PNWS-AWWA Water 2023
Training Session

Maximizing Booster Station Efficiency

Presented By:
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MEET THE PRESENTERS

Curtis Butterfield

Civil Engineer / Project Manager

Keller Associates

Jason King

Civil Engineer / W/WW Manager

Keller Associates

PRESENTATION OVERVIEW

- Project Overview & Background
- Cavitation
- Net Positive Suction Head
- Reading Pump Curves
- Determining Total Dynamic Head
- Evaluating Solutions

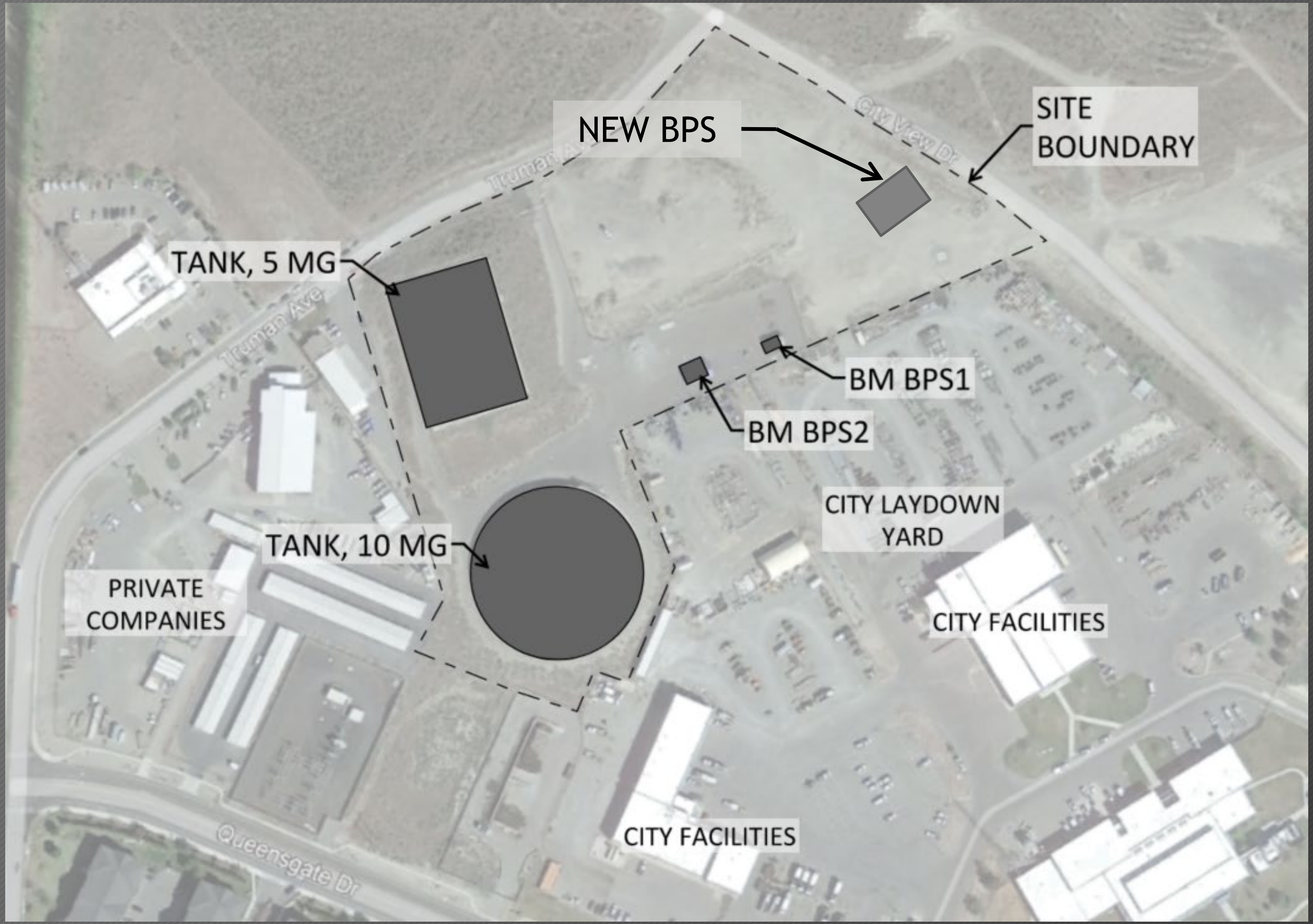
Project Overview & Background

LOCATION

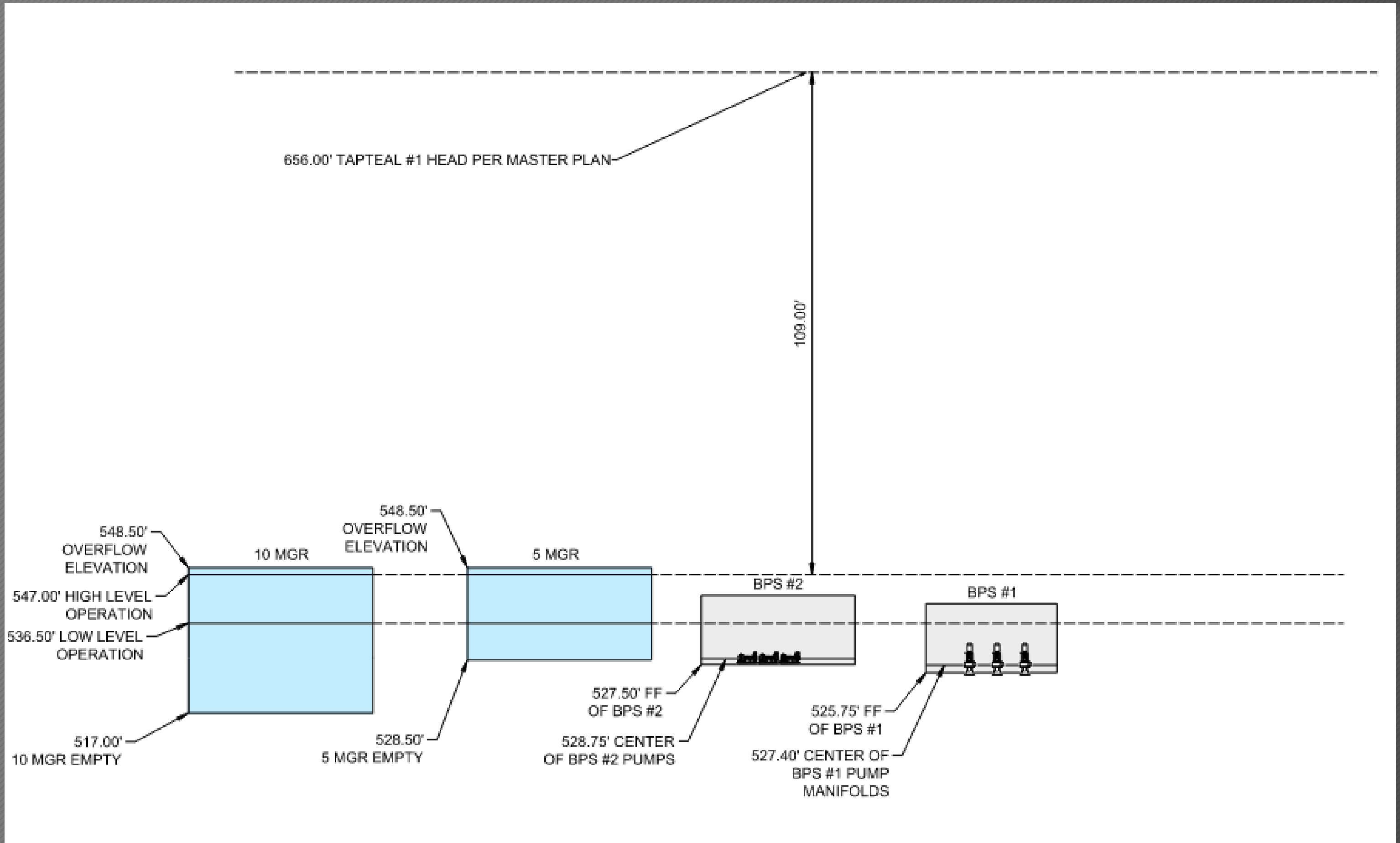

Richland, WA
Nanaimo
Richmond
Surrey
Abbotsford
Grand Forks
Trail
Victoria
Colville
COLVILLE RESERVATION
Everett
Seattle
QUINAULT RESERVATION
Leavenworth
Wenatchee
WASHINGTON
Tacoma
COEUR D'ALENE RESERV
Olympia
Moses Lake
Ellensburg
Pullman
Yakima
Lewiston
NEZ PERCE R
Astoria
YAKAMA INDIAN RESERVATION
Kennewick
Walla Walla
Hood River
Pendleton
Tillamook
Beaverton
Portland

SITE CONDITIONS

- Two Pump Stations
- Two Reservoirs
- Supply to City of Richland and City of West Richland



Existing System Hydraulic Considerations



ISSUES AND CONCERNS
Newer Booster Station

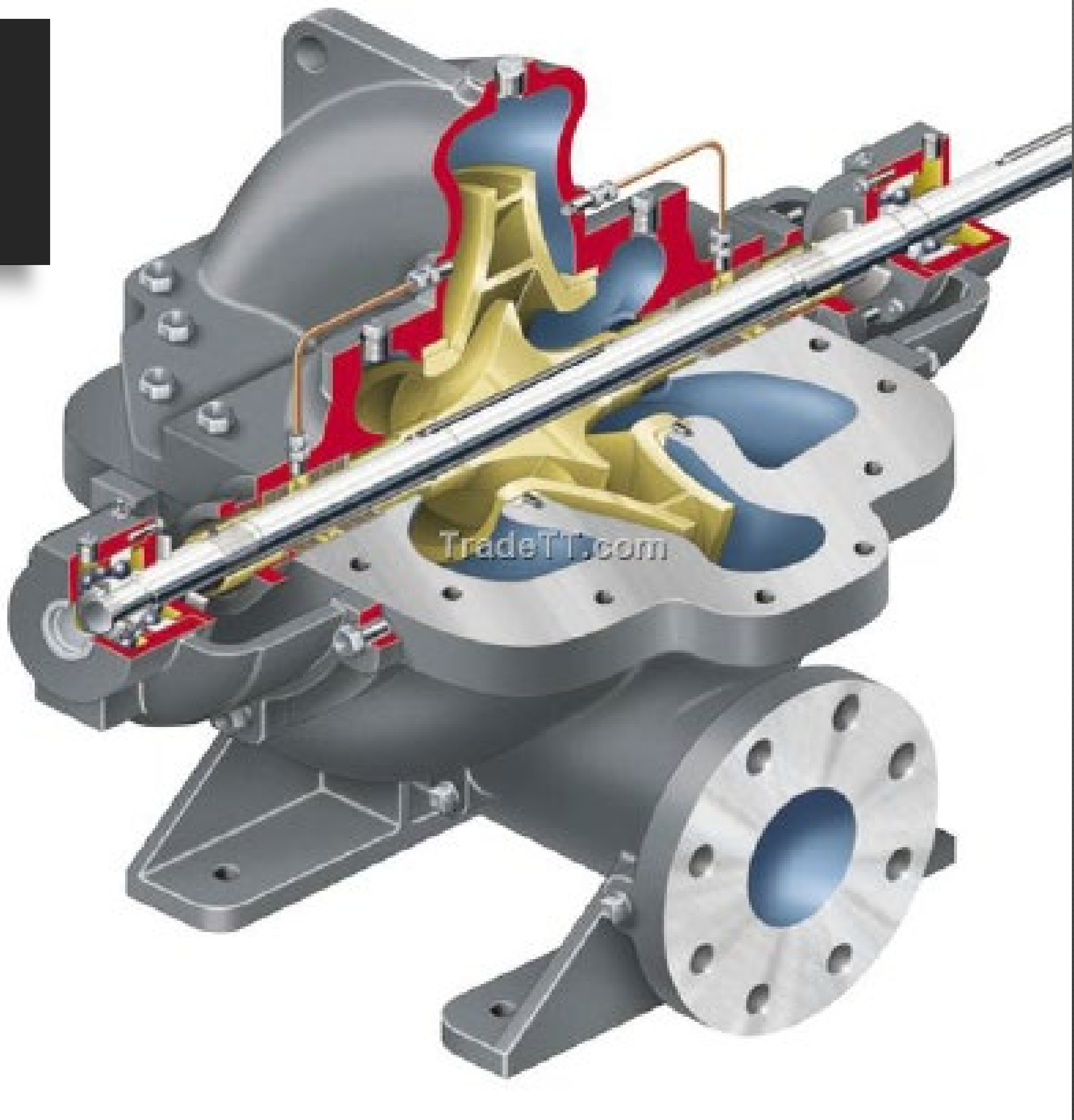
ISSUES AND CONCERNS
Older Booster Station

ISSUES AND CONCERNS

- Different Pump Technologies
- Split Case Pumps Cavitating
- Limitations on Tank Levels
- Aging Infrastructure & Equipment
- Change in chlorination method
- Inadequate capacity for future growth
- No backup power

NEWER BOOSTER STATION
Split Case Pumps

- Suction and discharge on opposite sides
- Double-hung impeller
- Shaft is perpendicular to flow
- Casing is split into top and bottom halves
- Top half is lifted off for service.



NEWER BOOSTER STATION
Split Case Pumps

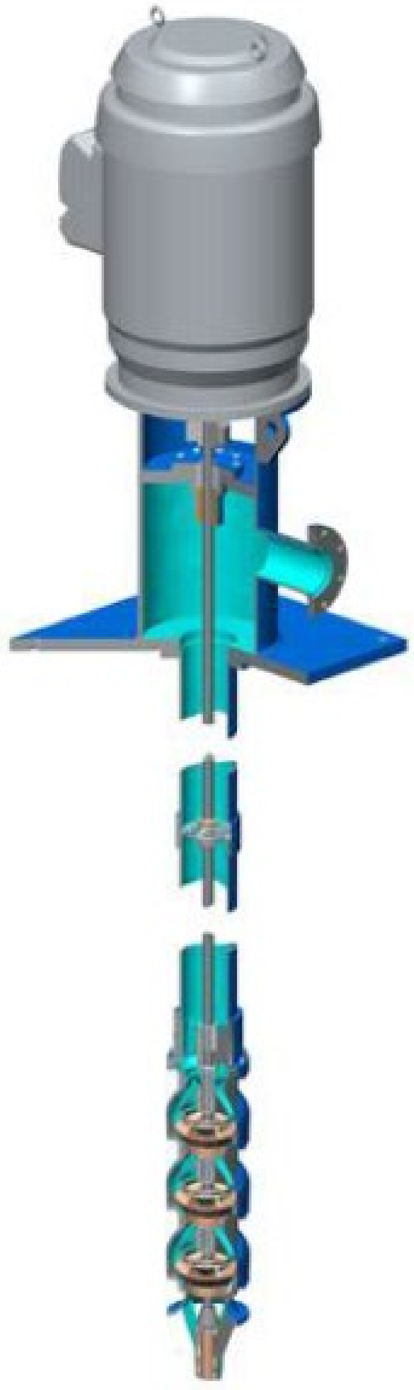
- Three existing pumps

NEWER BOOSTER STATION
Flow Control

- Throttling flows

OLDER BOOSTER STATION
Vertical Turbine Pumps

- Long-shaft pump
- The bowl is down in the water
- The discharge head is mounted above
- Line shaft runs up the discharge column
- Add multiple bowls in series for high head



OLDER BOOSTER STATION
Vertical Turbine Pumps

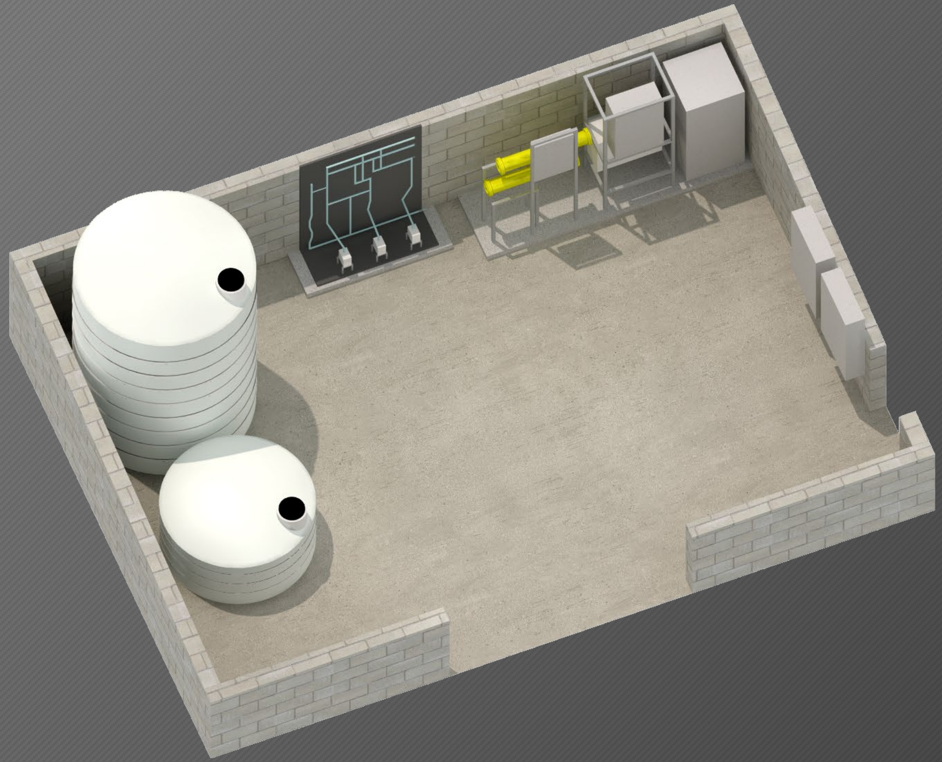
- Three existing pumps

CHLORINATION

- Accu-Tab system
- Standardizing around OSHG throughout system

PROJECT OBJECTIVES

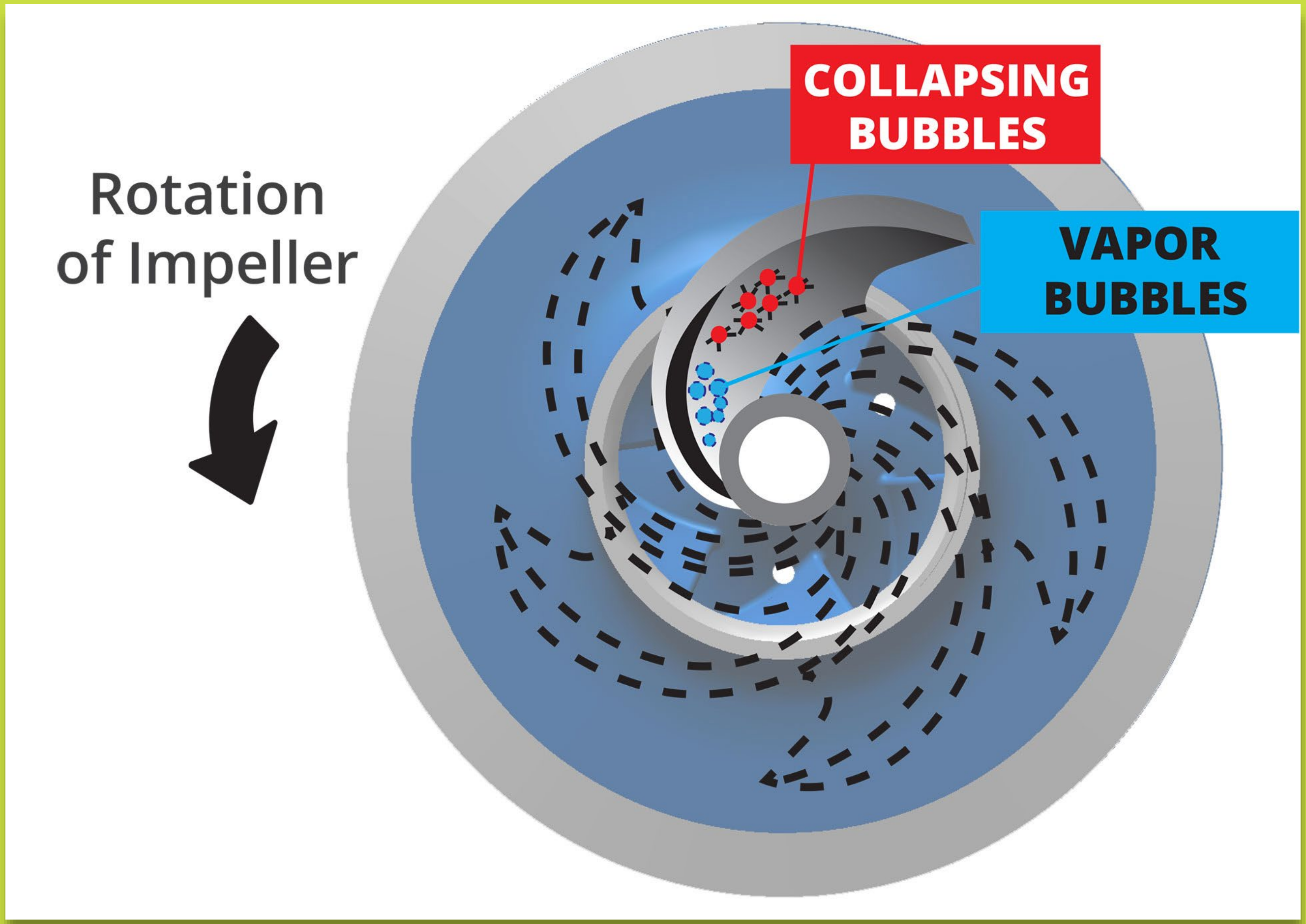
- Increase capacity to 12,200 gpm
- New onsite sodium hypochlorite generation
- Address NPSH issues in new design
- Maximize use of two onsite reservoirs
- Improve automation
- Improve energy efficiency
- Single pump technology



What is Cavitation?

CAVITATION

- Cavitation is the formation of vapor bubbles in any flow which are subjected to an ambient pressure equal to or less than the vapor pressure of the liquid being pumped.



CAVITATION

- Cavitation damage is the loss of material produced by the collapse of the vapor bubbles against the surfaces of the impeller or casing.
- Cavitation may be present in combination with erosion and corrosion – especially in wastewater.

Cavitation damage to an impeller

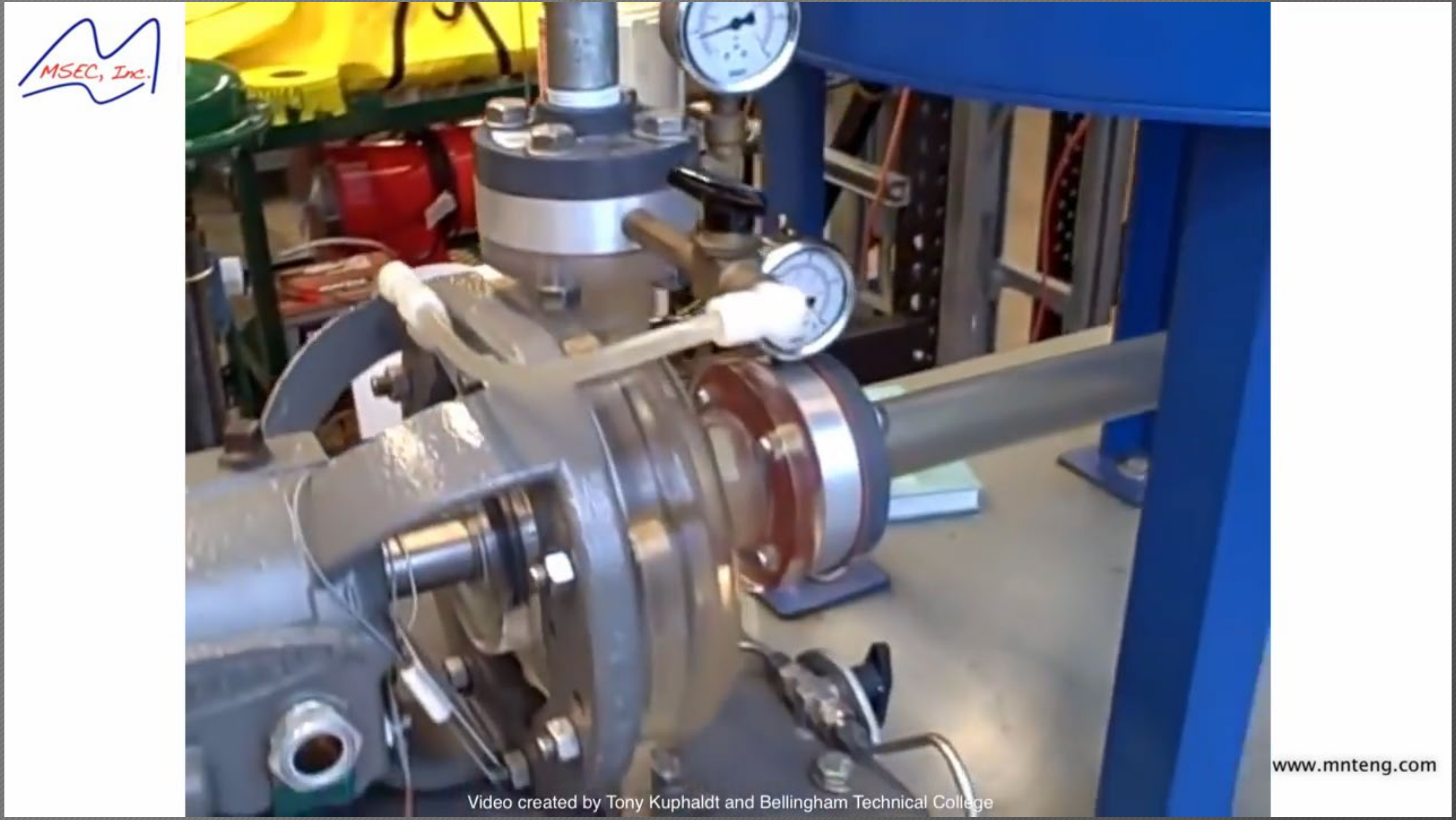
SUCTION CAVITATION

- Occurs when pump suction is under a low pressure / high-vacuum condition
- The pump is being starved or is not receiving enough flow.
- Bubbles form at the eye of the impeller

SUCTION CAVITATION

- As bubbles carry over to discharge side, pressure changes and compresses bubbles into a liquid causing it to implode against the face of the impeller.

SUCTION CAVITATION FURTHER EXPLAINED



SUCTION CAVITATION

- Possible Causes:
  - Clogged filters or strainers
  - Blockage in the pipe
  - Pump is running too far right on the pump curve
  - Poor piping design, or pump selection
  - Poor suction conditions (NPSH requirements)

DISCHARGE CAVITATION

- Occurs when pump discharge pressure is extremely high or runs less than 10% of its best efficiency point.
- High pressure makes it difficult for the fluid to flow out of the pump, so it circulates inside the pump.

DISCHARGE CAVITATION

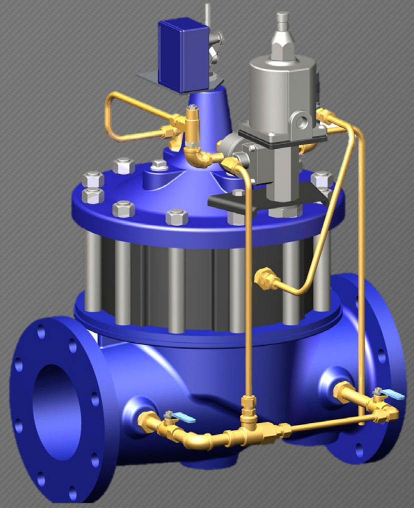
- Liquid flows between the impeller and the housing at very high velocity, causing a vacuum at the housing wall and the formation of bubbles.

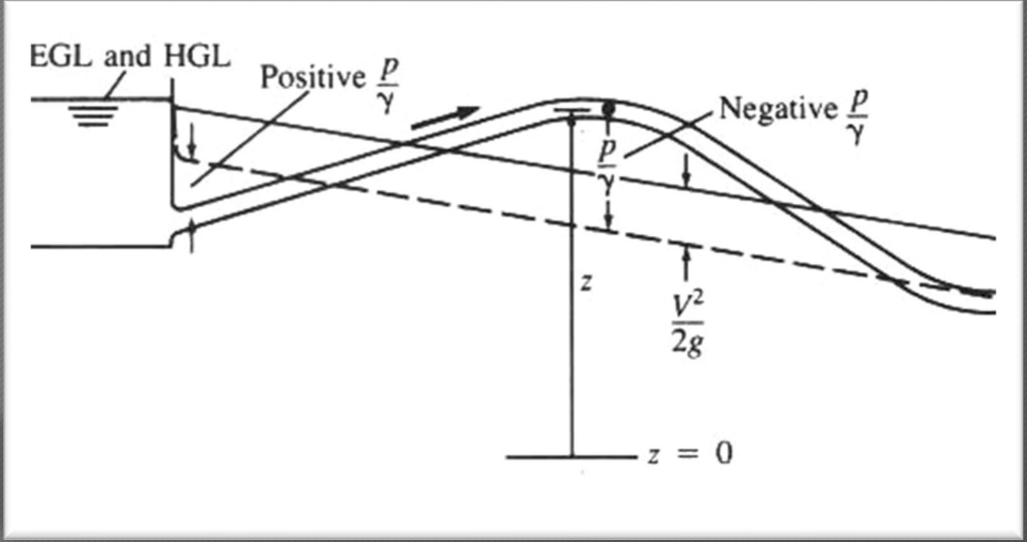
DISCHARGE CAVITATION

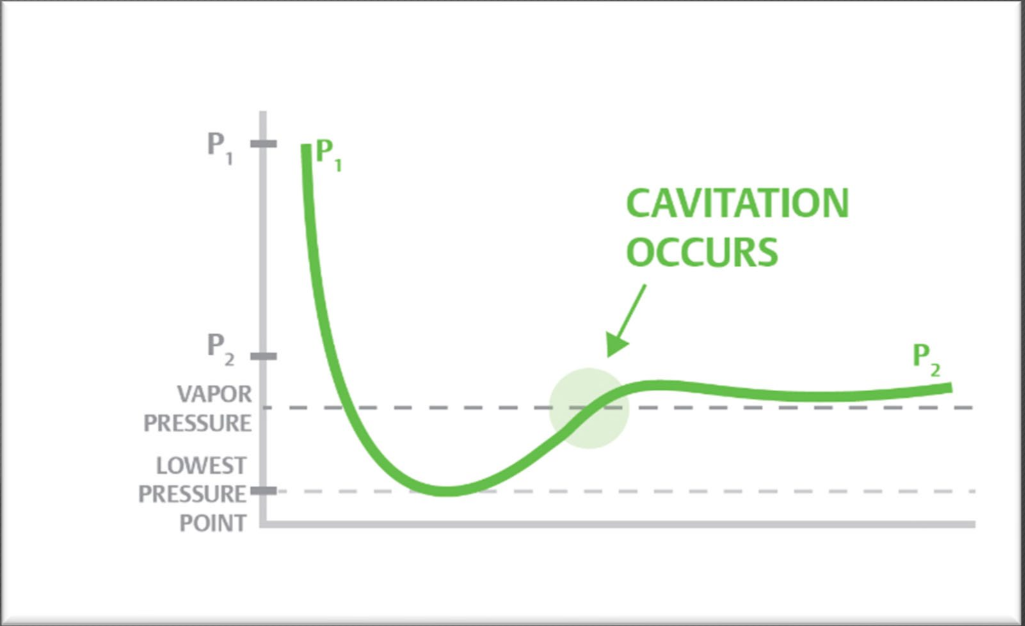
- Possible causes:
  - Blockage in the pipe on discharge side
  - Clogged filters or strainers
  - Running to far left on the pump curve
  - Poor piping design

Other Types of Cavitation

- Valves
  - Modulating Valves
  - Control Valves
- Piping Systems
  - Large changes in elevation







QUESTION

Which cavitation were we experiencing in Richland?

WHAT IS NET POSITIVE SUCTION HEAD?

- NPSH CURVE
- NPSH = Not Pumping So Hot?
- NPSH = **NET POSITIVE SUCTION HEAD**
- It is the net positive pressure at the pump inlet

UNDERSTANDING NPSH

System NPSHa (available)

$$NPSHA = h_{atm} + h_{z\,(s)} - h_{f\,(s)} - h_{vp}$$

$$h_{atm} = \frac{p_{atm}}{\gamma}$$

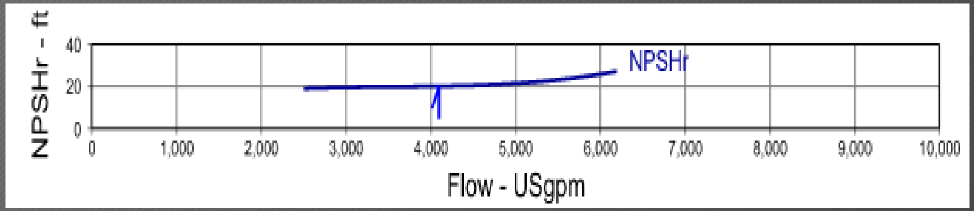
$$h_{z\,(s)} = WSE\ @\ Res - Center\ of\ Volute\ Elev$$

$$h_{f\,(s)} = \sum \frac{4.73 \times L \times Q^{1.85}}{D^{4.87} \times C^{1.85}} + \sum \frac{K \times v^2}{2 \times g}$$

$$h_{vp} = 0.301 \frac{lbs}{in^2} = 0.70\ ft$$

Pump NPSHr (required)

- Derived from pump characteristics
- Varies with different types of pumps
- Varies with flow
- Provided by the pump manufacturer



Understanding NPSH

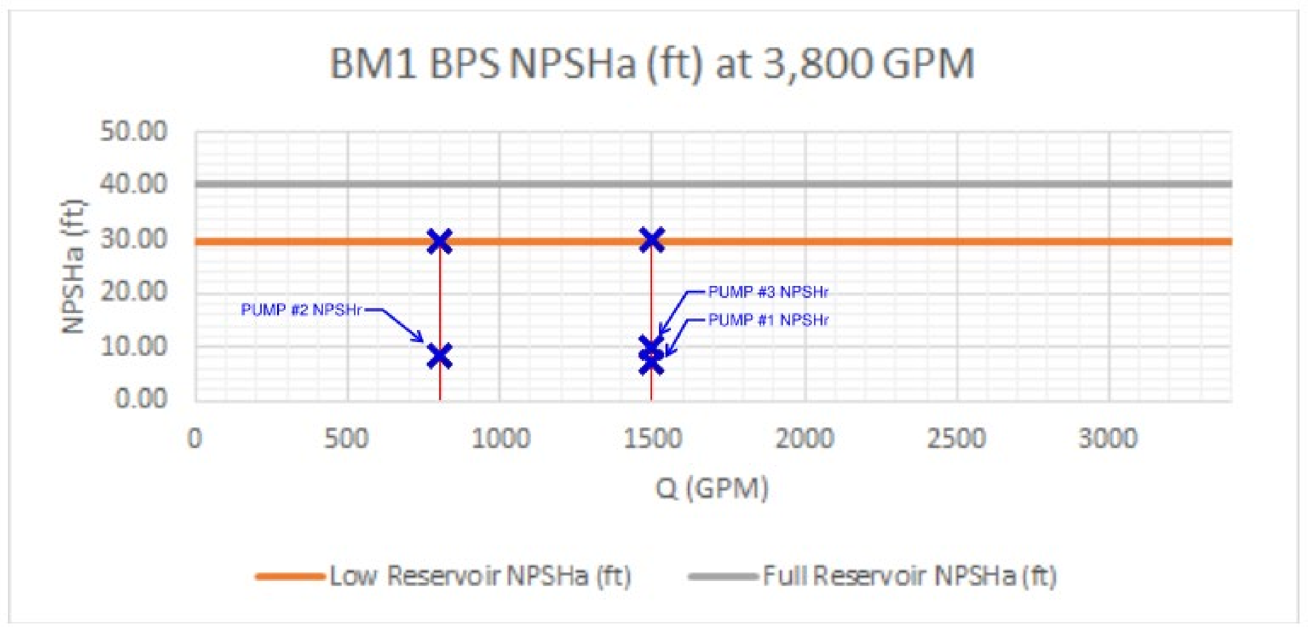
Factor of Safety (Delta & Margins)

- Delta is NPSHa – NPSHr, should always be positive > 4.9-ft
- Margins = $\frac{NPSHa}{NPSHr}$, should be > 1.5-ft, but in no cases less than 1.1-ft

NPSH Evaluation – BPS #1

NPSH Margins BPS #1

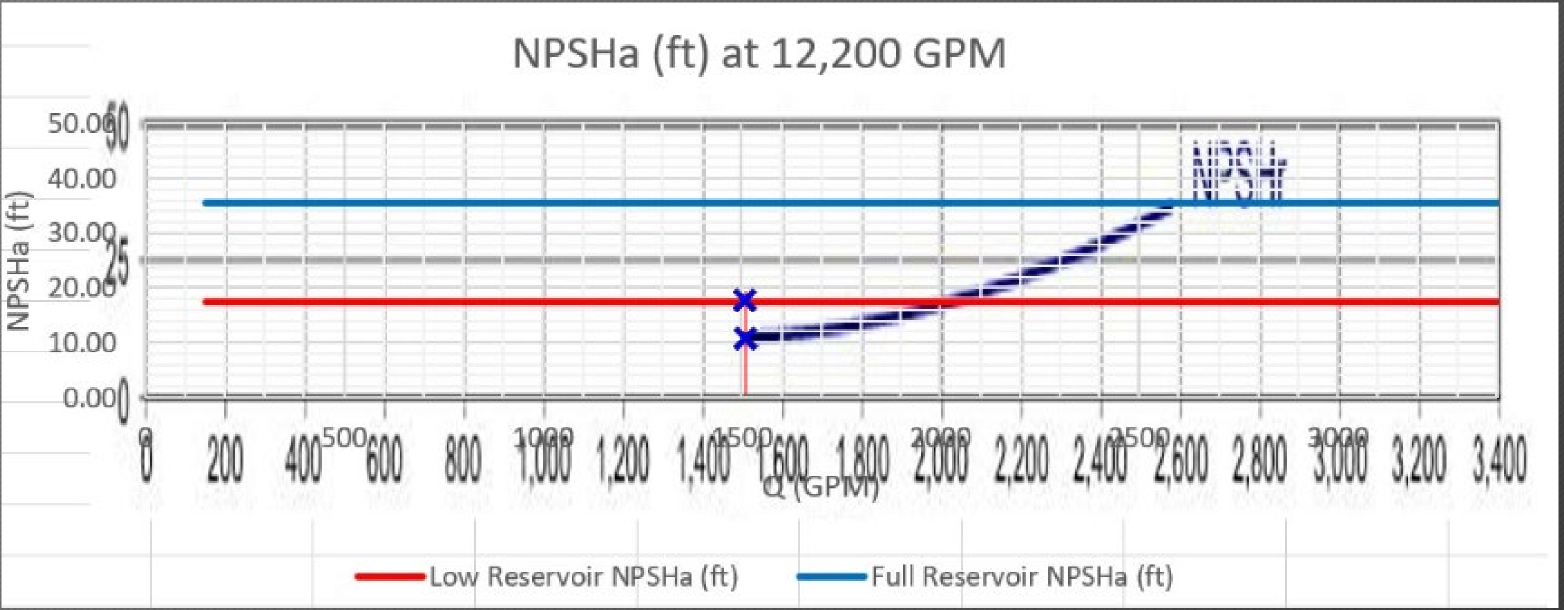
Pump	Flow (gpm)	Delta	Margin
1	1,500	23	4.29
2	800	22	3.75
3	1,500	20	3



NPSH Evaluation – BPS #2

NPSH Margins BPS #2

Pump	Flow (gpm)	Delta	Margin
1, 2 & 3	1,500	7	1.63



Evaluation

Pump Evaluation and Selection

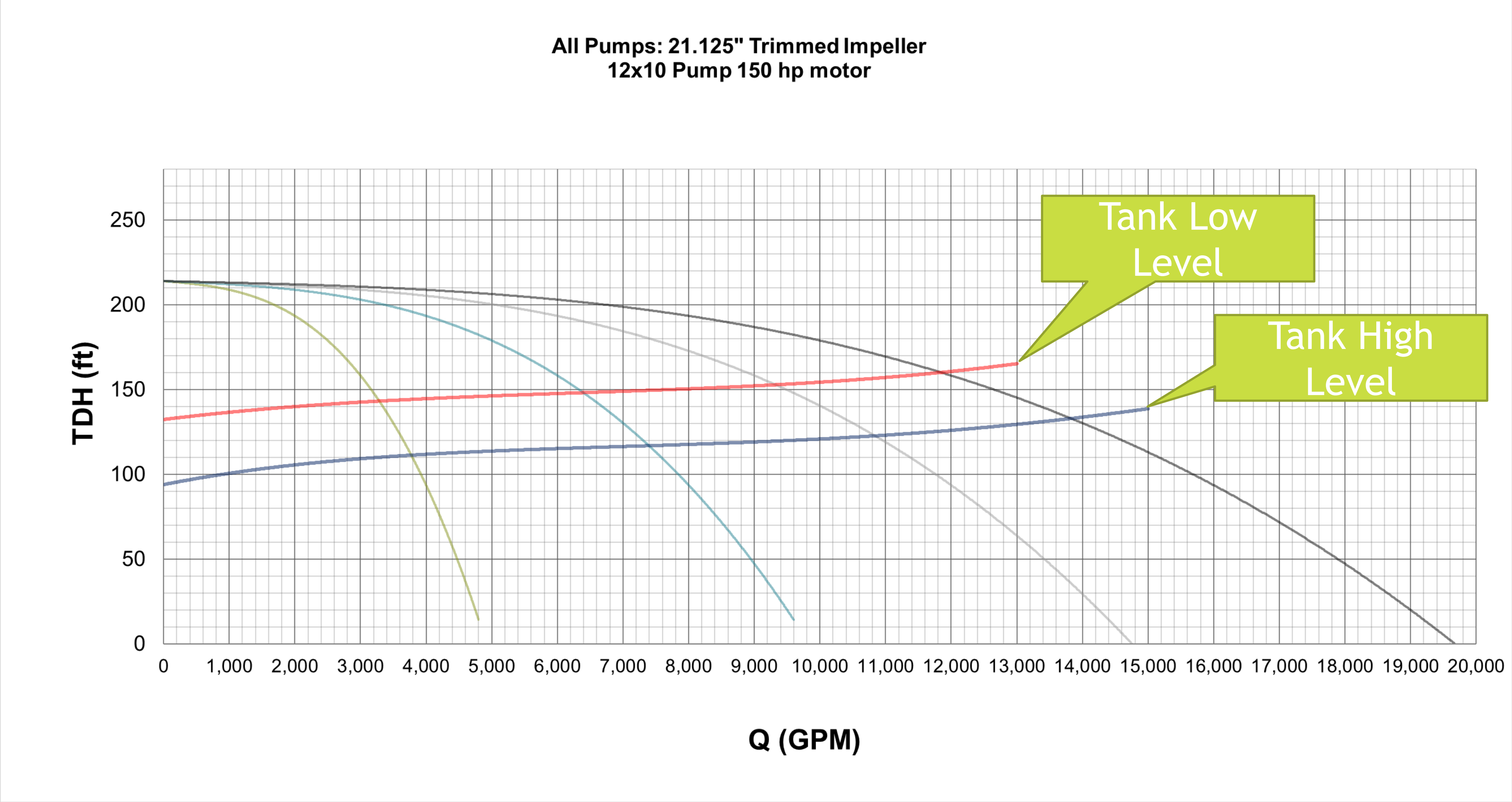
- Canned Turbine vs Split Case
  - Balance Cost & Functionality
- Number of pumps, flow rates
  - 4 Duty, 1 Standby
- Efficiency
  - Comparable

Manufacturer	Pump Type	Design Q (GPM)	Design Head (PSI)	NPSHr (ft)	Shutoff Head (PSI)	Cost per Pump[1]
National Pump Company	Canned Turbine	2,100	60	9	111	$148,053.00
National Pump Company	Canned Turbine	3,100	60	20.1	105	$184,124.00
National Pump Company	Canned Turbine	4,100	60	35.5	116	$222,027.00
Patterson	Split Case	2,100	60	14.2	82	$35,785.00
Patterson	Split Case	3,100	60	9.92	70	$50,942.00
Patterson	Split Case	4,100	60	9.74	74	$99,143.00

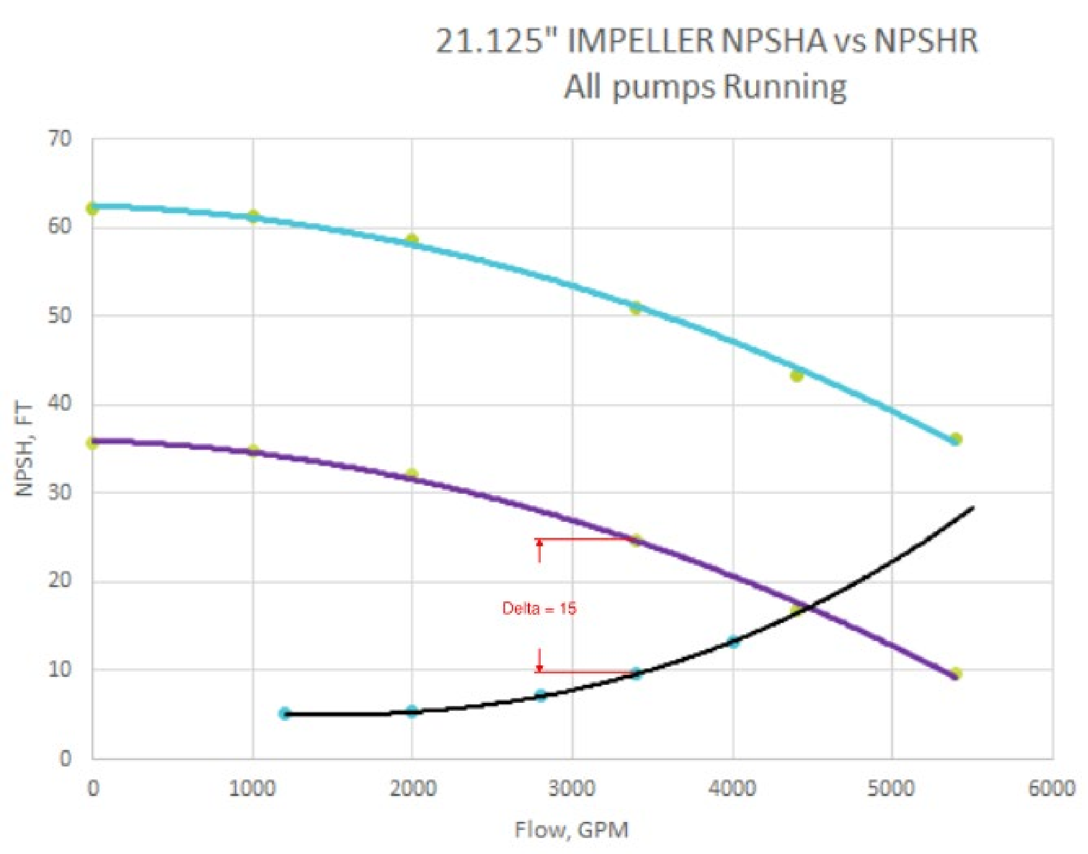
Note:

1. *Cost does not include installation*

Split Case – Pump Evaluation



Split Case – NPSH Evaluation



Proposed new pump with 21.125" impeller

Flow (gpm)	Delta	Margin
3,400	15	2.5

OSHG Evaluation and Selection

- OSHG
  - Benefits & Challenges
- Design Criteria
- Evaluation
  - Delivery
  - Controls

Description	Units	Min Month	Avg Month	Max Month	Peak Day
Flow Rate	GPM	1,400	3,850	7,300	12,200
Chemical Dose	mg/L	0.75	0.75	0.75	0.75
NaOCl Demand	lb/d	12.6	34.6	65.9	109.9
Chem Feed Rate	GPM	0.13	0.37	0.70	1.18
NaOCl Bulk Storage[1]	days	13	5	2.5	1.5
NaCl Bulk Storage[2]	days	530	193	101	61

Notes:
1. Based on a combined liquid storage of 2,500-gallon NaOCl at 0.65% solution
2. Based on a 20,000 lbs storage of FDA food grade salt brine storage

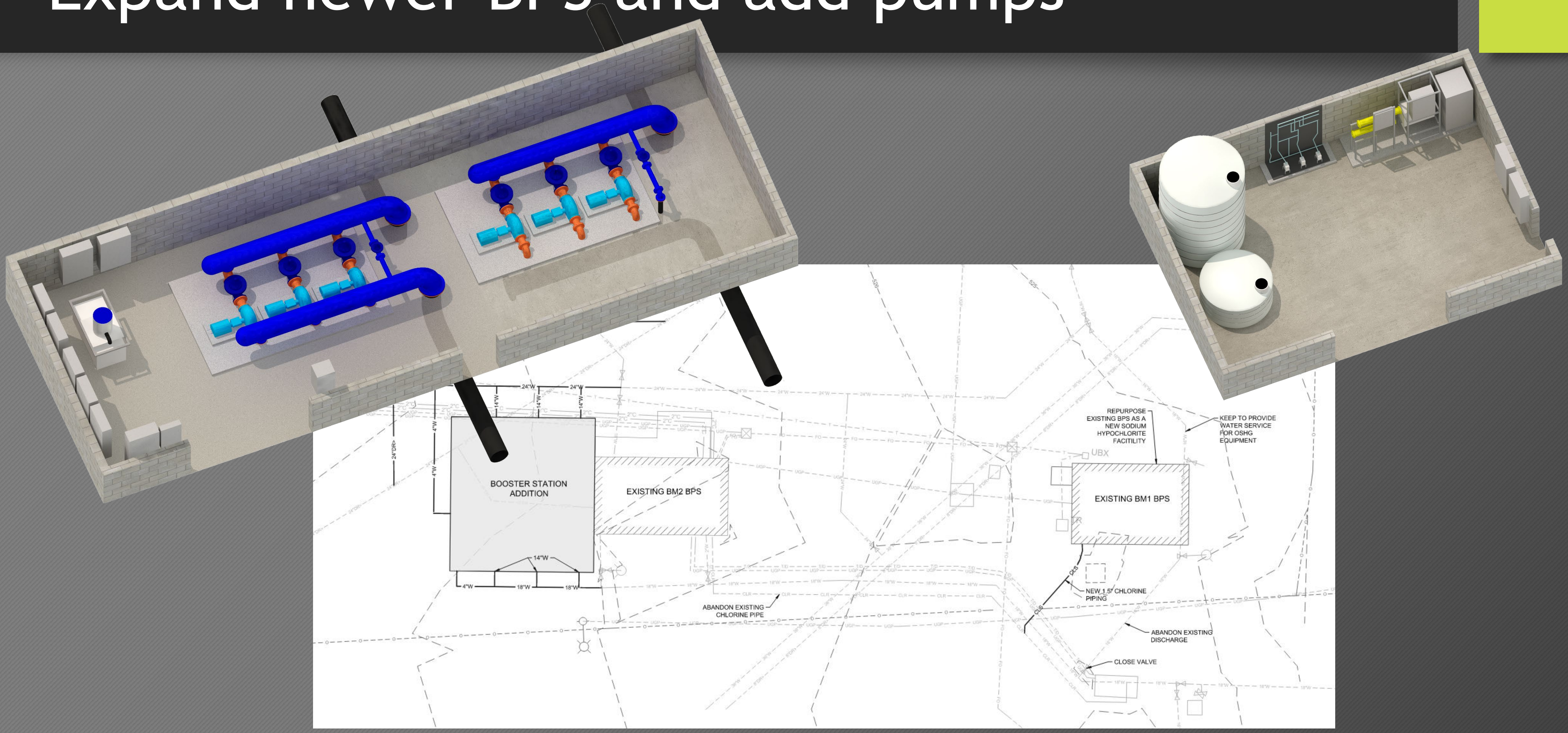
Description	Pros	Cons
Alternative #1 PSI Technologies	• Acid Cleaning System • Power Ventilation	• Higher Capital Costs
Alternative #2 De Nora (MIOX)	• Lower Capital Costs • Safe Passive Venting • Owner Familiarity	

Solutions

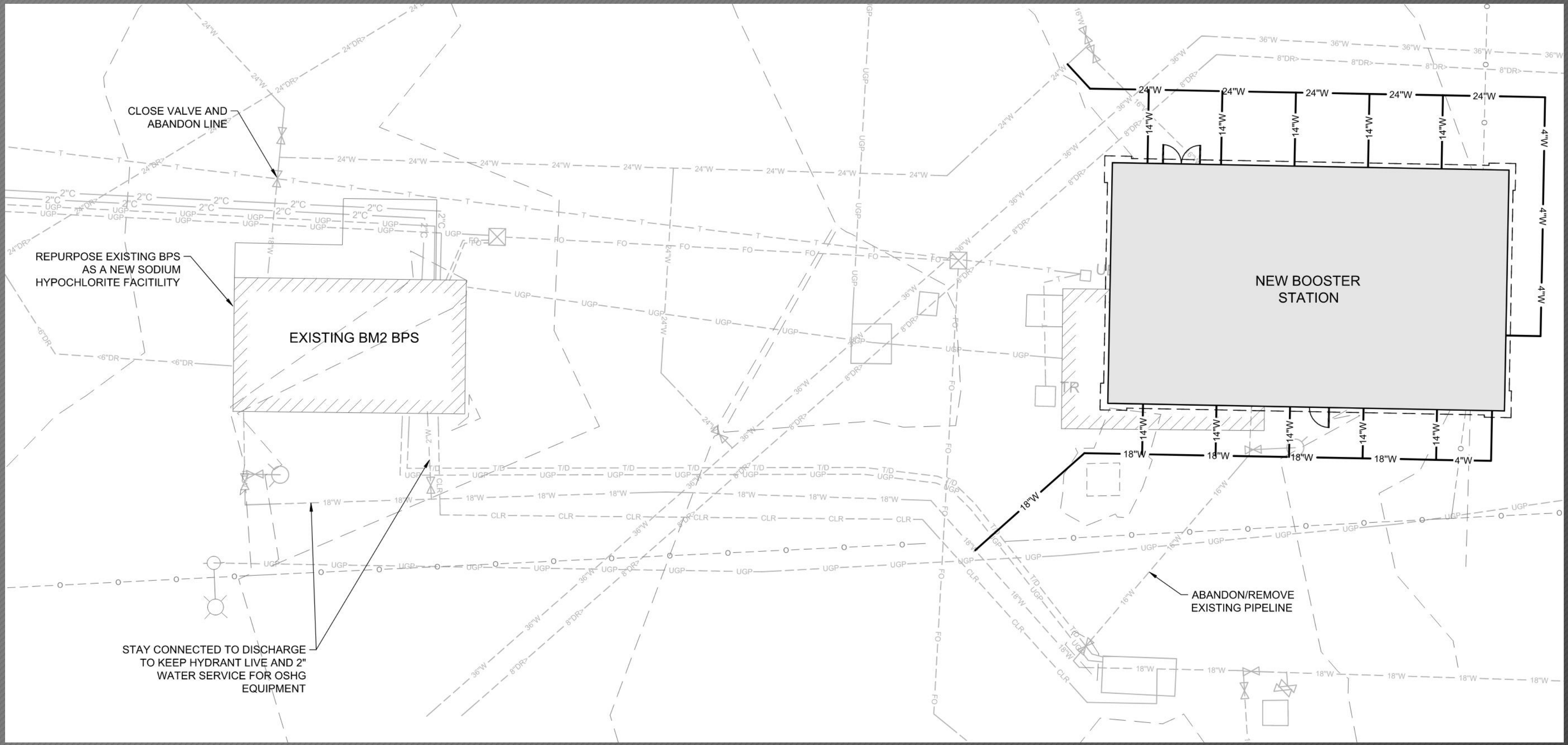
ALTERNATIVE #1 Add/Replace Pumps at Existing Facilities

ALTERNATIVE #2
Replace pumps in older BPS only

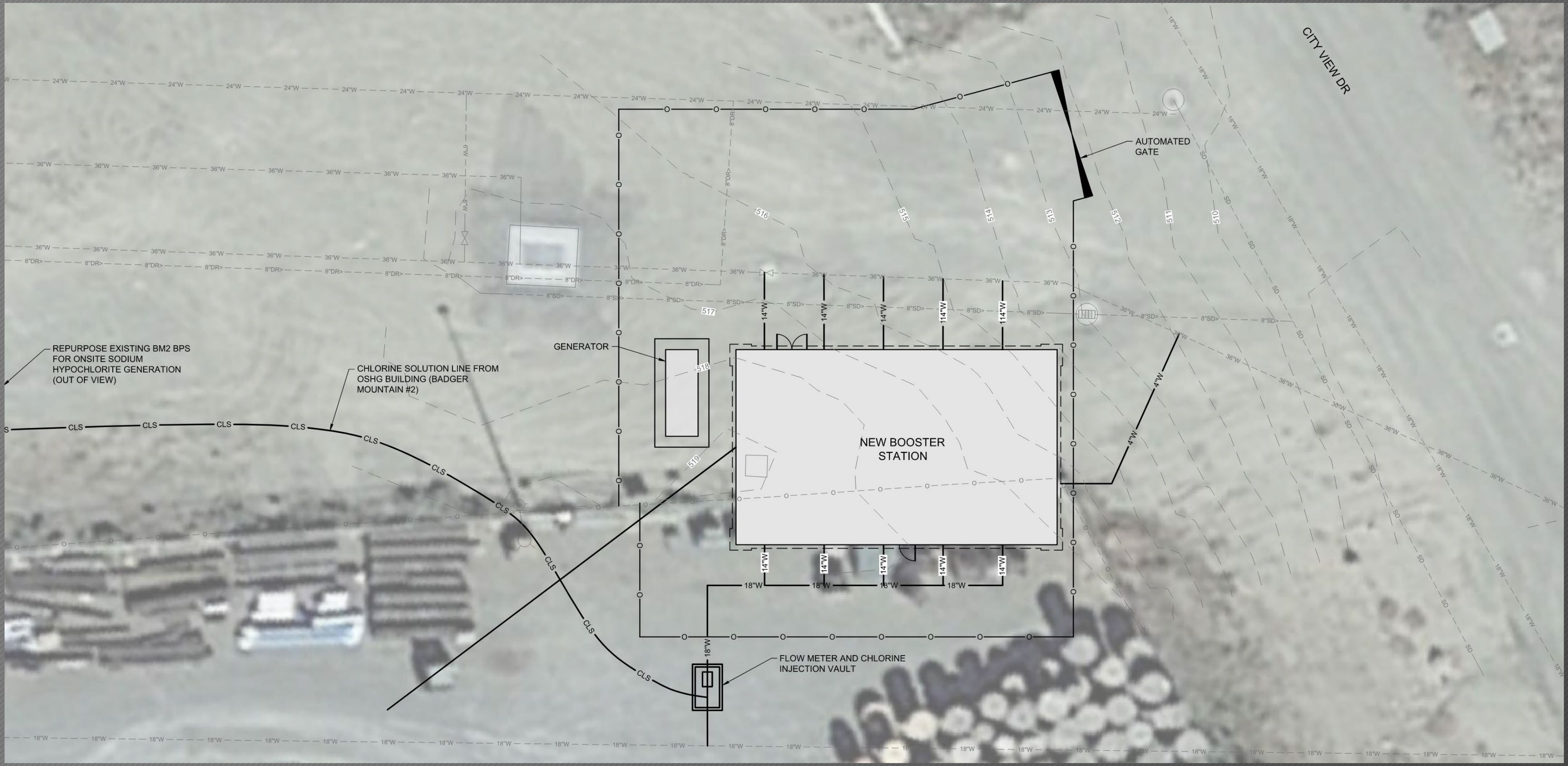
ALTERNATIVE #3
Expand newer BPS and add pumps



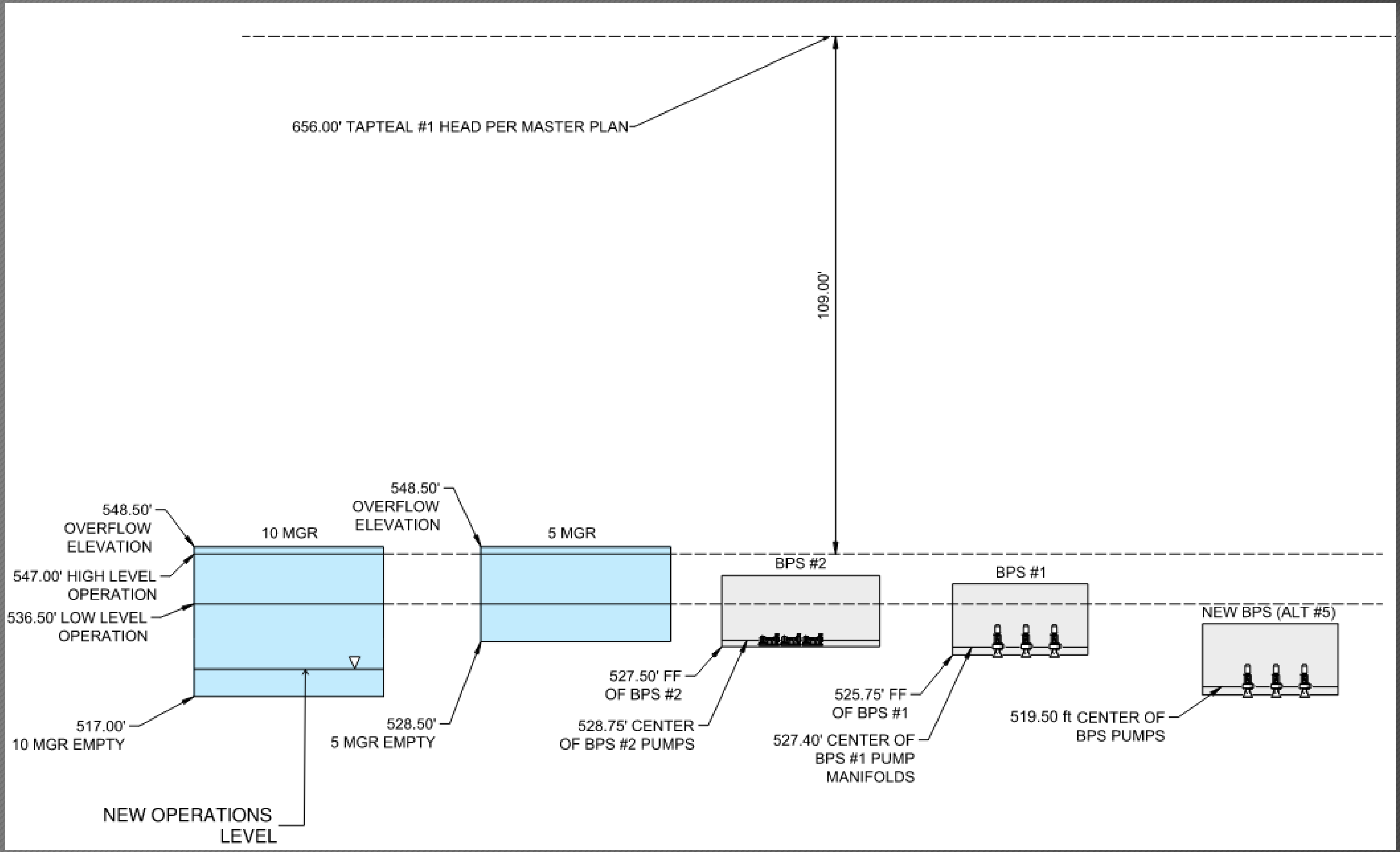
ALTERNATIVE #4
New BPS at existing site



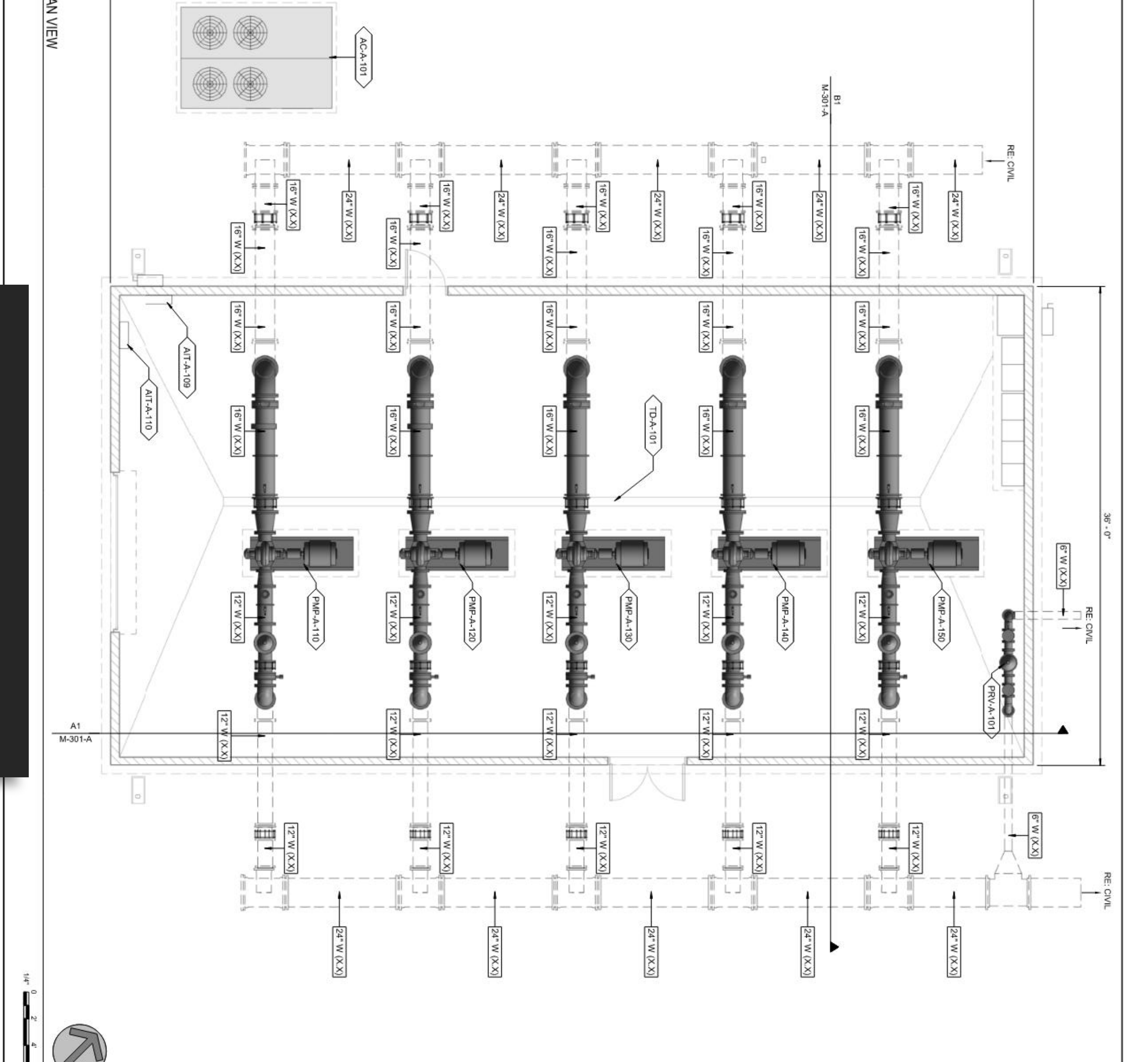
ALTERNATIVE #5
New BPS at new site

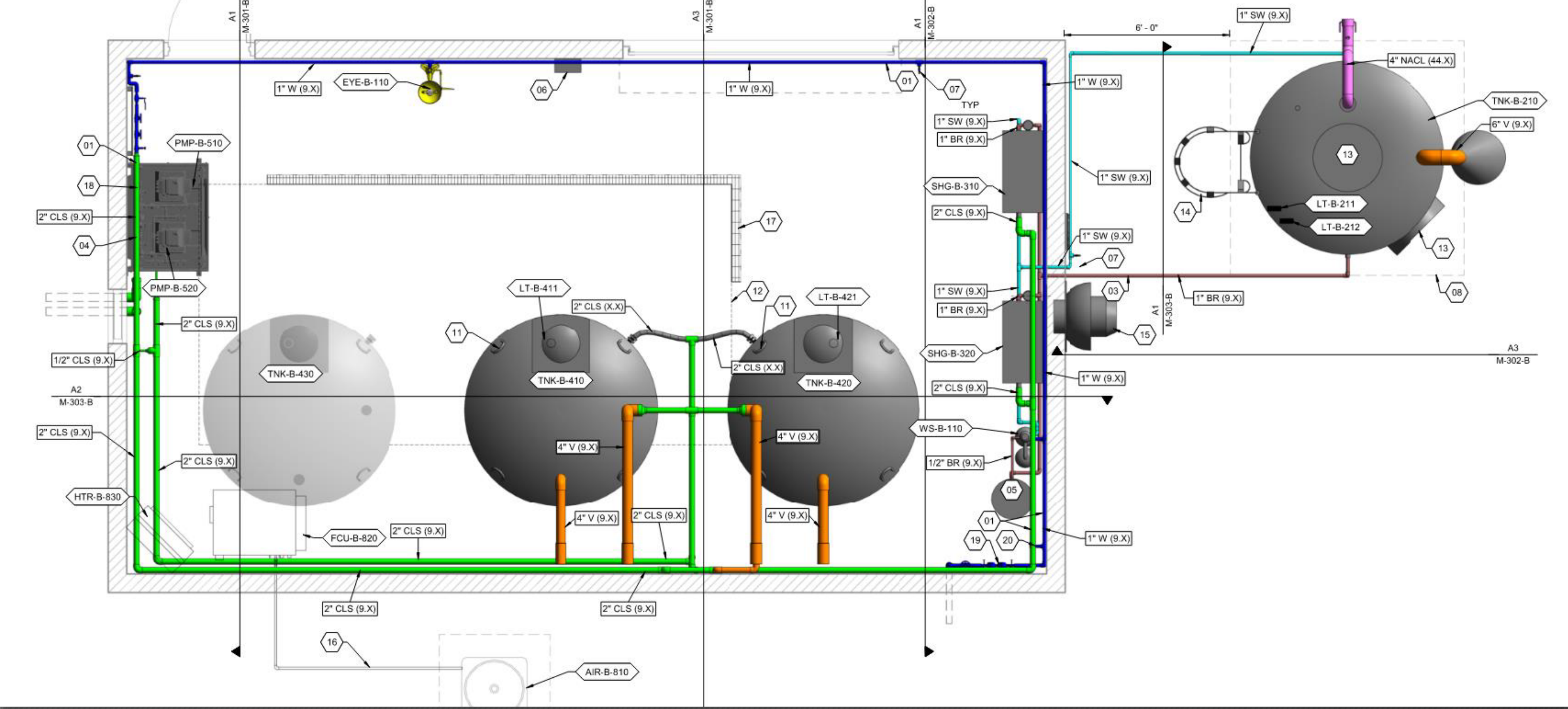


SOLUTIONS – Evaluating Use of Tank Levels



FINAL SOLUTION





FINAL SOLUTION

Questions?