Chapter 6

Hydraulic Analysis Report

6 Background

This chapter is a systematic plan that identifies potential deficiencies in the water system. This section is intended to summarize the basis for planning that went into developing a long range water system concept. A general evaluation of the water system using standard engineering concepts and the updated water system computer model is presented to develop an understanding of future water system needs. Assumptions are based on projected water needs in Chapter 3, and the criteria contained in Chapter 2. This section establishes the previous reports used in the basis of design, references the design criteria to determine deficiencies and provides calculations to plainly state deficiencies. The system deficiencies noted in this chapter will establish the need for various water system improvements and upgrades, which will be addressed later in this plan.

6.1 Water Needs

Water needs were determined in Chapter 3 based on a comprehensive planning approach. The following information & analyses were included:

- Population Growth (Low, Medium & High)
- Community Development Distribution
- Existing and Future Land Use
- Advanced Metering Infrastructure (AMI)
- Diurnal demand curves per Pressure zone
- Water Conservation (Current, Improved & Optimal)
- Historical & Projected Demands per Pressure zone

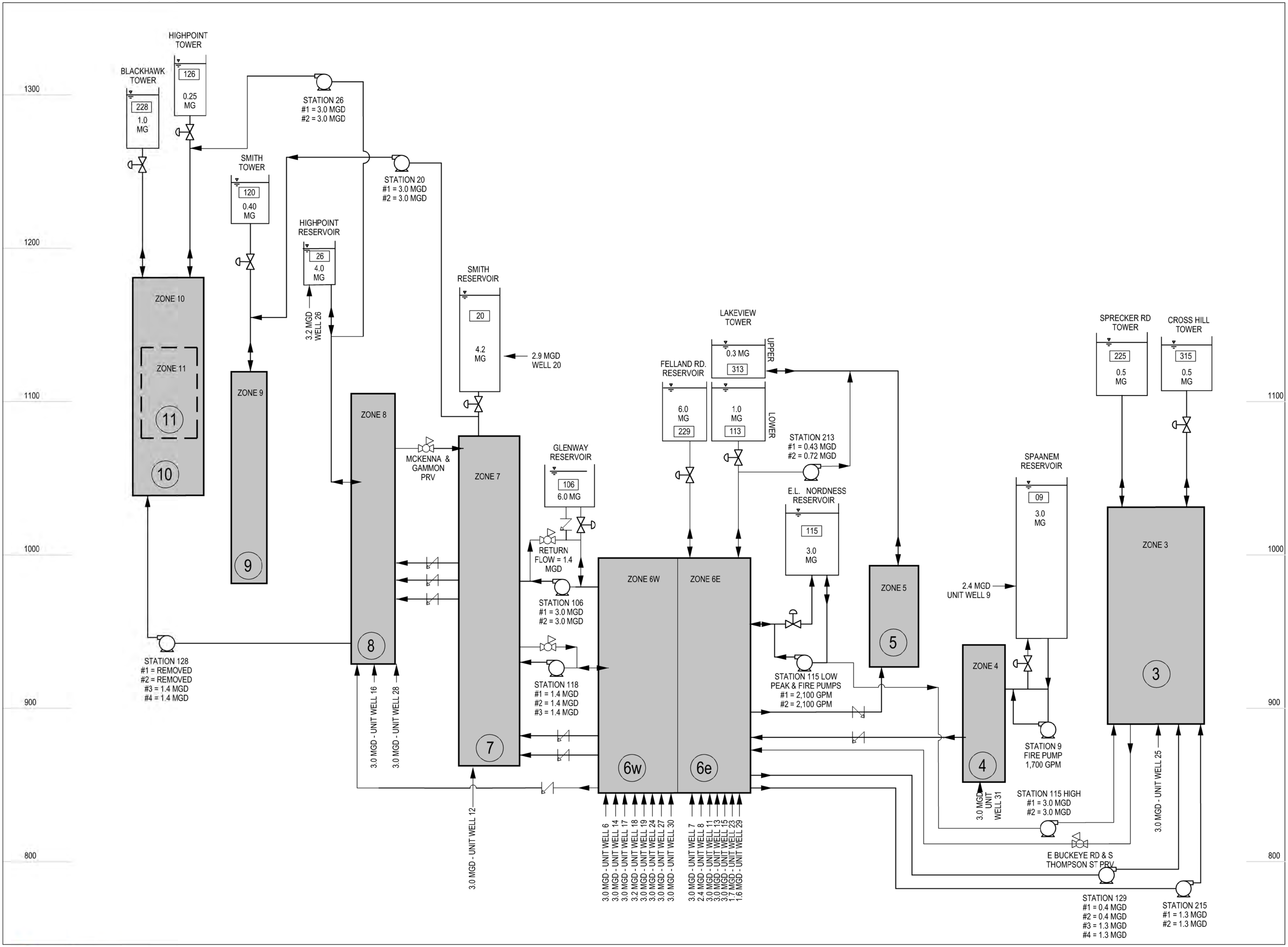
The projections from Chapter 3, were the basis of design for Chapter 6. Appendix 3-E provided the projections for average day water needs of each pressure zone. Appendix 3-F provided the projections for maximum day water needs of each pressure zone.

6.2 Review of Water System

The existing water system was reviewed and characterized in 2017 by SEH. Madison Water Utility (MWU) provided the most current version of the computer water model, the 2017 Geographic Information Systems (GIS) data, screen captures of every SCADA screen in each water facility, historical operator data, historical pumping data, AMI data, previous water master plans and the most current water system schematic. This information was used by SEH to update the water system schematic, update the computer water model and to characterize the operation of the water system. SEH conducted interviews with MWU operators to further understand water system operation.

6.2.1 Water System Schematic

The most current water system schematic is shown in figure 6-1 below. The water system contains ten pressure zones, each containing their own facilities and customers. During the planning discussions with MWU and generation of Chapter 2, it was decided Zone 11 to be a subzone of Zone 10, as the two entities will more closely operate together than other zones. In other words, MWU will operate Zone 10 and Zone 11 as if one pressure zone, even though there exists two separate but similar hydraulic grade lines

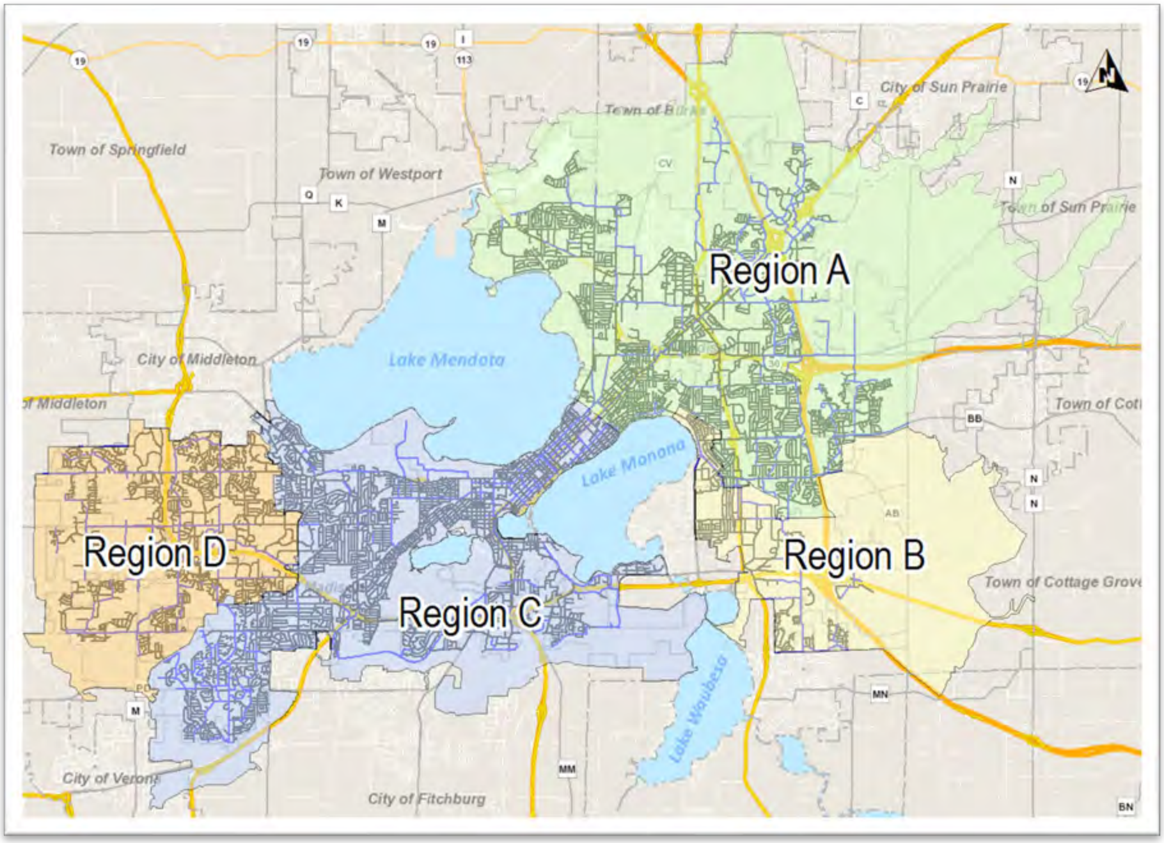


SEH Madison Water Utility

Supply Deficiency Analysis
2018 Water System Master Plan Update
Madison Water Utility

FIGURE 1-1
WATER SYSTEM SCHEMATIC

Figure 6-2 – Water System Hydraulic Regions



6.2.2 Water System Operation

Chapter 4 contains a description of the water system operation. In short, the water system is a highly complex system containing nine pressure zones with multiple reservoirs, unit wells and booster stations. The water system is generally divided into four hydraulic regions, based on how pressure zones are connected and isolated from each other, as the map in Figure 6-2 depicts. The hydraulic regions are given names in Chapter 4, for simplicity of discussion and are listed below:

- Region A – Zone 3, 5 & 6e
- Region B – Zone 4
- Region C – Zone 6w, 7 & 9
- Region D – Zone 8 & 10 (Zone 11 is assumed a subzone of Zone 10)

For purposes of Chapter 6, water supply needs will be evaluated on a regional basis, while storage and pumping capacity needs will be evaluated on a pressure zone basis.

6.2.3 Computer Water Model

Using the most recent computer water model, the 2017 GIS data and the operational data received, SEH updated the MWU computer water model to match June 2017 facility data. Demands were updated using AMI data to provide an accurate depiction of water use throughout the system. Chapter 5 describes the approach and results of the water model calibration. In short, the water model was extensively calibrated for system operation, demands and extended period simulation (EPS). The water model was checked for C-factors based on a series of flow tests by MWU, with the assumption the water model was extensively calibrated for C-factors in previous years.

6.3 Basis of Analysis

Evaluation of the water system is based upon Chapter 2 which outlines desired levels for system pressures, available flow for fire protection, water supply, storage needs, risk management, redundancy and emergency power supply.

6.3.1 Facility Risk Matrix

Throughout the development of the 2018 *Master Plan Update*, SEH and MWU collectively assessed the water system for risk in conjunction with the development of MWU's Asset Management Program. A risk matrix was established which characterized the operation and criticality of each water system facility and then assigned a priority number to each facility, with 1 being the most critical and 4 being the least critical. In addition, this document provides an assessment of each facilities overall condition, and limitations as they relate to water quality, production and general facility condition. This risk matrix is located in Appendix 6B.

6.4 Methods of Analysis

Chapter 6 uses a multiple step approach to identifying water system deficiencies. Methods utilized include analysis of system mass balance for development of supply and transfer deficiencies, hydraulic computer modeling, facility evaluations related to asset management, as well was water quality and facility age considerations.

6.4.1 Mass Balance – Water Supply and Storage Capacity Assessment

This approach was utilized to understand current and projected water supply and storage needs. First, existing and anticipated water system demands for each pressure zone and hydraulic region were established. Then, the required water storage and supply needs developed for each pressure zone and region based on the Chapter 2. Existing available facilities were then compared to the projected need to develop a list of future water facilities required to support projected water system demands. The results from the mass balance will be the basis for a scenario to be analyzed in the computer water model.

The mass balance analysis will examine four parameters in the water system, holistically and by pressure zone including:

- Total water supply/pumping capacity
- Firm water supply/pumping capacity,
- 12-hour water supply/pumping capacity and
- Storage capacity.

These four parameters will be compared to the water demand projections presented in Chapter 3 according to the criteria in Chapter 2.

Chapter 7 alternatives analysis will identify and evaluate alternatives to remedy the deficiencies found in this chapter. The alternatives will then be examined for cost, feasibility and hydraulic impact. Alternatives which are believed to be too expensive or infeasible from a high level may not need to be also tested in the computer water model.

6.4.2 Computer Water Model Analysis

Water distribution system modeling evaluations were performed on the existing Madison water distribution system. Along with the water system mass balance evaluations, the water model was utilized to identify additional water system deficiencies. The computer water model was constructed and calibrated to reflect the actual distribution system performance. The calibrated computer water model will provide a reasonable estimate of system performance which will identify system deficiencies. In Chapter 7 the water model will be utilized to test the feasibility of proposed alternatives suggested to remedy the identified system deficiencies.

6.4.2.1 Water Model Analysis Assumptions

6.4.2.1.1 Demands

The 2020 and 2040 demand scenarios will be used in the computer water modeling, assuming medium population growth with improved conservation, as defined in Chapter 3.

6.4.2.1.2 Daily Diurnal Curves

The diurnal curves, as shown in Appendix 3-C, will be the basis of design for hourly demand variations, expressed as a ratio of the daily demand. The diurnal curves are based on July 14, 2016 AMI data.

6.4.2.1.3 10-Day Demand Variation

The daily demand variations, as observed around the 2016 maximum day, will be the basis of design for daily demand variations, expressed as a ratio of the maximum day demand. The demand ratios are based on 10 days surrounding the maximum day of July 14, 2016. The daily demand factors are shown in Table 6-1.

Table 6-1 – Daily Demand Factors

Day	Date	Demand Factor
1	Saturday, July 11, 2020	0.92
2	Sunday, July 12, 2020	0.89
3	Monday, July 13, 2020	0.92
4	Tuesday, July 14, 2020	1.00
5	Wednesday, July 15, 2020	0.97
6	Thursday, July 16, 2020	0.92
7	Friday, July 17, 2020	0.89
8	Saturday, July 18, 2020	1.00
9	Sunday, July 19, 2020	0.99
10	Monday, July 20, 2020	0.69

The 10-day diurnal curves used for modeling in Chapter 6 are shown in Appendix 6A for each pressure zone, hour by hour for the 10 days around the maximum day demand.

6.4.2.1.4 Water System Controls

Accurately representing water system controls is imperative in order to accurately predict the water system in a scenario. SEH reviewed the system controls during calibration, during the operator interviews, and in meetings with MWU. A complete table of all controls as used in the computer water model is shown in Appendix 6B.

The controls in Appendix 6B reflect MWU's preference of various unit wells and booster stations in their lead and lag operation. SCADA data, SCADA screen captures, operator and utility opinion were all considered. Appendix 6B represents how the operators could potentially operate the system to prevent water system failure when the water system highly stressed for water. In some cases, lockouts are provided to prevent tanks from being totally emptied.

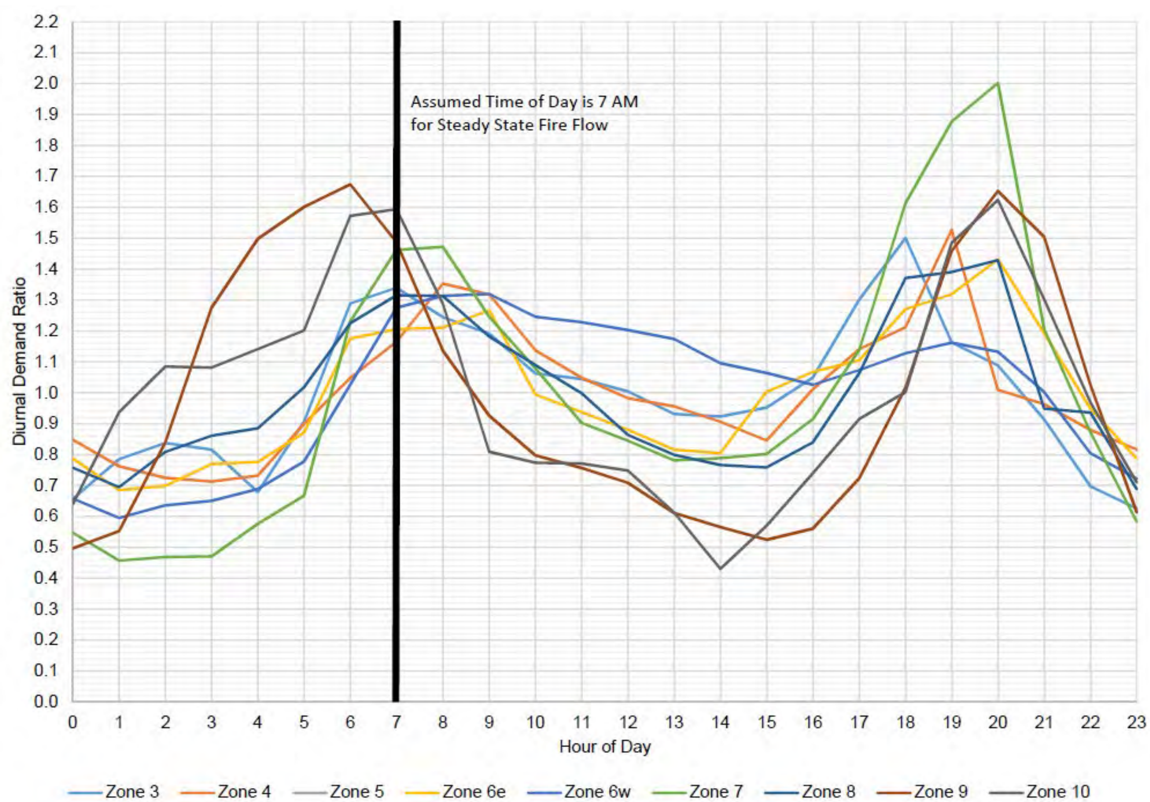
For maximum 10-day demand scenarios most unit wells are assumed having at least one high service pump continuously operating. For pumping stations with variable frequency drives, pressure limits were set on the pumping stations. The pressure limit was set by a fixed hydraulic grade line equal to the overflow elevation of the pressure zone plus an assumed 25 feet.

6.4.2.2 Steady State Fire Flow Evaluation (SS Fire)

The steady state fire flow evaluation will provide a snap shot of the system in how the system responds to a fire event. At each point in the system (one by one), a high flow event will stress the system to 20 psi. The steady state fire-flow evaluation will reveal areas of weak fire protection and low residual pressure during fire flow. Model outputs will be issued as available flow at 20 psi.

Steady State modeling will be tested against the demands in the system at 7 a.m. on the diurnal curve on the maximum day. Figure 2-1 shows all pressure zone diurnal curves and how they behave at 7 a.m. The results of the fire flow analysis will be overlaid with land use fire flow requirements. Deficiencies related to fire flow will be based on targeted fire flows estimated by nearby land use.

Figure 6-3 – Overlay of Pressure Zone Diurnal Curves



6.4.2.3 Maximum 10-Day EPS Evaluation (M10D)

MWU required the use of a maximum 10-day simulation as the baseline for all scenarios. The maximum 10-day EPS modeling is a major focus of this chapter. Two types of EPS models will be used: 1) standard system operation and 2) standard system operation with a fire event.

6.4.2.3.1 Standard System Operation (Standard EPS)

The standard system operation EPS modeling will test a scenario against the projected demand of both year 2020 and 2040. For purposes of this analysis, the water system will be operated over a 10-day period of maximum anticipated water use. The model will operate based on preset system controls to sustain water supply to the system with some facilities operating on and off based on tank levels and others on constantly. Model outputs include minimum pressure, maximum pressure and reservoir levels. The outcome of this modeling exercise will help to determine if there are any operational water system deficiencies which are induced by peak water system demands and extended system operation.

Reservoir levels will be the primary basis to determine if the system is deficient in supply capacity or storage. If the reservoir levels deplete and do not recover or continually decline over the 10 day period, the system may be assumed to have a deficiency in supply to the associated pressure zone. If the reservoirs fluctuate rapidly, the system may be assumed to have a deficiency in equalization storage volume. In areas with limited water storage, system pressure will be the primary basis for determining system deficiencies.

6.4.2.3.2 Standard System Operation with Fire Event (Fire EPS)

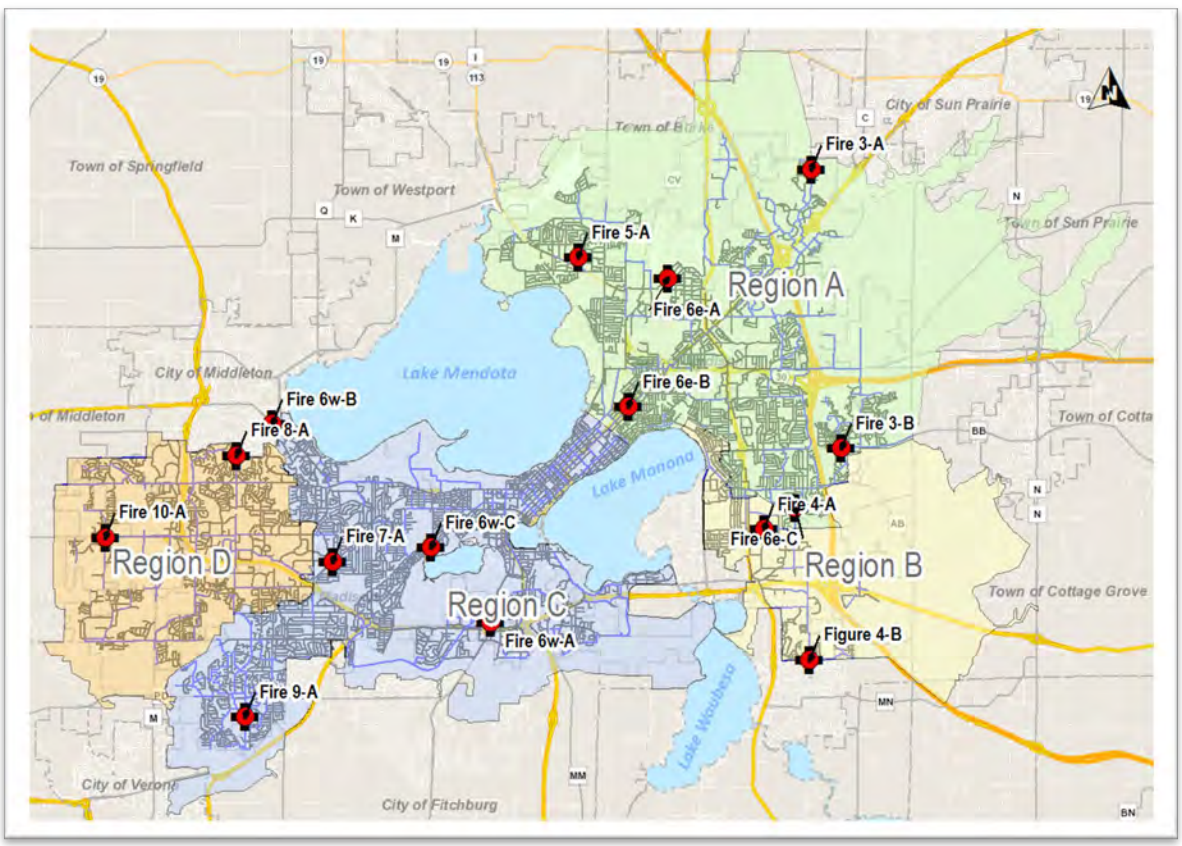
The standard system operation with fire event EPS modeling will test a scenario against the projected demand of both year 2020 and 2040. The assumptions for year 2020 and 2040 were stated previously in Chapter 5, model outputs will include minimum pressure, maximum pressure and reservoir levels

Similar to the standard EPS model, reservoir levels will be the primary basis to determine if the system is deficient in supply or storage. If the reservoir levels deplete rapidly in a fire event to near empty, the system may be assumed to have a deficiency in pumping capacity. Additionally, minimum water system pressures will be monitored to assure safe minimum water system pressures are maintained. In areas with limited water storage, system pressure will be the primary basis for determining system deficiencies.

Table 6-2 – Assumed Fire Events for Fire EPS Scenarios

Name	Intersection	Zone	Fire Flow (gpm)	Duration (hours)
East Side				
Fire 6e-A	Mitchell St & Hoffman St	6e	3,500	3
Fire 6e-B	N 4th St & Hwy 151	6e	3,500	3
Fire 6e-C	Cottage Grove Rd & Atlas Ave	6e	3,500	3
Fire 3-A	Eastpark Blvd & American Pkwy	3	3,500	3
Fire 3-B	Cottage Grove Rd & McLean Dr	3	2,500	3
Fire 4-A	Pflaum Rd & Advance Rd	4	3,500	3
Fire 5-A	Hanover St & Sunfield St	5	2,500	2
West Side				
Fire 6w-A	W Beltline Hwy & Fish Hatchery Rd	6w	3,500	3
Fire 6w-B	W Main St & MLK Jr Blvd	6w	3,500	3
Fire 6w-C	Campus Drive & University Bay	6w	3,500	3
Fire 7-A	Tokay Blvd & S Segoe Rd	7	3,500	3
Fire 8-A	Old Sauk Rd & N High Point Rd	8	3,500	3
Fire 9-A	Pinelake Dr & Maple Grove Dr	9	3,500	3
Fire 10-A	Mineral Point Rd & South Point Rd	10	3,500	3

Figure 6-4 – Assumed Fire Event Location for Fire EPS Scenarios



6.4.3 Additional Water System Assessment Tools

In addition to the evaluation methods noted above, additional considerations for evaluating system facilities were utilized. Through the use of the facility risk review, additional characteristics were cataloged related to each facilities water quality, facility condition and other system needs that may not be immediately evident solely from a hydraulic perspective.

6.5 Mass Balance – Water Supply & Storage Capacity Analyses

A mass balance analysis was completed for supply capacity for each region of the water system. Likewise, a mass balance analysis was completed for storage and pumping capacity for each pressure zone in the water system. The following text reviews the criteria for each of these mass balance analyses as a precursor to the various analyses completed later in this chapter.

6.5.1 Required Water Supply Capacity

Based on Chapter 2 and discussion with MWU, each hydraulic region shall have adequate water supply from a combination of supply wells and/or inter-region pumping capacity to meet the following requirements:

1. The 12-hour capacity of all supply sources into the region shall meet or exceed the average day demand for the region, and;
2. The greater of the following two criteria:
    a. The total capacity of all supply sources into the region shall be equal to or greater than 115 percent of the maximum day demand for the region, or
    b. The firm capacity of all supply sources into the region, defined as the largest unit offline (two units for Zones 6w and 6e), shall meet or exceed the maximum day demand for the region.
3. If a region or pressure zone is relying on inter-zone water transfer pumping to meet supply capacity, firm pumping capacity shall meet the supply criteria noted in 1, 2a and 2b above (each pressure zone must be capable of satisfying maximum day demand with the largest pumping unit offline defined as either the largest unit well or booster pump serving the zone).

6.5.2 Desired Level of Service for Storage

Each pressure zone shall have at least one gravity fed storage tank for supply reliability and a free surface point within the zone. Based on Chapter 2 and discussion with MWU, total storage capacity within each pressure zone shall be equal to or greater than the sum of the following:

1. 12 hours of average day demand (emergency storage), plus
2. Maximum day equalization storage, plus
3. Fire protection storage.

In addition to gravity fed water storage tanks, only ground level water storage facilities with backup power generation available were considered in the calculations for available water storage. Since a portion of the water stored is to satisfy emergency events, such as a power, emergency generation capacity would be required to make the water available to the system during a power outage.

The design criteria listed above provide a reasonable degree of redundancy and operational reliability for the Madison water system. Each pressure zone and hydraulic region is evaluated as separate entities thereby building reliability into the system.

6.5.3 System-wide design Criteria Summary

The following system-wide design criteria itemized in Chapter 2, will guide the evaluation of the hydraulics of the Madison distribution system:

1. **System-wide** supply shall meet maximum day demand with three wells offline.
2. Supply & inter-zone firm pumping capacity into each **region** shall meet the region's maximum day demand with one well offline in Region B & D and two wells offline in Regions A & C (firm capacity), not exceeding three wells offline system-wide at a time.
3. Wherever inter-zone transfer is required to meet projected water demands for a given pressure zone, the zone shall be evaluated using firm pumping capacity to ensure the zone has sufficient surplus capacity to reliably deliver to the receiving zone. Design criteria for average day and maximum day supply noted above shall be used to evaluate inter-zone transfer capacity.
4. Storage for each pressure zone shall meet the prescribed design guideline criteria.

The system will be evaluated in two parts, east side and west side. The east side shall consist of Regions A and B. The west side shall consist of Regions C and D. A total of three wells will be off line during evaluation of each side of the system. The assumption of three wells offline system-wide at any time due to maintenance activities and equipment breakdown is a reasonable assumption and has occurred in the past.

The following subsections align the mass balances analyses with the goals of Chapter 2. The schematic analyses later in Chapter 6 and in Chapter 7 will evaluate the system against the new criteria using the distribution system computer model.

6.5.4 Regional Well Supply Capacity Analysis

This section examines the supply capacity of each defined service region. Regional supply analyses assume water may freely move between pressure zones within each hydraulic region. In reality, inter-zone pumping stations limit how water may move between these zones. The purpose of the regional supply capacity analysis is to determine if supply deficiencies exist or will exist in the four regions regardless of inter-zone pumping capacity. Water supply capacity must be available, then the water may be transferred from one zone to the next. Inter-zone pumping will be evaluated as part of a separate analysis.

The existing well supply capacity for MWU is summarized in in Table 6-3 below. Additionally, Appendix 6C contains a more detailed summary of existing zone and regional supply capacity. This section analyzes the capabilities of the existing regional water supply sources to sustain future water system demand projections as set forth in Chapter 3 for the “medium population growth with improved conservation” water needs demand projection.

Table 6-3 – Regional Supply Capacity

Side	Region	Pressure Zone	Well Number	Well Capacity (gpm)	24-Hour Capacity (mgd)
East	A	6e	7	2,100	3.0
			8	1,650	2.4
			11	2,100	3.0
			13	2,100	3.0
			15	2,100	3.0
			23	-	
			29	1,100	1.6
		3	25	2,100	3.0
		Region A Firm Capacity		**9,050**	**13.0**
	B	4	9	1,700	2.4
			31	2,100	3.0
		Region B Firm Capacity		1,700	2.4
East Side Firm Capacity				**10,750**	**15.5**
West	C	6w	6	2,100	3.0
			14	2,100	3.0
			17	2,100	3.0
			18	2,200	3.2
			19	2,100	3.0
			24	2,100	3.0
			27	2,100	3.0
			30	2,100	3.0
		7	12	2,100	3.0
			20	2,000	2.9
		Region C Firm Capacity		**16,700**	**24.0**
	D	8	16	2,100	3.0
			26	2,200	3.2
			28	2,100	3.0
		Region D Firm Capacity		**4,200**	**6.0**
West Side Firm Capacity				**6,300**	**9.1**

6.5.4.2 Region A (Pressure Zones 3, 5 & 6e) – Well Supply Analysis

Region A of the water system includes Pressure Zones 3, 5 & 6e. This analysis will test Region A to see if it has sufficient supply capacity to support these three pressure zones according to the goals of Chapter 2. Table 6-4 analyzes the 12-hour capacity, total capacity and firm capacity of Region A.

As will be with the analysis of all of the regions, Table 6-4 assumes water is able to fully and freely move within the region in order to provide a baseline for supply capacity. Values shown below may not be the final determination for supply needs, as future sections will consider the inter-zone pumping capacity between pressure zones as well as between regions.

Table 6-4 – Well Supply Capacity Analysis for Region A

Supply Capacity Analysis	Design Year				
	2020	2025	2030	2035	2040
Condition 1 - Average Day Capacity					
Average Day Demand (mgd)[2]	9.4	9.6	9.8	10.0	10.2
Existing 12-Hour Pumping Capacity (mgd)[3]	11.1				
12-Hour Capacity Mass Balance (mgd)[4]	1.7	1.5	1.3	1.1	0.9
Condition 2a - Maximum Day Capacity					
Maximum Day Demand (mgd)[1]	15.8	16.5	17.1	17.6	18.2
Existing Firm Supply Capacity (mgd)[3]	13.0				
Firm Capacity Mass Balance (mgd)[4]	**-2.8**	**-3.5**	**-4.1**	**-4.6**	**-5.2**
Condition 2b - 115 % Maximum Day Capacity					
115 % Maximum Day Demand (mgd)	18.2	18.9	19.6	20.3	21.0
Existing Total Pumping Capacity (mgd)[3]	19.0				
115 % Max Day Capacity Mass Balance (mgd)[4]	0.8	0.1	-0.6	-1.3	-2.0

[1] See Appendix 3-F
[2] See Appendix 3-E.
[3] See Appendix 5-B. Unit Well 23 assumed to be abandoned in the near term.
[4] Positive numbers equals the potential pumping capacity surplus. Negative numbers equal the pumping capacity deficit.

6.5.4.3 Region B (Pressure Zone 4) – Well Supply Analysis

Region B of the water system contains only Pressure Zone 4. The analysis below tests if Region B has sufficient supply capacity to meet the established level of service itemized in Chapter 2.

Table 6-5 – Well Supply Capacity Analysis for Region B

Supply Capacity Analysis	Design Year				
	2020	2025	2030	2035	2040
Condition 1 - Average Day Capacity					
Average Day Demand (mgd)[2]	1.5	1.6	1.6	1.7	1.7
Existing 12-Hour Pumping Capacity (mgd)[3]	2.7				
12-Hour Capacity Mass Balance (mgd)[4]	**1.2**	**1.1**	**1.1**	**1.0**	**1.0**
Condition 2a - Maximum Day Capacity					
Maximum Day Demand (mgd)[1]	2.7	2.9	3.0	3.2	3.4
Existing Firm Supply Capacity (mgd)[3]	2.4				
Firm Capacity Mass Balance (mgd)[4]	**-0.3**	**-0.5**	**-0.6**	**-0.8**	**-1.0**
Condition 2b - 115 % Maximum Day Capacity					
115 % Maximum Day Demand (mgd)	3.1	3.3	3.5	3.7	3.9
Existing Total Pumping Capacity (mgd)[3]	5.4				
115 % Max Day Capacity Mass Balance (mgd)[4]	**2.3**	**2.1**	**1.9**	**1.7**	**1.5**

[1] See Appendix 3-F
[2] See Appendix 3-E.
[3] See Appendix 5-B.
[4] Positive numbers equals the potential pumping capacity surplus. Negative numbers equal the pumping capacity deficit.

By the year 2040, Region B is anticipated to have a **supply deficit of 1.0 mgd** based on the firm supply capacity requirement. Additional analyses later in Chapter 7 will determine if inter-zone pumping of water may be an option to satisfy the 2040 supply deficit.

6.5.4.4 Region C (Pressure Zones 6w, 7 & 9) – Well Supply Analysis

Region C of the water system contains Zones 6w, 7 & 9. By 2040, Region C is anticipated to have a **supply deficit of 0.6 mgd** by the year 2040 based on the firm supply capacity requirement.

Table 6-6 – Well Supply Capacity Analysis for Region C

Supply Capacity Analysis	Design Year				
	2020	2025	2030	2035	2040
Condition 1 - Average Day Capacity					
Average Day Demand (mgd)[2]	13.8	13.9	13.9	13.9	13.9
Existing 12-Hour Pumping Capacity (mgd)[3]	15.0				
12-Hour Capacity Mass Balance (mgd)[4]	**1.2**	**1.1**	**1.1**	**1.1**	**1.1**
Condition 2a - Maximum Day Capacity					
Maximum Day Demand (mgd)[1]	23.2	23.6	23.9	24.2	24.5
Existing Firm Supply Capacity (mgd)[3]	23.9				
Firm Capacity Mass Balance (mgd)[4]	**0.7**	**0.3**	**0.0**	**-0.3**	**-0.6**
Condition 2b - 115 % Maximum Day Capacity					
115 % Maximum Day Demand (mgd)	26.7	27.1	27.5	27.8	28.2
Existing Total Pumping Capacity (mgd)[3]	30.1				
115 % Max Day Capacity Mass Balance (mgd)[4]	**3.4**	**3.0**	**2.6**	**2.3**	**1.9**

1 See Appendix 3-F
2 See Appendix 3-E.
3 See Appendix 5-B.
4 Positive numbers equals the potential pumping capacity surplus. Negative numbers equal the pumping capacity deficit.

6.5.4.5 Region D (Pressure Zones 8 & 10) – Well Supply Analysis

Region D of the water system contains Zones 8 & 10.

Table 6-7 – Well Supply Capacity Analysis for Region D

Supply Capacity Analysis	Design Year				
	2020	2025	2030	2035	2040
Condition 1 - Average Day Capacity					
Average Day Demand (mgd)[2]	4.5	4.7	4.8	5.0	5.1
Existing 12-Hour Pumping Capacity (mgd)[3]	4.6				
12-Hour Capacity Mass Balance (mgd)[4]	0.1	-0.1	-0.2	-0.4	-0.5
Condition 2a - Maximum Day Capacity					
Maximum Day Demand (mgd)[1]	10.1	10.8	11.5	12.2	12.9
Existing Firm Supply Capacity (mgd)[3]	6.0				
Firm Capacity Mass Balance (mgd)[4]	**-4.1**	**-4.8**	**-5.5**	**-6.2**	**-6.9**
Condition 2b - 115 % Maximum Day Capacity					
115 % Maximum Day Demand (mgd)	11.6	12.4	13.2	14.0	14.8
Existing Total Pumping Capacity (mgd)[3]	9.2				
115 % Max Day Capacity Mass Balance (mgd)[4]	-2.4	-3.2	-4.0	-4.8	-5.6

[1] See Appendix 3-F
[2] See Appendix 3-E.
[3] See Appendix 5-B.
[4] Positive numbers equals the potential pumping capacity surplus. Negative numbers equal the pumping capacity deficit.

By 2040, Region D is anticipated to have a deficit of between 0.5 to 6.9 million gallons per day.

6.5.4.6 East Side Summary (Region A & B)

The previous analysis evaluated each hydraulic region independently, however it may be possible to transfer water between regions in some instances. As a result each side of the water system can be analyzed from a total supply capacity perspective. The east side, defined as everything east of the Yahara River, of the water system contains Region A and Region B.

This section will analyze the east side to see if it has sufficient supply capacity to support these two regions (containing four pressure zones) according to the goals of Chapter 2. Table 6-8 analyzes the 12-hour capacity, total capacity and firm capacity of the east side.

Table 6-8 – Well Supply Capacity Analysis for East Side

Supply Capacity Analysis	Design Year				
	2020	2025	2030	2035	2040
Condition 1 - Average Day Capacity					
Average Day Demand (mgd)[2]	10.9	11.2	11.5	11.7	12.0
Existing 12-Hour Pumping Capacity (mgd)[3]	13.8				
12-Hour Capacity Mass Balance (mgd)[4]	**2.9**	**2.6**	**2.3**	**2.1**	**1.8**
Condition 2a - Maximum Day Capacity					
Maximum Day Demand (mgd)[1]	18.5	19.3	20.1	20.9	21.6
Existing Firm Supply Capacity (mgd)[3]	15.4				
Firm Capacity Mass Balance (mgd)[4]	**-3.1**	**-3.9**	**-4.7**	**-5.5**	**-6.2**
Condition 2b - 115 % Maximum Day Capacity					
115 % Maximum Day Demand (mgd)	21.3	22.2	23.1	24.0	24.9
Existing Total Pumping Capacity (mgd)[3]	24.4				
115 % Max Day Capacity Mass Balance (mgd)[4]	**3.1**	**2.2**	**1.3**	**0.4**	**-0.5**

[1] See Appendix 3-F
[2] See Appendix 3-E.
[3] See Appendix 5-B.
[4] Positive numbers equals the potential pumping capacity surplus. Negative numbers equal the pumping capacity deficit.

By 2040, the east side is anticipated to have a maximum **supply deficit of 6.2 mgd** based on the firm supply capacity requirement.

6.5.4.7 West Side Summary (Region C & D)

The west side, defined as everything west of the Yahara River, of the water system contains Region C and Region D. This section will analyze the west side to see if it has sufficient supply capacity to support these two regions containing four pressure zones according to the goals of Chapter 2. Table 6-9 analyzes the 12-hour capacity, total capacity and firm capacity of the west side.

Table 6-9 – Well Supply Capacity Analysis for West Side

Supply Capacity Analysis	Design Year				
	2020	2025	2030	2035	2040
Condition 1 - Average Day Capacity					
Average Day Demand (mgd)[2]	18.3	18.5	18.7	18.9	19.0
Existing 12-Hour Pumping Capacity (mgd)[3]	19.6				
12-Hour Capacity Mass Balance (mgd)[4]	**1.3**	**1.1**	**0.9**	**0.7**	**0.6**
Condition 2a - Maximum Day Capacity					
Maximum Day Demand (mgd)[1]	33.3	34.4	35.4	36.4	37.4
Existing Firm Supply Capacity (mgd)[3]	29.9				
Firm Capacity Mass Balance (mgd)[4]	**-3.4**	**-4.5**	**-5.5**	**-6.5**	**-7.5**
Condition 2b - 115 % Maximum Day Capacity					
115 % Maximum Day Demand (mgd)	38.3	39.5	40.7	41.8	43.0
Existing Total Pumping Capacity (mgd)[3]	39.3				
115 % Max Day Capacity Mass Balance (mgd)[4]	**1.0**	**-0.2**	**-1.4**	**-2.5**	**-3.7**

1 See Appendix 3-F
2 See Appendix 3-E.
3 See Appendix 5-B.
4 Positive numbers equals the potential pumping capacity surplus. Negative numbers equal the pumping capacity deficit.

By 2040, the west side is anticipated to have a maximum supply deficit of **7.5 mgd** based on the firm supply capacity requirement.

6.5.4.8 Summary of Firm Well Supply Capacity Deficiencies

Table 6-10 summarizes the deficiencies identified from the mass balance supply capacity analysis developed for each region in Section 6.2.2. This mass balance relies on the assumption that the system has the hydraulic capacity to move water from an area of excess to an area of need. As a result, the east side analysis below assumes wells offline on the east side of the water system to test firm capacity. As a result water may be available from the west side during a facility outage in the east. In a similar fashion, if an outage were to occur in the west (as shown in the west side analysis below) water may be available from the east. This assumption will be further tested when computer analysis is completed. Depending on the hydraulic modeling of the system, more or fewer supply sources may be required depending on planned transfer of water and the sustainability of system pressures.

Table 6-10 – Regional Supply Mass Balance Summary

Condition		Service Area	2020 Mass Balance (mgd)	2040 Mass Balance (mgd)
East Side Analysis	UW 13, UW 25 & UW 31 Offline	Region A	-2.8	-5.2
		Region B	-0.3	-1.0
		East Side Total	**-3.1**	**-6.2**
		Region C	6.9	5.6
		Region D	-0.9	-3.7
		West Side Surplus Total	**6.0**	**1.9**
West Side Analysis	UW 12, UW 18 & UW 26 Offline	Region A	3.2	0.8
		Region B	2.7	2.0
		East Side Surplus Total	**5.9**	**2.8**
		Region C	0.7	-0.6
		Region D	-4.1	-6.9
		West Side Total	**-3.4**	**-7.5**

Table 6-11 – Summary of Supply Deficiencies

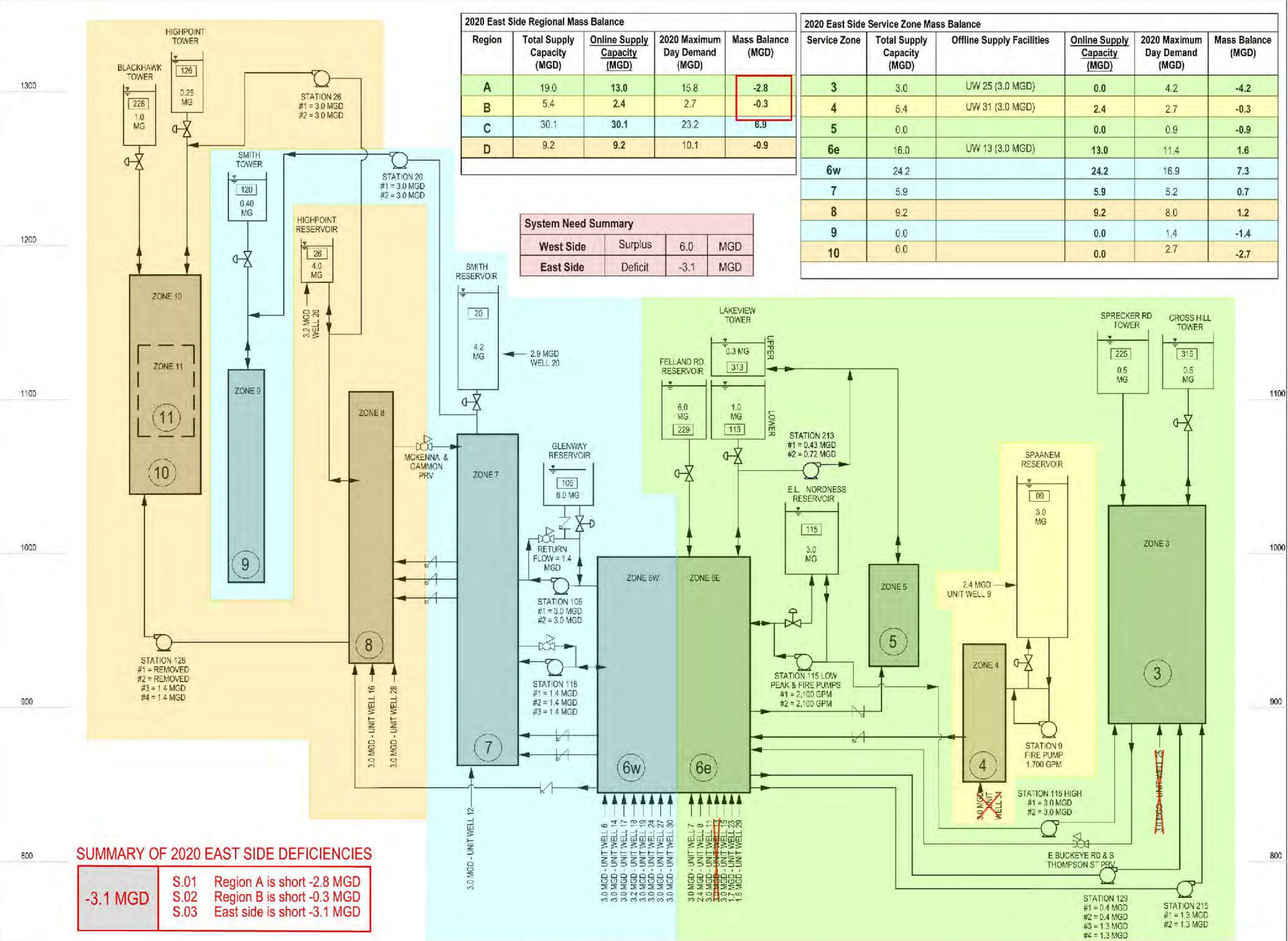
Deficiency ID	Region	Zone(s)	2020 Supply Deficiency (mgd)	2040 Supply Deficiency (mgd)
S.01	Region A	6e, 5, 3	-2.8	-5.2
S.02	Region B	4	-0.3	-1.0
S.03	East Side	6e, 5, 3, 4	-3.1	-6.2
S.04	Region C	6w,7,9	-	-0.6
S.05	Region D	8,10	-4.1	-6.9
S.06	West side	6w,7,9,8,10	-3.4	-7.5

The information summarized in the tables above provide an overview of expected water supply deficiencies through the 2040 planning period. The alternatives to remedy these deficiencies are described and analyzed as part of Chapter 7. The computer model analysis will determine the effectiveness of the existing unit well facilities and whether location and capacities of existing unit wells are adequate, based on hydraulic limitations in addition to water system volume mass balance

2020 East Side Regional Mass Balance				
Region	Total Supply Capacity (MGD)	Online Supply Capacity (MGD)	2020 Maximum Day Demand (MGD)	Mass Balance (MGD)
A	19.0	13.0	15.8	-2.8
B	5.4	2.4	2.7	-0.3
C	30.1	30.1	23.2	6.9
D	9.2	9.2	10.1	-0.9

2020 East Side Service Zone Mass Balance					
Service Zone	Total Supply Capacity (MGD)	Offline Supply Facilities	Online Supply Capacity (MGD)	2020 Maximum Day Demand (MGD)	Mass Balance (MGD)
3	3.0	UW 25 (3.0 MGD)	0.0	4.2	-4.2
4	5.4	UW 31 (3.0 MGD)	2.4	2.7	-0.3
5	0.0		0.0	0.9	-0.9
6e	16.0	UW 13 (3.0 MGD)	13.0	11.4	1.6
6w	24.2		24.2	16.9	7.3
7	5.9		5.9	5.2	0.7
8	9.2		9.2	8.0	1.2
9	0.0		0.0	1.4	-1.4
10	0.0		0.0	2.7	-2.7

System Need Summary			
West Side	Surplus	6.0	MGD
East Side	Deficit	-3.1	MGD



SUMMARY OF 2020 EAST SIDE DEFICIENCIES

-3.1 MGD	S.01	Region A is short -2.8 MGD
	S.02	Region B is short -0.3 MGD
	S.03	East side is short -3.1 MGD

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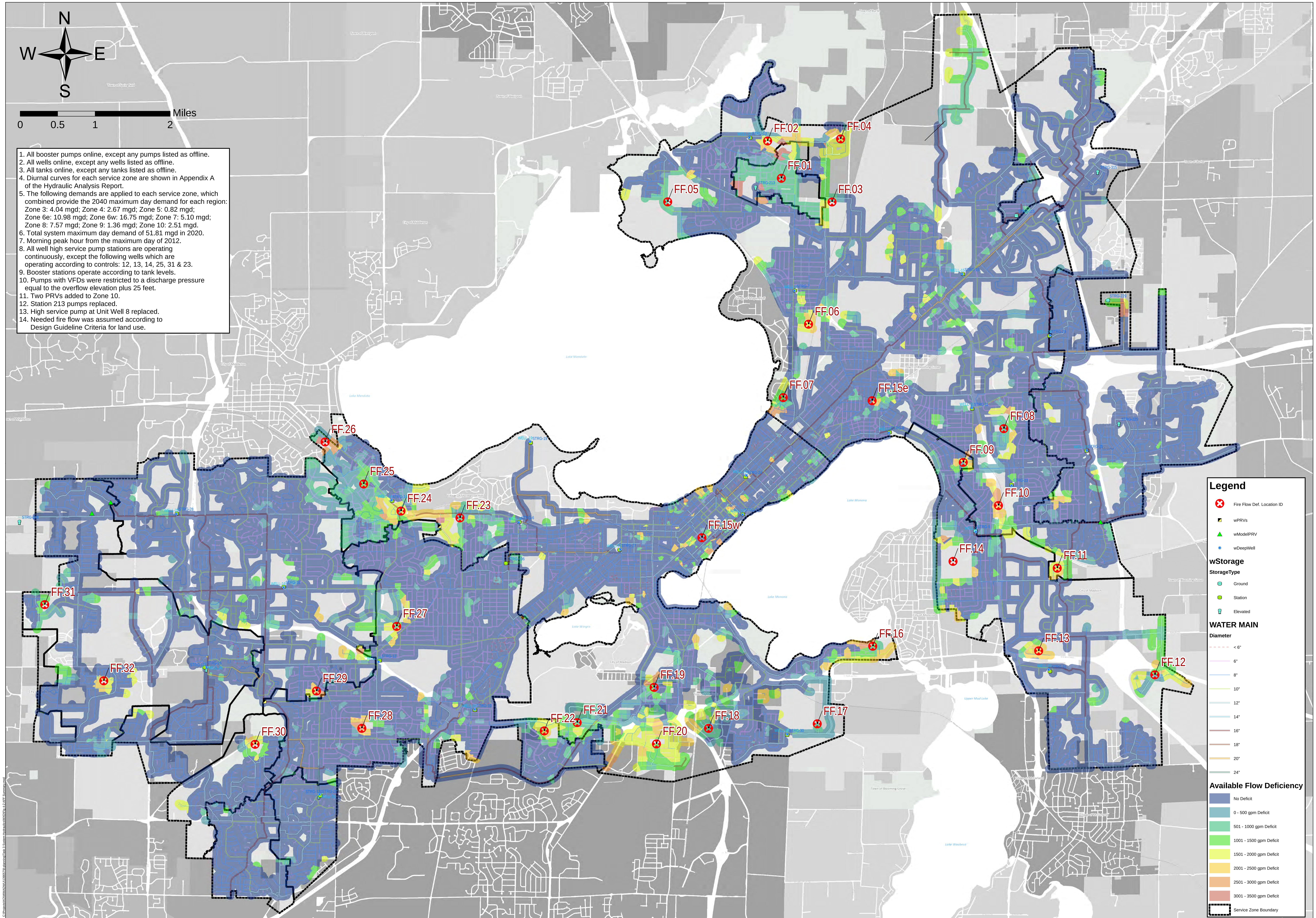
FIGURE 3-1
EAST SIDE - YEAR 2020 SUPPLY MASS BALANCE



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Map
6-5

2020 West Side Regional Mass Balance

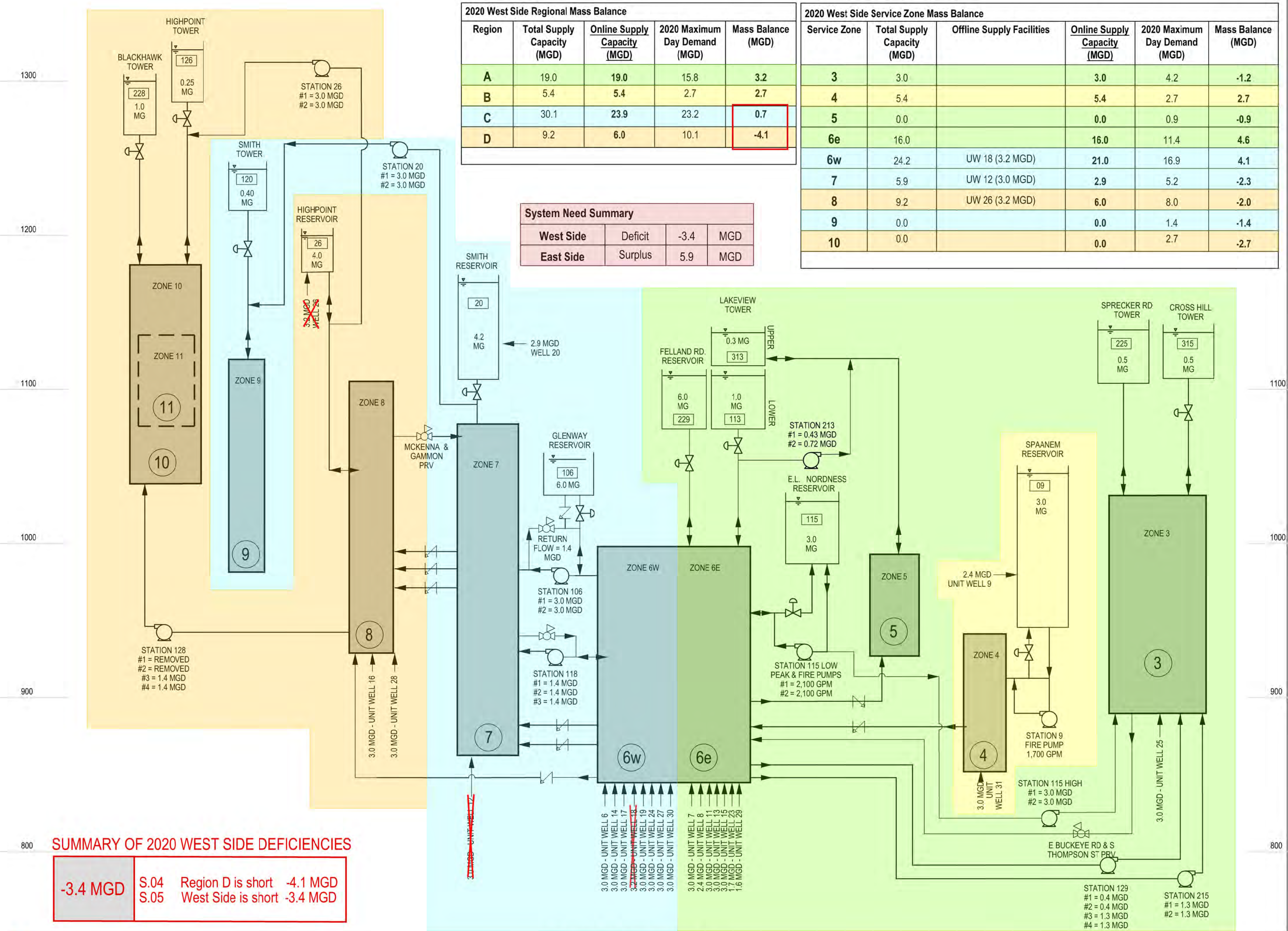
Region	Total Supply Capacity (MGD)	Online Supply Capacity (MGD)	2020 Maximum Day Demand (MGD)	Mass Balance (MGD)
A	19.0	19.0	15.8	3.2
B	5.4	5.4	2.7	2.7
C	30.1	23.9	23.2	0.7
D	9.2	6.0	10.1	-4.1

2020 West Side Service Zone Mass Balance

Service Zone	Total Supply Capacity (MGD)	Offline Supply Facilities	Online Supply Capacity (MGD)	2020 Maximum Day Demand (MGD)	Mass Balance (MGD)
3	3.0		3.0	4.2	-1.2
4	5.4		5.4	2.7	2.7
5	0.0		0.0	0.9	-0.9
6e	16.0		16.0	11.4	4.6
6w	24.2	UW 18 (3.2 MGD)	21.0	16.9	4.1
7	5.9	UW 12 (3.0 MGD)	2.9	5.2	-2.3
8	9.2	UW 26 (3.2 MGD)	6.0	8.0	-2.0
9	0.0		0.0	1.4	-1.4
10	0.0		0.0	2.7	-2.7

System Need Summary

West Side	Deficit	-3.4	MGD
East Side	Surplus	5.9	MGD



SUMMARY OF 2020 WEST SIDE DEFICIENCIES

-3.4 MGD	S.04	Region D is short	-4.1 MGD
	S.05	West Side is short	-3.4 MGD

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Figure 6-6
WEST SIDE - YEAR 2020 MASS BALANCE

2040 East Side Regional Mass Balance

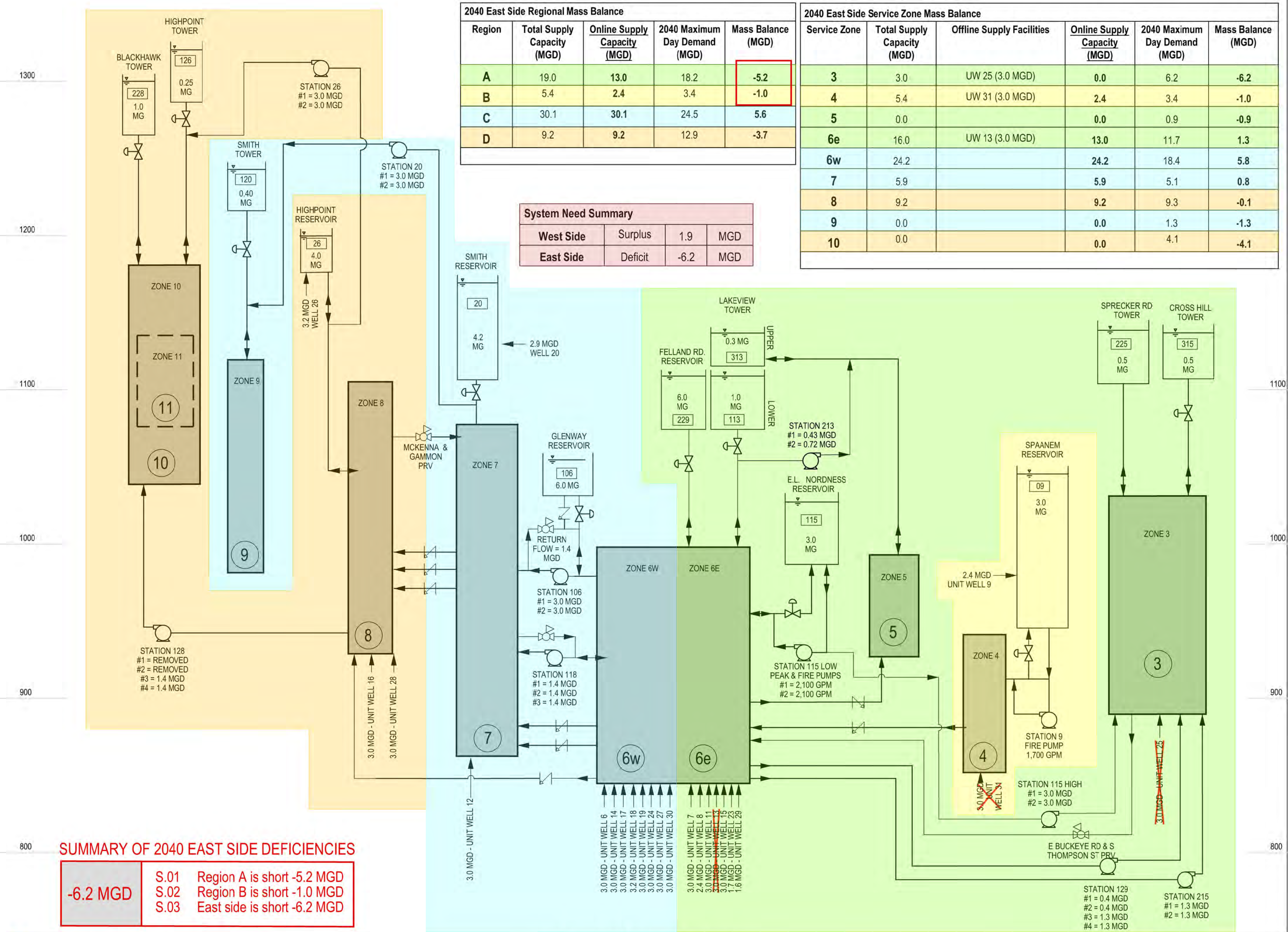
Region	Total Supply Capacity (MGD)	Online Supply Capacity (MGD)	2040 Maximum Day Demand (MGD)	Mass Balance (MGD)
A	19.0	13.0	18.2	-5.2
B	5.4	2.4	3.4	-1.0
C	30.1	30.1	24.5	5.6
D	9.2	9.2	12.9	-3.7

2040 East Side Service Zone Mass Balance

Service Zone	Total Supply Capacity (MGD)	Offline Supply Facilities	Online Supply Capacity (MGD)	2040 Maximum Day Demand (MGD)	Mass Balance (MGD)
3	3.0	UW 25 (3.0 MGD)	0.0	6.2	-6.2
4	5.4	UW 31 (3.0 MGD)	2.4	3.4	-1.0
5	0.0		0.0	0.9	-0.9
6e	16.0	UW 13 (3.0 MGD)	13.0	11.7	1.3
6w	24.2		24.2	18.4	5.8
7	5.9		5.9	5.1	0.8
8	9.2		9.2	9.3	-0.1
9	0.0		0.0	1.3	-1.3
10	0.0		0.0	4.1	-4.1

System Need Summary

West Side	Surplus	1.9	MGD
East Side	Deficit	-6.2	MGD



SUMMARY OF 2040 EAST SIDE DEFICIENCIES

-6.2 MGD	S.01	Region A is short -5.2 MGD
	S.02	Region B is short -1.0 MGD
	S.03	East side is short -6.2 MGD

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FIGURE 3-3
EAST SIDE - YEAR 2040 MASS BALANCE

2040 West Side Regional Mass Balance

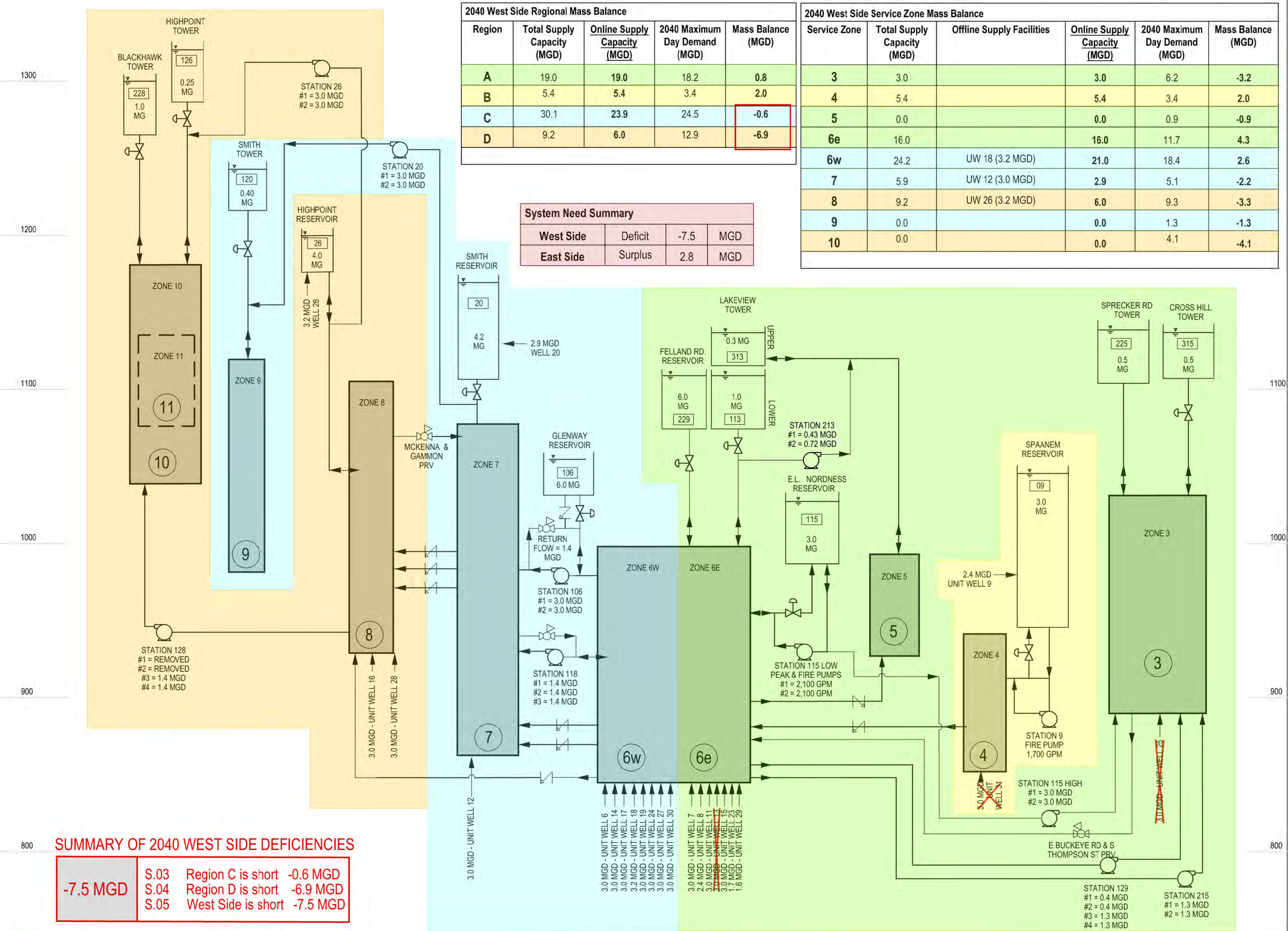
Region	Total Supply Capacity (MGD)	Online Supply Capacity (MGD)	2040 Maximum Day Demand (MGD)	Mass Balance (MGD)
A	19.0	19.0	18.2	0.8
B	5.4	5.4	3.4	2.0
C	30.1	23.9	24.5	-0.6
D	9.2	6.0	12.9	-6.9

2040 West Side Service Zone Mass Balance

Service Zone	Total Supply Capacity (MGD)	Offline Supply Facilities	Online Supply Capacity (MGD)	2040 Maximum Day Demand (MGD)	Mass Balance (MGD)
3	3.0		3.0	6.2	-3.2
4	5.4		5.4	3.4	2.0
5	0.0		0.0	0.9	-0.9
6e	16.0		16.0	11.7	4.3
6w	24.2	UW 18 (3.2 MGD)	21.0	18.4	2.6
7	5.9	UW 12 (3.0 MGD)	2.9	5.1	-2.2
8	9.2	UW 26 (3.2 MGD)	6.0	9.3	-3.3
9	0.0		0.0	1.3	-1.3
10	0.0		0.0	4.1	-4.1

System Need Summary

West Side	Deficit	-7.5	MGD
East Side	Surplus	2.8	MGD



SUMMARY OF 2040 WEST SIDE DEFICIENCIES

-7.5 MGD	S.03	Region C is short	-0.6 MGD
	S.04	Region D is short	-6.9 MGD
	S.05	West Side is short	-7.5 MGD

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FIGURE 3-4
WEST SIDE - YEAR 2040 MASS BALANCE