HRG
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Engineering & Related Services
AN EMPLOYEE-OWNED COMPANY

Hydraulic Water Modeling – A Capital Improvement Planning Tool

2016 PMAA Annual Conference and Trade Show

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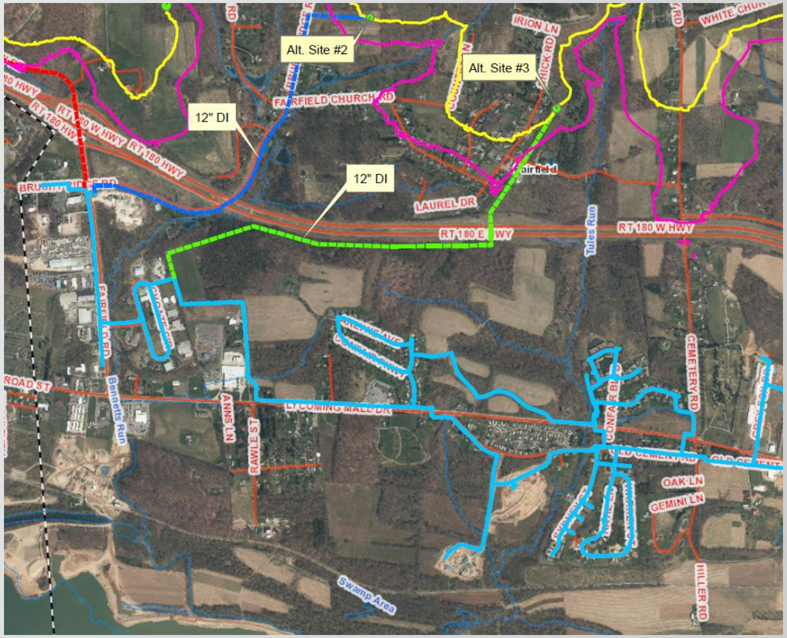


Presentation Overview

1. **What is a Water Model?**
2. **What Information is Needed?**
3. **System Analysis & Capital Improvement Planning**
   a) Water Pressures & Reliability
   b) Fire Protection Goals
   c) Future Growth and Development
   d) Water Quality Issues

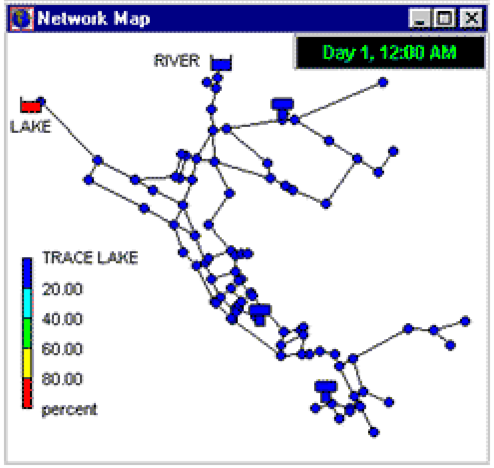
What is a Hydraulic Water Model?

- A computer simulation of a water distribution system that effectively allows for the analysis of various components of the system based on changing demands and can help demonstrate the effectiveness of proposed solutions.

- **Looks at:**
  - ✓ Water Distribution Piping Network
  - ✓ Pumping Systems
  - ✓ Water Storage Systems

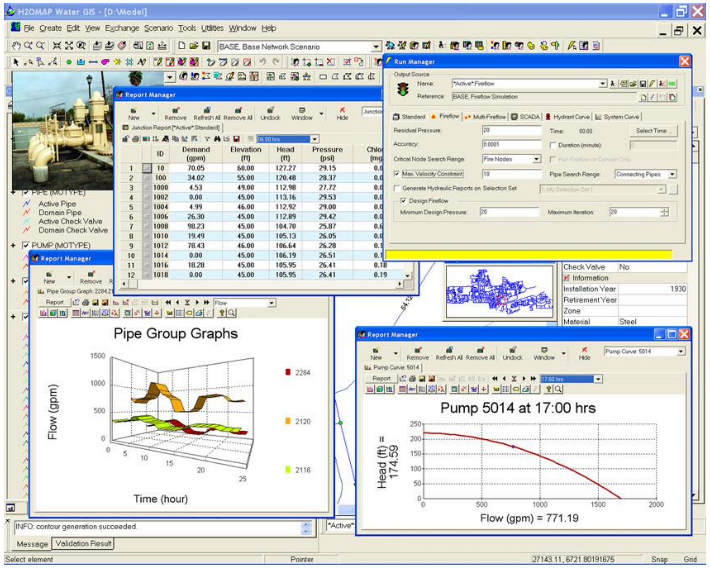
- **Provides Ability to:**
  - ✓ Identify Bottlenecks
  - ✓ Predict Pressures
  - ✓ Analyze Water Quality
  - ✓ Plan for the Future

Hydraulic Water Modeling Software



- **EPANET from the US EPA**
  - http://www.epa.gov/nrmrl/wswrd/dw/epanet.html
  - Free Software Online
  - Limited Functionality
  - No Formal Technical Support
  - Last Updated in 2005

- **Innovyze ® (H_2ONET ®, H_2OMAP Water ®, others)**
  - http://www.innovyze.com/
  - Numerous water modeling programs
  - Formerly MWH Soft



Hydraulic Water Modeling Software

- **Bentley® (Water CAD ®, WaterGEMS ®, HAMMER ®, others)**
  - http://www.bentley.com/en-US/
  - Numerous water modeling programs
  - Compatible with:
    - AutoCAD
    - ESRI ArcGIS
    - MicroStation
    - Stand-Alone Platform


Bentley
Sustaining Infrastructure

WaterGEMS

Water Distribution Modeling and Management

WaterGEMS is a hydraulic modeling application for water distribution systems with advanced interoperability, geospatial model building, optimization, and asset management tools. From fire flow and constituent concentration analyses, to energy consumption and capital cost management, WaterGEMS provides an easy-to-use environment for engineers to analyze, design, and optimize water distribution systems.

Superior Interoperability

WaterGEMS users enjoy the power and versatility afforded by working across CAD, GIS, and stand-alone platforms while accessing a single, shared, project data source. With WaterGEMS, utilities and consultants can choose to model from within four interoperable platforms:

- Windows stand-alone for ease of use, accessibility, and performance
- ArcGIS for GIS integration, thematic mapping, and publishing
- MicroStation for bridging geospatial planning and engineering design environments
- AutoCAD for CAD layout and drafting

WaterGEMS runs in its stand-alone platform, but also from within ArcGIS, AutoCAD, and MicroStation.

Presentation Modeling:

Bentley ® Water GEMS ® V8i

Presentation Mapping:

ESRI ® ArcMap™ 10.1

Getting Started…

- **The model is only as good as the information put into it!**
- **Informational Needs include:**
  - System Mapping
  - Waterline Characteristics
  - Tank Characteristics
  - Pump Stations, WTPs, Entry Points
  - Water Demands

➢ **The level of modeling desired will dictate the amount of information needed**

System Mapping

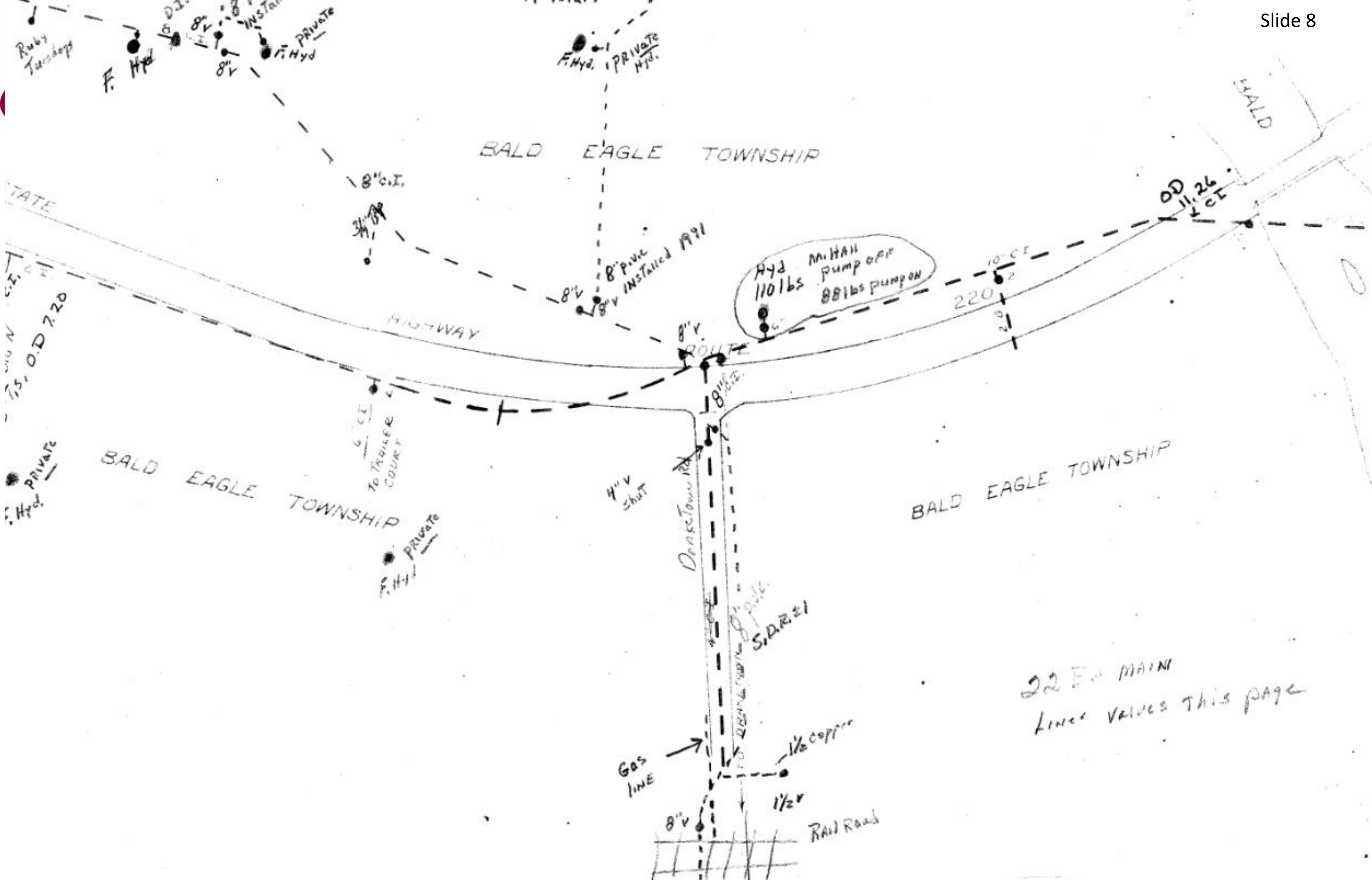
- **Useful mapping information can be obtained from:**
  - **Hard copies of system mapping**
  - **AutoCAD files**
  - **GIS Database**
  - **Record Drawings**

- **County and State GIS data is helpful**

- **Goal is to develop the critical water distribution network into a model**

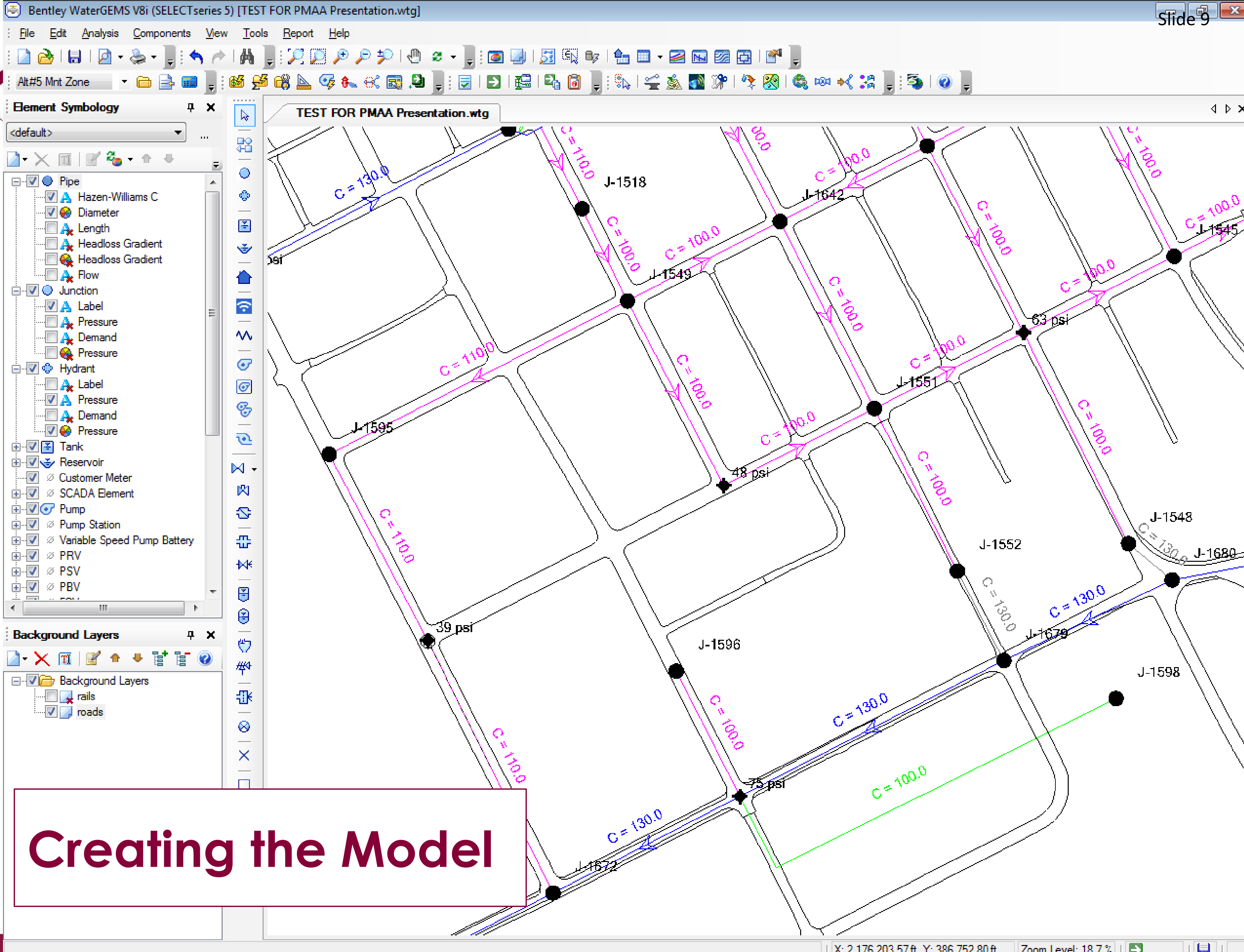
- **Precise location of the waterlines and appurtenances is not required**

- **Skeletonized Model can save time and create a valuable model**

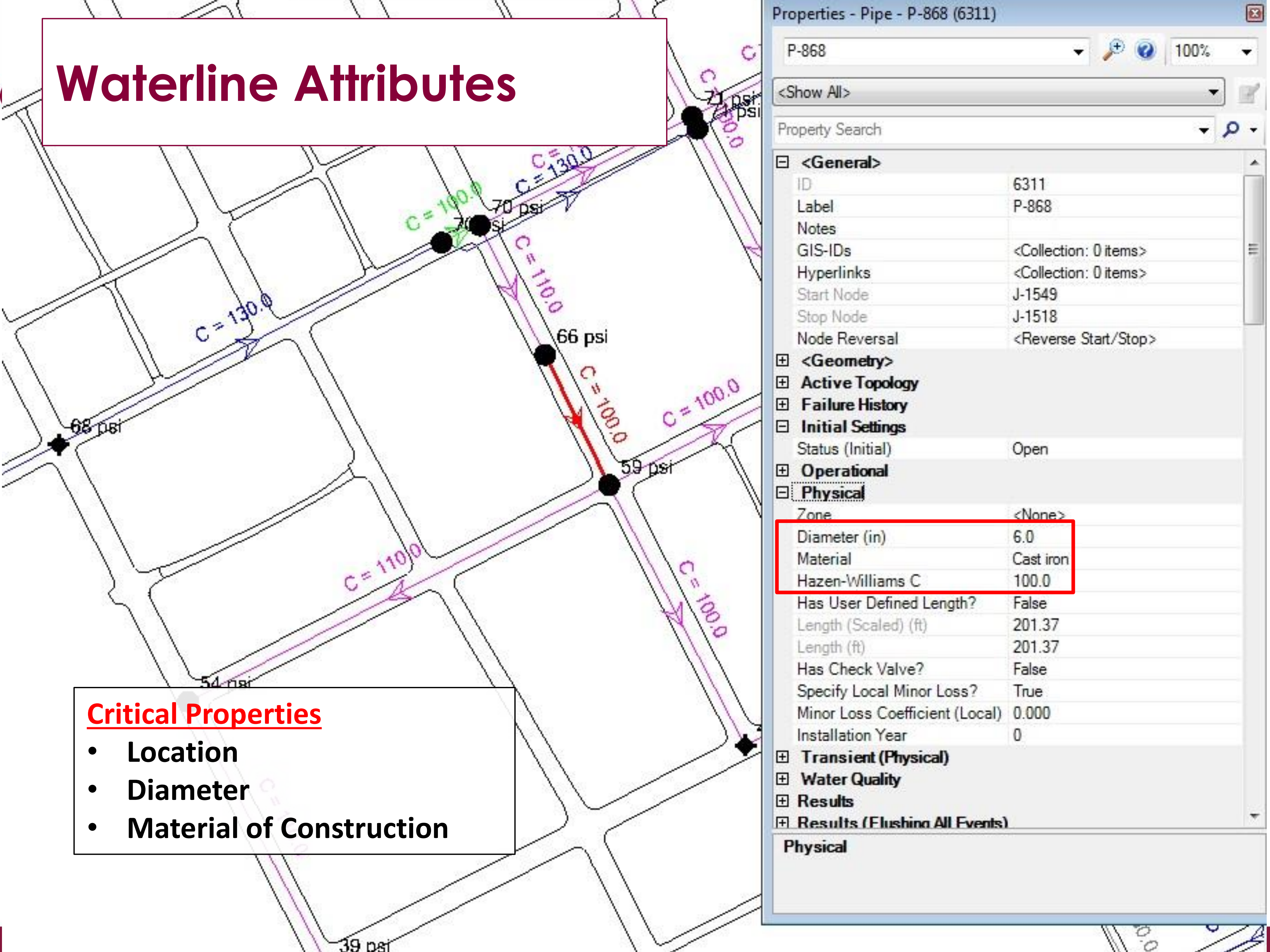


Sophisticated mapping is <u>not</u> needed!

Creating the Model



Waterline Attributes



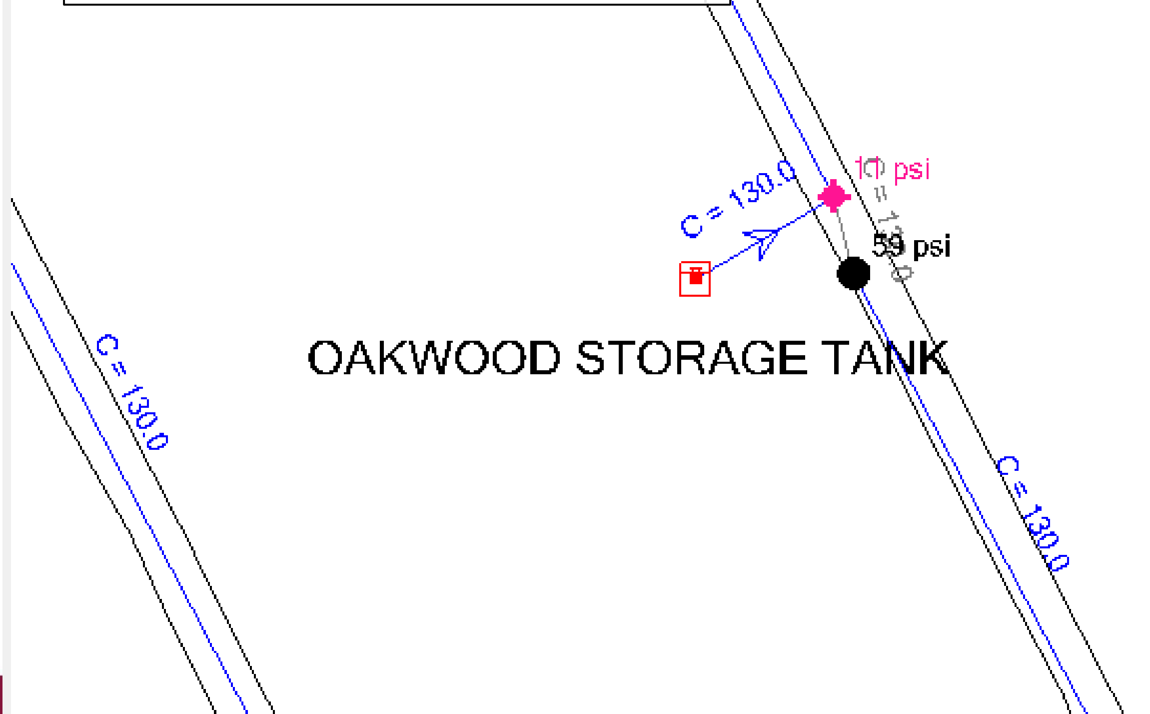
Critical Properties

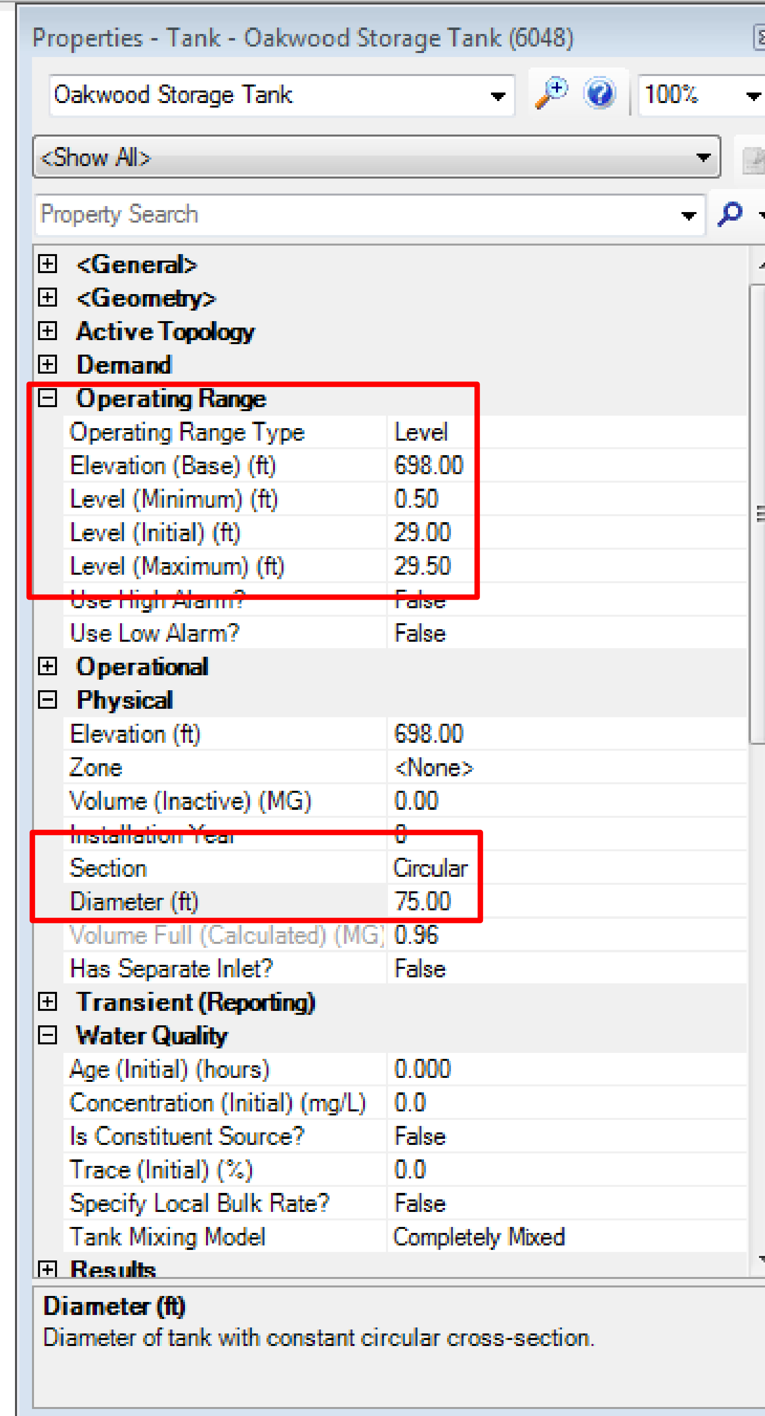
- Location
- Diameter
- Material of Construction

Storage Tank Attributes

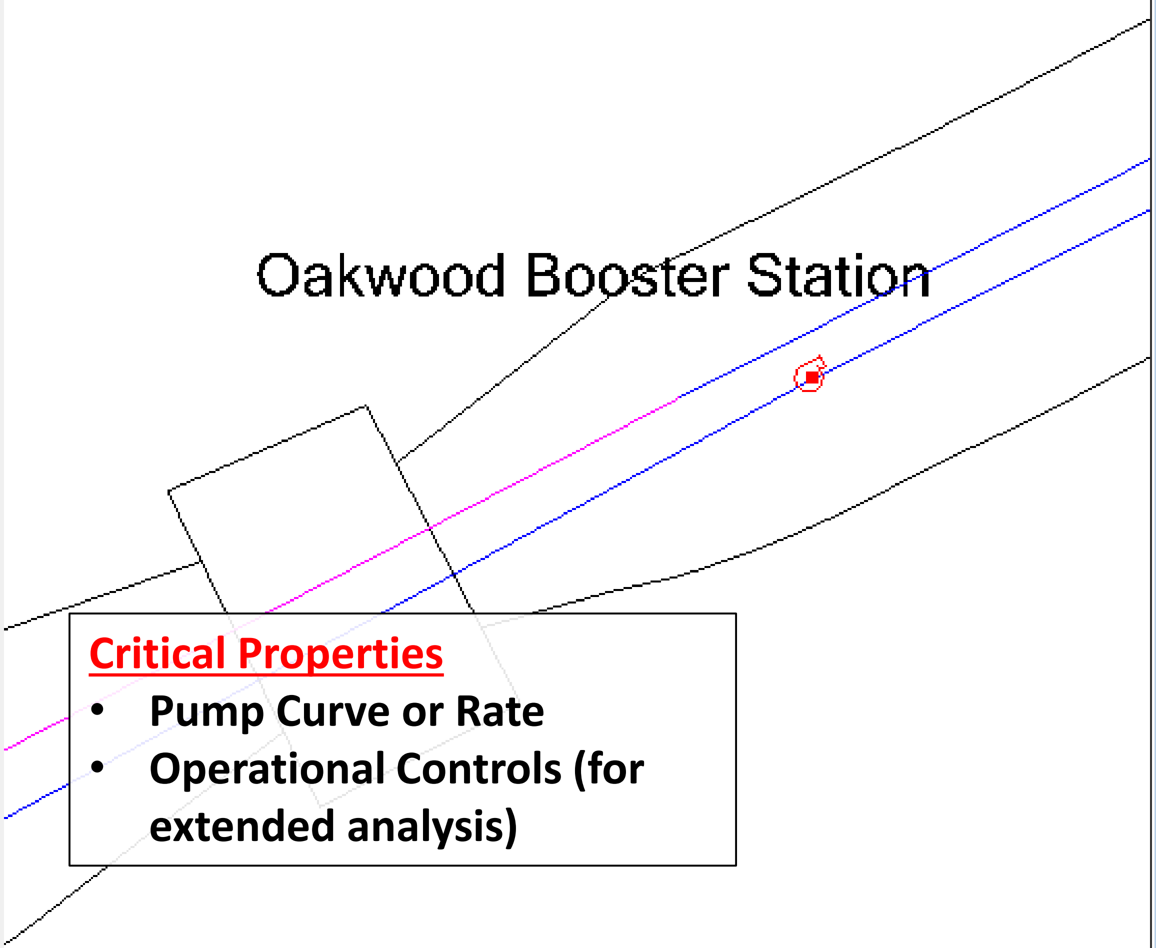
Critical Properties

- Base Elevation
- Low Water Level
- High Water Level
- Size/Configuration



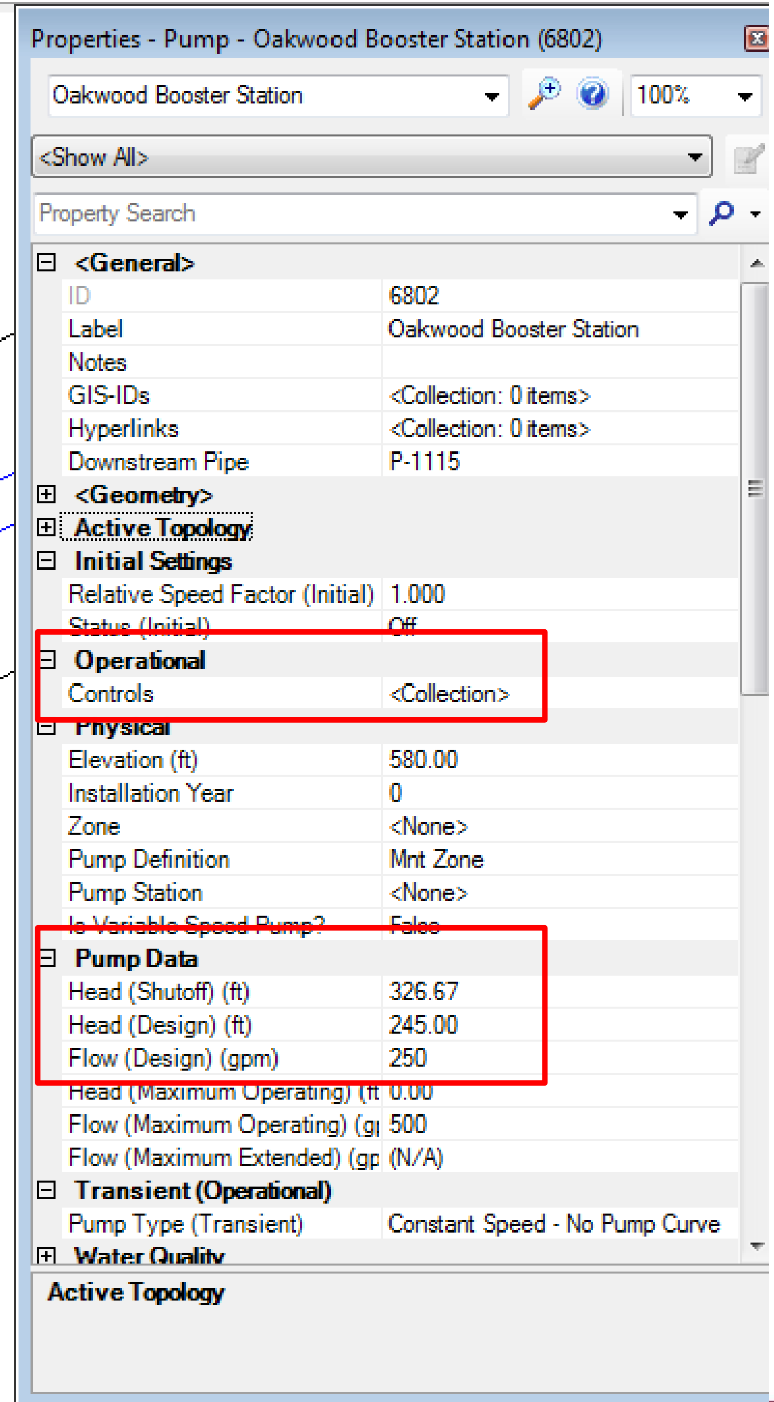


Pumping System Attributes

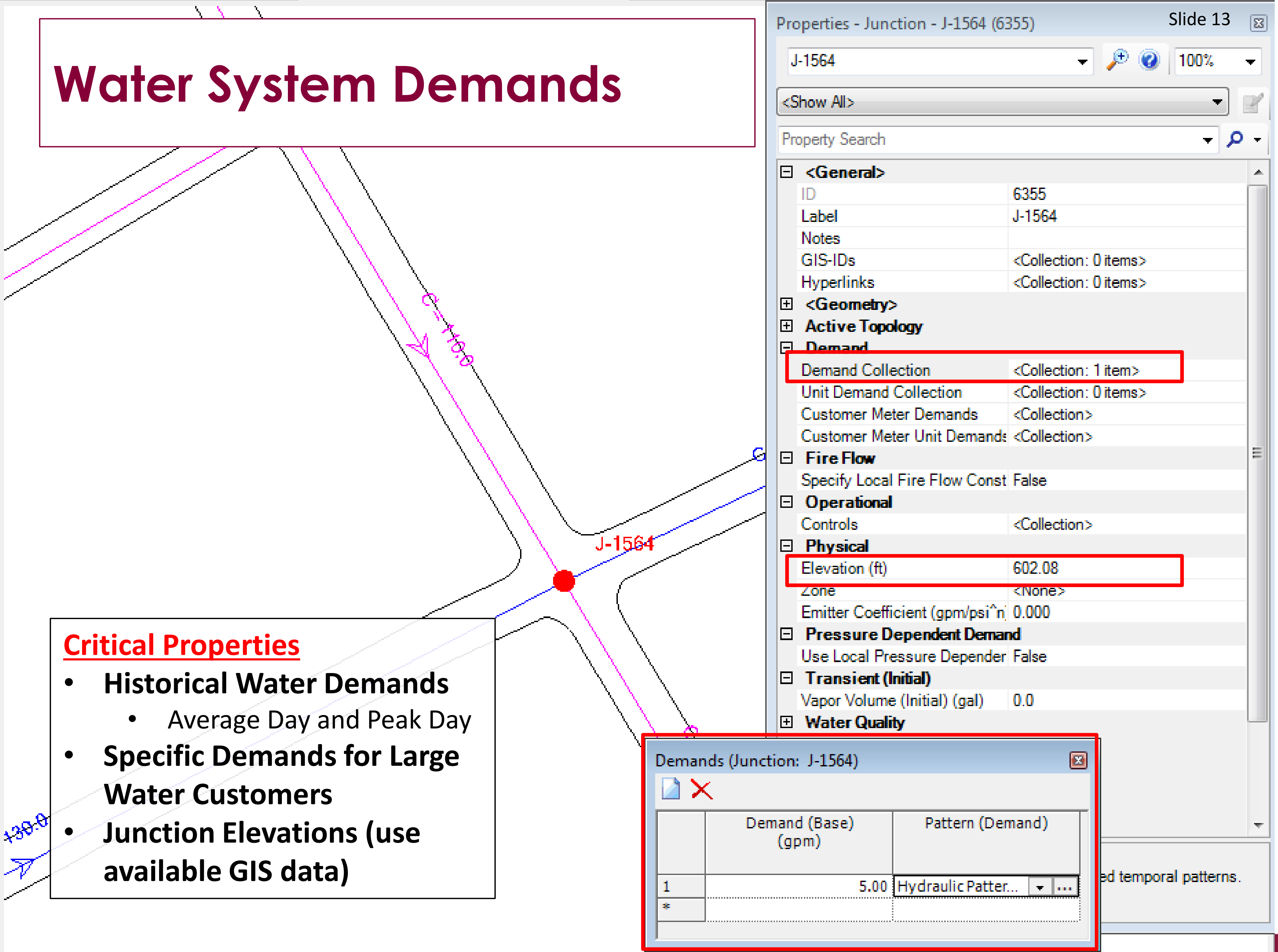


Critical Properties

- **Pump Curve or Rate**
- **Operational Controls (for extended analysis)**



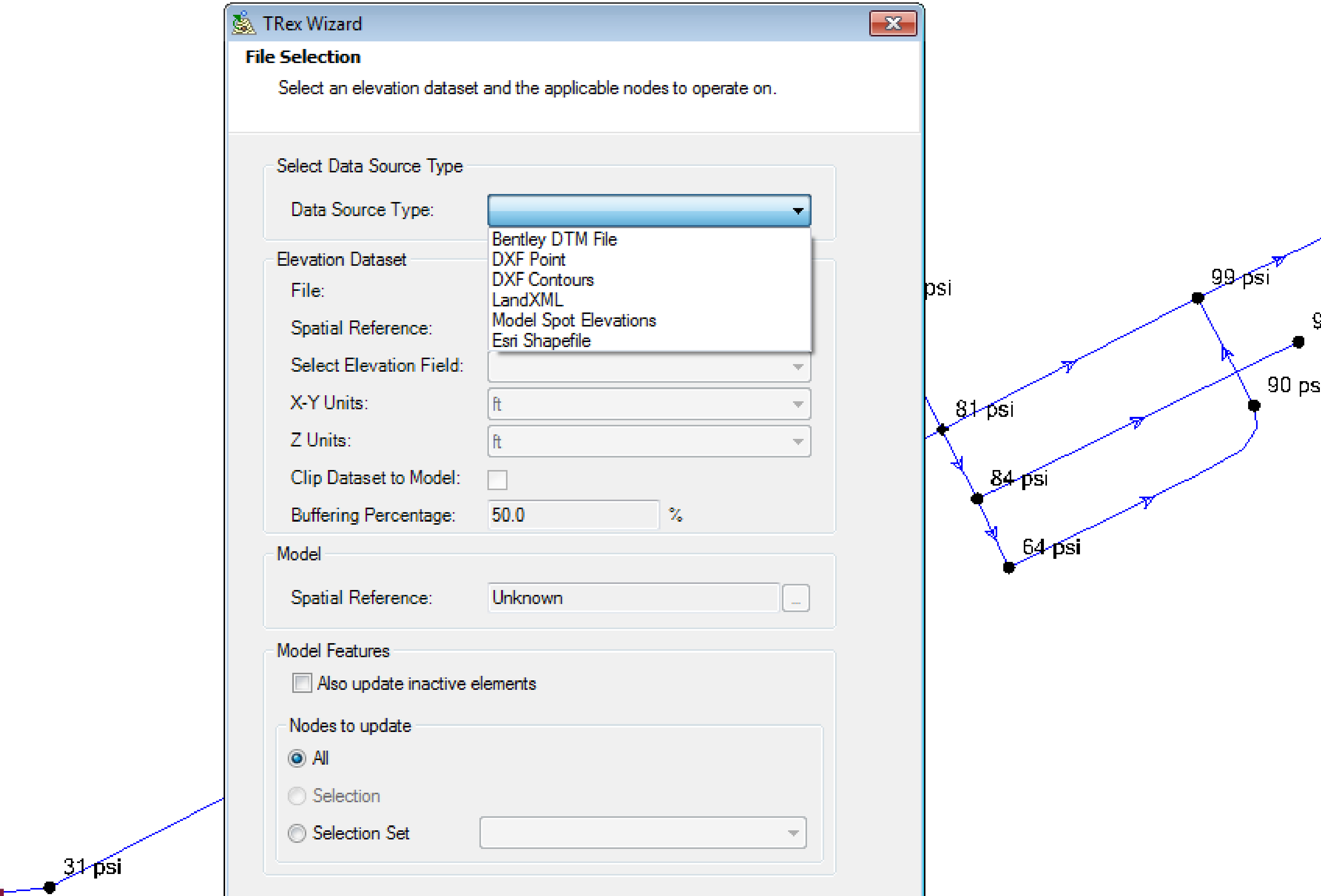
Water System Demands



Critical Properties

- **Historical Water Demands**
  - Average Day and Peak Day
- **Specific Demands for Large Water Customers**
- **Junction Elevations (use available GIS data)**

Junction Elevation Data



Model Calibration

- Historical Pressure Data
- Historical Fire Hydrant Flow Test Reports
- Targeted Fire Hydrant Flow Tests
- Pressure Loggers
- Field Survey to Determine Elevation of Critical Features
- Document system conditions during data collection!

Source: www.usabluebook .com

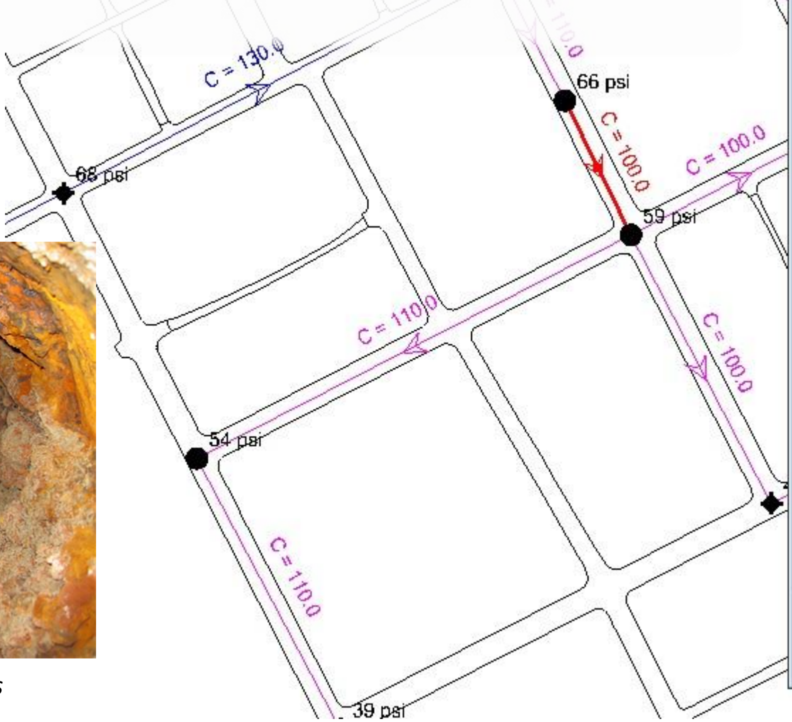
Source: www.grainger.com

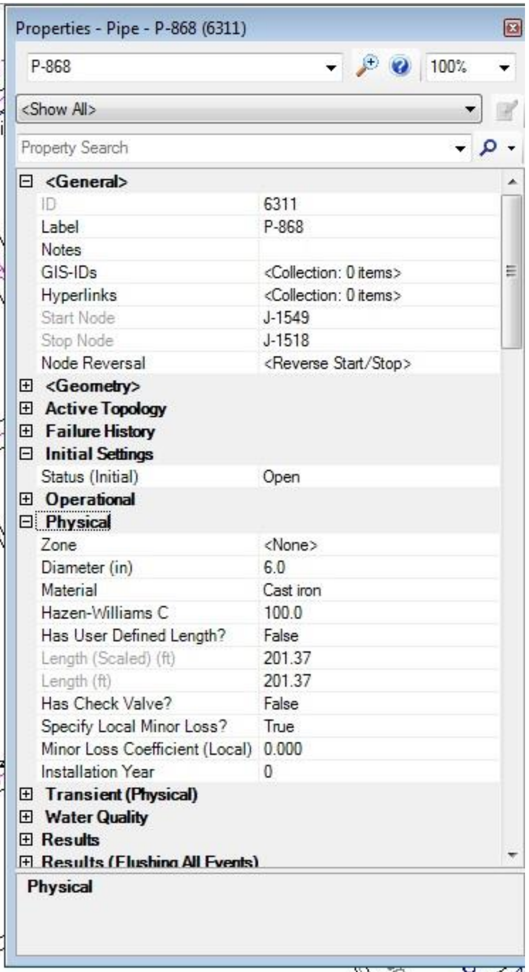
ENSURE MODEL REPRESENTS EXISTING CONDITIONS

Model Calibration

- **Use known pressure and flow data to adjust model**
- **Vary friction factor (Hazen-Williams C factor)**
- **Help identify closed valves, errors in piping network**

Source: www.mwra.state.ma.us



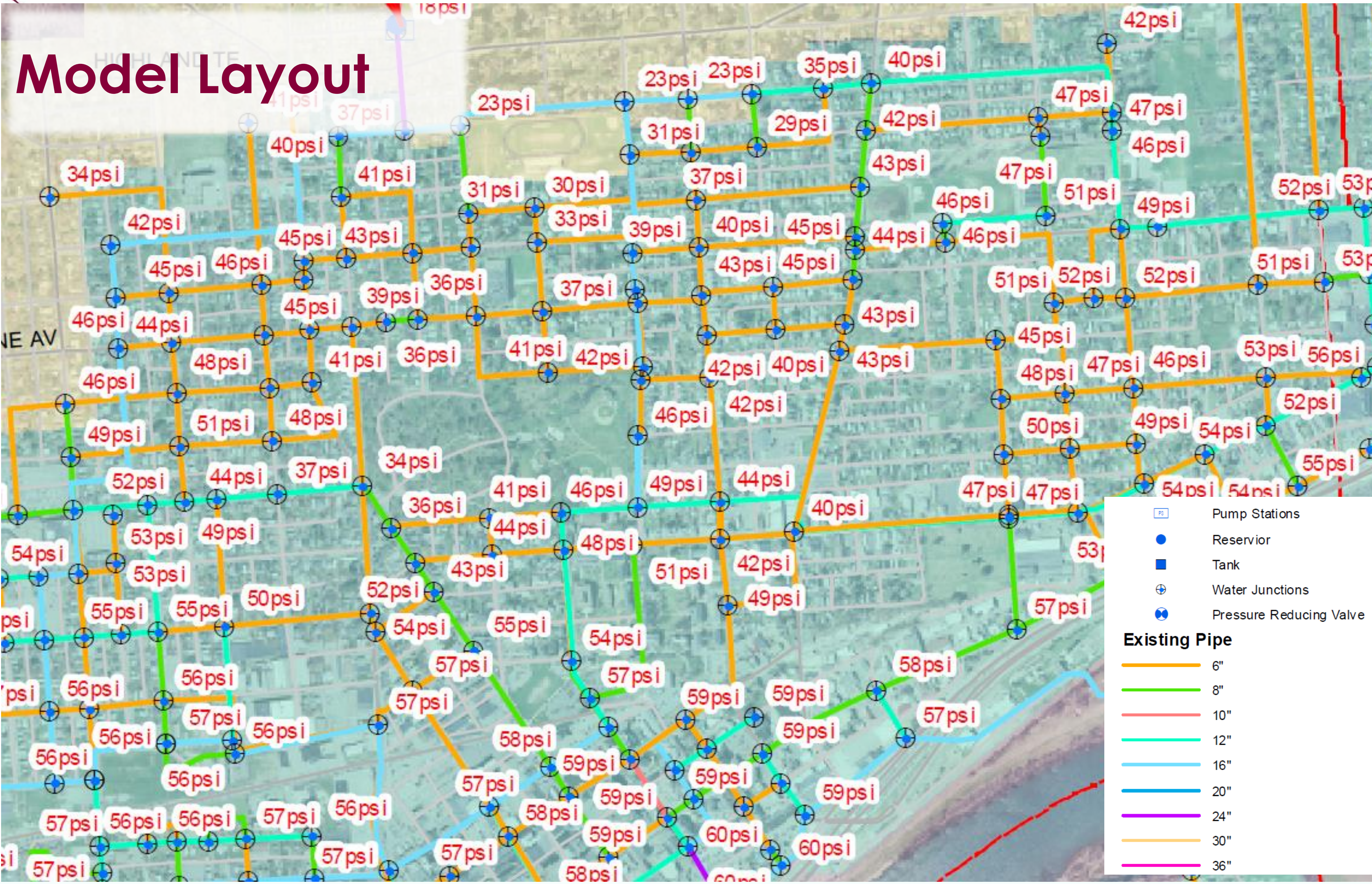


Model Calibration

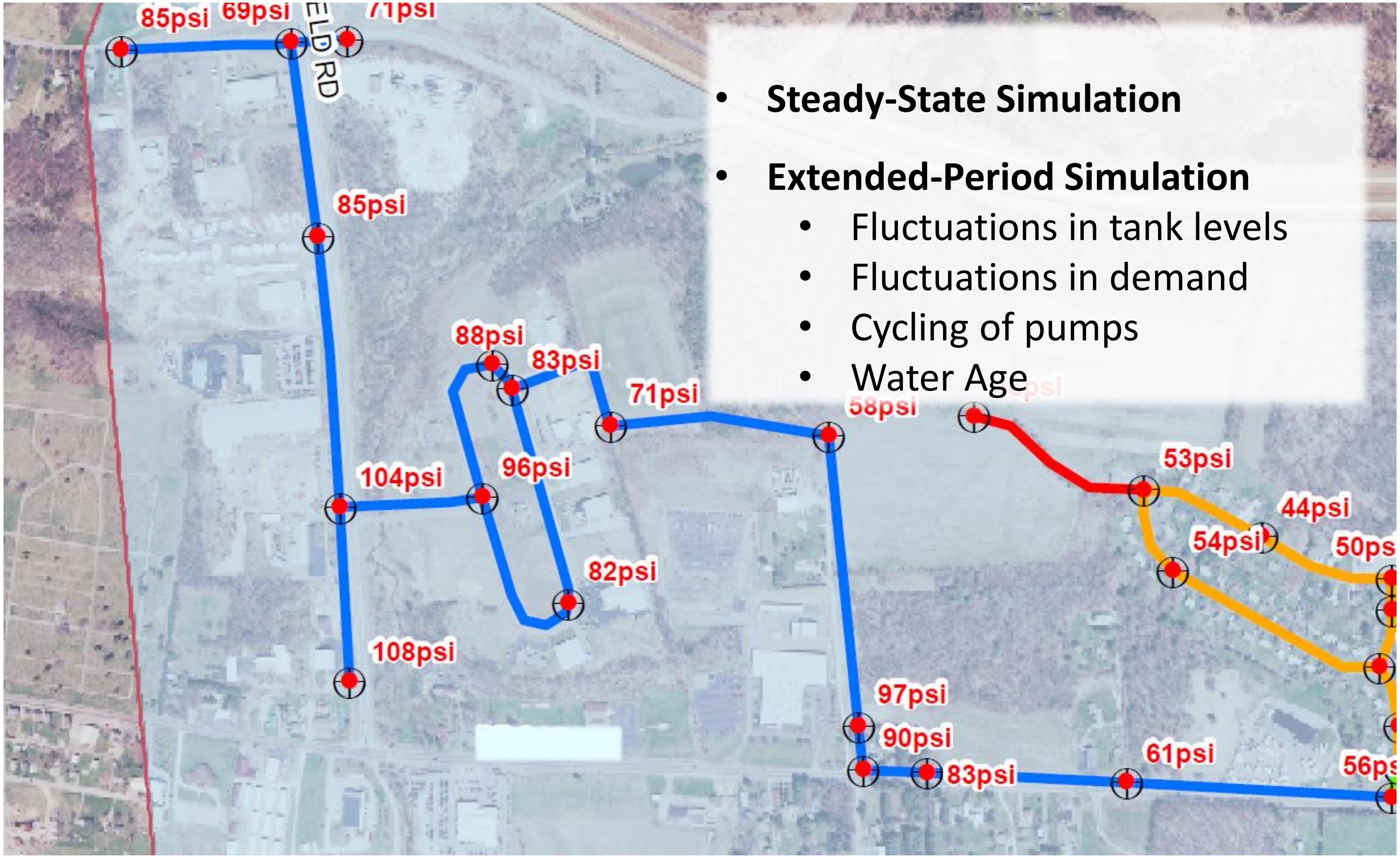
Hydrant Flow Test Results and Water Model Results

Test ID No.	Test Date	Static Pressure (psi)		Flow Rate (gpm)	Residual Pressure (psi)	
		Field	Model		Field	Model
1	5/6/2014	153	155	1,443	140	138
2	5/6/2014	55	51	3,262	42	43
3	5/6/2014	85	88	1,547	60	64
4	5/6/2014	105	103	1,186	67	69
5	5/6/2014	33	32	411	18	22
6	5/6/2014	180	177	1,256	162	167
7	5/6/2014	141	143	2,242	117	120
8	5/20/2014	54	58	1,181	52	56
9	5/20/2014	54	59	1,210	50	55
10	5/20/2014	26	26	692	25	26
11	5/20/2014	55	57	503	52	55

Model Layout



Model Analysis



- **Steady-State Simulation**
- **Extended-Period Simulation**
  - Fluctuations in tank levels
  - Fluctuations in demand
  - Cycling of pumps
  - Water Age

Steady-State Model Analysis

1. **Average Day Demand Typical Pressures**
2. **Peak Demand Pressures**
3. **Fire Flow Residual Pressures**
    - Where is the lowest residual pressure when operating a specific hydrant?
4. **Pressure Zone Boundaries and Isolation Locations**
5. **Pressure Reducing Valve Setpoints and Location**

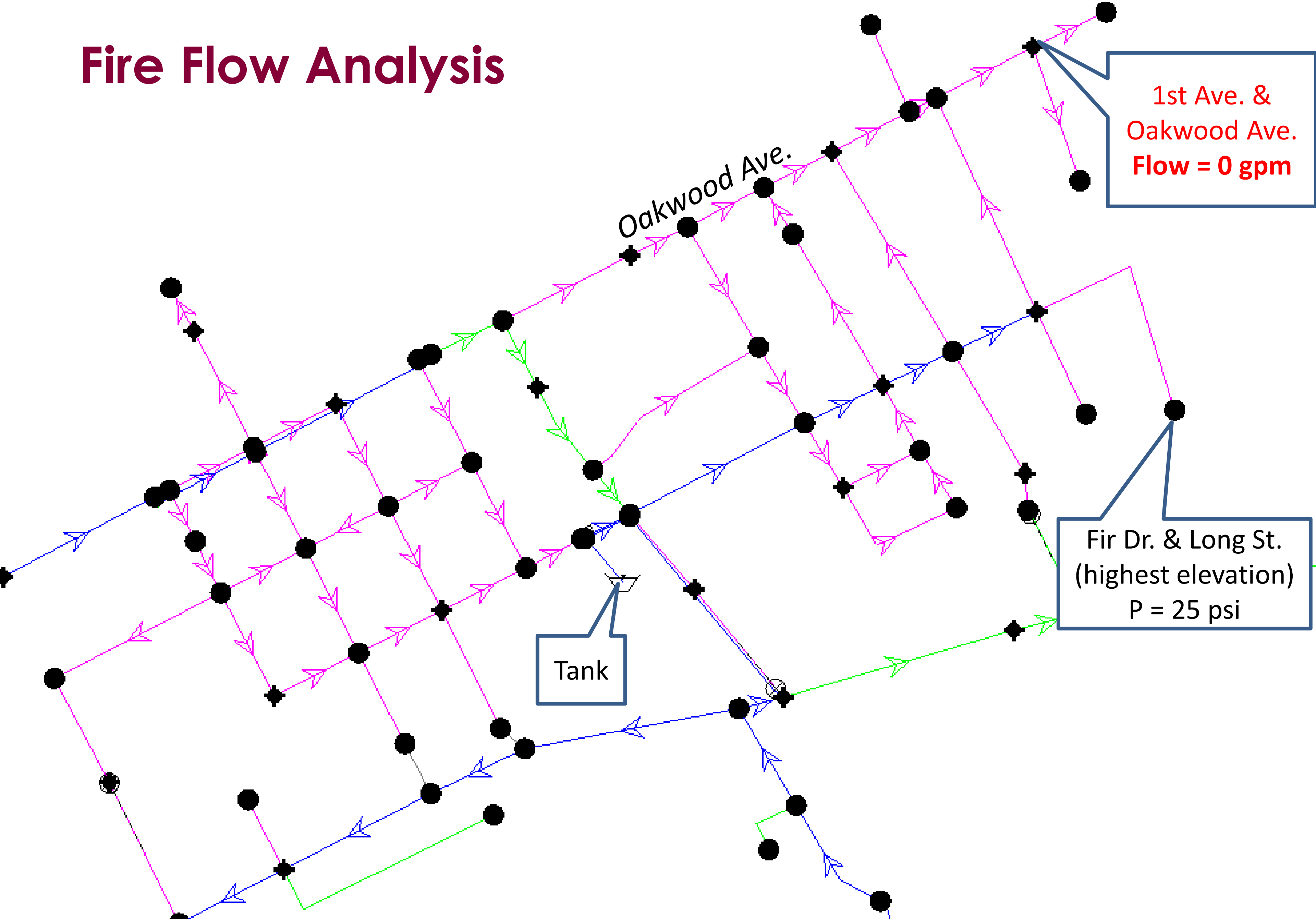
Steady-State Model Analysis

QUESTION:

How can I improve fire protection to a specific area of my distribution system?

I want to be able to provide for 1,000 gpm at the intersection of First Ave. and Oakwood Ave. while maintaining a minimum residual pressure of 20 psi at all locations.

Fire Flow Analysis



Fire Flow Analysis

Scenario	Fire Flow Location	Fire Flow, gpm	Reference Location #1	
			Location	Residual Pressure, (psi)
OAKWOOD PRESSURE ZONE				
Base - PDD	1st Ave. & Oakwood Ave.	0	Fir Dr. & Long St.	**25**
Base - PDD w/ Fire Flow	1st Ave. & Oakwood Ave.	1,000	Fir Dr. & Long St.	**-10**

Fire Flow Analysis

Scenario	Fire Flow Location	Fire Flow, gpm	Reference Location #1	
			Location	Residual Pressure, (psi)
OAKWOOD PRESSURE ZONE				
Base - PDD	1st Ave. & Oakwood Ave.	0	Fir Dr. & Long St.	**25**
Base - PDD w/ Fire Flow	1st Ave. & Oakwood Ave.	1,000	Fir Dr. & Long St.	**-10**
Alt #1 - Replace 1,200 l.f. along Oakwood w/ 8"	1st Ave. & Oakwood Ave.	1,000	Fir Dr. & Long St.	**14**

Fire Flow Analysis

Scenario	Fire Flow Location	Fire Flow, gpm	Reference Location #1	
			Location	Residual Pressure, (psi)
OAKWOOD PRESSURE ZONE				
Base - PDD	1st Ave. & Oakwood Ave.	0	Fir Dr. & Long St.	**25**
Base - PDD w/ Fire Flow	1st Ave. & Oakwood Ave.	1,000	Fir Dr. & Long St.	**-10**
Alt #1 - Replace 1,200 l.f. along Oakwood w/ 8"	1st Ave. & Oakwood Ave.	1,000	Fir Dr. & Long St.	**14**
Alt #2 - Replace 1,200 l.f. along Oakwood w/ 12"	1st Ave. & Oakwood Ave.	1,000	Fir Dr. & Long St.	**19**

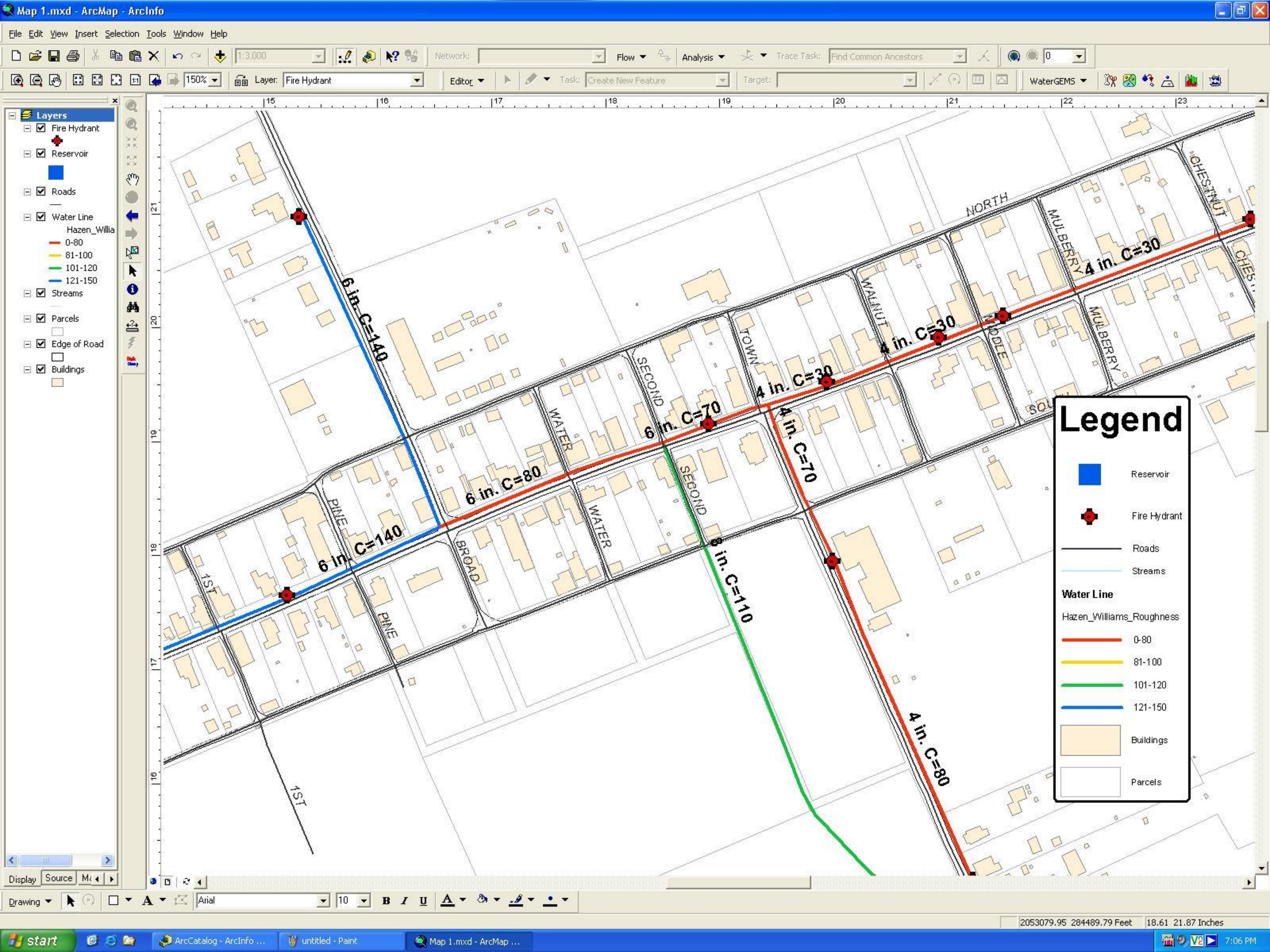
Fire Flow Analysis

Scenario	Fire Flow Location	Fire Flow, gpm	Reference Location #1	
			Location	Residual Pressure, (psi)
OAKWOOD PRESSURE ZONE				
Base - PDD	1st Ave. & Oakwood Ave.	0	Fir Dr. & Long St.	**25**
Base - PDD w/ Fire Flow	1st Ave. & Oakwood Ave.	1,000	Fir Dr. & Long St.	**-10**
Alt #1 - Replace 1,200 l.f. along Oakwood w/ 8"	1st Ave. & Oakwood Ave.	1,000	Fir Dr. & Long St.	**14**
Alt #2 - Replace 1,200 l.f. along Oakwood w/ 12"	1st Ave. & Oakwood Ave.	1,000	Fir Dr. & Long St.	**19**
Alt #3 - Replace 2,500 l.f. along Oakwood w/ 12"	1st Ave. & Oakwood Ave.	1,000	Fir Dr. & Long St.	**22**

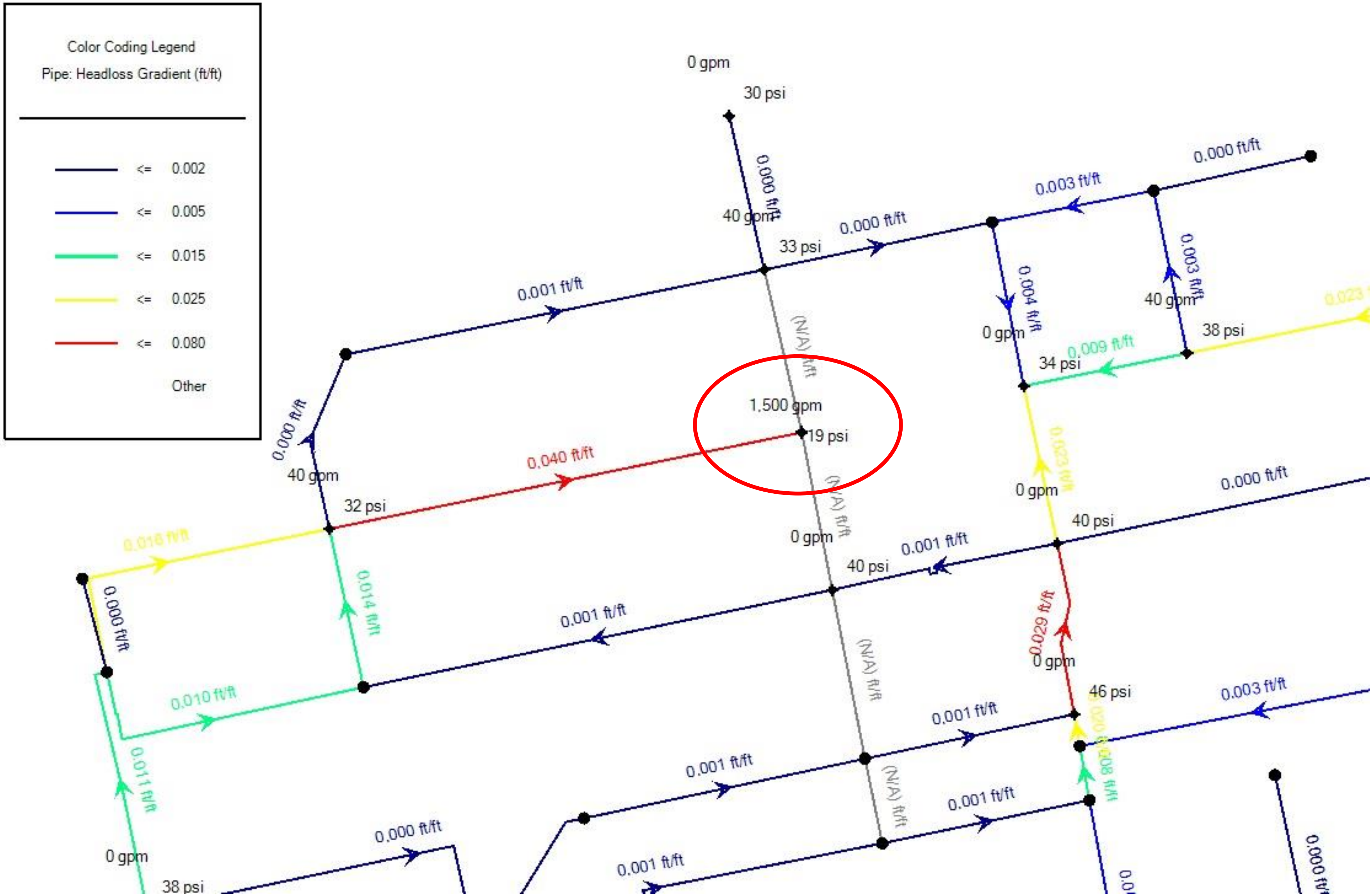
Steady-State Model Analysis

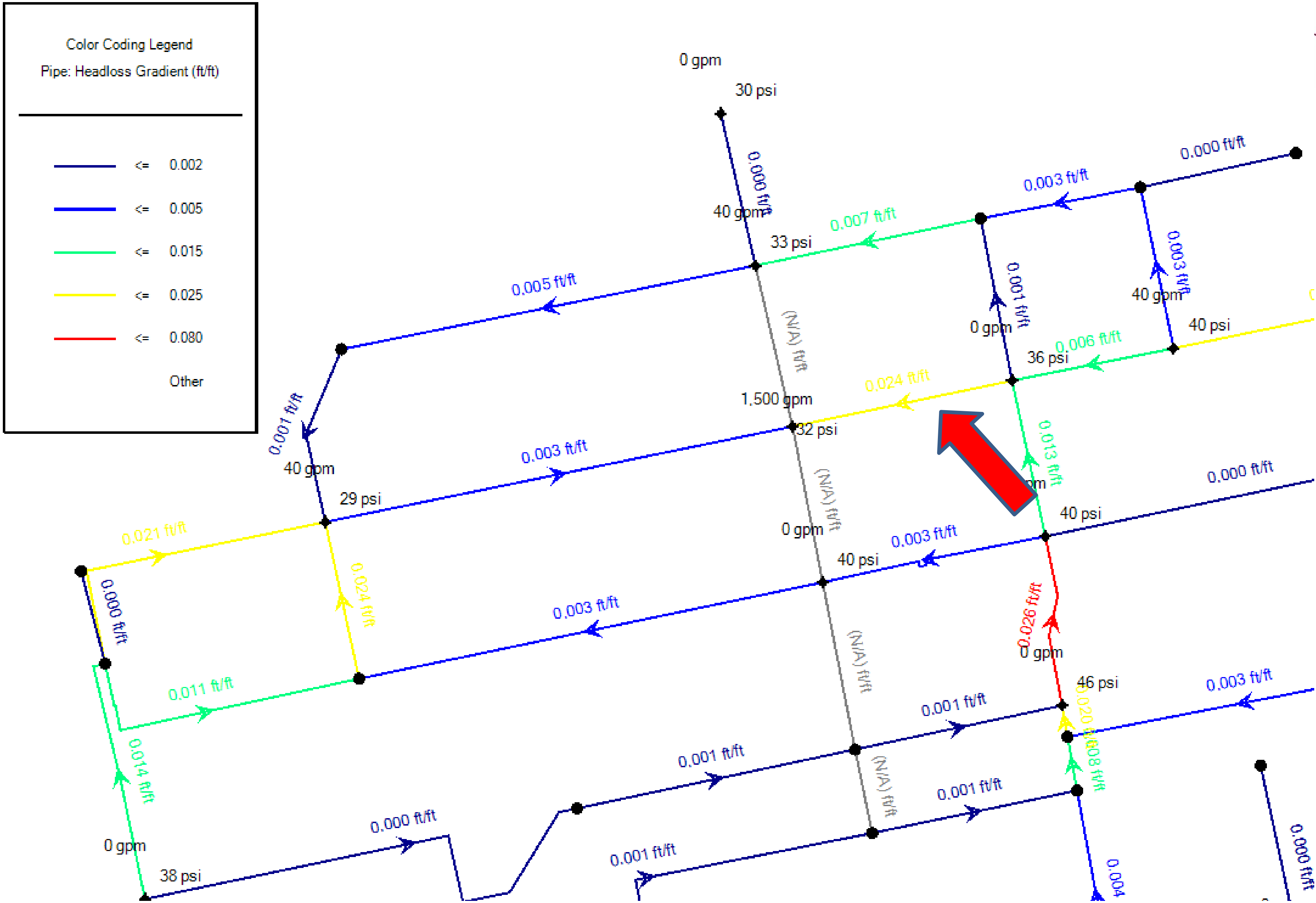
QUESTION:

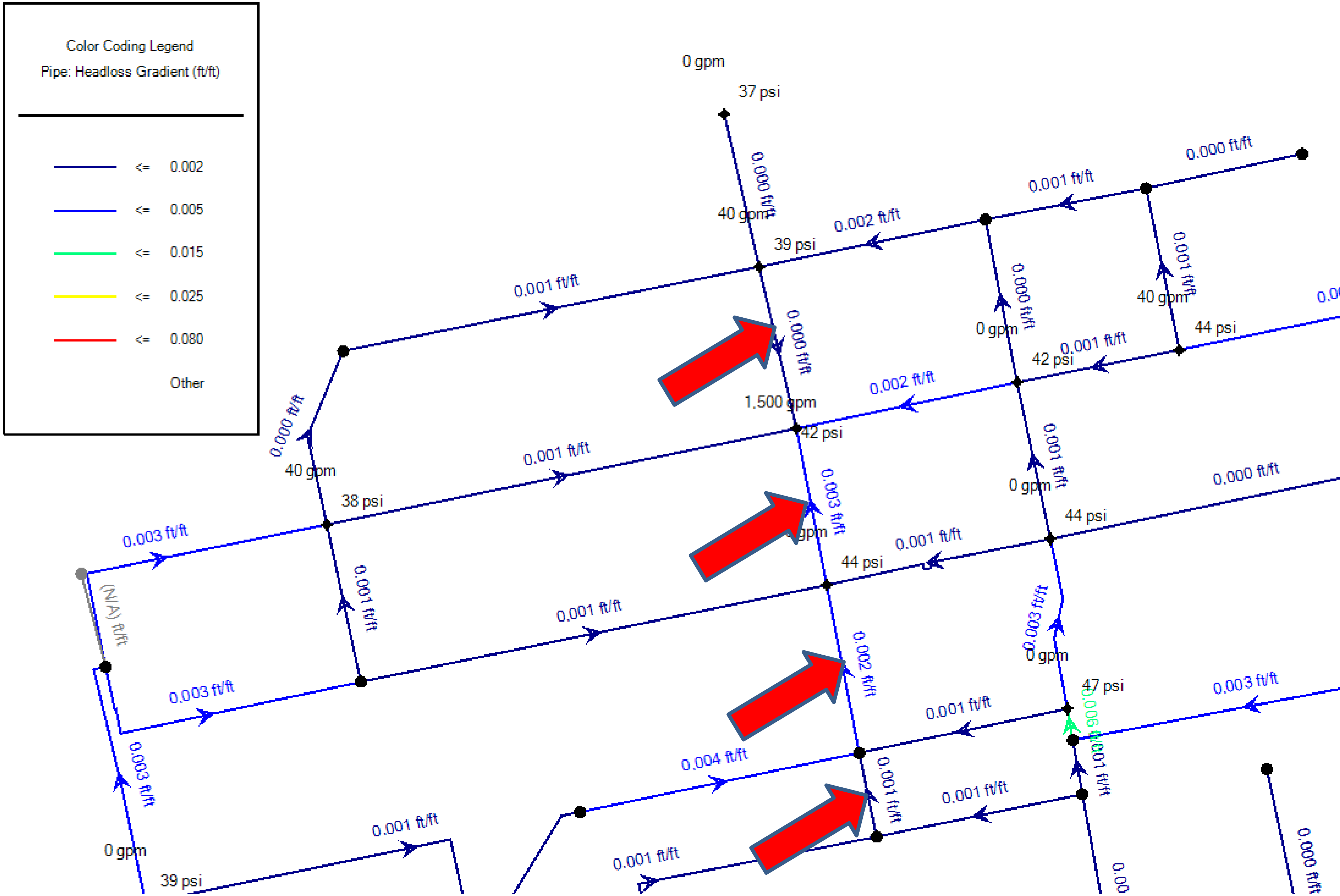
What waterlines are creating flow restrictions and pressures drops?



Map 1.mxd - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
Network:
Flow
Analysis
Trace Task:
Find Common Ancestors
Layer: Fire Hydrant
Editor
Task: Create New Feature
Target:
WaterGEMS
Layers
Fire Hydrant
Reservoir
Roads
Water Line
Hazen_Willia
0-80
81-100
101-120
121-150
Streams
Parcels
Edge of Road
Buildings
Display
Source
6 in. C=140
6 in. C=80
6 in. C=140
6 in. C=70
4 in. C=30
4 in. C=30
4 in. C=30
4 in. C=70
8 in. C=110
4 in. C=80
NORTH
MULBERRY
CHESTNUT
WALNUT
TOWN
SECOND
WATER
PINE
BROAD
1ST
MIDDLE
Legend
Reservoir
Fire Hydrant
Roads
Streams
Water Line
Hazen_Williams_Roughness
0-80
81-100
101-120
121-150
Buildings
Parcels
Drawing
Arial
2053079.95 284489.79 Feet
18.61 21.87 Inches
start
ArcCatalog - ArcInfo ...
untitled - Paint
Map 1.mxd - ArcMap ...
7:06 PM


Color Coding Legend
Pipe: Headloss Gradient (ft/ft)
<= 0.002
<= 0.005
<= 0.015
<= 0.025
<= 0.080
Other
0 gpm
30 psi
0.000 ft/ft
40 gpm
33 psi
0.000 ft/ft
0.003 ft/ft
0.000 ft/ft
0.001 ft/ft
0.004 ft/ft
0.003 ft/ft
40 gpm
38 psi
0 gpm
0.009 ft/ft
34 psi
(N/A) ft/ft
1,500 gpm
19 psi
0.000 ft/ft
40 gpm
0.040 ft/ft
32 psi
0.023 ft/ft
0 gpm
0.000 ft/ft
40 psi
(N/A) ft/ft
0 gpm
0.001 ft/ft
40 psi
0.016 ft/ft
0.000 ft/ft
0.014 ft/ft
0.001 ft/ft
0.029 ft/ft
0 gpm
(N/A) ft/ft
46 psi
0.003 ft/ft
0.010 ft/ft
0.001 ft/ft
0.001 ft/ft
0.011 ft/ft
(N/A) ft/ft
0.001 ft/ft
0.000 ft/ft
0 gpm
0.001 ft/ft
38 psi


Color Coding Legend
Pipe: Headloss Gradient (ft/ft)
<= 0.002
<= 0.005
<= 0.015
<= 0.025
<= 0.080
Other
0 gpm
30 psi
0.000 ft/ft
40 gpm
33 psi
0.007 ft/ft
0.003 ft/ft
0.000 ft/ft
0.005 ft/ft
0.001 ft/ft
0.003 ft/ft
40 gpm
40 psi
0 gpm
0.006 ft/ft
36 psi
(N/A) ft/ft
0.024 ft/ft
1,500 gpm
32 psi
0.001 ft/ft
40 gpm
0.003 ft/ft
0.013 ft/ft
29 psi
(N/A) ft/ft
0.000 ft/ft
40 psi
0 gpm
0.003 ft/ft
0.021 ft/ft
40 psi
0.000 ft/ft
0.024 ft/ft
0.003 ft/ft
0.026 ft/ft
(N/A) ft/ft
0 gpm
46 psi
0.003 ft/ft
0.011 ft/ft
0.001 ft/ft
0.001 ft/ft
0.014 ft/ft
(N/A) ft/ft
0.001 ft/ft
0.000 ft/ft
0 gpm
0.001 ft/ft
38 psi
0.004
0.000 ft/ft

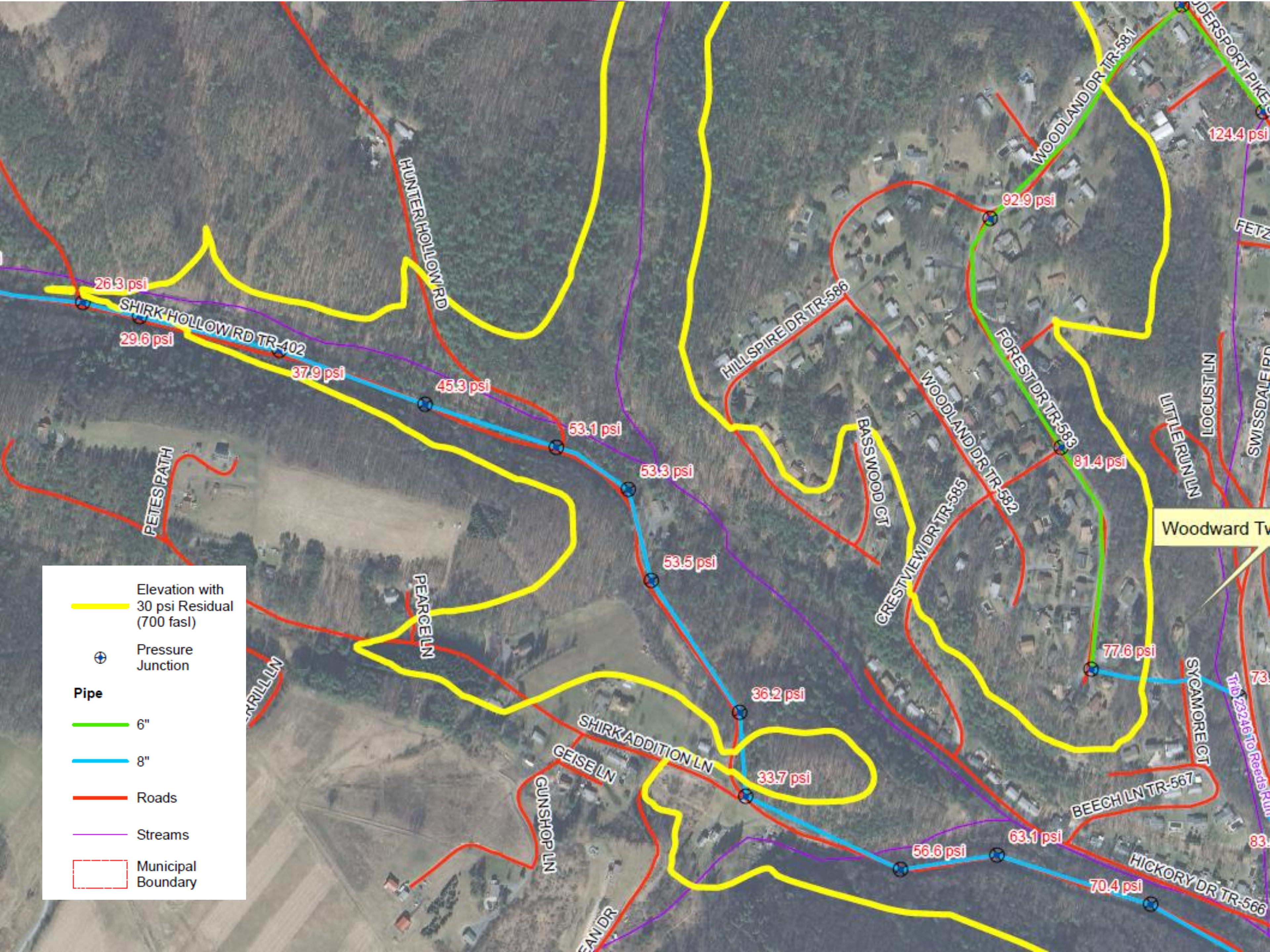


Color Coding Legend
Pipe: Headloss Gradient (ft/ft)
<= 0.002
<= 0.005
<= 0.015
<= 0.025
<= 0.080
Other
0 gpm
37 psi
0.000 ft/ft
40 gpm
39 psi
0.002 ft/ft
0.001 ft/ft
0.000 ft/ft
0.001 ft/ft
0.000 ft/ft
0.001 ft/ft
40 gpm
0 gpm
44 psi
0.001 ft/ft
42 psi
0.000 ft/ft
0.002 ft/ft
1,500 gpm
42 psi
0.000 ft/ft
40 gpm
0.001 ft/ft
38 psi
0.003 ft/ft
0.001 ft/ft
0 gpm
0.000 ft/ft
44 psi
0.001 ft/ft
44 psi
0.003 ft/ft
(N/A) ft/ft
0.001 ft/ft
0.001 ft/ft
0.003 ft/ft
0 gpm
0.002 ft/ft
0.003 ft/ft
47 psi
0.001 ft/ft
0.003 ft/ft
0.004 ft/ft
0.001 ft/ft
0.003 ft/ft
0.001 ft/ft
0.001 ft/ft
0.001 ft/ft
0 gpm
39 psi
0.001 ft/ft
0.000 ft/ft

Steady-State Model Analysis

QUESTION:

A developer is interested in developing several properties beyond the current water service area. How far up the road can our water system provide suitable water service?



Elevation with 30 psi Residual (700 fasl)
Pressure Junction
Pipe
6"
8"
Roads
Streams
Municipal Boundary
Woodward Tw
26.3 psi
29.6 psi
37.9 psi
45.3 psi
53.1 psi
53.3 psi
53.5 psi
36.2 psi
33.7 psi
56.6 psi
63.1 psi
70.4 psi
77.6 psi
81.4 psi
92.9 psi
124.4 psi
SHIRK HOLLOW RD TR-402
HUNTER HOLLOW RD
PETES PATH
PEARCE LN
SHIRK ADDITION LN
GEISE LN
GUNSHOP LN
HILLSPIRE DR TR-586
BASSWOOD CT
CRESTVIEW DR TR-585
WOODLAND DR TR-582
FOREST DR TR-583
WOODLAND DR TR-581
LITTLE RUN LN
LOCUST LN
SYCAMORE CT
BEECH LN TR-567
HICKORY DR TR-566

Steady-State Model Analysis

<u>OTHER USES FOR MODELING:</u>

1. **We want to install a bulk fill station. How much flow is available without impacting service pressures and fire protection?**

2. **Tank #1 needs to be taken out of service for maintenance. Will Tank #2 be capable of temporarily maintaining acceptable pressures in the system?**

3. **The 30" main from the old reservoir is scheduled for replacement. Would a new 12" waterline be adequate to replace it?**

Extended-Period Simulation

1. Cycling of Pumps
2. Fluctuations in Tank Levels
3. Fluctuations in Demand & Pressures
4. Water Age (in tank and mains)
5. Duration can range from hours to months

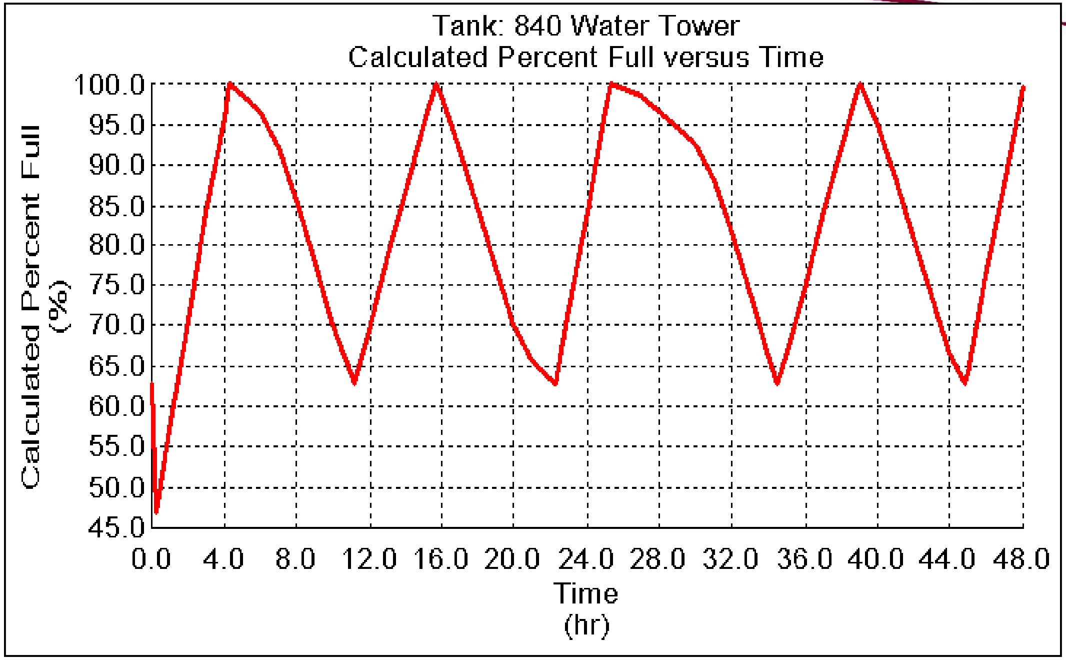
Requires additional inputs:

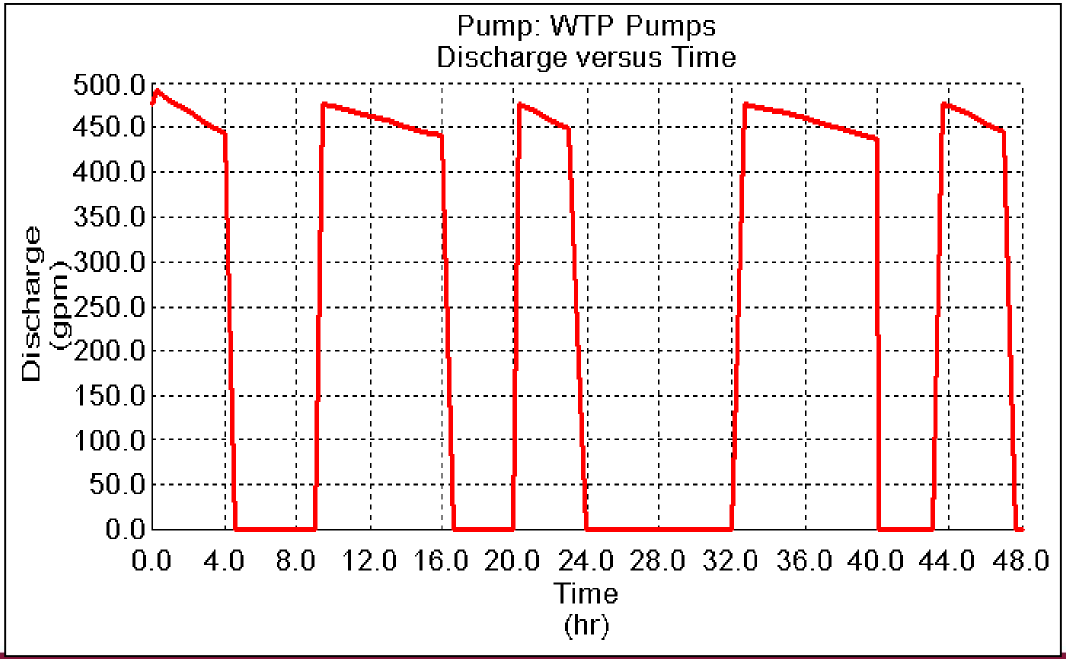
- Pump operational controls
- Working levels in storage tanks
- Diurnal demands

Water Level in Tank

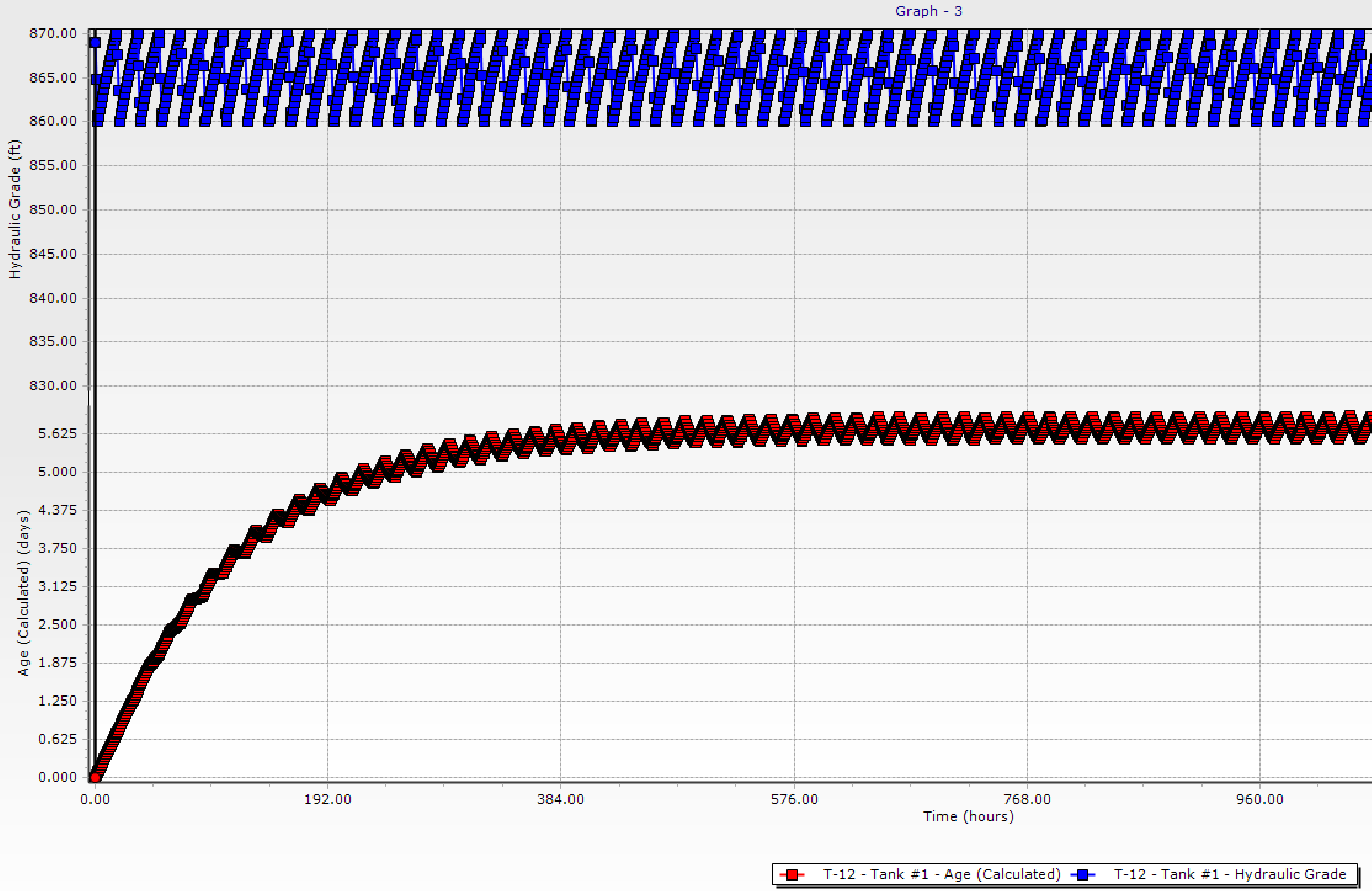
vs.

Pumping Rate

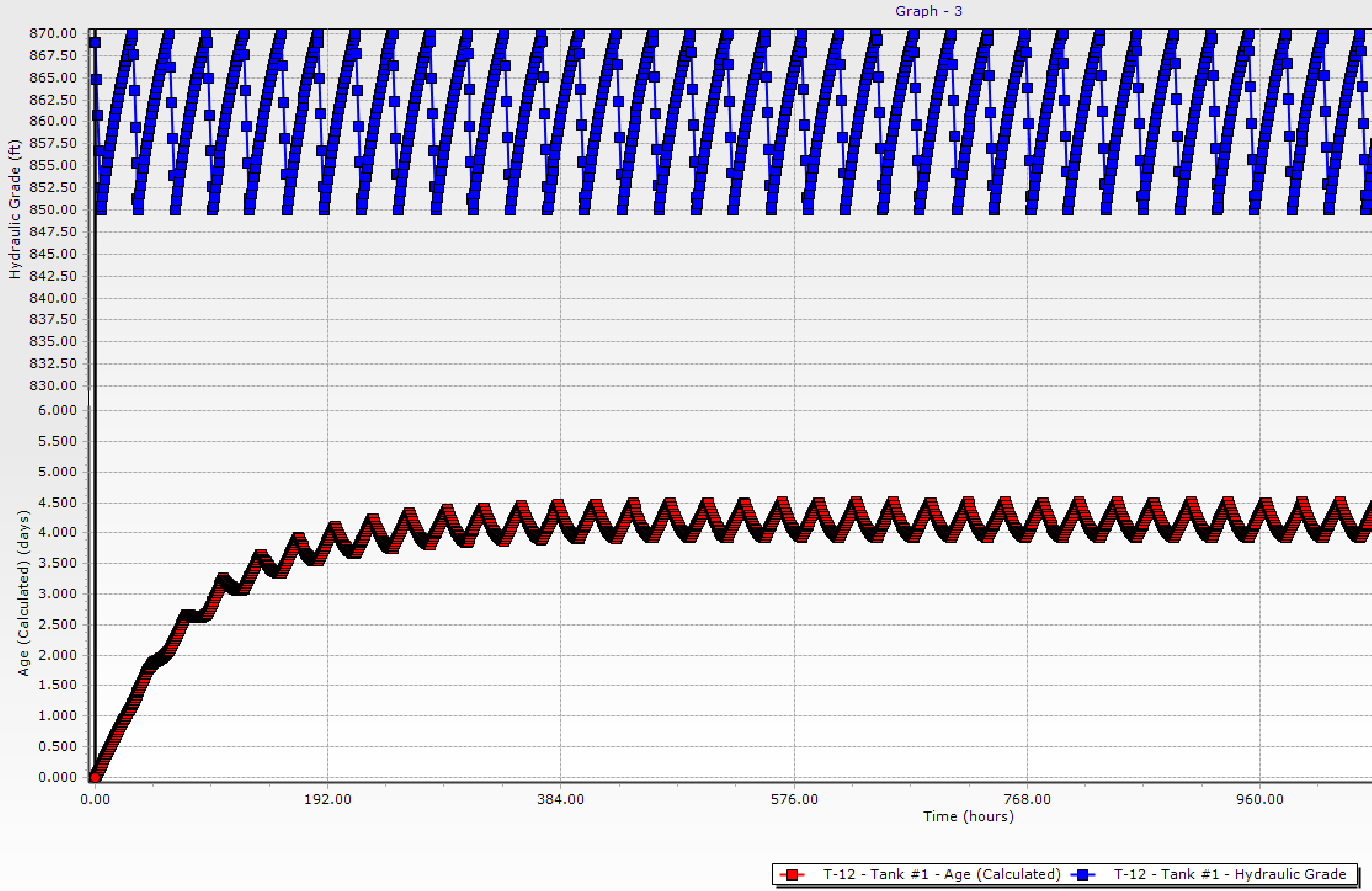




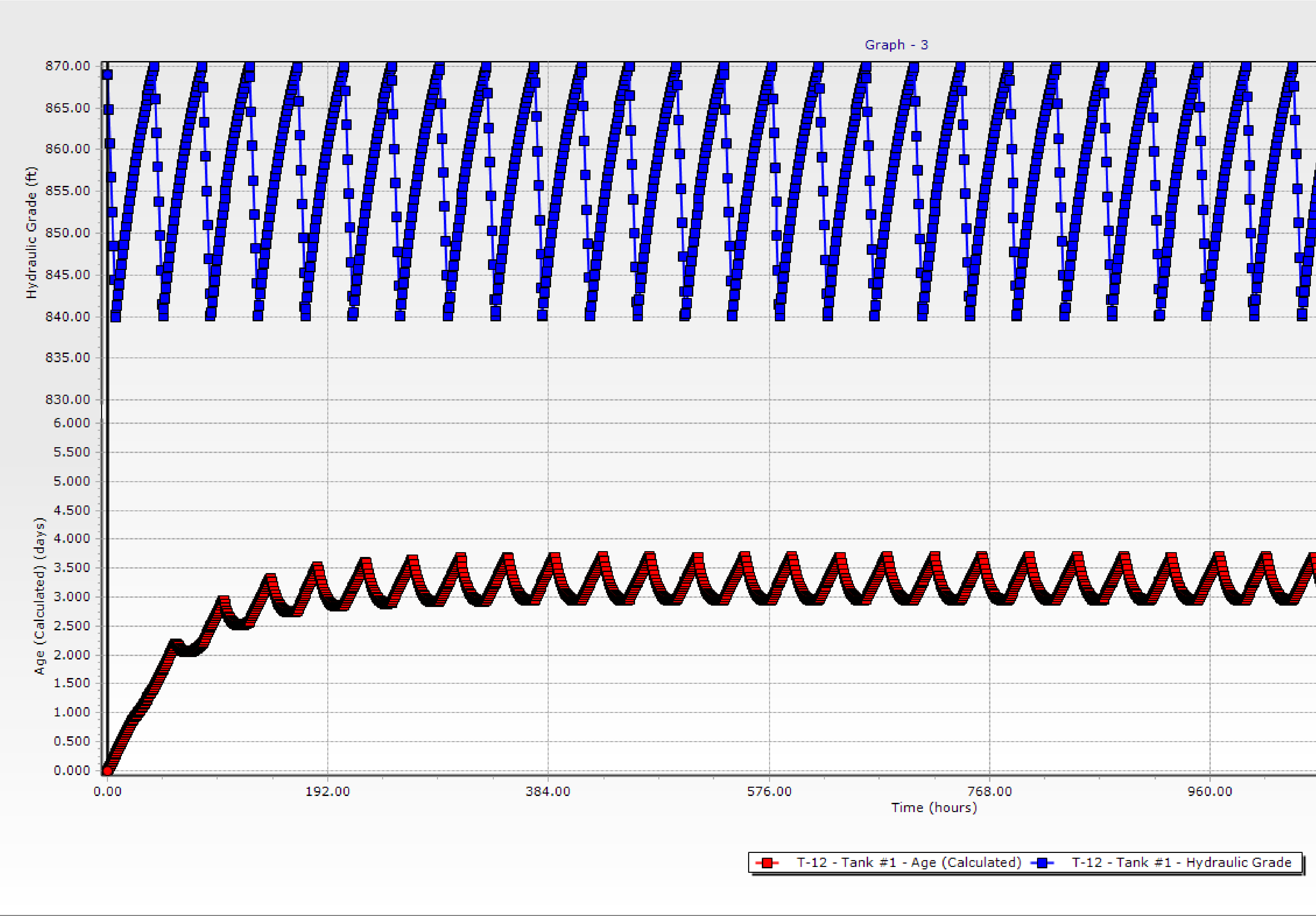
Tank Cycling & Water Age



Tank Cycling & Water Age



Tank Cycling & Water Age



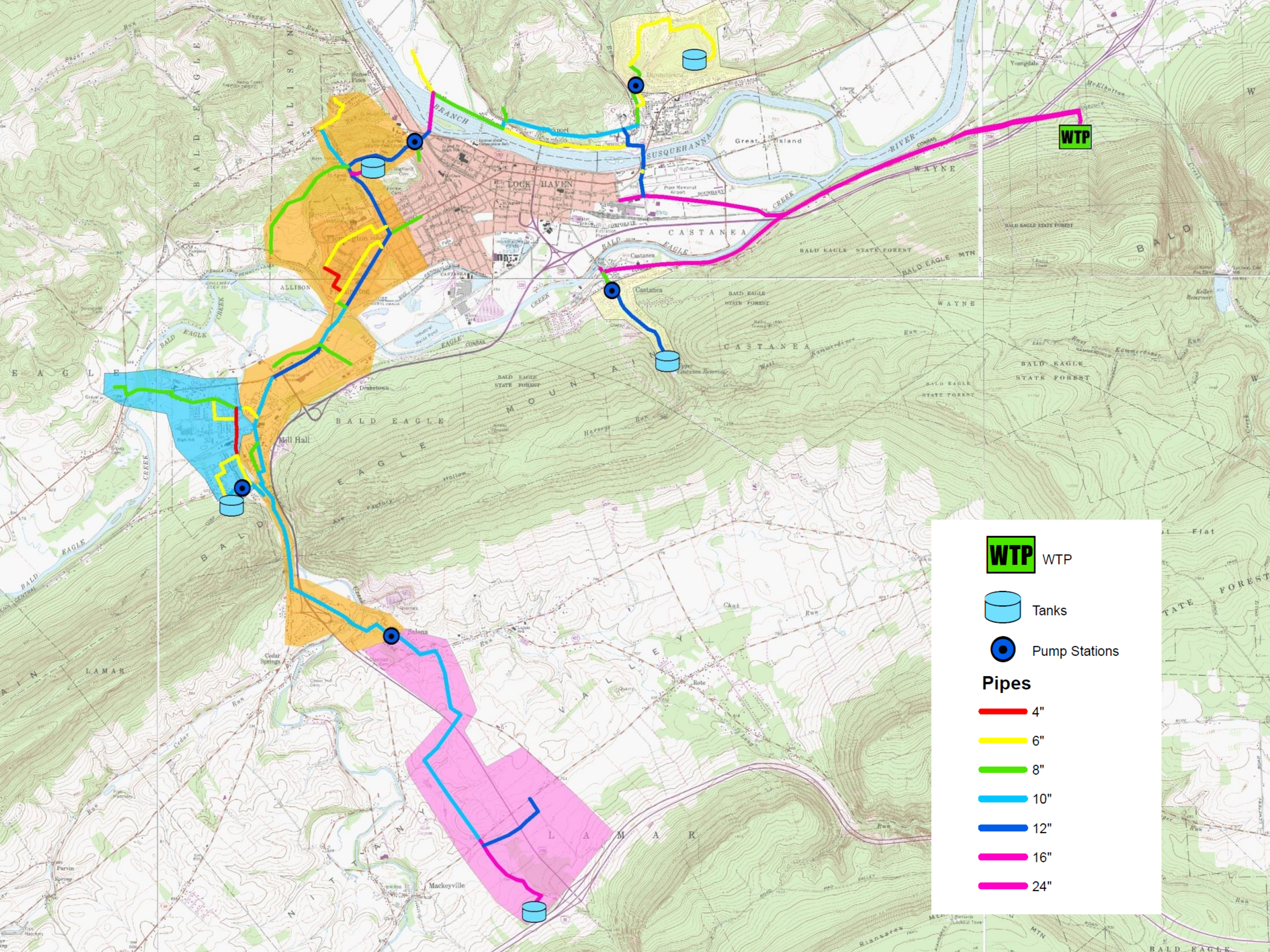
Extended-Period Simulation

- **Evaluate impacts of pumping and tank level control strategies on water age**
    - Prevent ice formation in winter
    - Prevent thermal stratification and loss of chlorine residual in summer

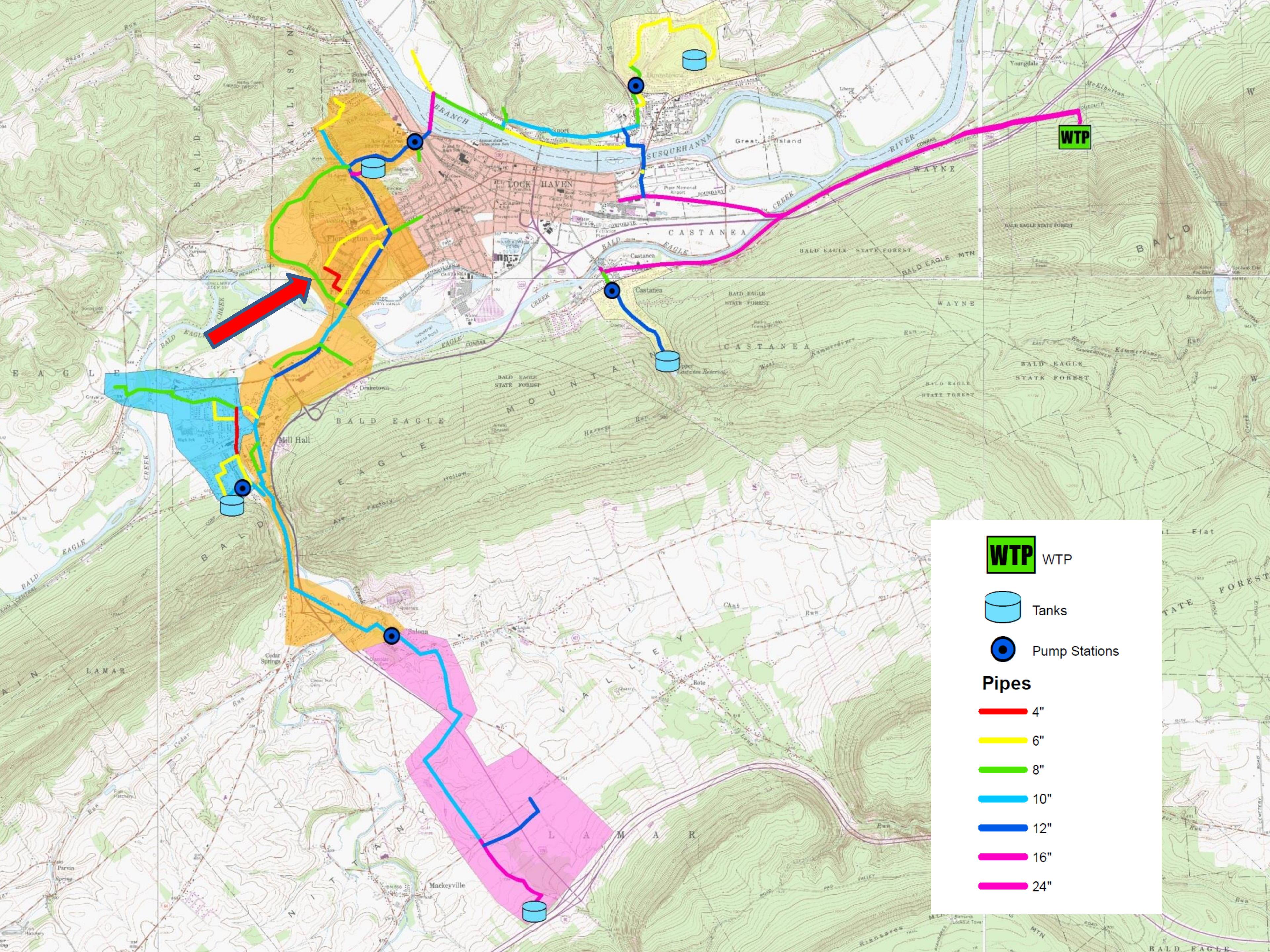
Doesn't replace detailed modeling of passive and active mixing systems offered by various manufacturers.

Case Study:
Suburban Lock Haven Water Authority

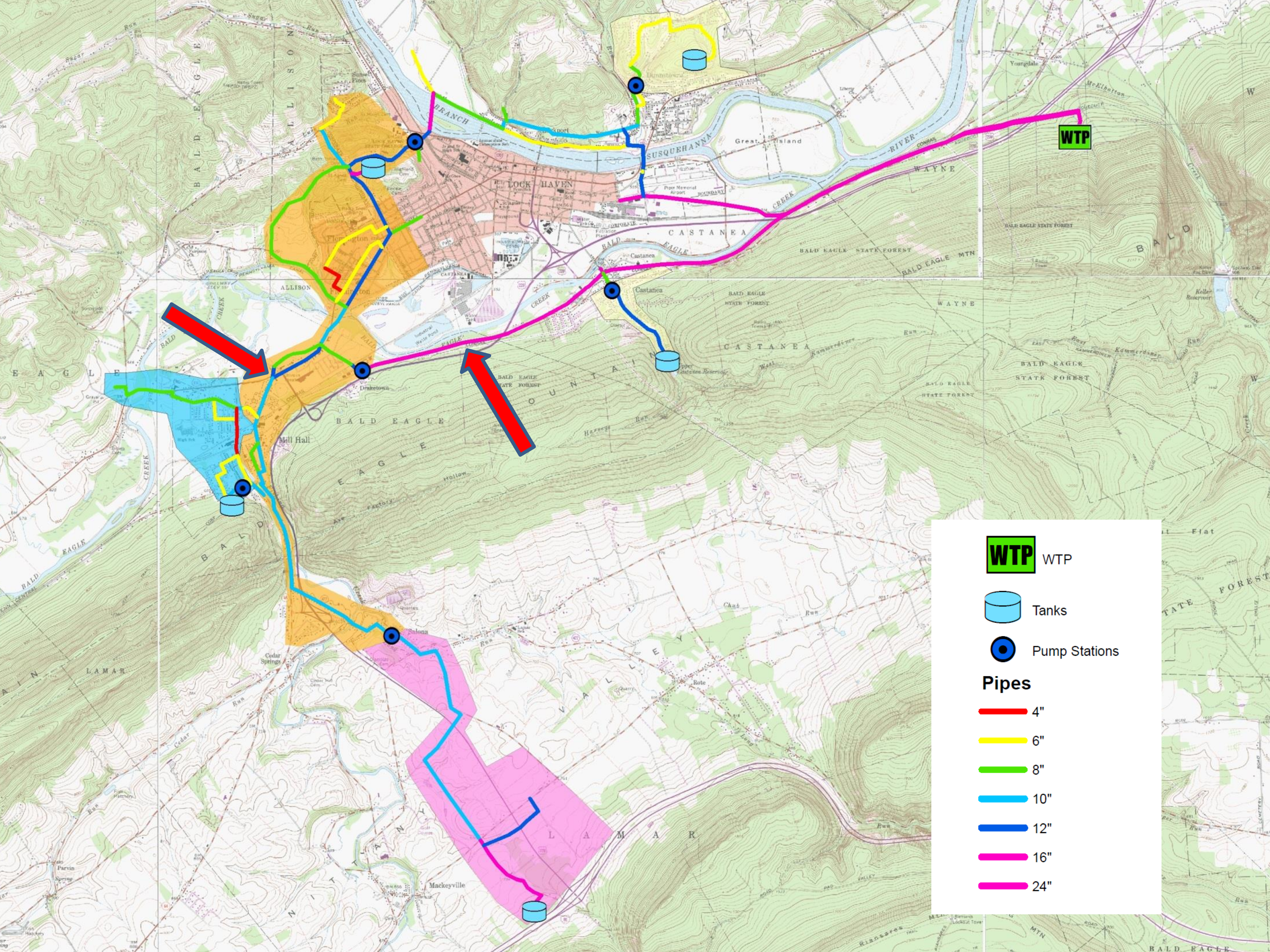
- **Skeletonized Model Created for Multiple Pressure Zones**
- **Model Utilized for Capital Improvement Planning**
- **Resulted in:**
    - Identification of bottlenecks and inefficiencies
    - Dramatic improvements in water service pressures and fire protection capabilities
    - Cost savings (elimination of booster station)
    - Strategic looping to minimize water service disruptions
    - Proactive planning of infrastructure to support economic development

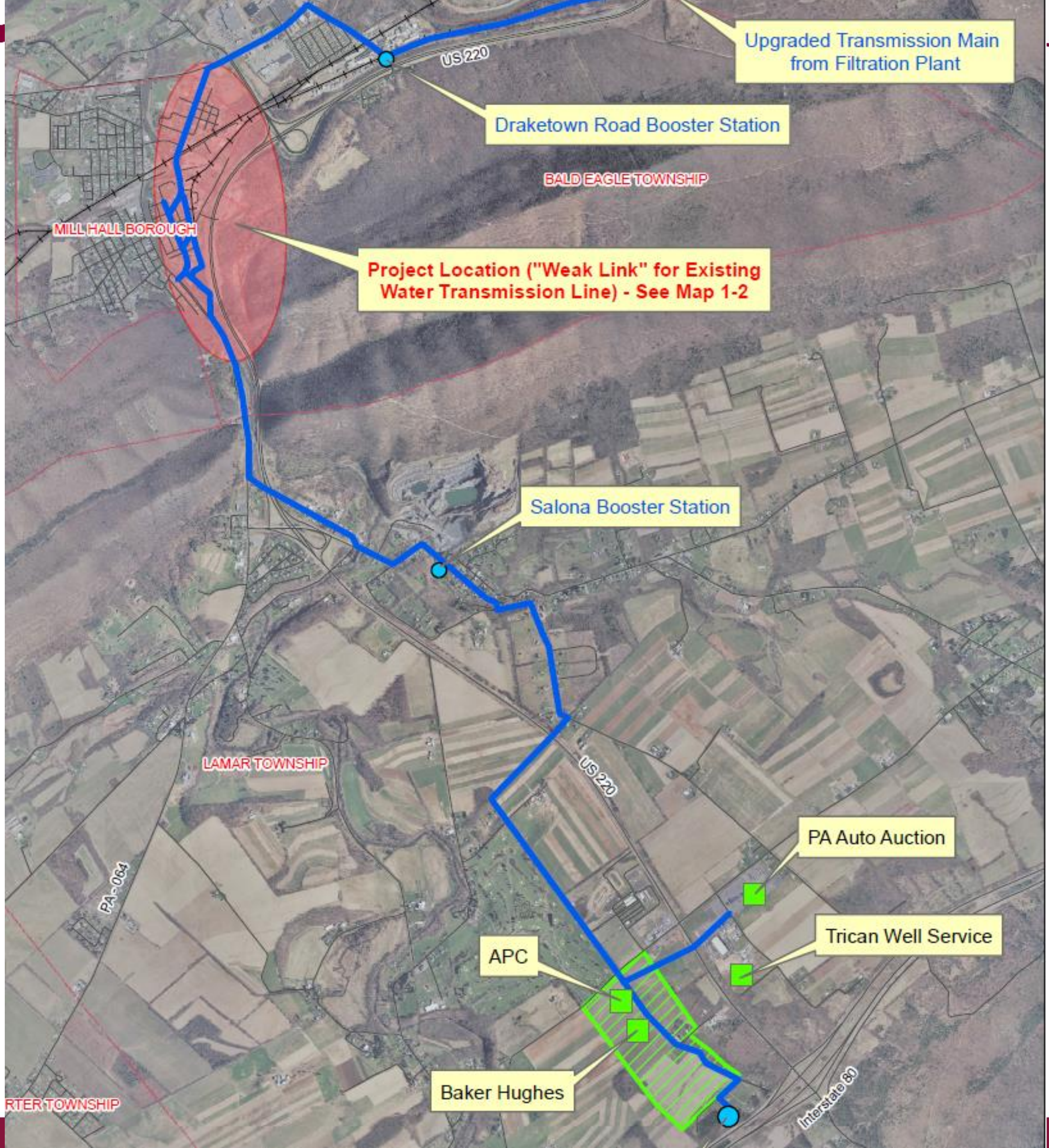


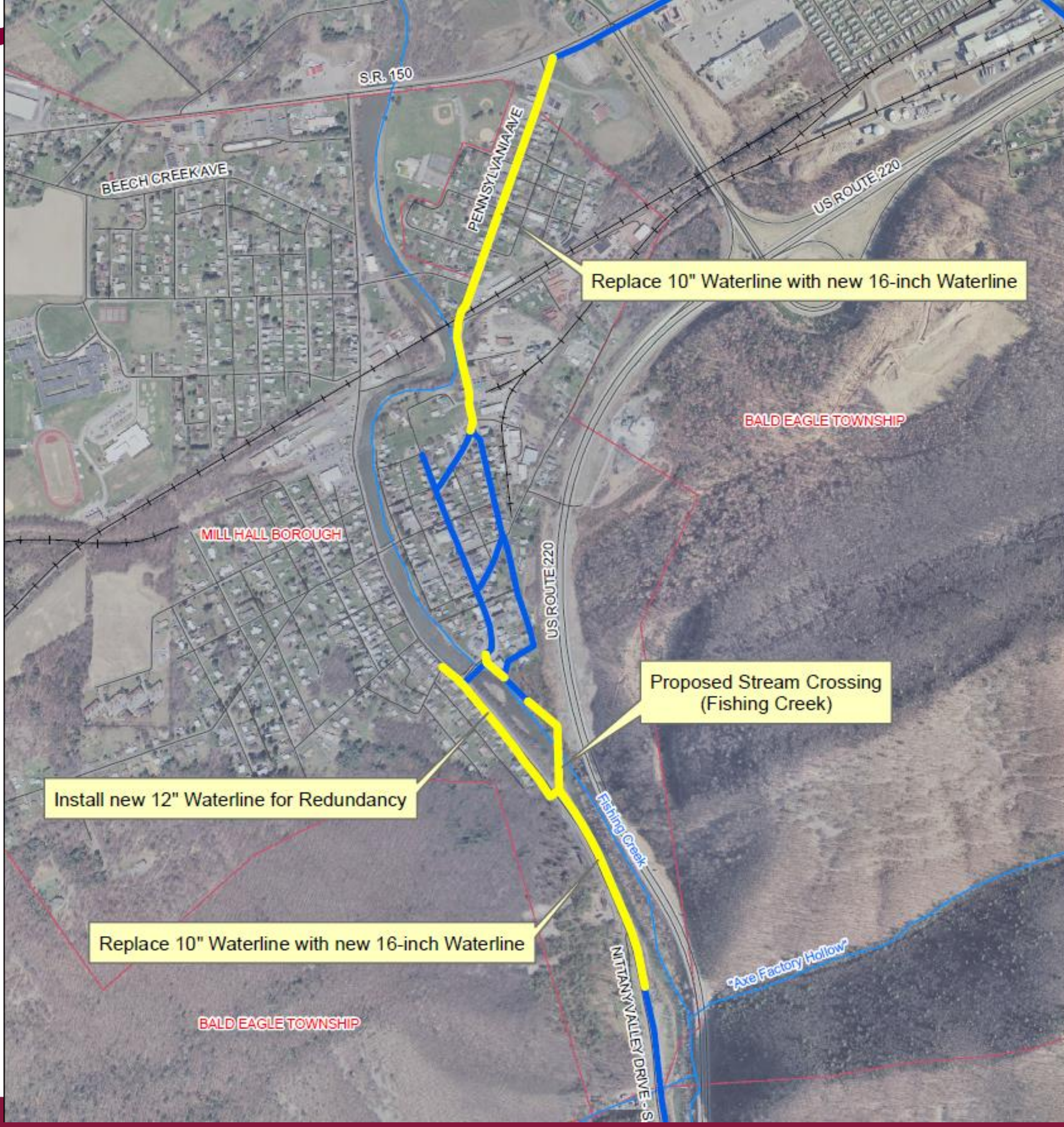
WTP
WTP
Tanks
Pump Stations
Pipes
4"
6"
8"
10"
12"
16"
24"
LOCK HAVEN
SUSQUEHANNA RIVER
Great Island
CASTANEA
Castanea
Mill Hall
Salona
Mackeyville
BALD EAGLE MOUNTAIN
BALD EAGLE STATE FOREST
WAYNE
LAMAR
ALLISON
Flemington
Drakestown
Cedar Springs
Parvin
Dunnstown



WTP
WTP
Tanks
Pump Stations
Pipes
4"
6"
8"
10"
12"
16"
24"
LOCK HAVEN
SUSQUEHANNA
CASTANEA
Mill Hall
Salona


WTP
WTP
Tanks
Pump Stations
Pipes
4"
6"
8"
10"
12"
16"
24"
LOCK HAVEN
SUSQUEHANNA RIVER
Mill Hall
Salona
Castanea
Mackeyville


Upgraded Transmission Main from Filtration Plant
US 220
Draketown Road Booster Station
BALD EAGLE TOWNSHIP
MILL HALL BOROUGH
Project Location ("Weak Link" for Existing Water Transmission Line) - See Map 1-2
Salona Booster Station
LAMAR TOWNSHIP
US 220
PA Auto Auction
PA - 064
Trican Well Service
APC
Baker Hughes
RTER TOWNSHIP
Interstate 80


S.R. 150
BEECH CREEK AVE
PENNSYLVANIA AVE
US ROUTE 220
Replace 10" Waterline with new 16-inch Waterline
BALD EAGLE TOWNSHIP
MILL HALL BOROUGH
US ROUTE 220
Proposed Stream Crossing
(Fishing Creek)
Install new 12" Waterline for Redundancy
Fishing Creek
Replace 10" Waterline with new 16-inch Waterline
"Axe Factory Hollow"
NITTANY VALLEY DRIVE - S
BALD EAGLE TOWNSHIP

Case Study:
Williamsport Municipal Water Authority

- **Detailed Hydraulic Water Model Created**
  - 7 Pressure Zones
  - 8 Storage Tanks
  - 7 Pump Stations
  - >200 miles of waterlines (all pipes ≥ 6-inches)
- **<u>Goal:</u> Develop and system-wide water model and evaluate the system to develop a logical and cost-effective capital improvements plan to address:**
  - Fire Protection Needs
  - Improved Water Service Pressures (Existing and Future Customers)
  - Strategic Replacement of Aging Infrastructure

Case Study:
Williamsport Municipal Water Authority

Written Report w/ Mapping:

- **14 Alternatives Developed and Evaluated**
  - Stabilization of Pressures
  - Fire Protection
  - Estimate of Probable Project Costs
- **Recommendations**
  - 0-5 year Planning Period
  - 5-10 year Planning Period
- **Future Considerations**
  - Realignment of Pressure Districts
  - Looping Dead Ends
  - Unaccounted for Water Evaluation

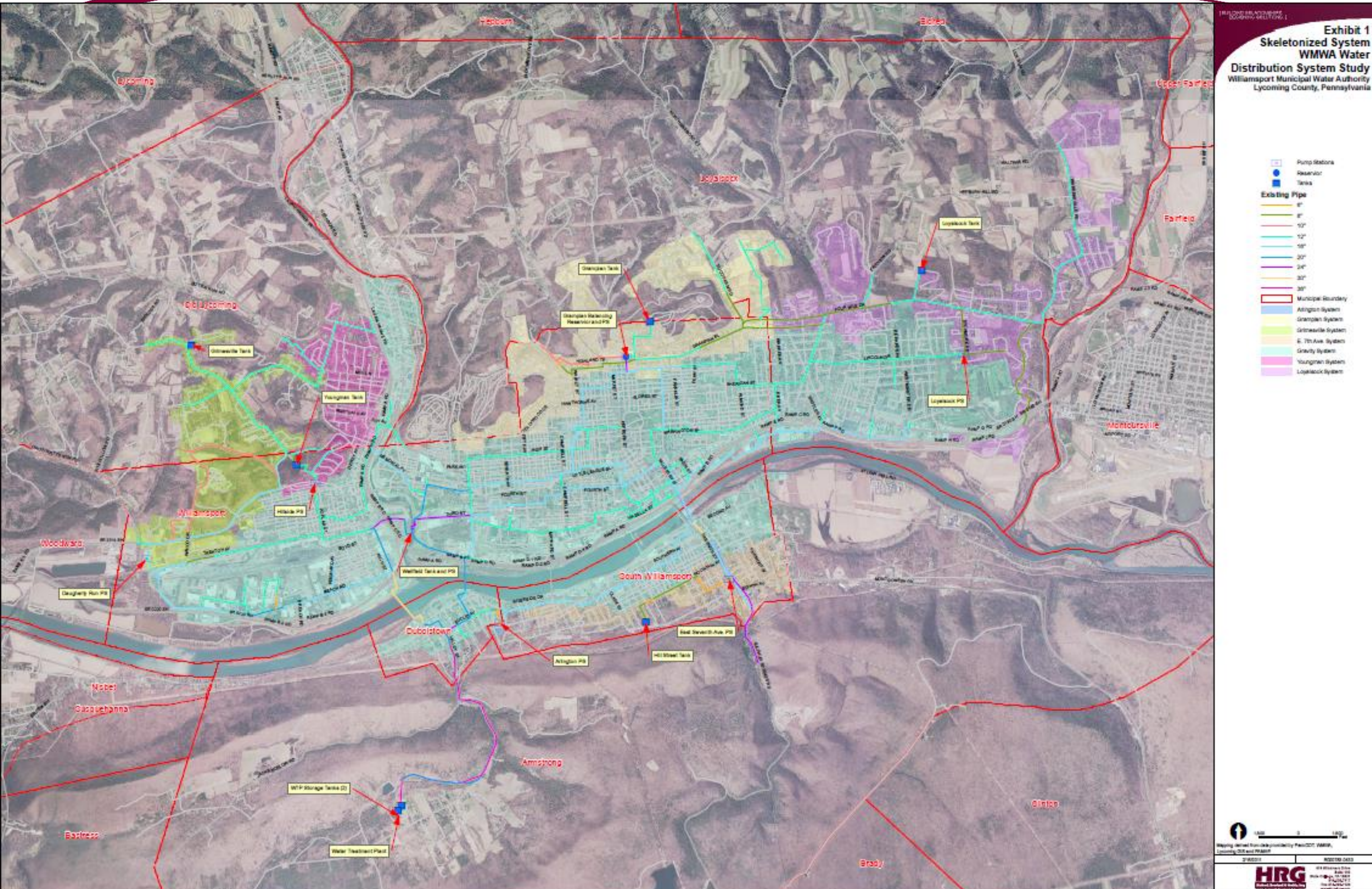


Exhibit 1
Skeletonized System
WMWA Water
Distribution System Study
Williamsport Municipal Water Authority
Lycoming County, Pennsylvania
Pump Stations
Reservoir
Tanks
Existing Pipe
Municipal Boundary
Arlington System
Grampian System
Grimesville System
E. 7th Ave. System
Gravity System
Youngman System
Loyalsock System
Hepburn
Eldred
Lycoming
Upper Fairfield
Loyalsock
Fairfield
Old Lycoming
Williamsport
Woodward
Montoursville
South Williamsport
Duboistown
Nisbet
Susquehanna
Armstrong
Clinton
Bastress
Brady
HRG

Herbert, Rowland & Grubic, Inc.
Engineering & Related Services
AN EMPLOYEE-OWNED COMPANY

Questions?

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