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ASSOCIATES
Consulting Engineers

TECHNICAL MEMORANDUM

DATE:	August 1, 2018	Project No.: 693-20-16-01 SENT VIA: EMAIL
TO:	SRWA Technical Advisory Committee	
FROM:	Polly Boissevain, R.C.E. #36164 Dakari Barksdale, R.C.E. #87542	
REVIEWED BY:	Gerry Nakano, RCE #29524	
SUBJECT:	Regional Surface Water Supply Project - Finished Water System Surge Analysis	

The purpose of this Technical Memorandum (TM) is to detail the hydraulic water system model setup, and report the results of the Regional Surface Water Supply Project (Project) finished water system transient analysis. The Turlock finished water system conveys water from the Regional Water Treatment Plant (WTP) clearwell to the Turlock terminal tank. Similarly, the Ceres Finished Water System conveys water from the WTP to the Ceres terminal tank.

The Turlock finished water pipeline includes a total of approximately 41,000 linear feet (LF) of 42-inch diameter cement mortar lined and coated steel pipe from the WTP to the Turlock terminal tank. The Ceres finished water pipeline includes a total of approximately 29,000 LF of 30-inch diameter cement mortar lined and coated steel pipe from the WTP to the Ceres terminal tank.

Hydraulic transients are generated in a water transmission/distribution system any time changes in flow and corresponding changes in velocity occur within the system. Hydraulic transients are generated under normal operating conditions due to sudden operational changes, such as pump starts and stops, valve opening or closing, hydrant operations, or due to unanticipated operations, such as pump station power failure or a water main break. Transients propagate through the water system at the speed of sound, about 3,600 feet/second. The pressure changes associated with transients can be quite large compared with normal operating pressures. For normal system operations, transients can be controlled by making slower changes in operations. For uncontrolled operational conditions, mitigation must be incorporated into facility design.

West Yost evaluated the Project finished water system using a model specifically developed for this transient analysis. The transient analysis uses the InfoSurge® software module, which runs within the InfoWater® modeling software package. InfoSurge® is a software analysis tool that uses the University of Kentucky surge analysis code, which has been widely used for many years for hydraulic transient analysis. The InfoSurge® software uses hydraulic information defined within the InfoWater® model, along with additional information needed for the hydraulic transient analysis to evaluate hydraulic transient scenarios. For the Project finished water system, the primary concerns are: 1) a low-pressure event and water column separation following an abrupt power failure at the raw water pump station, and the subsequent high-pressure surge that would occur when the water column rejoins within the pipeline; and, 2) maintaining pressurized flow in the pipeline to meet regulatory requirements and avoid potential pathogen intrusion.

This TM covers the following information:

- Modeling Assumptions
- Analysis Criteria
- Model Scenarios and Results
- Recommended Mitigation

MODELING ASSUMPTIONS

The Project finished water pipeline is 42-inches in diameter to Turlock and 30-inches in diameter to Ceres. Figure 1 shows the approximate location of the water treatment plant, finished water pipelines and terminal tanks. The following information was used to define facilities associated with Project:

- Clearwell Water Surface elevation of 114 feet and Finished Water Pump Station Elevation of 107 feet based on preliminary HGL profile figure provided in the pre-design TM prepared by Trussell Technologies, Inc.;
- Pipeline Elevations – based on survey data;
- Finished Water Pumps are all assumed to operate with variable frequency drives (VFDs);
- Turlock Finished Water Pump Station Phase 1 pre-design point of 3,500 gpm at 92 feet total dynamic head (TDH). Three pumps will be initially installed as part of the Project (two duty pumps, one standby);
- Turlock Finished Water Pump Station Buildout pre-design point of 3,500 gpm at 142 feet TDH. Four additional pumps will be installed in the future to meet buildout of the Project (six duty pumps, one standby);
- Ceres Finished Water Pump Station Phase 1 pre-design point of 3,500 gpm at 83 feet TDH. Two pumps will be initially installed as part of the Project (one duty pump, one standby);
- Ceres Finished Water Pump Station Buildout pre-design point of 3,500 gpm at 132 feet TDH. Two additional pumps will be installed in the future to meet buildout of the Project (three duty pumps, one standby);
- The Finished Water Pump Station Generator(s) are assumed to start up 10 seconds following power failure based on information from A T.E.E.M. Simultaneously, with the generator start, the first pump starts and ramps up to full speed in 30 seconds.

Each subsequent pump also ramps up to full speed in 30 seconds, however, there is a 30 second lag period before the next pump starts, see Figure 2;

- Wave speeds – assumed wave speed of 3,840 feet per second, based on pipeline materials and diameters;
- Hazen-Williams C-value is assumed to be 140 based on AWWA M-11 Steel Pipe – A Guide for Design and Installation;
- Terminal Tank bottom elevations assumed to be 117.1 feet and 108.7 feet for Turlock and Ceres, respectively, based on preliminary information from the design team. The water surface elevation was modeled as 10 feet above the terminal tank bottom elevations; and,
- Altitude valves supplying the tanks assumed to have sustaining feature, which maintains a pressure of 35 psi (80.9 feet) above the terminal tank bottom elevation, based on input from the Technical Advisory Committee at the May 26, 2016 Hydraulic Modeling Workshop #1. The assumed HGL for Turlock and Ceres sustaining valves is 198 and 190 feet, respectively.

ANALYSIS CRITERIA

Vacuum conditions and high-pressure surge are the risks associated with a power failure at the Finished Water Pump Station. The Finished Water System was evaluated to assess the potential for vacuum or low-pressure conditions to occur, which would require incorporating surge protection into the pipeline design. Since this is a finished water transmission system, the State Water Resources Control Board, Division of Drinking Water has discretion to require issuance of a boil water notice should system pressure drop below 5 psi (SWRCB, DDW, 2018). Therefore, a minimum pressure of 10 psi was used for the analysis. Although steel pipeline has a surge allowance of 150 percent of design pressure, mitigation for low pressures will reduce highest pressures to close to those seen under normal operating conditions.

MODEL SCENARIOS AND RESULTS

A pre-design transient analysis was performed to assist in determining the required mitigation measures to reduce the impacts caused by pressure surges and low pressure. Two different scenarios were developed and evaluated:

- Phase 1 design flow condition of 15 million gallons per day (mgd)
  - Turlock: 10 mgd flowing to Turlock terminal tank
  - Ceres: 5 mgd flowing to Ceres terminal tank
- Buildout design flow condition of 45 million gallons per day
  - Turlock: 30 mgd flowing to Turlock terminal tank
  - Ceres: 15 mgd flowing to Ceres terminal tank

Results for each of the scenarios are summarized on the next page.

Scenario 1 – Phase 1 Finished Water Pump Station Power Failure

Turlock

Power failure at the Turlock Finished Water Pump Station was evaluated with the pump station operating at its design flowrate of 10 mgd. With no mitigation, the entire pipeline drops to full vacuum conditions following power failure. Therefore, a hydropneumatic surge tank is recommended. The surge tank provides flow to the system until the generator starts and the pumps turn on one by one. Figure 3 shows the pressure at the pump station discharge header with a hydropneumatic surge tank, sized at 15,000 gallons. Immediately, after power failure, the pressure drops and continues to decrease until the generator comes on and the pumps turn on one by one. The 15,000-gallon size is required, both to sustain flow until the pumps re-start, and to maintain 10 psi at the pipeline high point elevation of 141 ft.

Figure 4 shows the surge tank air volume response following the power failure, with time, in seconds shown on the x-axis, and air volume, in cubic feet (ft^3) shown on the y-axis. The tank has an initial air volume of 1,300 ft^3 (9,700 gallons. Following pump station power failure, which occurs at 11 seconds into the simulation, water is supplied to the system from the surge tank, increasing the air volume in the tank, with a maximum air volume of 1,765 ft^3 (13,200 gallons). It is recommended that the surge tank be 15 percent larger than the maximum air volume, so the tank is not fully evacuated; a 15,000-gallon surge tank is recommended. Thus, the recommended operating air volume to total volume ratio is 65 percent. Figure 5 shows the minimum and maximum HGL and pressures that occur in the pipeline following the power failure.

Ceres

Power failure at the Ceres Finished Water Pump Station was evaluated with the pump station operating at its design flowrate of 5 mgd. Figure 6 shows the pressure at the pump station discharge header following pump station power failure, with a 9,000-gallon tank. The 9,000-gallon size is required, both to sustain flow until the pumps re-start, and to maintain 10 psi at the pipeline high point elevation of 141 ft. Figure 7 shows the surge tank air volume response, with an initial air volume of 800 ft^3 (6,000 gallons) and a maximum air volume of 1,027 ft^3 (7,700 gallons). Figure 8 shows the minimum and maximum HGL and pressures that occur in the pipeline following the power failure.

Scenario 2 – Buildout Finished Water Pump Station Power Failure

Turlock

Power failure at the Turlock Finished Water Pump Station was evaluated with the pump station operating at its full, anticipated design flowrate of 30 mgd. Figure 9 shows the pressure at the pump station discharge header following pump station power failure, with a 62,000-gallon surge tank. Figure 10 shows the surge tank air volume response, with an initial air volume of 4,250 ft^3 (31,800 gallons) and a maximum air volume of 7,220 ft^3 (54,000 gallons). Figure 11 shows the minimum and maximum HGL and pressures that occur in the pipeline following the power failure.

Ceres

Power failure at the Ceres Finished Water Pump Station was evaluated with the pump station operating at its full, anticipated design flowrate of 15 mgd. Figure 12 shows the pressure at the pump station discharge header following pump station power failure, with a 20,000-gallon surge tank. Figure 13 shows the surge tank air volume response, with an initial air volume of 1,400 ft^3 (10,500 gallons) and a maximum air volume of 2,320 ft^3 (17,400 gallons). Figure 14 shows the minimum and maximum HGL and pressures that occur in the pipeline following the power failure.

RECOMMENDED MITIGATION

It is recommended that surge tanks be installed to maintain a 10 psi minimum pressure in the finished water system following pump station power failure when operating at design conditions. In Phase 1, a 15,000-gallon surge tank volume with a 65 percent air volume ratio is recommended for the Turlock Finished Water System. A 9,000-gallon surge tank volume with a 70 percent air volume ratio is recommended for the Ceres Finished Water System.

At Buildout, the recommended surge tank volumes increase to 62,000 gallons and 20,000 gallons for Turlock and Ceres respectively. A 50 percent air volume ratio is recommended for both surge tanks at buildout. The surge tank volumes can be met with individual tanks or multiple tanks.

Tank sizes are based on preliminary design points as determined in the pre-design TM’s, and reasonable, conservative values for generator and pump re-start and ramp-up speeds following a power failure at the pump station, to make sure that adequate space is reserved for the surge tanks.

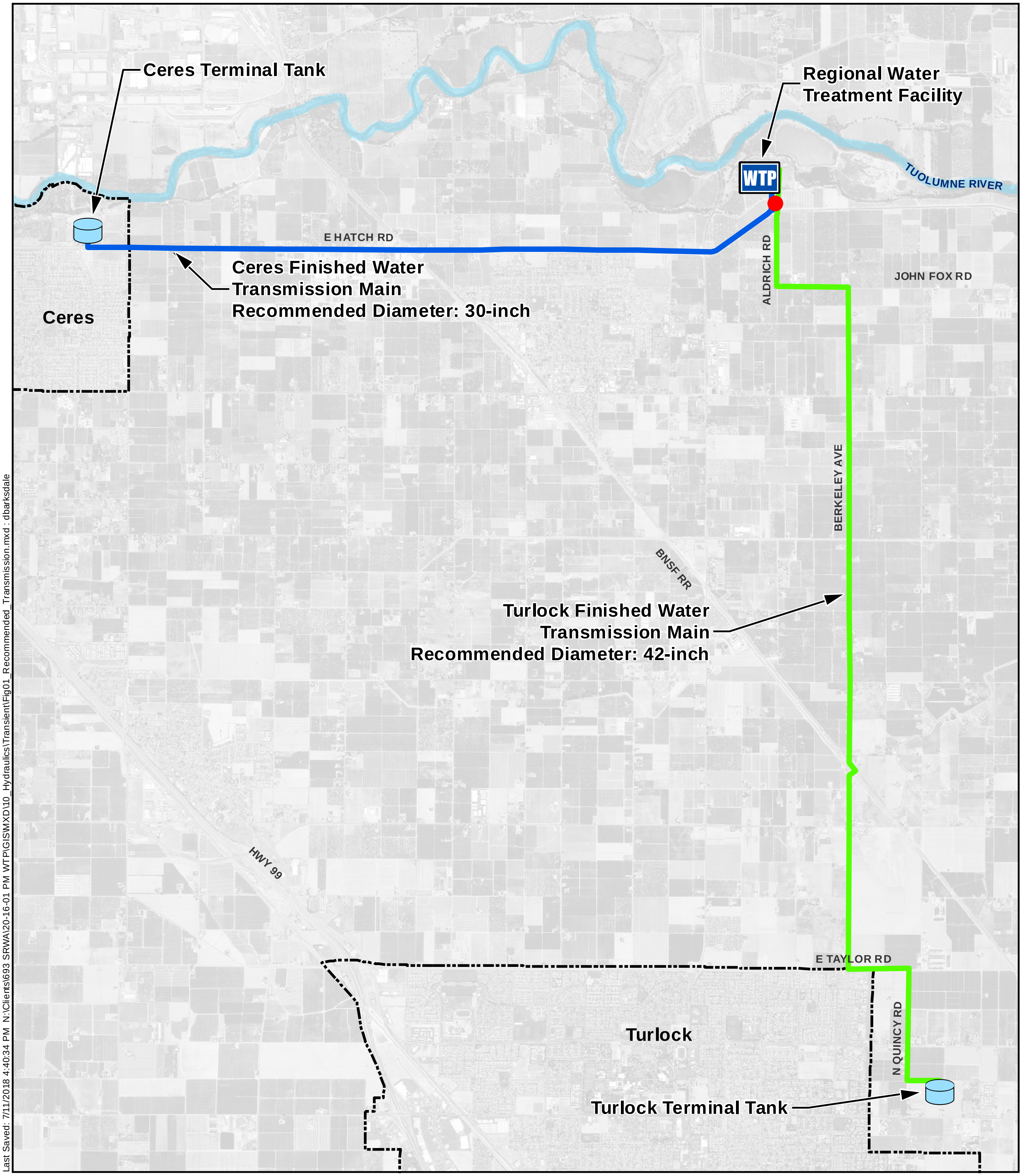
Tank sizes are dependent upon factors, including generator and pump selections, pump ramp up times and elevation changes along the pipeline. It is anticipated that the design-build team will optimize tank sizes based on specific pump and generator equipment selections and anticipated ramp up speeds, provided that 10 psi can be maintained in the finished water system. Options that could be considered include: selecting a range of pumps to meet the anticipated range of flow conditions, with larger pumps re-started first at higher flowrates; re-starting more than one pump simultaneously, when operating at higher flowrates; or ramping pumps up to full speed more quickly.

Depending on the design configuration of suction piping at the pump stations, the designer should also evaluate the need for pressure relief valves on the suction side of the pump station to maintain positive system pressure.

REFERENCES

State Water Resources Control Board, Division of Drinking Water, 2018. Unsafe Water Notification Guidance. April 2018. Accessed at:

https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/notices/PWS%20etc%20Unsafe%20Water%20Guidance.pdf



WTP Regional Water Treatment Facility

Tank

Alignment High Point (141 feet)

Turlock Finished Water Transmission Main

Ceres Finished Water Transmission Main

N

0 2,500 5,000

Scale in Feet

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Figure 1

Finished Water Facilities Locations

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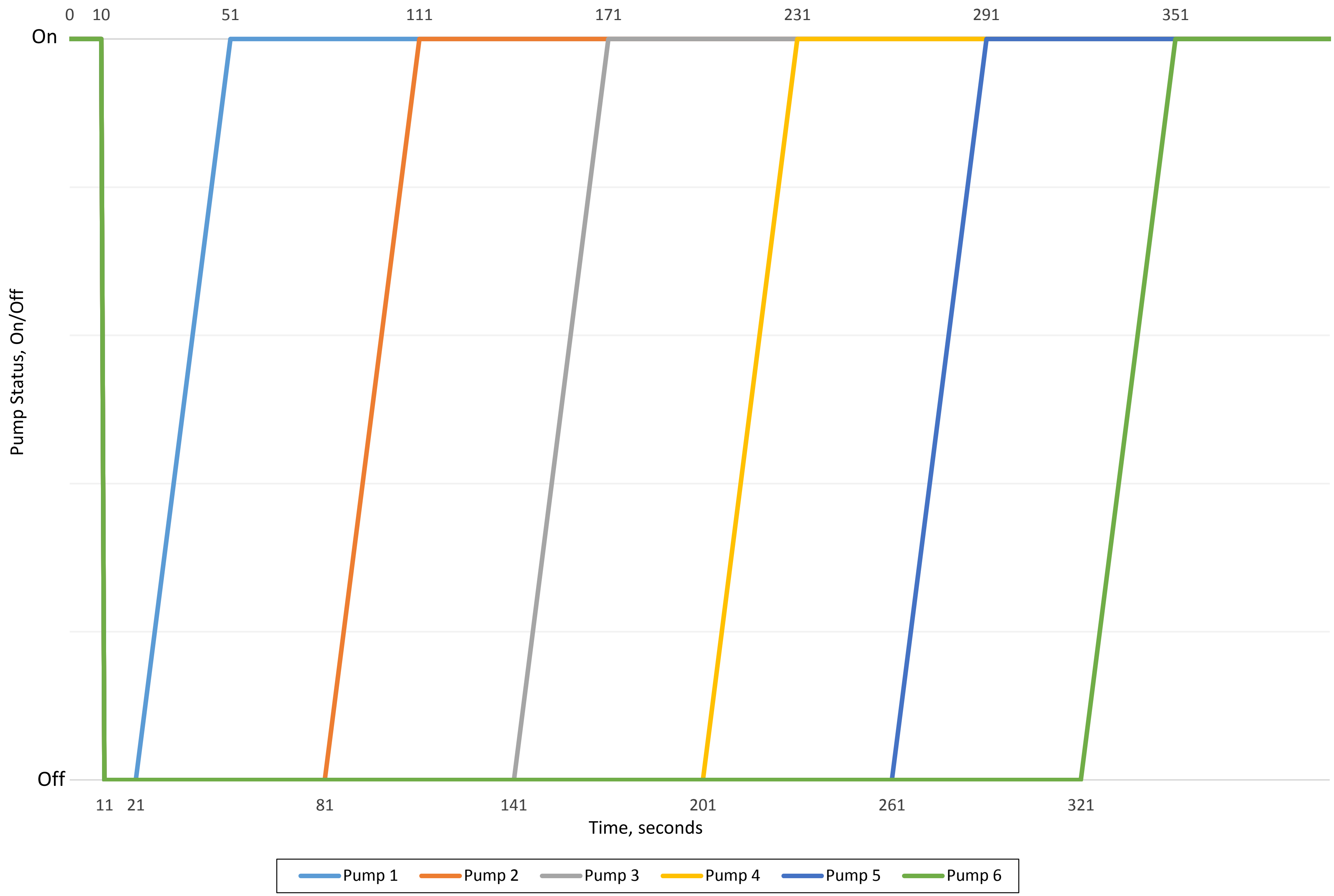
Surface Water Supply Project

Figure 2. Pump Trip and Restart Times



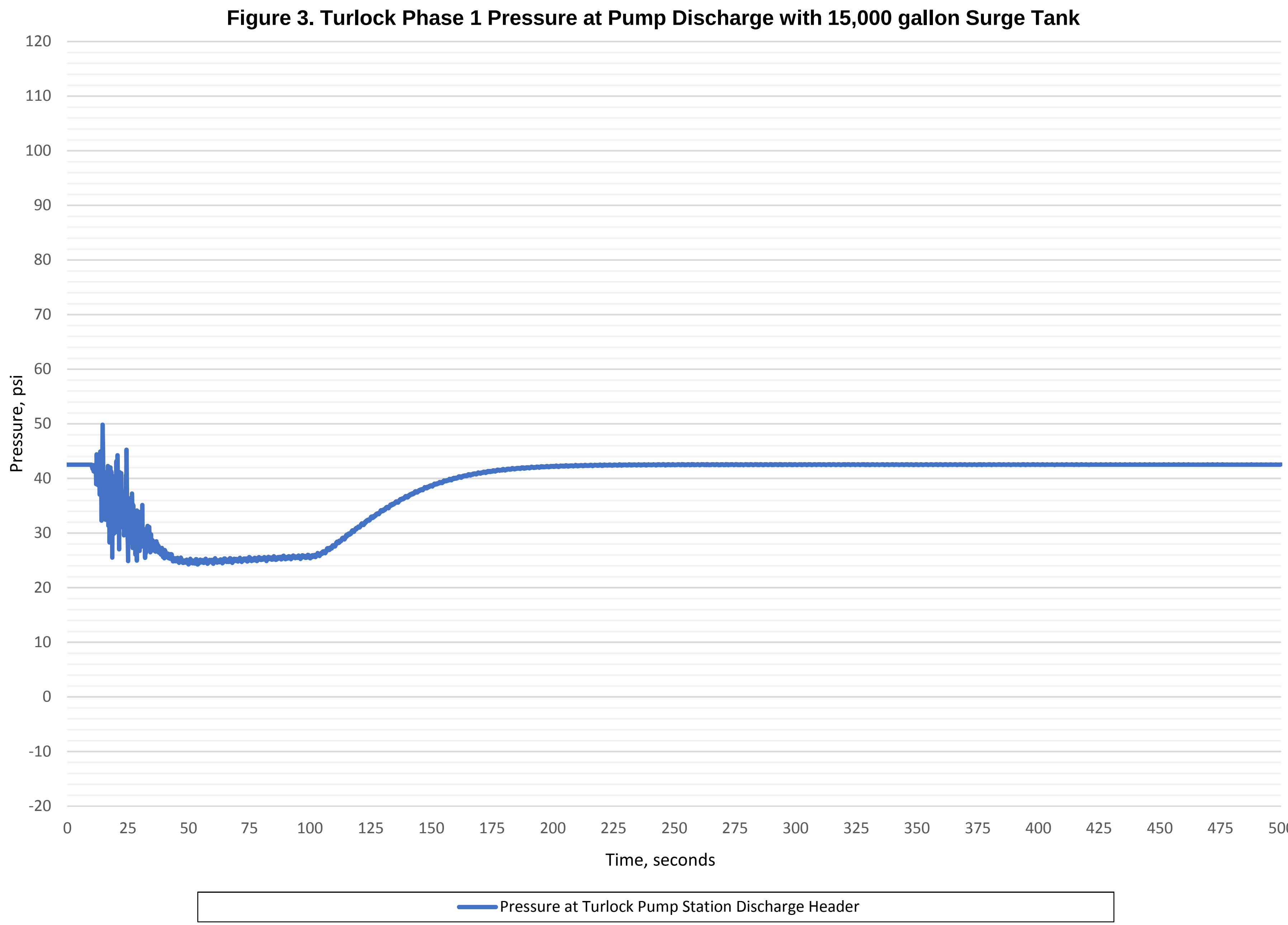
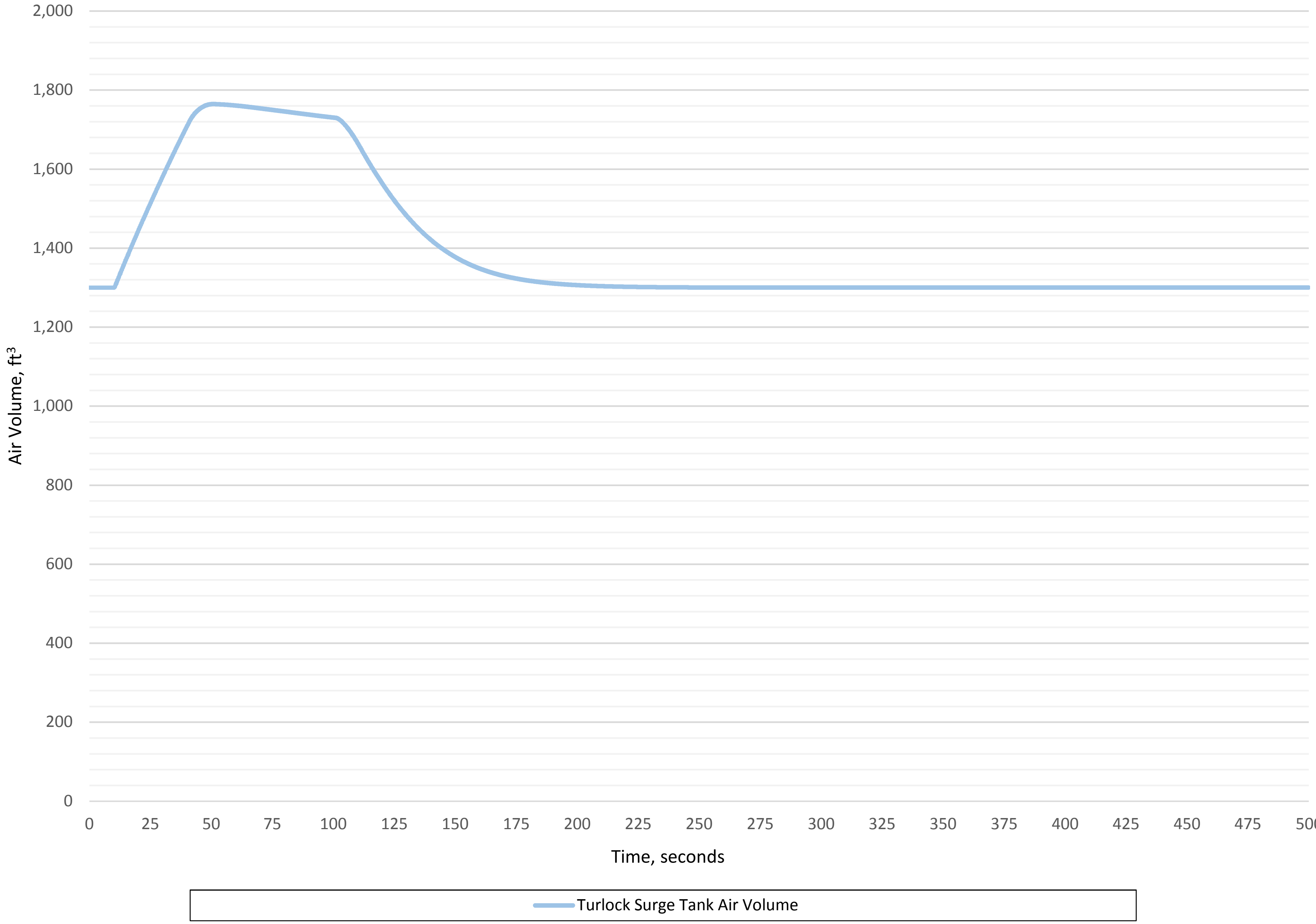
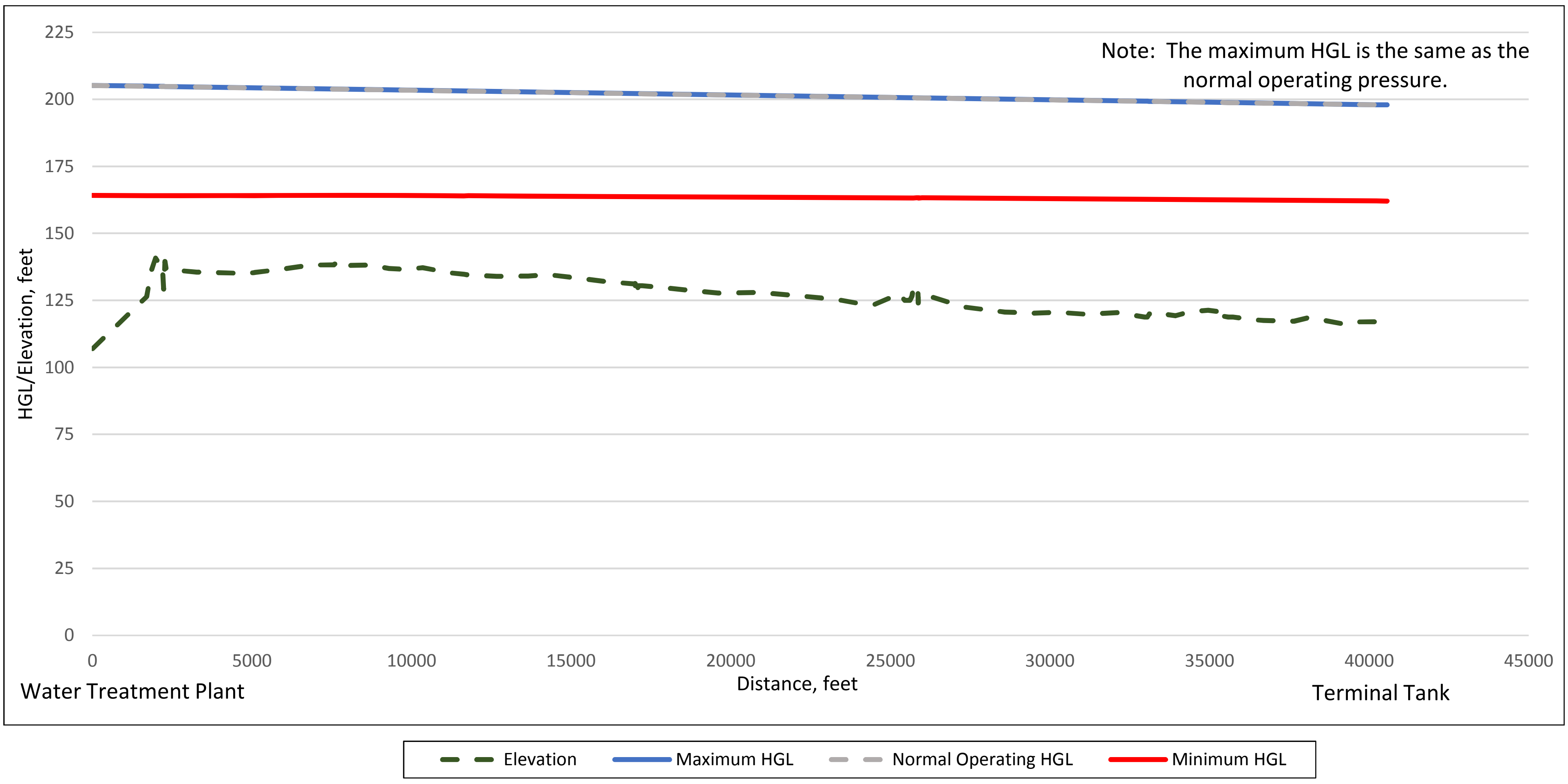


Figure 3. Turlock Phase 1 Pressure at Pump Discharge with 15,000 gallon Surge Tank
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
Pressure, psi
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
Time, seconds
Pressure at Turlock Pump Station Discharge Header

Figure 4. Turlock Phase 1 Surge Tank Air Volume (15,000 gallon Tank)



Turlock Phase 1 Hydraulic Grade Line Profile



Turlock Phase 1 Pressure Profile

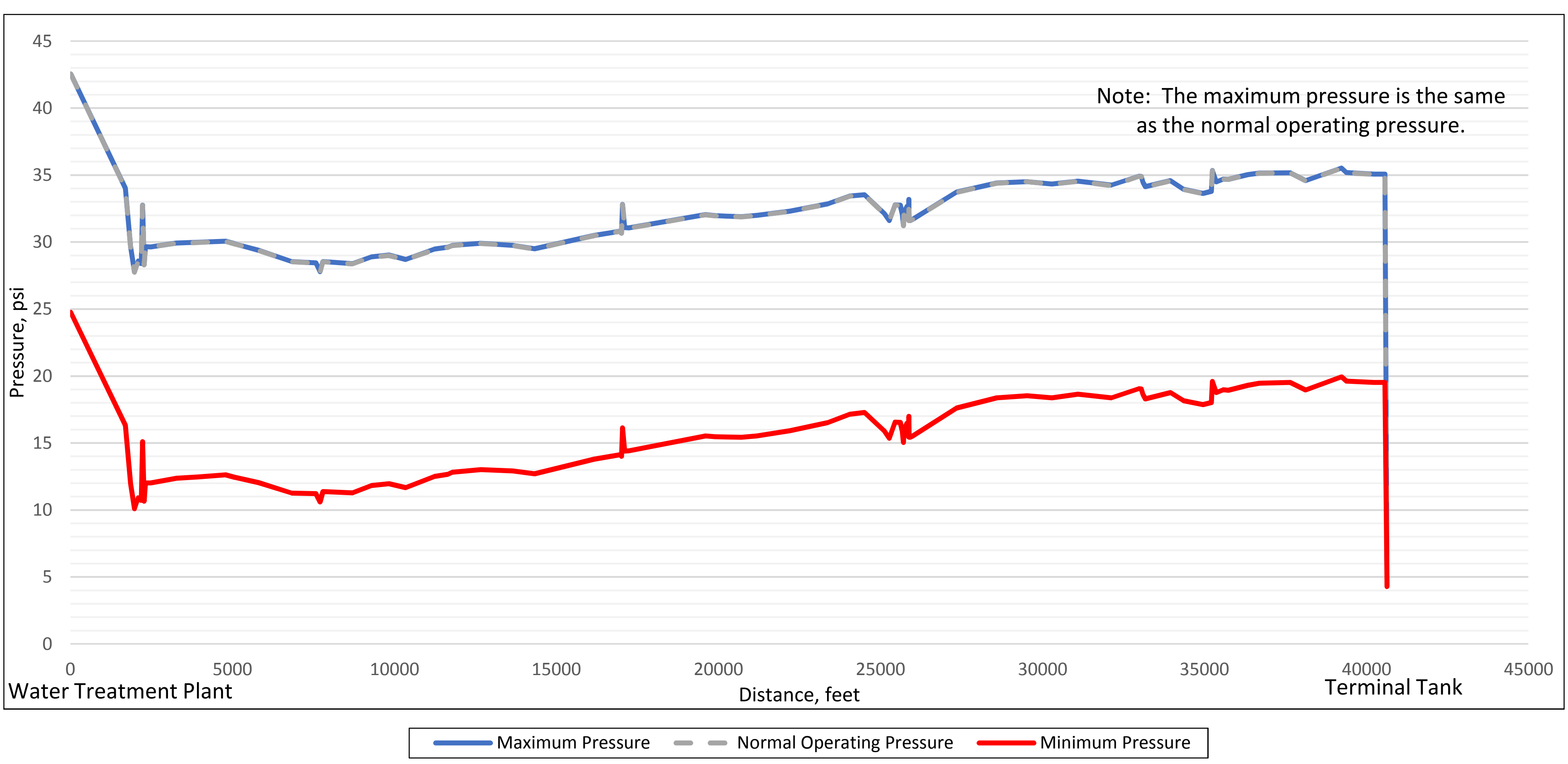


Figure 5

Turlock Finished Water Transmission Main Hydraulic Grade Line and Pressure Profile at Phase 1

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Figure 6. Ceres Phase 1 Pressure at Pump Discharge with 9,000 gallon Surge Tank

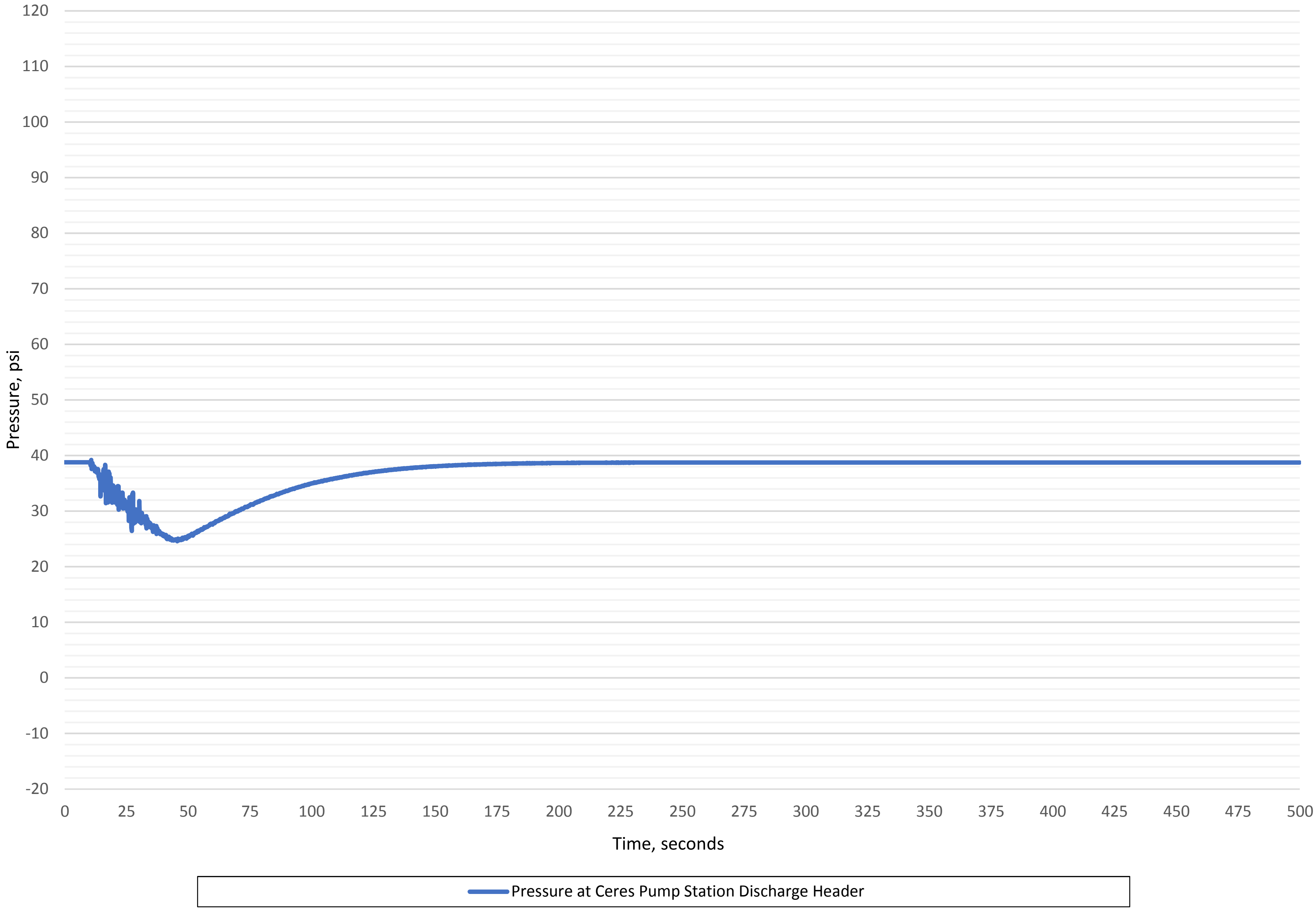
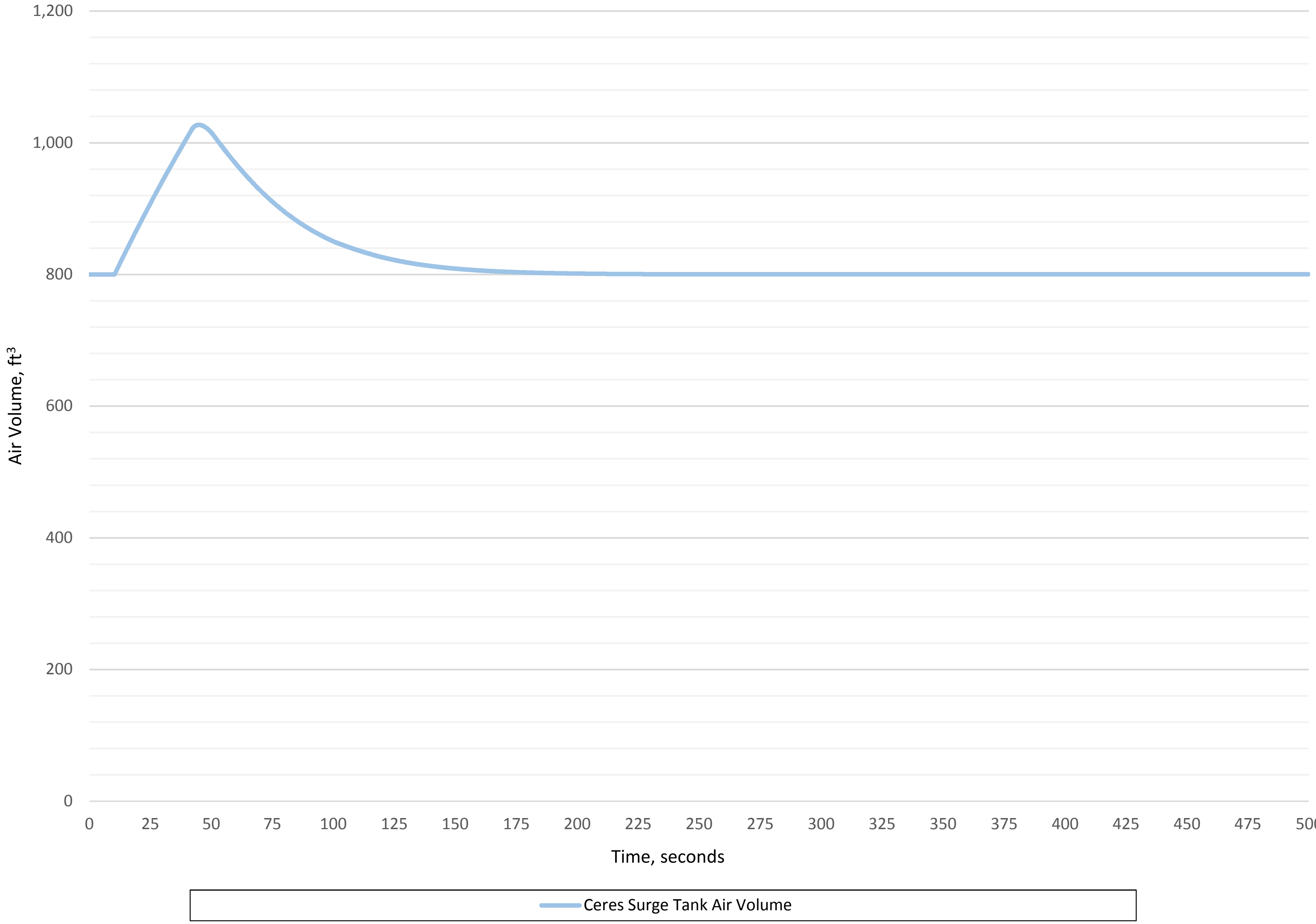
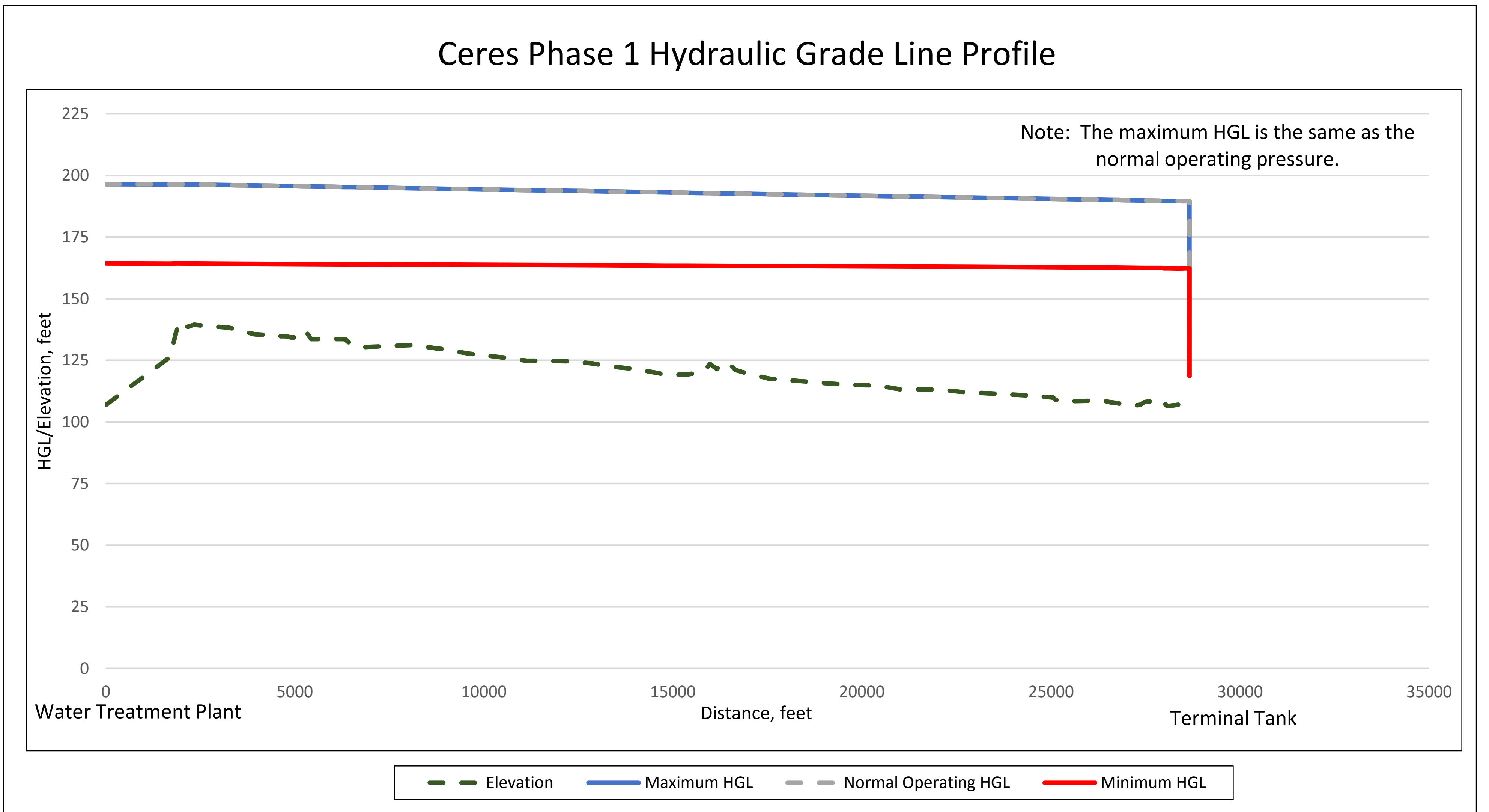


Figure 7. Ceres Phase 1 Surge Tank Air Volume (9,000 gallon Tank)





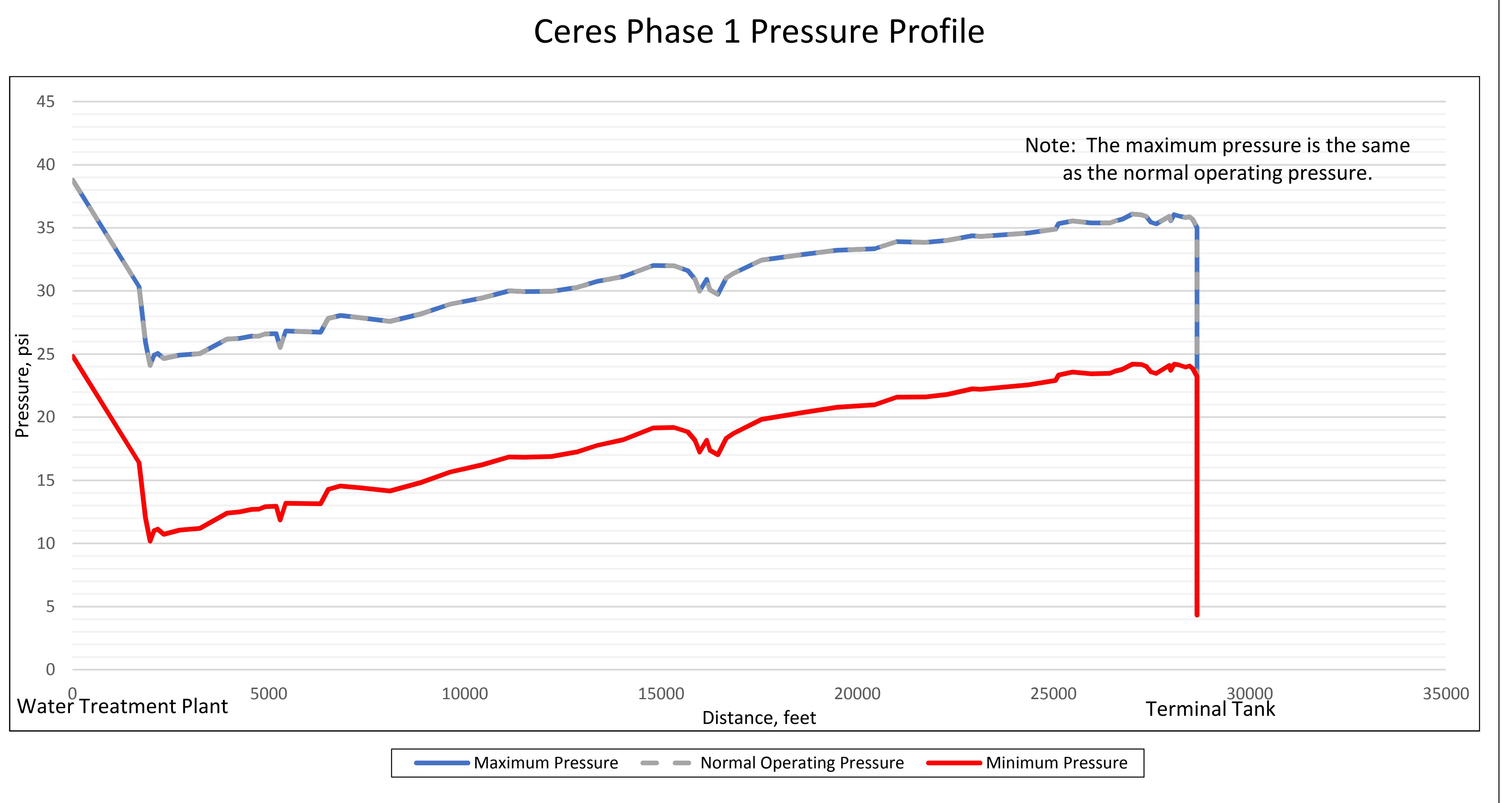


Figure 8

Ceres Finished Water Transmission Main Hydraulic Grade Line and Pressure Profile at Phase 1

Stanislaus Regional Water Authority
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Figure 9. Turlock Buildout Pressure at Pump Discharge with 62,000 gallon Surge Tank

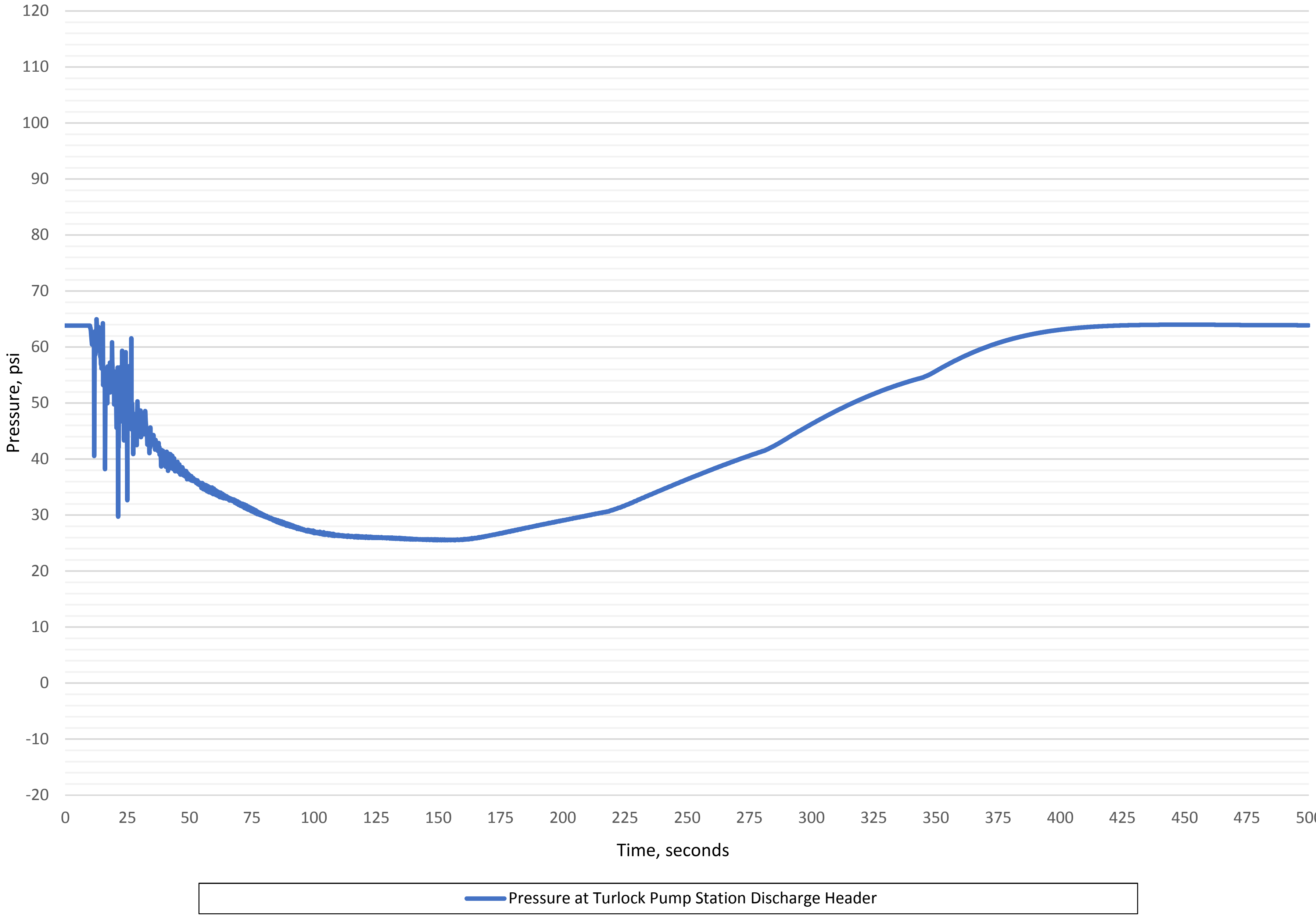
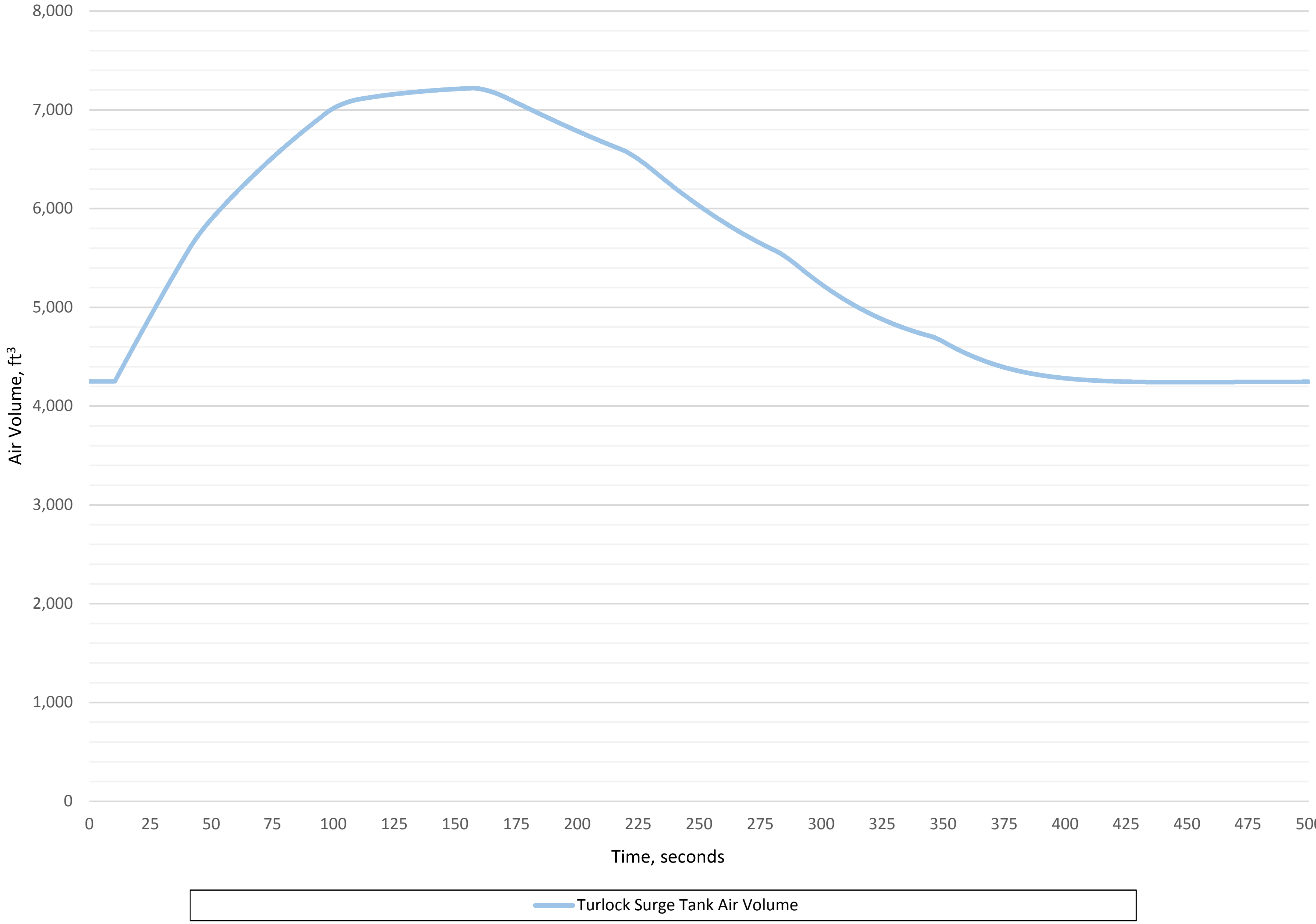
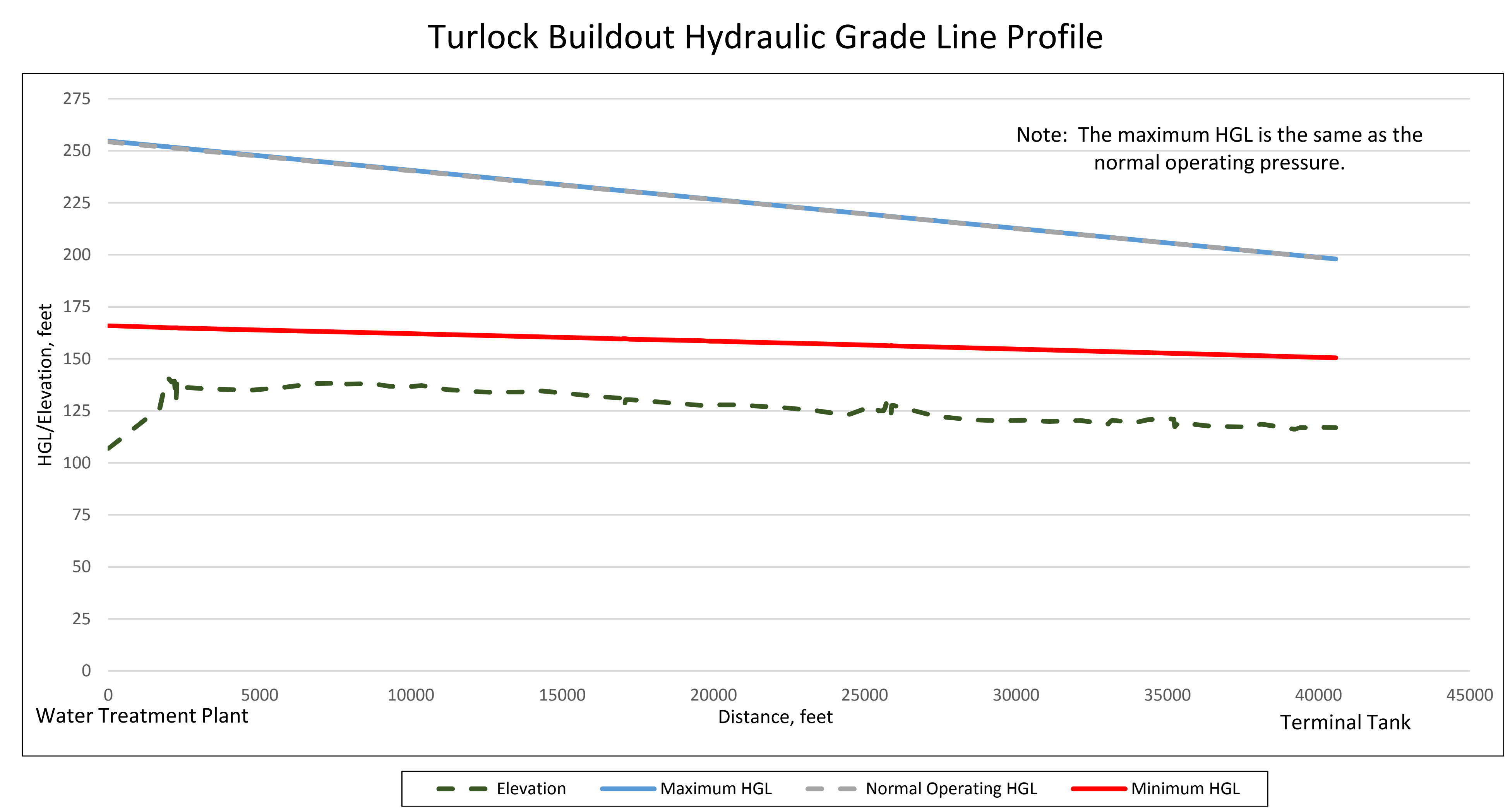


Figure 10. Turlock Buildout Surge Tank Air Volume (62,000 gallon Tank)





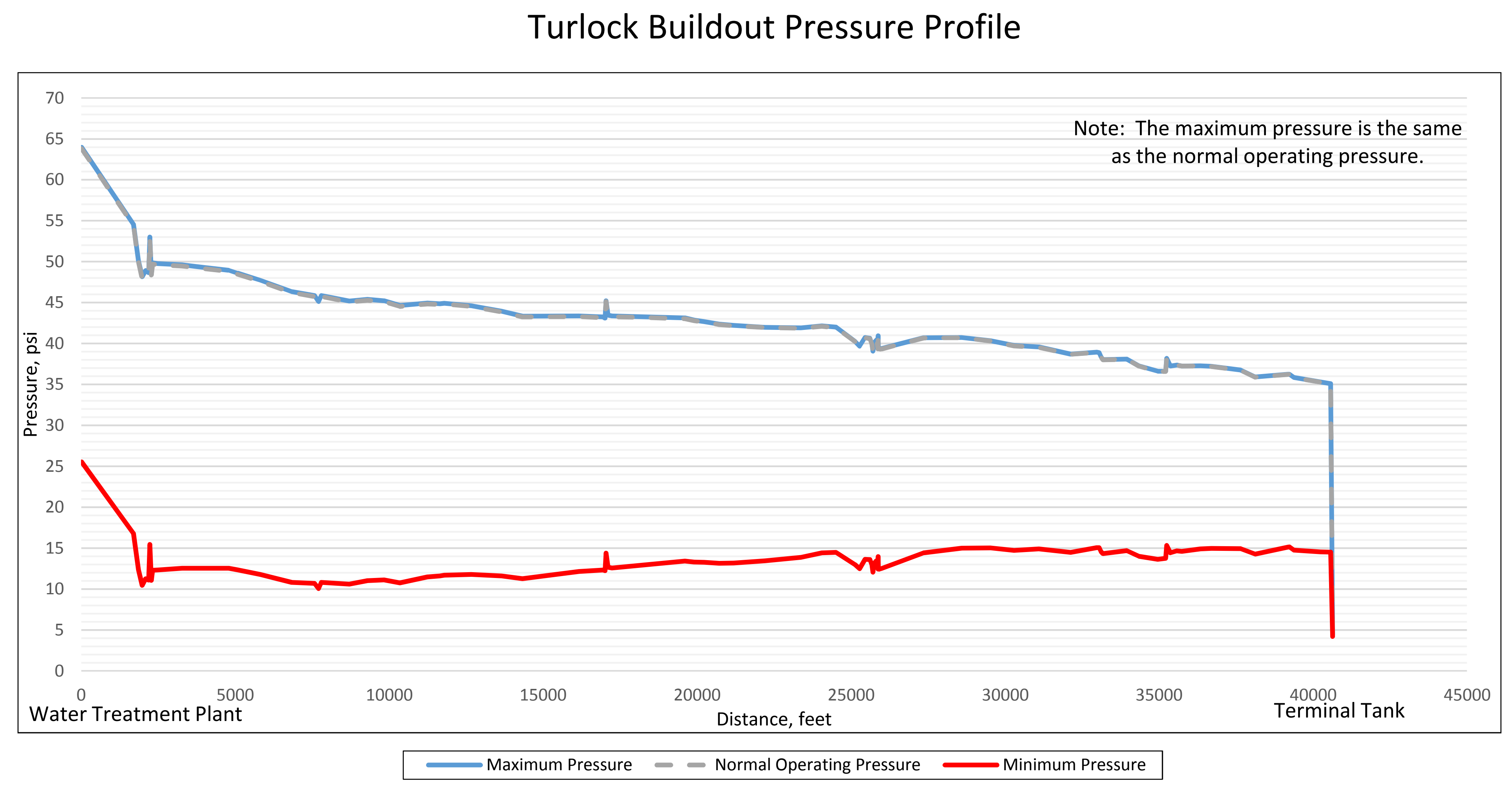


Figure 11

Turlock Finished Water Transmission Main Hydraulic Grade Line and Pressure Profile at Buildout

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Figure 12. Ceres Buildout Pressure at Pump Discharge with 20,000 gallon Surge Tank

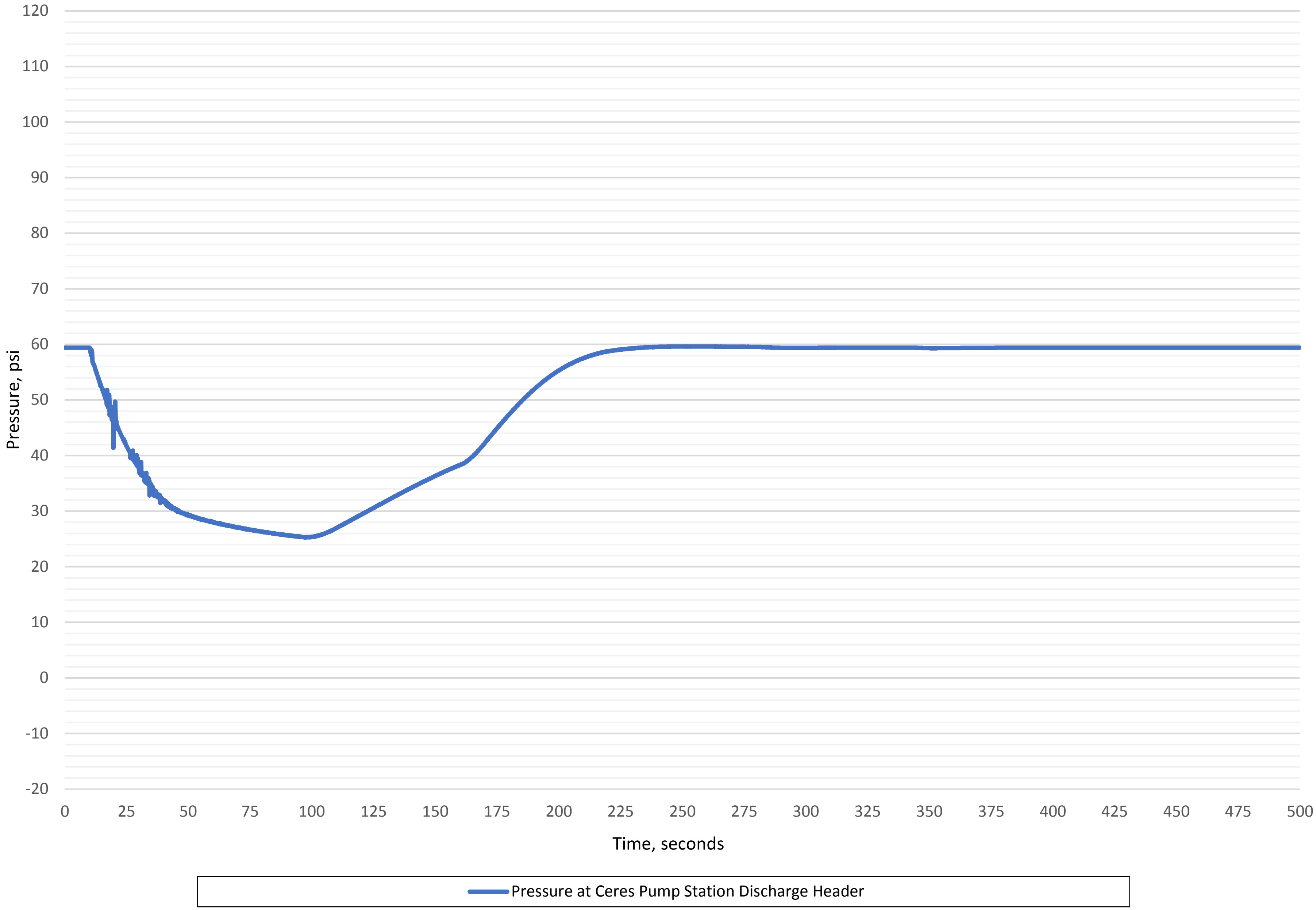
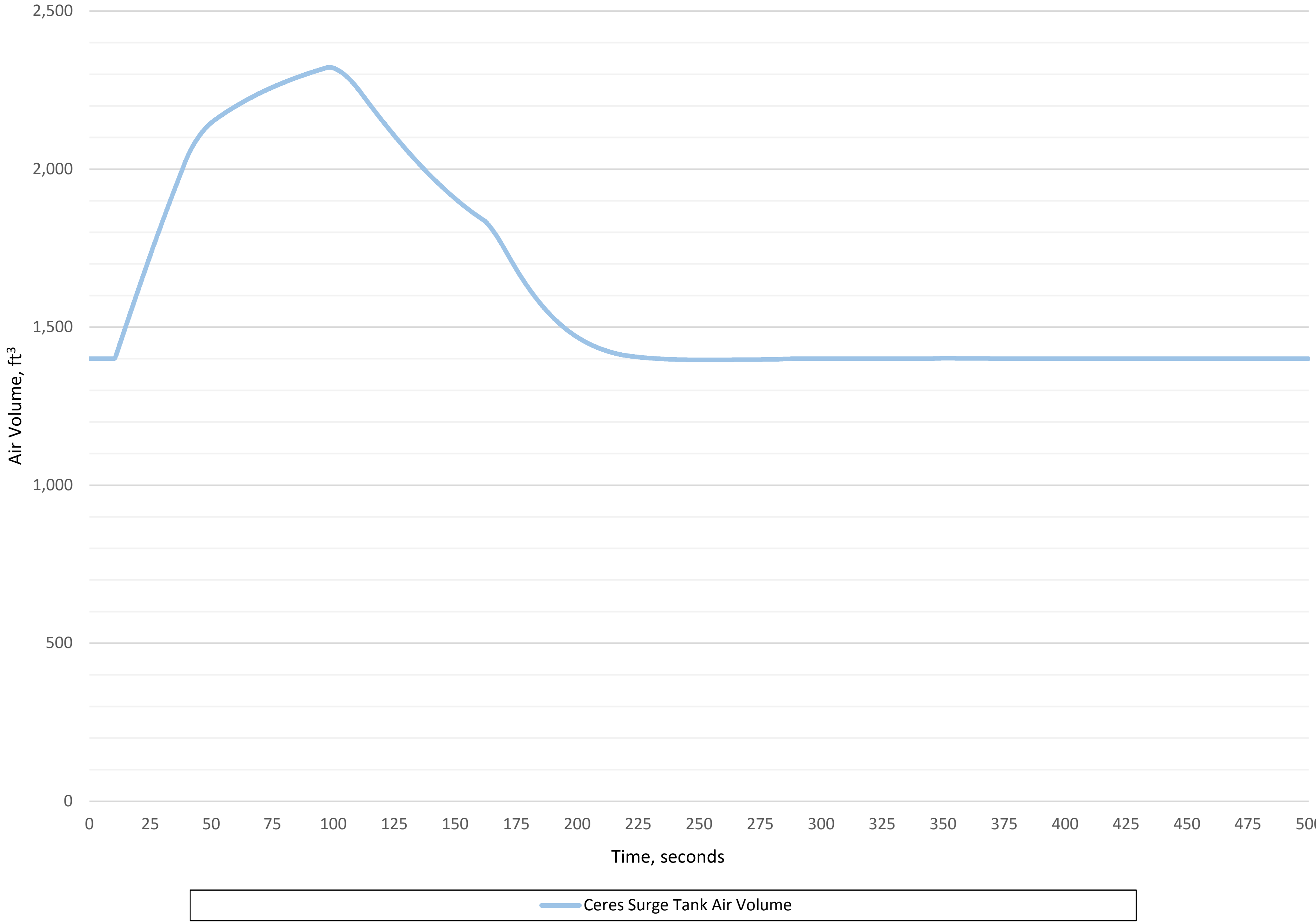


Figure 13. Ceres Buildout Surge Tank Air Volume (20,000 gallon Tank)



Ceres Buildout Hydraulic Grade Line Profile

Ceres Buildout Pressure Profile

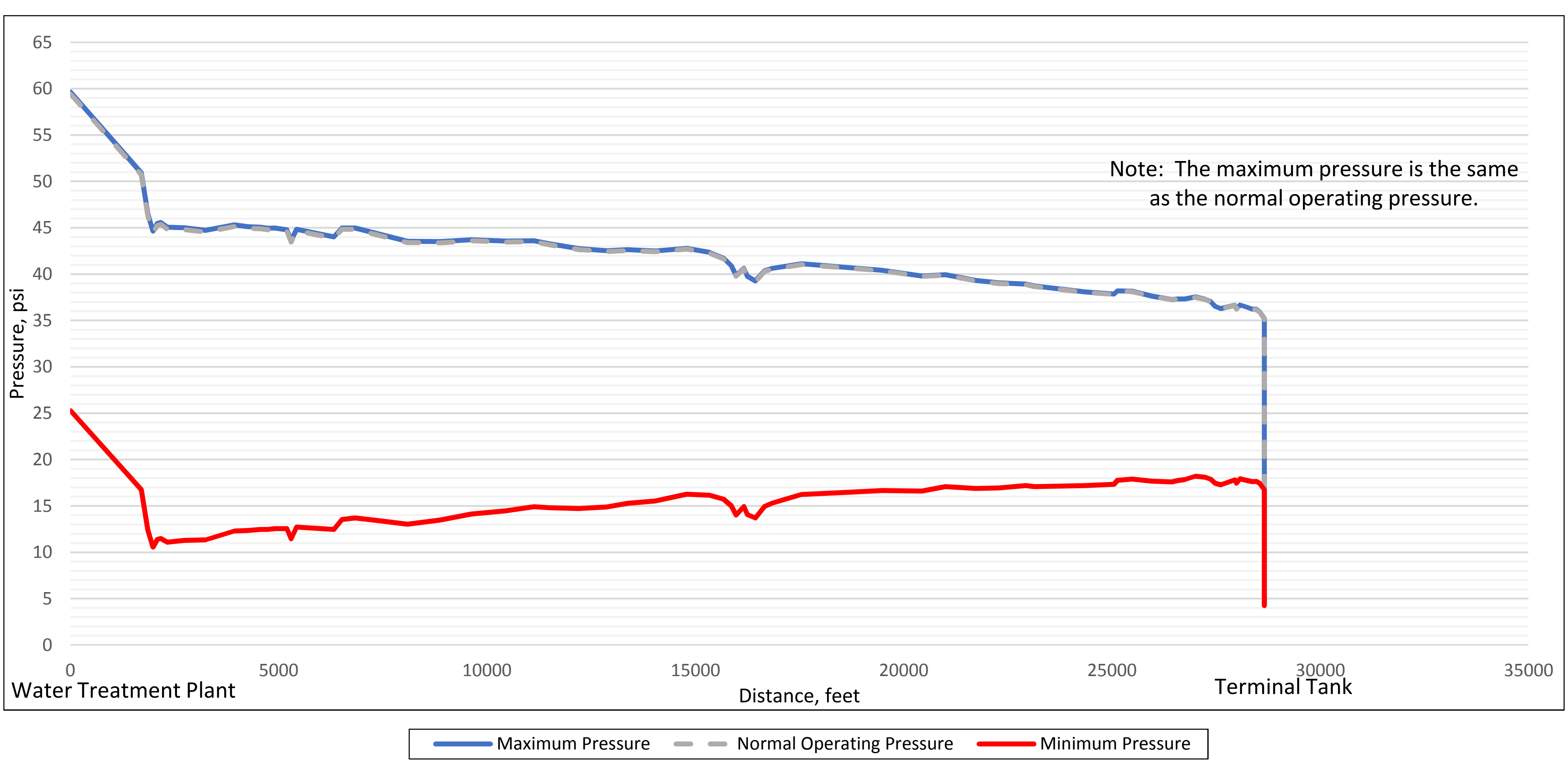


Figure 14

Ceres Finished Water Transmission Main Hydraulic Grade Line and Pressure Profile at Buildout

Stanislaus Regional Water Authority
Raw Water Transient Analysis