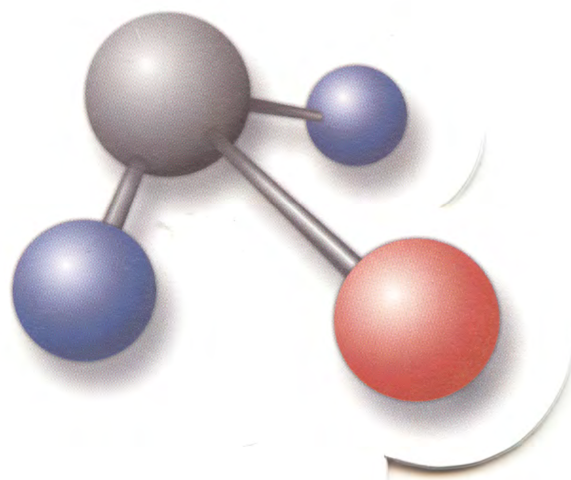
Water Facility Plan Update



PREPARED FOR:

BOZEMAN MT

AE2S Project No. P05097-2013-001

July 2017

REPORT

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WATER FACILITY PLAN UPDATE

FOR

Bozeman, MT

JULY 2017

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Montana.

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Date: July 5, 2017   Registration Number: 40518PE

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No. 40518 PE
LICENSED
PROFESSIONAL ENGINEER

Think Big. Go Beyond.

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GLOSSARY OF TERMS AND ABBREVIATIONS

A

AAD	Average Annual Demand
ACP	Asbestos Cement Pipe
ADD	Average Daily Demand
AE2S	Advanced Engineering and Environmental Services, Inc.
AWWA	American Water Works Association

BC

C-factor	Roughness Coefficient
CCP	Concrete Cylinder Pipe
CIP	Capital Improvement Plan
CI	Cast Iron Pipe

D

D/DBP	Disinfectants/ Disinfection By-Products
DI	Ductile Iron
DIP	Ductile Iron Pipe
DIPRA	Ductile Iron Pipe Research Association

EF

EPS	Extended Period Simulation
ET	Evapotranspiration
FPS	Feet per Second
FT	Feet
FT/1,000 FT	Feet per 1,000 Feet

G

GIS	Geographical Information System
GPCD	Gallons Per Capita Per Day
GPM	Gallons Per Minute
GSR	Ground Storage Reservoir

H

HGL	Hydraulic
HP	Horsepower
HVAC	Heating, Ventilation, and Air Conditioning

I

IBC	International Building Code
IFC	International Fire Code
IITRI	Illinois Institute of Technology Research Institute

ISO	Insurance Service Organization
ISU	Iowa State University
	JKLMN
MDD	Maximum Daily Demand
MG	Million Gallon
MGD	Million Gallons per Day
MMD	Maximum Month Demand
MR&I	Municipal, Rural, and Industrial
MSU	Montana State University
NAVD 88	North American Vertical Datum 1988
NFF	Needed Fire Flow
NFPA	National Fire Protection Association
NRW	Non-Revenue Water
	OPQ
PE	Polyethylene
PHD	Peak Hour Demand
PPC	Public Protection Classification
PRV	Pressure Reducing Valve
PSI	Pounds per Square Inch
PVC	Polyvinyl Chloride
	RSTUV
RCP	Reinforced Concrete Pipe
SCADA	Supervisory Control and Data Acquisition
SDWA	Safe Drinking Water Act
STL	Steel
TDH	Total Dynamic Head
UBO	Ultimate Build-out
USGS	United States Geological Survey
VFD	Variable Frequency Drive
	WXYZ
WDD	Winter Day Demand
WTP	Water Treatment Plant

CHAPTER 1 EXISTING SYSTEM

Major components of the water system include the following:

- Two water production facilities
- Six pressure zones
- 22 pressure regulating facilities
- Two booster stations
- Four finished water storage reservoirs
- Approximately 271 miles of transmission and distribution piping
- 2,448 fire hydrants

There is a Supervisory Control and Data Acquisition (SCADA) central site in place at the City Shop Complex that focuses on the reservoir facilities and Lyman Spring production. The Sourdough Water Treatment Plant (WTP) has SCADA locally, including Sourdough reservoir elevation, and the soon to be completed ground storage reservoir at the WTP. None of the twenty-two PRV facilities is on SCADA.

The components identified above provide water service to the City's existing population of approximately 43,405 people via 12,000 metered connections. The following sections provide an overview of the existing major components of the Bozeman water distribution system.

1.1 Overview of Existing Water Supply Facilities

The City's current water sources are Sourdough Creek and Hyalite Reservoir / Hyalite Creek in the Gallatin Mountains, and Lyman Spring in the Bridger Mountains. The sources of water are captured and utilized as described in **Section 1.1.1**.

Water production facilities include the Sourdough WTP, which treats water from the Hyalite and Sourdough drainages, and the Lyman Spring chemical treatment facility.

1.1.1 Hyalite/Sourdough Water Treatment Plant

The Sourdough WTP is a 22 Million Gallons per Day (MGD) membrane microfiltration plant constructed in 2014. It is located south of town at the mouth of Sourdough Canyon. The membrane filtration plant utilizes grit removal, conventional coagulation-flocculation-sedimentation and straining (300 microns) for membrane pre-treatment. Membrane feed water

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is then pressurized to Pall Aria microfiltration skids and through 0.1 micron membrane pores. Membrane filtrate is injected with sodium hypochlorite for disinfection, with contact time provided by a serpentine 96-inch diameter HDPE pipeline. Sodium hydroxide is added for pH adjustment and corrosion control, and fluoride is added for dental cavity prevention.

Current plant capacity is 22 MGD, with a future expansion capacity of up to 34 MGD.

1.1.2 Lyman Spring Water System

Lyman Creek originates as a spring, discharging from a Mission Canyon limestone formation in Lyman Canyon. The City has constructed three spring collectors since 1999. A spring collector junction box was added in 2008. The junction box feeds spring water into a 16-inch Ductile Iron Pipe (DIP) and 18-inch Asbestos Cement Pipe (ACP) transmission main, which conveys the water down Lyman Canyon to a chemical treatment facility. There are two pressure reducing vaults on the transmission main. The spring water is chlorinated and fluoridated before being discharged into the 5.0 MG Lyman reservoir, an in-ground lined concrete basin that is covered. Finished water is discharged from Lyman reservoir to the distribution system, by gravity.

1.2 Overview of Existing Pressure Zones

The City's water distribution system is comprised of six pressure zones that serve elevations that range from 4,600 to 5,100 (ft) above mean sea level. The pressures zones include the Gallatin Park, Northwest, West, Northeast, South, and Knolls.

Table 1.1 lists each pressure zone, operating Hydraulic Grade Line (HGL), elevation range, and pressure range across the zone. **Figure 1-1** shows the pressure zones described in this section. Summary descriptions of each pressure zone are provided in the following pages.

Pressure Zone	Operating HGL (ft)	Elevation Range (ft)		Pressure Range (psi)	
		Lowest	Highest	Lowest	Highest
Gallatin Park	4885	4684	4701	77	85
Northwest	4940	4609	4788	59	144
West	4980	4735	4820	69	107
Northeast (Lyman)	5038	4680	4806	91	145
South (Sourdough)	5125	4740	5105	6	160
Knolls	5185	4992	5064	52	83

Table 1.1: Existing Pressure Zone Summary

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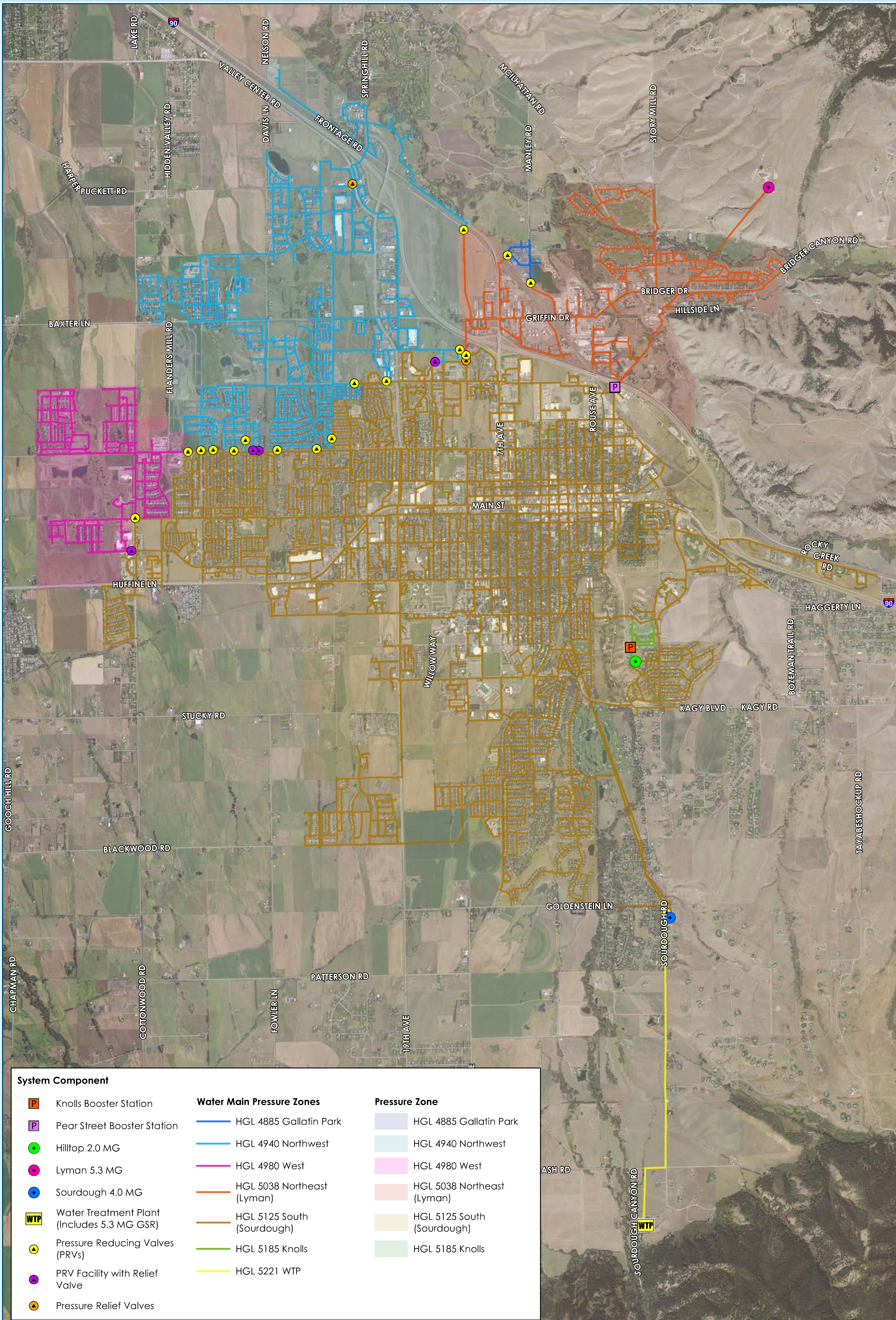

Figure 1-1: Existing Water Distribution System by Pressure Zone

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N

0 0.25 0.5 0.75 1 Miles

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Gallatin Park (HGL 4885)

The Gallatin Park Pressure Zone is a small sub-zone within the Northeast Zone. It operates at an HGL of 4885 ft. Two Pressure Reducing Valve (PRV) facilities provide water to this zone. There is no water production, storage or pressure relief facilities within this zone.

Northwest (HGL 4940)

The Northwest Pressure Zone is a large zone and operates at an HGL of 4940 ft, and 14 PRV facilities provide water to this zone. No water production or storage locations within this zone. The Northwest Zone is a sub-zone to the South Zone and the Northeast Zone. There is one pressure relief facility within this zone.

West (HGL 4980)

The West Pressure Zone is a small zone and operates at an HGL of 4980 ft. Three PRV facilities provide water to this zone. There are no water production, storage or pressure relief facilities within this zone. The West Zone is a sub-zone within the South Zone.

Northeast (Lyman) (HGL 5038)

The Northeast (Lyman) Pressure Zone is a large zone and operates at an HGL of 5038 ft. The Lyman reservoir and spring boxes provide water to this zone. The Lyman Creek water source generally produces between 600 and 2,600 Gallons per Minute (GPM), depending on the time of the year. Finished water is stored in a 5.3 MG reservoir. Pear Street Booster Station lies within this pressure zone and transfers water to the South Zone. One PRV actively provides water from the South zone to the Northeast Zone. A second PRV located within the Pear Street Booster Station can also transfer water from the South zone to the Northeast Zone, but it is not actively used.

South (Sourdough) (HGL 5125)

The South (Sourdough) Pressure Zone is the City's largest and is also referred to as the Sourdough zone, as the pressure is established by the water surface elevation in the Sourdough reservoir. It operates at HGL 5125 ft. Additional water may be pumped from the Northeast Zone into the South Zone through the Pear Street Booster Station. There are two finished water storage facilities within this zone. The Sourdough and Hilltop reservoirs, which hold 4 MG and 2 MG, respectively. Four pressure relief valves for this zone are located within PRV facilities feeding adjacent zones, and one facility is dedicated to pressure relief only.

Knolls (HGL 5185)

The Knolls Pressure Zone is a small sub-zone of the South Zone. It operates at HGL 5185 ft. The Knolls booster station provides water and pressure to this zone. This facility has multiple pumps to meet both domestic and fire flow requirements. There is a PRV located within the booster station. There are no water production or storage facilities within this zone.

Water Treatment Plant (HGL 5221)
The Water Treatment Plant Pressure Zone will operate at an HGL of 5221 ft when the WTP reservoir comes on line in 2017 and will have a storage volume of 5.3 MG. This zone does not serve users directly and only consists of the transmission main between the WTP and the Sourdough reservoir. An existing flow control valve controls the rate of flow from the WTP reservoir to the Sourdough reservoir.

Hydraulic Grade Line Profiles

Hydraulic grade line profiles have been developed for each pressure zone to graphically depict the water flow and pressure set points for all existing PRV facilities within the system. The profiles are included in **Appendix A**.

1.3 Overview of Existing Water Distribution Network

1.3.1 Pumping Facilities

There are two pump stations in the City's distribution system, Pear Street and the Knolls booster stations. Key criteria are summarized in the following paragraphs.

Pear Street Booster Station
The Pear Street Booster Station lies within the Northeast Zone and is used to pump water from the Northeast Zone to the South Zone. There are two large pumps and one small pump within the station. Currently, a single large pump is operated to transfer water into the South zone during the summer months when Lyman spring production is at its highest.

Lyman spring water does not require conventional treatment, so it is very inexpensive, but production from the spring exceeds the demand within the Northeast Zone during limited periods in the late spring and summer. The Pear Street Booster Station is utilized to increase the availability of the spring water to areas of the distribution system. **Table 1.2** provides a summary of the Pear Street Booster Station.

Pump	Manufacturer/ Model	VFD or Constant Speed	Horsepower (Hp)	Design Head (ft)	Design Flow (gpm)
Pear Street No. 1	Fairbanks Morse	constant	10	70	300
Pear Street No. 2	Fairbanks Morse	constant	50	93	800
Pear Street No. 3	Fairbanks Morse	constant	50	93	800
Total - Nominal Design Pump Capacity					1,900
Firm Pump Capacity (with the largest pump out of service)					1,100

Table 1.2: Pear Street Booster Station Summary

Knolls Booster Station

The Knolls booster station provides water to the Knolls Zone, which is situated on a bluff in the eastern-central portion of the City. Four pumps are sized to meet domestic water demand and provide constant pressure to the pressure zone through Variable Frequency Drives (VFD). Two fire pumps are sized to meet the fire flow requirements of the pressure zone. **Table 1.3** provides a summary of the Knolls booster station.

Domestic Pump	Manufacturer/ Model	VFD or Constant Speed	Horsepower (Hp)	Design Head (ft)	Design Flow (gpm)
Knolls No. 1	Grundfos CR 32-2-1	VFD	7.5	139	128
Knolls No. 2	Grundfos CR 32-2-1	VFD	7.5	139	128
Knolls No. 3	Grundfos CR 32-2-1	VFD	7.5	139	128
Knolls No. 4	Grundfos CR 32-2-1	VFD	7.5	139	128
Total - Nominal Design Pump Capacity for Domestic Service					512
Firm Pump Capacity for Domestic Service (with the largest pump out of service)					384

Fire Pump	Manufacturer/ Model	VFD or Constant Speed	Horsepower (Hp)	Design Head (ft)	Design Flow (gpm)
Knolls Fire No. 1	Peerless 8AE12	constant	40	70	1,650
Knolls Fire No. 2	Peerless 8AE12	constant	40	70	1,650
Total - Nominal Design Pump Capacity for Fire Service					3,300
Firm Pump Capacity for Fire Service (with the largest pump out of service)					1,650

Table 1.3: Knolls Booster Station Summary

1.3.2 Distribution Storage Facilities

The Bozeman water distribution system has three existing storage facilities that provide operational storage to meet the system demands, emergency storage, and fire flow storage; as well as maintain a uniform pressure in the distribution system during peak hourly demands. Water storage facilities include the Sourdough reservoir (4.0 MG), the Hilltop reservoir (2.0 MG), and the Lyman reservoir (5.3 MG). Water reservoir information including size, head range, base elevation, and overflow elevation is included in **Table 1.4**.

A new 5.3 MG ground storage reservoir will be constructed in 2017 at the Sourdough WTP. With the addition of this new reservoir, there will be four storage facilities with a combined capacity of 16.6 MG.

Water Storage Facility Name	Volume (MG)	Diameter (ft)	Max SWD (ft)	Base Elevation (ft)	Overflow Elevation (ft)
Sourdough Reservoir	4.0	147	31.5	5094.2	5125.7
Hilltop Reservoir	2.0	93	41.1	5084.0	5125.2
Lyman Reservoir	5.3		30.0	5008.3	5038.3
WTP Reservoir	5.3	212	20.0	5201.4	5221.4
Total	**16.6**				

Table 1.4: Distribution Storage Information

1.3.3 Water Main

The water distribution system network consists of approximately 271 miles of water main varying in size from four-inches up to 30-inches in diameter, with around 70 percent ranging in size from 6- to 8-inches. The water main in the distribution system consists primarily of ductile iron (DI) pipe. However, there is a substantial amount of cast iron (CI) pipe in the older parts of town. Also, there are approximately ten miles total of polyvinyl chloride (PVC) pipe, asbestos cement (AC) pipe, concrete cylinder pipe (CCP), and steel (STL) pipe within the distribution system.

Water main information, including size and material, is included in **Table 1.5**. Refer to **Figure 1-2** and **Figure 1-3** for detailed overviews of the existing water distribution by water main sizes and materials, respectively.

Note that this study does not include evaluation of private water mains located within the distribution system. Water distribution main that provides water service to Montana State University (MSU) is limited to the City's GIS database. As a result, some components maintained by MSU might not be captured in this analysis.

Pipe Size (in)	AC	CCP	CI	DI	PVC	STL	Total Pipe Length (ft)	Total Pipe Length (mi)
	Length of Pipe by Material (ft)							
4	-	-	12,660	2,009	3,227	-	17,897	3.4
6	2,634	-	165,565	182,930	4,906	31	356,066	67.4
8	-	-	38,665	617,279	138	42	656,124	124.3
10	-	-	23,799	99,469	-	-	123,268	23.3
12	-	-	17,124	150,248	-	-	167,373	31.7
14	-	-	15,135	17,184	-	1,510	33,829	6.4
16	-	-	3,091	8,447	-	-	11,538	2.2
18	-	117	8,744	2,309	-	12,900	24,069	4.6
20	-	-	-	1,017	-	-	1,017	0.2
24	-	7,812	673	12,662	-	6,115	27,262	5.2
30	-	13,346	-	208	-	-	13,554	2.6
Total Pipe Length (ft)	2,634	21,274	285,456	1,093,763	8,271	20,598	1,431,996	-
Total Pipe Length (mi)	0.5	4.0	54.1	207.2	1.6	3.9	-	271.2

Table 1.5: Water Main Information

1.3.4 Hydrants and Valves

Isolation valves enable isolation of small segments of the water distribution system so that repairs and maintenance can be accomplished while minimizing the number of customers affected. Isolation valves in the Bozeman water distribution system are predominantly gate valves with some butterfly valves located on the larger diameter water mains. GIS data provided by the City indicates that there are approximately 5,200 isolation valves in the City's distribution system.

PRV stations are utilized in the City's distribution system to maintain desired pressures upstream and downstream of the PRVs, by controlling flow into and out of the zones based on each zone's individual pressure requirements. **Figure 1-1** shows the locations of the 22 PRVs in the City's system.

There are approximately 2,448 fire hydrants used for fire protection in the Bozeman water distribution system.

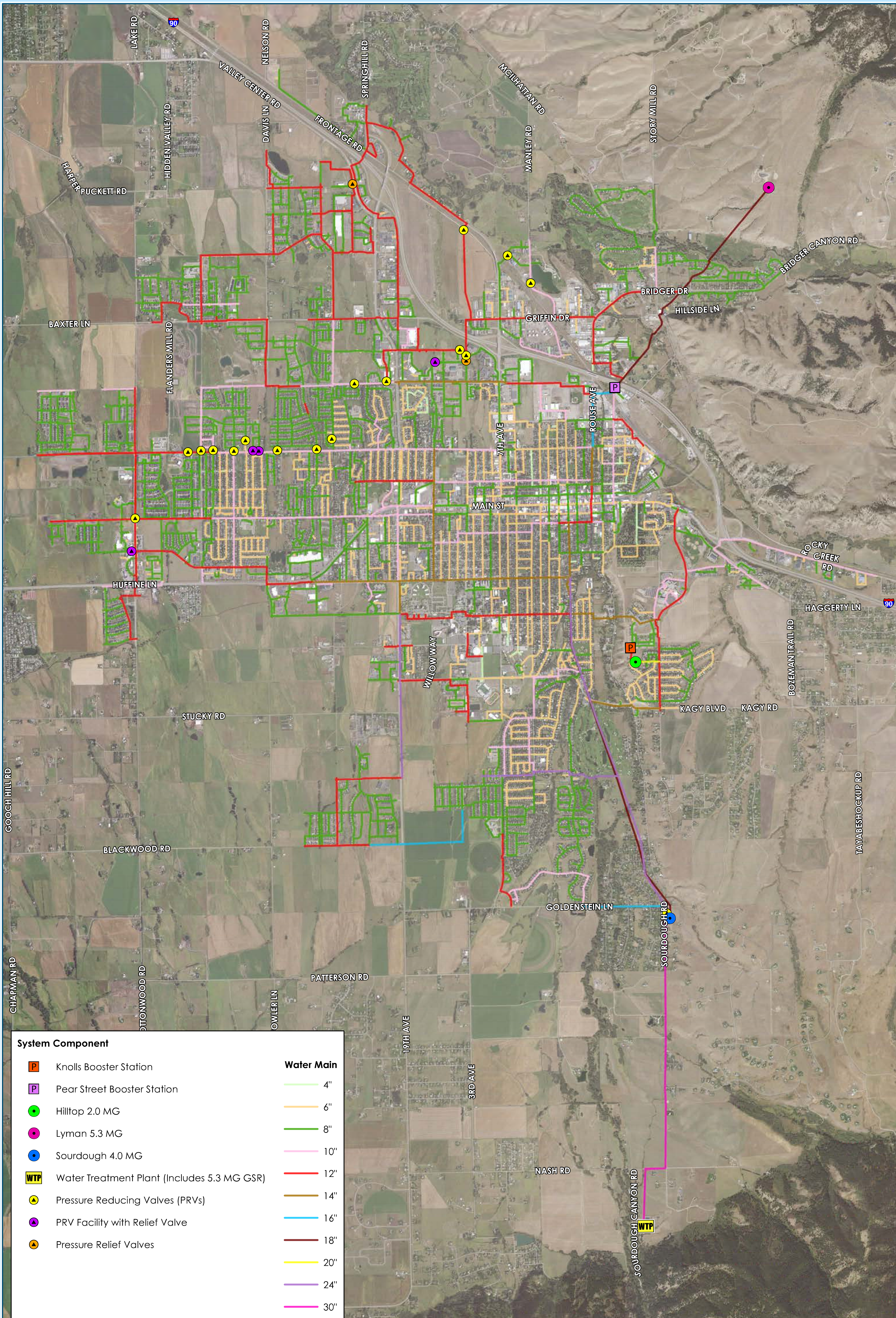

Figure 1-2: Existing Water Distribution System by Water Main Diameter

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0 0.25 0.5 0.75 1 Miles

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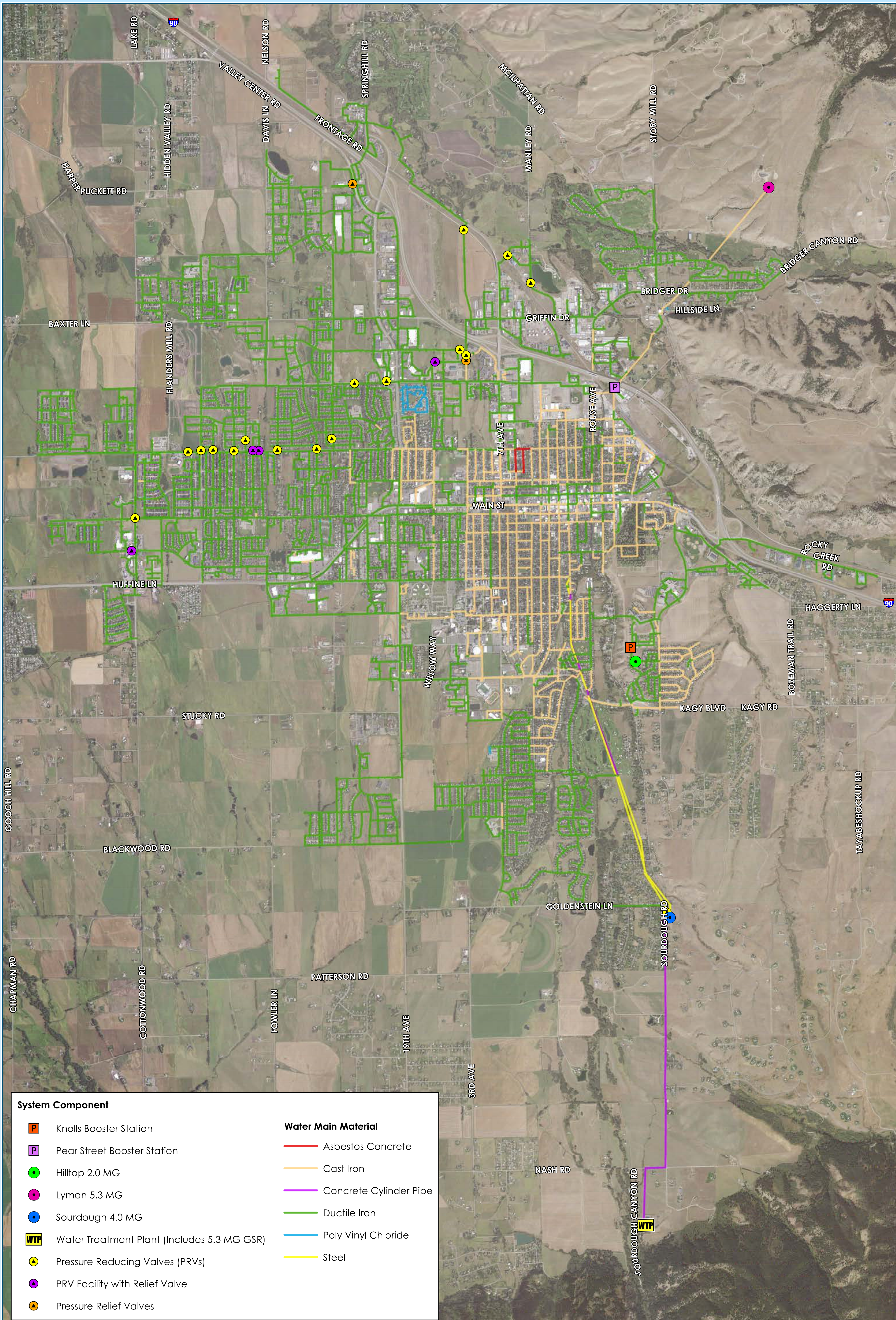

Figure 1-3: Existing Water Distribution System by Water Main Material

City of Bozeman Water Facility Plan Update

0 0.25 0.5 0.75 1 Miles

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CHAPTER 2 BASIS OF PLANNING

2.1 Project Objectives and Deliverables

The objectives of the Water Facility Plan Update are the following:

1) Provide an updated planning and service area map for the City's potable water distribution system.
2) Characterize current water use patterns, including water usage by user class and land use classification,
3) Project future water demand by usage class and land use, which includes the potential impacts of the ongoing water conservation program on future water demands.
4) Provide a comprehensive, calibrated, up-to-date water distribution system hydraulic model utilizing InfoWater by Innovyze®. The model will be integrated with the City's Geographic Information System (GIS), facilitating continuous updates as the distribution system is replaced, improved, and expanded. The model will utilize current and future water demand by user class and land classification, to enable spatial analysis of current and future demand.
5) Provide a thorough fire flow analysis utilizing the calibrated hydraulic model.
6) Identify and describe water system infrastructure improvements required to meet new service and population growth over the planning horizon. The planning horizon for this analysis is threefold: A short-term period to determine water system needs through FY2018-2022 (0-5 years), a near-term period (5-15 years), and a long-term period 15+ years.
7) Evaluate the City's existing pressure zone configuration and identify any feasible measures (future operational or design changes) necessary to achieve pressure reduction.
8) Provide a recommended capital improvement plan (CIP) packet that includes detailed descriptions of recommended CIP projects, maps of the project, categorization of the project (i.e. replacement or continued repair), and a proposed schedule and cost estimate.
9) Evaluate non-potable irrigation system costs, and develop recommended construction standards and specifications for non-potable irrigation infrastructure.

2.2 Previous Studies

There have been two major water facility plans completed for the City in the past two decades that were utilized in the preparation of this update:

- In 1993, a water facility plan was prepared by HKM Associates (currently DOWL) for the City's water and wastewater system. The plan included the evaluation of both the existing and future service areas along with water supply rights. A computer model of the water system was developed to help identify existing deficiencies within the water system and recommend improvements to meet future system requirements. Results from the study were used in creating the City's CIP.
- In 2005, a water facility plan was prepared by Allied Engineering Services, Inc. in conjunction with Robert Peccia and Associates and BETA Engineering. A primary objective of the 2005 plan was to perform an assessment of the old conventional WTP and evaluate options for its upgrade or replacement. In addition, both the existing and anticipated future water systems were modeled and analyzed. Recommend improvements identified in the analysis along with costs were used to create the City's CIP.

2.3 Planning Periods

The establishment of the planning periods is a critical component in the development of the Water Facility Plan Update. A total of three planning periods were established, including short-term, near-term, and long-term periods. The short-term planning period was established to determine water system needs through FY2018-2022 (0-5 years). A near-term planning period (5-15 years) was identified to complete CIP planning for the 5 to 15 year planning horizon and utilized the 2040 Plan Area established in the City's 2016 Transportation Master Plan. Finally, a long-term planning period was identified to capture major infrastructure projects necessary to accommodate ultimate build-out of the City.

For this report, ultimate build-out (UBO) was assumed as the Future Land Use Map published with the City's 2009 Community Plan. This map was modified slightly to include a northwest area from the Transportation Master Plan map. **Table 2.1** summarizes the three different planning periods defined.

Planning Period	Timeframe (years)	Years
Short-Term	0-5	2017 - 2022
Near-Term	5-15	2022 - 2032
Long-Term	15+	2033 and beyond

Table 2.1: Planning Period Summary

Capital improvement projects determined in this planning effort will be placed into the three different planning periods based on different criteria and discussion with City staff. This is further discussed in **Chapter 10**.

2.4 Study Service Area

For systems that are experiencing significant growth, such as the City of Bozeman, defining the study service area is necessary to provide a framework to: 1) define system capacity milestones, 2) develop appropriate phasing of capital improvements, and 3) strategically integrate improvements with existing infrastructure. The ultimate goal of this approach is to maximize the economic benefit of the improvements.

The study area was developed by reviewing current planning documentation, considering recently completed facility plans, evaluating geographical boundaries, and having discussions with City staff. Ultimately, this resulted in using boundaries already established from two recent planning efforts performed for the City, which include the following:

1) Bozeman Community Plan Future Land Use Map – Adopted by the Bozeman City Commission by the City of Bozeman Resolution No. 4163, dated June 1, 2009.
2) Bozeman Transportation Master Plan (TMP) 2016 – Study Area Boundary

These boundaries establish the future growth areas and provide consistency between recent planning efforts. The resulting study service area boundary for the Water Facility Plan Update is presented in **Figure 2-1**. As noted previously, a small area located in the northwest region, identified in the 2040 planning area map of the TMP, was added to the future buildout area (2009 Future Land Use Map) based on recommendations from City staff. This results in a final service area boundary of approximately 44,881 acres, of which 12,803 acres are located within the current municipal boundaries of Bozeman. The Water Facility Plan study area is considered the UBO service area. A more comprehensive review of the history, description, and development of these boundaries can be found in the aforementioned planning documents.

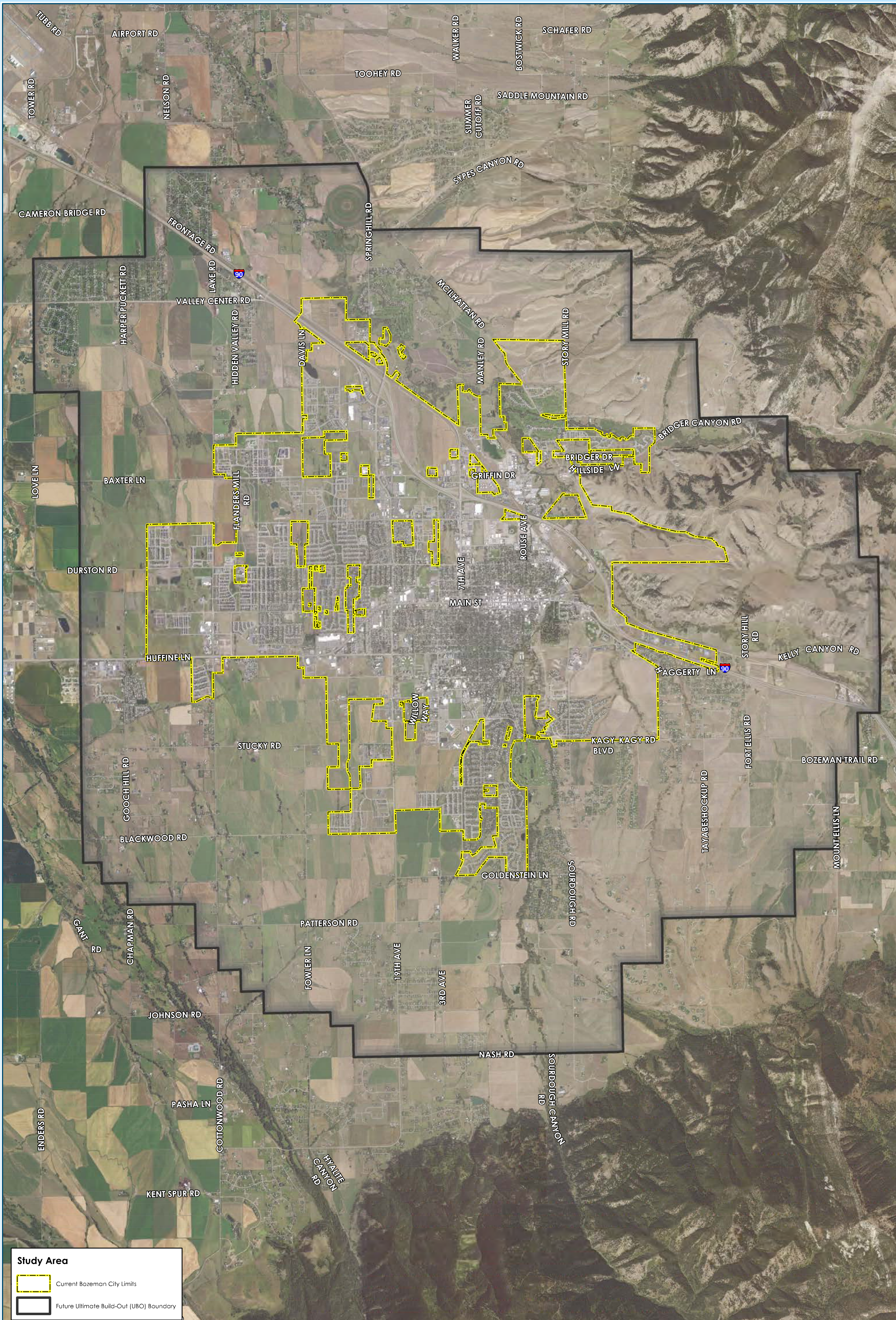

Figure 2-1: Water Facility Plan
Study Area Boundary

City of Bozeman Water Facility Plan Update

Miles
0 0.4 0.8 1.2 1.6

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CHAPTER 3 WATER USE CHARACTERIZATION

This section provides a description of effort required to characterize the City's historic water use trends and define recent water production and demand trends. It also presents the City's projected future water demand up to the UBO. Water Use Characterization is necessary to assess the capacity of the City's existing facilities and ensure that the design and functionality of future water system is sufficient. The Water Use Characterization includes the following components:

- Historical Water Use
- Environmental Conditions
- Water Demand Projections

Water demands discussed in this chapter were incorporated into the hydraulic model to evaluate both existing and future system performance. Results from the modeling analysis will ultimately guide future water system CIP recommendations.

3.1 Definition of Terms

Water demand is described in the following terms:

- Average Annual Demand (AAD) - The total volume of water delivered to the system in a full year expressed in gallons.
- Average Daily Demand (ADD) - The total volume of water delivered to the system over a year divided by 365 days. The average use in a single day expressed in gallons per day.
    - Averaged Daily Winter Demand (Winter Demand) - The gallons per day average during the months of December, January, and February when system demands are low.
    - Average Daily Summer Demand (Summer Demand) - The gallons per day average during the months of June, July, and August when system demands are high.
- Maximum Month Demand (MMD) - The gallons per day average during the month with the highest water demand. The highest monthly usage typically occurs during a summer month.
- Maximum Day Demand (MDD) - The largest volume of water delivered to the system in a single day expressed in gallons per day.

- Peak Hourly Demand (PHD) - The maximum volume of water delivered to the system in a single hour expressed in gallons per minute.

3.2 Source Data

The primary sources of data used to characterize historical water usage, existing demand, and future consumption includes the following items:

1) 2015 parcel information
2) 2009, 2012, and 2014 land use information
3) 2006 through 2015 monthly water meter readings
4) 2006 through 2015 water treatment plant production records
5) 2006 through 2014 census population estimates
6) 2009 Community Plan
7) 2015 Transportation Plan
8) 2015 Wastewater Collection Facilities Plan Update
9) Daily precipitation, temperature, and evapotranspiration (ET) records at Montana State University from Utah State Climate Center

3.2.1 Data Anomalies

A comparison between average annual WTP production data and the monthly water meter readings from 2006 through 2015 was completed to determine if there were any anomalies or errors within the data set provided. **Figure 3-1** shows the WTP production vs. metered water usage.

There are two distinct periods in which metered information did not correlate with WTP production. In 2008, there is a dip in water usage based on the metered information, but no change at the WTP. From 2012 to 2013, the metered data shows a spike in water usage, but no appreciable change in WTP production. These inconsistencies (labeled "Y Values" in the City's billing system) within the data set were presented to City staff. Staff indicated that there could have been some issues with the metering equipment during these periods, potentially causing errors with how the data was ultimately recorded. The City provided direction to remove the data inconsistencies for both of the identified periods, 2008 and 2012-2013. The removal of these data inconsistencies resulted in closer alignment between meter readings and WTP production data.

Figure 3-2 shows the final adjusted metered values used in this analysis. The difference between the water production and metered water, or water consumed, is non-revenue water (NRW). Water production, consumption, and NRW are discussed in the following sections.

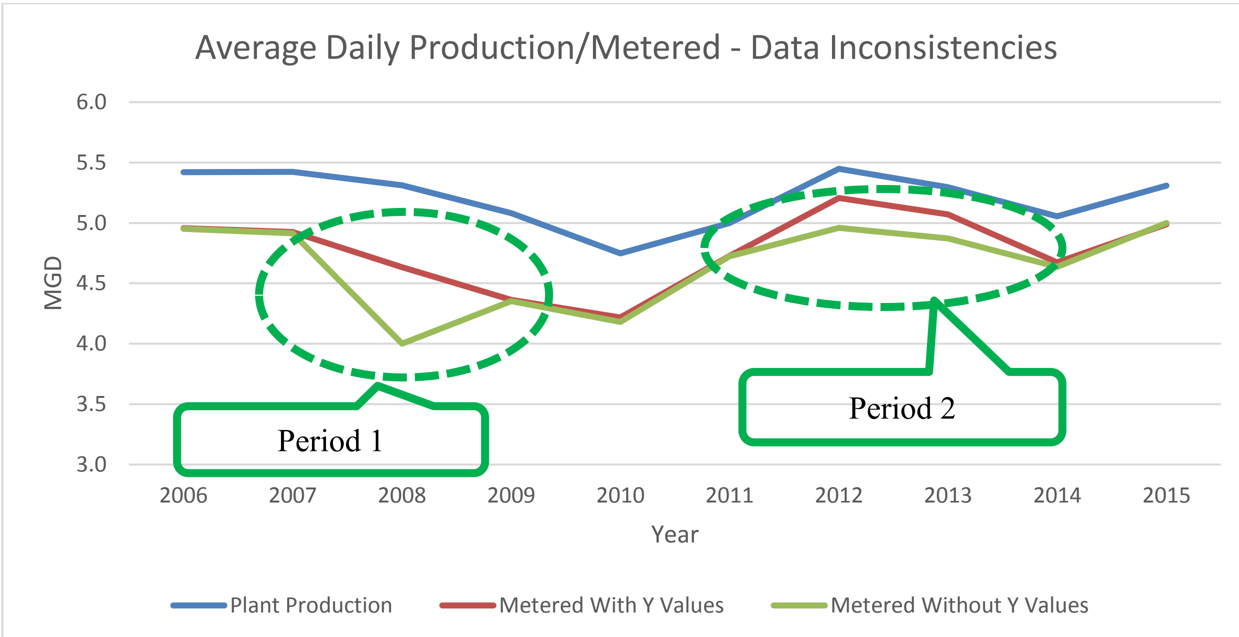

Figure 3-1: Average Annual WTP vs. Metered Data

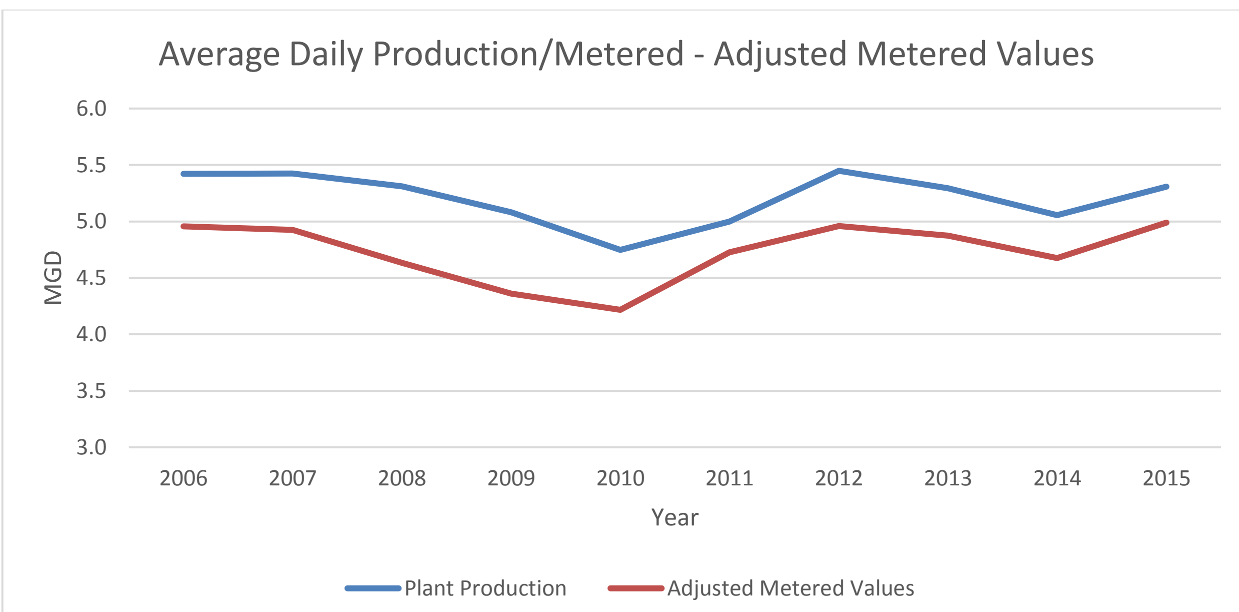

Figure 3-2: Adjusted Average Annual WTP vs. Metered Values

3.3 Historical Water Use

3.3.1 Water Production

The Sourdough WTP and Lyman spring currently provide the City with finished water. Both sites have master meters that are monitored via the City's SCADA system, which allows the City to accurately track the amount of water supplied to the system. Historical production records from 2006 through 2015 were evaluated to determine system demand and develop water usage parameters (i.e. ADD, MDD).

Figure 3-3 shows the ADD, MMD, MDD, and Maximum Day peaking factors observed from 2006 through 2015. Maximum Day peaking factors were calculated as the ratio of MDD to ADD.

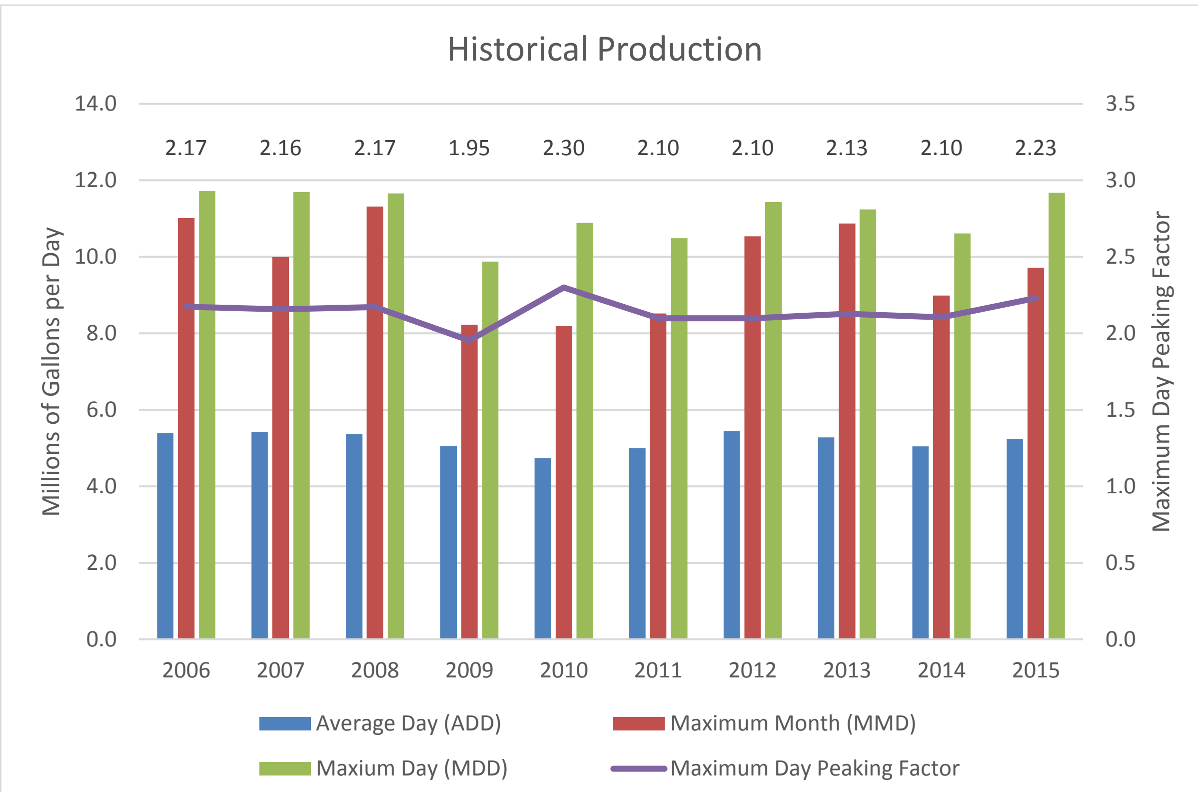

Figure 3-3: Historical Annual Water Production 2006 – 2015

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3.3.2 Water Consumption

3.3.2.1 *Water Production vs. Metered Water*

The City tracks water consumption through customer water meters. Historical water meter records from 2006 through 2015 were evaluated to determine overall customer water consumption, water demand by customer class, per capita usage, and seasonal variations in demand. **Figure 3-4** shows the City's annual water production vs. metered water consumption.

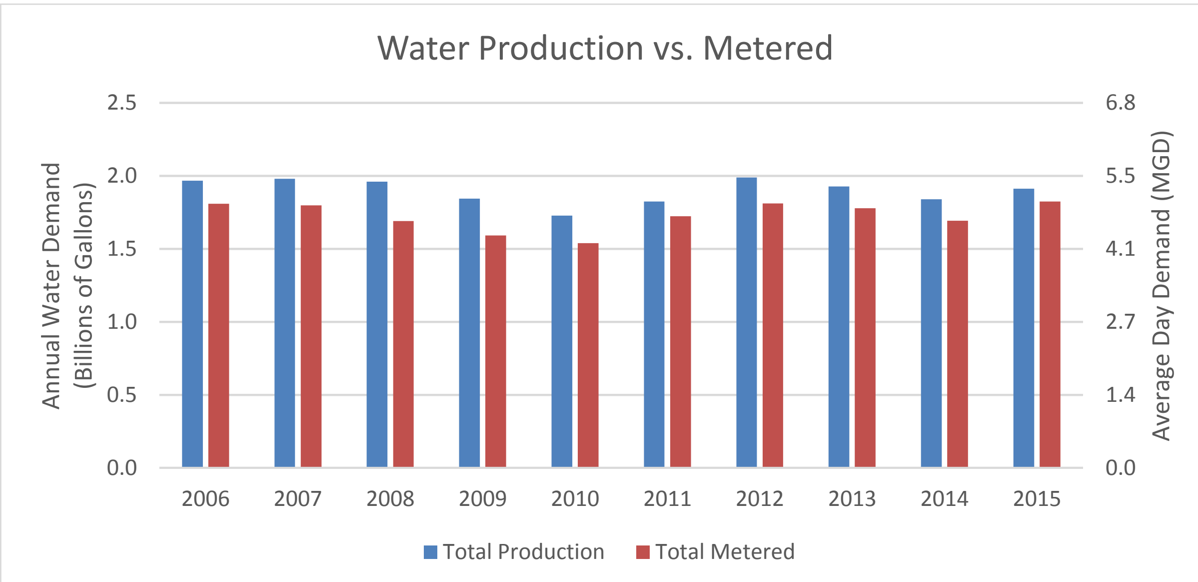

Figure 3-4: Water Production vs. Metered

Over the last ten years, the ADD based on metered data is approximately 4.7 MGD, which is slightly lower than the ADD of 5.2 MGD calculated from water production. The difference between these two values is considered NRW, which is discussed in more detail in **Section 3.3.3**.

3.3.2.2 *Seasonal Variations*

Noting that water usage varies depending on the season, the average daily water usage per month was evaluated to determine which months had the highest water demand.
Figure 3-5 shows the average daily water usage per month from 2006 to 2015.

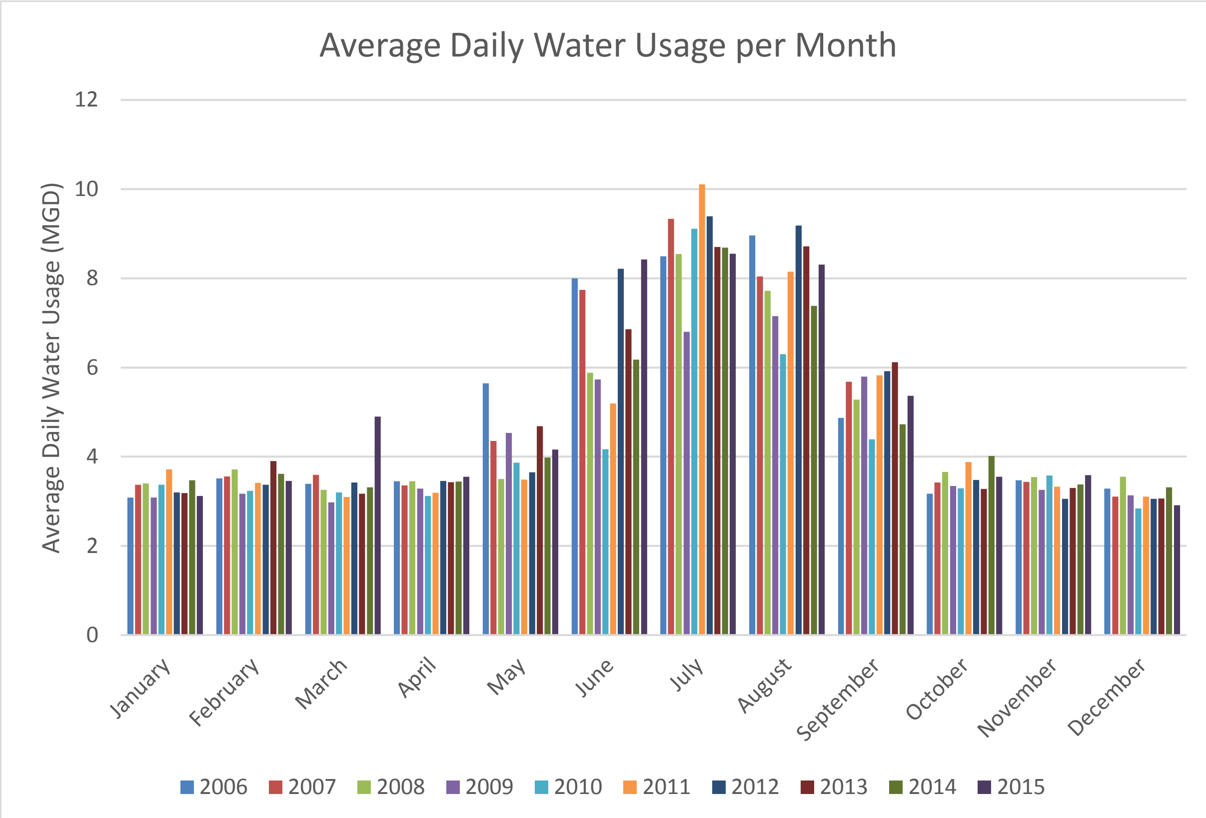

Figure 3-5: Average Daily Water Usage per Month

Average monthly water usage ranged from 3.1 MGD (January 2009) to 10.1 MGD (July 2011). As expected, the City experiences the highest demand during the summer months (June, July, August) when irrigation demand peaks. Demand during the summer months is approximately double to triple compared to winter demand. There does not appear to be an upward trend in overall water usage, which is notable given Bozeman's growth rate and could be due in part to the City's efforts to promote water conservation (established 2008). Per capita water usage is analyzed further in **Section 3.3.2.3**. Seasonal summer and winter demand separated by customer type is shown in **Figure 3-6**.

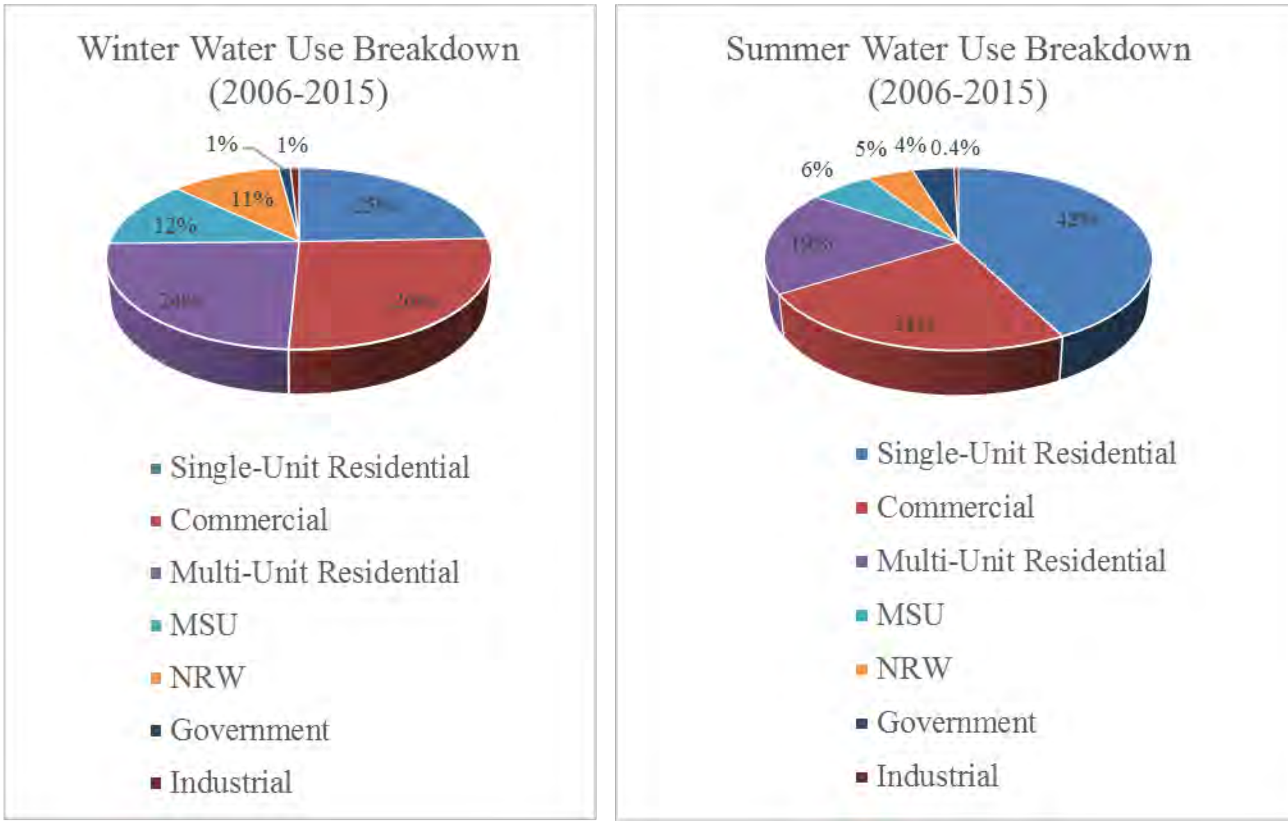

Figure 3-6: Summer (June – August) and Winter (November-March) Water Usage per Month by Customer Type

Noteable results of the seasonal water usage analysis are the following:

- Summer irrigation demand is heavily driven by single-unit residential;
- MSU operates its own non-potable irrigation system;the decline in water usage is attributable to reduced student enrollment during the summer semester;
- The data indicates that NRW, as a percent of total water use, decreases during the summer months, which is due to NRW being relatively constant throughout the year and as a result constitutes a higher percentage of the breakdown during periods of lower demand (i.e. winter). The phenomenon of experiencing a relatively constant rate of NRW is rational given the operating pressure of most areas of the distribution system does not increase during peak demand periods.

3.3.2.3 *Per Capita*

Figure 3-7 and **Figure 3-8** show the population growth from 1950 to 2015[1] and then in finer detail from 2005 to 2015, respectively. Historical population information was used to determine per capita demands.

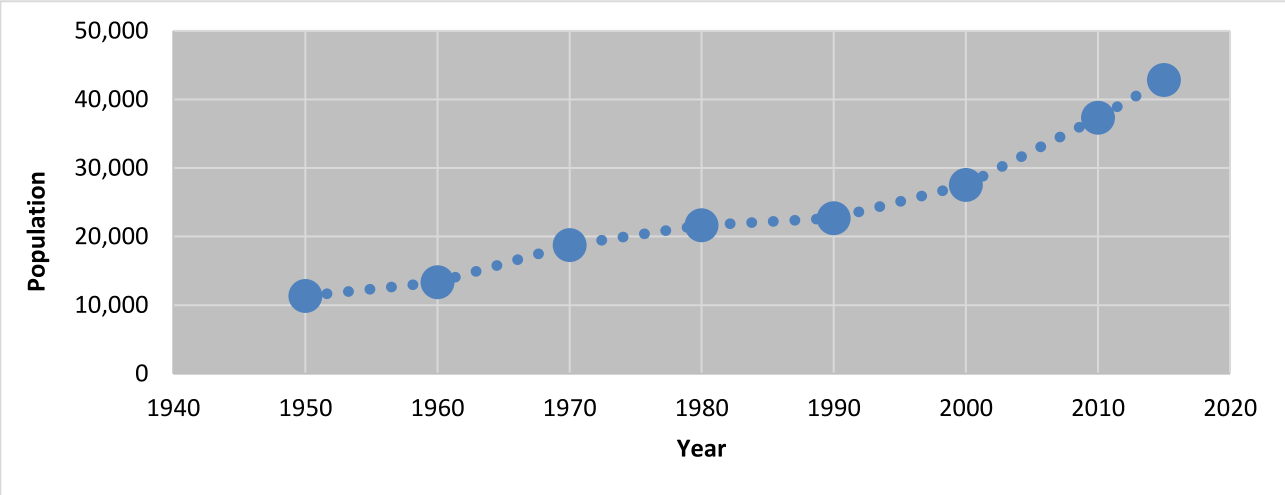

Figure 3-7: City of Bozeman Population Growth from 1950 to 2015

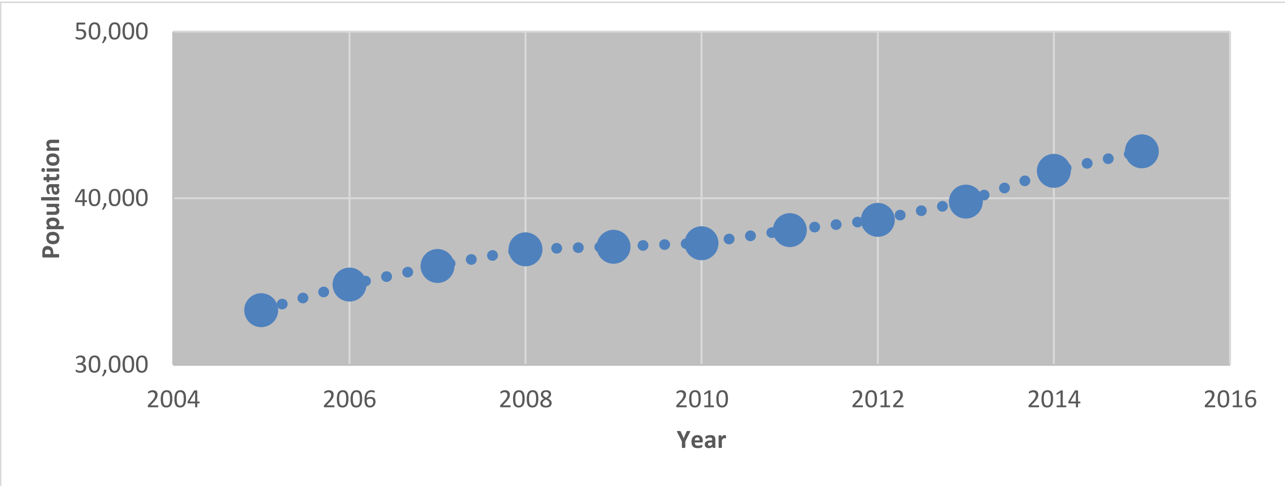

Figure 3-8: City of Bozeman Population Growth from 2005 to 2015

[1] U.S. Census Bureau (2016). *Cities and Towns Population Total Tables.* Retrieved from [https://www.census.gov/data/tables].

The total per capita water use for the City between 2006 and 2015 is shown in **Figure 3-9**. The per capita use rate is not the amount that the average person uses as it takes into account all water uses including residential, commercial, industrial, etc. NRW was not included in the per capita use rate.

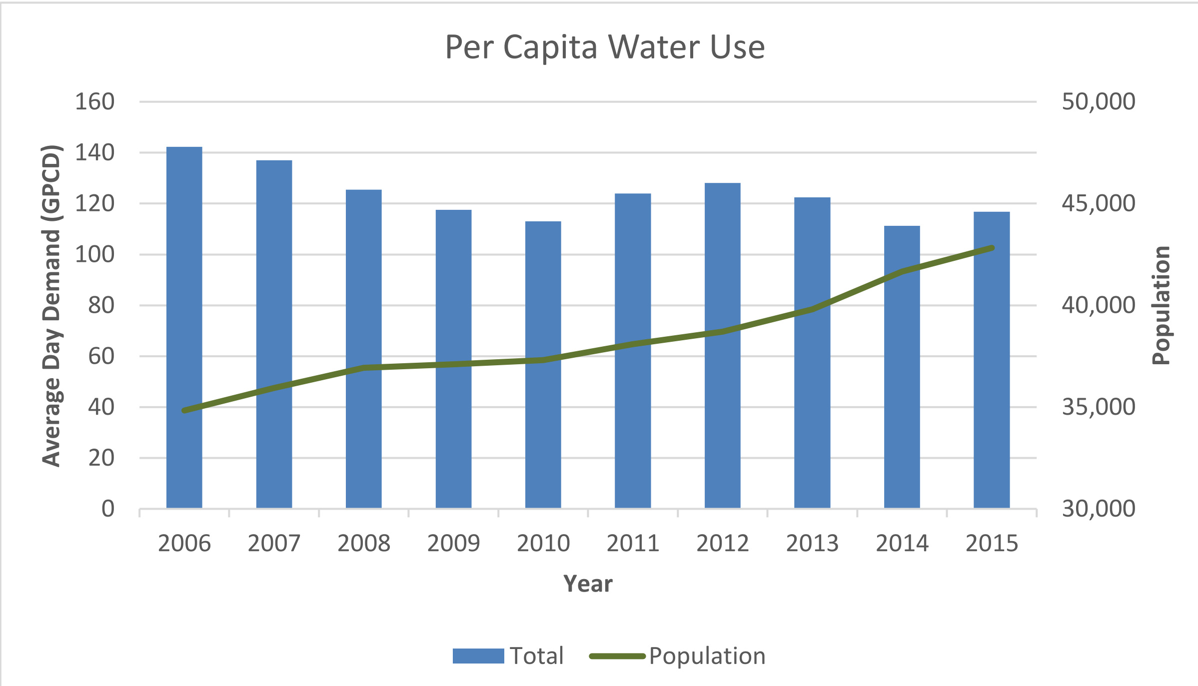

Figure 3-9: Per Capita Water Use

The 10-year annual daily per capita water use in the City ranges from 142 (2006) to 111 (2014) GPCD, with a 10-year average at 123 GPCD. The graph shows that, as City's population continued to grow, the overall GPCD decreased. This decreasing water usage trend is most likely due to the City's robust water conservation program; although minor decreases are also probably attributable to the increase in population that is driving multi-family development with reduced summer water demands and newer developments that are constructed with high efficiency fixtures.

As will be described in later sections, this Water Facility Plan Update utilizes water demand by land usage classification to estimate future water demand. If the City wishes to utilize per-capita average water demand by population, 123 GPCD is a reasonable estimate. However, 135 GPCD includes NRW and should be used to account for total system production and master planning.

Per capita water use by customer class for the City between 2006 and 2015 is shown in **Figure 3-10**. Single-unit residential, commercial and multi-unit residential represent the bulk of water usage in the City. Further analysis of the City's per capita water use by customer class shows that single-unit residential accounts for approximately 36 percent of water usage, followed by

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commercial at 27 percent, then multi-unit residential at 23 percent. There is very little industrial water usage in Bozeman.

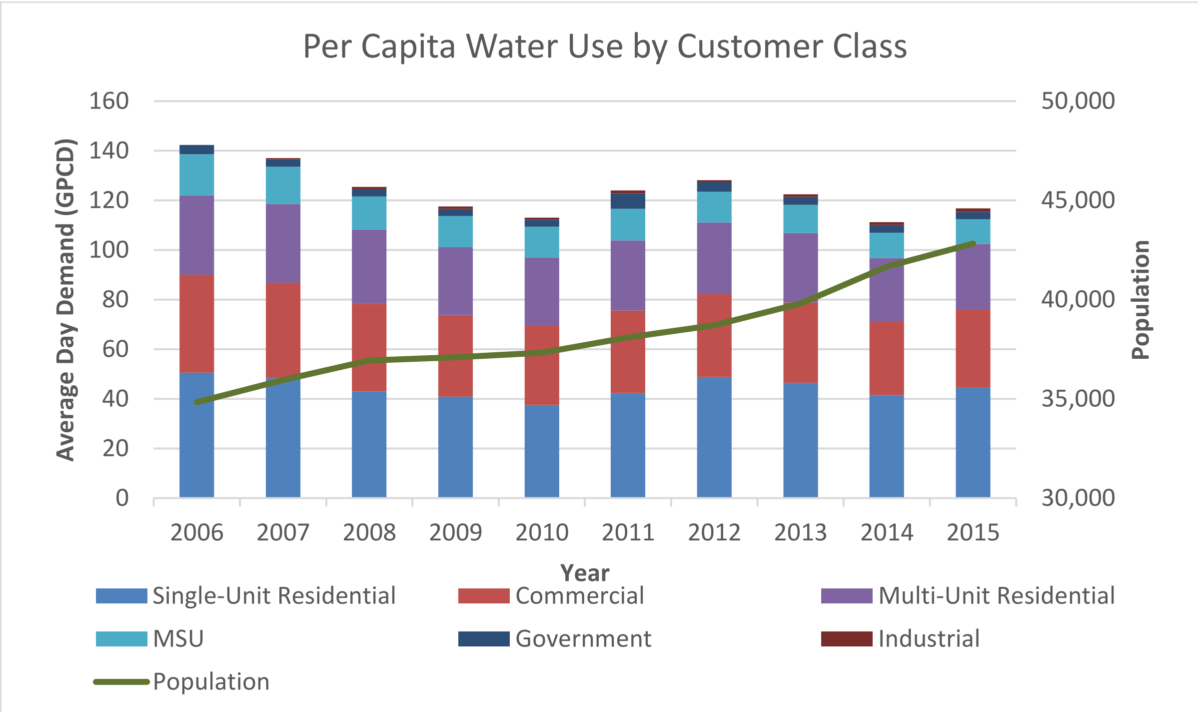
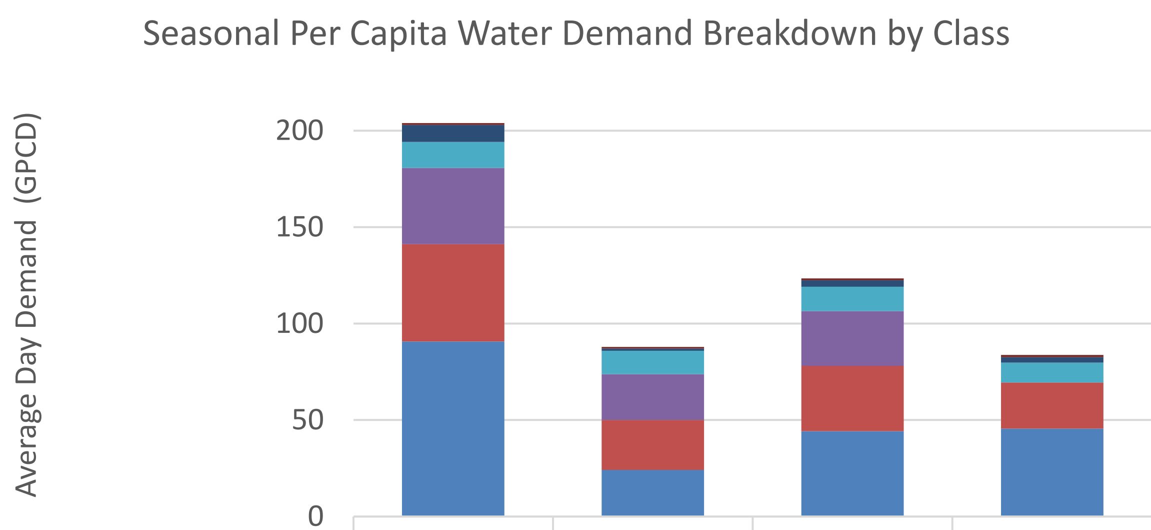


Figure 3-10: Average Per Capita Water Use by Customer Class

Figure 3-11 presents demand by customer type across summer (June - August) and winter (November - March). This illustrates that the increase in water demand in the summer months is predominately driven by single-unit residential, as usage increases by a factor of 3.8. The next highest increase in summer usage is caused by the commercial sector.

Customer class GPCD was calculated by segmenting the City's total GPCD into the different customer classes based on seasonal uses for each class. The data was then averaged from 2006 to 2015. The total average GPCD is approximately 123.4 GPCD. The residential customer classes (i.e. multi-unit and single-unit) account for approximately 60 percent of the total average water use.

GPCD values used in the City's wastewater facility plan, completed in June 2015 by HDR, Inc., are referenced for comparison purposes. The values in the HDR report were used to determine average wastewater flows for the City. Both analyses show similar average GPCD water usage by class



	Summer	Winter	Average	Waste Water Facility Plan (HDR)
Total	203.9	87.9	123.4	
Industrial	0.9	0.9	0.9	1.2
Government	8.8	1.2	3.4	2.8
MSU	13.4	12.1	12.6	10.3
Multi-Unit Residential	39.6	23.7	28.4	
Commercial	50.3	26.0	33.7	23.9
Single-Unit Residential	90.8	24.1	44.3	45.6

Figure 3-11: Seasonal Per Capita Water Use by Customer Class (2006-2015)

3.3.3 Non-Revenue Water

NRW is the difference between the volume of water produced and the volume of water that is consumed or billed to customers. For the purposes of this report, NRW are identified as the following components: real losses, apparent losses, unbilled authorized consumption, and unbilled unauthorized consumption.

- Real losses comprise leakage from all parts of the system and overflows at storage reservoirs. Excessive rates of real losses are caused by inadequate operations and maintenance procedures, the lack of active leakage control, and poor quality of underground assets.

- Apparent losses are caused by customer meter inaccuracies, data-handling errors, or potential theft of water.
- Unbilled authorized consumption includes water used by the utility for operational purposes (e.g., hydrant flushing), water used for firefighting, and water provided free to certain consumer groups (if practiced).
- Unbilled unauthorized consumption includes water used by unmetered connections, such as illegal connections, open bypasses around meters, misuse of fire hydrants, and meter tampering.

Figure 3-12 shows the yearly percentage of NRW the City has experienced from 2006-2015.

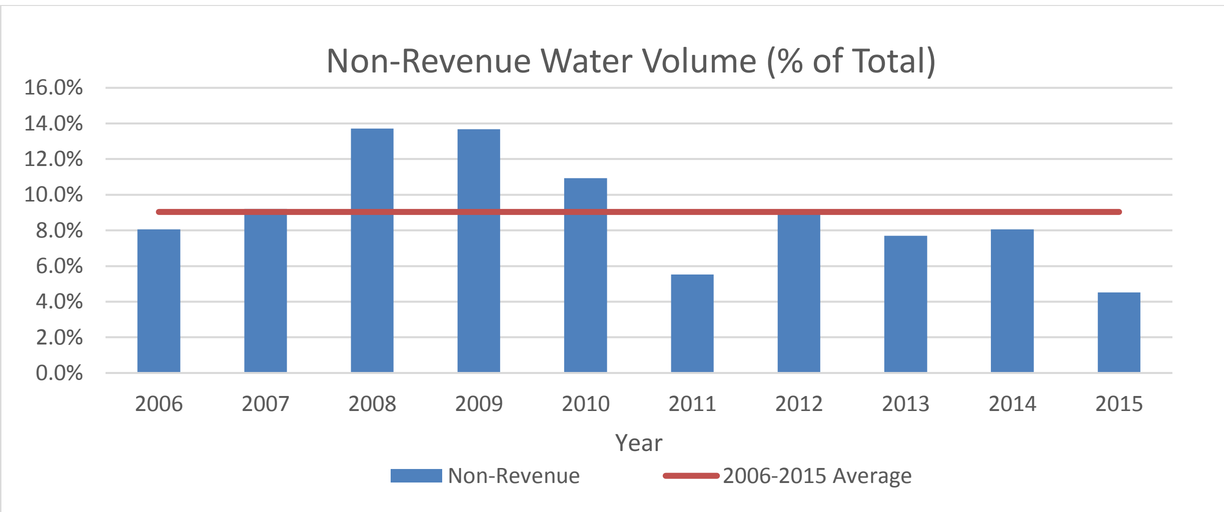


Figure 3-12: Non-Revenue Water Volume (% of Total)

Over the last ten years, the NRW ranged from 4.5 percent (2015) to 13.7 percent (2008, 2009), with an average of 9 percent. Currently, there is no national standard for NRW, but the guidance given by the U.S. EPA for maximum NRW is typically between 10-15 percent.[2] There appears to be a downward trend in NRW for Bozeman. The trend could be attributable to improved customer metering accuracy, improved plant metering accuracy, and recent identification and correction of significant sources of NRW via leak detection.

It is recommended that a NRW rate of 9 percent be utilized for future planning purposes.

[2] Control and mitigation of drinking water losses in distribution systems. (2010). Washington, D.C.: U.S. Environmental Protection Agency, Office of Water. Page 109

3.3.4 Existing Water Demand Summary

Table 3.1 summarizes water demands for the 2006 - 2015 analysis period utilized for the water demand characterization. The values listed are the demands imposed on the production system, or supply-side demands, and thus account for NRW. For the purpose of analyzing the existing system, the demand values listed in **Table 3.1** have been incorporated into the hydraulic model.

Demand Day	Demand (MGD)
Average Day	5.2
Summer Day	8.6
Maximum Day	11.7
Winter Day	3.6

Table 3.1: Existing System Demand Summary

3.4 Environmental/Meteorological Conditions

Changes in environmental conditions can greatly influence water supply and demand. This section evaluates historical data and presents the correlations identified between water demand and meteorological parameters (i.e. precipitation and evapotranspiration).

3.4.1 Summer Precipitation and Summer Water Demand

Precipitation during the summer months (June, July, and August) was evaluated to determine if water demands significantly decrease during periods of rainfall. **Figure 3-13** shows the last 10 years of summertime precipitation vs. metered system water demand .

3.4.2 Evapotranspiration

Evapotranspiration is the process by which water is transferred from the land to the atmosphere by evaporation from the soil and transpiration from plants. Evapotranspiration provides a quantifiable measurement of the amount of water that is needed to sustain landscaping. Evapotranspiration fluctuates throughout the year, primarily with changes in temperature and relative humidity. **Figure 3-14** shows the Monthly Evapotranspiration vs. metered water demand over the last 10 years (2006-2015), and illustrates how water use trends coincide with ET.[3]

[3] 2014-15 City of Bozeman Water Conservation Program Update – Annual Report to the City Commission.

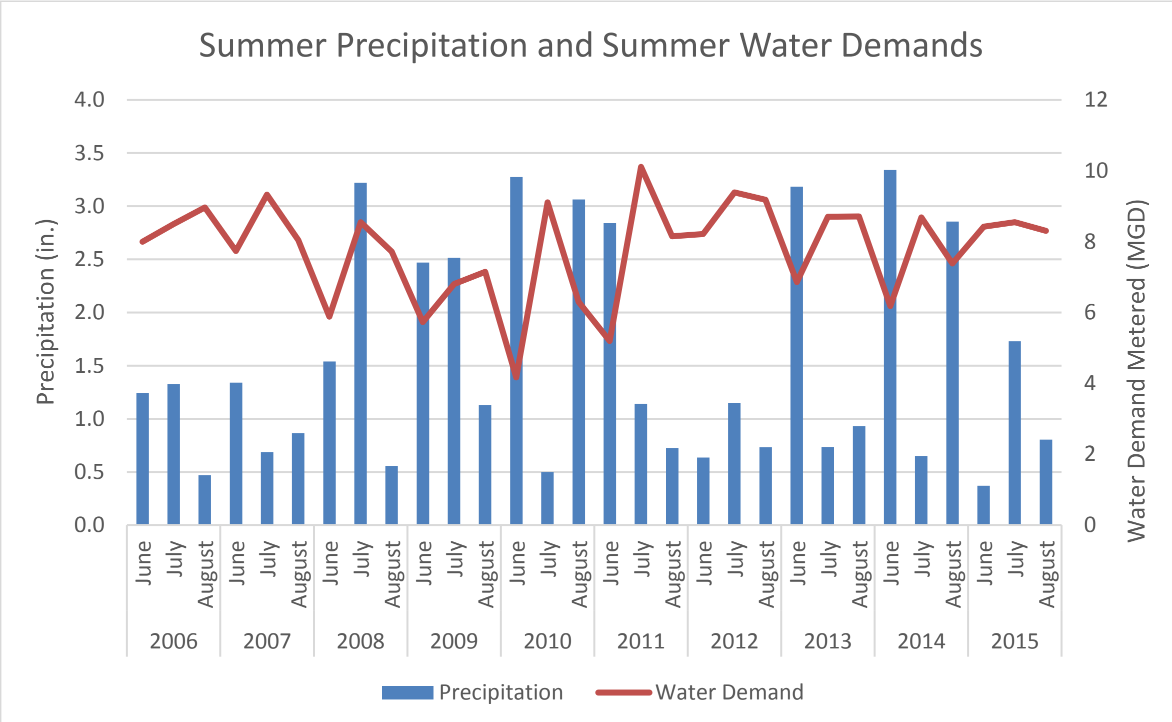


Figure 3-13: Summer Precipitation vs. Water Demand

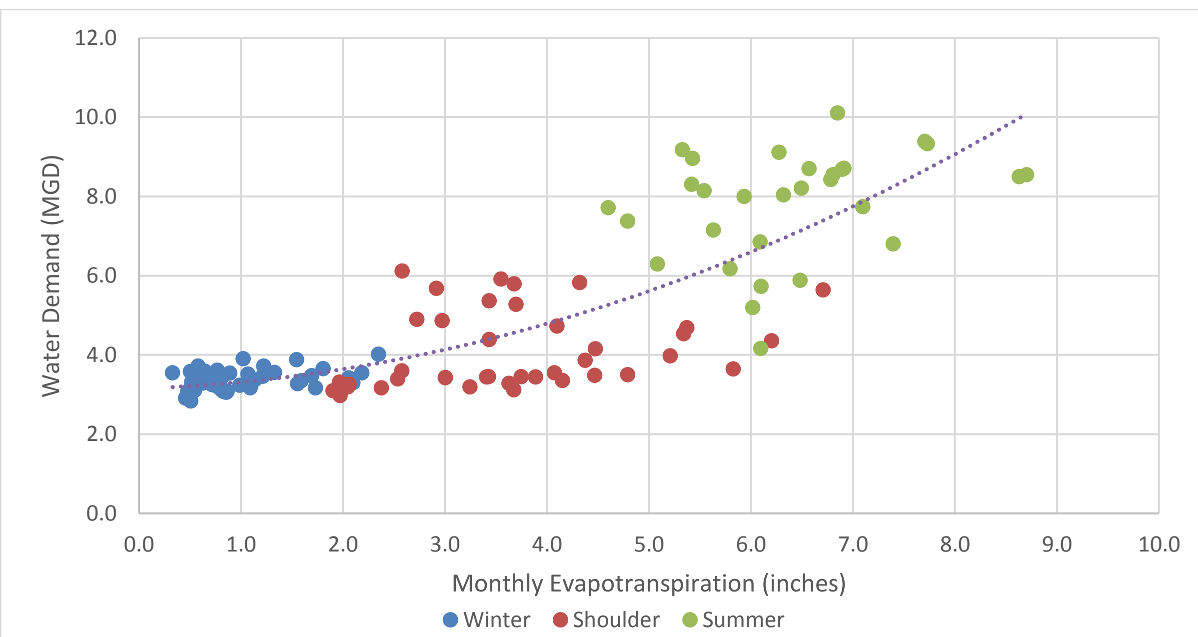


Figure 3-14: Evapotranspiration vs. Water Demand

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Figure 3-15 displays average summer water usage (metered and produced), maximum day (produced), total summer precipitation, and total ET.

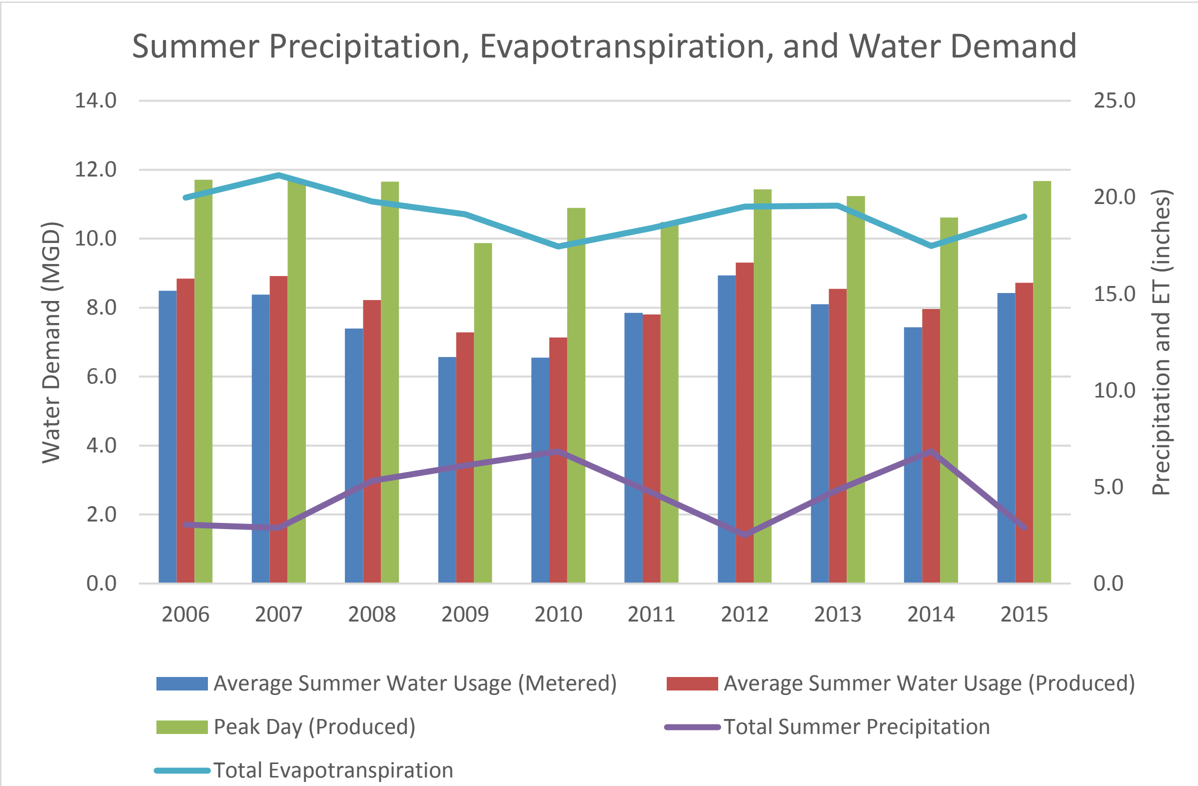

Figure 3-15: Summer Precipitation, Evapotranspiration, and Water Demand

The results from the analysis of the data presented above indicate the following:

- As shown in **Figure 3-13**, precipitation, or the lack thereof, has a direct impact on the seasonal use of water, whereas the demand for water increases as precipitation levels decrease. Conversely, the demand for water decreases during periods of increased precipitation levels.
- There is a general correlation between the seasonal evapotranspiration and Water Demand, in particular higher peak day demands correspond to years with higher evapotranspiration as shown in **Figure 3-14**.
- The trend between evapotranspiration and Water Demand is consistent but varies as shown in **Figure 3-14**, where some monthly demand and evapotranspiration pairs fall above or below the trend line. The variability is likely due to the intensity and duration of individual precipitation events or the varied impact that evapotranspiration days may have had on behavioral water demands.

- Monitoring evapotranspiration and its corollary relationship with water demand as shown in **Figure 3-15** could be used to generally predict seasonal increases or decreases in water demand trends.

The ability to predict water demands is of particular value to the City given the need to request changes to the amount of water released from Hyalite Reservoir 48 hours in advance.

3.4.3 Irrigation

Potable water used for irrigation is a major focus of the City's water conservation program. As the City continues to grow, understanding potable irrigation demands specifically by land use can help future conservation efforts and provide guidance for implementing best management practices. To that end, a high-level analysis was performed to determine potable irrigation rates by land use.

The information presented in this section is intended to provide a generalization of the City's potable irrigation usage by land use and does not reflect specific developments, landscaping, site location, elevation, or other key factors that may influence irrigation demand. To determine the potable irrigation demand, the following steps and corresponding assumptions were made:

- Irrigation demand was calculated by subtracting the average winter demand in year 2014 from the peak summer month demand in year 2014 for each type of land use. The difference was assumed to be the amount of potable water used for irrigation expressed in units of Gal/Day.
- To determine the amount of potable water being directly applied to the landscape, the amount of pervious area per land use was estimated using the City's impervious GIS layer. Areas outside of the impervious layer per land use class was also estimated and assumed to be 100 percent pervious. The 2014 impervious GIS Data was the most current data available at the time of the analysis.
- Irrigation demand per land use was then applied to the pervious land use layer. The new layer represents the amount of potable water used per irrigated acre in (Gal/Acre/Day).

The results of the analysis used to identify the amount of potable water used for irrigation by individual land use types is presented in **Table 3.2**.

General observations of the analysis include:

- The top irrigators in terms of total water used (gal/day) are residential land uses (single-household, multi-household, duplex/triplex).
- The top irrigators in terms of water per acre are also the residential land uses with the addition of hotel/motel, restaurant/bar and some additional commercial land users;

however, increases in summer water use could be due to increased services provided (increased hotel occupancy, more people eating at establishments, etc.) during the summer in addition to irrigation water use.

- The remaining land use categories use less water from both a total and per acre perspective.

Land Use	Description	2014 Irrigation Usage	
		Gal/Day	Gal/Acre/Day
SFR	Single-Household Residential	3,334,509	2,734
MFR	Multi-Household Residential	363,690	1,119
DTR	Duplex/Triplex Residential	308,456	1,850
POS	Parks or Open Space	271,935	203
CR	Commercial Retail Sales, Services, Banks	235,501	1,377
AP	Administrative Professional	148,909	1,493
HM	Hotel/Motel	146,303	3,009
MIXED	Mixed Use	105,853	843
CA	Commercial Auto Sales, Rental, Parts, Storage, Gas, Service	104,487	2,021
RB	Restaurant/Bar	53,892	4,180
PFP	Public Facility	43,241	109
CHURCH	Church	30,683	467
MHMP	Mobile Home, Mobile Park, Manufactured Housing	27,754	516
SEF	School/Educational Facility	23,676	37
LM	Light Manufacturing	16,685	61
GOLF	Golf Course	2,466	14
ROW	Right-of-Way	-	-
UDV	Undeveloped	-	-
VACANT	Vacant	-	-

Table 3.2: Estimated Irrigation Water Use

3.5 Water Demand Projections

Historical water use data is frequently used to project future usage demands. These future demand projections are crucial in developing capital improvement plans. For this analysis, future water demand projections are based on a combination of the following items:

- Historical water usage categorized by land use;
- Anticipated future land use characteristics (anticipated land use type, and associated area);
- Development of water duty factors (WDFs), which are a measurement of water demands in gallons per day per acre (gpd/ac). Adjustments to the WDFs can be made based on changes in development plans, water conservation, climate change, or any additional factors that affect the amount of water used. An overview of the demand projection methodology is provided in **Figure 3-16**.

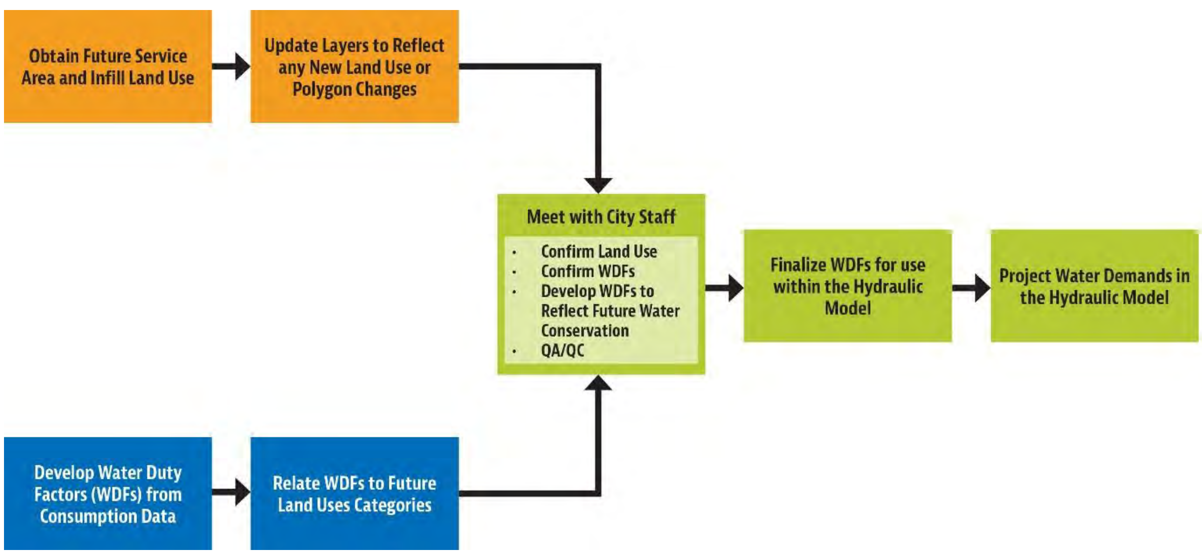

Figure 3-16: Overview of Future Water Demand Projection Methodology

3.5.1 Future Land Use

Future land use estimates were developed as follows:

1. The 2009 Bozeman Community Plan was used to identify future land use for the service area outside of the existing municipal City boundary.
2. Areas located within the municipal City boundary that are currently vacant or undeveloped are considered infill.
3. Land use designations for future infill were populated using existing City zoning classifications.
4. Future land use information for this study was provided by the City in a GIS database that contained mapped polygons and attributes. The City's GIS information was used as a starting point for the development of a new database that incorporated all future land use within the UBO.
5. Communication with City staff confirmed land use designations for future development; the City also provided information with respect to identified known land use changes and the use of outside information that was previously missing from the GIS database provided by the City. This resulted in the addition of Montana State University's (MSU) long-range growth plan, which includes MSU and MSU West[4]. In addition, a small area located northwest of existing City limits, which was not included in the 2009 Bozeman Community Plan, was classified as future urban.

Figure 3-17 and **Figure 3-18** present the proposed land use for the City infill and areas outside the existing municipal City boundary, respectively. The growth areas shown on these figures are summarized in **Table 3.3** and **Table 3.4**, respectively.

[4] Montana State University Long Range Campus Development Plan. (2008, December). Retrieved July, 2016, from http://www.montana.edu/lrcdp/documents/LRCDP_merge.pdf

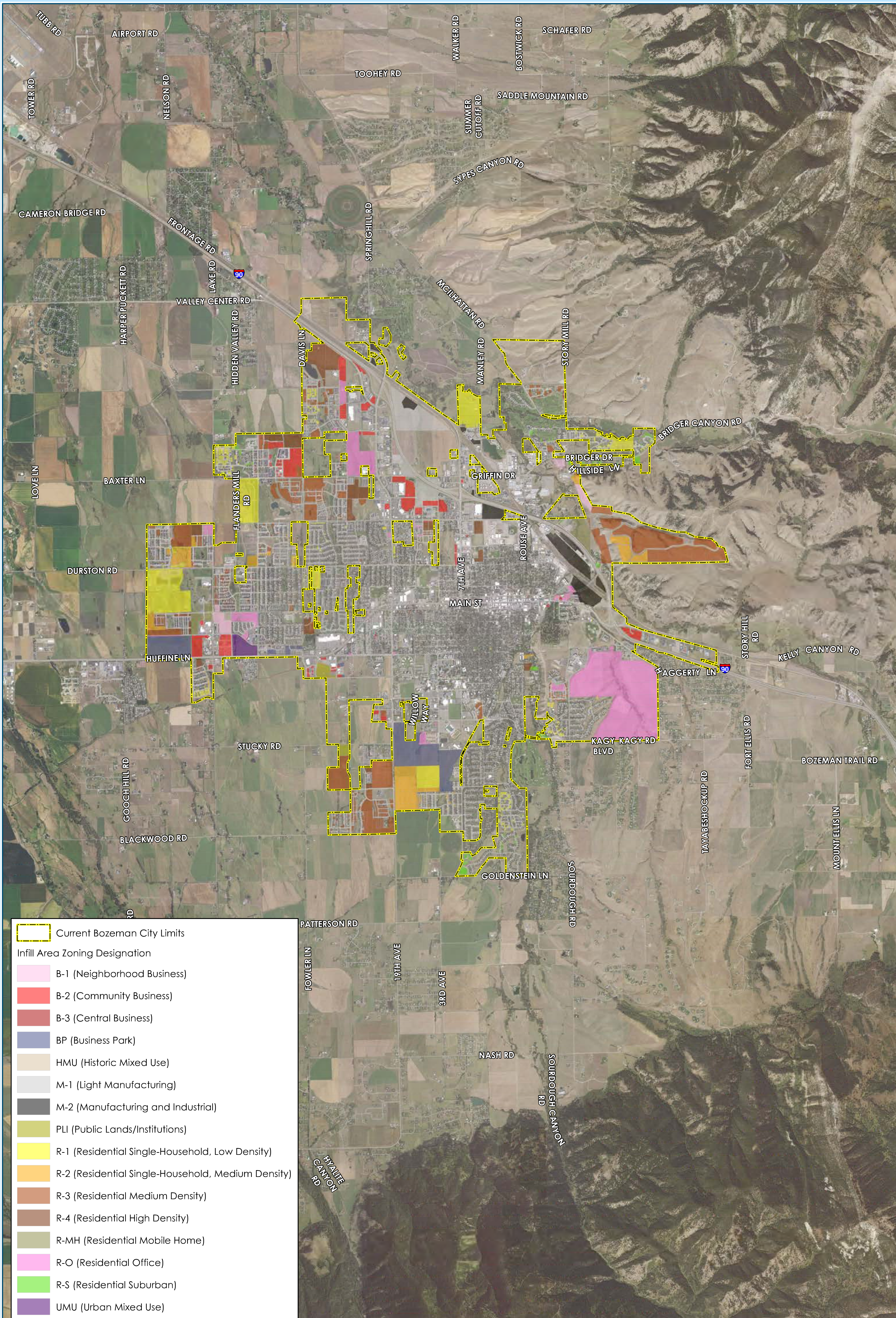

Figure 3-17: Water Facility Plan Study
Zoning Designations for Infill Areas
City of Bozeman Water Facility Plan Update

0 0.4 0.8 1.2 1.6 Miles

N

Advanced Engineering and Environmental Services, Inc.

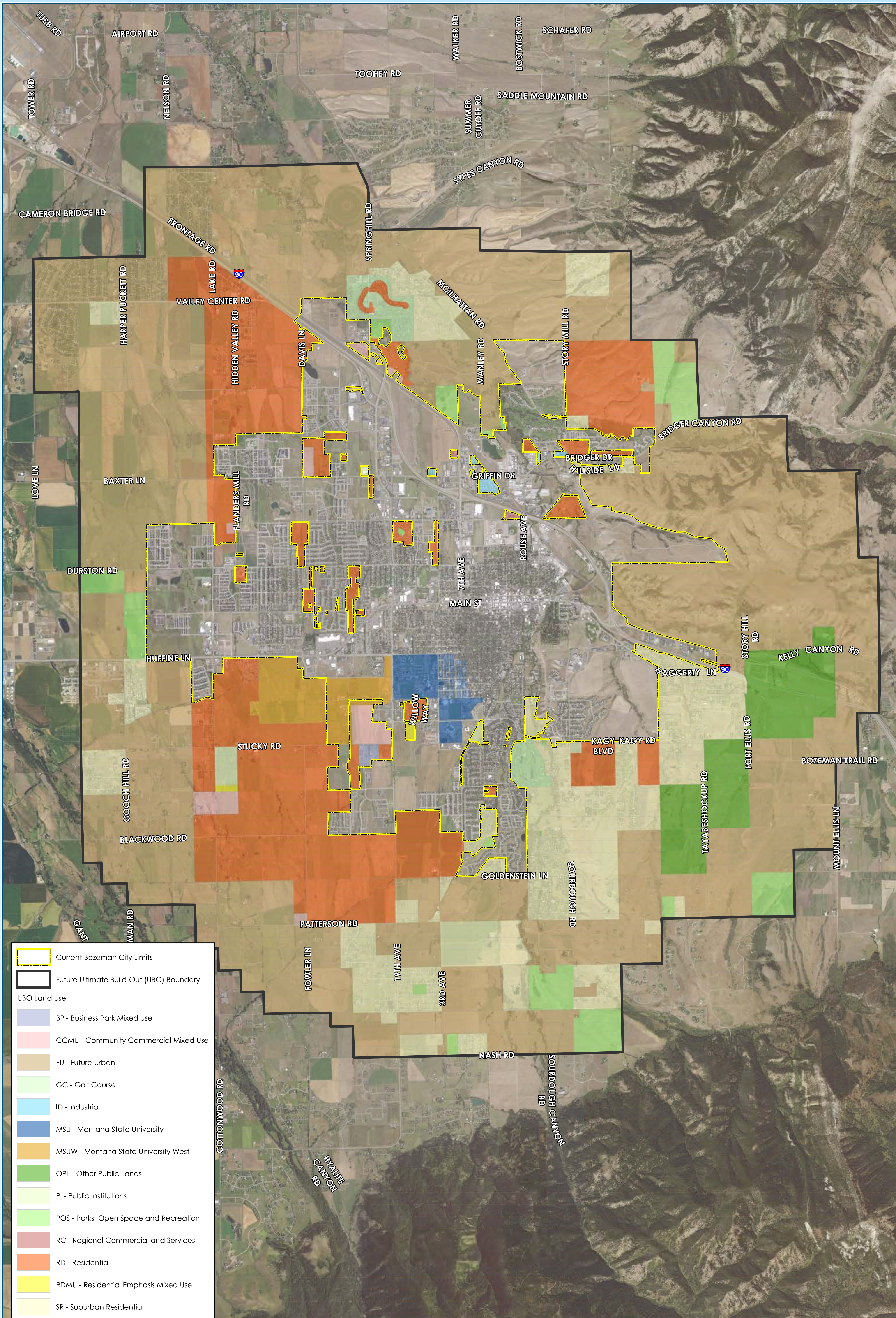

Figure 3-18: Ultimate Build-Out (UBO) Land Use Designations

City of Bozeman Water Facility Plan Update

0 0.4 0.8 1.2 1.6 Miles

N

AE2S Advanced Engineering and Environmental Services, Inc.

Zoning District	Infill Area (Acres)
Neighborhood Business District	47
Community Business District	206
Central Business District	1
Business Park District	141
Northeast Historic Mixed-Use District	2
Light Manufacturing District	210
Manufacturing and Industrial District	149
Public Lands and Institutions District	28
Residential Single-Household Low Density District	437
Residential Two-Household Medium Density District	206
Residential Medium Density District	674
Residential High Density District	190
Residential Mix Use	115
Residential Manufactured Home Community District	54
Residential Office District	596
Residential Suburban District	35
Urban Mixed Use	31
Total	3,120

Table 3.3: Future Infill Area Zoning Summary

Land Use Designations	Future Service Area (Acres)
Residential	5,790
Residential Emphasis Mixed Use	26
Suburban Residential	4,289
Regional Commercial and Services	15
Community Core	0
Community Commercial Mixed Use	259
Business Park Mixed Use (BP)	33
Industrial	50
Public Institutions	104
Parks, Open Space, and Recreational Lands	1,066
Other Public Lands	1,296
Golf Course	315
Future Urban	18,564
MSU	338
MSU West	560
Total	32,704

Table 3.4: Future Service Area Land Use Summary

The City's current UBO boundary (2009 Community Plan plus the new northwest section from the TMP) covers approximately 44,881 acres. Approximately 12,803 of these acres are located within the current municipal boundaries of Bozeman. A total of 3,120 acres is within the current boundary, but remain undeveloped. This area was designated as future infill, accounting for approximately seven percent of the future UBO area.

Approximately 32,704 acres of the 44,881 UBO acres are outside of the current municipal boundary, which is 71 percent of the total UBO land area. The predominant land use classes for future land use are expected to be future urban, residential, and suburban residential.

Together, the undeveloped areas (infill and future development) represent 78 percent of the total area within the UBO area.

3.5.2 Water Duty Factors

As presented in **Figure 3-16**, the demand projection methodology is based on land use and the development of WDFs. A WDF is a unit of measurement of consumption, in gallons per day per acre (gpd/ac). The five-step process used to develop WDFs is summarized below:

1. Analyze water meter consumption data provided by the City.
2. Geographically reference existing land use polygons to water meter locations.
3. Determine the average and maximum day demand for each land use polygon to identify current WDFs for each land use classification.
4. Apply the current WDFs calculated for each land use to future development (including infill) land use designations.
5. Adjust WDFs to reflect future water conservation estimates.

3.5.2.1 *Water Duty Demand Factor Development*

City staff provided customer water consumption data with spatially located water meter records from 2006 through 2015 and City parcel data (in the form of polygons with City land use designation attributes assigned) in GIS format. The water meter consumption data was analyzed to determine water use trends, patterns, and seasonal variation. Water consumption data remained relatively consistent over the 10-year time period.

Consumption data from 2009 (a wet year) and 2012 (a dry) were selected and georeferenced to the City's land use polygon layer. The City's water consumption data based on metered records were linked to their respective land parcels, which established a direct correlation to the amount of water used with the acreage served. The geographical link provided the means to then calculate the water use by area for each land use designation. **Figure 3-19** illustrates the methodology used to link the water meter records to the polygon layer.

Object ID	Land_Use01	Land_Use02	Land_Use03	Land_Use04	Acres
1	RD	CCM	PI	GC	0.5

Figure 3-19: Geographically Linked Water Meter Records to Land Use Polygon Illustration

The water consumption records linked to the City's land use polygons were then used to calculate WDFs (gpd/ac) by taking the total annual water demand by land use designation and dividing the resulting value by the associated total polygon acreage. Calculated WDFs are presented in **Table 3.5** for existing land use within the municipal City boundary for the 2009 and 2012 data sets.

The same process was used to calculate WDFs for infill areas within the City. The calculated WDFs for infill are presented in **Table 3.6**.

Key takeaways from the analysis to calculate the 2009 and 2012 WDFs include the following:

- Maximum day water usage increased for residential land uses (Duplex/Triplex Residential, Multi-Household Residential, Mobile Home, and Single Family Residential) during the 2012 dry year.
- Average day water usage is similar during wet and dry years.
- MDD is 9.8 MGD and 11.4 MGD for 2009 and 2012, respectively.

Land Use	Description	2009 Wet Year Maximum Day (gpd/ac)	2009 Wet Year Average Day (gpd/ac)	2012 Dry Year Maximum Day (gpd/ac)	2012 Dry Year Average Day (gpd/ac)
AG/OUT	Agriculture / Outside City	0	0	0	0
AP	Administrative Professional	2,520	1,300	2,230	1,210
CA	Commercial Auto Sales, Rental, Parts, Storage, Gas, Service	1,870	1,050	1,860	1,070
CHURCH	Church	700	310	680	250
CR	Commercial Retail Sales, Services, Banks	1,540	750	1,460	770
DTR	Duplex/Triplex Residential	2,890	1,510	3,110	1,500
GOLF	Golf Course	40	20	20	10
HM	Hotel/Motel	6,560	3,590	4,580	2,790
LM	Light Manufacturing	610	400	430	320
MFR	Multi-Household Residential	2,310	1,480	2,630	1,730
MHMP	Mobile Home, Mobile Park, Manufactured Housing	1,280	910	1,650	1,120
MIXED	Mixed Use	1,300	810	1,340	800
PFP	Public Facility	250	100	270	120
POS	Parks or Open Space	220	80	330	110
RB	Restaurant/Bar	4,270	2,630	3,920	2,430
ROW	Rights-of-Way	0	0	0	0
SEF	School/Educational Facility	810	480	520	310
SFR	Single-Household Residential	2,680	1,180	3,440	1,330
UDV	Undeveloped	0	0	0	0
VACANT	Vacant	0	0	0	0

Table 3.5: Existing Land Use WDFs

Zoning District	Description	2009 Wet Year Maximum (gpd/ac)	2009 Wet Year Average Day (gpd/ac)	2012 Dry Year Maximum (gpd/ac)	2012 Dry Year Average Day (gpd/ac)
B-1	Neighborhood Business District	1,660	940	1,840	940
B-2	Community Business District	1,420	780	1,100	640
B-3	Central Business District	5,000	2,890	3,300	1,920
BP	Business Park District	620	380	580	380
HMU	Northeast Historic Mixed-Use District	1,390	830	1,220	630
M-1	Light Manufacturing District	320	140	230	120
M-2	Manufacturing and Industrial District	220	150	60	30
PLI	Public Lands and Institutions District	470	250	390	180
R-1	Residential Single-Household Low Density District	1,520	650	1,590	600
R-2	Residential Two-Household Medium Density District	1,700	880	1,720	780
R-3	Residential Medium Density District	1,160	580	1,170	540
R-4	Residential High Density District	960	600	920	540
REMU	Residential Emphasis Mixed Use	0	0	0	0
R-MH	Residential Manufactured Home Community District	380	270	380	270
R-O	Residential-Office District	730	410	680	370
R-S	Residential Suburban District	160	70	190	70
UMU	Urban Mixed Use	0	0	0	0

Table 3.6: Existing Infill Zoning District WDFs

3.5.2.2 *Infill Water Duty Factors*

The values calculated for the 2009 and 2012 WDFs were adjusted to match the calculated ADD (5.2 MGD) and MDD (11.7 MGD) as shown in **Table 3.1**. The adjusted values were then averaged to estimate infill demand and are assumed to represent future infill demand within the City boundary. **Table 3.7** shows maximum and average day WDFs used in the hydraulic analysis.

Zoning District	Description	Maximum Day (gpd/ac)	Average Day (gpd/ac)	Infill Area (Acres)
B-1	Neighborhood Business District	1,925	935	47
B-2	Community Business District	1,405	705	206
B-3	Central Business District	4,650	2,400	1
BP	Business Park District	665	380	141
HMU	Northeast Historic Mixed-Use District	1,450	725	2
M-1	Light Manufacturing District	305	130	210
M-2	Manufacturing and Industrial District	160	95	149
PLI	Public Lands and Institutions District	480	220	28
R-1	Residential Single-Household Low Density District	1,720	620	437
R-2	Residential Two-Household Medium Density District	1,885	820	206
R-3	Residential Medium Density District	1,290	555	674
R-4	Residential High Density District	1,040	570	190
REMU	Residential Emphasis Mixed Use	1,823	873	115
R-MH	Residential Manufactured Home Community District	420	265	54
R-O	Residential-Office District	780	385	596
R-S	Residential Suburban District	190	70	35
UMU	Urban Mixed Use	1,757	751	31
			Total	3,120

Table 3.7: Future Infill Zoning District WDFs

3.5.2.3 *Future Land Use Water Duty Factors*

The values calculated for the 2009 and 2012 WDFs in both **Table 3.5** and **Table 3.6** were also used to represent future service area demands. Existing demands by land use class were assigned to consistent classes of future land use areas. However, there are discrepancies between current land use classifications in the City's GIS database and future land use categories identified in the 2009 Bozeman Community Plan. The inconsistencies required some minor adjustments and assumptions for cross-referencing. For example, existing single family residential was included in the future land use residential category. In some cases, multiple land use categories and their associated demands were assigned to a particular future land use, and a weighted average (based on current ratios of these classes to one another) was utilized. The initial data set was presented to the City and modified based on staff comments and reasonable judgment. **Table 3.8** shows the recommended WDF values for future land use areas.

Land Use	Maximum Day (Gal/Acre/Day)	Average Day (Gal/Acre/Day)	Future Service Area (Acres)
Residential	1,757	751	5,790
Residential Emphasis Mixed Use	1,455	805	26
Suburban Residential	419	182	4,289
Regional Commercial and Services	1,740	815	15
Community Core	2,635	1,285	0
Community Commercial Mixed Use	2,635	1,285	259
Business Park Mixed Use (BP)	1,525	780	33
Industrial	580	355	50
Public Institutions	290	110	104
Parks, Open Space, and Recreational Lands	480	90	1,066
Other Public Lands	480	220	1,296
Golf Course	35	15	315
Future Urban	1757	751	18,564
MSU	3,058	2,780	338
MSU West	1,133	1,030	560
		Total	32,704

Table 3.8: Future Service Area Land Use WDFs

3.5.2.4 *Future Water Duty Factors with Water Conservation*

Future land use WDFs developed previously and shown in **Table 3.8** do not account for the potential trends related to water conservation. Typically, newer construction incorporates better technologies to decrease water usage, such as high efficiency fixtures. Increased water use efficiency can reduce the overall system demand during peak periods, ideally saving water and delaying the need for expanding infrastructure (i.e. increasing capacity of WTP, adding new sources of supply, etc.).

To account for the results of future water conservation objectives established by the City, specific WDFs previously calculated in **Table 3.8** were reduced as follows:

- MDD was reduced by 10 percent across all land use categories
- ADD was reduced by 15 percent for all residential and future urban land uses.

The water use reduction targets were derived from estimates provided by Water Research Foundation[5] and in coordination with the City's Water Conservation Division. **Table 3.9** shows the future area land use WDFs following the application of the demand reduction factors.

Land Use	Maximum Day (Gal/Acre/Day)	Average Day (Gal/Acre/Day)	Future Service Area (Acres)
Residential	1,582	638	5,790
Residential Emphasis Mixed Use	1,310	684	26
Suburban Residential	377	155	4,289
Regional Commercial and Services	1,566	815	15
Community Core	2,372	1,285	0
Community Commercial Mixed Use	2,372	1,285	259
Business Park Mixed Use (BP)	1,373	780	33
Industrial	522	355	50
Public Institutions	261	94	104
Parks, Open Space, and Recreational Lands	432	90	1,066
Other Public Lands	432	220	1,296
Golf Course	32	15	315
Future Urban	1,582	638	18,564
MSU	2,752	2,780	338
MSU West	1,020	1,030	560
		Total	32,704

Table 3.9: Future Service Area Land Use WDFs with Water Conservation

[5] DeOreo, W. B., Mayer, P. W., Dziegielewski, B., & Kiefer, J. (2016). Residential end uses of water, version 2. Denver, CO: Water Research Foundation. Pages (211-233)

3.5.3 Future Water Demand Summary

The WDFs shown in **Table 3.7**, **Table 3.8**, and **Table 3.9** were spatially distributed based on their respective land use class within the hydraulic model. **Table 3.10** shows the resulting future system demands that represent the total overall system demand for the UBO system.

Demand Condition	UBO Water Demand (MGD)
Average Day Demand	23.8
Average Day Demand with Conservation	21.5
Maximum Day Demand	53.6
Maximum Day Demand with Conservation	49.8

Table 3.10: Future System Demands

CHAPTER 4 WATER DISTRIBUTION SYSTEM MODEL UPDATE

The following section provides an overview of the data sources used to create the hydraulic model of Bozeman's water distribution system.

InfoWater® (Version 10.5) hydraulic modeling software was used for development and calibration of the model. InfoWater® is a fully GIS integrated water distribution modeling and management software application. InfoWater®, which runs on the EPANET hydraulic engine, integrates water network modeling with ArcGIS.

4.1 Existing Model Conversion and Development

The following information was provided by the City and incorporated into the hydraulic model:

- GIS geodatabase of the water distribution system to develop the pipe network for the hydraulic model. GIS information included water main, valves, and hydrants.
- Finished water source locations and flows, booster station system pump curves, water storage reservoir information (volumes and elevations).
- Finished water flow rates, pressures, and water storage levels were collected from the supervisory control and data acquisition (SCADA) system in 5-minute increments during the testing periods, including fire flow testing, extended period simulation, and periods used for demand curve development.
- A digital elevation model (LiDAR) provided by the City was used to extract elevations for hydrants with unknown elevation. Elevation data was used to determine pressures throughout the distribution system during field testing and calibration.

A comprehensive "all-pipes" hydraulic model was developed for the City. As the name suggests, an all pipes model accounts for all water main, hydrants, and hydrant leads within the system.

To create the water pipe network for the hydraulic model, Feature Manipulation Engine (FME) data integration software was used to transform existing GIS feature class data into a format that allowed quality auditing and input into the hydraulic model. The FME script created to transform the data is explained in greater detail in **Appendix B**.

4.2 Demand Allocation

A crucial element of water distribution modeling is determining accurate, representative water demands. Equally important is the spatial distribution of these demands throughout the water distribution system. Water demand allocation is the process of accurately distributing these water demands to the correct points of consumption within the model.

4.2.1 Base Demand

Meter billing records from 2015 were analyzed and used to spatially distribute the base demand within the existing water distribution system. The records from 2015 were used because the data spatially represents all current users within the system with the most recent water use information at the time of model calibration. The monthly usage data was converted to an average consumption rate in units of gpm.

The consumption rates were spatially distributed using InfoWater Demand Allocator®. This InfoWater module uses GIS technology to assign geocoded consumption data to a designated location within the water distribution system. For each meter record, algorithms in the software were used to distribute the water demands to the closest pipe. The water demands were then allocated proportionally to the nodes at each end of the pipe. For each node within the model, all of the contributing water demands were summed to represent the total demand imposed on that particular node.

When comparing the total water usage from the meter billing records with the water production records, there were discrepancies within the data that needed to be resolved. These discrepancies are partially due to NRW loss. As discussed in **Section 3.3.3**, the NRW for the City of Bozeman ranged from 4.5 to 13.7 percent from 2006 through 2015 with a recommended value of 9 percent for planning purposes.

To resolve the inconsistency between water production records and computed customer usage, the NRW factor of 9 percent was globally applied to the water demands. The goal of these analyses is to balance water production and demands within the model and thereby create a mass balance of the water production, storage, and demands within the model of the distribution system.

4.2.2 Diurnal Demand Pattern

Water usage for any distribution system is highly variable over the course of a day, due to fluctuations in water demand. In municipal systems, there will typically be a morning and an evening peak in customer water use. The resulting daily demand pattern is referred to as the diurnal demand curve. Diurnal patterns are impacted by seasonal and climatic conditions (winter vs. summer, precipitation events, etc.). Large users such as industrial or commercial businesses also have an impact on diurnal demand patterns.

The diurnal demand curve for Bozeman's water distribution system was constructed using the flow balance technique. For a water distribution system, a flow balance simply indicates that the water that enters the distribution system must be equal to the water that exits the distribution system, plus or minus any changes to the volume contained in water storage facilities.

The following steps were taken to develop the diurnal demand pattern for Bozeman:

- A flow balance was constructed from water meters at the WTP and Lyman reservoir, and water storage reservoir level readings (Sourdough and Hilltop) from the SCADA system collected in five-minute increments.
- The data were then averaged into hourly increments to define the diurnal pattern over the entire day for the entire distribution system.
    - The summer diurnal demand curve was constructed using data from August 20th through August 26th, 2015.
    - Diurnal demand patterns were also prepared for each day during the fire flow testing period and the extended pressure testing period from October 12th through October 18th, 2015.
    - An average diurnal demand curve was constructed using the weekday August data. This data was assumed to represent average summer day and maximum day scenarios developed within the model.
    - An average diurnal demand curve was constructed from the weekday October data and assumed to represent the average day and winter day scenarios developed within the model.

Figure 4-1 shows the diurnal demand pattern for summer and maximum day demands. **Figure 4-2** shows the diurnal demand pattern for average and winter day demands. An hourly demand factor equal to 1.0 indicates that the system demand for the hour period is equal to the average hourly demand. An hourly demand factor equal to 1.75 indicates that the system demand for the hour period is 1.75 times higher than the average hourly demand. The diurnal demand patterns are applied to system demands to develop diurnal curves used for calibration and modeling.

The time step for the diurnal curve used in the model was one hour. Although a smaller time step could be used, it is not recommended because small errors in reservoir water levels on time steps shorter than one hour can lead to large errors in water use calculations. The diurnal demand curves were incorporated into the model and used in conjunction with the field data to assist in the calibration of the hydraulic model.

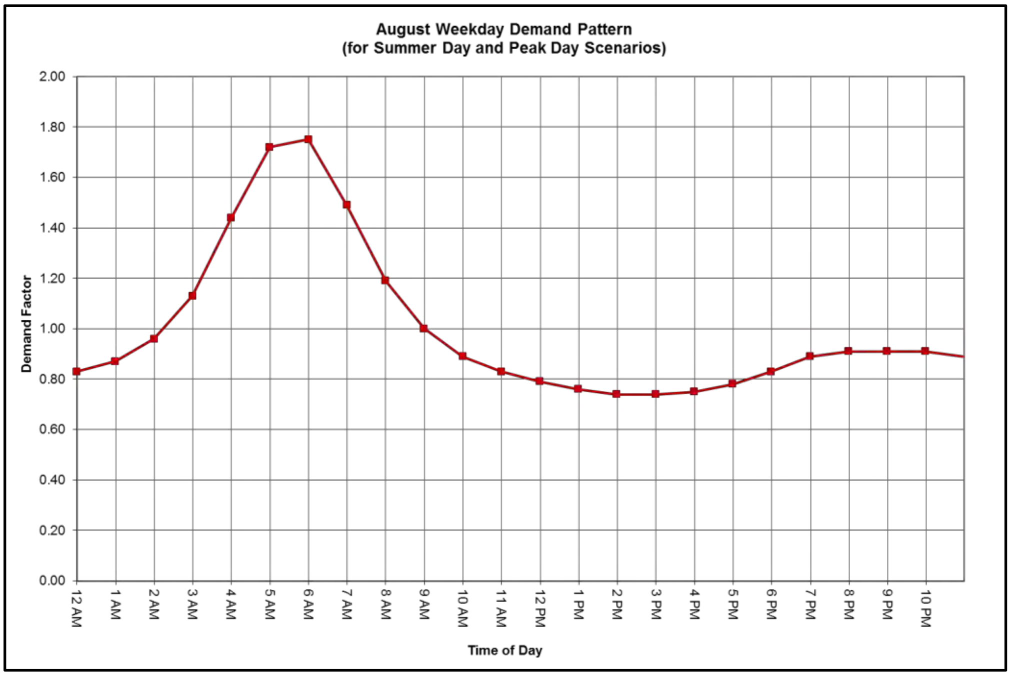

Figure 4-1: Typical Summer/Maximum Day Diurnal Demand Pattern

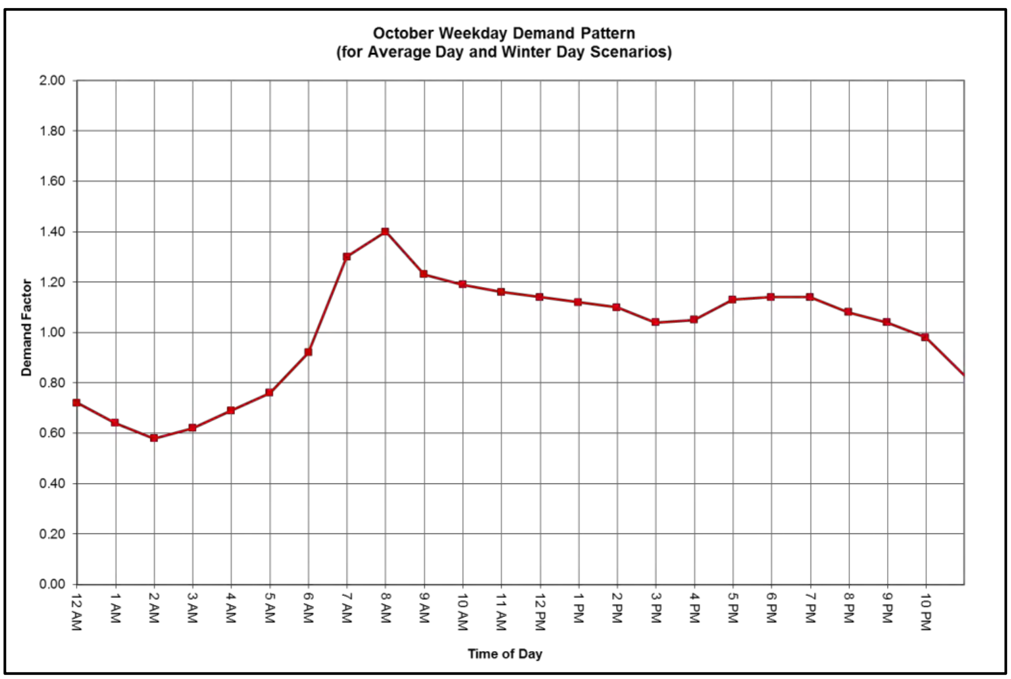

Figure 4-2: Typical Average/Winter Day Diurnal Demand Pattern

4.3 Field Testing & Data Collection

The objective of creating a model is to generate a tool for predicting the distribution system network's behavior within an acceptable range of accuracy. To generate an accurate model, a robust calibration process must be conducted.

Field data collected for calibration of the water distribution system model included water storage levels, fire hydrant flow tests, and extended pressure tests. Data was collected by the SCADA system during the period of field testing. Fire hydrant flow tests were conducted at 75 locations throughout the distribution system. Extended pressure tests were performed at 12 key locations within the distribution system to assist in estimating distribution system pipe roughness coefficients (C-factors). The tasks and protocol followed for performing these field tests are described in further detail in the following sections.

To verify the calibration of the hydraulic model, pressures generated by the hydraulic model were compared to actual observed system pressures. Once differences were known between actual field data and hydraulic model output, adjustments were made within the hydraulic model to better simulate the existing distribution system performance. The adjustments included modifications to piping roughness coefficients and system demands. The final results were compared with the observed field results to measure the calibration quality achieved.

Section 4.3 describes the field testing procedures performed, and **Section 4.4** addresses the calibration process performed in the model.

4.3.1 Fire Hydrant Flow Tests

Flow tests performed at fire hydrants provide valuable insight into the calibration of pipe roughness and system demands. Fire hydrant flow tests were conducted at 75 locations throughout the City. The hydrant flow testing was performed from September 28th through October 1st, 2015. A map indicating the location of each fire hydrant test is shown in **Figure 4-3**. Refer to **Appendix C** for field data sheets showing detailed locations of each fire flow test and data recorded during each test.

Two or more hydrants are involved in a fire hydrant flow test. One hydrant is identified as the pressure hydrant where all pressure measurements are taken, and the other hydrant(s) are flow hydrant(s), where water is discharged and flow measurements are taken. The pressure at the hydrants prior to opening any hydrants is the static pressure. When one or more flowed hydrants are open, the pressure at the pressure hydrant is called the residual pressure. If one hydrant does not create a large enough drop in pressure (NFPA 291 recommends a goal of at least a 25 percent drop in pressure), additional hydrants should be opened to generate larger flows and increased pressure drop.

Think Big. Go Beyond.

A Telog® Hydrant Pressure Recorder (HPR) was used to record the static and residual pressures at the pressure hydrant. The flow was recorded at the flowed hydrants using a Pollard hydrant diffuser and a HPR. The hydrant diffuser incorporates a pitot gauge connected to a threaded fitting. A HPR is threaded onto the diffuser to record the pressure head. The pitot gauge converts the velocity head associated with the discharge from the fire hydrant into pressure head that is recorded by the HPR. The HPRs were set to sample and record pressure data at 1-second intervals for the fire hydrant flow tests. The pressure head recorded by the HPR is converted into a hydrant discharge rate through the use of an orifice relationship equation.

To properly calibrate the model, the following information was recorded at the time of the fire hydrant flow test:

1. Time and date;
2. Hydrant location;
3. Flow rate of hydrant being flowed;
4. Duration of the hydrant flow test;
5. Static and residual pressures at the corresponding test hydrant location. The results of the fire hydrant flow tests are discussed in **Section 4.4**; and
6. Simultaneous information from the SCADA system on water storage levels, pump operation, and metered flow rates were also collected and used in the calibration process.

4.3.2 Extended Pressure Testing

To assist in the determination of the roughness coefficient of water mains, extended pressure testing was performed at 12 locations throughout Bozeman's water distribution system. HPRs were installed on fire hydrants for approximately two to three weeks to record changes in pressures within the distribution system. Data from one week (from October 12th through October 18th, 2015) was utilized during calibration. A map indicating the location of each extended pressure test is shown in **Figure 4-6**.

Refer to **Appendix D** for field data sheets showing detailed locations of each extended pressure test. The field pressures for the EPS tests were sampled at 1 second intervals and the minimum, maximum, and average pressures were recorded at 5 minute intervals to allow for extended data logging. This data was used to fine-tune pipe roughness coefficients of water mains in the distribution system. The results of the extended pressure testing are discussed in **Section 4.4.3**.

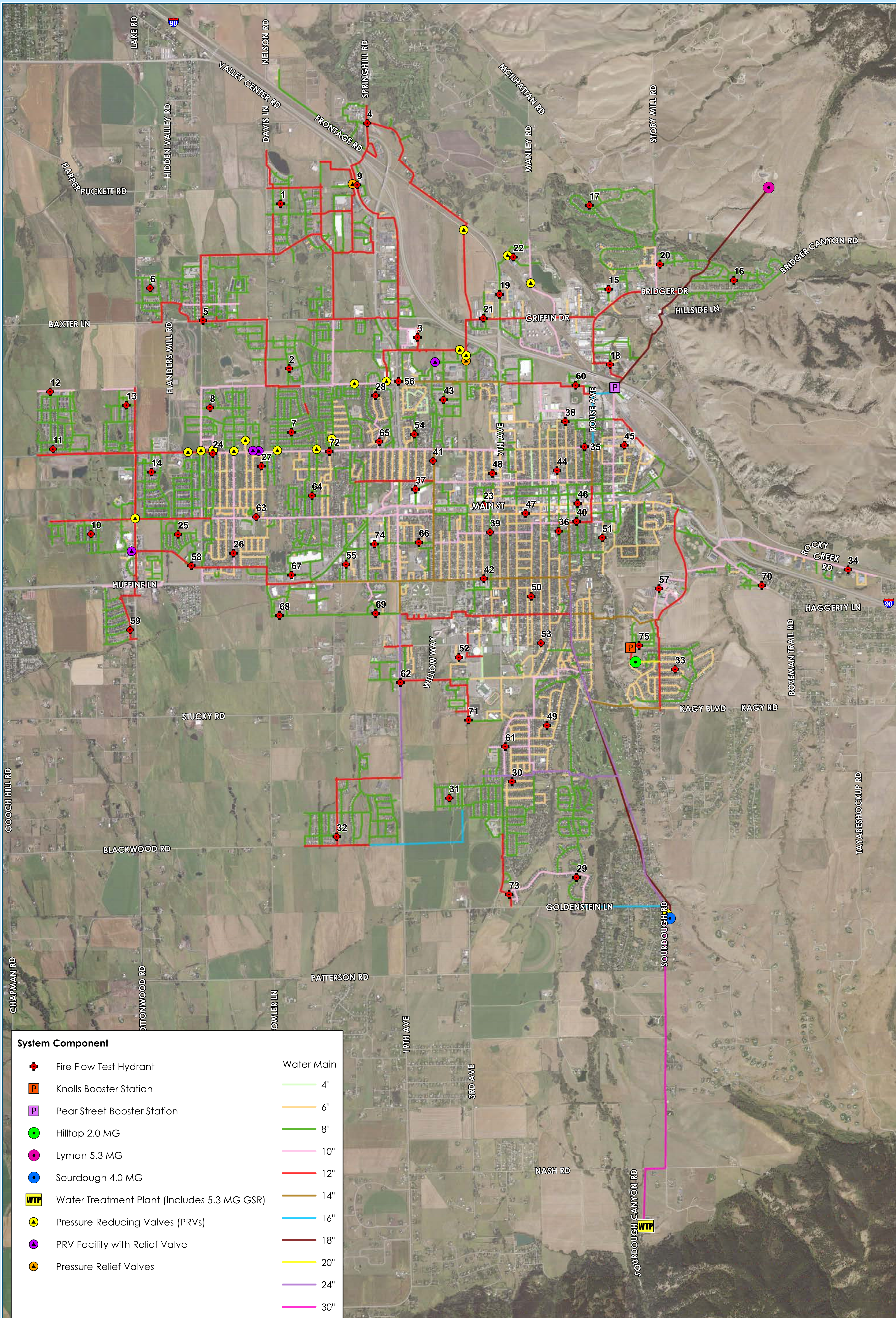

Figure 4-3: Fire Flow Test Locations

City of Bozeman Water Facility Plan Update

0 0.25 0.5 0.75 1 Miles

N

AE2S Advanced Engineering and Environmental Services, Inc.

Figure 4-4 shows the diffuser, HPR, and data collector used during the fire hydrant flow tests. **Figure 4-5** shows the operation of a flowed hydrant.

Figure 4-4: Diffuser, HPR, and Data Collector

Figure 4-5: Operation of a Flowed Hydrant

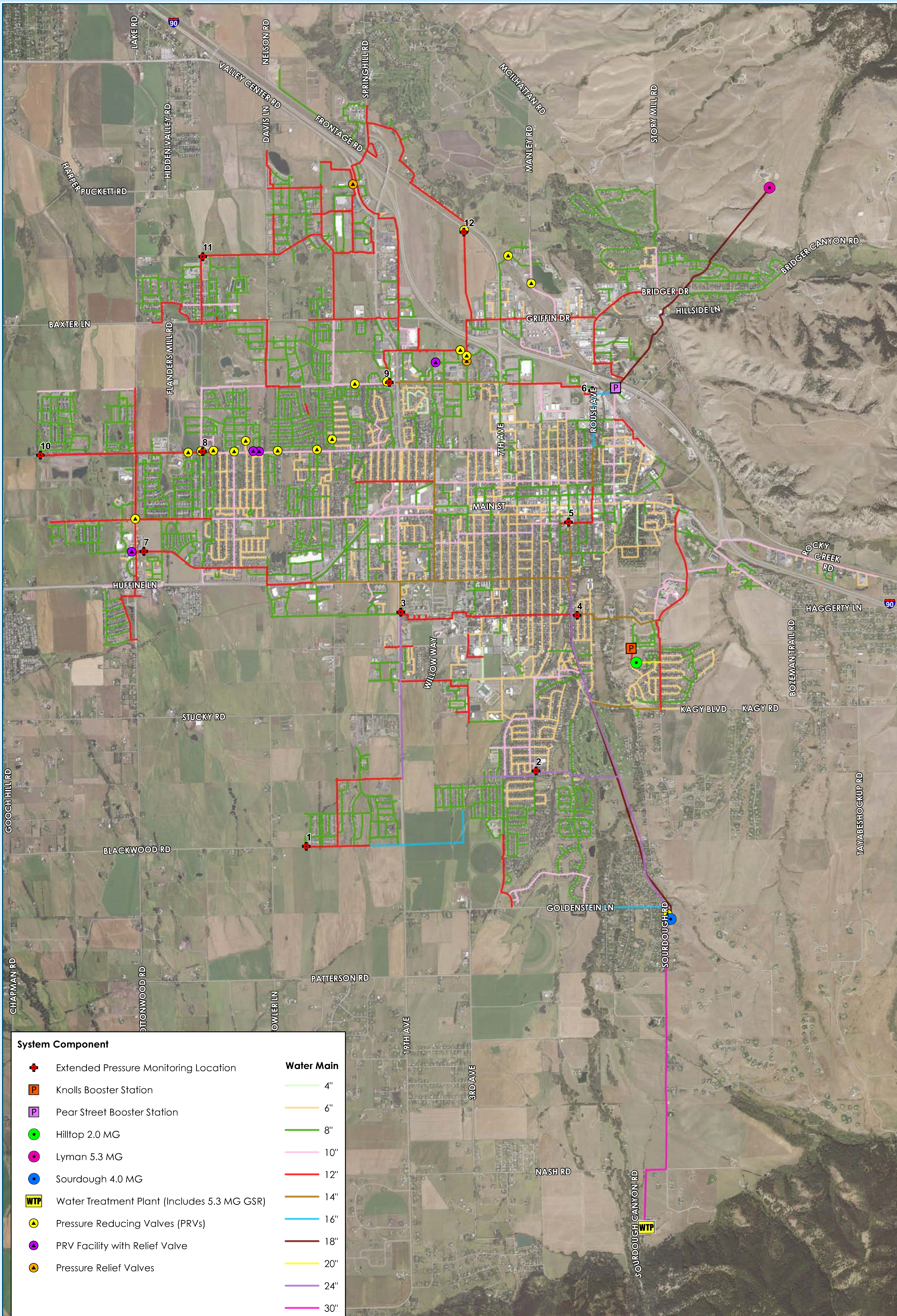

Figure 4-6: Extended Pressure Monitoring Locations

City of Bozeman Water Facility Plan Update

0 0.25 0.5 0.75 1 Miles

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AE2S Advanced Engineering and Environmental Services, Inc.

4.4 Model Calibration

The guidelines presented below by the authors of Water Distribution Modeling[6] give some numerical guidelines for calibration accuracy:

> *"The model should accurately predict hydraulic grade line (HGL) to within five to 10 feet at calibration data points during fire flow tests and to the accuracy of the elevation and pressure data during normal demands. It should also reproduce water storage level fluctuations to within three to six feet for EPS runs and match treatment plant/pump station flows to within 10 to 20 percent."*

The above guideline is not definitive, but is a good gauge of a model's accuracy. The more accurate the model, the more confidence there can be in future model simulations.

4.4.1 Calibration Process

A robust effort was made to allocate demands by meter location throughout the water distribution system, as described in **Section 4.2**. Therefore, the primary focus of the calibration effort was on pipe roughness coefficients used in the model. The coefficients were adjusted to more closely match field data collected during the fire hydrant flow tests.

The calibration process can be summarized in the following steps:

- System operational data such as water storage levels, pump and control valve operation, meter data, and estimated system demands were also entered into the model for each of the flow tests.
- After the background data was entered and the fire flow test was simulated, model results were compared with field measurements.
- When model results varied from the observed field measurements, the pipe roughness coefficients were adjusted.
- Adjustments were made to various pipe diameters and pipe materials until the model results matched the field measurements within an acceptable tolerance. City of Bozeman operations staff were consulted prior to making adjustments, and staff verified general pipe conditions prior to making adjustments (i.e. confirming smooth clean pipe for raising pipe roughness factors and confirming pipe diameter discrepancies where known).
- This adjustment process was also performed for the EPS tests

[6] Walski, T. M., Chase, D. V., & Savic, D. (2001). Water distribution modeling. Waterbury, CT, U.S.A.: Haestad Press.

4.4.2 Calibration Results

Final simulated results from the hydraulic model were compared to the observed field results to determine the calibration level achieved. The following sections provide an overview of the model calibration results that indicate a high quality calibration was achieved for the Bozeman water distribution model.

The results of testing for static and residual pressures during the fire flow tests are presented below and summarized in **Table 4.1**.

4.4.2.1 *Static Pressure Test Calibration Results*

Static pressures were taken at the pressure hydrant before initiating the fire hydrant flow tests. The observed static pressures along with the simulated pressure from the calibrated hydraulic model are shown in **Table 4.2**. Comparison of static pressures from field test results with simulated hydraulic model results showed that 73 of the 75 tests (97 percent) were within 5 feet (≈2.2 psi) of the field measurement and all 75 tests (100 percent) were within 10 feet (≈4.3 psi) of the field test measurement. This level of accuracy is acceptable according to established criteria identified in **Section 4.4**.

4.4.2.2 *Residual Pressure Test Calibration Results*

During each fire hydrant flow test, residual pressures were recorded at a hydrant near the flowing hydrants. The observed residual pressures along with the simulated pressure from the hydraulic model are shown in **Table 4.2**. Comparison of the observed field pressures and the simulated pressures obtained from the hydraulic model shows that 47 of the 75 tests (63 percent) were within 5 feet (≈2.2 psi) of the observed field measurement and 63 of the 75 test (84 percent) were within 10 feet (≈4.3 psi).

Fire Flow Tests	Simulated Pressure readings within 10 ft	Simulated Pressure readings within 5 ft
Static Pressure	100%	97%
Residual Pressure	84%	63%

Table 4.1: Fire Flow Test Model Calibration Results Summary

City staff and hydraulic modelers completed additional database and field investigations in an attempt to identify reasons for the residual pressure model results falling outside the recommended guidelines. City staff investigated the GIS database and system maps for possible missing water main loops or incorrect pipe diameters. The desktop investigation was completed in the vicinity of Test No. 17, 19, 24, 25, 27, 34, 45, 49, 54, and 59. While some minor inconsistencies were found and corrected, they did not correct all of the differences between the modeled and measured results.

Possible reasons for the reduced accuracy of the residual pressure results include the following:

1. Inaccuracies in model parameters, such as pipe roughness coefficients or nodal demand distribution.
2. Erroneous or inaccuracies in network data (pipe diameter, valve settings).
3. Incorrect network geometries (pipes connected to incorrect nodes).
4. Measurement equipment errors.
5. Demand variation. The diurnal curve created for the calibration days is used to determine demand at each hour for the fire flow tests. However, customer demands change within each hour which may not be recognized within the mass balance of the system resulting in a difference between modeled and actual system demands.
6. Demand variance in different pressure zones. A lack of sufficient distribution system flow meter data for each pressure zone of the system results in the use of a generalized diurnal curve for the entire system. With individual pressure zone diurnal curves, a more accurate demand can be captured as some zones have little to no irrigation demand and others have high irrigation demand.
7. Inaccuracies in elevation data. Elevations used throughout the system for junctions and valves are based on ground elevation from the DEM provided by the City. Elevations for pump stations and the WTP are based on record drawings. Survey data for the elevation of reservoirs was provided by the City.
8. Inaccuracies in pump flow between modeled and actual flow rates.

Every complex distribution network model will have some inaccuracy because of the ambiguity in assumed conditions versus actual conditions and available modeling techniques. The majority of the modeling results fall within the recommended calibration guidelines. Therefore, the hydraulic model is considered well calibrated.

Test No.	Measured Static Pressure (psi)	Measured Residual Pressure (psi)	Simulated Static Pressure (psi)	Simulated Residual Pressure (psi)	Pressure Difference Static Pressure (psi)	Pressure Difference Residual Pressure (psi)	Flow (gpm)	Flow (gpm)	Watermain Size (in)	Pressure Zone	Material
1	109.8	90.2	109.25	86.05	0.5	4.2	1,518	1,484	8	Northwest	DI
2	75.7	60.4	76.08	61.08	-0.3	-0.7	1,230	1,167	8	Northwest	DI
3	81.9	62.8	80.89	61.08	1.0	1.8	1,235	1,215	12	Northwest	DI
4	125.4	106.6	124.68	106.01	0.7	0.6	1,615	1,418	12	Northwest	DI
5	90.7	71.7	88.77	70.35	1.9	1.3	1,325	1,169	12	Northwest	DI
6	88.4	61.0	87.76	62.02	0.6	-1.0	1,287	1,246	8	Northwest	DI
7	61.7	46.0	62.09	47.62	-0.4	-1.6	1,083	1,049	8	Northwest	DI
8	67.4	57.7	69.24	59.17	-1.9	-1.5	1,212	1,195	8	Northwest	DI
9	112.5	97.7	114.92	94.70	-2.4	3.0	1,569	1,552	12	Northwest	DI
10	66.1	60.2	66.59	62.15	-0.5	-2.0	1,201	1,233	8	West	DI
11	84.6	72.8	85.21	71.67	-0.6	1.1	1,353	1,250	8	West	DI
12	95.3	76.0	95.83	73.35	-0.5	2.6	1,350	1,335	10	West	DI
13	90.2	85.1	90.14	84.40	0.1	0.7	1,435	1,340	8	West	DI
14	73.7	72.5	75.02	72.19	-1.3	0.3	1,342	1,365	8	West	DI
15	137.8	86.1	138.77	81.96	-0.9	4.1	1,441	1,426	8	Northeast	DI
16	110.3	94.8	111.56	94.41	-1.2	0.4	1,528	1,524	8	Northeast	DI
17	143.8	93.8	144.35	71.28	-0.6	22.5	1,571	1,540	8	Northeast	DI
18	124.3	109.2	124.93	107.60	-0.6	1.6	1,674	1,693	12	Northeast	DI
19	123.7	81.9	124.50	63.34	-0.8	18.5	1,483	1,448	8	Northeast	DI
20	127.4	113.1	128.73	112.40	-1.4	0.7	1,596	1,682	8	Northeast	DI
21	123.3	89.1	123.92	86.47	-0.6	2.6	1,508	1,419	12	Northeast	DI
22	76.4	65.1	77.31	63.12	-0.9	2.0	1,228	1,250	8	Gallatin	DI
23	129.9	119.9	131.73	121.47	-1.8	-1.6	1,720	1,610	8	South	DI
24	144.5	130.4	144.31	123.97	0.2	6.5	1,845	1,834	8	South	DI
25	128.9	115.7	130.05	110.14	-1.1	5.6	1,725	1,702	8	South	DI

Table 4.2: Fire Flow Test Results

Test No.	Measured Static Pressure (psi)	Measured Residual Pressure (psi)	Simulated Static Pressure (psi)	Simulated Residual Pressure (psi)	Pressure Difference Static Pressure (psi)	Pressure Difference Residual Pressure (psi)	Flow (gpm)	Flow (gpm)	Watermain Size (in)	Pressure Zone	Material
26	122.2	110.0	121.72	109.34	0.4	0.6	1,681	1,719	10	South	DI
27	139.3	104.1	139.96	89.28	-0.7	14.8	1,681	1,619	6	South	DI
28	152.6	128.6	153.68	131.31	-1.1	-2.7	1,956	1,739	6	South	DI
29	50.5	47.5	50.94	47.57	-0.4	-0.1	1,136	996	8	South	DI
30	60.3	58.5	61.60	57.47	-1.3	1.0	1,198		6	South	DI
31	52.5	50.2	53.46	50.33	-1.0	-0.1	1,096		8	South	DI
32	43.2	40.4	42.65	40.30	0.5	0.1	1,060		12	South	DI
33	48.3	41.4	49.08	36.50	-0.8	4.9	944	1,039	6	South	CI
34	124.2	60.9	123.42	47.31	0.8	13.6	1,176	1,247	10	South	DI
35	142.7	133.8	143.84	134.74	-1.1	-0.9	1,890	1,796	10	South	CI
36	127.1	123.6	126.95	123.22	0.1	0.4	1,765		8	South	CI
37	132.9	129.1	132.21	127.90	0.6	1.2	1,834		8	South	CI
38	150.0	139.3	149.91	138.86	0.1	0.5	1,855	1,404	6	South	CI
39	123.9	122.0	124.19	121.05	-0.3	1.0	1,673		10	South	CI
40	128.6	126.8	128.85	125.74	-0.3	1.0	1,802		12	South	CI
41	139.0	136.8	138.59	134.55	0.4	2.2	1,878		14	South	CI
42	107.5	105.3	106.73	104.36	0.7	0.9	1,396		14	South	CI
43	151.7	137.8	152.57	133.93	-0.8	3.9	1,989	1,866	8	South	DI
44	137.7	112.9	139.10	116.41	-1.4	-3.5	1,601	1,744	6	South	CI
45	145.0	128.9	145.38	121.59	-0.4	7.3	1,740	1,593	6	South	CI
46	129.9	118.0	131.10	120.93	-1.2	-3.0	1,723	1,615	6	South	CI
47	126.5	103.9	126.13	113.47	0.3	-9.6	1,595		6	South	CI
48	137.6	126.3	138.66	123.89	-1.0	2.4	1,817	1,661	6	South	CI
49	72.6	67.2	73.44	61.10	-0.8	6.1	1,237		6	South	CI
50	101.2	87.8	101.32	88.92	-0.1	-1.1	1,358		6	South	CI

Table 4.2 (cont.): Fire Flow Test Results

Test No.	Measured Static Pressure (psi)	Measured Residual Pressure (psi)	Simulated Static Pressure (psi)	Simulated Residual Pressure (psi)	Pressure Difference Static Pressure (psi)	Pressure Difference Residual Pressure (psi)	Flow (gpm)	Flow (gpm)	Watermain Size (in)	Pressure Zone	Material
51	125.8	109.6	125.25	110.67	0.5	-1.0	1,578		6	South	CI
52	88.4	64.7	87.87	62.66	0.5	2.0	1,206		6	South	DI
53	93.9	83.0	93.98	81.96	-0.1	1.1	1,312		6	South	CI
54	142.6	131.2	143.90	122.25	-1.3	8.9	1,869	1,822	8	South	CI
55	115.2	109.5	114.73	110.54	0.5	-1.0	1,673		8	South	DI
56	153.2	140.7	154.76	139.19	-1.6	1.5	1,998	1,725	14	South	DI
57	82.4	74.0	82.18	74.83	0.2	-0.8	1,342	1,299	10	South	DI
58	123.4	109.8	121.68	109.05	1.7	0.8	1,621	1,531	12	South	DI
59	111.3	88.0	110.38	80.25	0.9	7.8	1,491	1,521	12	South	DI
60	157.4	153.9	157.84	154.28	-0.4	-0.4	1,803		12	South	DI
61	71.1	70.7	72.11	71.02	-1.0	-0.3	1,277		10	South	DI
62	83.0	81.4	83.68	81.33	-0.7	0.1	1,362		24	South	DI
63	130.6	118.3	129.74	117.79	0.9	0.5	1,689	1,746	10	South	DI
64	131.5	128.3	131.90	126.69	-0.4	1.6	1,739		8	South	DI
65	142.6	133.7	143.09	131.35	-0.5	2.4	1,964	1,814	10	South	DI
66	120.3	116.7	119.80	116.32	0.5	0.4	1,732		8	South	DI
67	112.5	109.0	114.15	109.57	-1.7	-0.6	1,660		8	South	DI
68	100.8	98.7	102.90	97.50	-2.1	1.2	1,494		8	South	DI
69	101.8	92.6	101.50	91.08	0.3	1.6	1,446	1,532	8	South	DI
70	100.2	66.6	101.21	71.00	-1.0	-4.4	1,385	1,273	10	South	DI
71	69.2	66.7	69.06	65.60	0.2	1.1	1,305		12	South	DI
72	140.4	135.6	139.79	135.20	0.6	0.4	1,870		10	South	DI
73	36.4	32.8	37.01	33.19	-0.6	-0.3	823	810	12	South	DI
74	120.5	118.6	120.71	116.51	-0.2	2.1	1,748		8	South	DI
75	61.3	42.1	62.76	42.91	-1.5	-0.8	1,047	1,101	8	Knoll	DI

Table 4.2 (cont.): Fire Flow Test Results

4.4.3 Extended Period Simulation (EPS) Calibration Results

The hydraulic model was further refined to match water storage levels and extended pressure testing results with the hydraulic model during extended period simulations. Fine-tuning was accomplished through adjustment of both pipe roughness coefficient factors and global demand adjustments. SCADA information from August 20^{th} through August 26^{th}, 2015 and from October 12^{th} through October 18^{th}, 2015 was used to adjust and calibrate the hydraulic model for extended period simulations.

Most EPS calibrations concern the examination of curves of observed versus modeled water storage levels. Comparison of actual water storage levels and extended pressure testing was performed for each of the above-mentioned EPS test days. Comparisons of observed and modeled results for August 20^{th}, 2015 are shown graphically in **Figure 4-7** as a typical calibration chart. The storage level curves and detailed calibration results for the calibration period are presented in **Appendix E**. A comparison of the observed versus simulated model results is presented in **Table 4.3**. These results indicate that the hydraulic model simulation matches well with the observed water storage levels and pressure readings. The simulated water storage level curves trend closely with the observed data from the SCADA system.

The simulated water storage levels were within 6 feet of the observed water storage levels for 100 percent of the time for the fourteen (14) calibration days. In a comparison of simulated levels within 3 feet of the observed storage levels, results show that the model was within the tolerance 100 percent of the time. Differences that were observed within the calibration of storage levels could be caused by changes in demand or operations within the system that could not be identified during the calibration. Based upon the criteria set forth above, these results are within the acceptable level of tolerance for model calibration.

During the initial review of EPS field test data (October 12^{th} through the 18^{th}, 2015), it was determined that there was an unaccounted for pressure loss for EPS Test No. 11 and 12:

- Test No. 11 was located in the Northwest Zone near large multi-family housing structures and a middle school. Model results for this location differed from field testing data during the morning hours, suggesting that the demand pattern for this area might be different from the rest of the distribution system. A specific diurnal demand pattern for this area cannot be generated without significant field testing including additional flow and pressure monitoring in the Northwest Zone. The model differences for this area are not considered to have a significant impact on the existing system analysis or future planning efforts.

- Test No. 12 was located upstream of PRV 14 which feeds the Northwest Zone. Model results for this location differed from field testing data during morning hours through early afternoon. This difference in data for this test suggested that there was unaccounted headloss within the transmission main feeding PRV 14. This loss could not be attributed to typical C-factors. City staff exercised numerous system valves to find partially or fully closed valves on the transmission main; however, none were found. Because of the unknown source or magnitude of the headloss factor, the model was constructed without the headloss factor for the pipe upstream of PRV 14.

Table 4.3 lists the EPS results. The simulated pressure readings were within 10 feet of the observed pressure readings 99 percent of the time and within 5 feet of the observed readings approximately 95 percent of the time. Based upon the criteria established in **Section 4.4**, these results indicate an acceptable overall level of tolerance for model calibration. The majority of the outlying data points are located at EPS Test No. 11 and 12, as discussed.

Detailed EPS calibration results for each test location are presented in **Appendix E**.

Date	Reservoir Levels		Extended Pressure Tests*	
	Level readings within 6 ft	Level readings within 3 ft	Pressure readings within 10 ft	Pressure readings within 5 ft
August 20, 2015	100%	100%	-	-
August 21, 2015	100%	100%	-	-
August 22, 2015	100%	100%	-	-
August 23, 2015	100%	100%	-	-
August 24, 2015	100%	100%	-	-
August 25, 2015	100%	100%	-	-
August 26, 2015	100%	100%	-	-
October 12, 2015	100%	100%	99%	94%
October 13, 2015	100%	100%	99%	97%
October 14, 2015	100%	100%	99%	95%
October 15, 2015	100%	100%	100%	97%
October 16, 2015	100%	100%	100%	95%
October 17, 2015	100%	100%	98%	94%
October 18, 2015	100%	100%	98%	96%
Total	**100%**	**100%**	**99%**	**95%**

*Note: Nearly all data points that do not fall within parameters are at the following locations:

-Test No. 11 located within the NW pressure zone

-Test No. 12 located upstream of PRV 14 within the NE pressure zone

Table 4.3: Observed versus Simulated Model Results for Water Storage Levels and Extended Pressure Tests

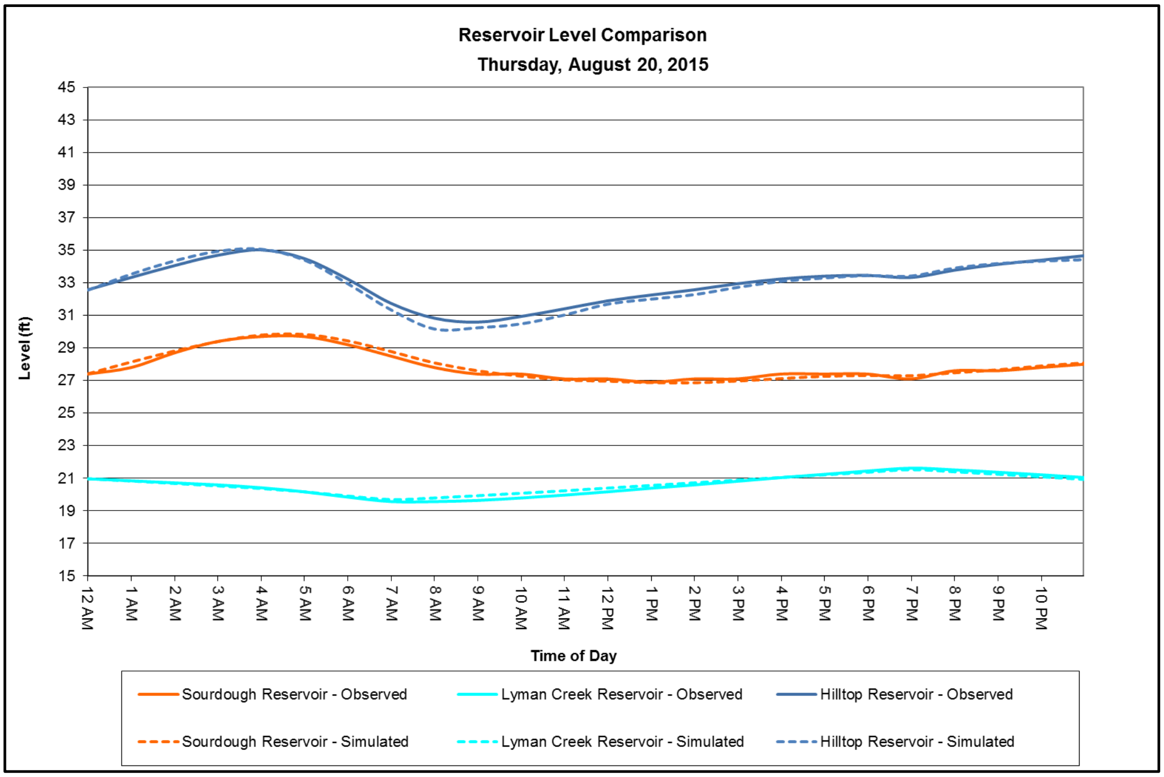

Figure 4-7: Water Storage Level Comparison – August 20, 2015

CHAPTER 5 DESIGN PARAMETERS AND EVALUATION CRITERIA

Design parameters identify the features and performance requirements of distribution system infrastructure, and provide the standard against which system performance is assessed. The design parameters and criteria presented within this section were used to evaluate the performance of the existing Bozeman water distribution system, and to conceptualize system improvements (water mains, storage, and pumping facilities) necessary to maintain system reliability and accommodate future growth and development of the system.

Design parameters and evaluation criteria are established herein for water system pressures, transmission and distribution piping, fire protection, and distribution system storage and pumping facilities. The criteria were established based on industry standards, Montana Department of Environmental Quality (MDEQ), existing City codes, and engineering judgment.

5.1 Water System Pressure

When evaluating the adequacy of a water distribution system, it is paramount to ensure that adequate pressure is supplied throughout the system. Generally, there are three design pressures that should be defined by each utility:

1. Minimum pressure during peak hour;
2. Minimum pressure during a fire flow; and
3. Maximum pressure.

Table 5.1 presents the water distribution system pressure criteria used for master planning purposes.

Distribution System Pressures	Criteria (psi)
Maximum Pressure	110
Mountain Zone Maximum Pressure[1]	150
Minimum Pressure during Peak Hour demand[2]	50
Minimum Pressure during a Fire Flow	20

Notes:
1. Mountain Zones involve regions within the study area with extreme topographic change such as the Bridger Foothills and Story Hills.
2. Areas near reservoirs and on the edge of pressure zones, a minimum pressure of 35 psi during PHD operations is acceptable.

Table 5.1: Hydraulic Criteria Pressure Recommendations

AES2 Think Big. Go Beyond.

5.1.1 Maximum Pressure

Maximum pressure refers to the maximum pressure that a customer will experience at their residential or business service connection. High pressures within distribution systems can be problematic, resulting in a number of issues such as increased wear on system components, more frequent leaks and breaks, and extreme pressure variations. These issues have been experienced by the City, as operators identified pressure transients and breaks in areas of the system that are known to have high pressure. For example, during a PRV repair on Oak Street, the distribution system experienced water hammer that caused fire sprinkler flow alarms to trigger throughout North 19th Avenue. Furthermore, water main breaks quickly become catastrophic, creating excessive damage to the surrounding area and creating a safety risk for both the community and City operations staff.

The *City of Bozeman Design Standards and Specifications Policy Document*, states the following in Section V: Utility Design Criteria:

- Pressure Reducing Valves: Pressure reducing valves shall be installed when the anticipated average day line pressure exceeds 120 psi.

A pressure evaluation of other cities in Montana was completed to determine if the City's current recommended maximum pressure should be adjusted. **Table 5.2** presents recommended operating pressures from the MDEQ Circular No.1[7] and other cities in Montana.

The pressure evaluation showed that other cities across the state of Montana have operating pressures that range from 35-150 psi. The establishment of 150 psi was based on engineering judgment of the community's specification. The City of Helena and City of Great Falls suggest a normal operating range of 50-110 psi. Based on the terrain of Bozeman, existing system pressures, and the operating ranges advised in **Table 5.2**, the recommended pressure ranges listed in **Table 5.3** are suggested to carry forward for master planning purposes.

[7] Circular DEQ 1 Standards for Water Works. (August 8, 2014). Helena, MT: Montana Department of Environmental Quality

Source	Recommended Operating Range (psi)	Source Notes
Montana DEQ[8]	35-80	"The minimum working pressure in the distribution system should be 35 psi (240 kPa) and the maximum normal working pressure should be approximately 60 to 80 psi (410-550 kPa)."
Great Falls[9]	35-110	"Water pressure varies throughout the city and is affected by the elevation at which the service is supplied and the reservoir or pumps which service your location. Pressure range varies from approximately 35 to 110 psi. Daily and seasonal usage may also cause pressure fluctuations. Pressure requirements for service are based upon average calculated pressures."
Helena[10]	50-110	"…The normal operating range of pressure allowed for water system design is 50-110 psi or as approved by the Public Works Department without the use of booster or fire pumps."
Billings[11]	35-150	"…**2.2.B.1 Revise Sentence to read:** Furnish Special Thickness Class 52 wall thickness meeting AWWA C 151, American National Standard for Ductile Iron Pipe **2.2.C.1 Add to the end of paragraph:** Furnish PVC water main pipe meeting AWWA C900 requirements, made to ductile iron O.D.'s for "push-on" joints. Assure pipe joints are bell and spigot having an elastomeric gasket. Use DR 14 Class 200 pipe." Based on engineering judgment the standard suggests that normal working pressures should be less than 150 psi.
Missoula	--	Not specified in Standard Specifications
Kalispell[12]	35-150	"Delete Subsections 3.4.A.1 & S of the Standard and Replace it with the following: 1. Perform hydrostatic and leakage testing in accordance with AWWA C600. Once the pipe is laid and backfilled, test for at least two hours, all newly laid pipe, or any valved section, to a hydrostatic pressure of either, 1.5 times the working pressure or 125 psi, whichever is greater." Based on engineering judgment the standard suggests that normal working pressures should be less than 150 psi.

Table 5.2: Montana Pressure Evaluation

[8] Montana Department of Environmental Quality (2014 Edition ed., Vol. 1, Circular DEQ).
[9] Retrieved February 03, 2016, from http://www.greatfallsmt.net/publicworks/water-pressure-and-flows
[10] Engineering and Design Standards. (June 10, 2013). Helena, MT: City of Helena Public Works Department.pg 13 (Water System, Section 2.2)
[11] City of Billings Standard Modifications to Montana Public Works Stand Specifications (Sixth Edition). (February 2015). Billings, MT: City of Billings.
[12] City of Kalispell Standard Modifications to Montana Public Works Stand Specifications (Sixth Edition). (February 2015). Kalispell, MT: City of Kalispell. Special Provisions Section 02660 Water Distribution

Distribution System Pressures	Current Range	Recommended Range (psi)
Operating Maximum Pressure Range	70 – 165[1]	50 – 110
Mountain Maximum Pressure Range[1]	NA	50-150

Notes:
1. Pressures based on review of PRV vault settings provided by City of Bozeman.
2. Mountain Zones involve regions within the study area with extreme topographic change.

Table 5.3: Recommended Maximum Pressures

The recommended maximum operating pressure range is 50-110 psi. However, there are regions located within the UBO that have extreme topographic change (e.g. Bridger Foothills and the Story Hills). In order to satisfy the recommended pressure criteria, additional pressure zones and PRV's would be required. In some cases, a mountain pressure zone would need four separate sub-zones. In an effort to reduce the overall amount of pressure reducing infrastructure in these regions, the maximum pressure range was increased to 150 psi, which is similar to the maximum pressure the existing system experiences.

A reduction in system operating pressures to a recommended maximum working pressure of 110 psi could potentially affect existing system hydraulic performance, since the City's current design standard establishes a maximum operating pressure of 120 psi. System pressure reduction is further evaluated and discussed in **Chapter 7**.

5.1.2 Minimum Pressure

MDEQ recommends that the minimum working pressure in the distribution system should be 35 psi. The Computer Modeling of Water Distribution Systems, AWWA Manual M32[13], recommends that minimum pressures of 40 to 50 psi be maintained during peak hour demand (PHD) to help ensure that there is adequate pressure to the second story fixtures within a property. The AWWA Manual M32 also notes that where residential fire sprinkler systems are required by legislation, the minimum acceptable pressure is 50 psi for the fire sprinklers to operate correctly. Additionally, backflow prevention devices are often required on many office, commercial, and industrial buildings. Currently, the City requires backflow on all new construction and renovations to existing buildings, with a goal to achieve 100-percent backflow prevention for all structures over time. With respect to minimum operating pressures, the pressure drop across backflow devices is often between 5 and 15 psi, which could further increase customer complaints about low water pressure.

[13] Computer modeling of water distribution systems (Manual M32). (2012). Denver, CO: American Water Works Association.

The minimum pressure during fire flows, as recommended by the National Fire Protection Association (NFPA), is 20 psi at any point in the distribution system. The value of 20 psi is used to ensure an adequate supply of water to the pumper fire trucks, while overcoming any friction losses within the pipeline branch, hydrant, and fire hoses.

Based on these guidelines, the minimum pressure performance criterion that was established for the Bozeman system during PHD is 50 psi. However, the City of Bozeman agreed that in areas in the vicinity of reservoirs and on the edge of pressure zones, a minimum pressure of 35 psi during PHD operations is acceptable. For fire flows, a minimum pressure of 20 psi was used for assessing the performance of the distribution system. **Table 5.4** summarizes the recommended minimum pressures for master planning purposes.

Distribution System Pressures	Recommended (psi)
Minimum Pressure during Peak Hour demand*	50*
Minimum Pressure during a Fire Flow	20

*Minimum 35 psi acceptable in the vicinity of reservoirs and on the edge of pressure zones.

Table 5.4: Recommended Minimum Pressures

5.2 Distribution System Storage

Water distribution system storage is provided to ensure reliability of supply, maintain pressure, equalize pumping and treatment rates, reduce the size of transmission mains, and improve operational flexibility and efficiency. Storage facilities should be sized to provide for the following:

1. Operational Storage – Provide storage to meet peak hour demands and pressure equalization;
2. Fire Protection Storage – supply storage for fire flow demands and emergencies (e.g., Treatment works or bulk transmission facilities out-of-service); and
3. Emergency Storage – to provide water reserves for contingencies such as system failures, power outages, emergencies, and operational flexibility/reliability (e.g. flooding, earthquake, ability to remove reservoir for maintenance without adverse consequence to customers etc.).

Figure 5-1 depicts storage requirements, inclusive of situations where sufficient capacity exists for winter (low-use) adjustment:

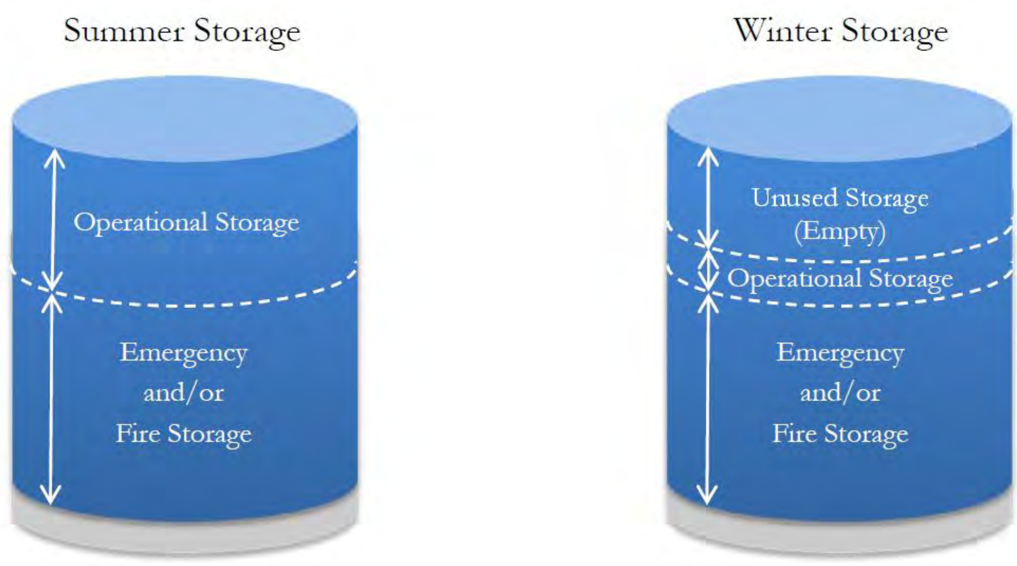

Figure 5-1: Storage Requirements Overview

All recommended storage requirements were verified such that that they satisfy MDEQ Circular No.1, which requires the following sizing criteria:

- The minimum allowable storage must be equal to the average day demand plus fire flow demand, as defined below, where fire protection is provided.
- Where fire protection is provided, fire flow demand must satisfy the governing fire protection agency recommendation.
- Each pressure zone of systems with multiple pressure zones must be analyzed separately and provided with sufficient storage to satisfy the above requirements.
- Excessive storage capacity should be avoided to prevent water quality deterioration and potential freezing problems.
- Finished water storage designed to facilitate fire flow requirements and meet average daily consumption should be designed to facilitate turnover of water in the finished water storage to minimize stagnation and stored water age.
- The variation between high and low levels in storage structures providing pressure to a distribution system should not exceed 30 feet.

Table 5.5 presents the water distribution system storage criteria used for master planning purposes.

Storage Capacity	Criteria
Operational Storage	40 percent of the maximum day demand
Fire Storage	Fire storage to be provided is based on two fires occurring within a 24-hr period
Emergency Storage	Emergency storage equal to 2 days average day demand
Total Water Storage Capacity[1]	Storage should be the greater of: 1. The sum of operational storage plus fire flow; or 2. The sum of emergency storage plus operational storage (which is equal to approximately 3 days average day demand)

Note 1. If groundwater supplies exist, water rights are obtainable and wells are cost-effective options for the City, well supplies can reduce the amount of above ground storage requirement up to 50 percent of the total requirement for zones within the service area protected by such ground storage

Table 5.5: Hydraulic Criteria Storage Recommendations

The following subsections discuss the design parameters established for the evaluation of the distribution system storage facilities and provide support for the development of improvement concepts.

5.2.1 Operational Storage

Operational storage enables the source, treatment, and pumping facilities to operate at a predetermined rate, depending on the utility's preference. Additionally, operational storage is generally less expensive than increased capacities of treatment and booster pump stations beyond that required to meet the MDD. Consequently, it is desirable to size the source, treatment, and pumping facilities to serve the water needs up to the MDD and provide operational storage for meeting peak instantaneous water demands.

The amount of operational storage required is a function of the WTP and booster pumping capacity, distribution piping capacity, and system demand characteristics. The fraction of water production that must be stored during a maximum day as operational storage depends on the individual utility, system configuration, and operational procedures.

An operational storage fraction of 40 percent of the MDD is recommended. This recommendation is based on the following factors:

- A relatively high peak hour/avg. day demand exists for Bozeman given its seasonal irrigation demands. The 40 percent factor allows reservoirs to be more fully utilized for peak demands while managing instantaneous pumping demands.

- Allows the filling/draining of reservoirs to promote circulation, which will increase the mixing and turnover for maintenance of water quality (particularly during higher demand periods of the year).
- Delays the need for treatment capacity upgrades over the long-term.
- Provides the City with increased operational flexibility.
- Decreases system risk during emergency periods and drought.

It is recommended that the operational storage be provided within the upper 50 percent of the storage reservoirs to allow the WTP operators with the ability to establish set points to maintain adequate system pressures and adequate fire and emergency storage within the distribution system. Ideally, storage should be situated to provide water by gravity to avoid the operation of pump systems.

5.2.2 Fire Storage

Fire storage volume was determined by multiplying the required maximum fire flow rate by the required duration of time. **Section 5.5.3** discusses the development of fire storage volume requirements in greater detail. In addition to fire storage volume requirements, the following criteria are recommended for planning purposes:

- Sufficient storage must exist for the worst case fire that could occur within a pressure zone served by gravity storage. If more than one reservoir serves the pressure zone, total storage reserved for fire flow demand among all reservoirs should be sufficient for the worst case fire.
- <u>Total storage to be provided is based on **two fires** occurring within a 24-hr period.</u> However, the fires will not occur in the same pressure zone in a 24-hr period
- Where a reservoir serves more than one pressure zone, the reservoir volume reserved for fire flow demand must be adequate for two worst case fires occurring within the pressure zones served by the reservoir.

5.2.3 Emergency Storage

Emergency storage provides water for domestic consumption during events such as transmission or distribution main failures, raw water contamination events, extended power outages, failure of raw water transmission facilities, failure of WTP facilities, or a natural disaster.

No industry-standard formula exists for determining the amount of emergency storage required by a utility. It is more of a policy decision that is based on an assessment of the perceived vulnerability of the utility's water supply, risk of failures, and the desired degree of system reliability.

If a utility has redundant sources and treatment facilities with auxiliary power, or power supplied from multiple sources, the need for emergency storage may be relatively small. However, enough emergency storage should be available to handle a catastrophic pipe break that cannot be isolated easily. If a utility has a single source without auxiliary power and a relatively unreliable distribution system, a significant volume of emergency storage may be prudent.

Based on a review of the reliability of the water supply, treatment, distribution system, and past system failures the following storage criteria was recommended for the City.

- Emergency storage shall be equal to 2 days of average day demand.

Storage equivalent to two days of average day demand is recommended so that sufficient time exists to correct an emergency situation (e.g., bulk transmission facilities are out-of-service or treatment works are unavailable). In addition, given the City's relatively high design maximum day:average day ratio (minimum 2.3:1), this amount of storage should also be sufficient for a maximum day demand with reserve for fire flow. For emergency situations, it is recommended that Bozeman would implement water use restrictions and rationing, reducing the system per capita demand rate to 100 GPCD, or approximately 25 percent less than the average day per capita demand.

5.2.4 Total Storage

The City's recommended total water storage capacity should be the greater of the following:

1. The sum of operational storage plus fire flow; or
2. The sum of emergency storage plus operational storage, which is equal to approximately three days of the average day demand.

The amount of total system storage and system demand capacity required to meet these criteria will change over time as the City continues to grow and water usage increases. The aforementioned criteria assume that all existing and future water supply is from surface water sources (i.e. Sourdough and Lyman); however, if groundwater supplies exist, water rights are obtainable and wells are cost-effective options for the City, well supplies could reduce the amount of above ground storage requirement up to 50 percent of the total requirement for zones within the service area protected by such ground storage.

5.3 Pumping Facility Capacity

Appropriate pumping facility capacity should be provided to meet the following conditions within the water system:

1. In pressure zones with storage – The station must have adequate firm capacity to supply maximum day demand (MDD) for the zone service area.
2. In pressure zones without storage - Pump stations supplying constant pressure service must have firm pumping capacity adequate to meet peak hour demand (PHD) for the zone service area while simultaneously supplying the largest fire flow demand in the zone.

Pump station capacity guidelines are based on firm capacity, which is defined as the capacity of the system with the largest pump out of service. Pumping facilities identified as critical (provides service to pressure zone(s) without sufficient fire or emergency storage) should be equipped with an on-site, backup power generator. Less critical facilities should be equipped with a receptacle to allow for a connection to a portable generator.

5.4 Transmission and Distribution Main

Guidelines for the design of transmission and distribution piping vary from state to state and from utility to utility. Ten States Standards provide design guidance on the minimum and maximum working pressures in a distribution system. The American Water Works Association (AWWA) also provides some guidelines on design parameters such as pipe velocity, head loss, and fire flows. The Insurance Service Organization (ISO) has established fire flow requirements for individual structures within a service area. Other guidelines for design parameters such as minimum and maximum pressures, head loss, and fire flows are established within design handbooks specifically written for water distribution system analyses.

Ultimately, the majority of the design criteria used in evaluating transmission and distribution piping remains at the discretion of the water utility and its utility engineer.

The following sections discuss the design parameters established for the evaluation of the Bozeman transmission and distribution piping system, and provide the basis for the selection of improvement concepts.

5.4.1 Velocity and Headloss Criteria

Pipelines are sized to meet maximum flow conditions, which generally occur during maximum day plus fire flow or peak hour demand conditions. Pipelines are expected to carry water from sources, including water towers, reservoirs, and pump stations, to the customer without excessive pressure loss.

Piping within the water distribution system was generalized into two categories for this study: 1) transmission pipelines, and 2) distribution pipelines.

The transmission pipelines are the larger pipes that carry water longer distances and branch off to feed the distribution pipelines. Distribution pipelines are generally referred to as those pipelines in the street to which fire hydrants and customer service leads are connected.

Establishing a maximum permissible velocity in a pipe, however, cannot be evaluated without consideration of headloss, as velocity is only indirectly the limiting factor in evaluating pipe sizes for a distribution system. Essentially, the headloss caused by the velocity, not the velocity itself, controls pipe sizing requirements. Pipeline velocities also have a direct effect on hydraulic surges and water hammer created in pipelines. As a result, criteria for both maximum permissible velocity and headloss were established for evaluating the performance of the Bozeman distribution system.

5.4.1.1 *Velocity Criteria*

Insight into performance guidelines with respect to pipeline velocities was obtained from Advanced Water Distribution Modeling and Management[14]. Because transmission pipelines carry water over longer distances than the distribution pipelines, the headloss should be kept to a minimum to avoid large pressure fluctuations. The authors acknowledge that in larger pressure zones (several miles across), velocities as low as three feet per second (fps) may cause excessive headloss within the distribution system. The authors also identify that at velocities of ten fps, pressures within the distribution system decline quickly and problems associated with water hammer become more pronounced.

AWWA Manual M32 states that a distribution system is considered to have deficient pipe looping or sizing when velocities greater than four to six fps occur under normal operating conditions. The recommended maximum velocity for this study is five fps.

Hydraulic surge, or transient pressure, is used to determine required pipe thickness under some pipe manufacturer guidelines. Calculations to determine required pipe thickness are based on internal pressure that includes a 100 psi allowance for surge pressure and a 2:1 safety factor. The surge pressure allowance is based on a 50 psi pressure rise for each foot per second of extinguished velocity, and the fact that most domestic water systems operate at approximately

[14] Walski, Thomas M.; Chase, Donald V.; Savic, Dragan A.; Grayman, Walter; Beckwith, Stephen; and Koelle, Edmundo, "Advanced Water Distribution Modeling and Management" (2003). Civil and Environmental Engineering and Engineering Mechanics Faculty Publications. Paper 18

two fps. As stated previously, AWWA recommends that maximum velocities for pipelines be five fps or less, and one of the reasons for this limit listed is to minimize hydraulic surge pressures.

For small diameter pipe at the maximum recommended velocity of five fps, a pipeline would need to be designed to accommodate a 250 psi pressure surge (five fps x 50 psi/fps), which significantly encroaches on the safety factor for the typical municipal distribution system pipe. Generally speaking, the class of ductile iron pipe used by the City can handle the high operating pressure and pressure surge.

High velocities can also scour pipe lining materials of various pipes. For DI pipe with cement-mortar lining, the Ductile Iron Pipe Research Association (DIPRA) recommends a maximum flow velocity of 14 fps to minimize disbonding of the cement-mortar lining from the inside of the pipe.

Based on the preceding information, the following design guidelines for acceptable pipeline velocities were established for this evaluation under PHD conditions:

- Transmission pipelines (12-inch and larger) = less than three fps
- Distribution pipelines (10-inch and smaller) = less than five fps

Velocity guidelines will be used in subsequent sections for the analysis of the distribution system for PHD under ADD and MDD conditions. Velocity guidelines assist in the indication of potential problems associated with hydraulic surge pressures. Existing pipelines that exceed these criteria will not necessarily be identified for replacement unless there are known existing problems within the distribution system. However, if new pipelines are planned to replace old deteriorated pipelines, then the new pipelines should be sized appropriately to meet these guidelines.

Dedicated transmission pipelines (i.e., pipelines not interconnected with the distribution system), can be designed for higher velocities than 3 fps without impacting distribution system performance. Velocity guidelines for these pipelines should be evaluated on a case-by-case basis.

5.4.1.2 *Headloss Criteria*

Headloss is a more important concern than velocity for determining pipe sizing requirements; therefore, it is desirable to set a limit on the amount of headloss in a pipe. Headloss provides a better indication of the capacity of pipelines in that this performance criterion takes into account the roughness coefficient of the pipeline, also known as the C-factor, and the associated velocities within the pipeline.

When describing headloss, it is most commonly referred to in terms of feet of headloss per 1,000 feet of pipe length (ft/1,000 ft). AWWA recommends that headloss not exceed six feet per 1,000 feet for pipes less than 16-inches in diameter and that headloss not exceed three feet per 1,000 feet for pipes greater than or equal to 16-inches in diameter during normal operation conditions. However, because higher headloss often contributes to inadequate distribution system pressures, performance standards used to evaluate larger diameter transmission pipelines and distribution pipelines are generally substantially lower than the AWWA guideline.

According to Modeling, Analysis, and Design of Water Distribution Systems[15], the author recommends that transmission pipelines be sized to handle the maximum hour flow. In order to maintain a reasonable headloss within transmission pipelines during maximum hour flow, headloss should be limited to between one and two ft/1,000 ft.

According to AWWA?, transmission pipelines should be sized to handle the largest of the following flows:

1) peak hour flow,
2) maximum day flow plus fire flow, or
3) replenishment flow rate.

Based on this consideration, the allowable headloss recommended for the Bozeman system should be limited to between two and five ft/1,000 ft. Based on the preceding information, the following design guidelines for acceptable pipeline headloss were established for this evaluation under PHD conditions:

- Transmission pipelines (12-inch and larger) = less than two ft/1,000 ft
- Distribution pipelines (10-inch and smaller) = less than five ft/1,000 ft

Headloss guidelines will be used in subsequent sections for the analysis of the distribution system PHD under ADD and MDD conditions. Headloss guidelines assist in the indication of potential problems associated with the hydraulic capacity of water mains to move water from the pumping facilities to water storage.

Existing pipelines that exceed these criteria will not necessarily be identified for replacement unless they are contributing to known existing problems within the distribution system. However, if new pipelines are planned to replace old deteriorated pipelines, then the new pipelines should be sized appropriately to meet these guidelines. As with the velocity

[15] Cesario, L. (1995). Modeling, analysis, and design of water distribution systems. Denver, CO: American Water Works Association.

guidelines for dedicated transmission pipelines, the rate of headloss experienced within dedicated transmission pipelines may exceed the guidelines presented herein, but should be evaluated on a case-by-case basis.

5.5 Fire Protection

There are no legal requirements that specify a water system must be sized adequately to provide water for fire protection. Fire protection is considered a secondary purpose for a public water system, and is an issue typically addressed at the policy level within each community.

The decision to provide water for fire protection requires careful consideration of fire flow requirements when sizing pipelines, pumps, and storage reservoirs because it results in higher capital and operation and maintenance (O&M) costs. Provisions for fire flows also provide a valuable public service, however, by reducing the potential loss of human life and property, and improving fire insurance ratings within the community, which can reduce insurance costs.

5.5.1 Methods for Calculating Fire Flow Requirements for Structures

This section summarizes the four commonly used methods of calculating fire flow requirements for structures in the United States. Later sections describe the concepts of needed fire flows (NFF), fire flow duration, and discuss the provisions that were established for evaluating the system.

As described in the AWWA Manual M31[16], there are three generally accepted methods for calculating fire flow requirements:

1. Iowa State University (ISU);
2. Illinois Institute of Technology Research Institute (IITRI); and
3. Insurance Services Organization (ISO).

Although not identified within the AWWA Manual M31, a fourth method of calculating fire flow requirements is the International Fire Code (IFC).

Iowa State University Method
The ISU method is the oldest of the four methods. It addresses the quantity of water required to extinguish a fire, and considers the effect of a range of application rates. The equation used to calculate the fire flow under this method is relatively simple, equal to the volume of building space in cubic feet divided by 100. The drawback to this method is the fact that for non-

[16] Distribution system requirements for fire protection (Manual M31). (2008). Denver, CO: American Water Works Association.

compartmentalized buildings, such as warehouses, the calculated flow would be quite large, as the equation assumes the entire structure is involved in the fire. This method assumes that water is supplied in an ideal manner and that maximum effectiveness is achieved.

Illinois Institute of Technology Research Institute (IITRI) Method

The IITRI method was developed based on statistics obtained from 134 actual fires of varying magnitude. Water application rates were calculated using the documented length and diameter of fire hose and the nozzle pressures. From this data, formulas for fire flows for residential and nonresidential occupancies were developed through a curve fitting analysis. These equations consider the actual area of the fire and, of the three methods described herein, this method generally projects the highest fire flow requirement.

Insurance Services Organization

The ISO method is the most commonly used of the three methods described in AWWA Manual M31, and develops or determines the rate of flow considered necessary to control a major fire within a specific structure. This method was derived as a tool for use by the insurance industry in establishing fire insurance rates for individual properties based on the community's fire defenses. The results calculated using this method are generally consistent with those calculated using the ISU method, although slightly higher due in part to the fact that the ISO method accounts for the need to protect the adjacent buildings as well.

The Needed Fire Flow (NFF) is described as the specific amount of water necessary to control a major fire in a specific building. This value is based on the size of the burning structure, construction materials, combustibility of the contents, and the proximity of nearby buildings. The NFF is expressed in units of gpm at a pressure of 20 psi for a range of two to four hours. The minimum NFF for a single building as identified by the ISO is 500 gpm. The City of Bozeman uses the ISO minimum NFF of 1,500 gpm for one and two family dwellings.

According to ISO, fires requiring 3,500 gpm or less are referred to as receiving "Public Fire Suppression", while those requiring greater than 3,500 gpm are classified as receiving "Individual Property Fire Suppression". Therefore, the public classification applies to properties with a needed fire flow of 3,500 gpm or less.

The Fire Suppression Rating Schedule is the manual ISO uses in reviewing the firefighting capabilities of individual communities. The schedule measures the major elements of a community's fire-suppression system and develops a numerical grading called a Public Protection Classification. ISO assigns a Public Protection Classification (PPC) from 1 to 10.

Class 1 represents the best protection, and Class 10 indicates no recognized protection. ISO classification ratings are based on the three following areas:

- Fire Department - 50 percent of the score looks at your local fire department, including staffing, training, geographic distribution of firehouses and adequacy of the fire equipment.
- Water Supply System - 40 percent of the score takes into account the community's water supply, including the placement and condition of fire hydrants and the amount of water that's available to put out fires
- Fire Alarm and Communication System - 10 percent of the score measures the efficiency of emergency communications, such as the 911 system and the number of emergency dispatchers.

To determine the rate of flow the water mains provide, ISO observes fire-flow tests at representative locations in the community. The ISO Fire Suppression rating affects insurance costs for properties with NFF of 3,500 gpm or less. The private and public protection at properties with larger NFF is individually evaluated, and may vary from the City classification.

International Fire Code

The International Fire Code (IFC) is a model code that regulates minimum fire safety requirements for new and existing buildings, facilities, and storage process. As stated in the IFC, the minimum fire flow required for one- and two-family dwellings that do not exceed 3,600 square feet and do not have an automatic sprinkler system is 1,000 gpm. For one- and two-family dwellings exceeding 3,600 square feet, and for all buildings other than one- and two-family dwellings, the minimum fire flow, and flow durations, are presented in **Table 5.6**. The minimum fire flow for these types of structures ranges from 1,500 gpm to 8,000 gpm, over durations from two to four hours.

5.5.2 City of Bozeman Fire Flow Requirements

The City uses ISO to evaluate the structural fire suppression delivery system. Virtually all U.S. insurers of homes and business property use ISO's Public Protection Classifications in calculating premiums. In general, the price of fire insurance in a community with a good PPC is substantially lower than a community with a poor PPC, assuming all other factors are equal.

The City of Bozeman currently has a Class 3 Public Protection Classification rating which affects insurance costs for properties with NFF of 3,500 gpm or less. The City's most recent ISO full survey was completed in October 2011 with the Class 3 rating applied on December 1, 2011. The private and public protection at properties with larger NFF is individually evaluated, and may vary from the City classification. If a structure is located in the public zoning area and is greater than the planned fire demand for that zone, the structure may be required to have a sprinkler system, or the City may need to review means of providing additional fire flow to the structure through either water main or storage improvements.

FIRE-FLOW CALCULATION AREA (square feet)					FIRE-FLOW (gallons per minute)[b]	FLOW DURATION (hours)
Type IA and IB[a]	Type IIA and IIIA[a]	Type IV and V-A[a]	Type IIB and IIIB[a]	Type V-B[a]		
0-22,700	0-12,700	0-8,200	0-5,900	0-3,600	1,500	2
22,701-30,200	12,701-17,000	8,201-10,900	5,901-7,900	3,601-4,800	1,750	
30,201-38,700	17,001-21,800	10,901-12,900	7,901-9,800	4,801-6,200	2,000	
38,701-48,300	21,801-24,200	12,901-17,400	9,801-12,600	6,201-7,700	2,250	
48,301-59,000	24,201-33,200	17,401-21,300	12,601-15,400	7,701-9,400	2,500	
59,001-70,900	33,201-39,700	21,301-25,500	15,401-18,400	9,401-11,300	2,750	
70,901-83,700	39,701-47,100	25,501-30,100	18,401-21,800	11,301-13,400	3,000	3
83,701-97,700	47,101-54,900	30,101-35,200	21,801-25,900	13,401-15,600	3,250	
97,701-112,700	54,901-63,400	35,201-40,600	25,901-29,300	15,601-18,000	3,500	
112,701-128,700	63,401-72,400	40,601-46,400	29,301-33,500	18,001-20,600	3,750	
128,701-145,900	72,401-82,100	46,401-52,500	33,501-37,900	20,601-23,300	4,000	4
145,901-164,200	82,101-92,400	52,501-59,100	37,901-42,700	23,301-26,300	4,250	
164,201-183,400	92,401-103,100	59,101-66,000	42,701-47,700	26,301-29,300	4,500	
183,401-203,700	103,101-114,600	66,001-73,300	47,701-53,000	29,301-32,600	4,750	
203,701-225,200	114,601-126,700	73,301-81,100	53,001-58,600	32,601-36,000	5,000	
225,201-247,700	126,701-139,400	81,101-89,200	58,601-65,400	36,001-39,600	5,250	
247,701-271,200	139,401-152,600	89,201-97,700	65,401-70,600	39,601-43,400	5,500	
271,201-295,900	152,601-166,500	97,701-106,500	70,601-77,000	43,401-47,400	5,750	
295,901-Greater	166,501-Greater	106,501-115,800	77,001-83,700	47,401-51,500	6,000	
—	—	115,801-125,500	83,701-90,600	51,501-55,700	6,250	
—	—	125,501-135,500	90,601-97,900	55,701-60,200	6,500	
—	—	135,501-145,800	97,901-106,800	60,201-64,800	6,750	
—	—	145,801-156,700	106,801-113,200	64,801-69,600	7,000	
—	—	156,701-167,900	113,201-121,300	69,601-74,600	7,250	
—	—	167,901-179,400	121,301-129,600	74,601-79,800	7,500	
—	—	179,401-191,400	129,601-138,300	79,801-85,100	7,750	
—	—	191,401-Greater	138,301-Greater	85,101-Greater	8,000	

For SI: 1 square foot = 0.0929 m^2, 1 gallon per minute = 3.785 L/m, 1 pound per square inch = 6.895 kPa.
a. Types of construction are based on the *International Building Code*.
b. Measured at 20 psi residual pressure.

Table 5.6: 2017 IFC Minimum Require Fire Flow and Flow Duration for Buildings

For structures, the City uses the International Building Code (IBC) and IFC requirements to determine the various fire safety aspects (e.g. fire and smoke protection features, interior finishes, fire protection systems, etc.). The City's fire department provides inspection and approval of these systems. Following these codes, automatic sprinklers systems are required for one or more of the following reasons:

1. The proposed occupancy or use in the building or fire area represents a high life-safety risk;
2. The occupant load of the building or fire area exceeds code-prescribed limits;
3. The building height or area warrants additional fire protection; and
4. The amount or hazards of materials stored or used inside the building.

A reduction of up to 75 percent of NFF is allowed when the building is provided with an approved automatic sprinkler system in accordance with the IBC and IFC requirements.

Between the structural delivery system (ISO) and building (IBC and IFC) requirements, the City works towards achieving the NFF requirement. Each building has different NFF requirements and should be evaluated on a case-by-case basis.

5.5.3 City of Bozeman Fire Flow Availability

The evaluation completed for the Water Facility Plan Update determined available fire flows (to assess the distribution system under current and future water demand conditions) by using zoning districts that represent different types of development. Therefore, the fire flow requirements set forth in this Water Facility Plan Update are intended only for general planning purposes, and may not be reflective of actual fire flow requirements required by the size and construction type of a specific development, and will not identify specific non-conforming developments. These guidelines are intended to comply with requirements in the City's Design Standards and Specifications calling for fire flow demands to be calculated as determined by ISO criteria.

Available fire flow is the flow rate of water supply available at the hydrants for firefighting measured at a residual pressure of 20 psi. The residual pressure of 20 psi represents the minimum pressure required to provide normal water pressure to a second story faucet while a nearby fire event is in progress. **Table 5.7** presents the recommended fire flow guidelines along with the required fire flow volumes used in the analysis. **Figure 5-2** shows fire flow guidelines for existing and future land use.

Zoning District	Category	Flow (gpm)	Duration (hrs)	No. of Fires	Total Demand (gal)
Residential Use					
R-4	Residential High Density	3,000	3	1	540,000
R-3	Residential Medium Density	3,000	3	1	540,000
R-2	Residential, Single-family Medium Density	1,500	2	1	180,000
R-1	Residential, Single-family Low Density	1,500	2	1	120,000
PU	Public Lands and Institutions	3,000	3	1	540,000
Commercial Use					
B-1	Neighborhood Business	3,000	3	1	540,000
B-2	Community Business	3,000	3	1	540,000
B-3	Central Business	4,000	4	1	960,000
Industrial Use					
M-1	Light Manufacturing	4,000	4	1	960,000
M-2	Manufacturing and Industrial	5,000	4	1	1,200,000

Table 5.7: Fire Flow Availability Guidelines

5.5.4 Considerations for Fire Suppression Design

Engineers and fire system designers use fire flow test data to design a fire protection system. Typically, the data, along with a minimum safety factor (i.e. 10 percent), is used to define the system for the remainder of its useful life, unless different design standards and specifications have been established.

Historically the City has allowed existing static pressure to be used for the design of fire suppression systems; however, because of issues associated with high pressure (i.e. increased breaks, transients, etc.), the City has expressed interest in lower existing pressure to reduce risk. **Chapter 7** presents the results of an evaluation regarding the potential to reduce existing operating pressures in the City, identifies issues associated with reducing system pressure, and provides recommendations on pressure management.

Results from the pressure zone and pressure reduction evaluation show that any significant change to the City's water distribution system can affect the performance capabilities of existing fire protection systems and that long-term pressure reduction is the best option for the City.

Any pressure reduction strategy would require the City to change its current policies and codes for establishing available fire flow and pressure for fire protection systems, particularly in areas that anticipate future pressure reduction. The following should be considered when establishing new fire pressure system design standards:

- Areas identified for future pressure reduction would utilize the calibrated hydraulic model to assess future demands as well as estimate available pressure and flows within the system. Engineers and fire system designers would use modeled data instead of actual flow test data.
- Areas that meet criteria set forth in this Chapter could use the calibrated model or actual water flow test data.
- Safety factors and adjustments should be established for both modeled and actual water flow test data. For example, a 10-percent safety factor is required to account for potential system changes or model errors.
- A fire protection professional engineer should review the proposed system modifications and assist with the development of new policies and codes to ensure the City meets all industry standards.

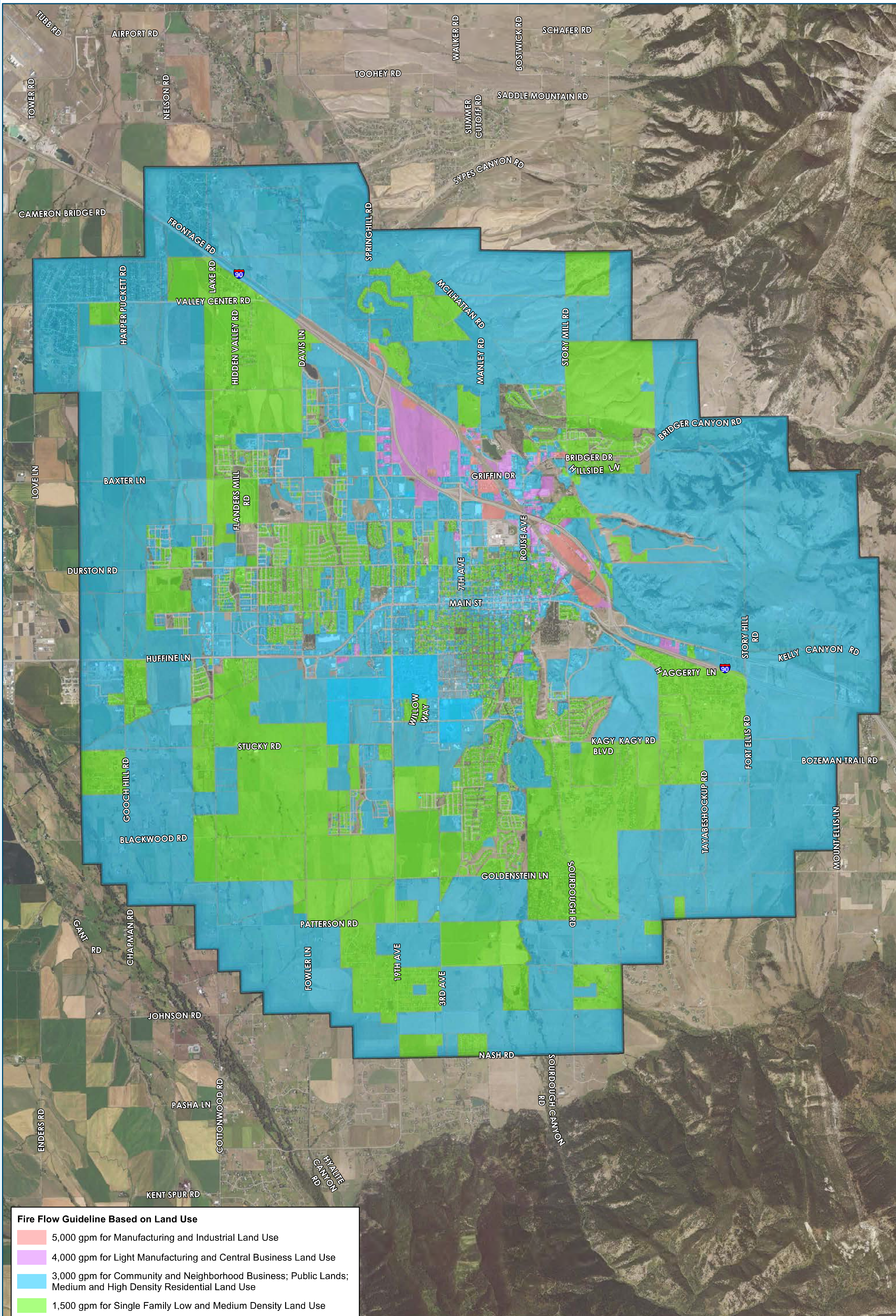

Figure 5-2: Fire Flow Availability Guideline Based on Land Use

City of Bozeman Water Facility Plan Update

0 0.4 0.8 1.2 1.6 Miles

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CHAPTER 6 EXISTING SYSTEM EVALUATION

This chapter presents the evaluation of the City's existing water distribution system and its ability to meet recommended water system service and performance criteria under various water demand conditions. The chapter includes evaluations for both system capacity and hydraulic performance. Key sections include the following:

- Water System Pressure
- Distribution System Storage;
- Distribution System Pumping Capacity;
- Transmission and Distribution Main Capacity; and
- Fire Flow Analysis

Evaluations, findings, and recommendations for addressing any deficiencies identified in the City's existing water distribution system are summarized and included in this chapter. These recommendations are used in the development of the CIP. The recommended CIP is described in further detail in **Chapter 10**.

6.1 Existing System Demands

Different demand scenarios were developed for use within the hydraulic model for evaluation of the existing system. The scenarios utilize different demand data sets that include average, winter, summer, and maximum day demands. Demand development is described in **Chapter 3,** and the demand allocation process is described in **Section 4.2.** Demand data sets are described below.

6.1.1 Existing Average Day Demand

The Average Day Demand (ADD) Scenario was developed to provide a modeling scenario representative of typical day-to-day operation of the water distribution system. Water consumption data from October 2015 metered data was used to spatially distribute water use within the model. The spatially allocated metered data was adjusted to 5.2 MGD, which is the ADD including NRW as determined by the water use characterization. The October diurnal demand pattern was used to calculate the average day diurnal demand curve, which is presented in **Figure 6-1**.

6.1.2 Existing Summer Day Demand

The Summer Day Scenario was developed to provide a modeling scenario representative of typical operation of during the months of June, July, and August, when demands are high due to irrigation. Water consumption data from August 2015 metered data was used to spatially distribute water use within the model. The spatially allocated metered data was adjusted to 8.6 MGD, which is the average metered data for the summer months, including NRW as determined by the water use characterization. The August diurnal demand pattern was used to calculate the summer day diurnal curve, which is presented in **Figure 6-1**.

6.1.3 Existing Maximum Day Demand

The Maximum Day Demand (MDD) Scenario was developed to provide a modeling scenario representative of the operation of the water distribution system during the historic maximum day demand of 11.7 MGD. Water consumption data from August 2015 metered data was used to spatially distribute water use within the model. The spatially allocated metered data was adjusted to 11.7 MGD, which is the historic MDD based on water production records as determined by the water use characterization. The August diurnal demand pattern was used to calculate the maximum day diurnal demand curve and is presented in **Figure 6-1**.

6.1.4 Existing Winter Day Demand

The Winter Day Demand Scenario was developed to provide a modeling scenario representative of typical operation during the months of December, January, and February, when demands are low. Water meter data from January 2015 was used to spatially distribute water use within the model. The spatially allocated metered data was adjusted to 3.6 MGD, which is the average metered data for the winter, including NRW as determined by the water use characterization. The October diurnal demand pattern was used to calculate the winter day diurnal demand curve and is presented in **Figure 6-1**.

6.1.5 Existing System Demand Summary

The demands, including NRW, used within the hydraulic model for the existing system are presented in **Table 6.1**. These demands can be used to evaluate the existing system because they are representative of previous usage patterns experienced historically.

Demand Day	Demand (MGD)
Average Day	5.2
Summer Day	8.6
Maximum Day	11.7
Winter Day	3.6

Table 6.1: Existing System Demands

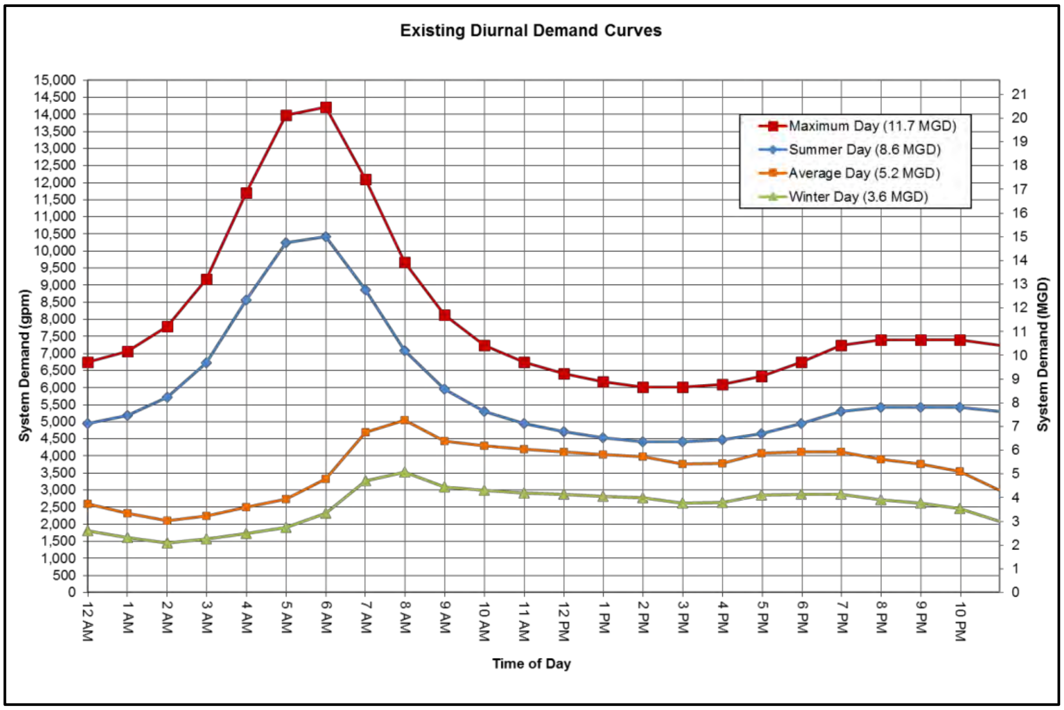

Figure 6-1: Diurnal Demand Curves

6.2 Existing System Modeling Scenarios

Demands presented in the previous section were used in four modeling scenarios to evaluate the existing system against the performance criteria documented in **Chapter 5**. **Table 6.2** lists the different modeling scenarios developed and used in the hydraulic analysis and evaluation of the existing system.

Modeling Scenario	Simulation Type	Description	Demand Condition	Demand (MGD)
EXIST_1000	EPS	This scenario evaluates the City's supply facilities and transmission/distribution system capabilities during existing ADD and day-to-day operations.	ADD	5.2
EXIST_3000	EPS	This scenario evaluates the City's supply facilities and transmission/distribution system capabilities during the peak demands of the existing MDD.	MDD	11.7
EXIST_3000	Steady State	This scenario calculates the available fire flow at a residual pressure of 20 psi during MDD conditions.	Available flow during MDD	11.7
EXIST_3200	EPS	This scenario is used to evaluate the City's storage facilities and transmission system during an event simulating two simultaneous fires in two separate pressure zones within the system.	MDD	11.7

Table 6.2: Existing System Modeling Scenarios

Think Big. Go Beyond.

6.3 Water System Pressure

When determining the adequacy of a distribution system, a primary parameter to check is the predicted pressure. The following are the pressure requirements that were established previously in **Chapter 5**:

- Maximum pressure, existing system = 110 psi
- Maximum pressure, new growth areas = 110 psi
- Minimum pressure during PHD = 50 psi
- Minimum pressure during a fire flow = 20 psi

6.3.1 System Pressure during Average Day Demand

Minimum system pressures within the existing distribution system during average day demand (ADD) conditions (5.2 MGD) are shown in **Figure 6-2** and summarized by pressure zone in **Table 6.3**. The majority of the system pressures range from 50 to 150 psi throughout the system.

There are locations near the reservoirs that experience pressures below 50 psi, and some even below 35 psi. This is because of the minimal elevation difference between these areas and their respective reservoir overflow elevations. The lowest pressures in the South Zone (6 psi) are located at the hydrants immediately adjacent to the Sourdough and Hilltop reservoirs.

The other locations that experience low pressures (less than 35 psi) during ADD include the following:

- A small area within the vicinity of the Hilltop reservoir and generally includes Kenyon Dr south the reservoir and Oconnell Dr between Kenyon Dr and Highland Blvd.
- The area along Blackwood Rd between 19th Ave and 31st Ave.
- The area along 3rd Ave between Cambridge Dr and Goldenstein Ln.

Low pressures experienced in these areas are the result of a combination of elevation and system headloss. Elevations in this area result in static pressures in the range of 35 to 45 psi. Additional looping within this area or construction of another major transmission main (discussed further **Chapter 9**) would increase minimum pressures from 5 to 10 psi.

A sizeable portion of the distribution system has pressure in excess of 110 psi, which exceeds the established maximum pressure criteria. The area that experiences the highest pressures (greater than 150 psi) are along Oak St between N 25th Ave and N Rouse Ave. **Chapter 7** includes a discussion regarding implications for adjusting pressure zones to reduce the maximum system pressures.

Zone	Pressures During ADD (psi)			Pressures During MDD (psi)		
	Min	Max	Avg	Min	Max	Avg
Gallatin Park	77	82	82	77	85	82
Northwest	62	149	96	59	144	93
West	70	107	90	69	107	89
Northeast (Lyman)	95	152	128	91	148	124
South (Sourdough)	8	165	112	6	161	106
Knolls	52	68	83	52	68	83

Table 6.3: Existing System Pressure during Average Day and Maximum Day Demand

6.3.2 System Pressure during Maximum Day Demand

Minimum system pressures within the existing distribution system during maximum day demand (MDD) conditions (11.7 MGD) are shown in **Figure 6-3** and summarized by pressure zone in **Table 6.3**. The system generally experiences similar pressures during MDD and ADD (within 5 psi). The majority of the system's low and high pressure issues occur during both ADD and MDD conditions.

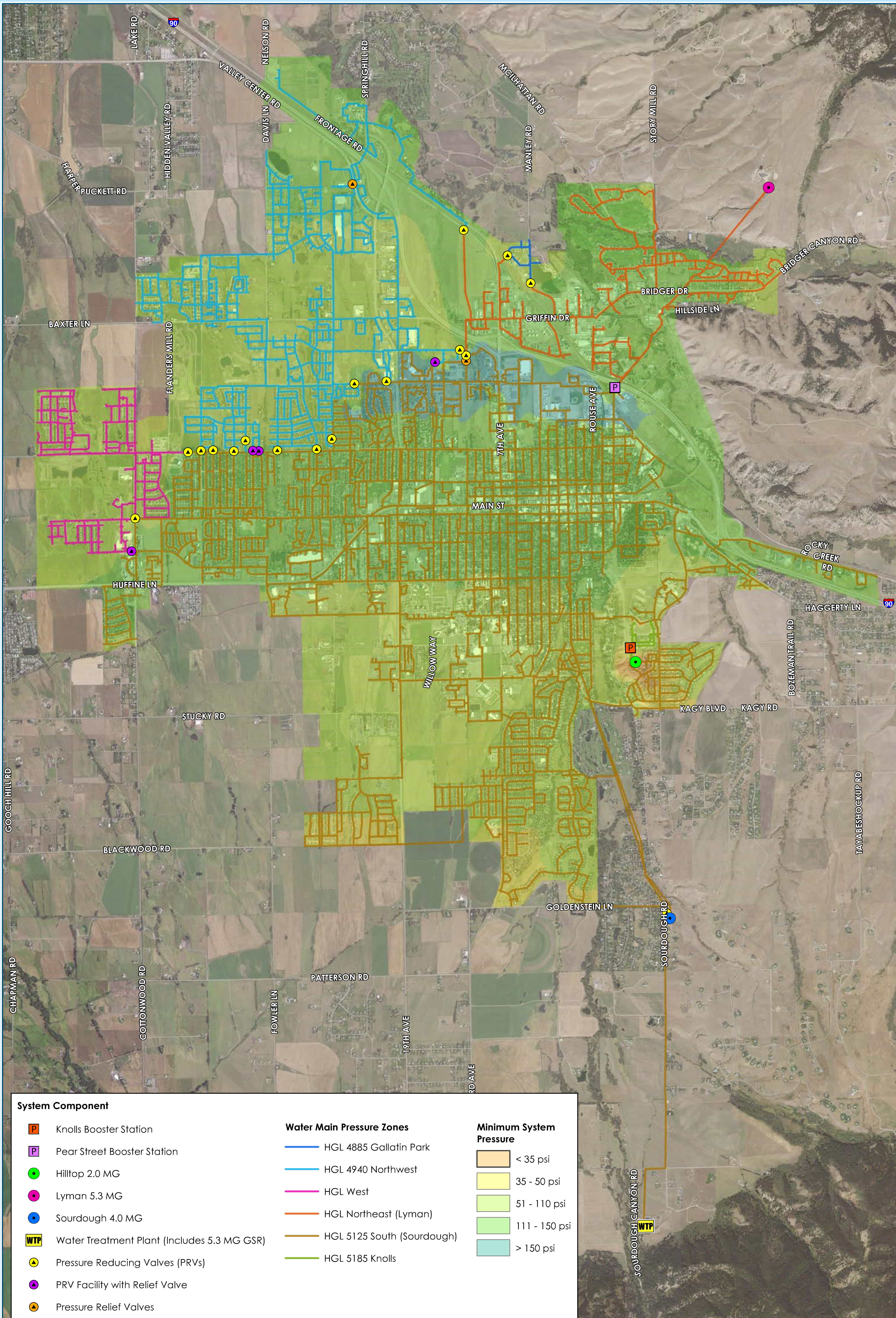

Figure 6-2: Existing Water Distribution System
Minimum Pressure during Average Day Demand (5.2 MGD)

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0 0.25 0.5 0.75 1 Miles

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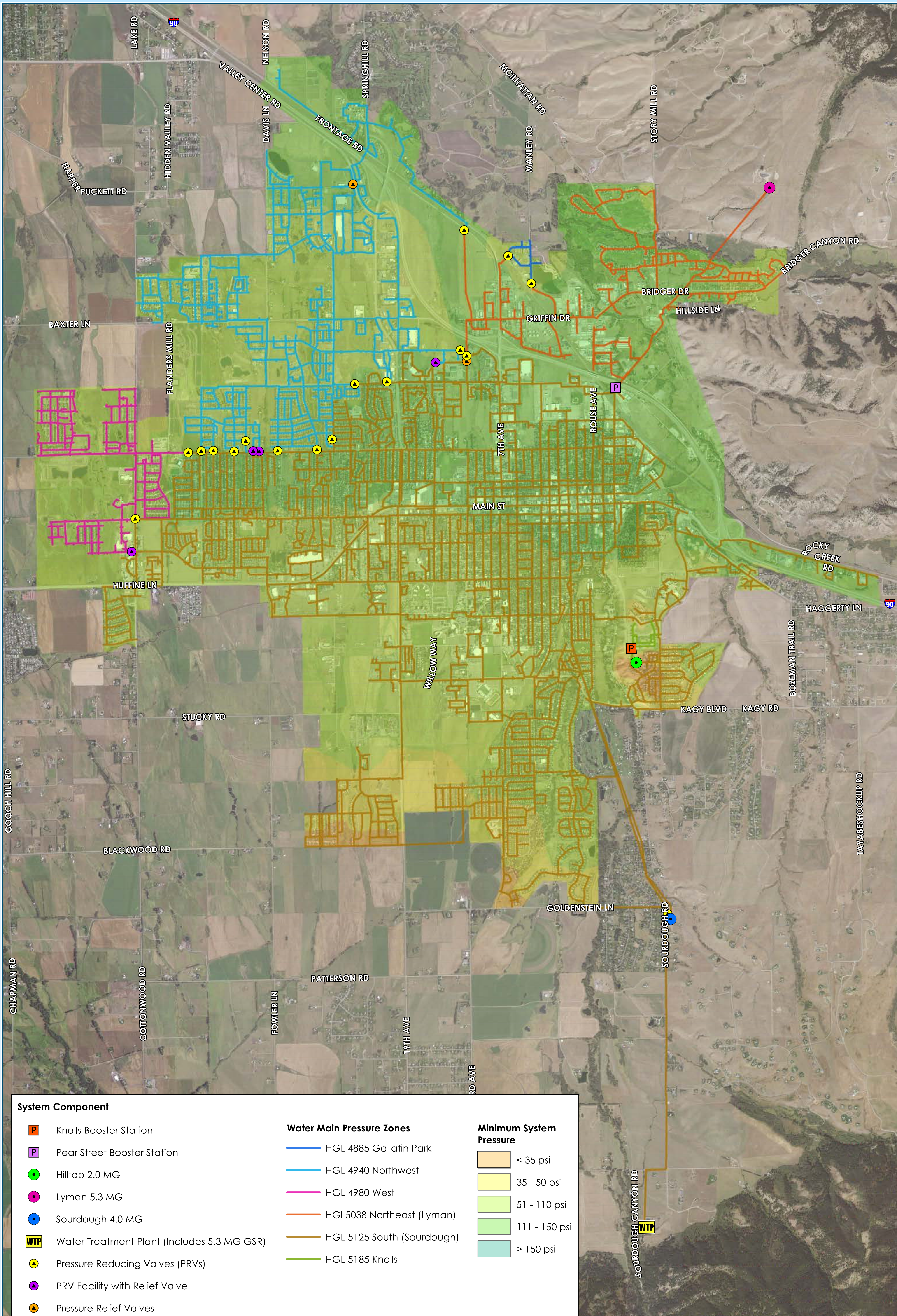

Figure 6-3: Existing Water Distribution System
Minimum Pressure during Maximum Day Demand (11.7 MGD)

City of Bozeman Water Facility Plan Update

0 0.25 0.5 0.75 1 Miles

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6.4 Distribution System Storage

The existing distribution system storage was evaluated for adequacy with respect to operational storage, fire protection storage, and emergency storage. The total system storage requirements that were established previously in **Chapter 5** indicate that the total system storage should be the greater of the following:

1. The sum of operational storage (40 percent MDD) plus fire storage, or
2. The sum of emergency storage plus operational storage,which is equal to approximately 3 days average day demand.

Table 6.4 provides an overview of the existing reservoirs in relation to the pressure zones served. Although WTP Reservoir 1 was not completed at the time of this Water Facility Plan Update, it has been included in the storage assessment as it will be brought online in 2017.

Zone with Storage	Reservoir ID	Reservoir Size (MG)	Total Storage Within Zone (MG)	Additional Comments
South (Sourdough)	Sourdough Hilltop	4.0 2.0	6.0	Possible to feed Northeast Zone through existing PRV facilities.
Northeast (Lyman)	Lyman Reservoir	5.3	5.3	Possible to feed South Zone through Pear Street Booster Station.
WTP	WTP Reservoir 1	5.3	5.3	Possible to feed South Zone through existing control valve.
	Total System Storage (Existing)		16.3	

Table 6.4: Existing Distribution Reservoir-Pressure Zone Summary

Table 6.5 provides an overview of the analysis of distribution storage based on the established storage requirement criteria. A comparison of the existing system to the storage criteria shows that there is sufficient fire storage volume in both zones with storage. Note that the South Zone requires more emergency storage than what is available within the zone. Emergency storage can be met storage from the WTP and Northeast Zones. Emergency storage from the WTP Zone is available through the existing flow control valve at the Sourdough reservoir and emergency storage. Emergency storage from the Northeast Zone must be pumped to the South Zone through the Pear Street Booster Station.

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Zone with Storage	Zones Served	Required Operational Storage[1] (MG)	Required Fire Storage[2] (MG)	Required Emergency Storage[3] (MG)	Criteria 1 Required Total Storage[4] (MG)	Criteria 2 Required Total Storage[5] (MG)	Controlling Criteria	Storage within Zone (MG)	Storage Capacity Surplus (Deficit) (MG)	Surplus Storage Available from Other Zones
South (Sourdough)	South West Northwest Knolls	4.5	2.40	10.0	6.9	14.5	**Criteria 2**	6.0	**(8.5)**	Use surplus from WTP & NE Zones
Northeast (Lyman)	Northeast Gallatin Park	0.2	2.40	0.1	2.6	0.3	**Criteria 1**	5.3	5.0	-
WTP	WTP	-	-	-	-	-	-	5.3	5.3	-
					Overall Total Storage Required	14.8				
					Total Storage (Existing)	16.6				

Notes:

[1] Based on 40 of MDD

[2] Based on zone and sub-zone fire flow requirements

[3] Based on 2 x ADD

[4] Operational Storage plus Fire Storage

[5] Operational Storage plus Emergency Storage (approximately 3 x ADD)

Table 6.5: Existing Distribution System Storage Evaluation

6.4.1 Reservoir Operations

Water reservoir levels and volumes were analyzed to determine if the reservoirs could maintain at least 60 percent of their volume throughout the entire day so that the volume of water allocated towards fire protection and emergencies would not be impacted by routine operations. The levels and volumes in the reservoirs were evaluated over a 24-hour period for both ADD and MDD conditions.

The City currently operates the reservoir levels at or near full for the majority of the year. This mode of operation is based on the current configuration of the distribution system and supply sources. The primary supply source for the City is from the WTP, which has a single 30-inch transmission pipeline that extends from the WTP to the Sourdough reservoir. The Lyman Reservoir and water source supplements the Sourdough source and primarily feeds the Northeast and Northwest pressures zones. Water from the Lyman reservoir and water source must be pumped into the South Zone to supplement the WTP source. Although the City is not completely reliant upon the WTP, a failure on the 30-inch transmission could cause a major interruption in service. Due to the potential risk and significance of an interruption caused by failure of the Sourdough transmission pipeline, water levels are maintained at a high level year-round. Reservoir levels are normally kept within 6 ft of overflow elevation during the summer demand period, and within 3 ft of overflow elevation during the winter. Graphs of reservoir water level fluctuations (percent full) during existing ADD conditions are shown in **Figure 6-4**.

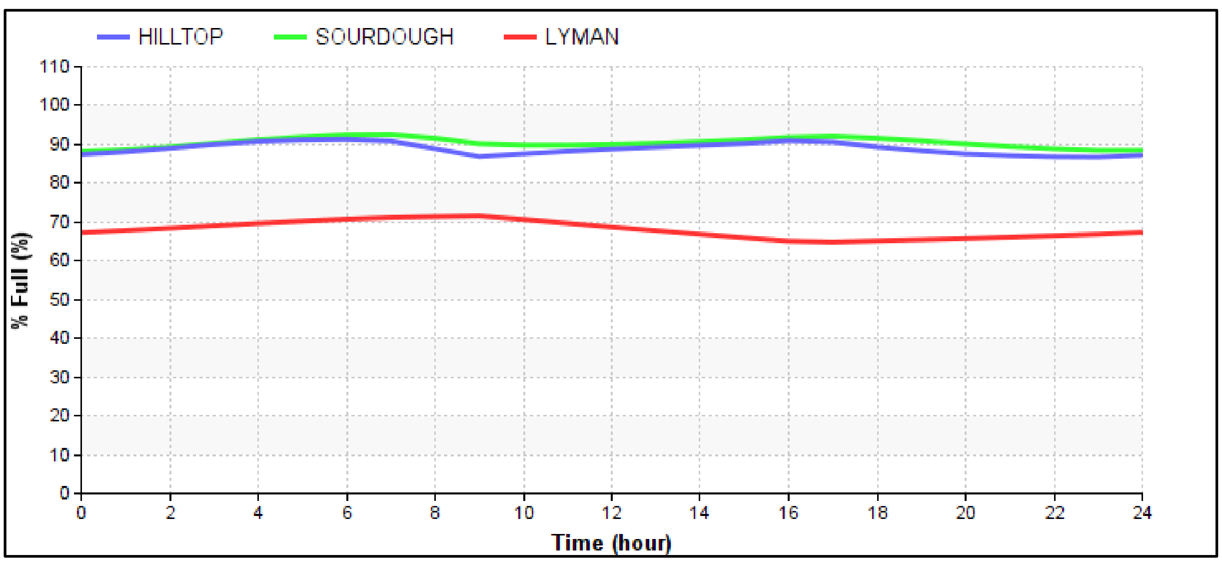

Figure 6-4: Existing Water Distribution System Reservoir Levels during Average Day Demand (5.2 MGD)

Reservoir water level fluctuations (representing percent full) during existing MDD conditions are shown in **Figure 6-5**. The Sourdough and Hilltop reservoirs show an increase in water turnover due to the higher demands. The lowest volume within the Hilltop reservoir is approximately 48 percent full. Water storage within the Sourdough reservoir is maintained above 75 percent throughout the MDD.

The Hilltop reservoir HGL operates significantly lower than the Sourdough reservoir during MDD conditions. This is indicative that the system experiences relatively high headloss while transferring water from Sourdough northward into the City and to the Hilltop reservoir during peak demand conditions.

The Lyman reservoir does not experience significant turnover even during MDD conditions. The relatively constant level is attributable to the size of the reservoir and the relative constant inflow/outflow due to the discharge of Lyman Spring and utilization of the water by the City.

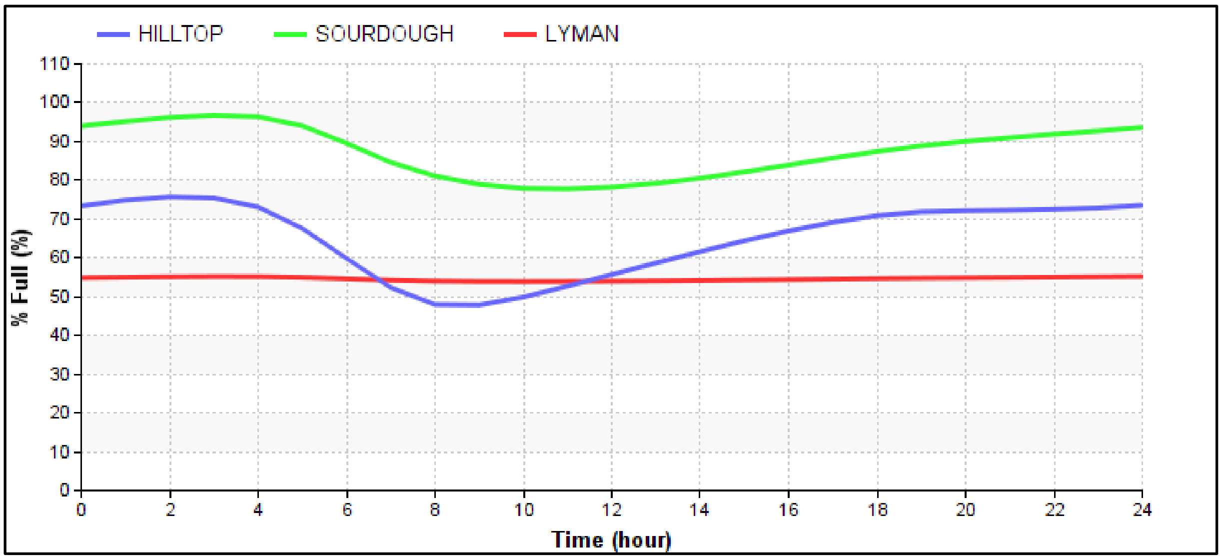

**Figure 6-5: Existing Water Distribution System
Reservoir Levels during Maximum Day Demand (11.7 MGD)**

6.4.2 Water Quality Considerations

Water quality issues associated with storage facilities can be classified as microbiological, chemical or physical. Increased water age can lead to water quality deterioration and can be conducive to microbial growth and chemical changes. Increased water age is generally caused by the following:

- Underutilization (e.g. water sits in the reservoir and is not cycled through), or
- Poor Mixing (including stratification).

Table 6.6 presents a summary of water quality problems associated with potable water storage facilities[17].

Chemical Issues	Biological Issues	Physical Issues
Taste and Odor	Taste and Odor	Sediment
Disinfectant Decay	Nitrification	Temperature/Stratification
Disinfectant By-product Formation	Pathogen Contamination	Corrosion
Chemical Contaminants	Microbial Regrowth	

Table 6.6: Summary of Typical Water Quality Problems Associated with Potable Storage Facilities

A water quality analysis was not performed as part of this Water Facility Plan Update; however, storage reservoir residence time (turnover) was evaluated with the hydraulic model. Additionally, discussions with City staff regarding reservoir operations and any known water quality issues were used to assess reservoir operations.

Typical recommended ranges for reservoir level operations include fluctuating levels by 20 to 50 percent, with 33 percent (1/3 total volume) being the recommended goal[18]. Fluctuating levels by 20 to 50 percent equate to a turnover of 2 to 5 days, assuming complete mixing within the reservoir. Water quality has not been a major concern for the City because of the high quality sources of supply.

[17] Finished Water Storage Facilities. Washington, DC: U.S. Environmental Protection Agency (EPA), Office of Ground and Drinking Water, 2002. Print.

[18] Computer modeling of water distribution systems (Manual M32). (2012). Denver, CO: American Water Works Association

Reservoir level operations during ADD conditions typically result in 5 percent level fluctuation, which are lower than the recommended 33 percent. Based on this observation the turnover within the reservoir would be about 20 days, assuming complete mixing within the reservoir.

Reservoir level operations during MDD conditions typically result in 10 percent level fluctuation within the Sourdough Reservoir, 33 percent level fluctuation within the Hilltop Reservoir, and a near continuous inflow/outflow within the Lyman Reservoir. Based on these observations, the turnover within the Sourdough Reservoir is about 10 days, and about 3 days within the Hilltop Reservoir. The turnover within the Lyman Reservoir is unknown and will depend on the level of mixing as the water passes through the Reservoir.

The City is aware of the minimum level fluctuation and long residence times during ADD conditions, but has not observed any water quality issues within the system. However, the City has noted icing issues and damage to the Hilltop Reservoir. Based on the City's desire to continue with current reservoir level operations (e.g. keeping reservoirs full for emergency services), it is recommended that the City install mixing systems in the reservoirs that have known stratification and icing issues (e.g. Hilltop reservoir) and monitor for the potential occurrence of water quality issues.

6.4.3 Multiple Fire Impact Evaluation

A scenario was developed to simulate two simultaneous fires occurring in two separate pressure zones during the MDD. Discussions with City staff led to the simulation of one of the fires located on the campus of MSU (South Zone) and the second fire located in a high density residential area within the Northwest Zone. Graphs of reservoir water level fluctuations (representing percent full) during the two-fire event are shown in **Figure 6-6**. A summary of the fire event is provided in **Table 6.7**.

The two fires were simulated to start at 7:00 am with a duration of four hours. Following the fire event, the flow control valve at the Sourdough reservoir was set to replenish the storage within the South Zone. The results indicate that the system has sufficient capacity to provide adequate water supply for the simultaneous fire event. The fire event draws the reservoir levels down below typical operation levels, however, adjustment to the flow control valve to draw additional water from the WTP reservoir allows for quick storage level recovery. Additional water is also available within the Lyman reservoir, which can be pumped into the South Zone through the Pear Street Booster Station.

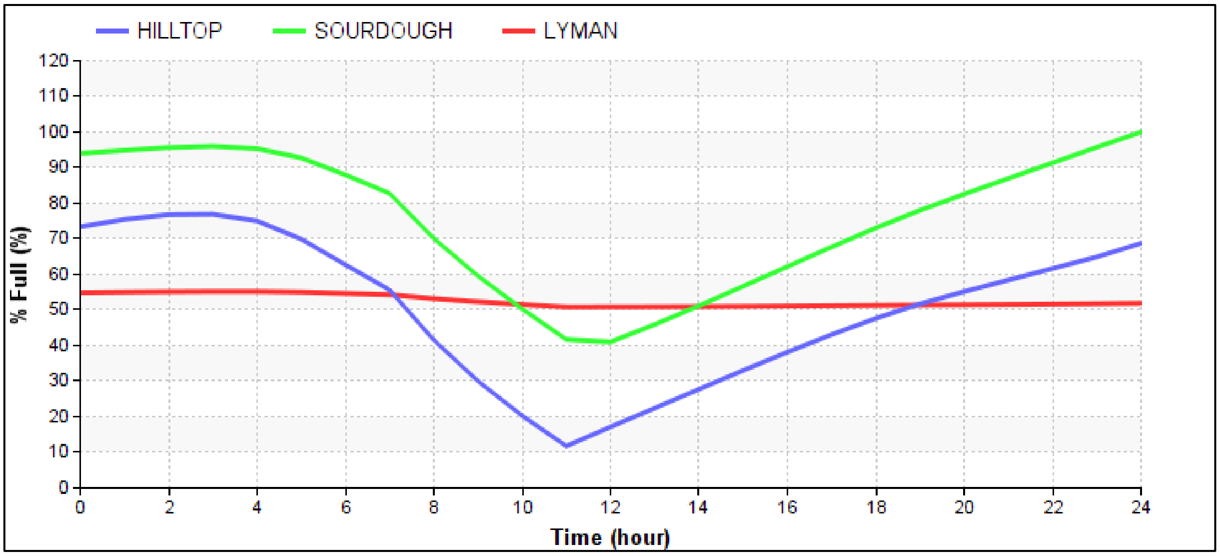

Figure 6-6: Existing Water Distribution System Reservoir Levels during Two-Fire Event

Fire Event	Flow (gpm)	Duration (hrs)	Volume (gal)	Hydrant ID	Location	Zone
1	5,000	4	1,200,000	WHY_1309	MSU Campus - Garfield St	South (Sourdough)
2	5,000	4	1,200,000	WHY_2220	Fen Way - North of Catamount St	Northwest

Table 6.7: Summary of Two-Fire Event

6.5 Distribution System Pumping Capacity

The existing system model was used to assess the pumping capacity of Pear Street and Knolls booster stations. Pump performance is based on conditions and variables in the distribution system:

- Water main capacity
- System demands
- Water storage levels

For this analysis it was assumed that water storage levels in reservoirs influencing pump station hydraulics were near full in order to determine the minimum capacity of the pumps. Pumps typically experience the highest head and lowest flow condition when storage levels are full.

6.5.1 Pear Street Booster Station Pumping

The Pear Street Booster Station has three pumps that transfer water from the Northeast Zone to the South Zone. The booster station allows the City to supply the South Zone with water from Lyman reservoir, in order to more fully utilize this high quality, inexpensive water source when flows from the spring exceed the demand from just the Northeast Zone. There is no specific design standard for determining the required capacity of a pump station that serves in a role such as that of the Pear Street Booster Station. Rather the performance is based on the ability of the pumps to operate at their design condition or their ability to transfer water at a rate satisfactory to the City.

Table 6.8 provides an overview of the average pump station capacity with a comparison of operating and design conditions. The pump station is not metered and the flow rates are estimated based on field testing, model calibration, and the available pump curve information provided by the City. Model calibration was performed with only one large pump operating to simulate the most critical condition. Under MDD conditions, a single large pump will provide between 1,180 gpm and 1,570 gpm depending on upstream and downstream pressure conditions.

	Design Pump Capacity (gpm)		Modeled Capacity (gpm)*	
Pump System	Total	Firm	Total	Firm
Pear Street	1,900	1,100	2,050	1,250

*Note: Analysis includes the two large pumps

Table 6.8: Pear Street Booster Station Capacity

The City will be replacing at least one of the large pumps in the near future. The model should be utilized to determine the duty points for the pump system to optimize selection of the new pump.

Modifications to Pear Street Booster Station

The Pear Street Booster Station is currently in need of significant repairs to provide the continued level of service desired. When properly rebuilt or replaced, it will continue provide an source of water supply to the South HGL 5125 zone, and provide a means for gravity flow from the South to the Northeast Zone when needed.

In order to realize the full benefit of the Pear Street booster, station it should be set up for bi-directional flow capabilities, with total pumping capacity equal to the maximum amount of water ever needed to be transferred from the Northeast to the South Zone. The pumping capacity requirement is approximately the maximum Lyman Spring production minus the average late spring / summer demand from the Northeast Zone.

A set of PRV's will also be required at the Pear Street Booster Station location to reduce water pressure approximately 40 psi from the South Zone. The PRVs will provide a redundant feed into the Northeast Zone, allowing required maintenance activities to occur on the Lyman spring system.

6.5.2 Knolls Booster Station Pumping

The Knolls booster station serves a small area of higher elevation southeast of downtown Bozeman. The Knolls booster station is fed by the Hilltop reservoir, and boosts the pressure to feed the Knolls Zone. The model simulation indicates that under MDD conditions, the domestic pumps provide between 15 gpm and 32 gpm for low flow and peak hour demand, respectively. The analysis shows there is ample domestic pump capacity. **Table 6.9** presents an overview of the Knolls booster station pump capacity.

The fire flow capacity for the booster station was evaluated at the pump discharge header and at the hydrants located within the pressure zone. The fire flow capacity analysis completed on the discharge header shows that there is sufficient capacity, and that the pumps supply more flow than the intended design point. The fire flow capacity analysis completed on the hydrants within the pressure zone indicates that the fire flow pumps do not produce the needed flow. The 8-inch distribution network causes significant headloss and only supplies available flow between 2,100 and 2,900 gpm at a residual pressure of 20 psi. The required fire flow is 3,000 gpm based on land use requirements. In order to increase the available flow, the fire pumps would require an additional 60 ft of head. However, this option is not feasible due to pressures exceeding the head of the domestic pumps. Another option to increase the available fire flow would be to increase a portion of the distribution network from 8-inch to 10-inch water main; however, this endeavor is likely cost prohibitive. The size of the pressure zone and layout of existing roads does not allow for cost effective system looping.

Pump System	Required Pumping Capacity (gpm)	Design Pump Capacity (gpm)		Modeled Capacity (gpm)	
		Total	Firm	Total	Firm
Knolls Domestic[1]	32	512	384	790	600
Knolls Fire[2] (analysis at pump discharge)	3,032	3,300	1,650	3,650	2,325
Knolls Fire[3] (analysis at hydrants)	3,032	3,300	1,650	2,100 – 2,900	1,750 – 2,325

Note 1: Analysis based on maintaining a discharge pressure of 60 psi.

Note 2: Analysis includes fire flow and peak hour demand and based on a discharge pressure of 30 psi.

Note 3: Analysis based on residual pressure of 20 psi at the hydrants within the pressure zone.

Table 6.9: Knolls Booster Station Capacity

6.6 Transmission and Distribution Main Capacity

As established in **Chapter 5**, a distribution system is considered to have deficient water main looping or sizing if the following conditions are experienced during PHD under MDD conditions:

- Velocities greater than 5 fps;
- Small diameter pipes (10-inch or less) have headlosses greater than 5 ft/1,000 ft; or
- Large diameter pipes (12-inch or greater) having headlosses greater than 2 ft/1,000 ft.

Although none of these thresholds are definitive, they pose a concern as they can indicate that there is a potentially diminished capacity to convey water or excess wear and tear on pipes. It is not recommended that existing pipelines that do not meet these performance criteria be replaced unless there is a known problem within the water distribution system. However, if these pipes are replaced due to street rehabilitation or other projects, the new pipelines should be sized to meet these maximum velocity and headloss guidelines.

Figure 6-7 illustrates the results of headloss analysis (per 1,000 feet) for existing conditions during PHD during MDD. Observations of headloss exceeding the established criteria for MDD conditions included the following:

- The 12-inch water main along Garfield St between Black Ave and 4th Ave has maximum headloss between 5 and 7 ft/1000 ft, and between 2 and 5 ft/1000 ft between 4th Ave and 8th Ave.
- The 14-inch water main along College St between Black Ave and 3rd Ave has maximum headloss between 5 and 7 ft/1000 ft, and between 2 and 5 ft/1000 ft between 3rd Ave and 12th Ave.
- The 14-inch water main along South Black Ave between College St and Story St has maximum headloss between 6 and 8 ft/1000 ft, and between 2 and 5 ft/1000 ft between Story St and Olive St.
- The 14-inch water main along 19th Ave between Garfield St and College St has maximum headloss between 2 and 4 ft/1000 ft.
- The 12-inch water main along Highland Blvd between Cedar View Dr and Aspen Pointe Dr has a maximum headloss between 2 and 5 ft/1000 ft.
- The 12-inch water main on Oak St between Rouse Ave and 7th Ave has maximum headloss between 2 and 5 ft/1000 ft.
- The 18-inch and 24-inch transmission main between the Sourdough reservoir and Graf St has maximum headloss between 2 and 2.25 ft/1000 ft.

- The 18-inch transmission main between the Lyman reservoir and Boylan Rd has maximum headloss between 2 and 3 ft/1000 ft. This headloss is due to the C-Factor of 100 established during model calibration and a peak flow rate of 2,250 gpm. Over half of the flow (> 1,200 gpm) is due to operation of the Pear Street Booster Station to transfer water from the Lyman reservoir to the South Zone.
- The 6-inch water main along Kagy Boulevard between South 3rd Avenue and South 11th Avenue has maximum headloss between 5 and 8 ft/1000 ft under MDD conditions.
- The remaining sections of pipe with higher headloss are spatially separated, in short sections, and primarily in areas with 6-inch diameter cast iron pipe.

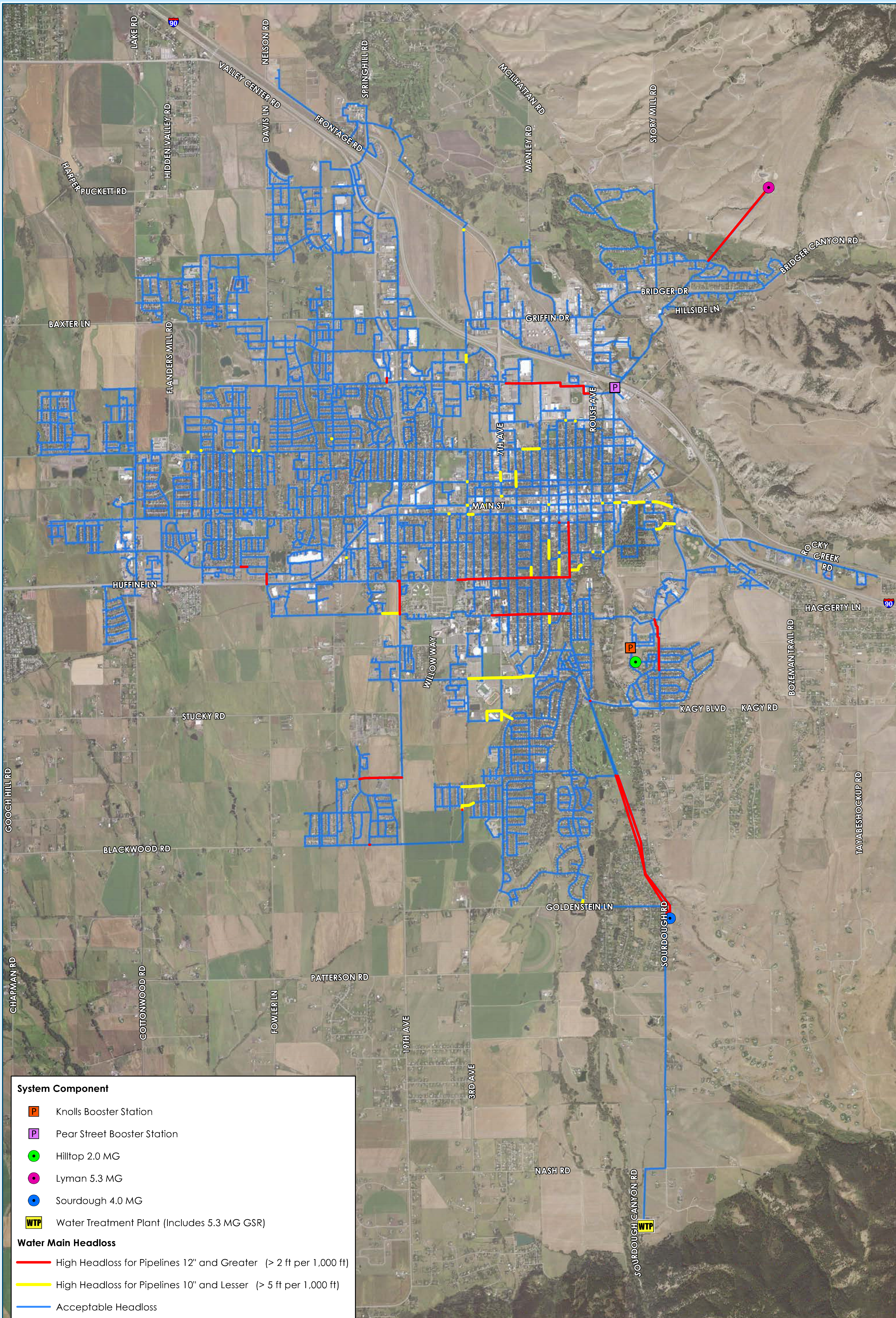

Figure 6-7: Existing Water Distribution System
Maximum Headloss during Maximum Day Demand (11.7 MGD)

City of Bozeman Water Facility Plan Update

0 0.25 0.5 0.75 1 Miles

N

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6.7 Fire Flow Analysis

A fire flow analysis was performed on hydrants throughout the entire existing distribution system to analyze the transmission and distribution system piping capacity. The results were calculated using a steady state scenario based on the following system conditions:

- Fire Flow availability is based on one hydrant flowing at a time.
- Minimum residual pressure of 20 psi.
- MDD conditions.
- Fire Pumps and Booster Station Pumps were in operation.
- Lag PRVs in operation. Lead (small diameter) PRVs were closed to improve model stability and reduce simulation runtime.
- Reservoir levels were set at 60 percent full (top 40 percent reserved for operational storage).

The fire flow analysis was performed on approximately 2,448 existing fire hydrants throughout the distribution system. A contour map was generated from the fire flow analysis to depict the available fire flows (at 20 psi) throughout the distribution system, and is presented in **Figure 6-8**. The analysis shows that a vast majority of the system (over 90 percent) achieves an available fire flow of greater than 3,000 gpm. There are only 10 locations within the system that do not meet a fire flow of 1,000 gpm. These locations are generally located in the zone of influence near the Hilltop reservoir and a few locations on South 5^{th} Avenue south of Grant Street at MSU.

As part of the fire flow analysis, the hydrant flow data was combined with fire flow availability criteria in **Table 5.7** to determine if the available fire flow could meet the needed fire flow requirements of adjacent parcels. Analyses showed that 94 percent of the system meets the fire flow requirements dictated by surrounding land use. **Table 6.10** provides a breakdown of the system hydrants and their ability to meet fire flow goal based on land use.

Condition	Number of Hydrants	Percent of System
Hydrants meeting >100% of fire flow goal	2,288	93.5
Hydrants meeting 90-100% of fire flow goal	46	1.9
Hydrants meeting 80-90% of fire flow goal	32	1.3
Hydrants meeting 70-80% of fire flow goal	31	1.3
Hydrants meeting 60-70% of fire flow goal	18	0.7
Hydrants meeting 50-60% of fire flow goal	15	0.6
Hydrants meeting 25-50% of fire flow goal	11	0.4
Hydrants meeting <25% of fire flow goal	7	0.3
Total System Hydrants (Active)	2,448	100

Table 6.10: Available Flow at System Hydrants

Figure 6-8 shows the locations of the hydrants that do not meet the fire flow goals of adjacent parcel(s). The hydrants were reviewed with the City's Water Distribution System Superintendent and Fire Chief and the following areas of concern were identified for future investigation:

- Hydrants not meeting fire flow goals located near MSU and generally located between Kagy Blvd and Garfield St and between 3rd Ave and 12th Ave.
- Hydrants not meeting fire flow goals located near the hospital on Highland Blvd between Ellis St and Knolls Dr.
- Hydrants not meeting fire flow goals located on the I-90 Frontage Rd east of Haggerty Ln.
- Hydrants not meeting fire flow goals located in the trailer court located southeast of the intersection of Black Powder Trail and 19th Ave. Note that these hydrants are outside of Bozeman's City limits, but are included here as an indication of the system's ability to deliver fire flow to this area.

As the City addresses the areas not achieving fire flow goals, the following steps are recommended to determine if a hydrant is deficient:

1. Verify Hydrant Fire Flow: Perform fire flow tests at the hydrant to verify model results before implementing any improvements.
2. Verify Land Use: Evaluate the actual development that has occurred and compare to land use zoning. For example, if the development that actually occurred was different

than what was analyzed, it may require less NFF (i.e. If a single family residential home was constructed in a multi-family land use zone, then it may require less fire flow than a multifamily structure).

3. Verify Fire Suppression: Evaluate if the surrounding buildings that would utilize the hydrant have fire suppression systems. A reduction of up to 75 percent of NFF is allowed when the building is provided with an approved automatic sprinkler system in accordance with the IBC and IFC requirements.
4. Determine Contributing Hydrants: Evaluate the number of fire hydrants in the area. Additional hydrants can contribute to the NFF. ISO states the following for fire hydrant flow credits.

    > Credit is awarded up to 1,000 gpm from each hydrant within 300 feet of the fire-risk building; 670 gpm from hydrants within 301 to 600 feet of the fire-risk building; and 250 gpm from hydrants within 601 to 1,000 feet of the fire-risk building.

If the fire flow goal is still not achieved after following the prescriptive steps listed above, then the following is recommended:

1. Evaluate system expansion: Review the potential for future looping by system growth and expansion, which may show that fire flow can be increased by closing loops.
2. Evaluate water main replacement: Use the model to determine if the deficiencies are large enough to warrant water main replacement with a larger size. In some locations it may be feasible to use multiple adjacent hydrants to obtain the fire flow goal.

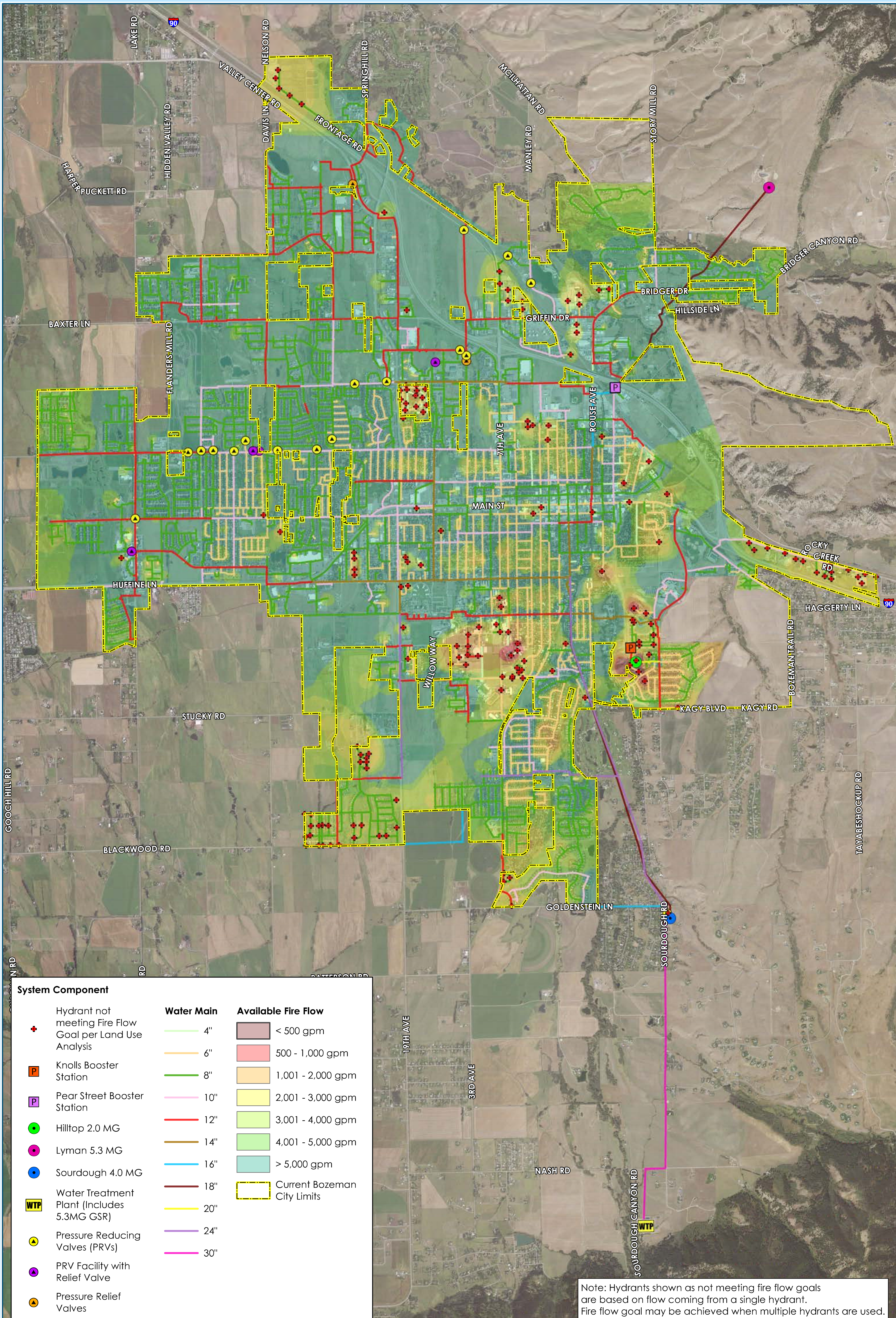

Figure 6-8: Existing Water Distribution System
Available Fire Flow during Maximum Day Demand (11.7 MGD)

City of Bozeman Water Facility Plan Update

Miles: 0, 0.25, 0.5, 0.75, 1

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6.8 Summary of Existing System Evaluation

An understanding of the limitations of the existing water distribution system is critical to the development and expansion of the system for satisfactory system performance, longevity and to accommodate future growth. The following represents a categorized summary of the key findings identified based on the analysis of the existing system.

6.8.1 Pressure Evaluation Summary

- System pressures were generally between 50 psi and 150 psi.
- The following locations operate under the highest pressures:
  - The area along Oak St between N 25th Ave and N Rouse Ave within the South Zone experiences pressures greater than 150 psi.
- The following locations operate under relatively low water pressures:
  - The vicinity of Hilltop reservoir with higher elevations experiences pressures less than 35 psi during ADD and MDD conditions.
  - An area with higher relative elevations in the southwest edge of the City experiences pressures less than 50 psi during ADD conditions and pressures less than 35 psi during MDD conditions. Low pressure in this area can be raised by 5 to 10 psi with additional looping in the area and construction of the west transmission main included in the CIP.
  - The area along Blackwood Rd between 19th Ave and 31st Ave.
  - The area along 3rd Ave between Cambridge Dr and Goldenstein Ln.

6.8.2 Storage Evaluation Summary

- Operational storage was determined to be adequate for the existing MDD conditions.
- Fire storage was determined to be adequate for the existing distribution system.
- Emergency storage was determined to be adequate for the existing system.
- Current operation of the reservoirs results in minimal water turnover. The City should consider increasing the operation range of reservoir levels or implementing reservoir mixing systems to improve water quality if it is determined that there are water age concerns and declining disinfectant residuals in the system.

6.8.3 Water Main Capacity Evaluation Summary

Observations of headloss exceeding the established criteria for PHD during MDD conditions included the following:

- The 12-inch water main along Garfield St between Black Ave and 4th Ave has maximum headloss between 5 and 7 ft/1000 ft, and between 2 and 5 ft/1000 ft between 4th Ave and 8th Ave.
- The 14-inch water main along College St between Black Ave and 3rd Ave has maximum headloss between 5 and 7 ft/1000 ft, and between 2 and 5 ft/1000 ft between 3rd Ave and 12th Ave.
- The 14-inch water main along South Black Ave between College St and Story St has maximum headloss between 6 and 8 ft/1000 ft, and between 2 and 5 ft/1000 ft between Story St and Olive St.
- The 14-inch water main along 19th Ave between Garfield St and College St has maximum headloss between 2 and 4 ft/1000 ft.
- The 12-inch water main along Highland Blvd between Cedar View Dr and Aspen Pointe Dr has maximum headloss between 2 and 5 ft/1000 ft.
- The 12-inch water main on Oak St between Rouse Ave and 7th Ave has maximum headloss between 2 and 5 ft/1000 ft.
- The 18-inch and 24-inch transmission main between the Sourdough reservoir and Graf St has maximum headloss between 2 and 2.25 ft/1000 ft.
- The 18-inch transmission main between the Lyman reservoir and Boylan Rd has maximum headloss between 2 and 3 ft/1000 ft. This headloss is due to the C-Factor of 100 established during model calibration and a peak flow rate of 2,250 gpm. Over half of the flow (> 1,200 gpm) is due to operation of the Pear Street Booster Station to transfer water from the Lyman reservoir to the South Zone.
- The 6-inch water main along Kagy Boulevard between South 3rd Avenue and South 11th Avenue has maximum headloss between 5 and 8 ft/1000 ft under MDD conditions.
- The remaining sections of pipe with higher headloss are spatially separated, in short sections, and primarily in areas with 6-inch diameter cast iron pipe.

6.8.4 Fire Flow Evaluation Summary

- The analysis shows that a vast majority of the system (over 90 percent) achieves an available fire flow of greater than 3,000 gpm.
- There are only 10 locations within the system that do not meet a fire flow of 1,000 gpm. These locations are generally located in the zone of influence near the Hilltop reservoir and a few locations on South 5th Avenue south of Grant Street at MSU.
- Analyses showed that 94 percent of the system meets the fire flow requirements dictated by surrounding land use. There are a number of isolated hydrants that do not meet the fire flow goal based on the land use analysis. Along with these areas, four larger areas were identified as the following:
    - Hydrants located near MSU between Kagy Blvd and Garfield St and between 3rd Ave and 12th Ave.
    - Hydrants located near the hospital on Highland Blvd between Ellis St and Knolls Dr.
    - Hydrants located on the I-90 Frontage Rd east of Haggerty Ln.
    - Hydrants located in the trailer court located southeast of the intersection of Black Powder Trl and 19th Ave.
- It is recommended that the City further investigate the hydrants shown as not achieving the fire flow goal based on the recommendations provided in **Section 6.7**.

6.9 Additional System Considerations and Recommendations

The recommendations included in this section augment the capital improvement projects found in **Chapter 10**.

6.9.1 Pressure Regulating Facilities

Pressure regulating facilities (PRV's) will be required at many new locations as development occurs, both to reduce pressure in new portions of the distribution system and to isolate new zones from high pressure zones in the City's current system.

The City has developed design standards for future PRV stations that utilizes a dual PRV (lead-lag) pressure reducing vault with pressure reducing and downstream pressure relief functionality.

Additional functionality should be considered including downstream surge, upstream pressure sustaining and upstream pressure relief to protect the upstream (high pressure) side of the system. These functions provide additional levels of protection for the distribution system:

- Downstream Surge Protection – Provides a stand-alone and quick response to close the PRV when downstream pressure exceeds safe parameters. It also serves as a backup control system to the normal reducing pilot should the closing function not operate as intended.

- Upstream Pressure Sustaining – Provides a mechanism to ensure upstream pressures do not fall below safe operating pressure during periods of increased demand downstream or limited supply upstream. This function is typically used where critical customers exist upstream or the piping network has limited capacity. It is important that other water sources exist to meet downstream demands when upstream sustaining requirements take precedence.

- Pressure Relief – Provides a means to quickly relieve elevated pressures within the system. This function can be set to monitor and relieve upstream and/or downstream pressures.

Ensuring pressure relief in individual pressure zones will remain a critical element of a multi-faceted approach to pressure management. Proper design and location of PRVs will continue to have heightened importance due to continued operation at elevated system pressures.

In addition to new PRV facilities, upgrades to the City's existing PRVs are recommended. The City should consider incorporating the following features at new and existing PRV facilities:

- Pressure and flow modes of control;
- Valve position monitoring;
- Thermostats;
- Chlorine residual analyzers;
- Means to monitor water levels in the vault (i.e. flood and sump pump runs); and
- Means to monitor/verify that good communications exist.

The City should survey all existing PRV vault and depth to the PRV to obtain the actual elevation of the PRV. Once true elevations are obtained, the hydraulic profiles should be updated and the operating HGLs reviewed for required updates or required changes in the field.

Additionally, the City should consider enhanced controls and monitoring through:

- Variable pilot settings on valves;
- Remote selection of flow/pressure modes;
- Remotely operated isolation valves; and
- Means to remove a PRV from service remotely.

For alarms, the City should consider:

- High/Low pressures;
- High flow;
- Pressure relief valves off seat;
- Excessive sump pump runs or duration;
- Intrusions;
- High/low temperatures; and
- Water quality parameters.

Ideally, the facilities will be retrofitted or designed to allow operators with convenient access and compliance with confined space requirements. Currently, the process of accessing the existing structures is difficult, and in some cases, not safe.

6.9.2 Existing PRV Facilities Abandonment

PRV Facility abandonment should be considered as a SCADA program is expanded to remote facilities, and budgets are established to address deficiencies at existing PRV stations. Some existing PRV stations could be abandoned without losing system function or performance.

A more in depth modeling effort would be needed to determine hydraulic capacity of each corridor and PRV station. The additional modeling is necessary to determine the level of redundancy needed to minimize risk and comply with the criteria within the Water Facility Plan Update.

Accessibility improvements and the installation of SCADA will be costly, but there will be incremental cost savings realized by eliminating redundant PRV stations. Future improvements should be based on a comprehensive cost/benefit analysis.

6.9.3 SCADA for Water Distribution Remote Facilities

As the system continues to evolve and additional remote facilities are added, the ability to monitor the entire water system by expanding SCADA to ensure system anomalies are detected, investigated and resolved when they occur will become increasingly important. This is particularly true if the City takes a long-term approach to phasing in lower system operating pressures, while continuing to operate infrastructure that continues to age at relatively high system pressures for the foreseeable future.

Future SCADA provisions that should be considered include:

- Electrical service and associated minimum clearances;
- Appropriately located taps for pressure monitoring devices;
- Provisions for flow monitoring;
- Valve position indicators;
- Sump pumps and intrusion alarms;
- Water quality analyzers may also be situated within these facilities allowing for continual system monitoring and data collection once a SCADA system is in place;
- SCADA elements will also include a wide-area network that is built upon a reliable infrastructure backbone;
- An organizational shift to prioritize technical proficiency and capabilities to maintain a much larger, more widespread SCADA system; and
- Tools to incorporate SCADA data into regular operation protocols.

6.9.4 Lead Service Line Connections

In the spring of 2016, the City embarked on a 3-year program to remove approximately 170 lead service lines. Each service lined is owned by the City in its entirety. To achieve its 3-year removal goal, a combination of City staff as well as a private contractor will complete the work. As of October 2016, a total of 50 lines have been removed and replaced. The average cost of replacement of a lead service line is around $4,800.

The City should continue this effort and make adjustments to the removal timeframe if water quality or regulatory drivers change.

CHAPTER 7 PRESSURE ZONE AND PRESSURE REDUCTION EVALUATION

The hydraulic analysis of the existing water distribution system identified areas of the network that exceed the recommended operating pressures outlined in **Chapter 5**. Operating at high pressures can result in increased water loss, create higher O&M costs due to more frequent failures, present unnecessary risk to City employees, and increase the risk of catastrophic pipe breaks. The goal of pressure management is to minimize unneeded excessive system pressure while maintaining the required level of service to meet the standards of water quality and fire protection.

This chapter presents the results of an evaluation of the potential to reduce existing operating pressures, identifies issues associated with reducing system pressure, and provides recommendations on pressure management.

7.1 Existing System Pressure Reduction Concept

The pressure reduction concept focuses on bringing the City into a more manageable pressure regime by modifying existing pressure zone boundaries or creating new zones that would allow the City to largely operate its system within the recommended pressure range of 50-110 psi, which would reduce system pressure in the downtown region by approximately 40 psi. Pressure reduction of this magnitude would particularly benefit the downtown business district by reducing the stress on older pipelines that have experienced significant pipe failures over the past decade. A strategy was developed to reduce system pressure and promote long-term operational flexibility to the City, which includes the following system modifications:

- Split the existing Northwest Zone into two pressure zones. A total of four new PRV stations would be required. The new northern pressure zone would operate at an HGL of 4840 ft. The new southern zone would operate at an HGL of 4940 ft, which is currently the HGL for the existing Northwest Zone.
- Combine the existing South and Northeast Zone and reduce the operating HGL to 5038 ft. A southern portion of the existing South Zone would be split from the new zone. A total of six new PRV stations would be required. This new southern zone would operate at an HGL of 5125 ft, which is currently the HGL of the existing South Zone (downtown area).

Figure 7-1 shows the proposed system modifications. The proposed pressure modifications were evaluated using the updated and calibrated hydraulic model to determine the resulting impacts on hydraulic performance, specifically pressure and fire flow. Outside of the hydraulic model, fire suppression systems were investigated to determine external system impacts.

7.2 Pressure Reduction Hydraulic Model Evaluation

7.2.1 Pressure Reduction Modeling Scenarios

The pressure reduction analysis included two model scenarios, which used existing system demands described in **Chapter 6**. Results from the existing system evaluation and hydraulic performance criteria described in **Chapter 5** were used to evaluate the model results. **Table 7.1** shows the different model scenarios used in the pressure reduction hydraulic analysis.

Modeling Scenario	Modeling Demand Condition	Demand (MGD)
RED_PR_3300	Maximum Day	11.7
RED_PR_3310	Available flow calculated during Maximum Day	11.7

Table 7.1: Existing System Modeling Scenarios

- RED_PR_3300 is an EPS scenario using the maximum day demand. This scenario simulates the City's supply facilities and transmission/distribution system capabilities during periods of high demand with pressure reduction.
- RED_PR_3310 is a Steady State scenario using maximum day demand, and is used to calculate the available fire flow to determine if both minimum residual system pressure and flow can be maintained in the event of a fire with pressure reduction.

7.2.2 Reduced Pressure Modeling Results

System Pressure

Figure 7-1 shows the minimum system pressures during MDD with the proposed pressure zone modifications. Notable results stemming from pressure reduction include the following:

- By adjusting the new PRV locations to operate the downtown area at HGL 5038 ft, the water pressure within the downtown corridor would be reduced by approximately 40 psi, from 165 psi to 125 psi.
- The new northern pressure zone of HGL 4840 would also have an overall pressure reduction of approximately 40 psi, from 150 psi to 110 psi.
- A majority of the system would operate in the recommended pressure range of 50-110 psi. Higher pressures in the northeast section of town would remain similar to existing conditions based on the future operational regime of the Lyman reservoir. Operational considerations include the following:

Think Big. Go Beyond.

- o Operating the downtown region at an HGL of 5038 ft eliminates the need for the Pear Street Booster Station, which would eliminate current pumping and O&M costs and enable City staff to reconsider pump replacement in the near term.
- o The Lyman spring water could be fed by gravity into the 5038 ft pressure zone.
- o Although higher pressures in the northeast exceed recommended operating pressures, providing the City with the ability to serve Lyman spring source water to as much of the distribution system as possible would help mitigate potential water shortages due to emergencies (forest fire, landslide, drought, etc.) that could affect the Sourdough and Hyalite sources.

- Pressures in the southern portion of the City and the Hilltop area would not experience significant changes in service pressure.

Available Fire Flow

As part of the fire flow analysis, the hydrant flow data was combined with land use data to determine if the available fire flow under reduced pressures could meet the needed fire flow requirements of adjacent parcels. **Figure 7-2** shows the available fire flow based on the proposed reduced pressure zone layout.

Analyses showed that 92 percent of the system meets the fire flow goal. This is a slight reduction (from 94 percent) in the percentage of the system that is currently estimated to achieve minimum fire flow goals under existing conditions (see **Section 6.7**).

Table 7.2 provides a breakdown of the system hydrants and their ability to meet required fire flow during reduced pressure conditions based on land use. **Table 7.2** provides a breakdown of the system hydrants and their ability to meet required fire flow during reduced pressure conditions based on land use.

Condition	Number of Hydrants	Percent of System (%)
Hydrants meeting >100% of fire flow goal	2,257	92.2
Hydrants meeting 90-100% of fire flow goal	49	2.0
Hydrants meeting 80-90% of fire flow goal	35	1.4
Hydrants meeting 70-80% of fire flow goal	24	1.0
Hydrants meeting 60-70% of fire flow goal	27	1.1
Hydrants meeting 50-60% of fire flow goal	21	0.9
Hydrants meeting 25-50% of fire flow goal	28	1.1
Hydrants meeting <25% of fire flow goal	7	0.3
Total System Hydrants (Active)	2,448	100

Table 7.2: Available Flow at System Hydrants with Reduced System Pressure

Fire Suppression Systems/Connections

A pressure reduction evaluation for each specific fire suppression system was not completed as part of this hydraulic analysis. Preliminary data provided from the City's GIS records suggest there are approximately 200 fire suppression systems/connections within the existing service area, the majority of which are located in the downtown and Oak Street areas. Further research revealed that there are well over 700 systems across the City. Any reduction in system pressures can impact a fire suppression system's performance, and should be evaluated on a case-by-case basis. The potential implications of pressure reduction, specifically in relation to fire suppression systems, is discussed in the following section.

7.3 Fire Suppression Systems

The City's current fire suppression design policy allows building owners to take advantage of the entire available pressure at the connection point to the local main. The vast majority of the existing fire suppression systems in the City have utilized all of the pressure available at the point of connection, in order to minimize costs (by reducing the size of sprinkler system piping and avoiding any fire pumps). Any reduction in pressure could change the performance of the suppression system.

To better quantify the number of fire suppression systems located within the proposed pressure reduction areas, Coffman Engineers, Inc. (Coffman) was contacted. Coffman specializes in fire protection engineering and has designed a majority of the fire suppression systems in the City.

Coffman provided the following information:

- The number of existing structures with sprinkler systems is much larger than what is currently documented in the City's GIS database (approximately 200). Coffman has provided design and construction assistance on approximately 786 different fire suppression projects in the service area. Some of these projects are likely for the same building, but Coffman is also not the sole design engineer offering technical assistance to building owners/operators. Therefore, this is probably a reasonable estimate of the number of fire suppression systems in Bozeman.

- Sprinkler system designs have typically utilized all of the available water pressure available from the distribution system, without any pressure reduction or safety factor, to minimize the expense of sprinkler system components.

- A reduction of just 10 psi would likely result in many fire systems failing performance standards.

- Fire suppression systems exist in numerous areas around the City, not just a few core areas, including in newly developed commercial areas to the west and northwest of the downtown core area. Installation of an otherwise-isolated, high pressure transmission pipeline to serve these specific systems would be extremely inefficient and cost prohibitive.

- In lieu of a dual pipeline network, modifications to individual sprinkler systems would be needed to compensate for lower water pressures. There are essentially two approaches to accomplish the modifications:

    1. Install a fire pump in a dedicated fire-rated enclosed room with a redundant power supply for the pump. Fire pumps require regular testing, and installation costs are likely to average approximately $100,000 per building.

    2. Upsize sprinkler mains and laterals. A case-by-case evaluation would be required to develop cost estimates for each system, but Coffman's rough estimate was anywhere from several thousand dollars to as much as $100,000 per building. Coffman also noted that such a program would be extremely unpopular, as businesses would have to shut down for significant periods to complete the work, and many would likely resist.

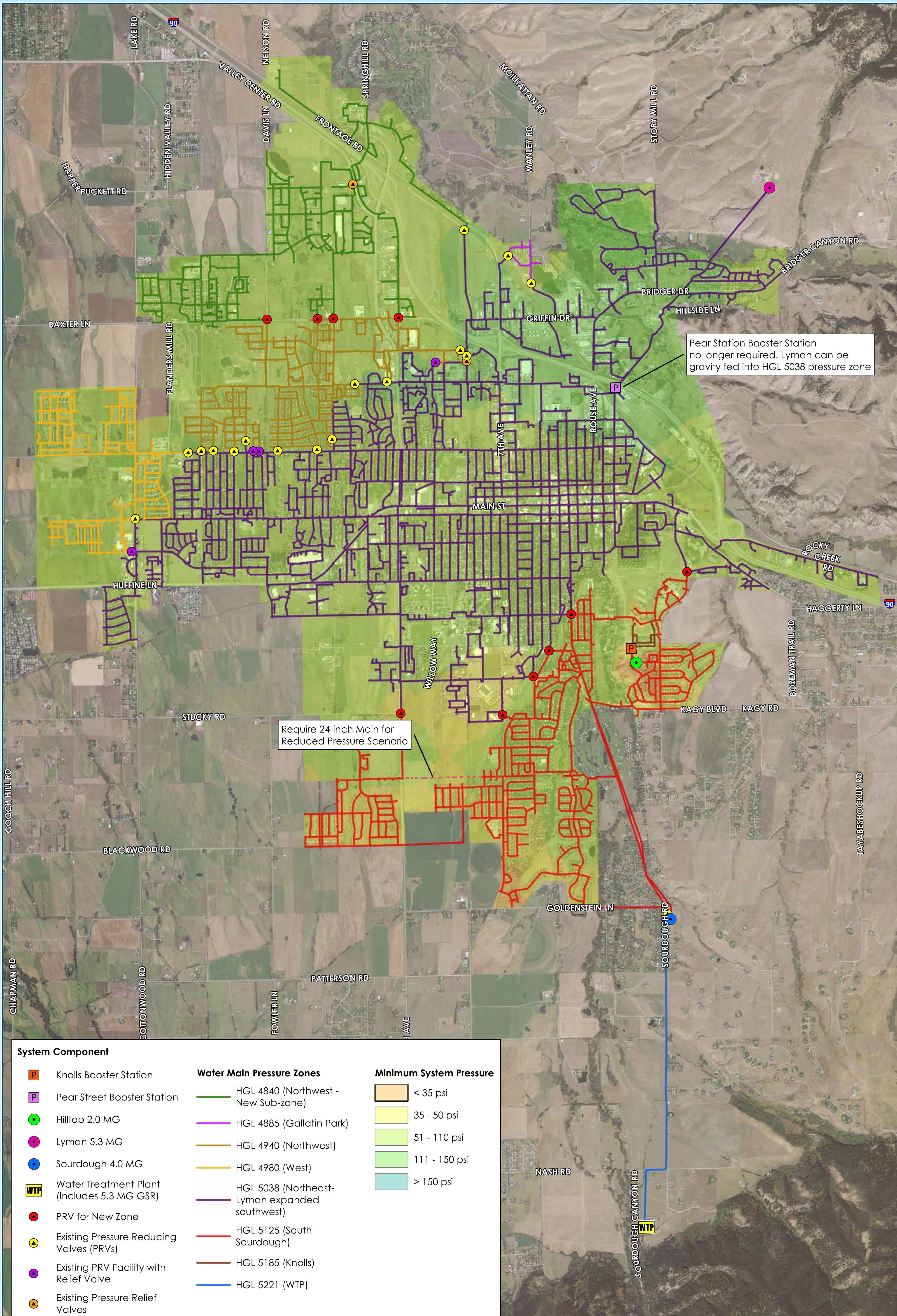

Figure 7-1: Idealized System Operation and Pressure Zone Boundaries (System Reconfiguration to Operating Working Pressures 50-110 psi)

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N

0 0.25 0.5 0.75 1 Miles

AE2S Advanced Engineering and Environmental Services, Inc.

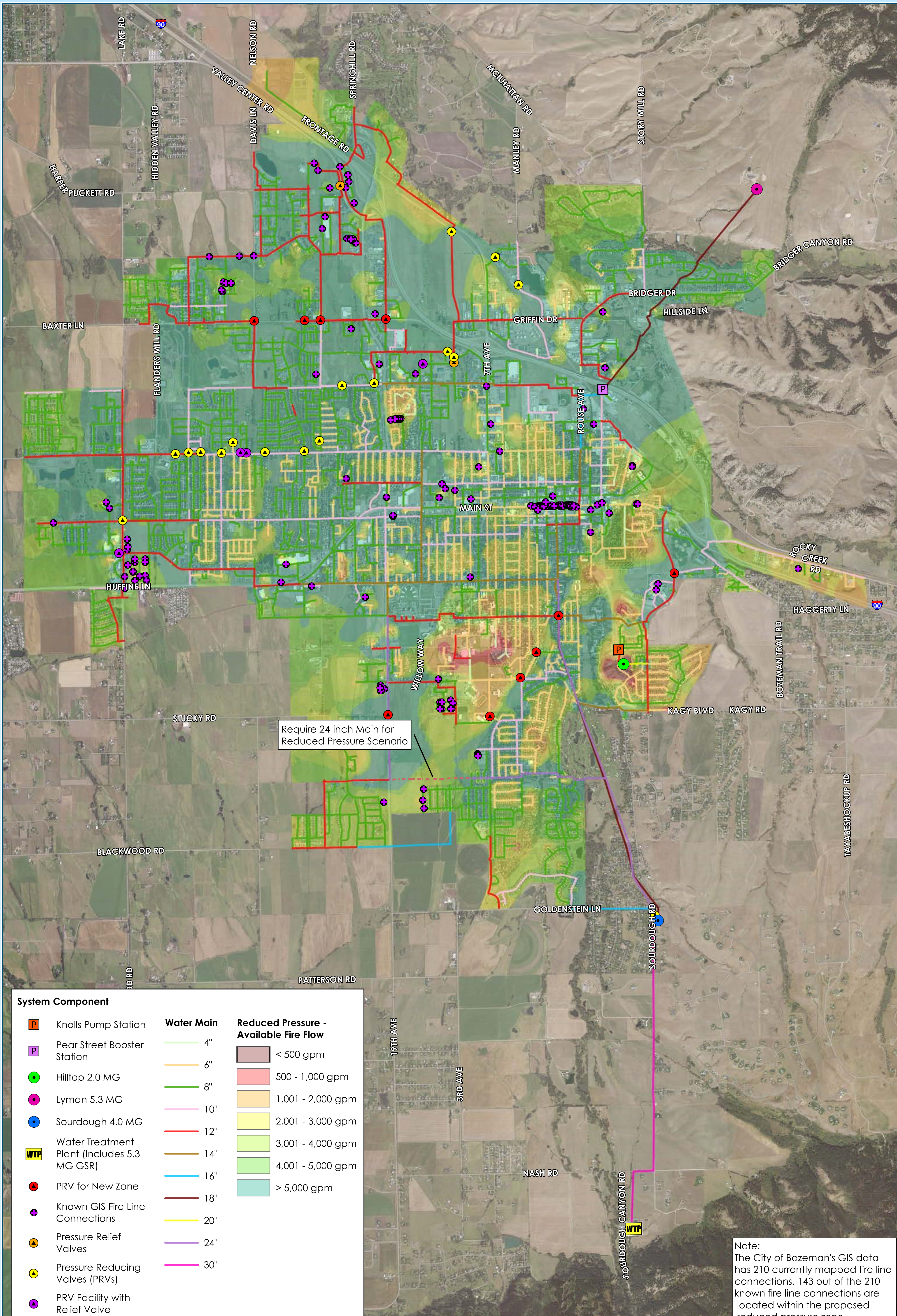

Figure 7-2: Water Distribution System Available Fire Flow during Maximum Day Demand and Reduced Pressure (11.7 MGD)

City of Bozeman Water Facility Plan Update

7.4 Pressure Reduction Options and Recommendation

Recognizing the significant impact a broad water pressure reduction effort would have on existing customers with fire suppression systems, three different alternatives were considered. One initial alternative entailed the construction of a high-pressure backbone that would connect to just the existing fire systems; however, this option was not considered feasible based on the geographic spread of the suppression systems and cost. The two most practical options from the pressure reduction analysis are described below, and followed with the recommended approach for the City.

7.4.1 Option 1: Existing System Pressure Reduction Concept

Option 1 is referred to as Existing System Pressure Reduction Concept, and entails the short-term creation of proposed pressure reduction zones consistent with that shown in Figure 7-1. The City can employ this approach only if the fire suppression system issue described previously is dealt with simultaneously. This would include the following:

- The City would adopt new policies and codes that require new fire suppression systems be designed to meet new pressure standards consistent with **Section 5.5.4**.
- Existing and planned fire suppression systems would need to be modified to meet new City codes and policies (i.e. fire pumps, piping, etc.).

7.4.2 Option 2: Phased Development of Long-Term Pressure Management

The City can take a longer-term, phased approach to achieve pressure reduction in the distribution system. This includes the following:

- The existing pressure zones would not be altered for the short-term/near-term. This maintains existing pressures needed to satisfy the present fire suppression system design requirements.
- As the City continues to expand into the UBO, all new pressure zones identified in the future UBO will be designed to conform to the hydraulic criteria recommended in **Chapter 5**. Future UBO pressure zones are identified and discussed in **Chapter 9**.
- The City would adopt new policies and codes that require new fire suppression systems be designed to meet new pressure standards as discussed in **Section 5.5.4**.
- Fire suppression systems that have been designed to operate off existing high pressure would be required to conform to new City codes and polices **only** when substantial building modifications or renovations occur. The transition to lower pressure in the core area would not occur until enough re-development of existing structures with fire

suppression systems has taken place to make retrofit of the remaining systems economical.

7.4.3 Recommended Pressure Reduction Approach for the City

Both options reduce system pressure and provide certain advantages to the City, which include:

- Lower pressures reduce operating stress on existing pipe infrastructure in key areas of the City.
- Lower pressures reduce the likelihood and magnitude of pressure spikes (transients) that can cause catastrophic pipe failures.
- Failures that do occur would likely result in less damage.
- Lower pressures limit water loss from system leaks.
- Reduced system pressures create a better environment for operators when making repairs or conducting routine maintenance.

Option 1 could be implemented immediately; however, existing fire suppression systems that would be affected by pressure reduction would need to be modified in conjunction to satisfy pre-pressure reduction design requirements. The cost to upgrade the existing fire suppression systems that have been designed for current system pressure is beyond the scope of this Facility Plan, but is likely on the order of tens of millions of dollars.

Option 2 largely follows the same methodology as Option 1; however, the system would be modified over a much longer period of time (decades) to achieve pressure reduction in the existing system. New pressure zones that are identified in the UBO would be required to conform to criteria set forth in **Chapter 5**, leaving existing pressure zones alone in the near-term timeframe. Option 2 is recommended based on the following reasons:

- Satisfies the City’s goal to reduce system pressure;
- Provides the City time to develop and implement code and policies changes.
- Avoids an extraordinary cost of a one-time upgrade to the vast majority of existing fire suppression systems. Allows the development community time to retrofit existing systems in a more cost-effective manner.

Because of the long-term nature associated with fire suppression modification and cost, the UBO analysis in **Chapter 9** is predicated on the following assumptions:

1. The existing system pressures shown for UBO are not reduced, to ensure that current fire suppression systems remain within their design criteria.
2. New areas of the system were designed to conform with criteria set forth in **Chapter 5**. The UBO analysis places PRV stations at strategic locations to isolate the new areas of development from existing areas with high pressure.

Once the City ultimately reduces pressure, the pressure zone configuration presented in **Chapter 9** (primarily the existing system) would need to be modified to reflect a similar layout shown in **Figure 7-1**.

CHAPTER 8 NON-POTABLE IRRIGATION EVALUATION

Several states and local municipalities across the U.S. have developed and implemented rules for the use and distribution of non-potable water and the design of these systems (sometimes also referred to as recycled, reuse, or reclaimed water systems). Non-potable use is of particular importance in areas where water sources are scarce and potable supplies are limited, especially during warm, dry months when irrigation accounts for a substantial portion of potable water use.

Potential benefits of using non-potable water for residential irrigation include: 1) decreased life cycle cost to utilities and municipalities; 2) preservation of potable quality water for potable use; 3) reduced peak water demands for potable systems (potentially reducing distribution pipe sizes, treatment facilities, and storage reservoirs); and 4) more reliable, local sources of water for irrigation and other non-potable applications.

This section of the Water Facility Plan Update provides standard specifications and details that could be adopted by the City to implement non-potable irrigation systems. The section also includes a study of a representative future development within the City and the associated cost and feasibility of implementing a non-potable irrigation system.

8.1 Non-Potable Specifications

Currently, the State of Montana does not specifically regulate the design and construction of non-potable water systems. Therefore, a goal of this report is to formulate a draft set of standard specifications for the City to utilize when developing programs and policies to encourage non-potable irrigation system development.

8.1.1 Non-Potable Irrigation Background

In principle, the non-potable water systems evaluated herein for the City are very similar to a reclaimed water system; therefore, reclaimed water system design and operation guidelines will be referenced extensively in this report. One of the most comprehensive general guidelines for developing non-potable water systems is the American Water Works Association (AWWA) M24 Manual for the Planning and Distribution of Reclaimed Water. Key elements of reclaimed (non-potable) water systems that are discussed in the AWWA guidelines and are applicable to all non-potable systems include:

- Pipeline and valve design
- Pipeline identification, testing, and placement
- Public notification of non-potable water use
- Valve boxes and covers

- Meters and meter boxes
- Backflow-prevention assemblies
- Cross-connection control
- Hose bibs
- Irrigation system controls
- Runoff control

General recommendations for any community planning a non-potable water system also include developing a map of the study area to show the location of the proposed water source, the location of existing and future customers, the location of right-of-ways, general elevations of the study area, and any pertinent boundaries. The identification of specific design criteria such as peaking factors, storage requirements, pump station sizing, minimum and maximum delivered pressure, pipe velocity requirements, and water delivery reliability is critical.

8.1.2 Non-Potable Irrigation System Standard Specifications

The non-potable design criteria are provided in **Appendix F** of this report. The specifications follow the same format as the City of Bozeman Design Standards and Specifications Policy, which also specifies the design criteria for water distribution pipelines, sanitary sewers, and storm sewers. The content for this project was specifically adapted from the AWWA M24 Manual guidelines with consideration of MDEQ regulations, Montana Public Works Standard Specifications (MPWSS), and the City of Bozeman Design Standards. The sample specifications provide guidance on the following factors:

- Pipe material and sizing
- Main extensions
- Service lines
- Valves, hydrants, air relief, and pressure reducing valves
- Thrust restraint
- Pressure and leakage testing
- Pipe separation requirements

The specifications also detail the requirements for identifying system components as "Non-Potable" and color-coding of pipe and appurtenances.

8.2 Non-Potable Study

The installation of separate distribution systems for delivery of potable and non-potable water to customers is commonly referred to as “dual pipe”, and that terminology will be used herein. Because dual pipe systems require additional infrastructure, the cost and benefits associated with these systems must be carefully evaluated. This section describes the conceptual design of a dual pipe system that would deliver non-potable water for irrigation and potable water for drinking water and fire flow in a representative developing area of Bozeman. The conceptual design was subsequently used to provide the basis for a Class 5 construction estimate. Life cycle cost comparisons are also presented to compare single and dual piped water systems.

8.2.1 Non-Potable Project Location

The study area that was selected for this project is located in the Northwest portion of the City of Bozeman’s service area and is shown in **Figure 8-1**. The site is bounded on the north by Baxter Road, on the south by Durston Road, on the east by Ferguson Street, and on the west by Gooch Hill Road. An existing potable water system already exists in a portion of the study area. It is assumed that the areas with existing piping would not be converted to the dual piped system.

The total study area is about 750 acres, not including the areas that are already developed. The topography is generally flat (slopes less than 0.01 foot/foot), with the higher elevations in the south-southeast corner and lower elevations in the north-northwest corner. Multiple creeks run through the area.

8.2.2 Non-Potable System Design

The conceptual water supply system for the undeveloped portion of the study area is designed as a dual pipe system providing non-potable surface water for irrigation and potable water for drinking, fire flow, and other uses. The proposed layout of the dual pipe system is shown in **Figure 8-1**.

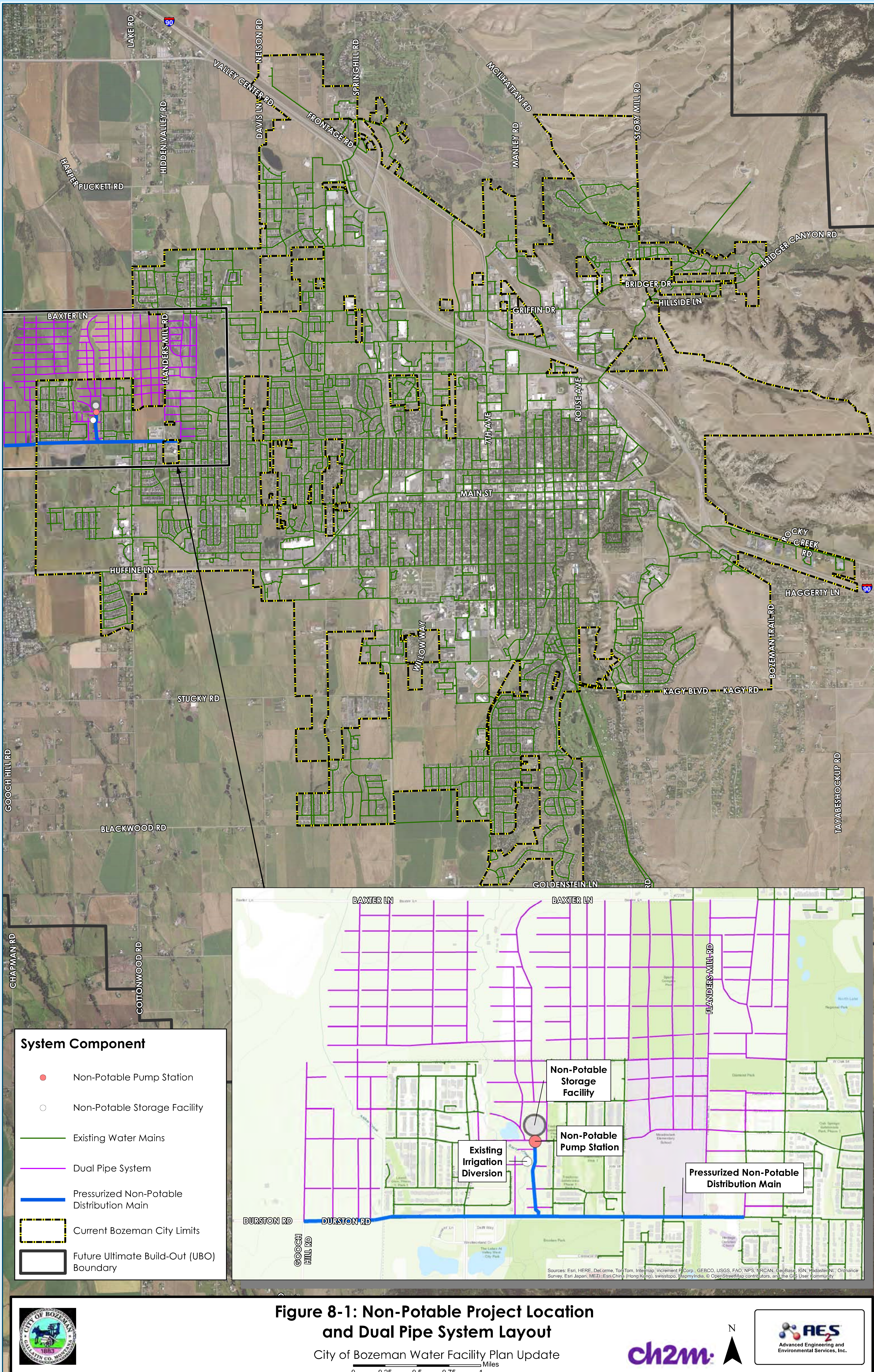

Figure 8-1: Non-Potable Project Location and Dual Pipe System Layout

City of Bozeman Water Facility Plan Update

8.2.2.1 *Water Demand Calculations*

Demand calculations for both potable and non-potable water were performed to provide estimates of the volumes and rates that the systems must provide. For the purposes of this study, it is assumed that:

- Annual Average Non-Potable (Irrigation) Water Demand Volume is 771 acre feet (ac-ft).
- Maximum Day Non-Potable (Irrigation) Demand is 1,808 gallons per minute (gpm).
- Annual Average Combined Potable and Non-Potable Water Demand Volume is 1,312 ac-ft.

Detailed descriptions of the calculations supporting each of these values is provided below.

8.2.2.1.1 Non-Potable (Irrigation) Water Demand

The projected irrigation water demand for non-potable water was calculated in two ways – using metered water use data to estimate outdoor water uses and using AgriMet climate data to estimate unit area turf irrigation water demands.

Within the study area, it was estimated that 40 percent of the total area, or 300 acres, is irrigated either as residential lawns or as open spaces and parks. This was based on the Oak Springs and Diamond Estates developments within the City, where the parks and open spaces occupy about 17 percent of the total developed area and other residential irrigation occupies about 23 percent of the total developed area.

Non-Potable Demand Estimated with Metered Water Use Data

Metered water use data for single-family residential users averaged across the City of Bozeman water service area was used to estimate the outdoor/irrigation demand for single-family homes. The estimated outdoor demand was calculated as the difference between peak month demand and winter month demands in 2012, which resulted in an estimated peak month outdoor demand of 2,120 gallons per acre per day (gal/ac/day) for the evaluated area. However, since parks and open spaces were not included in the metered water use data for single-family residential users, this calculated rate probably significantly underestimates the outdoor demand for a development with 40 percent of the total area under irrigation.

Non-Potable Demand Estimated with AgriMet Climate Data

Climate data collected from the U.S. Bureau of Reclamation's Bozeman, MT AgriMet meteorological station was analyzed to provide an estimate of the total irrigation demand within the representative development. The initial calculation assumes that irrigation areas are 100 percent sprinkler irrigated turf with cool season grasses and includes all residential, parks and open spaces. Based on the analysis of 10 years of AgriMet climate data, the estimated water demand for irrigation is 2.57 ac-ft/ac annually, with a peak month daily demand of 8,677 gal/ac/day (6.0 gallons per minute per acre [gpm/ac]) for areas that are 100 percent irrigated. 40 percent of the total 750 acre development (300 acres) is projected to be under irrigation. Therefore, the resulting peak month daily irrigation water demand that would have to be delivered across the total development area (750 acres) is 3,471 gal/ac/day. Applying the demands based on AgriMet climate data over just the estimated irrigated area of 300 acres results in:

- Peak Month Daily Demand: 2.6 MGD (8,677 gal/ac/day over 300 acres)
- Annual Average Irrigation Demand Volume: 771 ac-ft/yr (2.57 ac-ft/ac over 300 acres)
- Peak Instantaneous Irrigation Demand: 3,615 gpm (estimated peaking factor of 2)

The AgriMet based estimates result in a peak month demand that is about 64 percent higher than demands estimated using the metered water use data for single-family residential users. The AgriMet based estimates likely better represent the demands of the non-potable study area and are used as the design basis for the remainder of this analysis.

8.2.2.1.2 Potable Water Demand

For cost comparison purposes, the annual water volume demands for both potable and non-potable water are needed for the study area. The average daily demand for potable water, including all indoor and outdoor (irrigation) use, was calculated assuming the 135 gallons per day per capita water use rate documented in **Chapter 3**. With an estimated density of 5.5 dwellings per acre, and 2.14 people per dwelling, the average annual demand volume is 1,331 ac-ft/yr. With the outdoor non-potable water demand estimated at 771 ac-ft/yr as presented above, the annual indoor demand for the 750-acre development is estimated at 560 ac-ft for cost comparison purposes.

8.2.2.2 Non-Potable System Infrastructure

The non-potable system for this development would generally consist of a surface water diversion structure, a storage pond for equalization storage, an irrigation pump station, and the piped distribution system across the developed area. Individual system components are described below.

8.2.2.2.1 Non-Potable Water Sources

For small non-potable systems, it may be possible to utilize small existing exempt wells (limited to 35 gpm and 10 acre-feet per year annual use) in their existing places of use. These wells cannot be tied into an interconnected system and still maintain their exempt status. For larger non-potable systems such as the study area evaluated herein, centralized storage and pumping and the use of surface irrigation water rights will be necessary.

Within the study area, there are at least two existing surface irrigation water rights that partially cover the planned development. The portions of these water rights inside the study area have a combined irrigated area and diversion rate of 480 acres and 1,572 gpm, respectively. The rate of water application for irrigation purposes from the water rights is equivalent to 3.27 gpm/ac.

Additional surface water rights would be needed to feasibly satisfy all irrigation water demands within the study area. For the purposes of this evaluation, it is assumed that a sufficient quantity of surface water rights is available to cover the entire area of use and to satisfy the entire future non-potable system water demand. It is also assumed that the water for the non-potable system will be provided by the developer and diverted at the existing irrigation diversion point shown in **Figure 8-1**, which is used to deliver water to the existing surface irrigation water right areas.

When a new development is proposed within city limits, the City requires cash-in-lieu of water rights, calculated based on the total volume of water required for the development that will be served by the municipal potable water system. However, a development may propose the installation of non-potable water systems for irrigation, which may reduce the payment or amount of transferred water rights.

8.2.2.2.2 Water Storage

Water from the irrigation diversion point is assumed to flow via an existing gravity diversion to a new central, non-potable water storage pond.

The pond will be used to equalize inflows from the water supplies and outflows to water users and will be sized to hold 24-hours of maximum day water use (1,808 gpm). to provide adequate equalization, the active storage volume of the pond is 8.0 ac-ft, equivalent to about 3.8 days of supply at the annual average irrigation rate. It is assumed that the storage pond would occupy 2 acres of the study area, which would reduce the number of homes by 11 dwellings.

8.2.2.2.3 Pumping and Distribution

An irrigation pump station at the storage pond will be required to deliver the non-potable water to users at system pressure. The pump station includes a hydropneumatic tank to regulate system pressure and is sized to deliver peak instantaneous flows (3,615 gpm) to all users with a pressure range of 40 to 55 psi at the delivery points. Multiple pumps will be required at the pump station to cover a range of system flow demands.

The non-potable system is assumed to be conveyed through a total of 138,000 feet of 8-inch AWWA C900 (C900) pipe that would be supplied from a pressurized distribution main. The relatively low operating pressures and material costs associated C900 pipe make it a cost effective option as compared to the ductile iron pipe used by the City for its distribution system mains, which operate at considerably higher system pressures. No distribution system modeling was performed at this stage of the project, but based on the elevations within the study area, only one pressure zone is required.

For costing purposes, it is assumed that 10 feet of horizontal separation will be provided between potable and non-potable pipelines, and the burial depth will be 6.5 feet to the top of the pipe to avoid freezing if the pipe cannot be entirely drained while inactive during the winter months. If suitable provisions are provided to completely drain the system, a shallower depth of bury could be considered to reduce initial construction costs.

8.2.2.2.4 Potable System

The potable system is assumed to tie into the existing water mains for the areas that have already been developed. A total of 146,000 feet of 8-inch DIP is required for the development.

8.2.3 Cost-Benefit Comparison

8.2.3.1 Complete Study Area (Residential Irrigation, Parks and Open Spaces)

A cost-benefit analysis was developed to compare the dual piped system to a single-piped system. For each of the options, estimated capital costs, life cycle operating costs, life cycle income and other benefits were quantified.

The cost estimates are based on the following assumptions:

- The system is completed in one construction contract (not phased), and all construction costs are incurred at the beginning of the 30-year life cycle period.
- Costs are only included for items that are significant, or that are different between the potable and non-potable systems. For example, the potable pipelines included under the non-potable and potable systems would be identically sized (because fire flows drive pipe sizing), but are a significant cost and so are included in both estimates. The non-potable system does not connect (tap) into the potable distribution system.
- A discount rate of 3.375 percent.
- Water rights will be provided by the development installing the non-potable system, not by the City of Bozeman.
- Water rights are acquired as an upfront cost. The following water rights acquisition costs were assumed:
    - Non-Potable $600 per acre-ft
    - Potable $6,000 per acre-ft

- Revenue generated from providing water is the same for both alternatives. However, depending on how the non-potable system is developed and operated, the revenue could be different.
- One of the primary benefits of the dual pipe system is the deferment of expansion of the City's WTP.
    - The cost of the WTP expansion was estimated at $25 million, and the timing of this investment would be when MDD exceeds 22 million gallons per day.
    - The expansion was estimated to be necessary in 2040 for the potable only alternative. Implementation of non-potable irrigation for the study area would defer the expansion by approximately 7 years.

Table 8.1 provides a summary of the cost-benefit analysis for the dual piped and potable only alternatives. Detailed cost estimates are provided in **Appendix F**.

Dual Piped System and Potable Only System NPV Comparison					
Option	Capital Costs	Annual O&M Costs	O&M Costs Over Project Life[1]	Benefits[2]	Net Costs[3]
Dual Piped System	$34,200,000	$531,323	$9,930,000	($2,420,000)	$41,710,000
Potable Only System	$29,650,000	$669,186	$12,500,000	$0	$42,150,000
Notes:					

1. 30 year project life, 3.375% discount rate.
2. Deferred water treatment plant expansion.
3. Total Costs – Benefits.

Table 8.1: Cost-Benefit Summary

System Cost Difference Overview

Capital Costs

It is approximately $4.6 million more for a dual piped system for this particular development (study area).

The capital cost to install a dual pipe system is higher than the cost of a potable water only system. The increased cost is due to engineering and construction of additional infrastructure.

The magnitude of the construction cost difference between dual pipe and potable only system is offset by a reduction in water rights acquisition. At the current estimated water right acquisition cost of $6,000/ac-ft, the dual pipe system results in a water rights savings of $4.2 million. **Table 8.2** provides a capital-only cost overview.

Dual Pipe System and Potable Capital Cost Overview			
Component	**Potable Only System**	**Dual Piped System**	**Notes**
Potable Water Distribution Cost	$8,906,000	$8,906,000	146,000 ft of 8-inch DIP
Non-Potable Distribution Cost	$0	$4,606,000	138,000 ft of 8-inch C900
Water Rights Required (Acre-ft)	1,331 Potable	560 Potable 771 Non-Potable	$3,360,000 Potable $462,600 Non-Potable
Water Rights Acquisition Cost	$7,986,000	$3,360,000 Potable $462,600 Non-Potable	$6000/ac-ft Potable $600/ac-ft Non-Potable
Notes: Appendix F provides detailed cost estimates			

Table 8.2: Capital Cost Summary

Operation and Maintenance

Operation and maintenance costs are estimated to be approximately $2.6 million less for the dual pipe system.

The typical operation and maintenance costs (e.g., pipe and other infrastructure inspection and repairs, pumping) are higher for the dual pipe infrastructure than for a potable water only system, just due to the additional infrastructure that is included. For this study area, the cost to operate and maintain the dual pipe system is estimated at $347,323 per year. The cost to operate and maintain the potable only infrastructure is estimated at $231,186.

However, the reduced cost of water treatment with implementation of dual pipe more than offsets the typical operation and maintenance cost difference between the two systems. 1,331 acre-ft of potable water is required for the potable only compared to 560 ac-ft for the dual piped system. 771 acre-ft of water will not require potable-level treatment for the dual pipe alternative. Based on the City's current unit treatment costs of $0.00101 cents per gallon, this represents an annual cost savings of $254,000. Approximately $2.5 million would be saved over a 30-year period.

A dual-pipe system would not reduce distribution electricity costs, as the City of Bozeman distribution system is predominantly gravity fed, including the entire area included in the study area.

WTP Expansion Deferment

Deferring future expansion of the WTP is another cost savings provided by large-scale implementation of a dual pipe system. Potable water demands for the current City population is currently 11.7 MGD during MDD conditions. Based on the current MDD and anticipated growth of the City it was estimated that the existing 22 MGD Sourdough WTP will need to be expanded by 2040. At that time, an estimated $25 million dollar (in 2017 dollars) expansion of the Sourdough WTP will be required. The monetary value of the delayed WTP expansion benefit depends upon the rate of water demand growth and the rate of non-potable system development to offset demands.

The 300 irrigated acres in the proposed development requires a total of 2.6 MGD of peak month daily demand. At an assumed average annual demand growth rate of 2.0%, 2.6 MGD provides approximately 7 years of demand growth. Delaying a $25 million project by 7 years results in an approximately $2.4 million cost savings.

8.2.3.2 *Dual Pipe for Parks and Open Spaces Only*

A dual pipe system for parks and open spaces within the study area (excluding residential irrigation) was evaluated to determine if a more targeted dual pipe system would significantly alter the cost analysis. This alternative would provide non-potable water to parks and open spaces within the study area, but residences would use potable water for all indoor and outdoor applications. This alternative reduces the capital cost of the non-potable system by reducing the size of the distribution system, storage pond and booster station. Parks and open spaces represent approximately 17 percent of the total study area.

The estimated net cost for a non-potable system for the parks and open space areas is $39 million, $3.2 million less than the cost of a potable only system. The savings of eliminating residential dual-pipe is offset by the lack of savings in water rights acquisition costs. The deferment to the expansion of the Sourdough WTP would shorten from approximately 7 to 2 years. The results of the non-potable analysis for only parks and open spaces are summarized in **Table 8.3**.

Dual Piped System for All Outdoor Uses, Dual Piped System for Parks and Open Spaces Only, and Potable Only System

Option	Capital Costs	Annual O&M Costs	O&M Costs Over Project Life[1]	Benefits[2]	Net Costs[3]
Dual Piped System	$34,200,000	$531,323	$9,930,000	($2,420,000)	$41,710,000
Dual Piped System, Parks and Open Spaces	$29,250,000	$557,024	$10,410,000	($750,000)	$38,910,000
Potable Only System	$29,650,000	$669,186	$12,500,000	$0	$42,150,000

Notes:
1. 30 year project life, 3.375% discount rate.
2. Deferred treatment plant expansion.
3. Total Costs - Benefits.

Table 8.3: Overall Cost-Benefit Summary

8.2.4 Summary

The construction of a dual pipe system requires a larger up-front capital investment than the potable only system. These additional costs are due to the installation of a second set of piping and other infrastructure such as a storage pond and booster system. For the study area, the dual pipe system is approximately $4.6 million more than a potable only system.

The annual operations and maintenance costs are less for the dual piped system. The lower costs are due to the savings realized in reduced treatment costs when compared to treating irrigation water to potable standards. Over the life of the project, projected savings in operations and maintenance costs for the dual pipe system is estimated at approximately $2.6 million.

Delaying the expansion of the Sourdough WTP provides an additional $2.4 million dollars in savings for the dual pipe system.

1,331 acre-ft of potable water is required for the potable only compared to 560 ac-ft for the dual piped system. 771 acre-ft of water will not require potable-level treatment for the dual pipe alternative. At the current estimated water right acquisition cost of $6,000/ac-ft for potable and $600/ac-ft for non-potable, the dual pipe system results in a water rights savings of $4.2 million.

After considering all cost and benefit differences, the overall costs of a dual pipe system for the study area is estimated to be about $400,000 dollars less that a potable only system. This difference is insignificant relative to the level of accuracy of conceptual cost estimation.

Targeting implementation of non-potable irrigation for parks and open spaces only within the study area improves the comparison in favor of non-potable, but not to a great extent, due to the reduction in savings in water rights acquisition.

There are some key drivers of economic viability for dual pipe that may alter the application of this analysis:

- Economies of scale – smaller dual pipe systems for entire developments will not fare as well in a cost comparison against potable only systems. The cost to install the additional infrastructure will likely outweigh the benefit of reducing water treatment and water rights acquisition costs.
- Water rights acquisition costs – should water rights acquisition costs increase over time, the economics of dual pipe systems will benefit.
- Potable water treatment and distribution costs – currently water treatment and distribution costs are low in the City of Bozeman. If this changes with new sources then the economics of dual pipe systems will benefit.

CHAPTER 9 FUTURE SYSTEM EVALUATION

This chapter presents the plan for the City's future water distribution system and the expansions and improvements necessary to meet recommended water system service performance criteria under UBO water demand conditions. The hydraulic model was used to evaluate and identify future distribution system infrastructure needs and address deficiencies identified in the existing system evaluation discussed in **Chapter 6**.

Anticipated growth in the near-term (5-15 year horizon) is expected in the South Zone, the Northwest Zones, and the WTP Zone. The development of the CIP and scheduling of improvements is based on the expected community growth. Growth and development in the Mountain Zones is likely to occur in the long-term planning horizon, or beyond the 15-year horizon of the near-term planning period. The mountain zone areas were evaluated to ascertain UBO infrastructure improvements for transmission main, pumping stations, and reservoirs, such that the short-term and near-term improvements could be coordinated with the long-term vision of the water system. .

Additionally, three supplementary hydraulic modeling evaluations were completed to assess specific issues for the City's future growth. These evaluations include the following:

- Moving the Lyman reservoir to a higher HGL in the system;
- The addition of a groundwater source and water supply located west of the City; and
- The effect of future water conservation on hydraulic capacity.

9.1 Future System Demands

Demand data sets were developed within the hydraulic model for use in evaluation of the future system using the methodology described in **Section 3.5**. A summary of the future system demands used within the hydraulic model are presented in **Table 9.1**. The current diurnal demand curves (Average Day and Maximum Day) were applied to the future demand data to develop the future diurnal demand curves to conduct extended period simulation model runs.

Demand Day	Demand (MGD)	Demand with Water Conservation (MGD)
Average Day	23.8	21.5
Maximum Day	53.6	49.8

Table 9.1: Future System Demands

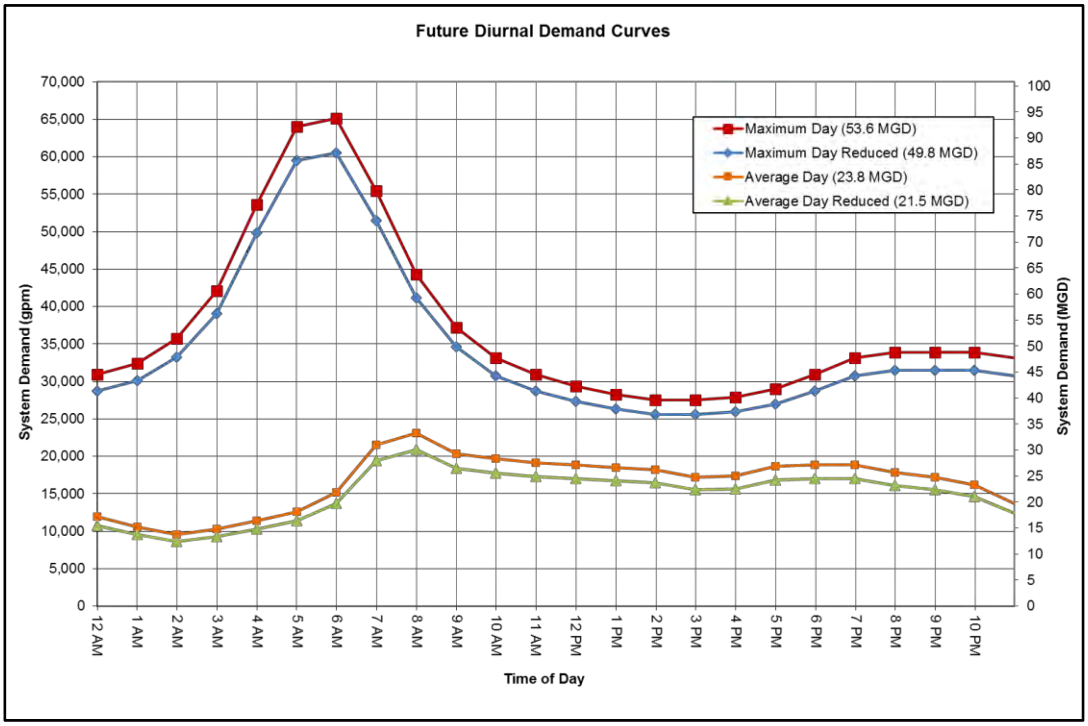

Figure 9-1: Typical Future Diurnal Demand Curves

The consumption rates in the UBO areas were spatially distributed using InfoWater Demand Allocator®. The InfoWater Demand Allocator® module uses GIS technology to assign land use consumption data (gpd/ac) to a designated node within the water distribution network. For each junction in the UBO area, algorithms in the software determine the area of influence, or area served by each node and adjacent pipe segments. The allocation tool then superimposes the land use polygon and corresponding consumption data over the area of influence to determine the total demand at each node. System demands for the UBO area are summarized by pressure zone in **Table 9.2**.

Zone	HGL (ft)	Modeled ADD (GPM)	Modeled ADD (MGD)	Modeled MDD (GPM)	Modeled MDD (MGD)	Modeled Fire Flow (gpm)
Northwest 3	4725	1,380	2.0	3,233	4.7	3,000
Northwest 2	4850	1,191	1.7	2,793	4.0	3,000
Gallatin Park	4885	34	0.0	94	0.1	4,000
Northwest 1	4975	2,128	3.1	5,419	7.8	3,000
Northeast (Lyman)	5038	435	0.6	1,109	1.6	5,000
South (Sourdough)	5125	6,755	9.7	13,648	19.7	5,000
Knolls	5185	6	0.0	28	0.0	3,000
Water Treatment Plant	5221	1,135	1.6	2,556	3.7	5,000
Southwest	5350	714	1.0	1,783	2.6	3,000
North Mountain (2 sub-zones)	5360	599	0.9	1,434	2.1	3,000
Southeast Mountain (2 sub-zones)	5560	857	1.2	2,108	3.0	3,000
East Mountain (3 sub-zones)	5630	1,327	1.9	3,105	4.5	3,000
Total	-	16,561	23.8	37,312	53.6	-

Table 9.2: Future System Demands by Pressure Zones

9.2 Future System Modeling Scenarios

The existing system was expanded to serve the future growth areas of the UBO in accordance with the projected demands presented in **Table 9.2**. Modeling scenarios were established to evaluate and address future system requirements. The modeling scenarios also included improvement concepts to address existing system issues highlighted in **Chapter 6**, which included pressure, storage, transmission, and fire flow goals. In summary, the goals for the future system modeling effort included the following:

- Develop and provide conceptual design of future pressure zones;
- Establish storage capacity and general locations;
- Identify future pumping requirements;
- Identity the size and location of distribution mains based on water demand allocation and hydraulics;
- Evaluate the potential impacts of water conservation; and
- Optimize overall system functionality utilizing performance criteria established in **Chapter 5**.

Think Big. Go Beyond.

Table 9.3 lists the modeling scenarios developed for the hydraulic analysis of the future distribution system. The scenarios used in the base model hydraulic evaluation are designated FUT_1000, 3000 and 3300, which assume that the sources of water system supply comes from both the Lyman reservoir (3 MGD maximum) and the Sourdough WTP (50.6 MGD maximum). The maximum demands are equivalent to the future maximum day demand determined in **Chapter 3**. The remaining scenarios and system evaluations, which are specific to issues associated with system redundancy, growth, and functionality, are presented and discussed in **Section 9.9**.

9.3 Future Water Distribution System Pipelines

The distribution system model was expanded to serve the UBO by adding water mains to the existing system model. In general, a framework of 16-inch and 12-inch water mains was used to establish the backbone and grid of the future distribution network. The 16-inch transmission mains were generally routed along section lines and in primary transportation corridors identified in the TMP. The 12-inch water mains were generally routed along half-section lines. Where required to meet specific hydraulic performance criteria, the water mains were upsized to handle larger flows, minimize headloss, or to convey water to storage reservoirs and pump stations within the planned distribution system. The resulting layout of transmission pipelines provides the City with the functionality to accommodate future growth in an efficient manner. **Figure 9-2** provides an overview of the future distribution system and identifies the proposed system by water main diameter.

Modeling Scenario	Simulation Type	Description	Demand Condition	Demand (MGD)	Source Allocation in Model (MGD)
FUT_1000	EPS	This scenario evaluates the City's supply facilities and transmission/distribution system capabilities during future day-to-day operations during future ADD.	ADD	23.8	Lyman (3) Sourdough WTP (20.8)
FUT_3000	EPS	This scenario evaluates the City's supply facilities and transmission/distribution system capabilities during the peak demands of the future MDD.	MDD	53.6	Lyman (3) Sourdough WTP (50.6)
FUT_3300	Steady State	This scenario calculates the available fire flow at a residual pressure of 20 psi during MDD conditions.	Available flow during MDD	53.6	Lyman (3) Sourdough WTP (50.6)
FUT_3200	EPS	This scenario is set up the same as FUT_3000, however assumes that the Lyman reservoir is raised to meet the HGL of the South Zone.	MDD	53.6	Lyman (3) Sourdough WTP (50.6)
FUT_5000	EPS	This scenario is set up the same as FUT_3000, however assumes that a substantial source of groundwater comes from the west (Four Corners Area) and is supplied into the UBO via a new transmission main.	MDD	53.6	Lyman (3) Sourdough WTP (34) Groundwater Wells (16.6)
FUT_1100	EPS	This scenario is set up the same as FUT_1000, but with Water Conservation. Assumes less water is supplied by the Sourdough WTP.	ADD with Conservation	21.5	Lyman (3) Sourdough WTP (18.5)
FUT_3100	EPS	This scenario is set up the same as Same as FUT_3000, but with Water Conservation. Assumes less water is supplied by the Sourdough WTP.	MDD with Conservation	49.8	Lyman (3) Sourdough WTP (46.8)
FUT_3110	Steady State	This scenario calculates the available fire flow at a residual pressure of 20 psi during MDD conditions with water conservation.	Available flow during MDD Conservation	49.8	Lyman (3) Sourdough WTP (46.8)
EC_3400	EPS	This scenario is set up the same as EXIST_3000 and assumes that the Phase 1 of the West Transmission Main is in Service.	MDD	11.7	Existing Conditions
EC_3410	EPS	This scenario is set up the same as EC_3400 and assumes that the Sourdough transmission main between the WTP and the Sourdough reservoir is offline.	MDD	11.7	Existing Conditions

Table 9.3: Future System Modeling Scenarios

Think Big. Go Beyond.

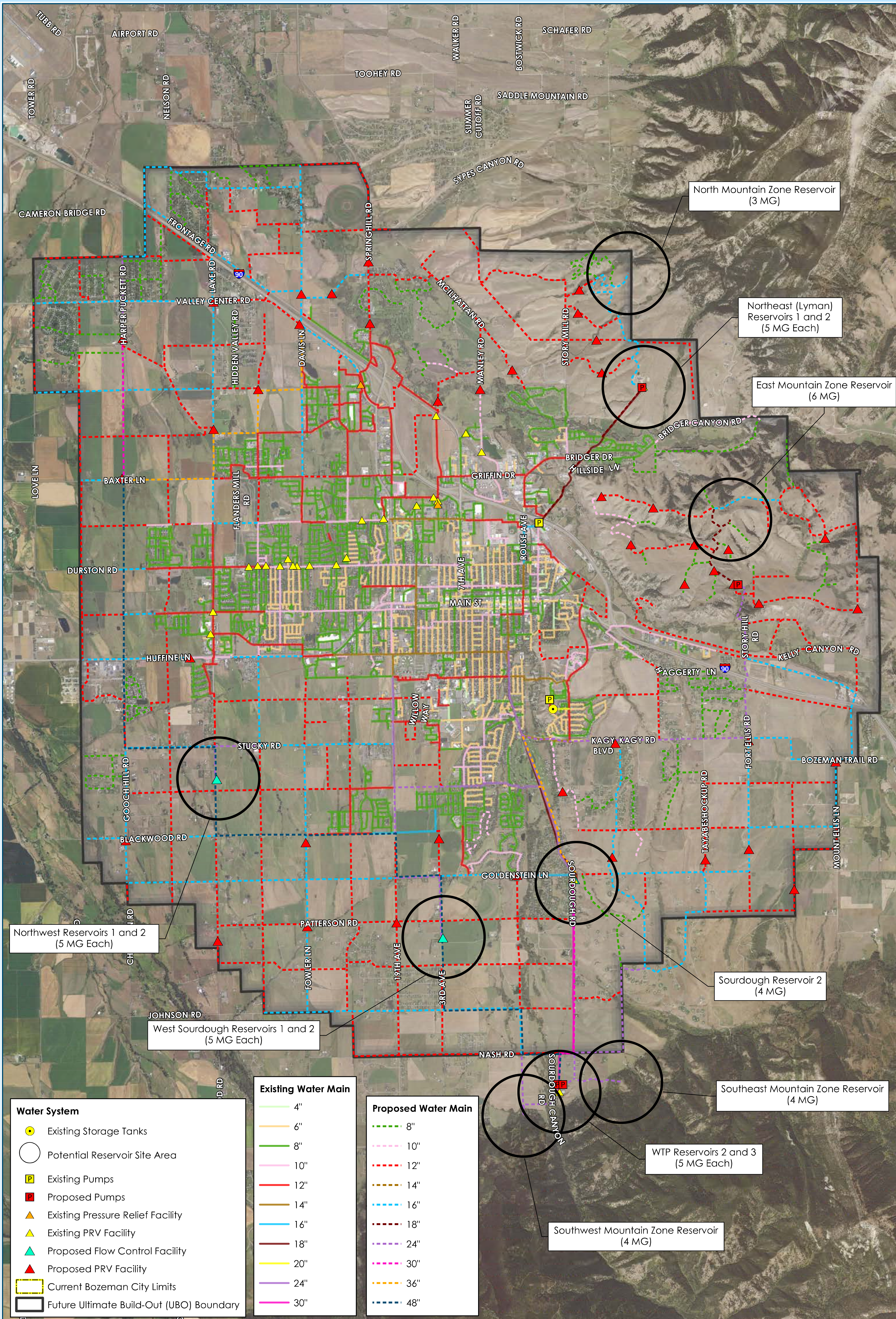

Figure 9-2: Proposed Water Distribution System by Water Main Diameter

City of Bozeman Water Facility Plan Update

0 0.4 0.8 1.2 1.6 Miles

9.4 Future Water System Pressure Evaluation

The future pressure zones were developed based on criteria established in **Chapter 5**. Specific pressure requirements are summarized as follows:

- Maximum pressure, existing system = 165 psi
- Maximum pressure, new growth areas = 110 psi
- Minimum pressure during PHD = 50 psi
- Minimum pressure during a fire flow = 20 psi
- Maximum pressure, mountain zones = 150 psi

9.4.1 Future Pressure Zone Overview

Based on the pressure zone evaluation, the future system will require new pressure zones. These future zones are driven either by basic elevation changes across the distribution system, as well as preservation of existing system pressures in the current core areas to continue to provide sufficient pressure to existing fire suppression systems but not carry the high pressures into future developments.

The future water distribution system is comprised of zone modification and new zones to serve elevations that range from 4,500 ft in the northwest to approximately 5,600 ft in the southeast and east growth areas. An overview of the future pressure zone layout is provided in **Figure 9-3**, and an overview of the system pressures by zone is provided in **Table 9.4**. The pressure zone modifications are identified and described below.

- Existing zones unchanged or expanded: South, Knolls, Northeast, and Gallatin Park.
- Modified existing zones: The West and Northwest existing zones are combined into a new zone identified as Northwest 1. The West and Northwest Zones can be combined when system expansion and development results in these zones abutting one another. Combining the zones will required a detailed review of PRV system settings and adjustments to bring the two zones under the same HGL 4975 ft. PRV vaults should be surveyed to confirm operating HGL, and the operating parameters should be adjusted accordingly.
- New pressure zones: Northwest 1, Northwest 2, Northwest 3, Southwest, Water Treatment Plant, Southeast Mountain, East Mountain, and North Mountain.
- New PRV facilities are recommended to have pressure relief, pressure sustaining, and surge protection features as described in **Section 6.9.1**.

- Transmission and major distribution mains were arranged to allow zone feed redundancy with two or more PRVs feeding the zone. However, the pressure zones along the West Transmission Main are primarily fed from the main transmission pipeline with additional connections to adjacent pressure zones serving as emergency or redundant connections.
- The City has historically provided redundancy through distribution sized connections as developments were constructed within a pressure zone, which resulted in a relatively large number of PRV facilities feeding the same zone. The City recognizes that a policy is required to control the number of PRV facilities constructed during expansion of existing and future pressure zones. The City should consider developing a policy that provides guidance to developers and establishes requirements on how the City will plan for expansion and UBO infrastructure that involves PRV facilities and the transfer of water between pressure zones.

Northwest 3 (HGL 4725)
The Northwest 3 Pressure Zone is a large zone and operates at an HGL of 4725 ft. One main PRV facility provides flow to this zone from the Northwest 2 Zone during day-to-day operations. Additional PRV facilities are recommended for installation with a lower pressure setting to provide fire flow and redundant supply from the Northwest 1 and Northwest 2 Zones. There are no water production or storage facilities located within this zone.

Northwest 2 (HGL 4850)
The Northwest 2 Pressure Zone is a large zone and operates at an HGL of 4850 ft. One main PRV facility provides flow to this zone from the Northwest 1 Zone during day-to-day operations. Additional PRV facilities are recommended for installation with a lower pressure setting to provide fire flow and redundant supply from the Northwest 1 and Northeast Zones. There are no water production or storage facilities located within this zone.

Northwest 1 (HGL 4975)
The Northwest 1 Pressure Zone is a large zone and operates at an HGL of 4975 ft. This zone will be fed from proposed northwest reservoirs 1 and 2 located on the west side of the City. Existing PRVs can be set at a lower pressure to provide emergency (or fire flow) from the South Zone. Recommended storage for this zone is two (2) reservoirs each sized at 5 MG.

Northeast (Lyman) (HGL 5038)
The Northeast (Lyman) Pressure Zone is an existing large zone and operates at an HGL of 5038 ft. Due to physical constraints that limit the extent of future development of the Northeast Zone, the UBO of this zone is similar to that of the existing zone with the exception of minor growth to the east of the existing zone. Demand by the North Mountain Zone will be served from the Lyman reservoir. The additional growth within the Northeast Zone and the addition of the North Mountain Zone increases the demand in the Northeast Zone to about 3.8 MGD during MDD.

The increased demand in the future for this zone will exceed Lyman Spring production rates, and that the Pear Street Booster Station will not be utilized under future MDD conditions.

Gallatin Park (HGL 4885)
The Gallatin Park Pressure Zone is an existing small zone and operates at an HGL of 4885 ft. The expansion of this zone is limited north and eastward from the existing zone, which is bound by the East Gallatin River and the Frontage Rd/railroad. Two existing pressure reducing valves provide water to this zone. There are no water production or storage facilities within this zone.

The Gallatin Park Zone operating at an HGL of 4885 ft is similar to the proposed Northwest 2 Zone operating at an HGL of 4850 ft. Lowering the Gallatin Park Zone to an HGL of 4850 ft will reduce pressure in the existing zone by about 15 psi. Further investigation regarding impacts to any existing fire suppression systems should be completed prior to lowering the operating HGL. Combining these two zones eliminates the need for a proposed PRV facility on Manley Rd, which is currently shown to separate these zones.

South (Sourdough) (HGL 5125)
The South (Sourdough) Pressure Zone is the largest existing zone and operates at an HGL of 5125 ft. The UBO of this zone indicates expansion on the south side of the City in an east-west direction. There are two existing finished water storage facilities within this zone: the Sourdough and Hilltop reservoirs, with volumes of 4 MG and 2 MG, respectively. Additional recommended storage for the UBO condition includes one new reservoir located on the site of the existing Sourdough reservoir sized at 4 MG, and two reservoirs located in the southwest portion of the zone sized at 5 MG each.

Knolls (HGL 5185)
The Knolls Pressure Zone is an existing small zone and operates at an HGL 5185 ft. The UBO of this zone involves infill only with no expansion in area. The Knolls booster station will continue to provide water and pressure to this zone. The existing pumps in the Knolls booster station are capable of meeting the domestic and fire flow requirements of the UBO system. There are no water production or storage facilities within this zone.

Water Treatment Plant (HGL 5221)
The Water Treatment Plant Pressure Zone will operate at an HGL of 5221 ft when the WTP reservoir comes on line in 2017 with a storage volume of 5.3 MG. The WTP reservoir will gravity feed this zone, which is roughly comprised of the area between Patterson Rd and Blackwood Dr west of Sourdough Rd. Additional storage for this zone includes two reservoirs, each sized at 5 MG. The total planned UBO storage volume in the WTP Zone is15.3 MG.

Southwest Mountain (HGL 5350)
A new pump station will be required to serve the new Southwest Mountain Pressure Zone with an HGL of 5350 ft. The zone is generally located south of the existing City and west of

Sourdough Rd. The preliminary location for the proposed pump station is adjacent to the existing Sourdough WTP. The Southwest Mountain Zone is projected to have a maximum day demand of approximately 1,800 gpm. The proposed pump station would have a capacity of about 1,800 gpm at UBO, with a TDH of approximately 130 feet. The pump station could be located adjacent to a proposed storage reservoir in this area. There is no redundant supply planned to serve the Southwest Mountain zone.

Southeast Mountain (HGL 5560)
A new pump station will be required to serve the new Southeast Mountain Pressure Zone with an HGL of 5560 ft. The Southeast Mountain Zone is generally located southeast of the City. The preliminary location for the proposed pump station is adjacent to the existing Sourdough WTP. The Southeast Mountain Zone is projected to have a maximum day demand of about 2,100 gpm. The pump station should have a capacity of about 2,100 gpm with a TDH of approximately 345 ft. A new storage reservoir with a volume of 4.0 MG is planned for this zone. There is no redundant supply planned to serve the Southeast Mountain Zone.

The Southeast Mountain Zone will require sub-zones to manage system pressures due to the extreme topographic relief across the zone. At a minimum, one sub-zone with a HGL of 5340 ft should be developed to limit pressures to a maximum of 150 psi. Additional sub-zones will be required to reduce pressures below 110 psi. Specific sub-zone pressures and system design should be evaluated as planning for development and buildout progresses for the Southeast Mountain Zone.

East Mountain (HGL 5630)
A new pump station will be required to serve the new East Mountain Pressure Zone with an HGL of 5630 ft. The East Mountain Zone is located east of the City. The preliminary location for the proposed pump station is along Story Hill Rd north of Kelly Canyon Rd. There are no existing transportation corridors or roadways in this proposed pressure zone; therefore, the layout of the proposed water system in this zone is conceptual.

The East Mountain Zone is projected to have a maximum day demand of approximately 2,715 gpm. The new pump station would have a capacity of approximately 2,715 gpm with a TDH of approximately 530 ft. Detailed design of the pump station will depend on the location of a proposed storage reservoir and pipeline configuration in this area.

None of the East Mountain Zone is within the 2040 TMP limits. The East Mountain Zone will require additional sub zones to manage system pressures due to the extreme topographic relief across the zone. At a minimum, two sub-zones should be created at an HGL of 5410 ft and an HGL of 5190 ft to limit pressures below 150 psi. Additional sub-zones will be required to reduce system pressures below 110 psi. Specific sub-zone pressures and system design should be evaluated as planning for development and buildout progresses for the East Mountain Zone.

North Mountain Zone (HGL 5360)

A new pump station will be required to serve the new North Mountain Pressure Zone with an HGL of 5360 ft. The North Mountain Zone is generally located north of the city and northwest of the Lyman Creek area. The preliminary location for the proposed pump station is near the existing Lyman system reservoir. There are no existing transportation corridors or roadways in the proposed pressure zone; therefore, the layout of the proposed water system in this zone is conceptual. There is no redundant supply planned to serve the North Mountain Zone.

The North Mountain Zone is projected to have a maximum day demand of about 1,000 gpm. The new pump station should have a capacity of about 1,450 gpm with a TDH of approximately 325 ft. Detailed design will depend on the location of a proposed storage reservoir and pipeline configuration in this area.

None of the North Mountain Zone is within the 2040 TMP limits. The North Mountain Zone may not develop for several decades, but when development occurs, additional sub-zones are necessary due to the extreme topographic relief across the zone. At a minimum, one sub-zone with an HGL of 5125 ft should be created to limit pressures below 150 psi. An additional zone would be required to reduce system pressures below 110 psi. Specific sub-zone pressures and system design should be evaluated as planning for development and buildout progresses for the North Mountain Zone.

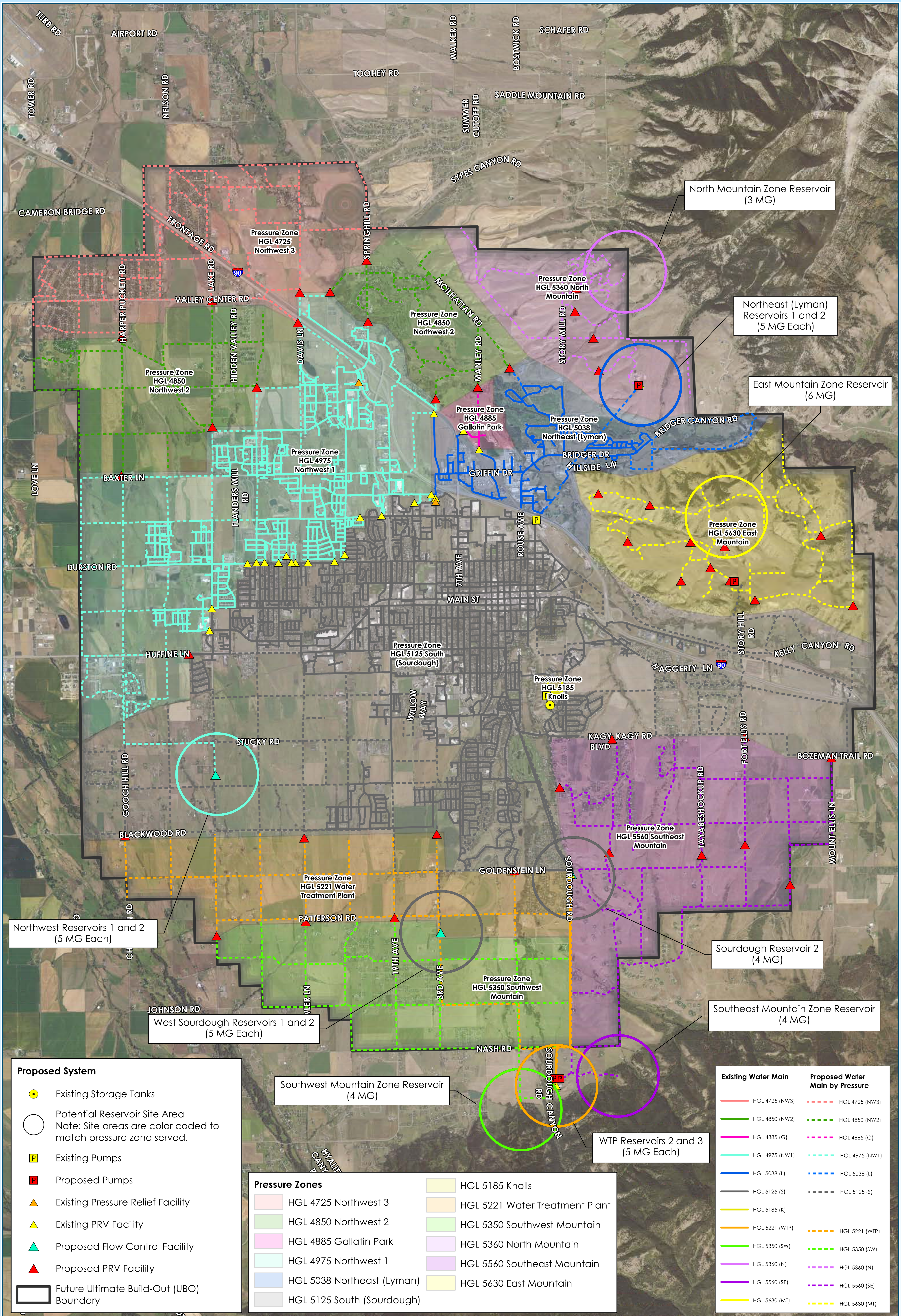

Figure 9-3: Proposed Water Distribution System by Pressure Zone

City of Bozeman Water Facility Plan Update

0 0.4 0.8 1.2 1.6 Miles

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AE2S Advanced Engineering and Environmental Services, Inc.

9.4.2 Average Demand Conditions

Minimum system pressures within the proposed distribution system during future ADD conditions (23.9 MGD) are presented in **Figure 9-4** and are summarized by pressure zone in **Table 9.4**. Pressures generally range from 50 to 150 psi throughout the distribution system.

Zone	Operating HGL (ft)	Pressures During ADD (psi)			Pressures During MDD (psi)		
		Min	Max	Avg	Min	Max	Avg
Northwest 3	4725	44	99	73	38	99	71
Northwest 2	4850	56	109	89	54	109	88
Gallatin Park	4885	72	80	77	72	80	77
Northwest 1	4975	43	160	103	41	158	101
Northeast (Lyman)	5038	100	155	131	98	155	131
South (Sourdough)	5125	6	165	110	7	162	107
Knolls	5185	52	68	83	52	68	83
Water Treatment Plant	5221	42	102	69	40	96	65
Southwest Mountain	5350	38	118	79	35	116	78
North Mountain (2 sub-zones)	5360	56	174	110	56	173	110
Southeast Mountain (2 sub-zones)	5560	41	169	106	38	169	106
East Mountain (3 sub-zones)	5630	28	160	103	26	159	102

Table 9.4: Future System Pressure during Average Day and Maximum Day Demand

There are locations near the reservoirs that experience pressures below 50 psi, and some even below 35 psi. This is because of the minimal elevation difference between these areas and the respective reservoir overflow elevations. The lowest pressures in the South Zone (6 psi) are located at the hydrants immediately adjacent to the Sourdough and Hilltop reservoirs.

The other locations that experience low pressures between 35 and 50 psi during future ADD include the following:

- The area along Blackwood Rd between 19th Ave and 31st Ave
- The area along 3rd Ave between Cambridge Dr and Goldenstein Ln.

These areas currently experience pressures less than 35 psi during present ADD conditions. Low pressures experienced in these areas are the result of a combination of elevation and system headloss challenges. Additional looping within this area and construction of the West Transmission Main Phase 1 are required to raise the existing minimum system pressures above 35 psi. Information regarding the West Transmission Main is presented in **Section 9.7.1**.

A small area within the vicinity of the Hilltop reservoir will continue to experience pressures less than the established criteria of 35 psi during future ADD conditions. This area generally includes Kenyon Dr south the reservoir and Oconnell Dr between Kenyon Dr and Highland Blvd. Portions of this low pressure area could be connected to the Knolls Zone to increase pressures; however, a detailed analysis should be completed to verify impacts to available fire flow, locations for valve isolation and separation between the Knolls and South Zone, and costs associated with pressure zone adjustment. Rehabilitation and Repair funds allotted in the CIP could be used to mitigate this issue.

Some downtown areas will continue to experience pressures exceeding performance criteria to maintain the designed functionality of existing fire suppression systems, as described in **Chapter 7.** If the City ultimately chooses a reduced pressure zone configuration, additional pressure reducing facilities will be required in the South Zone.

New pressure zones on the south, west, and northwest sides of the City are planned to maintain pressures between 50 and 110 psi. The new pressure zones in mountainous areas (Southeast, East, and North) were established to maintain pressures between 50 and 150 psi. The higher pressure areas are permitted under the guideline established in **Chapter 5** to minimize the number of pressure zones and PRV facilities. Some connections along pressure zone boundaries may vary slightly from the minimum and maximum pressure guidelines.

9.4.3 Maximum Day Demand Conditions

Minimum system pressures within the proposed distribution system during future MDD conditions (52.9 MGD) are shown in **Figure 9-5** and are summarized by pressure zone in **Table 9.4**. Pressures during MDD are generally within 2 to 6 psi of ADD conditions. The majority of the system pressures range from 50 to 150 psi throughout the system.

Similar to ADD conditions, there are locations near the reservoirs that experience pressures below 50 psi, and some even below 35 psi during MDD conditions. This is because of the minimal elevation difference between these areas and the respective reservoir overflow elevations. The lowest pressures in the South Zone (6 psi) are located at the hydrants immediately adjacent to the Sourdough and Hilltop reservoirs.

The other locations that experience low pressures between 35 and 50 psi during future MDD include the following:

- The area along Blackwood Rd between 19th Ave and 31st Ave
- The area along 3rd Ave between Cambridge Dr and Goldenstein Ln.

These areas currently experience pressures less than 35 psi during present MDD conditions. Low pressures experienced in these areas are the result of a combination of elevation and system headloss challenges. Additional looping within this area and construction of the West Transmission Main Phase 1 are required to raise the existing minimum system pressures above 35 psi. Information regarding the West Transmission Main is presented in **Section 9.7.1**.

A small area within the vicinity of the Hilltop reservoir will continue to experience pressures less than the established criteria of 35 psi during future MDD conditions. This area generally includes Kenyon Dr south the reservoir and Oconnell Dr between Kenyon Dr and Highland Blvd. Portions of this low pressure area could be connected to the Knolls Zone to increase pressures; however, a detailed analysis should be completed to verify impacts to available fire flow, locations for valve isolation and separation between the Knolls and South Zone, and costs associated with pressure zone adjustment. Rehabilitation and Repair funds allotted in the CIP could be used to mitigate this issue.

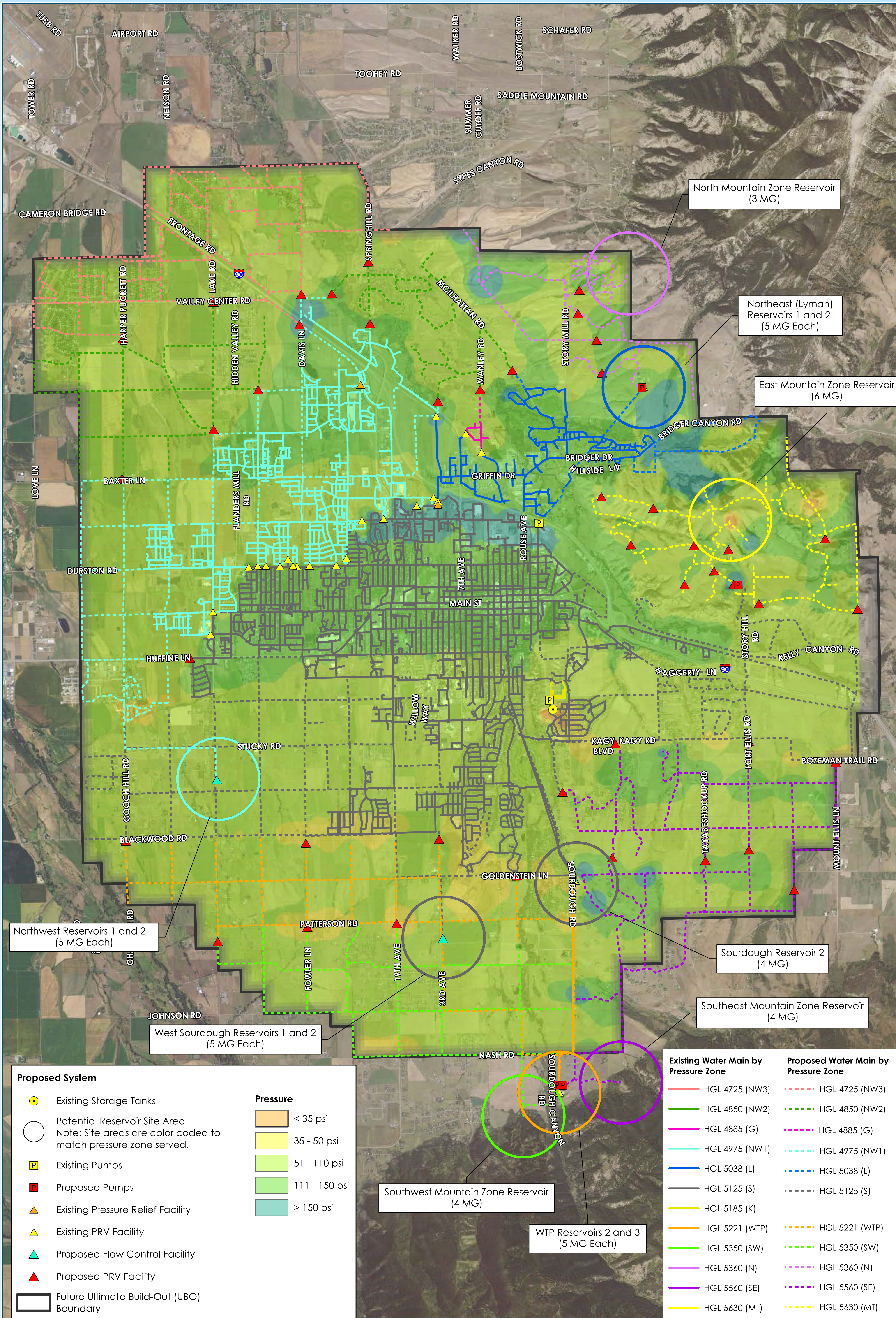

Figure 9-4: Proposed Water Distribution System
Minimum Pressure during Average Day Demand (23.9 MGD)

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Miles: 0 0.4 0.8 1.2 1.6

N

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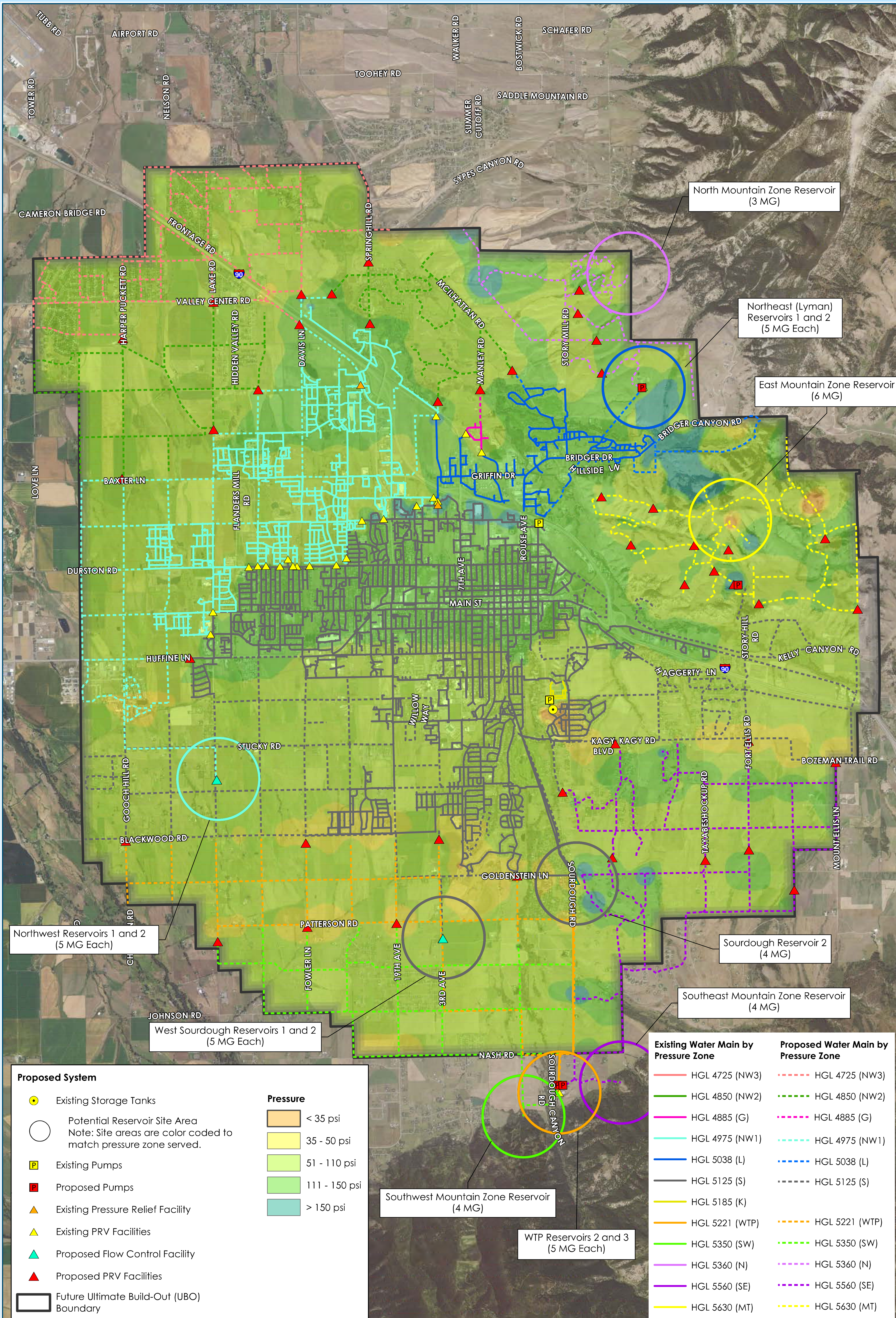

Figure 9-5: Proposed Water Distribution System
Minimum Pressure during Maximum Day Demand (53.6 MGD)

City of Bozeman Water Facility Plan Update

0 0.4 0.8 1.2 1.6 Miles

N

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9.5 Future Distribution System Storage Evaluation

Future system storage was evaluated based on the criteria established in **Chapter 5**. Based on the criteria developed, storage should be the greater of the following:

1. The sum of operational storage plus fire storage, or
2. The sum of emergency storage plus operational storage, which is equal to approximately 3 days average day demand.

Table 9.5 provides an overview of the existing and proposed storage reservoirs in relation to pressure zones. **Table 9.6** provides an overview of the distribution storage analysis based on the established criteria.

The storage analysis shows that the emergency plus operational storage (Criteria 2) is the controlling criteria for all pressure zones. The future system has an ADD of 23.8 MGD and an MDD of 53.6 MGD. Under Criteria 2, approximately 69.2 MG of overall system storage is required. The calculation for the storage applies when the source of supply is all surface water. If groundwater supplies are incorporated as another source of water, the amount of above ground storage in connected zones served with groundwater could be reduced.

The existing system storage includes 4.0 MG in the Sourdough reservoir, 2.0 MG in the Hilltop reservoir, 5.3 MG at the WTP (to be completed in 2017) and the existing Lyman reservoir is 5.3 MG.

The South Zone requires approximately 27 MG of storage at UBO; however, only 20 MG is physically located within the South Zone. To satisfy the required storage criteria, surplus storage located in ancillary zones can be used to augment the storage requirement if connections to adjacent pressure zones are provided. The WTP and Northeast Zones both have surplus water storage and can directly feed the South Zone via proposed PRVs, thereby eliminating the need for the incremental storage volume requirement in the South Zone.

The same concept is valid for the Northwest 1, 2 and 3 zones, which require nearly 20 MG of storage volume, but only 10 MG is physically proposed to be located in the zones. Ground storage is not feasible within this zone without pumping from the reservoir into the distribution system due to elevation and terrain limitations. Elevated storage was removed from consideration due to the volume of water required and a desire to preserve the unobstructed views of the mountains surrounding the community. Therefore, augmentation of supply from surrounding zones with surplus storage, through existing PRVs, is considered an acceptable way to comply with the storage volume criteria.

Zone with Storage	Reservoir ID	Overflow Elevation (ft)	Status	Reservoir Size (MG)	Total Storage Within Zone (MG)	Additional Comments
South (Sourdough)	Sourdough Sourdough 2 Hilltop West Sourdough Reservoir 1 West Sourdough Reservoir 2	5125.7 5125 5125.2 5125 5125	Existing Proposed Existing Proposed Proposed	4.0 4.0 2.0 5.0 5.0	20.0	Can emergency feed to Northwest and Northeast Zones through existing PRV facilities.
Southwest Mountain	Southwest Reservoir	5350	Proposed	4.0	4.0	Can emergency feed to WTP Zone with installation of PRV facilities.
WTP	WTP Reservoir 1 WTP Reservoir 2 WPT Reservoir 3	5221.4 5221 5221	Existing Proposed Proposed	5.3 5.0 5.0	15.3	Can emergency feed to South Zone with installation of PRV facilities.
Southeast Mountain	Southeast Reservoir	5560	Proposed	4.0	4.0	Can emergency feed to South Zone with installation of PRV facilities.
East Mountain	East Mountain Reservoir	5630	Proposed	6.0	6.0	
Northeast (Lyman)	Lyman Reservoir 1 Lyman Reservoir 2	5038	Existing Proposed	5.0 5.0	10.0	Can emergency feed Northwest Zone through PRV facilities and South Zone through Pear Street Booster Station.
North Mountain	North Mountain Reservoir	5360	Proposed	3.0	3.0	
Northwest	Northwest Reservoir 1 Northwest Reservoir 2	4975 4975	Proposed Proposed	5.0 5.0	10.0	
	Total System Storage (Existing and Proposed)				72.3	

Table 9.5: Proposed Distribution Reservoir-Pressure Zone Summary

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Zone with Storage	Zones Served	Required Operational Storage[1] (MG)	Required Fire Storage[2] (MG)	Required Emergency Storage[3] (MG)	Criteria 1 Required Total Storage[4] (MG)	Criteria 2 Required Total Storage[5] (MG)	Controlling Criteria	Storage within Zone (MG)	Storage Capacity Surplus (Deficit) (MG)	Surplus Storage Available from Other Zones
South (Sourdough)	South Knolls	7.9	2.40	19.5	10.3	27.3	**Criteria 2**	20.0	**(7.3)**	Use surplus from WTP & NE Zones
Southwest	Southwest	1.0	0.54	2.1	1.6	3.1	**Criteria 2**	4.0	0.9	-
WTP	WTP	1.5	1.74	3.3	3.2	4.7	**Criteria 2**	15.3	10.6	-
Southeast Mountain	Southeast 1 Southeast 2	1.2	1.08	2.5	2.3	3.7	**Criteria 2**	4.0	0.3	-
East Mountain	East 1 East 2 East 3	1.8	1.08	3.8	2.9	5.6	**Criteria 2**	6.0	0.4	-
Northeast (Lyman)	Northeast Gallatin Park	0.7	2.40	1.3	3.1	2.0	**Criteria 2**	10.0	8.0	-
North Mountain	North 1 North 2	0.8	1.08	1.7	1.9	2.6	**Criteria 2**	3.0	0.4	-
Northwest	Northwest 1 Northwest 2 Northwest 3	6.6	2.40	13.5	9.0	20.1	**Criteria 2**	10.0	**(10.1)**	Use surplus from WTP & NE Zones
					Overall Total Storage Required	69.2				
					Total Storage (Existing and Proposed)	72.4				

Notes:
[1] Based on 40 percent of MDD
[2] Based on zone and sub-zone fire flow requirements
[3] Based on 2 x ADD
[4] Operational Storage plus Fire Storage
[5] Operational Storage plus Emergency Storage (approximately 3 x ADD)

Table 9.6: Proposed Distribution System Storage Evaluation

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9.5.1 Reservoir Operations

A review of reservoir levels during ADD and MDD conditions is provided in the following discussion. Reservoirs were added to the model in appropriate locations and evaluated to ensure appropriate water levels could be maintained for extended periods during average and maximum day conditions. If necessary, portions of the proposed transmission pipeline network supplying the reservoir were upsized, and/or the reservoir volume was increased to maintain appropriate levels under all conditions.

9.5.1.1 *Average Day Demand*

Graphs of reservoir water level fluctuations, presented as percent full, during future ADD conditions are shown in **Figure 9-6**. As shown, all proposed reservoirs operate above the 60 percent full mark, which indicates that the reservoirs are being filled at an acceptable rate and have sufficient equalization storage volume. The remaining reservoir volume is available for emergency conditions.

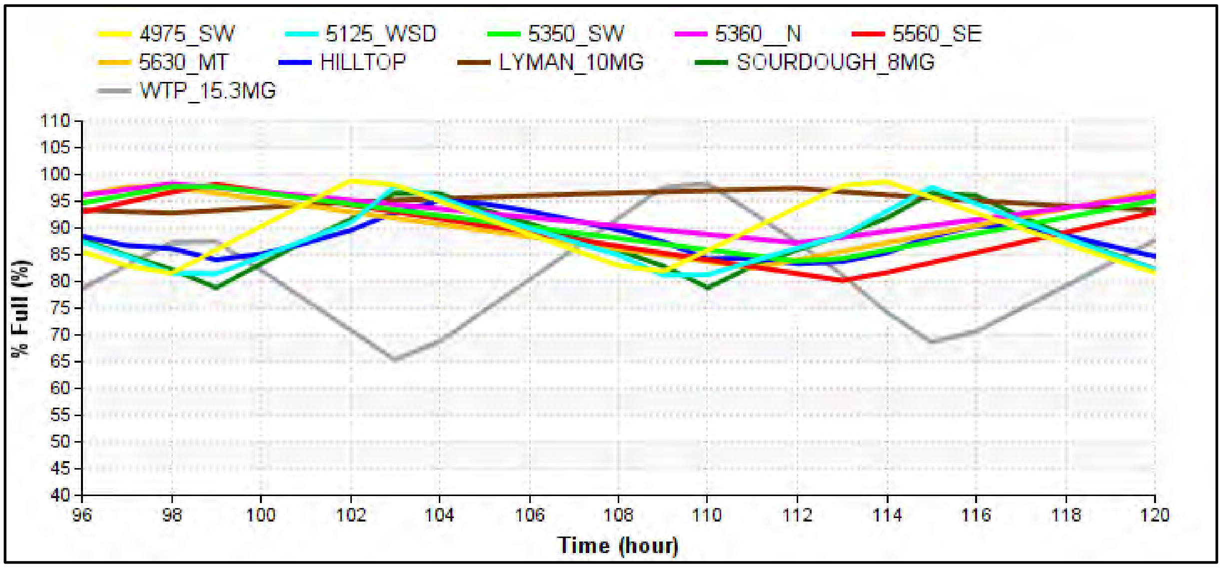

Figure 9-6: Proposed Water Distribution System Reservoir Levels during Average Day Demand (23.8 MGD)

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9.5.1.2 *Maximum Day Demand*

Graphs of water reservoir level fluctuations, presented as percent full, during future MDD conditions are shown in **Figure 9-7**. The graph shows that all proposed reservoirs operate above the 60 percent full mark, which indicates that the reservoirs are filled at an appropriate rate and have sufficient equalization storage volume. The remaining reservoir volume is reserved for emergency storage.

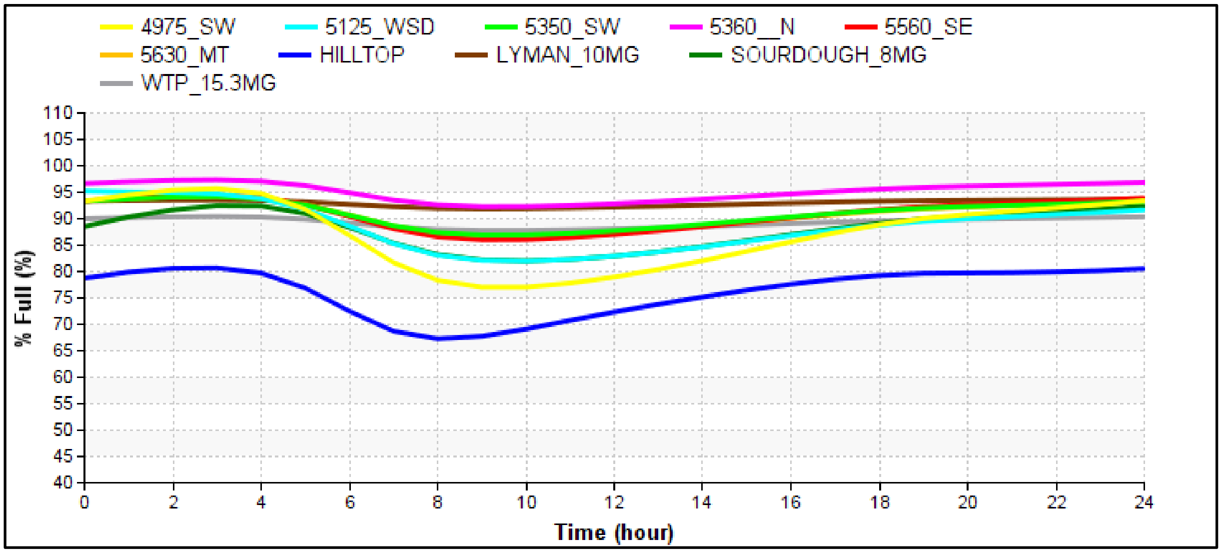

Figure 9-7: Proposed Water Distribution System Reservoir Levels during Maximum Day Demand (53.6 MGD)

9.6 Future Distribution System Pumping Capacity

The City's pumping facilities are used to deliver water to pressure zones that cannot maintain adequate system pressure via gravity alone (Knolls booster station), or to transfer water to higher pressure zones (Pear Street Booster Station). The future distribution system pumping capacity was evaluated based on criteria established in **Chapter 5**. Specific pumping capacity requirements are summarized as follows:

1. In pressure zones with storage – The station must have adequate firm capacity to supply maximum day demand (MDD) for the zone service area.
2. In pressure zones without storage - Pump stations supplying constant pressure service must have firm pumping capacity (largest unit out of service) adequate to meet peak hour demand (PHD) for the zone service area plus the largest fire flow demand in the zone.

Pumping facilities identified as critical, those providing service to pressure zone(s) without sufficient fire or emergency storage, should be equipped with an on-site, backup power generator. Less critical facilities should be equipped with a receptacle to allow for a connection to a portable generator

The evaluation of the future pumping facilities and their ability to meet projected water demand conditions at UBO is summarized in **Table 9.7**.

Pump Station	MDD (gpm)	TDH (ft)	Pump Size (gpm)	Number of Pumps (2 firm +1)	Motor Horsepower (Hp)	Installed Horsepower (Hp)
Southwest Mountain Zone	1,800	135	900	3	100	300
Southeast Mountain Zone	2,100	345	1,050	3	300	900
East Mountain Zone	3,100	530	1,550	3	700	2,100
North Mountain Zone	1,450	340	725	3	200	600

Table 9.7: Proposed Pump Station Capacity

New pump stations are required for the Southwest, Southeast Mountain, East Mountain, and North Mountain Zones. The proposed pumping facilities will convey water to reservoirs located in their respective pressure zones.

Existing pumping facilities (Pear Street and Knolls) will continue to operate to support the future system. However, the hydraulic analysis showed that the Pear Street Booster Station is not required during MDD because the demand in the Northeast Zone will eventually consume all of the supply. At that point in time, there will be no need to transfer capacity into the South Zone. The City should review pump operations periodically to assess the impact of any changes in system demand and ensure hydraulic criteria continues to be satisfied.

9.7 Future Transmission and Distribution Main Capacity

As discussed in **Chapter 5**, the distribution system is considered to have deficient water main looping or sizing if the following conditions are experienced:

- velocities greater than five fps;
- small diameter pipes (10-inch or less) have headlosses greater than five ft/1,000 ft;
- large diameter pipes (12-inch or greater) have headlosses greater than two ft/1,000 ft.

All new water mains are sized appropriately to meet these guidelines, during PHD under both ADD and MDD conditions. **Figure 9-8** provides an overview of system headloss during PHD and MDD conditions. The key results of this analysis are:

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- Proposed transmission and distribution mains meet the required velocity and headloss criteria.
- The existing system hydraulic analysis showed serval areas that exceeded the headloss criteria outlined previously , as shown in **Figure 6-7**. These same areas were evaluated under future conditions and showed an overall reduction in headloss. The headloss reduction is accomplished by additional future system looping, and the addition of large transmission mains. The system loops and transmission mains help convey water more efficiently throughout the distribution system, effectively reducing headloss at locations that previously had issues.
- A small number of pipe segments within the existing system still exceed the headloss criteria. The pipe segments are identified in **Figure 9-8**. To mitigate this issue, the pipe segments need to be upsized; however, the cost associated with upsizing existing infrastructure was deemed prohibitive based on the potential hydraulic gains, which would only be during periods of PHD under MDD. The City should monitor these areas and upsize these sections of water main only if a major road project is scheduled and pipeline rehabilitation or replacement is under consideration.

9.7.1 Future Transmission Main Overview

The hydraulic analysis of the UBO showed the need for additional transmission infrastructure to properly convey water throughout the distribution network.

Figure 10-2 provides a graphical depiction and overview of the following transmission mains that are required to satisfy UBO demand requirements:

- Sourdough Transmission Main: The Sourdough Transmission Main consists of two phases.
  - Phase I: Consists of constructing a 30-inch transmission main, connecting to a new 48-inch from the WTP and extending to the Sourdough reservoir. Phase I will parallel the existing 30-inch main and will provide a redundant connection between the WTP and the Sourdough reservoir. The beneficial redundancy provided by the Phase I Sourdough Transmission Pipeline will addresses the lack of system redundancy between the Sourdough WTP and the distribution system.
  - Phase II: Consists of constructing a 36-inch parallel transmission main between the Sourdough reservoir and Kagy Blvd. Phase II will supplement the capacity and operate in parallel to the existing 18-inch and 24-inch transmission mains in this area.
- Lyman Transmission Main: The Lyman Transmission Main project includes either the repair or replacement of existing 18-inch AC transmission main between the Lyman

reservoir and the Pear Street Booster Station. The replacement of the AC main will allow for additional conveyance capacity and reduce future O&M costs.

- West Transmission Main: The West Transmission Main is a large diameter pipeline originating at the Sourdough WTP, ultimately extending north/northwest. The proposed main helps satisfy UBO demand in the WTP Zone, the South Zone, and the Northwest 1, 2, and 3 zones of the future system. Additionally, Phase 1 of the West Transmission Main, consisting of the southern portion of the segment, serves as a redundant main to the existing 30-inch Sourdough transmission main.
- A phased approach was developed for the West Transmission Main to meet system expansion and budgetary needs:
  - Phase 1: Construct a new 48-inch transmission main from the Sourdough WTP to the southwestern edge of the existing distribution network at the location of S. 19th and Graf St. to serve future anticipated growth and provide water delivery redundancy. The proposed West Sourdough reservoirs will be located in reasonable proximity to the transmission main. Construction of the Phase 1 West Transmission Main addresses the low pressure currently experienced at the upper end of the South Zone in the vicinity of 3rd Ave between Cambridge Dr and Goldenstein Ln. Failure of the Sourdough transmission main would have significant consequences on providing adequate water system capacity to the City; therefore, Phase 1 of the West Transmission Main offers a meaningful near-term benefit.
  - Phase 2: Extend the 48-inch West Transmission Main – Phase 1 westward and north into the UBO to serve anticipated future growth and provide some redundancy to the South Zone and subsequently the Northwest and Northeast Zones. The proposed Northwest reservoirs will be positioned along this transmission main, which includes the following segments:
    - Blackwood Dr from 19th Ave to Cottonwood Rd
    - Cottonwood Dr between Blackwood Rd and Stucky Rd
    - Stucky Rd between Cottonwood Rd and Gooch Hill Rd
    - Gooch Hill Rd between Stucky Rd and Baxter Ln
  - Phase 3: Construct a branch off the West Transmission Main from the intersection of Baxter Ln and Gooch Hill Rd to the northeast with a 36-inch transmission main, to serve anticipated future growth and provide source redundancy to more of the City (extending approximately from Baxter Ln to the intersection of I-90 and Davis Ln).
  - Phase 4: Extend the West Transmission Main from the intersection of Baxter Ln and Gooch Hill Rd to the north with a 30-inch transmission main to serve

anticipated future growth and provide redundancy to the Northwest Zones (extending from Baxter Ln to south of Valley Center Rd).

  - Phase 5: Extend the West Transmission Main to the north, to serve anticipated future growth and provide redundancy to Northwest Zones (extending from south of Valley Center Rd to the north side of I-90).

- East Transmission Main: The East Transmission Main project is a 24-inch main on Kagy Blvd from east of Fairway Dr to Fort Ellis Rd and extending it northward, ultimately to a pump station that feeds the East Mountain Zone. The East Transmission Main is required to convey water to the east and southeast parts of the UBO distribution network.
- Southeast Mountain Zone Transmission Main: A 24-inch transmission main is required to serve the Southeast Mountain Zone. The transmission main will extend from the new booster station near the WTP to the reservoir storage located within the Southeast Mountain Zone. The main will continue into the zone where it eventually will split into 16-inch mains feeding the eastern and western parts of the pressure zone. The 16-inch transmission mains and proposed PRV facilities between the Southeast Mountain Zone and the South Zone allow for emergency storage in the Southeast Mountain Zone to benefit the South Zone. The PRV pilot settings would close the valve during normal operation and allow water to flow to the South Zone when pressures force the valve to open.
- Southwest Transmission Main: A 24-inch transmission main is recommended to serve the Southwest Mountain Zone. The transmission main will extend from the new booster station near the WTP to the reservoir storage within the Southwest Mountain Zone, and continue from the storage location prior to splitting into 16-inch mains feeding westward into the pressure zone. The 16-inch transmission mains and proposed PRV facilities between the Southwest Mountain Zone and the South Zone allow for emergency storage in the Southwest Mountain Zone to benefit the South Zone. The PRV pilot settings would close the valve during normal operation and allow water to flow to the South Zone when pressures force the valve to open.
- North Mountain Zone Transmission Main: A 16-inch transmission main is recommended to serve the North Mountain Zone. The transmission main will extend from the new booster station near the Lyman reservoir to the reservoir storage within the zone.
- East Mountain Zone Transmission Main: An 18-inch transmission main is recommended to serve the North Mountain Zone. The transmission main will extend from the new booster station to the reservoir storage within the zone. Once past the storage reservoir, the transmission pipeline will be downsized to 16-inch as it extends to the east.

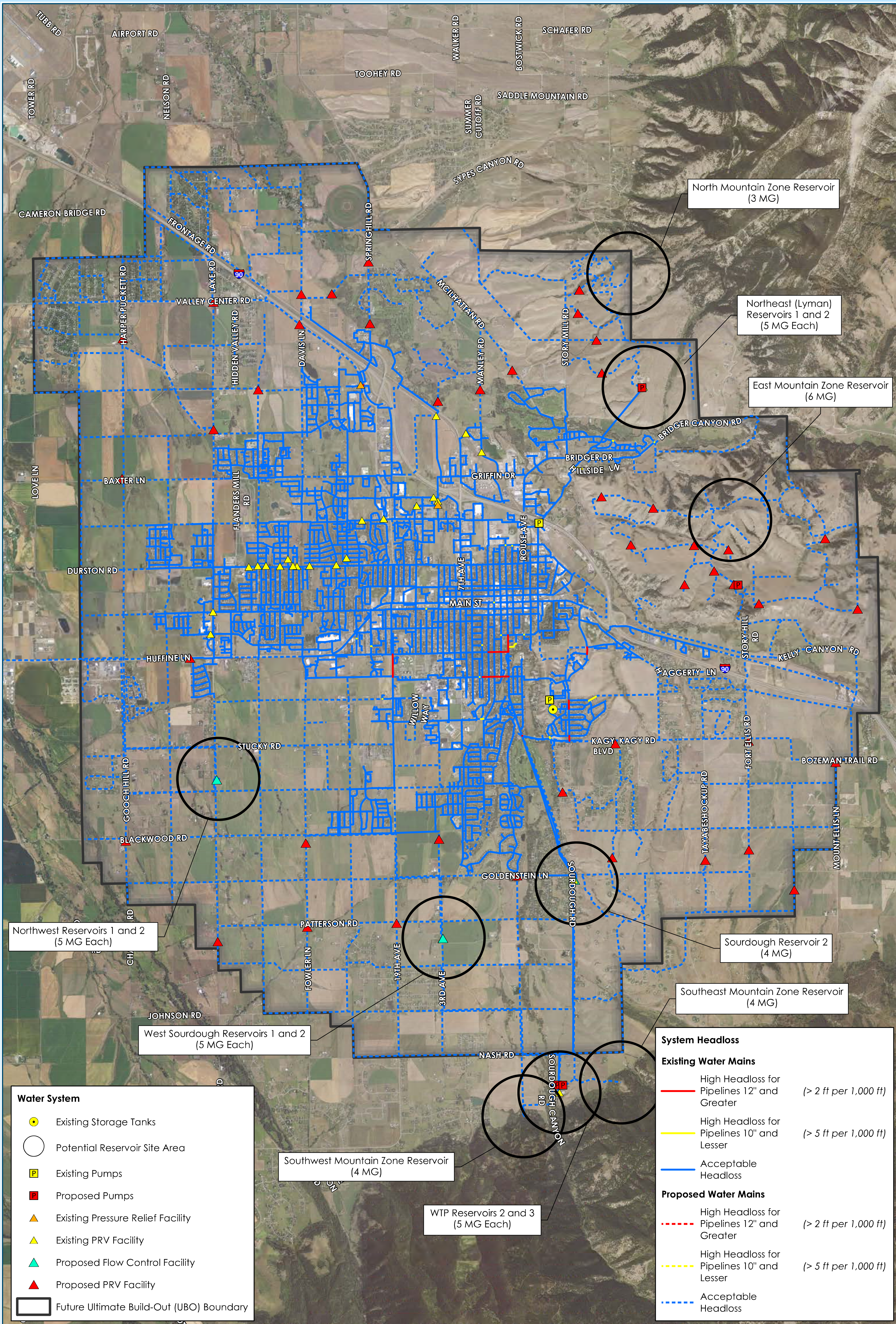

Figure 9-8: Proposed Water Distribution System Maximum Headloss during Maximum Day Demand (53.6 MGD)

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9.8 Future Fire Flow Analysis

The water mains in the UBO areas are sized to provide the fire flows identified for the various land use classifications. A fire flow analysis was completed for the proposed distribution system to analyze the transmission and distribution system piping capacity. The UBO model is only a skeletonized network of the ultimate system, but the fire flow analysis can verify that storage and transmission lines are appropriately sized for the intended land uses. A steady state analysis was utilized based on MDD conditions.

A contour map was generated from the fire flow analysis to depict the available fire flows (at 20 psi) throughout the distribution system, and is presented in **Figure 9-9**. The contour map is provided to illustrate the available fire flow throughout the City. As shown in the figure, some areas that currently have less than optimal fire flows, as discussed in **Section 6.7** and shown in **Figure 6-8**, still have lower than optimal fire flow after build-out of the system. The areas of lower fire flow are caused by small diameter distribution mains (generally 6-inch diameter or less), or are local spots of high elevation.

The UBO system shows 102 existing hydrants not meeting the fire flow goals compared to 160 hydrants under existing conditions. The improvement is primarily due to the benefits provided by proposed looping and transmission main projects. The recommended protocol for addressing the remaining fire flow goal deficiencies is outlined below:

1. Verify system deficiency: Perform fire flow tests at the hydrants not meeting the fire flow goal to verify model results prior to implementing improvement projects.
2. Evaluate system expansion: Review the potential for future looping by system growth and expansion, which may show that fire flow can be increased by closing loops.
3. Evaluate water main replacement: Use the hydraulic model to determine if the deficiencies are large enough to warrant water main replacement with a larger size. In some locations, the use of multiple adjacent hydrants may be an appropriate strategy to obtain the required fire flow.

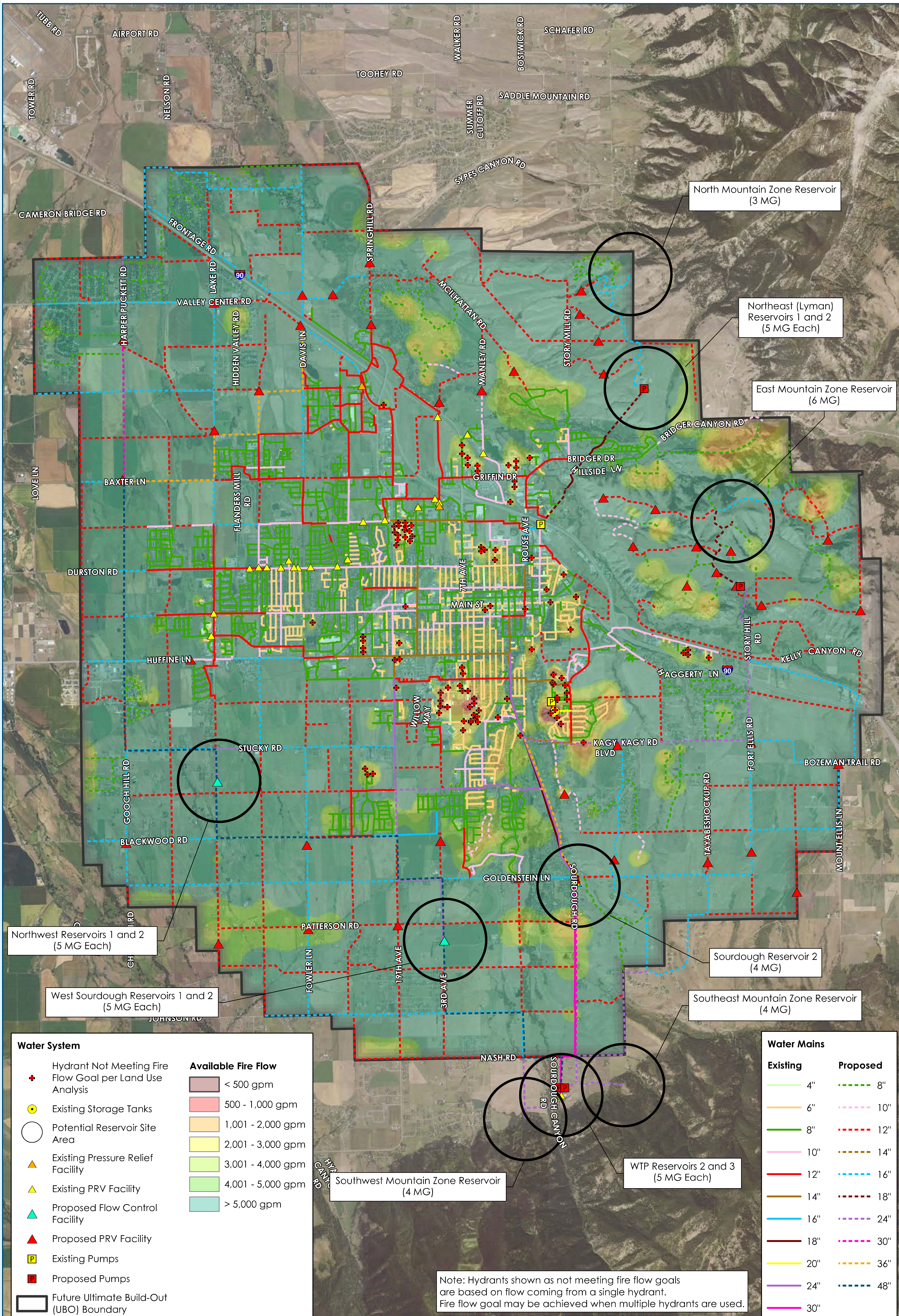

Figure 9-9: Proposed Water Distribution System
Available Fire Flow during Maximum Day Demand (53.6 MGD)

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0 0.4 0.8 1.2 1.6 Miles

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9.9 Additional Model Scenarios Evaluations

As part of the scope of Water Facility Plan Update, additional scenarios were developed to assess possible changes to the system including: 1) replacement and relocation of the Lyman reservoir; 2) adding wells to the water supply; 3) reduced demand due to increased water conservation; and 4) assessing the initial phase of the West Transmission Main. These scenarios and the key results are summarized below.

FUT_3200 (Lyman reservoir with raised HGL during future MDD)

The FUT_3200 scenario was simulated during future MDD conditions with the Lyman reservoir relocated to an elevation of 5125 ft to match the HGL of the South Zone. Notes on operation of the system are as follows:

- The Pear Street Booster Station was bypassed and the existing 18-inch transmission main was used to transfer water between zones.
- System pressures increase in the Northeast Zone by 30 to 35 psi due to the higher HGL. Operating pressures remain the same in the other pressure zones.
- The Lyman reservoir requires an alternative approach to control flow from the reservoir to account for the seasonal variability of water capacity captured by Lyman Spring.

The higher HGL will increase operating pressures across the Northeast Zone to between 130 and 190 psi. To reduce pressures within the system, the 18-inch transmission main should be isolated as a high pressure transmission main all the way to its connection with the South Zone. This will require installation of PRV facilities on the connections to the Northeast Zone from the 18-inch transmission main. Despite the opportunity to bypass the Pear Street Booster Station and increasing operating pressures, raising the HGL of the Lyman system to 5125 ft was determined to be prohibitively expensive.

FUT_5000 (Western Well Field during future MDD)

The FUT_5000 scenario was simulated during future MDD conditions with the inclusion of a new groundwater source located west of the City.

At the time of this analysis, the most likely location of significant groundwater supply was thought to be several miles west of the City. The model should be modified to evaluate the effect of connecting future sources of groundwater to the distribution system as projects evolve and actual conditions are better known.

Notes on operation of the system are as follows:

- Flow assumptions:
  - Flow from Lyman Creek is limited to 3 MGD;
  - Flow from Sourdough WTP is limited to 34 MGD;
  - Remaining flow from the Groundwater Well Fields is 16.6 MGD.
- Water from the western area of the City flows through a Groundwater Well Field Transmission Main (GWFTM) to the Northwest reservoirs.
- Water not used by the Northwest Zones, which are fed by the Northwest reservoirs, will need to be pumped into the South Zone due to the higher elevations. The capacity of the pump station is based on the desired system redundancy to feed water to the South Zone.
- System pressures and reservoir operations are similar to that of the FUT_3000 UBO modeling scenario.
- It is possible to reduce the size of the transmission main between the WTP and the West Sourdough reservoirs from 48-inch to 36-inch.

Figure 9-10 shows the proposed system with the inclusion of the assumed alignment of the GWFTM and highlights the Sourdough and Northwest transmission mains between the WTP and West reservoirs.

FUT_1100 (Future ADD with water conservation)

The FUT_1100 scenario was simulated during future ADD conditions with adjustments for water conservation. The scenario was simulated under the following conditions, which are described in **Section 3.5.2**:

- A global demand reduction factor was applied to the system to reduce the UBO ADD of 23.8 MGD to 21.5 MGD.
- The maximum source water capacity from Lyman Creek is 3 MGD and 18.5 MGD from the Sourdough WTP.

Model results indicate that there is no significant change in comparison to results from the full system demand under the FUT_1000 scenario. The system experiences similar pressures (within 1 psi) and essentially equivalent rates of headloss as compared to the baseline scenario without water conservation.

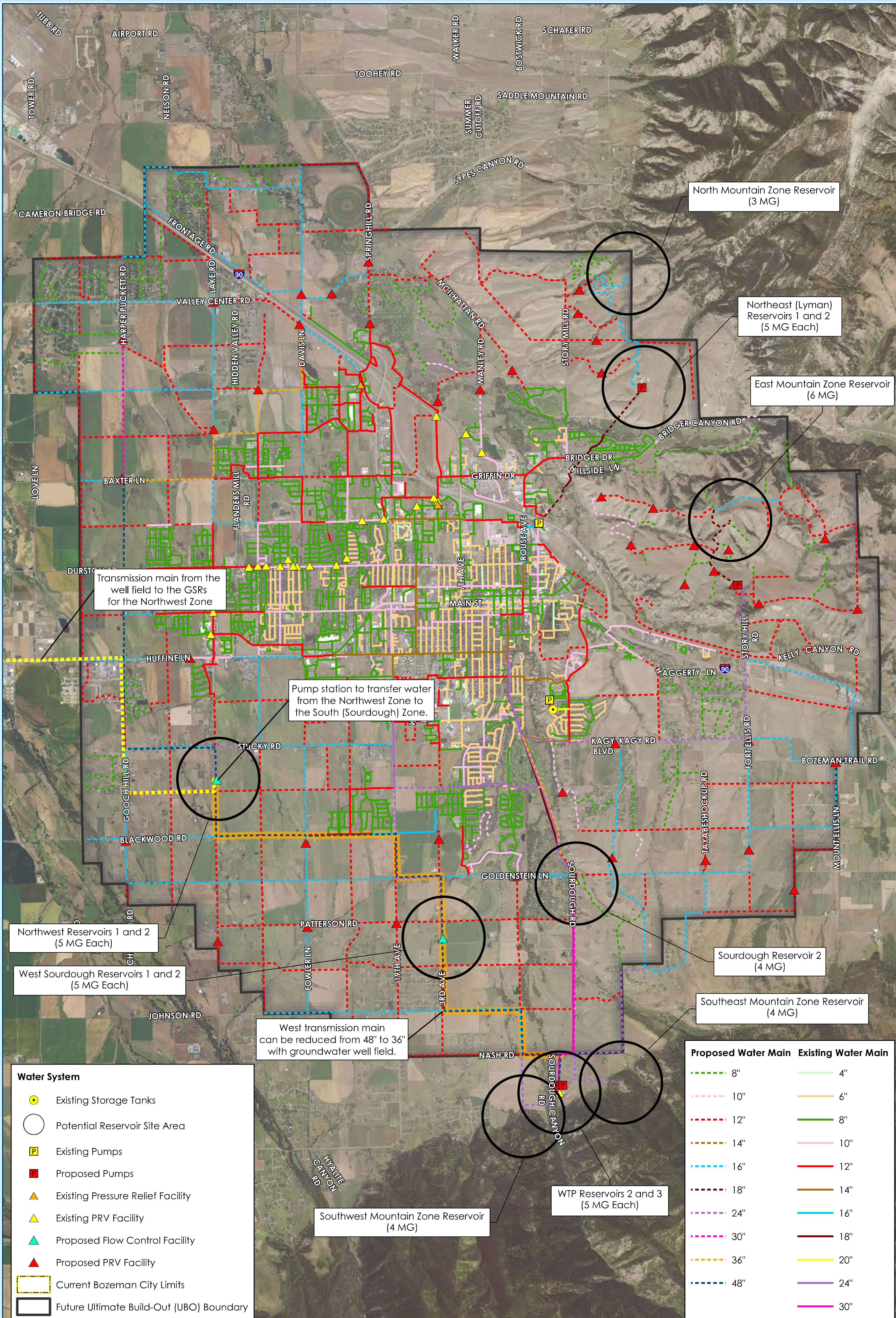

Figure 9-10: Proposed Water Distribution System with Groundwater Well Field

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0 0.4 0.8 1.2 1.6 Miles

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FUT_3100 (Future MDD with water conservation)

The FUT_3100 scenario was simulated during future MDD conditions with water conservation. This scenario was simulated under the following conditions, as described in **Section 3.5.2**:

- A global demand reduction factor was applied to the system to reduce the UBO MDD of 53.6 MGD to 49.8 MGD.
- The maximum source water capacity from Lyman Creek is 3 MGD and 46.8 MGD from the Sourdough WTP.

Model results indicate that there is no significant change in comparison to the model results for MDD conditions under the FUT_3000 scenario. The following highlights are noted:

- The system experiences similar pressures (within 3 psi), with some of the variability due to increased reservoir water surface elevation fluctuations.
- The system experiences similar maximum rates of headloss during peak hour conditions.
- Since water transmission and distribution mains are sized based on MDD and fire flows, the impact of a 10 percent reduction in MDD attributable to water conservation is not great enough to warrant a change in pipeline diameters associated with proposed improvements.

FUT_3110 (AFF during future MDD with water conservation)

The FUT_3110 scenario was simulated to determine available fire flow during future MDD with water conservation. The scenario was performed under the operating conditions established for the FUT_3100 scenario.

The results of the analysis shows that there is no significant change in available fire flow throughout the system. The average increase in available fire flow is approximately 0.3 percent. The results indicate that the system is sized to meet fire flow and that the magnitude of the MDD conditions with and without water conservation does not have a significant impact on distribution system performance.

<u>EC_3400 (Existing system during MDD with implementation of Phase I of the West Transmission Main</u>

The EC_3400 scenario represents an interim analysis of existing MDD conditions with construction of Phase 1 of the West Transmission Main from Nash Rd. to the intersection of 19th and Graf St. The scenario was developed in conjunction with EC_3410 to show how a redundant transmission main between the WTP and the distribution system could potentially benefit the City.

Figure 9-11 shows system reservoir operations with the transmission main installed. **Figure 9-12** provides information on the extent of proposed transmission main infrastructure utilized under this scenario. The following highlights are noted:

- A flow control structure will be required to control flow into the system from the new transmission main.
- The existing flow control valve that controls flow into the Sourdough reservoir will continue to operate.
- Under normal operating conditions, the existing and proposed flow control valve settings can be adjusted to provide flow from each control point into the distribution system.

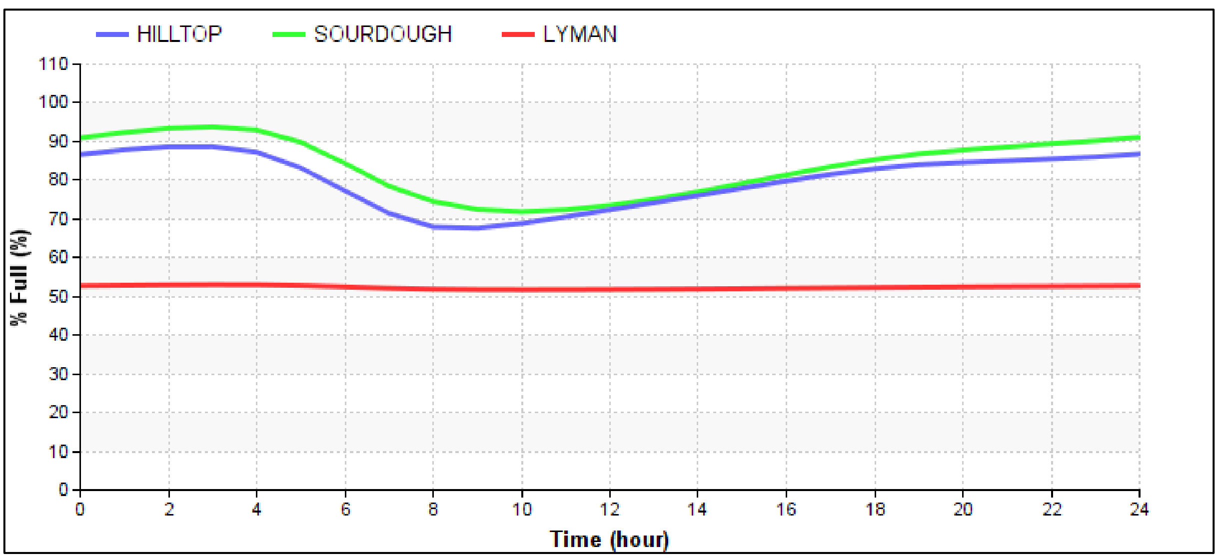

Figure 9-11: Proposed Water Distribution System Reservoir Levels with Phase 1 of the West Transmission Main

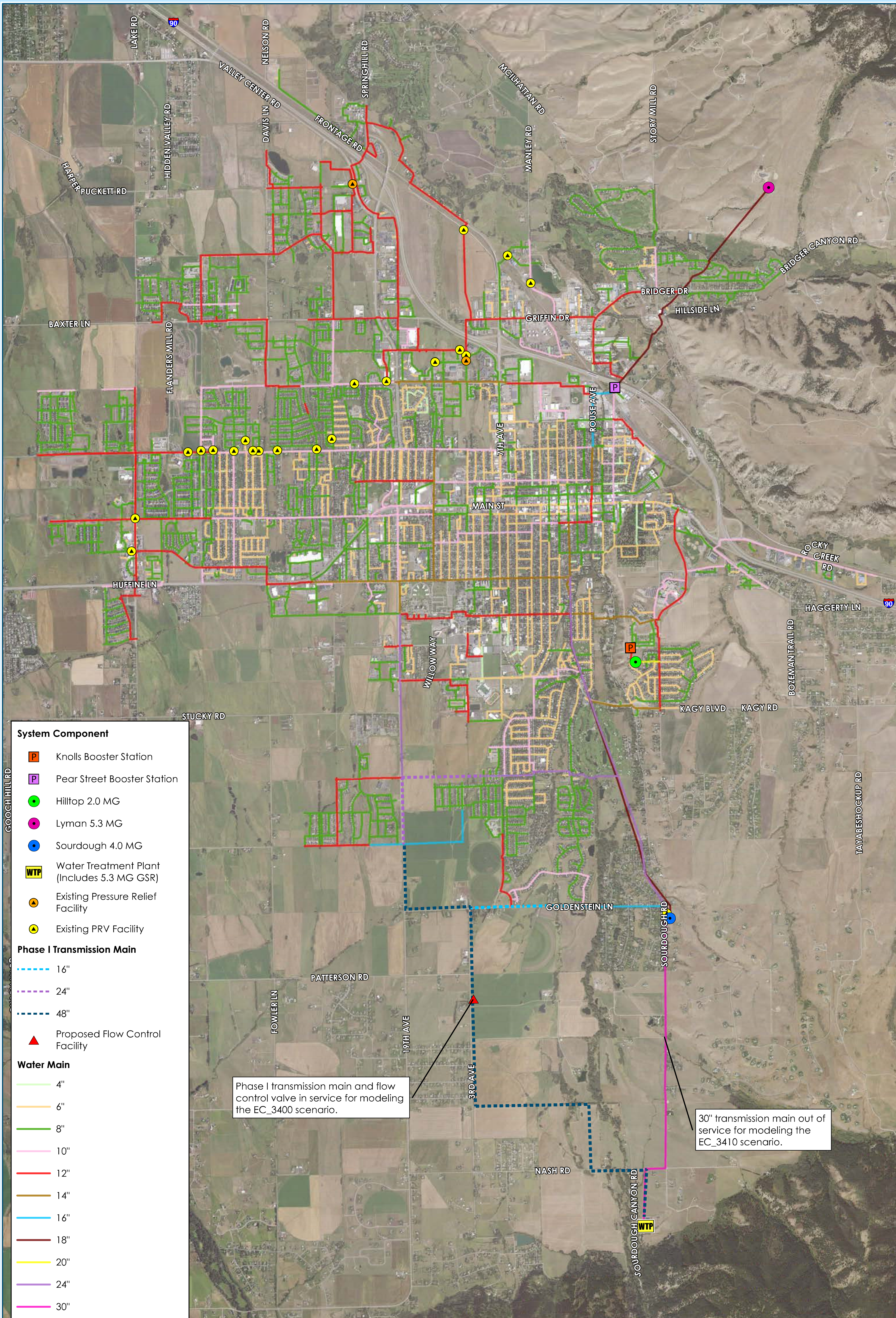

Figure 9-12: Existing Water Distribution System with Phase I of the West Transmission Main

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0 0.25 0.5 0.75 1 Miles

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EC_3410 (Existing system during MDD with implementation of Phase I of the West Transmission Main; and transmission main break.

The EC_3410 scenario simulates operation of the new Phase I West Transmission Main, with a transmission main break on the existing RCCP 30-inch main between the WTP and the Sourdough reservoirs. **Figure 9-12** provides information regarding the location of the simulated transmission main break. The following highlights of the model results are noted:

- The existing 30-inch transmission main between the WTP and the Sourdough reservoir was removed from service.
- No major operational issues were identified. The new flow control valve on the proposed transmission main will require adjustment to account for no flow entering the system at the Sourdough reservoir flow control valve.
- **Figure 9-13** shows reservoir level fluctuation with a transmission main break on the existing 30-inch main. Reservoir levels showed a slight decrease when the existing main was taken out of service; however, the decrease is considered insignificant.

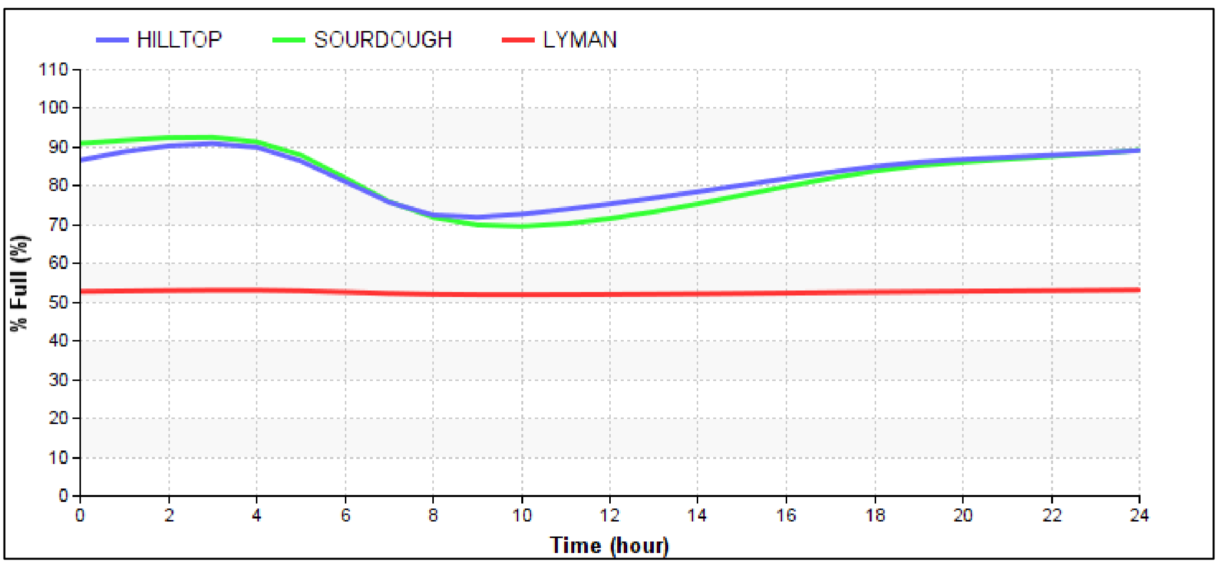

Figure 9-13: Proposed Water Distribution System Reservoir Levels with Phase I Transmission Main and shutdown between WTP and Sourdough Reservoir

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Construction of Phase I of the West Transmission Main provides a redundant connection to the source of the vast majority of the City's water supply. Specifically, the redundant transmission main provides the following benefits:

- The West Transmission Main will allow the existing Sourdough Transmission Main to be taken offline for inspection, maintenance and repair, if necessary.
- The West Transmission Main provides system redundancy for the existing 18-inch and 24-inch transmission mains between the Sourdough reservoir and Kagy Blvd. Two areas along the existing 18-inch and 24-inch transmission mains were assessed for failure with the new Phase I West Transmission Main installed:
  - If a failure occurs on either of the existing 18-inch and 24-inch transmission mains between the Sourdough reservoir and Graf St, the model indicates that the water level in the Hilltop Reservoir will likely drop to near empty within 24 hours of shutdown. The Phase I West Transmission Main will allow the City to maintain minimum levels within the Hilltop Reservoir and the Pear Street Booster Station would still be needed to supply water and assist in maintaining pressure in the South Zone.
  - If a failure occurs on either of the existing 18-inch and 24-inch transmission mains between Graf St and Kagy Blvd, the model indicates that the water level in the Hilltop Reservoir will drop lower than typical operations, but maintain a level of 30 to 60 percent full with the Phase I West Transmission Main installed. Without the Phase West I Transmission Main, the City would need to rely heavily on the Pear Street Booster Station to supply water and maintain pressure in the South Zone.

9.10 Summary of Future System

A summary of improvements necessary to serve the UBO water distribution system is provided in **Table 9.8**. The recommended improvements are further discussed in the following sections.

Facility Type	Existing	Additional Facility Improvements
Major Distribution Pipeline (miles) (size 12-inches to 14-inches)	38	106 miles of 12-inch major distribution main
Transmission Main (miles) (size 16-inches to 48-inches)	14	94 miles of transmission main ranging from 16-inches to 48-inches in diameter (47 miles included in the CIP)
Pressure Zones	6	8 new main pressure zones (2 existing zones are combined to a single new zone)
Pressure Reducing Stations	22	25 new Pressure Reducing Stations to serve new zones and to allow emergency flow between zones (does not include mountain sub-zones)
Storage Reservoirs (Volume)	4 (16.6 MG)	12 new reservoirs (72 MG total system storage)

Table 9.8: Summary of Proposed System Improvements

9.10.1 UBO Water Main Overview

A total of 200 miles of distribution and transmission main, ranging from 12-inches to 48-inches in diameter, is recommended to address future projected water demand requirements associated with projected UBO conditions. The proposed distribution layout follows these general concepts:

- A framework of 12-inch and 16-inch water main was used to establish the backbone of the future distribution network.
  - 12-inch water mains were routed along half-section lines.
  - 16-inch transmission mains were routed along section lines and large transportation corridors identified in the TMP.
  - .
- At certain locations, the water mains were upsized to handle larger flows, minimize headloss, or to convey adequate water to storage reservoirs or pump stations at planned locations within the distribution system.

9.10.2 Transmission Main

The proposed system is comprised of approximately 94 miles of new transmission main ranging in size from 16-inches to 48-inches in diameter. Nine key transmission mains are identified to serve the UBO and meet the hydraulic criteria established in **Chapter 5**. Three key transmission mains identified as near-term projects consist of the following:

- Sourdough Transmission Main (3.9 Miles of 30"-36" pipe)
    - The Sourdough Transmission Main provides system redundancy between the Sourdough WTP and the distribution system.
- Lyman Transmission Main (1.6 Miles of 18" pipe)
    - The Lyman Transmission Main replacing existing AC water main which will allow for additional conveyance capacity for existing anticipated growth areas.
- West Transmission Main (20.8 Miles of 16"-48" pipe)
    - The West Transmission Main serves anticipated growth area on the west side of the planning boundary and reduces head loss across the existing system.

There are six key transmission mains identified for implementation as long-term projects to serve the mountain zones and additional areas within the UBO. The long-term transmission main projects consist of the following:

- East Transmission Main (3.8 Miles of 24" pipe)
- Southeast Mountain Zone Transmission Main (5.6 Miles of 16"-24" pipe)
- Southwest Mountain Zone Transmission Main (1.4 Miles of 24"-30" pipe)
- North Mountain Zone Transmission Main (2.5 Miles of 16"-24" pipe)
- East Mountain Zone Transmission Main (1.6 Miles of 18"-24" pipe)
- Groundwater Well Field Transmission Main (5.7 Miles of 36" pipe)

9.10.3 System Pressure

The proposed UBO system is comprised of 12 pressure zones with a total of 44 new PRV stations. Twenty-five of the proposed PRV facilities are intended delineate boundaries between pressure zones or allow emergency flows from one zone to another. The remaining 19 PRV facilities are intended to establish sub-zones in the mountain zones.

- Pressures zones to serve the UBO are summarized in **Table 9.9**.
    - Four existing zones are unchanged or expanded: South, Knolls, Northeast, and Gallatin Park.
    - The West Zone and the Northwest Zone are combined to create a new zone called Northwest 1 Zone.

- Eight new pressure zones include: Northwest 1, Northwest 2, Northwest 3, Southwest Mountain, Water Treatment Plant, Southeast Mountain, East Mountain, and North Mountain.

- New pressure zones within the UBO are configured to maintain pressures between 50 psi and 110 psi.
- Areas with extreme topographic relief (Mountain Zones) are maintained between 50 psi and 150 psi. This larger pressure operating range was permitted in order to minimize the need for additional pressure control systems.
- Operating pressures within the South Zone, Northeast Zone, Knolls Zone, and Gallatin Park Zone were unaltered from existing conditions, but the demand for water reflects development of UBO areas. Maintaining existing system pressures is required to satisfy present fire suppression design parameters. With a modification to the City's code requirements as discussed in **Chapter 7**, eventual pressure reduction in the South Zone may become a possible strategy for future implementation.

Zone	HGL (ft)	Description
Northwest 3	4725	New zone to serve the growth area northwest of the City.
Northwest 2	4850	New zone to serve the growth area northwest of the City.
Northwest 1	4885	The existing West and Northwest Zones are combined to form the new Northwest 1 Zone.
Gallatin Park	4975	Existing Zone that will expand northward.
Northeast (Lyman)	5038	Existing Zone that grows to the east.
South (Sourdough)	5125	Existing zone that expands to the southwest and east at UBO.
Knolls	5185	Existing Zone that fills in at UBO and remains a sub-zone to the South Zone.
Water Treatment Plant	5221	Existing Zone that expands to the west to serve user directly from storage at the WTP.
Southwest Mountain	5350	New zone to serve an area southwest of the City.
North Mountain (2 sub-zones)	5360	New zone to serve the growth area north of the City.
Southeast Mountain (2 sub-zones)	5560	New zone to serve the growth area southeast of the City.
East Mountain (3 sub-zones)	5630	New zone to serve the growth area east of the City.

Table 9.9: Summary of Pressure Zones

9.10.4 System Storage

A total of 12 new storage reservoirs, with a total storage capacity of approximately 57 MG, is recommended to serve the future UBO projected demands and satisfy established hydraulic criteria. With existing storage, the total system storage for the UBO would be 72.3 MG. New storage locations include the following:

- Storage for each new mountain zone: North, East, Southeast, and Southwest;
- New storage at the Lyman reservoir;
- Additional storage at the WTP;
- Additional storage at the existing Sourdough reservoir site and at a location west of the existing site; and
- New storage in the southwest area of the City.

9.10.5 Pumping Capacity

The proposed mountain pressures zones in the UBO boundary will require new pump stations. Reservoirs are recommended for each of the mountain zones and pump stations are generally sized as follows to meet MDD at UBO for zones with storage. Pump stations required to serve the mountain zones include the following:

- Southwest Mountain Zone Pump Station: 1,800 gpm at 135 ft TDH
- Southeast Mountain Zone Pump Station: 2,100 gpm at 345 ft TDH
- East Mountain Zone Pump Station: 3,100 gpm at 530 ft TDH
- North Mountain Zone Pump Station: 1,450 gpm at 340ft TDH

CHAPTER 10 RECOMMENDED IMPROVEMENTS

This chapter presents recommended capital improvement projects identified in the course of assessing the current water system and evaluating near and long-term needs. The recommended water system improvement projects represent the results of: 1) the existing and future system evaluations (**Chapter 6** & **Chapter 9**); 2) the Pressure Zone and Pressure Reduction Evaluation presented in **Chapter 7**; and 3) multiple workshops and meetings with City staff. A comprehensive list of identified improvement projects was compiled. Cost estimates were provide for each project, and then the projects were prioritized utilizing a ranking process developed in collaboration with City staff.

This chapter includes descriptions of the project categories, cost estimates, prioritization ranking, implementation considerations, and of each of the recommended improvements.

10.1 CIP Project Categories

Projects within the CIP were dived into eight categories:

- Condition Assessment
- Growth and Development
- Optimization
- Rehabilitation and Repair
- Storage
- Studies
- Supply and Transmission

The development of these categories provided the conceptual framework of how the system would ideally work at UBO, facilitated CIP prioritization and timeframe progressions, and correlated projects to the City's present fiscal resources (i.e. what type of project makes the best use of the available capital improvement budget. Each category is described in the following subsections.

10.1.1 Condition Assessment

Condition assessment is a process used to identify degradation of a pipeline before failure, or to identify viable life remaining in a segment of pipeline to avoid spending money on unnecessary replacement or rehabilitation. There is a wide range of utility investment in condition assessment. The potential advantage of a robust condition assessment program is more efficient use of capital.

Currently, the City performs low-resolution inspections on its water mains using acoustic leak detection. Acoustic leak detection is an effective way to proactively identify leaks and attack water loss. Higher resolution acoustic equipment can be used to assess the wall thickness and therefore general condition of a pipe. To date the City has not performed, or contracted for, higher resolution inspection / condition assessment of its water distribution system.

The condition assessment projects identified in the Water Facility Plan Update were based on the City of Bozeman's risk assessment[19] of the existing distribution system and the tools and processes presented in Water Research Foundation Project 4656[20]. The research project tools use the estimated consequence of failure, with generalized economies of scale, to identify when different levels of condition assessment are cost-justified, based on the risk cost associated with failure of the pipe. This assessment for the City of Bozeman identified several condition assessment projects, which are cost-justified in order to prevent failure of the pipes.

10.1.2 Growth and Development

Areas of growth and development are shown in **Figure 10-2**. Projects identified for the growth and development category provide the necessary infrastructure to serve both existing and future customers. Growth and development projects meet three needs:

1. Service for future development.
2. Demand for water supply in already developed areas.
3. Infill and redevelopment.

These projects primarily consist of "backbone" water mains and PRV facilities to establish proposed pressure zones.

The timing of the need for growth and development projects can be difficult to predict. For this reason, the City treats this class as its own separate category, and the prioritization of improvements is evaluated as growth occurs. Therefore, infrastructure projects that are driven by growth and development are not included as specific capital improvement projects nor included in the CIP tables herein. Estimated costs per linear foot of pipeline along with an estimated cost per PRV facility were completed and provided to the City. **Appendix G** provides the cost sheets for growth and development projects.

[19] Water Distribution System Risk Assessment Response Plan. (April 2015). Bozeman, MT.

[20] Development of Integrated Master Planning and Condition Assessment: A Road Map for Utilities - 4656 (Tech.). (n.d.). Water Research Foundation.

10.1.3 Optimization

Projects identified for the optimization category improve system water quality, promote network water efficiency and movement, help with pressure management, or eliminate facilities to reduce operating cost and improve overall network performance. The projects include SCADA upgrades, PRV improvements, decommissioning of unnecessary assets, information management, and redundant (looped) mains.

10.1.4 Rehabilitation and Repair

Rehabilitation and repair projects are generally associated with pipe segments that experience high break rates, water quality issues, are undersized (cannot attain fire flow goal), or require maintenance. A risk assessment process utilizing these factors in a structured and systematic process was used as a means of identifying pipe segments with highest risk, measured through a consequence and likelihood of failure assessment, and then generating projects to mitigate the risk. Depending on the risk scoring, some of the rehabilitation and repair projects would undergo condition assessment first to better refine the scope of the risk mitigation project to be completed.

In order to budget for possible replacement of pipes identified by condition assessment as requiring replacement, projects were created for each CIP year as a placeholder for funds to perform the identified improvements.

10.1.5 Storage

Projects identified for the storage category were based on the evaluation criteria described in **Chapter 5** in conjunction with the existing and future system hydraulic modeling analysis. The projects increase the overall water storage capacity of the system, ensure adequate fire flow, and supplement water supply during periods of planned maintenance or emergencies. All recommended storage projects consist of ground storage reservoirs.

10.1.6 Studies

The objective of study projects is to perform additional analysis and develop better information such that the City can make informed decisions regarding future projects. Recommended studies include water supply investigations, water rights evaluations, SCADA master planning, hydrologic evaluations, reservoir siting, and transmission main planning.

10.1.7 Supply

Projects identified for the supply category were determined through the hydraulic modeling analysis. The intent of the projects is to increase the overall water supply available to the distribution system, which ensures the City maintains its current level of service and can adequately provide water to future customers.

Supply projects consist of groundwater well development, enhanced spring production, watershed hydrology evaluations, and expanding the Sourdough WTP.

10.1.8 Transmission

Projects identified for the transmission category were determined through the hydraulic modeling analysis. The identified projects consist of large diameter transmission main (16-inch to 48-inch) that originate from sources of supply and convey large volumes of water throughout the entire distribution system. The proposed transmission mains are critical to maintain both the existing and future levels of service.

10.2 Opinion of Probable Project for CIP Development

This section describes the methodology used to develop the Opinion of Probable Project Cost (OPPC) for the various types of projects outlined in the WFPU and contains the following information:

- Opinion of Probable Project Cost Basis
- Estimate Classification
- Estimating Exclusions
- Total Estimated Project Cost
- Total Opinion of Probable Project Cost

10.2.1 Opinion of Probable Project Costs Basis

The OPPC values were based on the total capital investment necessary to complete a project from engineering design through construction. All estimates are based on engineering experience and judgment, recent bid tabulations for projects of similar scope, and input from area contractors and material suppliers. All costs are presented in 2016 dollars with respect to cost index factors.

Total estimated project costs were categorized into five components, which include the following:

- Hard Costs – The actual physical construction of development (i.e. grading, excavation, materials).

- Soft Costs – Fees that are not directly related to labor and building materials (i.e. architecture and engineering fees, permitting/environmental, contract administration, legal).
- Property Acquisitions Costs – The cost to obtain property, right-of-way, and easements.
- Contingency - Amount added to the estimated cost to cover both identified and unidentified risk events that occur on the project.
- Inflation – The application of the cost index anticipated between the time an estimate is prepared and when the project is bid or projected for construction.

The sum of these five components is the total OPPC. The OPPC values are based on the preliminary concepts and layouts of the water system components developed as a result of the hydraulic modeling of the system and corresponding recommendations. The estimate is to be an indication of fair market value and is not necessarily a reflection of the lowest bid. Fair market value is assumed to be mid-range tender considering four or more competitive bids.

10.2.2 Estimate Classification

The Association for the Advancement of Cost Engineering (AACE) provides guidelines for applying the general principles of estimate classification to project cost estimates (i.e., cost estimates that are used to evaluate, approve, and/or fund projects). The purpose for following a classification process it to align the level of estimating with the use of the information. The estimates provided in the Water Facility Plan Update are classified in accordance with the criteria established by AACE cost estimating classification system referred to as Standard Practice 18R-97.

In accordance with AACE criteria, the OPPC values are representative of Class 4 estimates. A Class 4 estimate is defined as a Study or Feasibility Estimate. Typically, the engineering effort is from 1 to 15 percent complete. Class 4 estimates are used to prepare planning-level effort cost scopes or complete an evaluation of alternative schemes, technical feasibility, and preliminary budget approval or approval to proceed to the next stage of implementation.

Expected accuracy for Class 4 estimates typically range from -30 to +50 percent, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.

10.2.3 Estimating Exclusions

Unless specifically identified, the following estimating exclusions were assumed in the development of the cost estimates.

- Water right acquisition or transfers.

- Environmental mitigation of hazardous materials and/or disposal.
- O&M costs for the project components.

10.2.4 Total Estimated Project Cost

Hard Costs

Hard costs, or sometimes referred to as contractor construction costs, represents the actual physical construction of a project. This section was broken down into component unit costs and hard cost markups.

Component Unit Costs

Component Unit Costs - All estimates are based on engineering experience and judgment, recent bid tabulations for projects of similar scope, and input from area contractors and material suppliers. For specific equipment and materials, proposals were requested from vendors and suppliers. The costs were increased by applying a multiplication factor to include the related costs and expenses (such as labor, connections, and misc. materials) required to complete the installation.

Transmission Pipelines

The pipe material assumed for new waterlines was DIP Class 51 ranging from 8-inches to 48-inches in pipe diameter. **Table 10.1** presents the transmission pipeline construction costs. The cost is based on the following assumptions:

- Earthwork
    - Trench depth of 6.5 ft to 10 ft to the top of pipe
    - Utility bedding for pipe and conduit
    - Compaction of bedding in the trench
    - Structural backfill and compaction
- Fittings and valves (additional 20 percent applied to pipeline cost).
- Includes surface restoration of unpaved areas and county road impacts.

Think Big. Go Beyond.

Pipe Diameter (inch)	Ductile Iron Pipe ($/lf)
8	$61
10	$74
12	$87
14	$101
16	$118
18	$136
20	$157
24	$192
30	$294
36	$369
42	$453
48	$632

Table 10.1: Transmission Pipeline Cost per Linear Foot

Existing Pipeline Replacement

The pipe material assumed for water main replacement was DIP Class 51 for 4-inch to 30-inch diameter pipelines. **Table 10.2** presents the transmission pipeline construction costs for water main replacement. The cost is based on the following assumptions:

- Review of the 2005 Facility Plan replacement costs
- Review of historical bid prices for the City
- Indexed 2005 costs to July 2016 dollars
- Includes surface restoration (in town road repair and replacement)

Pipe Diameter (inch)	Ductile Iron Pipe ($/lf)
4	$208
6	$220
8	$233
10	$258
12	$276
14	$315
16	$341
18	$388
20	$444
24	$524
30	$673

Table 10.2: Existing Transmission Pipeline Cost per Linear Foot

Non-Potable Pipelines

The pipe material assumed for new non-potable pipelines is AWWA C900 PVC ranging from 4-inches to 10-inches in pipe diameter. **Table 10.3** presents the non-potable pipe construction costs. The cost is based on the following assumptions:

- Earthwork
  - Trench depth of 6.5ft to top of pipe
  - Utility bedding for pipe and conduit
  - Compaction of bedding in the trench
  - Structural backfill and compaction
- Fittings and valves (accounts for 20 percent of the pipeline cost)
- Includes surface restoration of unpaved areas

Pipe Diameter (inch)	PVC ($/lf)
4	$16
6	$21
8	$28
10	$37

Table 10.3: Non-Potable Pipeline Cost per Linear Foot

Storage Facilities

Project costs for proposed water storage facilities were prepared for AWWA D110 – Type I pre-stressed concrete tanks based on recent City construction estimates. The cost is based on the following assumptions:

- Circular structure at grade with a height ranging between 20 and 35 feet
- Includes major components (i.e. fittings, valves, electrical, and telemetry)
- Includes site access and landscaping

Project cost estimates for pre-stressed concrete construction were based on a planning level cost of $1per gallon of storage volume provided by the structure.

Pump Station

The costs for proposed pump stations are based on recent construction projects of similar scope, vendor quotes, and engineering experience and judgement. The estimated cost reflect the following assumptions:

- Includes building, pumps, process piping, meters, valves, gauges, electrical, I&C, HVAC, and telemetry
- Site access and landscaping costs are included in ground storage tank cost estimate
- Chemical feed systems are not required

Hard cost markups

Hard costs markups are applied to the hard costs and construction costs to calculate total construction costs. The hard cost markups are reflected in the individual capital improvement project cost estimates. Markups vary depending on the size and type of the project.

1. Mobilization – 0-10 percent
   Mobilization costs include the administrative costs and expenses to mobilize materials, equipment, and labor to the jobsite.

2. Traffic Control – 0-2 percent
   Traffic control was assigned to projects that occur in the public right-of-way, primarily transmission projects.

3. Erosion Control – 0-1 percent
   Erosion control will likely be required for all construction projects to ensure compliance with Storm Water Pollution Prevention Plans.

4. Contractor Indirect Project Costs – 0-15 percent
   Costs associated with contractor overhead variability including project management, bonding, insurance, subcontractors, etc.

Soft Costs

To adequately complete the planning, design, and construction of projects listed in this WFPU, there are significant soft costs that will be required. Soft costs are non-construction labor costs consisting of architecture and engineering fees, permitting and environmental compliance, contract administration, legal fees, etc.. Soft costs are applied to the hard costs plus the hard cost markups. A breakdown and summary of the soft costs that were included in the cost estimates are provided below.

1. Engineering – 0-15 percent
   Costs include preliminary engineering through final design, which involves the development of final project plans and specifications that will be stamped by a professional consulting engineer. Engineering costs include disciplines such as process, civil, electrical, mechanical, architectural, and structural. Costs also include surveying, testing, investigations, and inspection. Examples include surveys of pipeline alignments and facility parcels, security and safety inspections, material and geological testing, and inspection services.

2. Construction Administration and Management – 0-10 percent
   Costs include services to provide quality control, quality assurance, and construction management during the construction phase and services associated with the initial operational including training of operations, maintenance, and supervisory staff.

3. Legal and Administrative – 0-5 percent
   Costs associated with the local and State project approval process, and any legal costs. Responsible tasks may include, but not limited to road crossing permits, construction permits, county building permits, Inter-Disciplinary Team Meetings, NEPA compliance, expenses incurred by the City, etc.

Property Acquisition Costs

Property acquisition costs are associated with purchasing property and acquiring right-of-way or easements for the project. Costs generally consist of payments to landowners.

Contingency

A contingency is an amount added to the base cost to cover both identified and unidentified risk events that occur on the project. Depending on the project type, the contingency values ranged from 10 to 30 percent. The contingency values were added to the overall project base cost (i.e. hard and soft costs) in anticipation of uncertainties inherent to the planning-level analysis completed for the Water Facility Plan Update.

Inflation

Projects intended for construction several years in the future include a factor for inflationary impacts to address the general trend of cost indices, which accounts for future labor, material, and equipment cost increases beyond values at the time the estimate is prepared. For this planning-level analysis and the unknown nature of construction/project implementation, costs are reflective of 2016 dollars, and the adjustments for the inflation of construction costs is not considered necessary.

Summary of estimate markups

Table 10.4 provides a summary of the suggested hard costs markups, soft costs, and contingency rate percentages.

Item	Rate Range (%)
Hard Cost Markups	
Mobilization	0-2
Traffic Control	0-2
Erosion Control	0-1
Contractor Overhead and Profit	0-15
Soft Costs	
Engineering	0-15
Construction Administration and Management	0-10
Legal and Administrative	0-10
Project Unknowns	
Contingency	10-30

Table 10.4: Total Estimate Project Markup Summary

Opinion of Probable Project Cost Sheets

Appendix G provides the OPPC cost sheets used to generate estimated cost information for each proposed capital improvement project identified in this chapter.

10.3 CIP Prioritization and Implementation

As detailed in **Chapter 3**, projected future water demands will exceed both the Lyman Spring and existing Sourdough WTP capacity at some point in the future, which will require the City to evaluate a number of different options (e.g. Groundwater Well Field Development, natural storage of Sourdough water, increased production from Lyman Spring).

The extent of each of these conceptual projects precludes them from simultaneous implementation. Instead, the City will adjust future capital improvement projects as the feasibility and cost-effectiveness of these projects is revealed, based on studies scheduled for completion in the short-term. The study results may significantly alter the prioritization of these CIP projects, or clarify how much investment in each is warranted. To provide the City with the opportunity to select the most advantageous path forward to meet its future water system needs based on the outcomes of near-term study efforts, a framework was developed to facilitate decision-making at key milestones.

Figure 10-1 illustrates the resulting decision making process and provides a basic overview of the different planning options that would be evaluated. There are four, large competing project pathways that require large capital investments:

- Option 1 - If the groundwater wellfield assessment indicates good potential to develop a substantial groundwater supply, the City should implement the work necessary to capitalize on it in the near-term. Simultaneously, the near-term focus of the West Transmission Main should be to optimize delivery of this redundant source of supply to the Sourdough WTP.
- Option 2 – If significant groundwater supply development does not appear feasible, but natural storage on Sourdough Creek and/or additional Hyalite water is, then the City should focus on implementation of projects to increase long-term supply through the Sourdough WTP. The implementation of the West Transmission Main would be adjusted (larger transmission main) to convey this additional source water from the Sourdough WTP to the western side of the City.
- Option 3 – If groundwater supply, the implementation natural storage in Sourdough and additional source water from Hyalite do not prove viable in the short-term, the City should consider increasing the available storage on the Lyman system. The Lyman system is not capable of providing enough additional water to significantly contribute to the City's long-term water demands, but if other supplies or redundant sources are not viable, maximization of Lyman supply will be critical for reliability and use during potential emergencies.

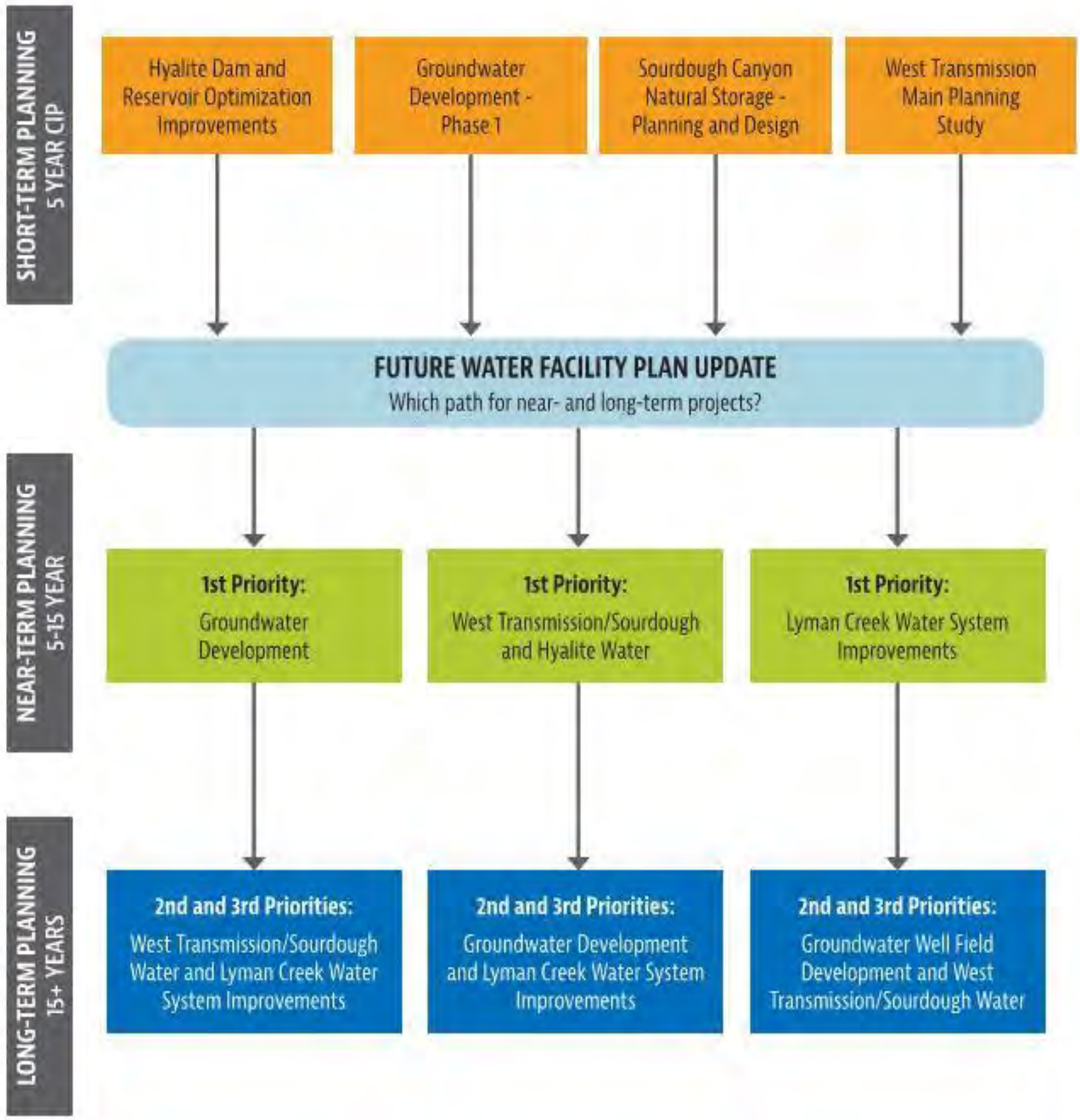


Figure 10-1: Future Project Implementation Pathways

10.3.1 CIP Prioritization Criteria and Process

A CIP prioritization methodology to facilitate spending limited capital in the most cost-effective manner possible and to provide a consistent and transparent assessment of each project.

The methodology consisted of developing project narratives for each identified project, using the City's capital planning worksheets. The worksheets are typically used by City staff to further describe a project, present anticipated costs and timeframes, and ultimately establish prioritization for implementation. The project team then developed a prioritization process, using a project scoring methodology with nine prioritization factors. The prioritization factors were modifications of questions that the City uses in internal CIP worksheets. In addition, a few additional, typical CIP factors were added. **Table 10.5** lists the final nine prioritization factors used in the matrix to develop the City's CIP.

Prioritization Factors	
1	Are there other affected projects? Coordination, prerequisite, opportunistic, etc.
2	How is capacity affected by this project?
3	Describe the criticality (i.e., importance) of this project to the operation.
4	How is connectivity affected by this project? (Reliability/Redundancy)
5	What safety issues are mitigated with this project?
6	What regulations or standards are attained with this project?
7	Risk Assessment
8	How is efficiency improved by this project?
9	What is the impact of this equipment?

Table 10.5: Prioritization Factors

Each prioritization factor was given an importance factor, so that greater importance could be given to factors most critical to the City. Six scoring levels were developed for each prioritization factor ranging from no impact to extreme impact. The projects were then ranked based on the aggregation of the categories' weighting factor multiplied by the impact score.

The timing of the CIP projects was divided into short-term (0 to 5 year), near-term (5 to 15 year) and long-term (unscheduled) timeframes. The prioritization process resulted in a ranking for every short-term project, with the highest scoring reflecting the highest priority for the City. **Appendix H** shows the initial short-term project prioritization ranking list.

The complete worksheets prepared for the short-term projects are included in **Appendix I**.

10.4 Recommended Capital Improvements

Draft capital improvement project descriptions, OPPC, and prioritization and planning worksheets were provided to the City in late August 2016 for use in the internal CIP development process. **Tables 10.2**, **10.3**, and **10.4** present the capital improvement projects recommended for initial consideration by the City for the short-term, near-term, and long-term planning periods, respectively.

Figure 10-2 provides an overview of the recommended capital improvements.

10.4.1 Short-Term (0-5 year) CIP Projects

Capital Improvement	Project Category	Project Description	Project Rank	Project ID	OPPC
Risk-Based CA #5 - Sourdough Transmission Main Condition Assessment	Condition Assessment	Perform high resolution condition assessment of Sourdough Transmission in accordance with 2015 Condition assessment report	1	WFP_02a	$719,785
Sourdough Transmission Main CA Based Rehab	Rehabilitation and Repair	The project consists of repairs/rehab work on the existing 30-inch bar wrapped concrete Sourdough transmission main, from the Sourdough water treatment plant to the Sourdough reservoir, and the 16-in bar-wrapped concrete pipe from Sourdough Reservoir to Kagy.	2	WFP_02b	$1,000,000
Sourdough Water Rights Utilization Study	Studies	Study to develop recommended project(s) to enable long-term utilization of Sourdough water rights.	3	WFP_04	$400,000
West Transmission Main Planning Study	Studies	Identify design parameters, right-of-way, route and permitting for the West Transmission Main, so that design and construction can proceed once funds are available.	4	WFP_01a	$400,000
Hilltop Reservoir Inspection and Mixing System	Optimization	Inspect reservoir. Furnish and Install Mixer(s), Power and Control and update Reservoir SCADA to include remote monitoring capability of mixer(s).	5	WFP_05	$239,616
SCADA Master Plan	Optimization	Evaluate options and develop recommendations for Wide-area network implementation for planned remote water infrastructure. Develop SCADA design, equipment and SCADA tagging and programming standards. Formulate data accessibility and SCADA integration with other City applications (e.g., CMMS)	6	WFP_12	$250,000
Risk Based CA # 4 - Lyman Creek Water Transmission Main	Condition Assessment	Prepare and evaluate condition assessment plan and execute condition assessment for the high consequence transmission main through the northeast Bozeman corridor to confirm likelihood of failure.	7	WFP_19a	$134,670
Groundwater Well Field Development - Phase 1	Supply	This project consists of three components: 1) Purchase land for construction and operation of a municipal groundwater well field; 2) Obtaining mitigation water necessary to implement a DNRC-approved mitigation plan; and 3) Water right permitting to obtain a beneficial water use permit, the legal water rights necessary to operate a municipal groundwater well, 4) Well development	8	WFP_10a	$8,612,400
Vertical Asset Risk Assessment Phase 1	Studies	Expand the use of risk to vertical plant assets including reservoirs, groundwater sources, PRV's, booster stations, and treatment plants. Create a generalized risk policy for the city that will allow for the comparison of risk across various asset classes on a comparable scale, which then allows for better allocation of CIP funding and effort to the highest risk assets across the entire utility. Develop implementation plan	9	WFP_13	$19,838
Sourdough Reservoir Inspection and Improvements	Optimization	This project would entail taking the Sourdough Reservoir offline (once the West Transmission Main is online), inspecting it and repairing it as necessary. This project may or may not include reconfiguration of the inlet/outlet configuration to provide flow-through hydraulics.	10	WFP_16	$500,000
Vertical Asset Risk Assessment Phase 2	Studies	Expand the use of risk to vertical plant assets including reservoirs, PRV's, booster stations, and treatment plants. Perform risk assessment per Implementation plan.	11	WFP_14	$85,963
Risk Based R&R	Rehabilitation and Repair	This bucket of funds could be used for both Risk-based CA and those which are only Fire-flow driven (or opportunistic upgrades)	12	WFP_15	$2,500,000
PRV Upgrades (approximately 16 sites)	Optimization	Waterproof, Install above-ground weather proof enclosures (for PLC rack, PLC, I/O, Power supply, battery charger, battery, control transformer, switch, network communication, HMI, and related equipment), single phase power source, wide area network communication connection, Electric Unit Heater, Vent fan, sump pump and safety access (Bilco Hatch access) in non-traveled way sites. Install field instrumentation for remote indication of pressure, flow, temperature, and select water quality parameters (as required). Standardize pressure controls, provide remote indication and control functionality, and improve upon confined space entry limitations.	13	WFP_18	$7,637,760
Lyman Transmission Main CA Based Rehab	Rehabilitation and Repair	This project consists of repair and rehabilitation work on the lower Lyman transmission pipeline, approximately between Lyman Reservoir and Pear Street Pump Station.	14	WFP_19b	$500,000
Integrated Water Resources Plan Update	Studies	Update to the 2013 Integrated Water Resources Plan	15	WFP_11	$150,000
Reservoir 1 - Siting	Studies	Location and land acquisition of the next major storage facility	16	WFP_09a	$350,000
Pear Street Booster Station Upgrade	Rehabilitation and Repair	Rehabilitate station by adding 2 - 1000 gpm high service pumps, 1 - 400 gpm normal service pump, electrical and control (either VFD and discharge check valve or Soft Starts with discharge control valves); verify condition or install new 5038 Zone PRVs (1 low range, 1 high range) to back feed Zone. Allows interim operation as booster station into South 5125 Zone for South Zone reservoirs, as well as back feed when Lyman Reservoir to be taken out of service. Provide SCADA control logic modifications as required.	17	WFP_38	$486,720

Think Big. Go Beyond.

SCADA Phase 1	Optimization	Install Wide Area Network infrastructure, connect PRV vaults, verify/ install Pressure relief per each pressure zone, central site improvements, update historian, and implement pressure management regimes to improve system pressure protection	18	WFP_24	$2,239,050
Risk Based CA #2 - Downtown Area	Condition Assessment	Prepare and evaluate condition assessment plan and execute condition assessment for the high consequence distribution and backbone mains through the downtown Bozeman corridor with moderate likelihood of failure to confirm or update likelihood of failure in order to more accurately identify pipes as candidates for R&R.	19	WFP_32	$28,116
West Transmission Main - Phase 1 Design	Transmission	Design of the first phase of the West Transmission Main, the criteria for which would be developed in the West Transmission Main Planning Study.	20	WFP_01b	$2,907,235
Redundant North 5038 Zone Feed	Optimization	Evaluate, and upgrade as required, 2nd location of redundant feed of 5125 Zone water into North (5038) Zone. This will ensure alternative source of water exists and is sufficient to feed North Mountain Zone in time when Lyman Creek source is unavailable.	21	WFP_26	$59,488
Risk Based CA # 1 - West Bozeman Transmission	Condition Assessment	Prepare and evaluate condition assessment plan and execute condition assessment for the high consequence transmission main through the southwest Bozeman corridor to confirm likelihood of failure.	22	WFP_34	$47,826
Risk Based CA #3 - Baxter/Oak south of Freeway	Condition Assessment	Prepare and evaluate condition assessment plan and execute condition assessment for the high consequence distribution and backbone mains through this corridor with moderate likelihood of failure to confirm or update likelihood of failure in order to more accurately identify pipes as candidates for R&R.	23	WFP_35	$23,775
Water Information Management Solutions (WIMS)	Optimization	Data management and analytical tool development to enhance water system information use	24	WFP_36	$186,300
Notes: NR = Not ranked				Total	$29,478,542

Table 10.6: Short-term (0-5 Year) Capital Improvement Recommendations

10.4.2 Near-Term (5-15 year) CIP Projects

Capital Improvement	Project Category	Project Description	Project Rank	Project ID	OPPC
Hyalite Watershed and Reservoir Study	Studies	Analyze long-term water supply provided by the Hyalite watershed and existing reservoir, assess current dam operation and feasibility of implementing control tower improvements and/or raising the dam, and the potential to create a strategic water reserve for reduced drought vulnerability.	NR	WFP_23	$350,000
Sourdough Canyon Natural Storage and Wetland Enhancement - Planning and Design	Studies	Evaluate the optimal project that will enable the City to utilize currently unused Sourdough water rights.	NR	WFP_53	$500,000
Hyalite Reservoir Infrastructure and Control Improvements	Studies	Armoring of the control tower (to enable some year-over-year storage capacity) and control upgrades to improve winter operation	NR	WFP_54	$3,858,300
Sourdough Transmission Main – Phase 1	Transmission	The project consists of constructing approximately 8,700 feet of 30-inch DIP transmission main, which would parallel the existing older 30-inch concrete main. The proposed transmission main would connect to a new 48-inch DIP coming from the WTP and extend to the Sourdough reservoir.	NR	WFP_03	$4,241,272
Groundwater Well Field Transmission Main - Phase 1	Transmission	The project consists of a constructing a new transmission 24-inch main that would connect the City's existing distribution system to a potential future groundwater well field system located west of the current City boundary. The precise location of the required main is dependent on groundwater yields and well locations, but will likely convey water from the Four Corners region to the City along Huffine Road.	NR	WFP_20	$8,974,969
Water Treatment Plant Master Metering	Optimization	The project consists of installing a master meter (42-inch mag meter) on the finished water pipe from the Sourdough Water Treatment plant.	NR	WFP_17	$750,000
PRV Abandonments (approximately 6 sites)	Optimization	Abandon (in place) existing PRV's serving Northwest Zone, at sites to be determined through detailed hydraulic modeling. Install looped mains to maintain connectivity. Project done in conjunction with other transmission main improvements serving Northwest Zones	NR	WFP_22	$460,512
SCADA Phase 2	Optimization	Same as SCADA Phase 1, less central site improvements. Use iHistorian data to enhance operations (e.g., reservoir cycling), maintenance (e.g., SCADA-CMMS integration). Addition of additional remote sites to network and network expansion as required.	NR	WFP_25	$2,595,840
Remote Water Quality Surveillance System	Optimization	Establish baseline Water Quality monitoring system using SCADA network. Refine/enhance flushing program, develop enhanced Lyman Creek Reservoir and any water reuse system components surveillance.	NR	WFP_33	$56,925
5125 West Sourdough Reservoir 1	Storage	The project consists of a constructing a new 5 MG gravity fed ground storage reservoir to the south/southwest of the City, which would tie into the West Water Transmission Main – Phase 1 and serve the existing City water distribution system.	NR	WFP_09b	$8,420,875
5560 Southeast Mountain Reservoir and Pump Station	Storage	The project consists of a constructing a new 4 MG ground storage reservoir, pump station, and transmission main that would serve two new future pressure zones located southeast of the existing City limits.	NR	WFP_30	$18,542,698
4975 Northwest Reservoir 1	Storage	The project consists of a constructing a new 5 MG ground storage reservoir southwest of town, which would tie into the West Transmission Main – Phase 2 and serve the City's future western and northern water distribution system.	NR	WFP_31	$8,420,875
Water Facility Plan Update	Studies	Update the 2016 Water Facility Plan	NR	WFP_27	$500,000
Drought Management Plan Update	Studies	Update the 2016 Drought Management Plan	NR	WFP_28	$20,000
Lyman Creek Water System Improvements	Supply	This project consists of 1) constructing new reservoirs on the Lyman spring source, located at a higher elevation, 2) replacement of existing 18-inch asbestos concrete transmission pipe between the new reservoirs and the City, 3) installation of Micro Hydro on the Lyman transmission line, 4) relocation of existing chlorine and fluoride chemical feeds, and 5) subsequent decommissioning of the existing Lyman Reservoir and Pear Street Booster Station and 6) installing pressure reducing vaults or micro hydro facilities on the tie-ins of the Lyman source to the Northeast Zone.	NR	WFP_07	$24,805,440
Groundwater Well Field Development - Phase 2	Supply	The project consists of a constructing second transmission 24-inch main that would connect the City's existing distribution system to a potential future groundwater well field system located west of the current City boundary. The precise location of the required main is dependent on groundwater yields and well locations, but will likely convey water from the Four Corners region to the City along Huffine Road.	NR	WFP_10b	$12,978,600
Lyman Spring Groundwater Well Development	Supply	Exploratory and test well drilling, and construction of well infrastructure to increase the firm yield of the Lyman Creek water source, within the existing water right.	NR	WFP_21	$2,500,000
Sourdough Canyon Natural Storage and Wetland Enhancement	Supply	Construction of Natural Storage and Wetland Enhancement	NR	WFP_51	$8,000,000

West Transmission Main – Phase 1 Construction	Transmission	The project consists of a constructing a new transmission main from the Sourdough water treatment plant to the southwestern edge of the existing distribution network (S. 19th and Graf St.) to serve future anticipated growth and provide water delivery redundancy.	NR	WFP_01c	$23,689,082
Sourdough Transmission Main – Phase 2	Transmission	The project will consist of constructing either a parallel transmission main or replacing and upsizing the existing transmission main between the existing Sourdough Reservoir and the Hilltop Reservoir. This scope and phasing of this project will depend on a condition assessment of the existing Sourdough transmission main.	NR	WFP_08	$5,785,788
East Transmission Main	Transmission	The project consists of a constructing a new transmission main that would ensure adequate water supply capacity for future developments located both east and northeast of the existing distribution system (extending approximately from East Kagy Blvd to Kelly Canyon Rd and Story Hill Rd).	NR	WFP_29	$6,092,316
West Transmission Main - Phase 2	Transmission	The project consists of extending the West Transmission Main – Phase 1 further northwest, to serve anticipated future growth and provide redundancy (extending approximately from South 19th to Baxter Lane).	NR	WFP_39	$35,891,887
Groundwater Well Field Transmission Main - Phase 2	Transmission		NR	WFP_52	$8,974,969
Notes: NR = Not ranked				Total	$186,410,348

Table 10.7: Near-term (5-15 Year) Capital Improvement Recommendations

Think Big. Go Beyond.

10.4.3 Long-Term (Unscheduled) CIP Projects

Capital Improvement	Project Category	Project Description	Project Rank	Project ID	OPPC
4975 Northwest Reservoir 2	Storage	The project consists of expanding storage at the site of the Phase I reservoir by constructing a second 5 MG ground storage reservoir southwest of town, which would tie into the West Transmission Main and serve the City's future western and northern water distribution system.	NR	WFP_40	$8,420,875
5125 West Sourdough Reservoir 2	Storage	The project consists of expanding storage at the site of the Phase I reservoir by constructing a second 5 MG ground storage reservoir to the south/southwest of the City, which would tie into the West Water Transmission Main and serve the existing City water distribution system.	NR	WFP_41	$8,420,875
5350 Southwest Reservoir and Pump Station	Storage	The project consists of a pump station located near the WTP, a transmission main to transfer water, and a new 4 MG reservoir to serve the new Southwest Mountain Zone.	NR	WFP_42	$13,795,846
5360 North Mountain Reservoir and Pump Station	Storage	The project consists of a pump station located near the Lyman reservoir, a transmission main to transfer water, and new 3 MG reservoir to serve the new North Mountain Zone.	NR	WFP_43	$10,584,320
5630 East Mountain Zone Reservoir and Pump Station	Storage	The project consists of a pump station located on the east end of the city, a transmission main to transfer water, and a new 6 MG reservoir to serve the new East Mountain Zone.	NR	WFP_44	$16,589,604
Sourdough Reservoir 2	Storage	The project consists of expanding storage at or near the existing Sourdough reservoir with a second 4 MG reservoir.	NR	WFP_45	$6,506,700
Water Treatment Plant Reservoir 2	Storage	The project consists of expanding storage at the WTP with an additional 5 MG of storage.	NR	WFP_46	$7,779,750
Water Treatment Plant Reservoir 3	Storage	The project consists of expanding storage at the WTP with an additional 5 MG of storage.	NR	WFP_47	$7,779,750
Sourdough Water Treatment Plant Expansion	Supply	Expand the Sourdough WTP to be able to produce approximately 34 MGD	NR	WFP_55	$25,000,000
West Transmission Main - Phase 3	Transmission	The project consists of extending the West Transmission Main from the intersection of Baxter Ln and Gooch Hill Rd to the northeast, to serve anticipated future growth and provide redundancy (extending approximately from Baxter Ln to the intersection of I-90 and Davis Ln).	NR	WFP_48	$10,936,342
West Transmission Main - Phase 4	Transmission	The project consists of extending the West Transmission Main from the intersection of Baxter Ln and Gooch Hill Rd to the north, to serve anticipated future growth and provide redundancy (extending from Baxter Ln to south of Valley Center Rd).	NR	WFP_49	$3,755,221
West Transmission Main - Phase 5	Transmission	The project consists of extending the West Transmission Main to the north, to serve anticipated future growth and provide redundancy (extending from south of Valley Center Rd to the north side of I-90).	NR	WFP_50	$2,457,009
Notes: NR = Not ranked				Total	$122,026,292

Table 10.8: Long-term (15+ Year) Capital Improvement Recommendation

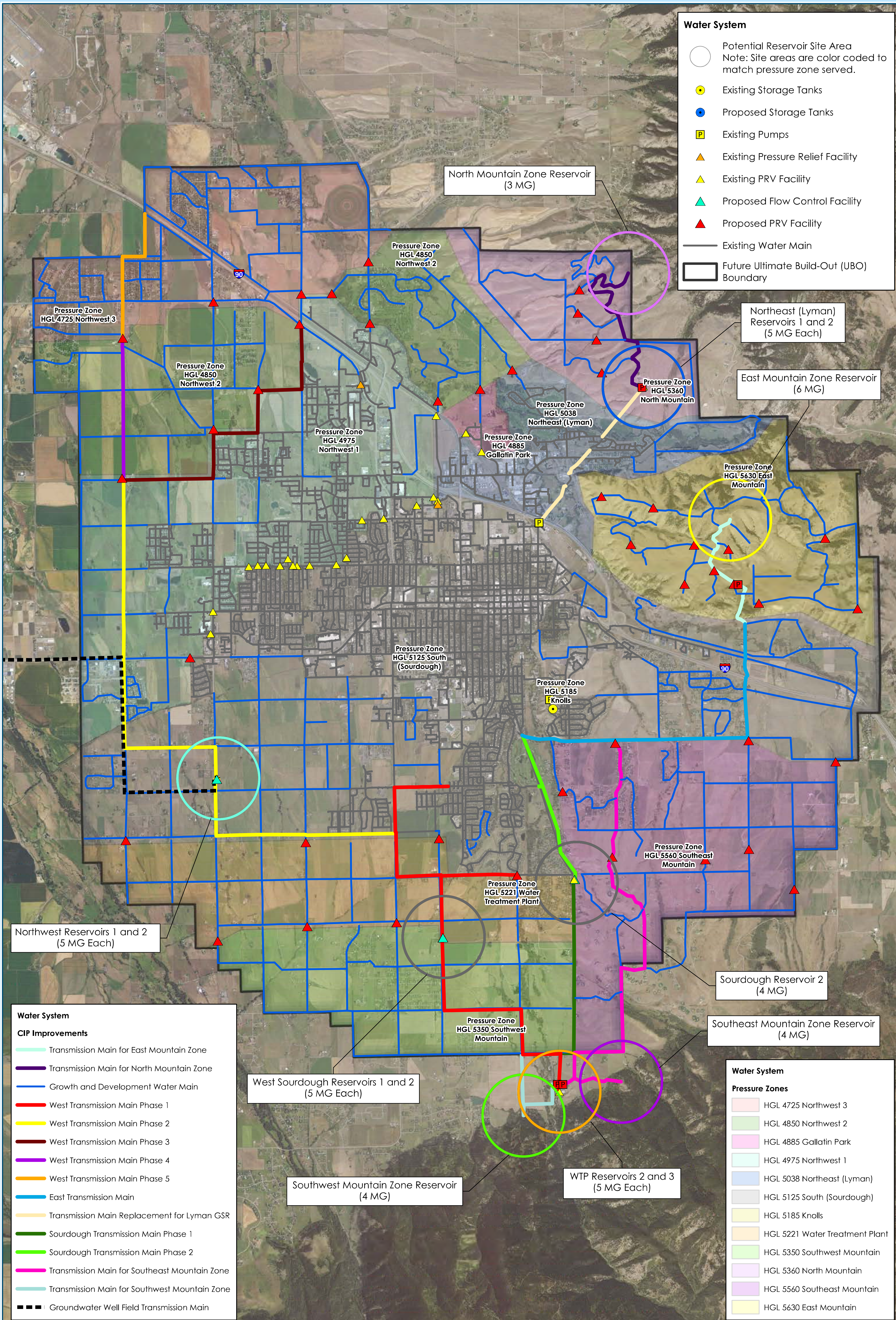


Figure 10-2: Recommended Capital Improvements Overview

City of Bozeman Water Facility Plan Update

Advanced Engineering and Environmental Services, Inc.

10.5 City of Bozeman Fiscal Years 2018-2022 Capital Improvements Program

As noted above, the recommended list of capital improvements presented in the previous section were provided to the City to assist in the internal CIP development process. During the development of the water CIP, City staff reviews it along with the capital improvement projects for each department (e.g. Wastewater, Stormwater, Parks, Transportation, Water, etc.) and make adjustments based on budgets, current overall City needs, and new information.

After reviewing the recommend list of capital improvements, City staff decided to move some planning-level projects from the near-term planning period to the short-term planning period:

- Sourdough Transmission Main – Phase 1
- Sourdough Canyon Natural Storage and Wetland Enhancement – Planning and Design
- Hyalite Watershed and Reservoir Study
- Hyalite Reservoir Infrastructure and Control Improvements
- Groundwater Well Field Transmission Main – Phase 1

The projects were moved into the short-term planning period for the following factors:

1) The primary focus of the short-term capital improvement projects was on transmission, storage, and distribution systems. Raw water supply needs were not weighted as heavily in the initial prioritization process. City staff recognized the need to place more emphasis on bolstering or securing future water supplies, supported by the recently completed Drought Management Plan.
    a. This emphasis moved the Sourdough and Hyalite watershed and infrastructure studies up in the CIP prioritization.
    b. Results from the initial groundwater assessment study indicated that developing a groundwater supply for the City is feasible.
    c. Once these short-term projects are completed the City will know what is the most cost-effective near-term path for water supply investments (as reflected in **Figure 10-1**.
2) Sourdough Transmission Main - Recently completed design work for storage at the Sourdough WTP identified a hydraulic bottleneck resulting from a local high spot in the profile of the existing Sourdough Transmission Pipeline (near the corner of Sourdough and Nash Rd). The high spot limits future peak capacity of the transmission line and output from the Sourdough WTP. It was decided by the City to include new Sourdough transmission main to the 5.3 MG water storage tank project slated for summer of 2017. Construction of this new transmission section negates the need for two projects that

were previously included in the short-term CIP (Risk-Based CA #5 and Sourdough Transmission Main CA Based Rehab). With this change in plans, Sourdough Transmission Main – Phases 1 and 2, were modified by City staff and split into 3 phases. The brief description of the modified phases is discussed below:

- Sourdough Transmission Main – Phase 1 (The project consists of constructing approximately 3,000 feet of 48-inch DIP transmission main, starting at the Sourdough WTP, cutting the corner at Nash and Sourdough, and tying into the existing transmission main).
- Sourdough Transmission Main – Phase 2 (The project consists of constructing approximately 8,000 feet of 30-inch DIP transmission main, which will start at the end of the Phase 1 connection point and go to the Sourdough Reservoir).
- Sourdough Transmission Main – Phase 3 (The project will consist of constructing either a parallel transmission main or replacing and upsizing the existing transmission main between the existing Sourdough Reservoir and the Hilltop Reservoir).

The CIP prioritization was adjusted, and affected projects were revised where modifications to the initial scope, cost, and timeframe were necessary. The final CIP was presented to the City Commission for consideration and approval in December of 2017.

The adopted City of Bozeman CIP for fiscal years 2018 - 2022 is provided in **Table 10.9**. The prioritization planning process created under the Water Facility Plan Update will be revisited annually by City staff and utilized during subsequent CIP planning periods. City staff will be able to reprioritize projects depending on outcomes of short-term studies and the direction of short-term growth and development currently being experienced by the City of Bozeman.

10.5.1 City of Bozeman Fiscal Years 2018-2022 Water Capital Improvements

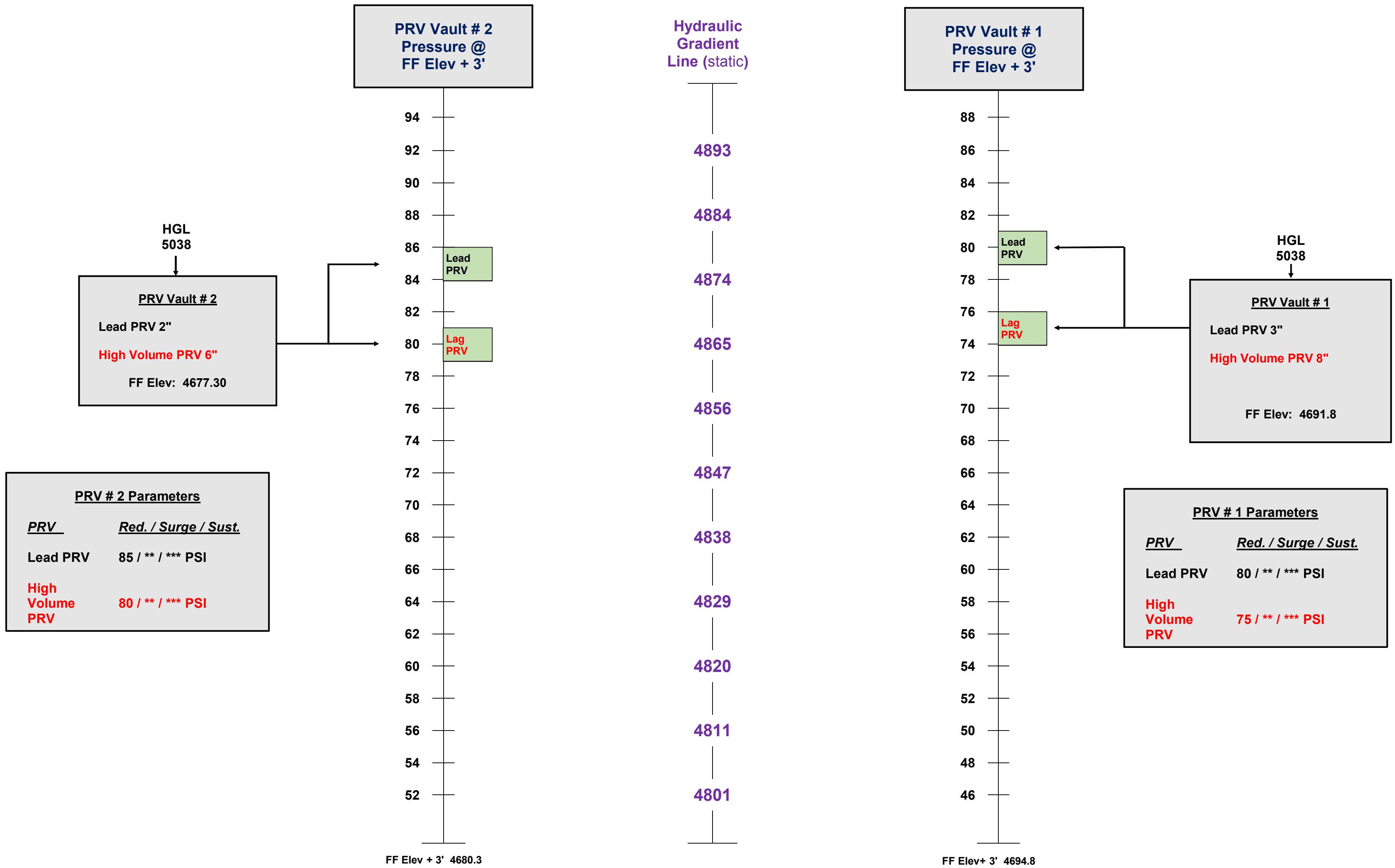
Capital Improvement	Project Description	Year Scheduled	OPPC
SCADA Master Plan	Evaluate options and develop recommendations for Wide-area network implementation for planned remote water infrastructure. Develop SCADA design, equipment and SCADA tagging and programming standards. Formulate data accessibility and SCADA integration with other City applications (e.g., CMMS)	FY18	$150,000
Pear Street Booster Station Upgrade	Rehabilitate station by adding 2 - 1000 gpm high service pumps, 1 - 400 gpm normal service pump, electrical and control (either VFD and discharge check valve or Soft Starts with discharge control valves); verify condition or install new 5038 Zone PRVs (1 low range, 1 high range) to backfeed Zone. Allows interim operation as booster station into South 5130 Zone for South Zone reservoirs, as well as backfeed when Lyman Reservoir to be taken out of service. Provide SCADA control logic modifications as required.	FY18	$547,000
Watershed & Reservoir Optimization Study	Hydrologic and operations study of Sourdough, Hyalite and Lyman Creek municipal watersheds to determine water yields of each respective watershed supply source, demonstrate the physical availability of needed water supplies for the City of Bozeman pursuant to the Montana Water Use Act, Optimize operations of hyalite reservoir source and identify improvements needed for year round withdrawals of stored water. Study will also provide for additional data collection needs.	FY18	$150,000
Lyman Transmission Main Condition Assessment	Prepare and evaluate condition assessment plan and execute condition assessment for the high consequence transmission main through the northeast bozeman corridor to confirm likelihood of failure.	FY18	$150,000
Water System Condition Assessment	Prepare and evaluate condition assessment plan and execute water main condition assessments in high risk portions of the city.	FY18	$100,000
Groundwater Test Well	Test well drilling, pumping and monitoring and water quality testing at one or more strategic well field sites identified in the 2016 Groundwater Investigation. Input data into transient hydrogeologic model developed with Groundwater Investigation project.	FY18	$400,000
Sourdough Transmission Main – Phase 1	The project consists of constructing approximately 3,000 feet of 48-inch DIP transmission main, starting at the WTP, cutting the corner at Nash and Sourdough, to tie into the existing transmission main.	FY18	$3,100,000
5125 West Sourdough Reservoir 1 - Siting	Siting study and land acquisition for 5MG ground storage reservoir to serve the South Zone from West Transmission Main	FY19	$350,000
Hilltop Tank Inspection and Mixing System	Inspect reservoir. Furnish and Install Mixer(s), Power and Control and update Reservoir SCADA to include remote monitoring capability of mixer(s).	FY19	$261,120
Sourdough Tank Inspection and Improvements	This project would entail taking the Sourdough Tank offline (once the West Transmission Main is online), inspecting it and repairing it as necessary. This project may or may not include reconfiguration of the inlet/outlet configuration to provide flow-through hydraulics.	FY19	$500,000
Lyman Tank and Transmission Main Design	Design of new Lyman Storage (5MG), new transmission design, chlorination/fluoridation design and CA based repairs design to existing transmission main.	FY19	$750,000
PRV Phase 1 - Mechanical and Structural Upgrades	Upgrade hatch/entry, valving, piping, pressure settings, sump pumps and provide power	FY19	$1,750,000
Groundwater Well Field and Transmission Main Design	Design of groundwater well field and transmission main including necessary appurtenances, instrumentation and controls, and DEQ approvals.	FY19	$500,000
S 11th 12" water main extension	Extension of 12" diameter main per AE2S WFPU in S 11th avenue from current terminus to Graf Street.	FY19	$136,010
Sourdough Canyon Natural Storage - Planning and Design	Alternatives planning and design for sourdough natural storage enhancement project	FY20	$500,000
Redundant North 5038 Zone Feed	Evaluate, and upgrade as required, 2nd location of redundant feed of 5130 Zone water into North (5038) Zone. This will ensure alternative source of water exists and is sufficient to feed North Mountain Zone in time when Lyman Creek source is unavailable.	FY20	$66,880
Water System Condition Assessment	Prepare and evaluate condition assessment plan and execute water main condition assessments in high risk portions of the city.	FY20	$100,000
Groundwater Well Field and Transmission Construction	Water right permitting and mitigation plan; purchase of mitigation water rights; construction of aquifer recharge or other mitigation infrastructure; acquisition of land for well field site; construction of wells, power, power backup, instrumentation and controls, SCADA, control bldg and site improvements; and transmission main construction to tie GW supply into the existing system.	FY20	$8,000,000
Davis 12" Water Main & Valley Center 16" Water Main Extension	Extension of 12" water main in Davis Ln from Catamount to Valley Center & Extension of 16" diameter water main in Valley Center from Davis to 27th. 16" main is per AE2S WFPU. 12" main extends existing 12" main in Davis. These mains needed to support development south of East Valley Center between Davis and 27th.	FY20	$725,729

Sourdough Transmission Main – Phase 2	The project consists of constructing approximately 8,000 feet of 30-inch DIP transmission main, which will start at the end of the Phase 1 connection point and go to the Sourdough Reservoir.	FY20	$4,800,000
Hyalite Dam and Reservoir Optimization Improvements	Armoring of the control tower (to enable some year-over-year storage capacity) and control upgrades to improve winter operation	FY21	$4,000,000
Lyman Tank and Transmission Main Construction	Construct a new 5MG storage tank at Lyman, decommission existing Lyman storage tank, CA-based repairs of the existing Lyman transmission main, new supply main tie in to new storage tank, new transmission main tie in from new storage tank to existing transmission main, new chlorination/fluoridation feed facility. Decommission Pear Street Booster Station if HGL of tank raised to meet Sourdough Tank.	FY21	$8,000,000
SCADA Upgrades & Improvements	Install Wide Area Network infrastructure, connect PRV vaults, verify/ install pressure relief per each pressure zone, central site improvements, update historian, and implement pressure management regimes to improve system pressure protection	FY22	$2,100,000
Water System Condition Assessment	Prepare and evaluate condition assessment plan and execute water main condition assessments in high risk portions of the city.	FY22	$100,000
PRV Phase 2 - Automation and Instrumentation Upgrades	Upgrade pressure instrumentation, automate valve actuation, provide a LAN connection and SCADA programming for real-time monitoring and remote control of PRV settings.	FY22	$6,710,000
		Total	$43,946,739

Table 10.9: City of Bozeman Fiscal Years 2018-2022 Capital Improvements

Appendix A – Existing System Hydraulic Profiles

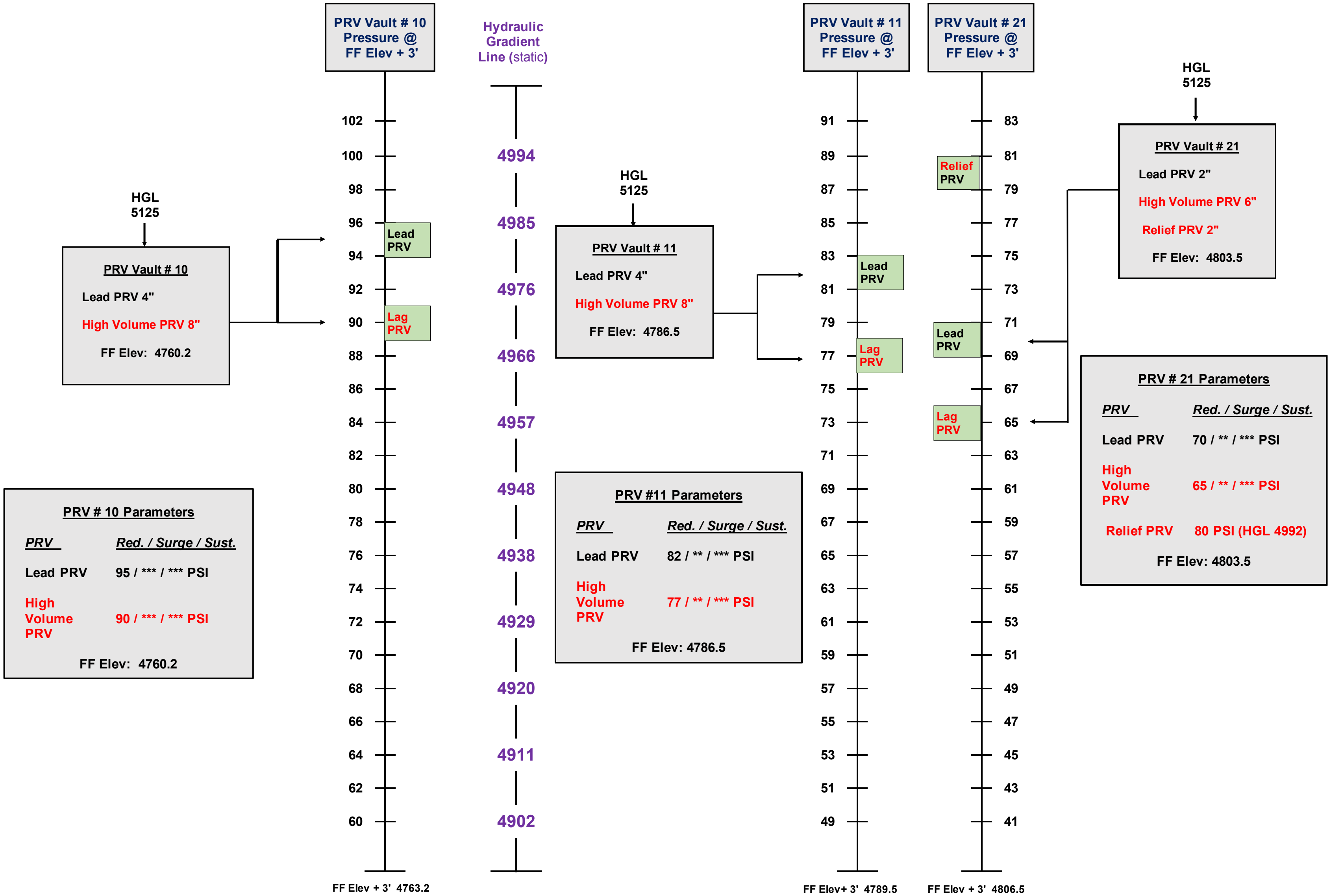
HGL 4885 Zone / Gallatin Park



City of Bozeman

HGL 4885 Pressure Zone / Gallatin Park 04/01/2017

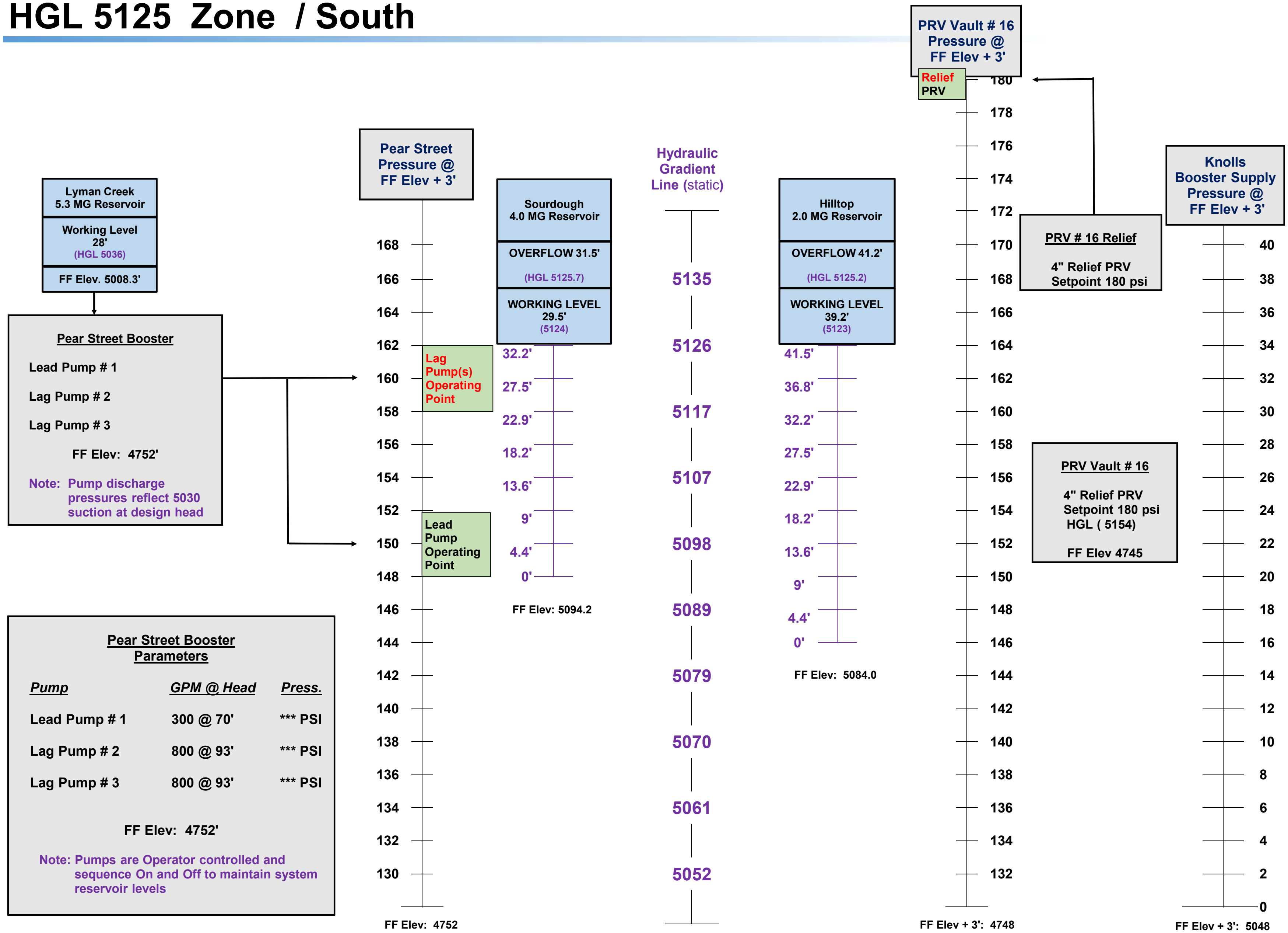
HGL 4980 Zone / West



City of Bozeman

HGL 4980 Pressure Zone / West   04/01/2017

HGL 5125 Zone / South



Pear Street Booster Parameters

Pump	*GPM @ Head*	*Press.*
Lead Pump # 1	300 @ 70'	*** PSI
Lag Pump # 2	800 @ 93'	*** PSI
Lag Pump # 3	800 @ 93'	*** PSI

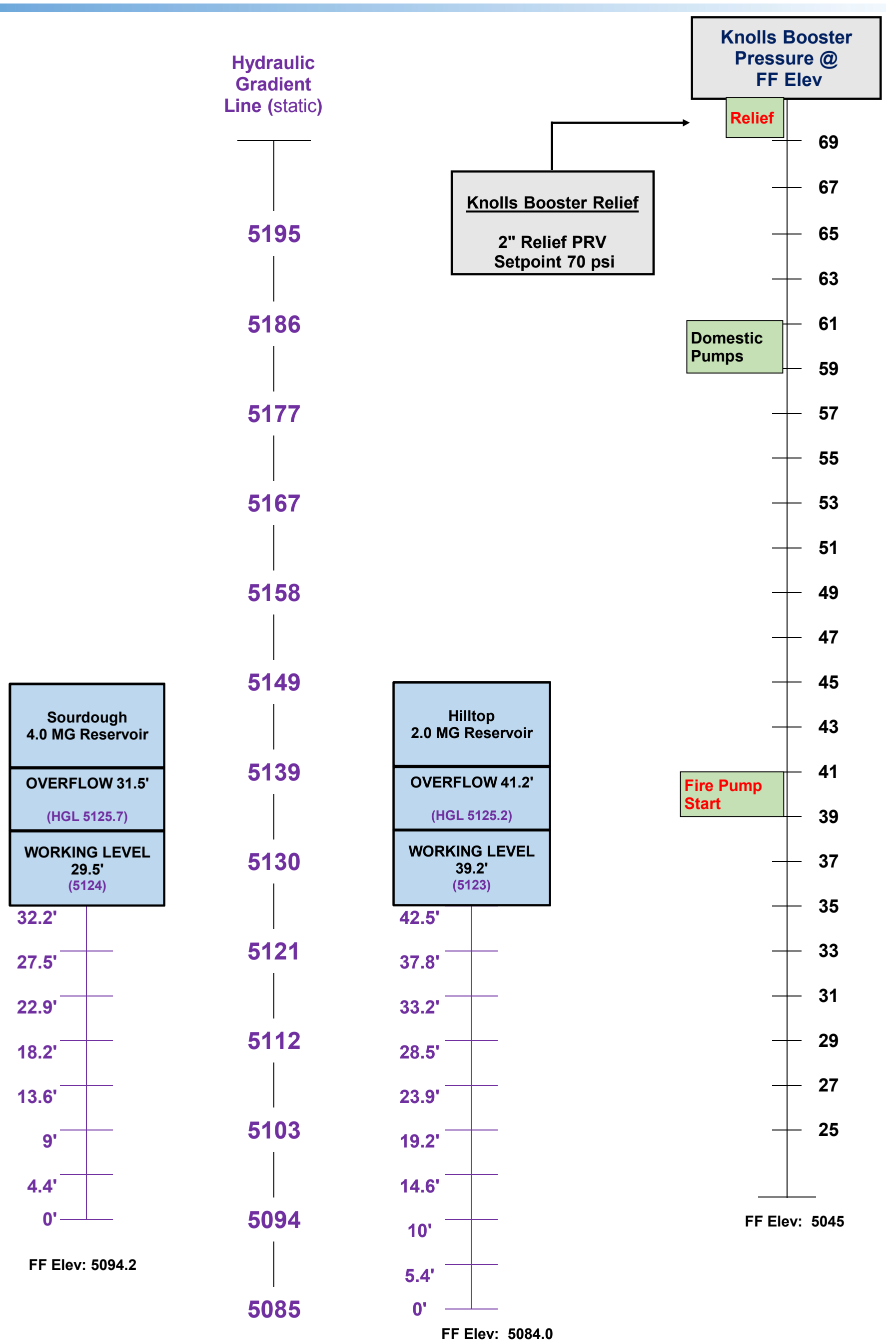
FF Elev: 4752'

Note: Pumps are Operator controlled and sequence On and Off to maintain system reservoir levels

City of Bozeman

HGL 5125 Pressure Zone / South   04/01/2017

HGL 5185 Zone / Knolls Booster Station



Hilltop 2.0 MG Reservoir	Sourdough 4.0 MG Reservoir
Working Level 39.2' (HGL 5123)	Working Level 29.5' (HGL 5124)
FF Elev. 5084.0'	FF Elev. 5094.2'

Knolls Street Booster

Pump	Start / Stop /
Domestic Pump # 1	Start: Up to 4 pumps operate when pressure falls below 60 psi
Domestic Pump # 2	
Domestic Pump # 3	Stop: pressure above 60 psi or flow above 800 GPM
Domestic Pump # 4	
Fire Pump # 1	Start: 40 psi or 800 gpm demand Stop: demand below 500 gpm
Fire Pump # 2	

2" Pressure Relief Valve set @ 70 psi / HGL 5207

FF Elev: 5045'

Note: Domestic pumps (1 - 4) operate 0 - 800 GPM
High Volume Pump (1) starts above 800 GPM or 40 psi

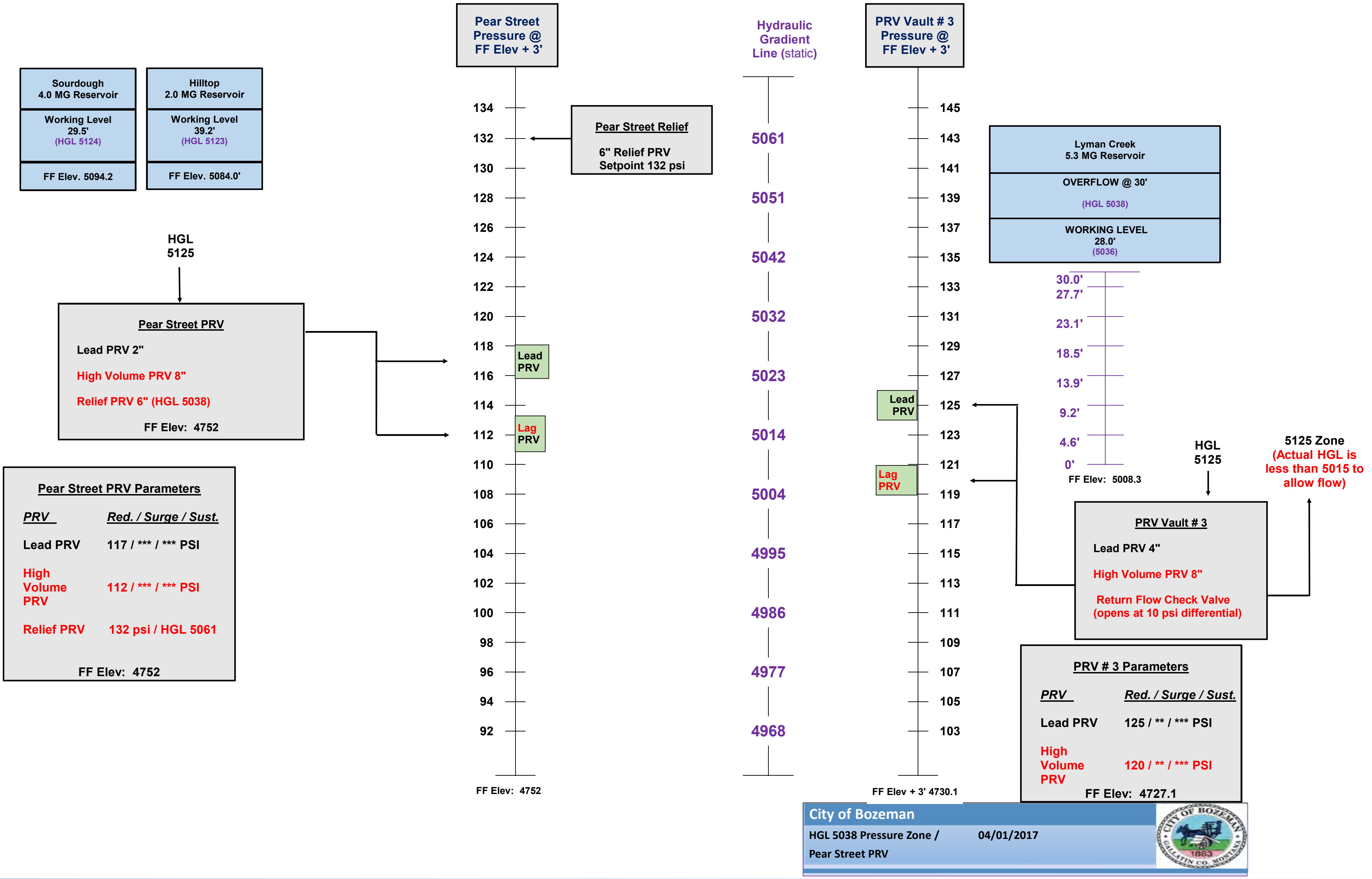
Knolls Street Booster Parameters

Pump	*GPM @ Head*	*Press.*
Domestic Pump # 1	140 @ 130'	*** PSI
Domestic Pump # 2	140 @ 130'	*** PSI
Domestic Pump # 3	140 @ 130'	*** PSI
Domestic Pump # 4	140 @ 130'	*** PSI
H V Pump # 1	1650 @ 70'	*** PSI
H V Pump # 2	1650 @ 70'	*** PSI

FF Elev: 5045'

Note: Pumps sequence On and Off (Cascade) to maintain system discharge pressure (HGL 5185)

HGL 5038 Zone / Pear Street PRV



HGL 4940 Zone / Northwest Master page 1

Hydraulic Gradient Line (static)	PRV Vault # 4 Pressure @ FF Elev + 3'	PRV Vault # 6 Pressure @ FF Elev + 3'	PRV Vault # 7 Pressure @ FF Elev + 3'	PRV Vault # 8 Pressure @ FF Elev + 3'	PRV Vault # 9 Pressure @ FF Elev + 3'	PRV Vault # 12 Pressure @ FF Elev + 3'	PRV Vault # 13 Pressure @ FF Elev + 3'	PRV Vault # 5 Pressure @ FF Elev + 3'	Hydraulic Gradient Line (static)
	102	95	97	83	82	85	83	137	
4964	100	93	95	81	80	83	81	135	4964
	98	91	93	79	78	81	79	133	
4955	96	89	91	77	76	79	77	131 Relief PRV	4955
	94	87	89	75	74	77	75	129	
4946	92	85	87	73	72	75	73	127	4946
	90	83	85	71	70	73	71	125	
4936	88	81	83	69	68	71	69	123	4936
	86	79 Lead PRV	81	67 Lead PRV	66	69 Lead PRV	67	121	
4927	84	77	79	65	64 Lead PRV	67	65 Lead PRV	119	4927
	82	75	77 Lead PRV	63	62	65	63	117	
4918	80 Lead / PRV	73 Lag PRV	75	61 Lag PRV	60 Lag PRV	63 Lag PRV	61	115	4918
	78	71	73	59	58	61	59 Lag PRV	113	
4908	76	69	71 Lag PRV	57	56	59	57	111	4908
	74 Lag	67	69	55	54	57	55	109	
4899	72	65	67	53	52	55	53	107	4899
	70	63	65	51	50	53	51	105	
4890	68	61	63	49	48	51	49	103	4890
	66	59	61	47	46	49	47	101	
4881	64	57	59	45	44	47	45	99	4881
	62	55	57	43	42	45	43	97	
4872	60	53	55	41	40	43	41	95	4872
	FF Elev+ 3' 4732.8	FF Elev+ 3' 4748.9	FF Elev+ 3' 4745.1	FF Elev+ 3' 4776.4	FF Elev+ 3' 4779.7	FF Elev+ 3' 4771.9	FF Elev+ 3' 4775.4	FF Elev+ 3' 4652.6	

City of Bozeman
HGL 4940 Pressure Zone / 04/01/2017
Northwest Master Page 1

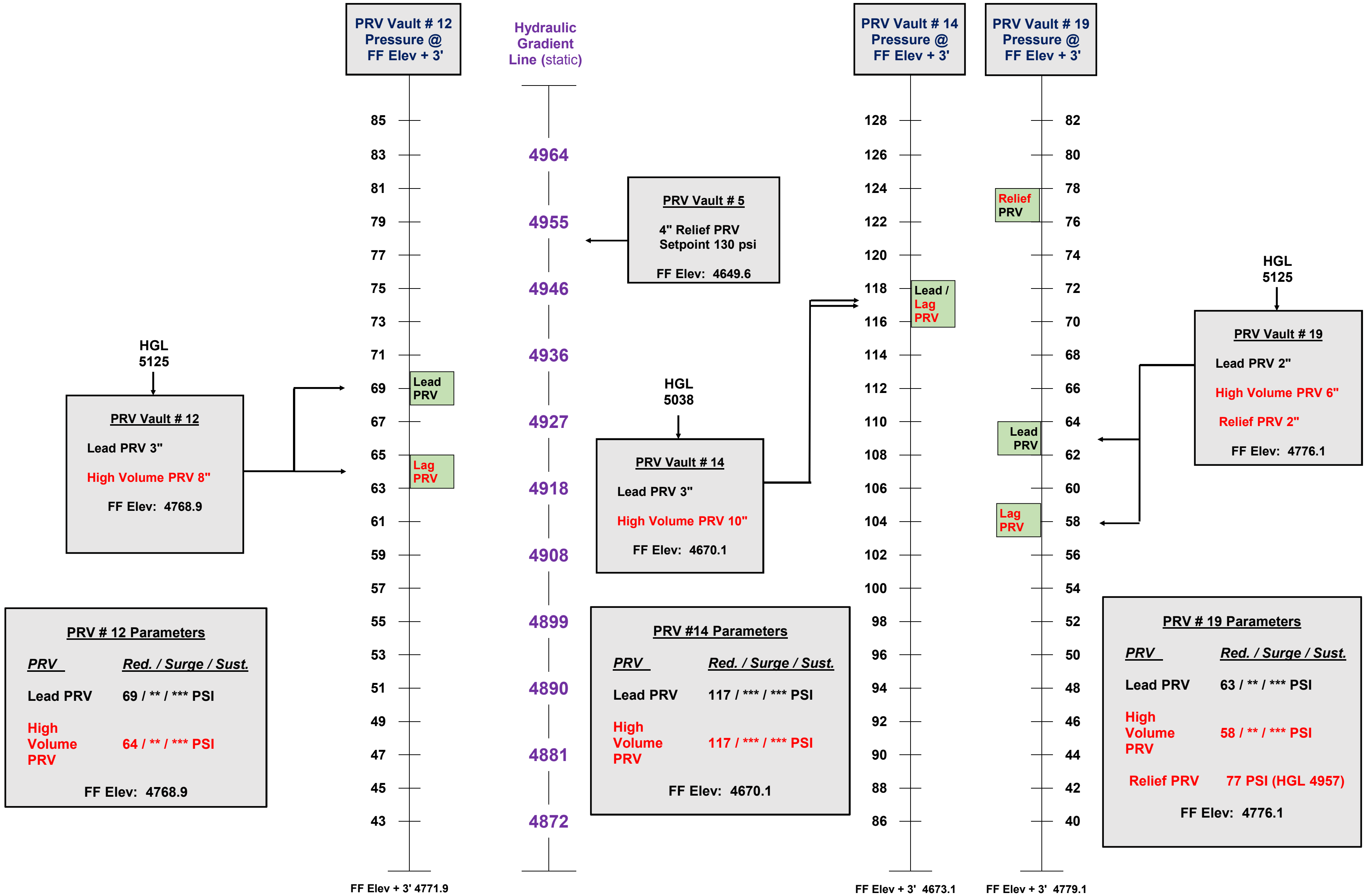
HGL 4940 Zone / Northwest Master page 2

Hydraulic Gradient Line (static)	PRV Vault # 14 Pressure @ FF Elev + 3'	PRV Vault # 15 Pressure @ FF Elev + 3'	PRV Vault # 17 Pressure @ FF Elev + 3'	PRV Vault # 18 Pressure @ FF Elev + 3'	PRV Vault # 19 Pressure @ FF Elev + 3'	PRV Vault # 20 Pressure @ FF Elev + 3'	PRV Vault # 22 Pressure @ FF Elev + 3'	PRV Vault # 5 Pressure @ FF Elev + 3'	Hydraulic Gradient Line (static)
	128	82	86	85	82	100	84	137	
4964	126	80	84	83	80	98	82	135	4964
	124	78	82	81	78 Relief PRV	96	80	133	
4955	122	76	80	79	76	94	78	131 Relief PRV	4955
	120	74	78	77	74	92	76	129	
4946	118 Lead / Lag PRV	72	76	75	72	90 Relief PRV	74 Relief	127	4946
	116	70	74	73	70	88	72	125	
4936	114	68	72	71	68	86	70	123	4936
	112	66	70	69	66	84	68	121	
4927	110	64	68	67 Lead PRV	64	82	66	119	4927
	108	62 Lead PRV	66 Lead PRV	65	62 Lead PRV	80 Lead PRV	64 Lead PRV	117	
4918	106	60	64	63	60	78	62	115	4918
	104	58	62 Lag PRV	61 Lag PRV	58 Lag PRV	76	60	113	
4908	102	56 Lag PRV	60	59	56	74 Lag PRV	58 Lag PRV	111	4908
	100	54	58	57	54	72	56	109	
4899	98	52	56	55	52	70	54	107	4899
	96	50	54	53	50	68	52	105	
4890	94	48	52	51	48	66	50	103	4890
	92	46	50	49	46	64	48	101	
4881	90	44	48	47	44	62	46	99	4881
	88	42	46	45	42	60	44	97	
4872	86	40	44	43	40	58	42	95	4872
	FF Elev+ 3' 4673.1	FF Elev+ 3' 4778.2	FF Elev+ 3' 4769.0	FF Elev+ 3' 4771.0	FF Elev+ 3' 4779.1	FF Elev+ 3' 4736.8	FF Elev+ 3' 4774.0	FF Elev+ 3' 4652.6	

City of Bozeman

HGL 4940 Pressure Zone / Northwest Master Page 2 04/01/2017

HGL 4940 Zone / Northwest



PRV # 12 Parameters

PRV	*Red. / Surge / Sust.*
Lead PRV	69 / ** / *** PSI
High Volume PRV	64 / ** / *** PSI

FF Elev: 4768.9

PRV #14 Parameters

PRV	*Red. / Surge / Sust.*
Lead PRV	117 / *** / *** PSI
High Volume PRV	117 / *** / *** PSI

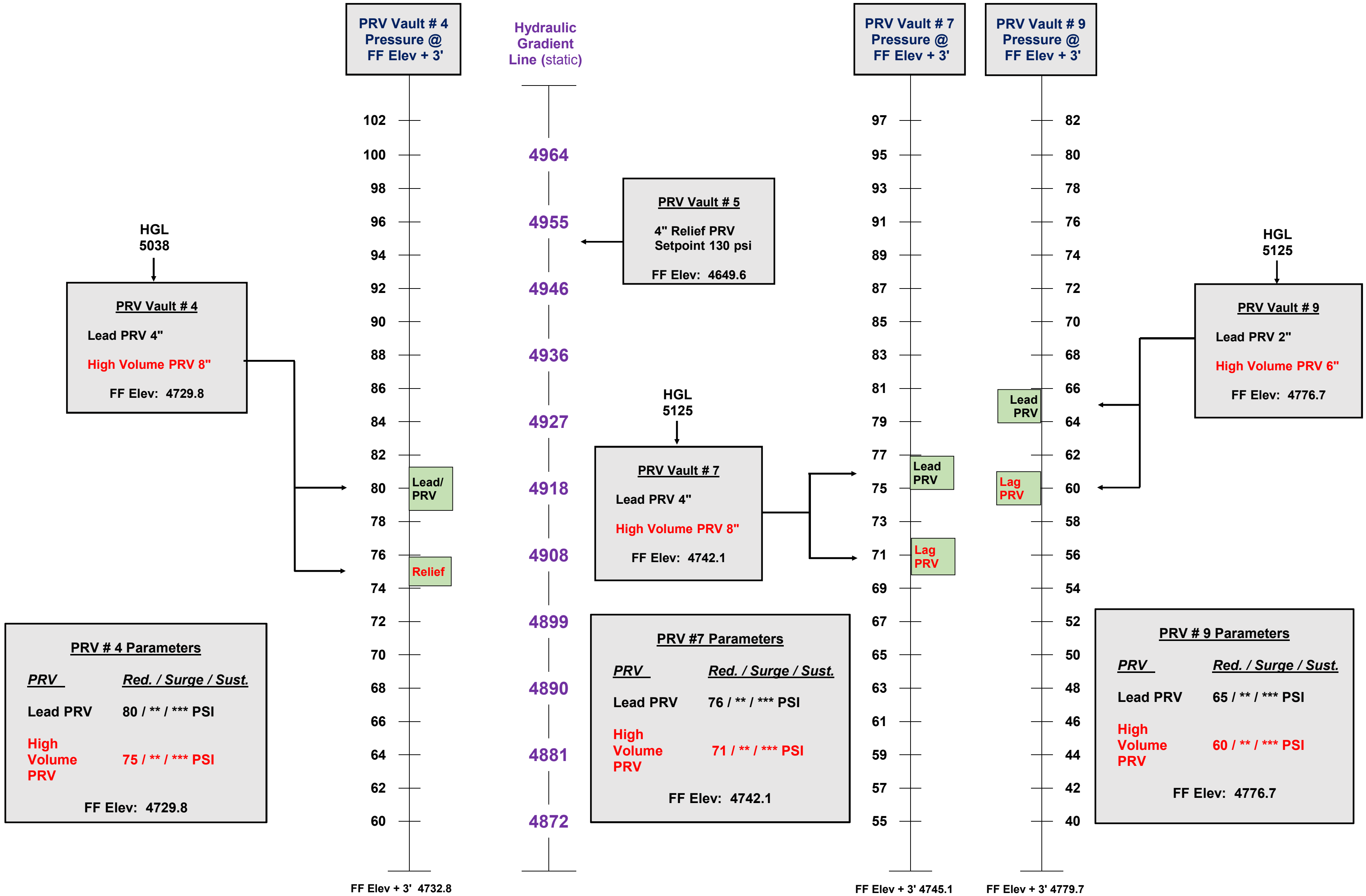
FF Elev: 4670.1

PRV # 19 Parameters

PRV	*Red. / Surge / Sust.*
Lead PRV	63 / ** / *** PSI
High Volume PRV	58 / ** / *** PSI
Relief PRV	77 PSI (HGL 4957)

FF Elev: 4776.1

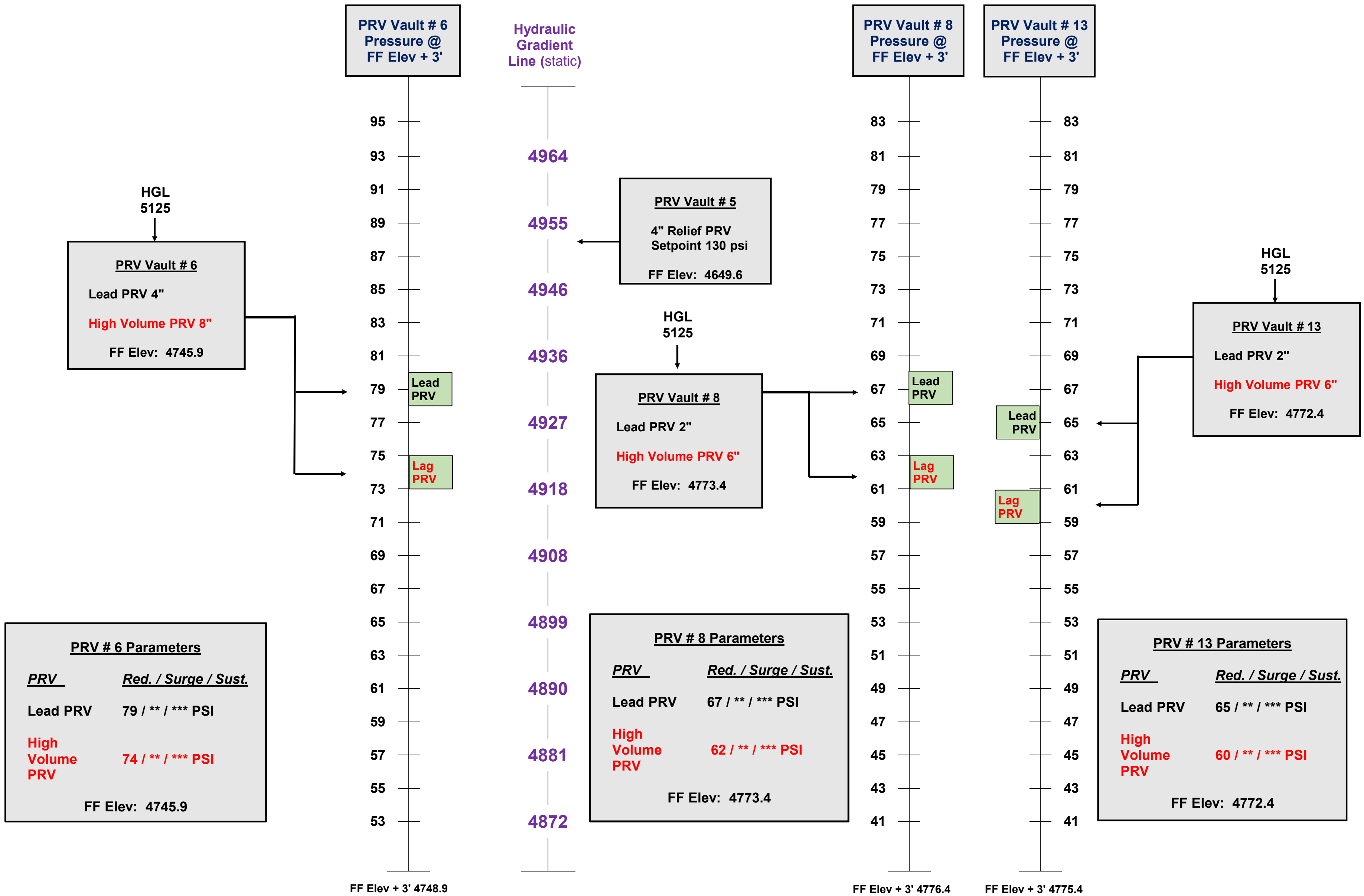
HGL 4940 Zone / Northwest



City of Bozeman

HGL 4940 Pressure Zone / Northwest — 04/01/2017

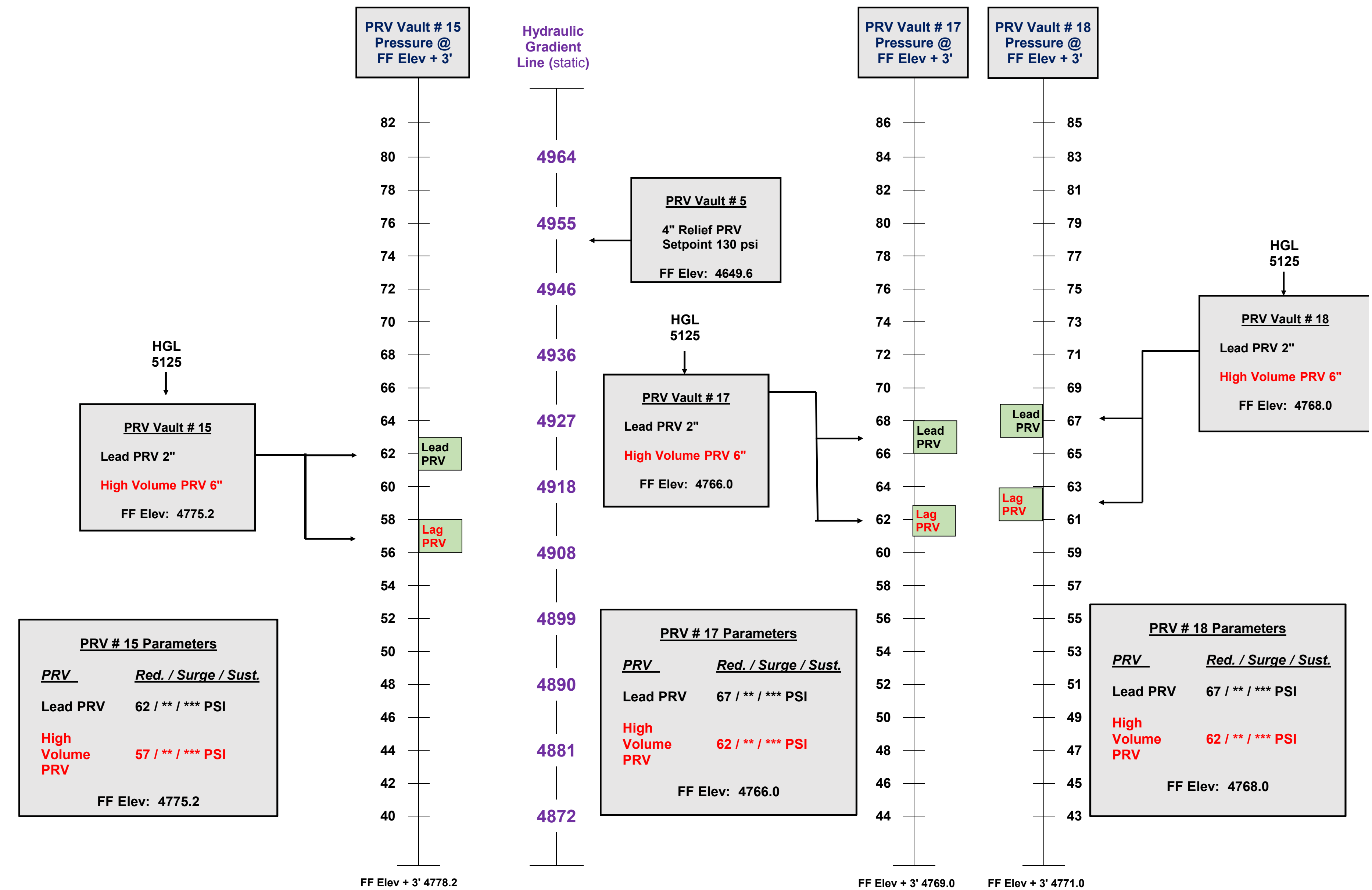
HGL 4940 Zone / Northwest



City of Bozeman

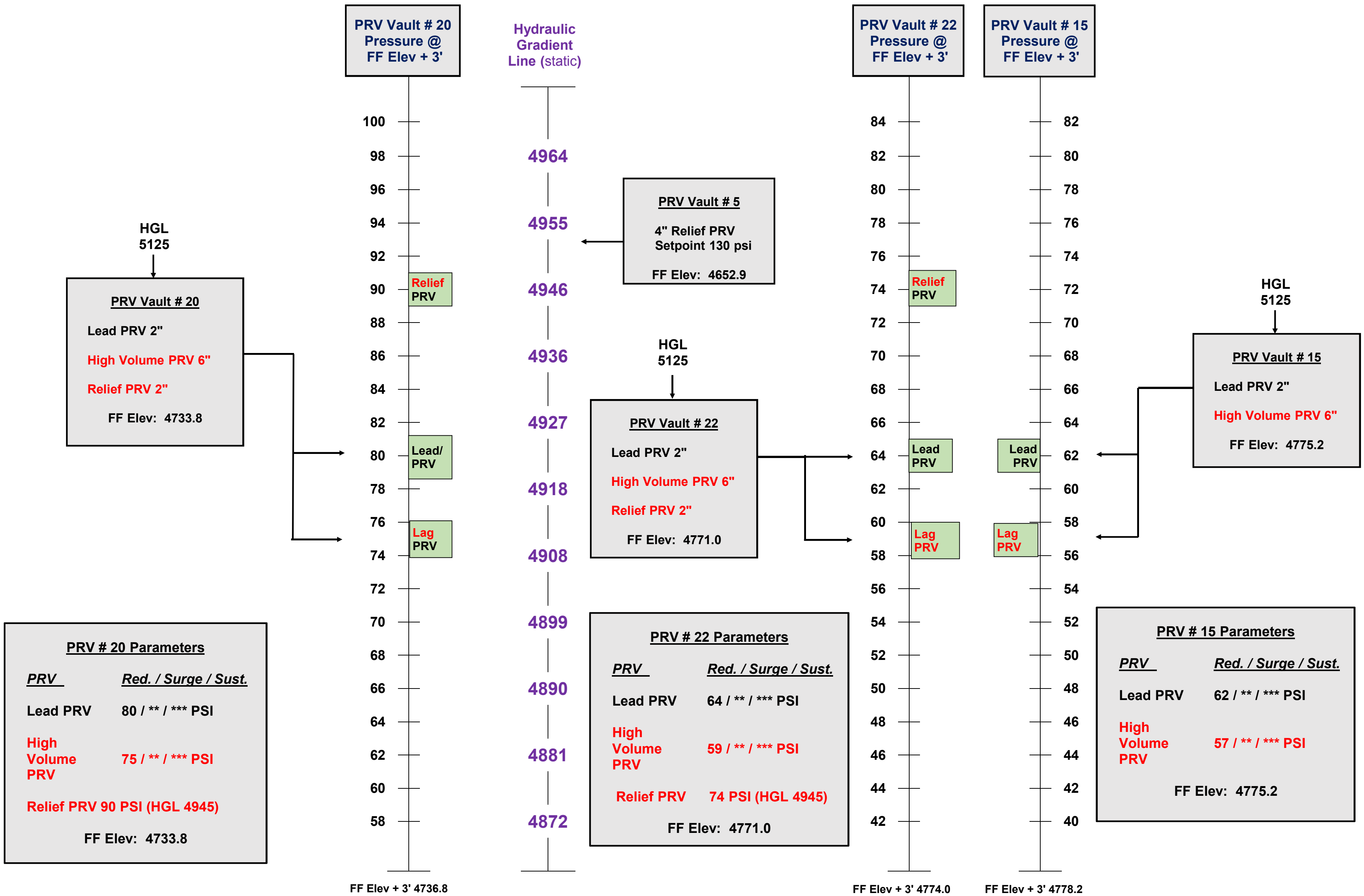
HGL 4940 Pressure Zone / Northwest 04/01/2017

HGL 4940 Zone / Northwest



City of Bozeman
HGL 4940 Pressure Zone / Northwest 04/01/2017

HGL 4940 Zone / Northwest



Appendix B – FME Script for GIS export/Model Import

Introduction

To create the water pipe network for the hydraulic model, a FME script was developed by StreamlineAM to transform the existing GIS feature classes into a working format to input into the hydraulic model. FME is a software that allows the ability to develop and implement workflows to alter the data into a working format.

- Include (abandoned) gravity water main with exception of inactive (abandoned) mains.
- Include hydrant leads from the lateral lines that are connected to hydrants.
- Include hydrants.
- Incorporate junctions and fill in elevations based on City's DEM.
- Fill in roughness coefficients based on corresponding table values for size and material.
- Fix connectivity by connecting junctions within an allowable distance.
- Fix connectivity by creating breaks and junctions within water main where water main intersect and are of the same pressure zone.

Script Development

The existing feature classes for water pipe network were evaluated for export and use for updating the water hydraulic model in InfoWater. Because of the complexity of the distribution facility integration, as well as the small number of facilities, the integration is recommended for only the horizontal plant (pipes and junctions). The data was evaluated and inputs were defined for two export feature classes to the hydraulic model: pipes and junctions. Only "Active" pipes were included in the exports. In addition, only hydrants were prepared as junctions with a link to the original GIS features – the remainder of the junctions were created by automated endpoint creation for the pipes that were included. Below is a summary of the inputs, calculated fields and outputs prepared for the model.

The scripts are based on "snapshots" of data received from the City of Bozeman. For this export to become a sustainable process, the source datasets should be reconnected to the City of Bozeman enterprise datasets where such datasets exist. In addition, one field change to two feature classes in the enterprise database is recommended.

Instructions to Run

The following instructions provide steps to run the FME script.

1. Rename HydraulicModelGISImportAudit.xls to HydraulicModelGISImportAudit_DATE.xls.
2. Copy HydraulicModelGISImportAudit_Template.xls to HydraulicModelGISImportAudit.xls.
3. Run 1_GISAudit_WaterModel.fmw.
4. Address any Audit issues Identified in Step 3.
5. Repeat Steps 1 through 3 until satisfied with Audit.
6. Run 2_GISExport_WaterModel.fmw.
7. Use InfoWater GIS Gateway and provided field maps to import all pipes and Junctions into model.
8. Facilities are maintained in the model.

Datasets Included, Excluded and Created

GIS Datasets Used:

- Wgravity_mains
- Wlateral_lines
- Whydrants
- DEM_Bozeman.gdb (converted to a file geodatabase from tiles)

GIS Feature Classes Not Used:

- Wcurb_boxes
- Wfittings
- wSystem_Valves
- wControl_Valves
- wStations

Additional Data Created/Mapped:

- AssigningData.gdb (non-spatial tables with FACILITYID)
  - wGravity_mains_Zone
  - wlateral_lines_Zone
  - tbl_Roughness
  - disconnectedWhy_Audit_Override

Export to "Pipes" and "Junctions" for Water Hydraulic Model

There are two scripts that were produced for the export. The first script (1_GISAudit_WaterModel.fmw) should be run first as a data validation for the model. Data issues identified in that script would need to be fixed prior to running the second script (2_GISExport_WaterModel.fmw). The second script creates the two feature classes which are used in the import module of InfoWater.

Scripts

- 1_GISAudit_WaterModel.fmw
- 2_GISExport_WaterModel.fmw

Source Data

- Wgravity_mains_20151007 (LIFE = "Active")
- Wlateral_lines_20151007 (Only those with an endpoint coincident with a feature from wHydrants)
- WHydrants_20151007
- disconnectedWhy_Audit_Override
- tbl_Roughness

Output Data

- HydraulicModelGISImportAudit.xlsx (Worksheet Tabs)
    - Audit 1: Attribute_Wgravity_mains
    - Audit 2: Attribute_Wlateral_lines
    - Audit 3: Attribute_Whydrants
    - Audit 4: Connectivity_Wgravity_mains
    - Audit 5: Connectivity_Wlateral_lines
    - Audit 6: Connectivity_Whydrants
- GIS_Output.gdb
    - WHYD_Junction
    - WHYD_Pipe

Automated Audit Exports
These are lists generated by feature class and issue that will require manual cleanup in GIS prior to running the export/translation from GIS to the format required by the hydraulic model. The audits contain lists that match one of the criteria below and are separated into separate tabs by source feature class and whether it is an attribute issue or a geometry/connectivity issue.

- Wgravity main – material "Unk" or "Unknown" or size = "0" or 8" CU
- Wlaterals connected to hydrants – material "Unk" or "Unknown" or size = "0" or 8" CU
- wHydrants – without a lateral line connecting
- wGravity main and wlaterials with junctions on them from other pipes that aren't at endpoints and for which both are in the same zone.

Inputs: wGravity_main, wlateral_lines, wHydrants, DEM

- Endpoints of applicable wGravity_mains and wlateral_lines – generated from the geometry information of the segments
- wHydrants – if not connected to a wGravity_main or a wLateral_line, flagged as "Reference" for the model)
- DEM – the elevation is assigned each feature generated

Inputs: WHYD_PIPE

- wGravity_Mains (Only Life = "Active")
- wLateral_lines (Only those features with a hydrant as an endpoint and Life = "Active")
- WHYD_JUNCTION

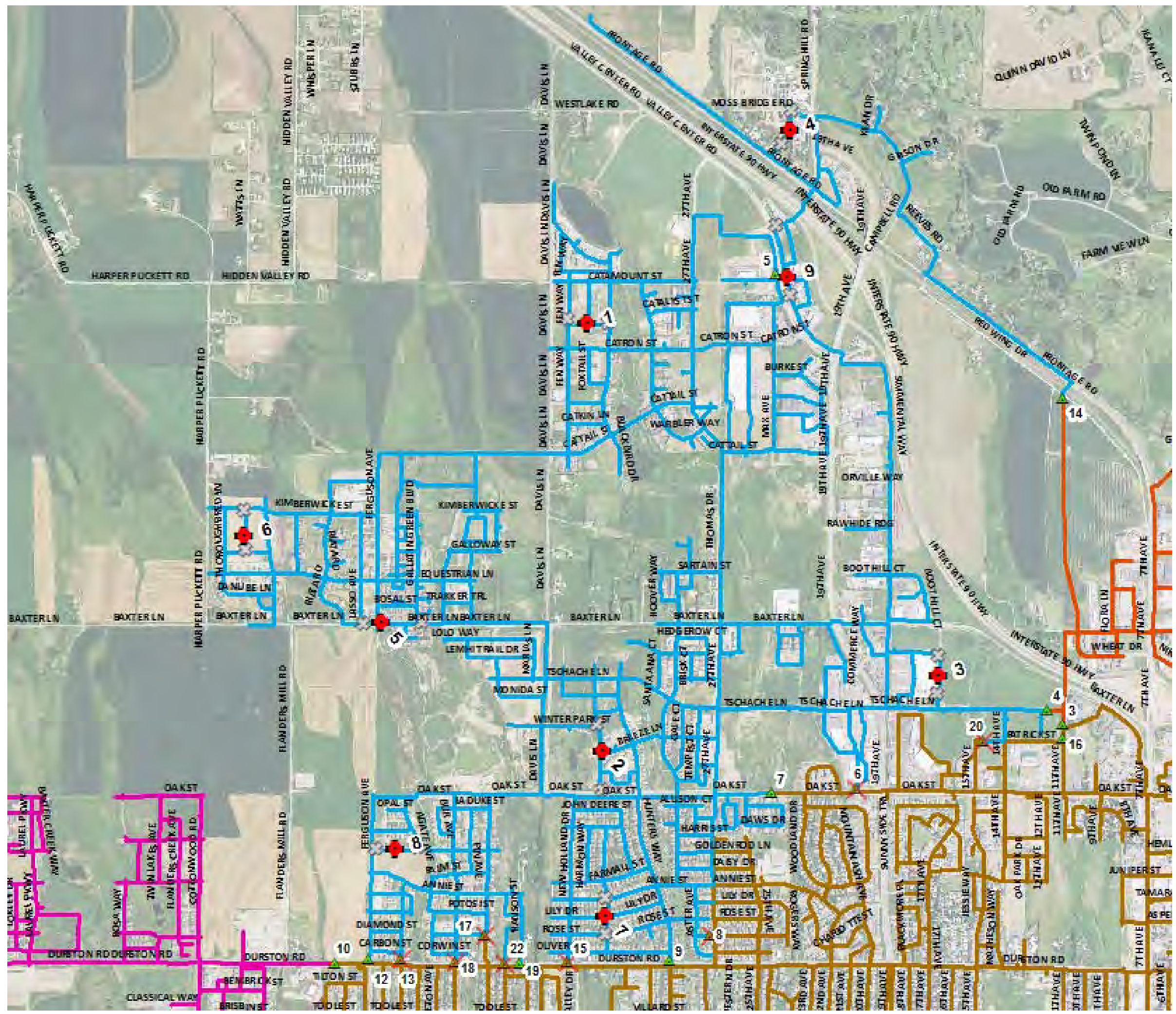
Table G.1: Creation of WHYD_Junction and WHYD_Pipe

Source DataSet	Data Fields	Data Calculations	MODEL Data Fields	Notes
Outputs: WHYD_JUNCTION, WHYD_PIPE				
wGravity_Mains, wLateral_lines, wHydrants	FACILITYID	FME: Calculated from Prefix + FacilityID + split number if multiples	ID	Prefix is "wg_" or "wl_" or "why_" dependent on source feature class; use "wnode_" for generated endpoints. The auto generated numbers for "wnode_" will not be consistent between runs.
wGravity_Mains, wLateral_lines wHydrants	INSTALL_DATE	Straight data port	YR_INST	If doesn't exist, use "0" as default. Should we use B_Year for wHydrants as a possible source?
wGravity_Mains, wLateral_lines, wHydrants, wGravity_Mains_Zone, wLateral_lines_Zone	ZONE	Join on the new zone data to the source feature classes by FACILITYID attribute for the pipes; zone for the junctions are spatially generated	ZONE	Recommendation is for this field to be added to the core GIS Datasets. If a Junction exists at a section where the Zone Changes, the first Zone is used.
wGravity_Mains, wLateral_lines	LIFE	Straight data port	STATUS	Hydrants which are not connected are flagged as "Inactive". "Active" used for all features.
	FME	"PIPES" or "JUNCTIONS"	MODEL_TYPE	Default values
wGravity_Mains, wLateral_lines, wHydrants	FACILITYID	Straight data port	GIS_FACILITYID	Is Null for the Auto generated endpoints
wGravity_Mains, wLateral_lines	None: Source Feature Class	Calculated from source feature class	SOURCE_GISFC	Name of source feature classes where the feature comes from or "FME_Automated_Junction" for the generated endpoints.
Outputs: WHYD_JUNCTION				
WHYD_Junction DEM		Adding Elevation data from DEM to points	ELEVATION_M	
WHYD_Junction DEM		Adding Elevation data from DEM to points	DEM_ELEVATION_M	
WHYD_Junction DEM		Adding Elevation data from DEM to points	ELEVATION_FT	
WHYD_Junction DEM		Adding Elevation data from DEM to points	DEM_ELEVATION_FT	
wHydrants	HYD	Straight data port	HYD_ID	
WHYD_Junction	FME	Generated from spatial location	X	Used projection as source feature classes
WHYD_Junction	FME	Generated from spatial location	Y	Used projection as source feature classes

Outputs: WHYD_PIPE				
wGravity_Mains, wLateral_lines	MATERIAL	Straight data port	MATERIAL	Straight data port for first load; not included in updates to existing features in model (Model Override Field)
wGravity_Mains, wLateral_lines	MATERIAL	Straight data port	GIS_MATERIAL	
wGravity_Mains, wLateral_lines	FME	Calculated from FME Geometry Info	GIS_LENGTH_M	Unchanged Length in Meters
wGravity_Mains, wLateral_lines	FME	Calculated from FME Geometry Info	GIS_LENGTH_FT	Unchanged Length in Feet
wGravity_Mains, wLateral_lines	DIAMETER	Straight data port	GIS_DIAMETER	
wGravity_Mains, wLateral_lines	SUBTYPE	Straight data port	GIS_SUBTYPE	
	FME	Calculated from FME Geometry Info for first load.	LENGTH_M	Length that may be adjusted in model for calibration - may be removed from script for long term maintenance. In meters.
	FME	Calculated from FME Geometry Info for first load.	LENGTH_FT	Length that may be adjusted in model for calibration - may be removed from script for long term maintenance. In Feet
	DIAMETER	Straight data port for first load; not included in updates to existing features in model (Model Override Field)	DIAMETER	Diameter that may be adjusted in model for calibration - may be removed from script for long term maintenance
WHYD_Junction	ID	Generated by spatial relationship	FROM	
WHYD_Junction	ID	Generated by spatial relationship	TO	
wGravity_Mains, wLateral_lines, tbl_Roughness	MATERIAL, DIAMETER, Roughness, Source Feature Class	From tbl_Roughness by material and material/diameter and source feature class	ROUGHNESS	Roughness table needs to be maintained

Appendix C – Fire Flow Tests

Fire Flow Testing Field Book

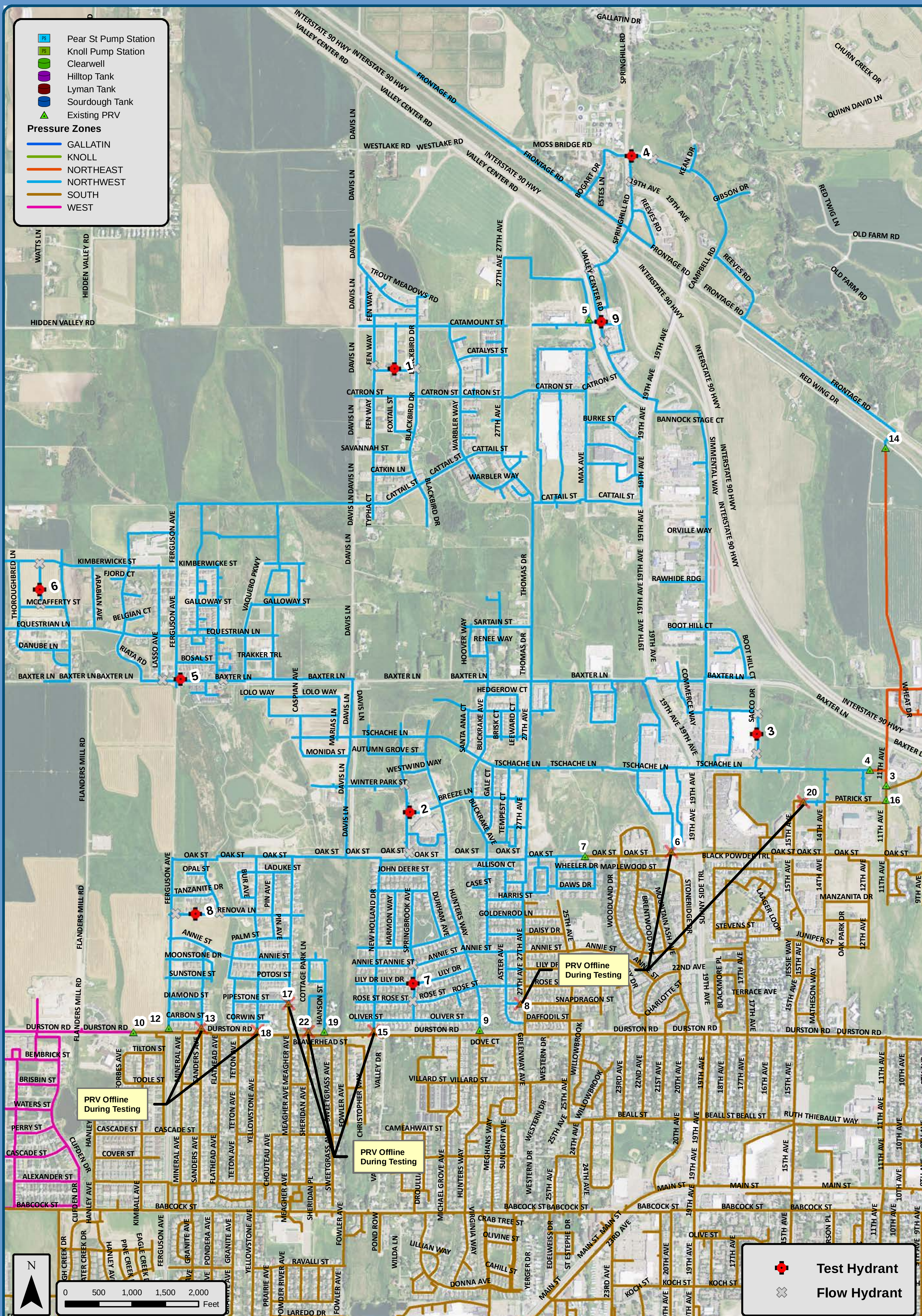


Northwest Pressure Zone

Flow Testing Protocol

<u>Northwest Pressure Zone</u>

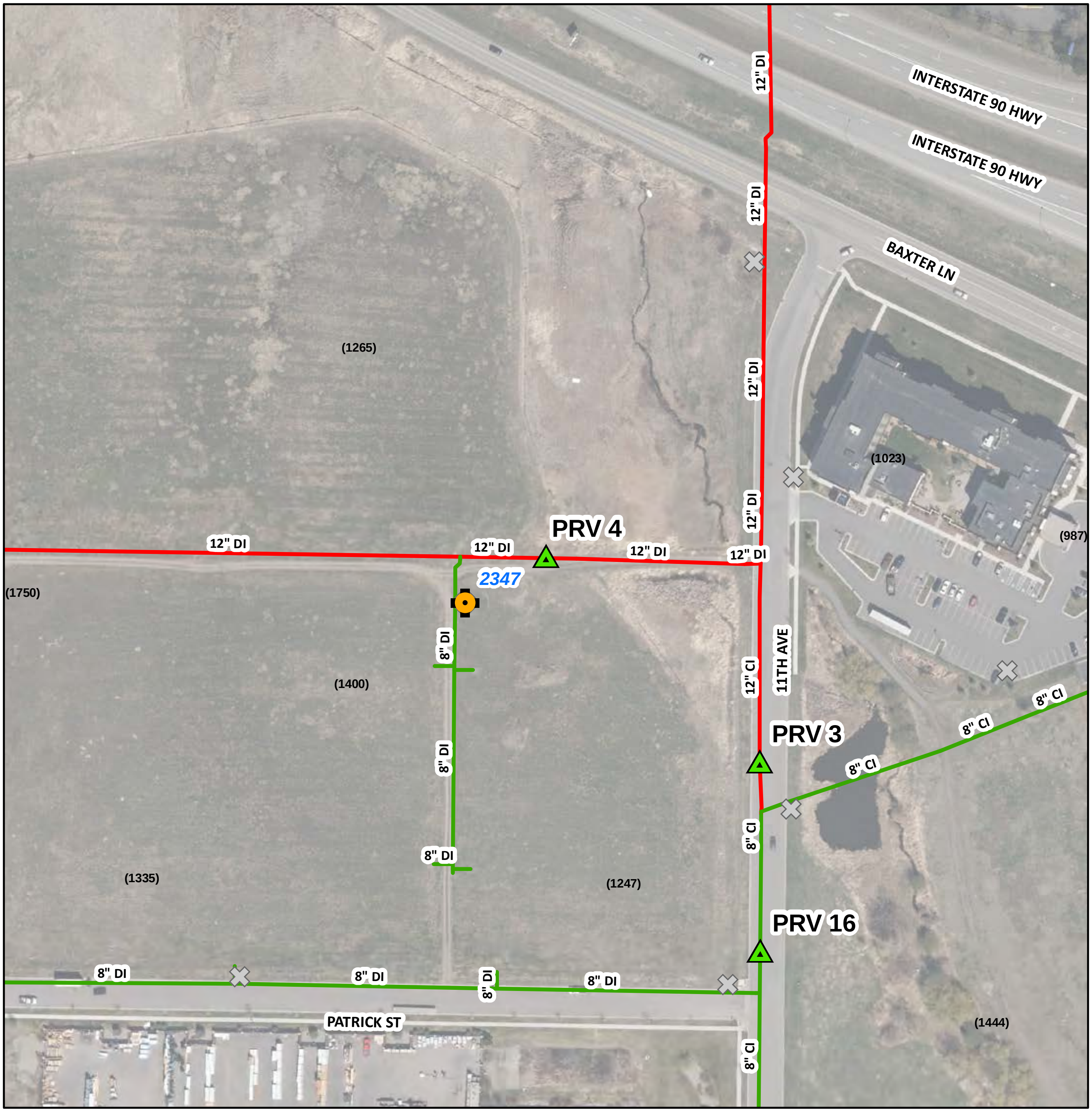
- 14 existing PRV Vaults (4, 6, 7, 8, 9, 12, 13, 14, 15, 17, 18, 19, 20, 22) – Request to reduce number of PRV Vaults supplying zone to 6 PRV Vaults (4, 7, 9, 12, 14, 19) by disabling the PRVs within 8 of the PRV vaults (6, 8, 13, 15, 17, 18, 20, 22).
- Operation of the selected 6 PRV Vaults would be set to only operate the large (lag) PRV to just able to flow when demand requires based on fire flow test. Disable the lead PRV in each of the 6 selected PRV vaults. Set the lag PRV in each of the 6 selected PRV vaults to flow at approximately the same hydraulic grade line.
- Disable PRV 3 that feeds from South Zone to Northeast (Lyman) Zone near PRV 4 during the flow testing.
- Install pressure recorder on a hydrant downstream side at each of the 6 PRV Vaults (4, 7, 9, 12, 14, 19).
- Install pressure recorders on the upstream hydrant of 3 selected PRV Vaults (4, 7, 12).
- Perform 9 fire flow tests within the pressure zone.
- Return PRVs in all 14 PRV Vaults back to original operation state (4, 6, 7, 8, 9, 12, 13, 14, 15, 17, 18, 19, 20, 22).
- Return PRV 3 back to original operation state or leave in this state till after completing flow testing for Northeast Pressure Zone.



Water Distribution System

Fire Flow Test Locations Within the Northwest Pressure Zone

Advanced Engineering and Environmental Services, Inc.



PRV Location: 4

Hydrant Upstream of PRV: None Recorder ID: __________

Hydrant Downstream of PRV: 2347 Recorder ID: __________

Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

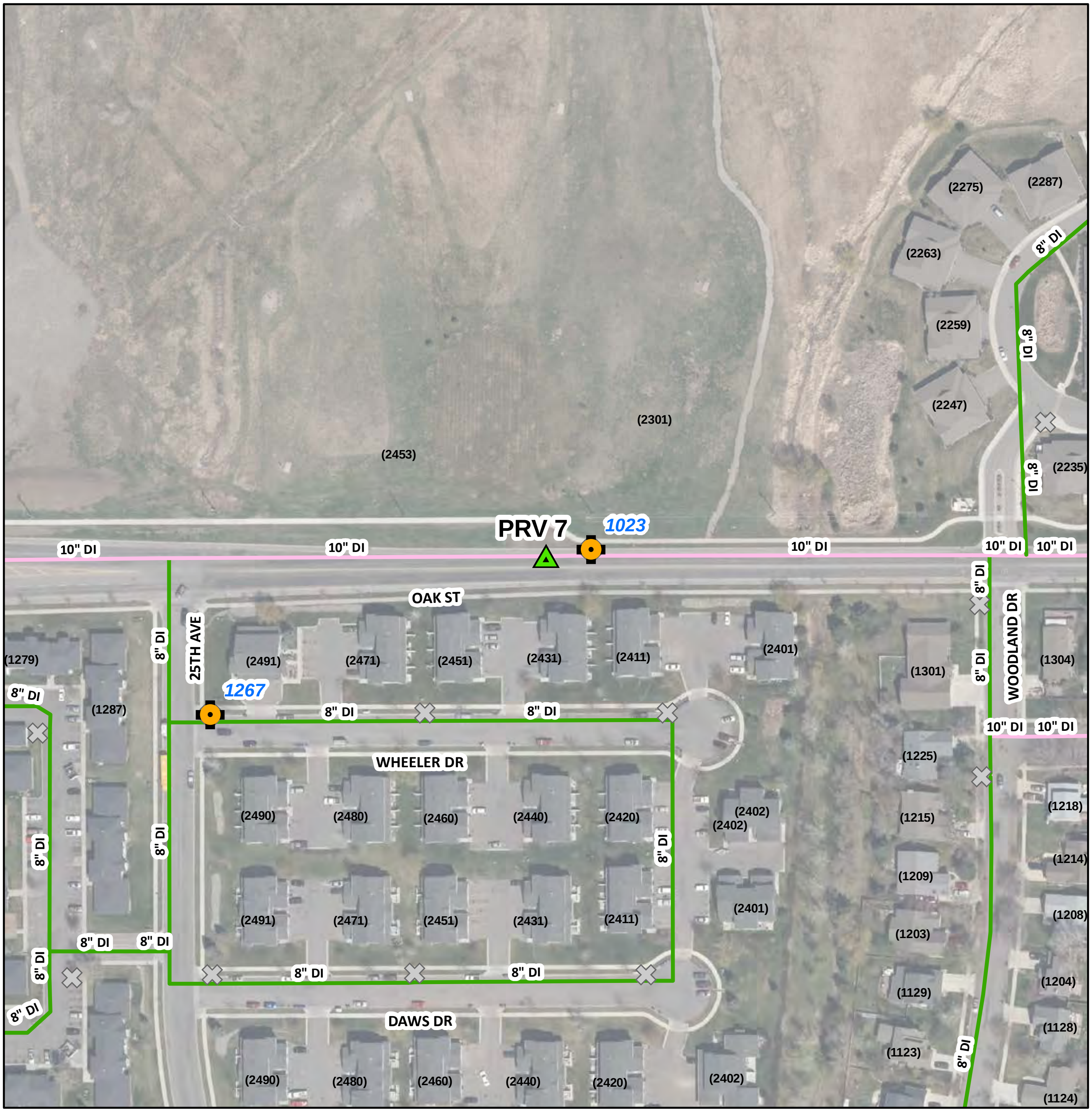
Installed/Removed By: _________

PRV Setup Prior to Flow Testing

Northwest Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

PRV Location 4



PRV Location: 7

Hydrant Upstream of PRV: 1023 Recorder ID: __________

Hydrant Downstream of PRV: 1267 Recorder ID: __________

Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

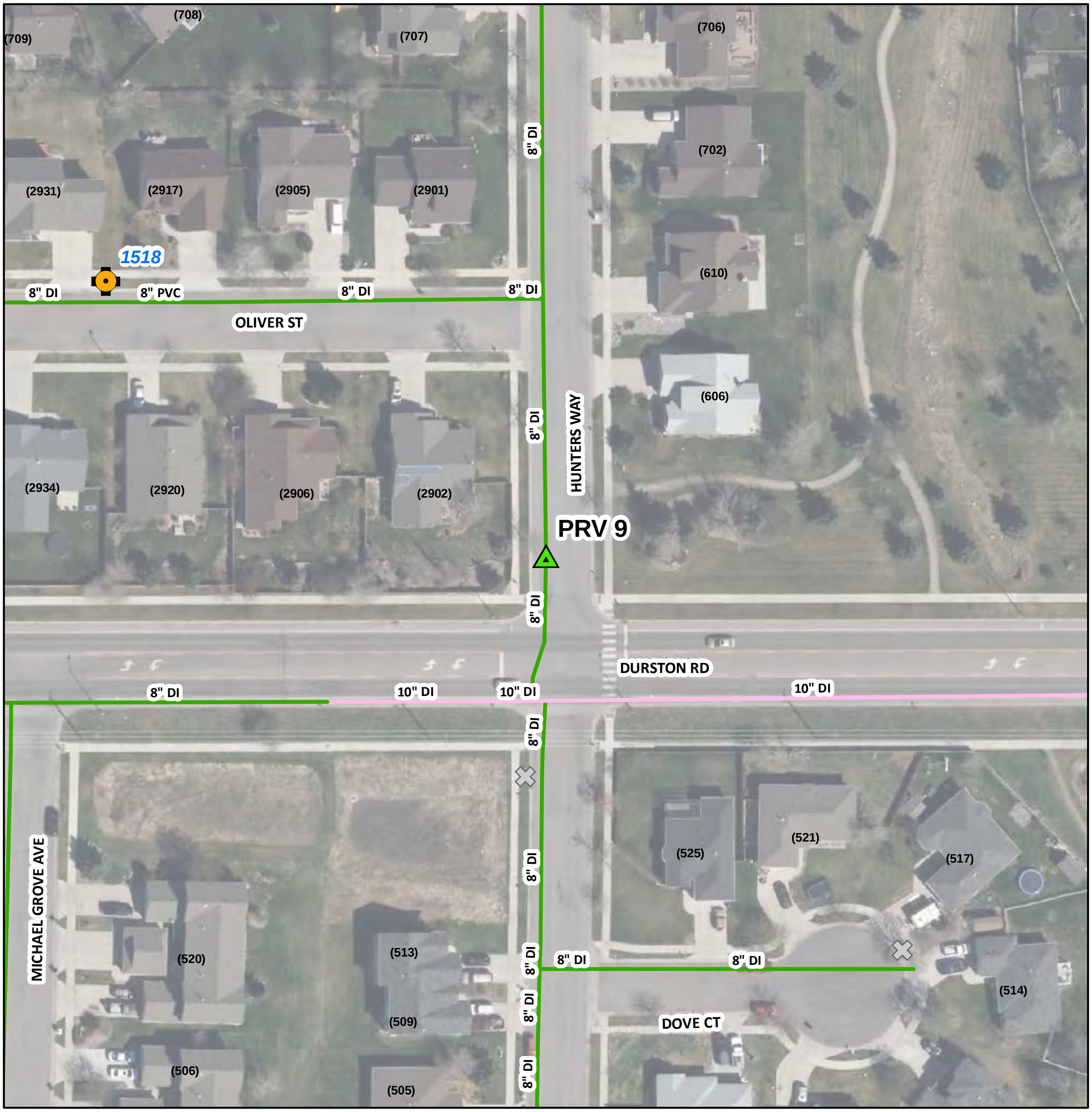
Installed/Removed By: _________

PRV Setup Prior to Flow Testing

Northwest Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

PRV Location 7



PRV Location: 9

Hydrant Upstream of PRV: None Recorder ID: __________

Hydrant Downstream of PRV: 1518 Recorder ID: __________

Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

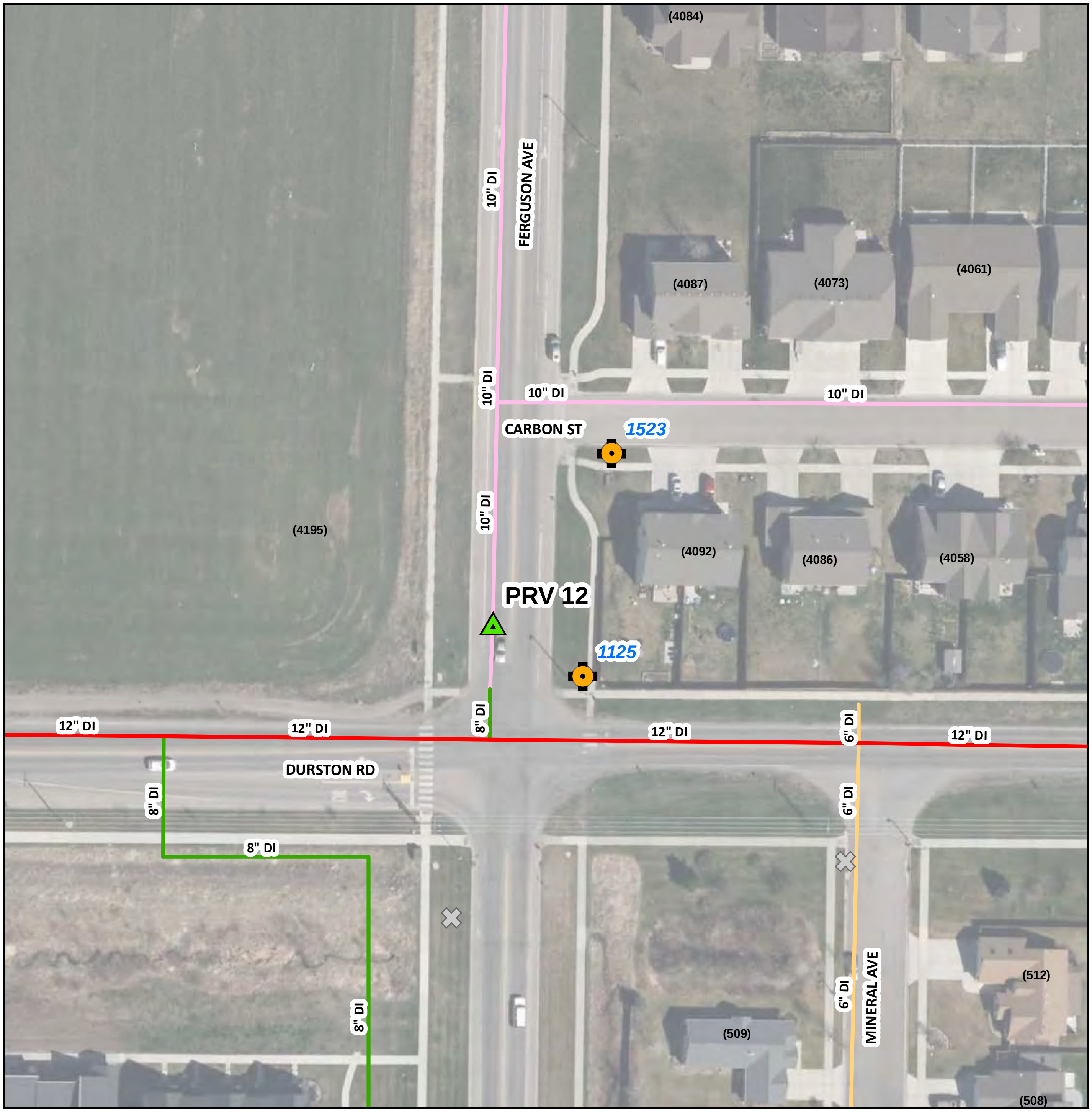
PRV Setup Prior to Flow Testing

Northwest Pressure Zone Flow Testing

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

PRV Location 9



PRV Location: 12

Hydrant Upstream of PRV: 1125 Recorder ID: __________

Hydrant Downstream of PRV: 1523 Recorder ID: __________

Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

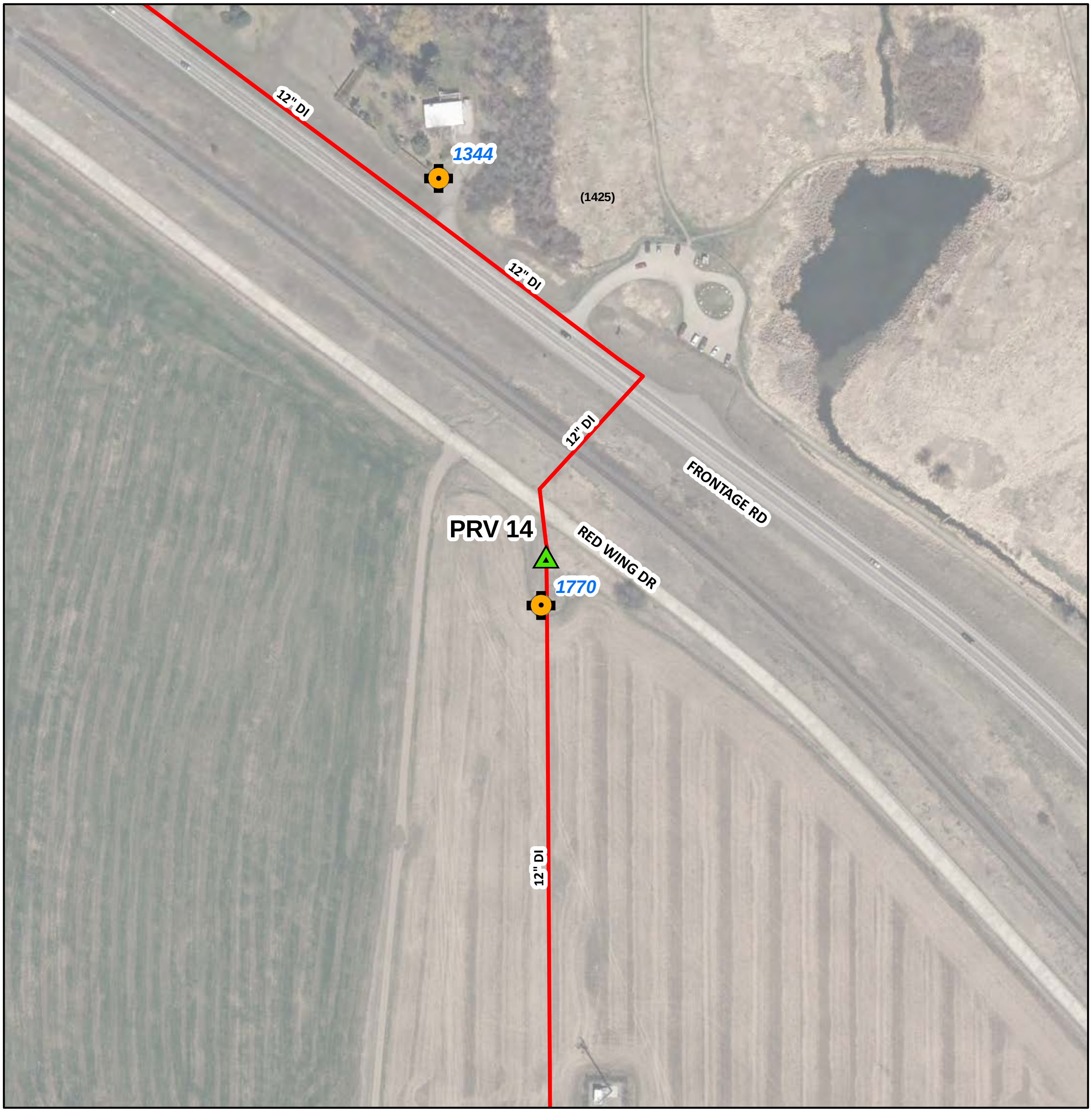
Installed/Removed By: _________

PRV Setup Prior to Flow Testing

Northwest Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

PRV Location 12



PRV Location: 14

Hydrant Upstream of PRV: 1770 Recorder ID: __________

Hydrant Downstream of PRV: 1344 Recorder ID: __________

Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

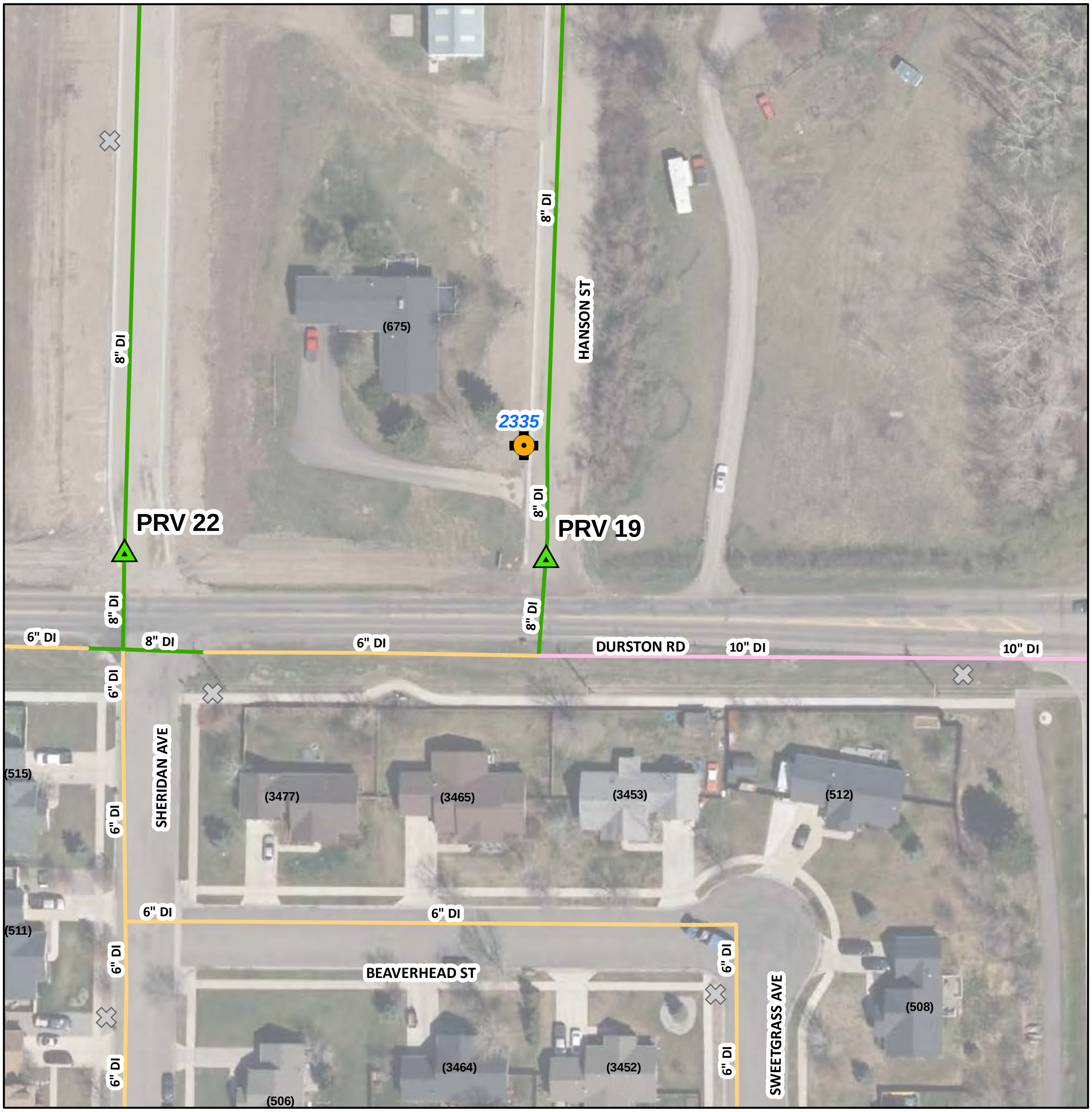
Installed/Removed By: _________

PRV Setup Prior to Flow Testing

Northwest Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

PRV Location 14



PRV Location: 19

Hydrant Upstream of PRV: None Recorder ID: __________

Hydrant Downstream of PRV: 2335 Recorder ID: __________

Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

PRV Setup Prior to Flow Testing

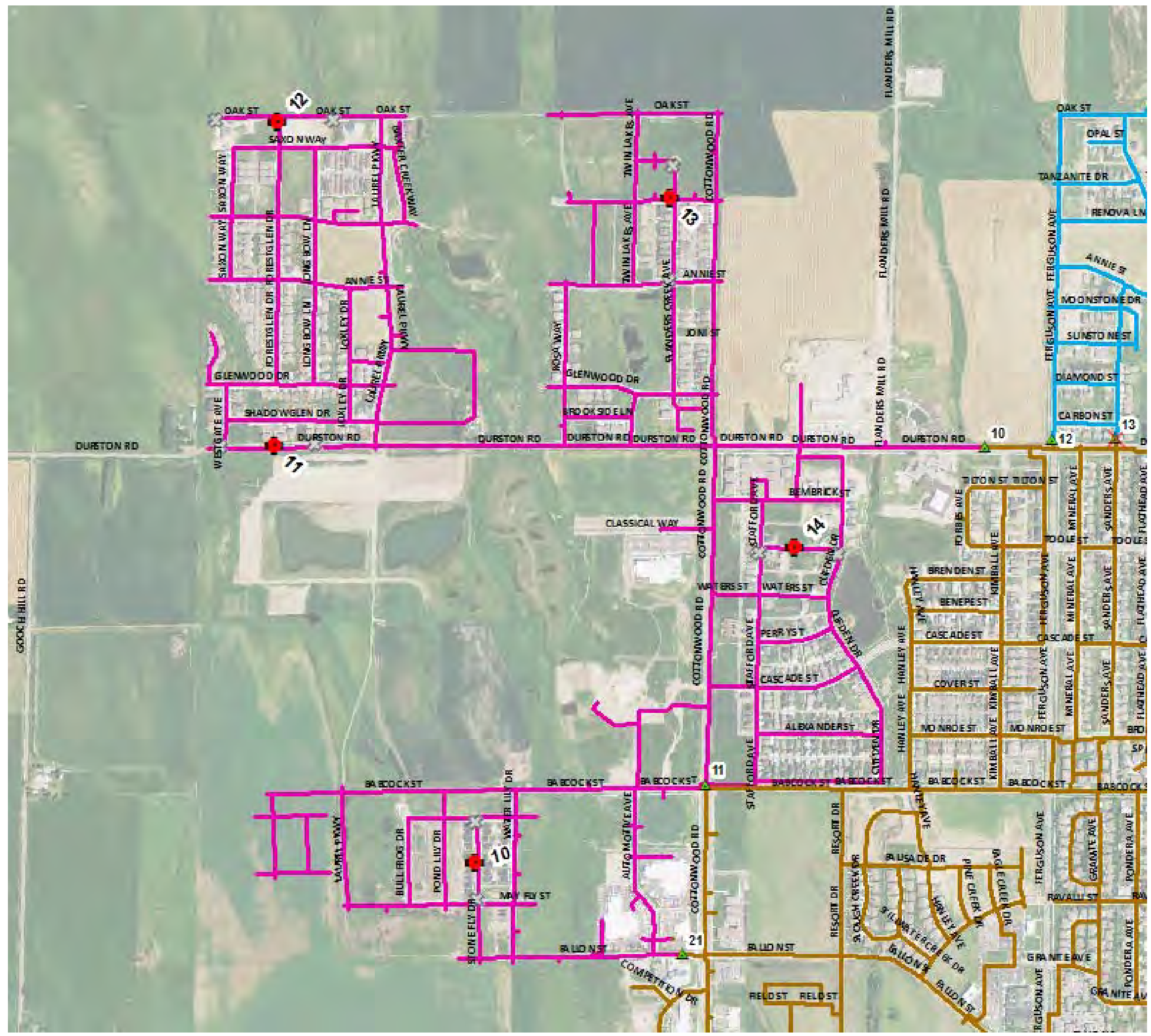
Northwest Pressure Zone Flow Testing

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

PRV Location 19

Fire Flow Testing Field Book

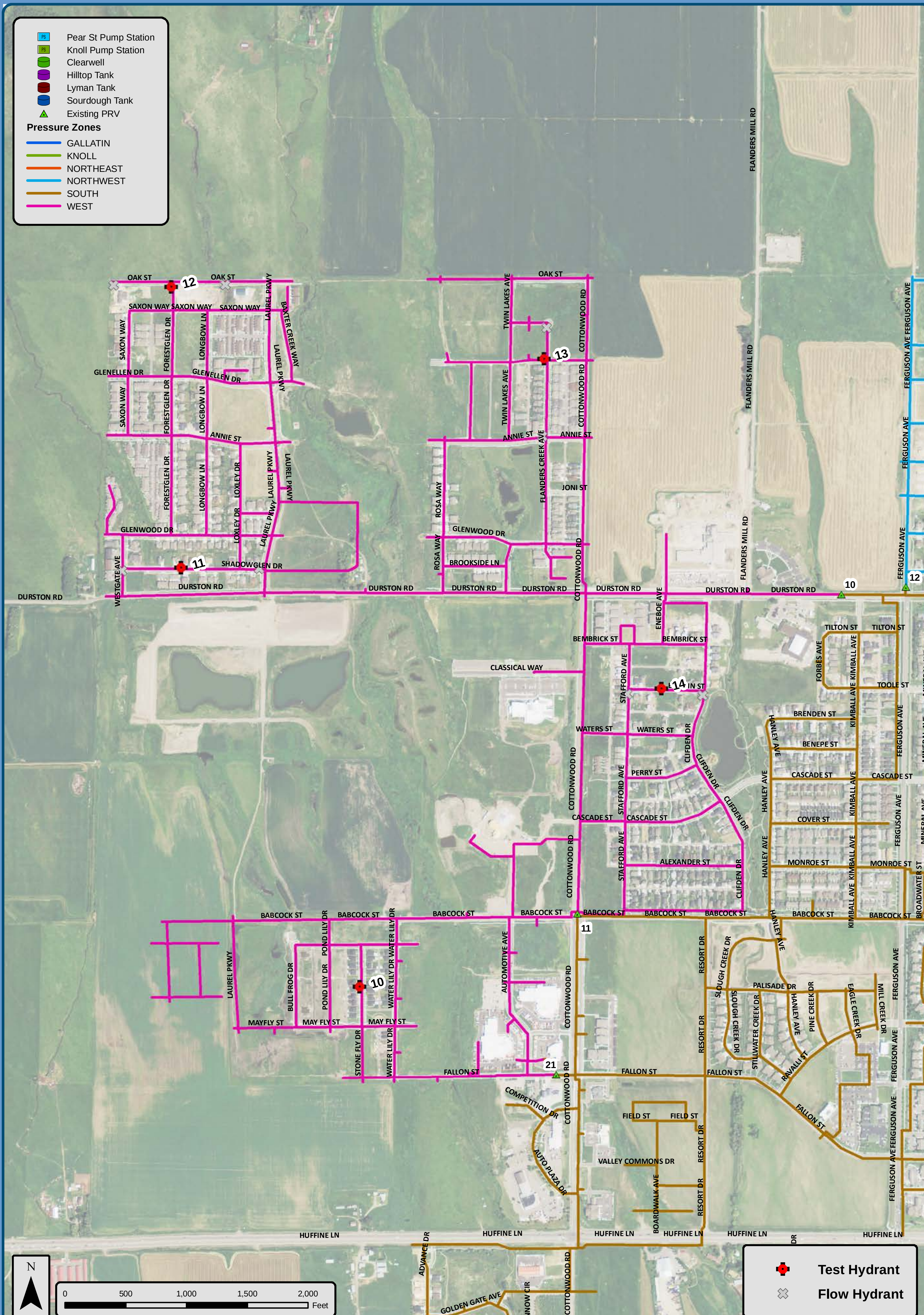


West Pressure Zone

Flow Testing Protocol

West Pressure Zone

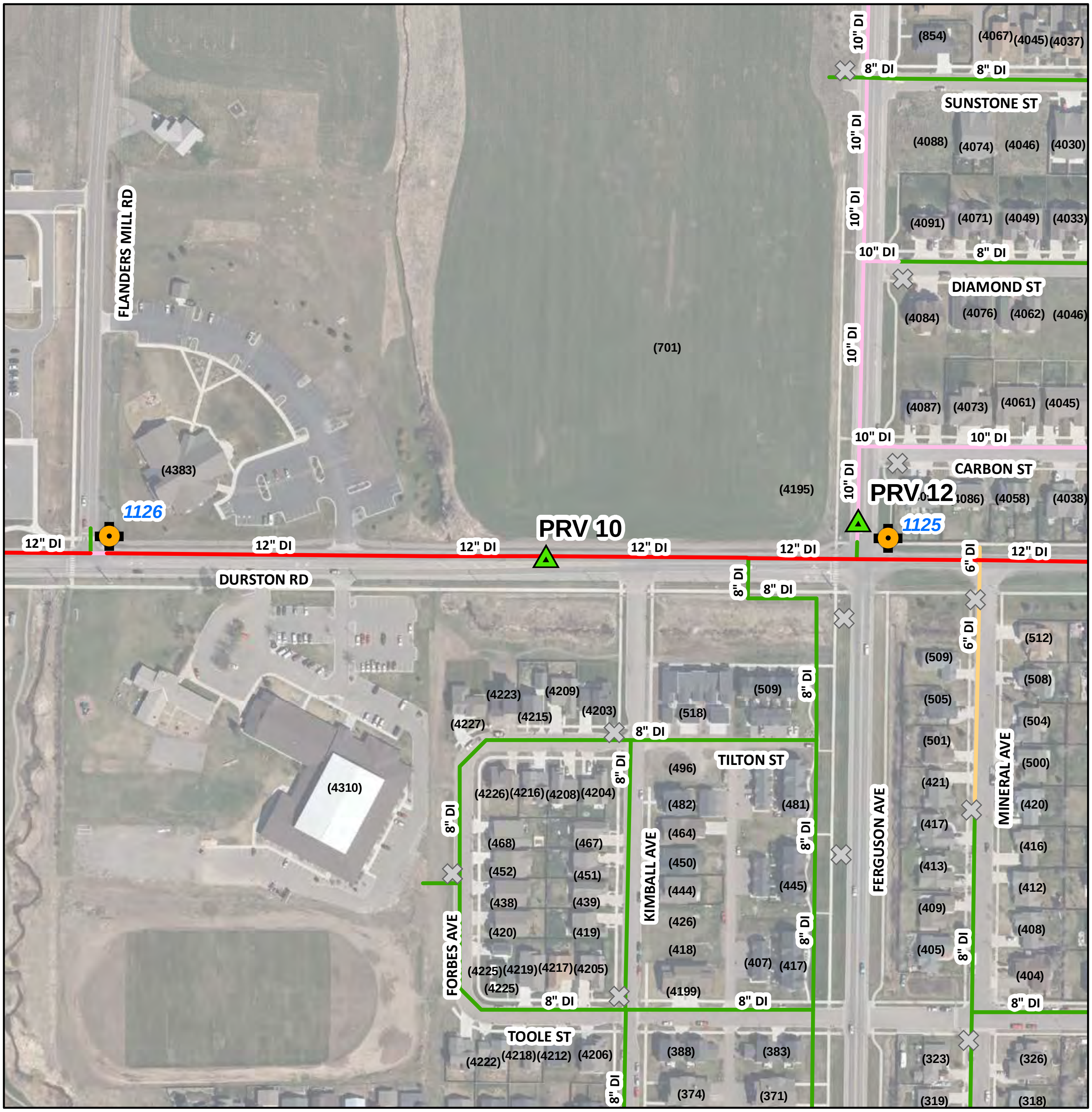
- 3 existing PRV Vaults (11, 12, 21)
- Operation of the PRV Vaults would be set to only operate the large (lag) PRV to just able to flow when demand requires based on fire flow test. Disable the lead PRV in each of the 3 PRV vaults. Set the lag PRV in each of the 3 PRV vaults to flow at approximately the same hydraulic grade line.
- Install pressure recorder on a downstream hydrant at each of the 3 PRV Vaults (11, 12, 21)
- Install pressure recorders on a upstream hydrant of each of 3 of the PRV Vaults (11, 12, 21)
- Perform 5 fire flow tests within the pressure zone.
- Return PRVs in all 3 PRV Vaults back to original operation state (11, 12, 21).



Water Distribution System

Fire Flow Test Locations
Within the West Pressure Zone

Advanced Engineering and Environmental Services, Inc.



PRV Location: 10

Hydrant Upstream of PRV: 1125 Recorder ID: __________

Hydrant Downstream of PRV: 1126 Recorder ID: __________

Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

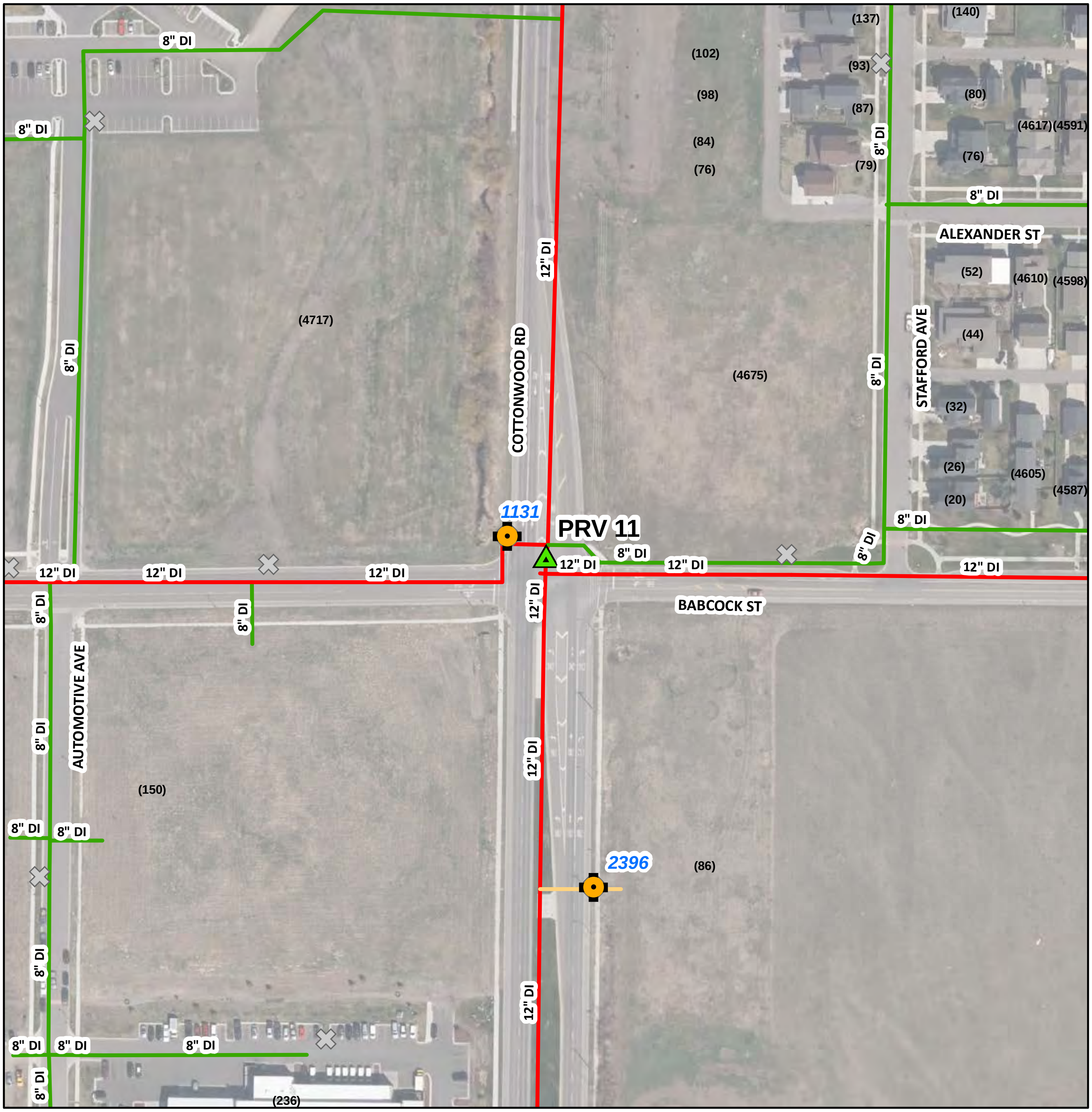
PRV Setup Prior to Flow Testing

West Pressure Zone Flow Testing

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

PRV Location 10



PRV Location: 11

Hydrant Upstream of PRV: 2396 Recorder ID: __________

Hydrant Downstream of PRV: 1131 Recorder ID: __________

Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

PRV Setup Prior to Flow Testing

West Pressure Zone Flow Testing

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

PRV Location 11

PRV Location: 21

Hydrant Upstream of PRV: 1754 Recorder ID: __________

Hydrant Downstream of PRV: 2424 Recorder ID: __________

Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

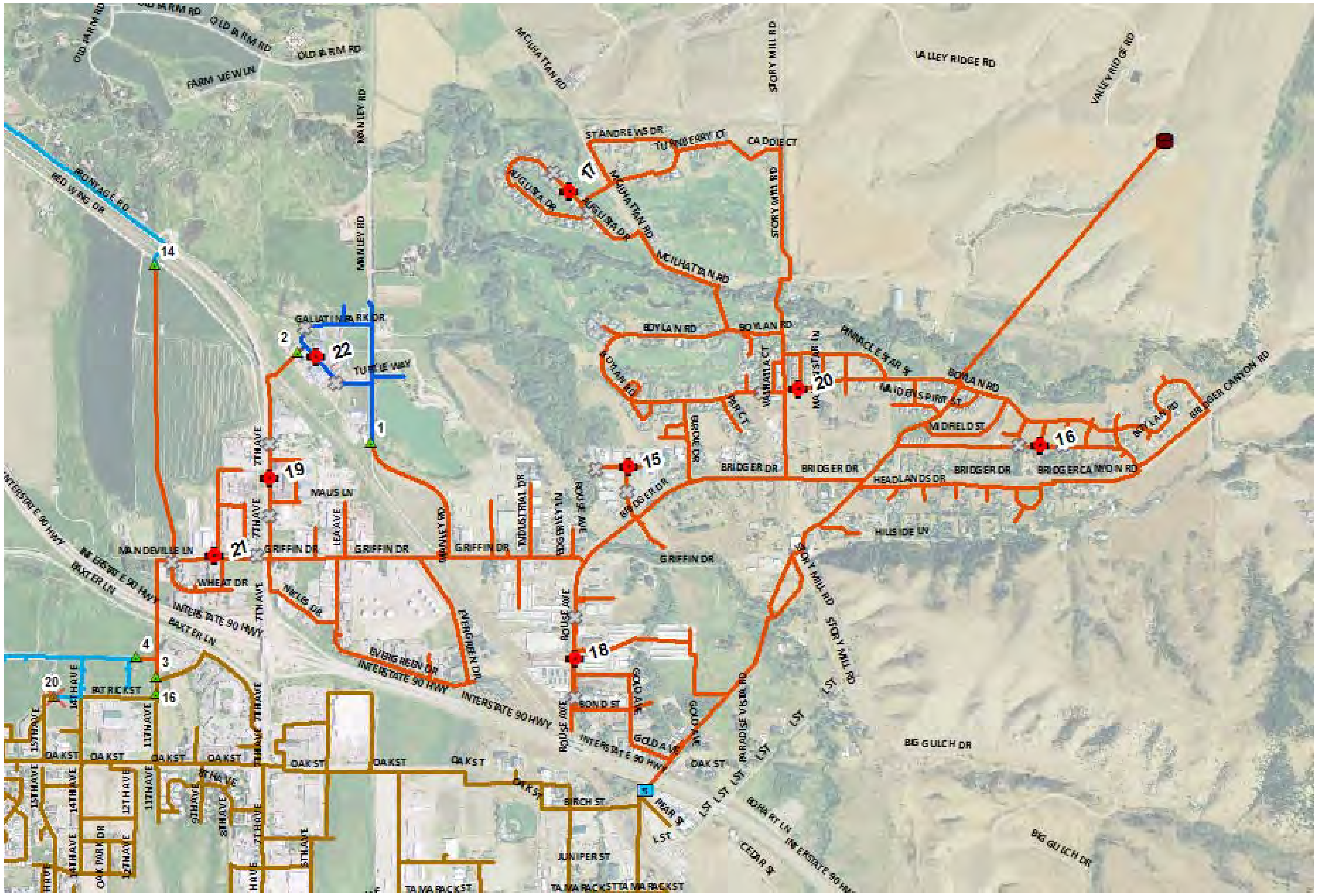
PRV Setup Prior to Flow Testing

West Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

PRV Location 21

Fire Flow Testing Field Book

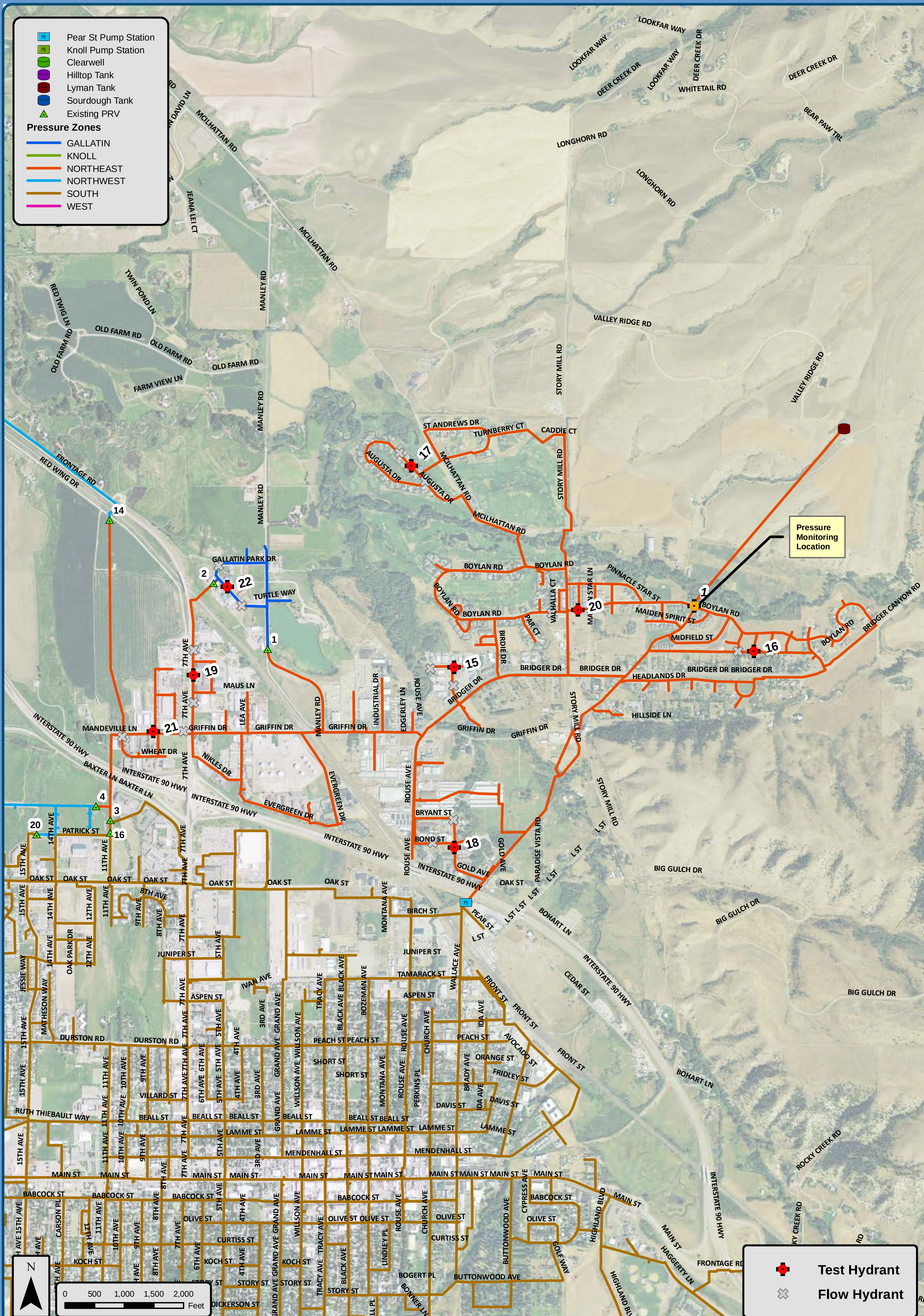


Northeast Pressure Zone

Flow Testing Protocol

<u>Northeast Pressure Zone and Gallatin Pressure Zone</u>

- Request pumps at the Pear Street Pump Station remain offline during testing.
- Disable Bypass from South Zone to Northeast Zone within Pear Street Pump Station.
- Request PRV Vault 3 be placed offline during testing (request current PRV settings).
- Request PRV Vaults 4 and 14 feeding the Northeast pressure zone be disabled to limit flow between the Northeast Zone and Northwest Zone during flow testing.
- Perform 8 fire flow tests within the pressure zone.
- Verify settings for PRV Vault 1 and PRV Vault 2 and perform 1 fire flow test within Gallatin Zone.
- Return Pear Street Pump Station and PRV Vault 3 back to original operation.
- Return PRV Vaults 4 and 14 back to original operational state.



Water Distribution System

Fire Flow Test Locations
Within the Northeast Pressure Zone

Advanced Engineering and Environmental Services, Inc.

Pressure Monitoring Location: 1

Hydrant ID: 2172

Recorder ID: __________ Pressure at Setup: __________

Installed - Date: __________ Time: __________

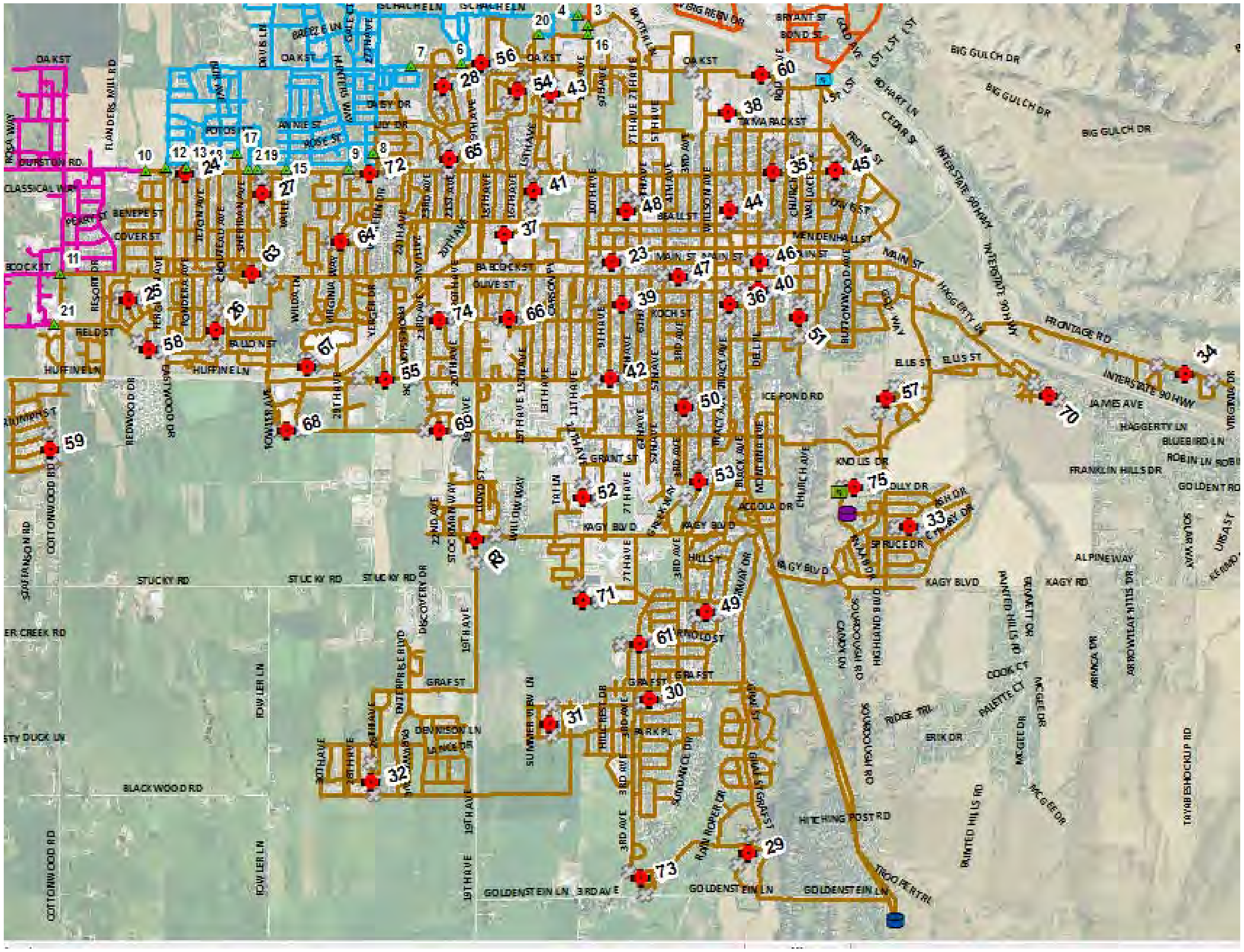
Removed - Date: __________ Time: __________

Installed/Removed By: _________

Pressure Monitoring
Setup Prior to Flow Testing
Northeast Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Fire Flow Testing Field Book



South Pressure Zone

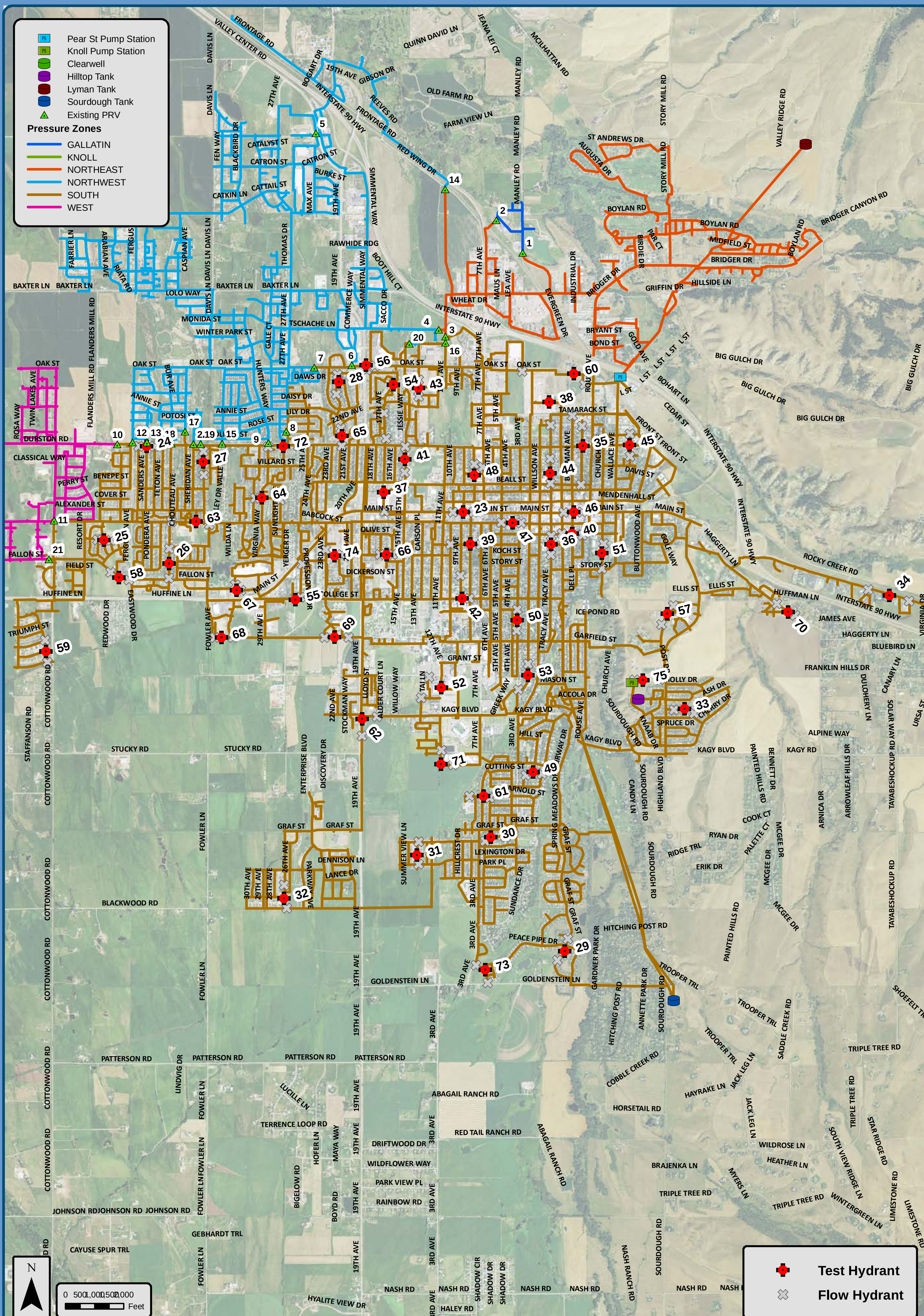
Flow Testing Protocol

South Pressure Zone

- Request pumps at the Pear Street Pump Station remain offline during flow testing.
- Install 9 pressure recorders at key locations along trunk watermain (10-in and larger).
- Perform 52 fire flow tests within the pressure zone.
- Return Pear Street Pump Station to original operation state.

Knoll Pressure Zone

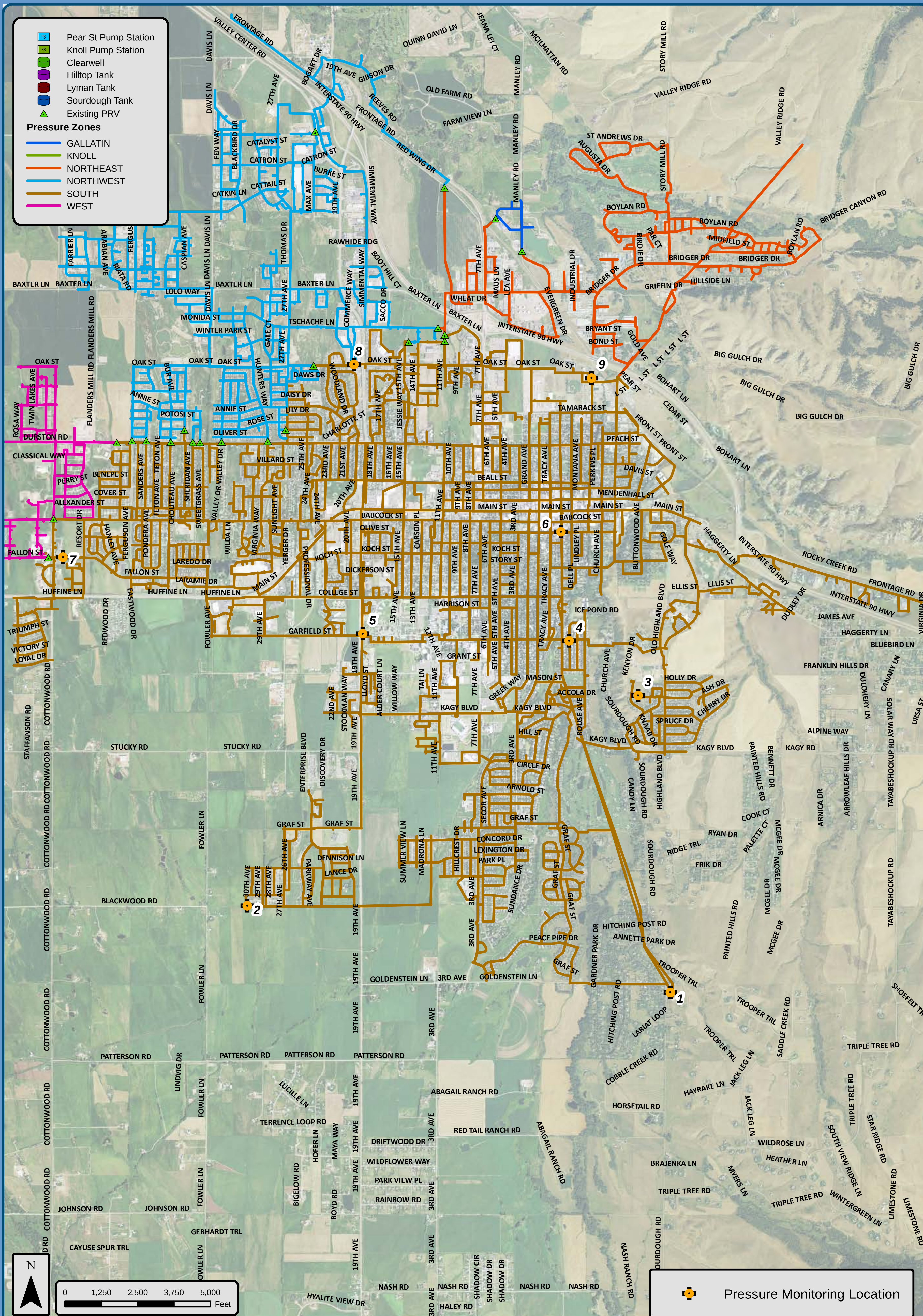
- Verify operation of Knoll Pump Station for fire flow testing.
- Perform 1 fire flow test within the pressure zone.



Water Distribution System

Fire Flow Test Locations Within the South Pressure Zone

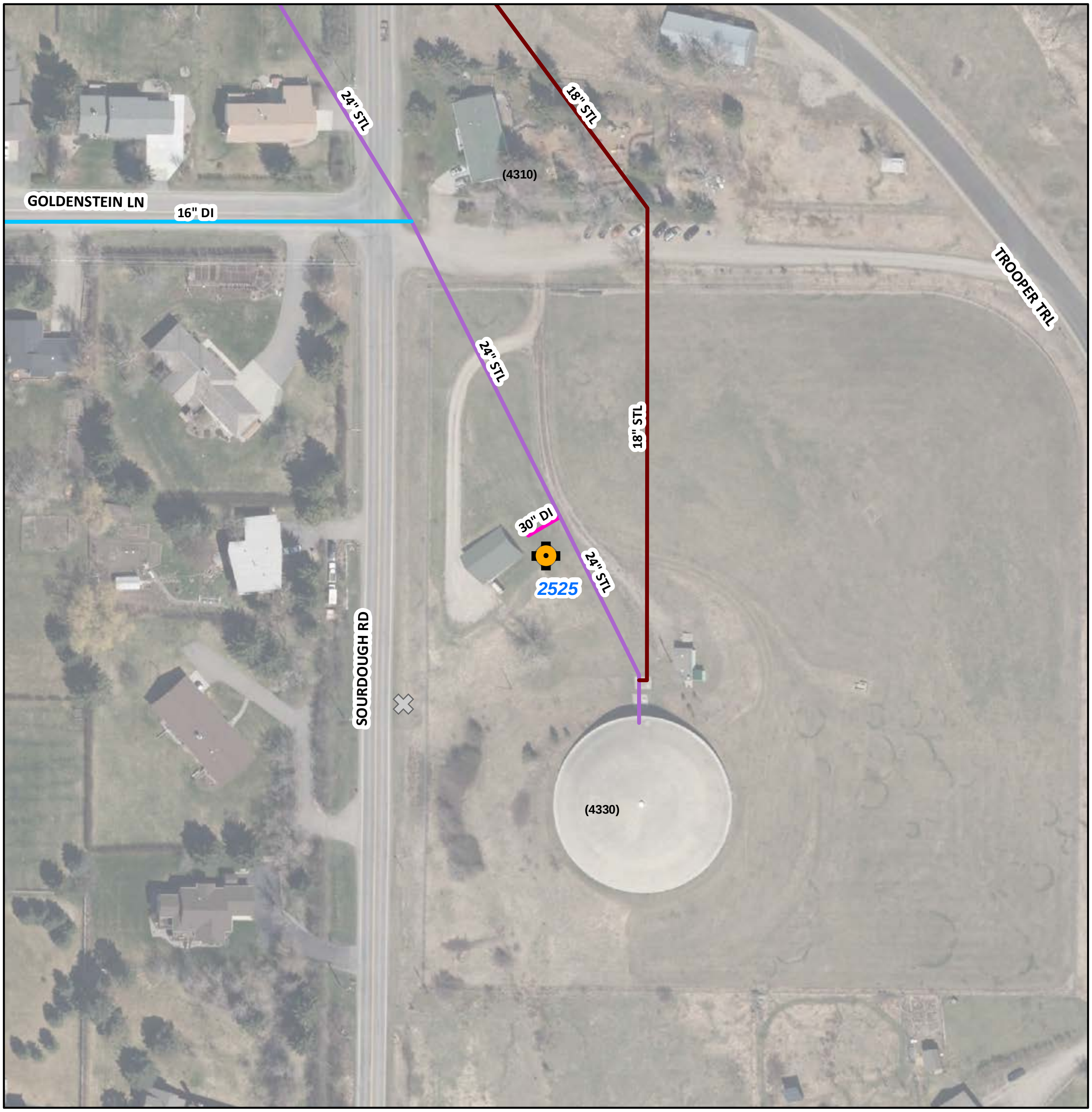
Advanced Engineering and Environmental Services, Inc.



Water Distribution System

Pressure Monitoring
Setup Prior to Flow Testing
South Pressure Zone Flow Testing

Advanced Engineering and Environmental Services, Inc.



Pressure Monitoring Location: 1

Hydrant ID: 2525

Recorder ID: __________ Pressure at Setup: __________

Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

Pressure Monitoring
Setup Prior to Flow Testing
South Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Pressure Monitoring Location: 2

Hydrant ID: 2107

Recorder ID: __________ Pressure at Setup: __________

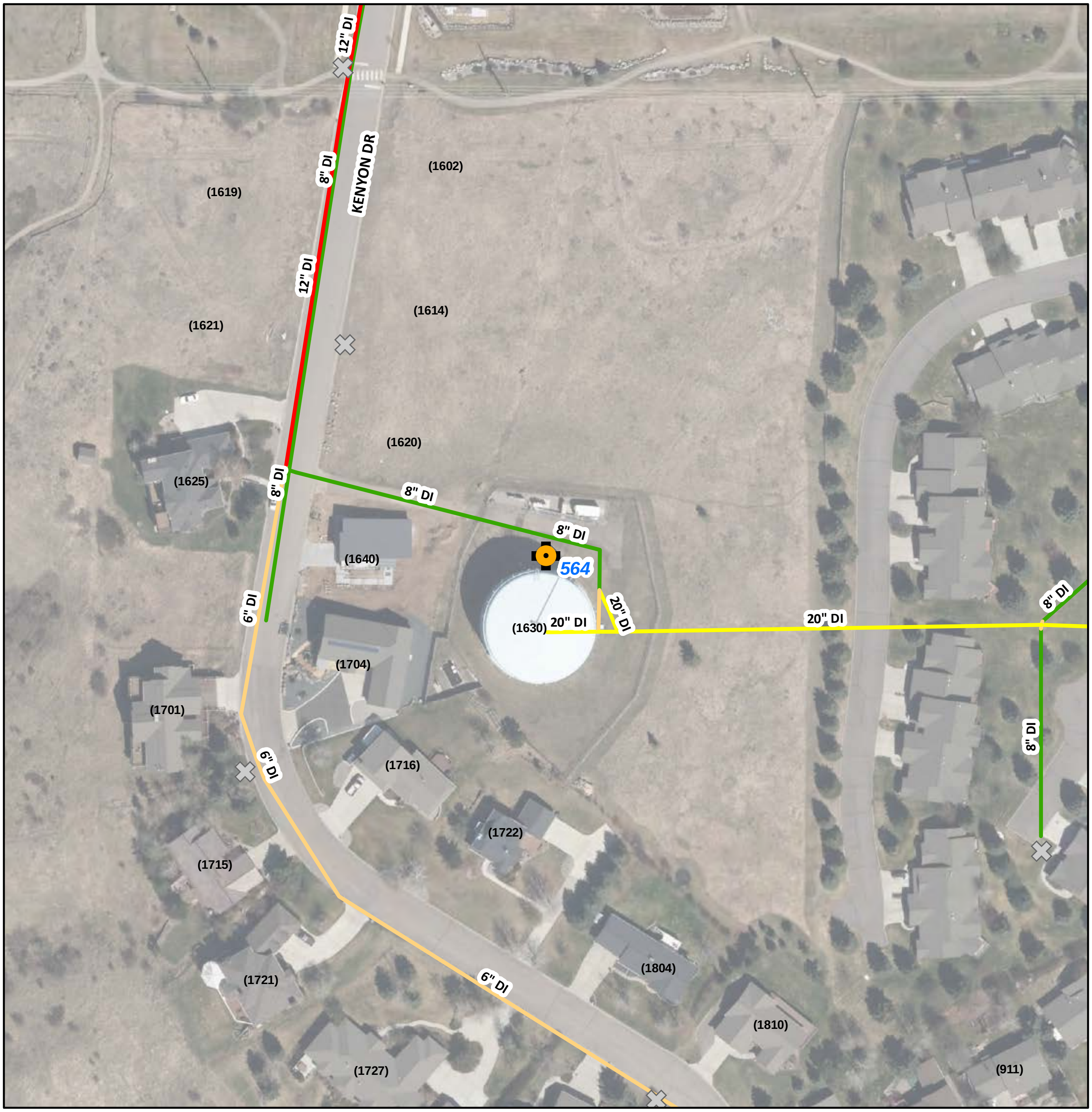
Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

Pressure Monitoring
Setup Prior to Flow Testing
South Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Pressure Monitoring Location: 3

Hydrant ID: 564

Recorder ID: __________ Pressure at Setup: __________

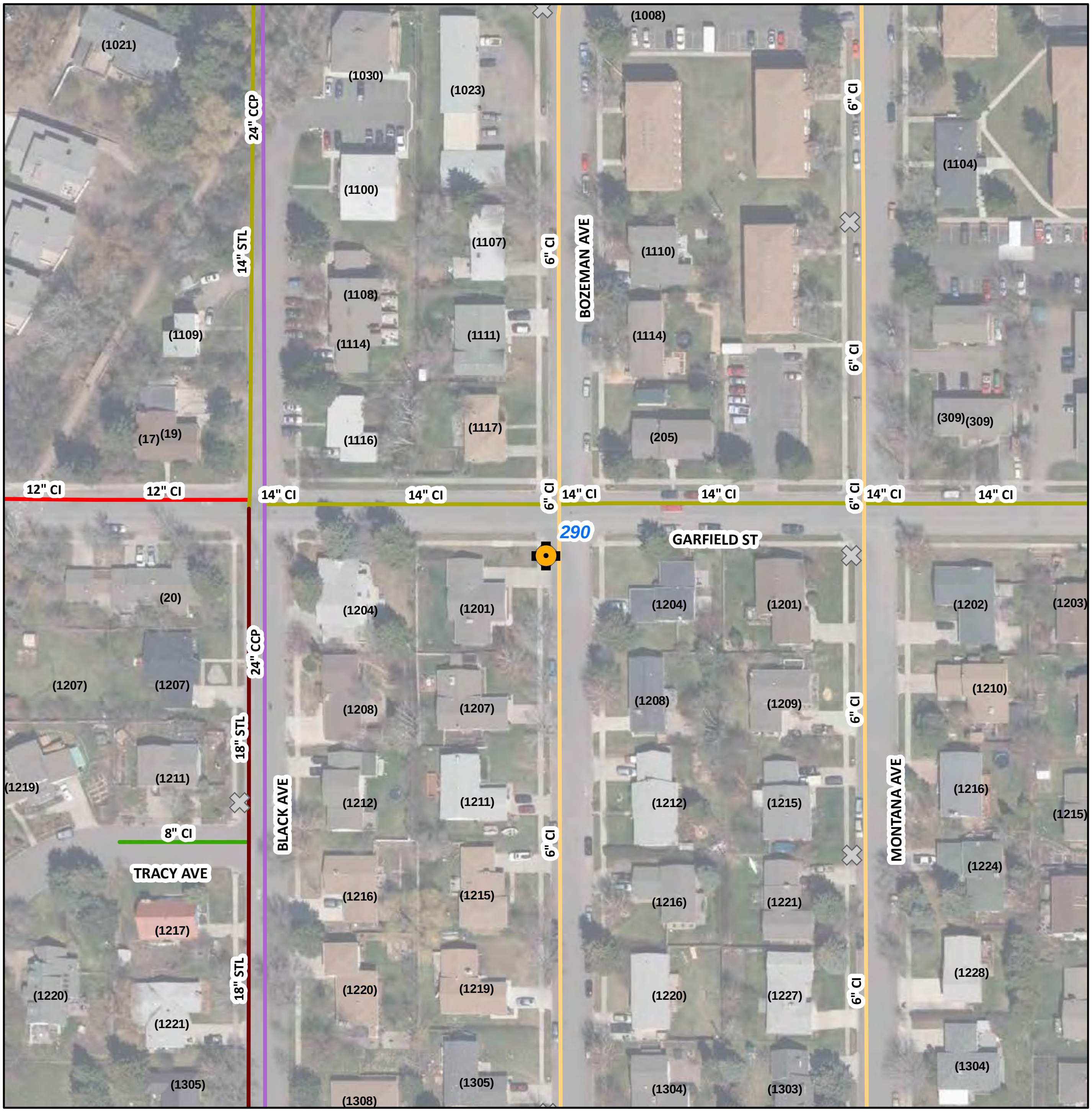
Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

Pressure Monitoring
Setup Prior to Flow Testing
South Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Pressure Monitoring Location: 4

Hydrant ID: 290

Recorder ID: __________ Pressure at Setup: __________

Installed - Date: __________ Time: __________

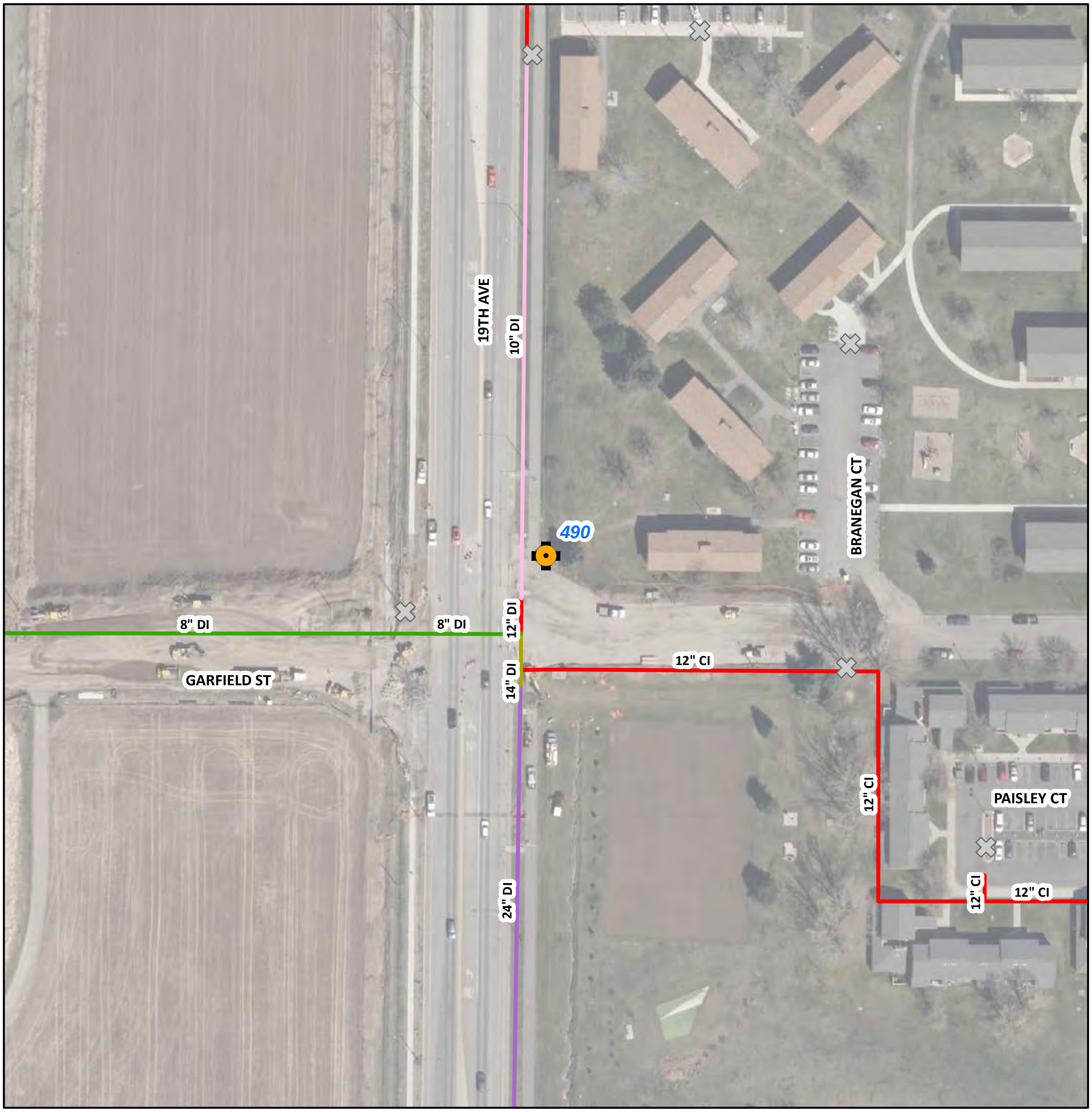
Removed - Date: __________ Time: __________

Installed/Removed By: _________

Pressure Monitoring
Setup Prior to Flow Testing
South Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

4



Pressure Monitoring Location: 5

Hydrant ID: 490

Recorder ID: __________ Pressure at Setup: __________

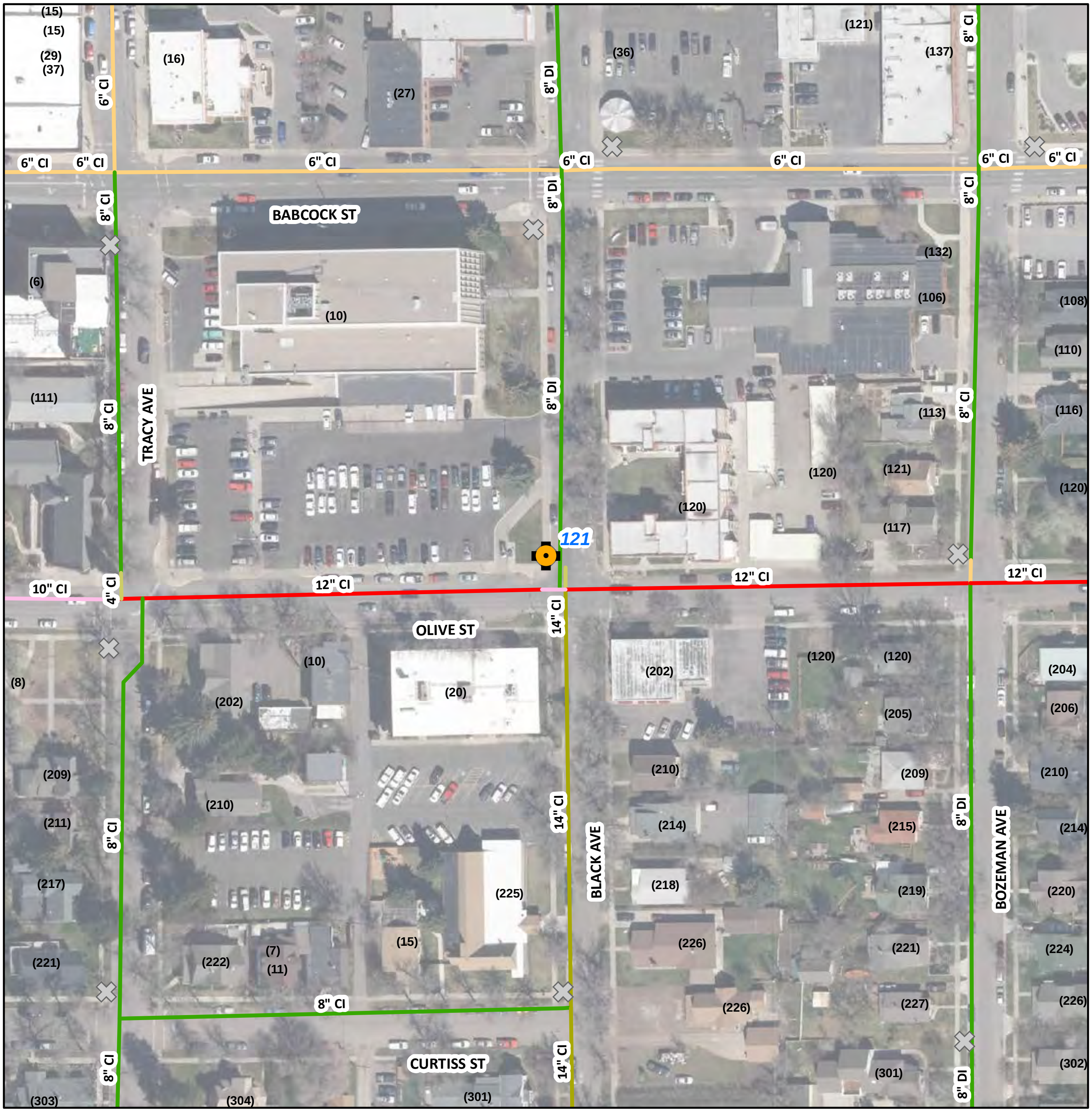
Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

Pressure Monitoring
Setup Prior to Flow Testing
South Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Pressure Monitoring Location: 6

Hydrant ID: 121

Recorder ID: __________ Pressure at Setup: __________

Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

Pressure Monitoring
Setup Prior to Flow Testing
South Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

6

Pressure Monitoring Location: 7

Hydrant ID: 1754

Recorder ID: __________ Pressure at Setup: __________

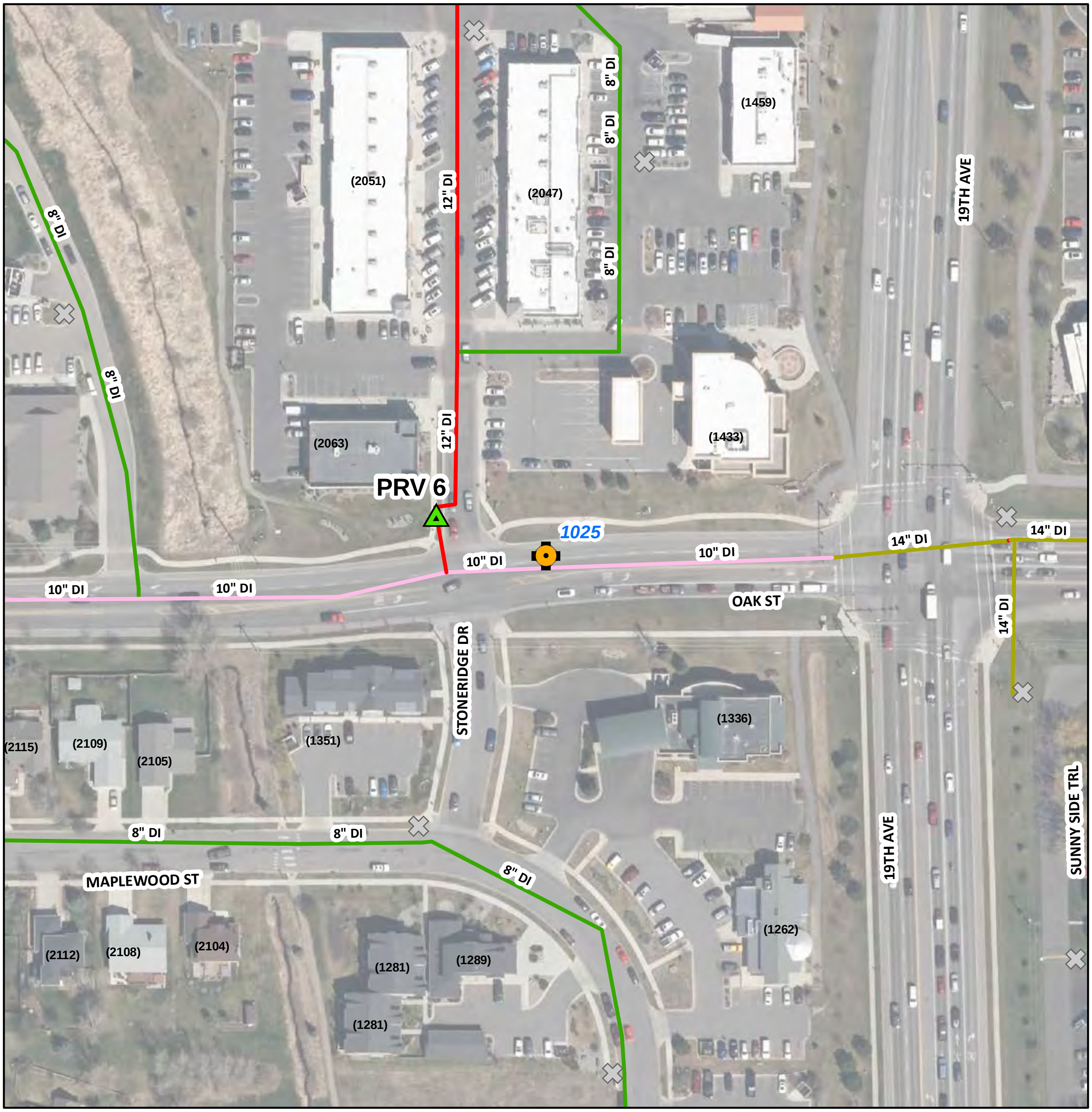
Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

Pressure Monitoring
Setup Prior to Flow Testing
South Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Pressure Monitoring Location: 8

Hydrant ID: 1025

Recorder ID: __________ Pressure at Setup: __________

Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

Pressure Monitoring
Setup Prior to Flow Testing
South Pressure Zone Flow Testing

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Pressure Monitoring Location: ___9___

Hydrant ID: ___1887___

Recorder ID: __________ Pressure at Setup: __________

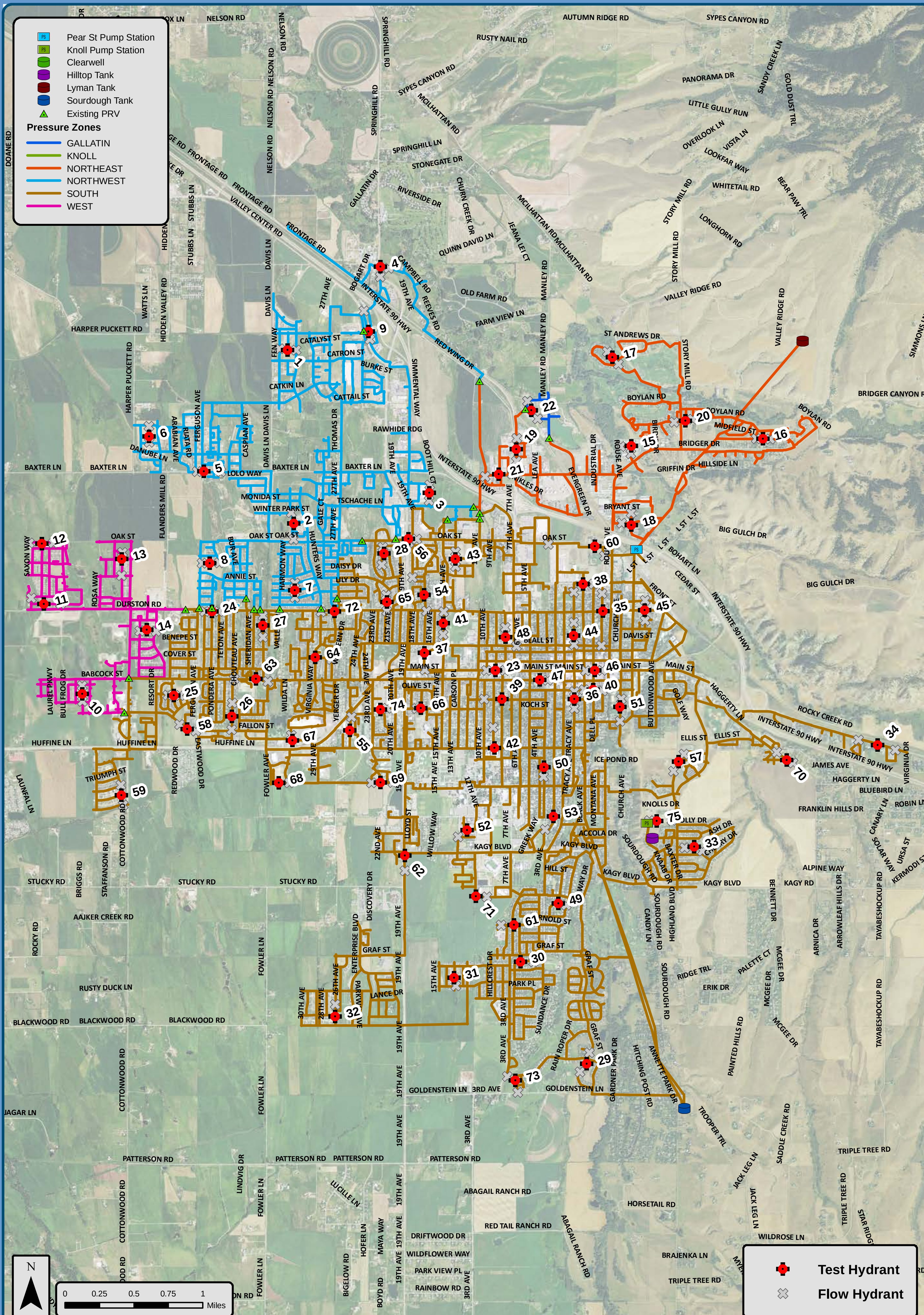
Installed - Date: __________ Time: __________

Removed - Date: __________ Time: __________

Installed/Removed By: _________

Pressure Monitoring
Setup Prior to Flow Testing
South Pressure Zone Flow Testing

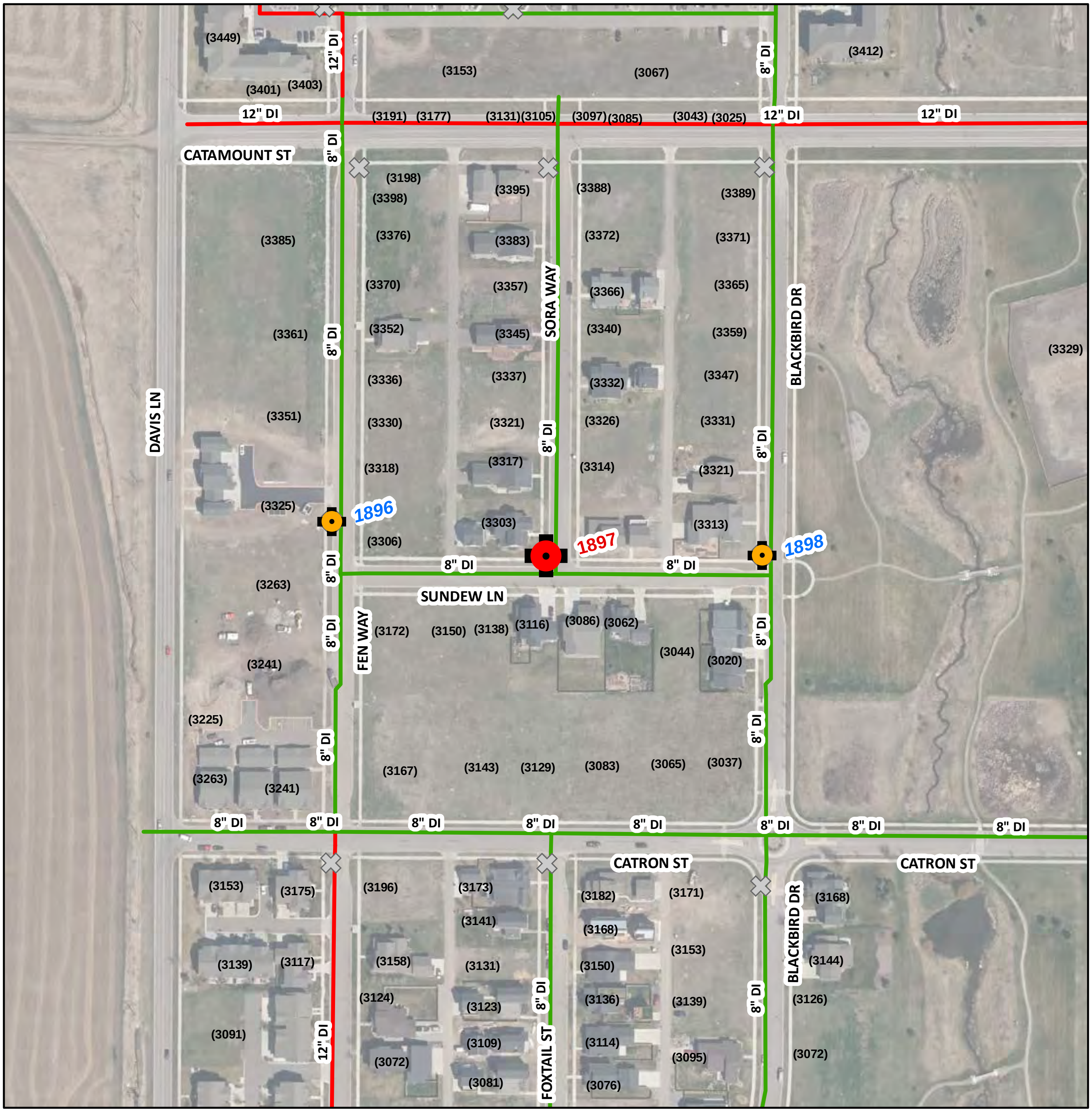
Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Water Distribution System

Fire Flow Test Locations
Shown with Pressure Zones

Advanced Engineering and Environmental Services, Inc.



Test Number: 1

Test Date: 9/28/2015

Start Time: 12:44 PM

End Time: 12:53 PM

Test By: JDH

Zone: NORTHWEST

RESIDUAL HYDRANT

Hydrant No. 1897

HPR No. 1240

Static: 109.8 psi

Residual: 90.2 psi

FLOW HYDRANT #1

Hydrant No. 1896

HPR No. 1241

Flow: 1,518 gpm

FLOW HYDRANT #2

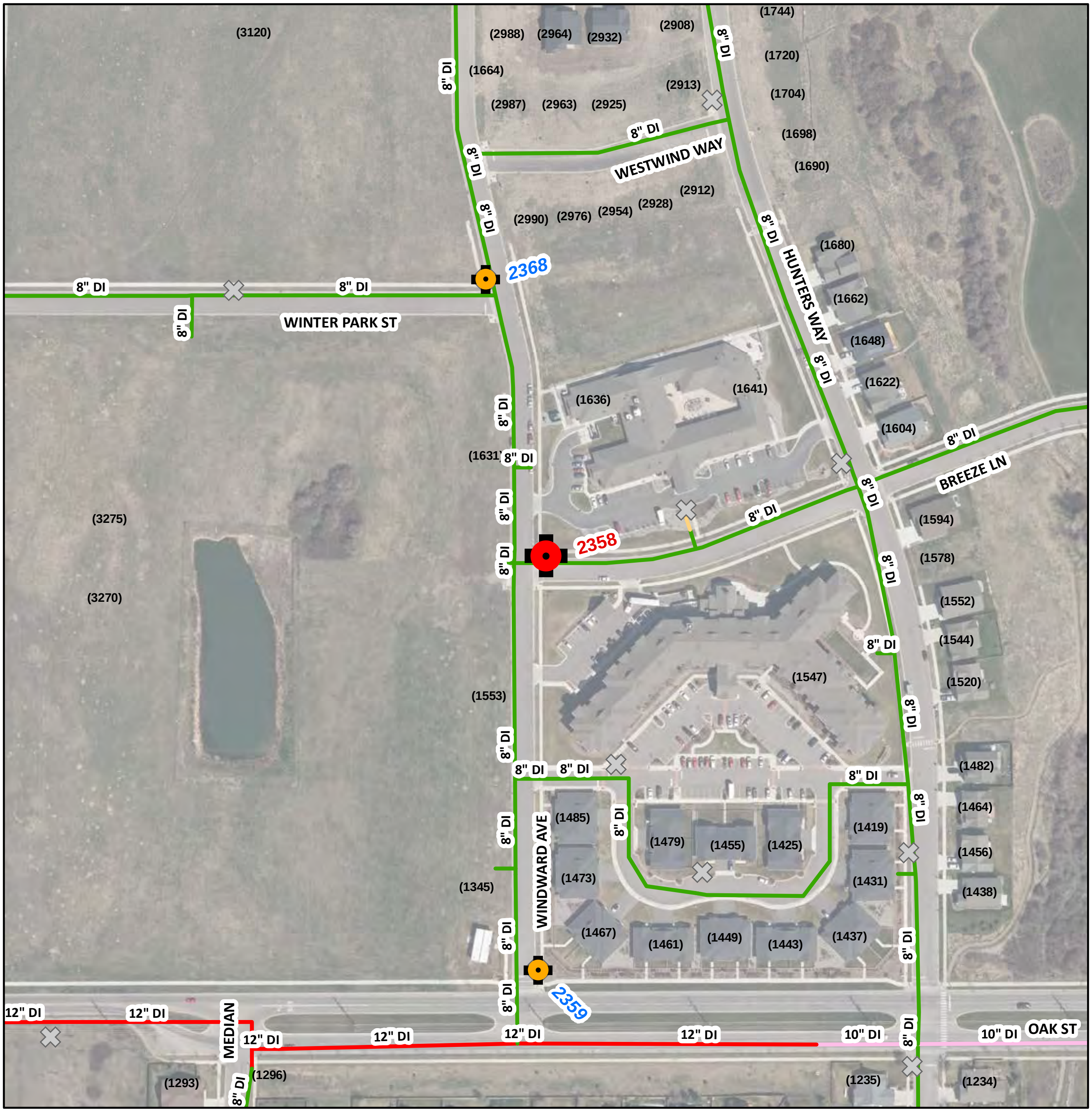
Hydrant No. 1898

HPR No. 201250

Flow: 1,484 gpm

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 2

Test Date: 9/28/2015

Start Time: 10:52 AM

End Time: 11:02 AM

Test By: JDH

Zone: NORTHWEST

RESIDUAL HYDRANT

Hydrant No. 2358

HPR No. 1240

Static: 75.7 psi

Residual: 60.4 psi

FLOW HYDRANT #1

Hydrant No. 2368

HPR No. 1241

Flow: 1,230 gpm

FLOW HYDRANT #2

Hydrant No. 2359

HPR No. 201250

Flow: 1,167 gpm

Test Hydrants | Flow Hydrants | Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 3

Test Date: 9/28/2015

Start Time: 11:14 AM

End Time: 11:25 AM

Test By: JDH

Zone: NORTHWEST

RESIDUAL HYDRANT

Hydrant No. 2064

HPR No. 1240

Static: 81.9 psi

Residual: 62.8 psi

FLOW HYDRANT #1

Hydrant No. 2058

HPR No. 1241

Flow: 1,235 gpm

FLOW HYDRANT #2

Hydrant No. 2063

HPR No. 201250

Flow: 1,215 gpm

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 4

Test Date: 9/28/2015

Start Time: 1:23 PM

End Time: 1:33 PM

Test By: JDH

Zone: NORTHWEST

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. 1726	Hydrant No. 1745	Hydrant No. 1727
HPR No. 1240	HPR No. 1241	HPR No. 201250
Static: 125.4 psi	Flow: 1,615 gpm	Flow: 1,418 gpm
Residual: 106.6 psi		

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 5

Test Date: 9/28/2015

Start Time: 12:05 PM

End Time: 12:14 PM

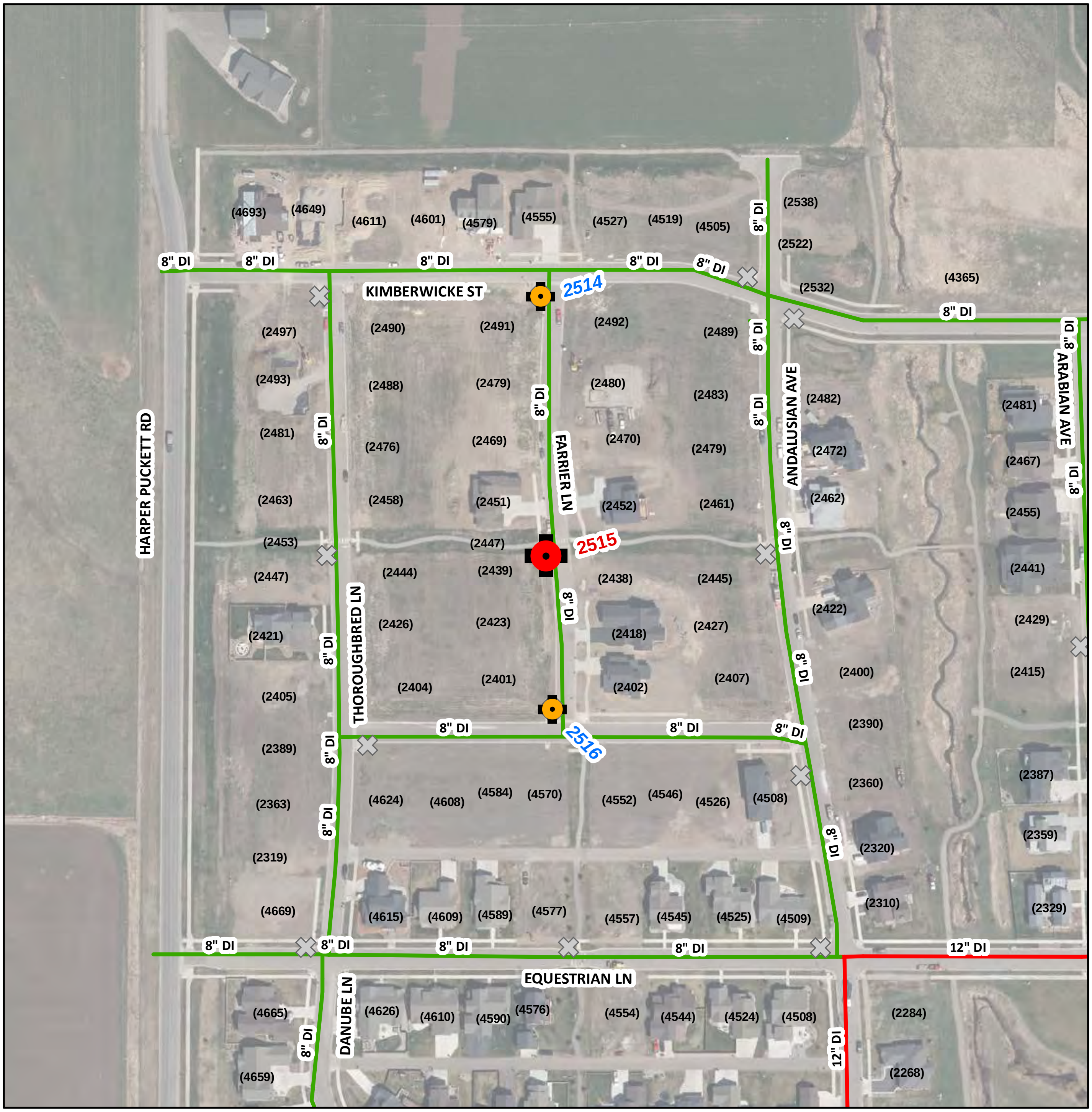
Test By: JDH

Zone: NORTHWEST

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	1604	Hydrant No.	1601	Hydrant No.	1609
HPR No.	1240	HPR No.	1241	HPR No.	201250
Static:	90.7 psi	Flow:	1,325 gpm	Flow:	1,169 gpm
Residual:	71.7 psi				

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 6

Test Date: 9/28/2015

Start Time: 12:22 PM

End Time: 12:30 PM

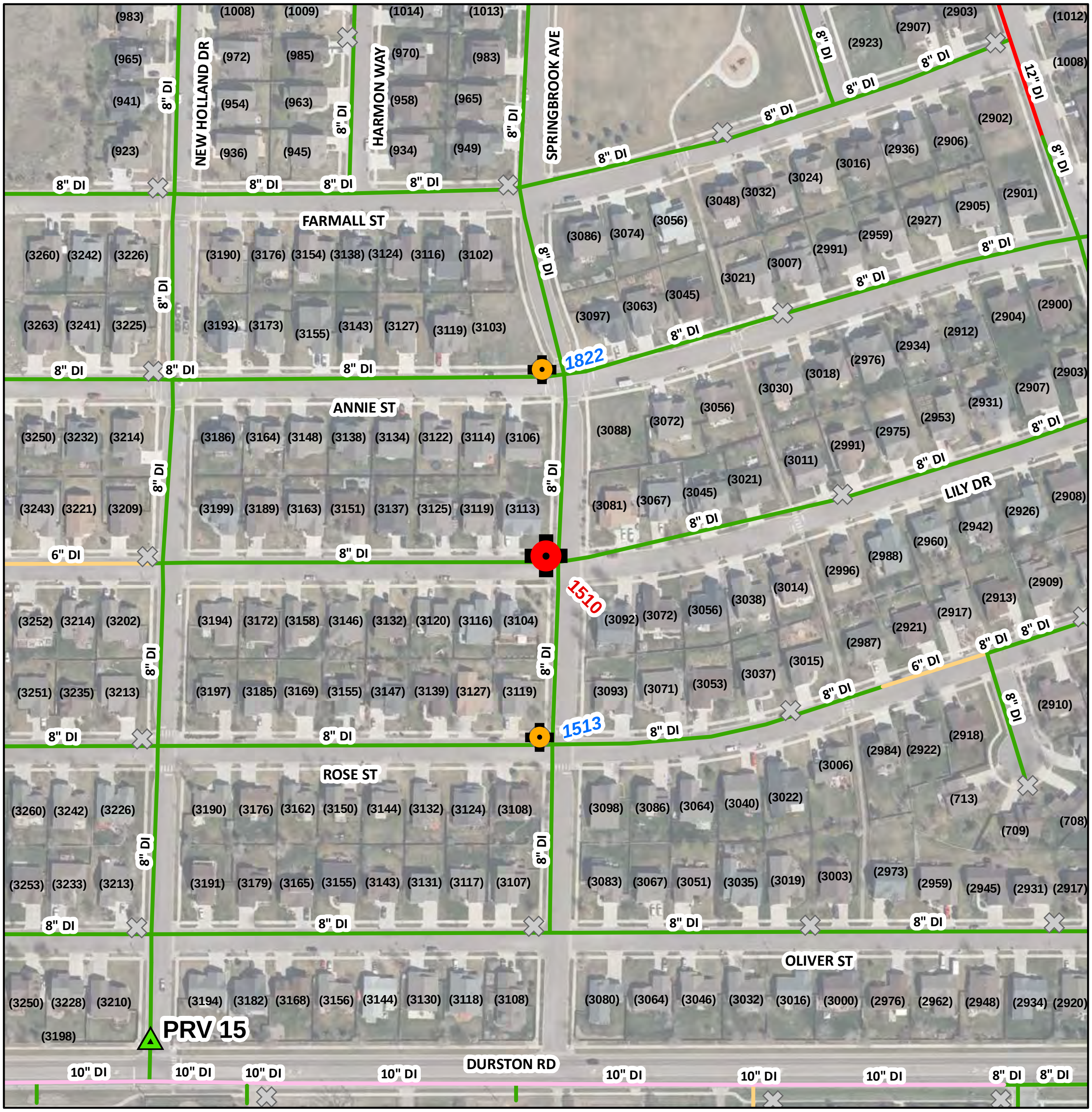
Test By: JDH

Zone: NORTHWEST

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. 2515	Hydrant No. 2514	Hydrant No. 2516
HPR No. 1240	HPR No. 1241	HPR No. 201250
Static: 88.4 psi	Flow: 1,287 gpm	Flow: 1,246 gpm
Residual: 61.0 psi		

Test Hydrants · Flow Hydrants · Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: *7*

Test Date: *9/28/2015*

Start Time: *10:37 AM*

End Time: *10:47 AM*

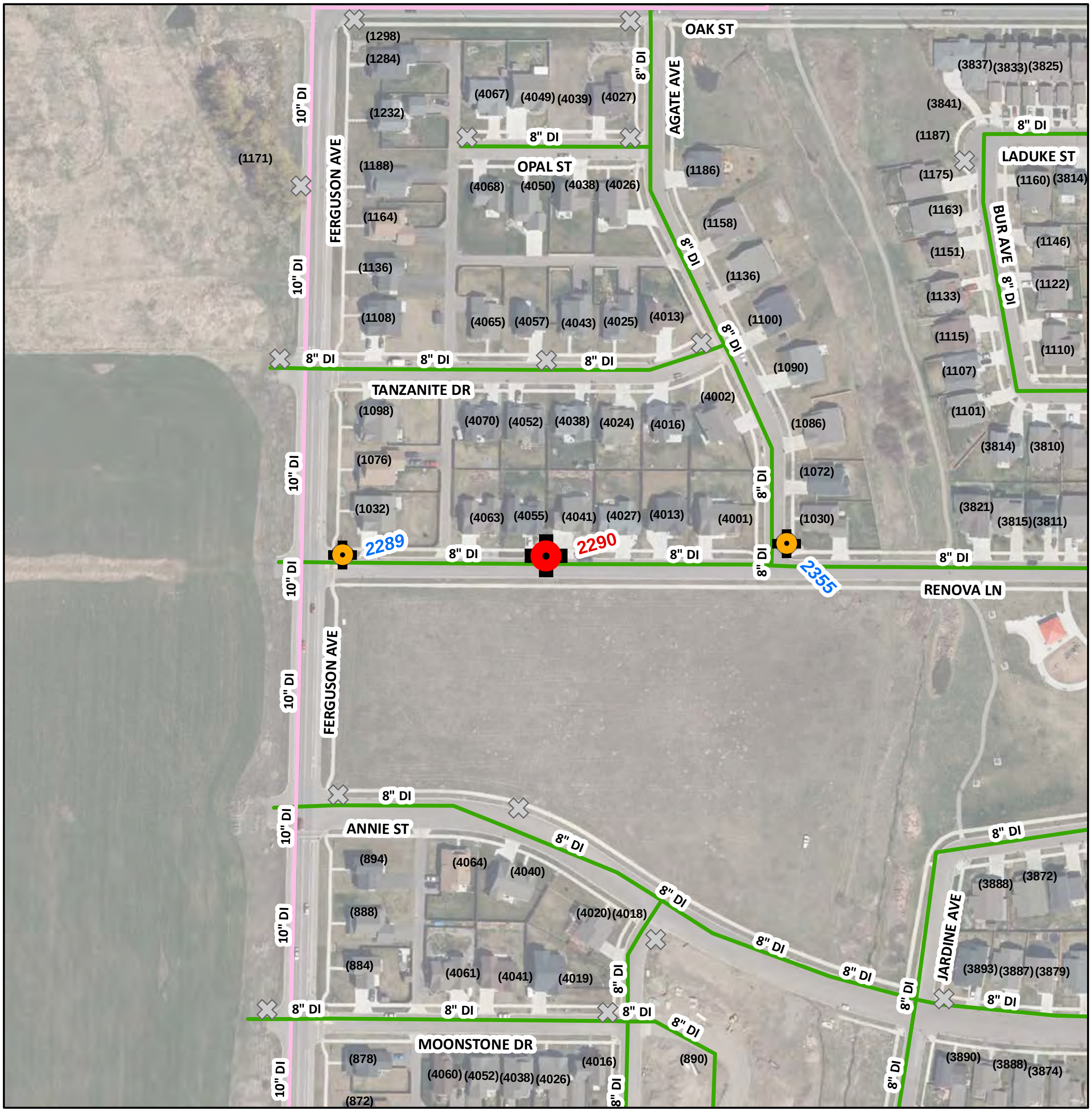
Test By: *JDH*

Zone: *NORTHWEST*

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. *1510*	Hydrant No. *1822*	Hydrant No. *1513*
HPR No. *1240*	HPR No. *1241*	HPR No. *201250*
Static: *61.7 psi*	Flow: *1,083 gpm*	Flow: *1,049 gpm*
Residual: *46.0 psi*		

Test Hydrants · Flow Hydrants · Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 8

Test Date: 9/28/2015

Start Time: 10:20 AM

End Time: 10:27 AM

Test By: JDH

Zone: NORTHWEST

RESIDUAL HYDRANT

Hydrant No. 2290

HPR No. 1240

Static: 67.4 psi

Residual: 57.7 psi

FLOW HYDRANT #1

Hydrant No. 2355

HPR No. 1241

Flow: 1,212 gpm

FLOW HYDRANT #2

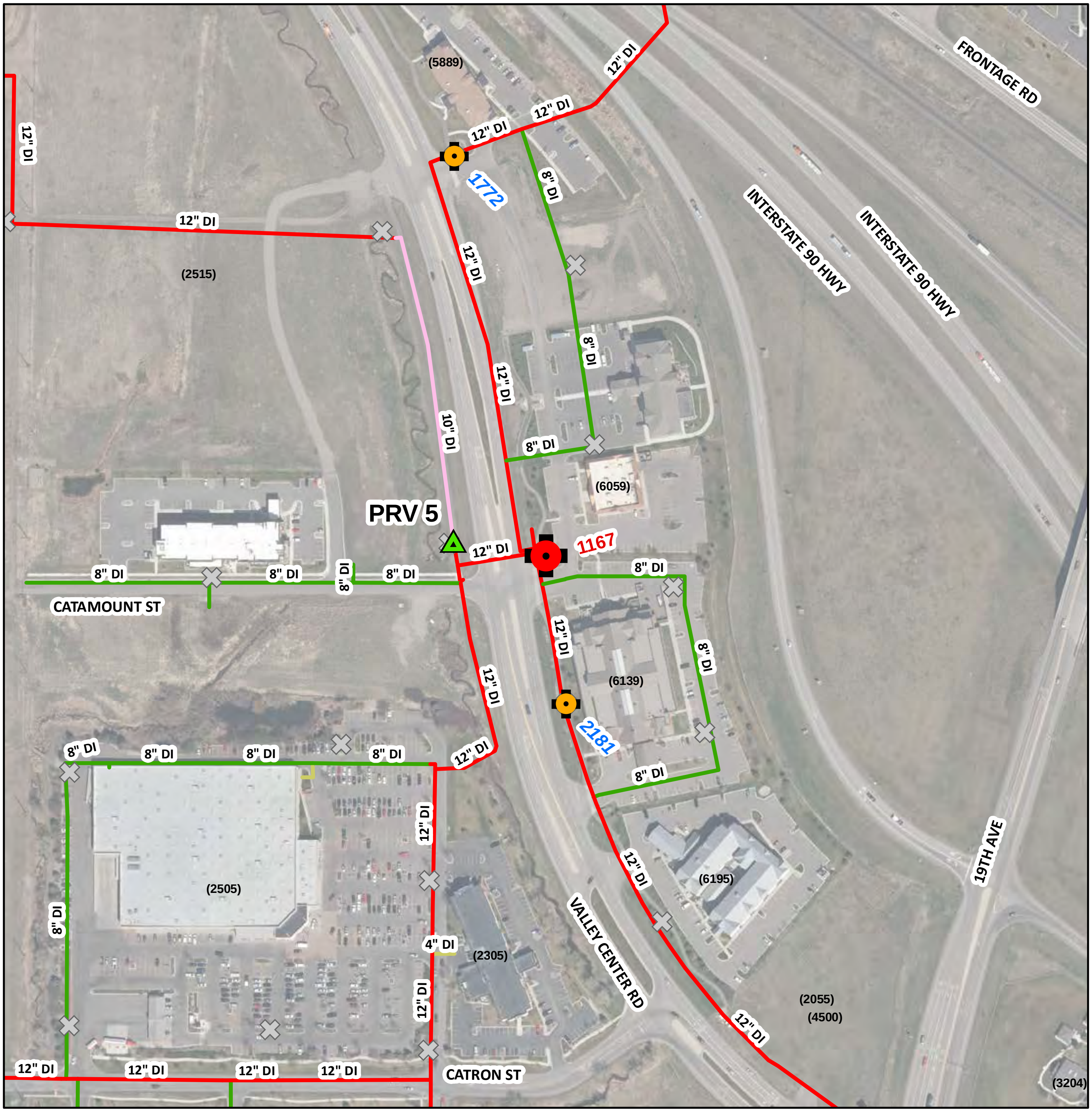
Hydrant No. 2289

HPR No. 201250

Flow: 1,195 gpm

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 9

Test Date: 9/28/2015

Start Time: 1:03 PM

End Time: 1:11 PM

Test By: JDH

Zone: NORTHWEST

RESIDUAL HYDRANT

Hydrant No. 1167

HPR No. 1240

Static: 112.5 psi

Residual: 97.7 psi

FLOW HYDRANT #1

Hydrant No. 1772

HPR No. 1241

Flow: 1,569 gpm

FLOW HYDRANT #2

Hydrant No. 2181

HPR No. 201250

Flow: 1,552 gpm

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 10

Test Date: 9/28/2015

Start Time: 4:23 PM

End Time: 4:32 PM

Test By: JDH

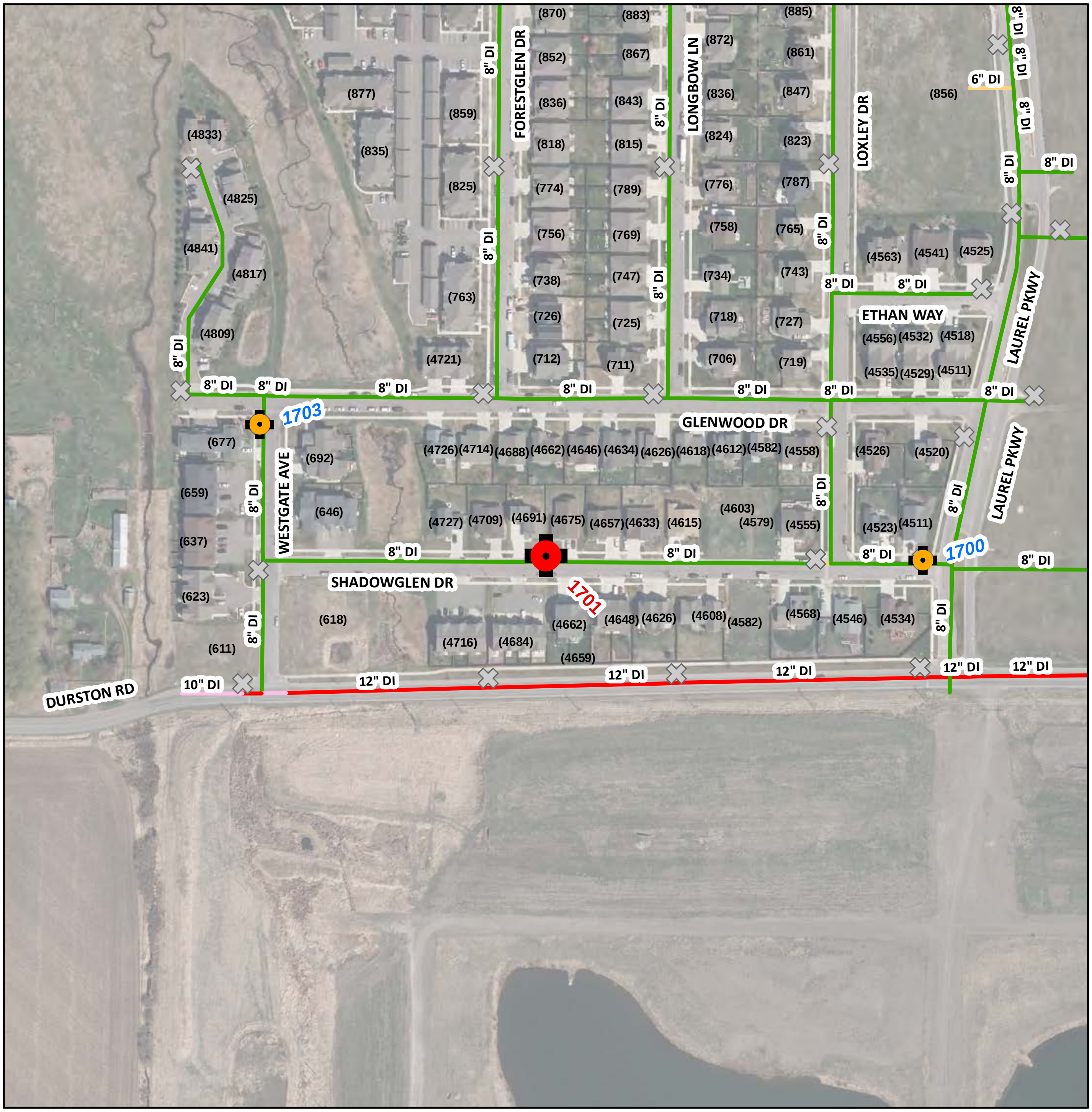
Zone: WEST

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. 2411	Hydrant No. 2410	Hydrant No. 2412
HPR No. 1240	HPR No. 1241	HPR No. 201250
Static: 66.1 psi	Flow: 1,201 gpm	Flow: 1,233 gpm
Residual: 60.2 psi		

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Test Number: 11

Test Date: 9/28/2015

Start Time: 5:16 PM

End Time: 5:29 PM

Test By: JDH

Zone: WEST

RESIDUAL HYDRANT

Hydrant No. 1701

HPR No. 1240

Static: 84.6 psi

Residual: 72.8 psi

FLOW HYDRANT #1

Hydrant No. 1700

HPR No. 1241

Flow: 1,353 gpm

FLOW HYDRANT #2

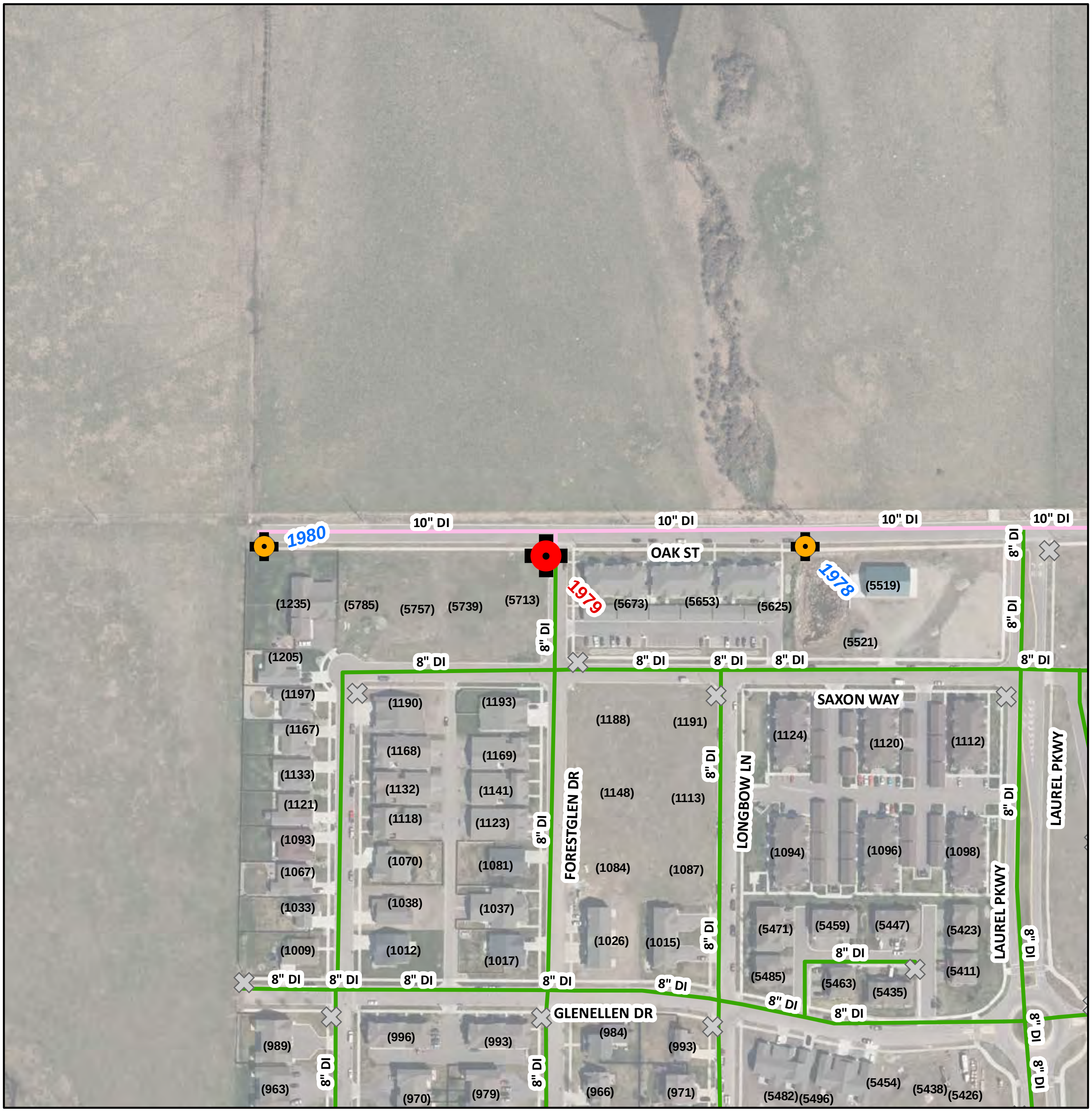
Hydrant No. 1703

HPR No. 201250

Flow: 1,250 gpm

Test Hydrants   Flow Hydrants   Other Hydrants

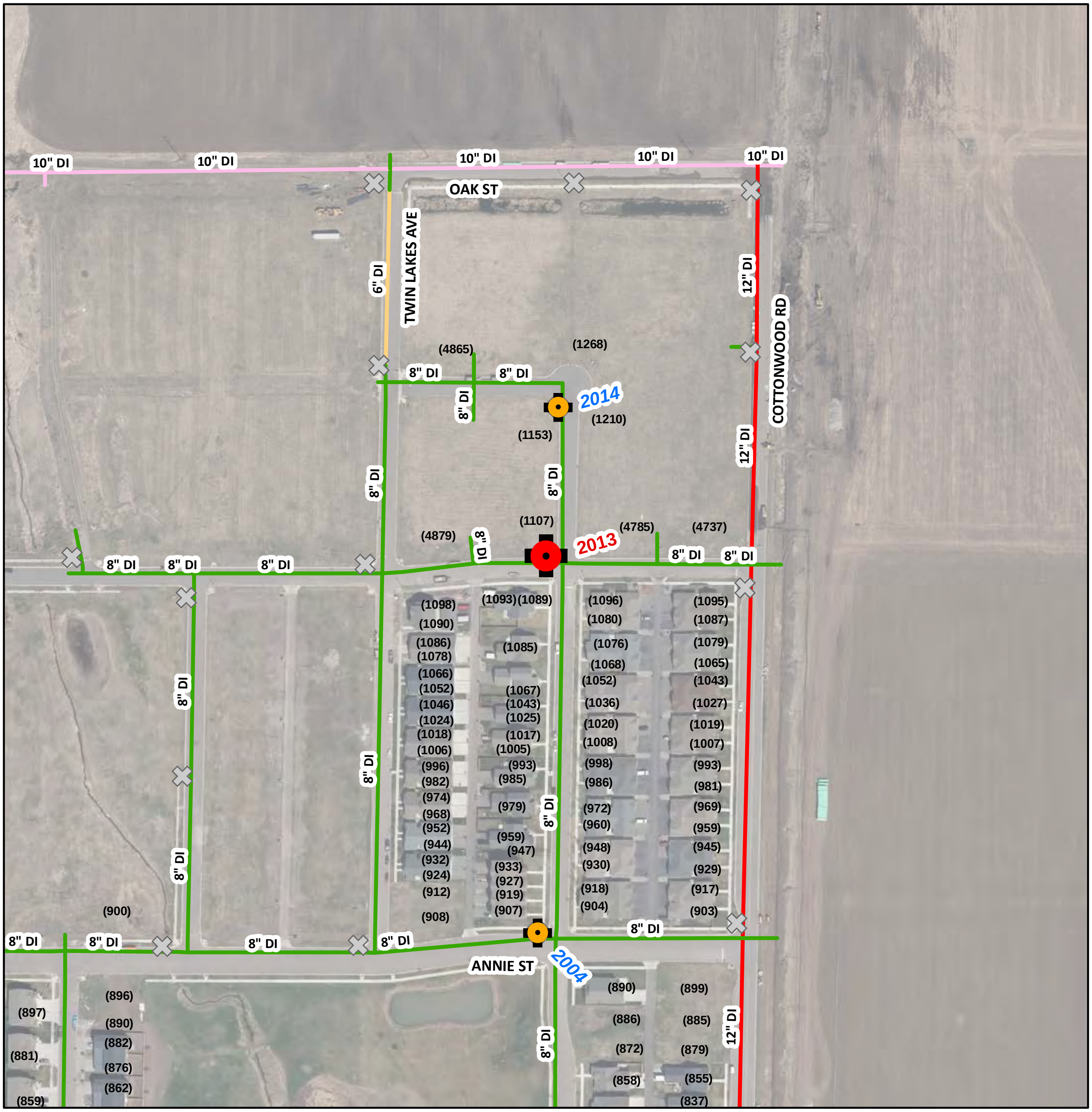
Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 12	**RESIDUAL HYDRANT**	**FLOW HYDRANT #1**	**FLOW HYDRANT #2**
Test Date: 9/28/2015	**Hydrant No.** 1979	**Hydrant No.** 1980	**Hydrant No.** 1978
Start Time: 5:38 PM	**HPR No.** 1240	**HPR No.** 1241	**HPR No.** 201250
End Time: 5:47 PM	**Static:** 95.3 psi	**Flow:** 1,350 gpm	**Flow:** 1,335 gpm
Test By: JDH	**Residual:** 76.0 psi		
Zone: WEST			

Test Hydrants — Flow Hydrants — Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: *13*

Test Date: *9/28/2015*

Start Time: *4:58 PM*

End Time: *5:08 PM*

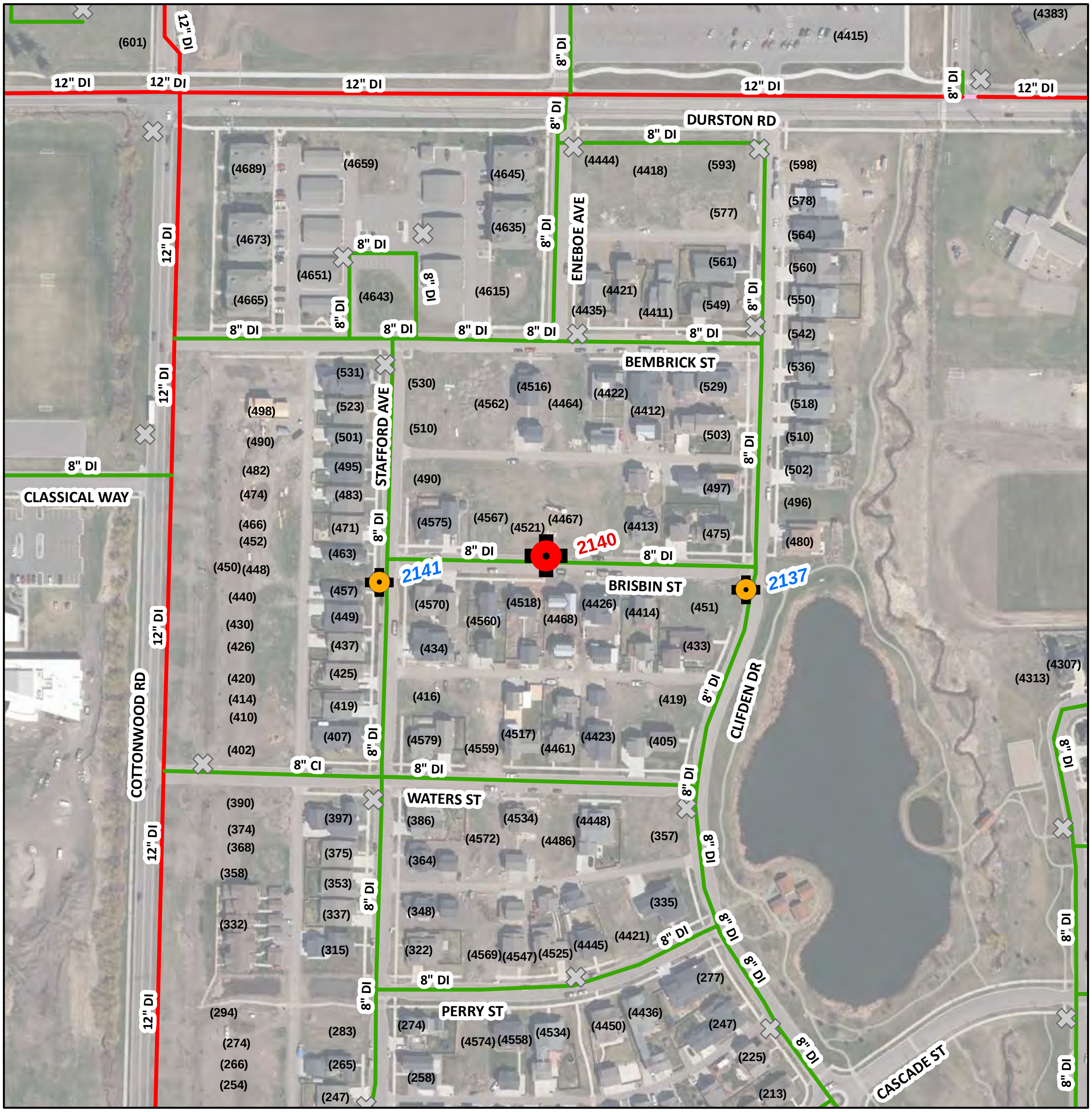
Test By: *JDH*

Zone: *WEST*

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. *2013*	Hydrant No. *2004*	Hydrant No. *2014*
HPR No. *1240*	HPR No. *1241*	HPR No. *201250*
Static: *90.2 psi*	Flow: *1,435 gpm*	Flow: *1,340 gpm*
Residual: *85.1 psi*		

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 14	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: 9/28/2015	Hydrant No. 2140	Hydrant No. 2137	Hydrant No. 2141
Start Time: 4:40 PM	HPR No. 1240	HPR No. 1241	HPR No. 201250
End Time: 4:48 PM	Static: 73.7 psi	Flow: 1,342 gpm	Flow: 1,365 gpm
Test By: JDH	Residual: 72.5 psi		
Zone: WEST			

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 15

Test Date: 9/29/2015

Start Time: 9:52 AM

End Time: 10:08 AM

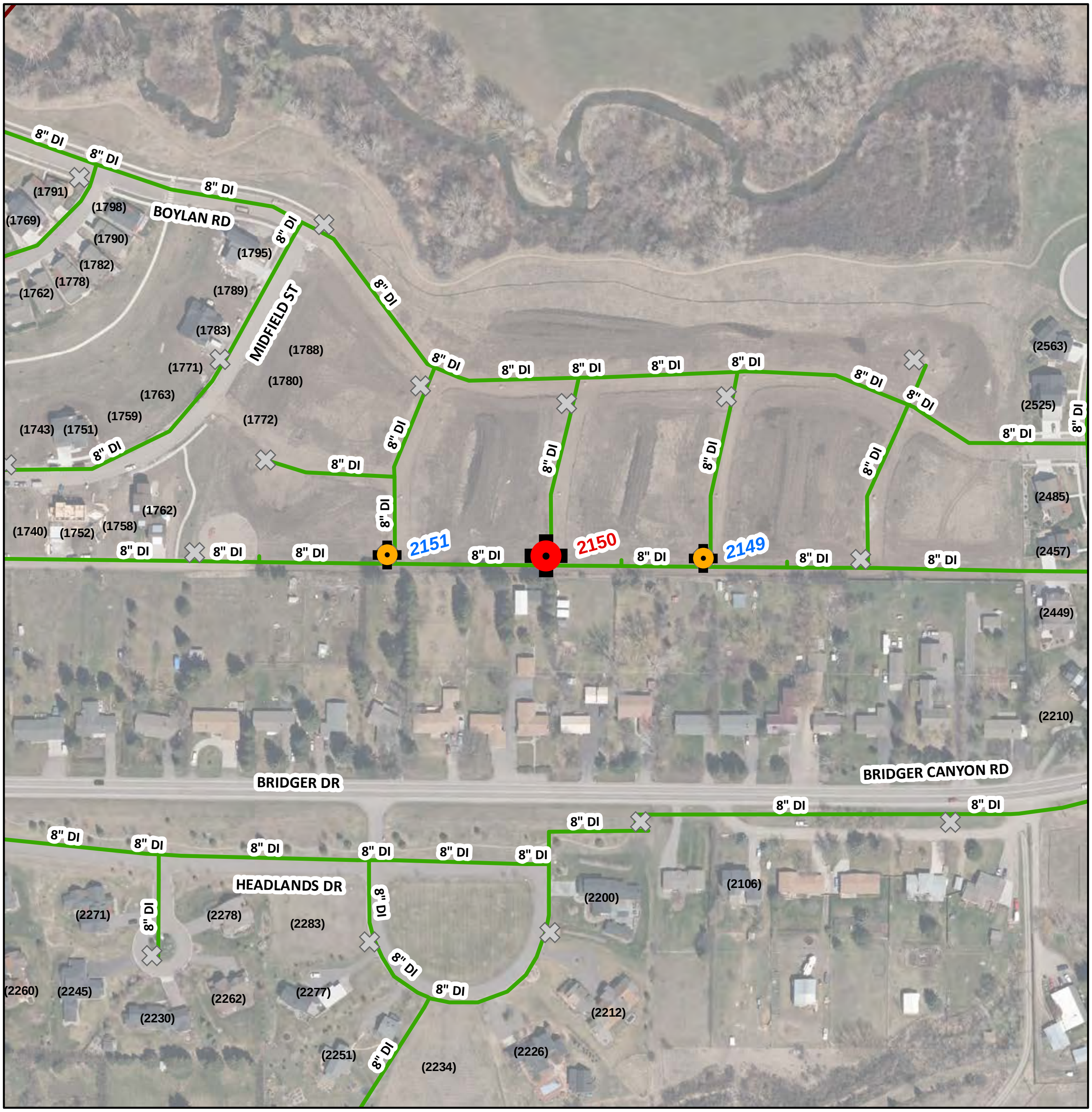
Test By: JDH

Zone: NORTHEAST

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	1861	Hydrant No.	1863	Hydrant No.	1862
HPR No.	1240	HPR No.	1241	HPR No.	201250
Static:	137.8 psi	Flow:	1,441 gpm	Flow:	1,426 gpm
Residual:	86.1 psi				

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 16

Test Date: 9/29/2015

Start Time: 10:54 AM

End Time: 11:08 AM

Test By: JDH

Zone: NORTHEAST

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. 2150	Hydrant No. 2151	Hydrant No. 2149
HPR No. 1240	HPR No. 1241	HPR No. 201250
Static: 110.3 psi	Flow: 1,528 gpm	Flow: 1,524 gpm
Residual: 94.8 psi		

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

Test Number: 17

Test Date: 9/29/2015

Start Time: 10:16 AM

End Time: 10:27 AM

Test By: JDH

Zone: NORTHEAST

RESIDUAL HYDRANT

Hydrant No. 1061

HPR No. 1240

Static: 143.8 psi

Residual: 93.8 psi

FLOW HYDRANT #1

Hydrant No. 1062

HPR No. 1241

Flow: 1,571 gpm

FLOW HYDRANT #2

Hydrant No. 1060

HPR No. 201250

Flow: 1,540 gpm

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 18

Test Date: 9/29/2015

Start Time: 9:29 AM

End Time: 9:42 AM

Test By: JDH

Zone: NORTHEAST

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. 622	Hydrant No. 2497	Hydrant No. 624
HPR No. 1240	HPR No. 1241	HPR No. 201250
Static: 124.3 psi	Flow: 1,674 gpm	Flow: 1,693 gpm
Residual: 109.2 psi		

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 19

Test Date: 9/29/2015

Start Time: 9:05 AM

End Time: 9:18 AM

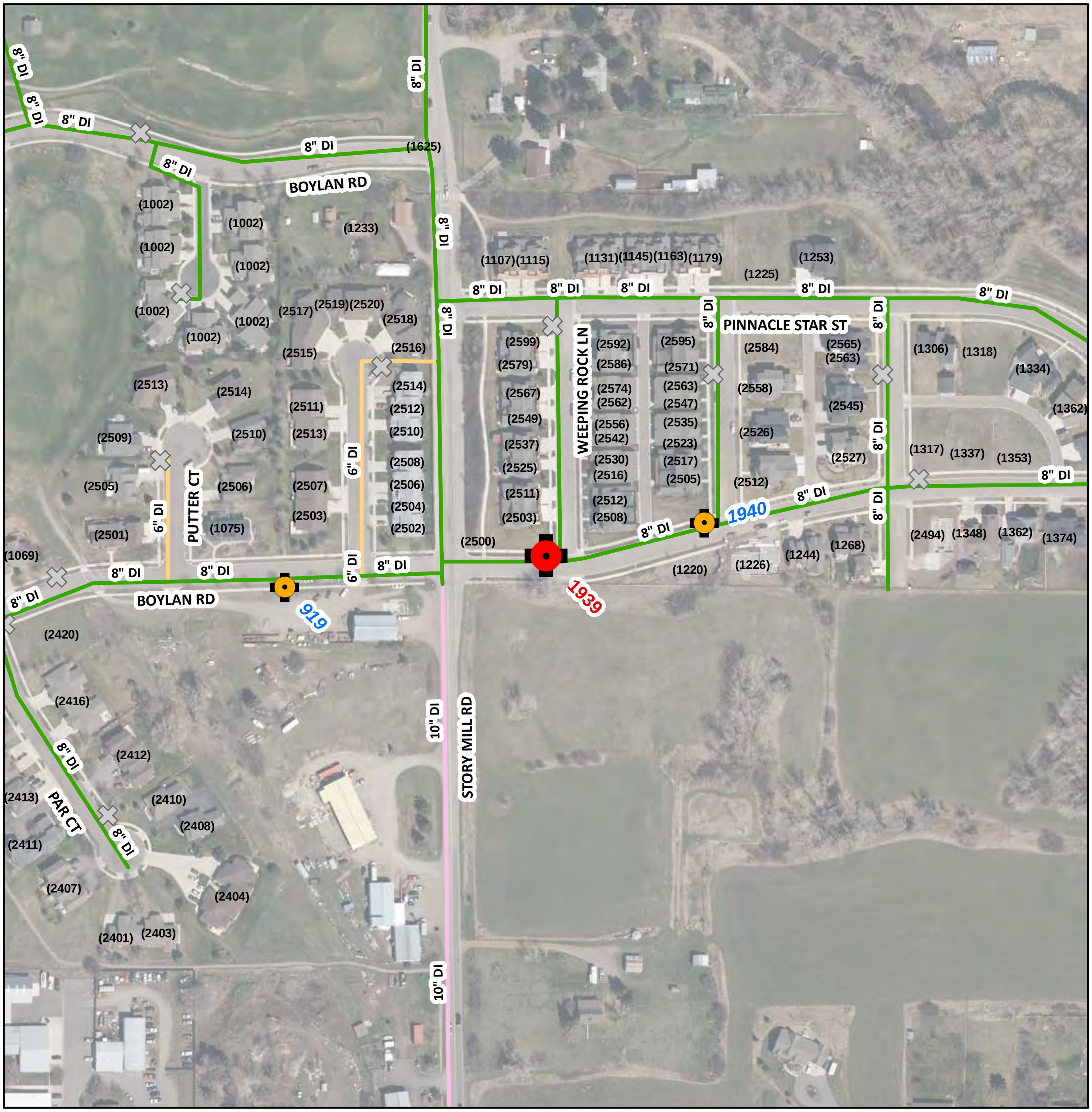
Test By: JDH

Zone: NORTHEAST

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	645	Hydrant No.	646	Hydrant No.	644
HPR No.	1240	HPR No.	1241	HPR No.	201250
Static:	123.7 psi	Flow:	1,483 gpm	Flow:	1,448 gpm
Residual:	81.9 psi				

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 20

Test Date: 9/29/2015

Start Time: 10:37 AM

End Time: 10:48 AM

Test By: JDH

Zone: NORTHEAST

RESIDUAL HYDRANT

Hydrant No. 1939

HPR No. 1240

Static: 127.4 psi

Residual: 113.1 psi

FLOW HYDRANT #1

Hydrant No. 1940

HPR No. 1241

Flow: 1,596 gpm

FLOW HYDRANT #2

Hydrant No. 919

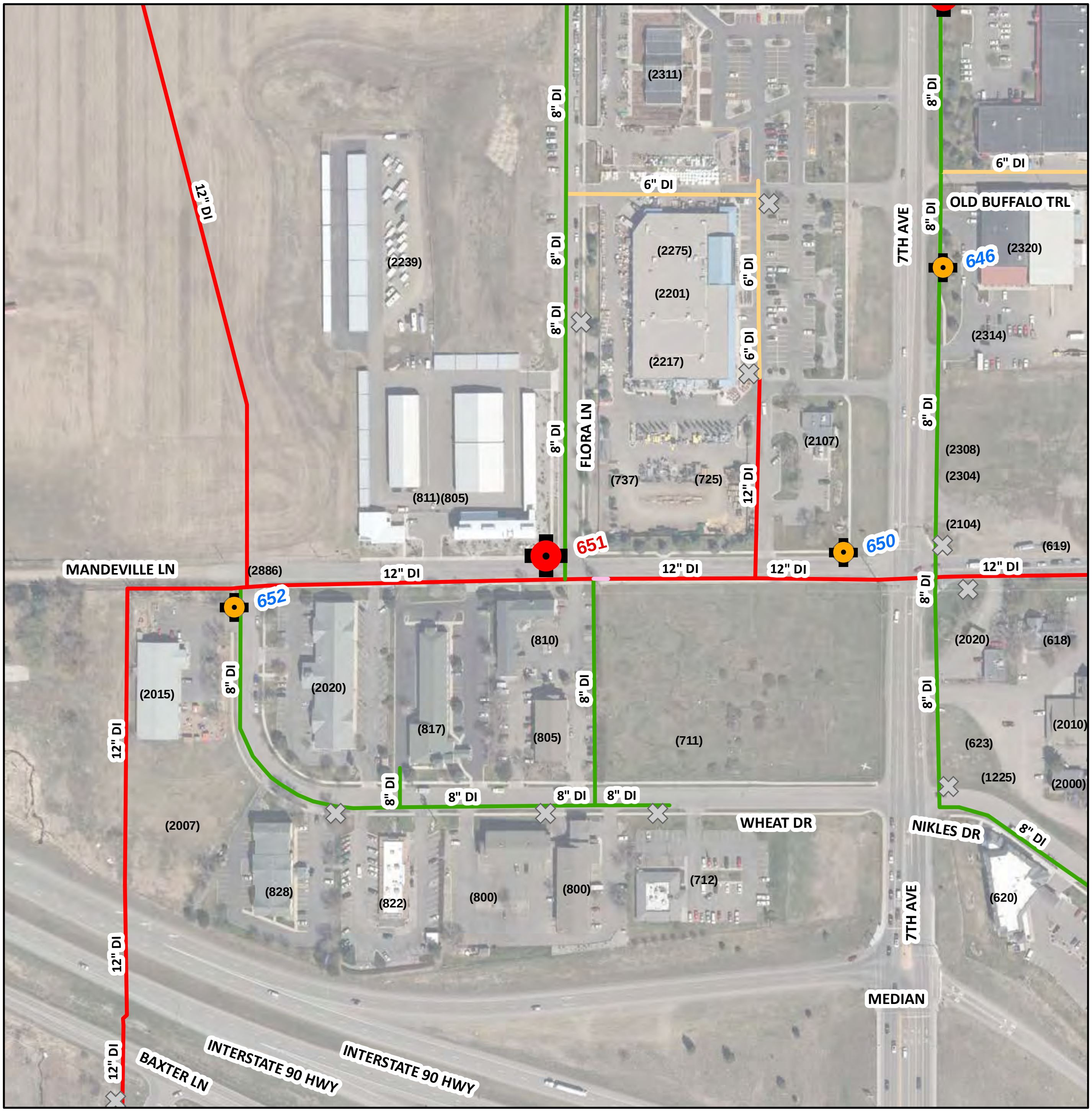
HPR No. 201250

Flow: 1,682 gpm

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Test Number: 21

Test Date: 9/29/2015

Start Time: 8:16 AM

End Time: 8:24 AM

Test By: JDH

Zone: NORTHEAST

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	651	Hydrant No.	650	Hydrant No.	652
HPR No.	1240	HPR No.	1241	HPR No.	201250
Static:	123.3 psi	Flow:	1,508 gpm	Flow:	1,419 gpm
Residual:	89.1 psi				

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 22

Test Date: 9/29/2015

Start Time: 8:38 AM

End Time: 8:56 AM

Test By: JDH

Zone: GALLATIN

RESIDUAL HYDRANT

Hydrant No. 1212

HPR No. 1240

Static: 76.4 psi

Residual: 65.1 psi

FLOW HYDRANT #1

Hydrant No. 1213

HPR No. 1241

Flow: 1,228 gpm

FLOW HYDRANT #2

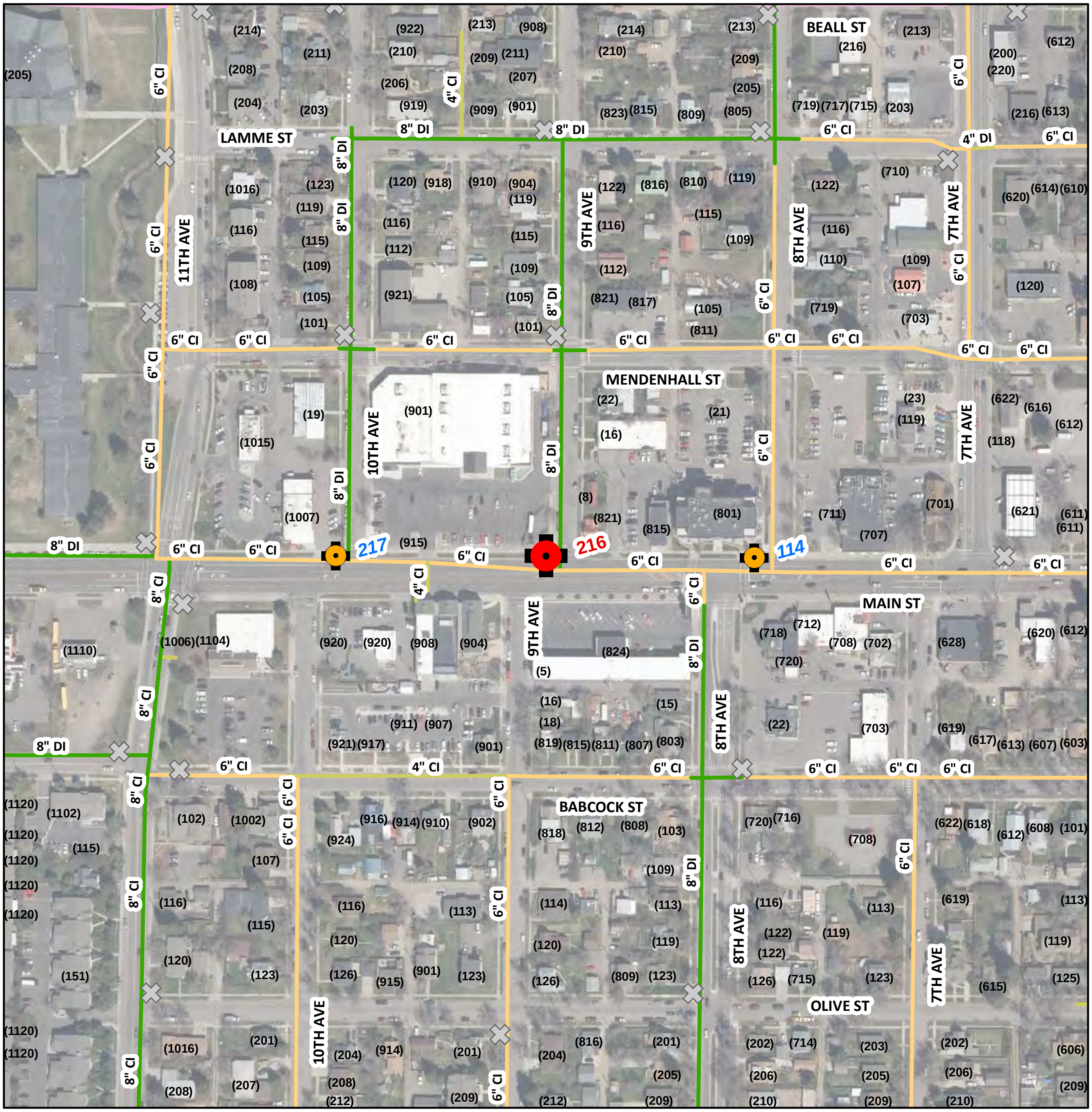
Hydrant No. 1211

HPR No. 201250

Flow: 1,250 gpm

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 23

Test Date: 9/30/2015

Start Time: 7:32 AM

End Time: 7:47 AM

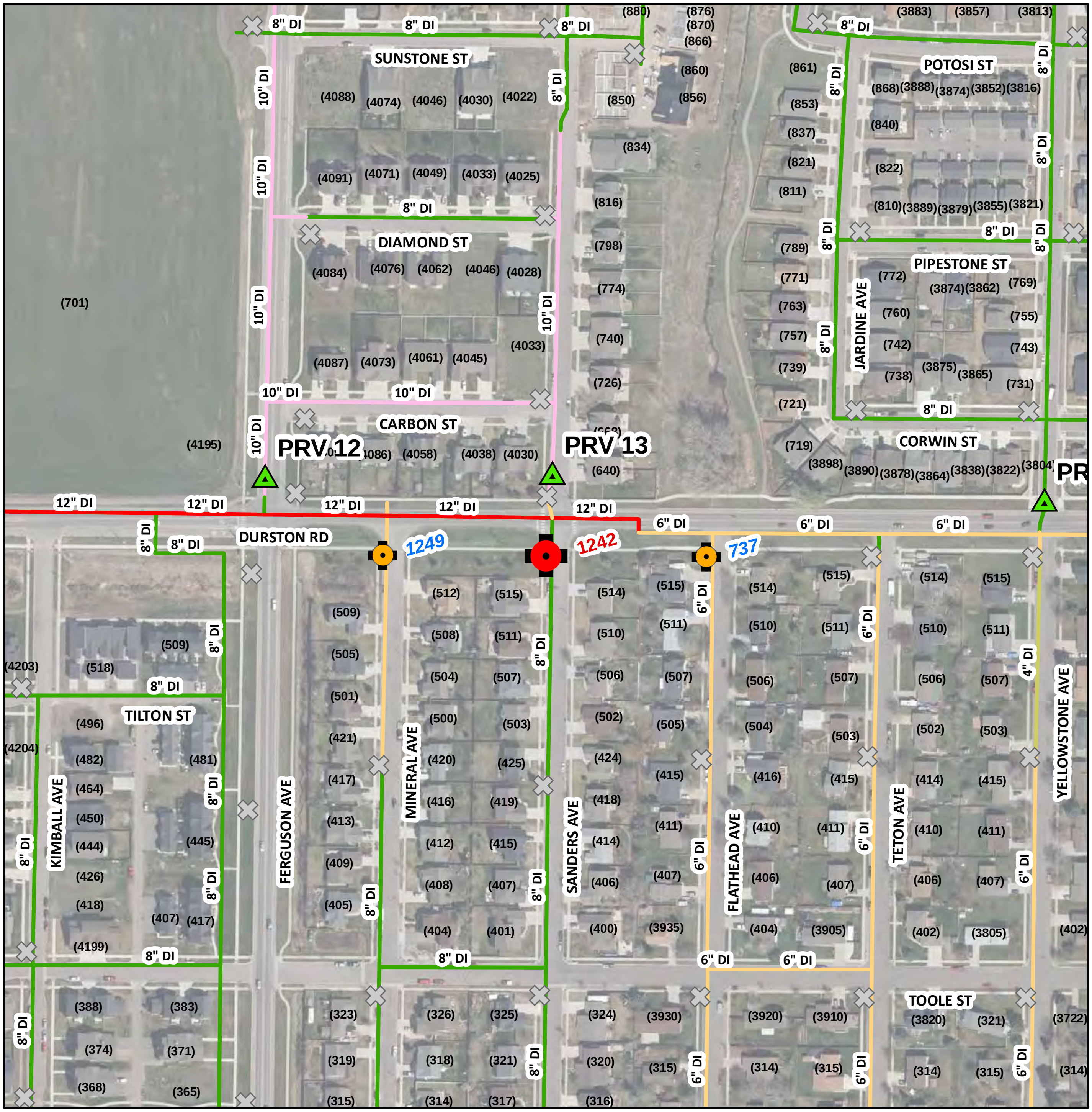
Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. 216	Hydrant No. 217	Hydrant No. 114
HPR No. 1240	HPR No. 1241	HPR No. 201250
Static: 129.9 psi	Flow: 1,720 gpm	Flow: 1,610 gpm
Residual: 119.9 psi		

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 24

Test Date: 10/1/2015

Start Time: 4:00 PM

End Time: 4:12 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 1242

HPR No. 1240

Static: 144.5 psi

Residual: 130.4 psi

FLOW HYDRANT #1

Hydrant No. 1249

HPR No. 1251

Flow: 1,845 gpm

FLOW HYDRANT #2

Hydrant No. 737

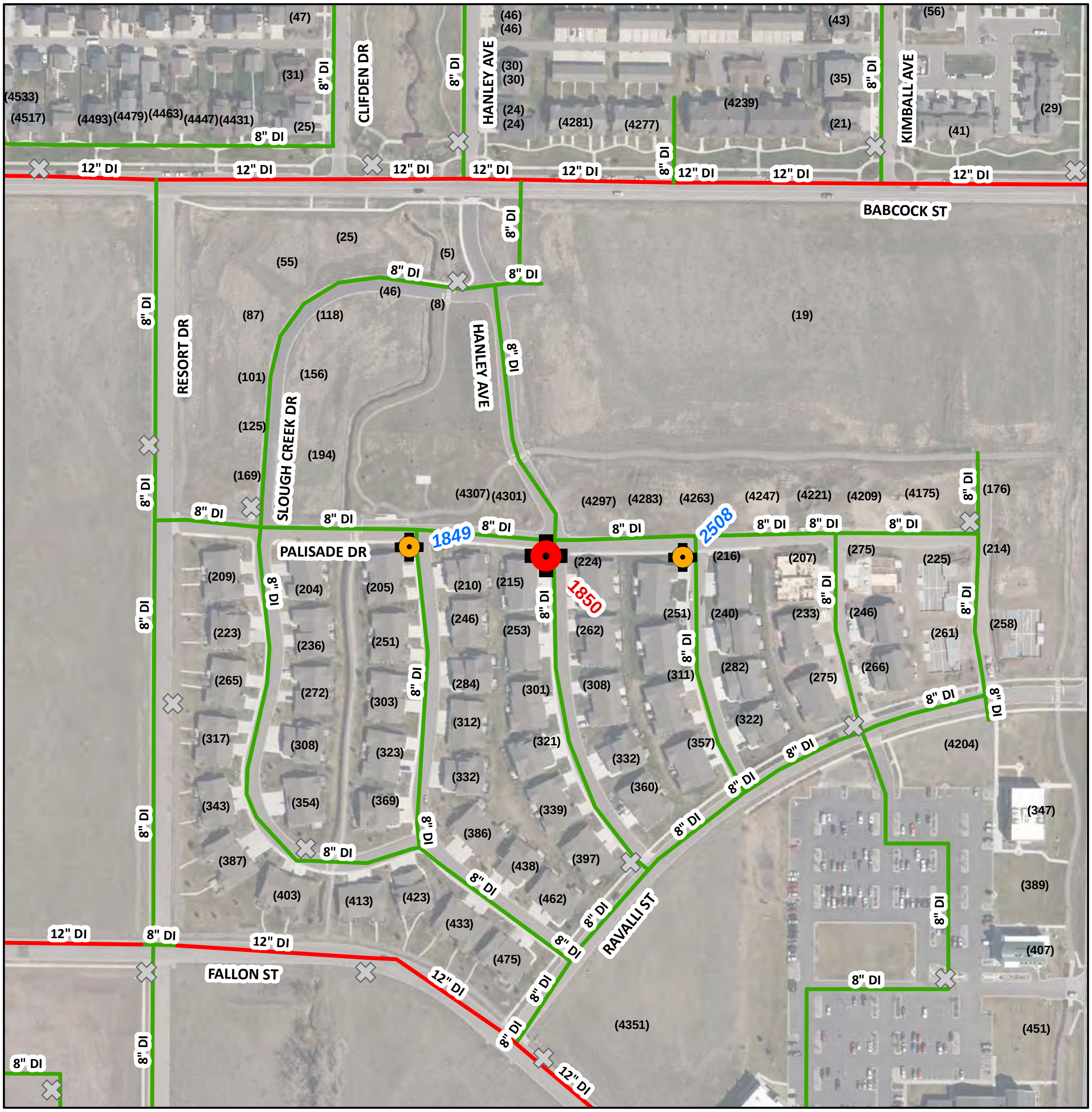
HPR No. 201250

Flow: 1,834 gpm

Test Hydrants | Flow Hydrants | Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Test Number: 25

Test Date: 10/1/2015

Start Time: 2:42 PM

End Time: 2:55 PM

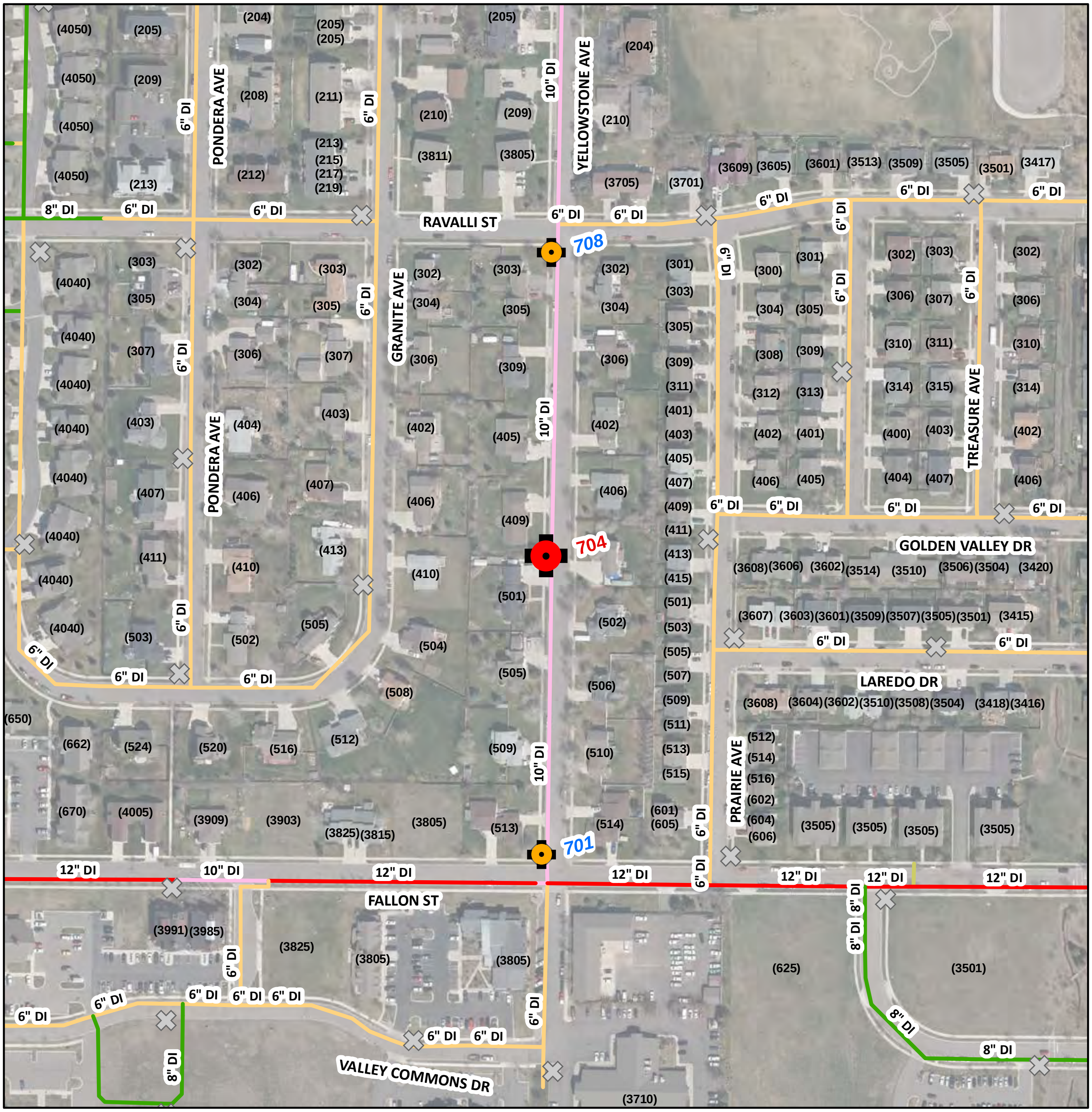
Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	1850	Hydrant No.	2508	Hydrant No.	1849
HPR No.	1240	HPR No.	1251	HPR No.	201250
Static:	128.9 psi	Flow:	1,725 gpm	Flow:	1,702 gpm
Residual:	115.7 psi				

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 26

Test Date: 10/1/2015

Start Time: 3:02 PM

End Time: 3:15 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 704

HPR No. 1240

Static: 122.2 psi

Residual: 110.0 psi

FLOW HYDRANT #1

Hydrant No. 701

HPR No. 1251

Flow: 1,681 gpm

FLOW HYDRANT #2

Hydrant No. 708

HPR No. 201250

Flow: 1,719 gpm

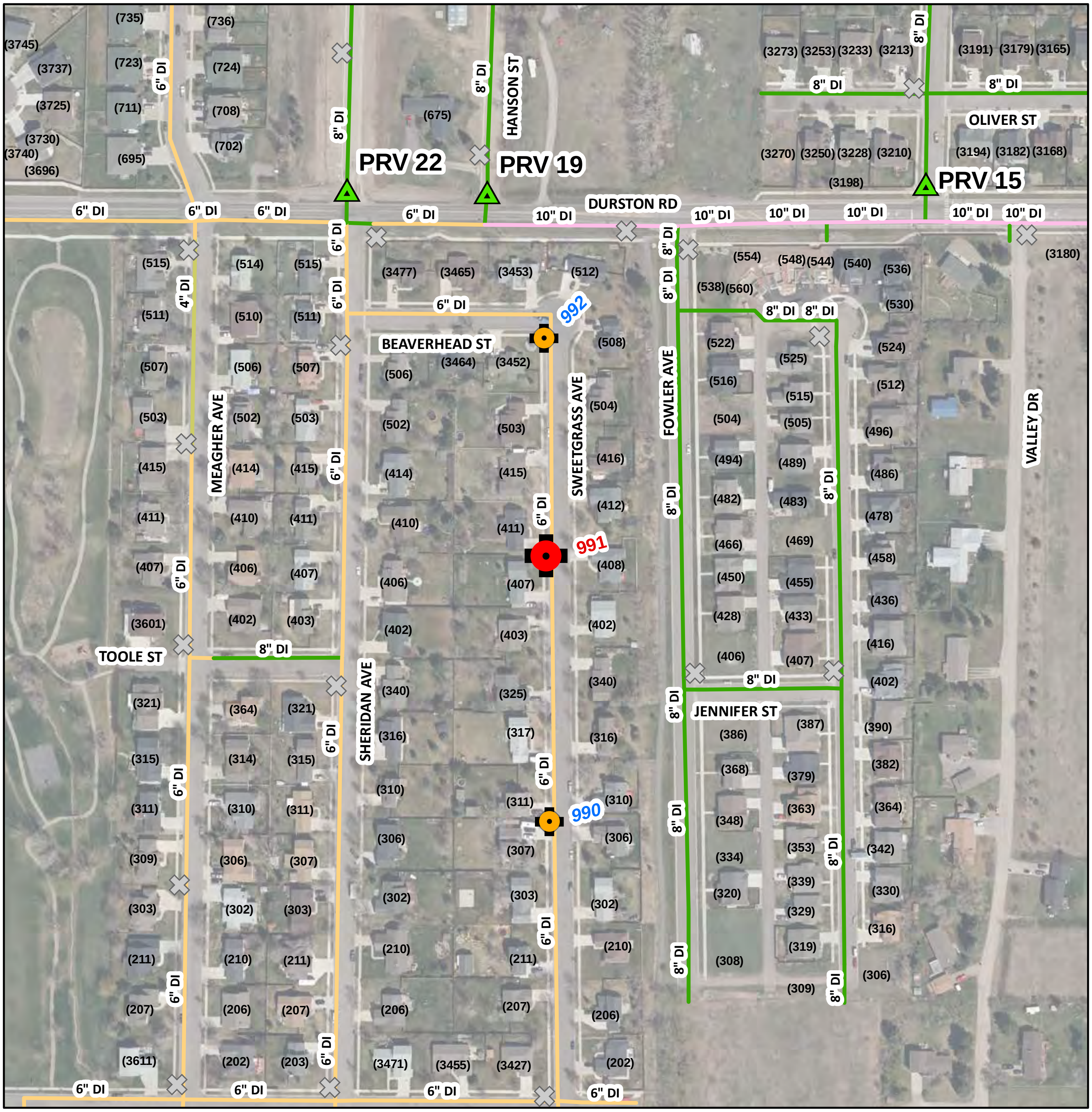
Test Hydrants

Flow Hydrants

Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Test Number: 27

Test Date: 10/1/2015

Start Time: 3:42 PM

End Time: 3:52 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 991

HPR No. 1240

Static: 139.3 psi

Residual: 104.1 psi

FLOW HYDRANT #1

Hydrant No. 992

HPR No. 1251

Flow: 1,681 gpm

FLOW HYDRANT #2

Hydrant No. 990

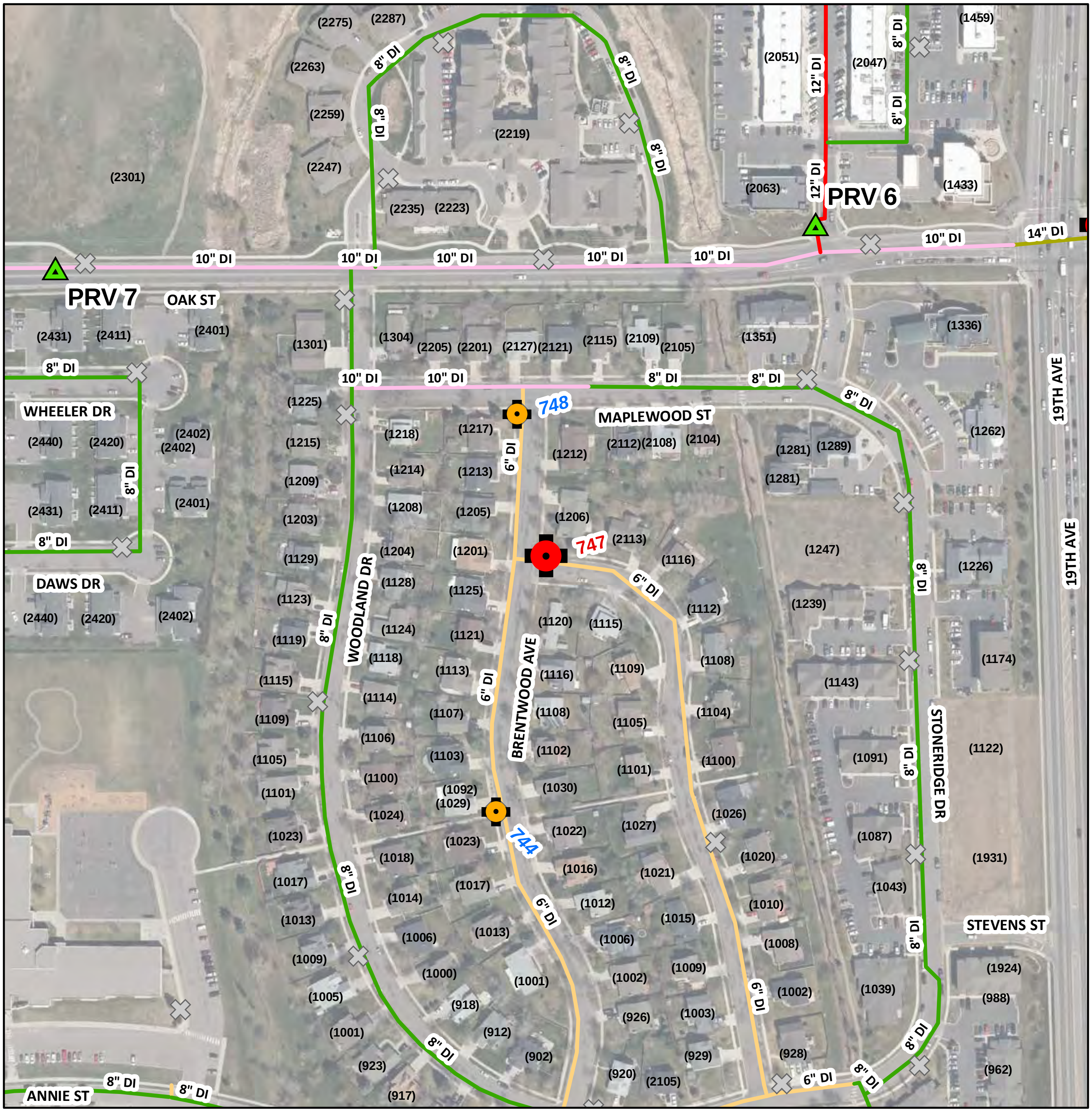
HPR No. 201250

Flow: 1,619 gpm

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Test Number: 28

Test Date: 9/30/2015

Start Time: 11:20 AM

End Time: 11:31 AM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. 747	Hydrant No. 748	Hydrant No. 744
HPR No. 1240	HPR No. 1241	HPR No. 201250
Static: 152.6 psi	Flow: 1,956 gpm	Flow: 1,739 gpm
Residual: 128.6 psi		

Test Hydrants Flow Hydrants Other Hydrants

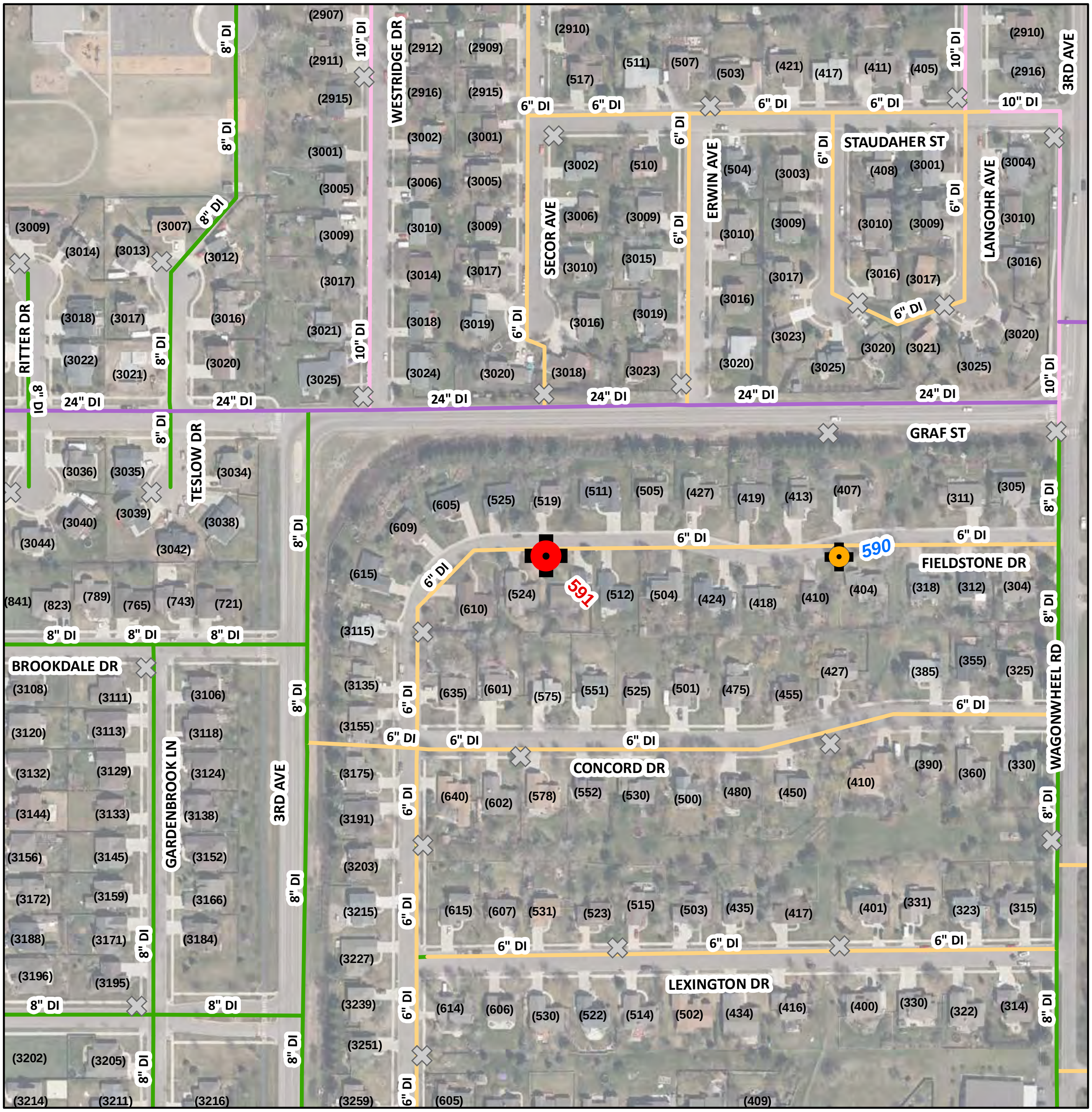
Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

Test Number: 29	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: 9/29/2015	Hydrant No. 1084	Hydrant No. 1190	Hydrant No. 1085
Start Time: 5:06 PM	HPR No. 1240	HPR No. 1241	HPR No. 201250
End Time: 5:15 PM	Static: 50.5 psi	Flow: 1,136 gpm	Flow: 996 gpm
Test By: JDH	Residual: 47.5 psi		
Zone: SOUTH			

Test Hydrants Flow Hydrants Other Hydrants

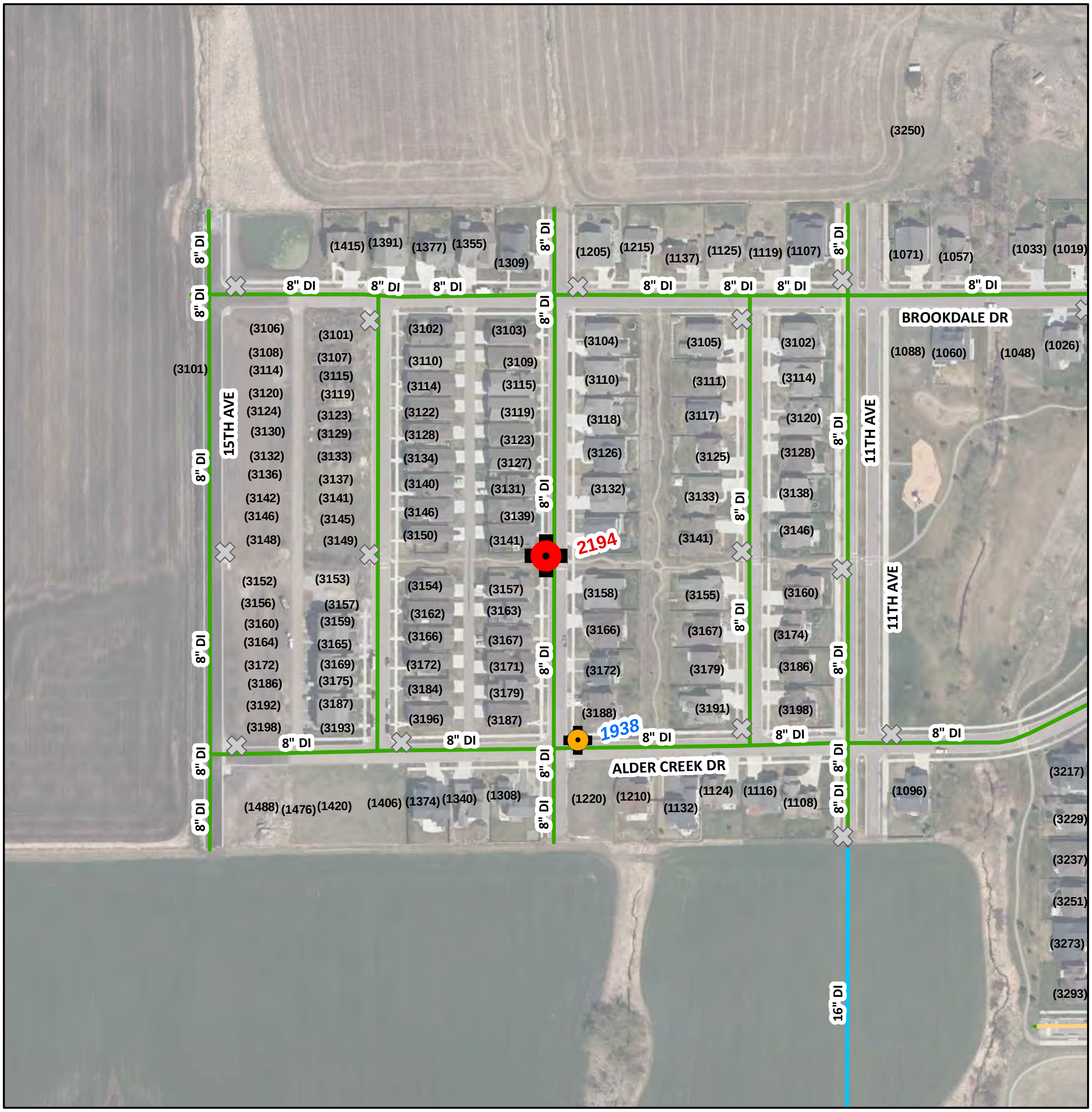
Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: *30*	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: *10/1/2015*	Hydrant No. *591*	Hydrant No. *590*	Hydrant No. ______
Start Time: *11:16 AM*	HPR No. *1240*	HPR No. *201250*	HPR No. ________
End Time: *11:28 AM*	Static: *60.3 psi*	Flow: *1,198 gpm*	Flow: ______________
Test By: *JDH*	Residual: *58.5 psi*		
Zone: *SOUTH*			

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 31	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: 10/1/2015	Hydrant No. 2194	Hydrant No. 1938	Hydrant No.
Start Time: 10:56 AM	HPR No. 1240	HPR No. 201250	HPR No.
End Time: 11:08 AM	Static: 52.5 psi	Flow: 1,096 gpm	Flow:
Test By: JDH	Residual: 50.2 psi		
Zone: SOUTH			

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 32

Test Date: 10/1/2015

Start Time: 10:34 AM

End Time: 10:42 AM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 2089

HPR No. 1240

Static: 43.2 psi

Residual: 40.4 psi

FLOW HYDRANT #1

Hydrant No. 2090

HPR No. 201250

Flow: 1,060 gpm

FLOW HYDRANT #2

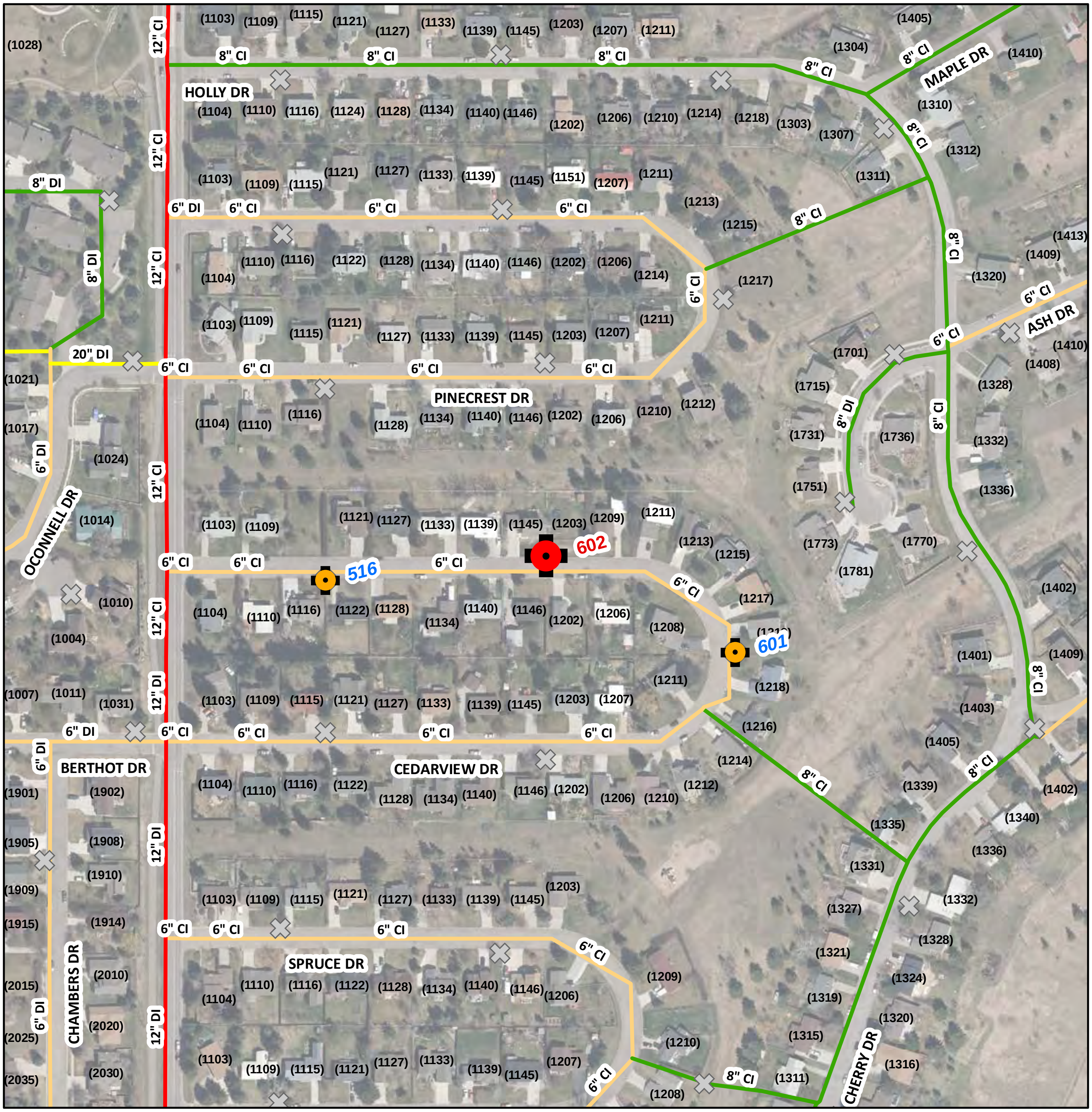
Hydrant No. ______

HPR No. ________

Flow: ______________

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 33

Test Date: 9/29/2015

Start Time: 4:40 PM

End Time: 4:50 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	602	Hydrant No.	516	Hydrant No.	601
HPR No.	1240	HPR No.	1241	HPR No.	201250
Static:	48.3 psi	Flow:	944 gpm	Flow:	1,039 gpm
Residual:	41.4 psi				

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 34

Test Date: 9/29/2015

Start Time: 3:16 PM

End Time: 3:27 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 851

HPR No. 1240

Static: 124.2 psi

Residual: 60.9 psi

FLOW HYDRANT #1

Hydrant No. 779

HPR No. 1241

Flow: 1,176 gpm

FLOW HYDRANT #2

Hydrant No. 850

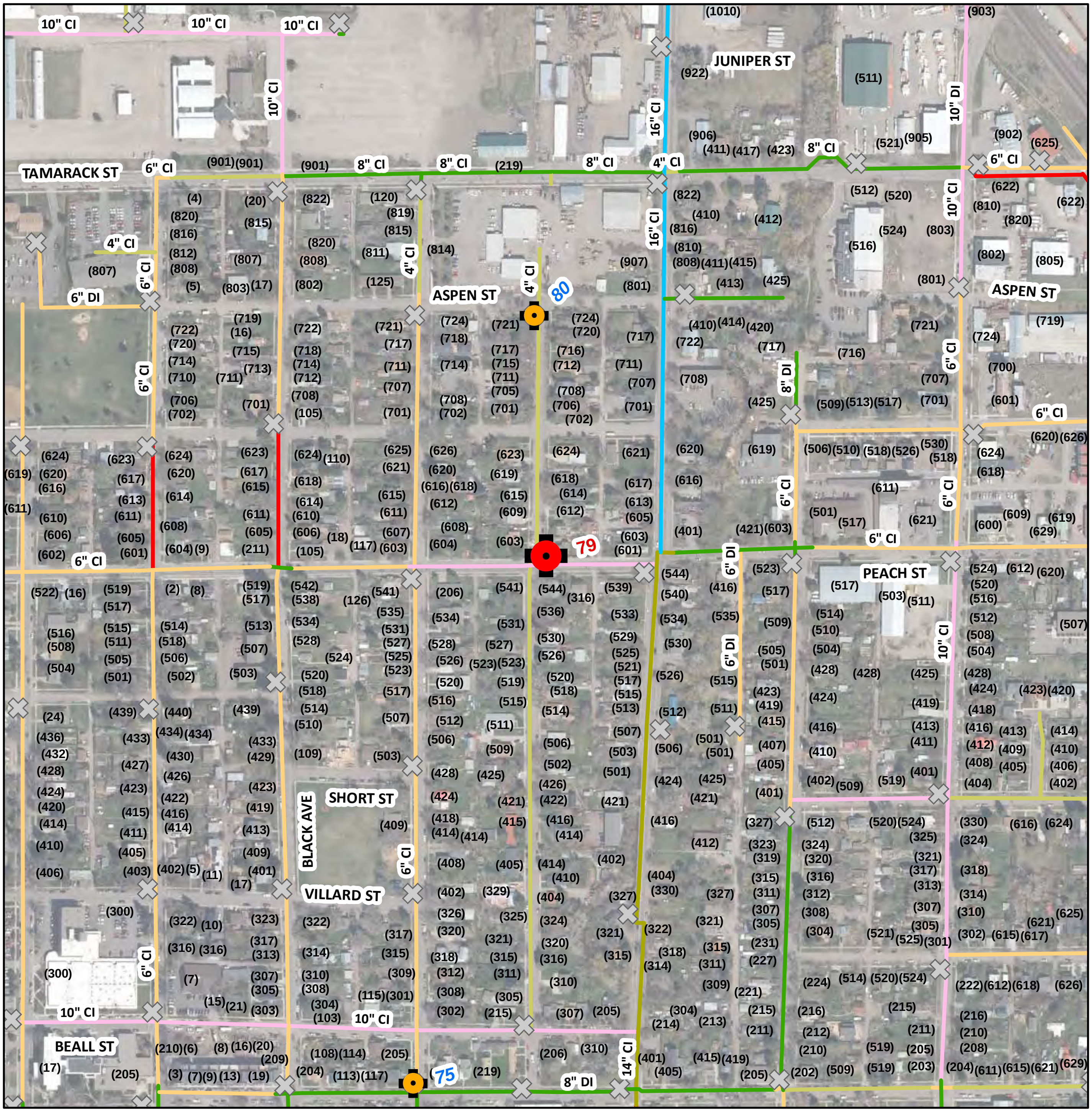
HPR No. 201250

Flow: 1,247 gpm

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Test Number: 35

Test Date: 9/30/2015

Start Time: 8:37 AM

End Time: 8:46 AM

Test By: JDH

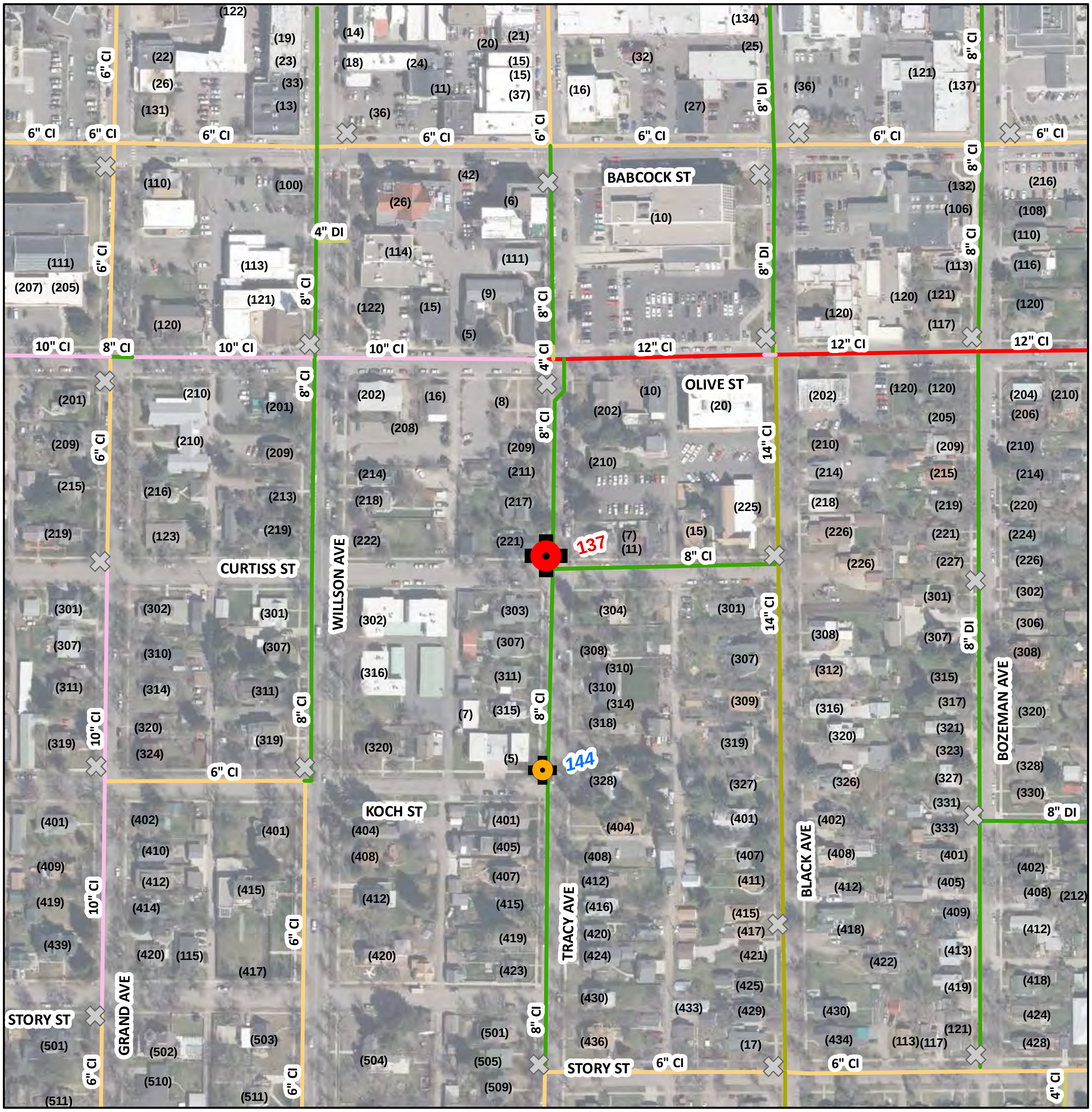
Zone: SOUTH

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. 79	Hydrant No. 80	Hydrant No. 75
HPR No. 1240	HPR No. 1241	HPR No. 201250
Static: 142.7 psi	Flow: 1,890 gpm	Flow: 1,796 gpm
Residual: 133.8 psi		

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

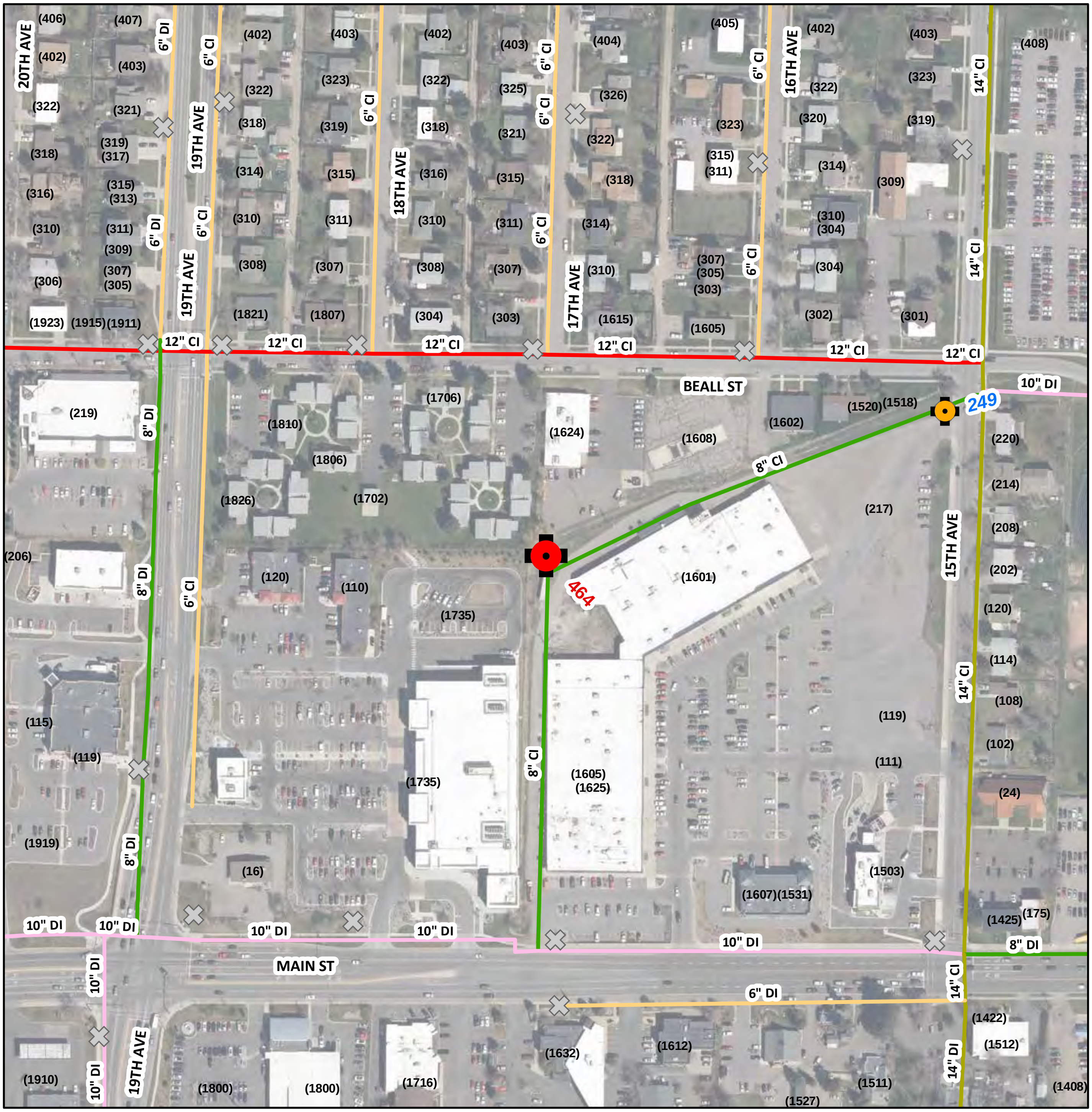


Test Number: 36	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: 10/1/2015	Hydrant No. 137	Hydrant No. 144	Hydrant No.
Start Time: 7:59 AM	HPR No. 1240	HPR No. 201250	HPR No.
End Time: 8:11 AM	Static: 127.1 psi	Flow: 1,765 gpm	Flow:
Test By: JDH	Residual: 123.6 psi		
Zone: SOUTH			

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Test Number: 37

Test Date: 9/30/2015

Start Time: 3:56 PM

End Time: 4:25 PM

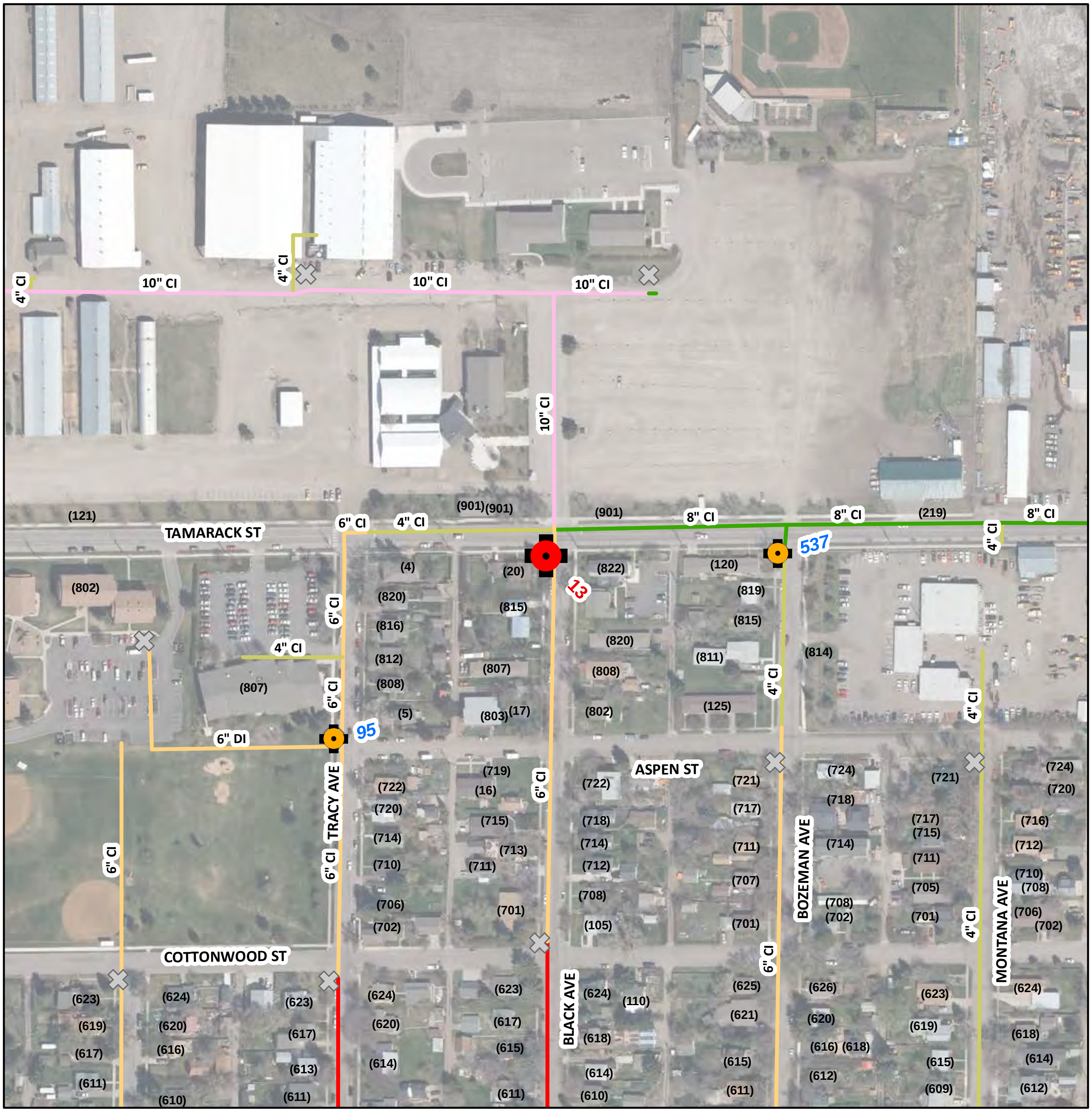
Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	464	Hydrant No.	249	Hydrant No.	
HPR No.	1240	HPR No.	201250	HPR No.	
Static:	132.9 psi	Flow:	1,834 gpm	Flow:	
Residual:	129.1 psi				

Test Hydrants Flow Hydrants Other Hydrants

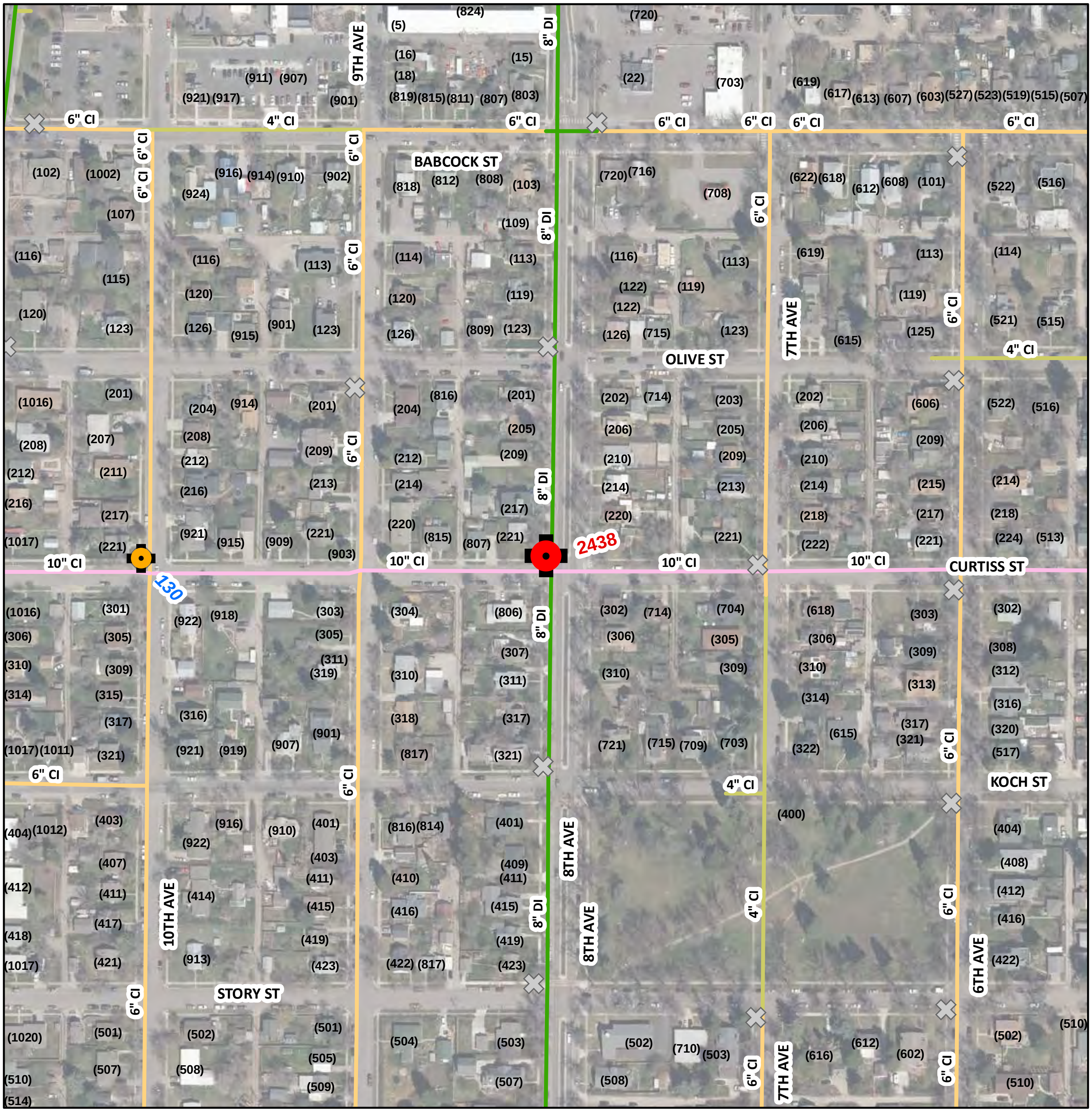
Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 38	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: 9/30/2015	Hydrant No. 13	Hydrant No. 537	Hydrant No. 95
Start Time: 9:20 AM	HPR No. 1240	HPR No. 1241	HPR No. 201250
End Time: 9:31 AM	Static: 150.0 psi	Flow: 1,855 gpm	Flow: 1,404 gpm
Test By: JDH	Residual: 139.3 psi		
Zone: SOUTH			

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 39

Test Date: 10/1/2015

Start Time: 7:42 AM

End Time: 7:53 AM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 2438

HPR No. 1240

Static: 123.9 psi

Residual: 122.0 psi

FLOW HYDRANT #1

Hydrant No. 130

HPR No. 201250

Flow: 1,673 gpm

FLOW HYDRANT #2

Hydrant No. ______

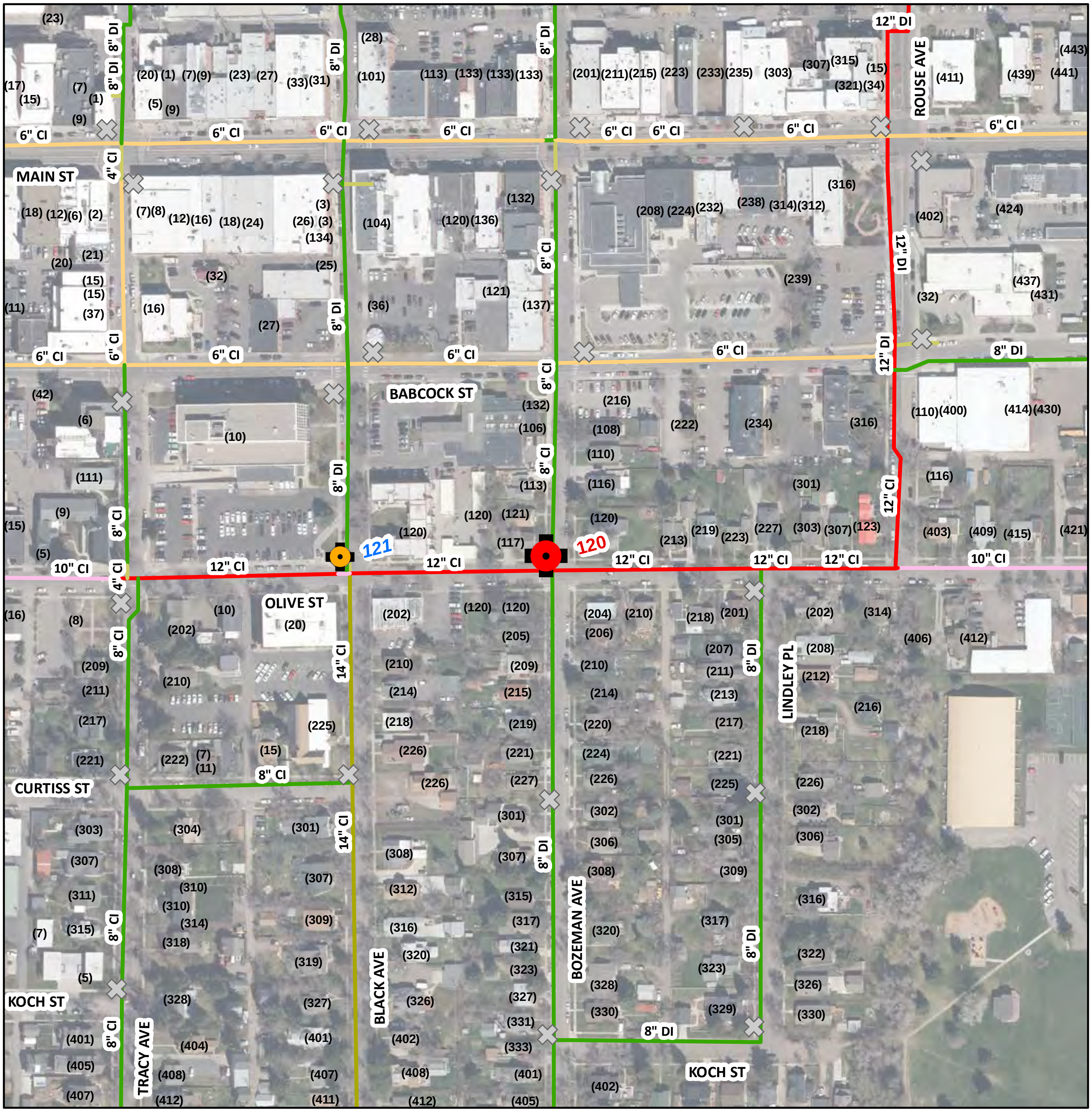
HPR No. ________

Flow: ______________

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Test Number: *40*

Test Date: *10/1/2015*

Start Time: *8:14 AM*

End Time: *8:26 AM*

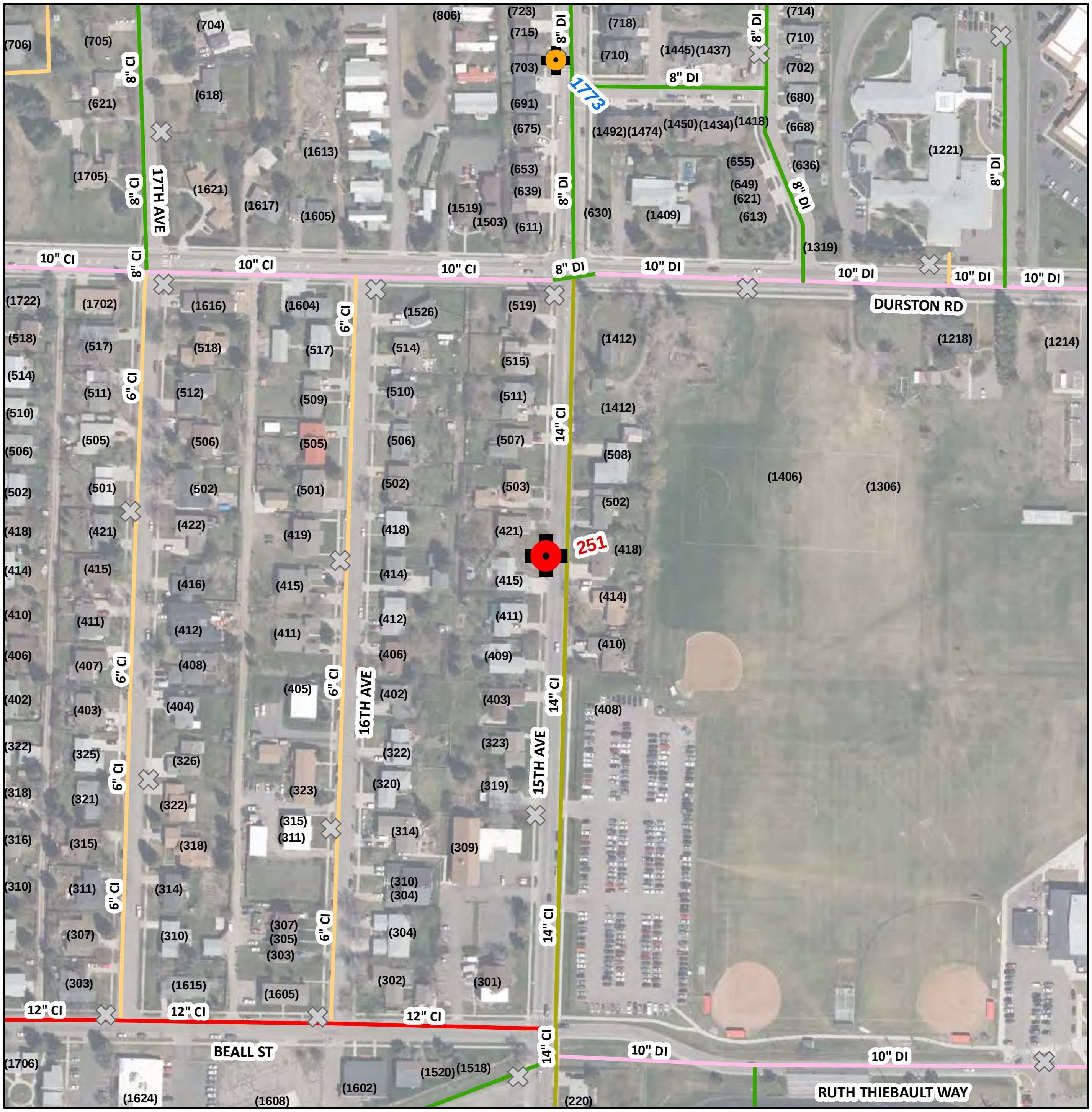
Test By: *JDH*

Zone: *SOUTH*

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	*120*	Hydrant No.	*121*	Hydrant No.	
HPR No.	*1240*	HPR No.	*201250*	HPR No.	
Static:	*128.6 psi*	Flow:	*1,802 gpm*	Flow:	
Residual:	*126.8 psi*				

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 41

Test Date: 9/30/2015

Start Time: 4:30 PM

End Time: 4:46 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 251

HPR No. 1240

Static: 139.0 psi

Residual: 136.8 psi

FLOW HYDRANT #1

Hydrant No. 1773

HPR No. 201250

Flow: 1,878 gpm

FLOW HYDRANT #2

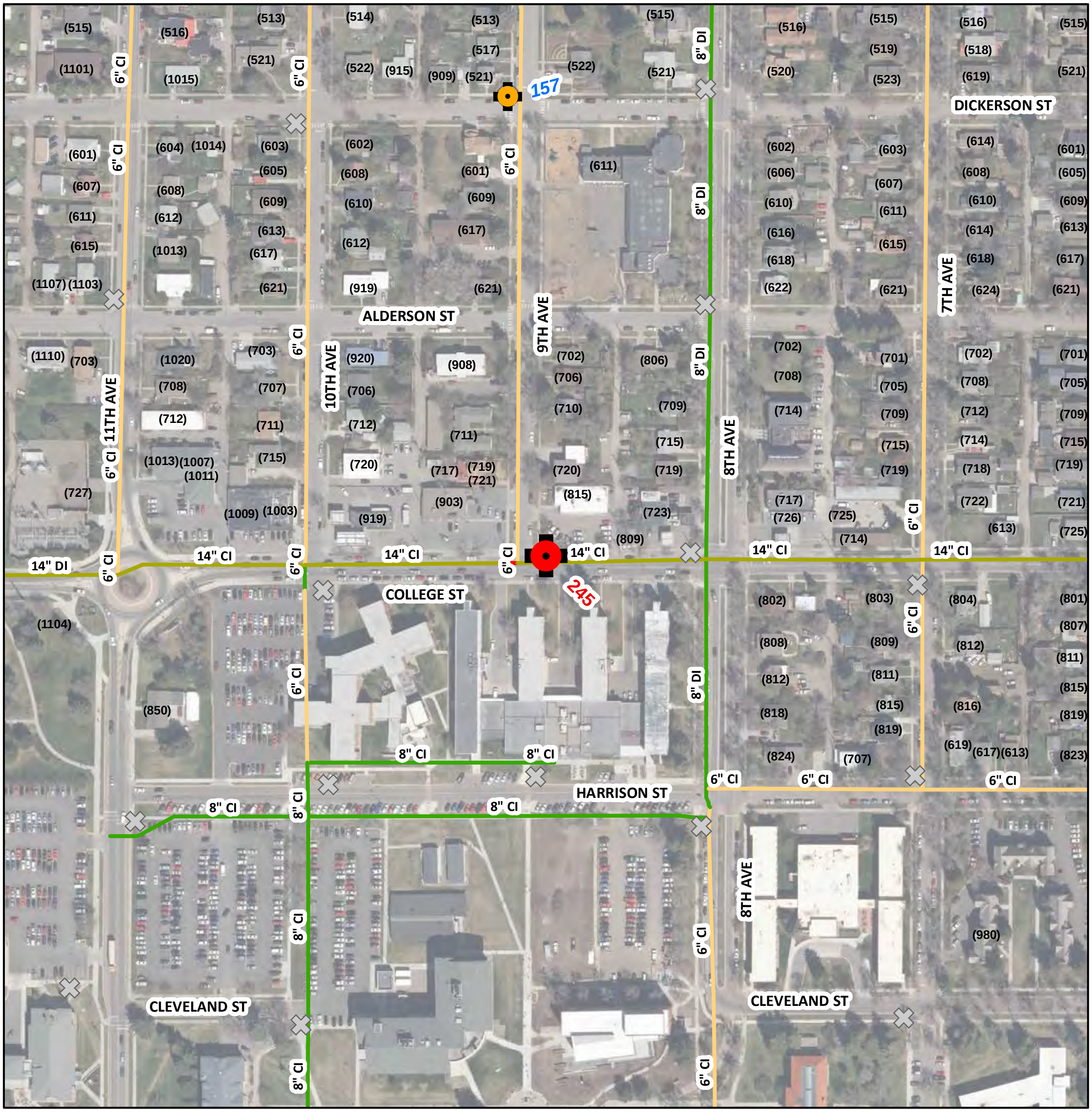
Hydrant No. ______

HPR No. ________

Flow: ______________

Test Hydrants Flow Hydrants Other Hydrants

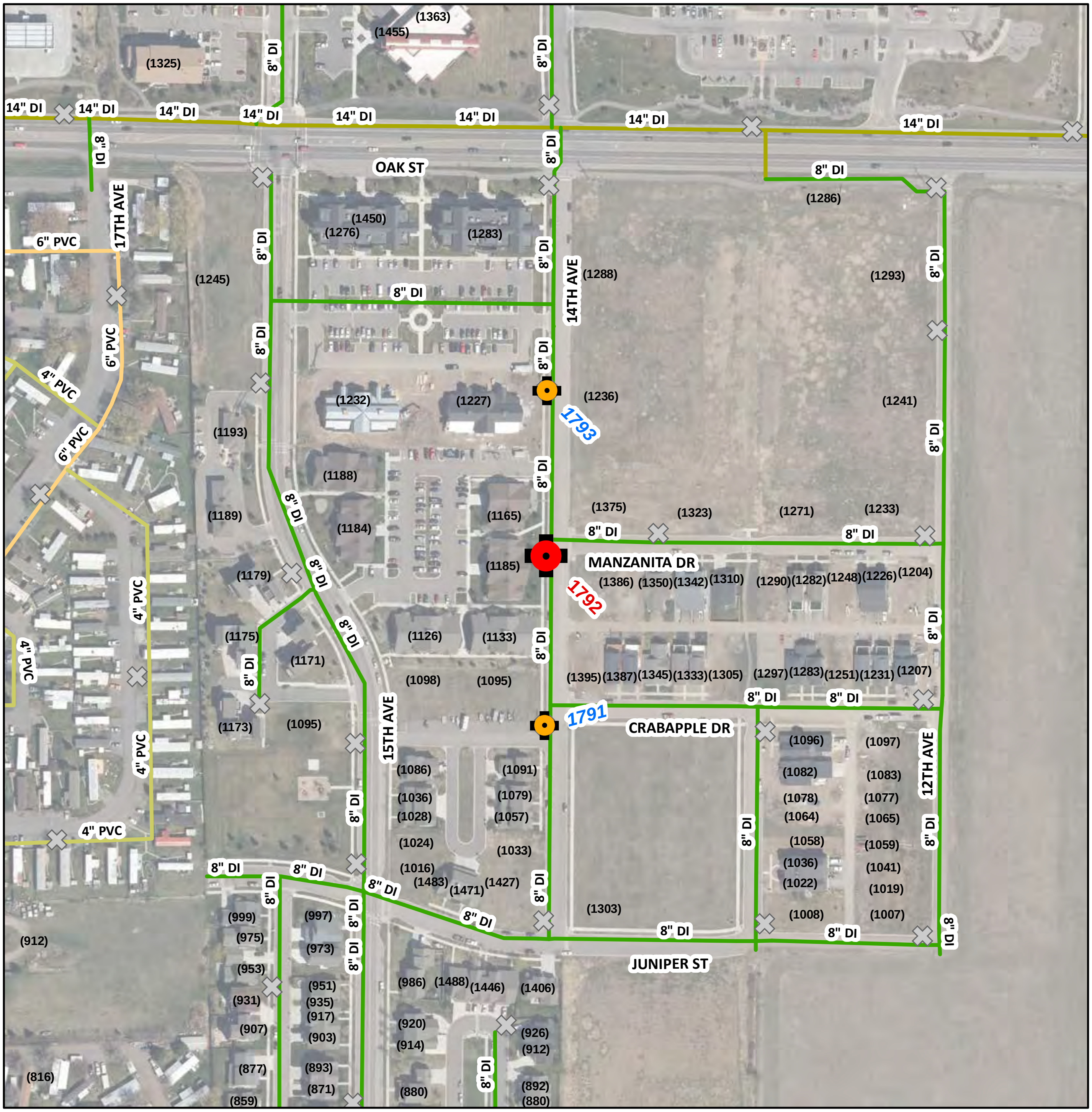
Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 42	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: 10/1/2015	Hydrant No. 245	Hydrant No. 157	Hydrant No.
Start Time: 9:12 AM	HPR No. 1240	HPR No. 201250	HPR No.
End Time: 9:25 AM	Static: 107.5 psi	Flow: 1,396 gpm	Flow:
Test By: JDH	Residual: 105.3 psi		
Zone: SOUTH			

Test Hydrants | Flow Hydrants | Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

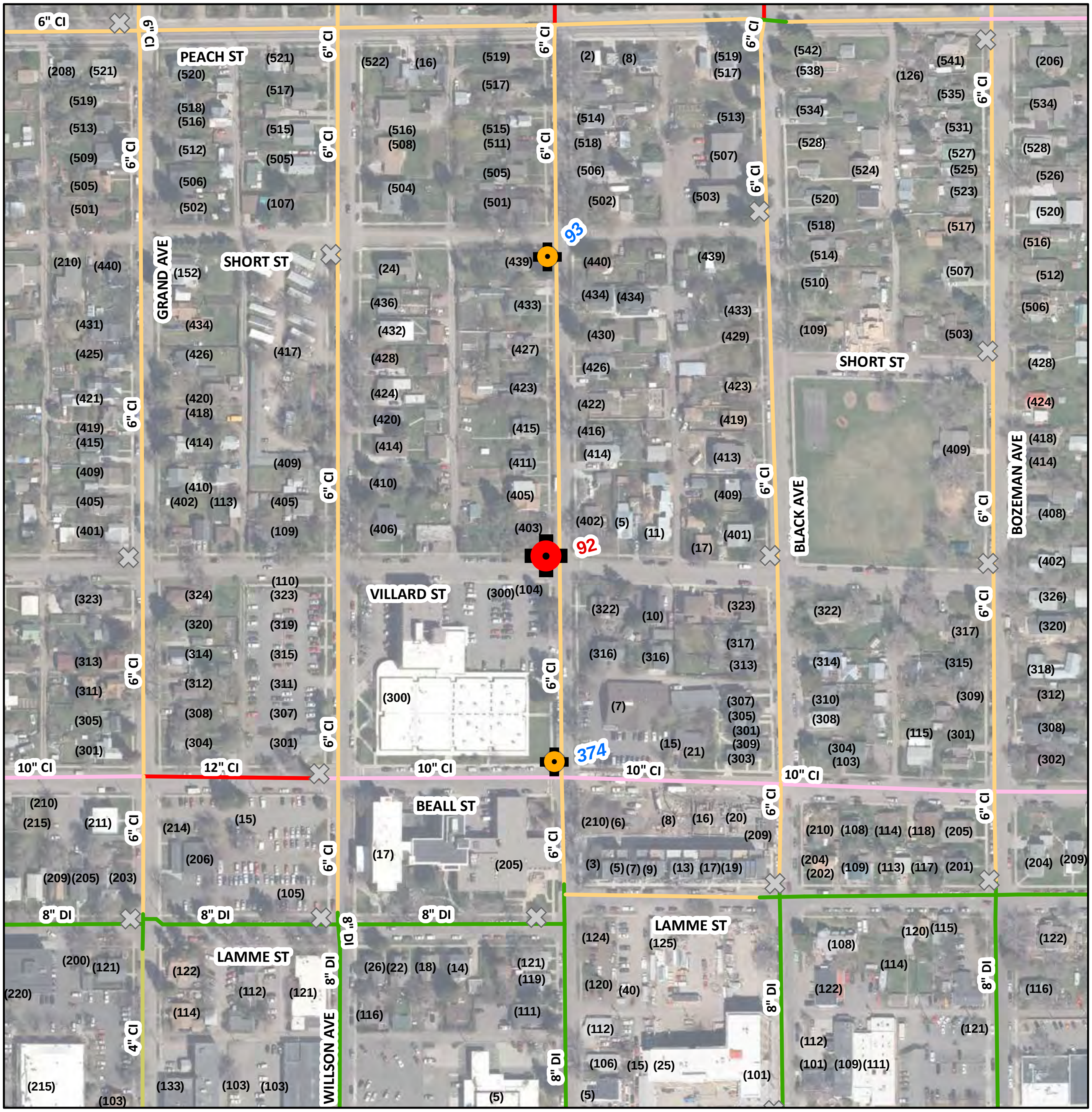


Test Number: 43	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: 9/30/2015	Hydrant No. 1792	Hydrant No. 1793	Hydrant No. 1791
Start Time: 10:05 AM	HPR No. 1240	HPR No. 1241	HPR No. 201250
End Time: 10:30 AM	Static: 151.7 psi	Flow: 1,989 gpm	Flow: 1,866 gpm
Test By: JDH	Residual: 137.8 psi		
Zone: SOUTH			

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Test Number: *44*

Test Date: *9/30/2015*

Start Time: *8:15 AM*

End Time: *8:25 AM*

Test By: *JDH*

Zone: *SOUTH*

RESIDUAL HYDRANT

Hydrant No. *92*

HPR No. *1240*

Static: *137.7 psi*

Residual: *112.9 psi*

FLOW HYDRANT #1

Hydrant No. *93*

HPR No. *1241*

Flow: *1,601 gpm*

FLOW HYDRANT #2

Hydrant No. *374*

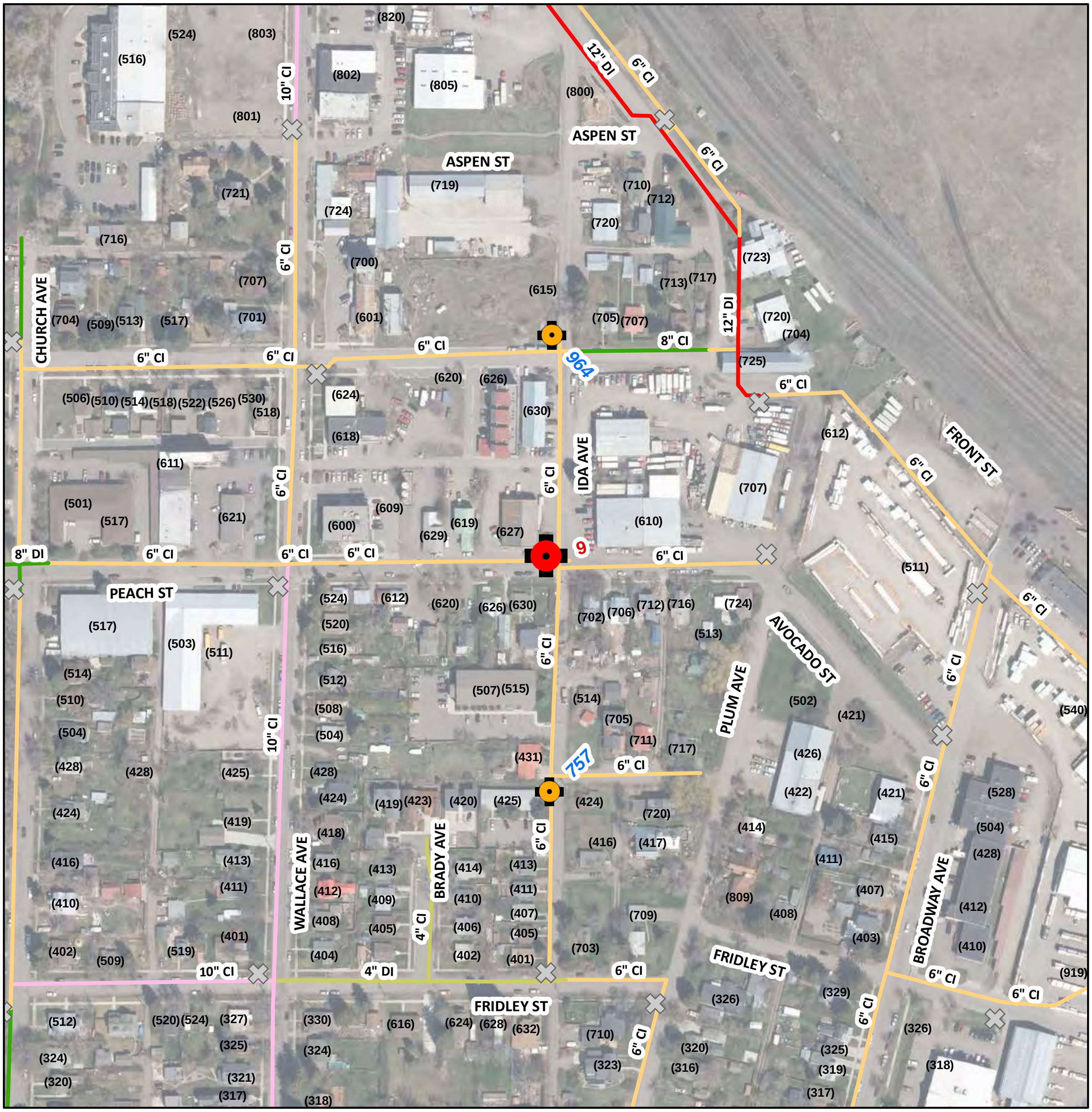
HPR No. *201250*

Flow: *1,744 gpm*

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Test Number: 45

Test Date: 9/30/2015

Start Time: 8:56 AM

End Time: 9:08 AM

Test By: JDH

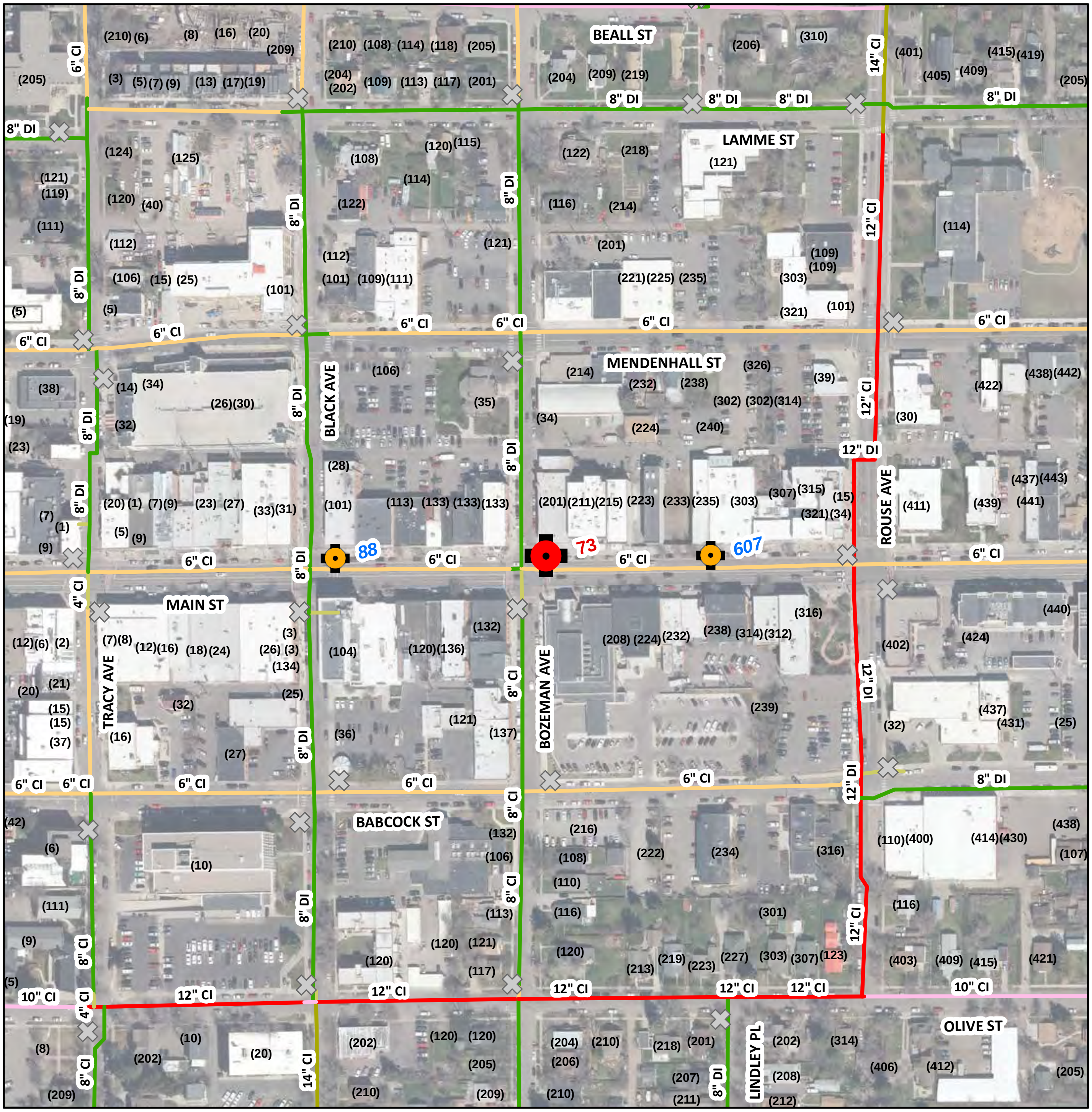
Zone: SOUTH

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. 9	Hydrant No. 757	Hydrant No. 964
HPR No. 1240	HPR No. 1241	HPR No. 201250
Static: 145.0 psi	Flow: 1,740 gpm	Flow: 1,593 gpm
Residual: 128.9 psi		

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Test Number: 46

Test Date: 9/30/2015

Start Time: 7:15 AM

End Time: 7:25 AM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 73

HPR No. 1240

Static: 129.9 psi

Residual: 118.0 psi

FLOW HYDRANT #1

Hydrant No. 88

HPR No. 1241

Flow: 1,723 gpm

FLOW HYDRANT #2

Hydrant No. 607

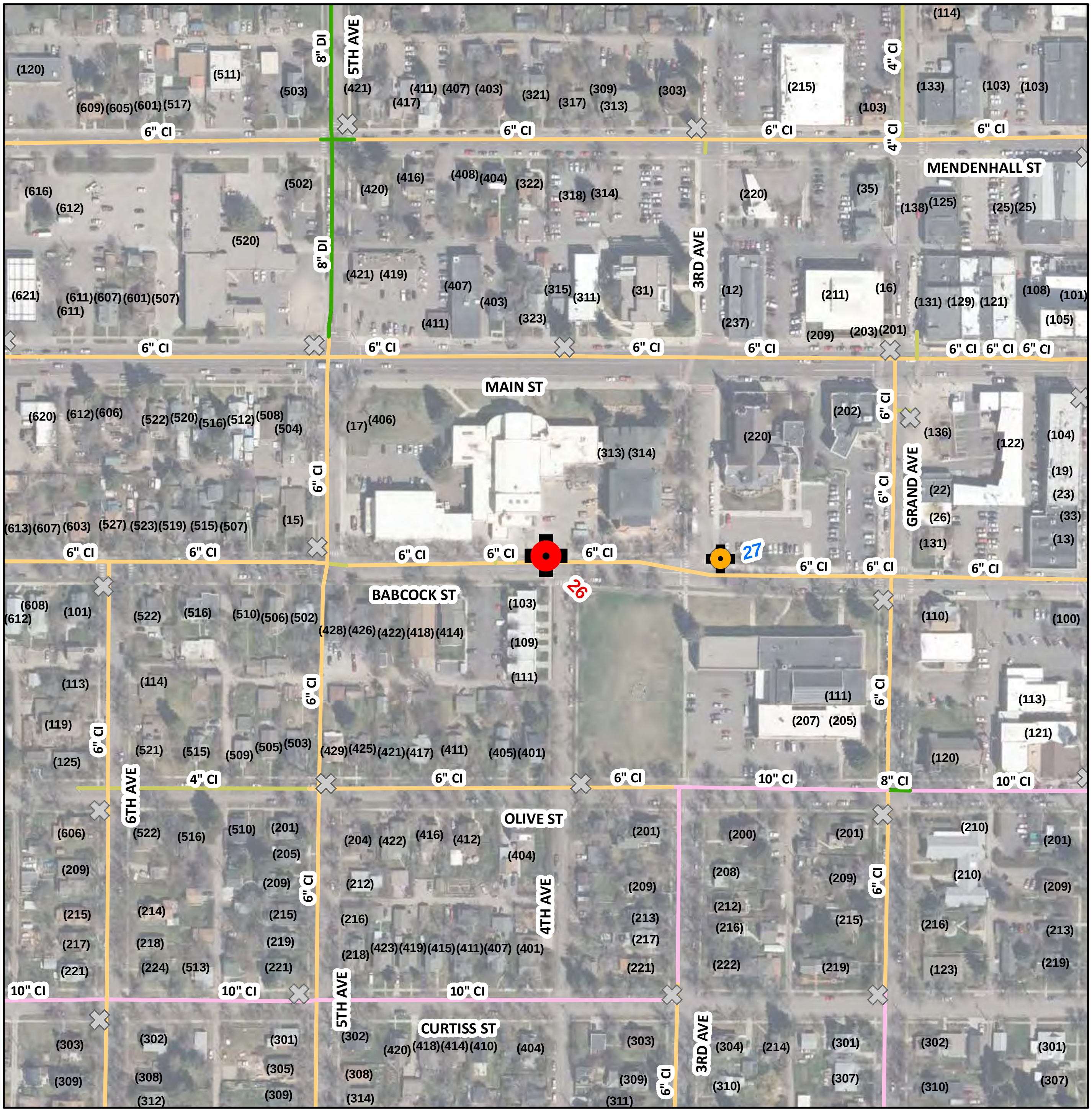
HPR No. 201250

Flow: 1,615 gpm

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

46



Test Number: 47

Test Date: 10/1/2015

Start Time: 7:24 AM

End Time: 7:34 AM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 26

HPR No. 1240

Static: 126.5 psi

Residual: 103.9 psi

FLOW HYDRANT #1

Hydrant No. 27

HPR No. 201250

Flow: 1,595 gpm

FLOW HYDRANT #2

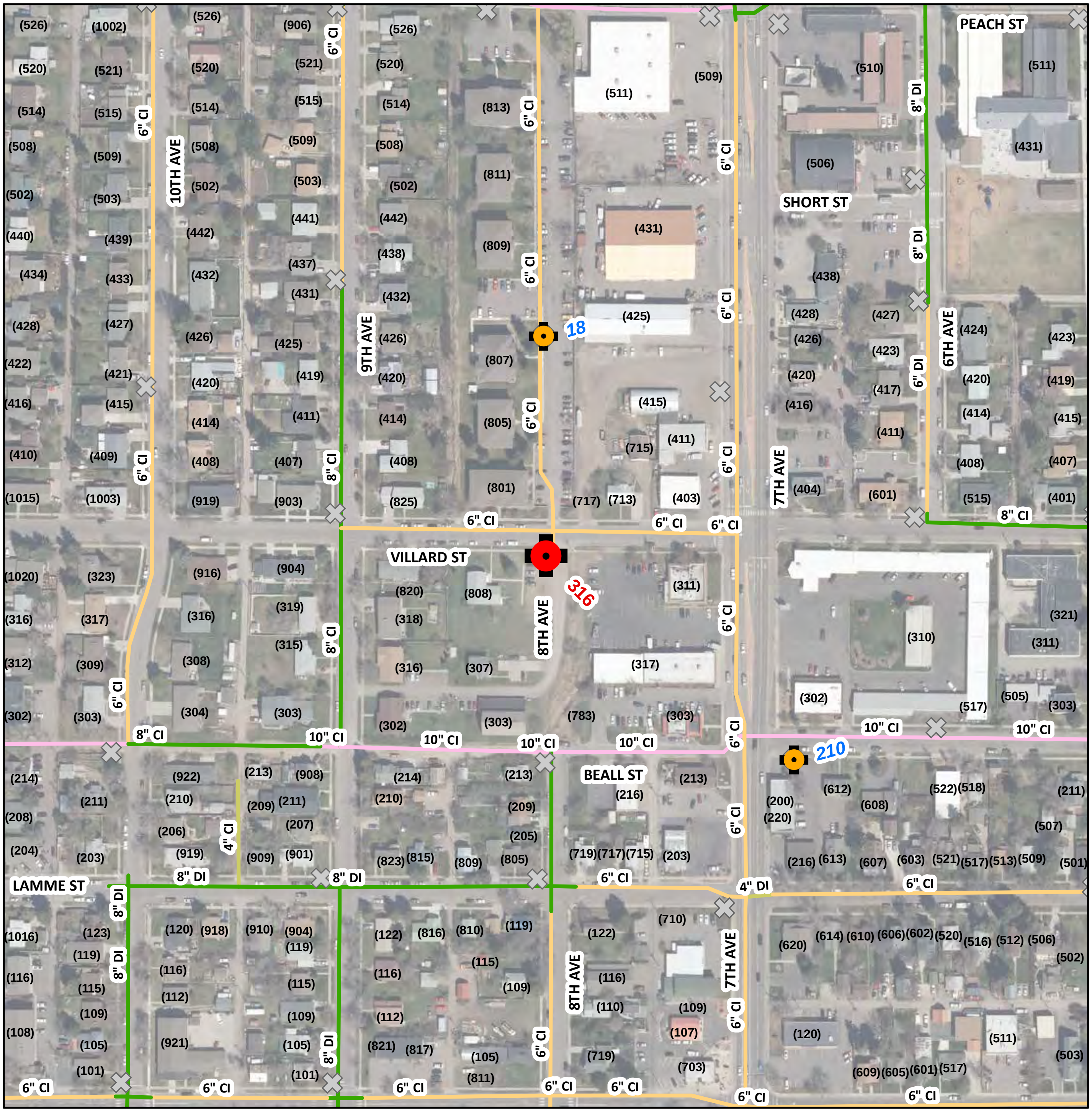
Hydrant No. ______

HPR No. ________

Flow: ______________

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: *48*

Test Date: *9/30/2015*

Start Time: *7:50 AM*

End Time: *8:07 AM*

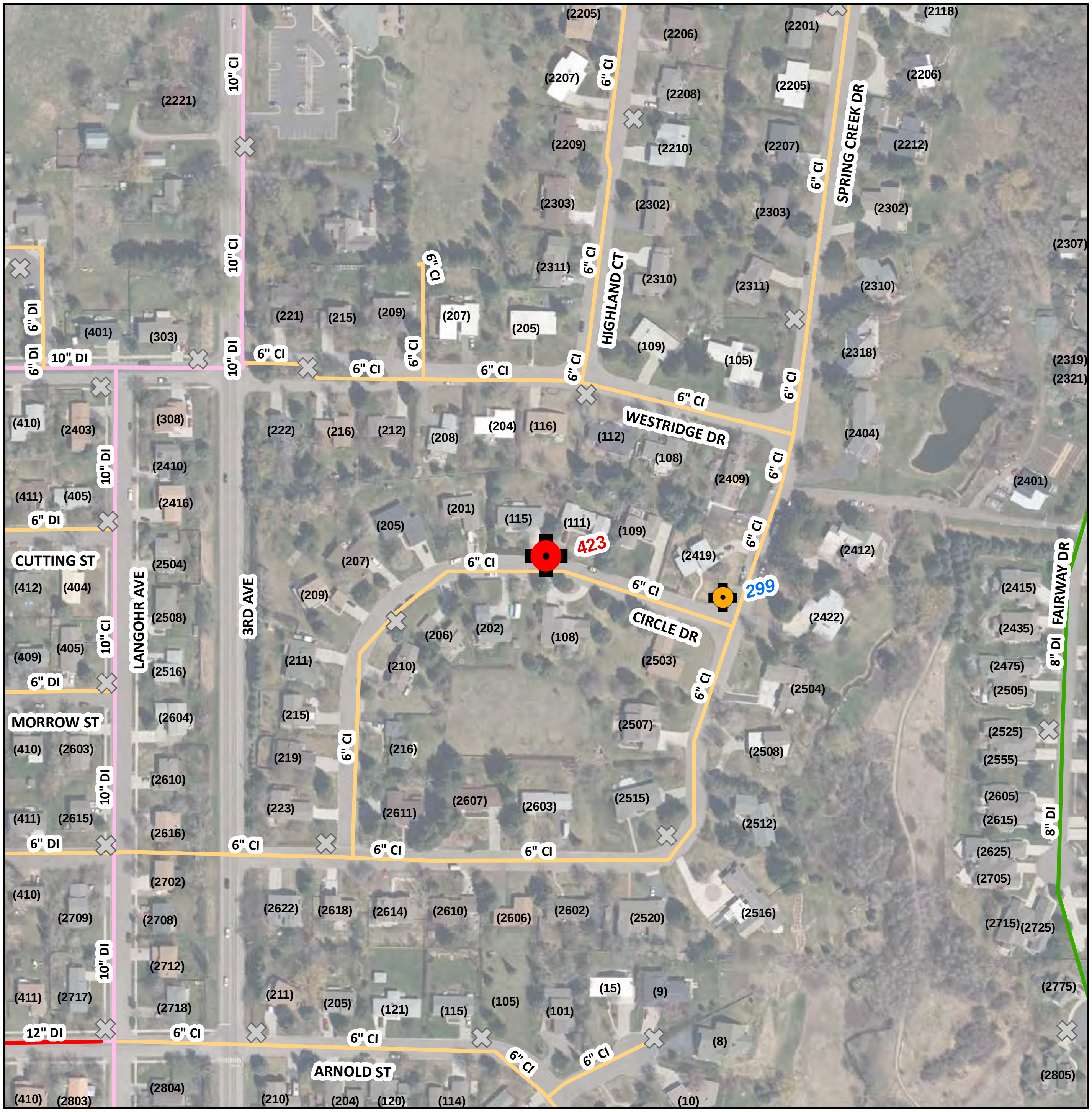
Test By: *JDH*

Zone: *SOUTH*

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	*316*	Hydrant No.	*18*	Hydrant No.	*210*
HPR No.	*1240*	HPR No.	*1241*	HPR No.	*201250*
Static:	*137.6 psi*	Flow:	*1,817 gpm*	Flow:	*1,661 gpm*
Residual:	*126.3 psi*				

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 49

Test Date: 10/1/2015

Start Time: 11:55 AM

End Time: 12:06 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 423

HPR No. 1240

Static: 72.6 psi

Residual: 67.2 psi

FLOW HYDRANT #1

Hydrant No. 299

HPR No. 201250

Flow: 1,237 gpm

FLOW HYDRANT #2

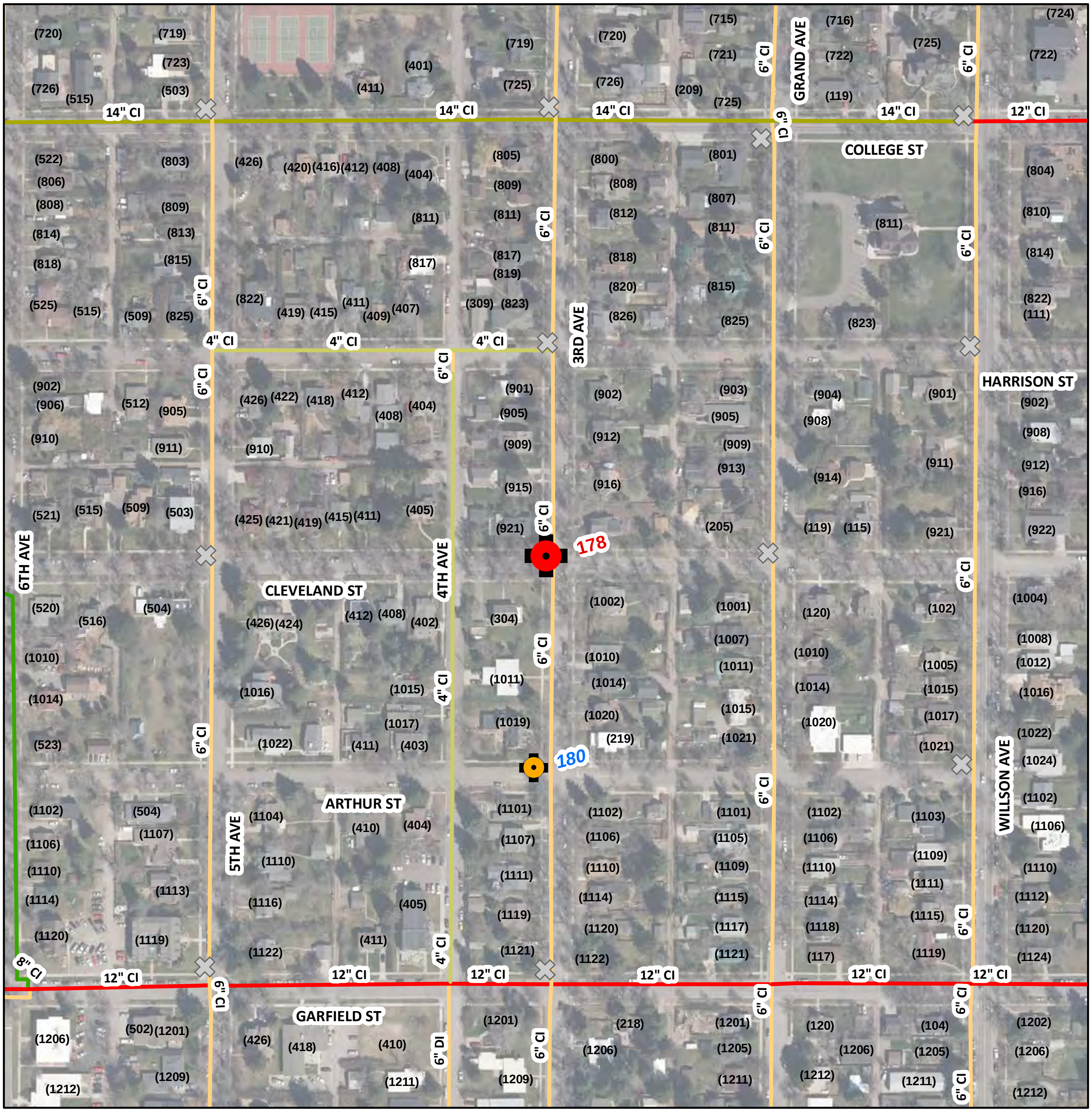
Hydrant No. ______

HPR No. ________

Flow: ______________

Test Hydrants | Flow Hydrants | Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 50

Test Date: 10/1/2015

Start Time: 8:52 AM

End Time: 9:07 AM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 178

HPR No. 1240

Static: 101.2 psi

Residual: 87.8 psi

FLOW HYDRANT #1

Hydrant No. 180

HPR No. 201250

Flow: 1,358 gpm

FLOW HYDRANT #2

Hydrant No. ______

HPR No. ________

Flow: ______________

Test Hydrants

Flow Hydrants

Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

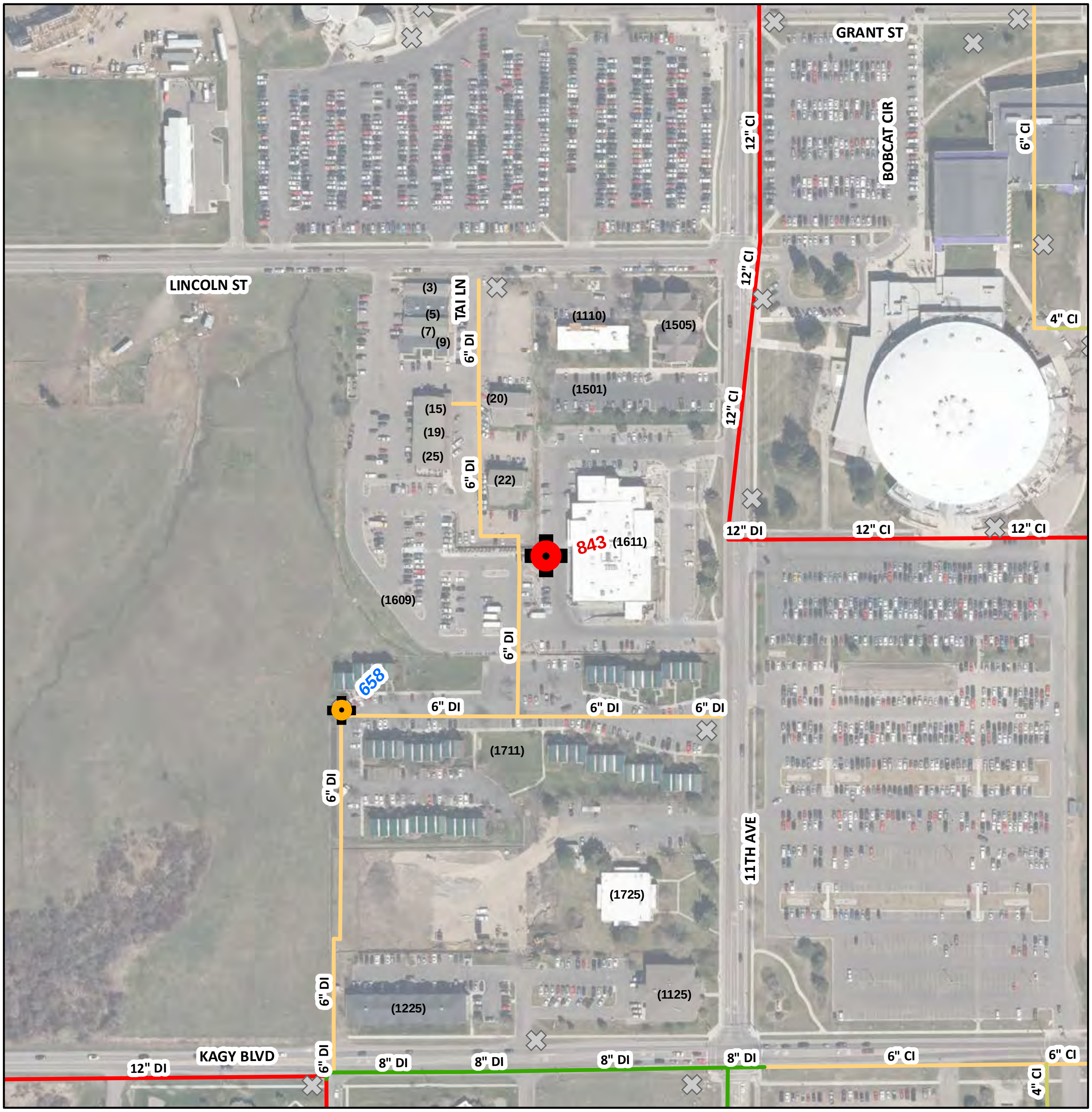
50

Test Number: **51**	**RESIDUAL HYDRANT**	**FLOW HYDRANT #1**	**FLOW HYDRANT #2**
Test Date: 10/1/2015	Hydrant No. 364	Hydrant No. 36	Hydrant No.
Start Time: 8:32 AM	HPR No. 1240	HPR No. 201250	HPR No.
End Time: 8:45 AM	Static: 125.8 psi	Flow: 1,578 gpm	Flow:
Test By: JDH	Residual: 109.6 psi		
Zone: SOUTH			

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution System Model Calibration

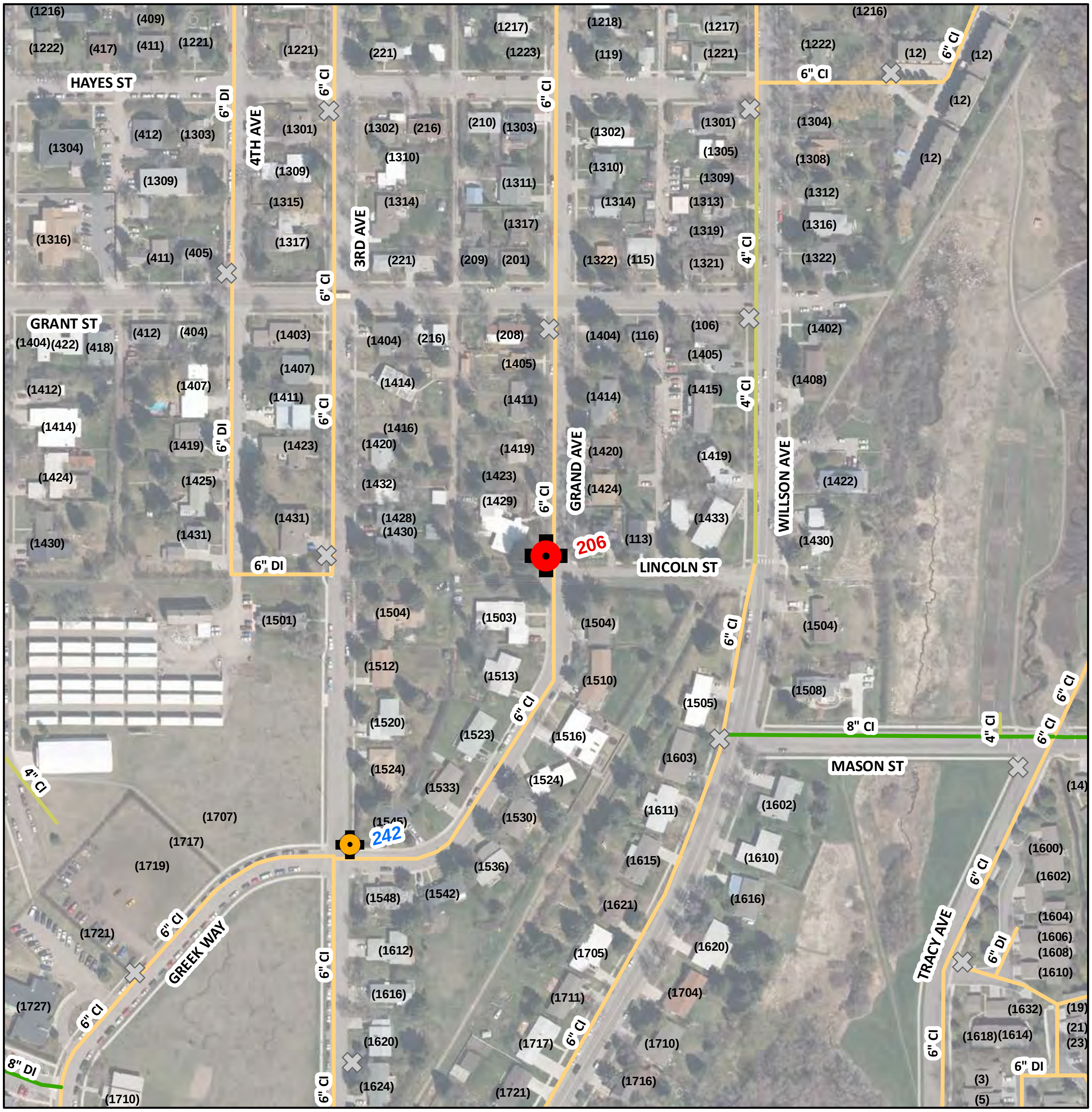
Field Test Data Sheet



Test Number: 52	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: 10/1/2015	Hydrant No. 843	Hydrant No. 658	Hydrant No.
Start Time: 9:55 AM	HPR No. 1240	HPR No. 201250	HPR No.
End Time: 10:07 AM	Static: 88.4 psi	Flow: 1,206 gpm	Flow:
Test By: JDH	Residual: 64.7 psi		
Zone: SOUTH			

Test Hydrants　Flow Hydrants　Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 53

Test Date: 10/1/2015

Start Time: 9:35 AM

End Time: 9:45 AM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 206

HPR No. 1240

Static: 93.9 psi

Residual: 83.0 psi

FLOW HYDRANT #1

Hydrant No. 242

HPR No. 201250

Flow: 1,312 gpm

FLOW HYDRANT #2

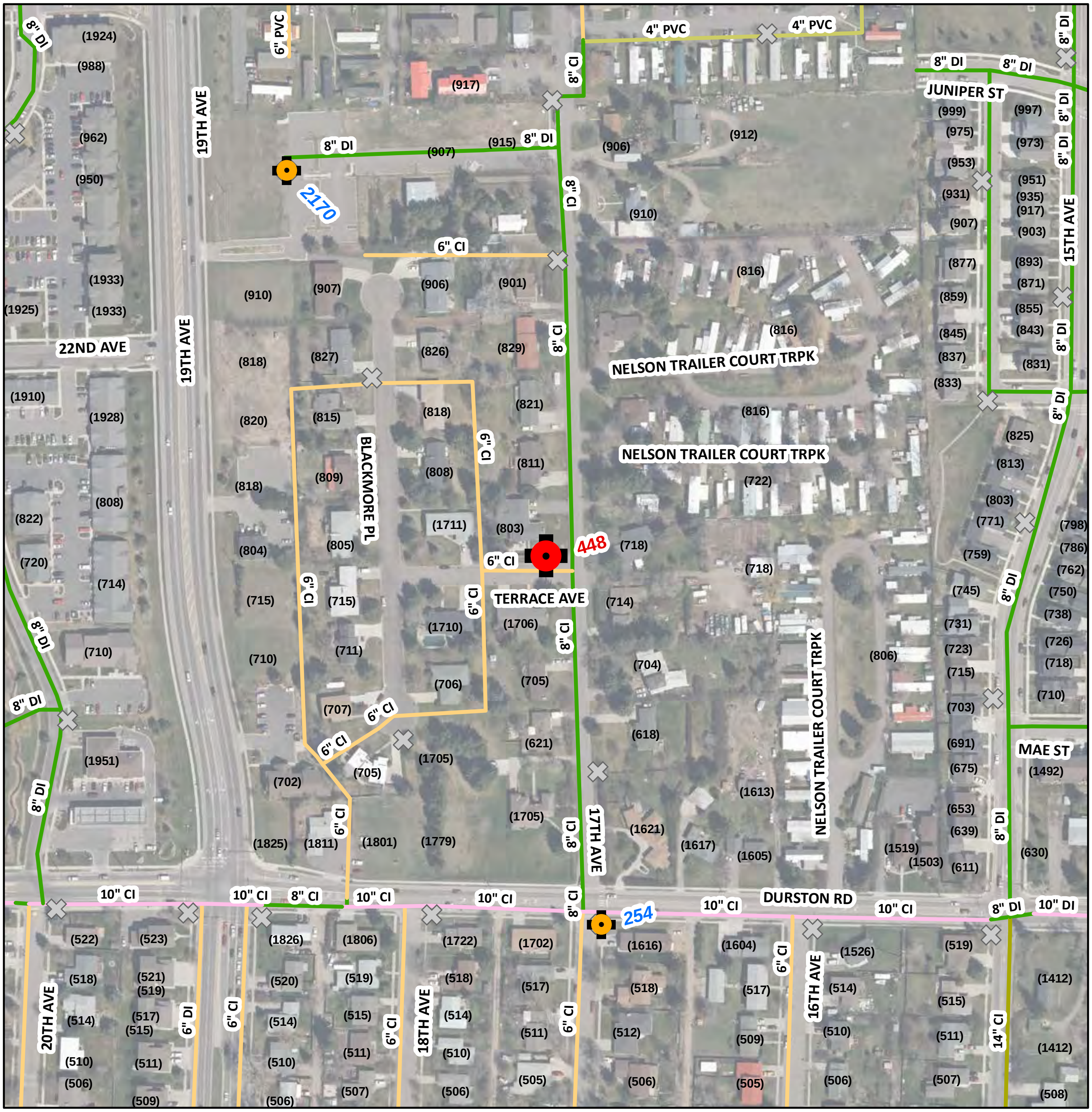
Hydrant No. ______

HPR No. ________

Flow: ____________

Test Hydrants　Flow Hydrants　Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 54

Test Date: 9/30/2015

Start Time: 10:40 AM

End Time: 10:53 AM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 448

HPR No. 1240

Static: 142.6 psi

Residual: 131.2 psi

FLOW HYDRANT #1

Hydrant No. 2170

HPR No. 1241

Flow: 1,869 gpm

FLOW HYDRANT #2

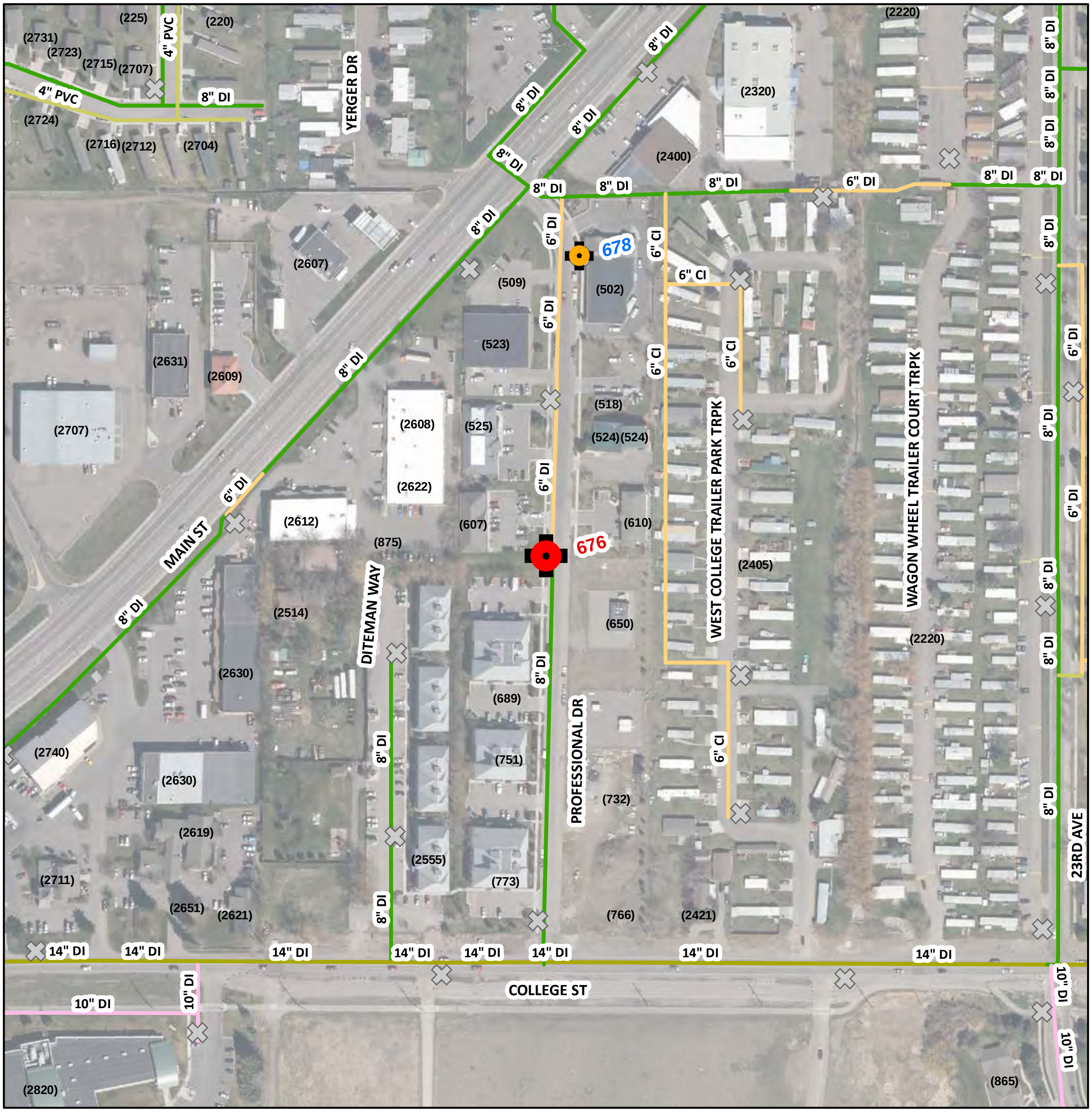
Hydrant No. 254

HPR No. 201250

Flow: 1,822 gpm

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 55

Test Date: 9/30/2015

Start Time: 3:00 PM

End Time: 3:15 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 676

HPR No. 1240

Static: 115.2 psi

Residual: 109.5 psi

FLOW HYDRANT #1

Hydrant No. 678

HPR No. 201250

Flow: 1,673 gpm

FLOW HYDRANT #2

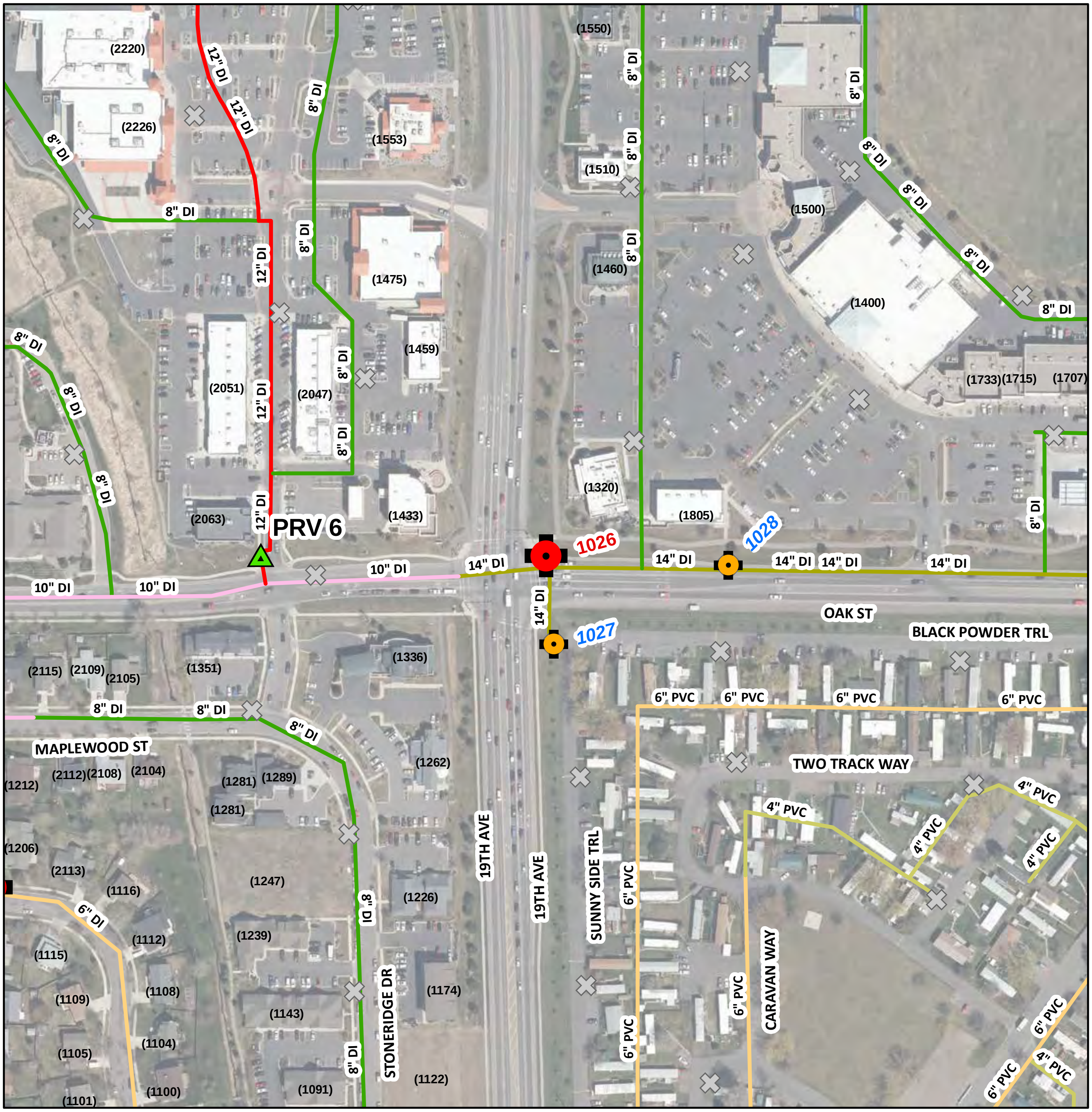
Hydrant No. ______

HPR No. ________

Flow: ______________

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 56	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: 9/30/2015	Hydrant No. 1026	Hydrant No. 1027	Hydrant No. 1028
Start Time: 11:00 AM	HPR No. 1240	HPR No. 1241	HPR No. 201250
End Time: 11:12 AM	Static: 153.2 psi	Flow: 1,998 gpm	Flow: 1,725 gpm
Test By: JDH	Residual: 140.7 psi		
Zone: SOUTH			

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

Test Number: 57

Test Date: 9/29/2015

Start Time: 3:58 PM

End Time: 4:07 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 1040

HPR No. 1240

Static: 82.4 psi

Residual: 74.0 psi

FLOW HYDRANT #1

Hydrant No. 2510

HPR No. 1241

Flow: 1,342 gpm

FLOW HYDRANT #2

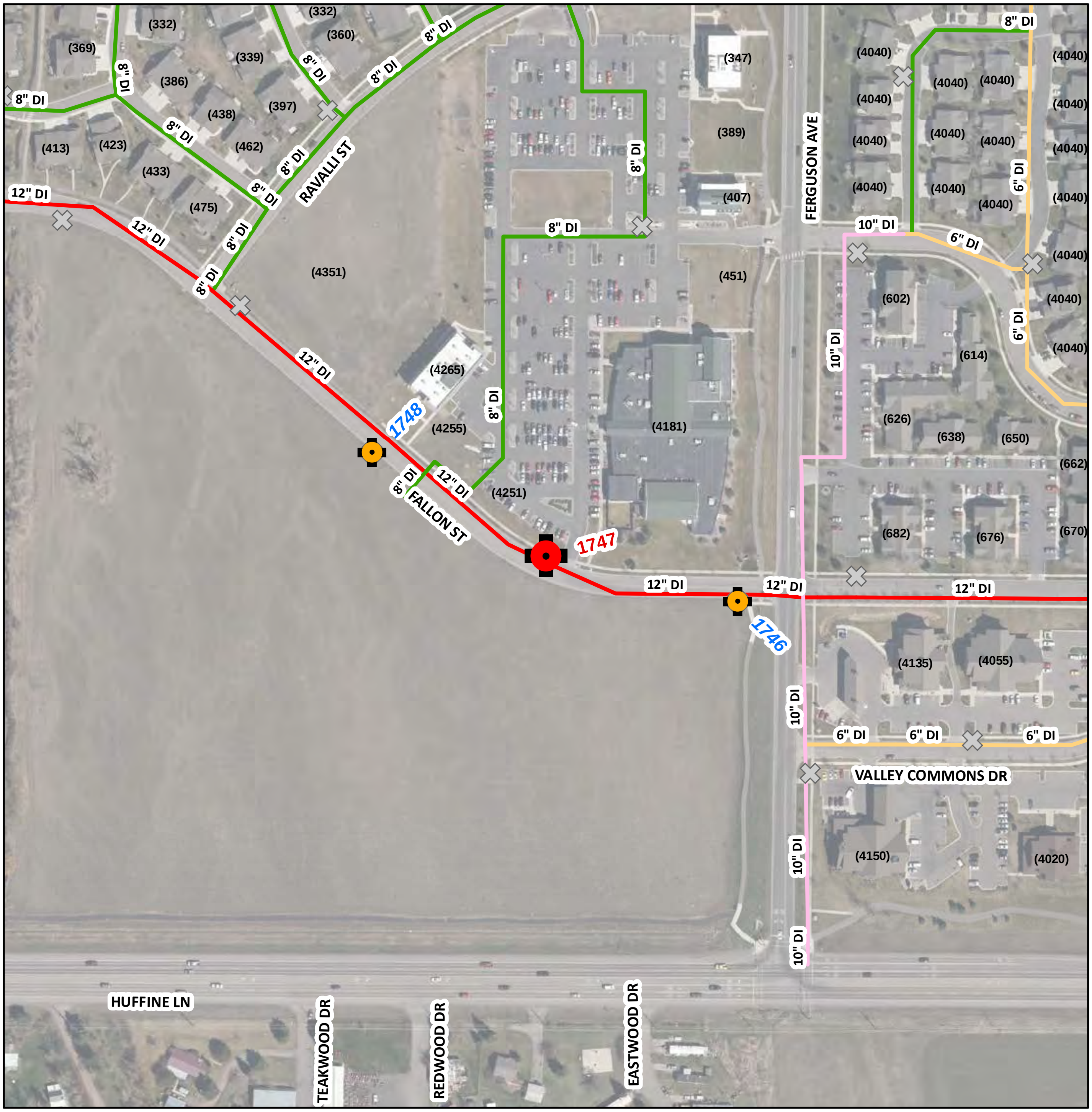
Hydrant No. 1041

HPR No. 201250

Flow: 1,299 gpm

Test Hydrants Flow Hydrants Other Hydrants

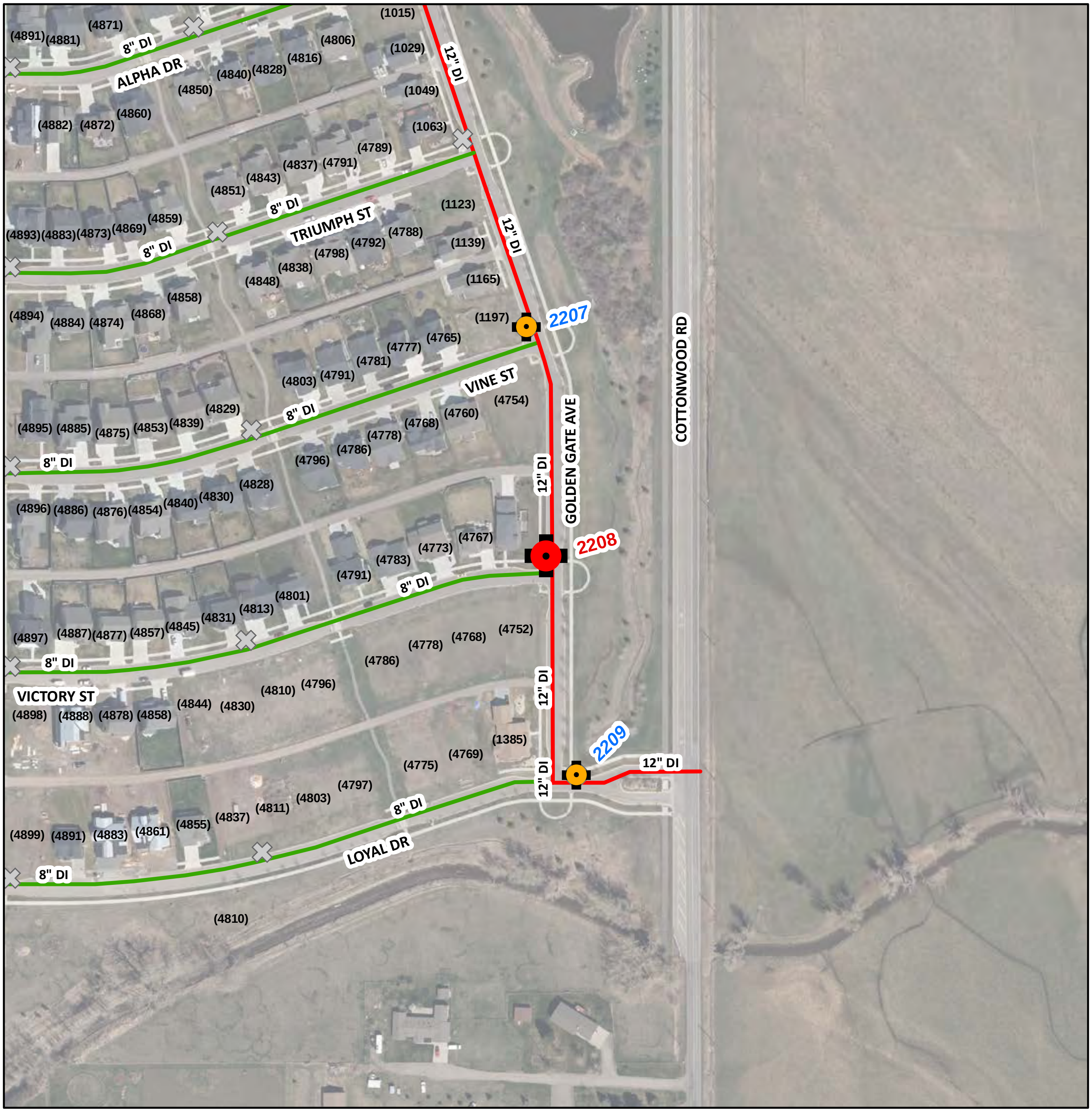
Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 58	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: 10/1/2015	Hydrant No. 1747	Hydrant No. 1746	Hydrant No. 1748
Start Time: 2:25 PM	HPR No. 1240	HPR No. 1251	HPR No. 201250
End Time: 2:37 PM	Static: 123.4 psi	Flow: 1,621 gpm	Flow: 1,531 gpm
Test By: JDH	Residual: 109.8 psi		
Zone: SOUTH			

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 59

Test Date: 10/1/2015

Start Time: 2:04 PM

End Time: 2:16 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 2208

HPR No. 1240

Static: 111.3 psi

Residual: 88.0 psi

FLOW HYDRANT #1

Hydrant No. 2209

HPR No. 1251

Flow: 1,491 gpm

FLOW HYDRANT #2

Hydrant No. 2207

HPR No. 201250

Flow: 1,521 gpm

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 60

Test Date: 9/30/2015

Start Time: 9:42 AM

End Time: 9:56 AM

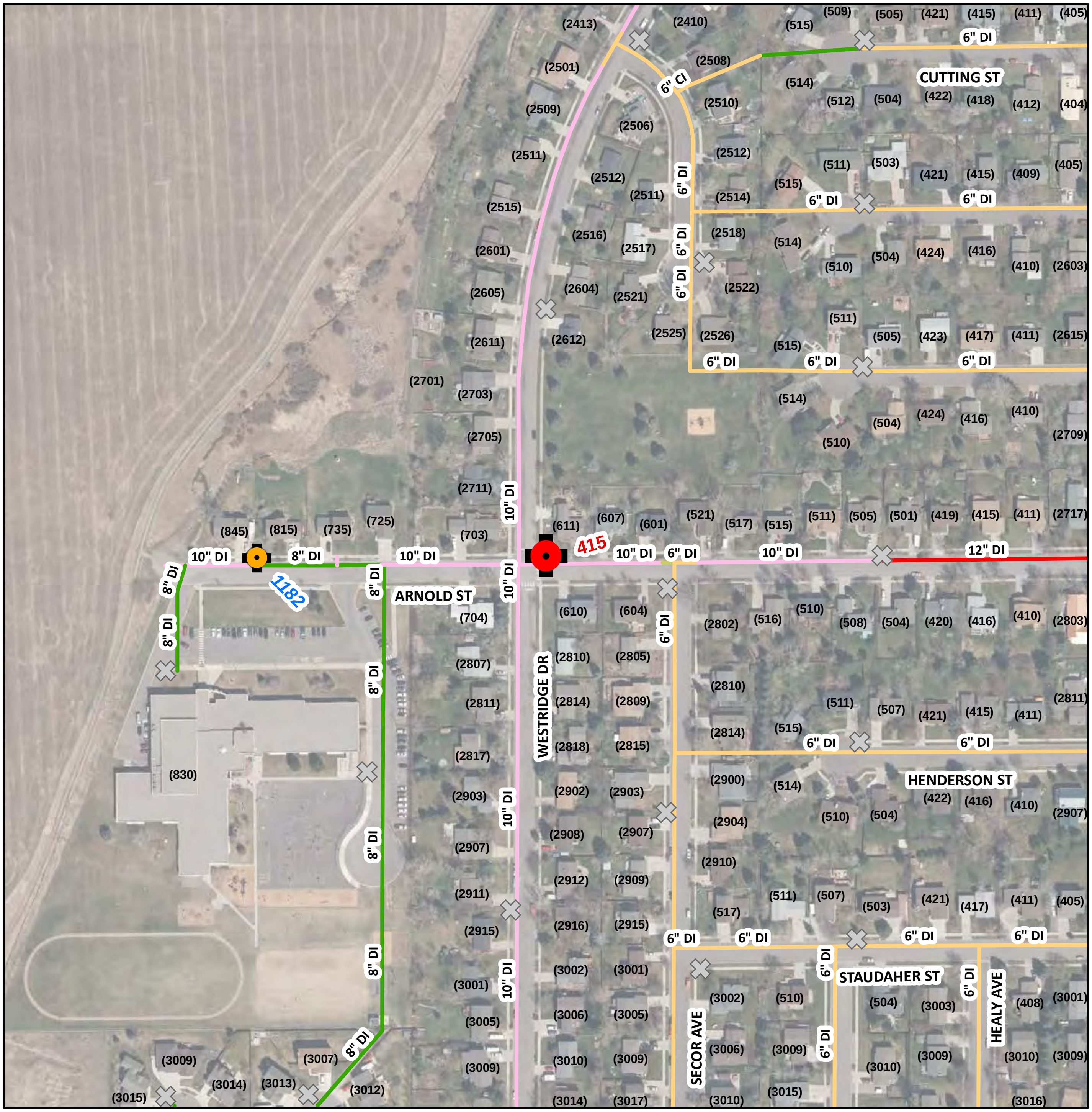
Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. 961	Hydrant No. 620	Hydrant No.
HPR No. 1240	HPR No. 201250	HPR No.
Static: 157.4 psi	Flow: 1,803 gpm	Flow:
Residual: 153.9 psi		

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 61

Test Date: 10/1/2015

Start Time: 11:38 AM

End Time: 11:50 AM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 415

HPR No. 1240

Static: 71.1 psi

Residual: 70.7 psi

FLOW HYDRANT #1

Hydrant No. 1182

HPR No. 201250

Flow: 1,277 gpm

FLOW HYDRANT #2

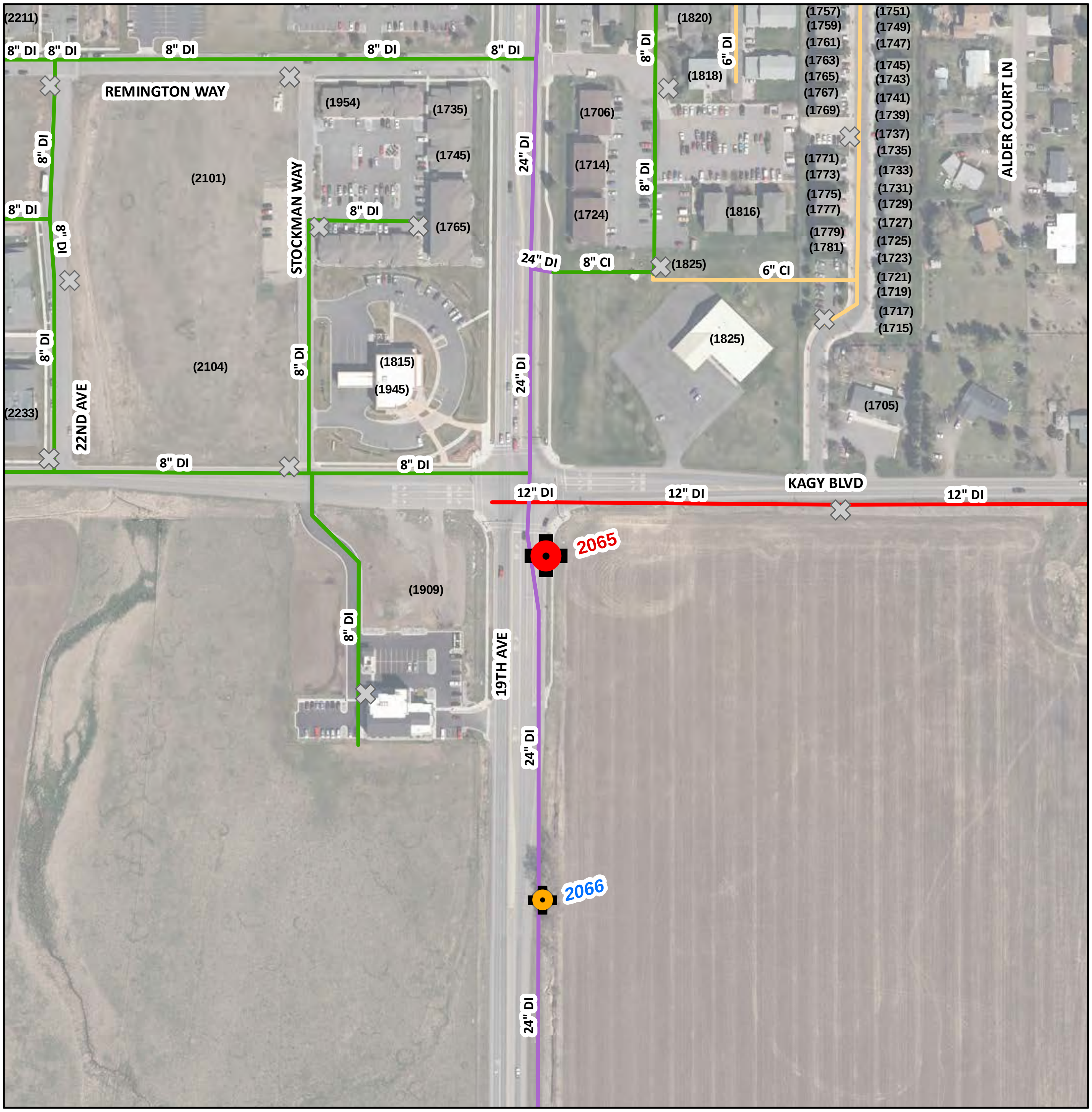
Hydrant No. ______

HPR No. ________

Flow: ______________

Test Hydrants   Flow Hydrants   Other Hydrants

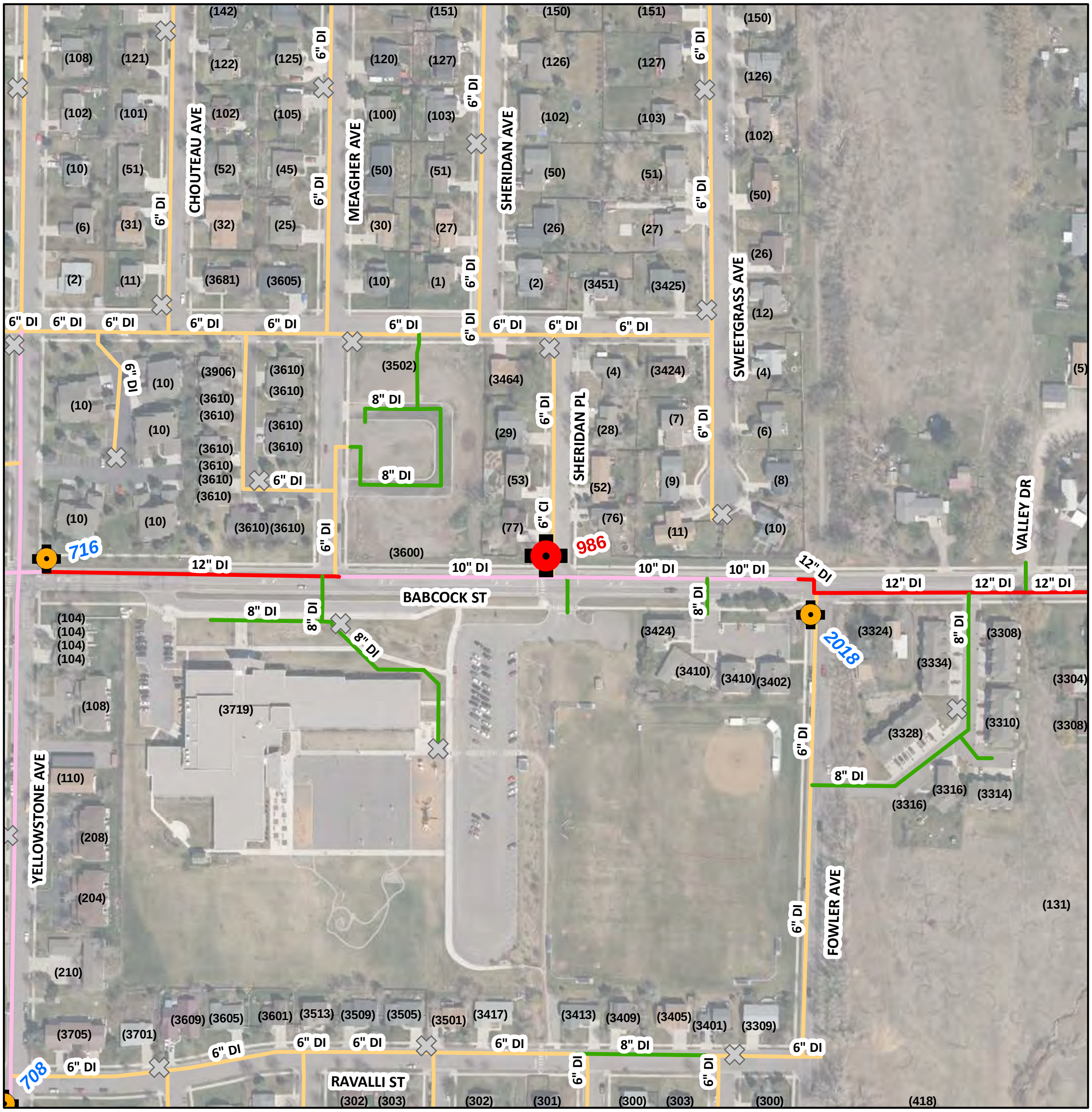
Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 62	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: 10/1/2015	Hydrant No. 2065	Hydrant No. 2066	Hydrant No.
Start Time: 10:15 AM	HPR No. 1240	HPR No. 201250	HPR No.
End Time: 10:30 AM	Static: 83.0 psi	Flow: 1,362 gpm	Flow:
Test By: JDH	Residual: 81.4 psi		
Zone: SOUTH			

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 63

Test Date: 10/1/2015

Start Time: 3:21 PM

End Time: 3:34 PM

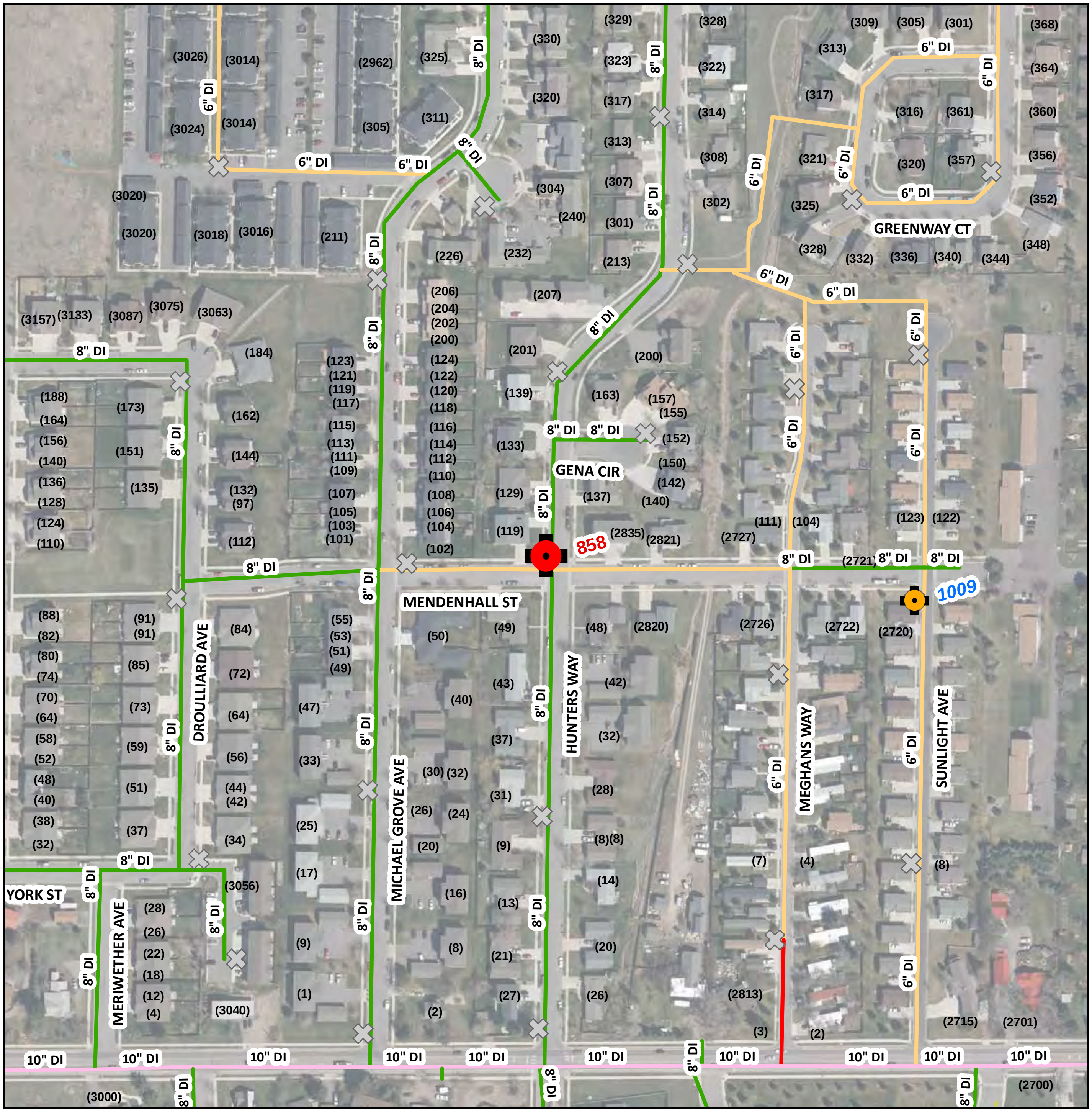
Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. 986	Hydrant No. 2018	Hydrant No. 716
HPR No. 1240	HPR No. 1251	HPR No. 201250
Static: 130.6 psi	Flow: 1,689 gpm	Flow: 1,746 gpm
Residual: 118.3 psi		

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 64

Test Date: 9/30/2015

Start Time: 5:25 PM

End Time: 5:40 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 858

HPR No. 1240

Static: 131.5 psi

Residual: 128.3 psi

FLOW HYDRANT #1

Hydrant No. 1009

HPR No. 201250

Flow: 1,739 gpm

FLOW HYDRANT #2

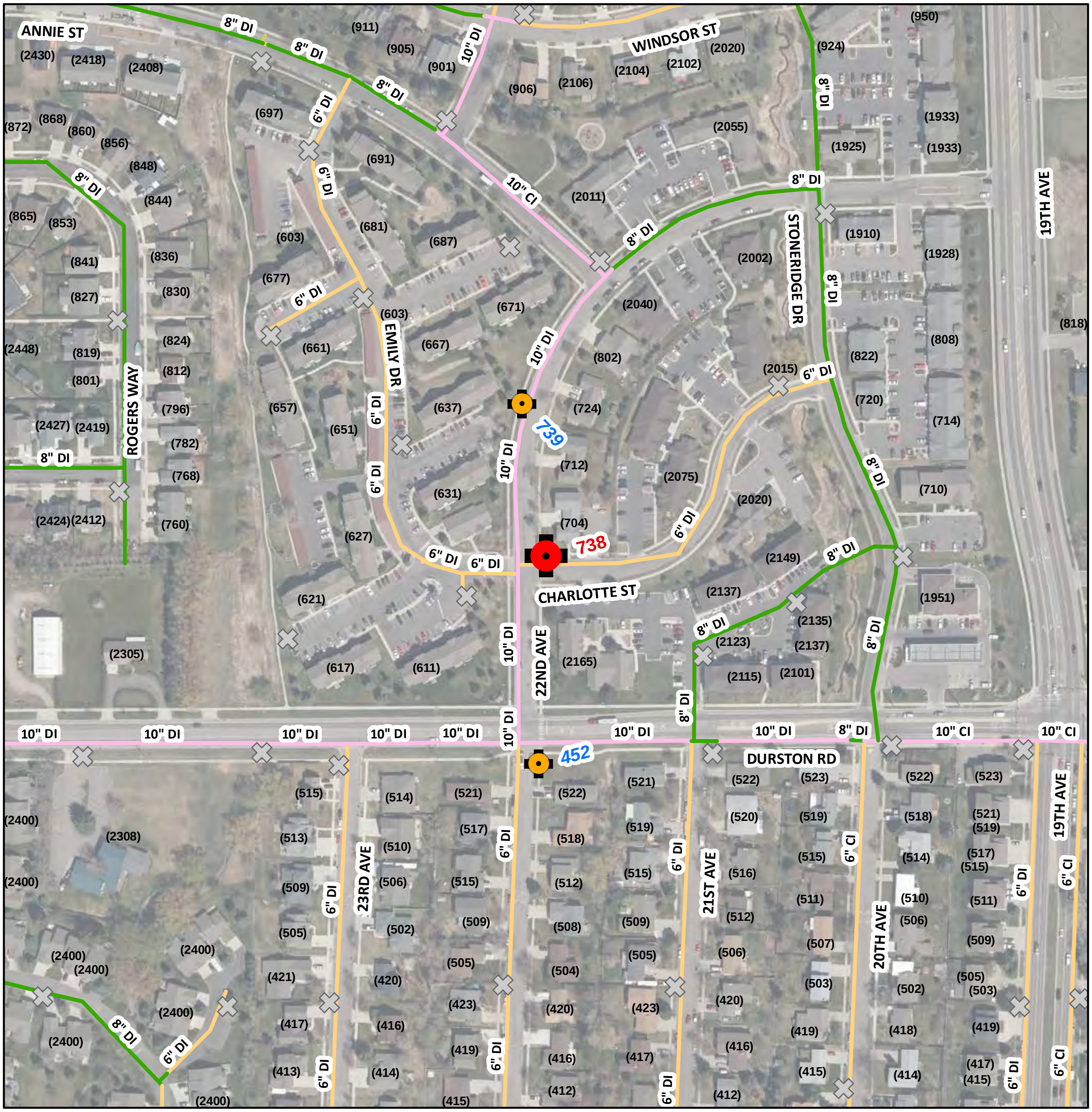
Hydrant No. ______

HPR No. ________

Flow: ______________

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 65

Test Date: 9/30/2015

Start Time: 11:40 AM

End Time: 11:51 AM

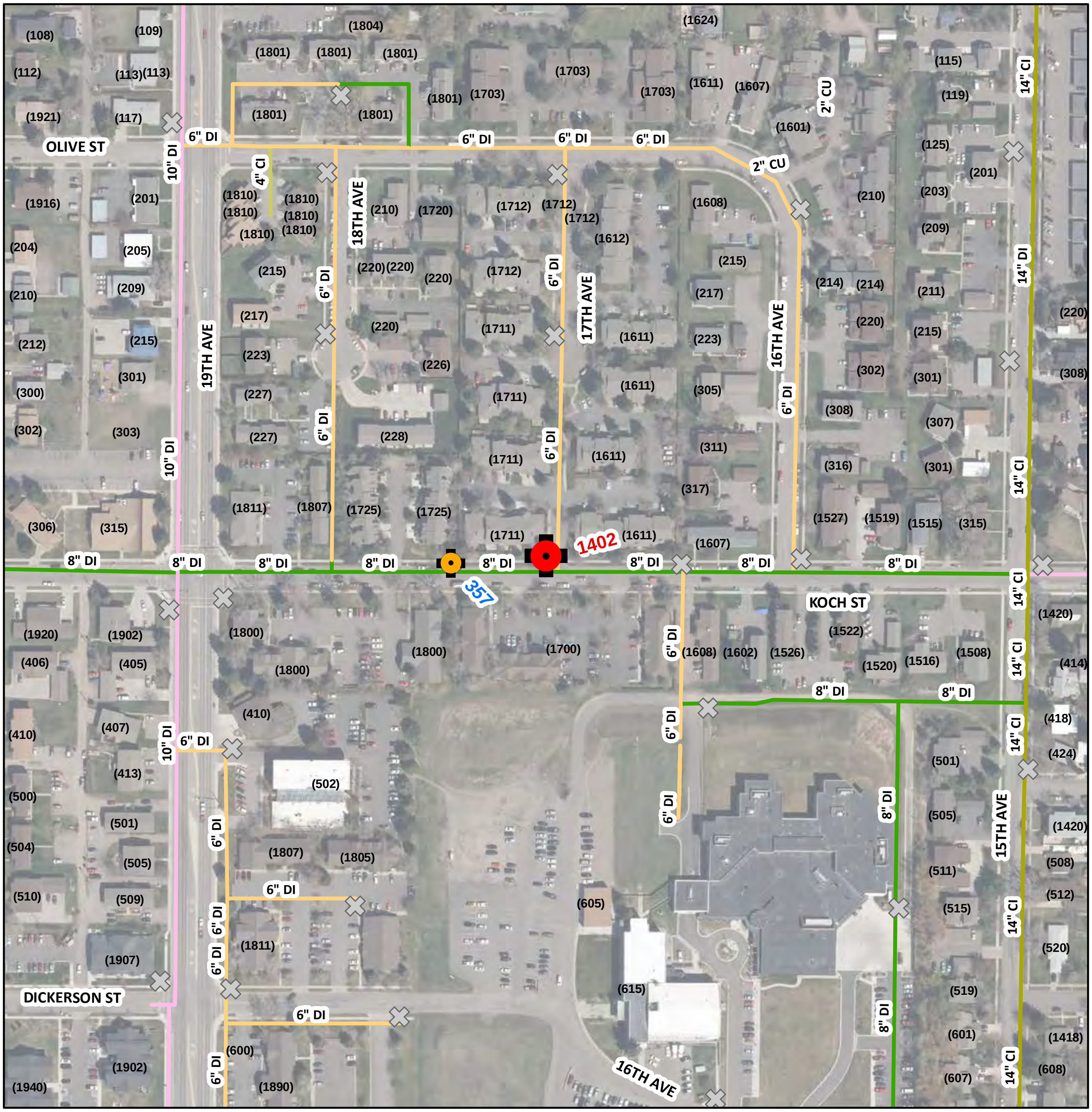
Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	738	Hydrant No.	739	Hydrant No.	452
HPR No.	1240	HPR No.	1241	HPR No.	201250
Static:	142.6 psi	Flow:	1,964 gpm	Flow:	1,814 gpm
Residual:	133.7 psi				

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 66

Test Date: 9/30/2015

Start Time: 3:36 PM

End Time: 3:50 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Hydrant No. 1402	Hydrant No. 357	Hydrant No.
HPR No. 1240	HPR No. 201250	HPR No.
Static: 120.3 psi	Flow: 1,732 gpm	Flow:
Residual: 116.7 psi		

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

66

Test Number: 67

Test Date: 9/30/2015

Start Time: 2:45 PM

End Time: 2:55 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 980

HPR No. 1240

Static: 112.5 psi

Residual: 109.0 psi

FLOW HYDRANT #1

Hydrant No. 979

HPR No. 201250

Flow: 1,660 gpm

FLOW HYDRANT #2

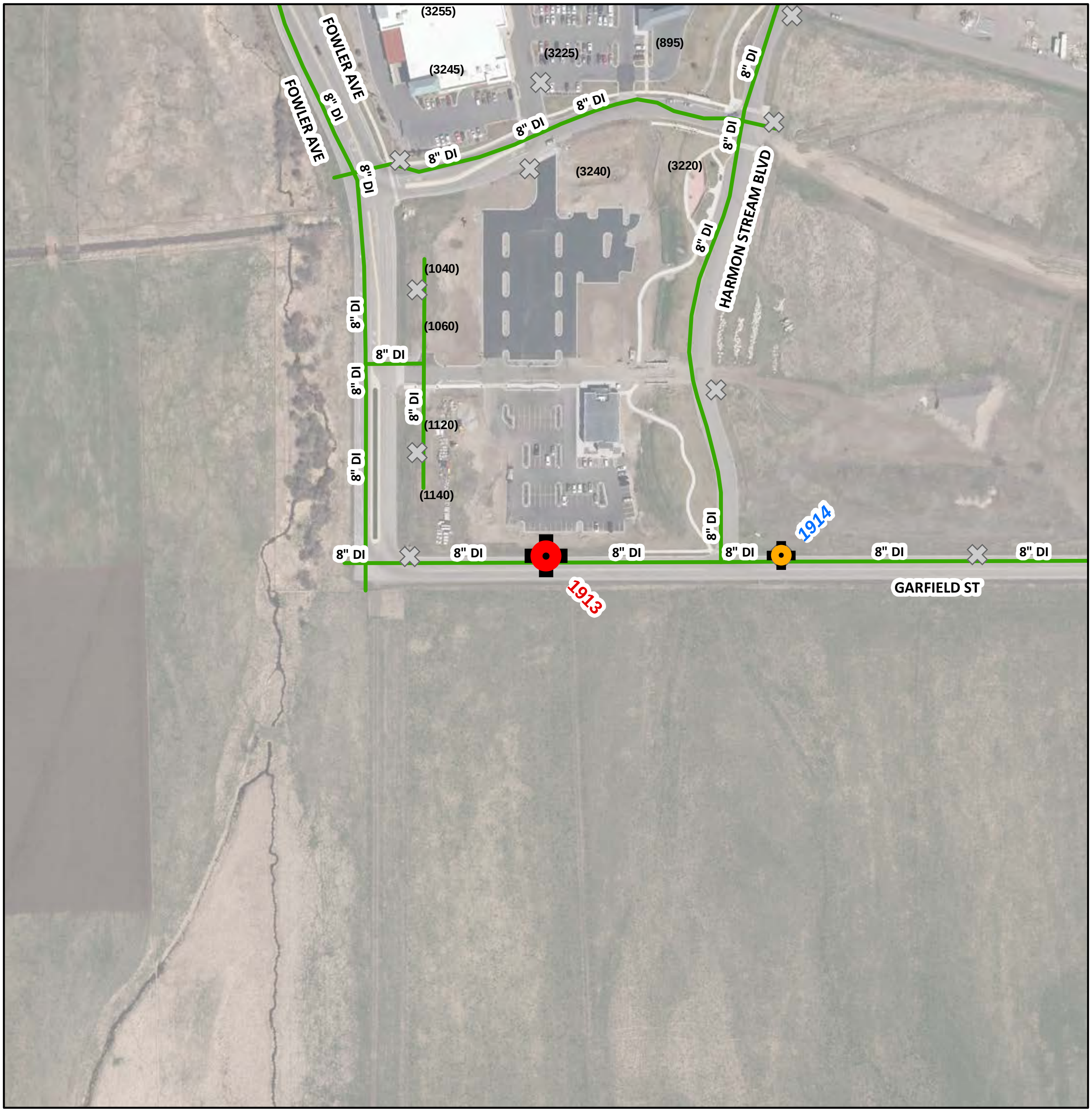
Hydrant No. ______

HPR No. ________

Flow: ______________

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 68

Test Date: 9/30/2015

Start Time: 2:28 PM

End Time: 2:38 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 1913

HPR No. 1240

Static: 100.8 psi

Residual: 98.7 psi

FLOW HYDRANT #1

Hydrant No. 1914

HPR No. 201250

Flow: 1,494 gpm

FLOW HYDRANT #2

Hydrant No. ______

HPR No. ________

Flow: ______________

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

Test Number: 69

Test Date: 9/30/2015

Start Time: 2:08 PM

End Time: 2:24 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 664

HPR No. 1240

Static: 101.8 psi

Residual: 92.6 psi

FLOW HYDRANT #1

Hydrant No. 1264

HPR No. 201247

Flow: 1,446 gpm

FLOW HYDRANT #2

Hydrant No. 663

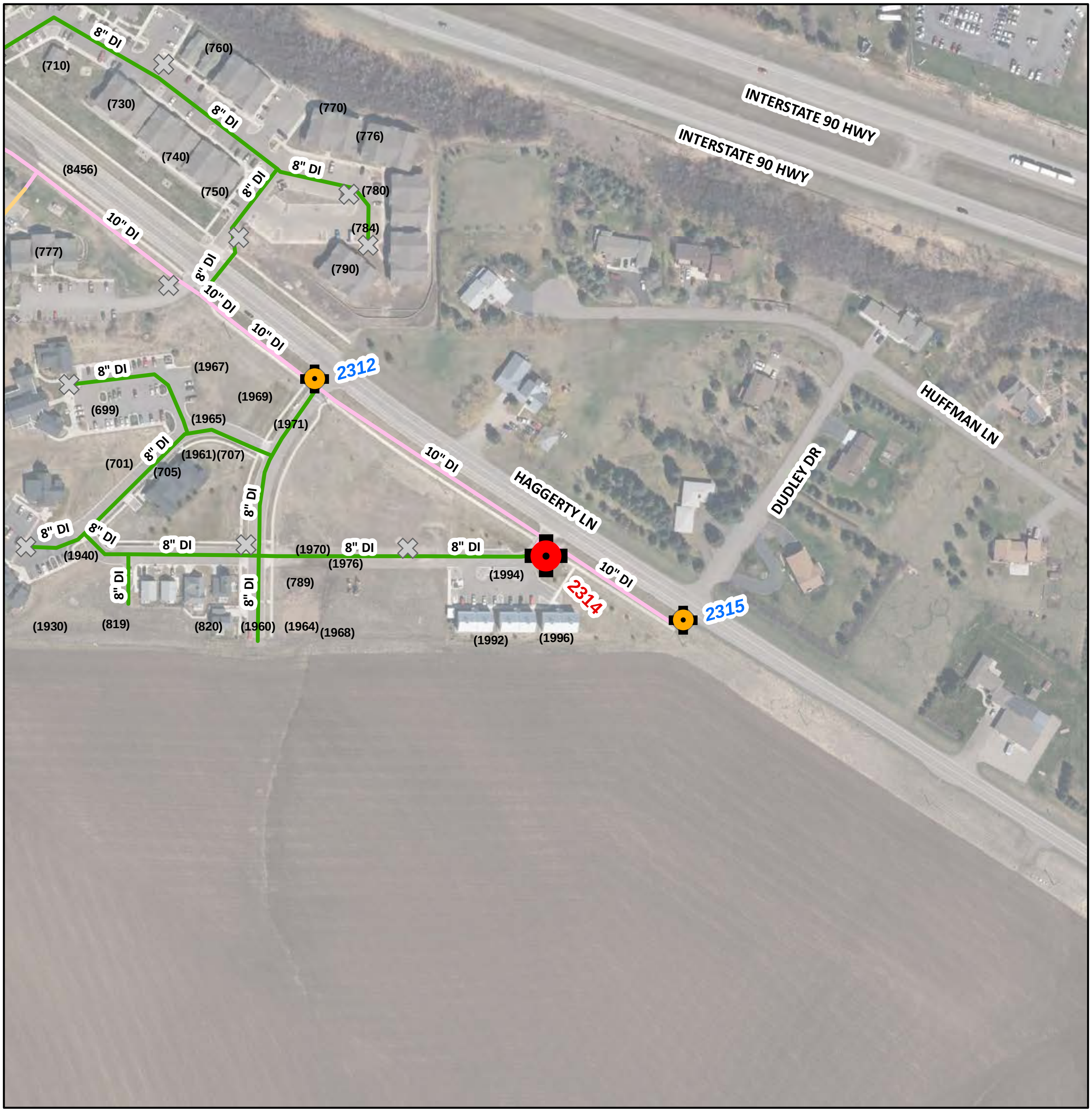
HPR No. 201250

Flow: 1,532 gpm

Test Hydrants   Flow Hydrants   Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Test Number: 70

Test Date: 9/29/2015

Start Time: 3:34 PM

End Time: 3:44 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	2314	Hydrant No.	2312	Hydrant No.	2315
HPR No.	1240	HPR No.	1241	HPR No.	201250
Static:	100.2 psi	Flow:	1,385 gpm	Flow:	1,273 gpm
Residual:	66.6 psi				

Test Hydrants　Flow Hydrants　Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 71

Test Date: 10/1/2015

Start Time: 12:17 PM

End Time: 12:28 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 1920

HPR No. 1240

Static: 69.2 psi

Residual: 66.7 psi

FLOW HYDRANT #1

Hydrant No. 1921

HPR No. 201250

Flow: 1,305 gpm

FLOW HYDRANT #2

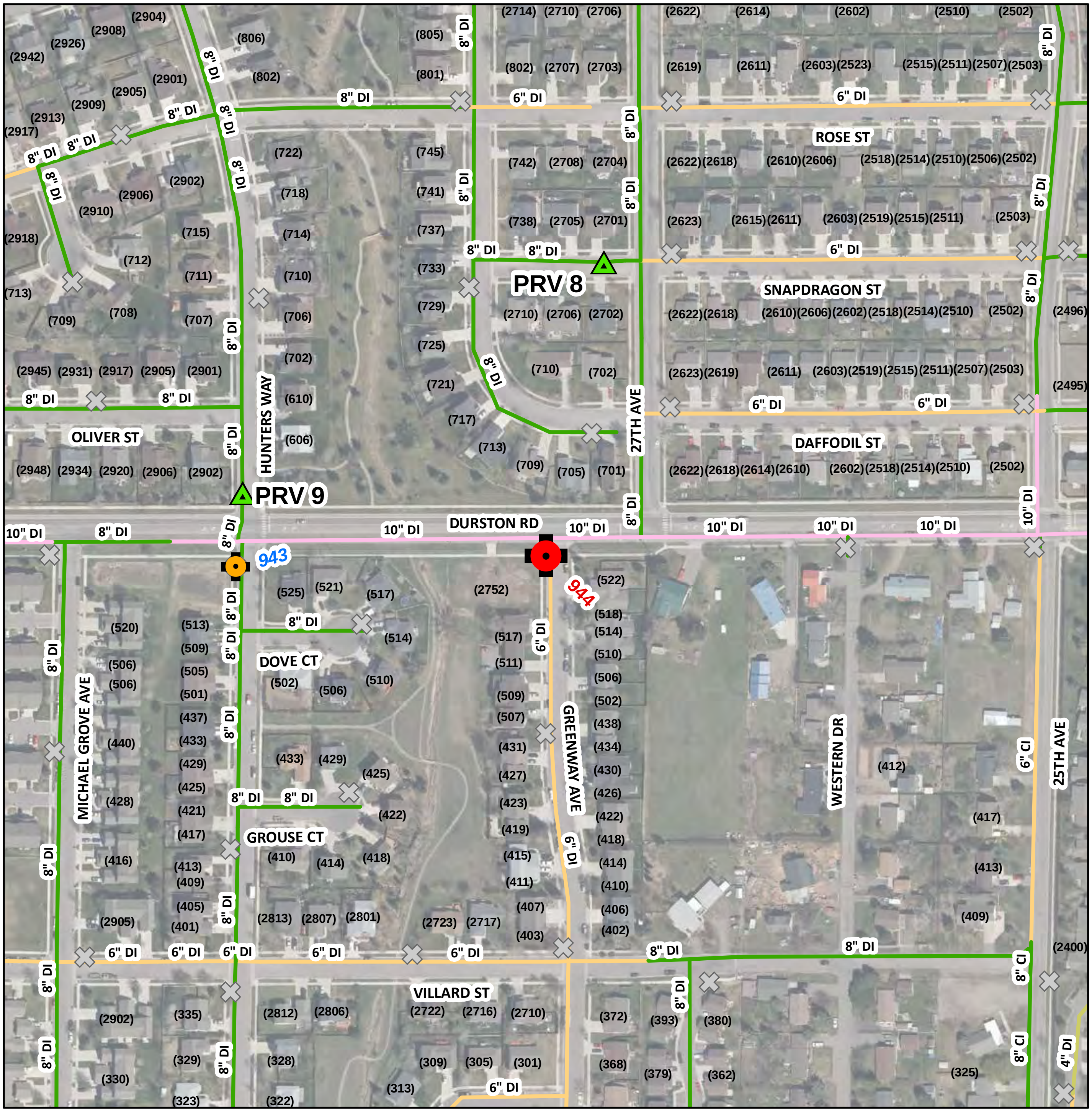
Hydrant No. ______

HPR No. ________

Flow: ______________

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 72

Test Date: 9/30/2015

Start Time: 5:04 PM

End Time: 5:17 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT

Hydrant No. 944

HPR No. 1240

Static: 140.4 psi

Residual: 135.6 psi

FLOW HYDRANT #1

Hydrant No. 943

HPR No. 201250

Flow: 1,870 gpm

FLOW HYDRANT #2

Hydrant No. ______

HPR No. ________

Flow: ____________

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 73

Test Date: 9/29/2015

Start Time: 5:22 PM

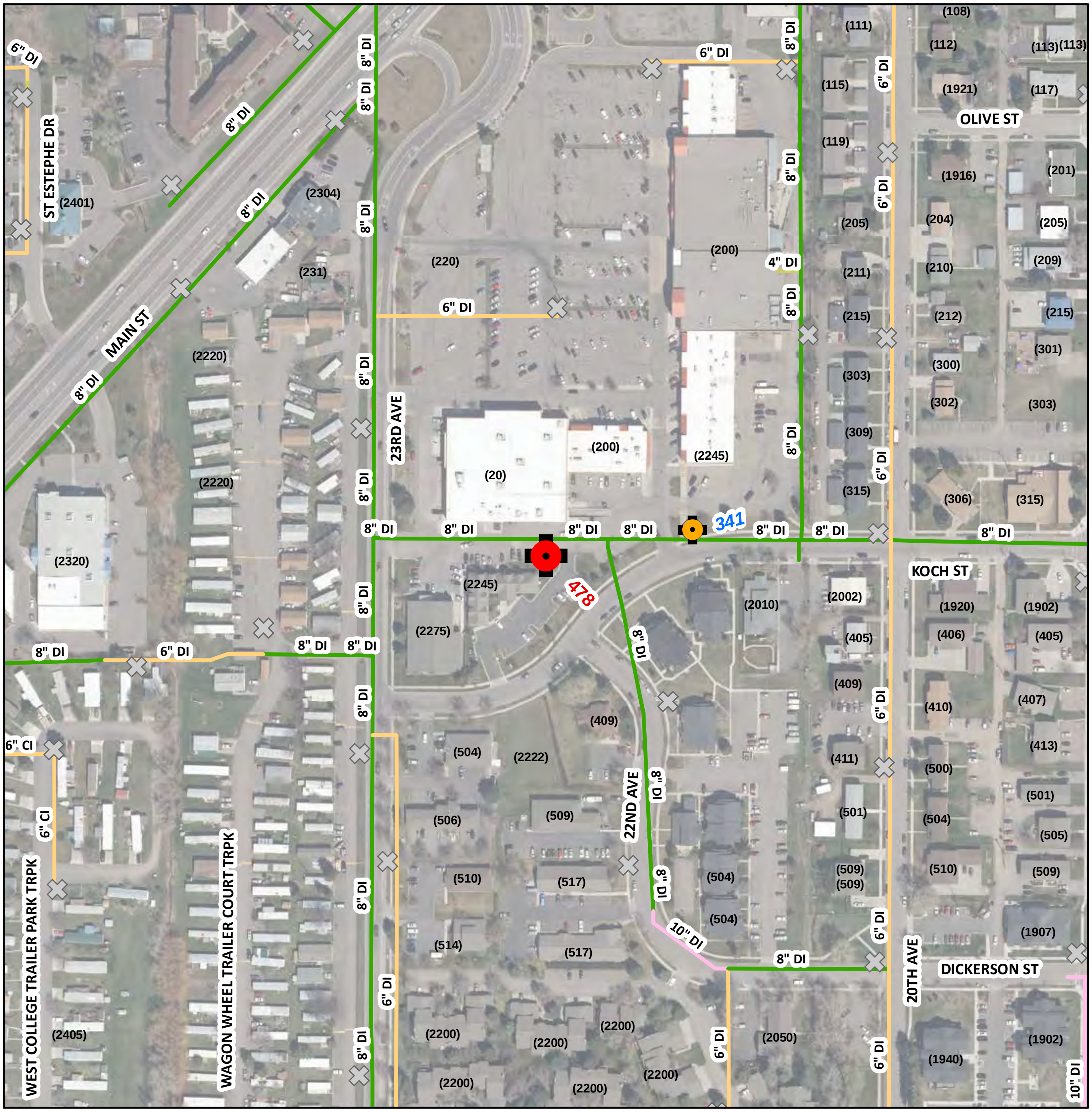
End Time: 5:33 PM

Test By: JDH

Zone: SOUTH

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	1076	Hydrant No.	1077	Hydrant No.	1075
HPR No.	1240	HPR No.	1241	HPR No.	201250
Static:	36.4 psi	Flow:	823 gpm	Flow:	810 gpm
Residual:	32.8 psi				

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet



Test Number: 74	RESIDUAL HYDRANT	FLOW HYDRANT #1	FLOW HYDRANT #2
Test Date: 9/30/2015	Hydrant No. 478	Hydrant No. 341	Hydrant No.
Start Time: 3:20 PM	HPR No. 1240	HPR No. 201250	HPR No.
End Time: 3:31 PM	Static: 120.5 psi	Flow: 1,748 gpm	Flow:
Test By: JDH	Residual: 118.6 psi		
Zone: SOUTH			

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution
System Model Calibration
Field Test Data Sheet

Test Number: 75

Test Date: 9/29/2015

Start Time: 4:16 PM

End Time: 4:30 PM

Test By: JDH

Zone: KNOLL

RESIDUAL HYDRANT		FLOW HYDRANT #1		FLOW HYDRANT #2	
Hydrant No.	2233	Hydrant No.	2230	Hydrant No.	2234
HPR No.	1240	HPR No.	1241	HPR No.	201250
Static:	61.3 psi	Flow:	1,047 gpm	Flow:	1,101 gpm
Residual:	42.1 psi				

Test Hydrants Flow Hydrants Other Hydrants

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

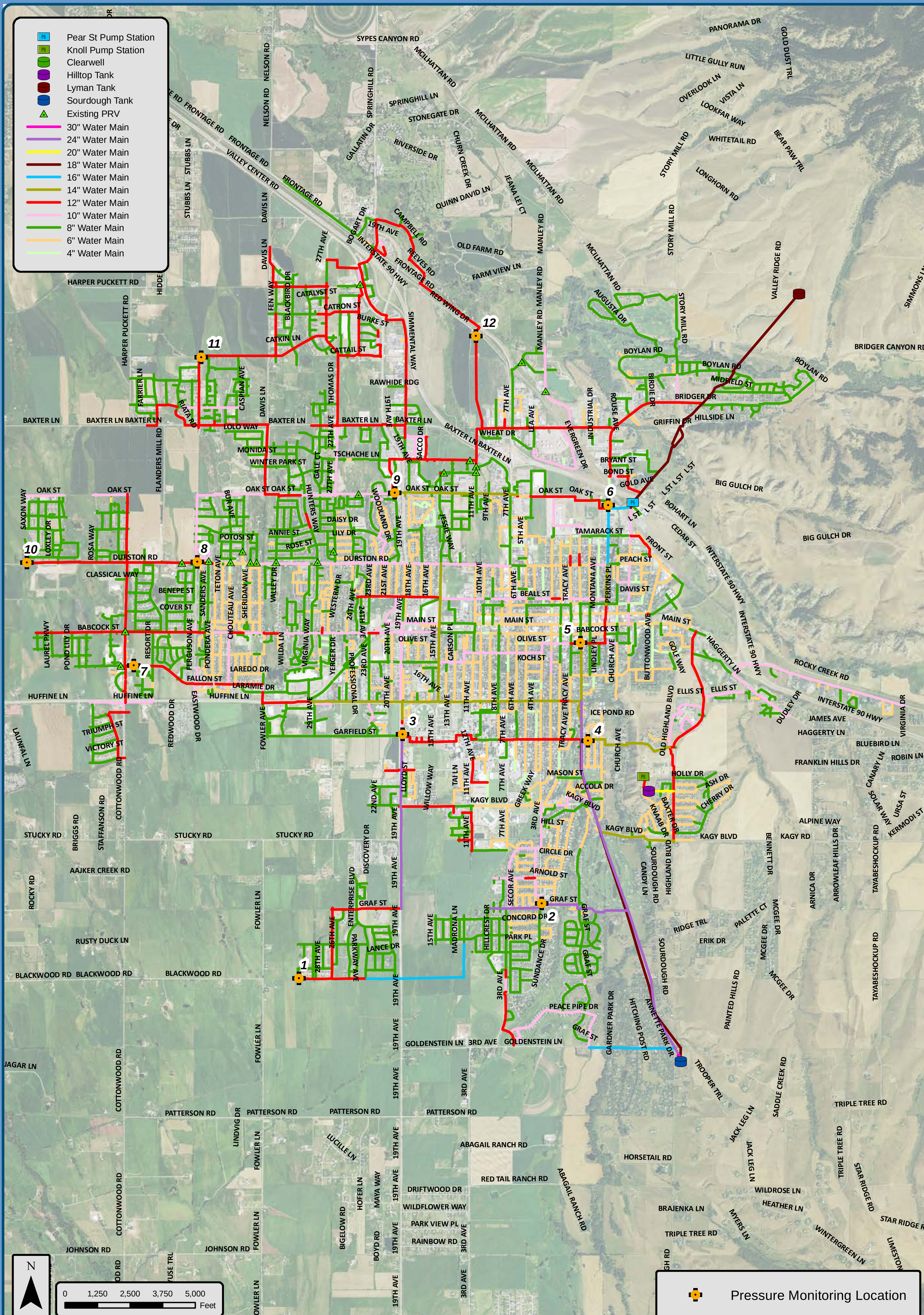
Appendix D - Extended Period Simulation (EPS) Tests

Field Book

Extended
Pressure
Testing

Extended Pressure Testing Protocol

- Install 12 hydrant pressure recorders at key locations throughout the distribution system
- Hydrants will remain live during the 2 week period of collecting flow data
- In case of emergency, cut lock and remove hydrant pressure recorder and return to AE2S



Water Distribution System

Extended Pressure Monitoring Locations

Advanced Engineering and Environmental Services, Inc.

Pressure Monitoring Location: 1

Hydrant ID: 2107

Recorder ID: 1242 Pressure at Setup: 38 psi

Installed - Date: 10/1/2015 Time: 5:47 PM

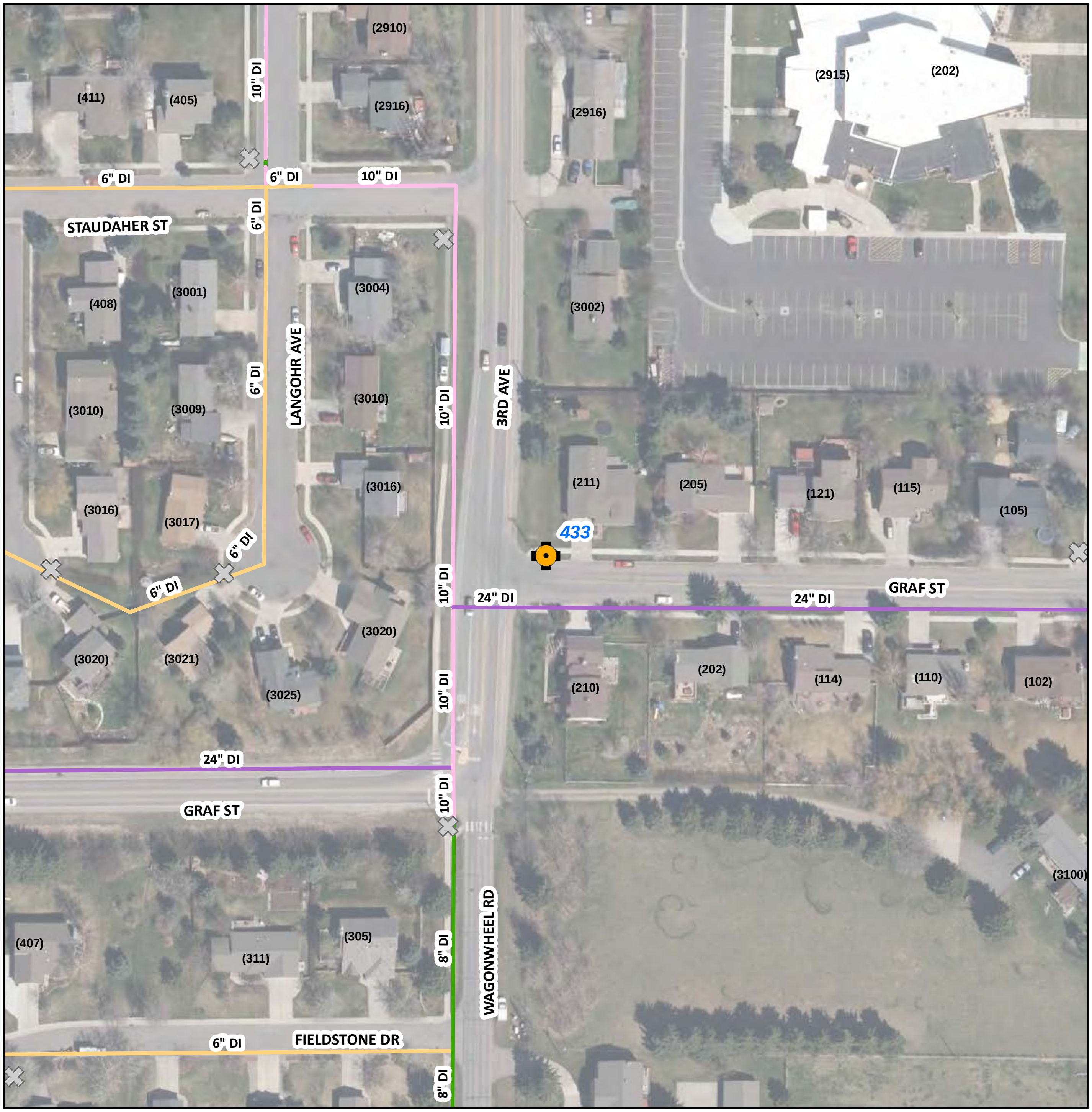
Removed - Date: 10/20/2015 Time: 2:30 PM

Installed/Removed By: JDH

Extended Pressure Monitoring

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Pressure Monitoring Location: 2

Hydrant ID: 433

Recorder ID: 1240 Pressure at Setup: 64 psi

Installed - Date: 10/1/2015 Time: 6:00 PM

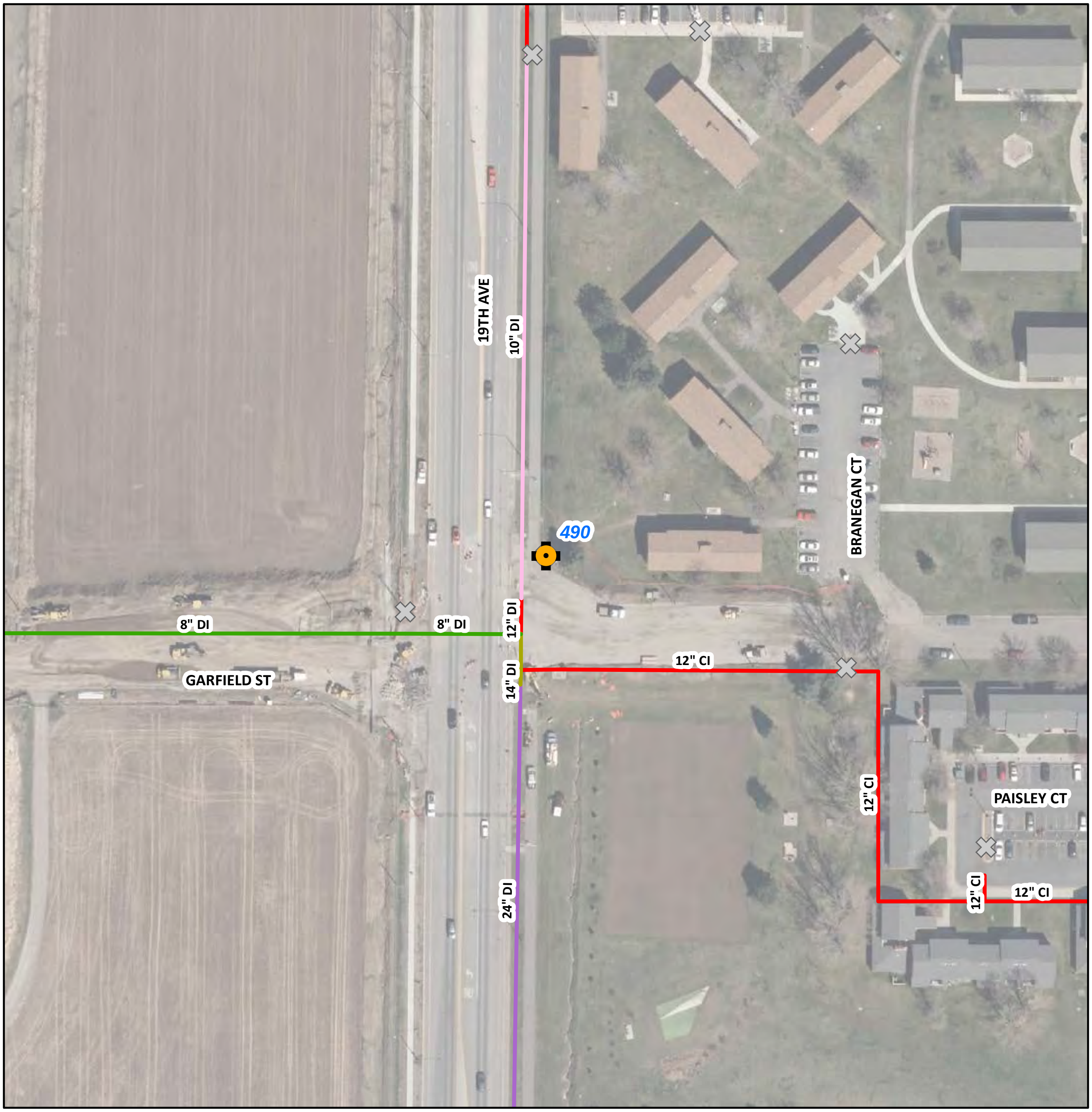
Removed - Date: 10/20/2015 Time: 2:45 PM

Installed/Removed By: JDH

Extended Pressure Monitoring

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Pressure Monitoring Location: 3

Hydrant ID: 490

Recorder ID: 1251 Pressure at Setup: 102 psi

Installed - Date: 10/1/2015 Time: 5:30 PM

Removed - Date: 10/20/2015 Time: 2:15 PM

Installed/Removed By: JDH

Extended Pressure Monitoring

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

Pressure Monitoring Location: 4

Hydrant ID: 278

Recorder ID: 1249 Pressure at Setup: 110 psi

Installed - Date: 10/1/2015 Time: 6:25 PM

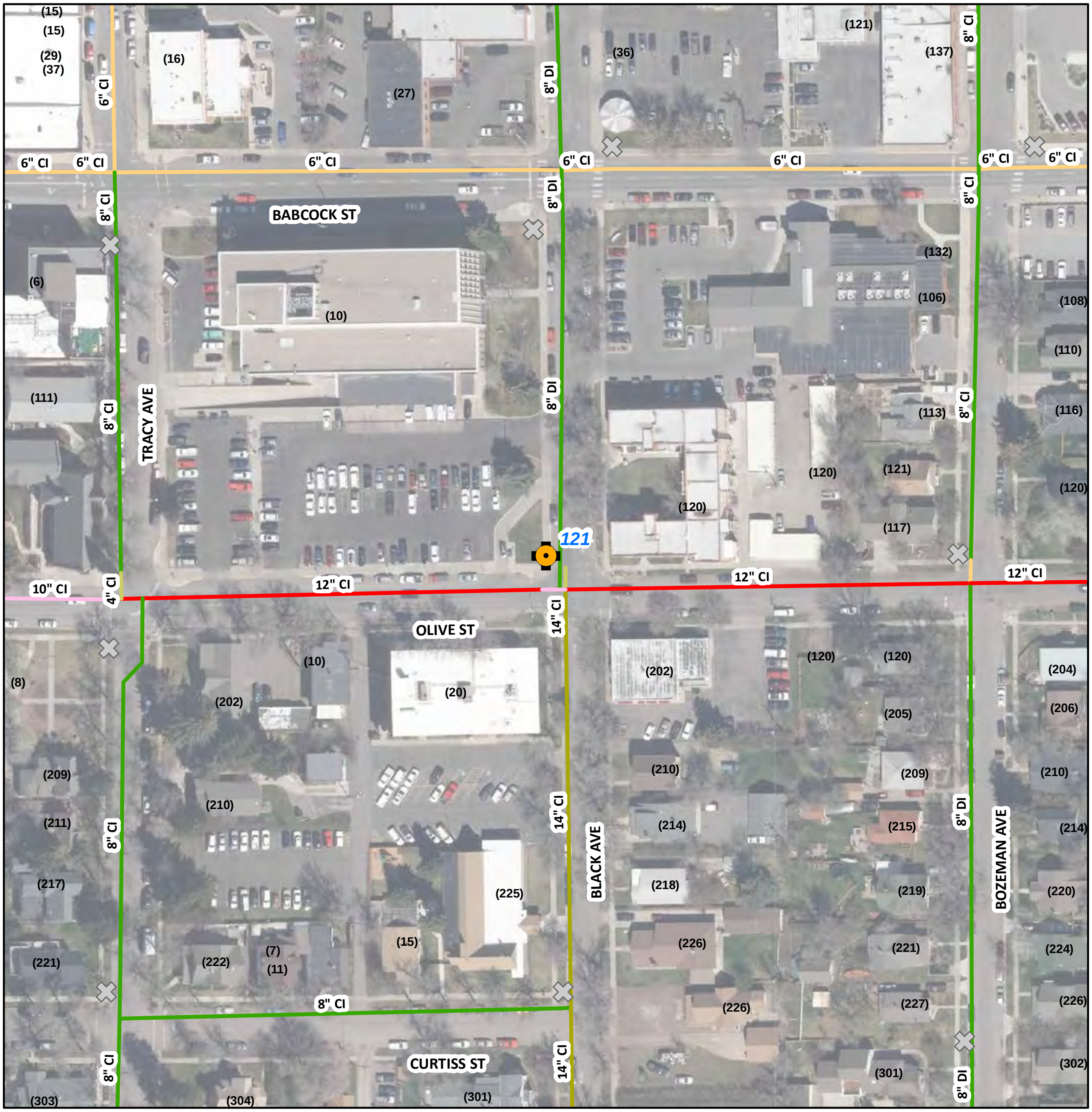
Removed - Date: 10/20/2015 Time: 2:55 PM

Installed/Removed By: JDH

Extended Pressure Monitoring

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Pressure Monitoring Location: 5

Hydrant ID: 121

Recorder ID: 341298 Pressure at Setup: 128 psi

Installed - Date: 10/1/2015 Time: 6:40 PM

Removed - Date: 10/20/2015 Time: 3:10 PM

Installed/Removed By: JDH

Extended Pressure Monitoring

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

Pressure Monitoring Location: 6

Hydrant ID: 1887

Recorder ID: 1245 Pressure at Setup: 152 psi

Installed - Date: 10/1/2015 Time: 6:50 PM

Removed - Date: 10/20/2015 Time: 3:25 PM

Installed/Removed By: JDH

Extended Pressure Monitoring

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

Pressure Monitoring Location: 7

Hydrant ID: 1754

Recorder ID: 341289 Pressure at Setup: 128 psi

Installed - Date: 10/1/2015 Time: 4:47 PM

Removed - Date: 10/20/2015 Time: 1:40 PM

Installed/Removed By: JDH

Extended Pressure Monitoring

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

Pressure Monitoring Location: 8

Hydrant ID: 1125

Recorder ID: 201250 Pressure at Setup: 143 psi

Installed - Date: 10/1/2015 Time: 4:35 PM

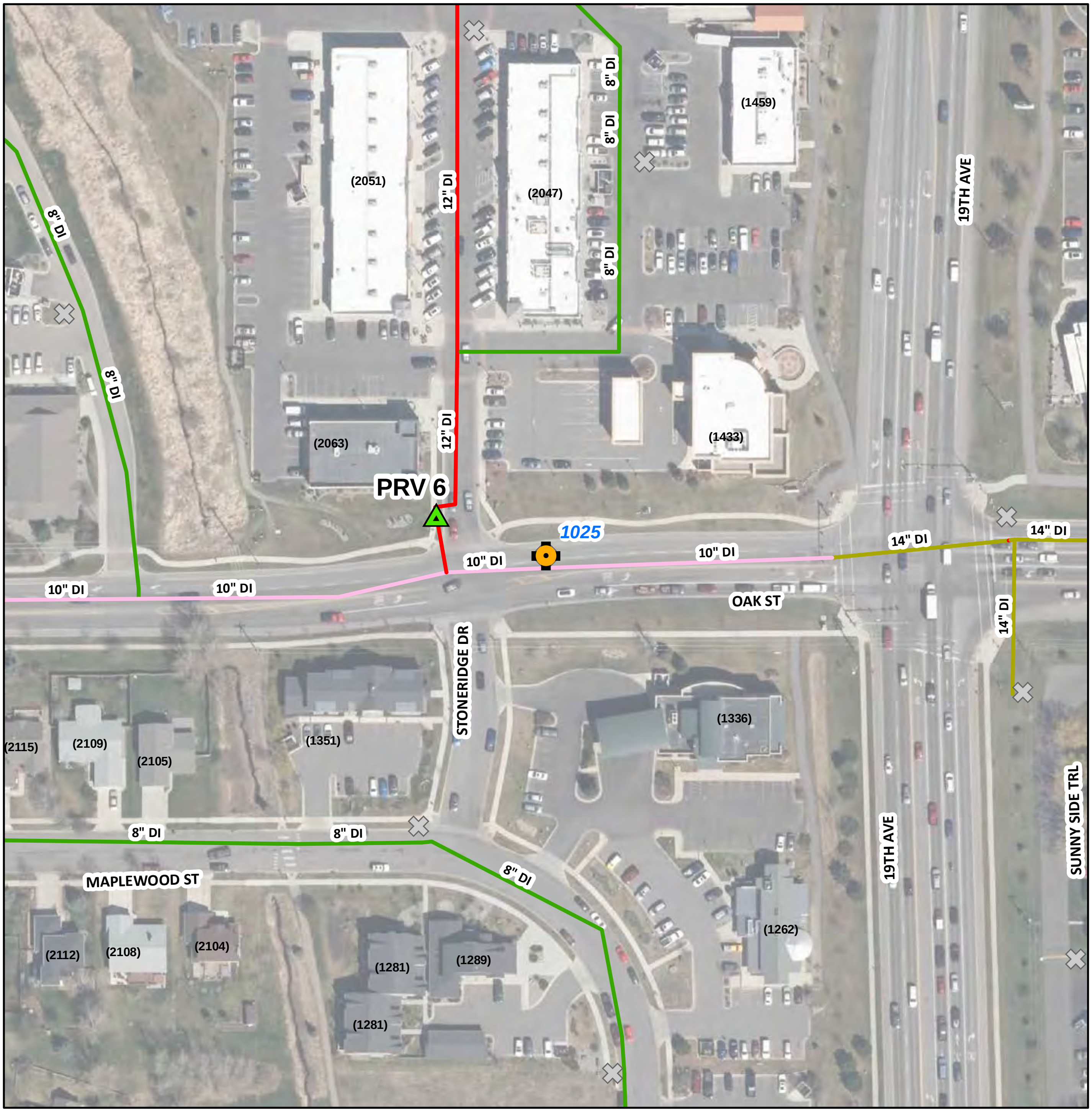
Removed - Date: 10/20/2015 Time: 1:50 PM

Installed/Removed By: JDH

Extended Pressure Monitoring

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Pressure Monitoring Location: 9

Hydrant ID: 1025

Recorder ID: 1243 Pressure at Setup: 156 psi

Installed - Date: 10/1/2015 Time: 5:16 PM

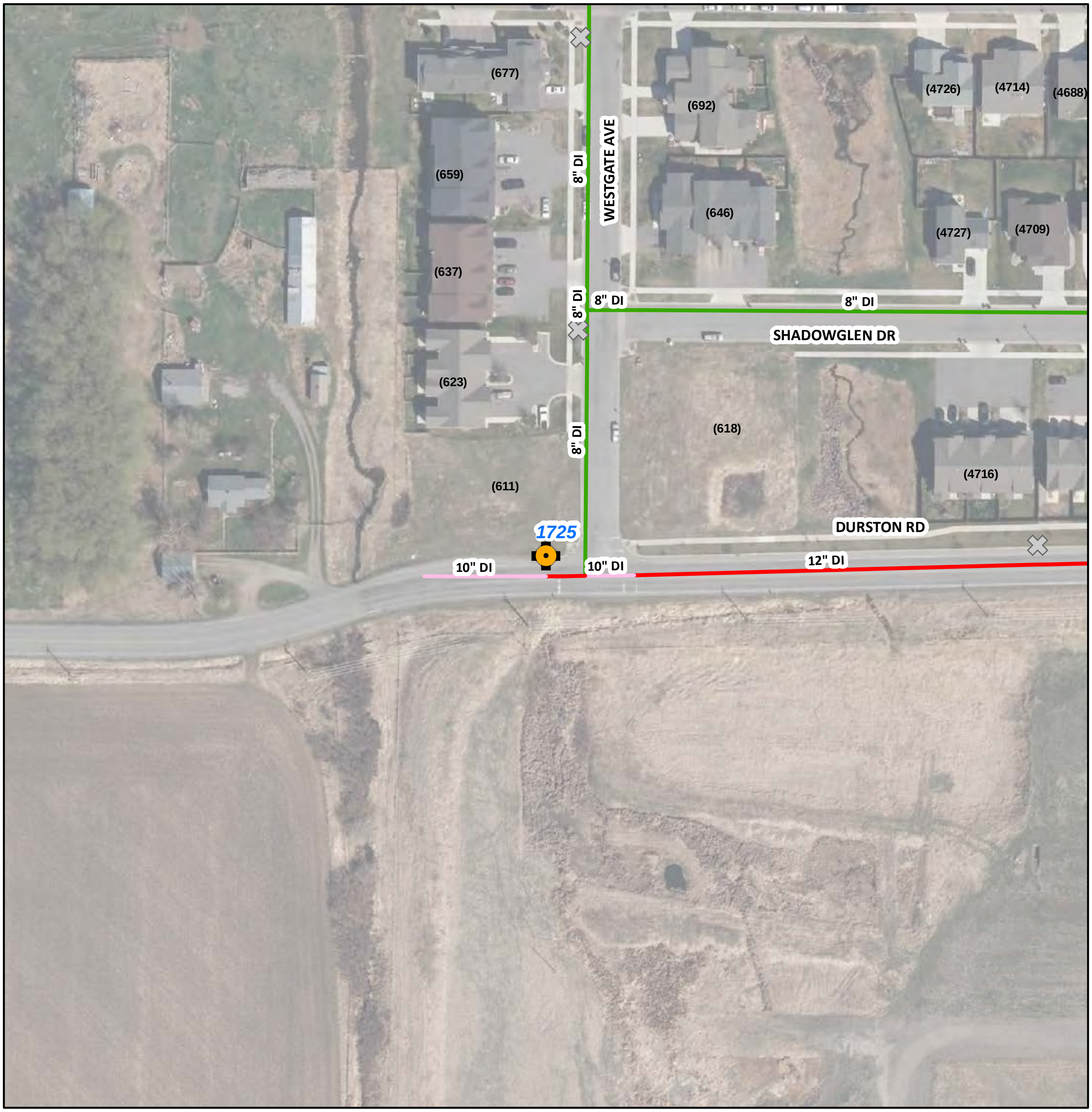
Removed - Date: 10/20/2015 Time: 1:05 PM

Installed/Removed By: JDH

Extended Pressure Monitoring

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Pressure Monitoring Location: 10

Hydrant ID: 1725

Recorder ID: 1241 Pressure at Setup: NA

Installed - Date: NA Time: NA

Removed - Date: NA Time: NA

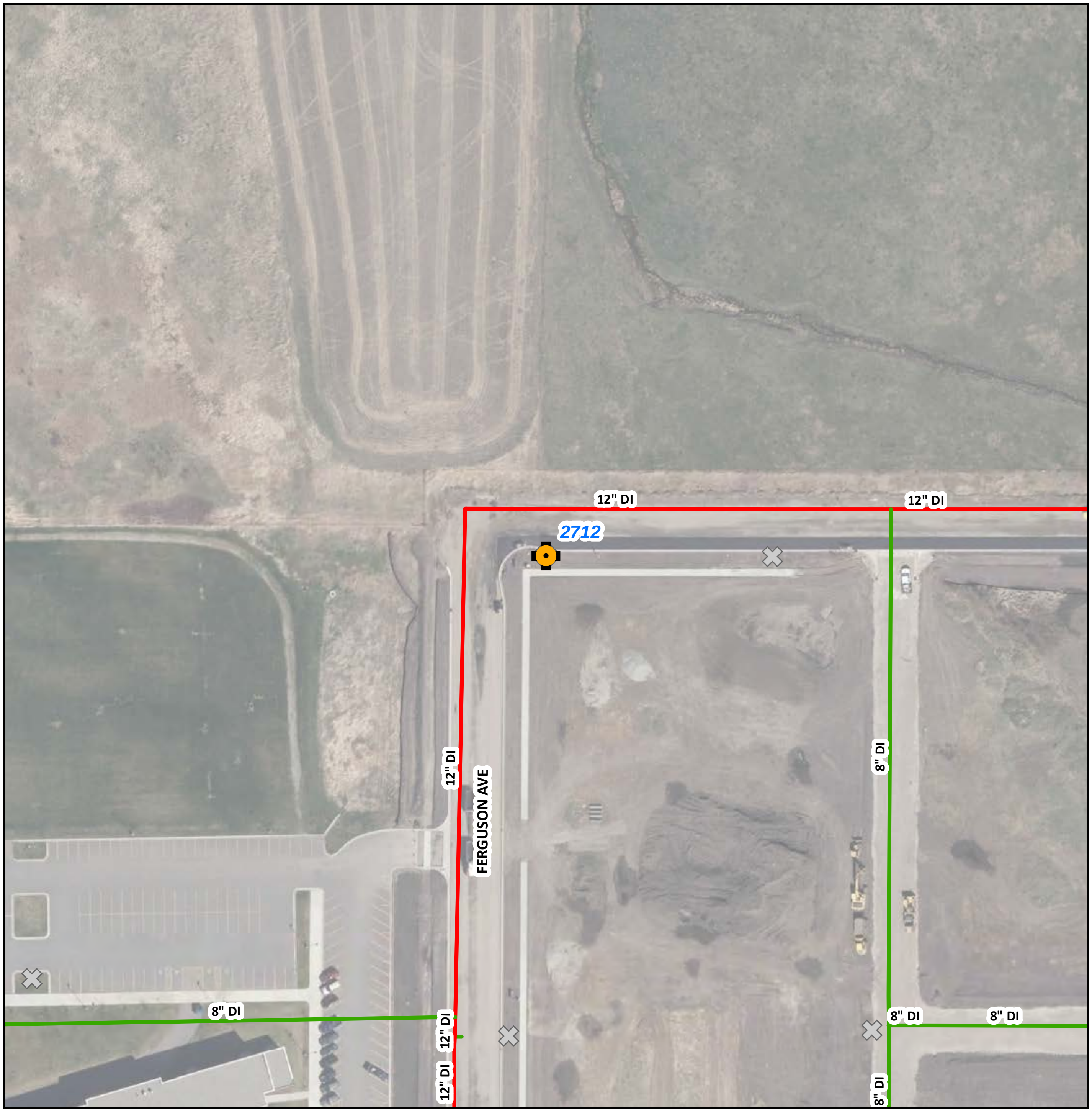
Installed/Removed By: JDH

Note:
No data was recorded at this location due to equipment error.

Extended Pressure Monitoring

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Pressure Monitoring Location: 11

Hydrant ID: 2712

Recorder ID: 1246 Pressure at Setup: 99 psi

Installed - Date: 10/5/2015 Time: 2:45 PM

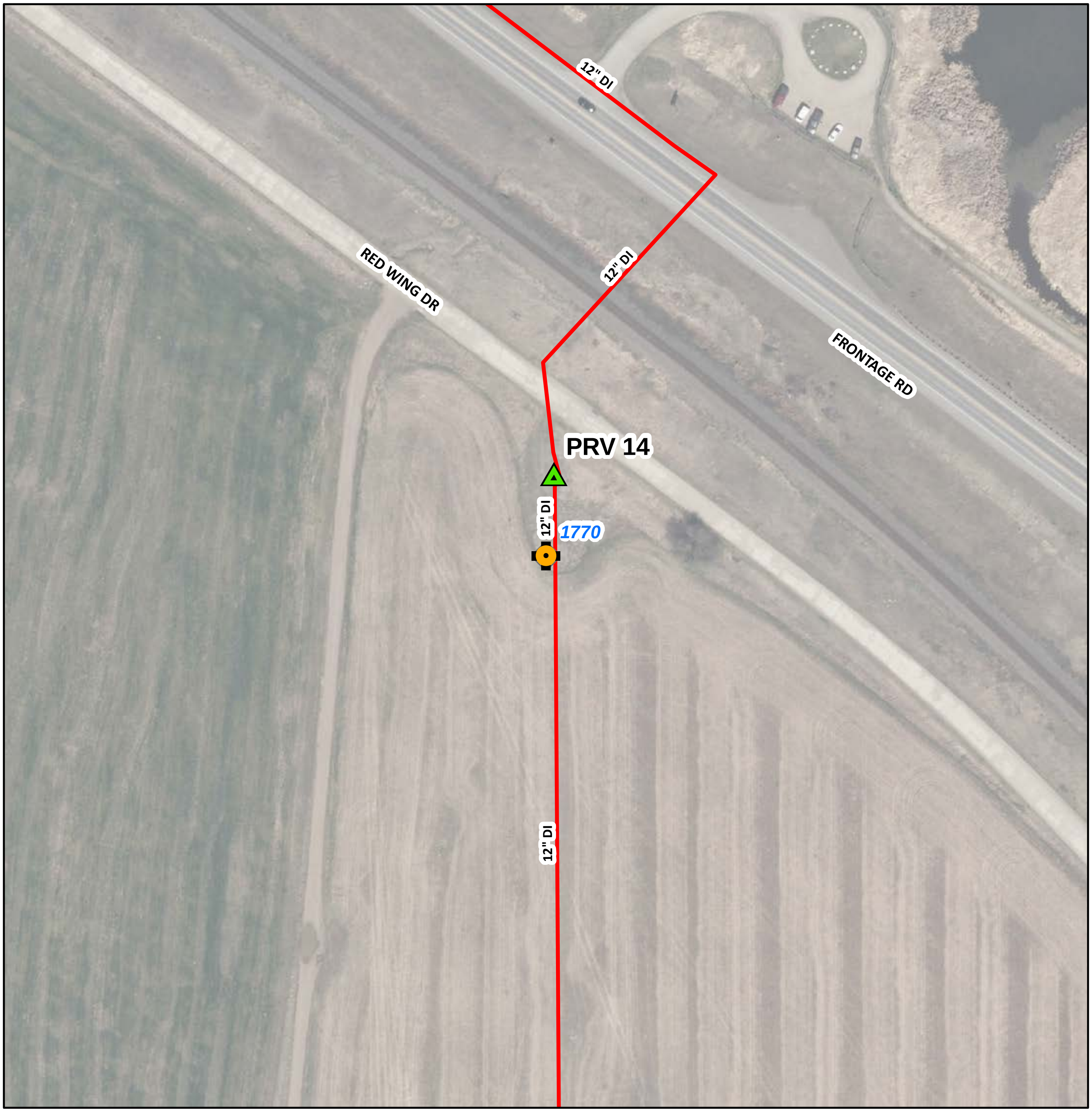
Removed - Date: 10/20/2015 Time: 1:20 PM

Installed/Removed By: JDH

Extended Pressure Monitoring

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet



Pressure Monitoring Location: 12

Hydrant ID: 1770

Recorder ID: 1244 Pressure at Setup: 138 psi

Installed - Date: 10/1/2016 Time: 7:00 PM

Removed - Date: 10/20/2015 Time: 3:35 PM

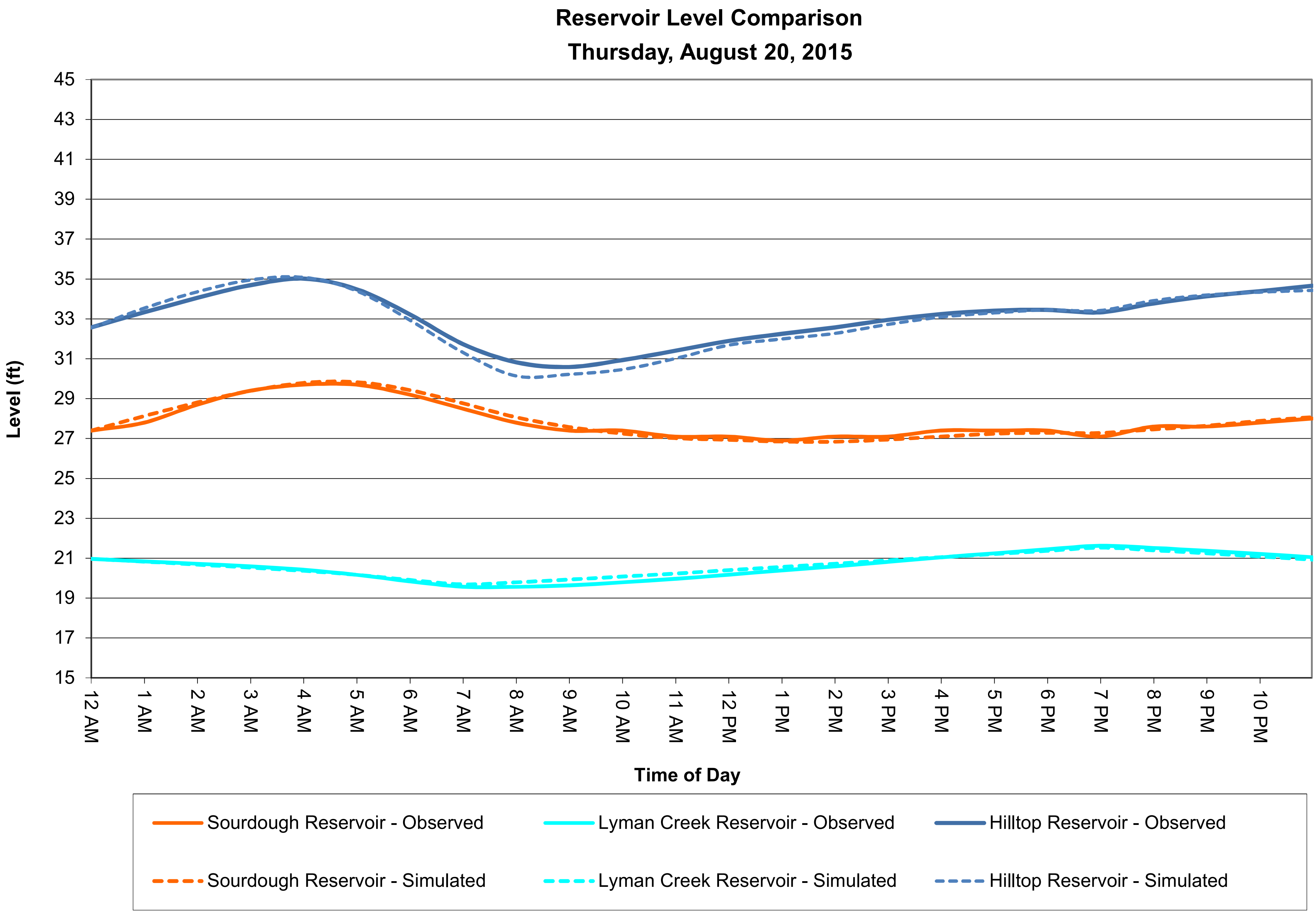
Installed/Removed By: JDH

Extended Pressure Monitoring

Bozeman Water Distribution System Model Calibration

Field Test Data Sheet

Appendix E – EPS Calibration Results

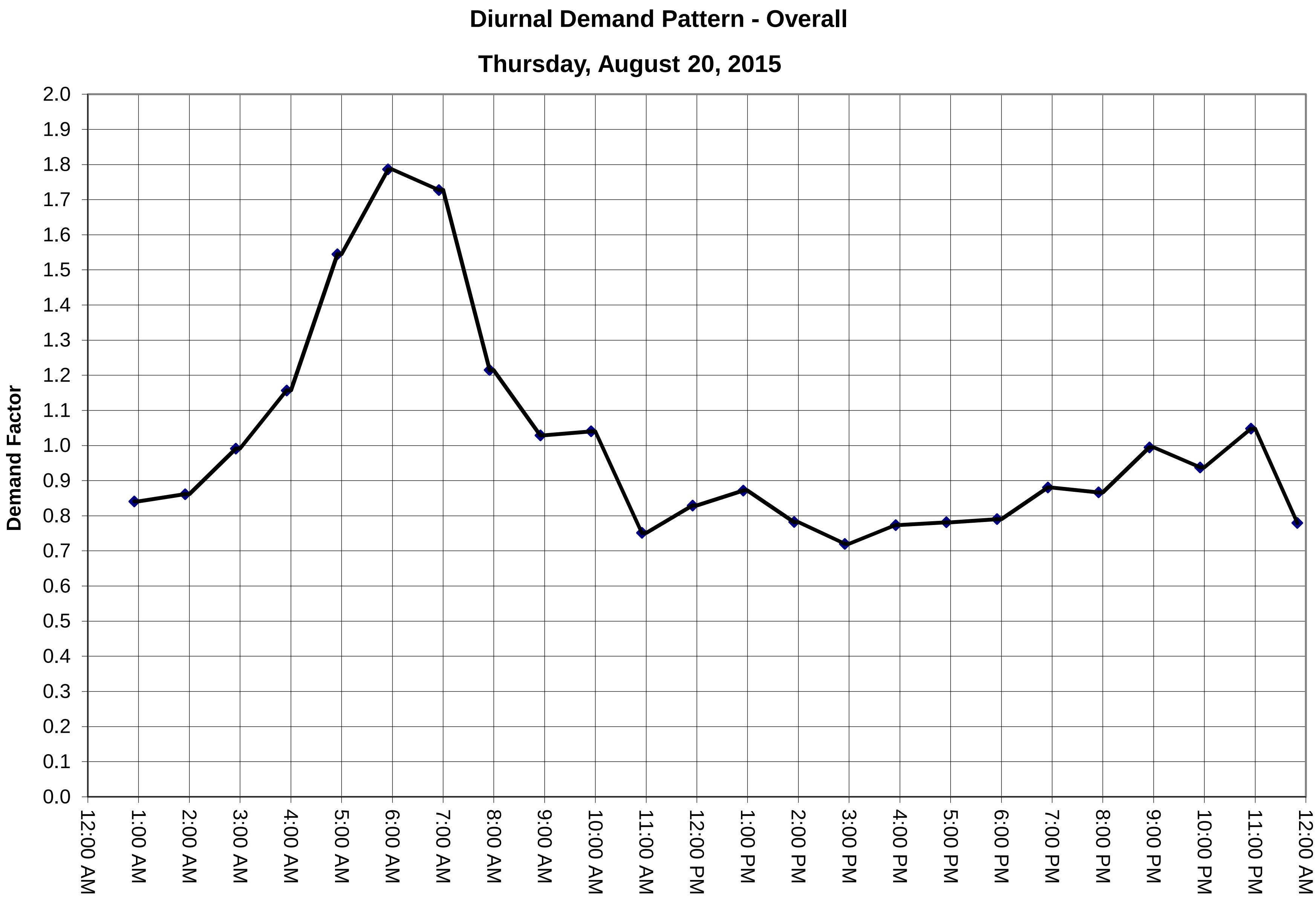


Reservoir Level Comparison
Thursday, August 20, 2015
Level (ft)
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

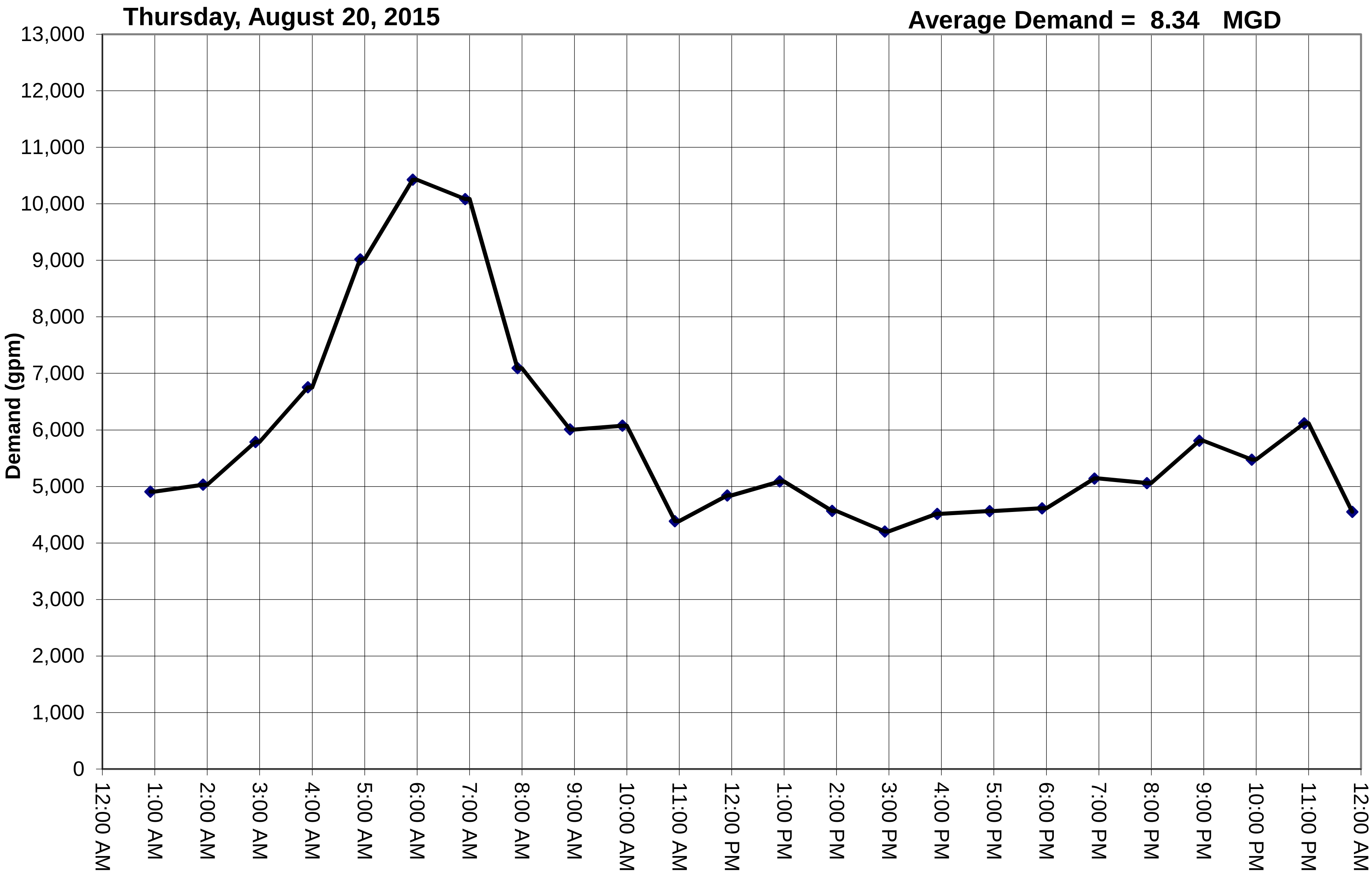
Water Distribution System Hydraulic Model Calibration
City of Bozeman

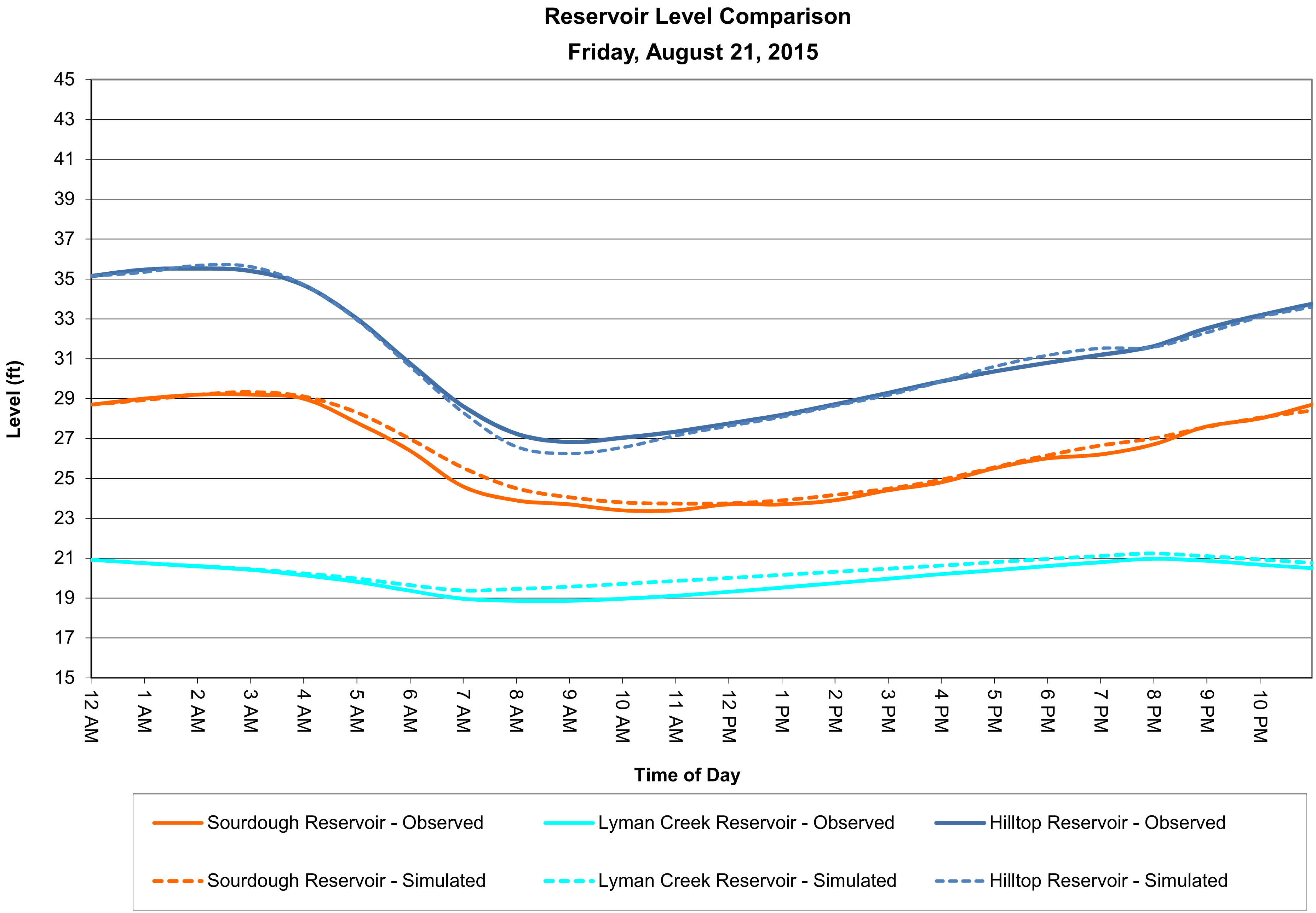
Reservoir Level Calibration
(Tower Level in ft)

Date/Time	Time	Sourdough Reservoir Level			Lyman Reservoir Level			Hilltop Reservoir Level		
		Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
8/20/2015 0:00	0:00	27.40	27.40	0.00	20.97	20.97	0.00	32.58	32.55	0.03
8/20/2015 1:00	1:00	27.80	28.13	-0.33	20.84	20.83	0.01	33.33	33.54	-0.21
8/20/2015 2:00	2:00	28.70	28.81	-0.11	20.72	20.68	0.04	34.06	34.36	-0.30
8/20/2015 3:00	3:00	29.40	29.39	0.01	20.59	20.53	0.06	34.69	34.95	-0.26
8/20/2015 4:00	4:00	29.70	29.79	-0.09	20.42	20.37	0.05	35.02	35.08	-0.06
8/20/2015 5:00	5:00	29.70	29.83	-0.13	20.17	20.17	0.00	34.49	34.40	0.09
8/20/2015 6:00	6:00	29.20	29.43	-0.23	19.84	19.91	-0.07	33.23	32.94	0.29
8/20/2015 7:00	7:00	28.50	28.77	-0.27	19.57	19.69	-0.12	31.74	31.32	0.42
8/20/2015 8:00	8:00	27.80	28.07	-0.27	19.57	19.79	-0.22	30.83	30.14	0.69
8/20/2015 9:00	9:00	27.40	27.58	-0.18	19.64	19.93	-0.29	30.59	30.22	0.37
8/20/2015 10:00	10:00	27.40	27.25	0.15	19.79	20.08	-0.29	30.93	30.46	0.47
8/20/2015 11:00	11:00	27.10	27.02	0.08	19.97	20.23	-0.26	31.40	31.01	0.39
8/20/2015 12:00	12:00	27.10	26.94	0.16	20.17	20.40	-0.23	31.89	31.68	0.21
8/20/2015 13:00	13:00	26.90	26.85	0.05	20.39	20.56	-0.17	32.25	31.99	0.26
8/20/2015 14:00	14:00	27.10	26.84	0.26	20.59	20.72	-0.13	32.57	32.27	0.30
8/20/2015 15:00	15:00	27.10	26.95	0.15	20.82	20.89	-0.07	32.94	32.72	0.22
8/20/2015 16:00	16:00	27.40	27.10	0.30	21.04	21.05	-0.01	33.24	33.09	0.15
8/20/2015 17:00	17:00	27.40	27.24	0.16	21.24	21.21	0.03	33.41	33.30	0.11
8/20/2015 18:00	18:00	27.40	27.29	0.11	21.45	21.37	0.08	33.46	33.45	0.01
8/20/2015 19:00	19:00	27.10	27.28	-0.18	21.62	21.53	0.09	33.33	33.42	-0.09
8/20/2015 20:00	20:00	27.60	27.46	0.14	21.52	21.40	0.12	33.77	33.91	-0.14
8/20/2015 21:00	21:00	27.60	27.64	-0.04	21.37	21.25	0.12	34.13	34.19	-0.06
8/20/2015 22:00	22:00	27.80	27.88	-0.08	21.22	21.09	0.13	34.39	34.34	0.05
8/20/2015 23:00	23:00	28.00	28.07	-0.07	21.05	20.93	0.12	34.66	34.43	0.23


Diurnal Demand Pattern - Overall
Thursday, August 20, 2015
Demand Factor
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

Diurnal Demand Curve - Overall



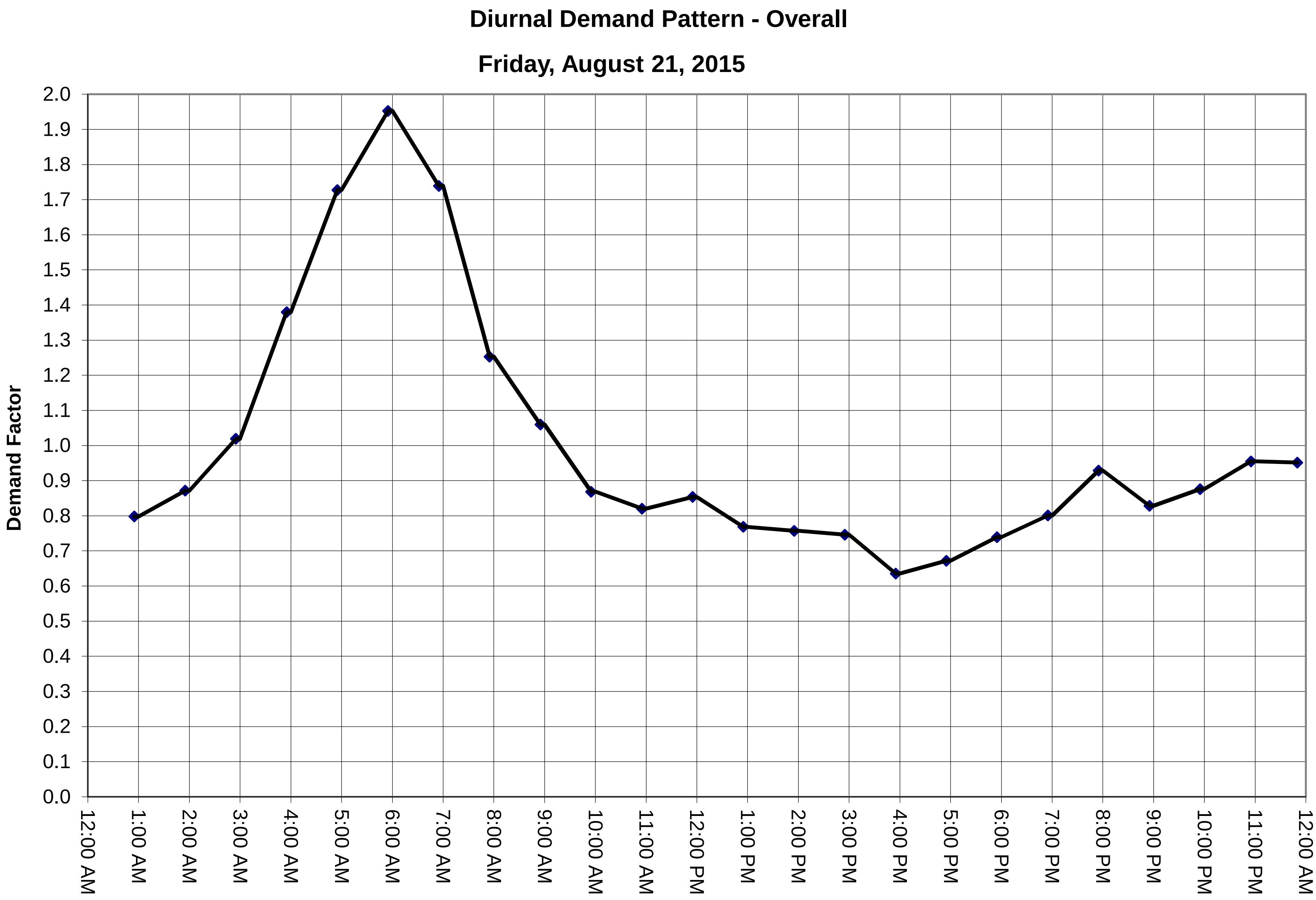


Reservoir Level Comparison
Friday, August 21, 2015
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
Level (ft)
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

Water Distribution System Hydraulic Model Calibration
City of Bozeman

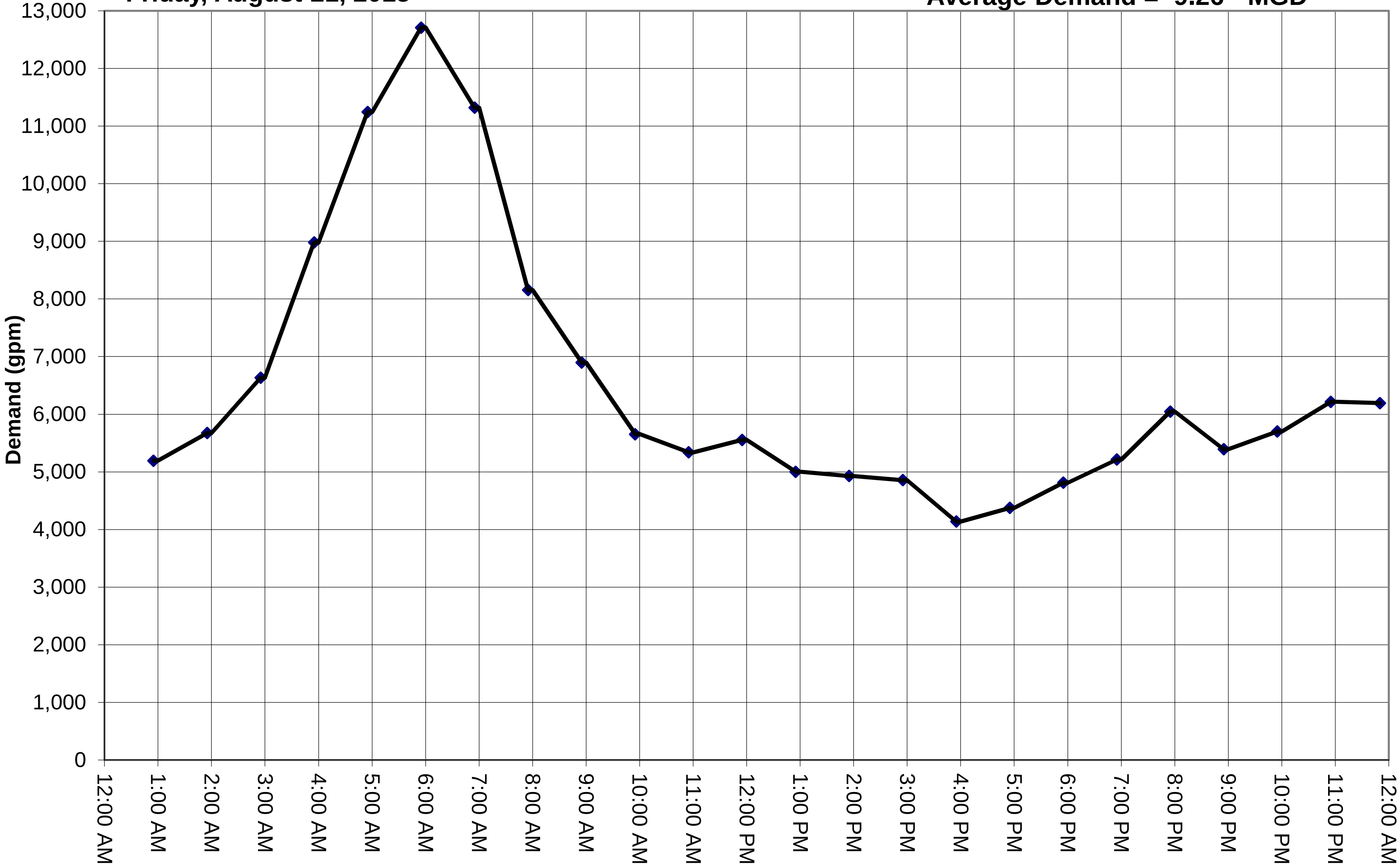
Reservoir Level Calibration
(Tower Level in ft)

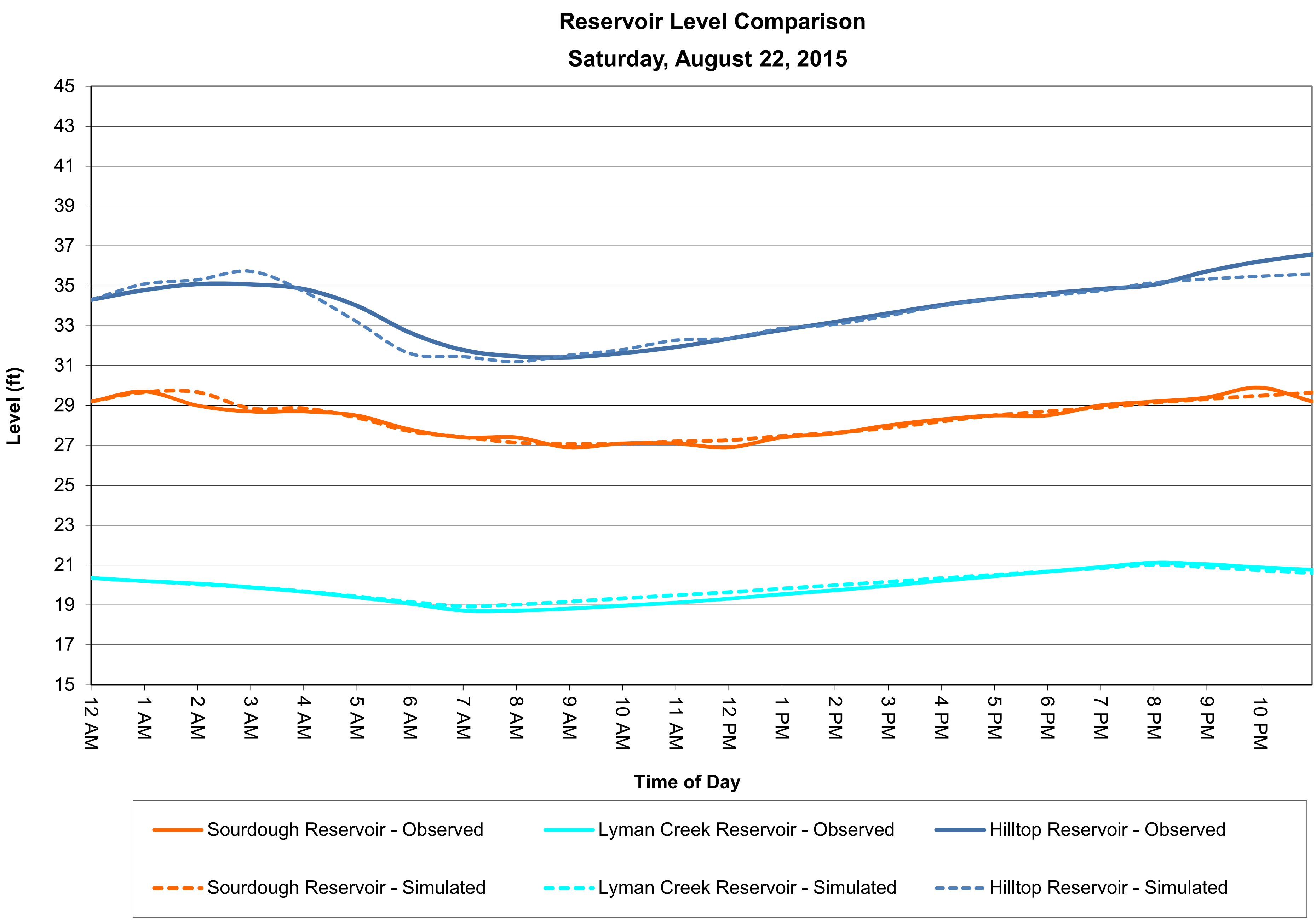
Date/Time	Time	Sourdough Reservoir Level			Lyman Reservoir Level			Hilltop Reservoir Level		
		Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
8/21/2015 0:00	0:00	28.70	28.70	0.00	20.92	20.92	0.00	35.15	35.15	0.00
8/21/2015 1:00	1:00	29.00	28.93	0.07	20.75	20.76	-0.01	35.47	35.34	0.13
8/21/2015 2:00	2:00	29.20	29.20	0.00	20.59	20.61	-0.02	35.53	35.68	-0.15
8/21/2015 3:00	3:00	29.20	29.33	-0.13	20.42	20.45	-0.03	35.41	35.62	-0.21
8/21/2015 4:00	4:00	29.00	29.11	-0.11	20.14	20.24	-0.10	34.69	34.72	-0.03
8/21/2015 5:00	5:00	27.80	28.31	-0.51	19.82	19.98	-0.16	33.02	32.96	0.06
8/21/2015 6:00	6:00	26.40	26.99	-0.59	19.37	19.65	-0.28	30.78	30.63	0.15
8/21/2015 7:00	7:00	24.60	25.54	-0.94	18.97	19.38	-0.41	28.63	28.32	0.31
8/21/2015 8:00	8:00	23.90	24.51	-0.61	18.87	19.46	-0.59	27.25	26.60	0.65
8/21/2015 9:00	9:00	23.70	24.06	-0.36	18.87	19.57	-0.70	26.82	26.25	0.57
8/21/2015 10:00	10:00	23.40	23.80	-0.40	18.97	19.71	-0.74	27.04	26.55	0.49
8/21/2015 11:00	11:00	23.40	23.74	-0.34	19.12	19.86	-0.74	27.34	27.14	0.20
8/21/2015 12:00	12:00	23.70	23.75	-0.05	19.32	20.01	-0.69	27.75	27.62	0.13
8/21/2015 13:00	13:00	23.70	23.90	-0.20	19.52	20.16	-0.64	28.18	28.08	0.10
8/21/2015 14:00	14:00	23.90	24.17	-0.27	19.75	20.32	-0.57	28.71	28.64	0.07
8/21/2015 15:00	15:00	24.40	24.48	-0.08	19.97	20.47	-0.50	29.28	29.17	0.11
8/21/2015 16:00	16:00	24.80	24.93	-0.13	20.20	20.63	-0.43	29.86	29.85	0.01
8/21/2015 17:00	17:00	25.50	25.55	-0.05	20.40	20.80	-0.40	30.36	30.60	-0.24
8/21/2015 18:00	18:00	26.00	26.15	-0.15	20.60	20.96	-0.36	30.79	31.17	-0.38
8/21/2015 19:00	19:00	26.20	26.65	-0.45	20.80	21.11	-0.31	31.19	31.52	-0.33
8/21/2015 20:00	20:00	26.70	27.01	-0.31	20.97	21.24	-0.27	31.62	31.58	0.04
8/21/2015 21:00	21:00	27.60	27.57	0.03	20.87	21.10	-0.23	32.51	32.30	0.21
8/21/2015 22:00	22:00	28.00	28.04	-0.04	20.68	20.94	-0.26	33.17	33.08	0.09
8/21/2015 23:00	23:00	28.70	28.41	0.29	20.50	20.76	-0.26	33.75	33.60	0.15


Diurnal Demand Pattern - Overall
Friday, August 21, 2015
Demand Factor
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

Diurnal Demand Curve - Overall

Friday, August 21, 2015 **Average Demand = 9.26 MGD**



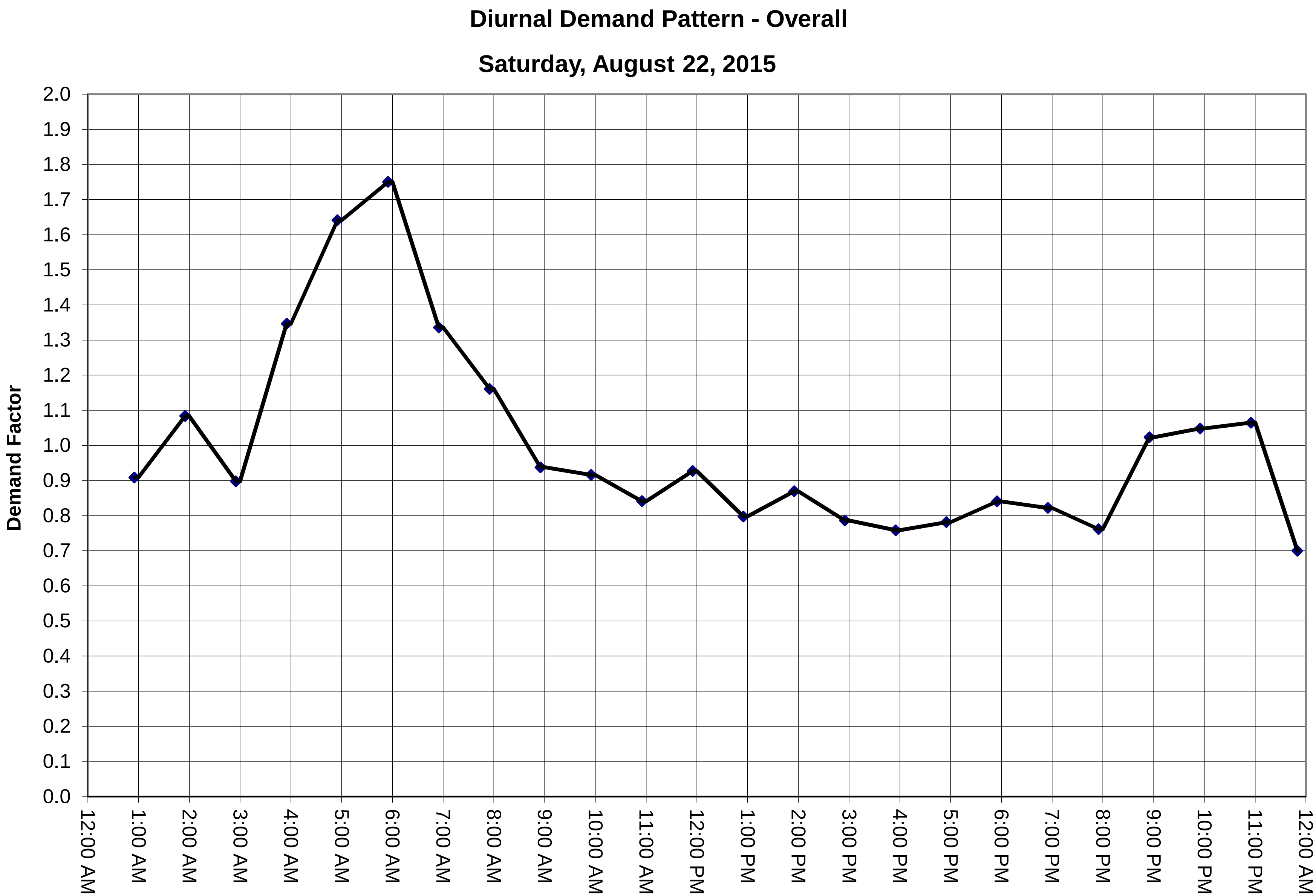


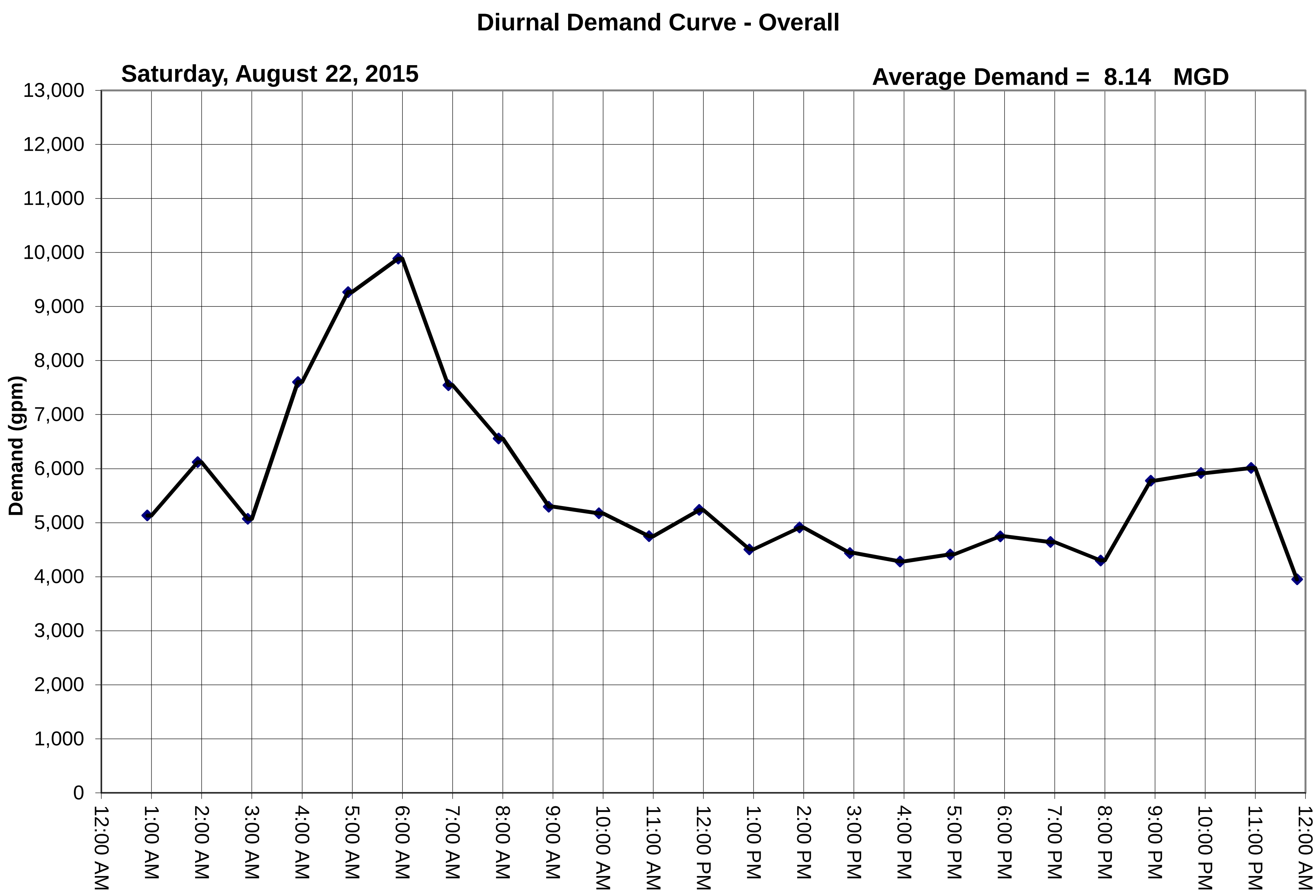
Reservoir Level Comparison
Saturday, August 22, 2015
Level (ft)
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Reservoir Level Calibration
(Tower Level in ft)

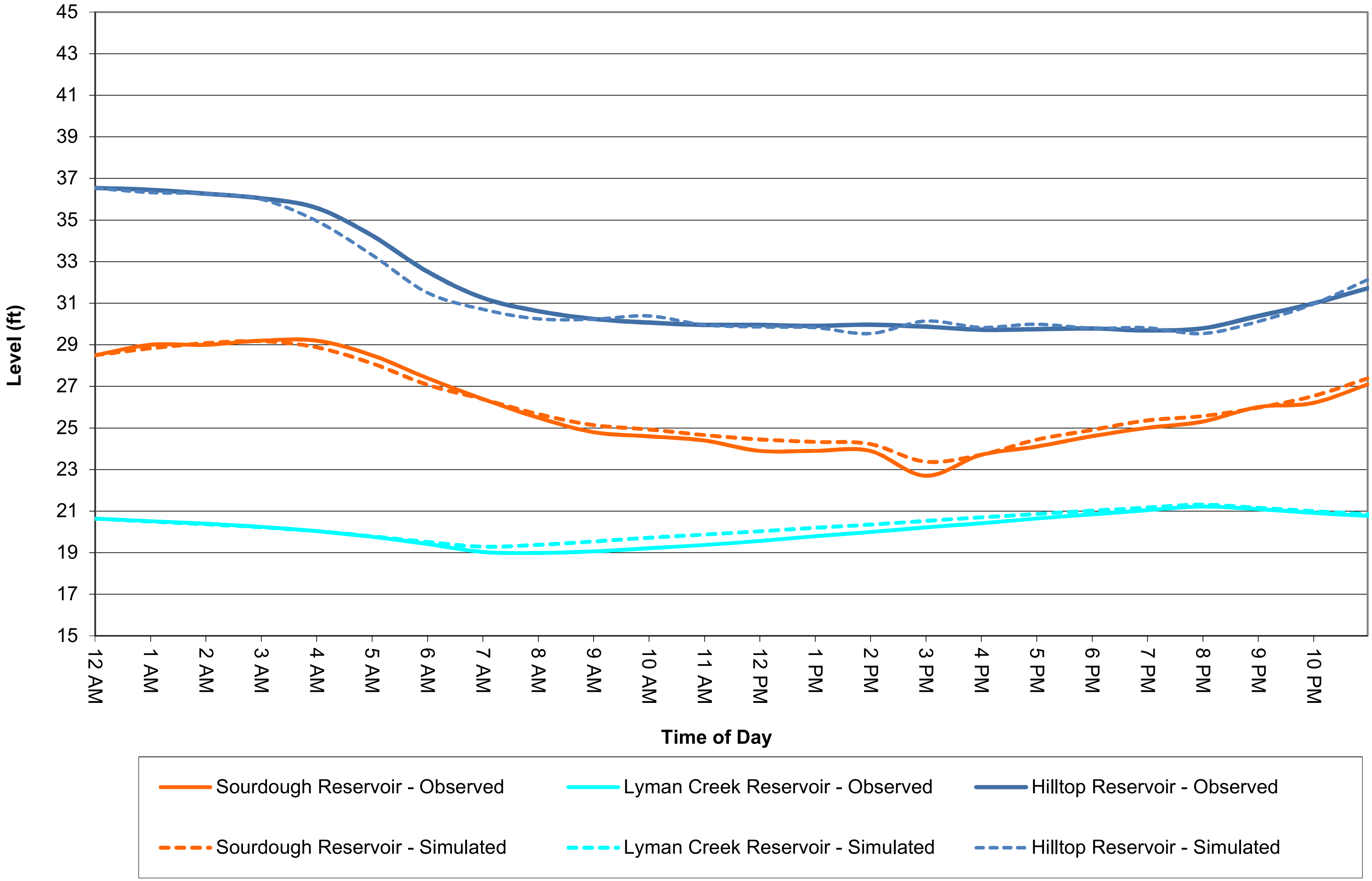
Date/Time	Time	Sourdough Reservoir Level			Lyman Reservoir Level			Hilltop Reservoir Level		
		Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
8/22/2015 0:00	0:00	29.20	29.20	0.00	20.35	20.35	0.00	34.30	34.30	0.00
8/22/2015 1:00	1:00	29.70	29.67	0.03	20.20	20.20	0.00	34.79	35.09	-0.30
8/22/2015 2:00	2:00	29.00	29.67	-0.67	20.07	20.04	0.03	35.08	35.30	-0.22
8/22/2015 3:00	3:00	28.70	28.86	-0.16	19.89	19.89	0.00	35.07	35.73	-0.66
8/22/2015 4:00	4:00	28.70	28.86	-0.16	19.67	19.69	-0.02	34.84	34.72	0.12
8/22/2015 5:00	5:00	28.50	28.40	0.10	19.39	19.43	-0.04	34.00	33.20	0.80
8/22/2015 6:00	6:00	27.80	27.71	0.09	19.07	19.16	-0.09	32.66	31.61	1.05
8/22/2015 7:00	7:00	27.40	27.42	-0.02	18.72	18.94	-0.22	31.78	31.45	0.33
8/22/2015 8:00	8:00	27.40	27.14	0.26	18.72	19.02	-0.30	31.46	31.20	0.26
8/22/2015 9:00	9:00	26.90	27.08	-0.18	18.82	19.17	-0.35	31.42	31.52	-0.10
8/22/2015 10:00	10:00	27.10	27.08	0.02	18.96	19.33	-0.37	31.62	31.80	-0.18
8/22/2015 11:00	11:00	27.10	27.20	-0.10	19.12	19.49	-0.37	31.92	32.27	-0.35
8/22/2015 12:00	12:00	26.90	27.26	-0.36	19.32	19.64	-0.32	32.35	32.37	-0.02
8/22/2015 13:00	13:00	27.40	27.47	-0.07	19.54	19.82	-0.28	32.78	32.86	-0.08
8/22/2015 14:00	14:00	27.60	27.63	-0.03	19.74	19.99	-0.25	33.18	33.06	0.12
8/22/2015 15:00	15:00	28.00	27.88	0.12	19.96	20.16	-0.20	33.61	33.50	0.11
8/22/2015 16:00	16:00	28.30	28.20	0.10	20.22	20.34	-0.12	34.03	33.98	0.05
8/22/2015 17:00	17:00	28.50	28.50	0.00	20.44	20.51	-0.07	34.35	34.36	-0.01
8/22/2015 18:00	18:00	28.50	28.71	-0.21	20.67	20.68	-0.01	34.62	34.52	0.10
8/22/2015 19:00	19:00	29.00	28.89	0.11	20.90	20.85	0.05	34.84	34.75	0.09
8/22/2015 20:00	20:00	29.20	29.14	0.06	21.12	21.02	0.10	35.05	35.15	-0.10
8/22/2015 21:00	21:00	29.40	29.32	0.08	21.04	20.90	0.14	35.71	35.34	0.37
8/22/2015 22:00	22:00	29.90	29.49	0.41	20.89	20.75	0.14	36.22	35.48	0.74
8/22/2015 23:00	23:00	29.20	29.65	-0.45	20.77	20.60	0.17	36.58	35.59	0.99


Diurnal Demand Pattern - Overall
Saturday, August 22, 2015
Demand Factor
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM



Diurnal Demand Curve - Overall
Saturday, August 22, 2015
Average Demand = 8.14 MGD
Demand (gpm)
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

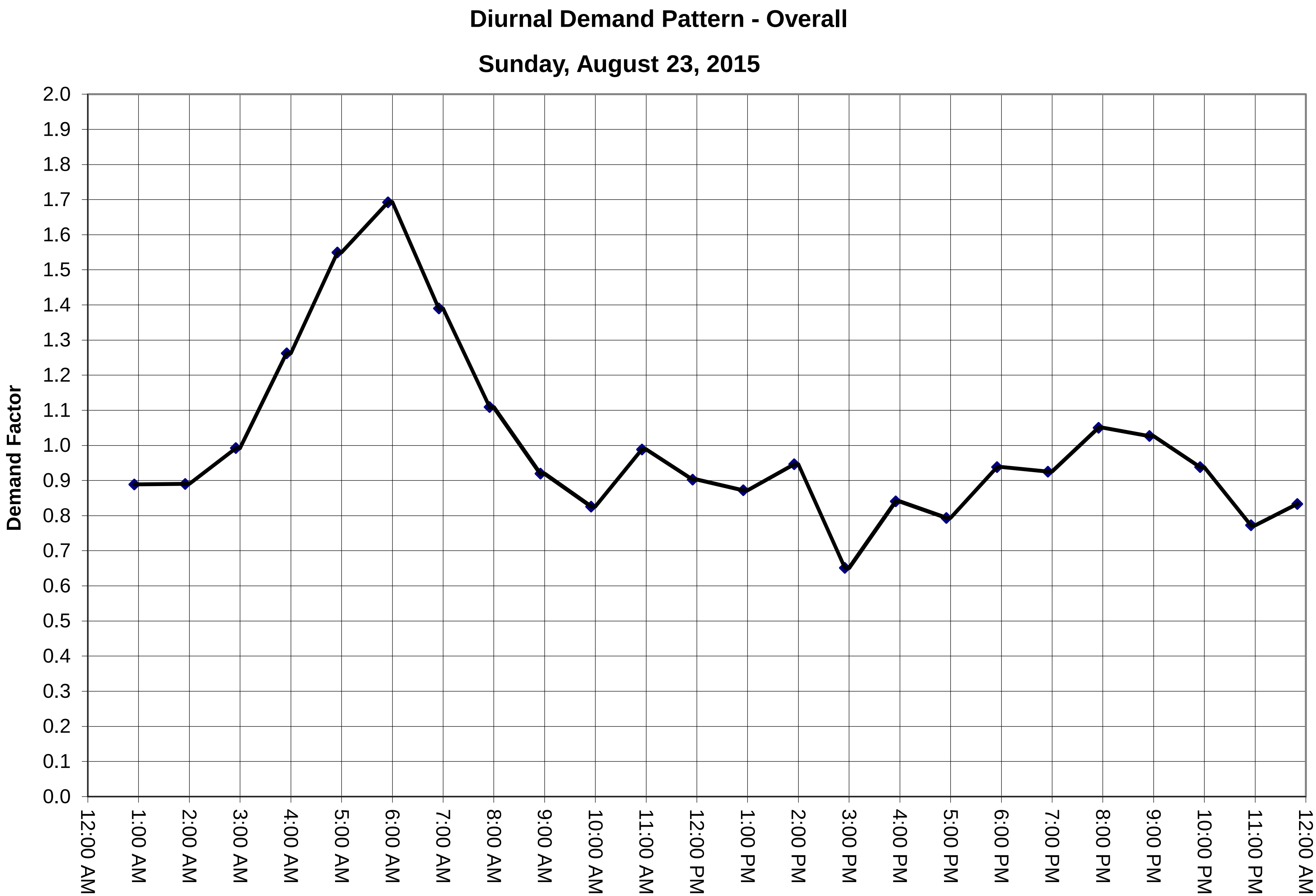
Reservoir Level Comparison
Sunday, August 23, 2015



Water Distribution System Hydraulic Model Calibration
City of Bozeman

Reservoir Level Calibration
(Tower Level in ft)

Date/Time	Time	Sourdough Reservoir Level			Lyman Reservoir Level			Hilltop Reservoir Level		
		Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
8/23/2015 0:00	0:00	28.50	28.50	0.00	20.64	20.64	0.00	36.54	36.54	0.00
8/23/2015 1:00	1:00	29.00	28.83	0.17	20.52	20.50	0.02	36.45	36.32	0.13
8/23/2015 2:00	2:00	29.00	29.08	-0.08	20.40	20.37	0.03	36.27	36.27	0.00
8/23/2015 3:00	3:00	29.20	29.17	0.03	20.25	20.22	0.03	36.05	36.00	0.05
8/23/2015 4:00	4:00	29.20	28.88	0.32	20.04	20.04	0.00	35.59	34.96	0.63
8/23/2015 5:00	5:00	28.50	28.11	0.39	19.77	19.79	-0.02	34.26	33.33	0.93
8/23/2015 6:00	6:00	27.40	27.08	0.32	19.42	19.52	-0.10	32.53	31.51	1.02
8/23/2015 7:00	7:00	26.40	26.39	0.01	19.04	19.29	-0.25	31.26	30.71	0.55
8/23/2015 8:00	8:00	25.50	25.67	-0.17	18.99	19.38	-0.39	30.62	30.25	0.37
8/23/2015 9:00	9:00	24.80	25.14	-0.34	19.06	19.54	-0.48	30.25	30.23	0.02
8/23/2015 10:00	10:00	24.60	24.93	-0.33	19.21	19.72	-0.51	30.07	30.39	-0.32
8/23/2015 11:00	11:00	24.40	24.66	-0.26	19.37	19.87	-0.50	29.96	29.96	0.00
8/23/2015 12:00	12:00	23.90	24.45	-0.55	19.56	20.03	-0.47	29.95	29.86	0.09
8/23/2015 13:00	13:00	23.90	24.33	-0.43	19.79	20.20	-0.41	29.91	29.83	0.08
8/23/2015 14:00	14:00	23.90	24.23	-0.33	19.99	20.35	-0.36	29.97	29.54	0.43
8/23/2015 15:00	15:00	22.70	23.38	-0.68	20.22	20.53	-0.31	29.87	30.14	-0.27
8/23/2015 16:00	16:00	23.70	23.71	-0.01	20.42	20.70	-0.28	29.73	29.84	-0.11
8/23/2015 17:00	17:00	24.10	24.43	-0.33	20.64	20.86	-0.22	29.75	29.99	-0.24
8/23/2015 18:00	18:00	24.60	24.90	-0.30	20.84	21.02	-0.18	29.79	29.80	-0.01
8/23/2015 19:00	19:00	25.00	25.36	-0.36	21.04	21.17	-0.13	29.69	29.82	-0.13
8/23/2015 20:00	20:00	25.30	25.57	-0.27	21.22	21.31	-0.09	29.79	29.54	0.25
8/23/2015 21:00	21:00	26.00	25.97	0.03	21.09	21.16	-0.07	30.37	30.11	0.26
8/23/2015 22:00	22:00	26.20	26.53	-0.33	20.92	21.00	-0.08	30.98	30.95	0.03
8/23/2015 23:00	23:00	27.10	27.39	-0.29	20.77	20.86	-0.09	31.72	32.14	-0.42



Diurnal Demand Pattern - Overall
Sunday, August 23, 2015
Demand Factor
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
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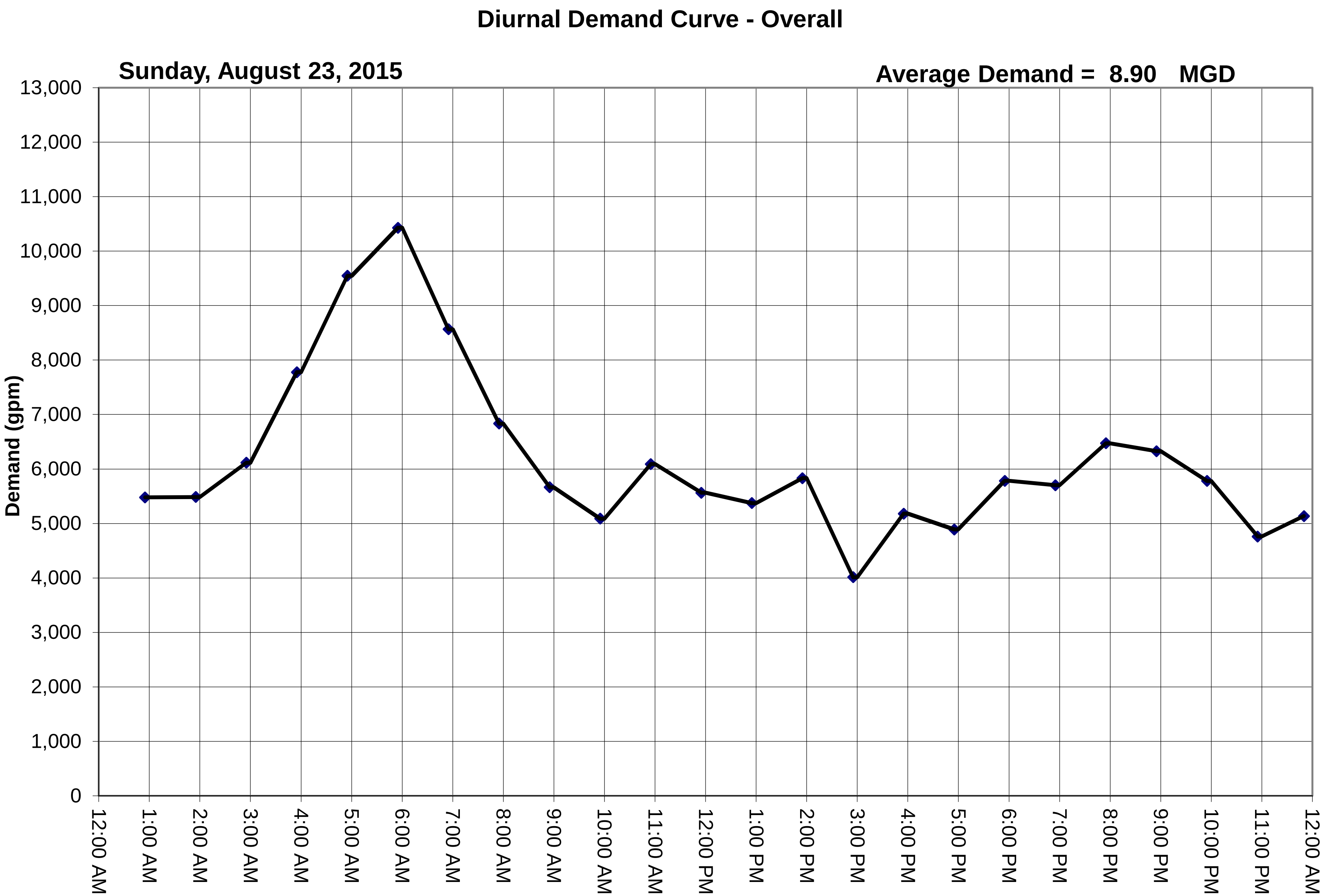
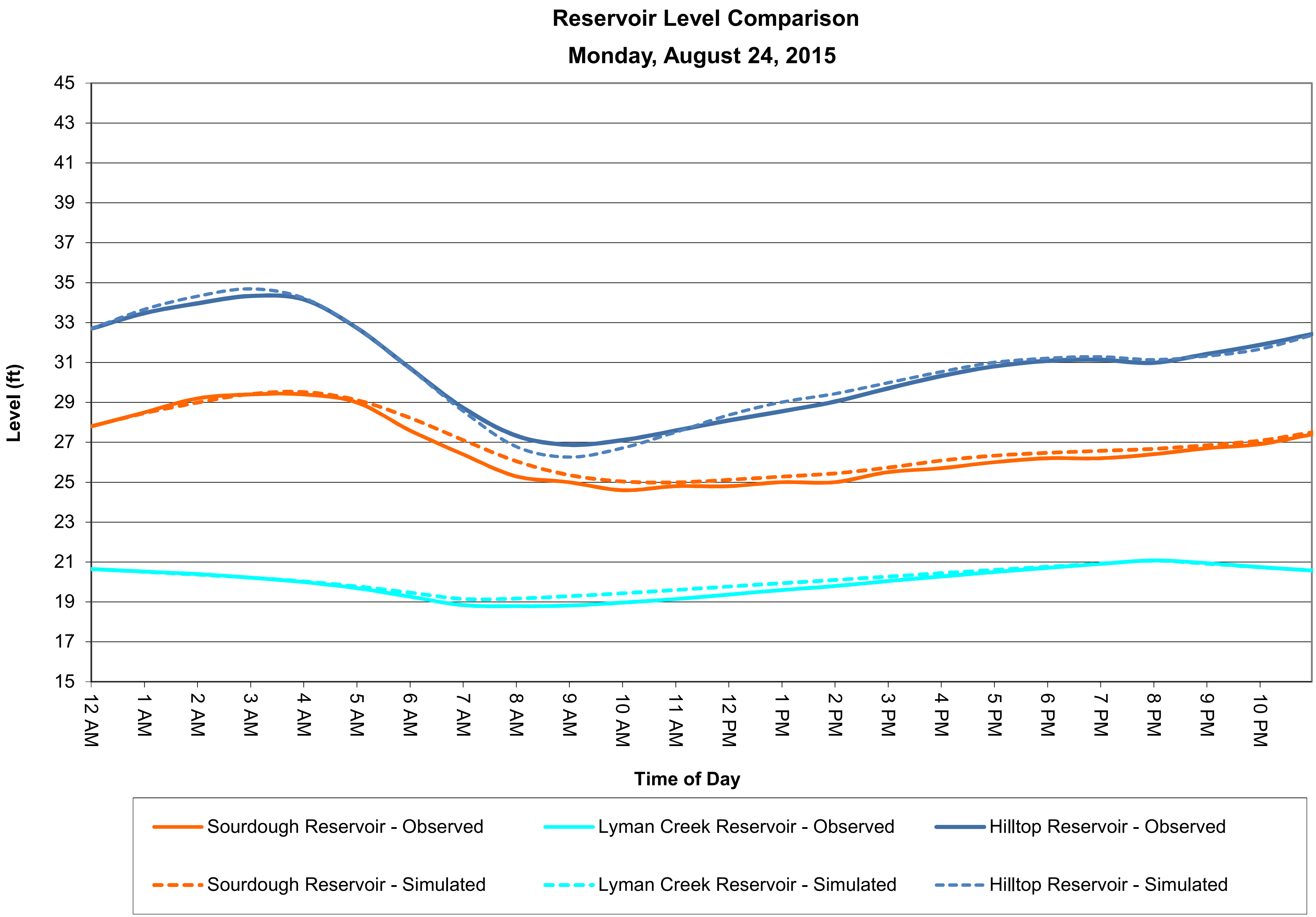
11:00 PM
12:00 AM


Diurnal Demand Curve - Overall
Sunday, August 23, 2015
Average Demand = 8.90 MGD
Demand (gpm)
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

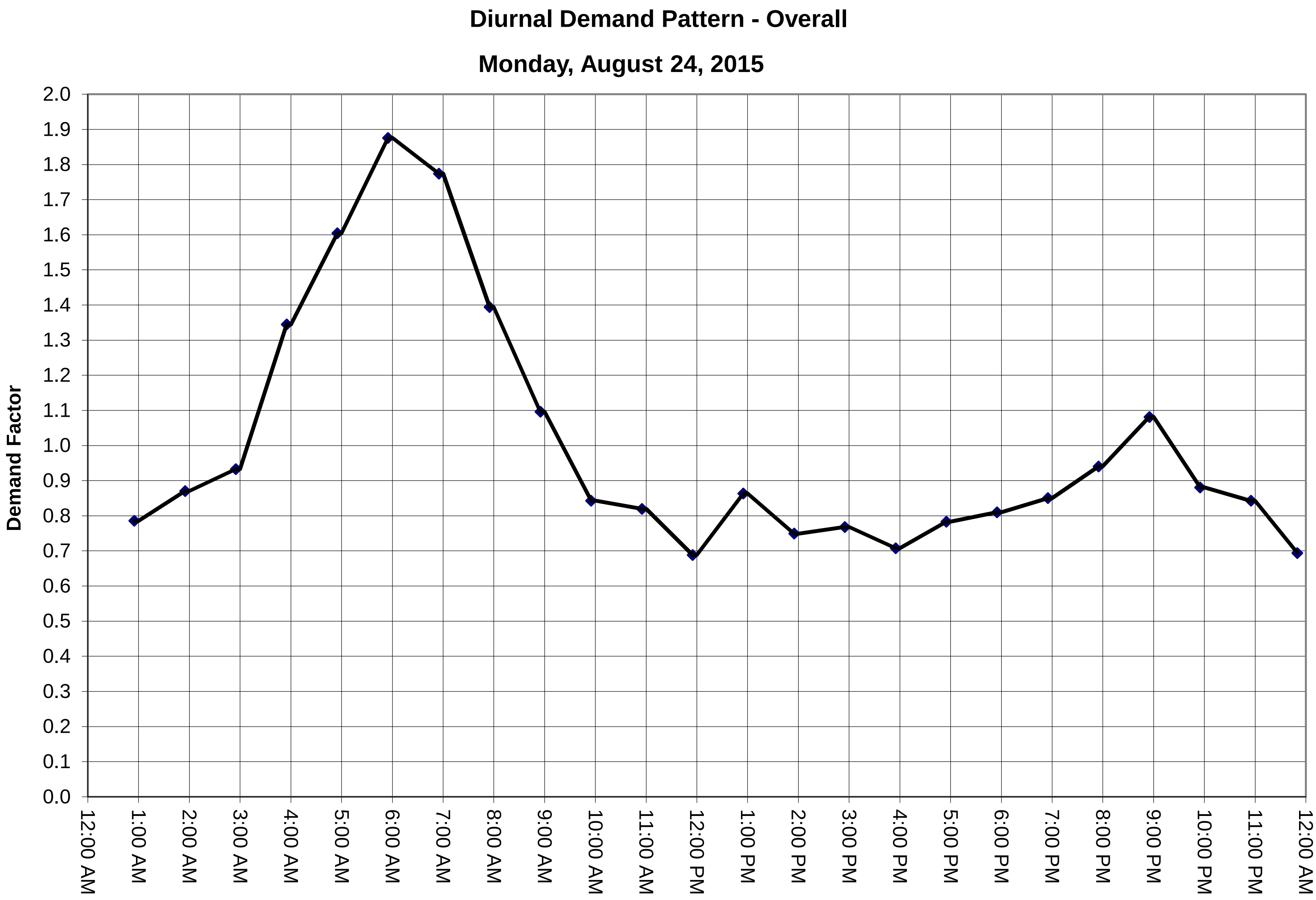


Reservoir Level Comparison
Monday, August 24, 2015
Level (ft)
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Reservoir Level Calibration
(Tower Level in ft)

Date/Time	Time	Sourdough Reservoir Level Observed	Sourdough Reservoir Level Simulated	Sourdough Reservoir Level Difference	Lyman Reservoir Level Observed	Lyman Reservoir Level Simulated	Lyman Reservoir Level Difference	Hilltop Reservoir Level Observed	Hilltop Reservoir Level Simulated	Hilltop Reservoir Level Difference
8/24/2015 0:00	0:00	27.80	27.80	0.00	20.65	20.65	0.00	32.69	32.69	0.00
8/24/2015 1:00	1:00	28.50	28.46	0.04	20.52	20.51	0.01	33.47	33.66	-0.19
8/24/2015 2:00	2:00	29.20	28.99	0.21	20.40	20.37	0.03	33.96	34.32	-0.36
8/24/2015 3:00	3:00	29.40	29.42	-0.02	20.22	20.22	0.00	34.33	34.69	-0.36
8/24/2015 4:00	4:00	29.40	29.52	-0.12	19.99	20.03	-0.04	34.16	34.23	-0.07
8/24/2015 5:00	5:00	29.00	29.12	-0.12	19.69	19.78	-0.09	32.74	32.75	-0.01
8/24/2015 6:00	6:00	27.60	28.23	-0.63	19.27	19.47	-0.20	30.72	30.70	0.02
8/24/2015 7:00	7:00	26.40	27.12	-0.72	18.84	19.15	-0.31	28.74	28.57	0.17
8/24/2015 8:00	8:00	25.30	26.06	-0.76	18.79	19.17	-0.38	27.34	26.79	0.55
8/24/2015 9:00	9:00	25.00	25.36	-0.36	18.82	19.29	-0.47	26.88	26.26	0.61
8/24/2015 10:00	10:00	24.60	25.04	-0.44	18.96	19.43	-0.47	27.10	26.71	0.39
8/24/2015 11:00	11:00	24.80	24.99	-0.19	19.14	19.60	-0.46	27.58	27.50	0.08
8/24/2015 12:00	12:00	24.80	25.12	-0.32	19.37	19.77	-0.40	28.09	28.36	-0.27
8/24/2015 13:00	13:00	25.00	25.28	-0.28	19.59	19.94	-0.35	28.55	29.01	-0.46
8/24/2015 14:00	14:00	25.00	25.44	-0.44	19.79	20.10	-0.31	29.04	29.43	-0.39
8/24/2015 15:00	15:00	25.50	25.73	-0.23	20.04	20.27	-0.23	29.70	29.98	-0.28
8/24/2015 16:00	16:00	25.70	26.08	-0.38	20.27	20.44	-0.17	30.32	30.53	-0.21
8/24/2015 17:00	17:00	26.00	26.33	-0.33	20.50	20.60	-0.10	30.80	31.00	-0.20
8/24/2015 18:00	18:00	26.20	26.47	-0.27	20.70	20.76	-0.06	31.08	31.21	-0.13
8/24/2015 19:00	19:00	26.20	26.57	-0.37	20.90	20.92	-0.02	31.14	31.29	-0.15
8/24/2015 20:00	20:00	26.40	26.67	-0.27	21.08	21.07	0.01	30.98	31.14	-0.16
8/24/2015 21:00	21:00	26.70	26.85	-0.15	20.95	20.92	0.03	31.42	31.32	0.10
8/24/2015 22:00	22:00	26.90	27.08	-0.18	20.75	20.74	0.01	31.87	31.66	0.21
8/24/2015 23:00	23:00	27.40	27.50	-0.10	20.57	20.58	-0.01	32.43	32.37	0.06


Diurnal Demand Pattern - Overall
Monday, August 24, 2015
Demand Factor
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
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10:00 AM
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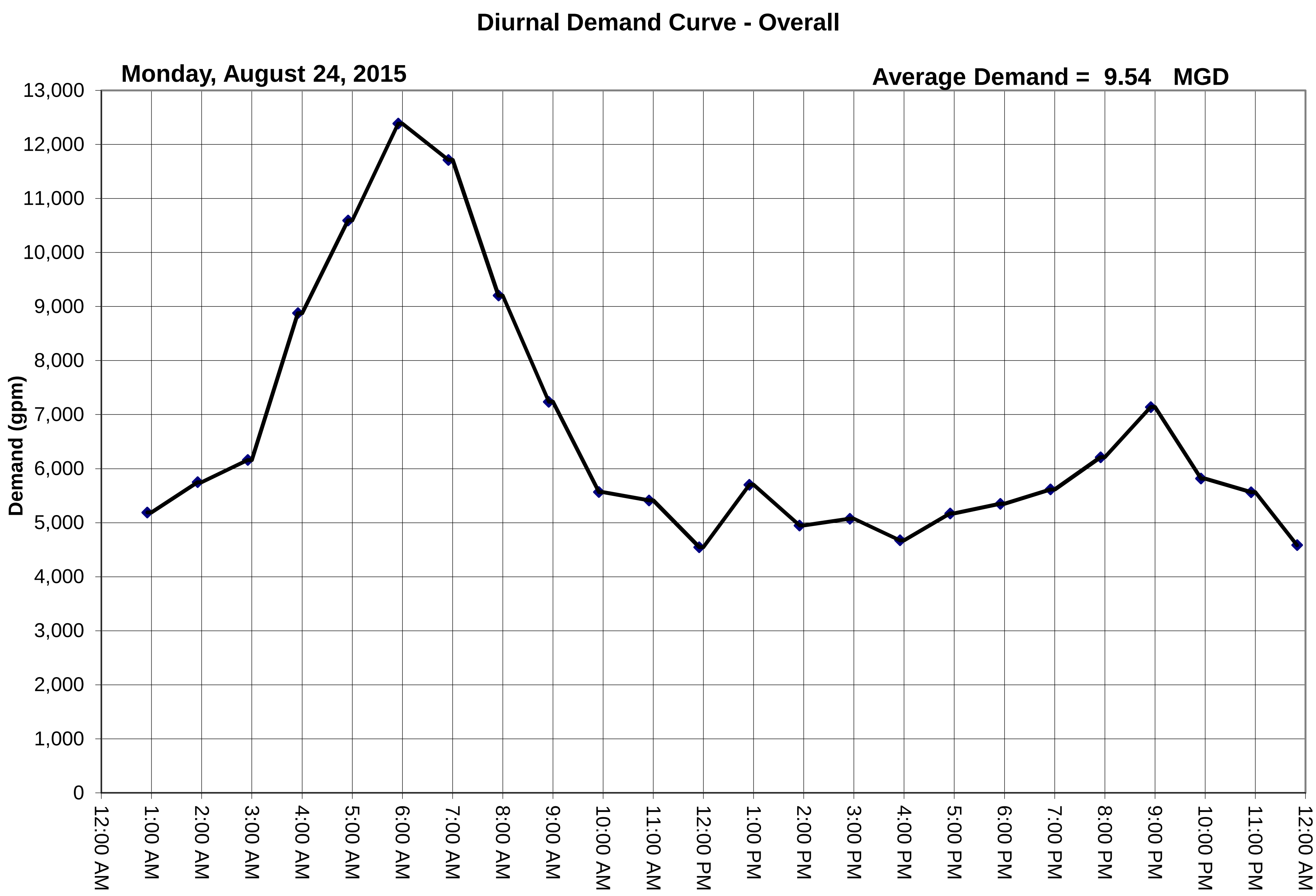
11:00 PM
12:00 AM



Diurnal Demand Curve - Overall
Monday, August 24, 2015
Average Demand = 9.54 MGD
Demand (gpm)
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
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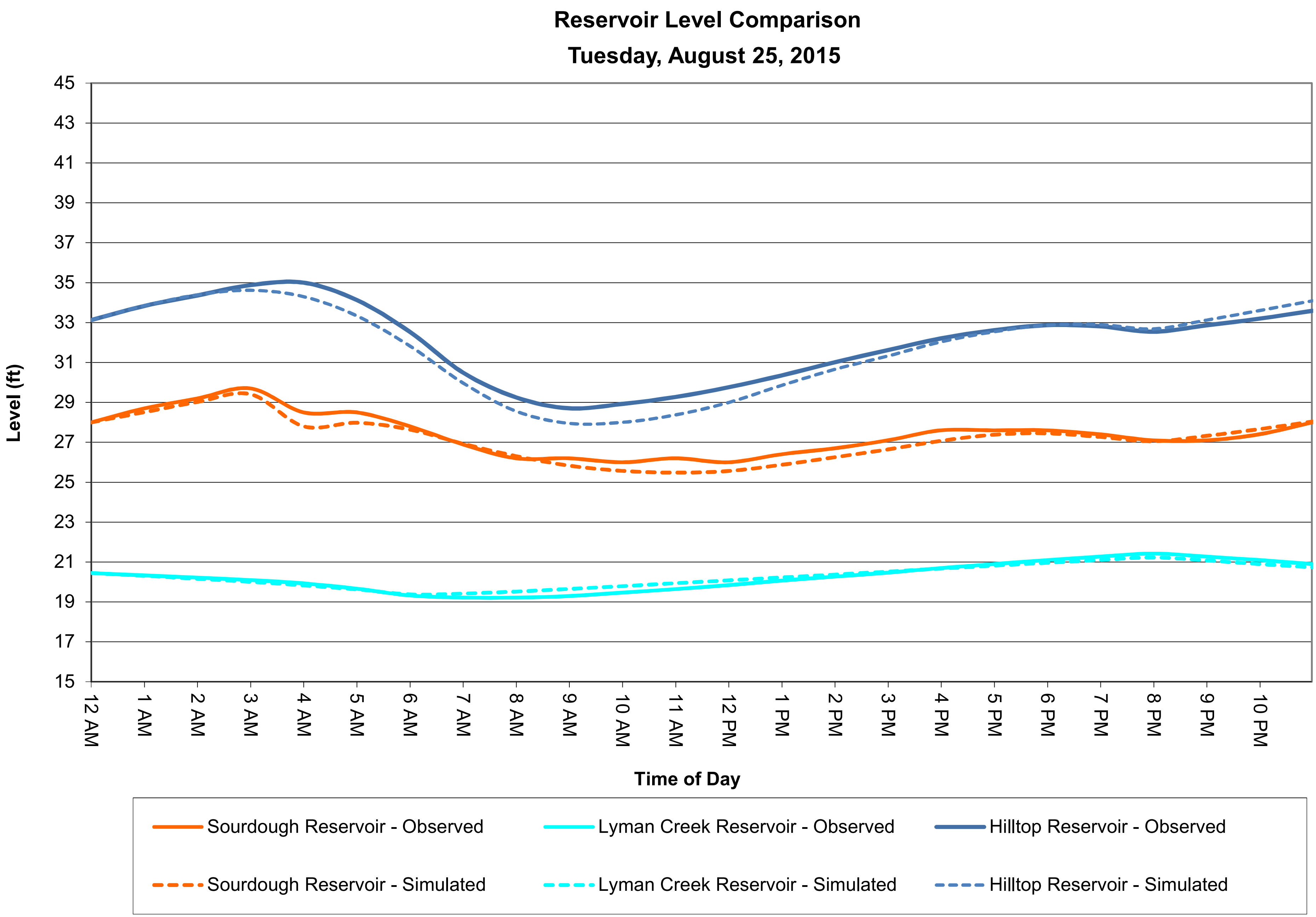
11:00 PM
12:00 AM



Reservoir Level Comparison
Tuesday, August 25, 2015
Level (ft)
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

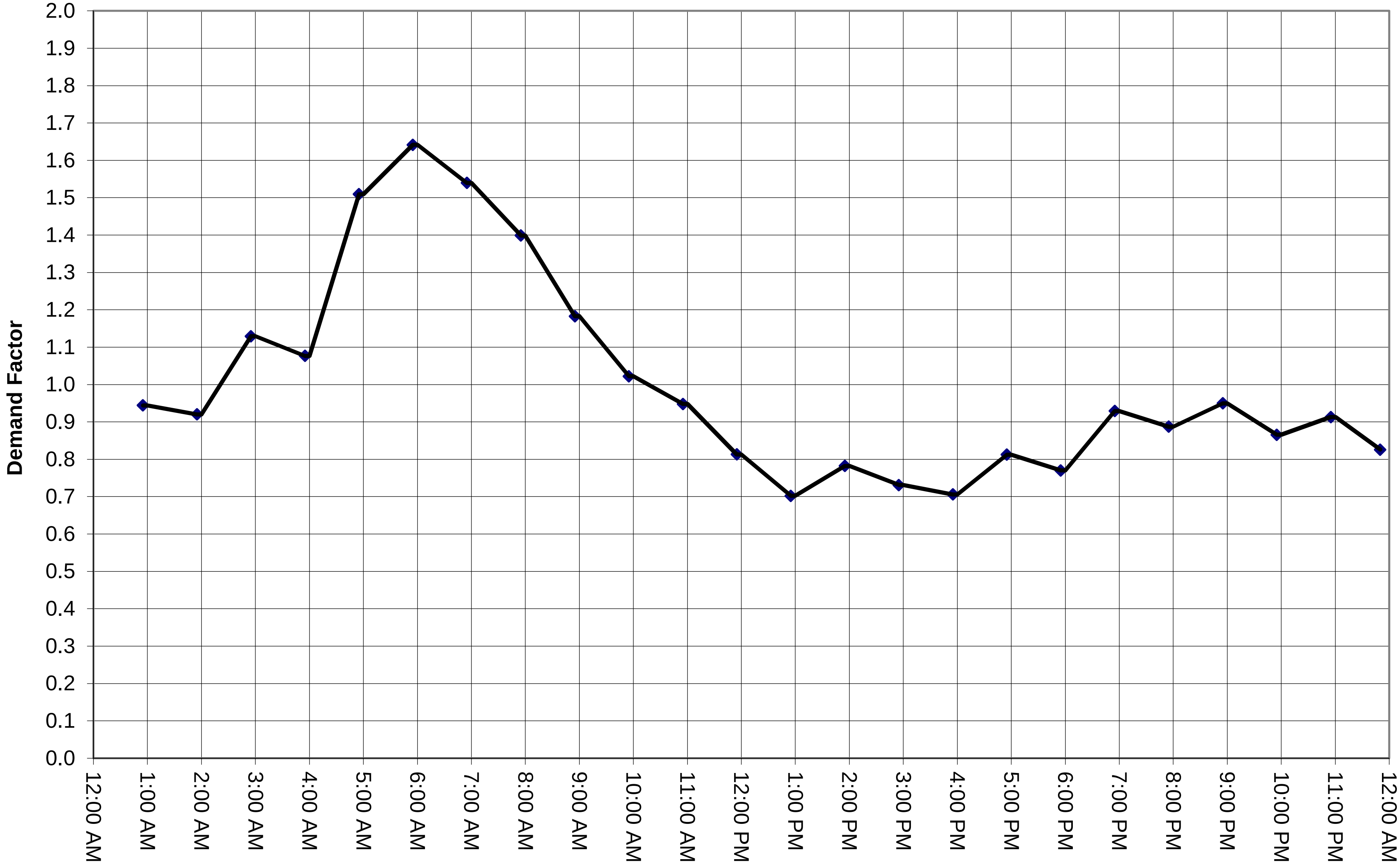
Water Distribution System Hydraulic Model Calibration
City of Bozeman

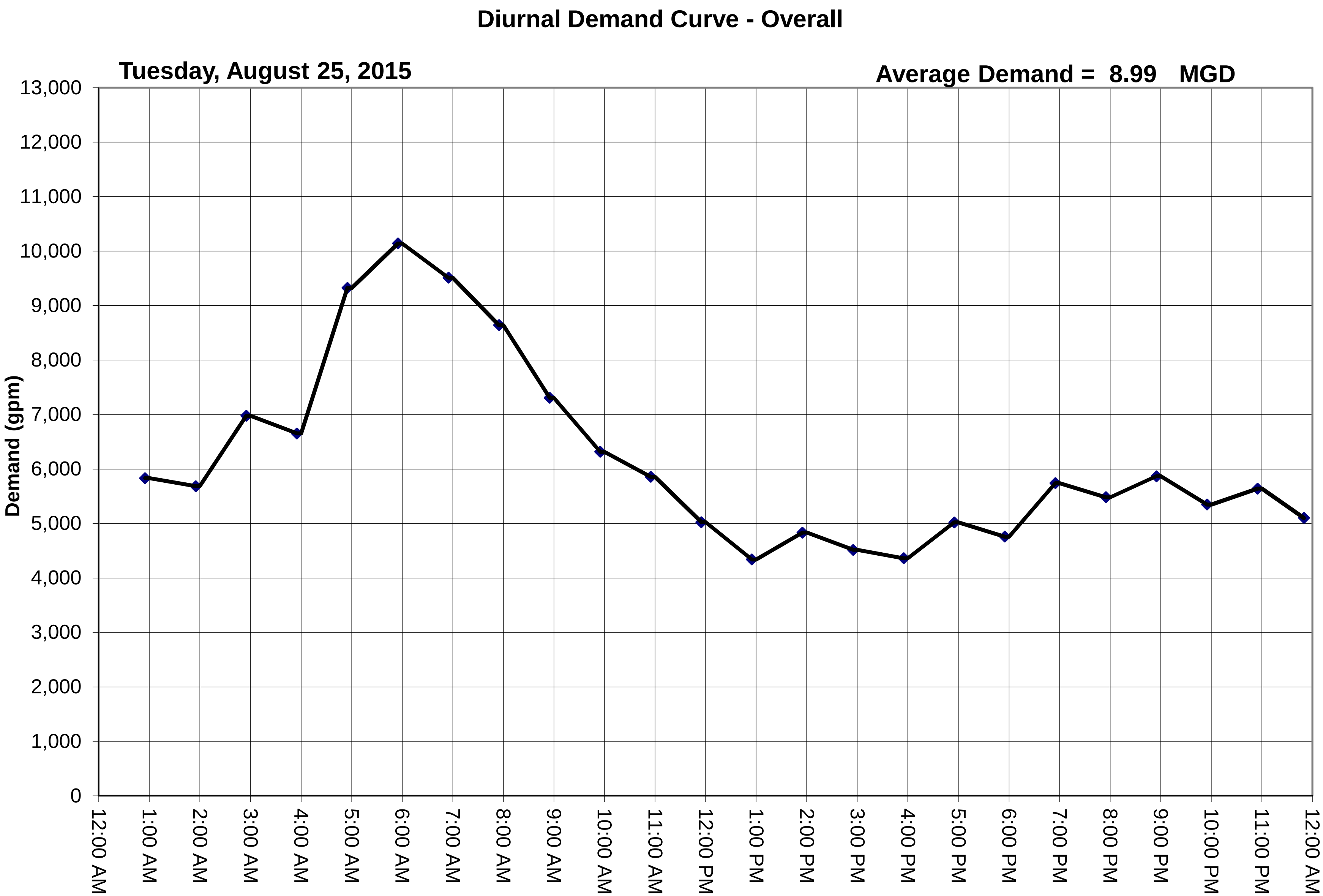
Reservoir Level Calibration
(Tower Level in ft)

Date/Time	Time	Sourdough Reservoir Level			Lyman Reservoir Level			Hilltop Reservoir Level		
		Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
8/25/2015 0:00	0:00	28.00	28.00	0.00	20.45	20.45	0.00	33.13	33.13	0.00
8/25/2015 1:00	1:00	28.70	28.51	0.19	20.33	20.31	0.02	33.83	33.85	-0.02
8/25/2015 2:00	2:00	29.20	29.02	0.18	20.22	20.16	0.06	34.36	34.39	-0.03
8/25/2015 3:00	3:00	29.70	29.41	0.29	20.10	20.01	0.09	34.88	34.62	0.26
8/25/2015 4:00	4:00	28.50	27.80	0.70	19.93	19.83	0.10	35.00	34.30	0.70
8/25/2015 5:00	5:00	28.50	27.98	0.52	19.67	19.63	0.04	34.13	33.34	0.79
8/25/2015 6:00	6:00	27.80	27.64	0.16	19.32	19.38	-0.06	32.54	31.83	0.71
8/25/2015 7:00	7:00	26.90	26.93	-0.03	19.22	19.42	-0.20	30.50	29.98	0.52
8/25/2015 8:00	8:00	26.20	26.31	-0.11	19.22	19.52	-0.30	29.25	28.56	0.69
8/25/2015 9:00	9:00	26.20	25.83	0.37	19.29	19.65	-0.36	28.70	27.95	0.75
8/25/2015 10:00	10:00	26.00	25.57	0.43	19.47	19.79	-0.32	28.92	28.00	0.92
8/25/2015 11:00	11:00	26.20	25.48	0.72	19.64	19.94	-0.30	29.27	28.37	0.90
8/25/2015 12:00	12:00	26.00	25.56	0.44	19.84	20.08	-0.24	29.75	28.99	0.76
8/25/2015 13:00	13:00	26.40	25.87	0.53	20.07	20.23	-0.16	30.35	29.85	0.50
8/25/2015 14:00	14:00	26.70	26.25	0.45	20.27	20.37	-0.10	31.01	30.65	0.36
8/25/2015 15:00	15:00	27.10	26.64	0.46	20.47	20.52	-0.05	31.62	31.32	0.30
8/25/2015 16:00	16:00	27.60	27.07	0.53	20.70	20.67	0.03	32.20	32.03	0.17
8/25/2015 17:00	17:00	27.60	27.38	0.22	20.90	20.82	0.08	32.62	32.54	0.08
8/25/2015 18:00	18:00	27.60	27.45	0.15	21.10	20.96	0.14	32.87	32.87	0.00
8/25/2015 19:00	19:00	27.40	27.27	0.13	21.27	21.10	0.17	32.82	32.90	-0.08
8/25/2015 20:00	20:00	27.10	27.05	0.05	21.43	21.23	0.20	32.54	32.68	-0.14
8/25/2015 21:00	21:00	27.10	27.32	-0.22	21.27	21.08	0.19	32.86	33.12	-0.26
8/25/2015 22:00	22:00	27.40	27.66	-0.26	21.10	20.90	0.20	33.19	33.60	-0.41
8/25/2015 23:00	23:00	28.00	28.04	-0.04	20.90	20.73	0.17	33.59	34.09	-0.50

Diurnal Demand Pattern - Overall

Tuesday, August 25, 2015





Diurnal Demand Curve - Overall
Tuesday, August 25, 2015
Average Demand = 8.99 MGD
Demand (gpm)
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
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7:00 PM
8:00 PM
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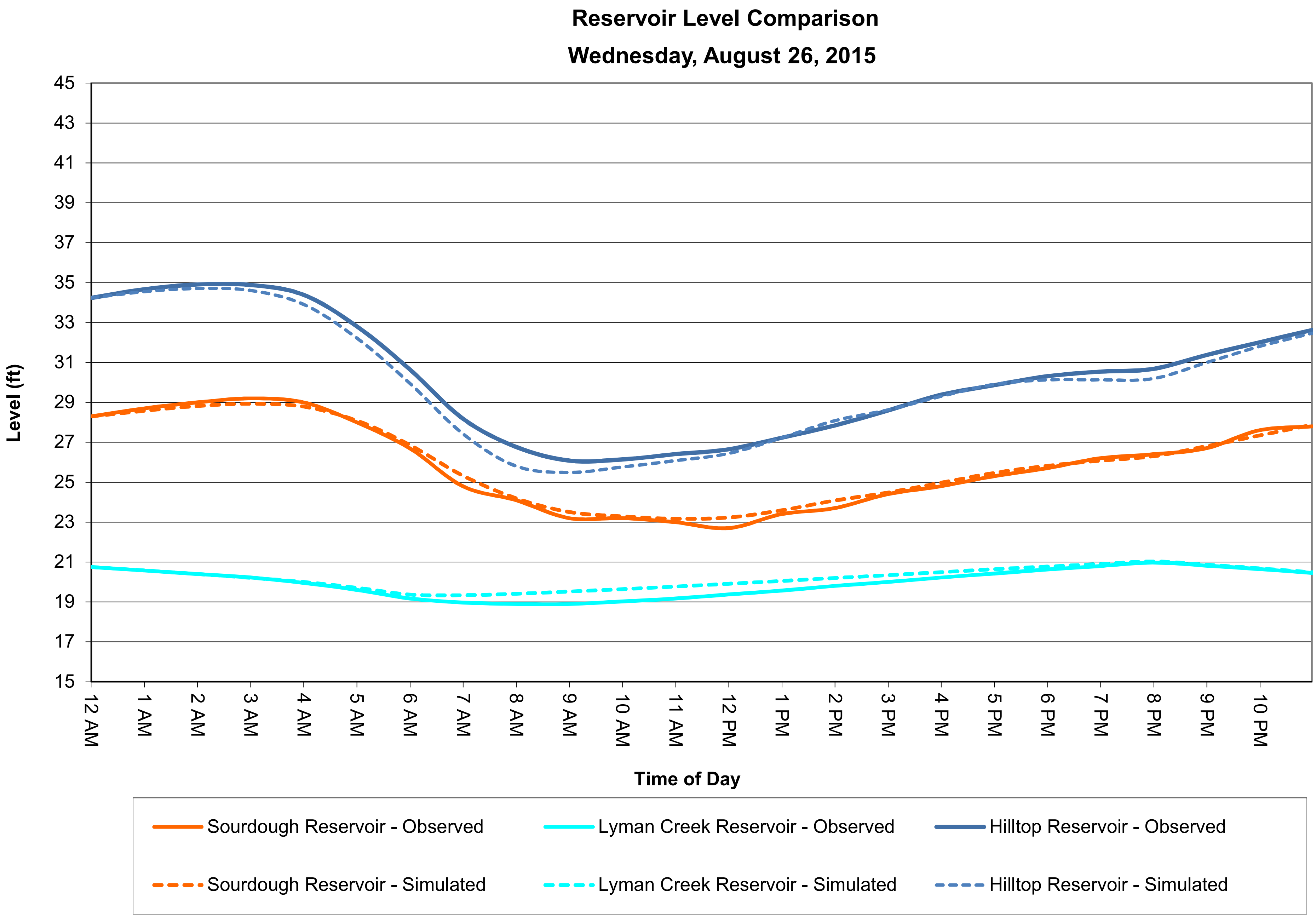
10:00 PM
11:00 PM
12:00 AM

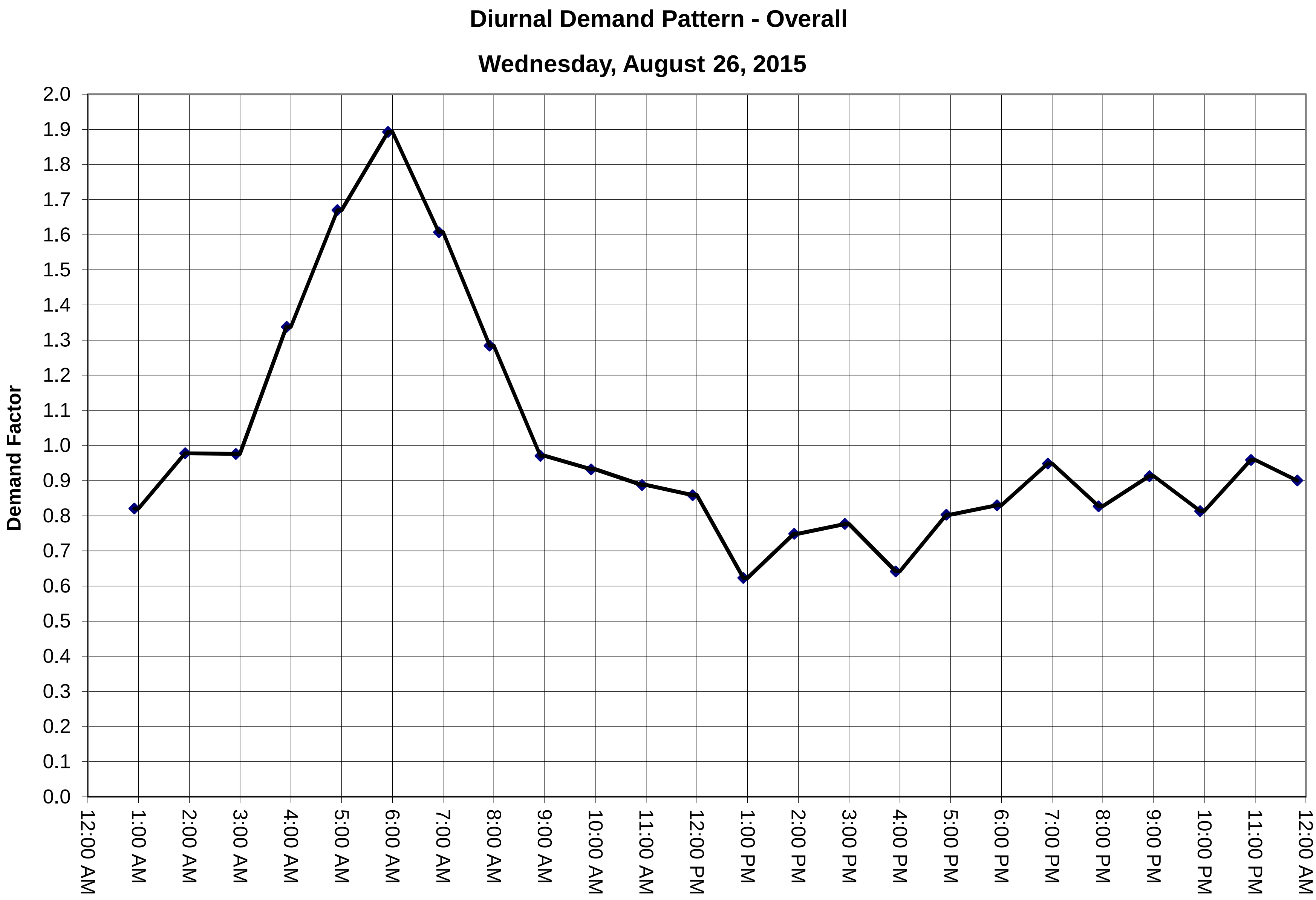


Reservoir Level Comparison
Wednesday, August 26, 2015
Level (ft)
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Reservoir Level Calibration
(Tower Level in ft)

Date/Time	Time	Sourdough Reservoir Level			Lyman Reservoir Level			Hilltop Reservoir Level		
		Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
8/26/2015 0:00	0:00	28.30	28.30	0.00	20.75	20.75	0.00	34.24	34.24	0.00
8/26/2015 1:00	1:00	28.70	28.58	0.12	20.57	20.58	-0.01	34.67	34.55	0.12
8/26/2015 2:00	2:00	29.00	28.82	0.18	20.40	20.40	0.00	34.91	34.71	0.20
8/26/2015 3:00	3:00	29.20	28.93	0.27	20.23	20.21	0.02	34.89	34.61	0.28
8/26/2015 4:00	4:00	29.00	28.79	0.21	19.95	20.00	-0.05	34.39	33.91	0.48
8/26/2015 5:00	5:00	28.00	28.09	-0.09	19.61	19.71	-0.10	32.82	32.23	0.59
8/26/2015 6:00	6:00	26.70	26.87	-0.17	19.18	19.37	-0.19	30.66	29.96	0.70
8/26/2015 7:00	7:00	24.80	25.33	-0.53	18.97	19.34	-0.37	28.19	27.43	0.76
8/26/2015 8:00	8:00	24.10	24.20	-0.10	18.89	19.41	-0.52	26.77	25.81	0.96
8/26/2015 9:00	9:00	23.20	23.51	-0.31	18.89	19.52	-0.63	26.09	25.49	0.60
8/26/2015 10:00	10:00	23.20	23.29	-0.09	19.02	19.64	-0.62	26.14	25.76	0.38
8/26/2015 11:00	11:00	23.00	23.17	-0.17	19.17	19.77	-0.60	26.41	26.08	0.33
8/26/2015 12:00	12:00	22.70	23.23	-0.53	19.38	19.91	-0.53	26.65	26.44	0.21
8/26/2015 13:00	13:00	23.40	23.59	-0.19	19.57	20.05	-0.48	27.22	27.22	0.00
8/26/2015 14:00	14:00	23.70	24.08	-0.38	19.80	20.20	-0.40	27.84	28.08	-0.24
8/26/2015 15:00	15:00	24.40	24.48	-0.08	20.00	20.34	-0.34	28.59	28.62	-0.03
8/26/2015 16:00	16:00	24.80	24.97	-0.17	20.22	20.49	-0.27	29.38	29.30	0.08
8/26/2015 17:00	17:00	25.30	25.46	-0.16	20.42	20.64	-0.22	29.86	29.90	-0.04
8/26/2015 18:00	18:00	25.70	25.82	-0.12	20.62	20.77	-0.15	30.31	30.13	0.18
8/26/2015 19:00	19:00	26.20	26.08	0.12	20.80	20.90	-0.10	30.54	30.13	0.41
8/26/2015 20:00	20:00	26.40	26.30	0.10	20.97	21.03	-0.06	30.68	30.19	0.49
8/26/2015 21:00	21:00	26.70	26.80	-0.10	20.82	20.87	-0.05	31.37	30.99	0.38
8/26/2015 22:00	22:00	27.60	27.34	0.26	20.65	20.68	-0.03	32.01	31.80	0.21
8/26/2015 23:00	23:00	27.80	27.88	-0.08	20.45	20.49	-0.04	32.63	32.47	0.16



Diurnal Demand Pattern - Overall
Wednesday, August 26, 2015
Demand Factor
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
12:00 AM
1:00 AM
2:00 AM
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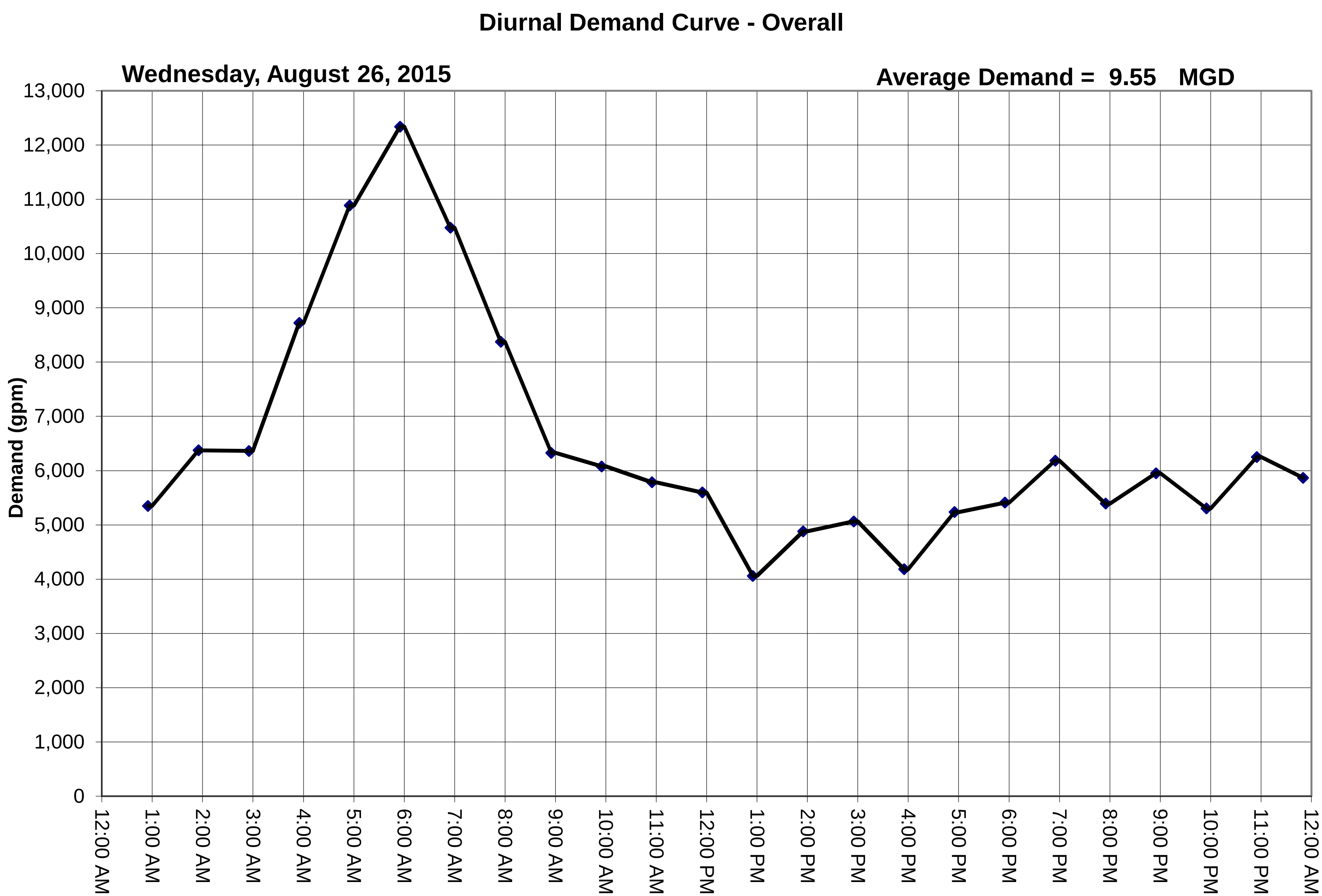
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM


Diurnal Demand Curve - Overall
Wednesday, August 26, 2015
Average Demand = 9.55 MGD
Demand (gpm)
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
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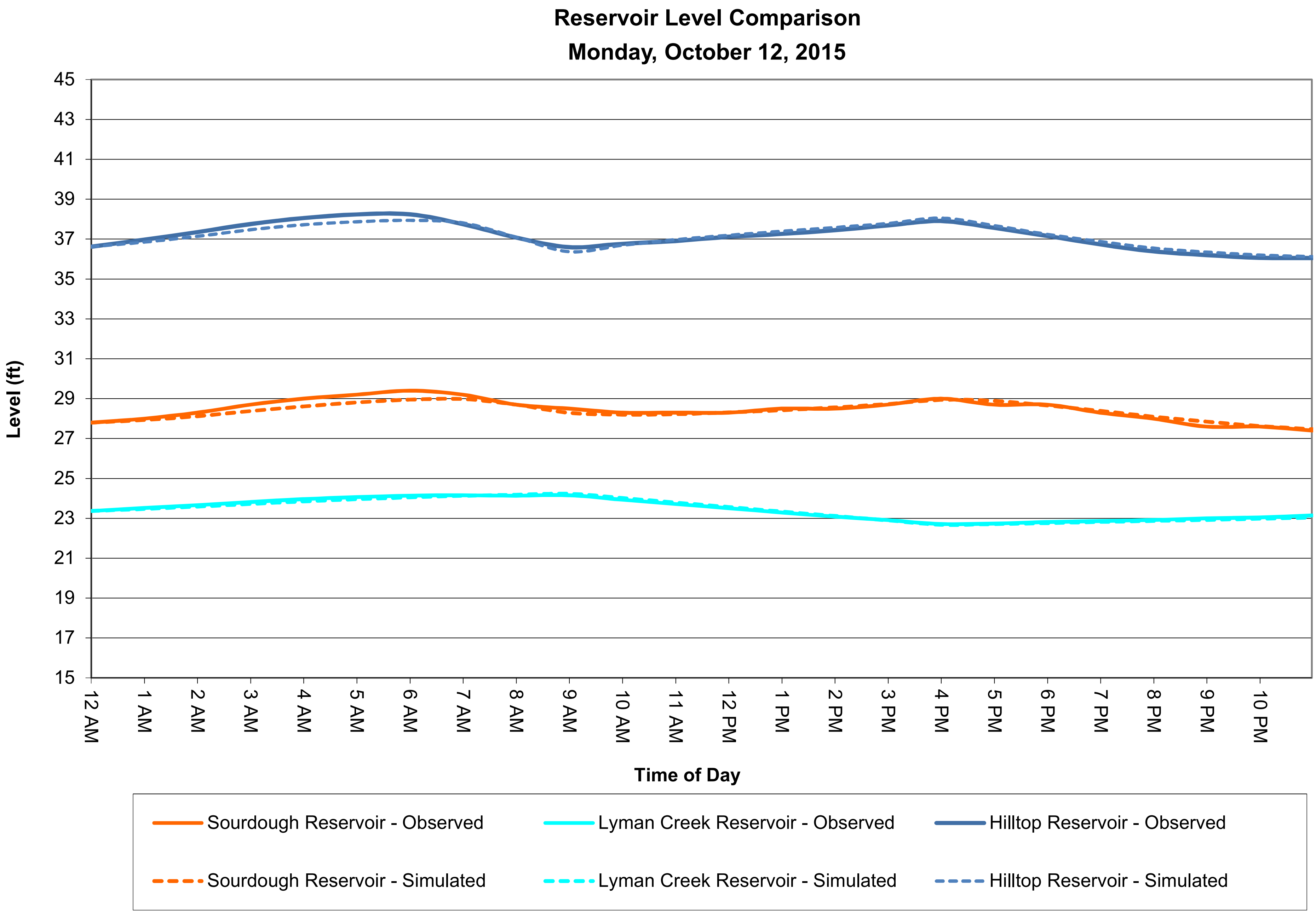
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM



Reservoir Level Comparison
Monday, October 12, 2015
Level (ft)
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

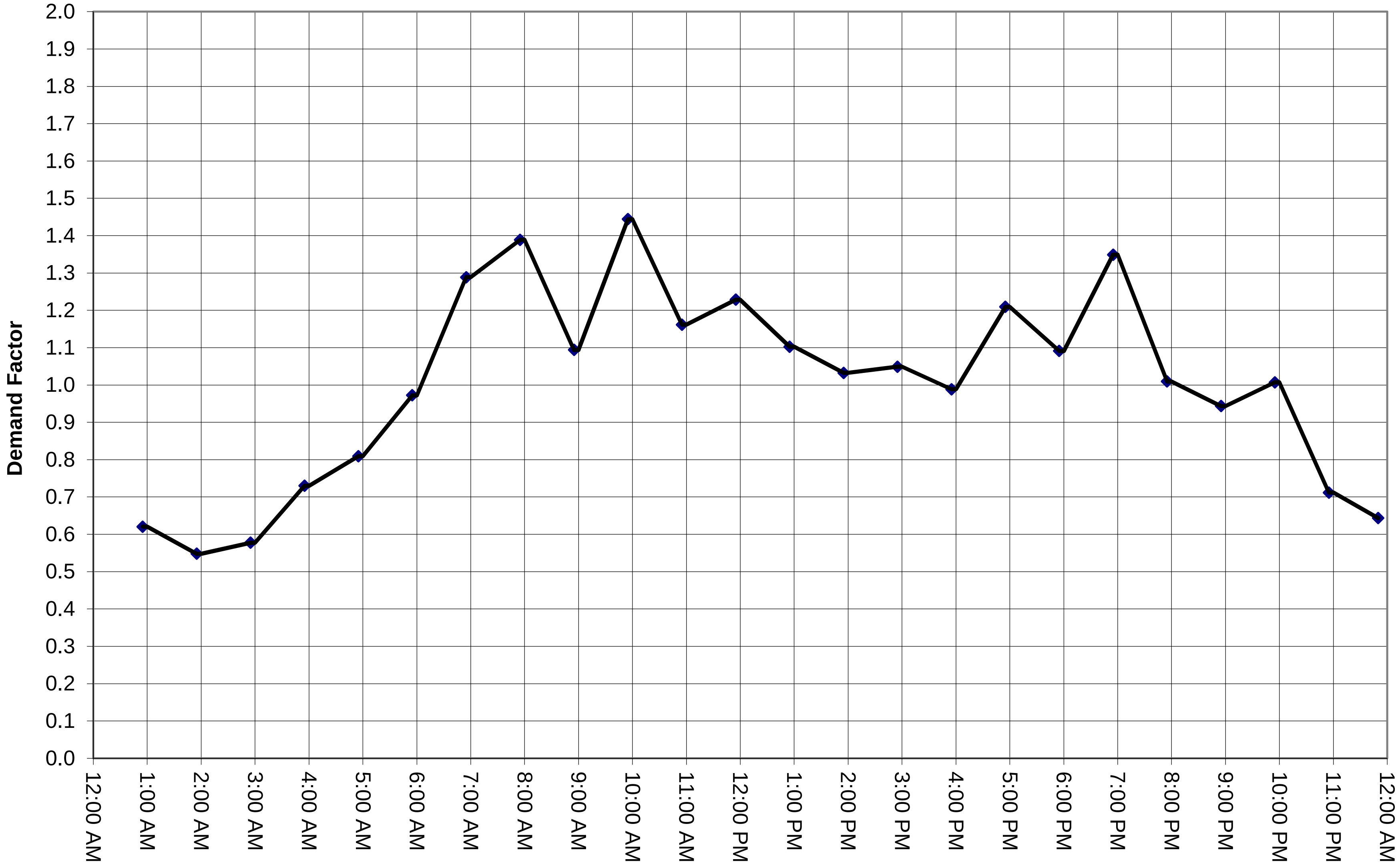
Water Distribution System Hydraulic Model Calibration
City of Bozeman

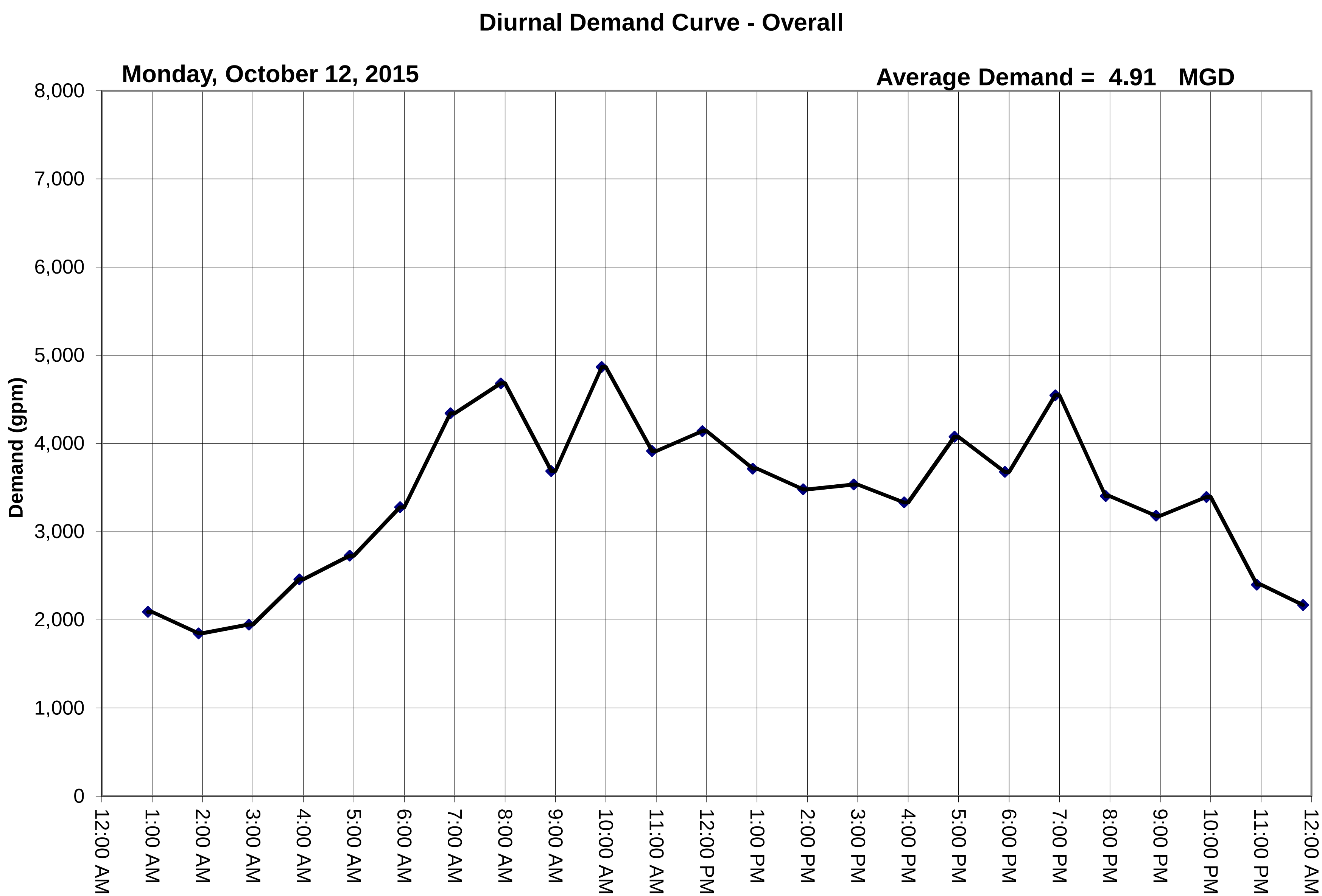
Reservoir Level Calibration
(Tower Level in ft)

Date/Time	Time	Sourdough Reservoir Level			Lyman Reservoir Level			Hilltop Reservoir Level		
		Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
10/12/2015 0:00	0:00	27.80	27.80	0.00	23.37	23.37	0.00	36.62	36.62	0.00
10/12/2015 1:00	1:00	28.00	27.93	0.07	23.52	23.47	0.05	36.97	36.85	0.12
10/12/2015 2:00	2:00	28.30	28.12	0.18	23.66	23.59	0.07	37.35	37.14	0.21
10/12/2015 3:00	3:00	28.70	28.38	0.32	23.81	23.72	0.09	37.76	37.47	0.29
10/12/2015 4:00	4:00	29.00	28.61	0.39	23.96	23.85	0.11	38.06	37.72	0.34
10/12/2015 5:00	5:00	29.20	28.81	0.39	24.06	23.96	0.10	38.24	37.87	0.37
10/12/2015 6:00	6:00	29.40	28.95	0.45	24.14	24.05	0.09	38.24	37.94	0.30
10/12/2015 7:00	7:00	29.20	28.98	0.22	24.15	24.13	0.02	37.75	37.81	-0.06
10/12/2015 8:00	8:00	28.70	28.70	0.00	24.13	24.18	-0.05	37.08	37.10	-0.02
10/12/2015 9:00	9:00	28.50	28.29	0.21	24.16	24.23	-0.07	36.60	36.37	0.23
10/12/2015 10:00	10:00	28.30	28.20	0.10	23.93	24.02	-0.09	36.76	36.69	0.07
10/12/2015 11:00	11:00	28.30	28.22	0.08	23.72	23.79	-0.07	36.91	36.97	-0.06
10/12/2015 12:00	12:00	28.30	28.31	-0.01	23.51	23.57	-0.06	37.12	37.19	-0.07
10/12/2015 13:00	13:00	28.50	28.42	0.08	23.29	23.34	-0.05	37.26	37.39	-0.13
10/12/2015 14:00	14:00	28.50	28.56	-0.06	23.09	23.12	-0.03	37.45	37.58	-0.13
10/12/2015 15:00	15:00	28.70	28.73	-0.03	22.91	22.90	0.01	37.69	37.78	-0.09
10/12/2015 16:00	16:00	29.00	28.94	0.06	22.72	22.68	0.04	37.91	38.05	-0.14
10/12/2015 17:00	17:00	28.70	28.89	-0.19	22.74	22.71	0.03	37.57	37.68	-0.11
10/12/2015 18:00	18:00	28.70	28.66	0.04	22.81	22.76	0.05	37.16	37.24	-0.08
10/12/2015 19:00	19:00	28.30	28.39	-0.09	22.86	22.82	0.04	36.74	36.88	-0.14
10/12/2015 20:00	20:00	28.00	28.10	-0.10	22.92	22.87	0.05	36.39	36.55	-0.16
10/12/2015 21:00	21:00	27.60	27.85	-0.25	23.00	22.92	0.08	36.20	36.35	-0.15
10/12/2015 22:00	22:00	27.60	27.63	-0.03	23.04	22.98	0.06	36.06	36.20	-0.14
10/12/2015 23:00	23:00	27.40	27.47	-0.07	23.14	23.04	0.10	36.05	36.12	-0.07

Diurnal Demand Pattern - Overall

Monday, October 12, 2015





Diurnal Demand Curve - Overall
Monday, October 12, 2015
Average Demand = 4.91 MGD
Demand (gpm)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 1			Test No. 2		
	Recorder #1242			Recorder #1240		
	Node =	Hydrant #2107		Node =	Hydrant #433	
	Elevation =	5024.74		Elevation =	4969.52	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/12/2015 0:00	5,120.52	5,120.61	(0.09)	5,120.47	5,121.26	(0.79)
10/12/2015 1:00	5,120.98	5,120.96	0.02	5,120.81	5,121.50	(0.69)
10/12/2015 2:00	5,121.43	5,121.32	0.11	5,121.26	5,121.78	(0.52)
10/12/2015 3:00	5,121.99	5,121.52	0.47	5,121.60	5,122.02	(0.42)
10/12/2015 4:00	5,121.88	5,121.63	0.25	5,121.83	5,122.20	(0.37)
10/12/2015 5:00	5,121.77	5,121.65	0.12	5,121.83	5,122.32	(0.49)
10/12/2015 6:00	5,120.75	5,121.38	(0.63)	5,121.60	5,122.29	(0.69)
10/12/2015 7:00	5,118.95	5,119.89	(0.94)	5,120.81	5,121.74	(0.93)
10/12/2015 8:00	5,117.93	5,118.96	(1.03)	5,120.25	5,121.15	(0.90)
10/12/2015 9:00	5,118.61	5,119.15	(0.54)	5,120.14	5,120.87	(0.73)
10/12/2015 10:00	5,118.95	5,120.50	(1.55)	5,120.36	5,121.45	(1.09)
10/12/2015 11:00	5,118.95	5,120.71	(1.76)	5,120.59	5,121.59	(1.00)
10/12/2015 12:00	5,118.27	5,120.91	(2.64)	5,120.70	5,121.74	(1.04)
10/12/2015 13:00	5,118.38	5,121.11	(2.73)	5,120.93	5,121.91	(0.98)
10/12/2015 14:00	5,118.16	5,121.33	(3.17)	5,121.04	5,122.08	(1.04)
10/12/2015 15:00	5,118.16	5,121.67	(3.51)	5,121.38	5,122.32	(0.94)
10/12/2015 16:00	5,118.16	5,121.88	(3.72)	5,121.60	5,122.54	(0.94)
10/12/2015 17:00	5,116.80	5,120.51	(3.71)	5,121.04	5,121.91	(0.87)
10/12/2015 18:00	5,116.35	5,120.15	(3.80)	5,120.59	5,121.58	(0.99)
10/12/2015 19:00	5,116.46	5,119.81	(3.35)	5,120.25	5,121.26	(1.01)
10/12/2015 20:00	5,116.58	5,119.72	(3.14)	5,119.80	5,121.03	(1.23)
10/12/2015 21:00	5,117.37	5,119.64	(2.27)	5,119.68	5,120.85	(1.17)
10/12/2015 22:00	5,117.59	5,119.63	(2.04)	5,119.57	5,120.73	(1.16)
10/12/2015 23:00	5,118.38	5,119.96	(1.58)	5,119.68	5,120.77	(1.09)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 3			Test No. 4		
	Recorder #1251			Recorder #1249		
	Node =	Hydrant #490		Node =	Hydrant #278	
	Elevation =	4880.25		Elevation =	4861.19	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/12/2015 0:00	5,119.32	5,120.33	(1.01)	5,121.13	5,120.83	0.30
10/12/2015 1:00	5,119.77	5,120.73	(0.96)	5,121.35	5,121.12	0.23
10/12/2015 2:00	5,120.22	5,121.13	(0.91)	5,121.81	5,121.44	0.37
10/12/2015 3:00	5,120.67	5,121.31	(0.64)	5,122.26	5,121.68	0.58
10/12/2015 4:00	5,120.56	5,121.38	(0.82)	5,122.48	5,121.85	0.63
10/12/2015 5:00	5,120.22	5,121.37	(1.15)	5,122.48	5,121.94	0.54
10/12/2015 6:00	5,118.98	5,121.00	(2.02)	5,122.03	5,121.83	0.20
10/12/2015 7:00	5,116.83	5,119.11	(2.28)	5,121.02	5,120.99	0.03
10/12/2015 8:00	5,115.71	5,118.04	(2.33)	5,120.34	5,120.24	0.10
10/12/2015 9:00	5,116.83	5,118.41	(1.58)	5,120.68	5,120.04	0.64
10/12/2015 10:00	5,117.85	5,120.14	(2.29)	5,120.79	5,121.01	(0.22)
10/12/2015 11:00	5,118.53	5,120.39	(1.86)	5,120.79	5,121.21	(0.42)
10/12/2015 12:00	5,118.41	5,120.61	(2.20)	5,120.68	5,121.40	(0.72)
10/12/2015 13:00	5,118.87	5,120.83	(1.96)	5,121.13	5,121.58	(0.45)
10/12/2015 14:00	5,119.20	5,121.05	(1.85)	5,121.24	5,121.78	(0.54)
10/12/2015 15:00	5,119.54	5,121.43	(1.89)	5,121.81	5,122.04	(0.23)
10/12/2015 16:00	5,119.54	5,121.64	(2.10)	5,122.37	5,122.27	0.10
10/12/2015 17:00	5,117.85	5,119.93	(2.08)	5,121.69	5,121.29	0.40
10/12/2015 18:00	5,116.95	5,119.54	(2.59)	5,121.24	5,120.92	0.32
10/12/2015 19:00	5,116.27	5,119.20	(2.93)	5,120.79	5,120.58	0.21
10/12/2015 20:00	5,116.16	5,119.17	(3.01)	5,120.68	5,120.37	0.31
10/12/2015 21:00	5,116.83	5,119.12	(2.29)	5,120.45	5,120.23	0.22
10/12/2015 22:00	5,116.72	5,119.17	(2.45)	5,120.23	5,120.15	0.08
10/12/2015 23:00	5,117.74	5,119.61	(1.87)	5,120.45	5,120.27	0.18

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

Date/Time	Test No. 5			Test No. 6		
	Recorder #341298			Recorder #1245		
	Node =	Hydrant #121		Node =	Hydrant #1887	
	Elevation =	4817.61		Elevation =	4754.53	
	Observed	Simulated	Difference	Observed	Simulated	Difference
10/12/2015 0:00	5,119.52	5,120.44	(0.92)	5,118.71	5,120.31	(1.60)
10/12/2015 1:00	5,120.12	5,120.80	(0.68)	5,119.17	5,120.70	(1.53)
10/12/2015 2:00	5,120.49	5,121.19	(0.70)	5,119.73	5,121.10	(1.37)
10/12/2015 3:00	5,121.09	5,121.38	(0.29)	5,120.41	5,121.29	(0.88)
10/12/2015 4:00	5,120.97	5,121.48	(0.51)	5,120.18	5,121.36	(1.18)
10/12/2015 5:00	5,120.73	5,121.49	(0.76)	5,119.84	5,121.35	(1.51)
10/12/2015 6:00	5,119.64	5,121.19	(1.55)	5,118.71	5,120.98	(2.27)
10/12/2015 7:00	5,117.82	5,119.57	(1.75)	5,116.46	5,119.12	(2.66)
10/12/2015 8:00	5,116.85	5,118.58	(1.73)	5,115.44	5,118.05	(2.61)
10/12/2015 9:00	5,117.94	5,118.80	(0.86)	5,116.91	5,118.40	(1.49)
10/12/2015 10:00	5,119.28	5,120.87	(1.59)	5,118.71	5,121.44	(2.73)
10/12/2015 11:00	5,119.64	5,121.09	(1.45)	5,118.26	5,121.66	(3.40)
10/12/2015 12:00	5,119.64	5,121.29	(1.65)	5,118.04	5,121.85	(3.81)
10/12/2015 13:00	5,119.88	5,121.48	(1.60)	5,118.26	5,122.04	(3.78)
10/12/2015 14:00	5,120.00	5,121.69	(1.69)	5,118.26	5,122.24	(3.98)
10/12/2015 15:00	5,120.37	5,121.99	(1.62)	5,118.26	5,122.56	(4.30)
10/12/2015 16:00	5,120.37	5,122.21	(1.84)	5,117.92	5,122.76	(4.84)
10/12/2015 17:00	5,118.18	5,120.26	(2.08)	5,114.77	5,119.93	(5.16)
10/12/2015 18:00	5,117.46	5,119.87	(2.41)	5,114.43	5,119.54	(5.11)
10/12/2015 19:00	5,116.61	5,119.52	(2.91)	5,114.09	5,119.19	(5.10)
10/12/2015 20:00	5,116.73	5,119.45	(2.72)	5,114.31	5,119.15	(4.84)
10/12/2015 21:00	5,117.33	5,119.38	(2.05)	5,115.10	5,119.11	(4.01)
10/12/2015 22:00	5,117.21	5,119.39	(2.18)	5,115.33	5,119.16	(3.83)
10/12/2015 23:00	5,118.06	5,119.75	(1.69)	5,116.57	5,119.59	(3.02)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 7			Test No. 8		
	Recorder #341289			Recorder #201250		
	Node =	Hydrant #1754		Node =	Hydrant #1125	
	Elevation =	4820.11		Elevation =	4779.50	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/12/2015 0:00	5,119.11	5,120.03	(0.92)	5,120.44	5,120.03	0.41
10/12/2015 1:00	5,119.71	5,120.48	(0.77)	5,121.01	5,120.49	0.52
10/12/2015 2:00	5,119.96	5,120.92	(0.96)	5,121.46	5,120.92	0.54
10/12/2015 3:00	5,120.44	5,121.08	(0.64)	5,122.02	5,121.08	0.94
10/12/2015 4:00	5,120.20	5,121.10	(0.90)	5,121.57	5,121.11	0.46
10/12/2015 5:00	5,119.47	5,121.04	(1.57)	5,121.12	5,121.04	0.08
10/12/2015 6:00	5,118.02	5,120.53	(2.51)	5,119.43	5,120.54	(1.11)
10/12/2015 7:00	5,115.23	5,118.01	(2.78)	5,116.61	5,118.02	(1.41)
10/12/2015 8:00	5,114.38	5,116.74	(2.36)	5,115.82	5,116.74	(0.92)
10/12/2015 9:00	5,115.83	5,117.44	(1.61)	5,117.28	5,117.44	(0.16)
10/12/2015 10:00	5,117.05	5,119.41	(2.36)	5,117.96	5,119.42	(1.46)
10/12/2015 11:00	5,117.41	5,119.71	(2.30)	5,118.19	5,119.72	(1.53)
10/12/2015 12:00	5,117.53	5,119.95	(2.42)	5,118.07	5,119.96	(1.89)
10/12/2015 13:00	5,117.77	5,120.20	(2.43)	5,118.30	5,120.21	(1.91)
10/12/2015 14:00	5,118.14	5,120.46	(2.32)	5,118.19	5,120.46	(2.27)
10/12/2015 15:00	5,118.26	5,120.91	(2.65)	5,118.19	5,120.92	(2.73)
10/12/2015 16:00	5,118.14	5,121.11	(2.97)	5,117.74	5,121.11	(3.37)
10/12/2015 17:00	5,116.20	5,119.13	(2.93)	5,115.82	5,119.14	(3.32)
10/12/2015 18:00	5,115.10	5,118.74	(3.64)	5,114.69	5,118.74	(4.05)
10/12/2015 19:00	5,114.62	5,118.38	(3.76)	5,114.46	5,118.39	(3.93)
10/12/2015 20:00	5,114.62	5,118.44	(3.82)	5,114.80	5,118.45	(3.65)
10/12/2015 21:00	5,115.71	5,118.46	(2.75)	5,115.93	5,118.47	(2.54)
10/12/2015 22:00	5,115.83	5,118.58	(2.75)	5,116.27	5,118.59	(2.32)
10/12/2015 23:00	5,116.92	5,119.22	(2.30)	5,117.51	5,119.23	(1.72)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

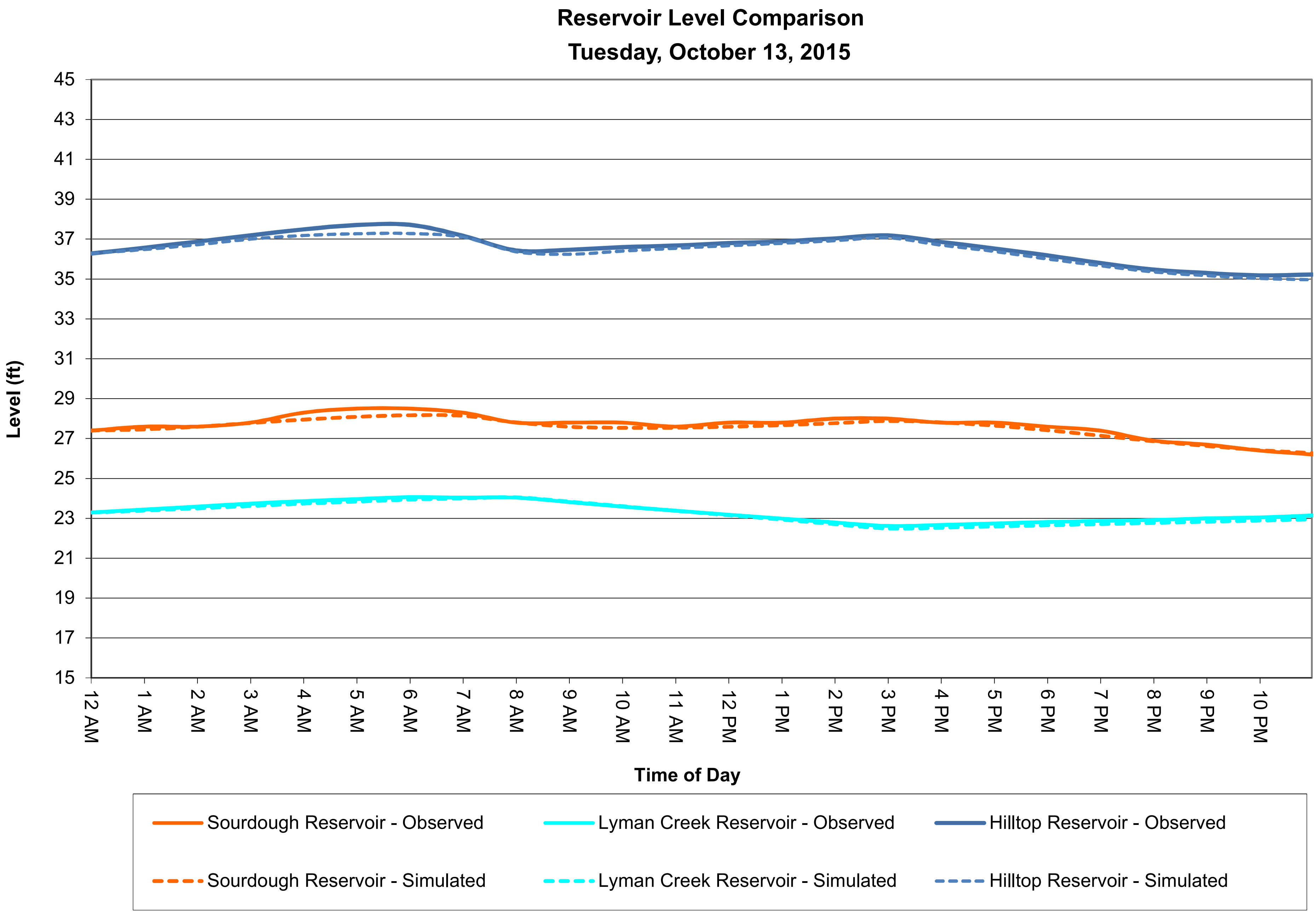
Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 9			Test No. 10		
	Recorder #1243			Recorder #1241		
	Node =	Hydrant #1025		Node =	Hydrant #	
	Elevation =	4755.67		Elevation =	0.00	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/12/2015 0:00	5,120.19	5,120.18	0.01	0.00	0.00	0.00
10/12/2015 1:00	5,120.76	5,120.60	0.16	0.00	0.00	0.00
10/12/2015 2:00	5,121.10	5,121.02	0.08	0.00	0.00	0.00
10/12/2015 3:00	5,121.55	5,121.19	0.36	0.00	0.00	0.00
10/12/2015 4:00	5,121.43	5,121.24	0.19	0.00	0.00	0.00
10/12/2015 5:00	5,120.98	5,121.20	(0.22)	0.00	0.00	0.00
10/12/2015 6:00	5,119.74	5,120.77	(1.03)	0.00	0.00	0.00
10/12/2015 7:00	5,117.15	5,118.56	(1.41)	0.00	0.00	0.00
10/12/2015 8:00	5,116.24	5,117.38	(1.14)	0.00	0.00	0.00
10/12/2015 9:00	5,117.37	5,117.92	(0.55)	0.00	0.00	0.00
10/12/2015 10:00	5,118.39	5,120.02	(1.63)	0.00	0.00	0.00
10/12/2015 11:00	5,118.73	5,120.29	(1.56)	0.00	0.00	0.00
10/12/2015 12:00	5,118.61	5,120.52	(1.91)	0.00	0.00	0.00
10/12/2015 13:00	5,118.84	5,120.75	(1.91)	0.00	0.00	0.00
10/12/2015 14:00	5,118.84	5,120.99	(2.15)	0.00	0.00	0.00
10/12/2015 15:00	5,118.84	5,121.41	(2.57)	0.00	0.00	0.00
10/12/2015 16:00	5,118.50	5,121.61	(3.11)	0.00	0.00	0.00
10/12/2015 17:00	5,116.47	5,119.55	(3.08)	0.00	0.00	0.00
10/12/2015 18:00	5,115.68	5,119.15	(3.47)	0.00	0.00	0.00
10/12/2015 19:00	5,115.45	5,118.80	(3.35)	0.00	0.00	0.00
10/12/2015 20:00	5,115.68	5,118.82	(3.14)	0.00	0.00	0.00
10/12/2015 21:00	5,116.47	5,118.82	(2.35)	0.00	0.00	0.00
10/12/2015 22:00	5,116.81	5,118.90	(2.09)	0.00	0.00	0.00
10/12/2015 23:00	5,117.71	5,119.42	(1.71)	0.00	0.00	0.00

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

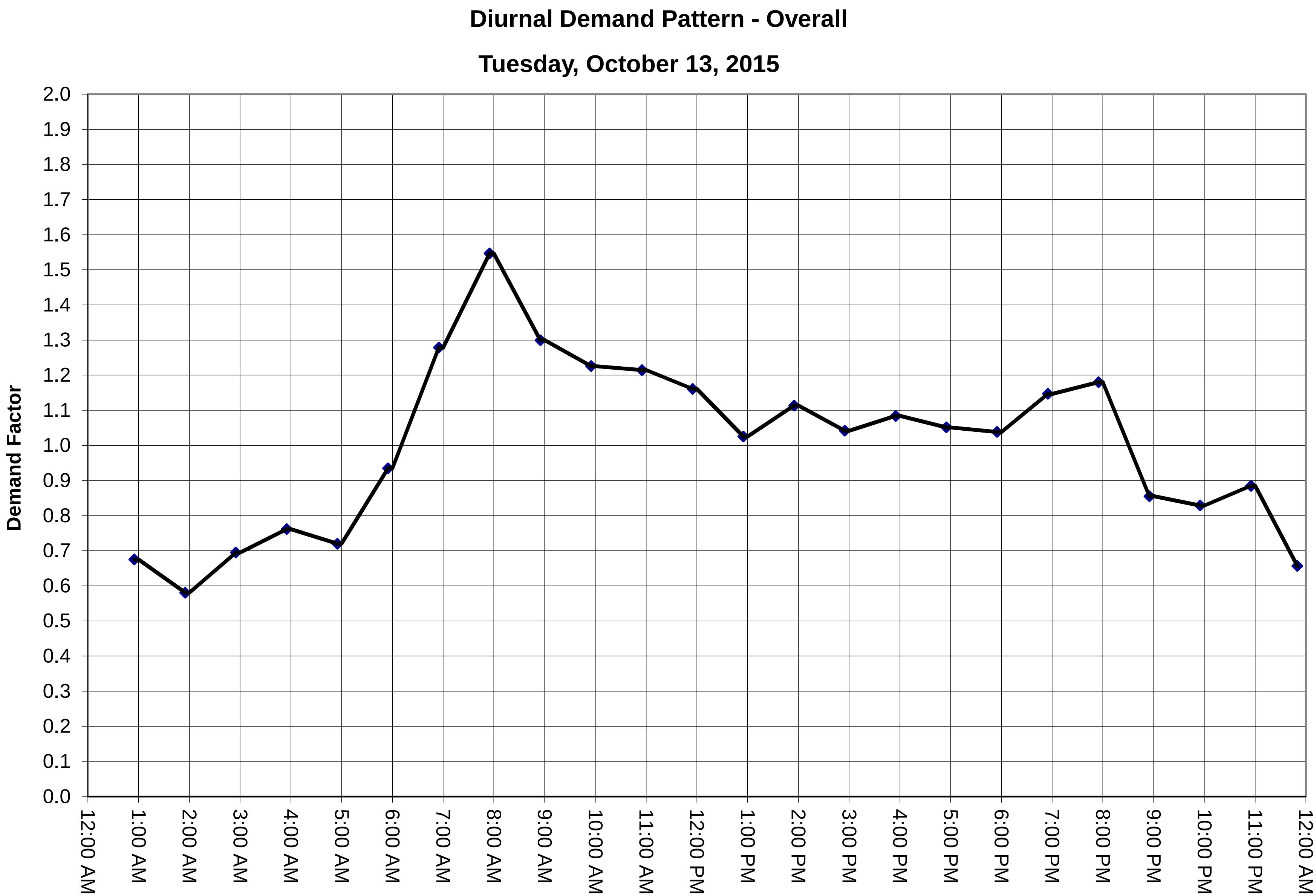
Date/Time	Test No. 11			Test No. 12		
	Recorder #1246			Recorder #1244		
	Node =	Hydrant #2712		Node =	Hydrant #1770	
	Elevation =	4692.64		Elevation =	4679.91	
	Observed	Simulated	Difference	Observed	Simulated	Difference
10/12/2015 0:00	4,924.94	4,925.06	(0.12)	5,027.85	5,028.21	(0.36)
10/12/2015 1:00	4,925.28	4,926.19	(0.91)	5,028.19	5,029.00	(0.81)
10/12/2015 2:00	4,926.52	4,926.96	(0.44)	5,029.20	5,029.60	(0.40)
10/12/2015 3:00	4,927.08	4,926.46	0.62	5,029.32	5,029.41	(0.09)
10/12/2015 4:00	4,925.05	4,925.50	(0.45)	5,027.85	5,028.95	(1.10)
10/12/2015 5:00	4,922.34	4,924.47	(2.13)	5,025.93	5,028.41	(2.48)
10/12/2015 6:00	4,918.28	4,921.79	(3.51)	5,021.53	5,026.84	(5.31)
10/12/2015 7:00	4,912.08	4,921.57	(9.49)	5,015.66	5,026.36	(10.70)
10/12/2015 8:00	4,914.45	4,921.51	(7.06)	5,018.15	5,026.27	(8.12)
10/12/2015 9:00	4,917.60	4,921.61	(4.01)	5,011.38	5,026.57	(15.19)
10/12/2015 10:00	4,916.14	4,921.63	(5.49)	5,009.57	5,018.47	(8.90)
10/12/2015 11:00	4,921.55	4,921.64	(0.09)	5,009.35	5,018.40	(9.05)
10/12/2015 12:00	4,920.42	4,921.65	(1.23)	5,011.94	5,018.30	(6.36)
10/12/2015 13:00	4,921.78	4,921.66	0.12	5,011.38	5,018.21	(6.83)
10/12/2015 14:00	4,922.46	4,921.66	0.80	5,012.73	5,018.12	(5.39)
10/12/2015 15:00	4,921.78	4,921.68	0.10	5,013.18	5,018.12	(4.94)
10/12/2015 16:00	4,921.21	4,921.68	(0.47)	5,015.89	5,017.98	(2.09)
10/12/2015 17:00	4,921.67	4,921.65	0.02	5,020.97	5,025.19	(4.22)
10/12/2015 18:00	4,921.21	4,921.65	(0.44)	5,021.42	5,025.23	(3.81)
10/12/2015 19:00	4,919.52	4,921.65	(2.13)	5,020.97	5,025.28	(4.31)
10/12/2015 20:00	4,916.93	4,921.67	(4.74)	5,020.74	5,025.41	(4.67)
10/12/2015 21:00	4,920.20	4,921.68	(1.48)	5,022.66	5,025.52	(2.86)
10/12/2015 22:00	4,922.00	4,921.72	0.28	5,023.90	5,025.65	(1.75)
10/12/2015 23:00	4,925.05	4,923.36	1.69	5,027.62	5,026.79	0.83

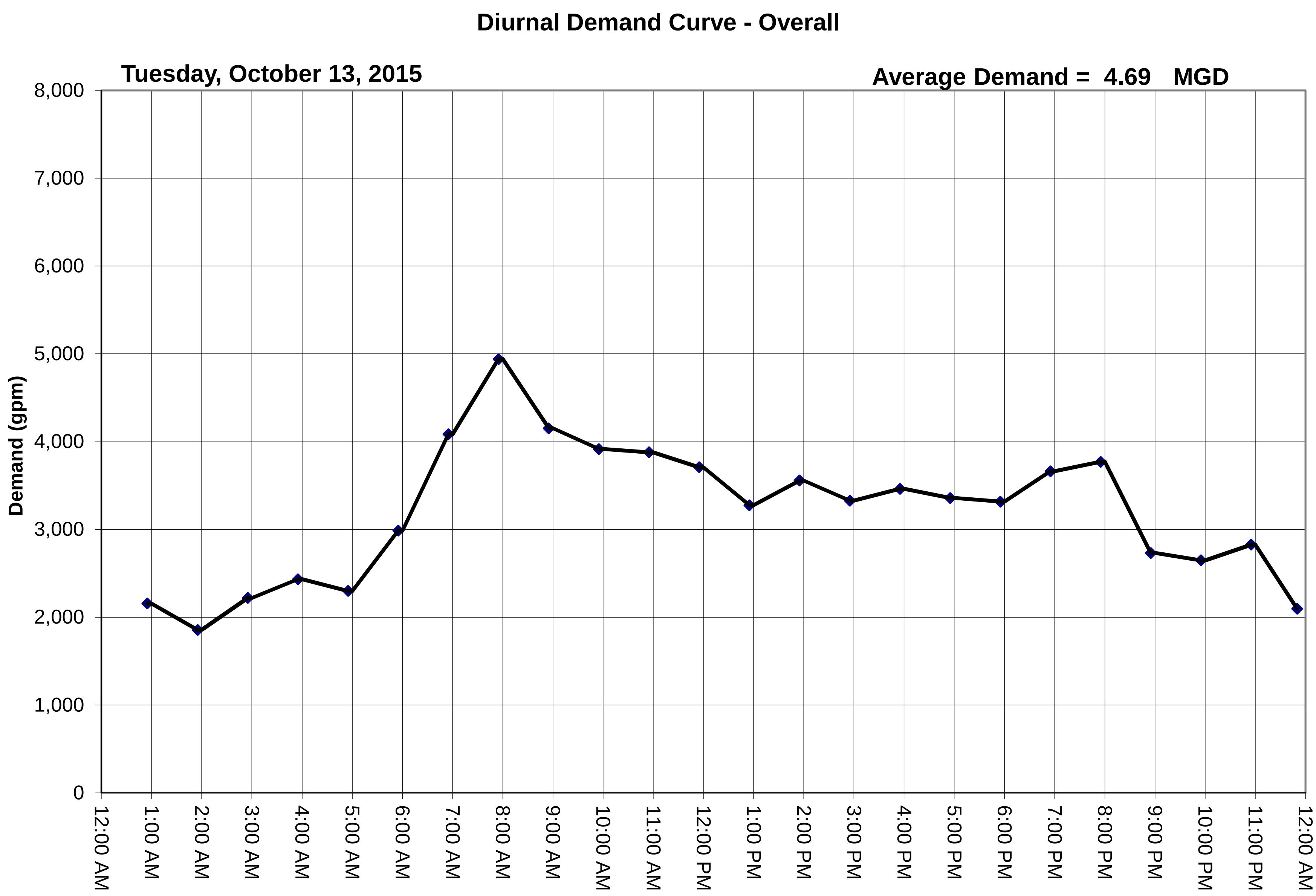

Reservoir Level Comparison
Tuesday, October 13, 2015
Level (ft)
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Reservoir Level Calibration
(Tower Level in ft)

Date/Time	Time	Sourdough Reservoir Level			Lyman Reservoir Level			Hilltop Reservoir Level		
		Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
10/13/2015 0:00	0:00	27.40	27.40	0.00	23.29	23.29	0.00	36.28	36.28	0.00
10/13/2015 1:00	1:00	27.60	27.46	0.14	23.44	23.39	0.05	36.57	36.48	0.09
10/13/2015 2:00	2:00	27.60	27.59	0.01	23.59	23.50	0.09	36.88	36.72	0.16
10/13/2015 3:00	3:00	27.80	27.78	0.02	23.74	23.62	0.12	37.19	37.00	0.19
10/13/2015 4:00	4:00	28.30	27.95	0.35	23.87	23.74	0.13	37.49	37.18	0.31
10/13/2015 5:00	5:00	28.50	28.09	0.41	23.97	23.84	0.13	37.71	37.27	0.44
10/13/2015 6:00	6:00	28.50	28.17	0.33	24.06	23.94	0.12	37.72	37.28	0.44
10/13/2015 7:00	7:00	28.30	28.14	0.16	24.04	24.00	0.04	37.17	37.10	0.07
10/13/2015 8:00	8:00	27.80	27.81	-0.01	24.04	24.05	-0.01	36.43	36.37	0.06
10/13/2015 9:00	9:00	27.80	27.59	0.21	23.81	23.84	-0.03	36.47	36.24	0.23
10/13/2015 10:00	10:00	27.80	27.54	0.26	23.59	23.61	-0.02	36.60	36.40	0.20
10/13/2015 11:00	11:00	27.60	27.54	0.06	23.39	23.38	0.01	36.68	36.54	0.14
10/13/2015 12:00	12:00	27.80	27.59	0.21	23.19	23.16	0.03	36.80	36.67	0.13
10/13/2015 13:00	13:00	27.80	27.67	0.13	22.99	22.94	0.05	36.89	36.79	0.10
10/13/2015 14:00	14:00	28.00	27.77	0.23	22.79	22.71	0.08	37.04	36.92	0.12
10/13/2015 15:00	15:00	28.00	27.88	0.12	22.62	22.49	0.13	37.18	37.07	0.11
10/13/2015 16:00	16:00	27.80	27.81	-0.01	22.67	22.53	0.14	36.87	36.70	0.17
10/13/2015 17:00	17:00	27.80	27.65	0.15	22.74	22.59	0.15	36.53	36.39	0.14
10/13/2015 18:00	18:00	27.60	27.42	0.18	22.82	22.65	0.17	36.19	36.01	0.18
10/13/2015 19:00	19:00	27.40	27.15	0.25	22.87	22.71	0.16	35.80	35.67	0.13
10/13/2015 20:00	20:00	26.90	26.87	0.03	22.92	22.77	0.15	35.47	35.36	0.11
10/13/2015 21:00	21:00	26.70	26.63	0.07	23.00	22.83	0.17	35.30	35.17	0.13
10/13/2015 22:00	22:00	26.40	26.42	-0.02	23.04	22.89	0.15	35.18	35.03	0.15
10/13/2015 23:00	23:00	26.20	26.27	-0.07	23.14	22.95	0.19	35.22	34.96	0.26


Diurnal Demand Pattern - Overall
Tuesday, October 13, 2015
Demand Factor
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM


Diurnal Demand Curve - Overall
Tuesday, October 13, 2015
Average Demand = 4.69 MGD
Demand (gpm)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

Date/Time	Test No. 1			Test No. 2		
	Recorder #1242			Recorder #1240		
	Node =	Hydrant #2107		Node =	Hydrant #433	
	Elevation =	5024.74		Elevation =	4969.52	
	Observed	Simulated	Difference	Observed	Simulated	Difference
10/13/2015 0:00	5,119.06	5,120.26	(1.20)	5,119.91	5,120.89	(0.98)
10/13/2015 1:00	5,119.62	5,120.55	(0.93)	5,120.25	5,121.06	(0.81)
10/13/2015 2:00	5,120.30	5,120.85	(0.55)	5,120.59	5,121.28	(0.69)
10/13/2015 3:00	5,120.52	5,120.99	(0.47)	5,120.93	5,121.47	(0.54)
10/13/2015 4:00	5,120.64	5,121.04	(0.40)	5,121.15	5,121.60	(0.45)
10/13/2015 5:00	5,120.86	5,121.01	(0.15)	5,121.26	5,121.66	(0.40)
10/13/2015 6:00	5,120.30	5,120.70	(0.40)	5,121.04	5,121.58	(0.54)
10/13/2015 7:00	5,117.93	5,119.19	(1.26)	5,120.02	5,120.98	(0.96)
10/13/2015 8:00	5,117.82	5,118.23	(0.41)	5,119.68	5,120.34	(0.66)
10/13/2015 9:00	5,119.06	5,119.89	(0.83)	5,120.02	5,120.87	(0.85)
10/13/2015 10:00	5,118.27	5,120.05	(1.78)	5,119.91	5,120.94	(1.03)
10/13/2015 11:00	5,118.16	5,120.20	(2.04)	5,120.25	5,121.02	(0.77)
10/13/2015 12:00	5,117.59	5,120.34	(2.75)	5,120.14	5,121.12	(0.98)
10/13/2015 13:00	5,117.59	5,120.48	(2.89)	5,120.36	5,121.23	(0.87)
10/13/2015 14:00	5,117.82	5,120.64	(2.82)	5,120.59	5,121.35	(0.76)
10/13/2015 15:00	5,117.82	5,120.92	(3.10)	5,120.81	5,121.54	(0.73)
10/13/2015 16:00	5,116.24	5,119.83	(3.59)	5,120.14	5,120.99	(0.85)
10/13/2015 17:00	5,115.56	5,119.32	(3.76)	5,119.91	5,120.68	(0.77)
10/13/2015 18:00	5,115.67	5,118.97	(3.30)	5,119.68	5,120.36	(0.68)
10/13/2015 19:00	5,115.67	5,118.65	(2.98)	5,119.12	5,120.06	(0.94)
10/13/2015 20:00	5,116.12	5,118.57	(2.45)	5,119.01	5,119.84	(0.83)
10/13/2015 21:00	5,116.46	5,118.49	(2.03)	5,118.78	5,119.67	(0.89)
10/13/2015 22:00	5,116.91	5,118.51	(1.60)	5,118.67	5,119.56	(0.89)
10/13/2015 23:00	5,117.82	5,118.80	(0.98)	5,118.89	5,119.59	(0.70)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

Date/Time	Test No. 3			Test No. 4		
	Recorder #1251			Recorder #1249		
	Node =	Hydrant #490		Node =	Hydrant #278	
	Elevation =	4880.25		Elevation =	4861.19	
	Observed	Simulated	Difference	Observed	Simulated	Difference
10/13/2015 0:00	5,118.41	5,119.99	(1.58)	5,120.68	5,120.48	0.20
10/13/2015 1:00	5,119.09	5,120.33	(1.24)	5,121.02	5,120.71	0.31
10/13/2015 2:00	5,119.54	5,120.66	(1.12)	5,121.35	5,120.97	0.38
10/13/2015 3:00	5,119.99	5,120.79	(0.80)	5,121.69	5,121.16	0.53
10/13/2015 4:00	5,119.99	5,120.81	(0.82)	5,121.81	5,121.28	0.53
10/13/2015 5:00	5,119.99	5,120.74	(0.75)	5,121.92	5,121.30	0.62
10/13/2015 6:00	5,118.87	5,120.33	(1.46)	5,121.69	5,121.15	0.54
10/13/2015 7:00	5,115.82	5,118.44	(2.62)	5,120.34	5,120.26	0.08
10/13/2015 8:00	5,115.93	5,117.34	(1.41)	5,120.11	5,119.48	0.63
10/13/2015 9:00	5,117.96	5,119.53	(1.57)	5,120.68	5,120.45	0.23
10/13/2015 10:00	5,117.85	5,119.73	(1.88)	5,120.45	5,120.58	(0.13)
10/13/2015 11:00	5,118.19	5,119.90	(1.71)	5,120.56	5,120.70	(0.14)
10/13/2015 12:00	5,118.19	5,120.06	(1.87)	5,120.34	5,120.82	(0.48)
10/13/2015 13:00	5,118.53	5,120.22	(1.69)	5,120.56	5,120.95	(0.39)
10/13/2015 14:00	5,118.75	5,120.39	(1.64)	5,121.02	5,121.08	(0.06)
10/13/2015 15:00	5,119.20	5,120.70	(1.50)	5,121.13	5,121.29	(0.16)
10/13/2015 16:00	5,117.17	5,119.35	(2.18)	5,120.79	5,120.45	0.34
10/13/2015 17:00	5,116.50	5,118.75	(2.25)	5,120.56	5,120.06	0.50
10/13/2015 18:00	5,116.16	5,118.38	(2.22)	5,120.34	5,119.71	0.63
10/13/2015 19:00	5,115.48	5,118.06	(2.58)	5,120.00	5,119.39	0.61
10/13/2015 20:00	5,115.71	5,118.03	(2.32)	5,119.89	5,119.20	0.69
10/13/2015 21:00	5,115.71	5,117.99	(2.28)	5,119.55	5,119.06	0.49
10/13/2015 22:00	5,116.16	5,118.07	(1.91)	5,119.32	5,119.00	0.32
10/13/2015 23:00	5,116.95	5,118.47	(1.52)	5,119.55	5,119.11	0.44

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

Date/Time	Test No. 5			Test No. 6		
	Recorder #341298			Recorder #1245		
	Node =	Hydrant #121		Node =	Hydrant #1887	
	Elevation =	4817.61		Elevation =	4754.53	
	Observed	Simulated	Difference	Observed	Simulated	Difference
10/13/2015 0:00	5,118.79	5,120.09	(1.30)	5,117.47	5,119.97	(2.50)
10/13/2015 1:00	5,119.40	5,120.40	(1.00)	5,118.26	5,120.30	(2.04)
10/13/2015 2:00	5,119.88	5,120.72	(0.84)	5,118.71	5,120.64	(1.93)
10/13/2015 3:00	5,120.25	5,120.87	(0.62)	5,119.28	5,120.77	(1.49)
10/13/2015 4:00	5,120.37	5,120.91	(0.54)	5,119.39	5,120.80	(1.41)
10/13/2015 5:00	5,120.37	5,120.87	(0.50)	5,119.39	5,120.73	(1.34)
10/13/2015 6:00	5,119.52	5,120.52	(1.00)	5,118.38	5,120.32	(1.94)
10/13/2015 7:00	5,116.85	5,118.89	(2.04)	5,115.44	5,118.45	(3.01)
10/13/2015 8:00	5,117.46	5,117.87	(0.41)	5,116.23	5,117.35	(1.12)
10/13/2015 9:00	5,119.40	5,120.29	(0.89)	5,119.28	5,120.86	(1.58)
10/13/2015 10:00	5,119.28	5,120.45	(1.17)	5,118.38	5,121.02	(2.64)
10/13/2015 11:00	5,119.28	5,120.59	(1.31)	5,118.49	5,121.17	(2.68)
10/13/2015 12:00	5,119.15	5,120.72	(1.57)	5,118.04	5,121.30	(3.26)
10/13/2015 13:00	5,119.52	5,120.86	(1.34)	5,117.47	5,121.43	(3.96)
10/13/2015 14:00	5,119.76	5,121.01	(1.25)	5,117.92	5,121.58	(3.66)
10/13/2015 15:00	5,119.88	5,121.25	(1.37)	5,118.38	5,121.83	(3.45)
10/13/2015 16:00	5,117.58	5,119.61	(2.03)	5,114.09	5,119.34	(5.25)
10/13/2015 17:00	5,116.73	5,119.06	(2.33)	5,113.52	5,118.74	(5.22)
10/13/2015 18:00	5,116.49	5,118.70	(2.21)	5,113.86	5,118.37	(4.51)
10/13/2015 19:00	5,116.00	5,118.37	(2.37)	5,113.41	5,118.05	(4.64)
10/13/2015 20:00	5,116.24	5,118.31	(2.07)	5,113.98	5,118.02	(4.04)
10/13/2015 21:00	5,116.24	5,118.23	(1.99)	5,114.43	5,117.97	(3.54)
10/13/2015 22:00	5,116.61	5,118.28	(1.67)	5,115.10	5,118.05	(2.95)
10/13/2015 23:00	5,117.33	5,118.60	(1.27)	5,116.01	5,118.44	(2.43)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

Date/Time	Test No. 7			Test No. 8		
	Recorder #341289			Recorder #201250		
	Node =	Hydrant #1754		Node =	Hydrant #1125	
	Elevation =	4820.11		Elevation =	4779.50	
	Observed	Simulated	Difference	Observed	Simulated	Difference
10/13/2015 0:00	5,117.89	5,119.70	(1.81)	5,118.75	5,119.70	(0.95)
10/13/2015 1:00	5,118.74	5,120.08	(1.34)	5,119.77	5,120.09	(0.32)
10/13/2015 2:00	5,119.11	5,120.46	(1.35)	5,120.11	5,120.46	(0.35)
10/13/2015 3:00	5,119.59	5,120.57	(0.98)	5,120.78	5,120.57	0.21
10/13/2015 4:00	5,119.59	5,120.54	(0.95)	5,120.67	5,120.55	0.12
10/13/2015 5:00	5,119.47	5,120.42	(0.95)	5,120.67	5,120.43	0.24
10/13/2015 6:00	5,117.77	5,119.88	(2.11)	5,118.98	5,119.89	(0.91)
10/13/2015 7:00	5,114.01	5,117.38	(3.37)	5,115.37	5,117.39	(2.02)
10/13/2015 8:00	5,114.62	5,116.09	(1.47)	5,115.93	5,116.09	(0.16)
10/13/2015 9:00	5,117.41	5,118.77	(1.36)	5,118.41	5,118.78	(0.37)
10/13/2015 10:00	5,117.05	5,119.03	(1.98)	5,117.85	5,119.04	(1.19)
10/13/2015 11:00	5,117.29	5,119.25	(1.96)	5,117.96	5,119.26	(1.30)
10/13/2015 12:00	5,117.05	5,119.43	(2.38)	5,117.28	5,119.44	(2.16)
10/13/2015 13:00	5,117.29	5,119.62	(2.33)	5,117.17	5,119.62	(2.45)
10/13/2015 14:00	5,117.53	5,119.82	(2.29)	5,117.40	5,119.82	(2.42)
10/13/2015 15:00	5,118.14	5,120.19	(2.05)	5,117.96	5,120.20	(2.24)
10/13/2015 16:00	5,115.83	5,118.71	(2.88)	5,115.37	5,118.71	(3.34)
10/13/2015 17:00	5,114.86	5,117.98	(3.12)	5,114.58	5,117.99	(3.41)
10/13/2015 18:00	5,114.62	5,117.60	(2.98)	5,114.46	5,117.61	(3.15)
10/13/2015 19:00	5,114.01	5,117.27	(3.26)	5,113.90	5,117.28	(3.38)
10/13/2015 20:00	5,114.50	5,117.34	(2.84)	5,114.69	5,117.34	(2.65)
10/13/2015 21:00	5,114.62	5,117.34	(2.72)	5,115.14	5,117.35	(2.21)
10/13/2015 22:00	5,115.23	5,117.52	(2.29)	5,115.93	5,117.53	(1.60)
10/13/2015 23:00	5,116.44	5,118.09	(1.65)	5,117.17	5,118.09	(0.92)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

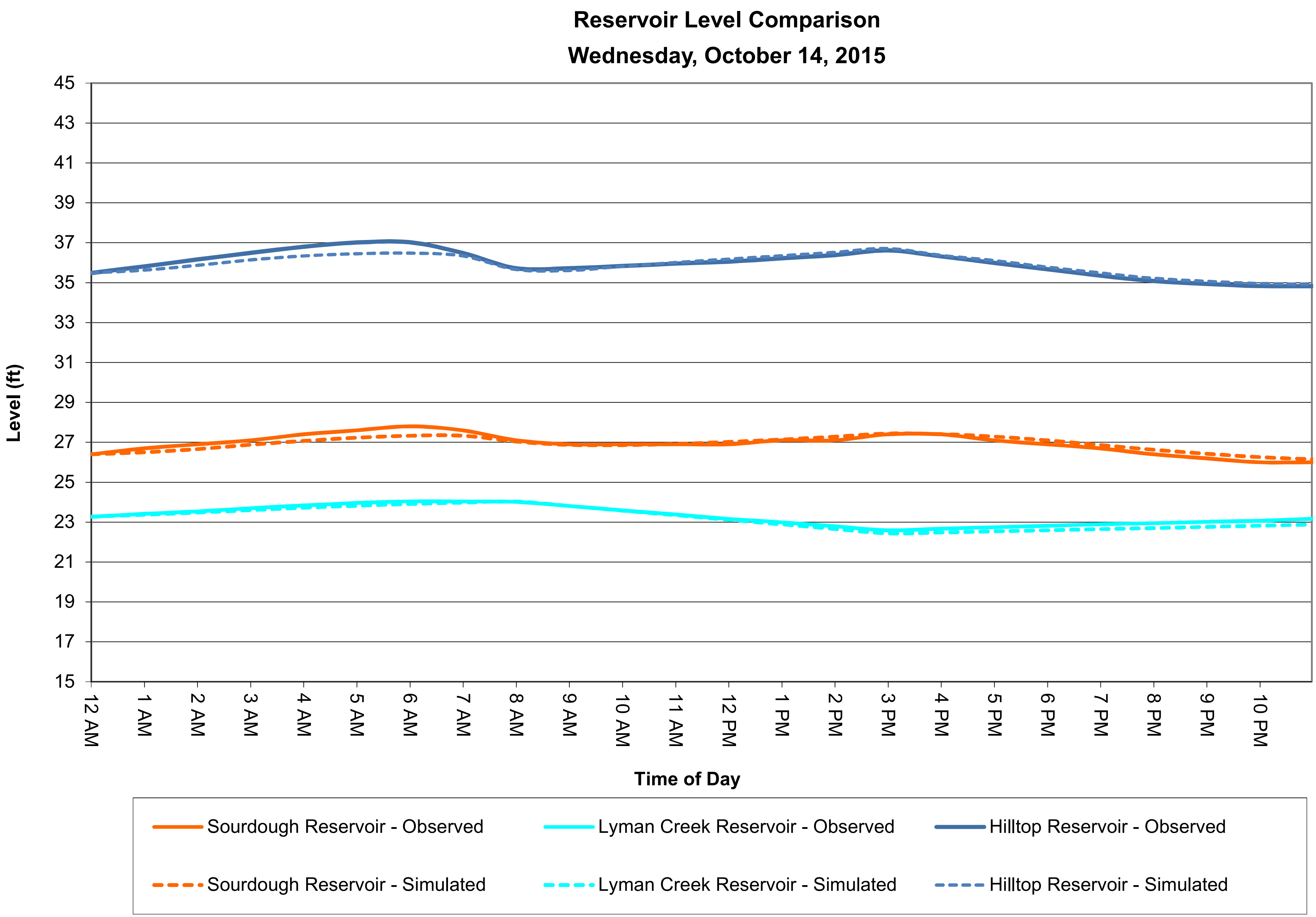
Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 9			Test No. 10		
	Recorder #1243			Recorder #1241		
	Node =	Hydrant #1025		Node =	Hydrant #	
	Elevation =	4755.67		Elevation =	0.00	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/13/2015 0:00	5,118.84	5,119.84	(1.00)	0.00	0.00	0.00
10/13/2015 1:00	5,119.63	5,120.20	(0.57)	0.00	0.00	0.00
10/13/2015 2:00	5,119.97	5,120.55	(0.58)	0.00	0.00	0.00
10/13/2015 3:00	5,120.53	5,120.68	(0.15)	0.00	0.00	0.00
10/13/2015 4:00	5,120.64	5,120.68	(0.04)	0.00	0.00	0.00
10/13/2015 5:00	5,120.64	5,120.58	0.06	0.00	0.00	0.00
10/13/2015 6:00	5,119.29	5,120.11	(0.82)	0.00	0.00	0.00
10/13/2015 7:00	5,116.02	5,117.91	(1.89)	0.00	0.00	0.00
10/13/2015 8:00	5,116.36	5,116.71	(0.35)	0.00	0.00	0.00
10/13/2015 9:00	5,118.73	5,119.39	(0.66)	0.00	0.00	0.00
10/13/2015 10:00	5,118.28	5,119.62	(1.34)	0.00	0.00	0.00
10/13/2015 11:00	5,118.39	5,119.82	(1.43)	0.00	0.00	0.00
10/13/2015 12:00	5,117.94	5,119.98	(2.04)	0.00	0.00	0.00
10/13/2015 13:00	5,118.05	5,120.16	(2.11)	0.00	0.00	0.00
10/13/2015 14:00	5,118.39	5,120.34	(1.95)	0.00	0.00	0.00
10/13/2015 15:00	5,118.73	5,120.68	(1.95)	0.00	0.00	0.00
10/13/2015 16:00	5,116.02	5,119.06	(3.04)	0.00	0.00	0.00
10/13/2015 17:00	5,115.23	5,118.38	(3.15)	0.00	0.00	0.00
10/13/2015 18:00	5,115.34	5,118.01	(2.67)	0.00	0.00	0.00
10/13/2015 19:00	5,114.89	5,117.68	(2.79)	0.00	0.00	0.00
10/13/2015 20:00	5,115.34	5,117.71	(2.37)	0.00	0.00	0.00
10/13/2015 21:00	5,115.68	5,117.69	(2.01)	0.00	0.00	0.00
10/13/2015 22:00	5,116.24	5,117.81	(1.57)	0.00	0.00	0.00
10/13/2015 23:00	5,117.26	5,118.28	(1.02)	0.00	0.00	0.00

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 11			Test No. 12		
	Recorder #1246			Recorder #1244		
	Node =	Hydrant #2712		Node =	Hydrant #1770	
	Elevation =	4692.64		Elevation =	4679.91	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/13/2015 0:00	4,926.52	4,925.22	1.30	5,028.86	5,028.23	0.63
10/13/2015 1:00	4,926.63	4,926.32	0.31	5,028.98	5,029.00	(0.02)
10/13/2015 2:00	4,926.86	4,927.07	(0.21)	5,029.32	5,029.58	(0.26)
10/13/2015 3:00	4,926.86	4,926.58	0.28	5,029.32	5,029.39	(0.07)
10/13/2015 4:00	4,925.39	4,925.66	(0.27)	5,028.53	5,028.93	(0.40)
10/13/2015 5:00	4,923.70	4,924.65	(0.95)	5,026.49	5,028.41	(1.92)
10/13/2015 6:00	4,918.85	4,922.04	(3.19)	5,021.53	5,026.88	(5.35)
10/13/2015 7:00	4,910.61	4,921.58	(10.97)	5,014.42	5,026.27	(11.85)
10/13/2015 8:00	4,915.23	4,921.52	(6.29)	5,007.99	5,026.17	(18.18)
10/13/2015 9:00	4,920.54	4,921.62	(1.08)	5,011.72	5,018.16	(6.44)
10/13/2015 10:00	4,921.78	4,921.63	0.15	5,012.39	5,018.09	(5.70)
10/13/2015 11:00	4,922.57	4,921.65	0.92	5,013.63	5,018.00	(4.37)
10/13/2015 12:00	4,922.34	4,921.65	0.69	5,013.41	5,017.89	(4.48)
10/13/2015 13:00	4,921.10	4,921.66	(0.56)	5,012.96	5,017.79	(4.83)
10/13/2015 14:00	4,922.23	4,921.67	0.56	5,013.41	5,017.68	(4.27)
10/13/2015 15:00	4,922.79	4,921.69	1.10	5,019.95	5,017.67	2.28
10/13/2015 16:00	4,922.91	4,921.68	1.23	5,022.77	5,025.14	(2.37)
10/13/2015 17:00	4,922.34	4,921.66	0.68	5,022.66	5,025.09	(2.43)
10/13/2015 18:00	4,921.33	4,921.65	(0.32)	5,020.74	5,025.14	(4.40)
10/13/2015 19:00	4,919.41	4,921.65	(2.24)	5,020.29	5,025.20	(4.91)
10/13/2015 20:00	4,919.63	4,921.67	(2.04)	5,021.42	5,025.33	(3.91)
10/13/2015 21:00	4,920.76	4,921.69	(0.93)	5,022.88	5,025.44	(2.56)
10/13/2015 22:00	4,920.20	4,921.73	(1.53)	5,023.00	5,025.59	(2.59)
10/13/2015 23:00	4,923.58	4,923.56	0.02	5,026.83	5,026.84	(0.01)


Reservoir Level Comparison
Wednesday, October 14, 2015
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
Level (ft)
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

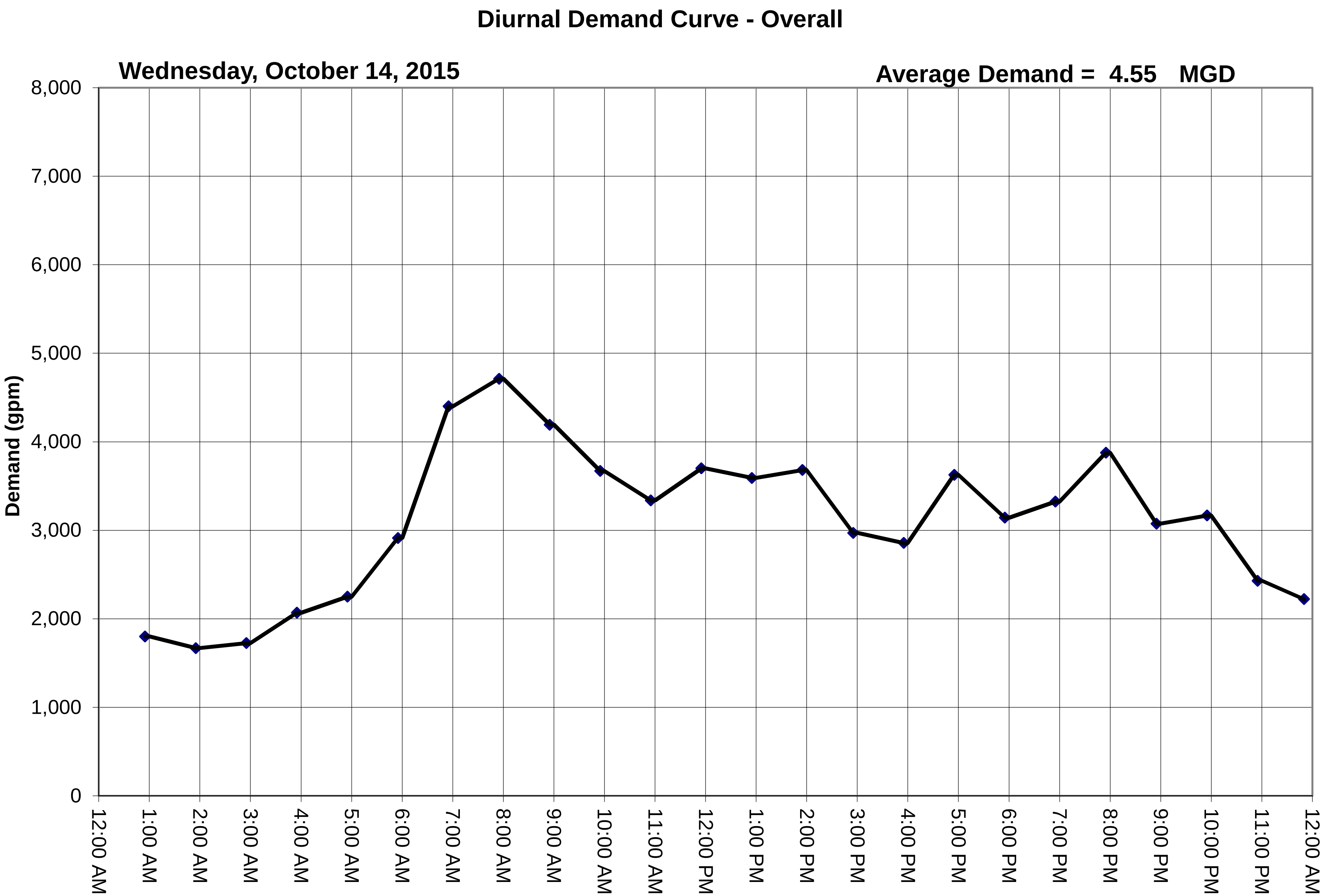
Water Distribution System Hydraulic Model Calibration
City of Bozeman

Reservoir Level Calibration
(Tower Level in ft)

Date/Time	Time	Sourdough Reservoir Level			Lyman Reservoir Level			Hilltop Reservoir Level		
		Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
10/14/2015 0:00	0:00	26.40	26.40	0.00	23.27	23.27	0.00	35.49	35.49	0.00
10/14/2015 1:00	1:00	26.70	26.50	0.20	23.42	23.37	0.05	35.82	35.63	0.19
10/14/2015 2:00	2:00	26.90	26.66	0.24	23.54	23.48	0.06	36.16	35.87	0.29
10/14/2015 3:00	3:00	27.10	26.88	0.22	23.69	23.60	0.09	36.49	36.14	0.35
10/14/2015 4:00	4:00	27.40	27.07	0.33	23.84	23.72	0.12	36.80	36.34	0.46
10/14/2015 5:00	5:00	27.60	27.23	0.37	23.96	23.82	0.14	37.01	36.45	0.56
10/14/2015 6:00	6:00	27.80	27.33	0.47	24.04	23.91	0.13	37.03	36.48	0.55
10/14/2015 7:00	7:00	27.60	27.33	0.27	24.04	23.98	0.06	36.49	36.34	0.15
10/14/2015 8:00	8:00	27.10	27.04	0.06	24.01	24.03	-0.02	35.72	35.66	0.06
10/14/2015 9:00	9:00	26.90	26.87	0.03	23.81	23.81	0.00	35.73	35.61	0.12
10/14/2015 10:00	10:00	26.90	26.86	0.04	23.59	23.58	0.01	35.83	35.82	0.01
10/14/2015 11:00	11:00	26.90	26.92	-0.02	23.38	23.35	0.03	35.96	36.01	-0.05
10/14/2015 12:00	12:00	26.90	27.02	-0.12	23.16	23.12	0.04	36.06	36.18	-0.12
10/14/2015 13:00	13:00	27.10	27.14	-0.04	22.99	22.89	0.10	36.22	36.35	-0.13
10/14/2015 14:00	14:00	27.10	27.28	-0.18	22.79	22.66	0.13	36.39	36.52	-0.13
10/14/2015 15:00	15:00	27.40	27.44	-0.04	22.59	22.44	0.15	36.62	36.71	-0.09
10/14/2015 16:00	16:00	27.40	27.41	-0.01	22.67	22.48	0.19	36.32	36.37	-0.05
10/14/2015 17:00	17:00	27.10	27.29	-0.19	22.74	22.54	0.20	35.99	36.11	-0.12
10/14/2015 18:00	18:00	26.90	27.10	-0.20	22.82	22.59	0.23	35.68	35.78	-0.10
10/14/2015 19:00	19:00	26.70	26.87	-0.17	22.90	22.65	0.25	35.36	35.49	-0.13
10/14/2015 20:00	20:00	26.40	26.63	-0.23	22.95	22.70	0.25	35.08	35.22	-0.14
10/14/2015 21:00	21:00	26.20	26.43	-0.23	23.02	22.76	0.26	34.94	35.07	-0.13
10/14/2015 22:00	22:00	26.00	26.26	-0.26	23.07	22.82	0.25	34.83	34.96	-0.13
10/14/2015 23:00	23:00	26.00	26.15	-0.15	23.17	22.88	0.29	34.83	34.92	-0.09

Diurnal Demand Pattern - Overall

Wednesday, October 14, 2015



Diurnal Demand Curve - Overall
Wednesday, October 14, 2015
Average Demand = 4.55 MGD
Demand (gpm)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 1			Test No. 2		
	Recorder #1242			Recorder #1240		
	Node =	Hydrant #2107		Node =	Hydrant #433	
	Elevation =	5024.74		Elevation =	4969.52	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/14/2015 0:00	5,118.72	5,119.42	(0.70)	5,119.23	5,119.99	(0.76)
10/14/2015 1:00	5,119.17	5,119.69	(0.52)	5,119.46	5,120.17	(0.71)
10/14/2015 2:00	5,119.62	5,120.00	(0.38)	5,119.80	5,120.40	(0.60)
10/14/2015 3:00	5,120.07	5,120.16	(0.09)	5,120.25	5,120.60	(0.35)
10/14/2015 4:00	5,120.19	5,120.24	(0.05)	5,120.36	5,120.75	(0.39)
10/14/2015 5:00	5,120.30	5,120.24	0.06	5,120.47	5,120.83	(0.36)
10/14/2015 6:00	5,119.28	5,119.97	(0.69)	5,120.25	5,120.78	(0.53)
10/14/2015 7:00	5,117.14	5,118.63	(1.49)	5,119.23	5,120.27	(1.04)
10/14/2015 8:00	5,116.91	5,117.76	(0.85)	5,118.89	5,119.70	(0.81)
10/14/2015 9:00	5,118.49	5,119.37	(0.88)	5,119.23	5,120.24	(1.01)
10/14/2015 10:00	5,117.93	5,119.57	(1.64)	5,119.23	5,120.35	(1.12)
10/14/2015 11:00	5,117.48	5,119.75	(2.27)	5,119.35	5,120.48	(1.13)
10/14/2015 12:00	5,117.37	5,119.93	(2.56)	5,119.46	5,120.62	(1.16)
10/14/2015 13:00	5,117.48	5,120.12	(2.64)	5,119.68	5,120.78	(1.10)
10/14/2015 14:00	5,117.48	5,120.32	(2.84)	5,119.91	5,120.95	(1.04)
10/14/2015 15:00	5,117.48	5,120.61	(3.13)	5,120.25	5,121.17	(0.92)
10/14/2015 16:00	5,115.90	5,119.60	(3.70)	5,119.57	5,120.67	(1.10)
10/14/2015 17:00	5,115.56	5,119.16	(3.60)	5,119.35	5,120.41	(1.06)
10/14/2015 18:00	5,115.22	5,118.86	(3.64)	5,119.12	5,120.13	(1.01)
10/14/2015 19:00	5,115.90	5,118.59	(2.69)	5,118.67	5,119.87	(1.20)
10/14/2015 20:00	5,116.24	5,118.53	(2.29)	5,118.44	5,119.69	(1.25)
10/14/2015 21:00	5,116.80	5,118.48	(1.68)	5,118.44	5,119.56	(1.12)
10/14/2015 22:00	5,117.03	5,118.52	(1.49)	5,118.22	5,119.48	(1.26)
10/14/2015 23:00	5,117.70	5,118.80	(1.10)	5,118.33	5,119.53	(1.20)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 3			Test No. 4		
	Recorder #1251			Recorder #1249		
	Node =	Hydrant #490		Node =	Hydrant #278	
	Elevation =	4880.25		Elevation =	4861.19	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/14/2015 0:00	5,117.85	5,119.18	(1.33)	5,119.89	5,119.64	0.25
10/14/2015 1:00	5,118.30	5,119.49	(1.19)	5,120.23	5,119.85	0.38
10/14/2015 2:00	5,118.87	5,119.82	(0.95)	5,120.56	5,120.11	0.45
10/14/2015 3:00	5,119.32	5,119.97	(0.65)	5,120.90	5,120.31	0.59
10/14/2015 4:00	5,119.20	5,120.02	(0.82)	5,121.13	5,120.45	0.68
10/14/2015 5:00	5,119.09	5,119.98	(0.89)	5,121.13	5,120.50	0.63
10/14/2015 6:00	5,117.85	5,119.63	(1.78)	5,120.79	5,120.38	0.41
10/14/2015 7:00	5,115.03	5,117.94	(2.91)	5,119.55	5,119.61	(0.06)
10/14/2015 8:00	5,114.92	5,116.95	(2.03)	5,119.32	5,118.90	0.42
10/14/2015 9:00	5,117.40	5,119.05	(1.65)	5,120.00	5,119.87	0.13
10/14/2015 10:00	5,117.29	5,119.29	(2.00)	5,119.77	5,120.03	(0.26)
10/14/2015 11:00	5,117.17	5,119.50	(2.33)	5,119.55	5,120.20	(0.65)
10/14/2015 12:00	5,117.62	5,119.69	(2.07)	5,119.66	5,120.36	(0.70)
10/14/2015 13:00	5,117.85	5,119.89	(2.04)	5,119.89	5,120.53	(0.64)
10/14/2015 14:00	5,118.08	5,120.10	(2.02)	5,120.23	5,120.71	(0.48)
10/14/2015 15:00	5,118.53	5,120.42	(1.89)	5,120.56	5,120.95	(0.39)
10/14/2015 16:00	5,116.61	5,119.16	(2.55)	5,120.34	5,120.17	0.17
10/14/2015 17:00	5,116.38	5,118.64	(2.26)	5,120.11	5,119.83	0.28
10/14/2015 18:00	5,115.59	5,118.32	(2.73)	5,119.77	5,119.53	0.24
10/14/2015 19:00	5,115.14	5,118.05	(2.91)	5,119.44	5,119.25	0.19
10/14/2015 20:00	5,115.26	5,118.03	(2.77)	5,119.21	5,119.10	0.11
10/14/2015 21:00	5,115.71	5,118.03	(2.32)	5,118.98	5,119.00	(0.02)
10/14/2015 22:00	5,115.82	5,118.12	(2.30)	5,118.87	5,118.96	(0.09)
10/14/2015 23:00	5,116.50	5,118.49	(1.99)	5,118.98	5,119.08	(0.10)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 5			Test No. 6		
	Recorder #341298			Recorder #1245		
	Node =	Hydrant #121		Node =	Hydrant #1887	
	Elevation =	4817.61		Elevation =	4754.53	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/14/2015 0:00	5,118.06	5,119.27	(1.21)	5,117.14	5,119.16	(2.02)
10/14/2015 1:00	5,118.67	5,119.56	(0.89)	5,117.47	5,119.47	(2.00)
10/14/2015 2:00	5,119.15	5,119.88	(0.73)	5,118.15	5,119.80	(1.65)
10/14/2015 3:00	5,119.64	5,120.04	(0.40)	5,118.71	5,119.96	(1.25)
10/14/2015 4:00	5,119.64	5,120.11	(0.47)	5,118.60	5,120.01	(1.41)
10/14/2015 5:00	5,119.52	5,120.10	(0.58)	5,118.60	5,119.97	(1.37)
10/14/2015 6:00	5,118.55	5,119.80	(1.25)	5,117.36	5,119.62	(2.26)
10/14/2015 7:00	5,116.12	5,118.35	(2.23)	5,114.65	5,117.95	(3.30)
10/14/2015 8:00	5,116.36	5,117.43	(1.07)	5,115.33	5,116.96	(1.63)
10/14/2015 9:00	5,118.67	5,119.76	(1.09)	5,118.83	5,120.36	(1.53)
10/14/2015 10:00	5,118.43	5,119.95	(1.52)	5,117.92	5,120.56	(2.64)
10/14/2015 11:00	5,118.43	5,120.13	(1.70)	5,117.14	5,120.74	(3.60)
10/14/2015 12:00	5,118.79	5,120.30	(1.51)	5,117.14	5,120.91	(3.77)
10/14/2015 13:00	5,118.67	5,120.47	(1.80)	5,116.91	5,121.08	(4.17)
10/14/2015 14:00	5,119.03	5,120.66	(1.63)	5,117.25	5,121.27	(4.02)
10/14/2015 15:00	5,119.15	5,120.93	(1.78)	5,117.36	5,121.54	(4.18)
10/14/2015 16:00	5,116.97	5,119.40	(2.43)	5,113.75	5,119.15	(5.40)
10/14/2015 17:00	5,116.61	5,118.92	(2.31)	5,113.52	5,118.64	(5.12)
10/14/2015 18:00	5,116.12	5,118.61	(2.49)	5,113.52	5,118.31	(4.79)
10/14/2015 19:00	5,115.64	5,118.33	(2.69)	5,113.30	5,118.04	(4.74)
10/14/2015 20:00	5,115.88	5,118.28	(2.40)	5,113.75	5,118.02	(4.27)
10/14/2015 21:00	5,116.12	5,118.25	(2.13)	5,114.54	5,118.01	(3.47)
10/14/2015 22:00	5,116.36	5,118.31	(1.95)	5,114.99	5,118.10	(3.11)
10/14/2015 23:00	5,116.85	5,118.61	(1.76)	5,115.78	5,118.46	(2.68)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 7			Test No. 8		
	Recorder #341289			Recorder #201250		
	Node =	Hydrant #1754		Node =	Hydrant #1125	
	Elevation =	4820.11		Elevation =	4779.50	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/14/2015 0:00	5,117.53	5,118.91	(1.38)	5,118.64	5,118.91	(0.27)
10/14/2015 1:00	5,117.89	5,119.27	(1.38)	5,119.09	5,119.27	(0.18)
10/14/2015 2:00	5,118.62	5,119.64	(1.02)	5,119.77	5,119.64	0.13
10/14/2015 3:00	5,118.99	5,119.76	(0.77)	5,120.22	5,119.77	0.45
10/14/2015 4:00	5,118.99	5,119.77	(0.78)	5,120.11	5,119.78	0.33
10/14/2015 5:00	5,118.62	5,119.69	(1.07)	5,119.99	5,119.69	0.30
10/14/2015 6:00	5,116.80	5,119.21	(2.41)	5,118.19	5,119.22	(1.03)
10/14/2015 7:00	5,113.53	5,116.98	(3.45)	5,114.92	5,116.99	(2.07)
10/14/2015 8:00	5,113.77	5,115.81	(2.04)	5,115.25	5,115.81	(0.56)
10/14/2015 9:00	5,116.80	5,118.37	(1.57)	5,118.07	5,118.38	(0.31)
10/14/2015 10:00	5,116.32	5,118.66	(2.34)	5,117.40	5,118.67	(1.27)
10/14/2015 11:00	5,116.56	5,118.91	(2.35)	5,117.17	5,118.92	(1.75)
10/14/2015 12:00	5,116.56	5,119.12	(2.56)	5,117.17	5,119.13	(1.96)
10/14/2015 13:00	5,116.80	5,119.35	(2.55)	5,117.28	5,119.35	(2.07)
10/14/2015 14:00	5,117.05	5,119.58	(2.53)	5,117.28	5,119.59	(2.31)
10/14/2015 15:00	5,117.77	5,119.96	(2.19)	5,117.85	5,119.97	(2.12)
10/14/2015 16:00	5,115.35	5,118.58	(3.23)	5,115.25	5,118.59	(3.34)
10/14/2015 17:00	5,114.74	5,117.94	(3.20)	5,114.69	5,117.95	(3.26)
10/14/2015 18:00	5,114.26	5,117.61	(3.35)	5,113.90	5,117.62	(3.72)
10/14/2015 19:00	5,113.77	5,117.33	(3.56)	5,113.79	5,117.34	(3.55)
10/14/2015 20:00	5,113.89	5,117.39	(3.50)	5,114.58	5,117.40	(2.82)
10/14/2015 21:00	5,114.74	5,117.46	(2.72)	5,115.59	5,117.47	(1.88)
10/14/2015 22:00	5,115.10	5,117.63	(2.53)	5,116.04	5,117.64	(1.60)
10/14/2015 23:00	5,115.95	5,118.13	(2.18)	5,117.06	5,118.14	(1.08)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

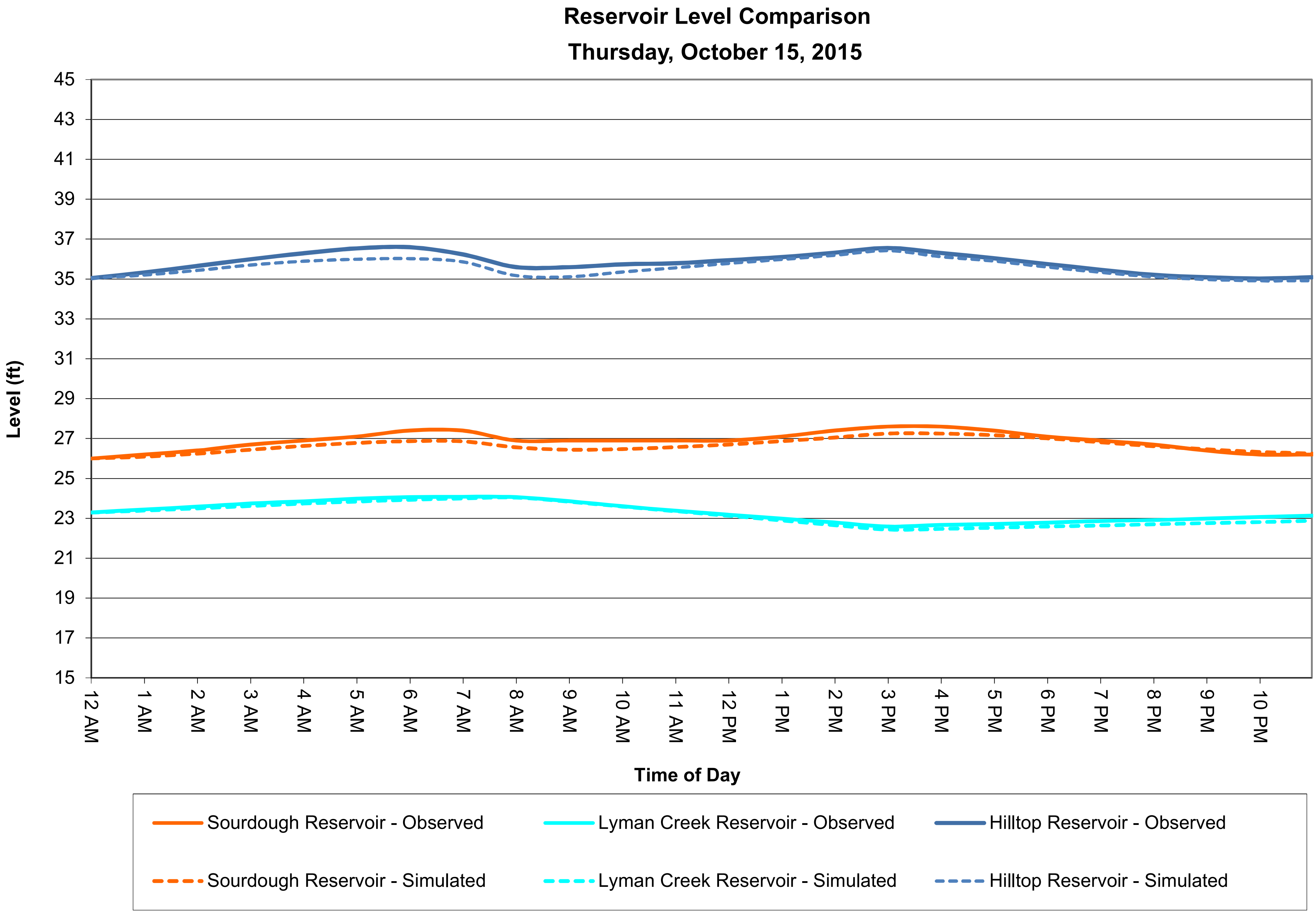
Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 9			Test No. 10		
	Recorder #1243			Recorder #1241		
	Node =	Hydrant #1025		Node =	Hydrant #	
	Elevation =	4755.67		Elevation =	0.00	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/14/2015 0:00	5,118.50	5,119.04	(0.54)	0.00	0.00	0.00
10/14/2015 1:00	5,118.73	5,119.38	(0.65)	0.00	0.00	0.00
10/14/2015 2:00	5,119.52	5,119.73	(0.21)	0.00	0.00	0.00
10/14/2015 3:00	5,119.97	5,119.87	0.10	0.00	0.00	0.00
10/14/2015 4:00	5,119.85	5,119.90	(0.05)	0.00	0.00	0.00
10/14/2015 5:00	5,119.74	5,119.84	(0.10)	0.00	0.00	0.00
10/14/2015 6:00	5,118.39	5,119.42	(1.03)	0.00	0.00	0.00
10/14/2015 7:00	5,115.34	5,117.48	(2.14)	0.00	0.00	0.00
10/14/2015 8:00	5,115.45	5,116.38	(0.93)	0.00	0.00	0.00
10/14/2015 9:00	5,118.28	5,118.95	(0.67)	0.00	0.00	0.00
10/14/2015 10:00	5,117.71	5,119.21	(1.50)	0.00	0.00	0.00
10/14/2015 11:00	5,117.71	5,119.45	(1.74)	0.00	0.00	0.00
10/14/2015 12:00	5,117.60	5,119.65	(2.05)	0.00	0.00	0.00
10/14/2015 13:00	5,117.49	5,119.86	(2.37)	0.00	0.00	0.00
10/14/2015 14:00	5,117.82	5,120.08	(2.26)	0.00	0.00	0.00
10/14/2015 15:00	5,118.28	5,120.42	(2.14)	0.00	0.00	0.00
10/14/2015 16:00	5,115.68	5,118.89	(3.21)	0.00	0.00	0.00
10/14/2015 17:00	5,115.23	5,118.32	(3.09)	0.00	0.00	0.00
10/14/2015 18:00	5,114.89	5,117.99	(3.10)	0.00	0.00	0.00
10/14/2015 19:00	5,114.55	5,117.71	(3.16)	0.00	0.00	0.00
10/14/2015 20:00	5,115.00	5,117.74	(2.74)	0.00	0.00	0.00
10/14/2015 21:00	5,115.91	5,117.76	(1.85)	0.00	0.00	0.00
10/14/2015 22:00	5,116.24	5,117.88	(1.64)	0.00	0.00	0.00
10/14/2015 23:00	5,117.03	5,118.31	(1.28)	0.00	0.00	0.00

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

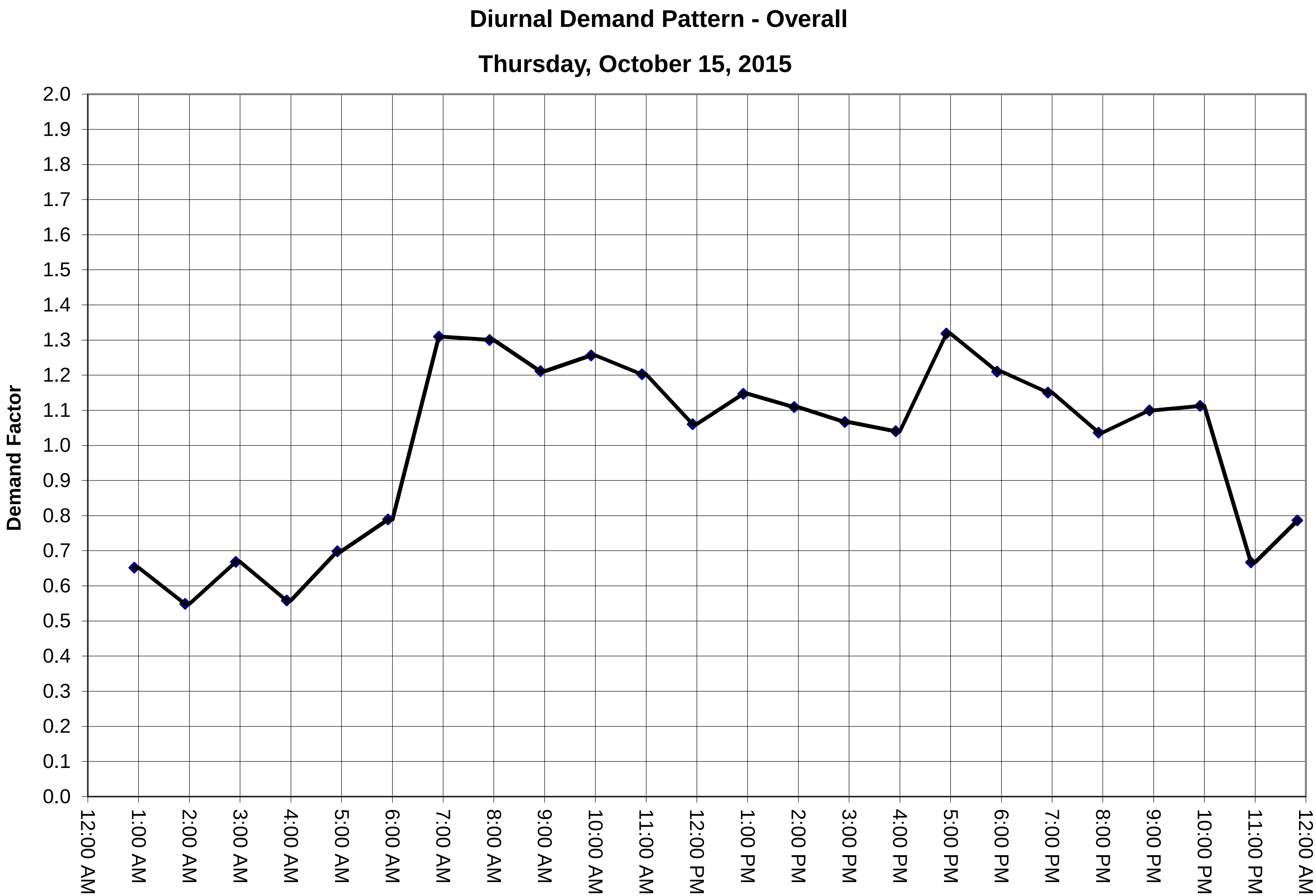
	Test No. 11			Test No. 12		
	Recorder #1246			Recorder #1244		
	Node =	Hydrant #2712		Node =	Hydrant #1770	
	Elevation =	4692.64		Elevation =	4679.91	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/14/2015 0:00	4,925.50	4,925.64	(0.14)	5,028.07	5,028.47	(0.40)
10/14/2015 1:00	4,925.61	4,926.66	(1.05)	5,028.30	5,029.19	(0.89)
10/14/2015 2:00	4,926.97	4,927.35	(0.38)	5,029.09	5,029.73	(0.64)
10/14/2015 3:00	4,927.31	4,926.90	0.41	5,029.43	5,029.56	(0.13)
10/14/2015 4:00	4,925.50	4,926.05	(0.55)	5,028.41	5,029.15	(0.74)
10/14/2015 5:00	4,923.70	4,925.11	(1.41)	5,026.95	5,028.68	(1.73)
10/14/2015 6:00	4,916.59	4,922.70	(6.11)	5,019.84	5,027.27	(7.43)
10/14/2015 7:00	4,910.38	4,921.61	(11.23)	5,014.20	5,026.33	(12.13)
10/14/2015 8:00	4,916.36	4,921.56	(5.20)	5,008.89	5,026.24	(17.35)
10/14/2015 9:00	4,920.99	4,921.64	(0.65)	5,012.73	5,018.15	(5.42)
10/14/2015 10:00	4,921.21	4,921.65	(0.44)	5,011.49	5,018.07	(6.58)
10/14/2015 11:00	4,922.34	4,921.66	0.68	5,012.39	5,017.96	(5.57)
10/14/2015 12:00	4,922.23	4,921.67	0.56	5,012.17	5,017.86	(5.69)
10/14/2015 13:00	4,921.44	4,921.67	(0.23)	5,012.73	5,017.75	(5.02)
10/14/2015 14:00	4,922.23	4,921.68	0.55	5,013.18	5,017.65	(4.47)
10/14/2015 15:00	4,922.23	4,921.72	0.51	5,020.63	5,017.63	3.00
10/14/2015 16:00	4,923.36	4,921.71	1.65	5,021.42	5,025.14	(3.72)
10/14/2015 17:00	4,920.20	4,921.67	(1.47)	5,020.97	5,025.10	(4.13)
10/14/2015 18:00	4,920.42	4,921.67	(1.25)	5,021.76	5,025.14	(3.38)
10/14/2015 19:00	4,920.88	4,921.67	(0.79)	5,022.55	5,025.20	(2.65)
10/14/2015 20:00	4,919.41	4,921.69	(2.28)	5,021.64	5,025.32	(3.68)
10/14/2015 21:00	4,918.96	4,921.72	(2.76)	5,020.85	5,025.44	(4.59)
10/14/2015 22:00	4,921.89	4,921.76	0.13	5,024.69	5,025.58	(0.89)
10/14/2015 23:00	4,924.26	4,924.11	0.15	5,027.62	5,027.11	0.51

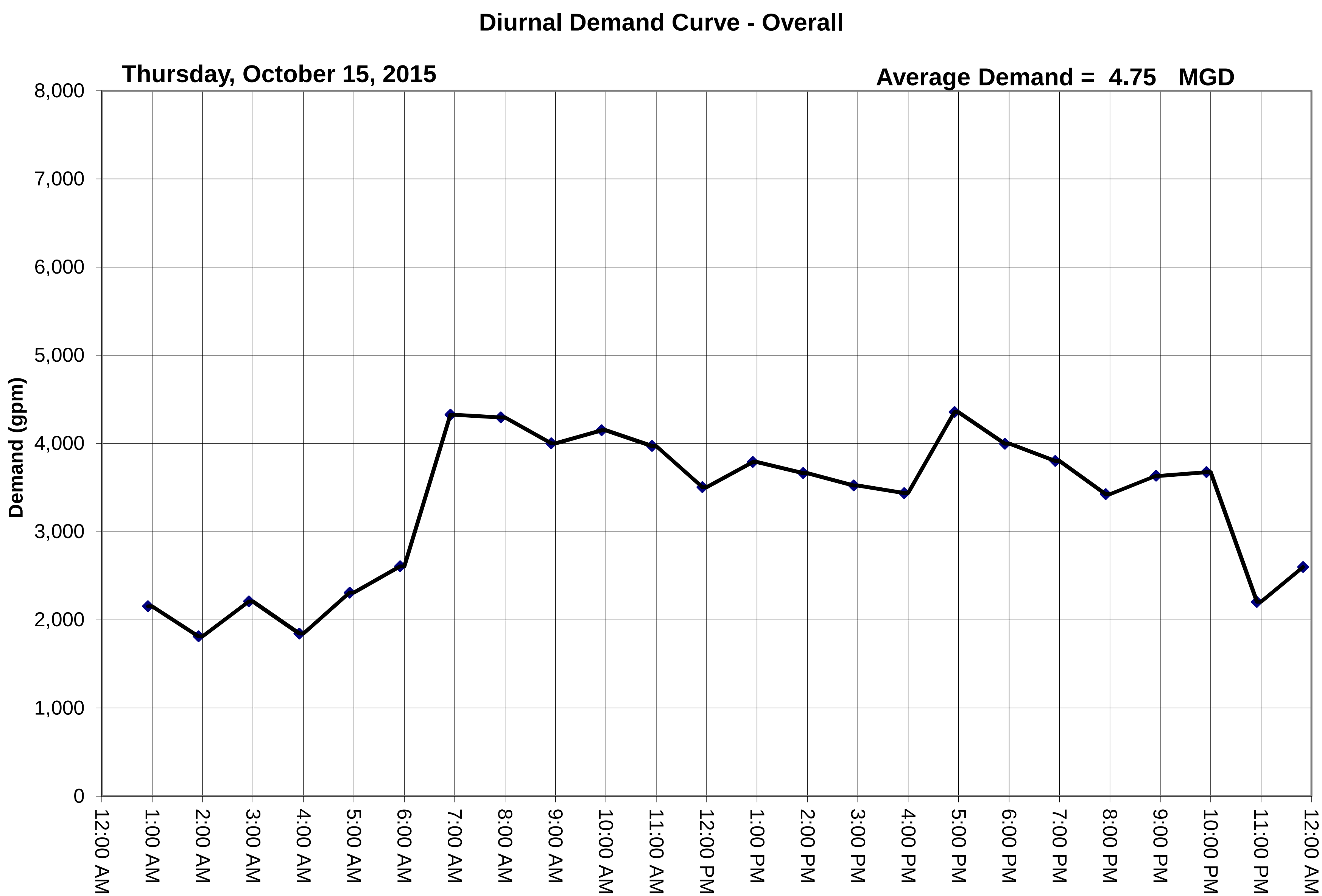

Reservoir Level Comparison
Thursday, October 15, 2015
Level (ft)
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Reservoir Level Calibration
(Tower Level in ft)

Date/Time	Time	Sourdough Reservoir Level			Lyman Reservoir Level			Hilltop Reservoir Level		
		Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
10/15/2015 0:00	0:00	26.00	26.00	0.00	23.29	23.29	0.00	35.04	35.04	0.00
10/15/2015 1:00	1:00	26.20	26.09	0.11	23.45	23.39	0.06	35.33	35.20	0.13
10/15/2015 2:00	2:00	26.40	26.24	0.16	23.59	23.50	0.09	35.65	35.43	0.22
10/15/2015 3:00	3:00	26.70	26.44	0.26	23.74	23.62	0.12	35.99	35.70	0.29
10/15/2015 4:00	4:00	26.90	26.63	0.27	23.86	23.74	0.12	36.29	35.89	0.40
10/15/2015 5:00	5:00	27.10	26.78	0.32	23.99	23.84	0.15	36.54	35.99	0.55
10/15/2015 6:00	6:00	27.40	26.87	0.53	24.06	23.93	0.13	36.59	36.02	0.57
10/15/2015 7:00	7:00	27.40	26.86	0.54	24.08	24.00	0.08	36.23	35.86	0.37
10/15/2015 8:00	8:00	26.90	26.56	0.34	24.06	24.04	0.02	35.60	35.17	0.43
10/15/2015 9:00	9:00	26.90	26.44	0.46	23.86	23.83	0.03	35.59	35.11	0.48
10/15/2015 10:00	10:00	26.90	26.47	0.43	23.61	23.59	0.02	35.74	35.35	0.39
10/15/2015 11:00	11:00	26.90	26.57	0.33	23.38	23.36	0.02	35.79	35.56	0.23
10/15/2015 12:00	12:00	26.90	26.70	0.20	23.18	23.13	0.05	35.94	35.78	0.16
10/15/2015 13:00	13:00	27.10	26.87	0.23	22.99	22.90	0.09	36.10	35.98	0.12
10/15/2015 14:00	14:00	27.40	27.05	0.35	22.79	22.66	0.13	36.32	36.19	0.13
10/15/2015 15:00	15:00	27.60	27.25	0.35	22.59	22.44	0.15	36.55	36.42	0.13
10/15/2015 16:00	16:00	27.60	27.25	0.35	22.67	22.47	0.20	36.31	36.12	0.19
10/15/2015 17:00	17:00	27.40	27.17	0.23	22.71	22.53	0.18	36.04	35.90	0.14
10/15/2015 18:00	18:00	27.10	27.01	0.09	22.78	22.59	0.19	35.75	35.60	0.15
10/15/2015 19:00	19:00	26.90	26.82	0.08	22.86	22.64	0.22	35.47	35.34	0.13
10/15/2015 20:00	20:00	26.70	26.62	0.08	22.91	22.70	0.21	35.21	35.11	0.10
10/15/2015 21:00	21:00	26.40	26.46	-0.06	22.99	22.76	0.23	35.09	34.98	0.11
10/15/2015 22:00	22:00	26.20	26.33	-0.13	23.06	22.81	0.25	35.02	34.91	0.11
10/15/2015 23:00	23:00	26.20	26.25	-0.05	23.13	22.88	0.25	35.09	34.92	0.17


Diurnal Demand Pattern - Overall
Thursday, October 15, 2015
Demand Factor
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM



Diurnal Demand Curve - Overall
Thursday, October 15, 2015
Average Demand = 4.75 MGD
Demand (gpm)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 1			Test No. 2		
	Recorder #1242			Recorder #1240		
	Node =	Hydrant #2107		Node =	Hydrant #433	
	Elevation =	5024.74		Elevation =	4969.52	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/15/2015 0:00	5,118.38	5,118.98	(0.60)	5,118.67	5,119.56	(0.89)
10/15/2015 1:00	5,118.95	5,119.25	(0.30)	5,118.89	5,119.74	(0.85)
10/15/2015 2:00	5,119.51	5,119.55	(0.04)	5,119.35	5,119.97	(0.62)
10/15/2015 3:00	5,119.85	5,119.71	0.14	5,119.57	5,120.16	(0.59)
10/15/2015 4:00	5,120.19	5,119.78	0.41	5,119.91	5,120.30	(0.39)
10/15/2015 5:00	5,120.30	5,119.77	0.53	5,120.02	5,120.38	(0.36)
10/15/2015 6:00	5,119.96	5,119.48	0.48	5,119.91	5,120.31	(0.40)
10/15/2015 7:00	5,118.16	5,118.09	0.07	5,119.23	5,119.77	(0.54)
10/15/2015 8:00	5,117.70	5,117.20	0.50	5,118.89	5,119.18	(0.29)
10/15/2015 9:00	5,118.38	5,118.87	(0.49)	5,119.12	5,119.77	(0.65)
10/15/2015 10:00	5,118.38	5,119.11	(0.73)	5,119.35	5,119.92	(0.57)
10/15/2015 11:00	5,118.27	5,119.33	(1.06)	5,119.35	5,120.09	(0.74)
10/15/2015 12:00	5,118.16	5,119.55	(1.39)	5,119.35	5,120.27	(0.92)
10/15/2015 13:00	5,118.27	5,119.78	(1.51)	5,119.57	5,120.46	(0.89)
10/15/2015 14:00	5,118.49	5,120.02	(1.53)	5,120.02	5,120.67	(0.65)
10/15/2015 15:00	5,118.49	5,120.36	(1.87)	5,120.25	5,120.94	(0.69)
10/15/2015 16:00	5,116.91	5,119.36	(2.45)	5,119.68	5,120.46	(0.78)
10/15/2015 17:00	5,116.80	5,118.94	(2.14)	5,119.57	5,120.23	(0.66)
10/15/2015 18:00	5,116.69	5,118.68	(1.99)	5,119.12	5,119.99	(0.87)
10/15/2015 19:00	5,117.03	5,118.44	(1.41)	5,118.78	5,119.77	(0.99)
10/15/2015 20:00	5,117.14	5,118.43	(1.29)	5,118.67	5,119.63	(0.96)
10/15/2015 21:00	5,117.37	5,118.42	(1.05)	5,118.56	5,119.53	(0.97)
10/15/2015 22:00	5,117.48	5,118.50	(1.02)	5,118.56	5,119.50	(0.94)
10/15/2015 23:00	5,118.27	5,118.83	(0.56)	5,118.78	5,119.59	(0.81)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 3			Test No. 4		
	Recorder #1251			Recorder #1249		
	Node =	Hydrant #490		Node =	Hydrant #278	
	Elevation =	4880.25		Elevation =	4861.19	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/15/2015 0:00	5,117.40	5,118.73	(1.33)	5,119.32	5,119.20	0.12
10/15/2015 1:00	5,117.85	5,119.05	(1.20)	5,119.66	5,119.41	0.25
10/15/2015 2:00	5,118.41	5,119.38	(0.97)	5,120.00	5,119.67	0.33
10/15/2015 3:00	5,118.64	5,119.52	(0.88)	5,120.34	5,119.87	0.47
10/15/2015 4:00	5,118.75	5,119.56	(0.81)	5,120.56	5,120.00	0.56
10/15/2015 5:00	5,118.87	5,119.51	(0.64)	5,120.79	5,120.04	0.75
10/15/2015 6:00	5,118.19	5,119.13	(0.94)	5,120.56	5,119.91	0.65
10/15/2015 7:00	5,115.93	5,117.39	(1.46)	5,119.77	5,119.10	0.67
10/15/2015 8:00	5,115.48	5,116.36	(0.88)	5,119.32	5,118.36	0.96
10/15/2015 9:00	5,116.83	5,118.54	(1.71)	5,119.66	5,119.38	0.28
10/15/2015 10:00	5,117.17	5,118.81	(1.64)	5,119.77	5,119.58	0.19
10/15/2015 11:00	5,117.06	5,119.06	(2.00)	5,119.89	5,119.78	0.11
10/15/2015 12:00	5,117.40	5,119.30	(1.90)	5,120.00	5,119.98	0.02
10/15/2015 13:00	5,117.74	5,119.54	(1.80)	5,120.23	5,120.19	0.04
10/15/2015 14:00	5,118.41	5,119.79	(1.38)	5,120.56	5,120.41	0.15
10/15/2015 15:00	5,118.53	5,120.16	(1.63)	5,120.79	5,120.70	0.09
10/15/2015 16:00	5,116.61	5,118.91	(2.30)	5,120.34	5,119.93	0.41
10/15/2015 17:00	5,116.38	5,118.40	(2.02)	5,120.11	5,119.63	0.48
10/15/2015 18:00	5,115.71	5,118.12	(2.41)	5,119.66	5,119.36	0.30
10/15/2015 19:00	5,115.48	5,117.88	(2.40)	5,119.32	5,119.12	0.20
10/15/2015 20:00	5,115.48	5,117.92	(2.44)	5,119.10	5,119.01	0.09
10/15/2015 21:00	5,115.71	5,117.95	(2.24)	5,118.98	5,118.94	0.04
10/15/2015 22:00	5,115.93	5,118.09	(2.16)	5,118.87	5,118.94	(0.07)
10/15/2015 23:00	5,116.83	5,118.51	(1.68)	5,119.21	5,119.10	0.11

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

Date/Time	Test No. 5			Test No. 6		
	Recorder #341298			Recorder #1245		
	Node =	Hydrant #121		Node =	Hydrant #1887	
	Elevation =	4817.61		Elevation =	4754.53	
	Observed	Simulated	Difference	Observed	Simulated	Difference
10/15/2015 0:00	5,117.70	5,118.83	(1.13)	5,116.80	5,118.71	(1.91)
10/15/2015 1:00	5,118.06	5,119.12	(1.06)	5,117.36	5,119.02	(1.66)
10/15/2015 2:00	5,118.55	5,119.43	(0.88)	5,117.92	5,119.35	(1.43)
10/15/2015 3:00	5,118.91	5,119.59	(0.68)	5,118.26	5,119.50	(1.24)
10/15/2015 4:00	5,119.15	5,119.65	(0.50)	5,118.38	5,119.54	(1.16)
10/15/2015 5:00	5,119.15	5,119.63	(0.48)	5,118.60	5,119.49	(0.89)
10/15/2015 6:00	5,118.67	5,119.31	(0.64)	5,118.04	5,119.12	(1.08)
10/15/2015 7:00	5,116.73	5,117.81	(1.08)	5,115.78	5,117.40	(1.62)
10/15/2015 8:00	5,116.73	5,116.86	(0.13)	5,115.89	5,116.37	(0.48)
10/15/2015 9:00	5,118.18	5,119.26	(1.08)	5,118.49	5,119.87	(1.38)
10/15/2015 10:00	5,118.43	5,119.49	(1.06)	5,118.49	5,120.10	(1.61)
10/15/2015 11:00	5,118.43	5,119.71	(1.28)	5,118.04	5,120.32	(2.28)
10/15/2015 12:00	5,118.67	5,119.92	(1.25)	5,117.92	5,120.53	(2.61)
10/15/2015 13:00	5,118.91	5,120.13	(1.22)	5,118.26	5,120.75	(2.49)
10/15/2015 14:00	5,119.28	5,120.36	(1.08)	5,118.71	5,120.97	(2.26)
10/15/2015 15:00	5,119.40	5,120.67	(1.27)	5,118.71	5,121.29	(2.58)
10/15/2015 16:00	5,117.09	5,119.14	(2.05)	5,115.10	5,118.90	(3.80)
10/15/2015 17:00	5,116.73	5,118.69	(1.96)	5,115.10	5,118.40	(3.30)
10/15/2015 18:00	5,116.49	5,118.41	(1.92)	5,114.88	5,118.11	(3.23)
10/15/2015 19:00	5,116.12	5,118.17	(2.05)	5,114.88	5,117.87	(2.99)
10/15/2015 20:00	5,116.24	5,118.17	(1.93)	5,114.99	5,117.91	(2.92)
10/15/2015 21:00	5,116.36	5,118.18	(1.82)	5,115.33	5,117.94	(2.61)
10/15/2015 22:00	5,116.49	5,118.27	(1.78)	5,115.56	5,118.06	(2.50)
10/15/2015 23:00	5,117.21	5,118.63	(1.42)	5,116.57	5,118.48	(1.91)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

Date/Time	Test No. 7			Test No. 8		
	Recorder #341289			Recorder #201250		
	Node =	Hydrant #1754		Node =	Hydrant #1125	
	Elevation =	4820.11		Elevation =	4779.50	
	Observed	Simulated	Difference	Observed	Simulated	Difference
10/15/2015 0:00	5,117.05	5,118.45	(1.40)	5,118.19	5,118.46	(0.27)
10/15/2015 1:00	5,117.53	5,118.82	(1.29)	5,118.75	5,118.82	(0.07)
10/15/2015 2:00	5,118.14	5,119.18	(1.04)	5,119.54	5,119.19	0.35
10/15/2015 3:00	5,118.50	5,119.31	(0.81)	5,119.77	5,119.31	0.46
10/15/2015 4:00	5,118.38	5,119.30	(0.92)	5,119.88	5,119.31	0.57
10/15/2015 5:00	5,118.50	5,119.20	(0.70)	5,119.99	5,119.21	0.78
10/15/2015 6:00	5,117.53	5,118.71	(1.18)	5,119.09	5,118.71	0.38
10/15/2015 7:00	5,114.74	5,116.40	(1.66)	5,116.38	5,116.41	(0.03)
10/15/2015 8:00	5,114.26	5,115.20	(0.94)	5,115.93	5,115.20	0.73
10/15/2015 9:00	5,116.44	5,117.84	(1.40)	5,117.85	5,117.85	(0.00)
10/15/2015 10:00	5,116.68	5,118.17	(1.49)	5,117.85	5,118.17	(0.32)
10/15/2015 11:00	5,116.32	5,118.46	(2.14)	5,117.28	5,118.46	(1.18)
10/15/2015 12:00	5,116.44	5,118.71	(2.27)	5,117.40	5,118.72	(1.32)
10/15/2015 13:00	5,116.68	5,118.98	(2.30)	5,117.62	5,118.99	(1.37)
10/15/2015 14:00	5,117.41	5,119.25	(1.84)	5,118.07	5,119.26	(1.19)
10/15/2015 15:00	5,117.41	5,119.69	(2.28)	5,118.07	5,119.69	(1.62)
10/15/2015 16:00	5,115.71	5,118.32	(2.61)	5,115.93	5,118.32	(2.39)
10/15/2015 17:00	5,115.35	5,117.69	(2.34)	5,115.71	5,117.69	(1.98)
10/15/2015 18:00	5,114.26	5,117.40	(3.14)	5,114.92	5,117.40	(2.48)
10/15/2015 19:00	5,114.13	5,117.15	(3.02)	5,115.14	5,117.15	(2.01)
10/15/2015 20:00	5,114.26	5,117.27	(3.01)	5,115.48	5,117.27	(1.79)
10/15/2015 21:00	5,114.74	5,117.37	(2.63)	5,116.04	5,117.38	(1.34)
10/15/2015 22:00	5,115.23	5,117.58	(2.35)	5,116.49	5,117.59	(1.10)
10/15/2015 23:00	5,116.32	5,118.14	(1.82)	5,117.74	5,118.15	(0.41)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

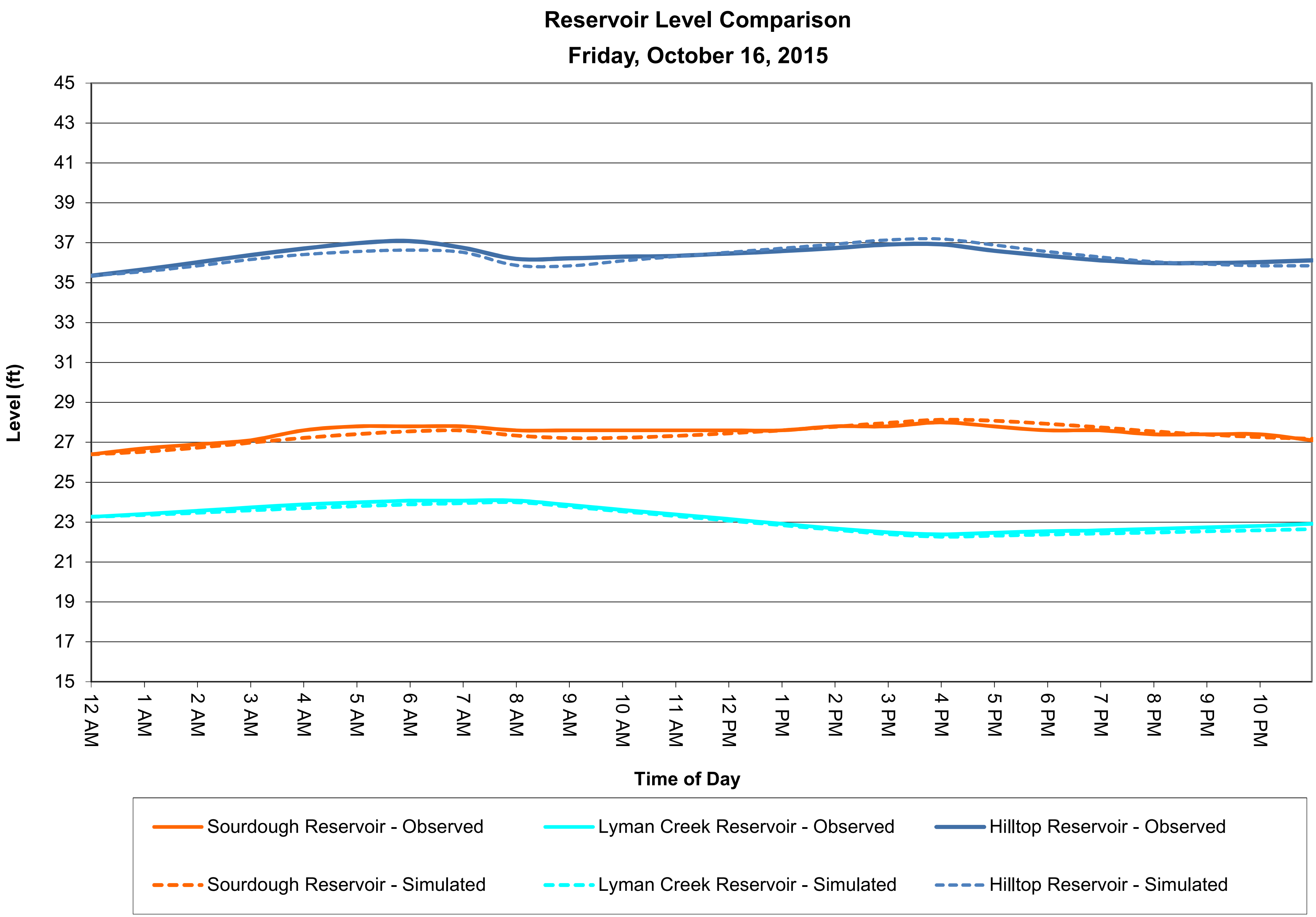
Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 9			Test No. 10		
	Recorder #1243			Recorder #1241		
	Node =	Hydrant #1025		Node =	Hydrant #	
	Elevation =	4755.67		Elevation =	0.00	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/15/2015 0:00	5,118.05	5,118.59	(0.54)	0.00	0.00	0.00
10/15/2015 1:00	5,118.50	5,118.93	(0.43)	0.00	0.00	0.00
10/15/2015 2:00	5,119.18	5,119.28	(0.10)	0.00	0.00	0.00
10/15/2015 3:00	5,119.40	5,119.41	(0.01)	0.00	0.00	0.00
10/15/2015 4:00	5,119.52	5,119.43	0.09	0.00	0.00	0.00
10/15/2015 5:00	5,119.74	5,119.36	0.38	0.00	0.00	0.00
10/15/2015 6:00	5,118.95	5,118.93	0.02	0.00	0.00	0.00
10/15/2015 7:00	5,116.58	5,116.91	(0.33)	0.00	0.00	0.00
10/15/2015 8:00	5,116.13	5,115.78	0.35	0.00	0.00	0.00
10/15/2015 9:00	5,118.05	5,118.44	(0.39)	0.00	0.00	0.00
10/15/2015 10:00	5,118.28	5,118.73	(0.45)	0.00	0.00	0.00
10/15/2015 11:00	5,117.94	5,119.00	(1.06)	0.00	0.00	0.00
10/15/2015 12:00	5,118.05	5,119.25	(1.20)	0.00	0.00	0.00
10/15/2015 13:00	5,118.16	5,119.50	(1.34)	0.00	0.00	0.00
10/15/2015 14:00	5,118.50	5,119.76	(1.26)	0.00	0.00	0.00
10/15/2015 15:00	5,118.61	5,120.15	(1.54)	0.00	0.00	0.00
10/15/2015 16:00	5,116.47	5,118.63	(2.16)	0.00	0.00	0.00
10/15/2015 17:00	5,116.24	5,118.07	(1.83)	0.00	0.00	0.00
10/15/2015 18:00	5,115.68	5,117.78	(2.10)	0.00	0.00	0.00
10/15/2015 19:00	5,115.79	5,117.53	(1.74)	0.00	0.00	0.00
10/15/2015 20:00	5,115.91	5,117.62	(1.71)	0.00	0.00	0.00
10/15/2015 21:00	5,116.24	5,117.68	(1.44)	0.00	0.00	0.00
10/15/2015 22:00	5,116.70	5,117.84	(1.14)	0.00	0.00	0.00
10/15/2015 23:00	5,117.60	5,118.32	(0.72)	0.00	0.00	0.00

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 11			Test No. 12		
	Recorder #1246			Recorder #1244		
	Node =	Hydrant #2712		Node =	Hydrant #1770	
	Elevation =	4692.64		Elevation =	4679.91	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/15/2015 0:00	4,925.28	4,925.52	(0.24)	5,027.85	5,028.42	(0.57)
10/15/2015 1:00	4,926.29	4,926.57	(0.28)	5,028.86	5,029.15	(0.29)
10/15/2015 2:00	4,926.86	4,927.27	(0.41)	5,029.65	5,029.70	(0.05)
10/15/2015 3:00	4,926.29	4,926.81	(0.52)	5,029.43	5,029.53	(0.10)
10/15/2015 4:00	4,925.50	4,925.94	(0.44)	5,028.75	5,029.10	(0.35)
10/15/2015 5:00	4,924.60	4,924.99	(0.39)	5,028.07	5,028.62	(0.55)
10/15/2015 6:00	4,919.86	4,922.52	(2.66)	5,022.66	5,027.18	(4.52)
10/15/2015 7:00	4,915.12	4,921.60	(6.48)	5,016.90	5,026.33	(9.43)
10/15/2015 8:00	4,914.45	4,921.55	(7.10)	5,006.07	5,026.23	(20.16)
10/15/2015 9:00	4,917.94	4,921.63	(3.69)	5,012.39	5,018.05	(5.66)
10/15/2015 10:00	4,920.31	4,921.65	(1.34)	5,012.39	5,017.97	(5.58)
10/15/2015 11:00	4,920.76	4,921.66	(0.90)	5,012.62	5,017.87	(5.25)
10/15/2015 12:00	4,922.91	4,921.67	1.24	5,012.73	5,017.75	(5.02)
10/15/2015 13:00	4,921.67	4,921.67	(0.00)	5,011.94	5,017.66	(5.72)
10/15/2015 14:00	4,922.68	4,921.68	1.00	5,013.29	5,017.56	(4.27)
10/15/2015 15:00	4,923.13	4,921.71	1.42	5,021.42	5,017.56	3.86
10/15/2015 16:00	4,922.79	4,921.71	1.08	5,023.45	5,025.13	(1.68)
10/15/2015 17:00	4,921.44	4,921.67	(0.23)	5,022.09	5,025.08	(2.99)
10/15/2015 18:00	4,920.99	4,921.67	(0.68)	5,021.87	5,025.12	(3.25)
10/15/2015 19:00	4,920.76	4,921.67	(0.91)	5,022.88	5,025.17	(2.29)
10/15/2015 20:00	4,921.89	4,921.68	0.21	5,024.35	5,025.30	(0.95)
10/15/2015 21:00	4,922.23	4,921.71	0.52	5,024.35	5,025.42	(1.07)
10/15/2015 22:00	4,922.00	4,921.75	0.25	5,025.03	5,025.56	(0.53)
10/15/2015 23:00	4,924.71	4,923.95	0.76	5,027.17	5,027.01	0.16

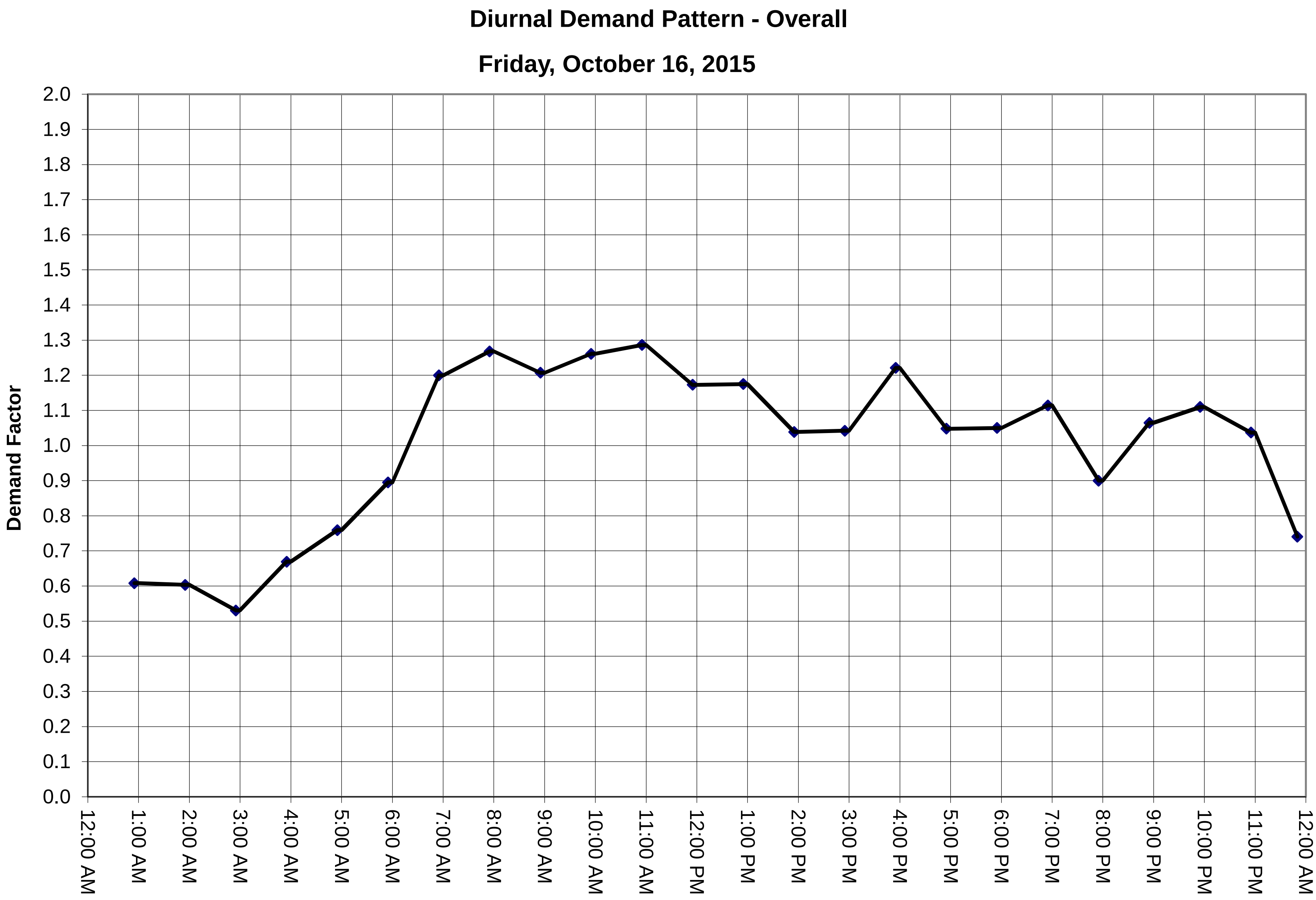


Reservoir Level Comparison
Friday, October 16, 2015
Level (ft)
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

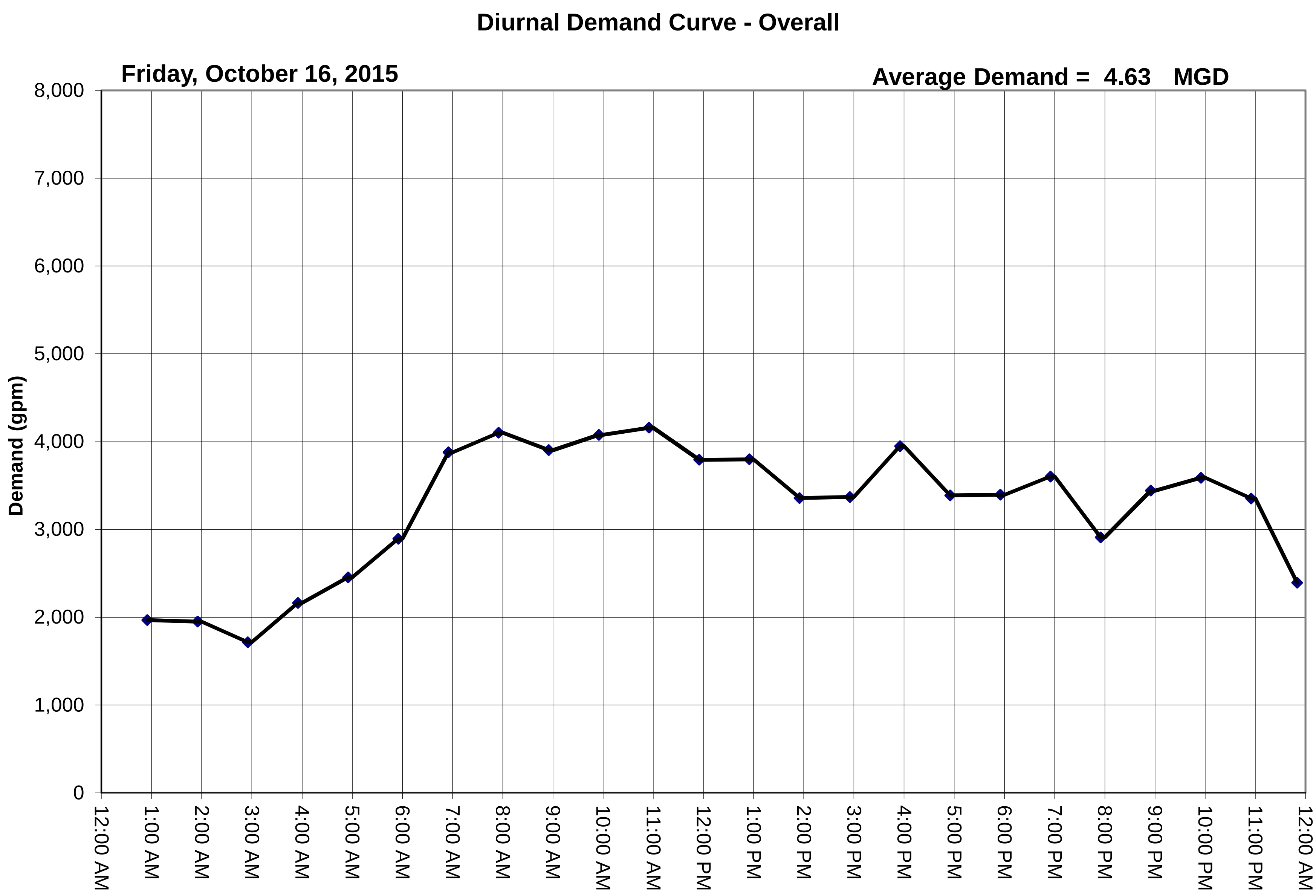
Water Distribution System Hydraulic Model Calibration
City of Bozeman

Reservoir Level Calibration
(Tower Level in ft)

Date/Time	Time	Sourdough Reservoir Level Observed	Sourdough Reservoir Level Simulated	Sourdough Reservoir Level Difference	Lyman Reservoir Level Observed	Lyman Reservoir Level Simulated	Lyman Reservoir Level Difference	Hilltop Reservoir Level Observed	Hilltop Reservoir Level Simulated	Hilltop Reservoir Level Difference
10/16/2015 0:00	0:00	26.40	26.40	0.00	23.27	23.27	0.00	35.35	35.35	0.00
10/16/2015 1:00	1:00	26.70	26.53	0.17	23.41	23.36	0.05	35.67	35.56	0.11
10/16/2015 2:00	2:00	26.90	26.73	0.17	23.56	23.47	0.09	36.02	35.84	0.18
10/16/2015 3:00	3:00	27.10	26.98	0.12	23.73	23.59	0.14	36.38	36.16	0.22
10/16/2015 4:00	4:00	27.60	27.22	0.38	23.88	23.70	0.18	36.71	36.41	0.30
10/16/2015 5:00	5:00	27.80	27.41	0.39	23.99	23.80	0.19	36.98	36.56	0.42
10/16/2015 6:00	6:00	27.80	27.55	0.25	24.08	23.89	0.19	37.08	36.63	0.45
10/16/2015 7:00	7:00	27.80	27.59	0.21	24.08	23.95	0.13	36.75	36.52	0.23
10/16/2015 8:00	8:00	27.60	27.34	0.26	24.08	24.00	0.08	36.19	35.87	0.32
10/16/2015 9:00	9:00	27.60	27.21	0.39	23.86	23.78	0.08	36.22	35.84	0.38
10/16/2015 10:00	10:00	27.60	27.23	0.37	23.61	23.54	0.07	36.30	36.09	0.21
10/16/2015 11:00	11:00	27.60	27.32	0.28	23.39	23.31	0.08	36.34	36.31	0.03
10/16/2015 12:00	12:00	27.60	27.45	0.15	23.16	23.08	0.08	36.46	36.52	-0.06
10/16/2015 13:00	13:00	27.60	27.60	0.00	22.92	22.85	0.07	36.58	36.72	-0.14
10/16/2015 14:00	14:00	27.80	27.78	0.02	22.69	22.62	0.07	36.74	36.93	-0.19
10/16/2015 15:00	15:00	27.80	27.97	-0.17	22.49	22.40	0.09	36.91	37.14	-0.23
10/16/2015 16:00	16:00	28.00	28.13	-0.13	22.39	22.27	0.12	36.92	37.19	-0.27
10/16/2015 17:00	17:00	27.80	28.08	-0.28	22.47	22.32	0.15	36.60	36.89	-0.29
10/16/2015 18:00	18:00	27.60	27.93	-0.33	22.54	22.38	0.16	36.35	36.56	-0.21
10/16/2015 19:00	19:00	27.60	27.75	-0.15	22.59	22.43	0.16	36.12	36.29	-0.17
10/16/2015 20:00	20:00	27.40	27.55	-0.15	22.66	22.48	0.18	35.99	36.05	-0.06
10/16/2015 21:00	21:00	27.40	27.39	0.01	22.74	22.54	0.20	35.99	35.93	0.06
10/16/2015 22:00	22:00	27.40	27.26	0.14	22.81	22.59	0.22	36.03	35.85	0.18
10/16/2015 23:00	23:00	27.10	27.18	-0.08	22.92	22.65	0.27	36.12	35.85	0.27



Diurnal Demand Pattern - Overall
Friday, October 16, 2015
Demand Factor
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM


Diurnal Demand Curve - Overall
Friday, October 16, 2015
Average Demand = 4.63 MGD
Demand (gpm)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 1			Test No. 2		
	Recorder #1242			Recorder #1240		
	Node =	Hydrant #2107		Node =	Hydrant #433	
	Elevation =	5024.74		Elevation =	4969.52	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/16/2015 0:00	5,118.83	5,119.34	(0.51)	5,119.01	5,119.94	(0.93)
10/16/2015 1:00	5,119.62	5,119.67	(0.05)	5,119.35	5,120.17	(0.82)
10/16/2015 2:00	5,120.07	5,120.02	0.05	5,119.68	5,120.44	(0.76)
10/16/2015 3:00	5,120.64	5,120.22	0.42	5,120.14	5,120.68	(0.54)
10/16/2015 4:00	5,120.86	5,120.33	0.53	5,120.36	5,120.86	(0.50)
10/16/2015 5:00	5,120.98	5,120.37	0.61	5,120.59	5,120.99	(0.40)
10/16/2015 6:00	5,120.52	5,120.13	0.39	5,120.47	5,120.97	(0.50)
10/16/2015 7:00	5,119.17	5,118.82	0.35	5,119.91	5,120.49	(0.58)
10/16/2015 8:00	5,118.16	5,117.98	0.18	5,119.57	5,119.95	(0.38)
10/16/2015 9:00	5,119.17	5,119.63	(0.46)	5,119.68	5,120.53	(0.85)
10/16/2015 10:00	5,118.38	5,119.86	(1.48)	5,119.80	5,120.67	(0.87)
10/16/2015 11:00	5,118.27	5,120.08	(1.81)	5,119.80	5,120.84	(1.04)
10/16/2015 12:00	5,118.16	5,120.29	(2.13)	5,119.91	5,121.01	(1.10)
10/16/2015 13:00	5,118.04	5,120.51	(2.47)	5,120.02	5,121.20	(1.18)
10/16/2015 14:00	5,117.93	5,120.74	(2.81)	5,120.36	5,121.40	(1.04)
10/16/2015 15:00	5,118.16	5,121.08	(2.92)	5,120.47	5,121.66	(1.19)
10/16/2015 16:00	5,116.58	5,120.36	(3.78)	5,120.25	5,121.43	(1.18)
10/16/2015 17:00	5,116.01	5,119.91	(3.90)	5,119.91	5,121.18	(1.27)
10/16/2015 18:00	5,116.01	5,119.63	(3.62)	5,119.80	5,120.94	(1.14)
10/16/2015 19:00	5,117.14	5,119.39	(2.25)	5,119.68	5,120.71	(1.03)
10/16/2015 20:00	5,117.82	5,119.37	(1.55)	5,119.57	5,120.57	(1.00)
10/16/2015 21:00	5,118.38	5,119.37	(0.99)	5,119.57	5,120.47	(0.90)
10/16/2015 22:00	5,118.72	5,119.45	(0.73)	5,119.57	5,120.43	(0.86)
10/16/2015 23:00	5,119.17	5,119.77	(0.60)	5,119.80	5,120.52	(0.72)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 3			Test No. 4		
	Recorder #1251			Recorder #1249		
	Node =	Hydrant #490		Node =	Hydrant #278	
	Elevation =	4880.25		Elevation =	4861.19	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/16/2015 0:00	5,117.51	5,119.09	(1.58)	5,119.55	5,119.55	(0.00)
10/16/2015 1:00	5,118.30	5,119.46	(1.16)	5,120.00	5,119.82	0.18
10/16/2015 2:00	5,118.64	5,119.84	(1.20)	5,120.34	5,120.13	0.21
10/16/2015 3:00	5,119.20	5,120.03	(0.83)	5,120.79	5,120.37	0.42
10/16/2015 4:00	5,119.32	5,120.11	(0.79)	5,121.02	5,120.54	0.48
10/16/2015 5:00	5,119.32	5,120.11	(0.79)	5,121.24	5,120.64	0.60
10/16/2015 6:00	5,118.64	5,119.79	(1.15)	5,121.13	5,120.55	0.58
10/16/2015 7:00	5,116.61	5,118.12	(1.51)	5,120.34	5,119.81	0.53
10/16/2015 8:00	5,115.59	5,117.14	(1.55)	5,119.89	5,119.12	0.77
10/16/2015 9:00	5,117.40	5,119.30	(1.90)	5,120.34	5,120.13	0.21
10/16/2015 10:00	5,117.29	5,119.57	(2.28)	5,120.23	5,120.33	(0.10)
10/16/2015 11:00	5,117.51	5,119.81	(2.30)	5,120.45	5,120.53	(0.08)
10/16/2015 12:00	5,117.74	5,120.04	(2.30)	5,120.23	5,120.72	(0.49)
10/16/2015 13:00	5,117.96	5,120.27	(2.31)	5,120.34	5,120.93	(0.59)
10/16/2015 14:00	5,118.41	5,120.51	(2.10)	5,120.68	5,121.14	(0.46)
10/16/2015 15:00	5,118.87	5,120.88	(2.01)	5,121.13	5,121.42	(0.29)
10/16/2015 16:00	5,117.29	5,119.92	(2.63)	5,120.90	5,120.95	(0.05)
10/16/2015 17:00	5,116.72	5,119.38	(2.66)	5,120.68	5,120.60	0.08
10/16/2015 18:00	5,116.50	5,119.08	(2.58)	5,120.56	5,120.31	0.25
10/16/2015 19:00	5,116.61	5,118.84	(2.23)	5,120.45	5,120.07	0.38
10/16/2015 20:00	5,116.72	5,118.87	(2.15)	5,120.11	5,119.95	0.16
10/16/2015 21:00	5,117.06	5,118.90	(1.84)	5,120.11	5,119.88	0.23
10/16/2015 22:00	5,117.40	5,119.03	(1.63)	5,120.23	5,119.88	0.35
10/16/2015 23:00	5,118.08	5,119.44	(1.36)	5,120.45	5,120.04	0.41

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 5			Test No. 6		
	Recorder #341298			Recorder #1245		
	Node =	Hydrant #121		Node =	Hydrant #1887	
	Elevation =	4817.61		Elevation =	4754.53	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/16/2015 0:00	5,117.94	5,119.18	(1.24)	5,117.14	5,119.07	(1.93)
10/16/2015 1:00	5,118.67	5,119.53	(0.86)	5,117.92	5,119.44	(1.52)
10/16/2015 2:00	5,119.03	5,119.90	(0.87)	5,118.38	5,119.82	(1.44)
10/16/2015 3:00	5,119.52	5,120.10	(0.58)	5,118.94	5,120.01	(1.07)
10/16/2015 4:00	5,119.76	5,120.20	(0.44)	5,118.94	5,120.09	(1.15)
10/16/2015 5:00	5,119.76	5,120.23	(0.47)	5,118.94	5,120.10	(1.16)
10/16/2015 6:00	5,119.40	5,119.96	(0.56)	5,118.38	5,119.77	(1.39)
10/16/2015 7:00	5,117.46	5,118.53	(1.07)	5,116.46	5,118.13	(1.67)
10/16/2015 8:00	5,117.09	5,117.63	(0.54)	5,116.35	5,117.15	(0.80)
10/16/2015 9:00	5,119.15	5,120.01	(0.86)	5,119.17	5,120.60	(1.43)
10/16/2015 10:00	5,118.91	5,120.24	(1.33)	5,118.60	5,120.83	(2.23)
10/16/2015 11:00	5,119.03	5,120.45	(1.42)	5,117.81	5,121.05	(3.24)
10/16/2015 12:00	5,119.15	5,120.65	(1.50)	5,117.70	5,121.25	(3.55)
10/16/2015 13:00	5,119.03	5,120.86	(1.83)	5,117.47	5,121.45	(3.98)
10/16/2015 14:00	5,119.40	5,121.08	(1.68)	5,117.81	5,121.67	(3.86)
10/16/2015 15:00	5,119.76	5,121.39	(1.63)	5,117.92	5,121.98	(4.06)
10/16/2015 16:00	5,117.58	5,120.16	(2.58)	5,114.43	5,119.92	(5.49)
10/16/2015 17:00	5,117.33	5,119.67	(2.34)	5,114.09	5,119.38	(5.29)
10/16/2015 18:00	5,117.09	5,119.37	(2.28)	5,114.54	5,119.08	(4.54)
10/16/2015 19:00	5,117.09	5,119.13	(2.04)	5,114.99	5,118.83	(3.84)
10/16/2015 20:00	5,117.21	5,119.12	(1.91)	5,115.33	5,118.86	(3.53)
10/16/2015 21:00	5,117.58	5,119.12	(1.54)	5,116.01	5,118.88	(2.87)
10/16/2015 22:00	5,117.70	5,119.22	(1.52)	5,116.35	5,119.01	(2.66)
10/16/2015 23:00	5,118.43	5,119.57	(1.14)	5,117.14	5,119.42	(2.28)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 7			Test No. 8		
	Recorder #341289			Recorder #201250		
	Node =	Hydrant #1754		Node =	Hydrant #1125	
	Elevation =	4820.11		Elevation =	4779.50	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/16/2015 0:00	5,117.05	5,118.81	(1.76)	5,118.41	5,118.82	(0.41)
10/16/2015 1:00	5,117.89	5,119.24	(1.35)	5,119.20	5,119.24	(0.04)
10/16/2015 2:00	5,118.26	5,119.65	(1.39)	5,119.65	5,119.65	0.00
10/16/2015 3:00	5,118.99	5,119.81	(0.82)	5,120.44	5,119.82	0.62
10/16/2015 4:00	5,118.99	5,119.85	(0.86)	5,120.44	5,119.86	0.58
10/16/2015 5:00	5,118.99	5,119.81	(0.82)	5,120.44	5,119.82	0.62
10/16/2015 6:00	5,117.89	5,119.36	(1.47)	5,119.32	5,119.37	(0.05)
10/16/2015 7:00	5,115.47	5,117.13	(1.66)	5,116.95	5,117.14	(0.19)
10/16/2015 8:00	5,114.50	5,115.98	(1.48)	5,116.04	5,115.98	0.06
10/16/2015 9:00	5,116.56	5,118.60	(2.04)	5,117.96	5,118.61	(0.65)
10/16/2015 10:00	5,116.56	5,118.92	(2.36)	5,117.62	5,118.93	(1.31)
10/16/2015 11:00	5,116.68	5,119.21	(2.53)	5,117.51	5,119.22	(1.71)
10/16/2015 12:00	5,116.56	5,119.46	(2.90)	5,117.51	5,119.47	(1.96)
10/16/2015 13:00	5,116.80	5,119.72	(2.92)	5,117.40	5,119.72	(2.32)
10/16/2015 14:00	5,117.41	5,119.98	(2.57)	5,117.74	5,119.99	(2.25)
10/16/2015 15:00	5,117.41	5,120.41	(3.00)	5,117.62	5,120.41	(2.79)
10/16/2015 16:00	5,115.95	5,119.34	(3.39)	5,115.82	5,119.35	(3.53)
10/16/2015 17:00	5,115.10	5,118.67	(3.57)	5,114.80	5,118.68	(3.88)
10/16/2015 18:00	5,115.10	5,118.36	(3.26)	5,114.80	5,118.37	(3.57)
10/16/2015 19:00	5,115.23	5,118.11	(2.88)	5,115.37	5,118.11	(2.74)
10/16/2015 20:00	5,115.83	5,118.22	(2.39)	5,116.27	5,118.23	(1.96)
10/16/2015 21:00	5,116.32	5,118.32	(2.00)	5,116.95	5,118.33	(1.38)
10/16/2015 22:00	5,116.68	5,118.54	(1.86)	5,117.51	5,118.54	(1.03)
10/16/2015 23:00	5,117.41	5,119.08	(1.67)	5,118.41	5,119.09	(0.68)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

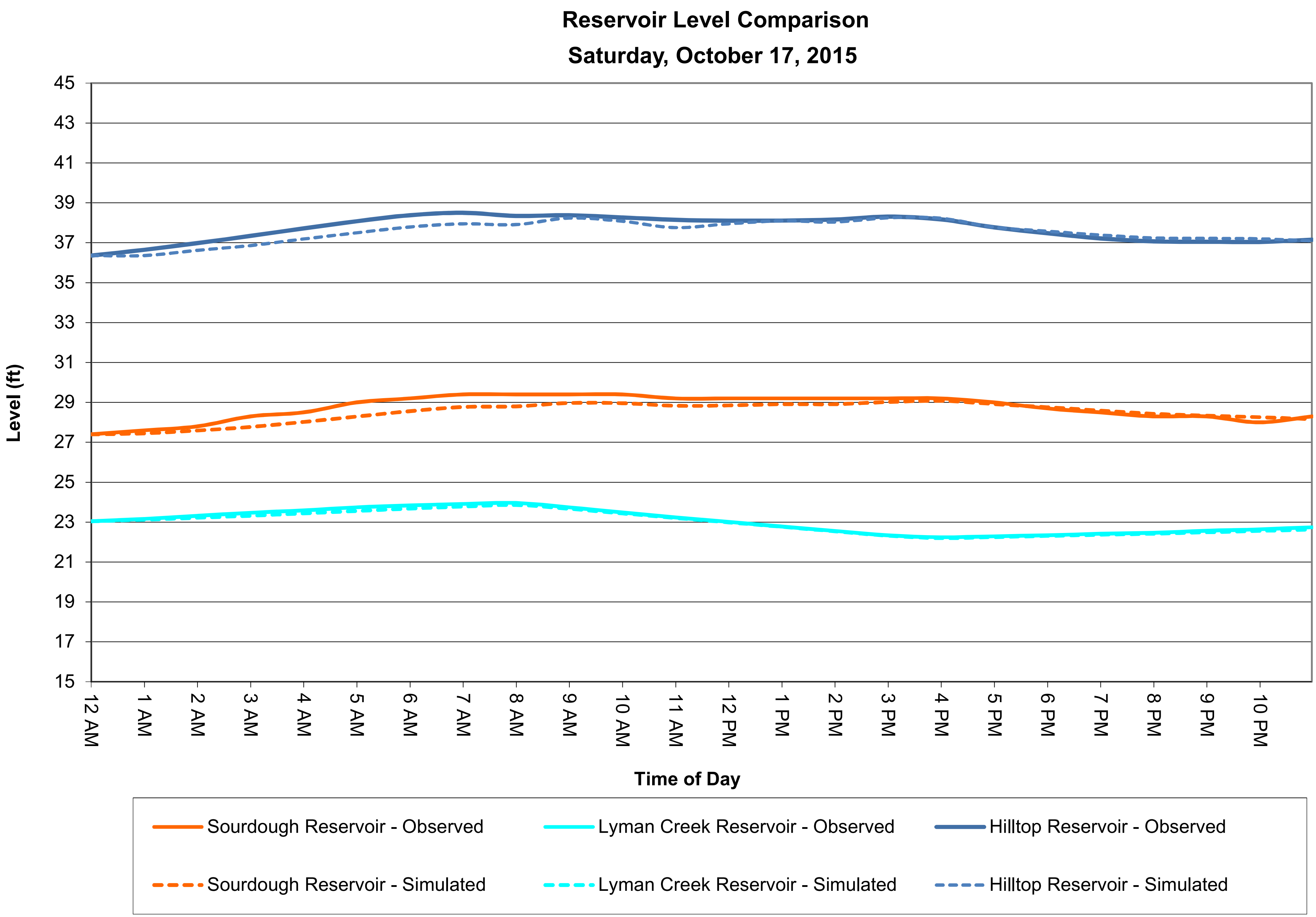
Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 9			Test No. 10		
	Recorder #1243			Recorder #1241		
	Node =	Hydrant #1025		Node =	Hydrant #	
	Elevation =	4755.67		Elevation =	0.00	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/16/2015 0:00	5,118.28	5,118.95	(0.67)	0.00	0.00	0.00
10/16/2015 1:00	5,119.06	5,119.35	(0.29)	0.00	0.00	0.00
10/16/2015 2:00	5,119.52	5,119.74	(0.22)	0.00	0.00	0.00
10/16/2015 3:00	5,120.19	5,119.92	0.27	0.00	0.00	0.00
10/16/2015 4:00	5,120.19	5,119.98	0.21	0.00	0.00	0.00
10/16/2015 5:00	5,120.31	5,119.96	0.35	0.00	0.00	0.00
10/16/2015 6:00	5,119.29	5,119.58	(0.29)	0.00	0.00	0.00
10/16/2015 7:00	5,117.26	5,117.64	(0.38)	0.00	0.00	0.00
10/16/2015 8:00	5,116.58	5,116.55	0.03	0.00	0.00	0.00
10/16/2015 9:00	5,118.39	5,119.19	(0.80)	0.00	0.00	0.00
10/16/2015 10:00	5,118.39	5,119.48	(1.09)	0.00	0.00	0.00
10/16/2015 11:00	5,118.16	5,119.75	(1.59)	0.00	0.00	0.00
10/16/2015 12:00	5,118.05	5,119.99	(1.94)	0.00	0.00	0.00
10/16/2015 13:00	5,117.94	5,120.23	(2.29)	0.00	0.00	0.00
10/16/2015 14:00	5,118.28	5,120.49	(2.21)	0.00	0.00	0.00
10/16/2015 15:00	5,118.16	5,120.87	(2.71)	0.00	0.00	0.00
10/16/2015 16:00	5,116.24	5,119.65	(3.41)	0.00	0.00	0.00
10/16/2015 17:00	5,115.45	5,119.05	(3.60)	0.00	0.00	0.00
10/16/2015 18:00	5,115.79	5,118.74	(2.95)	0.00	0.00	0.00
10/16/2015 19:00	5,116.13	5,118.49	(2.36)	0.00	0.00	0.00
10/16/2015 20:00	5,116.58	5,118.57	(1.99)	0.00	0.00	0.00
10/16/2015 21:00	5,117.15	5,118.63	(1.48)	0.00	0.00	0.00
10/16/2015 22:00	5,117.60	5,118.79	(1.19)	0.00	0.00	0.00
10/16/2015 23:00	5,118.28	5,119.26	(0.98)	0.00	0.00	0.00

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

Date/Time	Test No. 11			Test No. 12		
	Recorder #1246			Recorder #1244		
	Node =	Hydrant #2712		Node =	Hydrant #1770	
	Elevation =	4692.64		Elevation =	4679.91	
	Observed	Simulated	Difference	Observed	Simulated	Difference
10/16/2015 0:00	4,926.18	4,925.55	0.63	5,028.53	5,028.41	0.12
10/16/2015 1:00	4,926.40	4,926.59	(0.19)	5,029.09	5,029.14	(0.05)
10/16/2015 2:00	4,927.31	4,927.30	0.01	5,029.65	5,029.68	(0.03)
10/16/2015 3:00	4,927.65	4,926.83	0.82	5,030.10	5,029.51	0.59
10/16/2015 4:00	4,926.07	4,925.97	0.10	5,028.86	5,029.09	(0.23)
10/16/2015 5:00	4,924.60	4,925.02	(0.42)	5,027.51	5,028.60	(1.09)
10/16/2015 6:00	4,920.31	4,922.57	(2.26)	5,023.11	5,027.16	(4.05)
10/16/2015 7:00	4,915.35	4,921.60	(6.25)	5,018.03	5,026.29	(8.26)
10/16/2015 8:00	4,914.67	4,921.55	(6.88)	5,004.38	5,026.19	(21.81)
10/16/2015 9:00	4,916.70	4,921.63	(4.93)	5,009.01	5,018.15	(9.14)
10/16/2015 10:00	4,919.86	4,921.65	(1.79)	5,010.59	5,018.07	(7.48)
10/16/2015 11:00	4,920.76	4,921.66	(0.90)	5,011.83	5,017.98	(6.15)
10/16/2015 12:00	4,921.21	4,921.67	(0.46)	5,011.04	5,017.89	(6.85)
10/16/2015 13:00	4,920.09	4,921.67	(1.58)	5,010.14	5,017.79	(7.65)
10/16/2015 14:00	4,920.54	4,921.68	(1.14)	5,011.38	5,017.69	(6.31)
10/16/2015 15:00	4,921.78	4,921.72	0.06	5,012.28	5,017.69	(5.41)
10/16/2015 16:00	4,920.20	4,921.71	(1.51)	5,019.95	5,024.92	(4.97)
10/16/2015 17:00	4,919.63	4,921.67	(2.04)	5,019.50	5,024.87	(5.37)
10/16/2015 18:00	4,920.20	4,921.67	(1.47)	5,021.87	5,024.92	(3.05)
10/16/2015 19:00	4,920.76	4,921.67	(0.91)	5,023.00	5,024.96	(1.96)
10/16/2015 20:00	4,921.55	4,921.69	(0.14)	5,023.11	5,025.09	(1.98)
10/16/2015 21:00	4,922.46	4,921.71	0.75	5,023.45	5,025.20	(1.75)
10/16/2015 22:00	4,922.12	4,921.75	0.37	5,023.67	5,025.34	(1.67)
10/16/2015 23:00	4,924.94	4,924.00	0.94	5,026.16	5,026.81	(0.65)

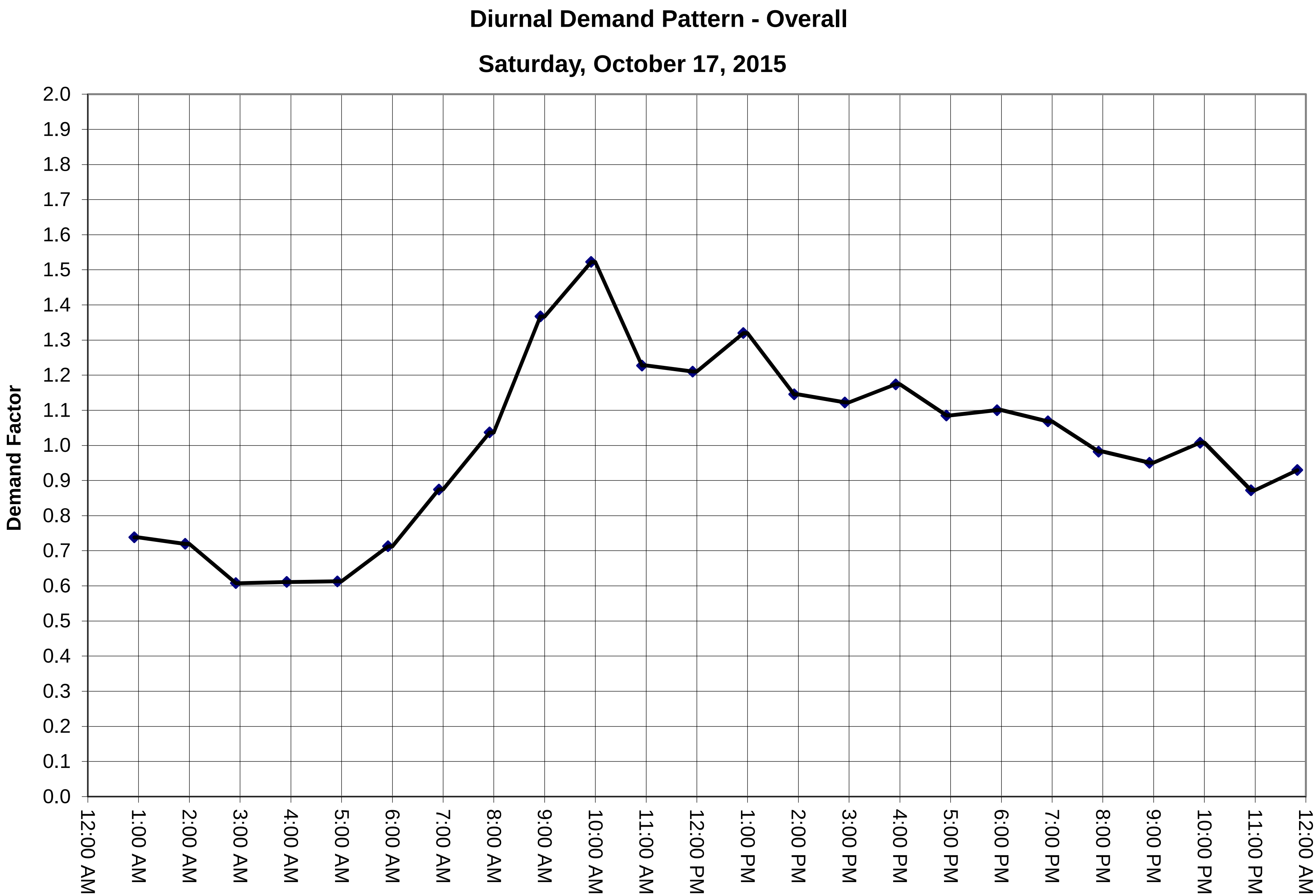


Reservoir Level Comparison
Saturday, October 17, 2015
Level (ft)
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

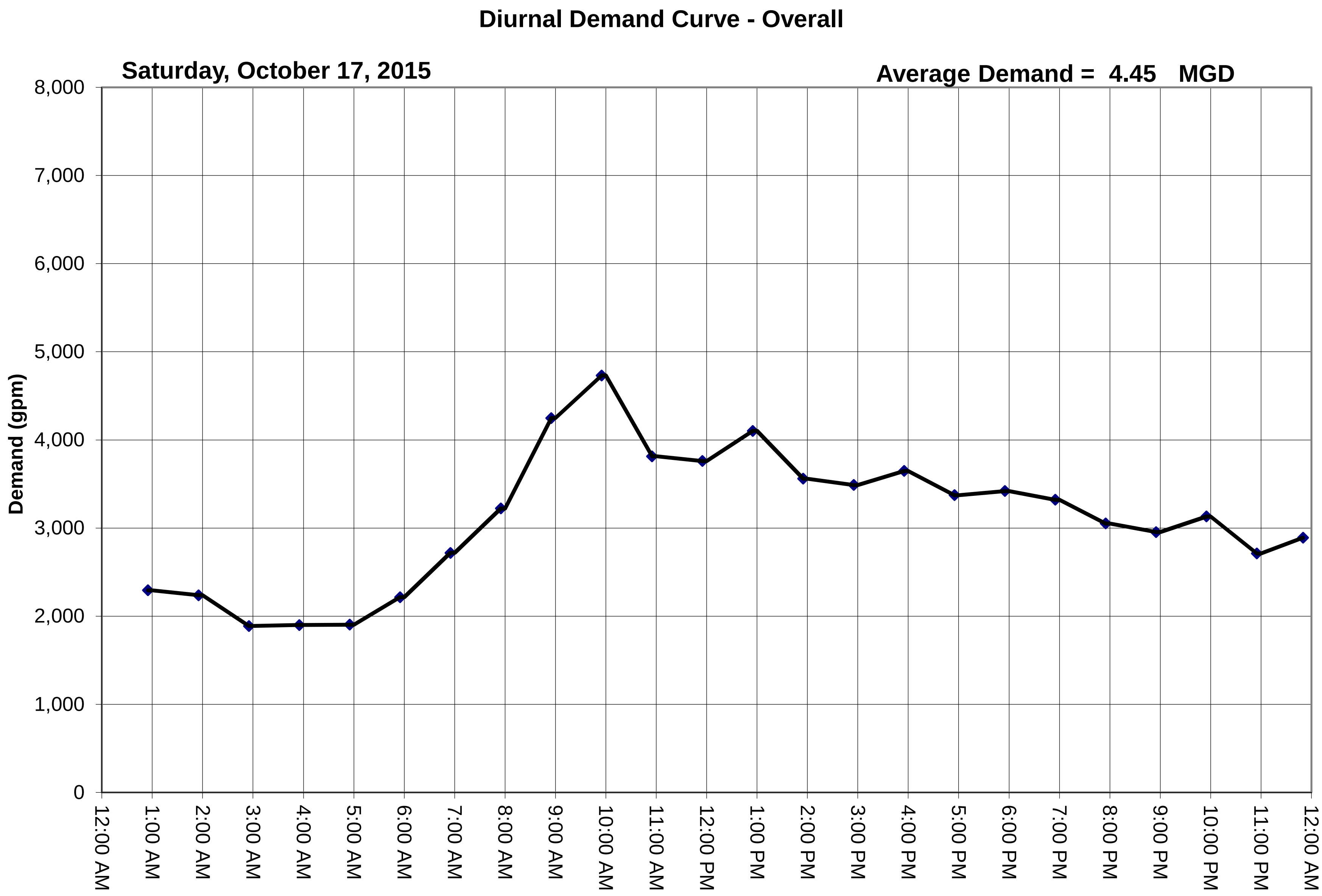
Water Distribution System Hydraulic Model Calibration
City of Bozeman

Reservoir Level Calibration
(Tower Level in ft)

		Sourdough Reservoir Level			Lyman Reservoir Level			Hilltop Reservoir Level		
Date/Time	Time	Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
10/17/2015 0:00	0:00	27.40	27.40	0.00	23.04	23.04	0.00	36.36	36.36	0.00
10/17/2015 1:00	1:00	27.60	27.45	0.15	23.16	23.12	0.04	36.65	36.36	0.29
10/17/2015 2:00	2:00	27.80	27.59	0.21	23.31	23.22	0.09	36.98	36.62	0.36
10/17/2015 3:00	3:00	28.30	27.77	0.53	23.47	23.32	0.15	37.35	36.86	0.49
10/17/2015 4:00	4:00	28.50	28.02	0.48	23.59	23.44	0.15	37.72	37.19	0.53
10/17/2015 5:00	5:00	29.00	28.29	0.71	23.74	23.56	0.18	38.08	37.50	0.58
10/17/2015 6:00	6:00	29.20	28.56	0.64	23.84	23.68	0.16	38.38	37.79	0.59
10/17/2015 7:00	7:00	29.40	28.77	0.63	23.91	23.78	0.13	38.50	37.95	0.55
10/17/2015 8:00	8:00	29.40	28.80	0.60	23.96	23.86	0.10	38.35	37.91	0.44
10/17/2015 9:00	9:00	29.40	28.97	0.43	23.74	23.67	0.07	38.38	38.24	0.14
10/17/2015 10:00	10:00	29.40	28.96	0.44	23.49	23.44	0.05	38.27	38.08	0.19
10/17/2015 11:00	11:00	29.20	28.83	0.37	23.24	23.21	0.03	38.15	37.76	0.39
10/17/2015 12:00	12:00	29.20	28.85	0.35	23.01	22.99	0.02	38.11	37.95	0.16
10/17/2015 13:00	13:00	29.20	28.91	0.29	22.78	22.77	0.01	38.11	38.10	0.01
10/17/2015 14:00	14:00	29.20	28.91	0.29	22.56	22.54	0.02	38.17	38.04	0.13
10/17/2015 15:00	15:00	29.20	29.02	0.18	22.34	22.32	0.02	38.31	38.25	0.06
10/17/2015 16:00	16:00	29.20	29.08	0.12	22.24	22.20	0.04	38.18	38.23	-0.05
10/17/2015 17:00	17:00	29.00	28.92	0.08	22.29	22.25	0.04	37.78	37.78	0.00
10/17/2015 18:00	18:00	28.70	28.76	-0.06	22.34	22.31	0.03	37.48	37.58	-0.10
10/17/2015 19:00	19:00	28.50	28.59	-0.09	22.42	22.37	0.05	37.22	37.39	-0.17
10/17/2015 20:00	20:00	28.30	28.43	-0.13	22.47	22.42	0.05	37.07	37.24	-0.17
10/17/2015 21:00	21:00	28.30	28.33	-0.03	22.57	22.49	0.08	37.05	37.22	-0.17
10/17/2015 22:00	22:00	28.00	28.26	-0.26	22.64	22.56	0.08	37.04	37.20	-0.16
10/17/2015 23:00	23:00	28.30	28.16	0.14	22.74	22.63	0.11	37.15	37.09	0.06



Diurnal Demand Pattern - Overall
Saturday, October 17, 2015
Demand Factor
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM


Diurnal Demand Curve - Overall
Saturday, October 17, 2015
Average Demand = 4.45 MGD
Demand (gpm)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 1			Test No. 2		
	Recorder #1242			Recorder #1240		
	Node =	Hydrant #2107		Node =	Hydrant #433	
	Elevation =	5024.74		Elevation =	4969.52	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/17/2015 0:00	5,119.96	5,120.03	(0.07)	5,120.14	5,120.81	(0.67)
10/17/2015 1:00	5,120.52	5,120.43	0.09	5,120.36	5,120.99	(0.63)
10/17/2015 2:00	5,120.98	5,120.66	0.32	5,120.81	5,121.19	(0.38)
10/17/2015 3:00	5,121.31	5,121.06	0.25	5,121.15	5,121.48	(0.33)
10/17/2015 4:00	5,121.88	5,121.35	0.53	5,121.60	5,121.76	(0.16)
10/17/2015 5:00	5,122.22	5,121.63	0.59	5,121.94	5,122.03	(0.09)
10/17/2015 6:00	5,122.22	5,121.74	0.48	5,122.05	5,122.24	(0.19)
10/17/2015 7:00	5,121.99	5,121.63	0.36	5,122.05	5,122.32	(0.27)
10/17/2015 8:00	5,121.20	5,121.27	(0.07)	5,121.94	5,122.19	(0.25)
10/17/2015 9:00	5,120.86	5,121.51	(0.65)	5,121.71	5,122.47	(0.76)
10/17/2015 10:00	5,120.19	5,121.00	(0.81)	5,121.60	5,122.26	(0.66)
10/17/2015 11:00	5,119.62	5,121.55	(1.93)	5,121.60	5,122.31	(0.71)
10/17/2015 12:00	5,119.06	5,121.69	(2.63)	5,121.49	5,122.41	(0.92)
10/17/2015 13:00	5,119.17	5,121.52	(2.35)	5,121.60	5,122.41	(0.81)
10/17/2015 14:00	5,118.95	5,121.90	(2.95)	5,121.83	5,122.54	(0.71)
10/17/2015 15:00	5,118.61	5,122.12	(3.51)	5,121.94	5,122.70	(0.76)
10/17/2015 16:00	5,117.59	5,121.18	(3.59)	5,121.60	5,122.35	(0.75)
10/17/2015 17:00	5,117.14	5,121.08	(3.94)	5,121.26	5,122.14	(0.88)
10/17/2015 18:00	5,117.48	5,120.91	(3.43)	5,121.04	5,121.96	(0.92)
10/17/2015 19:00	5,118.04	5,120.80	(2.76)	5,120.81	5,121.81	(1.00)
10/17/2015 20:00	5,118.72	5,120.88	(2.16)	5,120.70	5,121.74	(1.04)
10/17/2015 21:00	5,119.06	5,120.88	(1.82)	5,120.70	5,121.70	(1.00)
10/17/2015 22:00	5,119.51	5,120.70	(1.19)	5,120.70	5,121.59	(0.89)
10/17/2015 23:00	5,119.85	5,120.90	(1.05)	5,120.81	5,121.61	(0.80)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 3			Test No. 4		
	Recorder #1251			Recorder #1249		
	Node =	Hydrant #490		Node =	Hydrant #278	
	Elevation =	4880.25		Elevation =	4861.19	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/17/2015 0:00	5,118.87	5,119.71	(0.84)	5,120.79	5,120.39	0.40
10/17/2015 1:00	5,119.32	5,120.19	(0.87)	5,121.13	5,120.61	0.52
10/17/2015 2:00	5,119.77	5,120.43	(0.66)	5,121.47	5,120.83	0.64
10/17/2015 3:00	5,120.22	5,120.89	(0.67)	5,121.81	5,121.17	0.64
10/17/2015 4:00	5,120.67	5,121.17	(0.50)	5,122.26	5,121.46	0.80
10/17/2015 5:00	5,121.01	5,121.45	(0.44)	5,122.60	5,121.74	0.86
10/17/2015 6:00	5,120.78	5,121.52	(0.74)	5,122.71	5,121.93	0.78
10/17/2015 7:00	5,120.44	5,121.35	(0.91)	5,122.71	5,121.95	0.76
10/17/2015 8:00	5,119.54	5,120.89	(1.35)	5,122.48	5,121.75	0.73
10/17/2015 9:00	5,119.54	5,121.16	(1.62)	5,122.48	5,122.17	0.31
10/17/2015 10:00	5,119.32	5,120.54	(1.22)	5,122.14	5,121.88	0.26
10/17/2015 11:00	5,119.09	5,121.27	(2.18)	5,122.03	5,121.99	0.04
10/17/2015 12:00	5,118.98	5,121.43	(2.45)	5,121.81	5,122.13	(0.32)
10/17/2015 13:00	5,119.54	5,121.20	(1.66)	5,121.92	5,122.12	(0.20)
10/17/2015 14:00	5,119.77	5,121.67	(1.90)	5,122.03	5,122.27	(0.24)
10/17/2015 15:00	5,119.99	5,121.91	(1.92)	5,122.26	5,122.47	(0.21)
10/17/2015 16:00	5,118.87	5,120.69	(1.82)	5,122.26	5,121.85	0.41
10/17/2015 17:00	5,118.41	5,120.64	(2.23)	5,122.14	5,121.62	0.52
10/17/2015 18:00	5,117.85	5,120.46	(2.61)	5,121.81	5,121.44	0.37
10/17/2015 19:00	5,117.74	5,120.38	(2.64)	5,121.69	5,121.29	0.40
10/17/2015 20:00	5,118.08	5,120.51	(2.43)	5,121.58	5,121.27	0.31
10/17/2015 21:00	5,118.41	5,120.54	(2.13)	5,121.35	5,121.25	0.10
10/17/2015 22:00	5,118.75	5,120.33	(1.58)	5,121.35	5,121.14	0.21
10/17/2015 23:00	5,119.20	5,120.60	(1.40)	5,121.47	5,121.19	0.28

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 5			Test No. 6		
	Recorder #341298			Recorder #1245		
	Node =	Hydrant #121		Node =	Hydrant #1887	
	Elevation =	4817.61		Elevation =	4754.53	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/17/2015 0:00	5,119.15	5,119.86	(0.71)	5,117.92	5,119.69	(1.77)
10/17/2015 1:00	5,119.52	5,120.27	(0.75)	5,118.38	5,120.16	(1.78)
10/17/2015 2:00	5,120.00	5,120.51	(0.51)	5,118.94	5,120.41	(1.47)
10/17/2015 3:00	5,120.49	5,120.94	(0.45)	5,119.50	5,120.86	(1.36)
10/17/2015 4:00	5,120.97	5,121.23	(0.26)	5,119.96	5,121.15	(1.19)
10/17/2015 5:00	5,121.34	5,121.51	(0.17)	5,120.29	5,121.43	(1.14)
10/17/2015 6:00	5,121.34	5,121.61	(0.27)	5,120.29	5,121.51	(1.22)
10/17/2015 7:00	5,120.97	5,121.48	(0.51)	5,119.84	5,121.33	(1.49)
10/17/2015 8:00	5,120.61	5,121.08	(0.47)	5,119.73	5,120.88	(1.15)
10/17/2015 9:00	5,121.09	5,121.98	(0.89)	5,120.97	5,122.48	(1.51)
10/17/2015 10:00	5,120.85	5,121.53	(0.68)	5,120.18	5,121.97	(1.79)
10/17/2015 11:00	5,120.61	5,121.90	(1.29)	5,119.28	5,122.45	(3.17)
10/17/2015 12:00	5,120.61	5,122.04	(1.43)	5,118.60	5,122.59	(3.99)
10/17/2015 13:00	5,120.61	5,121.95	(1.34)	5,118.60	5,122.45	(3.85)
10/17/2015 14:00	5,120.73	5,122.22	(1.49)	5,118.94	5,122.78	(3.84)
10/17/2015 15:00	5,121.09	5,122.43	(1.34)	5,118.60	5,122.98	(4.38)
10/17/2015 16:00	5,119.15	5,120.97	(1.82)	5,115.56	5,120.69	(5.13)
10/17/2015 17:00	5,118.67	5,120.87	(2.20)	5,115.33	5,120.63	(5.30)
10/17/2015 18:00	5,118.18	5,120.69	(2.51)	5,115.44	5,120.45	(5.01)
10/17/2015 19:00	5,118.30	5,120.59	(2.29)	5,115.78	5,120.36	(4.58)
10/17/2015 20:00	5,118.55	5,120.68	(2.13)	5,116.46	5,120.49	(4.03)
10/17/2015 21:00	5,118.91	5,120.69	(1.78)	5,117.02	5,120.52	(3.50)
10/17/2015 22:00	5,119.15	5,120.51	(1.36)	5,117.36	5,120.31	(2.95)
10/17/2015 23:00	5,119.40	5,120.72	(1.32)	5,118.04	5,120.58	(2.54)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 7			Test No. 8		
	Recorder #341289			Recorder #201250		
	Node =	Hydrant #1754		Node =	Hydrant #1125	
	Elevation =	4820.11		Elevation =	4779.50	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/17/2015 0:00	5,118.50	5,119.32	(0.82)	5,119.43	5,119.32	0.11
10/17/2015 1:00	5,118.86	5,119.93	(1.07)	5,119.88	5,119.93	(0.05)
10/17/2015 2:00	5,119.47	5,120.18	(0.71)	5,120.56	5,120.19	0.37
10/17/2015 3:00	5,120.08	5,120.70	(0.62)	5,121.23	5,120.70	0.53
10/17/2015 4:00	5,120.56	5,120.99	(0.43)	5,121.68	5,120.99	0.69
10/17/2015 5:00	5,120.68	5,121.27	(0.59)	5,121.91	5,121.27	0.64
10/17/2015 6:00	5,120.68	5,121.28	(0.60)	5,121.80	5,121.29	0.51
10/17/2015 7:00	5,119.96	5,121.00	(1.04)	5,121.12	5,121.01	0.11
10/17/2015 8:00	5,118.74	5,120.41	(1.67)	5,119.99	5,120.42	(0.43)
10/17/2015 9:00	5,118.74	5,120.38	(1.64)	5,119.99	5,120.39	(0.40)
10/17/2015 10:00	5,118.26	5,119.54	(1.28)	5,119.20	5,119.54	(0.34)
10/17/2015 11:00	5,118.02	5,120.67	(2.65)	5,118.64	5,120.68	(2.04)
10/17/2015 12:00	5,117.65	5,120.86	(3.21)	5,118.07	5,120.86	(2.79)
10/17/2015 13:00	5,118.26	5,120.49	(2.23)	5,118.64	5,120.50	(1.86)
10/17/2015 14:00	5,118.38	5,121.16	(2.78)	5,118.53	5,121.17	(2.64)
10/17/2015 15:00	5,118.86	5,121.44	(2.58)	5,118.53	5,121.45	(2.92)
10/17/2015 16:00	5,117.29	5,120.02	(2.73)	5,116.83	5,120.03	(3.20)
10/17/2015 17:00	5,116.56	5,120.06	(3.50)	5,116.16	5,120.06	(3.90)
10/17/2015 18:00	5,116.32	5,119.90	(3.58)	5,115.82	5,119.91	(4.09)
10/17/2015 19:00	5,116.56	5,119.85	(3.29)	5,116.38	5,119.86	(3.48)
10/17/2015 20:00	5,117.17	5,120.08	(2.91)	5,117.28	5,120.09	(2.81)
10/17/2015 21:00	5,117.77	5,120.13	(2.36)	5,118.07	5,120.14	(2.07)
10/17/2015 22:00	5,118.02	5,119.88	(1.86)	5,118.53	5,119.89	(1.36)
10/17/2015 23:00	5,118.74	5,120.25	(1.51)	5,119.32	5,120.25	(0.93)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

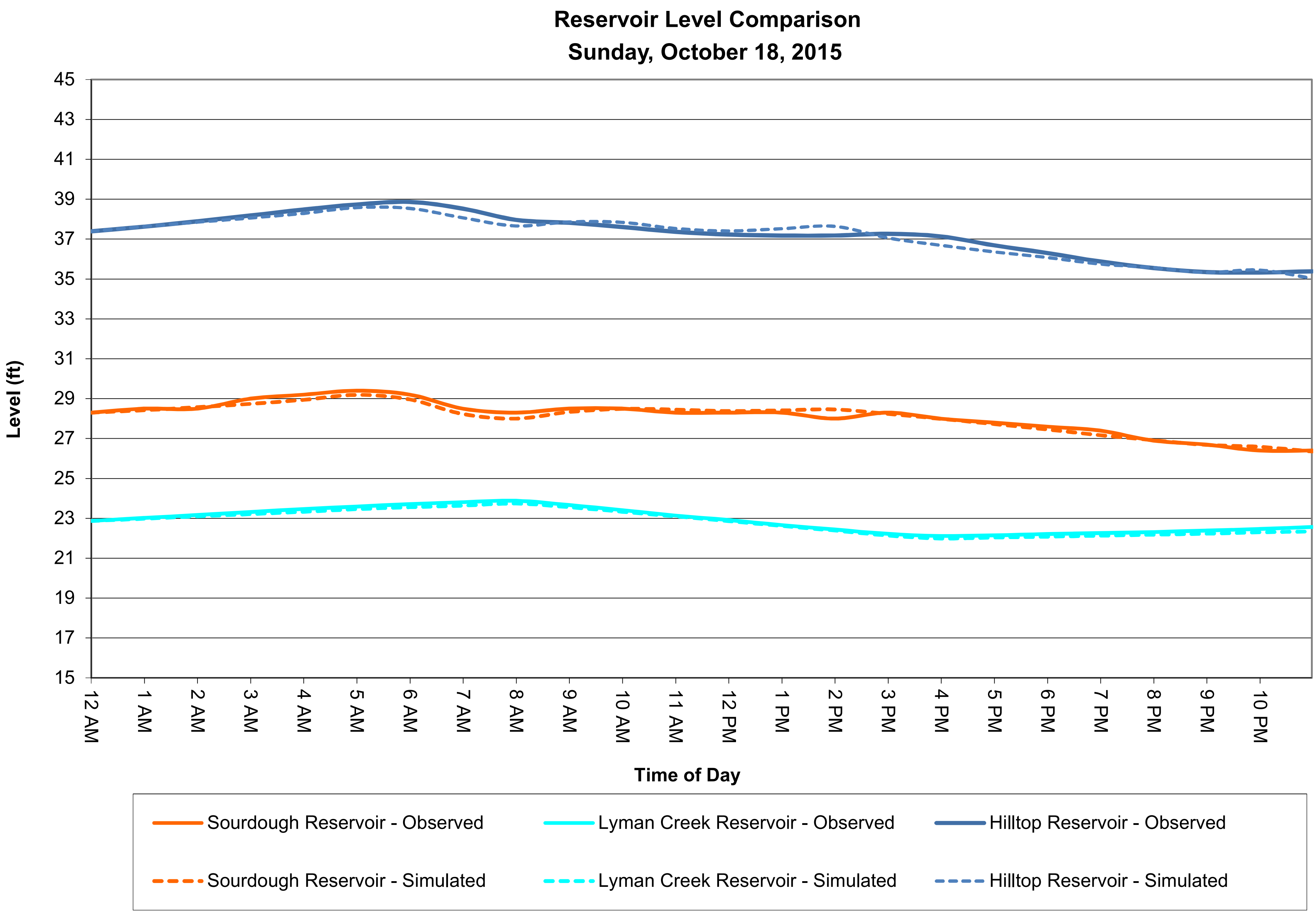
Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 9			Test No. 10		
	Recorder #1243			Recorder #1241		
	Node =	Hydrant #1025		Node =	Hydrant #	
	Elevation =	4755.67		Elevation =	0.00	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/17/2015 0:00	5,119.29	5,119.51	(0.22)	0.00	0.00	0.00
10/17/2015 1:00	5,119.74	5,120.05	(0.31)	0.00	0.00	0.00
10/17/2015 2:00	5,120.31	5,120.30	0.01	0.00	0.00	0.00
10/17/2015 3:00	5,120.98	5,120.79	0.19	0.00	0.00	0.00
10/17/2015 4:00	5,121.32	5,121.08	0.24	0.00	0.00	0.00
10/17/2015 5:00	5,121.55	5,121.36	0.19	0.00	0.00	0.00
10/17/2015 6:00	5,121.43	5,121.40	0.03	0.00	0.00	0.00
10/17/2015 7:00	5,120.87	5,121.18	(0.31)	0.00	0.00	0.00
10/17/2015 8:00	5,120.08	5,120.65	(0.57)	0.00	0.00	0.00
10/17/2015 9:00	5,120.42	5,121.02	(0.60)	0.00	0.00	0.00
10/17/2015 10:00	5,119.74	5,120.30	(0.56)	0.00	0.00	0.00
10/17/2015 11:00	5,119.40	5,121.20	(1.80)	0.00	0.00	0.00
10/17/2015 12:00	5,118.73	5,121.38	(2.65)	0.00	0.00	0.00
10/17/2015 13:00	5,119.06	5,121.09	(2.03)	0.00	0.00	0.00
10/17/2015 14:00	5,119.18	5,121.65	(2.47)	0.00	0.00	0.00
10/17/2015 15:00	5,119.18	5,121.90	(2.72)	0.00	0.00	0.00
10/17/2015 16:00	5,117.26	5,120.39	(3.13)	0.00	0.00	0.00
10/17/2015 17:00	5,116.58	5,120.37	(3.79)	0.00	0.00	0.00
10/17/2015 18:00	5,116.70	5,120.20	(3.50)	0.00	0.00	0.00
10/17/2015 19:00	5,117.15	5,120.13	(2.98)	0.00	0.00	0.00
10/17/2015 20:00	5,117.71	5,120.30	(2.59)	0.00	0.00	0.00
10/17/2015 21:00	5,118.28	5,120.34	(2.06)	0.00	0.00	0.00
10/17/2015 22:00	5,118.61	5,120.11	(1.50)	0.00	0.00	0.00
10/17/2015 23:00	5,119.18	5,120.42	(1.24)	0.00	0.00	0.00

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 11			Test No. 12		
	Recorder #1246			Recorder #1244		
	Node =	Hydrant #2712		Node =	Hydrant #1770	
	Elevation =	4692.64		Elevation =	4679.91	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/17/2015 0:00	4,925.61	4,923.34	2.27	5,027.74	5,026.77	0.97
10/17/2015 1:00	4,925.84	4,925.91	(0.07)	5,027.62	5,028.45	(0.83)
10/17/2015 2:00	4,926.97	4,926.14	0.83	5,028.75	5,028.71	0.04
10/17/2015 3:00	4,926.86	4,927.37	(0.51)	5,029.09	5,029.58	(0.49)
10/17/2015 4:00	4,925.73	4,927.37	(1.64)	5,028.30	5,029.70	(1.40)
10/17/2015 5:00	4,925.16	4,927.37	(2.21)	5,028.30	5,029.81	(1.51)
10/17/2015 6:00	4,924.37	4,926.26	(1.89)	5,027.28	5,029.24	(1.96)
10/17/2015 7:00	4,922.46	4,924.19	(1.73)	5,024.69	5,028.06	(3.37)
10/17/2015 8:00	4,916.70	4,921.75	(5.05)	5,008.44	5,026.61	(18.17)
10/17/2015 9:00	4,916.93	4,921.61	(4.68)	5,006.53	5,018.37	(11.84)
10/17/2015 10:00	4,915.35	4,921.53	(6.18)	5,006.53	5,017.81	(11.28)
10/17/2015 11:00	4,917.83	4,921.66	(3.83)	5,008.67	5,018.23	(9.56)
10/17/2015 12:00	4,917.27	4,921.67	(4.40)	5,006.98	5,018.13	(11.15)
10/17/2015 13:00	4,917.27	4,921.63	(4.36)	5,009.12	5,017.75	(8.63)
10/17/2015 14:00	4,919.30	4,921.69	(2.39)	5,009.23	5,017.91	(8.68)
10/17/2015 15:00	4,919.63	4,921.71	(2.08)	5,009.91	5,017.85	(7.94)
10/17/2015 16:00	4,919.30	4,921.68	(2.38)	5,019.27	5,024.78	(5.51)
10/17/2015 17:00	4,919.97	4,921.73	(1.76)	5,018.94	5,024.92	(5.98)
10/17/2015 18:00	4,918.85	4,921.72	(2.87)	5,020.52	5,024.99	(4.47)
10/17/2015 19:00	4,920.76	4,921.73	(0.97)	5,021.08	5,025.08	(4.00)
10/17/2015 20:00	4,922.00	4,921.84	0.16	5,023.45	5,025.25	(1.80)
10/17/2015 21:00	4,922.68	4,923.02	(0.34)	5,023.79	5,026.05	(2.26)
10/17/2015 22:00	4,922.00	4,922.08	(0.08)	5,023.67	5,025.53	(1.86)
10/17/2015 23:00	4,924.26	4,924.19	0.07	5,026.27	5,026.90	(0.63)

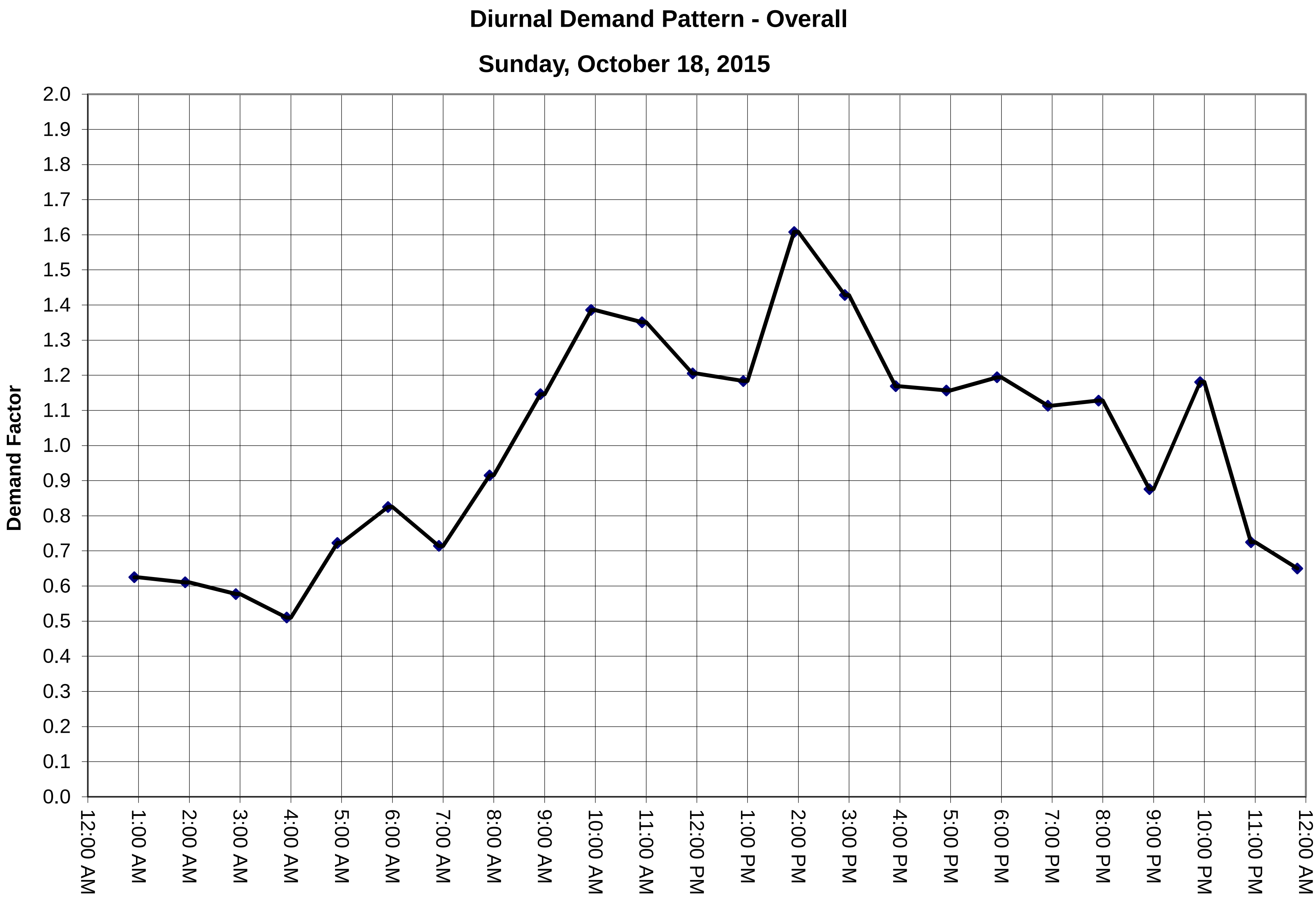


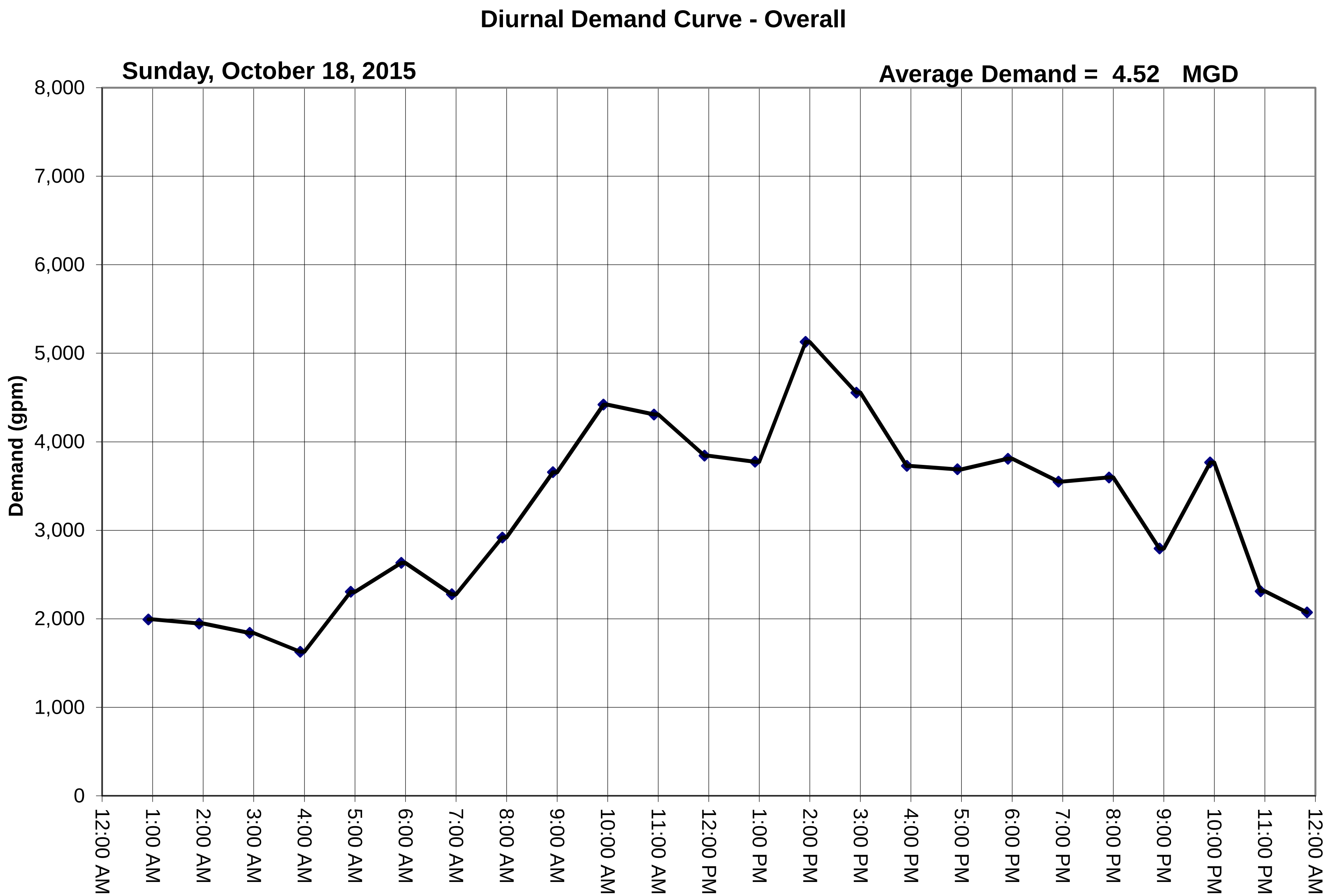
Reservoir Level Comparison
Sunday, October 18, 2015
Level (ft)
45
43
41
39
37
35
33
31
29
27
25
23
21
19
17
15
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
Time of Day
Sourdough Reservoir - Observed
Lyman Creek Reservoir - Observed
Hilltop Reservoir - Observed
Sourdough Reservoir - Simulated
Lyman Creek Reservoir - Simulated
Hilltop Reservoir - Simulated

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Reservoir Level Calibration
(Tower Level in ft)

Date/Time	Time	Sourdough Reservoir Level			Lyman Reservoir Level			Hilltop Reservoir Level		
		Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
10/18/2015 0:00	0:00	28.30	28.30	0.00	22.87	22.87	0.00	37.39	37.39	0.00
10/18/2015 1:00	1:00	28.50	28.42	0.08	23.02	22.98	0.04	37.63	37.63	0.00
10/18/2015 2:00	2:00	28.50	28.57	-0.07	23.17	23.10	0.07	37.89	37.85	0.04
10/18/2015 3:00	3:00	29.00	28.74	0.26	23.31	23.21	0.10	38.18	38.06	0.12
10/18/2015 4:00	4:00	29.20	28.94	0.26	23.47	23.33	0.14	38.48	38.29	0.19
10/18/2015 5:00	5:00	29.40	29.19	0.21	23.59	23.46	0.13	38.74	38.58	0.16
10/18/2015 6:00	6:00	29.20	28.96	0.24	23.71	23.56	0.15	38.87	38.54	0.33
10/18/2015 7:00	7:00	28.50	28.23	0.27	23.81	23.64	0.17	38.53	38.07	0.46
10/18/2015 8:00	8:00	28.30	28.00	0.30	23.88	23.74	0.14	37.97	37.66	0.31
10/18/2015 9:00	9:00	28.50	28.33	0.17	23.67	23.56	0.11	37.82	37.86	-0.04
10/18/2015 10:00	10:00	28.50	28.49	0.01	23.41	23.33	0.08	37.61	37.84	-0.23
10/18/2015 11:00	11:00	28.30	28.45	-0.15	23.14	23.10	0.04	37.37	37.53	-0.16
10/18/2015 12:00	12:00	28.30	28.38	-0.08	22.92	22.86	0.06	37.23	37.41	-0.18
10/18/2015 13:00	13:00	28.30	28.41	-0.11	22.66	22.62	0.04	37.18	37.52	-0.34
10/18/2015 14:00	14:00	28.00	28.46	-0.46	22.44	22.39	0.05	37.18	37.64	-0.46
10/18/2015 15:00	15:00	28.30	28.24	0.06	22.22	22.14	0.08	37.27	37.06	0.21
10/18/2015 16:00	16:00	28.00	27.99	0.01	22.12	21.99	0.13	37.14	36.69	0.45
10/18/2015 17:00	17:00	27.80	27.73	0.07	22.15	22.04	0.11	36.69	36.36	0.33
10/18/2015 18:00	18:00	27.60	27.46	0.14	22.21	22.08	0.13	36.31	36.08	0.23
10/18/2015 19:00	19:00	27.40	27.17	0.23	22.26	22.13	0.13	35.88	35.75	0.13
10/18/2015 20:00	20:00	26.90	26.92	-0.02	22.31	22.18	0.13	35.56	35.57	-0.01
10/18/2015 21:00	21:00	26.70	26.68	0.02	22.39	22.23	0.16	35.35	35.33	0.02
10/18/2015 22:00	22:00	26.40	26.59	-0.19	22.47	22.30	0.17	35.32	35.45	-0.13
10/18/2015 23:00	23:00	26.40	26.35	0.05	22.57	22.34	0.23	35.39	35.03	0.36


Diurnal Demand Pattern - Overall
Sunday, October 18, 2015
Demand Factor
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM



Diurnal Demand Curve - Overall
Sunday, October 18, 2015
Average Demand = 4.52 MGD
Demand (gpm)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 1			Test No. 2		
	Recorder #1242			Recorder #1240		
	Node =	Hydrant #2107		Node =	Hydrant #433	
	Elevation =	5024.74		Elevation =	4969.52	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/18/2015 0:00	5,120.41	5,121.47	(1.06)	5,121.04	5,121.95	(0.91)
10/18/2015 1:00	5,120.75	5,121.70	(0.95)	5,121.38	5,122.13	(0.75)
10/18/2015 2:00	5,120.98	5,121.90	(0.92)	5,121.60	5,122.32	(0.72)
10/18/2015 3:00	5,121.43	5,122.14	(0.71)	5,121.94	5,122.52	(0.58)
10/18/2015 4:00	5,121.65	5,122.47	(0.82)	5,122.17	5,122.79	(0.62)
10/18/2015 5:00	5,121.99	5,122.38	(0.39)	5,122.50	5,122.90	(0.40)
10/18/2015 6:00	5,121.43	5,122.01	(0.58)	5,122.17	5,122.64	(0.47)
10/18/2015 7:00	5,120.52	5,121.63	(1.11)	5,121.49	5,122.10	(0.61)
10/18/2015 8:00	5,119.62	5,120.91	(1.29)	5,121.04	5,121.66	(0.62)
10/18/2015 9:00	5,119.96	5,121.43	(1.47)	5,121.15	5,122.08	(0.93)
10/18/2015 10:00	5,119.06	5,120.87	(1.81)	5,120.81	5,121.96	(1.15)
10/18/2015 11:00	5,118.49	5,120.80	(2.31)	5,120.59	5,121.83	(1.24)
10/18/2015 12:00	5,118.16	5,121.08	(2.92)	5,120.70	5,121.88	(1.18)
10/18/2015 13:00	5,118.27	5,121.22	(2.95)	5,120.70	5,121.96	(1.26)
10/18/2015 14:00	5,118.27	5,120.00	(1.73)	5,120.59	5,121.59	(1.00)
10/18/2015 15:00	5,118.27	5,120.21	(1.94)	5,120.70	5,121.43	(0.73)
10/18/2015 16:00	5,117.25	5,119.72	(2.47)	5,120.36	5,121.03	(0.67)
10/18/2015 17:00	5,116.80	5,119.44	(2.64)	5,119.91	5,120.74	(0.83)
10/18/2015 18:00	5,116.69	5,119.08	(2.39)	5,119.68	5,120.43	(0.75)
10/18/2015 19:00	5,116.24	5,119.02	(2.78)	5,119.12	5,120.21	(1.09)
10/18/2015 20:00	5,116.46	5,118.75	(2.29)	5,118.89	5,119.97	(1.08)
10/18/2015 21:00	5,116.91	5,119.19	(2.28)	5,118.78	5,119.99	(1.21)
10/18/2015 22:00	5,117.37	5,118.37	(1.00)	5,118.78	5,119.69	(0.91)
10/18/2015 23:00	5,117.82	5,119.23	(1.41)	5,118.89	5,119.82	(0.93)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 3			Test No. 4		
	Recorder #1251			Recorder #1249		
	Node =	Hydrant #490		Node =	Hydrant #278	
	Elevation =	4880.25		Elevation =	4861.19	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/18/2015 0:00	5,119.77	5,121.27	(1.50)	5,121.81	5,121.62	0.19
10/18/2015 1:00	5,120.22	5,121.51	(1.29)	5,122.14	5,121.83	0.31
10/18/2015 2:00	5,120.44	5,121.72	(1.28)	5,122.37	5,122.04	0.33
10/18/2015 3:00	5,121.01	5,121.97	(0.96)	5,122.71	5,122.26	0.45
10/18/2015 4:00	5,121.23	5,122.33	(1.10)	5,122.93	5,122.55	0.38
10/18/2015 5:00	5,121.46	5,122.16	(0.70)	5,123.27	5,122.62	0.65
10/18/2015 6:00	5,121.01	5,121.75	(0.74)	5,123.05	5,122.37	0.68
10/18/2015 7:00	5,119.99	5,121.44	(1.45)	5,122.37	5,121.91	0.46
10/18/2015 8:00	5,118.87	5,120.61	(1.74)	5,121.92	5,121.36	0.56
10/18/2015 9:00	5,119.32	5,121.21	(1.89)	5,122.03	5,121.90	0.13
10/18/2015 10:00	5,118.30	5,120.48	(2.18)	5,121.58	5,121.65	(0.07)
10/18/2015 11:00	5,118.30	5,120.43	(2.13)	5,121.24	5,121.49	(0.25)
10/18/2015 12:00	5,118.30	5,120.79	(2.49)	5,121.24	5,121.57	(0.33)
10/18/2015 13:00	5,118.41	5,120.95	(2.54)	5,121.35	5,121.68	(0.33)
10/18/2015 14:00	5,118.53	5,119.40	(0.87)	5,121.35	5,121.13	0.22
10/18/2015 15:00	5,118.64	5,119.76	(1.12)	5,121.47	5,121.00	0.47
10/18/2015 16:00	5,117.40	5,119.17	(1.77)	5,121.02	5,120.42	0.60
10/18/2015 17:00	5,116.72	5,118.90	(2.18)	5,120.56	5,120.12	0.44
10/18/2015 18:00	5,116.38	5,118.50	(2.12)	5,120.23	5,119.79	0.44
10/18/2015 19:00	5,115.37	5,118.52	(3.15)	5,119.77	5,119.61	0.16
10/18/2015 20:00	5,115.48	5,118.23	(2.75)	5,119.44	5,119.37	0.07
10/18/2015 21:00	5,116.04	5,118.85	(2.81)	5,119.32	5,119.49	(0.17)
10/18/2015 22:00	5,116.38	5,117.83	(1.45)	5,119.44	5,119.10	0.34
10/18/2015 23:00	5,116.83	5,118.97	(2.14)	5,119.44	5,119.38	0.06

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

Date/Time	Test No. 5			Test No. 6		
	Recorder #341298			Recorder #1245		
	Node =	Hydrant #121		Node =	Hydrant #1887	
	Elevation =	4817.61		Elevation =	4754.53	
	Observed	Simulated	Difference	Observed	Simulated	Difference
10/18/2015 0:00	5,120.00	5,121.33	(1.33)	5,118.60	5,121.24	(2.64)
10/18/2015 1:00	5,120.49	5,121.58	(1.09)	5,119.17	5,121.49	(2.32)
10/18/2015 2:00	5,120.85	5,121.78	(0.93)	5,119.28	5,121.70	(2.42)
10/18/2015 3:00	5,121.22	5,122.03	(0.81)	5,119.73	5,121.96	(2.23)
10/18/2015 4:00	5,121.46	5,122.37	(0.91)	5,120.07	5,122.31	(2.24)
10/18/2015 5:00	5,121.70	5,122.26	(0.56)	5,120.41	5,122.15	(1.74)
10/18/2015 6:00	5,121.34	5,121.90	(0.56)	5,119.96	5,121.75	(1.79)
10/18/2015 7:00	5,120.49	5,121.56	(1.07)	5,118.83	5,121.44	(2.61)
10/18/2015 8:00	5,119.88	5,120.78	(0.90)	5,118.49	5,120.60	(2.11)
10/18/2015 9:00	5,120.49	5,121.82	(1.33)	5,120.07	5,122.40	(2.33)
10/18/2015 10:00	5,119.76	5,121.39	(1.63)	5,119.05	5,121.86	(2.81)
10/18/2015 11:00	5,119.76	5,121.27	(1.51)	5,118.38	5,121.76	(3.38)
10/18/2015 12:00	5,119.52	5,121.46	(1.94)	5,117.59	5,122.00	(4.41)
10/18/2015 13:00	5,119.64	5,121.58	(1.94)	5,118.26	5,122.13	(3.87)
10/18/2015 14:00	5,119.64	5,120.59	(0.95)	5,118.26	5,120.96	(2.70)
10/18/2015 15:00	5,119.76	5,120.69	(0.93)	5,118.38	5,121.14	(2.76)
10/18/2015 16:00	5,117.94	5,119.47	(1.53)	5,115.33	5,119.17	(3.84)
10/18/2015 17:00	5,117.21	5,119.18	(1.97)	5,114.77	5,118.89	(4.12)
10/18/2015 18:00	5,116.85	5,118.81	(1.96)	5,114.65	5,118.50	(3.85)
10/18/2015 19:00	5,116.12	5,118.77	(2.65)	5,113.98	5,118.51	(4.53)
10/18/2015 20:00	5,116.24	5,118.50	(2.26)	5,114.09	5,118.22	(4.13)
10/18/2015 21:00	5,116.61	5,118.99	(2.38)	5,114.65	5,118.83	(4.18)
10/18/2015 22:00	5,116.97	5,118.13	(1.16)	5,115.22	5,117.82	(2.60)
10/18/2015 23:00	5,117.33	5,119.05	(1.72)	5,115.67	5,118.94	(3.27)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

Date/Time	Test No. 7			Test No. 8		
	Recorder #341289			Recorder #201250		
	Node =	Hydrant #1754		Node =	Hydrant #1125	
	Elevation =	4820.11		Elevation =	4779.50	
	Observed	Simulated	Difference	Observed	Simulated	Difference
10/18/2015 0:00	5,119.47	5,121.04	(1.57)	5,120.11	5,121.05	(0.94)
10/18/2015 1:00	5,119.96	5,121.31	(1.35)	5,120.56	5,121.31	(0.75)
10/18/2015 2:00	5,120.20	5,121.52	(1.32)	5,120.67	5,121.52	(0.85)
10/18/2015 3:00	5,120.68	5,121.79	(1.11)	5,121.23	5,121.80	(0.57)
10/18/2015 4:00	5,120.80	5,122.19	(1.39)	5,121.46	5,122.19	(0.73)
10/18/2015 5:00	5,121.05	5,121.90	(0.85)	5,121.68	5,121.91	(0.23)
10/18/2015 6:00	5,120.56	5,121.42	(0.86)	5,121.23	5,121.43	(0.20)
10/18/2015 7:00	5,119.35	5,121.19	(1.84)	5,120.11	5,121.20	(1.09)
10/18/2015 8:00	5,118.02	5,120.20	(2.18)	5,118.86	5,120.21	(1.35)
10/18/2015 9:00	5,118.38	5,120.64	(2.26)	5,119.20	5,120.65	(1.45)
10/18/2015 10:00	5,117.05	5,119.60	(2.55)	5,117.74	5,119.61	(1.87)
10/18/2015 11:00	5,116.92	5,119.60	(2.68)	5,117.40	5,119.61	(2.21)
10/18/2015 12:00	5,117.05	5,120.16	(3.11)	5,117.06	5,120.17	(3.11)
10/18/2015 13:00	5,117.29	5,120.36	(3.07)	5,117.28	5,120.37	(3.09)
10/18/2015 14:00	5,117.29	5,118.14	(0.85)	5,117.28	5,118.14	(0.86)
10/18/2015 15:00	5,117.53	5,118.80	(1.27)	5,117.40	5,118.81	(1.41)
10/18/2015 16:00	5,115.83	5,118.44	(2.61)	5,115.93	5,118.45	(2.52)
10/18/2015 17:00	5,115.10	5,118.17	(3.07)	5,115.14	5,118.18	(3.04)
10/18/2015 18:00	5,114.86	5,117.74	(2.88)	5,114.92	5,117.75	(2.83)
10/18/2015 19:00	5,113.89	5,117.87	(3.98)	5,114.13	5,117.87	(3.74)
10/18/2015 20:00	5,114.26	5,117.55	(3.29)	5,114.58	5,117.56	(2.98)
10/18/2015 21:00	5,114.98	5,118.47	(3.49)	5,115.37	5,118.48	(3.11)
10/18/2015 22:00	5,115.47	5,117.09	(1.62)	5,116.16	5,117.09	(0.93)
10/18/2015 23:00	5,116.44	5,118.70	(2.26)	5,117.06	5,118.70	(1.64)

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 9			Test No. 10		
	Recorder #1243			Recorder #1241		
	Node =	Hydrant #1025		Node =	Hydrant #	
	Elevation =	4755.67		Elevation =	0.00	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/18/2015 0:00	5,119.97	5,121.15	(1.18)	0.00	0.00	0.00
10/18/2015 1:00	5,120.42	5,121.41	(0.99)	0.00	0.00	0.00
10/18/2015 2:00	5,120.53	5,121.62	(1.09)	0.00	0.00	0.00
10/18/2015 3:00	5,121.10	5,121.88	(0.78)	0.00	0.00	0.00
10/18/2015 4:00	5,121.32	5,122.25	(0.93)	0.00	0.00	0.00
10/18/2015 5:00	5,121.55	5,122.03	(0.48)	0.00	0.00	0.00
10/18/2015 6:00	5,121.21	5,121.59	(0.38)	0.00	0.00	0.00
10/18/2015 7:00	5,120.08	5,121.33	(1.25)	0.00	0.00	0.00
10/18/2015 8:00	5,119.06	5,120.41	(1.35)	0.00	0.00	0.00
10/18/2015 9:00	5,119.63	5,121.19	(1.56)	0.00	0.00	0.00
10/18/2015 10:00	5,118.50	5,120.29	(1.79)	0.00	0.00	0.00
10/18/2015 11:00	5,118.16	5,120.26	(2.10)	0.00	0.00	0.00
10/18/2015 12:00	5,118.05	5,120.71	(2.66)	0.00	0.00	0.00
10/18/2015 13:00	5,118.16	5,120.89	(2.73)	0.00	0.00	0.00
10/18/2015 14:00	5,118.16	5,119.04	(0.88)	0.00	0.00	0.00
10/18/2015 15:00	5,118.39	5,119.53	(1.14)	0.00	0.00	0.00
10/18/2015 16:00	5,116.58	5,118.83	(2.25)	0.00	0.00	0.00
10/18/2015 17:00	5,115.91	5,118.56	(2.65)	0.00	0.00	0.00
10/18/2015 18:00	5,115.68	5,118.14	(2.46)	0.00	0.00	0.00
10/18/2015 19:00	5,114.89	5,118.22	(3.33)	0.00	0.00	0.00
10/18/2015 20:00	5,115.12	5,117.92	(2.80)	0.00	0.00	0.00
10/18/2015 21:00	5,115.91	5,118.66	(2.75)	0.00	0.00	0.00
10/18/2015 22:00	5,116.36	5,117.47	(1.11)	0.00	0.00	0.00
10/18/2015 23:00	5,116.92	5,118.83	(1.91)	0.00	0.00	0.00

Water Distribution System Hydraulic Model Calibration
City of Bozeman

Extended Pressure Testing Calibration
(Hydraulic Grade Line Elevation in ft)

	Test No. 11			Test No. 12		
	Recorder #1246			Recorder #1244		
	Node =	Hydrant #2712		Node =	Hydrant #1770	
	Elevation =	4692.64		Elevation =	4679.91	
Date/Time	Observed	Simulated	Difference	Observed	Simulated	Difference
10/18/2015 0:00	4,925.39	4,926.65	(1.26)	5,027.17	5,028.69	(1.52)
10/18/2015 1:00	4,925.84	4,927.02	(1.18)	5,027.74	5,029.01	(1.27)
10/18/2015 2:00	4,926.97	4,927.12	(0.15)	5,028.53	5,029.20	(0.67)
10/18/2015 3:00	4,927.31	4,927.46	(0.15)	5,028.75	5,029.52	(0.77)
10/18/2015 4:00	4,925.84	4,928.17	(2.33)	5,028.07	5,030.08	(2.01)
10/18/2015 5:00	4,925.84	4,925.81	0.03	5,027.85	5,028.74	(0.89)
10/18/2015 6:00	4,924.49	4,924.30	0.19	5,026.49	5,027.91	(1.42)
10/18/2015 7:00	4,922.57	4,925.93	(3.36)	5,026.04	5,029.00	(2.96)
10/18/2015 8:00	4,916.81	4,922.93	(6.12)	5,008.67	5,027.24	(18.57)
10/18/2015 9:00	4,917.15	4,921.67	(4.52)	5,008.67	5,018.54	(9.87)
10/18/2015 10:00	4,913.43	4,921.57	(8.14)	5,003.37	5,017.84	(14.47)
10/18/2015 11:00	4,917.04	4,921.59	(4.55)	5,007.20	5,017.71	(10.51)
10/18/2015 12:00	4,915.80	4,921.65	(5.85)	5,004.49	5,017.82	(13.33)
10/18/2015 13:00	4,917.38	4,921.66	(4.28)	5,008.44	5,017.71	(9.27)
10/18/2015 14:00	4,920.65	4,921.44	(0.79)	5,010.70	5,016.49	(5.79)
10/18/2015 15:00	4,917.83	4,921.55	(3.72)	5,010.02	5,016.68	(6.66)
10/18/2015 16:00	4,918.73	4,921.67	(2.94)	5,020.29	5,024.52	(4.23)
10/18/2015 17:00	4,918.73	4,921.67	(2.94)	5,021.19	5,024.58	(3.39)
10/18/2015 18:00	4,920.88	4,921.66	(0.78)	5,021.30	5,024.60	(3.30)
10/18/2015 19:00	4,920.31	4,921.68	(1.37)	5,020.97	5,024.73	(3.76)
10/18/2015 20:00	4,919.86	4,921.68	(1.82)	5,020.85	5,024.75	(3.90)
10/18/2015 21:00	4,919.97	4,923.56	(3.59)	5,022.09	5,026.11	(4.02)
10/18/2015 22:00	4,922.91	4,921.66	1.25	5,024.80	5,024.82	(0.02)
10/18/2015 23:00	4,924.82	4,925.81	(0.99)	5,026.27	5,027.63	(1.36)

Appendix F – Non-Potable Irrigation Evaluation

NON-POTABLE WATER IRRIGATION SYSTEM DESIGN CRITERIA

1. Any proposed non-potable water system shall meet the requirements specified in section V, sub-sections A.2. and A.3. of the COB Design Standards and Specifications Policy for Water Distribution Lines Design Criteria for Master Plans and Engineering Design Reports. A separate non-potable water system master plan shall be submitted for each subdivision or major development prior to the approval and commissioning of the system. The engineering design report shall be prepared in accordance with this document by a professional engineer licensed in the state of Montana prior to submitting plans and specifications for regulatory review. All design criteria and critical conditions shall be shown on the overall plan for the study area.

2. The non-potable water systems designed and constructed under authority of this document shall be used for the sole purpose of irrigation and shall in no way be designated as "public water supply", "potable water", or "fire service". All manholes, valve boxes, air relief valves, blow-offs, hydrants, or other appurtenances associated with the non-potable water system shall be marked as "Non-Potable, Do Not Drink" and color coded purple.

3. Non-Potable Water Main Design: The non-potable water distribution system shall be designed to meet the peak hour demand as determined in the engineering design report listed in section E.1. of these specifications. The design report for each development shall include a detailed analysis of the estimated demands for all new customers and base the distribution pipe sizing on this demand plus an adequate factor of safety.

    a. Polyvinyl Chloride (PVC) pipe shall be used exclusively unless special approval, in writing, of alternative materials is given by the City Engineer. PVC shall be manufactured from class 1245A or 1245B compounds conforming to ASTM D1784 and have a minimum hydrostatic test basis (HDB) of 4,000 psi. All PVC pipe shall conform to AWWA C900 and shall be Class 150 psi (DR 18).
    b. A "C" factor of 150 should be used when modeling non-potable water systems with PVC pipe.
    c. The non-potable water system shall be designed to maintain a working pressure 5 – 10 psi less than adjacent potable water lines, with a maximum pressure of 55 psi and minimum pressure of 30 psi.
    d. All non-potable water system piping shall be manufactured, painted, or wrapped in polyethylene with purple coloring. The pipe may also be stenciled or marked with tape.

4. Main Extensions: All main extensions shall be looped, where possible. All permanent and temporary dead end mains shall end with a flushing hydrant or a 2" blow-off. Permanent dead-end mains shall not exceed 500-feet long.

5. Services: Non-potable water lines are designated as either a "service line" or "water main" based on its use, not its size. In general, a single irrigation line serving a residential or commercial property is considered a service line; a line serving more than one building, or intended to provide service to an entire development, is considered a non-potable water main. Service lines can range from ¾" to 2"; mains shall be 24" diameter or smaller.

a. Service pipes shall be either PVC Schedule 40 or polyethylene (PE) piping rated at 200 psi, colored purple. The COB will provide service stubs to each property. Each property owner will be responsible for installation of the irrigation system components downstream of the meter. A master control valve, shut-off valve, and wye strainer are required at each service connection.
b. All service stubs shall be installed in accordance with the COB Standard Drawings for water distribution service lines. The service lines shall be installed at the center of each lot, with a minimum horizontal distance of 3-feet from any potable water or gravity sewer line, unless otherwise approved by the Water Superintendent. The service line connections shall be uniform in size and shall be sized to adequately serve the maximum anticipated demand for the property being served.
c. No service line shall be extended into a building or home until a "Non-Potable Water New Customer Service Connection" application has been completed and a permit has been obtained from the COB.
d. No backflow prevention devices are required for non-potable water irrigation systems, however, a cross connection inspection performed by a certified COB technician is required prior to placing the new connection in service. Annual cross-connection inspections shall be required for each non-potable water customers. Refer to the **Quick Check List for Non-Potable Water Connections**. Backflow prevention devices are required for all potable water systems to protect the public water supply from any contamination or possible cross connections with the non-potable water system. Refer to the COB Design Standards and Specifications Policy Section V, Subsection A.6.e. for water system backflow prevention requirements.
e. Meters shall be installed inside the building by the Water Department for all service lines. Meter pits shall not be used unless specifically approved by the Water Superintendent. Where allowed, any meters or appurtenances installed in an outdoor pit, shall be designed to withstand freezing.

6. Valves: Valves shall be installed in accordance with the following unless otherwise approved or required by the Water Superintendent:

a. All connections to an existing non-potable water main shall begin with a new shut-off valve.
b. Valves shall not be located at more than 500-foot intervals
c. Every leg of a main intersection shall have a valve.
d. All valves shall open counterclockwise, opposite of potable water systems.
e. Valve boxes and all above-grade appurtenances shall be color coded purple and clearly labeled "Non-Potable".
f. Valves and controllers shall be keyed to limit access to authorized personnel only.

7. Hydrants: Flushing hydrants shall be placed at each street intersection, dead-end, and intermediate points at least every 500-feet.

8. Air Relief: Air relief valves shall be provided at all high points in the line where air can accumulate.

a. Automatic air relief valves may not be used in situations where flooding of the manhole or chamber can occur, use of manual air relief valves is recommended wherever possible.

b. The open end of a relief pipe must be extended to at least one foot above grade and provided screened, facing downward.
c. All relief pipes that extend above grade shall be purple and marked as "Non-Potable".

9. Pressure Reducing Valves: Pressure reducing valves should be placed where anticipated pressures exceed 50 psi. The Engineering Design Report should detail the hydraulic modeling or analysis for determination of high pressure zones.

10. Thrust Restraint: All thrust restraint shall be designed to withstand the test pressure or working pressure plus surge allowance, whichever is larger. Adequate factors of safety shall be employed in the design.

    a. The use of thrust blocks should be minimized to prevent leaking.
    b. Mechanically restrained joints should be used for restraining movement on PVC piping.

11. Pressure and Leakage Testing: The minimum required hydrostatic pressure for any non-potable water main is 200 psi.

    a. The testing gauge shall be marked in increments no greater than 10 psi.
    b. Conduct leakage testing concurrently with hydrostatic pressure testing for a minimum of 2 hours.
    c. Do not perform pressure or leakage testing until backfill over the pipe is complete.
    d. Visually inspect mains that cannot be hydrostatically tested.
    e. If there is leakage, repair defective pipe section and repeat hydrostatic test.

12. Pipe Separation: All non-potable water system mains shall have a minimum horizontal separation of 10-feet from any parallel water mains, sanitary sewers, or storm sewers. Any pipeline crossings shall be perpendicular and arranged such that non-potable water main pipeline joints are equidistant, and as far as possible from water or sewer main joints.

    a. All crossings shall have a minimum 18-inch vertical separation
    b. Where 18-inch vertical separation cannot be met, then 6-inch separation is required and the water or sewer main musts be encased in a watertight carrier pipe or 6-inches of flowable fill that extends 10 feet on both sides of the crossing.
    c. Non-potable water mains must be located inside COB right-of-way in accordance with Section V, Subsection D of the COB Design Standards and Specifications Policy.
    d. Non-potable water mains shall be located on the opposite side of the street from water mains.

13. Pumping and Storage Facility: Where the source of non-potable water is to be stored prior to distribution, a storage pond shall be constructed. A pumping and filtration system shall be used prior to discharging the water into the distribution system.
    a. Non-Potable Water Storage Pond
        (1) Pond shall not be located in the floodway
        (2) Design of pond shall conform to Montana DEQ Pond Guideline (latest version)
        (3) Usable volume of water storage shall be a minimum of peak daily demand.
        (4) Pond shall have screen on inlet capable of being cleaned/maintained and minimize debris from reaching pump station.

(5) Pond Liners:
   (a) The ponds, whether constructed of earthen or other impervious materials, shall be designed and constructed so as to minimize losses through seepage;
   (b) Soils used for pond lining shall be free from foreign material such as paper, brush, trees, and large rocks;
   (c) All soil liners must be of compacted material having a permeability less than or equal to 1 x 10-4 cm/sec, at least 18 inches thick, compacted in lifts no greater than 6 inches each;
   (d) Synthetic membrane linings shall have a minimum thickness of 40 mils.

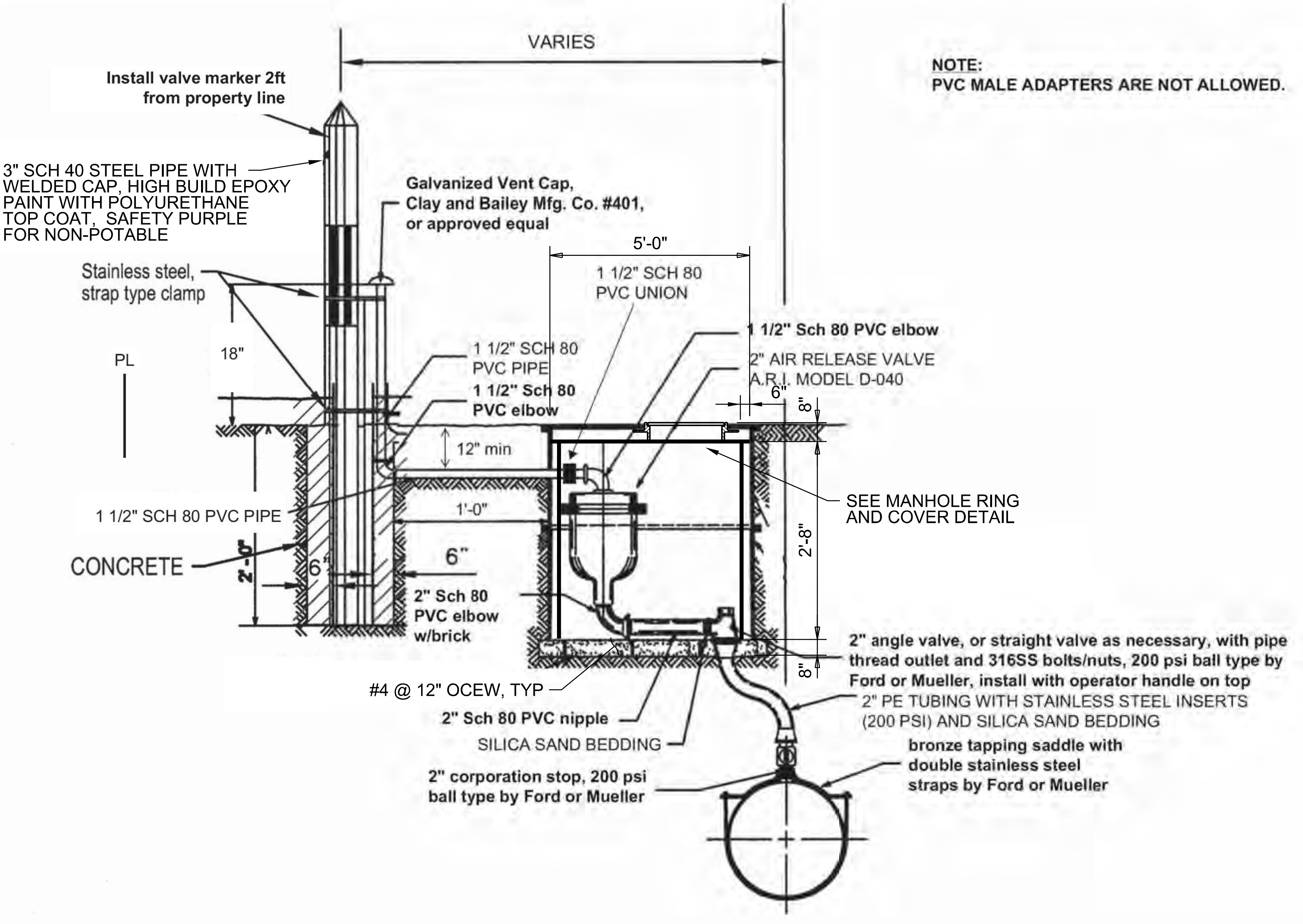
b. Pump Station/Filtration System
   (1) Pump station shall be designed to provide two times the peak day demand with one large pump off-line;
   (2) Pump station shall consist of at least three pumps, with the largest pump having a standby pump. Minimum pump station flow will be provided by hydropneumatics tank, with the station's smallest pump being sized to provide the minimum day demand with no more than two start-stop cycles per hour.
   (3) Pump station shall include flow meter and check valve.
   (4) Pumps, filters, and hydropneumatic tank shall be located within a weather-tight building that is adequately ventilated in non-freezing weather and heating to maintain an above-freezing temperature during freezing weather.
   (5) Pumps shall be sized to provide two times the peak daily demand.
   (6) Sequence of Operation: Station shall utilize three (3) pumps to maintain system pressure by sequencing pumps on and off, as required, to maintain smooth and efficient operation. Pumps start and stop on level of water in hydropneumatic tank. Tank is equipped with probes on a still well that starts and stops the pumps. Air compressor starts and stops based on air/water level in tank. Operating point shall be adjustable in the field. Pumps shall be sequenced off at user selectable intervals to reduce possibility of water hammer within the piping system. Lead pump shall rotate among operating pumps to equalize operating time of individual pumps.
   (7) Main switch gear controls must be located above grade, in areas not subject to flooding. All electric work must conform to the requirements of the National Electrical Code or to relevant state and local codes.
   (8) Filtration system shall be designed to remove solids equal to or greater than one-tenth the emitter opening diameter for irrigation system being served. Backwash time shall not exceed 10% of the operating time. Backwash shall be discharged to sanitary water system.
   (9) Hydropneumatic tank shall be sized to minimize pump start/stop cycles and shall be sized at a minimum volume equal to 20 minutes of peak demand.

Quick Checklist for Non-Potable Water Connections

This checklist establishes the application and permitting process for new customer service connections for the City of Bozeman Non-Potable Irrigation System. Each new customer musts adhere to the application procedure prior to bringing their system online.

1. City or Bozeman provides an application form that specifies the following:
    a. A description of the property to be served
    b. The applicants relationship to the property (owner or tenant)
    c. The purpose for which the property is to be used
    d. The estimated non-potable water demand
    e. Delivery requirements for pressure and time of day
    f. Specific purpose for the use of the non-potable water
2. Home owner to complete and sign the application.
3. Return the application to the City of Bozeman.
4. Once the application has been received and processed, a confirmation will be sent to the home owner.
5. Once the irrigation system is complete and operable, except for final connection to the non-potable water system, the home owner shall call to schedule the irrigation system and cross connection inspection.
6. The inspection will check for the following requirements:
    a. A complete and operable system.
    b. A master control valve
    c. A wye strainer (may be optional)
    d. Piping and appurtenances identified as non-potable with purple coloring and warning signs.
    e. Irrigation valve box with a lid indicating non-potable system.
    f. The new connection has met requirements for minimum separation from the potable water service line (typically 3 feet).
    g. If a soaker hose (semi-permeable) is part of the system, the supply pipe and terminal end must be painted purple and the hose must be permanently secured to the supply pipe.

Once the system passes inspection a permit will be issued, setting forth the conditions of the connection with regards to interruptions in service, public health and safety, liability, and maintenance responsibilities. The permit will also detail the requirements for the annual irrigation system and cross-connection inspections.



NON-POTABLE AIR RELIEF DETAIL

NTS

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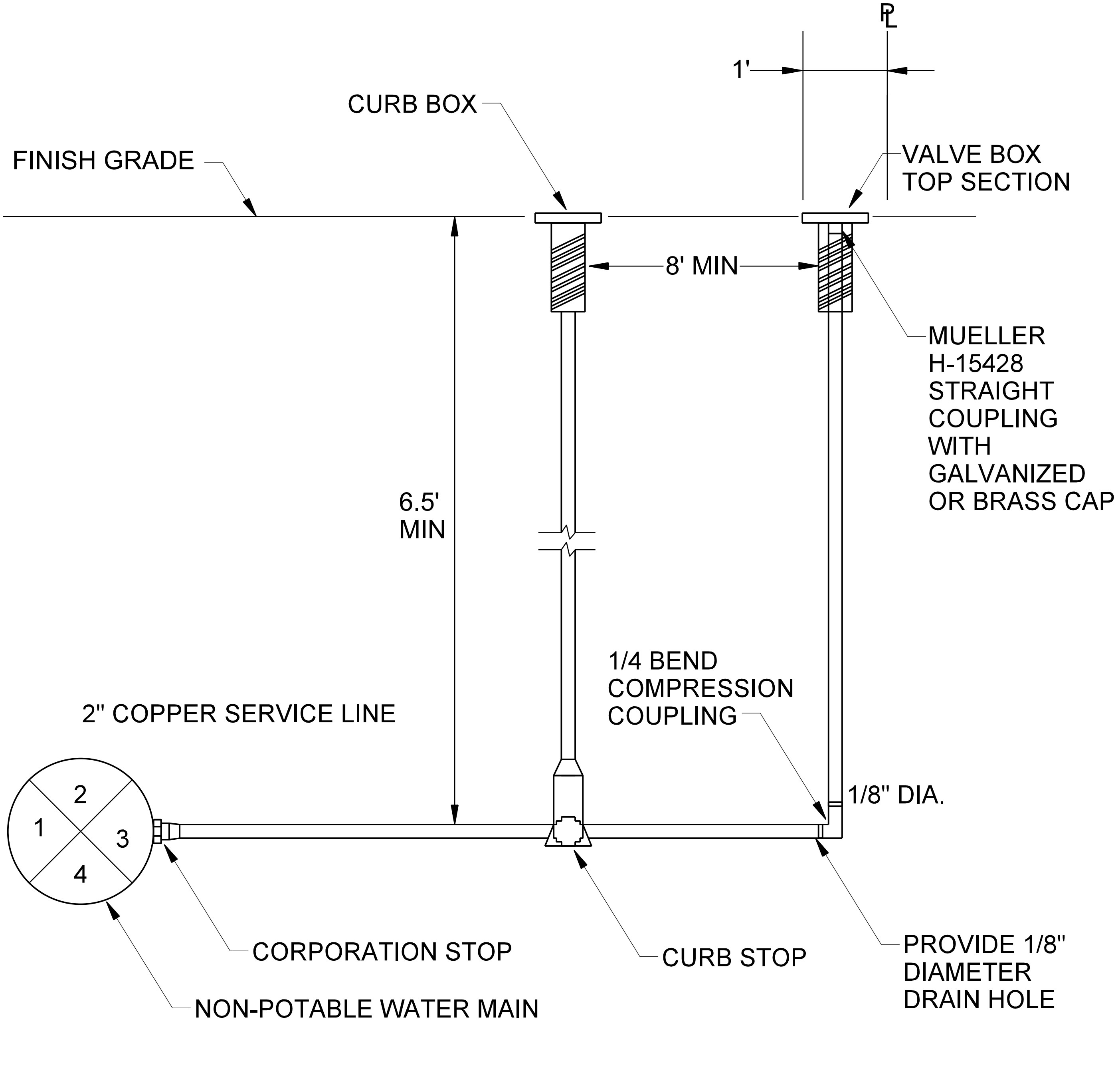

FLUSHING HYDRANT DETAIL

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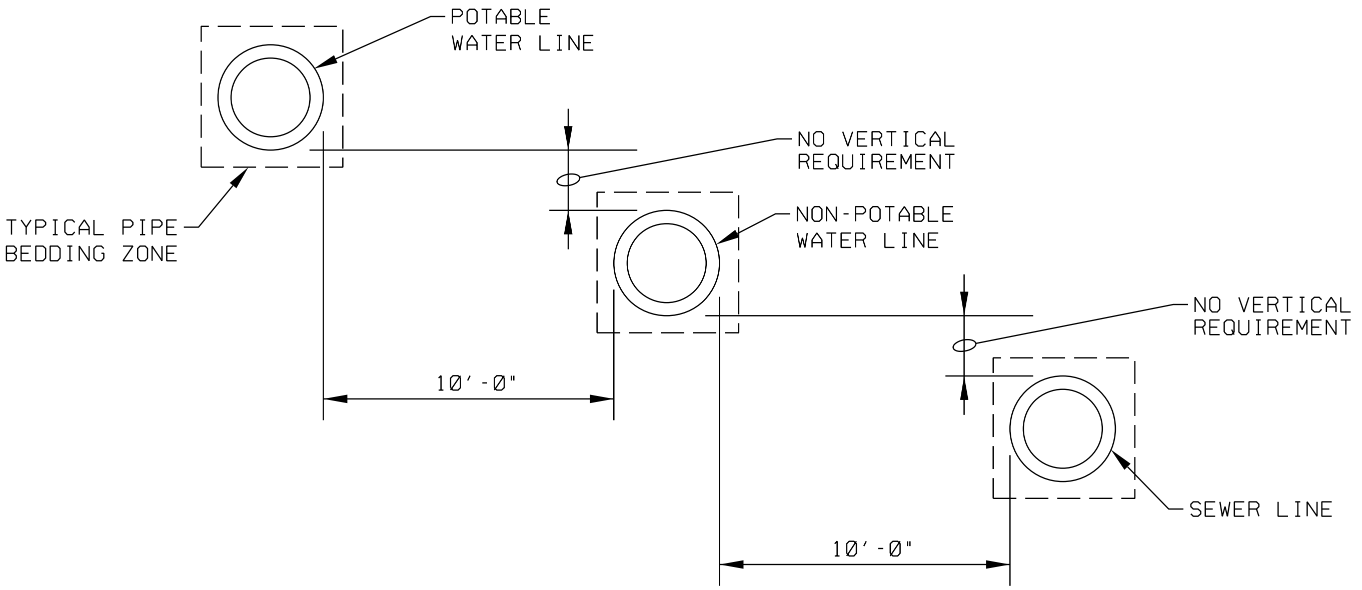
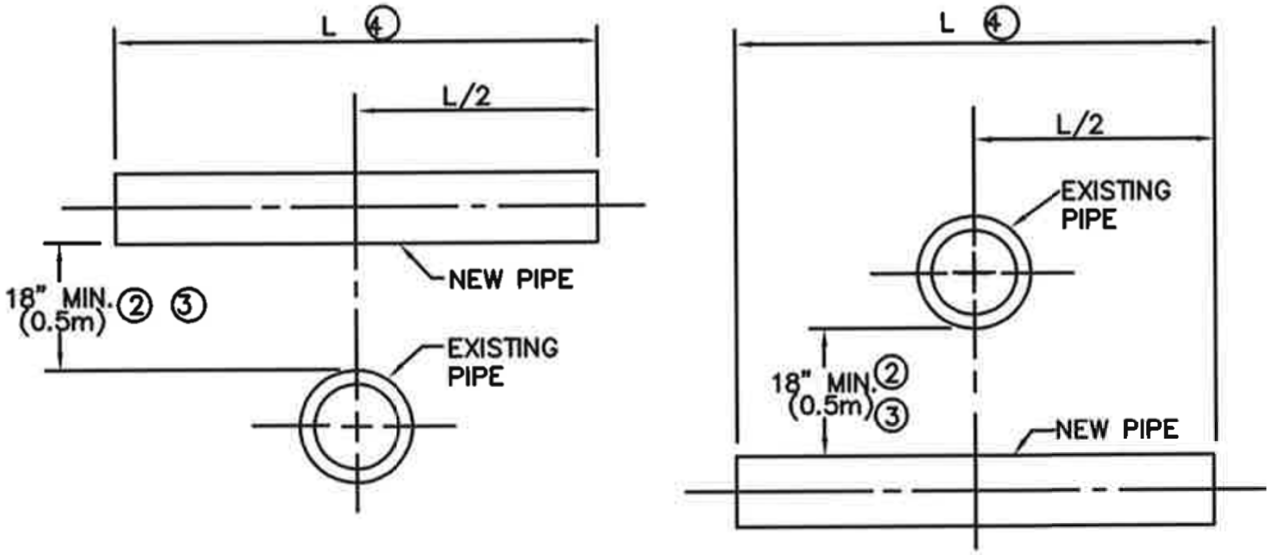




SEPARATION DISTANCE REQUIREMENTS FOR PARALLEL AND CROSSING PIPES

NOTES:

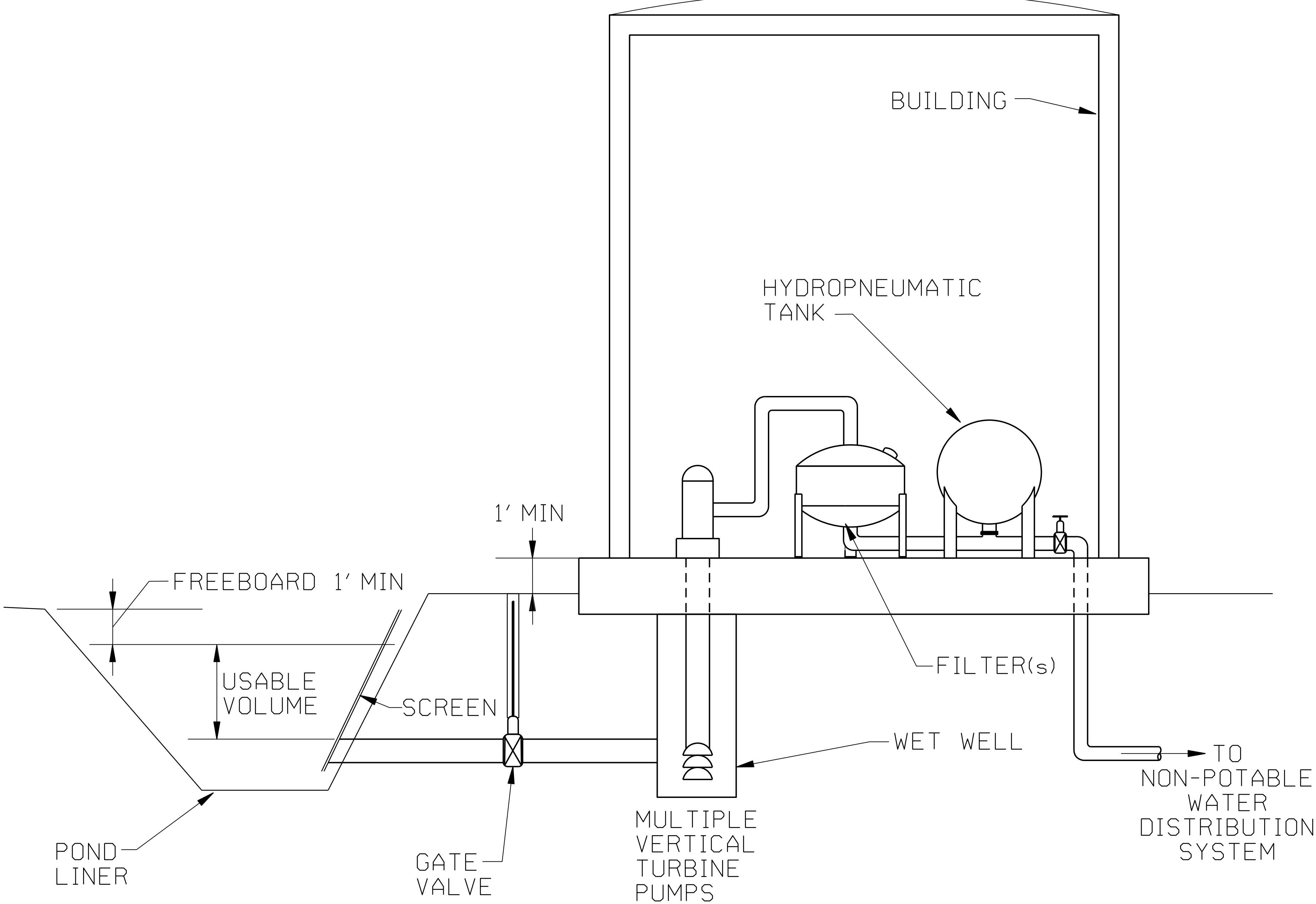
1. SPECIFIC APPROVAL IS REQUIRED FOR A DISTANCE LESS THAN 10 FEET(3M) BETWEEN MAIN, NON-POTABLE WATER LINE, AND/OR GRAVITY SEWERS.

2. NO EXCEPTION TO THE MIN. SEPARATION REQUIREMENT IS PERMITTED WHEN THE SEWAGE CARRYING PIPE IS A FORCE MAIN. AT CROSSINGS, ONE FULL LENGTH OF WATER MAIN OR NON-POTABLE PIPE SHALL BE LOCATED SO THAT BOTH JOINTS WILL BE AS FAR FROM THE FORCE MAIN AS POSSIBLE.

3. LESS THAN 18 INCHES(0.5M) OF SEPARATION IS PERMITTED WHEN THE GRAVITY SEWER AT THE CROSSING IS MADE FROM A SINGLE 20 FOOT(6.1M) LENGTH OF AWWA PRESSURE PIPE. SPECIFIC APPROVAL IS REQUIRED FOR A VERTICAL SEPARATION OF LESS THAN 18 INCHES(0.5M) BETWEEN WATER MAIN AND SANITARY SEWER.

4. "L" IS A STANDARD LENGTH OF PIPE AS SUPPLIED BY A PIPE MANUFACTURER.

5. ADEQUATE STRUCTURAL SUPPORT FOR PIPES AT CROSSINGS SHALL BE PROVIDED.



NON-POTABLE WATER STORAGE, PUMPING AND FILTRATION SYSTEM

NTS

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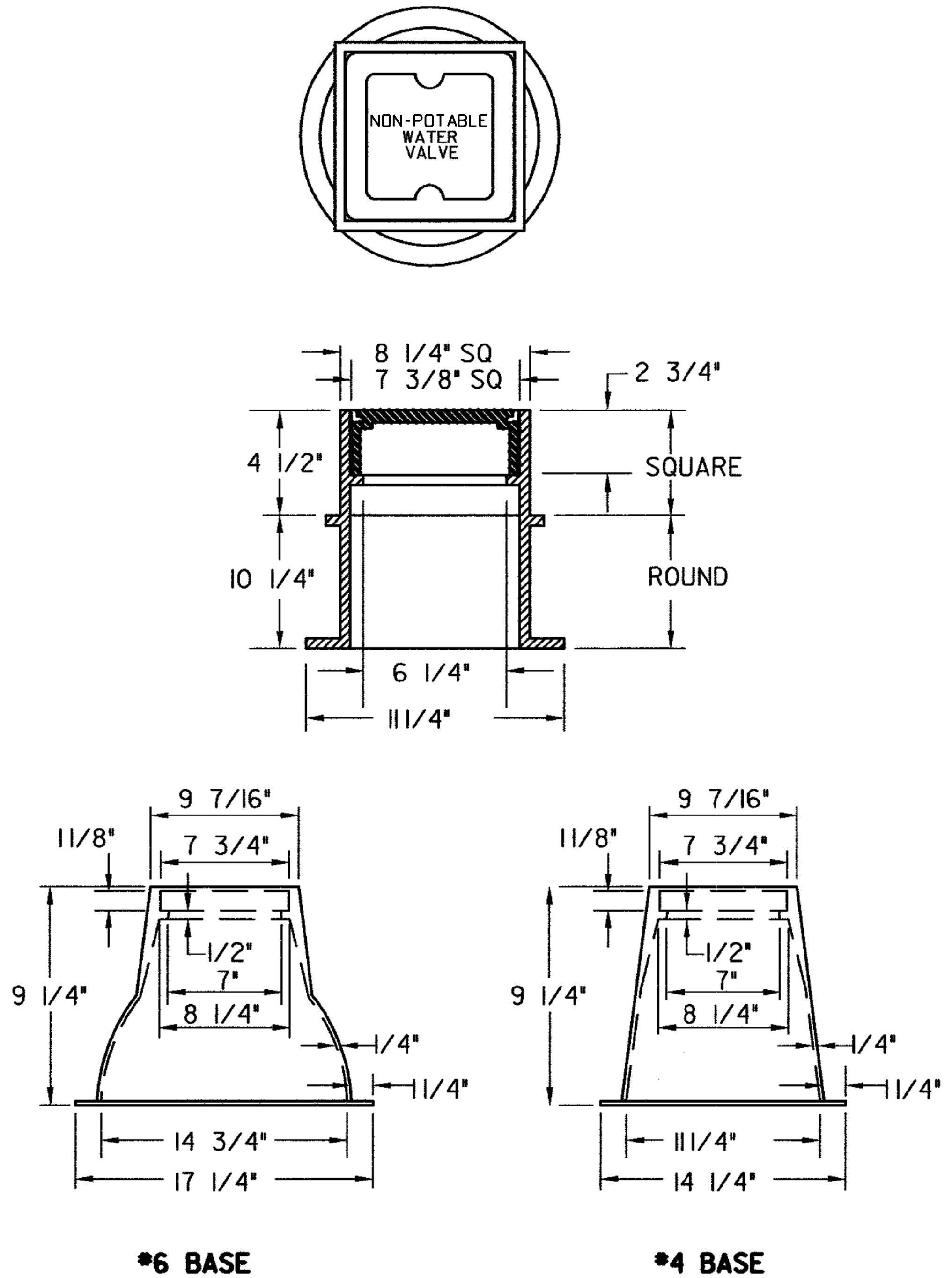

VALVE BOX DETAIL

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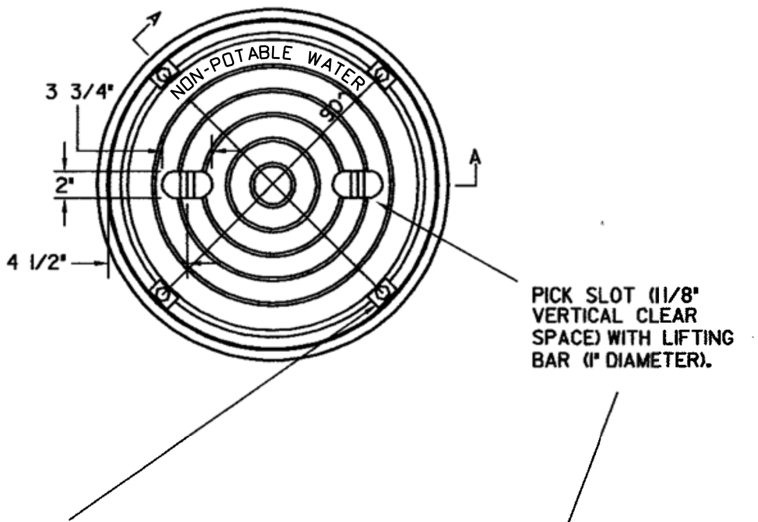
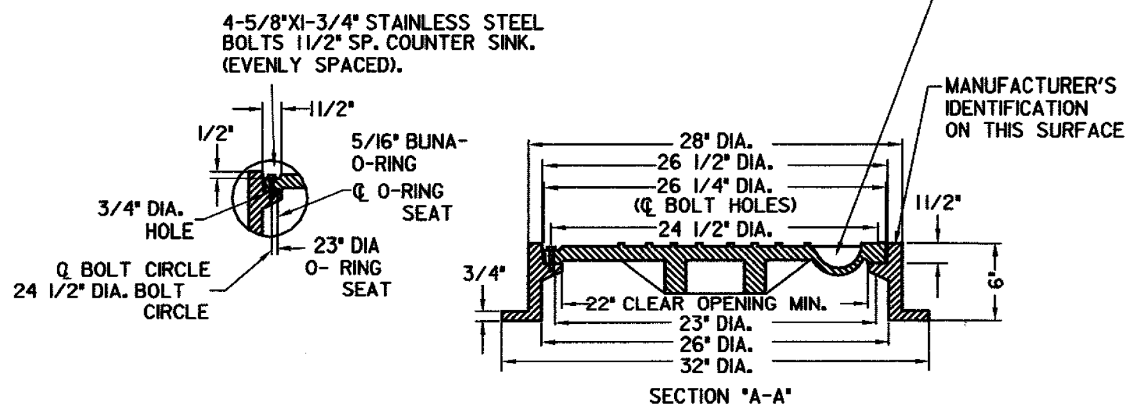


NOTES:

1. STANDARD MANHOLE RING AND COVER: ALL APPLICABLE DIMENSIONS SHALL CONFORM TO THE DIMENSIONS SHOWN HERE
2. THE BEARING SURFACES SHALL BE MACHINE GROUND.



NOTE:

ALL DIMENSIONS MAY VARY EXCEPT THE DIAMETER OF THE LID, THE DIAMETER OF THE CENTER LINE OF THE BOLT HOLES, AND THE MINIMUM DIAMETER OF THE CLEAR OPENING. THE COMBINED WEIGHT OF THE MANHOLE RING AND COVER MUST BE AT LEAST 400 LBS.

MANHOLE RING AND COVER DETAIL

NTS

678995_DD02.DGN

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Table F1. Capital Costs for Dual Piped System

Description	Quantity	Unit	Unit Price	Total
Non-Potable Water System				
Storage Pond	8.0	ac-ft	$ 26,000	$ 208,000
Distribution Main, 8-inch C900	8,000	lf	$ 28	$ 224,000
Distribution Pipe, 8-inch C900	138,000	lf	$ 28	$ 3,864,000
Stream Crossings	0	ea	$ -	$ -
Booster System	1	ea	$ 150,000	$ 150,000
Filters	5	ea	$ 4,000	$ 20,000
Building	1	ls	$ 25,000	$ 25,000
Hydropneumatic Tank, 10,000 gal	10,000	gal	$ 7.50	$ 75,000
Disinfection System	1	ls	$ 40,000	$ 40,000
Potable Water System				
Distribution Pipe, 8-inch DI	146,000	lf	$ 61	$ 8,906,000
	Subtotal Potable and Non-Potable Materials			$ 13,512,000
Hard Cost Markups				
Mobilization	1	ls	0.1	$ 1,351,000
Traffic Control	1	ls	0.02	$ 270,000
Erosion Control	1	ls	0.01	$ 135,000
Contractor Overhead and Profit	1	ls	0.15	$ 2,027,000
		Subtotal Hard Cost Markups		$ 3,783,000
Soft Cost Markups				
Engineering	1	ls	0.15	$ 2,594,000
Construction Admin and Mgmt	1	ls	0.05	$ 865,000
Legal and Administrative	1	ls	0.1	$ 1,730,000
		Subtotal Soft Cost Markups		$ 5,189,000
Water Rights				
Potable Water Rights to be Purchased	560	ac-ft	$ 6,000	$ 3,360,000
Non-Potable Water Rights to be Purchased	771	ac-ft	$ 600	$ 462,600
Project Contingency (Includes Water Rights)				
Contingency	1	ls	0.3	$ 7,892,000
Total Capital Costs				**$ 34,200,000**

Table Notes

Table F2. Capital Costs for Potable Only System

Description	Quantity	Unit	Unit Price	Total
Potable Water System				
Distribution Pipe, 8-inch DI	146,000	lf	$ 61	$ 8,906,000
Stream crossings	0	ea	$ -	$ -
		Subtotal Potable Materials		$ 8,906,000
Hard Cost Markups				
Mobilization	1	ls	0.1	$ 891,000
Traffic Control	1	ls	0.02	$ 178,000
Erosion Control	1	ls	0.01	$ 89,000
Contractor Overhead and Profit	1	ls	0.15	$ 1,336,000
		Subtotal Hard Cost Markups		$ 2,494,000
Soft Cost Markups				
Engineering	1	ls	0.15	$ 1,710,000
Construction Admin and Mgmt	1	ls	0.05	$ 570,000
Legal and Administrative	1	ls	0.1	$ 1,140,000
		Subtotal Soft Cost Markups		$ 3,420,000
Water Rights				
Potable Water Rights to be Purchased	1,331	ac-ft	$ 6,000.00	$ 7,988,523
Project Contingency (Includes Water Rights)				
Contingency	1	ls	0.3	$ 6,842,556.82
Total Capital Costs				**$ 29,650,000**

Table Notes

Table F3. Operations and Maintenance Costs for Dual Piped System

Table Caption

Description	Quantity	Unit	Unit Price	Total
Non-Potable Water System Operations Costs				
Pond (1.5% of Storage Pond Capital Costs)	1	ls	0.015	$ 3,000
Disinfection System (20% of Disinfection Capital Costs)	1	ls	0.2	$ 8,000
Pipeline (1% of Non-Potable Pipeline Capital Costs, excludes water right cost)	1	ls	0.01	$ 99,637
Pumping Energy Costs	99,681	kW-hr	$ 0.055	$ 5,500
			Subtotal	$ 116,137
Potable Water System Operations Costs				
Annual Treatment	182,601,124	gal	$ 0.00101	$ 184,000
Pipeline (1.2% of Capital Costs)	1	ls	0.012	$ 231,186
			Subtotal	$ 415,186
Total annual operations and maintenance costs				$ 531,323
Total Cost Over Life of Project	30	years	0.03375	$ 9,930,000

Table F4. Operations and Maintenance Costs for Potable Only System

Table Caption

Description	Quantity	Unit	Unit Price	Total
Potable Water System Operations Costs				
Annual Treatment	433,815,129	gal	$ 0.00101	$ 438,000
Pipeline (1.2% of Potable Pipeline Capital Costs, excludes water right cost)	1	ls	0.012	$ 231,186
			Subtotal	$ 669,186
Total annual operations and maintenance costs				$ 669,186
Total Cost Over Life of Project	30	years	0.03375	$ 12,500,000

Table F5. Water Rights Acquisition Cost Dual Piped System

Table Caption

Description	Quantity	Unit	Unit Price	Total
Non-Potable Water System				
Water Rights to be Purchased	771	ac-ft	$ 600	$ 462,600

Table F6. Water Rights Acquisition Cost Potable Only System

Table Caption

Description	Quantity	Unit	Unit Price	Total
Non-Potable Water System				
Water Rights to be Purchased	771	ac-ft	$ 6,000	$ 4,626,000

Table F7. Benefit of Delayed Water Treatment Plant Expansion

Table Caption

Description	Treatment Plant Expansion Cost in 2017 dollars	Years	Present Value Calculation
Treatment Plant Expansion Cost - Year 2040	$ 25,000,000	23	$ 11,350,073
Treatment Plant Expansion Cost - Year 2047	$ 25,000,000	30	$ 8,925,349
Difference			$ 2,420,000

Table F8. Dual Piped System for Parks and Open Spaces Only

Description	Quantity	Unit	Unit Price	Total
Non-Potable Water System				
Storage Pond	3.5	ac-ft	$ 26,000	$ 91,000
Distribution Main, 8-inch C900	8,000	lf	$ 28	$ 224,000
Distribution Pipe, 8-inch C900	2,000	lf	$ 28	$ 56,000
Stream Crossings	3	ea	$ -	$ -
Booster System	1	ea	$ 150,000	$ 150,000
Filters	5	ea	$ 4,000	$ 20,000
Building	1	ls	$ 25,000	$ 25,000
Hydropneumatic Tank, 10,000 gal	10,000	gal	$ 7.50	$ 75,000
Disinfection System	1	ls	$ 40,000	$ 40,000
Non-Potable Water Rights to be Purchased	327	ac-ft	$ 600	$ 196,081
Potable Water System				
Distribution Pipe, 8-inch DI	146,000	lf	$ 61	$ 8,906,000
	Subtotal Potable and Non-Potable Materials			$ 9,783,081
Hard Cost Markups				
Mobilization	1	ls	0.1	$ 978,000
Traffic Control	1	ls	0.02	$ 196,000
Erosion Control	1	ls	0.01	$ 98,000
Contractor Overhead and Profit	1	ls	0.15	$ 1,467,000
		Subtotal Hard Cost Markups		$ 2,739,000
Soft Cost Markups				
Engineering	1	ls	0.15	$ 1,878,000
Construction Admin and Mgmt	1	ls	0.05	$ 626,000
Legal and Administrative	1	ls	0.1	$ 1,252,000
		Subtotal Soft Cost Markups		$ 3,756,000
Water Rights				
Non-Potable Water Rights to be Purchased	327	ac-ft	$ 600.00	$ 196,081
Potable Water Rights to be Purchased	1,005	ac-ft	$ 6,000.00	$ 6,027,716
Project Contingency (Includes Water Rights)				
Contingency	1	ls	0.3	$ 6,751,000
Total Capital Costs				$ 29,250,000

Table Notes

Table F9. Dual Piped System for Parks and Open Spaces Only

Table Caption

Description	Quantity	Unit	Unit Price		Total	
Non-Potable Water System Operations Costs						
Pond (1.5% of Storage Pond Capital Costs)	1	ls		0.015	$	1,000
Disinfection System (20% of Disinfection Capital Costs)	1	ls		0.2	$	8,000
Pipeline (1% of Non-Potable Pipeline Capital Costs)	1	ls		0.01	$	14,731
Pumping Energy Costs	175,182	kW-hr	$	0.055	$	9,600
			Subtotal		$	33,331
Potable Water System Operations Costs						
Annual Treatment	327,333,886	gal	$	0.00101	$	331,000
Pipeline (1.2% of Capital Costs)	1	ls		0.012	$	192,693
			Subtotal		$	523,693
Total annual operations and maintenance costs					$	557,024
Total Cost Over Life of Project	30	years		0.03375	$	10,410,000

Table F10. Water Rights Acquisition Cost Dual Piped System for Parks and Open Spaces Only

Table Caption

Description	Quantity	Unit	Unit Price	Total
Non-Potable Water System				
Water Rights to be Purchased	327	ac-ft	$ 600	$ 196,081

Table F11. Benefit of Delayed Water Treatment Plant Expansion

Dual Piped System for Parks and Open Spaces Only

Description	Treatment Plant Expansion Cost in 2017 dollars	Years	Present Value Calculation
Treatment Plant Expansion Cost - Year 2040	$ 25,000,000	23	$ 11,350,073
Treatment Plant Expansion Cost - Year 2042	$ 25,000,000	25	$ 10,596,872
Difference			$ 750,000

Appendix G – Opinion of Probable Project Cost Methodology

Capital Improvement	Project Category	Planning Phase	CIP Type	Project Rank	Project ID	OPPC	Cost Reference
Risk-Based CA #5 - Sourdough Transmission Main Condition Assessment	Condition Assessment	Short-term	Non-Construction	1	WFP_02a	$719,785	OPPC Non-Construction
Sourdough Transmission Main CA Based Rehab	Rehabilitation and Repair	Short-term	Construction	2	WFP_02b	$1,000,000	Engineers Estimate
Sourdough Water Rights Utilization Study	Studies	Short-term	Non-Construction	3	WFP_04	$400,000	Engineers Estimate
West Transmission Main Planning Study	Studies	Short-term	Non-Construction	4	WFP_01a	$400,000	Engineers Estimate
Hilltop Reservoir Inspection and Mixing System	Optimization	Short-term	Construction	5	WFP_05	$239,616	OPPC Non-Construction
SCADA Master Plan	Optimization	Short-term	Non-Construction	6	WFP_12	$250,000	Engineers Estimate
Risk Based CA # 4 - Lyman Creek Water Transmission Main	Condition Assessment	Short-term	Non-Construction	7	WFP_19a	$134,670	OPPC Non-Construction
Groundwater Well Field Development - Phase 1	Supply	Short-term	Construction	8	WFP_10a	$8,612,400	OPPC Construction
Vertical Asset Risk Assessment Phase 1	Studies	Short-term	Non-Construction	9	WFP_13	$19,838	OPPC Non-Construction
Sourdough Tank Inspection and Improvements	Optimization	Short-term	Non-Construction	10	WFP_16	$500,000	Engineers Estimate
Vertical Asset Risk Assessment Phase 2	Studies	Short-term	Non-Construction	11	WFP_14	$85,963	Engineers Estimate
Risk Based R&R	Rehabilitation and Repair	Short-term	Construction	12	WFP_15	$2,500,000	City Provided
PRV Upgrades (approximately 16 sites)	Optimization	Short-term	Construction	13	WFP_18	$7,637,760	OPPC Construction
Lyman Transmission Main CA Based Rehab	Rehabilitation and Repair	Short-term	Construction	14	WFP_19b	$500,000	Engineers Estimate
Integrated Water Resources Plan Update	Studies	Short-term	Non-Construction	15	WFP_11	$150,000	Engineers Estimate
Reservoir 1 - Siting	Studies	Short-term	Non-Construction	16	WFP_09a	$350,000	Engineers Estimate
Pear St. Booster Station Upgrade	Rehabilitation and Repair	Short-term	Construction	17	WFP_38	$486,720	OPPC Construction
SCADA Phase 1	Optimization	Short-term	Construction	18	WFP_24	$2,239,050	OPPC Construction
Risk Based CA #2 - Downtown Area	Condition Assessment	Short-term	Non-Construction	19	WFP_32	$28,116	OPPC Non-Construction
West Transmission Main - Phase 1 Design	Transmission	Short-term	Non-Construction	20	WFP_01b	$2,907,235	OPPC - Legal and Engineering
Redundant North 5038 Zone Feed	Optimization	Short-term	Construction	21	WFP_26	$59,488	OPPC Construction
Risk Based CA # 1 - West Bozeman Transmission	Condition Assessment	Short-term	Non-Construction	22	WFP_34	$47,826	OPPC Non-Construction
Risk Based CA #3 - Baxter/Oak south of Freeway	Condition Assessment	Short-term	Non-Construction	23	WFP_35	$23,775	OPPC Non-Construction
Water Information Management Solutions (WIMS)	Optimization	Short-term	Non-Construction	24	WFP_36	$186,300	OPPC Non-Construction
Hyalite Watershed and Reservoir Study	Studies	Near-term	Non-Construction	NR	WFP_23	$350,000	Engineers Estimate
Sourdough Canyon Natural Storage and Wetland Enhancement - Planning and Design	Studies	Near-term	Non-Construction	NR	WFP_53	$500,000	Engineers Estimate
Hyalite Reservoir Infrastructure and Control Improvements	Optimization	Near-term	Construction	NR	WFP_54	$3,858,300	OPPC Construction
Sourdough Transmission Main – Phase 1	Transmission	Near-term	Construction	NR	WFP_03	$4,241,272	OPPC Construction
Groundwater Well Field Transmission Main - Phase 1	Transmission	Near-term	Construction	NR	WFP_20	$8,974,969	OPPC Construction
Water Treatment Plant Master Metering	Optimization	Near-term	Construction	NR	WFP_17	$750,000	City Provided
PRV Abandonments (approximately 6 sites)	Optimization	Near-term	Construction	NR	WFP_22	$460,512	OPPC Construction
SCADA Phase 2	Optimization	Near-term	Construction	NR	WFP_25	$2,595,840	OPPC Construction
Remote Water Quality Surveillance System	Optimization	Near-term	Non-Construction	NR	WFP_33	$56,925	OPPC Non-Construction
5125 West Sourdough Reservoir 1	Storage	Near-term	Construction	NR	WFP_09b	$8,420,875	OPPC Construction
5560 Southeast Mountain Reservoir and Pump Station	Storage	Near-term	Construction	NR	WFP_30	$18,542,698	OPPC Construction
4975 Northwest Reservoir 1	Storage	Near-term	Construction	NR	WFP_31	$8,420,875	OPPC Construction
Water Facility Plan Update	Studies	Near-term	Non-Construction	NR	WFP_27	$500,000	Engineers Estimate
Drought Management Plan Update	Studies	Near-term	Non-Construction	NR	WFP_28	$20,000	Engineers Estimate
Lyman Creek Water System Improvements	Supply	Near-term	Construction	NR	WFP_07	$24,805,440	OPPC Construction
Groundwater Well Field Development - Phase 2	Supply	Near-term	Construction	NR	WFP_10b	$12,978,600	OPPC Construction
Lyman Spring Groundwater Well Development	Supply	Near-term	Construction	NR	WFP_21	$2,500,000	Engineers Estimate
Sourdough Canyon Natural Storage and Wetland Enhancement	Supply	Near-term	Construction	NR	WFP_51	$8,000,000	Engineers Estimate
West Transmission Main – Phase 1 Construction	Transmission	Near-term	Construction	NR	WFP_01c	$23,689,082	OPPC Construction - WFP_01b
Sourdough Transmission Main – Phase 2	Transmission	Near-term	Construction	NR	WFP_08	$5,785,788	OPPC Construction
East Transmission Main	Transmission	Near-term	Construction	NR	WFP_29	$6,092,316	OPPC Construction
West Transmission Main - Phase 2	Transmission	Near-term	Construction	NR	WFP_39	$35,891,887	OPPC Construction
Groundwater Well Field Transmission Main - Phase 2	Transmission	Near-term	Construction	NR	WFP_52	$8,974,969	OPPC Construction
4975 Northwest Reservoir 2	Storage	Long-term	Construction	NR	WFP_40	$8,420,875	OPPC Construction
5125 West Sourdough Reservoir 2	Storage	Long-term	Construction	NR	WFP_41	$8,420,875	OPPC Construction
5350 Southwest Reservoir and Pump Station	Storage	Long-term	Construction	NR	WFP_42	$13,795,846	OPPC Construction
5360 North Mountain Reservoir and Pump Station	Storage	Long-term	Construction	NR	WFP_43	$10,584,320	OPPC Construction
5630 East Mountain Zone Reservoir and Pump Station	Storage	Long-term	Construction	NR	WFP_44	$16,589,604	OPPC Construction
Sourdough Reservoir 2	Storage	Long-term	Construction	NR	WFP_45	$6,506,700	OPPC Construction
Water Treatment Plant Reservoir 2	Storage	Long-term	Construction	NR	WFP_46	$7,779,750	OPPC Construction
Water Treatment Plant Reservoir 3	Storage	Long-term	Construction	NR	WFP_47	$7,779,750	OPPC Construction
Sourdough Water Treatment Plant Expansion	Supply	Long-term	Construction	NR	WFP_55	$25,000,000	Engineers Estimate
West Transmission Main - Phase 3	Transmission	Long-term	Construction	NR	WFP_48	$10,936,342	OPPC Construction
West Transmission Main - Phase 4	Transmission	Long-term	Construction	NR	WFP_49	$3,755,221	OPPC Construction
West Transmission Main - Phase 5	Transmission	Long-term	Construction	NR	WFP_50	$2,457,009	OPPC Construction
		$ 29,478,542				$337,915,182	
		$ 186,410,348					
		$ 122,026,292					
	Total	$ 337,915,182	Does not include Growth and Development	Does not include Growth and Development Costs			

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
August, 2016

Project ID: WFP_02a

CIP Name: Risk-Based CA #5 - Sourdough Transmission Main Condition Assessment

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Scope - Inspection and Assessment						
		1. High Resolution Assessment	1	LS	$500,000.00	$500,000		
		2. Transient Pressure Monitoring	1	LS	$10,000.00	$10,000		
		3. Field Modifications for Inspection	1	LS	$10,000.00	$10,000		
		4. Engr Analysis/Field Forensics	1	LS	$49,000.00	$49,000		
		Subtotal				$569,000		
Hard Cost - Marku	**2.0**							
		a. Mobilization (0%)	1	l.s.		$0.00		
		b. Traffic Control (0%)	1	l.s.		$0.00		
		c. Erosion Control (0%)	1	l.s.		$0.00		
		d. Contractor Overhead and Profit (0%)	1	l.s.		$0.00		
		Subtotal				$0.00		
							$569,000.00	**Estimated Hard Costs**
Soft Costs	**3.0**							
		a. Engineering (0%)	1	l.s.		$0		
		b. Construction Administration and Management (10%)	1	l.s.		$56,900		
		c. Legal and Administrative (0%)	1	l.s.		$0		
		Subtotal				$56,900		
							$56,900	**Estimated Soft Costs**
Property Acquisiti	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingen	**5.0**							
		a. Contingency (15%)	1	l.s.		$142,250		
		Subtotal				$142,250		
							$142,250	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$768,150.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
August, 2016

Project ID: WFP_05

CIP Name: Hilltop Tank Inspection and Mixing System

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	ONENT SUBT	
Hard Cost	**1.0**							
		a. Mixers, Electrical, Control, SCADA, Reservoir Cleaning						
		1. Reservoir Cleaning	1	LS	$5,000.00	$5,000		
		2. Reservoir Inspection	1	LS	$20,000.00	$20,000.00		
		2. F & I Mixers	2	LS	$25,000.00	$50,000		
		3. Elecrtrical and Local Controls	2	LS	$15,000.00	$30,000		
		4. SCADA	2	LS	$7,500.00	$15,000		
		Subtotal				$120,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization (10%)	1	l.s.		$12,000.00		
		b. Traffic Control (2%)	1	l.s.		$2,400.00		
		c. Erosion Control (1%)	1	l.s.		$1,200.00		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$18,000.00		
		Subtotal				$33,600.00		
							$153,600.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (5%)	1	l.s.		$7,680		
		b. Construction Administration and Management (10%)	1	l.s.		$15,360		
		c. Legal and Administrative (5%)	1	l.s.		$7,680		
		Subtotal				$30,720		
							$30,720	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (30%)	1	l.s.		$55,296		
		Subtotal				$55,296		
							$55,296	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$239,616.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
August, 2016

CIP ID: WFP_19a

CIP Name: Risk Based CA # 4 - Lyman Creek Water Transmission Main

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Scope - Inspection and Assessment						
		1. MedResolution Assessment	6,500	lf	$6.67	$43,355		
		2. Field Modifications for Inspection	3	EA	$5,000.00	$15,000		
		3. External Inspection	1	EA	$15,000.00	$15,000		
		4. Engr Analysis/Field Forensics/Report	1	LS	$20,000.00	$20,000		
						$93,355		
Hard Cost - Markups	**2.0**							
		a. Mobilization (10%)	1	l.s.		$9,335.50		
		b. Traffic Control (2%)	1	l.s.		$1,867.10		
		c. Erosion Control (0%)	1	l.s.		$0.00		
		d. Contractor Overhead and Profit (0%)	1	l.s.		$0.00		
		Subtotal				$11,202.60		
		10					$104,557.60	**Estimated Hard Costs**
Soft Costs	**3.0**							
		a. Engineering (0%)	1	l.s.		$2,091		
		b. Construction Administration and Management (10%)	1	l.s.		$10,456		
		c. Legal and Administrative (0%)	1	l.s.		$0		
		Subtotal				$12,547		
							$12,547	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Contingency (15%)	1	l.s.		$17,566		
		Subtotal				$17,566		
							$17,566	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$134,670.19	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID: WFP_10a

CIP Name: Groundwater Well Field - Design & Construction Phase 1

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. New Lyman Creek Water Reservoir						
		1. Site Development	3	LS	$250,000.00	$750,000		
		2. Wells, Power and Control	3	EA	$400,000.00	$1,200,000		
		3. Connect to Transmission Main(s)	3	LS	$100,000.00	$300,000		
		4. Junction and Booster Station	1	EA	$2,250,000.00	$2,250,000		
		5. Disinfection (Residual) Facilities	1	EA	$100,000.00	$100,000		
		Subtotal				$4,600,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization and Demobilization (2%)	1	l.s.		$92,000.00		
		b. Traffic Control (2%)	1	l.s.		$92,000.00		
		c. Erosion Control (1%)	1	l.s.		$46,000.00		
		d. Contractor Overhead and Profit (10%)	1	l.s.		$460,000.00		
		Subtotal				$690,000.00		
							$5,290,000.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$529,000		
		b. Construction Administration and Management (10%)	1	l.s.		$529,000		
		c. Legal and Administrative (10%)	1	l.s.		$529,000		
		Subtotal				$1,587,000		
							$1,587,000	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed 3 Acres	3	Acre	$100,000.00	$300,000		
		Subtotal				$300,000		
							$300,000	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (20%)	1	l.s.		$1,435,400		
		Subtotal				$1,435,400		
							$1,435,400	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$8,612,400.00	**Total Probable Project Cost (2016)**

CIP ID: WFP_13

CIP Name: Vertical Asset Risk Assessment Phase 1

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Scope - Phase I						
		1. Overall Risk Policy Framework-	1	LS	$0.00	$0		
		2. Implementation plan across COB	1	LS	$0.00	$0		
		3. Policy and Implementation Report	1	LS	$0.00	$0		
		4. Outreach	1	LS	$15,000.00	$15,000		
		Subtotal				$15,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization (0%)	1	l.s.		$0.00		
		b. Traffic Control (0%)	1	l.s.		$0.00		
		c. Erosion Control (0%)	1	l.s.		$0.00		
		d. Contractor Overhead and Profit (0%)	1	l.s.		$0.00		
		Subtotal				$0.00		
							$15,000.00	**Estimated Hard Costs**
Soft Costs	**3.0**							
		a. Engineering (15%)	1	l.s.		$2,250		
		b. Construction Administration and Management (15%)	1	l.s.		$0		
		c. Legal and Administrative (0%)	1	l.s.		$0		
		Subtotal				$2,250		
							$2,250	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Contingency (15%)	1	l.s.		$2,588		
		Subtotal				$2,588		
							$2,588	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$19,837.50	**Total Probable Project Cost (2016)**

CIP ID: WFP_14

CIP Name: Vertical Asset Risk Assessment Phase 2

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Scope - Phase I						
		1. Overall Risk Policy Framework-	1	LS	$0.00	$0		
		2. Implementation plan across COB	1	LS	$0.00	$0		
		3. Policy and Implementation Report	1	LS	$0.00	$0		
		4. Outreach	1	LS	$65,000.00	$65,000		
		Subtotal				$65,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization (0%)	1	l.s.		$0.00		
		b. Traffic Control (0%)	1	l.s.		$0.00		
		c. Erosion Control (0%)	1	l.s.		$0.00		
		d. Contractor Overhead and Profit (0%)	1	l.s.		$0.00		
		Subtotal				$0.00		
							$65,000.00	**Estimated Hard Costs**
Soft Costs	**3.0**							
		a. Engineering (15%)	1	l.s.		$9,750		
		b. Construction Administration and Management (15%)	1	l.s.		$0		
		c. Legal and Administrative (0%)	1	l.s.		$0		
		Subtotal				$9,750		
							$9,750	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Contingency (15%)	1	l.s.		$11,213		
		Subtotal				$11,213		
							$11,213	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$85,962.50	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
August, 2016

CIP ID: WFP_18

CIP Name: PRV Upgrades (approximately 16 sites)

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	PONENT SUBT(	
Hard Cost	**1.0**							
		a. Pumps, Electrical, Control, SCADA, PRV's						
		1. Waterproofing&sump pump	16	LS	$15,000.00	$240,000		
		2. Above grade SCADA/Control weather enclosure	16	LS	$90,000.00	$1,440,000		
		3. PRV's harnessing	16	LS	$7,500.00	$120,000		
		4. Electrical & Controls	16	LS	$80,000.00	$1,280,000		
		5. Heating& Ventilation/Dehumidification	16	LS	$2,000.00	$32,000		
		6. Bilco Hatch (Safety access - eliminate confined space entry)	16	LS	$5,000.00	$80,000		
		7. Power to site	16	LS	$20,000.00	$320,000		
		8. SCADA programming	16	LS	$10,000.00	$160,000		
		Subtotal				$3,672,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization (10%)	1	l.s.		$367,200.00		
		b. Traffic Control (2%)	1	l.s.		$73,440.00		
		c. Erosion Control (1%)	1	l.s.		$36,720.00		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$550,800.00		
		Subtotal				$1,028,160.00		
							$4,700,160.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$470,016		
		b. Construction Administration and Management (10%)	1	l.s.		$470,016		
		c. Legal and Administrative (5%)	1	l.s.		$235,008		
		Subtotal				$1,175,040		
							$1,175,040	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (30%)	1	l.s.		$1,762,560		
		Subtotal				$1,762,560		
							$1,762,560	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$7,637,760.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID: WFP_38

CIP Name: Pear St. Booster Station Upgrade

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
	a.	Pumps, Electrical, Control, SCADA, PRV's						
		1. Pump Mech	3	EA	$30,000.00	$90,000		
		2. Mechanical	1	LS	$10,000.00	$10,000		
		3. PRV's	2	EA	$7,500.00	$15,000		
		4. Electrical & Controls	1	LS	$90,000.00	$100,000		
		5. Connect to existing SCADA	1	LS	$10,000.00	$10,000		
		Subtotal				$225,000		
Hard Cost - Markups	**2.0**							
	a.	Mobilization (10%)	1	l.s.		$22,500.00		
	b.	Traffic Control (2%)	1	l.s.		$4,500.00		
	c.	Erosion Control (1%)	1	l.s.		$2,250.00		
	d.	Contractor Overhead and Profit (15%)	1	l.s.		$33,750.00		
		Subtotal				$63,000.00		
							$288,000.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
	a.	Engineering (15%)	1	l.s.		$43,200		
	b.	Construction Administration and Management (5%)	1	l.s.		$14,400		
	c.	Legal and Administrative (10%)	1	l.s.		$28,800		
		Subtotal				$86,400		
							$86,400	**Estimated Soft Costs**
Property Acquisition	**4.0**							
	a.	Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
	a.	Contingency (30%)	1	l.s.		$112,320		
		Subtotal				$112,320		
							$112,320	**Project Contingency**
Inflation	**6.0**							
	a.	Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$486,720.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: WFP_24
CIP Name: SCADA Phase 1

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Implement System-wide SCADA						
		1. SCADA Network	1	LS	$950,000.00	$950,000		
		2. SCADA Historian	1	LS	$150,000.00	$150,000		
		3. Central Site Improvements	2	LS	$150,000.00	$300,000		
		4. SCADA Configuration	1	LS	$75,000.00	$75,000		
		Subtotal				$1,475,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization (10%)	1	l.s.		$29,500.00		
		b. Traffic Control (2%)	1	l.s.		$29,500.00		
		c. Erosion Control (1%)	1	l.s.		$14,750.00		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$147,500.00		
		Subtotal				$221,250.00		
							$1,696,250.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (5%)	1	l.s.		$84,813		
		b. Construction Administration and Management (10%)	1	l.s.		$169,625		
		c. Legal and Administrative (5%)	1	l.s.		$84,813		
		Subtotal				$339,250		
							$339,250	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (10%)	1	l.s.		$203,550		
		Subtotal				$203,550		
							$203,550	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$2,239,050.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID **WFP_32**

CIP Name: Risk Based CA #2 - Downtown Area

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Scope - Inspection and Assessment						
		1. Medium Resolution Assessment	1,018	lf	$6.67	$6,790		
		3. Spot digs to validate low res assessment	1	LS	$5,000.00	$5,000		
		4. Engr Analysis/Field Forensics/Report	1	LS	$10,000.00	$10,000		
		Subtotal				$21,790		
Hard Cost - Markups	**2.0**							
		a. Mobilization (0%)	1	l.s.		$0.00		
		b. Traffic Control (2%)	1	l.s.		$435.80		
		c. Erosion Control (0%)	1	l.s.		$0.00		
		d. Contractor Overhead and Profit (0%)	1	l.s.		$0.00		
		Subtotal				$435.80		
							$22,225.86	**Estimated Hard Costs**
Soft Costs	**3.0**							
		a. Engineering (0%)	1	l.s.		$0		
		b. Construction Administration and Management (10%	1	l.s.		$2,223		
		c. Legal and Administrative (0%)	1	l.s.		$0		
		Subtotal				$2,223		
							$2,223	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Contingency (15%)	1	l.s.		$3,667		
		Subtotal				$3,667		
							$3,667	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$28,115.71	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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August, 2016

CIP Name: **WFP_26**

CIP Name: **Redundant North 5038 Zone Feed**

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	OTAL COS	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Electrical, Control, SCADA, PRV's						
		1. Verify PRV sizing, install new as reqd	2	EA	$7,500.00	$15,000		
		2. Mechanical	1	LS	$5,000.00	$5,000		
		3. Site miscellaneous	1	EA	$7,500.00	$7,500		
		Subtotal				$27,500		
Hard Cost - Markups	**2.0**							
		a. Mobilization (10%)	1	l.s.		$2,750.00		
		b. Traffic Control (2%)	1	l.s.		$550.00		
		c. Erosion Control (1%)	1	l.s.		$275.00		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$4,125.00		
		Subtotal				$7,700.00		
							$35,200.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (15%)	1	l.s.		$5,280		
		b. Construction Administration and Management (5%)	1	l.s.		$1,760		
		c. Legal and Administrative (10%)	1	l.s.		$3,520		
		Subtotal				$10,560		
							$10,560	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (30%)	1	l.s.		$13,728		
		Subtotal				$13,728		
							$13,728	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$59,488.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: WFP_34

CIP Name: Risk Based CA # 1 - West Bozeman Transmission

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Scope - Inspection and Assessment						
		1. Medium Resolution Assessment	1,809	lf	$6.67	$12,066		
		3. Field Modifications for Inspection	1	LS	$10,000.00	$10,000		
		4. Engr Analysis/Field Forensics/Report	1	LS	$15,000.00	$15,000		
		Subtotal				$37,066		
Hard Cost - Markups	**2.0**							
		a. Mobilization (0%)	1	l.s.		$0.00		
		b. Traffic Control (2%)	1	l.s.		$741.32		
		c. Erosion Control (0%)	1	l.s.		$0.00		
		d. Contractor Overhead and Profit (0%)	1	l.s.		$0.00		
		Subtotal				$741.32		
							$37,807.35	**Estimated Hard Costs**
Soft Costs	**3.0**							
		a. Engineering (0%)	1	l.s.		$0		
		b. Construction Administration and Management (10%)	1	l.s.		$3,781		
		c. Legal and Administrative (0%)	1	l.s.		$0		
		Subtotal				$3,781		
							$3,781	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Contingency (15%)	1	l.s.		$6,238		
		Subtotal				$6,238		
							$6,238	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$47,826.30	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: **WFP_35**

CIP Name: Risk Based CA #3 - Baxter/Oak south of Freeway

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Scope - Inspection and Assessment						
		1. Medium Resolution Assessment	267	lf	$6.67	$1,781		
		3. Spot digs to validate low res assessment	1	LS	$5,000.00	$5,000		
		3. Engr Analysis/Field Forensics/Report	1	LS	$10,000.00	$10,000		
		Subtotal				$16,781		
Hard Cost - Markups	**2.0**							
		a. Mobilization (10%)	1	l.s.		$1,678.09		
		b. Traffic Control (2%)	1	l.s.		$335.62		
		c. Erosion Control (0%)	1	l.s.		$0.00		
		d. Contractor Overhead and Profit (0%)	1	l.s.		$0.00		
		Subtotal				$2,013.71		
		10					$18,794.60	**Estimated Hard Costs**
Soft Costs	**3.0**							
		a. Engineering (0%)	1	l.s.		$0		
		b. Construction Administration and Management (10%)	1	l.s.		$1,879		
		c. Legal and Administrative (0%)	1	l.s.		$0		
		Subtotal				$1,879		
							$1,879	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Contingency (15%)	1	l.s.		$3,101		
		Subtotal				$3,101		
							$3,101	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$23,775.16	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: WFP_36
CIP Name: Water Information Management Solution

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Scope - Study report						
		1. Goals/objectives development	1	LS	$0.00	$0		
		2. Existing System Analysis	1	LS	$0.00			
		3. System Integration Design	1	LS	$0.00			
		4. Vendor procurement	1	LS	$0.00			
		5. Solution Development & Testing	1	LS	$0.00			
		7. Data integration with other PWD systems	1	LS	$0.00	$0		
		8. Rollout & Tech Support	1	LS	$0.00	$0		
		9. 3 yr. maintenance agreement	1	LS	$120,000.00	$120,000		
		Subtotal				$120,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization (10%)	1	l.s.		$0.00		
		b. Traffic Control (2%)	1	l.s.		$0.00		
		c. Erosion Control (1%)	1	l.s.		$0.00		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$0.00		
		Subtotal				$0.00		
							$120,000.00	**Estimated Hard Costs**
Soft Costs	**3.0**							
		a. Engineering (20%)	1	l.s.		$24,000		
		b. IT Administration and Management (15%)	1	l.s.		$18,000		
		c. Legal and Administrative (0%)	1	l.s.		$0		
		Subtotal				$42,000		
							$42,000	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Contingency (15%)	1	l.s.		$24,300		
		Subtotal				$24,300		
							$24,300	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$186,300.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: WFP_54

CIP Name: Hyalite Reservoir Infrastructure Improvements

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Hyalite Reservoir Infrastructure Improvements						
		1. Control Tower Armoring	3	LS	$250,000.00	$750,000		
		2. Controls Upgrades	3	EA	$400,000.00	$1,200,000		
		Subtotal				$1,950,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization and Demobilization (2%)	1	l.s.		$39,000.00		
		b. Traffic Control (2%)	1	l.s.		$39,000.00		
		c. Erosion Control (1%)	1	l.s.		$19,500.00		
		d. Contractor Overhead and Profit (10%)	1	l.s.		$195,000.00		
		Subtotal				$292,500.00		
							$2,242,500.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$224,250		
		b. Construction Administration and Management (10%)	1	l.s.		$224,250		
		c. Legal and Administrative (10%)	1	l.s.		$224,250		
		Subtotal				$672,750		
							$672,750	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed 3 Acres	3	Acre	$100,000.00	$300,000		
		Subtotal				$300,000		
							$300,000	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (20%)	1	l.s.		$643,050		
		Subtotal				$643,050		
							$643,050	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$3,858,300.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID: WFP_03

CIP Name: Sourdough Transmission Main – Phase 1

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**	**Water Transmission System**						
		a. Water Main						
		1. 30" DIP - Class 51	8,678	l.f	$294.00	$2,551,332		
		Subtotal				$2,551,332		
Hard Cost - Markups	**2.0**							
		a. Mobilization/Demobilization (2%)	1	l.s.		$51,026.64		
		b. Traffic Control (2%)	1	l.s.		$51,026.64		
		c. Erosion Control (1%)	1	l.s.		$25,513.32		
		d. Contractor Overhead and Profit (5%)	1	l.s.		$127,566.60		
		Subtotal				$255,133.20		
							$2,806,465	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$280,647		
		b. Construction Administration and Management (8%)	1	l.s.		$224,517		
		c. Legal and Administrative (5%)	1	l.s.		$140,323		
		Subtotal				$645,487		
							$645,487	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Right-of-way	8,678	l.f.	$9.50	$82,441		
		Subtotal				$82,441		
							$82,441	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (20%)	1	l.s.		$706,879		
		Subtotal				$706,879		
							$706,879	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$4,241,272	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: WFP_20

CIP Name: Groundwater Well Field Transmission Main - Phase 1

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**	**Water Transmission System**						
		a. Water Main						
		1. 24" DIP - Class 51	30,300	l.f	$192.00	$5,817,600		
		Subtotal				$5,817,600		
Hard Cost - Markups	**2.0**							
		a. Mobilization/Demobilization (2%)	1	l.s.		$116,352.00		
		b. Traffic Control (2%)	1	l.s.		$116,352.00		
		c. Erosion Control (1%)	1	l.s.		$58,176.00		
		d. Contractor Overhead and Profit (5%)	1	l.s.		$290,880.00		
		Subtotal				$581,760.00		
							$6,399,360.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$639,936		
		b. Construction Administration and Management (8%)	1	l.s.		$511,949		
		c. Legal and Administrative (5%)	1	l.s.		$319,968		
		Subtotal				$1,471,853		
							$1,471,853	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Right-of-way	30,300	l.f.	$9.50	$287,850		
		Subtotal				$287,850		
							$287,850	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (10%)	1	l.s.		$815,906		
		Subtotal				$815,906		
							$815,906	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$8,974,969.08	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: WFP_25
CIP Name: PRV Abandonment

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Pumps, Electrical, Control, SCADA, PRV's						
		1. Excavation and Backfill	6	LS	$2,500.00	$15,000		
		2. Salvage mechanical	6	LS	$4,000.00	$24,000		
		3. Vault Lid removal and capping	6	LS	$2,500.00	$15,000		
		4. Furnish & Install Valve Riser	6	LS	$2,000.00	$12,000		
		5. Import for vault	6	LS	$600.00	$3,600		
		6. Interconnection Pipe	600	LF	$233.00	$139,800		
		7. Site restoration	6	LS	$2,000.00	$12,000		
		Subtotal				$221,400		
Hard Cost - Markups	**2.0**							
		a. Mobilization (10%)	1	l.s.		$22,140.00		
		b. Traffic Control (2%)	1	l.s.		$4,428.00		
		c. Erosion Control (1%)	1	l.s.		$2,214.00		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$33,210.00		
		Subtotal				$61,992.00		
							$283,392.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$28,339		
		b. Construction Administration and Management (10%)	1	l.s.		$28,339		
		c. Legal and Administrative (5%)	1	l.s.		$14,170		
		Subtotal				$70,848		
							$70,848	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (30%)	1	l.s.		$106,272		
		Subtotal				$106,272		
							$106,272	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$460,512.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID WFP_25
CIP Name: SCADA Phase 2

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Implement System-wide SCADA						
		1. SCADA Equipment Additions	1	LS	$1,000,000.00	$1,000,000		
		2. SCADA Equipment Replacements	1	LS	$300,000.00	$300,000		
		Subtotal				$1,300,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization (10%)	1	l.s.		$130,000.00		
		b. Traffic Control (2%)	1	l.s.		$26,000.00		
		c. Erosion Control (1%)	1	l.s.		$13,000.00		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$195,000.00		
		Subtotal				$364,000.00		
							$1,664,000.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (5%)	1	l.s.		$83,200		
		b. Construction Administration and Management (10%)	1	l.s.		$166,400		
		c. Legal and Administrative (5%)	1	l.s.		$83,200		
		Subtotal				$332,800		
							$332,800	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (30%)	1	l.s.		$599,040		
		Subtotal				$599,040		
							$599,040	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$2,595,840.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: WFP_33
CIP Name: Remote WQ Surveillance System

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Scope - Study report						
		1. Goals/objectives development	1	LS	$0.00	$0		
		2. Evaluate exist/future WQ reporting reqts	1	LS	$0.00	$0		
		3. Hardware, programming, interface with SCADA	1	LS	$0.00	$0		
		4. Final Report and Implementation Plan	1	LS	$45,000.00	$45,000		
		Subtotal				$45,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization (10%)	1	l.s.		$0.00		
		b. Traffic Control (2%)	1	l.s.		$0.00		
		c. Erosion Control (1%)	1	l.s.		$0.00		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$0.00		
		Subtotal				$0.00		
							$45,000.00	**Estimated Hard Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$4,500		
		b. Construction Administration and Management (0%)	1	l.s.		$0		
		c. Legal and Administrative (0%)	1	l.s.		$0		
		Subtotal				$4,500		
							$4,500	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Contingency (30%)	1	l.s.		$7,425		
		Subtotal				$7,425		
							$7,425	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$56,925.00	**Total Probable Project Cost (2016)**

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CIP ID: WFP_09b

CIP Name: 5125 West Sourdough Reservoir 1

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. 5125 West Sourdough Reservoir 1						
		1. West Sourdough Reservoir 1 (5 MG)	5,000,000	MG	$1.00	$5,000,000		
		Subtotal				$5,000,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization and Demobilization (2%)	1	l.s.		$100,000.00		
		b. Traffic Control (2%)	1	l.s.		$100,000.00		
		c. Erosion Control (1%)	1	l.s.		$50,000.00		
		d. Contractor Overhead and Profit (10%)	1	l.s.		$500,000.00		
		Subtotal				$750,000.00		
							$5,750,000.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$575,000		
		b. Construction Administration and Management (8%)	1	l.s.		$460,000		
		c. Legal and Administrative (5%)	1	l.s.		$287,500		
		Subtotal				$1,322,500		
							$1,322,500	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed 2.5 Acres	2.5	Acre	$100,000.00	$250,000		
		Subtotal				$250,000		
							$250,000	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (15%)	1	l.s.		$1,098,375		
		Subtotal				$1,098,375		
							$1,098,375	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$8,420,875.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: WFP_30

CIP Name: 5560 Southeast Mountain Reservoir and Pump Station

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Southeast Reservoir and Pump Station						
		1. Southeast Reservoir Pump Station	1	l.s	$1,477,002	$1,477,002		
		2.Southeast Reservoir (4 MG)	4,000,000	MG	$1.00	$4,000,000		
		3. 16" DIP Class 51	14,895	l.f	$118.00	$1,757,610		
		4. 24" DIP Class 51	14,792	l.f.	$192.00	$2,840,064		
		Subtotal				$10,074,676		
Hard Cost - Markups	**2.0**							
		a. Mobilization and Demobilization (2%)	1	l.s.		$201,493.52		
		b. Traffic Control (2%)	1	l.s.		$201,493.52		
		c. Erosion Control (1%)	1	l.s.		$100,746.76		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$1,511,201.38		
		Subtotal				$2,014,935.17		
							$12,089,611.04	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$1,208,961		
		b. Construction Administration and Management (8%)	1	l.s.		$967,169		
		c. Legal and Administrative (5%)	1	l.s.		$604,481		
		Subtotal				$2,780,611		
							$2,780,611	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed 3 Acre Property Requirement	3	Acre	$100,000.00	$300,000		
		b. Right-of-way	29,687	l.f.	$9.50	$282,027		
		Subtotal				$582,027		
							$582,027	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (20%)	1	l.s.		$3,090,450		
		Subtotal				$3,090,450		
							$3,090,450	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$18,542,697.69	**Total Probable Project Cost (2016)**

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CIP Name: WFP_31

CIP Name: 4975 Northwest Reservoir 1

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. 4975 Northwest Reservoir 1						
		1. Northwest Reservoir 1 (5 MG)	5,000,000	MG	$1.00	$5,000,000		
		Subtotal				$5,000,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization and Demobilization (2%)	1	l.s.		$100,000.00		
		b. Traffic Control (2%)	1	l.s.		$100,000.00		
		c. Erosion Control (1%)	1	l.s.		$50,000.00		
		d. Contractor Overhead and Profit (10%)	1	l.s.		$500,000.00		
		Subtotal				$750,000.00		
							$5,750,000.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$575,000		
		b. Construction Administration and Management (8%)	1	l.s.		$460,000		
		c. Legal and Administrative (5%)	1	l.s.		$287,500		
		Subtotal				$1,322,500		
							$1,322,500	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed 2.5 Acre Property Requirement	2.5	Acre	$100,000.00	$250,000		
		Subtotal				$250,000		
							$250,000	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (15%)	1	l.s.		$1,098,375		
		Subtotal				$1,098,375		
							$1,098,375	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$8,420,875.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: WFP_07

CIP Name: Lyman Creek Water System Improvements

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Water Main						
		1. 18" DIP - Class 51 (Outside-City)	7,120	l.f	$136.00	$968,320		
		2. 18" DIP - Class 51 (In-City)	3,800	l.f	$388.00	$1,474,400		
		b. New Lyman Creek Water Reservoirs						
		1. Site Development	1	EA	$1,000,000.00	$1,000,000		
		2. Pressure Regulating Facilities	1	LS	$250,000.00	$250,000		
		3. Connect to existing Transmission Main(s)	1	EA	$100,000.00	$100,000		
		4. Reservoirs (2, 5 MG)	10,000,000	gal	$1.00	$10,000,000		
		5. Chlorination/Fluoridation Facilities	1	LS	$300,000.00	$300,000		
		c. Micro Hydro	1	LS	$400,000.00	$400,000		
		d. Lyman Reservoir Decommissiong	1	LS	$500,000.00	$500,000.00		
		c. Pear Street Pump Station Decommissioning	1	LS	$200,000.00	$200,000.00		
		d. New PRV/Micro Hydro NE of City	1	LS	$300,000.00	$300,000		
		Subtotal				$13,050,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization (2%)	1	l.s.		$261,000.00		
		b. Traffic Control (2%)	1	l.s.		$261,000.00		
		c. Erosion Control (1%)	1	l.s.		$130,500.00		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$1,957,500.00		
		Subtotal				$2,610,000.00		
							$15,660,000.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (12%)	1	l.s.		$1,879,200		
		b. Construction Administration and Management (10%)	1	l.s.		$1,566,000		
		c. Legal and Administrative (10%)	1	l.s.		$1,566,000		
		Subtotal				$5,011,200		
							$5,011,200	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed existing ROW and Land	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (20%)	1	l.s.		$4,134,240		
		Subtotal				$4,134,240		
							$4,134,240	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$24,805,440.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: WFP_10b

CIP Name: Groundwater Well Field - Design & Construction Phase 2

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. New Lyman Creek Water Reservoir						
		1. Site Development	5	LS	$250,000.00	$1,250,000		
		2. Wells, Power and Control	5	EA	$400,000.00	$2,000,000		
		3. Connect to Transmission Main(s)	5	LS	$100,000.00	$500,000		
		4. Junction and Booster Station	1	EA	$3,000,000.00	$3,000,000		
		5. Disinfection (Residual) Facilities Upgrade	1	EA	$150,000.00	$150,000		
		Subtotal				$6,900,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization and Demobilization (2%)	1	l.s.		$138,000.00		
		b. Traffic Control (2%)	1	l.s.		$138,000.00		
		c. Erosion Control (1%)	1	l.s.		$69,000.00		
		d. Contractor Overhead and Profit (10%)	1	l.s.		$690,000.00		
		Subtotal				$1,035,000.00		
							$7,935,000.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$793,500		
		b. Construction Administration and Management (10%)	1	l.s.		$793,500		
		c. Legal and Administrative (10%)	1	l.s.		$793,500		
		Subtotal				$2,380,500		
							$2,380,500	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed 5 Acres	5	Acre	$100,000.00	$500,000		
		Subtotal				$500,000		
							$500,000	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (20%)	1	l.s.		$2,163,100		
		Subtotal				$2,163,100		
							$2,163,100	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$12,978,600.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: WFP_01b,c

CIP Name: West Transmission Main – Phase 1

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**	**Water Transmission System**						
		a. Water Main						
		1. 48" DIP - Class 51	25,227	l.f	$632.00	$15,943,464		
		2. 24" DIP - Class 51	5,952	l.f.	$192.00	$1,142,784		
		3. 16" DIP - Class 51	4,520	l.f.	$118.00	$533,360		
		Subtotal				$17,619,608		
Hard Cost - Markups	**2.0**							
		a. Mobilization/Demobilization (2%)	1	l.s.		$352,392.16		
		b. Traffic Control (2%)	1	l.s.		$352,392.16		
		c. Erosion Control (1%)	1	l.s.		$176,196.08		
		d. Contractor Overhead and Profit (5%)	1	l.s.		$880,980.40		
		Subtotal				$1,761,960.80		
							$19,381,569	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$1,938,157		
		b. Construction Administration and Management (8%)	1	l.s.		$1,550,526		
		c. Legal and Administrative (5%)	1	l.s.		$969,078		
		Subtotal				$4,457,761		
							$4,457,761	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Right-of-way	35,699	l.f.	$9.50	$339,141		
		Subtotal				$339,141		
							$339,141	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (10%)	1	l.s.		$2,417,847		
		Subtotal				$2,417,847		
							$2,417,847	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$26,596,317	**Total Probable Project Cost (2016)**

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CIP ID WFP_08

CIP Name: Sourdough Transmission Main – Phase 2

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**	**Water Transmission System**						
		a. Water Main						
		1. 36" DIP - Class 51	9,477	l.f	$369.00	$3,497,013		
		Subtotal				$3,497,013		
Hard Cost - Markups	**2.0**							
		a. Mobilization/Demobilization (2%)	1	l.s.		$69,940.26		
		b. Traffic Control (2%)	1	l.s.		$69,940.26		
		c. Erosion Control (1%)	1	l.s.		$34,970.13		
		d. Contractor Overhead and Profit (5%)	1	l.s.		$174,850.65		
		Subtotal				$349,701.30		
							$3,846,714	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$384,671		
		b. Construction Administration and Management (8%)	1	l.s.		$307,737		
		c. Legal and Administrative (5%)	1	l.s.		$192,336		
		Subtotal				$884,744		
							$884,744	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Right-of-way	9,477	l.f.	$9.50	$90,032		
		Subtotal				$90,032		
							$90,032	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (20%)	1	l.s.		$964,298		
		Subtotal				$964,298		
							$964,298	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$5,785,788	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID: WFP_29

CIP Name: East Transmission Main

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**	**Water Transmission System**						
		a. Water Main						
		1. 24" DIP - Class 51	20,568	l.f	$192.00	$3,949,056		
		Subtotal				$3,949,056		
Hard Cost - Markups	**2.0**							
		a. Mobilization/Demobilization (2%)	1	l.s.		$78,981		
		b. Traffic Control (2%)	1	l.s.		$78,981		
		c. Erosion Control (1%)	1	l.s.		$39,491		
		d. Contractor Overhead and Profit (5%)	1	l.s.		$197,453		
		Subtotal				$394,905.60		
							$4,343,962	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$434,396		
		b. Construction Administration and Management (8%)	1	l.s.		$347,517		
		c. Legal and Administrative (5%)	1	l.s.		$217,198		
		Subtotal				$999,111		
							$999,111	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Right-of-way	20,568	l.f.	$9.50	$195,396		
		Subtotal				$195,396		
							$195,396	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (10%)	1	l.s.		$553,847		
		Subtotal				$553,847		
							$553,847	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$6,092,316	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID: WFP_39

CIP Name: West Transmission Main – Phase 2

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**	**Water Transmission System**						
	a.	Water Main						
		1. 48" DIP - Class 51	37,739	l.f	$632.00	$23,851,048		
		Subtotal				$23,851,048		
Hard Cost - Markups	**2.0**							
	a.	Mobilization/Demobilization (2%)	1	l.s.		$477,020.96		
	b.	Traffic Control (2%)	1	l.s.		$477,020.96		
	c.	Erosion Control (1%)	1	l.s.		$238,510.48		
	d.	Contractor Overhead and Profit (5%)	1	l.s.		$1,192,552.40		
		Subtotal				$2,385,104.80		
							$26,236,153	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
	a.	Engineering (10%)	1	l.s.		$2,623,615		
	b.	Construction Administration and Management (8%)	1	l.s.		$2,098,892		
	c.	Legal and Administrative (5%)	1	l.s.		$1,311,808		
		Subtotal				$6,034,315		
							$6,034,315	**Estimated Soft Costs**
Property Acquisition	**4.0**							
	a.	Right-of-way	37,739	l.f.	$9.50	$358,521		
		Subtotal				$358,521		
							$358,521	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
	a.	Total Project Contingency (10%)	1	l.s.		$3,262,899		
		Subtotal				$3,262,899		
							$3,262,899	**Project Contingency**
Inflation	**6.0**							
	a.	Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$35,891,887	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID: WFP_52

CIP Name: Groundwater Well Field Transmission Main - Phase 2

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**	**Water Transmission System**						
		a. Water Main						
		1. 24" DIP - Class 51	30,300	l.f	$192.00	$5,817,600		
		Subtotal				$5,817,600		
Hard Cost - Markups	**2.0**							
		a. Mobilization/Demobilization (2%)	1	l.s.		$116,352.00		
		b. Traffic Control (2%)	1	l.s.		$116,352.00		
		c. Erosion Control (1%)	1	l.s.		$58,176.00		
		d. Contractor Overhead and Profit (5%)	1	l.s.		$290,880.00		
		Subtotal				$581,760.00		
							$6,399,360.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$639,936		
		b. Construction Administration and Management (8%)	1	l.s.		$511,949		
		c. Legal and Administrative (5%)	1	l.s.		$319,968		
		Subtotal				$1,471,853		
							$1,471,853	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Right-of-way	30,300	l.f.	$9.50	$287,850		
		Subtotal				$287,850		
							$287,850	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (10%)	1	l.s.		$815,906		
		Subtotal				$815,906		
							$815,906	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$8,974,969.08	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
August, 2016

CIP ID WFP_40

CIP Name: 4975 Northwest Reservoir 2

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. 4975 Northwest Reservoir 2						
		1. Northwest Reservoir 2 (5 MG)	5,000,000	MG	$1.00	$5,000,000		
		Subtotal				$5,000,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization (10%)	1	l.s.		$100,000.00		
		b. Traffic Control (2%)	1	l.s.		$100,000.00		
		c. Erosion Control (1%)	1	l.s.		$50,000.00		
		d. Contractor Overhead and Profit (10%)	1	l.s.		$500,000.00		
		Subtotal				$750,000.00		
							$5,750,000.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$575,000		
		b. Construction Administration and Management (8%)	1	l.s.		$460,000		
		c. Legal and Administrative (5%)	1	l.s.		$287,500		
		Subtotal				$1,322,500		
							$1,322,500	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed 2.5 Acre Property Requirement	2.5	Acre	$100,000.00	$250,000		
		Subtotal				$250,000		
							$250,000	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (15%)	1	l.s.		$1,098,375		
		Subtotal				$1,098,375		
							$1,098,375	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$8,420,875.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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CIP ID: WFP_41

CIP Name: 5125 West Sourdough Reservoir 2

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. 5125 West Sourdough Reservoir 2						
		1. West Sourdough Reservoir 2 (5 MG)	5,000,000	MG	$1.00	$5,000,000		
		Subtotal				$5,000,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization and Demobilization (2%)	1	l.s.		$100,000.00		
		b. Traffic Control (2%)	1	l.s.		$100,000.00		
		c. Erosion Control (1%)	1	l.s.		$50,000.00		
		d. Contractor Overhead and Profit (10%)	1	l.s.		$500,000.00		
		Subtotal				$750,000.00		
							$5,750,000.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$575,000		
		b. Construction Administration and Management (8%)	1	l.s.		$460,000		
		c. Legal and Administrative (5%)	1	l.s.		$287,500		
		Subtotal				$1,322,500		
							$1,322,500	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed 2.5 Acre Property Requirement	2.5	l.s.	$100,000.00	$250,000		
		Subtotal				$250,000		
							$250,000	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (15%)	1	l.s.		$1,098,375		
		Subtotal				$1,098,375		
							$1,098,375	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$8,420,875.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
August, 2016

CIP ID: WFP_42

CIP Name: 5350 Southwest Reservoir and Pump Station

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Southwest Reservoir and Pump Station						
		1. Southwest Reservoir Pump Station	1	l.s	$1,354,181	$1,354,181		
		2. Southwest Reservoir (4 MG)	4,000,000	MG	$1.00	$4,000,000		
		3. 24" DIP Class 51	100	l.f	$192.00	$19,200		
		4. 30" DIP Class 51	7,525	l.f	$294.00	$2,212,350		
		Subtotal				$7,585,731		
Hard Cost - Markups	**2.0**							
		a. Mobilization and Demobilization (2%)	1	l.s.		$151,714.61		
		b. Traffic Control (2%)	1	l.s.		$151,714.61		
		c. Erosion Control (1%)	1	l.s.		$75,857.31		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$1,137,859.60		
		Subtotal				$1,517,146.14		
							$9,102,876.81	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$910,288		
		b. Construction Administration and Management (8%)	1	l.s.		$728,230		
		c. Legal and Administrative (5%)	1	l.s.		$455,144		
		Subtotal				$2,093,662		
							$2,093,662	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed 3 Acre Property Requirement	3	Acre	$100,000.00	$300,000		
		Subtotal				$300,000		
							$300,000	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (20%)	1	l.s.		$2,299,308		
		Subtotal				$2,299,308		
							$2,299,308	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$13,795,846.17	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
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August, 2016

CIP ID: WFP_43

CIP Name: 5360 North Mountain Reservoir and Pump Station

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. North Reservoir and Pump Station						
		1.North Reservoir Pump Station	1	l.s	$1,198,918	$1,198,918		
		2.North Reservoir (3 MG)	3,000,000	MG	$1.00	$3,000,000		
		3. 16" DIP Class 51	13,230	l.f	$118.00	$1,561,140		
		4. 24" DIP Class 51	65	l.f	$192.00	$12,480		
		Subtotal				$5,772,538		
Hard Cost - Markups	**2.0**							
		a. Mobilization and Demobilization (2%)	1	l.s.		$115,450.77		
		b. Traffic Control (2%)	1	l.s.		$115,450.77		
		c. Erosion Control (1%)	1	l.s.		$57,725.38		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$865,880.75		
		Subtotal				$1,154,507.66		
							$6,927,046	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$692,705		
		b. Construction Administration and Management (8%)	1	l.s.		$554,164		
		c. Legal and Administrative (5%)	1	l.s.		$346,352		
		Subtotal				$1,593,221		
							$1,593,221	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed 3 Acre Property Requirement	3	Acre	$100,000.00	$300,000		
		Subtotal				$300,000		
							$300,000	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (20%)	1	l.s.		$1,764,053		
		Subtotal				$1,764,053		
							$1,764,053	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$10,584,320	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID: WFP_44

CIP Name: 5630 East Mountain Zone Reservoir and Pump Station

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. East Mountain Zone						
		1. East Mountain Pump Station	1	l.s	$1,839,255	$1,839,255		
		2. East Mountain Reservoir (6 MG)	6,000,000	MG	$1.00	$6,000,000		
		3. 18" DIP Class 51	5,555	l.f	$136.00	$755,480		
		4. 24" DIP Class 51	2,960	l.f	$192.00	$568,320		
		Subtotal				$9,163,055		
Hard Cost - Markups	**2.0**							
		a. Mobilization/Demobilization (2%)	1	l.s.		$183,261		
		b. Traffic Control (2%)	1	l.s.		$183,261		
		c. Erosion Control (1%)	1	l.s.		$91,631		
		d. Contractor Overhead and Profit (15%)	1	l.s.		$1,374,458		
		Subtotal				$1,832,611		
							$10,995,666	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$1,099,567		
		b. Construction Administration and Management (8%)	1	l.s.		$879,653		
		c. Legal and Administrative (5%)	1	l.s.		$549,783		
		Subtotal				$2,529,003		
							$2,529,003	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed 3 Acre Property Requirement	3	Acre	$100,000.00	$300,000		
		Subtotal				$300,000		
							$300,000	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (20%)	1	l.s.		$2,764,934		
		Subtotal				$2,764,934		
							$2,764,934	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$16,589,604	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID: WFP_45

CIP Name: Sourdough Reservoir 2

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Sourdough Reservoir 2						
		1. Sourdough Reservoir 2 (4 MG)	4,000,000	MG	$1.00	$4,000,000		
		Subtotal				$4,000,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization and Demobilization (2%)	1	l.s.		$80,000.00		
		b. Traffic Control (2%)	1	l.s.		$80,000.00		
		c. Erosion Control (1%)	1	l.s.		$40,000.00		
		d. Contractor Overhead and Profit (10%)	1	l.s.		$400,000.00		
		Subtotal				$600,000.00		
							$4,600,000.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$460,000		
		b. Construction Administration and Management (8%)	1	l.s.		$368,000		
		c. Legal and Administrative (5%)	1	l.s.		$230,000		
		Subtotal				$1,058,000		
							$1,058,000	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed City owned Land at Sourdough Site	0	Acre		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (15%)	1	l.s.		$848,700		
		Subtotal				$848,700		
							$848,700	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$6,506,700.00	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID: WFP_46

CIP Name: Water Treatment Plant Reservoir 2

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Water Treatment Plant Reservoir 2						
		1. WTP Reservoir 2 (5 MG)	5,000,000	MG	$1.00	$5,000,000		
		Subtotal				$5,000,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization/Demobilization (2%)	1	l.s.		$100,000.00		
		b. Traffic Control (2%)	1	l.s.		$100,000.00		
		c. Erosion Control (1%)	1	l.s.		$50,000.00		
		d. Contractor Overhead and Profit (10%)	1	l.s.		$500,000.00		
		Subtotal				$750,000.00		
							$5,750,000.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$575,000		
		b. Construction Administration and Management (8%)	1	l.s.		$460,000		
		c. Legal and Administrative (5%)	1	l.s.		$287,500		
		Subtotal				$1,322,500		
							$1,322,500	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed City owned Land at WTP	0	Acre		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (10%)	1	l.s.		$707,250		
		Subtotal				$707,250		
							$707,250	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$7,779,750.00	**Total Probable Project Cost (2016)**

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CIP ID: WFP_47

CIP Name: Water Treatment Plant Reservoir 3

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Water Treatment Plant Reservoir 3						
		1. WTP Reservoir 3 (5 MG)	5,000,000	MG	$1.00	$5,000,000		
		Subtotal				$5,000,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization/Demobilization (2%)	1	l.s.		$100,000.00		
		b. Traffic Control (2%)	1	l.s.		$100,000.00		
		c. Erosion Control (1%)	1	l.s.		$50,000.00		
		d. Contractor Overhead and Profit (10%)	1	l.s.		$500,000.00		
		Subtotal				$750,000.00		
							$5,750,000.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$575,000		
		b. Construction Administration and Management (8%)	1	l.s.		$460,000		
		c. Legal and Administrative (5%)	1	l.s.		$287,500		
		Subtotal				$1,322,500		
							$1,322,500	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Assumed City owned Land at WTP	0	Acre		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (10%)	1	l.s.		$707,250		
		Subtotal				$707,250		
							$707,250	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$7,779,750.00	**Total Probable Project Cost (2016)**

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OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID: WFP_47

CIP Name: West Transmission Main – Phase 3

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**	**Water Transmission System**						
		a. Water Main						
		1. 36" DIP - Class 51	19,542	l.f	$369.00	$7,210,998		
		Subtotal				$7,210,998		
Hard Cost - Markups	**2.0**							
		a. Mobilization/Demobilization (2%)	1	l.s.		$144,219.96		
		b. Traffic Control (2%)	1	l.s.		$144,219.96		
		c. Erosion Control (1%)	1	l.s.		$72,109.98		
		d. Contractor Overhead and Profit (5%)	1	l.s.		$360,549.90		
		Subtotal				$721,099.80		
							$7,932,097.80	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$793,210		
		b. Construction Administration and Management (8%)	1	l.s.		$634,568		
		c. Legal and Administrative (5%)	1	l.s.		$396,605		
		Subtotal				$1,824,382		
							$1,824,382	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Right-of-way	19,542	l.f.	$9.50	$185,649		
		Subtotal				$185,649		
							$185,649	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (10%)	1	l.s.		$994,213		
		Subtotal				$994,213		
							$994,213	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$10,936,342	**Total Probable Project Cost (2016)**

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OPINION OF TOTAL PROBABLE PROJECT COST
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CIP ID: WFP_49

CIP Name: West Transmission Main – Phase 4

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**	**Water Transmission System**						
	a.	Water Main						
		1. 30" DIP - Class 51	8,382	l.f	$294.00	$2,464,308		
		Subtotal				$2,464,308		
Hard Cost - Markups	**2.0**							
	a.	Mobilization/Demobilization (2%)	1	l.s.		$49,286.16		
	b.	Traffic Control (2%)	1	l.s.		$49,286.16		
	c.	Erosion Control (1%)	1	l.s.		$24,643.08		
	d.	Contractor Overhead and Profit (5%)	1	l.s.		$123,215.40		
		Subtotal				$246,430.80		
							$2,710,739	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
	a.	Engineering (10%)	1	l.s.		$271,074		
	b.	Construction Administration and Management (8%)	1	l.s.		$216,859		
	c.	Legal and Administrative (5%)	1	l.s.		$135,537		
		Subtotal				$623,470		
							$623,470	**Estimated Soft Costs**
Property Acquisition	**4.0**							
	a.	Right-of-way	8,382	l.f.	$9.50	$79,629		
		Subtotal				$79,629		
							$79,629	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
	a.	Total Project Contingency (10%)	1	l.s.		$341,384		
		Subtotal				$341,384		
							$341,384	**Project Contingency**
Inflation	**6.0**							
	a.	Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$3,755,221	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
August, 2016

CIP ID: WFP_50

CIP Name: West Transmission Main – Phase 5

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**	**Water Transmission System**						
		a. Water Main						
		1. 24" DIP - Class 51	8,295	l.f	$192.00	$1,592,640		
		Subtotal				$1,592,640		
Hard Cost - Markups	**2.0**							
		a. Mobilization/Demobilization (2%)	1	l.s.		$31,852.80		
		b. Traffic Control (2%)	1	l.s.		$31,852.80		
		c. Erosion Control (1%)	1	l.s.		$15,926.40		
		d. Contractor Overhead and Profit (5%)	1	l.s.		$79,632.00		
		Subtotal				$159,264.00		
							$1,751,904	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (10%)	1	l.s.		$175,190		
		b. Construction Administration and Management (8%)	1	l.s.		$140,152		
		c. Legal and Administrative (5%)	1	l.s.		$87,595		
		Subtotal				$402,938		
							$402,938	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Right-of-way	8,295	l.f.	$9.50	$78,803		
		Subtotal				$78,803		
							$78,803	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (10%)	1	l.s.		$223,364		
		Subtotal				$223,364		
							$223,364	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
							$2,457,009	**Total Probable Project Cost (2016)**

Bozeman Water Facility Plan Update
OPINION OF TOTAL PROBABLE PROJECT COST
August, 2016

CIP Name: **G&D PRVs (approximately 42 sites)**

COST COMPONENT	ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST	COMPONENT SUBTOTAL	
Hard Cost	**1.0**							
		a. Pumps, Electrical, Control, SCADA, PRV's	1	l.s.		$235,000		
		1. Precast or cast in-place concrete vault (water tight)						
		2. Valving & piping						
		3. Above grade SCADA/Control weather enclosure						
		5. Electrical & Controls						
		6. Heating& Ventilation/Dehumidification						
		7. Hatch (Safety access - eliminate confined space entry)						
		8. Power to site						
		9. PRV's harnessing						
		10. SCADA programming						
		Subtotal				$235,000		
Hard Cost - Markups	**2.0**							
		a. Mobilization (5%)	1	l.s.		$11,750.00		
		b. Traffic Control (2%)	1	l.s.		$4,700.00		
		c. Erosion Control (1%)	1	l.s.		$2,350.00		
		d. Contractor Overhead and Profit (10%)	1	l.s.		$23,500.00		
		Subtotal				$42,300.00		
							$277,300.00	**Estimated Hard/Construction Costs**
Soft Costs	**3.0**							
		a. Engineering (5%)	1	l.s.		$13,865		
		b. Construction Administration and Management (5%)	1	l.s.		$13,865		
		c. Legal and Administrative (2%)	1	l.s.		$5,546		
		Subtotal				$33,276		
							$33,276	**Estimated Soft Costs**
Property Acquisition	**4.0**							
		a. Not Included	0	l.s.		$0		
		Subtotal				$0		
							$0	**Estimated Property Acquisition Costs**
Project Contingency	**5.0**							
		a. Total Project Contingency (30%)	1	l.s.		$93,173		
		Subtotal				$93,173		
							$93,173	**Project Contingency**
Inflation	**6.0**							
		a. Not Included	1	l.s.		$0		
		Subtotal				$0		
							$0	**Inflation**
					Cost Per PRV SITE		**$403,749**	**Total Probable Project Cost (2016)**

ID	DESCRIPTION	CIP_ITEMS	Cost
V8040	PRV - Flow for SE Mountain Zone	G&D	$ 403,749
V8042	PRV - Flow for SE Mountain Zone	G&D	$ 403,749
V8062	PRV - Emergency Flow from SD Zone to NW1 Zone	G&D	$ 403,749
V8072	PRV - Emergency Flow from WTP Zone to SD Zone	G&D	$ 403,749
V8074	PRV - Emergency Flow from SW Zone to WTP Zone	G&D	$ 403,749
V8076	PRV - Emergency Flow from WTP Zone to SD Zone	G&D	$ 403,749
V8080	PRV - Emergency Flow from WTP Zone to SD Zone	G&D	$ 403,749
V8086	PRV - Emergency Flow from WTP Zone to SD Zone	G&D	$ 403,749
V8092	PRV - Emergency Flow from WTP Zone to SD Zone	G&D	$ 403,749
V8098	PRV - Emergency Flow from WTP Zone to SD Zone	G&D	$ 403,749
V8104	PRV - Flow for SE Mountain Zone	G&D	$ 403,749
V8106	PRV - Emergency Flow from SE Mountain Zone to Sourdough Zone	G&D	$ 403,749
V8108	PRV - Emergency Flow from SE Mountain Zone to Sourdough Zone	G&D	$ 403,749
V8110	PRV - Emergency Flow from SE Mountain Zone to Sourdough Zone	G&D	$ 403,749
V8112	PRV - Emergency Flow from SE Mountain Zone to Sourdough Zone	G&D	$ 403,749
V8128	PRV - Emergency Flow from NW1 Zone to NW2 Zone	G&D	$ 403,749
V8130	PRV - Emergency Flow from NW1 Zone to NW2 Zone	G&D	$ 403,749
V8134	PRV - Emergency Flow from NW1 Zone to NW3 Zone	G&D	$ 403,749
V8142	PRV - Emergency Flow from NW1 Zone to NW3 Zone	G&D	$ 403,749
V8152	PRV - Emergency Flow from NW1 Zone to NW3 Zone	G&D	$ 403,749
V8162	PRV - Emergency Flow from NW2 Zone to NW3 Zone	G&D	$ 403,749
V8164	PRV - Flow from NW1 Zone to NW2 Zone	G&D	$ 403,749
V8166	PRV - Flow from NW1 Zone to NW2 Zone	G&D	$ 403,749
V8168	PRV - Flow from NW1 Zone to NW2 Zone	G&D	$ 403,749
V8178	PRV - Flow from for North Mountain Zone	G&D	$ 403,749
V8180	PRV - Flow from for North Mountain Zone	G&D	$ 403,749
V8182	PRV - Flow from for North Mountain Zone	G&D	$ 403,749
V8184	PRV - Flow from for North Mountain Zone	G&D	$ 403,749
V8186	PRV - Flow for SE Mountain Zone	G&D	$ 403,749
V8188	PRV - Flow for East Mountain Zone	G&D	$ 403,749
V8190	PRV - Flow for East Mountain Zone	G&D	$ 403,749
V8192	PRV - Flow for East Mountain Zone	G&D	$ 403,749
V8194	PRV - Flow for East Mountain Zone	G&D	$ 403,749
V8200	PRV - Flow for East Mountain Zone	G&D	$ 403,749
V8202	PRV - Flow for East Mountain Zone	G&D	$ 403,749
V8204	PRV - Flow for East Mountain Zone	G&D	$ 403,749
V8206	PRV - Flow for East Mountain Zone	G&D	$ 403,749
V8208	PRV - Flow for East Mountain Zone	G&D	$ 403,749
V8210	PRV - Flow for East Mountain Zone	G&D	$ 403,749
V8216	PRV - Flow for East Mountain Zone	G&D	$ 403,749
V8226	PRV - Emergency Flow Gallatin Park Zone to NW2 Zone	G&D	$ 403,749
V8228	PRV - Emergency Flow from Northeast Zone to NW2 Zone	G&D	$ 403,749

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT	Cost
FP_1610	Future Pipe	G&D	190.94	8	HGL 5360 (N)	61	$ 11,647
FP_1613	Future Pipe	G&D	1167.48	8	HGL 5360 (N)	61	$ 71,216
FP_1652	Future Pipe	G&D	1696.58	8	HGL 4725 (NW3)	61	$ 103,492
FP_1612	Future Pipe	G&D	2111.68	8	HGL 5360 (N)	61	$ 128,812
FP_1609	Future Pipe	G&D	3205.30	8	HGL 5360 (N)	61	$ 195,523
FP_1608	Future Pipe	G&D	857.33	8	HGL 5360 (N)	61	$ 52,297
FP_1611	Future Pipe	G&D	1272.90	8	HGL 5360 (N)	61	$ 77,647
FP_1648	Future Pipe	G&D	462.89	8	HGL 4725 (NW3)	61	$ 28,236
FP_1651	Future Pipe	G&D	2375.01	8	HGL 4725 (NW3)	61	$ 144,876
FP_1615	Future Pipe	G&D	810.53	8	HGL 5360 (N)	61	$ 49,442
FP_1650	Future Pipe	G&D	1167.09	8	HGL 4725 (NW3)	61	$ 71,192
FP_1649	Future Pipe	G&D	1229.17	8	HGL 4725 (NW3)	61	$ 74,979
FP_1578	Future Pipe	G&D	1041.45	8	HGL 4850 (NW2)	61	$ 63,528
FP_1581	Future Pipe	G&D	927.47	8	HGL 4850 (NW2)	61	$ 56,576
FP_1579	Future Pipe	G&D	837.71	8	HGL 4850 (NW2)	61	$ 51,100
FP_1592	Future Pipe	G&D	1018.06	8	HGL 4850 (NW2)	61	$ 62,102
FP_1576	Future Pipe	G&D	250.05	8	HGL 4850 (NW2)	61	$ 15,253
FP_1572	Future Pipe	G&D	1795.61	8	HGL 4850 (NW2)	61	$ 109,532
FP_1571	Future Pipe	G&D	1537.50	8	HGL 4850 (NW2)	61	$ 93,787
FP_1591	Future Pipe	G&D	1553.51	8	HGL 4850 (NW2)	61	$ 94,764
FP_1589	Future Pipe	G&D	1253.85	8	HGL 4850 (NW2)	61	$ 76,485
FP_1582	Future Pipe	G&D	1264.08	8	HGL 4850 (NW2)	61	$ 77,109
FP_1583	Future Pipe	G&D	2798.73	8	HGL 4850 (NW2)	61	$ 170,723
FP_1584	Future Pipe	G&D	2663.16	8	HGL 4850 (NW2)	61	$ 162,453
FP_1707	Future Pipe	G&D	928.98	8	HGL 4725 (NW3)	61	$ 56,668
FP_1718	Future Pipe	G&D	1927.51	8	HGL 4725 (NW3)	61	$ 117,578
FP_1717	Future Pipe	G&D	3154.81	8	HGL 4850 (NW2)	61	$ 192,443
FP_1713	Future Pipe	G&D	343.35	8	HGL 4725 (NW3)	61	$ 20,944
FP_1712	Future Pipe	G&D	418.92	8	HGL 4725 (NW3)	61	$ 25,554
FP_1711	Future Pipe	G&D	1200.84	8	HGL 4725 (NW3)	61	$ 73,251
FP_1710	Future Pipe	G&D	958.46	8	HGL 4725 (NW3)	61	$ 58,466
FP_1708	Future Pipe	G&D	1008.02	8	HGL 4725 (NW3)	61	$ 61,489
FP_1723	Future Pipe	G&D	2586.15	8	HGL 4850 (NW2)	61	$ 157,755
FP_1706	Future Pipe	G&D	365.51	8	HGL 4725 (NW3)	61	$ 22,296
FP_1705	Future Pipe	G&D	304.96	8	HGL 4725 (NW3)	61	$ 18,603
FP_1704	Future Pipe	G&D	286.98	8	HGL 4725 (NW3)	61	$ 17,506
FP_1702	Future Pipe	G&D	1562.36	8	HGL 4725 (NW3)	61	$ 95,304
FP_1701	Future Pipe	G&D	1380.32	8	HGL 4725 (NW3)	61	$ 84,200
FP_1709	Future Pipe	G&D	349.39	8	HGL 4725 (NW3)	61	$ 21,313
FP_1719	Future Pipe	G&D	860.25	8	HGL 4725 (NW3)	61	$ 52,475
FP_1722	Future Pipe	G&D	2552.39	8	HGL 4725 (NW3)	61	$ 155,696
FP_1728	Future Pipe	G&D	986.11	8	HGL 4850 (NW2)	61	$ 60,153
FP_1727	Future Pipe	G&D	1940.28	8	HGL 4850 (NW2)	61	$ 118,357
FP_1671	Future Pipe	G&D	693.62	8	HGL 4725 (NW3)	61	$ 42,311
FP_1670	Future Pipe	G&D	1137.95	8	HGL 4725 (NW3)	61	$ 69,415
FP_1669	Future Pipe	G&D	899.89	8	HGL 4725 (NW3)	61	$ 54,893
FP_1668	Future Pipe	G&D	553.54	8	HGL 4725 (NW3)	61	$ 33,766
FP_1667	Future Pipe	G&D	2599.58	8	HGL 4725 (NW3)	61	$ 158,574
FP_1666	Future Pipe	G&D	1363.27	8	HGL 4725 (NW3)	61	$ 83,160
FP_1659	Future Pipe	G&D	1543.98	8	HGL 4725 (NW3)	61	$ 94,183
FP_1658	Future Pipe	G&D	575.17	8	HGL 4725 (NW3)	61	$ 35,085
FP_1684	Future Pipe	G&D	1298.63	8	HGL 4725 (NW3)	61	$ 79,217
FP_1693	Future Pipe	G&D	1083.54	8	HGL 4725 (NW3)	61	$ 66,096
FP_1692	Future Pipe	G&D	1048.71	8	HGL 4725 (NW3)	61	$ 63,971
FP_1691	Future Pipe	G&D	1304.18	8	HGL 4725 (NW3)	61	$ 79,555

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT	Cost
FP_1690	Future Pipe	G&D	1048.91	8	HGL 4725 (NW3)	61	$ 63,983
FP_1689	Future Pipe	G&D	1222.54	8	HGL 4725 (NW3)	61	$ 74,575
FP_1688	Future Pipe	G&D	1083.54	8	HGL 4725 (NW3)	61	$ 66,096
FP_1672	Future Pipe	G&D	1507.77	8	HGL 4725 (NW3)	61	$ 91,974
FP_1685	Future Pipe	G&D	1222.54	8	HGL 4725 (NW3)	61	$ 74,575
FP_1533	Future Pipe	G&D	1400.69	8	HGL 5560 (SE)	61	$ 85,442
FP_1530	Future Pipe	G&D	1760.65	8	HGL 5560 (SE)	61	$ 107,400
FP_1532	Future Pipe	G&D	994.32	8	HGL 5560 (SE)	61	$ 60,654
FP_1531	Future Pipe	G&D	2510.93	8	HGL 5560 (SE)	61	$ 153,167
FP_1528	Future Pipe	G&D	2132.67	8	HGL 5560 (SE)	61	$ 130,093
FP_1492	Future Pipe	G&D	2075.58	8	HGL 5560 (SE)	61	$ 126,611
FP_1491	Future Pipe	G&D	1198.01	8	HGL 5560 (SE)	61	$ 73,078
FP_1490	Future Pipe	G&D	383.18	8	HGL 5560 (SE)	61	$ 23,374
FP_1505	Future Pipe	G&D	454.86	8	HGL 5560 (SE)	61	$ 27,747
FP_1501	Future Pipe	G&D	499.05	8	HGL 5560 (SE)	61	$ 30,442
FP_1504	Future Pipe	G&D	1663.78	8	HGL 5560 (SE)	61	$ 101,491
FP_1502	Future Pipe	G&D	702.90	8	HGL 5560 (SE)	61	$ 42,877
FP_2192	Future Pipe	G&D	969.28	8	HGL 4850 (NW2)	61	$ 59,126
FP_2226	Future Pipe	G&D	668.06	8	HGL 4850 (NW2)	61	$ 40,752
FP_2430	Future Pipe	G&D	411.88	8	HGL 5630 (MT)	61	$ 25,125
FP_2428	Future Pipe	G&D	639.26	8	HGL 5630 (MT)	61	$ 38,995
FP_2427	Future Pipe	G&D	34.60	8	HGL 5630 (MT)	61	$ 2,111
FP_2419	Future Pipe	G&D	2011.60	8	HGL 5630 (MT)	61	$ 122,708
FP_2409	Future Pipe	G&D	495.22	8	HGL 5630 (MT)	61	$ 30,208
FP_2408	Future Pipe	G&D	55.84	8	HGL 5630 (MT)	61	$ 3,406
FP_2407	Future Pipe	G&D	414.10	8	HGL 5630 (MT)	61	$ 25,260
FP_2406	Future Pipe	G&D	58.66	8	HGL 5630 (MT)	61	$ 3,578
FP_2460	Future Pipe	G&D	3541.08	8	HGL 5038 (L)	61	$ 216,006
FP_2459	Future Pipe	G&D	507.99	8	HGL 5038 (L)	61	$ 30,987
FP_2454	Future Pipe	G&D	1012.40	8	HGL 5038 (L)	61	$ 61,756
FP_2451	Future Pipe	G&D	42.50	8	HGL 5630 (MT)	61	$ 2,592
FP_2450	Future Pipe	G&D	75.42	8	HGL 5630 (MT)	61	$ 4,601
FP_2449	Future Pipe	G&D	28.67	8	HGL 5630 (MT)	61	$ 1,749
FP_2446	Future Pipe	G&D	67.16	8	HGL 5630 (MT)	61	$ 4,097
FP_2365	Future Pipe	G&D	1258.32	8	HGL 5038 (L)	61	$ 76,757
FP_2369	Future Pipe	G&D	603.64	8	HGL 5038 (L)	61	$ 36,822
FP_2351	Future Pipe	G&D	955.85	8	HGL 5630 (MT)	61	$ 58,307
FP_2350	Future Pipe	G&D	1104.52	8	HGL 5630 (MT)	61	$ 67,376
FP_2348	Future Pipe	G&D	1827.74	8	HGL 5630 (MT)	61	$ 111,492
FP_2347	Future Pipe	G&D	1569.91	8	HGL 5630 (MT)	61	$ 95,765
FP_2346	Future Pipe	G&D	1100.25	8	HGL 5630 (MT)	61	$ 67,115
FP_2345	Future Pipe	G&D	190.15	8	HGL 5630 (MT)	61	$ 11,599
FP_2383	Future Pipe	G&D	966.59	8	HGL 5630 (MT)	61	$ 58,962
FP_2402	Future Pipe	G&D	151.23	8	HGL 5630 (MT)	61	$ 9,225
FP_2401	Future Pipe	G&D	58.04	8	HGL 5630 (MT)	61	$ 3,540
FP_2396	Future Pipe	G&D	666.67	8	HGL 5630 (MT)	61	$ 40,667
FP_2391	Future Pipe	G&D	1715.64	8	HGL 5630 (MT)	61	$ 104,654
FP_2390	Future Pipe	G&D	734.33	8	HGL 5630 (MT)	61	$ 44,794
FP_2388	Future Pipe	G&D	853.16	8	HGL 5630 (MT)	61	$ 52,043
FP_2386	Future Pipe	G&D	1320.38	8	HGL 5630 (MT)	61	$ 80,543
FP_2367	Future Pipe	G&D	621.84	8	HGL 5038 (L)	61	$ 37,932
FP_2382	Future Pipe	G&D	1105.74	8	HGL 5630 (MT)	61	$ 67,450
FP_2381	Future Pipe	G&D	1295.61	8	HGL 5630 (MT)	61	$ 79,032
FP_2378	Future Pipe	G&D	3752.55	8	HGL 5038 (L)	61	$ 228,905
FP_2376	Future Pipe	G&D	1354.52	8	HGL 5630 (MT)	61	$ 82,626

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT	Cost
FP_2373	Future Pipe	G&D	1065.10	8	HGL 5630 (MT)	61	$ 64,971
FP_2385	Future Pipe	G&D	1627.62	8	HGL 5630 (MT)	61	$ 99,285
FP_1903	Future Pipe	G&D	243.06	8	HGL 4975 (NW1)	61	$ 14,826
FP_1842	Future Pipe	G&D	1709.03	8	HGL 5560 (SE)	61	$ 104,251
FP_1841	Future Pipe	G&D	717.28	8	HGL 5560 (SE)	61	$ 43,754
FP_1840	Future Pipe	G&D	1024.22	8	HGL 5560 (SE)	61	$ 62,478
FP_1902	Future Pipe	G&D	145.87	8	HGL 4975 (NW1)	61	$ 8,898
FP_1898	Future Pipe	G&D	2568.05	8	HGL 5126 (S)	61	$ 156,651
FP_1897	Future Pipe	G&D	1895.29	8	HGL 5126 (S)	61	$ 115,613
FP_1896	Future Pipe	G&D	781.25	8	HGL 5126 (S)	61	$ 47,656
FP_1895	Future Pipe	G&D	1242.48	8	HGL 5126 (S)	61	$ 75,791
FP_1894	Future Pipe	G&D	1675.37	8	HGL 5126 (S)	61	$ 102,198
FP_1893	Future Pipe	G&D	798.61	8	HGL 5126 (S)	61	$ 48,715
FP_1833	Future Pipe	G&D	2375.44	8	HGL 5126 (S)	61	$ 144,902
FP_1836	Future Pipe	G&D	1154.45	8	HGL 5126 (S)	61	$ 70,421
FP_1821	Future Pipe	G&D	1544.71	8	HGL 5126 (S)	61	$ 94,227
FP_1837	Future Pipe	G&D	794.77	8	HGL 5126 (S)	61	$ 48,481
FP_1832	Future Pipe	G&D	1106.21	8	HGL 5126 (S)	61	$ 67,479
FP_1831	Future Pipe	G&D	2662.07	8	HGL 5126 (S)	61	$ 162,387
FP_1830	Future Pipe	G&D	1710.77	8	HGL 5126 (S)	61	$ 104,357
FP_1829	Future Pipe	G&D	564.50	8	HGL 5126 (S)	61	$ 34,435
FP_1828	Future Pipe	G&D	846.40	8	HGL 5126 (S)	61	$ 51,631
FP_1827	Future Pipe	G&D	609.39	8	HGL 5126 (S)	61	$ 37,173
FP_1826	Future Pipe	G&D	782.87	8	HGL 5126 (S)	61	$ 47,755
FP_1825	Future Pipe	G&D	1493.39	8	HGL 5126 (S)	61	$ 91,097
FP_1824	Future Pipe	G&D	425.44	8	HGL 5126 (S)	61	$ 25,952
FP_1822	Future Pipe	G&D	667.52	8	HGL 5126 (S)	61	$ 40,719
FP_1820	Future Pipe	G&D	687.81	8	HGL 5126 (S)	61	$ 41,956
FP_1819	Future Pipe	G&D	1171.91	8	HGL 5126 (S)	61	$ 71,486
FP_1818	Future Pipe	G&D	1293.43	8	HGL 5126 (S)	61	$ 78,900
FP_1817	Future Pipe	G&D	399.31	8	HGL 5126 (S)	61	$ 24,358
FP_1816	Future Pipe	G&D	1478.79	8	HGL 5126 (S)	61	$ 90,206
FP_1815	Future Pipe	G&D	851.78	8	HGL 5126 (S)	61	$ 51,959
FP_1834	Future Pipe	G&D	1425.07	8	HGL 5126 (S)	61	$ 86,929
FP_1823	Future Pipe	G&D	1284.84	8	HGL 5126 (S)	61	$ 78,375
FP_1835	Future Pipe	G&D	278.32	8	HGL 5126 (S)	61	$ 16,978
FP_1904	Future Pipe	G&D	328.15	8	HGL 4975 (NW1)	61	$ 20,017
FP_2094	Future Pipe	G&D	1629.54	8	HGL 5560 (SE)	61	$ 99,402
FP_2092	Future Pipe	G&D	2175.44	8	HGL 5560 (SE)	61	$ 132,702
FP_1911	Future Pipe	G&D	229.17	8	HGL 4975 (NW1)	61	$ 13,979
FP_1920	Future Pipe	G&D	185.63	8	HGL 4975 (NW1)	61	$ 11,323
FP_1919	Future Pipe	G&D	871.54	8	HGL 4975 (NW1)	61	$ 53,164
FP_1918	Future Pipe	G&D	672.80	8	HGL 4975 (NW1)	61	$ 41,041
FP_1917	Future Pipe	G&D	735.33	8	HGL 4975 (NW1)	61	$ 44,855
FP_1916	Future Pipe	G&D	770.58	8	HGL 4975 (NW1)	61	$ 47,005
FP_1914	Future Pipe	G&D	619.21	8	HGL 4975 (NW1)	61	$ 37,772
FP_1912	Future Pipe	G&D	684.06	8	HGL 4975 (NW1)	61	$ 41,728
FP_1915	Future Pipe	G&D	396.21	8	HGL 4975 (NW1)	61	$ 24,169
FP_1910	Future Pipe	G&D	593.79	8	HGL 4975 (NW1)	61	$ 36,221
FP_1909	Future Pipe	G&D	787.92	8	HGL 4975 (NW1)	61	$ 48,063
FP_1908	Future Pipe	G&D	442.19	8	HGL 4975 (NW1)	61	$ 26,973
FP_1907	Future Pipe	G&D	423.67	8	HGL 4975 (NW1)	61	$ 25,844
FP_1906	Future Pipe	G&D	521.12	8	HGL 4975 (NW1)	61	$ 31,789
FP_1905	Future Pipe	G&D	128.52	8	HGL 4975 (NW1)	61	$ 7,840
FP_1913	Future Pipe	G&D	187.53	8	HGL 4975 (NW1)	61	$ 11,439

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT	Cost
FP_2317	Future Pipe	G&D	1894.14	8	HGL 4725 (NW3)	61	$ 115,543
FP_2334	Future Pipe	G&D	2895.44	8	HGL 5560 (SE)	61	$ 176,622
FP_2338	Future Pipe	G&D	1589.05	8	HGL 5630 (MT)	61	$ 96,932
FP_1755	Future Pipe	G&D	628.94	10	HGL 5126 (S)	74	$ 46,542
FP_1590	Future Pipe	G&D	1190.90	10	HGL 4850 (NW2)	74	$ 88,126
FP_1756	Future Pipe	G&D	369.63	10	HGL 5126 (S)	74	$ 27,352
FP_1588	Future Pipe	G&D	767.63	10	HGL 4850 (NW2)	74	$ 56,805
FP_1754	Future Pipe	G&D	577.53	10	HGL 5126 (S)	74	$ 42,737
FP_1751	Future Pipe	G&D	1802.89	10	HGL 5126 (S)	74	$ 133,414
FP_1752	Future Pipe	G&D	2054.01	10	HGL 5126 (S)	74	$ 151,997
FP_1499	Future Pipe	G&D	994.80	10	HGL 5560 (SE)	74	$ 73,615
FP_1498	Future Pipe	G&D	834.55	10	HGL 5560 (SE)	74	$ 61,757
FP_1508	Future Pipe	G&D	1177.87	10	HGL 5126 (S)	74	$ 87,162
FP_1506	Future Pipe	G&D	545.17	10	HGL 5126 (S)	74	$ 40,343
FP_1503	Future Pipe	G&D	1402.65	10	HGL 5560 (SE)	74	$ 103,796
FP_1507	Future Pipe	G&D	1419.76	10	HGL 5126 (S)	74	$ 105,062
FP_2429	Future Pipe	G&D	2827.76	10	HGL 5630 (MT)	74	$ 209,254
FP_2439	Future Pipe	G&D	50.86	10	HGL 5630 (MT)	74	$ 3,764
FP_2413	Future Pipe	G&D	56.99	10	HGL 5630 (MT)	74	$ 4,217
FP_2412	Future Pipe	G&D	522.61	10	HGL 5630 (MT)	74	$ 38,673
FP_2411	Future Pipe	G&D	3596.53	10	HGL 5630 (MT)	74	$ 266,143
FP_2410	Future Pipe	G&D	70.12	10	HGL 5630 (MT)	74	$ 5,189
FP_2456	Future Pipe	G&D	73.29	10	HGL 5038 (L)	74	$ 5,423
FP_2440	Future Pipe	G&D	54.88	10	HGL 5630 (MT)	74	$ 4,061
FP_2455	Future Pipe	G&D	1740.43	10	HGL 5038 (L)	74	$ 128,792
FP_2380	Future Pipe	G&D	524.43	10	HGL 5630 (MT)	74	$ 38,808
FP_2371	Future Pipe	G&D	1729.58	10	HGL 5038 (L)	74	$ 127,989
FP_2370	Future Pipe	G&D	3336.18	10	HGL 5038 (L)	74	$ 246,877
FP_2071	Future Pipe	G&D	251.09	10	HGL 5126 (S)	74	$ 18,581
FP_2332	Future Pipe	G&D	1675.39	10	HGL 5560 (SE)	74	$ 123,979
FP_2480	Future Pipe	G&D	1050.44	10	HGL 4850 (NW2)	74	$ 77,733
FP_2479	Future Pipe	G&D	1975.10	10	HGL 4885 (G)	74	$ 146,158
FP_1616	Future Pipe	G&D	1190.87	12	HGL 5360 (N)	87	$ 103,605
FP_1606	Future Pipe	G&D	3732.42	12	HGL 5360 (N)	87	$ 324,720
FP_1605	Future Pipe	G&D	1902.98	12	HGL 5360 (N)	87	$ 165,560
FP_1603	Future Pipe	G&D	778.92	12	HGL 4850 (NW2)	87	$ 67,766
FP_1600	Future Pipe	G&D	1178.88	12	HGL 4850 (NW2)	87	$ 102,563
FP_1599	Future Pipe	G&D	1895.18	12	HGL 4850 (NW2)	87	$ 164,881
FP_1598	Future Pipe	G&D	1438.40	12	HGL 4850 (NW2)	87	$ 125,141
FP_1623	Future Pipe	G&D	1501.40	12	HGL 5360 (N)	87	$ 130,622
FP_1646	Future Pipe	G&D	3385.32	12	HGL 4725 (NW3)	87	$ 294,523
FP_1645	Future Pipe	G&D	4013.79	12	HGL 4725 (NW3)	87	$ 349,200
FP_1641	Future Pipe	G&D	3085.78	12	HGL 5360 (N)	87	$ 268,463
FP_1621	Future Pipe	G&D	1882.08	12	HGL 5360 (N)	87	$ 163,741
FP_1620	Future Pipe	G&D	608.47	12	HGL 5360 (N)	87	$ 52,937
FP_1619	Future Pipe	G&D	1728.35	12	HGL 5360 (N)	87	$ 150,366
FP_1618	Future Pipe	G&D	1217.51	12	HGL 5360 (N)	87	$ 105,924
FP_1597	Future Pipe	G&D	808.82	12	HGL 4850 (NW2)	87	$ 70,367
FP_1640	Future Pipe	G&D	3338.81	12	HGL 5360 (N)	87	$ 290,476
FP_1763	Future Pipe	G&D	2682.42	12	HGL 5350 (SW)	87	$ 233,371
FP_1764	Future Pipe	G&D	2682.42	12	HGL 5350 (SW)	87	$ 233,371
FP_1580	Future Pipe	G&D	473.07	12	HGL 4975 (NW1)	87	$ 41,158
FP_1765	Future Pipe	G&D	2578.13	12	HGL 5350 (SW)	87	$ 224,297
FP_1766	Future Pipe	G&D	2660.57	12	HGL 5350 (SW)	87	$ 231,470
FP_1577	Future Pipe	G&D	1223.97	12	HGL 4850 (NW2)	87	$ 106,486

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT		Cost
FP_1575	Future Pipe	G&D	843.76	12	HGL 4850 (NW2)	87	$	73,407
FP_1574	Future Pipe	G&D	786.53	12	HGL 4850 (NW2)	87	$	68,428
FP_1573	Future Pipe	G&D	1917.01	12	HGL 4850 (NW2)	87	$	166,780
FP_1586	Future Pipe	G&D	288.15	12	HGL 4850 (NW2)	87	$	25,069
FP_1594	Future Pipe	G&D	2775.83	12	HGL 4850 (NW2)	87	$	241,497
FP_1593	Future Pipe	G&D	2167.85	12	HGL 4850 (NW2)	87	$	188,603
FP_1587	Future Pipe	G&D	992.74	12	HGL 4850 (NW2)	87	$	86,368
FP_1585	Future Pipe	G&D	1363.06	12	HGL 4850 (NW2)	87	$	118,586
FP_1757	Future Pipe	G&D	1316.36	12	HGL 5350 (SW)	87	$	114,524
FP_1758	Future Pipe	G&D	2708.46	12	HGL 5350 (SW)	87	$	235,636
FP_1759	Future Pipe	G&D	2968.87	12	HGL 5350 (SW)	87	$	258,292
FP_1595	Future Pipe	G&D	1136.12	12	HGL 4850 (NW2)	87	$	98,843
FP_1715	Future Pipe	G&D	1431.28	12	HGL 4725 (NW3)	87	$	124,522
FP_1714	Future Pipe	G&D	2040.01	12	HGL 4725 (NW3)	87	$	177,481
FP_1703	Future Pipe	G&D	2018.56	12	HGL 4725 (NW3)	87	$	175,615
FP_1700	Future Pipe	G&D	1111.25	12	HGL 4725 (NW3)	87	$	96,679
FP_1699	Future Pipe	G&D	2552.10	12	HGL 4725 (NW3)	87	$	222,033
FP_1737	Future Pipe	G&D	1275.69	12	HGL 5126 (S)	87	$	110,985
FP_1750	Future Pipe	G&D	959.10	12	HGL 5126 (S)	87	$	83,442
FP_1749	Future Pipe	G&D	838.91	12	HGL 5126 (S)	87	$	72,986
FP_1748	Future Pipe	G&D	741.84	12	HGL 5126 (S)	87	$	64,540
FP_1747	Future Pipe	G&D	677.73	12	HGL 5126 (S)	87	$	58,962
FP_1746	Future Pipe	G&D	1149.66	12	HGL 5126 (S)	87	$	100,021
FP_1744	Future Pipe	G&D	563.37	12	HGL 5126 (S)	87	$	49,013
FP_1743	Future Pipe	G&D	1099.27	12	HGL 5126 (S)	87	$	95,636
FP_1740	Future Pipe	G&D	687.87	12	HGL 5126 (S)	87	$	59,844
FP_1738	Future Pipe	G&D	1333.82	12	HGL 5126 (S)	87	$	116,042
FP_1735	Future Pipe	G&D	1324.49	12	HGL 5126 (S)	87	$	115,231
FP_1734	Future Pipe	G&D	1319.56	12	HGL 5126 (S)	87	$	114,802
FP_1733	Future Pipe	G&D	2006.40	12	HGL 5126 (S)	87	$	174,557
FP_1732	Future Pipe	G&D	1339.26	12	HGL 5126 (S)	87	$	116,515
FP_1725	Future Pipe	G&D	1301.46	12	HGL 4850 (NW2)	87	$	113,227
FP_1724	Future Pipe	G&D	1271.81	12	HGL 4725 (NW3)	87	$	110,648
FP_1695	Future Pipe	G&D	299.16	12	HGL 4725 (NW3)	87	$	26,027
FP_1739	Future Pipe	G&D	1322.48	12	HGL 5126 (S)	87	$	115,056
FP_1570	Future Pipe	G&D	1820.76	12	HGL 4850 (NW2)	87	$	158,406
FP_1665	Future Pipe	G&D	737.84	12	HGL 4725 (NW3)	87	$	64,192
FP_1674	Future Pipe	G&D	1341.40	12	HGL 4725 (NW3)	87	$	116,702
FP_1662	Future Pipe	G&D	515.61	12	HGL 4725 (NW3)	87	$	44,858
FP_1664	Future Pipe	G&D	2238.04	12	HGL 4725 (NW3)	87	$	194,710
FP_1694	Future Pipe	G&D	407.81	12	HGL 4725 (NW3)	87	$	35,480
FP_1683	Future Pipe	G&D	1891.68	12	HGL 4725 (NW3)	87	$	164,576
FP_1682	Future Pipe	G&D	1315.36	12	HGL 4725 (NW3)	87	$	114,437
FP_1681	Future Pipe	G&D	1394.95	12	HGL 4725 (NW3)	87	$	121,360
FP_1680	Future Pipe	G&D	1615.90	12	HGL 4725 (NW3)	87	$	140,583
FP_1679	Future Pipe	G&D	859.48	12	HGL 4725 (NW3)	87	$	74,774
FP_1678	Future Pipe	G&D	1302.15	12	HGL 4725 (NW3)	87	$	113,287
FP_1676	Future Pipe	G&D	1341.15	12	HGL 4725 (NW3)	87	$	116,680
FP_1675	Future Pipe	G&D	1744.99	12	HGL 4725 (NW3)	87	$	151,814
FP_1357	Future Pipe	G&D	1201.57	12	HGL 5221 (WTP)	87	$	104,537
FP_1445	Future Pipe	G&D	2812.72	12	HGL 4850 (NW2)	87	$	244,707
FP_1444	Future Pipe	G&D	1413.84	12	HGL 4850 (NW2)	87	$	123,004
FP_1442	Future Pipe	G&D	1407.16	12	HGL 4850 (NW2)	87	$	122,423
FP_1353	Future Pipe	G&D	1148.79	12	HGL 5221 (WTP)	87	$	99,944
FP_1354	Future Pipe	G&D	1367.19	12	HGL 5221 (WTP)	87	$	118,946

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT		Cost
FP_1355	Future Pipe	G&D	1013.82	12	HGL 5221 (WTP)	87	$	88,203
FP_1422	Future Pipe	G&D	1372.98	12	HGL 4975 (NW1)	87	$	119,449
FP_1356	Future Pipe	G&D	1519.10	12	HGL 5221 (WTP)	87	$	132,162
FP_1448	Future Pipe	G&D	1902.99	12	HGL 4725 (NW3)	87	$	165,560
FP_1358	Future Pipe	G&D	1393.23	12	HGL 5221 (WTP)	87	$	121,211
FP_1359	Future Pipe	G&D	1243.50	12	HGL 5221 (WTP)	87	$	108,185
FP_1360	Future Pipe	G&D	1432.46	12	HGL 5221 (WTP)	87	$	124,624
FP_1426	Future Pipe	G&D	691.35	12	HGL 4975 (NW1)	87	$	60,147
FP_1468	Future Pipe	G&D	607.39	12	HGL 4725 (NW3)	87	$	52,843
FP_1460	Future Pipe	G&D	708.47	12	HGL 4975 (NW1)	87	$	61,637
FP_1447	Future Pipe	G&D	2295.93	12	HGL 4850 (NW2)	87	$	199,745
FP_1456	Future Pipe	G&D	1753.84	12	HGL 4725 (NW3)	87	$	152,584
FP_1455	Future Pipe	G&D	2547.03	12	HGL 4725 (NW3)	87	$	221,592
FP_1350	Future Pipe	G&D	1343.86	12	HGL 5221 (WTP)	87	$	116,916
FP_1453	Future Pipe	G&D	463.51	12	HGL 4850 (NW2)	87	$	40,325
FP_1452	Future Pipe	G&D	2265.95	12	HGL 4850 (NW2)	87	$	197,137
FP_1386	Future Pipe	G&D	1328.19	12	HGL 5126 (S)	87	$	115,553
FP_1385	Future Pipe	G&D	1274.65	12	HGL 5126 (S)	87	$	110,895
FP_1384	Future Pipe	G&D	1328.13	12	HGL 5126 (S)	87	$	115,547
FP_1383	Future Pipe	G&D	1328.13	12	HGL 5126 (S)	87	$	115,547
FP_1382	Future Pipe	G&D	1263.02	12	HGL 5126 (S)	87	$	109,883
FP_1381	Future Pipe	G&D	1406.25	12	HGL 5126 (S)	87	$	122,344
FP_1423	Future Pipe	G&D	2534.73	12	HGL 4975 (NW1)	87	$	220,521
FP_1379	Future Pipe	G&D	1266.09	12	HGL 5126 (S)	87	$	110,150
FP_1391	Future Pipe	G&D	1317.46	12	HGL 5126 (S)	87	$	114,619
FP_1370	Future Pipe	G&D	1432.29	12	HGL 5221 (WTP)	87	$	124,610
FP_1369	Future Pipe	G&D	1193.78	12	HGL 5221 (WTP)	87	$	103,859
FP_1380	Future Pipe	G&D	1354.23	12	HGL 5126 (S)	87	$	117,818
FP_1401	Future Pipe	G&D	1322.11	12	HGL 5126 (S)	87	$	115,023
FP_1363	Future Pipe	G&D	1519.26	12	HGL 5221 (WTP)	87	$	132,175
FP_1408	Future Pipe	G&D	2624.35	12	HGL 4975 (NW1)	87	$	228,319
FP_1364	Future Pipe	G&D	1128.68	12	HGL 5221 (WTP)	87	$	98,195
FP_1406	Future Pipe	G&D	1337.90	12	HGL 5126 (S)	87	$	116,397
FP_1402	Future Pipe	G&D	2759.73	12	HGL 5126 (S)	87	$	240,096
FP_1399	Future Pipe	G&D	1348.92	12	HGL 5126 (S)	87	$	117,356
FP_1365	Future Pipe	G&D	1410.76	12	HGL 5221 (WTP)	87	$	122,736
FP_1366	Future Pipe	G&D	1258.87	12	HGL 5221 (WTP)	87	$	109,522
FP_1367	Future Pipe	G&D	1237.17	12	HGL 5221 (WTP)	87	$	107,634
FP_1394	Future Pipe	G&D	1320.61	12	HGL 5126 (S)	87	$	114,893
FP_1393	Future Pipe	G&D	1302.09	12	HGL 5126 (S)	87	$	113,281
FP_1392	Future Pipe	G&D	1341.21	12	HGL 5126 (S)	87	$	116,685
FP_1471	Future Pipe	G&D	1131.58	12	HGL 4725 (NW3)	87	$	98,447
FP_1403	Future Pipe	G&D	2652.54	12	HGL 5126 (S)	87	$	230,771
FP_1539	Future Pipe	G&D	464.43	12	HGL 5126 (S)	87	$	40,405
FP_1538	Future Pipe	G&D	154.87	12	HGL 5126 (S)	87	$	13,474
FP_1537	Future Pipe	G&D	470.93	12	HGL 5126 (S)	87	$	40,971
FP_1536	Future Pipe	G&D	659.72	12	HGL 5126 (S)	87	$	57,396
FP_1535	Future Pipe	G&D	276.30	12	HGL 5126 (S)	87	$	24,038
FP_1534	Future Pipe	G&D	1022.62	12	HGL 5126 (S)	87	$	88,968
FP_1349	Future Pipe	G&D	776.68	12	HGL 5221 (WTP)	87	$	67,571
FP_1542	Future Pipe	G&D	1618.93	12	HGL 5126 (S)	87	$	140,847
FP_1551	Future Pipe	G&D	734.93	12	HGL 5126 (S)	87	$	63,939
FP_1568	Future Pipe	G&D	611.36	12	HGL 4850 (NW2)	87	$	53,189
FP_1566	Future Pipe	G&D	1287.34	12	HGL 4725 (NW3)	87	$	111,999
FP_1565	Future Pipe	G&D	4125.95	12	HGL 4725 (NW3)	87	$	358,957

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT		Cost
FP_1556	Future Pipe	G&D	1919.69	12	HGL 4850 (NW2)	87	$	167,013
FP_1368	Future Pipe	G&D	1410.76	12	HGL 5221 (WTP)	87	$	122,736
FP_1555	Future Pipe	G&D	182.88	12	HGL 5126 (S)	87	$	15,910
FP_1554	Future Pipe	G&D	931.41	12	HGL 5126 (S)	87	$	81,033
FP_1540	Future Pipe	G&D	597.79	12	HGL 5126 (S)	87	$	52,008
FP_1552	Future Pipe	G&D	1502.72	12	HGL 5126 (S)	87	$	130,736
FP_1541	Future Pipe	G&D	1648.66	12	HGL 5126 (S)	87	$	143,433
FP_1550	Future Pipe	G&D	1111.51	12	HGL 5126 (S)	87	$	96,701
FP_1549	Future Pipe	G&D	1305.02	12	HGL 5126 (S)	87	$	113,537
FP_1548	Future Pipe	G&D	1294.31	12	HGL 5126 (S)	87	$	112,605
FP_1547	Future Pipe	G&D	516.75	12	HGL 5126 (S)	87	$	44,958
FP_1546	Future Pipe	G&D	1475.17	12	HGL 5126 (S)	87	$	128,339
FP_1545	Future Pipe	G&D	602.77	12	HGL 5126 (S)	87	$	52,441
FP_1544	Future Pipe	G&D	1108.27	12	HGL 5126 (S)	87	$	96,419
FP_1543	Future Pipe	G&D	2090.85	12	HGL 5126 (S)	87	$	181,904
FP_1553	Future Pipe	G&D	661.09	12	HGL 5126 (S)	87	$	57,515
FP_1486	Future Pipe	G&D	865.67	12	HGL 4975 (NW1)	87	$	75,313
FP_1346	Future Pipe	G&D	1404.03	12	HGL 5221 (WTP)	87	$	122,150
FP_1345	Future Pipe	G&D	853.20	12	HGL 5221 (WTP)	87	$	74,229
FP_1480	Future Pipe	G&D	1377.91	12	HGL 4975 (NW1)	87	$	119,878
FP_1478	Future Pipe	G&D	1275.39	12	HGL 4975 (NW1)	87	$	110,959
FP_1475	Future Pipe	G&D	964.08	12	HGL 4975 (NW1)	87	$	83,875
FP_1347	Future Pipe	G&D	683.87	12	HGL 5221 (WTP)	87	$	59,497
FP_1348	Future Pipe	G&D	1454.16	12	HGL 5221 (WTP)	87	$	126,512
FP_1569	Future Pipe	G&D	507.38	12	HGL 4850 (NW2)	87	$	44,142
FP_1483	Future Pipe	G&D	789.89	12	HGL 4975 (NW1)	87	$	68,720
FP_1470	Future Pipe	G&D	3679.17	12	HGL 4725 (NW3)	87	$	320,088
FP_1519	Future Pipe	G&D	2201.47	12	HGL 5560 (SE)	87	$	191,528
FP_1516	Future Pipe	G&D	1791.20	12	HGL 5560 (SE)	87	$	155,835
FP_1513	Future Pipe	G&D	2124.53	12	HGL 5560 (SE)	87	$	184,834
FP_1512	Future Pipe	G&D	517.25	12	HGL 5560 (SE)	87	$	45,001
FP_1340	Future Pipe	G&D	1349.35	12	HGL 5126 (S)	87	$	117,393
FP_2269	Future Pipe	G&D	3198.15	12	HGL 5350 (SW)	87	$	278,239
FP_2281	Future Pipe	G&D	2652.33	12	HGL 4975 (NW1)	87	$	230,752
FP_2280	Future Pipe	G&D	2050.05	12	HGL 5126 (S)	87	$	178,355
FP_2279	Future Pipe	G&D	2683.09	12	HGL 5126 (S)	87	$	233,429
FP_2278	Future Pipe	G&D	2667.79	12	HGL 5126 (S)	87	$	232,097
FP_2276	Future Pipe	G&D	2602.59	12	HGL 5126 (S)	87	$	226,425
FP_2275	Future Pipe	G&D	2657.69	12	HGL 5126 (S)	87	$	231,219
FP_2274	Future Pipe	G&D	2484.71	12	HGL 5221 (WTP)	87	$	216,170
FP_2273	Future Pipe	G&D	2364.13	12	HGL 5350 (SW)	87	$	205,679
FP_2272	Future Pipe	G&D	2491.08	12	HGL 5350 (SW)	87	$	216,724
FP_2241	Future Pipe	G&D	1720.58	12	HGL 4975 (NW1)	87	$	149,691
FP_2270	Future Pipe	G&D	2114.31	12	HGL 5350 (SW)	87	$	183,945
FP_2268	Future Pipe	G&D	3111.72	12	HGL 5350 (SW)	87	$	270,720
FP_2267	Future Pipe	G&D	1164.77	12	HGL 5350 (SW)	87	$	101,335
FP_2266	Future Pipe	G&D	1328.58	12	HGL 5221 (WTP)	87	$	115,587
FP_2265	Future Pipe	G&D	3075.87	12	HGL 5221 (WTP)	87	$	267,600
FP_2259	Future Pipe	G&D	5425.44	12	HGL 4975 (NW1)	87	$	472,013
FP_2247	Future Pipe	G&D	1238.00	12	HGL 5126 (S)	87	$	107,706
FP_2246	Future Pipe	G&D	511.23	12	HGL 5126 (S)	87	$	44,477
FP_2245	Future Pipe	G&D	2709.04	12	HGL 5126 (S)	87	$	235,687
FP_2244	Future Pipe	G&D	1356.87	12	HGL 5126 (S)	87	$	118,048
FP_2340	Future Pipe	G&D	187.05	12	HGL 5630 (MT)	87	$	16,273
FP_2271	Future Pipe	G&D	2764.10	12	HGL 5350 (SW)	87	$	240,476

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT		Cost
FP_2152	Future Pipe	G&D	2087.65	12	HGL 4975 (NW1)	87	$	181,625
FP_2308	Future Pipe	G&D	118.52	12	HGL 5360 (N)	87	$	10,311
FP_2307	Future Pipe	G&D	982.30	12	HGL 5360 (N)	87	$	85,460
FP_2306	Future Pipe	G&D	1023.39	12	HGL 5360 (N)	87	$	89,035
FP_2305	Future Pipe	G&D	1592.79	12	HGL 5360 (N)	87	$	138,573
FP_2303	Future Pipe	G&D	2880.34	12	HGL 5360 (N)	87	$	250,589
FP_2302	Future Pipe	G&D	1083.03	12	HGL 5360 (N)	87	$	94,224
FP_2300	Future Pipe	G&D	1297.12	12	HGL 5360 (N)	87	$	112,850
FP_2299	Future Pipe	G&D	1989.55	12	HGL 5360 (N)	87	$	173,091
FP_2298	Future Pipe	G&D	4616.83	12	HGL 5360 (N)	87	$	401,664
FP_2282	Future Pipe	G&D	1618.74	12	HGL 4975 (NW1)	87	$	140,831
FP_2296	Future Pipe	G&D	423.67	12	HGL 4850 (NW2)	87	$	36,859
FP_2283	Future Pipe	G&D	2676.32	12	HGL 4975 (NW1)	87	$	232,840
FP_2294	Future Pipe	G&D	3059.68	12	HGL 4850 (NW2)	87	$	266,192
FP_2293	Future Pipe	G&D	2188.96	12	HGL 4850 (NW2)	87	$	190,440
FP_2292	Future Pipe	G&D	2192.74	12	HGL 4850 (NW2)	87	$	190,768
FP_2291	Future Pipe	G&D	2658.68	12	HGL 4850 (NW2)	87	$	231,305
FP_2290	Future Pipe	G&D	2132.82	12	HGL 4850 (NW2)	87	$	185,556
FP_2289	Future Pipe	G&D	2597.17	12	HGL 4975 (NW1)	87	$	225,954
FP_2288	Future Pipe	G&D	2743.94	12	HGL 4975 (NW1)	87	$	238,723
FP_2287	Future Pipe	G&D	2586.16	12	HGL 4850 (NW2)	87	$	224,996
FP_2286	Future Pipe	G&D	2461.03	12	HGL 4975 (NW1)	87	$	214,109
FP_2240	Future Pipe	G&D	1196.31	12	HGL 5221 (WTP)	87	$	104,079
FP_2297	Future Pipe	G&D	510.42	12	HGL 4850 (NW2)	87	$	44,406
FP_2190	Future Pipe	G&D	65.35	12	HGL 4725 (NW3)	87	$	5,685
FP_2201	Future Pipe	G&D	674.53	12	HGL 5560 (SE)	87	$	58,684
FP_2198	Future Pipe	G&D	1214.42	12	HGL 4850 (NW2)	87	$	105,655
FP_2197	Future Pipe	G&D	813.88	12	HGL 4850 (NW2)	87	$	70,807
FP_2243	Future Pipe	G&D	896.12	12	HGL 5126 (S)	87	$	77,962
FP_2211	Future Pipe	G&D	1514.47	12	HGL 5360 (N)	87	$	131,758
FP_2187	Future Pipe	G&D	599.16	12	HGL 4975 (NW1)	87	$	52,127
FP_2179	Future Pipe	G&D	82.58	12	HGL 4975 (NW1)	87	$	7,184
FP_2173	Future Pipe	G&D	2624.40	12	HGL 5350 (SW)	87	$	228,323
FP_2171	Future Pipe	G&D	30.69	12	HGL 5126 (S)	87	$	2,670
FP_2224	Future Pipe	G&D	4222.89	12	HGL 4850 (NW2)	87	$	367,392
FP_2235	Future Pipe	G&D	105.88	12	HGL 5126 (S)	87	$	9,211
FP_2229	Future Pipe	G&D	2711.51	12	HGL 4850 (NW2)	87	$	235,902
FP_2228	Future Pipe	G&D	1778.12	12	HGL 4850 (NW2)	87	$	154,696
FP_2227	Future Pipe	G&D	1259.58	12	HGL 4850 (NW2)	87	$	109,584
FP_2203	Future Pipe	G&D	2597.54	12	HGL 5560 (SE)	87	$	225,986
FP_2225	Future Pipe	G&D	1833.53	12	HGL 4850 (NW2)	87	$	159,517
FP_2222	Future Pipe	G&D	2683.39	12	HGL 4975 (NW1)	87	$	233,455
FP_2221	Future Pipe	G&D	2757.14	12	HGL 4975 (NW1)	87	$	239,871
FP_2219	Future Pipe	G&D	1112.47	12	HGL 4975 (NW1)	87	$	96,785
FP_2213	Future Pipe	G&D	333.45	12	HGL 4975 (NW1)	87	$	29,010
FP_2212	Future Pipe	G&D	1916.61	12	HGL 5360 (N)	87	$	166,745
FP_2342	Future Pipe	G&D	258.28	12	HGL 5630 (MT)	87	$	22,470
FP_2433	Future Pipe	G&D	1015.12	12	HGL 5630 (MT)	87	$	88,315
FP_2431	Future Pipe	G&D	1096.01	12	HGL 5630 (MT)	87	$	95,353
FP_2426	Future Pipe	G&D	52.92	12	HGL 5630 (MT)	87	$	4,604
FP_2425	Future Pipe	G&D	2032.47	12	HGL 5630 (MT)	87	$	176,825
FP_2404	Future Pipe	G&D	1826.99	12	HGL 5630 (MT)	87	$	158,948
FP_2309	Future Pipe	G&D	610.77	12	HGL 5360 (N)	87	$	53,137
FP_2424	Future Pipe	G&D	1597.69	12	HGL 5630 (MT)	87	$	138,999
FP_2453	Future Pipe	G&D	206.50	12	HGL 5630 (MT)	87	$	17,966

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT		Cost
FP_2434	Future Pipe	G&D	608.33	12	HGL 5630 (MT)	87	$	52,925
FP_2452	Future Pipe	G&D	174.04	12	HGL 5630 (MT)	87	$	15,141
FP_2445	Future Pipe	G&D	36.47	12	HGL 5630 (MT)	87	$	3,173
FP_2442	Future Pipe	G&D	48.42	12	HGL 5630 (MT)	87	$	4,212
FP_2441	Future Pipe	G&D	90.54	12	HGL 5630 (MT)	87	$	7,877
FP_2403	Future Pipe	G&D	68.70	12	HGL 5630 (MT)	87	$	5,977
FP_2353	Future Pipe	G&D	1950.46	12	HGL 5630 (MT)	87	$	169,690
FP_2364	Future Pipe	G&D	167.43	12	HGL 5630 (MT)	87	$	14,566
FP_2363	Future Pipe	G&D	2175.61	12	HGL 5630 (MT)	87	$	189,278
FP_2362	Future Pipe	G&D	1415.82	12	HGL 5630 (MT)	87	$	123,177
FP_2361	Future Pipe	G&D	2527.17	12	HGL 5630 (MT)	87	$	219,864
FP_2359	Future Pipe	G&D	613.12	12	HGL 5630 (MT)	87	$	53,342
FP_2358	Future Pipe	G&D	2191.32	12	HGL 5630 (MT)	87	$	190,645
FP_2356	Future Pipe	G&D	2167.04	12	HGL 5630 (MT)	87	$	188,533
FP_2405	Future Pipe	G&D	49.79	12	HGL 5630 (MT)	87	$	4,332
FP_2354	Future Pipe	G&D	1926.82	12	HGL 5630 (MT)	87	$	167,633
FP_2352	Future Pipe	G&D	4062.47	12	HGL 5630 (MT)	87	$	353,435
FP_2349	Future Pipe	G&D	2723.24	12	HGL 5630 (MT)	87	$	236,922
FP_2344	Future Pipe	G&D	350.08	12	HGL 5630 (MT)	87	$	30,457
FP_2343	Future Pipe	G&D	1121.44	12	HGL 5630 (MT)	87	$	97,565
FP_2355	Future Pipe	G&D	3091.24	12	HGL 5630 (MT)	87	$	268,938
FP_2392	Future Pipe	G&D	1014.43	12	HGL 5630 (MT)	87	$	88,256
FP_2387	Future Pipe	G&D	799.11	12	HGL 5630 (MT)	87	$	69,522
FP_2366	Future Pipe	G&D	839.23	12	HGL 5630 (MT)	87	$	73,013
FP_2372	Future Pipe	G&D	1277.58	12	HGL 5630 (MT)	87	$	111,150
FP_2310	Future Pipe	G&D	2586.86	12	HGL 4975 (NW1)	87	$	225,057
FP_1852	Future Pipe	G&D	1119.35	12	HGL 5126 (S)	87	$	97,383
FP_1864	Future Pipe	G&D	887.50	12	HGL 5126 (S)	87	$	77,213
FP_1863	Future Pipe	G&D	2611.38	12	HGL 5126 (S)	87	$	227,190
FP_1862	Future Pipe	G&D	2258.55	12	HGL 5126 (S)	87	$	196,494
FP_1860	Future Pipe	G&D	2371.12	12	HGL 5126 (S)	87	$	206,288
FP_1859	Future Pipe	G&D	200.59	12	HGL 5126 (S)	87	$	17,451
FP_1858	Future Pipe	G&D	753.63	12	HGL 5126 (S)	87	$	65,565
FP_1857	Future Pipe	G&D	818.62	12	HGL 5126 (S)	87	$	71,220
FP_1866	Future Pipe	G&D	1203.36	12	HGL 5126 (S)	87	$	104,692
FP_1853	Future Pipe	G&D	1353.15	12	HGL 5126 (S)	87	$	117,724
FP_1867	Future Pipe	G&D	818.86	12	HGL 5126 (S)	87	$	71,241
FP_1851	Future Pipe	G&D	1789.11	12	HGL 5126 (S)	87	$	155,653
FP_1850	Future Pipe	G&D	1041.76	12	HGL 5126 (S)	87	$	90,633
FP_1849	Future Pipe	G&D	1697.55	12	HGL 5126 (S)	87	$	147,687
FP_1845	Future Pipe	G&D	3637.96	12	HGL 5126 (S)	87	$	316,502
FP_1844	Future Pipe	G&D	2773.78	12	HGL 5126 (S)	87	$	241,319
FP_1899	Future Pipe	G&D	892.39	12	HGL 4975 (NW1)	87	$	77,638
FP_1865	Future Pipe	G&D	2042.86	12	HGL 5126 (S)	87	$	177,729
FP_1886	Future Pipe	G&D	1216.06	12	HGL 5221 (WTP)	87	$	105,797
FP_1873	Future Pipe	G&D	2695.30	12	HGL 5126 (S)	87	$	234,491
FP_1872	Future Pipe	G&D	1669.67	12	HGL 5126 (S)	87	$	145,262
FP_1871	Future Pipe	G&D	1490.86	12	HGL 5126 (S)	87	$	129,705
FP_1870	Future Pipe	G&D	284.49	12	HGL 5126 (S)	87	$	24,750
FP_1869	Future Pipe	G&D	1008.45	12	HGL 5126 (S)	87	$	87,735
FP_1868	Future Pipe	G&D	848.07	12	HGL 5126 (S)	87	$	73,782
FP_1783	Future Pipe	G&D	2682.45	12	HGL 5350 (SW)	87	$	233,373
FP_1800	Future Pipe	G&D	2552.09	12	HGL 5560 (SE)	87	$	222,032
FP_1799	Future Pipe	G&D	1302.35	12	HGL 5560 (SE)	87	$	113,304
FP_1798	Future Pipe	G&D	1255.58	12	HGL 5560 (SE)	87	$	109,236

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT		Cost
FP_1797	Future Pipe	G&D	2635.00	12	HGL 5560 (SE)	87	$	229,245
FP_1796	Future Pipe	G&D	2778.20	12	HGL 5560 (SE)	87	$	241,703
FP_1792	Future Pipe	G&D	2630.21	12	HGL 5350 (SW)	87	$	228,829
FP_1791	Future Pipe	G&D	2630.73	12	HGL 5350 (SW)	87	$	228,873
FP_1788	Future Pipe	G&D	4557.97	12	HGL 5221 (WTP)	87	$	396,543
FP_1786	Future Pipe	G&D	4636.13	12	HGL 5350 (SW)	87	$	403,344
FP_1784	Future Pipe	G&D	2634.87	12	HGL 5221 (WTP)	87	$	229,233
FP_1780	Future Pipe	G&D	2616.96	12	HGL 5350 (SW)	87	$	227,675
FP_2341	Future Pipe	G&D	3040.26	12	HGL 5630 (MT)	87	$	264,503
FP_1779	Future Pipe	G&D	2620.71	12	HGL 5350 (SW)	87	$	228,002
FP_1778	Future Pipe	G&D	2574.54	12	HGL 5221 (WTP)	87	$	223,985
FP_1776	Future Pipe	G&D	2373.84	12	HGL 5350 (SW)	87	$	206,524
FP_1777	Future Pipe	G&D	399.68	12	HGL 5350 (SW)	87	$	34,772
FP_1785	Future Pipe	G&D	2630.34	12	HGL 5221 (WTP)	87	$	228,840
FP_1801	Future Pipe	G&D	1313.68	12	HGL 5560 (SE)	87	$	114,290
FP_2025	Future Pipe	G&D	17.83	12	HGL 5221 (WTP)	87	$	1,552
FP_2070	Future Pipe	G&D	1054.89	12	HGL 5560 (SE)	87	$	91,775
FP_2069	Future Pipe	G&D	331.04	12	HGL 5560 (SE)	87	$	28,800
FP_2058	Future Pipe	G&D	2171.74	12	HGL 5360 (N)	87	$	188,942
FP_2033	Future Pipe	G&D	653.00	12	HGL 5126 (S)	87	$	56,811
FP_2032	Future Pipe	G&D	2630.34	12	HGL 5350 (SW)	87	$	228,840
FP_2030	Future Pipe	G&D	74.96	12	HGL 5221 (WTP)	87	$	6,521
FP_2027	Future Pipe	G&D	902.39	12	HGL 5221 (WTP)	87	$	78,508
FP_2026	Future Pipe	G&D	12.33	12	HGL 5126 (S)	87	$	1,073
FP_2111	Future Pipe	G&D	3031.58	12	HGL 5350 (SW)	87	$	263,748
FP_2147	Future Pipe	G&D	2953.04	12	HGL 5350 (SW)	87	$	256,915
FP_2140	Future Pipe	G&D	1888.13	12	HGL 4725 (NW3)	87	$	164,267
FP_2118	Future Pipe	G&D	65.78	12	HGL 4850 (NW2)	87	$	5,723
FP_2112	Future Pipe	G&D	2972.53	12	HGL 5560 (SE)	87	$	258,610
FP_2120	Future Pipe	G&D	135.62	12	HGL 4975 (NW1)	87	$	11,799
FP_2097	Future Pipe	G&D	2048.62	12	HGL 5350 (SW)	87	$	178,230
FP_2096	Future Pipe	G&D	2544.20	12	HGL 5221 (WTP)	87	$	221,346
FP_2091	Future Pipe	G&D	2637.39	12	HGL 5560 (SE)	87	$	229,453
FP_1995	Future Pipe	G&D	447.71	12	HGL 5560 (SE)	87	$	38,951
FP_2012	Future Pipe	G&D	1371.65	12	HGL 5126 (S)	87	$	119,334
FP_2014	Future Pipe	G&D	1313.52	12	HGL 5126 (S)	87	$	114,276
FP_1994	Future Pipe	G&D	169.78	12	HGL 5560 (SE)	87	$	14,771
FP_2327	Future Pipe	G&D	2616.46	12	HGL 5560 (SE)	87	$	227,632
FP_2316	Future Pipe	G&D	2615.62	12	HGL 4725 (NW3)	87	$	227,559
FP_2321	Future Pipe	G&D	2342.63	12	HGL 5560 (SE)	87	$	203,809
FP_2322	Future Pipe	G&D	2605.08	12	HGL 5560 (SE)	87	$	226,642
FP_2311	Future Pipe	G&D	2632.48	12	HGL 4975 (NW1)	87	$	229,025
FP_2319	Future Pipe	G&D	936.90	12	HGL 4725 (NW3)	87	$	81,510
FP_2324	Future Pipe	G&D	2605.52	12	HGL 5560 (SE)	87	$	226,680
FP_2326	Future Pipe	G&D	1884.32	12	HGL 5560 (SE)	87	$	163,936
FP_2328	Future Pipe	G&D	2389.31	12	HGL 5560 (SE)	87	$	207,870
FP_2330	Future Pipe	G&D	1020.89	12	HGL 5560 (SE)	87	$	88,817
FP_2331	Future Pipe	G&D	2272.19	12	HGL 5560 (SE)	87	$	197,680
FP_2333	Future Pipe	G&D	1836.00	12	HGL 5560 (SE)	87	$	159,732
FP_2325	Future Pipe	G&D	1364.21	12	HGL 5560 (SE)	87	$	118,686
FP_2312	Future Pipe	G&D	2571.98	12	HGL 5126 (S)	87	$	223,762
FP_2482	Future Pipe	G&D	315.73	12	HGL 4850 (NW2)	87	$	27,468
FP_2481	Future Pipe	G&D	1395.98	12	HGL 5038 (L)	87	$	121,450
FP_1614	Future Pipe	G&D	1816.69	16	HGL 5360 (N)	118	$	214,370
FP_1653	Future Pipe	G&D	957.49	16	HGL 4725 (NW3)	118	$	112,984

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT		Cost
FP_1647	Future Pipe	G&D	937.60	16	HGL 4725 (NW3)	118	$	110,637
FP_1644	Future Pipe	G&D	463.49	16	HGL 4725 (NW3)	118	$	54,691
FP_1642	Future Pipe	G&D	1445.45	16	HGL 5360 (N)	118	$	170,563
FP_1625	Future Pipe	G&D	1755.90	16	HGL 5360 (N)	118	$	207,196
FP_1617	Future Pipe	G&D	4176.27	16	HGL 5360 (N)	118	$	492,800
FP_1771	Future Pipe	G&D	2214.16	16	HGL 5350 (SW)	118	$	261,271
FP_1762	Future Pipe	G&D	313.58	16	HGL 5350 (SW)	118	$	37,003
FP_1772	Future Pipe	G&D	2630.21	16	HGL 5350 (SW)	118	$	310,365
FP_1770	Future Pipe	G&D	2395.98	16	HGL 5350 (SW)	118	$	282,726
FP_1657	Future Pipe	G&D	1663.17	16	HGL 4725 (NW3)	118	$	196,254
FP_1760	Future Pipe	G&D	2578.26	16	HGL 5350 (SW)	118	$	304,235
FP_1761	Future Pipe	G&D	2370.37	16	HGL 5350 (SW)	118	$	279,704
FP_1655	Future Pipe	G&D	1534.28	16	HGL 4725 (NW3)	118	$	181,045
FP_1698	Future Pipe	G&D	928.98	16	HGL 4725 (NW3)	118	$	109,620
FP_1673	Future Pipe	G&D	2224.04	16	HGL 4725 (NW3)	118	$	262,437
FP_1663	Future Pipe	G&D	1210.11	16	HGL 4725 (NW3)	118	$	142,793
FP_1661	Future Pipe	G&D	2652.30	16	HGL 4725 (NW3)	118	$	312,971
FP_1660	Future Pipe	G&D	430.68	16	HGL 4725 (NW3)	118	$	50,820
FP_1656	Future Pipe	G&D	323.12	16	HGL 4725 (NW3)	118	$	38,128
FP_1654	Future Pipe	G&D	1408.28	16	HGL 4725 (NW3)	118	$	166,177
FP_1697	Future Pipe	G&D	587.82	16	HGL 4725 (NW3)	118	$	69,363
FP_1677	Future Pipe	G&D	2852.13	16	HGL 4725 (NW3)	118	$	336,551
FP_1687	Future Pipe	G&D	1102.09	16	HGL 4725 (NW3)	118	$	130,047
FP_1443	Future Pipe	G&D	2256.95	16	HGL 4850 (NW2)	118	$	266,320
FP_1440	Future Pipe	G&D	259.02	16	HGL 4975 (NW1)	118	$	30,564
FP_1430	Future Pipe	G&D	2465.97	16	HGL 4975 (NW1)	118	$	290,984
FP_1361	Future Pipe	G&D	1367.36	16	HGL 5221 (WTP)	118	$	161,349
FP_1425	Future Pipe	G&D	1365.95	16	HGL 4975 (NW1)	118	$	161,182
FP_1362	Future Pipe	G&D	1302.27	16	HGL 5221 (WTP)	118	$	153,667
FP_1561	Future Pipe	G&D	676.83	16	HGL 4725 (NW3)	118	$	79,866
FP_1436	Future Pipe	G&D	2637.30	16	HGL 4850 (NW2)	118	$	311,201
FP_1457	Future Pipe	G&D	3113.72	16	HGL 4725 (NW3)	118	$	367,418
FP_1469	Future Pipe	G&D	2452.33	16	HGL 4725 (NW3)	118	$	289,375
FP_1466	Future Pipe	G&D	1359.34	16	HGL 4725 (NW3)	118	$	160,403
FP_1465	Future Pipe	G&D	1897.91	16	HGL 4725 (NW3)	118	$	223,954
FP_1464	Future Pipe	G&D	1571.19	16	HGL 4725 (NW3)	118	$	185,401
FP_1463	Future Pipe	G&D	1666.91	16	HGL 4725 (NW3)	118	$	196,696
FP_1462	Future Pipe	G&D	1255.95	16	HGL 4725 (NW3)	118	$	148,202
FP_1461	Future Pipe	G&D	195.36	16	HGL 4725 (NW3)	118	$	23,053
FP_1446	Future Pipe	G&D	2606.23	16	HGL 4850 (NW2)	118	$	307,535
FP_1458	Future Pipe	G&D	1160.06	16	HGL 4725 (NW3)	118	$	136,887
FP_1451	Future Pipe	G&D	2601.66	16	HGL 4850 (NW2)	118	$	306,996
FP_1450	Future Pipe	G&D	2548.20	16	HGL 4850 (NW2)	118	$	300,687
FP_1352	Future Pipe	G&D	1302.27	16	HGL 5221 (WTP)	118	$	153,667
FP_1419	Future Pipe	G&D	1363.64	16	HGL 4975 (NW1)	118	$	160,909
FP_1459	Future Pipe	G&D	1087.71	16	HGL 4725 (NW3)	118	$	128,350
FP_1388	Future Pipe	G&D	1263.02	16	HGL 5126 (S)	118	$	149,037
FP_1387	Future Pipe	G&D	1439.06	16	HGL 5126 (S)	118	$	169,810
FP_1376	Future Pipe	G&D	1157.14	16	HGL 5126 (S)	118	$	136,543
FP_1375	Future Pipe	G&D	1484.61	16	HGL 5126 (S)	118	$	175,184
FP_1374	Future Pipe	G&D	1341.40	16	HGL 5126 (S)	118	$	158,285
FP_1373	Future Pipe	G&D	1354.17	16	HGL 5126 (S)	118	$	159,792
FP_1372	Future Pipe	G&D	1146.13	16	HGL 5126 (S)	118	$	135,244
FP_1371	Future Pipe	G&D	1450.32	16	HGL 5126 (S)	118	$	171,138
FP_1413	Future Pipe	G&D	2195.38	16	HGL 4975 (NW1)	118	$	259,055

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT	Cost
FP_1412	Future Pipe	G&D	2583.28	16	HGL 4975 (NW1)	118	$ 304,827
FP_1411	Future Pipe	G&D	50.91	16	HGL 5126 (S)	118	$ 6,008
FP_1405	Future Pipe	G&D	2630.21	16	HGL 5126 (S)	118	$ 310,365
FP_1404	Future Pipe	G&D	2672.96	16	HGL 5126 (S)	118	$ 315,409
FP_1389	Future Pipe	G&D	1354.23	16	HGL 5126 (S)	118	$ 159,799
FP_1390	Future Pipe	G&D	1263.09	16	HGL 5126 (S)	118	$ 149,045
FP_1773	Future Pipe	G&D	2708.46	16	HGL 5350 (SW)	118	$ 319,599
FP_1332	Future Pipe	G&D	1389.06	16	HGL 5221 (WTP)	118	$ 163,909
FP_1333	Future Pipe	G&D	1251.64	16	HGL 5221 (WTP)	118	$ 147,694
FP_1526	Future Pipe	G&D	776.30	16	HGL 5560 (SE)	118	$ 91,604
FP_1525	Future Pipe	G&D	937.13	16	HGL 5560 (SE)	118	$ 110,581
FP_1524	Future Pipe	G&D	1948.27	16	HGL 5560 (SE)	118	$ 229,896
FP_1334	Future Pipe	G&D	1287.53	16	HGL 5221 (WTP)	118	$ 151,929
FP_1564	Future Pipe	G&D	1284.83	16	HGL 4725 (NW3)	118	$ 151,610
FP_1562	Future Pipe	G&D	2151.74	16	HGL 4725 (NW3)	118	$ 253,906
FP_1521	Future Pipe	G&D	2446.52	16	HGL 5560 (SE)	118	$ 288,690
FP_1481	Future Pipe	G&D	1338.05	16	HGL 4975 (NW1)	118	$ 157,890
FP_1523	Future Pipe	G&D	1837.60	16	HGL 5560 (SE)	118	$ 216,837
FP_1485	Future Pipe	G&D	1263.51	16	HGL 4975 (NW1)	118	$ 149,094
FP_1484	Future Pipe	G&D	1375.96	16	HGL 4975 (NW1)	118	$ 162,364
FP_1482	Future Pipe	G&D	1267.94	16	HGL 4975 (NW1)	118	$ 149,616
FP_1479	Future Pipe	G&D	1293.67	16	HGL 4975 (NW1)	118	$ 152,653
FP_1477	Future Pipe	G&D	1741.67	16	HGL 4975 (NW1)	118	$ 205,517
FP_1474	Future Pipe	G&D	1582.05	16	HGL 4975 (NW1)	118	$ 186,682
FP_1517	Future Pipe	G&D	1974.46	16	HGL 5560 (SE)	118	$ 232,986
FP_1515	Future Pipe	G&D	1757.82	16	HGL 5560 (SE)	118	$ 207,422
FP_1514	Future Pipe	G&D	1685.38	16	HGL 5560 (SE)	118	$ 198,875
FP_1522	Future Pipe	G&D	1014.28	16	HGL 5560 (SE)	118	$ 119,685
FP_1335	Future Pipe	G&D	1367.36	16	HGL 5221 (WTP)	118	$ 161,349
FP_1336	Future Pipe	G&D	1367.36	16	HGL 5221 (WTP)	118	$ 161,349
FP_1337	Future Pipe	G&D	1280.38	16	HGL 5221 (WTP)	118	$ 151,085
FP_1338	Future Pipe	G&D	1323.79	16	HGL 5221 (WTP)	118	$ 156,207
FP_1339	Future Pipe	G&D	1367.36	16	HGL 5221 (WTP)	118	$ 161,349
FP_2284	Future Pipe	G&D	247.31	16	HGL 4975 (NW1)	118	$ 29,183
FP_2295	Future Pipe	G&D	2315.11	16	HGL 4850 (NW2)	118	$ 273,183
FP_2202	Future Pipe	G&D	1226.13	16	HGL 5560 (SE)	118	$ 144,683
FP_2200	Future Pipe	G&D	941.25	16	HGL 5126 (S)	118	$ 111,068
FP_2199	Future Pipe	G&D	1315.73	16	HGL 5560 (SE)	118	$ 155,257
FP_2196	Future Pipe	G&D	2677.36	16	HGL 4850 (NW2)	118	$ 315,928
FP_2195	Future Pipe	G&D	616.32	16	HGL 4725 (NW3)	118	$ 72,726
FP_2194	Future Pipe	G&D	560.47	16	HGL 4725 (NW3)	118	$ 66,135
FP_2186	Future Pipe	G&D	1918.96	16	HGL 4975 (NW1)	118	$ 226,437
FP_2185	Future Pipe	G&D	238.79	16	HGL 4975 (NW1)	118	$ 28,177
FP_2184	Future Pipe	G&D	763.97	16	HGL 4975 (NW1)	118	$ 90,149
FP_2183	Future Pipe	G&D	2237.69	16	HGL 4725 (NW3)	118	$ 264,048
FP_2181	Future Pipe	G&D	51.88	16	HGL 4975 (NW1)	118	$ 6,122
FP_2193	Future Pipe	G&D	326.20	16	HGL 4725 (NW3)	118	$ 38,492
FP_2239	Future Pipe	G&D	2520.66	16	HGL 5221 (WTP)	118	$ 297,437
FP_2237	Future Pipe	G&D	2629.42	16	HGL 5126 (S)	118	$ 310,272
FP_2236	Future Pipe	G&D	1638.16	16	HGL 5126 (S)	118	$ 193,303
FP_2234	Future Pipe	G&D	2563.11	16	HGL 5126 (S)	118	$ 302,446
FP_2231	Future Pipe	G&D	2655.70	16	HGL 4975 (NW1)	118	$ 313,373
FP_2230	Future Pipe	G&D	47.24	16	HGL 4975 (NW1)	118	$ 5,574
FP_2223	Future Pipe	G&D	3055.56	16	HGL 4850 (NW2)	118	$ 360,556
FP_2220	Future Pipe	G&D	1893.39	16	HGL 4975 (NW1)	118	$ 223,420

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT	Cost
FP_2464	Future Pipe	G&D	1260.55	16	HGL 4975 (NW1)	118	$ 148,745
FP_1774	Future Pipe	G&D	2548.61	16	HGL 5350 (SW)	118	$ 300,736
FP_2458	Future Pipe	G&D	2590.52	16	HGL 5560 (SE)	118	$ 305,682
FP_2457	Future Pipe	G&D	1316.54	16	HGL 5560 (SE)	118	$ 155,352
FP_1856	Future Pipe	G&D	1837.23	16	HGL 5126 (S)	118	$ 216,793
FP_1855	Future Pipe	G&D	3663.92	16	HGL 5126 (S)	118	$ 432,342
FP_1846	Future Pipe	G&D	2982.01	16	HGL 5126 (S)	118	$ 351,877
FP_1843	Future Pipe	G&D	973.50	16	HGL 5126 (S)	118	$ 114,873
FP_1854	Future Pipe	G&D	1436.90	16	HGL 5126 (S)	118	$ 169,554
FP_1888	Future Pipe	G&D	2712.21	16	HGL 5126 (S)	118	$ 320,041
FP_1892	Future Pipe	G&D	1241.44	16	HGL 5126 (S)	118	$ 146,490
FP_1891	Future Pipe	G&D	1024.45	16	HGL 5126 (S)	118	$ 120,886
FP_1889	Future Pipe	G&D	2655.31	16	HGL 5126 (S)	118	$ 313,327
FP_1887	Future Pipe	G&D	2441.41	16	HGL 5126 (S)	118	$ 288,087
FP_1885	Future Pipe	G&D	2646.41	16	HGL 5126 (S)	118	$ 312,277
FP_1884	Future Pipe	G&D	442.79	16	HGL 5126 (S)	118	$ 52,250
FP_1890	Future Pipe	G&D	2680.15	16	HGL 5221 (WTP)	118	$ 316,258
FP_1790	Future Pipe	G&D	2685.92	16	HGL 5350 (SW)	118	$ 316,939
FP_1806	Future Pipe	G&D	2626.37	16	HGL 5560 (SE)	118	$ 309,911
FP_1775	Future Pipe	G&D	2552.22	16	HGL 5350 (SW)	118	$ 301,162
FP_1805	Future Pipe	G&D	1317.72	16	HGL 5560 (SE)	118	$ 155,491
FP_1811	Future Pipe	G&D	2604.69	16	HGL 5126 (S)	118	$ 307,354
FP_1810	Future Pipe	G&D	1277.11	16	HGL 5126 (S)	118	$ 150,699
FP_1809	Future Pipe	G&D	2509.86	16	HGL 5126 (S)	118	$ 296,164
FP_1807	Future Pipe	G&D	51.20	16	HGL 5126 (S)	118	$ 6,042
FP_2037	Future Pipe	G&D	466.46	16	HGL 5126 (S)	118	$ 55,043
FP_2068	Future Pipe	G&D	2589.69	16	HGL 5560 (SE)	118	$ 305,583
FP_2059	Future Pipe	G&D	1211.20	16	HGL 5360 (N)	118	$ 142,921
FP_2057	Future Pipe	G&D	742.07	16	HGL 5360 (N)	118	$ 87,564
FP_2073	Future Pipe	G&D	140.71	16	HGL 5126 (S)	118	$ 16,604
FP_2040	Future Pipe	G&D	139.45	16	HGL 5126 (S)	118	$ 16,455
FP_2074	Future Pipe	G&D	149.28	16	HGL 5126 (S)	118	$ 17,615
FP_2036	Future Pipe	G&D	879.23	16	HGL 5221 (WTP)	118	$ 103,749
FP_2028	Future Pipe	G&D	139.28	16	HGL 5221 (WTP)	118	$ 16,435
FP_2121	Future Pipe	G&D	1241.35	16	HGL 4975 (NW1)	118	$ 146,480
FP_2117	Future Pipe	G&D	99.51	16	HGL 4850 (NW2)	118	$ 11,742
FP_2076	Future Pipe	G&D	1449.51	16	HGL 5360 (N)	118	$ 171,042
FP_2114	Future Pipe	G&D	2531.91	16	HGL 5560 (SE)	118	$ 298,765
FP_1921	Future Pipe	G&D	2644.02	16	HGL 5221 (WTP)	118	$ 311,994
FP_1969	Future Pipe	G&D	2534.73	16	HGL 4975 (NW1)	118	$ 299,098
FP_2015	Future Pipe	G&D	91.18	16	HGL 4975 (NW1)	118	$ 10,760
FP_2124	Future Pipe	G&D	872.71	16	HGL 4975 (NW1)	118	$ 102,980
FP_2003	Future Pipe	G&D	633.89	16	HGL 5360 (N)	118	$ 74,800
FP_2008	Future Pipe	G&D	1346.16	16	HGL 5126 (S)	118	$ 158,846
FP_2013	Future Pipe	G&D	1361.44	16	HGL 5126 (S)	118	$ 160,650
FP_2315	Future Pipe	G&D	1285.31	16	HGL 4725 (NW3)	118	$ 151,666
FP_2320	Future Pipe	G&D	1291.71	16	HGL 5560 (SE)	118	$ 152,422
FP_2314	Future Pipe	G&D	1426.13	16	HGL 4725 (NW3)	118	$ 168,283
FP_2323	Future Pipe	G&D	2625.97	16	HGL 5560 (SE)	118	$ 309,864
FP_2336	Future Pipe	G&D	2951.42	16	HGL 5630 (MT)	118	$ 348,267
FP_2337	Future Pipe	G&D	1094.03	16	HGL 5630 (MT)	118	$ 129,096
FP_2422	Future Pipe	G&D	207.32	18	HGL 5630 (MT)	136	$ 28,196
FP_2432	Future Pipe	G&D	780.02	18	HGL 5630 (MT)	136	$ 106,082
FP_2423	Future Pipe	G&D	585.48	18	HGL 5630 (MT)	136	$ 79,625
FP_2461	Future Pipe	G&D	19.53	18		136	$ 2,656

ID	DESCRIPTION	CIP_ITEMS	LENGTH_FT	DIAMETER	ZONE_NEW	Unit Cost $/FT		Cost
FP_2462	Future Pipe	G&D	46.96	18		136	$	6,386
FP_2435	Future Pipe	G&D	1427.21	18	HGL 5630 (MT)	136	$	194,101
FP_2360	Future Pipe	G&D	237.40	18	HGL 5630 (MT)	136	$	32,287
FP_2389	Future Pipe	G&D	517.69	18	HGL 5630 (MT)	136	$	70,406
FP_2384	Future Pipe	G&D	526.07	18	HGL 5630 (MT)	136	$	71,545
FP_2335	Future Pipe	G&D	1351.15	18	HGL 5630 (MT)	136	$	183,757
FP_2339	Future Pipe	G&D	1272.03	18	HGL 5630 (MT)	136	$	172,996
FP_1378	Future Pipe	G&D	1393.29	24	HGL 5126 (S)	192	$	267,512
FP_1377	Future Pipe	G&D	24.57	24	HGL 5126 (S)	192	$	4,717
FP_1398	Future Pipe	G&D	1315.11	24	HGL 5126 (S)	192	$	252,501
FP_1331	Future Pipe	G&D	1193.78	24	HGL 5221 (WTP)	192	$	229,205
FP_1330	Future Pipe	G&D	1410.76	24	HGL 5221 (WTP)	192	$	270,866
FP_2174	Future Pipe	G&D	66.03	24	HGL 5221 (WTP)	192	$	12,678
FP_2204	Future Pipe	G&D	646.58	24	HGL 5126 (S)	192	$	124,144
FP_2466	Future Pipe	G&D	70.14	24		192	$	13,468
FP_1782	Future Pipe	G&D	994.02	24	HGL 5221 (WTP)	192	$	190,851
FP_1781	Future Pipe	G&D	2644.26	24	HGL 5221 (WTP)	192	$	507,698
FP_2148	Future Pipe	G&D	63.73	24	HGL 5360 (N)	192	$	12,237
FP_2090	Future Pipe	G&D	2961.69	24	HGL 5126 (S)	192	$	568,644
FP_2009	Future Pipe	G&D	1270.14	24	HGL 5126 (S)	192	$	243,868
FP_2218	Future Pipe	G&D	17.35	30	HGL 5221 (WTP)	294	$	5,102
FP_2217	Future Pipe	G&D	20.13	30	HGL 5221 (WTP)	294	$	5,919
FP_2056	Future Pipe	G&D	50.25	30	HGL 5221 (WTP)	294	$	14,774

Appendix H – Prioritization Matrix

Project ID	Project Name	Are there other affected projects? Coordination, prerequisite, opportunistic, etc.	How is capacity affected by this project?	Describe the criticality (i.e., importance) of this project to the operation?	How is connectivity affected by this project? (Reliability/Redundancy)	What safety measures are mitigated with this project	What regulations or standards are attained with this project	Risk Assessment	How is effieciency improved by this project?	What is the impact for this equipment?	Additional Factor 1	Prioitization Score	Project Ranking	FY	2018	2019	2020	2021	2022
														Est Cost					
WFP_02a	Risk-Based CA #5 - Sourdough Transmission Main Condition Assessment	Impacts do not apply.	Impacts do not apply.	Major asset whose failure would affect a large population of end-users. There is no possibility of a work-around without asset.	Current system/asset is aging and/or exhibits problems and no immediate correction or workaround is available.	Low risk of minor injury	Impacts do not apply.	High risk of major system failure that would cause interruption of service, or damage to property or equipment.	impacts do not apply.	Impacts do not apply.	Impacts do not apply	35.6	1	$ 719,785	$ 719,785				
WFP_02b	Sourdough Transmission Main CA Based Rehab	Impacts do not apply.	Impacts do not apply.	Major asset whose failure would affect a large population of end-users. There is no possibility of a work-around without asset.	Current system/asset is aging and/or exhibits problems and no immediate correction or workaround is available.	Low risk of minor injury	Impacts do not apply.	High risk of major system failure that would cause interruption of service, or damage to property or equipment.	impacts do not apply.	Impacts do not apply.	Impacts do not apply	35.6	2	$ 1,000,000		$ 1,000,000			
WFP_04	Sourdough Water Rights Utilization Study	Window of opportunity for project is limited and project timeline is driven by an outside entity and there is immediate demonstrated need. Project is a prequisite for additional project stages and delay will delay multiple significant	Impacts do not apply.	Major asset whose failure would affect a large population of end-users. There is no possibility of a work-around without asset.	Impacts do not apply.	Impacts do not apply.	Regulation that requires compliance in near future 1-5 years OR Anticipated regulation with major implications for COB Operations	Impacts do not apply.	Impacts do not apply.	Has system-wide application and affects critical asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply	35.0	3	$ 400,000	$ 400,000				
WFP_01a	West Transmission Main Planning Study	Window of opportunity for project is limited and project timeline is driven by an outside entity and there is immediate demonstrated need. Project is a prequisite for additional project stages and delay will delay multiple significant	Impacts do not apply.	Impacts do not apply.	Current system/asset is aging and/or exhibits problems and no immediate correction or workaround is available.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Project's implementation will result in demonstrable enhanced revenues/cost reductions > $500,000 above the cost of the project. Alternatively, failure of un-maintained system would cost > $500,00 in higher costs.	Has system-wide application and affects critical asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply	30.0	4	$ 400,000		$ 400,000			
WFP_05	Hilltop Tank Inspection and Mixing System	Impacts do not apply.	Impacts do not apply.	Major asset whose failure would affect a large population of end-users. There is no possibility of a work-around without asset.	Current system/asset is aging and/or exhibits problems and no immediate correction or workaround is available.	Impacts do not apply.	Impacts do not apply.	Risk of subsystem failure and the potential for interruption of service, damage to property or equipment in a limited area.	Impacts do not apply.	Has subsystem application or affects major asset(s) and produces quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply	26.3	5	$ 239,616	$ 239,616				
WFP_12	SCADA Master Plan	Window of opportunity for project is limited and project timeline is driven by an outside entity and there is immediate demonstrated need. Project is a prequisite for additional project stages and delay will delay multiple significant projects.	Impacts do not apply.	Major asset whose failure would possibly affect a large population of end-users. Work-around possible with heavy burden on Utility resources. Asset is at or exceeds service capacity and does not allow for growth	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Risk of subsystem failure and the potential for interruption of service, damage to property or equipment in a limited area.	Between 50% and 100% of project's costs will be repaid through either enhanced revenues or lower costs. Alternatively, failure of un-maintained system would cost up to 50% and 100% of project's cost.	Has system-wide application and affects critical asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply.	23.1	6	$ 250,000	$ 250,000				
WFP_19a	Risk Based CA # 4 - Lyman Creek Water Transmission Main	Window of opportunity for project is limited and project timeline is driven by an outside entity and there is immediate demonstrated need. Project is a prequisite for additional project stages and delay will delay multiple significant projects.	Impacts do not apply.	Major asset whose failure would possibly affect a large population of end-users. Work-around possible with heavy burden on Utility resources. Asset is at or exceeds service capacity and does not allow for growth	Current system/asset is aging and/or exhibits problems and no immediate correction or workaround is available.	Low risk of minor injury	Impacts do not apply.	High risk of system failure and the potential for interruption of service, or damage to property or equipment.	impacts do not apply.	Impacts do not apply.	Impacts do not apply.	21.9	7	$ 134,670	$ 134,670		.		
WFP_10a	Groundwater Well Field Development - Phase 1	Window of opportunity for project is limited and project timeline is driven by an outside entity and there is immediate demonstrated need. Project is a prequisite for additional project stages and delay will delay multiple significant	Impacts do not apply.	Impacts do not apply.	Current system is aging but does not exhibit problems - a work around is available.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Project's implementation will result in demonstrable enhanced revenues/cost reductions > $250,000 above the cost of the project. Alternatively, failure of un-maintained system would cost < $500,000 or > $250,000 in higher	Has system-wide application and affects critical asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply	20.6	8	$ 8,612,400	$ 8,612,400				
WFP_13	Vertical Asset Risk Assessment Phase 1	An outside entity has a like-project which requires coordination and there is an immediate and demonstrated need for the project. Project is a prerequisite for additional project(s).	Impacts do not apply.	Major asset whose failure would possibly affect a large population of end-users. Work-around possible with heavy burden on Utility resources. Asset is at or exceeds service capacity and does not allow for growth	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Risk of subsystem failure and the potential for interruption of service, damage to property or equipment in a limited area.	Impacts do not apply.	Has system-wide application and affects critical asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply	20.0	9	$ 19,838		$ 19,838			
WFP_16	Sourdough Tank Inspection and Potential Improvements	There is a demonstrated long-term need for the project and an outside entity has a like-project. Intangible benefits can be realized by coordinating schedules to coincide.	Impacts do not apply.	Major asset whose failure would possibly affect a large population of end-users. Work-around possible with heavy burden on Utility resources. Asset is at or exceeds service capacity and does not allow for growth	Current system exhibits problems - a work around is available but is difficult to establish and is prone to error.	Impacts do not apply.	Impacts do not apply.	High risk of system failure and the potential for interruption of service, or damage to property or equipment.	Impacts do not apply.	Has subsystem application or affects major asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply.	20.0	10	$ 500,000		$ 500,000			
WFP_14	Vertical Asset Risk Assessment Phase 2	Impacts do not apply.	Impacts do not apply.	Major asset whose failure would possibly affect a large population of end-users. Work-around possible with heavy burden on Utility resources. Asset is at or exceeds service capacity and does not allow for growth	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Risk of subsystem failure and the potential for interruption of service, damage to property or equipment in a limited area.	Impacts do not apply.	Has system-wide application and affects critical asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply.	17.5	11	$ 85,963		$ 85,963			
WFP_15	R&R (Risk, Fire flow, Age, Condition, Size, etc)	Impacts do not apply.	Capacity is increased from deficient status to meet minimum acceptable service levels.	Moderate asset whose failure would affect a population of end-users where work-around is possible, however it is inconvenient and limits functionality.	Current system exhibits problems - a work around is available but is difficult to establish and is prone to error.	Low risk of minor injury	Anticipated regulation (regulation in the current legislative/regulator process)	Risk of subsystem failure and the potential for interruption of service, damage to property or equipment in a limited area.	Project's costs are repaid (through lower costs or enhanced revenues) within 5 years of completion: "Year 5 break even". Alternatively, failure of un-maintained system would cost what the proposed project costs in Year 5.	Has subsystem application or affects major asset(s) and produces quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply.	17.5	12	$ 2,500,000	$ 500,000	$ 500,000	$ 500,000	$ 500,000	$ 500,000
WFP_18	PRV Upgrades (approximately 16 sites)	The project may be needed. An outside entity has a like-project.	Impacts do not apply.	Moderate asset whose failure would affect a population of end-users where work-around is possible, however it is inconvenient and limits functionality.	Current system exhibits problems - a work around is available but is difficult to establish and is prone to error.	Low risk of a serious injury	Impacts do not apply.	Risk of subsystem failure and the potential for interruption of service, damage to property or equipment in a limited area.	Project's costs are repaid (through lower costs or enhanced revenues) within 5 years of completion: "Year 5 break even". Alternatively, failure of un-maintained system would cost what the proposed project costs in Year 5.	Has subsystem application or affects major asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply.	17.5	13	$ 7,637,760			$ 3,000,000	$ 4,000,000	$ 637,760
WFP_19b	Lyman Transmission Main CA Based Rehab	Impacts do not apply.	Impacts do not apply.	Major asset whose failure would possibly affect a large population of end-users. Work-around possible with heavy burden on Utility resources. Asset is at or exceeds service capacity and does not allow for growth	Current system/asset is aging and/or exhibits problems and no immediate correction or workaround is available.	Low risk of minor injury	Impacts do not apply.	High risk of system failure and the potential for interruption of service, or damage to property or equipment.	impacts do not apply.	Impacts do not apply.	Impacts do not apply.	16.9	14	$ 500,000		$ 500,000			
WFP_11	Integrated Water Resources Plan Update	An outside entity has a like-project which requires coordination and there is an immediate and demonstrated need for the project. Project is a prerequisite for additional project(s).	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Risk of subsystem failure and the potential for interruption of service, damage to property or equipment in a limited area.	Impacts do not apply.	Has system-wide application and affects critical asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply	16.3	15	$ 150,000			$ 150,000		
WFP_09a	Reservoir 1 - Siting	Window of opportunity for project is limited and project timeline is driven by an outside entity and there is immediate demonstrated need. Project is a prequisite for additional project stages and delay will delay multiple significant	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Project's implementation will result in demonstrable enhanced revenues/cost reductions > $250,000 above the cost of the project. Alternatively, failure of un-maintained system would cost < $500,000 or > $250,000 in higher	Has subsystem application or affects major asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply	15.0	16	$ 350,000		$ 350,000			

WFP_38	Pear Street Booster Station Upgrade	Impacts do not apply.	Capacity is increased from a severely deficient status to meet minimum acceptable service levels.	Moderate asset whose failure would affect a population of end-users where work-around is possible, however it is inconvenient and limits functionality.	Current system exhibits problems - a work around is available but is difficult to establish and is prone to error.	Impacts do not apply.	Impacts do not apply.	Risk of subsystem failure and the potential for interruption of service, damage to property or equipment in a limited area.	Between 50% and 100% of project's costs will be repaid through either enhanced revenues or lower costs. Alternatively, failure of un-maintained system would cost up to 50% and 100% of project's cost.	Has limited application and produces quantifiable benefits that improves product quality, process, or adoption of best industry practices.	Impacts do not apply	15	17	$ 486,720	$ 486,720				
WFP_24	SCADA Phase 1	There is a demonstrated long-term need for the project and an outside entity has a like-project. Intangible benefits can be realized by coordinating schedules to coincide.	Impacts do not apply.	Moderate asset whose failure would affect a population of end-users where work-around is possible, however it is inconvenient and limits functionality.	Current system exhibits problems - a work around is available.	Risk can affect quality of public service, employee stress	Impacts do not apply.	Impacts do not apply.	Between 50% and 100% of project's costs will be repaid through either enhanced revenues or lower costs. Alternatively, failure of un-maintained system would cost up to 50% and 100% of project's cost.	Has subsystem application or affects major asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply.	10.3	18	$ 2,239,050			$ 559,763	$ 839,644	$ 839,644
WFP_32	Risk Based CA #2 - Downtown Area	Impacts do not apply.	Impacts do not apply.	Major asset whose failure would possibly affect a large population of end-users. Work-around possible with heavy burden on Utility resources. Asset is at or exceeds service capacity and does not allow for growth	Current system exhibits problems - a work around is available but is difficult to establish and is prone to error.	Risk can affect quality of public service, employee stress	Impacts do not apply.	Risk of subsystem failure and the potential for interruption of service, damage to property or equipment in a limited area.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	10.3	19	$ 28,116	$ 28,116				
WFP_01b	West Transmission Main - Phase 1 Design	Window of opportunity for project is limited and project timeline is driven by an outside entity and there is immediate demonstrated need. Project is a prequisite for additional project stages and delay will delay multiple significant	Impacts do not apply.	Impacts do not apply.	Current system/asset is aging and/or exhibits problems and no immediate correction or workaround is available.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply	10.0	20	$ 2,907,235					$ 2,907,235
WFP_26	Redundant North 5038 Zone Feed	Impacts do not apply.	Capacity is increased from deficient status to meet minimum acceptable service levels.	Minor asset whose failure would affect a small population of end-users. Annoying, however, no significant adverse impact. A long-term work-around may be possible.	Current system exhibits problems - a work around is available.	Impacts do not apply.	Impacts do not apply.	Risk of subsystem failure and the potential for interruption of service, damage to property or equipment in a limited area.	Impacts do not apply.	Has subsystem application or affects major asset(s) and produces quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts do not apply	9.7	21	$ 59,488			$ 59,488		
WFP_34	Risk Based CA # 1 - West Bozeman Transmission	Impacts do not apply.	Impacts do not apply.	Major asset whose failure would possibly affect a large population of end-users. Work-around possible with heavy burden on Utility resources. Asset is at or exceeds service capacity and does not allow for growth	Current system is aging but does not exhibit problems - a work around is available.	Risk can affect quality of public service, employee stress	Impacts do not apply.	Risk of subsystem failure and the potential for interruption of service, damage to property or equipment in a limited area.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	8.4	22	$ 47,826	$ 47,826				
WFP_35	Risk Based CA #3 - Baxter/Oak south of Freeway	Impacts do not apply.	Impacts do not apply.	Moderate asset whose failure would affect a population of end-users where work-around is possible, however it is inconvenient and limits functionality.	Current system exhibits problems - a work around is available.	Risk can affect quality of public service, employee stress	Impacts do not apply.	Risk of subsystem failure and the potential for interruption of service, damage to property or equipment in a limited area.	Impacts do not apply.	Impacts do not apply.	Impacts do not apply.	7.2	23	$ 23,775	$ 23,775				
WFP_36	Water Information Management Solutions (WIMS)	Impacts do not apply.	Impacts do not apply.	Minor asset whose failure would affect a small population of end-users. Annoying, however, no significant adverse impact. A long-term work-around may be possible.	Impacts do not apply.	Impacts do not apply.	Potential regulation anticipated in next 5-10 years.	Impacts do not apply.	Between 50% and 100% of project's costs will be repaid through either enhanced revenues or lower costs. Alternatively, failure of un-maintained system would cost up to 50% and 100% of project's cost.	Has limited application and produces quantifiable benefits that improves product quality, process, or adoption of best industry practices.	Impacts do not apply	4.1	24	$ 186,300					$ 186,300

Appendix I – Short-Term Project Narratives

City of Bozeman
Water CIP - Projects
Recommended Short-Term CIP-Projects

CURRENT PROJECT RANKING:	2	14	8	13
Enter a project name	**Sourdough Transmission Main – CA Based Rehab**	**Lyman Transmission Main CA Based Rehab**	**Groundwater Well Field Development - Phase 1**	**PRV Upgrades (approximately 16 sites)**
CIP Project Number (*leave blank if this is a new project*)	WFP_02b	WFP_19b	WFP_10a	WFP_18
Department	Engineering	Engineering	Water Impact Fees	Engineering
Category	Infrastructure	Infrastructure	Infrastructure	Infrastructure
Enter a Brief Project Description (*one sentence*)	The project consists of repairs/rehab work on the existing 30-inch bar wrapped concrete Sourdough transmission main, from the Sourdough water treatment plant to the Sourdough reservoir, and the 16-in bar-wrapped concrete pipe from Sourdough Reservoir to Kagy. Project scope is dependent on condition assessment of the existing Sourdough transmission main (WFP_02a).	This project consists of repair and rehabilitation work on the lower Lyman transmission pipeline, approximately between Lyman Reservoir and Pear Street Pump Station. Scope will depend on the results of WFP_19a, condition assessment of the pipeline.	This project consists of three components: 1) Purchase land for construction and operation of a municipal groundwater well field; 2) Obtaining mitigation water necessary to implement a DNRC-approved mitigation plan; and 3) Water right permitting to obtain a beneficial water use permit, the legal water rights necessary to operate a municipal groundwater well, 4) Well development	Waterproof, Install above-ground weather proof enclosures (for PLC rack, PLC, I/O, Power supply, batter charger, battery, control transformer, switch, network communication,HMI,and related equipment), single phase power source, wide area network communication connection, Electric Unit Heater, Vent fan, sump pump and safety access (Bilco Hatch access) in non-traveled way sites. Install field instrumentation for remote indication of pressure, flow, temperature, and select water quality parameters (as required). Standardize pressure controls, provide remote indication and control functionality, and improve upon confined space entry limitations.
Contact Name	Brian Heaston	Brian Heaston	Brian Heaston	Brian Heaston
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Contact Phone Number	582-2280	582-2280	582-2282	582-2280
Cost of the Project	$1,000,000	$500,000	$8,612,400	$7,637,760
Year Scheduled	FY19	FY19	FY18	FY20
Select a Project Fund			Water Impact Fee	
What are the Alternatives Considered?	Replacement or paralleling of Sourdough Transmission Main, or construction of the West Transmission Main from WTP to Goldenstein and 19th.	Continue to operate Lyman transmission main as-is.	Slower development of potential groundwater supply	Status quo operation
What are the Advantages of Approval?		Repair of identified problems such that operation of the main can continue for the next several years.	Adds new source of water supply to the City of Bozeman, pursuant to the Integrated Water Resources Plan, to meet the City's future water supply needs.	Improve water distribution operations through increased understanding of system operating characteristics. Improve responsiveness to dynamic operating conditions. Facilitate improved access to existing sites now requiring confined space entry procedures. Standardize and improve surge control features throughout system.
What are the additional operating costs in the future (*if applicable-provide cost and a description*)?	Currently Unknown	Currently Unknown	Currently unknown	Debt service (if any) to construct, power costs, SCADA maintenance, vault maintenance, instrument maintenance, programming libraries
Are there any additional funding sources?			100% Water Impact Fees	
Are there other affected projects?	Currently Unknown	Currently Unknown		Pressure Management, PRV Abandonments
Is this a project or a piece of equipment?	Project	Project	Project	Project

How is capacity affected by this project?	No change	No change	A groundwater wellfield would substantially increase the City's water supply capacity	N/A
Describe the criticality (i.e., importance) of this project to the operation?	This main is currently a single-point of failure and is in unknown condition.	Lyman transmission into Pear Street PS is critical to provide some water from the Lyman system in the event of a failure in the Sourdough systems.	The City is facing a long-term water supply gap. Acquiring additional new sources of water is critical to the City being able to close this gap. Groundwater procurement is also critical to provide a backup source to the southern watersheds, in case of fire or other catastrophe. Finally, groundwater is the most drought resilient source of water, and procurement of groundwater would significantly reduce the City's vulnerability to drought.	Without project, system operators are without vital data on system operating conditions. Limited real time data limits capability to anticipate, diagnose, or correct abnormal operating conditions.
How is connectivity affected by this project	This project improves connectivity of the distribution system to the City's WTP.	Improved connectivity from the Lyman source to the City.	Currently the majority of the City's supply comes from the Hyalite and Sourdough watersheds, connected through the Sourdough WTP to the City's south side. Connecting a major new source of water from the west will greatly improve the connectivity of the City's supply and distribution systems.	Maintains existing connectivity
What safety or risk measures are mitigated with this project	Reduced risk of failure of the Sourdough Transmission Main. If this main fails the Sourdough and Hilltop reservoirs would provide 1 to 2 days of supply, depending on the season.	Reduced risk of a critical failure along the Lyman transmission main.	Risks to water supply from the City's southern watersheds. Lyman spring provides some risk reduction to major failures (wildfire, dam failure, contamination) in the southern watersheds, but is not sufficient to provide substantial redundancy. A groundwater wellfield would contribute to this redundancy, reducing these risks.	Standardized pressure controls offers improved protections from surge conditions which are likely cause of pipe failure. Improves service levels to existing customers where pressure transients cause leaks in sprinkler systems or within customer premises
What regulations or standards are attained with this project	Reliable water delivery infrastructure and sufficient fire flow.	Redundant water delivery infrastructure and sufficient fire flow to downtown.	Water supply redundancy	N/A
How is this project/equipment leveraged with other stakeholders/projects/funds?	Scope of the project will be dictated by the results of WFP_02a	Unknown	A groundwater wellfield project is inherently tied to construction of a transmission main from the wellfield to town, and other infrastructure (potentially a storage reservoir and booster station) necessary to distribute this water across the City.	Unknown

City of Bozeman
Water CIP - Projects
Recommended Short-Term CIP-Projects

CURRENT PROJECT RANKING:	18	5	21	12
Enter a project name	**SCADA Phase 1**	**Hilltop Tank Inspection and Mixing System**	**Redundant North 5038 Zone Feed**	**Risk Based R&R**
CIP Project Number (*leave blank if this is a new project*)	WFP_24	WFP_05	WFP_26	WFP_15
Department	Engineering	Water Operations	Water Operations	
Category	Infrastructure	Equipment	Equipment	Infrastructure
Enter a Brief Project Description (*one sentence*)	Install Wide Area Network infrastructure, connect PRV vaults, verify/ install Pressure relief per each Pressure Zone, central site improvements, update historian, and implement pressure management regimes to improve system pressure protection	Inspect reservoir. Furnish and Install Mixer(s), Power and Control and update Reservoir SCADA to include remote monitoring capability of mixer(s).	Evaluate, and upgrade as required, 2nd location of redundant feed of 5130 Zone water into North (5038) Zone. This will ensure alternative source of water exists and is sufficient to feed North Zone in time when Lyman Creek source is unavailable.	This bucket of funds could be used for both Risk-based CA and those which are only Fire-flow driven (or opportunistic upgrades)
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Contact Email	bheaston@bozeman.net	jalston@bozeman.net	jalston@bozeman.net	
Contact Phone Number	582-2280	582-2250	582-2250	
Cost of the Project	$2,239,050	$239,616	$59,488	$2,500,000
Year Scheduled	FY20	FY18	FY19	FY20
Select a Project Fund				
What are the Alternatives Considered?	Status Quo	Installation of separate inlet and outlet configurations per each Reservoir	Continue with single connection between pressure zones	
What are the Advantages of Approval?	improved surveillance of system operation, increased control and understanding of real-time system conditions, ability to implement tighter pressure management controls.	Least expensive way to effect reservoir mixing and added freeze protection	Use existing facilities and connectivity to provide redundant back up source of water	Fund for repair and rehabilitation of items the department considers most urgent, based on WFPU and experience, over the next 5 years.
What are the additional operating costs in the future (*if applicable- provide cost and a description*)?	SCADA WAN maintenance expenses, server and hardware maintenance, software maintenance and programming libraries	Energy costs for mixing; SCADA maintenance, scheduled mixer maintenance,	None	
Are there any additional funding sources?				
Are there other affected projects?	PRV vault upgrades, Reservoir mixing upgrades, new storage reservoir, Pear St. Booster Station upgrade, remote water quality surveillance system		Pear St. Booster Station Upgrade	
Is this a project or a piece of equipment?	Project	Equipment	Project	Project

How is capacity affected by this project?	N/A	N/A	N/A	Moderate improvements in fire flow capacity at some hydrants in the system
Describe the criticality (i.e., importance) of this project to the operation?	Improved surveillance of system operation, increased control and understanding of real-time system conditions, ability to implement tighter pressure management controls.	Without mixing of tank contents, Water Quality can be impacted, cold weather operation can create damage to reservoir contents	This provides a second path for water to move from South Zone to North Zone in event that Lyman source is unavailable.	Multiple hydrants were identified in the WFPU modeling work that have less than optimal fire flow for the surrounding land use. However, the deficiencies were slight and can be mitigated by other means.
How is connectivity affected by this project	Improves connectivity of remote sites to one another, enhancing overall system operation	N/A	N/A	
What safety or risk measures are mitigated with this project	Improved understanding of cause/effect allows improved overall system operation including more precise pressure control, real-time statusing during abnormal events,	Freeze protection reduces risk of ice damage to cathodic protection system, tank interior.	Second source from outside the Pressure Zone. Adds amount of redundancy to system needed in event Lyman source is unavailable	Reduced risk of lower fire flows in some fire hydrants
What regulations or standards are attained with this project	Compliance with applicable SCADA and security standards.	N/A	Meets City Hydraulic criteria	Fire flow maintenance
How is this project/equipment leveraged with other stakeholders/projects/funds?	Unknown	Unknown	Could be performed in conjunction with Pear St. Booster Upgrade to facilitate testing and commissioning	

City of Bozeman
Water CIP - Projects
Recommended Short-Term CIP-Projects

CURRENT PROJECT RANKING:	17	Not Previously Ranked	Not Previously Ranked	Not Previously Ranked
Enter a project name	**Pear St. Booster Station Upgrade**	**Hyalite Reservoir Infrastructure and Control Improvements**	**Groundwater Well Field Transmission Main - Phase 1**	**Sourdough Transmission Main – Phase 1**
CIP Project Number (*leave blank if this is a new project*)	WFP_38	WFP_54	WFP_20	WFP_03
Department			Engineering	Engineering
Category	Infrastructure	Infrastructure	Infrastructure	Infrastructure
Enter a Brief Project Description (*one sentence*)	Rehabilitate station by adding 2 - 1000 gpm high service pumps, 1 - 400 gpm normal service pump, electrical and control (either VFD and discharge check valve or Soft Starts with discharge control valves); verify condition or install new 5038 Zone PRVs (1 low range, 1 high range) to backfeed Zone. Allows interim operation as booster station into South 5130 Zone for South Zone reservoirs, as well as backfeed when Lyman Reservoir to be taken out of service. Provide SCADA control logic modifications as required.	Armoring of the control tower (to enable some year-over-year storage capacity) and control upgrades to improve winter operation	The project consists of a constructing a new transmission 24" main that would connect the City's existing distribution system to a potential future groundwater well field system located west of the current City boundary. The precise location of the required main is dependent on groundwater yields and well locations, but will likely convey water from the Four Corners region to the City along Huffine Road.	The project consists of constructing approximately 8,700 feet of 30-inch DIP transmission main, which would parallel the existing older 30-inch concrete main. The proposed transmission main would connect to a new 48-inch DIP coming from the WTP and extend to the Sourdough reservoir.
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Contact Phone Number	582-3200	582-3220	582-2280	582-2280
Cost of the Project	$486,720	$3,858,300	$8,974,969	$4,241,272
Year Scheduled	FY18	FY22	FY20	FY18
Select a Project Fund				
What are the Alternatives Considered?	Abandonment of Site as booster station. Status quo for backfeed from 5130 South Zone to 5038 North Zone	Continue to deal with current Hyalite dam operation	Alternatives are dependent on groundwater yield and location.	Conduct a condition assesment of the existing 30-inch concrete pipe and repair/rehabilitate as necessary.
What are the Advantages of Approval?	Maintain capability during high demand period to fill/maintain reservoir levels in Sourdough and Hilltop Reservoirs. Augment Sourdough supply during peak demand period. Provide capabability to backfeed North Zone in event Lyman Creek supply is insufficient or Lyman Reservoir is out of service.	Drought mitigation, improved water use and cost efficiencies	Construction of this main would provide a significant, redundant supply of water from a watershed other than the Sourdough/Hyalite systems, reducing the City's risk of dependency on the Sourdough Water Treatment Plant and providing a drought-resistant supply of water. In addition, this supply will contribute to adequate water supply capacity for the City's overall future development.	The condition of the existing transmission main from the WTP to the Sourdough reservoir is currently unknown. Approval of this project will provide redundancy for this main, and mitigate the risk and consequence of its failure.
What are the additional operating costs in the future (*if applicable-provide cost and a description*)?	No		Annual Operating & Maintenance Costs: Impact Fees can not be spent on annual operations and maintenance costs. The Water Utility will see incremental increases in general maintenance costs. Current cost estimate of $12,500 per water-main mile maintained annually.	Annual Operating & Maintenance Costs: Impact Fees can not be spent on annual operations and maintenance costs. The Water Utility will see incremental increases in general maintenance costs. Current cost estimate of $12,500 per water-main mile maintained annually.
Are there any additional funding sources?				
Are there other affected projects?		The ability to utilize some year-over-year storage in Hyalite to mitigate against a dry year reduces the criticality of obtainnig groundwater, or adding major storage to Lyman.	Currently Unknown	Currently Unknown
Is this a project or a piece of equipment?	Project	Project	Project	Project

How is capacity affected by this project?	Enables Lyman supply at approximately 2-3MGD to be fully utilized	Capacity could be improved in a major drought condition.	This project would increase Bozeman's long-term water supply capacity to potentially match growth projections. It is necessary to close the long-term water supply gap documented in the City's 2013 Integrated Water Resources Plan	This transmission main will provide additional capacity from the WTP to the Sourdough reservoir.
Describe the criticality (i.e., importance) of this project to the operation?	In absence of pumping capacity, Lyman source can not be fully exploited to fill reservoirs in South Zone. With limited storage, can affect capability to maintain storage for equalization, fire protection and emergency storage.	Current vulnerability of Bozeman to drought is very high, due to the lack of sources that are robust in drought (large raw water reservoirs with year-over-year storage capacity, large rivers, or groundwater). Hyalite Reservoir is capable of providing year-over-year storage, but is not operated in that manner due to concerns of ice damage to the control tower.	Development of a Groundwater Well Field is crucial to the City's long-term water supply, from capacity, redundancy and drought resiliency perspectives.	This project is critical to overcome vulnerabilities presented by the aging and unknown condition of the existing transmission main between the City's WTP and Sourdough Tank.
How is connectivity affected by this project	Maintains existing connectivity		Development of a ground water supply and transmission main will improve Bozeman's long-term water supply portfolio, drought resiliency and improve circulation and water age in the City's system.	This project improves connectivity between the WTP and the City.
What safety or risk measures are mitigated with this project	N/A	The risk of an extremely dry year resulting in the inability to fill the Hyalite reservoir with enough water for the City and irrigation uses.	Without a groundwater supply, the City's has substantial long-term risk to water supply insufficiency and water shortages due to drought or other disasters in the southern watersheds. Developing and connecting a groundwater supply will greatly reduce these risks.	The risk of not having adequate potable water and fire flow supplies to the City in the event of a failure to the existing bar-wrapped 30" main.
What regulations or standards are attained with this project	N/A	Drought resiliiency	Water supply security, drought resiliency	Water supply security
How is this project/equipment leveraged with other stakeholders/projects/funds?	Unknown	Project could potentially remove the 20% surcharge the City pays for Hyalite releases.	This project is tied to the development of a wellfield supply, which is dependent on ongoing hydrogeologic studies, water rights assessments, and environmental review.	This project's cost and administration could be improved if combined with the new 3,000 feet of 48" bypass pipe.

City of Bozeman
Water CIP - Equipment
Recommended Short-Term CIP Projects

PROJECT RANKING:	4	1	3	15	6	9
Enter a project name	**West Transmission Main Planning Study**	**Risk-Based CA #5 - Sourdough Transmission Main**	**Sourdough Water Rights Utilization Study**	**Integrated Water Resources Plan Update**	**SCADA Master Plan**	**Vertical Asset Risk Assessment - Ph 1**
CIP Project Number (*leave blank if this is a new project*)	WFP_01a	WFP_02a	WFP_04	WFP_11	WFP_12	WFP_13
Department	Engineering	Engineering	Engineering		SCADA	GIS
Category	Planning Document	Planning Document	Planning Document	Planning Document	Planning Document	Engineering Service
Enter a Brief Project Description	Water Facility Plan Update	Perform high resolution condition assessment of Sourdough Transmission in accordance with 2015 Condition assessment report	Study to develop recommended project(s) to enable long-term utilization of Sourdough water rights.	Update to the 2013 Integrated Water Resources Plan	Evaluate options and develop recommendations for Wide area network implementation for planned remote water infrastructure. Develop SCADA design, equipment and SCADA tagging and programming standards. Formulate data accessibility and SCADA integration with other City applications (e.g., CMMS)	Expand the use of risk to vertical plant assets including reservoirs, groundwater sources, PRV's, booster stations, and treatment plants. Create a generalized risk policy for the city that will allow for the comparison of risk across various asset classes on a comparable scale, which then allows for better allocation of CIP funding and effort to the highest risk assets across the entire utility. Develop implementation plan
Contact Name	Brian Heaston	Brian Heaston	Lain Leoniak	Brian Heaston	Unknown	Jon Henderson
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Contact Phone Number	582-2281	582-2280	582-3220	582-2282		582-2250
Cost of the Project	$400,000	$719,785	$400,000	$150,000	$250,000	$19,838
Year Scheduled	FY18	FY18	FY18	FY19	FY18	FY19
Select a Project Fund						
What are the Alternatives Considered?	Defer the study further out, deferring eventual construction of the West Transmission Main.	No inspection			Status quo operation of limited SCADA within distribution system and plant	Maintenance of existing policy and non-data driven decision making
What are the Advantages of Approval?	Identify key design parameters, right-of-way, route and permitting for the West Transmission Main, so that design and construction can proceed once funds are available.	reduce range of uncertainty of major pipeline integrity; identify areas in need of repair and/or rehabilitation		Updating this project will enable the City to hone in on the best approaches to closing the City's future water supply gap.	Leverage technology to improve understanding and real time remote control of infrastructure. Improved pressure management of high-pressure operation. Inform maintenance decisions with performance data.	Implement consistent treatment of business risk in CIP planning, Operational budget reviews and adjustment, and system repairs across all City asset classes.
What are the additional operating costs in the future (*if applicable- provide cost and a description*)?		Assuming project is capitalized, operating costs to be less than $35,000 for in-house labor				
Are there any additional funding sources?						
Are there other affected projects?	All subsequent phases of West Transmission Main design and construction				SCADA Phase 1, SCADA Phase 2, PRV Vault upgrades, Well field development, reservoir mixers, new booster stations, new reservoir sites	
Is this a project or a piece of equipment?	Project	project	project	Project	project	project
Which infrastructure assets are maintained by this equipment?		Sourdough Transmission Main			N/A	N/A
Describe the criticality (i.e., importance) of this equipment to the operation?	Eventual construction of the West Transmission Main is necessary to provide redundancy for the Sourdough Transmission Main as well as adequate potable water and fire flow for the City's west, northwest and north areas.	Criticality is dependent on completion of other risk reduction measures. At this time, item is highly critical. However, criticality is reduced if other structural improvements are completed as scheduled.	This project is critical for the City to maintain its water rights on Sourdough Creek.		Should be implemented in current fiscal year to adopt for planning processes for FY 18	Should be implemented in current fiscal year to adopt for planning processes for FY 18
How is efficiency improved with this equipment?	Conveyance of water to the City's western, northwestern and northern areas will be more efficient that moving water through downtown and existing PRVs	focus resources to where any defect is found, and eliminate unnecessary capital expense of rehabilitation and/or replacement			Data-driven decision making	Data-driven decision making

What is the impact (i.e., scope-of-use) for this equipment?		Address risk from pipeline failure and establish need for additional R&R expenses to maintain service. Establish baseline condition for future use in scheduling additional inspection/repairs	Critical securitization of water rights on Sourdough watershed			
What are the implications of deferring the purchase of this equipment?	Delay of eventual design and construction of the West Transmission Main, continued reliance on the single-point-of-failure Sourdough Transmission Main to convey water to the City from the WTP.	Opportunistic pipeline assessment can be done when factors limit expenses associated with inspection	Loss of some Sourdough water rights	Failure to monitor and avoid long-term water supply gap	this project is precursor to construction projects at critical facilities	
How is this project/equipment leveraged with other stakeholders/projects/funds?		Unknown	Recommended by IWRP, DMP		older/projects precursor to construction projects w critical facilities	Use funds allocated to FY 17 budget?

City of Bozeman
Water CIP - Equipment
Recommended Short-Term CIP Projects

PROJECT RANKING:	11	10	14	19	22	23
Enter a project name	**Vertical Asset Risk Assessment - Ph 2**	**Sourdough Tank Inspection and Improvements**	**Risk Based CA # 4 - Lyman Creek Water Transmission Main**	**Risk Based CA #2 - Downtown Area**	**Risk Based CA # 1 - West Bozeman Transmission**	**Risk Based CA #3 - Baxter/Oak south of Freeway**
CIP Project Number (*leave blank if this is a new project*)	WFP_14	WFP_16	WFP_19a	WFP_32	WFP_34	WFP_35
Department	GIS	Water Operations	Engineering	Engineering	Engineering	Engineering
Category	Engineering Service	Planning Document	Planning Document	Planning Document	Planning Document	Planning Document
Enter a Brief Project Description	Expand the use of risk to vertical plant assets including reservoirs, PRV's, booster stations, and treatment plants. Perform risk assessment per Implementation plan.	This project would entail taking the Sourdough Tank offline (once the West Transmission Main is online), inspecting it and repairing it as necessary. This project may or may not include reconfiguration of the inlet/outlet configuration to provide flow-through hydraulics.	Prepare and evaluate condition assessment plan and execute condition assessment for the high consequence transmission main through the northeast bozeman corridor to confirm likelihood of failure.	Prepare and evaluate condition assessment plan and execute condition assessment for the high consequence distribution and backbone mains through the downtown bozeman corridor with moderate likelihood of failure to confirm or update likelihood of failure in order to more accurately identify pipes as candidates for R&R.	Prepare and evaluate condition assessment plan and execute condition assessment for the high consequence transmission main through the southwest bozeman corridor to confirm likelihood of failure.	Prepare and evaluate condition assessment plan and execute condition assessment for the high consequence distribution and backbone mains through this corridor with moderate likelihood of failure to confirm or update likelihood of failure in order to more accurately identify pipes as candidates for R&R.
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Contact Phone Number	582-2250	582-2249	582-2280	582-2280	582-2280	582-2280
Cost of the Project	$85,963	$500,000	$134,670	$28,116	$47,826	$23,775
Year Scheduled	FY19	FY19	FY19	FY18	FY18	FY18
Select a Project Fund						
What are the Alternatives Considered?	Maintenance of existing policy and non-data driven decision making	Wait for critical failure	No inspection	No inspection	No inspection	No inspection
What are the Advantages of Approval?	Implement consistent treatment of business risk in CIP planning, Operational budget reviews and adjustment, and system repairs across all City asset classes.	Rehabilitation of critical storage infrastructure for several decades to come.	Doing planned condition assessment can provide a cost effective mechanism of identifying likely asset failures and thereby offering the opportunity of repairing the deficiency or the whole asset if needed prior to failure. Additionally, CA often can identify assets in good working condition, so only required repairs are completed thereby saving significant money in replacing assets in good working order.	Doing planned condition assessment can provide a cost effective mechanism of identifying likely asset failures and thereby offering the opportunity of repairing the deficiency or the whole asset if needed prior to failure. Additionally, CA often can identify assets in good working condition, so only required repairs are completed thereby saving significant money in replacing assets in good working order.	Doing planned condition assessment can provide a cost effective mechanism of identifying likely asset failures and thereby offering the opportunity of repairing the deficiency or the whole asset if needed prior to failure. Additionally, CA often can identify assets in good working condition, so only required repairs are completed thereby saving significant money in replacing assets in good working order.	Doing planned condition assessment can provide a cost effective mechanism of identifying likely asset failures and thereby offering the opportunity of repairing the deficiency or the whole asset if needed prior to failure. Additionally, CA often can identify assets in good working condition, so only required repairs are completed thereby saving significant money in replacing assets in good working order.
What are the additional operating costs in the future (*if applicable- provide cost and a description*)?		None	Assuming project is capitalized, operating costs to be less than $35,000 for in-house labor	No	No	No
Are there any additional funding sources?						
Are there other affected projects?						
Is this a project or a piece of equipment?	project	Project	Project	Project	Project	Project
Which infrastructure assets are maintained by this equipment?	N/A	N/A				
Describe the criticality (i.e., importance) of this equipment to the operation?	Should be implemented in current fiscal year to adopt for planning processes for FY 18	The condition of the Sourdough Tank is unknown. The hydraulics to and from the tank are suspected to be suboptimal. This project is critical to ensure that the Sourdough tank is reliable and operating well.	Major asset whose failure would possibly affect a large population of end-users. Work-around possible with heavy burden on Utility resources. Asset is at or exceeds service capacity and does not allow for growth	High risk assets whose failure would cause significant disruption of service and adverse social impacts. Assets are aging and may be nearly failure.	Major asset whose failure would possibly affect a large population of end-users. Work-around may be possible with heavy burden on Utility resources.	High risk assets whose failure would cause significant disruption of service and adverse social impacts. Assets are aging and may be nearly failure.
How is efficiency improved with this equipment?	Data-driven decision making	N/A				

What is the impact (i.e., scope-of-use) for this equipment?		Risk of critical failure of Sourdough Tank due to corrosion. Risk of long water age and reduced water quality due to poor hydraulics.	Has subsystem application or affects major asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Has subsystem application or affects major asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Has subsystem application or affects major asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Has subsystem application or affects major asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices
What are the implications of deferring the purchase of this equipment?		N/A				
How is this project/equipment leveraged with other stakeholders/projects/funds?	Use funds allocated to FY 17 budget?		Possibly	Possibly	Possibly	Possibly

City of Bozeman
Water CIP - Equipment
Recommended Short-Term CIP Projects

PROJECT RANKING:	24	20	16	25	Not Previously Ranked
Enter a project name	**Water Information Management Solution (WIMS)**	**West Transmission Main - Phase 1 Design**	**Reservoir 1 - Siting**	**Hyalite Watershed and Reservoir Hydrologic Study**	**Sourdough Canyon Natural Storage and Wetland Enhancement - Planning and Design**
CIP Project Number (*leave blank if this is a new project*)	WFP_36	WFP_01b	WFP_09a	WFP_23	WFP_53
Department	Water Operations			Engineering	Engineering
Category	Engineering Service	Planning Document		Planning Document	Planning Document
Enter a Brief Project Description	Data management and analytical tool development to enhance water system information use	Design of the first phase of the West Transmission Main, the criteria for which would be developed in the West Transmission Main Planning Study (WFP_01b)		Analyze long-term water supply provided by the Hyalite watershed and existing reservoir, assess current dam operation and feasibility of implementing control tower improvements and/or raising the dam, and the potential to create a strategic water reserve for reduced drought vulnerability.	Evaluate the optimal project that will enable the City to utilize currently unused Sourdough water rights.
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Contact Phone Number	582-2250	582-2280	582-2280	582-3220	582-3220
Cost of the Project	$186,300	$2,907,235	$350,000	$350,000	$500,000
Year Scheduled	FY22	FY22	FY19	FY19	FY18
Select a Project Fund					
What are the Alternatives Considered?	Status Quo	Defer design and construction of West Transmission Main	Wait until the need for the reservoir is more imminent	Postpone	Postpone
What are the Advantages of Approval?	automated compliance reporting; data analysis and reporting; SCADA-WIMS integration;	Potential to install the transmission main before significant growth and development occur along the route, reduced consequence of failure to Sourdough Transmission Main	Procurement of land while it is available, and less expensive	Develop understanding of long-term water availability in the Hyalite watershed and the necessary improvements to the reservoir to optimize its utilization	Demonstrate continued long-term attempt to utilize Sourdough water rights
What are the additional operating costs in the future (*if applicable- provide cost and a description*)?					
Are there any additional funding sources?					
Are there other affected projects?	N/A	Subsequent phases of West Transmission Main design and construction, construction of storage reservoirs on the City's west side.	Groundwater planning, engineering and construction West Transmission Main study, design, construction; reservoir design, construction projects	Long-term design of the West Transmission Main, Sourdough WTP expansion, quantification of groundwater needs	Final sizing of West Transmission Main, also informs long-term groundwater needs.
Is this a project or a piece of equipment?	Project	Project	Project, Land Acquisition	Project	Equipment
Which infrastructure assets are maintained by this equipment?	N/A				
Describe the criticality (i.e., importance) of this equipment to the operation?		Reduces the consequence of a failure on the Sourdough Transmission Main, by providing a second pipeline to convey water to the City from the WTP	The West Sourdough Reservoir will be the next necessary reservoir for the City to continue to provide adequate potable water and fire flow. Proper siting of this reservoir will provide redundant supply to Sourdough and Hilltop Reservoirs.	Understanding the Hyalite watershed's long-term supply capacity affects the sizing of the West Transmission Main and eventual WTP expansion, as well as the criticality of securing Sourdough rights and groundwater supply. In addition, this project will assess the feasibility of armoring the control tower, decreasing the City's drought vulnerability by enabling retention of water from wet years until the following year's water supply is assured.	If the City does not demonstrate intent to use Sourdough rights, it risks having them reduced.
How is efficiency improved with this equipment?	Facilitates mandatory compliance reporting; improved understanding of system behavior allows more efficient measures to be developed in operation	Water delivery to the City's western side will become more efficient	Greater efficiency in providing potable water and fire flows to the City's western areas. Better ability to take Sourdough or Hilltop reservoirs offline and still provide sufficient storage.		

What is the impact (i.e., scope-of-use) for this equipment?	Improved analysis of system behavior; cost savings, efficiency gains, water use optimization, water quality improvement		System wide improvement in water storage capacity	Has system wide application or affects major asset(s) and produces substantial & quantifiable benefits that improves product quality, processes, or adoption of best industry practices	Impacts the City's long-term water rights and helps close the approaching water supply gap
What are the implications of deferring the purchase of this equipment?	Continued reliance on existing manual systems	Continued reliance on Sourdough Transmission Main, a single point of failure for conveyance of water from the Sourdough WTP	Potential acquisition of the land by others, less optimal siting of the reservoir	Uncertainty in planning and designing Sourdough WTP supply, West Transmission Main and Groundwater systems. Continued high vulnerability to drought.	Risk of loss of some water rights
How is this project/equipment leveraged with other stakeholders/projects/funds?	Unknown			Schedule and need should be correlated with Sourdough water rights securitization and potential wellfield development	Potential FEMA involvement for flood control