Chapter 5

SYSTEM ANALYSIS

5.1 Introduction

Carollo Engineers, Inc. (Carollo) evaluated the City of Tumwater's (City) water distribution system for its supply and pumping capacity, reliability, and redundancy, the capacity of its storage facilities, and for adequate pressure, velocity, and fire flow capacity using the City's updated hydraulic model under 2028 and 2038 future conditions using the medium demand projection scenario presented in Chapter 3.

This section discusses recommendations to eliminate each of the deficiencies identified as part of the system analysis for this Water System Plan (Plan). These recommendations form the basis of the City's Capital Improvement Program (CIP) outlined in Chapter 7. Figure 5.1 depicts a simplified hydraulic profile of the City's existing system. Figure 5.2 depicts the system with recommended supply, pumping, and storage improvements.

The pumping analysis found that the City has adequate booster pumping capacity in its "C" Street and Zone 4 booster pump stations (BPS) to meet its reliability and redundancy goals through 2038. The recommended supply improvements outlined in Chapter 4 allow the system to meet all of its pumping criteria throughout the planning period.

The storage analysis found that approximately 3 million gallons (MG) of additional storage is required in the 350 Zone to meet future standby storage needs. The City has purchased land in the southeastern corner of the water system where it plans to build a new storage reservoir. The 454 Zone was found to have a small storage deficit that can be eliminated by adjusting pump control settings in order to reduce the operational storage in the Mottman B Tank. The 549 Zone was also identified as having a storage deficit of 0.2 MG. It is recommended that the City perform an alternatives analysis to determine if additional storage or installation of a tank booster pump would be most beneficial and cost-effective for the system in order to address the storage deficit.

The distribution system analysis identified areas of high average day demand (ADD) pressures, high velocities during peak hour demand (PHD), and fire flow deficiencies during maximum day demand (MDD) using the City's hydraulic model. Pipe improvement projects are recommended to eliminate each of the deficiencies. The pipe improvement projects include upsizing existing pipe, looping water mains, and installing new pipe.

A high-level earthquake preparedness evaluation was performed as part of this Plan. The evaluation identified potential critical customers and facilities within the retail water service area (RWSA) that are the highest priority in the aftermath of an earthquake. A preliminary target recovery matrix was also created, which helps the City identify the types of recovery goals a water system would want and at what timeframe would that goal be 30, 60, and 90 percent complete, or operational after a Cascadian Subduction Zone (CSZ) seismic event. It is recommended that the City follow up with a more in-depth seismic resiliency study, which would provide a more in-depth assessment of the City's structures and distribution system.

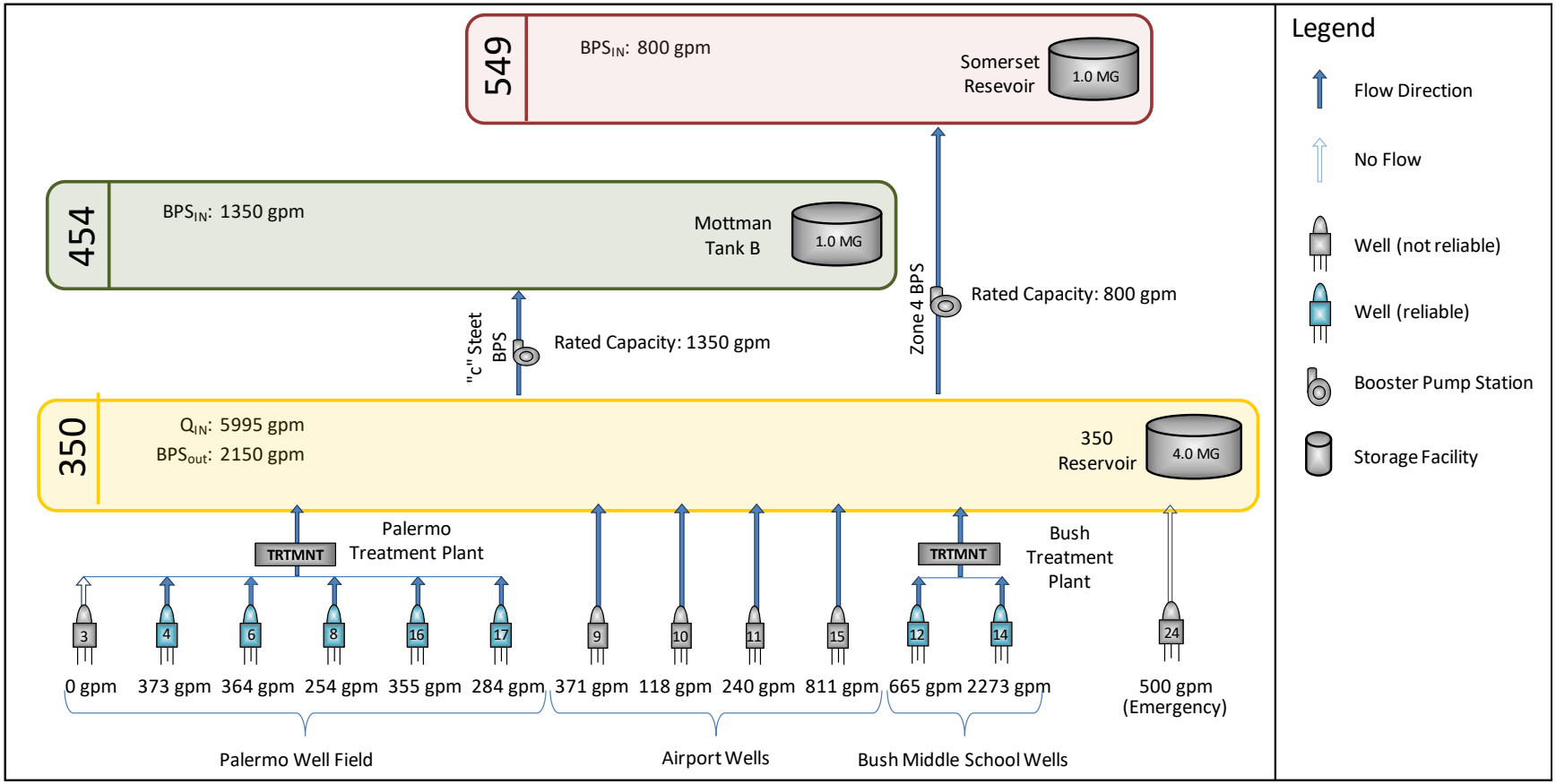

Figure 5.1 Existing Supply, Pumping, and Storage Configuration

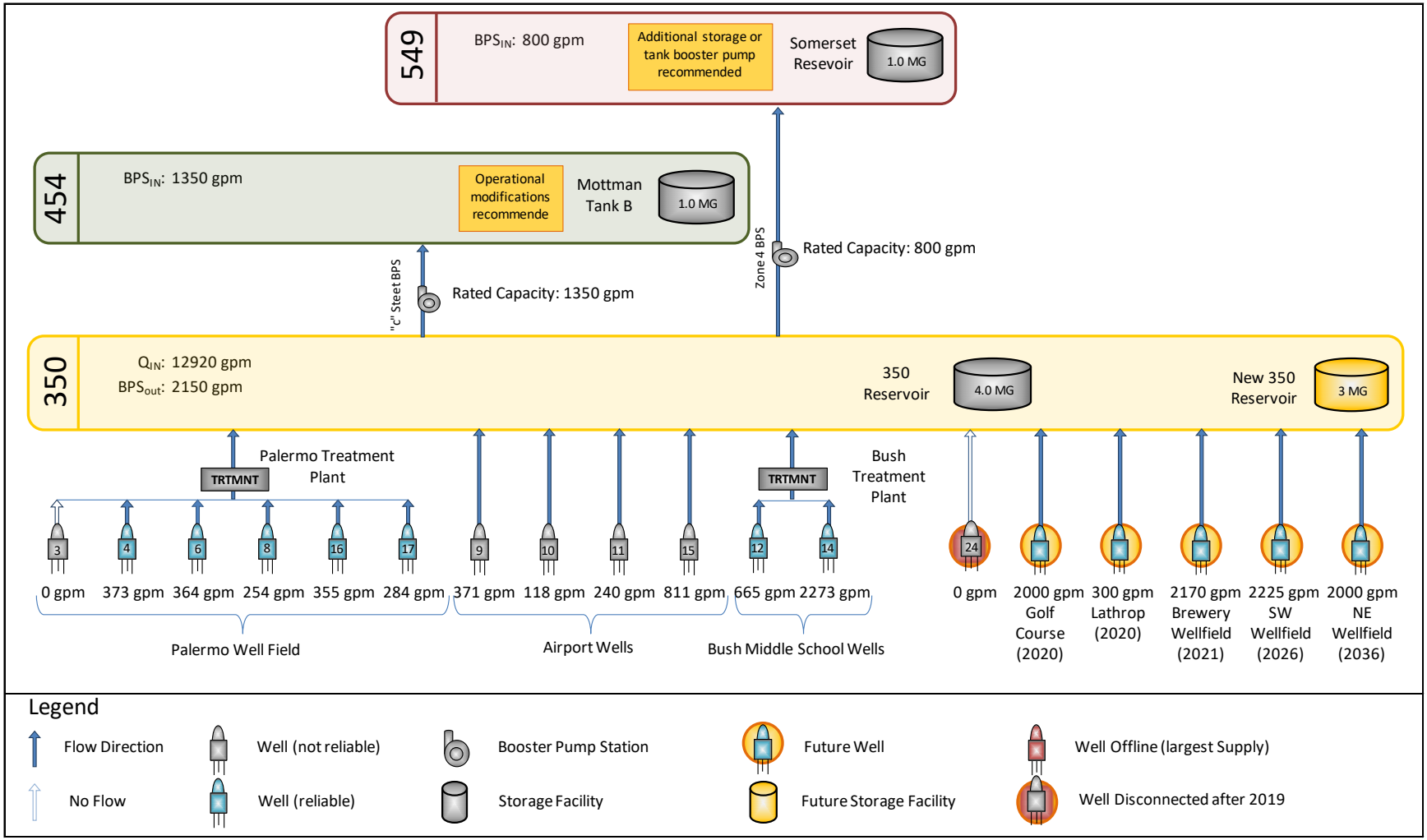

Figure 5.2 Recommended Future Supply, Pumping, and Storage Configuration

5.2 Pumping Analysis

5.2.1 Pumping Criteria

The capacity of pumping into each of the City's service areas was evaluated against the following criteria that are documented in Chapter 2:

1. **MDD Redundancy:** With the largest supply source out of service, the capacity of the system shall be sufficient to replenish depleted fire suppression storage within 72 hours while concurrently supplying MDD for the water system.
2. **BPS Redundancy:** BPS shall be capable of supplying MDD with the largest pump out of service.
3. **ADD Reliability:** The capacity of the source of supply, including wells and booster pump stations that have reliable back-up power shall be sufficient to meet ADD.

5.2.2 MDD Redundancy

The City's largest source is Well 14, which has a capacity of approximately 2,270 gallons per minute (gpm). With Well 14 out-of-service, the City has a well capacity of approximately 3,725 gpm. This firm capacity of the City's existing system cannot meet the future 2028 or 2038 MDD as shown in Table 5.1.

Figure 5.1 graphically shows the existing system's deficit in 2038. However, after implementing the supply improvements recommended in Chapter 4, the City will be able meet its MDD redundancy pumping criterion as shown in Table 5.2 and Figure 5.4. Well 14 will continue to be the City's largest supply source in the future. The remaining wells in the system will have adequate capacity to supply future MDD with Well 14 offline.

Table 5.1 MDD Redundancy Deficit with Existing System

Pressure Zone	350 Zone		454 Zone		549 Zone	
Planning Year	2028	2038	2028	2038	2028	2038
MDD + FSS(1) Requirement (gpm)	6,655	8,130	480	480	295	340
Firm Well Capacity (gpm)	3,725	3,725	0	0	0	0
BPS Capacity (gpm)	0	0	1,350	1,350	800	800
BPS_{IN} (gpm)(2)	0	0	480	480	295	340
BPS_{OUT} (gpm)(3)	775	820	0	0	0	0
Deficit (gpm)	**(3,705)**	**(5,225)**	**0**	**0**	**0**	**0**

Notes:
(1) FSS stands for fire suppression storage.
(2) BPS_{IN} represents the volume of booster pumping into the zone.
(3) BPS_{OUT} represents the volume of booster pumping out of the zone.

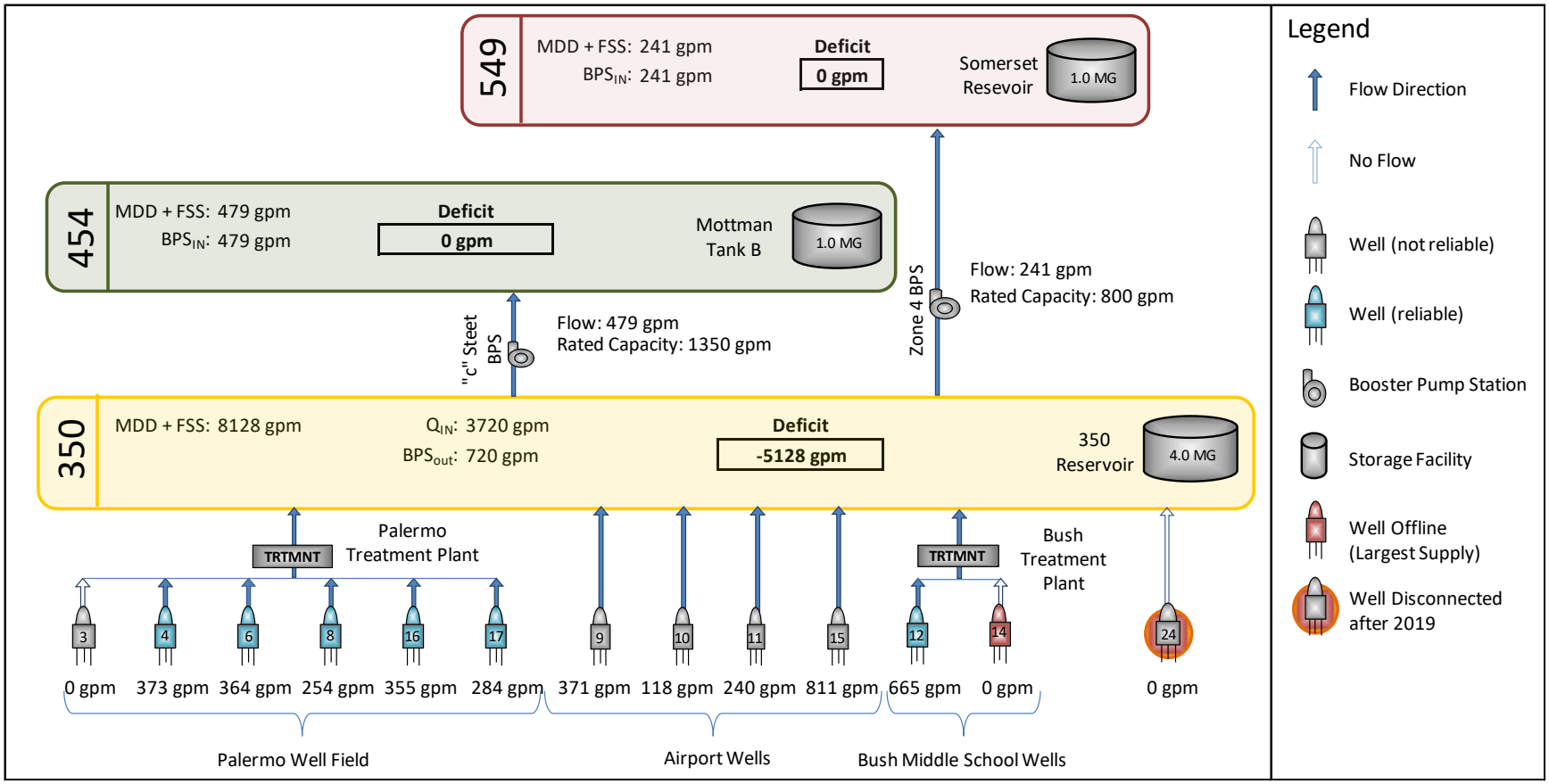

Figure 5.3 2038 MDD Redundancy Deficit with Existing System

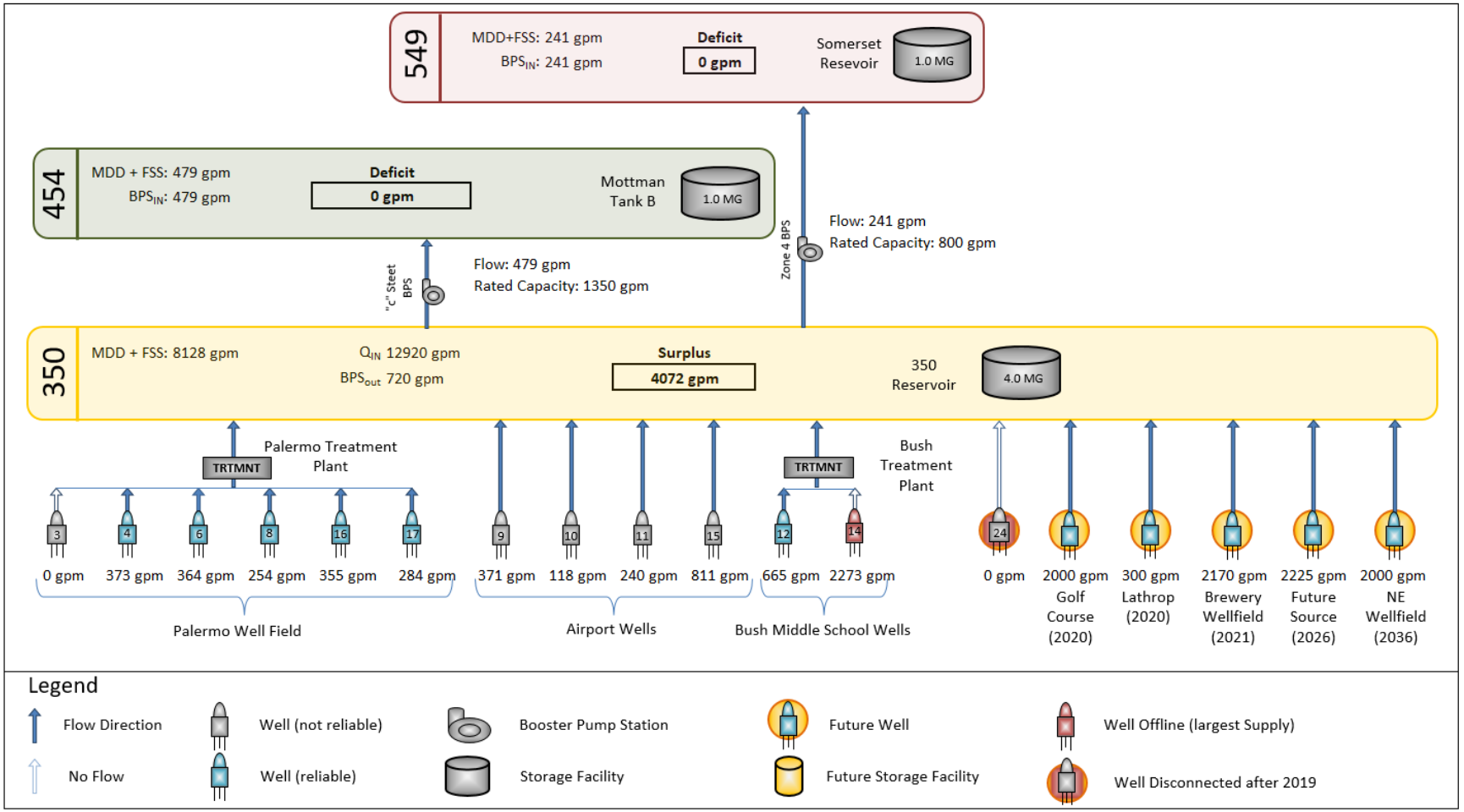

Figure 5.4 2038 MDD Redundancy with Recommended Supply Improvements

Table 5.2 MDD Redundancy Surplus with Recommended Supply Improvements

Pressure Zone	350 Zone		454 Zone		549 Zone	
Planning Year	2028	2038	2028	2038	2028	2038
MDD + FSS Requirement (gpm)	6,655	8,130	480	480	295	340
Firm Well Capacity (gpm)	10,920	12,920	0	0	0	0
BPS Capacity (gpm)	0	0	1,350	1,350	800	800
BPS_{IN} (gpm)	0	0	480	480	295	340
BPS_{OUT} (gpm)	775	820	0	0	0	0
Deficit (gpm)	**3,490**	**3,970**	**0**	**0**	**0**	**0**

5.2.3 BPS Redundancy

Both "C" Street BPS and Zone 4 BPS are capable of supplying 2038 MDD to their respective pressure zones with their largest pumps out of service as shown in Table 5.2 and Figure 5.5. The firm capacity of the "C" Street BPS is 900 gpm and the projected 2038 MDD of the 454 Zone is 335 gpm. The firm capacity of the Zone 4 BPS is 400 gpm, while 2038 MDD is only 195 gpm.

Table 5.3 BPS Redundancy Calculations

Pressure Zone	454 Zone		549 Zone	
Planning Year	2028	2038	2028	2038
MDD (gpm)	335	335	150	195
Firm BPS Capacity (gpm)	900	900	400	400
Surplus (gpm)	**565**	**565**	**250**	**205**

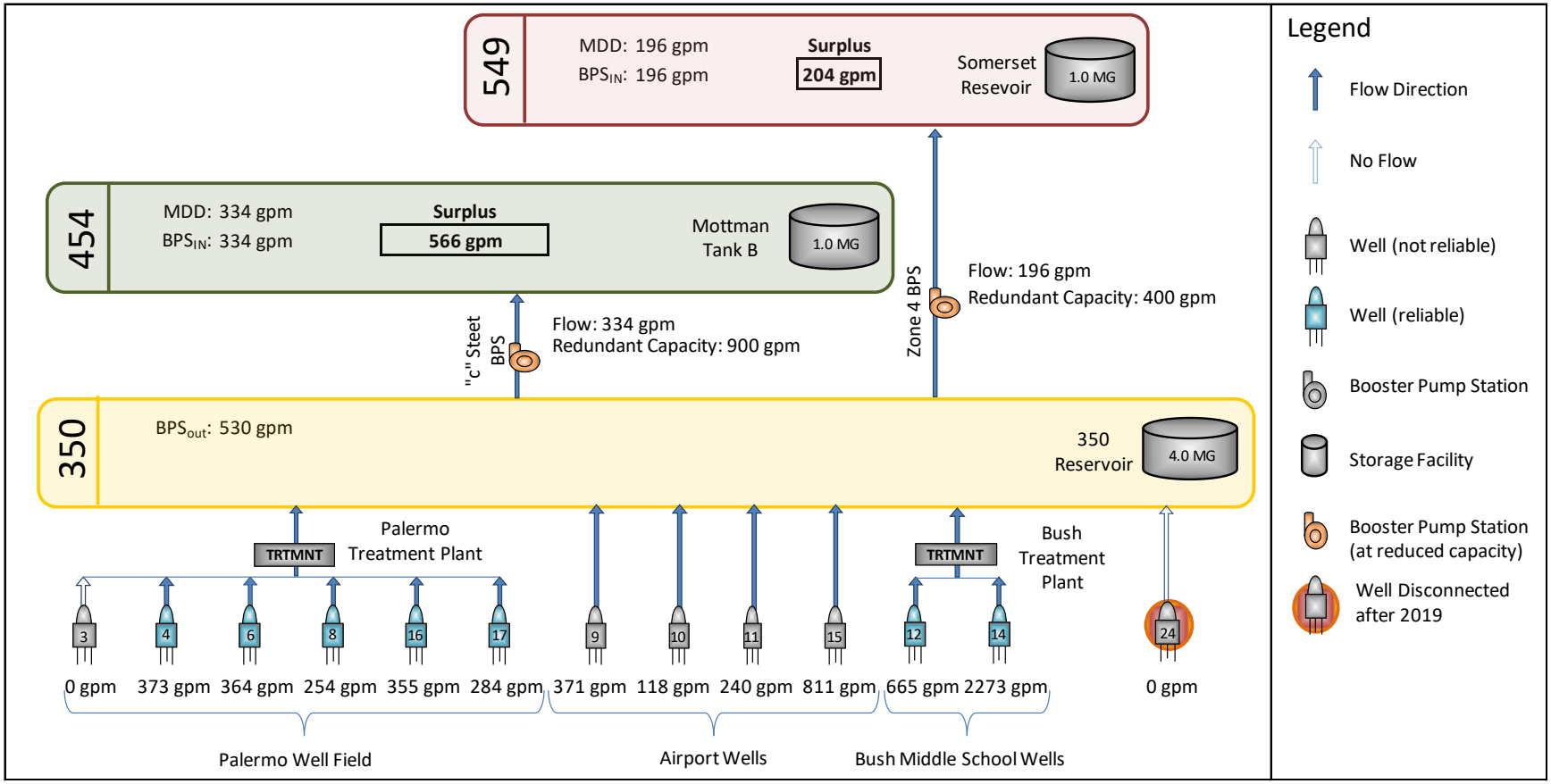

Figure 5.5 2038 BPS Redundancy with Existing System

5.2.4 ADD Reliability

Figure 5.6 shows that while the Airport wells are not considered reliable because they do not have back up power, the Palermo wells and Bush wells are reliable with a total reliable capacity of 4,455 gpm. The "C" Street BPS and Zone 4 BPS have reliable capacities of 450 gpm and 400 gpm, respectively. The reliable pumping capacity of the existing system can meet projected 2028 and 2038 ADD.

Table 5.4 ADD Reliability Calculations

Pressure Zone	350 Zone		454 Zone		549 Zone	
Planning Year	2028	2038	2028	2038	2028	2038
ADD (gpm)	3,125	3,840	160	160	75	95
Reliable Well Capacity (gpm)	4,455	4,455	0	0	0	0
Reliable BPS Capacity (gpm)	0	0	450	450	400	400
BPS_{IN} (gpm)	0	0	160	160	75	95
BPS_{OUT} (gpm)	235	255	0	0	0	0
Net Supply (gpm)(1)	4,220	4,200	160	160	75	95
Surplus (gpm)	**1,095**	**360**	**0**	**0**	**0**	**0**

Note:
(1) Net Supply = Reliable Well Capacity + BPS_{IN} - BPS_{OUT}.

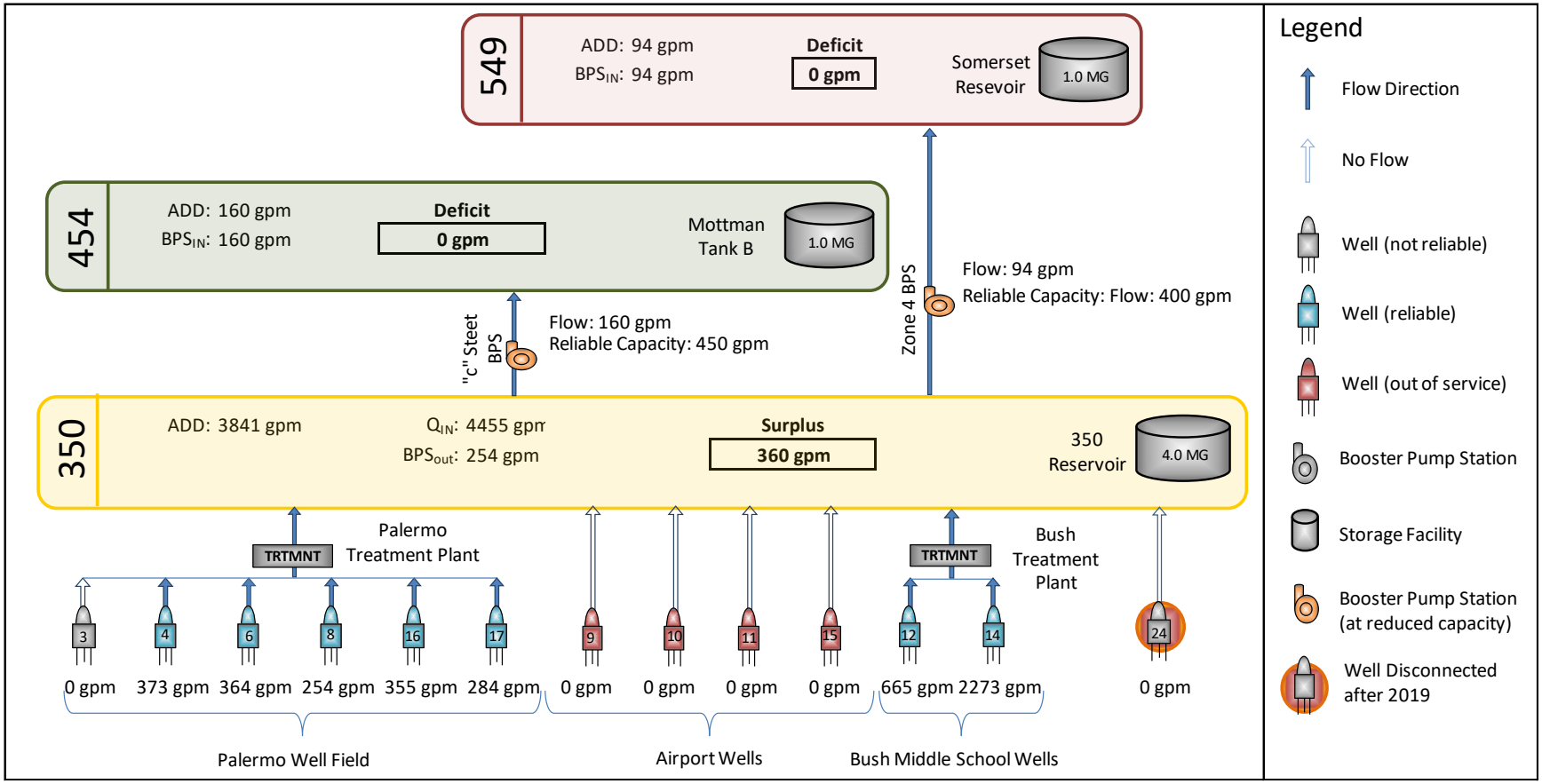

Figure 5.6 2038 ADD Reliability with Existing System

5.2.5 Pumping Recommendations

Beyond the supply recommendations outlined in Chapter 4, no other pumping improvements are required.

5.3 Storage Analysis

The City's storage system was evaluated based on their criteria described in Section 4. The City's storage requirements are dependent on the City's supply capacity, booster pump operation, water demands, fire flow requirements, and pressure requirements. The following sections summarize the available storage of the water system, describe the required storage components, and present recommendations to address identified storage deficits.

5.3.1 Storage Components and Governing Criteria

As described in Section 4, the five components of storage listed below and illustrated in Figure 5.5 must be considered for any water system:

1. Operational storage.
2. Equalizing storage.
3. Standby storage.
4. Fire Suppression storage.
5. Dead storage.

The Washington State Department of Health (DOH) requires that operational and equalizing storage are available to all customers at a residual pressure of at least 30 pounds per square inch (psi) under PHD flow conditions. Standby and fire suppression storage must be available to all customers at a residual pressure of at least 20 psi under MDD. City policy is to stack standby and fire suppression storage meaning that the City does not combine these two storage components. Each storage component is described in detail in Section 4. The following sections present the equations used to calculate each storage component.

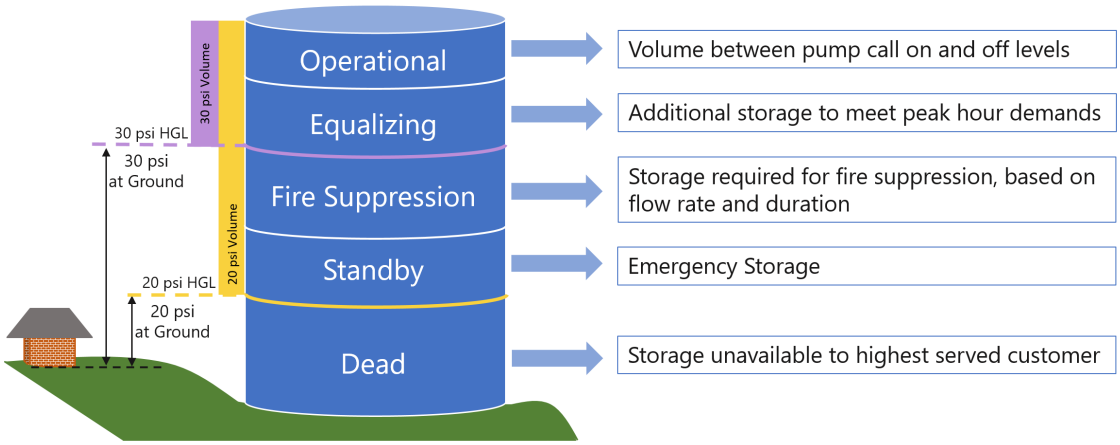

Figure 5.7 Storage Components

5.3.1.1 Operational Storage

The operational storage is based on the difference between the pump call on and off levels and the calculated equalizing storage for 2017. The operational storage is shown in Table 5.5. The equalizing storage for 2017 was calculated using the following equation from the DOH Water System Design Manual:

ES = (*PHD* – *MDD*)*150 minutes, but in no case less than zero

Where: *ES* = Equalizing storage component, in gallons

PHD = Peak hourly demand, in gpm

MDD = Maximum day demand, in gpm

PHD is also calculated using an equation from the DOH Water System Design Manual:

PHD = *MDD*/*N*(*C***N*+*F*) +18

Where: *N* = Number of Equivalent Residential Units (ERUs) served

C, *F* = Factors defined in DOH Water System Manual

The operational storage currently used in excess of the DOH-defined equalizing storage is representative of the daily system demands.

5.3.1.2 Equalizing Storage

Equalizing storage volume requirements are shown in Table 5.6 and were calculated using the equation outlined in Section 5.3.1.1.

5.3.1.3 Standby Storage

The City's standby storage policy is that the reservoirs in the water system should have enough standby storage to supply 116 gallons per ERU (gal/ERU). Standby storage requirement are shown in Table 5.7.

5.3.1.4 Fire Suppression Storage

The maximum fire flow requirements and durations for each service area are provided in Table 5.8.

5.3.2 Available Storage

The City's water system has three active storage tanks with a total capacity of 6 MG.

The available storage in each service area is controlled by the elevation of the highest customer in the system. The City's total available storage above the 20 psi hydraulic grade line (HGL) is 5.6 MG and the available storage above the 30 psi HGL is 3.6 MG. Table 5.9 shows the highest service elevation and the amount of available storage in each service area.

5.3.3 Required Storage

The operational, equalizing, fire suppression, and standby storage requirements are summarized in Table 5.9 for each service area and each planning year. The total required storage above the 30 psi HGL is the sum of operational and equalizing storage. The total required storage above the 20 psi HGL is the sum of operational, equalizing, fire suppression, and standby storage.

Analysis of the existing system shows that adequate available storage only exists in the 549 Zone to meet 2028 and 2038 demands. The 350 Zone has a deficit of 0.8 MG in 2028 and 2.0 MG by 2038. The 454 Zone has a 0.1 MG deficit in 2028 and 2038.

Table 5.5 Operational Storage Calculations

Pressure Zone	350 Zone	454 Zone	549 Zone
Facility	350 Reservoir	Mottman B Tank	Somerset Reservoir
Storage Capacity (gal)	4,000,000	1,000,000	1,000,000
Elevation of Overflow (ft)[1]	350	454	549
Base of Tank (ft)	320	421	421
Operating Band (ft)	8.5	10.0	12.8
Operating Band Volume (gal)	1,130,000	300,000	100,000
2017 DOH Equalizing Storage (gal)	410,200	40,900	25,100
Operational Volume (gal)	723,000	262,000	75,000
Percentage of Total Storage	18%	26%	7%

Note:
(1) ft: feet.

Table 5.6 Operational & Equalizing Storage Calculations

Pressure Zone	350 Zone		454 Zone		549 Zone	
Planning Year	2028	2038	2028	2038	2028	2038
ERUs	24,640	33,400	1,270	1,380	570	810
MDD (gpm)	6,510	7,985	335	335	150	195
PHD (gpm)	10,495	12,850	615	610	315	385
Required Equalizing Storage (gal)	598,000	730,000	42,000	41,000	25,000	29,000
Percentage of Total Storage	15%	18%	4%	4%	2%	3%

Note:
(1) DOH-defined variable.

Table 5.7 Standby Storage Calculations

Pressure Zone	350 Zone		454 Zone		549 Zone	
Planning Year	2028	2038	2028	2038	2028	2038
ERUs	24,640	33,400	1,270	1,380	570	810
Required Standby Storage (gal)	2,858,000	3,874,000	147,000	160,000	66,000	94,000
Percentage of Total Storage	71%	97%	15%	16%	10%	15%

Table 5.8 Fire Suppression Storage Requirements

Pressure Zone	Land Use of Largest Fire Flow Requirement in Zone	Fire Flow Requirement (gpm)	Fire Flow Duration (minutes)	Fire Suppression Storage Required (gal)
350 Zone	Industrial	3,500	180	630,000
454 Zone	Commercial	3,500	180	630,000
549 Zone	Tumwater Hill Elementary School	1,650	120	198,000

Table 5.9 Storage Analysis Results

Pressure Zone	350 Zone		454 Zone		549 Zone	
Planning Year	2028	2038	2028	2038	2028	2038
Available Storage (MG)						
Total Storage	4.00	4.00	1.00	1.00	1.00	1.00
Highest Service Elevation	262	262	364	364	420	420
Meeting 30 psi Requirement	2.49	2.49	0.63	0.63	0.47	0.47
Meeting 20 psi Requirement	4.00	4.00	1.00	1.00	0.65	0.65
Dead Storage	0.00	0.00	0.00	0.00	0.35	0.35
Required Storage Components (MG)						
Operational Storage	0.72	0.72	0.26	0.26	0.07	0.07
Equalizing Storage	0.60	0.73	0.04	0.04	0.03	0.03
Fire Suppression Storage	0.63	0.63	0.63	0.63	0.20	0.20
Standby Storage	2.86	3.87	0.15	0.16	0.07	0.09
Required Storage Components (MG)						
To meet 30 psi Requirement	1.32	1.45	0.30	0.30	0.10	0.10
To meet 20 psi Requirement	4.81	5.96	1.08	1.09	0.36	0.40
Storage Surplus / (Deficit) (MG)						
Meeting 30 psi Requirement	1.17	1.04	0.32	0.32	0.37	0.36
Meeting 20 psi Requirement	(0.81)	(1.96)	(0.08)	(0.09)	0.28	0.25
Overall Surplus/(Deficit)	**(0.81)**	**(1.96)**	**(0.08)**	**(0.09)**	**0.28**	**0.25**

5.3.4 Storage Recommendations

To address the 2028 storage deficit in the 350 Zone, the City plans to build a new storage tank in the southeast corner of the 350 Zone. The location of the storage tank in the extreme southeast corner of the zone will result in several feet of headloss as the tank supplies the system. Further analysis will need to be done to precisely size the tank. For planning purposes, it is assumed that a tank with a total capacity of approximately 3 MG will be necessary to include the operational storage needed to account for headloss.

To eliminate the 454 Zone storage deficit, it is recommended that the City modify the "C" Street BPS control setpoints in order to reduce the operational storage. This would be particularly helpful during the summer when equalizing storage is required. Adjusting the pump call-on setpoint to 28 feet from 23 feet would eliminate the 454 Zone storage deficit through 2038.

5.4 Limiting Capacity Analysis

The capacity of many water system components can be expressed as the number of ERUs that can be served. As described in Chapter 3, one ERU for the City's system consumes 205 gallons per day (gpd) on an average demand day. On a maximum day, an ERU consumes 425 gpd. These values do not include distribution system leakage.

To determine how many ERUs the City's sources and pump stations can serve on a maximum demand day, the supply to each pressure zone was divided by the MDD ERU value of 425 gpd. The MDD ERU value was also used to calculate the capacity of the City's equalizing storage in ERUs. The ERU capacity of standby storage was calculated by subtracting out each tank's equalizing storage, operational storage, and fire suppression storage under 2020 demand conditions from its total available storage capacity.

Table 5.10 lists the City's ERU projections for each pressure zone for the planning years for the purpose of comparison to the capacity of each existing system component and the limiting capacity of the existing system as a whole that is shown in Table 5.11. The capacity of the existing system is limited by the standby storage capacity.

The supply and storage improvements recommended in this Plan as shown in Figure 5.2 will increase the capacity of the water system sufficiently to meet the projected ERUs. This is demonstrated in Tables 5.12 and 5.13.

Table 5.10 ERU Projections

Planning Year	2020	2028	2038
350 Zone	17,060	24,640	33,400
454 Zone	1,130	1,270	1,380
549 Zone	490	570	810
Total	**18,680**	**26,470**	**35,590**

Table 5.11 Existing System Capacity in ERUs

Water System Component	350 Zone	454 Zone	549 Zone	System-wide	
				ADD	MDD
Sources	--	--	--	**30,250**	**27,100**
Treatment	--	--	--	35,710	
Pumping Capacity	27,100	4,570	2,710	27,100	
Equalizing Storage	32,950	7,830	7,090	47,820	
Standby Storage[1]	36,630	1,520	2,790	40,940	
Limiting Capacity[2]	**27,100**	**1,520**	**2,710**	27,100	
Tumwater ERU Values (gpd/ERU)				205	425

Note:
(1) Standby Storage available was calculated by subtracting 2020 required equalizing storage, operational storage, and fire suppressions storage from available storage above the 20 psi HGL.
(2) Analysis includes recently approved Golf Course Well Water Right Change and the planned new storage reservoir (design to start in 2021)

Table 5.12 2028 System Capacity in ERUs with Recommended Improvements

Water System Component	350 Zone	454 Zone	549 Zone	System-wide	
				ADD	MDD
Sources	--	--	--	**43,250**	**43,010**
Treatment	--	--	--	**51,630**	
Pumping Capacity	43,010	4,570	2,710	**43,010**	
Equalizing Storage	62,830	9,390	6,680	**78,900**	
Standby Storage(1)	35,390	1,520	2,790	**39,700**	
Limiting Capacity	**35,390**	**1,520**	**2,710**	**39,620**	
Tumwater ERU Values (gpd/ERU)				205	425

Note:
(1) Standby Storage available was calculated by subtracting 2038 required equalizing storage and operational storage from available storage above the 20 psi HGL.

Table 5.13 2038 System Capacity in ERUs with Recommended Improvements

Water System Component	350 Zone	454 Zone	549 Zone	System-wide	
				ADD	MDD
Sources	--	--	--	**52,830**	**49,790**
Treatment	--	--	--	**58,400**	
Pumping Capacity	49,790	4,570	2,710	**49,790**	
Equalizing Storage	67,060	9,390	6,680	**83,130**	
Standby Storage(1)	34,260	1,530	2,760	**38,550**	
Limiting Capacity	**34,260**	**1,530**	**2,710**	**38,500**	
Tumwater ERU Values (gpd/ERU)				205	425

Note:
(1) Standby Storage available was calculated by subtracting 2038 required equalizing storage and operational storage from available storage above the 20 psi HGL.

5.5 Hydraulic Model Update

The City's hydraulic model is the primary tool for evaluating the City's distribution system. The model evaluates how the City's water infrastructure handles future demands and verifies that recommended improvements will eliminate system deficiencies.

The City maintains the hydraulic model of their distribution system in *H20Net* by Innovyze. Carollo updated and calibrated the City's hydraulic model before performing the distribution system analysis. Information describing model update, calibration, and demand allocation is included in Appendix N.

5.5.1 Demand Allocation Process

Demands for planning years 2028 and 2038 from the medium demand projection scenario presented in Chapter 3 were allocated to the City's hydraulic model.

The demand projections were calculated based on number of accounts. These demands were converted to a demand per acre factor for each customer class and each pressure zone and then existing demands were allocated to parcels in a shapefile representing the City's existing customers. Then demand for each parcel was assigned to its closest model node. Demands for the City's eight largest consumers were applied to the model at the precise location of these customers.

For future planning years, demands for existing customers were not changed. Additional future demands for future customers were allocated to vacant parcels and parcels in areas of expected water system expansion, which was defined as parcels within 1/4 mile of an existing pipeline.

The resulting model demand allocation does not represent actual water use for individual customers. Rather, it represents typical water use based on large groups of customers. Similarly, the actual sites of future development within the planning period is not known, therefore future demands are spread across all vacant parcels and parcels that are likely to connect to the water system within the 20-year planning period.

5.5.2 Fire Flows

Fire flow demands were also confirmed in the model. The quantity of water available for firefighting establishes an important level of service for a water system. The City's established criteria for fire flow are based on the City's zoning map and were used to update the hydraulic model. The following criteria are minimum requirements for the 350 Zone and 454 Zone:

- 1,000 gpm for all single-family residential areas.
- 2,500 gpm for multi-family residential (MFR) areas.
- 3,000 gpm for mixed use areas.
- 3,000 gpm for public facilities.
- 3,500 gpm for commercial and industrial areas.
- Parks and open spaces within the City were not allocated fire flows.

The minimum fire flow requirements for the 549 Zone are 1,500 gpm for all hydrants except Tumwater Hill Elementary School, which has a fire flow requirement of 1,625 gpm.

Figure 5.8 shows the fire flow requirements throughout the distribution system.

5.6 Distribution System Analysis

The hydraulic model was used to evaluate the distribution system under future demand conditions. The distribution system was evaluated against four performance criteria. Areas not meeting the criteria are considered deficient and system improvements are identified to achieve the desired level of service.

5.6.1 Evaluation Criteria

These four evaluation criteria are from the City's policies and criteria presented in Chapter 2. These policies are at least as stringent as the DOH Design Manual and Washington Administrative Code (WAC) 246-290 requirements. The distribution system was evaluated for the following criteria:

1. High ADD Pressure. The City will provide a maximum pressure of 130 psi during normal demand conditions. Customers with pressures over 80 psi are advised to follow provisions of the Uniform Plumbing Code (UPC) for pressure reduction with individual pressure relief valves (PRVs).
2. Low PHD Pressure. Minimum allowed pressure is 30 psi during PHD.
3. High Velocity. Maximum allowed velocity is 5 feet per second (fps) during PHD.
4. Available Fire Flow. System pressures must remain above 20 psi during MDD plus fire flow conditions. During a fire, the velocity of water in the water mains shall be less than 8 fps.

5.6.2 Identified Deficiencies

5.6.2.1 High ADD Pressures

ADD conditions were simulated for 2028 and 2038 to identify areas where the system pressure is between 80 psi and 130 psi and areas where the system pressure is above 130 psi. Figure 5.9 shows model nodes with pressure between 80 psi and 130 psi (in orange) and above 130 psi (in yellow).

Areas experiencing high pressures above 130 psi during 2028 ADD include the section of the City east of I-5 and north of the Palermo Wellfield and the neighborhood surrounding Percival Creek between Somerset Hill Drive SW and Sapp Road SW. The high pressures east of I-5 and north of the Palermo Wellfield are likely from the newly added Golf Course Well, the Brewery Wellfield, the NE Wellfield, and the small diameter pipes in the area. The high pressures surrounding Percival Creek are likely due to the low elevations on Chapperel Drive SW and Cassie Drive SW.

For customers experiencing pressures over 130 psi, the City can install individual PRVs. No City action is required for customers experiencing pressure between 80 psi and 130 psi. The results are provided for the City's information.

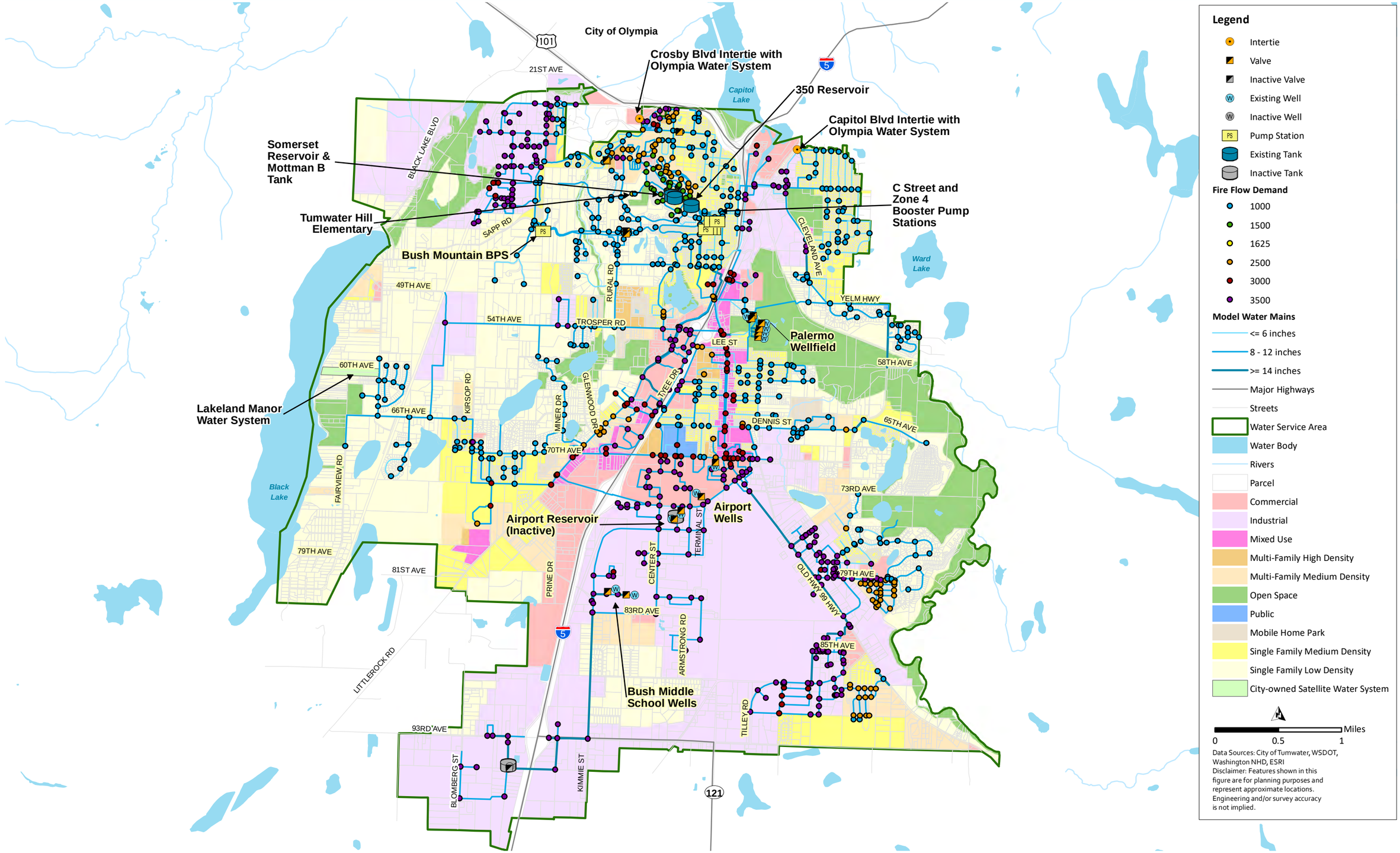

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Figure 5.8 Fire Flow Requirements

5.6.2.2 Low PHD Pressure

PHD conditions were simulated for 2028 and 2038 to identify areas with operating pressures below 30 psi. As Figure 5.10 shows, no locations were found where pressures dropped below 30 psi during 2028 PHD and 2038 PHD. Therefore, no improvements are recommended.

5.6.2.3 High Velocity

The City's goal is to maintain velocities under 5 fps in distribution pipes during the PHD. Figure 5.11 identifies areas where velocities are above 5 fps during 2028 PHD in red and areas where velocities are above 5 fps during 2038 PHD in orange. Areas of high velocities flagged during the analysis are at the following locations:

- Pipelines near the Bush Middle School Wells (2028).
- Pipelines near the Palermo Wellfield / Golf Course Well (2028).
- Pipelines near the NE Wellfield (2038).
- Pipelines near the 454 Zone BPS and 549 Zone BPS (2038).
- Pipeline on Custer Way SW between I-5 and Capitol Blvd (2028).

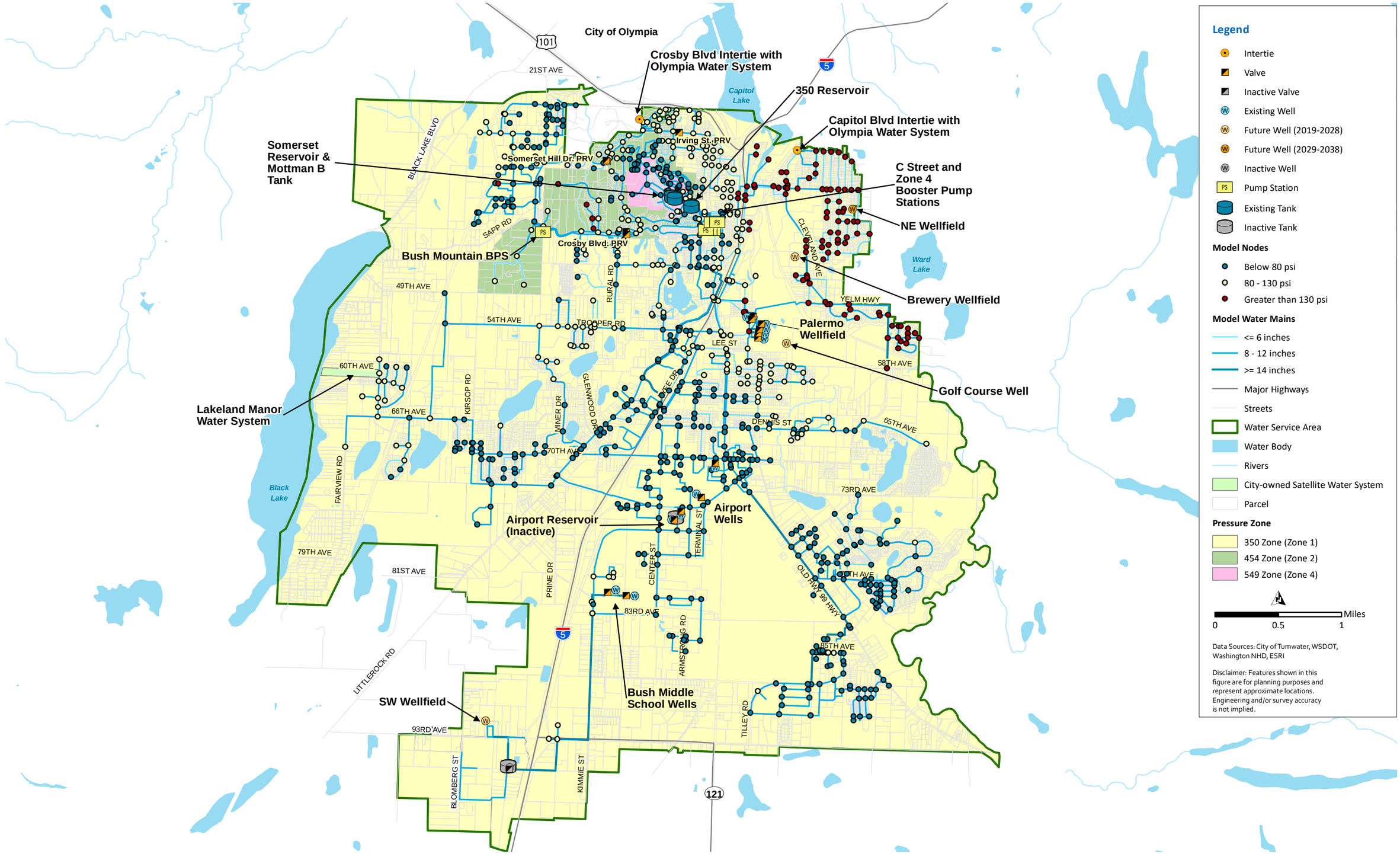
Recommended improvements to areas of high velocities are outlined in Section 5.6.3. These recommendations include pipe upsizing and installing parallel pipelines.

5.6.2.4 Available Fire Flow

One of the City's criteria requires fire flows to be met while supplying MDD and maintaining 20 psi throughout the distribution system. Fire flows are typically the largest flows a system experiences and are often a major factor in pipe sizing and configurations. The hydraulic model was used to simulate a fire at each model node representing a fire hydrant for each planning years. Deficient nodes that cannot provide required fire flows while maintaining system pressures everywhere else in the system above 20 psi in 2028 are shown in Figure 5.12; deficient nodes in 2038 are shown in Figure 5.13. Figures 5.12 and 5.13 show the percentage of required fire flow that is available while maintaining the 20 psi minimum pressure; and nodes with less than 100 percent fire flow available are considered deficient. Fire Flow requirements for 2038 are based on future land use zoning.

During the fire flow analysis, reservoirs were set at the 20 psi HGL, which is the bottom of the fire suppression storage component. This value is often much lower than typical operating levels, meaning that locations with sufficient pressure and flow during annual hydrant testing may be deficient with these lower reservoir levels.

Fire flow deficiencies were identified throughout the system. Areas of particular susceptibility are dead-end mains, areas of older 4-inch and 6-inch piping networks, and areas near high elevation points in a pressure zone. Most deficiencies appear by the year 2028. Additional deficiencies in 2038 occur in the SE section of the City. Fire flow deficiencies trigger recommended improvements that could include upsizing existing pipe, looping pipes, and installing new pipe, as outlined in section 5.6.3.



Legend

- Intertie
- Valve
- Inactive Valve
- Existing Well
- Future Well (2019-2028)
- Future Well (2029-2038)
- Inactive Well
- Pump Station
- Existing Tank
- Inactive Tank

Model Nodes

- Below 80 psi
- 80 - 130 psi
- Greater than 130 psi

Model Water Mains

- <= 6 inches
- 8 - 12 inches
- >= 14 inches
- Major Highways
- Streets
- Water Service Area
- Water Body
- Rivers
- City-owned Satellite Water System
- Parcel

Pressure Zone

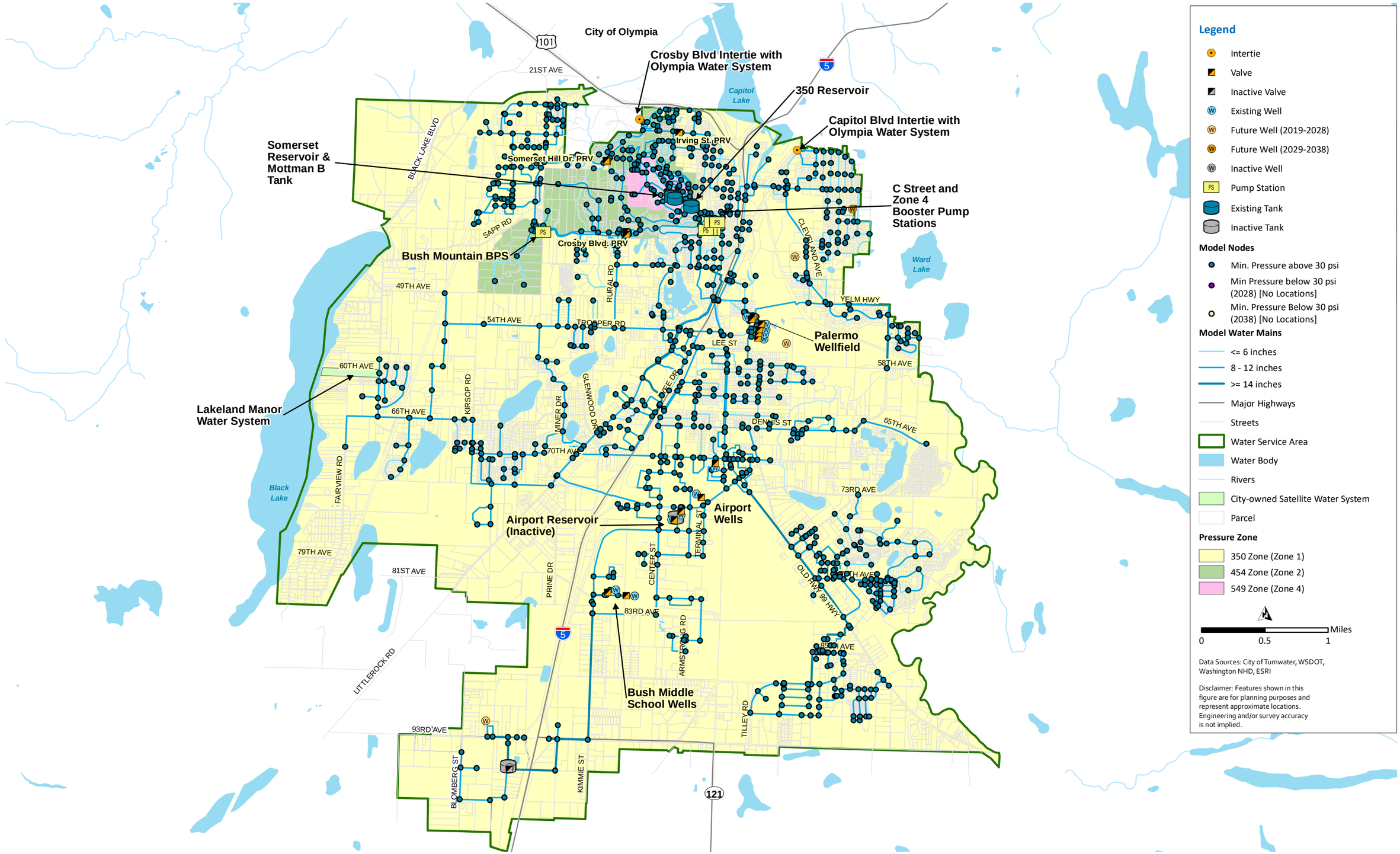
- 350 Zone (Zone 1)
- 454 Zone (Zone 2)
- 549 Zone (Zone 4)

0 0.5 1 Miles

Data Sources: City of Tumwater, WSDOT, Washington NHD, ESRI

Disclaimer: Features shown in this figure are for planning purposes and represent approximate locations. Engineering and/or survey accuracy is not implied.

Figure 5.9 High Pressure Nodes during 2038 ADD without Improvements



Legend

- Intertie
- Valve
- Inactive Valve
- Existing Well
- Future Well (2019-2028)
- Future Well (2029-2038)
- Inactive Well
- Pump Station
- Existing Tank
- Inactive Tank

Model Nodes

- Min. Pressure above 30 psi
- Min Pressure below 30 psi (2028) [No Locations]
- Min. Pressure Below 30 psi (2038) [No Locations]

Model Water Mains

- <= 6 inches
- 8 - 12 inches
- >= 14 inches
- Major Highways
- Streets
- Water Service Area
- Water Body
- Rivers
- City-owned Satellite Water System
- Parcel

Pressure Zone

- 350 Zone (Zone 1)
- 454 Zone (Zone 2)
- 549 Zone (Zone 4)

N

0 0.5 1 Miles

Data Sources: City of Tumwater, WSDOT, Washington NHD, ESRI

Disclaimer: Features shown in this figure are for planning purposes and represent approximate locations. Engineering and/or survey accuracy is not implied.

Figure 5.10 Low Pressure Nodes during PHD without Improvements (All Planning Years)

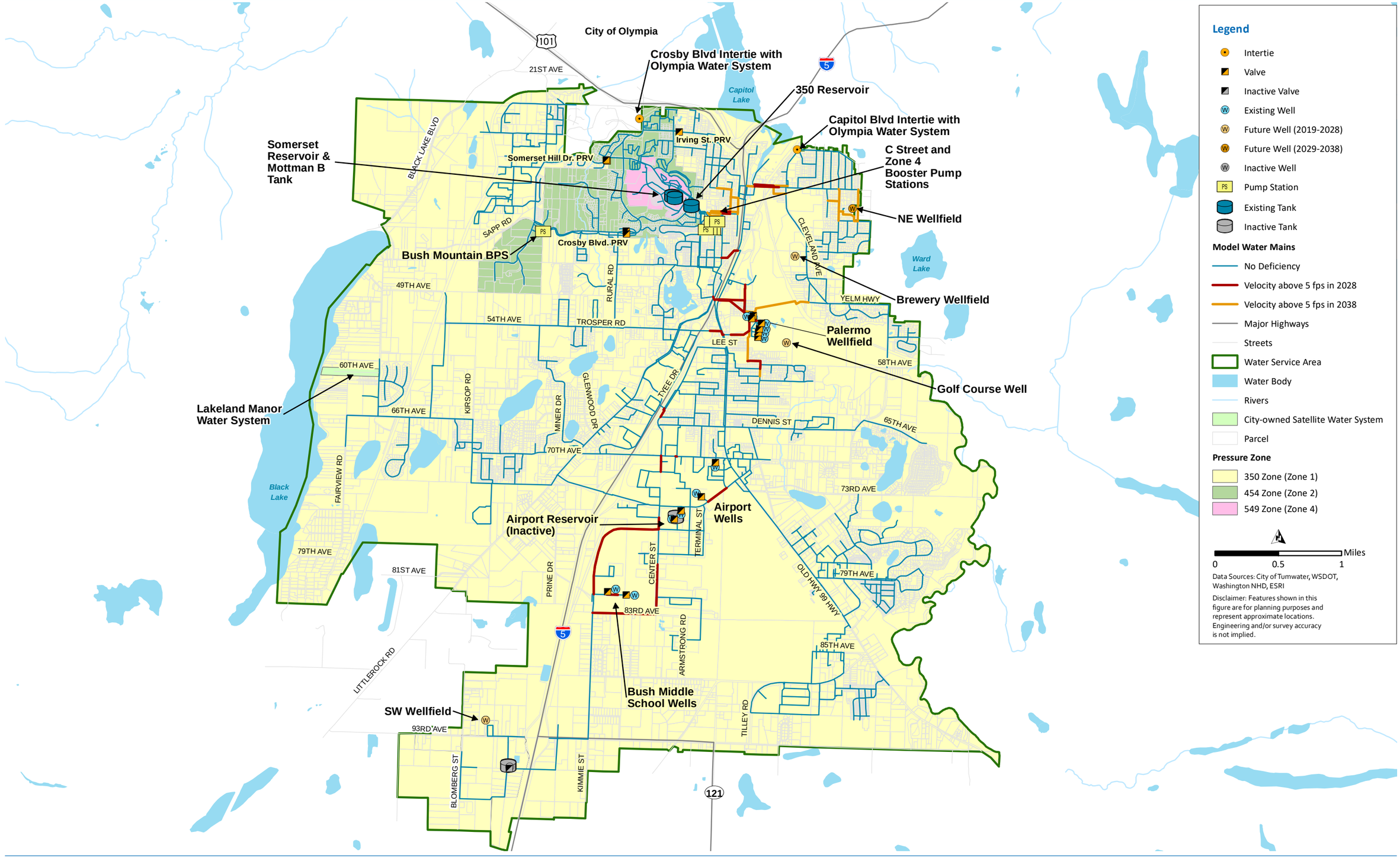
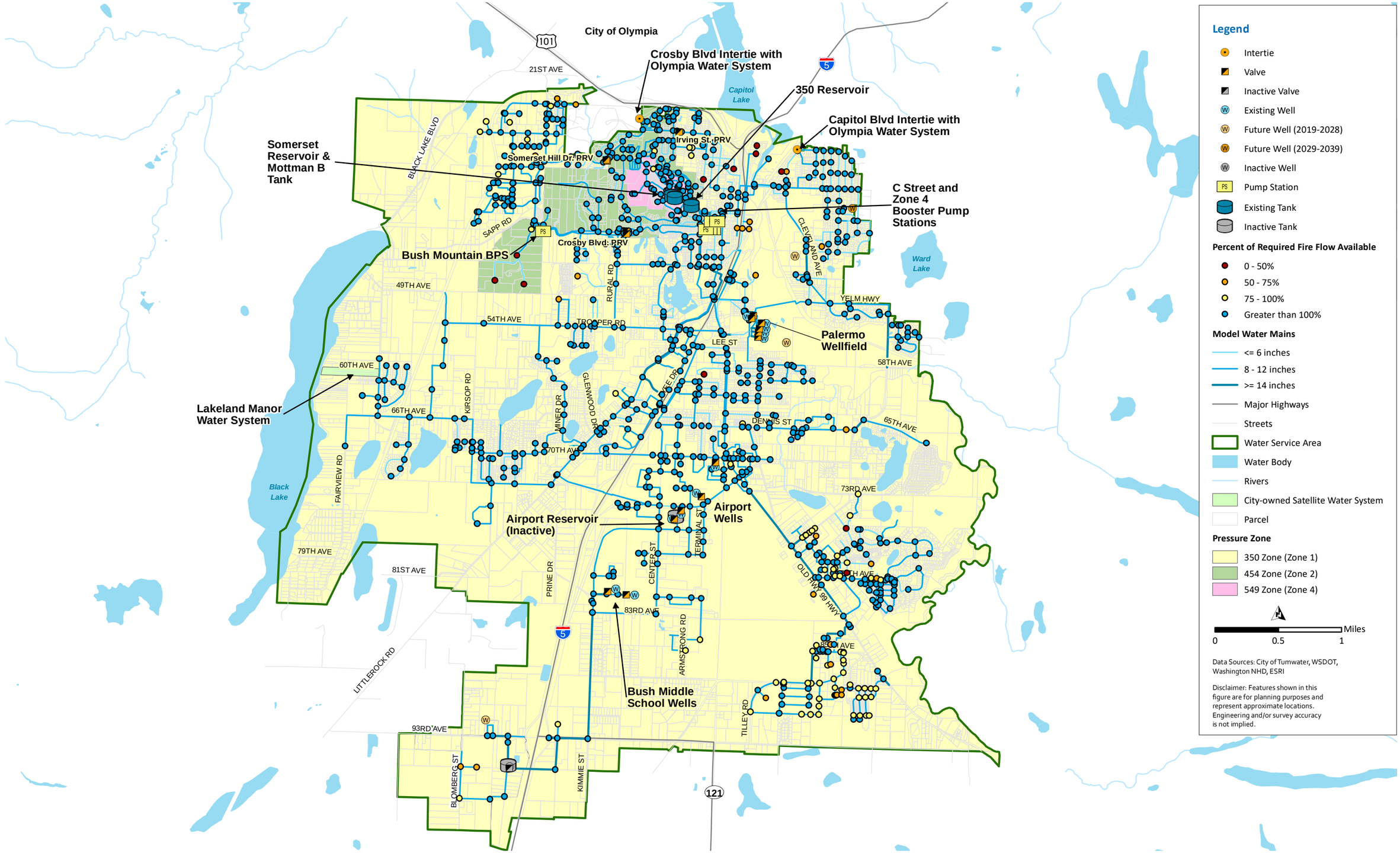


Figure 5.11 High Velocity Pipes during PHD without Improvements (All Planning Years)



Legend

- Intertie
- Valve
- Inactive Valve
- Existing Well
- Future Well (2019-2028)
- Future Well (2029-2039)
- Inactive Well
- Pump Station
- Existing Tank
- Inactive Tank

Percent of Required Fire Flow Available

- 0 - 50%
- 50 - 75%
- 75 - 100%
- Greater than 100%

Model Water Mains

- <= 6 inches
- 8 - 12 inches
- >= 14 inches
- Major Highways
- Streets
- Water Service Area
- Water Body
- Rivers
- City-owned Satellite Water System
- Parcel

Pressure Zone

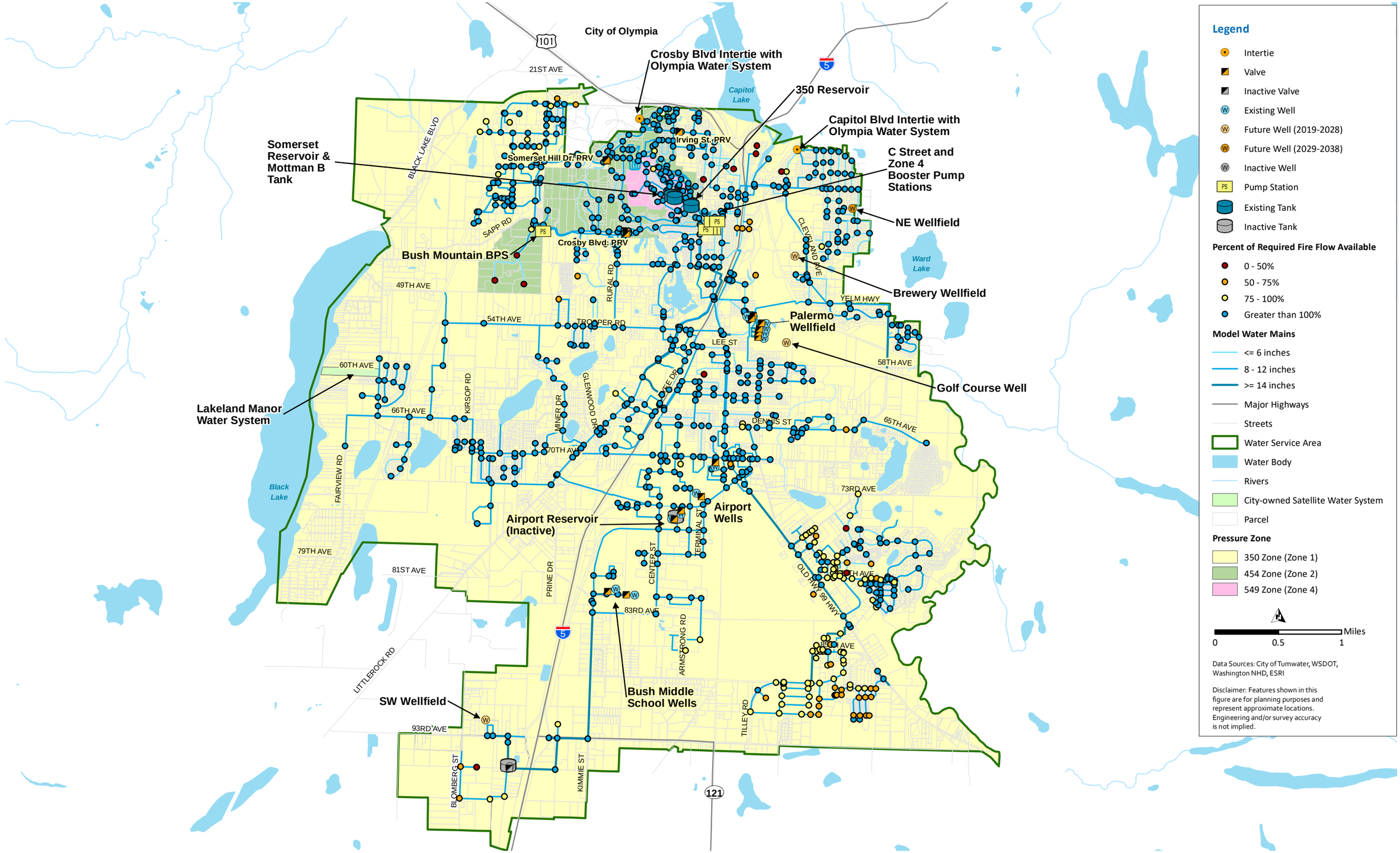
- 350 Zone (Zone 1)
- 454 Zone (Zone 2)
- 549 Zone (Zone 4)

0 0.5 1 Miles

Data Sources: City of Tumwater, WSDOT, Washington NHD, ESRI

Disclaimer: Features shown in this figure are for planning purposes and represent approximate locations. Engineering and/or survey accuracy is not implied.

Figure 5.12 Available Fire Flow during 2028 MDD without Improvements



Legend

- Intertie
- Valve
- Inactive Valve
- Existing Well
- Future Well (2019-2028)
- Future Well (2029-2038)
- Inactive Well
- Pump Station
- Existing Tank
- Inactive Tank

Percent of Required Fire Flow Available

- 0 - 50%
- 50 - 75%
- 75 - 100%
- Greater than 100%

Model Water Mains

- <= 6 inches
- 8 - 12 inches
- >= 14 inches
- Major Highways
- Streets
- Water Service Area
- Water Body
- Rivers
- City-owned Satellite Water System
- Parcel

Pressure Zone

- 350 Zone (Zone 1)
- 454 Zone (Zone 2)
- 549 Zone (Zone 4)

0 0.5 1 Miles

Data Sources: City of Tumwater, WSDOT, Washington NHD, ESRI

Disclaimer: Features shown in this figure are for planning purposes and represent approximate locations. Engineering and/or survey accuracy is not implied.

Figure 5.13 Available Fire Flow during 2038 MDD without Improvements

5.6.3 Recommended Distribution System Improvements

Improvements were recommended to meet the deficiencies identified in the previous sections. Improvements include pipe upsizing, main looping, and installing new pipe. The recommended projects are shown in Figure 5.14.

This section provides detailed information on each recommended pipe improvement. Individual projects are referenced based on the Project Identification shown in Figure 5.14. A summary of the recommended improvement projects can be seen in Table 5.14. Table 5.14 includes the following project component descriptions:

- Improvement ID: All projects in Table 5.14 are Distribution System (D) improvement projects.
- Improvement Type: new pipe or upsize pipe.
- Seismic Backbone Overlap: States if the pipe (either the whole project or a segment of the project) overlaps with the proposed seismic backbone.
- Pipe Length: Length of pipe to be installed or replaced.
- Existing Diameter: diameter of existing pipe (new pipe will have "n/a" in this column).
- Proposed Diameter: diameter of proposed pipe.
- Location: specific area where the project will be.
- Purpose: describes the deficiency the project will address or if the project is driven by future development or system build-out.

Each of the recommended improvements require further site-specific and project level engineering analysis before implementation.

5.7 Earthquake Preparedness Evaluation

A high-level earthquake preparedness evaluation was completed as part of this Plan and is shown in Appendix O. The evaluation consisted of following goals for the City:

- Identify and prioritize which hazard scenarios the City would like to prepare for.
- Define the critical customers that are highest priority to be served in the aftermath of an earthquake.
- Determine what the backbone system will be when a complete resiliency study is performed.
- Identify the next steps for developing a seismic resiliency plan.

The City has completed a Hazard Mitigation Plan (THMP), which identified potential hazards their water system could encounter. The earthquake hazard is a high risk to the system and was considered the highest priority when preparing the system for an event. The THMP showed areas of liquefaction within the RWSA, which helped prioritize which customers and structures would be recommended to increase their resiliency.

A seismic backbone map was created to identify critical structures and the distribution system that would be used to serve critical customers after a seismic event. The backbone map is shown in Figure 5.15 and will be updated by the City to prioritize the structures and pipelines when a complete resiliency study is performed. Figure 5.16 shows the recommended projects in Figure 5.14 that are part of the seismic backbone system. Those projects are recommended to be designed to the appropriate resiliency standards for the selected seismic event.

A seismic resiliency plan is also recommended as part of the City's CIP, which will provide a clear plan on what critical structures will be required to serve the critical customers during the recovery periods after a seismic event. The plan will also help identify any interdependencies the City has with other systems and utilities.

Table 5.14 Recommended Improvements

Improvement ID	Improvement Type	Seismic Backbone Overlap?	Pipe Length (LF)[3]	Existing Diameter (inches)	Proposed Diameter (inches)	Location	Purpose
D-01	Upsize Pipe	No	540	6	8	• North of 29th Ave SW and west of railroad	Project to provide fire flow when property is developed for industrial use. This project is developer driven.
D-02	New Pipe	No	1,100 700	n/a	8 12	• East end of 26th Ave SW north to Mottman Rd SW (12-inch) • 29th Ave SW from Ferguson St SW north to connect to existing pipe (8-inch) • Parking lot east of RW Johnson Blvd SW north to Mottman Rd SW (8-inch) • Across RW Johnson Blvd SW from South Puget Sound CC west to existing pipe (12-inch) • West end of Crites St SW north to existing pipe (8-inch)	Looping project to provide industrial/commercial and public fire flows in the area.
D-03	New Pipe	No	1,600	n/a	12	• Barnes Blvd SW from Vista Loop SW south to 454/549 Zone Reservoirs	This is a new pipe project to provide fire flows on Barnes Blvd SW and Vista Loop SW parallel to the existing pipe.
D-04	Upsize Pipe	No	1,800	4	8	• Grant St SW from N 9th Ave SW to N 7th Ave SW • N 7th Ave SW from Ferry St SW to Irving St SW • Alley between Grant St SW and Hayes St SW west of N 7th Ave SW	Upsize project to provide SFR fire flow to the area.
D-05	New Pipe	No	1,800	n/a	12	• N 5th Ave SW from Bates St SW to Division St SW • Division St SW from N 5th Ave SW to N 3rd Ave SW • E St SW from S 4th Ave SW to S 2nd Ave SW	Looping project to provide SFR fire flows in the area.
D-06	Upsize Pipe	Yes	950	6	8	• Clark St SW between N 6th Ave SW and N 7th Ave SW • S 2nd Ave SW from Division St SW to C St SW	Upsize project to lower velocity and provide fire flow in pipe.
D-07[2]	Upsize Pipe	Yes	6,100	4, 6	12	• Deschutes Pkwy SW from Boston St SE to Grant St SW • Grant St SW from Deschutes Pkwy SW to Deschutes St SE • Deschutes St SE to end of pipe • Deschutes Way SW from D ST SW north to I-5 pipe crossing • Clark Pl SE from Custer Way SE to Bates St SE • Bates St SE from Clark Pl SE to Cleveland Ave SE • Cleveland Ave SE from Custer Way SE to E Emerson St • E Emerson St from Cleveland Ave SE to Capitol Blvd	Upsize project to provide industrial/commercial fire flows in the area and to provide fire flow to Tumwater Historical Park.
D-08	Upsize Pipe	No	6,200	4, 6	8	• Sunset Way SE from Capitol Blvd to Burnaby Ave SE • Fairfield Rd SE from Sunset Way SE to Vista Ave SE • Vista Ave SE from Fairfield Rd SE to Maringo Rd SE • Maringo Rd SE from Carlyon Ave SE to 3201 Maringo Rd SE • Carlyon Ave SE from Capitol Blvd to Quince St SE • Moore St SE from North St SE north to 3498 Moore St SE • Hoadly St SE from North St SE north to 3307 Hoadly St SE	Upsize project to provide SFR fire flow to the area.
D-09	New Pipe	No	280	n/a	8	• Mountain View Pl SE from Peak St SE to Quince St SE	Looping project to provide SFR fire flows in the area.

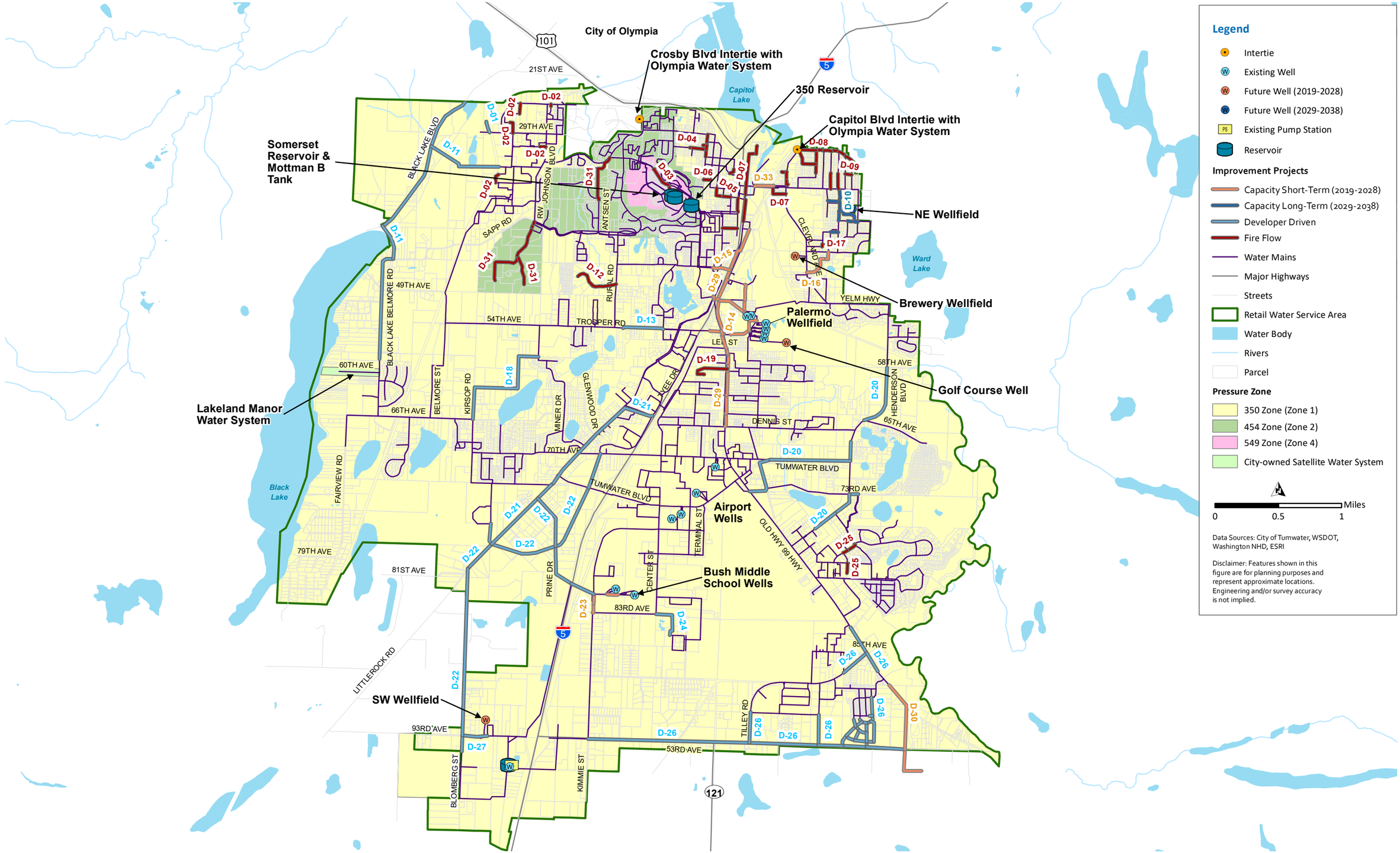
Table 5.14 Recommended Improvements (continued)

Improvement ID	Improvement Type	Seismic Backbone Overlap?	Pipe Length (LF)[3]	Existing Diameter (inches)	Proposed Diameter (inches)	Location	Purpose
D-10	Upsize Pipe	No	2,100 870 1,000	4, 6	8 12 16	• Hoadly St SE from North St SE to McDonald St SE (8-inch) • Hoadly St SE from McDonald St SE to Middle St SE (12-inch) • McDonald St SE from Hoadly St SE to Lorne St SE (8-inch) • Middle St SE from Southglen Ave SE to Hawthorne St SE (8-inch) • Hoadley Loop SE from Hoadly St SE to Middle St SE (16-inch) • Barclift Ln SE from Armstrong Ave SE to Hoadly St SE (8-inch)	Upsize project to provide transmission capacity when NE wellfield is online. May want to expand extent of project to replace aging AC and PVC pipe in the area.
D-11	New Pipe	No	18,900	n/a	12	• West from 32nd Ave SW to Regal Park Ln SW and continuing to Black Lake Blvd • Black Lake Blvd SW from City boundary south to Black Lake Belmore Rd SW • Black Lake Belmore Rd SW from Black Lake Blvd SW to connect to existing pipe at Dooley Ln SW • Sapp Rd SW from Black Lake Belmore Rd SW east to Union Pacific Railroad	Developer driven as water system expands.
D-12	Upsize Pipe	No	2,000	6	8	• 48th Ave SW from Rural Rd SW west to end of street	Upsize project to provide SFR fire flow to customers at dead end pipe.
D-13[2]	Upsize Pipe	No	1,700	8	12	• Trosper Rd SW from Commander Dr SW to Lake Park Rd SW	Upsize project proposed by City.
D-14[2]	Upsize Pipe	Yes	680 2,400 2,440	6, 8, 10, 12	8 12 16	• Pipe from Palermo Wellfield northwest to Q St (16-inch) and northwest to Capitol Blvd (12-inch) • Pipe from Palermo Wellfield southwest to Linda St SE (16-inch) • Capitol Blvd from M St SE to Linda St SE (16-inch) • Trosper Rd SW from Capitol Blvd west to I-5 (12-inch) • Capitol Blvd from La Quinta Inn & Suites south to pipe cross of I-5 (16-inch) • Pipe crossing of I-5 and west to Little St SW (16-inch) • Palermo Ave SE from O St NE north to M St SE (12-inch) and north to pipe between Capitol Blvd and Tumwater Valley Dr SE (8-inch)	Upsize project to provide transmission capacity when Golf Course well is online.
D-15	New Pipe	No	740 2,000	n/a	16 24	• Linwood Ave SW from S 5th Ave SW to Capitol Blvd (24-inch) • Capitol Blvd from Linwood Ave SW to E St SW (16-inch)	New pipe project proposed by the City.
D-16	Upsize Pipe	No	1,600	4	8	• Hansen St SE from South St SE to Roberts Rd SE	Looping project to provide SFR fire flows and to provide transmission capacity when Brewery wellfield is online.
D-17	New Pipe	No	110	n/a	8	• Lloyd St SE from Kelsey St SE to Primrose Ln SE	Looping project to provide SFR fire flow in the area.
D-18	New Pipe	No	5,300	n/a	12	• Kirsop Rd SW from 66th Ave SW north to Miner Dr SW	Developer driven as water system expands.
D-19	Upsize Pipe	No	1,700	6	12	• Pinehurst St SW from Capitol Blvd west end of pipe	Upsize project to provide MFR fire flow to customers at dead end pipe.
D-20	New/Upsize Pipe	No	2,500 8,400	n/a, 6, 8	12 16	• Henderson Blvd from Pioneer Park to 65th Ave and 68th Ave to Tumwater Blvd (16-inch) • Tumwater Blvd from Nikolas St to Israel Extension (12-inch), Israel Extension from Bonniewood on Tumwater Blvd (12-inch), and Tumwater Blvd from Israel Extension to Henderson Blvd (16-inch) • Henderson Blvd from west of Trails End to 73rd Ave (12-inch)	Developer driven as water system expands. Private developers have recently installed pipe in this area, including: • Henderson Blvd from Dennis St south to 71st Ave SE (10-inch) • Henderson Blvd from Israel Rd to 73rd Ave (12-inch) • 73rd Ave from Henderson Blvd east to existing pipe (8-inch)

Table 5.14 Recommended Improvements (continued)

Improvement ID	Improvement Type	Seismic Backbone Overlap?	Pipe Length (LF)[3]	Existing Diameter (inches)	Proposed Diameter (inches)	Location	Purpose
D-21	New Pipe	Yes	900 9,200	n/a	12 16	• Bishop Rd from Tyee Dr SW to Littlerock Rd SW (16-inch) • Littlerock Rd SW from Bishop Rd south to AG West Black Hills High School (16-inch) • Littlerock Rd SW north to AG West Black Hills High School (12-inch)	Developer driven as water system expands.
D-22	New Pipe	No	2,800 8,400 5,200 4,400	n/a	12 16 20 24	• Israel Rd SW south to Tumwater Blvd SW (24-inch) and from Tumwater Blvd SW south to Prine Dr SW (24-inch) • Prine Dr SW southeast and across I-5 to Kimmie St SW; and north to Littlerock Rd SW (20-inch) • Prine Dr SW west to Littlerock Rd SW (12-inch) • Littlerock Rd SW from Prine Dr SW south to AG West Black Hills High School (12-inch) • Littlerock Rd SW from AG West Black Hills High School south to 81st Ave SW and then south along Bloomberg St SW (16-inch)	Developer driven as water system expands.
D-23	Upsize Pipe	Yes	1,400	12	16	• Kimmie St SW from 80th Ave SW to 83rd Ave S • Between Bush MS wells 12 and 14	Upsize project to provide transmission capacity for Bush Middle School wells.
D-24	New Pipe	No	1,600	n/a	12	• 83rd Ave SW from Center St SW south to existing pipe	This project is developer driven as water system expands.
D-25	Upsize Pipe	No	450 680	6,8	8 12	• Arab Dr SE from Trails End Dr SE to 7701 Arab Dr SE (12-inch) and from 77th Trail SE south to end of pipe (8-inch)	Upsize project to provide industrial/commercial fire flow to customers at dead end pipe.
D-26	New Pipe	Yes	7,500 1,300 13,200	n/a	8 12 16	• The Preserve Development, extending to 93rd Ave SE (8-inch) • 93rd Ave SE from 1607 93rd Ave SE west to Kimmie St SW and Tilley Rd SE from 93rd Ave north to existing pipe (16-inch)	This project is developer driven as water system expands. Project is necessary for ST-1.
D-27	New Pipe	No	660 1,100	n/a	12 16	• 93rd Ave SW to Blomberg St S (16-inch) • Blomberg St SW from 93rd Ave SW south to existing Lathrop pipe (12-inch)	Looping project to provide industrial/commercial fire flows in the area.
D-28	Deleted						Project Removed
D-29	Upsize/New Pipe	Yes	7,000	6, 8, n/a	16	• Capitol Blvd from Linwood Ave SW to Dennis St SW	New Pipe Project proposed by City. Some pipe overlaps with project S-02. Any overlapping pipe will be designated to project S-02.
D-30[1]	New Pipe	Yes	1,600	n/a	24	• 93rd Ave south to new 350 Zone Reservoir	New pipe project corresponding to future 350 Zone storage reservoir.
D-31	New Pipe	No	7,100	n/a, 6,8	12	• Bush Mountain St SW from Sapp Rd SW to end of streets • Antsen St SW from Chapparel Dr SW to Somerset Hill Dr SW	Looping and upsize project to provide redundancy and SFR fire flow to Bush Mt area.
D-32	R&R	n/a	n/a	n/a	n/a	• System-wide	Annual program to replace aging water mains
D-33	New Pipe	Yes	1,000	n/a	12	• Custer Way from Boston St to east of Capitol Blvd.	Project is part of a joint water and storm project designed in 2019.

Notes:
(1) Projects are identified in the City's 6-year CFP.
(2) Some parts of this project could be part of the City's 6-Year Water Fund CFP and need to be verified by the City.
(3) LF – linear feet.
(4) Projects with "D" Improvement ID are distribution system improvement projects.



Legend

- Intertie
- Existing Well
- Future Well (2019-2028)
- Future Well (2029-2038)
- Existing Pump Station
- Reservoir

Improvement Projects

- Capacity Short-Term (2019-2028)
- Capacity Long-Term (2029-2038)
- Developer Driven
- Fire Flow
- Water Mains
- Major Highways
- Streets
- Retail Water Service Area
- Water Body
- Rivers
- Parcel

Pressure Zone

- 350 Zone (Zone 1)
- 454 Zone (Zone 2)
- 549 Zone (Zone 4)
- City-owned Satellite Water System

0 0.5 1 Miles

Data Sources: City of Tumwater, WSDOT, Washington NHD, ESRI

Disclaimer: Features shown in this figure are for planning purposes and represent approximate locations. Engineering and/or survey accuracy is not implied.

Figure 5.14 Recommended Distribution System Improvements

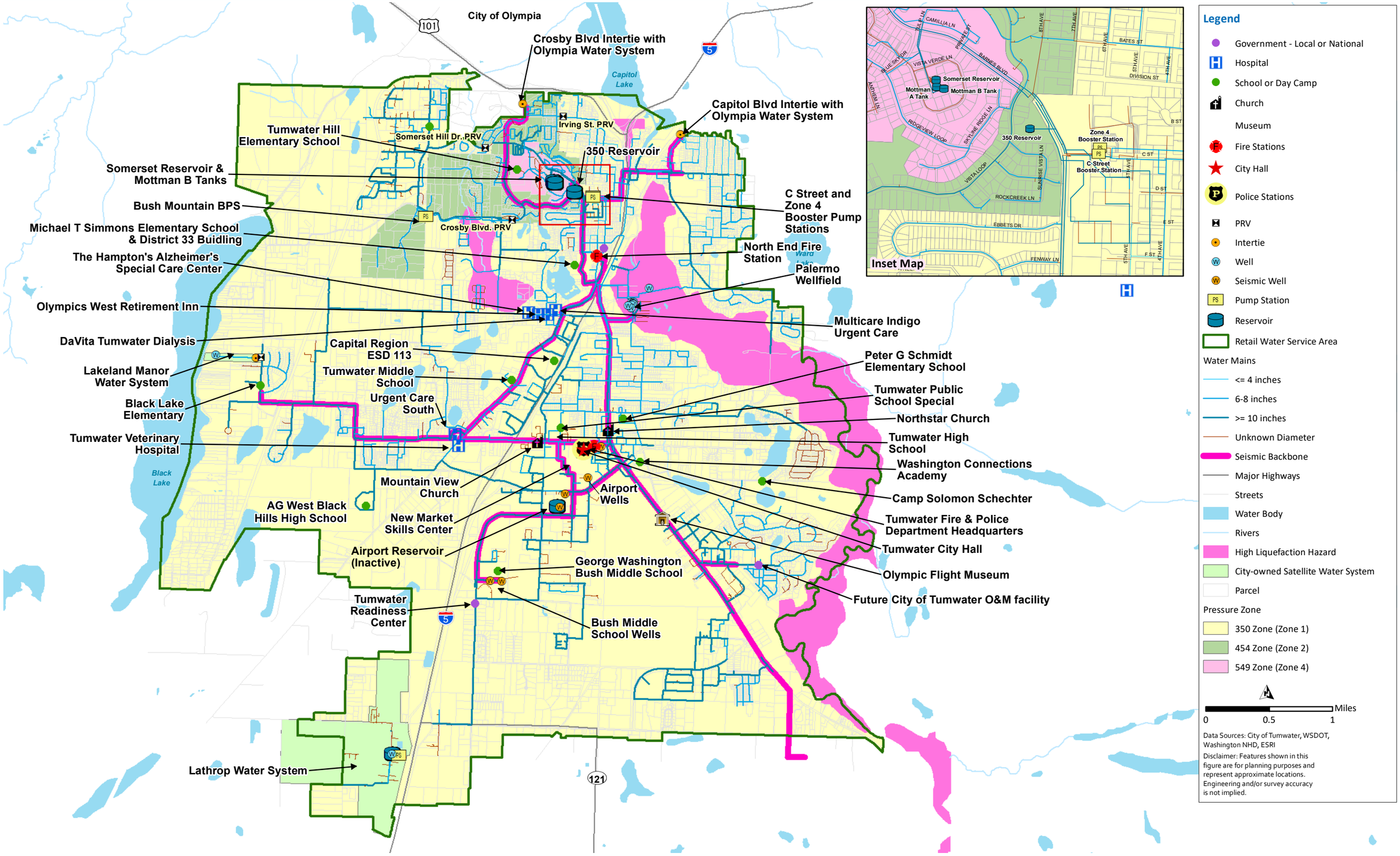
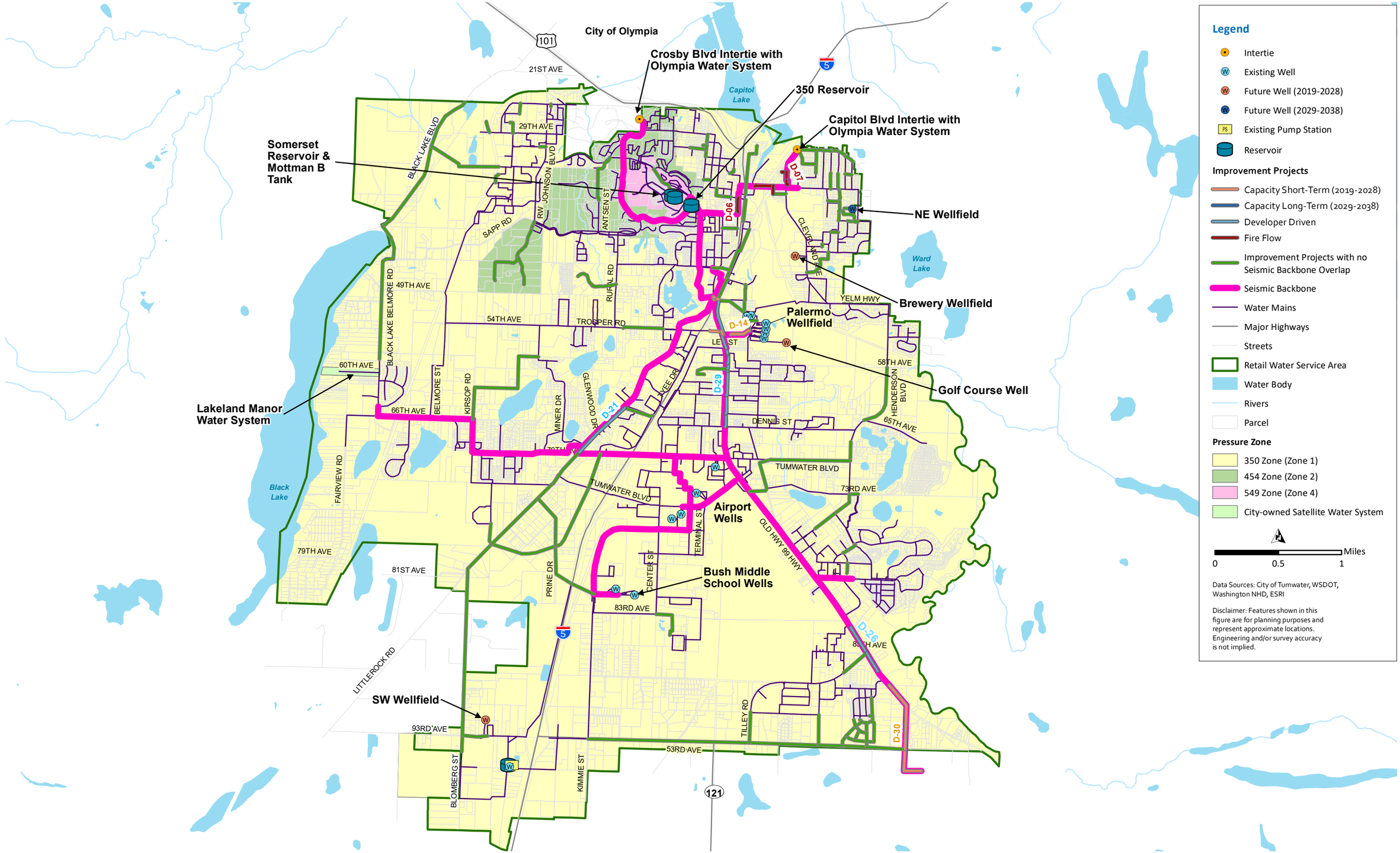


Figure 5.15 Seismic Backbone System Map



Legend

- Intertie
- Existing Well
- Future Well (2019-2028)
- Future Well (2029-2038)
- Existing Pump Station
- Reservoir

Improvement Projects

- Capacity Short-Term (2019-2028)
- Capacity Long-Term (2029-2038)
- Developer Driven
- Fire Flow
- Improvement Projects with no Seismic Backbone Overlap
- Seismic Backbone
- Water Mains
- Major Highways
- Streets
- Retail Water Service Area
- Water Body
- Rivers
- Parcel

Pressure Zone

- 350 Zone (Zone 1)
- 454 Zone (Zone 2)
- 549 Zone (Zone 4)
- City-owned Satellite Water System

0 0.5 1 Miles

Data Sources: City of Tumwater, WSDOT, Washington NHD, ESRI

Disclaimer: Features shown in this figure are for planning purposes and represent approximate locations. Engineering and/or survey accuracy is not implied.

Figure 5.16 Recommended Improvements for Seismic Backbone System