Building and Calibrating the New Bellevue Water System Model

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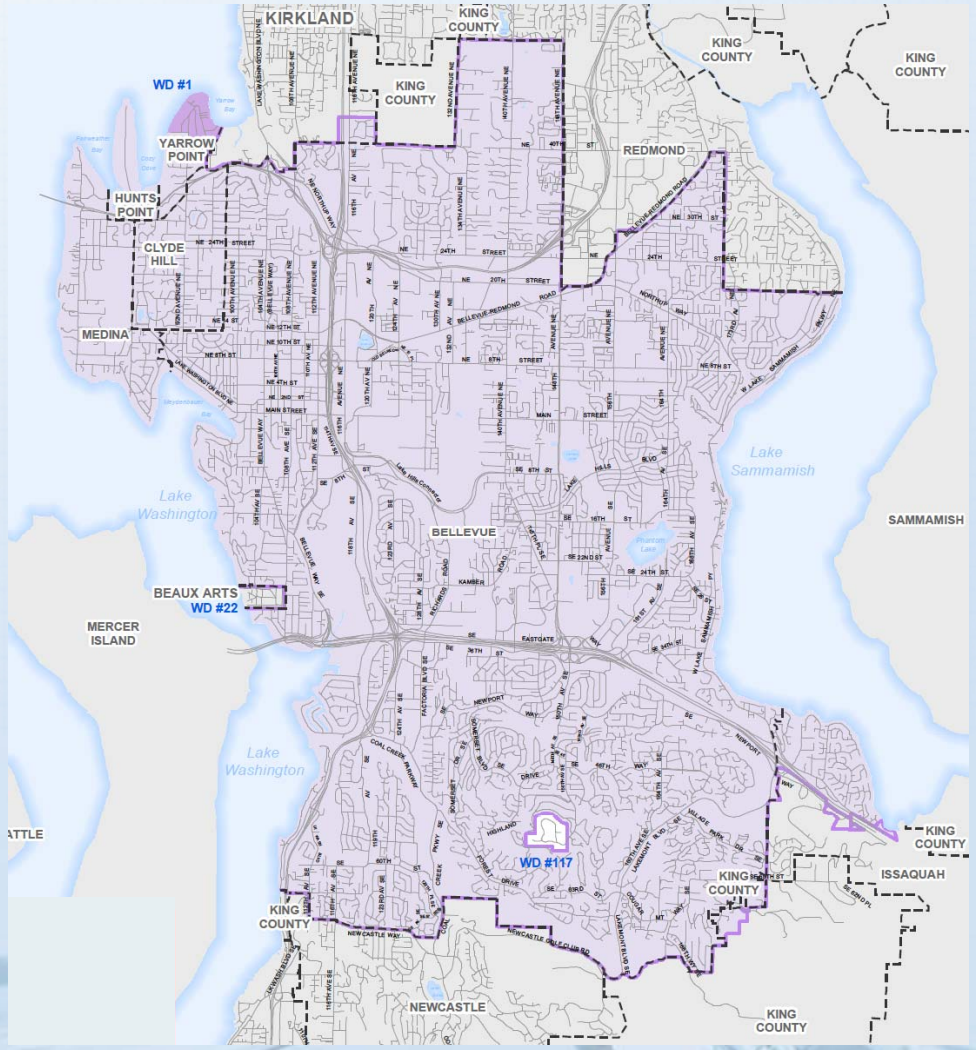
PNWS - AWWA

May 1, 2015

City of Bellevue Service Area

- 2014 population 140,000+ (~180,000 by 2040)
- 2014 employment 136,000+ (~214,000 by 2040)
- Bellevue plus portions of 7 other municipalities
- Regional Supply (SPU)



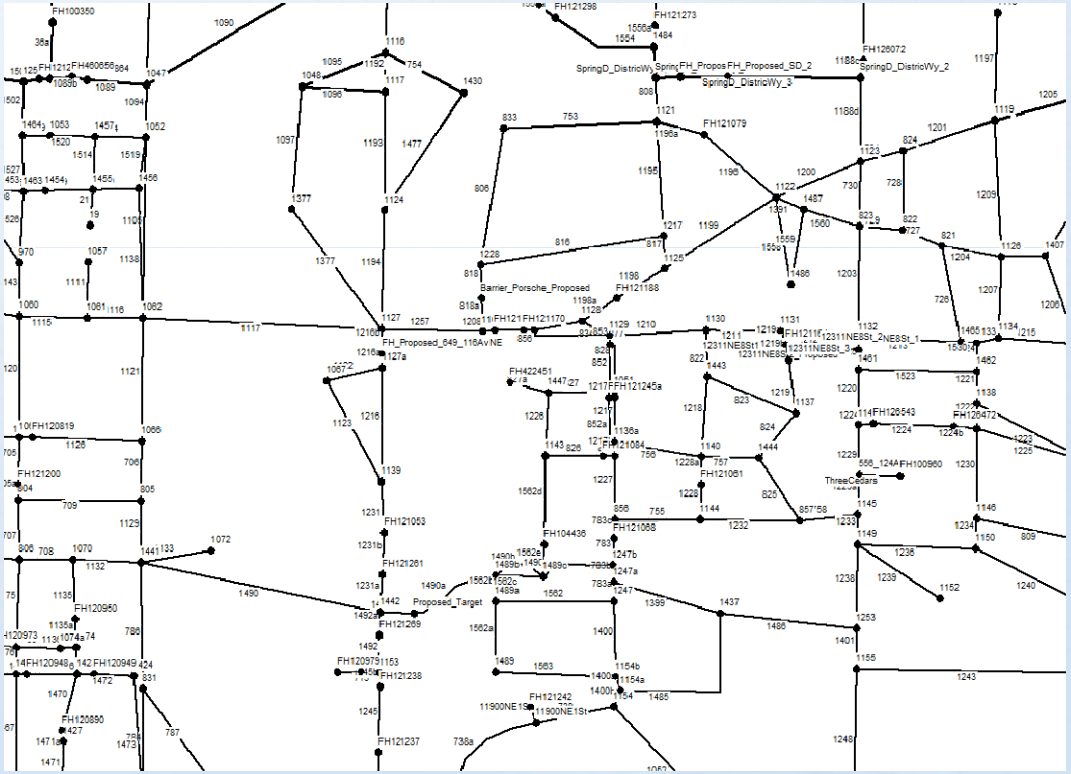
Water System Assets

- 600+ miles of pipe
- 64+ pressure zones
- 26 reservoirs (plus share of 4 outside service area)
- 23 pump stations
- 13 inlet stations
- 144 pressure reducing valve (PRV) stations

Bel-Red Inlet

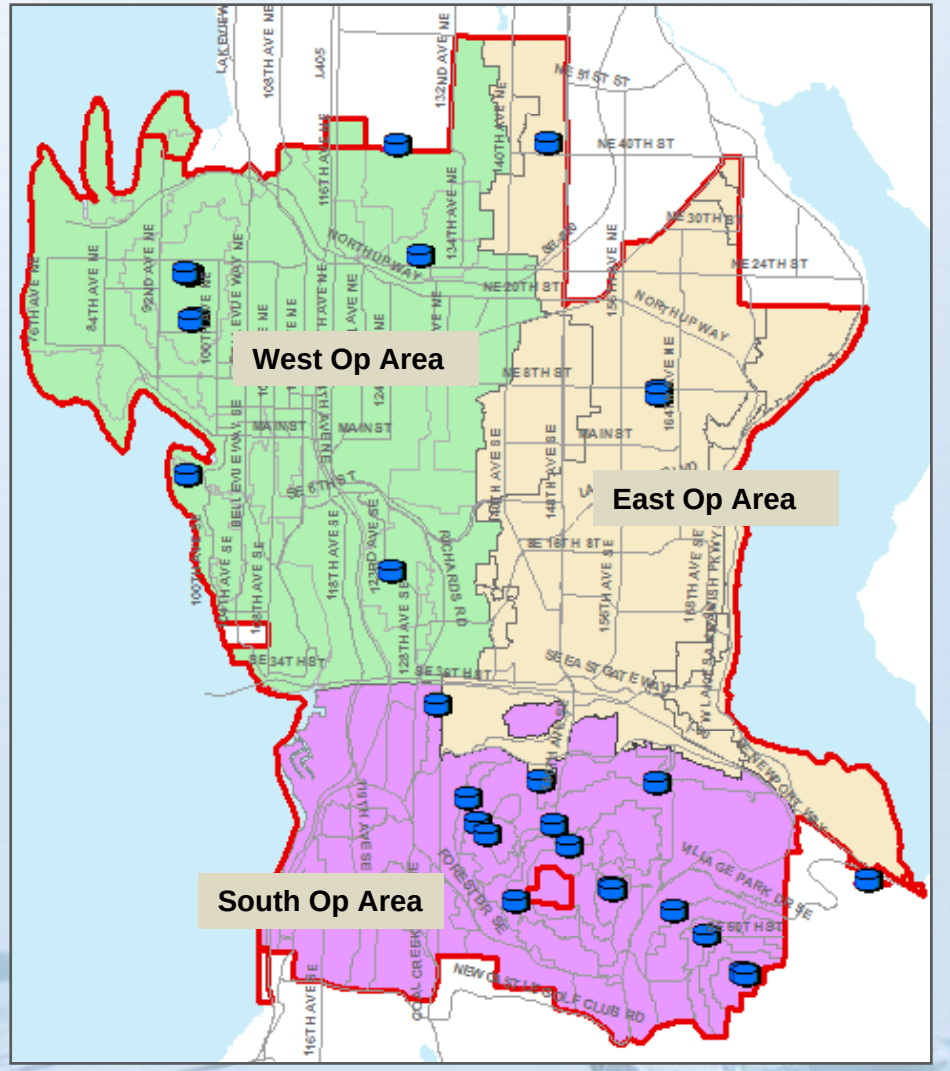
Bellevue Previously Used EPA-NET for Hydraulic Analysis

- Model results did not match field
- Manual iteration of each fire flow location
- Limited model capabilities



The City Needs an Integrated "all-pipe" Model of System

- East model previously developed
- New models for West and South:
  - Should be easily maintainable
  - Will be used for the ongoing WSP update
  - Will be used to aid in proposed redevelopment



Bellevue Provided Existing Data for Model Development of West and South Operating Areas

- EPA-NET models
- GIS data on system parts
  - Pipes, hydrants, key infrastructure locations
- Operational data
  - Pump controls
  - PRV, altitude valve, and throttle control valve settings
  - Tank information
- Existing demands by customer meter

Bellevue Collected New Data for Model Development

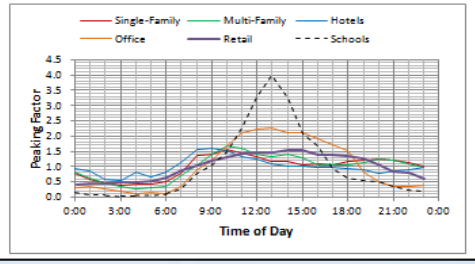
- Hydrants tests, including PRV conditions for many of the tests
- Static long-term pressure fluctuations
- The city conducted winter and summer diurnal pattern studies for 6 customer classes
  - Hotels, schools, retail, commercial, single-family residential, multi-family residential

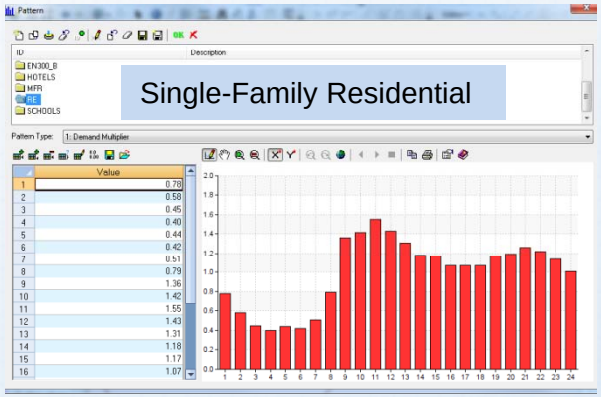
Custom Diurnal Patterns For Customer Classes

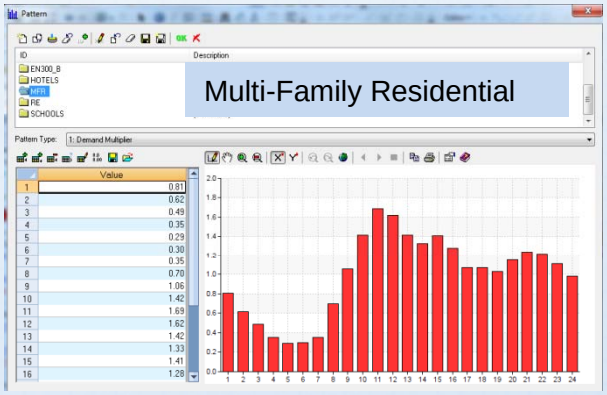
DESCRIPTION Multi-Family Housing Omni-Meter Readings
December 18, 2013 through January 16, 2014
BY D. Lane DATE 1/18/2014 CHECKED BY _____ DATE _____

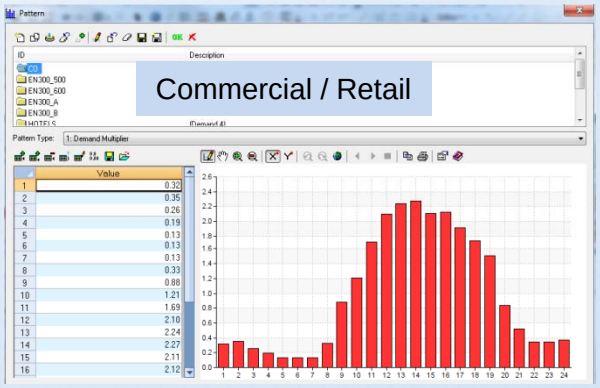
Average WDD Peaking Factors

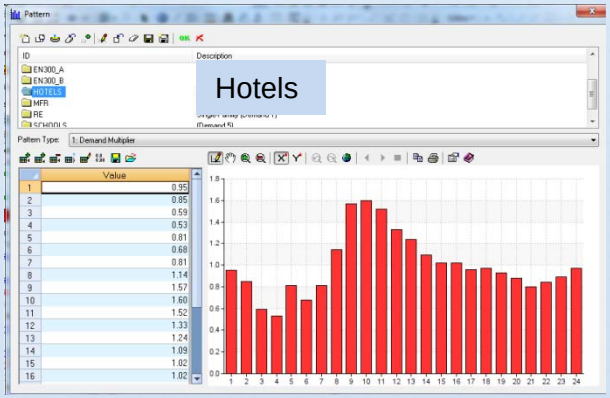
	Single-Family	Multi-Family	Hotels	Office	Retail	Schools
0:00	0.78	0.81	0.95	0.32	0.41	0.14
1:00	0.58	0.62	0.85	0.35	0.44	0.09
2:00	0.45	0.49	0.59	0.26	0.46	0.07
3:00	0.40	0.35	0.53	0.19	0.47	0.03
4:00	0.44	0.29	0.81	0.13	0.48	0.04
5:00	0.42	0.30	0.68	0.13	0.52	0.04
6:00	0.51	0.35	0.81	0.13	0.65	0.10
7:00	0.79	0.70	1.14	0.33	0.88	0.29
8:00	1.36	1.06	1.57	0.88	1.02	0.79
9:00	1.42	1.42	1.60	1.21	1.21	1.04
10:00	1.55	1.69	1.52	1.69	1.31	1.49
11:00	1.43	1.62	1.33	2.10	1.43	2.25
12:00	1.31	1.42	1.24	2.24	1.46	3.28
13:00	1.18	1.33	1.09	2.27	1.45	3.99
14:00	1.17	1.41	1.02	2.11	1.53	3.23
15:00	1.07	1.28	1.02	2.12	1.53	2.08
16:00	1.07	1.07	0.96	1.91	1.40	1.66
17:00	1.07	1.07	0.97	1.71	1.38	0.92
18:00	1.17	1.03	0.93	1.51	1.36	0.63
19:00	1.19	1.15	0.88	0.84	1.25	0.53
20:00	1.26	1.24	0.80	0.52	1.09	0.52
21:00	1.22	1.22	0.84	0.34	0.85	0.36
22:00	1.14	1.11	0.89	0.34	0.81	0.24
23:00	1.01	0.98	0.97	0.37	0.60	0.18
Average/Hr	1	1	1	1	1	1
Average/Day	24	24	24	24	24	24

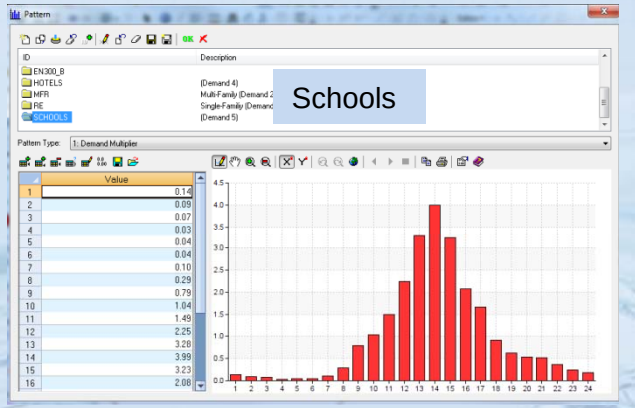






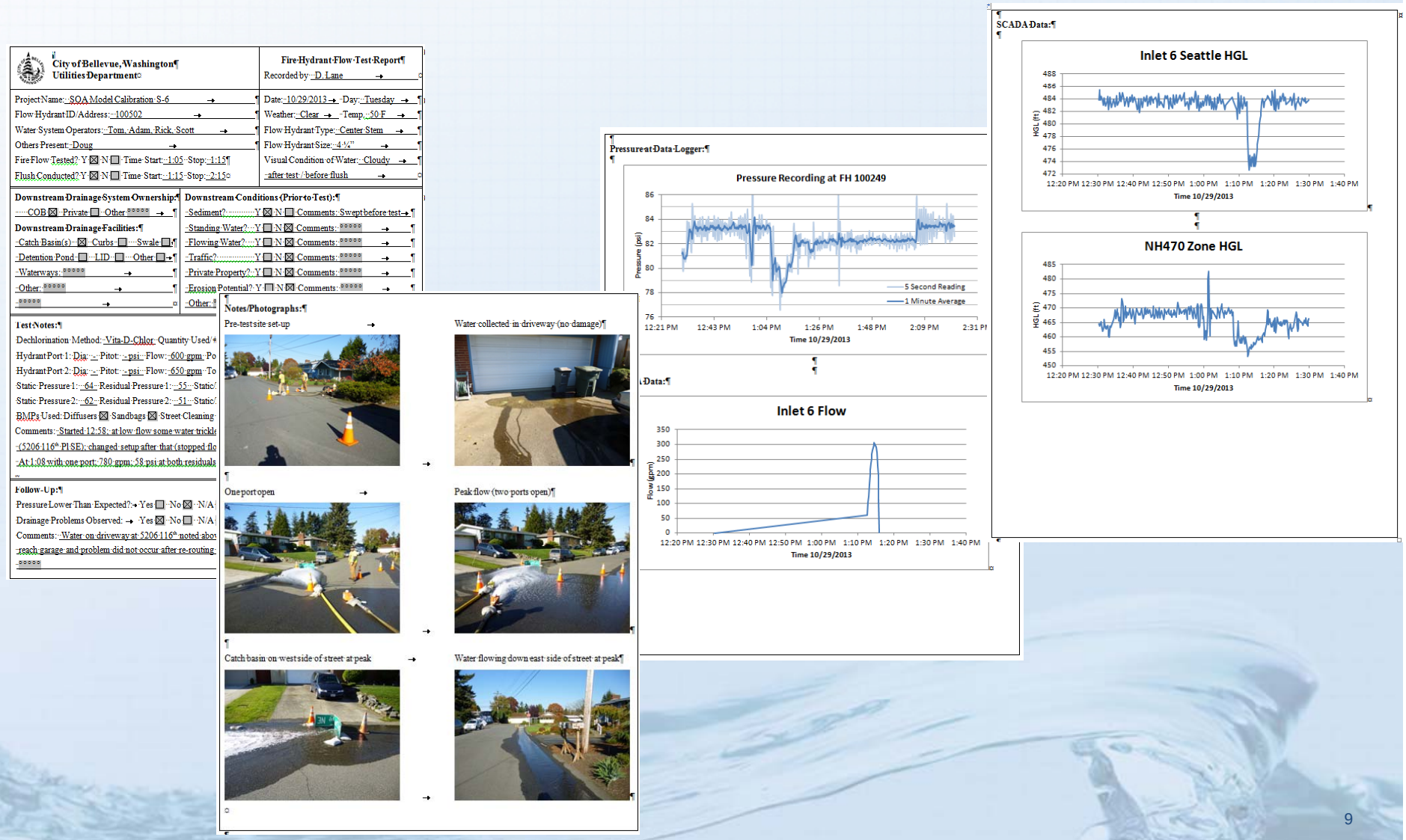






Example of Fire Hydrant Tests Summary

- Hydrant tests performed by the City



City of Bellevue, Washington
Utilities Department

Fire Hydrant Flow Test Report

Recorded by: D. Lane

Project Name: SQA Model Calibration S-6
Flow Hydrant ID/Address: 100502
Water System Operators: Tom, Adam, Rick, Scott
Others Present: Doug
Fire Flow Tested? Y ☒ N ☐ Time Start: 1:05 Stop: 1:15
Flush Conducted? Y ☒ N ☐ Time Start: 1:15 Stop: 2:15

Date: 10/29/2013 Day: Tuesday
Weather: Clear Temp.: 50 F
Flow Hydrant Type: Center Stem
Flow Hydrant Size: 4 ½"
Visual Condition of Water: Cloudy
after test / before flush

Downstream Drainage System Ownership:
COB ☒ Private ☐ Other

Downstream Drainage Facilities:
Catch Basin(s) ☒ Curbs ☐ Swale ☐
Detention Pond ☐ LID ☐ Other ☐
Waterways:
Other:

Downstream Conditions (Prior to Test):
Sediment? Y ☒ N ☐ Comments: Swept before test
Standing Water? Y ☐ N ☒ Comments:
Flowing Water? Y ☐ N ☒ Comments:
Traffic? Y ☐ N ☒ Comments:
Private Property? Y ☐ N ☒ Comments:
Erosion Potential? Y ☐ N ☒ Comments:
Other:

Test Notes:
Dechlorination Method: Vita-D-Chlor Quantity Used:
Hydrant Port 1: Dia: - Pitot: - psi Flow: 600 gpm Po
Hydrant Port 2: Dia: - Pitot: - psi Flow: 650 gpm To
Static Pressure 1: 64 Residual Pressure 1: 55 Static
Static Pressure 2: 62 Residual Pressure 2: 51 Static
BMPs Used: Diffusers ☒ Sandbags ☒ Street Cleaning
Comments: Started 12:58; at low flow some water trickle
(5206 116th PISE); changed setup after that (stopped flo
At 1:08 with one port: 780 gpm; 58 psi at both residuals

Follow-Up:
Pressure Lower Than Expected? Yes ☐ No ☒ N/A
Drainage Problems Observed: Yes ☒ No ☐ N/A
Comments: Water on driveway at 5206 116th noted abov
reach garage and problem did not occur after re-routing

Notes/Photographs:

Pre-test site set-up
Water collected in driveway (no damage)
One port open
Peak flow (two ports open)
Catch basin on west side of street at peak
Water flowing down east side of street at peak

Pressure at Data Logger:

Pressure Recording at FH 100249
Pressure (psi)
5 Second Reading
1 Minute Average
Time 10/29/2013

Data:

Inlet 6 Flow
Flow (gpm)
Time 10/29/2013

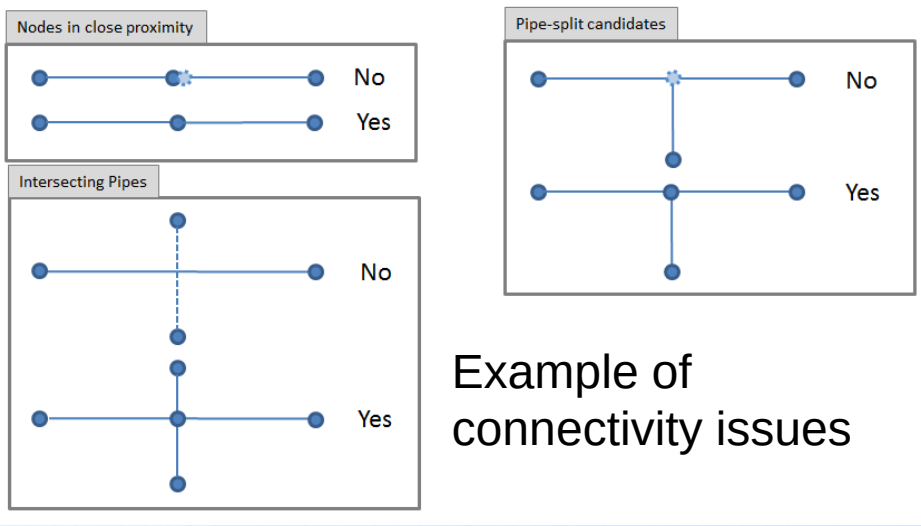
SCADA Data:

Inlet 6 Seattle HGL
HGL (ft)
Time 10/29/2013

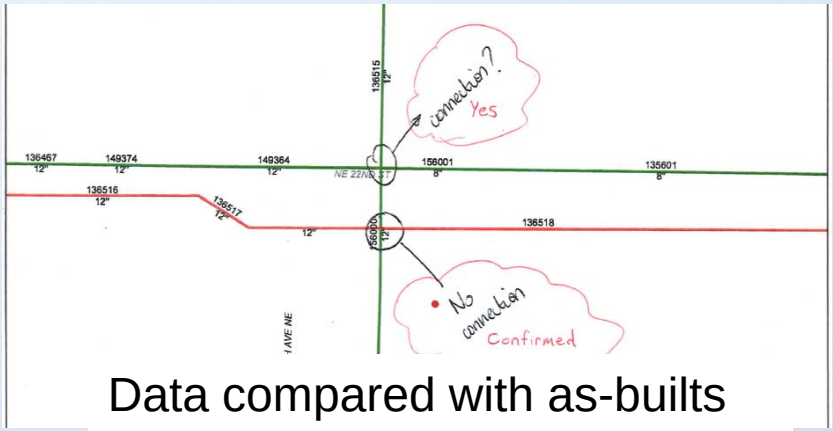
NH470 Zone HGL
HGL (ft)
Time 10/29/2013

GIS Cleaned, Organized and Formatted

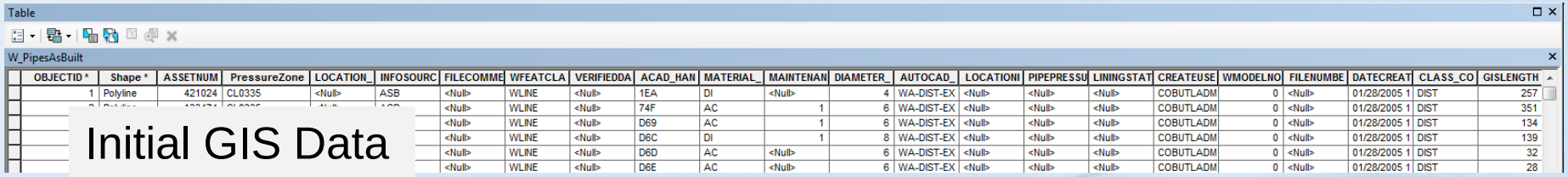
- Junctions created, elevation from 2-foot contours
- Piping connectivity checked



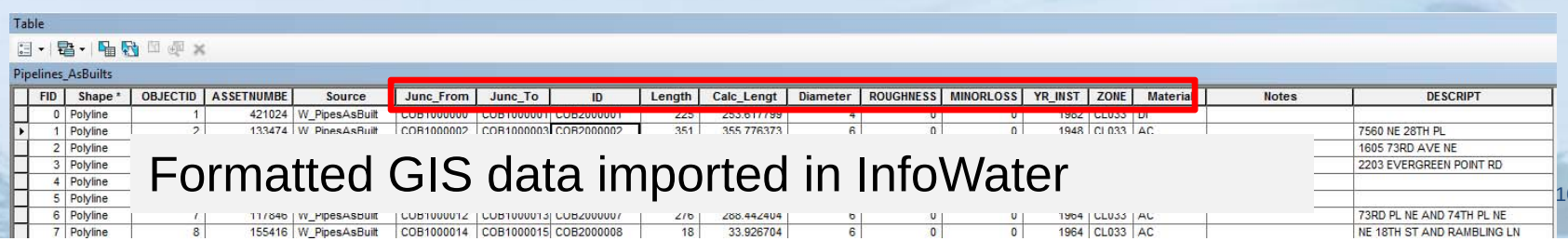
Example of connectivity issues



Data compared with as-builts



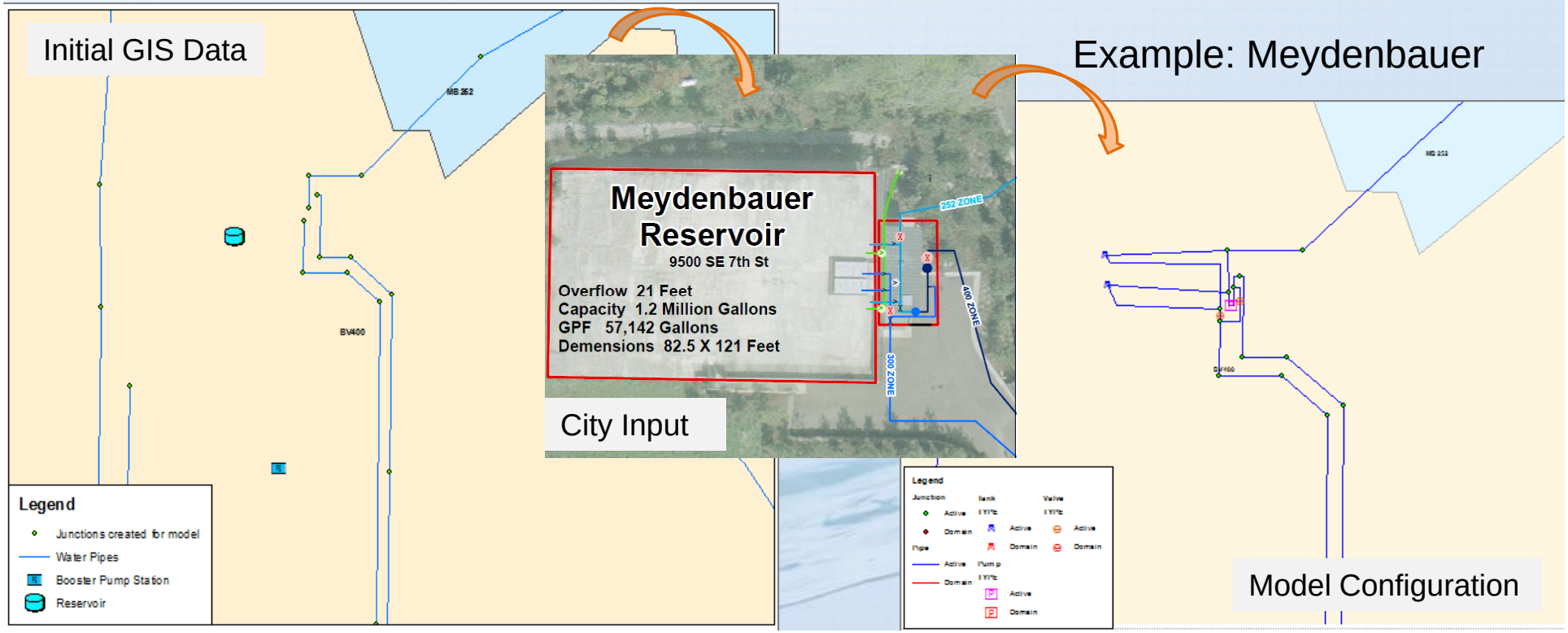
Initial GIS Data



Formatted GIS data imported in InfoWater

Site Configurations Added

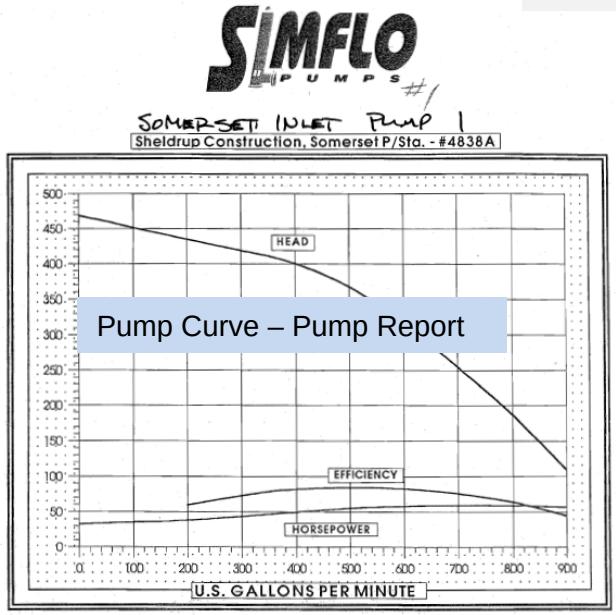
- Pump stations, reservoirs, inlets, and interties from site configuration drawings and as-built drawing



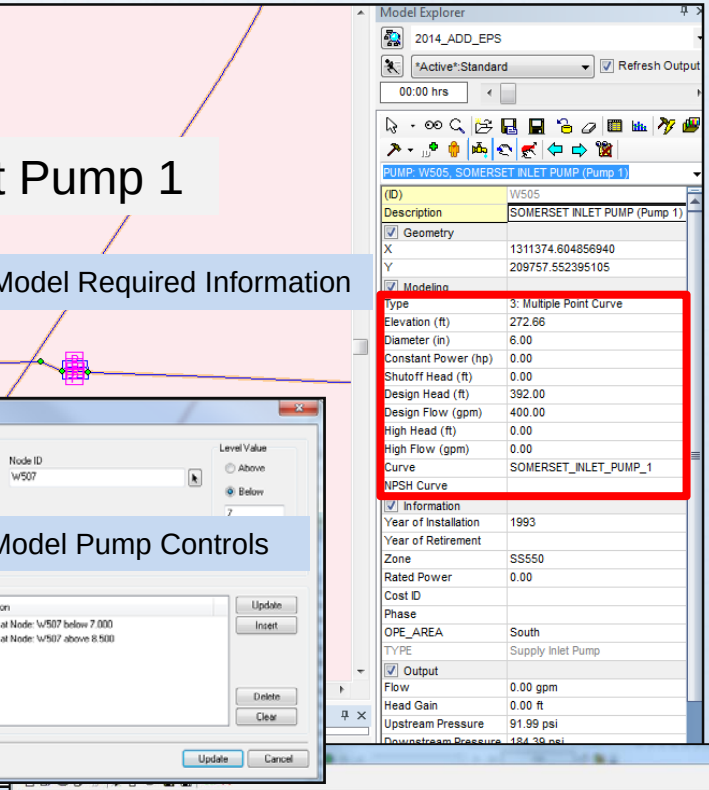
Facility Data Input in InfoWater

- Example: pump station required information

Example: Somerset Inlet Pump 1

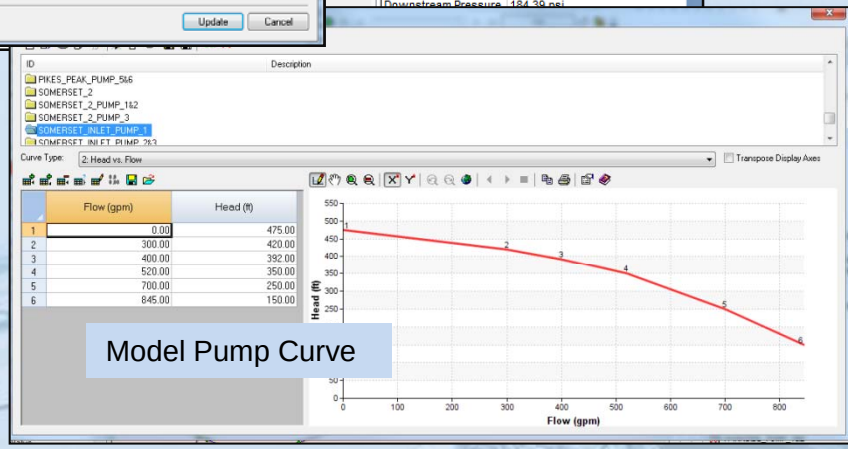


Pump Curve – Pump Report



Model Required Information

Model Pump Controls



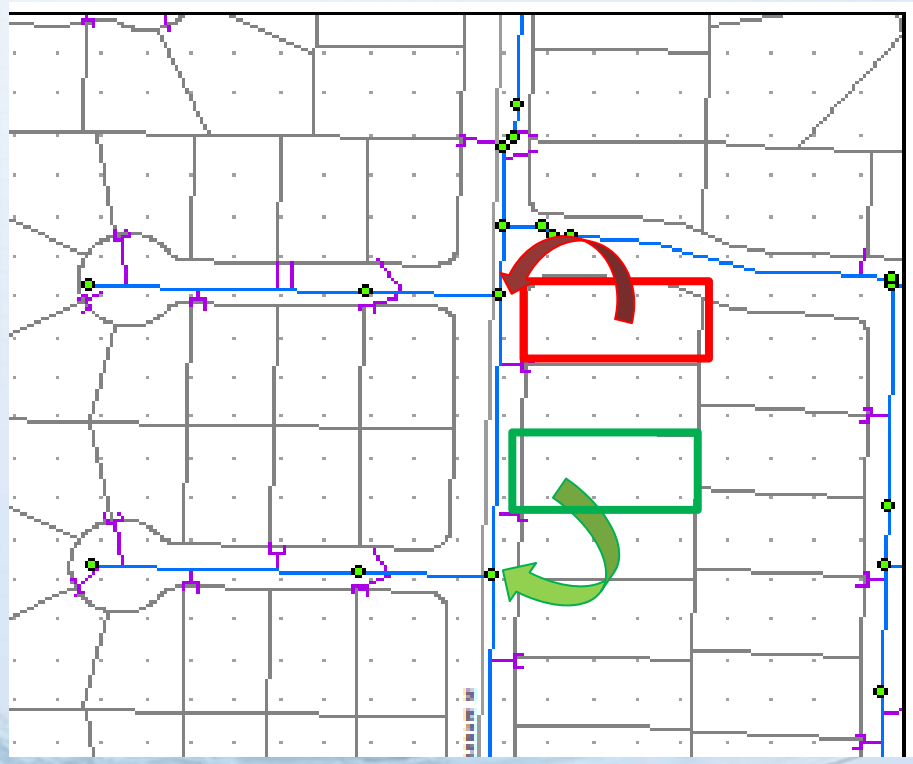
Model Pump Curve

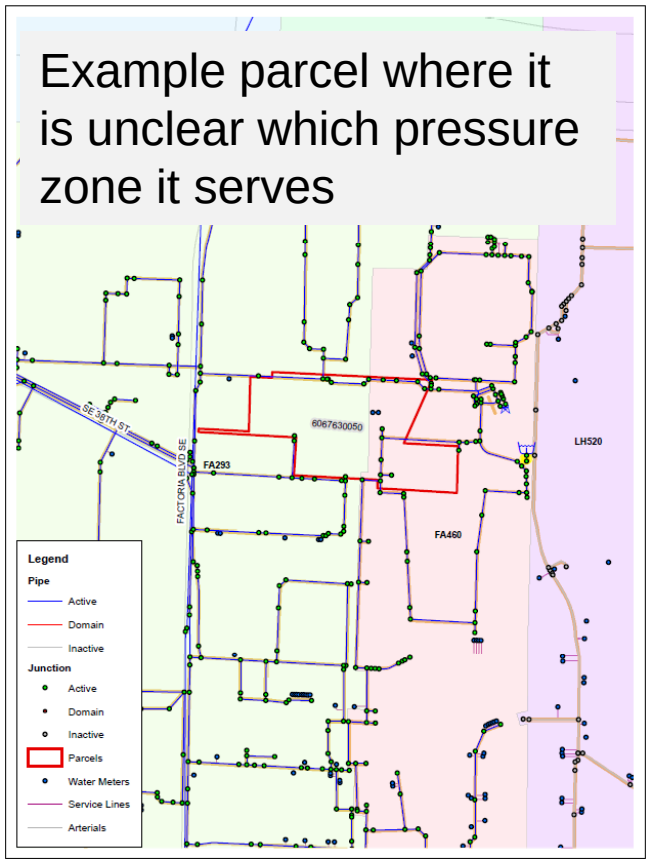
Somerset Inlet pumps to Somerset 2			
	Pump come on point	Pump shut off point	GPM Output
Pump 1	7	8.5	800
Pump 2	0	0	1500
Pump 3	0	0	1500
Pump 4	5.5	8	1200
Somerset 2 pumps to Forest Hills			
Pump 1			1100
Pump 2			1100
	17	17.5	850
NE 40th Res & Pump Station			
	The flow rate at the inlet valve controls the dyna		

City Provided Control Setpoints

Model Loading

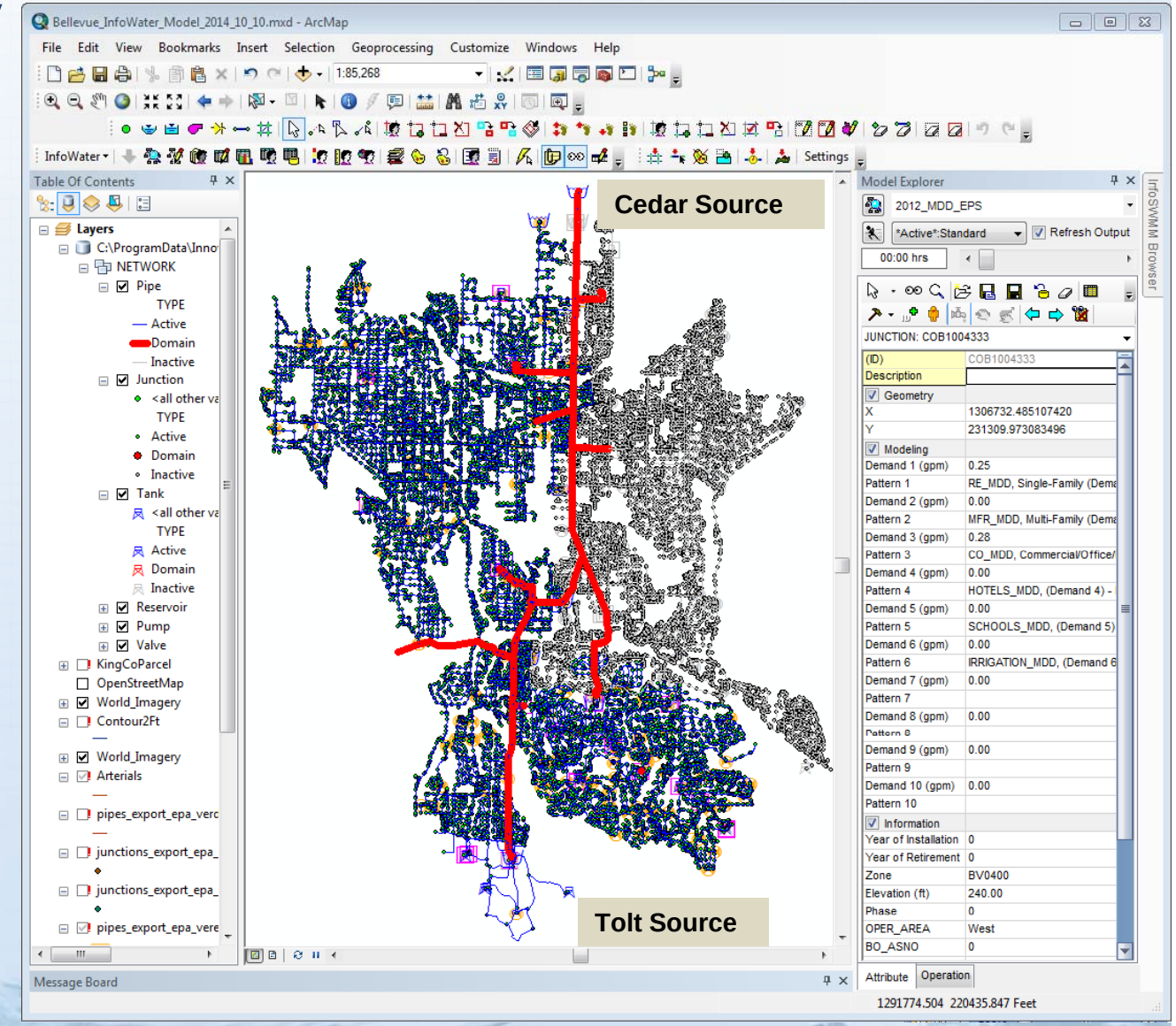
- Demand geocoding in GIS and allocation
- Demands provided by parcel land use type and allocated to the nearest model junction in the appropriate pressure zone
  - Demands are actual current demands
  - City input necessary to determine which zone to allocate the parcel to for certain areas





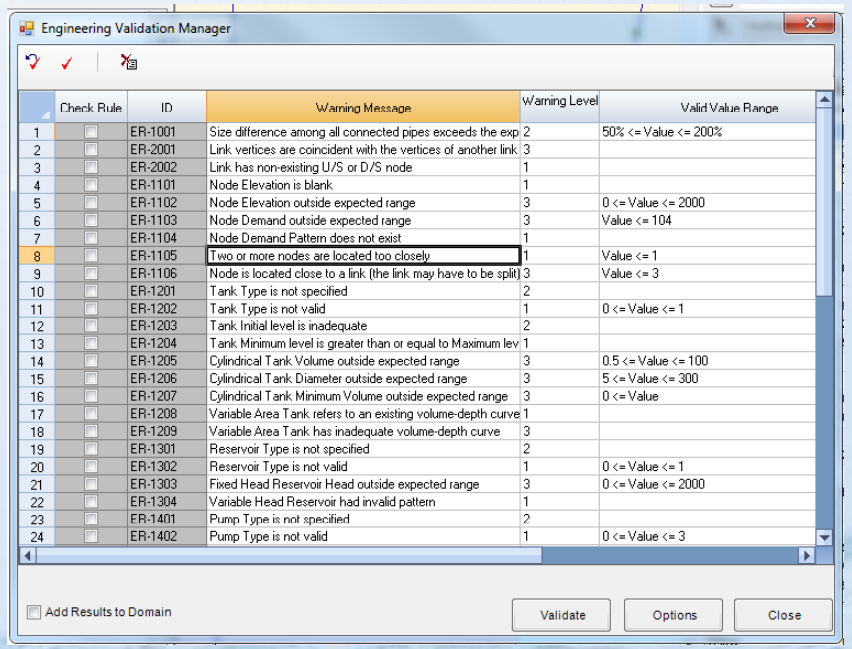
West and South Hydraulic Model with SPU Supply

- 40 pressure zones
- 202 PRVs (108 stations)
- 9 Altitude valves
- 19 Storage tanks
- 1 Hydropneumatic tank
- 45 Pump (16 stations)
- 8 SPU inlets



Initial Model Checks

- System pressures comparison used to locate major errors in model creation
- Facility characteristics from pumps, sources, valves were used to identify problems in system operations

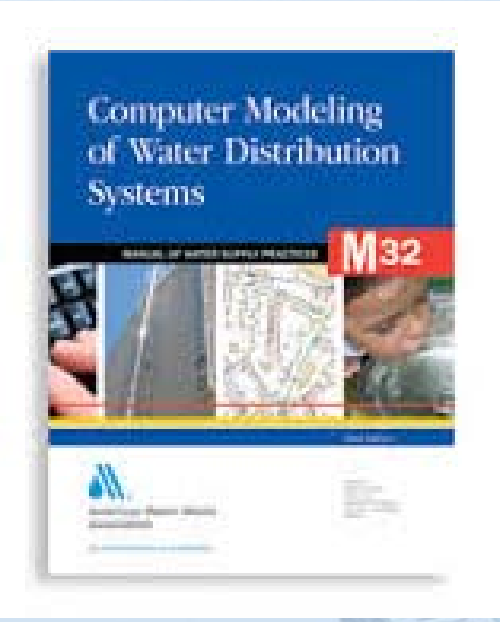


	Check Rule	ID	Warning Message	Warning Level	Valid Value Range
1		ER-1001	Size difference among all connected pipes exceeds the exp	2	50% <= Value <= 200%
2		ER-2001	Link vertices are coincident with the vertices of another link	3	
3		ER-2002	Link has non-existing U/S or D/S node	1	
4		ER-1101	Node Elevation is blank	1	
5		ER-1102	Node Elevation outside expected range	3	0 <= Value <= 2000
6		ER-1103	Node Demand outside expected range	3	Value <= 104
7		ER-1104	Node Demand Pattern does not exist	1	
8		ER-1105	Two or more nodes are located too closely	1	Value <= 1
9		ER-1106	Node is located close to a link (the link may have to be split)	3	Value <= 3
10		ER-1201	Tank Type is not specified	2	
11		ER-1202	Tank Type is not valid	1	0 <= Value <= 1
12		ER-1203	Tank Initial level is inadequate	2	
13		ER-1204	Tank Minimum level is greater than or equal to Maximum lev	1	
14		ER-1205	Cylindrical Tank Volume outside expected range	3	0.5 <= Value <= 100
15		ER-1206	Cylindrical Tank Diameter outside expected range	3	5 <= Value <= 300
16		ER-1207	Cylindrical Tank Minimum Volume outside expected range	3	0 <= Value
17		ER-1208	Variable Area Tank refers to an existing volume-depth curve	1	
18		ER-1209	Variable Area Tank has inadequate volume-depth curve	3	
19		ER-1301	Reservoir Type is not specified	2	
20		ER-1302	Reservoir Type is not valid	1	0 <= Value <= 1
21		ER-1303	Fixed Head Reservoir Head outside expected range	3	0 <= Value <= 2000
22		ER-1304	Variable Head Reservoir had invalid pattern	1	
23		ER-1401	Pump Type is not specified	2	
24		ER-1402	Pump Type is not valid	1	0 <= Value <= 3

Model ready for Calibration

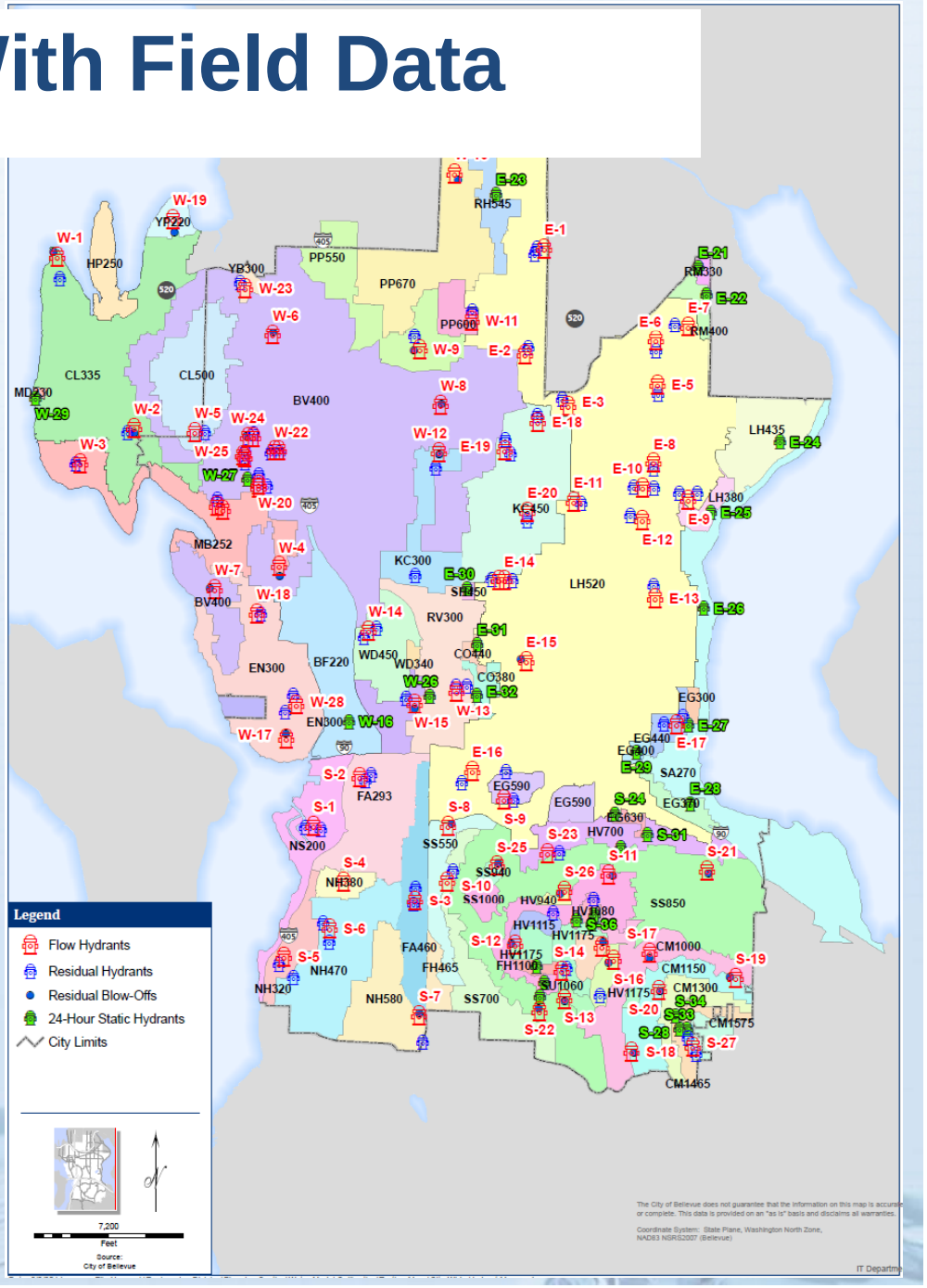
Fire Hydrant Calibration Criteria

- Review of AWWA M32 and the 1999 ECAC calibration recommendations: M32 master planning static calibration goals from hydrant test data:
  - HGL predicted should be within +/- 10 feet **(+/- 4.3 psi**) of measured values.



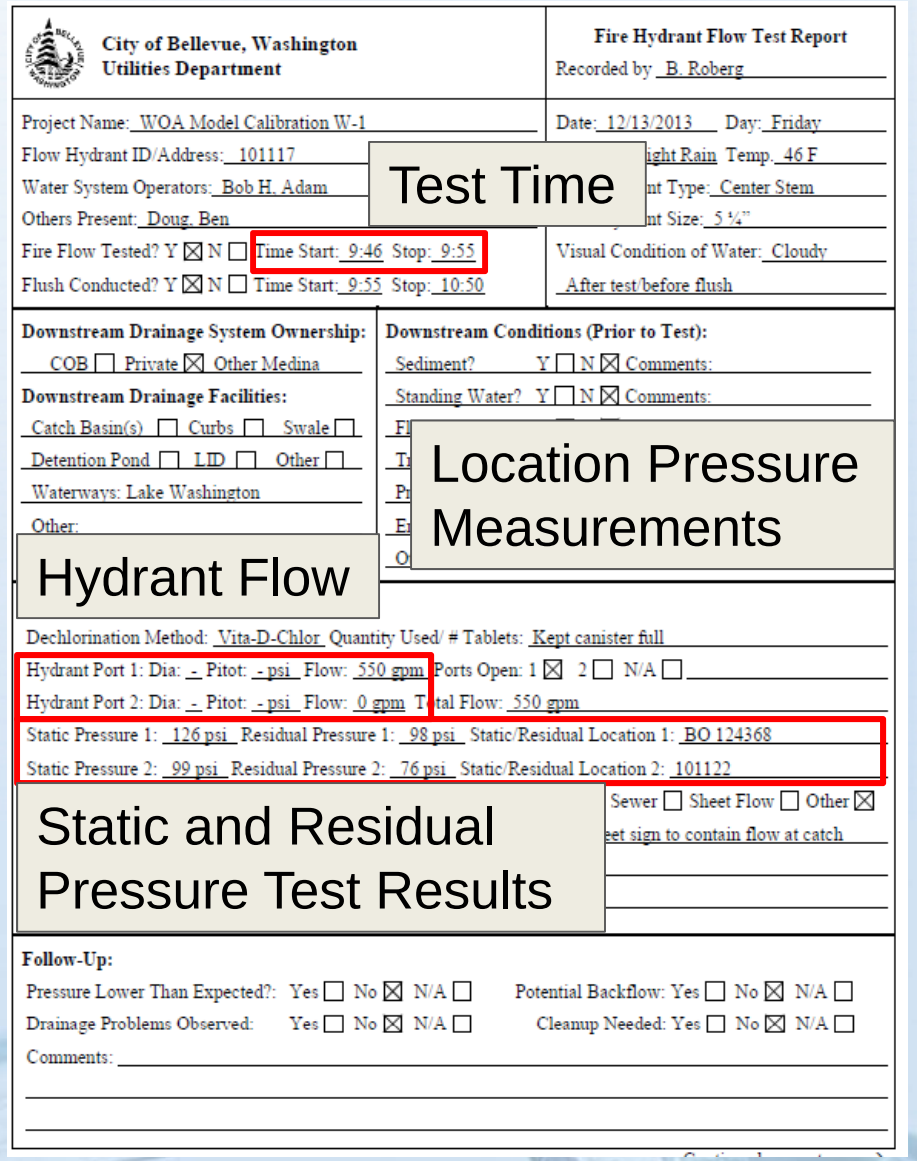
Model Calibration With Field Data

- 70 hydrant tests
- Numerous residual pressure recorders
- SCADA telemetry

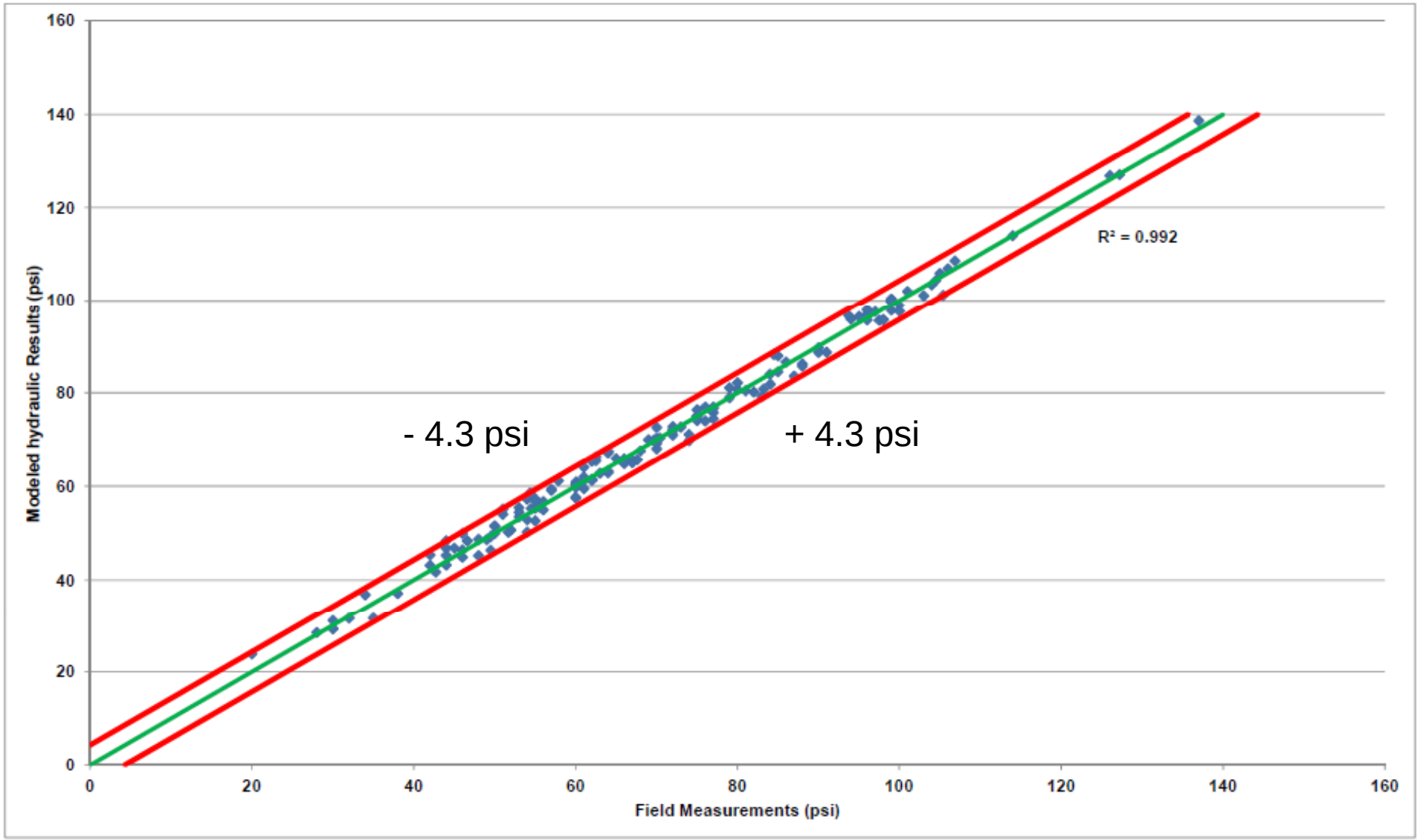


Fire Hydrant Calibration

- Demands set to test time using diurnal pattern
- Pumps and tanks set from SCADA
- Parameters adjusted to match field results
  - PRV settings mainly to match static conditions
  - Pump curves
  - Tank elevations
  - Hazen-Williams C factors on pipes mainly to match residual conditions
    - Try to hold C factors constant within every pressure zone

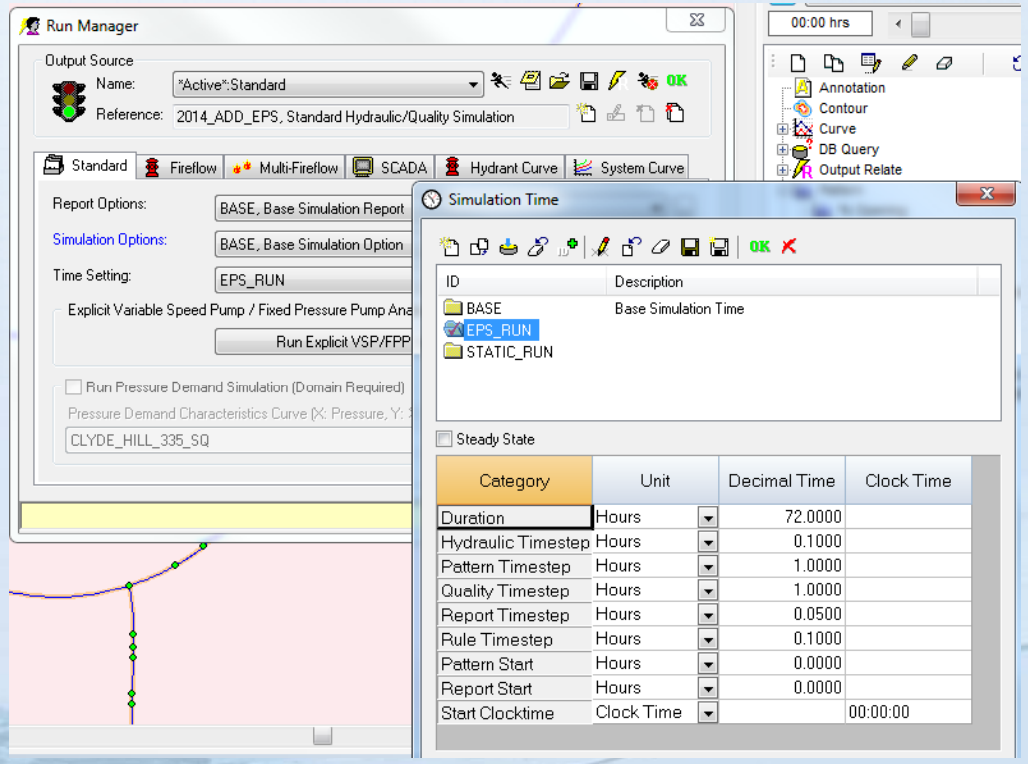


Hydrant Test Results Summary For All Tests



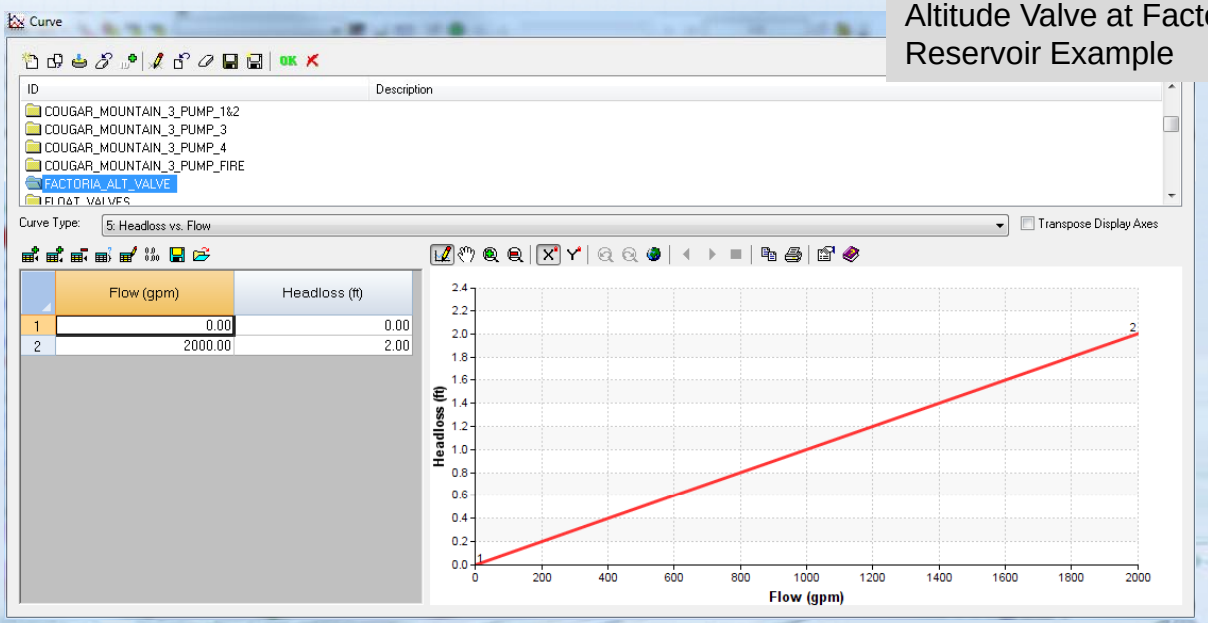
EPS Run

- Necessary adjustments for EPS run
  - Time step
  - Pump controls
  - Altitude valves headloss curves



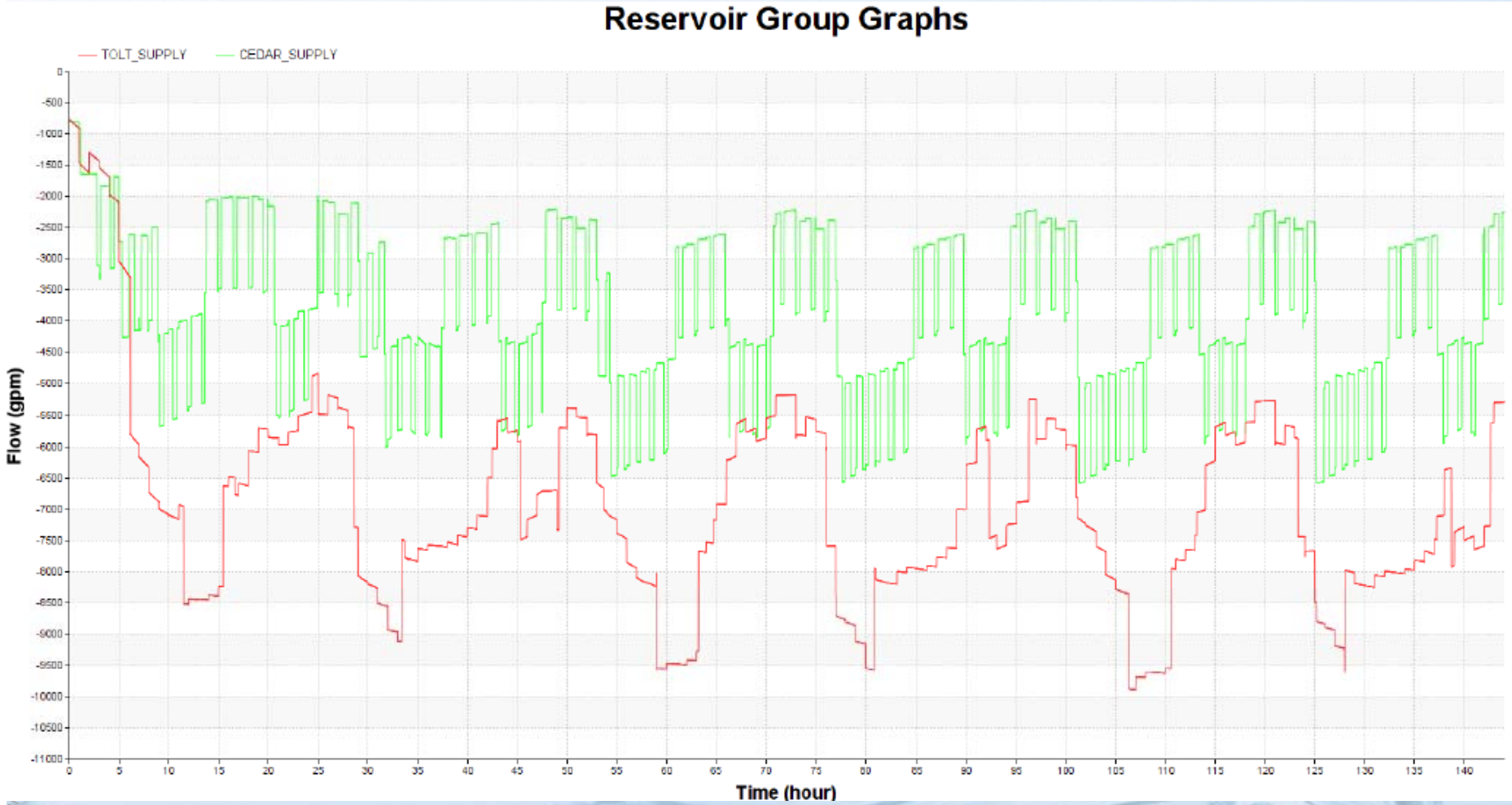
EPS Run – Altitude Valves

- Altitude valves modeled as float valves and require headloss vs flow type curve.
- Typical curve is adjusted to match SCADA data provided by the City.

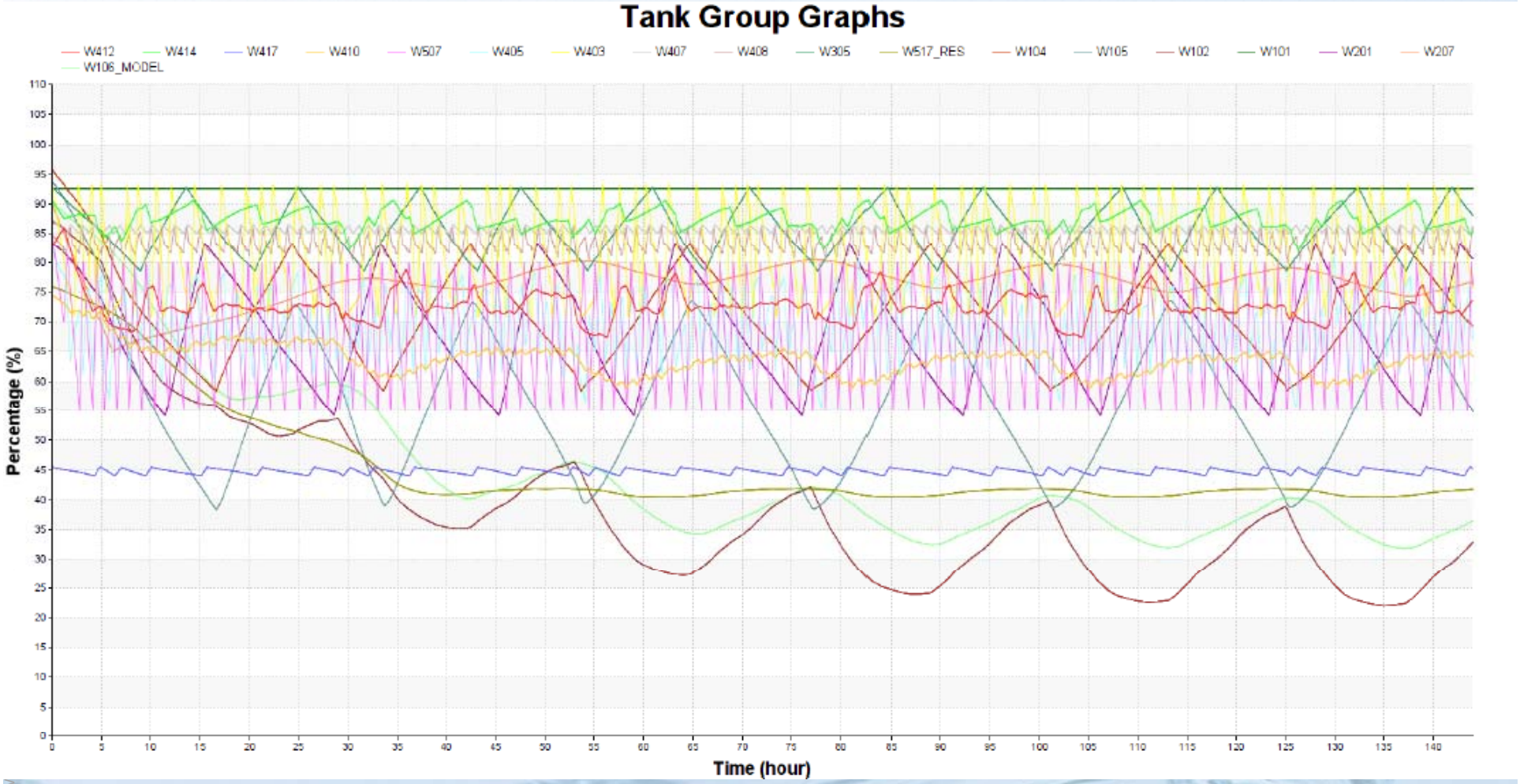


Altitude Valve at Factoria Reservoir Example

EPS Inlet Results Summary for MDD

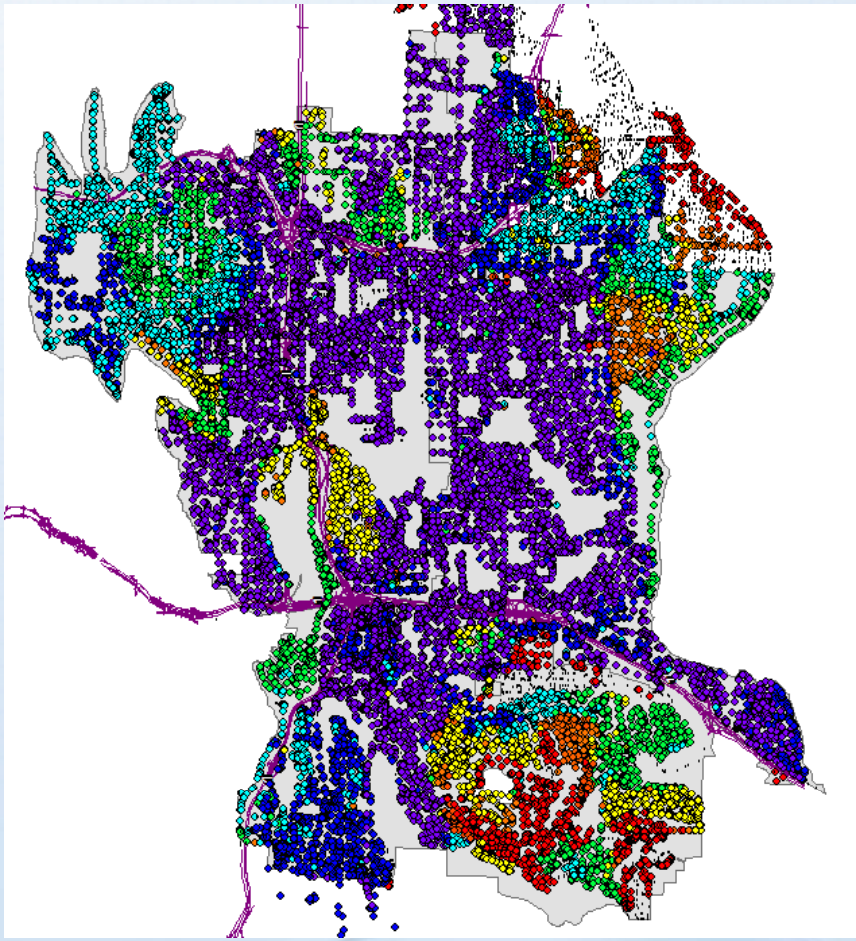


EPS Tank Results Summary for MDD



Subsequent work by the City

- Continual updates
- Added East Operating Area (now entire system)
- Automatic fire flow analysis (all 6,000 hydrants at once)
- Water age mapping
- What-ifs and alternatives analysis



System-Wide Water Age Simulation

Model Development Summary

- A new all pipes integrated model was developed for Bellevue's water service area
- The model is well calibrated for static and EPS making it a good tool for:
  - Fire flow analyses
  - System operations
  - Future projections
  - Water quality

Questions on Building and Calibrating the New Bellevue Water System Model

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PNWS - AWWA

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