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Introduction to System Curves

Basic Hydraulic Considerations

Disclaimer: This information is provided ***as-is*** for the purposes of *general guidance* for hydraulic modelers. Each user is ultimately responsible for how this information is applied and used for any a specific model. The user accepts this responsibility when using these materials.

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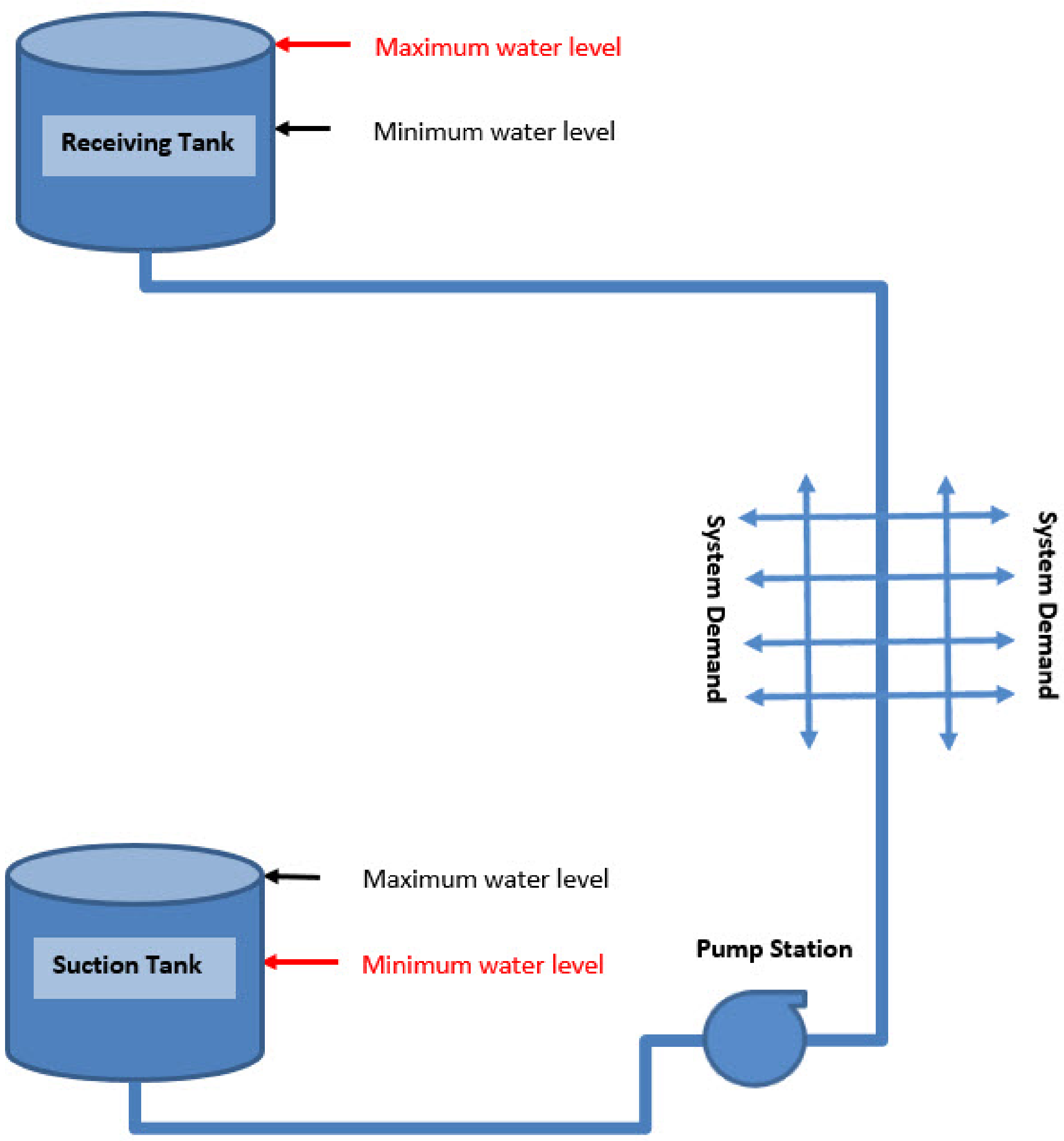
What is a system curve?

- A curve showing the energy required to push water into a water system.
- Energy required increases as flow increases

Typical Pumping System Layout



How do modelers make use of System Curves?

- Pumps run where the pump curve and the system curve intersect
- Evaluate existing pump operation
- Most often used to Guide selection of new pumps
  - Critical task! Mistakes are costly to fix
  - Are the pumps properly sized?
  - Check pump efficiency (minimize operating cost)
  - Pump Operation will not damage the pump

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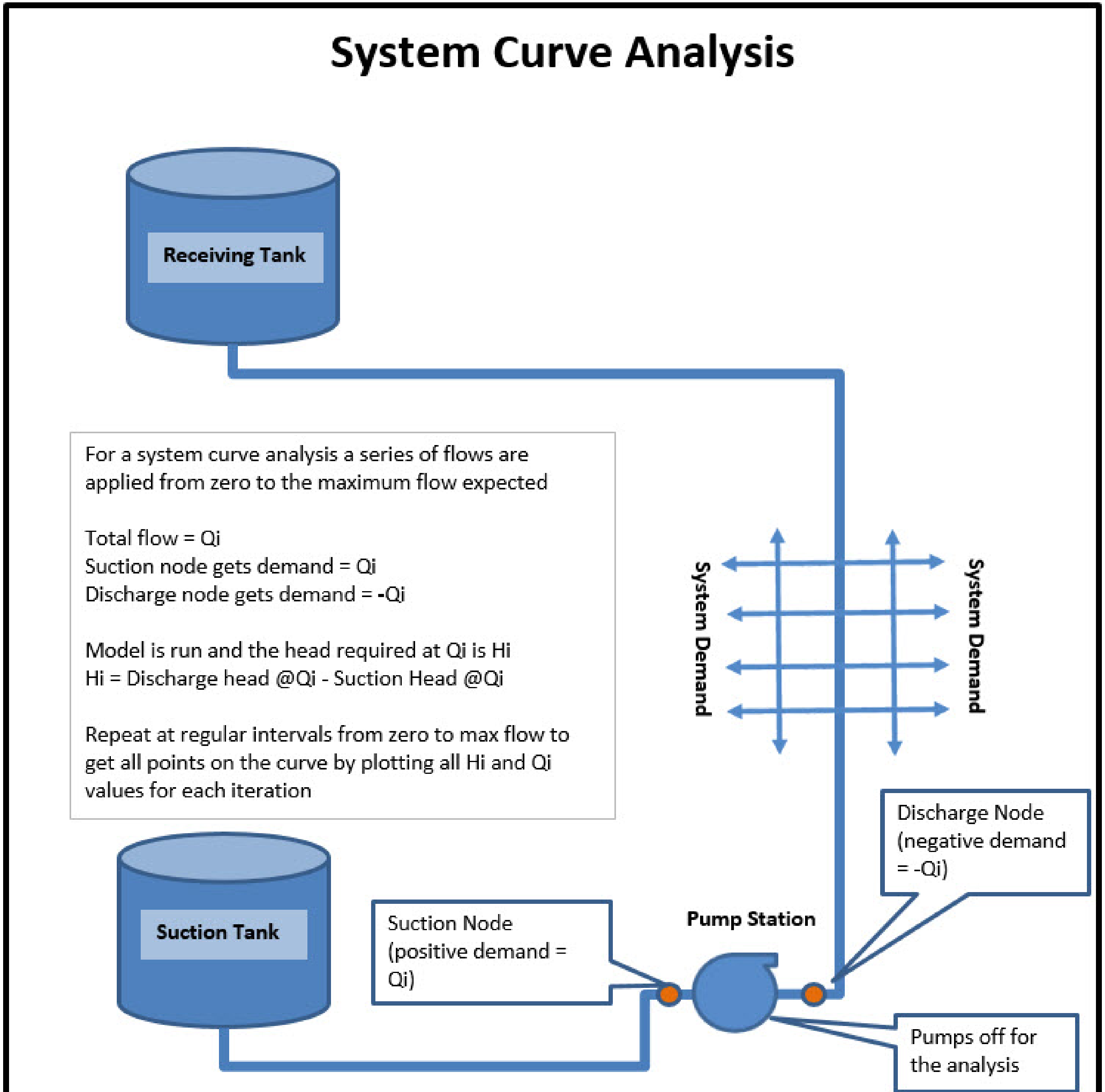
How do you calculate a system curve?

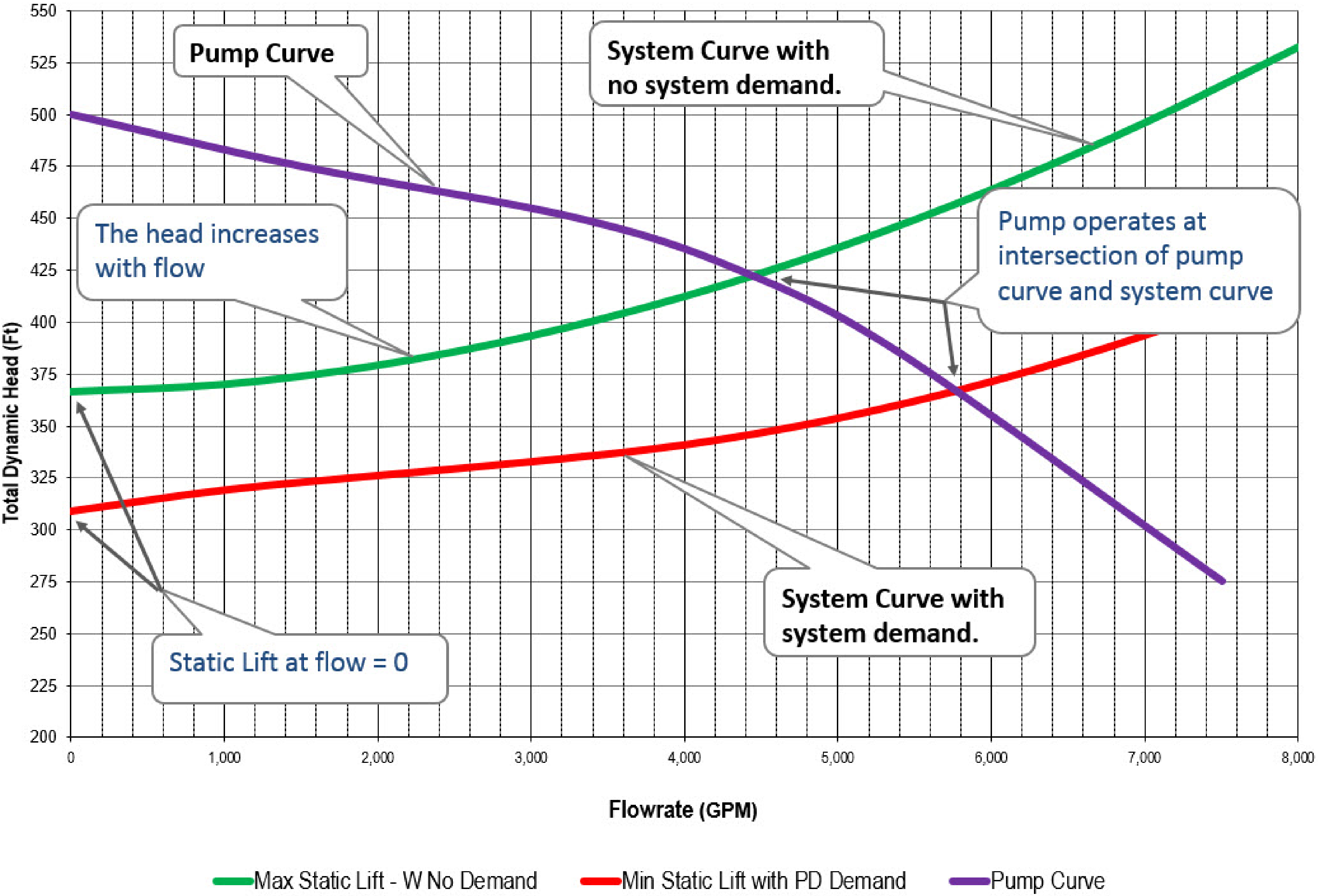
- Run a series of analyses on a pump station
- Place positive demands on suction node
- Place an equal negative demand on discharge node
- Run a series of flow values from zero to max flow
- Difference in head between discharge and suction is head required at that flow


System Curve Analysis
Receiving Tank
For a system curve analysis a series of flows are applied from zero to the maximum flow expected
Total flow = Qi
Suction node gets demand = Qi
Discharge node gets demand = -Qi
Model is run and the head required at Qi is Hi
Hi = Discharge head @Qi - Suction Head @Qi
Repeat at regular intervals from zero to max flow to get all points on the curve by plotting all Hi and Qi values for each iteration
System Demand
System Demand
Discharge Node (negative demand = -Qi)
Pump Station
Suction Tank
Suction Node (positive demand = Qi)
Pumps off for the analysis

Key Hydraulic Factors in System Curves

- Static Lift – minimum head required to push any water into the system
  - This generally changes as the system operates
- Headloss – Increases as flow increases
  - On discharge side and suction side
- Most often are a *family* of curves
  - The upper and lower bounds are the most critical
- Run on entire pump station not a single pump

Basic System Curve Elements



Determining System Curve Bounds

- What is generally the highest system curve?
  - Maximum Static Lift
    - suction tank lowest & receiving tank at highest
  - No system demand
  - Highest headloss (all water to receiving tank)
- What is generally the lowest system curve?
  - Minimum Static Lift
    - Suction tank at highest & receiving tank at lowest
  - Highest system demand
  - Other pump supplies to the zone are off

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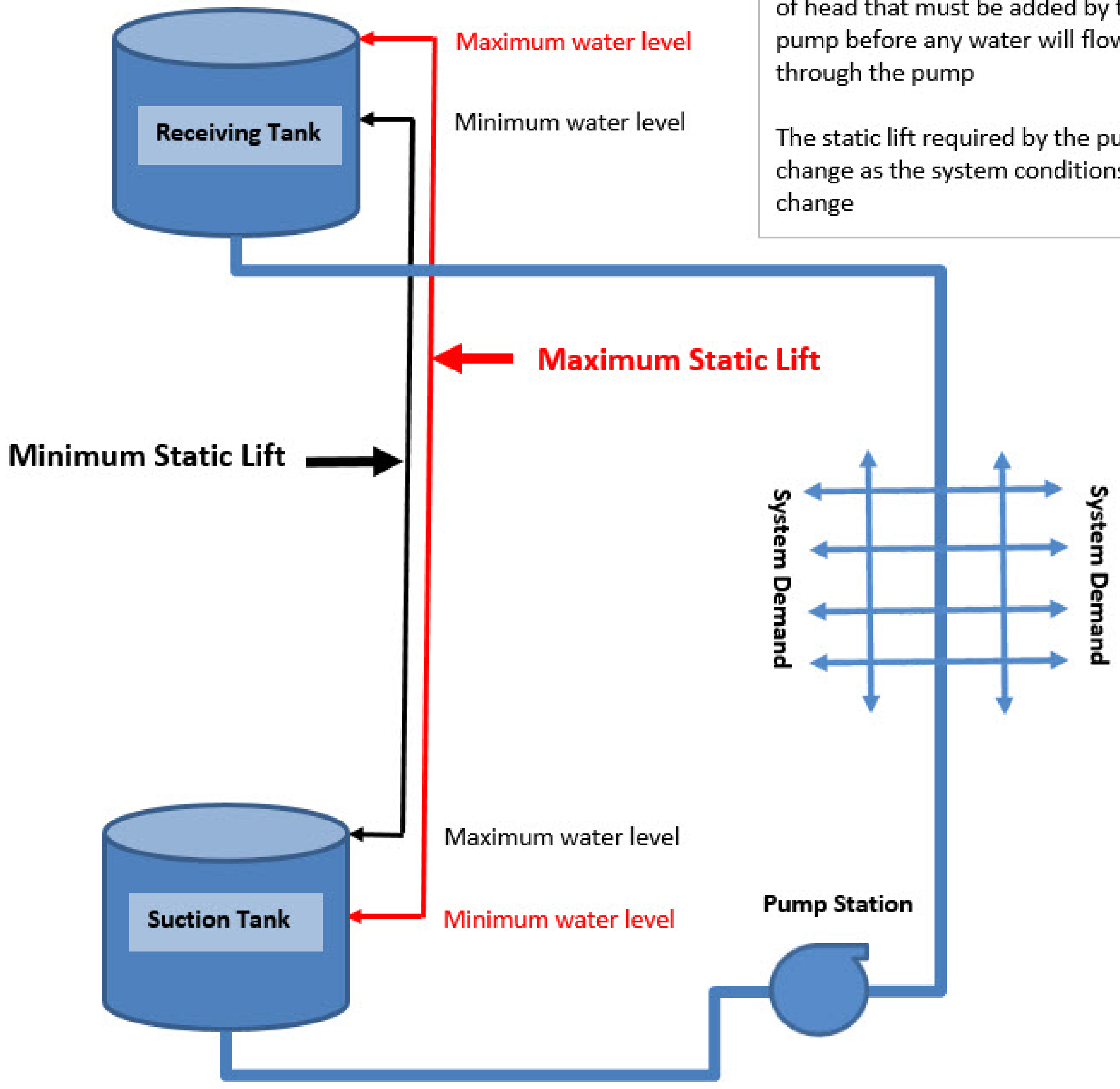
Maximum and Minimum Static Lift

Note: Static lift is the *minimum* amount of head that must be added by the pump before any water will flow through the pump

The static lift required by the pump will change as the system conditions change



Why are the System Curve Bounds Important?

- All other curves fall inside the boundaries
- If pumps work at boundaries it will work for all intermediate points
- All pump operation on line in-between max and min curves
- NOTE: The Engineer should always verify the boundary curves for each system

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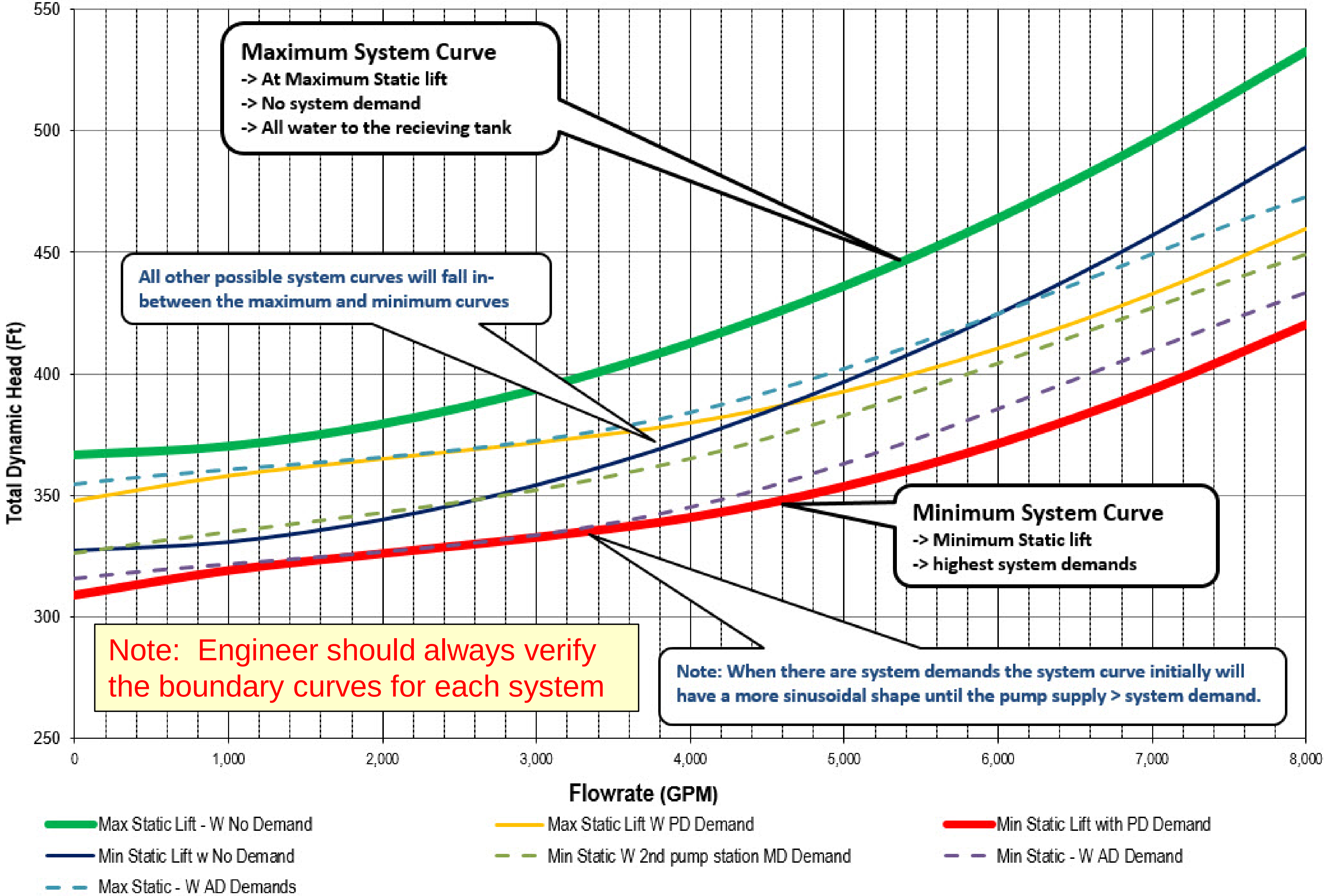
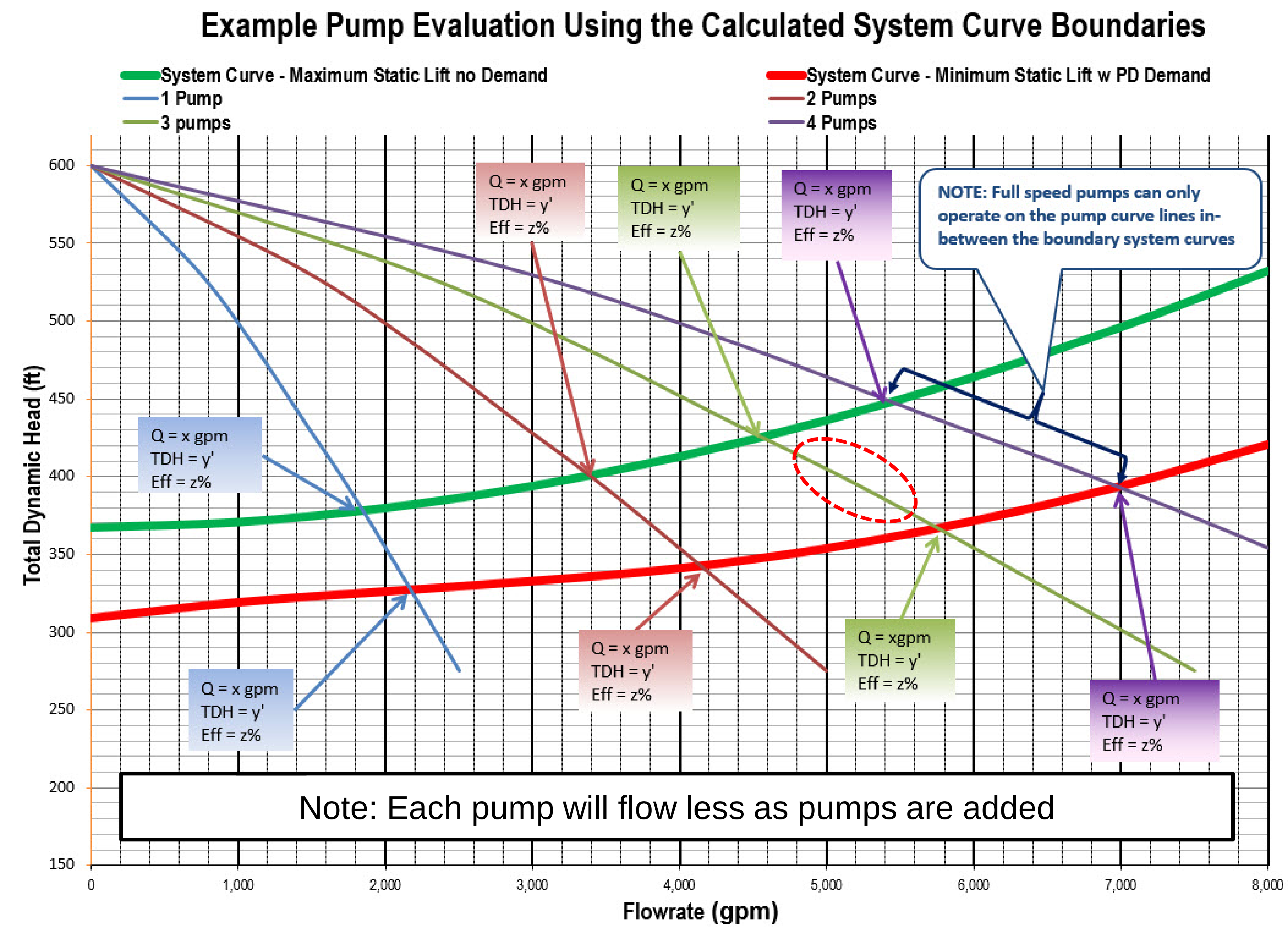
Example Family of System Curves

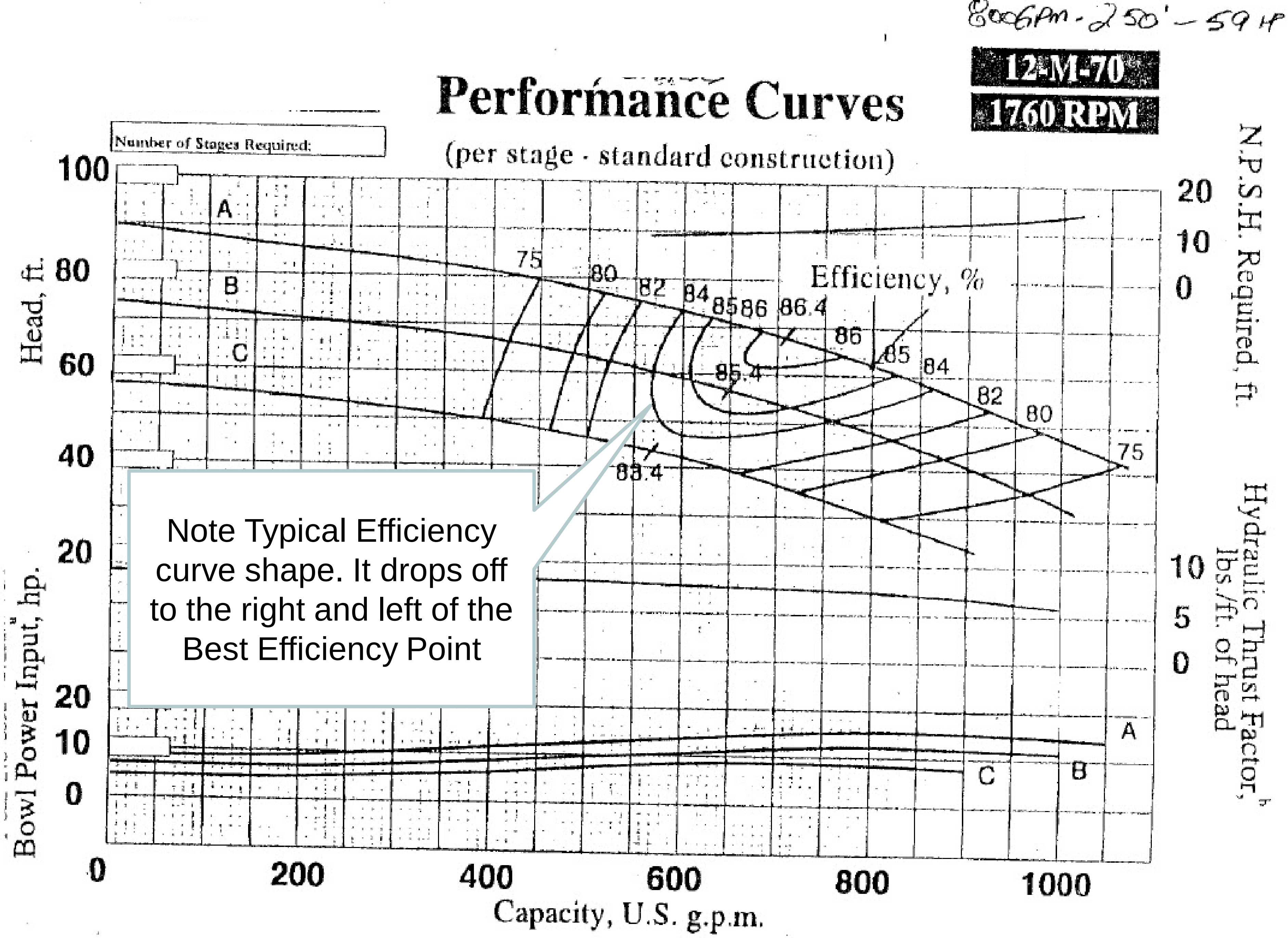


Checking Pump Operation

- Check efficiency at upper and lower bounds
- Check pump operation at boundaries for each mode of operation
  - 1 pump, 2 pumps, 3 pumps, etc.
- Best to maximize pump efficiency & operation in region where pumps will most often operate
  - Use engineering judgment and historical operation



Example Pump Evaluation Using the Calculated System Curve Boundaries
System Curve - Maximum Static Lift no Demand
1 Pump
3 pumps
System Curve - Minimum Static Lift w PD Demand
2 Pumps
4 Pumps
Total Dynamic Head (ft)
600
550
500
450
400
350
300
250
200
150
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Flowrate (gpm)
Q = x gpm
TDH = y'
Eff = z%
NOTE: Full speed pumps can only operate on the pump curve lines in-between the boundary system curves
Q = xgpm
TDH = y'
Eff = z%
Note: Each pump will flow less as pumps are added



Note Typical Efficiency curve shape. It drops off to the right and left of the Best Efficiency Point

Using SCADA Data to Verify Curves

- SCADA data can be used to calculate pump(s) TDH & flow
  - Pump TDH = Discharge Head - Suction Head
  - Discharge Head = discharge pressure head + elevation
  - Suction Head = suction tank level + elevation (if tank is near the station) ***or*** = suction pressure head + elevation
  - Plot each calculated TDH at its flow and overlay on the system curve (as shown in next slide)
  - If available in SCADA, user can also sort data for specific pumps and pump combinations as desired
- Use the calculated TDH and flow data to verify boundary curves
- This data can also be used to guide adjustments to the pump curves as necessary (points should fall on the pump curve lines)
  - Note: Calculated points under VSP operation will fall in-between full speed pump curve lines

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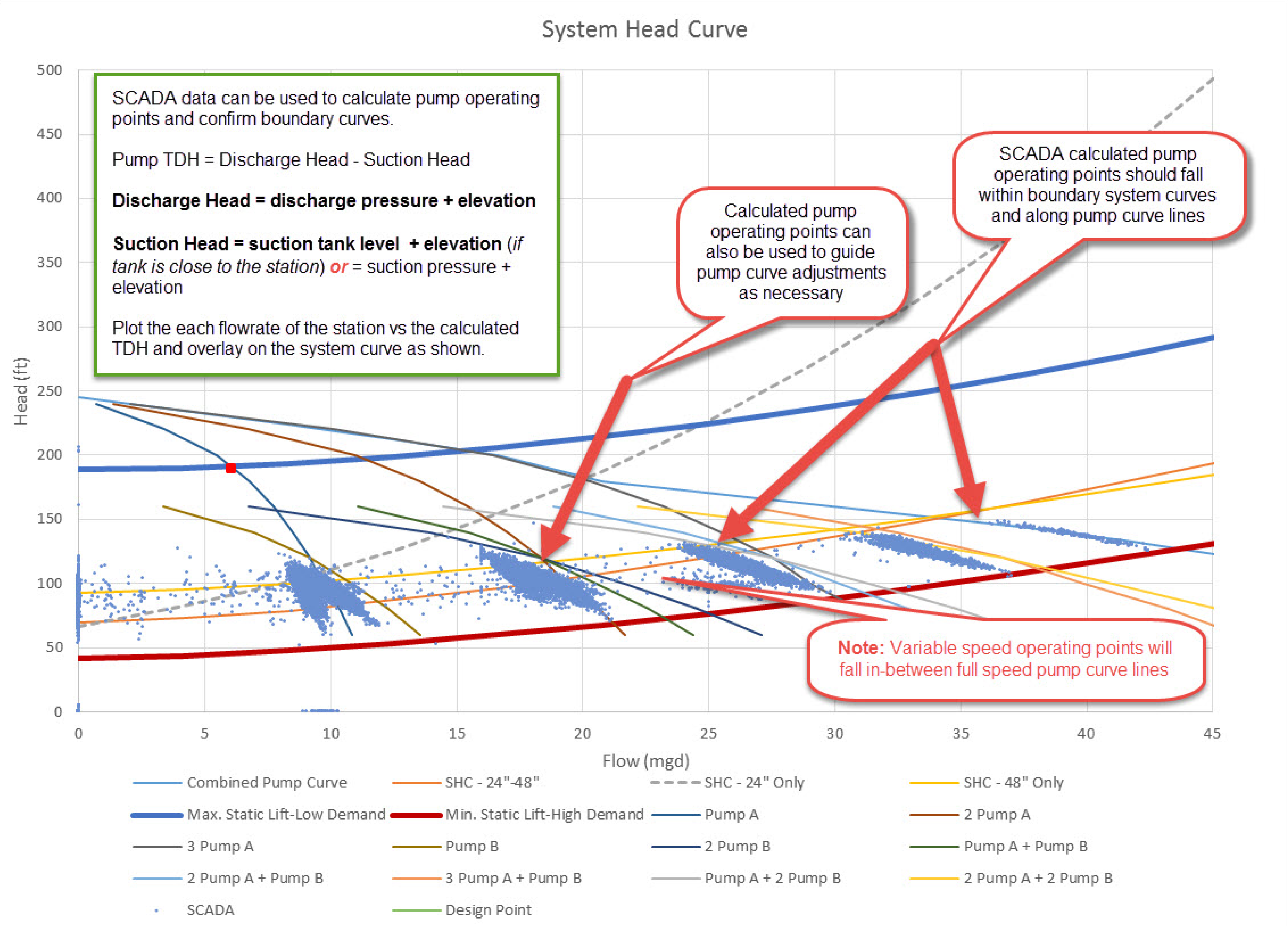
System Head Curve
SCADA data can be used to calculate pump operating points and confirm boundary curves.
Pump TDH = Discharge Head - Suction Head
Discharge Head = discharge pressure + elevation
Suction Head = suction tank level + elevation (if tank is close to the station) or = suction pressure + elevation
Plot the each flowrate of the station vs the calculated TDH and overlay on the system curve as shown.
Calculated pump operating points can also be used to guide pump curve adjustments as necessary
SCADA calculated pump operating points should fall within boundary system curves and along pump curve lines
Note: Variable speed operating points will fall in-between full speed pump curve lines
Head (ft)
500
450
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
Flow (mgd)
Combined Pump Curve
SHC - 24"-48"
SHC - 24" Only
SHC - 48" Only
Max. Static Lift-Low Demand
Min. Static Lift-High Demand
Pump A
2 Pump A
3 Pump A
Pump B
2 Pump B
Pump A + Pump B
2 Pump A + Pump B
3 Pump A + Pump B
Pump A + 2 Pump B
2 Pump A + 2 Pump B
SCADA
Design Point

How Model calculates system curves

- Key User Input
  - Select one pump
  - Select curve type (exponential or multipoint)
  - Flow interval based on number of points (10 minimum)
- Assumptions
  - All water will flow through that pump and its connected pipes
  - Max Flow at point where pump head is zero on pump curve
  - Current system conditions apply
- Model Run
  - Series of steady state runs from zero to max flow
  - Positive demand on suction node (hidden)
  - Equal value Negative demand on discharge node (hidden)
  - Calculates head difference between discharge and suction nodes at each flow
  - Plots all points and the pump curve in a graph

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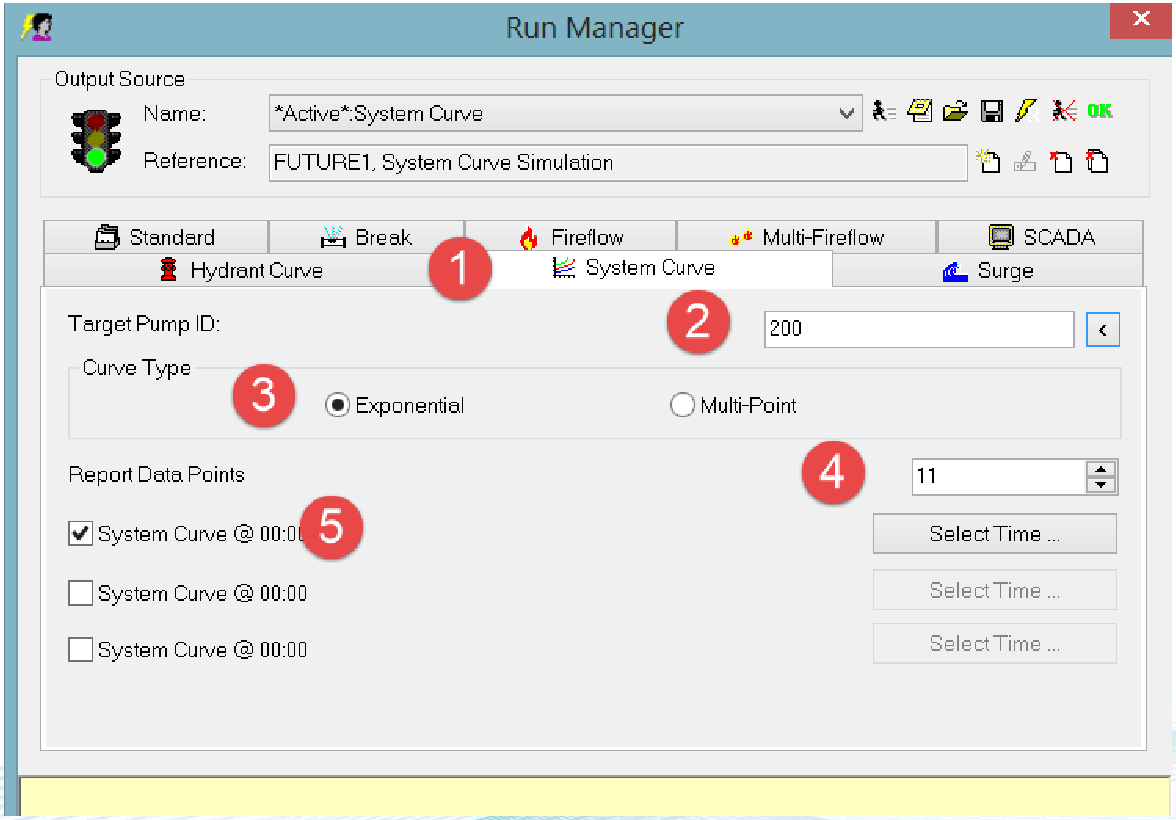
Running a system curve

- **Open Run manager**
- 1: Select system curve tab
- 2: Select pump
- 3: Choose curve type
- 4: Select # of data points
  - Recommend at least 10
- 5: Select the time to run



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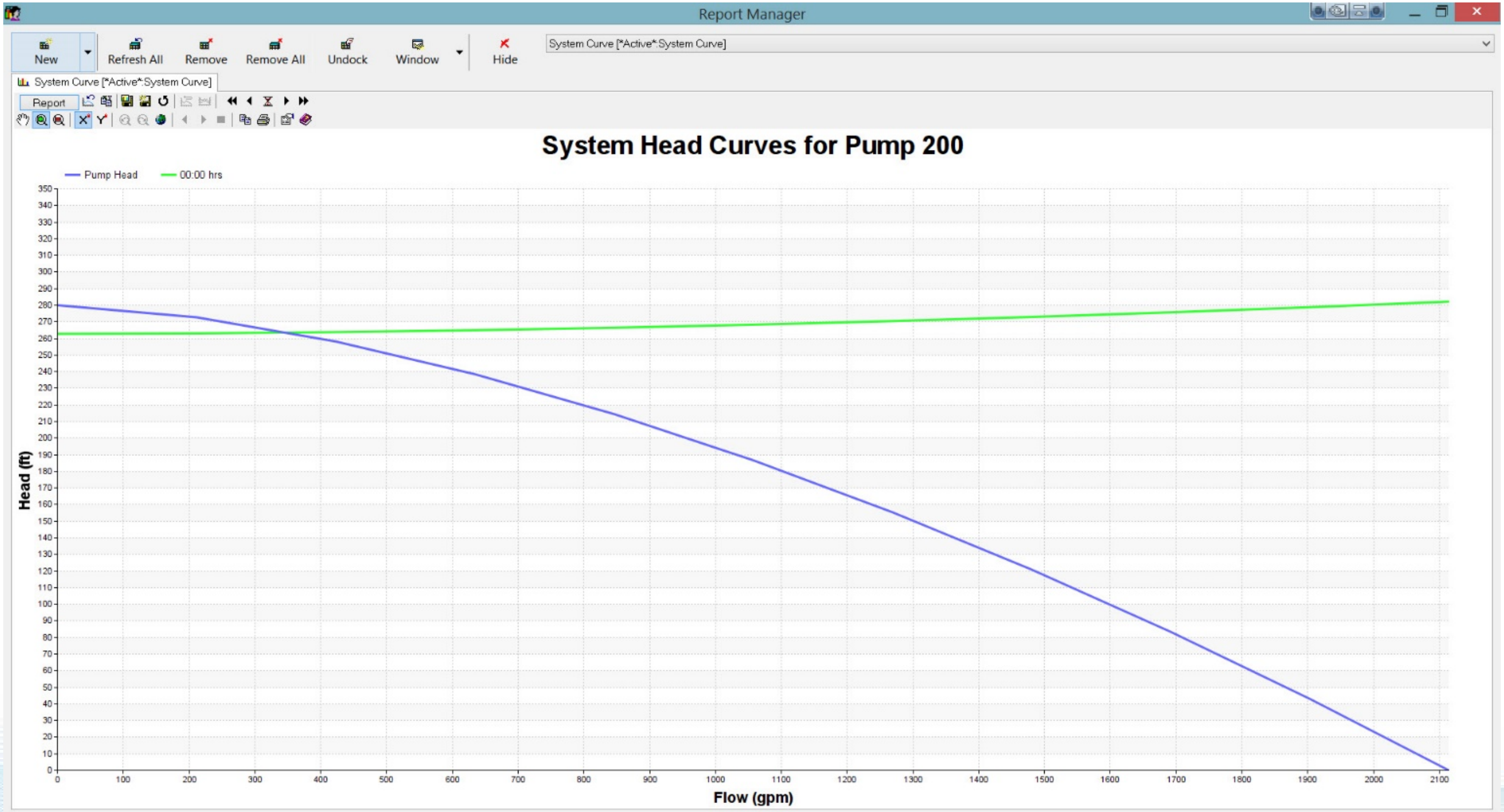
Model System Curves



Key Modeling Considerations

- All pumps at station should be off and controls off
  - Could be easier just to make all but one evaluated inactive
- A dummy pump is often useful
  - Pipes for single may be too small for entire station flow
  - Single pump curve max flow is often too small for full station flow
  - Dummy Pump would use combined pump curve
    - Head remains constant and just add flows of each pump
- Boundary conditions are key
  - Two runs to get upper and lower bounds
  - Set up conditions for each in separate scenarios

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Pump System Analyst

- Available with any Suite License in InfoWater and H2ONET
- Allows user to select multiple pumps together
  - User can also specify parallel pumps of same size
- Combined pump curves show region where all pumps operate
  - Any flow region where 1 or more pumps are shutoff is not shown
- Flow Range
  - Can use specific pump flow max flow at pump head = 0
  - User ***can also specify the max flow range*** of the system curve
- Same methodology as run manager System Curve
- Boundary conditions are key
  - Two runs to get upper and lower bounds
  - Set up conditions for each in separate scenarios

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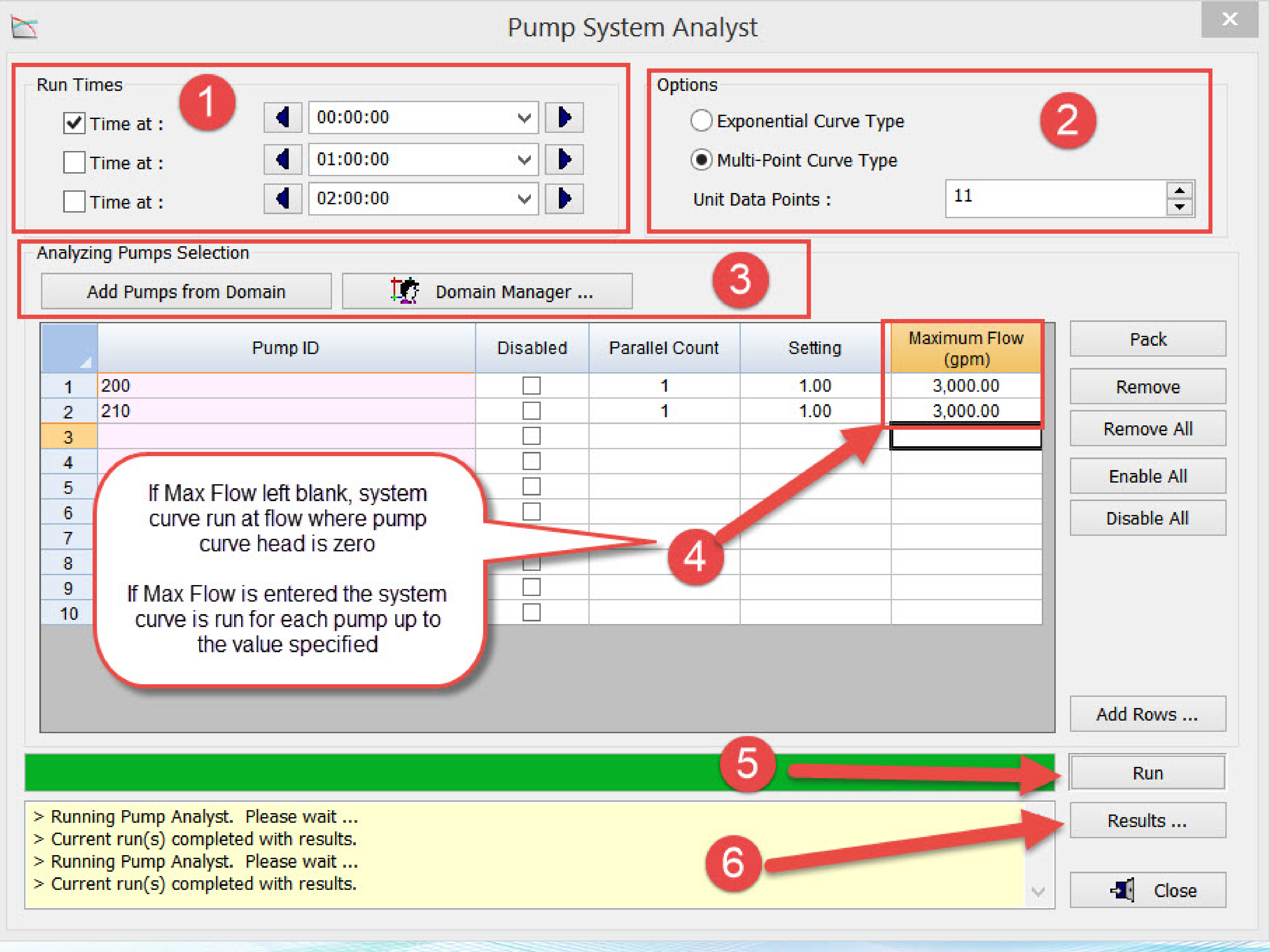
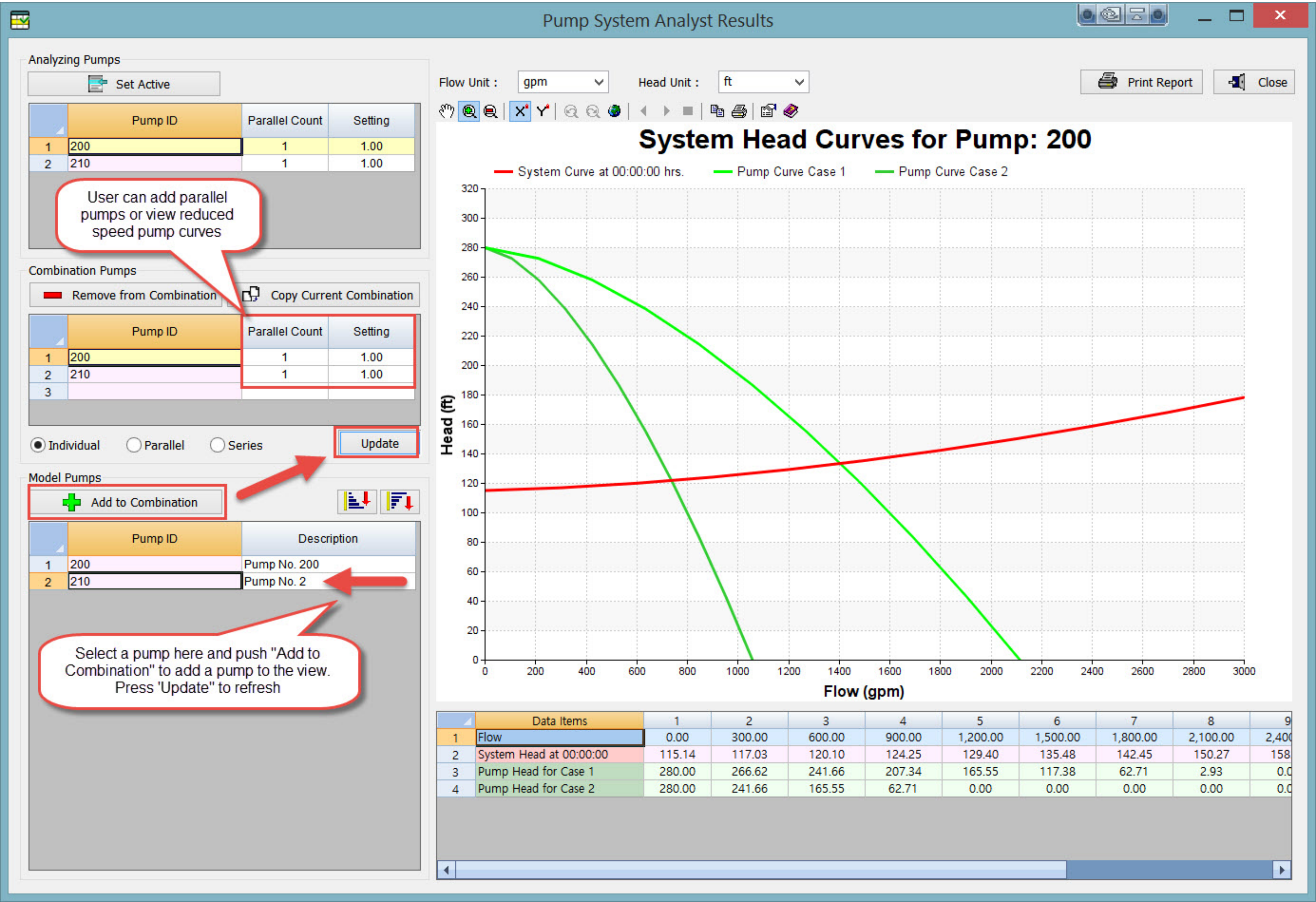
Pump System Analyst Setup

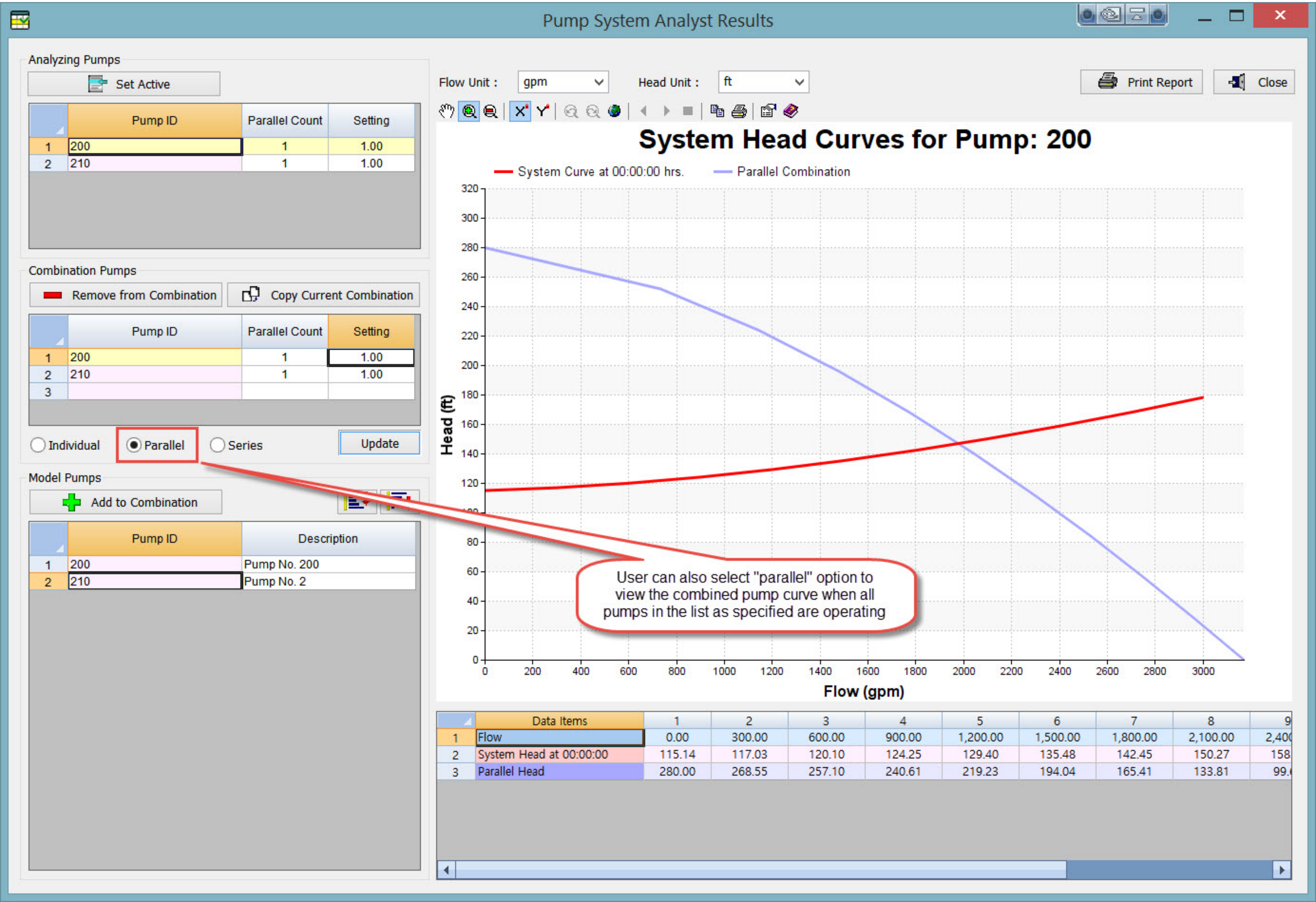
- Open Tool
  - Tools-> Add on Manager -> Select PSA Pump system Analyst Module
- Select Run time and options
- Select pumps to analyze
  - Use Domain manager to add pumps to the domain
  - Use Add pumps from domain to add to table
- Choose Max Flow for analysis
  - If blank, model assumes max flow is where pump head = zero
- Press “Run” to run the analysis and select “Results” to view


Pump System Analyst
Run Times
Time at :
00:00:00
Time at :
01:00:00
Time at :
02:00:00
1
Options
Exponential Curve Type
Multi-Point Curve Type
Unit Data Points :
11
2
Analyzing Pumps Selection
Add Pumps from Domain
Domain Manager ...
3
Pump ID
Disabled
Parallel Count
Setting
Maximum Flow (gpm)
1 200 1 1.00 3,000.00
2 210 1 1.00 3,000.00
3
4
5
6
7
8
9
10
If Max Flow left blank, system curve run at flow where pump curve head is zero
If Max Flow is entered the system curve is run for each pump up to the value specified
4
Pack
Remove
Remove All
Enable All
Disable All
Add Rows ...
5
Run
Results ...
6
Close
> Running Pump Analyst. Please wait ...
> Current run(s) completed with results.
> Running Pump Analyst. Please wait ...
> Current run(s) completed with results.

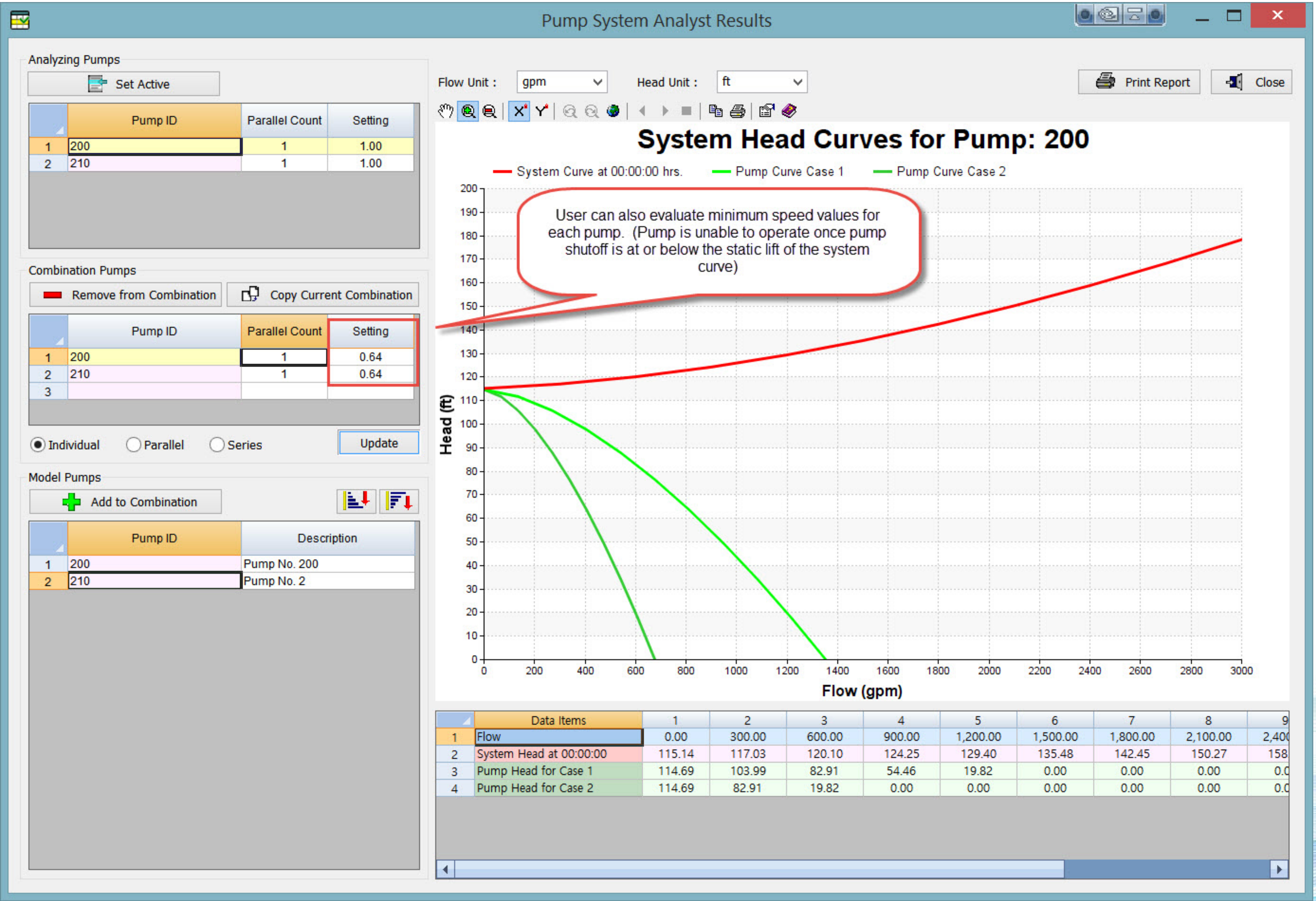
PSA- Overlay Pump Curves



PSA- Evaluate Parallel Pumps



PSA- Evaluate Minimum Speed



Special Case System Curves

- Closed Zone (pumped only)
  - Can cause errors using the System Curve tool. Best to run manually
    - Zero Flow disconnection
    - Supply must exactly equal demand
  - Make all pumps inactive or off.
  - Select two points one on suction side and one on discharge side of PS
  - Need to add a dummy tank for model requirements
    - Set tank elevation at HGL goal – 10 ft.; Max Height at 20 ft., initial level at 10 ft. Locate Tank at far end of system or at high point or at the PS discharge. Diameter of 10 ft.
    - Can also use a fixed head reservoir set at the goal HGL
  - Best to set pump station positive and negative demands equal to total system base demand
  - Use a pattern to get flows from near zero to maximum
    - Note: Can't use a zero multiplier. Make 0.01 for 1st point
    - Assign pattern to all demand nodes in the closed zone
    - Assign pattern to positive and negative demand nodes

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Special Case System Curves

- Closed Zone (pumped only)
  - Check for static lift changes on suction side
    - Set up boundary conditions appropriately
  - Run as EPS analysis
    - Recommended Time Settings -------------->
    - Duration = #pattern values -1

Category	Unit	Decimal Time	Clock Time
Duration	Minutes	14.0000	
Hydraulic Timestep	Minutes	1.0000	
Pattern Timestep	Minutes	1.0000	
Quality Timestep	Minutes	0.1000	
Report Timestep	Minutes	1.0000	
Rule Timestep	Minutes	0.1000	
Pattern Start	Hours	0.0000	
Report Start	Hours	0.0000	
Start Clocktime	Clock Time		00:00:00

  - System Curve
    - For each flow, calculate the difference in head between the suction & discharge node. Use results for the Head vs Flow curve
  - Checks – Make sure no flow to tank
  - Other Notes: - User may need to adjust patterns for the remaining system to constant (value of 1) to keep the demands for the rest of the system at a constant value for the entire run.

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Special Case System Curves

- In-line booster with no tanks
  - (pumped zone to pumped zone)
  - Only 1 curve possible
    - No static lift changes due to no tank levels
  - Have to run with system demand
  - Make all pumps inactive or off.
  - Can run using model tool if demand can be satisfied from other model sources.
    - If errors use similar method as closed zone

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Have Further Questions?

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