Protecting Public Health
Through Safe Drinking Water

SURGE ANALYSIS OF PUMPING SYSTEMS

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October 14, 2014

Engineers...Working Wonders With Water™

Agenda

- Factors Causing Surge in Pumping Systems
- Factors Influencing Surge Severity
- Why Should I Care about Surge?
- Types of Surge Suppression Systems
- Case Studies:
  - Oklahoma City, OK
  - Central Arkansas Water Little Rock, AR
  - SUA Stillwater, OK
- Recommendations

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Factors Causing Surge

- Primary Surge Transients
  - Pump Startup
  - Pump Shutdown
  - Power Loss
  - Valve Shutdown
- Secondary Surge Transients
  - Air Valve
  - Water Column Separation

Factors Causing Surge

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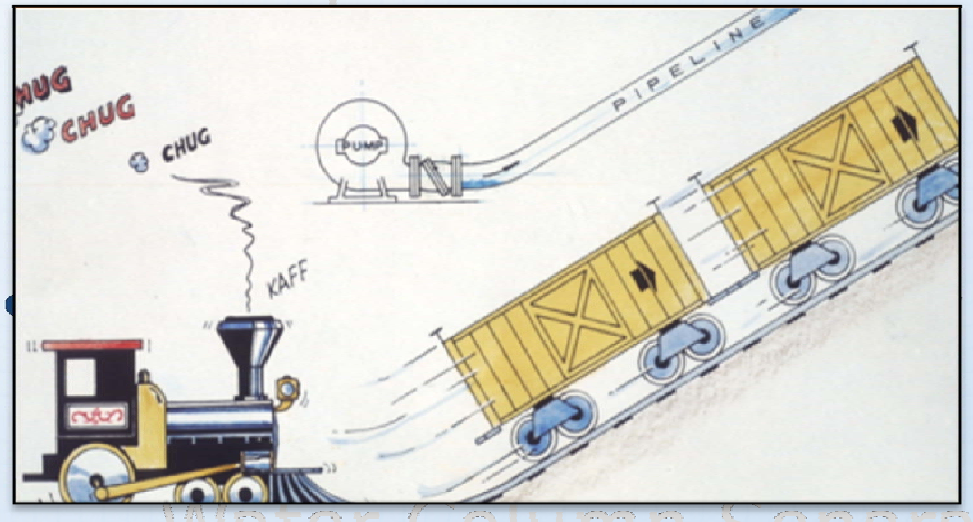

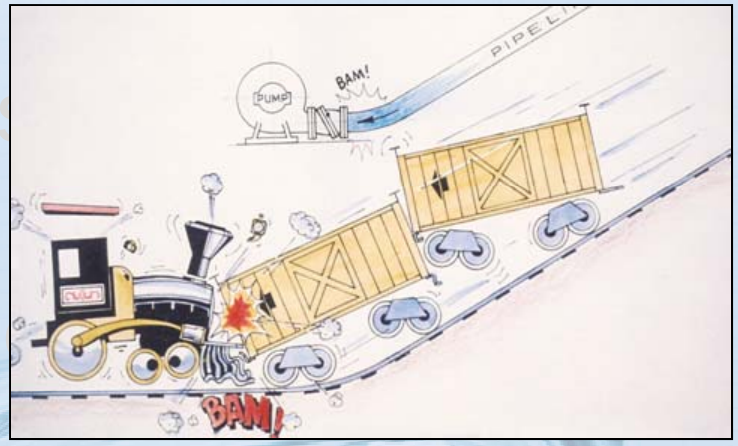

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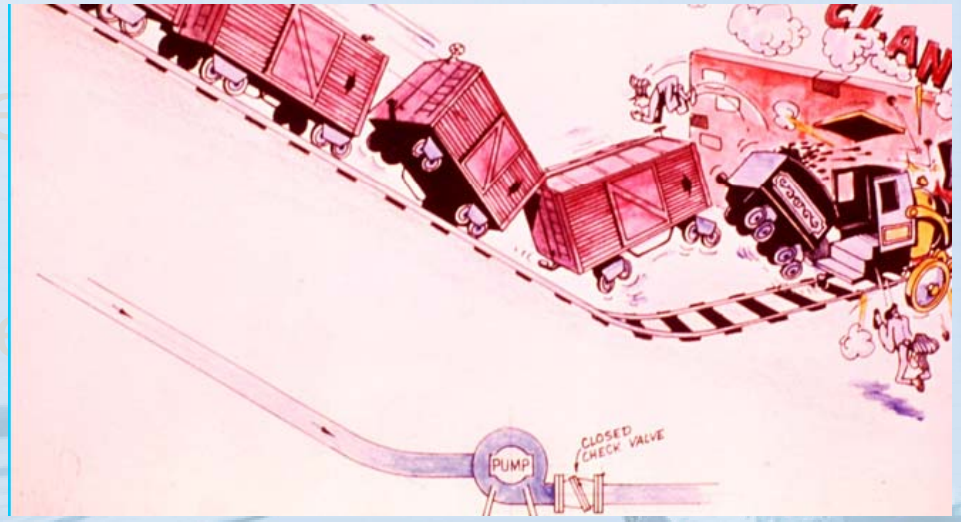

Factors Causing Surge

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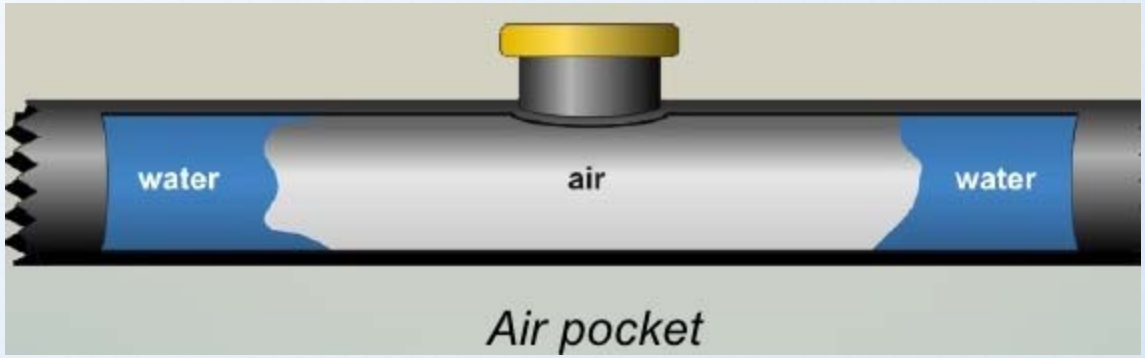
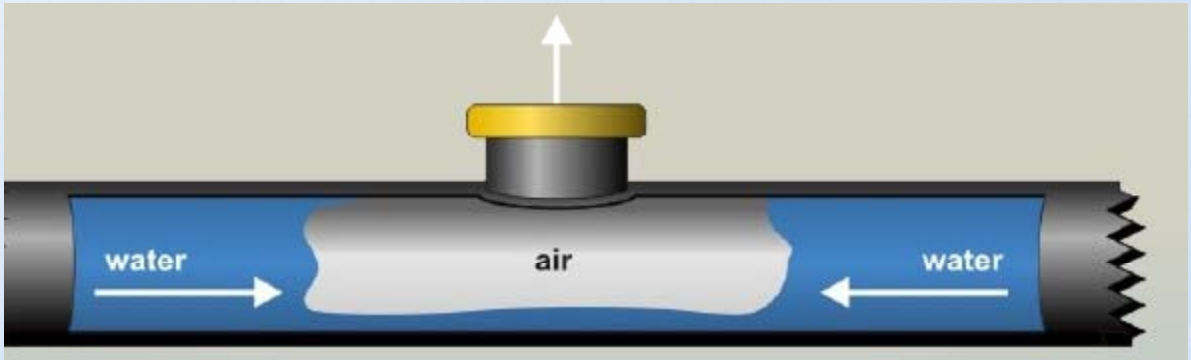
Factors Causing Surge

Air Valve Caused Surge

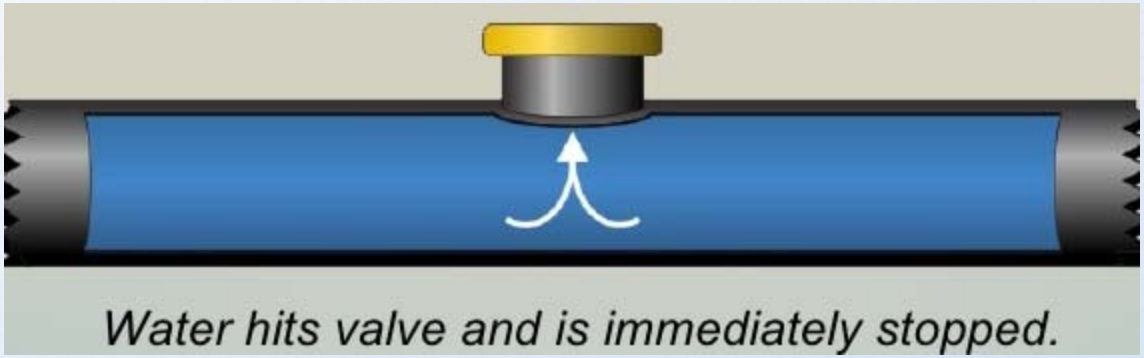


Air pocket



Air is quickly expelled out of valve.

Air Valve Caused Surge



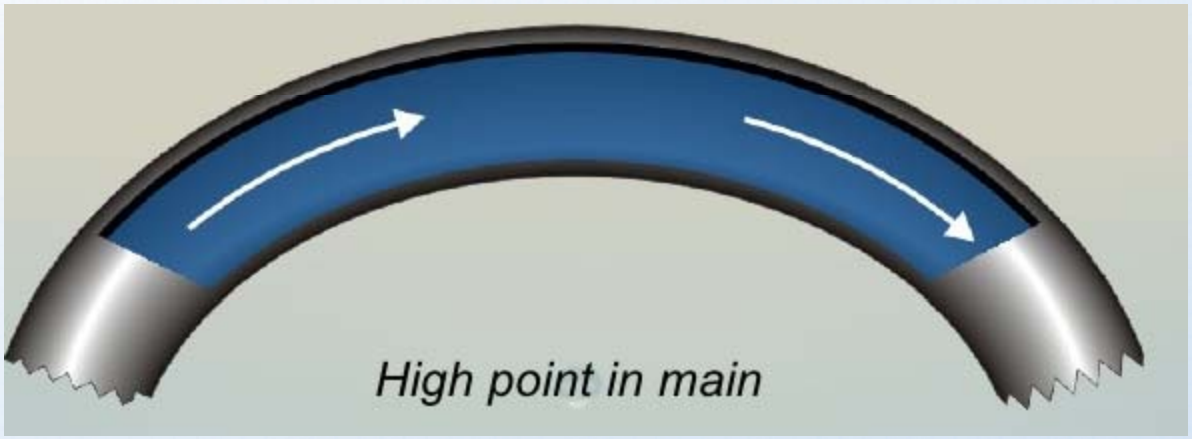
Water hits valve and is immediately stopped.

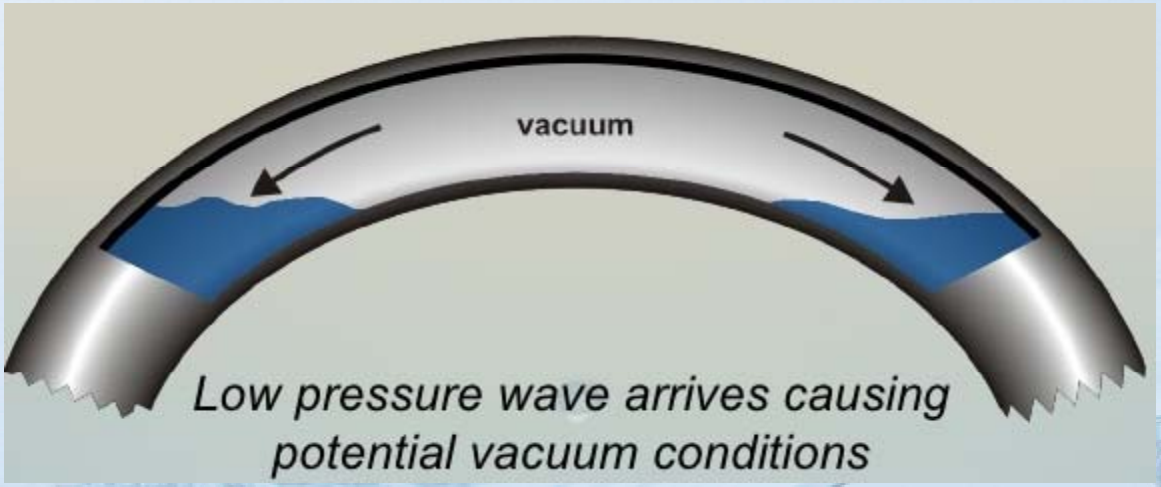
Secondary transient starts

Factors Causing Surge

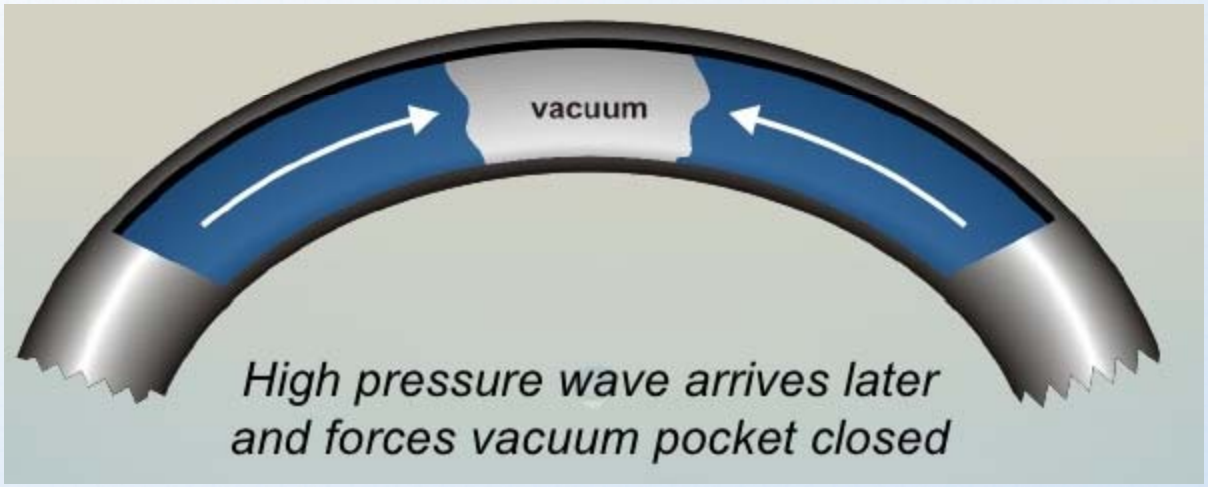
- Primary Surge Transients
  - Pump Startup
  - Pump Shutdown
  - Power Loss
  - Valve Shutdown
- Secondary Surge Transients
  - Air Valve
  - Water Column Separation @ High Spots

Water Column Separation





Water Column Separation



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Factors Influencing Surge Formation

- Pipeline Properties
  - Pipeline profile (particularly high points)
  - Pipeline and lining Material
  - Configuration (Storage locations)
- Pipe Appurtenances
  - Air valve Location and Types
  - Valve Types and opening/Closing
  - Type of Check Valves
- Pump Features
  - Pump performance curves and operating speeds
  - Rotational moment of inertia's for pump/motor assemblies

Common Surge Misconceptions

- Pipeline velocities must be low to reduce the effects of water hammer
- Surges only occur in long pipelines
- The noise and knock in a system is an indicator of the magnitude of a surge
- Surge protection devices should be installed on an experimental basis because it is not possible to accurately determine the magnitude of surges
- The use of surge protection devices are not economically viable
- Pressures in a system must be high before dangerous surges can occur

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How can you determine if Surge is an Issue?

- Banging Noises and Vibration
  - Pressure waves bouncing from piping
  - Check valve slamming
- Frequent pipe breaks in the Same places especially near pump station or low/high points in the system.
- System Measurements (transients occur too quickly for normal PT's)
- Difficult to observe due to infrequent occurrence and difficulty in monitoring.

Why Should You Care About Water Hammer.

- Catastrophic Service Breaks
- Pipe Materials Behave Differently:
  - Plastic: Lower propagation but more susceptible to fatigue from cyclic loading.
  - Steel, Concrete: Higher pressure rise but less susceptible to cyclic loading.
- Contamination Potential
- Damage to system instrumentation (Gauges, Flowmeters, etc.)
- Control and Alarm Issues

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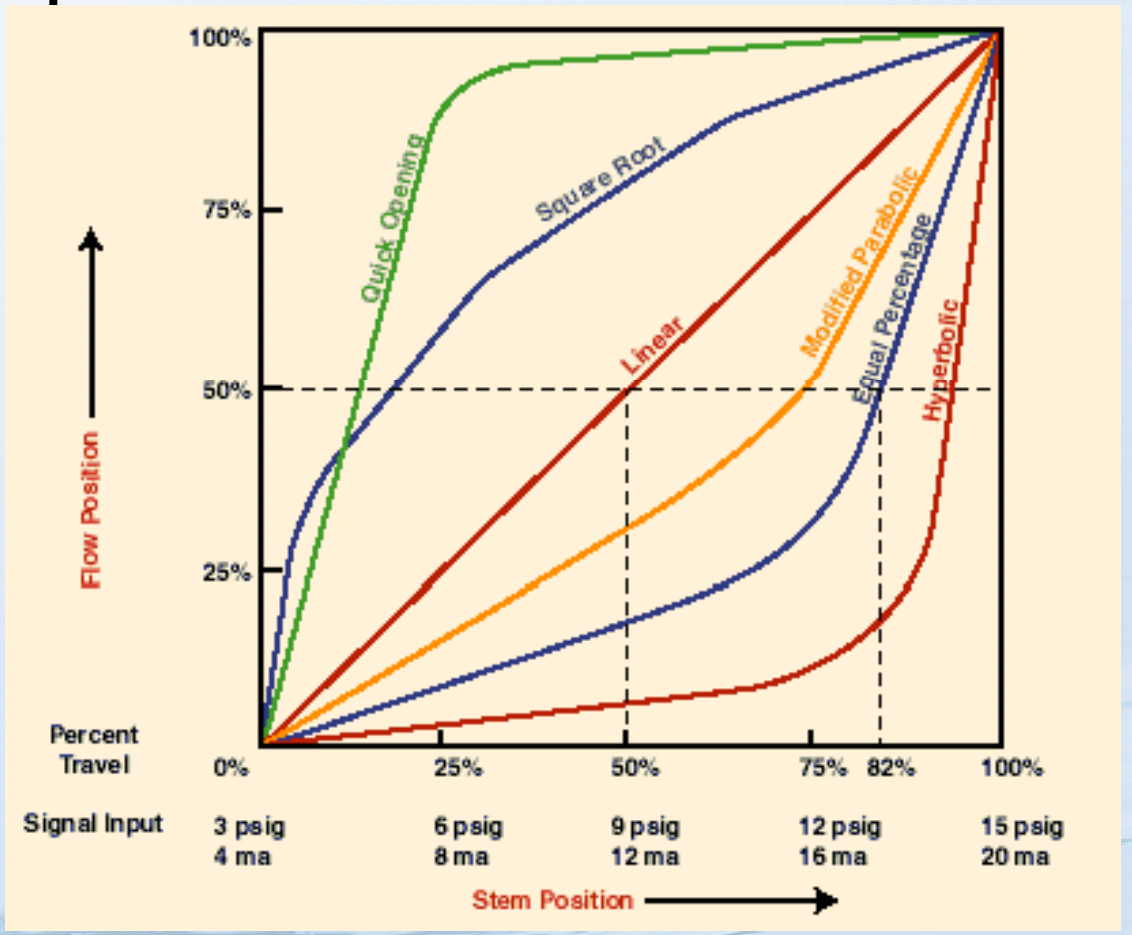
Types of Surge Suppression Equipment - Passive

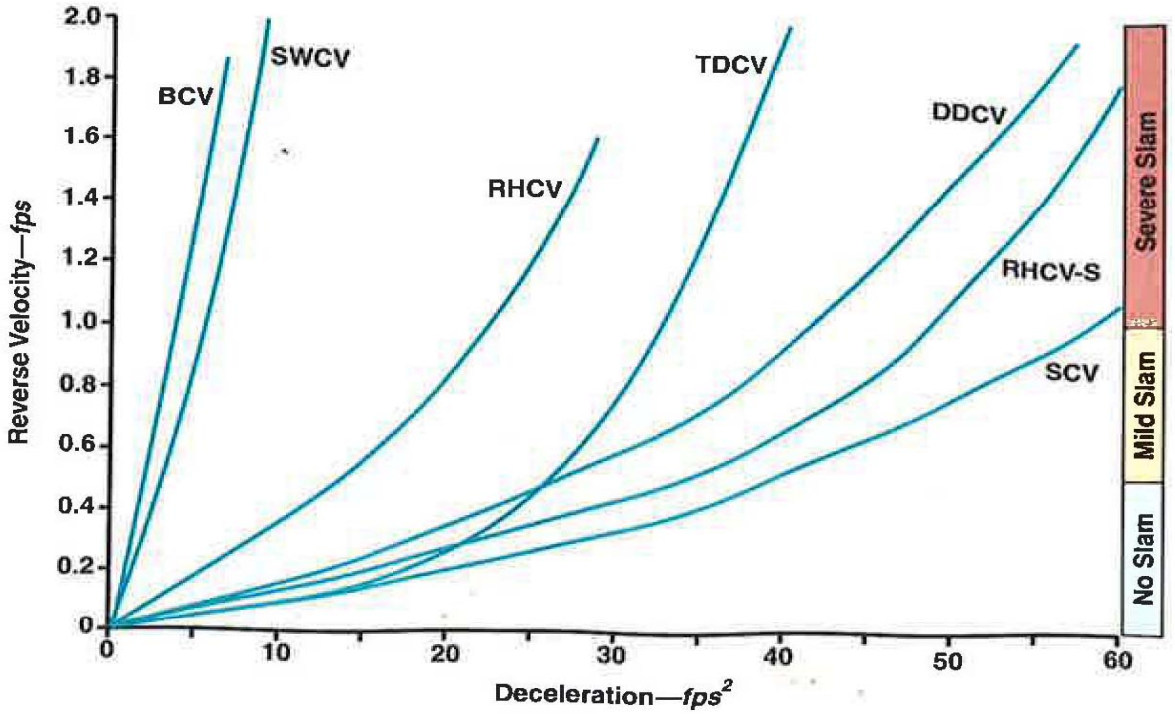
- Pump Control Valves Characteristics:



Types of Surge Suppression Equipment- Passive

- Pump Check Valve Characteristics:

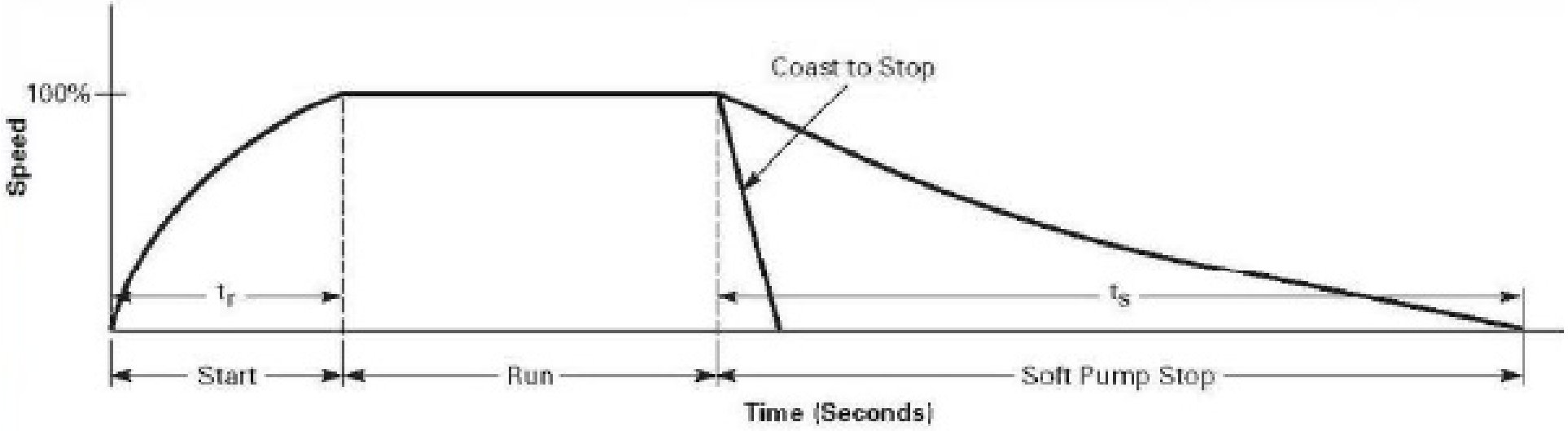
FIGURE 6 Dynamic characteristics of various check valves



BCV—ball check valve, DDCV—dual-disc check valve, RHCV—resilient hinge check valve, RHCV-S—resilient hinge check valve with spring, SCV—silent check valve, SWCV—swing check valve, TDCV—tilted-disc check valve

Types of Surge Suppression Equipment- Passive

- Controlled Pump Startup/Shutdown
  - Provide wirth “S-curve feature” to Time with Valves
  - Not all Soft Starts Created Equal
  - Voltage/Torque Control More Important than Current.

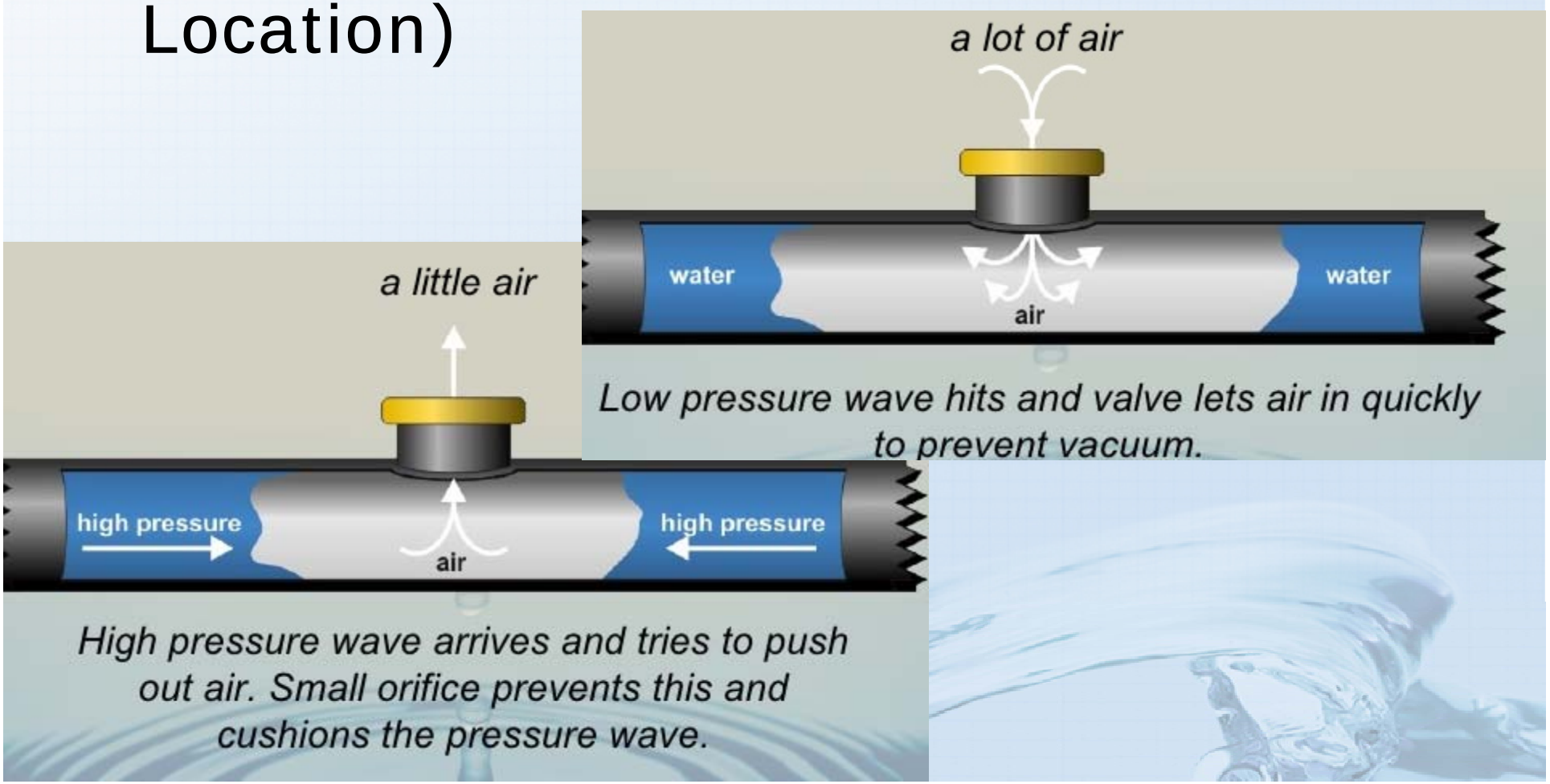


Types of Surge Suppression Equipment

- Pump Design Features:
  - Pump Curve
  - Pump Impeller Moment of Inertia
  - Anti Reverse - Ratchet

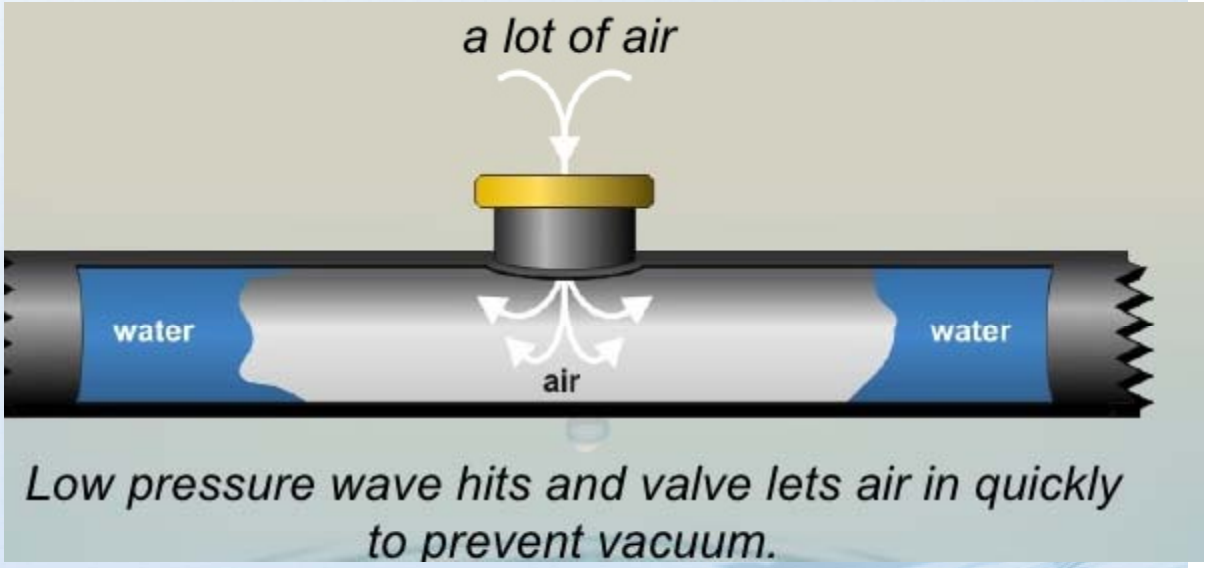
Types of Surge Suppression Equipment - Active

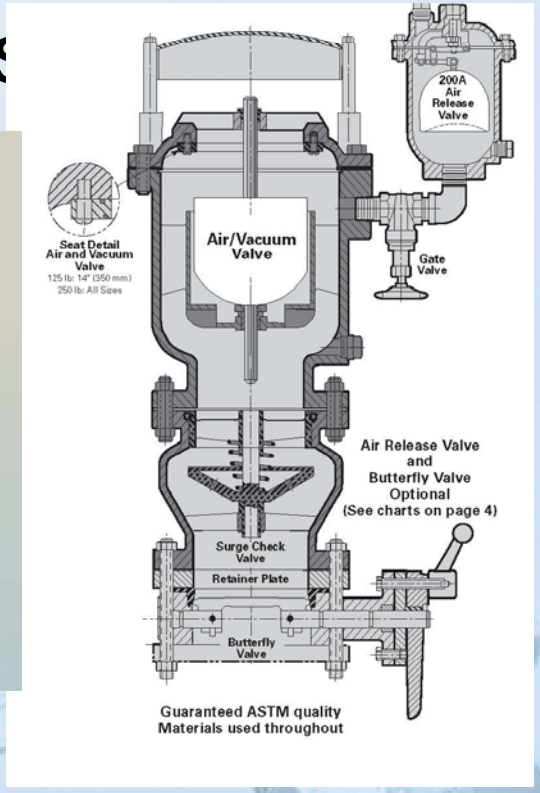
- Air/Vacuum Relief Valves (Size and Location)



Types of Surge Suppression Equipment - Active

- Air/Vacuum Relief Valves (Size and Location)
- AVV Surge Check Devices





Types of Surge Suppression Devices - Active

- Surge Anticipation Valves
- Surge Tanks
  - Bladder
  - Hydropneumatic
  - Surge Towers

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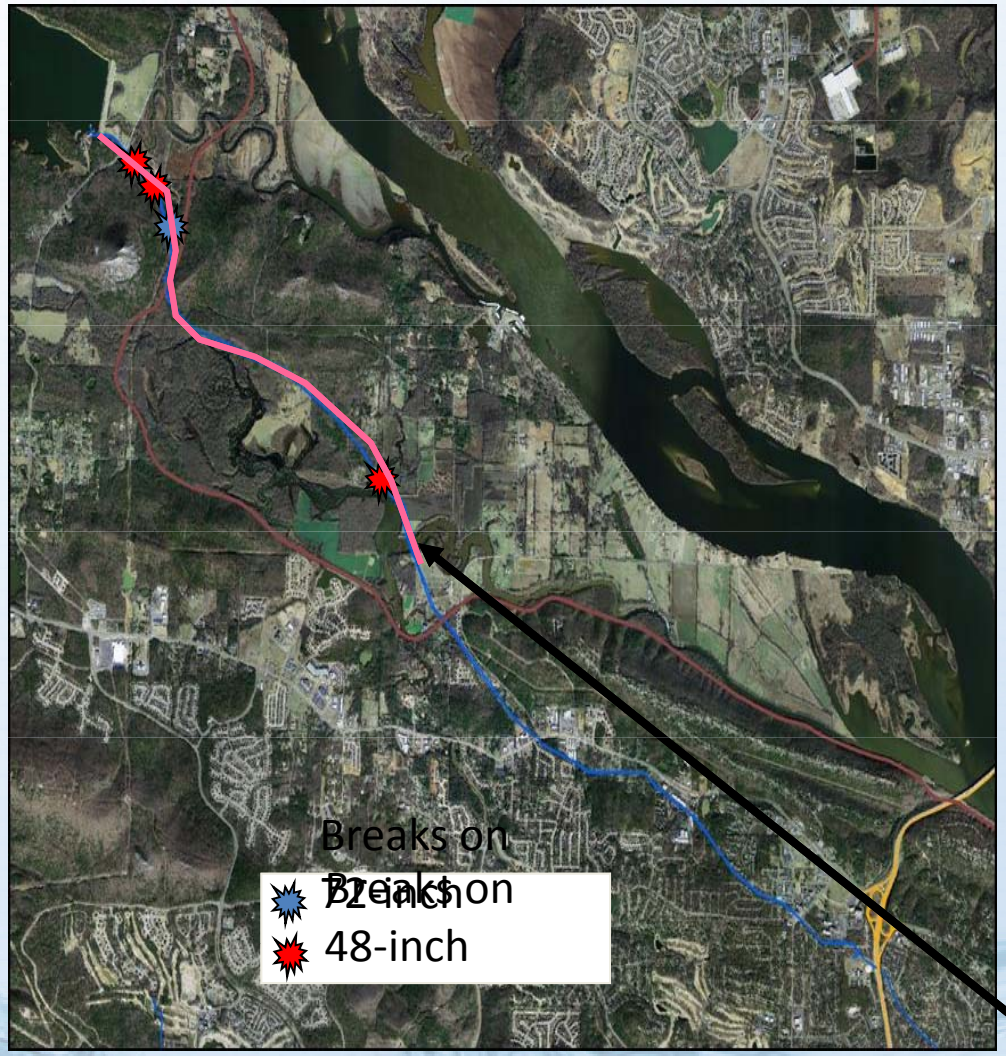
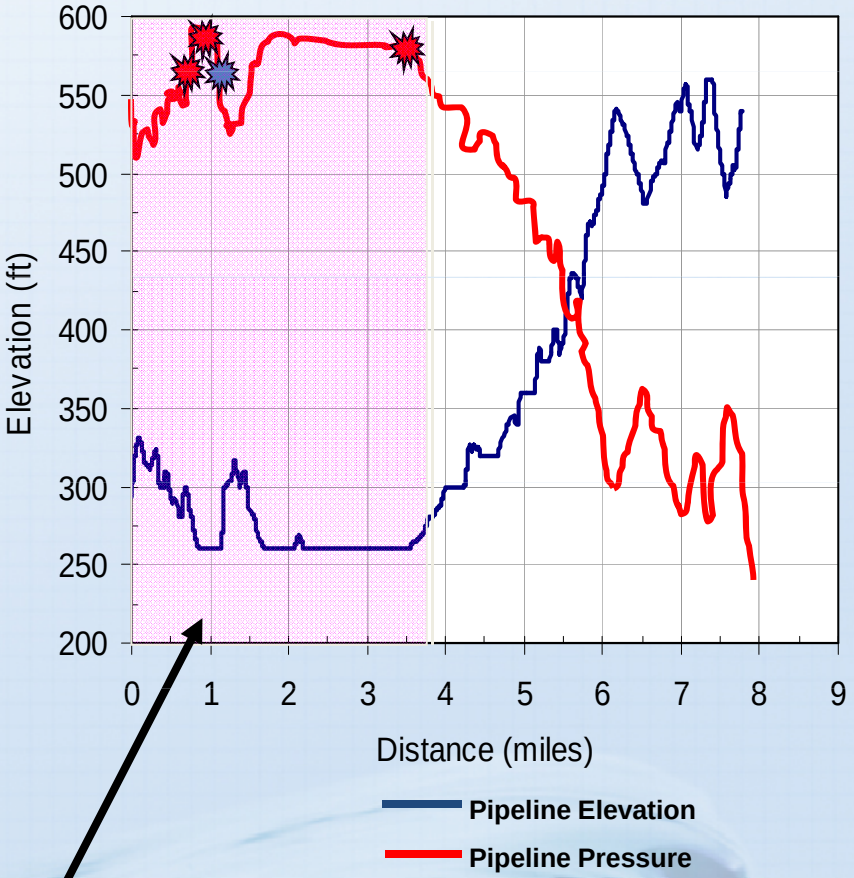
CAW Maumelle Pump Station History





Protect, Replace or Bypass Area of Highest Pressures

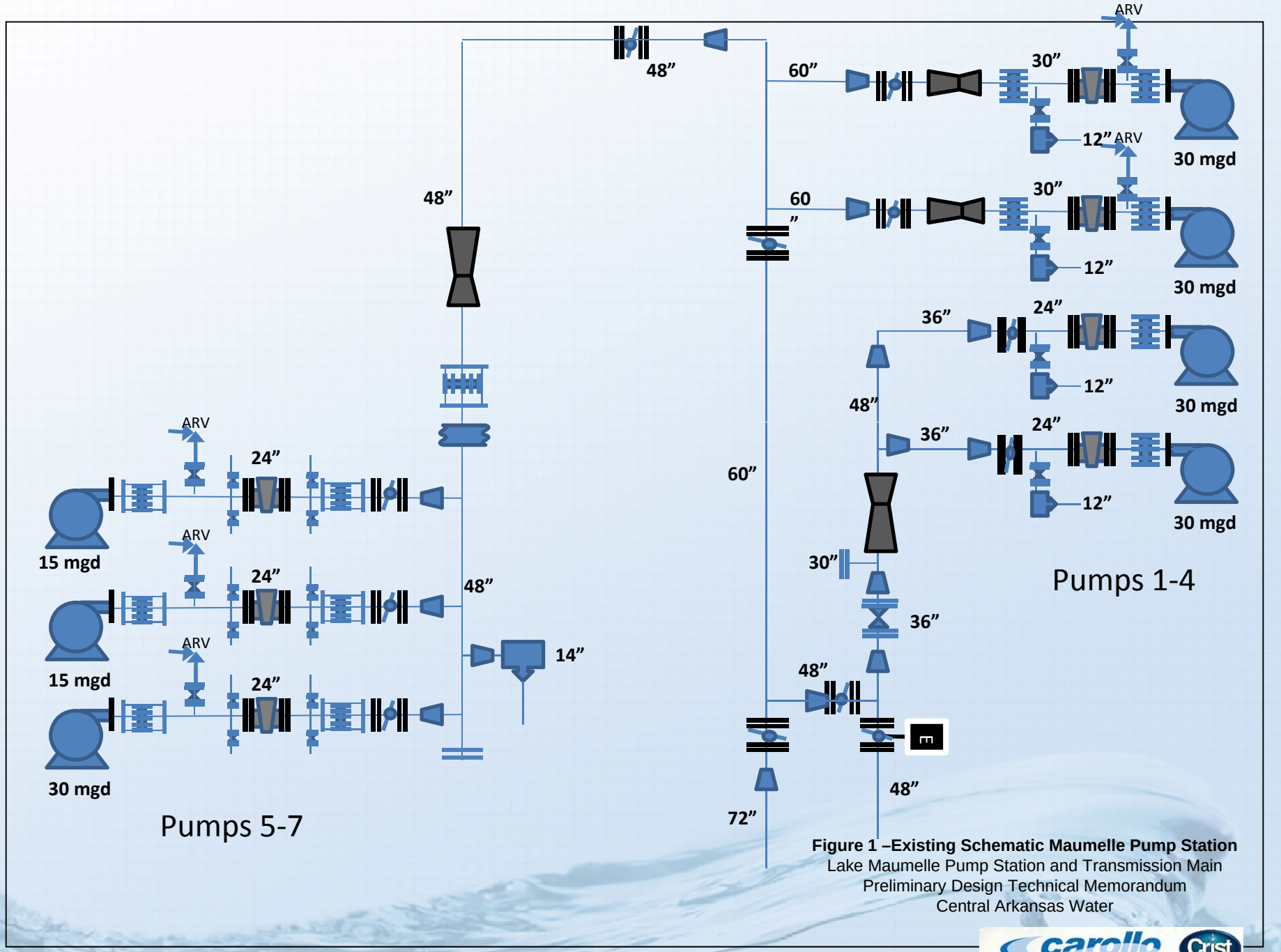


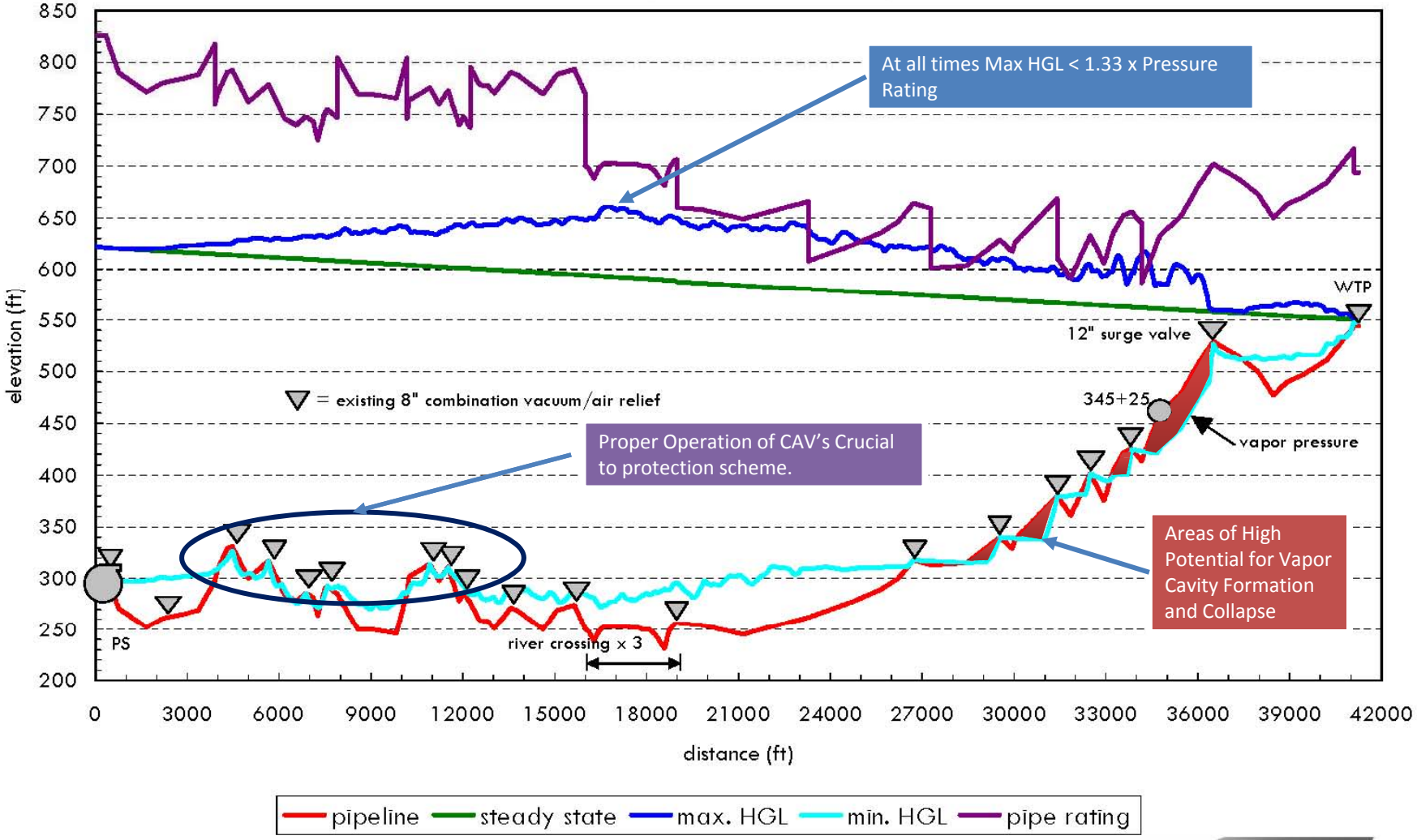
Figure 1 –Existing Schematic Maumelle Pump Station
Lake Maumelle Pump Station and Transmission Main
Preliminary Design Technical Memorandum
Central Arkansas Water

Surge Analysis Assumptions

- All Air/Vacuum Relief Valves equipped with controlled venting/slow closing.
- All seven pumps are operating (174 mgd at 333-341 TDH)
- One of the river crossings is out of service (highest velocity)
- Pump Control Valves Close within 60 seconds of power loss.
- All five Surge Anticipator Valves (SAV's) fully open following activation (Pressure below 75 psig).
- SAV's Remain in operation for 30 seconds and close within 260 seconds.
- Both the 72-inch and 48-inch Transmission Mains are hydraulically connected.

CAW Maumelle PS and RWTL

Figure 1 - HGL between PS's and WTP along 72-inch TM following PS power failure with existing protection: vacuum valves and surge anticipator valves, Q total = 174 MGD



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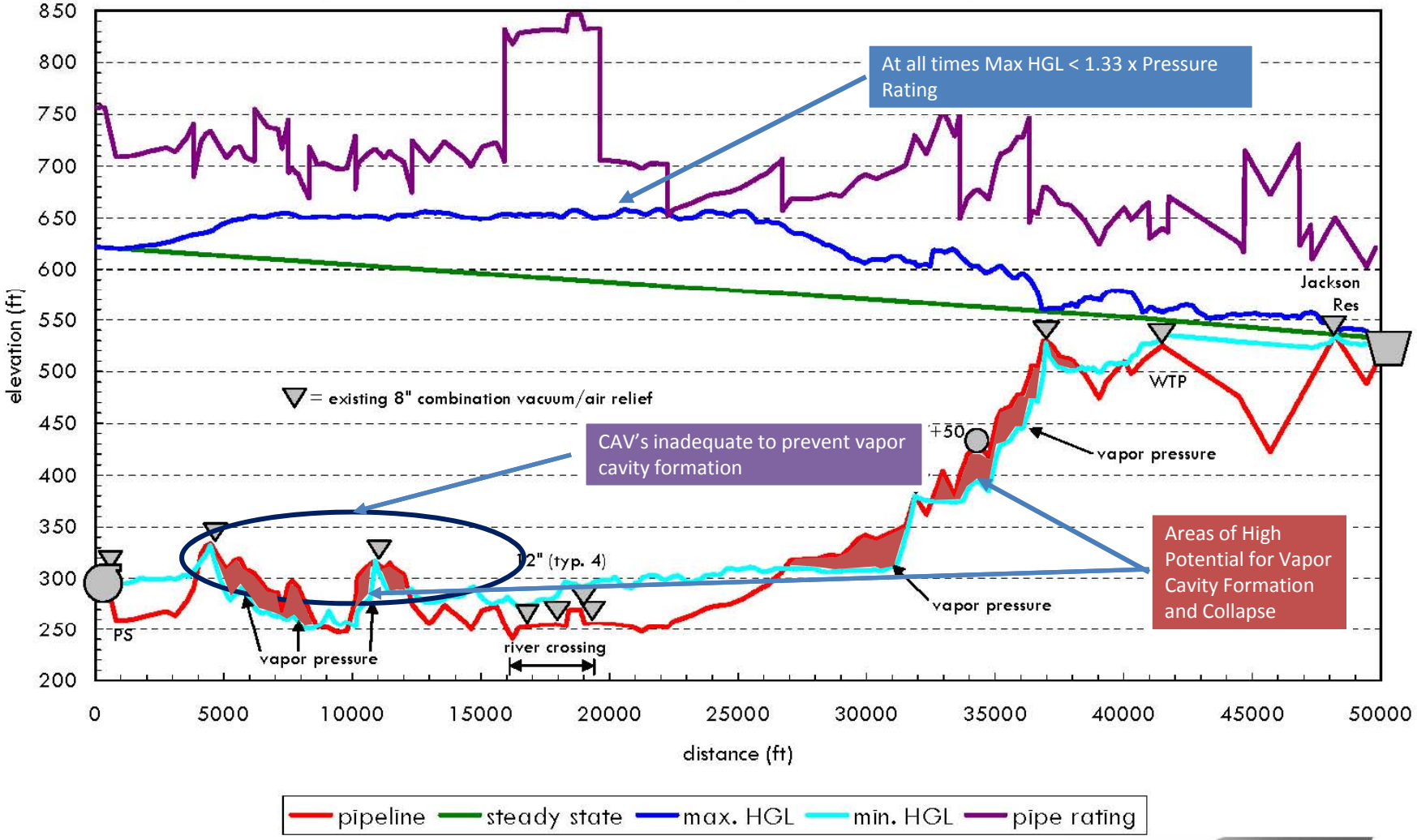
CAW Maumelle PS and RWTL

Figure 2 - HGL between PS's and Jackson Reservoir along 48-inch TM following PS power failure with existing protection: vacuum valves and surge anticipator valves, Q total = 174 MGD



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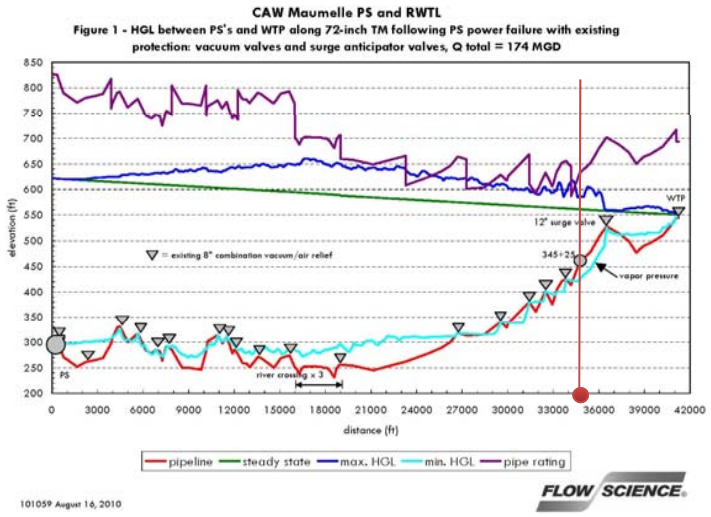
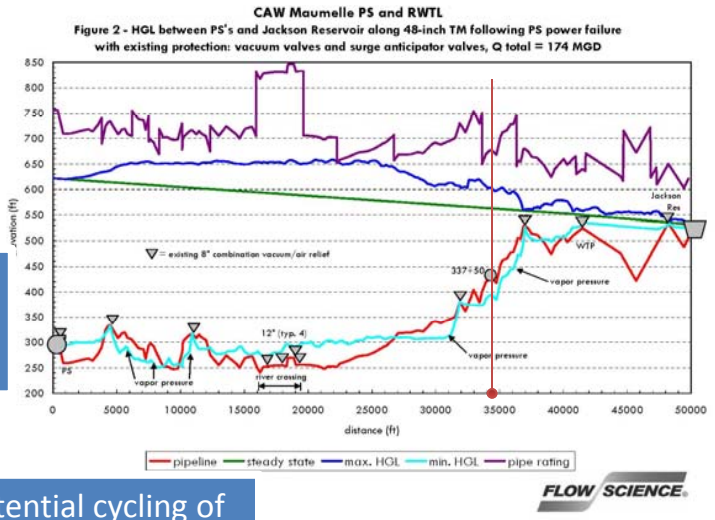




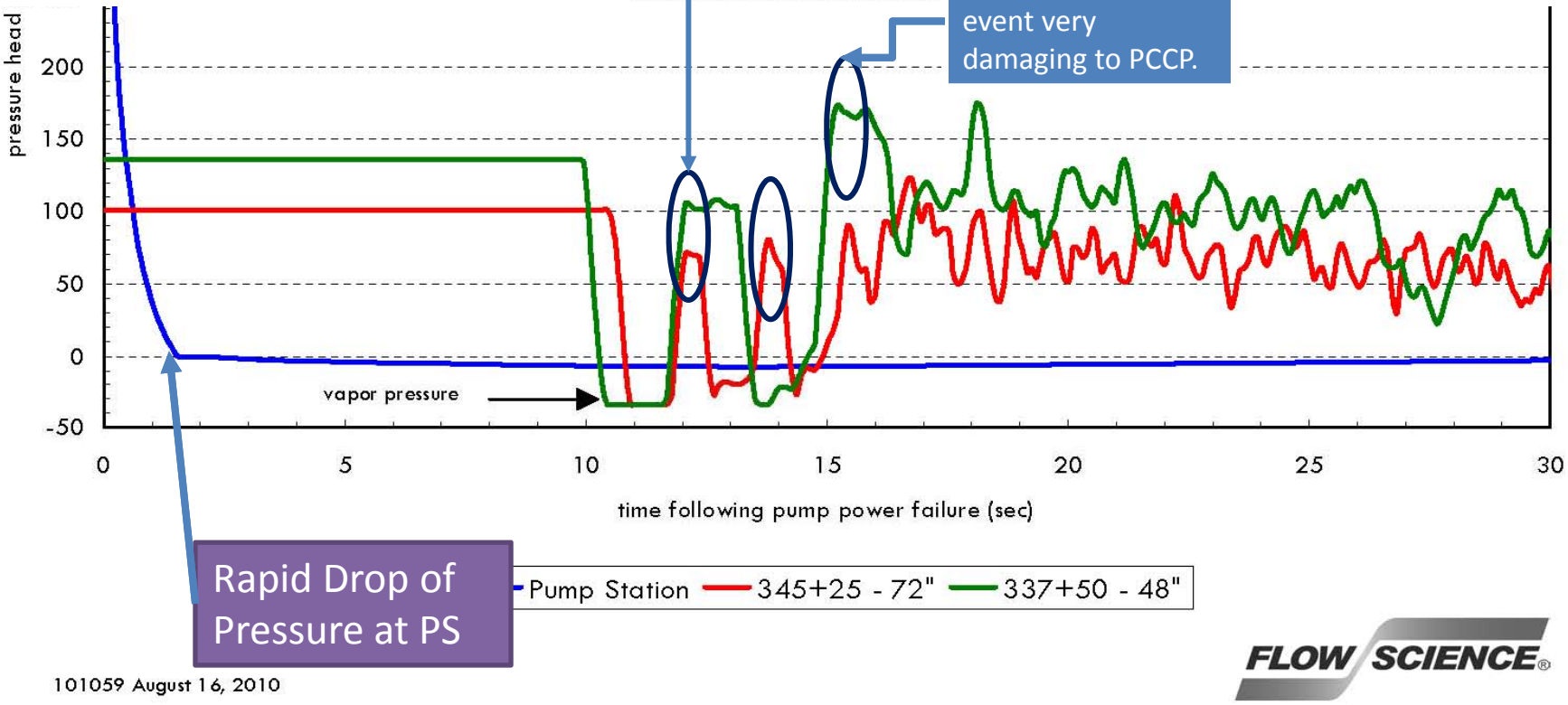
V Maumelle PS and RW

sure head records followin

alves and surge anticipato

Repressurization and potential for VC collapse

Potential cycling of event very damaging to PCCP.



Rapid Drop of Pressure at PS

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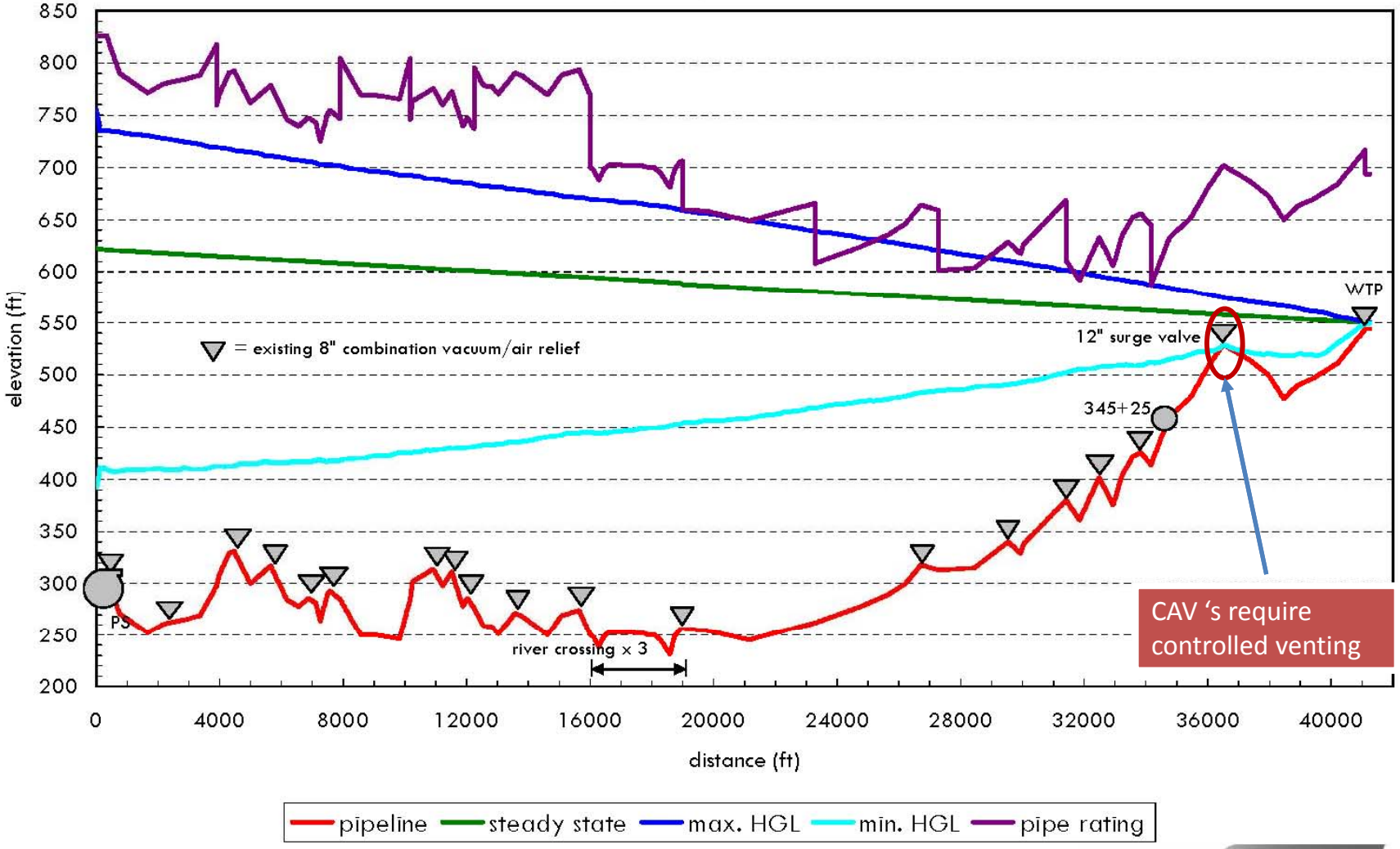
Surge Analysis Mitigation

- Install Three 12 ft diameter x 60 ft long surge tanks with 45% air.
- Install tanks at pump station.
- Install new valves to close within 5 seconds of power failure at pump station.
- Retain existing SAV's for increased level of protection.
- Install Surge Checks on CAV's at stations further down the pipes.

CAW Maumelle PS and RWTL

Figure 5 - HGL between PS's and WTP along 72-inch TM following PS power failure

3-12'x60' surge tanks, Q total = 174 MGD



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CAW Maumelle PS and RWTL

Figure 6 - HGL between PS's and Jackson Reservoir along 48-inch TM following PS power failure
3-12'x60' surge tanks, Q total = 174 MGD

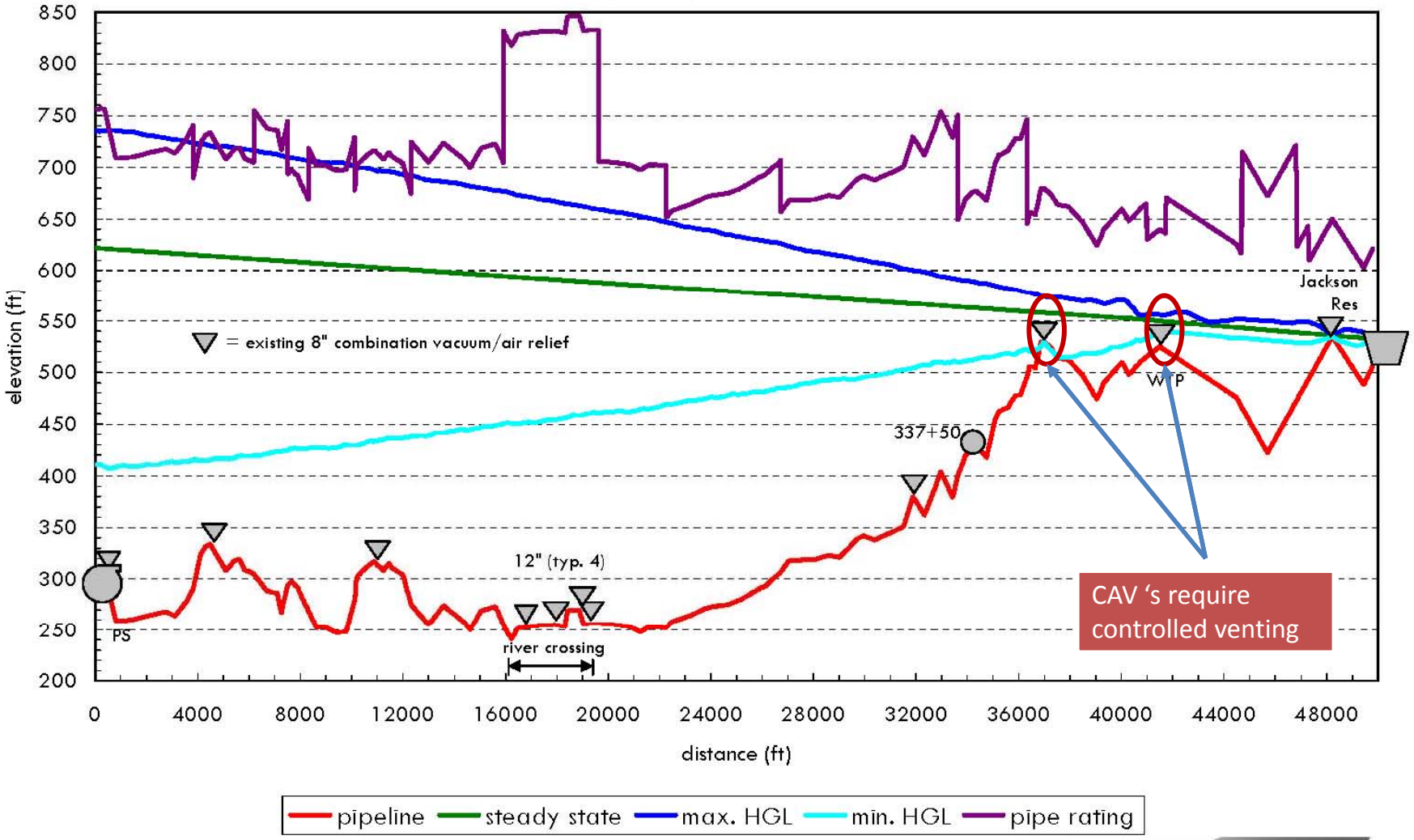

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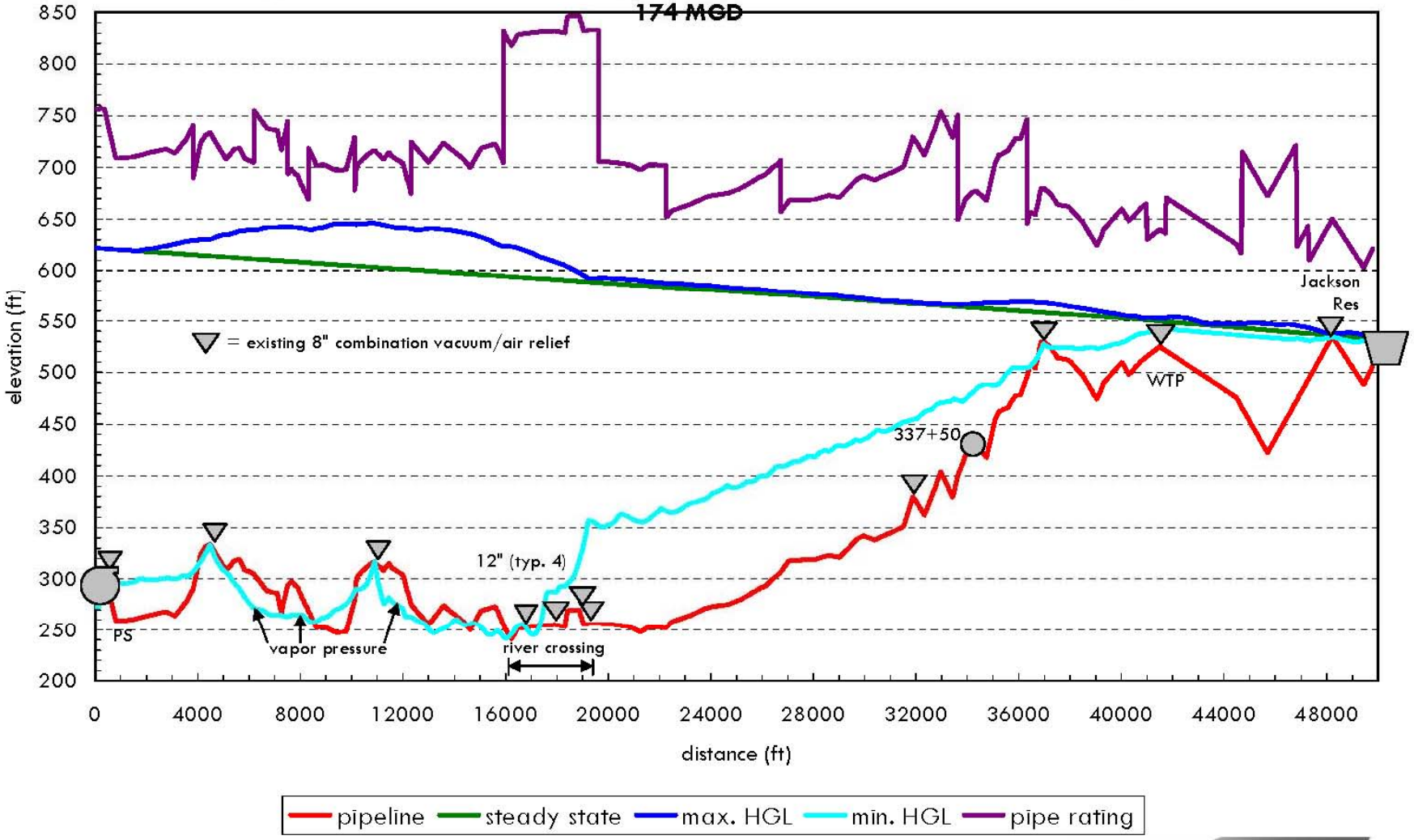
Figure 12 - HGL between PS's and Jackson Reservoir along 48-inch TM following PS power failure with existing protection and 2-12'x60' surge tanks at downstream side of river crossing, Q total = ~~174 MGD~~



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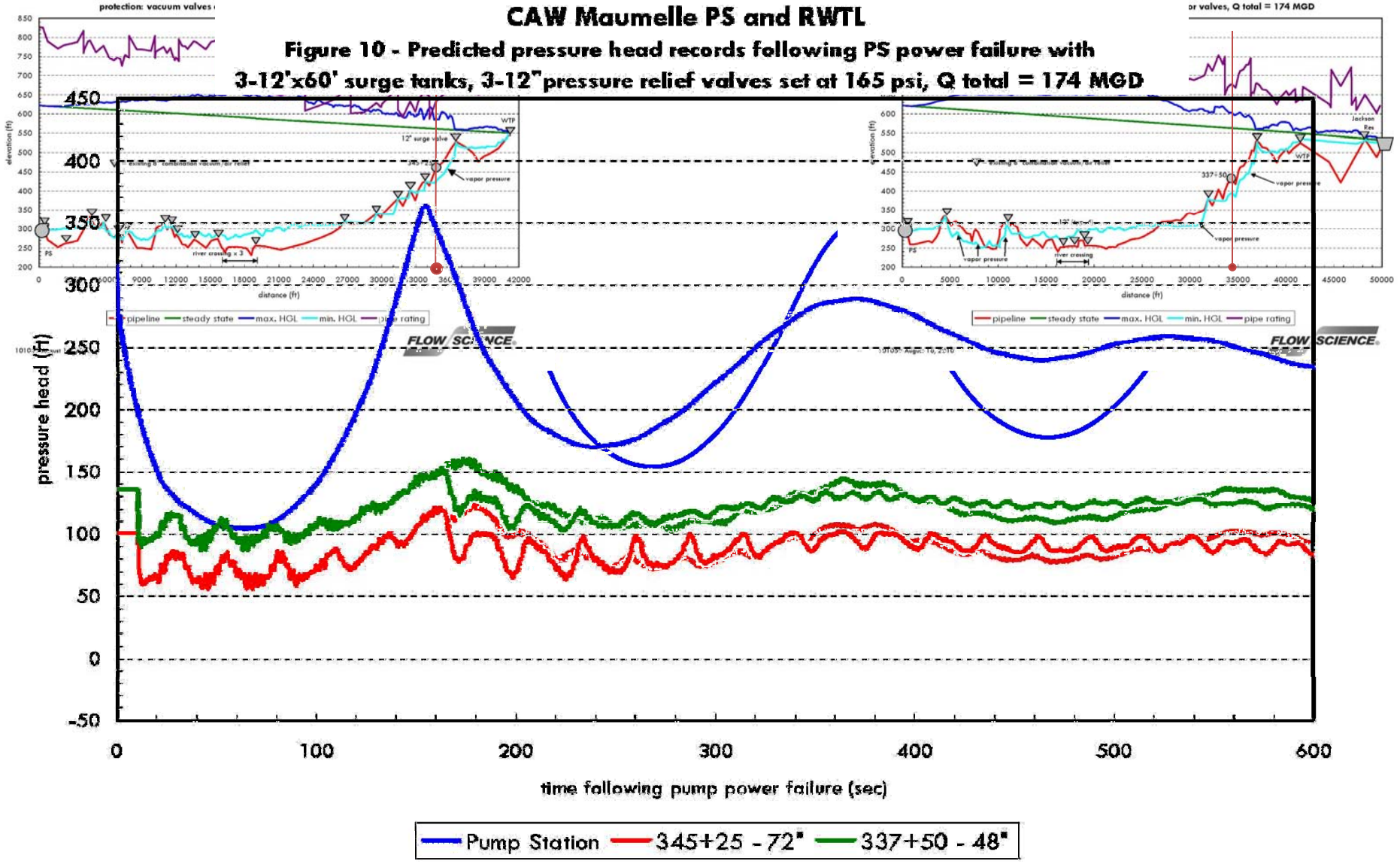
CAW Maumelle PS and RWTL

Figure 10 - Predicted pressure head records following PS power failure with 3-12'x60' surge tanks, 3-12" pressure relief valves set at 165 psi, Q total = 174 MGD



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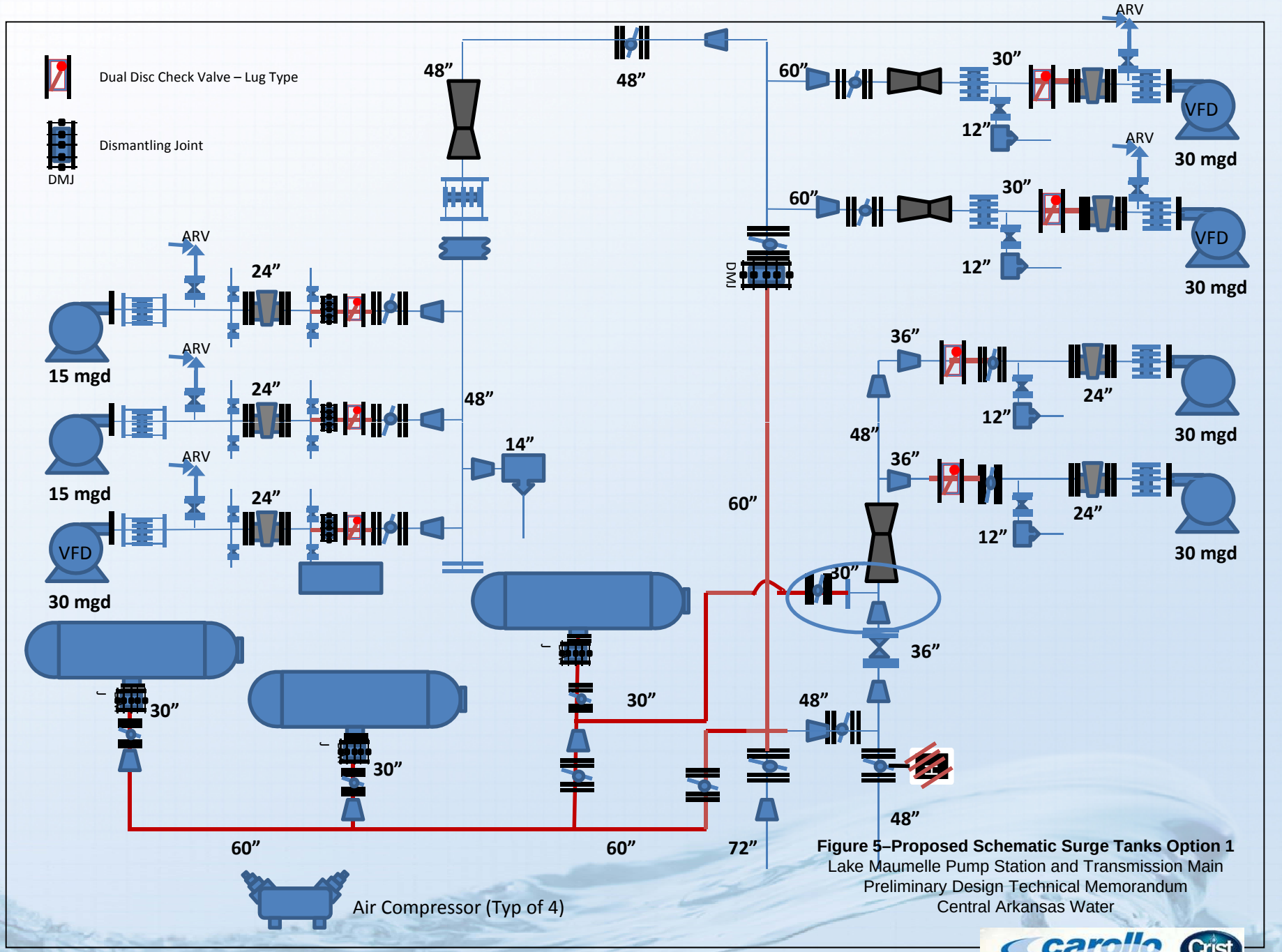

Figure 5–Proposed Schematic Surge Tanks Option 1
Lake Maumelle Pump Station and Transmission Main
Preliminary Design Technical Memorandum
Central Arkansas Water

CAW Surge Suppression System

CAW Surge Suppression System

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Existing Kaw Raw Water Pipeline Schematic

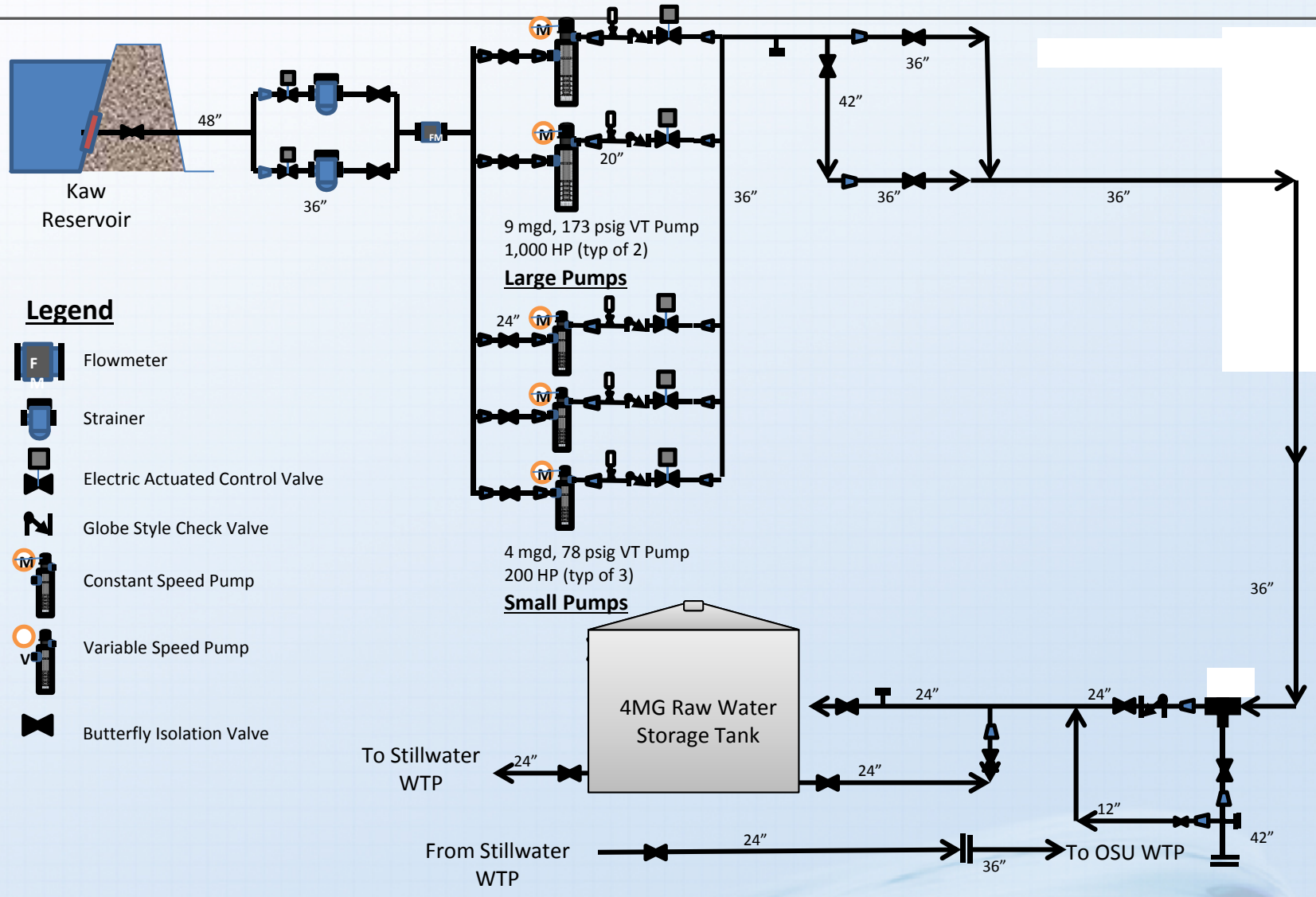
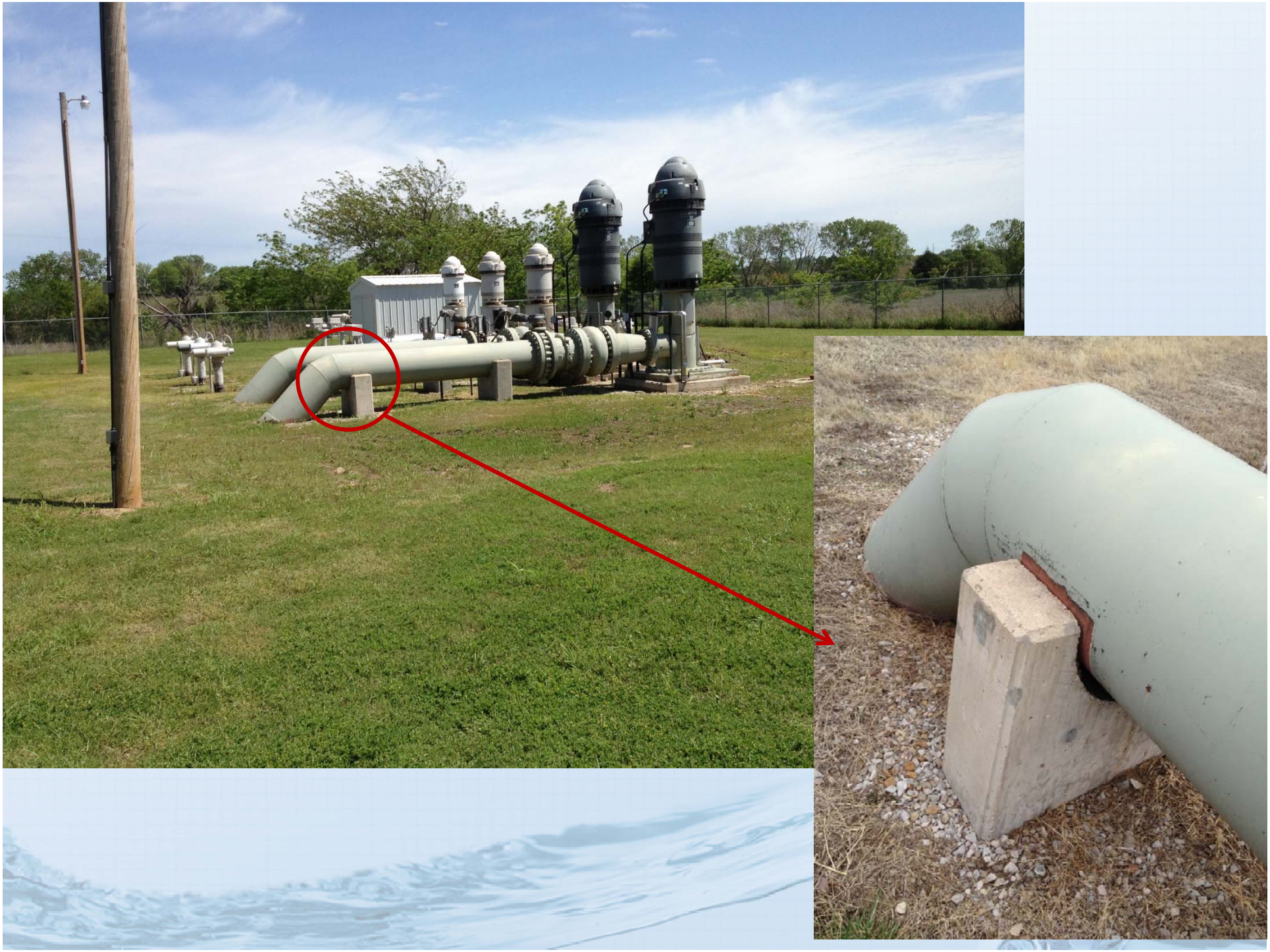
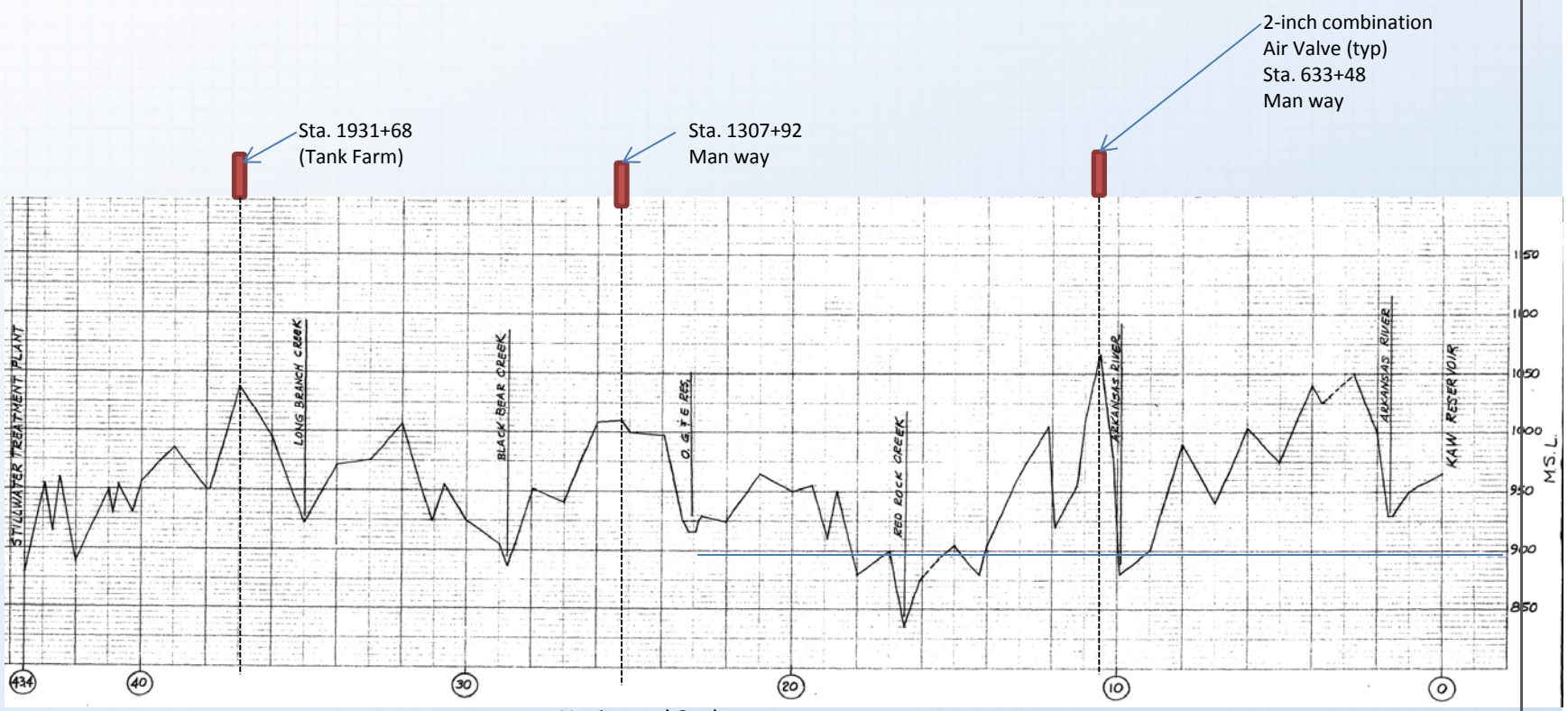


FIGURE 1.1



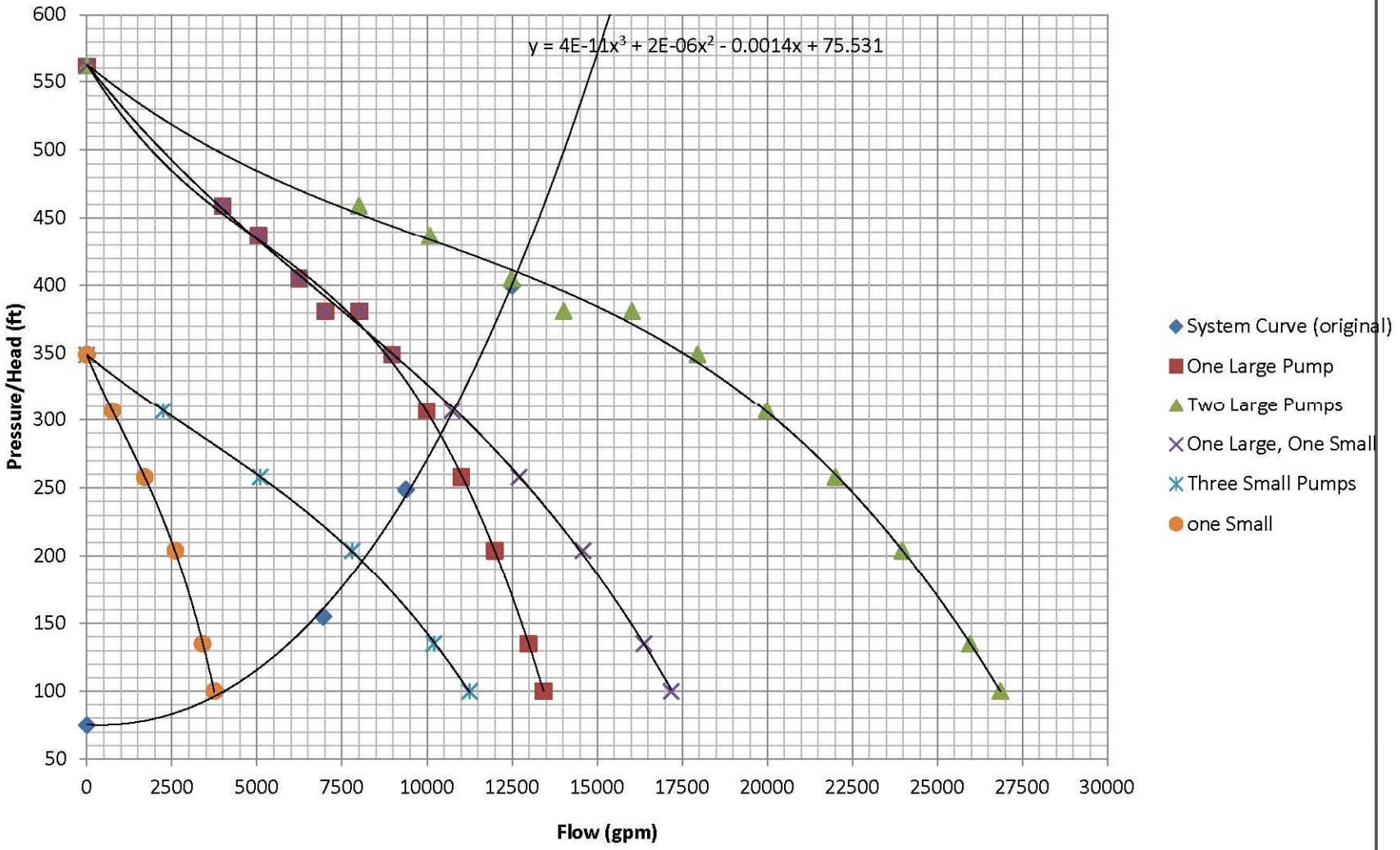
Existing Kaw Raw Water Pipeline Profile



Horizontal Scale:
0.5 inch = 2 miles

FIGURE 2.3

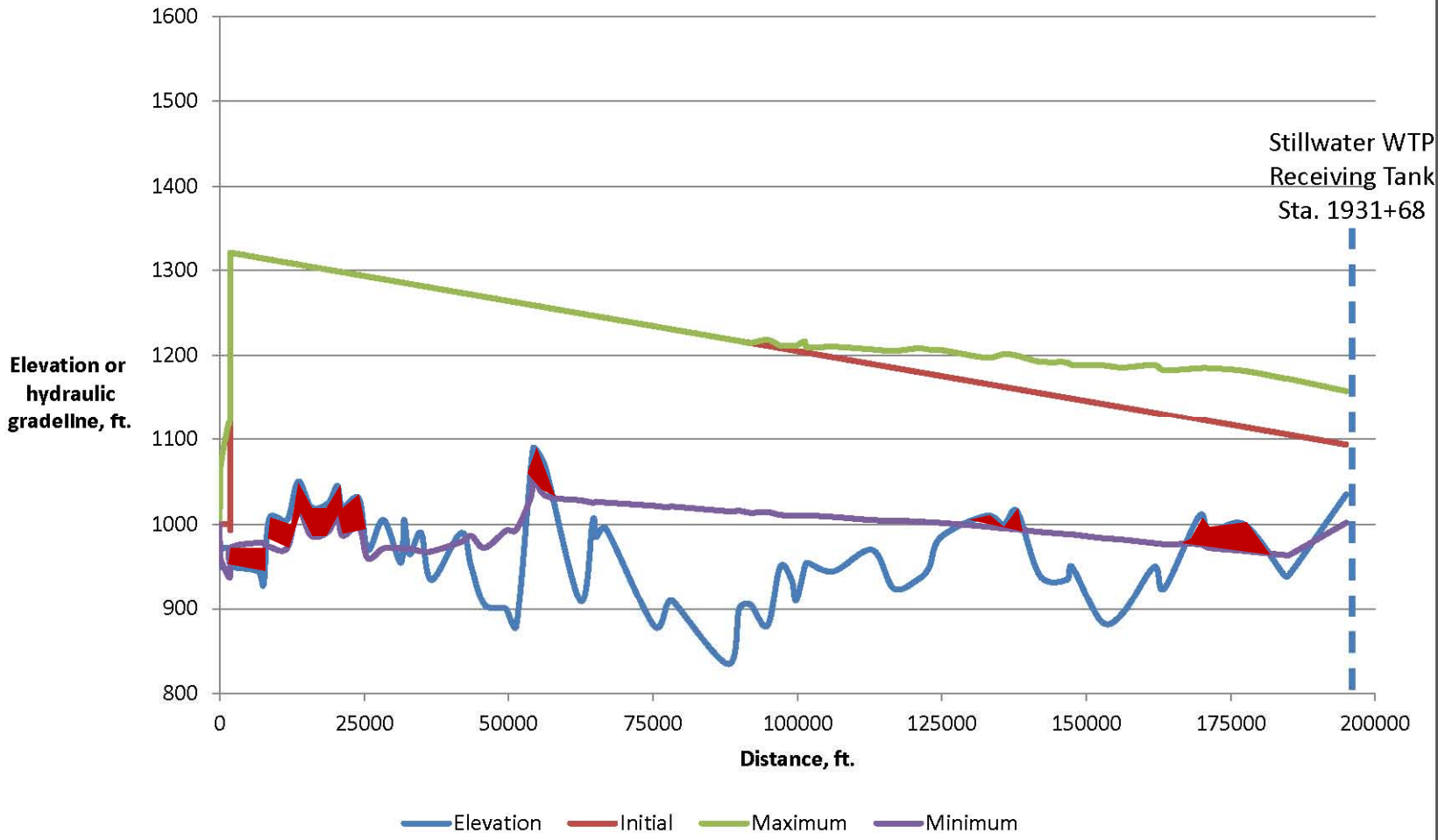
Design Pump and System Curves



Source: Pump Station Orientation and Operating Guide (1982)

FIGURE 2.2

Scenario No. 1 Hydraulic Grade Line



Source: Infor Surge Model

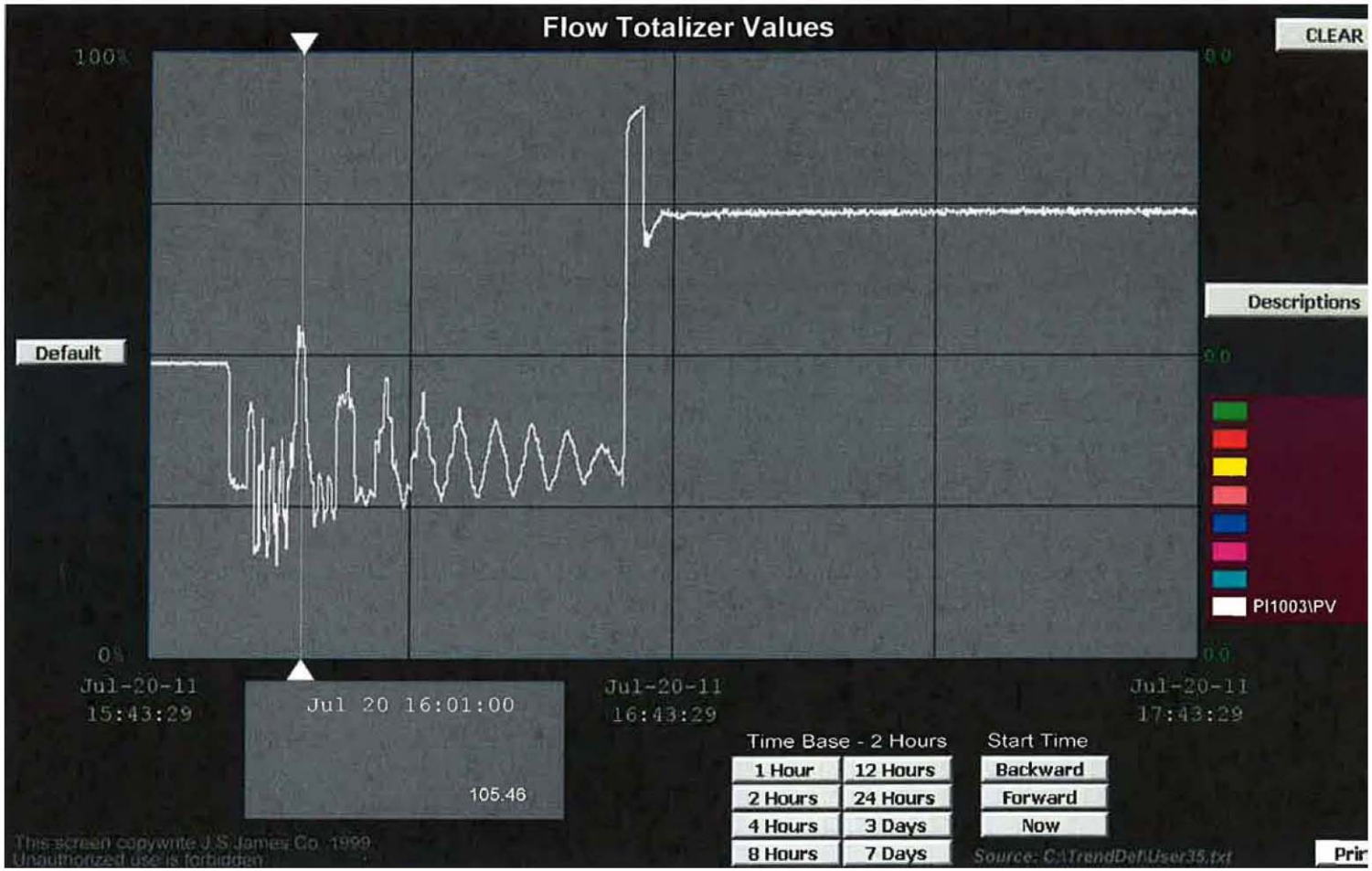
FIGURE 3.1

carollo

Surge Analysis of Kaw Raw Water Pipeline

Final Report October 2012

Results of Instantaneous Monitoring – Large Pump Startup



Source: Jason Consultants Monitoring Data (2012)

FIGURE 2.6

Surge Analysis Results

- Potentially Damaging Surge Waves were occurring due to:
  - Large Pump Startup/Shutdown
  - Lack of Proper Air/Vacuum Relief Valves

Recommended Locations for CAV's

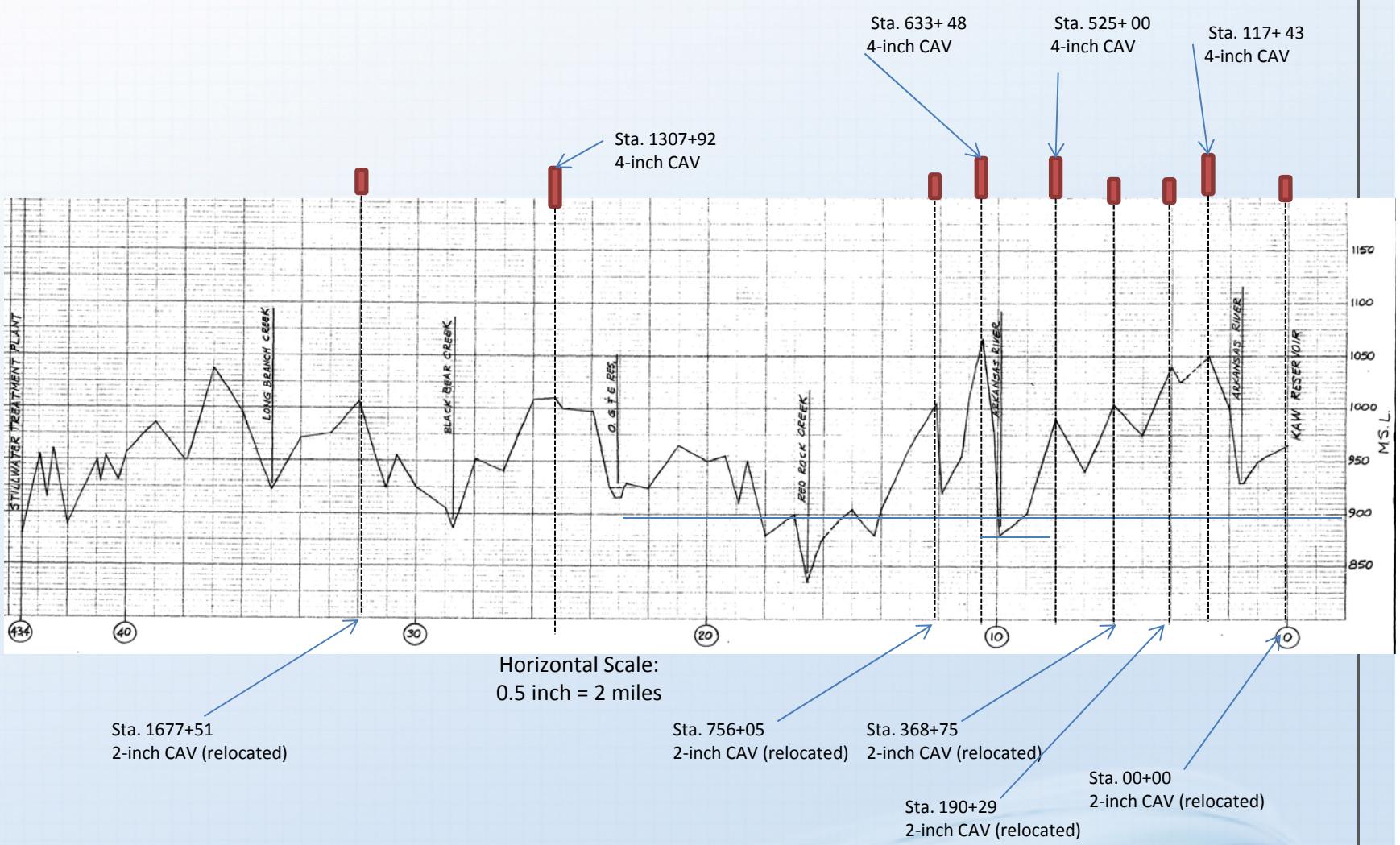


FIGURE 4.1

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Conclusions and Recommendations

- Do not assume that low velocities = No Surge
- Always perform a surge hydraulic analysis:
  - On new systems
  - On existing systems to change conditions
  - To determine timing of pump/valve startup.
- System conditions will dictate solution:
  - Active or Passive
  - Type of Active

Questions