Technical Memorandum

Wes Brown High Service Pump Station Hydraulic Transient Analysis
city of Thornton, CO

To: Stacy Roberts, PE

From: Nathan Walker, PE

Date: February 9th, 2021

Prepared by: Jason Coontz, PE

Reviewed by: Marcela Duran, PE

Subject: Final Transient Analysis

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1. Purpose

The Wes Brown Water Treatment Plant (WBWTP) is one of the main sources of water supply for the city of Thornton (Thornton), CO. Supply from the treatment plant is delivered to the distribution system through the Wes Brown High Service Pump Station (WBHSPS). Additional supply is provided by the Thornton Water Treatment Plant (TWTP). The Holly Street Booster Pump Station (HSBPS) maintains pressure in the system during peak demands.

Thornton has noticed a high frequency of pipe breaks in asbestos cement pipes downstream of the WBHSPS and contracted AECOM to evaluate the possibility of transient events contributing to this problem. This technical memorandum (TM) documents the preliminary results of the WBHSPS existing system transient analysis. The analysis includes the following three types of transient events at the WBHSPS:

1. Pump Trip: An unexpected sudden shutdown of one to three pumps.
2. Pump Shutdown: The shutting down of one pump under normal, non-emergency conditions.
3. Pump Startup: The normal starting of one pump.

These types of transient events were selected to represent the most critical conditions likely to occur in the system.

2. Development of the Transient Model

The transient analysis was conducted using Innovyze InfoSurge, a hydraulic transient modeling software, beginning with the InfoWater 2015 Model provided by Thornton. The transient model construction process, model inputs used, and model scenarios evaluated are summarized in section.

Model Construction

The transient model was built using the steady state, EX_MDD_SS scenario (39 million gallons per day demand) from Thornton's existing model. The model was skeletonized to only include Zone 1 elements. Figure 1 shows the skeletonized portion of the entire model used for the transient analysis. Pressure reducing valves and pump stations between Zone 1 and other zones were eliminated from the model and replaced with demand nodes to match the flow in the full model. The skeletonization was then validated by confirming the full model and the skeletonized transient model pipe flows and node hydraulic grade lines were consistent.

After preliminary discussion with Thornton, the existing surge tank at Thornton Parkway and York Street and the existing air valves on the critical 42-inch steel transmission line were added to the model.

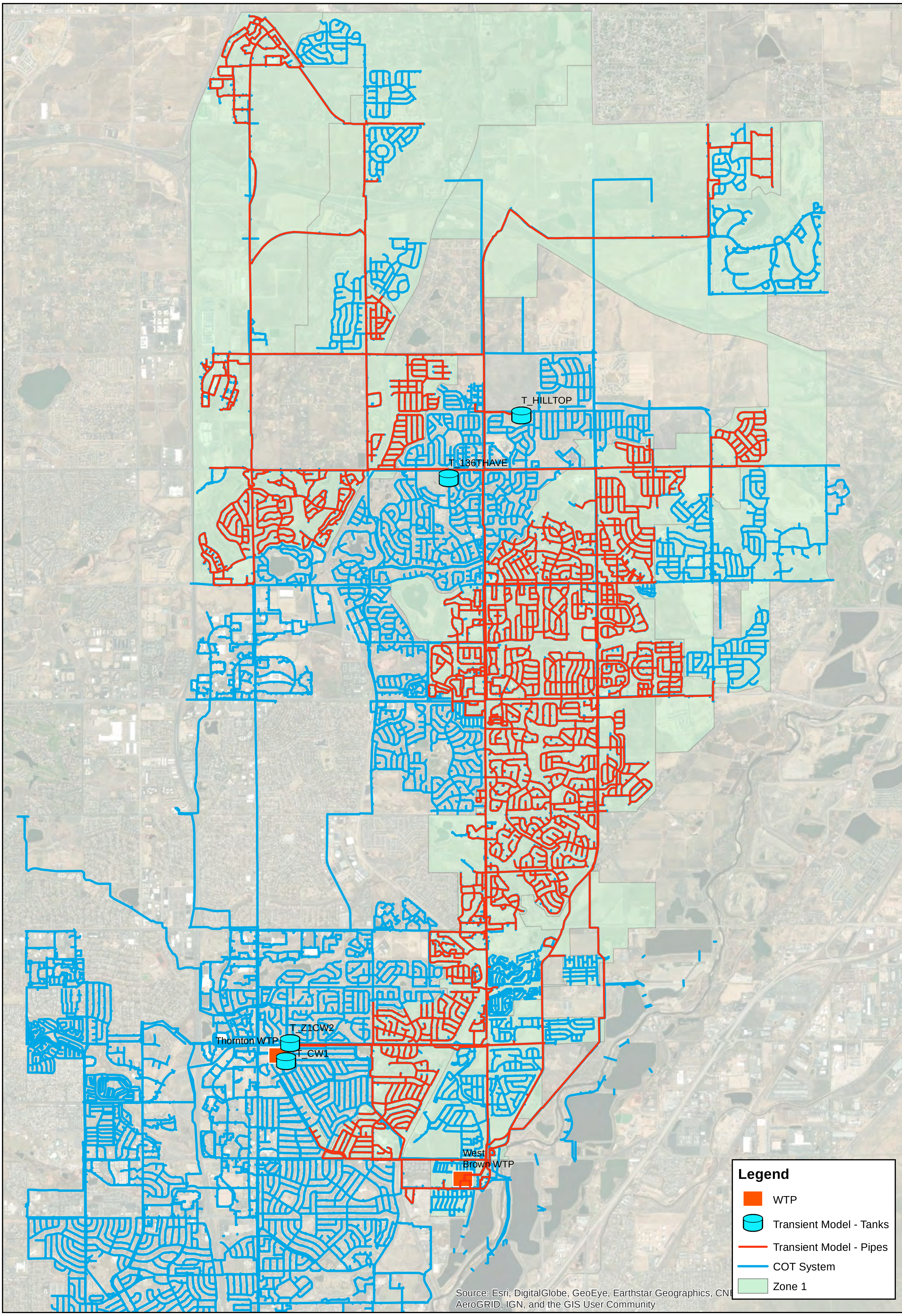

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Figure 1
Skeletonization of Thornton Hydraulic Model

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1 inch = 4,000 feet

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The model pipes representing WBHSPS were updated to match the pump station layout, pipe materials, pipe sizes, pipe lengths, minor losses, and surge protection equipment shown in the piping and instrumentation diagrams, process drawings, and data provided by Thornton. Figure 2 shows the updated pump station layout with the surge protection equipment identified.

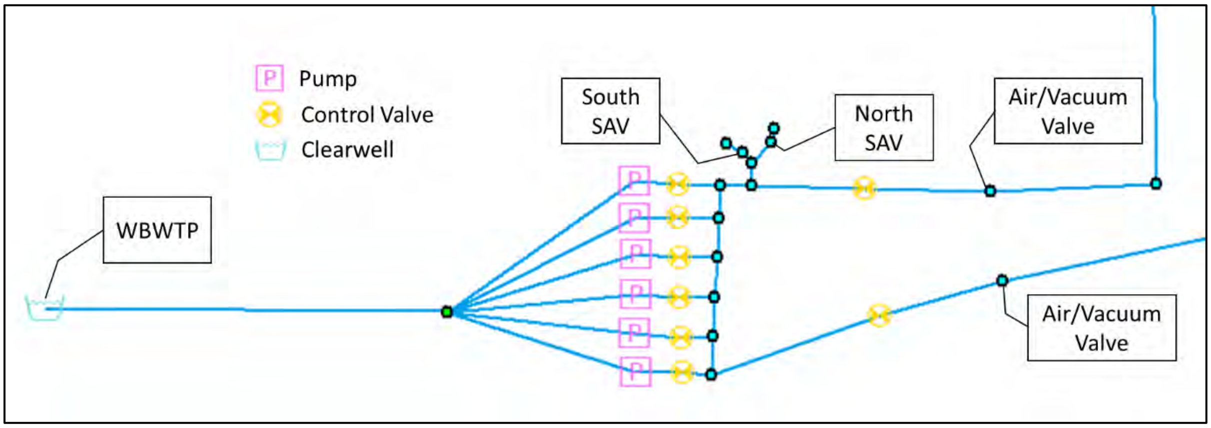

Figure 2: WBHSPS Layout showing Surge Protection Equipment

The transient model was then calibrated for both maximum day demand (MDD) and minimum day demand (MinDD). Supply from WBHSPS and TWTP, pumping rate at HSBPS, and levels for Thornton Clearwell (CW#2), 136th Avenue tank and Hilltop tank were extracted using a typical day of supervisory control and data acquisition (SCADA) data. For the MDD calibration, demands were globally scaled up to match the supply. For the MinDD calibration, irrigation demands were removed, and the remaining demands were globally scaled down to match the supply. The model pump discharge pressures for each scenario were within 5% of the SCADA values, so no changes to the model were made and the transient model was deemed calibrated.

An additional demand scenario was added based on input from Thornton to approximate future conditions. The MDD scenario was scaled up 70 million gallons per day (MGD), with 50 MGD of supply coming from WBHSPS and 20 MGD from TWTP.

Transient Model Inputs

In addition to the hydraulic model data, the following information is required to perform surge analysis:

- Wave speed for each pipe in the model, which is based on the pipe material (Young's modulus and Poisson's ratio), the pipe's dimension ratio, and the fluid properties of water.
- Surge data for WBHSPS, including pump speed, pump efficiency, pump and motor combined rotational inertia, and startup and shutdown times.
- Surge operational characteristics for control valves, including opening and closing times, and valve operation during loss of power. This information was provided by Thornton.

A global wave speed for each pipe material type was used in the transient model. Table 1 summarizes the pipe wave speed for each material type input into the model.

Table 1. Pipe Wave Speeds Assumption

Pipe Material	Wave Speed (ft/s)
Steel	3,200
Ductile Iron	3,600
PVC	1,100
Asbestos Cement	2,300

The pump data used for the WBHSPS model is included in Table 2. The inertia was calculated using the InfoSurge inertia calculator based on the pump speed, flow, head, and efficiency. Pump curves were developed from performance test results provided by Thornton. Typical ball valve curves (Cv vs. Percent [%] Open) were used to model valve operation.

Table 2: Pump Input Data

	Value
Number of Pumps	6
Pump Efficiency (each pump, %)	87
Pump Speed (each pump, rpm)	1,180
Pump Inertia (each pump, lb-ft^2)	899
Control Information (each pump)	
Pump Control Valve Size and Type	18" Ball Valve
Check Valve	none
Valve closing time after power failure (sec)	25
Normal Pump Shutdown Time (sec)	300
Normal Pump Startup Time (sec)	300

Transient Model Scenarios

A total of five transient analysis model scenarios were developed for this evaluation. The scenarios are described in Table 3. These scenarios cover a range of pump operating conditions during unexpected or non-emergency situations.

Table 3: Surge Analysis Model Scenarios

Scenario	Name	Tank Levels	Demand Scenario	Initial Pump Conditions	Final Pump Conditions
1	Pump Trip, Max Flow	CW#2 = 11.87 ft 136th Ave = 24.60 ft Hilltop = 24.25 ft	MDD	3 pumps running, Flow = 23,292 gpm	All pumps shut down, no flow
2	Pump Trip, Min Flow	CW#2 = 18.16 ft 136th Ave = 25.38 ft Hilltop = Offline	MinDD	1 pump running, Flow = 4,518 gpm	All pumps shut down, no flow
3	Pump Trip, Future Flow	CW#2 = 11.87 ft 136th Ave = 24.60 ft Hilltop = 24.25 ft	Future MDD	5 pumps running, Flow = 34,722 gpm	All pumps shut down, no flow
4	Pump Shutdown	CW#2 = 18.16 ft 136th Ave = 25.38 ft Hilltop = Offline	MinDD	1 pump running, Flow = 4,518 gpm	All pumps shut down, no flow
5	Pump Startup	CW#2 = 18.16 ft 136th Ave = 25.38 ft Hilltop = Offline	MinDD	All pumps shut down, no flow	1 pump running, Flow = 4,518 gpm

3. Evaluation Criteria

The high- and low-pressure criteria for each pipe material used to evaluate each scenario in the model is included in Table 4.

Table 4: Surge Analysis Evaluation Criteria

Pipe Material	Upper Pressure Limit	Lower Pressure Limit	Source
Steel	350+	0	Assumed
Ductile Iron	350	-5	AWWA (CL 250 assumed) / Denver Water
PVC	240	-14.4	AWWA (PC 150 assumed) / Manufacturer
Asbestos Cement	250	-5	AWWA (Class 50 assumed)

4. Summary of Results – Existing System

A summary of the scenarios passing the high-pressure and low-pressure criteria without additional mitigation is included in Table 5. The system was evaluated with the existing configuration, assuming no additional mitigation.

Table 5: Surge Analysis Model Scenarios

Scenario	Name	Meet Low-Pressure Criteria at WBHSPS?	Meet High-Pressure Criteria at WBHSPS?	Meet Low-Pressure Criteria in Distribution System?	Meet High-Pressure Criteria Distribution System?
1	Pump Trip, Max Flow	Yes	Yes	No	No
2	Pump Trip, Min Flow	Yes	Yes	No	Yes
3	Pump Shutdown	Yes	Yes	No	Yes
4	Pump Startup	Yes	Yes	No	Yes

Scenario 1: Pump Trip, Max Flow – Existing System

A summary of the minimum and maximum pressures by pipe material for the Pump Trip, Max Flow scenario are summarized in Table 6. A map of the high-pressure nodes for the Pump Trip, Max Flow scenario is included in Figure 3. A map of the low-pressure nodes for the Pump Trip, Max Flow scenario is included in Figure 4.

Table 6: Pump Trip, Max Flow Transient Results Summary by Pipe Material

	Asbestos Cement	PVC	Ductile Iron	Steel[1]
Scenario Max Pressure (psi)	643	171	246	145
Number of Nodes Failing High Pressure Criteria	8	0	0	0
Scenario Min Pressure (psi)	-14.4	-14.4	-14.4	-14.4
Number of Nodes Failing Low Pressure Criteria	98	0	88	14

[1] A pipe thickness calculation determined that the pipes failing the criteria are able to withstand full vacuum conditions of -14.4 psi (a pipe thickness of 0.25 inch was assumed).

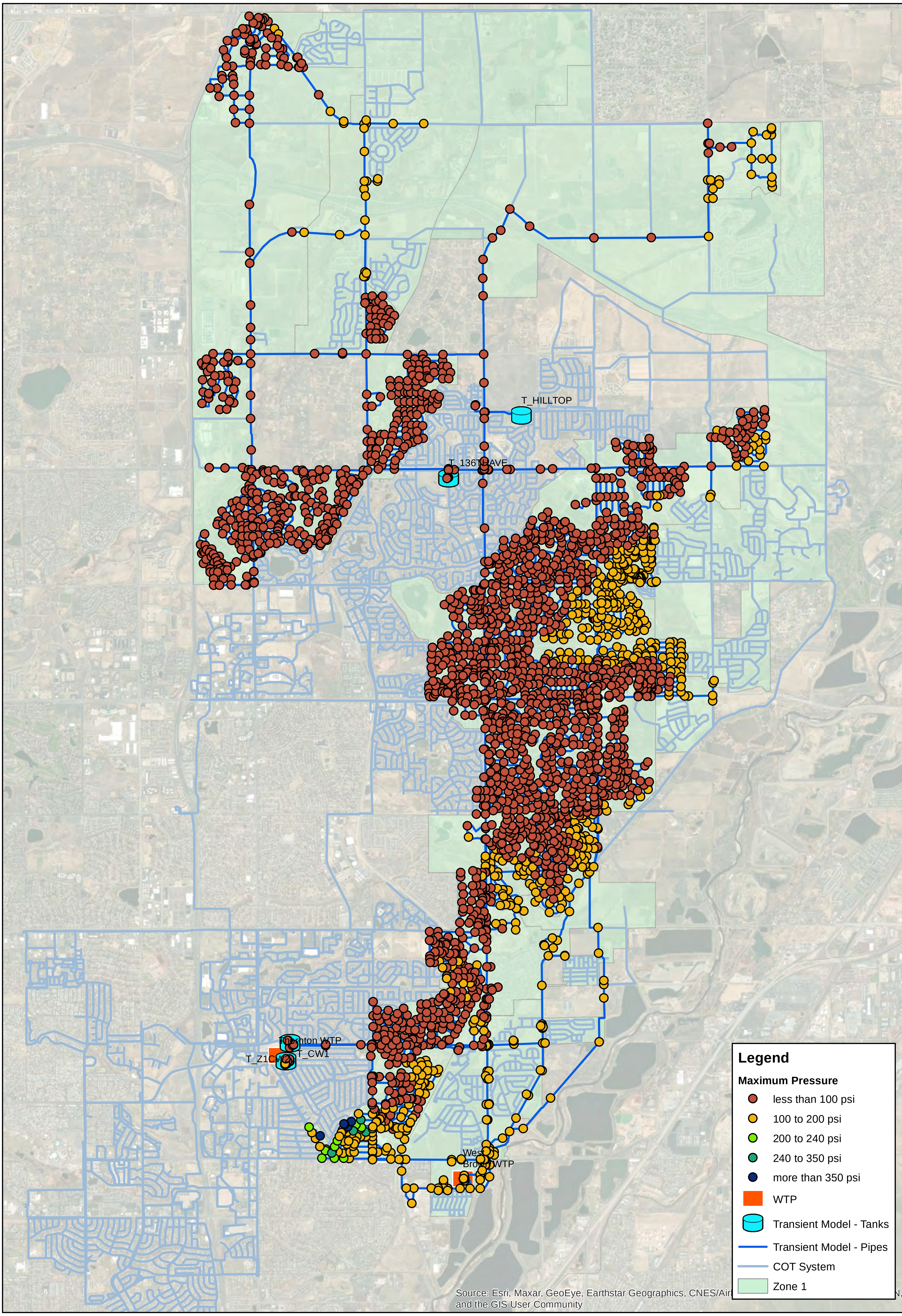

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Figure 3
Pump Trip - Max Flow
Maximum Pressure

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1 inch = 4,000 feet

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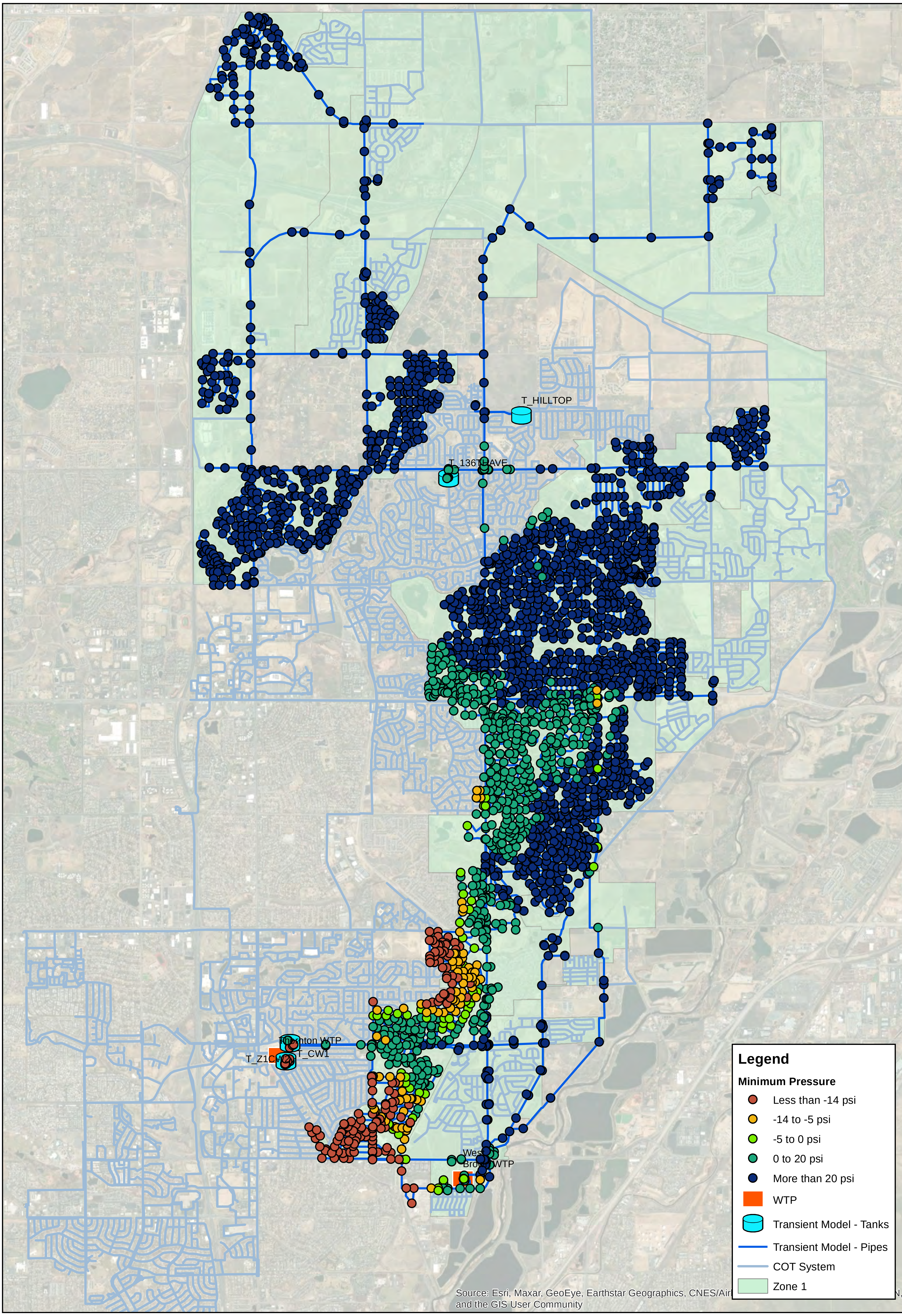

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Figure 4
Pump Trip - Max Flow
Minimum Pressure

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1 inch = 4,000 feet

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Scenario 2: Pump Trip, Min Flow – Existing System

A summary of the minimum and maximum pressures by pipe material for the Pump Trip, Min Flow scenario are summarized in Table 7. A map of the high-pressure nodes for the Pump Trip, Min Flow scenario is included in Figure 5. A map of the low-pressure nodes for the Pump Trip, Min Flow scenario is included in Figure 6.

Table 7: Pump Trip, Min Flow Transient Results Summary by Pipe Material

	Asbestos Cement	PVC	Ductile Iron	Steel[1]
Scenario Max Pressure (psi)	145	144	150	144
Number of Nodes Failing High Pressure Criteria	0	0	0	0
Scenario Min Pressure (psi)	-2.6	12.2	-14.4	-1.9
Number of Nodes Failing Low Pressure Criteria[2]	0	0	2	2

[1] A pipe thickness calculation determined that the pipes failing the criteria are able to withstand full vacuum conditions of -14.4 psi (a pipe thickness of 0.25 inch was assumed).
[2] Mitigation was deemed unnecessary for the 2 ductile iron nodes violating the criteria in this scenario.

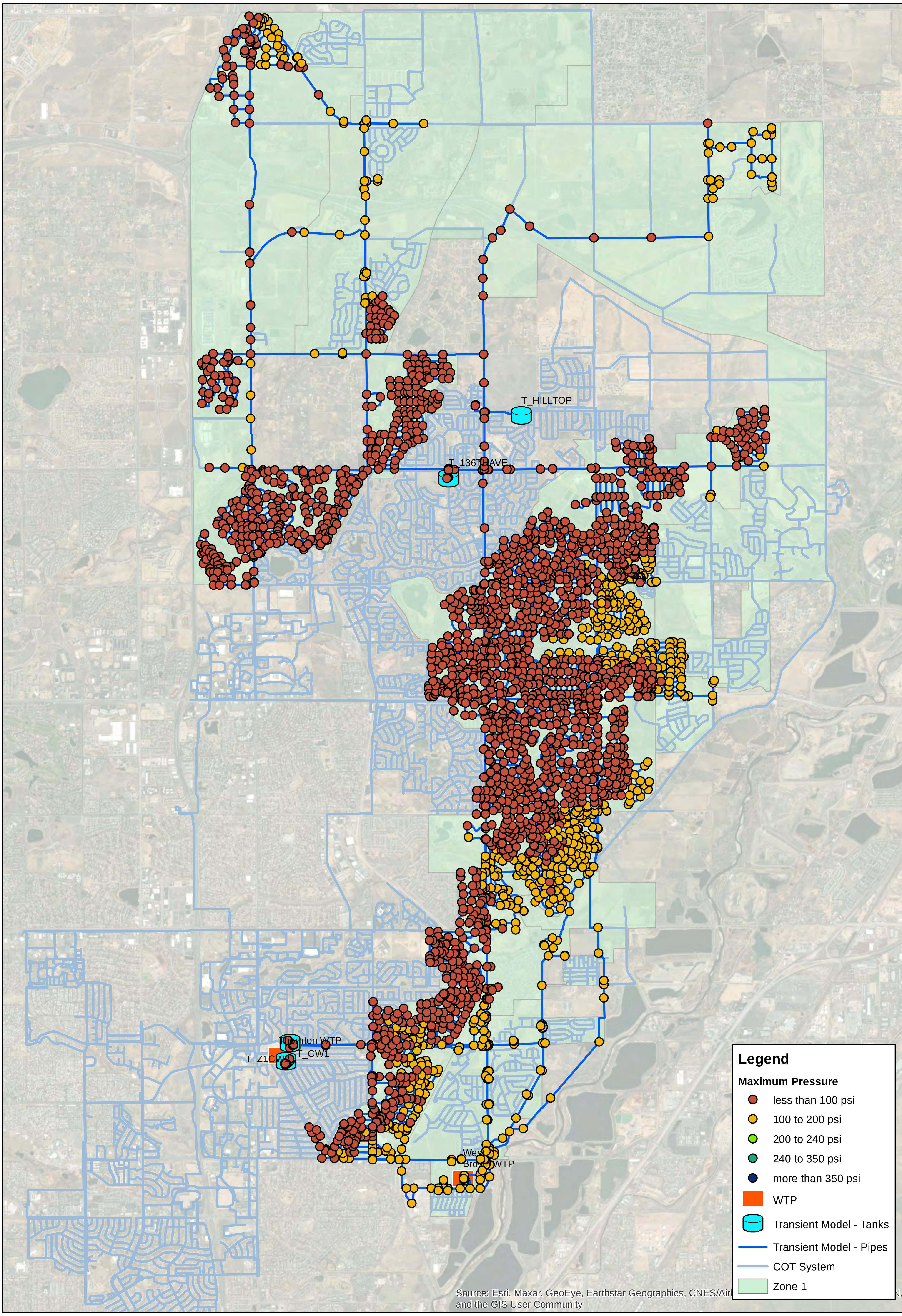

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Figure 5
Pump Trip - Min Flow
Maximum Pressure

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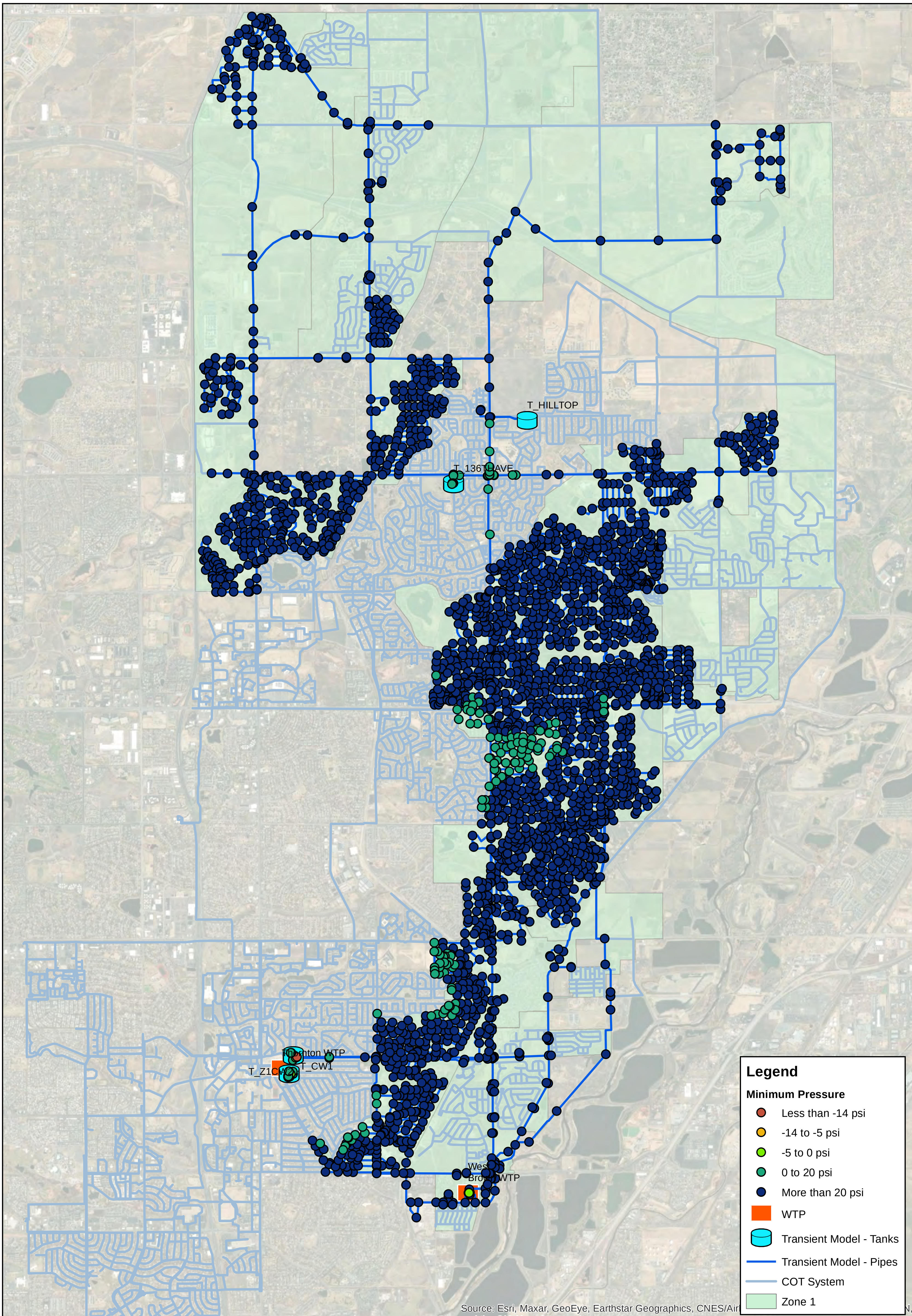

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Figure 6
Pump Trip - Min Flow
Minimum Pressure

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1 inch = 4,000 feet

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Scenario 3: Pump Trip, Future Flow – Existing System

A summary of the minimum and maximum pressures by pipe material for the Pump Trip, Future Flow scenario are summarized in Table 8. A map of the high-pressure nodes for the Pump Trip, Future Flow scenario is included in Figure 7. A map of the low-pressure nodes for the Pump Trip, Future Flow scenario is included in Figure 8.

Table 8: Pump Trip, Future Flow Transient Results Summary by Pipe Material

	Asbestos Cement	PVC	Ductile Iron	Steel[1]
Scenario Max Pressure (psi)	735	216	461	145
Number of Nodes Failing High Pressure Criteria	15	0	6	0
Scenario Min Pressure (psi)	-14.4	-14.4	-14.4	-14.4
Number of Nodes Failing Low Pressure Criteria	128	0	100	13

[1] A pipe thickness calculation determined that the pipes failing the criteria are able to withstand full vacuum conditions of -14.4 psi (a pipe thickness of 0.25 inch was assumed).

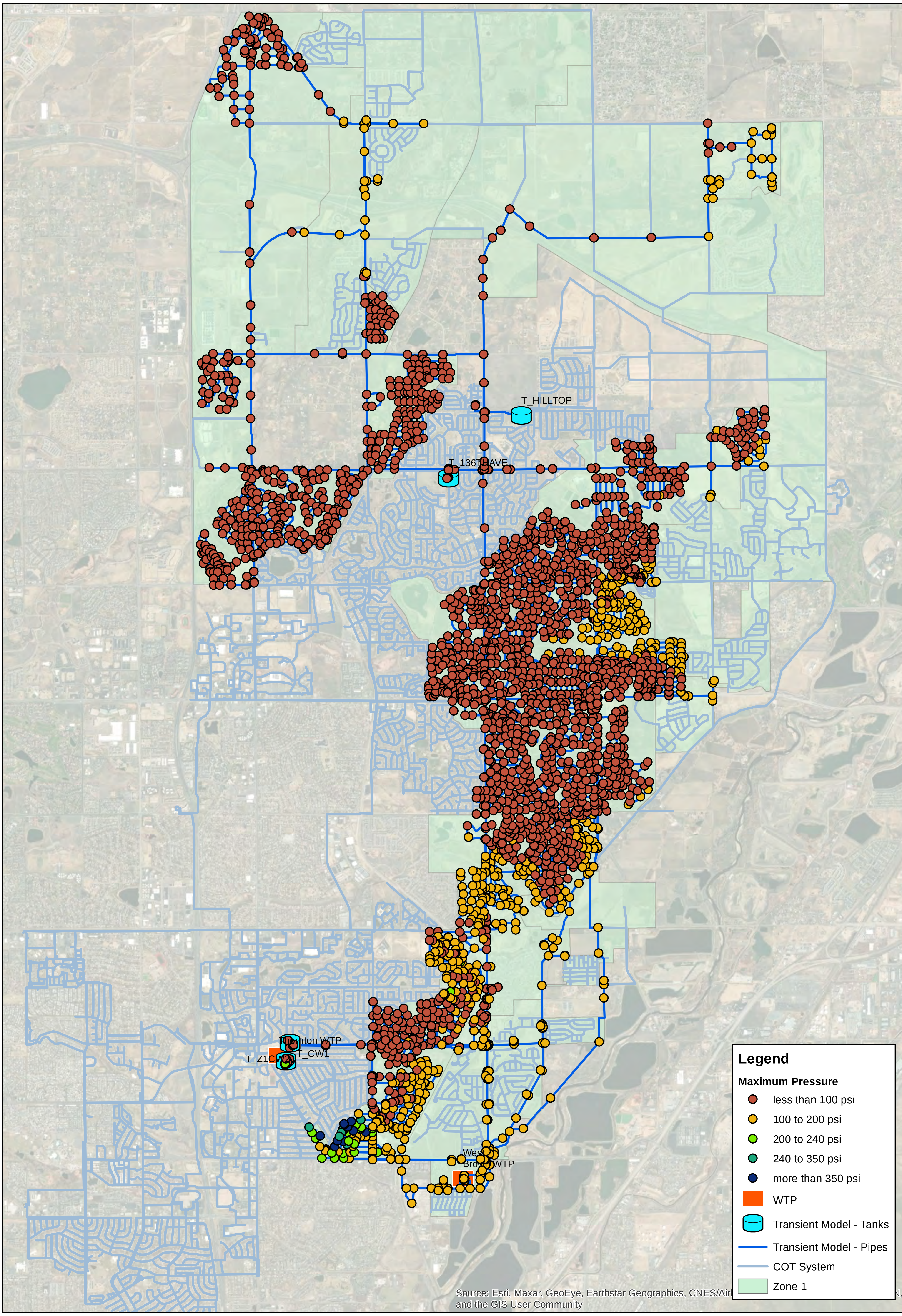

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Figure 7
Pump Trip - Future Flow
Maximum Pressure

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1 inch = 4,000 feet

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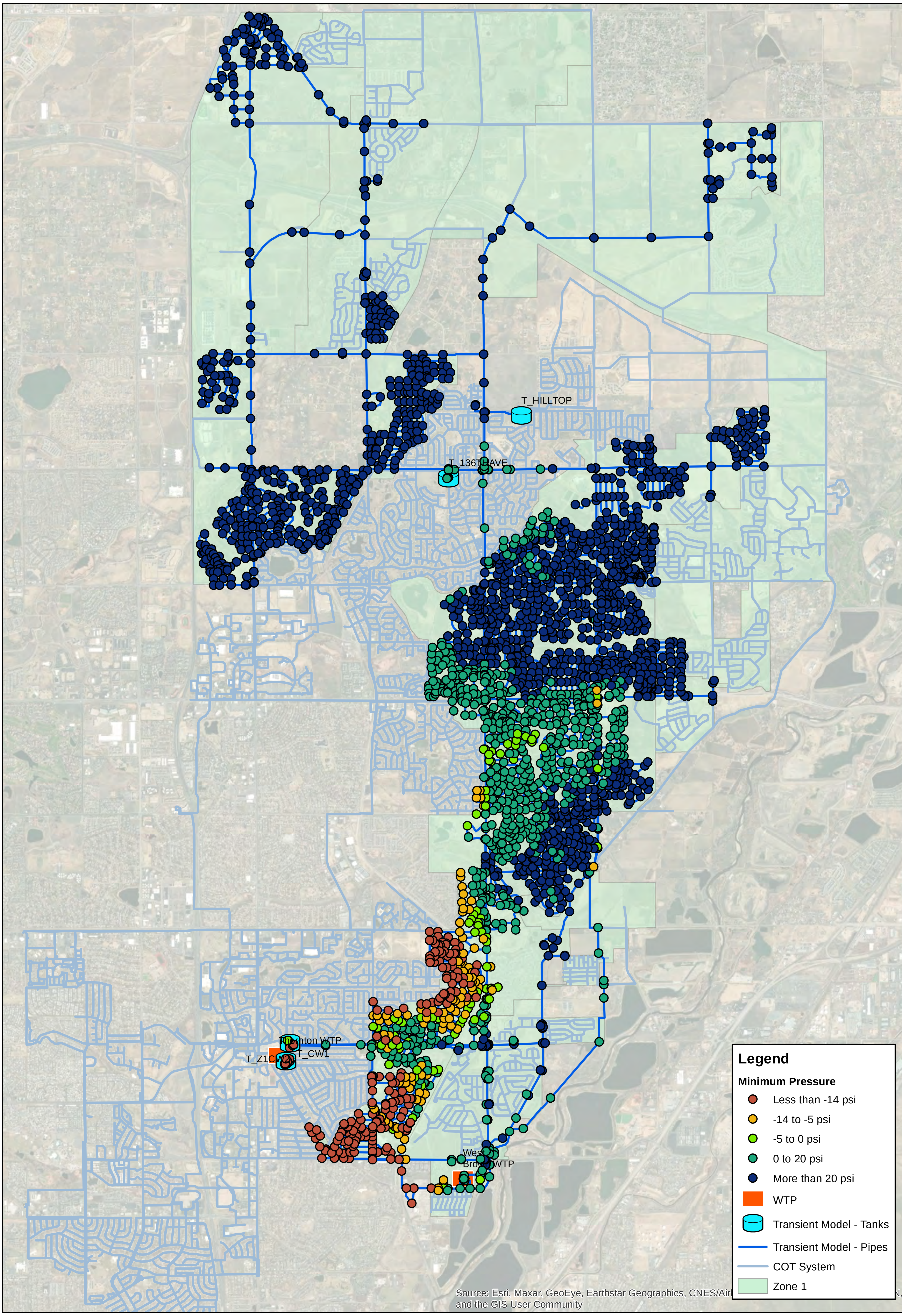

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Figure 8
Pump Trip - Future Flow
Minimum Pressure

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1 inch = 4,000 feet

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Scenario 4: Pump Shutdown – Existing System

A summary of the minimum and maximum pressures by pipe material for the Pump Shutdown scenario summarized in Table 9. A map of the high-pressure nodes for the Pump Shutdown scenario is included in Figure 9. A map of the low-pressure nodes for the Pump Shutdown scenario is included in Figure 10.

Table 9: Pump Shutdown Transient Results Summary by Pipe Material

	Asbestos Cement	PVC	Ductile Iron	Steel[1]
Scenario Max Pressure (psi)	132	141	136	148
Number of Nodes Failing High Pressure Criteria	0	0	0	0
Scenario Min Pressure (psi)	4.4	8.3	-14.4	-3.5
Number of Nodes Failing Low Pressure Criteria[2]	0	0	1	1

[1] A pipe thickness calculation determined that the pipes failing the criteria are able to withstand full vacuum conditions of -14.4 psi (a pipe thickness of 0.25 inch was assumed).
[2] Mitigation was deemed unnecessary for the 1 ductile iron node violating the criteria in this scenario.

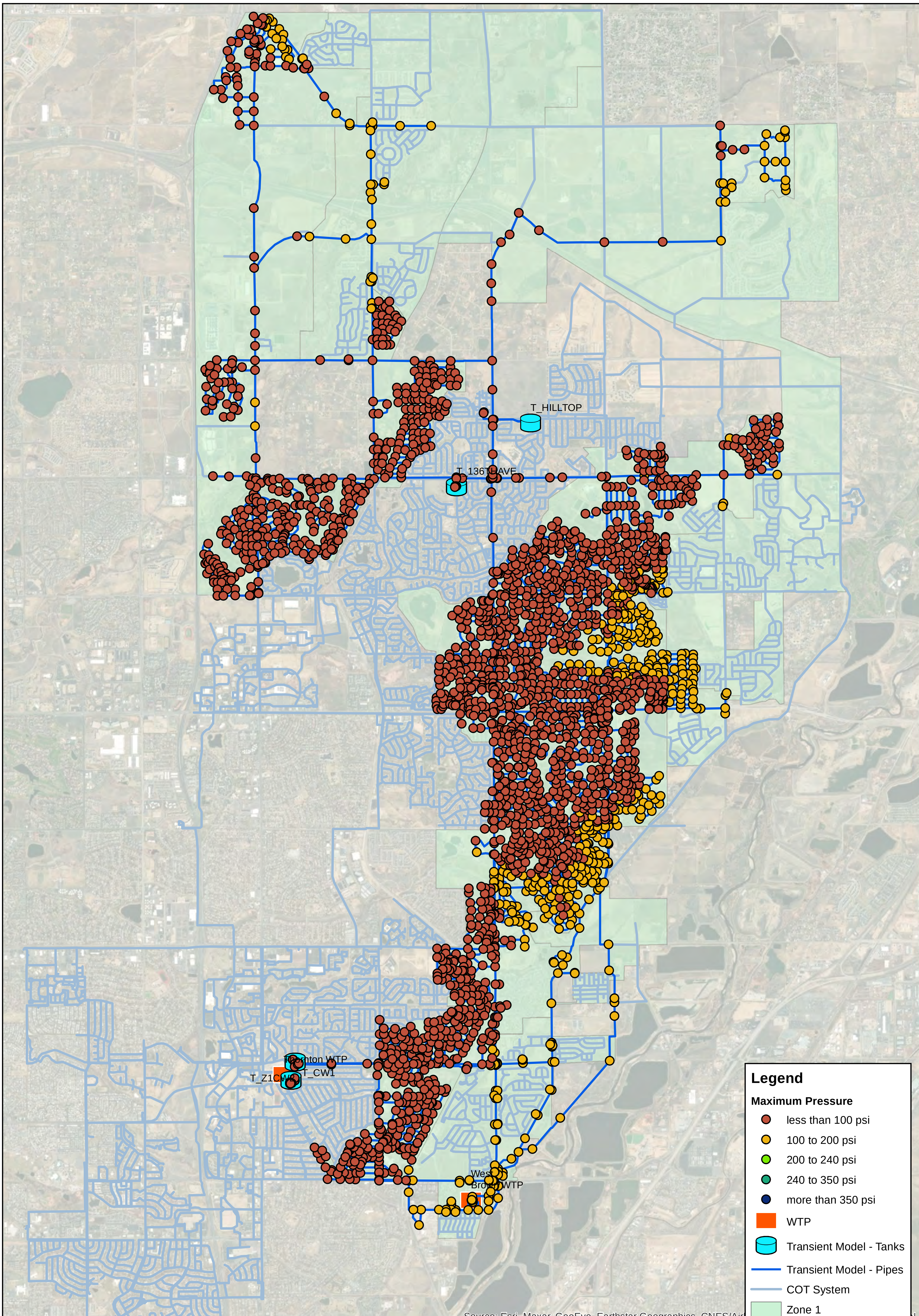

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Figure 9
Pump Shutdown
Maximum Pressure

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1 inch = 4,000 feet

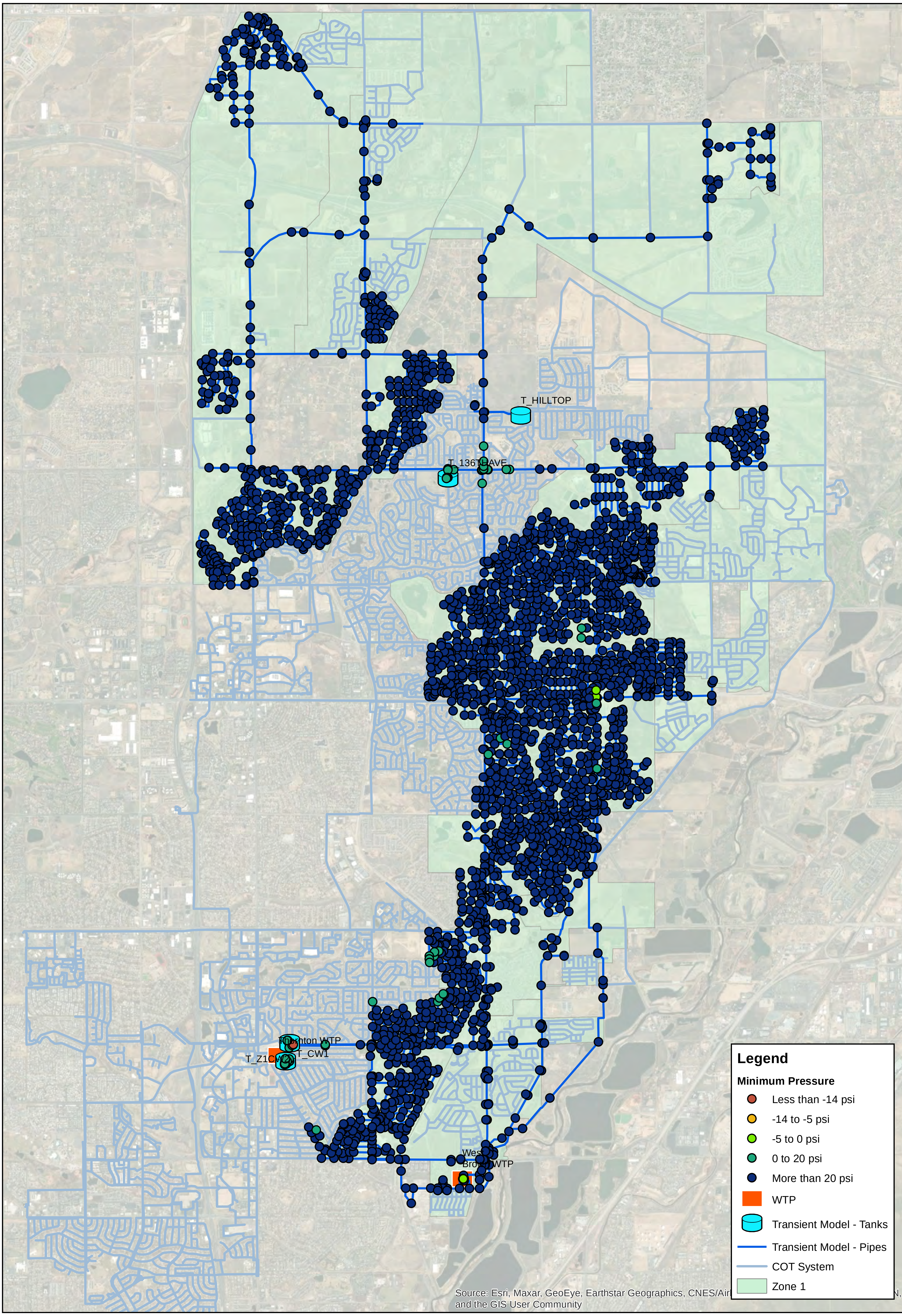

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Figure 10
Pump Shutdown
Minimum Pressure

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1 inch = 4,000 feet

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Scenario 5: Pump Startup – Existing System

A summary of the minimum and maximum pressures by pipe material for the Pump Startup scenario summarized in Table 10. A map of the high-pressure nodes for the Pump Startup scenario is included in Figure 11. A map of the low-pressure nodes for the Pump Startup scenario is included in Figure 12.

Table 10: Pump Startup Transient Results Summary by Pipe Material

	Asbestos Cement	PVC	Ductile Iron	Steel[1]
Scenario Max Pressure (psi)	132	149	138	147
Number of Nodes Failing High Pressure Criteria	0	0	0	0
Scenario Min Pressure (psi)	4.5	-0.5	-14.4	-10.3
Number of Nodes Failing Low Pressure Criteria[2]	0	0	1	1

[1] A pipe thickness calculation determined that the pipes failing the criteria are able to withstand full vacuum conditions of -14.4 psi (a pipe thickness of 0.25 inch was assumed).
[2] Mitigation was deemed unnecessary for the 1 ductile iron node violating the criteria in this scenario.

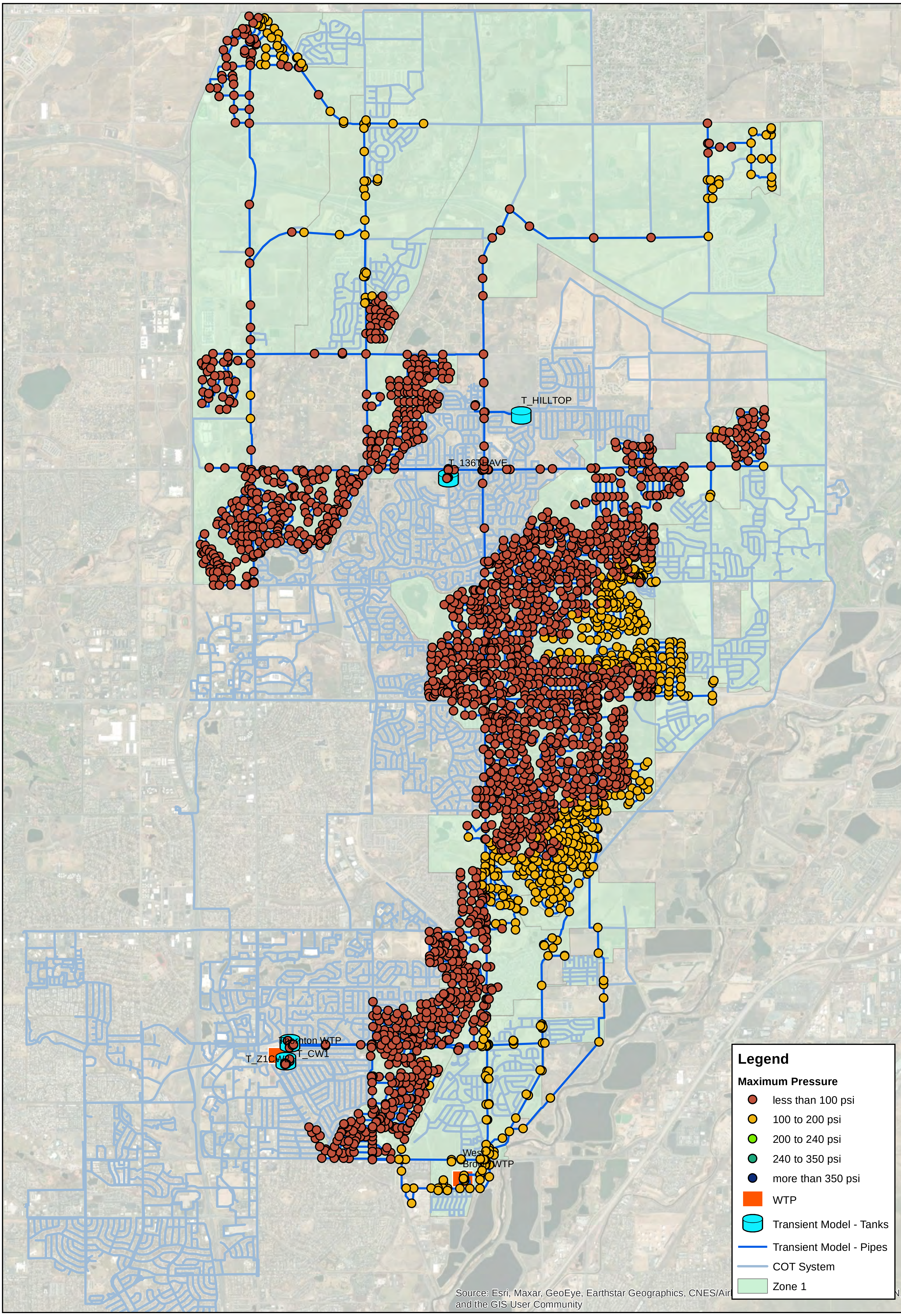

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Figure 11
Pump Startup
Maximum Pressure

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1 inch = 4,000 feet

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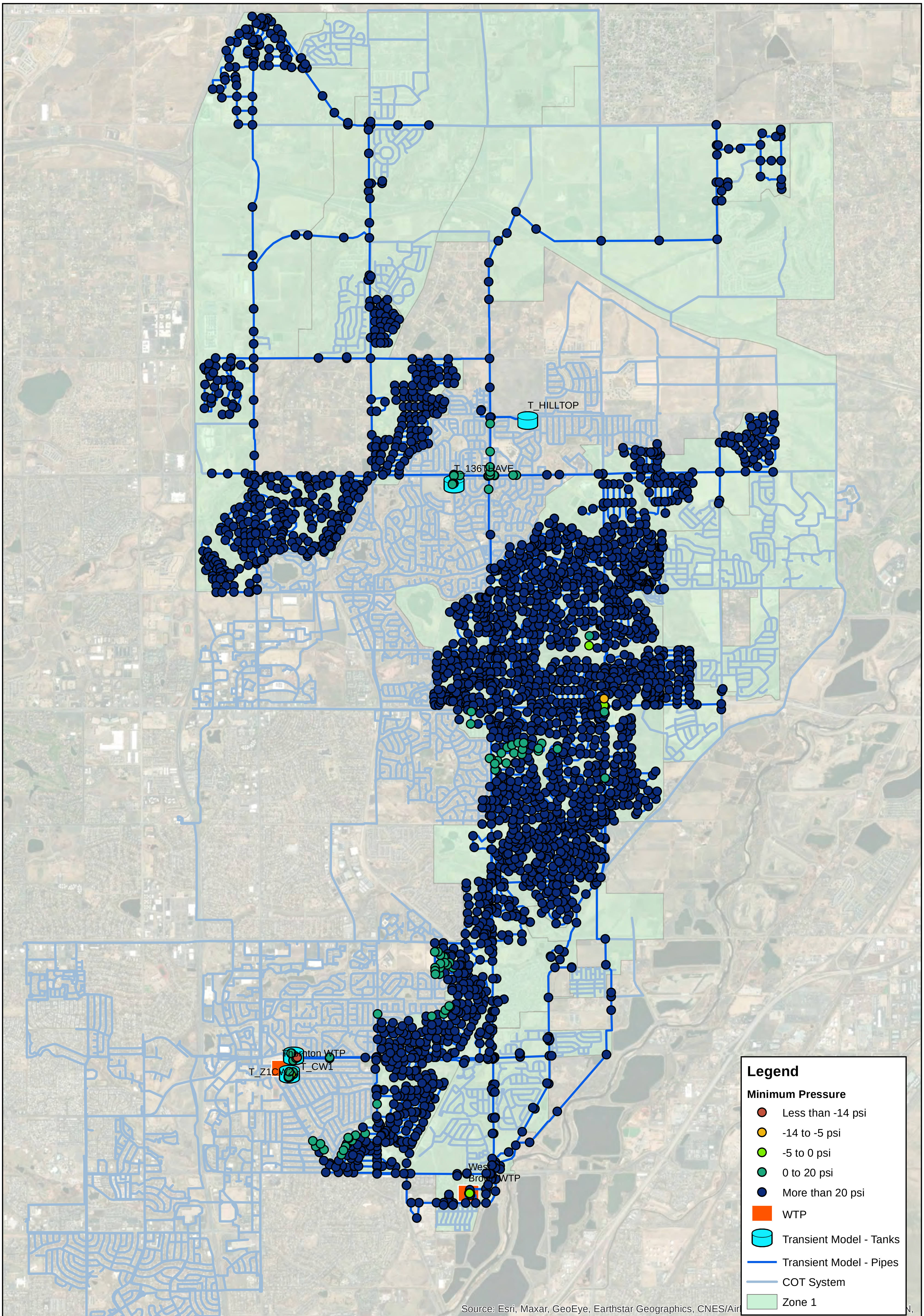

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Figure 12
Pump Startup
Minimum Pressure

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1 inch = 4,000 feet

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5. Summary of Results – Mitigation Options

Two mitigation alternatives were identified as viable options for the WBWTP facility and Zone 1 System. These mitigation alternatives were sized to address transient pressures observed during the Pump Trip, Max Flow scenario: adding combination air valves throughout the distribution system and adding a hydropneumatic surge tank at the WBHSPS.

Alternative 1: Air Valves

To eliminate vacuum pressures in the system, a total of 180, 2-inch combination air valves were required in the distribution system. The air valve locations for this mitigation option are shown in Figure 13.

A summary of the minimum and maximum pressures by pipe material for the Air Valves mitigation alternative are summarized in Table 11. A map of the high-pressure nodes for the Air Valves Mitigation alternative is included in Figure 14. A map of the low-pressure nodes for the Air Valves Mitigation alternative is included in Figure 15.

Table 11: Air Valves Mitigation Alternative Transient Results Summary by Pipe Material

	Asbestos Cement	PVC	Ductile Iron	Steel[1]
Scenario Max Pressure (psi)	129	134	148	155
Number of Nodes Failing High Pressure Criteria	0	0	0	0
Scenario Min Pressure (psi)	-5.2	-14.4	-6.9	-14.4
Number of Nodes Failing Low Pressure Criteria[2]	2	0	1	7

[1] A pipe thickness calculation determined that the pipes failing the criteria are able to withstand full vacuum conditions of -14.4 psi (a pipe thickness of 0.25 inch was assumed).
[2] Final design will be used to confirm air valve locations and bring the remaining nodes violating the criteria into compliance.

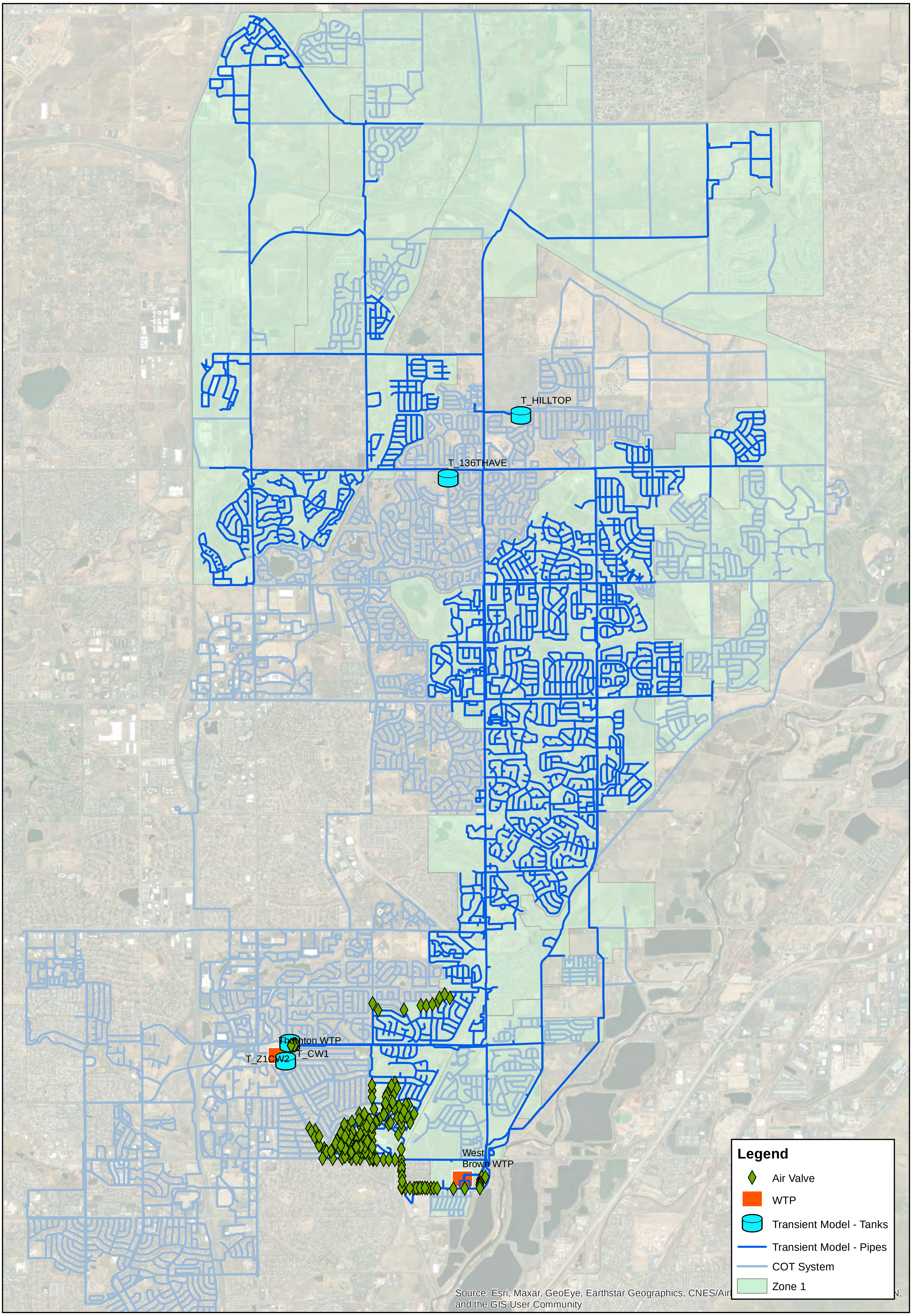

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Figure 13
Air Valves Mitigation
Air Valve Locations

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1 inch = 4,000 feet

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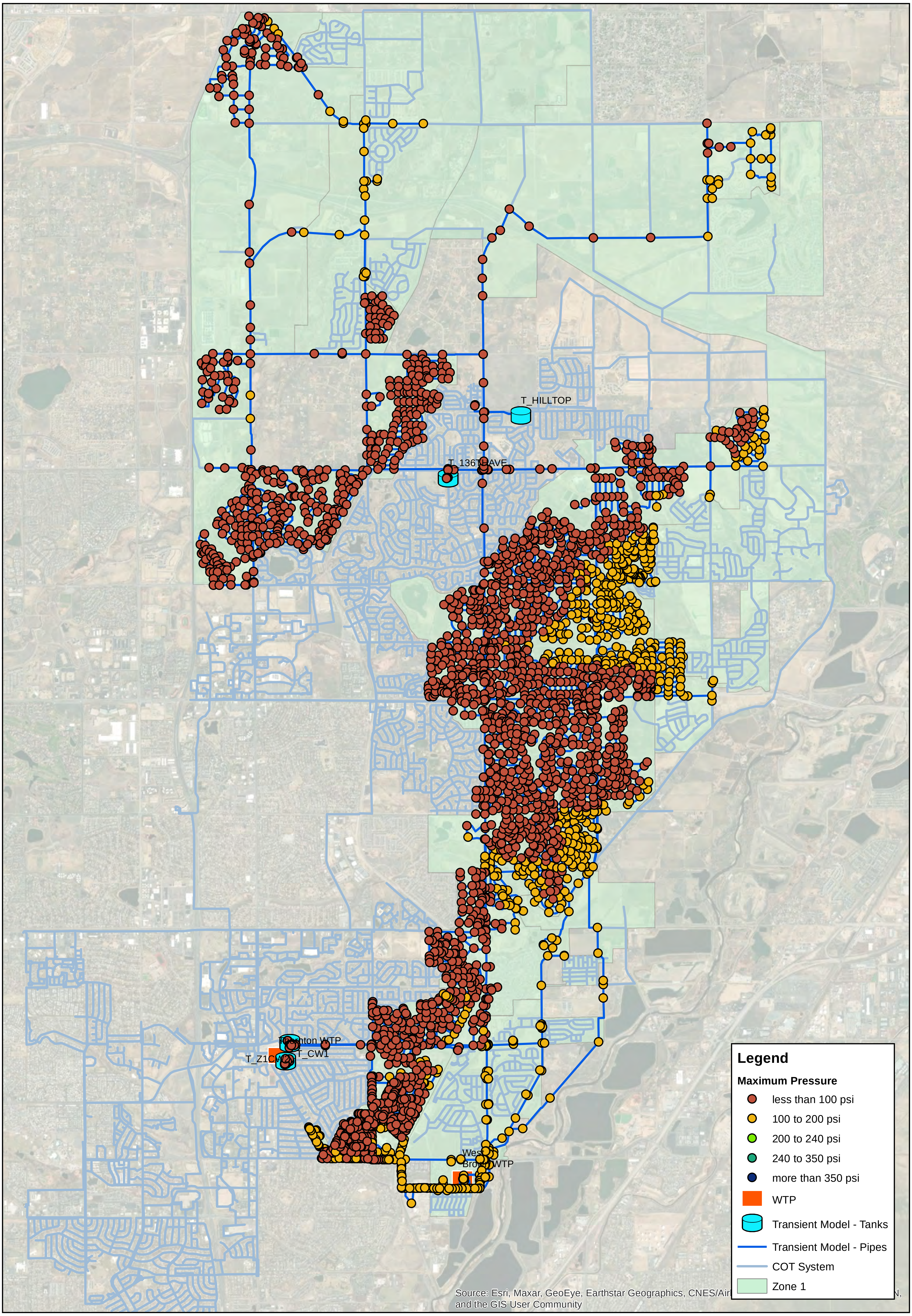

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Figure 14
Air Valves Mitigation
Maximum Pressure

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1 inch = 4,000 feet

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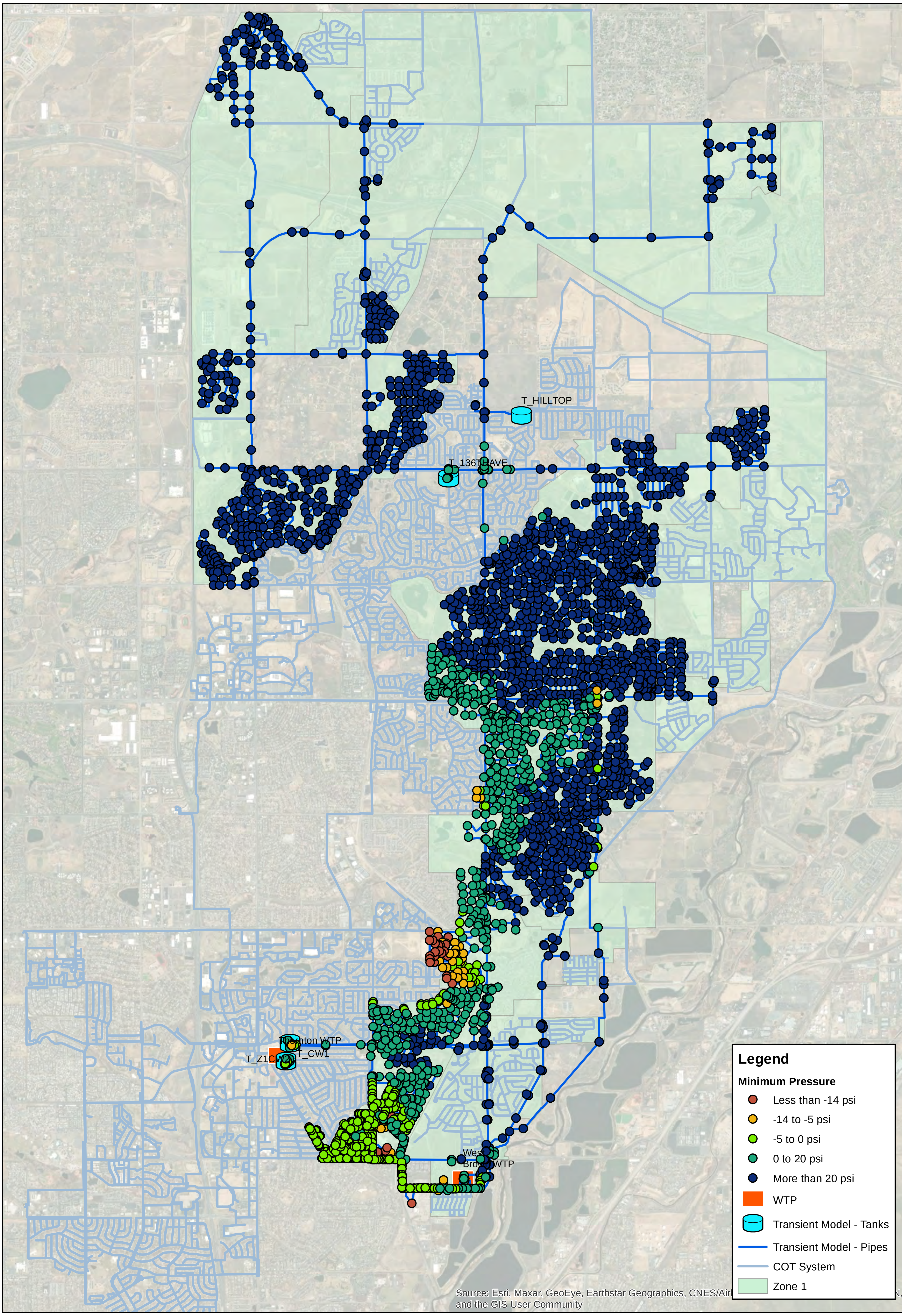

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Figure 15
Air Valves Mitigation
Minimum Pressure

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1 inch = 4,000 feet

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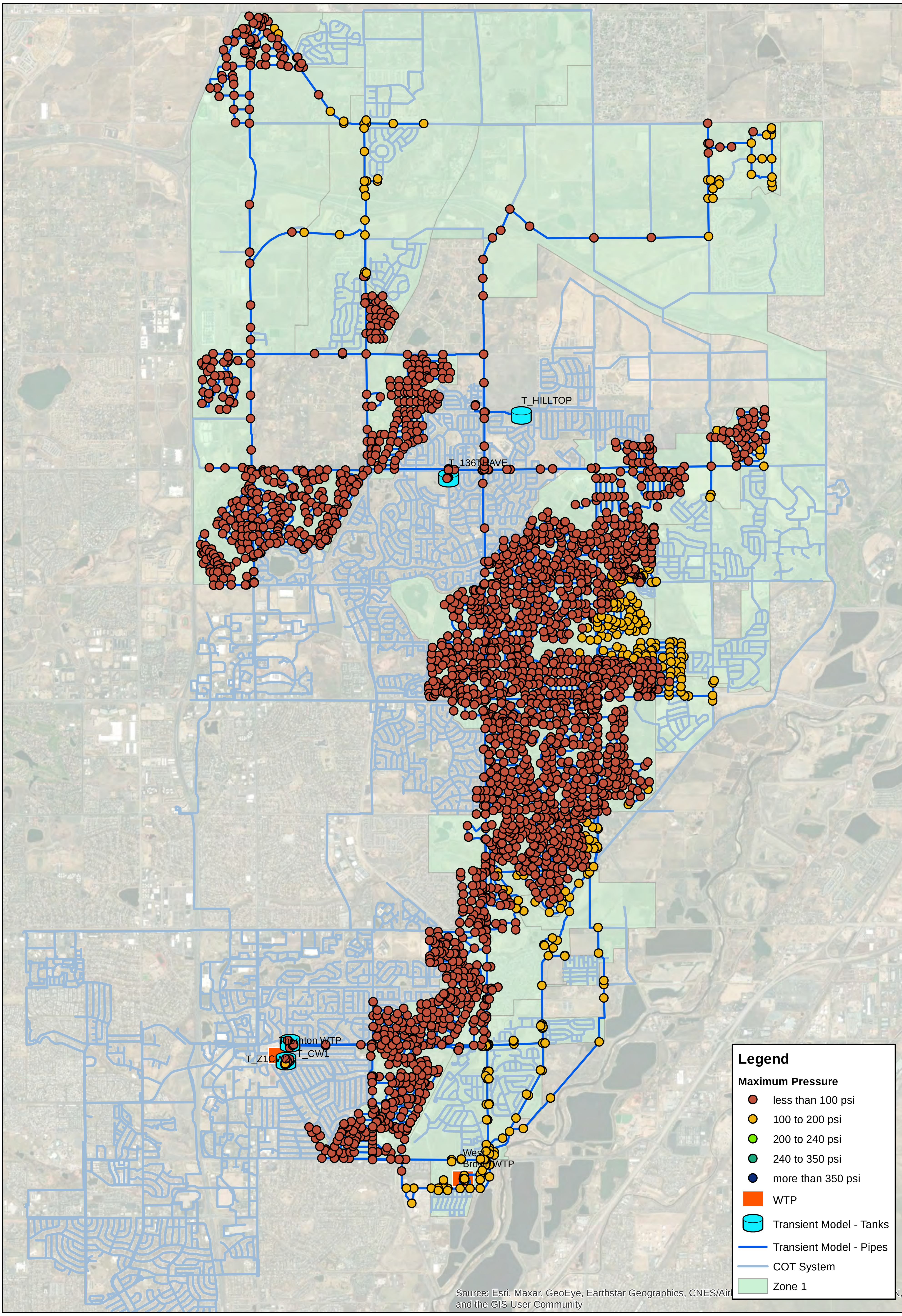
Alternative 2: Surge Tank

An 8,980-gallon hydropneumatic surge tank was added to the WBHSPS discharge header for this mitigation option. A summary of the minimum and maximum pressures by pipe material for the Surge Tank Mitigation alternative are summarized in Table 12. A map of the high-pressure nodes for the Surge Tank Mitigation alternative is included in Figure 16. A map of the low-pressure nodes for the Surge Tank Mitigation alternative is included in Figure 17.

Table 12: Surge Tank Mitigation Alternative Transient Results Summary by Pipe Material

	Asbestos Cement[1]	PVC	Ductile Iron[1]	Steel[2]
Scenario Max Pressure (psi)	151	137	228	137
Number of Nodes Failing High Pressure Criteria	0	0	0	0
Scenario Min Pressure (psi)	-14.4	-14.4	-14.4	-14.4
Number of Nodes Failing Low Pressure Criteria	4	0	36	12

[1] The pipes included here violating the low-pressure criteria are the result of boundary condition model issues that are not expected to reflect actual conditions in these areas.
[2] A pipe thickness calculation determined that the pipes failing the criteria are able to withstand full vacuum conditions of -14.4 psi (a pipe thickness of 0.25 inch was assumed).



City of Thornton
9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

AECOM 6200 South Quebec Street
Greenwood Village, Colorado 80111

Figure 16
Surge Tank Mitigation
Maximum Pressure

2/9/2021

1 inch = 4,000 feet

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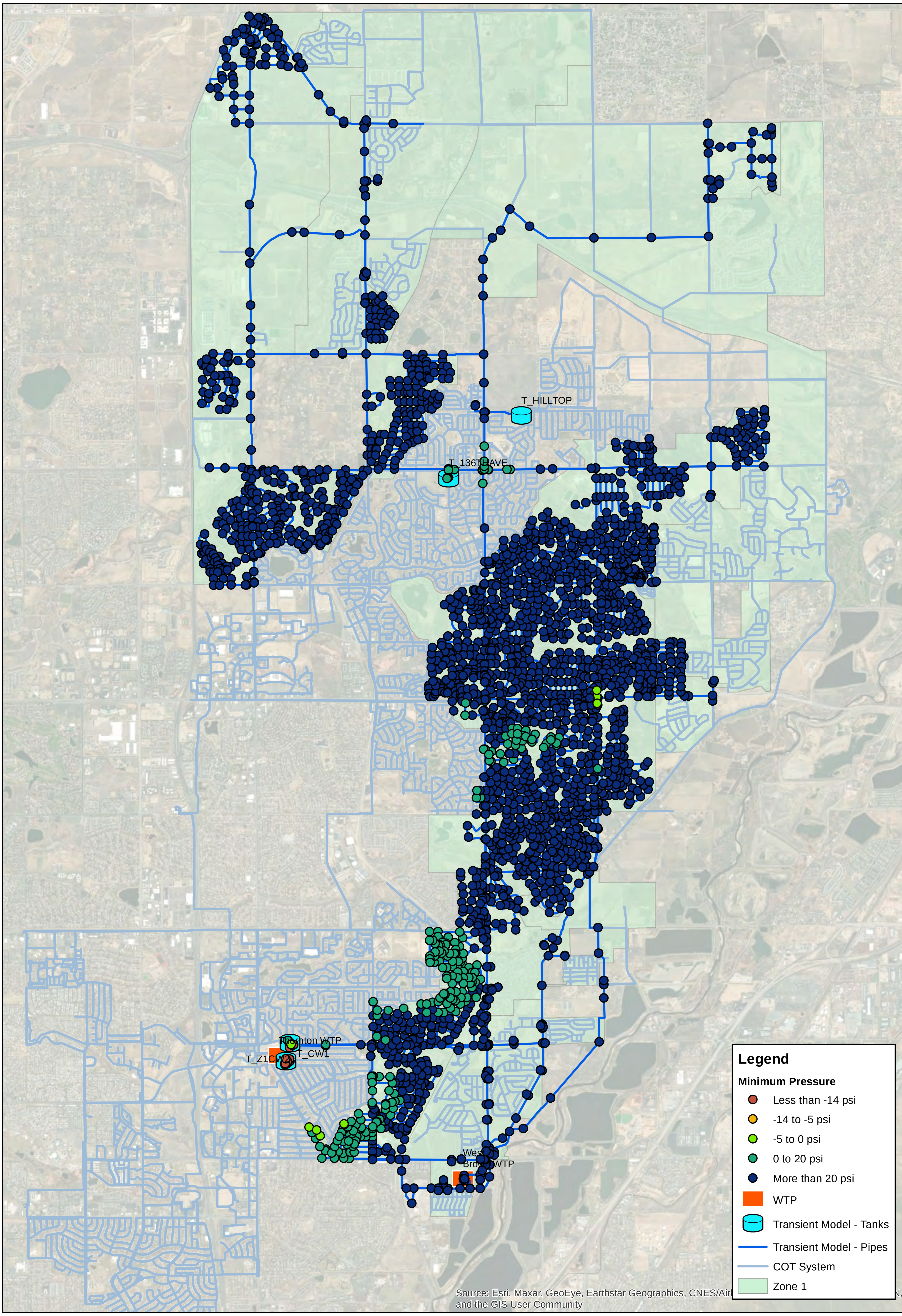
M:\DCS\Projects\WTR\60560104_Thornton M\500-Deliverables\501-Deliverables for Water and Wastewater MP\Task 6 and 7 Tech Memo\Figures\Water Distribution\Water Distribution Figures.mxd, Date: 10/22/2020 , Time: 9:45:05 AM



City of Thornton
9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

AECOM 6200 South Quebec Street
Greenwood Village, Colorado 80111

Figure 17
Surge Tank Mitigation
Minimum Pressure

2/9/2021

1 inch = 4,000 feet

C:\Users\jason.coontz\Documents\1-JASON\Wes Brown Surge\TM\Final Results TM\Figures\COT_WBSURGETM_Final_F17.mxd

M:\DCS\Projects\WTR\60560104_Thornton M\500-Deliverables\501-Deliverables for Water and Wastewater MP\Task 6 and 7 Tech Memo\Figures\Water Distribution\Water Distribution Figures.mxd, Date: 10/22/2020 , Time: 9:48:12 AM

6. Discussion

This section provides a discussion of the historic pipe breaks in the distribution system, the special case of cavitation tolerance in steel pipes 42-inch and smaller, the mitigation alternatives evaluated in this TM, and the cost estimating provided for the surge tank mitigation.

Historic Pipe Breaks

Thornton has experienced a high number of pipe breaks in the distribution system. Pump trips during maximum flow conditions may be contributing to pipe break incidences. A summary of historic pipe breaks is shown in Table 13. These pump trip events may be a contributing factor to the high number of asbestos cement and ductile iron pipe breaks. A map showing the low-pressure results alongside the historic pipe break locations is included in Figure 18; some correlation between the two can be observed.

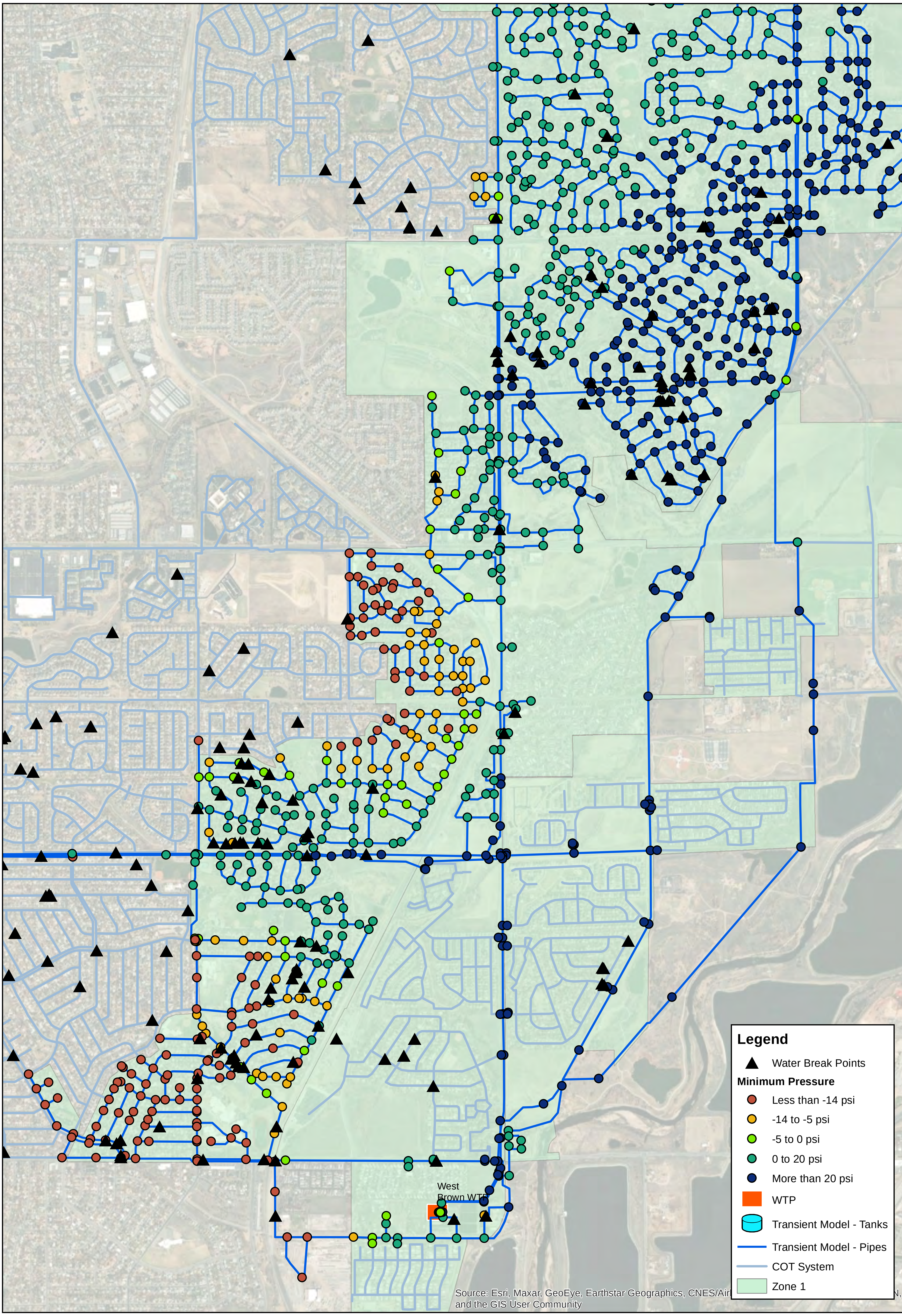
Table 13: Historic Pipe Break Summary

Pipe Material	Number of Historic Pipe Breaks
Asbestos Cement	210
PVC	91
Ductile Iron	96
Steel	5

Steel Pipe Cavitation Tolerance

A low point in a critical 42-inch steel pipeline consistently failed the low-pressure criteria of 0 psi, despite the air valves located nearby. Before introducing options to mitigate this one pipeline, a steel pipe calculation, using the approach outlined in AWWA M11, was performed to determine the actual negative pressure limit for this pipeline.

Assuming a conservative pipe thickness of 0.25 inch, the pipe is expected to be tolerant of a full cavitation pressure of -14.4 psi. Steel pipes smaller than 42-inch are expected to have the same negative pressure tolerance using the same pipe thickness assumption. Therefore, mitigation was not provided to bring steel pipes 42-inch and smaller into compliance with the low-pressure criteria.



City of Thornton
9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

AECOM 6200 South Quebec Street
Greenwood Village, Colorado 80111

Figure 18
Pump Trip - Max Flow
Minimum Pressure and Water Break Points

2/9/2021

1 inch = 1,500 feet

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Mitigation with Air Valves

The 180 air valves added to the system to mitigate the low-pressure results also reduced the high-pressure results to meet the criteria. The areas in need of mitigation totaled 46,000 feet of pipe; therefore, an air valve was added every 250 feet on average in these areas. If a new combination air valve and vault is assumed to cost $3,500 to $5,000, the total capital cost to implement this mitigation option is $630,000 to $900,000.

Mitigation with a Surge Tank – Existing Conditions

The minimum hydropneumatic surge tank size predicted by the model to mitigate the results to meet the criteria during the Pump Trip, Max Flow scenario is 8,980 gallons. The surge tank was located on the WBHSPS discharge line and tank input assumptions used to evaluate this mitigation alternative are included in Table 14. Four additional hydropneumatic surge tanks were added to the system: one on Thornton Pkwy near York St (3,170 gallons), one on the discharge line of HSBPS (1,585 gallons), and two on the suction line of HSBPS (1,850 gallons each).

Table 14: Surge Tank Assumptions

Parameter	Value
Precharge Pressure (psi)	46
Tank Inlet/Outlet Diameter (in)	24
Surge Tank Non-Return Valve Included?	no
Inflow/Outflow Resistance	0.01
Surge Tank Pipe Diameter (in)	24
Surge Tank Pipe Length to Main Line (ft)	350

The hydraulic model simulations indicate the existing surge anticipation valves (SAVs) interfere with the surge tank operation. The SAVs opened during the mitigated scenario, draining the tank volume back into the WBHSPS clearwell instead of to the distribution system where it was needed. If a surge tank is installed, the SAVs will need to be deactivated or relocated.

Also, the valve closure time is a factor that has an effect in the operation of the surge tank. The 25-second valve closure time after a pump trip causes significant reverse flow back into the clearwell. Like the interference caused by the SAVs, this reduces the efficacy of the surge tank by reducing the volume delivered to the distribution system. A check valve downstream of each pump eliminates the reverse flow through the pumps and significantly improves the transient results. This change will need to be implemented in conjunction with the surge tank.

For this scenario, some junctions in the hydraulic model show a minimum pressure criteria violation around TWTP and Clearwell 2; those were not addressed because they are the result of model boundary condition interference in Zone 1. A sensitivity analysis determined that the results at these locations do not match established hydraulic transient theory, and they are not likely to reflect actual conditions in the scenario modeled. Mitigation was, therefore, not extended to these locations.

The hydraulic model was shared with a surge tank manufacturer, Charlatte, who conduct their own surge analysis of this scenario using KY Pipe. Charlatte concluded that smaller tanks may adequately protect the system, but AECOM was unable to confirm their results. It is recommended that the size be verified in final design to determine whether the size can be decreased, or if the results presented by Charlatte are due to inaccurate system boundary conditions.

An 8,980-gallon surge tank is expected to be approximately 8 ft in diameter and 26 ft long. A Charlatte Large Vessel cut sheet showing a range of surge tank sizes and dimensions is included in Appendix A. A drawing showing a similar-sized surge tank is included in Appendix B.

Mitigation with a Surge Tank – Future Conditions

The minimum hydropneumatic surge tank size predicted by the model to mitigate the results to meet the criteria during the Pump Trip, Future Flow scenario is 25,440 gallons. The surge tank was located on the WBHSPS discharge line and tank input assumptions used to evaluate this mitigation alternative are included in Table 15. Four additional hydropneumatic surge tanks were added to the system: one on Thornton Pkwy near York St (3,170 gallons), one on the discharge line of HSBPS (1,585 gallons), and two on the suction line of HSBPS (1,850 gallons each).

Table 15: Updated Surge Tank Assumptions

Parameter	Value
Precharge Pressure (psi)	46
Tank Inlet/Outlet Diameter (in)	24
Surge Tank Non-Return Valve Included?	no
Inflow/Outflow Resistance	0.01
Surge Tank Pipe Diameter (in)	24
Surge Tank Pipe Length to Main Line (ft)	350

The hydraulic model simulations indicate the existing SAVs interfere with the surge tank operation. The SAVs opened during the mitigated scenario, draining the tank volume back into the WBHSPS clearwell instead of to the distribution system where it was needed. If a surge tank is installed, the SAVs will need to be deactivated or relocated.

Also, the valve closure time is a factor that has an effect in the operation of the surge tank. The 25-second valve closure time after a pump trip causes significant reverse flow back into the clearwell. Like the interference caused by the SAVs, this reduces the efficacy of the surge tank by reducing the volume delivered to the distribution system. A check valve downstream of each pump eliminates the reverse flow through the pumps and significantly improves the transient results. This change will need to be implemented in conjunction with the surge tank.

For this scenario, some junctions in the hydraulic model show a minimum pressure criteria violation around TWTP and Clearwell 2; those were not addressed because they are the result of model boundary condition interference in Zone 1. A sensitivity analysis determined that the results at these locations do not match established hydraulic transient theory, and they are not likely to reflect actual conditions in the scenario modeled. Mitigation was, therefore, not extended to these locations.

The hydraulic model was shared with a surge tank manufacturer, Charlatte, who conduct their own surge analysis of this scenario using KY Pipe. Charlatte concluded that smaller tanks may adequately protect the system, but AECOM was unable to confirm their results. It is recommended that the size be verified in final design to determine whether the size can be decreased, or if the results presented by Charlatte are due to inaccurate system boundary conditions.

A 25,440-gallon surge tank is expected to be approximately 10 ft in diameter and 50 ft long. A Charlatte Large Vessel cut sheet showing a range of surge tank sizes and dimensions is included in Appendix A. A drawing showing a similar-sized surge tank is included in Appendix C. Another option is to split the volume into two tanks, installing a 12,720-gallon tank in the near-term, and another 12,720-gallon tank in the future when the additional surge tank volume is required.

Surge Tank Cost Estimating

AECOM has compiled a budgetary cost estimate for the existing conditions and future conditions tank sizes, for both indoor and outdoor installation. The cost estimate includes the addition of a ValMatic Surgebuster Check Valve at each pump discharge line (cut sheet included in Appendix D). Based on preliminary surge results, it is expected that without these check valves, the surge tank size will need to increase by approximately 300% for the Pump Trip, Max Flow scenario and 250% for the Pump Trip, Future Flow scenario. The total costs for the existing and future conditions are included in Table 16, and the complete cost estimates are included in Appendix E.

Table 16: Budgetary Cost Estimate

	Outdoor Installation Cost	Indoor Installation Cost
Pump Trip, Max Flow Existing Conditions	$665,500	$972,500
Pump Trip, Future Flow Future Conditions	$1,103,700	1,546,900

7. Conclusions

Based on the surge analysis presented in this TM, AECOM concludes the following:

1. The minimum and maximum pressure criteria were not violated at the WBHSPS for any of the scenarios.
2. Low pressures in the distribution system violate the criteria more than high pressures.
3. Pump trips during high flow conditions may be contributing to pipe breaks in the distribution system.
4. No changes to normal pump shutdown operations at WBHSPS are recommended.
5. No changes to normal pump startup operations at WBHSPS are recommended.
6. Approximately 180 air valves would be required to mitigate the transient pressure results predicted by the model during the Pump Trip, Max Flow scenario. That is equivalent to one air valve per 250 feet of pipe.
7. A hydropneumatic surge tank with a volume of approximately 9,000 gallons as described above is required to mitigate the transient pressure results predicted by the model during the Pump Trip, Max Flow scenario. As part of this mitigation option, the SAVs will need to be removed and check valves will need to be added to the pump discharge lines.
8. A hydropneumatic surge tank with a volume of approximately 25,500 gallons as described above is required to mitigate the transient pressure results predicted by the model during the Pump Trip, Future Flow scenario. As part of this mitigation option, the SAVs will need to be removed and the check valves will need to be added to the pump discharge lines. This volume may be split into two tanks, with one tank installed to mitigate the existing conditions and a second installed at a later date to mitigate the future conditions.
9. If the check valves improvements are not completed, the surge tanks required to mitigate the Pump Trip, Max Flow and Pump Trip, Future Flow scenarios will increase substantially.
10. The hydropneumatic surge tank sizes should be verified in final design to determine if they can be decreased.

Appendix A – Charlatte Large Vessel Surge Tank Cut Sheet

Large Vessel

793 to 18492 Gallons

RANGE clear water

SURPRESSION ● REGULATION ● PROTECTION ANTI-BELIER

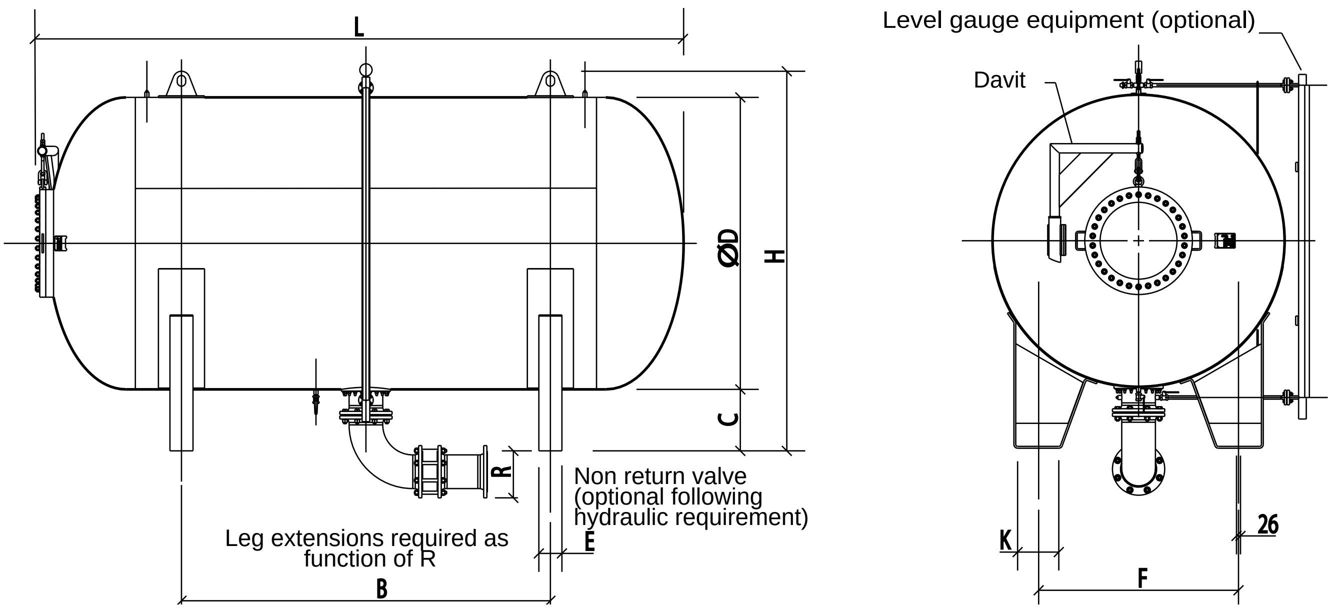
Large vessels with food quality butyl bladder

PAINT
Internal. NSF 61 approved epoxy paint, thickness upon request.
External. Anti corrosion polyurethane finishing, thickness upon request.

BLADDER
Interchangeable food quality butyl.

WARRANTY
Not including parts subject to wear and tear and subject to use under normal conditions.

PACKING
Without.

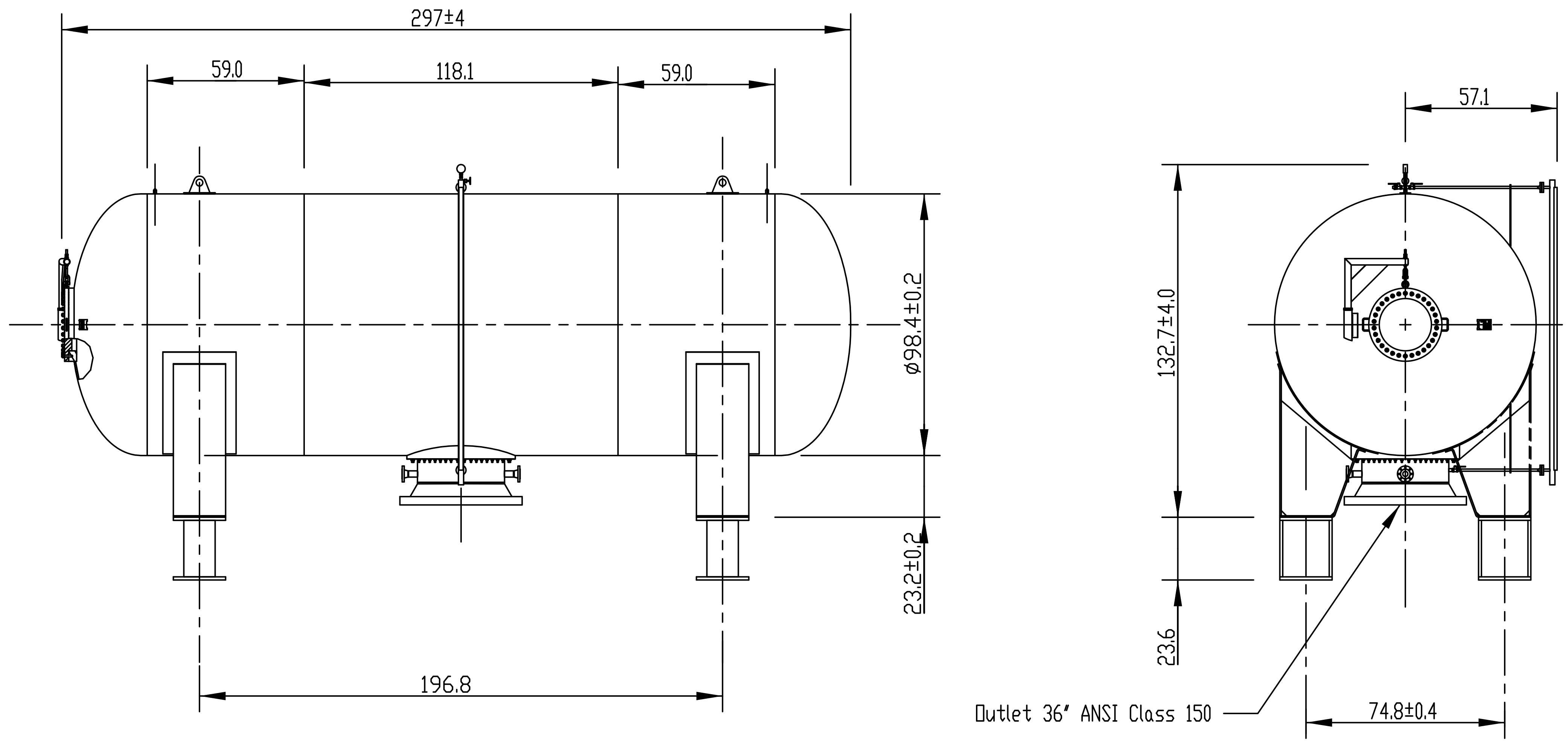


Capacity G	Diameter D	Length L	Height H	Size B	Size E	Size F	Size K	Size C	Davit
793	47	119	70	63	6	35	7	16	No
1057	47	150	70	94	6	35	7	16	No
1321	59	125	81	67	6	47	6	16	No
1585	59	158	81	87	6	47	6	16	No
1849	59	176	81	98	6	47	6	16	No
2113	59	196	81	126	6	47	6 6	616	No
2378	59	215	81	146	6	47	6	16	No
2642	75	167	97	87	6	51	11	16	Yes
2642	83	140	105	63	12	63	13	16	Yes
3170	75	189	97	118	6	51	11	16	Yes
3170	83	163	105	87	12	63	13	16	Yes
3963	75	233	97	146	6	51	11	16	Yes
3963	83	194	105	118	12	63	13	16	Yes
4755	75	283	97	205	6	51	11	16	Yes
4755	83	257	105	154	12	63	13	16	Yes
5283	75	305	97	217	6	51	11	16	Yes
5283	83	250	105	173	12	63	13	16	Yes
6604	75	374	97	224	6	51	11	16	Yes
6604	83	307	105	217	12	63	13	16	Yes
6604	98	219	130	124	20	75	20	23	Yes
7925	83	307	105	224	12	63	12	16	Yes
7925	98	269	130	165	20	75	20	23	Yes
9246	98	313	130	213	20	75	20	23	Yes
9246	118	230	150	118	20	75	20	23	Yes
10567	118	253	150	142	20	75	20	23	Yes
13209	118	308	150	197	20	75	20	23	Yes
15850	118	367	150	236	20	75	20	23	Yes
18492	118	426	150	295	20	75	20	23	Yes

Contact us for upper capacities.
The dimensions shown are indicative and can be modified without warning.

CHARLATTE
FAYAT GROUP

Appendix B – Existing Conditions Surge Tank Drawing



Note: All dimensions in inches

BLADDER SURGE TANK 8230 GALLONS

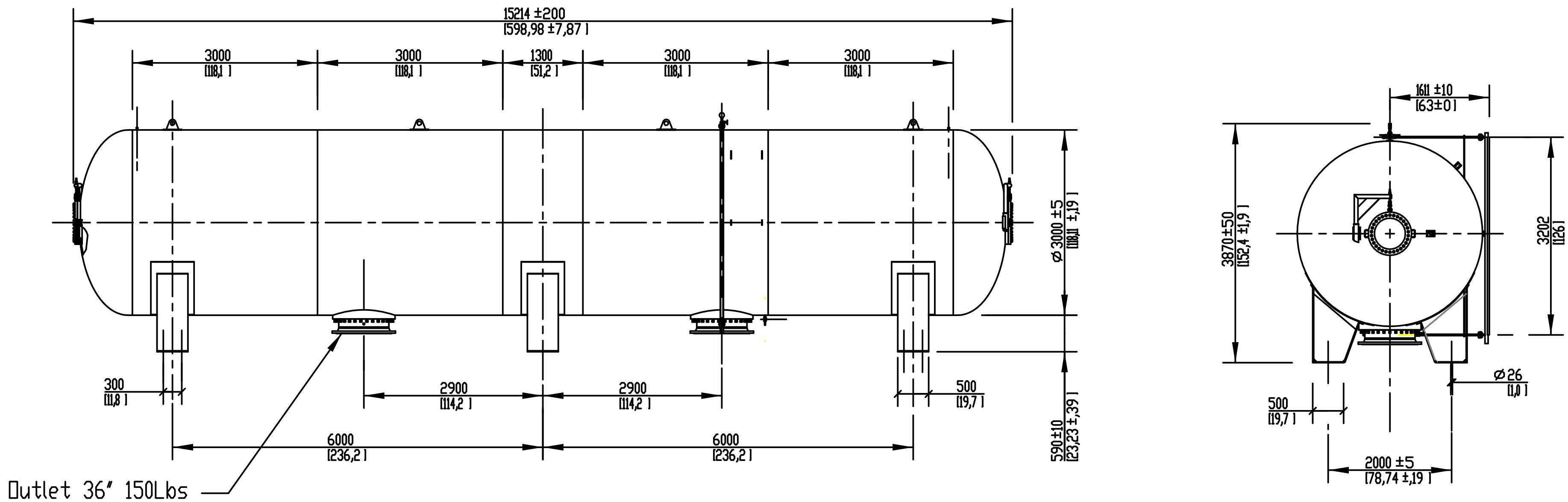
Working pressure : 175 psi - Test pressure : 263 psi

CHARLATTE réservoirs FAYAT GROUP

LLOYD'S REGISTER QUALITY ASSURANCE ISO9001

SCALE : 0,020		A3
DATE : 08-Dec-20	GENE. TOL. : ±0.2	
WEIGHT : 32000 lb	MATERIAL : S/ENS	
TREATMENT : /		
N° 20120801		
REV. 00	323-02	

Appendix C – Future Conditions Surge Tank Drawing



Note: All dimensions in millimeters [inches]

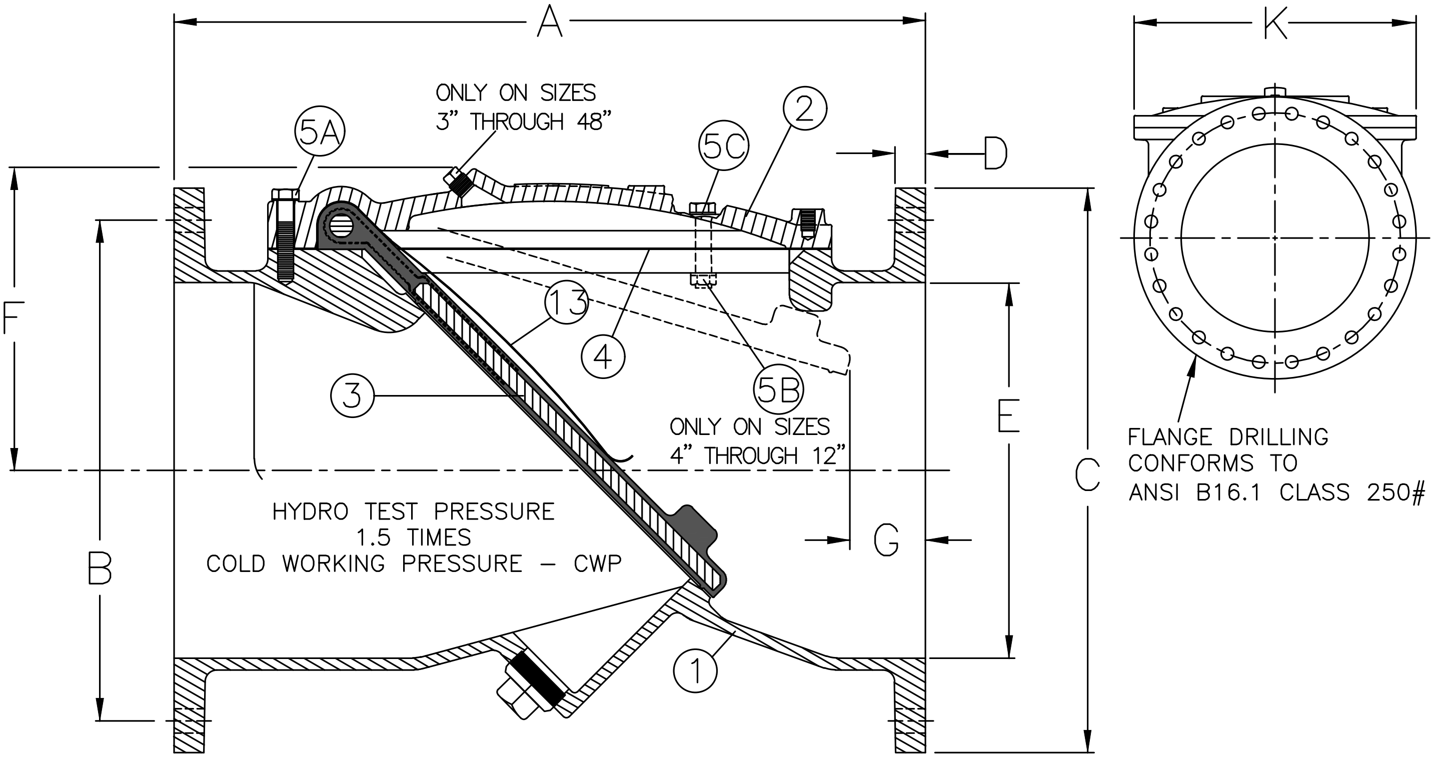
BLADDER SURGE TANK 26420 GALLONS

Working pressure : 175 psi – Test pressure : 263 psi

CHARLATTE réservoirs FAYAT GROUP

SCALE : 0,015		A3
DATE : 08-Dec-20	GENE. TOL. : ±5	
WEIGHT : 56000 lb	MATERIAL : S/ENS	
TREATMENT :		
N° 20120802		
REV. 00	160.04	

Appendix D – ValMatic Surgebuster Check Valve Cut Sheet



SEE DRAWING NO. VM-7202-M FOR STANDARD MATERIALS OF CONSTRUCTION. DRAWING DEPICTS 24" SIZE TO SCALE.

DIMENSIONS, INCHES

VALVE SIZE	MODEL NO.	CWP (PSI)	A	B	C	D	E	F	G	K	BOLT SIZE	NO. OF BOLTS	NO. BOLTS TAPPED
2	7202	250	8.00	5.00	6.50	0.69	2.00	3.38	1.63	5.18	5/8	8	--
2 1/2	7225	250	8.50	5.88	7.50	0.75	2.50	3.38	1.63	5.18	3/4	8	--
3	7203	250	9.50	6.63	8.25	0.81	3.00	5.13	1.63	7.50	3/4	8	--
4	7204	250	11.50	7.88	10.00	0.75	4.00	5.75	2.13	8.25	3/4	8	--
6	7206C	250	14.00	10.63	12.50	0.75	6.00	6.88	1.63	11.13	3/4	12	--
8	7208	250	19.50	13.00	15.00	0.88	8.00	8.38	2.88	16.00	7/8	12	--
10	7210	250	24.50	15.25	17.50	1.18	10.00	10.75	3.13	21.00	1	16	--
12	7212	250	27.50	17.75	20.50	1.25	12.00	12.50	3.43	24.00	1 1/8	16	--
14	7214	250	31.00	20.25	23.00	1.38	14.00	13.00	3.63	23.25	1 1/8	20	--
16	7216C	250	36.00	22.50	25.50	1.43	16.00	14.25	5.25	25.25	1 1/4	20	--
18	7218C	250	40.00	24.75	28.00	1.56	18.00	15.25	5.13	28.25	1 1/4	24	--
20	7220	250	40.00	27.00	30.50	1.68	20.00	16.88	3.50	30.63	1 1/4	24	--
24	7224	250	48.00	32.00	36.00	1.88	24.00	19.25	5.00	36.00	1 1/2	24	--
30	7230A	250	56.00	39.25	43.00	2.13	30.00	23.00	5.75	45.88	1 3/4	28	--
36	7236A	250	63.00	46.00	50.00	2.38	36.00	27.38	3.88	55.00	2	32	8
42	7242A	250	70.00	52.75	57.00	2.63	42.00	36.88	0.13	60.18	2	36	10
48	7248A	250	76.00	60.75	65.00	2.75	48.00	40.66	0.13	68.00	2	44	12

SURGEBUSTER CHECK VALVE WITH 250# FLANGES

DATE 11-6-17

VAL-MATIC® VALVE AND MANUFACTURING CORP.

DRWG. NO. SS-3894

Appendix E – Surge Tank Cost Estimates

AECOM

CITY OF THORNTON
WBHSPS
Surge Tank Budget Estimate
Existing Conditions Tank Size
February 9, 2021

ITEM NO.	ITEM DESCRIPTION	Unit	Outdoor Installation Option			Indoor Installation Option		
			Quantity	Unit Cost	BUDGETARY COST	Quantity	Unit Cost	BUDGETARY COST
Surge Tank Construction								
1	8,980 Gallon Hydropneumatic Surge Tank	EA.	1	$ 170,000	$ 170,000	1	$ 170,000	$ 170,000
2	24-Inch Water Line w/ fittings and valves	L.F.	350	$ 250	$ 87,500	350	$ 250	$ 87,500
3	Electrical Systems	L.S.	1	-	$ 20,000	1	-	$ 20,000
4	Building Installation w/ HVAC and Lighting	S.F.	-	$ 600	-	580	$ 600	$ 348,000
5	Tank Insulation and Heat Tracing	EA.	1	$ 51,000	$ 51,000	-	$ 51,000	-
6	Concrete Equipment Pad	C.Y.	32	$ 850	$ 27,200	-	$ 850	-
7	SCADA Integration	L.S.	1	-	$ 15,000	1	-	$ 15,000
8	Discharge Control Valve Actuator and Check Valve Replacement	EA.	6	$ 17,000	$ 102,000	6	$ 17,000	$ 102,000
9	Bollards	EA.	28	$ 1,200	$ 33,600	-	$ 1,200	-
10	Asphalt Paving Removal and Repair	L.S.	1	-	$ 3,270	1	-	$ 3,270
11	Site Restoration & Reclamation	S.F.	4,630	$ 0.50	$ 2,315	4,630	$ 0.50	$ 2,315
	Subtotal				**$ 511,900**			**$ 748,100**
Additional Costs								
	Project Subtotal				**$ 511,900**			**$ 748,100**
	Miscellaneous Items and Contingencies	30%			$ 153,570			$ 224,430
	Total Estimated Project Budget				**$ 665,500**			**$ 972,500**

Notes:

1. Costs are for budgetary purposes only.

2. Engineering, Survey and Construction Management costs not included.

3. Surge tank and insulation and heat tracing costs are based on similar sized tank quotes provided by the vendor.

CITY OF THORNTON
WBHSPS
Surge Tank Budget Estimate
Future Conditions Tank Size
February 9, 2021

ITEM NO.	ITEM DESCRIPTION	Unit	Outdoor Installation Option: Quantity	Outdoor: Unit Cost	Outdoor: BUDGETARY COST	Indoor Installation Option: Quantity	Indoor: Unit Cost	Indoor: BUDGETARY COST
Surge Tank Construction								
1	25,440 Gallon Hydropneumatic Surge Tank	EA.	1	$ 410,000	$ 410,000	1	$ 410,000	$ 410,000
2	24-Inch Water Line w/ fittings and valves	L.F.	350	$ 250	$ 87,500	350	$ 250	$ 87,500
3	Electrical Systems	L.S.	1	-	$ 20,000	1	-	$ 20,000
4	Building Installation w/ HVAC and Lighting	S.F.	-	$ 600	-	912	$ 600	$ 547,200
5	Tank Insulation and Heat Tracing	EA.	1	$ 123,000	$ 123,000	-	$ 123,000	-
6	Concrete Equipment Pad	C.Y.	50	$ 850	$ 42,500	-	$ 850	-
7	SCADA Integration	L.S.	1	-	$ 15,000	1	-	$ 15,000
8	Discharge Control Valve Actuator and Check Valve Replacement	EA.	6	$ 17,000	$ 102,000	6	$ 17,000	$ 102,000
9	Bollards	EA.	34	$ 1,200	$ 40,800	-	$ 1,200	-
10	Asphalt Paving Removal and Repair	L.S.	1	-	$ 4,560	1	-	$ 4,560
11	Site Restoration & Reclamation	S.F.	7,200	$ 0.50	$ 3,600	7,200	$ 0.50	$ 3,600
	Subtotal				**$ 849,000**			**$ 1,189,900**
Additional Costs								
	Project Subtotal				**$ 849,000**			**$ 1,189,900**
	Miscellaneous Items and Contingencies	30%			$ 254,700			$ 356,970
	Total Estimated Project Budget				**$ 1,103,700**			**$ 1,546,900**

Notes:

1. Costs are for budgetary purposes only.

2. Engineering, Survey and Construction Management costs not included.

3. Surge tank and insulation and heat tracing costs are based on similar sized tank quotes provided by the vendor.