

Appendix M
Hydraulic Model Development and Calibration

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FINAL TECHNICAL MEMORANDUM

DATE: December 14, 2016

PROJECT: 16-1773

TO: Sammamish Plateau Water

FROM: Murray, Smith & Associates, Inc.

RE: Hydraulic Model Development & Calibration



Overview

This document summarizes the procedures, assumptions, and key findings of the Sammamish Plateau Water (SPW) hydraulic model update and calibration. SPW had developed H2OMap hydraulic models for the Plateau Zone and Cascade View Zone areas of the system. Since that time, there have been new developments and capital improvement projects, and the utility now has better GIS and customer water use information; the updated model incorporates the new information and represents the current state of the network.

Hydraulic Model Update

This project began by reviewing the current GIS database for topology accuracy. Modifications were made in the GIS database to allow for a one to one comparison of elements (excluding facilities) between the data sources. Once these initial QA/QC iterations were completed the water system GIS was imported to InfoWater (by Innovyze). The existing facility inventory was added to the model while keeping the pipe alignment as close to the GIS as possible. PRV stations were modeled to include bypass and main, true to the field configuration. Wells and pump stations were modeled consistently with the previous H2OMap model. The updated model is a comprehensive representation of the entire system's piping and infrastructure with a consistent level of detail. It includes 300 miles of pipe, 8 storage tanks, 7 booster stations, 10 pump stations, 3 interties, and 10 wells.

The model updating process was based on the following sources of information:

- Current GIS database inventory
- Updated pump curves
- Well production
- Customer consumption data, from billing records

Naming Convention

Pipes were identified by the SPW ID that began with “WM” followed by six numerical digits, ranging from 000002 to 094100 (consistent with the GIS and asset management database). Wells, tanks, and pump stations were delineated and identified by their name in the Hydraulic Grade Line (HGL) Profile and as identified by previous master planning and modeling efforts. Pressure Reducing Valves (PRVs) were identified according to their number and designation as either “Main” or “Bypass.” These IDs were also provided by SPW. Pressure zones were based on previous work and validated with updated information from the GIS as a shapefile and attributed to the pipe and node tables. There are a total of 30 pressure zones between the two services areas, Cascade View and Plateau Zone. The Plateau Zone is the larger of the two, with a total of 25 pressure zones, while the Cascade View Zone covers a total of five pressure zones.

Existing Average Day Demands

Existing system demands were developed from customer meter information and linked to parcels through a common identification number. Monthly meter information for 2015 was used to develop average daily demand (ADD) for each parcel. Parcels were assigned to the closest model junction within the corresponding pressure zone. Water production records were used to scale (i.e., peak) the billed demand up to account for water losses and unaccounted-for water and to, ultimately, meet overall production. **Table 1** presents the allocated average day demands by pressure zone.

**Table 1
Existing Average Day Demand, by Pressure Zone**

Service Area	Pressure Zone(s)	In Model	Total Demand (gpm)
Cascade View Zone	642	642	1
Cascade View Zone	730	730, 730 CV	115
Cascade View Zone	550 CV	550 CV	19
Cascade View Zone	590 CV	590 CV	6
Cascade View Zone	650 CV	650 CV	6
Total			147
Service Area	Pressure Zone(s)	In Model	Total Demand (gpm)
Plateau Zone	297	297	284
Plateau Zone	300	300	0
Plateau Zone	310	310	1
Plateau Zone	375	375	11
Plateau Zone	390	390	15
Plateau Zone	400 BROD	400	12
Plateau Zone	400 WAV	400	13
Plateau Zone	450	450	7
Plateau Zone	450 WAK	450	67
Plateau Zone	466	466	7
Plateau Zone	475	475	93
Plateau Zone	475 PH	475	3
Plateau Zone	475 SAMSUN	475	11
Plateau Zone	499	499	6
Plateau Zone	510	510	1
Plateau Zone	540	540	16
Plateau Zone	550	550	258
Plateau Zone	550 ALD	550	66
Plateau Zone	566	566	8
Plateau Zone	590	590	59
Plateau Zone	650	650	2,406
Plateau Zone	700	700	172
Plateau Zone	700 BC	700	1
Plateau Zone	700 SH	700	0
Total			3,517

Model Calibration & Validation

The updated hydraulic model was calibrated by comparing model results to field data, obtained from field tests carried out in June, July, and October 2016. A total of 45 locations were selected to perform field tests. The locations were selected to measure all pressure zones and were spatially distributed to cover the service areas. In all zones that were of medium to large size at least two tests were conducted. The test locations are presented in **Figure 1**. Field tests were not carried out in a few of the smaller pressure zones due to either the lack of hydrants or their specific location, including 400 OV, 475 PH, 566, 700 OV, and 700 BC.

A field test consisted of measuring the static pressure, time, and date at a pressure hydrant followed by opening of a nearby hydrant (i.e., flow hydrant) to generate a pressure drop of at least 10 psi, and collect flow and residual pressure information. Calibration information also included pump status, supply from/to interconnections, and reservoir levels at the time of each test. These parameters were obtained from SCADA. Further, the total production for each testing day was used to adjust the overall model demand.

Simulated results were compared with field data to see how well the model reproduced real world conditions. PRV settings were adjusted to match field test data.

The calibration process used in this planning effort enables the model to be used for planning level evaluations and as an aid during design. The model was calibrated for steady state conditions.



SAMMAMISH PLATEAU WATER

2016 FIELD TEST LOCATIONS



Booster Pump Station — Water Main — Service Area

Field Test Hydrants* — Cascade View

Pressure

Flow (#1)

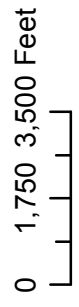
Flow (#2)

Tank

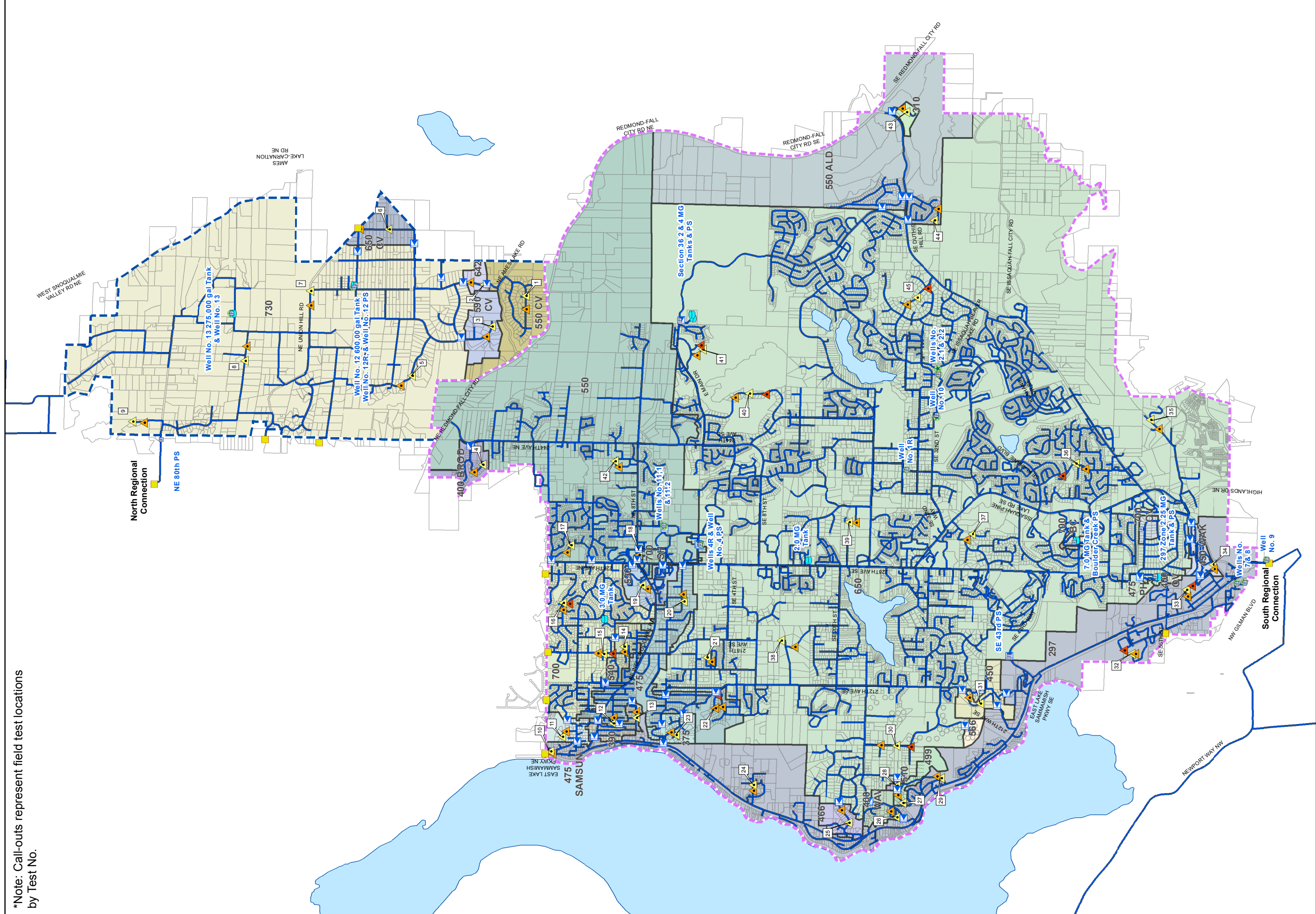
Well

PRV

Intertie



*Note: Call-outs represent field test locations by Test No.



Calibration & Validation Results

Table 2 shows the calibration results for the field tests versus the model results and is organized by pressure zone. **Table 3** shows the overall level of calibration confidence of each pressure zone. A level of confidence for each location was assigned based on the absolute and proportional error of both static and residual results:

- “High” – static error less than 5 percent or 7 psi and residual error less than 10 percent or 10 psi
- “Medium” – static error less than 10 percent or 10 psi and residual error less than 15 percent or 15 psi, and
- “Low” – static and residual errors exceeding the “Medium” ranges

Figure 2 presents the results of the calibration, in terms of both pressure difference and percent difference. The primary conclusions drawn from the calibration include:

- The model presented a High level of accuracy for static pressure at all 45 testing locations.
- The model presented a High level of accuracy for residual pressure at 42 of the 45 testing locations.
- All 25 of the pressure zones tested are considered calibrated to a High level of overall accuracy with respect to static pressures. 22 pressure zones, of the 25 tested, meet a High level of overall accuracy with respect to residual pressures.
- Three pressure zones meet a Medium level of overall accuracy with respect to residual pressures.
- The overall calibration indicates that 24 of the 25 pressure zones possess a High overall accuracy and only one zone, Plateau Zone 475, is identified as a Medium overall accuracy.

Test No. 12 is an area that requires additional investigation as the two other tests (Test No. 20, Test No. 22) in the same pressure zone (Plateau Zone 475, Inglewood Hill), returned High levels of calibration confidence for both static and residual calibration. In response, both the flow testing was repeated and a validation of pipe connectivity and diameter was completed by SPW for this location; however, results similar to the original ones were confirmed. The causes of this could be a closed or partially closed valve between the test locations in Plateau Zone 475 or an incorrect PRV setting. It is recommended that additional testing be carried out, after current water main project construction in this area has been completed, to determine the reason of the low residual pressure in this area.

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Table 2
Summary of Calibration Results – Absolute & Percent Error for Field v. Model Results

Test ID	Service Area	Pressure Zone	Static Pressure (psi), Field	Static Pressure (psi), Model	Static Error (psi)	Static Pressure Confidence	Static Percent Error (%)	Static Percent Confidence	Residual Pressure (psi), Field	Residual Pressure (psi), Model	Residual Error (psi)	Residual Pressure Confidence	Residual Percent Error (%)	Residual Percent Confidence
2	Cascade View Zone	642	93	100	7	High	7%	Medium	93	90	-3	High	-3%	High
5	Cascade View Zone	730	108	110	2	High	2%	High	92	86	-6	High	-7%	High
7	Cascade View Zone	730	50	54	4	High	8%	Medium	40	43	3	High	7%	High
8	Cascade View Zone	730	53	53	0	High	0%	High	43	47	4	High	9%	High
9	Cascade View Zone	730	71	71	0	High	0%	High	42	42	0	High	0%	High
1	Cascade View Zone	550 CV	50	50	0	High	1%	High	32	34	2	High	6%	High
3	Cascade View Zone	590 CV	100	97	-3	High	-3%	High	75	81	6	High	7%	High
6	Cascade View Zone	650 CV	96	96	0	High	1%	High	86	91	5	High	6%	High
10	Plateau Zone	Inglewood Hill, 297	80	76	-4	High	-5%	High	42	48	6	High	15%	Medium
24	Plateau Zone	Inglewood Hill, 297	80	74	-6	High	-8%	Medium	48	49	1	High	1%	High
29	Plateau Zone	SW Lake Sammamish, 297	84	80	-4	High	-5%	High	60	70	10	Medium	17%	Low
32	Plateau Zone	Freeguard, 297	102	104	2	High	2%	High	88	97	9	High	10%	High
33	Plateau Zone	Freeguard, 297	89	82	-7	High	-8%	Medium	83	80	-3	High	-3%	High
43	Plateau Zone	South Plateau, 310	74	71	-3	High	-5%	High	59	68	9	High	15%	Medium
23	Plateau Zone	Inglewood Hill, 375	112	106	-6	High	-6%	High	96	93	-3	High	-3%	High
13	Plateau Zone	Inglewood Hill, 390	60	58	-2	High	-3%	High	40	42	2	High	5%	High
31	Plateau Zone	SW Lake Sammamish, 450	80	83	3	High	3%	High	65	71	6	High	10%	High
25	Plateau Zone	Inglewood Hill, 466	68	71	3	High	4%	High	57	63	6	High	11%	Medium
12	Plateau Zone	Inglewood Hill, 475	78	71	-7	High	-8%	Medium	32	48	16	Low	49%	Low
20	Plateau Zone	Inglewood Hill, 475	56	52	-4	High	-7%	High	40	46	6	High	16%	Low
22	Plateau Zone	Inglewood Hill, 475	63	60	-3	High	-4%	High	53	52	-1	High	-2%	High
27	Plateau Zone	SW Lake Sammamish, 499	89	91	2	High	3%	High	69	63	-6	High	-8%	High
28	Plateau Zone	SW Lake Sammamish, 510	66	66	0	High	0%	High	0	0		High		High
14	Plateau Zone	Inglewood Hill, 540	72	75	3	High	4%	High	50	59	9	High	18%	Low
17	Plateau Zone	North Plateau, 550	38	44	6	High	16%	Low	32	41	9	High	29%	Low
42	Plateau Zone	North Plateau, 550	60	57	-3	High	-5%	High	52	55	3	High	6%	High
19	Plateau Zone	Inglewood Hill, 590	90	87	-3	High	-3%	High	75	84	9	High	12%	Medium
21	Plateau Zone	Inglewood Hill, 650	62	64	2	High	4%	High	52	51	-1	High	-1%	High
30	Plateau Zone	SW Lake Sammamish, 650	110	108	-2	High	-2%	High	96	96	0	High	0%	High
35	Plateau Zone	Freeguard, 650	103	108	5	High	5%	High	93	88	-5	High	-5%	High
36	Plateau Zone	South Plateau, 650	96	91	-5	High	-5%	High	86	88	2	High	2%	High

Test ID	Service Area	Pressure Zone	Static Pressure (psi), Field	Static Pressure (psi), Model	Static Error (psi)	Static Pressure Confidence	Static Percent Error (%)	Static Percent Confidence	Residual Pressure (psi), Field	Residual Pressure (psi), Model	Residual Error (psi)	Residual Pressure Confidence	Residual Percent Error (%)	Residual Percent Confidence
37	Plateau Zone	South Plateau, 650	125	122	-3	High	-3%	High	105	114	9	High	9%	High
38	Plateau Zone	Inglewood Hill, 650	117	120	3	High	3%	High	105	102	-3	High	-3%	High
39	Plateau Zone	North Plateau, 650	113	116	3	High	3%	High	97	100	3	High	3%	High
40	Plateau Zone	North Plateau, 650	70	72	2	High	2%	High	54	47	-7	High	-13%	Medium
41	Plateau Zone	North Plateau, 650	49	49	0	High	1%	High	39	29	-10	Medium	-26%	Low
45	Plateau Zone	South Plateau, 650	97	96	-1	High	-1%	High	87	84	-4	High	-4%	High
15	Plateau Zone	Inglewood Hill, 700	99	105	6	High	6%	High	89	96	7	High	7%	High
16	Plateau Zone	Inglewood Hill, 700	70	70	0	High	0%	High	60	63	3	High	4%	High
4	Plateau Zone	North Plateau, 400 BROD	25	25	0	High	-1%	High	0	0	0	High	0%	High
26	Plateau Zone	SW Lake Sammamish, 400 WAV	102	103	1	High	1%	High	88	95	7	High	8%	High
34	Plateau Zone	Freeguard, 450 WAK	118	115	-3	High	-2%	High	104	109	5	High	5%	High
11	Plateau Zone	Inglewood Hill, 475 SAMSUN	92	94	2	High	3%	High	56	65	9	High	16%	Low
44	Plateau Zone	South Plateau, 550 ALD	57	57	0	High	0%	High	41	50	9	High	22%	Low
18	Plateau Zone	North Plateau, 700 SH	145	150	5	High	4%	High	0	0	0	High	0%	High

Table 3
Summary of Calibration Results – Pressure Zone Overview

Service Area	Pressure Zone	Static Error (psi)	Static Error (%)	Overall Static Confidence	Residual Error (psi)	Residual Error (%)	Overall Residual Confidence	Overall Pressure Zone Confidence
Cascade View Zone	642	6.8	7.3%	High	-2.6	-2.8%	High	High
Cascade View Zone	730	1.4	2.4%	High	0.1	2.4%	High	High
Cascade View Zone	550 CV	0.4	0.9%	High	2.0	6.1%	High	High
Cascade View Zone	590 CV	-3.1	-3.1%	High	5.6	7.4%	High	High
Cascade View Zone	650 CV	0.5	0.5%	High	4.9	5.7%	High	High
Plateau Zone	297	-3.8	-4.7%	High	4.6	8.0%	High	High
Plateau Zone	310	-3.4	-4.6%	High	8.8	15.0%	High	High
Plateau Zone	375	-6.4	-5.7%	High	-3.0	-3.1%	High	High
Plateau Zone	390	-1.8	-2.9%	High	2.0	5.0%	High	High
Plateau Zone	450	2.7	3.4%	High	6.4	9.8%	High	High
Plateau Zone	466	2.6	3.8%	High	6.4	11.2%	High	High
Plateau Zone	475	-4.4	-6.5%	High	7.0	20.9%	High	Medium*
Plateau Zone	499	2.3	2.6%	High	-5.6	-8.1%	High	High
Plateau Zone	510	0.1	0.2%	High	0.0	0.0%	High	High
Plateau Zone	540	3.1	4.4%	High	9.2	18.3%	Medium	High
Plateau Zone	550	1.6	5.5%	High	6.1	17.2%	High	High
<i>Plateau Zone</i>	<i>566</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>
Plateau Zone	590	-2.6	-2.9%	High	9.3	12.4%	Medium	High
Plateau Zone	650	0.5	0.7%	High	-1.4	-3.7%	High	High
Plateau Zone	700	2.6	2.6%	High	4.6	5.9%	High	High
Plateau Zone	400 BROD	-0.2	-0.8%	High	0.0	0.0%	High	High
<i>Plateau Zone</i>	<i>400 OV</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>
Plateau Zone	400 WAV	1.1	1.1%	High	7.0	7.9%	High	High
Plateau Zone	450 WAK	-2.9	-2.4%	High	4.9	4.8%	High	High
<i>Plateau Zone</i>	<i>475 PH</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>
Plateau Zone	475 SAMSUN	2.3	2.5%	High	9.2	16.4%	Medium	High
Plateau Zone	550 ALD	0.0	0.0%	High	8.8	21.5%	High	High
<i>Plateau Zone</i>	<i>700 BC</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>
<i>Plateau Zone</i>	<i>700 OV</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>
Plateau Zone	700 SH	5.3	3.7%	High	0.0	0.0%	High	High

*General Note: Pressure Zone 475 has an overall confidence of "Medium" due to inconsistencies with Test No. 12 within the Inglewood Hill zone.



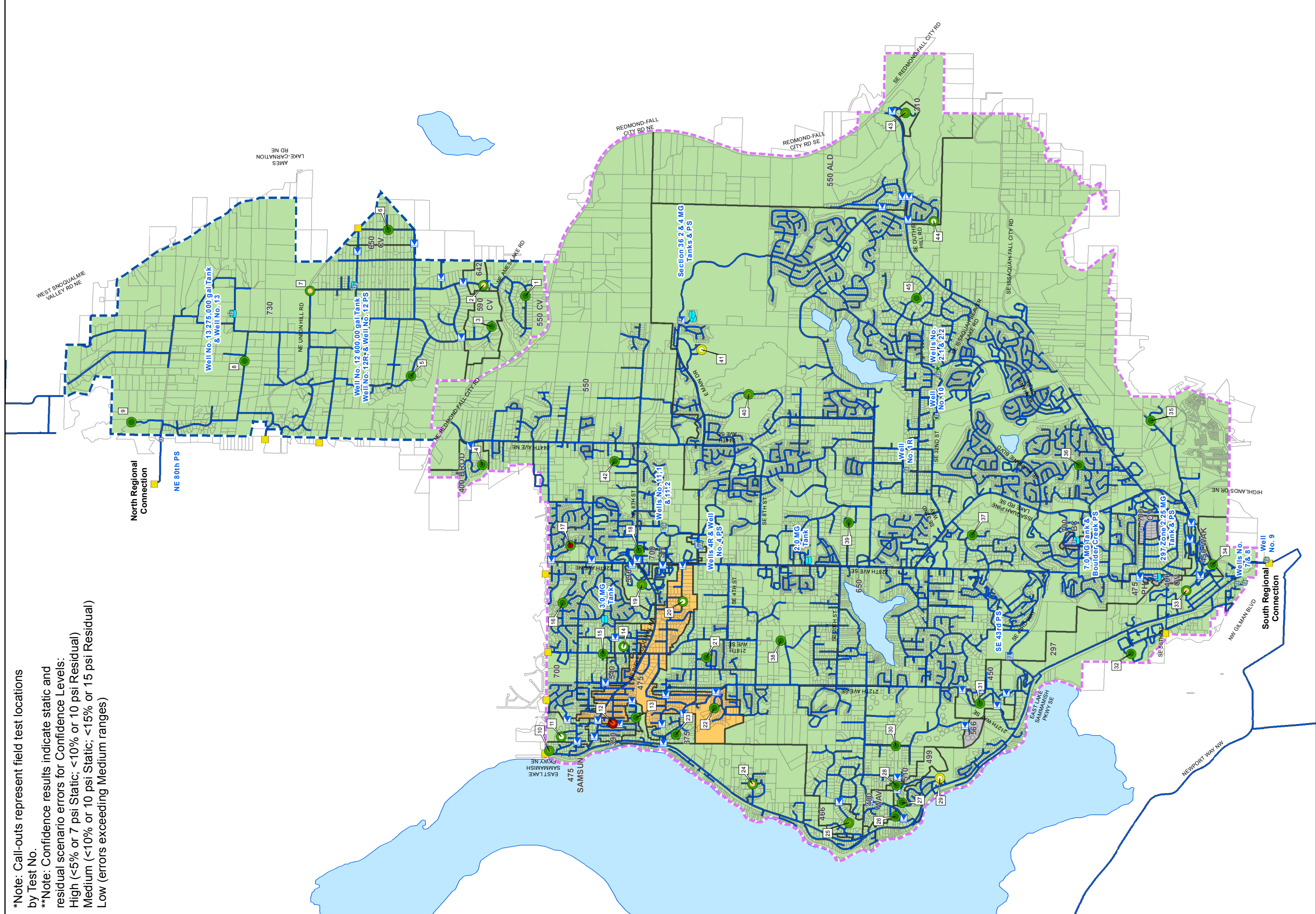
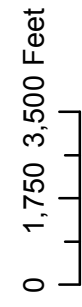
**SAMMAMISH
PLATEAU WATER
2016 CALIBRATION
CONFIDENCE**



*Note: Call-outs represent field test locations by Test No.

**Note: Confidence results indicate static and residual scenario errors for Confidence Levels:
High (<5% or 7 psi Static; <10% or 10 psi Residual)
Medium (<10% or 10 psi Static; <15% or 15 psi Residual)
Low (errors exceeding Medium ranges)

Booster Pump Station Tank Well PRV Intertie Water Main	Cascade View Plateau Parcel Water Body	Confidence (Percent Error)** High Static, High Residual High Static, Medium Residual High Static, Low Residual Medium Static, High Residual Medium Static, Medium Residual Medium Static, Low Residual Low Static, Low Residual	Confidence (Absolute Pressure)** High Static, High Residual High Static, Medium Residual High Static, Low Residual	Overall Pressure Zone Confidence High Confidence Medium Confidence Not Tested
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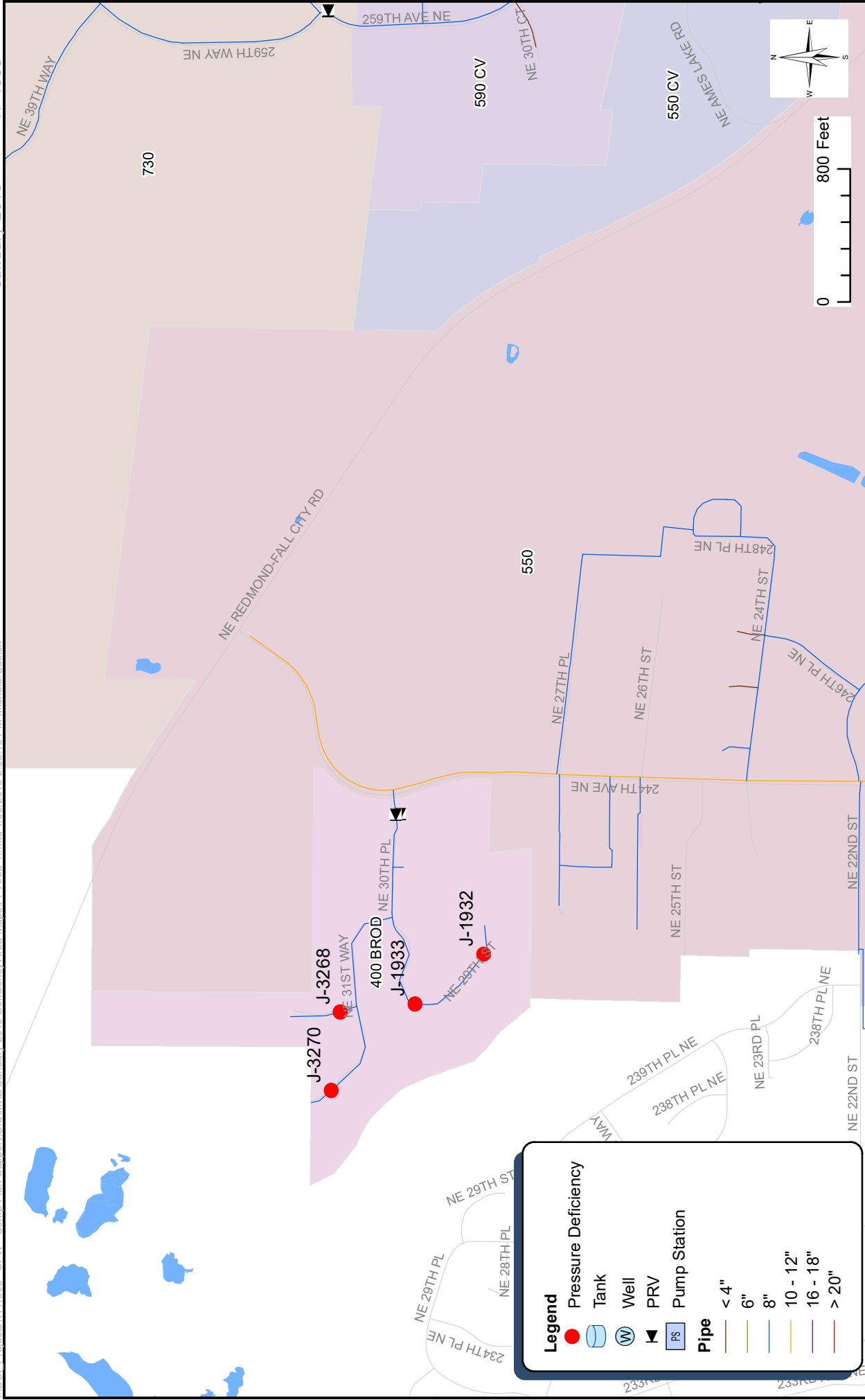
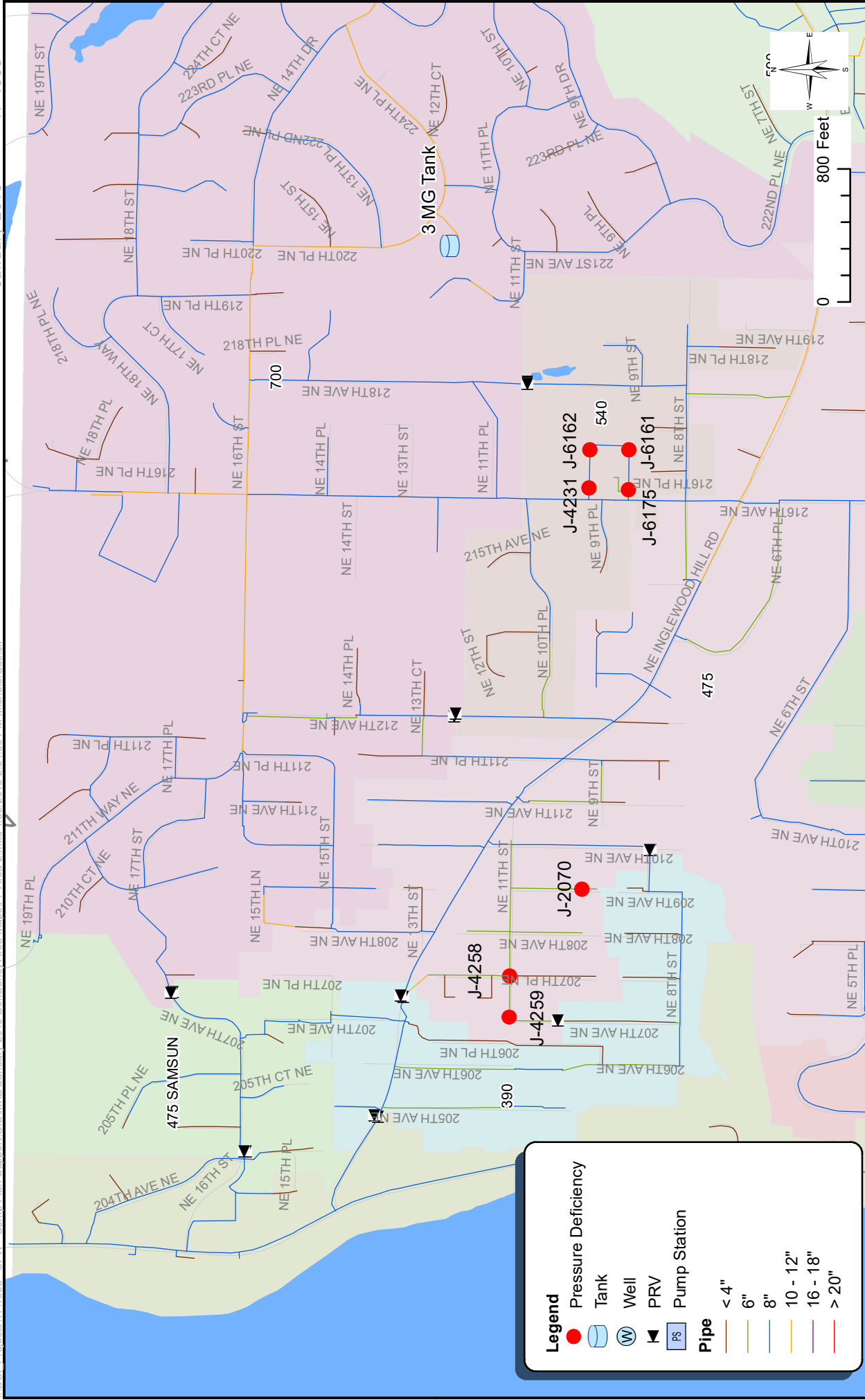


Figure 1
FF Area 1

Sammamish Plateau Water
2037 FF Deficiencies





Legend

- Pressure Deficiency
- ⊕ Tank
- ⊕ Well
- ⊕ PRV
- ⊕ Pump Station

Pipe

- < 4"
- 6"
- 8"
- 10 - 12"
- 16 - 18"
- > 20"



**Sammamish Plateau Water
2037 FF Deficiencies**

**Figure 2
FF Area 2 & 3**



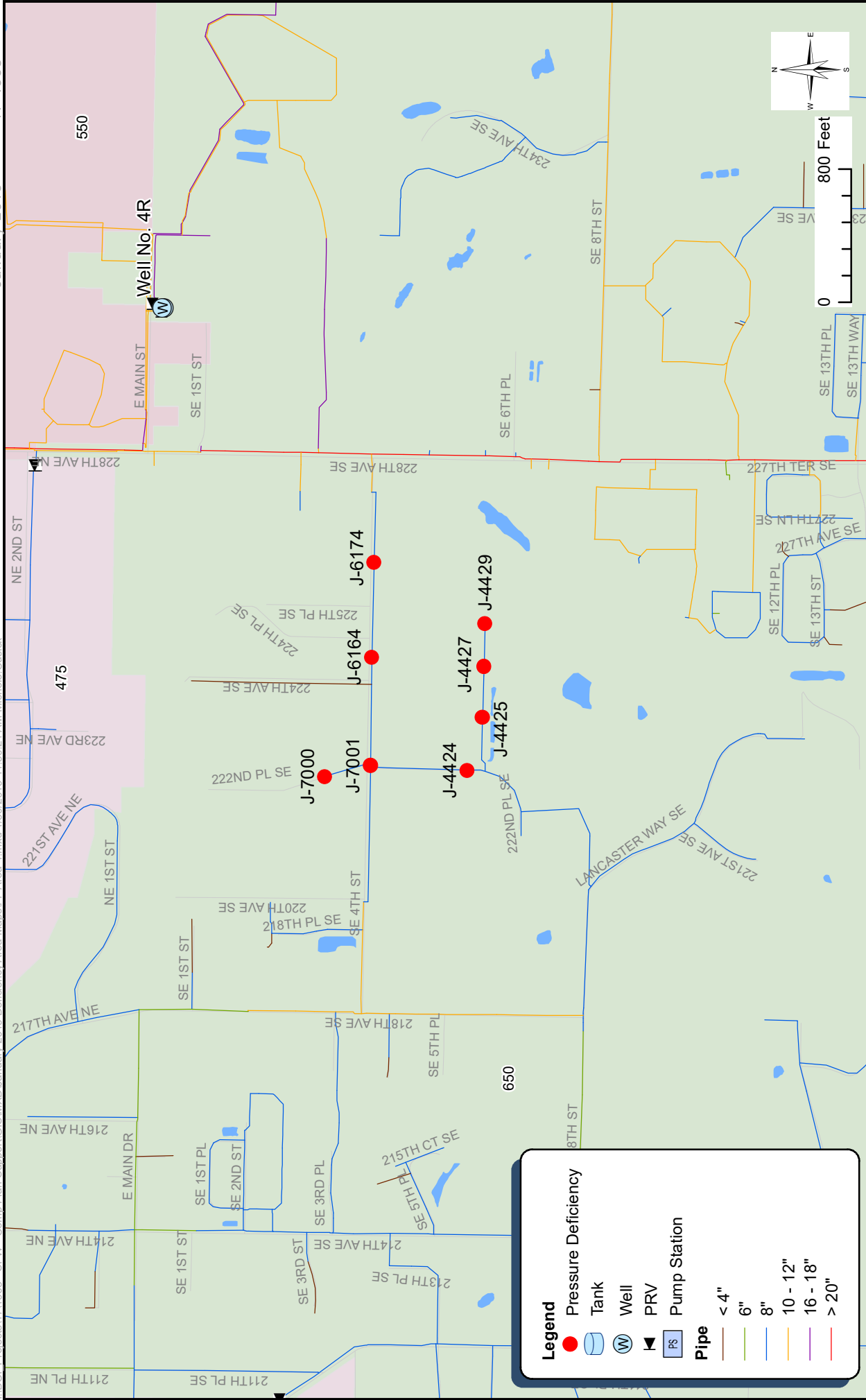






Figure 3
FF Area 4

Sammamish Plateau Water
2037 FF Deficiencies





Legend

- Pressure Deficiency
-  Tank
-  Well
-  PRV
-  Pump Station

Pipe

- < 4"
- 6"
- 8"
- 10 - 12"
- 16 - 18"
- > 20"



**Sammamish Plateau Water
2037 FF Deficiencies**

**Figure 4
FF Area 5**



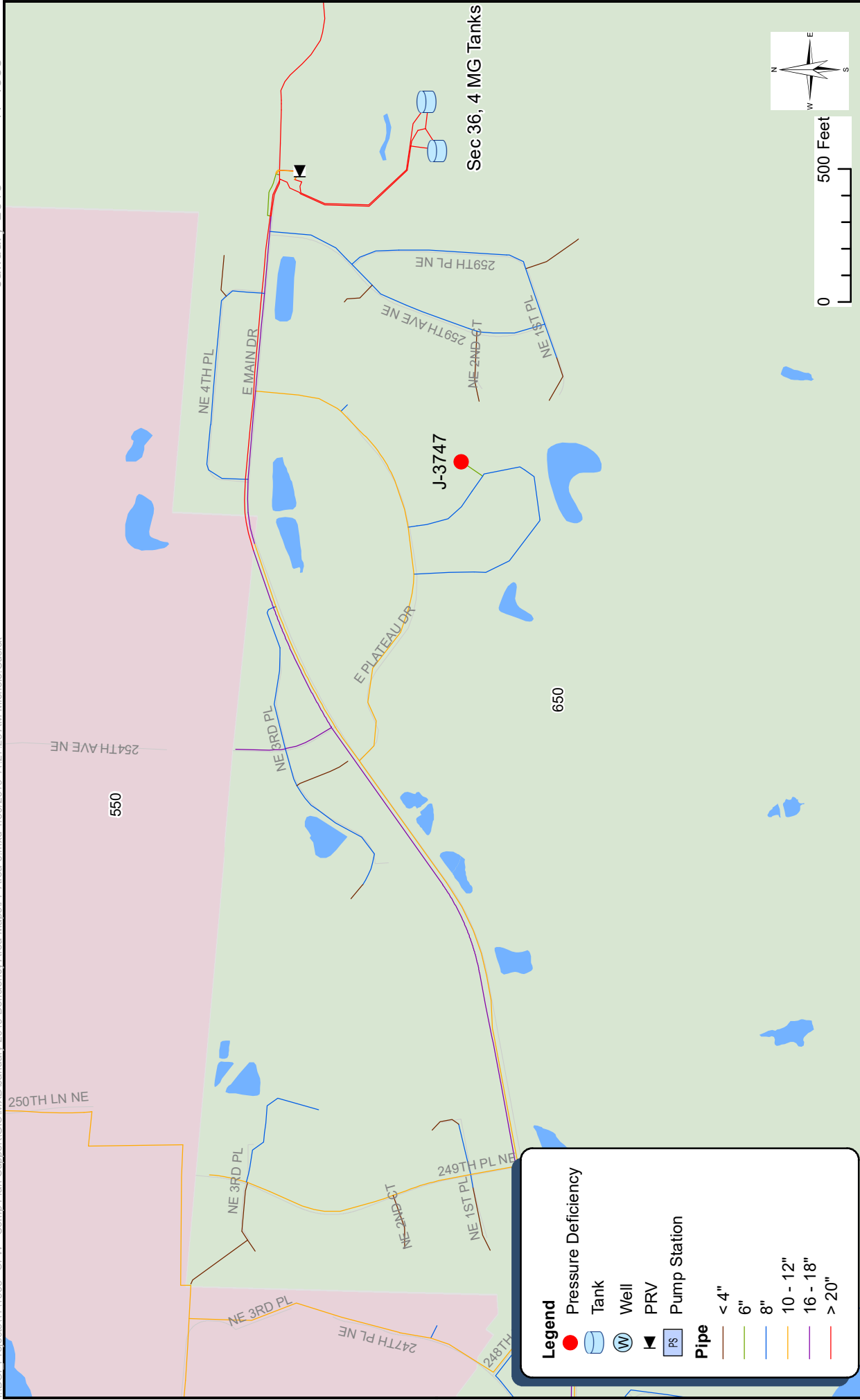
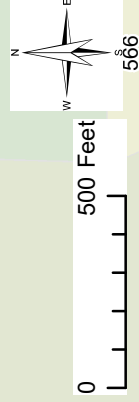
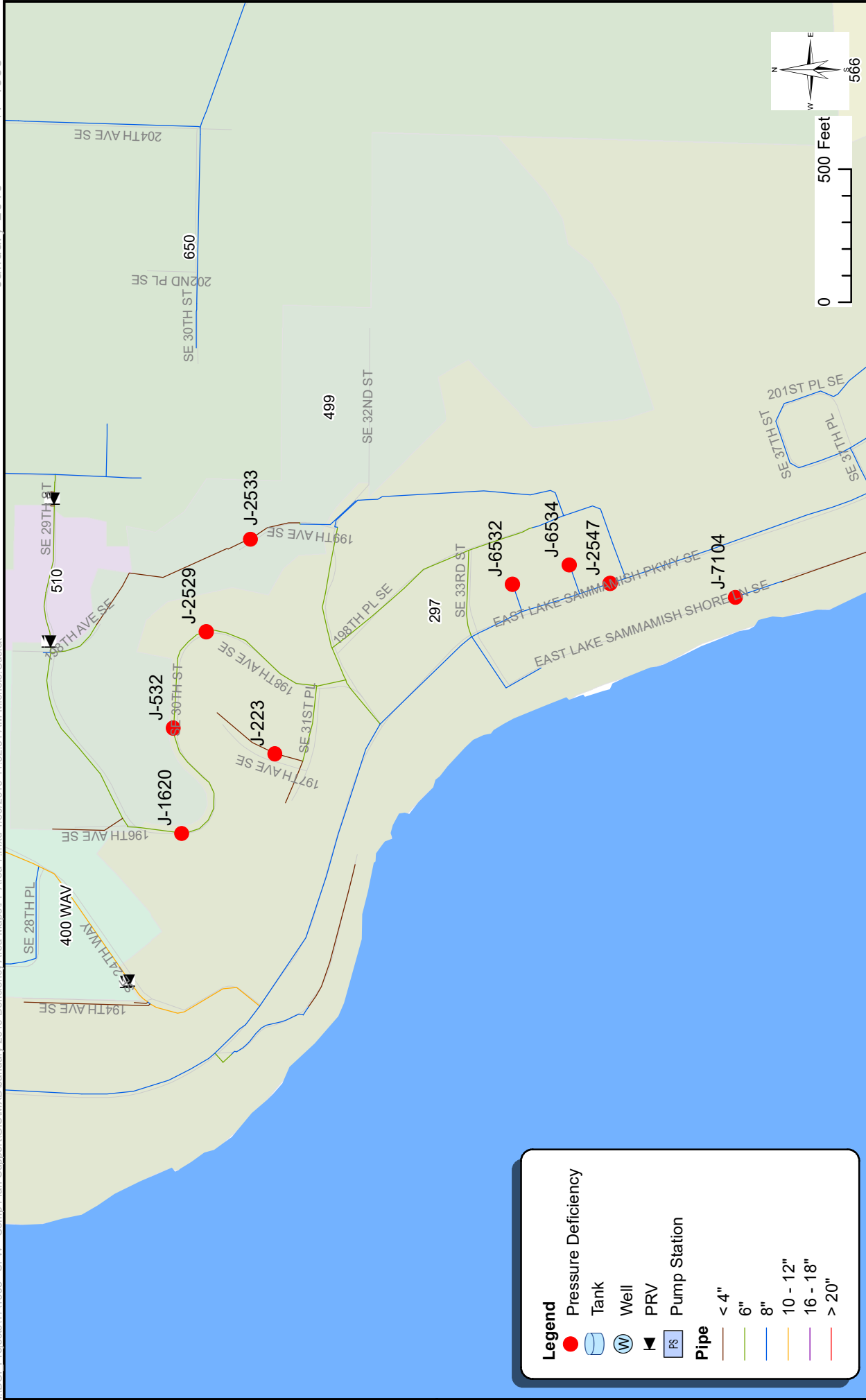


Figure 5
FF Area 6

Sammamish Plateau Water
2037 FF Deficiencies





Legend

- Pressure Deficiency
- Tank
- Well
- PRV
- Pump Station

Pipe

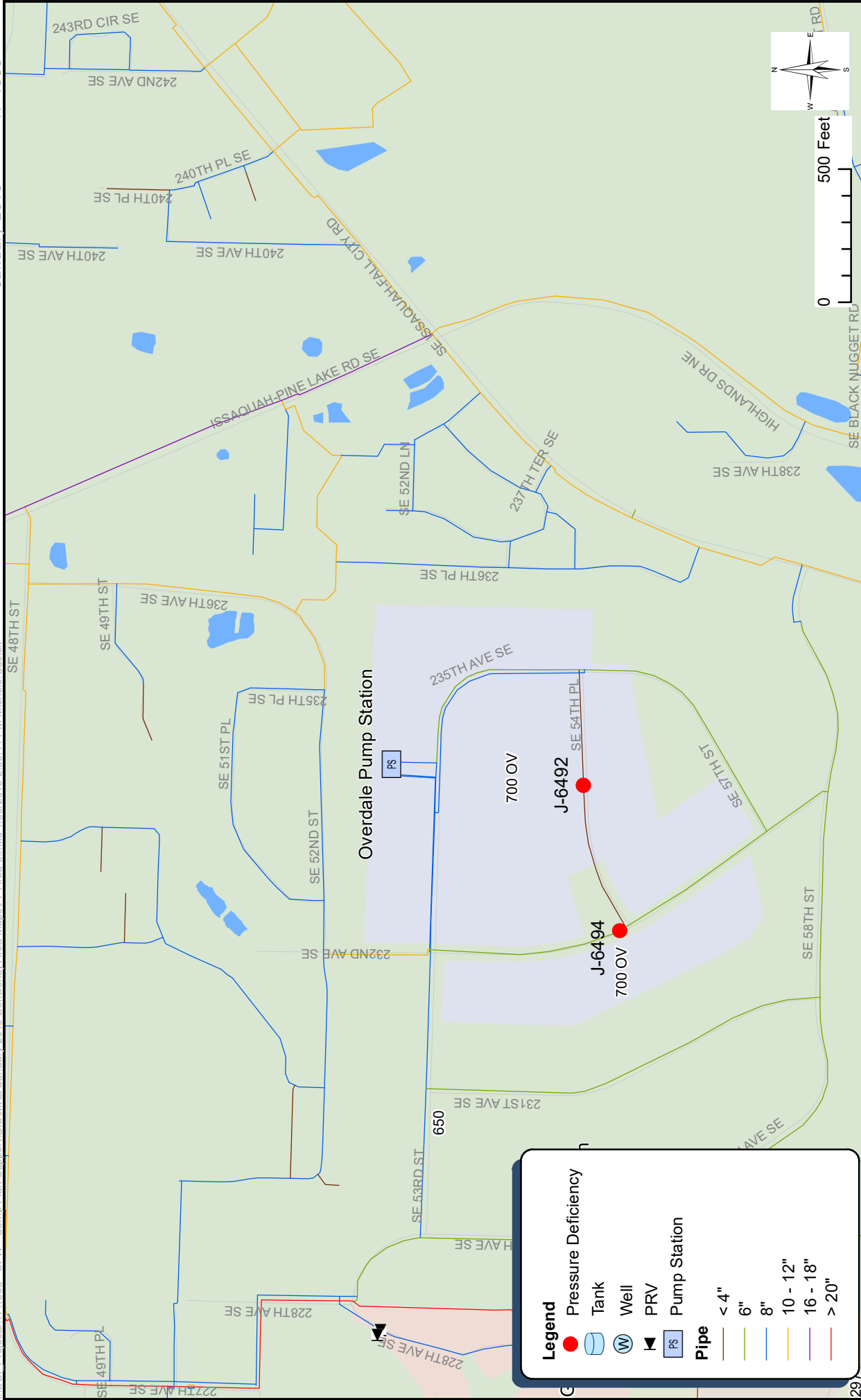
- < 4"
- 6"
- 8"
- 10 - 12"
- 16 - 18"
- > 20"

Sammamish Plateau Water 2037 FF Deficiencies

**Figure 6
FF Area 7**



N:\BOI_Projects\171968 - SPW - Comp Plan_Support\GIS\MXD\January_2019_DeficiencyArea_Maps\FF Area 8.mxd:1/30/2019 2:59:41 PM\Michele Cusick
 January 2019
 17 - 1968



Legend

- Pressure Deficiency
- Tank
- ⊕ Well
- ⏏ PRV
- PS Pump Station

Pipe

- < 4"
- 6"
- 8"
- 10 - 12"
- 16 - 18"
- > 20"



Sammamish Plateau Water 2037 FF Deficiencies

Figure 7 FF Area 8



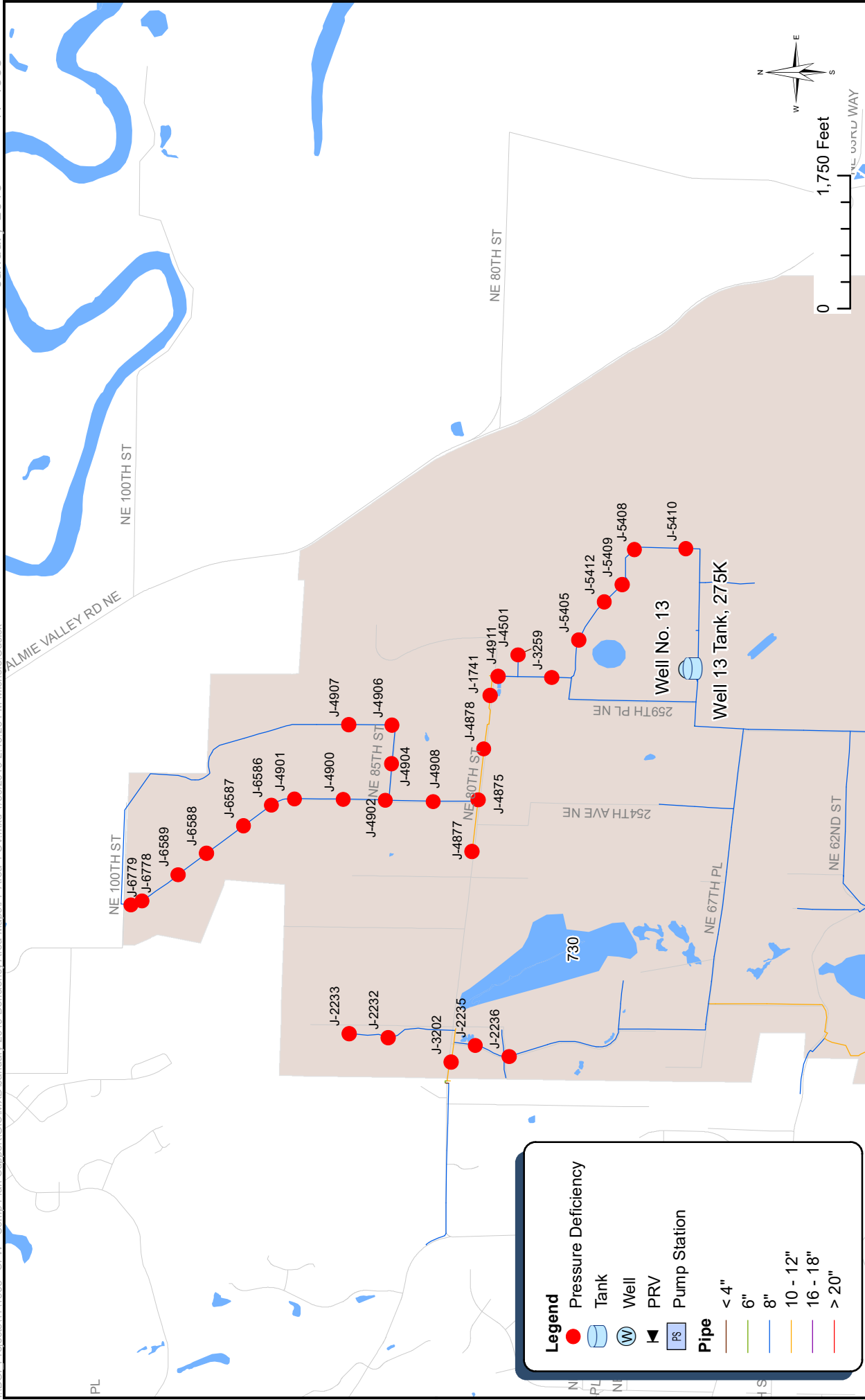


Figure 8
FF Area 1 CV

Sammamish Plateau Water
2037 FF Deficiencies



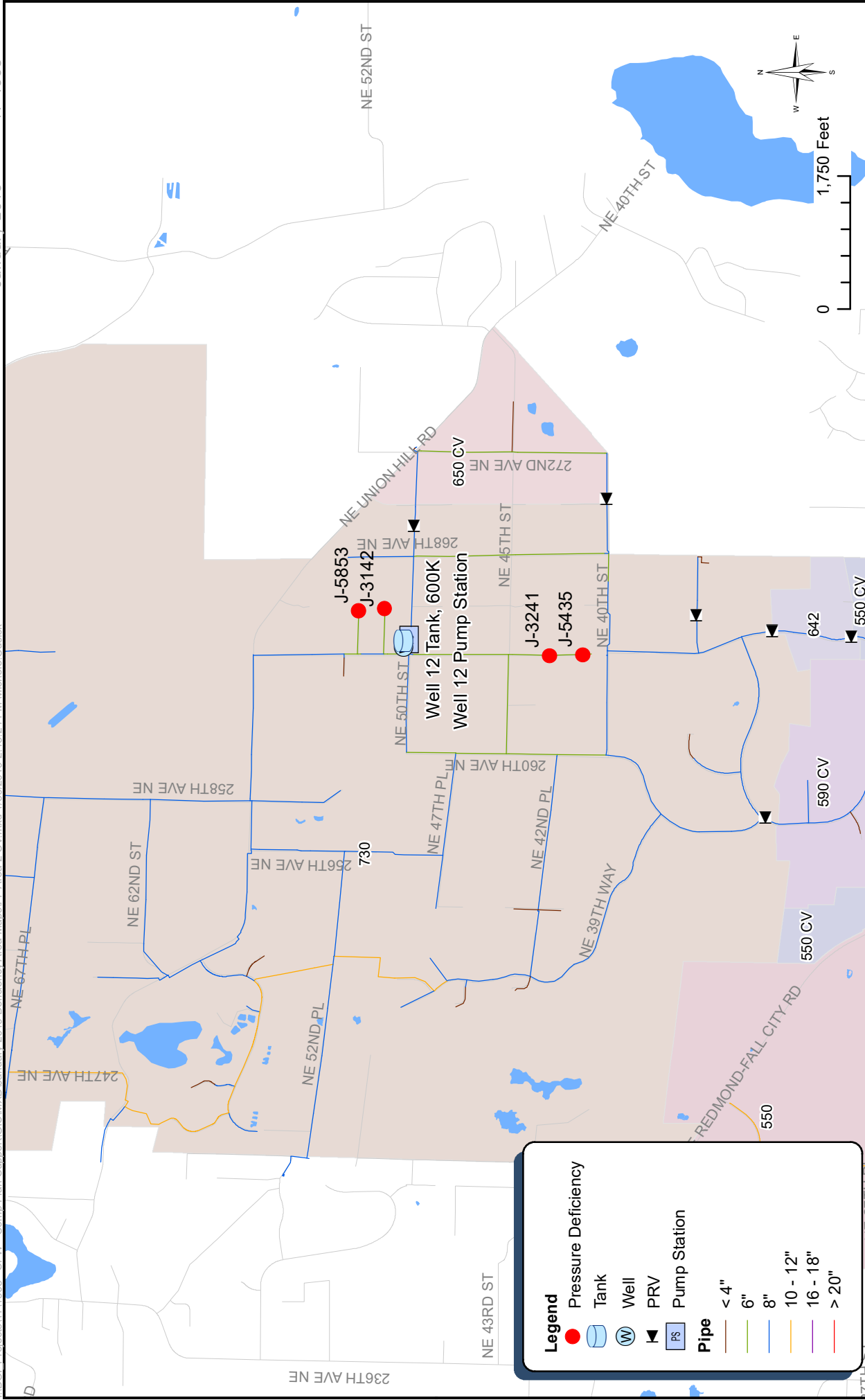


Figure 9
FF Area 2 CV

Sammamish Plateau Water
2037 FF Deficiencies



Table 3-10 - 2037 Fire Flow Deficiencies Plateau Zone

Area ID	Zone	Model Junction ID	Fire Flow Required (gpm)	2037 Available Flow (gpm)	Notes (see Figures 8-1 & 8-2)
FF Area 1	400 Broad	J-1932	1,000	555	Addressed by CIP Project FF-1 (8" main and PRV)
		J-1933	1,000	677	
		J-3268	1,000	974	
		J-3270	1,000	977	
FF Area 2	475	J-2070	1,000	909	Addressed by CIP Projects FF-3 and FF-4 (8" main)
		J-4258	1,000	833	
		J-4259	1,000	834	
FF Area 3	540	J-4231	3,000	1,492	Addressed by CIP Project FF-5 (PRV)
		J-6161	3,000	1,509	
		J-6162	3,000	1,508	
		J-6175	3,000	1,518	
FF Area 4	650	J-4424	4,000	1,557	Addressed by CIP Projects FF-6 and FF-7 (16" and 12" main)
		J-4425	4,000	1,573	
		J-4427	4,000	1,556	
		J-4429	4,000	1,618	
		J-6164	4,000	1,522	
		J-6174	4,000	2,253	
		J-7000	4,000	1,538	
		J-7001	4,000	1,529	
FF Area 5	297	J-5168	1,000	884	Addressed by CIP projects FF-9 and FF-10 (8" main and PRV)
FF Area 6	650	J-3747	3,000	2,309	Addressed by CIP Project FF-8 (12" main)
FF Area 7	297	J-223	1,000	976	Addressed by CIP Project FF-11 (8" main and PRV)
		J-532	1,000	505	
		J-1620	1,000	428	
		J-2529	1,000	613	
		J-2547	2,500	1,781	
		J-6532	3,000	1,743	
		J-6534	3,000	1,762	
	J-7104	1,000	883	Addressed by CIP Project FF-12 (8" main)	
FF Area 7	499	J-2533	1,000	580	Addressed by CIP Project FF-11 (8" main)
FF Area 8	700 OV	J-6492	1,000	264	Addressed by CIP Project FF-13
		J-6494	1,000	263	

Table 3-11 - 2037 Fire Flow Deficiencies Cascade View Zone

Area ID	Zone	Model Junction ID	Fire Flow Required (gpm)	2037 Available Flow (gpm)	Notes (see Figures 8-1 & 8-2)
FF Area 1 CV	730	J-1741	1,000	878	Addressed by CIP Projects FF-14 and FF- 15
		J-3259	1,000	899	
		J-4501	1,000	899	
		J-4875	1,000	854	
		J-4877	1,000	855	
		J-4878	1,000	853	
		J-4900	1,000	854	
		J-4901	1,000	854	
		J-4902	1,000	854	
		J-4904	1,000	853	
		J-4906	1,000	853	
		J-4907	1,000	853	
		J-4908	1,000	854	
		J-4911	1,000	889	
		J-5405	1,000	818	
		J-5408	1,000	857	
		J-5409	1,000	788	
		J-5410	1,000	944	
		J-5412	1,000	749	
		J-6586	1,000	853	
		J-6587	1,000	854	
		J-6588	1,000	853	
		J-6589	1,000	853	
		J-6778	1,000	853	
J-6779	1,000	853			
J-2233	1,000	948			
J-3202	1,000	965			
J-2232	1,000	966			
FF Area 1 CV	730	J-2235	1,000	967	Addressed by CIP Projects FF-14 and FF- 15
		J-2236	1,000	976	
FF Area 2 CV	730	J-5853	1,000	929	Addressed by CIP Project FF-16
		J-3142	1,000	911	
		J-3241	1,000	923	Addressed by CIP Project FF-17
J-5435	1,000	922			

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