

2018 Water System Plan, Tacoma Water

Chapter 6, Appendix I: Distribution System Analysis

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Author: M. Hubbard

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Chapter 6, Appendix I: Distribution System Analysis

Chapter I1. Modeled Demands

Projected Demands and Factors for TW Hydraulic Model Analysis

Factor to multiply FROM 2017 ADD TO:

2027 pADD	0.863
2037 pADD	0.797
2017 pMDD	2.548
2027 pMDD	2.550
2037 pMDD	2.553

Factor to multiply FROM ADD TO:

PHD (residential)	3.11
PHD (commerical)	1.16

Assumed ERU Value:

ERU (gpd/ERU)	184.22
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Figures from "ADD by Rate Cat - Consev" and "MDD - WSP.xlsx, MDD" for Maximum Day using the Maximum Monthly Demand value per Year

Year	MGD		
	Total	Simpson	Calculated Remainder
2017 Projected ADD	48.18	16.07	32.11
MDD	97.90	16.07	81.83
Factor	2.032	---	2.548

2027 Projected ADD	43.80	16.07	27.73
MDD	97.97	16.07	81.90
Factor	2.237	---	2.954

2037 Projected ADD	41.66	16.07	25.59
MDD	98.06	16.07	81.99
Factor	2.354	---	3.204

Adjust actual 2016 ADD Demand to 2017 projected

	Total	Simpson	Calculated Remainder
2016 Actual ADD	53.64	15.51	38.13
2017 Projected ADD	48.18	16.07	32.11
Factor	0.898	1.036	0.842

Note 53.64 was total average production for 2016 on "Monthly and Annual Production" and does not include 9.43 MGD for Partners

Calculated Remainder includes:

Wholesale accounts other than Partners (Fife, etc)

Residential

Commercial

Partners flow to remain flat at 9.43 MGD

PHD demand factors were calculated based on data from 2009-2016

Residential PHD calculations assumed outputs from Indian Hills Pump Station, pumps #1 and #2, is representative of residential demand

Commerical PHD calculations assumed output Hood Street's 24" outlet, serving the downtown core, is representative of commerical demand

Lowercase "p" denotes a projected demand

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Chapter 12. Peak Hour Demand Assessment

Peak Hour Demand Assessment															
Pressure Zone and HGL Elevation (ft)	Minimum Pressure, Non-Zero Demand Nodes (psi)	Nodes Below 30 psi, Non-Zero Demand	Demand Below 30 psi (gpm)	Calculated ERU's Below 30 psi	Nodes Below 27 psi, Non-Zero Demand	Demand Below 27 psi (gpm)	Calculated ERU's Below 27 psi	Total Nodes in Zone	Total Demand in Zone (gpm)	Calculated ERU's in Zone	Overall Assessment	Recommended Action/ Comment	2017 Assessment	2027 Assessment	2037 Assessment
Bonney Lake 1010	57.6	0	0	0	0	0	0	178	86	673	Adequate	None	Adequate	Adequate	Adequate
Bonney Lake 950	73.6	0	0	0	0	0	0	778	136	1,061	Adequate	None	Adequate	Adequate	Adequate
Cumberland 931	29.4	1	1	8	0	0	0	50	8	64	Adequate*	*Field verification required (model shows 29.42 psi, within 10% of 30 psi), connection between 8" and 12" main just south of Cumberland Tank connection	Adequate*	Adequate*	Adequate*
Bonney Lake 860	58.1	0	0	0	0	0	0	30	21	162	Adequate	None	Adequate	Adequate	Adequate
Prairie Ridge 810	43.8	0	0	0	0	0	0	2,830	1,405	10,981	Adequate	None	Adequate	Adequate	Adequate
McMillin 706	35.0	0	0	0	0	0	0	3,094	1,805	14,110	Adequate	None	Adequate	Adequate	Adequate
Fennel Creek 705	51.7	0	0	0	0	0	0	205	102	801	Adequate	None	Adequate	Adequate	Adequate
South Summit High 669	70.4	0	0	0	0	0	0	885	401	3,135	Adequate	None	Adequate	Adequate	Adequate
Indian Hill 649	40.3	0	0	0	0	0	0	641	336	2,629	Adequate	None	Adequate	Adequate	Adequate
80th Avenue E 626	53.7	0	0	0	0	0	0	26	24	191	Adequate	None	Adequate	Adequate	Adequate
Alder Lane 626	70.9	0	0	0	0	0	0	14	8	62	Adequate	None	Adequate	Adequate	Adequate
Highland 621	30.1	0	0	0	0	0	0	523	269	2,103	Adequate	None	Adequate	Adequate	Adequate
Frederickson 588	50.9	0	0	0	0	0	0	59	41	319	Adequate	None	Adequate	Adequate	Adequate
South East Tacoma 581	41.2	0	0	0	0	0	0	11	2	15	Adequate	None	Adequate	Adequate	Adequate
Fletcher Heights 581	41.9	0	0	0	0	0	0	253	113	886	Adequate	None	Adequate	Adequate	Adequate
Woodland 581	55.2	0	0	0	0	0	0	357	210	1,642	Adequate	None	Adequate	Adequate	Adequate
South Hill 581	40.0	0	0	0	0	0	0	1,327	537	4,201	Adequate	None	Adequate	Adequate	Adequate
Canyon 581	27.3	1	1	9	0	0	0	5,597	3,105	24,273	Adequate*	*Field verification required (model shows 27.3 psi, within 10% of 30 psi), intersection of E 53rd Street and E J Street	Adequate*	Adequate*	Adequate*
Bonney Lake 581	N/A	0	0	0	0	0	0	4	0	0	Adequate	None	Adequate	Adequate	Adequate
Park Royal 556	47.5	0	0	0	0	0	0	207	118	925	Adequate	None	Adequate	Adequate	Adequate
Northeast Tacoma 549	29.2	2	1	6	0	0	0	3,393	1,785	13,952	Adequate*	*Field verification required (model shows 29.2 psi, within 10% of 30 psi), intersection of Norpoint Way and Northshore Highway	Adequate*	Adequate*	Adequate*
Westgate / Fletcher Service 538	38.1	0	0	0	0	0	0	1,597	1,186	9,272	Adequate	None	Adequate	Adequate	Adequate
University Place 531	44.5	0	0	0	0	0	0	2,307	1,302	10,180	Adequate	None	Adequate	Adequate	Adequate
South East Tacoma 520	57.1	0	0	0	0	0	0	1,158	616	4,817	Adequate	None	Adequate	Adequate	Adequate
Sunrise Terrace 519	29.2	2	0.3	3	0	0	0	86	24	190	Adequate*	*Field verification required (model shows 29.2 psi, within 10% of 30 psi), intersection of 120th St E and Military Rd E	Adequate*	Adequate*	Adequate*

Peak Hour Demand Assessment															
Pressure Zone and HGL Elevation (ft)	Minimum Pressure, Non-Zero Demand Nodes (psi)	Nodes Below 30 psi, Non-Zero Demand	Demand Below 30 psi (gpm)	Calculated ERU's Below 30 psi	Nodes Below 27 psi, Non-Zero Demand	Demand Below 27 psi (gpm)	Calculated ERU's Below 27 psi	Total Nodes in Zone	Total Demand in Zone (gpm)	Calculated ERU's in Zone	Overall Assessment	Recommended Action/ Comment	2017 Assessment	2027 Assessment	2037 Assessment
Beverly Heights 486	47.2	0	0	0	0	0	0	114	52	409	Adequate	None	Adequate	Adequate	Adequate
High Service 478	20.5	26	25	198	7	4	28	22,373	13,393	104,690	Adequate*	*Project in progress to address 7 nodes less than 27psi; field verification required for other 26 locations	Adequate*	Adequate*	Adequate*
Middle Service 446	32.0	0	0	0	0	0	0	1,184	849	6,639	Adequate	None	Adequate	Adequate	Adequate
North End Service 446	28.3	3	6	43	0	0	0	1,426	1,001	7,824	Adequate*	*Field verification required (model shows 28.3 psi, within 10% of 30 psi), intersection of N Bennet Street and N 35th Street	Adequate*	Adequate*	Adequate*
Harbor View 426	59.5	0	0	0	0	0	0	40	28	216	Adequate	None	Adequate	Adequate	Adequate
Woodland 426	54.1	0	0	0	0	0	0	81	60	471	Adequate	None	Adequate	Adequate	Adequate
Dash High Point 411	39.4	0	0	0	0	0	0	39	27	209	Adequate	None	Adequate	Adequate	Adequate
Fife Heights Low 411	48.8	0	0	0	0	0	0	114	63	494	Adequate	None	Adequate	Adequate	Adequate
Twin Lakes 411	39.0	0	0	0	0	0	0	956	470	3,676	Adequate	None	Adequate	Adequate	Adequate
Overlook 370	51.7	0	0	0	0	0	0	87	89	695	Adequate	None	Adequate	Adequate	Adequate
Grandview 351	38.7	0	0	0	0	0	0	168	67	526	Adequate	None	Adequate	Adequate	Adequate
Salmon Beach North 350	N/A	0	0	0	0	0	0	11	0	0	Adequate	None	Adequate	Adequate	Adequate
Browns / Dash Points 346	34.9	0	0	0	0	0	0	386	125	979	Adequate	None	Adequate	Adequate	Adequate
North East Tacoma 346	37.8	0	0	0	0	0	0	550	143	1,117	Adequate	None	Adequate	Adequate	Adequate
Old Town 346	46.7	0	0	0	0	0	0	69	50	389	Adequate	None	Adequate	Adequate	Adequate
Portland Avenue 346	30.9	0	0	0	0	0	0	424	219	1,709	Adequate	None	Adequate	Adequate	Adequate
Narrows 328	39.4	0	0	0	0	0	0	640	352	2,755	Adequate	None	Adequate	Adequate	Adequate
High Cedars 316	71.6	0	0	0	0	0	0	423	215	1,682	Adequate	None	Adequate	Adequate	Adequate
Chambers Bay 290	107.6	0	0	0	0	0	0	17	0	3	Adequate	None	Adequate	Adequate	Adequate
Low Service 251	30.9	0	0	0	0	0	0	3,361	14,649	114,509	Adequate	None	Adequate	Adequate	Adequate
Dash Low Point 226	49.3	0	0	0	0	0	0	35	15	119	Adequate	None	Adequate	Adequate	Adequate
Hyada 226	42.1	0	0	0	0	0	0	152	104	813	Adequate	None	Adequate	Adequate	Adequate
Titlow 226	45.5	0	0	0	0	0	0	122	94	733	Adequate	None	Adequate	Adequate	Adequate
Day Island 202	65.8	0	0	0	0	0	0	53	39	306	Adequate	None	Adequate	Adequate	Adequate
Lakota Beach 186	49.2	0	0	0	0	0	0	62	30	231	Adequate	None	Adequate	Adequate	Adequate
Sunset Beach 155	61.3	0	0	0	0	0	0	6	4	35	Adequate	None	Adequate	Adequate	Adequate

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Chapter I3. Maximum Day Demand + Fire Flow Assessment

Maximum Day Demand + Fire Flow Assessment														
Pressure Zone and HGL Elevation (ft)	Maximum Available FF (gpm)	Minimum Available FF (gpm)	Basic Land Use Type	Tacoma Water Land Use Planning Level FF Target (gpm)	Jurisdiction Land Use Type	Jurisdiction	Jurisdiction Required FF (gpm)	Nodes Below 20 psi During FF	Total Nodes in Zone	Overall Assessment	Recommended Action/ Comment	2017 Assessment	2027 Assessment	2037 Assessment
Bonney Lake 1010	1,791	1,306	Residential	1,500	Employment Based Planned Community	Pierce County	750	0	178	Adequate	None	Adequate	Adequate	Adequate
Bonney Lake 950	1,966	1,355	Residential	1,500	Employment Based Planned Community	Pierce County	750	0	778	Adequate	None	Adequate	Adequate	Adequate
Cumberland 931	1,741	1,057	Residential	1,500	Rural Area	King	1,000	0	50	Adequate	None	Adequate	Adequate	Adequate
Bonney Lake 860	1,405	1,313	Residential	1,500	Employment Based Planned Community	Pierce County	750	0	30	Adequate	None	Adequate	Adequate	Adequate
Prairie Ridge 810	19,466	1,081	City	3,500	Bonney Lake	Pierce	1,500	0	2,830	Adequate	Multiple land use types within zone, fire flow requirements are met for each type	Adequate	Adequate	Adequate
McMillin 706	104,580	868	Commercial	3,500	Community Center	Pierce County	1,500	3	3,094	Additional Analysis Required	Multiple land use types within zone, review 6" AC main on 132nd Ave E for upsizing	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Fennel Creek 705	1,504	1,500	Residential	1,500	Rural 5	Pierce County	750	0	205	Adequate	None	Adequate	Adequate	Adequate
South Summit High 669	16,552	635	Commercial	3,500	Community Employment	Pierce	1,500	17	885	Additional Analysis Required	Select mains should be assessed for replacement, it appears 4" mains are reducing available fire flow	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Indian Hill 649	3,292	377	Residential	1,500	Single Family Residential	Tacoma	1,000	142	641	Additional Analysis Required	Node located at intersection of Tower Ln NE and Tower Dr NE is limiting FF due to elevation, review system for adjusting zone pressure upwards	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
80th Avenue E 626	2,118	1,285	Residential	1,500	Moderate Density Single Family	Pierce	1,000	0	26	Adequate	None	Adequate	Adequate	Adequate
Alder Lane 626	1,012	368	Residential	1,500	Moderate Density Single Family	Pierce County	750	2	14	Additional Analysis Required	Mains should be assessed for replacement, it appears 4" mains are reducing available fire flow	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Highland 621	2,621	625	Residential High Density	3,500	High Density Single Family	Pierce County	1,500	23	523	Additional Analysis Required	Review pressure zone and pump station settings for potentially adjusting pressure upwards	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required

Maximum Day Demand + Fire Flow Assessment														
Pressure Zone and HGL Elevation (ft)	Maximum Available FF (gpm)	Minimum Available FF (gpm)	Basic Land Use Type	Tacoma Water Land Use Planning Level FF Target (gpm)	Jurisdiction Land Use Type	Jurisdiction	Jurisdiction Required FF (gpm)	Nodes Below 20 psi During FF	Total Nodes in Zone	Overall Assessment	Recommended Action/ Comment	2017 Assessment	2027 Assessment	2037 Assessment
Frederickson 588	4,006	2,256	Commercial	3,500	Employment Center	Pierce	1,500	0	59	Adequate	None	Adequate	Adequate	Adequate
South East Tacoma 581	246	124	Commercial	3,500	Community Employment	Pierce	1,500	11	11	Additional Analysis Required	Nodes are served directly off of 58" transmission main with 2" galvanized steel manifolds, review for eliminating 2" manifolds	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Fletcher Heights 581	10,148	861	Commercial	3,500	Major Institutional Campus	Tacoma	1,500	7	253	Additional Analysis Required	Review for adjusting pressure zone boundary on western edge of zone, 6' main appears to limit flow at dead ends	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Woodland 581	11,407	715	Residential	1,500	Moderate Density Single Family	Pierce County	750	3	357	Additional Analysis Required	Review 4" and 6" AC mains for upsizing or looping, deficient node is located at dead end	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
South Hill 581	55,418	592	Commercial	3,500	Community Center	Pierce	1,500	4	1,327	Additional Analysis Required	Mains should be assessed for replacement, it appears 4" mains are reducing available fire flow along 72nd Ave E and 73rd Ave E	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Canyon 581	51,998	195	Mixed Use	3,500	Mixed Use District	Pierce County	1,500	57	5,597	Additional Analysis Required	Review 4" and 6" AC/Plastic aquired mains for upsizing or looping, deficient nodes generally located at dead ends	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Bonney Lake 581	37,774	37,225	Residential	1,500	Rural 10	Pierce	750	0	4	Adequate	None	Adequate	Adequate	Adequate
Park Royal 556	2,562	814	City	3,500	University Place	Pierce County	1,500	22	207	Additional Analysis Required	Review 6" AC aquired mains for upsizing or looping throughout zone, deficient nodes generally located at dead ends of cul-de-sacs	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required

Maximum Day Demand + Fire Flow Assessment														
Pressure Zone and HGL Elevation (ft)	Maximum Available FF (gpm)	Minimum Available FF (gpm)	Basic Land Use Type	Tacoma Water Land Use Planning Level FF Target (gpm)	Jurisdiction Land Use Type	Jurisdiction	Jurisdiction Required FF (gpm)	Nodes Below 20 psi During FF	Total Nodes in Zone	Overall Assessment	Recommended Action/ Comment	2017 Assessment	2027 Assessment	2037 Assessment
Northeast Tacoma 549	17,816	888	Commercial	5,000	General Commercial	King County	1,000	10	3,393	Additional Analysis Required	Multiple land use types within zone, fire flow requirements are met for each type; 6 nodes are deficient on edge of zone, review 6" and 4" mains for upsizing at these locations	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Westgate / Fletcher Service 538	8,198	316	Commercial	3,500	Major Institutional Campus	Tacoma	1,500	41	1,597	Additional Analysis Required	Nodes are generally deficient along dead ends east of N Stevens Ave, Review old 6" cast iron mains for upsizing at these locations	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
University Place 531	7,856	403	City	3,500	University Place	Pierce County	1,500	17	2,307	Additional Analysis Required	Review 6" mains for upsizing, particularly near pressure zone boundaries	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
South East Tacoma 520	5,897	301	Mixed Use	3,500	Commercial Mixed Use District	Pierce County	1,500	16	1,158	Additional Analysis Required	Review 4" AC mains for upsizing, identified nodes are located at constrictions and dead end	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Sunrise Terrace 519	2,217	528	Residential	1,500	Moderate Density Single Family	Pierce	750	8	86	Additional Analysis Required	6" ductile iron main along 120th Street E appears to be undersized, review for upsizing or looping	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Beverly Heights 486	2,748	1,787	Residential	1,500	Single Family Residential	Tacoma	1,000	0	114	Adequate	None	Adequate	Adequate	Adequate
High Service 478	38,599	29	Commercial	5,000	General Commercial	Tacoma	1,500	457	22,373	Additional Analysis Required	Review 6" mains for upsizing, particularly near pressure zone boundaries	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Middle Service 446	6,292	568	Mixed Use	3,500	Downtown Regional Growth Center	Tacoma	1,500	6	1,184	Additional Analysis Required	Multiple land use types within zone, fire flow requirements are met for each type; 4 nodes are deficient on edge of zone boundary with 478 on north Yakima Ave and N 8th Street, can likely be addressed by adjusting zone boundary	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required

Maximum Day Demand + Fire Flow Assessment

Pressure Zone and HGL Elevation (ft)	Maximum Available FF (gpm)	Minimum Available FF (gpm)	Basic Land Use Type	Tacoma Water Land Use Planning Level FF Target (gpm)	Jurisdiction Land Use Type	Jurisdiction	Jurisdiction Required FF (gpm)	Nodes Below 20 psi During FF	Total Nodes in Zone	Overall Assessment	Recommended Action/ Comment	2017 Assessment	2027 Assessment	2037 Assessment
North End Service 446	569	235	Residential High Density	3,500	Multi-Family (High Density)	Tacoma	1,500	546	1,426	Additional Analysis Required	Node located at intersection of N 35th and N Shirley is limiting FF due to elevation, review system for adjusting zone pressure upwards	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Harbor View 426	3,449	1,951	Residential	1,500	Single Family Residential	Tacoma	1,000	0	40	Adequate	None	Adequate	Adequate	Adequate
Woodland 426	3,449	736	Residential	1,500			750	7	81	Additional Analysis Required	6" AC main along Woodland Ave should be assessed for replacement, it appears to be reducing available fire flow	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Dash High Point 411	2,900	1,032	Residential	1,500	Single Family	Pierce	1,000	0	39	Adequate	None	Adequate	Adequate	Adequate
Fife Heights Low 411	1,875	929	Residential	1,500	Moderate Density Single Family	Pierce County	750	0	114	Adequate	None	Adequate	Adequate	Adequate
Twin Lakes 411	8,737	737	Residential	1,500	Undesignated	King County	1,000	2	956	Additional Analysis Required	Review 6" AC main for upsizing	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Overlook 370	4,013	2,104	Residential	1,500	Single Family Residential	Tacoma	1,000	0	87	Adequate	None	Adequate	Adequate	Adequate
Grandview 351	2,471	1,511	City	3,500	University Place	Pierce	1,500	0	168	Adequate	None	Adequate	Adequate	Adequate
Salmon Beach North 350	1,096	1,096	Park	1,000	Parks and Open Space	Tacoma	1,000	0	11	Adequate	None	Adequate	Adequate	Adequate
Browns / Dash Points 346	4,103	1,179	Commercial	2,000	Neighborhood Center	Pierce	1,500	0	386	Adequate	Multiple land use types within zone, fire flow requirements are met for each type	Adequate	Adequate	Adequate
North East Tacoma 346	2,667	592	Residential	1,500	Undesignated	King	1,000	8	550	Additional Analysis Required	Review 6" mains for upsizing and looping, deficiencies located near service provided to Dash Point State Park	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Old Town 346	1,638	732	Residential	1,500	Single Family Residential	Tacoma	1,000	2	69	Additional Analysis Required	Review 4" and 6" mains for upsizing	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Portland Avenue 346	3,599	551	Residential	1,500	Multi-Family (Low Density)	Tacoma	1,000	96	424	Additional Analysis Required	Review early 1900's 4" and 6" mains for upsizing	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Narrows 328	3,546	938	Residential	1,500	Multi-Family (Low Density)	Tacoma	1,000	1	640	Additional Analysis Required	Review zone boundary to determine if changing zones will improve fire flow, 1 node is identified	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required

Maximum Day Demand + Fire Flow Assessment														
Pressure Zone and HGL Elevation (ft)	Maximum Available FF (gpm)	Minimum Available FF (gpm)	Basic Land Use Type	Tacoma Water Land Use Planning Level FF Target (gpm)	Jurisdiction Land Use Type	Jurisdiction	Jurisdiction Required FF (gpm)	Nodes Below 20 psi During FF	Total Nodes in Zone	Overall Assessment	Recommended Action/ Comment	2017 Assessment	2027 Assessment	2037 Assessment
High Cedars 316	3,468	1,678	Industrial	5,000	Rural Industrial Center	Pierce County	2,000	0	423	Adequate	Multiple land use types within zone, fire flow requirements are met for each type	Adequate	Adequate	Adequate
Chambers Bay 290	2,653	2,450	City	3,500	University Place	Pierce County	1,500	0	17	Adequate	None	Adequate	Adequate	Adequate
Low Service 251	62,649	378	Industrial	5,000	Heavy Industrial	Tacoma	2,000	8	3,361	Additional Analysis Required	Three locations identified with fire flow restrictions, review 4" and 6" CI mains for upsizing	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Dash Low Point 226	1,076	773	Residential	1,500	Single Family	Pierce	750	0	35	Adequate	None	Adequate	Adequate	Adequate
Hyada 226	3,407	864	Residential	1,500	Single Family	Pierce	750	0	152	Adequate	None	Adequate	Adequate	Adequate
Titlow 226	2,995	1,149	Residential	1,500	Single Family Residential	Tacoma	1,000	0	122	Adequate	None	Adequate	Adequate	Adequate
Day Island 202	1,464	534	City	3,500	University Place	Pierce County	1,500	35	53	Additional Analysis Required	Review 4" and 6" mains for upsizing	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Lakota Beach 186	1,023	517	Residential	1,500	Single-Family Residential	King	1,000	21	62	Additional Analysis Required	Review 6" AC mains for upsizing, this zone appears to be undersized to provide 1,000 gpm	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required
Sunset Beach 155	705	700	City	3,500	University Place	Pierce County	1,500	2	6	Additional Analysis Required	4" DI pipe in PRV station should be assessed for replacement, it appears to be reducing available fire flow	Additional Analysis Required	Additional Analysis Required	Additional Analysis Required

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**Chapter I4. Technical Memo (RH2, 9/20/2017),
Hydraulic Model Updates**



RH2 TECHNICAL MEMORANDUM

Client: Tacoma Water

Project: Hydraulic Model Update and Calibration

Project File: TAC 517.122.01.102 Project Manager: Michele Campbell, PE

Composed by: Ryan Withers, PE

Reviewed by: Geoff Dillard, PE

Subject: Stage 1 Updates

Date: September 20, 2017



9/20/2017



9/20/2017



9/20/2017

This technical memorandum summarizes the updates made in Tacoma Water’s hydraulic model by RH2 Engineering, Inc., (RH2) as part of the Stage 1 updates requested by Tacoma Water. Stage 1 consists of the following six updates.

1. Add minor losses to the 25 booster pump stations (BPS) in the hydraulic model.
2. Review and update check valve and variable frequency drive (VFD) functionality.
3. Compute pipe roughness coefficients and compare to existing pipe roughness coefficients.
4. Initialize “no services” and “facility” junctions.
5. Initialize planning-level fire flow requirements.
6. Create peak hour demand (PHD) demand sets.

BACKGROUND

In 2016, Tacoma Water created a new InfoWater hydraulic model from Tacoma Water’s ESRI Geographical Information System (GIS) database. In 2016 and 2017, Tacoma Water updated the model to include demand allocations, simple controls at existing facilities, and additional water system properties such as pressure zone information, pipe roughness coefficients, land use information, and reservoir geometry. Tacoma Water is preparing to utilize the hydraulic model for system analyses in its 2017 *Water System Plan* and requested that RH2 perform the Stage 1 updates using InfoWater version 12.7, Update No. 2.

UPDATE 1 – BPS MINOR LOSSES

Minor losses occur throughout water systems at valves, tees, bends, reducers, and other fittings, and can be significant within facilities where water velocities are typically higher than in the transmission or distribution system. Based on conversations between Tacoma Water and RH2 at the project scoping meeting on July 14, 2017, Tacoma Water estimated minor losses in each of its BPSs to be 10 feet in the hydraulic model, with 3 feet of minor losses assumed on the suction side of each pump, and 7 feet of minor losses assumed on the discharge side of each pump. RH2 initialized the minor losses at each BPS based on the design capacity of each BPS, which is shown in **Table 1**. The minor losses were entered into the Tacoma Water hydraulic model as resistance coefficients (K values) on the suction and discharge pipes at each BPS. The resistance coefficient added to the suction and discharge pipes at each BPS is shown in **Table 1**.

Table 1: BPS Resistance Coefficients

BPS Name	Capacity (MGD)	Capacity (gpm)	Suction Piping			Discharge Piping		
			Model Pipe ID	Pipe Size (inches)	Resistance Coefficient (K Value)	Model Pipe ID	Pipe Size (inches)	Resistance Coefficient (K Value)
Alder Lane	0.7	486	M-0106940	4	1.3	M-0106941	4	2.9
Cumberland	0.5	347	M-0061645	6	12.4	M-0026032	6	29.0
Fennel Creek	3.4	2,361	M-0056905	12	4.3	M-0106532	12	10.0
Frederickson	0.2	139	M-0106660	6	77.8	M-0059547	6	181.5
Highland	1.0	694	M-0078868	8	9.8	M-0078896	8	22.9
Hood Street	15.0	10,417	M-0070401	48	56.6	M-0070323	24	8.3
Indian Hill No. 1	2.2	1,528	M-0068974	10	5.0	M-0068982	10	11.6
Indian Hill No. 2	1.9	1,319	M-0068302	12	13.8	M-0068310	12	32.2
Marine View Drive (1 - 4)	3.7	2,569	M-0099228	12	3.6	M-0056729	12	8.5
Marine View Drive (5 - 7)	7.0	4,861	M-0099199	12	1.0	M-0099005	16	7.5
McMillin No. 1	3.3	2,292	M-0105953	12	4.6	M-0062892	12	10.7
McMillin No. 2	4.2	2,917	M-0062683	24	45.2	M-0062705	24	105.4
Mildred Street	1.2	833	M-0099320	12	34.6	M-0105915	12	80.7
North End	8.5	5,903	M-0106336	24	11.0	M-0107063	24	25.7
Palmer	0.1	69	M-0105167	2	3.8	M-0105173	2	9.0
Prairie Ridge	1.8	1,250	M-0106458	18	77.8	M-0067828	18	181.5
South Tacoma	14.4	10,000	M-0056558	14	5.3	M-0106320	30	21.9
			M-0056559	14	5.3			
			M-0056560	14	5.3			
			M-0056561	14	5.3			
South Summit	2.2	1,528	M-0056749	8	2.0	M-0056750	8	4.7
128th and 62nd (Summit and 62nd)	0.6	417	M-0056773	6	8.6	M-0056774	6	20.2
198th Avenue	3.4	2,361	M-0106468	18	21.8	M-0106467	18	50.9
214th Avenue E	8.6	5,993	M-0056889	16	2.1	M-0056879	8	0.3
356th/357th Street	5.8	4,028	M-0106301	24	23.7	M-0106294	24	55.2
83rd and Cirque	0.5	347	M-0106930	6	12.4	M-0056543	8	91.8
80th Avenue	0.03	21	M-0101721	4	682.9	M-0101715	4	1593.4
21st and Pearl	3.3	2,257	M-0028955	12	4.7	M-0106922	12	11.0

MGD = million gallons per day

UPDATE 2 – CHECK VALVE AND VFD FUNCTIONALITY

CHECK VALVE FUNCTIONALITY

The Tacoma Water hydraulic model includes 112 check valves assigned to pipes throughout the distribution system; however, Tacoma Water indicated that the hydraulic model does not properly compute with the active check valves, and has closed the pipes that are associated with the check valves. Among the 112 check valves, 15 are located at facilities, and 97 are located along pressure zone boundaries. RH2 reviewed and updated the valves to enable the model to properly compute and the valves to function in the model in a manner that matches their function in the actual water system. All facility check valves were determined to be oriented in the proper direction and the pipes associated with these valves have been opened in the hydraulic model.

Among the 97 check valves located at pressure zone boundaries, 42 were found to be oriented in the incorrect direction. The direction of these check valves has been updated, and 96 of the 97 check valves located at zone boundaries have been activated in the hydraulic model. One check valve, assigned to Pipe ID No. M-0107007, appears to be located within the 538 Zone distribution system and is believed to have been erroneously identified as a check valve location. RH2 removed the check valve assignment from this pipe, and updated the pipe to operate as a pipe capable of two-way conveyance. It is recommended that Tacoma Water confirm the lack of a check valve at this location. If a check valve is present at this location, it is recommended that Tacoma Water confirm the flow direction of the valve, and update this pipe if necessary.

An additional check valve, assigned to Pipe ID No. M-0106929, is located at the convergence of three pressure zones near the 83rd Avenue and Cirque Drive BPS. RH2 opened the pipe associated with this check valve based on the assumption that the check valve allows 531 Zone water to be conveyed to the 556 Zone during an emergency event. It is recommended that Tacoma Water confirm the flow direction of this valve, and update this check valve if necessary.

Table 2 presents a summary of each check valve in the hydraulic model, the pressure zone on each side of the valve, and the changes made to the valve direction (if any). The aforementioned pipes recommended for review by Tacoma Water are shown highlighted in **Table 2**.

Table 2: Check Valve Summary

Pipe No.	Zone or Facility?	Pressure Zone		Direction Correct?
		To	From	
M-0106934	Facility	626	581	Yes
M-0106407	Facility	669	581	Yes
M-0106467	Facility	198th Ave BPS Discharge		Yes
M-0107052	Facility	Sunrise Res. Outlet		Yes
M-0107053	Facility	Sunrise Res. Inlet		Yes
M-0065881	Facility	McMillin Res. Outlet		Yes
M-0106958	Facility	Palmer BPS Bypass		Yes
M-0106957	Facility	Palmer BPS Discharge		Yes
M-0107066	Facility	North End BPS		Yes
M-0106327	Facility	Trans	538	Yes
M-0106956	Facility	Trans	931	Yes
M-0107051	Facility	Trans	McMillin Res.	Yes
M-0107020	Facility	UP Reservoirs to 478 Zone		Yes
M-0106831	Facility	Well PA1 Discharge		Yes

Table 2: Check Valve Summary (continued)

Pipe No.	Zone or Facility?	Pressure Zone		Direction Correct?
		To	From	
M-0107054	Zone	328	226	Yes
M-0107055	Zone	328	226	Yes
M-0106974	Zone	346	251	Yes
M-0107017	Zone	346	251	No, RH2 changed
M-0107025	Zone	346	251	Yes
M-0106995	Zone	478	328	Yes
M-0107032	Zone	478	346	No, RH2 changed
M-0106994	Zone	478	446N	Yes
M-0107023	Zone	478	446N	Yes
M-0107027	Zone	478	446N	No, RH2 changed
M-0107004	Zone	520	478	Yes
M-0107037	Zone	520	478	No, RH2 changed
M-0107040	Zone	520	478	Yes
M-0107057	Zone	520	478	Yes
M-0107058	Zone	520	478	Yes
M-0000860	Zone	531	478	Yes
M-0106959	Zone	531	478	Yes
M-0106961	Zone	531	478	No, RH2 changed
M-0106964	Zone	531	478	Yes
M-0107015	Zone	531	478	Yes
M-0107022	Zone	531	478	No, RH2 changed
M-0107059	Zone	531	478	No, RH2 changed
M-0106338	Zone	538	478	Yes
M-0106924	Zone	538	478	No, RH2 changed
M-0106975	Zone	538	478	No, RH2 changed
M-0106976	Zone	538	478	No, RH2 changed
M-0106977	Zone	538	478	Yes
M-0106979	Zone	538	478	No, RH2 changed
M-0106980	Zone	538	478	No, RH2 changed
M-0106981	Zone	538	478	No, RH2 changed
M-0106982	Zone	538	478	No, RH2 changed
M-0106983	Zone	538	478	No, RH2 changed
M-0106984	Zone	538	478	Yes
M-0106985	Zone	538	478	No, RH2 changed
M-0106986	Zone	538	478	No, RH2 changed
M-0106987	Zone	538	478	No, RH2 changed
M-0106988	Zone	538	478	No, RH2 changed
M-0106989	Zone	538	478	Yes
M-0106990	Zone	538	478	Yes
M-0106991	Zone	538	478	Yes
M-0106992	Zone	538	478	Yes
M-0106993	Zone	538	478	No, RH2 changed
M-0107005	Zone	538	478	No, RH2 changed
M-0107006	Zone	538	478	Yes
M-0107008	Zone	538	478	Yes
M-0107010	Zone	538	478	No, RH2 changed
M-0107011	Zone	538	478	No, RH2 changed
M-0107012	Zone	538	478	Yes
M-0107014	Zone	538	478	Yes

Table 2: Check Valve Summary (continued)

Pipe No.	Zone or Facility?	Pressure Zone		Direction Correct?
		To	From	
M-0107018	Zone	538	478	Yes
M-0107019	Zone	538	478	No, RH2 changed
M-0107026	Zone	538	478	No, RH2 changed
M-0107007	Zone	538	538	Not Applicable
M-0106962	Zone	556	478	Yes
M-0106960	Zone	556	531	No, RH2 changed
M-0106963	Zone	556	531	Yes
M-0107016	Zone	556	531	Yes
M-0107021	Zone	556	531	No, RH2 changed
M-0106972	Zone	581	478	Yes
M-0106973	Zone	581	478	No, RH2 changed
M-0106996	Zone	581	478	Yes
M-0106997	Zone	581	478	Yes
M-0107024	Zone	581	478	Yes
M-0107028	Zone	581	478	No, RH2 changed
M-0107035	Zone	581	478	No, RH2 changed
M-0107036	Zone	581	478	Yes
M-0106999	Zone	588	581	No, RH2 changed
M-0107043	Zone	588	581	Yes
M-0069363	Zone	621	581	Yes
M-0106418	Zone	621	581	Yes
M-0107003	Zone	621	581	Yes
M-0106691	Zone	626	581	No, RH2 changed
M-0106952	Zone	626	581	Yes
M-0107039	Zone	626	581	No, RH2 changed
M-0106965	Zone	649	549	No, RH2 changed
M-0106966	Zone	649	549	No, RH2 changed
M-0106967	Zone	649	549	Yes
M-0106968	Zone	649	549	No, RH2 changed
M-0106969	Zone	649	549	No, RH2 changed
M-0106970	Zone	649	549	No, RH2 changed
M-0106971	Zone	649	549	No, RH2 changed
M-0107031	Zone	649	549	Yes
M-0107033	Zone	649	549	Yes
M-0107034	Zone	649	549	No, RH2 changed
M-0107000	Zone	669	581	Yes
M-0107001	Zone	669	581	Yes
M-0107002	Zone	669	581	Yes
M-0107029	Zone	669	581	Yes
M-0107030	Zone	669	581	Yes
M-0107038	Zone	669	581	Yes
M-0107041	Zone	669	581	Yes
M-0107042	Zone	669	581	Yes
M-0107050	Zone	669	581	Yes
M-0106455	Zone	706	581	Yes
M-0106615	Zone	706	621	Yes
M-0106998	Zone	950	860	No, RH2 changed
M-0107056	Zone	Trans	Trans	Yes
M-0106929	Zone/Facility	556	531	Yes

NOTE: Highlighted rows indicate check valves recommended for review by Tacoma Water.

VFD FUNCTIONALITY

The Tacoma Water hydraulic model includes 25 booster pump stations, 10 of which have at least 1 pump equipped with a VFD. Tacoma Water indicated that the hydraulic model does not properly compute with all BPSs and VFDs active. RH2 reviewed the pumps and updated them to enable the model to properly compute and the pumps to function in the model in a manner that matches their intended function in the actual water system.

Among the 25 BPSs, 4 were set as inactive by Tacoma Water and were not activated by RH2. None of these four BPSs had control settings indicating that the pumps were equipped with VFDs, and the operation of these pumps were not evaluated by RH2. These four BPSs are identified in **Table 3**.

Table 3: VFD Summary

BPS	VFD?	Current Initial Status	Pressure Setpoint (psi)	Pump Control
Inactive BPSs and Not Evaluated by RH2				
Hood Street	No	Inactive	---	---
Marine View Drive (1 - 4)	No	Inactive	---	---
Marine View Drive (5 - 7)	No	Inactive	---	---
South Tacoma	No	Inactive	---	---
BPSs Operating Properly and Not Adjusted by RH2				
Alder Lane	Yes	1 Pump Open	70	Open
Cumberland	No	Pumps Open	---	Cumberland Res.
Fennel Creek	Yes	1 Pump Open	99	Open
Frederickson	Yes	1 Pump Open	55	Open
Highland	Yes	1 Pump Open	73	Open
Indian Hill No. 1	Yes	Pumps Open	45	Open
Indian Hill No. 2	No	Closed	---	Open
North End	No	Closed	---	Open
Palmer	No	Closed	---	Open
Prairie Ridge	Yes	1 Pump Open	95	Open
South Summit	Yes	1 Pump Open	90	Open
128th and 62nd (Summit & 62nd Ave)	No	Closed	---	Open
198th Avenue	No	Pumps Open	---	Prairie Ridge Res.
214th Avenue E	No	3 Pumps Open	---	Prairie Ridge Res.
356th/357th Street	No	Closed	---	Open
83rd and Cirque	Yes	Pump Open	55	Open
BPSs Adjusted by RH2				
McMillin No. 1	No	Pumps Open	---	Sunrise Standpipe
McMillin No. 2	No	Pumps Open	---	Sunrise Standpipe
Mildred Street	No	Pump Open	---	Open
80th Avenue	Yes	1 Pump Open	72	Open
21st and Pearl	Yes	Pump Open	65	Open

Among the 21 BPSs that were set as active in the model received by RH2, 16 were determined to be operating properly and were not adjusted by RH2. These 16 BPSs are identified in **Table 3**.

The remaining five BPSs were adjusted by RH2 for the model to properly compute and the pumps to function in the model in a manner that matches their function in the actual water system. These five BPSs are identified in **Table 3**, and a summary of the adjustments made by RH2 is as follows.

McMillin No. 1 and No. 2 BPSs

Both the McMillin No. 1 BPS and the McMillin No. 2 BPS had two pumps closed in the model received by RH2. RH2 changed the initial status of these pumps to “none” to allow them to operate during normal operating conditions. The proper initialization of the check valves in the vicinity of the McMillin BPS and Reservoir site prevents the reverse flow through the McMillin No. 1 BPS and the McMillin No. 2 BPS that was occurring in the model received by RH2.

Mildred Street BPS

The Mildred Street BPS was inactive and labeled as “Temp_OOS” (temporarily out of service) in the model received by RH2. RH2 activated this BPS to operate during normal operating conditions.

80th Avenue BPS

The 80th Avenue BPS provides supply to a closed pressure zone. Both pumps within this BPS were identified as being equipped with VFDs and had pump types identified as “constant power pumps,” with one pump identified as having a 2 horsepower (HP) motor, and the other pump identified as having a 1 HP motor. By definition, “constant power pumps” cannot have variable speeds. RH2 updated the pump types for both pumps in this BPS to have “design point curve” pump types. The total dynamic head for each pump was assumed to be 45 feet based on the hydraulic grade differential between the 581 South Hill Zone on the suction side of the BPS and the 626 80th Avenue E Zone on the discharge side of the BPS. Based on the 1 HP and 2 HP motor sizes identified in the model received by RH2, and an assumed pump efficiency of 70 percent for each pump, the pump design flow for the two pumps was initialized as 60 gallons per minute (gpm) and 120 gpm, respectively. RH2 initialized the VFD control for both pumps as 70 pounds per square inch (psi) to match the hydraulic grade of the 626 80th Avenue E Zone, and the BPS now operates properly in the model.

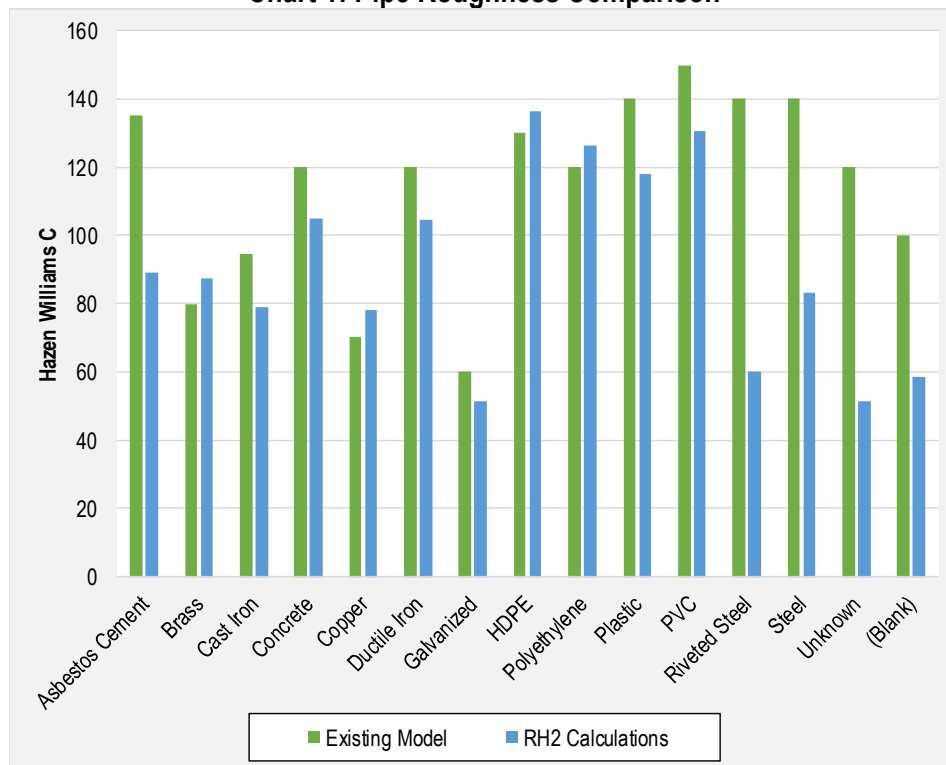
21st and Pearl BPS

The 21st and Pearl BPS pump was closed in the model received by RH2. RH2 changed the initial status of this pump to “none” to allow it to operate during normal operating conditions.

UPDATE 3 – PIPE ROUGHNESS COEFFICIENTS

Hazen Williams roughness coefficients were entered into the model by Tacoma Water based on roughness calculations and research performed over 10 years ago, per Tacoma Water staff at a July 14, 2017, scoping meeting with RH2. Tacoma Water requested that RH2 compare the hydraulic model roughness coefficients with roughness coefficients based on recent research and measurements performed on pipe interiors by RH2. RH2’s computations assume that the internal surface of the pipes becomes rougher as it ages; therefore, older pipes were assigned higher roughness coefficients than newer pipes. The computed RH2 pipe roughness coefficients were compared to the values entered by Tacoma Water based on the average pipe roughness coefficient for each pipe material. The pipe roughness comparison for each pipe material is shown in **Chart 1**. Among the 15 different pipe materials identified in the hydraulic model received by RH2 (including unknown and blank materials), the roughness coefficients calculated by RH2 are within 20 percent of the coefficients entered by Tacoma Water for 10 of the materials. The other five pipe materials, asbestos cement, riveted steel, steel, unknown, and blank, have roughness coefficients in the model that differ from RH2’s calculations by an average of 46 percent. RH2 presented this information to Tacoma Water during an August 30, 2017, kickoff meeting. Tacoma Water requested that RH2 update the hydraulic model roughness coefficients for these five pipe materials to match the values calculated by RH2, and not update the coefficients for the other ten materials. RH2 revised the roughness coefficients for pipes identified with asbestos cement, riveted steel, steel, unknown, and blank materials in the hydraulic model, and will further evaluate pipe roughness coefficients during the Stage 2 (steady-state hydraulic model calibration) portion of the contract.

Chart 1: Pipe Roughness Comparison



UPDATE 4 – “NO SERVICES” AND “FACILITY” JUNCTIONS

Junctions throughout the hydraulic model were assigned pressure zone information by Tacoma Water based on the pressure zone the junction is physically within, or identified as being a junction on a transmission main (“Trans”). Junctions with assigned pressure zones that are located either at facilities or in locations without services can limit the fire flow availability calculated by the model during batch fire flow analyses, as these junctions are typically located in areas where the residual pressure is less than the minimum pressure constraints identified in the fire flow simulation options (typically 20 psi). Examples of junctions in these areas include junctions near a tank or reservoir, or on the suction side of a pump. RH2 updated the pressure zone assignment of more than 1,100 junctions as “facility” if the junction is located near a facility, or “no services” if the junctions are located elsewhere in the water system in a location without any water services. Junctions not located near a facility that were not assigned pressure zones by Tacoma Water were not evaluated or updated by RH2, as it is outside of RH2’s scope to do so. Junctions that have pressures below 25 psi in the existing average day demand (ADD) scenario (QS_NW_2017_PADD scenario) that were not updated by RH2 because there appear to be active water services near these locations, are shown in **Table 4**. Following initialization of the fire flow analyses to be performed by Tacoma Water in fall 2017, it is recommended that Tacoma Water review the junctions that limit the fire flow availability in each pressure zone and determine if any additional junctions need to be assigned to the “no services” or “facility” pressure zone.

Table 4: Low Pressure Junctions with Pressure Zone Assignments

Junction ID No.	Junction Elevation (feet)	Hydraulic Grade (feet)	Pressure (psi)	Pressure Zone
J38468	392.6	436.9	19.2	446N
J39414	391.4	436.9	19.7	446N
J125988	429.1	474.9	19.8	478
J21468	429.1	474.9	19.8	478
J19768	429.1	474.9	19.8	478
J19770	429.1	474.9	19.9	478
J38660	429.2	477.1	20.7	478
J127778	429.0	477.0	20.8	478
J127780	429.0	477.0	20.8	478
J127782	429.0	477.0	20.8	478
J38670	429.0	477.0	20.8	478
J70092	429.0	477.0	20.8	478
J38672	428.9	477.0	20.9	478
J38674	428.9	477.0	20.9	478
J122512	428.8	477.1	20.9	478
J71312	428.8	477.1	20.9	478
J121732	427.9	477.0	21.3	478
J70150	427.9	477.0	21.3	478
J70158	427.9	477.0	21.3	478
J3652	424.4	476.0	22.4	478
J3654	424.4	476.0	22.4	478
J3678	424.4	476.0	22.4	478
J3616	424.1	476.0	22.5	478
J3650	424.1	476.0	22.5	478
J84720	422.9	474.9	22.5	478
J39416	381.7	436.8	23.9	446N
J47122	422.2	477.5	23.9	581 Fletcher Hts
J33478	385.3	442.6	24.8	478

UPDATE 5 – PLANNING-LEVEL FIRE FLOW REQUIREMENTS

Planning-level fire flow requirements were identified by Tacoma Water for the different land use categories to provide a target level of service for planning for and sizing of future water facilities. The planning-level fire flow requirement for each land use category is shown in **Table 5**. RH2 created a “Basic_LU” database set for junctions that have a basic land use assigned in the hydraulic model, and initialized the planning-level fire flow requirement for each junction in the fire flow table based on the land use categories shown in **Table 5**.

Table 5: Planning-level Fire Flow Requirements

Land Use	Planning-level Fire Flow Requirement (gpm)	Duration (hours)
Agricultural	1,000	2
City	3,500	4
Commercial	5,000	5
Industrial	5,000	5
Mixed Use	3,500	4
Park	1,000	2
Residential	1,500	2
Residential High Density	3,500	4
Undesignated	3,500	4

UPDATE 6 – PHD DEMAND SETS

The hydraulic model originally provided to RH2 included ADD and maximum day demand (MDD) demand sets for the 2017, 2027, and 2037 planning periods. Tacoma Water provided PHD/ADD peaking factors for various land uses and requested that RH2 create PHD demand sets for the 2017, 2027, and 2037 planning periods. The peaking factors provided by Tacoma Water are as follows.

- PHD/ADD = 3.11 for city, mixed use, residential, residential high density, and undesignated land uses.
- PHD/ADD = 1.16 for agricultural, commercial, industrial, and park land uses.

RH2 created the PHD demand sets and scenarios for the 2017, 2027, and 2037 planning periods based on these PHD/ADD peaking factors. Within the hydraulic model, the peaking factor applied to each demand allocation group is as follows.

- “Res,” “Res-Multi,” “Res-Irrig” = 3.11.
- “Commercial,” “Com-Irrig,” “Wholesale,” “Simpson,” “Partners” = 1.16.
- “Res-Fire,” “Com-Fire” = 1.00 (no change between ADD and PHD).

The resulting system-wide PHDs for the 2017, 2027, and 2037 planning periods are shown in **Table 6**, as are the system-wide PHD/ADD peaking factors. The 2027 and 2037 ADD demand sets have lower demands than the 2017 ADD demand set; therefore, the 2027 and 2037 PHD

demands are less than the 2017 PHD. The PHD/ADD peaking factors differ for the 2017, 2027, and 2037 planning periods because the percentage of demands with a 3.11 PHD/ADD peaking factor is less in the future planning periods compared to the 2017 planning period.

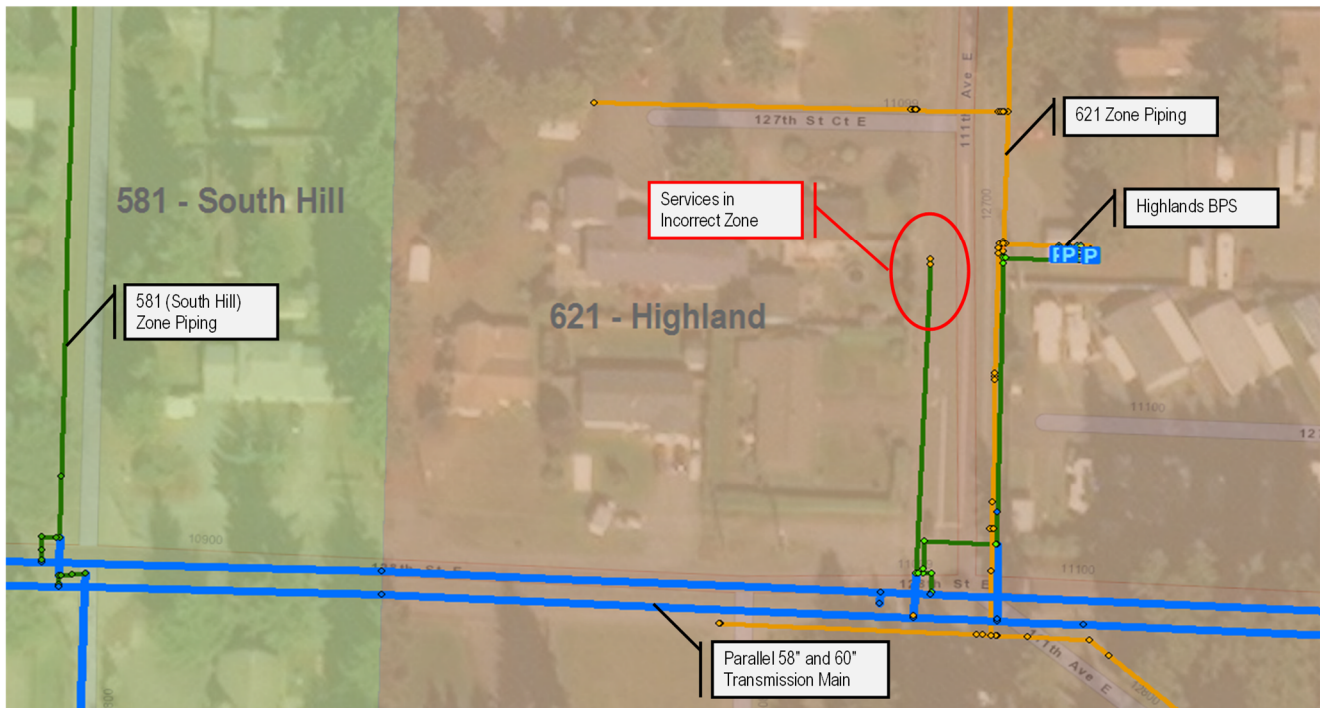
Table 6: System-wide Demands

Demand Type	System-wide Demand (gpm)	System-wide PHD/ADD Factor
2017 Planning Period		
2017 ADD	34,462	1.85
2017 PHD	63,656	
2027 Planning Period		
2027 ADD	32,078	1.80
2027 PHD	57,747	
2037 Planning Period		
2037 ADD	30,975	1.77
2037 PHD	54,899	

OTHER OBSERVATIONS

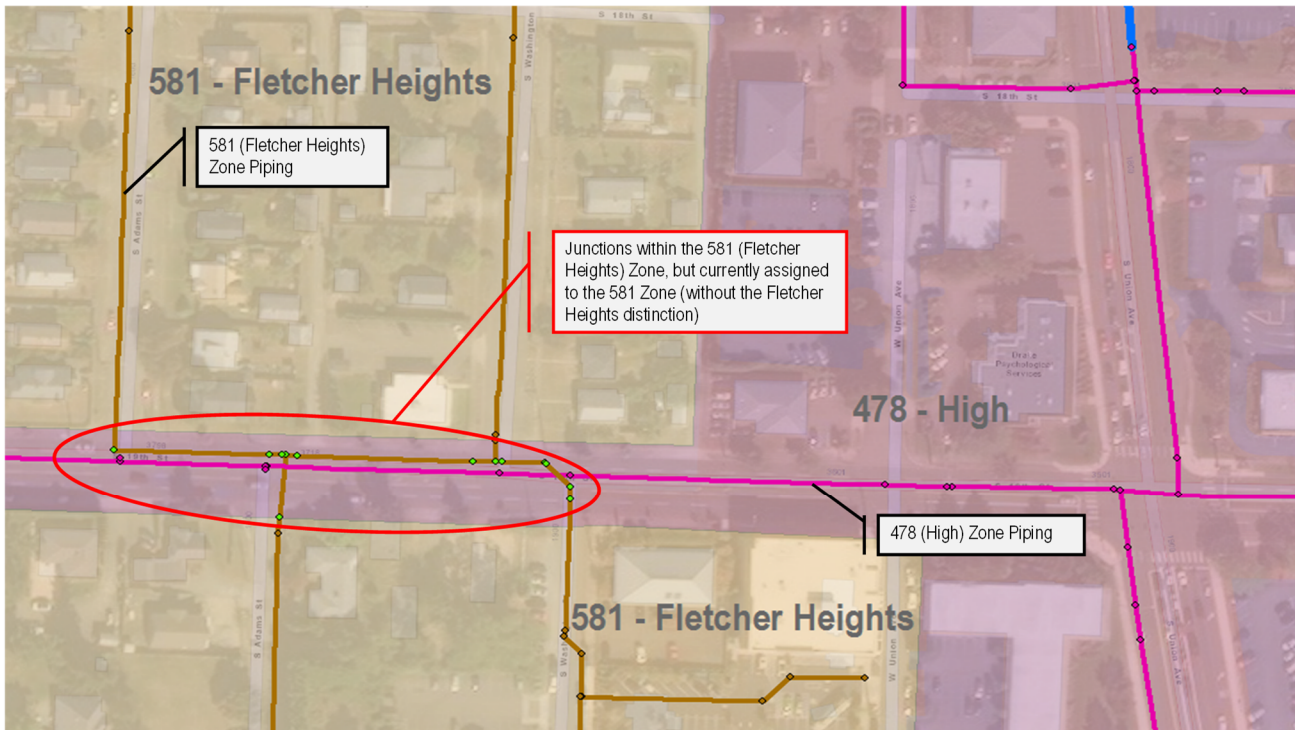
While the six Stage 1 updates were being performed in the hydraulic model, RH2 identified numerous junctions and pipes with pressure zone assignments that differed from the actual pressure zone they actually convey water to. One example of this occurs near the intersection of 111th Avenue E and 128th Street E near the boundary between the 621 (Highland) Zone and the 581 (South Hill) Zone. Junctions on the west side of 111th Avenue E, directly west of the Highland BPS, are assigned to the 621 Zone, but are actually served by the 581 Zone, as shown in **Figure 1**.

Figure 1: Example of Junctions and Piping with Incorrect Zone Assignments



Another example of pressure zone assignments recommended for additional review by Tacoma Water include pressure zones with the same hydraulic grade that are physically disconnected. The Tacoma Water distribution system provides service to multiple pressure zones with a 581-foot hydraulic grade. The pressure zone assignments for the junctions in these zones typically are indicated with a descriptor, such as “581 SE Tacoma” or “581 Fletcher Hts.” However, there are instances wherein the 581 Zone assignments are incorrect. One example of this occurs along S 19th Street, west of the intersection with S Union Avenue near the boundary between the 581 (Fletcher Heights) Zone and the 478 (High) Zone, as shown in **Figure 2**. Junctions in the 581 (Fletcher Heights) Zone are properly assigned on either side of S 19th Street, but the junctions within S 19th Street currently have a “581” pressure zone assignment; therefore, they would not be considered as part of the minimum pressure check during fire flow analyses for the 581 (Fletcher Heights) Zone.

Figure 2: Example of Junctions and Piping with Incorrect Zone Assignments



It is outside RH2’s scope of work to resolve pressure zone discrepancies similar to those shown in **Figures 1** and **2** throughout the hydraulic model. Junctions with an incorrect pressure zone assignment may erroneously limit or over-report the fire flow availability throughout the pressure zone; therefore, it is recommended that Tacoma Water review the pressure zone assignments for junctions and pipes as part of the fire flow analyses to be set up and performed by Tacoma Water for inclusion in Tacoma Water’s 2017 *Water System Plan*. Additionally, some junctions within the distribution system do not have pressure zone assignments. It is recommended that Tacoma Water include a pressure zone assignment for every junction in the model, including any additional junctions requiring a “no services” or “facility” assignment.

CONCLUSION

RH2 is transmitting the hydraulic model with the six Stage 1 updates to Tacoma Water with this technical memorandum. RH2 recommends that Tacoma Water review the updates and contact RH2 with questions or comments regarding the updates prior to performing hydraulic analyses for inclusion in Tacoma Water’s 2017 *Water System Plan*.

Chapter 6, Appendix I: Distribution System Analysis

**Chapter I5. Technical Memo (RH2, 2/14/2018),
Hydraulic Model Steady State Model Calibration**

RH2 TECHNICAL
ENGINEERING MEMORANDUM
40 YEARS SINCE 1978

Client: Tacoma Water
Project: Hydraulic Model Update and Calibration
Project File: TAC 517.122.02.201 Project Manager: Michele Campbell, PE
Composed by: Ryan Withers, PE
Reviewed by: Geoff Dillard, PE
Subject: Stage 2 Updates
Date: February 14, 2018



This technical memorandum contains a description of the calibration of Tacoma Water’s hydraulic model performed by RH2 Engineering, Inc. (RH2). The results of the calibration analyses and updates performed by RH2 in the hydraulic model are also contained in this technical memorandum.

BACKGROUND

In 2016, Tacoma Water created a new InfoWater hydraulic model of its entire water system from Tacoma Water’s ESRI Geographic Information System (GIS) database. In 2016 and 2017, Tacoma Water updated the model to include demand allocations, simple controls, and operational setpoints at existing facilities, as well as additional water system properties such as pressure zone information, pipe roughness coefficients, elevation data, land use information, and reservoir geometry. In September 2017, RH2 performed the Stage 1 hydraulic model updates, which consisted of the following six updates.

1. Add minor losses to the 25 booster pump stations (BPS) in the hydraulic model.
2. Review and update check valve and variable frequency drive (VFD) functionality.
3. Compute pipe roughness coefficients and compare to existing pipe roughness coefficients.
4. Initialize “no services” and “facility” junctions.
5. Initialize planning-level fire flow requirements.
6. Create peak hour demand (PHD) demand sets.

Following the Stage 1 updates, Tacoma Water requested that RH2 perform the Stage 2 updates using InfoWater version 12.7, which included identifying strategic locations in the water system to be field tested and using the results to calibrate the water model. The hydraulic model was calibrated for steady-state simulations to provide a greater degree of insight into the operation of the system.

FIELD HYDRANT FLOW AND PRESSURE TESTING

Between October 2, 2017, and November 2, 2017, field flow tests were performed at 141 locations by RH2 and Tacoma Water staff. A subsequent single day of field flow tests were performed on January 18, 2018, at nine locations by RH2 and Tacoma Water staff. In total, 150 flow tests were performed at 147 unique locations, as three locations tested in January 2018 were the same locations tested in October and November 2017.

The location of each flow test is shown in **Figures 1** through **11**. Locations identified with a yellow symbol indicate the location of the static hydrant, and locations identified with an orange symbol indicate the location of the flowing hydrant. Locations identified with a green symbol were used for pressure transducers to monitor distribution system behavior before, during, and after the flow tests. The following is a summary of the flow testing procedures.

- The static pressure was measured and recorded at the static and flowing hydrants with all hydrants closed.
- One hose port on the flowing hydrant was opened. The flow from this port was measured and recorded, and the residual pressure at the static hydrant was recorded.
- If the measured pressure drop at the static hydrant was approximately 20 pounds per square inch (psi) or less, or the residual pressure exceeded approximately 40 psi, the second port of the flowing hydrant was opened. The flow from both ports was measured and recorded, and the residual pressure at the static hydrant was recorded.
- Both hose ports at the flowing hydrant were closed.
- The measurements obtained during each flow test were entered into a spreadsheet and are shown in the attached **Hydraulic Model Calibration Data** tables.

In total, 294 static pressure tests and 275 flow tests were performed at the 147 locations. At most locations, two static pressure tests were performed (one each at the residual and flowing hydrants). Two flow tests were also performed at most locations (one with a single hose port on the flowing hydrant open, and one with two hose ports on the flowing hydrant open). **Table 1** presents the total number of locations, static tests, and flow tests in each of Tacoma Water's operating areas. In general, each operating area includes multiple pressure zones.

Table 1: Field Hydrant Flow and Pressure Testing Summary

Operating Area	No. of Unique Locations	No. of Static Tests	No. of Flow Tests	No. of Pressure Transducers
Bonney Lake	8	16	15	13
McMillin	10	20	17	11
South Hill	11	22	21	12
Canyon	8	16	16	10
SE Tacoma	14	28	28	20
478 High Zone	27	54	53	38
West and NW Tacoma	28	55	51	32
Port of Tacoma & Fife Heights	10	20	18	10
549 NE Tacoma Zone	11	22	21	16
Other NE Tacoma Zones	20	41	35	22
TOTALS	147	294	275	184

In addition to the data recorded at the static and flowing hydrants, data was recorded by pressure transducers strategically located throughout the distribution system during the flow tests, and Tacoma Water provided supervisory control and data acquisition (SCADA) data for facilities within the operating area that were being tested each day. Throughout the 25 days of hydrant flow testing, 184 pressure transducers were installed in the distribution system, each recording pressures at 2-second intervals. Based on an average deployment of approximately 5 hours per transducer, approximately 1.6 million pressure readings were recorded, analyzed and considered by RH2 during the calibration analyses. Similarly, Tacoma Water provided RH2 with SCADA data for 148 facilities encompassing the 25 days of hydrant flow testing, each with 1-minute recording intervals. The SCADA data primarily included reservoir water levels, pump flow rates, and suction and discharge pressures at facilities. In total, approximately 578,000 SCADA data points were provided to RH2 that were analyzed and considered during the calibration analyses. Although each individual pressure reading and SCADA data point were not evaluated during the steady-state calibration analysis, the data corresponding to each of the 294 static and 275 flow tests were evaluated and were essential to the overall success of the hydraulic model calibration, as described in subsequent sections of this technical memorandum.

CALIBRATION SUMMARY

RH2 began the calibration analysis with the version of the hydraulic model created as part of the Stage 1 hydraulic model updates. RH2 prepared a technical memorandum documenting the Stage 1 updates, and provided it to Tacoma Water on September 20, 2017. Year 2017 average day demands, which were calculated and allocated by Tacoma Water, were utilized for calibration scenarios. After conducting hydraulic analyses with the model simulating each of the field tests, model results were compared with actual field results. The model was then calibrated by adjusting pipe roughness coefficients, elevations, and facility settings (pressure reducing valve (PRV) settings, BPS settings, etc.) to bring the model into closer calibration with the field results. In some situations, RH2 identified pipe network connectivity or facility setpoints differed in the field from those in the hydraulic model; these locations were revised in the model to reflect field conditions. The identification of these differences were generally the result of sensitivity analyses, which consist of iterative model adjustments to assist in troubleshooting the cause of a discrepancy between field measurements and model calculations. Examples of

sensitivity analyses performed for the Tacoma Water hydraulic model include temporarily opening or closing a PRV to identify if the PRV opened in the field but not in the model (or vice versa), temporarily adjusting the pressure setpoints of pumps or valves to determine the impact on system pressures, or temporarily closing pipes or adding check valves to pipes to confirm the presence of a zone valve or check valve at pressure zone boundaries.

The calibration goals selected for the static pressure readings were established to be consistent with the guidelines published by the Engineering Computer Applications Committee (ECAC) in 1999, which suggest that field pressure measurements be within plus or minus 2 psi for 90 percent of readings when compared to the pressures calculated by the model at the same location. The calibration goals selected for the dynamic pressure readings were established to be consistent with the guidelines published by Walski et al. (Walski) in the 2003 *Advanced Water Distribution Modeling and Management* book, which suggest that the hydraulic model be able to predict the hydraulic grade line (HGL) to within 5 to 10 feet at model calibration points during peak demands. The ECAC and Walski calibration guidelines represent two of the three guidelines described in the Washington State Department of Health (DOH) *Water System Design Manual*.

SYSTEM-WIDE SUMMARY – STATIC CONDITIONS

Of the static pressure measurements recorded in Tacoma Water’s system, 91 percent are within plus or minus 2 psi of the static pressure calculated by the hydraulic model under the same conditions, as shown in **Table 2**. This level of accuracy meets the ECAC guideline of having at least 90 percent of field measurements being within plus or minus 2 psi of the model’s calculations. The only area within the system with less than 90 percent of measurements meeting the ECAC guideline is the smaller zones in western and northwestern Tacoma, not including the 478 High Zone, wherein 76 percent of field measurements are within plus or minus 2 psi of the model’s calculations. This area is described in more detail in the **Operating Area Summary** in a subsequent section of this technical memorandum.

Table 2: Static Pressure Measurement Correlation

ECAC (+/- 2 psi: Static Tests)			
Location	No. of Tests	No. within + or - 2 psi	% within + or - 2 psi
Bonney Lake	16	15	94%
McMillin	20	18	90%
South Hill	22	21	95%
Canyon	16	16	100%
SE Tacoma	28	27	96%
478 High	54	53	98%
West and NW Tacoma	55	42	76%
Port of Tacoma & Fife Heights	20	19	95%
549 NE Tacoma	22	20	91%
Other NE Tacoma Zones	41	37	90%
TOTALS	294	268	91%

SYSTEM-WIDE SUMMARY – DYNAMIC CONDITIONS

Ninety-eight percent of the dynamic tests performed in Tacoma Water’s system resulted in the headloss measured in the field being within 5 to 10 feet of the hydraulic grade (4.33 psi) of the headloss calculated by the hydraulic model, as shown in **Table 3**. This level of accuracy results in all 275 tests meeting the Walski calibration guideline of the model predicting the hydraulic grade line to within 5 to 10 feet at model calibration points during peak demands, such as fire flows. The dynamic test results are described in more detail in the **Operating Area Summary** in a subsequent section of this technical memorandum.

Table 3: Residual Pressure Correlation

WALSKI (+/- 10 feet HGL: Dynamic Tests)				
Location	No. of Tests	No. within 5 feet	No. within 10 feet	% within 10 feet
Bonney Lake	15	11	15	100%
McMillin	17	9	17	100%
South Hill	21	19	21	100%
Canyon	16	8	16	100%
SE Tacoma	28	21	28	100%
478 High	53	39	53	100%
West and NW Tacoma	51	28	51	100%
Port of Tacoma & Fife Heights	18	14	18	100%
549 NE Tacoma	21	19	21	100%
Other NE Tacoma Zones	35	24	35	100%
TOTALS	275	192	275	100%
		70%	100%	---

OPERATING AREA SUMMARY

Bonney Lake Area (Figure 1)

- Pressure Zones
 - 705 Fennel Creek
 - 810 Prairie Ridge
 - 860 Bonney Lake
 - 950 Bonney Lake
 - 1010 Bonney Lake
- Calibration Progress
 - Static Pressure Measurements
 - ECAC: 15 of 16 (94 percent) static pressure measurements within plus or minus 2 psi.
 - Dynamic Pressure Measurements
 - Walski: 15 of 15 (100 percent) of residual pressure measurements predict the hydraulic grade line differential between static and residual conditions to within 10 feet.
- Model Updates for Steady State Calibration
 - a. A portion of the 20-inch-diameter main that connects the 810 Prairie Ridge Zone to the Prairie Ridge Reservoir was found to be disconnected between

Junctions J91116 and J81816. Pipe M-0109952 was created to connect these two junctions, with the same properties as the pipes on either side of these junctions.

- b. The pressure sustaining valve in the 214th BPS was allowing approximately 2,600 gallons per minute (gpm) into the 48-inch-diameter transmission main while also not sustaining any pressure or otherwise providing hydraulic benefit during static or dynamic analyses. This valve was closed for the calibration analyses and in the model accompanying this technical memorandum. It is recommended that this valve be inspected in the field for proper operation before it is opened in the model for future analyses.
- c. A minor loss coefficient of 6.0 was initialized for the piping in the 198th Avenue E and Cascadia Boulevard E PRV station.
- d. The Tahaleh 860 PRV station setpoints were changed from 69 and 72 psi, to 73 and 76 psi.

McMillin Area (Figure 2)

- Pressure Zones
 - 316 High Cedars
 - 519 Sunrise Terrace
 - 621 Highland
 - 706 McMillin
- Calibration Progress
 - Static Pressure Measurements
 - ECAC: 18 of 20 (90 percent) static pressure measurements within plus or minus 2 psi.
 - Dynamic Pressure Measurements
 - Walski: 17 of 17 (100 percent) of residual pressure measurements predict the hydraulic grade line differential between static and residual conditions to within 10 feet.
- Model Updates for Steady State Calibration
 - a. The 316 High Cedars Zone PRV station elevations increased by 9.2 feet, from 115.83 feet to 125.00 feet.
 - b. The 316 High Cedars Zone PRV station (142nd Avenue Court E and 128th Street E) has four PRVs that have setpoints that are hydraulically similar, and cause the model to not converge during dynamic analyses. Sensitivity analyses were performed to close varying combinations of PRVs to allow the model to converge. For the purposes of the calibration analyses, the PRV set at 82 psi needs to be closed, and either one of the PRVs set at 79 psi or 84 psi needs to be closed. The PRVs set at 79 psi and 82 psi are closed in the model accompanying this technical memorandum.
 - c. For Flow Test No. 9, pressure transducer data indicates that the PRV set at 86 psi was flowing during static conditions, and the PRV set at 79 psi was also flowing during both low and high flow dynamic conditions.
 - d. For Flow Test No. 10, pressure transducer data indicates that the PRV set at 86 psi was flowing during static conditions, and the PRV set at 84 psi was also flowing during both low and high flow dynamic conditions.

- e. All 316 High Cedars Zone ductile iron pipe Hazen Williams coefficients were increased to 125.
- f. All 706 McMillin Zone ductile iron pipe Hazen Williams coefficients were increased to 130.
- g. For Flow Test No. 17, the static pressures measured in the field differ by approximately 6 psi compared to the static pressures calculated by the hydraulic model. A review of elevations in Google Earth indicates that elevations in the model differ by approximately 10 feet in 111th Street Court E and in Shawnee Road E north of the intersection with 111th Street Court E. The elevations of the following junctions were updated in the model to match the Google Earth elevations.
 - i. J107254
 - ii. J107258
 - iii. J107260
 - iv. J107262
 - v. J107264
 - vi. J107280
 - vii. J107294
- h. The setpoint of the large (4-inch diameter) valve in the 136th Avenue and Military Road PRV was changed to 12.5 psi.
- i. The VFD control setpoint for the Highland BPS was changed from 73 psi to 76 psi.

South Hill Area (Figure 3)

- Pressure Zones
 - 426 Woodland
 - 581 Woodland
 - 581 South Hill
 - 626 80th Avenue E
 - 626 Alder Lane
- Calibration Progress
 - Static Pressure Measurements
 - ECAC: 21 of 22 (95 percent) static pressure measurements within plus or minus 2 psi.
 - Dynamic Pressure Measurements
 - Walski: 21 of 21 (100 percent) of residual pressure measurements predict the hydraulic grade line differential between static and residual conditions to within 10 feet.
- Model Updates for Steady State Calibration
 - a. All 581 South Hill Zone asbestos cement pipe Hazen Williams coefficients were increased by 10.
 - b. Elevations in the 626 80th Avenue E Zone were decreased by 3 feet.
 - c. The VFD control setpoint for the 80th Avenue BPS was changed from 70 psi to 68 psi.

- d. The VFD control setpoint for the Alder Lane BPS was changed from 70 psi to 75 psi.
- e. All 626 Alder Lane Zone asbestos cement pipe Hazen Williams coefficients were increased to 120.
- f. All 581 and 426 Woodland Zone asbestos cement pipe Hazen Williams coefficients were increased to 127.
- g. All 581 and 426 Woodland Zone ductile iron pipe Hazen Williams coefficients were increased to 135, except the ductile iron pipe within 72nd Avenue, which was increased to 140.
- h. The Woodland Avenue and 84th Street PRV station setpoints were 57 psi and 55 psi for the small and large valves, respectively. The small valve setpoint was changed to 59 psi, and the large valve setpoint was unchanged.

Canyon Road Area (Figure 4)

- Pressure Zones
 - 581 Canyon
 - 588 Frederickson
 - 669 S Summit High
- Calibration Progress
 - Static Pressure Measurements
 - ECAC: 16 of 16 (100 percent) static pressure measurements within plus or minus 2 psi.
 - Dynamic Pressure Measurements
 - Walski: 16 of 16 (100 percent) of residual pressure measurements predict the hydraulic grade line differential between static and residual conditions to within 10 feet.
- Model Updates for Steady State Calibration
 - a. The Canyon BPS 30 horsepower (HP) VFD control maximum speed setting was changed from 1.2 to 1.0, and the additional parallel pumps were changed from 1 to 0 because only one large pump turned on during field flow testing. The Canyon BPS 5 HP pump was closed.
 - b. The Canyon BPS 30 HP VFD pressure setting was changed from 90 psi to 92 psi.
 - c. The Canyon BPS minor losses were not initialized previously in the Stage 1 portion of this project. Based on the field pressure measurements, a minor loss coefficient of 8.50 was initialized on the discharge side of the BPS (Pipe M-0056747), and a minor loss coefficient of 2.00 was initialized on the suction side of the BPS (Pipe M-0056749).
 - d. All 669 South Summit High Zone asbestos cement pipe Hazen Williams coefficients were increased to 115.
 - e. A fake reservoir (Reservoir "FAKE_RES") located at the intersection of 66th Avenue and 156th Street Court was deactivated.
 - f. Test No. 34: The model was initially calculating approximately 20 psi of additional headloss during the high flow test compared to the headloss measured during the field testing. During field testing, the hydraulic grade at the static hydrant during the high flow test was approximately equal to the hydraulic grade

of the 581 South Hill Zone. Sensitivity analyses were performed to determine possible check valve and/or connection locations between the 669 South Summit High Zone and the 581 Canyon Zone. The analyses indicate that reverse flow was likely occurring through the 148th Street E and Woodland PRV station during Test No. 34. A check valve was added to the model at this PRV station to simulate the ability of this PRV station to have reverse flows during these conditions. Pipe M-0056430A was added to the model at this location to simulate the check valve.

Southeast Tacoma Area (Figure 5)

- Pressure Zones
 - 520 SE Tacoma
 - 581 SE Tacoma
- Calibration Progress
 - Static Pressure Measurements
 - ECAC: 27 of 28 (96 percent) static pressure measurements within plus or minus 2 psi.
 - Dynamic Pressure Measurements
 - Walski: 28 of 28 (100 percent) of residual pressure measurements predict the hydraulic grade line differential between static and residual conditions to within 10 feet.
- Model Updates for Steady State Calibration
 - a. The Well SE11 throttle control valve was changed to a flow control valve.
 - b. All 581 SE Tacoma Zone asbestos cement pipe Hazen Williams coefficients were increased by 15.
 - c. Model elevations in the vicinity of Flow Test No. 45 and data logger SET6 were increased by 4 feet to better correlate with field-measured pressures.
 - d. The Hazen Williams roughness coefficient of the 8-inch-diameter piping in the 108th Street Court E and 109th Street Court E loop located west of Golden Given Road E (at the Test No. 43 location) was decreased from 120 to 100.
 - e. Hazen Williams roughness coefficients for piping in the vicinity of Flow Test No. 46 were increased by 20.

478 High Zone (Figures 6, 7, 8, and 11)

- Pressure Zones
 - 478 High
- Calibration Progress
 - Static Pressure Measurements
 - ECAC: 53 of 54 (98 percent) static pressure measurements within plus or minus 2 psi.
 - Dynamic Pressure Measurements
 - Walski: 53 of 53 (100 percent) of residual pressure measurements predict the hydraulic grade line differential between static and residual conditions to within 10 feet.

- Following the October and November 2017 flow testing, the field-measured residual pressures of the low and high flow tests performed at Flow Test Nos. 59, 60, and 61 were not within 10 feet of the residual pressures calculated by the hydraulic model. These three flow tests are located in the southeastern portion of the 478 High Zone, approximately bound by Interstate 5 to the north and west, by S 48th Street to the south, and by the east side of the 478 High Zone boundary to the east. Sensitivity analyses were performed to identify the discrepancy between the field measurements and the model calculations, but a single discrepancy source was not able to be identified that impacts this area enough to allow these three tests to calibrate within the Walski guideline. Tacoma Water water quality staff indicated that this area has historically experienced flow from unexpected directions when assessing chlorine residuals. Tacoma Water also indicated that there may be undocumented valves, some of which may be check valves, in this area of the system. Tacoma Water investigated the possibility of undocumented and closed valves in this area during the week of December 11, 2017, but no closed valves were found. Nine additional flow tests were performed in this area on January 18, 2018, including retesting Flow Test Nos. 59, 60, and 61 to confirm the previously-recorded data at these locations, and for comparison with the data recorded at the other six flow test locations. The additional data provided critical information that was used to identify the discrepancy between the field measurements and model calculations in this area, allowing all 478 High Zone tests to calibrate within the Walski guideline. These nine flow test locations are shown separately from the other 478 High Zone flow test locations in **Figure 11**.
- Model Updates for Steady State Calibration
 - a. A large percentage of the 478 High Zone distribution system consists of cast iron pipe that is over 60 years old. There are many short sections of ductile iron pipe in the hydraulic model at locations where hydrants, tees, and other fittings have been connected to the old cast iron main. A minor loss (K value) coefficient of 5.0 was added to all ductile iron pipes in west and northwest Tacoma (including the 478 High Zone) that have a length of 5 feet or less to represent the headlosses associated with the couplings and transitions to different pipe materials.
 - i. Ductile iron pipes with a length of 5 feet or less were not applied a minor loss (K value) coefficient of 5 in four locations within the 478 High Zone. These locations are as follows, wherein the minor loss (K value) coefficient was initialized as 0.
 1. Within 37th Street W, between Tahoma Place W and Grandview Drive W, in the vicinity of Flow Test No. 72.
 2. Within 53rd Street W, between Grandview Drive W and 95th Avenue Court W, in the vicinity of Flow Test No. 73.
 3. At the intersection of S Madison Street and S 69th Street, in the vicinity of Flow Test No. 75.

4. At the intersection 54th Avenue Court W and Cirque Drive, in the vicinity of Flow Test No. 76.
 - ii. Cast iron pipe in the vicinity of Flow Test No. 65 was first initialized with Hazen Williams roughness coefficients of 70 and 75, depending on the age of the piping. All cast iron piping in the vicinity of Flow Test No. 65 was set to 70 for calibration analyses.
- b. The results of the January 2018 field testing, which including retests at Flow Test Nos. 59 through 61, and Flow Test Nos. 147 through 152, indicate that cast iron pipe in the southeastern portion of the 478 High Zone installed prior to 1945 has a significantly different conveyance capacity than cast iron pipe in the same area that was installed in or more recently than 1945. The Hazen Williams roughness coefficients of cast iron pipe were adjusted in the hydraulic model to reflect the field-measured data in two distinct areas of the southeastern portion of the 478 High Zone, which are shown in **Figure 11** as Area A and Area B. Area A is approximately bound by Interstate 5 to the north and west, S 48th Street to the south, and S Thompson Avenue to the east. Area B is approximately bound by Interstate 5 to the north, State Route 7 and the Tacoma Rail right-of-way to the west, E 49th Street to the south, and by the east side of the 478 High Zone boundary to the east. The Hazen Williams coefficient adjustments differed in Areas A and B, and are as follows.
 - i. The Hazen Williams coefficient of all cast iron pipe installed prior to 1945 located within Area A were initialized to 45.
 - ii. The Hazen Williams coefficient of all cast iron pipe installed prior to 1945 located within Area B were initialized to 53.
 - iii. The Hazen Williams coefficient of all cast iron pipe installed in and after 1945 in Areas A and B were initialized to 120.

The relatively low Hazen Williams coefficients of 45 and 53 for cast iron pipe installed prior to 1945 is supported by data presented in Table 2.3 of Haestad Methods' *Advanced Water Distribution Modeling and Management*, which presents Hazen Williams coefficients for various pipe materials based on pipe age and the loss of carrying capacity in the pipe depending on the corrosiveness of the water being carried. Table 2.3 indicates that 6- and 12-inch-diameter cast iron pipe between 60 and 100 years old that has had "appreciable" or "severe" attack on the pipe would have Hazen Williams roughness coefficients ranging between 30 and 66.

A preliminary hydraulic model was provided to Tacoma Water in December 2017 that was used for Tacoma Water's Water System Plan hydraulic analyses. The December 2017 version of the hydraulic model included preliminary calibration of the 478 High Zone, but the Hazen Williams coefficients of the piping within Areas A and B in **Figure 11** had not yet been updated to reflect the values identified in (i), (ii), and (iii) of this section. These Hazen Williams coefficient adjustments were made within the model accompanying this technical memorandum.

West and Northwest Tacoma Area (Pressure Zones Adjacent to the 478 High Zone) (Figures 6, 7, and 8)

- Pressure Zones
 - Figure 6
 - 346 Portland Avenue
 - 478 High
 - Figure 7
 - 155 Sunset Beach
 - 202 Day Island
 - 226 Titlow
 - 290 Chambers Bay
 - 328 Narrows
 - 351 Grandview
 - 478 High
 - 531 University Place
 - 556 Park Royal
 - Figure 8
 - 251 Low
 - 346 Old Town
 - 350 Salmon Beach
 - 446 Middle
 - 446 North End
 - 478 High
 - 538 Fletcher Heights
 - 538 Westgate
 - 581 Fletcher Heights
- Calibration Progress
 - Static Pressure Measurements
 - ECAC: 42 of 55 (76 percent) static pressure measurements within plus or minus 2 psi.
 - ECAC: 50 of 55 (91 percent) static pressure measurements within plus or minus 3 psi.
 - ECAC: 55 of 55 (100 percent) static pressure measurements within plus or minus 4 psi.
 - Many of the pressure zones within this operating area are served by PRV stations and include steep slopes adjacent to Puget Sound. Elevations in areas with steep slopes are more susceptible to inaccuracies because significant elevation changes can occur with slight changes to the X and Y coordinates of a junction or valve. Therefore, it is recommended that a more relaxed guideline of plus or minus 3 psi be considered for the static pressure measurements in these zones. It is also recommended that if water system infrastructure is being designed within these zones and the elevation or pressure is critical to the design, that a pre-design survey be performed to identify more accurate elevations in these

zones. As survey-level data is obtained in these areas for other purposes, it is recommended that the hydraulic model be updated accordingly.

- Dynamic Pressure Measurements
 - Walski: 51 of 51 (100 percent) of residual pressure measurements predict the hydraulic grade line differential between static and residual conditions to within 10 feet.
- Model Updates for Steady State Calibration
 - a. The Mildred Street BPS was closed for all calibration analyses, consistent with the SCADA data provided for the field testing days in the 538 Westgate and Fletcher Heights Zone. The Mildred Street BPS was activated (initial status set to “none”) in the model accompanying this technical memorandum.
 - b. Flow Test Nos. 78 through 90: The 531 University Place Zone was functioning approximately as a 581 Zone during field testing. Sensitivity analyses indicate that the North End Reservoir was likely not filling or filling at a relatively limited rate in order for the hydraulic grade line of the 531 University Place Zone to increase to approximately 581 feet. For the purposes of the calibration analyses, it was assumed that the North End Reservoir’s inlet pipe was closed for all field tests performed on and before October 20, 2017, and open for all field tests performed on and after October 23, 2017 (no tests were performed on October 21st or 22nd). The North End Reservoirs’ inlet pipe was opened in the model accompanying this technical memorandum.
 - i. Flow Test Nos. 78 and 79: The 83rd Avenue and Cirque Drive BPS was not operational during field testing due to the elevated hydraulic grade line in the 531 University Place Zone. Supply to the 556 Park Royal Zone was provided via a check valve at 83rd Avenue and the Cirque Drive BPS during field testing. The inlet pipe to the North End Reservoir was closed for the calibration analyses to allow the 531 University Place Zone to operate with a hydraulic grade of approximately 581 feet, consistent with the pressures measured during the field testing.
 - c. Flow Test No. 83: The Chambers Bay PRV station setpoint was changed to represent a hydraulic grade in the zone of approximately 330 feet, compared to the previous setting of 291 feet. The PRV station setpoints were changed to 46 psi and 39 psi for the small and large valves, respectively.
 - d. Flow Test No. 84: The minor loss coefficient in the piping at the 48th Street and Grandview Drive PRV station were increased from 5 to 10 (Pipe M-0105778), and the large valve setpoint was decreased 1 psi to 47 psi. The minor loss coefficient of Pipe M-0032836 at the 4300 Soundview PRV station was increased from 5 to 15.
 - e. Flow Test No. 85: The Day Island Road PRV station setpoint changed to represent a hydraulic grade in the zone of approximately 202 feet, compared to the previous setting of 199 feet. The PRV station setpoints were increased by 1 psi for all valves. The minor loss coefficients were set to 0 for all Day Island Zone distribution pipes. All ductile iron pipe Hazen Williams roughness

coefficients were initialized to 120, and all cast iron pipe Hazen Williams roughness coefficients were initialized to 80.

- f. Flow Test No. 86: The elevation of Junction J44108, the static hydrant during Flow Test No. 86, is shown as 58 feet in Google Earth, which is approximately 9 feet lower than the elevation previously initialized in the hydraulic model. The elevation of this junction was set to 58 feet in the hydraulic model to match the Google Earth elevation. Other elevations in the vicinity of Junction J44108 were reviewed in Google Earth and compared to the hydraulic model elevations and were found to be within approximately 1 foot in all instances. No other junction elevations were updated.
 - i. Minor loss coefficients of piping at the intersections of S 19th Street and 88th Avenue W, and Walters Road and 88th Avenue W, were set to 0.
- g. Flow Test Nos. 91 through 95: With the North End Reservoir filling during calibration analyses, the hydraulic grade in the 538 Fletcher and Westgate Zones decreases by approximately 10 psi across zone from southeast to northwest. This hydraulic grade decrease was not occurring during field testing based on the static pressure measurements and transducer data. Although no SCADA data other than reservoir level at the NE Reservoir site is available, the field-measured static and dynamic pressures indicate that the North End BPS was operational during field testing. North End BPS pump 1 was turned on in the hydraulic model for Flow Test Nos. 91 through 95, and was returned to its initialized state (closed) in the model accompanying this technical memorandum.
 - i. If this assumption is incorrect and the North End BPS was not operational during field testing, the hydraulic grade in the transmission line supplying the 538 Fletcher and Westgate Zones was at least 5 feet higher during the field testing than is calculated by the hydraulic model. A review of the SCADA data, if available, from the source of the transmission line could determine if the upstream hydraulic grade of the transmission line is greater than is initialized in the hydraulic model, or if a lower flow rate is being conveyed through the transmission main than is calculated by the model.
- h. Flow Test No. 93: Two disconnected pipe sections were identified.
 - i. A 6-inch-diameter pipe in N 18th Street, near the intersection with N Ferdinand Street, was disconnected between Junctions J69780 and J36428. Pipe M-0014817a was added between these junctions with the same properties as Pipe M-0014817 immediately to the east.
 - ii. An 8-inch-diameter pipe in 6th Avenue, near the intersection with S Adams Street was disconnected between Junctions J83778 and J47070. Pipe M-0019042a was added between these junctions with the same properties as Pipe M-0019042 immediately to the east.
- i. Flow Test No. 95: The check valve direction of Pipe M-0106987 was reversed.
- j. Flow Test Nos. 101 through 103: The Alaska Street Reservoir water level data was not provided. Instead, transducer data from location D3 was used to initialize the Alaska Street Reservoir water level to 30 feet for the calibration analyses.

- i. The Hazen Williams roughness coefficient of the cast iron pipe water main extending from the Alaska Street Reservoir to Yakima Avenue was reduced by 10, from 85 to 75.
- k. Flow Test Nos. 145 and 146: The Portland Avenue Zone is served by three active PRV stations in the hydraulic model. Besides the 2-inch-diameter lead PRV for the zone, located in the Portland Avenue and 38th Street E PRV station and set to a hydraulic grade of 346 feet, the other pressure reducing valves are set at the same or very similar hydraulic grades (341 feet, 338 feet, and 341 feet). With these setpoints, the hydraulic model calculates very minimal pressure drops during Flow Test Nos. 145 and 146, which is not consistent with the pressure measured in the field at both test sites and locations PA1 and PA2 that are immediately downstream of the PRVs. Sensitivity analyses were performed to attempt to determine if some of the valves either did not open during field testing or if their setpoints are significantly lower than were initialized in the model. The results indicate that the static pressures of the zone match very well between the field and the model, indicating that the 2-inch-diameter valve setpoint is accurate. The field results also indicate that significant (approximately 30 psi) headloss occurs between the Portland Avenue PRV station and location PA1, whereas only 6 to 10 psi of pressure drop was measured between the two easterly PRV stations (E 38th Street and T Street PRV station, and E 38th Street and Roosevelt PRV station) and location PA2. Sensitivity analyses were also performed with all PRVs functioning as initialized in the hydraulic model, but with closed valves at various locations on Portland Avenue, T Street, Roosevelt Avenue, and Fairbanks Street.
 - i. Calibration within the Walski guideline was achieved with the large (4-inch diameter) valve in the Portland Avenue and 38th Street E PRV station closed, as well as the 8-inch-diameter valve in the E 38th Street and Roosevelt Avenue PRV station closed. The 6-inch diameter E 38th Street and T Street PRV station valve was active and set at 57 psi; and the setpoint of the 2-inch diameter valve in the Portland Avenue PRV station was unchanged. These revised PRV setpoints were included in the model accompanying this technical memorandum. However, even though the resulting static and dynamic pressures at Flow Test Nos. 145 and 146 correlate well between the field and the model, it is unlikely that these initial modelling settings accurately reflect the actual field settings or system configuration. It is recommended that the pressure setpoint of these three PRV stations be confirmed. If the PRV setpoints are correct, a review of the pipe diameters and connectivity in this pressure zone, and an investigation into a possibly closed mainline valve is recommended to take place. Based on the current modeling settings, the static pressures in the zone are consistent between the field and model, and the dynamic pressures are consistent along Portland Avenue and north of Fairbanks Street. Based on the transducer located at PA2 during field testing, the model is calculating dynamic pressures approximately 10 psi lower than the field measurements along T Street and Roosevelt Avenue (and south of Fairbanks Street).

- ii. In addition to the three active PRV stations, the hydraulic model includes three additional 346 Portland Avenue PRV stations that are inactive and without setpoints in the hydraulic model. These PRV stations include the E 34th Street and Fairbanks Street PRV, the E 34th Street and N Street PRV, and the E Harrison Street and N Street PRV (which is physically disconnected from the 346 Portland Avenue Zone). The inactive status of these PRV stations was maintained as part of the calibration analyses.

Port of Tacoma and Fife Heights Area (Figure 9)

- Pressure Zones
 - 251 Low
 - 411 Fife Heights Low
- Calibration Progress
 - Static Pressure Measurements
 - ECAC: 19 of 20 (95 percent) static pressure measurements within plus or minus 2 psi.
 - Dynamic Pressure Measurements
 - Walski: 18 of 18 (100 percent) of residual pressure measurements predict the hydraulic grade line differential between static and residual conditions to within 10 feet.
- Model Updates for Steady State Calibration
 - a. Piping at the intersection of E 11th Street and Alexander Avenue was not connected in the hydraulic model. Pipe M-0032248B and Junction J128282 were added to connect the piping at this intersection. Pipe M-0032248 was also split as part of the reconfiguration of this intersection in the hydraulic model. The new pipe, M-0032248B, was assumed to have the same properties as the adjacent pipe in Alexander Avenue. Without this reconfigured intersection, Flow Test No. 110 does not calibrate within the Walski guideline, and the accuracy of Flow Test No. 111 is reduced. It is recommended that Tacoma Water review the piping configuration at the intersection of E 11th Street and Alexander Avenue to confirm that these changes accurately represent the existing system configuration.
 - b. Flow Test Nos. 112 and 113: The setpoint of the small and large valves in the Fife Heights PRV station (66th Avenue E and 4th Street E) were 54 and 52 psi, respectively. The large valve setpoint was changed to 50 psi as part of the calibration analyses.

549 NE Tacoma Zone (Figure 10)

- Pressure Zones
 - 549 NE Tacoma
- Calibration Progress
 - Static Pressure Measurements
 - ECAC: 20 of 22 (91 percent) static pressure measurements within plus or minus 2 psi.
 - Dynamic Pressure Measurements
 - Walski: 21 of 21 (100 percent) of residual pressure measurements predict the hydraulic grade line differential between static and residual conditions to within 10 feet.
- Model Updates for Steady State Calibration
 - a. The Indian Hills 0.5 million-gallon (MG) Reservoir and associated piping and junctions were activated in the hydraulic model for calibration analyses, and were returned to its initialized state (inactive) in the model accompanying this technical memorandum.
 - b. The pressure reducing valve setpoints at the 356th Street BPS were reduced to 77 psi to match SCADA data for calibration analyses to reflect conditions during field testing, and was returned to its initialized setting (83 psi) in the model accompanying this technical memorandum. The control settings for these PRVs were changed to open when the Indian Hills 3.5 MG Reservoir water level reaches 16.0 feet, and to close when the Indian Hills 3.5 MG Reservoir water level reaches 19.2 feet to match SCADA data. The updated control settings were included in the model accompanying this technical memorandum.
 - c. A 6-inch-diameter pipe was disconnected between Junctions J13404 and J70738. Pipe M-0005591A was added between these junctions with the same properties as Pipe M-0005591, which is immediately adjacent to these junctions.
 - d. A 6-inch-diameter pipe was disconnected between Junctions J72908 and J72909. Pipe M-0031333A was added between these junctions with the same properties as Pipe M-0031333, which is immediately adjacent to these junctions.

NE Tacoma Area (Pressure Zones Adjacent to the 549 NE Tacoma Zone) (Figure 10)

- Pressure Zones
 - 186 Lakota Beach
 - 226 Dash Point Low
 - 226 Hayada
 - 346 Browns and Dash Point
 - 346 NE Tacoma
 - 370 Overlook
 - 411 Dash Point High
 - 411 Twin Lakes
 - 426 Harbor View
 - 486 Beverly Heights

- 549 NE Tacoma
- 649 Indian Hill
- Calibration Progress
 - Static Pressure Measurements
 - ECAC: 37 of 41 (90 percent) static pressure measurements within plus or minus 2 psi.
 - Dynamic Pressure Measurements
 - Walski: 35 of 35 (100 percent) of residual pressure measurements predict the hydraulic grade line differential between static and residual conditions to within 10 feet.
- Model Updates for Steady State Calibration
 - a. Flow Test No. 126: The 6-inch-diameter large valve in the NE 44th Avenue and 33rd Street NE PRV station was set at 33 psi, only 2 psi lower than the small (2-inch diameter) valve at the same station. Pressure transducer data indicates these setpoints are closer to 5 psi apart; therefore, the large valve was set to 30 psi.
 - b. Flow Test No. 136: Hazen Williams roughness coefficients of all pipes in the 226 Dash Point Low Zone were reduced by 20, and the minor loss coefficients in the discharge piping of each PRV station serving this zone were set to 20. Pressure transducer data indicates that one of the PRV stations did not open during the flow test. Sensitivity analyses indicate that the PRV station that did not open was the Markam Avenue PRV, which is understood to be the lag PRV in the zone. For calibration analyses, this PRV was closed, and was initialized as closed in the model accompanying this technical memorandum. It is recommended that this PRV be inspected in the field for proper operation before it is opened in the model for future analyses.
 - c. Flow Test Nos. 141 through 143: The 47th Avenue and SW 316th PRV station was oriented the wrong way in the hydraulic model. The direction of Pipes M-0061609 and M-0064331 were reversed.
 - d. Flow Test Nos. 127 through 129: When only the Indian Hills 2 BPS is operational (i.e., all pumps at the Indian Hills 1 BPS are off), the hydraulic grade of the 649 Indian Hills Zone decreases 16 feet, from 649 to 633 feet. Controls were added to the pressure sustaining valve in the Indian Hills 2 BPS to reflect this condition. Additionally, the Indian Hills 1 and Indian Hills 2 BPSs were cycling on and off during these flow tests. Based on the SCADA data provided by Tacoma Water, the status of each of these BPSs during these flow tests is shown in **Table 4**.

Table 4: Indian Hills 1 and 2 BPSs Status During Flow Testing

Flow Test No.	Indian Hills 1 BPS	Indian Hills 2 BPS
127 Static	OFF	ON
127 Low and High Flows	ON	ON
128 Static	ON	OFF
128 Low and High Flows	ON	ON
129 Static	ON	ON
129 Low and High Flows	ON	ON

These BPSs were initialized in the model as shown in **Table 4** for the calibration analyses. When the Indian Hills 1 BPS is operational, only Pump 3 is on in the hydraulic model, which has controls to be modeled as a single VFD or to reflect the combined pumping capacity of Indian Hills 1 BPS Pumps 1 through 3. When the Indian Hills 2 BPS is operational, only Pump 4 was on in the hydraulic model. Following completion of the calibration analyses, Indian Hills 1 BPS Pump 3, and Indian Hills 2 BPS Pump 4 were initialized as active in the model accompanying this technical memorandum. All other pumps in these BPSs were closed.

CONCLUSION

STEADY-STATE CALIBRATION CONCLUSION

The steady-state model is calibrated within industry-recognized guidelines for the majority of the Tacoma Water distribution system. Over 91 percent of field-measured static pressures systemwide are within plus or minus 2 psi of the static pressures calculated in the hydraulic model, which meets the ECAC guideline for static pressure measurements. All 100 percent of the dynamic tests performed in the system resulted in the headloss measured in the field being within 5 to 10 feet of hydraulic grade (4.33 psi) of the headloss calculated by the hydraulic model. This level of accuracy results in all 275 tests meeting the Walski calibration guideline of the model predicting the hydraulic grade line to within 5 to 10 feet at model calibration points during peak demands, such as fire flows.

The only area not meeting industry-recognized guidelines include the static pressure measurements in the non-478 High Zone pressure zones in west and northwest Tacoma. In this area, 76 percent of the field-measured static pressures systemwide are within plus or minus 2 psi of the static pressures calculated in the hydraulic model. Many of the pressure zones within this operating area are served by PRV stations and include steep slopes adjacent to Puget Sound. Elevations in areas with steep slopes are more susceptible to inaccuracies because significant elevation changes can occur with slight changes to the X and Y coordinates of a junction or valve. Over 90 percent of field-measured static pressures in these zones are within plus or minus 3 psi of the static pressures calculated in the hydraulic model.

OTHER OBSERVATIONS

520 SE Tacoma Zone

The 520 SE Tacoma Zone is a closed zone served by a PRV station. Pressure transducers indicate that a pressure fluctuation of approximately 5 psi is occurring every 1 to 2 minutes in the 520 SE Tacoma Zone during static conditions, as shown in **Charts 1** and **2**. The location of these transducers, SET11 and SET12, are shown in **Figure 5**. It is recommended that the setpoint and operation of the PRV station serving the 520 SE Tacoma Zone be evaluated to confirm proper operation and possibly reduce the pressure fluctuation that was observed to be occurring during static conditions.

Chart 1: SET11 Pressure Transducer Data

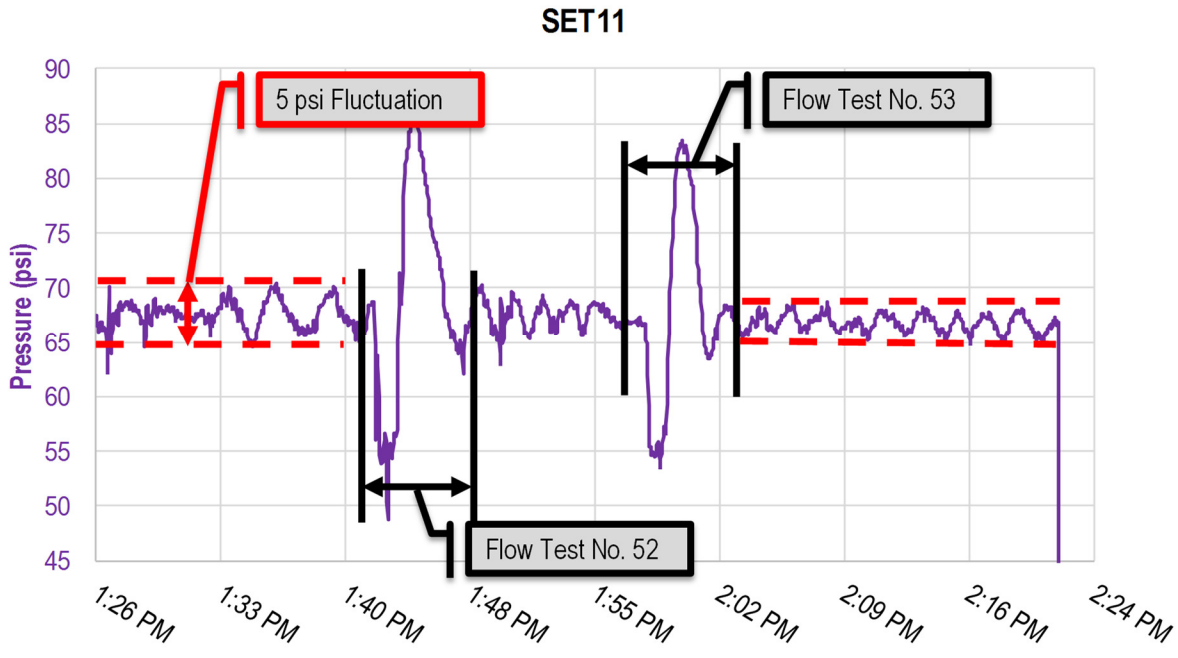
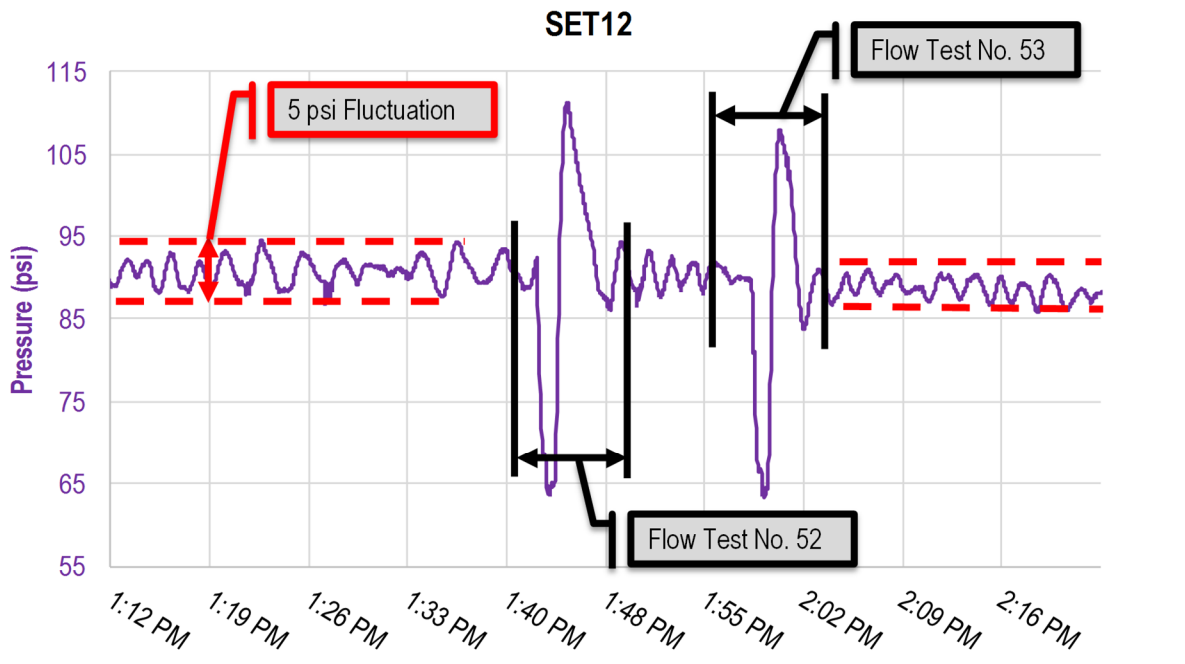


Chart 2: SET12 Pressure Transducer Data



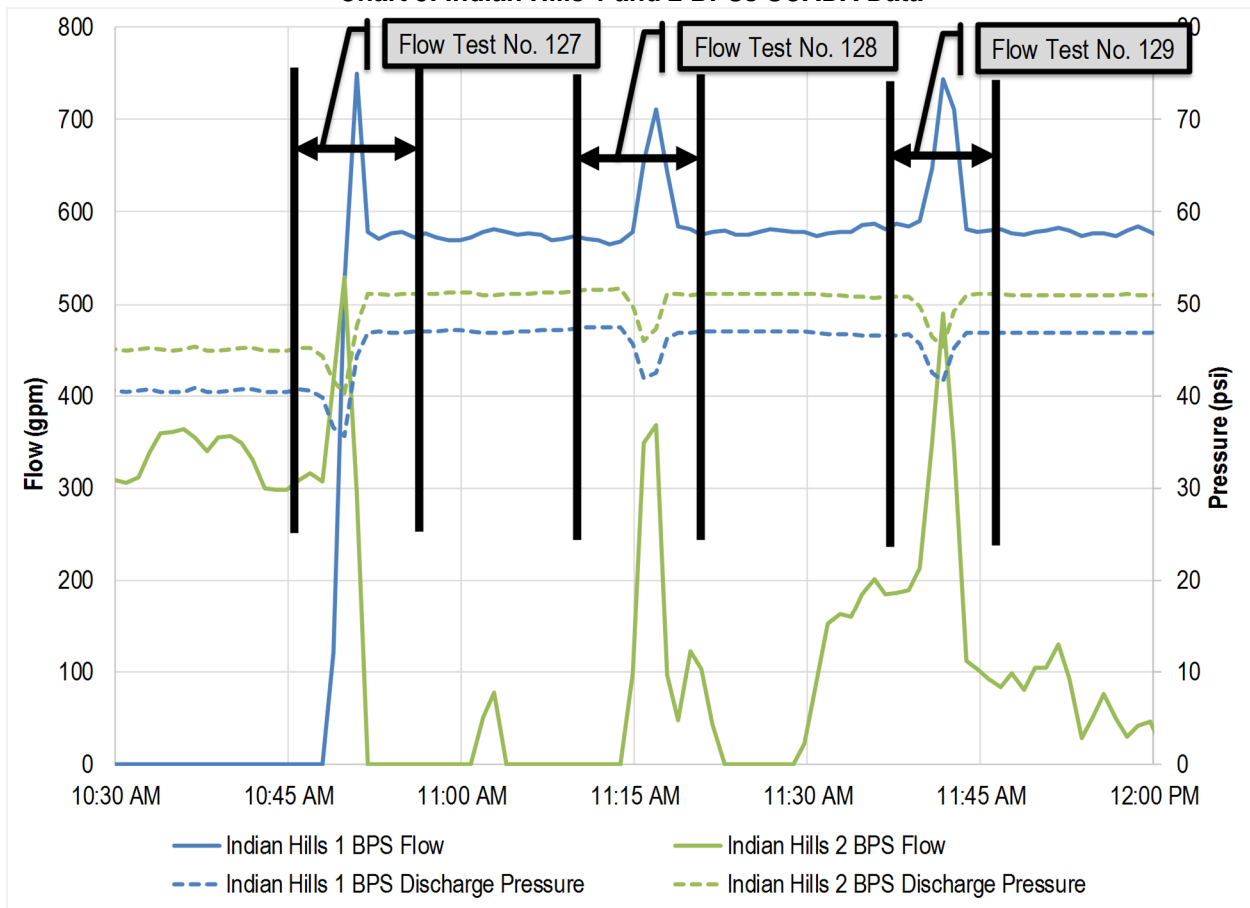
649 Indian Hills Zone

As described in the **NE Tacoma Area** calibration summary, the 649 Indian Hills Zone is a closed zone served by two BPSs, and the hydraulic grade of the pressure zone fluctuates depending on the supply rate of the two BPSs. The SCADA data from the day of field testing for Flow Test Nos. 127, 128, and 129 is shown in **Chart 3** for each BPS. As shown in **Chart 3**, the pressure during non-flow test periods ranged from approximately 45 to 51 psi at the Indian Hills 1 BPS, and ranged from approximately 40 to 47 psi at the Indian Hills 2 BPS.

Additionally, during Flow Test Nos. 127, 128, and 129, the pressure at the Indian Hills 1 and 2 BPSs decreased by approximately 5 psi compared to the pressure during non-flow test periods. This decrease in pressure indicates that additional pumps were not called to operate, and the pumps that were operating were moving “to the right” on the pump curves to meet the normal demand and hydrant demand in the zone while reducing the hydraulic grade of the zone.

Depending on any building-specific fire flow or level-of-service requirements in the 649 Indian Hills Zone, it may be necessary to adjust the pump setpoints to allow increased flow to be provided from the Indian Hills 1 and 2 BPSs without reducing the hydraulic grade of the zone.

Chart 3: Indian Hills 1 and 2 BPSs SCADA Data



NEXT STEPS

346 Portland Avenue Zone Investigation

It is recommended that Tacoma Water confirm the pressure setpoint of the three active PRV stations that serve the 346 Portland Avenue Zone and confirm that each PRV is able to operate as intended. Additionally, it is recommended that Tacoma Water confirm that the three PRV stations that are inactive in the hydraulic model (E 34th Street and Fairbanks Street PRV, the E 34th Street and N Street PRV, and the E Harrison Street and N Street PRV) be confirmed to not be active in the water system.

During a December 13, 2017 meeting, Tacoma Water indicated that a recent emergency event occurred in this zone and that PRV setpoints or initial statuses may have been adjusted during the event and then not returned to the setpoints or statuses that are initialized in the hydraulic model. Following an investigation of the PRV setpoints and statuses, approximately two additional flow tests may be recommended by RH2 to provide additional data to allow the flow tests in this zone to confirm that the field data and modeled results continue to meet at least one of the hydraulic model calibration criteria identified in the *DOH Water System Design Manual*.

581 Canyon Zone Investigation

It is recommended that Tacoma Water confirm the possibility of reverse flow occurring through the 148th Street E and Woodland PRV station, either through a check valve in the PRV station or through the PRV itself. A check valve was added to this PRV station in the model accompanying this technical memorandum as the analyses performed for Test No. 34 indicate that reverse flow was likely occurring through this PRV station during the field flow test.

West and Northwest Tacoma Static Pressures

Many of the pressure zones in west and northwest Tacoma that are adjacent to the 478 High Zone have field-measured static pressures that are within plus or minus 3 psi of the modeled static pressures, but not within the ECAC guideline of plus or minus 2 psi. Some of these zones include steep slopes adjacent to Puget Sound. Elevations in areas with steep slopes are more susceptible to inaccuracies because significant elevation changes can occur with slight changes to the X and Y coordinates of a junction or valve. Tacoma Water has indicated that a high-resolution digital elevation model or similar representation of the water system's terrain is planned to be created in 2018. It is recommended that the hydraulic model elevations in these pressure zones be compared and updated with the forthcoming elevation data to determine if the updated elevation data results in at least 90 percent of the static pressures correlating within the ECAC guideline of plus or minus 2 psi. If the resulting static pressure measurements and calculations are not within plus or minus 2 psi, it is recommended that the setpoints of the PRV stations serving these pressure zones be confirmed by Tacoma Water, and that the elevation of the PRV stations be field-surveyed and updated in the hydraulic model.

As elevation data is confirmed or updated in the hydraulic model, it is recommended that the source of the elevation data be added to each node, as well as the date that the elevation was confirmed or updated. One suggested method to track the source and date of the elevation

updates is to add editable fields to each node to be updated as elevations are confirmed or updated.

Facility Setpoint Confirmation

It is recommended that Tacoma Water review the facility setpoint adjustments presented in this technical memorandum and compare these setpoints with the actual field setpoints. In some cases, it may be necessary to visit a facility and open a hydrant or otherwise temporarily adjust the setpoint of another facility to be able to confirm the model's setpoint assumptions.

Extended Period Simulation Calibration

The model accompanying this technical memorandum is calibrated for steady state scenarios, which provides instantaneous flow and pressure results based on user-defined initial conditions (reservoir water levels, pump status, demands, etc.). Additional confirmation of the Tacoma Water hydraulic model's accuracy can occur if the model is calibrated for extended period simulation (EPS) scenarios, which would allow Tacoma Water to better analyze the operation of each facility over a period of time, including (but not limited to) the ability to analyze pump cycles and runtimes, reservoir water levels, diurnal demand curves, and water age.

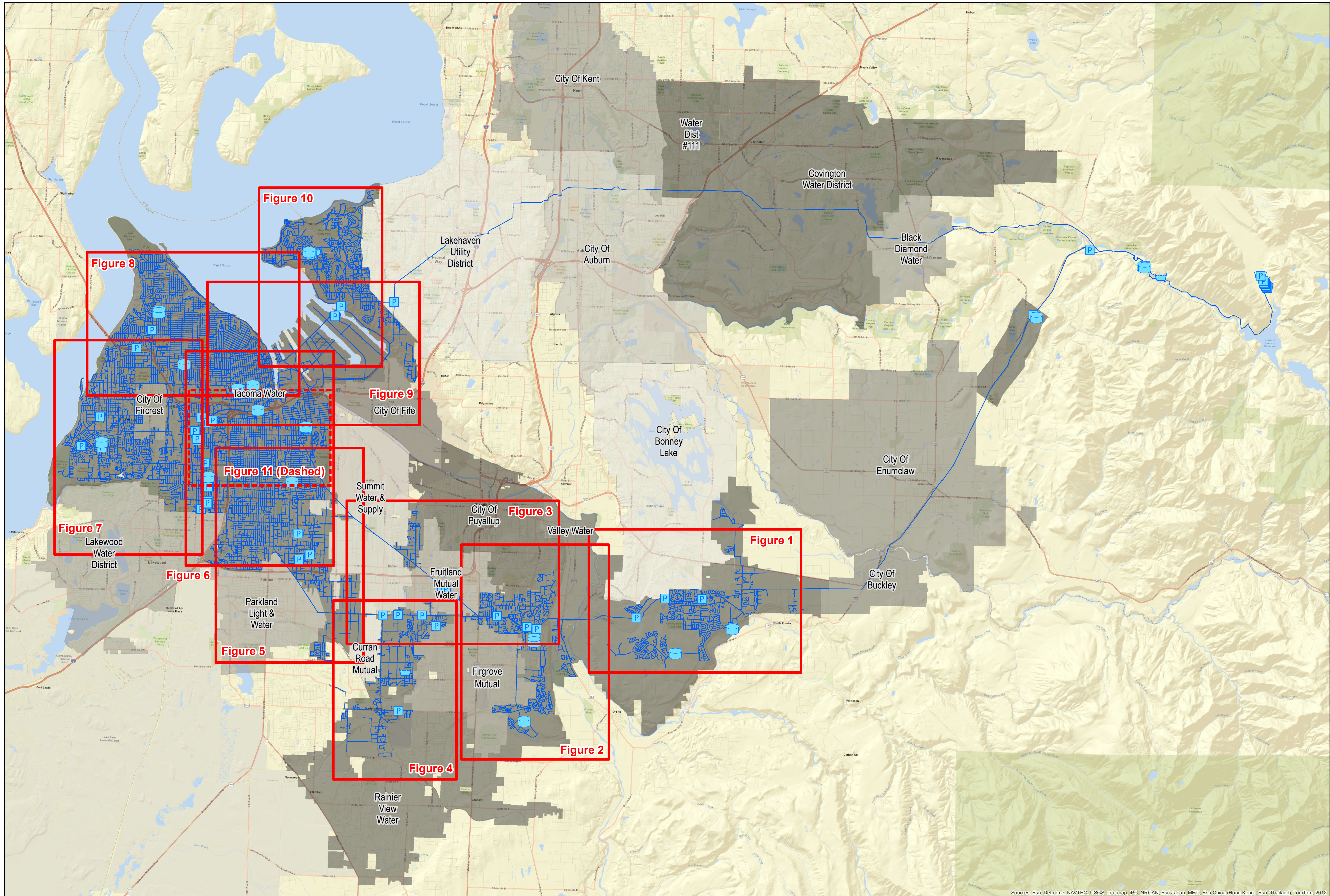
ATTACHMENTS

Water System Overview Figure (Figures 1 through 11 index)

Figures 1 through 11: Field Test Locations

Hydraulic Model Calibration Data

FIGURES



Vicinity Map



Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2012

Water System Overview
Tacoma Water
Hydraulic Model Update and Calibration

Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet

By: rwithers

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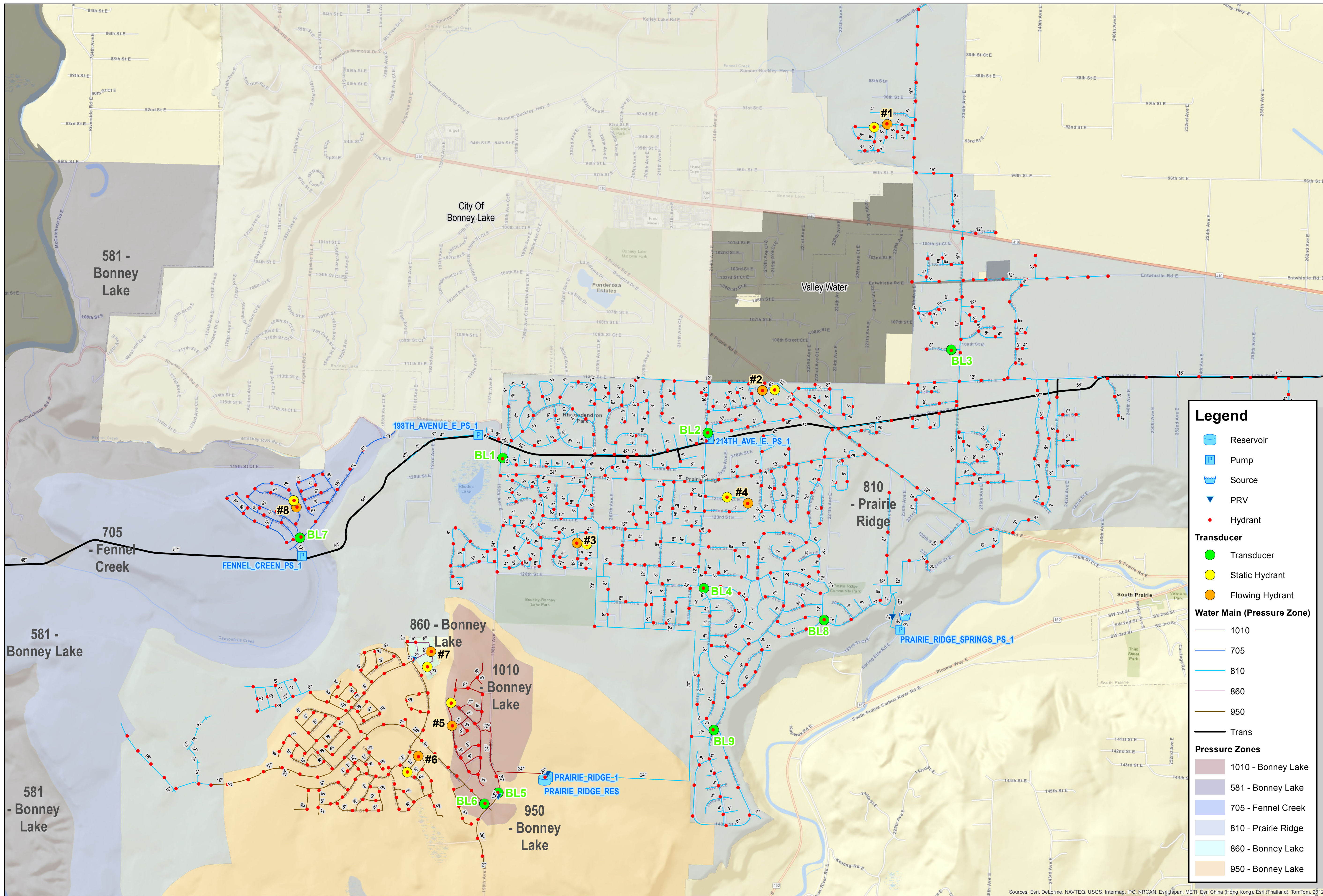


1 inch = 7,500 feet
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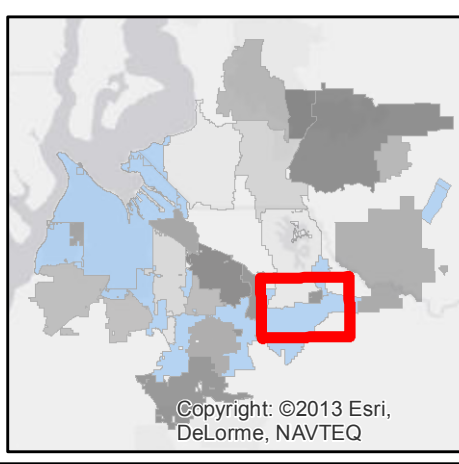
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Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2012



Vicinity Map



**Figure 1
Flow Tests - Bonney Lake Area**

**Tacoma Water
Hydraulic Model Update and Calibration**

Legend

- Reservoir
- Pump
- Source
- PRV
- Hydrant
- Transducer**
- Transducer
- Static Hydrant
- Flowing Hydrant
- Water Main (Pressure Zone)**
- 1010
- 705
- 810
- 860
- 950
- Trans
- Pressure Zones**
- 1010 - Bonney Lake
- 581 - Bonney Lake
- 705 - Fennel Creek
- 810 - Prairie Ridge
- 860 - Bonney Lake
- 950 - Bonney Lake

Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet

By: rwithers

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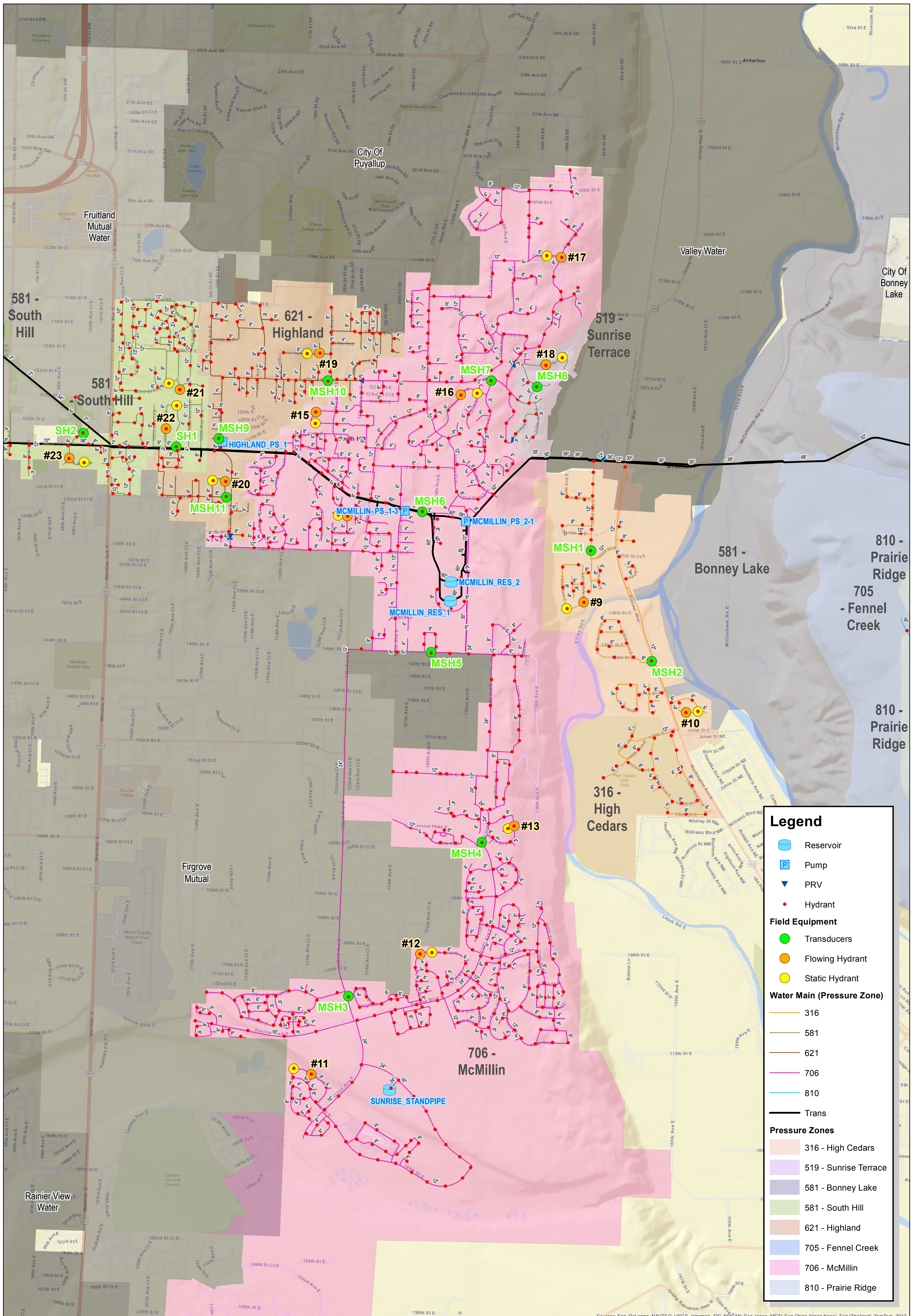


1 inch = 1,200 feet
0 600 1,200 2,400 Feet

Plot Date: 12/14/2017



Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2012



Legend

- Reservoir
- Pump
- PRV
- Hydrant

Field Equipment

- Transducers
- Flowing Hydrant
- Static Hydrant

Water Main (Pressure Zone)

- 316
- 581
- 621
- 706
- 810
- Trans

Pressure Zones

- 316 - High Cedars
- 519 - Sunrise Terrace
- 581 - Bonney Lake
- 581 - South Hill
- 621 - Highland
- 705 - Fennel Creek
- 706 - McMillin
- 810 - Prairie Ridge

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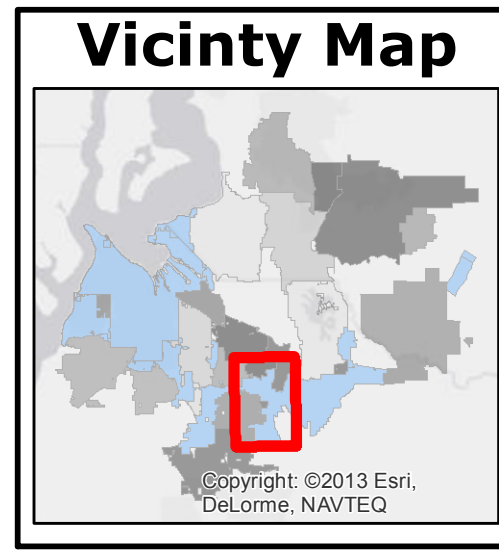


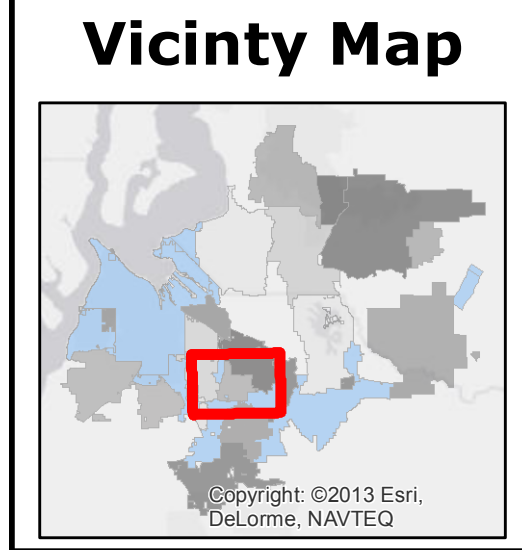
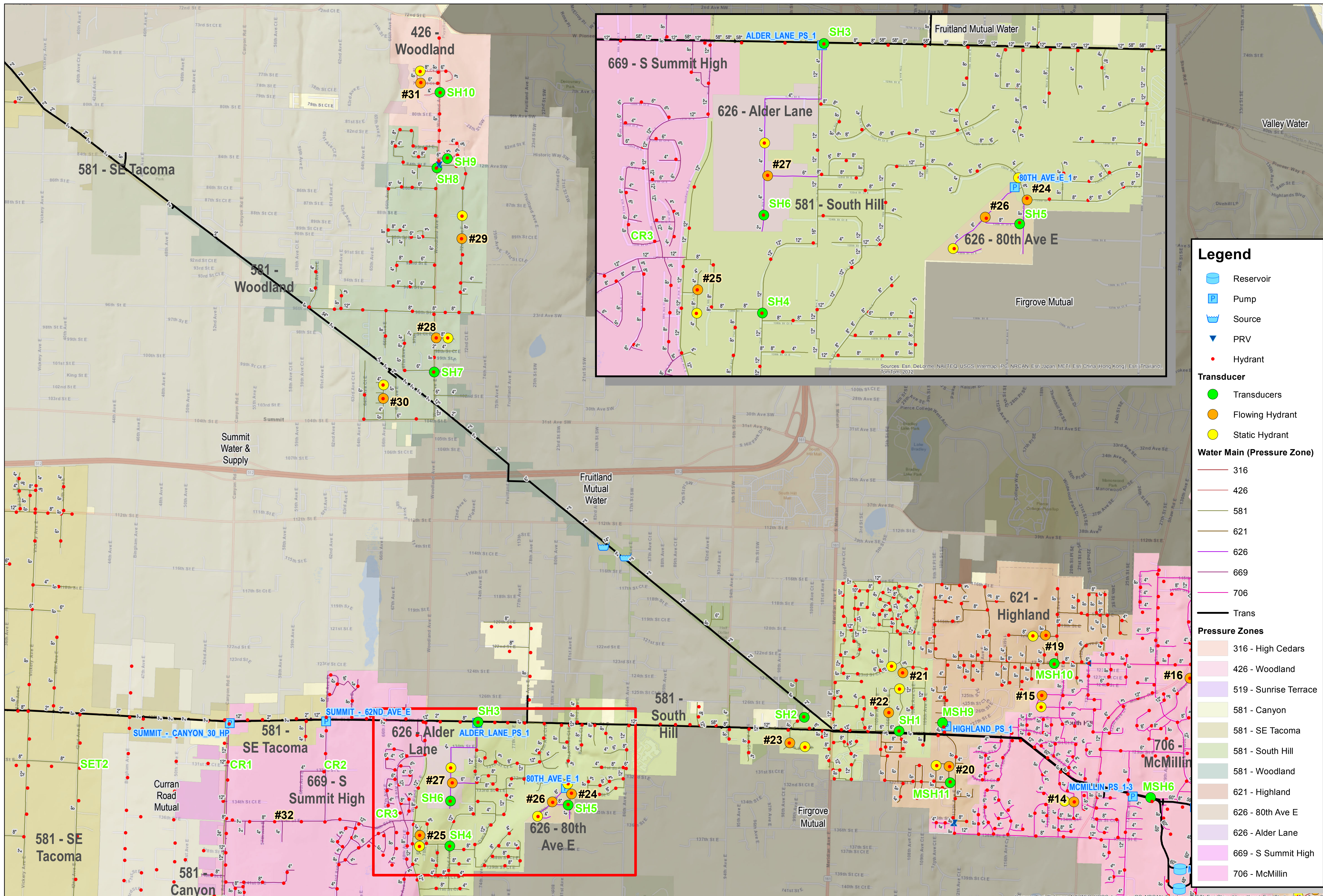
Figure 2 Flow Tests - McMillin Area

Tacoma Water Hydraulic Model Update and Calibration

1 inch = 1,200 feet

0 600 1,200 2,400 Feet

Plot Date: 12/14/2017



Legend

- Reservoir
- Pump
- Source
- PRV
- Hydrant

Transducer

- Transducers
- Flowing Hydrant
- Static Hydrant

Water Main (Pressure Zone)

- 316
- 426
- 581
- 621
- 626
- 669
- 706
- Trans

Pressure Zones

- 316 - High Cedars
- 426 - Woodland
- 519 - Sunrise Terrace
- 581 - Canyon
- 581 - SE Tacoma
- 581 - South Hill
- 581 - Woodland
- 621 - Highland
- 626 - 80th Ave E
- 626 - Alder Lane
- 669 - S Summit High
- 706 - McMillin

Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet
 By: rwithers
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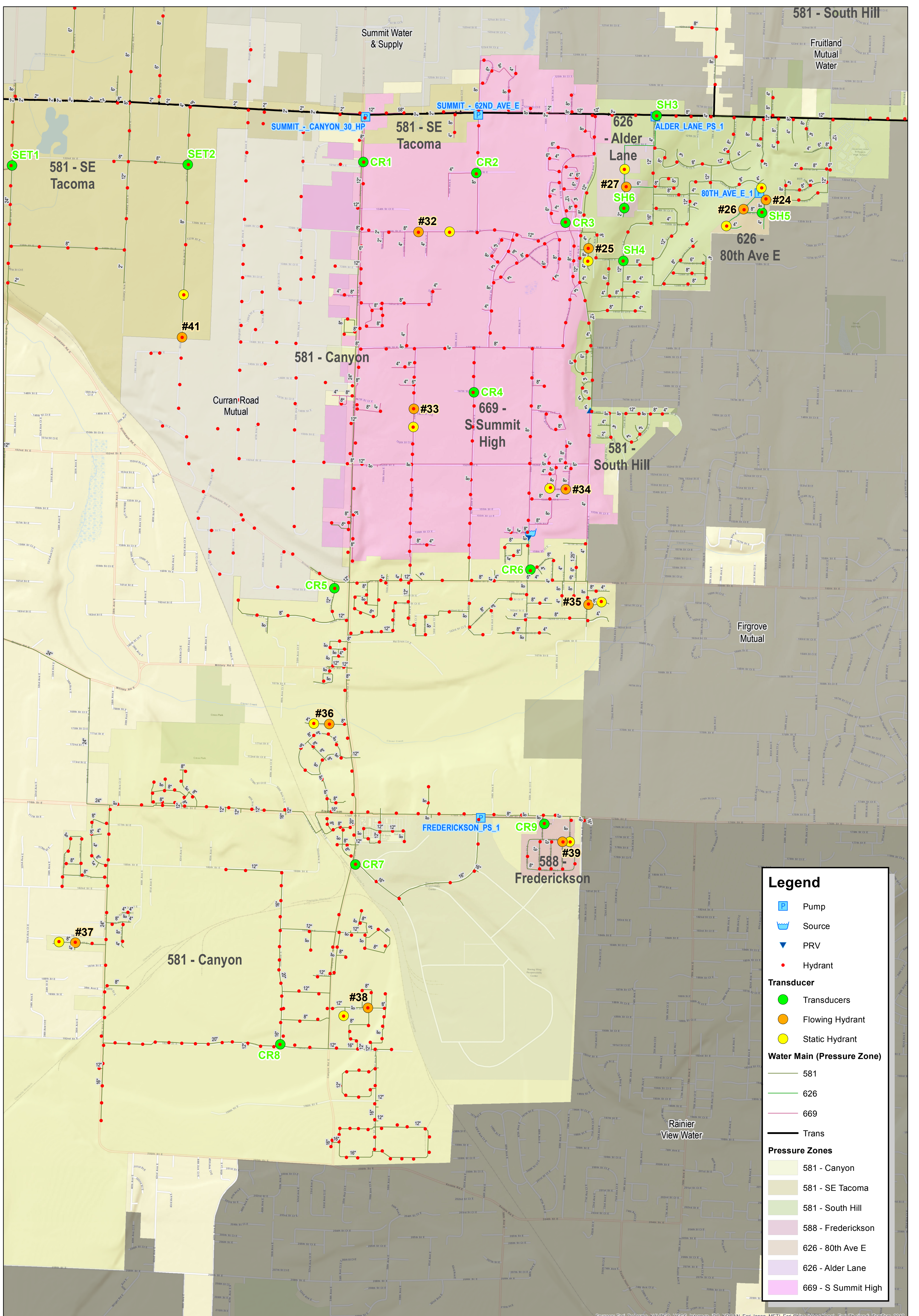
Figure 3 Flow Tests - South Hill Area Tacoma Water Hydraulic Model Update and Calibration



1 inch = 1,200 feet
 0 600 1,200 2,400 Feet
 Plot Date: 12/14/2017



Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, IPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2012



Legend

- Pump
- Source
- PRV
- Hydrant

Transducer

- Transducers
- Flowing Hydrant
- Static Hydrant

Water Main (Pressure Zone)

- 581
- 626
- 669
- Trans

Pressure Zones

- 581 - Canyon
- 581 - SE Tacoma
- 581 - South Hill
- 588 - Frederickson
- 626 - 80th Ave E
- 626 - Alder Lane
- 669 - S Summit High

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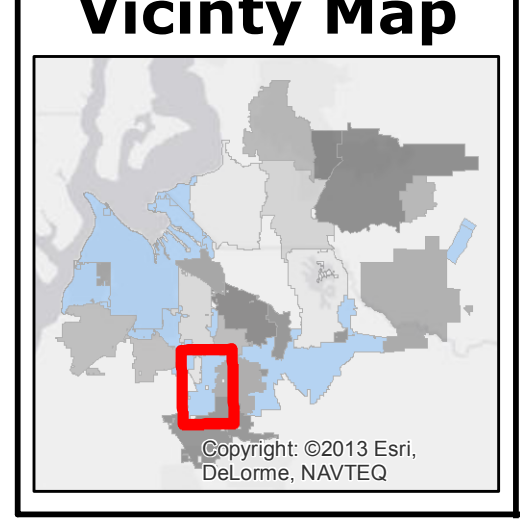


Figure 4

Flow Tests - Canyon Road Area

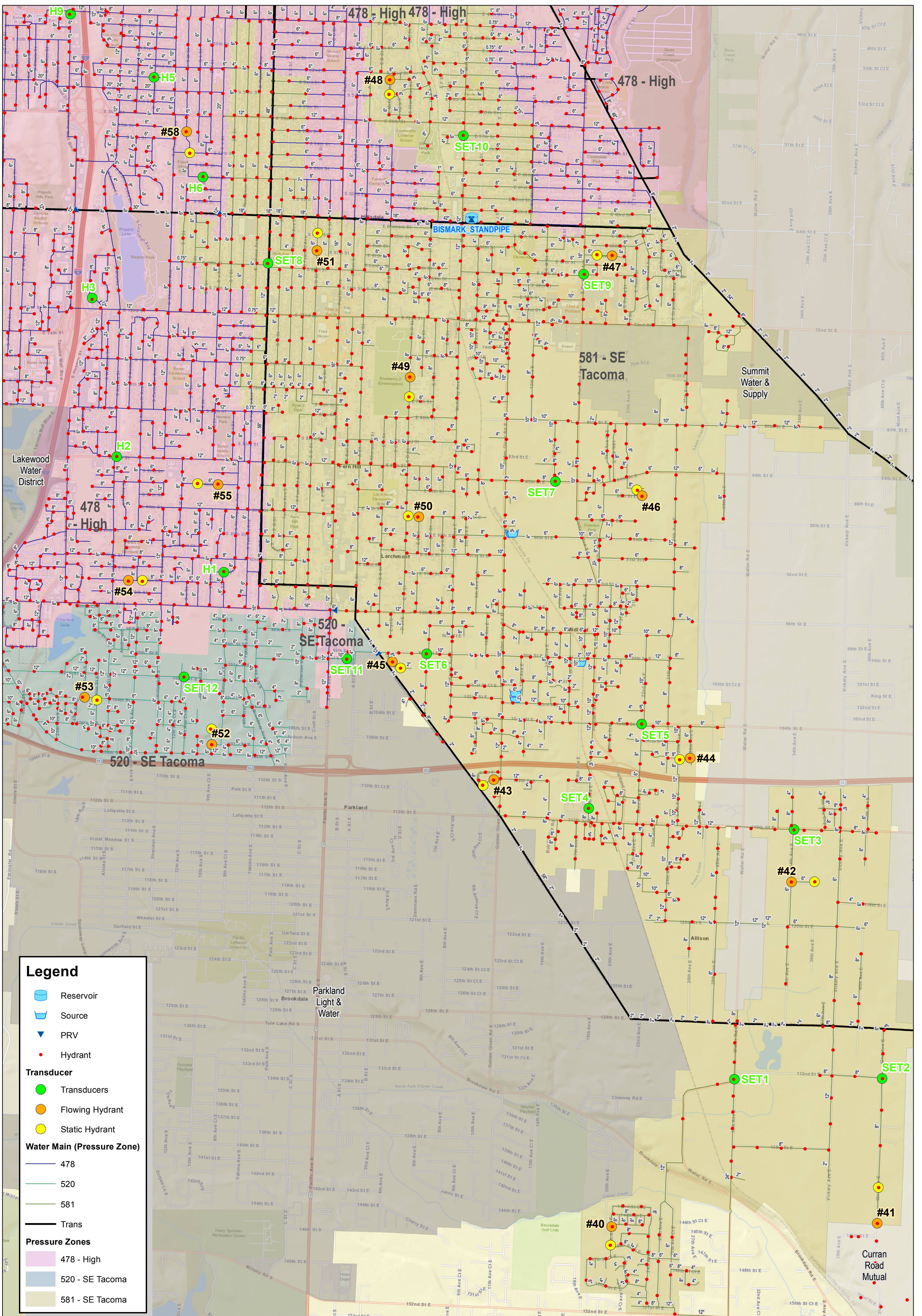
Tacoma Water

Hydraulic Model Update and Calibration

1 inch = 1,000 feet

0 500 1,000 2,000 Feet

Plot Date: 12/14/2017



Legend

- Reservoir
- Source
- PRV
- Hydrant

Transducer

- Transducers
- Flowing Hydrant
- Static Hydrant

Water Main (Pressure Zone)

- 478
- 520
- 581
- Trans

Pressure Zones

- 478 - High
- 520 - SE Tacoma
- 581 - SE Tacoma

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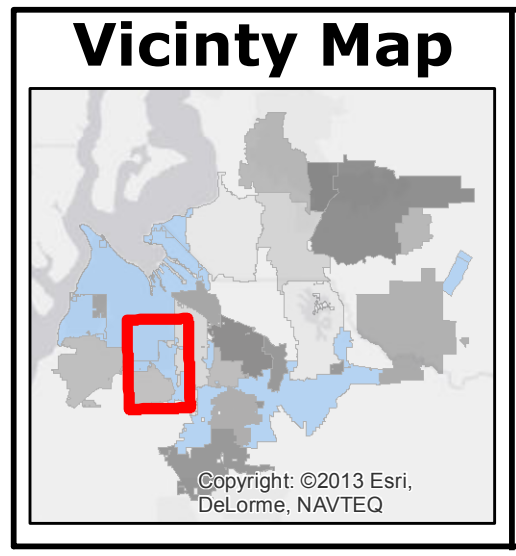
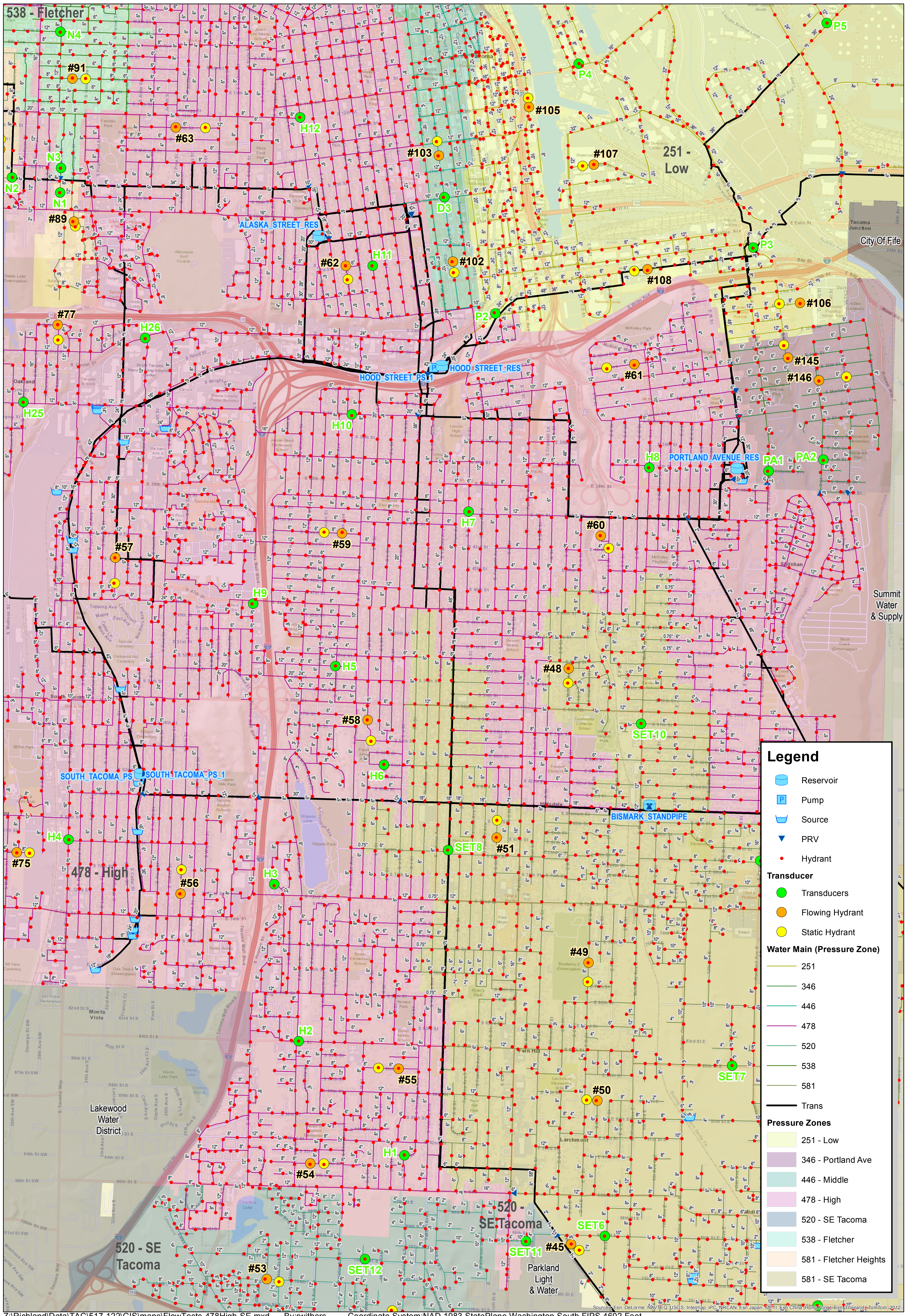


Figure 5 Flow Tests - SE Tacoma Area

Tacoma Water Hydraulic Model Update and Calibration

1 inch = 1,200 feet
0 600 1,200 2,400 Feet
Plot Date: 12/14/2017





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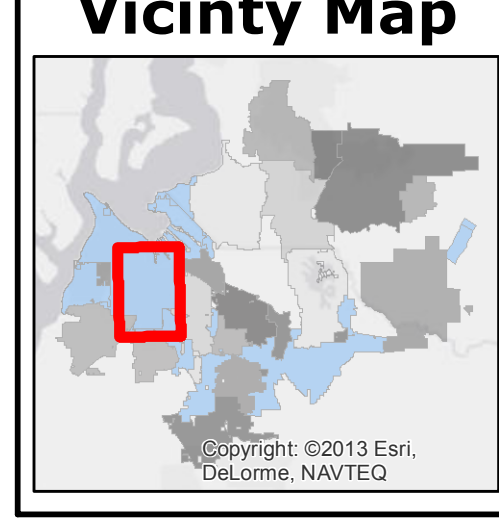


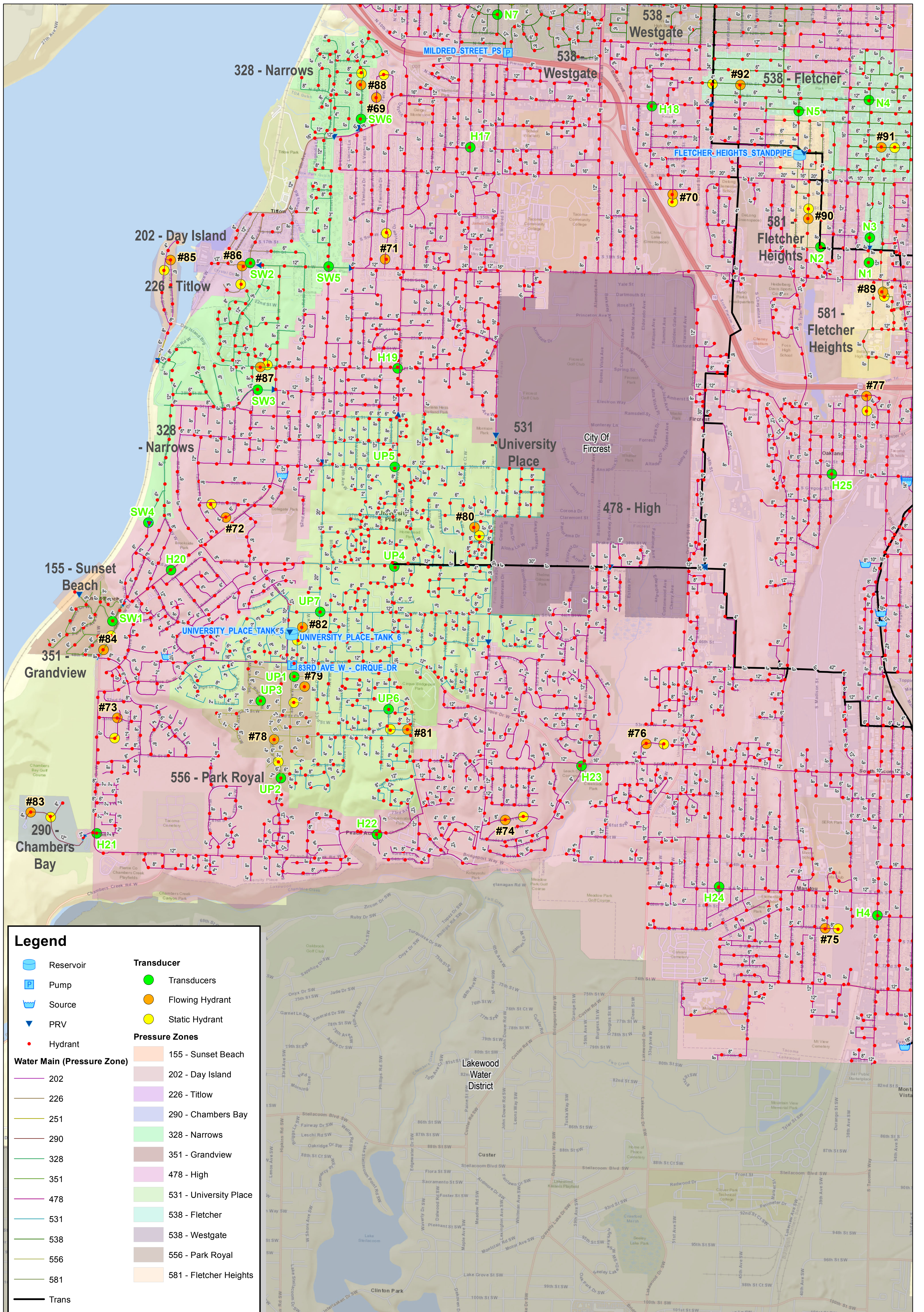
Figure 6 Flow Tests - 478 High Zone Area - SE

Tacoma Water Hydraulic Model Update and Calibration

1 inch = 1,200 feet

0 600 1,200 2,400 Feet

Plot Date: 12/14/2017



Legend

	Reservoir		Transducers
	Pump		Flowing Hydrant
	Source		Static Hydrant
	PRV		
	Hydrant		

Water Main (Pressure Zone)

	202		155 - Sunset Beach
	226		202 - Day Island
	251		226 - Titlow
	290		290 - Chambers Bay
	328		328 - Narrows
	351		351 - Grandview
	478		478 - High
	531		531 - University Place
	538		538 - Fletcher
	538		538 - Westgate
	556		556 - Park Royal
	581		581 - Fletcher Heights
	Trans		

Z:\Richland\Data\TAC\517-122\GIS\maps\Flow Tests-478High-SW.mxd By:rwitthers Coordinate System:NAD 1983 StatePlane Washington South FIPS 4602 Feet

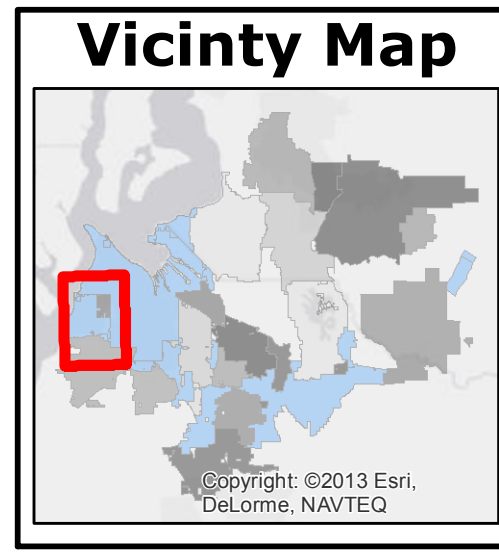


Figure 7

Flow Tests - 478 High Zone Area - SW

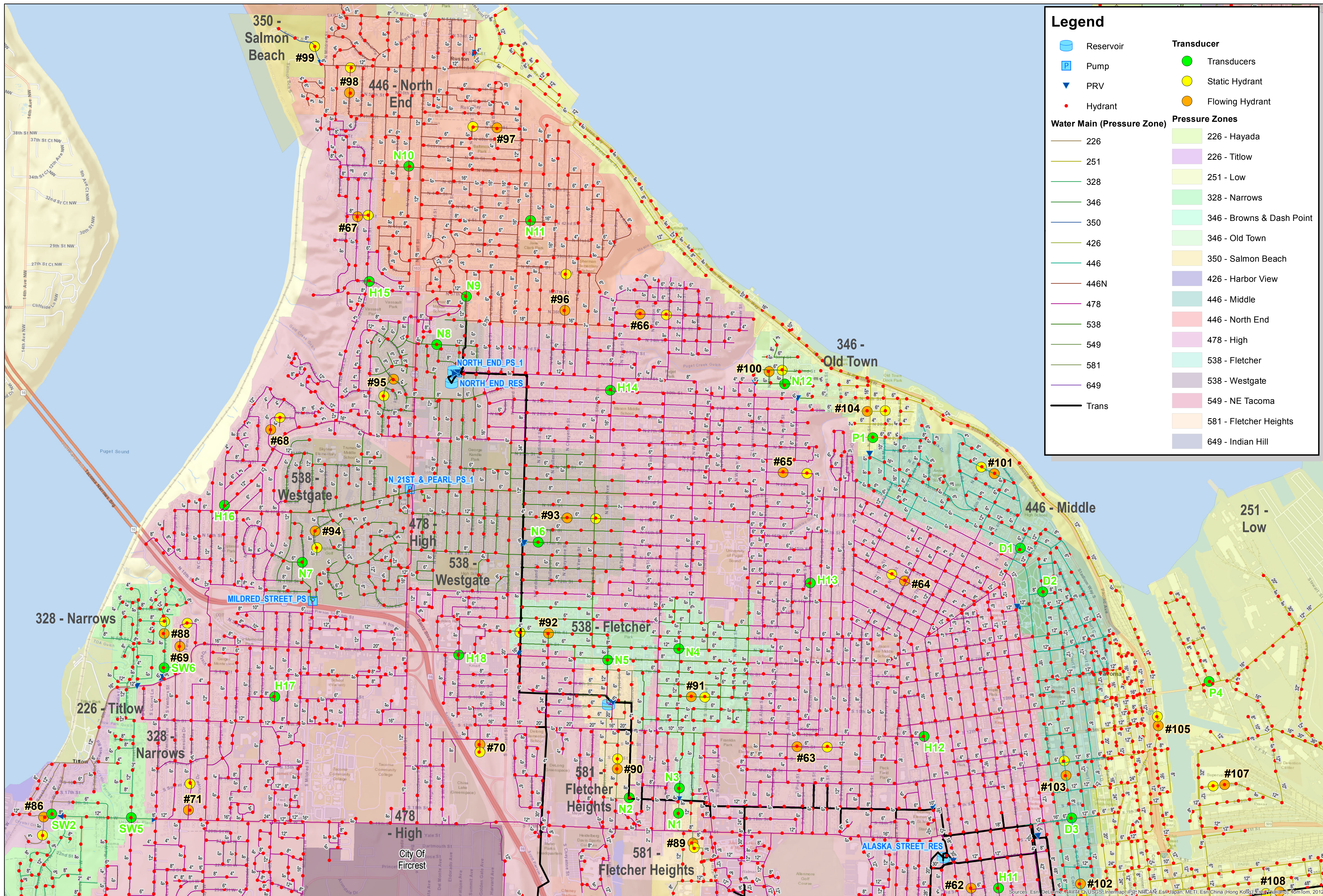
Tacoma Water

Hydraulic Model Update and Calibration

1 inch = 1,200 feet

0 600 1,200 2,400 Feet

Plot Date: 12/14/2017



Legend

	Reservoir		Transducers
	Pump		Static Hydrant
	PRV		Flowing Hydrant
	Hydrant		

Water Main (Pressure Zone)

	226
	251
	328
	346
	350
	426
	446
	446N
	478
	538
	549
	581
	649
	Trans

Pressure Zones

	226 - Hayada
	226 - Titlow
	251 - Low
	328 - Narrows
	346 - Browns & Dash Point
	346 - Old Town
	350 - Salmon Beach
	426 - Harbor View
	446 - Middle
	446 - North End
	478 - High
	538 - Fletcher
	538 - Westgate
	549 - NE Tacoma
	581 - Fletcher Heights
	649 - Indian Hill

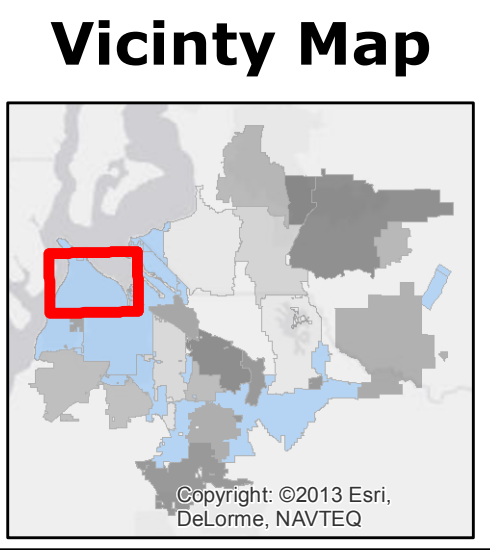


Figure 8
Flow Tests - 478 High Zone Area - North
Tacoma Water
Hydraulic Model Update and Calibration

Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet
 By: rwithers



1 inch = 1,200 feet
 0 600 1,200 2,400 Feet
 Plot Date: 12/14/2017



Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Swisstopo, Mapbox, TomTom, 2012

Legend

- Reservoir
- Pump
- Source
- PRV
- Hydrant

Transducer

- Transducers
- Static Hydrant
- Flowing Hydrant

Water Main (Pressure Zone)

- 251
- 346
- 370
- 411
- 446
- 478
- 538
- 549
- Trans

Pressure Zones

- 251 - Low
- 346 - Old Town
- 346 - Portland Ave
- 370 - Overlook
- 411 - Fife Heights Low
- 446 - Middle
- 478 - High
- 486 - Beverly Heights
- 538 - Fletcher
- 549 - NE Tacoma

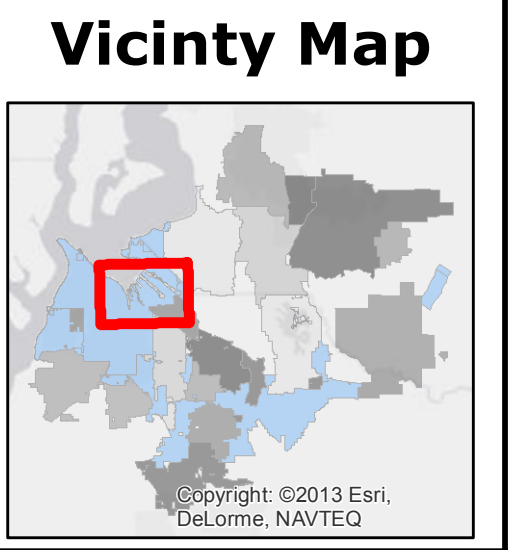
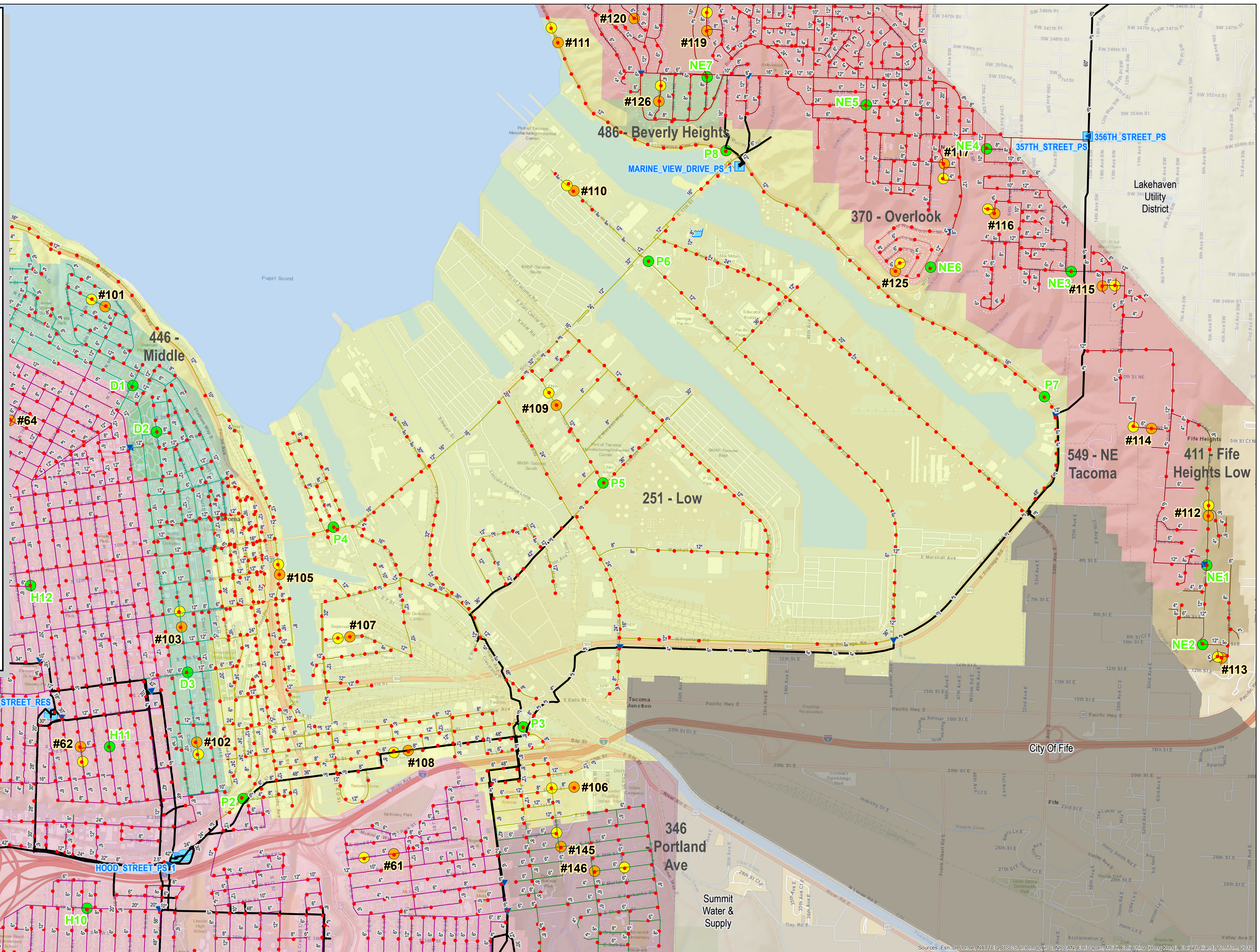


Figure 9
Flow Tests - Port of Tacoma Area
Tacoma Water
Hydraulic Model Update and Calibration

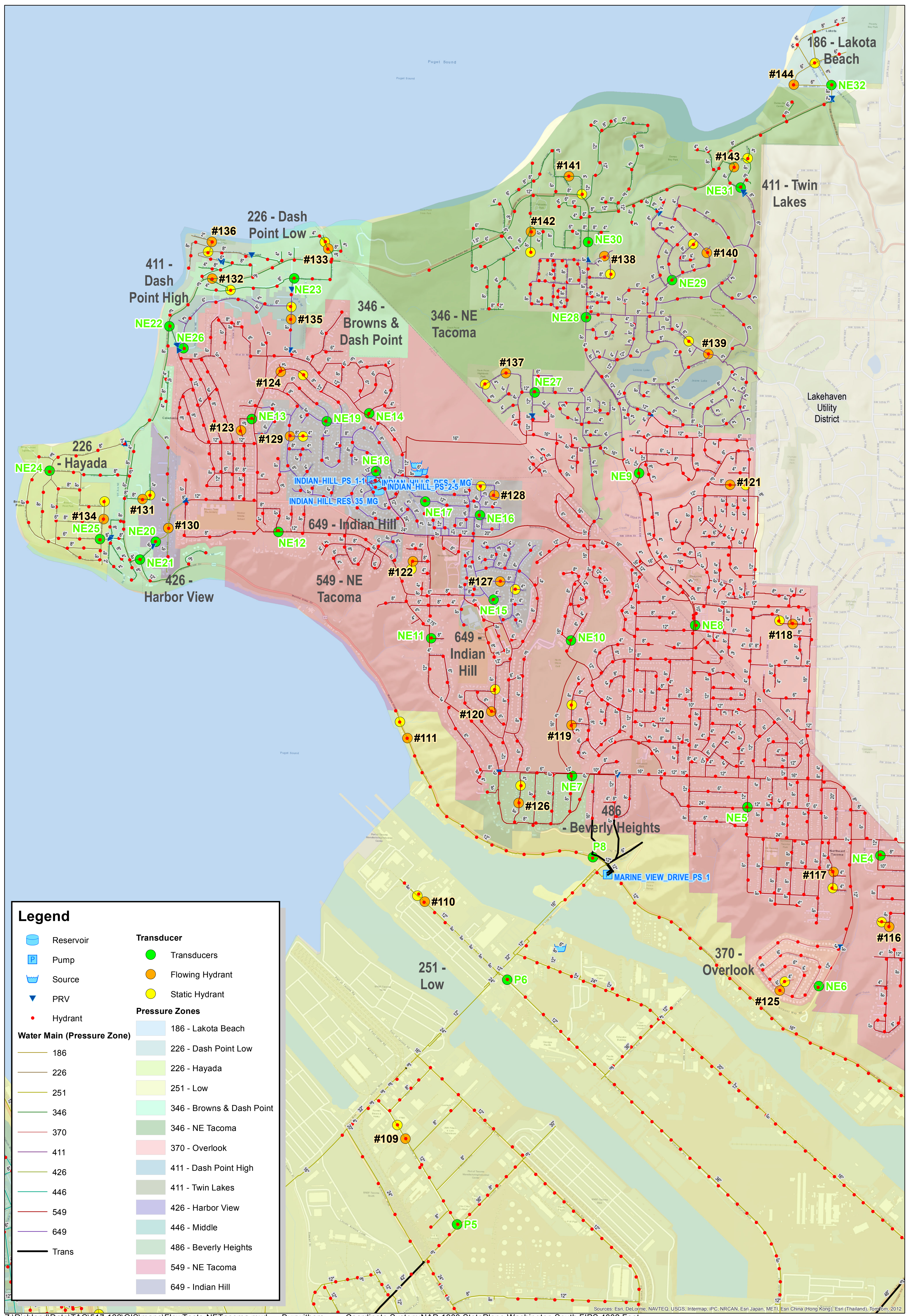
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1 inch = 1,200 feet
 0 600 1,200 2,400 Feet
 Plot Date: 12/14/2017



Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2012



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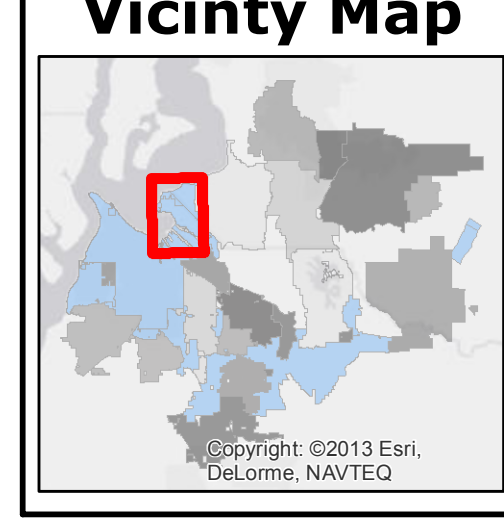


Figure 10 Flow Tests - NE Tacoma Area

Tacoma Water Hydraulic Model Update and Calibration

1 inch = 1,000 feet

0 500 1,000 2,000 Feet

Plot Date: 12/14/2017

Legend

- Reservoir
- Pump
- Source
- PRV
- Hydrant

Transducer

- Transducers
- Flowing Hydrant
- Static Hydrant
- Static Hydrant - Transducer Only

Water Main (Pressure Zone)

- 251
- 346
- 446
- 478
- 581
- Trans

Pressure Zones

- 251 - Low
- 346 - Portland Ave
- 446 - Middle
- 478 - High
- 581 - Fletcher Heights
- 581 - SE Tacoma

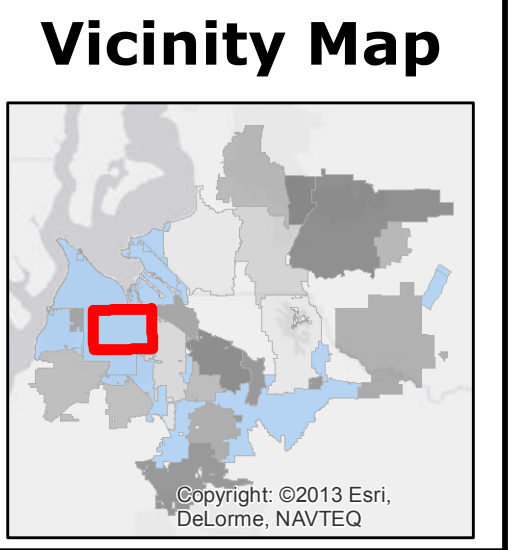
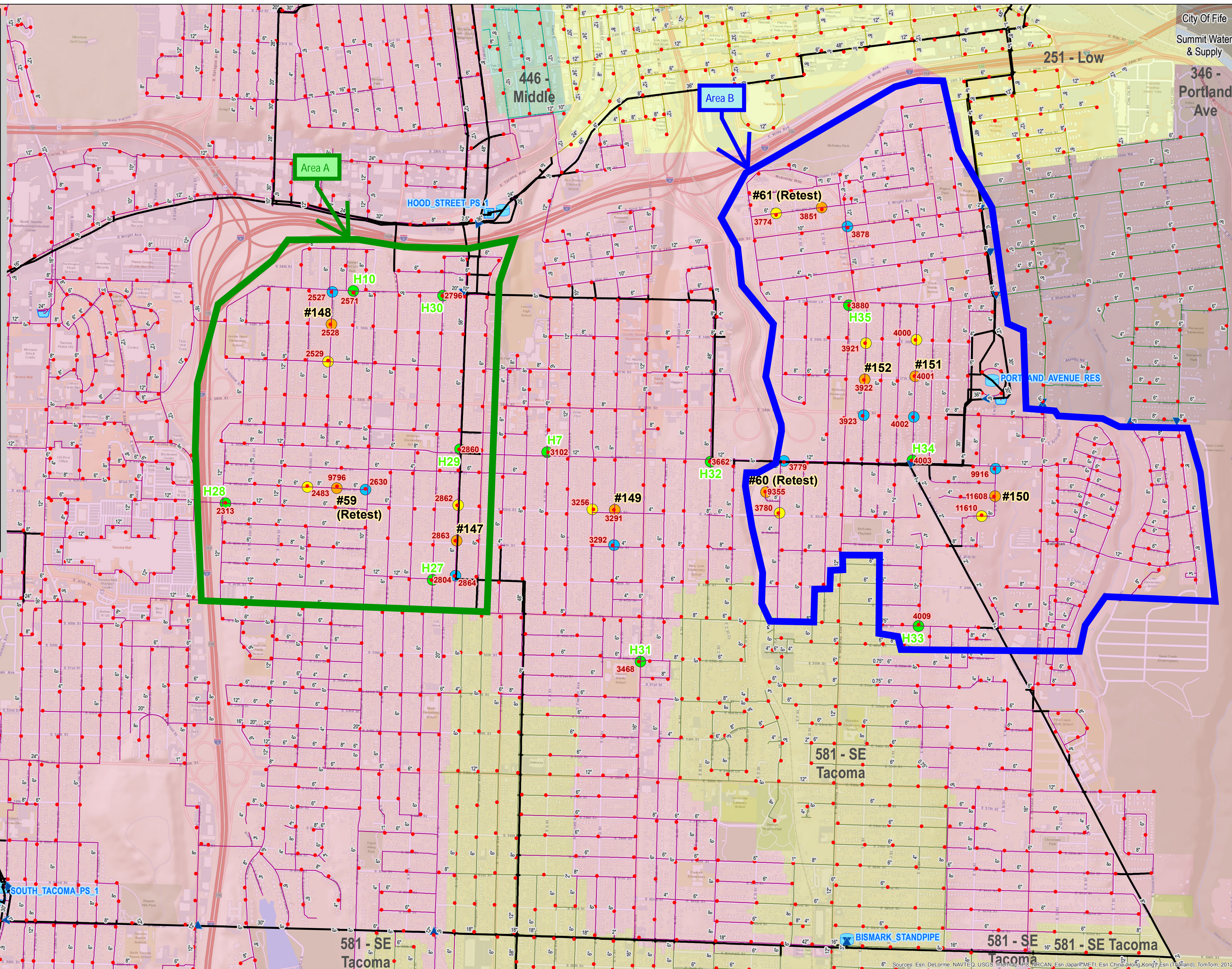


Figure 11
Flow Tests - 478 High Zone Sensitivity
Tacoma Water
Hydraulic Model Update and Calibration

Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet
 By: rwithers



1 inch = 800 feet
 0 400 800 1,600 Feet

Plot Date: 1/24/2018



Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, Inc., Swire, NRCAN, Esri Japan, METI, Esri China, Hong Kong, Esri (Taiwan), TomTom, 2012

DATA TABLES

**Tacoma Water
Hydraulic Model Calibration Data
Bonney Lake Operating Area**

Test No.	HGL (feet)	Pressure Zone Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested				Hydrant for Pressure Measurements						Model Results			Field Diff Pressure		Model Diff Pressure		Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hyd) (psi)	Static P Diff (Static Hyd) (psi)
							Field Measurements				Field Measurements						F1 Static Pressure (psi)	R1 Static Pressure (psi)	R1 Residual Pressure (psi)	F1	F1						
							Location	F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	Location	R1 Model Node No.	Hydrant No.	R1 Static Pressure (psi)	R1 Residual Pressure (psi)	F1 Static Pressure (psi)	R1 Static Pressure (psi)	R1 Residual Pressure (psi)	(psi)	(psi)						
1	810	Prairie Ridge	1	10/2/2017	1:55 PM	1	92nd Street at intersection with 227th Avenue (Catch Basin)	J47468	9520	939	93	[West of Flow Hydrant] 92nd Street at intersection with 226th Avenue	J47484	9522	99	88	92.2	97.4	83.7	11.0	13.7	2.7	0.0	0.8	1.6		
	1:57 PM				3	1,504				65					66.1	34.0			31.3			-2.7					
2	810	Prairie Ridge	1	10/2/2017	2:27 PM	2	218th Avenue at intersection with 113th Street (Catch Basin)	J49604	7536	791	60	[East of Flow Hydrant] Approx. 21816 113th Street	J92676	7537	60	57	59.8	58.9	57.1	3.0	1.8	-1.2	-1.0	0.2	1.1		
	2:29 PM				3	1,369				55					54.7	5.0			4.2			-0.8					
3	810	Prairie Ridge	1	10/3/2017	9:18 AM	1	204th Avenue Ct at intersection with 125th Street Ct (Catch Basin)	J50272	7474	809	66	[East of Flow Hydrant] 125th Street Ct cul-de-sac	J100742	7476	63	60	66.9	63.3	61.4	3.0	1.9	-1.1	-0.9	-0.8	-0.3		
	9:19 AM				2	1,489				57					58.0	6.0			5.3			-0.7					
4	810	Prairie Ridge	1	10/3/2017	10:38 AM	1	217th Avenue Ct at intersection with 121st Street Ct (Catch Basin)	J49344	6936	843	73	[West of Flow Hydrant] 121st Street Ct (Mid-block)	J49276	6935	74	67	74.2	73.3	67.0	7.0	6.3	-0.7	1.1	-1.2	0.7		
	10:39 AM				2	1,451				62					58.3	12.0			15.0			3.0					
5	1010	Bonney Lake	1	10/2/2017	10:27 AM	2	Intersection of Overlook Drive and 140th Street (Catch Basin)	J111950	12327	413	62	[North of Flow Hydrant] Intersection of Overlook Drive and Parkview Drive	J111994	12324	61	55	60.8	61.7	59.4	6.0	2.3	-3.7	-1.3	1.2	-0.7		
	10:30 AM				3	962				52					51.6	9.0			10.1			1.1					
6	950	Bonney Lake	1	10/2/2017	10:59 AM	2	Intersection of 193rd Avenue and 143rd Street (Catch Basin)	J90324	11707	1,012	99	[Southwest of Flow Hydrant] Intersection of 143rd Street and Knoll Park Drive	J47812	11708	98	91	101.3	98.1	92.0	7.0	6.1	-0.9	-0.7	-2.3	-0.1		
	11:03 AM				4	1,736				85					85.6	13.0			12.5			-0.5					
7	860	Bonney Lake	1	10/2/2017	11:29 AM	2	Intersection of Village Court and 193rd Avenue (Catch Basin)	J48166	11715	754	63	[Southeast of Flow Hydrant] 193rd Avenue cul-de-sac	J48206	11716	63	56	63.5	60.5	53.6	6.5	6.9	0.4	0.8	-0.5	2.0		
	11:31 AM				3	1,141				45					41.9	17.5			18.7			1.2					
8	705	Fennel Creek	1	10/2/2017	12:15 PM	1	Approx. 12110 181st Avenue (Catch Basin)	J51408	9967	843	84	[Northwest of Flow Hydrant] 181st Avenue at intersection with 121st Street	J51410	9968	80	60	84.4	81.2	--	20.0	---	---	2.1	-0.4	-1.2		
	12:17 PM				2	1,736				68					67.1	12.0			14.1							2.1	

**Tacoma Water
Hydraulic Model Calibration Data
McMillin Operating Area**

Test No.	HGL (feet)	Pressure Zone Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested				Hydrant for Pressure Measurements					Model Results			Field Diff Pressure (psi)	Model Diff Pressure (psi)	Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hyd) (psi)	Static P Diff (Static Hyd) (psi)	
							Field Measurements				Field Measurements					Model Results									
							Location	F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	Location	R1 Model Node No.	Hydrant No.	R1 Static Pressure (psi)	R1 Residual Pressure (psi)	F1 Static Pressure (psi)	R1 Static Pressure (psi)							R1 Residual Pressure (psi)
9	316	High Cedars	2	10/5/2017	10:22 AM	1	Intersection of 141st Avenue and 140th Street (Catch Basin)	J84952	8620	893	81	[West of Flow Hydrant] Intersection of 140th Street and 139th Avenue	J84922	8633	78	67	81.6	79.7	67.0	11.0	12.7	1.7	0.8	-0.6	-1.7
	10:23 AM				1	1,404					58				59.8	20.0			19.9						
10	316	High Cedars	2	10/5/2017	9:32 AM	1	148th Street just east of intersection with 148th Avenue Court (Catch Basin)	J90226	7134	843	79	[East of Flow Hydrant] Intersection of 148th Street and 151st Avenue	J47906	7132	84	75	78.8	80.0	67.4	9.0	12.7	3.7	0.4	0.2	4.0
	9:33 AM				2	1,391					53				51.8	31.0			28.2						
11	706	McMillin	2	10/4/2017	1:35 PM	1	181st Street at intersection with 120th Avenue (Catch Basin)	J52640	9456	939	88	[West of Flow Hydrant] Intersection of 181st Street and 118th Avenue Court	J52600	9455	90	87	87.5	88.8	86.6	2.5	2.3	-0.3	0.6	0.5	0.7
	1:37 PM				2	1,801					84				81.9	5.5			6.9						
12	706	McMillin	2	SKIPPED			168th Street Court at intersection with 128th Avenue (Catch Basin)	J53388	7653			[East of Flow Hydrant] Approx. 12900 168th Street Court	J53402	7654											
	706																								
13	706	McMillin	2	10/4/2017	2:51 PM	1	Intersection of 136th Avenue Court and 158th Street Court (Catch Basin)	J90840	7865	754	57	[West of Flow Hydrant] Mid-block on 158th Street Court, towards cul-de-sac	J54526	7866	51	49	55.8	51.8	49.2	2.5	2.7	0.2	-0.3	1.2	-0.8
	706																								
14	706	McMillin	2	SKIPPED			On 122nd Avenue at intersection with 133rd Street (Catch Basin)	J93066	8299			[West of Flow Hydrant] Mid-block on 133rd Street, towards cul-de-sac	J57244	8300											
	706																								
15	706	McMillin	2	10/4/2017	10:05 AM	2	At intersection of 124th Street Court and 118th Avenue Court (Catch Basin)	J58376	5389	843	73	[South of Flow Hydrant] On 125th Street Court, just east of 118th Avenue Court	J58370	5390	69	66	71.9	70.3	63.8	3.0	6.4	3.4	0.1	1.1	-1.3
	706																								
16	706	McMillin	2	10/4/2017	11:35 AM	2	Approx. 12360 Tatoosh Road- In front of Stratton Park (Catch Basin)	J58128	5478	893	78	[Northeast of Flow Hydrant] 132nd Avenue, just south of intersection with Tatoosh Road	J102522	5477	71	56	77.0	70.1	58.5	14.7	11.6	-3.2	-0.2	1.1	0.9
	706																								
17	706	McMillin	2	10/4/2017	9:28 AM	2	Intersection of Shawnee Road and 111th Street Court (Catch Basin)	J107294	11818	969	84	[West of Flow Hydrant] Mid-block on 111th Street Court, towards cul-de-sac	J107254	11820	83	79	82.5	81.7	73.4	4.0	8.2	4.2	0.5	1.5	1.3
	706																								
18	519	Sunrise Terrace	2	10/3/2017	1:59 PM	1	120th Street at intersection with 137th Avenue Court (Catch Basin)	J108562	5526	600	59	[East of Flow Hydrant] 120th Street at intersection with 138th Avenue	J108604	12303	83	65	56.5	82.7	66.5	18.0	16.3	-1.7	-1.7	2.6	0.3
	519																								
19	621	Highland	2	10/3/2017	1:14 PM	2	Intersection of 120th Street and 119th Avenue (Catch Basin)	J103202	11729	773	72	[West of Flow Hydrant] ~300 feet west of flow hydrant on 120th Street at end of sidewalk	J58616	5393	61	47	70.4	62.2	49.6	14.0	12.6	-1.4	-1.4	1.6	-1.2
	621																								
20	621	Highland	2	10/3/2017	12:38 PM	2	Near intersection of 111th Avenue Court and 130th Street Court (Catch Basin)	J57054	7640	754	61	[West of Flow Hydrant] Near intersection of 130th Street Court and 110th Avenue Court	J57060	7639	59	48	60.9	58.8	45.9	11.0	12.9	1.9	1.9	0.1	0.2
	621																								

**Tacoma Water
Hydraulic Model Calibration Data
South Hill Operating Area**

Test No.	Pressure Zone HGL (feet) Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested				Hydrant for Pressure Measurements						Model Results			Field Diff Pressure F1 (psi)	Model Diff Pressure F1 (psi)	Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hyd) (psi)	Static P Diff (Static Hyd) (psi)	
						Field Measurements				Field Measurements						F1 Static Pressure (psi)	R1 Static Pressure (psi)	R1 Residual Pressure (psi)							
						Location	F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	Location	R1 Model Node No.	Hydrant No.	R1 Static Pressure (psi)	R1 Residual Pressure (psi)	F1 Static Pressure (psi)	R1 Static Pressure (psi)	R1 Residual Pressure (psi)							
21	581SH	South Hill	3	10/5/2017	1:41 PM	1	On private road south/southwest of intersection of 123rd Street Court and 107th Avenue Court (Field/vacant lots)	J58682	5356	716	48	[North/northwest of Flow Hydrant] Intersection of 123rd Street Court and 106th Avenue Court	J58744	5352	40	39	47.2	41.9	40.1	1.0	1.8	0.8	1.4	0.8	-1.9
	1:42 PM				1	1,118				38					37.9	2.0			4.0		2.0				
22	581SH	South Hill	3	11/1/2017	11:15 AM	1	Approx. 12600 106th Avenue Court on east side of road (Catch Basin)	J104190	5353	631	50	[Northeast of Flow Hydrant] Intersection of 125th Street and 107th Avenue Court	J58786	5357	49	48	49.9	48.3	46.9	1.0	1.4	0.4	0.1	0.1	0.7
	11:17 AM				2	1,117				45					44.4	4.0			3.9		-0.1				
23	581SH	South Hill	3	11/1/2017	11:36 AM	1	Intersection of 99th Avenue and 129th Street Court (Catch Basin)	J56524	5306	809	58	[East of Flow Hydrant] Mid-block on 129th Street Court, towards cul-de-sac	J56504	5307	60	58	57.1	57.8	55.4	2.0	2.4	0.4	0.1	0.9	2.2
	11:38 AM				2	1,449				53					50.9	7.0			6.8		-0.2				
24	581SH	South Hill	3	10/5/2017	2:59 PM	1	Intersection of 133rd Street and 81st Avenue (Catch Basin)	J99376	9747	640	50	[North of Flow Hydrant] Just north of intersection of 132nd Street Court 80th Avenue	J56370	6418	46	45	48.9	47.4	46.0	1.0	1.4	0.4	0.6	1.1	-1.4
	3:00 PM				2	1,159				43					43.6	3.0			3.9		0.9				
25	581SH	South Hill	3	10/5/2017	12:43 PM	1	Intersection of 137th Street Ct and 69th Ave Ct	J88254	6881	653	43	69th Avenue Ct Dead end	J55550	6882	47	44	43.1	46.4	42.9	3.0	3.6	0.6	1.3	-0.1	0.6
	12:43 PM				1	1,092				40					37.5	7.0			9.0		2.0				
26	626	80th Avenue E	3	10/9/2017	11:43 AM	1	Intersection of 80th Avenue and 134th Street Court (Catch Basin)	J99384	9855	631	60	[Southwest of Flow Hydrant] Intersection of 80th Avenue and 135th Street Court	J56352	9856	60	39	58.9	59.0	36.5	21.0	22.5	1.5	1.9	1.1	1.1
	11:44 AM				2	1,118				36					32.6	24.0			26.3		2.3				
27	626	Alder Lane	3	10/9/2017	10:57 AM	1	Approx. 13300 72nd Avenue (Grass Ditch)	J56130	5240	608	70	[North of Flow Hydrant] Approx. 13120 72nd Avenue	J56110	5269	72	41	69.7	71.0	35.9	31.0	35.1	4.1	2.7	0.3	1.0
	10:57 AM				1	846				33					30.8	39.0			40.2		1.2				
28	581W	Woodland	3	10/6/2017	10:53 AM	1	Intersection of Woodland Avenue and 97th Street Court (Grass Ditch and Catch Basin to east)	J59500	7923	893	69	[East of Flow Hydrant] On 97th Street Court towards dead end	J59502	7924	77	73	68.6	76.2	71.8	4.0	4.4	0.4	0.8	0.4	0.8
	10:54 AM				1	1,432				68					66.1	9.0			10.1		1.1				
29	581W	Woodland	3	10/6/2017	11:39 AM	1	Approx. 8921 72nd Avenue (Grass Ditch/Field)	J96378	7208	1,040	115	[North of Flow Hydrant] Approx. 600 feet north of flow hydrant on 72nd Avenue	J51950	7207	122	106	115.6	119.7	102.2	15.5	17.5	2.0	0.2	-0.6	1.8
	11:41 AM				2	1,812				73					72.8	48.5			46.9		-1.6				
30	581W	Woodland	3	10/6/2017	9:48 AM	1	On 66th Avenue between 102nd Street and 103rd Street (Grass field across street, and catch basin to north)	J59412	5216	695	71	[North of Flow Hydrant] Intersection of 66th Avenue and 101st Street	J59448	7202	71	43	70.6	71.5	42.0	28.0	29.4	1.4	1.4	0.4	-0.5
	9:49 AM				1	923				23					22.0	48.0			49.5		1.5				
31	426	Woodland	3	10/6/2017	1:18 PM	1	77th Street Court cul-de-sac (Catch Basin to east)	J52246	7562	608	72	[North of Flow Hydrant] 5th Avenue Court cul-de-sac	J52260	9392	84	50	72.7	83.3	48.1	34.0	35.2	1.2	1.2	-0.7	0.7
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**Tacoma Water
Hydraulic Model Calibration Data
Canyon Operating Area**

Test No.	HGL (feet)	Pressure Zone Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested					Hydrant for Pressure Measurements					Model Results			Field Diff Pressure F1 (psi)	Model Diff Pressure F1 (psi)	Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hyd) (psi)	Static P Diff (Static Hyd) (psi)	
							Field Measurements					Field Measurements					F1 Static Pressure (psi)	R1 Residual Pressure (psi)	F1 Static Pressure (psi)							R1 Residual Pressure (psi)
							F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	Location	R1 Model Node No.	Hydrant No.	R1 Static Pressure (psi)	R1 Residual Pressure (psi)	F1 Static Pressure (psi)										
32	669	S Summit High	4	10/9/2017	10:25 AM	1	136th Avenue between 57th Avenue and 58th Avenue (Catch Basin/Ditch)	J55654	5181	773	89	[East of Flow Hydrant] Approx. 6000 136th Street (700 feet east of flow hydrant)	J55656	5194	87	54	88.3	85.7	54.4	33.0	31.3	-1.7	-1.7	0.8	1.3	
	10:27 AM				2	1,186				43					43.4	44.0			42.3							
33	669	S Summit High	4	10/9/2017	1:25 PM	1	58th Avenue just north of intersection with 148th Street Court (Grass Ditch)	J88120	6327	809	95	[South of Flow Hydrant] On 58th Avenue approximately 400 feet south of flow hydrant	J88118	6326	92	72	93.3	93.3	77.7	19.8	15.6	-4.2	-1.6	1.7	-1.3	
	1:25 PM				1	1,283				47					47.4	45.0			45.9	0.9						
34	669	S Summit High	4	10/9/2017	1:50 PM	1	Intersection of 68th Avenue Court and 153rd Street Court (Catch Basin)	J55156	9359	653	88	[West of Flow Hydrant] 153rd Street Court cul-de-sac	J87984	9360	93	46	89.3	91.9	43.0	47.0	48.9	1.9	2.2	-1.3	1.1	
	1:51 PM				2	1,039				35					31.3	58.0			60.6	2.6						
35	581C	Canyon	4	10/11/2017	1:00 PM	1	161st Street Ct and 70th Ave E	J53318	7987	640	75	[East of Flow Hydrant] 161st Street Ct cul-de-sac	J53308	7988	77	60	73.6	77.1	61.6	17.0	15.5	-1.5	0.4	1.4	0.0	
	1:01 PM				1	1,181				48					45.6	29.0			31.4	2.4						
36	581C	Canyon	4	10/11/2017	11:19 AM	1	170th Street, mid-block west of intersection with Canyon Road (Catch Basin)	J89042	7952	954	98	[West of Flow Hydrant] 170th Street cul-de-sac	J61140	7953	99	91	97.7	97.8	93.3	8.0	4.5	-3.5	-1.0	0.3	1.2	
	11:19 AM				1	1,801				87					84.4	12.0			13.4	1.4						
37	581C	Canyon	4	10/11/2017	10:47 AM	1	Intersection of 185th Street Courth and 36th Avenue (Catch Basin)	J60942	9567	939	81	[West of Flow Hydrant] 185th Street Court cul-de-sac	J60936	9568	82	76	80.6	81.4	74.7	6.0	6.8	0.8	0.5	0.4	0.6	
	10:48 AM				1	1,542				66					65.3	16.0			16.2	0.1						
38	581C	Canyon	4	10/11/2017	9:57 AM	1	189th Street, east of intersection with Canyon Road and in front of Hall Forest Products (Catch Basin)	J52778	7493	954	81	[West of Flow Hydrant] In parking lot west of flow hydrant (In Rainier View Water Co. and Richardson Well Drilling parking lot)	J95884	11619	80	81	79.7	78.6	77.0	-1.0	1.6	2.6	3.0	1.3	1.4	
	9:59 AM				3	1,703				80					75.2	0.0			3.4	3.4						
39	588	Frederickson	4	10/26/2017	9:13 AM	1	Intersection of 69th Avenue and 177th Street Court (Catch Basin)	J52926	8525	716	60	[East of Flow Hydrant] Intersection of 177th Street Court and 69th Avenue Court	J52984	8524	59	47	60.9	60.2	44.4	12.0	15.8	3.8	0.7	-0.9	-1.2	
	9:15 AM				2	1,117				39					42.5	20.0			17.7	-2.3						

**Tacoma Water
Hydraulic Model Calibration Data
SE Tacoma Operating Area**

Test No.	Pressure Zone HGL (feet) Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested					Hydrant for Pressure Measurements					Model Results			Field Diff Pressure F1 (psi)	Model Diff Pressure F1 (psi)	Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hydr) (psi)	Static P Diff (Static Hydr) (psi)			
						Field Measurements		Field Measurements			Field Measurements		Field Measurements			F1 Static Pressure (psi)	R1 Static Pressure (psi)	R1 Residual Pressure (psi)							F1 Static Pressure (psi)	R1 Static Pressure (psi)	R1 Residual Pressure (psi)
						F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	Location	F1 Model Node No.	Hydrant No.	R1 Static Pressure (psi)	R1 Residual Pressure (psi)	Location												
40	581SE	SE Tacoma	5	10/10/2017	9:48 AM	1	Intersection of 145th Street and 20th Avenue Court (Catch Basin)	J114906	11020	1,067	102	[South of Flow Hydrant] Intersection of 20th Avenue Court and 146th Street Court	J114932	6582	105	100	103.0	103.4	98.1	5.0	5.3	0.3	-0.6	-1.0	1.6		
	581SE				9:50 AM	1				1,832					90	89.9			15.0	13.6	-1.4						
41	581SE	SE Tacoma	5	10/10/2017	10:25 AM	1	Approx. 14300 42nd Avenue (Ditch)	J115190	5157	716	66	[North of Flow Hydrant] Approx. 14100 42nd Avenue	J115194	5156	65	47	67.0	65.2	48.0	18.0	17.3	-0.7	0.5	-1.0	-0.2		
	581SE				10:26 AM	1				1,030					33	31.5			32.0	33.7	1.7						
42	581SE	SE Tacoma	5	10/12/2017	9:37 AM	1	Intersection of 34th Avenue and 116th Street Court (Catch Basin)	J104600	5126	716	61	[East of Flow Hydrant] 116th Street Court Dead End	J104596	7392	58	45	59.8	57.1	41.4	13.0	15.6	2.6	2.1	1.2	0.9		
	581SE				9:38 AM	1				1,039					29	26.6			29.0	30.5	1.5						
43	581SE	SE Tacoma	5	10/13/2017	1:47 PM	1	Just west of intersection of Golden Given Road E and 109th Street Ct (southern entrance to townhome development)	J105388	9904	640	83	[Southwest of Flow Hydrant] Within townhome development in southwest portion of development	J105392	9903	80	75	84.4	81.1	79.3	5.0	1.7	-3.3	-3.7	-1.4	-1.1		
	581SE				1:47 PM	1				1,617					68	73.2			12.0	7.9	-4.1						
44	581SE	SE Tacoma	5	10/12/2017	10:06 AM	1	Intersection of 106th Street and 26th Avenue (Ditch/Catch Basin)	J113994	8941	826	68	[West of Flow Hydrant] Intersection of 106th Street and 25th Avenue	J113976	8940	63	60	65.4	61.1	58.0	3.0	3.1	0.1	-0.7	2.6	1.4		
	581SE				10:07 AM	1				1,350					55	54.6			8.0	6.5	-1.5						
45	581SE	SE Tacoma	5	10/12/2017	10:40 AM	1	2nd Avenue Court at entrance to cul-de-sac (south of 2nd Avenue intersection with 99th Street) (Catch Basin)	J96908	9149	876	78	[Southeast of Flow Hydrant] Approx. 10500 2nd Avenue Court, towards dead end	J96852	9150	79	70	78.7	77.1	67.5	9.0	9.6	0.6	-0.1	-0.7	1.9		
	581SE				10:40 AM	1				1,407					58	57.0			21.0	20.1	-0.9						
46	581SE	SE Tacoma	5	10/12/2017	11:21 AM	1	On 86th Street, east of intersection with 21st Avenue (Ditch)	J60390	9390	876	69	[Northwest of Flow Hydrant] Intersection of 21st Avenue and 85th Street Court	J60486	9807	70	68	68.2	67.8	63.3	1.5	4.5	3.0	2.4	0.8	1.7		
	581SE				11:22 AM	1				1,449					61	57.5			8.5	10.3	1.8						
47	581SE	SE Tacoma	5	10/13/2017	9:23 AM	1	Mid-block of Sweet Street, approximately 400 feet west of intersection of Sweet Street and Sonia Street	J20364	7158	843	76	[West of Flow Hydrant] Mid-block of Sweet Street, approximately 300 feet east of intersection of Sweet Street and	J20370	7155	69	66	74.3	69.1	66.7	3.0	2.4	-0.6	-0.3	1.7	-0.1		
	581SE				9:24 AM	2				1,432					63	63.1			6.0	6.0	0.0						
48	581SE	SE Tacoma	5	10/13/2017	10:03 AM	1	Intersection of McDaccer Avenue and North Lane (Catch Basin)	J22012	3691	908	82	[South of Flow Hydrant] On McDaccer Avenue near intersection with 54th Street/Tanglewood Ave	J22018	3692	81	75	81.4	81.9	74.0	6.0	7.9	1.9	0.3	0.6	-0.9		
	581SE				10:03 AM	1				1,410					63	65.2			18.0	16.8	-1.3						
49	581SE	SE Tacoma	5	10/13/2017	10:52 AM	1	D Street north of intersection with 77th Street (Flow into woods to west)	J19292	3749	924	79	[South of Flow Hydrant] D Street north of intersection with 78th Street	J19290	3748	76	73	79.0	74.6	73.0	3.0	1.7	-1.3	-1.5	0.0	1.4		
	581SE				10:54 AM	2				1,669					70	70.3			6.0	4.3	-1.7						
50	581SE	SE Tacoma	5	10/12/2017	1:07 PM	1	8802 E Street (E Street Dead End) (Catch Basin)	J16516	3795	893	79	[West of Flow Hydrant] Intersection of D Street and 88th Street (just east of intersection)	J16490	3752	78	74	77.2	77.2	75.0	4.0	2.2	-1.8	-1.4	1.8	0.8		
	581SE				1:08 PM	2				1,582					72	71.7			6.5	5.5	-1.0						
51	581SE	SE Tacoma	5	10/13/2017	12:08 PM	1	Intersection of D Street and S 67th Street (Catch Basin)	J77518	3306	893	81	[North of Flow Hydrant] Intersection of D Street and 65th Street (just north of intersection, on D Street)	J77478	3305	79	76	80.8	80.0	74.8	3.0	5.2	2.2	2.5	0.2	-1.0		
	581SE				12:09 PM	1				1,411					70	68.2			9.0	11.8	2.8						
52	520SE	SE Tacoma	5	10/16/2017	1:42 PM	1	Intersection of 107th Street and 9th Avenue Court (Catch Basin/Grass)	J117868	9085	843	87	[North of Flow Hydrant] Towards 9th Avenue Court Dead End	J116918	9083	80	55	86.4	78.0	51.4	24.9	26.6	1.7	2.0	0.6	1.9		
	520SE				1:44 PM	2				1,388					46	41.8			33.9	36.1	2.2						
53	520SE	SE Tacoma	5	10/16/2017	1:59 PM	1	Intersection of 104th Street and 18th Avenue (Grass/Vacant Lot)	J62610	9228	791	91	[East of Flow Hydrant] Intersection of 104th Street and Wilkeson Street (Just south of intersection on Wilkeson St)	J62416	9245	87	65	91.1	87.3	64.5	22.0	22.9	0.9	0.2	-0.1	-0.3		
	520SE				1:59 PM	2				1,261					61	61.7			26.0	25.6	-0.4						

Tacoma Water
Hydraulic Model Calibration Data
478 High Zone

Test No.	HGL (feet)	Pressure Zone Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested					Hydrant for Pressure Measurements					Model Results			Field Diff Pressure F1 (psi)	Model Diff Pressure F1 (psi)	Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hyd) (psi)	Static P Diff (Static Hyd) (psi)	
							Field Measurements			Hydrant No.		Field Measurements		Hydrant No.			R1 Residual Pressure (psi)	F1 Static Pressure (psi)	R1 Static Pressure (psi)							R1 Residual Pressure (psi)
							F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	F1 Model Node No.	D/S Hydrant No.	R1 Static Pressure (psi)	R1 Residual Pressure (psi)	F1 Static Pressure (psi)	R1 Static Pressure (psi)										
54	478	High	6	SKIPPED																						
	478																									
55	478	High	6	10/16/2017	9:47 AM	1			773	2971	773	60														
	478						9:48 AM	2			1,259				61	56	61.6	61.1	55.9	5.0	5.2	0.2	0.2	-1.6	-0.1	
56	478	High	6	10/16/2017	10:26 AM	1			939	2058	939	89														
	478						10:27 AM	1			1,563				86	81	88.2	85.5	80.1	5.0	5.4	0.4	0.3	0.8	0.5	
57	478	High	6	10/16/2017	11:06 AM	1			826	1761	826	71														
	478						11:07 AM	1			1,306				66	61	71.0	64.9	60.9	5.0	4.0	-1.0	-1.0	0.0	1.1	
58	478	High	6	10/16/2017	11:28 AM	1			716	2698	716	54														
	478						11:30 AM	2			1,039				51	47	53.3	49.8	47.5	4.0	2.3	-1.7	-1.8	0.7	1.2	
59 (Retest)	478	High	11	1/18/2018	9:28 AM	1			675	9796	675	53														
	478						9:29 AM	1			983				56	41	53.0	54.3	41.2	15.0	13.1	-1.9	-2.3	0.0	1.7	
60 (Retest)	478	High	11	1/18/2018	12:22 PM	1			631	9355	631	59														
	478						---	---			---				54	35	59.9	52.7	37.8	19.0	14.9	-4.1	-4.1	-0.9	1.3	
61 (Retest)	478	High	11	1/18/2018	11:56 AM	1			826	3851	826	82														
	478						11:57 AM	1			1,259				80	60	81.9	79.5	62.2	20.0	17.3	-2.7	0.4	0.1	0.5	
62	478	High	6	10/17/2017	10:09 AM	1			675	2565	675	48														
	478						10:10 AM	1			1,192				52	50	49.7	52.6	50.4	2.0	2.2	0.2	1.6	-1.7	-0.6	
63	478	High	8	10/17/2017	10:55 AM	1			631	1934	631	41														
	478						10:55 AM	1			919				37	34	41.4	37.4	34.2	3.0	3.2	0.2	0.3	-0.4	-0.4	
64	478	High	8	SKIPPED																						
	478																									
65	478	High	8	10/17/2017	11:19 AM	1			924	1885	924	69														
	478						11:20 AM	1			1,328				75	71	68.4	73.8	68.4	4.0	5.4	1.4	-0.5	0.6	1.2	
66	478	High	8	10/17/2017	11:48 AM	1			675	1385	675	72														
	478						11:49 AM	1			954				74	71	72.9	71.1	67.1	3.0	4.0	1.0	0.7	-0.9	2.9	
67	478	High	8	10/17/2017	1:47 PM	1			735	328	735	59														
	478						1:49 PM	2			1,328				64	60	57.6	63.1	58.9	4.0	4.2	0.2	1.6	1.4	0.9	
68	478	High	8	10/17/2017	2:06 PM	1			675	132	675	74														
	478						2:06 PM	1			1,429				65	62	72.7	65.0	62.6	3.0	2.5	-0.5	0.4	1.3	0.0	
69	478	High	8	10/18/2017	9:16 AM	1			1,067	42	1,067	115														
	478						9:18 AM	2			1,769				101	94	113.0	99.3	91.4	7.0	8.0	1.0	-0.1	2.0	1.7	
70	478	High	8	10/18/2017	9:53 AM	1			809	6759	809	69														
	478						9:54 AM	1			1,430				63	60	67.3	61.8	59.6	3.0	2.2	-0.9	0.1	1.7	1.2	
71	478	High	8	10/18/2017	10:24 AM	1			716	58	716	70														
	478						10:25 AM	1			952				72	67	69.2	72.3	68.6	5.0	3.7	-1.3	-2.6	0.8	-0.3	
72	478	High	7	10/18/2017	10:47 AM	1			984	5755	984	95														
	478						10:48 AM	1			1,634				98	95	94.4	96.0	92.4	3.0	3.7	0.7	1.3	0.6	2.0	
73	478	High	7	10/18/2017	11:21 AM	1			1,040	5782	1,040	104														
	478						11:22 AM	2			1,767				102	100	102.4	102.4	98.3	1.5	4.2	2.7	2.7	1.6	-0.9	

**Tacoma Water
Hydraulic Model Calibration Data
478 High Zone**

Test No.	HGL (feet)	Pressure Zone Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested				Hydrant for Pressure Measurements					Model Results			Field Diff Pressure F1 (psi)	Model Diff Pressure F1 (psi)	Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hydr) (psi)	Static P Diff (Static Hydr) (psi)			
							Field Measurements				Field Measurements					Model Results											
							F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	F1 Model Node No.	D/S Hydrant No.	R1 Static Pressure (psi)	R1 Residual Pressure (psi)	F1 Static Pressure (psi)	R1 Static Pressure (psi)	R1 Residual Pressure (psi)										
74	478	High	7	SKIPPED			Approx. 6501 60th Street (Catch Basin)	J68226	8158																		
75	478	High	7	10/19/2017	9:16 AM	1	Intersection of 69th Street and Proctor Street (Catch Basin)	J93950	11657	998	102	[East of Flow Hydrant] 69th Street Dead End	J93956	11658	103	93	102.0	104.0	94.8	10.0	9.2	-0.8	-1.8	0.0	-1.0		
	9:17 AM				1	1,719				76					79.8	27.0			24.2	-2.8							
76	478	High	7	10/19/2017	9:43 AM	1	Approx. 5400 54th Street (On 54th north of intersection with Cirque Drive) (Catch Basin)	J1106	9679	1,093	111	[East of Flow Hydrant] 54th Street Dead End	J1102	9680	99	94	111.1	98.2	90.0	5.0	8.2	3.2	2.6	-0.1	0.8		
	9:45 AM				1	1,848				80					77.3	19.0			20.9	1.9							
77	478	High	7	10/19/2017	10:14 AM	1	Intersection of 29th Street and Adams Street (Catch Basin to west)	J100208	1497	716	51	[West of Flow Hydrant] 3852 29th Street (Entrance to Sunrise Ridge Apartments)	J43384	7306	53	53	51.6	52.5	51.3	0.0	1.2	1.2	0.8	-0.6	0.5		
	10:15 AM				1	1,306				50					49.2	3.0			3.3	0.3							
147	478	High	11	1/18/2018	8:54 AM	1	Intersection of S. 45th Street and S. J Street (Catch Basin)	J25144	2863	653	40	[North of Flow Hydrant] Intersection of S. 43rd Street and S. J Street	J25148	2862	44	41	40.7	44.3	40.9	3.0	3.3	0.3	0.7	-0.7	-0.3		
	8:56 AM				2	1,066				37					36.3	7.0			8.0	1.0							
148	478	High	11	1/18/2018	9:50 AM	1	Intersection of S. Ainsworth Ave and S. 36th Street (Catch Basin)	J25586	2529	695	54	[South of Flow Hydrant] Intersection of S. Ainsworth Ave and S. 37th Street	J25686	2528	55	54	54.2	53.7	53.2	1.0	0.5	-0.5	-0.3	-0.1	1.3		
	9:51 AM				1	1,092				54					52.8	1.0			0.9	-0.1							
149	478	High	11	1/18/2018	10:18 AM	1	Intersection of S. 43rd Street and S. D Street (Catch Basin)	J26408	3291	695	56	[West of Flow Hydrant] Intersection of Fawcett Ave and S. 43rd Street	J78912	3256	53	53	55.9	51.6	50.5	0.5	1.1	0.6	-0.1	0.1	1.4		
	10:19 AM				2	1,092				50					49.4	3.0			2.2	-0.8							
150	478	High	11	1/18/2018	11:27 AM	1	Intersection of E. 42nd Street E. N Street (Catch Basin)	J27312	11608	954	85	[Southwest of Flow Hydrant] Approx. 1329 E. 43rd Street.	J27300	11610	80	78	84.9	79.0	74.3	2.0	4.6	2.6	1.2	0.1	1.0		
	11:28 AM				1	1,703				68					67.3	12.0			11.7	-0.3							
151	478	High	11	1/18/2018	10:54 AM	1	Intersection of E. 37th Street and E. K Street (Catch Basin)	J27400	4001	653	79	[North of Flow Hydrant] Intersection of E. 36th Street and E. K Street	J27402	4000	77	56	78.3	76.9	59.0	21.0	17.9	-3.1	-0.7	0.7	0.1		
	10:55 AM				2	954				44					42.2	33.0			34.7	1.7							
152	478	High	11	1/18/2018	2:21 PM	1	Intersection of 37th Street and Spokane Street (Catch Basin)	J27468	3922	608	64	[North of Flow Hydrant] Intersection of E. 36th Street and Spokane Street	J27472	3921	64	46	63.6	62.1	45.8	18.0	16.3	-1.7	-0.1	0.4	1.9		
	2:22 PM				1	859				36					32.6	28.0			29.5	1.5							

Tacoma Water
Hydraulic Model Calibration Data
West and NW Tacoma Operating Area (Not Including 478 High Zone)

Test No.	HGL (feet)	Pressure Zone Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested				Hydrant for Pressure Measurements				Model Results			Field Diff Pressure F1 (psi)	Model Diff Pressure F1 (psi)	Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hyd) (psi)	Static P Diff (Static Hyd) (psi)		
							Field Measurements		Field Measurements		Field Measurements		Field Measurements		F1 Static Pressure (psi)	R1 Residual Pressure (psi)	F1 Static Pressure (psi)							R1 Residual Pressure (psi)	
							F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	F1 Model Node No.	Hydrant No.	R1 Static Pressure (psi)	R1 Residual Pressure (psi)											
78	556	Park Royal	7	10/18/2017	12:30 PM	1	Academy Terrace Drive, just north of intersection with 54th Street Ct (Catch Basin to NW, may need to use sandbags to contain flow in	J3178	5875	809	72	[South of Flow Hydrant] On Academy Terrace Drive, just south of intersection with 56th Street	J2502	5876	75	65	73.9	75.8	68.1	10.0	7.6	-2.4	0.4	-1.9	-0.8
	556				12:32 PM	2		1,369	60	57.6	15.0	18.1	3.1												
79	556	Park Royal	7	10/18/2017	1:00 PM	1	Intersection/loop of 82nd Avenue Ct and 50th Street Ct (Catch Basin - Hydrant is in driveway and obscured by	J1990	5904	843	73	[Southwest of Flow Hydrant] Intersection of 83rd Avenue and 51st Street Ct	J1764	5893	66	63	75.8	67.1	62.5	3.0	4.6	1.6	1.0	-2.8	-1.1
	556				1:01 PM	2		1,390	57	57.6	9.0	9.5	0.5												
80	531	University Place	7	10/19/2017	12:00 PM	1	Mid-block of 68th Avenue Ct, between Boulders Way and 37th Street Ct (Catch Basin)	J73778	11759	924	88	[South of Flow Hydrant] 37th Street Ct, mid-block	J73772	11758	85	76	88.5	86.6	78.9	9.0	7.7	-1.3	1.0	-0.5	-1.6
	531				12:01 PM	1		1,617	68	66.3	17.0	20.3	3.3												
81	531	University Place	7	10/19/2017	1:05 PM	1	East side of 53rd Street Ct dead end (Catch Basin)	J2308	8547	876	80	[West of Flow Hydrant] Intersection of 53rd Street and Drum Road	J2306	8546	80	69	82.7	81.9	72.5	11.0	9.4	-1.6	-1.2	-2.7	-1.9
	531				1:06 PM	1		1,470	57	59.8	23.0	22.1	-0.9												
82	531	University Place	7	10/19/2017	1:51 PM	1	4510 82nd Avenue Ct (Catch Basin)	J74538	591	809	67	[South of Flow Hydrant - accessed from Cirque Way - street doesn't connect] 82nd Avenue Ct dead end	J4984	5901	66	60	70.8	68.3	65.5	6.0	2.8	-3.2	-2.2	-3.8	-2.3
	531				1:51 PM	1		1,451	58	61.7	8.0	6.7	-1.3												
83	290	Chambers Bay	7	10/18/2017	1:33 PM	1	West side of Chambers Bay driveway, near parking lot entrance (Stormwater pond to south?)	J3346	11029	1,053	127	[East of Flow Hydrant] At driveway intersection to northeast	J72132	11027	103	84	129.9	103.5	88.8	19.0	14.8	-4.3	-0.3	-2.9	-0.5
	290				1:34 PM	1		1,847	76	72.9	27.0	30.7	3.7												
84	351	Grandview	7	10/19/2017	2:30 PM	1	4526 Grandview Drive (Catch Basin)	J4154	5741	675	50	[South of Flow Hydrant] On Grandview Drive, approx. 300 feet north of roundabout intersection	J75248	5743	50	41	47.7	48.0	42.2	9.0	5.8	-3.2	-2.2	2.3	2.0
	351				2:31 PM	1		1,143	40	39.2	10.0	8.8	-1.2												
85	202	Day Island	7	10/20/2017	9:25 AM	1	Intersection of E Day Island Blvd and 19th Street (Catch Basin - 1 PORT ONLY)	J118610	8373	695	80	[Southwest of Flow Hydrant] 1916 Day Island Blvd W	J118538	8365	73	43	78.9	69.2	37.5	30.0	31.7	1.7	1.7	1.1	3.8
	202				---	---		---	---	---	---	---	---												
86	226	Titlow	7	10/20/2017	9:47 AM	1	Intersection of 19th Street and 88th Avenue (Catch Basin)	J93582	7407	860	74	[South of Flow Hydrant] On 88th Ave, approximately 500 feet south of flowing hydrant	J44108	7408	72	62	72.6	69.5	63.0	10.0	6.4	-3.6	-2.6	1.4	2.6
	226				9:50 AM	2		1,526	55	54.1	17.0	15.3	-1.7												
87	328	Narrows	7	10/20/2017	10:20 AM	1	On 27th Street, just east of intersection with Elwood Drive in school field turn-off area (Catch Basin)	J6960	5843	773	57	[East of Flow Hydrant] Intersection of 27th Street and 86th Avenue	J44072	7628	58	54	57.3	55.2	50.0	4.0	5.3	1.3	2.0	-0.3	2.8
	328				10:22 AM	2		1,326	48	42.6	10.0	12.7	2.7												
88	328	Narrows	7	10/20/2017	11:16 AM	1	Approx. 916 Mountain View Ave (West side of street) (Catch Basin)	J45070	7744	860	80	[North of Flow Hydrant] Intersection of Mountain View Ave and 10th Street	J106536	7745	87	80	80.4	83.7	79.7	7.0	4.1	-2.9	-2.9	-0.4	3.3
	328				11:18 AM	2		1,563	74	73.5	13.0	10.2	-2.8												
89	581F	Fletcher Heights	8	10/20/2017	1:08 PM	1	On Washington Street, ~300 feet south of intersection with 19th Street on west side of road (Catch Basin)	J43952	9342	939	82	[South of Flow Hydrant] On gravel access road behind apartment/condo building	J93422	6227	87	84	85.8	87.3	84.5	3.0	2.8	-0.2	-0.2	-3.8	-0.3
	581F				1:10 PM	2		1,686	79	79.6	8.0	7.7	-0.3												
90	581F	Fletcher Heights	8	10/20/2017	1:47 PM	1	Intersection of Tyler Street and 15th Street (Catch Basin)	J46200	11802	893	76	[North of Flow Hydrant] Intersection of Tyler Street and 14th Street	J46264	1301	75	69	80.1	75.5	70.7	6.0	4.9	-1.1	0.3	-3.6	-0.5
	581F				1:49 PM	2		1,546	64	62.9	11.0	12.7	1.7												
91	538F	Fletcher	8	10/23/2017	8:59 AM	1	Intersection of 9th Street and Washington Street (Catch Basin)	J83684	9957	716	66	[East of Flow Hydrant] Intersection of 9th Street and Union Ave	J46880	1565	64	56	66.9	65.3	58.3	8.5	7.0	-1.5	-1.6	-0.9	-1.3
	538F				9:01 AM	2		1,262	47	49.5	17.5	15.8	-1.7												
92	538F	Fletcher	8	10/23/2017	9:21 AM	1	Intersection of 8th Street and Mullen Street (Catch Basin)	J83548	1101	809	71	[West of Flow Hydrant] Intersection of 8th Street and Huson Street	J46580	1028	73	64	72.9	76.0	68.2	9.0	7.8	-1.2	0.8	-1.9	-3.0
	538F				9:23 AM	2		1,306	60	60.2	13.0	15.7	2.7												
93	538W	Westgate	8	10/23/2017	9:42 AM	1	Intersection of 18th Street and Cheyenne Street (Catch Basin)	J69832	1141	826	70	[East of Flow Hydrant] Intersection of Stevens Street and 18th Street	J69808	1233	64	60	71.1	65.9	61.1	4.0	4.9	0.9	0.0	-1.1	-1.9
	538W				9:44 AM	2		1,261	55	57.8	9.0	8.2	-0.8												
94	538W	Westgate	8	10/23/2017	10:08 AM	1	On Bel Air Road, southwest of intersection with Highlands Parkway (and southwest of entrance to Westgate Green	J37006	293	773	60	[South of Flow Hydrant] On Bel Air Road, approximately 450 feet south of flowing hydrant	J68964	315	61	56	60.6	62.1	55.3	5.0	6.8	1.8	2.5	-0.6	-1.1
	538W				10:10 AM	2		1,306	50	48.1	11.0	14.1	3.1												
95	538W	Westgate	8	10/23/2017	10:52 AM	1	Intersection of Claremont Drive and Bristol Drive (Catch Basin)	J38872	443	716	55	[Southwest of Flow Hydrant] 2816 Bristol Street (south of intersection with 30th Street)	J71388	385	56	51	56.8	57.6	50.3	5.0	7.4	2.4	2.9	-1.8	-1.6
	538W				10:53 AM	2		1,216	43	41.3	13.0	16.4	3.4												
96	446	North End	8	10/24/2017	11:27 AM	1	Intersection of 36th Street and Gove Street (Catch Basin)	J39916	1173	477	41	[North of Flow Hydrant] Intersection of Gove Street and 38th Street	J40006	1174	49	44	41.7	49.2	47.0	5.0	2.2	-2.8	-3.2	-0.7	-0.2
	446				11:28 AM	2		718	41	44.8	8.0	4.4	-3.6												
97	446	North End	8	10/24/2017	11:55 AM	1	Intersection of Baltimore Street and Ruby Street (Catch Basin)	J105232	911	1,026	96	[West of Flow Hydrant] Intersection of Ruby Street and Shirley Street	J105206	856	101	95	94.1	100.6	93.5	6.0	7.2	1.2	0.0	1.9	0.4
	446				11:57 AM	2		1,618	84	84.8	17.0	15.8	-1.2												

Tacoma Water
Hydraulic Model Calibration Data
West and NW Tacoma Operating Area (Not Including 478 High Zone)

Test No.	Pressure Zone HGL (feet)	Pressure Zone Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested				Hydrant for Pressure Measurements				Model Results			Field Diff Pressure F1 (psi)	Model Diff Pressure F1 (psi)	Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hyd) (psi)	Static P Diff (Static Hyd) (psi)		
							Field Measurements				Field Measurements				F1 Static Pressure (psi)	R1 Static Pressure (psi)	R1 Residual Pressure (psi)								
							Location	F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	Location	R1 Model Node No.	Hydrant No.										R1 Static Pressure (psi)	R1 Residual Pressure (psi)
98	446	North End	8	10/24/2017	12:23 PM	1	Intersection of 50th Street and Frace Avenue (Catch Basin)	J41064	290	939	80	[North of Flow Hydrant] Intersection of 51st Street and Frace Avenue	J41056	291	96	93	80.2	95.6	91.2	3.0	4.4	1.4	0.0	-0.2	0.4
	12:25 PM				2	1,508				85					86.1	9.5			-1.5						
99	350	Salmon Beach	8	10/20/2017	12:39 PM	---	NO FLOW - RECORD PRESSURE ONLY	J41268	11613	---	---	Obtain pressure measurement on first hydrant on Salmon Beach Road (east side of road, approx. 500 feet north of 51st Street)	J41268	11613	75	---	---	74.9	---	---	---	---	---	0.1	
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100	346	Old Town	8	10/23/2017	1:16 PM	1	Intersection of Alder Street and 32nd Street (Catch Basin - 1 PORT ONLY)	J10666	7430	695	64	[East of Flow Hydrant] Intersection of Cedar Street and 32nd Street	J10698	1889	67	49	63.7	66.8	52.0	18.0	14.8	-3.2	-3.2	0.3	0.2
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101	446	Middle	8	10/24/2017	10:05 AM	1	Intersection of 6th Street and C Street (Catch Basin - Use sandbags to contain water in catch basin)	J79426	3421	969	103	[West of Flow Hydrant] Intersection of 7th Street and C Street	J79422	3422	112	100	101.3	112.1	99.1	12.0	13.0	1.0	2.5	1.7	-0.1
	10:06 AM				2	1,635				83					79.4	4.1									
102	446	Middle	6	10/24/2017	8:59 AM	1	Approx. 2335 South G Street (west side of street)	J67310	3093	843	80	[South of Flow Hydrant] Intersection of South G Street and Court G	J67306	11815	81	75	78.5	80.4	75.6	6.0	4.9	-1.1	-1.3	1.5	0.6
	9:01 AM				2	1,507				67					67.9	-1.4									
103	446	Middle	8	10/24/2017	9:29 AM	1	Intersection of 16th Street and South G Street (Catch Basin)	J33004	3087	843	70	[North of Flow Hydrant] Intersection of 15th Street and South G Street	J33104	3086	71	66	70.1	70.6	67.8	5.0	2.8	-2.2	-1.8	-0.1	0.4
	9:31 AM				2	1,369				64					64.9	-1.4									
145	346	Portland Ave.	6	11/1/2017	9:18 AM	1	Intersection of E 34th Street and E. R Street (Catch Basin)	J28120	4197	969	120	[North of Flow Hydrant] Intersection of E. R Street and E. Wright Street	J28062	11606	122	90	120.0	121.7	86.3	32.0	35.4	3.4	3.4	0.0	0.3
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146	346	Portland Ave.	6	11/1/2017	9:55 AM	1	Intersection of Harrison Street and E. T Street	J28104	4220	893	110	[East of Flow Hydrant] Intersection of E. Roosevelt Ave and E Harrison Street	J27934	4265	73	46	110.5	73.0	43.2	27.0	29.9	2.9	-0.3	-0.5	0.0
	9:57 AM				2	1,216				24					27.5	-3.4									

Tacoma Water
Hydraulic Model Calibration Data
Port of Tacoma and Fife Heights Operating Area

Test No.	Pressure Zone HGL (feet)	Pressure Zone Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested				Hydrant for Pressure Measurements					Model Results			Field Diff Pressure F1 (psi)	Model Diff Pressure F1 (psi)	Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hyd) (psi)	Static P Diff (Static Hyd) (psi)	
							Field Measurements				Field Measurements					F1 Static Pressure (psi)	R1 Static Pressure (psi)	R1 Residual Pressure (psi)							
							Location	F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	Location	R1 Model Node No.	Hydrant No.	R1 Static Pressure (psi)										R1 Residual Pressure (psi)
104	251	Low	8	10/25/2017	8:45 AM	1	Intersection of 29th Street and Carr Street (Catch Basin)	J72200	6640	826	81	[East of Flow Hydrant] Intersection of 29th Street and McCarver Street	J72204	3210	79	74	79.6	77.3	71.7	5.0	5.6	0.6	-0.6	1.4	1.7
	8:47 AM				2	1,542				71						71.1			8.0	6.2	-1.8				
105	251	Low	9	10/25/2017	9:54 AM	1	Approx. 1160 Dock Street (2nd hydrant north on Dock Street from intersection with E 15th Street - Catch Basin)	J34926	3560	1,053	100	[North of Flow Hydrant] Approx. 1140 Dock Street	J34934	9850	102	100	100.4	100.2	99.0	2.0	1.2	-0.8	-0.3	-0.4	1.8
	9:56 AM				2	1,952				99						97.1			3.0	3.1	0.1				
106	251	Low	9	10/25/2017	11:40 AM	1	East side of 30th Street dead end, east of intersection with R Street (Grass/vacant lot)	J28804	6228	1,012	94	[West of Flow Hydrant] Intersection of 30th Street and R Street	J28806	4187	91	89	94.3	89.3	87.8	2.0	1.6	-0.4	-0.5	-0.3	1.7
	11:41 AM				2	1,753				86						85.0			5.0	4.3	-0.7				
107	251	Low	9	10/25/2017	10:22 AM	1	Approx. 750 feet east of intersection of E, D Street and E. 18th Street. (Next to Supervalu warehouse)	J34466	5554	1,053	101	[West of Flow Hydrant] Approx. 350 feet east of intersection of E, D Street and E. 18th Street.	J86928	3768	101	99	100.0	99.8	96.9	2.0	2.9	0.9	1.2	1.0	1.2
	10:24 AM				2	1,778				95						92.4			6.0	7.5	1.5				
108	251	Low	9	10/25/2017	11:07 AM	1	On 26th Street approx. 400 feet west of intersection with J Street	J101884	3927	1,012	103	[West of Flow Hydrant] On 26th Street approx. 400 feet east of intersection with G Street	J101850	3872	102	96	101.9	101.8	94.2	6.0	7.6	1.6	2.4	1.1	0.2
	11:09 AM				2	1,703				85						81.6			17.0	20.2	3.2				
109	251	Low	9	10/25/2017	12:49 PM	1	Approx. 1380 Thorne Road (Catch Basin)	J79438	4387	1,053	99	[Northwest of Flow Hydrant] Approx. 375 feet northwest of flow hydrant on Thorne Road	J7602	4386	99	98	98.3	98.1	96.6	1.0	1.5	0.5	0.5	0.7	0.9
	12:51 PM				3	1,862				96						94.7			3.0	3.4	0.4				
110	251	Low	9	10/25/2017	1:30 PM	1	Approx. 120 Alexander Ave (On west side of road, next to catch basin)	J11020	4434	1,040	100	[Northwest of Flow Hydrant] On Alexander Ave, across from TOTE driveway entrance (on east side of road)	J74220	4433	99	94	98.4	98.0	89.8	5.0	8.2	3.2	1.4	1.6	1.0
	1:32 PM				2	1,768				78						77.3			21.0	20.7	-0.3				
111	251	Low	9	10/25/2017	1:56 PM	1	On Marine View Drive, just south of home with address 4532 Marine View Drive (Flow to west in grass towards)	J70872	4556	1,026	95	[North of Flow Hydrant] On Marine View Drive, just north of home with address 4532 Marine View Drive	J70874	4557	97	91	95.7	95.2	85.1	6.0	10.1	4.1	3.3	-0.7	1.8
	1:58 PM				2	1,720				74						69.7			23.0	25.5	2.5				
112	411	Fife Heights	9	10/24/2017	1:45 PM	1	Approx. 10 66th Avenue (Just south of intersection with 1st Street) (Ditch - 1 PORT ONLY)	J52378	8053	608	81	[North of Flow Hydrant] On 66th Avenue, just north of intersection with 1st Street	J51764	4827	58	48	51.5	56.5	48.1	10.0	8.4	-1.6	-1.6	29.5	1.5
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113	411	Fife Heights	9	10/24/2017	2:28 PM	1	Intersection of 11th Street and 67th Ave Ct (Catch Basin - Likely Only 1 Port)	J52326	7398	1,053	111	[West of Flow Hydrant] Intersection of 11th Street and 67th Ave Ct	J92792	7399	104	93	111.2	105.5	92.9	11.0	12.6	1.6	1.6	-0.2	-1.5
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Tacoma Water
Hydraulic Model Calibration Data
549 NE Tacoma Zone

Test No.	HGL (feet)	Pressure Zone Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested				Hydrant for Pressure Measurements				Model Results			Field Diff Pressure F1 (psi)	Model Diff Pressure F1 (psi)	Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hyd) (psi)	Static P Diff (Static Hyd) (psi)		
							Location	F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	Location	R1 Model Node No.	Hydrant No.	R1 Static Pressure (psi)	R1 Residual Pressure (psi)	F1 Static Pressure (psi)							R1 Static Pressure (psi)	R1 Residual Pressure (psi)
114	549	NE Tacoma	9	10/26/2017	11:14 AM	1	Approx. 6000 6th Street (Catch Basin/Ditches)	J96292	9633	653	59	[West of Flow Hydrant] Intersection of 6th Street and 59th Ave Ct	J109118	4842	55	40	60.0	56.1	42.0	15.0	14.1	-0.9	-0.9	-1.0	-1.1
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115	549	NE Tacoma	9	10/26/2017	11:45 AM	1	Intersection of 56th Ave and 17th Street Ct	J51920	7101	809	64	[East of Flow Hydrant] Intersection of 57th Ave and 17th Street Ct	J96354	7102	68	58	65.3	68.1	57.2	10.0	10.8	0.8	0.3	-1.3	-0.1
	11:47 AM				2	1,348				43					43.4	25.0			24.7	-0.3					
116	549	NE Tacoma	9	10/26/2017	12:47 PM	1	South side of 63rd Ave, just south of intersection with 23rd Street (Catch Basin)	J11614	7984	826	71	[Northwest of Flow Hydrant] Approx. 6225 23rd Street	J11606	8054	69	58	72.1	70.6	59.5	11.0	11.1	0.1	-1.0	-1.6	-1.6
	12:49 PM				2	1,284				44					47.7	25.0			22.9	-2.1					
117	549	NE Tacoma	10	10/26/2017	1:37 PM	1	Intersection of 27th Street and 59th Ave (Catch Basin)	J86676	4804	908	74	[South of Flow Hydrant] Intersection of 59th Avenue and 26th Street	J11820	4817	72	70	75.3	72.7	69.2	2.0	3.6	1.6	1.7	-1.3	-0.7
	1:40 PM				2	1,580				66					64.9	6.0			7.8	1.8					
118	549	NE Tacoma	10	10/27/2017	10:10 AM	1	Intersection of SW 341st Street and 32nd Ave SW (Catch Basin)	J64476	4869	876	66	[West of Flow Hydrant] Approx. 34025 SW 33rd Ave	J64460	9537	72	70	69.2	73.6	70.4	2.0	3.2	1.2	1.0	-3.2	-1.6
	10:12 AM				2	1,582				66					66.7	6.0			6.9	0.9					
119	549	NE Tacoma	10	10/27/2017	10:46 AM	1	Intersection of Spyglass Drive and 36th Street NE (Catch Basin)	J74574	7625	1,067	101	[North of Flow Hydrant] Approx. 3630 Spyglass Drive	J74672	7622	101	98	102.1	102.4	98.2	3.0	4.2	1.2	1.5	-1.1	-1.4
	10:47 AM				2	1,827				94					93.7	7.0			8.8	1.8					
120	549	NE Tacoma	10	10/27/2017	11:23 AM	1	Intersection of Larchmont Ave NE and Braeburn Drive NE (Catch Basin)	J13730	4589	716	70	[North of Flow Hydrant] Intersection of Larchmont Ave NE and Oakmont Street NE	J13818	4590	73	70	71.4	72.2	68.9	3.0	3.3	0.3	0.1	-1.4	0.8
	11:24 AM				1	1,164				66					65.4	7.0			6.8	-0.2					
121	549	NE Tacoma	10	10/27/2017	12:51 PM	1	Approx. 3628 SW 331st Place (Catch Basin)	J83018	4890	860	70	[East of Flow Hydrant] Intersection of SW 331st Place and 36th Avenue SW	J83016	4889	77	74	68.6	76.6	74.0	3.0	2.6	-0.5	-0.5	1.4	0.4
	12:52 PM				2	1,563				71					71.0	6.0			5.5	-0.5					
122	549	NE Tacoma	10	10/30/2017	9:10 AM	1	Intersection of 47th Street NE and 29th Avenue NE (Catch Basin)	J74306	7224	695	48	[South of Flow Hydrant] 29th Ave NE cul-de-sac	J74236	7225	49	47	47.8	48.6	46.4	2.0	2.3	0.3	0.6	0.2	0.4
	9:11 AM				2	1,208				44					42.6	5.0			6.0	1.0					
123	549	NE Tacoma	10	10/30/2017	9:31 AM	1	Approx. 5518 Green Hills Ave NE (Catch Basin)	J87156	4658	791	62	[Northeast of Flow Hydrant] Intersection of Browns Point Blvd NE and 57th Street NE - Same hydrant as NE13	J14748	4689	56	55	61.2	53.6	51.3	1.0	2.3	1.3	2.4	0.8	2.4
	9:32 AM				2	1,410				54					47.9	2.0			5.6	3.6					
124	549	NE Tacoma	10	10/30/2017	9:46 AM	1	Approx. 1863 Overview Drive NE (Catch Basin)	J15118	4693	954	83	[East of Flow Hydrant] Approx. 1891 Overview Drive	J92318	4694	87	85	81.3	85.4	82.5	2.0	2.9	0.9	1.8	1.7	1.7
	9:48 AM				2	1,719				82					77.6	5.0			7.7	2.7					

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Test No.	HGL (feet)	Pressure Zone Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested				Hydrant for Pressure Measurements				Model Results		Field Diff Pressure		Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hyd) (psi)	Static P Diff Static Hyd (psi)				
							Field Measurements		Field Measurements		Field Measurements		F1 Static Pressure (psi)	F1 Residual Pressure (psi)	F1 Static Pressure (psi)	F1 Residual Pressure (psi)	F1 (psi)	F1 (psi)								
							F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	F1 Model Node No.	Hydrant No.	R1 Static Pressure (psi)	R1 Residual Pressure (psi)	F1 Static Pressure (psi)	F1 Residual Pressure (psi)	F1 (psi)	F1 (psi)								
125	370	Overlook	10	11/2/2017	10:25 AM	1	J76336	8132	954	81	[Northeast of Flow Hydrant] Beacon Ct cul-de-sac	J76298	8133	81	76	79.5	78.5	72.5	4.5	6.0	1.5	2.3	1.6	2.0		
					10:27 AM	2			1,669						70			65.3	10.1	13.2	3.1					
126	486	Beverly Heights	10	11/2/2017	9:47 AM	1	J11278	7360	924	87	[North of Flow Hydrant] 37th Ave near cul-de-sac	J11274	7361	89	75	87.7	88.1	78.1	14.0	9.9	-4.1	-1.7	-0.7	1.0		
					9:49 AM	2			1,527						68			66.3	21.0	21.8	0.8					
127	649	Indian Hill	10	10/30/2017	10:52 AM	1	J14012	7818	924	72	[Southeast of Flow Hydrant] Intersection of 36th Ave NE and 45th Street NE	J73004	7817	86	80	71.3	86.6	81.9	6.0	4.8	-1.2	1.1	0.8	-0.6		
					10:54 AM	2			1,430						72			69.2	14.0	17.4	3.4					
128	649	Indian Hill	10	10/30/2017	11:18 AM	1	J15410	8167	826	72	[Northwest of Flow Hydrant] Approx. 3460 Laurelwood Circle NE (SE side of Laurelwood Circle) (Catch Basin)	J15394	8168	78	72	70.0	75.8	71.8	6.0	4.0	-2.0	-2.5	2.0	2.2		
					11:20 AM	2			1,350						59			59.7	19.0	16.1	-2.9					
129	649	Indian Hill	10	10/30/2017	11:44 AM	1	J15898	7532	809	66	[East of Flow Hydrant] Davis Ct NE cul-de-sac	J15896	7533	62	53	66.7	61.1	53.9	9.0	7.2	-1.8	-0.8	-0.7	0.9		
					11:46 AM	2			1,306						40			38.8	22.0	22.3	0.3					
130	426	Harbor View	10	11/2/2017	8:55 AM	---	---	---	---	---	On Slayden Road, between intersections with Varco Road and Kennedy Road	J87154	4623	64	---	---	64.3	---	---	---	---	---	---	-0.3		
					---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
131 - Statics	346	Browns and Dash Point	10	10/30/2017	1:18 PM	---	J14514	8118	---	72	[Northeast of Flow Hydrant] Heron Ridge Drive dead end	J76690	8120	36	---	71.4	34.9	---	---	---	---	---	---	---	0.6	1.1
					---	---			---						---			---	---	---	---	---	---	---	---	---
131 - Rev.	346	Browns and Dash Point	10	10/30/2017	2:44 PM	1	J14824	9571	809	70	[East of Flow Hydrant] Just north of intersection of 51st Street and Caledonia Road NE	J14848	7322	59	48	68.3	59.6	50.7	11.0	8.9	-2.1	-2.1	1.7	-0.6		
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132	346	Browns and Dash Point	10	10/30/2017	1:39 PM	1	J101386	4716	809	70	[Southeast of Flow Hydrant] Intersection of Whittier Street NE and Dash Point Blvd NE	J59774	4936	39	34	66.9	38.2	35.0	5.0	3.3	-1.7	-1.7	3.1	0.8		
					1:40 PM	2			1,391						31			31.8	8.0	6.4	-1.6					
133	346	Browns and Dash Point	10	10/30/2017	2:00 PM	1	J59626	7672	1,067	111	[North of Flow Hydrant] On east side of Water Street NE, just south of fork in road with Alder Street NE sign	J59624	7674	118	108	109.7	118.4	106.7	10.0	11.7	1.7	1.7	1.3	-0.4		
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134	226	Hayada	10	11/2/2017	11:11 AM	1	J14838	7916	735	54	[North of Flow Hydrant] Wa Tau Ga Ave NE and Mana Wana Place NE	J14886	7915	58	47	53.3	55.9	48.3	10.9	7.6	-3.3	-2.3	1.1	2.0		
					11:13 AM	2			1,261						45			44.3	12.9	11.6	-1.3					
135	411	Dash Point High	10	11/2/2017	11:53 AM	1	J100722	7164	735	59	[North of Flow Hydrant] On 21st Ave at intersection with 63rd Street NE (Catch Basin)	J75302	4732	69	61	59.0	70.1	65.7	8.0	4.4	-3.6	-2.4	0.0	-1.1		
					11:54 AM	2			1,328						58			60.3	11.0	9.7	-1.3					
136	226	Dash Point Low	10	11/2/2017	12:41 PM	1	J101426	676	754	93	[South of Flow Hydrant] Intersection of Soundview Drive NE and Beach Drive NE (Catch Basin at Dash Point Park entrance)	J59698	4721	85	63	91.9	84.0	62.4	22.0	21.6	-0.4	-0.6	1.1	1.0		
					12:43 PM	2			954						53			52.9	32.0	31.1	-0.9					
137	411	Twin Lakes	10	10/31/2017	8:50 AM	1	J64554	5048	754	58	[West of Flow Hydrant] On SW 324th Place in front of Dash Point Highlands Park	J64564	5055	58	54	59.9	58.3	55.1	4.0	3.2	-0.8	-1.9	-1.9	-0.3		
					8:52 AM	3			1,324						48			51.3	10.0	7.0	-3.0					
138	411	Twin Lakes	10	10/31/2017	9:44 AM	1	J103556	5008	908	84	[Southeast of Flow Hydrant] Just north of intersection of 45th Place SW and SW 317th Place	J66062	5007	72	61	85.6	72.7	65.6	11.0	7.1	-3.9	-2.6	-1.6	-0.7		
					9:46 AM	2			1,468						47			49.0	25.0	23.7	-1.3					
139	411	Twin Lakes	10	10/31/2017	9:17 AM	1	J103034	4956	969	85	[Northwest of Flow Hydrant] Approx. 4014 SW 321st Street	J103036	4955	84	77	88.2	85.2	78.6	7.0	6.6	-0.4	-0.3	-3.2	-1.2		
					9:18 AM	2			1,518						70			71.5	14.0	13.8	-0.3					
140	411	Twin Lakes	10	10/31/2017	10:47 AM	1	J65658	4934	754	55	[Northwest of Flow Hydrant] Intersection of SW 314th Street and 40th Avenue SW	J65712	9544	52	38	57.3	53.9	43.8	14.0	10.2	-3.9	-0.3	-2.3	-1.9		
					10:49 AM	2			1,212						33			31.7	19.0	22.2	3.2					
141	346	NE Tacoma	10	10/31/2017	12:18 PM	1	J66202	5039	773	64	[Northwest of Flow Hydrant] Approx. 4830 SW 310th Street (Ditch)	J99792	5080	64	61	62.7	62.4	58.6	2.7	3.8	1.1	1.0	1.3	1.3		
					12:20 PM	2			1,167						57			54.8	6.7	7.7	0.9					
142	346	NE Tacoma	10	10/31/2017	11:54 AM	1	J65952	9809	754	55	[South of Flow Hydrant] South end of 51st Avenue SW at dead end	J65956	5049	47	41	53.1	45.1	39.0	6.0	6.1	0.1	-0.2	1.9	1.9		
					11:57 AM	2			1,237						32			30.6	15.0	14.5	-0.5					

Tacoma Water
Hydraulic Model Calibration Data
NE Tacoma Operating Area (Not Including 549 NE Tacoma Zone)

Test No.	HGL (feet)	Pressure Zone Descriptor	Figure No.	Date	Time	Duration of Test (mins)	Hydrant Flow Tested				Hydrant for Pressure Measurements					Model Results			Field Diff Pressure F1 (psi)	Model Diff Pressure F1 (psi)	Error (per flow) (psi)	Error (per site) (psi)	Static P Diff (Flow Hyd) (psi)	Static P Diff (Static Hyd) (psi)		
							Field Measurements				Field Measurements					F1 Static Pressure (psi)	R1 Static Pressure (psi)	R1 Residual Pressure (psi)								
							F1 Model Node No.	Hydrant No.	Flow Calc (gpm)	Static Pressure (psi)	F1 Model Node No.	Hydrant No.	R1 Static Pressure (psi)	R1 Residual Pressure (psi)	F1 Static Pressure (psi)										R1 Static Pressure (psi)	R1 Residual Pressure (psi)
143	346	NE Tacoma	10	10/31/2017	12:42 PM	1	On 37th Place SW just south of intersection with SW 309th Street (Catch Basin)	J99876	657	1,012	89	[Northeast of Flow Hydrant]		J99864	658	79	63	88.8	80.4	66.9	15.5	13.5	-2.0	0.7	0.2	-1.9
	12:44 PM				1	1,580				45		43.4	33.5			37.0	3.5									
144	186	Lakota Beach	10	10/31/2017	1:11 PM	1	Intersection of SW 304th Street and 33rd Ave SW (Only flow 1 port and direct flow to south into woods)	J100340	4872	754	66	[Northeast of Flow Hydrant]		J66510	4859	60	48	65.6	58.3	45.9	12.0	12.4	0.4	0.4	0.4	1.7
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