Introduction to Water Distribution System Modeling (Part 2)

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This program is made possible under a cooperative agreement with US EPA.

Instructor

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  Tennessee Water Resources Research Center
  - Manage technical assistance and training projects for water and wastewater utilities, specializing in:

Geographic Information Systems (GIS)	Asset Management Plans	Hydraulic Modeling (WDS and CS)

  - **Always looking for utilities to work with**
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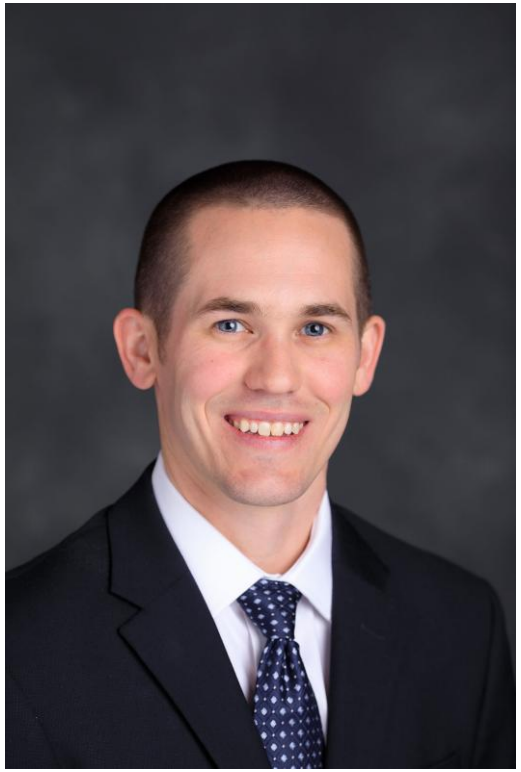
  - Visit: TNWaterTA.sites.utk.edu



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Recap of Part 1

Introduction to WDS Modeling

- What is a WDS model?
- Why is a WDS model useful?
- How does a WDS model work?

WDS Model Development

- Select modeling software
- Determine model scale
- Create the network
- Add node information
- Add link information

Video Link

Introduction to WDS Modeling Webinar (Part 1)

https://www.youtube.com/watch?v=zV0nbDble-4

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Today's Outline

- Simulation Types and Applications
- Model Scenarios
- Running Steady State Simulations
- Running Extended Period Simulations

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Example Model File

From the University of Kentucky's WDS Research Database (https://uknowledge.uky.edu/wdst_us/)

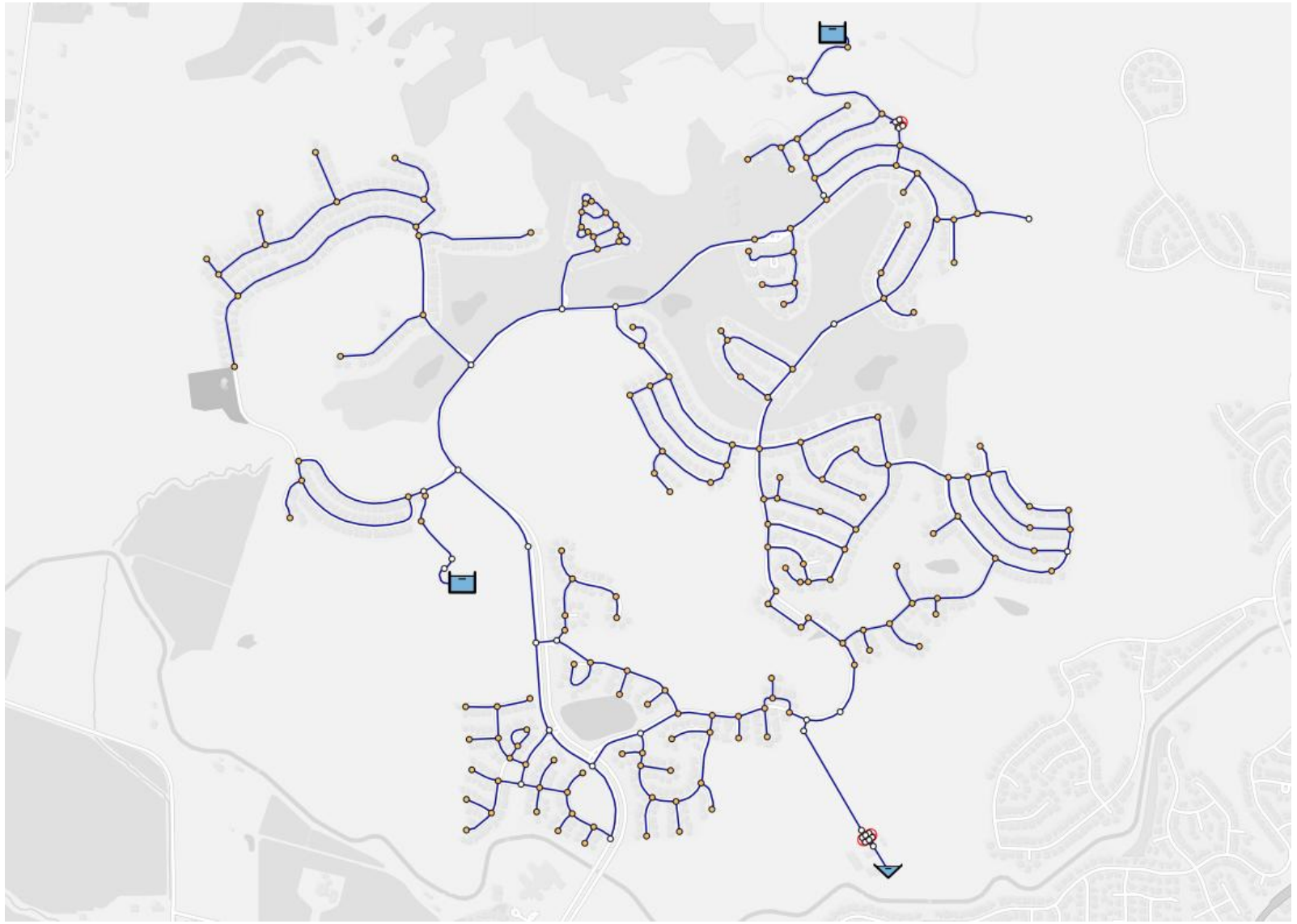
CA1 System

- Based on a real network of a system's pressure zone in California
- 18.3 miles of pipe
- Pipe diameters range from 6-inch to 16-inch
- Elevations: 114 – 531 ft
- 0.25 MGD (residential) + 0.5 MGD (golf course irrigation)

EPANET

QGIS

QGISRed



Basic Simulation Types

1. Steady-State Simulation

2. Extended Period Simulation (EPS)

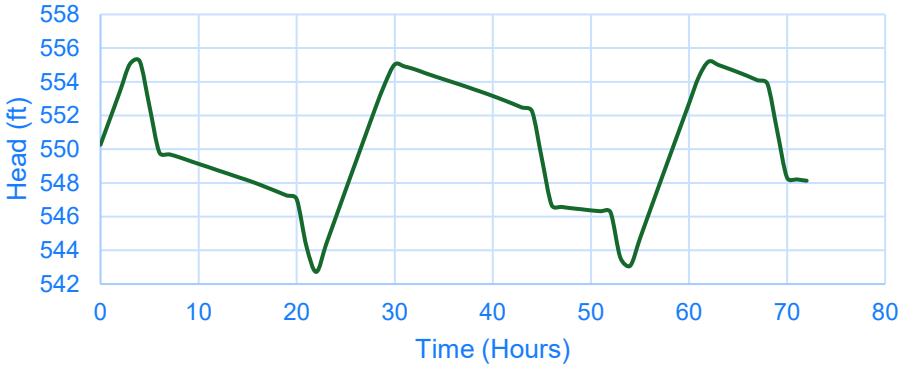
Steady-State Simulation

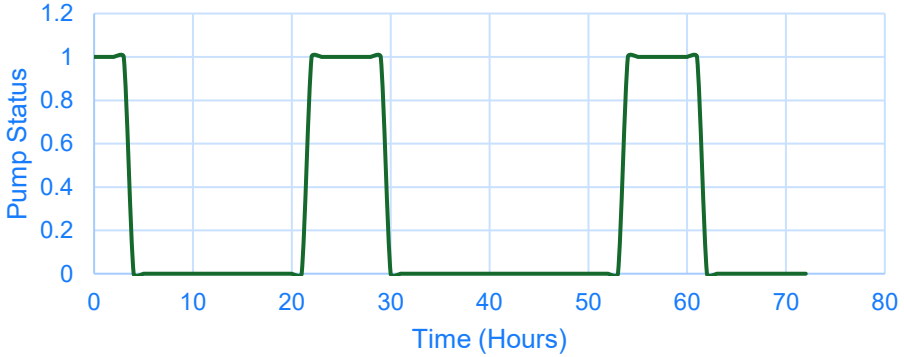
"Computes the state of the system (flows, pressures, pump operating attributes, valve position, and so on) assuming that hydraulic demands and boundary conditions do not change with respect to time."[1]

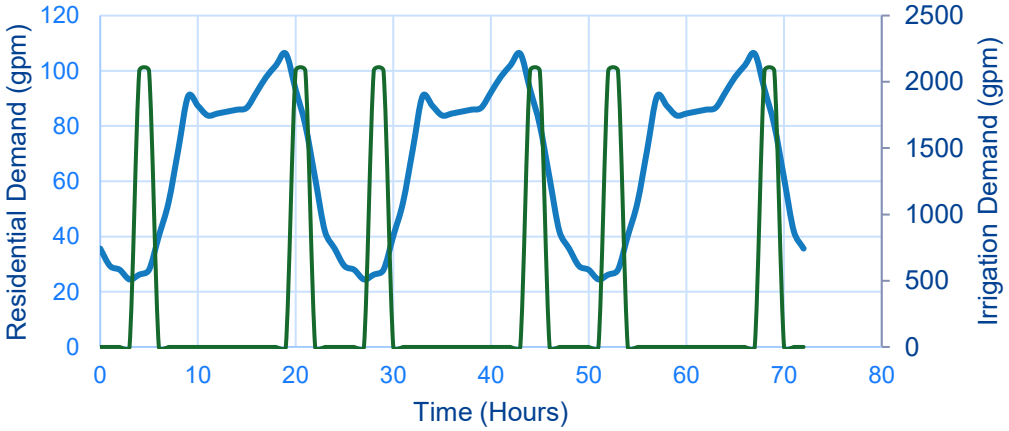
Think of a steady-state simulation as a snapshot of your system.

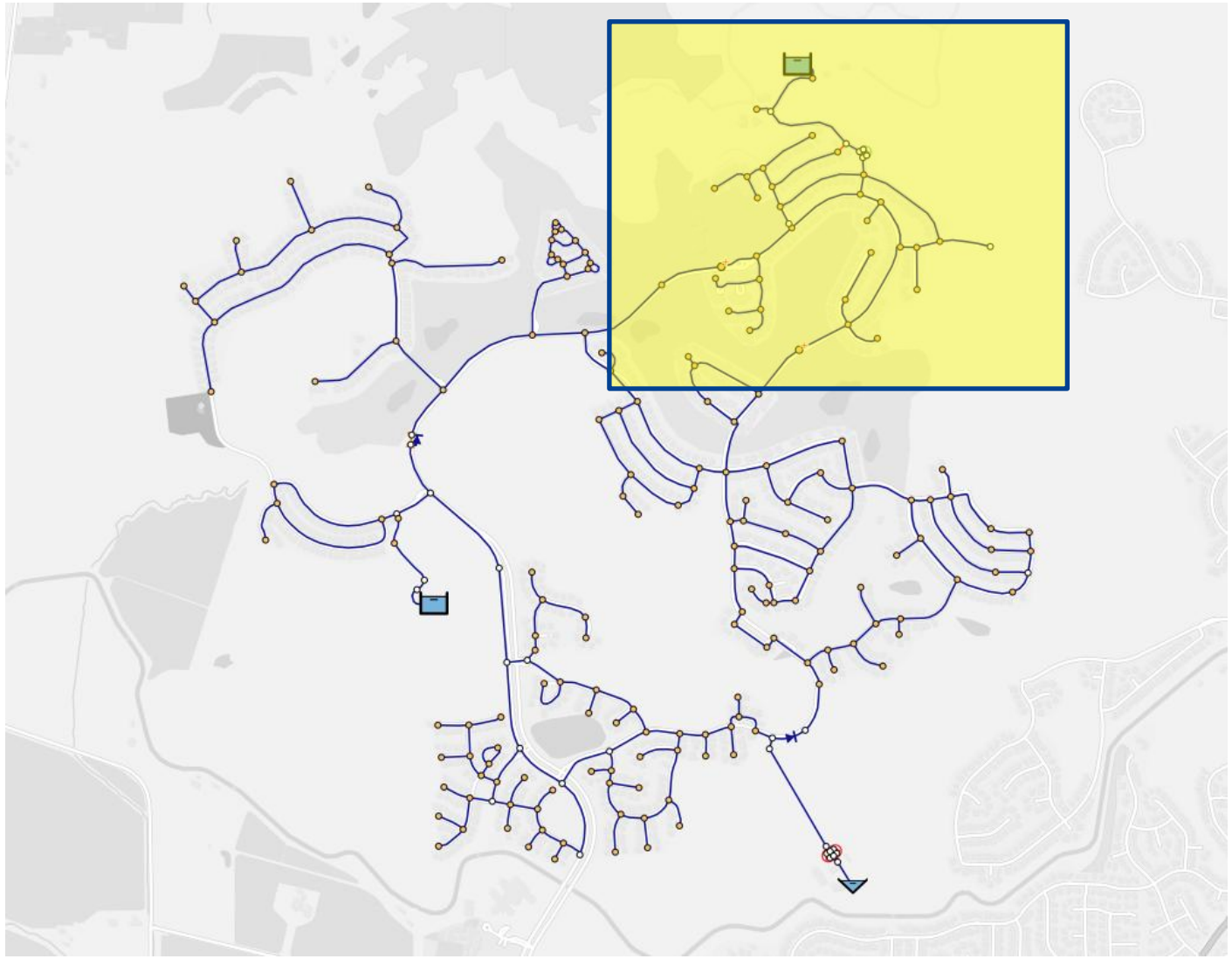
[1]Walski et al. (2007). "Advanced Water Distribution Modeling and Management." Bentley Institute Press, Bentley Systems.

Steady-State Simulation Example









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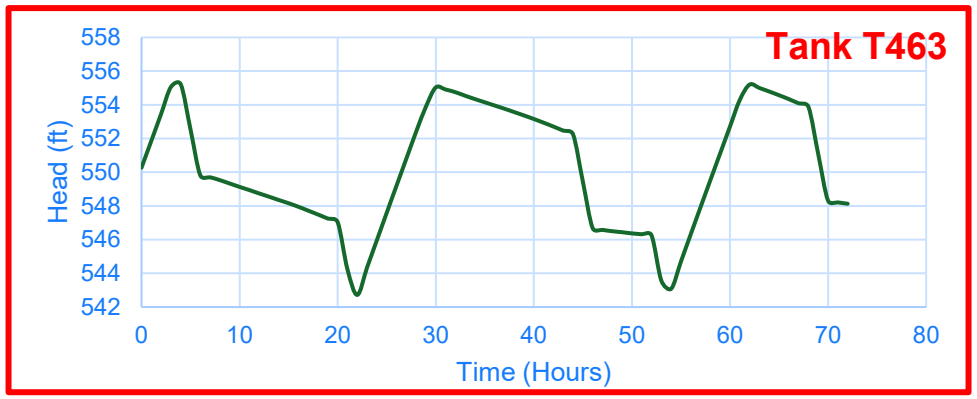

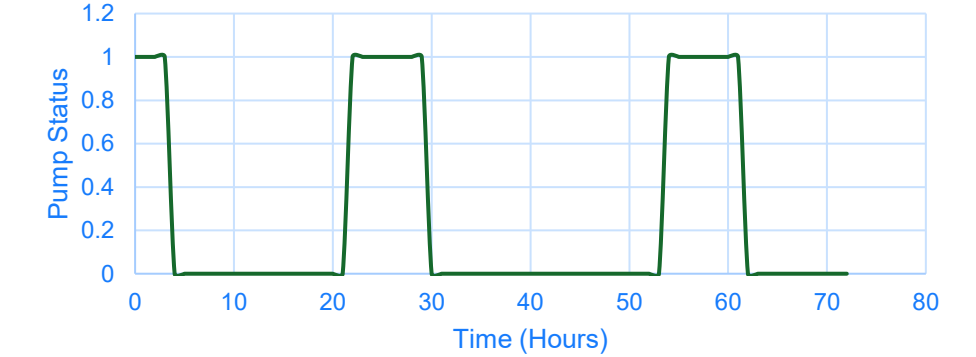

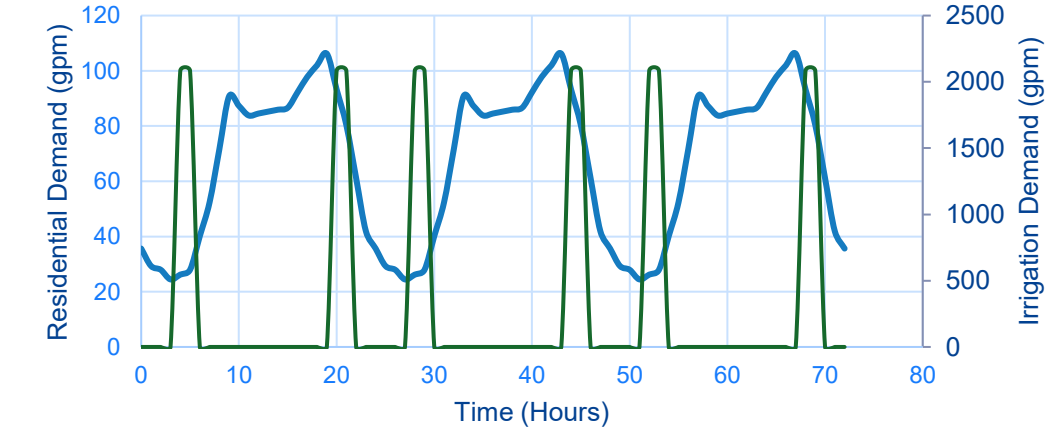

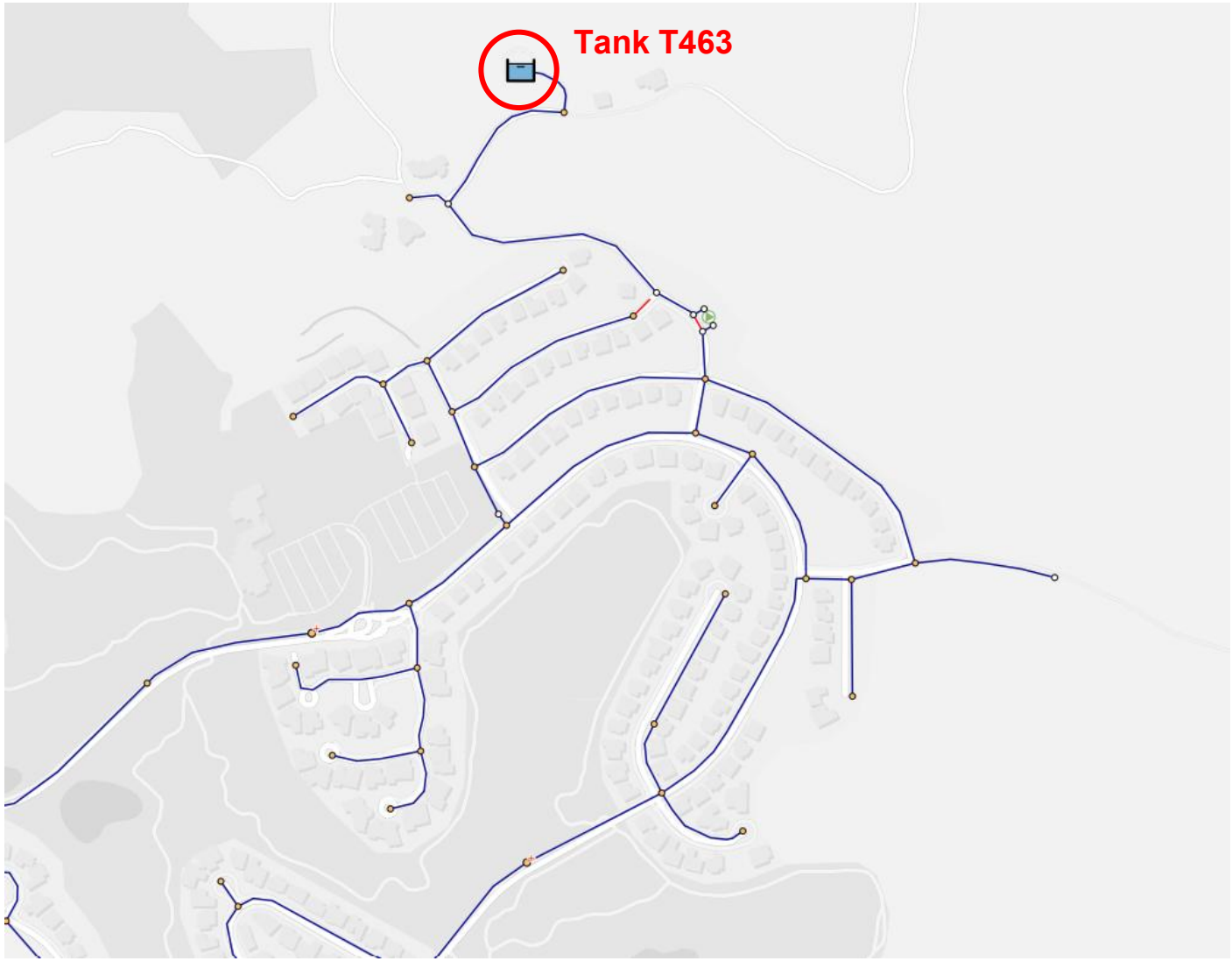

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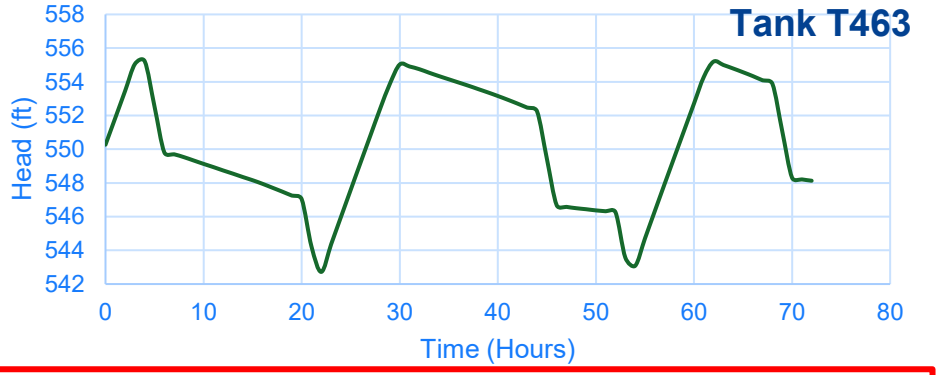

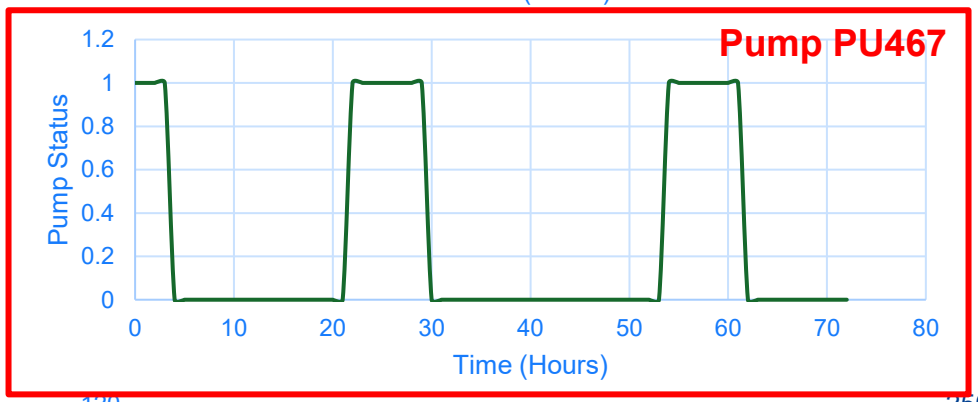

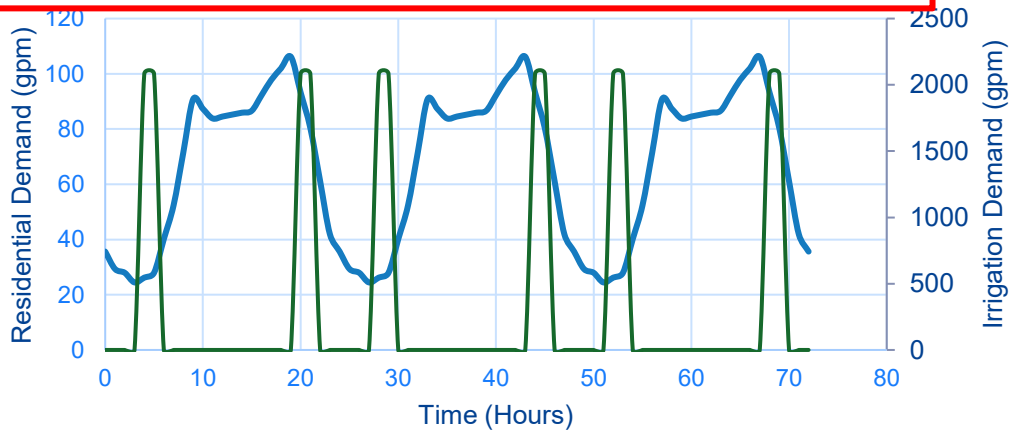

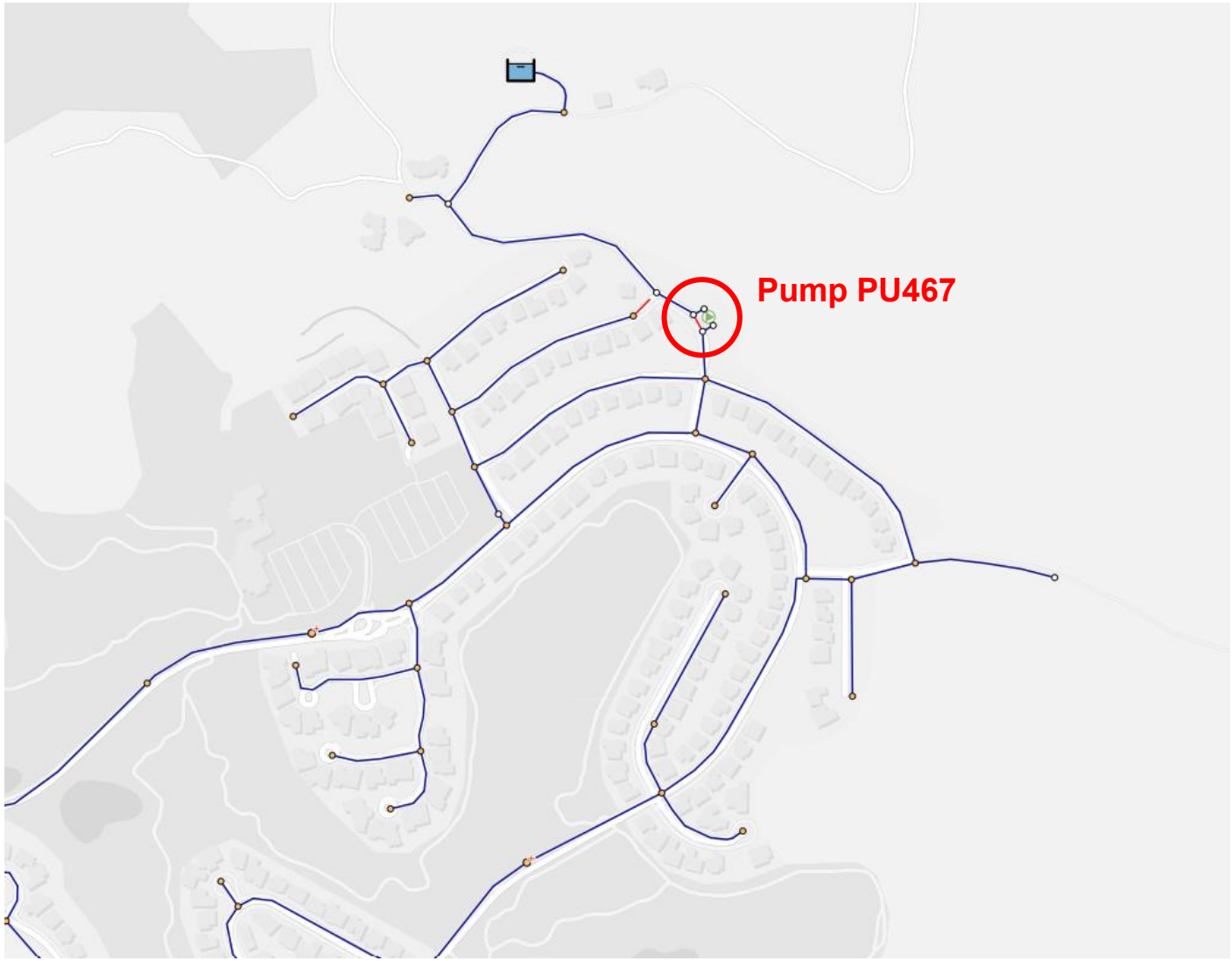

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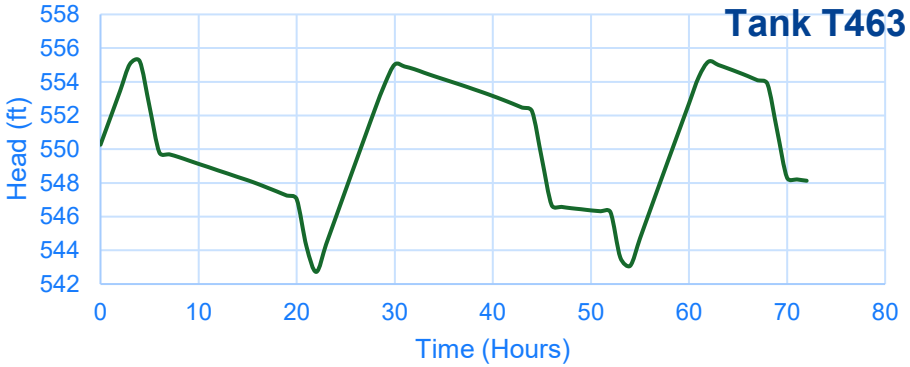

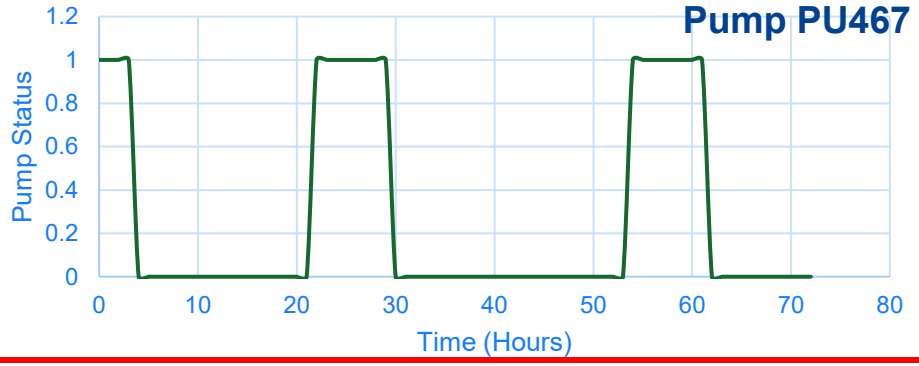

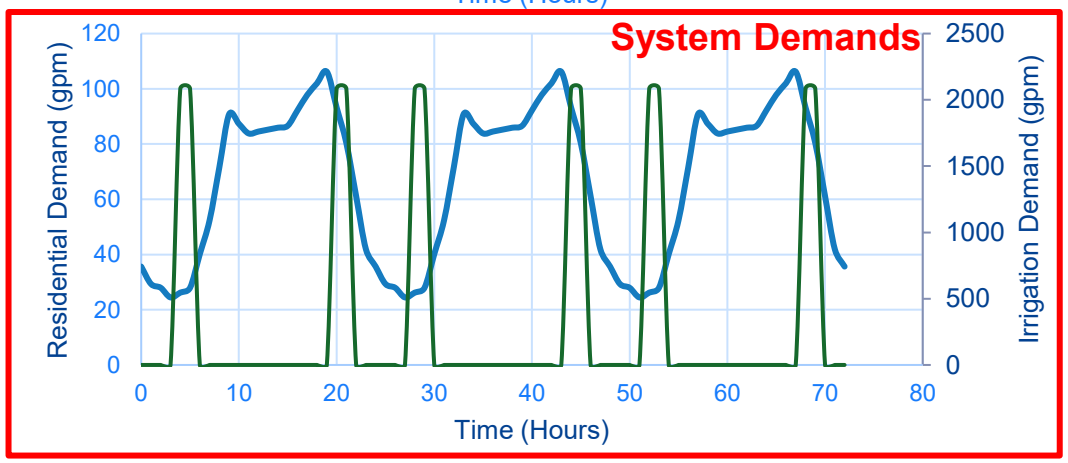

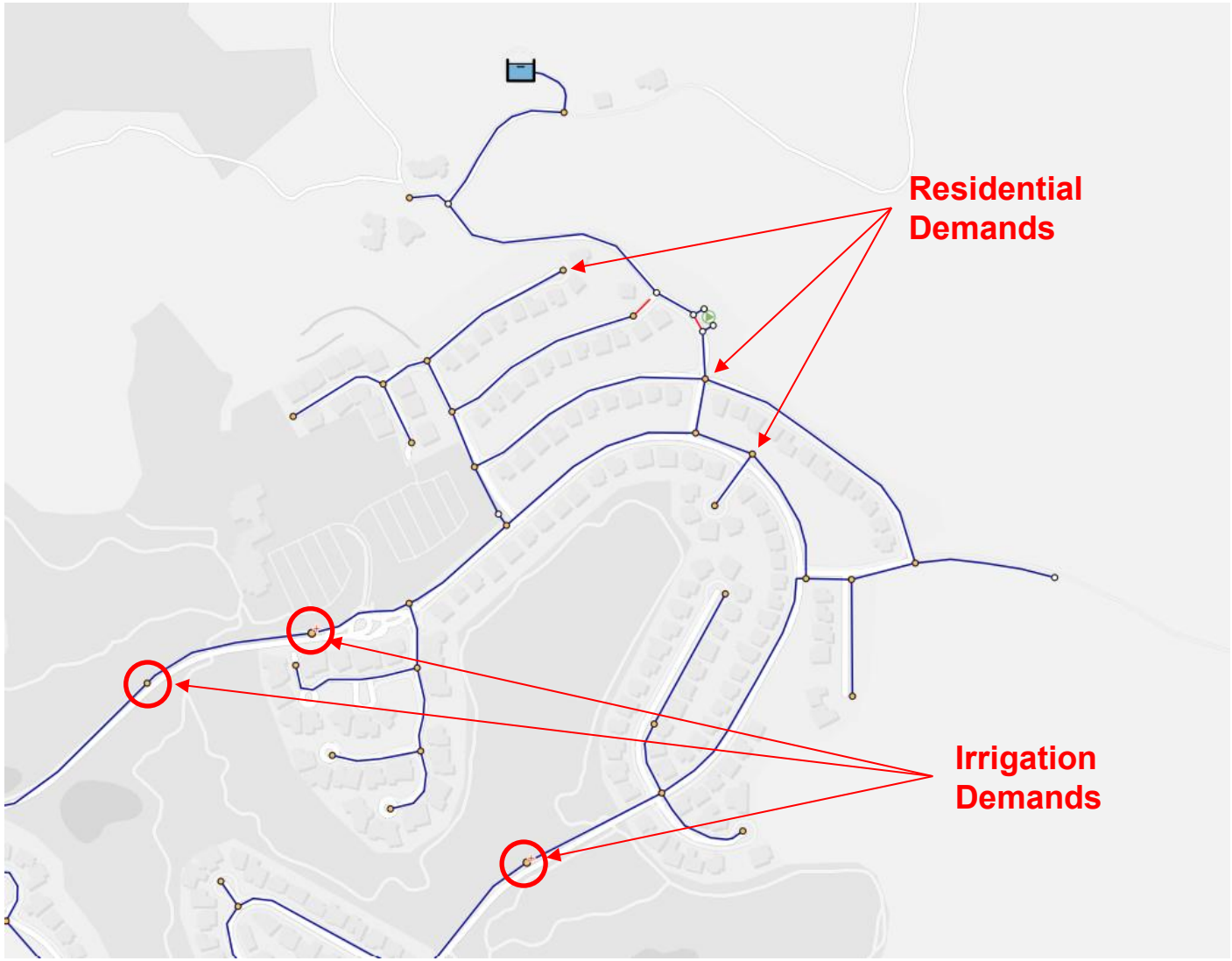

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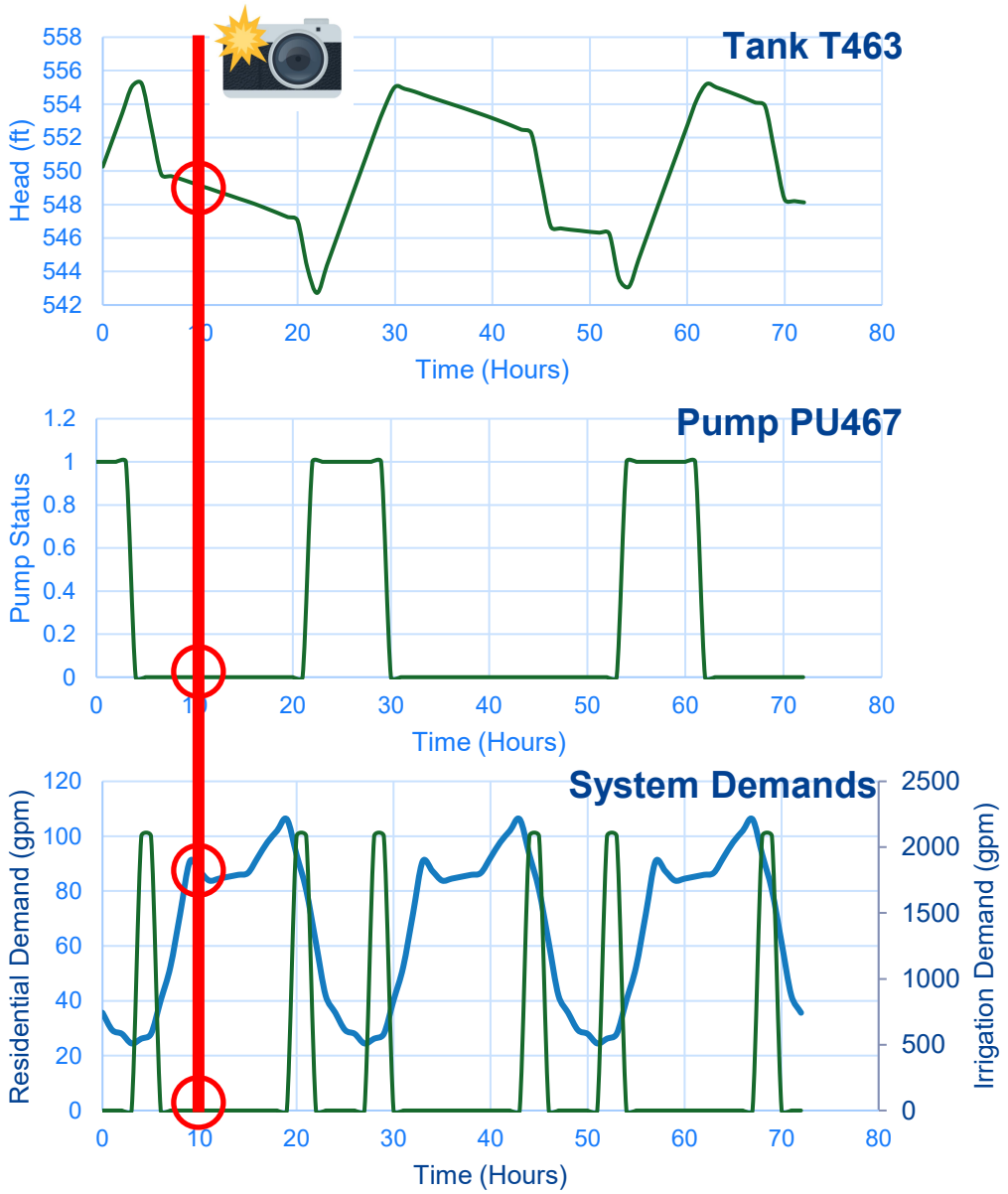

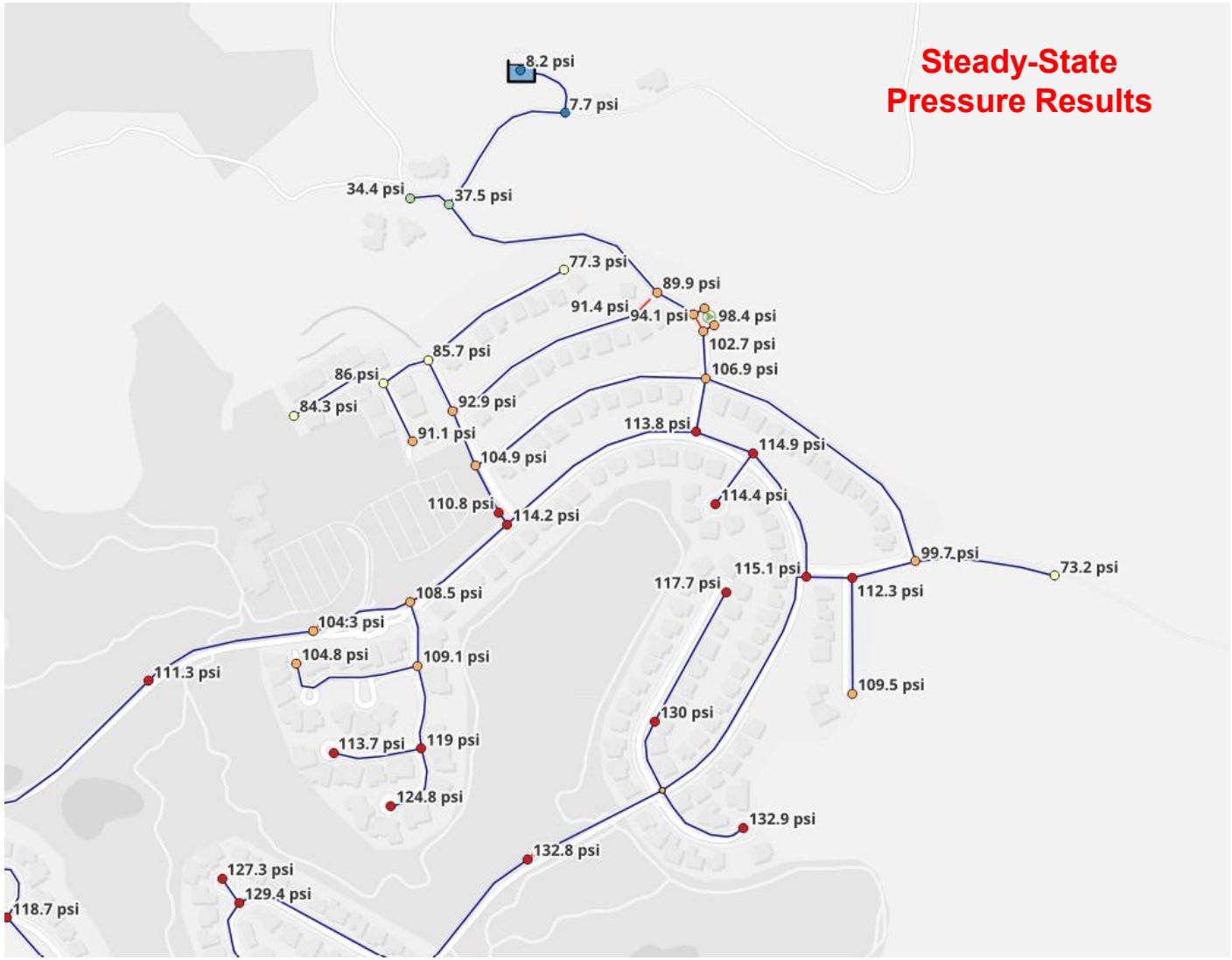

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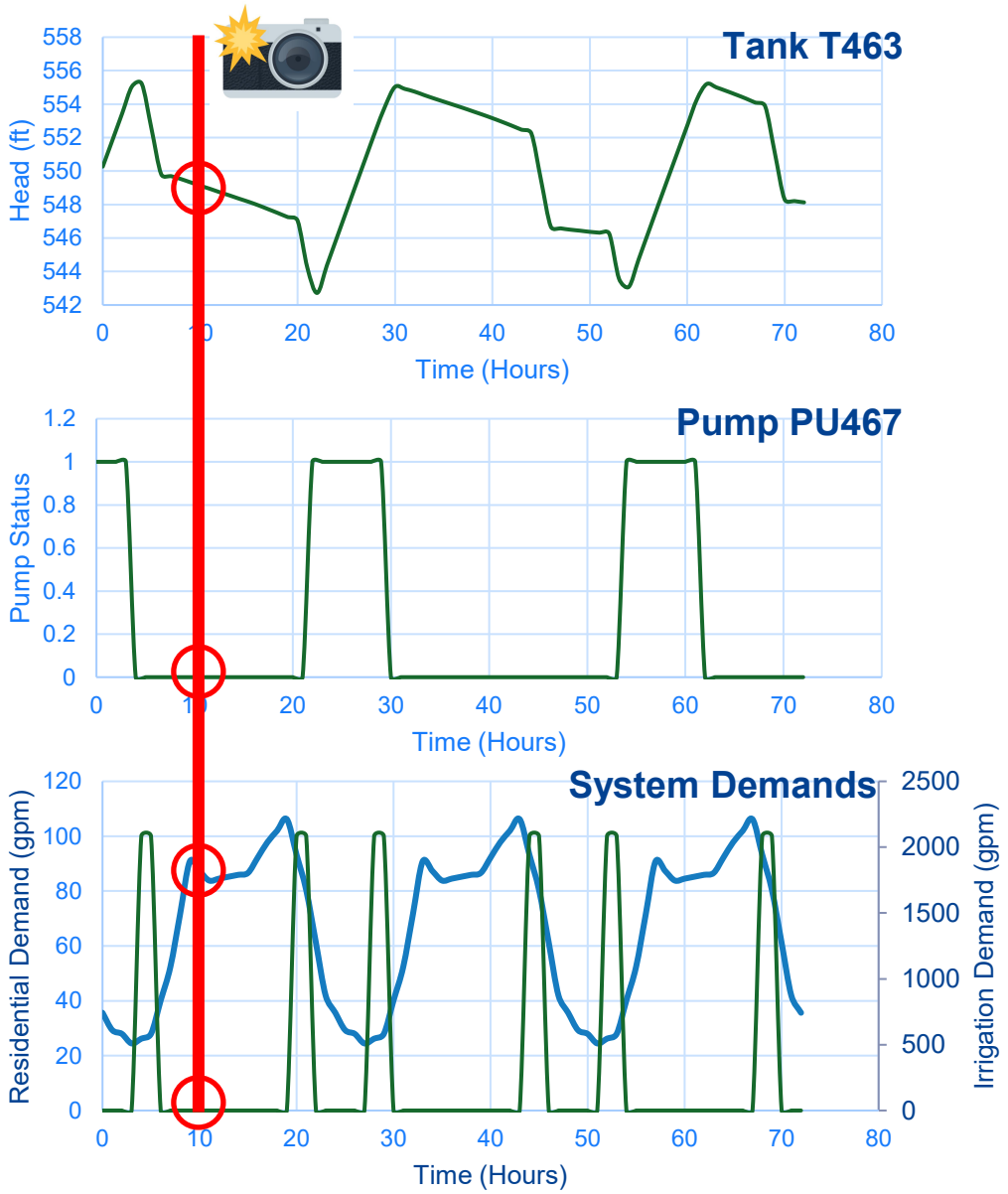

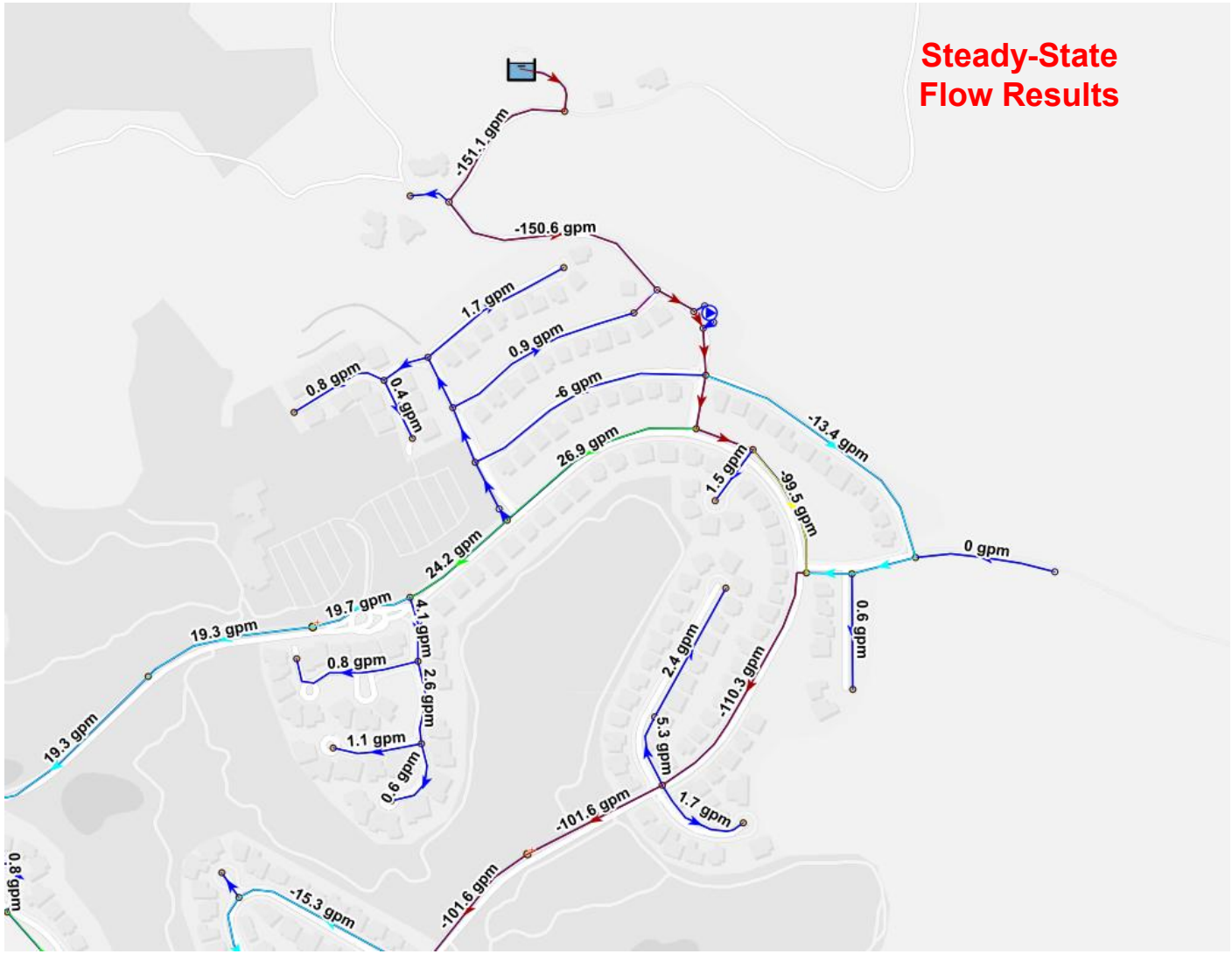

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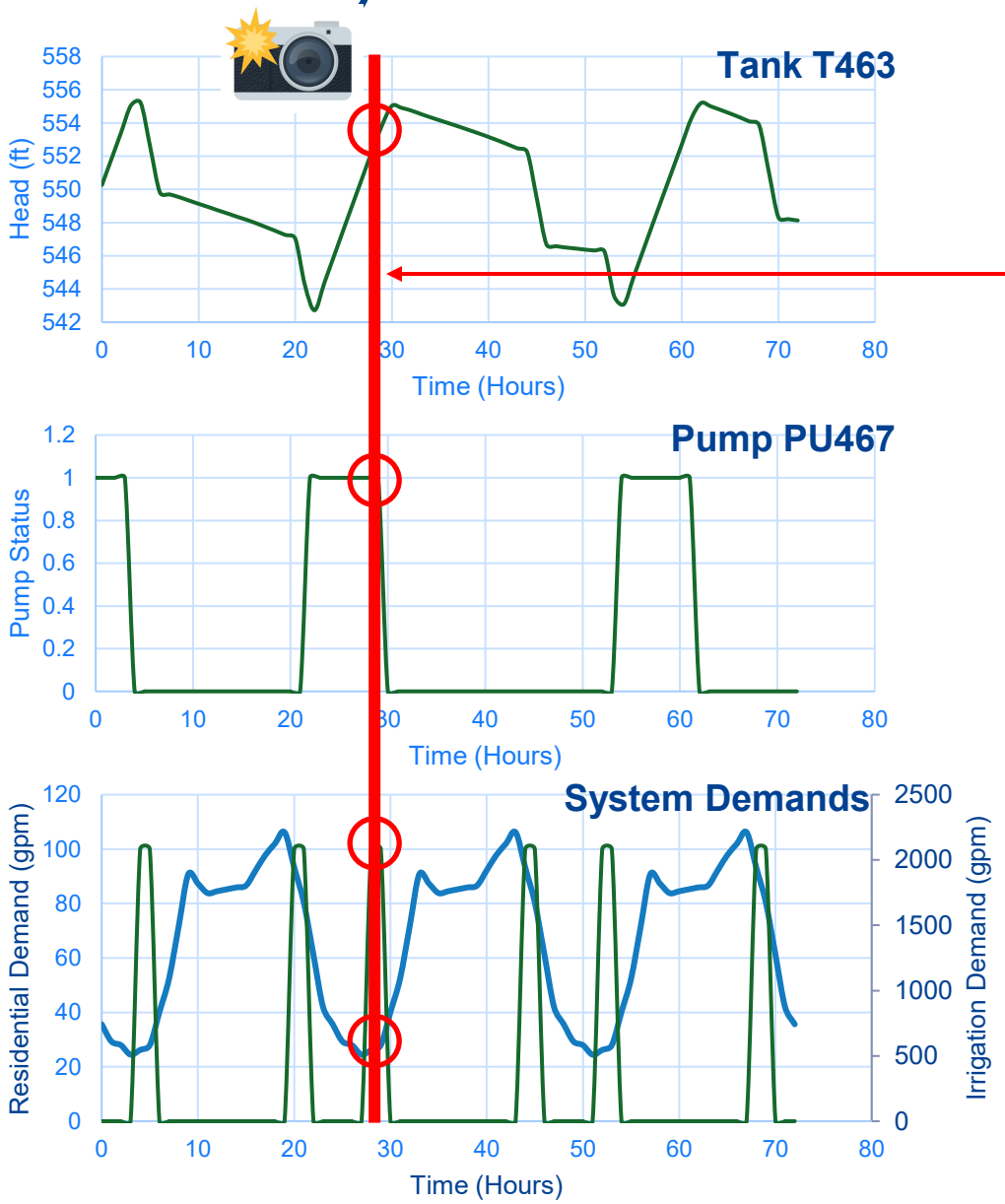
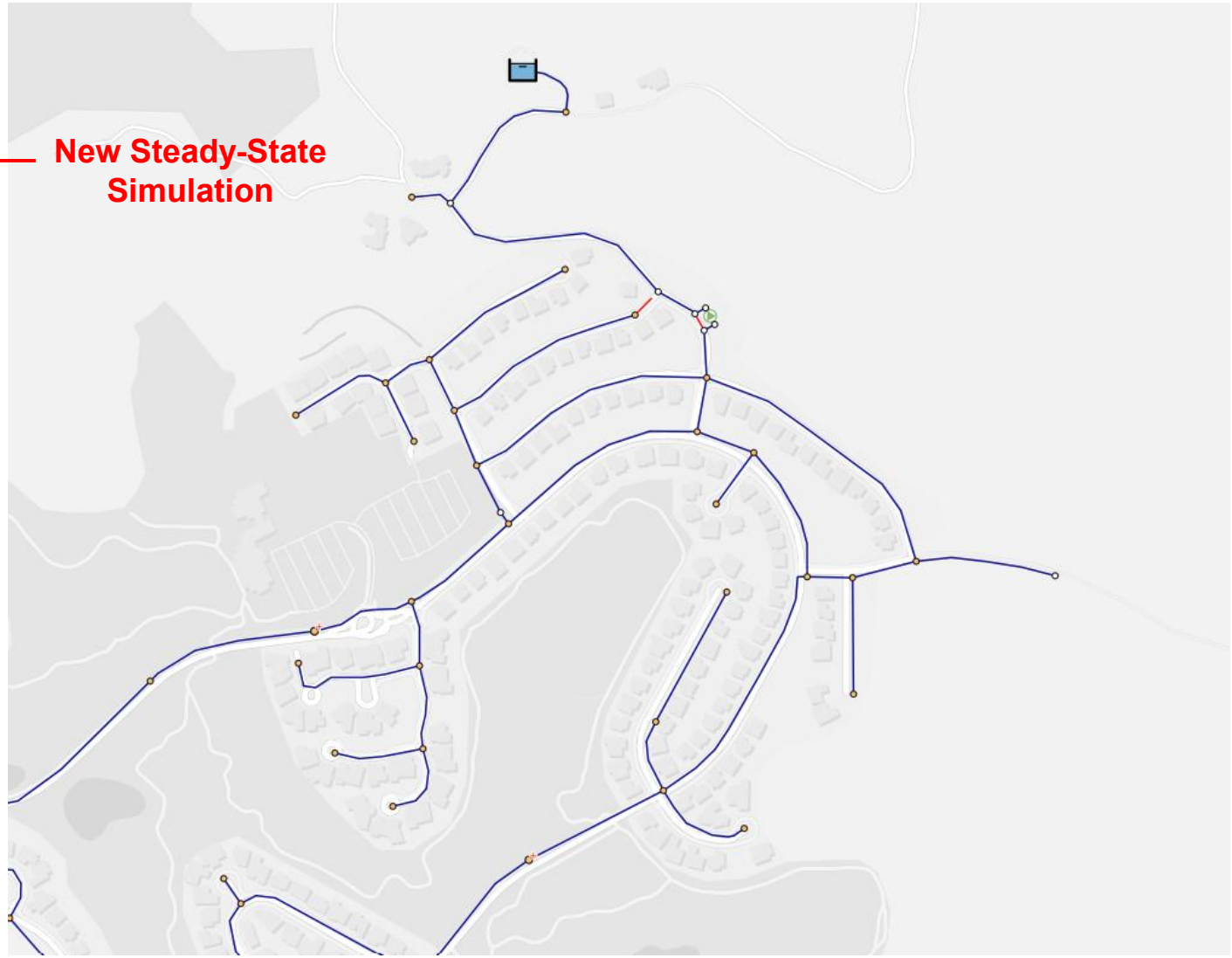


New Steady-State Simulation



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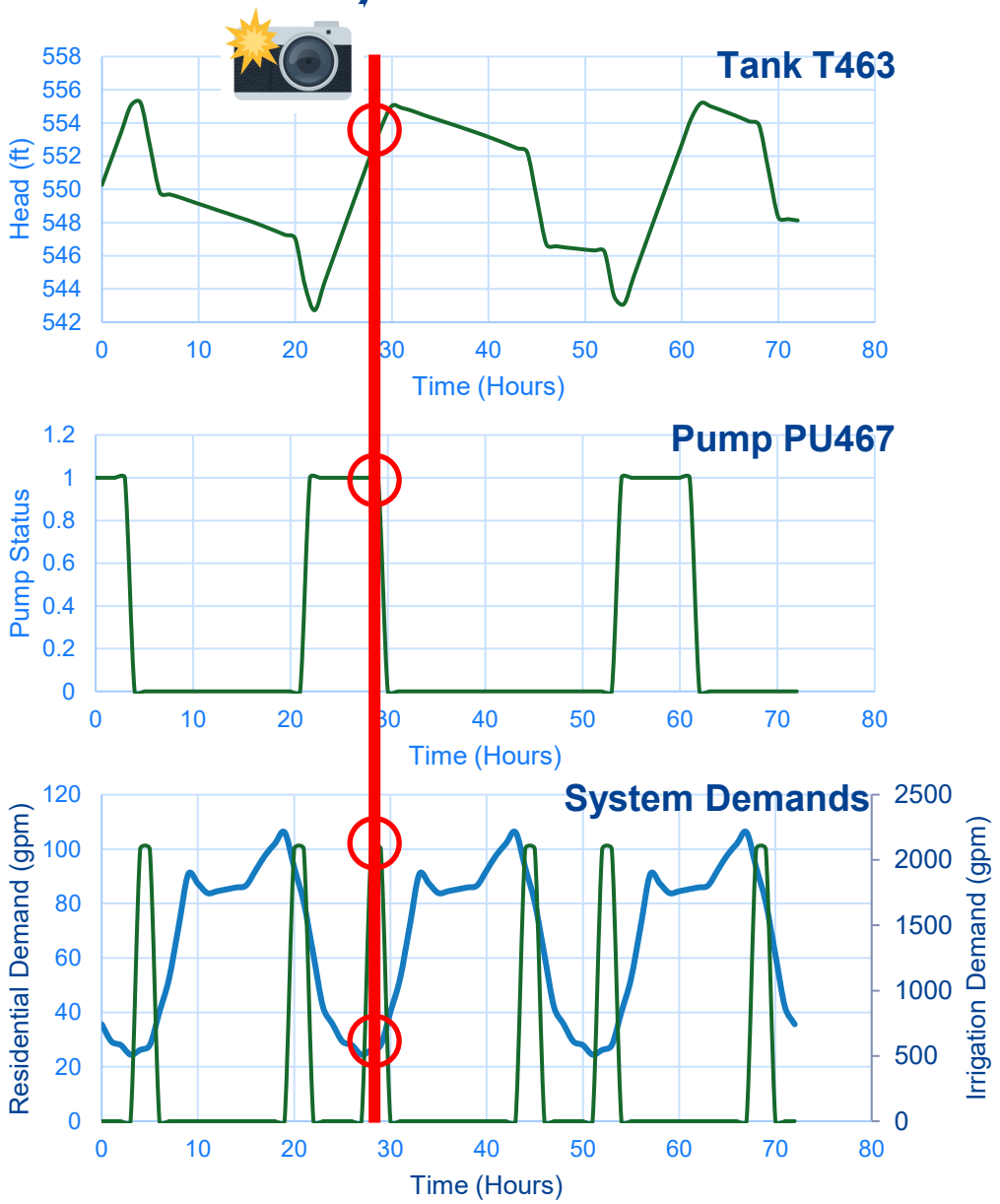

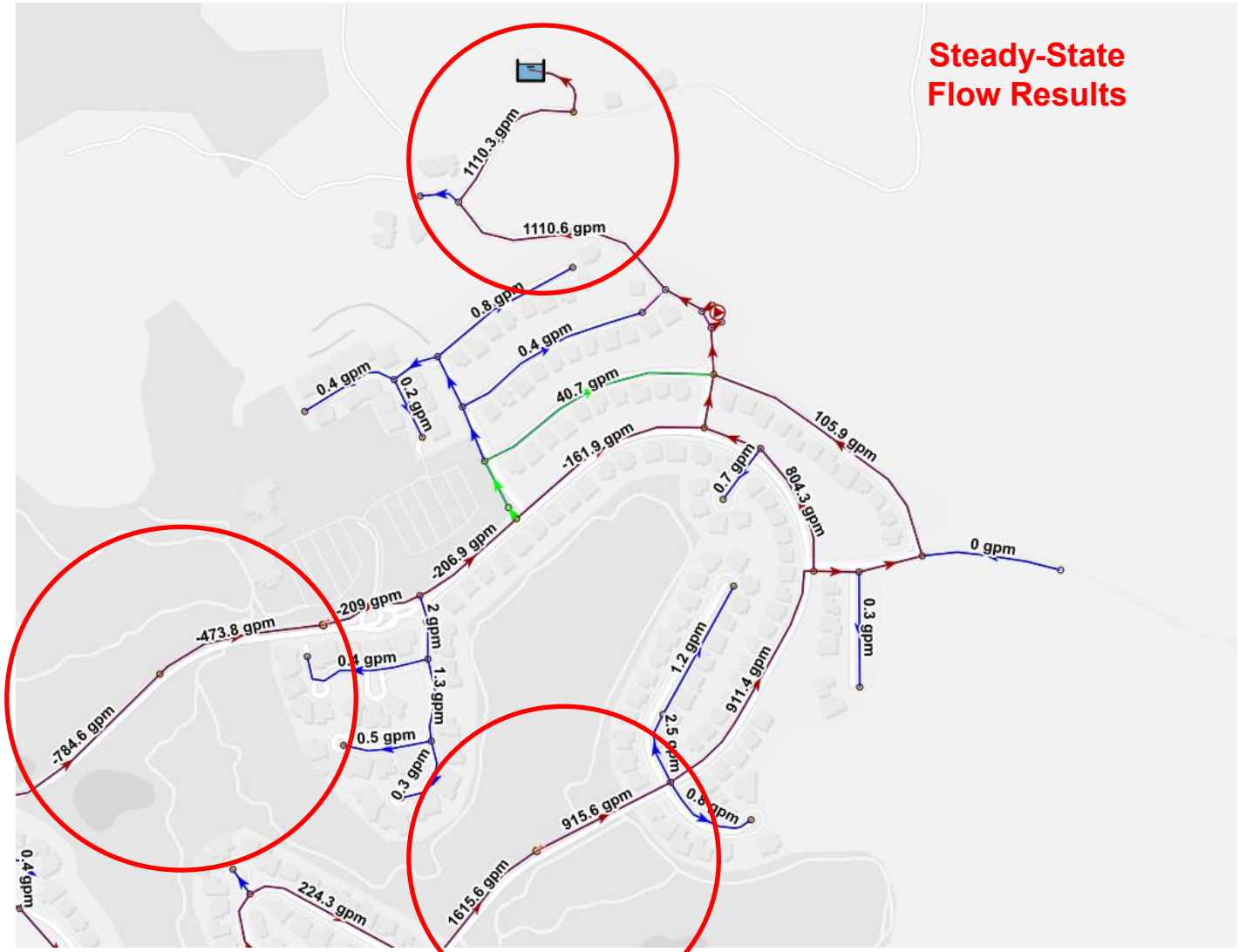

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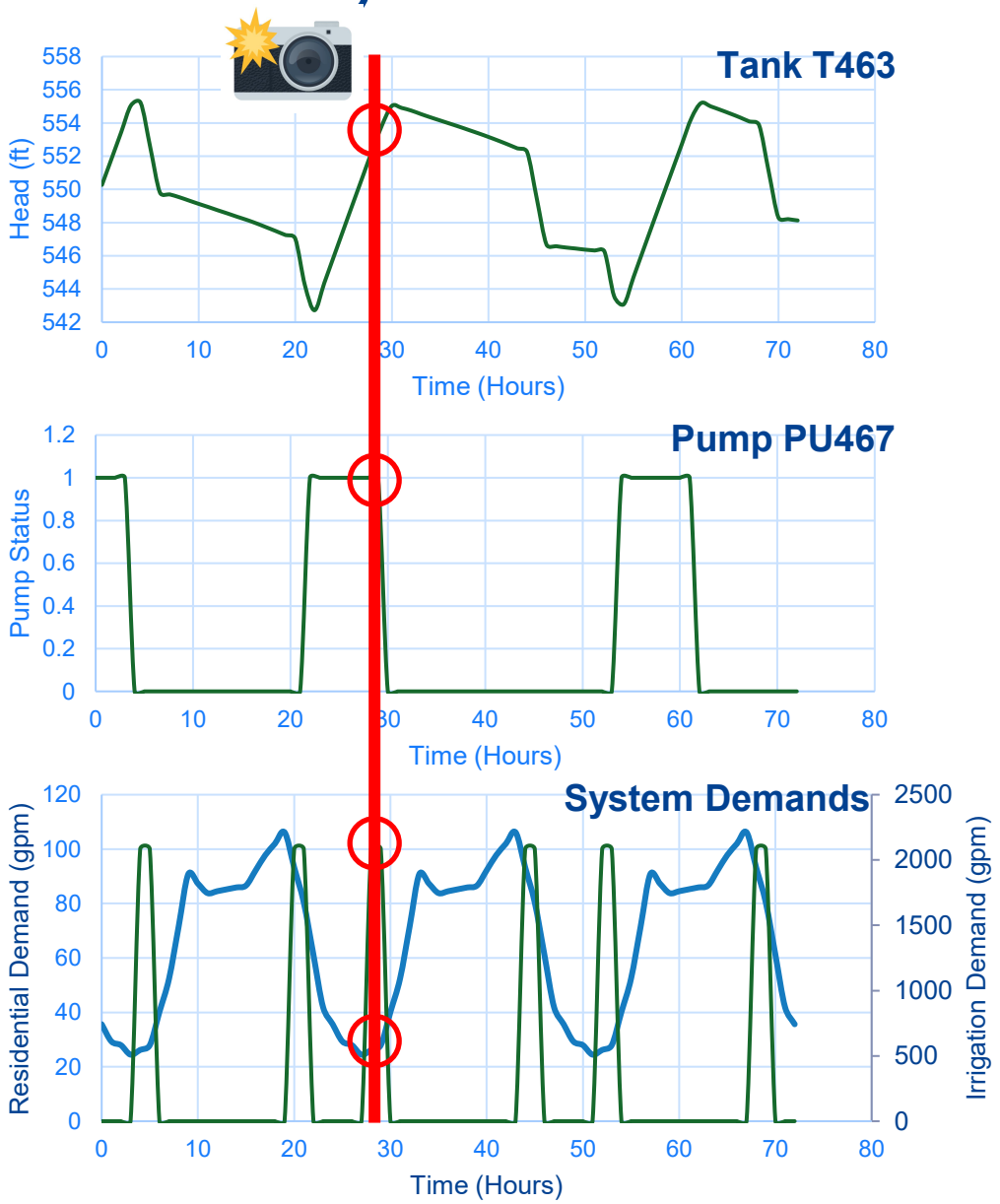

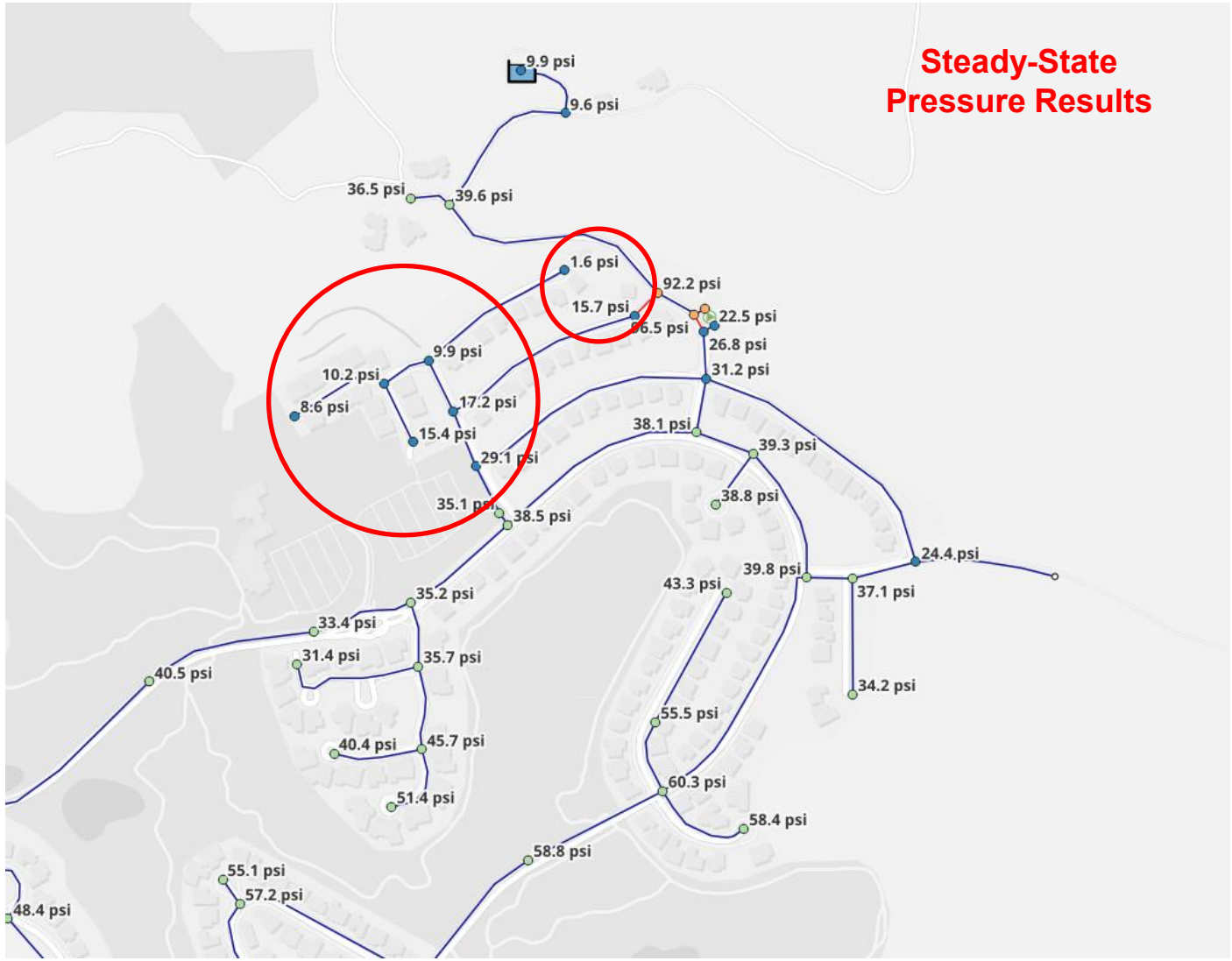

Steady-State Simulation Applications

- Steady-state simulations are typically used to model "worst-case or system-defining conditions."[2]
- Some common applications include:

Planning

- System expansions for new development
- Purchase water or wholesale connections
- Replacement and rehabilitation projects
- Emergency preparedness

Design

- Used by engineers to evaluate infrastructure alternatives and size new mains, pumps, tanks, etc.

Operations

- Peak hour system performance
- Troubleshoot recurring hydraulic issues
- Fire flow analysis
- Pump/valve set points
- UDF program planning
- Emergency response

[2]Cooper et al. (2017). "Computer Modeling of Water Distribution Systems – Manual of Water Supply Practices, M32 (4th Edition)." American Water Works Association.

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Extended Period Simulation (EPS)

- "Determines the quasi-dynamic behavior of a system over a period of time, computing the state of the system as a series of steady-state simulations in which hydraulic demands and boundary conditions do change with respect to time."[1]

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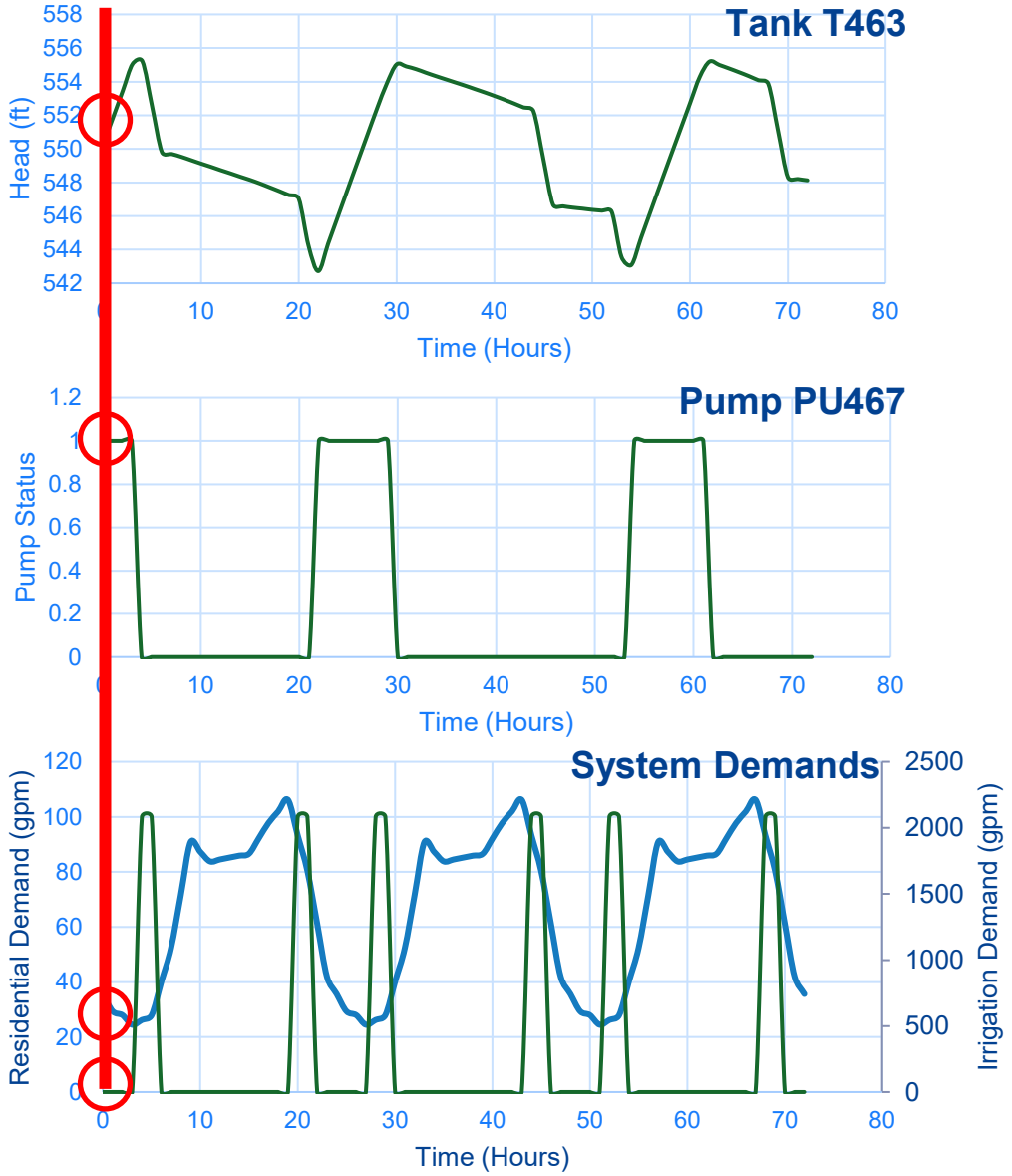
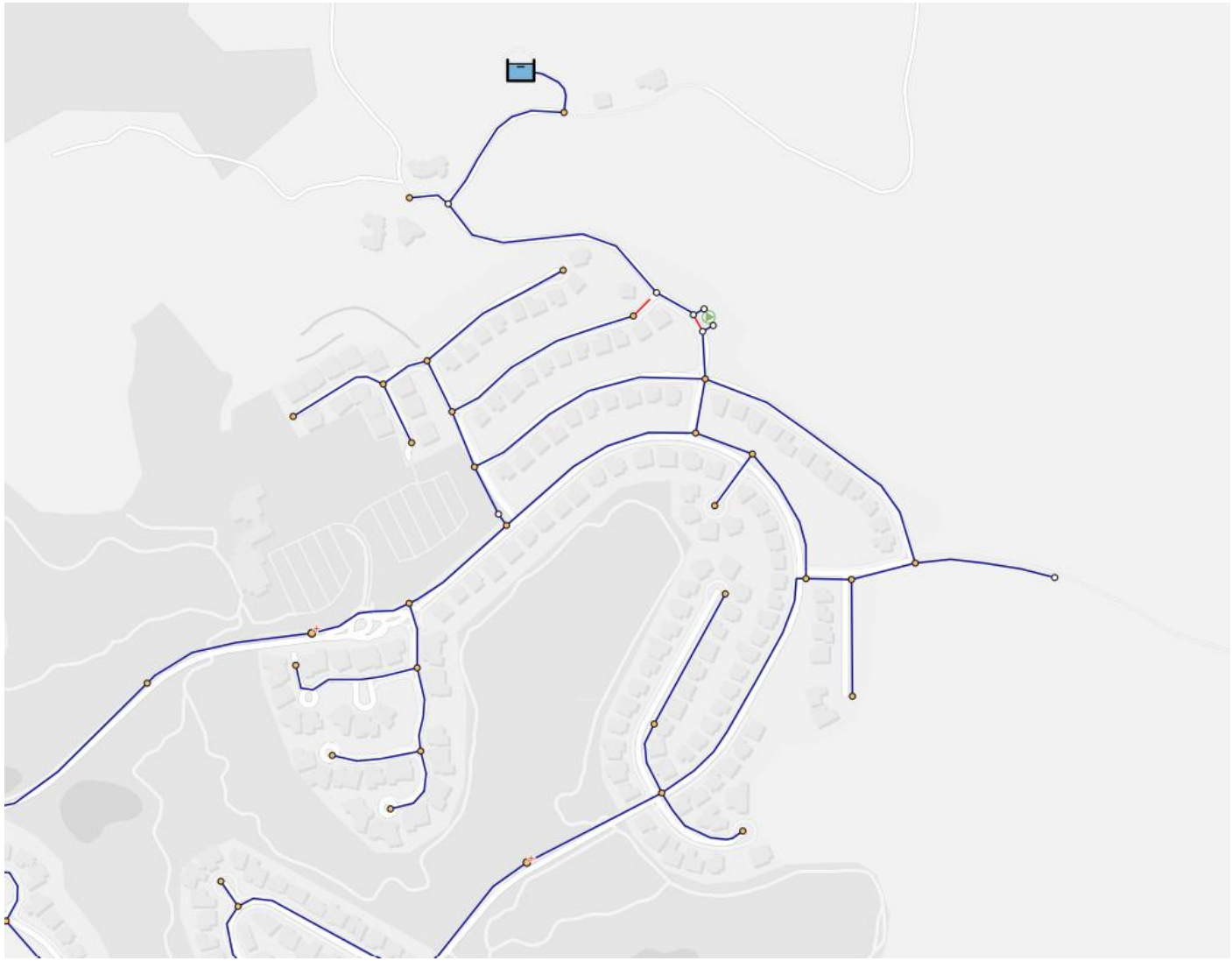
[1]Walski et al. (2007). "Advanced Water Distribution Modeling and Management." Bentley Institute Press, Bentley Systems.

Extended Period Simulation Example





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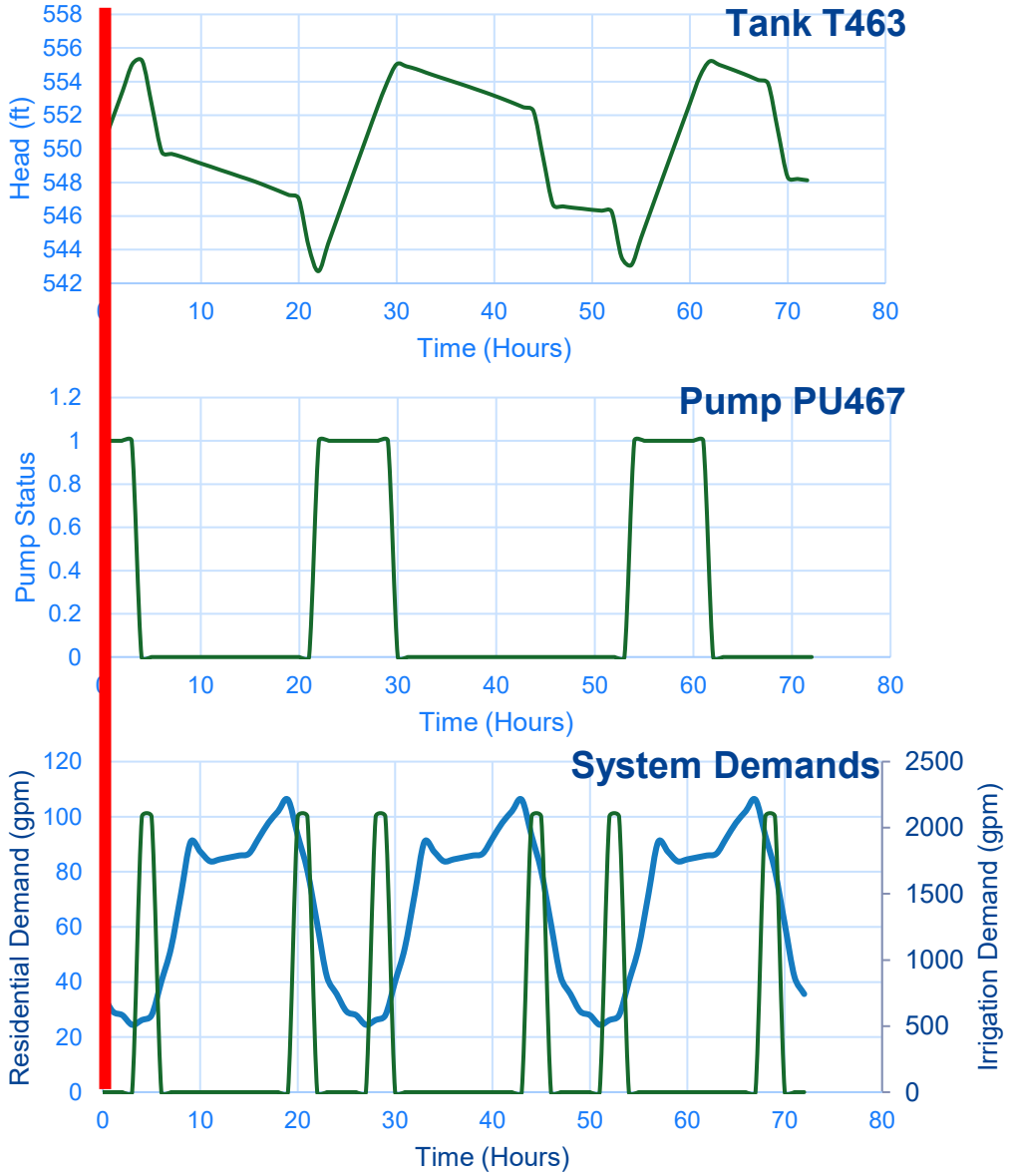

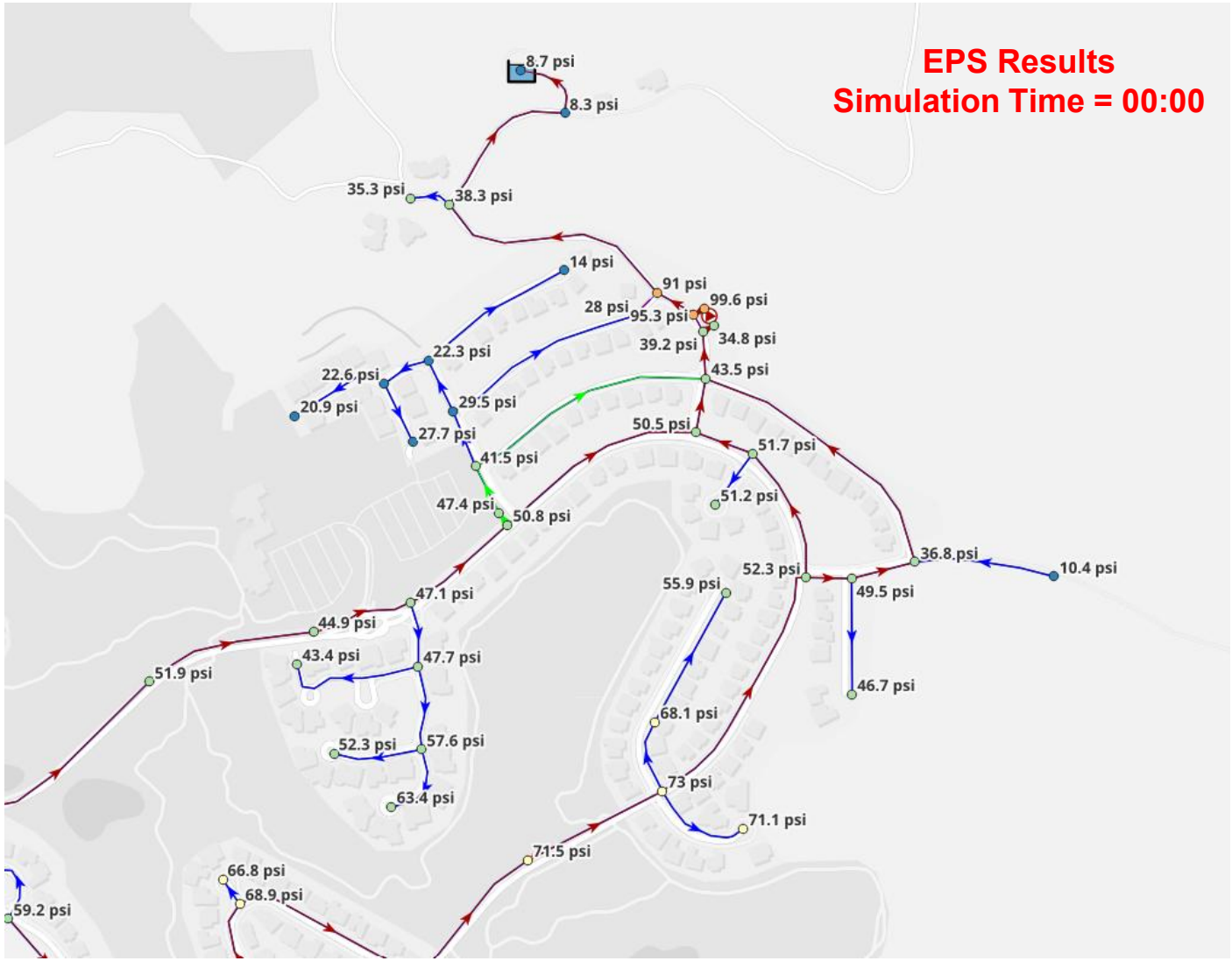

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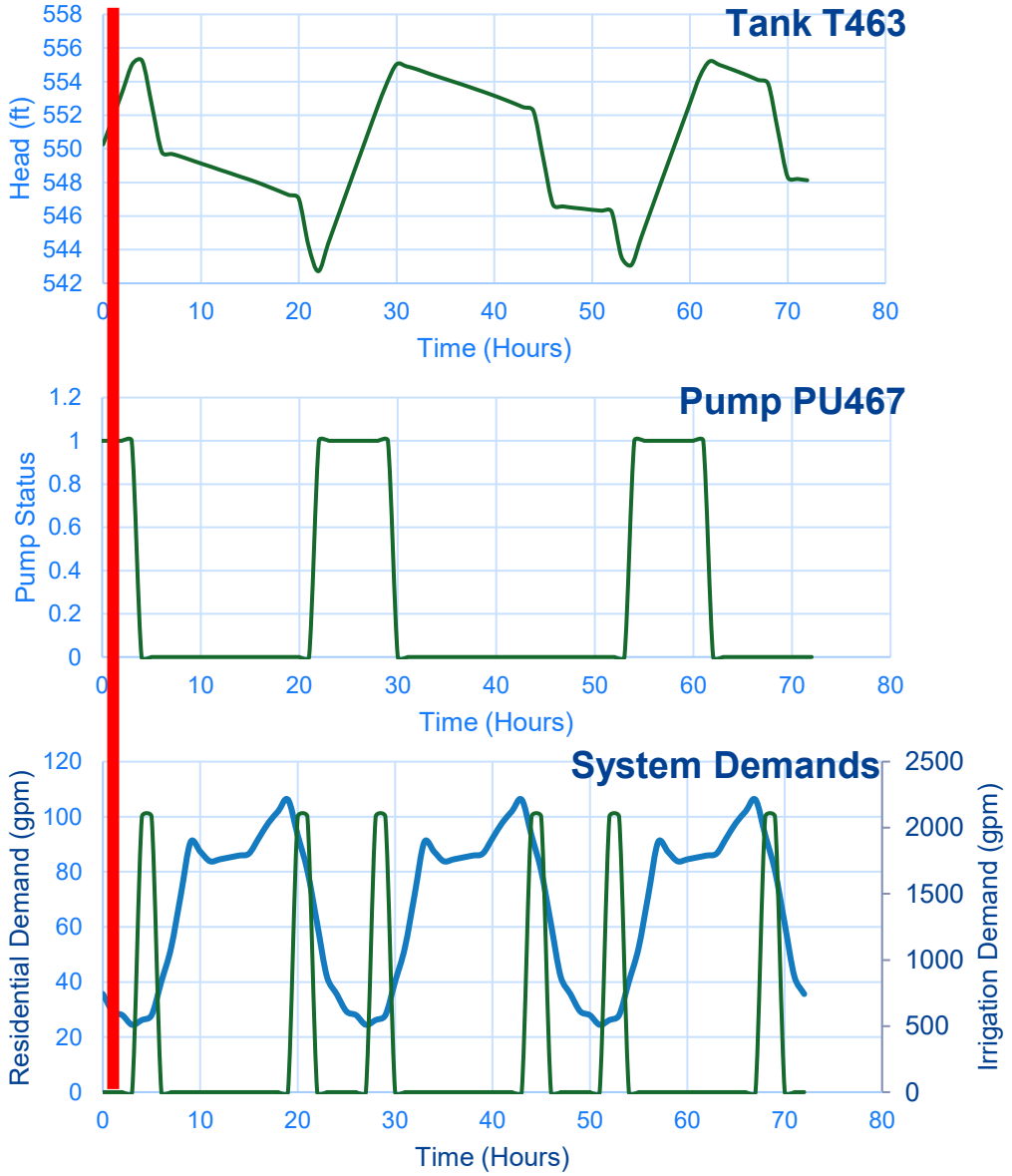

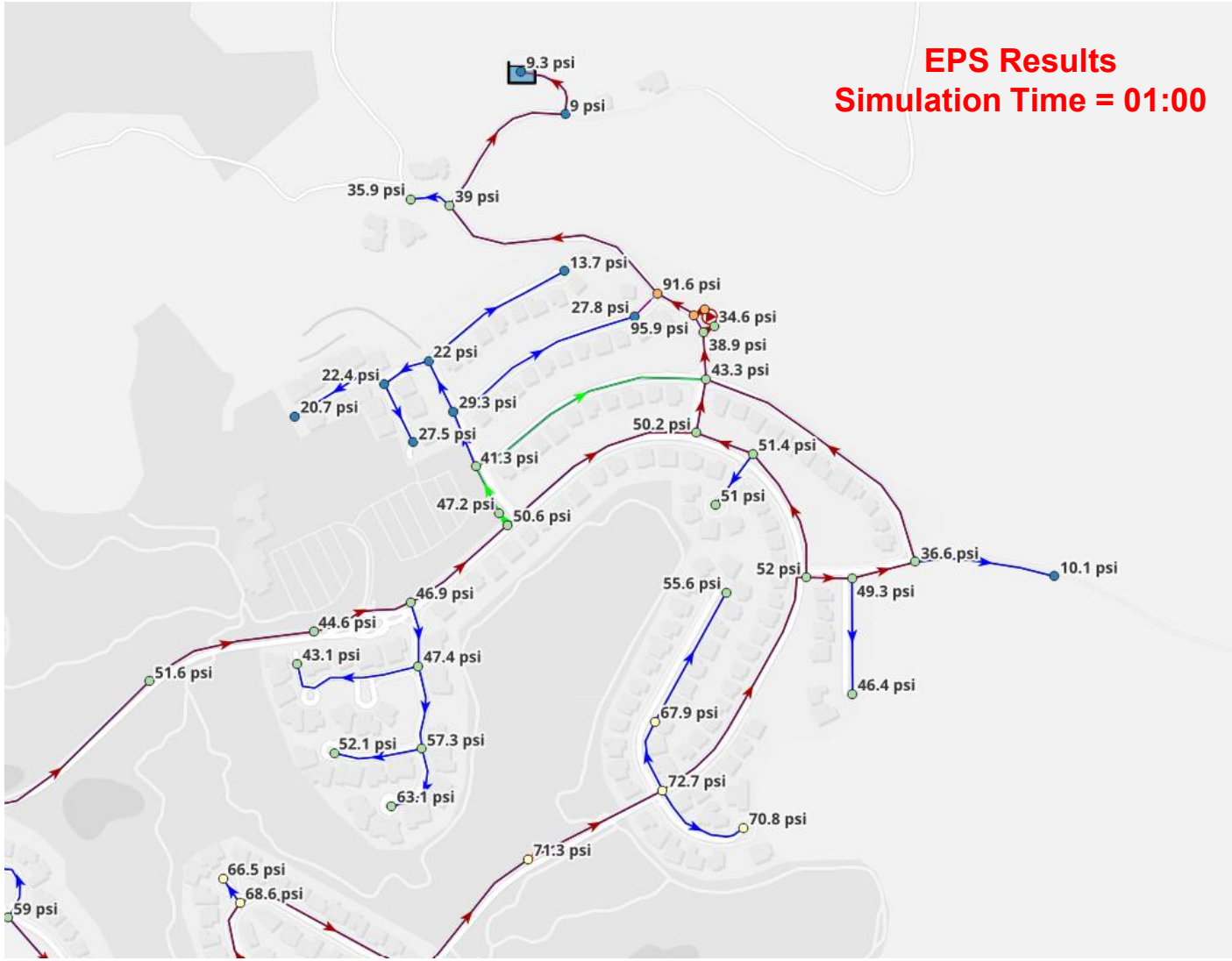

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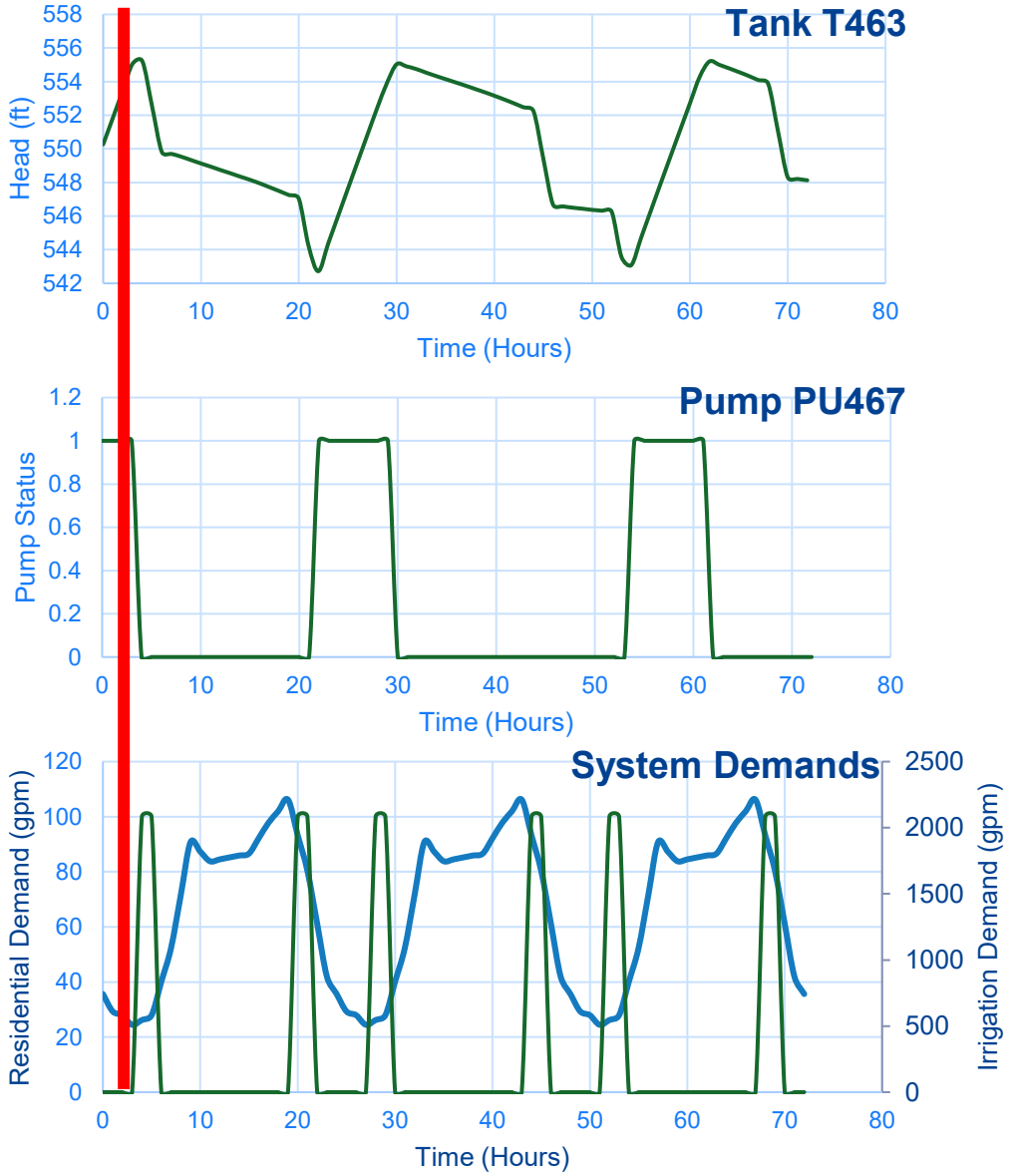

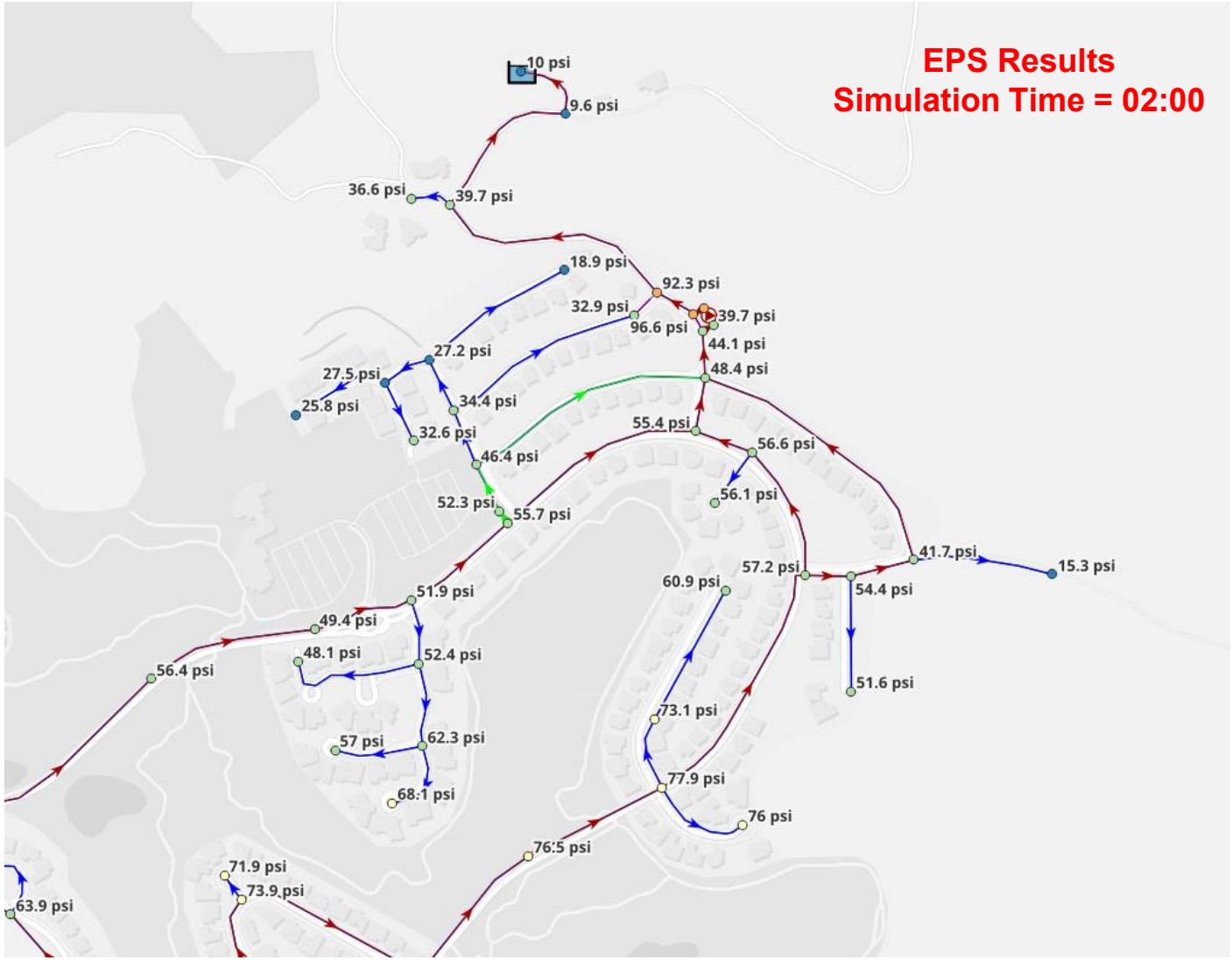

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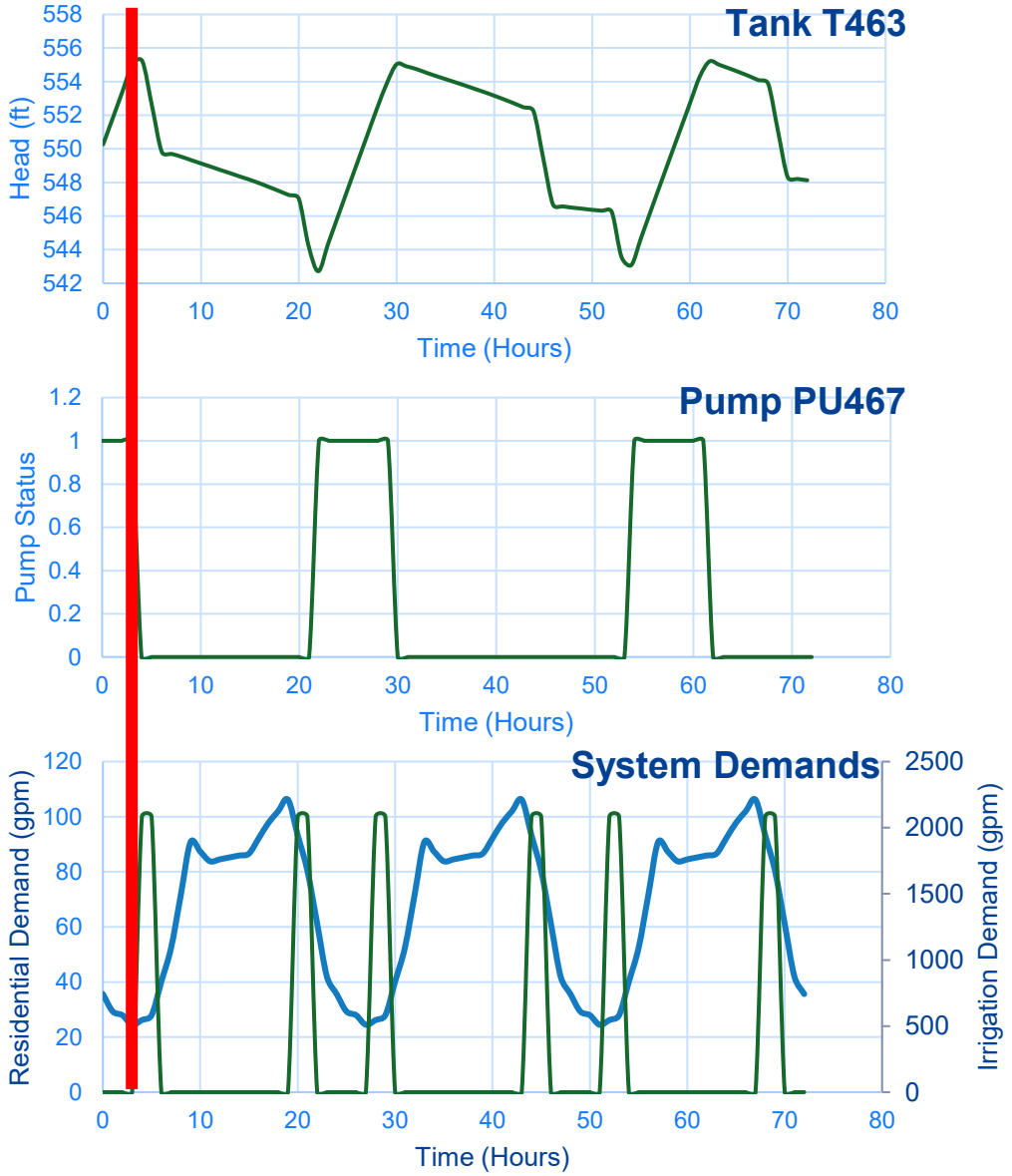

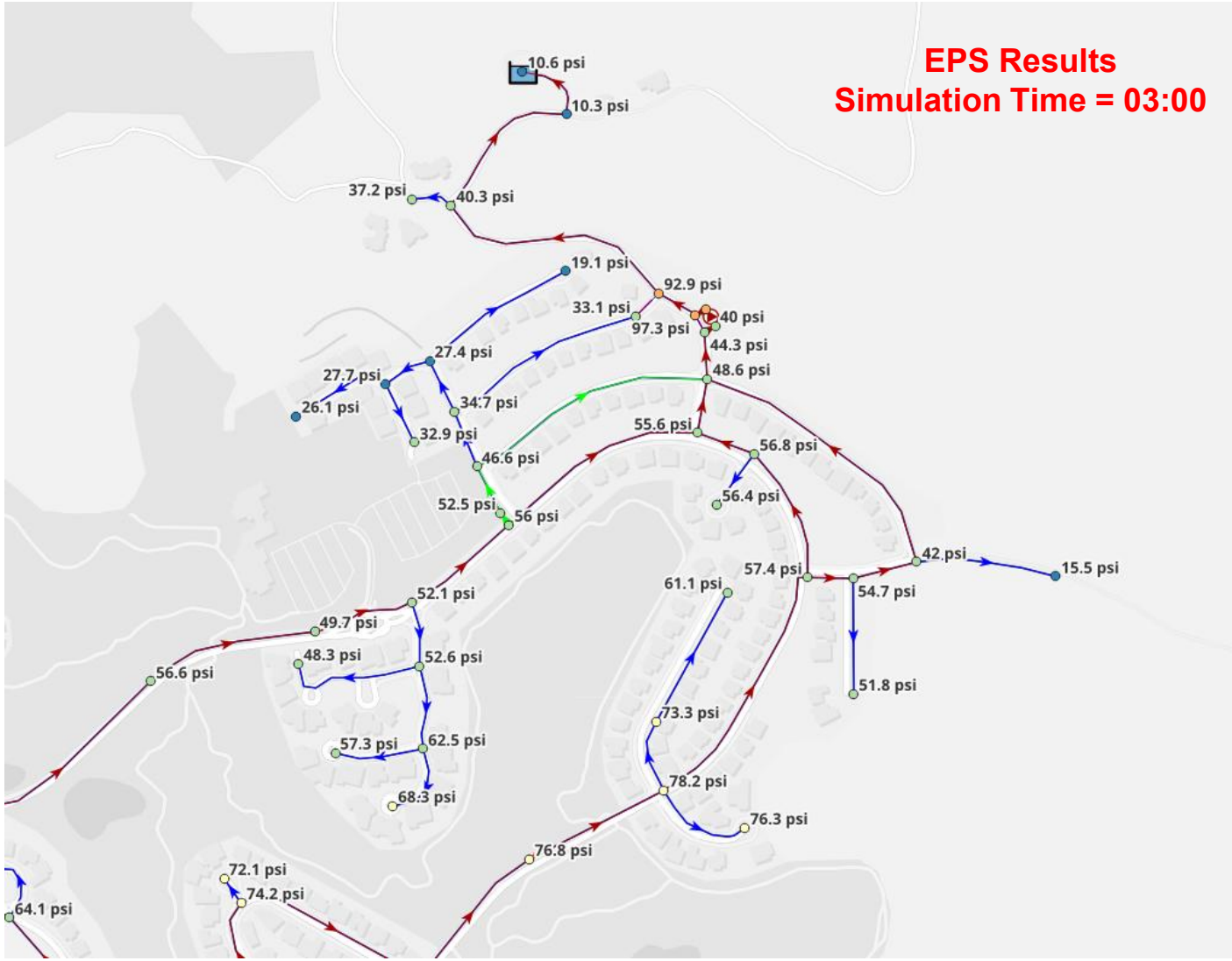

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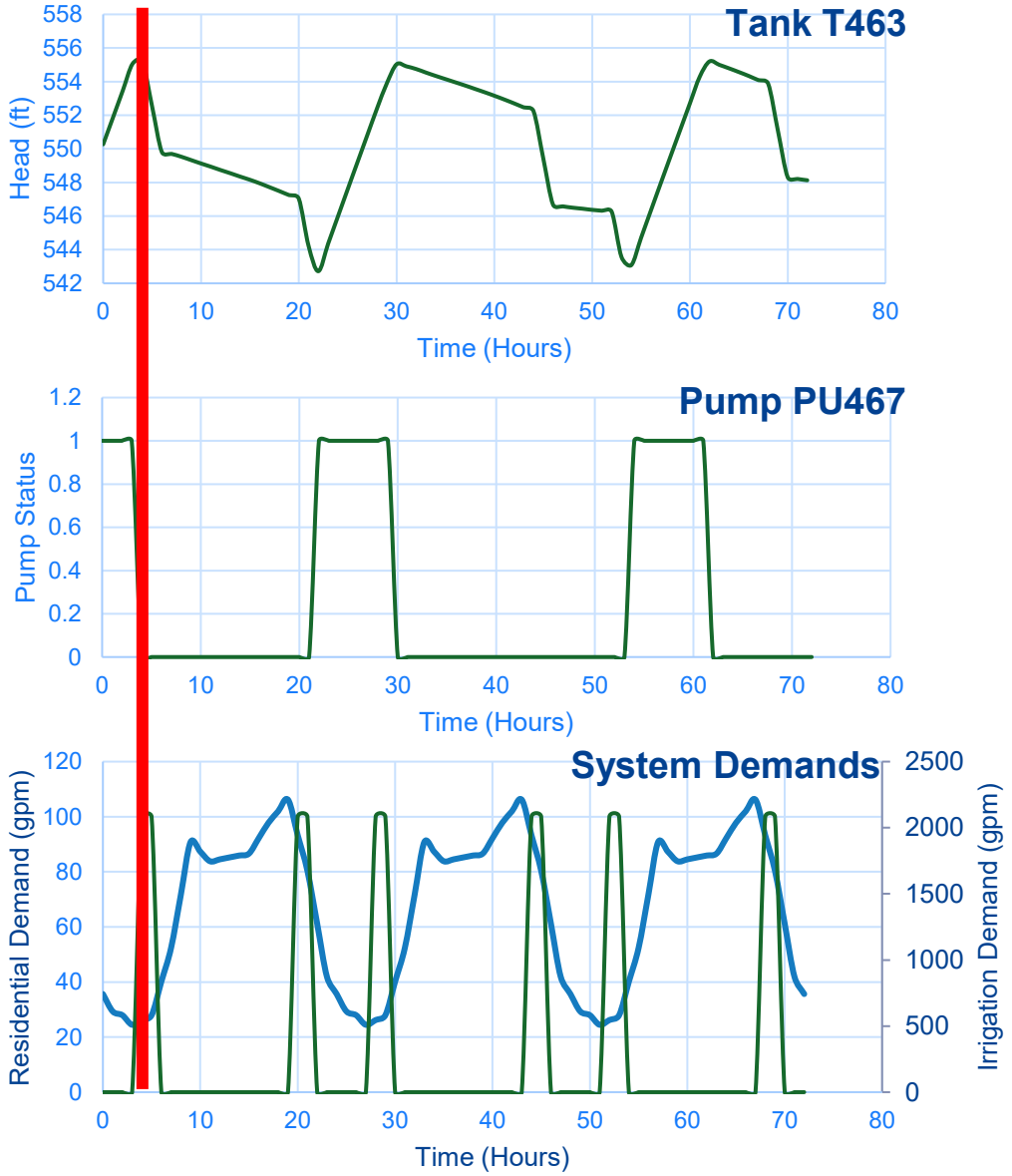

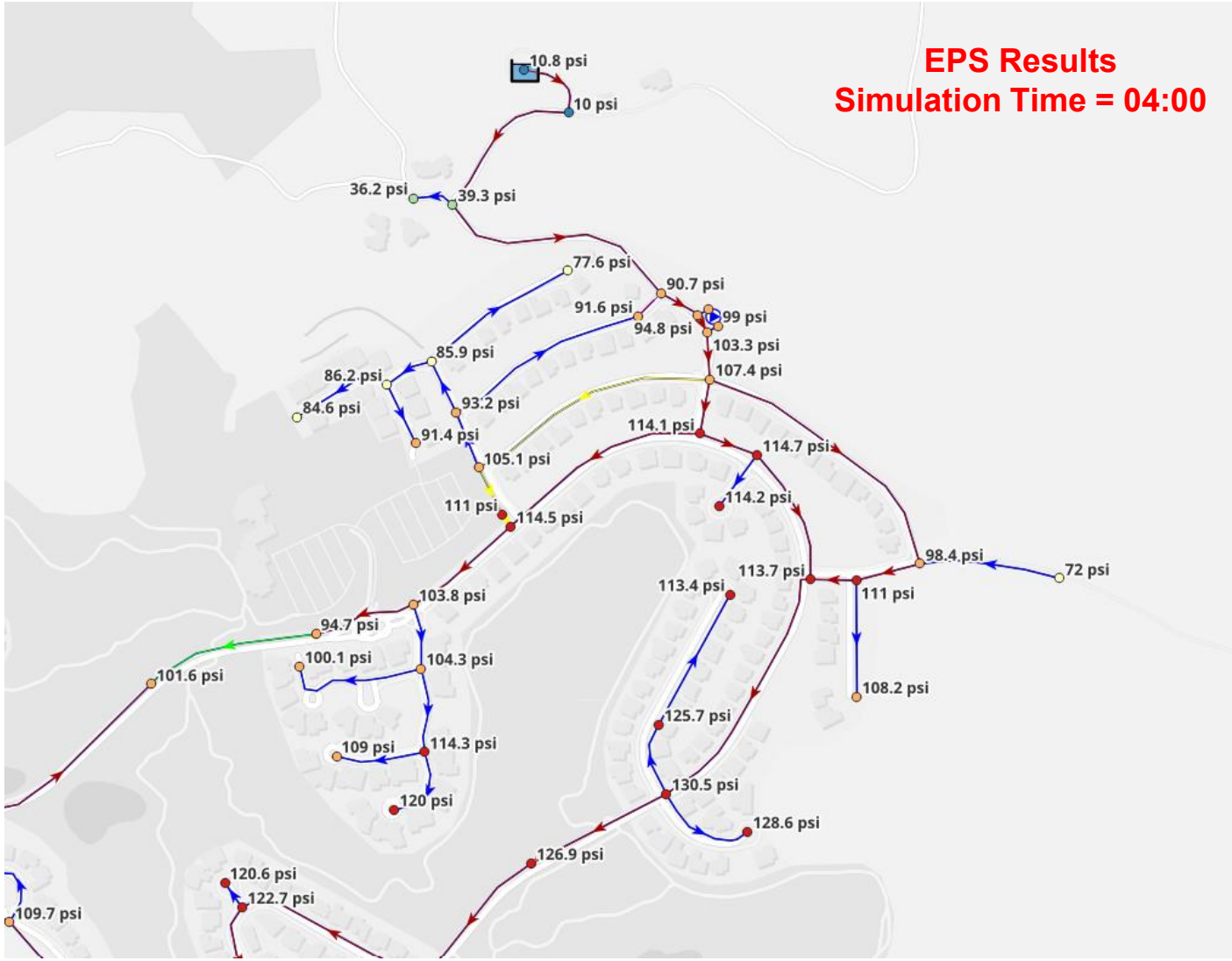

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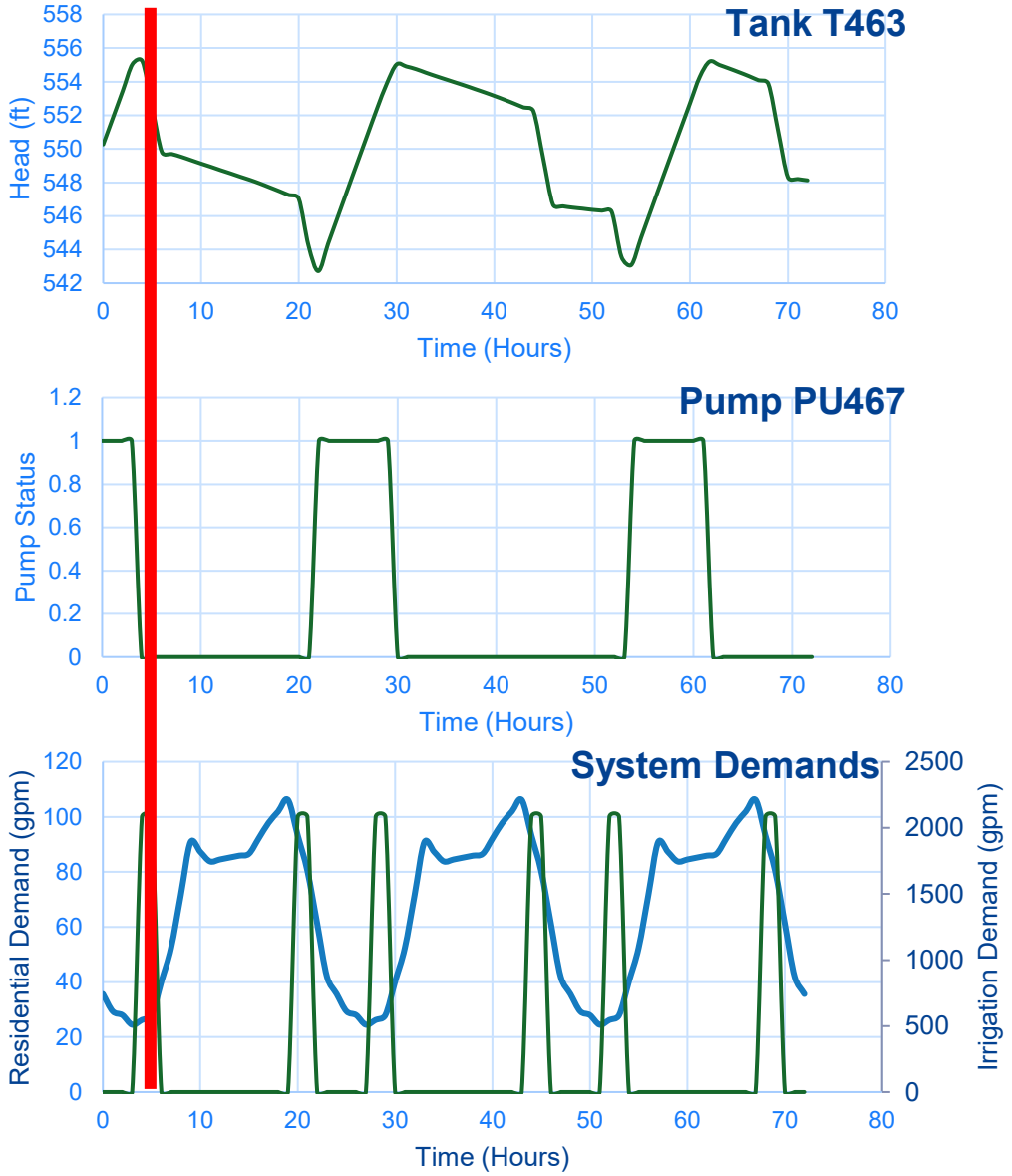

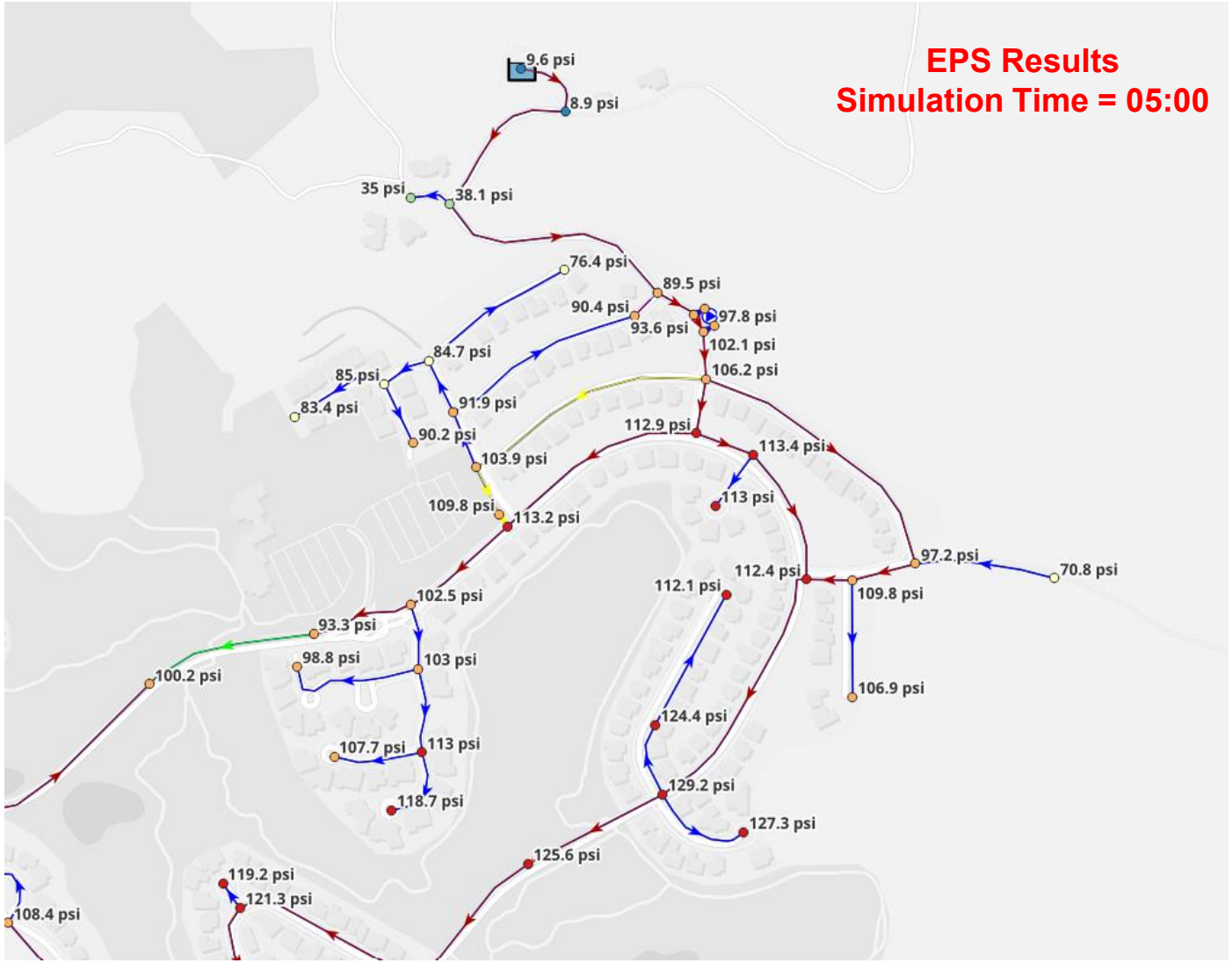

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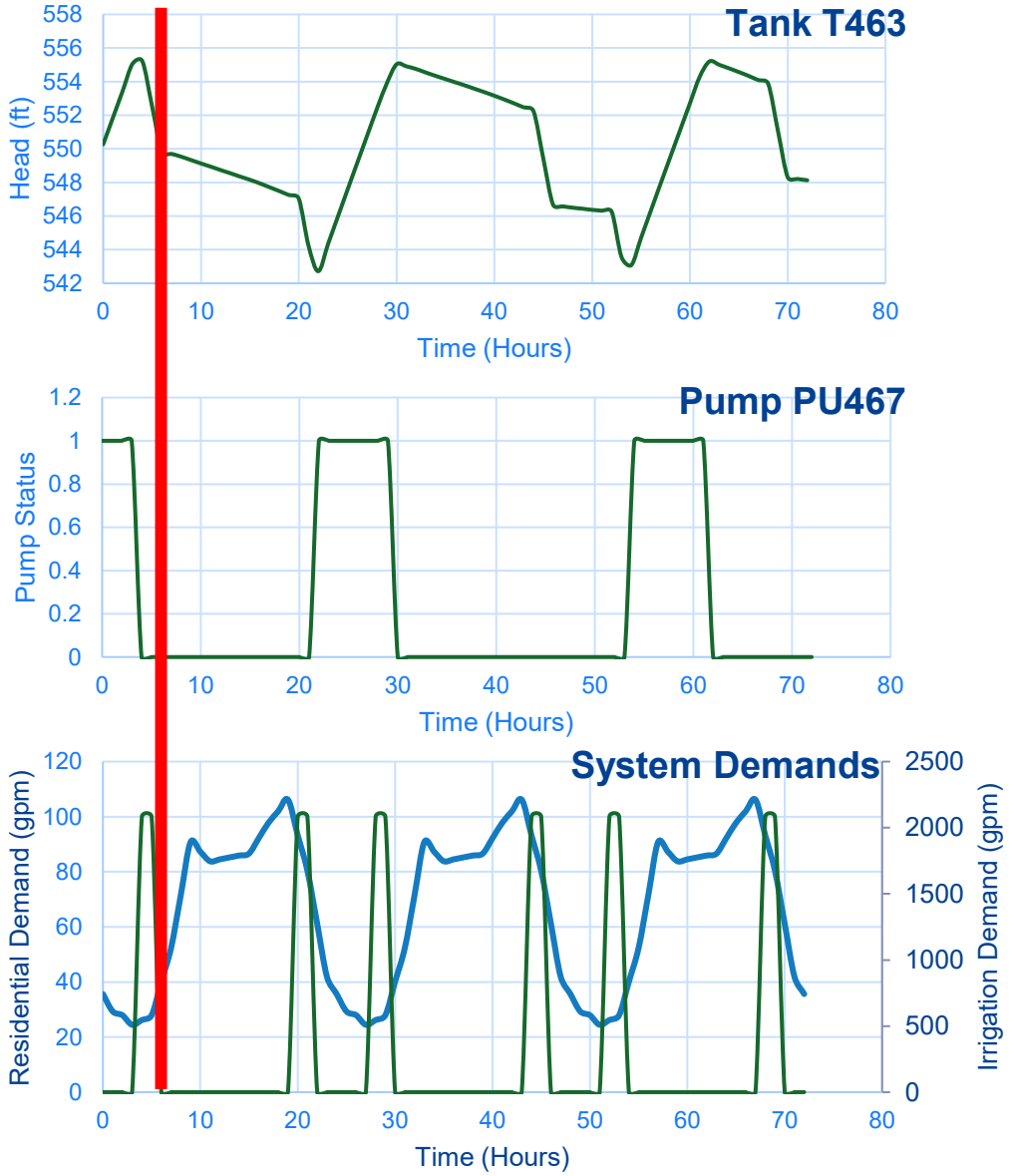

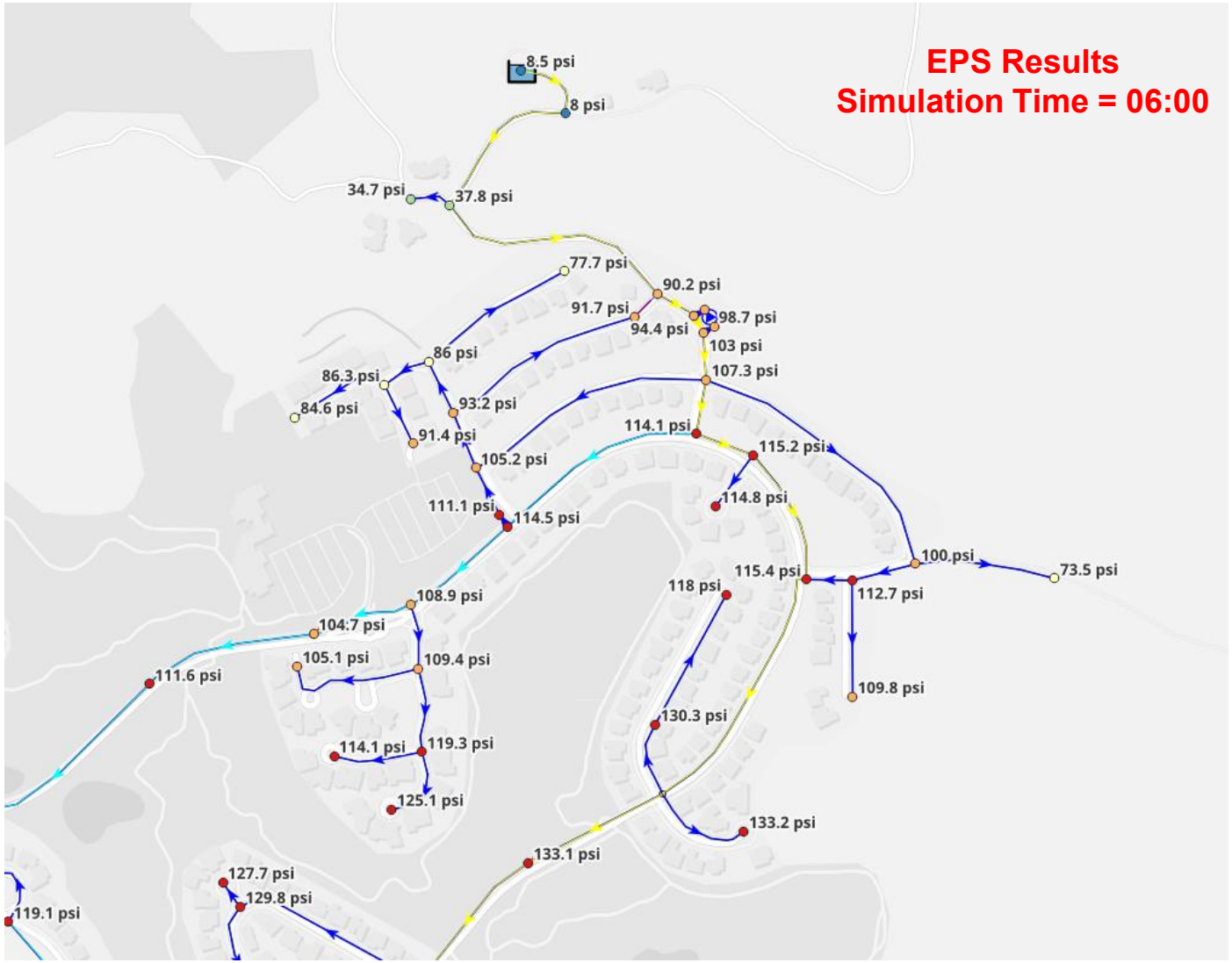

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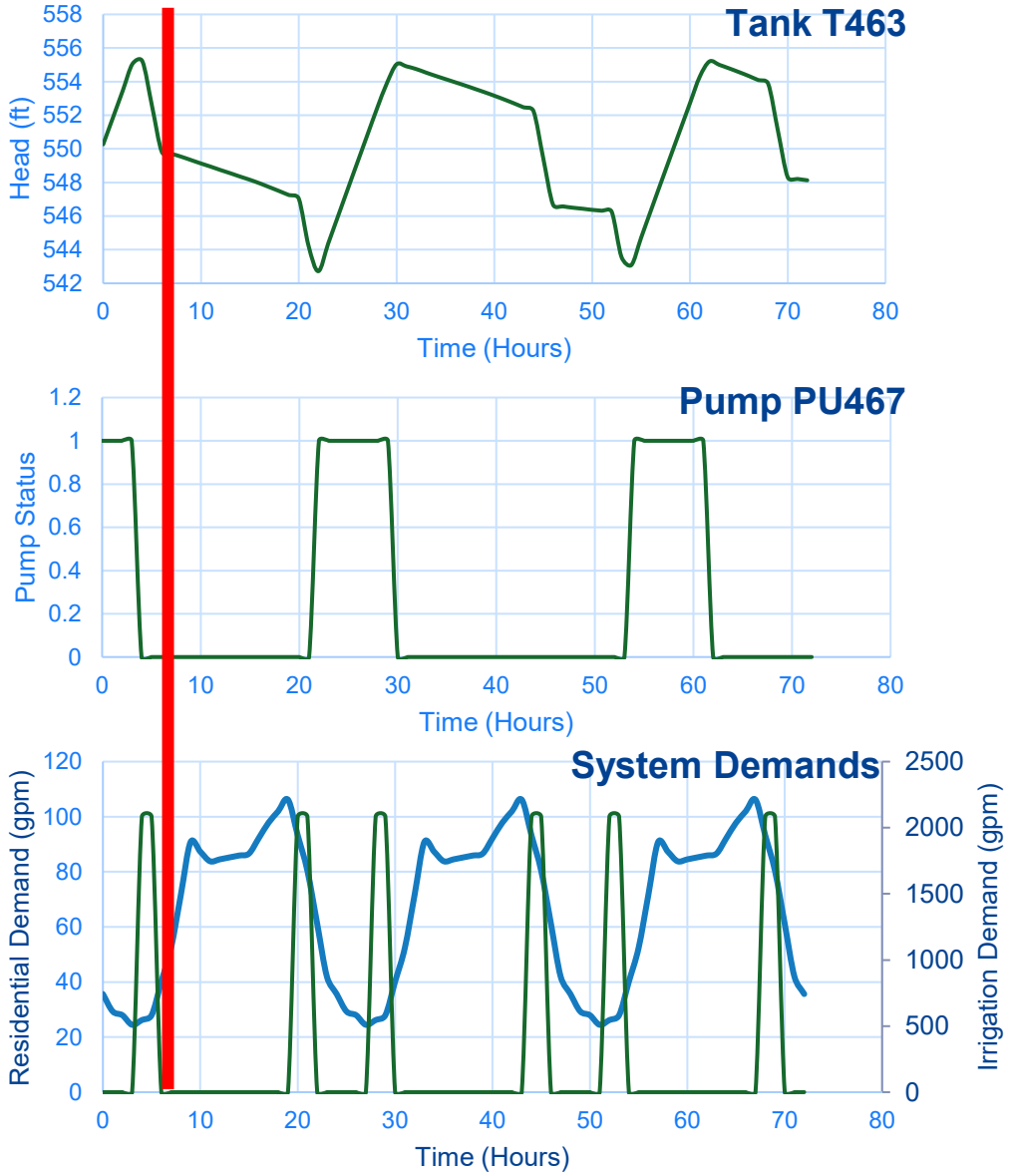

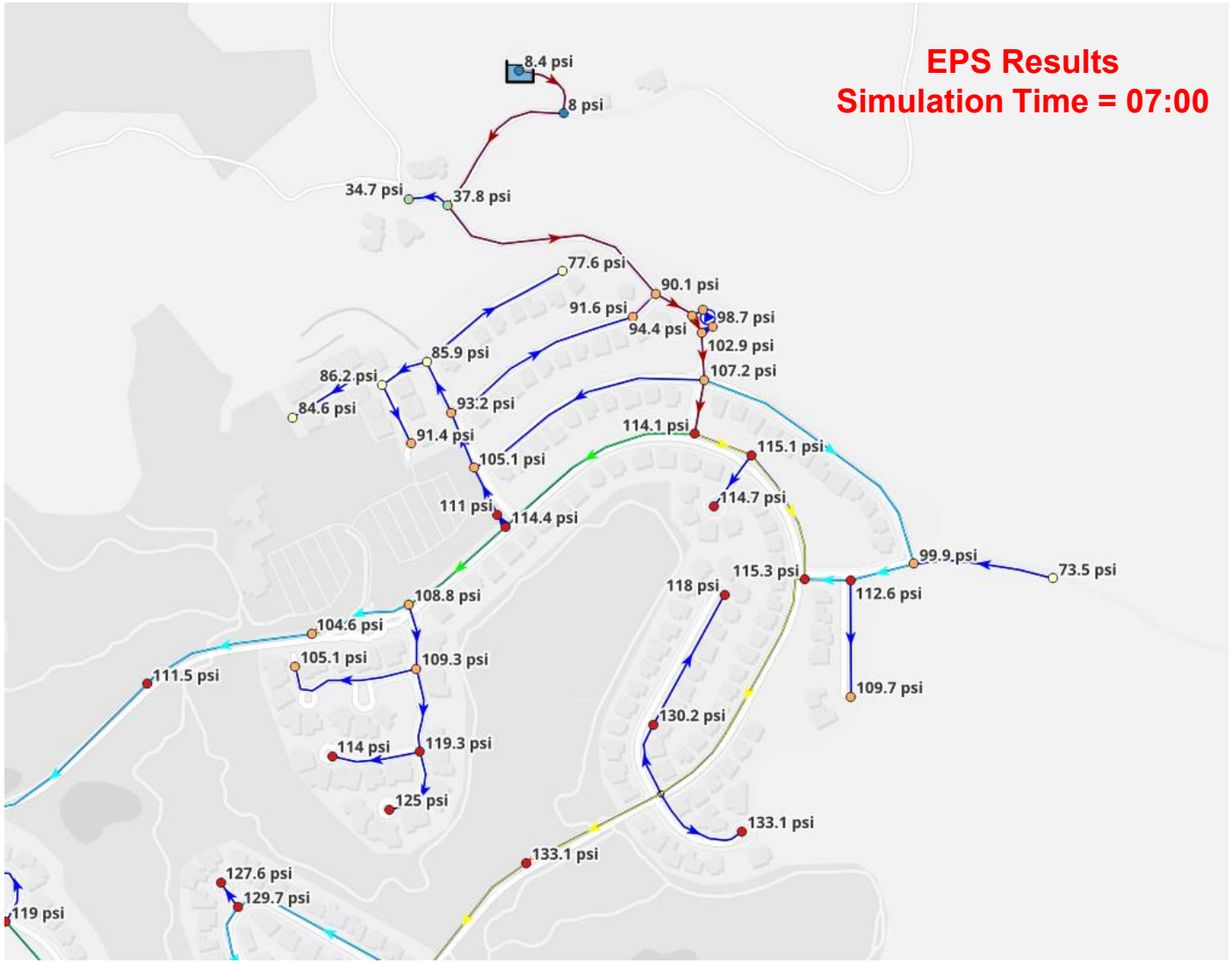

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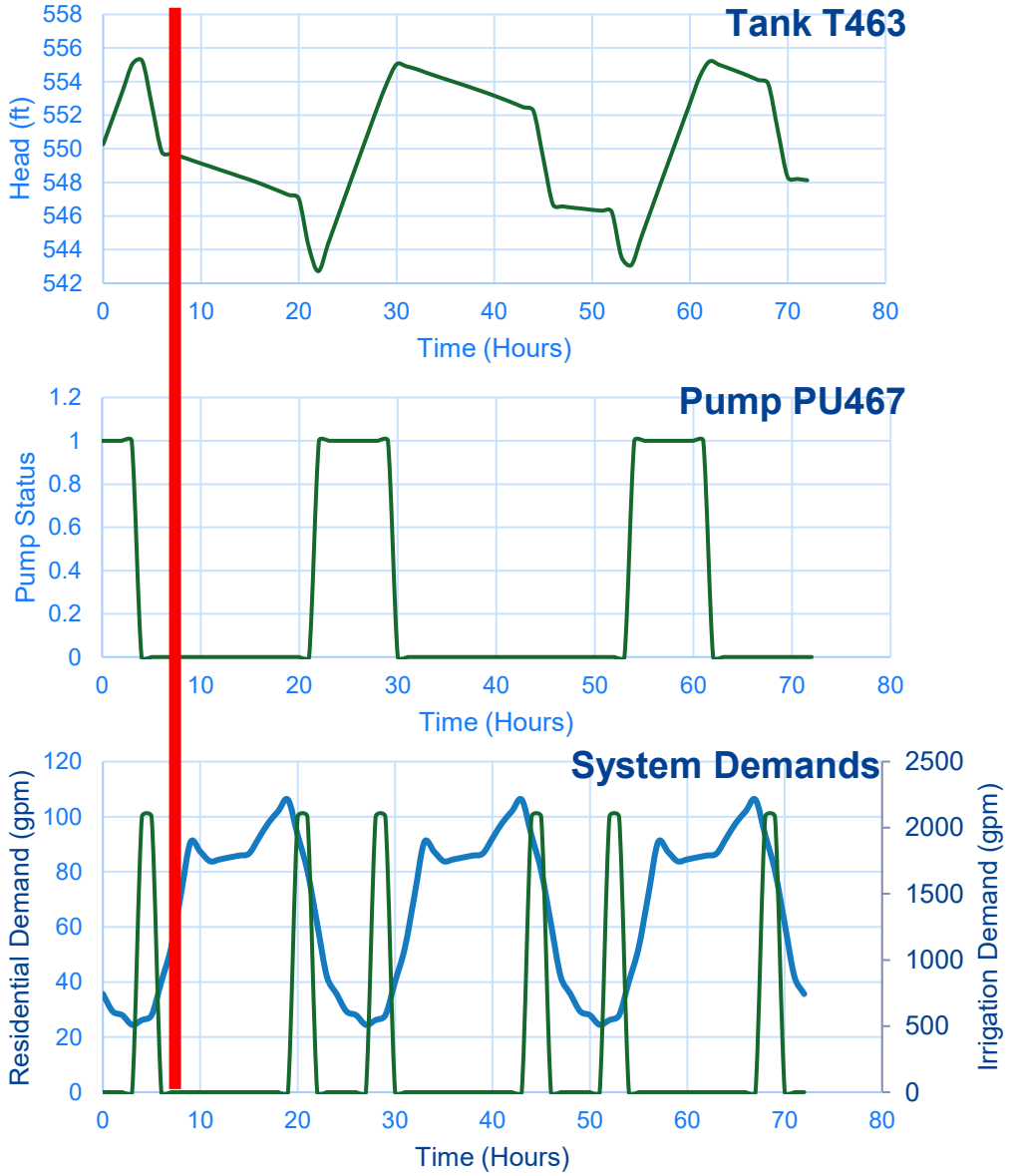

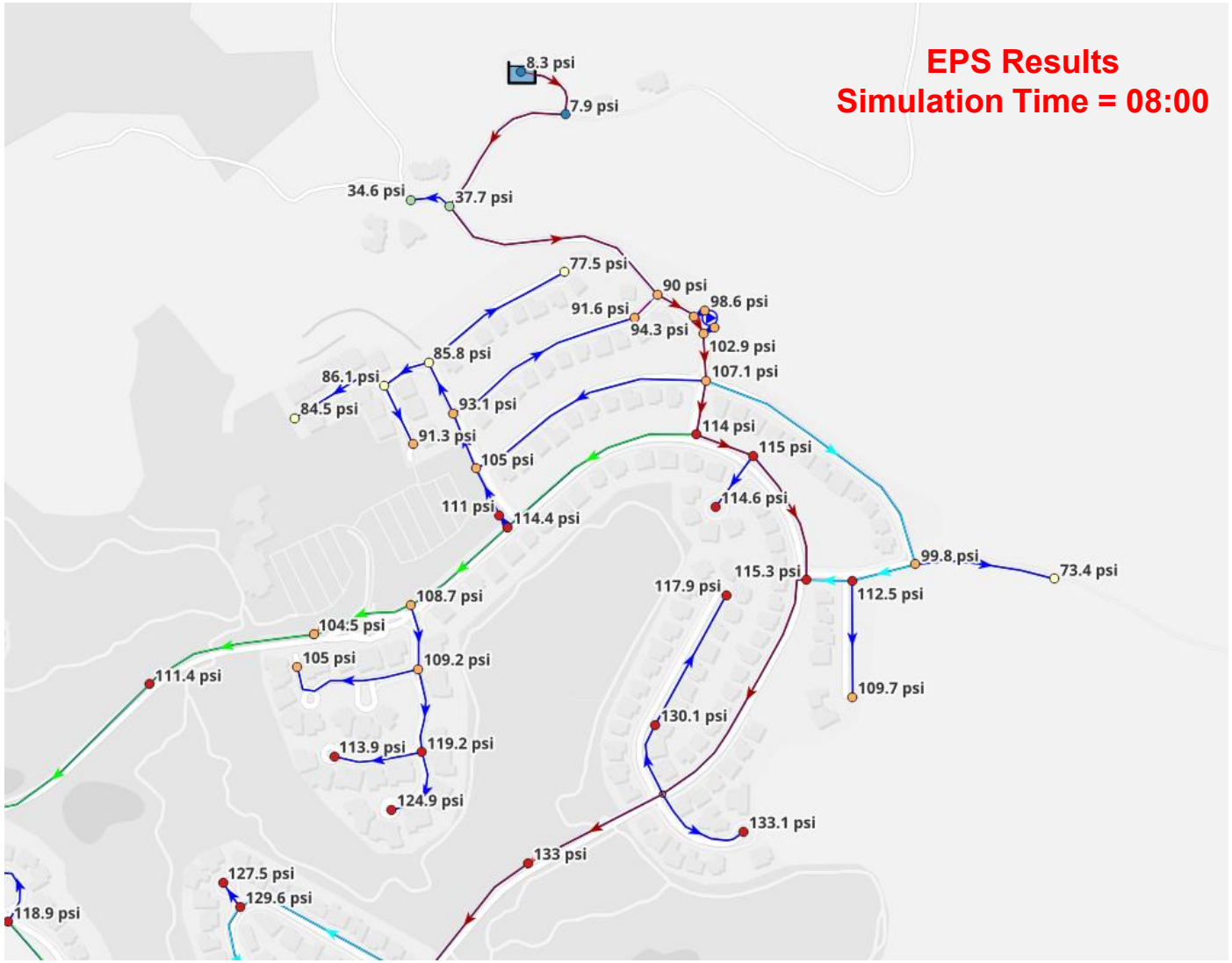

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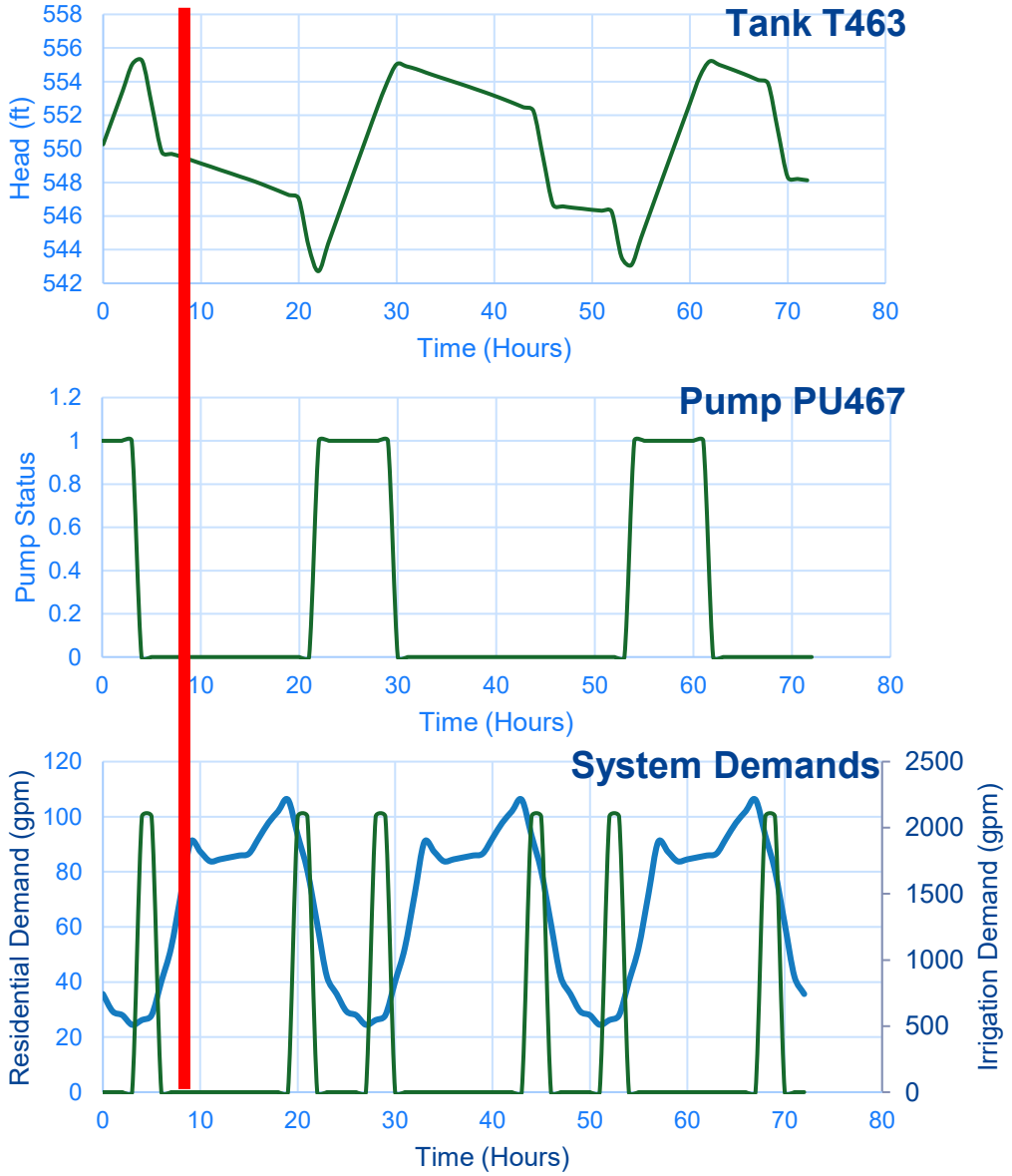

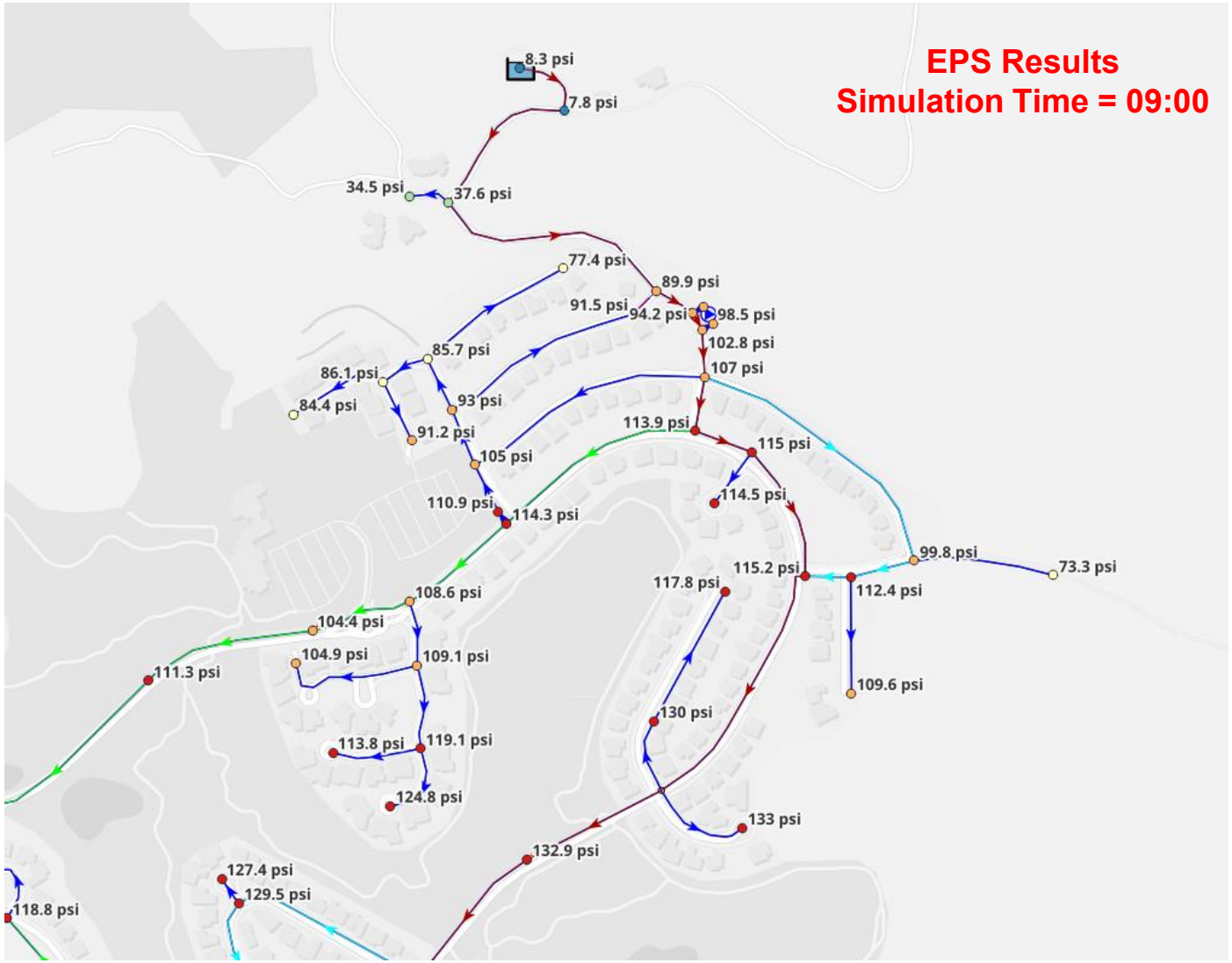

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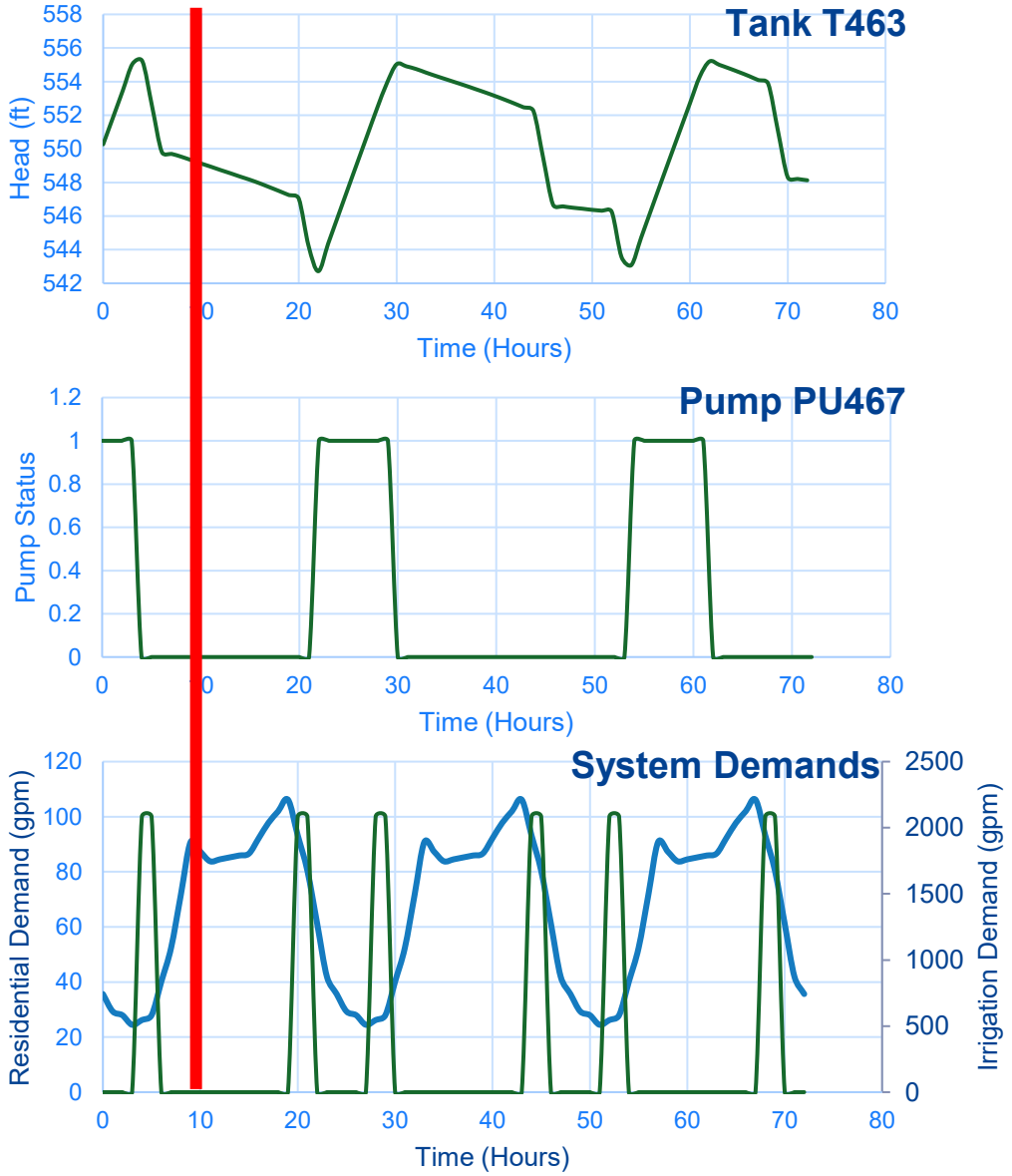
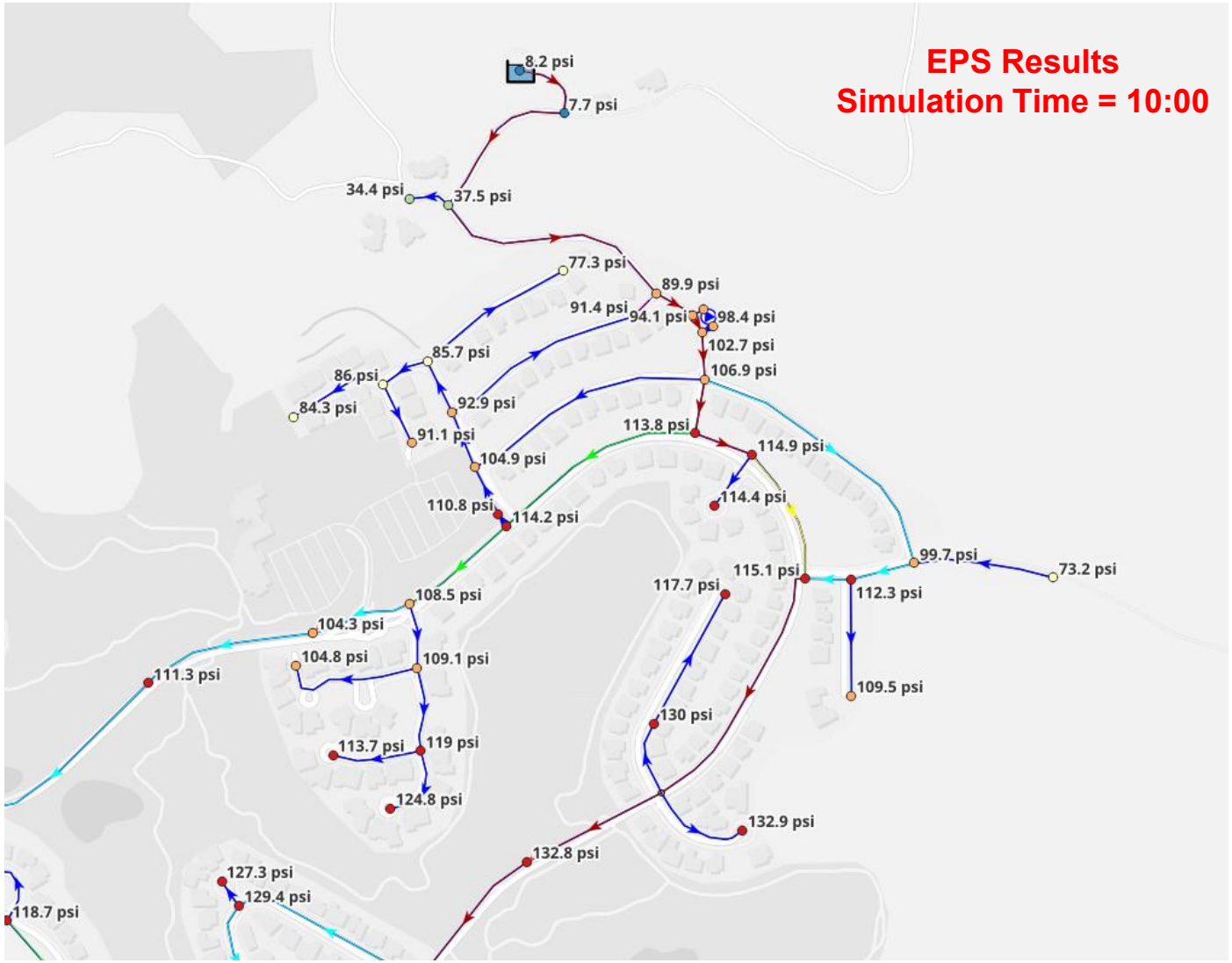


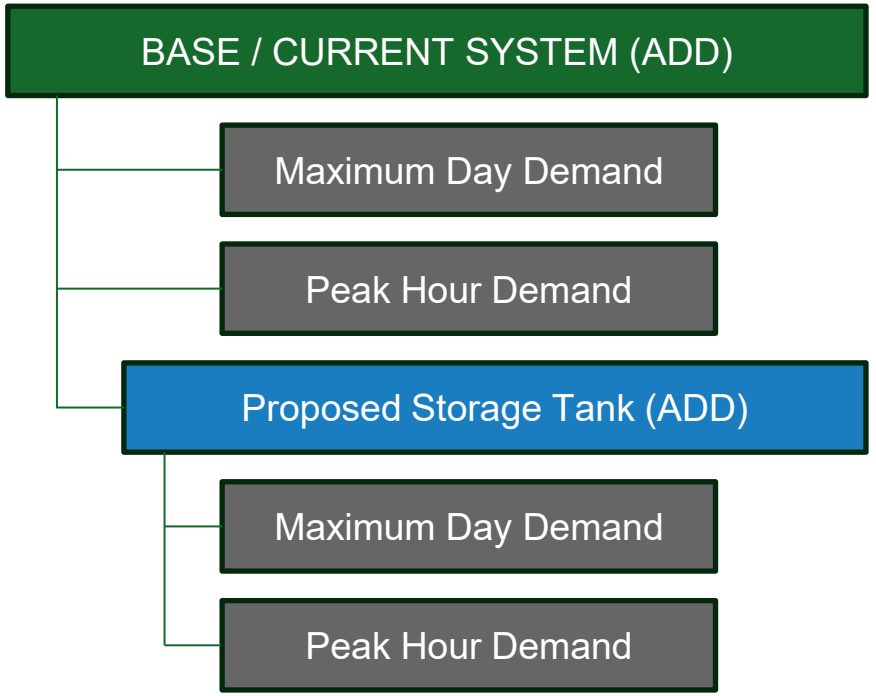


EPS Applications

- EPS simulations required more input data, but can also be used for more advanced analysis
- EPS simulations may be used to:
  - Evaluate storage capacity
  - Evaluate pump controls
  - Analyze system-wide interactions
  - Advanced planning (new development; emergency response)
  - Advanced analysis options (water quality; energy use)

Model Scenarios

- In hydraulic modeling, “scenarios” are used to define sets of input parameters
- Scenarios are often set up in a parent-child relationship, where children inherit parameters
- Scenarios are most often used to model demand sets and proposed infrastructure changes



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Demand Scenarios

Average Day Demand (ADD)

Maximum Day Demand (MDD)

Peak Hour Demand (PHD)

"The average rate of demand for an average day."[1]

CUSTOMER A

JANUARY USAGE: 4200 gal -> 140 gallons per day

$$4200\frac{gal}{month} \times \frac{1\ month}{30\ days} \times \frac{1\ day}{1{,}440\ min} = 0.097\ gpm$$

[1]Walski et al. (2007). "Advanced Water Distribution Modeling and Management." Bentley Institute Press, Bentley Systems.

Demand Scenarios

Average Day Demand (ADD)

Maximum Day Demand (MDD)

Peak Hour Demand (PHD)

"The average rate of demand for an average day."[1]

CUSTOMER A – USAGE

JAN: 4200 gal
FEB: 4100 gal
MAR: 4400 gal
…
JUL: 4800 gal
AUG: 5100 gal
…
NOV: 4600 gal
DEC: 4500 gal

Monthly Avg: 4500 gal

Average Day: 150 gpd

0.104 gpm

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[1]Walski et al. (2007). "Advanced Water Distribution Modeling and Management." Bentley Institute Press, Bentley Systems.

Demand Scenarios

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Demand Scenarios

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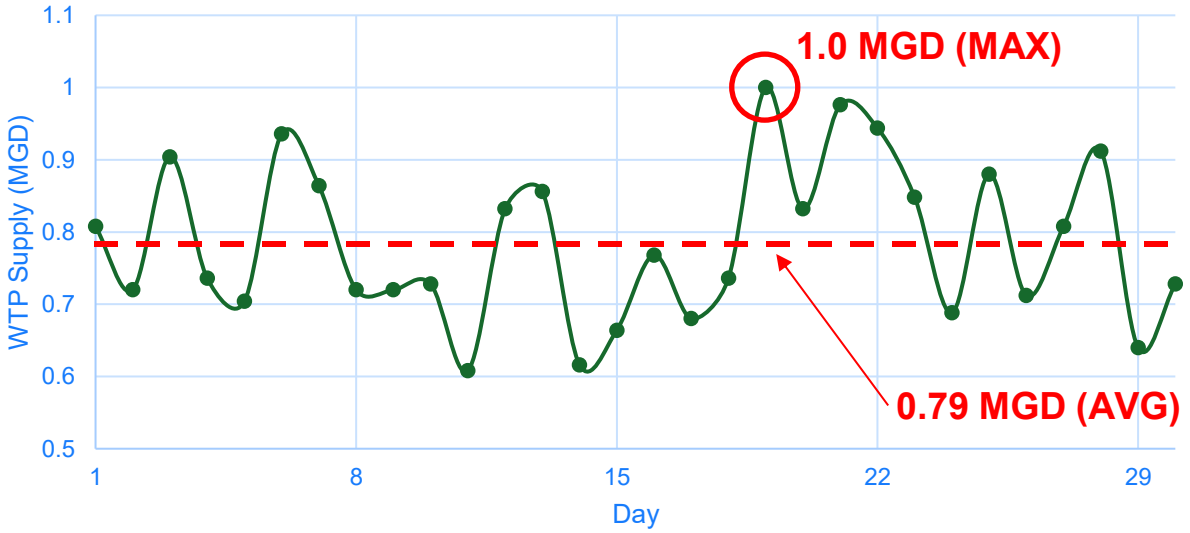


[1]Walski et al. (2007). "Advanced Water Distribution Modeling and Management." Bentley Institute Press, Bentley Systems.

Demand Scenarios

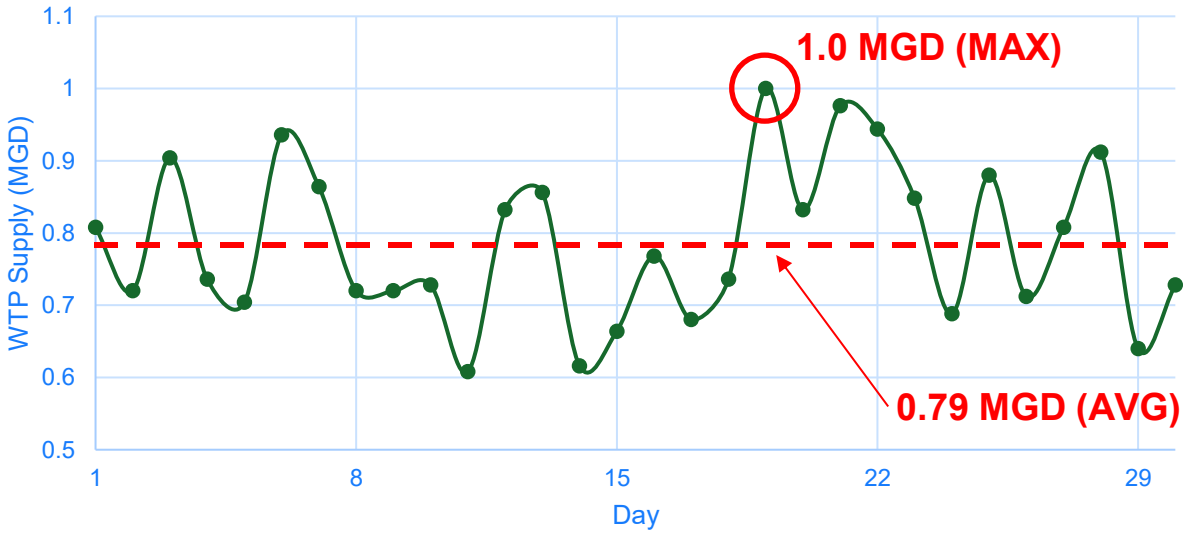
Demand Multiplier

A number that is used to modify the base demand through multiplication.

Example:
Base (Avg) Demand = 0.79 MGD
Demand Multiplier = 1.27

$$0.79\ MGD \times 1.27\ = 1.0\ MGD$$

"The average rate of demand on the maximum usage day."[1]



[1]Walski et al. (2007). "Advanced Water Distribution Modeling and Management." Bentley Institute Press, Bentley Systems.

Demand Scenarios

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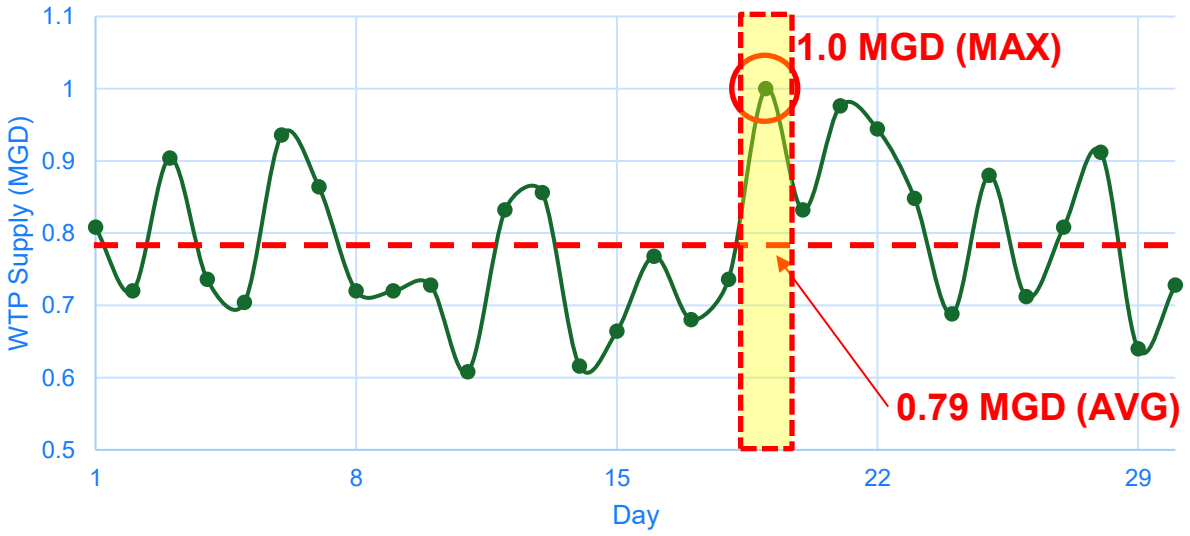

[1]Walski et al. (2007). "Advanced Water Distribution Modeling and Management." Bentley Institute Press, Bentley Systems.

Demand Scenarios

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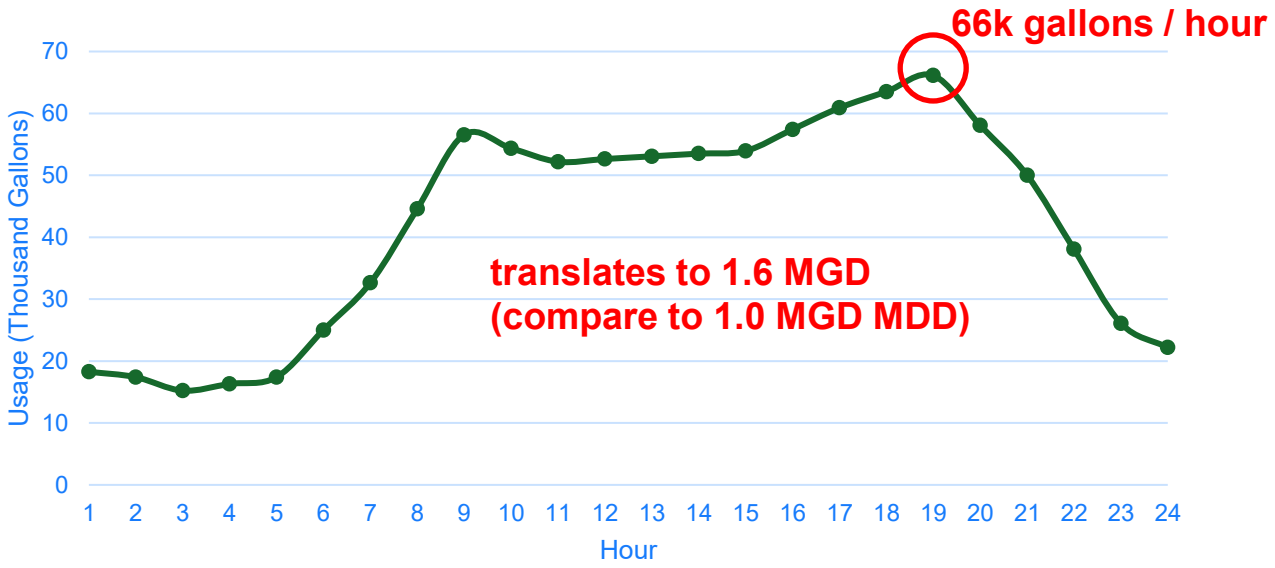

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[1]Walski et al. (2007). "Advanced Water Distribution Modeling and Management." Bentley Institute Press, Bentley Systems.

Demand Scenario Considerations

Unaccounted-for water (UFW)

- Separate UFW estimates from customer demands
- Use demand multipliers
- Start with uniform UFW allocation (i.e., all nodes)
- Tweak allocation with better information (e.g., pipe/meter age; known areas with high leakage)

Projecting future demands

- Use historical demand and population data to make projections
- Anticipate growth areas (new suburban development vs. downtown re-development)
- Include changes to UFW and fire protection standards
- Consider impact of industrial customers

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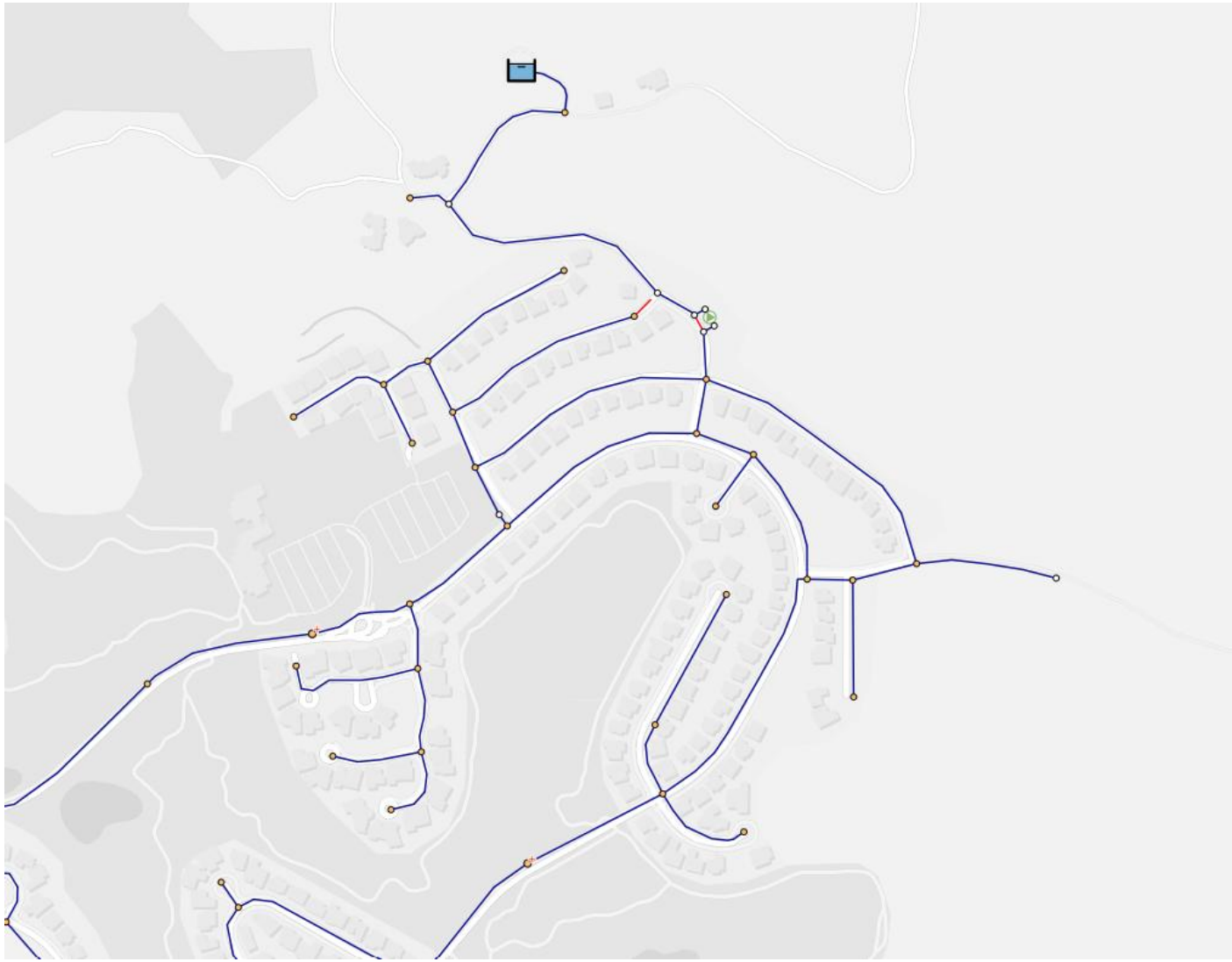
Infrastructure Sets

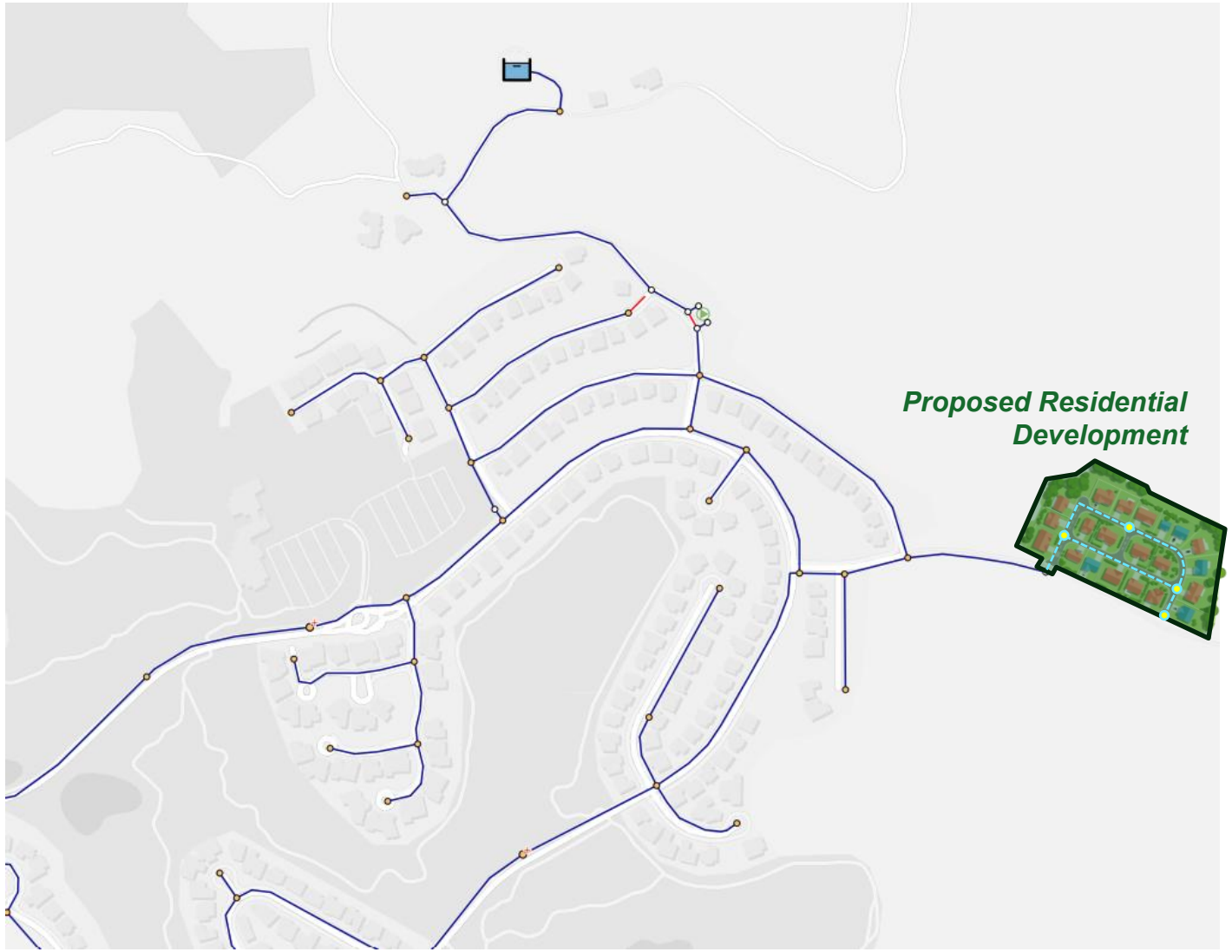
BASE (ACTIVE) NETWORK



Infrastructure Sets

BASE (ACTIVE) NETWORK

Proposed Residential Development



Infrastructure Sets

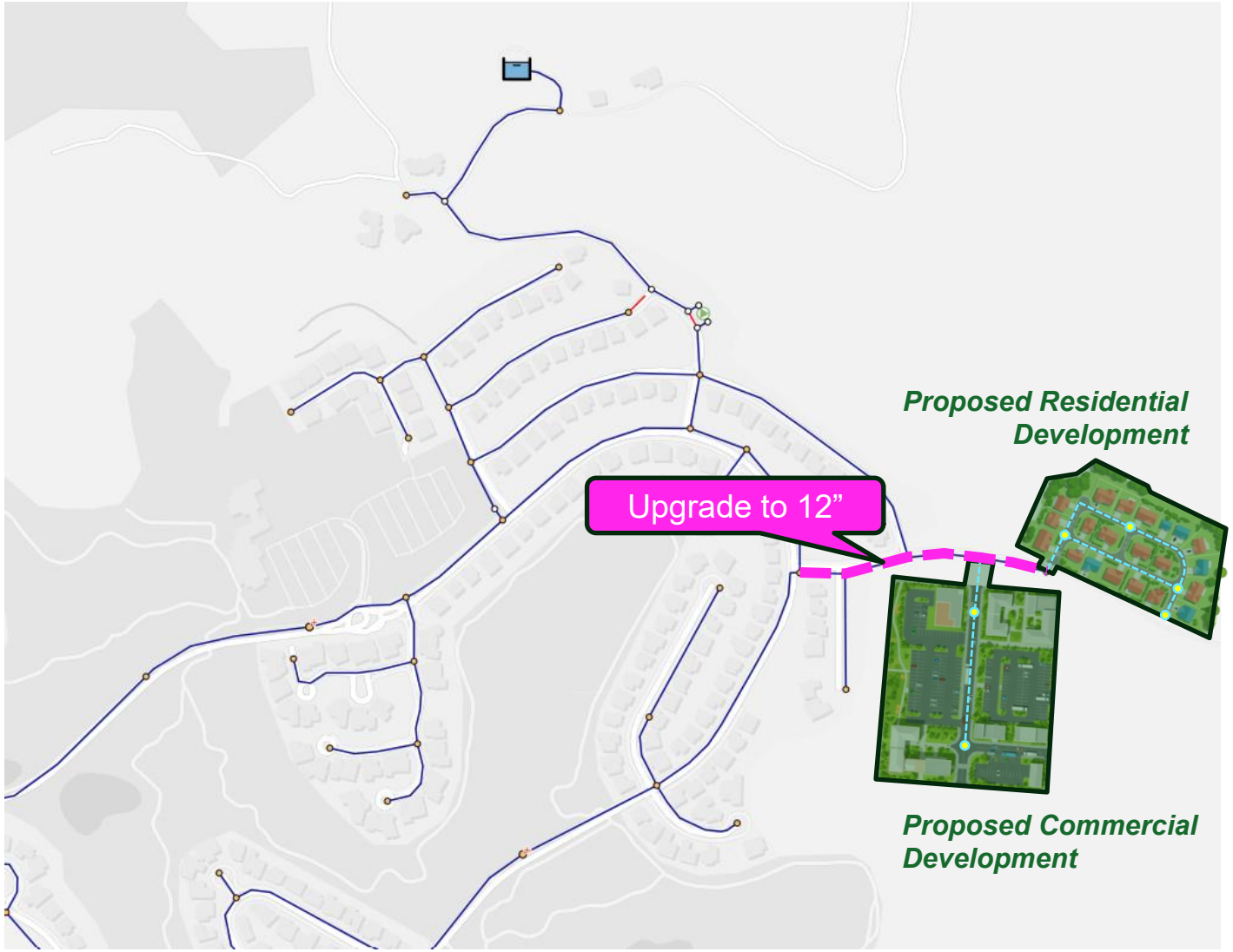
- BASE (ACTIVE) NETWORK
  - Proposed Residential Development
  - Proposed Commercial Development

Infrastructure Sets

- BASE (ACTIVE) NETWORK
  - Proposed Residential Development
  - Proposed Commercial Development
  - Proposed Combined Development (Residential & Commercial)

Infrastructure Sets

- BASE (ACTIVE) NETWORK
  - Proposed Residential Development
  - Proposed Commercial Development
  - Proposed Combined Development (Residential & Commercial)
    - Replace 6” main with 12”



Scenario Managers

- Feature of most (if not all) commercial software that allows you to easily create, save, and switch between model scenarios
- EPANET does not have a built-in scenario manager (yet) – but it does allow you to import/export scenarios (information only; e.g., demands)
- If you are using EPANET:
  - Use scenario import/export for changing demands and controls
  - Use separate model files for proposed infrastructure changes
  - File organization will be critical!

Running Steady State Simulations

- Pre-Simulation Checklist
  - Simulation Options
  - Network Check
- Run Status
- Viewing Results

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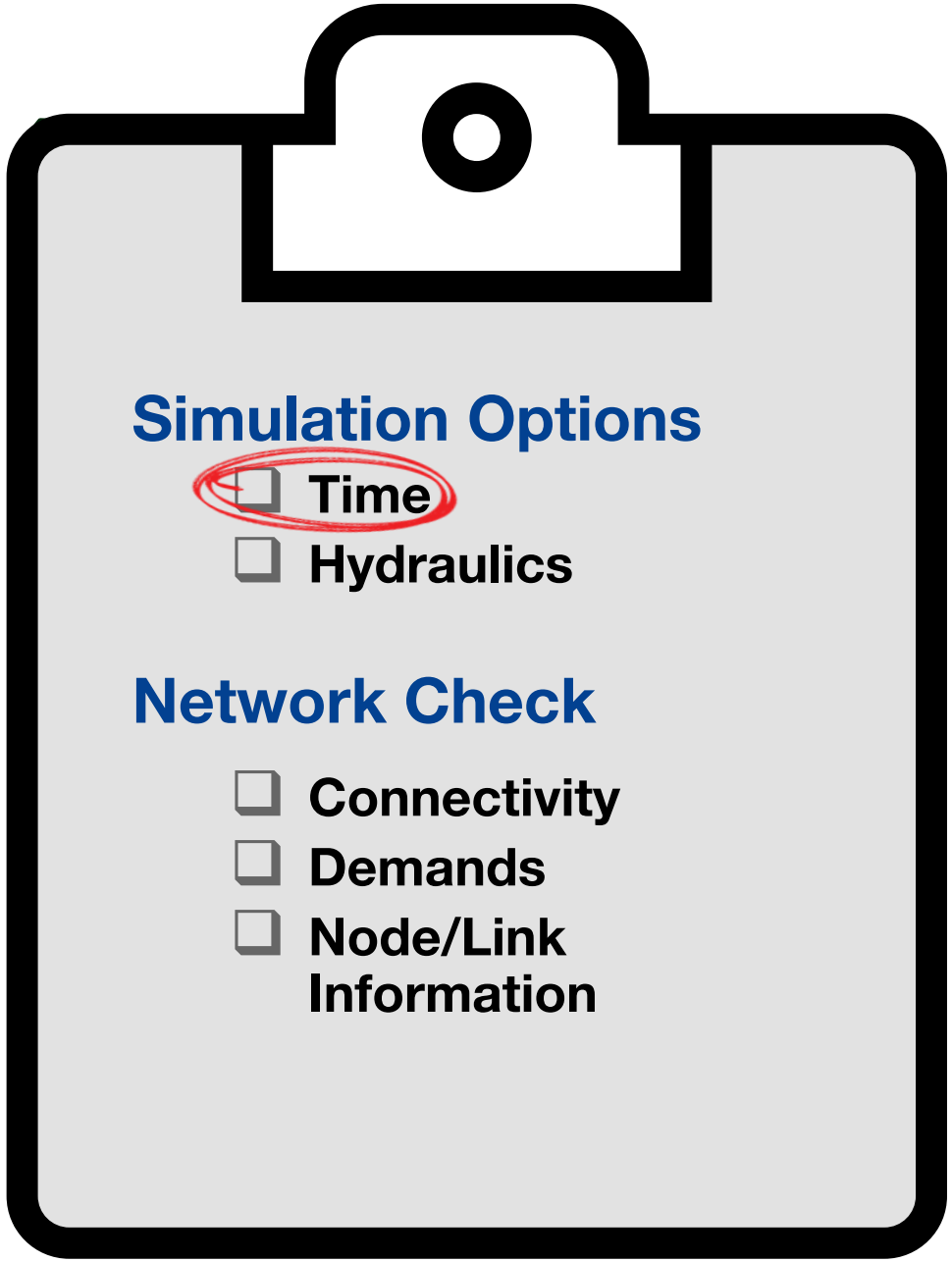
Steady-State Pre-Simulation Checklist

Parameter	Setting (Example)	Description
Total Duration	00:00	Total length of a simulation (in hours). Set to 0 for steady-state simulation. Default is 00:00.
Clock Start Time	08:00	Defines clock time at which simulation begins. Does not impact simulation. Default is 12:00am.

**For more advanced modelers, if your model is already set up for EPS, you can adjust the Pattern Start Time for a steady-state simulation to efficiently adjust the demands.*

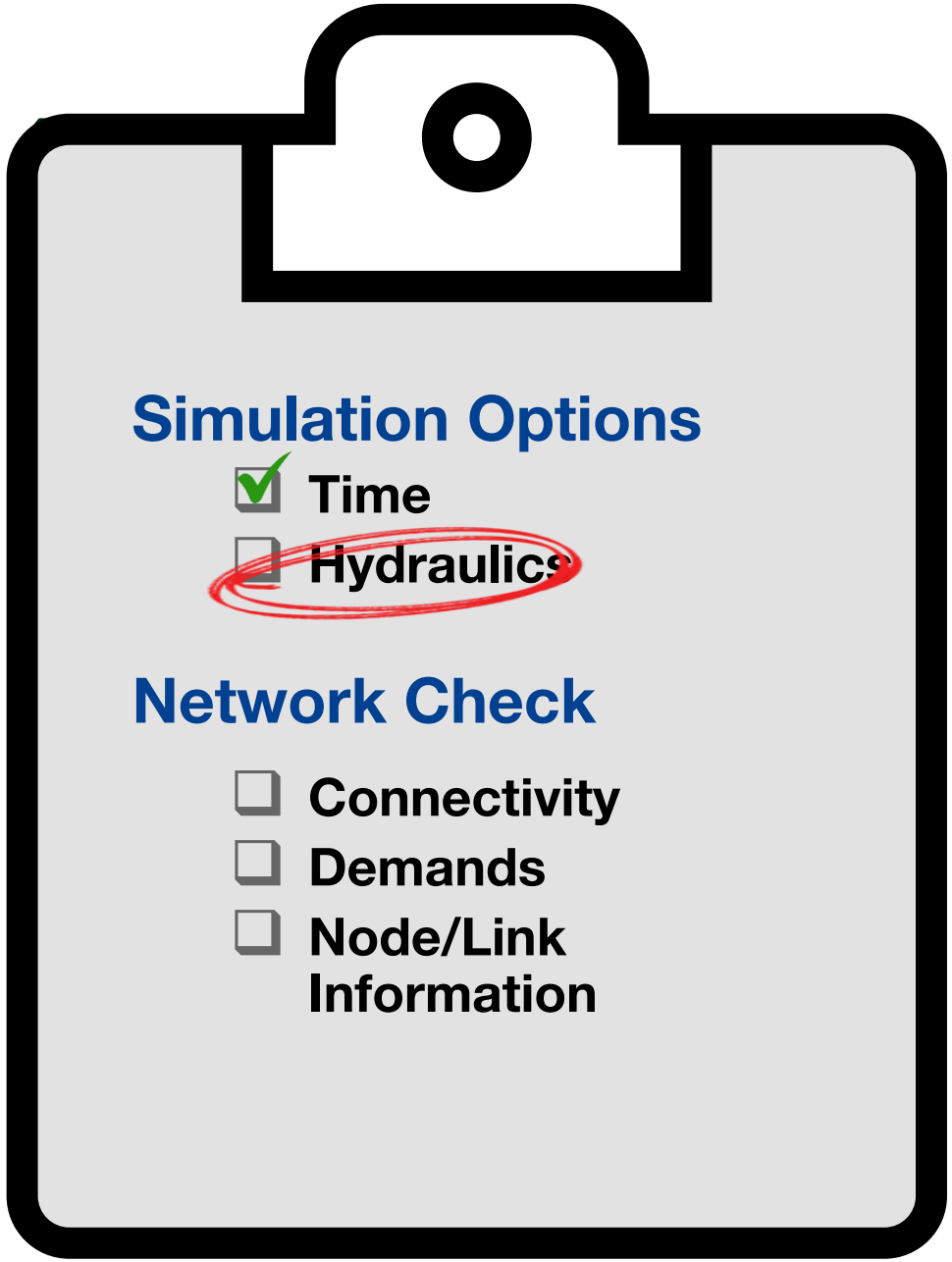


Steady-State Pre-Simulation Checklist

Parameter	Setting (Example)	Description
Flow Units	GPM	Set desired flow units; options: GPM, CFS, MGD, LPS, AFD, etc.
Headloss Formula	H-W	Defines which headloss formula the model will use; options: Hazen-Williams (H-W), Darcy-Weisbach (D-W), Chezy-Manning (C-M)

Note: changing these settings does not always automatically adjust demand or pipe roughness values.

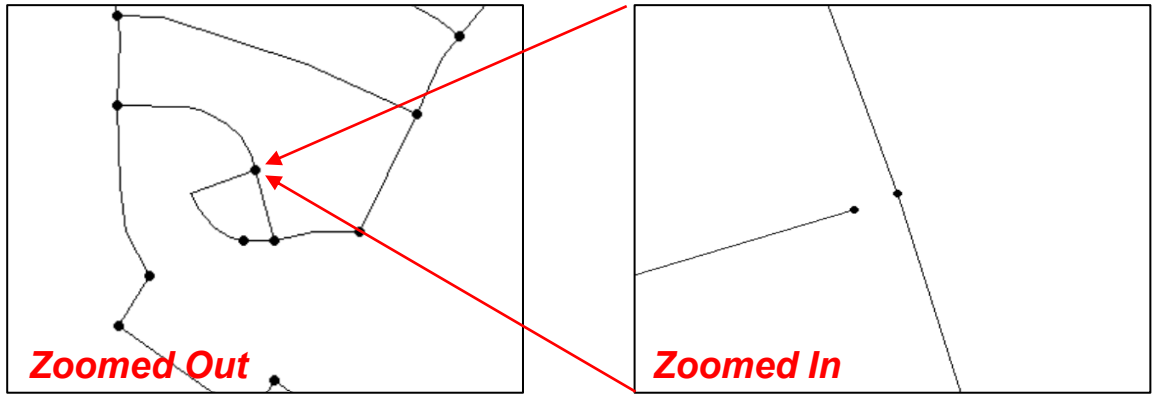
Refer to EPANET User's Manual for additional hydraulics parameters: https://usepa.github.io/EPANET2.2/index.html



Steady-State Pre-Simulation Checklist

Are all my demands connected to a source (tank/reservoir)? → ***Simulation Error***

Are my pipes connected properly? → ***No Simulation Error***



Simulation Options

- ☑ Time
- ☑ Hydraulics

Network Check

- ☐ Connectivity
- ☐ Demands
- ☐ Node/Link Information

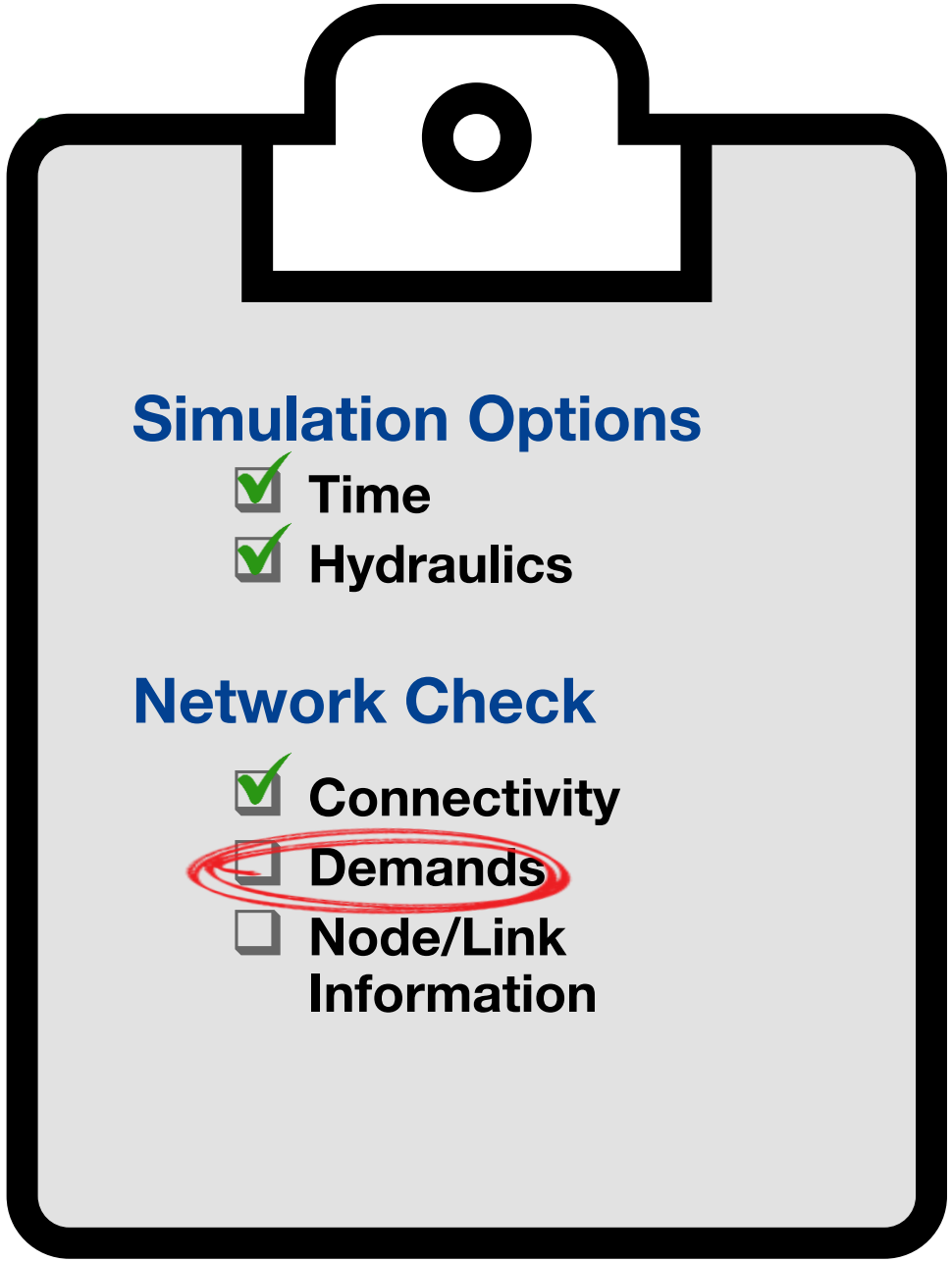
Steady-State Pre-Simulation Checklist

Which scenario am I running?

- Average Day Demand (ADD)
- Max Day Demand (MDD)
- Peak Hour Demand (PHD)
- MDD + Fireflow

Check the following:

- Nodal base demands (totals)
- Demand multipliers/patterns
- Flow results vs. demand settings (after simulation)



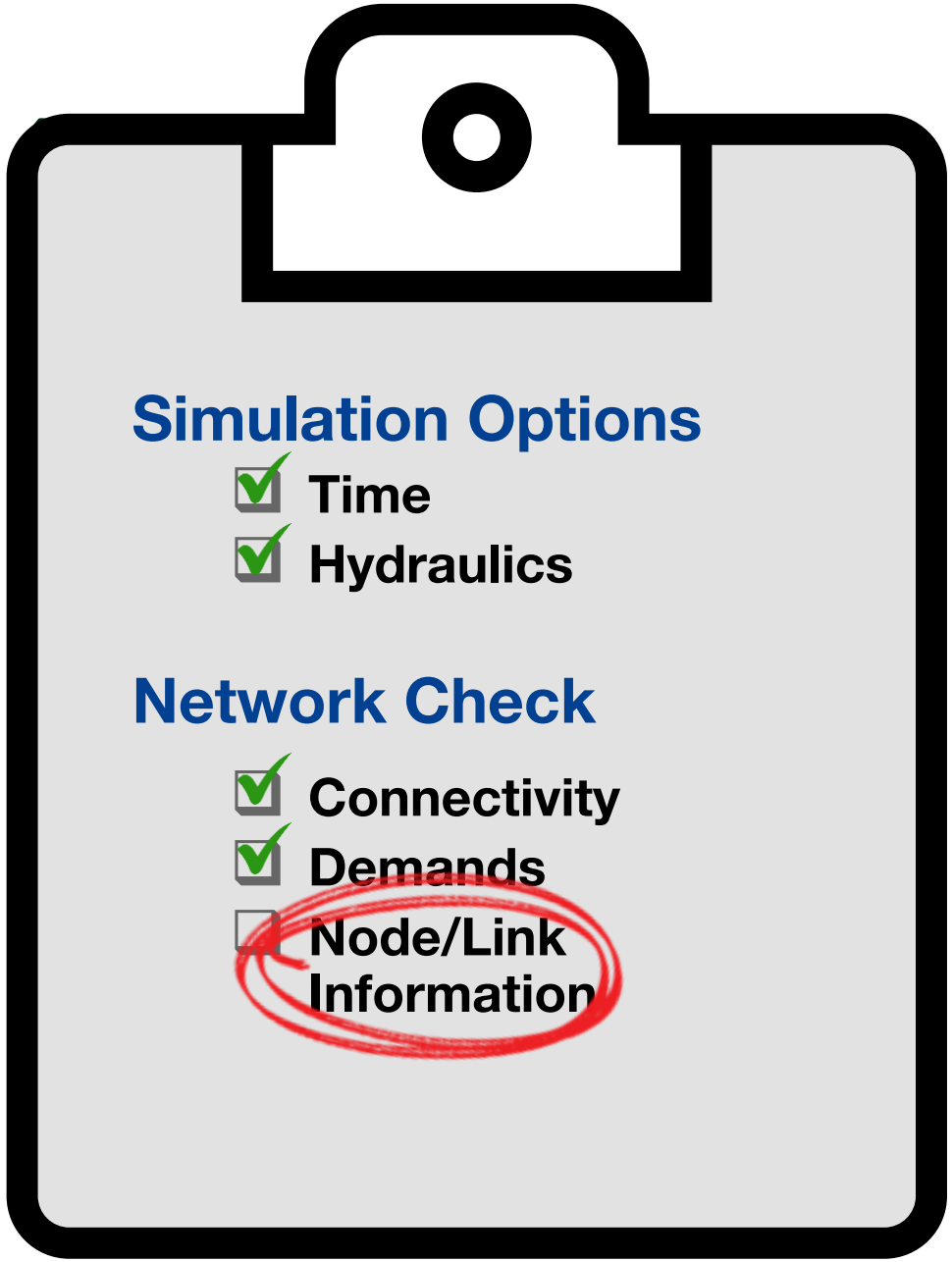
Steady-State Pre-Simulation Checklist

Quick spot checks for nodes:

- Junction Elevations (check min/max)
- Junction Demands (check min/max and units)
- Tank/Reservoir Levels

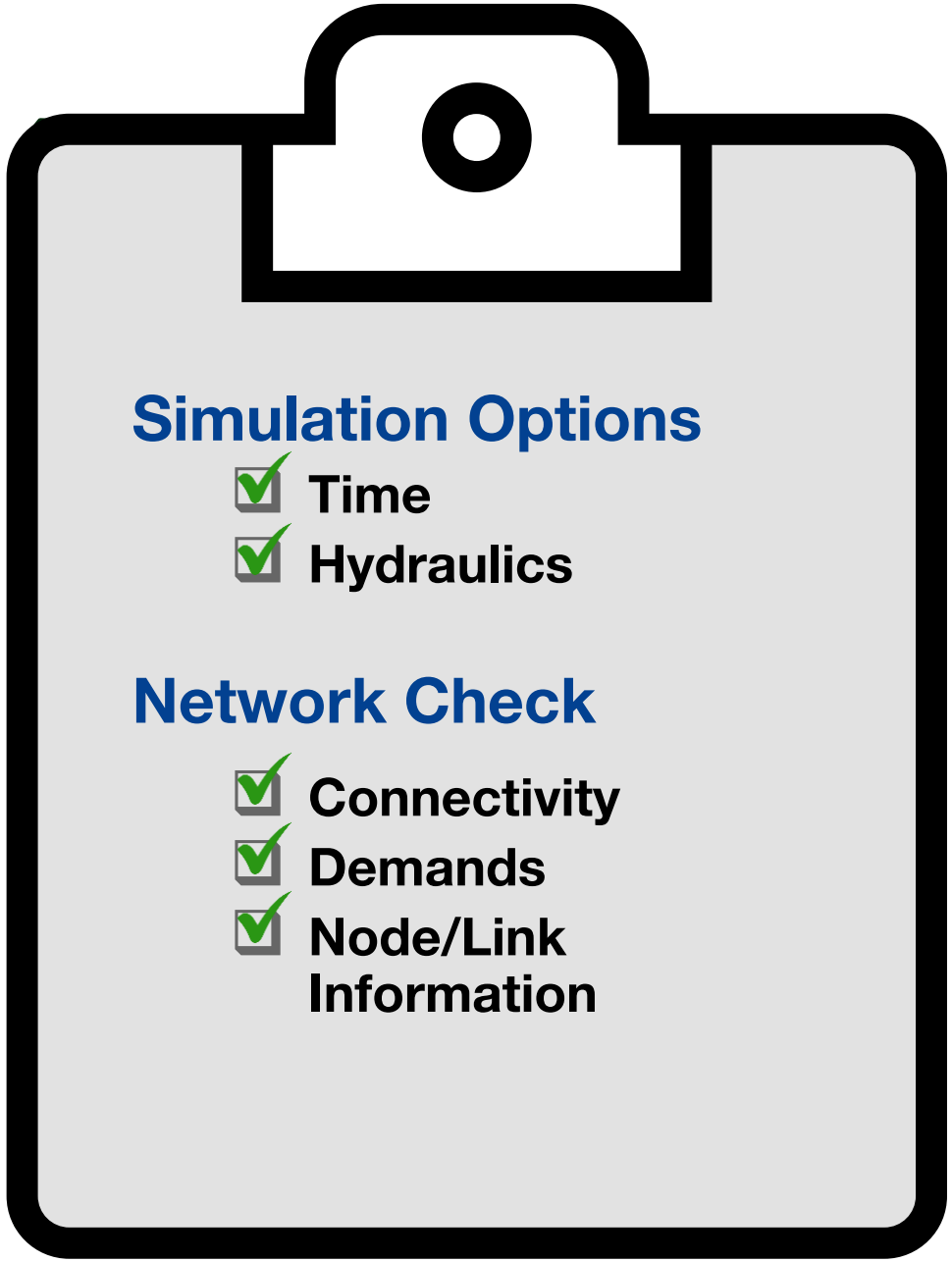
Quick spot checks for links:

- Pipe Diameter, Length, and Roughness (check units and min/max)
- Pump Direction (Start/End Nodes), Setting
- Valve Direction (Start/End Nodes), Setting



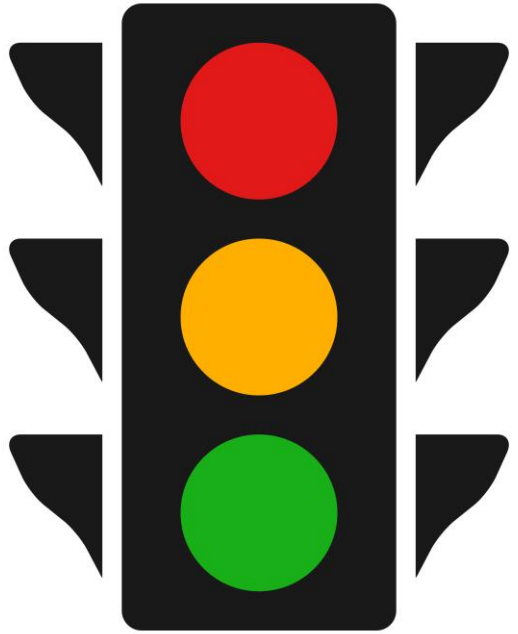
Steady-State Pre-Simulation Checklist

Ready to run!



Run Status

- Run should generate report (software dependent) with run status (success, warning, or error)
- Common errors/warnings:
  - Network Disconnected
  - Negative Pressures Exist
  - Pumps Cannot Deliver Flow or Head
  - System Unbalanced



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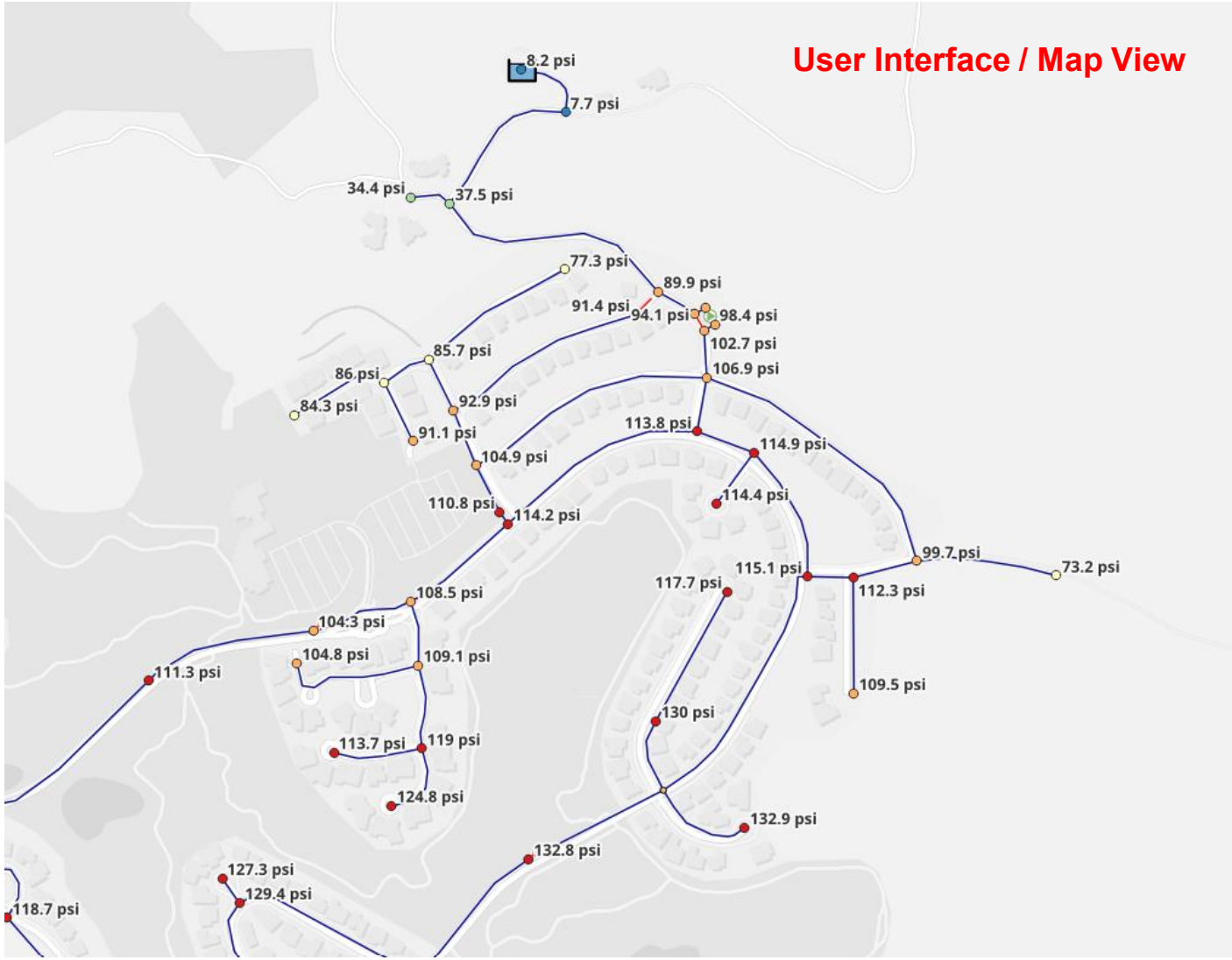
Viewing Results

- Type of Results
  - Nodes – Pressure/Head
  - Links – Flow/Velocity; (Unit) Headloss; friction factor (Darcy-Weisbach only)
- Viewing Options
  - User Interface / Map
  - Report / Table
  - Graphs / Plots



Viewing Results

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  - Links – Flow/Velocity; (Unit) Headloss; friction factor (Darcy-Weisbach only)
- Viewing Options
  - User Interface / Map
  - Report / Table
  - Graphs / Plots

Table View (similar to report)

Network Table - Links at 9:00 Hrs

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft
Pipe 119	-901.41	2.56	1.82
Pipe 121	0.78	0.01	0.00
Pipe 122	-902.58	2.56	1.83
Pipe 123	0.98	0.01	0.00
Pipe 124	-903.95	2.56	1.83
Pipe 130	0.20	0.00	0.00
Pipe 137	0.59	0.01	0.00
Pipe 138	-92.63	0.26	0.03
Pipe 139	0.98	0.01	0.00
Pipe 141	-94.98	0.27	0.03
Pipe 142	-970.66	2.75	2.09
Pipe 143	-1065.83	3.02	2.49
Pipe 144	0.78	0.01	0.00
Pipe 145	-1067.00	3.03	2.49
Pipe 146	0.98	0.01	0.00

Viewing Results

- Type of Results
  - Nodes – Pressure/Head
  - Links – Flow/Velocity; (Unit) Headloss; friction factor (Darcy-Weisbach only)
- Viewing Options
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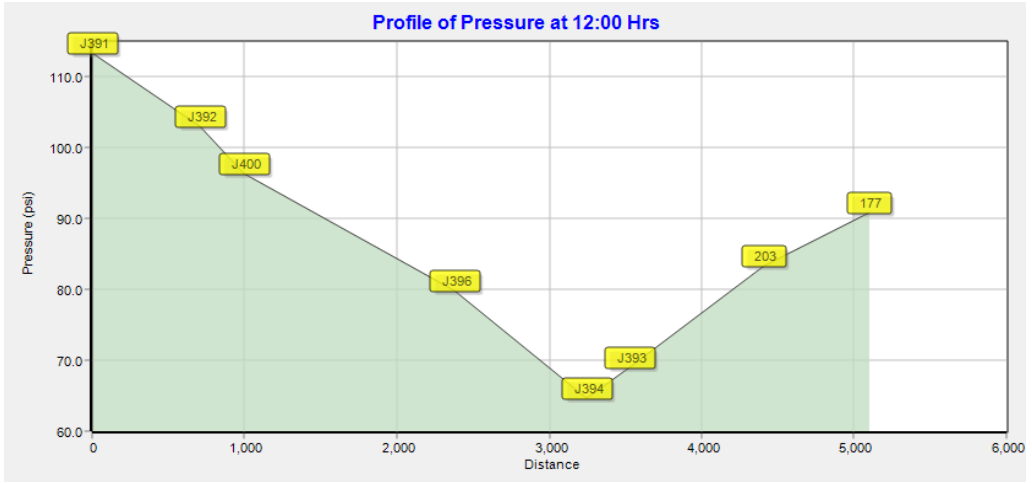
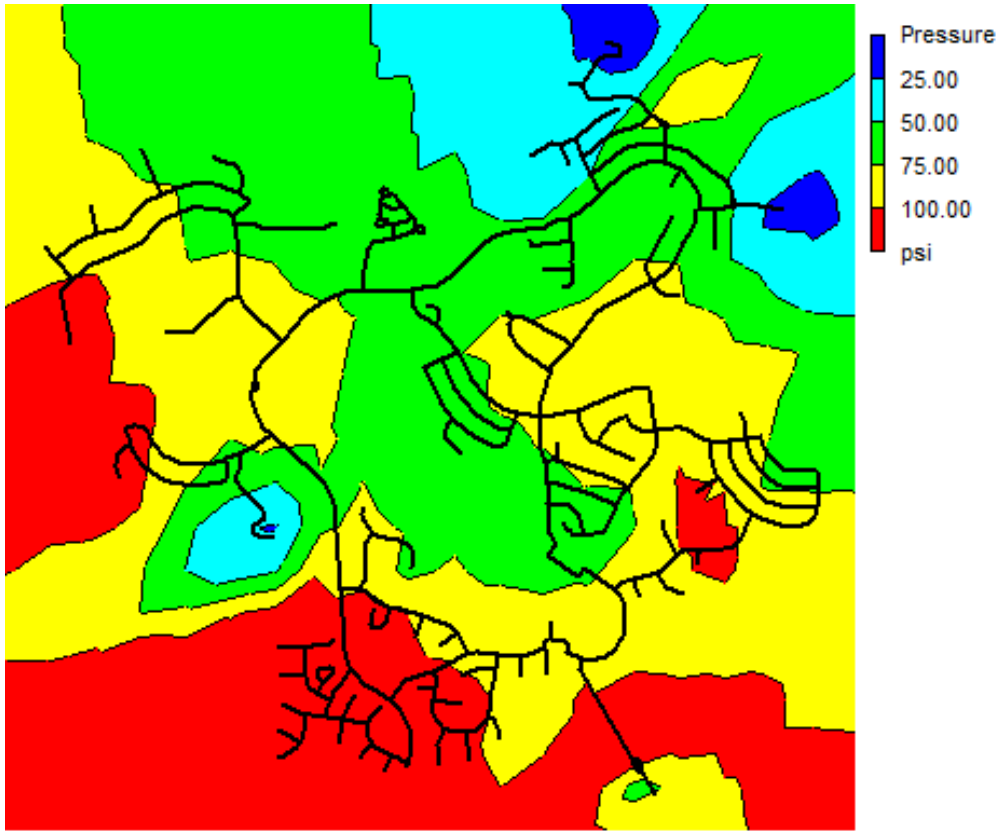


Profile Plot

Contour Plot



Running Extended Period Simulations

- Pre-Simulation Checklist
  - Simulation Options
  - Network Check
    - Demand Categories/Patterns
    - Curves
    - Controls
- Viewing Results

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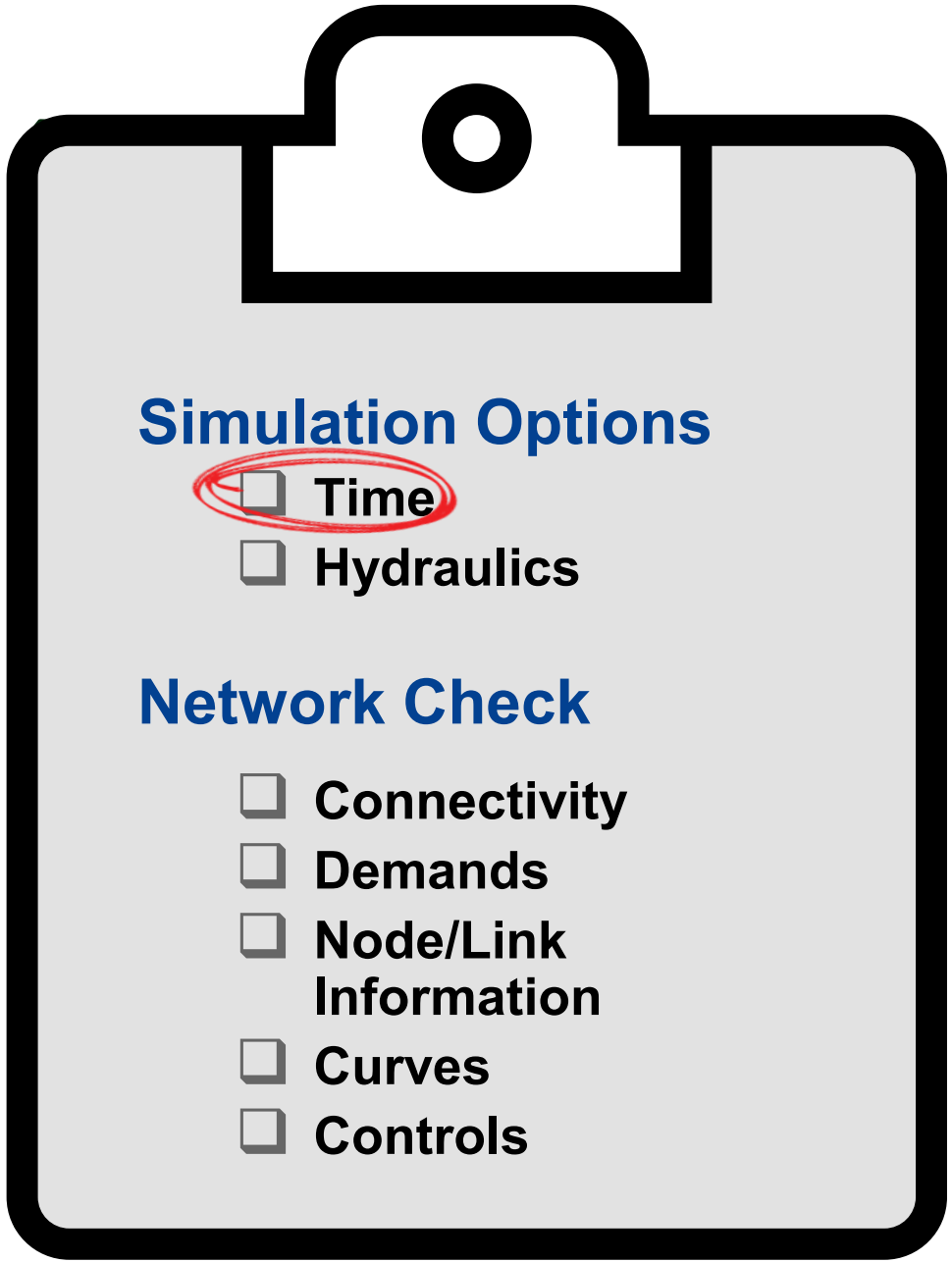
Extended Period Pre-Simulation Checklist

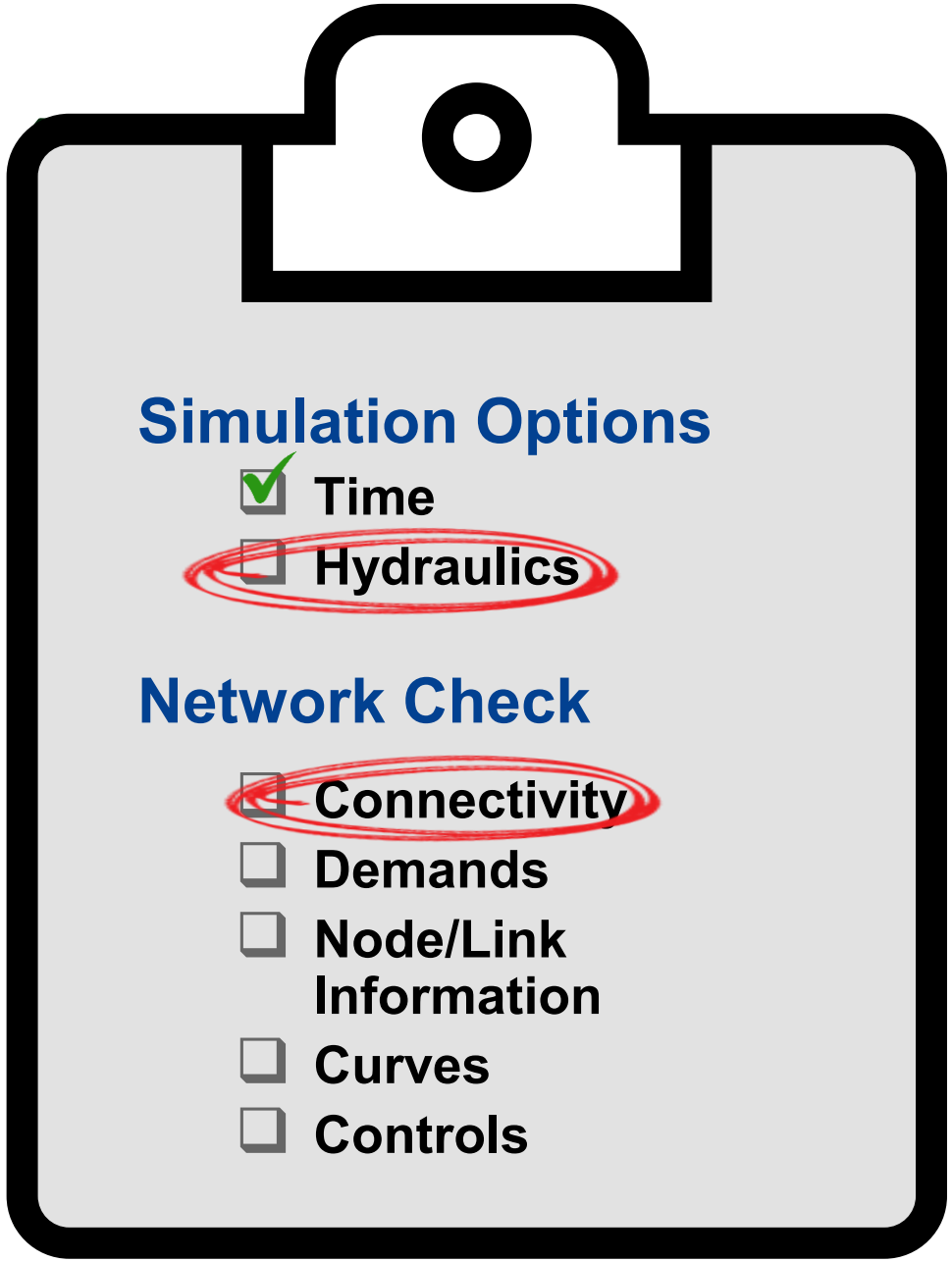
Parameter	Setting (Example)	Description
Total Duration	72:00	Total length of a simulation (in hours). Set to 0 for steady-state simulation. Default is 00:00.
Hydraulic Time Step	01:00	Time interval between re-computation of system hydraulics (in hours). Default is 01:00.

**For more advanced modelers, you can adjust the Pattern Step and Start Times for an EPS.*



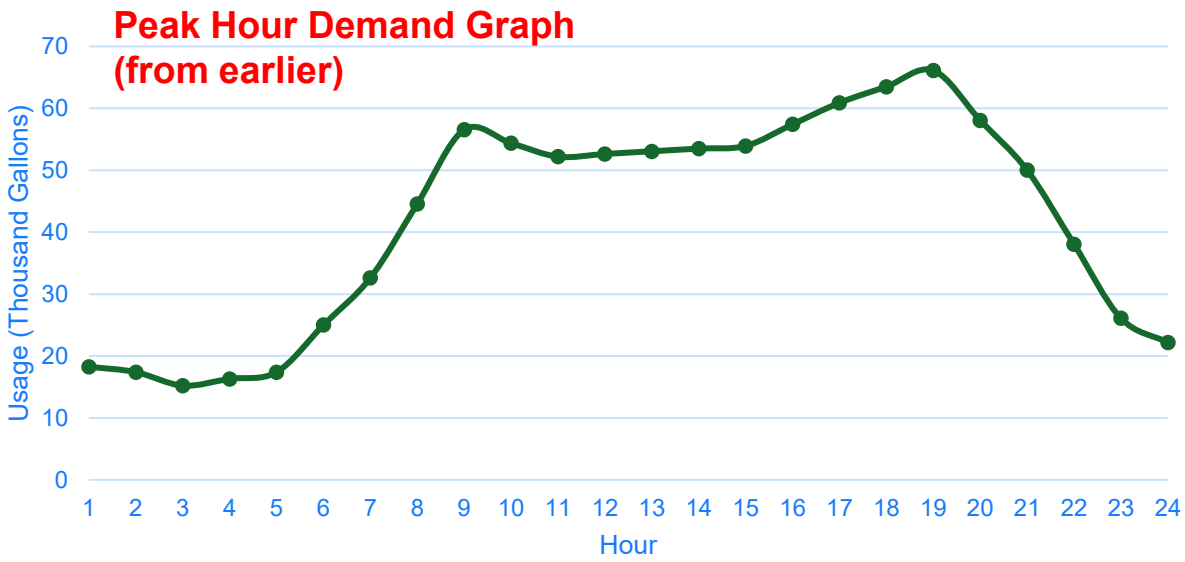
Extended Period Pre-Simulation Checklist

Same as steady-state



Extended Period Pre-Simulation Checklist

Same as steady-state, except…



Simulation Options

- [x] Time
- [x] Hydraulics

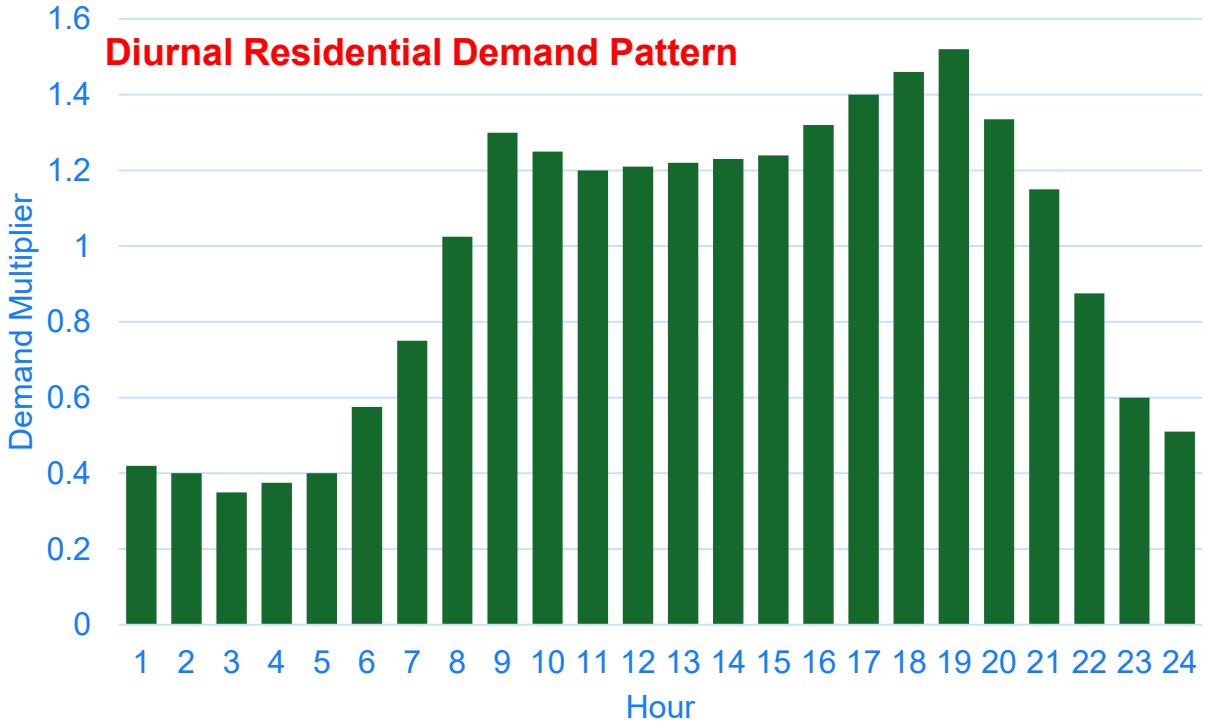
Network Check

- [x] Connectivity
- [ ] Demands
- [ ] Node/Link Information
- [ ] Curves
- [ ] Controls

Extended Period Pre-Simulation Checklist

Demand Pattern

A series of demand multipliers that increase or decrease the base demand over time following an average pattern of demand based on user type (residential, commercial, industrial)



Simulation Options

- [x] Time
- [x] Hydraulics

Network Check

- [x] Connectivity
- [ ] Demands
- [ ] Node/Link Information
- [ ] Curves
- [ ] Controls

Extended Period Pre-Simulation Checklist

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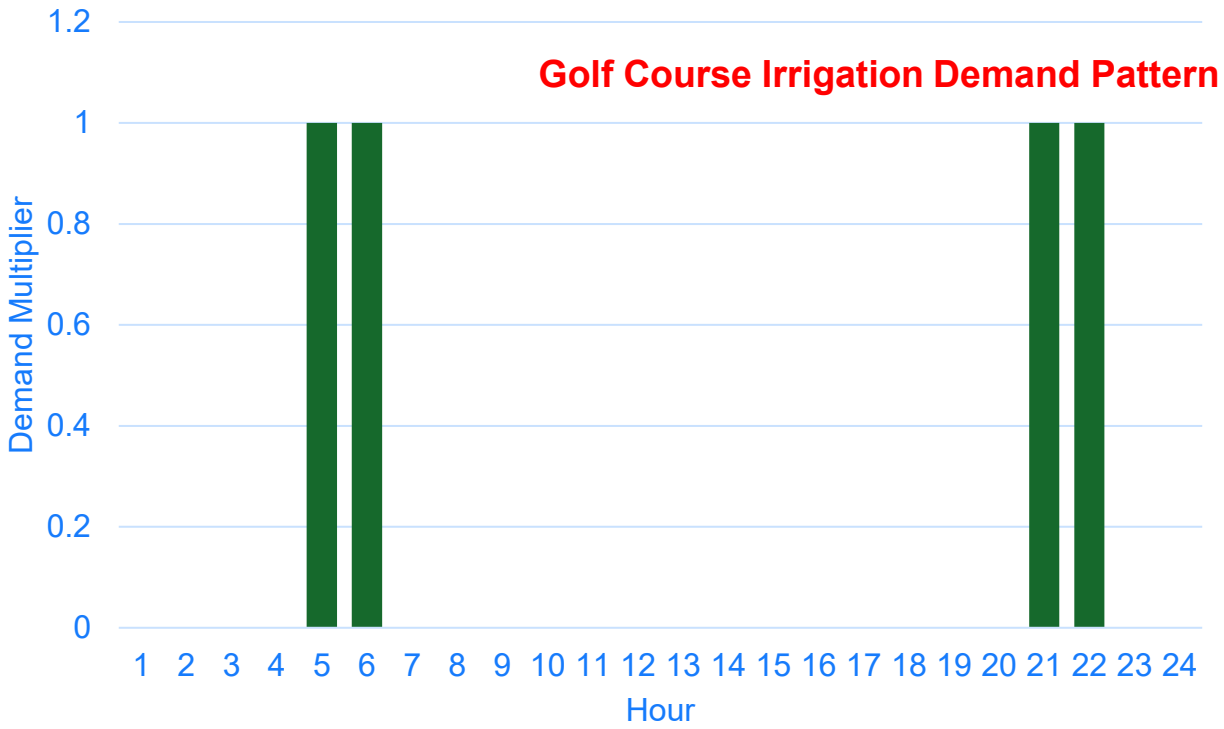


Simulation Options

- [x] Time
- [x] Hydraulics

Network Check

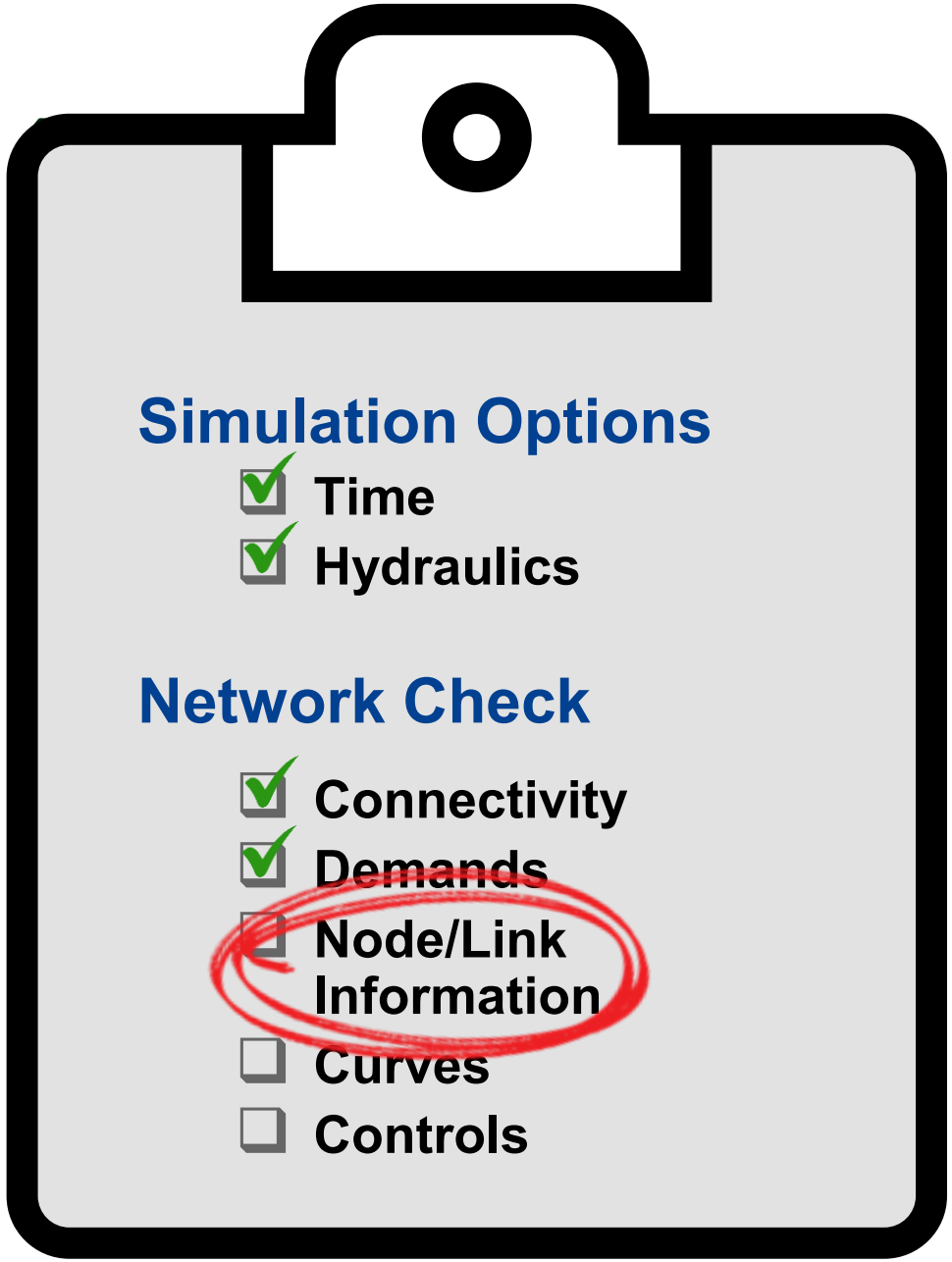
- [x] Connectivity
- [ ] Demands
- [ ] Node/Link Information
- [ ] Curves
- [ ] Controls

Extended Period Pre-Simulation Checklist

Each demand must be assigned a demand pattern.

If no demand pattern is assigned, the default demand pattern is applied (1 for every time step).

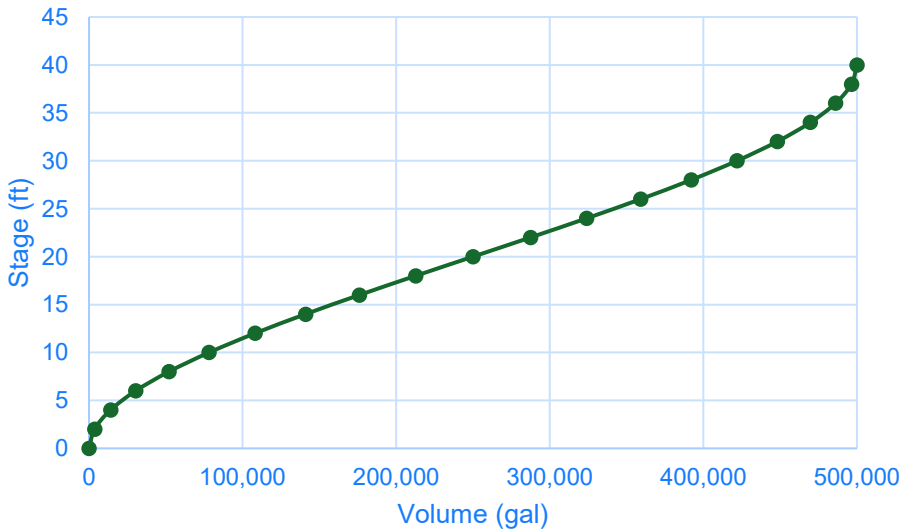
Parameter	Value (Example)
Junction ID	183
Elevation	251.3 ft
Base Demand	1.1 gpm
Demand Pattern	Diurnal



Extended Period Pre-Simulation Checklist

EPS Simulations keep track of volume in/out of storage tanks.

Storage tanks must be assigned a stage-volume curve. If no curve is assigned, a cylindrical tank is assumed and volume is calculated based on tank levels and diameter.



Simulation Options

- [x] Time
- [x] Hydraulics

Network Check

- [x] Connectivity
- [x] Demands
- [x] Node/Link Information
- [ ] Curves
- [ ] Controls

Extended Period Pre-Simulation Checklist

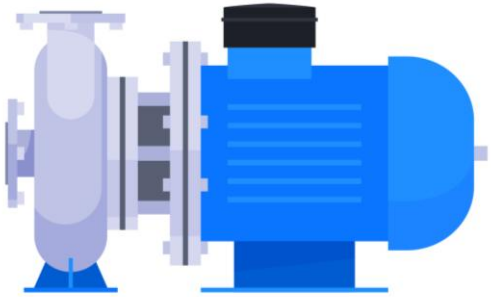
Controls are statements/rules used to change how the network is operated during the simulation.

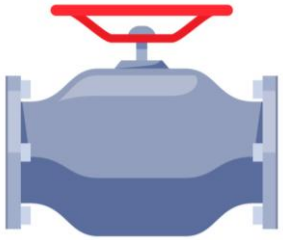
LINK PU467 OPEN IF NODE T463 BELOW 12

LINK PU467 CLOSED IF NODE T463 ABOVE 25

LINK P471_V2_3 CLOSED IF NODE T463 BELOW 12

LINK P471_V2_3 OPEN IF NODE T463 ABOVE 25





Simulation Options

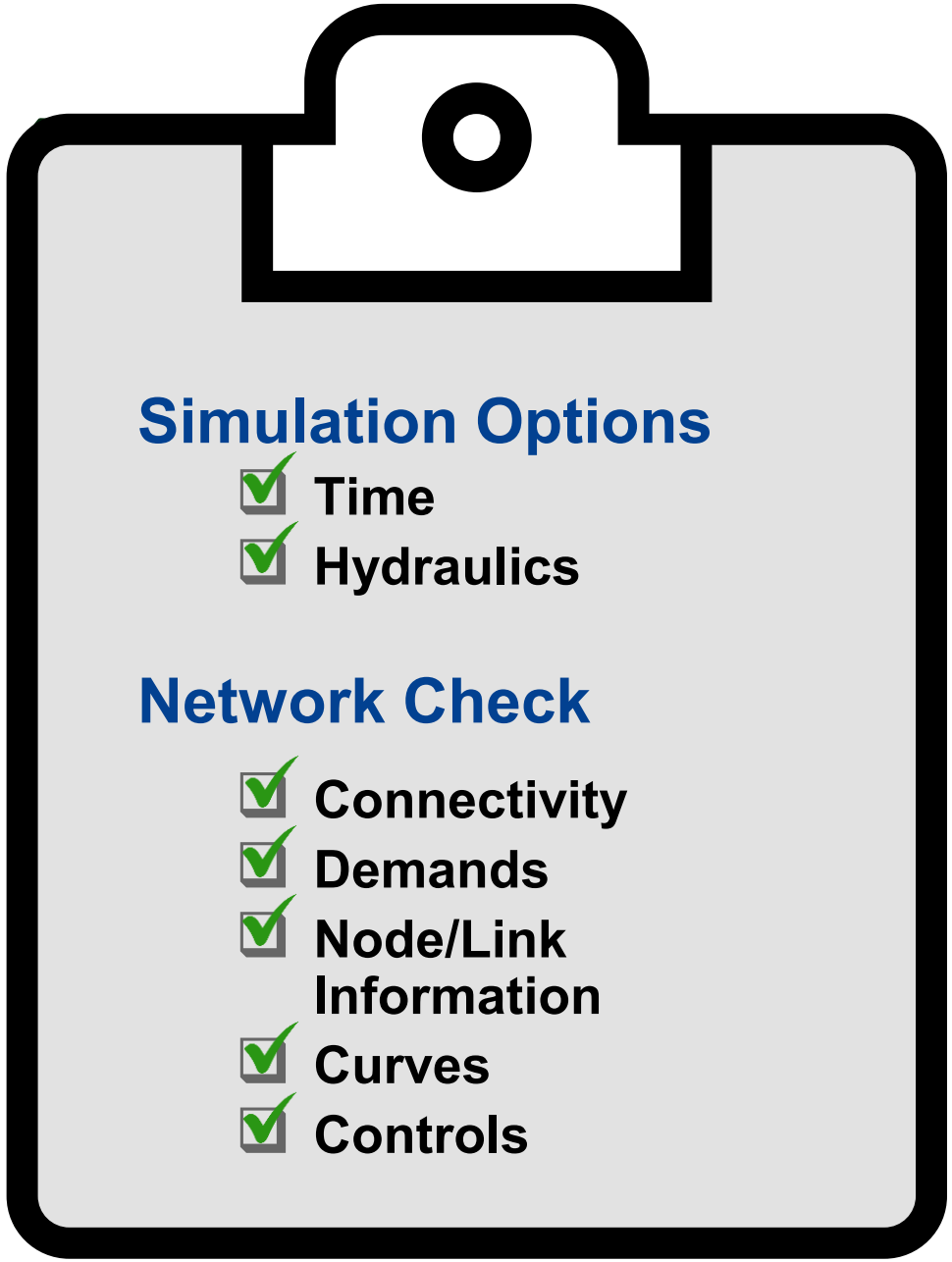
- [x] Time
- [x] Hydraulics

Network Check

- [x] Connectivity
- [x] Demands
- [x] Node/Link Information
- [x] Curves
- [ ] Controls

Extended Period Pre-Simulation Checklist

Ready to run!

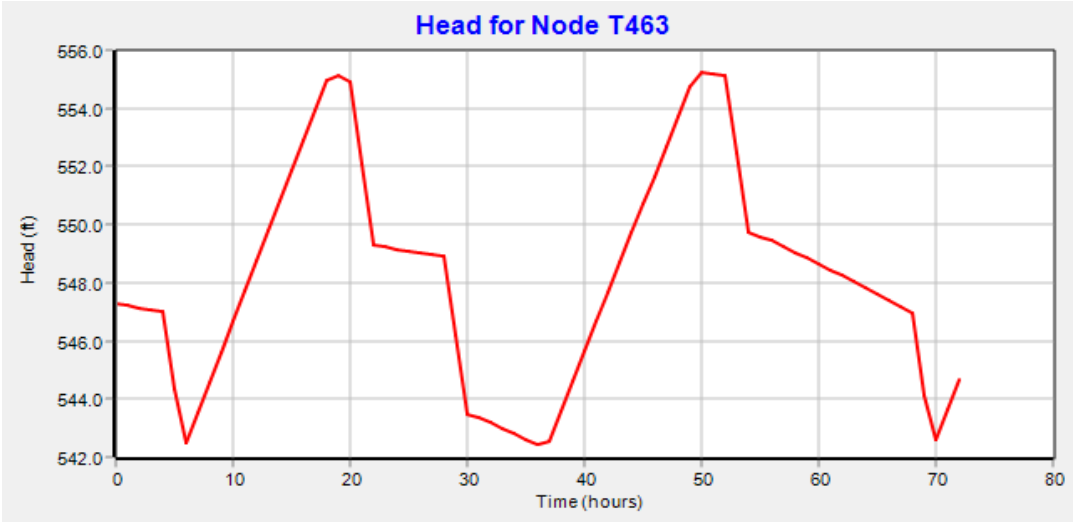


Viewing Results

Same type of results (node and link) as steady-state.

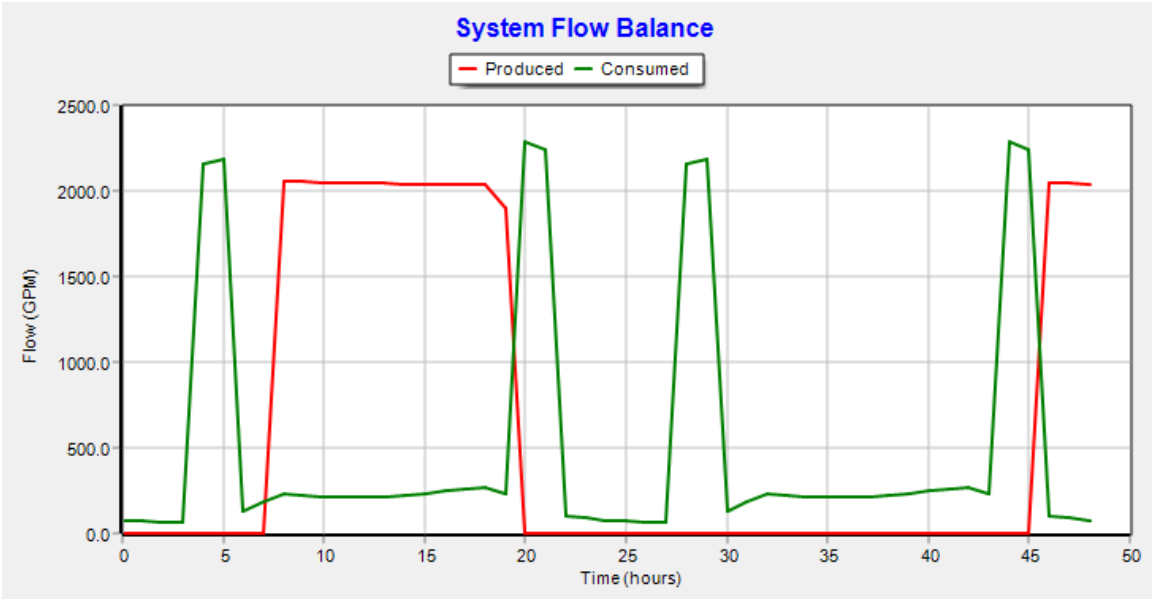
Results for every time step – more to analyze.

EPS results may also be viewed by time series and flow balance plots.

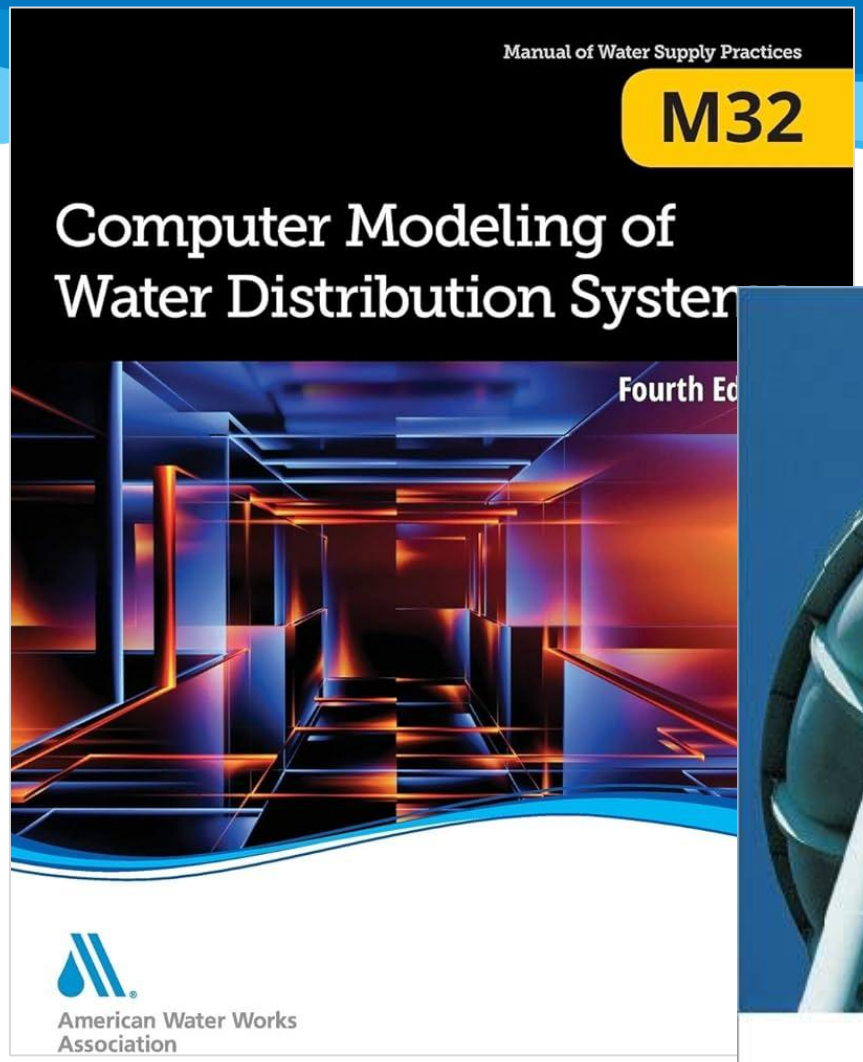


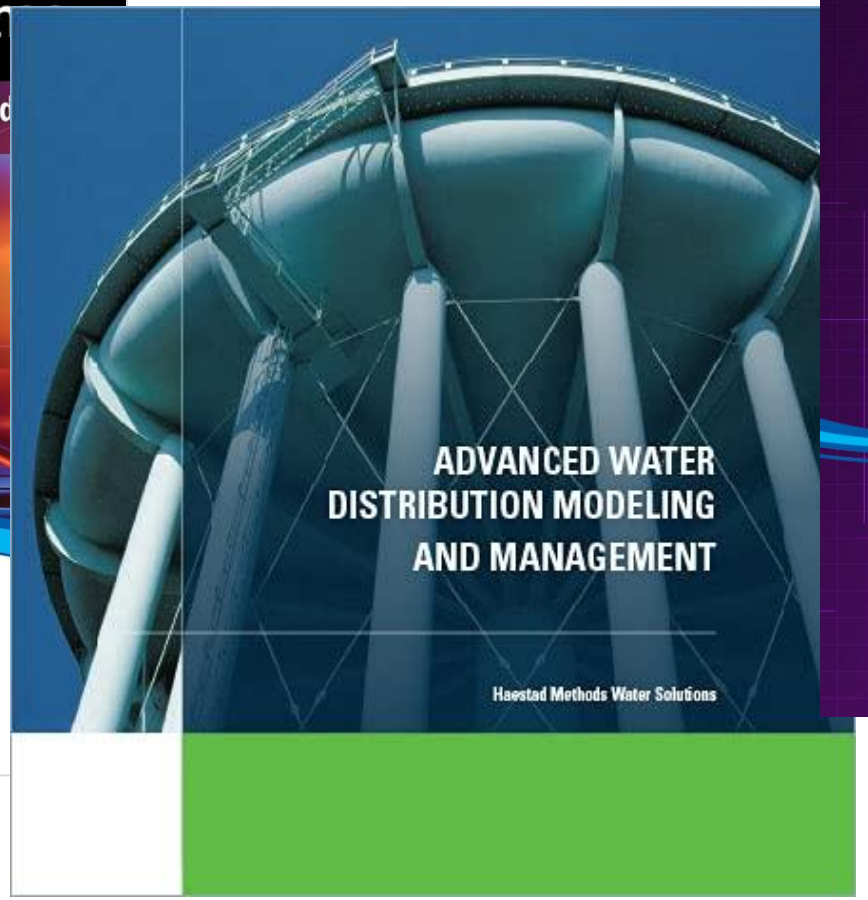
Time Series

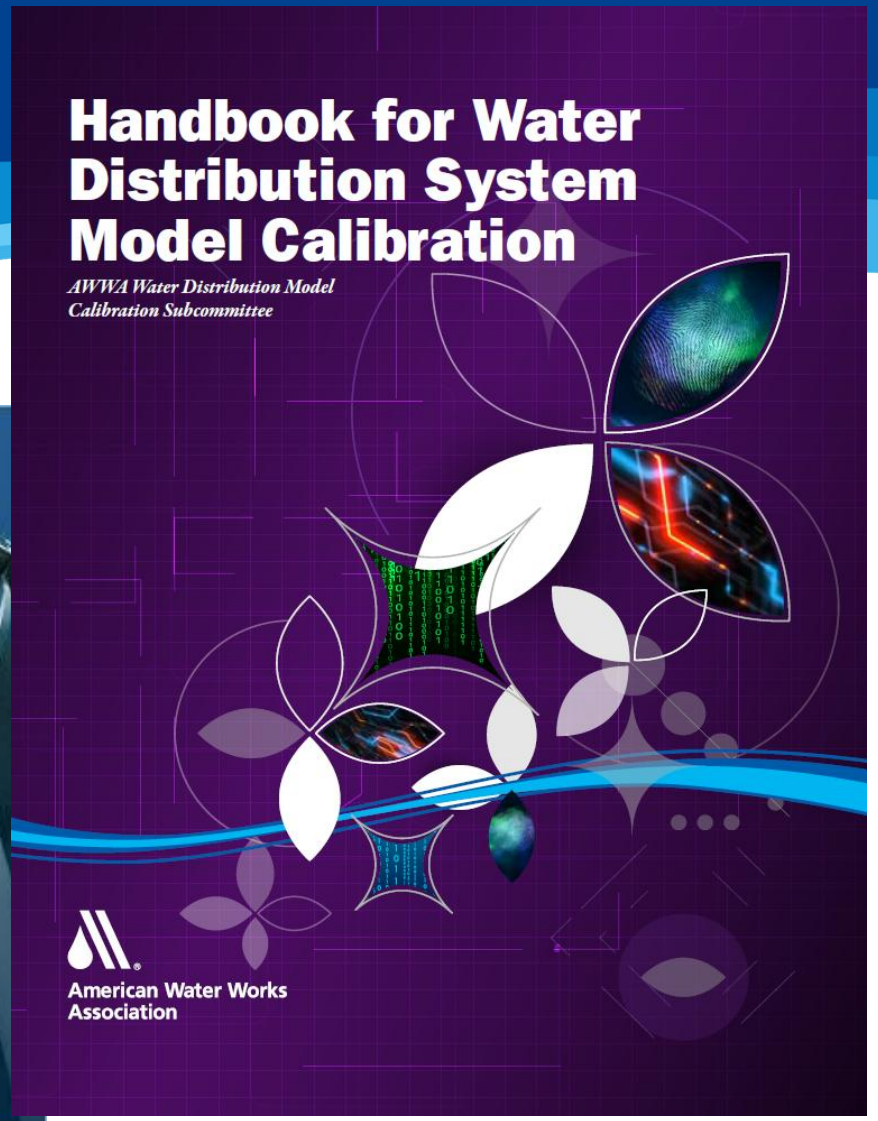
Flow Balance



Recommended Resources







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Thank you!

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Email: hoagland@utk.edu