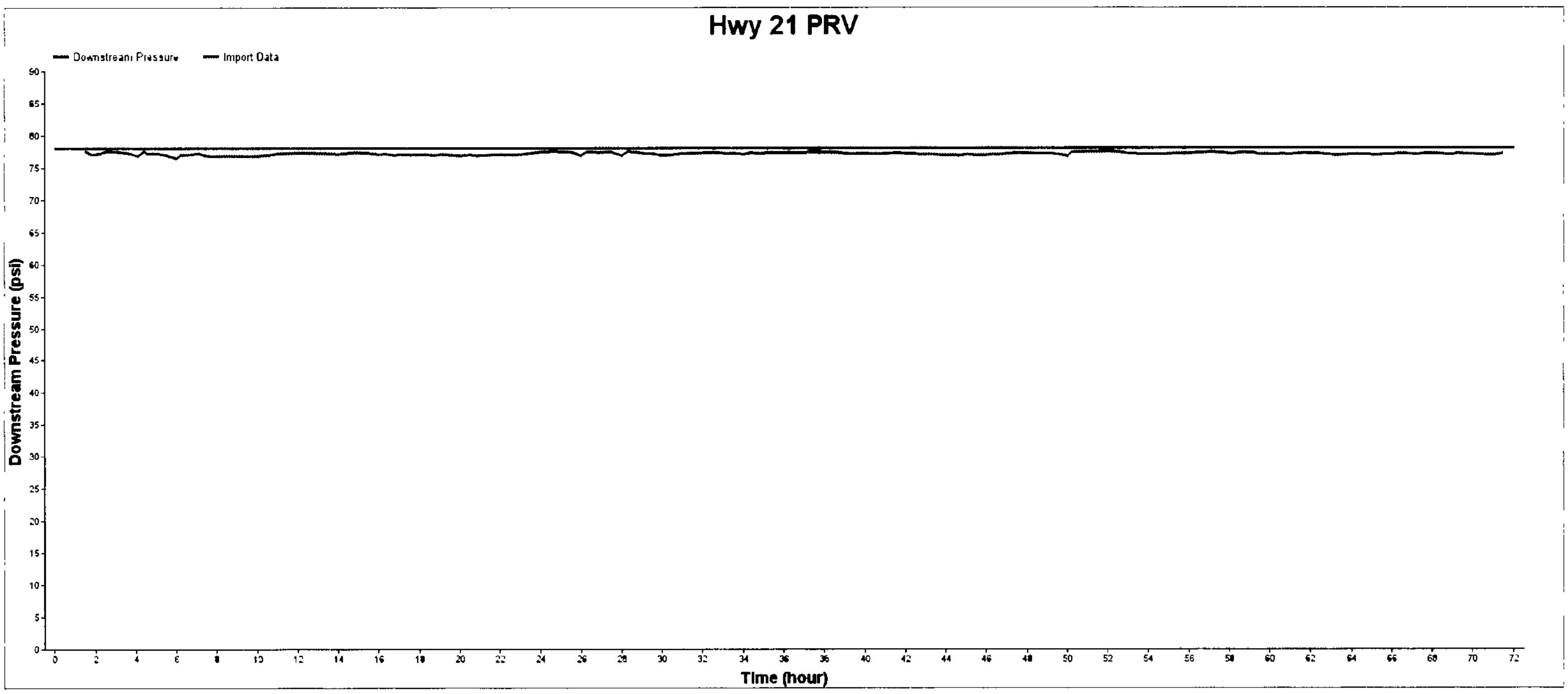

Mountain High PDR
Pressure
Import Data
Pressure (psi)
Time (hour)

Posey & Old Bastrop PDR




Stonehaven PDR
Pressure
Import Data
Pressure (psi)
Time (hour)


Lindsey & Comanche PDR
Pressure
Import Data
Pressure (psi)
Time (hour)
EQUIPMENT ERROR SUSPECTED


Hwy 21 PRV
Downstream Pressure
Import Data
Downstream Pressure (psi)
Time (hour)