BOOM! Hydraulic Transient Problems – Emergency and Long-term Solutions for Lexington's Main Wastewater Pumping Station

Town of Lexington, Massachusetts

Presented by:

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NEWEA Collection System Specialty Conference

September 12, 2016

WRIGHT-PIERCE
Engineering a Better Environment

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1642 CAMBRIDGE FARMS
1713 LEXINGTON
APRIL 19TH
LEXINGTON

Project Team

- **Town of Lexington**
  - John Livsey, PE, Town Engineer
  - Mike Flamang, PE, Senior Civil Engineer
  - David Pavlik, Assistant Engineer
  - William Hadley, DPW Director
  - Ralph Pecora, Water and Sewer Supervisor

- **Wright-Pierce Team**
  - Kevin Olson, PE, Project Manager
  - Barry Yaceshyn, PE, Lead Project Engineer
  - Amanda Ruggiero, PE, Project Engineer
  - Northwest Hydraulic Consultants (NHC)

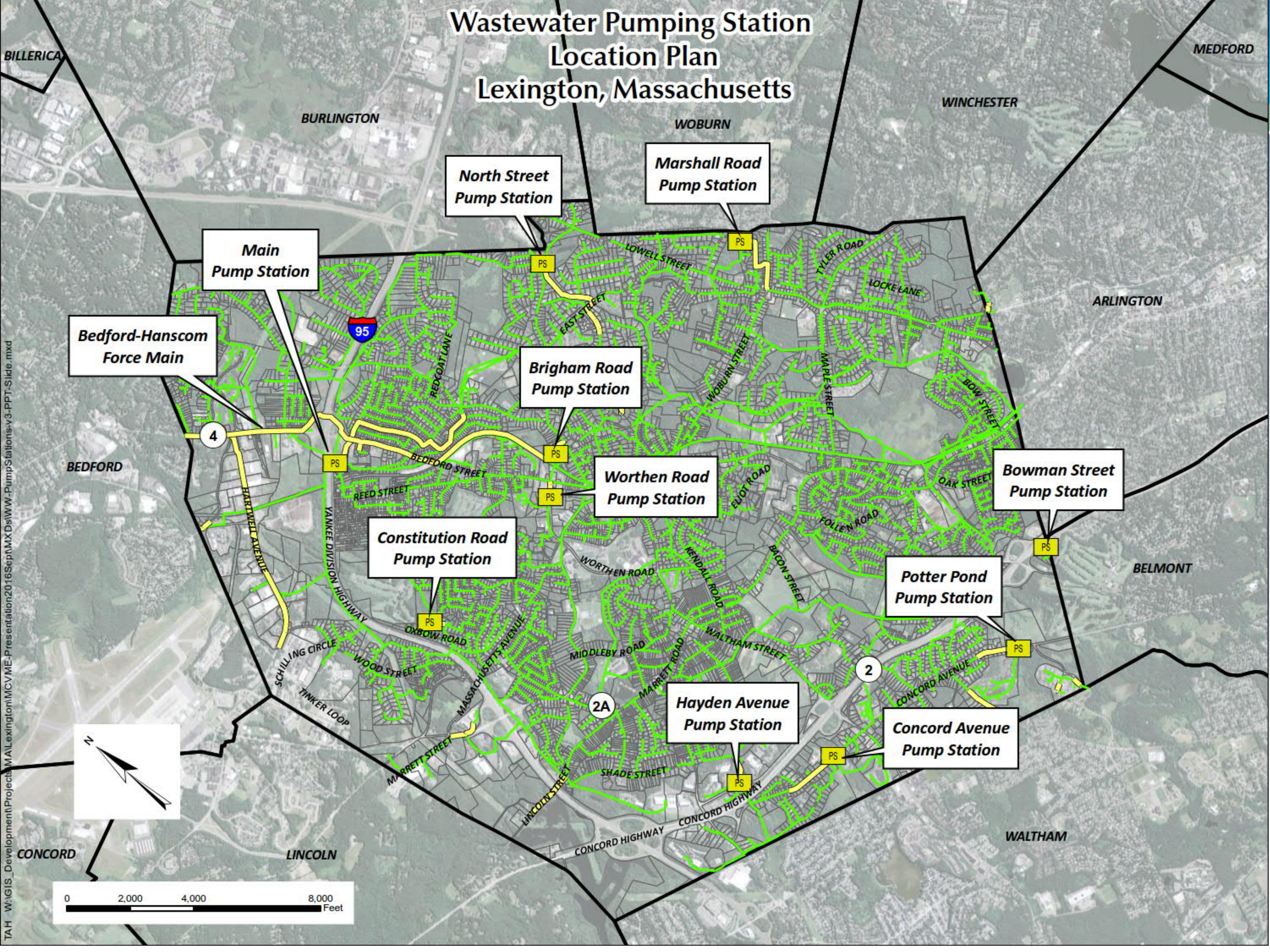
- **General Contractors – Methuen Const. and W&S CMR**

Presentation Outline

- Introduction and Background
- Existing Conditions
- The Problem
- Analyses/Evaluations Performed
- Solutions
- Questions and Discussion

Introduction and Background

- Formerly Known as "North Lexington Pump Station"
- Largest of 10 Stations in the System
- "Backbone" of the System – 60 Percent of Pumped Flow
- Complete Upgrade in 1993 (23 years ago)
- Located Between On/Off Ramps to Route 95/128 at Route 4/225
- MWRA Sewer Community



Wastewater Pumping Station
Location Plan
Lexington, Massachusetts
BILLERICA
BURLINGTON
WOBURN
WINCHESTER
MEDFORD
ARLINGTON
BELMONT
WALTHAM
LINCOLN
CONCORD
BEDFORD
North Street Pump Station
Marshall Road Pump Station
Main Pump Station
Bedford-Hanscom Force Main
Brigham Road Pump Station
Worthen Road Pump Station
Bowman Street Pump Station
Constitution Road Pump Station
Potter Pond Pump Station
Hayden Avenue Pump Station
Concord Avenue Pump Station
PS
95
4
2
2A
LOWELL STREET
TYLER ROAD
LOCKE LANE
EAST STREET
REDCOAT LANE
WOBURN STREET
MAPLE STREET
BOW STREET
BEDFORD STREET
REED STREET
ELIOT ROAD
OAK STREET
FOLLEN ROAD
HARTWELL AVENUE
YANKEE DIVISION HIGHWAY
WORTHEN ROAD
KENDALL ROAD
BACON STREET
OXBOW ROAD
MASSACHUSETTS AVENUE
MIDDLEBY ROAD
WALTHAM STREET
MARRETT ROAD
CONCORD AVENUE
SCHILLING CIRCLE
WOOD STREET
TINKER LOOP
MARRETT STREET
LINCOLN STREET
SHADE STREET
CONCORD HIGHWAY
N
0
2,000
4,000
8,000
Feet
TAH W:\GIS_Development\Projects\MA\Lexington\MCVME_Presentation2016Sept\MXDs\WW_PumpStations-v3-PPT-Slide.mxd

Existing Pump Station Specifics

Main Wastewater Pumping Station

- Custom, Flooded Suction Type Station
- Two Levels Below Grade (pump room 38 feet below grade)
- Three 150 Hp, Constant Speed Pumps
- Air-cushioned Check Valves
- Dual Wetwells
- Influent Grinding via Channel Grinders
- Flow Measurement via Doppler Flow Meter
- Mission Communication Alarm System

Current Pump Station Flows/Capacity

- 8 mgd (5,500 gpm) Total Flow Capacity
  - Current/Future Average Flow ~ 1.2/1.6 mgd
  - Current/Future Peak Flow ~ 3.9/5.4 mgd

- Pumps Rated at 3,500 gpm at 135 Feet

- Drawdown Testing Results
  - Pump 1 – 3,060 gpm
  - Pump 2 – 2,500 gpm
  - Pump 3 – 2,740 gpm
  - Two in Parallel – 4,800 gpm (pumps 1 and 2)

- Pumps Operate in Lead, Lag, Standby Mode

Future Pump Station Flows/Capacity

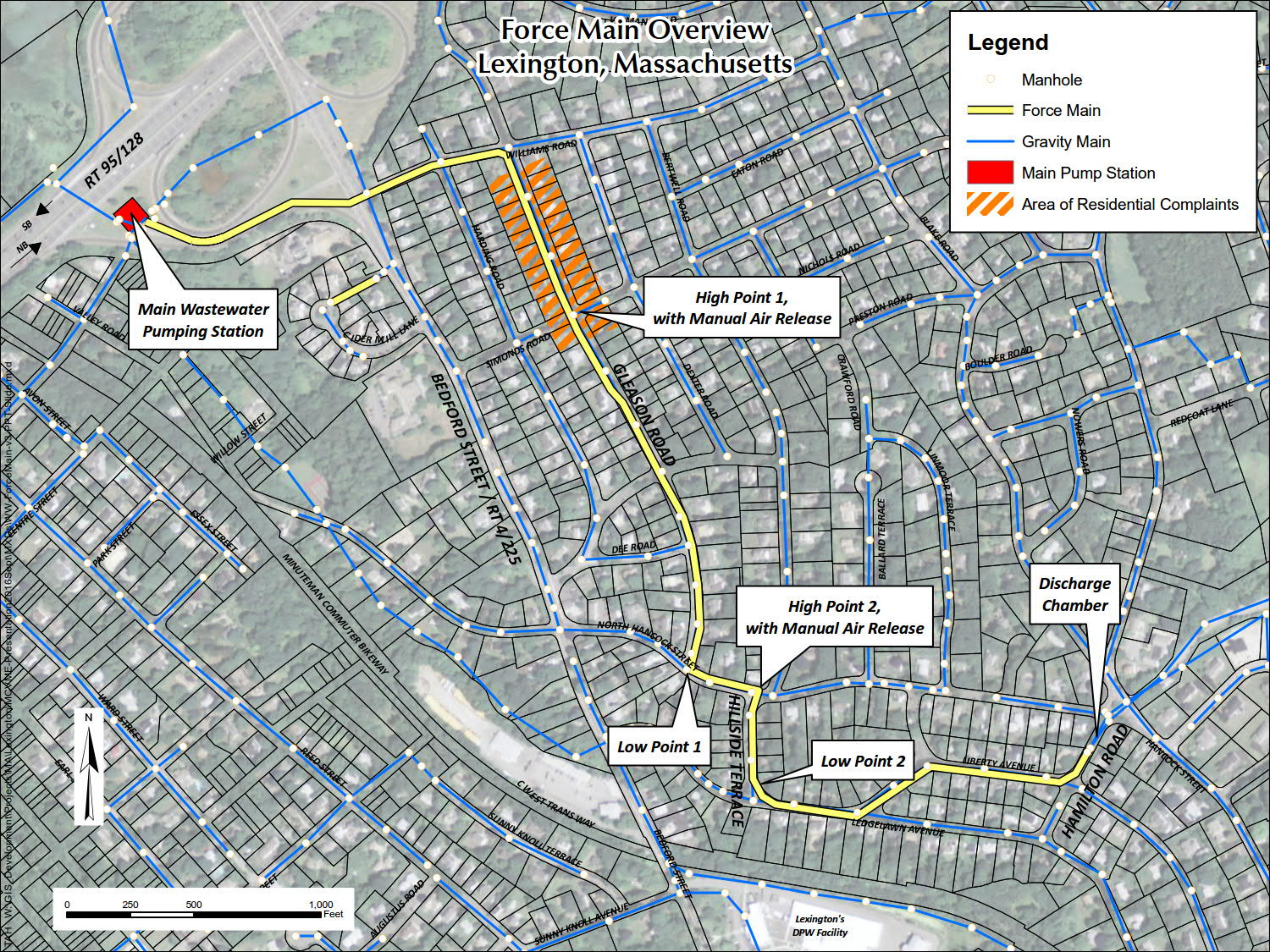
Item	Flow (gpm)
Measured Average Daily Flow	800
Peaking Factor	3.4
Estimated Existing Peak Flow	2,700
Assumed Growth for this PS	37%
Estimated Future Peak Flow	3,700
Pump Capacity	3,500

Force Main Specifics

- 5,850 Linear Feet
- 24-inch Diameter DI Pipe
- Route is Largely Through Residential Neighborhoods
- Discharges to Dual Gravity Sewers on Hamilton Road
- Two Intermediate High and Low Points with Manual Air Release Valves

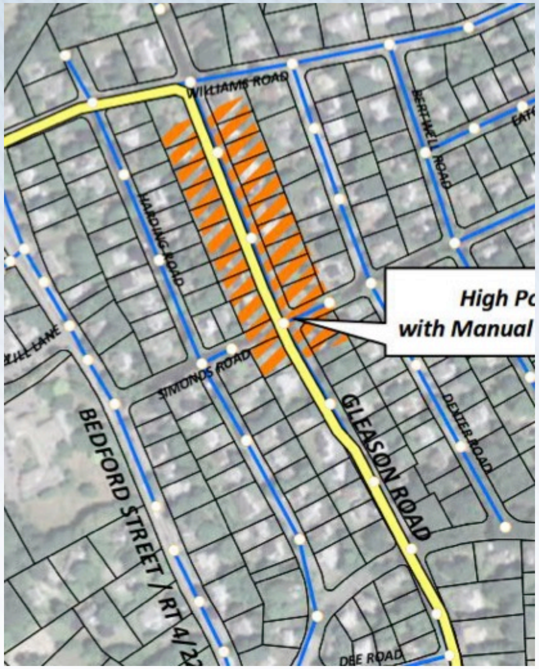
Force Main Discharge Chamber

Force Main Overview
Lexington, Massachusetts



The Problem

- Noises Reported by Residents Along Force Main Route (primarily Gleason Road) – Fall of 2014
- Vibration Reported by Residents
- Noise and Vibration Causing Quality of Life Issues
- Residents Pushed for a Quick Solution



Initial Questions

- Was this a New Condition, or Occurring for Years?
- Was this a Problem Along the Entire FM, or Just Gleason Road Area?
- Was the Existing Force Main at Risk of Imminent Failure?
- How Quickly could the Problem be Addressed?

Initial System Observations

- Noise Associated with Pump Shut-down
- Noise Observed at Discharge Manhole, FM High Points, Homes and at PS discharge piping
- Air Cushioned Swing Check Valves <u>not</u> "Slamming" Shut
- No "Soft Starts or Stops"
- Air Release Blow-offs at FM High Points were Manually-Operated Valves with Drain Piping

Force Main Discharge Video

- Video of Force Main Discharge Prior to Implementing any “Fix" (February 2015)

Evaluations and Solution Implementation

1. Develop Immediate Solutions to Minimize Noise to Residents

2. Identify and Evaluate Longer-term Solutions
   - Including Hydraulic Transient Analysis (Modeling) for Surge Protection

3. Condition Assessment of Existing FM System
   - Town Performed Acoustic Testing of System

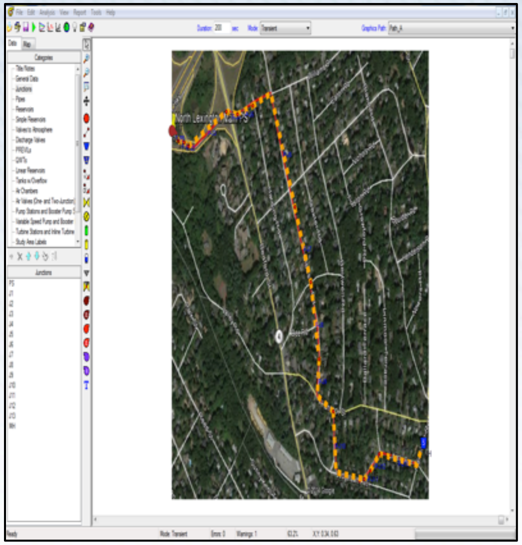
- Design, Bid and Construct Long-term Solutions

Hydraulic Transient Analysis

- Transient Pressures Could Cause Damage or Force Main Failure and Contribute to Noise/Vibrations

- Computer Model Developed and Run for Different Scenarios

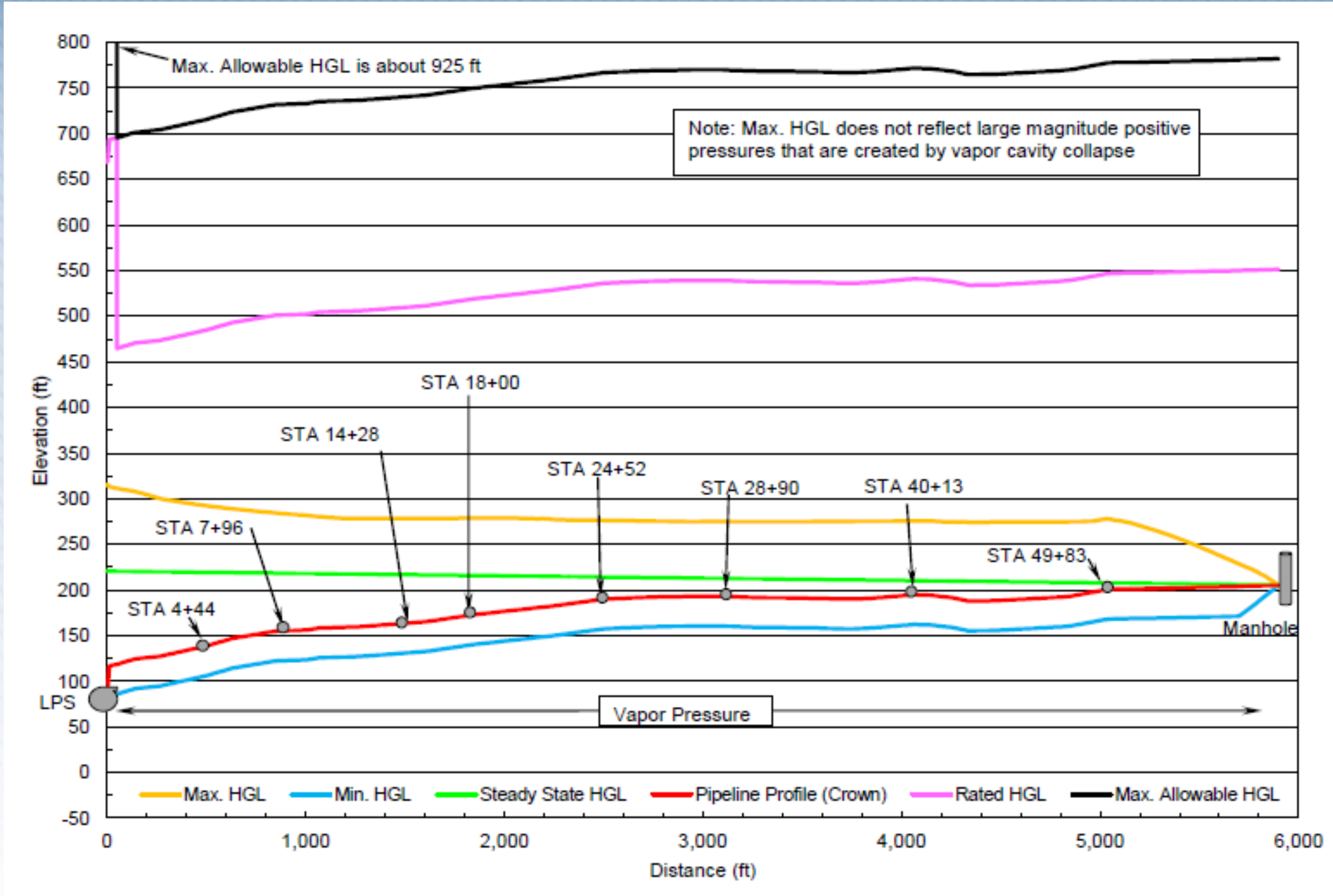
  1. Planned Pump Shut-down (similar to power failure)
  2. Power Failure
  3. Pump Start-up



Transient Modeling Results

- Following Planned Pump Shut-down, a Rapid Drop in Flow Rate and Pressure Results, Causing a Low Pressure Wave (drop)
- Low Pressure Wave Propagates out from Station to Discharge Chamber
- Minimum HGL (Elevation) was shown to Drop Sufficiently to Create Vapor Pressure throughout Force Main
- Repressurization of the Force Main by Flow Reversal (Water Hammer Wave Reflection) Causes Vapor Cavities to Collapse and Produce Significant Positive Pressures that can Damage Piping and Contribute to Noise/Vibration

Pump Shutdown without Surge Protection and Air-Vacuum Control



Surge Control Alternatives Modeled

- Strategy 1
  - Install Eight Air-Vacuum Relief Valves on the FM
  - Install Surge Relief Valve on the Discharge Header at PS

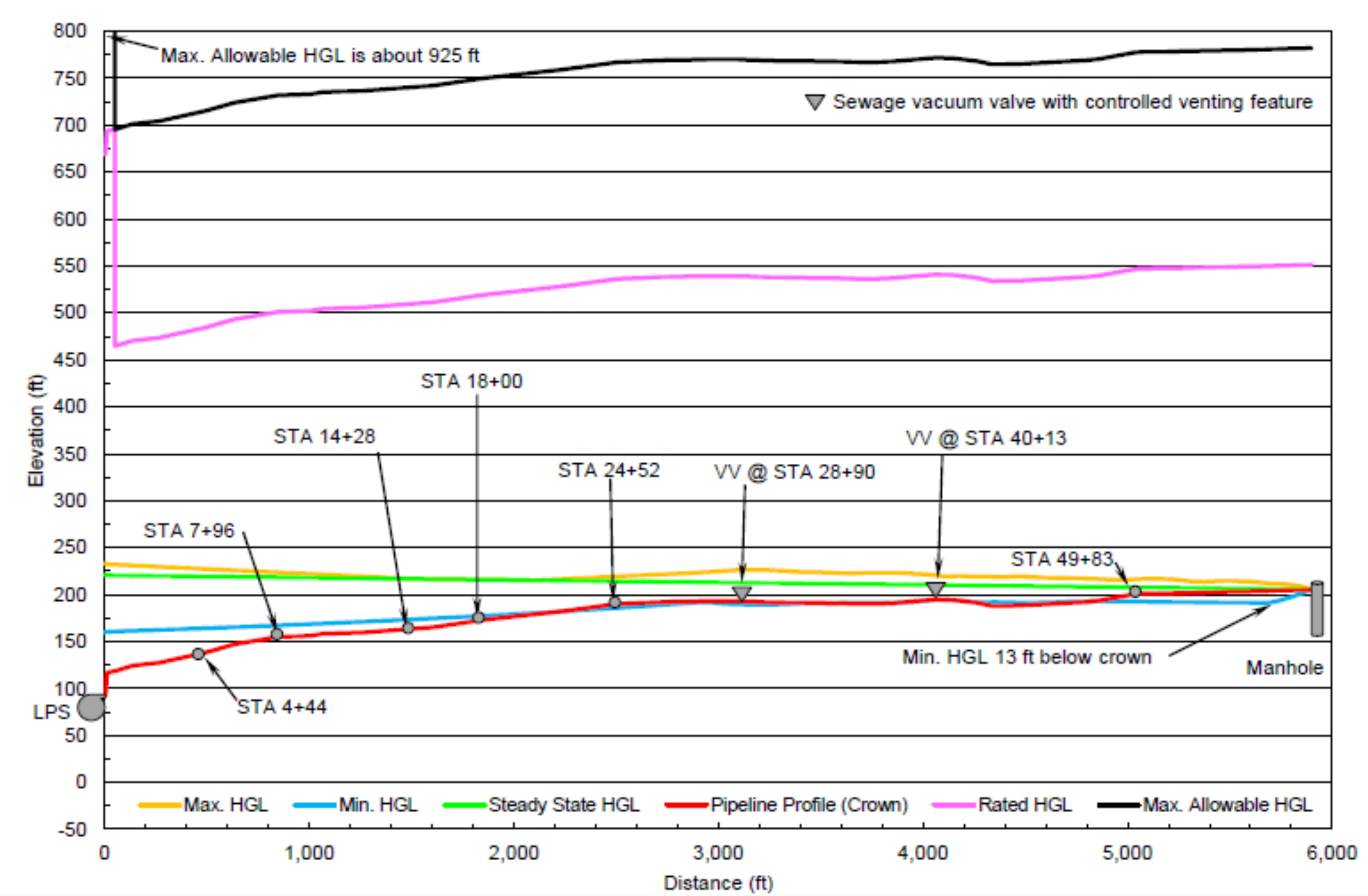
- Strategy 2
  - Install 2.5-foot Diameter Flywheel on Each Pump/Motor Unit
- Strategy 3
  - Install a 396 ft^3 (2,960 gallon) Surge Tank at the Pump Station
  - Install Two Air-Vacuum Relief Valves on the FM
  - Install Bottom-Mounted Dashpot, "Oil-Cushioned" Check Valves

Modeling Summary

- Strategy 1 (air-vacuum relief valves)
  - Least Effective at Attenuating Pressure Waves and Noise
  - Requires High Level of Maintenance
- Strategy 2 (flywheels)
  - Moderately Effective at Attenuating Pressure Waves and Noise
  - Harmonic Issues if Installed with VFD's
- Strategy 3 (surge tank)
  - Most Effective at Attenuating Pressure Waves and Noise
  - Replacement of Manual Air Release Valves with Automatic Air/ Vacuum Relief Valves
  - Replace Air-Cushioned Check Valves with Oil-Cushioned Type

Note – Installation of VFD's are not a Solution for Surge Protection

Pump Shutdown with Pressurized Surge Tank and Air-Vacuum Control



Force Main Condition Assessment

- Considered Several Techniques:
  - CCTV Inspection of Force Main
  - Excavate Piping, Cut-out Coupons, Visual Inspection, Thickness Testing and Soils Testing
  - Smart Ball® Force Main Assessment
    - Pipe Wall Assessment
    - Leak and Gas Pocket Detection
  - Pigging – Standard and Ice-pigging

  - Combination of Techniques

Force Main Condition Assessment Challenges

- CCTV Preferred but Not Feasible Due to:
  - Inability to By-pass Pump Current Flow
  - Time between Pump Starts
  - Only Partial Inspection from Discharge End (not critical area)

- Excavation and Destructive Testing
  - "Snapshot" of the Force Main
  - Concerns About Cutting into Pipe

- Conventional Pigging – concerns About Getting Pig "Stuck"

- Ice Pigging – High Cost; Small Segment; Concerns about Pigging Effectiveness

Force Main Condition Assessment - Approach

- Perform Testing During Construction of Longer-Term Solutions
  - At both FM Relative High Points – UT Pipe and Soils Testing
  - Check FM Pipe Thickness (Pipe Coupon) During Installation of Automatic Air-Vacuum Valves
- Perform Smart Ball® Testing of entire FM

Smart Ball® Testing

- Collected Acoustic and Pipe Wall Assessment Data (Magnetic Changes)

- Sensors (4)Located Along Force Main for Tracking
- Ball Records Flow Velocity Through System
- Continuous and Constant Flow During Test
- No Air Pockets, Identified 19 Anomalies (small-medium)
  - Recommended to Excavate and Assess FM at 4 Locations

Solutions Implemented

- Immediate (Emergency) Solutions
  - Install VFD on Pump No. 2 – Created “soft start/stop
    - Immediate Positive Affect
  - Communicate Weekly with Residents
  - Run Pumps at Full Speed Occasionally to Flush FM

- Longer-Term Solutions
  - Install Surge Tank on Force Main Header at PS
  - Install New Automatic Air-Vacuum Valves on FM
  - Install New Oil-Cushioned Check Valves
  - Install VFD’s and New Motors on all Pumps
  - Install New Control System
  - Install New Pig-Launch Assembly at PS

Solution Implementation Timeline

- Immediate Solutions – January/February 2015
- Longer-Term Solutions
  - **Hydraulic Transient Analysis**
    January–March 2015
  - **Design (Plans & Specifications)**
    March-June 2015
  - **Bidding** – July/August 2015
  - **Construction** - September 2015 – September 2016
    - Equipment Procurement – September 2015 – May 2016
    - Construction – May – September 2016

Project Costs

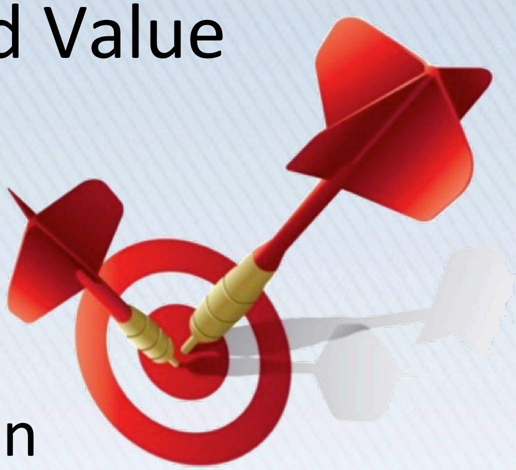
- Immediate Solutions - $95,000
- Longer-Term Solutions
  - Construction (GC) - $1,316,000
  - Engineering & Admin. Costs - $357,000
- Total Project Cost - $1,798,000

Other Project Challenges

- Resident Communications and Coordination
- Immediate Solution Timeframe
- Additional Items During Construction
  - Line Stop and Valve Required
  - HVAC Additions
  - Emergency Lighting Updated
  - Mission Alarm System Improvements

Project Outcome

- Immediate Solutions and Resident Communication were Critical
- Hydraulic Transient Modeling Provided Value
- Longer-Term Solutions
  - VFD's and Controls – in Operation
  - Check Valves – in Operation
  - FM Air and Vacuum Valves – in Operation
  - Surge Tank – Ready, but not yet in Operation
  - Pig Launch – Ready for Use



Emergency VFD Installation

Force Main Air-Vacuum Valves and Drains

Force Main UT Testing

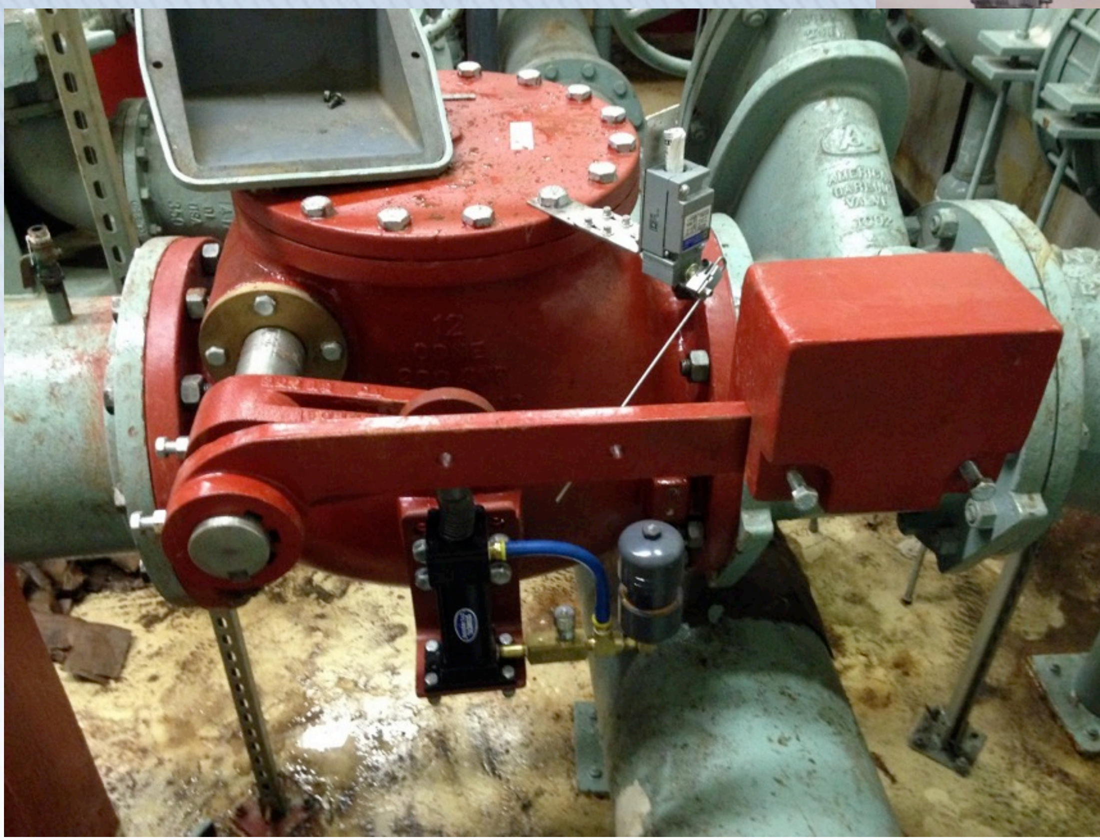
Force Main UT Testing

Smart Ball Testing

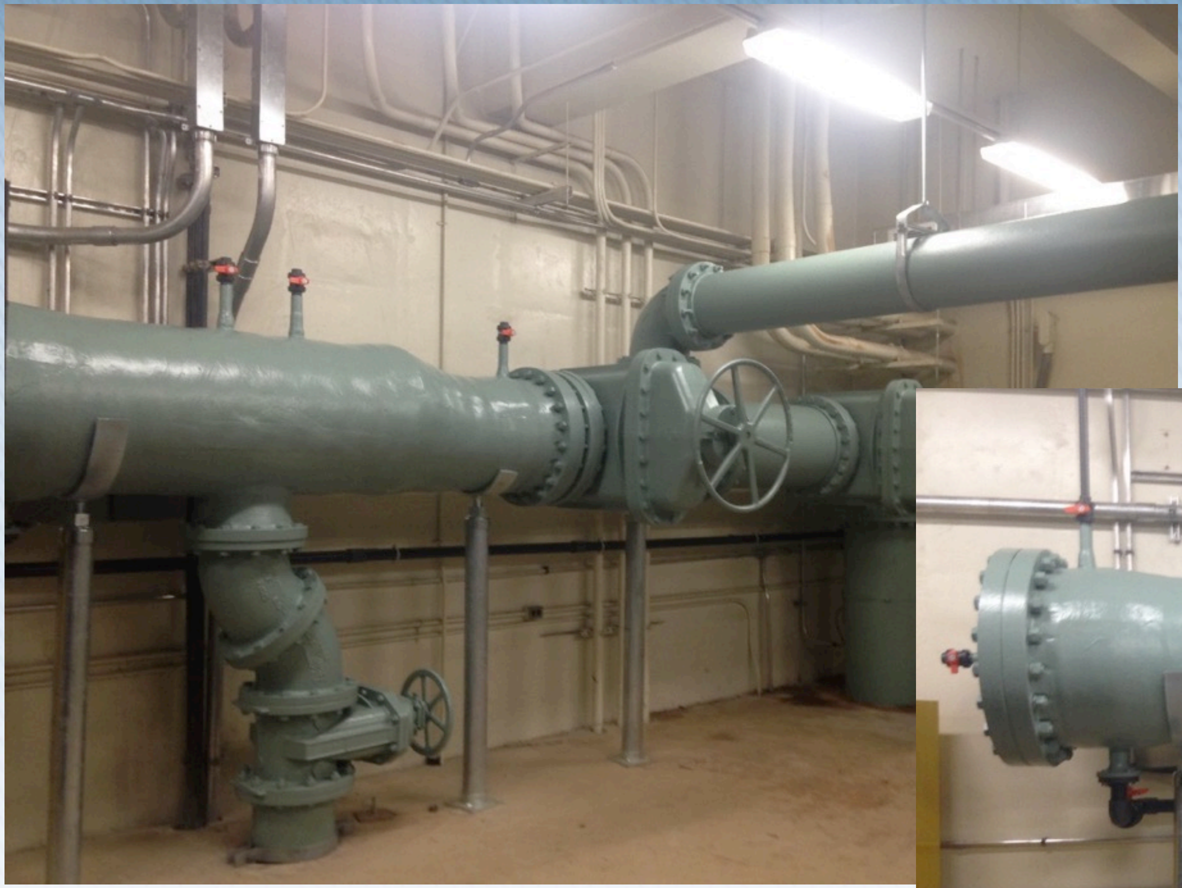
Pump Station Surge Tank

Pump Station Controls

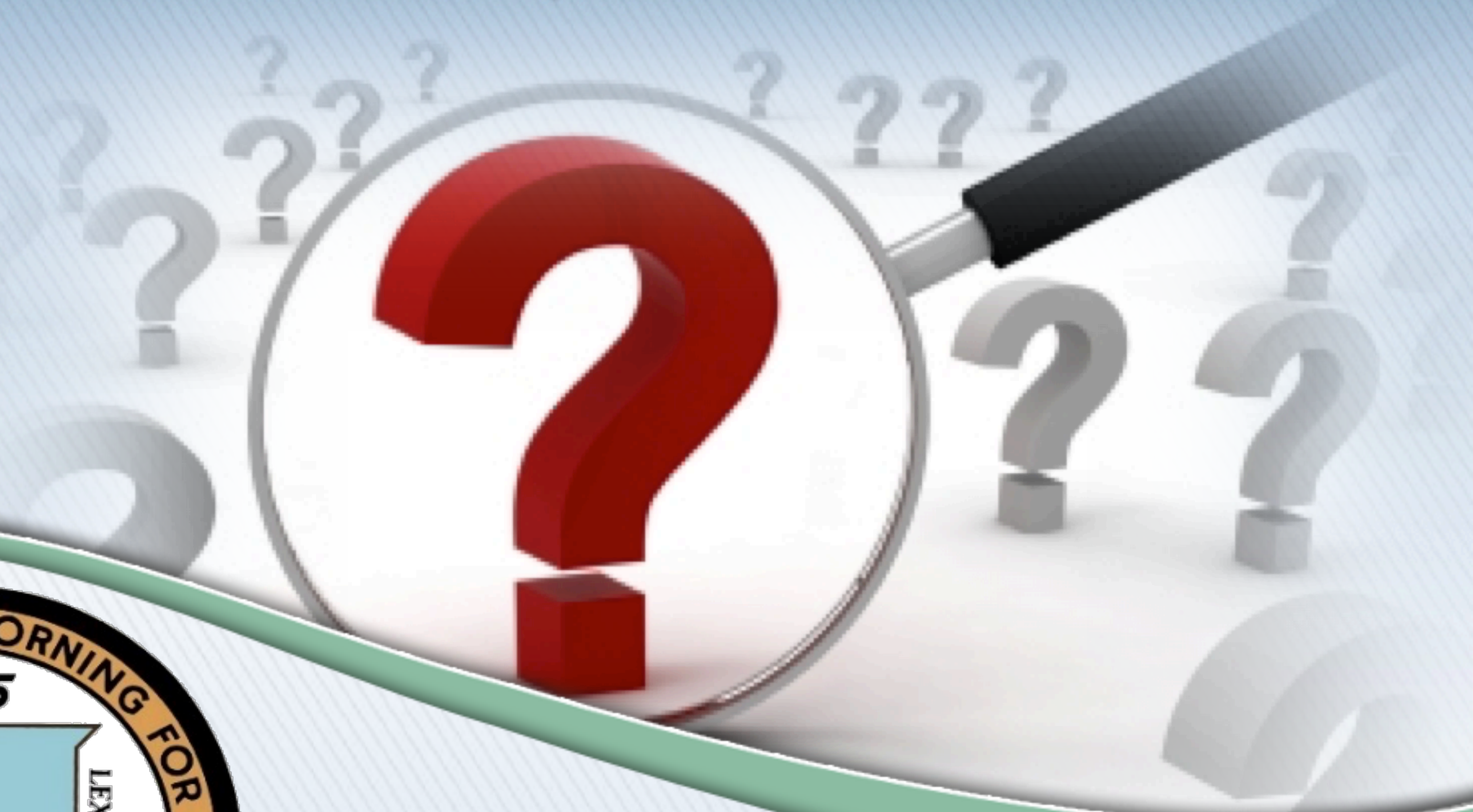
Pump Station Oil-Cushioned Check Valves



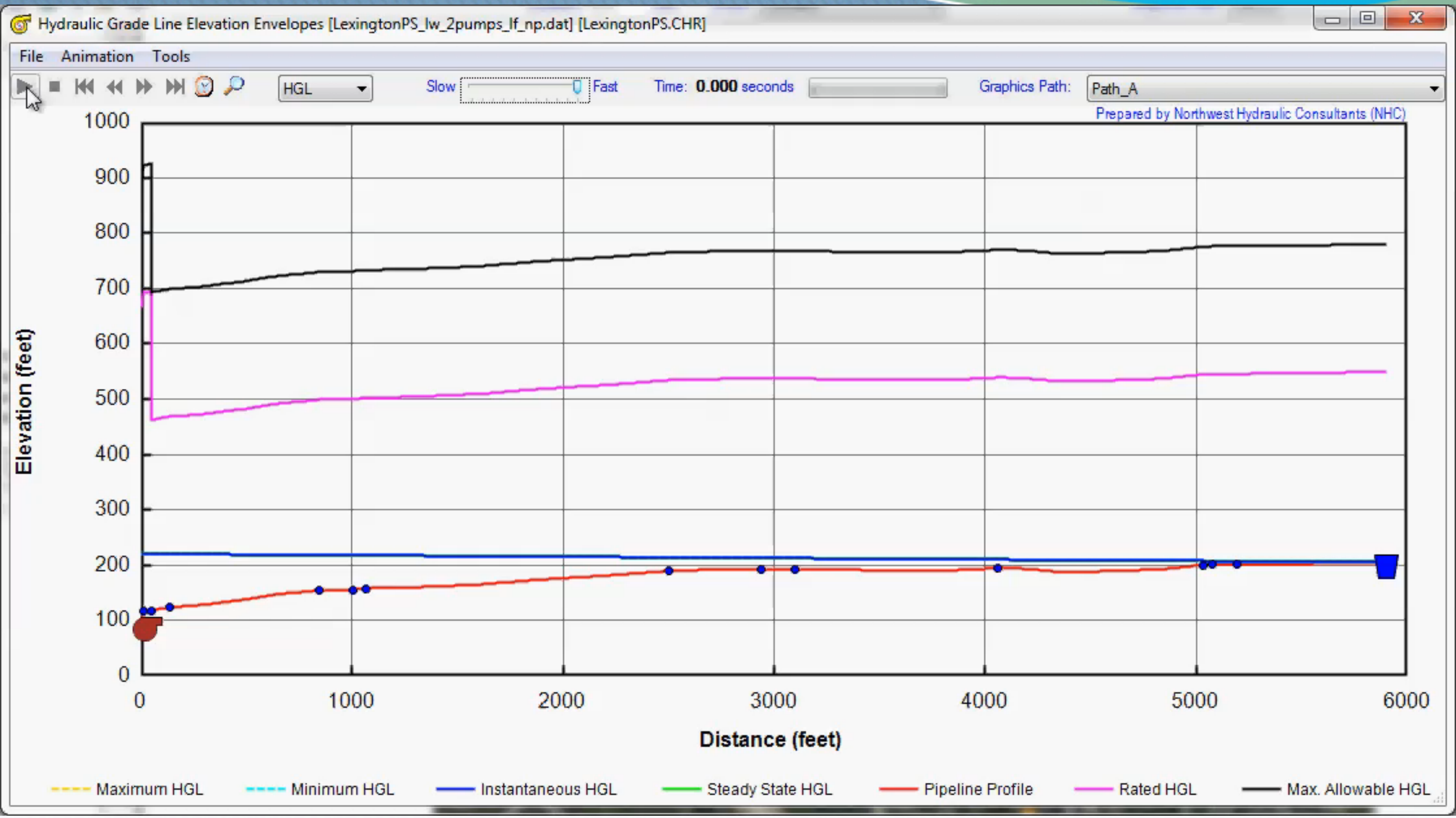
Pump Station Pig Launch



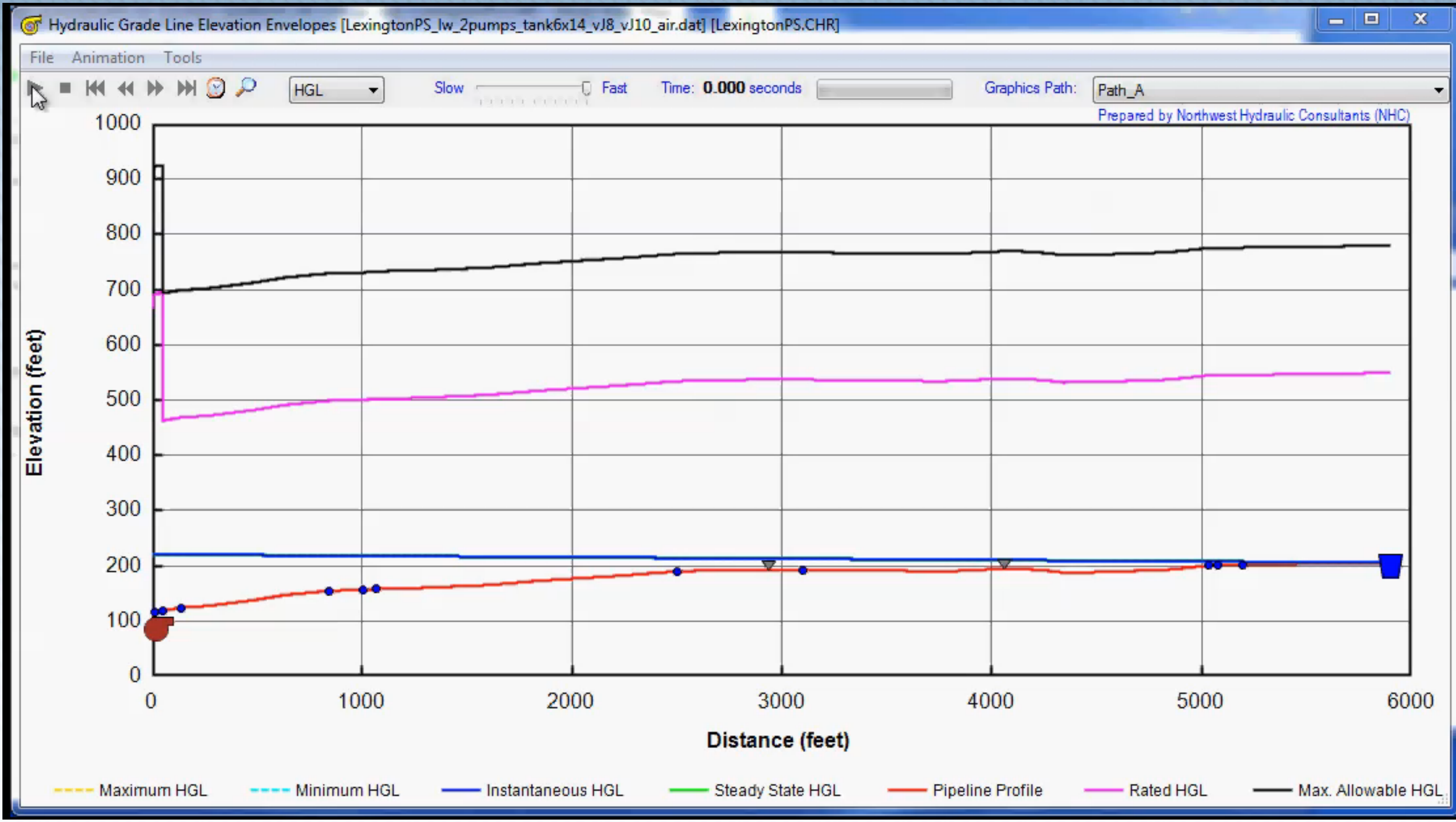
Questions / Discussion



Power Failure without Surge Protection (Movie)



Power Failure with Pressurized Surge Tank (Movie)



Pump Station Force Main Line Stop and Valve