

Building and Calibrating the New Bellevue Water System Model

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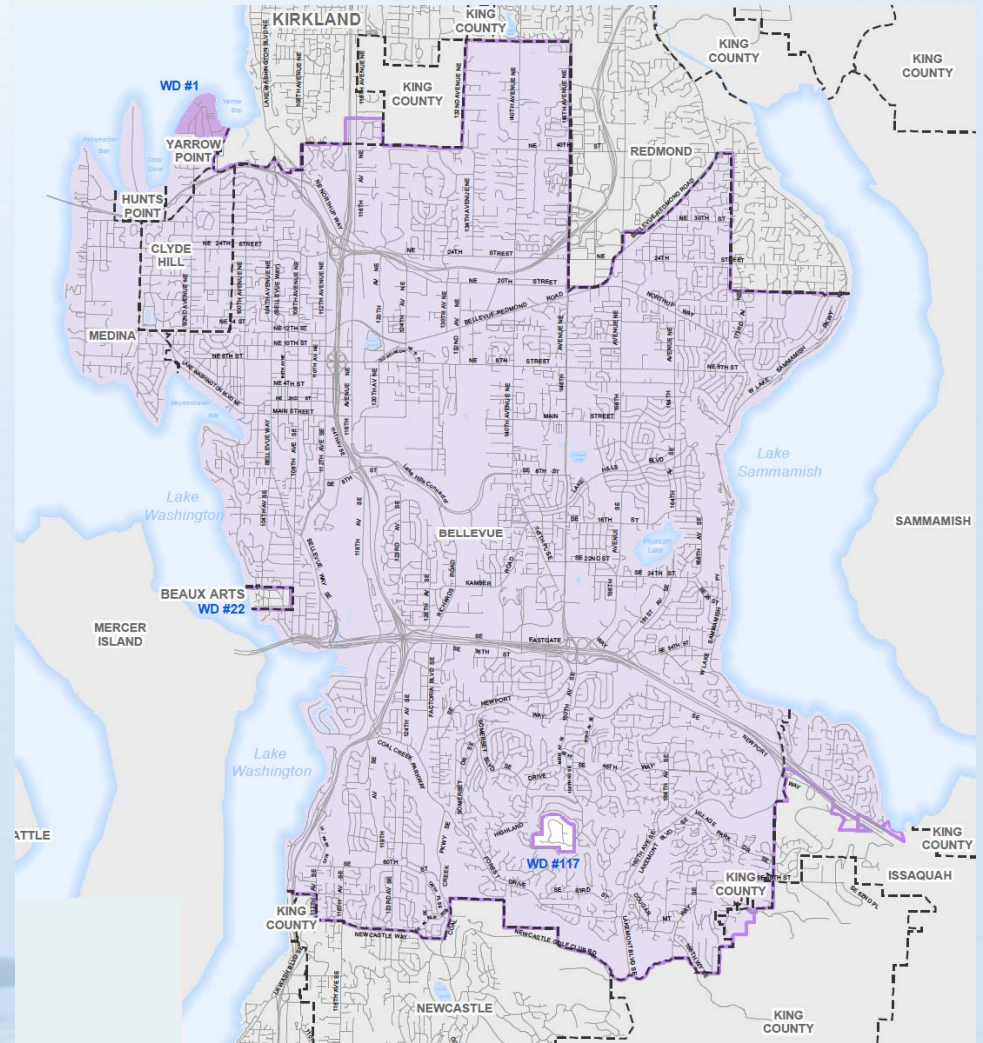
PNWS - AWWA

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

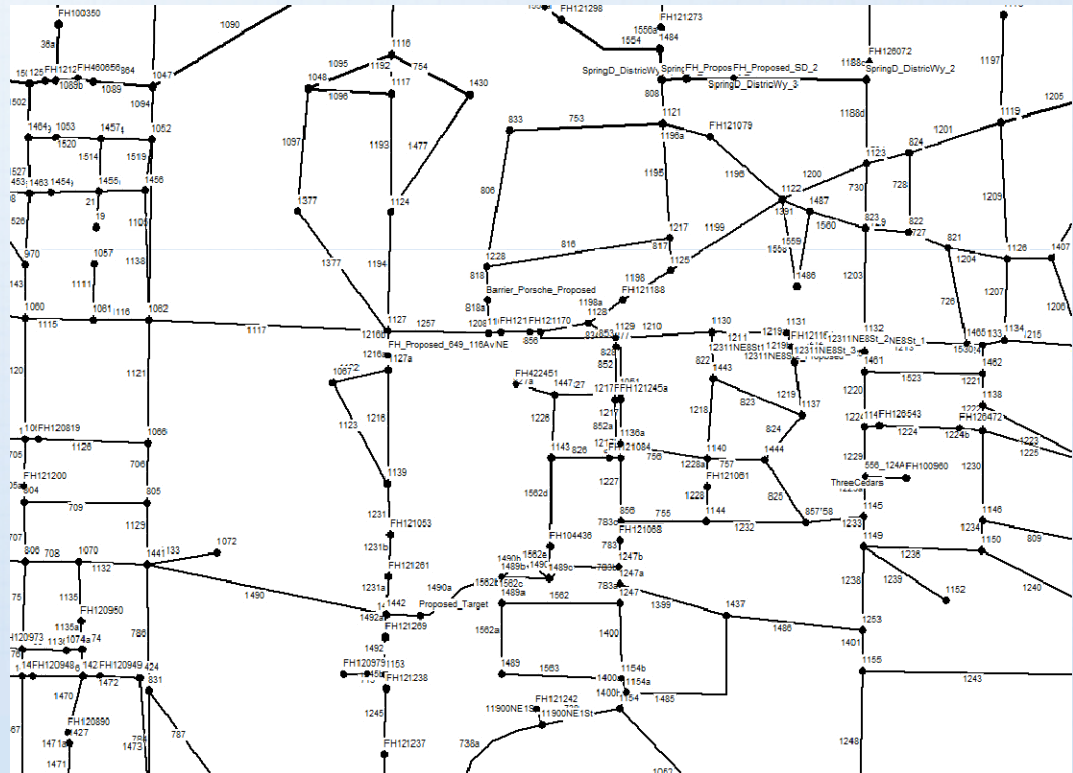
- 600+ miles of pipe
- 64+ pressure zones
- 26 reservoirs (plus share of 4 outside service area)
- 23 pump stations
- 13 inlet stations
- 144 pressure reducing valve (PRV) stations

Bel-Red Inlet



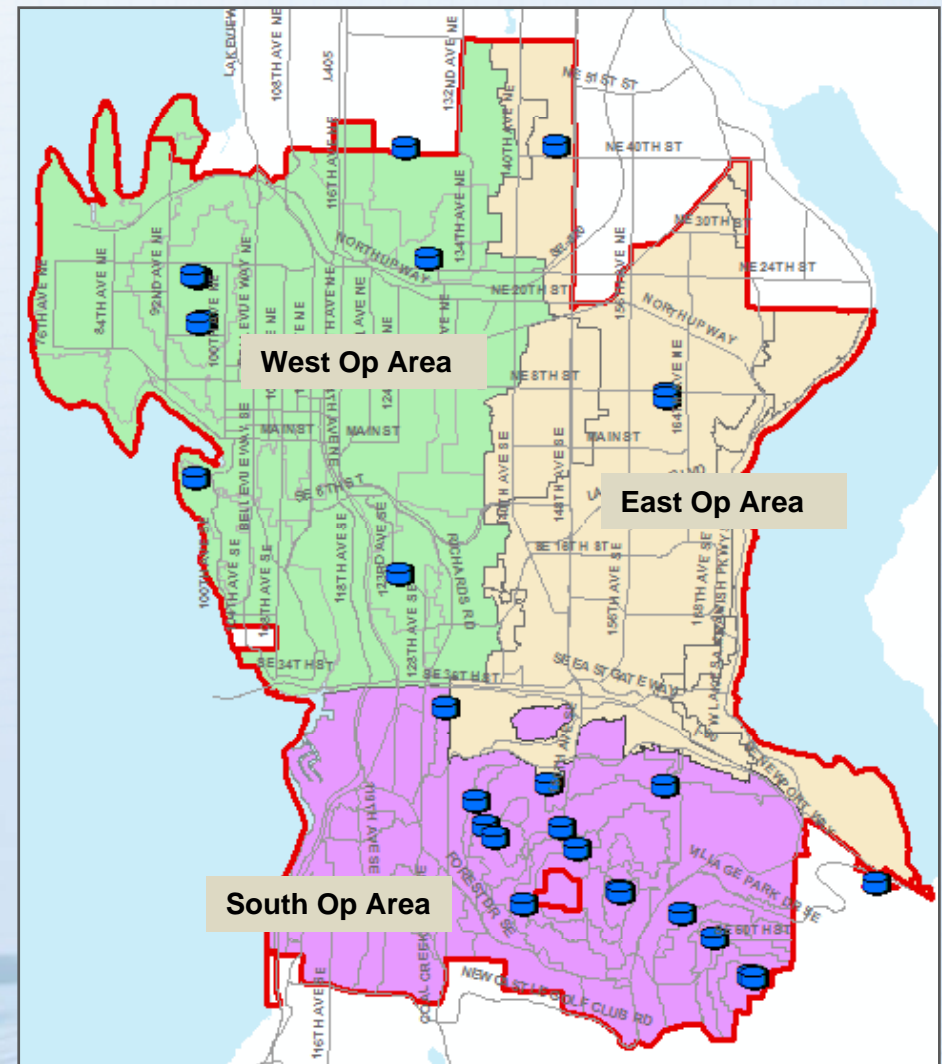
Bellevue Previously Used EPA-NET for Hydraulic Analysis

- 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

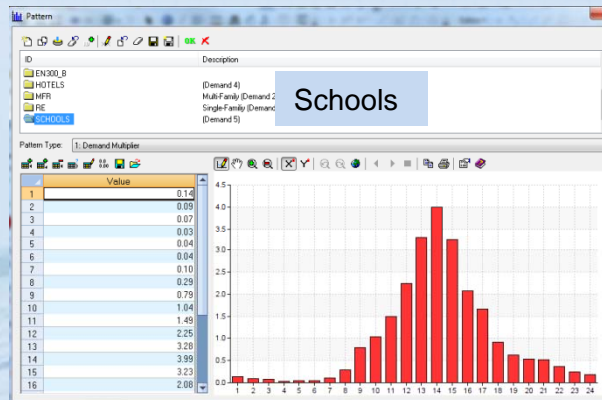
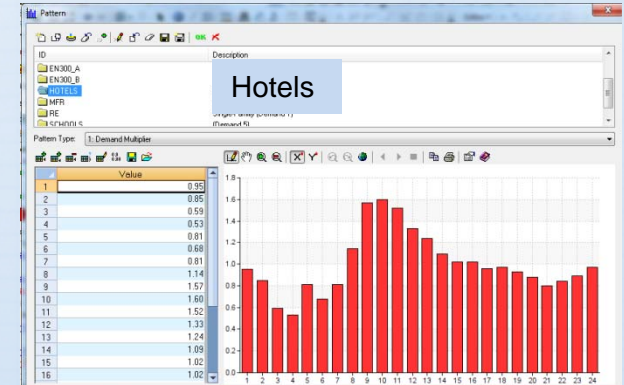
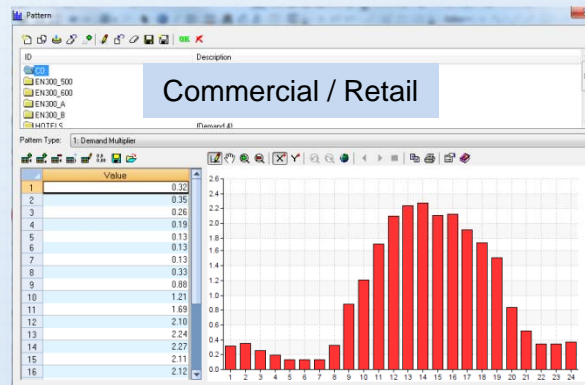
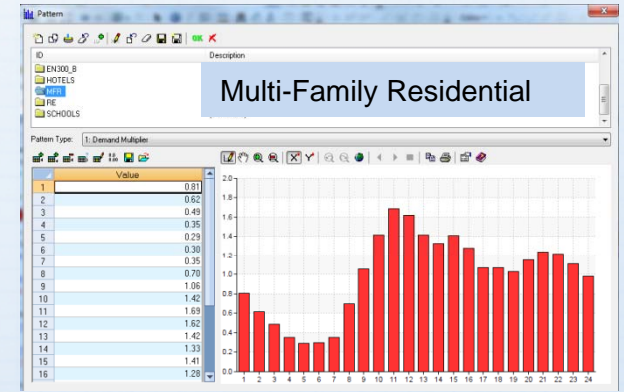
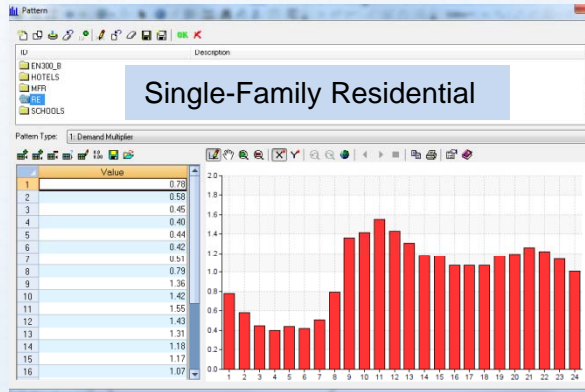
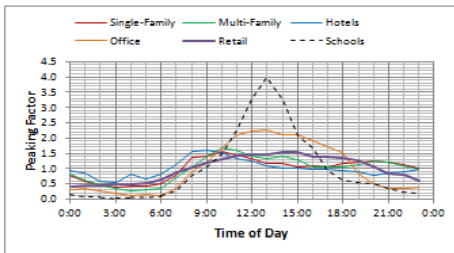
CITY OF BELLEVUE WASHINGTON

DESCRIPTION: Multi-Family Housing Omni-Meter Readings
 Date: 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	1.05	1.69	1.52	1.69	1.31	1.49
11:00	1.43	1.62	1.33	2.40	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

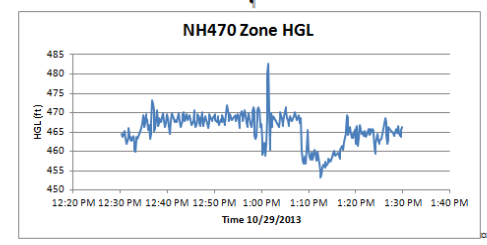
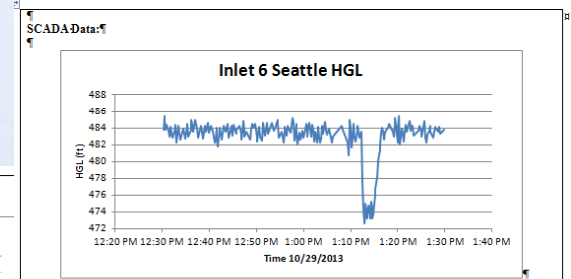
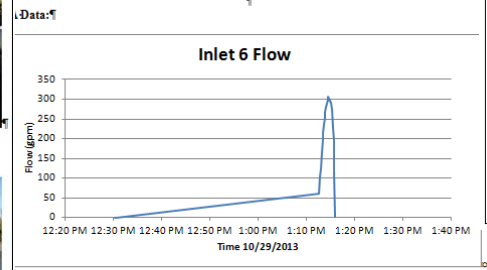
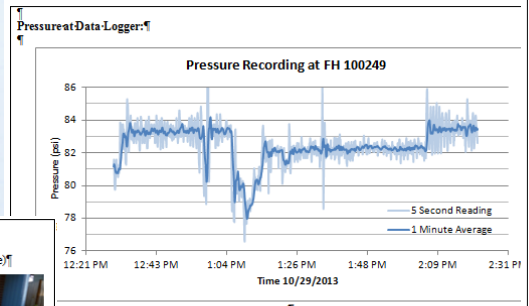


Example of Fire Hydrant Tests Summary

- Hydrant tests performed by the City

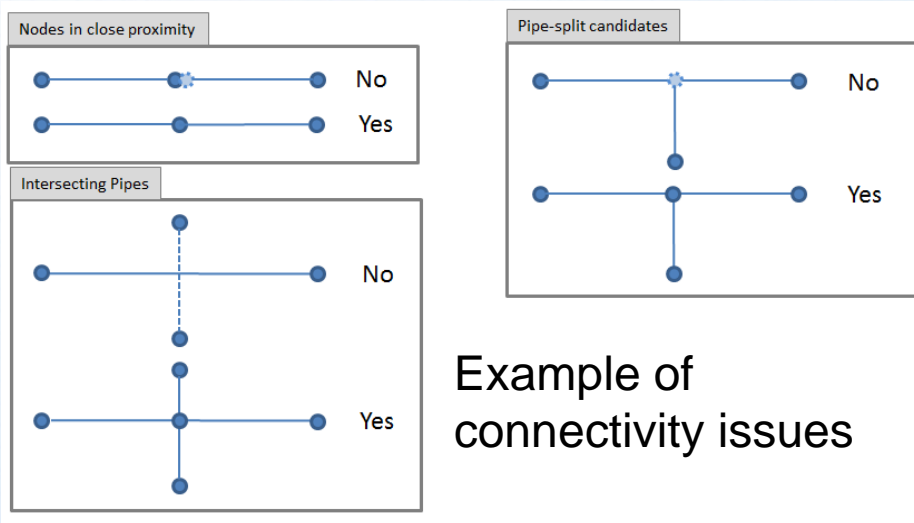
City of Bellevue, Washington Utilities Department		Fire Hydrant Flow Test Report	
Project Name: SOA Model Calibration S-6		Recorded by: D. Lane	
Date: 10/29/2013 Day: Tuesday		Weather: Clear Temp: 50 F	
Flow Hydrant ID Address: 100502		Flow Hydrant Type: Center Stem	
Water System Operators: Tom, Adam, Rick, Scott		Flow Hydrant Size: 4 1/2"	
Others Present: Doug		Visual Condition of Water: Cloudy	
Fire Flow Tested? <input checked="" type="checkbox"/> Y <input type="checkbox"/> N Time Start: 1:05 Stop: 1:15		Flush Conducted? <input checked="" type="checkbox"/> Y <input type="checkbox"/> N Time Start: 1:15 Stop: 2:15	
Downstream Drainage System Ownership: <input type="checkbox"/> COB <input type="checkbox"/> Private <input type="checkbox"/> Other		Downstream Conditions (Prior to Test):	
Downstream Drainage Facilities:		Sediment? <input checked="" type="checkbox"/> Y <input type="checkbox"/> N Comments: Swept before test	
Catch Basin(s): <input checked="" type="checkbox"/> Curbs <input type="checkbox"/> Swales <input type="checkbox"/>		Standing Water? <input type="checkbox"/> Y <input checked="" type="checkbox"/> N Comments: *****	
Detection Pond <input type="checkbox"/> LID <input type="checkbox"/> Other <input type="checkbox"/>		Flowing Water? <input type="checkbox"/> Y <input checked="" type="checkbox"/> N Comments: *****	
Waterways: *****		Traffic? <input type="checkbox"/> Y <input checked="" type="checkbox"/> N Comments: *****	
Other: *****		Private Property? <input type="checkbox"/> Y <input checked="" type="checkbox"/> N Comments: *****	
*****		Erosion Potential? <input type="checkbox"/> Y <input checked="" type="checkbox"/> 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 <input checked="" type="checkbox"/> Sandbags <input checked="" type="checkbox"/> Street Cleaning			
Comments: Started 12:58. at low flow some water trickled			
. (5206116 PISE) changed setup after that (stopped flow			
. At 1:38 with one port. 780 gpm. 38 psi at both residuals			

Follow-Up:			
Pressure Lower Than Expected? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> N/A			
Drainage Problems Observed: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> N/A			
Comments: Water on driveway at 5206116 noted about			
. reach garage and problem did not occur after re-routing			
. *****			

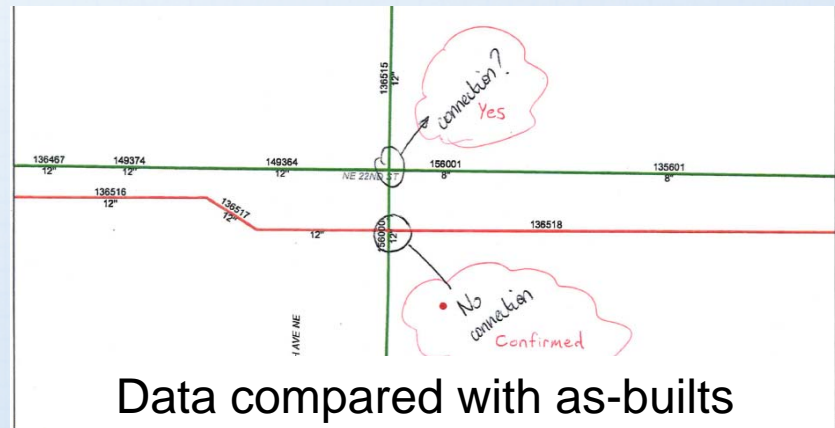


GIS Cleaned, Organized and Formatted

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



Example of connectivity issues



Table

W_PipesAsBUILT

OBJECTID *	Shape *	ASSETNUM	PressureZone	LOCATION	INFOSOURC	FILECOMME	WFEATCLA	VERIFIEDDA	ACAD_HAN	MATERIAL	MAINTENAN	DIAMETER	AUTOCAD	LOCATIONI	PIPEPRESSU	LININGSTAT	CREATEUSE	VMODELNO	FILENUMBE	DATECREAT	CLASS_CO	GISLENGTH	
1	Polyline	421024	CL0335	<Null>	ASB	<Null>	WLINE	<Null>	1EA	DI	<Null>	4	WA-DIST-EX	<Null>	<Null>	<Null>	COBUTLADM	0	<Null>	01/28/2005	1	DIST	257
							WLINE	<Null>	74F	AC	1	6	WA-DIST-EX	<Null>	<Null>	<Null>	COBUTLADM	0	<Null>	01/28/2005	1	DIST	351
							WLINE	<Null>	D69	AC	1	6	WA-DIST-EX	<Null>	<Null>	<Null>	COBUTLADM	0	<Null>	01/28/2005	1	DIST	134
							WLINE	<Null>	D6C	DI	1	8	WA-DIST-EX	<Null>	<Null>	<Null>	COBUTLADM	0	<Null>	01/28/2005	1	DIST	139
							WLINE	<Null>	D6D	AC	<Null>	6	WA-DIST-EX	<Null>	<Null>	<Null>	COBUTLADM	0	<Null>	01/28/2005	1	DIST	32
							WLINE	<Null>	D6E	AC	<Null>	6	WA-DIST-EX	<Null>	<Null>	<Null>	COBUTLADM	0	<Null>	01/28/2005	1	DIST	28

Initial GIS Data

Table

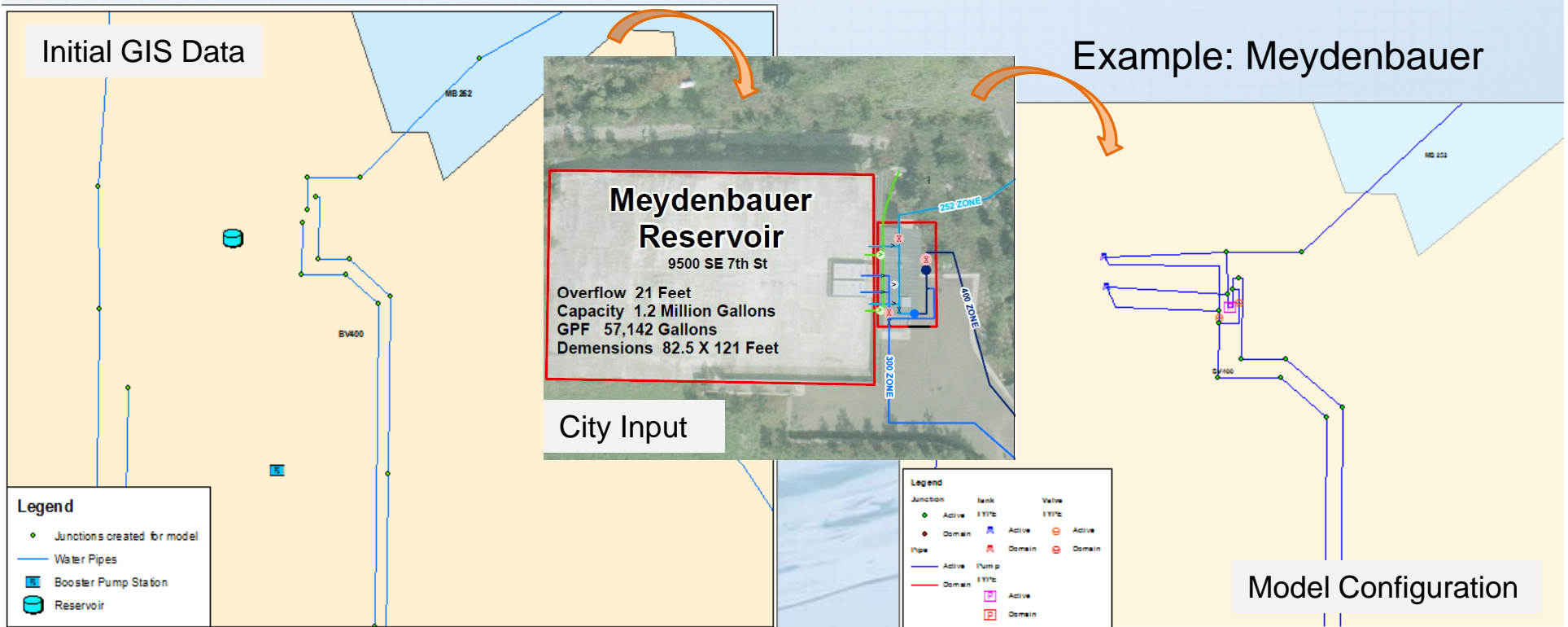
Pipelines_AsBuilts

FID	Shape *	OBJECTID	ASSETNUMBE	Source	Junc_From	Junc_To	ID	Length	Calc_Lengt	Diameter	ROUGHNESS	MINORLOSS	YR_INST	ZONE	Material	Notes	DESCRIPT
0	Polyline	1	421024	W_PipesAsBuilt	COB1000000	COB2000001	COB2000001	225	253.817789	4	0	0	1982	CL033	DI		
1	Polyline	2	133474	W_PipesAsBuilt	COB1000002	COB1000003	COB2000002	351	355.776373	6	0	0	1948	CI 033	AC		7560 NE 28TH PL 1605 73RD AVE NE 2203 EVERGREEN POINT RD
2	Polyline																
3	Polyline																
4	Polyline																
5	Polyline																
6	Polyline	7	117040	W_PipesAsBuilt	COB1000012	COB1000013	COB2000007	270	266.442404	6	0	0	1964	CL033	AC		73RD PL NE AND 74TH PL NE
7	Polyline	8	155416	W_PipesAsBuilt	COB1000014	COB1000015	COB2000008	18	33.926704	6	0	0	1964	CL033	AC		NE 18TH ST AND RAMBLING LN

Formatted GIS data imported in InfoWater

Site Configurations Added

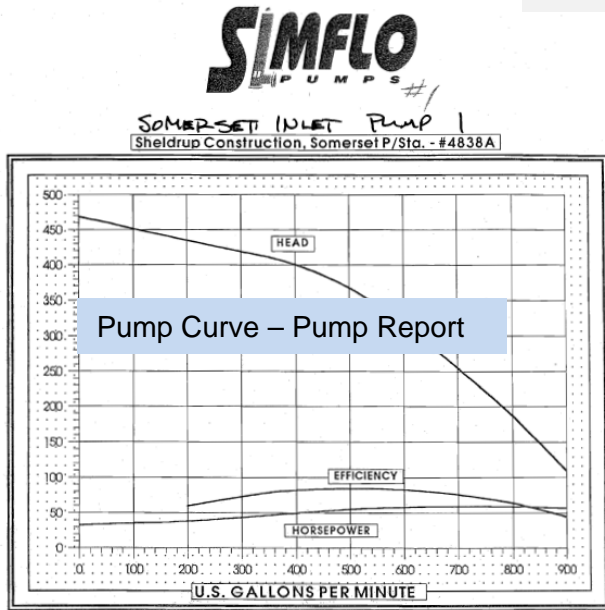
- Pump stations, reservoirs, inlets, and interties from site configuration drawings and as-built drawing



Facility Data Input in InfoWater

- Example: pump station required information

Example: Somerset Inlet Pump 1



GPM	HEAD	HP	EFF.
0	458.26	32.80	0.00
200	434.50	37.00	59.31
300	418.76	43.53	72.87
350	411.34	46.12	78.82
400	401.28	49.33	82.17
500	371.41	55.13	85.07
600	318.78	57.96	83.33
700	256.02	59.20	76.45
800	188.48	58.70	64.86
900	109.94	56.48	48.24

Somerset Inlet pumps to Somerset 2			
Pump	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			
Pump 1			1100
Pump 2			1100
	17	17.5	850

City Provided Control Setpoints

The flow rate at the inlet valve controls the dyna

Model Explorer

2014_ADD_EPS
"Active":Standard
Refresh Output
00:00 hrs

PUMP: W505, SOMERSET INLET PUMP (Pump 1)

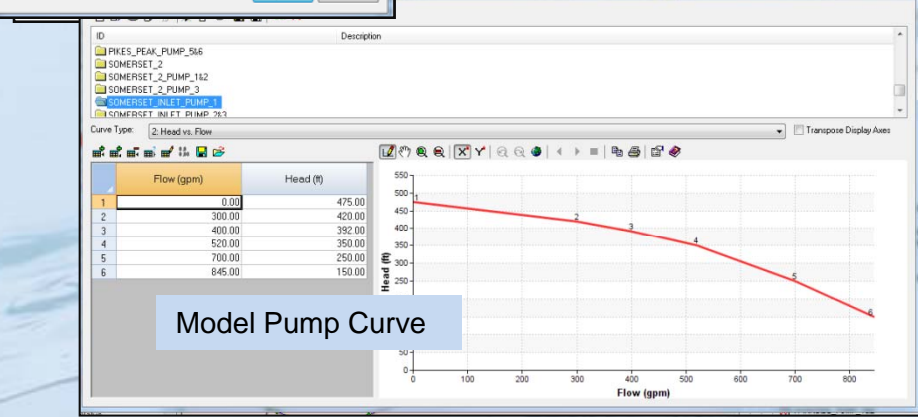
(ID)	W505
Description	SOMERSET INLET PUMP (Pump 1)
Geometry	
X	1311374.604856940
Y	209757.552395105
Modeling	
Type	3: Multiple Point Curve
Elevation (ft)	272.66
Diameter (in)	6.00
Constant Power (hp)	0.00
Shutoff Head (ft)	0.00
Design Head (ft)	392.00
Design Flow (gpm)	400.00
High Head (ft)	0.00
High Flow (gpm)	0.00
Curve	SOMERSET_INLET_PUMP_1
NPSH Curve	
Information	
Year of Installation	1993
Year of Retirement	
Zone	SS550
Rated Power	0.00
Cost ID	
Phase	
OPER_AREA	South
TYPE	Supply Inlet Pump
Output	
Flow	0.00 gpm
Head Gain	0.00 ft
Upstream Pressure	91.99 psi
Downstream Pressure	184.30 psi

Pump Control: W505 (Defined)

Status Type: Open
Method: Pressure/Head
Node ID: W507
Level Value: Below

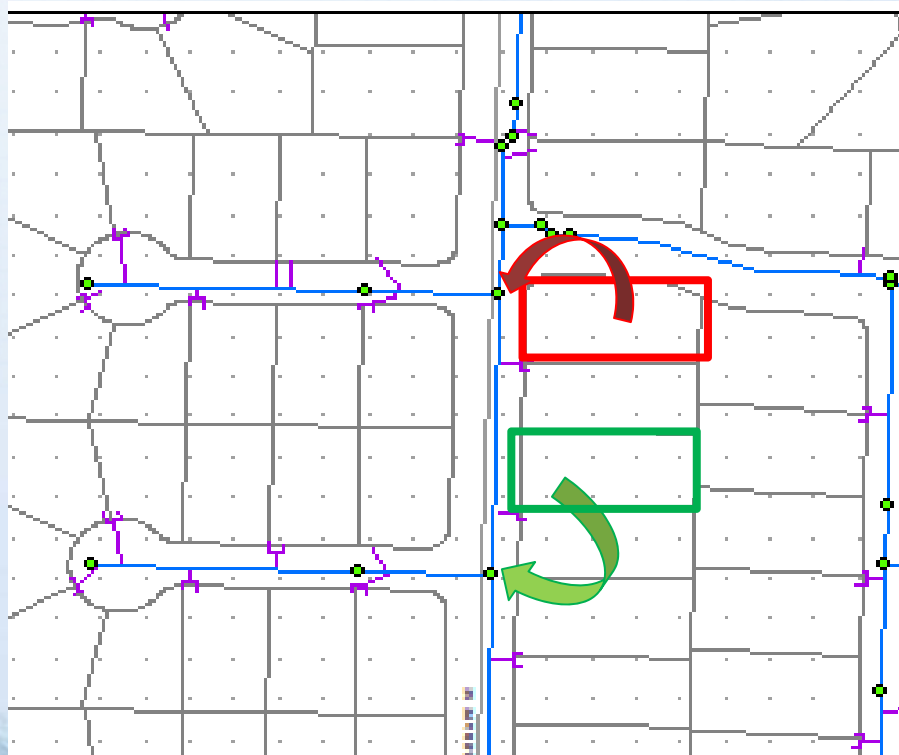
Control Data:

Disabled	Action	Condition
<input type="checkbox"/>	No	# level at Node: W507 below 7.000
<input type="checkbox"/>	No	# level at Node: W507 above 8.500

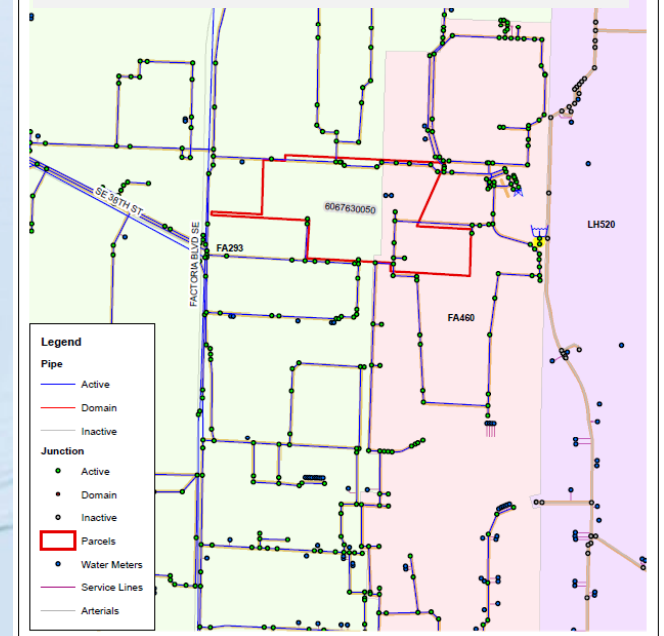


Model Loading

- 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

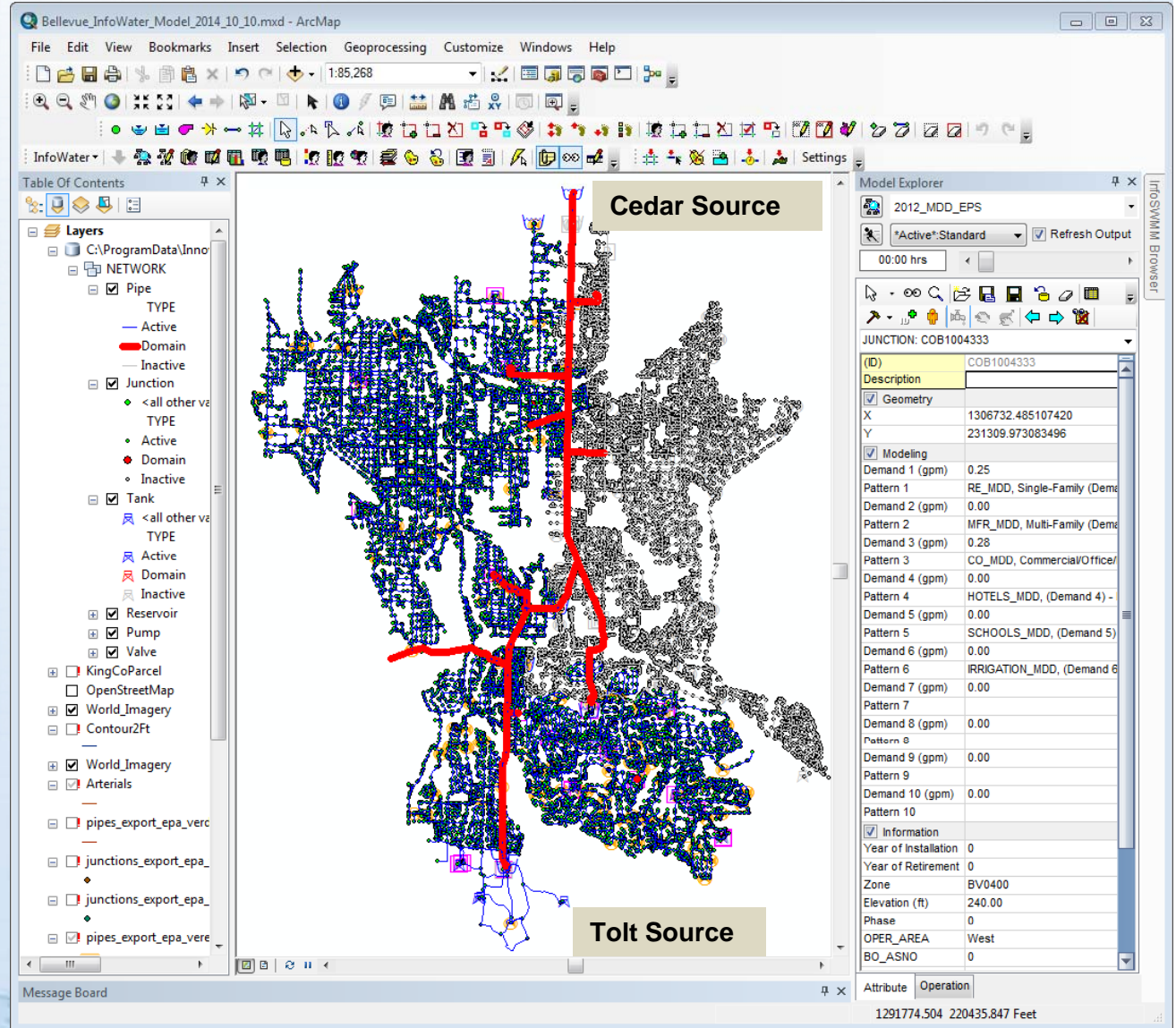


Example parcel where it is unclear which pressure zone it serves



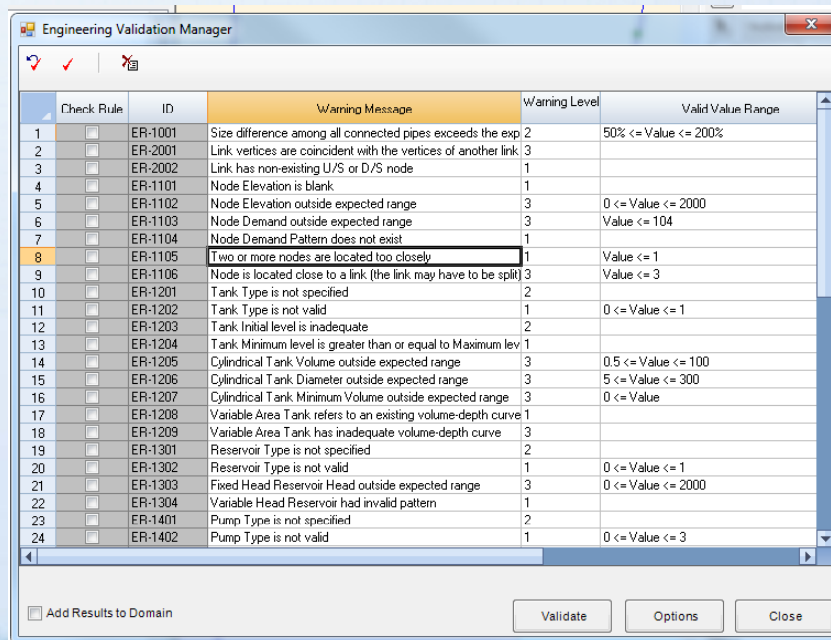
West and South Hydraulic Model with SPU Supply

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



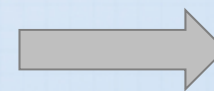
Initial Model Checks

- 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



The screenshot shows the 'Engineering Validation Manager' window with a table of validation rules. The table has columns for 'Check Rule', 'ID', 'Warning Message', 'Warning Level', and 'Valid Value Range'. Row 8 is highlighted, showing a warning for 'Two or more nodes are located too closely'.

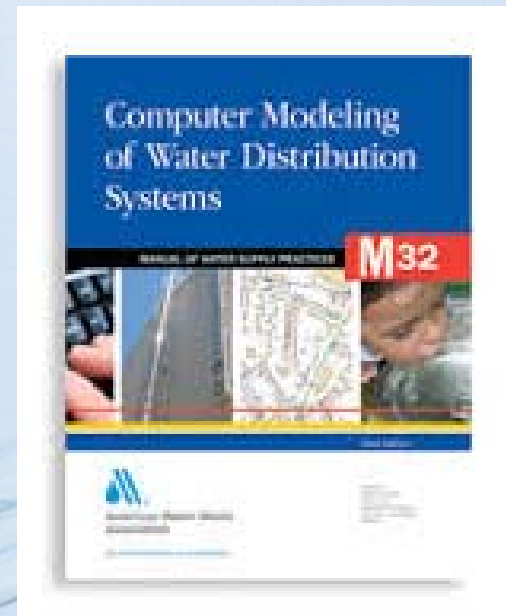
Check Rule	ID	Warning Message	Warning Level	Valid Value Range
1	ER-1001	Size difference among all connected pipes exceeds the exp	2	50% <= Value <= 200%
2	ER-2001	Link vertices are coincident with the vertices of another link	3	
3	ER-2002	Link has non-existing U/S or D/S node	1	
4	ER-1101	Node Elevation 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

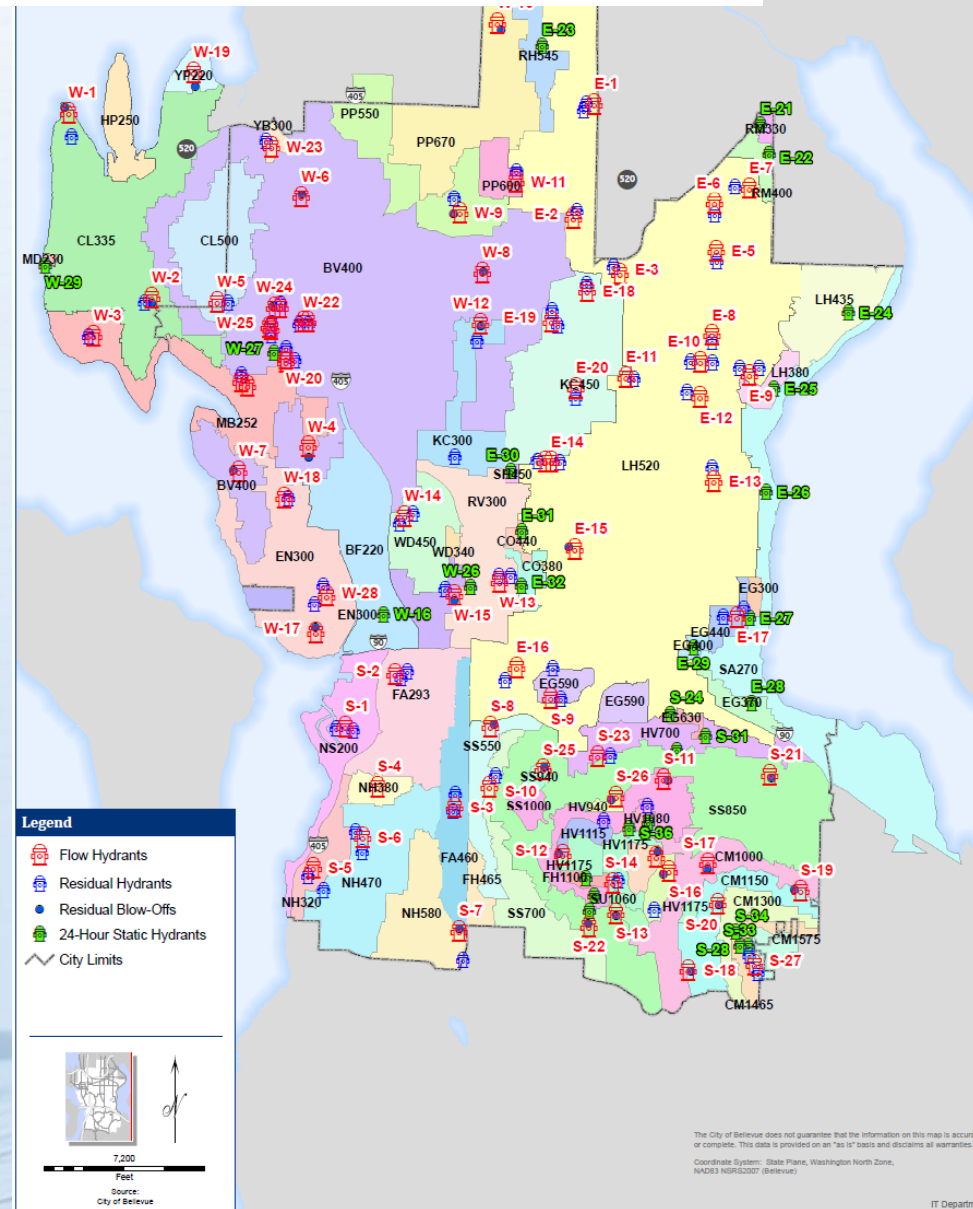
Fire Hydrant Calibration Criteria

- 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

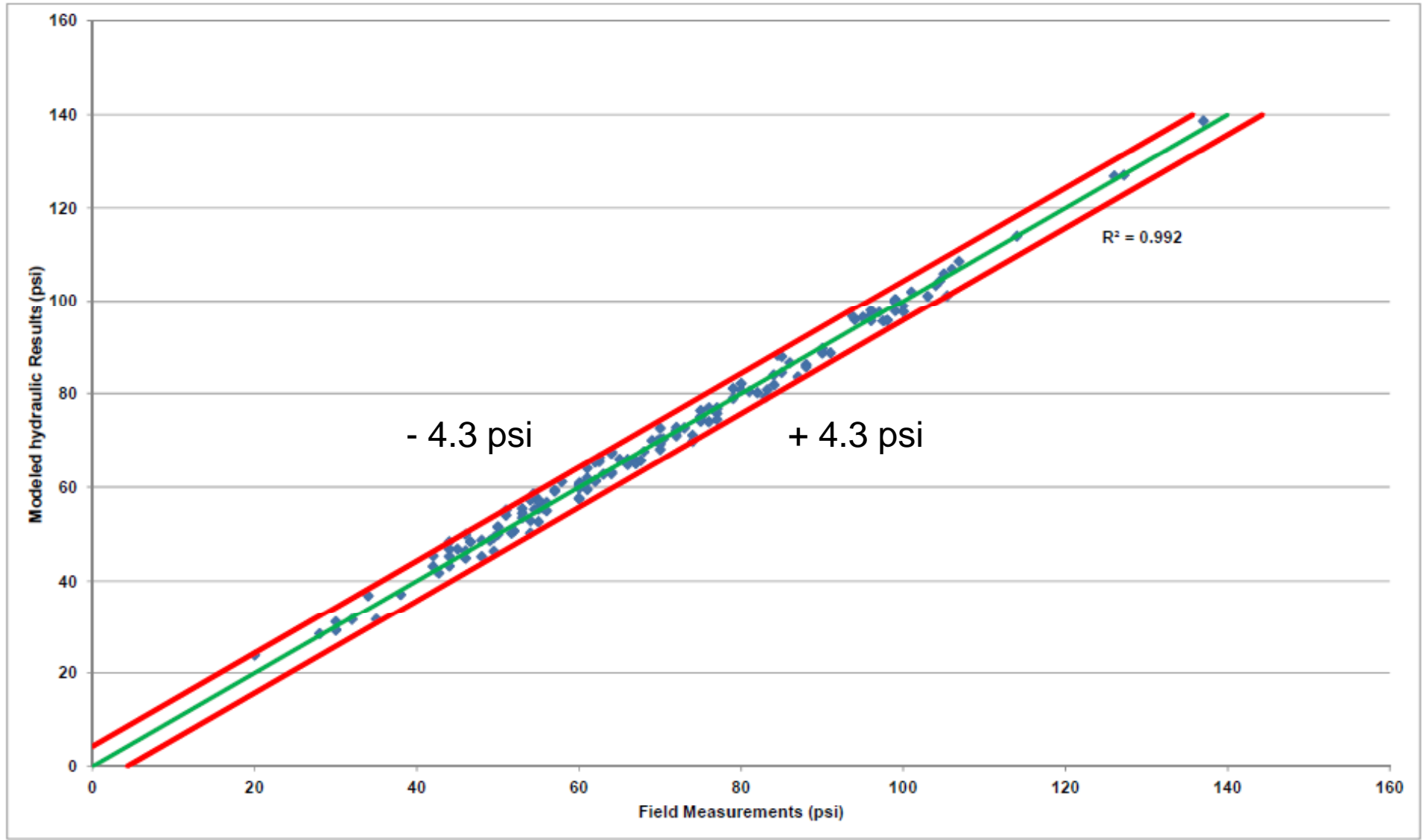


Fire Hydrant Calibration

- 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

City of Bellevue, Washington Utilities Department		Fire Hydrant Flow Test Report Recorded by <u>B. Roberg</u>	
Project Name: <u>WOA Model Calibration W-1</u>		Date: <u>12/13/2013</u> Day: <u>Friday</u>	
Flow Hydrant ID/Address: <u>101117</u>		Light Rain Temp: <u>46 F</u>	
Water System Operators: <u>Bob H. Adam</u>		Hydrant Type: <u>Center Stem</u>	
Others Present: <u>Doug, Ben</u>		Hydrant Size: <u>5 1/4"</u>	
Fire Flow Tested? Y <input checked="" type="checkbox"/> N <input type="checkbox"/> Time Start: <u>9:46</u> Stop: <u>9:55</u>		Visual Condition of Water: <u>Cloudy</u>	
Flush Conducted? Y <input checked="" type="checkbox"/> N <input type="checkbox"/> Time Start: <u>9:55</u> Stop: <u>10:50</u>		After test before flush	
Downstream Drainage System Ownership: COB <input type="checkbox"/> Private <input checked="" type="checkbox"/> Other Medina		Downstream Conditions (Prior to Test): Sediment? Y <input type="checkbox"/> N <input checked="" type="checkbox"/> Comments:	
Downstream Drainage Facilities: Catch Basin(s) <input type="checkbox"/> Curbs <input type="checkbox"/> Swale <input type="checkbox"/> Detention Pond <input type="checkbox"/> LID <input type="checkbox"/> Other <input type="checkbox"/> Waterways: <u>Lake Washington</u> Other:		Standing Water? Y <input type="checkbox"/> N <input checked="" type="checkbox"/> Comments:	
Hydrant Flow		Location Pressure Measurements	
Dechlorination Method: <u>Vita-D-Chlor</u> Quantity Used/ # Tablets: <u>Kept canister full</u>			
Hydrant Port 1: Dia: <u>-</u> Pitot: <u>-</u> psi Flow: <u>550 gpm</u> Ports Open: 1 <input checked="" type="checkbox"/> 2 <input type="checkbox"/> N/A <input type="checkbox"/>			
Hydrant Port 2: Dia: <u>-</u> Pitot: <u>-</u> psi Flow: <u>0 gpm</u> Total Flow: <u>550 gpm</u>			
Static Pressure 1: <u>126 psi</u> Residual Pressure 1: <u>98 psi</u> Static/Residual Location 1: <u>BO 124368</u>			
Static Pressure 2: <u>99 psi</u> Residual Pressure 2: <u>76 psi</u> Static/Residual Location 2: <u>101122</u>			
Static and Residual Pressure Test Results		Sewer <input type="checkbox"/> Sheet Flow <input type="checkbox"/> Other <input checked="" type="checkbox"/>	
Set sign to contain flow at catch			
Follow-Up: Pressure Lower Than Expected?: Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> N/A <input type="checkbox"/> Potential Backflow: Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> N/A <input type="checkbox"/> Drainage Problems Observed: Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> N/A <input type="checkbox"/> Cleanup Needed: Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> N/A <input type="checkbox"/> Comments:			

Hydrant Test Results Summary For All Tests



EPS Run

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

The screenshot shows the 'Run Manager' window with the following settings:

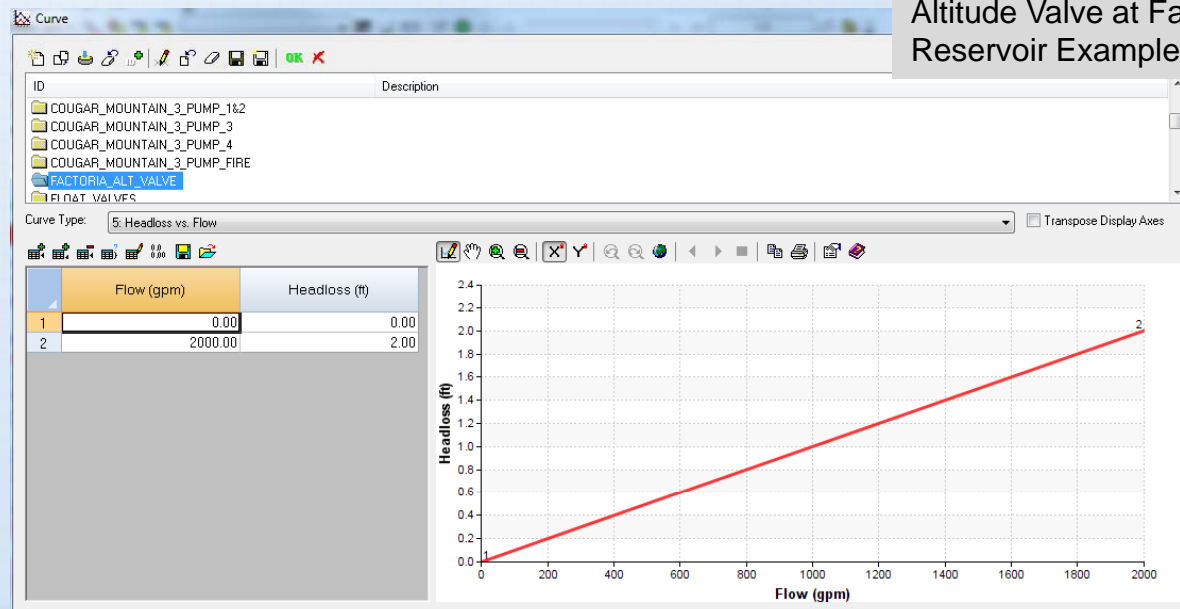
- Output Source: Name: *Active*:Standard, Reference: 2014_ADD_EPS, Standard Hydraulic/Quality Simulation
- Standard: Selected
- Report Options: BASE, Base Simulation Report
- Simulation Options: BASE, Base Simulation Option
- Time Setting: EPS_RUN
- Explicit Variable Speed Pump / Fixed Pressure Pump And: Run Explicit VSP/FPP
- Run Pressure Demand Simulation (Domain Required):
- Pressure Demand Characteristics Curve (X: Pressure, Y:): CLYDE_HILL_335_SQ

The 'Simulation Time' dialog box is open, showing the following table:

Category	Unit	Decimal Time	Clock Time
Duration	Hours	72.0000	
Hydraulic Timestep	Hours	0.1000	
Pattern Timestep	Hours	1.0000	
Quality Timestep	Hours	1.0000	
Report Timestep	Hours	0.0500	
Rule Timestep	Hours	0.1000	
Pattern Start	Hours	0.0000	
Report Start	Hours	0.0000	
Start Clocktime	Clock Time		00:00:00

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.



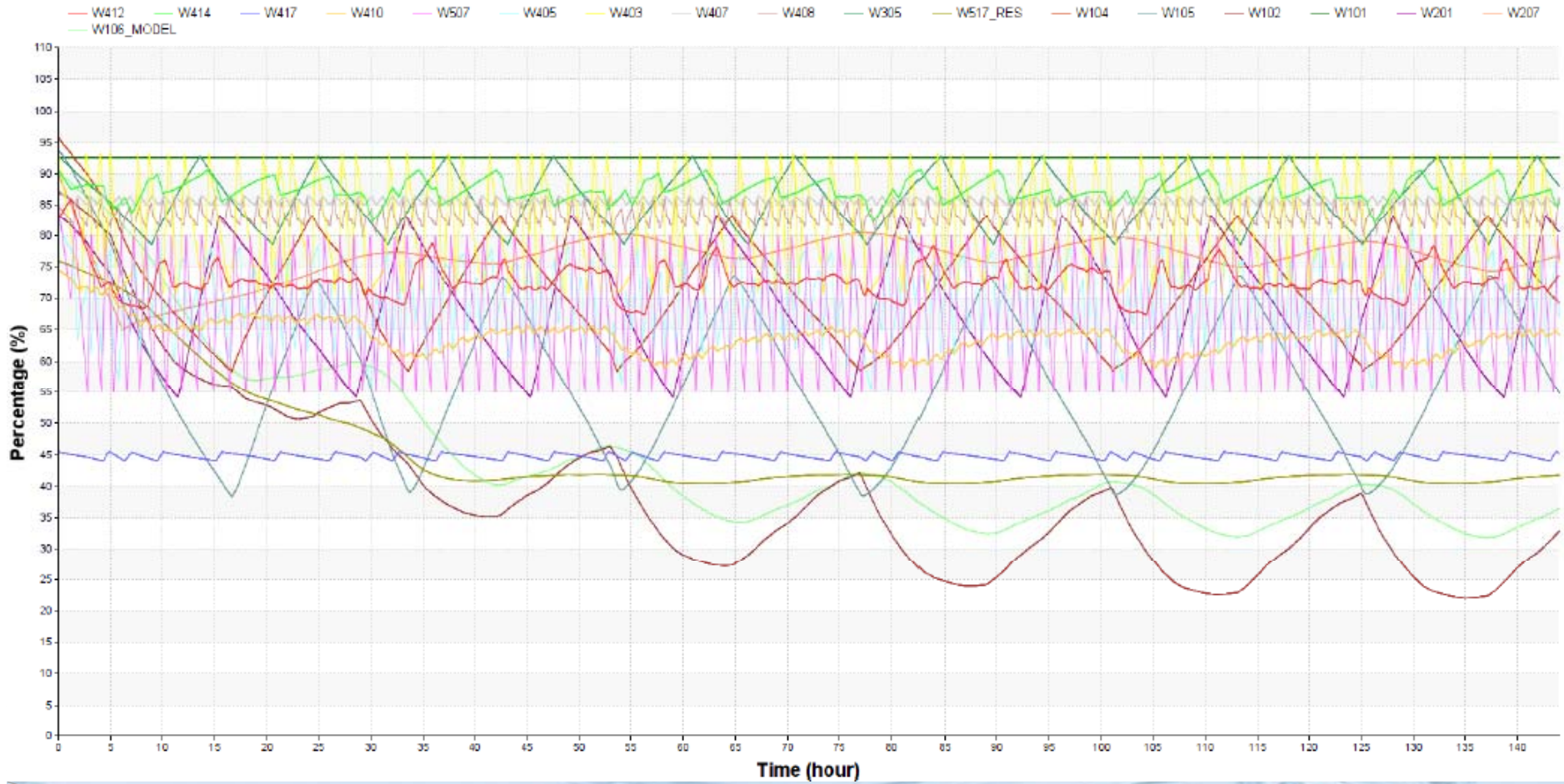
EPS Inlet Results Summary for MDD

Reservoir Group Graphs



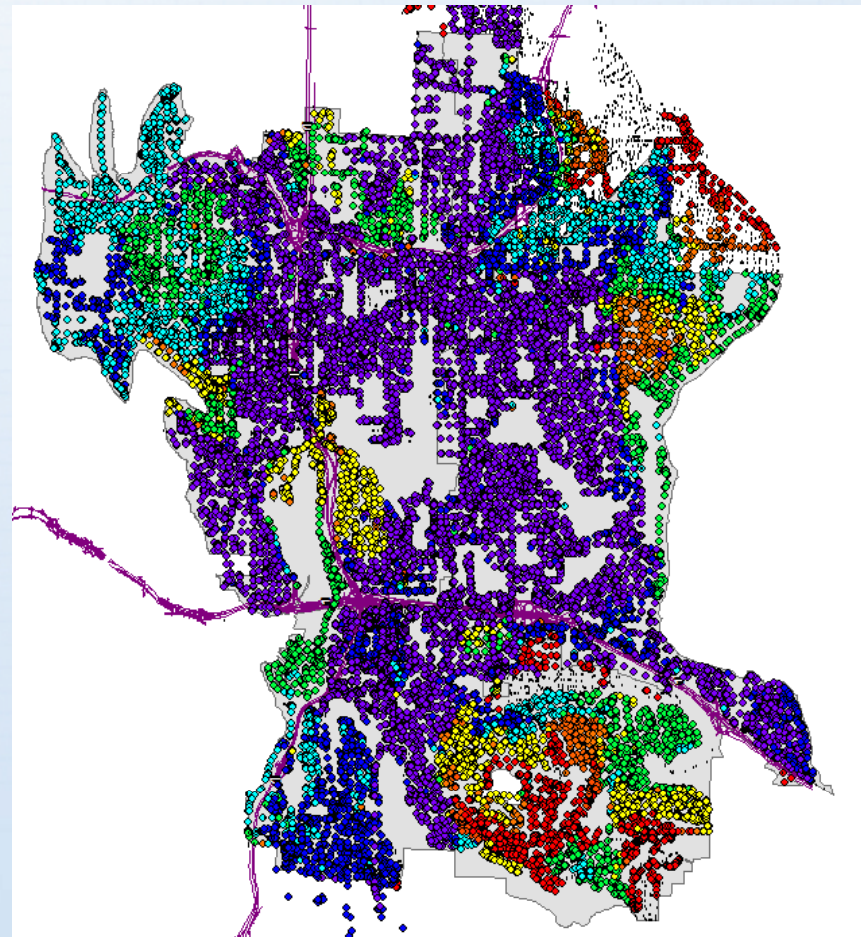
EPS Tank Results Summary for MDD

Tank Group Graphs



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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